

EMPIRE DA

0.1

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# Chapter 1

## EMPIRE Data Assimilation Documentation

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### Date

Time-stamp: <2014-09-26 10:21:42 pbrowne>

## 1.1 Downloading

These codes are hosted on [www.bitbucket.org](http://www.bitbucket.org) and can be attained with the following commands:

```
git clone git@bitbucket.org:pbrowne/empire-data-assimilation.git
```

or

```
wget https://bitbucket.org/pbrowne/empire-data-assimilation/get/c25362521bd3.zip && unzip c25362521bd3.zip
```

### Copyright

These codes are distributed under the GNU GPU v3 Licence. See LICENCE.txt.

## 1.2 Compiling

### 1.2.1 Compilation of the source code

The Makefile must be edited for the specific compiler setup. In the main directory you will find the file `Makefile`.

Edit the variables as follows:

- `FC` The fortran compiler
- `FCOPTS` The options for the fortran compiler
- `LIB_LIST` The libraries to be called. Note this must include BLAS

To compile the source code, simply then type the command

```
make
```

If successful, the following executables are created in the bin/ folder:

- [empire](#)
- [alltests](#)
- [test\\_h](#)
- [test\\_hqhtr](#)
- [test\\_q](#)
- [test\\_r](#)

To remove the object and executable files if compilation fails for some reason, run the following:

```
make clean
```

### 1.2.2 Compilation of the documentation

Documentation of the code is automatically generated using Doxygen, dot and pdflatex.

All of these packages must be installed for the following to work.

```
make docs
```

This will make an html webpage for the code, the mainpage for which is located in doc/html/index.html.

A latex version of the documentation will be built to the file doc/latex/refman.pdf.

To simply make the html version of the documentation (if pdflatex is not available) then use the command

```
make doc_html
```

## 1.3 Customising for specific models

*This is where the science and all the effort should happen!!*

The file [model\\_specific.f90](#) should be edited for the specific model which you wish to use. This contains a number of subroutines which need to be adapted for the model and the observation network. We list these subsequently.

- [configure\\_model](#) This is called early in the code and can be used to read in any data from files before subsequently using them in the below operations.
- [h](#) This is the observation operator
- [ht](#) This is the transpose of the observation operator
- [r](#) This is the observation error covariance matrix  $R$
- [rhalf](#) This is the square root of the observation error covariance matrix  $R^{\frac{1}{2}}$
- [solve\\_r](#) This is a linear solve with the observation error covariance matrix, i.e. given  $b$ , find  $x$  such that  $Rx = b$  or indeed,  $x = R^{-1}b$
- [solve\\_rhalf](#) This is a linear solve with the square root of the observation error covariance matrix, i.e. given  $b$ , find  $x$  such that  $R^{\frac{1}{2}}x = b$  or indeed,  $x = R^{-\frac{1}{2}}b$
- [q](#) This is the model error covariance matrix  $Q$
- [qhalf](#) This is the square root model error covariance matrix  $Q^{\frac{1}{2}}$
- [solve\\_hqht\\_plus\\_r](#) This is a linear solve with the matrix  $(HQH^T + R)$

Not all of these subroutines will be required for each filtering method you wish to use, so it may be advantageous to only implement the necessary ones.

## 1.4 Testing

You can test your user supplied routines by running the test codes found in the folder bin/.

These are by no means full-proof ways of ensuring that you have implemented things correctly, but should at least check what you have done for logical consistency.

For example, they will test if  $HH^T x = x$ , and if  $Q^{\frac{1}{2}} Q^{\frac{1}{2}} x = Qx$  for various different vectors  $x$ .

## 1.5 Linking to your model using EMPIRE

Full instructions on how to put the EMPIRE MPI commands into a new model can be found at [www.met.rdg.ac.uk/~darc/empire](http://www.met.rdg.ac.uk/~darc/empire).

## 1.6 Running

For example, to run **N\_MDL** copies of the model with **N\_DA** copies of empire, then the following are possible:

```
mpirun -np N_MDL model_executable : -np N_DA empire
```

```
aprun -n N_MDL -N N_MDL model_executable : -n N_DA -N N_DA empire
```

The empire executable is controlled by the namelist data file [pf\\_parameters.dat](#). As such, this file should be put in the directory where empire is executed.

## 1.7 Bug Reports and Functionality Requests

While the code is not too large, you may email me the issue or request [here](#).

However there is a webpage set up for this:

<https://bitbucket.org/pbrowne/empire-data-assimilation/issues>



## Chapter 2

# Data Type Index

### 2.1 Data Types List

Here are the data types with brief descriptions:

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<a href="#">histogram_data</a>	Module to control what variables are used to generate rank histograms . . . . .	11
<a href="#">hqht_plus_r</a>	. . . . .	12
<a href="#">pf_control</a>	Module <a href="#">pf_control</a> holds all the information to control the the main program . . . . .	12
<a href="#">pf_control::pf_control_type</a>	. . . . .	16
<a href="#">qdata</a>	Module as a place to store user specified data for $Q$ . . . . .	20
<a href="#">random</a>	A module for random number generation from the following distributions: . . . . .	22
<a href="#">rdata</a>	Module to hold user supplied data for $R$ observation error covariance matrix . . . . .	31
<a href="#">sizes</a>	Module that stores the dimension of observation and state spaces . . . . .	33





## Chapter 3

# File Index

### 3.1 File List

Here is a list of all files with brief descriptions:

<a href="#">model_specific.f90</a>	35
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## Chapter 4

# Data Type Documentation

### 4.1 comms Module Reference

Module containing EMPIRE coupling data.

#### Public Member Functions

- subroutine [allocate\\_data](#)
- subroutine [deallocate\\_data](#)
- subroutine [initialise\\_mpi](#)

*subroutine to make EMPIRE connections and saves details into [pf\\_control](#) module*

#### Public Attributes

- integer [cpl\\_mpi\\_comm](#)
- integer [mype\\_id](#)
- integer [myrank](#)
- integer [nproc](#)
- integer [pf\\_mpi\\_comm](#)
- integer [pfrank](#)
- integer [npfs](#)
- integer, dimension(:), allocatable [gblcount](#)
- integer, dimension(:), allocatable [gbldisp](#)

#### 4.1.1 Detailed Description

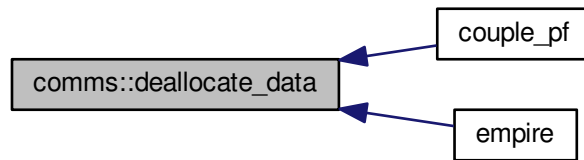
Module containing EMPIRE coupling data.

#### 4.1.2 Member Function/Subroutine Documentation

##### 4.1.2.1 subroutine `comms::allocate_data` ( )

#### 4.1.2.2 subroutine `comms::deallocate_data ( )`

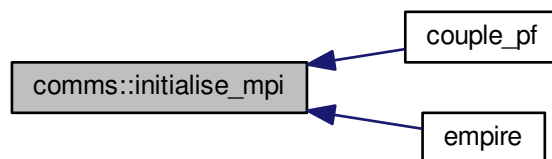
Here is the caller graph for this function:



#### 4.1.2.3 subroutine `comms::initialise_mpi ( )`

subroutine to make EMPIRE connections and saves details into `pf_control` module

Here is the caller graph for this function:



### 4.1.3 Member Data Documentation

4.1.3.1 integer `comms::cpl_mpi_comm`

4.1.3.2 integer, dimension(:), allocatable `comms::gblcount`

4.1.3.3 integer, dimension(:), allocatable `comms::gbldisp`

4.1.3.4 integer `comms::mype_id`

4.1.3.5 integer `comms::myrank`

4.1.3.6 integer `comms::npfs`

4.1.3.7 integer `comms::nproc`

4.1.3.8 integer `comms::pf_mpi_comm`

## 4.1.3.9 integer comms::pfrank

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

- [src/utils/comms.f90](#)

## 4.2 histogram\_data Module Reference

Module to control what variables are used to generate rank histograms.

### Public Member Functions

- subroutine [load\\_histogram\\_data](#)  
*subroutine to read from variables\_hist.dat which variables to be used to make the rank histograms*
- subroutine [kill\\_histogram\\_data](#)  
*subroutine to clean up arrays used in rank histograms*

### Public Attributes

- integer, dimension(:), allocatable [rank\\_hist\\_list](#)
- integer, dimension(:), allocatable [rank\\_hist\\_nums](#)
- integer [rhl\\_n](#)
- integer [rhn\\_n](#)

### 4.2.1 Detailed Description

Module to control what variables are used to generate rank histograms.

