

Reference Manual

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Chapter 1

Main Page

About

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This software is provided as supplementary material with:

- De Cruz, L., Demaeyer, J. and Vannitsem, S.: A modular arbitrary-order ocean-atmosphere model: MAOOA-M, Geosci. Model Dev. Discuss., [doi:xx/xxx](#), 2016.

Please cite this article 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 at [doi:yy/yyy](#) for updates, and [our website](#) for additional resources.

A pdf version of this manual is available [here](#).

Installation

The code should be compiled with gfortran 4.7+ (allows for allocatable arrays in namelists). Unpack the archive in a folder, and run: make

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

For Windows users, a minimalistic GNU development environment (including gfortran and make) is available at www.mingw.org.

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.

- [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.
- [integrator.f90](#) : A module which contains the integrator for the model equations.

- Makefile : The Makefile.
- [params.f90](#) : The model parameters module.
- [maooam_tl_ad.f90](#) : Tangent Linear (TL) and Adjoint (AD) model tensors definition module
- [tl_ad_integrator.f90](#) : 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.
- [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.

Usage

The user first has to fill the [params.nml](#) and [int_params.nml](#) namelist files according to their needs.

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(NBATM,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.

Model and integration parameters can be specified in the [params.nml](#) namelist file.

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 [maooam_tl_ad](#) and [tl_ad_integrator](#) module. It is documented [here](#).

Implementation notes

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

$$\frac{dy_i}{dt} = \sum_{j,k=0}^{ndim} \mathcal{T}_{i,j,k} y_k y_j$$

with $y_0 = 1$.

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 dy_i/dt proportional to $y_j y_k$.
- Furthermore, y_0 is always equal to 1, so that $\mathcal{T}_{i,0,0}$ is the constant contribution to dy_i/dt
- $\mathcal{T}_{i,j,0} + \mathcal{T}_{i,0,j}$ is the contribution to dy_i/dt which is linear in y_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 `aotensor_def` and uses the inner products defined in `inprod_analytic`.

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

$$\begin{aligned} \frac{d\delta y_i}{dt} &= \sum_{j=1}^{ndim} \sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}^{TL} y_k^* \delta y_j. \\ -\frac{d\delta y_i}{dt} &= \sum_{j=1}^{ndim} \sum_{k=0}^{ndim} \mathcal{T}_{i,j,k}^{AD} y_k^* \delta y_j. \end{aligned}$$

where y^* is the point where the Tangent model is defined (with $y_0^* = 1$).

Implementation :

The two tensors are implemented in the module `maooam_tl_ad` and must be initialized (after calling `params::init_params` and `aotensor_def::aotensor`) by calling `maooam_tl_ad::init_tlensor()` and `maooam_tl_ad::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 `tl_ad_maooam`. An example on how to use it can be found in the test file `test_tl_ad.f90`

Chapter 3

Data Type Index

3.1 Data Types List

Here are the data types with brief descriptions:

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	11
inprod_analytic::atm_tensors	Type holding the atmospheric inner products tensors	14
inprod_analytic::atm_wavenum	Atmospheric bloc specification type	15
tensor::coolist	Coordinate list. Type used to represent the sparse tensor	16
tensor::coolist_elem	Coordinate list element type. Elementary elements of the sparse tensors	17
ic_def	Module to load the initial condition	17
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	18
integrator	Module with the integration routines	24
maooam_tl_ad	Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module	26
inprod_analytic::ocean_tensors	Type holding the oceanic inner products tensors	32
inprod_analytic::ocean_wavenum	Oceanic bloc specification type	33
params	The model parameters module	33
stat	Statistics accumulators	42
tensor	Tensor utility module	44
tl_ad_integrator	Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module	48
util	Utility module	51

Chapter 4

File Index

4.1 File List

Here is a list of all files with brief descriptions:

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Chapter 5

Data Type Documentation

5.1 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.

Public Member Functions

- subroutine, public [init_aotensor](#)
Subroutine to initialise the [aotensor](#) tensor.

Public Attributes

- [type\(coolist\)](#), [dimension\(:\)](#),
[allocatable](#), public [aotensor](#)
 $\mathcal{T}_{i,j,k}$ - Tensor representation of the tendencies.

Private Member Functions

- 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](#).

Private Attributes

- 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.

5.1.1 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 ../../lua/aomodel_extended/aotensor.lua

Definition at line 21 of file aotensor_def.f90.

5.1.2 Member Function/Subroutine Documentation

5.1.2.1 integer function aotensor_def::a (integer i) [private]

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

Definition at line 75 of file aotensor_def.f90.

5.1.2.2 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 123 of file aotensor_def.f90.

5.1.2.3 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 98 of file aotensor_def.f90.

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

Subroutine to compute the tensor [aotensor](#).

Parameters

<i>func</i>	External function to be used
-------------	------------------------------

Definition at line 131 of file aotensor_def.f90.

5.1.2.5 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 201 of file aotensor_def.f90.

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

Kronecker delta function.

Definition at line 87 of file aotensor_def.f90.

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

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

Definition at line 63 of file aotensor_def.f90.

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

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

Definition at line 81 of file aotensor_def.f90.

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

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

Definition at line 69 of file aotensor_def.f90.

5.1.3 Member Data Documentation

5.1.3.1 type(colist), 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.

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

Vector used to count the tensor elements.

Definition at line 37 of file aotensor_def.f90.

5.1.3.3 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.

The documentation for this module was generated from the following file:

- [aotensor_def.f90](#)

5.2 inprod_analytic::atm_tensors Type Reference

Type holding the atmospheric inner products tensors.

Private Attributes

- real(kind=8), dimension(:,:), allocatable [a](#)
- real(kind=8), dimension(:,:), allocatable [c](#)
- real(kind=8), dimension(:,:), allocatable [d](#)
- real(kind=8), dimension(:,:), allocatable [s](#)
- real(kind=8), dimension(:,:,:), allocatable [b](#)
- real(kind=8), dimension(:,:,:), allocatable [g](#)

5.2.1 Detailed Description

Type holding the atmospheric inner products tensors.

