Reference Manual

Generated by Doxygen 1.8.11

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Chapter 1

Modular arbitrary-order ocean-atmosphere model: MAOOAM -- Stochastic Fortran implementation

About

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See LICENSE.txt for license information.

This software is provided as supplementary material with:

- De Cruz, L., Demaeyer, J. and Vannitsem, S.: The Modular Arbitrary-Order Ocean-Atmosphere Model: M↩
AOOAM v1.0, Geosci. Model Dev., 9, 2793-2808, doi:10.5194/gmd-9-2793-2016, 2016.

for the MAOOAM original code, and with

- for the stochastic part.

Please cite both articles if you use (a part of) this software for a publication.

The authors would appreciate it if you could also send a reprint of your paper to lesley.decruz@meteo.be, jonathan.demaeyer@meteo.be and svn@meteo.be.

Consult the MAOOAM code repository for updates, and our website for additional resources.

A pdf version of this manual is available here.

Installation

The program can be installed with Makefile. We provide configuration files for two compilers : gfortran and ifort.

By default, gfortran is selected. To select one or the other, simply modify the Makefile accordingly or pass the CO↩
MPILER flag to `make`. If gfortran is selected, the code should be compiled with gfortran 4.7+ (allows for allocatable arrays in namelists). If ifort is selected, the code has been tested with the version 14.0.2 and we do not guarantee compatibility with older compiler version.

To install, unpack the archive in a folder or clone with git:

```
git clone https://github.com/Climdyn/MAOOAM.git
cd MAOOAM
```

and run:

```
make
```

By default, the inner products of the basis functions, used to compute the coefficients of the ODEs, are not stored in memory. If you want to enable the storage in memory of these inner products, run make with the following flag:

```
make RES=store
```

Depending on the chosen resolution, storing the inner products may result in a huge memory usage and is not recommended unless you need them for a specific purpose.

Remark: The command "make clean" removes the compiled files.

Description of the files

The model tendencies are represented through a tensor called aotensor which includes all the coefficients. This tensor is computed once at the program initialization.

The following files are part of the MAOOAM model alone:

- maooam.f90 : Main program.
- aotensor_def.f90 : Tensor aotensor computation module.
- IC_def.f90 : A module which loads the user specified initial condition.
- inprod_analytic.f90 : Inner products computation module.
- rk2_integrator.f90 : A module which contains the Heun integrator for the model equations.
- rk4_integrator.f90 : A module which contains the RK4 integrator for the model equations.
- Makefile : The Makefile.
- params.f90 : The model parameters module.
- tl_ad_tensor.f90 : Tangent Linear (TL) and Adjoint (AD) model tensors definition module
- rk2_tl_ad_integrator.f90 : Heun Tangent Linear (TL) and Adjoint (AD) model integrators module
- rk4_tl_ad_integrator.f90 : RK4 Tangent Linear (TL) and Adjoint (AD) model integrators module

- test_tl_ad.f90 : Tests for the Tangent Linear (TL) and Adjoint (AD) model versions
- README.md : A read me file.
- LICENSE.txt : The license text of the program.
- util.f90 : A module with various useful functions.
- tensor.f90 : Tensor utility module.
- stat.f90 : A module for statistic accumulation.
- params.nml : A namelist to specify the model parameters.
- int_params.nml : A namelist to specify the integration parameters.
- modeselection.nml : A namelist to specify which spectral decomposition will be used.

with the addition of the files:

- maooam_stoch.f90 : Stochastic implementation of MAOOAM.
- maooam_MTV.f90 : Main program - MTV implementation for MAOOAM.
- maooam_WL.f90 : Main program - WL implementation for MAOOAM.
- corrmod.f90 : Unresolved variables correlation matrix initialization module.
- corr_tensor.f90 : Correlations and derivatives for the memory term of the WL parameterization.
- dec_tensor.f90 : Tensor resolved-unresolved components decomposition module.
- int_comp.f90 : Utility module containing the routines to perform the integration of functions.
- int_corr.f90 : Module to compute or load the integrals of the correlation matrices.
- MAR.f90 : Multidimensional AutoRegressive (MAR) module to generate the correlation for the WL parameterization.
- memory.f90 : WL parameterization memory term M_3 computation module.
- MTV_int_tensor.f90 : MTV tensors computation module.
- MTV_sigma_tensor.f90 : MTV noise sigma matrices computation module.
- WL_tensor.f90 : WL tensors computation module.
- rk2_stoch_integrator.f90 : Stochastic RK2 integration routines module.
- rk2_ss_integrator.f90 : Stochastic uncoupled resolved nonlinear and tangent linear RK2 dynamics integration module.
- rk2_MTV_integrator.f90 : MTV RK2 integration routines module.
- rk2_WL_integrator.f90 : WL RK2 integration routines module.
- sf_def.f90 : Module to select the resolved-unresolved components.
- SF.nml : A namelist to select the resolved-unresolved components.
- sqrt_mod.f90 : Utility module with various routine to compute matrix square root.
- stoch_mod.f90 : Utility module containing the stochastic related routines.
- stoch_params.f90 : Stochastic models parameters module.
- stoch_params.nml : A namelist to specify the stochastic models parameters.

which belong specifically to the stochastic implementation.

MAOOAM Usage

The user first has to fill the params.nml and int_params.nml namelist files according to their needs. Indeed, model and integration parameters can be specified respectively in the params.nml and int_params.nml namelist files. Some examples related to already published article are available in the params folder.

The modeselection.nml namelist can then be filled :

- NBOC and NBATM specify the number of blocks that will be used in respectively the ocean and the atmosphere. Each block corresponds to a given x and y wavenumber.
- The OMS and AMS arrays are integer arrays which specify which wavenumbers of the spectral decomposition will be used in respectively the ocean and the atmosphere. Their shapes are OMS(NBOC,2) and AMS(NB↩ATM,2).
- The first dimension specifies the number attributed by the user to the block and the second dimension specifies the x and the y wavenumbers.
- The VDDG model, described in Vannitsem et al. (2015) is given as an example in the archive.
- Note that the variables of the model are numbered according to the chosen order of the blocks.

The Makefile allows to change the integrator being used for the time evolution. The user should modify it according to its need. By default a RK2 scheme is selected.

Finally, the IC.nml file specifying the initial condition should be defined. To obtain an example of this configuration file corresponding to the model you have previously defined, simply delete the current IC.nml file (if it exists) and run the program :

```
./maooam
```

It will generate a new one and start with the 0 initial condition. If you want another initial condition, stop the program, fill the newly generated file and restart :

```
./maooam
```

It will generate two files :

- evol_field.dat : the recorded time evolution of the variables.
- mean_field.dat : the mean field (the climatology)

The tangent linear and adjoint models of MAOOAM are provided in the tl_ad_tensor, rk2_tl_ad_integrator and rk4_tl_ad_integrator modules. It is documented here.

Stochastic code usage

The user first has to fill the MAOOAM model namelist files according to their needs (see the previous section). Additional namelist files for the fine tuning of the parameterization must then be filled, and some "definition" files (with the extension .def) must be provided. An example is provided with the code.

Full details over the parameterization options and definition files are available here.

The program "maooam_stoch" will generate the evolution of the full stochastic dynamics with the command:

```
./maooam_stoch
```

or any other dynamics if specified as an argument (see the header of `maooam_stoch.f90`). It will generate two files :

- evol_field.dat : the recorded time evolution of the variables.
- mean_field.dat : the mean field (the climatology)

The program "maooam_MTV" will generate the evolution of the MTV parameterization evolution, with the command:

```
./maooam_MTV
```

It will generate three files :

- evol_MTV.dat : the recorded time evolution of the variables.
- ptend_MTV.dat : the recorded time evolution of the tendencies (used for debugging).
- mean_field_MTV.dat : the mean field (the climatology)

The program "maooam_WL" will generate the evolution of the MTV parameterization evolution, with the command:

```
./maooam_WL
```

It will generate three files :

- evol_WL.dat : the recorded time evolution of the variables.
- ptend_WL.dat : the recorded time evolution of the tendencies (used for debugging).
- mean_field_WL.dat : the mean field (the climatology)

MAOOAM Implementation notes

As the system of differential equations is at most bilinear in z_j ($j = 1..n$), $\boldsymbol{z}$ being the array of variables, it can be expressed as a tensor contraction :

$$\frac{dz_i}{dt} = \sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, z_k\, z_j$$

with $z_0 = 1$.

The tensor aotensor_def::aotensor is the tensor $\mathcal{T}$ that encodes the differential equations is composed so that:

- $\mathcal{T}_{i,j,k}$ contains the contribution of dz_i/dt proportional to $z_j\, z_k$.
- Furthermore, z_0 is always equal to 1, so that $\mathcal{T}_{i,0,0}$ is the constant contribution to dz_i/dt
- $\mathcal{T}_{i,j,0} + \mathcal{T}_{i,0,j}$ is the contribution to dz_i/dt which is linear in z_j.

Ideally, the tensor aotensor_def::aotensor is composed as an upper triangular matrix (in the last two coordinates).

The tensor for this model is composed in the aotensor_def module and uses the inner products defined in the inprod_analytic module.

Stochastic code implementation notes

A stochastic version of MAOOAM and two stochastic parameterization methods (MTV and WL) are provided with this code.

The stochastic version of MAOOAM is given by

$$\frac{d\boldsymbol{z}}{dt} = f(\boldsymbol{z}) + \boldsymbol{q} \cdot \boldsymbol{dW}(t)$$

where $\boldsymbol{dW}$ is a vector of standard Gaussian White noise and where several choice for $f(\boldsymbol{z})$ are available. For instance, the default choice is to use the full dynamics:

$$f(\boldsymbol{z}) = \sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, z_k\, z_j.$$

The implementation uses the tensorial framework described above and add some noise to it. This stochastic version is further detailed here.

The MTV parameterization for MAOOAM is given by

$$\frac{d\boldsymbol{x}}{dt} = F_x(\boldsymbol{x}) + \frac{1}{\delta} R(\boldsymbol{x}) + G(\boldsymbol{x}) + \sqrt{2}\, \boldsymbol{\sigma}(\boldsymbol{x}) \cdot \boldsymbol{dW}$$

where $\boldsymbol{x}$ is the set of resolved variables and $\boldsymbol{dW}$ is a vector of standard Gaussian White noise. F_x is the set of tendencies of resolved system alone and δ is the timescale separation parameter.

The WL parameterizations for MAOOAM is given by

$$\frac{d\boldsymbol{x}}{dt} = F_x(\boldsymbol{x}) + \varepsilon\, M_1(\boldsymbol{x}) + \varepsilon^2\, M_2(\boldsymbol{x}, t) + \varepsilon^2\, M_3(\boldsymbol{x}, t)$$

where ε is the resolved-unresolved components coupling strenght and where the different terms M_i account for different effect.

The implementation for these two approaches uses the tensorial framework described above, with the addition of new tensors to account for the terms $R, G, \sigma, M_1, M_2, M_3$. They are detailed more completely here.

Final Remarks

The authors would like to thank Kris for help with the lua2fortran project. It has greatly reduced the amount of (error-prone) work.

No animals were harmed during the coding process.

Chapter 2

Modular arbitrary-order ocean-atmosphere model: The Tangent Linear and Adjoint model

Description :

The Tangent Linear and Adjoint model model are implemented in the same way as the nonlinear model, with a tensor storing the different terms. The Tangent Linear (TL) tensor $\mathcal{T}_{i,j,k}^{TD}$ is defined as:

$$\mathcal{T}_{i,j,k}^{TL} = \mathcal{T}_{i,k,j} + \mathcal{T}_{i,j,k}$$

while the Adjoint (AD) tensor $\mathcal{T}_{i,j,k}^{AD}$ is defined as:

$$\mathcal{T}_{i,j,k}^{AD} = \mathcal{T}_{j,k,i} + \mathcal{T}_{j,i,k}.$$

where $\mathcal{T}_{i,j,k}$ is the tensor of the nonlinear model.

These two tensors are used to compute the trajectories of the models, with the equations

$$\frac{d\delta z_i}{dt} = \sum_{j=1}^{ndim} \sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}^{TL} \, y_k^* \, \delta z_j.$$

$$-\frac{d\delta z_i}{dt} = \sum_{j=1}^{ndim} \sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}^{AD} \, y_k^* \, \delta z_j.$$

where $\boldsymbol{y}^*$ is the point where the Tangent model is defined (with $z_0^* = 1$).

Implementation :

The two tensors are implemented in the module tl_ad_tensor and must be initialized (after calling params::init_params and aotensor_def::aotensor) by calling tl_ad_tensor::init_tltensor() and tl_ad_tensor::init_adtensor(). The tendencies are then given by the routine tl(t,ystar,deltay,buf) and ad(t,ystar,deltay,buf). An integrator with the Heun method is available in the module rk2_tl_ad_integrator and a fourth-order Runge-Kutta integrator in rk4_tl_ad_integrator. An example on how to use it can be found in the test file test_tl_ad.f90

Chapter 3

Modular arbitrary-order ocean-atmosphere model: The MTV and WL parameterizations

The stochastic version of MAOOAM

The stochastic version of MAOOAM is given by

$$\frac{d\boldsymbol{z}}{dt} = f(\boldsymbol{z}) + \boldsymbol{q} \cdot \boldsymbol{dW}(t)$$

where $\boldsymbol{dW}$ is a vector of standard Gaussian White noise and where several choice for $f(\boldsymbol{z})$ are available. For instance, the default choice is to use the full dynamics:

$$f(\boldsymbol{z}) = \sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k} \, z_k \, z_j.$$

The implementation uses thus the tensorial framework of MAOOAM and add some noise to it. To study parameterization methods in MAOOAM, the models variables $\boldsymbol{z}$ is divised in two components: the resolved component $\boldsymbol{x}$ and the unresolved component $\boldsymbol{y}$ (see below for more details).

Since MAOOAM is a ocean-atmosphere model, it can be decomposed further into oceanic and atmospheric components:

$$\boldsymbol{z} = \{\boldsymbol{x}_{\mathsf{a}}, \boldsymbol{x}_{\mathsf{o}}, \boldsymbol{y}_{\mathsf{a}}, \boldsymbol{y}_{\mathsf{o}}\}$$

and in the present implementation, the noise amplitude can be set in each component:

$$\frac{d\boldsymbol{x}_{\mathsf{a}}}{dt} = f_{x,\mathsf{a}}(\boldsymbol{z}) + \boldsymbol{q}_{x,\mathsf{a}} \cdot \boldsymbol{dW}_{x,\mathsf{a}}(t)$$

$$\frac{d\boldsymbol{x}_{\mathsf{o}}}{dt} = f_{x,\mathsf{o}}(\boldsymbol{z}) + \boldsymbol{q}_{x,\mathsf{o}} \cdot \boldsymbol{dW}_{x,\mathsf{o}}(t)$$

$$\frac{d\boldsymbol{y}_{\mathsf{a}}}{dt} = f_{y,\mathsf{a}}(\boldsymbol{z}) + \boldsymbol{q}_{y,\mathsf{a}} \cdot \boldsymbol{dW}_{y,\mathsf{a}}(t)$$

$$\frac{d\boldsymbol{y}_{\mathsf{o}}}{dt} = f_{y,\mathsf{o}}(\boldsymbol{z}) + \boldsymbol{q}_{y,\mathsf{o}} \cdot \boldsymbol{dW}_{y,\mathsf{o}}(t)$$

through the parameters stoch_params::q_ar, stoch_params::q_au, stoch_params::q_or and stoch_params::q_ou.

The resolved-unresolved components

Due to the decomposition into resoved variables $\boldsymbol{x}$ and unresolved variables $\boldsymbol{y}$, the equation of the MAOOAM model can be rewritten:

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{H}^x + \boldsymbol{L}^{xx} \cdot \boldsymbol{x} + \boldsymbol{L}^{xy} \cdot \boldsymbol{y} + \boldsymbol{B}^{xxx} : \boldsymbol{x} \otimes \boldsymbol{x} + \boldsymbol{B}^{xxy} : \boldsymbol{x} \otimes \boldsymbol{y} + \boldsymbol{B}^{xyy} : \boldsymbol{y} \otimes \boldsymbol{y} + \boldsymbol{q}_x \cdot \boldsymbol{dW}_x$$
$$\frac{d\boldsymbol{y}}{dt} = \boldsymbol{H}^y + \boldsymbol{L}^{yx} \cdot \boldsymbol{x} + \boldsymbol{L}^{yy} \cdot \boldsymbol{y} + \boldsymbol{B}^{yxx} : \boldsymbol{x} \otimes \boldsymbol{x} + \boldsymbol{B}^{yxy} : \boldsymbol{x} \otimes \boldsymbol{y} + \boldsymbol{B}^{yyy} : \boldsymbol{y} \otimes \boldsymbol{y} + \boldsymbol{q}_y \cdot \boldsymbol{dW}_y$$

where $\boldsymbol{q}_x = \{\boldsymbol{q}_{x,\text{a}}, \boldsymbol{q}_{x,\text{o}}\}$ and $\boldsymbol{q}_y = \{\boldsymbol{q}_{y,\text{a}}, \boldsymbol{q}_{y,\text{o}}\}$. We have thus also $\boldsymbol{dW}_x = \{\boldsymbol{dW}_{x,\text{a}}, \boldsymbol{dW}_{x,\text{o}}\}$ and $\boldsymbol{dW}_y = \{\boldsymbol{dW}_{y,\text{a}}, \boldsymbol{dW}_{y,\text{o}}\}$. The various terms of the equations above are accessible in the dec_tensor module. To specify which variables belong to the resolved (unresolved) component, the user must fill the SF.nml namelist file by setting the component of the vector sf_def::sf to 0 (1). This file must be filled before starting any of the stochastic and parameterization codes. If this file is not present, launch one of the programs. It will generate a new SF.nml file and then abort.

The purpose of the parameterization is to reduce the $\boldsymbol{x}$ equation by closing it while keeping the statisical properies of the full system. To apply the parameterizations proposed in this implementation, we consider a modified version of the equation above:

$$\frac{d\boldsymbol{x}}{dt} = F_x(\boldsymbol{x}) + \boldsymbol{q}_x \cdot \boldsymbol{dW}_x + \frac{\varepsilon}{\delta}\,\Psi_x(\boldsymbol{x}, \boldsymbol{y})$$
$$\frac{d\boldsymbol{y}}{dt} = \frac{1}{\delta^2}\left(F_y(\boldsymbol{y}) + \delta\,\boldsymbol{q}_y \cdot \boldsymbol{dW}_y\right) + \frac{\varepsilon}{\delta}\,\Psi_y(\boldsymbol{x}, \boldsymbol{y})$$

where ε is the resolved-unresolved components coupling strength given by the parameter stoch_params::eps_pert. δ is the timescale separation parameter given by the parameter stoch_params::tdelta. By setting those to 1, one recover the first equations above.

The function Ψ_x includes all the $\boldsymbol{x}$ terms, and thus F_x and Ψ_x are unequivocally defined. On the other hand, depending on the value of the parameter stoch_params::mode, the terms regrouped in the function F_y can be different. Indeed, if stoch_params::mode is set to

- 'qfst', then:

  $$F_y(\boldsymbol{y}) = \boldsymbol{B}^{yyy} : \boldsymbol{y} \otimes \boldsymbol{y}$$

- 'ures', then:

  $$F_y(\boldsymbol{y}) = \boldsymbol{H}^y + \boldsymbol{L}^{yy} \cdot \boldsymbol{y} + \boldsymbol{B}^{yyy} : \boldsymbol{y} \otimes \boldsymbol{y}$$

  However, for the WL parameterization, this parameter must be set to 'ures' by definition. See the article accompagnying this code for more details.

The MTV parameterization

This parameterization is also called homogenization. Its acronym comes from the names of the authors that proposed this approach for climate modes: Majda, Timofeyev and Vanden Eijnden (Majda et al., 2001). It is given by

$$\frac{d\boldsymbol{x}}{dt} = F_X(\boldsymbol{x}) + \frac{1}{\delta}R(\boldsymbol{x}) + G(\boldsymbol{x}) + \sqrt{2}\,\boldsymbol{\sigma}(\boldsymbol{x}) \cdot \boldsymbol{dW}$$

where $\boldsymbol{x}$ is the set of resolved variables and $\boldsymbol{dW}$ is a vector of standard Gaussian White noise. F_x is the set of tendencies of resolved system alone and δ is the timescale separation parameter.

Correlations specification

The ingredients needed to compute the terms $R, G, \boldsymbol{\sigma}$ of this parametrization are the unresolved variables covariance matrix and the integrated correlation matrices. The unresolved variables covariance matrix is given by

$$\boldsymbol{\sigma}_y = \langle \boldsymbol{y} \otimes \boldsymbol{y} \rangle$$

and is present in the implementation through the matrices corrmod::corr_i and corrmod::corr_i_full. Their inverses are also available through corrmod::inv_corr_i and corrmod::inv_corr_i_full . The integrated correlation matrices are given by

$$\boldsymbol{\Sigma} = \int_0^\infty ds \langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$$

$$\boldsymbol{\Sigma}_2 = \int_0^\infty ds \, (\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle \otimes \langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle)$$

and is present in the implementation through the matrices int_corr::corrint and int_corr::corr2int .

These matrices are computed from the correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ which is accessible through the function corrmod::corrcomp. For instance, the covariance matrix $\boldsymbol{\sigma}_y$ is then simply the correlation matrix at the lagtime 0, and $\boldsymbol{\Sigma}$ and $\boldsymbol{\Sigma}_2$ can be computed via integration over the lagtime.

There exists three different ways to load the correlation matrix, specified by the value of the parameters stoch_params::load_mode and stoch_params::int_corr_mode . The stoch_params::load_mode specify how the correlation matrix is loaded can take three different values:

- 'defi': from an analytical definition encoded in the corrmod module function corrmod::corrcomp_from_def .
- 'spli': from a spline definition file 'corrspline.def' .
- 'expo': from a fit with exponentials definition file 'correxpo.def'

The stoch_params::int_corr_mode specify how the correlation are integrated and can take two different values:

- 'file': Integration results provided by files 'corrint.def' and 'corr2int.def'
- 'prog': Integration computed directly by the program with the correlation matrix. Write 'corrint.def' and 'corr2int.def' files to be reused later.

These parameters can be set up in the namelist file stoch_params.nml . Examples of the ".def" files specifying the integrals are provided with the code.

Other MTV setup parameters

Some additional parameters complete the options possible for the MTV parameters :

- stoch_params::mnuti : Multiplicative noise update time interval – Time interval over which the matrix $\boldsymbol{\sigma}(\boldsymbol{x})$ is updated.
- stoch_params::t_trans_stoch : Transient period of the stochastic model.
- stoch_params::maxint : Specify the upper limit of the numerical integration if stoch_params::int_corr_mode is set to 'prog'.

Definition files

The following definition files are needed by the parameterization, depending on the value of the parameters described above. Examples of those files are joined to the code. The files include:

- 'mean.def' : Mean $\langle \boldsymbol{y} \rangle$ of the unresolved variables.
- 'correxpo.def': Coefficients a_k of the fit of the elements of the correlations matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ with the function

$$a_4 + a_0 \exp\left(-\frac{s}{a_1}\right) \cos(a_2\, s + a_3)$$

  where t is the lag-time and τ is the decorrelation time. Used if stoch_params::load_mode is set to 'expo'.
- 'corrspline.def': Coefficients b_k of the spline used to model the elements of the correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$. Used if stoch_params::load_mode is set to 'spli'.
- 'corrint.def': File holding the matrix $\boldsymbol{\Sigma}$. Used if stoch_params::int_corr_mode is set to 'file'.
- 'corr2int.def': File holding the matrix $\boldsymbol{\Sigma}_2$.

The various terms are then constructed according to these definition files. More details on the format of the definition files can be found here.

The WL parameterization

This parameterization is based on the Ruelle response theory. Its acronym comes from the names of the authors that proposed this approach: Wouters and Lucarini (Wouters and Lucarini, 2012). It is given by

$$\frac{d\boldsymbol{x}}{dt} = F_x(\boldsymbol{x}) + \varepsilon\, M_1(\boldsymbol{x}) + \varepsilon^2\, M_2(\boldsymbol{x}, t) + \varepsilon^2\, M_3(\boldsymbol{x}, t)$$

where ε is the resolved-unresolved components coupling strength and where the different terms M_i account for average, correlation and memory effects.

Correlations specification

The ingredients needed to compute the M_i terms of this parametrization are the unresolved variable covariance matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y} \rangle$ and correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$. The unresolved variables covariance matrix is given by

$$\boldsymbol{\sigma}_y = \langle \boldsymbol{y} \otimes \boldsymbol{y} \rangle$$

and is present in the implementation through the matrices corrmod::corr_i and corrmod::corr_i_full. Their inverses are also available through corrmod::inv_corr_i and corrmod::inv_corr_i_full.

The correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ is accessible through the function corrmod::corrcomp.

As for the MTV case, there exists three different ways to load the correlation matrix, specified by the value of the parameters stoch_params::load_mode and stoch_params::int_corr_mode . The stoch_params::load_mode specify how the correlation matrix is loaded can take three different values:

- 'defi': from an analytical definition encoded in the corrmod module function corrmod::corrcomp_from_def .
- 'spli': from a spline definition file 'corrspline.def' .
- 'expo': from a fit with exponentials definition file 'correxpo.def'

The correlation term M_2 is emulated by an order m multidimensional AutoRegressive (MAR) process:

$$\boldsymbol{u}_n = \sum_{i=1}^{m} \boldsymbol{u}_{n-i} \cdot \boldsymbol{W}_i + \boldsymbol{Q} \cdot \boldsymbol{\xi}_n$$

of which the $\boldsymbol{W}_i$ and $\boldsymbol{Q}$ matrices are also needed (the $\boldsymbol{\xi}_n$ are vectors of standard Gaussian white noise). It is implemented in the MAR module.

Other WL setup parameters

Some additional parameters complete the options possible for the WL parameters :

- stoch_params::muti : Memory term M_3 update time interval.
- stoch_params::t_trans_stoch : Transient period of the stochastic model.
- stoch_params::meml : Time over which the memory kernel is numericaly integrated.
- stoch_params::t_trans_mem : Transient period of the stochastic model to initialize the memory term.
- stoch_params::dts : Intrisic resolved dynamics time step.
- stoch_params::x_int_mode : Integration mode for the resolved component (not used for the moment – must be set to 'reso').

Note that the stoch_params::mode must absolutely be set to 'ures', by definition.

Definition files

The following definition files are needed by the parameterization, depending on the value of the parameters described above. Examples of those files are joined to the code. The files include:

- 'correxpo.def': Coefficients a_k of the fit of the elements of the correlations matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ with the function

  $$a_4 + a_0 \, \exp\left(-\frac{s}{a_1}\right) \, \cos(a_2 \, s + a_3)$$

  where t is the lag-time and τ is the decorrelation time. Used if stoch_params::load_mode is set to 'expo'.
- 'corrspline.def': Coefficients b_k of the spline used to model the elements of the correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$. Used if stoch_params::load_mode is set to 'spli'.
- 'MAR_R_params.def': File specifying the $\boldsymbol{R} = \boldsymbol{Q}^2$ matrix for the MAR.
- 'MAR_W_params.def': File specifying the $\boldsymbol{W}_i$ matrices for the MAR.

The various terms are then constructed according to these definition files. More details on the format of the definition files can be found here.

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Please see the main article for the full list of references.

Chapter 4

Modular arbitrary-order ocean-atmosphere model: Definition files formats

This page describes the format of the definition files needed by the stochastic model.

MTV parameterization

The following definition files are needed by the MTV parameterization. Examples of those files are joined to the code. The files include:

- 'mean.def' : Mean $\langle \boldsymbol{y} \rangle$ of the unresolved variables.
  - **Format**: one line per $\langle y_i \rangle$ value
- 'correxpo.def': Coefficients a_k of the fit of the elements of the correlations matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ with the function

  $$a_4 + a_0 \, \exp\left(-\frac{s}{a_1}\right) \, \cos(a_2 \, s + a_3)$$

  where t is the lag-time and τ is the decorrelation time.
  - **Format**: First line is two numbers: the number of unresolved variables and the value of stoch_params↩ ::maxint to be used (range of validity of the fit).
    Then each line specify the fit of an element i, j of the matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ as follow:

    $$i, j, a_0, a_1, a_2, a_3$$
  - Used if stoch_params::load_mode is set to 'expo'.
- 'corrspline.def': Coefficients b_k of the spline used to model the elements of the correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$.
  - **Format**: First line is two numbers: the number of unresolved variables and the number of points used.
    Second line is the times τ_k of the points in timeunits.
    Then $i \times j$ sequences of 3 lines occurs as follow:
    1. i, j
    2. Values of $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle_{i,j}$ at τ_k
    3. Coefficients b_k of the spline giving the second derivative of the interpolating function at τ
  - Used if stoch_params::load_mode is set to 'spli'.
- 'corrint.def': File holding the matrix $\boldsymbol{\Sigma} = \int_0^\infty \, ds \langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$.

  - **Format**: Matrix in a Fortran-contiguous format
  - Used if stoch_params::int_corr_mode is set to 'file'.
- 'corr2int.def': File holding the matrix $\mathbf{\Sigma}_2 = \int_0^\infty ds\ (\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle \otimes \langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle)$.
  - **Format**: Matrix in a sparse format, params::ndim sequences with
    1. a first line with the first index i of the matrix and then the number of entries the sub-matrix $\Sigma_{2,i,\cdot,\cdot,\cdot}$ has
    2. a list of the entries of the matrix in the format:

$$i, j, k, l, v$$

    where v is the value of the entry

WL parameterization

The following definition files are needed by the parameterization, depending on the value of the parameters described above. Examples of those files are joined to the code. The files include:

- 'mean.def' : Mean $\langle \boldsymbol{y} \rangle$ of the unresolved variables.
  - **Format**: one line per $\langle y_i \rangle$ value
- 'correxpo.def': Coefficients a_k of the fit of the elements of the correlations matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ with the function

$$a_4 + a_0 \exp\left(-\frac{s}{a_1}\right)\ \cos(a_2\, s + a_3)$$

  where t is the lag-time and τ is the decorrelation time.
  - **Format**: First line is two numbers: the number of unresolved variables and the value of stoch_params↩::maxint to be used (range of validity of the fit).
    Then each line specify the fit of an element i, j of the matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$ as follow:

$$i, j, a_0, a_1, a_2, a_3$$

  - Used if stoch_params::load_mode is set to 'expo'.
- 'corrspline.def': Coefficients b_k of the spline used to model the elements of the correlation matrix $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle$.
  - **Format**: First line is two numbers: the number of unresolved variables and the number of points used.
    Second line is the times τ_k of the points in timeunits.
    Then $i \times j$ sequences of 3 lines occurs as follow:
    1. i, j
    2. Values of $\langle \boldsymbol{y} \otimes \boldsymbol{y}^s \rangle_{i,j}$ at τ_k
    3. Coefficients b_k of the spline giving the second derivative of the interpolating function at τ
  - Used if stoch_params::load_mode is set to 'spli'.
- 'MAR_R_params.def': File specifying the $\boldsymbol{R} = \boldsymbol{Q}^2$ matrix for the MAR.
  - **Format**: Matrix in a Fortran-contiguous format
- 'MAR_W_params.def': File specifying the $\boldsymbol{W}_i$ matrices for the MAR.
  - **Format**: Matrix in a Fortran-contiguous format

Chapter 5

Modules Index

5.1 Modules List

Here is a list of all modules with brief descriptions:

Chapter 6

Data Type Index

6.1 Data Types List

Here are the data types with brief descriptions:

Chapter 7

File Index

7.1 File List

Here is a list of all files with brief descriptions:

Chapter 8

Module Documentation

8.1 aotensor_def Module Reference

The equation tensor for the coupled ocean-atmosphere model with temperature which allows for an extensible set of modes in the ocean and in the atmosphere.

Functions/Subroutines

- integer function psi (i)

  Translate the $\psi_{a,i}$ coefficients into effective coordinates.
- integer function theta (i)

  Translate the $\theta_{a,i}$ coefficients into effective coordinates.
- integer function a (i)

  Translate the $\psi_{o,i}$ coefficients into effective coordinates.
- integer function t (i)

  Translate the $\delta T_{o,i}$ coefficients into effective coordinates.
- integer function kdelta (i, j)

  Kronecker delta function.
- subroutine coeff (i, j, k, v)

  Subroutine to add element in the aotensor $\mathcal{T}_{i,j,k}$ structure.
- subroutine add_count (i, j, k, v)

  Subroutine to count the elements of the aotensor $\mathcal{T}_{i,j,k}$. Add +1 to count_elems(i) for each value that is added to the tensor i-th component.
- subroutine compute_aotensor (func)

  Subroutine to compute the tensor aotensor.
- subroutine, public init_aotensor

  Subroutine to initialise the aotensor tensor.

Variables

- integer, dimension(:), allocatable count_elems

  Vector used to count the tensor elements.
- real(kind=8), parameter real_eps = 2.2204460492503131e-16

  Epsilon to test equality with 0.
- type(coolist), dimension(:), allocatable, public aotensor

  $\mathcal{T}_{i,j,k}$ - Tensor representation of the tendencies.

8.1.1 Detailed Description

The equation tensor for the coupled ocean-atmosphere model with temperature which allows for an extensible set of modes in the ocean and in the atmosphere.

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Remarks

Generated Fortran90/95 code from aotensor.lua

8.1.2 Function/Subroutine Documentation

8.1.2.1 integer function aotensor_def::a (integer *i*) [private]

Translate the $\psi_{o,i}$ coefficients into effective coordinates.

Definition at line 76 of file aotensor_def.f90.

```
76      INTEGER :: i,a
77      a = i + 2 * natm
```

8.1.2.2 subroutine aotensor_def::add_count (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Subroutine to count the elements of the aotensor $\mathcal{T}_{i,j,k}$. Add +1 to count_elems(i) for each value that is added to the tensor i-th component.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value that will be added

Definition at line 124 of file aotensor_def.f90.

```
124      INTEGER, INTENT(IN) :: i,j,k
125      REAL(KIND=8), INTENT(IN)  :: v
126      IF (abs(v) .ge. real_eps) count_elems(i)=count_elems(i)+1
```

8.1.2.3 subroutine aotensor_def::coeff (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Subroutine to add element in the aotensor $\mathcal{T}_{i,j,k}$ structure.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value to add

Definition at line 99 of file aotensor_def.f90.

```
99      INTEGER, INTENT(IN) :: i,j,k
100      REAL(KIND=8), INTENT(IN) :: v
101      INTEGER :: n
102      IF (.NOT. ALLOCATED(aotensor)) stop "*** coeff routine : tensor not yet allocated ***"
103      IF (.NOT. ALLOCATED(aotensor(i)%elems)) stop "*** coeff routine : tensor not yet allocated ***"
104      IF (abs(v) .ge. real_eps) THEN
105         n=(aotensor(i)%nelems)+1
106         IF (j .LE. k) THEN
107            aotensor(i)%elems(n)%j=j
108            aotensor(i)%elems(n)%k=k
109         ELSE
110            aotensor(i)%elems(n)%j=k
111            aotensor(i)%elems(n)%k=j
112         END IF
113         aotensor(i)%elems(n)%v=v
114         aotensor(i)%nelems=n
115      END IF
```

8.1.2.4 subroutine aotensor_def::compute_aotensor (external *func*) [private]

Subroutine to compute the tensor aotensor.

Parameters

func	External function to be used

Definition at line 132 of file aotensor_def.f90.

8.1.2.5 subroutine, public aotensor_def::init_aotensor ( )

Subroutine to initialise the aotensor tensor.

Remarks

> This procedure will also call params::init_params() and inprod_analytic::init_inprod() . It will finally call inprod_analytic::deallocate_inprod() to remove the inner products, which are not needed anymore at this point.

Definition at line 203 of file aotensor_def.f90.

```
203      INTEGER :: i
204      INTEGER :: allocstat
205
206      CALL init_params  ! Iniatialise the parameter
207
208      CALL init_inprod  ! Initialise the inner product tensors
209
210      ALLOCATE(aotensor(ndim),count_elems(ndim), stat=allocstat)
211      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
```

```
count_elems=0

CALL compute_aotensor(add_count)

DO i=1,ndim
   ALLOCATE(aotensor(i)%elems(count_elems(i)), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
END DO

DEALLOCATE(count_elems, stat=allocstat)
IF (allocstat /= 0) stop "*** Deallocation problem ! ***"

CALL compute_aotensor(coeff)

CALL simplify(aotensor)

```

8.1.2.6 integer function aotensor_def::kdelta (integer *i*, integer *j*) [private]

Kronecker delta function.

Definition at line 88 of file aotensor_def.f90.

```
INTEGER :: i,j,kdelta
kdelta=0
IF (i == j) kdelta = 1
```

8.1.2.7 integer function aotensor_def::psi (integer *i*) [private]

Translate the $\psi_{a,i}$ coefficients into effective coordinates.

Definition at line 64 of file aotensor_def.f90.

```
INTEGER :: i,psi
psi = i
```

8.1.2.8 integer function aotensor_def::t (integer *i*) [private]

Translate the $\delta T_{o,i}$ coefficients into effective coordinates.

Definition at line 82 of file aotensor_def.f90.

```
INTEGER :: i,t
t = i + 2 * natm + noc
```

8.1.2.9 integer function aotensor_def::theta (integer *i*) [private]

Translate the $\theta_{a,i}$ coefficients into effective coordinates.

Definition at line 70 of file aotensor_def.f90.

```
INTEGER :: i,theta
theta = i + natm
```

8.1.3 Variable Documentation

8.1.3.1 type(coolist), dimension(:), allocatable, public aotensor_def::aotensor

$\mathcal{T}_{i,j,k}$ - Tensor representation of the tendencies.

Definition at line 45 of file aotensor_def.f90.

```
45   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: aotensor
```

8.1.3.2 integer, dimension(:), allocatable aotensor_def::count_elems [private]

Vector used to count the tensor elements.

Definition at line 37 of file aotensor_def.f90.

```
37   INTEGER, DIMENSION(:), ALLOCATABLE :: count_elems
```

8.1.3.3 real(kind=8), parameter aotensor_def::real_eps = 2.2204460492503131e-16 [private]

Epsilon to test equality with 0.

Definition at line 40 of file aotensor_def.f90.

```
40   REAL(KIND=8), PARAMETER :: real_eps = 2.2204460492503131e-16
```

8.2 corr_tensor Module Reference

Module to compute the correlations and derivatives used to compute the memory term of the WL parameterization.

Functions/Subroutines

- subroutine, public init_corr_tensor

    Subroutine to initialise the correlations tensors.

Variables

- type(coolist), dimension(:,:), allocatable, public yy

  Coolist holding the $\langle Y \otimes Y^s \rangle$ terms.
- type(coolist), dimension(:,:), allocatable, public dy

  Coolist holding the $\langle \partial_Y \otimes Y^s \rangle$ terms.
- type(coolist), dimension(:,:), allocatable, public ydy

  Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \rangle$ terms.
- type(coolist), dimension(:,:), allocatable, public dyy

  Coolist holding the $\langle \partial_Y \otimes Y^s \otimes Y^s \rangle$ terms.
- type(coolist4), dimension(:,:), allocatable, public ydyy

  Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \otimes Y^s \rangle$ terms.
- real(kind=8), dimension(:), allocatable dumb_vec

  Dumb vector to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable dumb_mat1

  Dumb matrix to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable dumb_mat2

  Dumb matrix to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable expm

  Matrix holding the product inv_corr_i$*$corr_ij at time s.

8.2.1 Detailed Description

Module to compute the correlations and derivatives used to compute the memory term of the WL parameterization.

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Remarks

8.2.2 Function/Subroutine Documentation

8.2.2.1 subroutine, public corr_tensor::init_corr_tensor ( )

Subroutine to initialise the correlations tensors.

Definition at line 45 of file corr_tensor.f90.

```
45      INTEGER :: i,j,m,allocstat
46
47      CALL init_corr
48
49      print*, 'Computing the time correlation tensors...'
50
51      ALLOCATE(yy(ndim,mems),dy(ndim,mems), dyy(ndim,mems), stat=allocstat)
52      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
53
54      ALLOCATE(ydy(ndim,mems), ydyy(ndim,mems), stat=allocstat)
55      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
56
57      ALLOCATE(dumb_vec(ndim), stat=allocstat)
```

```
  IF (allocstat /= 0) stop "*** Not enough memory ! ***"

  ALLOCATE(dumb_mat1(ndim,ndim), dumb_mat2(ndim,ndim), stat=allocstat)
  IF (allocstat /= 0) stop "*** Not enough memory ! ***"

  ALLOCATE(expm(n_unres,n_unres), stat=allocstat)
  IF (allocstat /= 0) stop "*** Not enough memory ! ***"

  DO m=1,mems
     CALL corrcomp((m-1)*muti)

     ! YY
     CALL ireduce(dumb_mat2,corr_ij,n_unres,ind,rind)
     CALL matc_to_coo(dumb_mat2,yy(:,m))

     ! dY
     expm=matmul(inv_corr_i,corr_ij)
     CALL ireduce(dumb_mat2,expm,n_unres,ind,rind)
     CALL matc_to_coo(dumb_mat2,dy(:,m))

     ! YdY
     DO i=1,n_unres
        CALL ireduce(dumb_mat2,mean(i)*expm,n_unres,ind,rind)
        CALL add_matc_to_tensor(ind(i),dumb_mat2,ydy(:,m))
     ENDDO

     ! dYY
     dumb_vec(1:n_unres)=matmul(mean,expm)
     DO i=1,n_unres
        CALL vector_outer(expm(i,:),dumb_vec(1:n_unres),dumb_mat2(1:n_unres,1:n_unres))
        CALL ireduce(dumb_mat1,dumb_mat2+transpose(dumb_mat2),n_unres,ind,rind)
        CALL add_matc_to_tensor(ind(i),dumb_mat1,dyy(:,m))
     ENDDO

     ! YdYY
     DO i=1,n_unres
        DO j=1,n_unres
           CALL vector_outer(corr_ij(i,:),expm(j,:),dumb_mat2(1:n_unres,1:n_unres))
           CALL ireduce(dumb_mat1,dumb_mat2+transpose(dumb_mat2),n_unres,ind,rind)
           CALL add_matc_to_tensor4(ind(i),ind(j),dumb_mat1,ydyy(:,m))
        ENDDO
     ENDDO
   ENDDO

   DEALLOCATE(dumb_mat1, dumb_mat2, stat=allocstat)
   IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

   DEALLOCATE(dumb_vec, stat=allocstat)
   IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"
```

8.2.3 Variable Documentation

8.2.3.1 real(kind=8), dimension(:,:), allocatable corr_tensor::dumb_mat1 [private]

Dumb matrix to be used in the calculation.

Definition at line 37 of file corr_tensor.f90.

```
37    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat1 !< Dumb matrix to be used in the calculation
```

8.2.3.2 real(kind=8), dimension(:,:), allocatable corr_tensor::dumb_mat2 [private]

Dumb matrix to be used in the calculation.

Definition at line 38 of file corr_tensor.f90.

```
38    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat2 !< Dumb matrix to be used in the calculation
```

8.2.3.3 real(kind=8), dimension(:), allocatable corr_tensor::dumb_vec [private]

Dumb vector to be used in the calculation.

Definition at line 36 of file corr_tensor.f90.

```
36   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dumb_vec !< Dumb vector to be used in the calculation
```

8.2.3.4 type(coolist), dimension(:,:), allocatable, public corr_tensor::dy

Coolist holding the $\langle \partial_Y \otimes Y^s \rangle$ terms.

Definition at line 31 of file corr_tensor.f90.

```
31   TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: dy !< Coolist holding the  \f$\langle \partial_Y
       \otimes Y^s \rangle\f$ terms
```

8.2.3.5 type(coolist), dimension(:,:), allocatable, public corr_tensor::dyy

Coolist holding the $\langle \partial_Y \otimes Y^s \otimes Y^s \rangle$ terms.

Definition at line 33 of file corr_tensor.f90.

```
33   TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: dyy !< Coolist holding the  \f$\langle \partial_Y
       \otimes Y^s \otimes Y^s \rangle\f$ terms
```

8.2.3.6 real(kind=8), dimension(:,:), allocatable corr_tensor::expm [private]

Matrix holding the product inv_corr_i∗corr_ij at time s.

Definition at line 39 of file corr_tensor.f90.

```
39   REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: expm !< Matrix holding the product inv_corr_i*corr_ij at
       time \f$s\f$
```

8.2.3.7 type(coolist), dimension(:,:), allocatable, public corr_tensor::ydy

Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \rangle$ terms.

Definition at line 32 of file corr_tensor.f90.

```
32   TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: ydy !< Coolist holding the  \f$\langle Y \otimes
       \partial_Y \otimes Y^s \rangle\f$ terms
```

8.2.3.8 type(coolist4), dimension(:,:), allocatable, public corr_tensor::ydyy

Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \otimes Y^s \rangle$ terms.

Definition at line 34 of file corr_tensor.f90.

```
34    TYPE(coolist4), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: ydyy !< Coolist holding the  \f$\langle Y \otimes
        \partial_Y \otimes Y^s \otimes Y^s \rangle\f$ terms
```

8.2.3.9 type(coolist), dimension(:,:), allocatable, public corr_tensor::yy

Coolist holding the $\langle Y \otimes Y^s \rangle$ terms.

Definition at line 30 of file corr_tensor.f90.

```
30    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: yy !< Coolist holding the  \f$\langle Y \otimes Y^s
        \rangle\f$ terms
```

8.3 corrmod Module Reference

Module to initialize the correlation matrix of the unresolved variables.

Functions/Subroutines

- subroutine, public init_corr

  Subroutine to initialise the computation of the correlation.
- subroutine corrcomp_from_def (s)

  Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the definition given inside the module.
- subroutine corrcomp_from_spline (s)

  Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the spline representation.
- subroutine splint (xa, ya, y2a, n, x, y)

  Routine to compute the spline representation parameters.
- real(kind=8) function fs (s, p)

  Exponential fit function.
- subroutine corrcomp_from_fit (s)

  Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the exponential representation.

Variables

- real(kind=8), dimension(:), allocatable, public mean
  Vector holding the mean of the unresolved dynamics (reduced version)
- real(kind=8), dimension(:), allocatable, public mean_full
  Vector holding the mean of the unresolved dynamics (full version)
- real(kind=8), dimension(:,:), allocatable, public corr_i_full
  Covariance matrix of the unresolved variables (full version)
- real(kind=8), dimension(:,:), allocatable, public inv_corr_i_full
  Inverse of the covariance matrix of the unresolved variables (full version)
- real(kind=8), dimension(:,:), allocatable, public corr_i
  Covariance matrix of the unresolved variables (reduced version)
- real(kind=8), dimension(:,:), allocatable, public inv_corr_i
  Inverse of the covariance matrix of the unresolved variables (reduced version)
- real(kind=8), dimension(:,:), allocatable, public corr_ij
  Matrix holding the correlation matrix at a given time.
- real(kind=8), dimension(:,:,:), allocatable y2
  Vector holding coefficient of the spline and exponential correlation representation.
- real(kind=8), dimension(:,:,:), allocatable ya
  Vector holding coefficient of the spline and exponential correlation representation.
- real(kind=8), dimension(:), allocatable xa
  Vector holding coefficient of the spline and exponential correlation representation.
- integer nspl
  Integers needed by the spline representation of the correlation.
- integer klo
- integer khi
- procedure(corrcomp_from_spline), pointer, public corrcomp
  Pointer to the correlation computation routine.

8.3.1 Detailed Description

Module to initialize the correlation matrix of the unresolved variables.

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Remarks

8.3.2 Function/Subroutine Documentation

8.3.2.1 subroutine corrmod::corrcomp_from_def (real(kind=8), intent(in) *s*) [private]

Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the definition given inside the module.

Parameters

s	time s at which the correlation is computed

Definition at line 148 of file corrmod.f90.

```
148     REAL(KIND=8), INTENT(IN) :: s
149     REAL(KIND=8) :: y
150     INTEGER :: i,j
151 
152     ! Definition of the corr_ij matrix as a function of time
153 
154     corr_ij(10,10)=((7.66977252307669*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (1.0240906173830213*cos(&
155          &0.07283568782600224*s))/exp(0.017262015588746404*s) - (0.6434985372062336*sin(0.039597160512071454*s&
156          &))/exp(0.06567483898489704*s) + (0.6434985372062335*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
157     corr_ij(10,9)=((0.6434985372062321*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) - (0.6434985372062324*co&
158          &s(0.07283568782600224*s))/exp(0.017262015588746404*s) + (7.669772523076694*sin(0.039597160512071454*&
159          &s))/exp(0.06567483898489704*s) + (1.024090617383021*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
160     corr_ij(10,8)=0
161     corr_ij(10,7)=0
162     corr_ij(10,6)=0
163     corr_ij(10,5)=((-2.236364132659011*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (6.952804148086198*cos&
164          &(0.07283568782600224*s))/exp(0.017262015588746404*s) - (1.4494534432272481*sin(0.039597160512071454*&
165          &s))/exp(0.06567483898489704*s) - (0.6818177416446283*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
166     corr_ij(10,4)=((1.4494534432272483*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (0.6818177416446293*co&
167          &s(0.07283568782600224*s))/exp(0.017262015588746404*s) - (2.2363641326590127*sin(0.039597160512071454&
168          &*s))/exp(0.06567483898489704*s) + (6.952804148086195*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
169     corr_ij(10,3)=0
170     corr_ij(10,2)=0
171     corr_ij(10,1)=0
172     corr_ij(9,10)=((-0.6434985372062344*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (0.643498537206234*co&
173          &s(0.07283568782600224*s))/exp(0.017262015588746404*s) - (7.669772523076689*sin(0.039597160512071454*&
174          &s))/exp(0.06567483898489704*s) - (1.0240906173830204*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
175     corr_ij(9,9)=((7.66977252307669*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (1.0240906173830204*cos(&
176          &0.07283568782600224*s))/exp(0.017262015588746404*s) - (0.643498537206233*sin(0.039597160512071454*s)&
177          &)/exp(0.06567483898489704*s) + (0.6434985372062327*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
178     corr_ij(9,8)=0
179     corr_ij(9,7)=0
180     corr_ij(9,6)=0
181     corr_ij(9,5)=((-1.4494534432272477*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) - (0.6818177416446249*c&
182          &os(0.07283568782600224*s))/exp(0.017262015588746404*s) + (2.2363641326590105*sin(0.03959716051207145&
183          &4*s))/exp(0.06567483898489704*s) - (6.952804148086195*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
184     corr_ij(9,4)=((-2.2363641326590127*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (6.952804148086194*co&
185          &s(0.07283568782600224*s))/exp(0.017262015588746404*s) - (1.4494534432272486*sin(0.039597160512071454&
186          &*s))/exp(0.06567483898489704*s) - (0.6818177416446249*sin(0.07283568782600224*s))/exp(0.017262015588746404*s))
187     corr_ij(9,3)=0
188     corr_ij(9,2)=0
189     corr_ij(9,1)=0
190     corr_ij(8,10)=0
191 
192     corr_ij(8,9)=0
193     corr_ij(8,8)=(9.135647293470983/exp(0.05076718239027029*s) + 2.2233889637758932/exp(0.016285467000648854*s))
194     corr_ij(8,7)=0
195     corr_ij(8,6)=0
196     corr_ij(8,5)=0
197     corr_ij(8,4)=0
198     corr_ij(8,3)=(-5.938566084855411/exp(0.05076718239027029*s) + 11.97129741027622/exp(0.016285467000648854
```

```
4*s))
  corr_ij(8,2)=0
  corr_ij(8,1)=0
  corr_ij(7,10)=0

  corr_ij(7,9)=0
  corr_ij(7,8)=0
  corr_ij(7,7)=((11.518026982819887*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.05351107
793747755*c&
       &os(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.14054811601869432*sin(0.0293414097268
719&
       &26*s))/exp(0.04435489221745234*s) + (0.14054811601869702*sin(0.11425932545092894*s))/exp(0.019700
737327669783*s))
  corr_ij(7,6)=((0.14054811601869532*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) - (0.1405481
1601869702*&
       &cos(0.11425932545092894*s))/exp(0.019700737327669783*s) + (11.518026982819887*sin(0.0293414097268
719&
       &26*s))/exp(0.04435489221745234*s) + (0.0535110779374777*sin(0.11425932545092894*s))/exp(0.0197007
37327669783*s))
  corr_ij(7,5)=0
  corr_ij(7,4)=0
  corr_ij(7,3)=0
  corr_ij(7,2)=((-0.732907009016115*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (2.72884503
1386875*cos&
       &(0.11425932545092894*s))/exp(0.019700737327669783*s) - (2.4717920234033532*sin(0.029341409726871 9
26*&
       &s))/exp(0.04435489221745234*s) - (0.24003801347124257*sin(0.11425932545092894*s))/exp(0.019700737
327669783*s))
  corr_ij(7,1)=((2.4717920234033532*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.24003801
34712426*co&
       &s(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.7329070090161153*sin(0.029341409726871
926&
       &*s))/exp(0.04435489221745234*s) + (2.728845031386876*sin(0.11425932545092894*s))/exp(0.0197007373
27669783*s))
  corr_ij(6,10)=0

  corr_ij(6,9)=0
  corr_ij(6,8)=0
  corr_ij(6,7)=((-0.1405481160186977*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.1405481
1601869713*&
       &cos(0.11425932545092894*s))/exp(0.019700737327669783*s) - (11.518026982819885*sin(0.0293414097268
719&
       &26*s))/exp(0.04435489221745234*s) - (0.05351107793747755*sin(0.11425932545092894*s))/exp(0.019700
737327669783*s))
  corr_ij(6,6)=((11.518026982819885*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.05351107
793747768*c&
       &os(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.14054811601869832*sin(0.0293414097268
719&
       &26*s))/exp(0.04435489221745234*s) + (0.14054811601869707*sin(0.11425932545092894*s))/exp(0.019700
737327669783*s))
  corr_ij(6,5)=0
  corr_ij(6,4)=0
  corr_ij(6,3)=0
  corr_ij(6,2)=((-2.471792023403353*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) - (0.24003801
34712425*co&
       &s(0.11425932545092894*s))/exp(0.019700737327669783*s) + (0.7329070090161155*sin(0.029341409726871
926&
       &*s))/exp(0.04435489221745234*s) - (2.7288450313868755*sin(0.11425932545092894*s))/exp(0.019700737
327669783*s))
  corr_ij(6,1)=((-0.7329070090161154*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (2.7288450
31386876*co&
       &s(0.11425932545092894*s))/exp(0.019700737327669783*s) - (2.4717920234033524*sin(0.029341409726871
926&
       &*s))/exp(0.04435489221745234*s) - (0.24003801347124343*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))
  corr_ij(5,10)=((0.5794534449999711*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (4.1369865
70427212*cos&
       &(0.07283568782600224*s))/exp(0.017262015588746404*s) - (1.0360597341248128*sin(0.0395971605120714
54*&
       &s))/exp(0.06567483898489704*s) + (3.167330918996692*sin(0.07283568782600224*s))/exp(0.01726201558
8746404*s))
  corr_ij(5,9)=((1.0360597341248134*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) - (3.16733091
89966856*co&
       &s(0.07283568782600224*s))/exp(0.017262015588746404*s) + (0.5794534449999746*sin(0.039597160512071
454&
       &*s))/exp(0.06567483898489704*s) + (4.1369865704272115*sin(0.07283568782600224*s))/exp(0.017262015
588746404*s))
  corr_ij(5,8)=0
  corr_ij(5,7)=0
  corr_ij(5,6)=0
  corr_ij(5,5)=((-0.37825091063447547*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (30.09469
0926061638*&
       &cos(0.07283568782600224*s))/exp(0.017262015588746404*s) + (0.16085380971100194*sin(0.039597160512
071&
       &454*s))/exp(0.06567483898489704*s) - (0.1608538097109995*sin(0.07283568782600224*s))/exp(0.017262
015588746404*s))
  corr_ij(5,4)=((-0.16085380971100238*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (0.160853
```

```
80971100127&
        &*cos(0.07283568782600224*s))/exp(0.017262015588746404*s) - (0.37825091063447586*sin(0.03959716051
207&
        &1454*s))/exp(0.06567483898489704*s) + (30.09469092606163*sin(0.07283568782600224*s))/exp(0.017262
015588746404*s))
   corr_ij(5,3)=0
   corr_ij(5,2)=0
   corr_ij(5,1)=0
   corr_ij(4,10)=((-1.0360597341248106*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (3.167330
918996689*co&
        &s(0.07283568782600224*s))/exp(0.017262015588746404*s) - (0.5794534449999716*sin(0.039597160512071
454&
        &*s))/exp(0.06567483898489704*s) - (4.1369865704272115*sin(0.07283568782600224*s))/exp(0.017262015
588746404*s))
   corr_ij(4,9)=((0.5794534449999711*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (4.13698657
04272115*co&
        &s(0.07283568782600224*s))/exp(0.017262015588746404*s) - (1.0360597341248114*sin(0.039597160512071
454&
        &*s))/exp(0.06567483898489704*s) + (3.1673309189966843*sin(0.07283568782600224*s))/exp(0.017262015
588746404*s))
   corr_ij(4,8)=0
   corr_ij(4,7)=0
   corr_ij(4,6)=0
   corr_ij(4,5)=((0.16085380971100194*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) - (0.1608538
0971100371*&
        &cos(0.07283568782600224*s))/exp(0.017262015588746404*s) + (0.37825091063447497*sin(0.039597160512
071&
        &454*s))/exp(0.06567483898489704*s) - (30.094690926061617*sin(0.07283568782600224*s))/exp(0.017262
015588746404*s))
   corr_ij(4,4)=((-0.37825091063447536*cos(0.039597160512071454*s))/exp(0.06567483898489704*s) + (30.09469
0926061617*&
        &cos(0.07283568782600224*s))/exp(0.017262015588746404*s) + (0.16085380971100172*sin(0.039597160512
071&
        &454*s))/exp(0.06567483898489704*s) - (0.16085380971100616*sin(0.07283568782600224*s))/exp(0.01726
2015588746404*s))
   corr_ij(4,3)=0
   corr_ij(4,2)=0
   corr_ij(4,1)=0
   corr_ij(3,10)=0

   corr_ij(3,9)=0
   corr_ij(3,8)=(0.24013456462471527/exp(0.05076718239027029*s) + 5.792596760796093/exp(0.0162854670006488
54*s))
   corr_ij(3,7)=0
   corr_ij(3,6)=0
   corr_ij(3,5)=0
   corr_ij(3,4)=0
   corr_ij(3,3)=(-0.15609785880208227/exp(0.05076718239027029*s) + 31.18882918422289/exp(0.016285467000648
854*s))
   corr_ij(3,2)=0
   corr_ij(3,1)=0
   corr_ij(2,10)=0

   corr_ij(2,9)=0
   corr_ij(2,8)=0
   corr_ij(2,7)=((1.6172201305728584*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.37871789
179790255*c&
        &os(0.11425932545092894*s))/exp(0.019700737327669783*s) + (1.2889451151208258*sin(0.02934140972687
192&
        &6*s))/exp(0.04435489221745234*s) + (1.4228849217537705*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))
   corr_ij(2,6)=((-1.2889451151208255*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) - (1.4228849
217537702*c&
        &os(0.11425932545092894*s))/exp(0.019700737327669783*s) + (1.6172201305728586*sin(0.02934140972687
192&
        &6*s))/exp(0.04435489221745234*s) + (0.3787178917979035*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))
   corr_ij(2,5)=0
   corr_ij(2,4)=0
   corr_ij(2,3)=0
   corr_ij(2,2)=((0.1789135645266575*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (26.8170244
57844113*co&
        &s(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.4268927977731004*sin(0.029341409726871
926&
        &*s))/exp(0.04435489221745234*s) + (0.4268927977730982*sin(0.11425932545092894*s))/exp(0.019700737
327669783*s))
   corr_ij(2,1)=((0.4268927977731007*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) - (0.42689279
777309963*c&
        &os(0.11425932545092894*s))/exp(0.019700737327669783*s) + (0.17891356452665746*sin(0.0293414097268
719&
        &26*s))/exp(0.04435489221745234*s) + (26.81702445784412*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))
   corr_ij(1,10)=0

   corr_ij(1,9)=0
   corr_ij(1,8)=0
   corr_ij(1,7)=((1.288945115120824*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (1.422884921
```

```
7537711*cos&
      &(0.11425932545092894*s))/exp(0.019700737327669783*s) - (1.617220130572856*sin(0.02934140972687192
6*s&
      &))/exp(0.04435489221745234*s) - (0.3787178917979028*sin(0.11425932545092894*s))/exp(0.01970073732
7669783*s))
  corr_ij(1,6)=((1.6172201305728564*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.37871789
179790377*c&
      &os(0.11425932545092894*s))/exp(0.019700737327669783*s) + (1.2889451151208242*sin(0.02934140972687
192&
      &6*s))/exp(0.04435489221745234*s) + (1.4228849217537711*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))
  corr_ij(1,5)=0
  corr_ij(1,4)=0
  corr_ij(1,3)=0
  corr_ij(1,2)=((-0.4268927977731002*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (0.4268927
977730981*c&
      &os(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.1789135645266573*sin(0.02934140972687
192&
      &6*s))/exp(0.04435489221745234*s) - (26.81702445784412*sin(0.11425932545092894*s))/exp(0.019700737
327669783*s))
  corr_ij(1,1)=((0.1789135645266574*cos(0.029341409726871926*s))/exp(0.04435489221745234*s) + (26.8170244
57844113*co&
      &s(0.11425932545092894*s))/exp(0.019700737327669783*s) - (0.42689279777310024*sin(0.02934140972687
192&
      &6*s))/exp(0.04435489221745234*s) + (0.4268927977730997*sin(0.11425932545092894*s))/exp(0.01970073
7327669783*s))

  corr_ij=q_au**2*corr_ij

```

8.3.2.2 subroutine corrmod::corrcomp_from_fit (real(kind=8), intent(in) *s*) [private]

Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the exponential representation.