### 4.2.2 Member Function/Subroutine Documentation

#### 4.2.2.1 subroutine histogram\_data::kill\_histogram\_data ( )

subroutine to clean up arrays used in rank histograms

#### 4.2.2.2 subroutine histogram\_data::load\_histogram\_data ( )

subroutine to read from variables\_hist.dat which variables to be used to make the rank histograms

### 4.2.3 Member Data Documentation

#### 4.2.3.1 integer, dimension(:), allocatable histogram\_data::rank\_hist\_list

#### 4.2.3.2 integer, dimension(:), allocatable histogram\_data::rank\_hist\_nums

#### 4.2.3.3 integer histogram\_data::rhl\_n

#### 4.2.3.4 integer histogram\_data::rhn\_n

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

- [src/utils/histogram.f90](#)

## 4.3 hqht\_plus\_r Module Reference

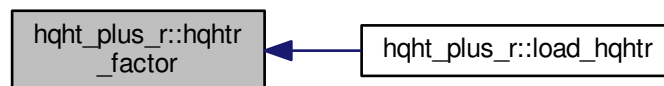
### Public Member Functions

- subroutine [load\\_hqhtr](#)
- subroutine [hqhtr\\_factor](#)
- subroutine [kill\\_hqhtr](#)

#### 4.3.1 Member Function/Subroutine Documentation

##### 4.3.1.1 subroutine hqht\_plus\_r::hqhtr\_factor ( )

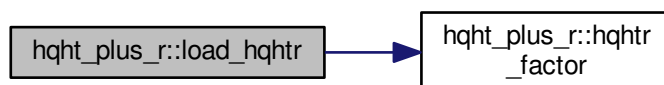
Here is the caller graph for this function:



##### 4.3.1.2 subroutine hqht\_plus\_r::kill\_hqhtr ( )

##### 4.3.1.3 subroutine hqht\_plus\_r::load\_hqhtr ( )

Here is the call graph for this function:



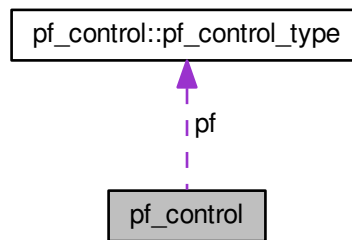
The documentation for this module was generated from the following file:

- [src/data/Rdata.f90](#)

## 4.4 pf\_control Module Reference

module [pf\\_control](#) holds all the information to control the the main program

Collaboration diagram for pf\_control:



## Data Types

- type [pf\\_control\\_type](#)

## Public Member Functions

- subroutine [set\\_pf\\_controls](#)  
*subroutine to ensure [pf\\_control](#) data is ok*
- subroutine [parse\\_pf\\_parameters](#)  
*subroutine to read the namelist file and save it to pf datatype Here we read [pf\\_parameters.dat](#)*
- subroutine [allocate\\_pf](#)  
*subroutine to allocate space for the filtering code*
- subroutine [deallocate\\_pf](#)  
*subroutine to deallocate space for the filtering code*

## Public Attributes

- [type\(pf\\_control\\_type\) pf](#)  
*the derived data type holding all controlling data*

### 4.4.1 Detailed Description

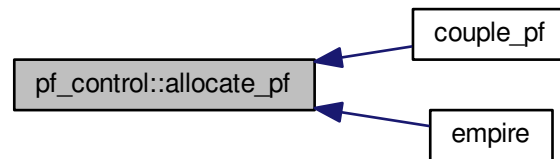
module [pf\\_control](#) holds all the information to control the the main program

### 4.4.2 Member Function/Subroutine Documentation

#### 4.4.2.1 subroutine pf\_control::allocate\_pf ( )

subroutine to allocate space for the filtering code

Here is the caller graph for this function:



#### 4.4.2.2 subroutine `pf_control::deallocate_pf ( )`

subroutine to deallocate space for the filtering code

#### 4.4.2.3 subroutine `pf_control::parse_pf_parameters ( )`

subroutine to read the namelist file and save it to pf datatype Here we read [pf\\_parameters.dat](#)

[pf\\_parameters.dat](#) is a fortran namelist file. As such, within it there must be a line beginning `&pf_params`

To make it (probably) work, ensure there is a forward slash on the penultimate line and a blank line to end the file

This is just the fortran standard for namelists though.

On to the content...in any order, the [pf\\_parameters.dat](#) may contain the following things:

Integers:

- [time\\_obs](#)
- [time\\_bwn\\_obs](#)

Reals, double precision:

- [nudgefac](#)
- [nfac](#)
- [ufac](#)
- [Qscale](#)
- [keep](#)

2 Characters:

- [type](#)

1 Character:

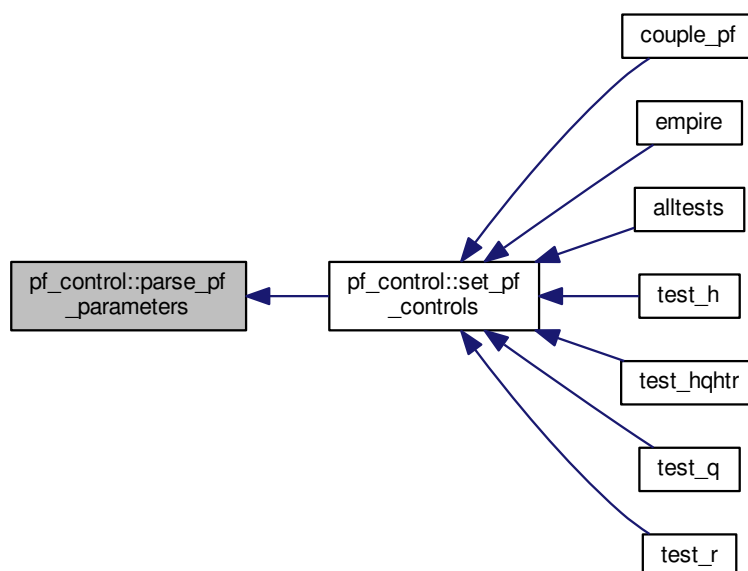
- [init](#)

Logicals:



- [gen\\_Q](#)
- [gen\\_data](#)
- [use\\_talagrand](#)
- [use\\_weak](#)
- [use\\_var](#)
- [use\\_traj](#)
- [use\\_rmse](#)
- [human\\_readable](#)

Here is the caller graph for this function:



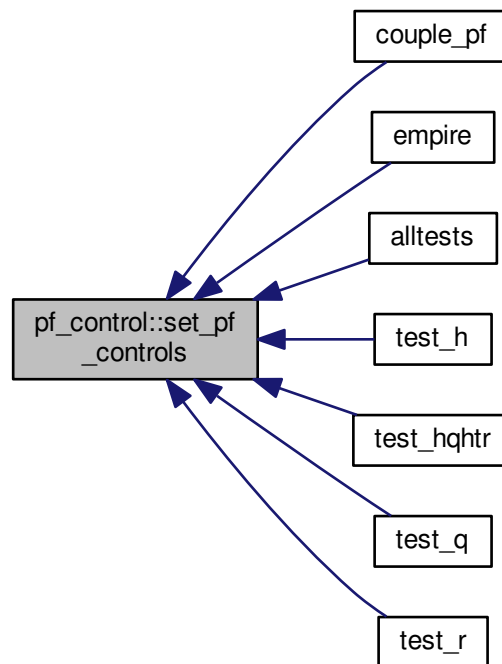
#### 4.4.2.4 subroutine `pf_control::set_pf_controls ( )`

subroutine to ensure `pf_control` data is ok

Here is the call graph for this function:



Here is the caller graph for this function:



#### 4.4.3 Member Data Documentation

##### 4.4.3.1 `type(pf_control_type) pf_control::pf`

the derived data type holding all controlling data

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

- [src/controllers/pf\\_control.f90](#)

## 4.5 `pf_control::pf_control_type` Type Reference

### Public Attributes

- integer [nens](#)  
*the total number of ensemble members*
- `real(kind=kind(1.0d0))`, dimension(:), allocatable [weight](#)  
*the negative log of the weights of the particles*
- integer [time\\_obs](#)  
*the number of observations we will assimilate*
- integer [time\\_bwn\\_obs](#)  
*the number of model timesteps between observations*
- `real(kind=kind(1.0d0))` [nudgefac](#)

- the nudging factor*
- logical [gen\\_data](#)
  - true generates synthetic obs for a twin experiment*
- logical [gen\\_q](#)
  - true attempts to build up  $Q$  from long model run*
- logical [human\\_readable](#)
  - unused*
- integer [timestep](#) =0
  - the current timestep as the model progresses*
- real(kind=kind(1.0d0)), dimension(:,:), allocatable [psi](#)
  - state vector of ensemble members on this mpi process*
- real(kind=kind(1.0d0)), dimension(:), allocatable [mean](#)
  - mean state vector*
- real(kind=kind(1.0d0)) [nfac](#)
  - standard deviation of normal distribution in mixture density*
- real(kind=kind(1.0d0)) [ufac](#)
  - half width of the uniform distribution in mixture density*
- real(kind=kind(1.0d0)) [efac](#)
- real(kind=kind(1.0d0)) [keep](#)
  - proportion of particles to keep in EWPF EW step*
- real(kind=kind(1.0d0)) [time](#)
  - dunno*
- real(kind=kind(1.0d0)) [qscale](#)
  - scalar to multiply  $Q$  by*
- integer [couple\\_root](#)
  - empire master processor*
- logical [use\\_talagrand](#)
  - switch if true outputs rank histograms*
- logical [use\\_weak](#)
  - switch unused*
- logical [use\\_mean](#)
  - switch if true outputs ensemble mean*
- logical [use\\_var](#)
  - switch if true outputs ensemble variance*
- logical [use\\_traj](#)
  - switch if true outputs trajectories*
- logical [use\\_rmse](#)
  - switch if true outputs Root Mean Square Errors*
- integer, dimension(:,:), allocatable [talagrand](#)
  - storage for rank histograms*
- integer [count](#)
  - number of ensemble members associated with this MPI process*
- integer, dimension(:), allocatable [particles](#)
  - particles associates with this MPI process*
- character(2) [type](#)
  - which filter to use*
- character(1) [init](#)
  - which method to initialise ensemble*