Definition at line 52 of file inprod_analytic.f90.

5.2.2 Member Data Documentation

5.2.2.1 real(kind=8), dimension(:,:), allocatable inprod_analytic::atm_tensors::a [private]

Definition at line 53 of file inprod_analytic.f90.

5.2.2.2 real(kind=8), dimension(:,:,:), allocatable inprod_analytic::atm_tensors::b [private]

Definition at line 54 of file inprod_analytic.f90.

5.2.2.3 real(kind=8), dimension(:,:), allocatable inprod_analytic::atm_tensors::c [private]

Definition at line 53 of file inprod_analytic.f90.

5.2.2.4 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::atm_tensors::d` `[private]`

Definition at line 53 of file inprod_analytic.f90.

5.2.2.5 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::atm_tensors::g` `[private]`

Definition at line 54 of file inprod_analytic.f90.

5.2.2.6 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::atm_tensors::s` `[private]`

Definition at line 53 of file inprod_analytic.f90.

The documentation for this type was generated from the following file:

- [inprod_analytic.f90](#)

5.3 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.`

5.3.1 Detailed Description

Atmospheric bloc specification type.

Definition at line 39 of file inprod_analytic.f90.

5.3.2 Member Data Documentation

5.3.2.1 `integer inprod_analytic::atm_wavenum::h = 0` `[private]`

Definition at line 41 of file inprod_analytic.f90.

5.3.2.2 `integer inprod_analytic::atm_wavenum::m = 0` `[private]`

Definition at line 41 of file inprod_analytic.f90.

5.3.2.3 `real(kind=8) inprod_analytic::atm_wavenum::nx = 0.` `[private]`

Definition at line 42 of file inprod_analytic.f90.

5.3.2.4 `real(kind=8) inprod_analytic::atm_wavenum::ny = 0.` `[private]`

Definition at line 42 of file `inprod_analytic.f90`.

5.3.2.5 `integer inprod_analytic::atm_wavenum::p = 0` `[private]`

Definition at line 41 of file `inprod_analytic.f90`.

5.3.2.6 `character inprod_analytic::atm_wavenum::typ` `[private]`

Definition at line 40 of file `inprod_analytic.f90`.

The documentation for this type was generated from the following file:

- [inprod_analytic.f90](#)

5.4 `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.

5.4.1 Detailed Description

Coordinate list. Type used to represent the sparse tensor.

Definition at line 27 of file `tensor.f90`.

5.4.2 Member Data Documentation

5.4.2.1 `type(coolist_elem)`, `dimension(:)`, allocatable `tensor::coolist::elems`

Lists of elements `tensor::coolist_elem`.

Definition at line 28 of file `tensor.f90`.

5.4.2.2 `integer tensor::coolist::nelems` = 0

Number of elements in the list.

Definition at line 29 of file `tensor.f90`.

The documentation for this type was generated from the following file:

- [tensor.f90](#)

5.5 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.

5.5.1 Detailed Description

Coordinate list element type. Elementary elements of the sparse tensors.

Definition at line 20 of file tensor.f90.

5.5.2 Member Data Documentation

5.5.2.1 integer tensor::coolist_elem::j [private]

Index j of the element.

Definition at line 21 of file tensor.f90.

5.5.2.2 integer tensor::coolist_elem::k [private]

Index k of the element.

Definition at line 22 of file tensor.f90.

5.5.2.3 real(kind=8) tensor::coolist_elem::v [private]

Value of the element.

Definition at line 23 of file tensor.f90.

The documentation for this type was generated from the following file:

- [tensor.f90](#)

5.6 ic_def Module Reference

Module to load the initial condition.

Public Member Functions

- 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.

Public Attributes

- `real(kind=8), dimension(:), allocatable, public ic`
Initial condition vector.

Private Attributes

- logical `exists`
Boolean to test for file existence.

5.6.1 Detailed Description

Module to load the initial condition.

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Definition at line 12 of file `ic_def.f90`.

5.6.2 Member Function/Subroutine Documentation

5.6.2.1 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 31 of file `ic_def.f90`.

5.6.3 Member Data Documentation

5.6.3.1 logical `ic_def::exists` [`private`]

Boolean to test for file existence.

Definition at line 21 of file `ic_def.f90`.

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

Initial condition vector.

Definition at line 23 of file `ic_def.f90`.

The documentation for this module was generated from the following file:

- [ic_def.f90](#)

5.7 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.

Public Member Functions

- subroutine, public [init_inprod](#)
Initialisation of the inner product.
- subroutine, public [deallocate_inprod](#)
Deallocation of the inner products.

Public Attributes

- 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.

Private Member Functions

- 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.
- subroutine [calculate_a](#)

- Eigenvalues of the Laplacian (atmospheric)*
- subroutine [calculate_b](#)
- Streamfunction advection terms (atmospheric)*
- subroutine [calculate_c_atm](#)
- Beta term for the atmosphere.*
- subroutine [calculate_d](#)
- Forcing of the ocean on the atmosphere.*
- subroutine [calculate_g](#)
- Temperature advection terms (atmospheric)*
- subroutine [calculate_s](#)
- Forcing (thermal) of the ocean on the atmosphere.*
- subroutine [calculate_k](#)
- Forcing of the atmosphere on the ocean.*
- subroutine [calculate_m](#)
- Forcing of the ocean fields on the ocean.*
- subroutine [calculate_n](#)
- Beta term for the ocean.*
- subroutine [calculate_o](#)
- Temperature advection term (passive scalar)*
- subroutine [calculate_c_oc](#)
- Streamfunction advection terms (oceanic)*
- subroutine [calculate_w](#)
- Short-wave radiative forcing of the ocean.*

5.7.1 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 ../../lua/aomodel_extended/inprod_analytic.lua

Definition at line 23 of file inprod_analytic.f90.

5.7.2 Member Function/Subroutine Documentation

5.7.2.1 `REAL(KIND=8)` function `inprod_analytic::b1 (integer Pi, integer Pj, integer Pk)` `[private]`

Cehelsky & Tung Helper functions.