Parameters

s	time s at which the correlation is computed

Definition at line 399 of file corrmod.f90.

```
399   REAL(KIND=8), INTENT(IN) :: s
400   REAL(KIND=8) :: y
401   INTEGER :: i,j
402
403   corr_ij=0.d0
404   DO i=1,n_unres
405      DO j=1,n_unres
406         corr_ij(i,j)=fs(s,ya(i,j,:))
407      END DO
408   END DO
```

8.3.2.3 subroutine corrmod::corrcomp_from_spline (real(kind=8), intent(in) *s*) [private]

Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ at time s from the spline representation.

Parameters

s	time s at which the correlation is computed

Definition at line 333 of file corrmod.f90.

```
333   REAL(KIND=8), INTENT(IN) :: s
```

```
334     REAL(KIND=8) :: y
335     INTEGER :: i,j
336     corr_ij=0.d0
337     DO i=1,n_unres
338        DO j=1,n_unres
339           CALL splint(xa,ya(i,j,:),y2(i,j,:),nspl,s,y)
340           corr_ij(i,j)=y
341        END DO
342     END DO
```

8.3.2.4 real(kind=8) function corrmod::fs (real(kind=8), intent(in) *s*, real(kind=8), dimension(5), intent(in) *p*) [private]

Exponential fit function.

Parameters

s	time s at which the function is evaluated
p	vector holding the coefficients of the fit function

Definition at line 388 of file corrmod.f90.

```
388     REAL(KIND=8), INTENT(IN) :: s
389     REAL(KIND=8), DIMENSION(5), INTENT(IN) :: p
390     REAL(KIND=8) :: fs
391     fs=p(1)*exp(-s/p(2))*cos(p(3)*s+p(4))
392     RETURN
```

8.3.2.5 subroutine, public corrmod::init_corr ( )

Subroutine to initialise the computation of the correlation.

Definition at line 46 of file corrmod.f90.

```
46     INTEGER :: allocstat,i,j,k,nf
47     REAL(KIND=8), DIMENSION(5) :: dumb
48     LOGICAL :: ex
49
50     ! Selection of the loading mode
51     SELECT CASE (load_mode)
52     CASE ('defi')
53        corrcomp => corrcomp_from_def
54     CASE ('spli')
55        INQUIRE(file='corrspline.def',exist=ex)
56        IF (.not.ex) stop "*** File corrspline.def not found ! ***"
57        OPEN(20,file='corrspline.def',status='old')
58        READ(20,*) nf,nspl
59        IF (nf /= n_unres) stop "*** Dimension in files corrspline.def and sf.nml do not correspond ! ***"
60        ALLOCATE(xa(nspl), ya(n_unres,n_unres,nspl), y2(n_unres,n_unres,nspl),
       stat=allocstat)
61        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
62        READ(20,*) xa
63        maxint=xa(nspl)/2
64        DO k=1,n_unres*n_unres
65           READ(20,*) i,j
66           READ(20,*) ya(i,j,:)
67           READ(20,*) y2(i,j,:)
68        ENDDO
69        CLOSE(20)
70        corrcomp => corrcomp_from_spline
71        klo=1
72        khi=nspl
73     CASE ('expo')
74        INQUIRE(file='correxpo.def',exist=ex)
75        IF (.not.ex) stop "*** File correxpo.def not found ! ***"
76        OPEN(20,file='correxpo.def',status='old')
```

```
      READ(20,*) nf,maxint
      IF (nf /= n_unres) stop "*** Dimension in files correxpo.def and sf.nml do not correspond ! ***"
      ALLOCATE(ya(n_unres,n_unres,5), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
      DO k=1,n_unres*n_unres
         READ(20,*) i,j,dumb
         ya(i,j,:)=dumb
      ENDDO
      CLOSE(20)
      corrcomp => corrcomp_from_fit
   CASE DEFAULT
      stop '*** LOAD_MODE variable not properly defined in corrmod.nml ***'
   END SELECT

   ALLOCATE(mean(n_unres),mean_full(0:ndim), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ALLOCATE(inv_corr_i(n_unres,n_unres), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ALLOCATE(corr_i(n_unres,n_unres), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ALLOCATE(corr_ij(n_unres,n_unres), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ALLOCATE(corr_i_full(ndim,ndim), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ALLOCATE(inv_corr_i_full(ndim,ndim), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   corr_ij=0.d0

   CALL corrcomp(0.d0)
   corr_i=corr_ij
   inv_corr_i=invmat(corr_i)

   corr_i_full=0.d0
   DO i=1,n_unres
      DO j=1,n_unres
         corr_i_full(ind(i),ind(j))=corr_i(i,j)
      ENDDO
   ENDDO

   inv_corr_i_full=0.d0
   DO i=1,n_unres
      DO j=1,n_unres
         inv_corr_i_full(ind(i),ind(j))=inv_corr_i(i,j)
      ENDDO
   ENDDO

   mean=0.d0
   INQUIRE(file='mean.def',exist=ex)
   IF (ex) THEN
      OPEN(20,file='mean.def',status='old')
      READ(20,*) mean
      CLOSE(20)
   ENDIF

   mean_full=0.d0
   DO i=1,n_unres
      mean_full(ind(i))=mean(i)
   ENDDO

```

8.3.2.6 subroutine corrmod::splint (real(kind=8), dimension(n), intent(in) *xa*, real(kind=8), dimension(n), intent(in) *ya*, real(kind=8), dimension(n), intent(in) *y2a*, integer, intent(in) *n*, real(kind=8), intent(in) *x*, real(kind=8), intent(out) *y*) [private]

Routine to compute the spline representation parameters.

Definition at line 347 of file corrmod.f90.

```
347     INTEGER, INTENT(IN) :: n
348     REAL(KIND=8), INTENT(IN), DIMENSION(n) :: xa,y2a,ya
349     REAL(KIND=8), INTENT(IN) :: x
350     REAL(KIND=8), INTENT(OUT) :: y
```

```
  INTEGER :: k
  REAL(KIND=8) :: a,b,h
  if ((khi-klo.gt.1).or.(xa(klo).gt.x).or.(xa(khi).lt.x)) then
     if ((khi-klo.eq.1).and.(xa(klo).lt.x)) then
        khi=klo
        DO WHILE (xa(khi).lt.x)
           khi=khi+1
        END DO
        klo=khi-1
     else
        khi=n
        klo=1
        DO WHILE (khi-klo.gt.1)
           k=(khi+klo)/2
           if(xa(k).gt.x)then
              khi=k
           else
              klo=k
           endif
        END DO
     end if
  !    print*, "search",x,khi-klo,xa(klo),xa(khi)
  ! else
  !    print*, "ok",x,khi-klo,xa(klo),xa(khi)
  endif
  h=xa(khi)-xa(klo)
  if (h.eq.0.) stop 'bad xa input in splint'
  a=(xa(khi)-x)/h
  b=(x-xa(klo))/h
  y=a*ya(klo)+b*ya(khi)+((a**3-a)*y2a(klo)+(b**3-b)*y2a(khi))*(h**2)/6.
  return
```

8.3.3 Variable Documentation

8.3.3.1 real(kind=8), dimension(:,:), allocatable, public corrmod::corr_i

Covariance matrix of the unresolved variables (reduced version)

Definition at line 30 of file corrmod.f90.

```
30  REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: corr_i !< Covariance matrix of the unresolved
      variables (reduced version)
```

8.3.3.2 real(kind=8), dimension(:,:), allocatable, public corrmod::corr_i_full

Covariance matrix of the unresolved variables (full version)

Definition at line 28 of file corrmod.f90.

```
28  REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: corr_i_full !< Covariance matrix of the unresolved
      variables (full version)
```

8.3.3.3 real(kind=8), dimension(:,:), allocatable, public corrmod::corr_ij

Matrix holding the correlation matrix at a given time.

Definition at line 32 of file corrmod.f90.

```
32  REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: corr_ij !< Matrix holding the correlation matrix at
      a given time
```

8.3.3.4 procedure(corrcomp_from_spline), pointer, public corrmod::corrcomp

Pointer to the correlation computation routine.

Definition at line 41 of file corrmod.f90.

```
41    PROCEDURE(corrcomp_from_spline), POINTER, PUBLIC :: corrcomp
```

8.3.3.5 real(kind=8), dimension(:,:), allocatable, public corrmod::inv_corr_i

Inverse of the covariance matrix of the unresolved variables (reduced version)

Definition at line 31 of file corrmod.f90.

```
31    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: inv_corr_i !< Inverse of the covariance matrix of
        the unresolved variables (reduced version)
```

8.3.3.6 real(kind=8), dimension(:,:), allocatable, public corrmod::inv_corr_i_full

Inverse of the covariance matrix of the unresolved variables (full version)

Definition at line 29 of file corrmod.f90.

```
29    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: inv_corr_i_full !< Inverse of the covariance matrix
        of the unresolved variables (full version)
```

8.3.3.7 integer corrmod::khi [private]

Definition at line 38 of file corrmod.f90.

8.3.3.8 integer corrmod::klo [private]

Definition at line 38 of file corrmod.f90.

8.3.3.9 real(kind=8), dimension(:), allocatable, public corrmod::mean

Vector holding the mean of the unresolved dynamics (reduced version)

Definition at line 26 of file corrmod.f90.

```
26    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: mean !< Vector holding the mean of the unresolved
        dynamics (reduced version)
```

8.3.3.10 real(kind=8), dimension(:), allocatable, public corrmod::mean_full

Vector holding the mean of the unresolved dynamics (full version)

Definition at line 27 of file corrmod.f90.

```
27    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: mean_full !< Vector holding the mean of the unresolved
        dynamics (full version)
```

8.3.3.11 integer corrmod::nspl [private]

Integers needed by the spline representation of the correlation.

Definition at line 38 of file corrmod.f90.

```
38    INTEGER :: nspl,klo,khi
```

8.3.3.12 real(kind=8), dimension(:), allocatable corrmod::xa [private]

Vector holding coefficient of the spline and exponential correlation representation.

Definition at line 35 of file corrmod.f90.

```
35    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: xa !< Vector holding coefficient of the spline and exponential
        correlation representation
```

8.3.3.13 real(kind=8), dimension(:,:,:), allocatable corrmod::y2 [private]

Vector holding coefficient of the spline and exponential correlation representation.

Definition at line 33 of file corrmod.f90.

```
33    REAL(KIND=8), DIMENSION(:,:,:), ALLOCATABLE :: y2 !< Vector holding coefficient of the spline and
        exponential correlation representation
```

8.3.3.14 real(kind=8), dimension(:,:,:), allocatable corrmod::ya [private]

Vector holding coefficient of the spline and exponential correlation representation.

Definition at line 34 of file corrmod.f90.

```
34    REAL(KIND=8), DIMENSION(:,:,:), ALLOCATABLE :: ya !< Vector holding coefficient of the spline and
        exponential correlation representation
```

8.4 dec_tensor Module Reference

The resolved-unresolved components decomposition of the tensor.

Functions/Subroutines

- subroutine suppress_and (t, cst, v1, v2)

  Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 and SF(k)=v2.
- subroutine suppress_or (t, cst, v1, v2)

  Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 or SF(k)=v2.
- subroutine reorder (t, cst, v)

  Subroutine to reorder the tensor t_{ijk} components : if SF(j)=v then it return t_{ikj}.
- subroutine init_sub_tensor (t, cst, v)

  Subroutine that suppress all the components of a tensor t_{ijk} where if SF(i)=v.
- subroutine, public init_dec_tensor

  Subroutine that initialize and compute the decomposed tensors.

Variables

- type(coolist), dimension(:), allocatable, public ff_tensor

  Tensor holding the part of the unresolved tensor involving only unresolved variables.
- type(coolist), dimension(:), allocatable, public sf_tensor

  Tensor holding the part of the resolved tensor involving unresolved variables.
- type(coolist), dimension(:), allocatable, public ss_tensor

  Tensor holding the part of the resolved tensor involving only resolved variables.
- type(coolist), dimension(:), allocatable, public fs_tensor

  Tensor holding the part of the unresolved tensor involving resolved variables.
- type(coolist), dimension(:), allocatable, public hx

  Tensor holding the constant part of the resolved tendencies.
- type(coolist), dimension(:), allocatable, public lxx

  Tensor holding the linear part of the resolved tendencies involving the resolved variables.
- type(coolist), dimension(:), allocatable, public lxy

  Tensor holding the linear part of the resolved tendencies involving the unresolved variables.
- type(coolist), dimension(:), allocatable, public bxxx

  Tensor holding the quadratic part of the resolved tendencies involving resolved variables.
- type(coolist), dimension(:), allocatable, public bxxy

  Tensor holding the quadratic part of the resolved tendencies involving both resolved and unresolved variables.
- type(coolist), dimension(:), allocatable, public bxyy

  Tensor holding the quadratic part of the resolved tendencies involving unresolved variables.
- type(coolist), dimension(:), allocatable, public hy

  Tensor holding the constant part of the unresolved tendencies.
- type(coolist), dimension(:), allocatable, public lyx

  Tensor holding the linear part of the unresolved tendencies involving the resolved variables.
- type(coolist), dimension(:), allocatable, public lyy

  Tensor holding the linear part of the unresolved tendencies involving the unresolved variables.
- type(coolist), dimension(:), allocatable, public byxx

  Tensor holding the quadratic part of the unresolved tendencies involving resolved variables.
- type(coolist), dimension(:), allocatable, public byxy

  Tensor holding the quadratic part of the unresolved tendencies involving both resolved and unresolved variables.

- type(coolist), dimension(:), allocatable, public byyy

  Tensor holding the quadratic part of the unresolved tendencies involving unresolved variables.
- type(coolist), dimension(:), allocatable, public ss_tl_tensor

  Tensor of the tangent linear model tendencies of the resolved component alone.
- type(coolist), dimension(:), allocatable dumb

  Dumb coolist to make the computations.

8.4.1 Detailed Description

The resolved-unresolved components decomposition of the tensor.

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Remarks

8.4.2 Function/Subroutine Documentation

8.4.2.1 subroutine, public dec_tensor::init_dec_tensor ( )

Subroutine that initialize and compute the decomposed tensors.

Definition at line 195 of file dec_tensor.f90.

```
195   USE params, only:ndim
196   USE aotensor_def, only:aotensor
197   USE sf_def, only: load_sf
198   USE tensor, only:copy_coo,add_to_tensor,
  scal_mul_coo
199   USE tl_ad_tensor, only: init_tltensor,tltensor
200   USE stoch_params, only: init_stoch_params,mode,
  tdelta,eps_pert
201   INTEGER :: allocstat
202
203   CALL init_stoch_params
204
205   CALL init_tltensor  ! and tl tensor
206
207   CALL load_sf  ! Load the resolved-unresolved decomposition
208
209   ! Allocating the returned arrays
210
211   ALLOCATE(ff_tensor(ndim),fs_tensor(ndim),sf_tensor(ndim),ss_tensor(
  ndim), stat=allocstat)
212   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
213
214   ALLOCATE(ss_tl_tensor(ndim), stat=allocstat)
215   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
216
217   ALLOCATE(hx(ndim),lxx(ndim),lxy(ndim),bxxx(ndim),bxxy(ndim),bxyy(
  ndim), stat=allocstat)
218   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
219
220   ALLOCATE(hy(ndim),lyx(ndim),lyy(ndim),byxx(ndim),byxy(ndim),byyy(
  ndim), stat=allocstat)
221   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
222
223   ! General decomposition
224   ! ff tensor
225   ALLOCATE(dumb(ndim), stat=allocstat)
226   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
```

```

    IF (mode.ne.'qfst') THEN
        CALL copy_coo(aotensor,dumb) !Copy the tensors
        CALL init_sub_tensor(dumb,0,0)
        CALL suppress_or(dumb,1,0,0) ! Clear entries with resolved variables
        CALL copy_coo(dumb,ff_tensor)
    ELSE
        CALL copy_coo(aotensor,dumb) !Copy the tensors
        CALL init_sub_tensor(dumb,0,0)
        CALL suppress_or(dumb,0,0,0) ! Clear entries with resolved variables and linear and constant terms
        CALL copy_coo(dumb,ff_tensor)
    ENDIF

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! fs tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    IF (mode.ne.'qfst') THEN
        CALL copy_coo(aotensor,dumb) !Copy the tensors
        CALL init_sub_tensor(dumb,0,0)
        CALL suppress_and(dumb,1,1,1) ! Clear entries with only unresolved variables and constant
        CALL copy_coo(dumb,fs_tensor)
    ELSE
        CALL copy_coo(aotensor,dumb) !Copy the tensors
        CALL init_sub_tensor(dumb,0,0)
        CALL suppress_and(dumb,0,1,1) ! Clear entries with only quadratic unresolved variables
        CALL copy_coo(dumb,fs_tensor)
    ENDIF

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! sf tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"


    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,1,1)
    CALL suppress_and(dumb,0,0,0) ! Clear entries with only unresolved variables and constant
    CALL copy_coo(dumb,sf_tensor)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! ss tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"


    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,1,1)
    CALL suppress_or(dumb,0,1,1) ! Clear entries with only unresolved variables and constant
    CALL copy_coo(dumb,ss_tensor)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! ss tangent linear tensor

    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(tltensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,1,1)
    CALL suppress_or(dumb,0,1,1) ! Clear entries with only unresolved variables and constant
    CALL copy_coo(dumb,ss_tl_tensor)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! Multiply the aotensor part that need to be by the perturbation and time
    ! separation parameter

    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(ss_tensor,dumb)
    CALL scal_mul_coo(1.d0/tdelta**2,ff_tensor)
```

```
    CALL scal_mul_coo(eps_pert/tdelta,fs_tensor)
    CALL add_to_tensor(ff_tensor,dumb)
    CALL add_to_tensor(fs_tensor,dumb)
    CALL scal_mul_coo(eps_pert/tdelta,sf_tensor)
    CALL add_to_tensor(sf_tensor,dumb)

    allocstat=0
    DEALLOCATE(aotensor, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ALLOCATE(aotensor(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(dumb,aotensor)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! MTV decomposition
    ! Unresolved tensors

    ! Hy tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,0,0)
    CALL suppress_or(dumb,0,1,1) ! Clear entries with unresolved variables
    CALL suppress_or(dumb,1,0,0) ! Suppress linear and nonlinear resolved terms
    CALL copy_coo(dumb,hy)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! Lyx tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,0,0)
    CALL suppress_or(dumb,0,1,1) ! Clear entries with unresolved variables
    CALL suppress_and(dumb,1,1,1) ! Clear constant entries
    CALL suppress_and(dumb,1,0,0) ! Clear entries with nonlinear resolved terms
    CALL reorder(dumb,1,0) ! Resolved variables must be the third (k) index
    CALL copy_coo(dumb,lyx)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! Lyy tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,0,0)
    CALL suppress_or(dumb,1,0,0) ! Clear entries with resolved variables
    CALL suppress_and(dumb,0,1,1) ! Clear entries with nonlinear unresolved terms
    CALL suppress_and(dumb,0,0,0) ! Clear constant entries
    CALL reorder(dumb,0,1) ! Unresolved variables must be the third (k) index
    CALL copy_coo(dumb,lyy)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! Byxy tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL copy_coo(aotensor,dumb) !Copy the tensors
    CALL init_sub_tensor(dumb,0,0)
    CALL suppress_and(dumb,1,1,1) ! Clear constant or linear terms and nonlinear unresolved only entries
    CALL suppress_and(dumb,0,0,0) ! Clear entries with only resolved variables and constant
    CALL reorder(dumb,0,1) ! Unresolved variables must be the third (k) index
    CALL copy_coo(dumb,byxy)

    allocstat=0
    DEALLOCATE(dumb, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    ! Byyy tensor
    ALLOCATE(dumb(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

```

```
CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,0,0)
CALL suppress_or(dumb,0,0,0) ! Clear entries with resolved variables and linear and constant terms
CALL copy_coo(dumb,byyy)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Byxx tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,0,0)
CALL suppress_or(dumb,1,1,1) ! Clear entries with unresolved variables and linear and constant terms
CALL copy_coo(dumb,byxx)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Resolved tensors

! Hx tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_or(dumb,1,0,0) ! Clear entries with resolved variables
CALL suppress_or(dumb,0,1,1) ! Suppress linear and nonlinear unresolved terms
CALL copy_coo(dumb,hx)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Lxy tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_or(dumb,1,0,0) ! Clear entries with resolved variables
CALL suppress_and(dumb,0,0,0) ! Clear constant entries
CALL suppress_and(dumb,0,1,1) ! Clear entries with nonlinear unresolved terms
CALL reorder(dumb,0,1) ! Resolved variables must be the third (k) index
CALL copy_coo(dumb,lxy)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Lxx tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_or(dumb,0,1,1) ! Clear entries with unresolved variables
CALL suppress_and(dumb,1,0,0) ! Clear entries with nonlinear resolved terms
CALL suppress_and(dumb,1,1,1) ! Clear constant entries
CALL reorder(dumb,1,0) ! Resolved variables must be the third (k) index
CALL copy_coo(dumb,lxx)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Bxxy tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_and(dumb,1,1,1) ! Clear constant or linear terms and nonlinear unresolved only entries
CALL suppress_and(dumb,0,0,0) ! Clear entries with only resolved variables and constant
CALL reorder(dumb,0,1) ! Unresolved variables must be the third (k) index
CALL copy_coo(dumb,bxxy)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Bxxx tensor
ALLOCATE(dumb(ndim), stat=allocstat)
```

```
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_or(dumb,1,1,1) ! Clear entries with unresolved variables and linear and constant terms
CALL copy_coo(dumb,bxxx)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

! Bxyy tensor
ALLOCATE(dumb(ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

CALL copy_coo(aotensor,dumb) !Copy the tensors
CALL init_sub_tensor(dumb,1,1)
CALL suppress_or(dumb,0,0,0) ! Clear entries with resolved variables and linear and constant terms
CALL copy_coo(dumb,bxyy)

allocstat=0
DEALLOCATE(dumb, stat=allocstat)
IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"
```

8.4.2.2 subroutine dec_tensor::init_sub_tensor (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *cst*, integer, intent(in) *v*)

Subroutine that suppress all the components of a tensor t_{ijk} where if SF(i)=v.

Parameters

t	tensor over which the routine acts
cst	constant which controls if the 0 index is taken as a unresolved or a resolved one
v	constant of the conditional (0 to suppress resolved, 1 for unresolved)

Definition at line 174 of file dec_tensor.f90.

```
USE params, only:ndim
USE sf_def, only: sf
TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
INTEGER, INTENT(IN) :: cst,v
INTEGER :: i

sf(0)=cst ! control wether 0 index is considered unresolved or not
DO i=1,ndim
   IF (sf(i)==v) t(i)%nelems=0
ENDDO
```

8.4.2.3 subroutine dec_tensor::reorder (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *cst*, integer, intent(in) *v*)

Subroutine to reorder the tensor t_{ijk} components : if SF(j)=v then it return t_{ikj}.

Parameters

t	tensor over which the routine acts
cst	constant which controls if the 0 index is taken as a unresolved or a resolved one
v	constant of the conditional (0 to invert resolved, 1 for unresolved)

Definition at line 148 of file dec_tensor.f90.

```
148     USE params, only:ndim
149     USE sf_def, only: sf
150     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
151     INTEGER, INTENT(IN) :: cst,v
152     INTEGER :: i,n,li,liii
153
154     sf(0)=cst ! control wether 0 index is considered unresolved or not
155     DO i=1,ndim
156
157        n=t(i)%nelems
158        DO li=1,n
159           IF (sf(t(i)%elems(li)%j)==v) THEN
160              liii=t(i)%elems(li)%j
161              t(i)%elems(li)%j=t(i)%elems(li)%k
162              t(i)%elems(li)%k=liii
163           ENDIF
164        ENDDO
165     ENDDO
166
```

8.4.2.4 subroutine dec_tensor::suppress_and (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *cst*, integer, intent(in) *v1*, integer, intent(in) *v2*) [private]

Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 and SF(k)=v2.

Parameters

t	tensor over which the routine acts
cst	constant which controls if the 0 index is taken as a unresolved or a resolved one
v1	first constant of the conditional (0 to suppress resolved, 1 for unresolved)
v2	second constant of the conditional (0 to suppress resolved, 1 for unresolved)

Definition at line 77 of file dec_tensor.f90.

```
77     USE params, only:ndim
78     USE sf_def, only: sf
79     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
80     INTEGER, INTENT(IN) :: cst,v1,v2
81     INTEGER :: i,n,li,liii
82
83     sf(0)=cst ! control wether 0 index is considered unresolved or not
84     DO i=1,ndim
85        n=t(i)%nelems
86        DO li=1,n
87           ! Clear entries with only resolved variables and shift rest of the items one place down.
88           ! Make sure not to skip any entries while shifting!
89
90           DO WHILE ((sf(t(i)%elems(li)%j)==v1).and.(sf(t(i)%elems(li)%k)==v2))
91              !print*, i,li,t(i)%nelems,n
92              DO liii=li+1,n
93                 t(i)%elems(liii-1)%j=t(i)%elems(liii)%j
94                 t(i)%elems(liii-1)%k=t(i)%elems(liii)%k
95                 t(i)%elems(liii-1)%v=t(i)%elems(liii)%v
96              ENDDO
97              t(i)%nelems=t(i)%nelems-1
98              IF (li>t(i)%nelems) exit
99           ENDDO
100           IF (li>t(i)%nelems) exit
101        ENDDO
102     ENDDO
103
```

8.4.2.5 subroutine dec_tensor::suppress_or (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *cst*, integer, intent(in) *v1*, integer, intent(in) *v2*)

Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 or SF(k)=v2.

Parameters

t	tensor over which the routine acts
cst	constant which controls if the 0 index is taken as a unresolved or a resolved one
v1	first constant of the conditional (0 to suppress resolved, 1 for unresolved)
v2	second constant of the conditional (0 to suppress resolved, 1 for unresolved)

Definition at line 113 of file dec_tensor.f90.

```
113     USE params, only:ndim
114     USE sf_def, only: sf
115     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
116     INTEGER, INTENT(IN) :: cst,v1,v2
117     INTEGER :: i,n,li,liii
118 
119     sf(0)=cst ! control wether 0 index is considered unresolved or not
120     DO i=1,ndim
121        n=t(i)%nelems
122        DO li=1,n
123           ! Clear entries with only resolved variables and shift rest of the items one place down.
124           ! Make sure not to skip any entries while shifting!
125 
126           DO WHILE ((sf(t(i)%elems(li)%j)==v1).or.(sf(t(i)%elems(li)%k)==v2))
127              !print*, i,li,t(i)%nelems,n
128              DO liii=li+1,n
129                 t(i)%elems(liii-1)%j=t(i)%elems(liii)%j
130                 t(i)%elems(liii-1)%k=t(i)%elems(liii)%k
131                 t(i)%elems(liii-1)%v=t(i)%elems(liii)%v
132              ENDDO
133              t(i)%nelems=t(i)%nelems-1
134              IF (li>t(i)%nelems) exit
135           ENDDO
136           IF (li>t(i)%nelems) exit
137        ENDDO
138     ENDDO
139 
```

8.4.3 Variable Documentation

8.4.3.1 type(coolist), dimension(:), allocatable, public dec_tensor::bxxx

Tensor holding the quadratic part of the resolved tendencies involving resolved variables.

Definition at line 39 of file dec_tensor.f90.

```
39   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: bxxx !< Tensor holding the quadratic part of
       the resolved tendencies involving resolved variables
```

8.4.3.2 type(coolist), dimension(:), allocatable, public dec_tensor::bxxy

Tensor holding the quadratic part of the resolved tendencies involving both resolved and unresolved variables.

Definition at line 40 of file dec_tensor.f90.

```
40   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: bxxy !< Tensor holding the quadratic part of
       the resolved tendencies involving both resolved and unresolved variables
```

8.4.3.3 type(coolist), dimension(:), allocatable, public dec_tensor::bxyy

Tensor holding the quadratic part of the resolved tendencies involving unresolved variables.

Definition at line 41 of file dec_tensor.f90.

```
41   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: bxyy !< Tensor holding the quadratic part of
       the resolved tendencies involving unresolved variables
```

8.4.3.4 type(coolist), dimension(:), allocatable, public dec_tensor::byxx

Tensor holding the quadratic part of the unresolved tendencies involving resolved variables.

Definition at line 46 of file dec_tensor.f90.

```
46   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: byxx !< Tensor holding the quadratic part of
       the unresolved tendencies involving resolved variables
```

8.4.3.5 type(coolist), dimension(:), allocatable, public dec_tensor::byxy

Tensor holding the quadratic part of the unresolved tendencies involving both resolved and unresolved variables.

Definition at line 47 of file dec_tensor.f90.

```
47   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: byxy !< Tensor holding the quadratic part of
       the unresolved tendencies involving both resolved and unresolved variables
```

8.4.3.6 type(coolist), dimension(:), allocatable, public dec_tensor::byyy

Tensor holding the quadratic part of the unresolved tendencies involving unresolved variables.

Definition at line 48 of file dec_tensor.f90.

```
48   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: byyy !< Tensor holding the quadratic part of
       the unresolved tendencies involving unresolved variables
```

8.4.3.7 type(coolist), dimension(:), allocatable dec_tensor::dumb [private]

Dumb coolist to make the computations.

Definition at line 53 of file dec_tensor.f90.

```
53   TYPE(coolist), DIMENSION(:), ALLOCATABLE :: dumb !< Dumb coolist to make the computations
```

8.4.3.8 type(coolist), dimension(:), allocatable, public dec_tensor::ff_tensor

Tensor holding the part of the unresolved tensor involving only unresolved variables.

Definition at line 31 of file dec_tensor.f90.

```
31   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: ff_tensor !< Tensor holding the part of the
       unresolved tensor involving only unresolved variables
```

8.4.3.9 type(coolist), dimension(:), allocatable, public dec_tensor::fs_tensor

Tensor holding the part of the unresolved tensor involving resolved variables.

Definition at line 34 of file dec_tensor.f90.

```
34   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: fs_tensor !< Tensor holding the part of the
       unresolved tensor involving resolved variables
```

8.4.3.10 type(coolist), dimension(:), allocatable, public dec_tensor::hx

Tensor holding the constant part of the resolved tendencies.

Definition at line 36 of file dec_tensor.f90.

```
36   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: hx !< Tensor holding the constant part of the
       resolved tendencies
```

8.4.3.11 type(coolist), dimension(:), allocatable, public dec_tensor::hy

Tensor holding the constant part of the unresolved tendencies.

Definition at line 43 of file dec_tensor.f90.

```
43   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: hy !< Tensor holding the constant part of the
       unresolved tendencies
```

8.4.3.12 type(coolist), dimension(:), allocatable, public dec_tensor::lxx

Tensor holding the linear part of the resolved tendencies involving the resolved variables.

Definition at line 37 of file dec_tensor.f90.

```
37   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: lxx !< Tensor holding the linear part of the
       resolved tendencies involving the resolved variables
```

8.4.3.13 type(coolist), dimension(:), allocatable, public dec_tensor::lxy

Tensor holding the linear part of the resolved tendencies involving the unresolved variables.

Definition at line 38 of file dec_tensor.f90.

```
38   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: lxy !< Tensor holding the linear part of the
      resolved tendencies involving the unresolved variables
```

8.4.3.14 type(coolist), dimension(:), allocatable, public dec_tensor::lyx

Tensor holding the linear part of the unresolved tendencies involving the resolved variables.

Definition at line 44 of file dec_tensor.f90.

```
44   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: lyx !< Tensor holding the linear part of the
      unresolved tendencies involving the resolved variables
```

8.4.3.15 type(coolist), dimension(:), allocatable, public dec_tensor::lyy

Tensor holding the linear part of the unresolved tendencies involving the unresolved variables.

Definition at line 45 of file dec_tensor.f90.

```
45   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: lyy !< Tensor holding the linear part of the
      unresolved tendencies involving the unresolved variables
```

8.4.3.16 type(coolist), dimension(:), allocatable, public dec_tensor::sf_tensor

Tensor holding the part of the resolved tensor involving unresolved variables.

Definition at line 32 of file dec_tensor.f90.

```
32   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: sf_tensor !< Tensor holding the part of the
      resolved tensor involving unresolved variables
```

8.4.3.17 type(coolist), dimension(:), allocatable, public dec_tensor::ss_tensor

Tensor holding the part of the resolved tensor involving only resolved variables.

Definition at line 33 of file dec_tensor.f90.

```
33   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: ss_tensor !< Tensor holding the part of the
      resolved tensor involving only resolved variables
```

8.4.3.18 type(coolist), dimension(:), allocatable, public dec_tensor::ss_tl_tensor

Tensor of the tangent linear model tendencies of the resolved component alone.

Definition at line 50 of file dec_tensor.f90.

```
50   TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: ss_tl_tensor !< Tensor of the tangent linear
       model tendencies of the resolved component alone
```

8.5 ic_def Module Reference

Module to load the initial condition.

Functions/Subroutines

- subroutine, public load_ic

    Subroutine to load the initial condition if IC.nml exists. If it does not, then write IC.nml with 0 as initial condition.

Variables

- logical exists

    Boolean to test for file existence.
- real(kind=8), dimension(:), allocatable, public ic

    Initial condition vector.

8.5.1 Detailed Description

Module to load the initial condition.

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8.5.2 Function/Subroutine Documentation

8.5.2.1 subroutine, public ic_def::load_ic ( )

Subroutine to load the initial condition if IC.nml exists. If it does not, then write IC.nml with 0 as initial condition.

Definition at line 32 of file ic_def.f90.

```
INTEGER :: i,allocstat,j
CHARACTER(len=20) :: fm
REAL(KIND=8) :: size_of_random_noise
INTEGER, DIMENSION(:), ALLOCATABLE :: seed
CHARACTER(LEN=4) :: init_type
namelist /iclist/ ic
namelist /rand/ init_type,size_of_random_noise,seed


fm(1:6)='(F3.1)'

CALL random_seed(size=j)

IF (ndim == 0) stop "*** Number of dimensions is 0! ***"
ALLOCATE(ic(0:ndim),seed(j), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

INQUIRE(file='./IC.nml',exist=exists)

IF (exists) THEN
   OPEN(8, file="IC.nml", status='OLD', recl=80, delim='APOSTROPHE')
   READ(8,nml=iclist)
   READ(8,nml=rand)
   CLOSE(8)
   SELECT CASE (init_type)
     CASE ('seed')
       CALL random_seed(put=seed)
       CALL random_number(ic)
       ic=2*(ic-0.5)
       ic=ic*size_of_random_noise*10.d0
       ic(0)=1.0d0
       WRITE(6,*) "*** IC.nml namelist written. Starting with 'seeded' random initial condition !***"
     CASE ('rand')
       CALL init_random_seed()
       CALL random_seed(get=seed)
       CALL random_number(ic)
       ic=2*(ic-0.5)
       ic=ic*size_of_random_noise*10.d0
       ic(0)=1.0d0
       WRITE(6,*) "*** IC.nml namelist written. Starting with random initial condition !***"
     CASE ('zero')
       CALL init_random_seed()
       CALL random_seed(get=seed)
       ic=0
       ic(0)=1.0d0
       WRITE(6,*) "*** IC.nml namelist written. Starting with initial condition in IC.nml !***"
     CASE ('read')
       CALL init_random_seed()
       CALL random_seed(get=seed)
       ic(0)=1.0d0
       ! except IC(0), nothing has to be done IC has already the right values
       WRITE(6,*) "*** IC.nml namelist written. Starting with initial condition in IC.nml !***"
   END SELECT
ELSE
   CALL init_random_seed()
   CALL random_seed(get=seed)
   ic=0
   ic(0)=1.0d0
   init_type="zero"
   size_of_random_noise=0.d0
   WRITE(6,*) "*** IC.nml namelist written. Starting with 0 as initial condition !***"
END IF
OPEN(8, file="IC.nml", status='REPLACE')
WRITE(8,'(a)') "!------------------------------------------------------------------------------!"
WRITE(8,'(a)') "! Namelist file :                                                              !"
WRITE(8,'(a)') "! Initial condition.                                                           !"
WRITE(8,'(a)') "!------------------------------------------------------------------------------!"
WRITE(8,*) ""
 WRITE(8,'(a)') "&ICLIST"
 WRITE(8,*) " ! psi variables"
 DO i=1,natm
    WRITE(8,*) " IC("//trim(str(i))//") = ",ic(i),"   ! typ= "&
         &//awavenum(i)%typ//", Nx= "//trim(rstr(awavenum(i)&
         &%Nx,fm))//", Ny= "//trim(rstr(awavenum(i)%Ny,fm))
 END DO
 WRITE(8,*) " ! theta variables"
 DO i=1,natm
    WRITE(8,*) " IC("//trim(str(i+natm))//") = ",ic(i+natm),"   ! typ= "&
         &//awavenum(i)%typ//", Nx= "//trim(rstr(awavenum(i)&
         &%Nx,fm))//", Ny= "//trim(rstr(awavenum(i)%Ny,fm))
 END DO

 WRITE(8,*) " ! A variables"
 DO i=1,noc
    WRITE(8,*) " IC("//trim(str(i+2*natm))//") = ",ic(i+2*natm),"   ! Nx&
         &= "//trim(rstr(owavenum(i)%Nx,fm))//", Ny= "&
         &//trim(rstr(owavenum(i)%Ny,fm))
```

```
    END DO
    WRITE(8,*) " ! T variables"
    DO i=1,noc
       WRITE(8,*) " IC("//trim(str(i+noc+2*natm))//") = ",ic(i+2*natm+noc),"   &
            &! Nx= "//trim(rstr(owavenum(i)%Nx,fm))//", Ny= "&
            &//trim(rstr(owavenum(i)%Ny,fm))
    END DO

    WRITE(8,'(a)') "&END"
    WRITE(8,*) ""
    WRITE(8,'(a)') "!-----------------------------------------------------------------------------!"
    WRITE(8,'(a)') "! Initialisation type.                                                        !"
    WRITE(8,'(a)') "!-----------------------------------------------------------------------------!"
    WRITE(8,'(a)') "! type = 'read': use IC above (will generate a new seed);"
    WRITE(8,'(a)') "!        'rand': random state (will generate a new seed);"
    WRITE(8,'(a)') "!        'zero': zero IC (will generate a new seed);"
    WRITE(8,'(a)') "!        'seed': use the seed below (generate the same IC)"
    WRITE(8,*) ""
    WRITE(8,'(a)') "&RAND"
    WRITE(8,'(a)') "  init_type= '"//init_type//"'"
    WRITE(8,'(a,d15.7)') "  size_of_random_noise = ",size_of_random_noise
    DO i=1,j
       WRITE(8,*) " seed("//trim(str(i))//") = ",seed(i)
    END DO
    WRITE(8,'(a)') "&END"
    WRITE(8,*) ""
    CLOSE(8)
```

8.5.3 Variable Documentation

8.5.3.1 logical ic_def::exists [private]

Boolean to test for file existence.

Definition at line 21 of file ic_def.f90.

```
21  LOGICAL :: exists !< Boolean to test for file existence.
```

8.5.3.2 real(kind=8), dimension(:), allocatable, public ic_def::ic

Initial condition vector.

Definition at line 23 of file ic_def.f90.

```
23  REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: ic !< Initial condition vector
```

8.6 inprod_analytic Module Reference

Inner products between the truncated set of basis functions for the ocean and atmosphere streamfunction fields. These are partly calculated using the analytical expressions from Cehelsky, P., & Tung, K. K. : Theories of multiple equilibria and weather regimes-A critical reexamination. Part II: Baroclinic two-layer models. Journal of the atmospheric sciences, 44(21), 3282-3303, 1987.

Data Types

- type atm_tensors

  Type holding the atmospheric inner products tensors.
- type atm_wavenum

  Atmospheric bloc specification type.
- type ocean_tensors

  Type holding the oceanic inner products tensors.
- type ocean_wavenum

  Oceanic bloc specification type.

Functions/Subroutines

- real(kind=8) function b1 (Pi, Pj, Pk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function b2 (Pi, Pj, Pk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function delta (r)

  Integer Dirac delta function.
- real(kind=8) function flambda (r)

  "Odd or even" function
- real(kind=8) function s1 (Pj, Pk, Mj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function s2 (Pj, Pk, Mj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function s3 (Pj, Pk, Hj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function s4 (Pj, Pk, Hj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function calculate_a (i, j)

  Eigenvalues of the Laplacian (atmospheric)
- real(kind=8) function calculate_b (i, j, k)

  Streamfunction advection terms (atmospheric)
- real(kind=8) function calculate_c_atm (i, j)

  Beta term for the atmosphere.
- real(kind=8) function calculate_d (i, j)

  Forcing of the ocean on the atmosphere.
- real(kind=8) function calculate_g (i, j, k)

  Temperature advection terms (atmospheric)
- real(kind=8) function calculate_s (i, j)

  Forcing (thermal) of the ocean on the atmosphere.
- real(kind=8) function calculate_k (i, j)

  Forcing of the atmosphere on the ocean.
- real(kind=8) function calculate_m (i, j)

  Forcing of the ocean fields on the ocean.
- real(kind=8) function calculate_n (i, j)

  Beta term for the ocean.
- real(kind=8) function calculate_o (i, j, k)

  Temperature advection term (passive scalar)
- real(kind=8) function calculate_c_oc (i, j, k)

Streamfunction advection terms (oceanic)

- real(kind=8) function calculate_w (i, j)

  Short-wave radiative forcing of the ocean.

- subroutine, public init_inprod

  Initialisation of the inner product.

Variables

- type(atm_wavenum), dimension(:), allocatable, public awavenum

  Atmospheric blocs specification.

- type(ocean_wavenum), dimension(:), allocatable, public owavenum

  Oceanic blocs specification.

- type(atm_tensors), public atmos

  Atmospheric tensors.

- type(ocean_tensors), public ocean

  Oceanic tensors.

8.6.1 Detailed Description

Inner products between the truncated set of basis functions for the ocean and atmosphere streamfunction fields. These are partly calculated using the analytical expressions from Cehelsky, P., & Tung, K. K. : Theories of multiple equilibria and weather regimes-A critical reexamination. Part II: Baroclinic two-layer models. Journal of the atmospheric sciences, 44(21), 3282-3303, 1987.

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Remarks

Generated Fortran90/95 code from inprod_analytic.lua

8.6.2 Function/Subroutine Documentation

8.6.2.1 real(kind=8) function inprod_analytic::b1 (integer *Pi*, integer *Pj*, integer *Pk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 100 of file inprod_analytic.f90.

```
100     INTEGER :: pi,pj,pk
101     b1 = (pk + pj) / REAL(pi)
```

8.6.2.2 real(kind=8) function inprod_analytic::b2 (integer *Pi*, integer *Pj*, integer *Pk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 106 of file inprod_analytic.f90.

```
106     INTEGER :: pi,pj,pk
107     b2 = (pk - pj) / REAL(pi)
```

8.6.2.3 real(kind=8) function inprod_analytic::calculate_a (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Eigenvalues of the Laplacian (atmospheric)

$a_{i,j} = (F_i, \nabla^2 F_j)$.

Definition at line 164 of file inprod_analytic.f90.

```
164     INTEGER, INTENT(IN) :: i,j
165     TYPE(atm_wavenum) :: ti
166
167     calculate_a = 0.d0
168     IF (i==j) THEN
169        ti = awavenum(i)
170        calculate_a = -(n**2) * ti%Nx**2 - ti%Ny**2
171     END IF
```

8.6.2.4 real(kind=8) function inprod_analytic::calculate_b (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*) [private]

Streamfunction advection terms (atmospheric)

$b_{i,j,k} = (F_i, J(F_j, \nabla^2 F_k))$.

Definition at line 178 of file inprod_analytic.f90.

```
178     INTEGER, INTENT(IN) :: i,j,k
179
180     calculate_b = calculate_a(k,k) * calculate_g(i,j,k)
181
```

8.6.2.5 real(kind=8) function inprod_analytic::calculate_c_atm (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Beta term for the atmosphere.

$c_{i,j} = (F_i, \partial_x F_j)$.

Definition at line 188 of file inprod_analytic.f90.

```
188     INTEGER, INTENT(IN) :: i,j
189     TYPE(atm_wavenum) :: ti, tj
190
191     ti = awavenum(i)
192     tj = awavenum(j)
193     calculate_c_atm = 0.d0
194     IF ((ti%typ == "K") .AND. (tj%typ == "L")) THEN
195        calculate_c_atm = n * ti%M * delta(ti%M - tj%H) * delta(ti%P - tj%P)
196     ELSE IF ((ti%typ == "L") .AND. (tj%typ == "K")) THEN
197        ti = awavenum(j)
198        tj = awavenum(i)
199        calculate_c_atm = - n * ti%M * delta(ti%M - tj%H) * delta(ti%P - tj%P)
200     END IF
201
```

8.6.2.6 real(kind=8) function inprod_analytic::calculate_c_oc (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*) [private]

Streamfunction advection terms (oceanic)

$C_{i,j,k} = (\eta_i, J(\eta_j, \nabla^2\eta_k))$.

Definition at line 412 of file inprod_analytic.f90.

```
412     INTEGER, INTENT(IN) :: i,j,k
413
414     calculate_c_oc = calculate_m(k,k) * calculate_o(i,j,k)
415
```

8.6.2.7 real(kind=8) function inprod_analytic::calculate_d (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Forcing of the ocean on the atmosphere.

$d_{i,j} = (F_i, \nabla^2\eta_j)$.

Definition at line 208 of file inprod_analytic.f90.

```
208     INTEGER, INTENT(IN) :: i,j
209
210     calculate_d=calculate_s(i,j) * calculate_m(j,j)
211
```

8.6.2.8 real(kind=8) function inprod_analytic::calculate_g (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*) [private]

Temperature advection terms (atmospheric)

$g_{i,j,k} = (F_i, J(F_j, F_k))$.

Definition at line 218 of file inprod_analytic.f90.

```
218     INTEGER, INTENT(IN) :: i,j,k
219     TYPE(atm_wavenum) :: ti,tj,tk
220     REAL(KIND=8) :: val,vb1, vb2, vs1, vs2, vs3, vs4
221     INTEGER, DIMENSION(3) :: a,b
222     INTEGER, DIMENSION(3,3) :: w
223     CHARACTER, DIMENSION(3) :: s
224     INTEGER :: par
225
226     ti = awavenum(i)
227     tj = awavenum(j)
228     tk = awavenum(k)
229
230     a(1)=i
231     a(2)=j
232     a(3)=k
233
234     val=0.d0
235
236     IF ((ti%typ == "L") .AND. (tj%typ == "L") .AND. (tk%typ == "L")) THEN
237
238        CALL piksrt(3,a,par)
239
240        ti = awavenum(a(1))
241        tj = awavenum(a(2))
242        tk = awavenum(a(3))
243
```

```
      vs3 = s3(tj%P,tk%P,tj%H,tk%H)
      vs4 = s4(tj%P,tk%P,tj%H,tk%H)
      val = vs3 * ((delta(tk%H - tj%H - ti%H) - delta(tk%H &
           &- tj%H + ti%H)) * delta(tk%P + tj%P - ti%P) +&
           & delta(tk%H + tj%H - ti%H) * (delta(tk%P - tj%P&
           & + ti%P) - delta(tk%P - tj%P - ti%P))) + vs4 *&
           & ((delta(tk%H + tj%H - ti%H) * delta(tk%P - tj&
           &%P - ti%P)) + (delta(tk%H - tj%H + ti%H) -&
           & delta(tk%H - tj%H - ti%H)) * (delta(tk%P - tj&
           &%P - ti%P) - delta(tk%P - tj%P + ti%P)))
   ELSE

      s(1)=ti%typ
      s(2)=tj%typ
      s(3)=tk%typ

      w(1,:)=isin("A",s)
      w(2,:)=isin("K",s)
      w(3,:)=isin("L",s)

      IF (any(w(1,:)/=0) .AND. any(w(2,:)/=0) .AND. any(w(3,:)/=0)) THEN
         b=w(:,1)
         ti = awavenum(a(b(1)))
         tj = awavenum(a(b(2)))
         tk = awavenum(a(b(3)))
         call piksrt(3,b,par)
         vb1 = b1(ti%P,tj%P,tk%P)
         vb2 = b2(ti%P,tj%P,tk%P)
         val = -2 * sqrt(2.) / pi * tj%M * delta(tj%M - tk%H) * flambda(ti%P + tj%P + tk%P)
         IF (val /= 0.d0) val = val * (vb1**2 / (vb1**2 - 1) - vb2**2 / (vb2**2 - 1))
      ELSEIF ((w(2,2)/=0) .AND. (w(2,3)==0) .AND. any(w(3,:)/=0)) THEN
         ti = awavenum(a(w(2,1)))
         tj = awavenum(a(w(2,2)))
         tk = awavenum(a(w(3,1)))
         b(1)=w(2,1)
         b(2)=w(2,2)
         b(3)=w(3,1)
         call piksrt(3,b,par)
         vs1 = s1(tj%P,tk%P,tj%M,tk%H)
         vs2 = s2(tj%P,tk%P,tj%M,tk%H)
         val = vs1 * (delta(ti%M - tk%H - tj%M) * delta(ti%P -&
              & tk%P + tj%P) - delta(ti%M- tk%H - tj%M) *&
              & delta(ti%P + tk%P - tj%P) + (delta(tk%H - tj%M&
              & + ti%M) + delta(tk%H - tj%M - ti%M)) *&
              & delta(tk%P + tj%P - ti%P)) + vs2 * (delta(ti%M&
              & - tk%H - tj%M) * delta(ti%P - tk%P - tj%P) +&
              & (delta(tk%H - tj%M - ti%M) + delta(ti%M + tk%H&
              & - tj%M)) * (delta(ti%P - tk%P + tj%P) -&
              & delta(tk%P - tj%P + ti%P)))
      ENDIF
   ENDIF
   calculate_g=par*val*n

```

8.6.2.9 real(kind=8) function inprod_analytic::calculate_k (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Forcing of the atmosphere on the ocean.

$K_{i,j} = (\eta_i, \nabla^2 F_j)$.

Definition at line 336 of file inprod_analytic.f90.

```
336   INTEGER, INTENT(IN) :: i,j
337
338   calculate_k = calculate_s(j,i) * calculate_a(j,j)
```

8.6.2.10 real(kind=8) function inprod_analytic::calculate_m (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Forcing of the ocean fields on the ocean.

$M_{i,j} = (eta_i, \nabla^2 \eta_j)$.

Definition at line 345 of file inprod_analytic.f90.

```
345     INTEGER, INTENT(IN) :: i,j
346     TYPE(ocean_wavenum) :: di
347
348     calculate_m=0.d0
349     IF (i==j) THEN
350        di = owavenum(i)
351        calculate_m = -(n**2) * di%Nx**2 - di%Ny**2
352     END IF
```

8.6.2.11 real(kind=8) function inprod_analytic::calculate_n (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Beta term for the ocean.

$N_{i,j} = (\eta_i, \partial_x \eta_j)$.

Definition at line 359 of file inprod_analytic.f90.

```
359     INTEGER, INTENT(IN) :: i,j
360     TYPE(ocean_wavenum) :: di,dj
361     REAL(KIND=8) :: val
362
363     di = owavenum(i)
364     dj = owavenum(j)
365     calculate_n = 0.d0
366     IF (dj%H/=di%H) THEN
367        val = delta(di%P - dj%P) * flambda(di%H + dj%H)
368        calculate_n = val * (-2) * dj%H * di%H * n / ((dj%H**2 - di%H**2) * pi)
369     ENDIF
370
```

8.6.2.12 real(kind=8) function inprod_analytic::calculate_o (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*) [private]

Temperature advection term (passive scalar)

$O_{i,j,k} = (\eta_i, J(\eta_j, \eta_k))$.

Definition at line 377 of file inprod_analytic.f90.

```
377     INTEGER, INTENT(IN) :: i,j,k
378     TYPE(ocean_wavenum) :: di,dj,dk
379     REAL(KIND=8) :: vs3,vs4,val
380     INTEGER, DIMENSION(3) :: a
381     INTEGER :: par
382
383     val=0.d0
384
385     a(1)=i
386     a(2)=j
387     a(3)=k
388
389     CALL piksrt(3,a,par)
390
391     di = owavenum(a(1))
392     dj = owavenum(a(2))
393     dk = owavenum(a(3))
394
395     vs3 = s3(dj%P,dk%P,dj%H,dk%H)
396     vs4 = s4(dj%P,dk%P,dj%H,dk%H)
397     val = vs3*((delta(dk%H - dj%H - di%H) - delta(dk%H - dj&
398          &%H + di%H)) * delta(dk%P + dj%P - di%P) + delta(dk&
399          &%H + dj%H - di%H) * (delta(dk%P - dj%P + di%P) -&
400          & delta(dk%P - dj%P - di%P))) + vs4 * ((delta(dk%H &
401          &+ dj%H - di%H) * delta(dk%P - dj%P - di%P)) +&
402          & (delta(dk%H - dj%H + di%H) - delta(dk%H - dj%H -&
403          & di%H)) * (delta(dk%P - dj%P - di%P) - delta(dk%P &
404          &- dj%P + di%P)))
405     calculate_o = par * val * n / 2
```

8.6.2.13 real(kind=8) function inprod_analytic::calculate_s (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Forcing (thermal) of the ocean on the atmosphere.

$$s_{i,j} = (F_i, \eta_j) \; .$$

Definition at line 303 of file inprod_analytic.f90.

```
303     INTEGER, INTENT(IN) :: i,j
304     TYPE(atm_wavenum) :: ti
305     TYPE(ocean_wavenum) :: dj
306     REAL(KIND=8) :: val
307
308     ti = awavenum(i)
309     dj = owavenum(j)
310     val=0.d0
311     IF (ti%typ == "A") THEN
312        val = flambda(dj%H) * flambda(dj%P + ti%P)
313        IF (val /= 0.d0) THEN
314           val = val*8*sqrt(2.)*dj%P/(pi**2 * (dj%P**2 - ti%P**2) * dj%H)
315        END IF
316     ELSEIF (ti%typ == "K") THEN
317        val = flambda(2 * ti%M + dj%H) * delta(dj%P - ti%P)
318        IF (val /= 0.d0) THEN
319           val = val*4*dj%H/(pi * (-4 * ti%M**2 + dj%H**2))
320        END IF
321     ELSEIF (ti%typ == "L") THEN
322        val = delta(dj%P - ti%P) * delta(2 * ti%H - dj%H)
323     END IF
324     calculate_s=val
325
```

8.6.2.14 real(kind=8) function inprod_analytic::calculate_w (integer, intent(in) *i*, integer, intent(in) *j*) [private]

Short-wave radiative forcing of the ocean.

$$W_{i,j} = (\eta_i, F_j) \; .$$

Definition at line 422 of file inprod_analytic.f90.

```
422     INTEGER, INTENT(IN) :: i,j
423
424     calculate_w = calculate_s(j,i)
425
```

8.6.2.15 real(kind=8) function inprod_analytic::delta (integer *r*) [private]

Integer Dirac delta function.