### 4.5.1 Member Data Documentation

#### 4.5.1.1 integer pf\_control::pf\_control\_type::count

number of ensemble members associated with this MPI process

#### 4.5.1.2 integer pf\_control::pf\_control\_type::couple\_root

empire master processor

#### 4.5.1.3 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::efac

#### 4.5.1.4 logical pf\_control::pf\_control\_type::gen\_data

true generates synthetic obs for a twin experiment

#### 4.5.1.5 logical pf\_control::pf\_control\_type::gen\_q

true attempts to build up  $Q$  from long model run

#### 4.5.1.6 logical pf\_control::pf\_control\_type::human\_readable

unused

#### 4.5.1.7 character(1) pf\_control::pf\_control\_type::init

which method to initialise ensemble

#### 4.5.1.8 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::keep

proportion of particles to keep in EWPF EW step

#### 4.5.1.9 real(kind=kind(1.0d0)), dimension(:), allocatable pf\_control::pf\_control\_type::mean

mean state vector

#### 4.5.1.10 integer pf\_control::pf\_control\_type::nens

the total number of ensemble members

#### 4.5.1.11 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::nfac

standard deviation of normal distribution in mixture density

#### 4.5.1.12 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::nudgef

the nudging factor

4.5.1.13 integer, dimension(:), allocatable pf\_control::pf\_control\_type::particles

particles associates with this MPI process

4.5.1.14 real(kind=kind(1.0d0)), dimension(:,), allocatable pf\_control::pf\_control\_type::psi

state vector of ensemble members on this mpi process

4.5.1.15 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::qscale

scalar to multiply Q by

4.5.1.16 integer, dimension(:,), allocatable pf\_control::pf\_control\_type::talagrand

storage for rank histograms

4.5.1.17 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::time

dunno

4.5.1.18 integer pf\_control::pf\_control\_type::time\_bwn\_obs

the number of model timesteps between observations

4.5.1.19 integer pf\_control::pf\_control\_type::time\_obs

the number of observations we will assimilate

4.5.1.20 integer pf\_control::pf\_control\_type::timestep =0

the current timestep as the model progresses

4.5.1.21 character(2) pf\_control::pf\_control\_type::type

which filter to use

4.5.1.22 real(kind=kind(1.0d0)) pf\_control::pf\_control\_type::ufac

half width of the uniform distribution in mixture density

4.5.1.23 logical pf\_control::pf\_control\_type::use\_mean

switch if true outputs ensemble mean

4.5.1.24 logical pf\_control::pf\_control\_type::use\_rmse

switch if true outputs Root Mean Square Errors

#### 4.5.1.25 logical pf\_control::pf\_control\_type::use\_talagrand

switch if true outputs rank histograms

#### 4.5.1.26 logical pf\_control::pf\_control\_type::use\_traj

switch if true outputs trajectories

#### 4.5.1.27 logical pf\_control::pf\_control\_type::use\_var

switch if true outputs ensemble variance

#### 4.5.1.28 logical pf\_control::pf\_control\_type::use\_weak

switch unused

#### 4.5.1.29 real(kind=kind(1.0d0)), dimension(:), allocatable pf\_control::pf\_control\_type::weight

the negative log of the weights of the particles

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

- [src/controllers/pf\\_control.f90](#)

## 4.6 qdata Module Reference

Module as a place to store user specified data for  $Q$ .

### Public Member Functions

- subroutine [loadq](#)  
*Subroutine to load in user data for  $Q$ .*
- subroutine [killq](#)

### Public Attributes

- integer [qn](#)
- integer [qne](#)
- integer, dimension(:), allocatable [qrow](#)
- integer, dimension(:), allocatable [qcol](#)
- real(kind=kind(1.0d0)), dimension(:), allocatable [qval](#)
- real(kind=kind(1.0d0)), dimension(:), allocatable [qdiag](#)
- real(kind=kind(1.0d0)) [qscale](#)

#### 4.6.1 Detailed Description

Module as a place to store user specified data for  $Q$ .

- the model error covariance matrix

## 4.6.2 Member Function/Subroutine Documentation

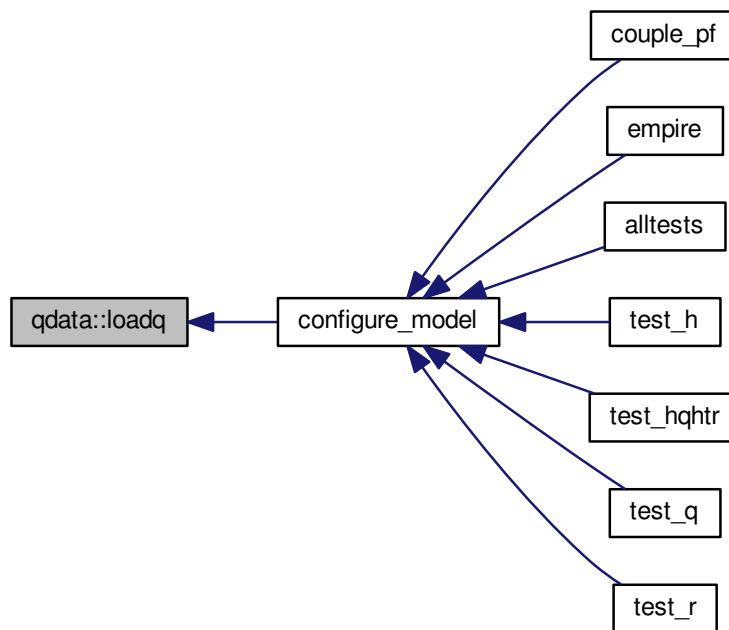
### 4.6.2.1 subroutine qdata::killq ( )

Subroutine to deallocate user data for Q

### 4.6.2.2 subroutine qdata::loadq ( )

Subroutine to load in user data for Q.

Here is the caller graph for this function:



## 4.6.3 Member Data Documentation

4.6.3.1 integer, dimension(:), allocatable qdata::qcol

4.6.3.2 real(kind=kind(1.0d0)), dimension(:), allocatable qdata::qdiag

4.6.3.3 integer qdata::qn

4.6.3.4 integer qdata::qne

4.6.3.5 integer, dimension(:), allocatable qdata::qrow

4.6.3.6 real(kind=kind(1.0d0)) qdata::qscale

4.6.3.7 real(kind=kind(1.0d0)), dimension(:), allocatable qdata::qval

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

- [src/data/Qdata.f90](#)

## 4.7 random Module Reference

A module for random number generation from the following distributions:

### Public Member Functions

- `real(kind=kind(1.0d+0))` function [random\\_normal](#) ()  
*function to get random normal with zero mean and stdev 1*
- `real(kind=kind(1.0d+0))` function [random\\_gamma](#) (s, first)
- `real(kind=kind(1.0d+0))` function [random\\_gamma1](#) (s, first)
- `real(kind=kind(1.0d+0))` function [random\\_gamma2](#) (s, first)
- `real(kind=kind(1.0d+0))` function [random\\_chisq](#) (ndf, first)
- `real(kind=kind(1.0d+0))` function [random\\_exponential](#) ()
- `real(kind=kind(1.0d+0))` function [random\\_weibull](#) (a)
- `real(kind=kind(1.0d+0))` function [random\\_beta](#) (aa, bb, first)
- `real(kind=kind(1.0d+0))` function [random\\_t](#) (m)
- subroutine [random\\_mvnorm](#) (n, h, d, f, first, x, ier)
- `real(kind=kind(1.0d+0))` function [random\\_inv\\_gauss](#) (h, b, first)
- integer function [random\\_poisson](#) (mu, first)
- integer function [random\\_binomial1](#) (n, p, first)
- `real(kind=kind(1.0d+0))` function [bin\\_prob](#) (n, p, r)
- `real(dp)` function [lngamma](#) (x)
- integer function [random\\_binomial2](#) (n, pp, first)
- integer function [random\\_neg\\_binomial](#) (sk, p)
- `real(kind=kind(1.0d+0))` function [random\\_von\\_mises](#) (k, first)
- `real(kind=kind(1.0d+0))` function [random\\_cauchy](#) ()
- subroutine [random\\_order](#) (order, n)
- subroutine [seed\\_random\\_number](#) (iounit)

### Public Attributes

- integer, parameter `dp` = `SELECTED_REAL_KIND(12, 60)`

#### 4.7.1 Detailed Description

A module for random number generation from the following distributions:

Distribution Function/subroutine name

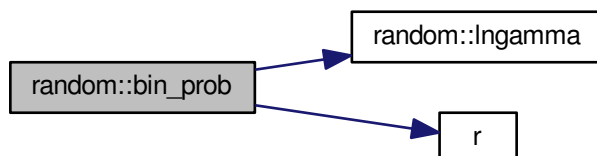
Normal (Gaussian) [random\\_normal](#) Gamma [random\\_gamma](#) Chi-squared [random\\_chisq](#) Exponential [random\\_exponential](#) Weibull [random\\_weibull](#) Beta [random\\_beta](#) t [random\\_t](#) Multivariate normal [random\\_mvnorm](#) Generalized inverse Gaussian [random\\_inv\\_gauss](#) Poisson [random\\_poisson](#) Binomial [random\\_binomial1](#) \* [random\\_binomial2](#) \* Negative binomial [random\\_neg\\_binomial](#) von Mises [random\\_von\\_mises](#) Cauchy [random\\_cauchy](#)



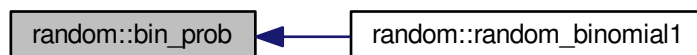
### 4.7.2 Member Function/Subroutine Documentation

4.7.2.1 `real(kind=kind(1.0d+0)) function random::bin_prob ( integer, intent(in) n, real(kind=kind(1.0d+0)), intent(in) p, integer, intent(in) r )`

Here is the call graph for this function:

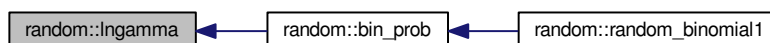


Here is the caller graph for this function:



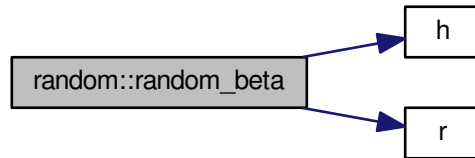
4.7.2.2 `real(dp) function random::lngamma ( real(dp), intent(in) x )`