Definition at line 90 of file inprod_analytic.f90.

5.7.2.2 `REAL(KIND=8)` function `inprod_analytic::b2 (integer Pi, integer Pj, integer Pk)` `[private]`

Cehelsky & Tung Helper functions.

Definition at line 96 of file inprod_analytic.f90.

5.7.2.3 subroutine inprod_analytic::calculate_a () [private]

Eigenvalues of the Laplacian (atmospheric)

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

Definition at line 154 of file inprod_analytic.f90.

5.7.2.4 subroutine inprod_analytic::calculate_b () [private]

Streamfunction advection terms (atmospheric)

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

Remarks

Atmospheric g and a tensors must be computed before calling this routine

Definition at line 181 of file inprod_analytic.f90.

5.7.2.5 subroutine inprod_analytic::calculate_c_atm () [private]

Beta term for the atmosphere.

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

Remarks

Strict function !! Only accepts KL type. For any other combination, it will not calculate anything

Definition at line 215 of file inprod_analytic.f90.

5.7.2.6 subroutine inprod_analytic::calculate_c_oc () [private]

Streamfunction advection terms (oceanic)

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

Remarks

Requires O_{i,j,k} and M_{i,j} to be calculated beforehand.

Definition at line 567 of file inprod_analytic.f90.

5.7.2.7 subroutine inprod_analytic::calculate_d () [private]

Forcing of the ocean on the atmosphere.

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

Remarks

Atmospheric s tensor and oceanic M tensor must be computed before calling this routine !

Definition at line 254 of file inprod_analytic.f90.

5.7.2.8 subroutine inprod_analytic::calculate_g () [private]

Temperature advection terms (atmospheric)

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

Definition at line 287 of file inprod_analytic.f90.

5.7.2.9 subroutine inprod_analytic::calculate_k () [private]

Forcing of the atmosphere on the ocean.

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

Remarks

atmospheric a and s tensors must be computed before calling this function !

Definition at line 433 of file inprod_analytic.f90.

5.7.2.10 subroutine inprod_analytic::calculate_m () [private]

Forcing of the ocean fields on the ocean.

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

Definition at line 463 of file inprod_analytic.f90.

5.7.2.11 subroutine inprod_analytic::calculate_n () [private]

Beta term for the ocean.

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

Definition at line 486 of file inprod_analytic.f90.

5.7.2.12 subroutine inprod_analytic::calculate_o () [private]

Temperature advection term (passive scalar)

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

Definition at line 515 of file inprod_analytic.f90.

5.7.2.13 subroutine inprod_analytic::calculate_s () [private]

Forcing (thermal) of the ocean on the atmosphere.

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

Definition at line 379 of file inprod_analytic.f90.

5.7.2.14 subroutine inprod_analytic::calculate_w () [private]

Short-wave radiative forcing of the ocean.

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

Remarks

atmospheric s tensor must be computed before calling this function !

Definition at line 604 of file inprod_analytic.f90.

5.7.2.15 subroutine, public inprod_analytic::deallocate_inprod ()

Deallocation of the inner products.

Definition at line 721 of file inprod_analytic.f90.

5.7.2.16 REAL(KIND=8) function inprod_analytic::delta (integer *r*) [private]

Integer Dirac delta function.

Definition at line 102 of file inprod_analytic.f90.

5.7.2.17 REAL(KIND=8) function inprod_analytic::flambda (integer *r*) [private]

"Odd or even" function

Definition at line 112 of file inprod_analytic.f90.

5.7.2.18 subroutine, public inprod_analytic::init_inprod ()

Initialisation of the inner product.

Definition at line 638 of file inprod_analytic.f90.

5.7.2.19 REAL(KIND=8) function inprod_analytic::s1 (integer *Pj*, integer *Pk*, integer *Mj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 122 of file inprod_analytic.f90.

5.7.2.20 REAL(KIND=8) function inprod_analytic::s2 (integer *Pj*, integer *Pk*, integer *Mj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 128 of file inprod_analytic.f90.

5.7.2.21 REAL(KIND=8) function inprod_analytic::s3 (integer *Pj*, integer *Pk*, integer *Hj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 134 of file inprod_analytic.f90.

5.7.2.22 REAL(KIND=8) function inprod_analytic::s4 (integer *Pj*, integer *Pk*, integer *Hj*, integer *Hk*) [private]

Cehelsky & Tung Helper functions.

Definition at line 140 of file inprod_analytic.f90.

5.7.3 Member Data Documentation

5.7.3.1 `type(atm_tensors)`, public `inprod_analytic::atmos`

Atmospheric tensors.

Definition at line 69 of file `inprod_analytic.f90`.

5.7.3.2 `type(atm_wavenum)`, `dimension(:)`, allocatable, public `inprod_analytic::awavenum`

Atmospheric blocs specification.

Definition at line 64 of file `inprod_analytic.f90`.

5.7.3.3 `type(ocean_tensors)`, public `inprod_analytic::ocean`

Oceanic tensors.

Definition at line 71 of file `inprod_analytic.f90`.

5.7.3.4 `type(ocean_wavenum)`, `dimension(:)`, allocatable, public `inprod_analytic::owavenum`

Oceanic blocs specification.

Definition at line 66 of file `inprod_analytic.f90`.

The documentation for this module was generated from the following file:

- [inprod_analytic.f90](#)

5.8 integrator Module Reference

Module with the integration routines.

Public Member Functions

- subroutine, public [init_integrator](#)
Routine to initialise the integration buffers.
- subroutine, public [step](#) (`y`, `t`, `dt`, `res`)
Routine to perform an integration step (Heun algorithm). The incremented time is returned.

Private Member Functions

- subroutine [tendencies](#) (`t`, `y`, `res`)
Routine computing the tendencies of the model.

Private Attributes

- `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.

5.8.1 Detailed Description

Module with the 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.

Definition at line 19 of file `integrator.f90`.

5.8.2 Member Function/Subroutine Documentation

5.8.2.1 subroutine, public `integrator::init_integrator ()`

Routine to initialise the integration buffers.