Definition at line 112 of file inprod_analytic.f90.

```
112     INTEGER :: r
113     IF (r==0) THEN
114        delta = 1.d0
115     ELSE
116        delta = 0.d0
117     ENDIF
```

8.6.2.16 real(kind=8) function inprod_analytic::flambda (integer r) [private]

"Odd or even" function

Definition at line 122 of file inprod_analytic.f90.

```
122     INTEGER :: r
123     IF (mod(r,2)==0) THEN
124        flambda = 0.d0
125     ELSE
126        flambda = 1.d0
127     ENDIF
```

8.6.2.17 subroutine, public inprod_analytic::init_inprod ( )

Initialisation of the inner product.

Definition at line 436 of file inprod_analytic.f90.

```
436     INTEGER :: i,j
437     INTEGER :: allocstat
438
439     IF (natm == 0 ) THEN
440        stop "*** Problem : natm==0 ! ***"
441     ELSEIF (noc == 0) then
442        stop "*** Problem : noc==0 ! ***"
443     END IF
444
445
446     ! Definition of the types and wave numbers tables
447
448     ALLOCATE(owavenum(noc),awavenum(natm), stat=allocstat)
449     IF (allocstat /= 0) stop "*** Not enough memory ! ***"
450
451     j=0
452     DO i=1,nbatm
453        IF (ams(i,1)==1) THEN
454           awavenum(j+1)%typ='A'
455           awavenum(j+2)%typ='K'
456           awavenum(j+3)%typ='L'
457
458           awavenum(j+1)%P=ams(i,2)
459           awavenum(j+2)%M=ams(i,1)
460           awavenum(j+2)%P=ams(i,2)
461           awavenum(j+3)%H=ams(i,1)
462           awavenum(j+3)%P=ams(i,2)
463
464           awavenum(j+1)%Ny=REAL(ams(i,2))
465           awavenum(j+2)%Nx=REAL(ams(i,1))
466           awavenum(j+2)%Ny=REAL(ams(i,2))
467           awavenum(j+3)%Nx=REAL(ams(i,1))
468           awavenum(j+3)%Ny=REAL(ams(i,2))
469
470           j=j+3
471        ELSE
472           awavenum(j+1)%typ='K'
473           awavenum(j+2)%typ='L'
474
475           awavenum(j+1)%M=ams(i,1)
476           awavenum(j+1)%P=ams(i,2)
477           awavenum(j+2)%H=ams(i,1)
478           awavenum(j+2)%P=ams(i,2)
479
480           awavenum(j+1)%Nx=REAL(ams(i,1))
481           awavenum(j+1)%Ny=REAL(ams(i,2))
482           awavenum(j+2)%Nx=REAL(ams(i,1))
483           awavenum(j+2)%Ny=REAL(ams(i,2))
484
485           j=j+2
486
487        ENDIF
488     ENDDO
489
490     DO i=1,noc
491        owavenum(i)%H=oms(i,1)
```

```
      owavenum(i)%P=oms(i,2)

      owavenum(i)%Nx=oms(i,1)/2.d0
      owavenum(i)%Ny=oms(i,2)

    ENDDO

    ! Pointing to the atmospheric inner products functions

    atmos%a => calculate_a
    atmos%g => calculate_g
    atmos%s => calculate_s
    atmos%b => calculate_b
    atmos%d => calculate_d
    atmos%c => calculate_c_atm

    ! Pointing to the oceanic inner products functions

    ocean%M => calculate_m
    ocean%N => calculate_n
    ocean%O => calculate_o
    ocean%C => calculate_c_oc
    ocean%W => calculate_w
    ocean%K => calculate_k

```

8.6.2.18 real(kind=8) function inprod_analytic::s1 (integer *Pj*, integer *Pk*, integer *Mj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 132 of file inprod_analytic.f90.

```
132     INTEGER :: pk,pj,mj,hk
133     s1 = -((pk * mj + pj * hk)) / 2.d0
```

8.6.2.19 real(kind=8) function inprod_analytic::s2 (integer *Pj*, integer *Pk*, integer *Mj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 138 of file inprod_analytic.f90.

```
138     INTEGER :: pk,pj,mj,hk
139     s2 = (pk * mj - pj * hk) / 2.d0
```

8.6.2.20 real(kind=8) function inprod_analytic::s3 (integer *Pj*, integer *Pk*, integer *Hj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 144 of file inprod_analytic.f90.

```
144     INTEGER :: pj,pk,hj,hk
145     s3 = (pk * hj + pj * hk) / 2.d0
```

8.6.2.21 real(kind=8) function inprod_analytic::s4 (integer *Pj*, integer *Pk*, integer *Hj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 150 of file inprod_analytic.f90.

```
150     INTEGER :: pj,pk,hj,hk
151     s4 = (pk * hj - pj * hk) / 2.d0
```

8.6.3 Variable Documentation

8.6.3.1 type(atm_tensors), public inprod_analytic::atmos

Atmospheric tensors.

Definition at line 78 of file inprod_analytic.f90.

```
78   TYPE(atm_tensors), PUBLIC :: atmos
```

8.6.3.2 type(atm_wavenum), dimension(:), allocatable, public inprod_analytic::awavenum

Atmospheric blocs specification.

Definition at line 73 of file inprod_analytic.f90.

```
73   TYPE(atm_wavenum), DIMENSION(:), ALLOCATABLE, PUBLIC :: awavenum
```

8.6.3.3 type(ocean_tensors), public inprod_analytic::ocean

Oceanic tensors.

Definition at line 80 of file inprod_analytic.f90.

```
80   TYPE(ocean_tensors), PUBLIC :: ocean
```

8.6.3.4 type(ocean_wavenum), dimension(:), allocatable, public inprod_analytic::owavenum

Oceanic blocs specification.

Definition at line 75 of file inprod_analytic.f90.

```
75   TYPE(ocean_wavenum), DIMENSION(:), ALLOCATABLE, PUBLIC :: owavenum
```

8.7 int_comp Module Reference

Utility module containing the routines to perform the integration of functions.

Functions/Subroutines

- subroutine, public integrate (func, ss)

  Routine to compute integrals of function from O to #maxint.
- subroutine qromb (func, a, b, ss)

  Romberg integration routine.
- subroutine qromo (func, a, b, ss, choose)

  Romberg integration routine on an open interval.
- subroutine polint (xa, ya, n, x, y, dy)

  Polynomial interpolation routine.
- subroutine trapzd (func, a, b, s, n)

  Trapezoidal rule integration routine.
- subroutine midpnt (func, a, b, s, n)

  Midpoint rule integration routine.
- subroutine midexp (funk, aa, bb, s, n)

  Midpoint routine for bb infinite with funk decreasing infinitely rapidly at infinity.

8.7.1 Detailed Description

Utility module containing the routines to perform the integration of functions.

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Remarks

Most are taken from the Numerical Recipes

8.7.2 Function/Subroutine Documentation

8.7.2.1 subroutine, public int_comp::integrate (external *func*, real(kind=8) *ss*)

Routine to compute integrals of function from O to #maxint.

Parameters

func	function to integrate
ss	result of the integration

Definition at line 30 of file int_comp.f90.

```
REAL(KIND=8) :: ss,func,b
EXTERNAL func
b=maxint
! CALL qromo(func,0.D0,1.D0,ss,midexp)
CALL qromb(func,0.d0,b,ss)
```

8.7.2.2 subroutine int_comp::midexp (external *funk*, real(kind=8) *aa*, real(kind=8) *bb*, real(kind=8) *s*, integer *n*) [private]

Midpoint routine for bb infinite with funk decreasing infinitely rapidly at infinity.

Parameters

funk	function to integrate
aa	lower limit of the integral
bb	higher limit of the integral
s	result of the integration
n	higher stage of the rule to be computed

Definition at line 200 of file int_comp.f90.

```
200      INTEGER :: n
201      REAL(KIND=8) :: aa,bb,s,funk
202      EXTERNAL funk
203      INTEGER :: it,j
204      REAL(KIND=8) :: ddel,del,sum,tnm,x,func,a,b
205      func(x)=funk(-log(x))/x
206      b=exp(-aa)
207      a=0.
208      if (n.eq.1) then
209         s=(b-a)*func(0.5*(a+b))
210      else
211         it=3**(n-2)
212         tnm=it
213         del=(b-a)/(3.*tnm)
214         ddel=del+del
215         x=a+0.5*del
216         sum=0.
217         do j=1,it
218            sum=sum+func(x)
219            x=x+ddel
220            sum=sum+func(x)
221            x=x+del
222         end do
223         s=(s+(b-a)*sum/tnm)/3.
224      endif
225      return
```

8.7.2.3 subroutine int_comp::midpnt (external *func*, real(kind=8) *a*, real(kind=8) *b*, real(kind=8) *s*, integer *n*) [private]

Midpoint rule integration routine.

Parameters

func	function to integrate
a	lower limit of the integral
b	higher limit of the integral
s	result of the integration
n	higher stage of the rule to be computed

Definition at line 167 of file int_comp.f90.

```
167     INTEGER :: n
168     REAL(KIND=8) :: a,b,s,func
169     EXTERNAL func
170     INTEGER :: it,j
171     REAL(KIND=8) :: ddel,del,sum,tnm,x
172     if (n.eq.1) then
173        s=(b-a)*func(0.5*(a+b))
174     else
175        it=3**(n-2)
176        tnm=it
177        del=(b-a)/(3.*tnm)
178        ddel=del+del
179        x=a+0.5*del
180        sum=0.
181        do j=1,it
182           sum=sum+func(x)
183           x=x+ddel
184           sum=sum+func(x)
185           x=x+del
186        end do
187        s=(s+(b-a)*sum/tnm)/3.
188     endif
189     return
```

8.7.2.4 subroutine int_comp::polint (real(kind=8), dimension(n) *xa*, real(kind=8), dimension(n) *ya*, integer *n*, real(kind=8) *x*, real(kind=8) *y*, real(kind=8) *dy*) [private]

Polynomial interpolation routine.

Definition at line 91 of file int_comp.f90.

```
91     INTEGER :: n,nmax
92     REAL(KIND=8) :: dy,x,y,xa(n),ya(n)
93     parameter(nmax=10)
94     INTEGER :: i,m,ns
95     REAL(KIND=8) :: den,dif,dift,ho,hp,w,c(nmax),d(nmax)
96     ns=1
97     dif=abs(x-xa(1))
98     do i=1,n
99        dift=abs(x-xa(i))
100       if (dift.lt.dif) then
101          ns=i
102          dif=dift
103       endif
104       c(i)=ya(i)
105       d(i)=ya(i)
106    end do
107    y=ya(ns)
108    ns=ns-1
109    do m=1,n-1
110       do i=1,n-m
111          ho=xa(i)-x
112          hp=xa(i+m)-x
113          w=c(i+1)-d(i)
114          den=ho-hp
115          if(den.eq.0.)stop 'failure in polint'
116          den=w/den
117          d(i)=hp*den
118          c(i)=ho*den
119       end do
120       if (2*ns.lt.n-m)then
121          dy=c(ns+1)
122       else
123          dy=d(ns)
124          ns=ns-1
125       endif
126       y=y+dy
127    end do
128    return
```

8.7.2.5 subroutine int_comp::qromb (external *func*, real(kind=8) *a*, real(kind=8) *b*, real(kind=8) *ss*) [private]

Romberg integration routine.

Parameters

func	function to integrate
a	lower limit of the integral
b	higher limit of the integral
func	function to integrate
ss	result of the integration

Definition at line 44 of file int_comp.f90.

```
44      INTEGER :: jmax,jmaxp,k,km
45      REAL(KIND=8) :: a,b,func,ss,eps
46      EXTERNAL func
47      parameter(eps=1.d-6, jmax=20, jmaxp=jmax+1, k=5, km=k-1)
48      INTEGER j
49      REAL(KIND=8) :: dss,h(jmaxp),s(jmaxp)
50      h(1)=1.
51      DO j=1,jmax
52         CALL trapzd(func,a,b,s(j),j)
53         IF (j.ge.k) THEN
54            CALL polint(h(j-km),s(j-km),k,0.d0,ss,dss)
55            IF (abs(dss).le.eps*abs(ss)) RETURN
56         ENDIF
57         s(j+1)=s(j)
58         h(j+1)=0.25*h(j)
59      ENDDO
60      stop 'too many steps in qromb'
```

8.7.2.6 subroutine int_comp::qromo (external *func*, real(kind=8) *a*, real(kind=8) *b*, real(kind=8) *ss*, external *choose*) [private]

Romberg integration routine on an open interval.

Parameters

a	lower limit of the integral
b	higher limit of the integral
func	function to integrate
ss	result of the integration
chose	routine to perform the integration

Definition at line 70 of file int_comp.f90.

```
70      INTEGER :: jmax,jmaxp,k,km
71      REAL(KIND=8) :: a,b,func,ss,eps
72      EXTERNAL func,choose
73      parameter(eps=1.e-6, jmax=14, jmaxp=jmax+1, k=5, km=k-1)
74      INTEGER :: j
75      REAL(KIND=8) :: dss,h(jmaxp),s(jmaxp)
76      h(1)=1.
77      DO j=1,jmax
78         CALL choose(func,a,b,s(j),j)
79         IF (j.ge.k) THEN
80            call polint(h(j-km),s(j-km),k,0.d0,ss,dss)
81            if (abs(dss).le.eps*abs(ss)) return
82         ENDIF
83         s(j+1)=s(j)
84         h(j+1)=h(j)/9.
85      ENDDO
86      stop 'too many steps in qromo'
```

8.7.2.7 subroutine int_comp::trapzd (external *func*, real(kind=8) *a*, real(kind=8) *b*, real(kind=8) *s*, integer *n*) [private]

Trapezoidal rule integration routine.

Parameters

func	function to integrate
a	lower limit of the integral
b	higher limit of the integral
s	result of the integration
n	higher stage of the rule to be computed

Definition at line 138 of file int_comp.f90.

```
138     INTEGER :: n
139     REAL(KIND=8) :: a,b,s,func
140     EXTERNAL func
141     INTEGER :: it,j
142     REAL(KIND=8) :: del,sum,tnm,x
143     if (n.eq.1) then
144        s=0.5*(b-a)*(func(a)+func(b))
145     else
146        it=2**(n-2)
147        tnm=it
148        del=(b-a)/tnm
149        x=a+0.5*del
150        sum=0.
151        do j=1,it
152           sum=sum+func(x)
153           x=x+del
154        end do
155        s=0.5*(s+(b-a)*sum/tnm)
156     endif
157     return
```

8.8 int_corr Module Reference

Module to compute or load the integrals of the correlation matrices.

Functions/Subroutines

- subroutine, public init_corrint

  Subroutine to initialise the integrated matrices and tensors.
- real(kind=8) function func_ij (s)

  Function that returns the component oi and oj of the correlation matrix at time s.
- real(kind=8) function func_ijkl (s)

  Function that returns the component oi,oj,ok and ol of the outer product of the correlation matrix with itself at time s.
- subroutine, public comp_corrint

  Routine that actually compute or load the integrals.

Variables

- integer oi
- integer oj
- integer ok
- integer ol

    Integers that specify the matrices and tensor component considered as a function of time.
- real(kind=8), parameter real_eps = 2.2204460492503131e-16

    Small epsilon constant to determine equality with zero.
- real(kind=8), dimension(:,:), allocatable, public corrint

    Matrix holding the integral of the correlation matrix.
- type(coolist4), dimension(:), allocatable, public corr2int

    Tensor holding the integral of the correlation outer product with itself.

8.8.1 Detailed Description

Module to compute or load the integrals of the correlation matrices.

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Remarks

8.8.2 Function/Subroutine Documentation

8.8.2.1 subroutine, public int_corr::comp_corrint ( )

Routine that actually compute or load the integrals.

Definition at line 75 of file int_corr.f90.

```
75      IMPLICIT NONE
76      INTEGER :: i,j,k,l,n,allocstat
77      REAL(KIND=8) :: ss
78      LOGICAL :: ex
79
80      INQUIRE(file='corrint.def',exist=ex)
81      SELECT CASE (int_corr_mode)
82      CASE ('file')
83         IF (ex) THEN
84            OPEN(30,file='corrint.def',status='old')
85            READ(30,*) corrint
86            CLOSE(30)
87         ELSE
88            stop "*** File corrint.def not found ! ***"
89         END IF
90      CASE ('prog')
91         DO i = 1,n_unres
92            DO j= 1,n_unres
93               oi=i
94               oj=j
95               CALL integrate(func_ij,ss)
96               corrint(ind(i),ind(j))=ss
97            END DO
98         END DO
99
100         OPEN(30,file='corrint.def')
```

```
      WRITE(30,*) corrint
      CLOSE(30)
   END SELECT


   INQUIRE(file='corr2int.def',exist=ex)
   SELECT CASE (int_corr_mode)
   CASE ('file')
      IF (ex) THEN
         CALL load_tensor4_from_file("corr2int.def",corr2int)
      ELSE
         stop "*** File corr2int.def not found ! ***"
      END IF
   CASE ('prog')
      DO i = 1,n_unres
         n=0
         DO j= 1,n_unres
            DO k= 1,n_unres
               DO l = 1,n_unres
                  oi=i
                  oj=j
                  ok=k
                  ol=l

                  CALL integrate(func_ijkl,ss)
                  IF (abs(ss)>real_eps) n=n+1
               ENDDO
            ENDDO
         ENDDO
         IF (n/=0) THEN
            ALLOCATE(corr2int(ind(i))%elems(n), stat=allocstat)
            IF (allocstat /= 0) stop "*** Not enough memory ! ***"

            n=0
            DO j= 1,n_unres
               DO k= 1,n_unres
                  DO l = 1,n_unres
                     oi=i
                     oj=j
                     ok=k
                     ol=l

                     CALL integrate(func_ijkl,ss)
                     IF (abs(ss)>real_eps) THEN
                        n=n+1
                        corr2int(ind(i))%elems(n)%j=ind(j)
                        corr2int(ind(i))%elems(n)%k=ind(k)
                        corr2int(ind(i))%elems(n)%l=ind(l)
                        corr2int(ind(i))%elems(n)%v=ss
                     END IF
                  ENDDO
               ENDDO
            ENDDO
            corr2int(ind(i))%nelems=n
         END IF
      ENDDO

      CALL write_tensor4_to_file("corr2int.def",corr2int)
   CASE DEFAULT
      stop '*** INT_CORR_MODE variable not properly defined in corrmod.nml ***'
   END SELECT

```

8.8.2.2 real(kind=8) function int_corr::func_ij (real(kind=8) *s*) [private]

Function that returns the component oi and oj of the correlation matrix at time s.

Parameters

s	time at which the function is evaluated

Definition at line 55 of file int_corr.f90.

```
55    IMPLICIT NONE
```

```
56      REAL(KIND=8) :: s,func_ij
57      CALL corrcomp(s)
58      func_ij=corr_ij(oi,oj)
59      RETURN
```

8.8.2.3 real(kind=8) function int_corr::func_ijkl (real(kind=8) *s*) [private]

Function that returns the component oi,oj,ok and ol of the outer product of the correlation matrix with itself at time s.

Parameters

s	time at which the function is evaluated

Definition at line 66 of file int_corr.f90.

```
66      IMPLICIT NONE
67      REAL(KIND=8) :: s,func_ijkl
68      CALL corrcomp(s)
69      func_ijkl=corr_ij(oi,oj)*corr_ij(ok,ol)
70      RETURN
```

8.8.2.4 subroutine, public int_corr::init_corrint ( )

Subroutine to initialise the integrated matrices and tensors.

Definition at line 38 of file int_corr.f90.

```
38      INTEGER :: allocstat
39
40      ALLOCATE(corrint(ndim,ndim), stat=allocstat)
41      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
42
43      ALLOCATE(corr2int(ndim), stat=allocstat)
44      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
45
46      CALL init_corr ! Initialize the correlation matrix function
47
48      corrint=0.d0
49
```

8.8.3 Variable Documentation

8.8.3.1 type(coolist4), dimension(:), allocatable, public int_corr::corr2int

Tensor holding the integral of the correlation outer product with itself.

Definition at line 30 of file int_corr.f90.

```
30    TYPE(coolist4), DIMENSION(:), ALLOCATABLE, PUBLIC :: corr2int !< Tensor holding the integral of
        the correlation outer product with itself
```

8.8.3.2 real(kind=8), dimension(:,:), allocatable, public int_corr::corrint

Matrix holding the integral of the correlation matrix.

Definition at line 29 of file int_corr.f90.

```
29   REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: corrint !< Matrix holding the integral of the
       correlation matrix
```

8.8.3.3 integer int_corr::oi [private]

Definition at line 26 of file int_corr.f90.

```
26   INTEGER :: oi,oj,ok,ol !< Integers that specify the matrices and tensor component considered as a
       function of time
```

8.8.3.4 integer int_corr::oj [private]

Definition at line 26 of file int_corr.f90.

8.8.3.5 integer int_corr::ok [private]

Definition at line 26 of file int_corr.f90.

8.8.3.6 integer int_corr::ol [private]

Integers that specify the matrices and tensor component considered as a function of time.

Definition at line 26 of file int_corr.f90.

8.8.3.7 real(kind=8), parameter int_corr::real_eps = 2.2204460492503131e-16 [private]

Small epsilon constant to determine equality with zero.

Definition at line 27 of file int_corr.f90.

```
27   REAL(KIND=8), PARAMETER :: real_eps = 2.2204460492503131e-16 !< Small epsilon constant to determine
       equality with zero
```

8.9 integrator Module Reference

Module with the integration routines.

Functions/Subroutines

- subroutine, public init_integrator

  Routine to initialise the integration buffers.
- subroutine tendencies (t, y, res)

  Routine computing the tendencies of the model.
- subroutine, public step (y, t, dt, res)

  Routine to perform an integration step (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable buf_y1

  Buffer to hold the intermediate position (Heun algorithm)
- real(kind=8), dimension(:), allocatable buf_f0

  Buffer to hold tendencies at the initial position.
- real(kind=8), dimension(:), allocatable buf_f1

  Buffer to hold tendencies at the intermediate position.
- real(kind=8), dimension(:), allocatable buf_ka

  Buffer A to hold tendencies.
- real(kind=8), dimension(:), allocatable buf_kb

  Buffer B to hold tendencies.

8.9.1 Detailed Description

Module with the integration routines.

Module with the RK4 integration routines.

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Remarks

This module actually contains the Heun algorithm routines. The user can modify it according to its preferred integration scheme. For higher-order schemes, additional buffers will probably have to be defined.

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Remarks

This module actually contains the RK4 algorithm routines. The user can modify it according to its preferred integration scheme. For higher-order schemes, additional buffers will probably have to be defined.

8.9.2 Function/Subroutine Documentation

8.9.2.1 subroutine public integrator::init_integrator ( )

Routine to initialise the integration buffers.

Definition at line 37 of file rk2_integrator.f90.

```
37      INTEGER :: allocstat
38      ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim) ,stat=allocstat)
39      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
```

8.9.2.2 subroutine public integrator::step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform an integration step (Heun algorithm). The incremented time is returned.

Routine to perform an integration step (RK4 algorithm). The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
res	Final point after the step.

Definition at line 61 of file rk2_integrator.f90.

```
61      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
62      REAL(KIND=8), INTENT(INOUT) :: t
63      REAL(KIND=8), INTENT(IN) :: dt
64      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
65
66      CALL tendencies(t,y,buf_f0)
67      buf_y1 = y+dt*buf_f0
68      CALL tendencies(t+dt,buf_y1,buf_f1)
69      res=y+0.5*(buf_f0+buf_f1)*dt
70      t=t+dt
```

8.9.2.3 subroutine integrator::tendencies (real(kind=8), intent(in) *t*, real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(out) *res*) [private]

Routine computing the tendencies of the model.

Parameters

t	Time at which the tendencies have to be computed. Actually not needed for autonomous systems.
y	Point at which the tendencies have to be computed.
res	vector to store the result.

Remarks

Note that it is NOT safe to pass `y` as a result buffer, as this operation does multiple passes.

Definition at line 49 of file rk2_integrator.f90.

```
49     REAL(KIND=8), INTENT(IN) :: t
50     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
51     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
52     CALL sparse_mul3(aotensor, y, y, res)
```

8.9.3 Variable Documentation

8.9.3.1 real(kind=8), dimension(:), allocatable integrator::buf_f0 [private]

Buffer to hold tendencies at the initial position.

Definition at line 28 of file rk2_integrator.f90.

```
28   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_f0 !< Buffer to hold tendencies at the initial position
```

8.9.3.2 real(kind=8), dimension(:), allocatable integrator::buf_f1 [private]

Buffer to hold tendencies at the intermediate position.

Definition at line 29 of file rk2_integrator.f90.

```
29   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_f1 !< Buffer to hold tendencies at the intermediate
       position
```

8.9.3.3 real(kind=8), dimension(:), allocatable integrator::buf_ka [private]

Buffer A to hold tendencies.

Definition at line 28 of file rk4_integrator.f90.

```
28   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_ka !< Buffer A to hold tendencies
```

8.9.3.4 real(kind=8), dimension(:), allocatable integrator::buf_kb [private]

Buffer B to hold tendencies.

Definition at line 29 of file rk4_integrator.f90.

```
29   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_kb !< Buffer B to hold tendencies
```

8.9.3.5 real(kind=8), dimension(:), allocatable integrator::buf_y1 [private]

Buffer to hold the intermediate position (Heun algorithm)

Definition at line 27 of file rk2_integrator.f90.

```
27   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1 !< Buffer to hold the intermediate position (Heun
       algorithm)
```

8.10 mar Module Reference

Multidimensional Autoregressive module to generate the correlation for the WL parameterization.

Functions/Subroutines

- subroutine, public init_mar

  Subroutine to initialise the MAR.
- subroutine, public mar_step (x)

  Routine to generate one step of the MAR.
- subroutine, public mar_step_red (xred)

  Routine to generate one step of the reduce MAR.
- subroutine stoch_vec (dW)

Variables

- real(kind=8), dimension(:,:), allocatable, public q

  Square root of the noise covariance matrix.
- real(kind=8), dimension(:,:), allocatable, public qred

  Reduce version of Q.
- real(kind=8), dimension(:,:), allocatable, public rred

  Covariance matrix of the noise.
- real(kind=8), dimension(:,:,:), allocatable, public w

  W_i matrix.
- real(kind=8), dimension(:,:,:), allocatable, public wred

  Reduce W_i matrix.
- real(kind=8), dimension(:), allocatable buf_y
- real(kind=8), dimension(:), allocatable dw
- integer, public ms

  order of the MAR

8.10.1 Detailed Description

Multidimensional Autoregressive module to generate the correlation for the WL parameterization.

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Remarks

Based on the equation $y_n = \sum_{i=1}^m y_{n-i} \cdot W_i + Q \cdot \xi_n for an order$

8.10.2 Function/Subroutine Documentation

8.10.2.1 subroutine, public mar::init_mar ( )

Subroutine to initialise the MAR.

Definition at line 45 of file MAR.f90.

```
45      INTEGER :: allocstat,nf,i,info,info2
46      INTEGER, DIMENSION(3) :: s
47
48      print*, 'Initializing the MAR integrator...'
49
50      print*, 'Loading the MAR config from files...'
51
52      OPEN(20,file='MAR_R_params.def',status='old')
53      READ(20,*) nf,ms
54      IF (nf /= n_unres) stop "*** Dimension in files MAR_R_params.def and sf.nml do not correspond ! ***"
55      ALLOCATE(qred(n_unres,n_unres),rred(n_unres,n_unres),wred(ms,n_unres,n_unres),
       stat=allocstat)
56      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
57      ALLOCATE(q(ndim,ndim),w(ms,ndim,ndim), stat=allocstat)
58      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
59      ALLOCATE(buf_y(0:ndim), dw(ndim), stat=allocstat)
60      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
61      READ(20,*) rred
62      CLOSE(20)
63
64      OPEN(20,file='MAR_W_params.def',status='old')
65      READ(20,*) nf,ms
66      s=shape(wred)
67      IF (nf /= n_unres) stop "*** Dimension in files MAR_W_params.def and sf.nml do not correspond ! ***"
68      IF (s(1) /= ms) stop "*** MAR order in files MAR_R_params.def and MAR_W_params.def do not correspond !
        ***"
69      DO i=1,ms
70         READ(20,*) wred(i,:,:)
71      ENDDO
72      CLOSE(20)
73
74      CALL init_sqrt
75      CALL sqrtm(rred,qred,info,info2)
76      CALL ireduce(q,qred,n_unres,ind,rind)
77
78      DO i=1,ms
79         CALL ireduce(w(i,:,:),wred(i,:,:),n_unres,ind,rind)
80      ENDDO
81
82      ! Kept for internal testing - Uncomment if not needed
83      ! DEALLOCATE(Wred,Rred,Qred, STAT=AllocStat)
84      ! IF (AllocStat /= 0) STOP "*** Deallocation problem ! ***"
85
86      print*, 'MAR of order',ms,'found!'
87
```

8.10.2.2 subroutine, public mar::mar_step (real(kind=8), dimension(0:ndim,ms), intent(inout) *x*)

Routine to generate one step of the MAR.

Parameters

x	State vector of the MAR (store the y_i)

Definition at line 93 of file MAR.f90.

```
93      REAL(KIND=8), DIMENSION(0:ndim,ms), INTENT(INOUT) :: x
94      INTEGER :: j
95
```

```
CALL stoch_vec(dw)
buf_y=0.d0
buf_y(1:ndim)=matmul(q,dw)
DO j=1,ms
   buf_y(1:ndim)=buf_y(1:ndim)+matmul(x(1:ndim,j),w(j,:,:))
 ENDDO
 x=eoshift(x,shift=-1,boundary=buf_y,dim=2)
```

8.10.2.3 subroutine, public mar::mar_step_red (real(kind=8), dimension(0:ndim,ms), intent(inout) *xred*)

Routine to generate one step of the reduce MAR.

Parameters

xred	State vector of the MAR (store the y_i)

Remarks

For debugging purpose only

Definition at line 110 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(0:ndim,ms), INTENT(INOUT) :: xred
INTEGER :: j

CALL stoch_vec(dw)
buf_y=0.d0
buf_y(1:n_unres)=matmul(qred,dw(1:n_unres))
DO j=1,ms
   buf_y(1:n_unres)=buf_y(1:n_unres)+matmul(xred(1:n_unres,j),wred(j,:,:))
ENDDO
xred=eoshift(xred,shift=-1,boundary=buf_y,dim=2)
```

8.10.2.4 subroutine mar::stoch_vec (real(kind=8), dimension(ndim), intent(inout) *dW*) [private]

Definition at line 125 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(ndim), INTENT(INOUT) :: dw
INTEGER :: i
DO i=1,ndim
   dw(i)=gasdev()
ENDDO
```

8.10.3 Variable Documentation

8.10.3.1 real(kind=8), dimension(:), allocatable mar::buf_y [private]

Definition at line 34 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y,dw
```

8.10.3.2 real(kind=8), dimension(:), allocatable mar::dw [private]

Definition at line 34 of file MAR.f90.

8.10.3.3 integer, public mar::ms

order of the MAR

Definition at line 36 of file MAR.f90.

```
INTEGER :: ms !< order of the MAR
```

8.10.3.4 real(kind=8), dimension(:,:), allocatable, public mar::q

Square root of the noise covariance matrix.

Definition at line 29 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: q !< Square root of the noise covariance matrix
```

8.10.3.5 real(kind=8), dimension(:,:), allocatable, public mar::qred

Reduce version of Q.

Definition at line 30 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: qred !< Reduce version of Q
```

8.10.3.6 real(kind=8), dimension(:,:), allocatable, public mar::rred

Covariance matrix of the noise.

Definition at line 31 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: rred !< Covariance matrix of the noise
```

8.10.3.7 real(kind=8), dimension(:,:,:), allocatable, public mar::w

W_i matrix.

Definition at line 32 of file MAR.f90.

```
REAL(KIND=8), DIMENSION(:,:,:), ALLOCATABLE :: w !< W_i matrix
```

8.10.3.8 real(kind=8), dimension(:,:,:), allocatable, public mar::wred

Reduce W_i matrix.

Definition at line 33 of file MAR.f90.

```
33    REAL(KIND=8), DIMENSION(:,:,:), ALLOCATABLE :: wred !< Reduce W_i matrix
```

8.11 memory Module Reference

Module that compute the memory term M_3 of the WL parameterization.

Functions/Subroutines

- subroutine, public init_memory

  Subroutine to initialise the memory.
- subroutine, public compute_m3 (y, dt, dtn, savey, save_ev, evolve, inter, h_int)

  Compute the integrand of M_3 at each time in the past and integrate to get the memory term.
- subroutine, public test_m3 (y, dt, dtn, h_int)

  Routine to test the #compute_M3 routine.

Variables

- real(kind=8), dimension(:,:), allocatable x

  Array storing the previous state of the system.
- real(kind=8), dimension(:,:), allocatable xs

  Array storing the resolved time evolution of the previous state of the system.
- real(kind=8), dimension(:,:), allocatable zs

  Dummy array to replace Xs in case where the evolution is not stored.
- real(kind=8), dimension(:), allocatable buf_m

  Dummy vector.
- real(kind=8), dimension(:), allocatable buf_m3

  Dummy vector to store the M_3 integrand.
- integer t_index

  Integer storing the time index (current position in the arrays)
- procedure(ss_step), pointer step

  Procedural pointer pointing on the resolved dynamics step routine.

8.11.1 Detailed Description

Module that compute the memory term M_3 of the WL parameterization.

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Remarks

8.11.2 Function/Subroutine Documentation

8.11.2.1 subroutine, public memory::compute_m3 (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, logical, intent(in) *savey*, logical, intent(in) *save_ev*, logical, intent(in) *evolve*, real(kind=8), intent(in) *inter*, real(kind=8), dimension(0:ndim), intent(out) *h_int*)

Compute the integrand of M_3 at each time in the past and integrate to get the memory term.

Parameters

y	current state
dt	timestep
dtn	stochastic timestep
savey	set if the state is stored in X at the end
save_ev	set if the result of the resolved time evolution is stored in Xs at the end
evolve	set if the resolved time evolution is performed
inter	set over which time interval the resolved time evolution must be computed
h_int	result of the integration - give the memory term

Definition at line 86 of file memory.f90.

```
86      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
87      REAL(KIND=8), INTENT(IN) :: dt,dtn
88      LOGICAL, INTENT(IN) :: savey,save_ev,evolve
89      REAL(KIND=8), INTENT(IN) :: inter
90      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: h_int
91      REAL(KIND=8) :: t
92      INTEGER :: i,j
93
94      x(:,t_index)=y
95      IF (b23def) THEN
96         xs(:,t_index)=y
97         zs(:,t_index)=y
98         DO i=1,mems-1
99            j=modulo(t_index+i-1,mems)+1
100           zs(:,j)=xs(:,j)
101           IF (evolve) THEN
102              IF (dt.lt.inter) THEN
103                 t=0.d0
104                 DO WHILE (t+dt<inter)
105                    CALL step(zs(:,j),y,t,dt,dtn,zs(:,j))
106                 ENDDO
107                 CALL step(zs(:,j),y,t,inter-t,sqrt(inter-t),zs(:,j))
108              ELSE
109                 CALL step(zs(:,j),y,t,inter,sqrt(inter),zs(:,j))
110              ENDIF
111           ENDIF
112           IF (save_ev) xs(:,j)=zs(:,j)
113        ENDDO
114     ENDIF
115
116
117     ! Computing the integral
118     h_int=0.d0
119
120     DO i=1,mems
121        j=modulo(t_index+i-2,mems)+1
122        buf_m3=0.d0
123        IF (ldef) THEN
124           CALL sparse_mul3(ltot(:,i),y,x(:,j),buf_m)
125           buf_m3=buf_m3+buf_m
126        ENDIF
127        IF (b14def) THEN
128           CALL sparse_mul3(b14(:,i),x(:,j),x(:,j),buf_m)
129           buf_m3=buf_m3+buf_m
130        ENDIF
131        IF (b23def) THEN
132           CALL sparse_mul3(b23(:,i),x(:,j),zs(:,j),buf_m)
133           buf_m3=buf_m3+buf_m
134        ENDIF
```

```
      IF (mdef) THEN
         CALL sparse_mul4(mtot(:,i),x(:,j),x(:,j),zs(:,j),buf_m)
         buf_m3=buf_m3+buf_m
      ENDIF
      IF ((i.eq.1).or.(i.eq.mems)) THEN
         h_int=h_int+0.5*buf_m3
      ELSE
         h_int=h_int+buf_m3
      ENDIF
   ENDDO

   h_int=muti*h_int
   IF (savey) THEN
      t_index=t_index-1
      IF (t_index.eq.0) t_index=mems
   ENDIF
```

8.11.2.2 subroutine, public memory::init_memory ( )

Subroutine to initialise the memory.

Definition at line 45 of file memory.f90.

```
45     INTEGER :: allocstat
46
47     t_index=mems
48
49     ALLOCATE(x(0:ndim,mems), stat=allocstat)
50     IF (allocstat /= 0) stop "*** Not enough memory ! ***"
51
52     x=0.d0
53
54     IF (b23def) THEN
55        ALLOCATE(xs(0:ndim,mems), zs(0:ndim,mems), stat=allocstat)
56        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
57
58        xs=0.d0
59     ENDIF
60
61     ALLOCATE(buf_m3(0:ndim), buf_m(0:ndim), stat=allocstat)
62     IF (allocstat /= 0) stop "*** Not enough memory ! ***"
63
64     SELECT CASE (x_int_mode)
65     CASE('reso')
66        step => ss_step
67     CASE('tang')
68        step => ss_tl_step
69     CASE DEFAULT
70        stop '*** X_INT_MODE variable not properly defined in stoch_params.nml ***'
71     END SELECT
72
```

8.11.2.3 subroutine, public memory::test_m3 (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *h_int*)

Routine to test the #compute_M3 routine.

Parameters

y	current state
dt	timestep
dtn	stochastic timestep
h_int	result of the integration - give the memory term

Definition at line 159 of file memory.f90.

```
REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
REAL(KIND=8), INTENT(IN) :: dt,dtn
REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: h_int
INTEGER :: i,j

CALL compute_m3(y,dt,dtn,.true.,.true.,.true.,muti,h_int)
print*, t_index
print*, 'X'
DO i=1,mems
   j=modulo(t_index+i-1,mems)+1
   print*, i,j,x(1,j)
ENDDO

IF (b23def) THEN
   print*, 'Xs'
   DO i=1,mems
      j=modulo(t_index+i-1,mems)+1
      print*, i,j,xs(1,j)
   ENDDO
ENDIF
print*, 'h_int',h_int
```

8.11.3 Variable Documentation

8.11.3.1 real(kind=8), dimension(:), allocatable memory::buf_m [private]

Dummy vector.

Definition at line 31 of file memory.f90.

```
31 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_m !< Dummy vector
```

8.11.3.2 real(kind=8), dimension(:), allocatable memory::buf_m3 [private]

Dummy vector to store the M_3 integrand.

Definition at line 32 of file memory.f90.

```
32 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_m3 !< Dummy vector to store the \f$M_3\f$ integrand
```

8.11.3.3 procedure(ss_step), pointer memory::step [private]

Procedural pointer pointing on the resolved dynamics step routine.

Definition at line 36 of file memory.f90.

```
36 PROCEDURE(ss_step), POINTER :: step !< Procedural pointer pointing on the resolved dynamics step routine
```

8.11.3.4 integer memory::t_index [private]

Integer storing the time index (current position in the arrays)

Definition at line 34 of file memory.f90.

```
34 INTEGER :: t_index !< Integer storing the time index (current position in the arrays)
```

8.11.3.5 real(kind=8), dimension(:,:), allocatable memory::x [private]

Array storing the previous state of the system.

Definition at line 28 of file memory.f90.

```
28   REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: x !< Array storing the previous state of the system
```

8.11.3.6 real(kind=8), dimension(:,:), allocatable memory::xs [private]

Array storing the resolved time evolution of the previous state of the system.

Definition at line 29 of file memory.f90.

```
29   REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: xs !< Array storing the resolved time evolution of the
       previous state of the system
```

8.11.3.7 real(kind=8), dimension(:,:), allocatable memory::zs [private]

Dummy array to replace Xs in case where the evolution is not stored.

Definition at line 30 of file memory.f90.

```
30   REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: zs !< Dummy array to replace Xs in case where the evolution
       is not stored
```

8.12 mtv_int_tensor Module Reference

The MTV tensors used to integrate the MTV model.

Functions/Subroutines

- subroutine, public init_mtv_int_tensor

  Subroutine to initialise the MTV tensor.

Variables

- real(kind=8), dimension(:), allocatable, public h1

  First constant vector.
- real(kind=8), dimension(:), allocatable, public h2

  Second constant vector.
- real(kind=8), dimension(:), allocatable, public h3

  Third constant vector.
- real(kind=8), dimension(:), allocatable, public htot

  Total constant vector.
- type(coolist), dimension(:), allocatable, public l1

  First linear tensor.
- type(coolist), dimension(:), allocatable, public l2

  Second linear tensor.
- type(coolist), dimension(:), allocatable, public l3

  Third linear tensor.
- type(coolist), dimension(:), allocatable, public ltot

  Total linear tensor.
- type(coolist), dimension(:), allocatable, public b1

  First quadratic tensor.
- type(coolist), dimension(:), allocatable, public b2

  Second quadratic tensor.
- type(coolist), dimension(:), allocatable, public btot

  Total quadratic tensor.
- type(coolist4), dimension(:), allocatable, public mtot

  Tensor for the cubic terms.
- real(kind=8), dimension(:,:), allocatable, public q1

  Constant terms for the state-dependent noise covariance matrix.
- real(kind=8), dimension(:,:), allocatable, public q2

  Constant terms for the state-independent noise covariance matrix.
- type(coolist), dimension(:), allocatable, public utot

  Linear terms for the state-dependent noise covariance matrix.
- type(coolist4), dimension(:), allocatable, public vtot

  Quadratic terms for the state-dependent noise covariance matrix.
- real(kind=8), dimension(:), allocatable dumb_vec

  Dummy vector.
- real(kind=8), dimension(:,:), allocatable dumb_mat1

  Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat2

  Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat3

  Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat4

  Dummy matrix.

8.12.1 Detailed Description

The MTV tensors used to integrate the MTV model.

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Remarks

See : Franzke, C., Majda, A. J., & Vanden-Eijnden, E. (2005). Low-order stochastic mode reduction for a realistic barotropic model climate. Journal of the atmospheric sciences, 62(6), 1722-1745.

8.12.2 Function/Subroutine Documentation

8.12.2.1 subroutine, public mtv_int_tensor::init_mtv_int_tensor ( )

Subroutine to initialise the MTV tensor.

Definition at line 89 of file MTV_int_tensor.f90.

```
89      INTEGER :: allocstat,i,j,k,l
90
91      print*, 'Initializing the decomposition tensors...'
92      CALL init_dec_tensor
93      print*, "Initializing the correlation matrices and tensors..."
94      CALL init_corrint
95      print*, "Computing the correlation integrated matrices and tensors..."
96      CALL comp_corrint
97
98      !H part
99      print*, "Computing the H term..."
100
101      ALLOCATE(h1(0:ndim), h2(0:ndim), h3(0:ndim), htot(0:ndim),
       stat=allocstat)
102      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
103
104      ALLOCATE(dumb_mat1(ndim,ndim), dumb_mat2(ndim,ndim), stat=allocstat)
105      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
106
107      ALLOCATE(dumb_mat3(ndim,ndim), dumb_mat4(ndim,ndim), stat=allocstat)
108      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
109
110      !H1
111      CALL coo_to_mat_ik(lxy,dumb_mat1)
112      dumb_mat2=matmul(dumb_mat1,corrint)
113      CALL sparse_mul3_with_mat(bxxy,dumb_mat2,h1)
114
115      ! H2
116      h2=0.d0
117      IF (mode.ne.'ures') THEN
118         CALL coo_to_mat_ik(lyy,dumb_mat1)
119         dumb_mat1=matmul(inv_corr_i_full,dumb_mat1)
120
121         DO i=1,ndim
122            CALL coo_to_mat_i(i,bxyy,dumb_mat2)
123            CALL sparse_mul4_with_mat_jl(corr2int,dumb_mat2,dumb_mat3)
124            CALL sparse_mul4_with_mat_jl(corr2int,transpose(dumb_mat2),dumb_mat4)
125            dumb_mat3=dumb_mat3+dumb_mat4
126            h2(i)=mat_contract(dumb_mat1,dumb_mat3)
127         ENDDO
128      ENDIF
129
130      !H3
131      h3=0.d0
132      CALL sparse_mul3_with_mat(bxyy,corr_i_full,h3)
133
134      !Htot
135      htot=0.d0
136      htot=h1+h2+h3
```

```
    print*, "Computing the L terms..."
    ALLOCATE(l1(ndim), l2(ndim), l3(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    !L1
    CALL coo_to_mat_ik(lyx,dumb_mat1)
    CALL coo_to_mat_ik(lxy,dumb_mat2)
    dumb_mat3=matmul(inv_corr_i_full,corrint)
    dumb_mat4=matmul(dumb_mat2,matmul(transpose(dumb_mat3),dumb_mat1))
    CALL matc_to_coo(dumb_mat4,l1)

    !L2
    dumb_mat4=0.d0
    DO i=1,ndim
       DO j=1,ndim
          CALL coo_to_mat_i(i,bxyy,dumb_mat1)
          CALL sparse_mul4_with_mat_jl(corr2int,dumb_mat1+transpose(dumb_mat1),dumb_mat2)

          CALL coo_to_mat_j(j,byxy,dumb_mat1)
          dumb_mat1=matmul(inv_corr_i_full,dumb_mat1)
          dumb_mat4(i,j)=mat_contract(dumb_mat1,dumb_mat2)
       END DO
    END DO
    CALL matc_to_coo(dumb_mat4,l2)

    !L3
    dumb_mat4=0.d0
    DO i=1,ndim
       DO j=1,ndim
          CALL coo_to_mat_j(j,bxxy,dumb_mat1)
          CALL coo_to_mat_i(i,bxxy,dumb_mat2)
          dumb_mat4(i,j)=mat_trace(matmul(dumb_mat1,matmul(corrint,transpose(dumb_mat2))))
       ENDDO
    END DO
    CALL matc_to_coo(dumb_mat4,l3)

    !Ltot

    ALLOCATE(ltot(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    CALL add_to_tensor(l1,ltot)
    CALL add_to_tensor(l2,ltot)
    CALL add_to_tensor(l3,ltot)

    print*, "Computing the B terms..."
    ALLOCATE(b1(ndim), b2(ndim), btot(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    ALLOCATE(dumb_vec(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    ! B1
    CALL coo_to_mat_ik(lxy,dumb_mat1)
    dumb_mat2=matmul(inv_corr_i_full,corrint)

    dumb_mat3=matmul(dumb_mat1,transpose(dumb_mat2))
    DO j=1,ndim
       DO k=1,ndim
          CALL coo_to_vec_jk(j,k,byxx,dumb_vec)
          dumb_vec=matmul(dumb_mat3,dumb_vec)
          CALL add_vec_jk_to_tensor(j,k,dumb_vec,b1)
       ENDDO
    END DO

    ! B2
    CALL coo_to_mat_ik(lyx,dumb_mat3)
    dumb_mat2=matmul(inv_corr_i_full,corrint)

    dumb_mat4=matmul(transpose(dumb_mat2),dumb_mat3)
    DO i=1,ndim
       CALL coo_to_mat_i(i,bxxy,dumb_mat1)
       dumb_mat2=matmul(dumb_mat1,dumb_mat4)
       CALL add_matc_to_tensor(i,dumb_mat2,b2)
    ENDDO

    CALL add_to_tensor(b1,btot)
    CALL add_to_tensor(b2,btot)

    !M

    print*, "Computing the M term..."

    ALLOCATE(mtot(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    dumb_mat2=matmul(inv_corr_i_full,corrint)
```

```
      DO i=1,ndim
         CALL coo_to_mat_i(i,bxxy,dumb_mat1)
         dumb_mat3=matmul(dumb_mat1,transpose(dumb_mat2))
         DO k=1,ndim
            DO l=1,ndim
               CALL coo_to_vec_jk(k,l,byxx,dumb_vec)
               dumb_vec=matmul(dumb_mat3,dumb_vec)
               CALL add_vec_ikl_to_tensor4(i,k,l,dumb_vec,mtot)
            ENDDO
         END DO
      END DO

      !Q

      print*, "Computing the Q terms..."
      ALLOCATE(q1(ndim,ndim), q2(ndim,ndim), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"

      !Q1

      CALL coo_to_mat_ik(lxy,dumb_mat1)
      q1=matmul(dumb_mat1,matmul(corrint,transpose(dumb_mat1)))

      !Q2

      DO i=1,ndim
         DO j=1,ndim
            CALL coo_to_mat_i(i,bxyy,dumb_mat1)
            CALL coo_to_mat_i(j,bxyy,dumb_mat2)
            CALL sparse_mul4_with_mat_jl(corr2int,dumb_mat2,dumb_mat3)
            CALL sparse_mul4_with_mat_jl(corr2int,transpose(dumb_mat2),dumb_mat4)
            dumb_mat2=dumb_mat3+dumb_mat4
            q2(i,j)=mat_contract(dumb_mat1,dumb_mat2)
         END DO
      END DO

      !U

      ALLOCATE(utot(ndim), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"

      CALL coo_to_mat_ik(lxy,dumb_mat1)
      DO i=1,ndim
         CALL coo_to_mat_i(i,bxxy,dumb_mat2)
         dumb_mat3=matmul(dumb_mat1,matmul(corrint,transpose(dumb_mat2)))
         CALL add_matc_to_tensor(i,dumb_mat3,utot)
      ENDDO

      DO j=1,ndim
         CALL coo_to_mat_i(j,bxxy,dumb_mat2)
         dumb_mat3=matmul(dumb_mat1,matmul(corrint,transpose(dumb_mat2)))
         DO k=1,ndim
            CALL add_vec_jk_to_tensor(j,k,dumb_mat3(:,k),utot)
         ENDDO
      ENDDO

      !V

      ALLOCATE(vtot(ndim), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"

      DO i=1,ndim
         DO j=1,ndim
            CALL coo_to_mat_i(i,bxxy,dumb_mat1)
            CALL coo_to_mat_i(j,bxxy,dumb_mat2)
            dumb_mat3=matmul(dumb_mat1,matmul(corrint,transpose(dumb_mat2)))
            CALL add_matc_to_tensor4(j,i,dumb_mat3,vtot)
         ENDDO
      ENDDO

      DEALLOCATE(dumb_mat1, dumb_mat2, stat=allocstat)
      IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

      DEALLOCATE(dumb_mat3, dumb_mat4, stat=allocstat)
      IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

      DEALLOCATE(dumb_vec, stat=allocstat)
      IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"
```

8.12.3 Variable Documentation

8.12.3.1 type(coolist), dimension(:), allocatable, public mtv_int_tensor::b1

First quadratic tensor.

Definition at line 54 of file MTV_int_tensor.f90.

```
54 TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: b1 !< First quadratic tensor
```

8.12.3.2 type(coolist), dimension(:), allocatable, public mtv_int_tensor::b2

Second quadratic tensor.

Definition at line 55 of file MTV_int_tensor.f90.

```
55 TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: b2 !< Second quadratic tensor
```

8.12.3.3 type(coolist), dimension(:), allocatable, public mtv_int_tensor::btot

Total quadratic tensor.

Definition at line 56 of file MTV_int_tensor.f90.

```
56 TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: btot !< Total quadratic tensor
```

8.12.3.4 real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat1 [private]

Dummy matrix.

Definition at line 67 of file MTV_int_tensor.f90.

```
67 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat1 !< Dummy matrix
```

8.12.3.5 real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat2 [private]

Dummy matrix.

Definition at line 68 of file MTV_int_tensor.f90.

```
68 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat2 !< Dummy matrix
```

8.12.3.6 real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat3 [private]

Dummy matrix.

Definition at line 69 of file MTV_int_tensor.f90.

```
69    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat3 !< Dummy matrix
```

8.12.3.7 real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat4 [private]

Dummy matrix.

Definition at line 70 of file MTV_int_tensor.f90.

```
70    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat4 !< Dummy matrix
```

8.12.3.8 real(kind=8), dimension(:), allocatable mtv_int_tensor::dumb_vec [private]

Dummy vector.

Definition at line 66 of file MTV_int_tensor.f90.

```
66    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dumb_vec !< Dummy vector
```

8.12.3.9 real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h1

First constant vector.

Definition at line 42 of file MTV_int_tensor.f90.

```
42    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: h1   !< First constant vector
```

8.12.3.10 real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h2

Second constant vector.

Definition at line 43 of file MTV_int_tensor.f90.

```
43    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: h2   !< Second constant vector
```

8.12.3.11 real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h3

Third constant vector.

Definition at line 44 of file MTV_int_tensor.f90.

```
REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: h3   !< Third constant vector
```

8.12.3.12 real(kind=8), dimension(:), allocatable, public mtv_int_tensor::htot

Total constant vector.

Definition at line 45 of file MTV_int_tensor.f90.

```
REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: htot !< Total constant vector
```

8.12.3.13 type(coolist), dimension(:), allocatable, public mtv_int_tensor::l1

First linear tensor.

Definition at line 48 of file MTV_int_tensor.f90.

```
TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: l1   !< First linear tensor
```

8.12.3.14 type(coolist), dimension(:), allocatable, public mtv_int_tensor::l2

Second linear tensor.

Definition at line 49 of file MTV_int_tensor.f90.

```
TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: l2   !< Second linear tensor
```

8.12.3.15 type(coolist), dimension(:), allocatable, public mtv_int_tensor::l3

Third linear tensor.

Definition at line 50 of file MTV_int_tensor.f90.

```
TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: l3   !< Third linear tensor
```

8.12.3.16 type(coolist), dimension(:), allocatable, public mtv_int_tensor::ltot

Total linear tensor.

Definition at line 51 of file MTV_int_tensor.f90.

```
51    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: ltot !< Total linear tensor
```

8.12.3.17 type(coolist4), dimension(:), allocatable, public mtv_int_tensor::mtot

Tensor for the cubic terms.

Definition at line 58 of file MTV_int_tensor.f90.

```
58    TYPE(coolist4), DIMENSION(:), ALLOCATABLE, PUBLIC :: mtot !< Tensor for the cubic terms
```

8.12.3.18 real(kind=8), dimension(:,:), allocatable, public mtv_int_tensor::q1

Constant terms for the state-dependent noise covariance matrix.

Definition at line 61 of file MTV_int_tensor.f90.

```
61    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: q1 !< Constant terms for the state-dependent noise
        covariance matrix
```

8.12.3.19 real(kind=8), dimension(:,:), allocatable, public mtv_int_tensor::q2

Constant terms for the state-independent noise covariance matrix.

Definition at line 62 of file MTV_int_tensor.f90.

```
62    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: q2 !< Constant terms for the state-independent noise
        covariance matrix
```

8.12.3.20 type(coolist), dimension(:), allocatable, public mtv_int_tensor::utot

Linear terms for the state-dependent noise covariance matrix.

Definition at line 63 of file MTV_int_tensor.f90.

```
63    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: utot !< Linear terms for the state-dependent
        noise covariance matrix
```

8.12.3.21 type(coolist4), dimension(:), allocatable, public mtv_int_tensor::vtot

Quadratic terms for the state-dependent noise covariance matrix.

Definition at line 64 of file MTV_int_tensor.f90.

```
64   TYPE(coolist4), DIMENSION(:), ALLOCATABLE, PUBLIC :: vtot !< Quadratic terms for the
       state-dependent noise covariance matrix
```

8.13 params Module Reference

The model parameters module.

Functions/Subroutines

- subroutine, private init_nml

  Read the basic parameters and mode selection from the namelist.
- subroutine init_params

  Parameters initialisation routine.