Here is the caller graph for this function:



4.7.2.3 `real(kind=kind(1.0d+0)) function random::random_beta ( real(kind=kind(1.0d+0)), intent(in) aa, real(kind=kind(1.0d+0)), intent(in) bb, logical, intent(in) first )`

Here is the call graph for this function:



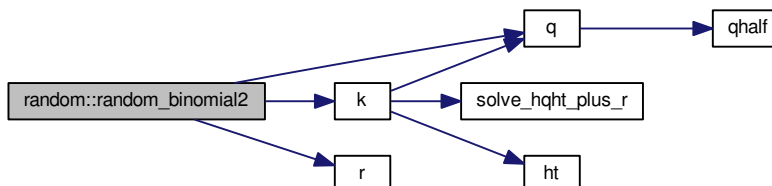
4.7.2.4 `integer function random::random_binomial1 ( integer, intent(in) n, real(kind=kind(1.0d+0)), intent(in) p, logical, intent(in) first )`

Here is the call graph for this function:



4.7.2.5 `integer function random::random_binomial2 ( integer, intent(in) n, real(kind=kind(1.0d+0)), intent(in) pp, logical, intent(in) first )`

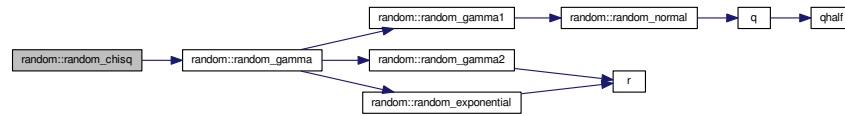
Here is the call graph for this function:



4.7.2.6 `real(kind=kind(1.0d+0)) function random::random_cauchy ( )`

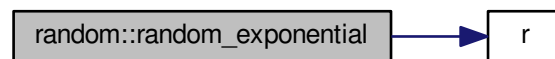
4.7.2.7 `real(kind=kind(1.0d+0)) function random::random_chisq ( integer, intent(in) ndf, logical, intent(in) first )`

Here is the call graph for this function:

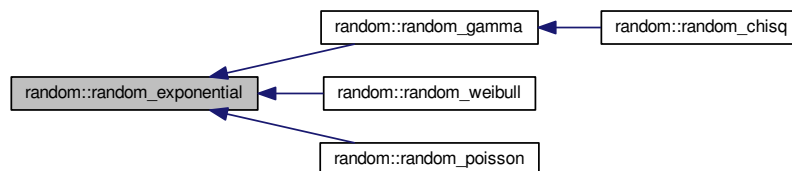


4.7.2.8 `real(kind=kind(1.0d+0)) function random::random_exponential ( )`

Here is the call graph for this function:

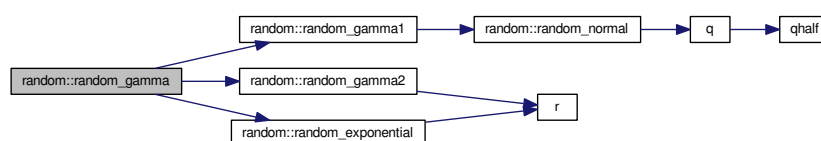


Here is the caller graph for this function:



4.7.2.9 `real(kind=kind(1.0d+0)) function random::random_gamma ( real(kind=kind(1.0d+0)), intent(in) s, logical, intent(in) first )`

Here is the call graph for this function:

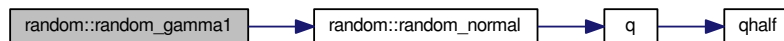


Here is the caller graph for this function:

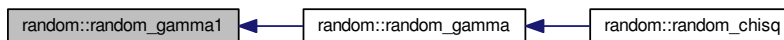


4.7.2.10 `real(kind=kind(1.0d+0)) function random::random_gamma1 ( real(kind=kind(1.0d+0)), intent(in) s, logical, intent(in) first )`

Here is the call graph for this function:

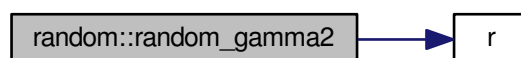


Here is the caller graph for this function:

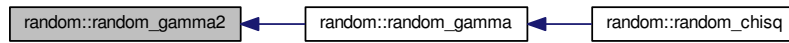


4.7.2.11 `real(kind=kind(1.0d+0)) function random::random_gamma2 ( real(kind=kind(1.0d+0)), intent(in) s, logical, intent(in) first )`

Here is the call graph for this function:

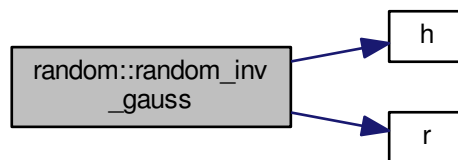


Here is the caller graph for this function:



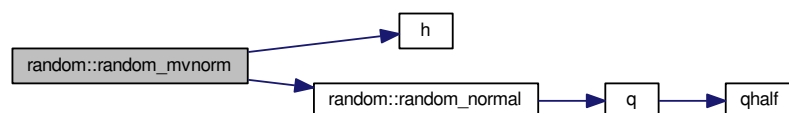
4.7.2.12 `real(kind=kind(1.0d+0)) function random::random_inv_gauss ( real(kind=kind(1.0d+0)), intent(in) h,  
real(kind=kind(1.0d+0)), intent(in) b, logical, intent(in) first )`

Here is the call graph for this function:



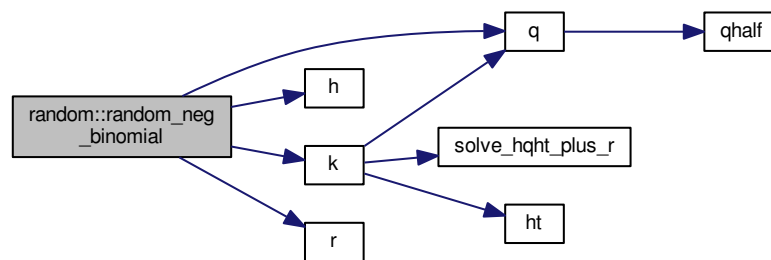
4.7.2.13 `subroutine random::random_mvnorm ( integer, intent(in) n, real(kind=kind(1.0d+0)), dimension(:), intent(in) h,  
real(kind=kind(1.0d+0)), dimension(:), intent(in) d, real(kind=kind(1.0d+0)), dimension(:), intent(inout) f, logical,  
intent(in) first, real(kind=kind(1.0d+0)), dimension(:), intent(out) x, integer, intent(out) ier )`

Here is the call graph for this function:



4.7.2.14 integer function `random::random_neg_binomial` ( `real(kind=kind(1.0d+0))`, intent(in) `sk`, `real(kind=kind(1.0d+0))`, intent(in) `p` )

Here is the call graph for this function:



4.7.2.15 `real(kind=kind(1.0d+0))` function `random::random_normal` ( )

function to get random normal with zero mean and stdev 1

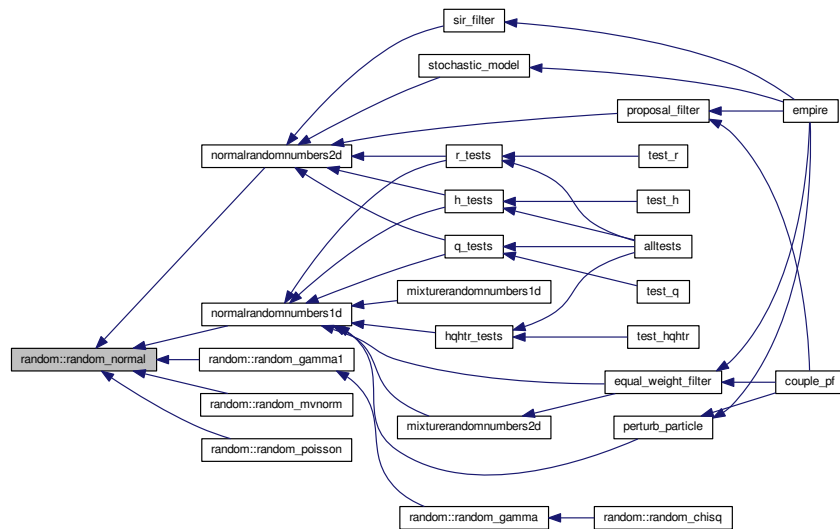
Returns

`fn_val`

Here is the call graph for this function:

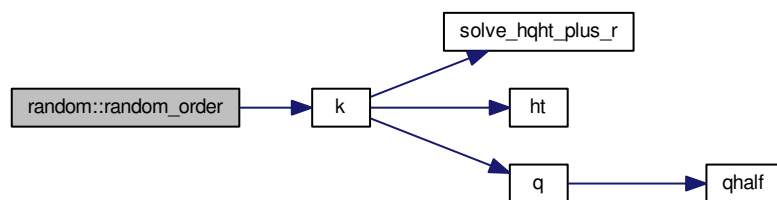


Here is the caller graph for this function:



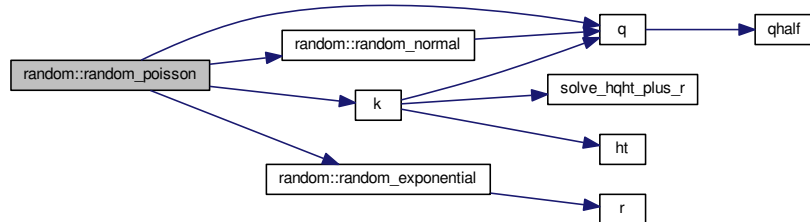
4.7.2.16 subroutine `random::random_order` ( integer, dimension(n), intent(out) *order*, integer, intent(in) *n* )