Definition at line 36 of file `integrator.f90`.

5.8.2.2 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.

Parameters

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

Definition at line 60 of file `integrator.f90`.

5.8.2.3 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

<code>t</code>	Time at which the tendencies have to be computed. Actually not needed for autonomous systems.
<code>y</code>	Point at which the tendencies have to be computed.
<code>res</code>	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 48 of file `integrator.f90`.

5.8.3 Member Data Documentation**5.8.3.1** `real(kind=8), dimension(:), allocatable integrator::buf_f0` `[private]`

Buffer to hold tendencies at the initial position.

Definition at line 28 of file `integrator.f90`.

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

Buffer to hold tendencies at the intermediate position.

Definition at line 29 of file `integrator.f90`.

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

Buffer to hold the intermediate position (Heun algorithm)

Definition at line 27 of file `integrator.f90`.

The documentation for this module was generated from the following file:

- [integrator.f90](#)

5.9 maoam_tl_ad Module Reference

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module.

Public Member Functions

- subroutine, public [init_tlensor](#)
Routine to initialize the TL tensor.
- subroutine, public [init_adtensor](#)
Routine to initialize the AD tensor.
- subroutine, public [init_adtensor_ref](#)
Alternate method to initialize the AD tensor 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.

Public Attributes

- `type(coolist), dimension(:), allocatable, public` [tlensor](#)
Tensor representation of the Tangent Linear tendencies.
- `type(coolist), dimension(:), allocatable, public` [adtensor](#)
Tensor representation of the Adjoint tendencies.

Private Member Functions

- `type(coolist)` function,
`dimension(ndim) jacobian (ystar)`
Compute the Jacobian of MAOOAM in point ystar.
- `real(kind=8)` function,
`dimension(ndim, ndim) jacobian_mat (ystar)`
Compute the Jacobian of MAOOAM in point ystar.
- 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 `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 used to compute the AD tensor entries.
- 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.

Private Attributes

- `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.

5.9.1 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 !

Definition at line 19 of file `maoam_tl_ad.f90`.

5.9.2 Member Function/Subroutine Documentation

5.9.2.1 subroutine, public `maooam_tl_ad::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

<i>t</i>	time
<i>ystar</i>	vector with the variables (current point in trajectory)
<i>deltay</i>	vector with the perturbation of the variables at time <i>t</i>
<i>buf</i>	vector (buffer) to store derivatives.

Definition at line 390 of file `maooam_tl_ad.f90`.

5.9.2.2 subroutine `maooam_tl_ad::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>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value that will be added

Definition at line 249 of file `maooam_tl_ad.f90`.

5.9.2.3 subroutine `maooam_tl_ad::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>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value that will be added

Definition at line 352 of file `maooam_tl_ad.f90`.

5.9.2.4 subroutine `maooam_tl_ad::ad_coeff` (`integer`, intent(in) *i*, `integer`, intent(in) *j*, `integer`, intent(in) *k*, `real(kind=8)`, intent(in) *v*) [private]

Parameters

<i>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value to add

Definition at line 263 of file `maooam_tl_ad.f90`.

5.9.2.5 subroutine maoam_tl_ad::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>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value to add

Definition at line 364 of file maoam_tl_ad.f90.

5.9.2.6 subroutine maoam_tl_ad::compute_adtensor (external *func*) [private]

Subroutine to compute the AD tensor from the original MAOOAM one.

Parameters

<i>func</i>	subroutine used to do the computation
-------------	---------------------------------------

Definition at line 223 of file maoam_tl_ad.f90.

5.9.2.7 subroutine maoam_tl_ad::compute_adtensor_ref (external *func*) [private]

Alternate subroutine to compute the AD tensor from the TL one.

Parameters

<i>func</i>	subroutine used to do the computation
-------------	---------------------------------------

Definition at line 324 of file maoam_tl_ad.f90.

5.9.2.8 subroutine maoam_tl_ad::compute_tltensor (external *func*) [private]

Routine to compute the TL tensor from the original MAOOAM one.

Parameters

<i>func</i>	subroutine used to do the computation
-------------	---------------------------------------

Definition at line 127 of file maoam_tl_ad.f90.

5.9.2.9 subroutine, public maoam_tl_ad::init_adtensor ()

Routine to initialize the AD tensor.

Definition at line 199 of file maoam_tl_ad.f90.

5.9.2.10 subroutine, public maoam_tl_ad::init_adtensor_ref ()

Alternate method to initialize the AD tensor from the TL tensor.

Remarks

The `tlensor` must be initialised before using this method.

Definition at line 300 of file `maooam_tl_ad.f90`.

5.9.2.11 subroutine, public `maooam_tl_ad::init_tltensor ()`

Routine to initialize the TL tensor.

Definition at line 103 of file `maooam_tl_ad.f90`.

5.9.2.12 type(`coolist`) function, dimension(`ndim`) `maooam_tl_ad::jacobian (real(kind=8), dimension(0:ndim), intent(in) ystar) [private]`

Compute the Jacobian of MAOOAM in point `ystar`.

Parameters

<code>ystar</code>	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 81 of file `maooam_tl_ad.f90`.

5.9.2.13 real(kind=8) function, dimension(`ndim`,`ndim`) `maooam_tl_ad::jacobian_mat (real(kind=8), dimension(0:ndim), intent(in) ystar) [private]`

Compute the Jacobian of MAOOAM in point `ystar`.

Parameters

<code>ystar</code>	array with variables in which the jacobian should be evaluated.
--------------------	---

Returns

Jacobian in matrix form

Definition at line 90 of file `maooam_tl_ad.f90`.

5.9.2.14 subroutine, public `maooam_tl_ad::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

<code>t</code>	time
<code>ystar</code>	vector with the variables (current point in trajectory)
<code>deltay</code>	vector with the perturbation of the variables at time <code>t</code>
<code>buf</code>	vector (buffer) to store derivatives.

Definition at line 402 of file `maooam_tl_ad.f90`.

5.9.2.15 subroutine maoam_tl_ad::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>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value that will be added

Definition at line 153 of file maoam_tl_ad.f90.