Variables

- real(kind=8) n

  $n = 2L_y/L_x$ *- Aspect ratio*
- real(kind=8) phi0

  Latitude in radian.
- real(kind=8) rra

  Earth radius.
- real(kind=8) sig0

  σ_0 *- Non-dimensional static stability of the atmosphere.*
- real(kind=8) k

  Bottom atmospheric friction coefficient.
- real(kind=8) kp

  k' *- Internal atmospheric friction coefficient.*
- real(kind=8) r

  Frictional coefficient at the bottom of the ocean.
- real(kind=8) d

  Merchanical coupling parameter between the ocean and the atmosphere.
- real(kind=8) f0

  f_0 *- Coriolis parameter*
- real(kind=8) gp

  g' *Reduced gravity*
- real(kind=8) h

  Depth of the active water layer of the ocean.
- real(kind=8) phi0_npi

  Latitude exprimed in fraction of pi.
- real(kind=8) lambda

  λ *- Sensible + turbulent heat exchange between the ocean and the atmosphere.*

- real(kind=8) co

  C_a - *Constant short-wave radiation of the ocean.*
- real(kind=8) go

  γ_o - *Specific heat capacity of the ocean.*
- real(kind=8) ca

  C_a - *Constant short-wave radiation of the atmosphere.*
- real(kind=8) to0

  T_o^0 - *Stationary solution for the 0-th order ocean temperature.*
- real(kind=8) ta0

  T_a^0 - *Stationary solution for the 0-th order atmospheric temperature.*
- real(kind=8) epsa

  ϵ_a - *Emissivity coefficient for the grey-body atmosphere.*
- real(kind=8) ga

  γ_a - *Specific heat capacity of the atmosphere.*
- real(kind=8) rr

  R - *Gas constant of dry air*
- real(kind=8) scale

  $L_y = L\,\pi$ - *The characteristic space scale.*
- real(kind=8) pi

  π
- real(kind=8) lr

  L_R - *Rossby deformation radius*
- real(kind=8) g

  γ
- real(kind=8) rp

  r' - *Frictional coefficient at the bottom of the ocean.*
- real(kind=8) dp

  d' - *Non-dimensional mechanical coupling parameter between the ocean and the atmosphere.*
- real(kind=8) kd

  k_d - *Non-dimensional bottom atmospheric friction coefficient.*
- real(kind=8) kdp

  k'_d - *Non-dimensional internal atmospheric friction coefficient.*
- real(kind=8) cpo

  C'_a - *Non-dimensional constant short-wave radiation of the ocean.*
- real(kind=8) lpo

  λ'_o - *Non-dimensional sensible + turbulent heat exchange from ocean to atmosphere.*
- real(kind=8) cpa

  C'_a - *Non-dimensional constant short-wave radiation of the atmosphere.*
- real(kind=8) lpa

  λ'_a - *Non-dimensional sensible + turbulent heat exchange from atmosphere to ocean.*
- real(kind=8) sbpo

  $\sigma'_{B,o}$ - *Long wave radiation lost by ocean to atmosphere & space.*
- real(kind=8) sbpa

  $\sigma'_{B,a}$ - *Long wave radiation from atmosphere absorbed by ocean.*
- real(kind=8) lsbpo

  $S'_{B,o}$ - *Long wave radiation from ocean absorbed by atmosphere.*
- real(kind=8) lsbpa

  $S'_{B,a}$ - *Long wave radiation lost by atmosphere to space & ocean.*
- real(kind=8) l

  L - *Domain length scale*
- real(kind=8) sc

Ratio of surface to atmosphere temperature.

- real(kind=8) sb

  Stefan–Boltzmann constant.

- real(kind=8) betp

  β' *- Non-dimensional beta parameter*

- real(kind=8) nua =0.D0

  Dissipation in the atmosphere.

- real(kind=8) nuo =0.D0

  Dissipation in the ocean.

- real(kind=8) nuap

  Non-dimensional dissipation in the atmosphere.

- real(kind=8) nuop

  Non-dimensional dissipation in the ocean.

- real(kind=8) t_trans

  Transient time period.

- real(kind=8) t_run

  Effective intergration time (length of the generated trajectory)

- real(kind=8) dt

  Integration time step.

- real(kind=8) tw

  Write all variables every tw time units.

- logical writeout

  Write to file boolean.

- integer nboc

  Number of atmospheric blocks.

- integer nbatm

  Number of oceanic blocks.

- integer natm =0

  Number of atmospheric basis functions.

- integer noc =0

  Number of oceanic basis functions.

- integer ndim

  Number of variables (dimension of the model)

- integer, dimension(:,:), allocatable oms

  Ocean mode selection array.

- integer, dimension(:,:), allocatable ams

  Atmospheric mode selection array.

8.13.1 Detailed Description

The model parameters module.

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Remarks

Once the init_params() subroutine is called, the parameters are loaded globally in the main program and its subroutines and function

8.13.2 Function/Subroutine Documentation

8.13.2.1 subroutine, private params::init_nml ( ) [private]

Read the basic parameters and mode selection from the namelist.

Definition at line 97 of file params.f90.

```
97      INTEGER :: allocstat
98
99      namelist /aoscale/  scale,f0,n,rra,phi0_npi
100      namelist /oparams/  gp,r,h,d,nuo
101      namelist /aparams/  k,kp,sig0,nua
102      namelist /toparams/ go,co,to0
103      namelist /taparams/ ga,ca,epsa,ta0
104      namelist /otparams/ sc,lambda,rr,sb
105
106      namelist /modeselection/ oms,ams
107      namelist /numblocs/ nboc,nbatm
108
109      namelist /int_params/ t_trans,t_run,dt,tw,writeout
110
111      OPEN(8, file="params.nml", status='OLD', recl=80, delim='APOSTROPHE')
112
113      READ(8,nml=aoscale)
114      READ(8,nml=oparams)
115      READ(8,nml=aparams)
116      READ(8,nml=toparams)
117      READ(8,nml=taparams)
118      READ(8,nml=otparams)
119
120      CLOSE(8)
121
122      OPEN(8, file="modeselection.nml", status='OLD', recl=80, delim='APOSTROPHE')
123      READ(8,nml=numblocs)
124
125      ALLOCATE(oms(nboc,2),ams(nbatm,2), stat=allocstat)
126      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
127
128      READ(8,nml=modeselection)
129      CLOSE(8)
130
131      OPEN(8, file="int_params.nml", status='OLD', recl=80, delim='APOSTROPHE')
132      READ(8,nml=int_params)
133
```

8.13.2.2 subroutine params::init_params ( )

Parameters initialisation routine.

Definition at line 138 of file params.f90.

```
138      INTEGER, DIMENSION(2) :: s
139      INTEGER :: i
140      CALL init_nml
141
142      !---------------------------------------------------------!
143      !                                                         !
144      ! Computation of the dimension of the atmospheric         !
145      ! and oceanic components                                  !
146      !                                                         !
147      !---------------------------------------------------------!
148
149      natm=0
150      DO i=1,nbatm
151         IF (ams(i,1)==1) THEN
152            natm=natm+3
153         ELSE
154            natm=natm+2
155         ENDIF
156      ENDDO
157      s=shape(oms)
158      noc=s(1)
```

```
ndim=2*natm+2*noc

!-----------------------------------------------------------!
!                                                           !
! Some general parameters (Domain, beta, gamma, coupling)   !
!                                                           !
!-----------------------------------------------------------!

pi=dacos(-1.d0)
l=scale/pi
phi0=phi0_npi*pi
lr=sqrt(gp*h)/f0
g=-l**2/lr**2
betp=l/rra*cos(phi0)/sin(phi0)
rp=r/f0
dp=d/f0
kd=k*2
kdp=kp

!-----------------------------------------------------!
!                                                     !
! DERIVED QUANTITIES                                  !
!                                                     !
!-----------------------------------------------------!

cpo=co/(go*f0) * rr/(f0**2*l**2)
lpo=lambda/(go*f0)
cpa=ca/(ga*f0) * rr/(f0**2*l**2)/2 ! Cpa acts on psi1-psi3, not on theta
lpa=lambda/(ga*f0)
sbpo=4*sb*to0**3/(go*f0) ! long wave radiation lost by ocean to atmosphere space
sbpa=8*epsa*sb*ta0**3/(go*f0) ! long wave radiation from atmosphere absorbed by ocean
lsbpo=2*epsa*sb*to0**3/(ga*f0) ! long wave radiation from ocean absorbed by atmosphere
lsbpa=8*epsa*sb*ta0**3/(ga*f0) ! long wave radiation lost by atmosphere to space & ocea
nuap=nua/(f0*l**2)
nuop=nuo/(f0*l**2)
```

8.13.3 Variable Documentation

8.13.3.1 integer, dimension(:,:), allocatable params::ams

Atmospheric mode selection array.

Definition at line 87 of file params.f90.

```
87    INTEGER, DIMENSION(:,:), ALLOCATABLE :: ams   !< Atmospheric mode selection array
```

8.13.3.2 real(kind=8) params::betp

β' - Non-dimensional beta parameter

Definition at line 67 of file params.f90.

```
67    REAL(KIND=8) :: betp      !< \f$\beta'\f$ - Non-dimensional beta parameter
```

8.13.3.3 real(kind=8) params::ca

C_a - Constant short-wave radiation of the atmosphere.

Definition at line 40 of file params.f90.

```
40    REAL(KIND=8) :: ca        !< \f$C_a\f$ - Constant short-wave radiation of the atmosphere.
```

8.13.3.4 real(kind=8) params::co

C_a - Constant short-wave radiation of the ocean.

Definition at line 38 of file params.f90.

```
38   REAL(KIND=8) :: co         !< \f$C_a\f$ - Constant short-wave radiation of the ocean.
```

8.13.3.5 real(kind=8) params::cpa

C'_a - Non-dimensional constant short-wave radiation of the atmosphere.

Remarks

Cpa acts on psi1-psi3, not on theta.

Definition at line 58 of file params.f90.

```
58   REAL(KIND=8) :: cpa        !< \f$C'_a\f$ - Non-dimensional constant short-wave radiation of the
       atmosphere. @remark Cpa acts on psi1-psi3, not on theta.
```

8.13.3.6 real(kind=8) params::cpo

C'_a - Non-dimensional constant short-wave radiation of the ocean.

Definition at line 56 of file params.f90.

```
56   REAL(KIND=8) :: cpo        !< \f$C'_a\f$ - Non-dimensional constant short-wave radiation of the ocean.
```

8.13.3.7 real(kind=8) params::d

Merchanical coupling parameter between the ocean and the atmosphere.

Definition at line 31 of file params.f90.

```
31   REAL(KIND=8) :: d          !< Merchanical coupling parameter between the ocean and the atmosphere.
```

8.13.3.8 real(kind=8) params::dp

d' - Non-dimensional mechanical coupling parameter between the ocean and the atmosphere.

Definition at line 52 of file params.f90.

```
52   REAL(KIND=8) :: dp         !< \f$d'\f$ - Non-dimensional mechanical coupling parameter between the ocean
       and the atmosphere.
```

8.13.3.9 real(kind=8) params::dt

Integration time step.

Definition at line 77 of file params.f90.

```
77    REAL(KIND=8) :: dt         !< Integration time step
```

8.13.3.10 real(kind=8) params::epsa

ϵ_a - Emissivity coefficient for the grey-body atmosphere.

Definition at line 43 of file params.f90.

```
43    REAL(KIND=8) :: epsa       !< \f$\epsilon_a\f$ - Emissivity coefficient for the grey-body atmosphere.
```

8.13.3.11 real(kind=8) params::f0

f_0 - Coriolis parameter

Definition at line 32 of file params.f90.

```
32    REAL(KIND=8) :: f0         !< \f$f_0\f$ - Coriolis parameter
```

8.13.3.12 real(kind=8) params::g

γ

Definition at line 50 of file params.f90.

```
50    REAL(KIND=8) :: g          !< \f$\gamma\f$
```

8.13.3.13 real(kind=8) params::ga

γ_a - Specific heat capacity of the atmosphere.

Definition at line 44 of file params.f90.

```
44    REAL(KIND=8) :: ga         !< \f$\gamma_a\f$ - Specific heat capacity of the atmosphere.
```

8.13.3.14 real(kind=8) params::go

γ_o - Specific heat capacity of the ocean.

Definition at line 39 of file params.f90.

```
39 REAL(KIND=8) :: go        !< \f$\gamma_o\f$ - Specific heat capacity of the ocean.
```

8.13.3.15 real(kind=8) params::gp

g'Reduced gravity

Definition at line 33 of file params.f90.

```
33 REAL(KIND=8) :: gp        !< \f$g'\f$Reduced gravity
```

8.13.3.16 real(kind=8) params::h

Depth of the active water layer of the ocean.

Definition at line 34 of file params.f90.

```
34 REAL(KIND=8) :: h         !< Depth of the active water layer of the ocean.
```

8.13.3.17 real(kind=8) params::k

Bottom atmospheric friction coefficient.

Definition at line 28 of file params.f90.

```
28 REAL(KIND=8) :: k         !< Bottom atmospheric friction coefficient.
```

8.13.3.18 real(kind=8) params::kd

k_d - Non-dimensional bottom atmospheric friction coefficient.

Definition at line 53 of file params.f90.

```
53 REAL(KIND=8) :: kd        !< \f$k_d\f$ - Non-dimensional bottom atmospheric friction coefficient.
```

8.13.3.19 real(kind=8) params::kdp

k'_d - Non-dimensional internal atmospheric friction coefficient.

Definition at line 54 of file params.f90.

```
54   REAL(KIND=8) :: kdp       !< \f$k'_d\f$ - Non-dimensional internal atmospheric friction coefficient.
```

8.13.3.20 real(kind=8) params::kp

k' - Internal atmospheric friction coefficient.

Definition at line 29 of file params.f90.

```
29   REAL(KIND=8) :: kp        !< \f$k'\f$ - Internal atmospheric friction coefficient.
```

8.13.3.21 real(kind=8) params::l

L - Domain length scale

Definition at line 64 of file params.f90.

```
64   REAL(KIND=8) :: l         !< \f$L\f$ - Domain length scale
```

8.13.3.22 real(kind=8) params::lambda

λ - Sensible + turbulent heat exchange between the ocean and the atmosphere.

Definition at line 37 of file params.f90.

```
37   REAL(KIND=8) :: lambda    !< \f$\lambda\f$ - Sensible + turbulent heat exchange between the ocean and the
       atmosphere.
```

8.13.3.23 real(kind=8) params::lpa

λ'_a - Non-dimensional sensible + turbulent heat exchange from atmosphere to ocean.

Definition at line 59 of file params.f90.

```
59   REAL(KIND=8) :: lpa       !< \f$\lambda'_a\f$ - Non-dimensional sensible + turbulent heat exchange from
       atmosphere to ocean.
```

8.13.3.24 real(kind=8) params::lpo

λ'_o - Non-dimensional sensible + turbulent heat exchange from ocean to atmosphere.

Definition at line 57 of file params.f90.

```
57    REAL(KIND=8) :: lpo       !< \f$\lambda'_o\f$ - Non-dimensional sensible + turbulent heat exchange from
      ocean to atmosphere.
```

8.13.3.25 real(kind=8) params::lr

L_R - Rossby deformation radius

Definition at line 49 of file params.f90.

```
49    REAL(KIND=8) :: lr        !< \f$L_R\f$ - Rossby deformation radius
```

8.13.3.26 real(kind=8) params::lsbpa

$S'_{B,a}$ - Long wave radiation lost by atmosphere to space & ocean.

Definition at line 63 of file params.f90.

```
63    REAL(KIND=8) :: lsbpa     !< \f$S'_{B,a}\f$ - Long wave radiation lost by atmosphere to space & ocean.
```

8.13.3.27 real(kind=8) params::lsbpo

$S'_{B,o}$ - Long wave radiation from ocean absorbed by atmosphere.

Definition at line 62 of file params.f90.

```
62    REAL(KIND=8) :: lsbpo     !< \f$S'_{B,o}\f$ - Long wave radiation from ocean absorbed by atmosphere.
```

8.13.3.28 real(kind=8) params::n

$n = 2L_y/L_x$ - Aspect ratio

Definition at line 24 of file params.f90.

```
24    REAL(KIND=8) :: n         !< \f$n = 2 L_y / L_x\f$ - Aspect ratio
```

8.13.3.29 integer params::natm =0

Number of atmospheric basis functions.

Definition at line 83 of file params.f90.

```
83   INTEGER :: natm=0 !< Number of atmospheric basis functions
```

8.13.3.30 integer params::nbatm

Number of oceanic blocks.

Definition at line 82 of file params.f90.

```
82   INTEGER :: nbatm  !< Number of oceanic blocks
```

8.13.3.31 integer params::nboc

Number of atmospheric blocks.

Definition at line 81 of file params.f90.

```
81   INTEGER :: nboc   !< Number of atmospheric blocks
```

8.13.3.32 integer params::ndim

Number of variables (dimension of the model)

Definition at line 85 of file params.f90.

```
85   INTEGER :: ndim   !< Number of variables (dimension of the model)
```

8.13.3.33 integer params::noc =0

Number of oceanic basis functions.

Definition at line 84 of file params.f90.

```
84   INTEGER :: noc=0  !< Number of oceanic basis functions
```

8.13.3.34 real(kind=8) params::nua =0.D0

Dissipation in the atmosphere.

Definition at line 69 of file params.f90.

```
69   REAL(KIND=8) :: nua=0.d0  !< Dissipation in the atmosphere
```

8.13.3.35 real(kind=8) params::nuap

Non-dimensional dissipation in the atmosphere.

Definition at line 72 of file params.f90.

```
72   REAL(KIND=8) :: nuap      !< Non-dimensional dissipation in the atmosphere
```

8.13.3.36 real(kind=8) params::nuo =0.D0

Dissipation in the ocean.

Definition at line 70 of file params.f90.

```
70   REAL(KIND=8) :: nuo=0.d0  !< Dissipation in the ocean
```

8.13.3.37 real(kind=8) params::nuop

Non-dimensional dissipation in the ocean.

Definition at line 73 of file params.f90.

```
73   REAL(KIND=8) :: nuop      !< Non-dimensional dissipation in the ocean
```

8.13.3.38 integer, dimension(:,:), allocatable params::oms

Ocean mode selection array.

Definition at line 86 of file params.f90.

```
86   INTEGER, DIMENSION(:,:), ALLOCATABLE :: oms   !< Ocean mode selection array
```

8.13.3.39 real(kind=8) params::phi0

Latitude in radian.

Definition at line 25 of file params.f90.

```
REAL(KIND=8) :: phi0      !< Latitude in radian
```

8.13.3.40 real(kind=8) params::phi0_npi

Latitude exprimed in fraction of pi.

Definition at line 35 of file params.f90.

```
REAL(KIND=8) :: phi0_npi  !< Latitude exprimed in fraction of pi.
```

8.13.3.41 real(kind=8) params::pi

π

Definition at line 48 of file params.f90.

```
REAL(KIND=8) :: pi        !< \f$\pi\f$
```

8.13.3.42 real(kind=8) params::r

Frictional coefficient at the bottom of the ocean.

Definition at line 30 of file params.f90.

```
REAL(KIND=8) :: r         !< Frictional coefficient at the bottom of the ocean.
```

8.13.3.43 real(kind=8) params::rp

r' - Frictional coefficient at the bottom of the ocean.

Definition at line 51 of file params.f90.

```
REAL(KIND=8) :: rp        !< \f$r'\f$ - Frictional coefficient at the bottom of the ocean.
```

8.13.3.44 real(kind=8) params::rr

R - Gas constant of dry air

Definition at line 45 of file params.f90.

```
45    REAL(KIND=8) :: rr        !< \f$R\f$ - Gas constant of dry air
```

8.13.3.45 real(kind=8) params::rra

Earth radius.

Definition at line 26 of file params.f90.

```
26    REAL(KIND=8) :: rra       !< Earth radius
```

8.13.3.46 real(kind=8) params::sb

Stefan–Boltzmann constant.

Definition at line 66 of file params.f90.

```
66    REAL(KIND=8) :: sb        !< Stefan-Boltzmann constant
```

8.13.3.47 real(kind=8) params::sbpa

$\sigma'_{B,a}$ - Long wave radiation from atmosphere absorbed by ocean.

Definition at line 61 of file params.f90.

```
61    REAL(KIND=8) :: sbpa      !< \f$\sigma'_{B,a}\f$ - Long wave radiation from atmosphere absorbed by ocean.
```

8.13.3.48 real(kind=8) params::sbpo

$\sigma'_{B,o}$ - Long wave radiation lost by ocean to atmosphere & space.

Definition at line 60 of file params.f90.

```
60    REAL(KIND=8) :: sbpo      !< \f$\sigma'_{B,o}\f$ - Long wave radiation lost by ocean to atmosphere &
        space.
```

8.13.3.49 real(kind=8) params::sc

Ratio of surface to atmosphere temperature.

Definition at line 65 of file params.f90.

```
65    REAL(KIND=8) :: sc        !< Ratio of surface to atmosphere temperature.
```

8.13.3.50 real(kind=8) params::scale

$L_y = L\,\pi$ - The characteristic space scale.

Definition at line 47 of file params.f90.

```
47    REAL(KIND=8) :: scale     !< \f$L_y = L \, \pi\f$ - The characteristic space scale.
```

8.13.3.51 real(kind=8) params::sig0

σ_0 - Non-dimensional static stability of the atmosphere.

Definition at line 27 of file params.f90.

```
27    REAL(KIND=8) :: sig0      !< \f$\sigma_0\f$ - Non-dimensional static stability of the atmosphere.
```

8.13.3.52 real(kind=8) params::t_run

Effective intergration time (length of the generated trajectory)

Definition at line 76 of file params.f90.

```
76    REAL(KIND=8) :: t_run     !< Effective intergration time (length of the generated trajectory)
```

8.13.3.53 real(kind=8) params::t_trans

Transient time period.

Definition at line 75 of file params.f90.

```
75    REAL(KIND=8) :: t_trans   !< Transient time period
```

8.13.3.54 real(kind=8) params::ta0

T_a^0 - Stationary solution for the 0-th order atmospheric temperature.

Definition at line 42 of file params.f90.

```
42    REAL(KIND=8) :: ta0        !< \f$T_a^0\f$ -  Stationary solution for the 0-th order atmospheric
      temperature.
```

8.13.3.55 real(kind=8) params::to0

T_o^0 - Stationary solution for the 0-th order ocean temperature.

Definition at line 41 of file params.f90.

```
41    REAL(KIND=8) :: to0        !< \f$T_o^0\f$ -  Stationary solution for the 0-th order ocean temperature.
```

8.13.3.56 real(kind=8) params::tw

Write all variables every tw time units.

Definition at line 78 of file params.f90.

```
78    REAL(KIND=8) :: tw         !< Write all variables every tw time units
```

8.13.3.57 logical params::writeout

Write to file boolean.

Definition at line 79 of file params.f90.

```
79    LOGICAL :: writeout        !< Write to file boolean
```

8.14 rk2_mtv_integrator Module Reference

Module with the MTV rk2 integration routines.

Functions/Subroutines

- subroutine, public init_integrator

    Subroutine to initialize the MTV rk2 integrator.
- subroutine init_noise

    Routine to initialize the noise vectors and buffers.
- subroutine init_g

    Routine to initialize the G term.
- subroutine compg (y)

    Routine to actualize the G term based on the state y of the MTV system.
- subroutine, public step (y, t, dt, dtn, res, tend)

    Routine to perform an integration step (Heun algorithm) of the MTV system. The incremented time is returned.
- subroutine, public full_step (y, t, dt, dtn, res)

    Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable buf_y1
- real(kind=8), dimension(:), allocatable buf_f0
- real(kind=8), dimension(:), allocatable buf_f1

    Integration buffers.
- real(kind=8), dimension(:), allocatable dw
- real(kind=8), dimension(:), allocatable dwmult

    Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable dwar
- real(kind=8), dimension(:), allocatable dwau
- real(kind=8), dimension(:), allocatable dwor
- real(kind=8), dimension(:), allocatable dwou

    Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable anoise
- real(kind=8), dimension(:), allocatable noise

    Additive noise term.
- real(kind=8), dimension(:), allocatable noisemult

    Multiplicative noise term.
- real(kind=8), dimension(:), allocatable g

    G term of the MTV tendencies.
- real(kind=8), dimension(:), allocatable buf_g

    Buffer for the G term computation.
- logical mult

    Logical indicating if the sigma1 matrix must be computed for every state change.
- logical q1fill

    Logical indicating if the matrix Q1 is non-zero.
- logical compute_mult

    Logical indicating if the Gaussian noise for the multiplicative noise must be computed.
- real(kind=8), parameter sq2 = sqrt(2.D0)

    Hard coded square root of 2.

8.14.1 Detailed Description

Module with the MTV rk2 integration routines.

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Remarks

This module actually contains the Heun algorithm routines.

8.14.2 Function/Subroutine Documentation

8.14.2.1 subroutine rk2_mtv_integrator::compg (real(kind=8), dimension(0:ndim), intent(in) *y*) [private]

Routine to actualize the G term based on the state y of the MTV system.

Parameters

y	State of the MTV system

Definition at line 105 of file rk2_MTV_integrator.f90.

```
105     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
106
107     g=htot
108     CALL sparse_mul2_k(ltot,y,buf_g)
109     g=g+buf_g
110     CALL sparse_mul3(btot,y,y,buf_g)
111     g=g+buf_g
112     CALL sparse_mul4(mtot,y,y,y,buf_g)
113     g=g+buf_g
```

8.14.2.2 subroutine, public rk2_mtv_integrator::full_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastoc integration timestep (normally square-root of dt).
res	Final point after the step.

Definition at line 170 of file rk2_MTV_integrator.f90.

```
REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
REAL(KIND=8), INTENT(INOUT) :: t
REAL(KIND=8), INTENT(IN) :: dt,dtn
REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
CALL stoch_atm_res_vec(dwar)
CALL stoch_atm_unres_vec(dwau)
CALL stoch_oc_res_vec(dwor)
CALL stoch_oc_unres_vec(dwou)
anoise=(q_ar*dwar+q_au*dwau+q_or*dwor+q_ou*dwou)*dtn
CALL sparse_mul3(aotensor,y,y,buf_f0)
buf_y1 = y+dt*buf_f0+anoise
CALL sparse_mul3(aotensor,buf_y1,buf_y1,buf_f1)
res=y+0.5*(buf_f0+buf_f1)*dt+anoise
t=t+dt
```

8.14.2.3 subroutine rk2_mtv_integrator::init_g ( ) [private]

Routine to initialize the G term.

Definition at line 97 of file rk2_MTV_integrator.f90.

```
INTEGER :: allocstat
ALLOCATE(g(0:ndim), buf_g(0:ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"
```

8.14.2.4 subroutine, public rk2_mtv_integrator::init_integrator ( )

Subroutine to initialize the MTV rk2 integrator.

Definition at line 50 of file rk2_MTV_integrator.f90.

```
INTEGER :: allocstat

CALL init_ss_integrator ! Initialize the uncoupled resolved dynamics

ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim),stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

buf_y1=0.d0
buf_f1=0.d0
buf_f0=0.d0

print*, 'Initializing the integrator ...'
CALL init_sigma(mult,q1fill)
CALL init_noise
CALL init_g
```

8.14.2.5 subroutine rk2_mtv_integrator::init_noise ( ) [private]

Routine to initialize the noise vectors and buffers.

Definition at line 69 of file rk2_MTV_integrator.f90.

```
    INTEGER :: allocstat
    ALLOCATE(dw(0:ndim), dwmult(0:ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    ALLOCATE(dwar(0:ndim),dwau(0:ndim),dwor(0:ndim),dwou(0:ndim),
   stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    ALLOCATE(anoise(0:ndim), noise(0:ndim), noisemult(0:ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    dw=0.d0
    dwmult=0.d0

    dwar=0.d0
    dwor=0.d0
    dwau=0.d0
    dwou=0.d0

    anoise=0.d0
    noise=0.d0
    noisemult=0.d0

    compute_mult=((q1fill).OR.(mult))

```

8.14.2.6 subroutine, public rk2_mtv_integrator::step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*, real(kind=8), dimension(0:ndim), intent(out) *tend*)

Routine to perform an integration step (Heun algorithm) of the MTV system. The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastic integration timestep (normally square-root of dt).
res	Final point after the step.
tend	Partial or full tendencies used to perform the step (used for debugging).

Definition at line 124 of file rk2_MTV_integrator.f90.

```
124    REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
125    REAL(KIND=8), INTENT(INOUT) :: t
126    REAL(KIND=8), INTENT(IN) :: dt,dtn
127    REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res,tend
128
129    CALL compg(y)
130
131    CALL stoch_atm_res_vec(dwar)
132    CALL stoch_oc_res_vec(dwor)
133    anoise=q_ar*dwar+q_or*dwor
134    CALL stoch_vec(dw)
135    IF (compute_mult) CALL stoch_vec(dwmult)
136    noise(1:ndim)=matmul(sig2,dw(1:ndim))
137    IF ((mult).and.(mod(t,mnuti)<dt)) CALL compute_mult_sigma(y)
138    IF (compute_mult) noisemult(1:ndim)=matmul(sig1,dwmult(1:ndim))
139
140    CALL tendencies(t,y,buf_f0)
141    buf_y1 = y+dt*(buf_f0+g)+(anoise+sq2*(noise+noisemult))*dtn
142
143    buf_f1=g
144    CALL compg(buf_y1)
145    g=0.5*(g+buf_f1)
146
147    IF ((mult).and.(mod(t,mnuti)<dt)) CALL compute_mult_sigma(buf_y1)
148    IF (compute_mult) THEN
149       buf_f1(1:ndim)=matmul(sig1,dwmult(1:ndim))
```

```
      noisemult(1:ndim)=0.5*(noisemult(1:ndim)+buf_f1(1:ndim))
   ENDIF


   CALL tendencies(t,buf_y1,buf_f1)
   buf_f0=0.5*(buf_f0+buf_f1)
   res=y+dt*(buf_f0+g)+(anoise+sq2*(noise+noisemult))*dtn
   ! tend=G+sq2*(noise+noisemult)/dtn
   tend=sq2*noisemult/dtn
   t=t+dt
```

8.14.3 Variable Documentation

8.14.3.1 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::anoise [private]

Definition at line 33 of file rk2_MTV_integrator.f90.

```
33 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: anoise,noise         !< Additive noise term
```

8.14.3.2 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_f0 [private]

Definition at line 30 of file rk2_MTV_integrator.f90.

8.14.3.3 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_f1 [private]

Integration buffers.

Definition at line 30 of file rk2_MTV_integrator.f90.

8.14.3.4 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_g [private]

Buffer for the G term computation.

Definition at line 36 of file rk2_MTV_integrator.f90.

```
36 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_g                !< Buffer for the G term computation
```

8.14.3.5 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_y1 [private]

Definition at line 30 of file rk2_MTV_integrator.f90.

```
30 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1,buf_f0,buf_f1 !< Integration buffers
```

8.14.3.6 logical rk2_mtv_integrator::compute_mult [private]

Logical indicating if the Gaussian noise for the multiplicative noise must be computed.

Definition at line 40 of file rk2_MTV_integrator.f90.

```
40    LOGICAL :: compute_mult                                   !< Logical indicating if the Gaussian
        noise for the multiplicative noise must be computed
```

8.14.3.7 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dw [private]

Definition at line 31 of file rk2_MTV_integrator.f90.

```
31    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dw, dwmult          !< Standard gaussian noise buffers
```

8.14.3.8 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwar [private]

Definition at line 32 of file rk2_MTV_integrator.f90.

```
32    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dwar,dwau,dwor,dwou  !< Standard gaussian noise buffers
```

8.14.3.9 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwau [private]

Definition at line 32 of file rk2_MTV_integrator.f90.

8.14.3.10 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwmult [private]

Standard gaussian noise buffers.

Definition at line 31 of file rk2_MTV_integrator.f90.

8.14.3.11 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwor [private]

Definition at line 32 of file rk2_MTV_integrator.f90.

8.14.3.12 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwou [private]

Standard gaussian noise buffers.

Definition at line 32 of file rk2_MTV_integrator.f90.

8.14.3.13 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::g [private]

G term of the MTV tendencies.

Definition at line 35 of file rk2_MTV_integrator.f90.

```
REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: g                    !< G term of the MTV tendencies
```

8.14.3.14 logical rk2_mtv_integrator::mult [private]

Logical indicating if the sigma1 matrix must be computed for every state change.

Definition at line 38 of file rk2_MTV_integrator.f90.

```
LOGICAL :: mult                                                 !< Logical indicating if the sigma1
  matrix must be computed for every state change
```

8.14.3.15 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::noise [private]

Additive noise term.

Definition at line 33 of file rk2_MTV_integrator.f90.

8.14.3.16 real(kind=8), dimension(:), allocatable rk2_mtv_integrator::noisemult [private]

Multiplicative noise term.

Definition at line 34 of file rk2_MTV_integrator.f90.

```
REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: noisemult            !< Multiplicative noise term
```

8.14.3.17 logical rk2_mtv_integrator::q1fill [private]

Logical indicating if the matrix Q1 is non-zero.

Definition at line 39 of file rk2_MTV_integrator.f90.

```
LOGICAL :: q1fill                                               !< Logical indicating if the matrix Q1 is
  non-zero
```

8.14.3.18 real(kind=8), parameter rk2_mtv_integrator::sq2 = sqrt(2.D0) [private]

Hard coded square root of 2.

Definition at line 42 of file rk2_MTV_integrator.f90.

```
REAL(KIND=8), PARAMETER :: sq2 = sqrt(2.d0)                     !< Hard coded square root of 2
```

8.15 rk2_ss_integrator Module Reference

Module with the stochastic uncoupled resolved nonlinear and tangent linear rk2 dynamics integration routines.

Functions/Subroutines

- subroutine, public init_ss_integrator

    Subroutine to initialize the uncoupled resolved rk2 integrator.
- subroutine, public tendencies (t, y, res)

    Routine computing the tendencies of the uncoupled resolved model.
- subroutine, public tl_tendencies (t, y, ys, res)

    Tendencies for the tangent linear model of the uncoupled resolved dynamics in point ystar for perturbation deltay.
- subroutine, public ss_step (y, ys, t, dt, dtn, res)

    Routine to perform a stochastic integration step of the unresolved uncoupled dynamics (Heun algorithm). The incremented time is returned.
- subroutine, public ss_tl_step (y, ys, t, dt, dtn, res)

    Routine to perform a stochastic integration step of the unresolved uncoupled tangent linear dynamics (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable dwar
- real(kind=8), dimension(:), allocatable dwor

    Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable anoise

    Additive noise term.
- real(kind=8), dimension(:), allocatable buf_y1
- real(kind=8), dimension(:), allocatable buf_f0
- real(kind=8), dimension(:), allocatable buf_f1

    Integration buffers.

8.15.1 Detailed Description

Module with the stochastic uncoupled resolved nonlinear and tangent linear rk2 dynamics integration routines.

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Remarks

This module actually contains the Heun algorithm routines.

8.15.2 Function/Subroutine Documentation

8.15.2.1 subroutine, public rk2_ss_integrator::init_ss_integrator ( )

Subroutine to initialize the uncoupled resolved rk2 integrator.

Definition at line 40 of file rk2_ss_integrator.f90.

```
40      INTEGER :: allocstat
41
42      ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim),stat=allocstat)
43      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
44
45      ALLOCATE(anoise(0:ndim),stat=allocstat)
46      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
47
48      ALLOCATE(dwar(0:ndim),dwor(0:ndim),stat=allocstat)
49      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
50
51      dwar=0.d0
52      dwor=0.d0
53
```

8.15.2.2 subroutine, public rk2_ss_integrator::ss_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(in) *ys*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform a stochastic integration step of the unresolved uncoupled dynamics (Heun algorithm). The incremented time is returned.

Parameters

y	Initial point.
ys	Dummy argument for compatibility.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastic integration timestep (normally square-root of dt).
res	Final point after the step.

Definition at line 92 of file rk2_ss_integrator.f90.

```
92      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y,ys
93      REAL(KIND=8), INTENT(INOUT) :: t
94      REAL(KIND=8), INTENT(IN) :: dt,dtn
95      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
96
97      CALL stoch_atm_res_vec(dwar)
98      CALL stoch_oc_res_vec(dwor)
99      anoise=(q_ar*dwar+q_or*dwor)*dtn
100      CALL tendencies(t,y,buf_f0)
101      buf_y1 = y+dt*buf_f0+anoise
102      CALL tendencies(t,buf_y1,buf_f1)
103      res=y+0.5*(buf_f0+buf_f1)*dt+anoise
104      t=t+dt
```

8.15.2.3 subroutine, public rk2_ss_integrator::ss_tl_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(in) *ys*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform a stochastic integration step of the unresolved uncoupled tangent linear dynamics (Heun algorithm). The incremented time is returned.

Parameters

y	Initial point.
ys	point in trajectory to which the tangent space belongs.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastic integration timestep (normally square-root of dt).
res	Final point after the step.

Definition at line 117 of file rk2_ss_integrator.f90.

```
117     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y,ys
118     REAL(KIND=8), INTENT(INOUT) :: t
119     REAL(KIND=8), INTENT(IN) :: dt,dtn
120     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
121
122     CALL stoch_atm_res_vec(dwar)
123     CALL stoch_oc_res_vec(dwor)
124     anoise=(q_ar*dwar+q_or*dwor)*dtn
125     CALL tl_tendencies(t,y,ys,buf_f0)
126     buf_y1 = y+dt*buf_f0+anoise
127     CALL tl_tendencies(t,buf_y1,ys,buf_f1)
128     res=y+0.5*(buf_f0+buf_f1)*dt+anoise
129     t=t+dt
```

8.15.2.4 subroutine, public rk2_ss_integrator::tendencies (real(kind=8), intent(in) *t*, real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine computing the tendencies of the uncoupled resolved model.

Parameters

t	Time at which the tendencies have to be computed. Actually not needed for autonomous systems.
y	Point at which the tendencies have to be computed.
res	vector to store the result.

Remarks

Note that it is NOT safe to pass `y` as a result buffer, as this operation does multiple passes.

Definition at line 63 of file rk2_ss_integrator.f90.

```
63     REAL(KIND=8), INTENT(IN) :: t
64     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
65     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
66     CALL sparse_mul3(ss_tensor, y, y, res)
```

8.15.2.5 subroutine, public rk2_ss_integrator::tl_tendencies (real(kind=8), intent(in) *t*, real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(in) *ys*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Tendencies for the tangent linear model of the uncoupled resolved dynamics in point ystar for perturbation deltay.

Parameters

t	time
y	point of the tangent space at which the tendencies have to be computed.
ys	point in trajectory to which the tangent space belongs.
res	vector to store the result.

Definition at line 76 of file rk2_ss_integrator.f90.

```
76      REAL(KIND=8), INTENT(IN) :: t
77      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y,ys
78      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
79      CALL sparse_mul3(ss_tl_tensor, y, ys, res)
```

8.15.3 Variable Documentation

8.15.3.1 real(kind=8), dimension(:), allocatable rk2_ss_integrator::anoise [private]

Additive noise term.

Definition at line 30 of file rk2_ss_integrator.f90.

```
30    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: anoise !< Additive noise term
```

8.15.3.2 real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_f0 [private]

Definition at line 32 of file rk2_ss_integrator.f90.

8.15.3.3 real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_f1 [private]

Integration buffers.

Definition at line 32 of file rk2_ss_integrator.f90.

8.15.3.4 real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_y1 [private]

Definition at line 32 of file rk2_ss_integrator.f90.

```
32    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1,buf_f0,buf_f1 !< Integration buffers
```

8.15.3.5 real(kind=8), dimension(:), allocatable rk2_ss_integrator::dwar [private]

Definition at line 28 of file rk2_ss_integrator.f90.

```
28 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dwar,dwor !< Standard gaussian noise buffers
```

8.15.3.6 real(kind=8), dimension(:), allocatable rk2_ss_integrator::dwor [private]

Standard gaussian noise buffers.

Definition at line 28 of file rk2_ss_integrator.f90.

8.16 rk2_stoch_integrator Module Reference

Module with the stochastic rk2 integration routines.

Functions/Subroutines

- subroutine, public init_integrator (force)

  Subroutine to initialize the integrator.
- subroutine tendencies (t, y, res)

  Routine computing the tendencies of the selected model.
- subroutine, public step (y, t, dt, dtn, res, tend)

  Routine to perform a stochastic step of the selected dynamics (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable dwar
- real(kind=8), dimension(:), allocatable dwau
- real(kind=8), dimension(:), allocatable dwor
- real(kind=8), dimension(:), allocatable dwou

  Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable buf_y1
- real(kind=8), dimension(:), allocatable buf_f0
- real(kind=8), dimension(:), allocatable buf_f1

  Integration buffers.
- real(kind=8), dimension(:), allocatable anoise

  Additive noise term.
- type(coolist), dimension(:), allocatable int_tensor

  Dummy tensor that will hold the tendencies tensor.

8.16.1 Detailed Description

Module with the stochastic rk2 integration routines.

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Remarks

This module actually contains the Heun algorithm routines. There are four modes for this integrator:

- full: use the full dynamics
- ures: use the intrinsic unresolved dynamics
- qfst: use the quadratic terms of the unresolved tendencies
- reso: use the resolved dynamics alone

8.16.2 Function/Subroutine Documentation

8.16.2.1 subroutine, public rk2_stoch_integrator::init_integrator (character∗4, intent(in), optional *force*)

Subroutine to initialize the integrator.

Parameters

force	Parameter to force the mode of the integrator

Definition at line 48 of file rk2_stoch_integrator.f90.

```
48      INTEGER :: allocstat
49      CHARACTER*4, INTENT(IN), OPTIONAL :: force
50      CHARACTER*4 :: test
51
52      ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim),stat=allocstat)
53      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
54
55      ALLOCATE(anoise(0:ndim),stat=allocstat)
56      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
57
58      ALLOCATE(dwar(0:ndim),dwau(0:ndim),dwor(0:ndim),dwou(0:ndim),
       stat=allocstat)
59      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
60
61      ALLOCATE(int_tensor(ndim),stat=allocstat)
62      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
63
64      dwar=0.d0
65      dwor=0.d0
66      dwau=0.d0
67      dwou=0.d0
68
69      IF (PRESENT(force)) THEN
70         test=force
71      ELSE
72         test=mode
73      ENDIF
74
75      SELECT CASE (test)
76      CASE('full')
77         CALL copy_coo(aotensor,int_tensor)
78      CASE('ures')
79         CALL copy_coo(ff_tensor,int_tensor)
```

```
   CASE('qfst')
      CALL copy_coo(byyy,int_tensor)
   CASE('reso')
      CALL copy_coo(ss_tensor,int_tensor)
   CASE DEFAULT
      stop '*** MODE variable not properly defined ***'
   END SELECT

```

8.16.2.2 subroutine, public rk2_stoch_integrator::step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*, real(kind=8), dimension(0:ndim), intent(out) *tend*)

Routine to perform a stochastic step of the selected dynamics (Heun algorithm). The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastic integration timestep (normally square-root of dt).
res	Final point after the step.
tend	Partial or full tendencies used to perform the step (used for debugging).

Definition at line 112 of file rk2_stoch_integrator.f90.

```
    REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
    REAL(KIND=8), INTENT(INOUT) :: t
    REAL(KIND=8), INTENT(IN) :: dt,dtn
    REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res,tend

    CALL stoch_atm_res_vec(dwar)
    CALL stoch_atm_unres_vec(dwau)
    CALL stoch_oc_res_vec(dwor)
    CALL stoch_oc_unres_vec(dwou)
    anoise=(q_ar*dwar+q_au*dwau+q_or*dwor+q_ou*dwou)*dtn
    CALL tendencies(t,y,buf_f0)
    CALL sparse_mul3(int_tensor,y,y,tend)
    buf_y1 = y+dt*buf_f0+anoise
    CALL sparse_mul3(int_tensor,buf_y1,buf_y1,buf_f1)
    tend=0.5*(tend+buf_f1)
    CALL tendencies(t,buf_y1,buf_f1)
    res=y+0.5*(buf_f0+buf_f1)*dt+anoise
    t=t+dt
```

8.16.2.3 subroutine rk2_stoch_integrator::tendencies (real(kind=8), intent(in) *t*, real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(out) *res*) [private]

Routine computing the tendencies of the selected model.

Parameters

t	Time at which the tendencies have to be computed. Actually not needed for autonomous systems.
y	Point at which the tendencies have to be computed.
res	vector to store the result.

Remarks

Note that it is NOT safe to pass `y` as a result buffer, as this operation does multiple passes.

Definition at line 97 of file rk2_stoch_integrator.f90.

```
97      REAL(KIND=8), INTENT(IN) :: t
98      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
99      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
100      CALL sparse_mul3(int_tensor, y, y, res)
```

8.16.3 Variable Documentation

8.16.3.1 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::anoise [private]

Additive noise term.

Definition at line 37 of file rk2_stoch_integrator.f90.

```
37    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: anoise !< Additive noise term
```

8.16.3.2 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_f0 [private]

Definition at line 35 of file rk2_stoch_integrator.f90.

8.16.3.3 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_f1 [private]

Integration buffers.

Definition at line 35 of file rk2_stoch_integrator.f90.

8.16.3.4 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_y1 [private]

Definition at line 35 of file rk2_stoch_integrator.f90.

```
35    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1,buf_f0,buf_f1 !< Integration buffers
```

8.16.3.5 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwar [private]

Definition at line 33 of file rk2_stoch_integrator.f90.

```
33    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dwar,dwau,dwor,dwou !< Standard gaussian noise buffers
```

8.16.3.6 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwau [private]

Definition at line 33 of file rk2_stoch_integrator.f90.

8.16.3.7 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwor [private]

Definition at line 33 of file rk2_stoch_integrator.f90.

8.16.3.8 real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwou [private]

Standard gaussian noise buffers.

Definition at line 33 of file rk2_stoch_integrator.f90.

8.16.3.9 type(coolist), dimension(:), allocatable rk2_stoch_integrator::int_tensor [private]

Dummy tensor that will hold the tendencies tensor.

Definition at line 39 of file rk2_stoch_integrator.f90.

```
39   TYPE(coolist), DIMENSION(:), ALLOCATABLE :: int_tensor !< Dummy tensor that will hold the
       tendencies tensor
```

8.17 rk2_wl_integrator Module Reference

Module with the WL rk2 integration routines.

Functions/Subroutines

- subroutine, public init_integrator

  Subroutine that initialize the MARs, the memory unit and the integration buffers.
- subroutine compute_m1 (y)

  Routine to compute the M_1 term.
- subroutine compute_m2 (y)

  Routine to compute the M_2 term.
- subroutine, public step (y, t, dt, dtn, res, tend)

  Routine to perform an integration step (Heun algorithm) of the WL system. The incremented time is returned.
- subroutine, public full_step (y, t, dt, dtn, res)

  Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable buf_y1
- real(kind=8), dimension(:), allocatable buf_f0
- real(kind=8), dimension(:), allocatable buf_f1

    Integration buffers.
- real(kind=8), dimension(:), allocatable buf_m2
- real(kind=8), dimension(:), allocatable buf_m1
- real(kind=8), dimension(:), allocatable buf_m3
- real(kind=8), dimension(:), allocatable buf_m
- real(kind=8), dimension(:), allocatable buf_m3s

    Dummy buffers holding the terms /f$M_i.
- real(kind=8), dimension(:), allocatable anoise

    Additive noise term.
- real(kind=8), dimension(:), allocatable dwar
- real(kind=8), dimension(:), allocatable dwau
- real(kind=8), dimension(:), allocatable dwor
- real(kind=8), dimension(:), allocatable dwou

    Standard gaussian noise buffers.
- real(kind=8), dimension(:,:), allocatable x1

    Buffer holding the subsequent states of the first MAR.
- real(kind=8), dimension(:,:), allocatable x2

    Buffer holding the subsequent states of the second MAR.

8.17.1 Detailed Description

Module with the WL rk2 integration routines.

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Remarks

This module actually contains the Heun algorithm routines.

8.17.2 Function/Subroutine Documentation

8.17.2.1 subroutine rk2_wl_integrator::compute_m1 (real(kind=8), dimension(0:ndim), intent(in) *y*) [private]

Routine to compute the M_1 term.

Parameters

y	Present state of the WL system

Definition at line 106 of file rk2_WL_integrator.f90.

```
106     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
```

```
buf_m1=0.d0
IF (m12def) CALL sparse_mul2_k(m12, y, buf_m1)
buf_m1=buf_m1+m1tot
```

8.17.2.2 subroutine rk2_wl_integrator::compute_m2 (real(kind=8), dimension(0:ndim), intent(in) *y*) [private]

Routine to compute the M_2 term.

Parameters

y	Present state of the WL system

Definition at line 115 of file rk2_WL_integrator.f90.

```
115 REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
116 buf_m=0.d0
117 buf_m2=0.d0
118 IF (m21def) CALL sparse_mul3(m21, y, x1(0:ndim,1), buf_m)
119 IF (m22def) CALL sparse_mul3(m22, x2(0:ndim,1), x2(0:ndim,1), buf_m2)
120 buf_m2=buf_m2+buf_m
```

8.17.2.3 subroutine, public rk2_wl_integrator::full_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastoc integration timestep (normally square-root of dt).
res	Final point after the step.

Definition at line 185 of file rk2_WL_integrator.f90.

```
185 REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
186 REAL(KIND=8), INTENT(INOUT) :: t
187 REAL(KIND=8), INTENT(IN) :: dt,dtn
188 REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
189 CALL stoch_atm_res_vec(dwar)
190 CALL stoch_atm_unres_vec(dwau)
191 CALL stoch_oc_res_vec(dwor)
192 CALL stoch_oc_unres_vec(dwou)
193 anoise=(q_ar*dwar+q_au*dwau+q_or*dwor+q_ou*dwou)*dtn
194 CALL sparse_mul3(aotensor,y,y,buf_f0)
195 buf_y1 = y+dt*buf_f0+anoise
196 CALL sparse_mul3(aotensor,buf_y1,buf_y1,buf_f1)
197 res=y+0.5*(buf_f0+buf_f1)*dt+anoise
198 t=t+dt
```

8.17.2.4 subroutine, public rk2_wl_integrator::init_integrator ( )

Subroutine that initialize the MARs, the memory unit and the integration buffers.

Definition at line 44 of file rk2_WL_integrator.f90.

```
INTEGER :: allocstat,i

CALL init_ss_integrator

print*, 'Initializing the integrator ...'

IF (mode.ne.'ures') THEN
   print*, '*** Mode set to ',mode,' in stoch_params.nml ***'
   print*, '*** WL configuration only support unresolved mode ***'
   stop "*** Please change to 'ures' and perform the configuration again ! ***"
ENDIF

ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim),stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

ALLOCATE(buf_m1(0:ndim), buf_m2(0:ndim), buf_m3(0:ndim), buf_m(0:
ndim), buf_m3s(0:ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

ALLOCATE(dwar(0:ndim),dwau(0:ndim),dwor(0:ndim),dwou(0:ndim),
stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

ALLOCATE(anoise(0:ndim), stat=allocstat)
IF (allocstat /= 0) stop "*** Not enough memory ! ***"

buf_y1=0.d0
buf_f1=0.d0
buf_f0=0.d0

dwar=0.d0
dwor=0.d0
dwau=0.d0
dwou=0.d0

buf_m1=0.d0
buf_m2=0.d0
buf_m3=0.d0
buf_m3s=0.d0
buf_m=0.d0

print*, 'Initializing the MARs ...'

CALL init_mar

ALLOCATE(x1(0:ndim,ms), x2(0:ndim,ms), stat=allocstat)

x1=0.d0
DO i=1,50000
   CALL mar_step(x1)
ENDDO

x2=0.d0
DO i=1,50000
   CALL mar_step(x2)
ENDDO

CALL init_memory
```

8.17.2.5 subroutine, public rk2_wl_integrator::step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), intent(in) *dtn*, real(kind=8), dimension(0:ndim), intent(out) *res*, real(kind=8), dimension(0:ndim), intent(out) *tend*)

Routine to perform an integration step (Heun algorithm) of the WL system. The incremented time is returned.

Parameters

y	Initial point.
t	Actual integration time
dt	Integration timestep.
dtn	Stochastic integration timestep (normally square-root of dt).
res	Final point after the step.
tend	Partial or full tendencies used to perform the step (used for debugging).

Definition at line 132 of file rk2_WL_integrator.f90.

```
132     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
133     REAL(KIND=8), INTENT(INOUT) :: t
134     REAL(KIND=8), INTENT(IN) :: dt,dtn
135     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res,tend
136     INTEGER :: i
137
138     IF (mod(t,muti)<dt) THEN
139        CALL compute_m3(y,dts,dtsn,.true.,.true.,.true.,muti/2,buf_m3s)
140        buf_m3=buf_m3s
141        DO i=1,1
142           CALL compute_m3(y,dts,dtsn,.false.,.true.,.true.,muti/2,buf_m3s)
143           buf_m3=buf_m3+buf_m3s
144        ENDDO
145        !DO i=1,2
146        !   CALL compute_M3(y,dts,dtsn,.false.,.true.,.true.,muti/2,buf_M3s)
147        !   buf_M3=buf_M3+buf_M3s
148        !ENDDO
149        buf_m3=buf_m3/2
150     ENDIF
151
152
153     CALL stoch_atm_res_vec(dwar)
154     CALL stoch_oc_res_vec(dwor)
155     anoise=(q_ar*dwar+q_or*dwor)*dtn
156
157     CALL tendencies(t,y,buf_f0)
158     CALL mar_step(x1)
159     CALL mar_step(x2)
160     CALL compute_m1(y)
161     CALL compute_m2(y)
162     buf_f0= buf_f0+buf_m1+buf_m2+buf_m3
163     buf_y1 = y+dt*buf_f0+anoise
164
165     CALL tendencies(t+dt,buf_y1,buf_f1)
166     CALL compute_m1(buf_y1)
167     CALL compute_m2(buf_y1)
168     !IF (mod(t,muti)<dt) CALL compute_M3(buf_y1,dts,dtsn,.false.,.true.,buf_M3)
169
170     buf_f0=0.5*(buf_f0+buf_f1+buf_m1+buf_m2+buf_m3)
171     res=y+dt*buf_f0+anoise
172
173     tend=buf_m3
174     t=t+dt
175
```

8.17.3 Variable Documentation

8.17.3.1 real(kind=8), dimension(:), allocatable rk2_wl_integrator::anoise [private]

Additive noise term.

Definition at line 33 of file rk2_WL_integrator.f90.

```
33  REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: anoise          !< Additive noise term
```

8.17.3.2 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_f0 [private]

Definition at line 31 of file rk2_WL_integrator.f90.

8.17.3.3 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_f1 [private]

Integration buffers.

Definition at line 31 of file rk2_WL_integrator.f90.

8.17.3.4 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m [private]

Definition at line 32 of file rk2_WL_integrator.f90.

8.17.3.5 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m1 [private]

Definition at line 32 of file rk2_WL_integrator.f90.

8.17.3.6 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m2 [private]

Definition at line 32 of file rk2_WL_integrator.f90.

```
32   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_m2,buf_m1,buf_m3,buf_m,buf_m3s !< Dummy buffers holding
       the terms /f$M_i\f$ of the parameterization
```

8.17.3.7 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m3 [private]

Definition at line 32 of file rk2_WL_integrator.f90.

8.17.3.8 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m3s [private]

Dummy buffers holding the terms /f$M_i.

Definition at line 32 of file rk2_WL_integrator.f90.

8.17.3.9 real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_y1 [private]

Definition at line 31 of file rk2_WL_integrator.f90.

```
31   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1,buf_f0,buf_f1 !< Integration buffers
```

8.17.3.10 real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwar [private]

Definition at line 34 of file rk2_WL_integrator.f90.

```
34 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dwar,dwau,dwor,dwou  !< Standard gaussian noise buffers
```

8.17.3.11 real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwau [private]

Definition at line 34 of file rk2_WL_integrator.f90.

8.17.3.12 real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwor [private]

Definition at line 34 of file rk2_WL_integrator.f90.

8.17.3.13 real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwou [private]

Standard gaussian noise buffers.

Definition at line 34 of file rk2_WL_integrator.f90.

8.17.3.14 real(kind=8), dimension(:,:), allocatable rk2_wl_integrator::x1 [private]

Buffer holding the subsequent states of the first MAR.

Definition at line 36 of file rk2_WL_integrator.f90.

```
36 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: x1 !< Buffer holding the subsequent states of the first MAR
```

8.17.3.15 real(kind=8), dimension(:,:), allocatable rk2_wl_integrator::x2 [private]

Buffer holding the subsequent states of the second MAR.

Definition at line 37 of file rk2_WL_integrator.f90.

```
37 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: x2 !< Buffer holding the subsequent states of the second MAR
```

8.18 sf_def Module Reference

Module to select the resolved-unresolved components.

Functions/Subroutines

- subroutine, public load_sf

  Subroutine to load the unresolved variable defintion vector SF *from SF.nml if it exists. If it does not, then write SF.nml with no unresolved variables specified (null vector).*

Variables

- logical exists

  Boolean to test for file existence.
- integer, dimension(:), allocatable, public sf

  Unresolved variable definition vector.
- integer, dimension(:), allocatable, public ind
- integer, dimension(:), allocatable, public rind

  Unresolved reduction indices.
- integer, dimension(:), allocatable, public sl_ind
- integer, dimension(:), allocatable, public sl_rind

  Resolved reduction indices.
- integer, public n_unres

  Number of unresolved variables.
- integer, public n_res

  Number of resolved variables.
- integer, dimension(:,:), allocatable, public bar
- integer, dimension(:,:), allocatable, public bau
- integer, dimension(:,:), allocatable, public bor
- integer, dimension(:,:), allocatable, public bou

  Filter matrices.

8.18.1 Detailed Description

Module to select the resolved-unresolved components.

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8.18.2 Function/Subroutine Documentation

8.18.2.1 subroutine, public sf_def::load_sf ( )

Subroutine to load the unresolved variable defintion vector SF from SF.nml if it exists. If it does not, then write SF.nml with no unresolved variables specified (null vector).