Here is the call graph for this function:



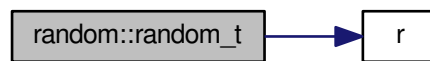
4.7.2.17 integer function random::random\_poisson ( real(kind=kind(1.0d+0)), intent(in) *mu*, logical, intent(in) *first* )

Here is the call graph for this function:



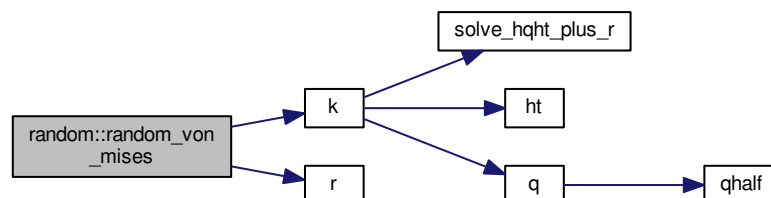
4.7.2.18 real(kind=kind(1.0d+0)) function random::random\_t ( integer, intent(in) *m* )

Here is the call graph for this function:



4.7.2.19 real(kind=kind(1.0d+0)) function random::random\_von\_mises ( real(kind=kind(1.0d+0)), intent(in) *k*, logical, intent(in) *first* )

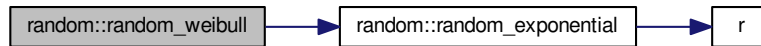
Here is the call graph for this function:





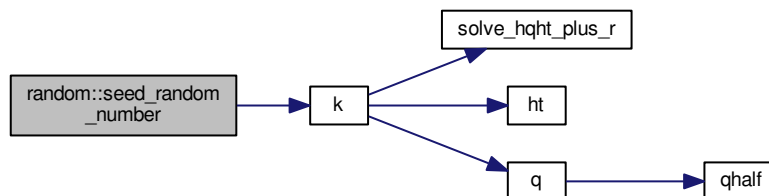
4.7.2.20 `real(kind=kind(1.0d+0)) function random::random_weibull ( real(kind=kind(1.0d+0)), intent(in) a )`

Here is the call graph for this function:



4.7.2.21 `subroutine random::seed_random_number ( integer, intent(in) iounit )`

Here is the call graph for this function:



## 4.7.3 Member Data Documentation

4.7.3.1 `integer, parameter random::dp = SELECTED_REAL_KIND(12, 60)`

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

- [src/utls/random\\_d.f90](#)

## 4.8 rdata Module Reference

Module to hold user supplied data for  $R$  observation error covariance matrix.

### Public Member Functions

- subroutine [loadr](#)  
Subroutine to load data for  $R$ .
- subroutine [killr](#)

### Public Attributes

- integer [rn](#)
- integer [rne](#)

- integer, dimension(:), allocatable [rrow](#)
- integer, dimension(:), allocatable [rcol](#)
- real(kind=kind(1.0d0)), dimension(:), allocatable [rval](#)
- real(kind=kind(1.0d0)), dimension(:), allocatable [rdiag](#)

#### 4.8.1 Detailed Description

Module to hold user supplied data for  $R$  observation error covariance matrix.

#### 4.8.2 Member Function/Subroutine Documentation

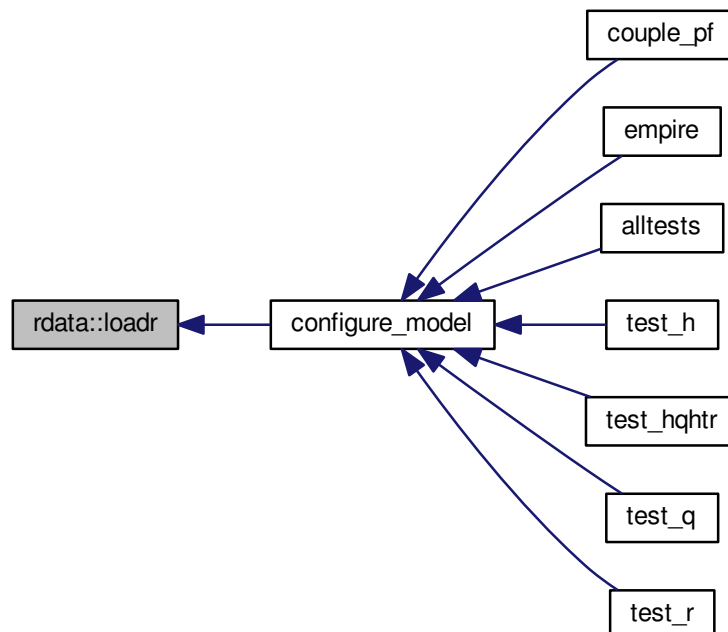
##### 4.8.2.1 subroutine rdata::killr ( )

SUbroutine to deallocate R data

##### 4.8.2.2 subroutine rdata::loadr ( )

Subroutine to load data for R.

Here is the caller graph for this function:



#### 4.8.3 Member Data Documentation

##### 4.8.3.1 integer, dimension(:), allocatable rdata::rcol

##### 4.8.3.2 real(kind=kind(1.0d0)), dimension(:), allocatable rdata::rdiag

4.8.3.3 integer rdata::rn

4.8.3.4 integer rdata::rne

4.8.3.5 integer, dimension(:), allocatable rdata::rrow

4.8.3.6 real(kind=kind(1.0d0)), dimension(:), allocatable rdata::rval

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

- src/data/[Rdata.f90](#)

## 4.9 sizes Module Reference

Module that stores the dimension of observation and state spaces.

### Public Attributes

- integer [obs\\_dim](#)  
*size of the observation space*
- integer [state\\_dim](#)  
*dimension of the model*

### 4.9.1 Detailed Description

Module that stores the dimension of observation and state spaces.

### 4.9.2 Member Data Documentation

4.9.2.1 integer sizes::obs\_dim

size of the observation space

4.9.2.2 integer sizes::state\_dim

dimension of the model

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

- src/controllers/[sizes.f90](#)



## Chapter 5

# File Documentation

### 5.1 model\_specific.f90 File Reference

#### Functions/Subroutines

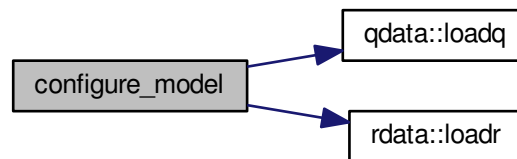
- subroutine `configure_model`  
*subroutine called initially to set up details and data for model specific functions*
- subroutine `solve_r` (obsDim, nrhs, y, v, t)  
*subroutine to take an observation vector y and return v in observation space.*
- subroutine `solve_rhalf` (obsdim, nrhs, y, v, t)  
*subroutine to take an observation vector y and return v in observation space.*
- subroutine `solve_hqht_plus_r` (obsdim, y, v, t)  
*subroutine to take an observation vector y and return v in observation space.*
- subroutine `q` (nrhs, x, Qx)  
*subroutine to take a full state vector x and return Qx in state space.*
- subroutine `qhalf` (nrhs, x, Qx)  
*subroutine to take a full state vector x and return  $Q^{1/2}x$  in state space.*
- subroutine `r` (obsDim, nrhs, y, Ry, t)  
*subroutine to take an observation vector x and return Rx in observation space.*
- subroutine `rhalf` (obsDim, nrhs, y, Ry, t)  
*subroutine to take an observation vector x and return Rx in observation space.*
- subroutine `h` (obsDim, nrhs, x, hx, t)  
*subroutine to take a full state vector x and return  $H(x)$  in observation space.*
- subroutine `ht` (obsDim, nrhs, y, x, t)  
*subroutine to take an observation vector y and return  $x = H^T(y)$  in full state space.*
- subroutine `dist_st_ob` (xp, yp, dis, t)  
*subroutine to compute the distance between the variable in the state vector and the variable in the observations*

#### 5.1.1 Function/Subroutine Documentation

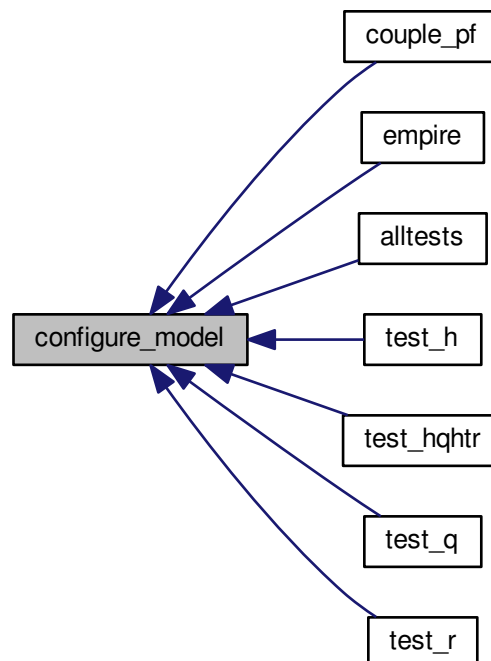
##### 5.1.1.1 subroutine `configure_model` ( )

subroutine called initially to set up details and data for model specific functions

Here is the call graph for this function:



Here is the caller graph for this function:



**5.1.1.2** subroutine `dist_st_ob` ( integer, intent(in) *xp*, integer, intent(in) *yp*, real(kind=kind(1.0d0)), intent(out) *dis*, integer, intent(in) *t* )

subroutine to compute the distance between the variable in the state vector and the variable in the observations

Compute  $\text{dist}(x(xp), y(yp))$

## Parameters

in	<i>xp</i>	the index in the state vector
in	<i>yp</i>	the index in the observation vector
out	<i>dis</i>	the distance between $x(xp)$ and $y(yp)$
in	<i>t</i>	the current time index for observations