5.9.2.16 subroutine maoam_tl_ad::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>i</i>	tensor <i>i</i> index
<i>j</i>	tensor <i>j</i> index
<i>k</i>	tensor <i>k</i> index
<i>v</i>	value to add

Definition at line 167 of file maoam_tl_ad.f90.

5.9.3 Member Data Documentation

5.9.3.1 type(coolist), dimension(:), allocatable, public maoam_tl_ad::adtensor

Tensor representation of the Adjoint tendencies.

Definition at line 51 of file maoam_tl_ad.f90.

5.9.3.2 integer, dimension(:), allocatable maoam_tl_ad::count_elems [private]

Vector used to count the tensor elements.

Definition at line 45 of file maoam_tl_ad.f90.

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

Epsilon to test equality with 0.

Definition at line 42 of file maoam_tl_ad.f90.

5.9.3.4 type(coolist), dimension(:), allocatable, public maoam_tl_ad::tltensor

Tensor representation of the Tangent Linear tendencies.

Definition at line 48 of file maoam_tl_ad.f90.

The documentation for this module was generated from the following file:

- [maoam_tl_ad.f90](#)

5.10 inprod_analytic::ocean_tensors Type Reference

Type holding the oceanic inner products tensors.

Private Attributes

- `real(kind=8), dimension(:,,:), allocatable k`
- `real(kind=8), dimension(:,,:), allocatable m`
- `real(kind=8), dimension(:,,:), allocatable n`
- `real(kind=8), dimension(:,,:), allocatable w`
- `real(kind=8), dimension(:,,:), allocatable o`
- `real(kind=8), dimension(:,,:), allocatable c`

5.10.1 Detailed Description

Type holding the oceanic inner products tensors.

Definition at line 58 of file `inprod_analytic.f90`.

5.10.2 Member Data Documentation

5.10.2.1 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::c` `[private]`

Definition at line 60 of file `inprod_analytic.f90`.

5.10.2.2 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::k` `[private]`

Definition at line 59 of file `inprod_analytic.f90`.

5.10.2.3 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::m` `[private]`

Definition at line 59 of file `inprod_analytic.f90`.

5.10.2.4 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::n` `[private]`

Definition at line 59 of file `inprod_analytic.f90`.

5.10.2.5 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::o` `[private]`

Definition at line 60 of file `inprod_analytic.f90`.

5.10.2.6 `real(kind=8), dimension(:,,:), allocatable inprod_analytic::ocean_tensors::w` `[private]`

Definition at line 59 of file `inprod_analytic.f90`.

The documentation for this type was generated from the following file:

- [inprod_analytic.f90](#)

5.11 inprod_analytic::ocean_wavenum Type Reference

Oceanic bloc specification type.

Private Attributes

- integer [p](#)
- integer [h](#)
- real(kind=8) [nx](#)
- real(kind=8) [ny](#)

5.11.1 Detailed Description

Oceanic bloc specification type.

Definition at line 46 of file inprod_analytic.f90.

5.11.2 Member Data Documentation

5.11.2.1 integer inprod_analytic::ocean_wavenum::h [private]

Definition at line 47 of file inprod_analytic.f90.

5.11.2.2 real(kind=8) inprod_analytic::ocean_wavenum::nx [private]

Definition at line 48 of file inprod_analytic.f90.

5.11.2.3 real(kind=8) inprod_analytic::ocean_wavenum::ny [private]

Definition at line 48 of file inprod_analytic.f90.

5.11.2.4 integer inprod_analytic::ocean_wavenum::p [private]

Definition at line 47 of file inprod_analytic.f90.

The documentation for this type was generated from the following file:

- [inprod_analytic.f90](#)

5.12 params Module Reference

The model parameters module.

Public Member Functions

- subroutine [init_params](#)
Parameters initialisation routine.

Public Attributes

- 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**
σ'_{B,o} - Long wave radiation lost by ocean to atmosphere & space.
- real(kind=8) **sbpa**
σ'_{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**
- 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.

Private Member Functions

- subroutine, private [init_nml](#)

Read the basic parameters and mode selection from the namelist.

5.12.1 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

Definition at line 18 of file params.f90.

5.12.2 Member Function/Subroutine Documentation

5.12.2.1 subroutine, private params::init_nml () [private]

Read the basic parameters and mode selection from the namelist.

Definition at line 90 of file params.f90.

5.12.2.2 subroutine params::init_params ()

Parameters initialisation routine.

Definition at line 134 of file params.f90.

5.12.3 Member Data Documentation

5.12.3.1 integer, dimension(:,:), allocatable params::ams

Atmospheric mode selection array.

Definition at line 81 of file params.f90.

5.12.3.2 real(kind=8) params::betp

Definition at line 67 of file params.f90.

5.12.3.3 `real(kind=8) params::ca`

C_a - Constant short-wave radiation of the atmosphere.

Definition at line 40 of file params.f90.

5.12.3.4 `real(kind=8) params::co`

C_a - Constant short-wave radiation of the ocean.

Definition at line 38 of file params.f90.

5.12.3.5 `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.

5.12.3.6 `real(kind=8) params::cpo`

C'_a - Non-dimensional constant short-wave radiation of the ocean.

Definition at line 56 of file params.f90.

5.12.3.7 `real(kind=8) params::d`

Mechanical coupling parameter between the ocean and the atmosphere.

Definition at line 31 of file params.f90.

5.12.3.8 `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.

5.12.3.9 `real(kind=8) params::dt`

Integration time step.

Definition at line 71 of file params.f90.

5.12.3.10 `real(kind=8) params::epsa`

ϵ_a - Emissivity coefficient for the grey-body atmosphere.

Definition at line 43 of file params.f90.

5.12.3.11 `real(kind=8) params::f0`

f_0 - Coriolis parameter

Definition at line 32 of file params.f90.

5.12.3.12 real(kind=8) params::g γ

Definition at line 50 of file params.f90.

5.12.3.13 real(kind=8) params::ga

γ_a - Specific heat capacity of the atmosphere.

Definition at line 44 of file params.f90.