Definition at line 37 of file sf_def.f90.

```fortran
 INTEGER :: i,allocstat,n,ns
 CHARACTER(len=20) :: fm

 namelist /sflist/ sf

 fm(1:6)='(F3.1)'

 IF (ndim == 0) stop "*** Number of dimensions is 0! ***"
 ALLOCATE(sf(0:ndim), stat=allocstat)
 IF (allocstat /= 0) stop "*** Not enough memory ! ***"

 INQUIRE(file='./SF.nml',exist=exists)

 IF (exists) THEN
    OPEN(8, file="SF.nml", status='OLD', recl=80, delim='APOSTROPHE')
    READ(8,nml=sflist)
    CLOSE(8)
    n_unres=0
    DO i=1,ndim ! Computing the number of unresolved variables
       IF (sf(i)==1) n_unres=n_unres+1
    ENDDO
    IF (n_unres==0) stop "*** No unresolved variable specified! ***"
    n_res=ndim-n_unres
    ALLOCATE(ind(n_unres), rind(0:ndim), sl_ind(n_res), sl_rind(0:ndim),
stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    ALLOCATE(bar(0:ndim,0:ndim), bau(0:ndim,0:ndim), bor(0:
ndim,0:ndim), bou(0:ndim,0:ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    rind=0
    n=1
    ns=1
    DO i=1,ndim
       IF (sf(i)==1) THEN
          ind(n)=i
          rind(i)=n
          n=n+1
       ELSE
          sl_ind(ns)=i
          sl_rind(i)=ns
          ns=ns+1
       ENDIF
    ENDDO
    bar=0
    bau=0
    bor=0
    bou=0
    DO i=1,2*natm
       IF (sf(i)==1) THEN
          bau(i,i)=1
       ELSE
          bar(i,i)=1
       ENDIF
    ENDDO
    DO i=2*natm+1,ndim
       IF (sf(i)==1) THEN
          bou(i,i)=1
       ELSE
          bor(i,i)=1
       ENDIF
    ENDDO
 ELSE
    OPEN(8, file="SF.nml", status='NEW')
    WRITE(8,'(a)') "!------------------------------------------------------------------------------!"
    WRITE(8,'(a)') "! Namelist file :                                                              !"
     WRITE(8,'(a)') "! Unresolved variables specification (1 -> unresolved, 0 -> resolved)
          !"
     WRITE(8,'(a)') "!------------------------------------------------------------------------------!"
     WRITE(8,*) ""
     WRITE(8,'(a)') "&SFLIST"
     WRITE(8,*) " ! psi variables"
     DO i=1,natm
        WRITE(8,*) " SF("//trim(str(i))//") = 0"//"   ! typ= "&
             &//awavenum(i)%typ//", Nx= "//trim(rstr(awavenum(i)&
             &%Nx,fm))//", Ny= "//trim(rstr(awavenum(i)%Ny,fm))
     END DO
     WRITE(8,*) " ! theta variables"
     DO i=1,natm
        WRITE(8,*) " SF("//trim(str(i+natm))//") = 0"//"   ! typ= "&
             &//awavenum(i)%typ//", Nx= "//trim(rstr(awavenum(i)&
             &%Nx,fm))//", Ny= "//trim(rstr(awavenum(i)%Ny,fm))
     END DO

     WRITE(8,*) " ! A variables"
     DO i=1,noc
        WRITE(8,*) " SF("//trim(str(i+2*natm))//") = 0"//"   ! Nx&
             &= "//trim(rstr(owavenum(i)%Nx,fm))//", Ny= "&
```

```
                &//trim(rstr(owavenum(i)%Ny,fm))
         END DO
         WRITE(8,*) " ! T variables"
         DO i=1,noc
            WRITE(8,*) " SF("//trim(str(i+noc+2*natm))//") = 0"//"    &
                 &! Nx= "//trim(rstr(owavenum(i)%Nx,fm))//", Ny= "&
                 &//trim(rstr(owavenum(i)%Ny,fm))
         END DO

         WRITE(8,'(a)') "&END"
         WRITE(8,*) ""
         CLOSE(8)
         stop "*** SF.nml namelist written. Fill in the file and rerun !***"
      ENDIF
```

8.18.3 Variable Documentation

8.18.3.1 integer, dimension(:,:), allocatable, public sf_def::bar

Definition at line 28 of file sf_def.f90.

```
28    INTEGER, DIMENSION(:,:), ALLOCATABLE, PUBLIC :: bar,bau,bor,bou  !< Filter matrices
```

8.18.3.2 integer, dimension(:,:), allocatable, public sf_def::bau

Definition at line 28 of file sf_def.f90.

8.18.3.3 integer, dimension(:,:), allocatable, public sf_def::bor

Definition at line 28 of file sf_def.f90.

8.18.3.4 integer, dimension(:,:), allocatable, public sf_def::bou

Filter matrices.

Definition at line 28 of file sf_def.f90.

8.18.3.5 logical sf_def::exists [private]

Boolean to test for file existence.

Definition at line 21 of file sf_def.f90.

```
21    LOGICAL :: exists !< Boolean to test for file existence.
```

8.18.3.6 integer, dimension(:), allocatable, public sf_def::ind

Definition at line 24 of file sf_def.f90.

```
24    INTEGER, DIMENSION(:), ALLOCATABLE, PUBLIC :: ind,rind        !< Unresolved reduction indices
```

8.18.3.7 integer, public sf_def::n_res

Number of resolved variables.

Definition at line 27 of file sf_def.f90.

```
27   INTEGER, PUBLIC :: n_res !< Number of resolved variables
```

8.18.3.8 integer, public sf_def::n_unres

Number of unresolved variables.

Definition at line 26 of file sf_def.f90.

```
26   INTEGER, PUBLIC :: n_unres !< Number of unresolved variables
```

8.18.3.9 integer, dimension(:), allocatable, public sf_def::rind

Unresolved reduction indices.

Definition at line 24 of file sf_def.f90.

8.18.3.10 integer, dimension(:), allocatable, public sf_def::sf

Unresolved variable definition vector.

Definition at line 23 of file sf_def.f90.

```
23   INTEGER, DIMENSION(:), ALLOCATABLE, PUBLIC :: sf              !< Unresolved variable definition vector
```

8.18.3.11 integer, dimension(:), allocatable, public sf_def::sl_ind

Definition at line 25 of file sf_def.f90.

```
25   INTEGER, DIMENSION(:), ALLOCATABLE, PUBLIC :: sl_ind,sl_rind  !< Resolved reduction indices
```

8.18.3.12 integer, dimension(:), allocatable, public sf_def::sl_rind

Resolved reduction indices.

Definition at line 25 of file sf_def.f90.

8.19 sigma Module Reference

The MTV noise sigma matrices used to integrate the MTV model.

Functions/Subroutines

- subroutine, public init_sigma (mult, Q1fill)

    Subroutine to initialize the sigma matices.
- subroutine, public compute_mult_sigma (y)

    Routine to actualize the matrix σ_1 based on the state y of the MTV system.

Variables

- real(kind=8), dimension(:,:), allocatable, public sig1

    $\sigma_1(X)$ state-dependent noise matrix
- real(kind=8), dimension(:,:), allocatable, public sig2

    σ_2 state-independent noise matrix
- real(kind=8), dimension(:,:), allocatable, public sig1r

    Reduced $\sigma_1(X)$ state-dependent noise matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat1

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat2

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat3

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat4

    Dummy matrix.
- integer, dimension(:), allocatable ind1
- integer, dimension(:), allocatable rind1
- integer, dimension(:), allocatable ind2
- integer, dimension(:), allocatable rind2

    Reduction indices.
- integer n1
- integer n2

8.19.1 Detailed Description

The MTV noise sigma matrices used to integrate the MTV model.

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Remarks

See : Franzke, C., Majda, A. J., & Vanden-Eijnden, E. (2005). Low-order stochastic mode reduction for a realistic barotropic model climate. Journal of the atmospheric sciences, 62(6), 1722-1745.

8.19.2 Function/Subroutine Documentation

8.19.2.1 subroutine, public sigma::compute_mult_sigma (real(kind=8), dimension(0:ndim), intent(in) *y*)

Routine to actualize the matrix σ_1 based on the state y of the MTV system.

Parameters

y	State of the MTV system

Definition at line 93 of file MTV_sigma_tensor.f90.

```
93      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y
94      INTEGER :: info,info2
95      CALL sparse_mul3_mat(utot,y,dumb_mat1)
96      CALL sparse_mul4_mat(vtot,y,y,dumb_mat2)
97      dumb_mat3=dumb_mat1+dumb_mat2+q1
98      CALL reduce(dumb_mat3,dumb_mat1,n1,ind1,rind1)
99      IF (n1 /= 0) THEN
100         CALL sqrtm_svd(dumb_mat1(1:n1,1:n1),dumb_mat2(1:n1,1:n1),info,info2,min(max(n1/2,2),64))
101         ! dumb_mat2=0.D0
102         ! CALL chol(0.5*(dumb_mat1(1:n1,1:n1)+transpose(dumb_mat1(1:n1,1:n1))),dumb_mat2(1:n1,1:n1),info)
103         IF ((.not.any(isnan(dumb_mat2))).and.(info.eq.0).and.(.not.any(dumb_mat2>huge(0.d0)))) THEN
104            CALL ireduce(sig1,dumb_mat2,n1,ind1,rind1)
105         ELSE
106            sig1=sig1r
107         ENDIF
108      ELSE
109         sig1=sig1r
110      ENDIF
```

8.19.2.2 subroutine, public sigma::init_sigma (logical, intent(out) *mult,* logical, intent(out) *Q1fill*)

Subroutine to initialize the sigma matices.

Definition at line 48 of file MTV_sigma_tensor.f90.

```
48       LOGICAL, INTENT(OUT) :: mult,q1fill
49       INTEGER :: allocstat,info1,info2
50
51       CALL init_sqrt
52
53       ALLOCATE(sig1(ndim,ndim), sig2(ndim,ndim), sig1r(ndim,
       ndim),stat=allocstat)
54       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
55
56       ALLOCATE(ind1(ndim), rind1(ndim), ind2(ndim), rind2(ndim),
       stat=allocstat)
57       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
58
59       ALLOCATE(dumb_mat1(ndim,ndim), dumb_mat2(ndim,ndim), stat=allocstat)
60       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
61
62       ALLOCATE(dumb_mat3(ndim,ndim), dumb_mat4(ndim,ndim), stat=allocstat)
63       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
64
65       print*, "Initializing the sigma matrices"
66
67       CALL reduce(q2,dumb_mat1,n2,ind2,rind2)
68       IF (n2 /= 0) THEN
69          CALL sqrtm_svd(dumb_mat1(1:n2,1:n2),dumb_mat2(1:n2,1:n2),info1,info2,min(max(n2/2,2),64))
70          CALL ireduce(sig2,dumb_mat2,n2,ind2,rind2)
71       ELSE
72          sig2=0.d0
73       ENDIF
74
75       mult=(.not.((tensor_empty(utot)).and.(tensor4_empty(vtot))))
76       q1fill=.true.
77       CALL reduce(q1,dumb_mat1,n1,ind1,rind1)
78       IF (n1 /= 0) THEN
79
80          CALL sqrtm_svd(dumb_mat1(1:n1,1:n1),dumb_mat2(1:n1,1:n1),info1,info2,min(max(n1/2,2),64))
81          CALL ireduce(sig1,dumb_mat2,n1,ind1,rind1)
82       ELSE
83          q1fill=.false.
84          sig1=0.d0
85       ENDIF
86       sig1r=sig1
87
```

8.19.3 Variable Documentation

8.19.3.1 real(kind=8), dimension(:,:), allocatable sigma::dumb_mat1 [private]

Dummy matrix.

Definition at line 35 of file MTV_sigma_tensor.f90.

```
35 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat1 !< Dummy matrix
```

8.19.3.2 real(kind=8), dimension(:,:), allocatable sigma::dumb_mat2 [private]

Dummy matrix.

Definition at line 36 of file MTV_sigma_tensor.f90.

```
36 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat2 !< Dummy matrix
```

8.19.3.3 real(kind=8), dimension(:,:), allocatable sigma::dumb_mat3 [private]

Dummy matrix.

Definition at line 37 of file MTV_sigma_tensor.f90.

```
37 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat3 !< Dummy matrix
```

8.19.3.4 real(kind=8), dimension(:,:), allocatable sigma::dumb_mat4 [private]

Dummy matrix.

Definition at line 38 of file MTV_sigma_tensor.f90.

```
38 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat4 !< Dummy matrix
```

8.19.3.5 integer, dimension(:), allocatable sigma::ind1 [private]

Definition at line 39 of file MTV_sigma_tensor.f90.

```
39 INTEGER, DIMENSION(:), ALLOCATABLE :: ind1,rind1,ind2,rind2 !< Reduction indices
```

8.19.3.6 integer, dimension(:), allocatable sigma::ind2 [private]

Definition at line 39 of file MTV_sigma_tensor.f90.

8.19.3.7 integer sigma::n1 [private]

Definition at line 41 of file MTV_sigma_tensor.f90.

```
INTEGER :: n1,n2
```

8.19.3.8 integer sigma::n2 [private]

Definition at line 41 of file MTV_sigma_tensor.f90.

8.19.3.9 integer, dimension(:), allocatable sigma::rind1 [private]

Definition at line 39 of file MTV_sigma_tensor.f90.

8.19.3.10 integer, dimension(:), allocatable sigma::rind2 [private]

Reduction indices.

Definition at line 39 of file MTV_sigma_tensor.f90.

8.19.3.11 real(kind=8), dimension(:,:), allocatable, public sigma::sig1

$\sigma_1(X)$ state-dependent noise matrix

Definition at line 31 of file MTV_sigma_tensor.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: sig1 !< \f$\sigma_1(X)\f$ state-dependent noise
  matrix
```

8.19.3.12 real(kind=8), dimension(:,:), allocatable, public sigma::sig1r

Reduced $\sigma_1(X)$ state-dependent noise matrix.

Definition at line 33 of file MTV_sigma_tensor.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: sig1r !< Reduced \f$\sigma_1(X)\f$ state-dependent
  noise matrix
```

8.19.3.13 real(kind=8), dimension(:,:), allocatable, public sigma::sig2

σ_2 state-independent noise matrix

Definition at line 32 of file MTV_sigma_tensor.f90.

```
REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: sig2 !< \f$\sigma_2\f$ state-independent noise
  matrix
```

8.20 sqrt_mod Module Reference

Utility module with various routine to compute matrix square root.

Functions/Subroutines

- subroutine, public init_sqrt
- subroutine, public sqrtm (A, sqA, info, info_triu, bs)

    Routine to compute a real square-root of a matrix.
- logical function selectev (a, b)
- subroutine sqrtm_triu (A, sqA, info, bs)
- subroutine csqrtm_triu (A, sqA, info, bs)
- subroutine rsf2csf (T, Z, Tz, Zz)
- subroutine, public chol (A, sqA, info)

    Routine to perform a Cholesky decomposition.
- subroutine, public sqrtm_svd (A, sqA, info, info_triu, bs)

    Routine to compute a real square-root of a matrix via a SVD decomposition.

Variables

- real(kind=8), dimension(:), allocatable work
- integer lwork
- real(kind=8), parameter real_eps = 2.2204460492503131e-16

8.20.1 Detailed Description

Utility module with various routine to compute matrix square root.

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Remarks

Mainly based on the numerical recipes and from: Edvin Deadman, Nicholas J. Higham, Rui Ralha (2013) "↩
Blocked Schur Algorithms for Computing the Matrix Square Root", Lecture Notes in Computer Science, 7782. pp. 171-182.

8.20.2 Function/Subroutine Documentation

8.20.2.1 subroutine, public sqrt_mod::chol (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *sqA*, integer, intent(out) *info*)

Routine to perform a Cholesky decomposition.

Parameters

A	Matrix whose decomposition is evaluated.
sqA	Cholesky decomposition of `A`.
info	Information code returned by the Lapack routines.

Definition at line 386 of file sqrt_mod.f90.

```
REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: sqa
INTEGER, INTENT(OUT) :: info

sqa=a
CALL dpotrf('L',SIZE(sqa,1),sqa,SIZE(sqa,1),info)
```

8.20.2.2 subroutine sqrt_mod::csqrtm_triu (complex(kind=16), dimension(:,:), intent(in) *A*, complex(kind=16), dimension(:,:), intent(out) *sqA*, integer, intent(out) *info*, integer, intent(in), optional *bs*) [private]

Definition at line 235 of file sqrt_mod.f90.

```
COMPLEX(KIND=16), DIMENSION(:,:), INTENT(IN) :: a
INTEGER, INTENT(IN), OPTIONAL :: bs
COMPLEX(KIND=16), DIMENSION(:,:), INTENT(OUT) :: sqa
INTEGER, INTENT(OUT) :: info
COMPLEX(KIND=16), DIMENSION(SIZE(A,1)) :: a_diag
COMPLEX(KIND=16), DIMENSION(SIZE(A,1),SIZE(A,1)) :: r,sm,rii,rjj
INTEGER, DIMENSION(2*SIZE(A,1),2) :: start_stop_pairs
COMPLEX(KIND=16) :: s,denom,scale
INTEGER :: i,j,k,start,n,sstop,m
INTEGER :: istart,istop,jstart,jstop
INTEGER :: nblocks,blocksize
INTEGER :: bsmall,blarge,nlarge,nsmall

blocksize=64
IF (PRESENT(bs)) blocksize=bs
n=SIZE(a,1)
! print*,  blocksize

CALL cdiag(a,a_diag)
r=0.d0
DO i=1,n
   r(i,i)=sqrt(a_diag(i))
ENDDO


nblocks=max(floordiv(n,blocksize),1)
bsmall=floordiv(n,nblocks)
nlarge=mod(n,nblocks)
blarge=bsmall+1
nsmall=nblocks-nlarge
IF (nsmall*bsmall + nlarge*blarge /= n) stop 'Sqrtm: Internal inconsistency'

! print*, nblocks,bsmall,nsmall,blarge,nlarge

start=1
DO i=1,nsmall
   start_stop_pairs(i,1)=start
   start_stop_pairs(i,2)=start+bsmall-1
   start=start+bsmall
ENDDO
DO i=nsmall+1,nsmall+nlarge
   start_stop_pairs(i,1)=start
   start_stop_pairs(i,2)=start+blarge-1
   start=start+blarge
ENDDO

! DO i=1,SIZE(start_stop_pairs,1)
!    print*, i
!    print*, start_stop_pairs(i,1),start_stop_pairs(i,2)
! END DO

DO k=1,nsmall+nlarge
```

```
287      start=start_stop_pairs(k,1)
288      sstop=start_stop_pairs(k,2)
289      DO j=start,sstop
290         DO i=j-1,start,-1
291            s=0.d0
292            IF (j-i>1) s= dot_product(r(i,i+1:j-1),r(i+1:j-1,j))
293            denom= r(i,i)+r(j,j)
294            IF (denom==0.d0) stop 'Sqrtm: Failed to find the matrix square root'
295            r(i,j)=(a(i,j)-s)/denom
296         END DO
297      END DO
298   END DO
299
300   ! print*, 'R'
301   ! CALL printmat(R)
302
303   DO j=1,nblocks
304      jstart=start_stop_pairs(j,1)
305      jstop=start_stop_pairs(j,2)
306      DO i=j-1,1,-1
307         istart=start_stop_pairs(i,1)
308         istop=start_stop_pairs(i,2)
309         sm=0.d0
310         sm(istart:istop,jstart:jstop)=a(istart:istop,jstart:jstop)
311         IF (j-i>1) sm(istart:istop,jstart:jstop) = sm(istart:istop&
312              &,jstart:jstop) - matmul(r(istart:istop,istop:jstart)&
313              &,r(istop:jstart,jstart:jstop))
314         rii=0.d0
315         rii = r(istart:istop, istart:istop)
316         rjj=0.d0
317         rjj = r(jstart:jstop, jstart:jstop)
318         m=istop-istart+1
319         n=jstop-jstart+1
320         k=1
321         ! print*, m,n
322         ! print*, istart,istop
323         ! print*, jstart,jstop
324
325         ! print*, 'Rii',Rii(istart:istop, istart:istop)
326         ! print*, 'Rjj',Rjj(jstart:jstop,jstart:jstop)
327         ! print*, 'Sm',Sm(istart:istop,jstart:jstop)
328
329         CALL ztrsyl('N','N',k,m,n,rii(istart:istop, istart:istop),m&
330              &,rjj(jstart:jstop,jstart:jstop),n,sm(istart:istop&
331              &,jstart:jstop),m,scale,info)
332         r(istart:istop,jstart:jstop)=sm(istart:istop,jstart:jstop)*scale
333      ENDDO
334   ENDDO
335   sqa=r
```

8.20.2.3 subroutine, public sqrt_mod::init_sqrt ( )

Definition at line 39 of file sqrt_mod.f90.

```
39   INTEGER :: allocstat
40   lwork=10
41   lwork=ndim*lwork
42
43   ! print*, lwork
44
45   IF (ALLOCATED(work)) THEN
46      DEALLOCATE(work, stat=allocstat)
47      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
48   ENDIF
49   ALLOCATE(work(lwork), stat=allocstat)
50   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
51
52   ! ALLOCATE(zwork(lwork), STAT=AllocStat)
53   ! IF (AllocStat /= 0) STOP "*** Not enough memory ! ***"
```

8.20.2.4 subroutine sqrt_mod::rsf2csf (real(kind=8), dimension(:,:), intent(in) *T*, real(kind=8), dimension(:,:), intent(in) *Z*, complex(kind=16), dimension(:,:), intent(out) *Tz*, complex(kind=16), dimension(:,:), intent(out) *Zz*) [private]

Definition at line 339 of file sqrt_mod.f90.

```
    REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: t,z
    COMPLEX(KIND=16), DIMENSION(:,:), INTENT(OUT) :: tz,zz
    INTEGER, PARAMETER :: nb=2
    COMPLEX(KIND=16), DIMENSION(nb) :: w
    !COMPLEX(KIND=16), DIMENSION(nb,nb) :: vl,vr
    COMPLEX(KIND=16) :: r,c,s,mu
    COMPLEX(KIND=16), DIMENSION(nb,nb) :: g,gc
    INTEGER :: n,m!,info
    !REAL(KIND=8), DIMENSION(2*nb) :: rwork
    !REAL(KIND=8), DIMENSION(2*nb) :: ztwork

    ! print*, lwork
    tz=cmplx(t,kind=16)
    zz=cmplx(z,kind=16)
    n=SIZE(t,1)
    DO m=n,2,-1
       IF (abs(tz(m,m-1)) > real_eps*(abs(tz(m-1,m-1)) + abs(tz(m,m)))) THEN
          g=tz(m-1:m,m-1:m)
          ! CALL printmat(dble(G))
          ! CALL zgeev('N','N',nb,G,nb,w,vl,nb,vr,nb,ztwork,2*nb,rwork,info)
          ! CALL cprintmat(G)
          ! print*, m,w,info
          s=g(1,1)+g(2,2)
          c=g(1,1)*g(2,2)-g(1,2)*g(2,1)
          w(1)=s/2+sqrt(s**2/4-c)
          mu=w(1)-tz(m,m)
          r=sqrt(mu*conjg(mu)+tz(m,m-1)*conjg(tz(m,m-1)))
          c=mu/r
          s=tz(m,m-1)/r
          g(1,1)=conjg(c)
          g(1,2)=s
          g(2,1)=-s
          g(2,2)=c
          gc=conjg(transpose(g))
          tz(m-1:m,m-1:n)=matmul(g,tz(m-1:m,m-1:n))
          tz(1:m,m-1:m)=matmul(tz(1:m,m-1:m),gc)
          zz(:,m-1:m)=matmul(zz(:,m-1:m),gc)
       END IF
       tz(m,m-1)=cmplx(0.d0,kind=16)
    END DO
```

8.20.2.5 logical function sqrt_mod::selectev (real(kind=8) *a*, real(kind=8) *b*) [private]

Definition at line 122 of file sqrt_mod.f90.

```
122     REAL(KIND=8) :: a,b
123     LOGICAL selectev
124     selectev=.false.
125     ! IF (a>b) selectev=.true.
126     RETURN
```

8.20.2.6 subroutine, public sqrt_mod::sqrtm (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *sqA*, integer, intent(out) *info*, integer, intent(out) *info_triu*, integer, intent(in), optional *bs*)

Routine to compute a real square-root of a matrix.

Parameters

A	Matrix whose square root to evaluate.
sqA	Square root of `A`.
info	Information code returned by the Lapack routines.
info_triu	Information code returned by the triangular matrix Lapack routines.
bs	Optional blocksize specification variable.

Definition at line 63 of file sqrt_mod.f90.

```
    REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
    REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: sqa
    INTEGER, INTENT(IN), OPTIONAL :: bs
    INTEGER, INTENT(OUT) :: info,info_triu
    REAL(KIND=8), DIMENSION(SIZE(A,1),SIZE(A,1)) :: t,z,r
    COMPLEX(KIND=16), DIMENSION(SIZE(A,1),SIZE(A,1)) :: tz,zz,rz
    REAL(KIND=8), DIMENSION(SIZE(A,1)) :: wr,wi
    LOGICAL, DIMENSION(SIZE(A,1)) :: bwork
    LOGICAL :: selectev
    INTEGER :: n
    INTEGER :: sdim=0
    n=SIZE(a,1)
    t=a
    ! print*, n,size(work,1)
    CALL dgees('v','n',selectev,n,t,n,sdim,wr,wi,z,n,work,lwork,bwork,info)
    ! print*, 'Z'
    ! CALL printmat(Z)
    ! print*, 'T'
    ! CALL printmat(T)
    ! CALL DGEES('V','N',SIZE(T,1),T,SIZE(T,1),0,wr,wi,Z,SIZE(Z,1),work,lwork,info)
    ! print*, info
    CALL triu(t,r)
    IF (any(t /= r)) THEN
       ! print*, 'T'
       ! CALL printmat(T)
       ! print*, 'Z'
       ! CALL printmat(Z)
       CALL rsf2csf(t,z,tz,zz)
       ! print*, 'Tz'
       ! CALL printmat(dble(Tz))
       ! print*, 'iTz'
       ! CALL printmat(dble(aimag(Tz)))
       ! print*, 'Zz'
       ! CALL printmat(dble(Zz))
       ! print*, 'iZz'
       ! CALL printmat(dble(aimag(Zz)))
       IF (PRESENT(bs)) THEN
          CALL csqrtm_triu(tz,rz,info_triu,bs)
       ELSE
          CALL csqrtm_triu(tz,rz,info_triu)
       END IF
       rz=matmul(zz,matmul(rz,conjg(transpose(zz))))
       ! print*, 'sqAz'
       ! CALL printmat(dble(Rz))
       ! print*, 'isqAz'
       ! CALL printmat(dble(aimag(Rz)))
       sqa=dble(rz)
    ELSE
       IF (PRESENT(bs)) THEN
          CALL sqrtm_triu(t,r,info_triu,bs)
       ELSE
          CALL sqrtm_triu(t,r,info_triu)
       END IF
       sqa=matmul(z,matmul(r,transpose(z)))
    ENDIF
```

8.20.2.7 subroutine, public sqrt_mod::sqrtm_svd (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *sqA*, integer, intent(out) *info*, integer, intent(out) *info_triu*, integer, intent(in), optional *bs*)

Routine to compute a real square-root of a matrix via a SVD decomposition.

Parameters

A	Matrix whose square root to evaluate.
sqA	Square root of `A`.
info	Information code returned by the Lapack routines.
info_triu	Not used (present for compatibility).
bs	Not used (present for compatibility).

Definition at line 401 of file sqrt_mod.f90.

```
REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: sqa
INTEGER, INTENT(IN), OPTIONAL :: bs
INTEGER, INTENT(OUT) :: info,info_triu
REAL(KIND=8), DIMENSION(SIZE(A,1)) :: s
REAL(KIND=8), DIMENSION(SIZE(A,1),SIZE(A,1)) :: sq,u,vt
INTEGER :: i,n

sqa=a
n=SIZE(sqa,1)
CALL dgesvd('A','A',n,n,sqa,n,s,u,n,vt,n,work,lwork,info)
sq=0.d0
DO i=1,n
   sq(i,i)=sqrt(s(i))
ENDDO
sqa=matmul(u,matmul(sq,vt))
```

8.20.2.8 subroutine sqrt_mod::sqrtm_triu (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *sqA*, integer, intent(out) *info*, integer, intent(in), optional *bs*) [private]

Definition at line 131 of file sqrt_mod.f90.

```
REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
INTEGER, INTENT(IN), OPTIONAL :: bs
REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: sqa
INTEGER, INTENT(OUT) :: info
REAL(KIND=8), DIMENSION(SIZE(A,1)) :: a_diag
REAL(KIND=8), DIMENSION(SIZE(A,1),SIZE(A,1)) :: r,sm,rii,rjj
INTEGER, DIMENSION(2*SIZE(A,1),2) :: start_stop_pairs
REAL(KIND=8) :: s,denom,scale
INTEGER :: i,j,k,start,n,sstop,m
INTEGER :: istart,istop,jstart,jstop
INTEGER :: nblocks,blocksize
INTEGER :: bsmall,blarge,nlarge,nsmall

blocksize=64
IF (PRESENT(bs)) blocksize=bs
n=SIZE(a,1)
! print*,  blocksize

CALL diag(a,a_diag)
r=0.d0
DO i=1,n
   r(i,i)=sqrt(a_diag(i))
ENDDO


nblocks=max(floordiv(n,blocksize),1)
bsmall=floordiv(n,nblocks)
nlarge=mod(n,nblocks)
blarge=bsmall+1
nsmall=nblocks-nlarge
IF (nsmall*bsmall + nlarge*blarge /= n) stop 'Sqrtm: Internal inconsistency'

! print*, nblocks,bsmall,nsmall,blarge,nlarge

start=1
DO i=1,nsmall
   start_stop_pairs(i,1)=start
   start_stop_pairs(i,2)=start+bsmall-1
   start=start+bsmall
ENDDO
DO i=nsmall+1,nsmall+nlarge
   start_stop_pairs(i,1)=start
   start_stop_pairs(i,2)=start+blarge-1
   start=start+blarge
ENDDO

! DO i=1,SIZE(start_stop_pairs,1)
!    print*, i
!    print*, start_stop_pairs(i,1),start_stop_pairs(i,2)
! END DO

DO k=1,nsmall+nlarge
   start=start_stop_pairs(k,1)
   sstop=start_stop_pairs(k,2)
   DO j=start,sstop
      DO i=j-1,start,-1
         s=0.d0
```

```
            IF (j-i>1) s= dot_product(r(i,i+1:j-1),r(i+1:j-1,j))
            denom= r(i,i)+r(j,j)
            IF (denom==0.d0) stop 'Sqrtm: Failed to find the matrix square root'
            r(i,j)=(a(i,j)-s)/denom
         END DO
      END DO
   END DO

   ! print*, 'R'
   ! CALL printmat(R)

   DO j=1,nblocks
      jstart=start_stop_pairs(j,1)
      jstop=start_stop_pairs(j,2)
      DO i=j-1,1,-1
         istart=start_stop_pairs(i,1)
         istop=start_stop_pairs(i,2)
         sm=0.d0
         sm(istart:istop,jstart:jstop)=a(istart:istop,jstart:jstop)
         IF (j-i>1) sm(istart:istop,jstart:jstop) = sm(istart:istop&
              &,jstart:jstop) - matmul(r(istart:istop,istop:jstart)&
              &,r(istop:jstart,jstart:jstop))
         rii=0.d0
         rii = r(istart:istop, istart:istop)
         rjj=0.d0
         rjj = r(jstart:jstop, jstart:jstop)
         m=istop-istart+1
         n=jstop-jstart+1
         k=1
         ! print*, m,n
         ! print*, istart,istop
         ! print*, jstart,jstop

         ! print*, 'Rii',Rii(istart:istop, istart:istop)
         ! print*, 'Rjj',Rjj(jstart:jstop,jstart:jstop)
         ! print*, 'Sm',Sm(istart:istop,jstart:jstop)

         CALL dtrsyl('N','N',k,m,n,rii(istart:istop, istart:istop),m&
              &,rjj(jstart:jstop,jstart:jstop),n,sm(istart:istop&
              &,jstart:jstop),m,scale,info)
         r(istart:istop,jstart:jstop)=sm(istart:istop,jstart:jstop)*scale
      ENDDO
   ENDDO
   sqa=r
```

8.20.3 Variable Documentation

8.20.3.1 integer sqrt_mod::lwork [private]

Definition at line 30 of file sqrt_mod.f90.

```
30   INTEGER :: lwork
```

8.20.3.2 real(kind=8), parameter sqrt_mod::real_eps = 2.2204460492503131e-16 [private]

Definition at line 32 of file sqrt_mod.f90.

```
32   REAL(KIND=8), PARAMETER :: real_eps = 2.2204460492503131e-16
```

8.20.3.3 real(kind=8), dimension(:), allocatable sqrt_mod::work [private]

Definition at line 27 of file sqrt_mod.f90.

```
27   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: work
```

8.21 stat Module Reference

Statistics accumulators.

Functions/Subroutines

- subroutine, public init_stat
  Initialise the accumulators.
- subroutine, public acc (x)
  Accumulate one state.
- real(kind=8) function, dimension(0:ndim), public mean ()
  Function returning the mean.
- real(kind=8) function, dimension(0:ndim), public var ()
  Function returning the variance.
- integer function, public iter ()
  Function returning the number of data accumulated.
- subroutine, public reset
  Routine resetting the accumulators.

Variables

- integer i =0
  Number of stats accumulated.
- real(kind=8), dimension(:), allocatable m
  Vector storing the inline mean.
- real(kind=8), dimension(:), allocatable mprev
  Previous mean vector.
- real(kind=8), dimension(:), allocatable v
  Vector storing the inline variance.
- real(kind=8), dimension(:), allocatable mtmp

8.21.1 Detailed Description

Statistics accumulators.

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8.21.2 Function/Subroutine Documentation

8.21.2.1 subroutine, public stat::acc (real(kind=8), dimension(0:ndim), intent(in) *x*)

Accumulate one state.

Definition at line 48 of file stat.f90.

```
48      IMPLICIT NONE
49      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: x
50      i=i+1
51      mprev=m+(x-m)/i
52      mtmp=mprev
53      mprev=m
54      m=mtmp
55      v=v+(x-mprev)*(x-m)
```

8.21.2.2 subroutine, public stat::init_stat ( )

Initialise the accumulators.

Definition at line 35 of file stat.f90.

```
35      INTEGER :: allocstat
36
37      ALLOCATE(m(0:ndim),mprev(0:ndim),v(0:ndim),mtmp(0:ndim),
     stat=allocstat)
38      IF (allocstat /= 0) stop '*** Not enough memory ***'
39      m=0.d0
40      mprev=0.d0
41      v=0.d0
42      mtmp=0.d0
43
```

8.21.2.3 integer function, public stat::iter ( )

Function returning the number of data accumulated.

Definition at line 72 of file stat.f90.

```
72      INTEGER :: iter
73      iter=i
```

8.21.2.4 real(kind=8) function, dimension(0:ndim), public stat::mean ( )

Function returning the mean.

Definition at line 60 of file stat.f90.

```
60      REAL(KIND=8), DIMENSION(0:ndim) :: mean
61      mean=m
```

8.21.2.5 subroutine, public stat::reset ( )

Routine resetting the accumulators.

Definition at line 78 of file stat.f90.

```
78      m=0.d0
79      mprev=0.d0
80      v=0.d0
81      i=0
```

8.21.2.6 real(kind=8) function, dimension(0:ndim), public stat::var ( )

Function returning the variance.

Definition at line 66 of file stat.f90.

```
66      REAL(KIND=8), DIMENSION(0:ndim) :: var
67      var=v/(i-1)
```

8.21.3 Variable Documentation

8.21.3.1 integer stat::i =0 [private]

Number of stats accumulated.

Definition at line 20 of file stat.f90.

```
20   INTEGER :: i=0 !< Number of stats accumulated
```

8.21.3.2 real(kind=8), dimension(:), allocatable stat::m [private]

Vector storing the inline mean.

Definition at line 23 of file stat.f90.

```
23   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: m       !< Vector storing the inline mean
```

8.21.3.3 real(kind=8), dimension(:), allocatable stat::mprev [private]

Previous mean vector.

Definition at line 24 of file stat.f90.

```
24   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: mprev   !< Previous mean vector
```

8.21.3.4 real(kind=8), dimension(:), allocatable stat::mtmp [private]

Definition at line 26 of file stat.f90.

```
26   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: mtmp
```

8.21.3.5 real(kind=8), dimension(:), allocatable stat::v [private]

Vector storing the inline variance.

Definition at line 25 of file stat.f90.

```
25   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: v       !< Vector storing the inline variance
```

8.22 stoch_mod Module Reference

Utility module containing the stochastic related routines.

Functions/Subroutines

- real(kind=8) function, public gasdev ()
- subroutine, public stoch_vec (dW)

  Routine to fill a vector with standard Gaussian noise process values.
- subroutine, public stoch_atm_vec (dW)

  routine to fill the atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_atm_res_vec (dW)

  routine to fill the resolved atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_atm_unres_vec (dW)

  routine to fill the unresolved atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_oc_vec (dW)

  routine to fill the oceanic component of a vector with standard gaussian noise process values
- subroutine, public stoch_oc_res_vec (dW)

  routine to fill the resolved oceanic component of a vector with standard gaussian noise process values
- subroutine, public stoch_oc_unres_vec (dW)

  routine to fill the unresolved oceanic component of a vector with standard gaussian noise process values

Variables

- integer iset =0
- real(kind=8) gset

8.22.1 Detailed Description

Utility module containing the stochastic related routines.

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Remarks

8.22.2 Function/Subroutine Documentation

8.22.2.1 real(kind=8) function, public stoch_mod::gasdev ( )

Definition at line 32 of file stoch_mod.f90.

```
32      REAL(KIND=8) :: gasdev
33      REAL(KIND=8) :: fac,rsq,v1,v2,r
34      IF (iset.eq.0) THEN
35         DO
36            CALL random_number(r)
37            v1=2.d0*r-1.
38            CALL random_number(r)
39            v2=2.d0*r-1.
40            rsq=v1**2+v2**2
41            IF (rsq.lt.1.d0.and.rsq.ne.0.d0) EXIT
42         ENDDO
43         fac=sqrt(-2.*log(rsq)/rsq)
44         gset=v1*fac
45         gasdev=v2*fac
46         iset=1
47      ELSE
48         gasdev=gset
49         iset=0
50      ENDIF
51      RETURN
```

8.22.2.2 subroutine, public stoch_mod::stoch_atm_res_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the resolved atmospheric component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 77 of file stoch_mod.f90.

```
77      real(kind=8), dimension(0:ndim), intent(inout) :: dw
78      integer :: i
79      dw=0.d0
80      do i=1,2*natm
81         IF (sf(i)==0) dw(i)=gasdev()
82      enddo
```

8.22.2.3 subroutine, public stoch_mod::stoch_atm_unres_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the unresolved atmospheric component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 88 of file stoch_mod.f90.

```
88      real(kind=8), dimension(0:ndim), intent(inout) :: dw
89      integer :: i
90      dw=0.d0
91      do i=1,2*natm
92         IF (sf(i)==1) dw(i)=gasdev()
93      enddo
```

8.22.2.4 subroutine, public stoch_mod::stoch_atm_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the atmospheric component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 67 of file stoch_mod.f90.

```
67      real(kind=8), dimension(0:ndim), intent(inout) :: dw
68      integer :: i
69      do i=1,2*natm
70         dw(i)=gasdev()
71      enddo
```

8.22.2.5 subroutine, public stoch_mod::stoch_oc_res_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the resolved oceanic component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 109 of file stoch_mod.f90.

```
109     real(kind=8), dimension(0:ndim), intent(inout) :: dw
110     integer :: i
111     dw=0.d0
112     do i=2*natm+1,ndim
113        IF (sf(i)==0) dw(i)=gasdev()
114     enddo
```

8.22.2.6 subroutine, public stoch_mod::stoch_oc_unres_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the unresolved oceanic component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 120 of file stoch_mod.f90.

```
120     real(kind=8), dimension(0:ndim), intent(inout) :: dw
121     integer :: i
122     dw=0.d0
123     do i=2*natm+1,ndim
124        IF (sf(i)==1) dw(i)=gasdev()
125     enddo
```

8.22.2.7 subroutine, public stoch_mod::stoch_oc_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

routine to fill the oceanic component of a vector with standard gaussian noise process values

Parameters

dW	vector to fill

Definition at line 99 of file stoch_mod.f90.

```
99     real(kind=8), dimension(0:ndim), intent(inout) :: dw
100     integer :: i
101     do i=2*natm+1,ndim
102        dw(i)=gasdev()
103     enddo
```

8.22.2.8 subroutine, public stoch_mod::stoch_vec (real(kind=8), dimension(0:ndim), intent(inout) *dW*)

Routine to fill a vector with standard Gaussian noise process values.

Parameters

dW	Vector to fill

Definition at line 57 of file stoch_mod.f90.

```
REAL(KIND=8), DIMENSION(0:ndim), INTENT(INOUT) :: dw
INTEGER :: i
DO i=1,ndim
   dw(i)=gasdev()
ENDDO
```

8.22.3 Variable Documentation

8.22.3.1 real(kind=8) stoch_mod::gset [private]

Definition at line 24 of file stoch_mod.f90.

```
REAL(KIND=8) :: gset
```

8.22.3.2 integer stoch_mod::iset =0 [private]

Definition at line 23 of file stoch_mod.f90.

```
INTEGER :: iset=0
```

8.23 stoch_params Module Reference

The stochastic models parameters module.

Functions/Subroutines

- subroutine init_stoch_params

  Stochastic parameters initialization routine.

Variables

- real(kind=8) mnuti

    Multiplicative noise update time interval.
- real(kind=8) t_trans_stoch

    Transient time period of the stochastic model evolution.
- real(kind=8) q_ar

    Atmospheric resolved component noise amplitude.
- real(kind=8) q_au

    Atmospheric unresolved component noise amplitude.
- real(kind=8) q_or

    Oceanic resolved component noise amplitude.
- real(kind=8) q_ou

    Oceanic unresolved component noise amplitude.
- real(kind=8) dtn

    Square root of the timestep.
- real(kind=8) eps_pert

    Perturbation parameter for the coupling.
- real(kind=8) tdelta

    Time separation parameter.
- real(kind=8) muti

    Memory update time interval.
- real(kind=8) meml

    Time over which the memory kernel is integrated.
- real(kind=8) t_trans_mem

    Transient time period to initialize the memory term.
- character(len=4) x_int_mode

    Integration mode for the resolved component.
- real(kind=8) dts

    Intrisic resolved dynamics time step.
- integer mems

    Number of steps in the memory kernel integral.
- real(kind=8) dtsn

    Square root of the intrisic resolved dynamics time step.
- real(kind=8) maxint

    Upper integration limit of the correlations.
- character(len=4) load_mode

    Loading mode for the correlations.
- character(len=4) int_corr_mode

    Correlation integration mode.
- character(len=4) mode

    Stochastic mode parameter.

8.23.1 Detailed Description

The stochastic models parameters module.

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Remarks

8.23.2 Function/Subroutine Documentation

8.23.2.1 subroutine stoch_params::init_stoch_params ( )

Stochastic parameters initialization routine.

Definition at line 58 of file stoch_params.f90.

```
58
59     namelist /mtvparams/ mnuti
60     namelist /stparams/ q_ar,q_au,q_or,q_ou,eps_pert,tdelta,t_trans_stoch
61     namelist /wlparams/ muti,meml,x_int_mode,dts,t_trans_mem
62     namelist /corr_init_mode/ load_mode,int_corr_mode,maxint
63     namelist /stoch_int_params/ mode
64
65
66     OPEN(8, file="stoch_params.nml", status='OLD', recl=80, delim='APOSTROPHE')
67     READ(8,nml=mtvparams)
68     READ(8,nml=wlparams)
69     READ(8,nml=stparams)
70     READ(8,nml=stoch_int_params)
71     READ(8,nml=corr_init_mode)
72     CLOSE(8)
73
74     dtn=sqrt(dt)
75     dtsn=sqrt(dts)
76     mems=ceiling(meml/muti)
77
78     q_au=q_au/tdelta
79     q_ou=q_ou/tdelta
80
```

8.23.3 Variable Documentation

8.23.3.1 real(kind=8) stoch_params::dtn

Square root of the timestep.

Definition at line 32 of file stoch_params.f90.

```
32   REAL(KIND=8) :: dtn                !< Square root of the timestep
```

8.23.3.2 real(kind=8) stoch_params::dts

Intrisic resolved dynamics time step.

Definition at line 40 of file stoch_params.f90.

```
40   REAL(KIND=8) :: dts                !< Intrisic resolved dynamics time step
```

8.23.3.3 real(kind=8) stoch_params::dtsn

Square root of the intrisic resolved dynamics time step.

Definition at line 43 of file stoch_params.f90.

```
43   REAL(KIND=8) :: dtsn               !< Square root of the intrisic resolved dynamics time step
```

8.23.3.4 real(kind=8) stoch_params::eps_pert

Perturbation parameter for the coupling.

Definition at line 33 of file stoch_params.f90.

```
33 REAL(KIND=8) :: eps_pert           !< Perturbation parameter for the coupling
```

8.23.3.5 character(len=4) stoch_params::int_corr_mode

Correlation integration mode.

Definition at line 47 of file stoch_params.f90.

```
47 CHARACTER(LEN=4) :: int_corr_mode  !< Correlation integration mode
```

8.23.3.6 character(len=4) stoch_params::load_mode

Loading mode for the correlations.

Definition at line 46 of file stoch_params.f90.

```
46 CHARACTER(LEN=4) :: load_mode      !< Loading mode for the correlations
```

8.23.3.7 real(kind=8) stoch_params::maxint

Upper integration limit of the correlations.

Definition at line 45 of file stoch_params.f90.

```
45 REAL(KIND=8) :: maxint             !< Upper integration limit of the correlations
```

8.23.3.8 real(kind=8) stoch_params::meml

Time over which the memory kernel is integrated.

Definition at line 37 of file stoch_params.f90.

```
37 REAL(KIND=8) :: meml               !< Time over which the memory kernel is integrated
```

8.23.3.9 integer stoch_params::mems

Number of steps in the memory kernel integral.

Definition at line 42 of file stoch_params.f90.

```
42 INTEGER :: mems                    !< Number of steps in the memory kernel integral
```

8.23.3.10 real(kind=8) stoch_params::mnuti

Multiplicative noise update time interval.

Definition at line 25 of file stoch_params.f90.

```
25 REAL(KIND=8) :: mnuti              !< Multiplicative noise update time interval
```

8.23.3.11 character(len=4) stoch_params::mode

Stochastic mode parameter.

Definition at line 49 of file stoch_params.f90.

```
49 CHARACTER(len=4) :: mode           !< Stochastic mode parameter
```

8.23.3.12 real(kind=8) stoch_params::muti

Memory update time interval.

Definition at line 36 of file stoch_params.f90.

```
36 REAL(KIND=8) :: muti                !< Memory update time interval
```

8.23.3.13 real(kind=8) stoch_params::q_ar

Atmospheric resolved component noise amplitude.

Definition at line 28 of file stoch_params.f90.

```
28 REAL(KIND=8) :: q_ar               !< Atmospheric resolved component noise amplitude
```

8.23.3.14 real(kind=8) stoch_params::q_au

Atmospheric unresolved component noise amplitude.

Definition at line 29 of file stoch_params.f90.

```
29    REAL(KIND=8) :: q_au               !< Atmospheric unresolved component noise amplitude
```

8.23.3.15 real(kind=8) stoch_params::q_or

Oceanic resolved component noise amplitude.

Definition at line 30 of file stoch_params.f90.

```
30    REAL(KIND=8) :: q_or               !< Oceanic resolved component noise amplitude
```

8.23.3.16 real(kind=8) stoch_params::q_ou

Oceanic unresolved component noise amplitude.

Definition at line 31 of file stoch_params.f90.

```
31    REAL(KIND=8) :: q_ou               !< Oceanic unresolved component noise amplitude
```

8.23.3.17 real(kind=8) stoch_params::t_trans_mem

Transient time period to initialize the memory term.

Definition at line 38 of file stoch_params.f90.

```
38    REAL(KIND=8) :: t_trans_mem        !< Transient time period to initialize the memory term
```

8.23.3.18 real(kind=8) stoch_params::t_trans_stoch

Transient time period of the stochastic model evolution.

Definition at line 27 of file stoch_params.f90.

```
27    REAL(KIND=8) :: t_trans_stoch      !< Transient time period of the stochastic model evolution
```

8.23.3.19 real(kind=8) stoch_params::tdelta

Time separation parameter.

Definition at line 34 of file stoch_params.f90.

```
34    REAL(KIND=8) :: tdelta             !< Time separation parameter
```

8.23.3.20 character(len=4) stoch_params::x_int_mode

Integration mode for the resolved component.

Definition at line 39 of file stoch_params.f90.

```
39    CHARACTER(len=4) :: x_int_mode     !< Integration mode for the resolved component
```

8.24 tensor Module Reference

Tensor utility module.

Data Types

- type coolist

    Coordinate list. Type used to represent the sparse tensor.
- type coolist4

    4d coordinate list. Type used to represent the rank-4 sparse tensor.
- type coolist_elem

    Coordinate list element type. Elementary elements of the sparse tensors.
- type coolist_elem4

    4d coordinate list element type. Elementary elements of the 4d sparse tensors.

Functions/Subroutines

- subroutine, public copy_coo (src, dst)

    Routine to copy a coolist.
- subroutine, public mat_to_coo (src, dst)

    Routine to convert a matrix to a tensor.
- subroutine, public sparse_mul3 (coolist_ijk, arr_j, arr_k, res)

    Sparse multiplication of a tensor with two vectors: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j\, b_k$.
- subroutine, public jsparse_mul (coolist_ijk, arr_j, jcoo_ij)

Sparse multiplication of two tensors to determine the Jacobian:

$$J_{i,j} = \sum_{k=0}^{ndim} (\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j})\, a_k.$$

It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$, we add to $J_{i,j}$ as follows:

$$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k}\, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k}\, a_j$$

This version return a coolist (sparse tensor).

- subroutine, public jsparse_mul_mat (coolist_ijk, arr_j, jcoo_ij)

  Sparse multiplication of two tensors to determine the Jacobian:

  $$J_{i,j} = \sum_{k=0}^{ndim} (\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j})\, a_k.$$

  It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$, we add to $J_{i,j}$ as follows:

  $$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k}\, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k}\, a_j$$

  This version return a matrix.
- subroutine, public sparse_mul2 (coolist_ij, arr_j, res)

  Sparse multiplication of a 2d sparse tensor with a vector: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j.$
- subroutine, public simplify (tensor)

  Routine to simplify a coolist (sparse tensor). For each index i, it upper triangularize the matrix

  $$\mathcal{T}_{i,j,k} \qquad 0 \leq j,k \leq ndim.$$

  .
- subroutine, public add_elem (t, i, j, k, v)

  Subroutine to add element to a coolist.
- subroutine, public add_check (t, i, j, k, v, dst)

  Subroutine to add element to a coolist and check for overflow. Once the t buffer tensor is full, add it to the destination buffer.
- subroutine, public add_to_tensor (src, dst)

  Routine to add a rank-3 tensor to another one.
- subroutine, public print_tensor (t, s)

  Routine to print a rank 3 tensor coolist.
- subroutine, public write_tensor_to_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public load_tensor_from_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public add_matc_to_tensor (i, src, dst)

  Routine to add a matrix to a rank-3 tensor.
- subroutine, public add_matc_to_tensor4 (i, j, src, dst)

  Routine to add a matrix to a rank-4 tensor.
- subroutine, public add_vec_jk_to_tensor (j, k, src, dst)

  Routine to add a vector to a rank-3 tensor.
- subroutine, public add_vec_ikl_to_tensor4_perm (i, k, l, src, dst)

  Routine to add a vector to a rank-4 tensor plus permutation.
- subroutine, public add_vec_ikl_to_tensor4 (i, k, l, src, dst)

  Routine to add a vector to a rank-4 tensor.
- subroutine, public add_vec_ijk_to_tensor4 (i, j, k, src, dst)

  Routine to add a vector to a rank-4 tensor.
- subroutine, public tensor_to_coo (src, dst)

  Routine to convert a rank-3 tensor from matrix to coolist representation.

- subroutine, public tensor4_to_coo4 (src, dst)

  Routine to convert a rank-4 tensor from matrix to coolist representation.
- subroutine, public print_tensor4 (t)

  Routine to print a rank-4 tensor coolist.
- subroutine, public sparse_mul3_mat (coolist_ijk, arr_k, res)

  Sparse multiplication of a rank-3 tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}\, b_k$. *Its output is a matrix.*
- subroutine, public sparse_mul4 (coolist_ijkl, arr_j, arr_k, arr_l, res)

  Sparse multiplication of a rank-4 tensor coolist with three vectors: $\sum_{j,k,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, a_j\, b_k\, c_l$.
- subroutine, public sparse_mul4_mat (coolist_ijkl, arr_k, arr_l, res)

  Sparse multiplication of a tensor with two vectors: $\sum_{k,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, b_k\, c_l$.
- subroutine, public sparse_mul2_j (coolist_ijk, arr_j, res)

  Sparse multiplication of a 3d sparse tensor with a vectors: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j$.
- subroutine, public sparse_mul2_k (coolist_ijk, arr_k, res)

  Sparse multiplication of a rank-3 sparse tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}\, a_k$.
- subroutine, public coo_to_mat_ik (src, dst)

  Routine to convert a rank-3 tensor coolist component into a matrix with i and k indices.
- subroutine, public coo_to_mat_ij (src, dst)

  Routine to convert a rank-3 tensor coolist component into a matrix with i and j indices.
- subroutine, public coo_to_mat_i (i, src, dst)

  Routine to convert a rank-3 tensor coolist component into a matrix.
- subroutine, public coo_to_vec_jk (j, k, src, dst)

  Routine to convert a rank-3 tensor coolist component into a vector.
- subroutine, public coo_to_mat_j (j, src, dst)

  Routine to convert a rank-3 tensor coolist component into a matrix.
- subroutine, public sparse_mul4_with_mat_jl (coolist_ijkl, mat_jl, res)

  Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, m_{j,l}$.
- subroutine, public sparse_mul4_with_mat_kl (coolist_ijkl, mat_kl, res)

  Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, m_{k,l}$.
- subroutine, public sparse_mul3_with_mat (coolist_ijk, mat_jk, res)

  Sparse multiplication of a rank-3 tensor coolist with a matrix: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, m_{j,k}$.
- subroutine, public matc_to_coo (src, dst)

  Routine to convert a matrix to a rank-3 tensor.
- subroutine, public scal_mul_coo (s, t)

  Routine to multiply a rank-3 tensor by a scalar.
- logical function, public tensor_empty (t)

  Test if a rank-3 tensor coolist is empty.
- logical function, public tensor4_empty (t)

  Test if a rank-4 tensor coolist is empty.
- subroutine, public load_tensor4_from_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public write_tensor4_to_file (s, t)

  Load a rank-4 tensor coolist from a file definition.

Variables

- real(kind=8), parameter real_eps = 2.2204460492503131e-16
  Parameter to test the equality with zero.

8.24.1 Detailed Description

Tensor utility module.

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Remarks

coolist is a type and also means "coordinate list"

8.24.2 Function/Subroutine Documentation

8.24.2.1 subroutine, public tensor::add_check (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*, type(coolist), dimension(ndim), intent(inout) *dst*)

Subroutine to add element to a coolist and check for overflow. Once the t buffer tensor is full, add it to the destination buffer.

Parameters

t	temporary buffer tensor for the destination tensor
i	tensor i index
j	tensor j index
k	tensor k index
v	value to add
dst	destination tensor

Definition at line 332 of file tensor.f90.

```
332     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
333     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: dst
334     INTEGER, INTENT(IN) :: i,j,k
335     REAL(KIND=8), INTENT(IN) :: v
336     INTEGER :: n
337     CALL add_elem(t,i,j,k,v)
338     IF (t(i)%nelems==size(t(i)%elems)) THEN
339        CALL add_to_tensor(t,dst)
340        DO n=1,ndim
341           t(n)%nelems=0
342        ENDDO
343     ENDIF
```

8.24.2.2 subroutine, public tensor::add_elem (type(coolist), dimension(ndim), intent(inout) *t*, integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*)

Subroutine to add element to a coolist.

Parameters

t	destination tensor
i	tensor i index
j	tensor j index
k	tensor k index
v	value to add

Definition at line 310 of file tensor.f90.

```
TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
INTEGER, INTENT(IN) :: i,j,k
REAL(KIND=8), INTENT(IN) :: v
INTEGER :: n
IF (abs(v) .ge. real_eps) THEN
   n=(t(i)%nelems)+1
   t(i)%elems(n)%j=j
   t(i)%elems(n)%k=k
   t(i)%elems(n)%v=v
   t(i)%nelems=n
END IF
```

8.24.2.3 subroutine, public tensor::add_matc_to_tensor (integer, intent(in) *i*, real(kind=8), dimension(ndim,ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(inout) *dst*)

Routine to add a matrix to a rank-3 tensor.

Parameters

i	Add to tensor component i
src	Matrix to add
dst	Destination tensor

Definition at line 474 of file tensor.f90.

```
INTEGER, INTENT(IN) :: i
REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN) :: src
TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: dst
TYPE(coolist_elem), DIMENSION(:), ALLOCATABLE :: celems
INTEGER :: j,k,r,n,nsrc,allocstat

nsrc=0
DO j=1,ndim
   DO k=1,ndim
      IF (abs(src(j,k))>real_eps) nsrc=nsrc+1
   END DO
END DO

IF (dst(i)%nelems==0) THEN
   IF (ALLOCATED(dst(i)%elems)) THEN
      DEALLOCATE(dst(i)%elems, stat=allocstat)
      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
   ENDIF
   ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"
   n=0
ELSE
   n=dst(i)%nelems
   ALLOCATE(celems(n), stat=allocstat)
   DO j=1,n
      celems(j)%j=dst(i)%elems(j)%j
      celems(j)%k=dst(i)%elems(j)%k
      celems(j)%v=dst(i)%elems(j)%v
   ENDDO
```

```
      DEALLOCATE(dst(i)%elems, stat=allocstat)
      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
      ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
      DO j=1,n
         dst(i)%elems(j)%j=celems(j)%j
         dst(i)%elems(j)%k=celems(j)%k
         dst(i)%elems(j)%v=celems(j)%v
      ENDDO
      DEALLOCATE(celems, stat=allocstat)
      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
   ENDIF
   r=0
   DO j=1,ndim
      DO k=1,ndim
         IF (abs(src(j,k))>real_eps) THEN
            r=r+1
            dst(i)%elems(n+r)%j=j
            dst(i)%elems(n+r)%k=k
            dst(i)%elems(n+r)%v=src(j,k)
         ENDIF
      ENDDO
   END DO
   dst(i)%nelems=nsrc+n

```

8.24.2.4 subroutine, public tensor::add_matc_to_tensor4 (integer, intent(in) *i*, integer, intent(in) *j*, real(kind=8), dimension(ndim,ndim), intent(in) *src*, type(coolist4), dimension(ndim), intent(inout) *dst*)

Routine to add a matrix to a rank-4 tensor.