Here is the caller graph for this function:



**5.1.1.3** subroutine *h* ( integer, intent(in) *obsDim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(state\_dim,nrhs), intent(in) *x*,  
real(kind=rk), dimension(obsdim,nrhs), intent(out) *hx*, integer, intent(in) *t* )

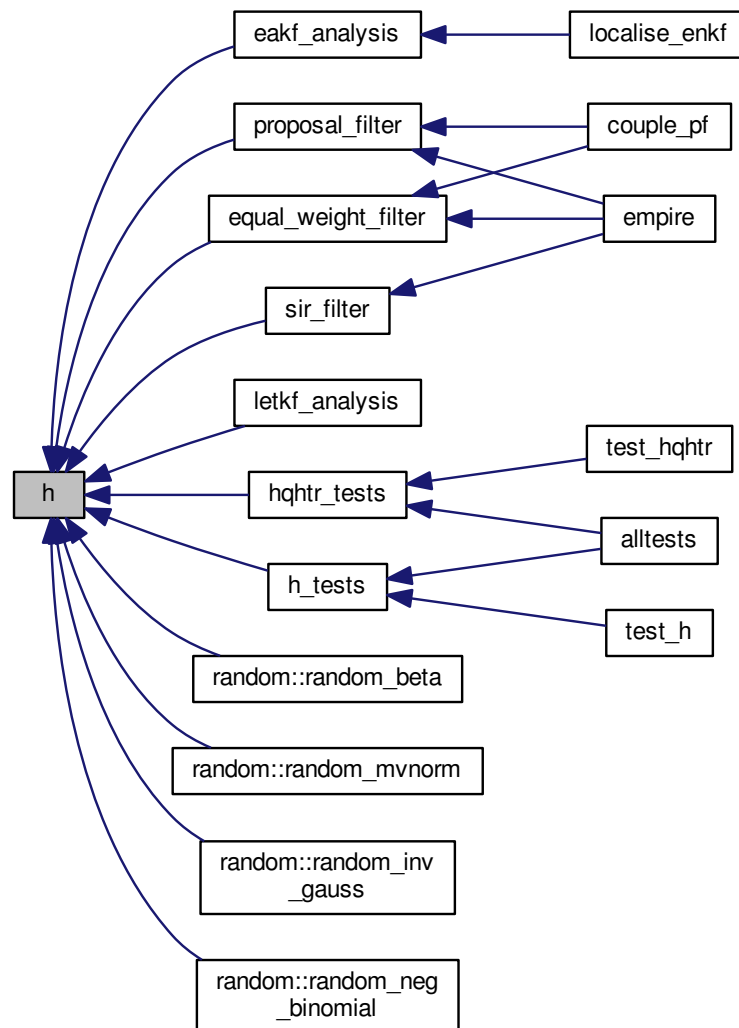
subroutine to take a full state vector  $x$  and return  $H(x)$  in observation space.

Given  $x$  compute  $Hx$

## Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>nrhs</i>	the number of right hand sides
in	<i>x</i>	the input vectors in state space
out	<i>hx</i>	the resulting vector in observation space where $hx = Hx$
in	<i>t</i>	the timestep

Here is the caller graph for this function:



5.1.1.4 subroutine `ht` ( integer, intent(in) *obsDim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(in) *y*, real(kind=rk), dimension(*state\_dim*,*nrhs*), intent(out) *x*, integer, intent(in) *t* )

subroutine to take an observation vector  $y$  and return  $x = H^T(y)$  in full state space.

Given  $y$  compute  $x = H^T(y)$

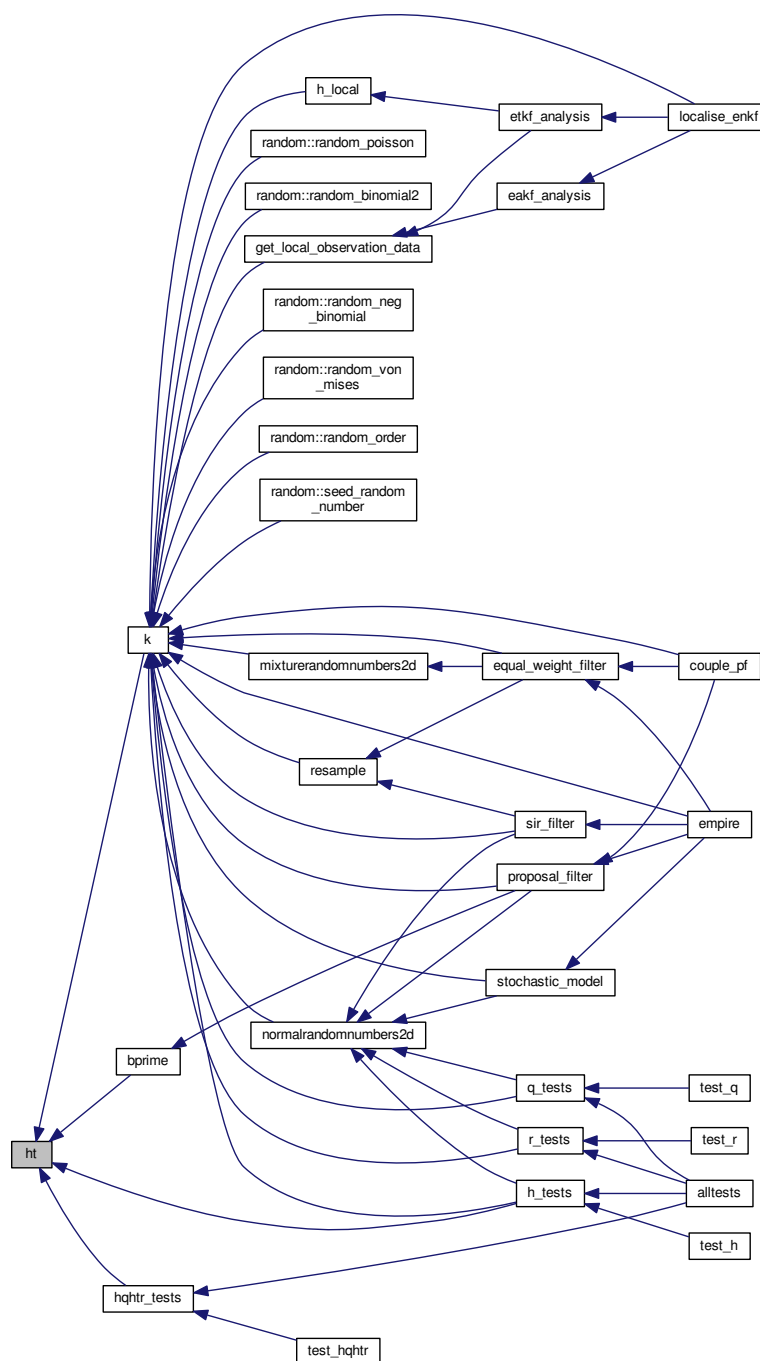
#### Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>nrhs</i>	the number of right hand sides



in	$y$	the input vectors in observation space
out	$x$	the resulting vector in state space where $x = H^T y$
in	$t$	the timestep

Here is the caller graph for this function:



5.1.1.5 subroutine q ( integer, intent(in) *nrhs*, real(kind=rk), dimension(state\_dim,nrhs), intent(in) *x*, real(kind=rk), dimension(state\_dim,nrhs), intent(out) *Qx* )

subroutine to take a full state vector *x* and return *Qx* in state space.

Given *x* compute  $Qx$

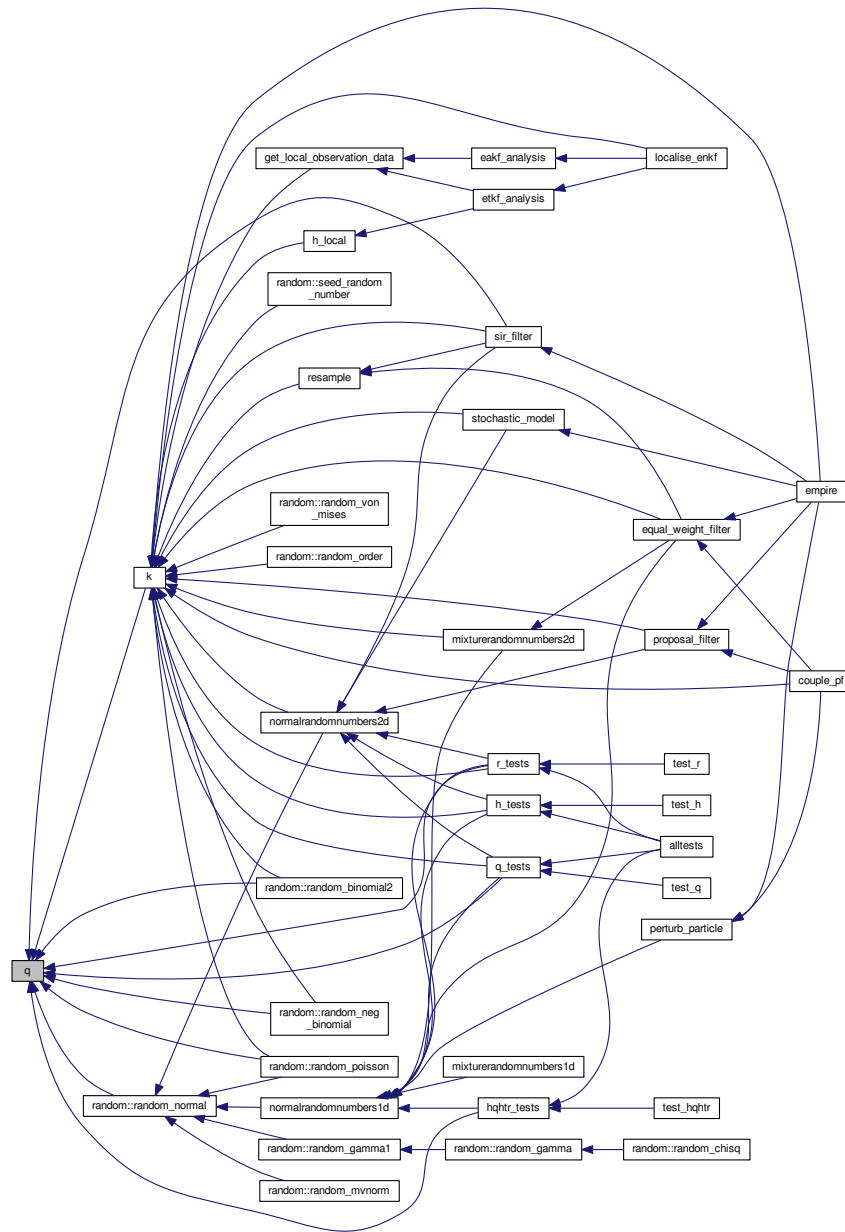
#### Parameters

in	<i>nrhs</i>	the number of right hand sides
in	<i>x</i>	the input vector
out	<i>qx</i>	the resulting vector where $Qx = Qx$