5.12.3.14 real(kind=8) params::go

γ_o - Specific heat capacity of the ocean.

Definition at line 39 of file params.f90.

5.12.3.15 real(kind=8) params::gp

g' Reduced gravity

Definition at line 33 of file params.f90.

5.12.3.16 real(kind=8) params::h

Depth of the active water layer of the ocean.

Definition at line 34 of file params.f90.

5.12.3.17 real(kind=8) params::k

Bottom atmospheric friction coefficient.

Definition at line 28 of file params.f90.

5.12.3.18 real(kind=8) params::kd

k_d - Non-dimensional bottom atmospheric friction coefficient.

Definition at line 53 of file params.f90.

5.12.3.19 real(kind=8) params::kdp

k'_d - Non-dimensional internal atmospheric friction coefficient.

Definition at line 54 of file params.f90.

5.12.3.20 real(kind=8) params::kp

k' - Internal atmospheric friction coefficient.

Definition at line 29 of file params.f90.

5.12.3.21 `real(kind=8) params::l`

L - Domain length scale

Definition at line 64 of file params.f90.

5.12.3.22 `real(kind=8) params::lambda`

λ - Sensible + turbulent heat exchange between the ocean and the atmosphere.

Definition at line 37 of file params.f90.

5.12.3.23 `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.

5.12.3.24 `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.

5.12.3.25 `real(kind=8) params::lr`

L_R - Rossby deformation radius

Definition at line 49 of file params.f90.

5.12.3.26 `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.

5.12.3.27 `real(kind=8) params::lsbpo`

$S'_{B,o}$ - Long wave radiation from ocean absorbed by atmosphere.

Definition at line 62 of file params.f90.

5.12.3.28 `real(kind=8) params::n`

$n = 2L_y/L_x$ - Aspect ratio

Definition at line 24 of file params.f90.

5.12.3.29 `integer params::natm = 0`

Number of atmospheric basis functions.

Definition at line 77 of file params.f90.

5.12.3.30 integer params::nbatm

Number of oceanic blocks.

Definition at line 76 of file params.f90.

5.12.3.31 integer params::nboc

Number of atmospheric blocks.

Definition at line 75 of file params.f90.

5.12.3.32 integer params::ndim

Number of variables (dimension of the model)

Definition at line 79 of file params.f90.

5.12.3.33 integer params::noc =0

Number of oceanic basis functions.

Definition at line 78 of file params.f90.

5.12.3.34 integer, dimension(:,,:), allocatable params::oms

Ocean mode selection array.

Definition at line 80 of file params.f90.

5.12.3.35 real(kind=8) params::phi0

Latitude in radian.

Definition at line 25 of file params.f90.

5.12.3.36 real(kind=8) params::phi0_npi

Latitude exprimed in fraction of pi.

Definition at line 35 of file params.f90.

5.12.3.37 real(kind=8) params::pi

π

Definition at line 48 of file params.f90.

5.12.3.38 real(kind=8) params::r

Frictional coefficient at the bottom of the ocean.

Definition at line 30 of file params.f90.

5.12.3.39 `real(kind=8) params::rp`

r' - Frictional coefficient at the bottom of the ocean.

Definition at line 51 of file params.f90.

5.12.3.40 `real(kind=8) params::rr`

R - Gas constant of dry air

Definition at line 45 of file params.f90.

5.12.3.41 `real(kind=8) params::rra`

Earth radius.

Definition at line 26 of file params.f90.

5.12.3.42 `real(kind=8) params::sb`

Stefan–Boltzmann constant.

Definition at line 66 of file params.f90.

5.12.3.43 `real(kind=8) params::sbpa`

$\sigma'_{B,a}$ - Long wave radiation from atmosphere absorbed by ocean.

Definition at line 61 of file params.f90.

5.12.3.44 `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.

5.12.3.45 `real(kind=8) params::sc`

Ratio of surface to atmosphere temperature.

Definition at line 65 of file params.f90.

5.12.3.46 `real(kind=8) params::scale`

$L_y = L\pi$ - The characteristic space scale.

Definition at line 47 of file params.f90.

5.12.3.47 `real(kind=8) params::sig0`

σ_0 - Non-dimensional static stability of the atmosphere.

Definition at line 27 of file params.f90.

5.12.3.48 `real(kind=8) params::t_run`

Effective intergration time (length of the generated trajectory)

Definition at line 70 of file params.f90.

5.12.3.49 `real(kind=8) params::t_trans`

Transient time period.

Definition at line 69 of file params.f90.

5.12.3.50 `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.

5.12.3.51 `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.

5.12.3.52 `real(kind=8) params::tw`

Write all variables every tw time units.

Definition at line 72 of file params.f90.

5.12.3.53 `logical params::writeout`

Write to file boolean.

Definition at line 73 of file params.f90.

The documentation for this module was generated from the following file:

- [params.f90](#)

5.13 stat Module Reference

Statistics accumulators.

Public Member Functions

- 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.

Private Attributes

- 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](#)

5.13.1 Detailed Description

Statistics accumulators.

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Definition at line 14 of file stat.f90.

5.13.2 Member Function/Subroutine Documentation

5.13.2.1 subroutine, public stat::acc (real(kind=8), dimension(0:ndim), intent(in) x)

Accumulate one state.

Definition at line 47 of file stat.f90.

5.13.2.2 subroutine, public stat::init_stat ()

Initialise the accumulators.

Definition at line 34 of file stat.f90.

5.13.2.3 integer function, public stat::iter ()

Function returning the number of data accumulated.

Definition at line 71 of file stat.f90.

5.13.2.4 `real(kind=8) function, dimension(0:ndim), public stat::mean ()`

Function returning the mean.

Definition at line 59 of file stat.f90.

5.13.2.5 `subroutine, public stat::reset ()`

Routine resetting the accumulators.

Definition at line 77 of file stat.f90.

5.13.2.6 `real(kind=8) function, dimension(0:ndim), public stat::var ()`

Function returning the variance.

Definition at line 65 of file stat.f90.