Parameters

i	Add to tensor component i,j
j	Add to tensor component i,j
src	Matrix to add
dst	Destination tensor

Definition at line 537 of file tensor.f90.

```
   INTEGER, INTENT(IN) :: i,j
   REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN) :: src
   TYPE(coolist4), DIMENSION(ndim), INTENT(INOUT) :: dst
   TYPE(coolist_elem4), DIMENSION(:), ALLOCATABLE :: celems
   INTEGER :: k,l,r,n,nsrc,allocstat

   nsrc=0
   DO k=1,ndim
      DO l=1,ndim
         IF (abs(src(k,l))>real_eps) nsrc=nsrc+1
      END DO
   END DO

   IF (dst(i)%nelems==0) THEN
      IF (ALLOCATED(dst(i)%elems)) THEN
         DEALLOCATE(dst(i)%elems, stat=allocstat)
         IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
      ENDIF
      ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
      n=0
   ELSE
      n=dst(i)%nelems
      ALLOCATE(celems(n), stat=allocstat)
      DO k=1,n
         celems(k)%j=dst(i)%elems(k)%j
         celems(k)%k=dst(i)%elems(k)%k
         celems(k)%l=dst(i)%elems(k)%l
         celems(k)%v=dst(i)%elems(k)%v
      ENDDO
      DEALLOCATE(dst(i)%elems, stat=allocstat)
      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
```

```
      ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
      DO k=1,n
         dst(i)%elems(k)%j=celems(k)%j
         dst(i)%elems(k)%k=celems(k)%k
         dst(i)%elems(k)%l=celems(k)%l
         dst(i)%elems(k)%v=celems(k)%v
      ENDDO
      DEALLOCATE(celems, stat=allocstat)
      IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
   ENDIF
   r=0
   DO k=1,ndim
      DO l=1,ndim
         IF (abs(src(k,l))>real_eps) THEN
            r=r+1
            dst(i)%elems(n+r)%j=j
            dst(i)%elems(n+r)%k=k
            dst(i)%elems(n+r)%l=l
            dst(i)%elems(n+r)%v=src(k,l)
         ENDIF
      ENDDO
   END DO
   dst(i)%nelems=nsrc+n

```

8.24.2.5 subroutine, public tensor::add_to_tensor (type(coolist), dimension(ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(inout) *dst*)

Routine to add a rank-3 tensor to another one.

Parameters

src	Tensor to add
dst	Destination tensor

Definition at line 350 of file tensor.f90.

```
   TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
   TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: dst
   TYPE(coolist_elem), DIMENSION(:), ALLOCATABLE :: celems
   INTEGER :: i,j,n,allocstat

   DO i=1,ndim
      IF (src(i)%nelems/=0) THEN
         IF (dst(i)%nelems==0) THEN
            IF (ALLOCATED(dst(i)%elems)) THEN
               DEALLOCATE(dst(i)%elems, stat=allocstat)
               IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
            ENDIF
            ALLOCATE(dst(i)%elems(src(i)%nelems), stat=allocstat)
            IF (allocstat /= 0) stop "*** Not enough memory ! ***"
            n=0
         ELSE
            n=dst(i)%nelems
            ALLOCATE(celems(n), stat=allocstat)
            DO j=1,n
               celems(j)%j=dst(i)%elems(j)%j
               celems(j)%k=dst(i)%elems(j)%k
               celems(j)%v=dst(i)%elems(j)%v
            ENDDO
            DEALLOCATE(dst(i)%elems, stat=allocstat)
            IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
            ALLOCATE(dst(i)%elems(src(i)%nelems+n), stat=allocstat)
            IF (allocstat /= 0) stop "*** Not enough memory ! ***"
            DO j=1,n
               dst(i)%elems(j)%j=celems(j)%j
               dst(i)%elems(j)%k=celems(j)%k
               dst(i)%elems(j)%v=celems(j)%v
            ENDDO
            DEALLOCATE(celems, stat=allocstat)
            IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
         ENDIF
         DO j=1,src(i)%nelems
```

```
            dst(i)%elems(n+j)%j=src(i)%elems(j)%j
            dst(i)%elems(n+j)%k=src(i)%elems(j)%k
            dst(i)%elems(n+j)%v=src(i)%elems(j)%v
         ENDDO
         dst(i)%nelems=src(i)%nelems+n
      ENDIF
   ENDDO

```

8.24.2.6 subroutine, public tensor::add_vec_ijk_to_tensor4 (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), dimension(ndim), intent(in) *src*, type(coolist4), dimension(ndim), intent(inout) *dst*)

Routine to add a vector to a rank-4 tensor.

Parameters

i,j,k	Add to tensor component i,j and k
src	Vector to add
dst	Destination tensor

Definition at line 785 of file tensor.f90.

```
785    INTEGER, INTENT(IN) :: i,j,k
786    REAL(KIND=8), DIMENSION(ndim), INTENT(IN) :: src
787    TYPE(coolist4), DIMENSION(ndim), INTENT(INOUT) :: dst
788    TYPE(coolist_elem4), DIMENSION(:), ALLOCATABLE :: celems
789    INTEGER :: l,ne,r,n,nsrc,allocstat
790
791    nsrc=0
792    DO l=1,ndim
793       IF (abs(src(l))>real_eps) nsrc=nsrc+1
794    ENDDO
795
796    IF (dst(i)%nelems==0) THEN
797       IF (ALLOCATED(dst(i)%elems)) THEN
798          DEALLOCATE(dst(i)%elems, stat=allocstat)
799          IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
800       ENDIF
801       ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
802       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
803       n=0
804    ELSE
805       n=dst(i)%nelems
806       ALLOCATE(celems(n), stat=allocstat)
807       DO ne=1,n
808          celems(ne)%j=dst(i)%elems(ne)%j
809          celems(ne)%k=dst(i)%elems(ne)%k
810          celems(ne)%l=dst(i)%elems(ne)%l
811          celems(ne)%v=dst(i)%elems(ne)%v
812       ENDDO
813       DEALLOCATE(dst(i)%elems, stat=allocstat)
814       IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
815       ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
816       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
817       DO ne=1,n
818          dst(i)%elems(ne)%j=celems(ne)%j
819          dst(i)%elems(ne)%k=celems(ne)%k
820          dst(i)%elems(ne)%l=celems(ne)%l
821          dst(i)%elems(ne)%v=celems(ne)%v
822       ENDDO
823       DEALLOCATE(celems, stat=allocstat)
824       IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
825    ENDIF
826    r=0
827    DO l=1,ndim
828       IF (abs(src(l))>real_eps) THEN
829          r=r+1
830          dst(i)%elems(n+r)%j=j
831          dst(i)%elems(n+r)%k=k
832          dst(i)%elems(n+r)%l=l
833          dst(i)%elems(n+r)%v=src(l)
834       ENDIF
835    ENDDO
836    dst(i)%nelems=nsrc+n
```

8.24.2.7 subroutine, public tensor::add_vec_ikl_to_tensor4 (integer, intent(in) *i*, integer, intent(in) *k*, integer, intent(in) *l*, real(kind=8), dimension(ndim), intent(in) *src*, type(coolist4), dimension(ndim), intent(inout) *dst*)

Routine to add a vector to a rank-4 tensor.

Parameters

i,k,l	Add to tensor component i,k and l
src	Vector to add
dst	Destination tensor

Definition at line 726 of file tensor.f90.

```
726     INTEGER, INTENT(IN) :: i,k,l
727     REAL(KIND=8), DIMENSION(ndim), INTENT(IN) :: src
728     TYPE(coolist4), DIMENSION(ndim), INTENT(INOUT) :: dst
729     TYPE(coolist_elem4), DIMENSION(:), ALLOCATABLE :: celems
730     INTEGER :: j,ne,r,n,nsrc,allocstat
731
732     nsrc=0
733     DO j=1,ndim
734        IF (abs(src(j))>real_eps) nsrc=nsrc+1
735     ENDDO
736
737     IF (dst(i)%nelems==0) THEN
738        IF (ALLOCATED(dst(i)%elems)) THEN
739           DEALLOCATE(dst(i)%elems, stat=allocstat)
740           IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
741        ENDIF
742        ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
743        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
744        n=0
745     ELSE
746        n=dst(i)%nelems
747        ALLOCATE(celems(n), stat=allocstat)
748        DO ne=1,n
749           celems(ne)%j=dst(i)%elems(ne)%j
750           celems(ne)%k=dst(i)%elems(ne)%k
751           celems(ne)%l=dst(i)%elems(ne)%l
752           celems(ne)%v=dst(i)%elems(ne)%v
753        ENDDO
754        DEALLOCATE(dst(i)%elems, stat=allocstat)
755        IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
756        ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
757        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
758        DO ne=1,n
759           dst(i)%elems(ne)%j=celems(ne)%j
760           dst(i)%elems(ne)%k=celems(ne)%k
761           dst(i)%elems(ne)%l=celems(ne)%l
762           dst(i)%elems(ne)%v=celems(ne)%v
763        ENDDO
764        DEALLOCATE(celems, stat=allocstat)
765        IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
766     ENDIF
767     r=0
768     DO j=1,ndim
769        IF (abs(src(j))>real_eps) THEN
770           r=r+1
771           dst(i)%elems(n+r)%j=j
772           dst(i)%elems(n+r)%k=k
773           dst(i)%elems(n+r)%l=l
774           dst(i)%elems(n+r)%v=src(j)
775        ENDIF
776     ENDDO
777     dst(i)%nelems=nsrc+n
```

8.24.2.8 subroutine, public tensor::add_vec_ikl_to_tensor4_perm (integer, intent(in) *i*, integer, intent(in) *k*, integer, intent(in) *l*, real(kind=8), dimension(ndim), intent(in) *src*, type(coolist4), dimension(ndim), intent(inout) *dst*)

Routine to add a vector to a rank-4 tensor plus permutation.

Parameters

i,k,l	Add to tensor component i,k and l
src	Vector to add
dst	Destination tensor

Definition at line 657 of file tensor.f90.

```
657     INTEGER, INTENT(IN) :: i,k,l
658     REAL(KIND=8), DIMENSION(ndim), INTENT(IN) :: src
659     TYPE(coolist4), DIMENSION(ndim), INTENT(INOUT) :: dst
660     TYPE(coolist_elem4), DIMENSION(:), ALLOCATABLE :: celems
661     INTEGER :: j,ne,r,n,nsrc,allocstat
662 
663     nsrc=0
664     DO j=1,ndim
665        IF (abs(src(j))>real_eps) nsrc=nsrc+1
666     ENDDO
667     nsrc=nsrc*3
668     IF (dst(i)%nelems==0) THEN
669        IF (ALLOCATED(dst(i)%elems)) THEN
670           DEALLOCATE(dst(i)%elems, stat=allocstat)
671           IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
672        ENDIF
673        ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
674        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
675        n=0
676     ELSE
677        n=dst(i)%nelems
678        ALLOCATE(celems(n), stat=allocstat)
679        DO ne=1,n
680           celems(ne)%j=dst(i)%elems(ne)%j
681           celems(ne)%k=dst(i)%elems(ne)%k
682           celems(ne)%l=dst(i)%elems(ne)%l
683           celems(ne)%v=dst(i)%elems(ne)%v
684        ENDDO
685        DEALLOCATE(dst(i)%elems, stat=allocstat)
686        IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
687        ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
688        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
689        DO ne=1,n
690           dst(i)%elems(ne)%j=celems(ne)%j
691           dst(i)%elems(ne)%k=celems(ne)%k
692           dst(i)%elems(ne)%l=celems(ne)%l
693           dst(i)%elems(ne)%v=celems(ne)%v
694        ENDDO
695        DEALLOCATE(celems, stat=allocstat)
696        IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
697     ENDIF
698     r=0
699     DO j=1,ndim
700        IF (abs(src(j))>real_eps) THEN
701           r=r+1
702           dst(i)%elems(n+r)%j=j
703           dst(i)%elems(n+r)%k=k
704           dst(i)%elems(n+r)%l=l
705           dst(i)%elems(n+r)%v=src(j)
706           r=r+1
707           dst(i)%elems(n+r)%j=k
708           dst(i)%elems(n+r)%k=l
709           dst(i)%elems(n+r)%l=j
710           dst(i)%elems(n+r)%v=src(j)
711           r=r+1
712           dst(i)%elems(n+r)%j=l
713           dst(i)%elems(n+r)%k=j
714           dst(i)%elems(n+r)%l=k
715           dst(i)%elems(n+r)%v=src(j)
716        ENDIF
717     ENDDO
718     dst(i)%nelems=nsrc+n
```

8.24.2.9 subroutine, public tensor::add_vec_jk_to_tensor (integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), dimension(ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(inout) *dst*)

Routine to add a vector to a rank-3 tensor.

Parameters

j,k	Add to tensor component j and k
src	Vector to add
dst	Destination tensor

Definition at line 602 of file tensor.f90.

```
602     INTEGER, INTENT(IN) :: j,k
603     REAL(KIND=8), DIMENSION(ndim), INTENT(IN) :: src
604     TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: dst
605     TYPE(coolist_elem), DIMENSION(:), ALLOCATABLE :: celems
606     INTEGER :: i,l,r,n,nsrc,allocstat
607
608     DO i=1,ndim
609        nsrc=0
610        IF (abs(src(i))>real_eps) nsrc=1
611        IF (dst(i)%nelems==0) THEN
612           IF (ALLOCATED(dst(i)%elems)) THEN
613              DEALLOCATE(dst(i)%elems, stat=allocstat)
614              IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
615           ENDIF
616           ALLOCATE(dst(i)%elems(nsrc), stat=allocstat)
617           IF (allocstat /= 0) stop "*** Not enough memory ! ***"
618           n=0
619        ELSE
620           n=dst(i)%nelems
621           ALLOCATE(celems(n), stat=allocstat)
622           DO l=1,n
623              celems(l)%j=dst(i)%elems(l)%j
624              celems(l)%k=dst(i)%elems(l)%k
625              celems(l)%v=dst(i)%elems(l)%v
626           ENDDO
627           DEALLOCATE(dst(i)%elems, stat=allocstat)
628           IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
629           ALLOCATE(dst(i)%elems(nsrc+n), stat=allocstat)
630           IF (allocstat /= 0) stop "*** Not enough memory ! ***"
631           DO l=1,n
632              dst(i)%elems(l)%j=celems(l)%j
633              dst(i)%elems(l)%k=celems(l)%k
634              dst(i)%elems(l)%v=celems(l)%v
635           ENDDO
636           DEALLOCATE(celems, stat=allocstat)
637           IF (allocstat /= 0) stop "*** Deallocation problem ! ***"
638        ENDIF
639        r=0
640        IF (abs(src(i))>real_eps) THEN
641           r=r+1
642           dst(i)%elems(n+r)%j=j
643           dst(i)%elems(n+r)%k=k
644           dst(i)%elems(n+r)%v=src(i)
645        ENDIF
646        dst(i)%nelems=nsrc+n
647     END DO
648
649
```

8.24.2.10 subroutine, public tensor::coo_to_mat_i (integer, intent(in) *i*, type(coolist), dimension(ndim), intent(in) *src*, real(kind=8), dimension(ndim,ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor coolist component into a matrix.

Parameters

i	Component to convert
src	Source tensor
dst	Destination matrix

Definition at line 1112 of file tensor.f90.

```
1112    INTEGER, INTENT(IN) :: i
1113    TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
1114    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: dst
1115    INTEGER :: n
1116
1117    dst=0.d0
1118    DO n=1,src(i)%nelems
1119       dst(src(i)%elems(n)%j,src(i)%elems(n)%k)=src(i)%elems(n)%v
1120    ENDDO
```

8.24.2.11 subroutine, public tensor::coo_to_mat_ij (type(coolist), dimension(ndim), intent(in) *src*, real(kind=8), dimension(ndim,ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor coolist component into a matrix with i and j indices.

Parameters

src	Source tensor
dst	Destination matrix

Definition at line 1079 of file tensor.f90.

```
1079    TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
1080    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: dst
1081    INTEGER :: i,n
1082
1083    dst=0.d0
1084    DO i=1,ndim
1085       DO n=1,src(i)%nelems
1086          dst(i,src(i)%elems(n)%j)=src(i)%elems(n)%v
1087       ENDDO
1088    ENDDO
```

8.24.2.12 subroutine, public tensor::coo_to_mat_ik (type(coolist), dimension(ndim), intent(in) *src*, real(kind=8), dimension(ndim,ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor coolist component into a matrix with i and k indices.

Parameters

src	Source tensor
dst	Destination matrix

Definition at line 1063 of file tensor.f90.

```
1063    TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
1064    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: dst
1065    INTEGER :: i,n
1066
1067    dst=0.d0
1068    DO i=1,ndim
1069       DO n=1,src(i)%nelems
1070          dst(i,src(i)%elems(n)%k)=src(i)%elems(n)%v
1071       ENDDO
1072    ENDDO
```

8.24.2.13 subroutine, public tensor::coo_to_mat_j (integer, intent(in) *j*, type(coolist), dimension(ndim), intent(in) *src*, real(kind=8), dimension(ndim,ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor coolist component into a matrix.

Parameters

j	Component to convert
src	Source tensor
dst	Destination matrix

Definition at line 1148 of file tensor.f90.

```
1148    INTEGER, INTENT(IN) :: j
1149    TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
1150    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: dst
1151    INTEGER :: i,n
1152
1153    dst=0.d0
1154    DO i=1,ndim
1155       DO n=1,src(i)%nelems
1156          IF (src(i)%elems(n)%j==j) dst(i,src(i)%elems(n)%k)=src(i)%elems(n)%v
1157       ENDDO
1158    END DO
```

8.24.2.14 subroutine, public tensor::coo_to_vec_jk (integer, intent(in) *j*, integer, intent(in) *k*, type(coolist), dimension(ndim), intent(in) *src*, real(kind=8), dimension(ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor coolist component into a vector.

Parameters

j	Component j,k to convert
k	Component j,k to convert
src	Source tensor
dst	Destination vector

Definition at line 1129 of file tensor.f90.

```
1129    INTEGER, INTENT(IN) :: j,k
1130    TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
1131    REAL(KIND=8), DIMENSION(ndim), INTENT(OUT) :: dst
1132    INTEGER :: i,n
1133
1134    dst=0.d0
1135    DO i=1,ndim
1136       DO n=1,src(i)%nelems
1137          IF ((src(i)%elems(n)%j==j).and.(src(i)%elems(n)%k==k)) dst(i)=src(i)%elems(n)%v
1138       END DO
1139    ENDDO
```

8.24.2.15 subroutine, public tensor::copy_coo (type(coolist), dimension(ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(out) *dst*)

Routine to copy a coolist.

Parameters

src	Source coolist
dst	Destination coolist

Remarks

The destination tensor have to be an empty tensor, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 72 of file tensor.f90.

```
72      TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: src
73      TYPE(coolist), DIMENSION(ndim), INTENT(OUT) :: dst
74      INTEGER :: i,j,allocstat
75
76      DO i=1,ndim
77         IF (dst(i)%nelems/=0) stop "*** copy_coo : Destination coolist not empty ! ***"
78         ALLOCATE(dst(i)%elems(src(i)%nelems), stat=allocstat)
79         IF (allocstat /= 0) stop "*** Not enough memory ! ***"
80         DO j=1,src(i)%nelems
81            dst(i)%elems(j)%j=src(i)%elems(j)%j
82            dst(i)%elems(j)%k=src(i)%elems(j)%k
83            dst(i)%elems(j)%v=src(i)%elems(j)%v
84         ENDDO
85         dst(i)%nelems=src(i)%nelems
86      ENDDO
```

8.24.2.16 subroutine, public tensor::jsparse_mul (type(coolist), dimension(ndim), intent(in) *coolist_ijk*, real(kind=8), dimension(0:ndim), intent(in) *arr_j*, type(coolist), dimension(ndim), intent(out) *jcoo_ij*)

Sparse multiplication of two tensors to determine the Jacobian:

$$J_{i,j} = \sum_{k=0}^{ndim} \left(\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j} \right) a_k.$$

It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$, we add to $J_{i,j}$ as follows:

$$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k} \, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k} \, a_j$$

This version return a coolist (sparse tensor).

Parameters

coolist↔_ijk	a coordinate list (sparse tensor) of which index 2 or 3 will be contracted.
arr_j	the vector to be contracted with index 2 and then index 3 of ffi_coo_ijk
jcoo_ij	a coolist (sparse tensor) to store the result of the contraction

Definition at line 153 of file tensor.f90.

```
153      TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
154      TYPE(coolist), DIMENSION(ndim), INTENT(OUT):: jcoo_ij
155      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_j
156      REAL(KIND=8) :: v
157      INTEGER :: i,j,k,n,nj,allocstat
158      DO i=1,ndim
159         IF (jcoo_ij(i)%nelems/=0) stop "*** jsparse_mul : Destination coolist not empty ! ***"
160         nj=2*coolist_ijk(i)%nelems
```

```
        ALLOCATE(jcoo_ij(i)%elems(nj), stat=allocstat)
        IF (allocstat /= 0) stop "*** Not enough memory ! ***"
        nj=0
        DO n=1,coolist_ijk(i)%nelems
           j=coolist_ijk(i)%elems(n)%j
           k=coolist_ijk(i)%elems(n)%k
           v=coolist_ijk(i)%elems(n)%v
           IF (j /=0) THEN
              nj=nj+1
              jcoo_ij(i)%elems(nj)%j=j
              jcoo_ij(i)%elems(nj)%k=0
              jcoo_ij(i)%elems(nj)%v=v*arr_j(k)
           END IF

           IF (k /=0) THEN
              nj=nj+1
              jcoo_ij(i)%elems(nj)%j=k
              jcoo_ij(i)%elems(nj)%k=0
              jcoo_ij(i)%elems(nj)%v=v*arr_j(j)
           END IF
        END DO
        jcoo_ij(i)%nelems=nj
     END DO
```

8.24.2.17 subroutine, public tensor::jsparse_mul_mat (type(coolist), dimension(ndim), intent(in) *coolist_ijk*, real(kind=8), dimension(0:ndim), intent(in) *arr_j*, real(kind=8), dimension(ndim,ndim), intent(out) *jcoo_ij*)

Sparse multiplication of two tensors to determine the Jacobian:

$$J_{i,j} = \sum_{k=0}^{ndim} \left(\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j} \right) a_k.$$

It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$, we add to $J_{i,j}$ as follows:

$$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k} \, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k} \, a_j$$

This version return a matrix.

Parameters

coolist←_ijk	a coordinate list (sparse tensor) of which index 2 or 3 will be contracted.
arr_j	the vector to be contracted with index 2 and then index 3 of ffi_coo_ijk
jcoo_ij	a matrix to store the result of the contraction

Definition at line 196 of file tensor.f90.

```
196     TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
197     REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT):: jcoo_ij
198     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)   :: arr_j
199     REAL(KIND=8) :: v
200     INTEGER :: i,j,k,n
201     jcoo_ij=0.d0
202     DO i=1,ndim
203        DO n=1,coolist_ijk(i)%nelems
204           j=coolist_ijk(i)%elems(n)%j
205           k=coolist_ijk(i)%elems(n)%k
206           v=coolist_ijk(i)%elems(n)%v
207           IF (j /=0) jcoo_ij(i,j)=jcoo_ij(i,j)+v*arr_j(k)
208           IF (k /=0) jcoo_ij(i,k)=jcoo_ij(i,k)+v*arr_j(j)
209        END DO
210     END DO
```

8.24.2.18 subroutine, public tensor::load_tensor4_from_file (character (len=*), intent(in) *s*, type(coolist4), dimension(ndim), intent(out) *t*)

Load a rank-4 tensor coolist from a file definition.

Parameters

s	Filename of the tensor definition file
t	The loaded coolist

Remarks

The destination tensor have to be an empty tensor, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 1322 of file tensor.f90.

```
1322      CHARACTER (LEN=*), INTENT(IN) :: s
1323      TYPE(coolist4), DIMENSION(ndim), INTENT(OUT) :: t
1324      INTEGER :: i,ir,j,k,l,n,allocstat
1325      REAL(KIND=8) :: v
1326      OPEN(30,file=s,status='old')
1327      DO i=1,ndim
1328         READ(30,*) ir,n
1329         IF (n /= 0) THEN
1330            ALLOCATE(t(i)%elems(n), stat=allocstat)
1331            IF (allocstat /= 0) stop "*** Not enough memory ! ***"
1332            t(i)%nelems=n
1333         ENDIF
1334         DO n=1,t(i)%nelems
1335            READ(30,*) ir,j,k,l,v
1336            t(i)%elems(n)%j=j
1337            t(i)%elems(n)%k=k
1338            t(i)%elems(n)%l=l
1339            t(i)%elems(n)%v=v
1340         ENDDO
1341      END DO
1342      CLOSE(30)
```

8.24.2.19 subroutine, public tensor::load_tensor_from_file (character (len=∗), intent(in) *s*, type(coolist), dimension(ndim), intent(out) *t*)

Load a rank-4 tensor coolist from a file definition.

Parameters

s	Filename of the tensor definition file
t	The loaded coolist

Remarks

The destination tensor have to be an empty tensor, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 445 of file tensor.f90.

```
445      CHARACTER (LEN=*), INTENT(IN) :: s
446      TYPE(coolist), DIMENSION(ndim), INTENT(OUT) :: t
447      INTEGER :: i,ir,j,k,n,allocstat
448      REAL(KIND=8) :: v
449      OPEN(30,file=s,status='old')
450      DO i=1,ndim
451         READ(30,*) ir,n
452         IF (n /= 0) THEN
453            ALLOCATE(t(i)%elems(n), stat=allocstat)
454            IF (allocstat /= 0) stop "*** Not enough memory ! ***"
455            t(i)%nelems=n
456         ENDIF
```

```
      DO n=1,t(i)%nelems
         READ(30,*) ir,j,k,v
         t(i)%elems(n)%j=j
         t(i)%elems(n)%k=k
         t(i)%elems(n)%v=v
      ENDDO
   END DO
   CLOSE(30)
```

8.24.2.20 subroutine, public tensor::mat_to_coo (real(kind=8), dimension(0:ndim,0:ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(out) *dst*)

Routine to convert a matrix to a tensor.

Parameters

src	Source matrix
dst	Destination tensor

Remarks

The destination tensor have to be an empty tensor, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 94 of file tensor.f90.

```
94      REAL(KIND=8), DIMENSION(0:ndim,0:ndim), INTENT(IN) :: src
95      TYPE(coolist), DIMENSION(ndim), INTENT(OUT) :: dst
96      INTEGER :: i,j,n,allocstat
97      DO i=1,ndim
98         n=0
99         DO j=1,ndim
100           IF (abs(src(i,j))>real_eps) n=n+1
101        ENDDO
102        IF (n/=0) THEN
103           IF (dst(i)%nelems/=0) stop "*** mat_to_coo : Destination coolist not empty ! ***"
104           ALLOCATE(dst(i)%elems(n), stat=allocstat)
105           IF (allocstat /= 0) stop "*** Not enough memory ! ***"
106           n=0
107           DO j=1,ndim
108              IF (abs(src(i,j))>real_eps) THEN
109                 n=n+1
110                 dst(i)%elems(n)%j=j
111                 dst(i)%elems(n)%k=0
112                 dst(i)%elems(n)%v=src(i,j)
113              ENDIF
114           ENDDO
115        ENDIF
116        dst(i)%nelems=n
117     ENDDO
```

8.24.2.21 subroutine, public tensor::matc_to_coo (real(kind=8), dimension(ndim,ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(out) *dst*)

Routine to convert a matrix to a rank-3 tensor.

Parameters

src	Source matrix
dst	Destination tensor

Remarks

The destination tensor have to be an empty tensor, i.e. with unallocated list of elements and nelems set to 0. The j component will be set to 0.

Definition at line 1244 of file tensor.f90.

```
1244    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN) :: src
1245    TYPE(coolist), DIMENSION(ndim), INTENT(OUT) :: dst
1246    INTEGER :: i,j,n,allocstat
1247    DO i=1,ndim
1248       n=0
1249       DO j=1,ndim
1250          IF (abs(src(i,j))>real_eps) n=n+1
1251       ENDDO
1252       IF (n/=0) THEN
1253          IF (dst(i)%nelems/=0) stop "*** mat_to_coo : Destination coolist not empty ! ***"
1254          ALLOCATE(dst(i)%elems(n), stat=allocstat)
1255          IF (allocstat /= 0) stop "*** Not enough memory ! ***"
1256          n=0
1257          DO j=1,ndim
1258             IF (abs(src(i,j))>real_eps) THEN
1259                n=n+1
1260                dst(i)%elems(n)%j=0
1261                dst(i)%elems(n)%k=j
1262                dst(i)%elems(n)%v=src(i,j)
1263             ENDIF
1264          ENDDO
1265       ENDIF
1266       dst(i)%nelems=n
1267    ENDDO
```

8.24.2.22 subroutine, public tensor::print_tensor (type(coolist), dimension(ndim), intent(in) *t*, character, intent(in), optional *s*)

Routine to print a rank 3 tensor coolist.

Parameters

t	coolist to print

Definition at line 399 of file tensor.f90.

```
399     USE util, only: str
400     TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: t
401     CHARACTER, INTENT(IN), OPTIONAL :: s
402     CHARACTER :: r
403     INTEGER :: i,n,j,k
404     IF (PRESENT(s)) THEN
405        r=s
406     ELSE
407        r="t"
408     END IF
409     DO i=1,ndim
410        DO n=1,t(i)%nelems
411           j=t(i)%elems(n)%j
412           k=t(i)%elems(n)%k
413           IF( abs(t(i)%elems(n)%v) .GE. real_eps) THEN
414              write(*,"(A,ES12.5)") r//"["//trim(str(i))//"]["//trim(str(j)) &
415                   &//"]["//trim(str(k))//"] = ",t(i)%elems(n)%v
416           END IF
417        END DO
418     END DO
```

8.24.2.23 subroutine, public tensor::print_tensor4 (type(coolist4), dimension(ndim), intent(in) *t*)

Routine to print a rank-4 tensor coolist.

Parameters

t	coolist to print

Definition at line 922 of file tensor.f90.

```
USE util, only: str
TYPE(coolist4), DIMENSION(ndim), INTENT(IN) :: t
INTEGER :: i,n,j,k,l
DO i=1,ndim
   DO n=1,t(i)%nelems
      j=t(i)%elems(n)%j
      k=t(i)%elems(n)%k
      l=t(i)%elems(n)%l
      IF( abs(t(i)%elems(n)%v) .GE. real_eps) THEN
         write(*,"(A,ES12.5)") "tensor["//trim(str(i))//"]["//trim(str(j)) &
              &//"]["//trim(str(k))//"]["//trim(str(l))//"] = ",t(i)%elems(n)%v
      END IF
   END DO
END DO
```

8.24.2.24 subroutine, public tensor::scal_mul_coo (real(kind=8), intent(in) *s*, type(coolist), dimension(ndim), intent(inout) *t*)

Routine to multiply a rank-3 tensor by a scalar.

Parameters

s	The scalar
t	The tensor

Definition at line 1274 of file tensor.f90.

```
REAL(KIND=8), INTENT(IN) :: s
TYPE(coolist), DIMENSION(ndim), INTENT(INOUT) :: t
INTEGER :: i,li,n
DO i=1,ndim
   n=t(i)%nelems
   DO li=1,n
     t(i)%elems(li)%v=s*t(i)%elems(li)%v
   ENDDO
ENDDO
```

8.24.2.25 subroutine, public tensor::simplify (type(coolist), dimension(ndim), intent(inout) *tensor*)

Routine to simplify a coolist (sparse tensor). For each index i, it upper triangularize the matrix

$$\mathcal{T}_{i,j,k} \qquad 0 \leq j,k \leq ndim.$$

.

Parameters

tensor	a coordinate list (sparse tensor) which will be simplified.

Definition at line 238 of file tensor.f90.

```
TYPE(coolist), DIMENSION(ndim), INTENT(INOUT):: tensor
INTEGER :: i,j,k
INTEGER :: li,lii,liii,n
DO i= 1,ndim
   n=tensor(i)%nelems
   DO li=n,2,-1
      j=tensor(i)%elems(li)%j
      k=tensor(i)%elems(li)%k
      DO lii=li-1,1,-1
         IF (((j==tensor(i)%elems(lii)%j).AND.(k==tensor(i)&
              &%elems(lii)%k)).OR.((j==tensor(i)%elems(lii)%k).AND.(k==tensor(i)%elems(lii)%j))) THEN
            ! Found another entry with the same i,j,k: merge both into
            ! the one listed first (of those two).
            tensor(i)%elems(lii)%v=tensor(i)%elems(lii)%v+tensor(i)%elems(li)%v
            IF (j>k) THEN
               tensor(i)%elems(lii)%j=tensor(i)%elems(li)%k
               tensor(i)%elems(lii)%k=tensor(i)%elems(li)%j
            ENDIF

            ! Shift the rest of the items one place down.
            DO liii=li+1,n
               tensor(i)%elems(liii-1)%j=tensor(i)%elems(liii)%j
               tensor(i)%elems(liii-1)%k=tensor(i)%elems(liii)%k
               tensor(i)%elems(liii-1)%v=tensor(i)%elems(liii)%v
            END DO
            tensor(i)%nelems=tensor(i)%nelems-1
            ! Here we should stop because the li no longer points to the
            ! original i,j,k element
            EXIT
         ENDIF
      ENDDO
   ENDDO
   n=tensor(i)%nelems
   DO li=1,n
      ! Clear new "almost" zero entries and shift rest of the items one place down.
      ! Make sure not to skip any entries while shifting!
      DO WHILE (abs(tensor(i)%elems(li)%v) < real_eps)
         DO liii=li+1,n
            tensor(i)%elems(liii-1)%j=tensor(i)%elems(liii)%j
            tensor(i)%elems(liii-1)%k=tensor(i)%elems(liii)%k
            tensor(i)%elems(liii-1)%v=tensor(i)%elems(liii)%v
         ENDDO
         tensor(i)%nelems=tensor(i)%nelems-1
         if (li > tensor(i)%nelems) THEN
            EXIT
         ENDIF
      ENDDO
   ENDDO

   n=tensor(i)%nelems
   DO li=1,n
      ! Upper triangularize
      j=tensor(i)%elems(li)%j
      k=tensor(i)%elems(li)%k
      IF (j>k) THEN
         tensor(i)%elems(li)%j=k
         tensor(i)%elems(li)%k=j
      ENDIF
   ENDDO


ENDDO
```

8.24.2.26 subroutine, public tensor::sparse_mul2 (type(coolist), dimension(ndim), intent(in) *coolist_ij*, real(kind=8), dimension(0:ndim), intent(in) *arr_j*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a 2d sparse tensor with a vector: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k} \, a_j$.

Parameters

coolist←_ij	a coordinate list (sparse tensor) of which index 2 will be contracted.
arr_j	the vector to be contracted with index 2 of coolist_ijk
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_j` as a result buffer, as this operation does multiple passes.

Definition at line 221 of file tensor.f90.

```
221     TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ij
222     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_j
223     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
224     INTEGER :: i,j,n
225     res=0.d0
226     DO i=1,ndim
227        DO n=1,coolist_ij(i)%nelems
228          j=coolist_ij(i)%elems(n)%j
229          res(i) = res(i) + coolist_ij(i)%elems(n)%v * arr_j(j)
230       END DO
231    END DO
```

8.24.2.27 subroutine, public tensor::sparse_mul2_j (type(coolist), dimension(ndim), intent(in) *coolist_ijk,* real(kind=8), dimension(0:ndim), intent(in) *arr_j,* real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a 3d sparse tensor with a vectors: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k} \, a_j$.

Parameters

coolist_ijk	a coordinate list (sparse tensor) of which index 2 will be contracted.
arr_j	the vector to be contracted with index 2 of coolist_ijk
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_j` as a result buffer, as this operation does multiple passes.

Definition at line 1024 of file tensor.f90.

```
1024     TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
1025     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_j
1026     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
1027     INTEGER :: i,j,n
1028     res=0.d0
1029     DO i=1,ndim
1030        DO n=1,coolist_ijk(i)%nelems
1031          j=coolist_ijk(i)%elems(n)%j
1032          res(i) = res(i) + coolist_ijk(i)%elems(n)%v * arr_j(j)
1033       END DO
1034    END DO
```

8.24.2.28 subroutine, public tensor::sparse_mul2_k (type(coolist), dimension(ndim), intent(in) *coolist_ijk,* real(kind=8), dimension(0:ndim), intent(in) *arr_k,* real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a rank-3 sparse tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k} \, a_k$.

Parameters

coolist←↩ _ijk	a coordinate list (sparse tensor) of which index k will be contracted.
arr_k	the vector to be contracted with index k of coolist_ijk
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_k` as a result buffer, as this operation does multiple passes.

Definition at line 1045 of file tensor.f90.

```
1045     TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
1046     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_k
1047     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
1048     INTEGER :: i,k,n
1049     res=0.d0
1050     DO i=1,ndim
1051        DO n=1,coolist_ijk(i)%nelems
1052          k=coolist_ijk(i)%elems(n)%k
1053          res(i) = res(i) + coolist_ijk(i)%elems(n)%v * arr_k(k)
1054       END DO
1055    END DO
```

8.24.2.29 subroutine, public tensor::sparse_mul3 (type(coolist), dimension(ndim), intent(in) *coolist_ijk*, real(kind=8), dimension(0:ndim), intent(in) *arr_j*, real(kind=8), dimension(0:ndim), intent(in) *arr_k*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a tensor with two vectors: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k} \, a_j \, b_k$.

Parameters

coolist←↩ _ijk	a coordinate list (sparse tensor) of which index 2 and 3 will be contracted.
arr_j	the vector to be contracted with index 2 of coolist_ijk
arr_k	the vector to be contracted with index 3 of coolist_ijk
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_j/arr_k` as a result buffer, as this operation does multiple passes.

Definition at line 129 of file tensor.f90.

```
129     TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
130     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_j, arr_k
131     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
132     INTEGER :: i,j,k,n
133     res=0.d0
134     DO i=1,ndim
135        DO n=1,coolist_ijk(i)%nelems
136          j=coolist_ijk(i)%elems(n)%j
137          k=coolist_ijk(i)%elems(n)%k
138          res(i) = res(i) + coolist_ijk(i)%elems(n)%v * arr_j(j)*arr_k(k)
139       END DO
140    END DO
```

8.24.2.30 subroutine, public tensor::sparse_mul3_mat (type(coolist), dimension(ndim), intent(in) *coolist_ijk*, real(kind=8), dimension(0:ndim), intent(in) *arr_k*, real(kind=8), dimension(ndim,ndim), intent(out) *res*)

Sparse multiplication of a rank-3 tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k} \, b_k$. Its output is a matrix.

Parameters

coolist_ijk	a coolist (sparse tensor) of which index k will be contracted.
arr_k	the vector to be contracted with index k of coolist_ijk
res	matrix (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_k` as a result buffer, as this operation does multiple passes.

Definition at line 948 of file tensor.f90.

```
948      TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
949      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_k
950      REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: res
951      INTEGER :: i,j,k,n
952      res=0.d0
953      DO i=1,ndim
954         DO n=1,coolist_ijk(i)%nelems
955           j=coolist_ijk(i)%elems(n)%j
956           IF (j /= 0) THEN
957              k=coolist_ijk(i)%elems(n)%k
958              res(i,j) = res(i,j) + coolist_ijk(i)%elems(n)%v * arr_k(k)
959           ENDIF
960        END DO
961     END DO
```

8.24.2.31 subroutine, public tensor::sparse_mul3_with_mat (type(coolist), dimension(ndim), intent(in) *coolist_ijk*, real(kind=8), dimension(ndim,ndim), intent(in) *mat_jk*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a rank-3 tensor coolist with a matrix: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k} \, m_{j,k}$.

Parameters

coolist_ijk	a coolist (sparse tensor) of which index j and k will be contracted.
mat_jk	the matrix to be contracted with index j and k of coolist_ijk
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `mat_jk` as a result buffer, as this operation does multiple passes.

Definition at line 1220 of file tensor.f90.

```
    TYPE(coolist), DIMENSION(ndim), INTENT(IN):: coolist_ijk
    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN)  :: mat_jk
    REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
    INTEGER i,j,k,n

    res=0.d0
    DO i=1,ndim
       DO n=1,coolist_ijk(i)%nelems
          j=coolist_ijk(i)%elems(n)%j
          k=coolist_ijk(i)%elems(n)%k

          res(i) = res(i) + coolist_ijk(i)%elems(n)%v * mat_jk(j,k)
       ENDDO
    END DO

```

8.24.2.32 subroutine, public tensor::sparse_mul4 (type(coolist4), dimension(ndim), intent(in) *coolist_ijkl,* real(kind=8), dimension(0:ndim), intent(in) *arr_j,* real(kind=8), dimension(0:ndim), intent(in) *arr_k,* real(kind=8), dimension(0:ndim), intent(in) *arr_l,* real(kind=8), dimension(0:ndim), intent(out) *res*)

Sparse multiplication of a rank-4 tensor coolist with three vectors: $\sum_{j,k,l=0}^{ndim} \mathcal{T}_{i,j,k,l} \, a_j \, b_k \, c_l$.

Parameters

coolist_ijkl	a coolist (sparse tensor) of which index j, k and l will be contracted.
arr_j	the vector to be contracted with index j of coolist_ijkl
arr_k	the vector to be contracted with index k of coolist_ijkl
arr_l	the vector to be contracted with index l of coolist_ijkl
res	vector (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_j`/`arr_k`/`arr_l` as a result buffer, as this operation does multiple passes.

Definition at line 974 of file tensor.f90.

```
    TYPE(coolist4), DIMENSION(ndim), INTENT(IN):: coolist_ijkl
    REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_j, arr_k, arr_l
    REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
    INTEGER :: i,j,k,n,l
    res=0.d0
    DO i=1,ndim
       DO n=1,coolist_ijkl(i)%nelems
         j=coolist_ijkl(i)%elems(n)%j
         k=coolist_ijkl(i)%elems(n)%k
         l=coolist_ijkl(i)%elems(n)%l
         res(i) = res(i) + coolist_ijkl(i)%elems(n)%v * arr_j(j)*arr_k(k)*arr_l(l)
      END DO
   END DO
```

8.24.2.33 subroutine, public tensor::sparse_mul4_mat (type(coolist4), dimension(ndim), intent(in) *coolist_ijkl,* real(kind=8), dimension(0:ndim), intent(in) *arr_k,* real(kind=8), dimension(0:ndim), intent(in) *arr_l,* real(kind=8), dimension(ndim,ndim), intent(out) *res*)

Sparse multiplication of a tensor with two vectors: $\sum_{k,l=0}^{ndim} \mathcal{T}_{i,j,k,l} \, b_k \, c_l$.

Parameters

coolist_ijkl	a coordinate list (sparse tensor) of which index 3 and 4 will be contracted.
arr_k	the vector to be contracted with index 3 of coolist_ijkl
arr_l	the vector to be contracted with index 4 of coolist_ijkl
res	matrix (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `arr_k`/`arr_l` as a result buffer, as this operation does multiple passes.

Definition at line 998 of file tensor.f90.

```
TYPE(coolist4), DIMENSION(ndim), INTENT(IN):: coolist_ijkl
REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN)  :: arr_k, arr_l
 REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: res
 INTEGER :: i,j,k,n,l
 res=0.d0
 DO i=1,ndim
    DO n=1,coolist_ijkl(i)%nelems
      j=coolist_ijkl(i)%elems(n)%j
      IF (j /= 0) THEN
         k=coolist_ijkl(i)%elems(n)%k
         l=coolist_ijkl(i)%elems(n)%l
         res(i,j) = res(i,j) + coolist_ijkl(i)%elems(n)%v * arr_k(k) * arr_l(l)
      ENDIF
   END DO
END DO
```

8.24.2.34 subroutine, public tensor::sparse_mul4_with_mat_jl (type(coolist4), dimension(ndim), intent(in) *coolist_ijkl*, real(kind=8), dimension(ndim,ndim), intent(in) *mat_jl*, real(kind=8), dimension(ndim,ndim), intent(out) *res*)

Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l} \, m_{j,l}$.

Parameters

coolist_ijkl	a coolist (sparse tensor) of which index j and l will be contracted.
mat_jl	the matrix to be contracted with indices j and l of coolist_ijkl
res	matrix (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `mat_jl` as a result buffer, as this operation does multiple passes.

Definition at line 1169 of file tensor.f90.

```
TYPE(coolist4), DIMENSION(ndim), INTENT(IN):: coolist_ijkl
REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN)  :: mat_jl
REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: res
INTEGER i,j,k,l,n

res=0.d0
DO i=1,ndim
   DO n=1,coolist_ijkl(i)%nelems
      j=coolist_ijkl(i)%elems(n)%j
```

```
1178         k=coolist_ijkl(i)%elems(n)%k
1179         l=coolist_ijkl(i)%elems(n)%l
1180 
1181         res(i,k) = res(i,k) + coolist_ijkl(i)%elems(n)%v * mat_jl(j,l)
1182       ENDDO
1183    END DO
1184 
```

8.24.2.35 subroutine, public tensor::sparse_mul4_with_mat_kl (type(coolist4), dimension(ndim), intent(in) *coolist_ijkl*, real(kind=8), dimension(ndim,ndim), intent(in) *mat_kl*, real(kind=8), dimension(ndim,ndim), intent(out) *res*)

Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l} \, m_{k,l}$.

Parameters

coolist_ijkl	a coolist (sparse tensor) of which index k and l will be contracted.
mat_kl	the matrix to be contracted with indices k and l of coolist_ijkl
res	matrix (buffer) to store the result of the contraction

Remarks

Note that it is NOT safe to pass `mat_kl` as a result buffer, as this operation does multiple passes.

Definition at line 1194 of file tensor.f90.

```
1194    TYPE(coolist4), DIMENSION(ndim), INTENT(IN):: coolist_ijkl
1195    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(IN)  :: mat_kl
1196    REAL(KIND=8), DIMENSION(ndim,ndim), INTENT(OUT) :: res
1197    INTEGER i,j,k,l,n
1198 
1199    res=0.d0
1200    DO i=1,ndim
1201       DO n=1,coolist_ijkl(i)%nelems
1202          j=coolist_ijkl(i)%elems(n)%j
1203          k=coolist_ijkl(i)%elems(n)%k
1204          l=coolist_ijkl(i)%elems(n)%l
1205 
1206          res(i,j) = res(i,j) + coolist_ijkl(i)%elems(n)%v * mat_kl(k,l)
1207       ENDDO
1208    END DO
1209 
```

8.24.2.36 logical function, public tensor::tensor4_empty (type(coolist4), dimension(ndim), intent(in) *t*)

Test if a rank-4 tensor coolist is empty.

Parameters

t	rank-4 tensor coolist to be tested

Definition at line 1304 of file tensor.f90.

```
1304     TYPE(coolist4), DIMENSION(ndim), INTENT(IN) :: t
```

```
    LOGICAL :: tensor4_empty
    INTEGER :: i
    tensor4_empty=.true.
    DO i=1,ndim
       IF (t(i)%nelems /= 0) THEN
          tensor4_empty=.false.
          RETURN
       ENDIF
    END DO
    RETURN
```

8.24.2.37 subroutine, public tensor::tensor4_to_coo4 (real(kind=8), dimension(ndim,0:ndim,0:ndim,0:ndim), intent(in) *src*, type(coolist4), dimension(ndim), intent(out) *dst*)

Routine to convert a rank-4 tensor from matrix to coolist representation.

Parameters

src	Source matrix
dst	Destination coolist

Remarks

The destination coolist have to be an empty one, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 883 of file tensor.f90.

```
   REAL(KIND=8), DIMENSION(ndim,0:ndim,0:ndim,0:ndim), INTENT(IN) :: src
   TYPE(coolist4), DIMENSION(ndim), INTENT(OUT) :: dst
   INTEGER :: i,j,k,l,n,allocstat

   DO i=1,ndim
      n=0
      DO j=0,ndim
         DO k=0,ndim
            DO l=0,ndim
               IF (abs(src(i,j,k,l))>real_eps) n=n+1
            ENDDO
         ENDDO
      ENDDO
      IF (n/=0) THEN
         IF (dst(i)%nelems/=0) stop "*** tensor_to_coo : Destination coolist not empty ! ***"
         ALLOCATE(dst(i)%elems(n), stat=allocstat)
         IF (allocstat /= 0) stop "*** Not enough memory ! ***"
         n=0
         DO j=0,ndim
            DO k=0,ndim
               DO l=0,ndim
                  IF (abs(src(i,j,k,l))>real_eps) THEN
                     n=n+1
                     dst(i)%elems(n)%j=j
                     dst(i)%elems(n)%k=k
                     dst(i)%elems(n)%l=l
                     dst(i)%elems(n)%v=src(i,j,k,l)
                  ENDIF
               ENDDO
            ENDDO
         ENDDO
      ENDIF
      dst(i)%nelems=n
   ENDDO
```

8.24.2.38 logical function, public tensor::tensor_empty (type(coolist), dimension(ndim), intent(in) *t*)

Test if a rank-3 tensor coolist is empty.

Parameters

t	rank-3 tensor coolist to be tested

Definition at line 1288 of file tensor.f90.

```
TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: t
LOGICAL :: tensor_empty
INTEGER :: i
tensor_empty=.true.
DO i=1,ndim
   IF (t(i)%nelems /= 0) THEN
      tensor_empty=.false.
      RETURN
   ENDIF
END DO
RETURN
```

8.24.2.39 subroutine, public tensor::tensor_to_coo (real(kind=8), dimension(ndim,0:ndim,0:ndim), intent(in) *src*, type(coolist), dimension(ndim), intent(out) *dst*)

Routine to convert a rank-3 tensor from matrix to coolist representation.

Parameters

src	Source matrix
dst	Destination coolist

Remarks

The destination coolist have to be an empty one, i.e. with unallocated list of elements and nelems set to 0.

Definition at line 847 of file tensor.f90.

```
REAL(KIND=8), DIMENSION(ndim,0:ndim,0:ndim), INTENT(IN) :: src
TYPE(coolist), DIMENSION(ndim), INTENT(OUT) :: dst
INTEGER :: i,j,k,n,allocstat

DO i=1,ndim
   n=0
   DO j=0,ndim
      DO k=0,ndim
         IF (abs(src(i,j,k))>real_eps) n=n+1
      ENDDO
   ENDDO
   IF (n/=0) THEN
      IF (dst(i)%nelems/=0) stop "*** tensor_to_coo : Destination coolist not empty ! ***"
      ALLOCATE(dst(i)%elems(n), stat=allocstat)
      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
      n=0
      DO j=0,ndim
         DO k=0,ndim
            IF (abs(src(i,j,k))>real_eps) THEN
               n=n+1
               dst(i)%elems(n)%j=j
               dst(i)%elems(n)%k=k
               dst(i)%elems(n)%v=src(i,j,k)
            ENDIF
         ENDDO
      ENDDO
   ENDIF
   dst(i)%nelems=n
ENDDO
```

8.24.2.40 subroutine, public tensor::write_tensor4_to_file (character (len=*), intent(in) *s*, type(coolist4), dimension(ndim), intent(in) *t*)

Load a rank-4 tensor coolist from a file definition.

Parameters

s	Destination filename
t	The coolist to write

Definition at line 1349 of file tensor.f90.

```
CHARACTER (LEN=*), INTENT(IN) :: s
TYPE(coolist4), DIMENSION(ndim), INTENT(IN) :: t
INTEGER :: i,j,k,l,n
OPEN(30,file=s)
DO i=1,ndim
   WRITE(30,*) i,t(i)%nelems
   DO n=1,t(i)%nelems
      j=t(i)%elems(n)%j
      k=t(i)%elems(n)%k
      l=t(i)%elems(n)%l
      WRITE(30,*) i,j,k,l,t(i)%elems(n)%v
   END DO
END DO
CLOSE(30)
```

8.24.2.41 subroutine, public tensor::write_tensor_to_file (character (len=*), intent(in) *s*, type(coolist), dimension(ndim), intent(in) *t*)

Load a rank-4 tensor coolist from a file definition.

Parameters

s	Destination filename
t	The coolist to write

Definition at line 425 of file tensor.f90.

```
CHARACTER (LEN=*), INTENT(IN) :: s
TYPE(coolist), DIMENSION(ndim), INTENT(IN) :: t
INTEGER :: i,j,k,n
OPEN(30,file=s)
DO i=1,ndim
   WRITE(30,*) i,t(i)%nelems
   DO n=1,t(i)%nelems
      j=t(i)%elems(n)%j
      k=t(i)%elems(n)%k
      WRITE(30,*) i,j,k,t(i)%elems(n)%v
   END DO
END DO
CLOSE(30)
```

8.24.3 Variable Documentation

8.24.3.1 real(kind=8), parameter tensor::real_eps = 2.2204460492503131e-16

Parameter to test the equality with zero.

Definition at line 50 of file tensor.f90.

```
REAL(KIND=8), PARAMETER :: real_eps = 2.2204460492503131e-16
```

8.25 tl_ad_integrator Module Reference

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

Functions/Subroutines

- subroutine, public init_tl_ad_integrator
  Routine to initialise the integration buffers.
- subroutine, public ad_step (y, ystar, t, dt, res)
  Routine to perform an integration step (Heun algorithm) of the adjoint model. The incremented time is returned.
- subroutine, public tl_step (y, ystar, t, dt, res)
  Routine to perform an integration step (Heun algorithm) of the tangent linear model. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable buf_y1
  Buffer to hold the intermediate position (Heun algorithm) of the tangent linear model.
- real(kind=8), dimension(:), allocatable buf_f0
  Buffer to hold tendencies at the initial position of the tangent linear model.
- real(kind=8), dimension(:), allocatable buf_f1
  Buffer to hold tendencies at the intermediate position of the tangent linear model.
- real(kind=8), dimension(:), allocatable buf_ka
  Buffer to hold tendencies in the RK4 scheme for the tangent linear model.
- real(kind=8), dimension(:), allocatable buf_kb
  Buffer to hold tendencies in the RK4 scheme for the tangent linear model.

8.25.1 Detailed Description

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

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Remarks

This module actually contains the Heun algorithm routines. The user can modify it according to its preferred integration scheme. For higher-order schemes, additional buffers will probably have to be defined.

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Remarks

This module actually contains the RK4 algorithm routines. The user can modify it according to its preferred integration scheme. For higher-order schemes, additional bufers will probably have to be defined.

8.25.2 Function/Subroutine Documentation

8.25.2.1 subroutine public tl_ad_integrator::ad_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(in) *ystar*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform an integration step (Heun algorithm) of the adjoint model. The incremented time is returned.

Routine to perform an integration step (RK4 algorithm) of the adjoint model. The incremented time is returned.

Parameters

y	Initial point.
ystar	Adjoint model at the point ystar.
t	Actual integration time
dt	Integration timestep.
res	Final point after the step.

Definition at line 61 of file rk2_tl_ad_integrator.f90.

```
61      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y,ystar
62      REAL(KIND=8), INTENT(INOUT) :: t
63      REAL(KIND=8), INTENT(IN) :: dt
64      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
65
66      CALL ad(t,ystar,y,buf_f0)
67      buf_y1 = y+dt*buf_f0
68      CALL ad(t+dt,ystar,buf_y1,buf_f1)
69      res=y+0.5*(buf_f0+buf_f1)*dt
70      t=t+dt
```

8.25.2.2 subroutine public tl_ad_integrator::init_tl_ad_integrator ( )

Routine to initialise the integration buffers.

Routine to initialise the TL-AD integration bufers.

Definition at line 41 of file rk2_tl_ad_integrator.f90.

```
41      INTEGER :: allocstat
42      ALLOCATE(buf_y1(0:ndim),buf_f0(0:ndim),buf_f1(0:ndim),stat=allocstat)
43      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
```

8.25.2.3 subroutine public tl_ad_integrator::tl_step (real(kind=8), dimension(0:ndim), intent(in) *y*, real(kind=8), dimension(0:ndim), intent(in) *ystar*, real(kind=8), intent(inout) *t*, real(kind=8), intent(in) *dt*, real(kind=8), dimension(0:ndim), intent(out) *res*)

Routine to perform an integration step (Heun algorithm) of the tangent linear model. The incremented time is returned.

Routine to perform an integration step (RK4 algorithm) of the tangent linear model. The incremented time is returned.

Parameters

y	Initial point.
ystar	Adjoint model at the point ystar.
t	Actual integration time
dt	Integration timestep.
res	Final point after the step.

Definition at line 86 of file rk2_tl_ad_integrator.f90.

```
86      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: y,ystar
87      REAL(KIND=8), INTENT(INOUT) :: t
88      REAL(KIND=8), INTENT(IN) :: dt
89      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: res
90
91      CALL tl(t,ystar,y,buf_f0)
92      buf_y1 = y+dt*buf_f0
93      CALL tl(t+dt,ystar,buf_y1,buf_f1)
94      res=y+0.5*(buf_f0+buf_f1)*dt
95      t=t+dt
```

8.25.3 Variable Documentation

8.25.3.1 real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_f0 [private]

Buffer to hold tendencies at the initial position of the tangent linear model.

Definition at line 31 of file rk2_tl_ad_integrator.f90.

```
31    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_f0 !< Buffer to hold tendencies at the initial position of
        the tangent linear model
```

8.25.3.2 real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_f1 [private]

Buffer to hold tendencies at the intermediate position of the tangent linear model.