Here is the call graph for this function:



Here is the caller graph for this function:



5.1.1.6 subroutine qhalf ( integer, intent(in) nrhs, real(kind=rk), dimension(state\_dim,nrhs), intent(in) x, real(kind=rk), dimension(state\_dim,nrhs), intent(out) Qx )

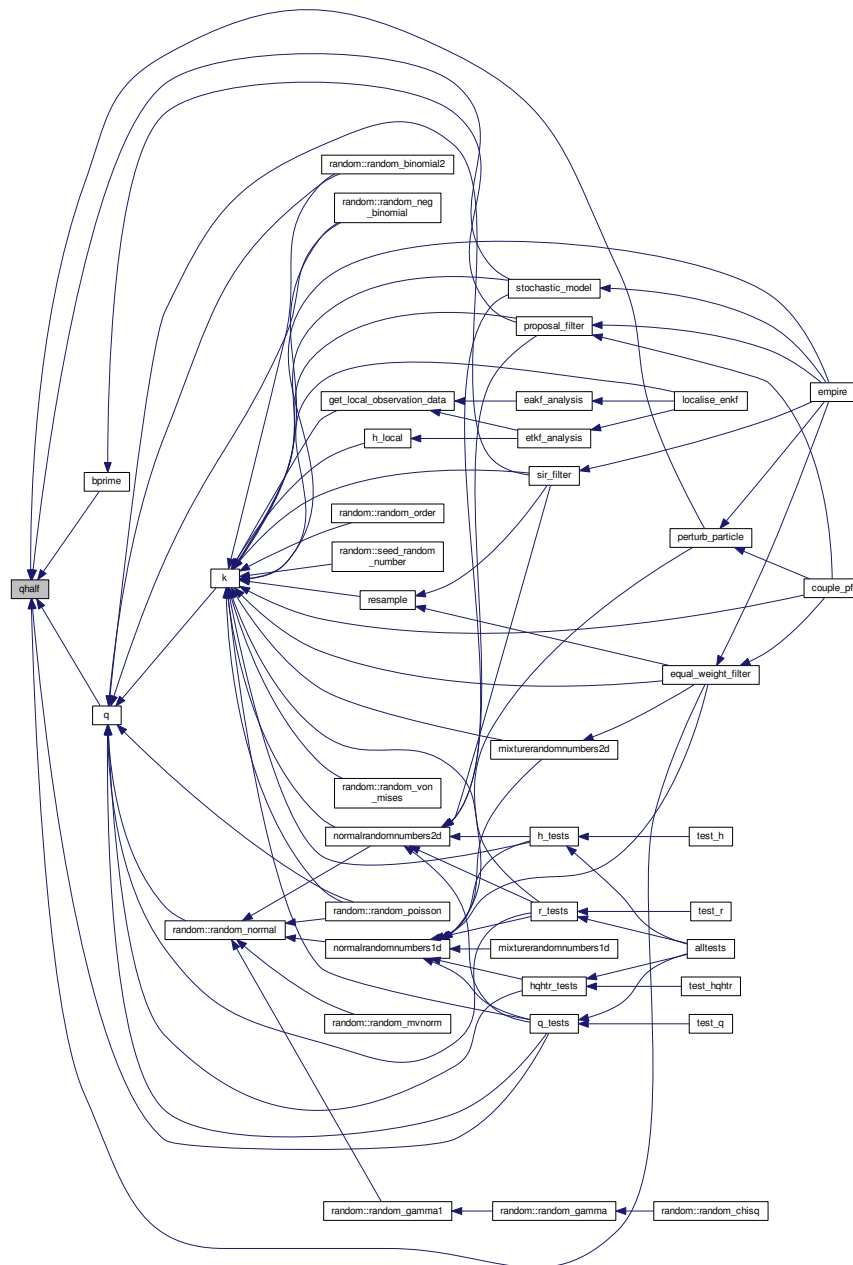
subroutine to take a full state vector  $x$  and return  $Q^{1/2}x$  in state space.

Given  $x$  compute  $Q^{\frac{1}{2}}x$

Parameters

in	<i>nrhs</i>	the number of right hand sides
in	<i>x</i>	the input vector
out	<i>qx</i>	the resulting vector where $Qx = Q^{\frac{1}{2}}x$

Here is the caller graph for this function:



**5.1.1.7 subroutine *r* ( integer, intent(in) *obsDim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(obsdim,nrhs), intent(in) *y*, real(kind=rk), dimension(obsdim,nrhs), intent(out) *Ry*, integer, intent(in) *t* )**

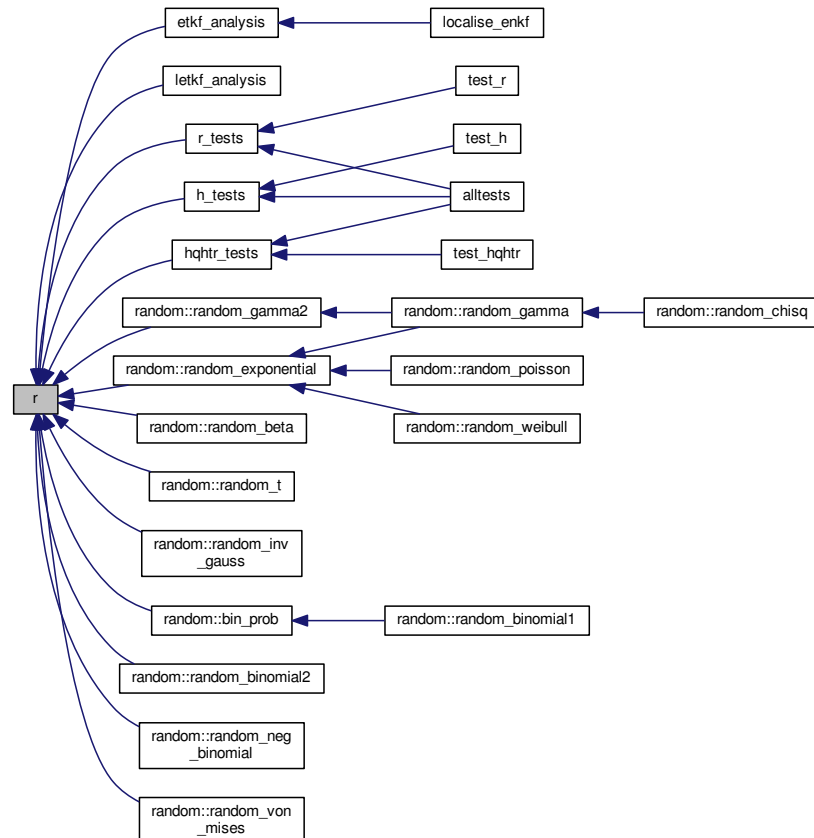
subroutine to take an observation vector *x* and return *Rx* in observation space.

Given *y* compute *Ry*

## Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>nrhs</i>	the number of right hand sides
in	<i>y</i>	the input vector
out	<i>ry</i>	the resulting vectors where $Ry = Ry$
in	<i>t</i>	the timestep

Here is the caller graph for this function:



**5.1.1.8** subroutine rhalf ( integer, intent(in) *obsDim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(in) *y*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(out) *Ry*, integer, intent(in) *t* )

subroutine to take an observation vector *x* and return *Rx* in observation space.