5.13.3 Member Data Documentation

5.13.3.1 `integer stat::i =0 [private]`

Number of stats accumulated.

Definition at line 20 of file stat.f90.

5.13.3.2 `real(kind=8), dimension(:), allocatable stat::m [private]`

Vector storing the inline mean.

Definition at line 23 of file stat.f90.

5.13.3.3 `real(kind=8), dimension(:), allocatable stat::mprev [private]`

Previous mean vector.

Definition at line 24 of file stat.f90.

5.13.3.4 `real(kind=8), dimension(:), allocatable stat::mtmp [private]`

Definition at line 26 of file stat.f90.

5.13.3.5 `real(kind=8), dimension(:), allocatable stat::v [private]`

Vector storing the inline variance.

Definition at line 25 of file stat.f90.

The documentation for this module was generated from the following file:

- [stat.f90](#)

5.14 tensor Module Reference

Tensor utility module.

Data Types

- type `coolist`
Coordinate list. Type used to represent the sparse tensor.
- type `coolist_elem`
Coordinate list element type. Elementary elements of the sparse tensors.

Public Member Functions

- subroutine, public `copy_tensor` (src, dst)
Routine to copy a tensor.
- 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 vectors:
$$\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k} a_j b_k.$$

- subroutine, public `simplify` (tensor)
Routine to simplify a coolist (sparse tensor). For each index i, it upper triangularize the matrix

$$\mathcal{T}_{i,j,k} \quad 0 \leq j, k \leq ndim.$$

Public Attributes

- real(kind=8), parameter `real_eps` = 2.2204460492503131e-16
Parameter to test the equality with zero.

5.14.1 Detailed Description

Tensor utility module.

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Definition at line 13 of file tensor.f90.

5.14.2 Member Function/Subroutine Documentation

5.14.2.1 subroutine, public `tensor::copy_tensor (type(coolist), dimension(ndim), intent(in) src, type(coolist), dimension(ndim), intent(out) dst)`

Routine to copy a tensor.

Parameters

<i>src</i>	Source tensor
<i>dst</i>	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 43 of file tensor.f90.

5.14.2.2 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:

$$J_{i,j} = \sum_{k=0}^{ndim} (\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j}) a_k.$$

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).

Parameters

<i>coolist_ijk</i>	a coordinate list (sparse tensor) of which index 2 or 3 will be contracted.
<i>arr_j</i>	the vector to be contracted with index 2 and then index 3 of <i>ffi_coo_ijk</i>
<i>jcoo_ij</i>	a coolist (sparse tensor) to store the result of the contraction

Definition at line 122 of file tensor.f90.

5.14.2.3 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:

$$J_{i,j} = \sum_{k=0}^{ndim} (\mathcal{T}_{i,j,k} + \mathcal{T}_{i,k,j}) a_k.$$

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.

Parameters

<i>coolist_ijk</i>	a coordinate list (sparse tensor) of which index 2 or 3 will be contracted.
<i>arr_j</i>	the vector to be contracted with index 2 and then index 3 of ffi_coo_ijk
<i>jcoo_ij</i>	a matrix to store the result of the contraction

Definition at line 165 of file tensor.f90.

5.14.2.4 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

<i>src</i>	Source matrix
<i>dst</i>	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 65 of file tensor.f90.

5.14.2.5 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

$$\mathcal{T}_{i,j,k} \quad 0 \leq j, k \leq ndim.$$

.

Parameters

<i>tensor</i>	a coordinate list (sparse tensor) which will be simplified.
---------------	---

Definition at line 207 of file tensor.f90.

5.14.2.6 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 vectors: $\sum_{j=0}^{ndim} \mathcal{T}_{i,j,k} a_j b_k$.

Parameters

<i>coolist_ij</i>	a coordinate list (sparse tensor) of which index 2 will be contracted.
<i>arr_j</i>	the vector to be contracted with index 2 of coolist_ijk
<i>res</i>	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 190 of file `tensor.f90`.

5.14.2.7 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

<code>coolist_ijk</code>	a coordinate list (sparse tensor) of which index 2 and 3 will be contracted.
<code>arr_j</code>	the vector to be contracted with index 2 of <code>coolist_ijk</code>
<code>arr_k</code>	the vector to be contracted with index 3 of <code>coolist_ijk</code>
<code>res</code>	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 98 of file `tensor.f90`.

5.14.3 Member Data Documentation

5.14.3.1 `real(kind=8), parameter tensor::real_eps = 2.2204460492503131e-16`

Parameter to test the equality with zero.

Definition at line 33 of file `tensor.f90`.

The documentation for this module was generated from the following file:

- [tensor.f90](#)

5.15 tl_ad_integrator Module Reference

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

Public Member Functions

- subroutine, public [init_ad_integrator](#)
Routine to initialise the adjoint model 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 [init_tl_integrator](#)
Routine to initialise the tangent linear model integration buffers.
- 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.

Private Attributes

- real(kind=8), dimension(:),
allocatable [ad_buf_y1](#)
Buffer to hold the intermediate position (Heun algorithm) of the adjoint model.
- real(kind=8), dimension(:),
allocatable [ad_buf_f0](#)
Buffer to hold tendencies at the initial position of the adjoint model.
- real(kind=8), dimension(:),
allocatable [ad_buf_f1](#)
Buffer to hold tendencies at the intermediate position of the adjoint model.
- real(kind=8), dimension(:),
allocatable [tl_buf_y1](#)
Buffer to hold the intermediate position (Heun algorithm) of the tangent linear model.
- real(kind=8), dimension(:),
allocatable [tl_buf_f0](#)
Buffer to hold tendencies at the initial position of the tangent linear model.
- real(kind=8), dimension(:),
allocatable [tl_buf_f1](#)
Buffer to hold tendencies at the intermediate position of the tangent linear model.

5.15.1 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.

Definition at line 22 of file `tl_ad_integrator.f90`.

5.15.2 Member Function/Subroutine Documentation

- 5.15.2.1 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.