Definition at line 32 of file rk2_tl_ad_integrator.f90.

```
32    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_f1 !< Buffer to hold tendencies at the intermediate
        position of the tangent linear model
```

8.25.3.3 real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_ka [private]

Buffer to hold tendencies in the RK4 scheme for the tangent linear model.

Definition at line 33 of file rk4_tl_ad_integrator.f90.

```
33    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_ka !< Buffer to hold tendencies in the RK4 scheme for the
        tangent linear model
```

8.25.3.4 real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_kb [private]

Buffer to hold tendencies in the RK4 scheme for the tangent linear model.

Definition at line 34 of file rk4_tl_ad_integrator.f90.

```
34    REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_kb !< Buffer to hold tendencies in the RK4 scheme for the
        tangent linear model
```

8.25.3.5 real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_y1 [private]

Buffer to hold the intermediate position (Heun algorithm) of the tangent linear model.

Buffer to hold the intermediate position of the tangent linear model.

Definition at line 30 of file rk2_tl_ad_integrator.f90.

```
30   REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: buf_y1 !< Buffer to hold the intermediate position (Heun
       algorithm) of the tangent linear model
```

8.26 tl_ad_tensor Module Reference

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module.

Functions/Subroutines

- type(coolist) function, dimension(ndim) jacobian (ystar)
  Compute the Jacobian of MAOOAM in point ystar.
- real(kind=8) function, dimension(ndim, ndim), public jacobian_mat (ystar)
  Compute the Jacobian of MAOOAM in point ystar.
- subroutine, public init_tltensor
  Routine to initialize the TL tensor.
- subroutine compute_tltensor (func)
  Routine to compute the TL tensor from the original MAOOAM one.
- subroutine tl_add_count (i, j, k, v)
  Subroutine used to count the number of TL tensor entries.
- subroutine tl_coeff (i, j, k, v)
  Subroutine used to compute the TL tensor entries.
- subroutine, public init_adtensor
  Routine to initialize the AD tensor.
- subroutine compute_adtensor (func)
  Subroutine to compute the AD tensor from the original MAOOAM one.
- subroutine ad_add_count (i, j, k, v)
  Subroutine used to count the number of AD tensor entries.
- subroutine ad_coeff (i, j, k, v)
- subroutine, public init_adtensor_ref
  Alternate method to initialize the AD tensor from the TL tensor.
- subroutine compute_adtensor_ref (func)
  Alternate subroutine to compute the AD tensor from the TL one.
- subroutine ad_add_count_ref (i, j, k, v)
  Alternate subroutine used to count the number of AD tensor entries from the TL tensor.
- subroutine ad_coeff_ref (i, j, k, v)
  Alternate subroutine used to compute the AD tensor entries from the TL tensor.
- subroutine, public ad (t, ystar, deltay, buf)
  Tendencies for the AD of MAOOAM in point ystar for perturbation deltay.
- subroutine, public tl (t, ystar, deltay, buf)
  Tendencies for the TL of MAOOAM in point ystar for perturbation deltay.

Variables

- real(kind=8), parameter real_eps = 2.2204460492503131e-16

    Epsilon to test equality with 0.
- integer, dimension(:), allocatable count_elems

    Vector used to count the tensor elements.
- type(coolist), dimension(:), allocatable, public tltensor

    Tensor representation of the Tangent Linear tendencies.
- type(coolist), dimension(:), allocatable, public adtensor

    Tensor representation of the Adjoint tendencies.

8.26.1 Detailed Description

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module.

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Remarks

The routines of this module should be called only after params::init_params() and aotensor_def::init_↩ aotensor() have been called !

8.26.2 Function/Subroutine Documentation

8.26.2.1 subroutine, public tl_ad_tensor::ad (real(kind=8), intent(in) *t*, real(kind=8), dimension(0:ndim), intent(in) *ystar*, real(kind=8), dimension(0:ndim), intent(in) *deltay*, real(kind=8), dimension(0:ndim), intent(out) *buf*)

Tendencies for the AD of MAOOAM in point ystar for perturbation deltay.

Parameters

t	time
ystar	vector with the variables (current point in trajectory)
deltay	vector with the perturbation of the variables at time t
buf	vector (buffer) to store derivatives.

Definition at line 384 of file tl_ad_tensor.f90.

```
384     REAL(KIND=8), INTENT(IN) :: t
385     REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: ystar,deltay
386     REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: buf
387     CALL sparse_mul3(adtensor,deltay,ystar,buf)
```

8.26.2.2 subroutine tl_ad_tensor::ad_add_count (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Subroutine used to count the number of AD tensor entries.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value that will be added

Definition at line 243 of file tl_ad_tensor.f90.

```
243     INTEGER, INTENT(IN) :: i,j,k
244     REAL(KIND=8), INTENT(IN)  :: v
245     IF ((abs(v) .ge. real_eps).AND.(i /= 0)) THEN
246        IF (k /= 0) count_elems(k)=count_elems(k)+1
247        IF (j /= 0) count_elems(j)=count_elems(j)+1
248     ENDIF
```

8.26.2.3 subroutine tl_ad_tensor::ad_add_count_ref (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Alternate subroutine used to count the number of AD tensor entries from the TL tensor.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value that will be added

Definition at line 346 of file tl_ad_tensor.f90.

```
346     INTEGER, INTENT(IN) :: i,j,k
347     REAL(KIND=8), INTENT(IN)  :: v
348     IF ((abs(v) .ge. real_eps).AND.(j /= 0)) count_elems(j)=count_elems(j)+1
```

8.26.2.4 subroutine tl_ad_tensor::ad_coeff (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value to add

Definition at line 257 of file tl_ad_tensor.f90.

```
257     INTEGER, INTENT(IN) :: i,j,k
258     REAL(KIND=8), INTENT(IN) :: v
259     INTEGER :: n
```

```
    IF (.NOT. ALLOCATED(adtensor)) stop "*** ad_coeff routine : tensor not yet allocated ***"
    IF ((abs(v) .ge. real_eps).AND.(i /=0)) THEN
       IF (k /=0) THEN
          IF (.NOT. ALLOCATED(adtensor(k)%elems)) stop "*** ad_coeff routine : tensor not yet allocated
   ***"
          n=(adtensor(k)%nelems)+1
          adtensor(k)%elems(n)%j=i
          adtensor(k)%elems(n)%k=j
          adtensor(k)%elems(n)%v=v
          adtensor(k)%nelems=n
       END IF
       IF (j /=0) THEN
          IF (.NOT. ALLOCATED(adtensor(j)%elems)) stop "*** ad_coeff routine : tensor not yet allocated
   ***"
          n=(adtensor(j)%nelems)+1
          adtensor(j)%elems(n)%j=i
          adtensor(j)%elems(n)%k=k
          adtensor(j)%elems(n)%v=v
          adtensor(j)%nelems=n
       END IF
    END IF
```

8.26.2.5 subroutine tl_ad_tensor::ad_coeff_ref (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Alternate subroutine used to compute the AD tensor entries from the TL tensor.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value to add

Definition at line 358 of file tl_ad_tensor.f90.

```
358     INTEGER, INTENT(IN) :: i,j,k
359     REAL(KIND=8), INTENT(IN) :: v
360     INTEGER :: n
361     IF (.NOT. ALLOCATED(adtensor)) stop "*** ad_coeff_ref routine : tensor not yet allocated ***"
362     IF ((abs(v) .ge. real_eps).AND.(j /=0)) THEN
363        IF (.NOT. ALLOCATED(adtensor(j)%elems)) stop "*** ad_coeff_ref routine : tensor not yet allocated
    ***"
364        n=(adtensor(j)%nelems)+1
365        adtensor(j)%elems(n)%j=i
366        adtensor(j)%elems(n)%k=k
367        adtensor(j)%elems(n)%v=v
368        adtensor(j)%nelems=n
369     END IF
```

8.26.2.6 subroutine tl_ad_tensor::compute_adtensor (external *func*) [private]

Subroutine to compute the AD tensor from the original MAOOAM one.

Parameters

func	subroutine used to do the computation

Definition at line 217 of file tl_ad_tensor.f90.

8.26.2.7 subroutine tl_ad_tensor::compute_adtensor_ref (external *func*) [private]

Alternate subroutine to compute the AD tensor from the TL one.

Parameters

func	subroutine used to do the computation

Definition at line 318 of file tl_ad_tensor.f90.

8.26.2.8 subroutine tl_ad_tensor::compute_tltensor (external *func*) [private]

Routine to compute the TL tensor from the original MAOOAM one.

Parameters

func	subroutine used to do the computation

Definition at line 121 of file tl_ad_tensor.f90.

8.26.2.9 subroutine, public tl_ad_tensor::init_adtensor ( )

Routine to initialize the AD tensor.

Definition at line 193 of file tl_ad_tensor.f90.

```
    INTEGER :: i
    INTEGER :: allocstat
    ALLOCATE(adtensor(ndim),count_elems(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    count_elems=0
    CALL compute_adtensor(ad_add_count)

    DO i=1,ndim
       ALLOCATE(adtensor(i)%elems(count_elems(i)), stat=allocstat)
       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    END DO

    DEALLOCATE(count_elems, stat=allocstat)
    IF (allocstat /= 0) stop "*** Deallocation problem ! ***"

    CALL compute_adtensor(ad_coeff)

    CALL simplify(adtensor)

```

8.26.2.10 subroutine, public tl_ad_tensor::init_adtensor_ref ( )

Alternate method to initialize the AD tensor from the TL tensor.

Remarks

The tltensor must be initialised before using this method.

Definition at line 294 of file tl_ad_tensor.f90.

```
    INTEGER :: i
    INTEGER :: allocstat
    ALLOCATE(adtensor(ndim),count_elems(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    count_elems=0
    CALL compute_adtensor_ref(ad_add_count_ref)

    DO i=1,ndim
       ALLOCATE(adtensor(i)%elems(count_elems(i)), stat=allocstat)
       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    END DO

    DEALLOCATE(count_elems, stat=allocstat)
    IF (allocstat /= 0) stop "*** Deallocation problem ! ***"

    CALL compute_adtensor_ref(ad_coeff_ref)

    CALL simplify(adtensor)

```

8.26.2.11 subroutine, public tl_ad_tensor::init_tltensor ( )

Routine to initialize the TL tensor.

Definition at line 97 of file tl_ad_tensor.f90.

```
   INTEGER :: i
   INTEGER :: allocstat
   ALLOCATE(tltensor(ndim),count_elems(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    count_elems=0
    CALL compute_tltensor(tl_add_count)

    DO i=1,ndim
       ALLOCATE(tltensor(i)%elems(count_elems(i)), stat=allocstat)
       IF (allocstat /= 0) stop "*** Not enough memory ! ***"
    END DO

    DEALLOCATE(count_elems, stat=allocstat)
    IF (allocstat /= 0) stop "*** Deallocation problem ! ***"

    CALL compute_tltensor(tl_coeff)

    CALL simplify(tltensor)

```

8.26.2.12 type(coolist) function, dimension(ndim) tl_ad_tensor::jacobian (real(kind=8), dimension(0:ndim), intent(in) *ystar*) [private]

Compute the Jacobian of MAOOAM in point ystar.

Parameters

ystar	array with variables in which the jacobian should be evaluated.

Returns

Jacobian in coolist-form (table of tuples {i,j,0,value})

Definition at line 75 of file tl_ad_tensor.f90.

```
75      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: ystar
76      TYPE(coolist), DIMENSION(ndim) :: jacobian
77      CALL jsparse_mul(aotensor,ystar,jacobian)
```

8.26.2.13 real(kind=8) function, dimension(ndim,ndim), public tl_ad_tensor::jacobian_mat (real(kind=8), dimension(0:ndim), intent(in) *ystar*)

Compute the Jacobian of MAOOAM in point ystar.

Parameters

ystar	array with variables in which the jacobian should be evaluated.

Returns

Jacobian in matrix form

Definition at line 84 of file tl_ad_tensor.f90.

```
84      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: ystar
85      REAL(KIND=8), DIMENSION(ndim,ndim) :: jacobian_mat
86      CALL jsparse_mul_mat(aotensor,ystar,jacobian_mat)
```

8.26.2.14 subroutine, public tl_ad_tensor::tl (real(kind=8), intent(in) *t,* real(kind=8), dimension(0:ndim), intent(in) *ystar,* real(kind=8), dimension(0:ndim), intent(in) *deltay,* real(kind=8), dimension(0:ndim), intent(out) *buf*)

Tendencies for the TL of MAOOAM in point ystar for perturbation deltay.

Parameters

t	time
ystar	vector with the variables (current point in trajectory)
deltay	vector with the perturbation of the variables at time t
buf	vector (buffer) to store derivatives.

Definition at line 396 of file tl_ad_tensor.f90.

```
396      REAL(KIND=8), INTENT(IN) :: t
397      REAL(KIND=8), DIMENSION(0:ndim), INTENT(IN) :: ystar,deltay
398      REAL(KIND=8), DIMENSION(0:ndim), INTENT(OUT) :: buf
399      CALL sparse_mul3(tltensor,deltay,ystar,buf)
```

8.26.2.15 subroutine tl_ad_tensor::tl_add_count (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Subroutine used to count the number of TL tensor entries.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value that will be added

Definition at line 147 of file tl_ad_tensor.f90.

```
147     INTEGER, INTENT(IN) :: i,j,k
148     REAL(KIND=8), INTENT(IN)  :: v
149     IF (abs(v) .ge. real_eps) THEN
150        IF (j /= 0) count_elems(i)=count_elems(i)+1
151        IF (k /= 0) count_elems(i)=count_elems(i)+1
152     ENDIF
```

8.26.2.16 subroutine tl_ad_tensor::tl_coeff (integer, intent(in) *i*, integer, intent(in) *j*, integer, intent(in) *k*, real(kind=8), intent(in) *v*) [private]

Subroutine used to compute the TL tensor entries.

Parameters

i	tensor i index
j	tensor j index
k	tensor k index
v	value to add

Definition at line 161 of file tl_ad_tensor.f90.

```
161     INTEGER, INTENT(IN) :: i,j,k
162     REAL(KIND=8), INTENT(IN) :: v
163     INTEGER :: n
164     IF (.NOT. ALLOCATED(tltensor)) stop "*** tl_coeff routine : tensor not yet allocated ***"
165     IF (.NOT. ALLOCATED(tltensor(i)%elems)) stop "*** tl_coeff routine : tensor not yet allocated
       ***"
166     IF (abs(v) .ge. real_eps) THEN
167        IF (j /=0) THEN
168           n=(tltensor(i)%nelems)+1
169           tltensor(i)%elems(n)%j=j
170           tltensor(i)%elems(n)%k=k
171           tltensor(i)%elems(n)%v=v
172           tltensor(i)%nelems=n
173        END IF
174        IF (k /=0) THEN
175           n=(tltensor(i)%nelems)+1
176           tltensor(i)%elems(n)%j=k
177           tltensor(i)%elems(n)%k=j
178           tltensor(i)%elems(n)%v=v
179           tltensor(i)%nelems=n
180        END IF
181     END IF
```

8.26.3 Variable Documentation

8.26.3.1 type(coolist), dimension(:), allocatable, public tl_ad_tensor::adtensor

Tensor representation of the Adjoint tendencies.

Definition at line 44 of file tl_ad_tensor.f90.

```
44    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: adtensor
```

8.26.3.2 integer, dimension(:), allocatable tl_ad_tensor::count_elems [private]

Vector used to count the tensor elements.

Definition at line 38 of file tl_ad_tensor.f90.

```
38    INTEGER, DIMENSION(:), ALLOCATABLE :: count_elems
```

8.26.3.3 real(kind=8), parameter tl_ad_tensor::real_eps = 2.2204460492503131e-16 [private]

Epsilon to test equality with 0.

Definition at line 35 of file tl_ad_tensor.f90.

```
35    REAL(KIND=8), PARAMETER :: real_eps = 2.2204460492503131e-16
```

8.26.3.4 type(coolist), dimension(:), allocatable, public tl_ad_tensor::tltensor

Tensor representation of the Tangent Linear tendencies.

Definition at line 41 of file tl_ad_tensor.f90.

```
41    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: tltensor
```

8.27 util Module Reference

Utility module.

Functions/Subroutines

- character(len=20) function, public str (k)

    Convert an integer to string.
- character(len=40) function, public rstr (x, fm)

    Convert a real to string with a given format.
- integer function, dimension(size(s)), public isin (c, s)

    Determine if a character is in a string and where.
- subroutine, public init_random_seed ()

    Random generator initialization routine.
- subroutine, public piksrt (k, arr, par)

    Simple card player sorting function.
- subroutine, public init_one (A)

    Initialize a square matrix A as a unit matrix.
- real(kind=8) function, public mat_trace (A)
- real(kind=8) function, public mat_contract (A, B)
- subroutine, public choldc (a, p)
- subroutine, public printmat (A)
- subroutine, public cprintmat (A)
- real(kind=8) function, dimension(size(a, 1), size(a, 2)), public invmat (A)
- subroutine, public triu (A, T)
- subroutine, public diag (A, d)
- subroutine, public cdiag (A, d)
- integer function, public floordiv (i, j)
- subroutine, public reduce (A, Ared, n, ind, rind)
- subroutine, public ireduce (A, Ared, n, ind, rind)
- subroutine, public vector_outer (u, v, A)

8.27.1 Detailed Description

Utility module.

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8.27.2 Function/Subroutine Documentation

8.27.2.1 subroutine, public util::cdiag (complex(kind=16), dimension(:,:), intent(in) *A*, complex(kind=16), dimension(:), intent(out) *d*)

Definition at line 269 of file util.f90.

```
269     COMPLEX(KIND=16), DIMENSION(:,:), INTENT(IN) :: a
270     COMPLEX(KIND=16), DIMENSION(:), INTENT(OUT) :: d
271     INTEGER :: i
272
273     DO i=1,SIZE(a,1)
274        d(i)=a(i,i)
275     END DO
```

8.27.2.2 subroutine, public util::choldc (real(kind=8), dimension(:,:) *a*, real(kind=8), dimension(:) *p*)

Definition at line 176 of file util.f90.

```
REAL(KIND=8), DIMENSION(:,:) :: a
REAL(KIND=8), DIMENSION(:) :: p
INTEGER :: n
INTEGER :: i,j,k
REAL(KIND=8) :: sum
n=size(a,1)
DO i=1,n
   DO j=i,n
      sum=a(i,j)
      DO k=i-1,1,-1
         sum=sum-a(i,k)*a(j,k)
      END DO
      IF (i.eq.j) THEN
         IF (sum.le.0.) stop 'choldc failed'
         p(i)=sqrt(sum)
      ELSE
         a(j,i)=sum/p(i)
      ENDIF
   END DO
END DO
RETURN
```

8.27.2.3 subroutine, public util::cprintmat (complex(kind=16), dimension(:,:), intent(in) *A*)

Definition at line 209 of file util.f90.

```
COMPLEX(KIND=16), DIMENSION(:,:), INTENT(IN) :: a
INTEGER :: i

DO i=1,SIZE(a,1)
   print*, a(i,:)
END DO
```

8.27.2.4 subroutine, public util::diag (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:), intent(out) *d*)

Definition at line 259 of file util.f90.

```
REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
REAL(KIND=8), DIMENSION(:), INTENT(OUT) :: d
INTEGER :: i

DO i=1,SIZE(a,1)
   d(i)=a(i,i)
END DO
```

8.27.2.5 integer function, public util::floordiv (integer *i*, integer *j*)

Definition at line 280 of file util.f90.

```
INTEGER :: i,j,floordiv
floordiv=int(floor(real(i)/real(j)))
RETURN
```

8.27.2.6 subroutine, public util::init_one (real(kind=8), dimension(:,:), intent(inout) *A*)

Initialize a square matrix A as a unit matrix.

Definition at line 139 of file util.f90.

```
139       REAL(KIND=8), DIMENSION(:,:),INTENT(INOUT) :: a
140       INTEGER :: i,n
141       n=size(a,1)
142       a=0.0d0
143       DO i=1,n
144         a(i,i)=1.0d0
145       END DO
146
```

8.27.2.7 subroutine, public util::init_random_seed ( )

Random generator initialization routine.

Definition at line 64 of file util.f90.

8.27.2.8 real(kind=8) function, dimension(size(a,1),size(a,2)), public util::invmat (real(kind=8), dimension(:,:), intent(in) *A*)

Definition at line 218 of file util.f90.

```
218      REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
219      REAL(KIND=8), DIMENSION(SIZE(A,1),SIZE(A,2)) :: ainv
220
221      REAL(KIND=8), DIMENSION(SIZE(A,1)) :: work  ! work array for LAPACK
222      INTEGER, DIMENSION(SIZE(A,1)) :: ipiv   ! pivot indices
223      INTEGER :: n, info
224
225      ! Store A in Ainv to prevent it from being overwritten by LAPACK
226      ainv = a
227      n = size(a,1)
228
229      ! DGETRF computes an LU factorization of a general M-by-N matrix A
230      ! using partial pivoting with row interchanges.
231      CALL dgetrf(n, n, ainv, n, ipiv, info)
232
233      IF (info /= 0) THEN
234         stop 'Matrix is numerically singular!'
235      ENDIF
236
237      ! DGETRI computes the inverse of a matrix using the LU factorization
238      ! computed by DGETRF.
239      CALL dgetri(n, ainv, n, ipiv, work, n, info)
240
241      IF (info /= 0) THEN
242         stop 'Matrix inversion failed!'
243      ENDIF
```

8.27.2.9 subroutine, public util::ireduce (real(kind=8), dimension(:,:), intent(out) *A*, real(kind=8), dimension(:,:), intent(in) *Ared*, integer, intent(in) *n*, integer, dimension(:), intent(in) *ind*, integer, dimension(:), intent(in) *rind*)

Definition at line 314 of file util.f90.

```
314      REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: a
315      REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: ared
316      INTEGER, INTENT(IN) :: n
317      INTEGER, DIMENSION(:), INTENT(IN) :: ind,rind
318      INTEGER :: i,j
319      a=0.d0
320      DO i=1,n
321         DO j=1,n
322            a(ind(i),ind(j))=ared(i,j)
323         END DO
324      END DO
```

8.27.2.10 integer function, dimension(size(s)), public util::isin (character, intent(in) *c*, character, dimension(:), intent(in) *s*)

Determine if a character is in a string and where.

Remarks

: return positions in a vector if found and 0 vector if not found

Definition at line 47 of file util.f90.

```
47      CHARACTER, INTENT(IN) :: c
48      CHARACTER, DIMENSION(:), INTENT(IN) :: s
49      INTEGER, DIMENSION(size(s)) :: isin
50      INTEGER :: i,j
51
52      isin=0
53      j=0
54      DO i=size(s),1,-1
55         IF (c==s(i)) THEN
56            j=j+1
57            isin(j)=i
58         END IF
59      END DO
```

8.27.2.11 real(kind=8) function, public util::mat_contract (real(kind=8), dimension(:,:) *A*, real(kind=8), dimension(:,:) *B*)

Definition at line 162 of file util.f90.

```
162      REAL(KIND=8), DIMENSION(:,:) :: a,b
163      REAL(KIND=8) :: mat_contract
164      INTEGER :: i,j,n
165      n=size(a,1)
166      mat_contract=0.d0
167      DO i=1,n
168         DO j=1,n
169            mat_contract=mat_contract+a(i,j)*b(i,j)
170         END DO
171      ENDDO
172      RETURN
```

8.27.2.12 real(kind=8) function, public util::mat_trace (real(kind=8), dimension(:,:) *A*)

Definition at line 150 of file util.f90.

```
150      REAL(KIND=8), DIMENSION(:,:) :: a
151      REAL(KIND=8) :: mat_trace
152      INTEGER :: i,n
153      n=size(a,1)
154      mat_trace=0.d0
155      DO i=1,n
156         mat_trace=mat_trace+a(i,i)
157      END DO
158      RETURN
```

8.27.2.13 subroutine, public util::piksrt (integer, intent(in) *k*, integer, dimension(k), intent(inout) *arr*, integer, intent(out) *par*)

Simple card player sorting function.

Definition at line 118 of file util.f90.

```
118     INTEGER, INTENT(IN) :: k
119     INTEGER, DIMENSION(k), INTENT(INOUT) :: arr
120     INTEGER, INTENT(OUT) :: par
121     INTEGER :: i,j,a,b
122
123     par=1
124
125     DO j=2,k
126        a=arr(j)
127        DO i=j-1,1,-1
128           if(arr(i).le.a) EXIT
129           arr(i+1)=arr(i)
130           par=-par
131        END DO
132        arr(i+1)=a
133     ENDDO
134     RETURN
```

8.27.2.14 subroutine, public util::printmat (real(kind=8), dimension(:,:), intent(in) *A*)

Definition at line 200 of file util.f90.

```
200     REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
201     INTEGER :: i
202
203     DO i=1,SIZE(a,1)
204        print*, a(i,:)
205     END DO
```

8.27.2.15 subroutine, public util::reduce (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *Ared*, integer, intent(out) *n*, integer, dimension(:), intent(out) *ind*, integer, dimension(:), intent(out) *rind*)

Definition at line 286 of file util.f90.

```
286     REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
287     REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: ared
288     INTEGER, INTENT(OUT) :: n
289     INTEGER, DIMENSION(:), INTENT(OUT) :: ind,rind
290     LOGICAL, DIMENSION(SIZE(A,1)) :: sel
291     INTEGER :: i,j
292
293     ind=0
294     rind=0
295     sel=.false.
296     n=0
297     DO i=1,SIZE(a,1)
298        IF (any(a(i,:)/=0)) THEN
299           n=n+1
300           sel(i)=.true.
301           ind(n)=i
302           rind(i)=n
303        ENDIF
304     END DO
305     ared=0.d0
306     DO i=1,SIZE(a,1)
307        DO j=1,SIZE(a,1)
308           IF (sel(i).and.sel(j)) ared(rind(i),rind(j))=a(i,j)
309        ENDDO
310     ENDDO
```

8.27.2.16 character(len=40) function, public util::rstr (real(kind=8), intent(in) *x*, character(len=20), intent(in) *fm*)

Convert a real to string with a given format.

Definition at line 38 of file util.f90.

```
38      REAL(KIND=8), INTENT(IN) :: x
39      CHARACTER(len=20), INTENT(IN) :: fm
40      WRITE (rstr, trim(adjustl(fm))) x
41      rstr = adjustl(rstr)
```

8.27.2.17 character(len=20) function, public util::str (integer, intent(in) *k*)

Convert an integer to string.

Definition at line 31 of file util.f90.

```
31      INTEGER, INTENT(IN) :: k
32      WRITE (str, *) k
33      str = adjustl(str)
```

8.27.2.18 subroutine, public util::triu (real(kind=8), dimension(:,:), intent(in) *A*, real(kind=8), dimension(:,:), intent(out) *T*)

Definition at line 247 of file util.f90.

```
247      REAL(KIND=8), DIMENSION(:,:), INTENT(IN) :: a
248      REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: t
249      INTEGER i,j
250      t=0.d0
251      DO i=1,SIZE(a,1)
252         DO j=i,SIZE(a,1)
253            t(i,j)=a(i,j)
254         END DO
255      END DO
```

8.27.2.19 subroutine, public util::vector_outer (real(kind=8), dimension(:), intent(in) *u*, real(kind=8), dimension(:), intent(in) *v*, real(kind=8), dimension(:,:), intent(out) *A*)

Definition at line 328 of file util.f90.

```
328      REAL(KIND=8), DIMENSION(:), INTENT(IN) :: u,v
329      REAL(KIND=8), DIMENSION(:,:), INTENT(OUT) :: a
330      INTEGER :: i,j
331
332      a=0.d0
333      DO i=1,SIZE(u)
334         DO j=1,SIZE(v)
335            a(i,j)=u(i)*v(j)
336         ENDDO
337      ENDDO
```

8.28 wl_tensor Module Reference

The WL tensors used to integrate the model.

Functions/Subroutines

- subroutine, public init_wl_tensor

    Subroutine to initialise the WL tensor.

Variables

- real(kind=8), dimension(:), allocatable, public m11

    First component of the M1 term.
- type(coolist), dimension(:), allocatable, public m12

    Second component of the M1 term.
- real(kind=8), dimension(:), allocatable, public m13

    Third component of the M1 term.
- real(kind=8), dimension(:), allocatable, public m1tot

    Total M_1 vector.
- type(coolist), dimension(:), allocatable, public m21

    First tensor of the M2 term.
- type(coolist), dimension(:), allocatable, public m22

    Second tensor of the M2 term.
- type(coolist), dimension(:,:), allocatable, public l1

    First linear tensor.
- type(coolist), dimension(:,:), allocatable, public l2

    Second linear tensor.
- type(coolist), dimension(:,:), allocatable, public l4

    Fourth linear tensor.
- type(coolist), dimension(:,:), allocatable, public l5

    Fifth linear tensor.
- type(coolist), dimension(:,:), allocatable, public ltot

    Total linear tensor.
- type(coolist), dimension(:,:), allocatable, public b1

    First quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public b2

    Second quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public b3

    Third quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public b4

    Fourth quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public b14

    Joint 1st and 4th tensors.
- type(coolist), dimension(:,:), allocatable, public b23

    Joint 2nd and 3rd tensors.
- type(coolist4), dimension(:,:), allocatable, public mtot

    Tensor for the cubic terms.
- real(kind=8), dimension(:), allocatable dumb_vec

    Dummy vector.
- real(kind=8), dimension(:,:), allocatable dumb_mat1

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat2

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable dumb_mat3

Dummy matrix.

- real(kind=8), dimension(:,:), allocatable dumb_mat4

  Dummy matrix.

- logical, public m12def
- logical, public m21def
- logical, public m22def
- logical, public ldef
- logical, public b14def
- logical, public b23def
- logical, public mdef

  Boolean to (de)activate the computation of the terms.

8.28.1 Detailed Description

The WL tensors used to integrate the model.

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Remarks

8.28.2 Function/Subroutine Documentation

8.28.2.1 subroutine, public wl_tensor::init_wl_tensor ( )

Subroutine to initialise the WL tensor.

Definition at line 94 of file WL_tensor.f90.

```
94      INTEGER :: allocstat,i,j,k,m
95
96      print*, 'Initializing the decompostion tensors...'
97      CALL init_dec_tensor
98      print*, "Initializing the correlation matrices and tensors..."
99      CALL init_corr_tensor
100
101      !M1 part
102      print*, "Computing the M1 terms..."
103
104      ALLOCATE(m11(0:ndim), m12(ndim), m13(0:ndim), m1tot(0:ndim),
     stat=allocstat)
105      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
106
107      ALLOCATE(dumb_mat1(ndim,ndim), dumb_mat2(ndim,ndim), stat=allocstat)
108      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
109
110      ALLOCATE(dumb_mat3(ndim,ndim), dumb_mat4(ndim,ndim), stat=allocstat)
111      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
112
113      ALLOCATE(dumb_vec(ndim), stat=allocstat)
114      IF (allocstat /= 0) stop "*** Not enough memory ! ***"
115
116      !M11
117      m11=0.d0
118      ! CALL coo_to_mat_ik(Lxy,dumb_mat1)
119      ! M11(1:ndim)=matmul(dumb_mat1,mean_full(1:ndim))
120
121      !M12
```

```
    ! dumb_mat2=0.D0
    ! DO i=1,ndim
    !    CALL coo_to_mat_i(i,Bxxy,dumb_mat1)
    !    dumb_mat2(i,:)=matmul(dumb_mat1,mean_full(1:ndim))
    ! ENDDO
    ! CALL matc_to_coo(dumb_mat2,M12)

    m12def=.not.tensor_empty(m12)

    !M13
    m13=0.d0
    CALL sparse_mul3_with_mat(bxyy,corr_i_full,m13)

    !M1tot
    m1tot=0.d0
    m1tot=m11+m13

    print*, "Computing the M2 terms..."
    ALLOCATE(m21(ndim), m22(ndim), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    !M21
    CALL copy_coo(lxy,m21)
    CALL add_to_tensor(bxxy,m21)

    m21def=.not.tensor_empty(m21)

    !M22
    CALL copy_coo(bxyy,m22)

    m22def=.not.tensor_empty(m22)

    !M3 tensor
    print*, "Computing the M3 terms..."
    ! Linear terms
    print*, "Computing the L subterms..."
    ALLOCATE(l1(ndim,mems), l2(ndim,mems), l4(ndim,mems), l5(ndim,mems),
  stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    !L1
    CALL coo_to_mat_ik(lyx,dumb_mat1)
    CALL coo_to_mat_ik(lxy,dumb_mat2)
    DO m=1,mems
       CALL coo_to_mat_ik(dy(:,m),dumb_mat3)
       dumb_mat4=matmul(dumb_mat2,matmul(transpose(dumb_mat3),dumb_mat1))
       CALL matc_to_coo(dumb_mat4,l1(:,m))
    ENDDO

    !L2
    DO m=1,mems
       dumb_mat4=0.d0
       DO i=1,ndim
          CALL coo_to_mat_i(i,bxyy,dumb_mat1)
          CALL sparse_mul4_with_mat_kl(ydyy(:,m),dumb_mat1,dumb_mat2)
          DO j=1,ndim
             CALL coo_to_mat_j(j,byxy,dumb_mat1)
             dumb_mat4(i,j)=mat_trace(matmul(dumb_mat1,dumb_mat2))
          ENDDO
       END DO
       CALL matc_to_coo(dumb_mat4,l2(:,m))
    ENDDO

    !L4
    ! DO m=1,mems
    !    dumb_mat4=0.D0
    !    DO i=1,ndim
    !       CALL coo_to_mat_i(i,Bxyy,dumb_mat1)
    !       CALL sparse_mul3_with_mat(dYY(:,m),dumb_mat1,dumb_vec) ! Bxyy*dYY
    !       CALL coo_to_mat_ik(Lyx,dumb_mat1)
    !       dumb_mat4(i,:)=matmul(transpose(dumb_mat1),dumb_vec)
    !    ENDDO
    !    CALL matc_to_coo(dumb_mat4,L4(:,m))
    ! ENDDO

    !L5

    ! CALL coo_to_mat_ik(Lxy,dumb_mat1)
    ! DO m=1,mems
    !    dumb_mat4=0.D0
    !    DO i=1,ndim
    !       CALL sparse_mul3_mat(YdY(:,m),dumb_mat1(i,:),dumb_mat2)
    !       DO j=1,ndim
    !          CALL coo_to_mat_j(j,Byxy,dumb_mat3)
    !          dumb_mat4(i,j)=mat_trace(matmul(dumb_mat3,dumb_mat2))
    !       ENDDO
    !    END DO
```

```
   !    CALL matc_to_coo(dumb_mat4,L5(:,m))
   ! ENDDO

   !Ltot

   ALLOCATE(ltot(ndim,mems), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   DO m=1,mems
      CALL add_to_tensor(l1(:,m),ltot(:,m))
      CALL add_to_tensor(l2(:,m),ltot(:,m))
      CALL add_to_tensor(l4(:,m),ltot(:,m))
      CALL add_to_tensor(l5(:,m),ltot(:,m))
   ENDDO

   ldef=.not.tensor_empty(ltot)

   print*, "Computing the B terms..."
   ALLOCATE(b1(ndim,mems), b2(ndim,mems), b3(ndim,mems), b4(ndim,mems),
 stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   ! B1
   CALL coo_to_mat_ik(lxy,dumb_mat1)
   dumb_mat1=transpose(dumb_mat1)
   DO m=1,mems
      CALL coo_to_mat_ik(dy(:,m),dumb_mat2)
      dumb_mat2=matmul(dumb_mat2,dumb_mat1)
      DO j=1,ndim
         DO k=1,ndim
            CALL coo_to_vec_jk(j,k,byxx,dumb_vec)
            dumb_vec=matmul(dumb_vec,dumb_mat2)
            CALL add_vec_jk_to_tensor(j,k,dumb_vec,b1(:,m))
         ENDDO
      ENDDO
   ENDDO

   ! B2
   CALL coo_to_mat_ik(lyx,dumb_mat3)
   dumb_mat3=transpose(dumb_mat3)
   DO m=1,mems
      DO i=1,ndim
         CALL coo_to_mat_i(i,bxxy,dumb_mat1)
         CALL coo_to_mat_ik(dy(:,m),dumb_mat2)
         dumb_mat1=matmul(dumb_mat2,transpose(dumb_mat1))
         dumb_mat1=matmul(dumb_mat3,dumb_mat1)
         CALL add_matc_to_tensor(i,dumb_mat1,b2(:,m))
      ENDDO
   ENDDO

   ! B3
   ! DO m=1,mems
   !    DO i=1,ndim
   !       CALL coo_to_mat_i(i,Bxxy,dumb_mat1)
   !       dumb_mat4=0.D0
   !       DO j=1,ndim
   !          CALL coo_to_mat_j(j,YdY(:,m),dumb_mat2)
   !          CALL coo_to_mat_i(j,Byxy,dumb_mat3)
   !          dumb_mat2=matmul(dumb_mat3,dumb_mat2)
   !          dumb_mat4=dumb_mat4+dumb_mat2
   !       ENDDO
   !       dumb_mat4=matmul(dumb_mat4,transpose(dumb_mat1))
   !       CALL add_matc_to_tensor(i,dumb_mat4,B3(:,m))
   !    ENDDO
   ! ENDDO

   ! B4
   ! DO m=1,mems
   !    DO i=1,ndim
   !       CALL coo_to_mat_i(i,Bxyy,dumb_mat1)
   !       CALL sparse_mul3_with_mat(dYY(:,m),dumb_mat1,dumb_vec) ! Bxyy*dYY
   !       DO j=1,ndim
   !          CALL coo_to_mat_j(j,Byxx,dumb_mat1)
   !          dumb_mat4(j,:)=matmul(transpose(dumb_mat1),dumb_vec)
   !       ENDDO
   !       CALL add_matc_to_tensor(i,dumb_mat4,B4(:,m))
   !    ENDDO
   ! ENDDO

   ALLOCATE(b14(ndim,mems), b23(ndim,mems), stat=allocstat)
   IF (allocstat /= 0) stop "*** Not enough memory ! ***"

   DO m=1,mems
      CALL add_to_tensor(b1(:,m),b14(:,m))
      CALL add_to_tensor(b2(:,m),b23(:,m))
      CALL add_to_tensor(b4(:,m),b14(:,m))
      CALL add_to_tensor(b3(:,m),b23(:,m))
```

```
    ENDDO

    b14def=.not.tensor_empty(b14)
    b23def=.not.tensor_empty(b23)

    !M

    print*, "Computing the M term..."

    ALLOCATE(mtot(ndim,mems), stat=allocstat)
    IF (allocstat /= 0) stop "*** Not enough memory ! ***"

    DO m=1,mems
       DO i=1,ndim
          CALL coo_to_mat_i(i,bxxy,dumb_mat1)
          CALL coo_to_mat_ik(dy(:,m),dumb_mat2)
          dumb_mat1=matmul(dumb_mat2,transpose(dumb_mat1))
          DO j=1,ndim
             DO k=1,ndim
                CALL coo_to_vec_jk(j,k,byxx,dumb_vec)
                dumb_vec=matmul(dumb_vec,dumb_mat1)
                CALL add_vec_ijk_to_tensor4(i,j,k,dumb_vec,mtot(:,m))
             ENDDO
          END DO
       END DO
    END DO

    mdef=.not.tensor4_empty(mtot)


    DEALLOCATE(dumb_mat1, dumb_mat2, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    DEALLOCATE(dumb_mat3, dumb_mat4, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"

    DEALLOCATE(dumb_vec, stat=allocstat)
    IF (allocstat /= 0)  stop "*** Problem to deallocate ! ***"
```

8.28.3 Variable Documentation

8.28.3.1 type(coolist), dimension(:,:), allocatable, public wl_tensor::b1

First quadratic tensor.

Definition at line 60 of file WL_tensor.f90.

```
60   TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b1    !< First quadratic tensor
```

8.28.3.2 type(coolist), dimension(:,:), allocatable, public wl_tensor::b14

Joint 1st and 4th tensors.

Definition at line 64 of file WL_tensor.f90.

```
64   TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b14   !< Joint 1st and 4th tensors
```

8.28.3.3 logical, public wl_tensor::b14def

Definition at line 75 of file WL_tensor.f90.

8.28.3.4 type(coolist), dimension(:,:), allocatable, public wl_tensor::b2

Second quadratic tensor.

Definition at line 61 of file WL_tensor.f90.

```
61    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b2    !< Second quadratic tensor
```

8.28.3.5 type(coolist), dimension(:,:), allocatable, public wl_tensor::b23

Joint 2nd and 3rd tensors.

Definition at line 65 of file WL_tensor.f90.

```
65    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b23   !< Joint 2nd and 3rd tensors
```

8.28.3.6 logical, public wl_tensor::b23def

Definition at line 75 of file WL_tensor.f90.

8.28.3.7 type(coolist), dimension(:,:), allocatable, public wl_tensor::b3

Third quadratic tensor.

Definition at line 62 of file WL_tensor.f90.

```
62    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b3    !< Third quadratic tensor
```

8.28.3.8 type(coolist), dimension(:,:), allocatable, public wl_tensor::b4

Fourth quadratic tensor.

Definition at line 63 of file WL_tensor.f90.

```
63    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: b4    !< Fourth quadratic tensor
```

8.28.3.9 real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat1 [private]

Dummy matrix.

Definition at line 70 of file WL_tensor.f90.

```
70    REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat1 !< Dummy matrix
```

8.28.3.10 real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat2 [private]

Dummy matrix.

Definition at line 71 of file WL_tensor.f90.

```
71 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat2 !< Dummy matrix
```

8.28.3.11 real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat3 [private]

Dummy matrix.

Definition at line 72 of file WL_tensor.f90.

```
72 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat3 !< Dummy matrix
```

8.28.3.12 real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat4 [private]

Dummy matrix.

Definition at line 73 of file WL_tensor.f90.

```
73 REAL(KIND=8), DIMENSION(:,:), ALLOCATABLE :: dumb_mat4 !< Dummy matrix
```

8.28.3.13 real(kind=8), dimension(:), allocatable wl_tensor::dumb_vec [private]

Dummy vector.

Definition at line 69 of file WL_tensor.f90.

```
69 REAL(KIND=8), DIMENSION(:), ALLOCATABLE :: dumb_vec !< Dummy vector
```

8.28.3.14 type(coolist), dimension(:,:), allocatable, public wl_tensor::l1

First linear tensor.

Definition at line 53 of file WL_tensor.f90.

```
53 TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: l1    !< First linear tensor
```

8.28.3.15 type(coolist), dimension(:,:), allocatable, public wl_tensor::l2

Second linear tensor.

Definition at line 54 of file WL_tensor.f90.

```
54    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: l2    !< Second linear tensor
```

8.28.3.16 type(coolist), dimension(:,:), allocatable, public wl_tensor::l4

Fourth linear tensor.

Definition at line 55 of file WL_tensor.f90.

```
55    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: l4    !< Fourth linear tensor
```

8.28.3.17 type(coolist), dimension(:,:), allocatable, public wl_tensor::l5

Fifth linear tensor.

Definition at line 56 of file WL_tensor.f90.

```
56    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: l5    !< Fifth linear tensor
```

8.28.3.18 logical, public wl_tensor::ldef

Definition at line 75 of file WL_tensor.f90.

8.28.3.19 type(coolist), dimension(:,:), allocatable, public wl_tensor::ltot

Total linear tensor.

Definition at line 57 of file WL_tensor.f90.

```
57    TYPE(coolist), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: ltot  !< Total linear tensor
```

8.28.3.20 real(kind=8), dimension(:), allocatable, public wl_tensor::m11

First component of the M1 term.

Definition at line 42 of file WL_tensor.f90.

```
42    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: m11    !< First component of the M1 term
```

8.28.3.21 type(coolist), dimension(:), allocatable, public wl_tensor::m12

Second component of the M1 term.

Definition at line 43 of file WL_tensor.f90.

```
43    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: m12   !< Second component of the M1 term
```

8.28.3.22 logical, public wl_tensor::m12def

Definition at line 75 of file WL_tensor.f90.

```
75    LOGICAL, PUBLIC :: m12def,m21def,m22def,ldef,b14def,b23def,mdef !< Boolean to (de)activate the
        computation of the terms
```

8.28.3.23 real(kind=8), dimension(:), allocatable, public wl_tensor::m13

Third component of the M1 term.

Definition at line 44 of file WL_tensor.f90.

```
44    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: m13    !< Third component of the M1 term
```

8.28.3.24 real(kind=8), dimension(:), allocatable, public wl_tensor::m1tot

Total M_1 vector.

Definition at line 45 of file WL_tensor.f90.

```
45    REAL(KIND=8), DIMENSION(:), ALLOCATABLE, PUBLIC :: m1tot  !< Total \f$M_1\f$ vector
```

8.28.3.25 type(coolist), dimension(:), allocatable, public wl_tensor::m21

First tensor of the M2 term.

Definition at line 48 of file WL_tensor.f90.

```
48    TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: m21   !< First tensor of the M2 term
```

8.28.3.26 logical, public wl_tensor::m21def

Definition at line 75 of file WL_tensor.f90.

8.28.3.27 type(coolist), dimension(:), allocatable, public wl_tensor::m22

Second tensor of the M2 term.

Definition at line 49 of file WL_tensor.f90.

```
49 TYPE(coolist), DIMENSION(:), ALLOCATABLE, PUBLIC :: m22   !< Second tensor of the M2 term
```

8.28.3.28 logical, public wl_tensor::m22def

Definition at line 75 of file WL_tensor.f90.

8.28.3.29 logical, public wl_tensor::mdef

Boolean to (de)activate the computation of the terms.

Definition at line 75 of file WL_tensor.f90.

8.28.3.30 type(coolist4), dimension(:,:), allocatable, public wl_tensor::mtot

Tensor for the cubic terms.

Definition at line 67 of file WL_tensor.f90.

```
67 TYPE(coolist4), DIMENSION(:,:), ALLOCATABLE, PUBLIC :: mtot !< Tensor for the cubic terms
```

Chapter 9

Data Type Documentation

9.1 inprod_analytic::atm_tensors Type Reference

Type holding the atmospheric inner products tensors.

Private Attributes

- procedure(calculate_a), pointer, nopass a
- procedure(calculate_b), pointer, nopass b
- procedure(calculate_c_atm), pointer, nopass c
- procedure(calculate_d), pointer, nopass d
- procedure(calculate_g), pointer, nopass g
- procedure(calculate_s), pointer, nopass s

9.1.1 Detailed Description

Type holding the atmospheric inner products tensors.

Definition at line 53 of file inprod_analytic.f90.

9.1.2 Member Data Documentation

9.1.2.1 procedure(calculate_a), pointer, nopass inprod_analytic::atm_tensors::a [private]

Definition at line 54 of file inprod_analytic.f90.

```
54      PROCEDURE(calculate_a), POINTER, NOPASS :: a
```

9.1.2.2 procedure(calculate_b), pointer, nopass inprod_analytic::atm_tensors::b [private]

Definition at line 55 of file inprod_analytic.f90.

```
55      PROCEDURE(calculate_b), POINTER, NOPASS :: b
```

9.1.2.3 procedure(calculate_c_atm), pointer, nopass inprod_analytic::atm_tensors::c [private]

Definition at line 56 of file inprod_analytic.f90.

```
56      PROCEDURE(calculate_c_atm), POINTER, NOPASS :: c
```

9.1.2.4 procedure(calculate_d), pointer, nopass inprod_analytic::atm_tensors::d [private]

Definition at line 57 of file inprod_analytic.f90.

```
57      PROCEDURE(calculate_d), POINTER, NOPASS :: d
```

9.1.2.5 procedure(calculate_g), pointer, nopass inprod_analytic::atm_tensors::g [private]

Definition at line 58 of file inprod_analytic.f90.

```
58      PROCEDURE(calculate_g), POINTER, NOPASS :: g
```

9.1.2.6 procedure(calculate_s), pointer, nopass inprod_analytic::atm_tensors::s [private]

Definition at line 59 of file inprod_analytic.f90.

```
59      PROCEDURE(calculate_s), POINTER, NOPASS :: s
```

The documentation for this type was generated from the following file:

- inprod_analytic.f90

9.2 inprod_analytic::atm_wavenum Type Reference

Atmospheric bloc specification type.

Private Attributes

- character typ
- integer m =0
- integer p =0
- integer h =0
- real(kind=8) nx =0.
- real(kind=8) ny =0.

9.2.1 Detailed Description

Atmospheric bloc specification type.

Definition at line 40 of file inprod_analytic.f90.

9.2.2 Member Data Documentation

9.2.2.1 integer inprod_analytic::atm_wavenum::h =0 [private]

Definition at line 42 of file inprod_analytic.f90.

9.2.2.2 integer inprod_analytic::atm_wavenum::m =0 [private]

Definition at line 42 of file inprod_analytic.f90.

```
42      INTEGER :: m=0,p=0,h=0
```

9.2.2.3 real(kind=8) inprod_analytic::atm_wavenum::nx =0. [private]

Definition at line 43 of file inprod_analytic.f90.

```
43      REAL(KIND=8) :: nx=0.,ny=0.
```

9.2.2.4 real(kind=8) inprod_analytic::atm_wavenum::ny =0. [private]

Definition at line 43 of file inprod_analytic.f90.

9.2.2.5 integer inprod_analytic::atm_wavenum::p =0 [private]

Definition at line 42 of file inprod_analytic.f90.

9.2.2.6 character inprod_analytic::atm_wavenum::typ [private]

Definition at line 41 of file inprod_analytic.f90.

```
41      CHARACTER :: typ
```

The documentation for this type was generated from the following file:

- inprod_analytic.f90

9.3 tensor::coolist Type Reference

Coordinate list. Type used to represent the sparse tensor.

Public Attributes

- type(coolist_elem), dimension(:), allocatable elems

  Lists of elements tensor::coolist_elem.
- integer nelems = 0

  Number of elements in the list.

9.3.1 Detailed Description

Coordinate list. Type used to represent the sparse tensor.

Definition at line 38 of file tensor.f90.

9.3.2 Member Data Documentation

9.3.2.1 type(coolist_elem), dimension(:), allocatable tensor::coolist::elems

Lists of elements tensor::coolist_elem.

Definition at line 39 of file tensor.f90.

```
39      TYPE(coolist_elem), DIMENSION(:), ALLOCATABLE :: elems !< Lists of elements
       tensor::coolist_elem
```

9.3.2.2 integer tensor::coolist::nelems = 0

Number of elements in the list.

Definition at line 40 of file tensor.f90.

```
40      INTEGER :: nelems = 0 !< Number of elements in the list.
```

The documentation for this type was generated from the following file:

- tensor.f90

9.4 tensor::coolist4 Type Reference

4d coordinate list. Type used to represent the rank-4 sparse tensor.

Public Attributes

- type(coolist_elem4), dimension(:), allocatable elems
- integer nelems = 0

9.4.1 Detailed Description

4d coordinate list. Type used to represent the rank-4 sparse tensor.

Definition at line 44 of file tensor.f90.

9.4.2 Member Data Documentation

9.4.2.1 type(coolist_elem4), dimension(:), allocatable tensor::coolist4::elems

Definition at line 45 of file tensor.f90.

```
45       TYPE(coolist_elem4), DIMENSION(:), ALLOCATABLE :: elems
```

9.4.2.2 integer tensor::coolist4::nelems = 0

Definition at line 46 of file tensor.f90.

```
46       INTEGER :: nelems = 0
```

The documentation for this type was generated from the following file:

- tensor.f90

9.5 tensor::coolist_elem Type Reference

Coordinate list element type. Elementary elements of the sparse tensors.

Private Attributes

- integer j

  Index j of the element.
- integer k

  Index k of the element.
- real(kind=8) v

  Value of the element.

9.5.1 Detailed Description

Coordinate list element type. Elementary elements of the sparse tensors.

Definition at line 25 of file tensor.f90.

9.5.2 Member Data Documentation

9.5.2.1 integer tensor::coolist_elem::j [private]

Index j of the element.

Definition at line 26 of file tensor.f90.

```
26      INTEGER :: j !< Index \f$j\f$ of the element
```

9.5.2.2 integer tensor::coolist_elem::k [private]

Index k of the element.

Definition at line 27 of file tensor.f90.

```
27      INTEGER :: k !< Index \f$k\f$ of the element
```

9.5.2.3 real(kind=8) tensor::coolist_elem::v [private]

Value of the element.

Definition at line 28 of file tensor.f90.

```
28      REAL(KIND=8) :: v !< Value of the element
```

The documentation for this type was generated from the following file:

- tensor.f90

9.6 tensor::coolist_elem4 Type Reference

4d coordinate list element type. Elementary elements of the 4d sparse tensors.

Private Attributes

- integer j
- integer k
- integer l
- real(kind=8) v

9.6.1 Detailed Description

4d coordinate list element type. Elementary elements of the 4d sparse tensors.

Definition at line 32 of file tensor.f90.

9.6.2 Member Data Documentation

9.6.2.1 integer tensor::coolist_elem4::j [private]

Definition at line 33 of file tensor.f90.

```
33      INTEGER :: j,k,l
```

9.6.2.2 integer tensor::coolist_elem4::k [private]

Definition at line 33 of file tensor.f90.

9.6.2.3 integer tensor::coolist_elem4::l [private]

Definition at line 33 of file tensor.f90.

9.6.2.4 real(kind=8) tensor::coolist_elem4::v [private]

Definition at line 34 of file tensor.f90.

```
34      REAL(KIND=8) :: v
```

The documentation for this type was generated from the following file:

- tensor.f90

9.7 inprod_analytic::ocean_tensors Type Reference

Type holding the oceanic inner products tensors.

Private Attributes

- procedure(calculate_k), pointer, nopass k
- procedure(calculate_m), pointer, nopass m
- procedure(calculate_c_oc), pointer, nopass c
- procedure(calculate_n), pointer, nopass n
- procedure(calculate_o), pointer, nopass o
- procedure(calculate_w), pointer, nopass w

9.7.1 Detailed Description

Type holding the oceanic inner products tensors.

Definition at line 63 of file inprod_analytic.f90.

9.7.2 Member Data Documentation

9.7.2.1 procedure(calculate_c_oc), pointer, nopass inprod_analytic::ocean_tensors::c [private]

Definition at line 66 of file inprod_analytic.f90.

```
66     PROCEDURE(calculate_c_oc), POINTER, NOPASS :: c
```

9.7.2.2 procedure(calculate_k), pointer, nopass inprod_analytic::ocean_tensors::k [private]

Definition at line 64 of file inprod_analytic.f90.

```
64     PROCEDURE(calculate_k), POINTER, NOPASS :: k
```

9.7.2.3 procedure(calculate_m), pointer, nopass inprod_analytic::ocean_tensors::m [private]

Definition at line 65 of file inprod_analytic.f90.

```
65     PROCEDURE(calculate_m), POINTER, NOPASS :: m
```

9.7.2.4 procedure(calculate_n), pointer, nopass inprod_analytic::ocean_tensors::n [private]

Definition at line 67 of file inprod_analytic.f90.

```
67     PROCEDURE(calculate_n), POINTER, NOPASS :: n
```

9.7.2.5 procedure(calculate_o), pointer, nopass inprod_analytic::ocean_tensors::o [private]

Definition at line 68 of file inprod_analytic.f90.

```
68      PROCEDURE(calculate_o), POINTER, NOPASS :: o
```

9.7.2.6 procedure(calculate_w), pointer, nopass inprod_analytic::ocean_tensors::w [private]

Definition at line 69 of file inprod_analytic.f90.

```
69      PROCEDURE(calculate_w), POINTER, NOPASS :: w
```

The documentation for this type was generated from the following file:

- inprod_analytic.f90

9.8 inprod_analytic::ocean_wavenum Type Reference

Oceanic bloc specification type.

Private Attributes

- integer p
- integer h
- real(kind=8) nx
- real(kind=8) ny

9.8.1 Detailed Description

Oceanic bloc specification type.

Definition at line 47 of file inprod_analytic.f90.

9.8.2 Member Data Documentation

9.8.2.1 integer inprod_analytic::ocean_wavenum::h [private]

Definition at line 48 of file inprod_analytic.f90.

9.8.2.2 real(kind=8) inprod_analytic::ocean_wavenum::nx [private]

Definition at line 49 of file inprod_analytic.f90.

```
49      REAL(KIND=8) :: nx,ny
```

9.8.2.3 real(kind=8) inprod_analytic::ocean_wavenum::ny [private]

Definition at line 49 of file inprod_analytic.f90.

9.8.2.4 integer inprod_analytic::ocean_wavenum::p [private]

Definition at line 48 of file inprod_analytic.f90.

```
48      INTEGER :: p,h
```

The documentation for this type was generated from the following file:

- inprod_analytic.f90

Chapter 10

File Documentation

10.1 aotensor_def.f90 File Reference

Modules

- module aotensor_def

  The equation tensor for the coupled ocean-atmosphere model with temperature which allows for an extensible set of modes in the ocean and in the atmosphere.

Functions/Subroutines

- integer function aotensor_def::psi (i)

  Translate the $\psi_{a,i}$ coefficients into effective coordinates.
- integer function aotensor_def::theta (i)

  Translate the $\theta_{a,i}$ coefficients into effective coordinates.
- integer function aotensor_def::a (i)

  Translate the $\psi_{o,i}$ coefficients into effective coordinates.
- integer function aotensor_def::t (i)

  Translate the $\delta T_{o,i}$ coefficients into effective coordinates.
- integer function aotensor_def::kdelta (i, j)

  Kronecker delta function.
- subroutine aotensor_def::coeff (i, j, k, v)

  Subroutine to add element in the aotensor $\mathcal{T}_{i,j,k}$ structure.
- subroutine aotensor_def::add_count (i, j, k, v)

  Subroutine to count the elements of the aotensor $\mathcal{T}_{i,j,k}$. Add +1 to count_elems(i) for each value that is added to the tensor i-th component.
- subroutine aotensor_def::compute_aotensor (func)

  Subroutine to compute the tensor aotensor.
- subroutine, public aotensor_def::init_aotensor

  Subroutine to initialise the aotensor tensor.

Variables

- integer, dimension(:), allocatable aotensor_def::count_elems

  Vector used to count the tensor elements.
- real(kind=8), parameter aotensor_def::real_eps = 2.2204460492503131e-16

  Epsilon to test equality with 0.
- type(coolist), dimension(:), allocatable, public aotensor_def::aotensor

  $\mathcal{T}_{i,j,k}$ *- Tensor representation of the tendencies.*

10.2 corr_tensor.f90 File Reference

Modules

- module corr_tensor

  Module to compute the correlations and derivatives used to compute the memory term of the WL parameterization.

Functions/Subroutines

- subroutine, public corr_tensor::init_corr_tensor

  Subroutine to initialise the correlations tensors.

Variables

- type(coolist), dimension(:,:), allocatable, public corr_tensor::yy

  Coolist holding the $\langle Y \otimes Y^s \rangle$ *terms.*
- type(coolist), dimension(:,:), allocatable, public corr_tensor::dy

  Coolist holding the $\langle \partial_Y \otimes Y^s \rangle$ *terms.*
- type(coolist), dimension(:,:), allocatable, public corr_tensor::ydy

  Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \rangle$ *terms.*
- type(coolist), dimension(:,:), allocatable, public corr_tensor::dyy

  Coolist holding the $\langle \partial_Y \otimes Y^s \otimes Y^s \rangle$ *terms.*
- type(coolist4), dimension(:,:), allocatable, public corr_tensor::ydyy

  Coolist holding the $\langle Y \otimes \partial_Y \otimes Y^s \otimes Y^s \rangle$ *terms.*
- real(kind=8), dimension(:), allocatable corr_tensor::dumb_vec

  Dumb vector to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable corr_tensor::dumb_mat1

  Dumb matrix to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable corr_tensor::dumb_mat2

  Dumb matrix to be used in the calculation.
- real(kind=8), dimension(:,:), allocatable corr_tensor::expm

  Matrix holding the product inv_corr_i$*$corr_ij at time s.

10.3 corrmod.f90 File Reference

Modules

- module corrmod

  Module to initialize the correlation matrix of the unresolved variables.

Functions/Subroutines

- subroutine, public corrmod::init_corr

    Subroutine to initialise the computation of the correlation.
- subroutine corrmod::corrcomp_from_def (s)

    Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ *at time* s *from the definition given inside the module.*
- subroutine corrmod::corrcomp_from_spline (s)

    Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ *at time* s *from the spline representation.*
- subroutine corrmod::splint (xa, ya, y2a, n, x, y)

    Routine to compute the spline representation parameters.
- real(kind=8) function corrmod::fs (s, p)

    Exponential fit function.
- subroutine corrmod::corrcomp_from_fit (s)

    Subroutine to compute the correlation of the unresolved variables $\langle Y \otimes Y^s \rangle$ *at time* s *from the exponential representation.*

Variables

- real(kind=8), dimension(:), allocatable, public corrmod::mean

    Vector holding the mean of the unresolved dynamics (reduced version)
- real(kind=8), dimension(:), allocatable, public corrmod::mean_full

    Vector holding the mean of the unresolved dynamics (full version)
- real(kind=8), dimension(:,:), allocatable, public corrmod::corr_i_full

    Covariance matrix of the unresolved variables (full version)
- real(kind=8), dimension(:,:), allocatable, public corrmod::inv_corr_i_full

    Inverse of the covariance matrix of the unresolved variables (full version)
- real(kind=8), dimension(:,:), allocatable, public corrmod::corr_i

    Covariance matrix of the unresolved variables (reduced version)
- real(kind=8), dimension(:,:), allocatable, public corrmod::inv_corr_i

    Inverse of the covariance matrix of the unresolved variables (reduced version)
- real(kind=8), dimension(:,:), allocatable, public corrmod::corr_ij

    Matrix holding the correlation matrix at a given time.
- real(kind=8), dimension(:,:,:), allocatable corrmod::y2

    Vector holding coefficient of the spline and exponential correlation representation.
- real(kind=8), dimension(:,:,:), allocatable corrmod::ya

    Vector holding coefficient of the spline and exponential correlation representation.
- real(kind=8), dimension(:), allocatable corrmod::xa

    Vector holding coefficient of the spline and exponential correlation representation.
- integer corrmod::nspl

    Integers needed by the spline representation of the correlation.
- integer corrmod::klo
- integer corrmod::khi
- procedure(corrcomp_from_spline), pointer, public corrmod::corrcomp

    Pointer to the correlation computation routine.

10.4 dec_tensor.f90 File Reference

Modules

- module dec_tensor

    The resolved-unresolved components decomposition of the tensor.

Functions/Subroutines

- subroutine dec_tensor::suppress_and (t, cst, v1, v2)

  Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 and SF(k)=v2.
- subroutine dec_tensor::suppress_or (t, cst, v1, v2)

  Subroutine to suppress from the tensor t_{ijk} components satisfying SF(j)=v1 or SF(k)=v2.
- subroutine dec_tensor::reorder (t, cst, v)

  Subroutine to reorder the tensor t_{ijk} components : if SF(j)=v then it return t_{ikj}.
- subroutine dec_tensor::init_sub_tensor (t, cst, v)

  Subroutine that suppress all the components of a tensor t_{ijk} where if SF(i)=v.
- subroutine, public dec_tensor::init_dec_tensor

  Subroutine that initialize and compute the decomposed tensors.

Variables

- type(coolist), dimension(:), allocatable, public dec_tensor::ff_tensor

  Tensor holding the part of the unresolved tensor involving only unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::sf_tensor

  Tensor holding the part of the resolved tensor involving unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::ss_tensor

  Tensor holding the part of the resolved tensor involving only resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::fs_tensor

  Tensor holding the part of the unresolved tensor involving resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::hx

  Tensor holding the constant part of the resolved tendencies.
- type(coolist), dimension(:), allocatable, public dec_tensor::lxx

  Tensor holding the linear part of the resolved tendencies involving the resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::lxy

  Tensor holding the linear part of the resolved tendencies involving the unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::bxxx

  Tensor holding the quadratic part of the resolved tendencies involving resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::bxxy

  Tensor holding the quadratic part of the resolved tendencies involving both resolved and unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::bxyy

  Tensor holding the quadratic part of the resolved tendencies involving unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::hy

  Tensor holding the constant part of the unresolved tendencies.
- type(coolist), dimension(:), allocatable, public dec_tensor::lyx

  Tensor holding the linear part of the unresolved tendencies involving the resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::lyy

  Tensor holding the linear part of the unresolved tendencies involving the unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::byxx

  Tensor holding the quadratic part of the unresolved tendencies involving resolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::byxy

  Tensor holding the quadratic part of the unresolved tendencies involving both resolved and unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::byyy

  Tensor holding the quadratic part of the unresolved tendencies involving unresolved variables.
- type(coolist), dimension(:), allocatable, public dec_tensor::ss_tl_tensor

  Tensor of the tangent linear model tendencies of the resolved component alone.
- type(coolist), dimension(:), allocatable dec_tensor::dumb

  Dumb coolist to make the computations.

10.5 doc/def_doc.md File Reference

10.6 doc/gen_doc.md File Reference

10.7 doc/sto_doc.md File Reference

10.8 doc/tl_ad_doc.md File Reference

10.9 ic_def.f90 File Reference

Modules

- module ic_def
  Module to load the initial condition.

Functions/Subroutines

- subroutine, public ic_def::load_ic
  Subroutine to load the initial condition if IC.nml exists. If it does not, then write IC.nml with 0 as initial condition.

Variables

- logical ic_def::exists
  Boolean to test for file existence.
- real(kind=8), dimension(:), allocatable, public ic_def::ic
  Initial condition vector.

10.10 inprod_analytic.f90 File Reference

Data Types

- type inprod_analytic::atm_wavenum
  Atmospheric bloc specification type.
- type inprod_analytic::ocean_wavenum
  Oceanic bloc specification type.
- type inprod_analytic::atm_tensors
  Type holding the atmospheric inner products tensors.
- type inprod_analytic::ocean_tensors
  Type holding the oceanic inner products tensors.

Modules

- module inprod_analytic

  Inner products between the truncated set of basis functions for the ocean and atmosphere streamfunction fields. These are partly calculated using the analytical expressions from Cehelsky, P., & Tung, K. K. : Theories of multiple equilibria and weather regimes-A critical reexamination. Part II: Baroclinic two-layer models. Journal of the atmospheric sciences, 44(21), 3282-3303, 1987.

Functions/Subroutines

- real(kind=8) function inprod_analytic::b1 (Pi, Pj, Pk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::b2 (Pi, Pj, Pk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::delta (r)

  Integer Dirac delta function.
- real(kind=8) function inprod_analytic::flambda (r)

  "Odd or even" function
- real(kind=8) function inprod_analytic::s1 (Pj, Pk, Mj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::s2 (Pj, Pk, Mj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::s3 (Pj, Pk, Hj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::s4 (Pj, Pk, Hj, Hk)

  Cehelsky & Tung Helper functions.
- real(kind=8) function inprod_analytic::calculate_a (i, j)

  Eigenvalues of the Laplacian (atmospheric)
- real(kind=8) function inprod_analytic::calculate_b (i, j, k)

  Streamfunction advection terms (atmospheric)
- real(kind=8) function inprod_analytic::calculate_c_atm (i, j)

  Beta term for the atmosphere.
- real(kind=8) function inprod_analytic::calculate_d (i, j)

  Forcing of the ocean on the atmosphere.
- real(kind=8) function inprod_analytic::calculate_g (i, j, k)

  Temperature advection terms (atmospheric)
- real(kind=8) function inprod_analytic::calculate_s (i, j)

  Forcing (thermal) of the ocean on the atmosphere.
- real(kind=8) function inprod_analytic::calculate_k (i, j)

  Forcing of the atmosphere on the ocean.
- real(kind=8) function inprod_analytic::calculate_m (i, j)

  Forcing of the ocean fields on the ocean.
- real(kind=8) function inprod_analytic::calculate_n (i, j)

  Beta term for the ocean.
- real(kind=8) function inprod_analytic::calculate_o (i, j, k)

  Temperature advection term (passive scalar)
- real(kind=8) function inprod_analytic::calculate_c_oc (i, j, k)

  Streamfunction advection terms (oceanic)
- real(kind=8) function inprod_analytic::calculate_w (i, j)

  Short-wave radiative forcing of the ocean.
- subroutine, public inprod_analytic::init_inprod

  Initialisation of the inner product.

Variables

- type(atm_wavenum), dimension(:), allocatable, public inprod_analytic::awavenum

  Atmospheric blocs specification.
- type(ocean_wavenum), dimension(:), allocatable, public inprod_analytic::owavenum

  Oceanic blocs specification.
- type(atm_tensors), public inprod_analytic::atmos

  Atmospheric tensors.
- type(ocean_tensors), public inprod_analytic::ocean

  Oceanic tensors.

10.11 int_comp.f90 File Reference

Modules

- module int_comp

  Utility module containing the routines to perform the integration of functions.

Functions/Subroutines

- subroutine, public int_comp::integrate (func, ss)

  Routine to compute integrals of function from O to #maxint.
- subroutine int_comp::qromb (func, a, b, ss)

  Romberg integration routine.
- subroutine int_comp::qromo (func, a, b, ss, choose)

  Romberg integration routine on an open interval.
- subroutine int_comp::polint (xa, ya, n, x, y, dy)

  Polynomial interpolation routine.
- subroutine int_comp::trapzd (func, a, b, s, n)

  Trapezoidal rule integration routine.
- subroutine int_comp::midpnt (func, a, b, s, n)

  Midpoint rule integration routine.
- subroutine int_comp::midexp (funk, aa, bb, s, n)

  Midpoint routine for bb infinite with funk decreasing infinitely rapidly at infinity.

10.12 int_corr.f90 File Reference

Modules

- module int_corr

  Module to compute or load the integrals of the correlation matrices.

Functions/Subroutines

- subroutine, public int_corr::init_corrint

  Subroutine to initialise the integrated matrices and tensors.
- real(kind=8) function int_corr::func_ij (s)

  Function that returns the component oi and oj of the correlation matrix at time s.
- real(kind=8) function int_corr::func_ijkl (s)

  Function that returns the component oi,oj,ok and ol of the outer product of the correlation matrix with itself at time s.
- subroutine, public int_corr::comp_corrint

  Routine that actually compute or load the integrals.

Variables

- integer int_corr::oi
- integer int_corr::oj
- integer int_corr::ok
- integer int_corr::ol

  Integers that specify the matrices and tensor component considered as a function of time.
- real(kind=8), parameter int_corr::real_eps = 2.2204460492503131e-16

  Small epsilon constant to determine equality with zero.
- real(kind=8), dimension(:,:), allocatable, public int_corr::corrint

  Matrix holding the integral of the correlation matrix.
- type(coolist4), dimension(:), allocatable, public int_corr::corr2int

  Tensor holding the integral of the correlation outer product with itself.

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Functions

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Variables

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10.14 maooam.f90 File Reference

Functions/Subroutines

- program maooam

  Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM.

10.14.1 Function/Subroutine Documentation

10.14.1.1 program maooam ( )

Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM.

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Definition at line 13 of file maooam.f90.

10.15 maooam_MTV.f90 File Reference

Functions/Subroutines

- program maooam_mtv

  Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM - MTV parameterization.

10.15.1 Function/Subroutine Documentation

10.15.1.1 program maooam_mtv ( )

Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM - MTV parameterization.

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Definition at line 12 of file maooam_MTV.f90.

10.16 maooam_stoch.f90 File Reference

Functions/Subroutines

- program maooam_stoch

  Fortran 90 implementation of the stochastic modular arbitrary-order ocean-atmosphere model MAOOAM.

10.16.1 Function/Subroutine Documentation

10.16.1.1 program maooam_stoch ( )

Fortran 90 implementation of the stochastic modular arbitrary-order ocean-atmosphere model MAOOAM.

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Remarks

There are four dynamics modes:

- full: generate the full dynamics
- unres: generate the intrinsic unresolved dynamics
- qfst: generate dynamics given by the quadratic terms of the unresolved tendencies
- reso: use the resolved dynamics alone

Definition at line 24 of file maooam_stoch.f90.

10.17 maooam_WL.f90 File Reference

Functions/Subroutines

- program maooam_wl

  Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM - WL parameterization.

10.17.1 Function/Subroutine Documentation

10.17.1.1 program maooam_wl ( )

Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere model MAOOAM - WL parameterization.

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Definition at line 12 of file maooam_WL.f90.

10.18 MAR.f90 File Reference

Modules

- module mar

  Multidimensional Autoregressive module to generate the correlation for the WL parameterization.

Functions/Subroutines

- subroutine, public mar::init_mar

  Subroutine to initialise the MAR.
- subroutine, public mar::mar_step (x)

  Routine to generate one step of the MAR.
- subroutine, public mar::mar_step_red (xred)

  Routine to generate one step of the reduce MAR.
- subroutine mar::stoch_vec (dW)

Variables

- real(kind=8), dimension(:,:), allocatable, public mar::q

  Square root of the noise covariance matrix.
- real(kind=8), dimension(:,:), allocatable, public mar::qred

  Reduce version of Q.
- real(kind=8), dimension(:,:), allocatable, public mar::rred

  Covariance matrix of the noise.
- real(kind=8), dimension(:,:,:), allocatable, public mar::w

  W_i matrix.
- real(kind=8), dimension(:,:,:), allocatable, public mar::wred

  Reduce W_i matrix.
- real(kind=8), dimension(:), allocatable mar::buf_y
- real(kind=8), dimension(:), allocatable mar::dw
- integer, public mar::ms

  order of the MAR

10.19 memory.f90 File Reference

Modules

- module memory

  Module that compute the memory term M_3 of the WL parameterization.

Functions/Subroutines

- subroutine, public memory::init_memory

  Subroutine to initialise the memory.
- subroutine, public memory::compute_m3 (y, dt, dtn, savey, save_ev, evolve, inter, h_int)

  Compute the integrand of M_3 at each time in the past and integrate to get the memory term.
- subroutine, public memory::test_m3 (y, dt, dtn, h_int)

  Routine to test the #compute_M3 routine.

Variables

- real(kind=8), dimension(:,:), allocatable memory::x

    Array storing the previous state of the system.
- real(kind=8), dimension(:,:), allocatable memory::xs

    Array storing the resolved time evolution of the previous state of the system.
- real(kind=8), dimension(:,:), allocatable memory::zs

    Dummy array to replace Xs in case where the evolution is not stored.
- real(kind=8), dimension(:), allocatable memory::buf_m

    Dummy vector.
- real(kind=8), dimension(:), allocatable memory::buf_m3

    Dummy vector to store the M_3 integrand.
- integer memory::t_index

    Integer storing the time index (current position in the arrays)
- procedure(ss_step), pointer memory::step

    Procedural pointer pointing on the resolved dynamics step routine.

10.20 MTV_int_tensor.f90 File Reference

Modules

- module mtv_int_tensor

    The MTV tensors used to integrate the MTV model.

Functions/Subroutines

- subroutine, public mtv_int_tensor::init_mtv_int_tensor

    Subroutine to initialise the MTV tensor.

Variables

- real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h1

    First constant vector.
- real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h2

    Second constant vector.
- real(kind=8), dimension(:), allocatable, public mtv_int_tensor::h3

    Third constant vector.
- real(kind=8), dimension(:), allocatable, public mtv_int_tensor::htot

    Total constant vector.
- type(coolist), dimension(:), allocatable, public mtv_int_tensor::l1

    First linear tensor.
- type(coolist), dimension(:), allocatable, public mtv_int_tensor::l2

    Second linear tensor.
- type(coolist), dimension(:), allocatable, public mtv_int_tensor::l3

    Third linear tensor.
- type(coolist), dimension(:), allocatable, public mtv_int_tensor::ltot

    Total linear tensor.
- type(coolist), dimension(:), allocatable, public mtv_int_tensor::b1

First quadratic tensor.

- type(coolist), dimension(:), allocatable, public mtv_int_tensor::b2

  Second quadratic tensor.

- type(coolist), dimension(:), allocatable, public mtv_int_tensor::btot

  Total quadratic tensor.

- type(coolist4), dimension(:), allocatable, public mtv_int_tensor::mtot

  Tensor for the cubic terms.

- real(kind=8), dimension(:,:), allocatable, public mtv_int_tensor::q1

  Constant terms for the state-dependent noise covariance matrix.

- real(kind=8), dimension(:,:), allocatable, public mtv_int_tensor::q2

  Constant terms for the state-independent noise covariance matrix.

- type(coolist), dimension(:), allocatable, public mtv_int_tensor::utot

  Linear terms for the state-dependent noise covariance matrix.

- type(coolist4), dimension(:), allocatable, public mtv_int_tensor::vtot

  Quadratic terms for the state-dependent noise covariance matrix.

- real(kind=8), dimension(:), allocatable mtv_int_tensor::dumb_vec

  Dummy vector.

- real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat1

  Dummy matrix.

- real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat2

  Dummy matrix.

- real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat3

  Dummy matrix.

- real(kind=8), dimension(:,:), allocatable mtv_int_tensor::dumb_mat4

  Dummy matrix.

10.21 MTV_sigma_tensor.f90 File Reference

Modules

- module sigma

  The MTV noise sigma matrices used to integrate the MTV model.

Functions/Subroutines

- subroutine, public sigma::init_sigma (mult, Q1fill)

  Subroutine to initialize the sigma matices.

- subroutine, public sigma::compute_mult_sigma (y)

  Routine to actualize the matrix σ_1 based on the state y of the MTV system.

Variables

- real(kind=8), dimension(:,:), allocatable, public sigma::sig1

    $\sigma_1(X)$ state-dependent noise matrix
- real(kind=8), dimension(:,:), allocatable, public sigma::sig2

    σ_2 state-independent noise matrix
- real(kind=8), dimension(:,:), allocatable, public sigma::sig1r

    Reduced $\sigma_1(X)$ state-dependent noise matrix.
- real(kind=8), dimension(:,:), allocatable sigma::dumb_mat1

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable sigma::dumb_mat2

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable sigma::dumb_mat3

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable sigma::dumb_mat4

    Dummy matrix.
- integer, dimension(:), allocatable sigma::ind1
- integer, dimension(:), allocatable sigma::rind1
- integer, dimension(:), allocatable sigma::ind2
- integer, dimension(:), allocatable sigma::rind2

    Reduction indices.
- integer sigma::n1
- integer sigma::n2

10.22 params.f90 File Reference

Modules

- module params

    The model parameters module.

Functions/Subroutines

- subroutine, private params::init_nml

    Read the basic parameters and mode selection from the namelist.
- subroutine params::init_params

    Parameters initialisation routine.

Variables

- real(kind=8) params::n

    $n = 2L_y/L_x$ - Aspect ratio
- real(kind=8) params::phi0

    Latitude in radian.
- real(kind=8) params::rra

    Earth radius.
- real(kind=8) params::sig0

    σ_0 - Non-dimensional static stability of the atmosphere.

- real(kind=8) params::k

  Bottom atmospheric friction coefficient.
- real(kind=8) params::kp

  k' *- Internal atmospheric friction coefficient.*
- real(kind=8) params::r

  Frictional coefficient at the bottom of the ocean.
- real(kind=8) params::d

  Merchanical coupling parameter between the ocean and the atmosphere.
- real(kind=8) params::f0

  f_0 *- Coriolis parameter*
- real(kind=8) params::gp

  g' *Reduced gravity*
- real(kind=8) params::h

  Depth of the active water layer of the ocean.
- real(kind=8) params::phi0_npi

  Latitude exprimed in fraction of pi.
- real(kind=8) params::lambda

  λ *- Sensible + turbulent heat exchange between the ocean and the atmosphere.*
- real(kind=8) params::co

  C_a *- Constant short-wave radiation of the ocean.*
- real(kind=8) params::go

  γ_o *- Specific heat capacity of the ocean.*
- real(kind=8) params::ca

  C_a *- Constant short-wave radiation of the atmosphere.*
- real(kind=8) params::to0

  T_o^0 *- Stationary solution for the 0-th order ocean temperature.*
- real(kind=8) params::ta0

  T_a^0 *- Stationary solution for the 0-th order atmospheric temperature.*
- real(kind=8) params::epsa

  ϵ_a *- Emissivity coefficient for the grey-body atmosphere.*
- real(kind=8) params::ga

  γ_a *- Specific heat capacity of the atmosphere.*
- real(kind=8) params::rr

  R *- Gas constant of dry air*
- real(kind=8) params::scale

  $L_y = L\,\pi$ *- The characteristic space scale.*
- real(kind=8) params::pi

  π
- real(kind=8) params::lr

  L_R *- Rossby deformation radius*
- real(kind=8) params::g

  γ
- real(kind=8) params::rp

  r' *- Frictional coefficient at the bottom of the ocean.*
- real(kind=8) params::dp

  d' *- Non-dimensional mechanical coupling parameter between the ocean and the atmosphere.*
- real(kind=8) params::kd

  k_d *- Non-dimensional bottom atmospheric friction coefficient.*
- real(kind=8) params::kdp

  k'_d *- Non-dimensional internal atmospheric friction coefficient.*
- real(kind=8) params::cpo

C'_a - Non-dimensional constant short-wave radiation of the ocean.
- real(kind=8) params::lpo

  λ'_o - Non-dimensional sensible + turbulent heat exchange from ocean to atmosphere.
- real(kind=8) params::cpa

  C'_a - Non-dimensional constant short-wave radiation of the atmosphere.
- real(kind=8) params::lpa

  λ'_a - Non-dimensional sensible + turbulent heat exchange from atmosphere to ocean.
- real(kind=8) params::sbpo

  ${\sigma'}_{B,o}$ - Long wave radiation lost by ocean to atmosphere & space.
- real(kind=8) params::sbpa

  ${\sigma'}_{B,a}$ - Long wave radiation from atmosphere absorbed by ocean.
- real(kind=8) params::lsbpo

  $S'_{B,o}$ - Long wave radiation from ocean absorbed by atmosphere.
- real(kind=8) params::lsbpa

  $S'_{B,a}$ - Long wave radiation lost by atmosphere to space & ocean.
- real(kind=8) params::l

  L - Domain length scale
- real(kind=8) params::sc

  Ratio of surface to atmosphere temperature.
- real(kind=8) params::sb

  Stefan–Boltzmann constant.
- real(kind=8) params::betp

  β' - Non-dimensional beta parameter
- real(kind=8) params::nua =0.D0

  Dissipation in the atmosphere.
- real(kind=8) params::nuo =0.D0

  Dissipation in the ocean.
- real(kind=8) params::nuap

  Non-dimensional dissipation in the atmosphere.
- real(kind=8) params::nuop

  Non-dimensional dissipation in the ocean.
- real(kind=8) params::t_trans

  Transient time period.
- real(kind=8) params::t_run

  Effective intergration time (length of the generated trajectory)
- real(kind=8) params::dt

  Integration time step.
- real(kind=8) params::tw

  Write all variables every tw time units.
- logical params::writeout

  Write to file boolean.
- integer params::nboc

  Number of atmospheric blocks.
- integer params::nbatm

  Number of oceanic blocks.
- integer params::natm =0

  Number of atmospheric basis functions.
- integer params::noc =0

  Number of oceanic basis functions.
- integer params::ndim

  Number of variables (dimension of the model)

- integer, dimension(:,:), allocatable params::oms

  Ocean mode selection array.
- integer, dimension(:,:), allocatable params::ams

  Atmospheric mode selection array.

10.23 rk2_integrator.f90 File Reference

Modules

- module integrator

  Module with the integration routines.

Functions/Subroutines

- subroutine, public integrator::init_integrator

  Routine to initialise the integration buffers.
- subroutine integrator::tendencies (t, y, res)

  Routine computing the tendencies of the model.
- subroutine, public integrator::step (y, t, dt, res)

  Routine to perform an integration step (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable integrator::buf_y1

  Buffer to hold the intermediate position (Heun algorithm)
- real(kind=8), dimension(:), allocatable integrator::buf_f0

  Buffer to hold tendencies at the initial position.
- real(kind=8), dimension(:), allocatable integrator::buf_f1

  Buffer to hold tendencies at the intermediate position.

10.24 rk2_MTV_integrator.f90 File Reference

Modules

- module rk2_mtv_integrator

  Module with the MTV rk2 integration routines.

Functions/Subroutines

- subroutine, public rk2_mtv_integrator::init_integrator

  Subroutine to initialize the MTV rk2 integrator.
- subroutine rk2_mtv_integrator::init_noise

  Routine to initialize the noise vectors and buffers.
- subroutine rk2_mtv_integrator::init_g

  Routine to initialize the G term.
- subroutine rk2_mtv_integrator::compg (y)

  Routine to actualize the G term based on the state y of the MTV system.
- subroutine, public rk2_mtv_integrator::step (y, t, dt, dtn, res, tend)

  Routine to perform an integration step (Heun algorithm) of the MTV system. The incremented time is returned.
- subroutine, public rk2_mtv_integrator::full_step (y, t, dt, dtn, res)

  Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_y1
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_f0
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_f1

  Integration buffers.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dw
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwmult

  Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwar
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwau
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwor
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::dwou

  Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::anoise
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::noise

  Additive noise term.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::noisemult

  Multiplicative noise term.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::g

  G term of the MTV tendencies.
- real(kind=8), dimension(:), allocatable rk2_mtv_integrator::buf_g

  Buffer for the G term computation.
- logical rk2_mtv_integrator::mult

  Logical indicating if the sigma1 matrix must be computed for every state change.
- logical rk2_mtv_integrator::q1fill

  Logical indicating if the matrix Q1 is non-zero.
- logical rk2_mtv_integrator::compute_mult

  Logical indicating if the Gaussian noise for the multiplicative noise must be computed.
- real(kind=8), parameter rk2_mtv_integrator::sq2 = sqrt(2.D0)

  Hard coded square root of 2.

10.25 rk2_ss_integrator.f90 File Reference

Modules

- module rk2_ss_integrator

  Module with the stochastic uncoupled resolved nonlinear and tangent linear rk2 dynamics integration routines.

Functions/Subroutines

- subroutine, public rk2_ss_integrator::init_ss_integrator

  Subroutine to initialize the uncoupled resolved rk2 integrator.
- subroutine, public rk2_ss_integrator::tendencies (t, y, res)

  Routine computing the tendencies of the uncoupled resolved model.
- subroutine, public rk2_ss_integrator::tl_tendencies (t, y, ys, res)

  Tendencies for the tangent linear model of the uncoupled resolved dynamics in point ystar for perturbation deltay.
- subroutine, public rk2_ss_integrator::ss_step (y, ys, t, dt, dtn, res)

  Routine to perform a stochastic integration step of the unresolved uncoupled dynamics (Heun algorithm). The incremented time is returned.
- subroutine, public rk2_ss_integrator::ss_tl_step (y, ys, t, dt, dtn, res)

  Routine to perform a stochastic integration step of the unresolved uncoupled tangent linear dynamics (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable rk2_ss_integrator::dwar
- real(kind=8), dimension(:), allocatable rk2_ss_integrator::dwor

  Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable rk2_ss_integrator::anoise

  Additive noise term.
- real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_y1
- real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_f0
- real(kind=8), dimension(:), allocatable rk2_ss_integrator::buf_f1

  Integration buffers.

10.26 rk2_stoch_integrator.f90 File Reference

Modules

- module rk2_stoch_integrator

  Module with the stochastic rk2 integration routines.

Functions/Subroutines

- subroutine, public rk2_stoch_integrator::init_integrator (force)

  Subroutine to initialize the integrator.
- subroutine rk2_stoch_integrator::tendencies (t, y, res)

  Routine computing the tendencies of the selected model.
- subroutine, public rk2_stoch_integrator::step (y, t, dt, dtn, res, tend)

  Routine to perform a stochastic step of the selected dynamics (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwar
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwau
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwor
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::dwou

  Standard gaussian noise buffers.
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_y1
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_f0
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::buf_f1

  Integration buffers.
- real(kind=8), dimension(:), allocatable rk2_stoch_integrator::anoise

  Additive noise term.
- type(coolist), dimension(:), allocatable rk2_stoch_integrator::int_tensor

  Dummy tensor that will hold the tendencies tensor.

10.27 rk2_tl_ad_integrator.f90 File Reference

Modules

- module tl_ad_integrator

  Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

Functions/Subroutines

- subroutine, public tl_ad_integrator::init_tl_ad_integrator

  Routine to initialise the integration buffers.
- subroutine, public tl_ad_integrator::ad_step (y, ystar, t, dt, res)

  Routine to perform an integration step (Heun algorithm) of the adjoint model. The incremented time is returned.
- subroutine, public tl_ad_integrator::tl_step (y, ystar, t, dt, res)

  Routine to perform an integration step (Heun algorithm) of the tangent linear model. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_y1

  Buffer to hold the intermediate position (Heun algorithm) of the tangent linear model.
- real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_f0

  Buffer to hold tendencies at the initial position of the tangent linear model.
- real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_f1

  Buffer to hold tendencies at the intermediate position of the tangent linear model.

10.28 rk2_WL_integrator.f90 File Reference

Modules

- module rk2_wl_integrator

  Module with the WL rk2 integration routines.

Functions/Subroutines

- subroutine, public rk2_wl_integrator::init_integrator

  Subroutine that initialize the MARs, the memory unit and the integration buffers.
- subroutine rk2_wl_integrator::compute_m1 (y)

  Routine to compute the M_1 term.
- subroutine rk2_wl_integrator::compute_m2 (y)

  Routine to compute the M_2 term.
- subroutine, public rk2_wl_integrator::step (y, t, dt, dtn, res, tend)

  Routine to perform an integration step (Heun algorithm) of the WL system. The incremented time is returned.
- subroutine, public rk2_wl_integrator::full_step (y, t, dt, dtn, res)

  Routine to perform an integration step (Heun algorithm) of the full stochastic system. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_y1
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_f0
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_f1

  Integration buffers.
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m2
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m1
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m3
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::buf_m3s

  Dummy buffers holding the terms /f$M_i.
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::anoise

  Additive noise term.
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwar
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwau
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwor
- real(kind=8), dimension(:), allocatable rk2_wl_integrator::dwou

  Standard gaussian noise buffers.
- real(kind=8), dimension(:,:), allocatable rk2_wl_integrator::x1

  Buffer holding the subsequent states of the first MAR.
- real(kind=8), dimension(:,:), allocatable rk2_wl_integrator::x2

  Buffer holding the subsequent states of the second MAR.

10.29 rk4_integrator.f90 File Reference

Modules

- module integrator

  Module with the integration routines.

Functions/Subroutines

- subroutine, public integrator::init_integrator

  Routine to initialise the integration buffers.
- subroutine integrator::tendencies (t, y, res)

  Routine computing the tendencies of the model.
- subroutine, public integrator::step (y, t, dt, res)

  Routine to perform an integration step (Heun algorithm). The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable integrator::buf_ka

  Buffer A to hold tendencies.
- real(kind=8), dimension(:), allocatable integrator::buf_kb

  Buffer B to hold tendencies.

10.30 rk4_tl_ad_integrator.f90 File Reference

Modules

- module tl_ad_integrator

  Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

Functions/Subroutines

- subroutine, public tl_ad_integrator::init_tl_ad_integrator

  Routine to initialise the integration buffers.
- subroutine, public tl_ad_integrator::ad_step (y, ystar, t, dt, res)

  Routine to perform an integration step (Heun algorithm) of the adjoint model. The incremented time is returned.
- subroutine, public tl_ad_integrator::tl_step (y, ystar, t, dt, res)

  Routine to perform an integration step (Heun algorithm) of the tangent linear model. The incremented time is returned.

Variables

- real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_ka

  Buffer to hold tendencies in the RK4 scheme for the tangent linear model.
- real(kind=8), dimension(:), allocatable tl_ad_integrator::buf_kb

  Buffer to hold tendencies in the RK4 scheme for the tangent linear model.

10.31 sf_def.f90 File Reference

Modules

- module sf_def

  Module to select the resolved-unresolved components.

Functions/Subroutines

- subroutine, public sf_def::load_sf

  Subroutine to load the unresolved variable defintion vector SF from SF.nml if it exists. If it does not, then write SF.nml with no unresolved variables specified (null vector).

Variables

- logical sf_def::exists
  Boolean to test for file existence.
- integer, dimension(:), allocatable, public sf_def::sf
  Unresolved variable definition vector.
- integer, dimension(:), allocatable, public sf_def::ind
- integer, dimension(:), allocatable, public sf_def::rind
  Unresolved reduction indices.
- integer, dimension(:), allocatable, public sf_def::sl_ind
- integer, dimension(:), allocatable, public sf_def::sl_rind
  Resolved reduction indices.
- integer, public sf_def::n_unres
  Number of unresolved variables.
- integer, public sf_def::n_res
  Number of resolved variables.
- integer, dimension(:,:), allocatable, public sf_def::bar
- integer, dimension(:,:), allocatable, public sf_def::bau
- integer, dimension(:,:), allocatable, public sf_def::bor
- integer, dimension(:,:), allocatable, public sf_def::bou
  Filter matrices.

10.32 sqrt_mod.f90 File Reference

Modules

- module sqrt_mod
  Utility module with various routine to compute matrix square root.

Functions/Subroutines

- subroutine, public sqrt_mod::init_sqrt
- subroutine, public sqrt_mod::sqrtm (A, sqA, info, info_triu, bs)
  Routine to compute a real square-root of a matrix.
- logical function sqrt_mod::selectev (a, b)
- subroutine sqrt_mod::sqrtm_triu (A, sqA, info, bs)
- subroutine sqrt_mod::csqrtm_triu (A, sqA, info, bs)
- subroutine sqrt_mod::rsf2csf (T, Z, Tz, Zz)
- subroutine, public sqrt_mod::chol (A, sqA, info)
  Routine to perform a Cholesky decomposition.
- subroutine, public sqrt_mod::sqrtm_svd (A, sqA, info, info_triu, bs)
  Routine to compute a real square-root of a matrix via a SVD decomposition.

Variables

- real(kind=8), dimension(:), allocatable sqrt_mod::work
- integer sqrt_mod::lwork
- real(kind=8), parameter sqrt_mod::real_eps = 2.2204460492503131e-16

10.33 stat.f90 File Reference

Modules

- module stat

  Statistics accumulators.

Functions/Subroutines

- subroutine, public stat::init_stat

  Initialise the accumulators.
- subroutine, public stat::acc (x)

  Accumulate one state.
- real(kind=8) function, dimension(0:ndim), public stat::mean ()

  Function returning the mean.
- real(kind=8) function, dimension(0:ndim), public stat::var ()

  Function returning the variance.
- integer function, public stat::iter ()

  Function returning the number of data accumulated.
- subroutine, public stat::reset

  Routine resetting the accumulators.

Variables

- integer stat::i =0

  Number of stats accumulated.
- real(kind=8), dimension(:), allocatable stat::m

  Vector storing the inline mean.
- real(kind=8), dimension(:), allocatable stat::mprev

  Previous mean vector.
- real(kind=8), dimension(:), allocatable stat::v

  Vector storing the inline variance.
- real(kind=8), dimension(:), allocatable stat::mtmp

10.34 stoch_mod.f90 File Reference

Modules

- module stoch_mod

  Utility module containing the stochastic related routines.

Functions/Subroutines

- real(kind=8) function, public stoch_mod::gasdev ()
- subroutine, public stoch_mod::stoch_vec (dW)

  Routine to fill a vector with standard Gaussian noise process values.
- subroutine, public stoch_mod::stoch_atm_vec (dW)

  routine to fill the atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_mod::stoch_atm_res_vec (dW)

  routine to fill the resolved atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_mod::stoch_atm_unres_vec (dW)

  routine to fill the unresolved atmospheric component of a vector with standard gaussian noise process values
- subroutine, public stoch_mod::stoch_oc_vec (dW)

  routine to fill the oceanic component of a vector with standard gaussian noise process values
- subroutine, public stoch_mod::stoch_oc_res_vec (dW)

  routine to fill the resolved oceanic component of a vector with standard gaussian noise process values
- subroutine, public stoch_mod::stoch_oc_unres_vec (dW)

  routine to fill the unresolved oceanic component of a vector with standard gaussian noise process values

Variables

- integer stoch_mod::iset =0
- real(kind=8) stoch_mod::gset

10.35 stoch_params.f90 File Reference

Modules

- module stoch_params

  The stochastic models parameters module.

Functions/Subroutines

- subroutine stoch_params::init_stoch_params

  Stochastic parameters initialization routine.

Variables

- real(kind=8) stoch_params::mnuti

  Multiplicative noise update time interval.
- real(kind=8) stoch_params::t_trans_stoch

  Transient time period of the stochastic model evolution.
- real(kind=8) stoch_params::q_ar

  Atmospheric resolved component noise amplitude.
- real(kind=8) stoch_params::q_au

  Atmospheric unresolved component noise amplitude.
- real(kind=8) stoch_params::q_or

  Oceanic resolved component noise amplitude.

- real(kind=8) stoch_params::q_ou

  Oceanic unresolved component noise amplitude.
- real(kind=8) stoch_params::dtn

  Square root of the timestep.
- real(kind=8) stoch_params::eps_pert

  Perturbation parameter for the coupling.
- real(kind=8) stoch_params::tdelta

  Time separation parameter.
- real(kind=8) stoch_params::muti

  Memory update time interval.
- real(kind=8) stoch_params::meml

  Time over which the memory kernel is integrated.
- real(kind=8) stoch_params::t_trans_mem

  Transient time period to initialize the memory term.
- character(len=4) stoch_params::x_int_mode

  Integration mode for the resolved component.
- real(kind=8) stoch_params::dts

  Intrisic resolved dynamics time step.
- integer stoch_params::mems

  Number of steps in the memory kernel integral.
- real(kind=8) stoch_params::dtsn

  Square root of the intrisic resolved dynamics time step.
- real(kind=8) stoch_params::maxint

  Upper integration limit of the correlations.
- character(len=4) stoch_params::load_mode

  Loading mode for the correlations.
- character(len=4) stoch_params::int_corr_mode

  Correlation integration mode.
- character(len=4) stoch_params::mode

  Stochastic mode parameter.

10.36 tensor.f90 File Reference

Data Types

- type tensor::coolist_elem

  Coordinate list element type. Elementary elements of the sparse tensors.
- type tensor::coolist_elem4

  4d coordinate list element type. Elementary elements of the 4d sparse tensors.
- type tensor::coolist

  Coordinate list. Type used to represent the sparse tensor.
- type tensor::coolist4

  4d coordinate list. Type used to represent the rank-4 sparse tensor.

Modules

- module tensor

  Tensor utility module.

Functions/Subroutines

- subroutine, public tensor::copy_coo (src, dst)

  Routine to copy a coolist.
- subroutine, public tensor::mat_to_coo (src, dst)

  Routine to convert a matrix to a tensor.
- subroutine, public tensor::sparse_mul3 (coolist_ijk, arr_j, arr_k, res)

  Sparse multiplication of a tensor with two vectors: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j\, b_k$.
- subroutine, public tensor::jsparse_mul (coolist_ijk, arr_j, jcoo_ij)

  Sparse multiplication of two tensors to determine the Jacobian:

  $$J_{i,j} = \sum_{k=0}^{ndim} \left(\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j} \right)\, a_k.$$

  It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$*, we add to* $J_{i,j}$ *as follows:*

  $$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k}\, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k}\, a_j$$

  This version return a coolist (sparse tensor).
- subroutine, public tensor::jsparse_mul_mat (coolist_ijk, arr_j, jcoo_ij)

  Sparse multiplication of two tensors to determine the Jacobian:

  $$J_{i,j} = \sum_{k=0}^{ndim} \left(\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j} \right)\, a_k.$$

  It's implemented slightly differently: for every $\mathcal{T}_{i,j,k}$*, we add to* $J_{i,j}$ *as follows:*

  $$J_{i,j} = J_{i,j} + \mathcal{T}_{i,j,k}\, a_k J_{i,k} = J_{i,k} + \mathcal{T}_{i,j,k}\, a_j$$

  This version return a matrix.
- subroutine, public tensor::sparse_mul2 (coolist_ij, arr_j, res)

  Sparse multiplication of a 2d sparse tensor with a vector: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j$.
- subroutine, public tensor::simplify (tensor)

  Routine to simplify a coolist (sparse tensor). For each index i*, it upper triangularize the matrix*

  $$\mathcal{T}_{i,j,k} \qquad 0 \le j,k \le ndim.$$

  .
- subroutine, public tensor::add_elem (t, i, j, k, v)

  Subroutine to add element to a coolist.
- subroutine, public tensor::add_check (t, i, j, k, v, dst)

  Subroutine to add element to a coolist and check for overflow. Once the t buffer tensor is full, add it to the destination buffer.
- subroutine, public tensor::add_to_tensor (src, dst)

  Routine to add a rank-3 tensor to another one.
- subroutine, public tensor::print_tensor (t, s)

  Routine to print a rank 3 tensor coolist.
- subroutine, public tensor::write_tensor_to_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public tensor::load_tensor_from_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public tensor::add_matc_to_tensor (i, src, dst)

  Routine to add a matrix to a rank-3 tensor.
- subroutine, public tensor::add_matc_to_tensor4 (i, j, src, dst)

  Routine to add a matrix to a rank-4 tensor.

- subroutine, public tensor::add_vec_jk_to_tensor (j, k, src, dst)

    Routine to add a vector to a rank-3 tensor.
- subroutine, public tensor::add_vec_ikl_to_tensor4_perm (i, k, l, src, dst)

    Routine to add a vector to a rank-4 tensor plus permutation.
- subroutine, public tensor::add_vec_ikl_to_tensor4 (i, k, l, src, dst)

    Routine to add a vector to a rank-4 tensor.
- subroutine, public tensor::add_vec_ijk_to_tensor4 (i, j, k, src, dst)

    Routine to add a vector to a rank-4 tensor.
- subroutine, public tensor::tensor_to_coo (src, dst)

    Routine to convert a rank-3 tensor from matrix to coolist representation.
- subroutine, public tensor::tensor4_to_coo4 (src, dst)

    Routine to convert a rank-4 tensor from matrix to coolist representation.
- subroutine, public tensor::print_tensor4 (t)

    Routine to print a rank-4 tensor coolist.
- subroutine, public tensor::sparse_mul3_mat (coolist_ijk, arr_k, res)

    Sparse multiplication of a rank-3 tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}\, b_k$. *Its output is a matrix.*
- subroutine, public tensor::sparse_mul4 (coolist_ijkl, arr_j, arr_k, arr_l, res)

    Sparse multiplication of a rank-4 tensor coolist with three vectors: $\sum_{j,k,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, a_j\, b_k\, c_l$.
- subroutine, public tensor::sparse_mul4_mat (coolist_ijkl, arr_k, arr_l, res)

    Sparse multiplication of a tensor with two vectors: $\sum_{k,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, b_k\, c_l$.
- subroutine, public tensor::sparse_mul2_j (coolist_ijk, arr_j, res)

    Sparse multiplication of a 3d sparse tensor with a vectors: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k}\, a_j$.
- subroutine, public tensor::sparse_mul2_k (coolist_ijk, arr_k, res)

    Sparse multiplication of a rank-3 sparse tensor coolist with a vector: $\sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}\, a_k$.
- subroutine, public tensor::coo_to_mat_ik (src, dst)

    Routine to convert a rank-3 tensor coolist component into a matrix with i and k indices.
- subroutine, public tensor::coo_to_mat_ij (src, dst)

    Routine to convert a rank-3 tensor coolist component into a matrix with i and j indices.
- subroutine, public tensor::coo_to_mat_i (i, src, dst)

    Routine to convert a rank-3 tensor coolist component into a matrix.
- subroutine, public tensor::coo_to_vec_jk (j, k, src, dst)

    Routine to convert a rank-3 tensor coolist component into a vector.
- subroutine, public tensor::coo_to_mat_j (j, src, dst)

    Routine to convert a rank-3 tensor coolist component into a matrix.
- subroutine, public tensor::sparse_mul4_with_mat_jl (coolist_ijkl, mat_jl, res)

    Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, m_{j,l}$.
- subroutine, public tensor::sparse_mul4_with_mat_kl (coolist_ijkl, mat_kl, res)

    Sparse multiplication of a rank-4 tensor coolist with a matrix : $\sum_{j,l=0}^{ndim} \mathcal{T}_{i,j,k,l}\, m_{k,l}$.
- subroutine, public tensor::sparse_mul3_with_mat (coolist_ijk, mat_jk, res)

    Sparse multiplication of a rank-3 tensor coolist with a matrix: $\sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k}\, m_{j,k}$.
- subroutine, public tensor::matc_to_coo (src, dst)

Routine to convert a matrix to a rank-3 tensor.

- subroutine, public tensor::scal_mul_coo (s, t)

  Routine to multiply a rank-3 tensor by a scalar.
- logical function, public tensor::tensor_empty (t)

  Test if a rank-3 tensor coolist is empty.
- logical function, public tensor::tensor4_empty (t)

  Test if a rank-4 tensor coolist is empty.
- subroutine, public tensor::load_tensor4_from_file (s, t)

  Load a rank-4 tensor coolist from a file definition.
- subroutine, public tensor::write_tensor4_to_file (s, t)

  Load a rank-4 tensor coolist from a file definition.

Variables

- real(kind=8), parameter tensor::real_eps = 2.2204460492503131e-16

  Parameter to test the equality with zero.

10.37 test_aotensor.f90 File Reference

Functions/Subroutines

- program test_aotensor

  Small program to print the inner products.

10.37.1 Function/Subroutine Documentation

10.37.1.1 program test_aotensor ( )

Small program to print the inner products.

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Definition at line 13 of file test_aotensor.f90.

10.38 test_corr.f90 File Reference

Functions/Subroutines

- program test_corr

  Small program to print the correlation and covariance matrices.

10.38.1 Function/Subroutine Documentation

10.38.1.1 program test_corr ( )

Small program to print the correlation and covariance matrices.

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Definition at line 12 of file test_corr.f90.

10.39 test_corr_tensor.f90 File Reference

Functions/Subroutines

- program test_corr_tensor

  Small program to print the time correlations tensors.

10.39.1 Function/Subroutine Documentation

10.39.1.1 program test_corr_tensor ( )

Small program to print the time correlations tensors.

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Definition at line 12 of file test_corr_tensor.f90.

10.40 test_dec_tensor.f90 File Reference

Functions/Subroutines

- program test_dec_tensor

  Small program to print the decomposed tensors.

10.40.1 Function/Subroutine Documentation

10.40.1.1 program test_dec_tensor ( )

Small program to print the decomposed tensors.

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Definition at line 12 of file test_dec_tensor.f90.

10.41 test_inprod_analytic.f90 File Reference

Functions/Subroutines

- program inprod_analytic_test

  Small program to print the inner products.

10.41.1 Function/Subroutine Documentation

10.41.1.1 program inprod_analytic_test ( )

Small program to print the inner products.

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Remarks

Print in the same order as test_inprod.lua

Definition at line 18 of file test_inprod_analytic.f90.

10.42 test_MAR.f90 File Reference

Functions/Subroutines

- program test_mar

  Small program to test the Multivariate AutoRegressive model.

10.42.1 Function/Subroutine Documentation

10.42.1.1 program test_mar ( )

Small program to test the Multivariate AutoRegressive model.

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Definition at line 12 of file test_MAR.f90.

10.43 test_memory.f90 File Reference

Functions/Subroutines

- program test_memory

    Small program to test the WL memory module.

10.43.1 Function/Subroutine Documentation

10.43.1.1 program test_memory ( )

Small program to test the WL memory module.

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Definition at line 12 of file test_memory.f90.

10.44 test_MTV_int_tensor.f90 File Reference

Functions/Subroutines

- program test_mtv_int_tensor

    Small program to print the MTV integrated tensors.

10.44.1 Function/Subroutine Documentation

10.44.1.1 program test_mtv_int_tensor ( )

Small program to print the MTV integrated tensors.

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Definition at line 12 of file test_MTV_int_tensor.f90.

10.45 test_MTV_sigma_tensor.f90 File Reference

Functions/Subroutines

- program test_sigma

    Small program to test the MTV noise sigma matrices.

10.45.1 Function/Subroutine Documentation

10.45.1.1 program test_sigma ( )

Small program to test the MTV noise sigma matrices.

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Definition at line 12 of file test_MTV_sigma_tensor.f90.

10.46 test_sqrtm.f90 File Reference

Functions/Subroutines

- program test_sqrtm

  Small program to test the matrix square-root module.

10.46.1 Function/Subroutine Documentation

10.46.1.1 program test_sqrtm ( )

Small program to test the matrix square-root module.

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Definition at line 12 of file test_sqrtm.f90.

10.47 test_tl_ad.f90 File Reference

Functions/Subroutines

- program test_tl_ad

  Tests for the Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM.

10.47.1 Function/Subroutine Documentation

10.47.1.1 program test_tl_ad ( )

Tests for the Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM.

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Definition at line 14 of file test_tl_ad.f90.

10.48 test_WL_tensor.f90 File Reference

Functions/Subroutines

- program test_wl_tensor

    Small program to print the WL tensors.

10.48.1 Function/Subroutine Documentation

10.48.1.1 program test_wl_tensor ( )

Small program to print the WL tensors.

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Definition at line 11 of file test_WL_tensor.f90.

10.49 tl_ad_tensor.f90 File Reference

Modules

- module tl_ad_tensor

    Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module.

Functions/Subroutines

- type(coolist) function, dimension(ndim) tl_ad_tensor::jacobian (ystar)

    Compute the Jacobian of MAOOAM in point ystar.
- real(kind=8) function, dimension(ndim, ndim), public tl_ad_tensor::jacobian_mat (ystar)

    Compute the Jacobian of MAOOAM in point ystar.
- subroutine, public tl_ad_tensor::init_tltensor

    Routine to initialize the TL tensor.
- subroutine tl_ad_tensor::compute_tltensor (func)

    Routine to compute the TL tensor from the original MAOOAM one.
- subroutine tl_ad_tensor::tl_add_count (i, j, k, v)

    Subroutine used to count the number of TL tensor entries.
- subroutine tl_ad_tensor::tl_coeff (i, j, k, v)

    Subroutine used to compute the TL tensor entries.
- subroutine, public tl_ad_tensor::init_adtensor

    Routine to initialize the AD tensor.
- subroutine tl_ad_tensor::compute_adtensor (func)

    Subroutine to compute the AD tensor from the original MAOOAM one.
- subroutine tl_ad_tensor::ad_add_count (i, j, k, v)

    Subroutine used to count the number of AD tensor entries.
- subroutine tl_ad_tensor::ad_coeff (i, j, k, v)

- subroutine, public tl_ad_tensor::init_adtensor_ref
  Alternate method to initialize the AD tensor from the TL tensor.
- subroutine tl_ad_tensor::compute_adtensor_ref (func)
  Alternate subroutine to compute the AD tensor from the TL one.
- subroutine tl_ad_tensor::ad_add_count_ref (i, j, k, v)
  Alternate subroutine used to count the number of AD tensor entries from the TL tensor.
- subroutine tl_ad_tensor::ad_coeff_ref (i, j, k, v)
  Alternate subroutine used to compute the AD tensor entries from the TL tensor.
- subroutine, public tl_ad_tensor::ad (t, ystar, deltay, buf)
  Tendencies for the AD of MAOOAM in point ystar for perturbation deltay.
- subroutine, public tl_ad_tensor::tl (t, ystar, deltay, buf)
  Tendencies for the TL of MAOOAM in point ystar for perturbation deltay.

Variables

- real(kind=8), parameter tl_ad_tensor::real_eps = 2.2204460492503131e-16
  Epsilon to test equality with 0.
- integer, dimension(:), allocatable tl_ad_tensor::count_elems
  Vector used to count the tensor elements.
- type(coolist), dimension(:), allocatable, public tl_ad_tensor::tltensor
  Tensor representation of the Tangent Linear tendencies.
- type(coolist), dimension(:), allocatable, public tl_ad_tensor::adtensor
  Tensor representation of the Adjoint tendencies.

10.50 util.f90 File Reference

Modules

- module util
  Utility module.

Functions/Subroutines

- character(len=20) function, public util::str (k)
  Convert an integer to string.
- character(len=40) function, public util::rstr (x, fm)
  Convert a real to string with a given format.
- integer function, dimension(size(s)), public util::isin (c, s)
  Determine if a character is in a string and where.
- subroutine, public util::init_random_seed ()
  Random generator initialization routine.
- integer function lcg (s)
- subroutine, public util::piksrt (k, arr, par)
  Simple card player sorting function.
- subroutine, public util::init_one (A)
  Initialize a square matrix A as a unit matrix.
- real(kind=8) function, public util::mat_trace (A)
- real(kind=8) function, public util::mat_contract (A, B)

- subroutine, public util::choldc (a, p)
- subroutine, public util::printmat (A)
- subroutine, public util::cprintmat (A)
- real(kind=8) function, dimension(size(a, 1), size(a, 2)), public util::invmat (A)
- subroutine, public util::triu (A, T)
- subroutine, public util::diag (A, d)
- subroutine, public util::cdiag (A, d)
- integer function, public util::floordiv (i, j)
- subroutine, public util::reduce (A, Ared, n, ind, rind)
- subroutine, public util::ireduce (A, Ared, n, ind, rind)
- subroutine, public util::vector_outer (u, v, A)

10.50.1 Function/Subroutine Documentation

10.50.1.1 integer function init_random_seed::lcg (integer(int64) *s*)

Definition at line 104 of file util.f90.

```
104       integer :: lcg
105       integer(int64) :: s
106       IF (s == 0) THEN
107          s = 104729
108       ELSE
109          s = mod(s, 4294967296_int64)
110       END IF
111       s = mod(s * 279470273_int64, 4294967291_int64)
112       lcg = int(mod(s, int(huge(0), int64)), kind(0))
113    END FUNCTION lcg
```

10.51 WL_tensor.f90 File Reference

Modules

- module wl_tensor

  The WL tensors used to integrate the model.

Functions/Subroutines

- subroutine, public wl_tensor::init_wl_tensor

  Subroutine to initialise the WL tensor.

Variables

- real(kind=8), dimension(:), allocatable, public wl_tensor::m11

    First component of the M1 term.
- type(coolist), dimension(:), allocatable, public wl_tensor::m12

    Second component of the M1 term.
- real(kind=8), dimension(:), allocatable, public wl_tensor::m13

    Third component of the M1 term.
- real(kind=8), dimension(:), allocatable, public wl_tensor::m1tot

    Total M_1 vector.
- type(coolist), dimension(:), allocatable, public wl_tensor::m21

    First tensor of the M2 term.
- type(coolist), dimension(:), allocatable, public wl_tensor::m22

    Second tensor of the M2 term.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::l1

    First linear tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::l2

    Second linear tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::l4

    Fourth linear tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::l5

    Fifth linear tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::ltot

    Total linear tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b1

    First quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b2

    Second quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b3

    Third quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b4

    Fourth quadratic tensor.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b14

    Joint 1st and 4th tensors.
- type(coolist), dimension(:,:), allocatable, public wl_tensor::b23

    Joint 2nd and 3rd tensors.
- type(coolist4), dimension(:,:), allocatable, public wl_tensor::mtot

    Tensor for the cubic terms.
- real(kind=8), dimension(:), allocatable wl_tensor::dumb_vec

    Dummy vector.
- real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat1

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat2

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat3

    Dummy matrix.
- real(kind=8), dimension(:,:), allocatable wl_tensor::dumb_mat4

    Dummy matrix.
- logical, public wl_tensor::m12def
- logical, public wl_tensor::m21def
- logical, public wl_tensor::m22def

- logical, public wl_tensor::ldef
- logical, public wl_tensor::b14def
- logical, public wl_tensor::b23def
- logical, public wl_tensor::mdef

    Boolean to (de)activate the computation of the terms.

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