Parameters

<i>y</i>	Initial point.
<i>ystar</i>	Adjoint model at the point <i>ystar</i> .
<i>t</i>	Actual integration time
<i>dt</i>	Integration timestep.
<i>res</i>	Final point after the step.

Definition at line 62 of file `tl_ad_integrator.f90`.

5.15.2.2 subroutine, public `tl_ad_integrator::init_ad_integrator ()`

Routine to initialise the adjoint model integration buffers.

Definition at line 50 of file `tl_ad_integrator.f90`.

5.15.2.3 subroutine, public `tl_ad_integrator::init_tl_integrator ()`

Routine to initialise the tangent linear model integration buffers.

Definition at line 82 of file `tl_ad_integrator.f90`.

5.15.2.4 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.

Parameters

<i>y</i>	Initial point.
<i>ystar</i>	Adjoint model at the point ystar.
<i>t</i>	Actual integration time
<i>dt</i>	Integration timestep.
<i>res</i>	Final point after the step.

Definition at line 94 of file `tl_ad_integrator.f90`.

5.15.3 Member Data Documentation

5.15.3.1 `real(kind=8), dimension(:), allocatable tl_ad_integrator::ad_buf_f0` [private]

Buffer to hold tendencies at the initial position of the adjoint model.

Definition at line 31 of file `tl_ad_integrator.f90`.

5.15.3.2 `real(kind=8), dimension(:), allocatable tl_ad_integrator::ad_buf_f1` [private]

Buffer to hold tendencies at the intermediate position of the adjoint model.

Definition at line 32 of file `tl_ad_integrator.f90`.

5.15.3.3 `real(kind=8), dimension(:), allocatable tl_ad_integrator::ad_buf_y1` [private]

Buffer to hold the intermediate position (Heun algorithm) of the adjoint model.

Definition at line 30 of file `tl_ad_integrator.f90`.

5.15.3.4 `real(kind=8), dimension(:), allocatable tl_ad_integrator::tl_buf_f0` [private]

Buffer to hold tendencies at the initial position of the tangent linear model.

Definition at line 35 of file `tl_ad_integrator.f90`.

5.15.3.5 `real(kind=8), dimension(:), allocatable tl_ad_integrator::tl_buf_f1` `[private]`

Buffer to hold tendencies at the intermediate position of the tangent linear model.

Definition at line 36 of file `tl_ad_integrator.f90`.

5.15.3.6 `real(kind=8), dimension(:), allocatable tl_ad_integrator::tl_buf_y1` `[private]`

Buffer to hold the intermediate position (Heun algorithm) of the tangent linear model.

Definition at line 34 of file `tl_ad_integrator.f90`.

The documentation for this module was generated from the following file:

- [tl_ad_integrator.f90](#)

5.16 util Module Reference

Utility module.

Public Member Functions

- `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.

5.16.1 Detailed Description

Utility module.

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Definition at line 13 of file `util.f90`.

5.16.2 Member Function/Subroutine Documentation

5.16.2.1 `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 35 of file `util.f90`.

5.16.2.2 `CHARACTER(len=20)` function, public `util::str` (`integer`, `intent(in)` `k`)

Convert an integer to string.

Definition at line 28 of file `util.f90`.

The documentation for this module was generated from the following file:

- [util.f90](#)

Chapter 6

File Documentation

6.1 aotensor_def.f90 File Reference

Data Types

- 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.

6.2 doc/gen_doc.md File Reference

6.3 doc/tl_ad_doc.md File Reference

6.4 ic_def.f90 File Reference

Data Types

- module [ic_def](#)

Module to load the initial condition.

6.5 inprod_analytic.f90 File Reference

Data Types

- 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.

- 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.

6.6 integrator.f90 File Reference

Data Types

- module [integrator](#)

Module with the integration routines.

6.7 LICENSE.txt File Reference

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6.8 maoam.f90 File Reference

Functions/Subroutines

- program [maoam](#)

Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere ! model MAOOAM. !

6.8.1 Function/Subroutine Documentation

6.8.1.1 program maoam ()

Fortran 90 implementation of the modular arbitrary-order ocean-atmosphere ! model MAOOAM. !

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Definition at line 13 of file maoam.f90.

6.9 maoam_tl_ad.f90 File Reference

Data Types

- module [maoam_tl_ad](#)

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Tensors definition module.

6.10 params.f90 File Reference

Data Types

- module [params](#)

The model parameters module.

6.11 stat.f90 File Reference

Data Types

- module [stat](#)

Statistics accumulators.

6.12 tensor.f90 File Reference

Data Types

- module [tensor](#)

Tensor utility module.

- type [tensor::coolist_elem](#)

Coordinate list element type. Elementary elements of the sparse tensors.

- type [tensor::coolist](#)

Coordinate list. Type used to represent the sparse tensor.

6.13 test_aotensor.f90 File Reference

Functions/Subroutines

- program [test_aotensor](#)
Small program to print the inner products.

6.13.1 Function/Subroutine Documentation

6.13.1.1 program test_aotensor ()

Small program to print the inner products.

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Definition at line 13 of file test_aotensor.f90.

6.14 test_inprod_analytic.f90 File Reference

Functions/Subroutines

- program [inprod_analytic_test](#)
Small program to print the inner products.

6.14.1 Function/Subroutine Documentation

6.14.1.1 program inprod_analytic_test ()

Small program to print the inner products.

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Definition at line 13 of file test_inprod_analytic.f90.

6.15 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.
- real(kind=8) function [gasdev](#) (idum)
- real(kind=8) function [ran2](#) (idum)

6.15.1 Function/Subroutine Documentation

6.15.1.1 real(kind=8) function gasdev (integer idum)

Definition at line 149 of file test_tl_ad.f90.

6.15.1.2 real(kind=8) function ran2 (integer idum)

Definition at line 174 of file test_tl_ad.f90.

6.15.1.3 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.

6.16 tl_ad_integrator.f90 File Reference

Data Types

- module [tl_ad_integrator](#)

Tangent Linear (TL) and Adjoint (AD) model versions of MAOOAM. Integrators module.

6.17 util.f90 File Reference

Data Types

- module [util](#)

Utility module.

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