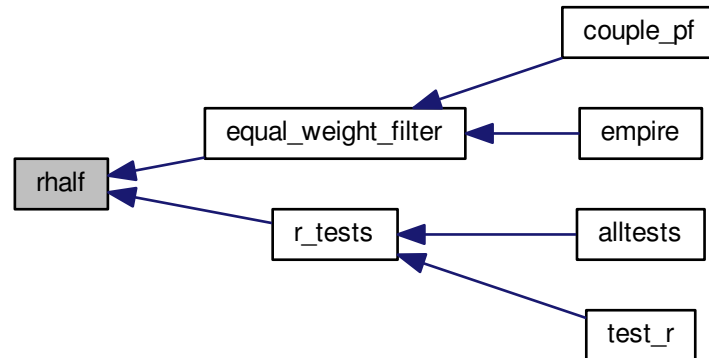
Given *y* compute  $R^{\frac{1}{2}}y$

## Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>nrhs</i>	the number of right hand sides
in	<i>y</i>	the input vector

out	$ry$	the resulting vector where $Ry = R^{\frac{1}{2}}y$
in	$t$	the timestep

Here is the caller graph for this function:



5.1.1.9 subroutine solve\_hqht\_plus\_r ( integer, intent(in) *obsdim*, real(kind=rk), dimension(obsdim), intent(in) *y*, real(kind=rk), dimension(obsdim), intent(out) *v*, integer, intent(in) *t* )

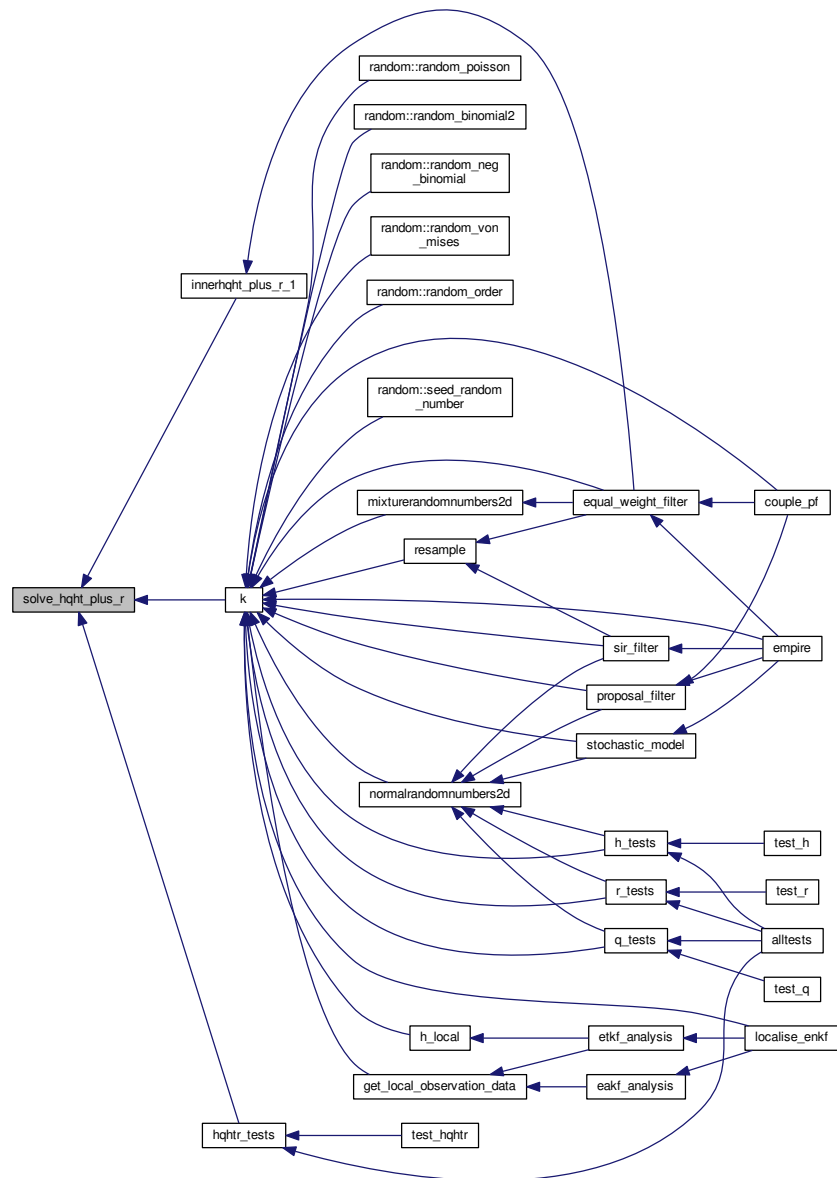
subroutine to take an observation vector *y* and return *v* in observation space.

Given *y* find *v* such that  $(HQH^T + R)v = y$

#### Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>y</i>	the input vector
out	<i>v</i>	the result where $v = (HQH^T + R)^{-1}y$
in	<i>t</i>	the timestep

Here is the caller graph for this function:



**5.1.1.10** subroutine `solve_r` ( integer, intent(in) *obsDim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(in) *y*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(out) *v*, integer, intent(in) *t* )

subroutine to take an observation vector *y* and return *v* in observation space.

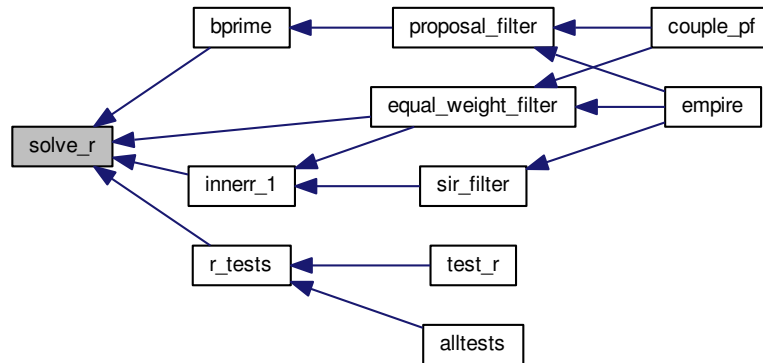
Given *y* find *v* such that  $Rv = y$

**Parameters**

<i>in</i>	<i>obsdim</i>	the dimension of the observations
-----------	---------------	-----------------------------------

in	<i>nrhs</i>	the number of right hand sides
in	<i>y</i>	input vector
out	<i>v</i>	result vector where $v = R^{-1}y$
in	<i>t</i>	the timestep

Here is the caller graph for this function:



5.1.1.11 subroutine `solve_rhalf` ( integer, intent(in) *obsdim*, integer, intent(in) *nrhs*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(in) *y*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(out) *v*, integer, intent(in) *t* )

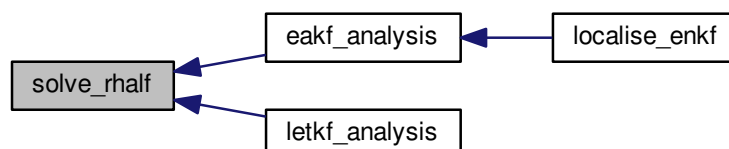
subroutine to take an observation vector *y* and return *v* in observation space.

Given *y* find *v* such that  $R^{\frac{1}{2}}v = y$

#### Parameters

in	<i>obsdim</i>	the dimension of the observations
in	<i>nrhs</i>	the number of right hand sides
in	<i>y</i>	input vector
out	<i>v</i>	result vector where $v = R^{-\frac{1}{2}}y$
in	<i>t</i>	the timestep

Here is the caller graph for this function:





## 5.2 src/controllers/old\_pf\_couple.f90 File Reference

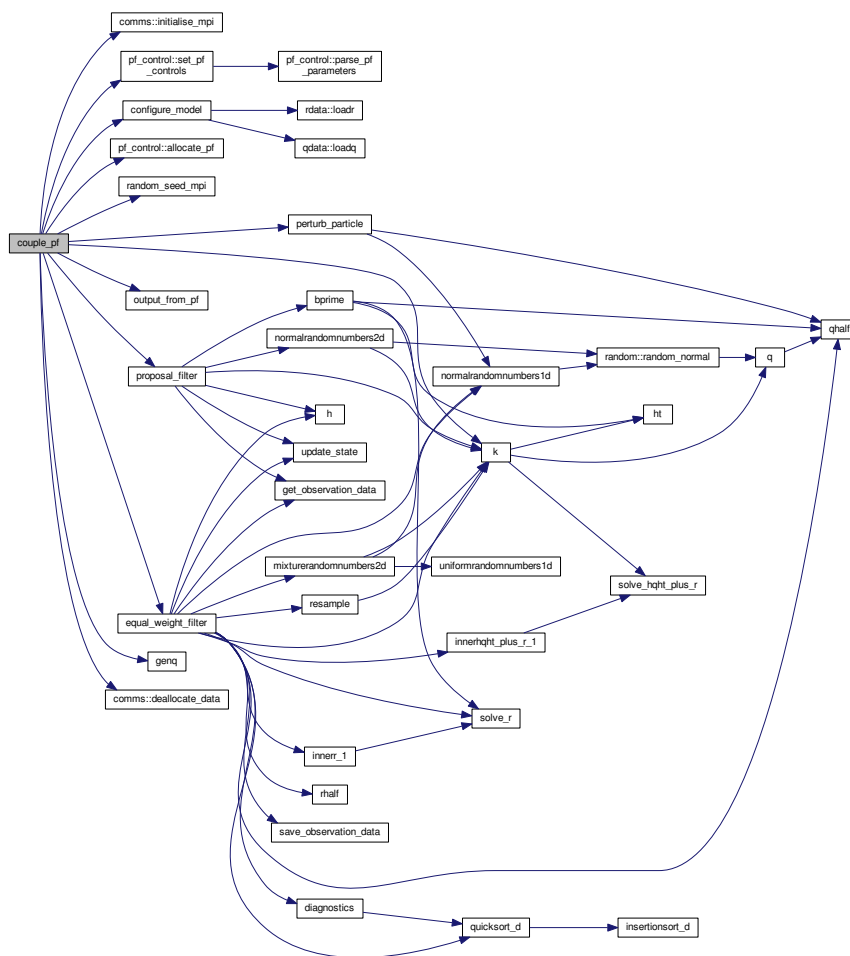
### Functions/Subroutines

- program [couple\\_pf](#)

#### 5.2.1 Function/Subroutine Documentation

##### 5.2.1.1 program `couple_pf ( )`

Here is the call graph for this function:



## 5.3 src/controllers/pf\_control.f90 File Reference

### Data Types

- module [pf\\_control](#)  
*module `pf_control` holds all the information to control the the main program*
- type [pf\\_control::pf\\_control\\_type](#)

## 5.4 src/controllers/pf\_couple.f90 File Reference

### Functions/Subroutines

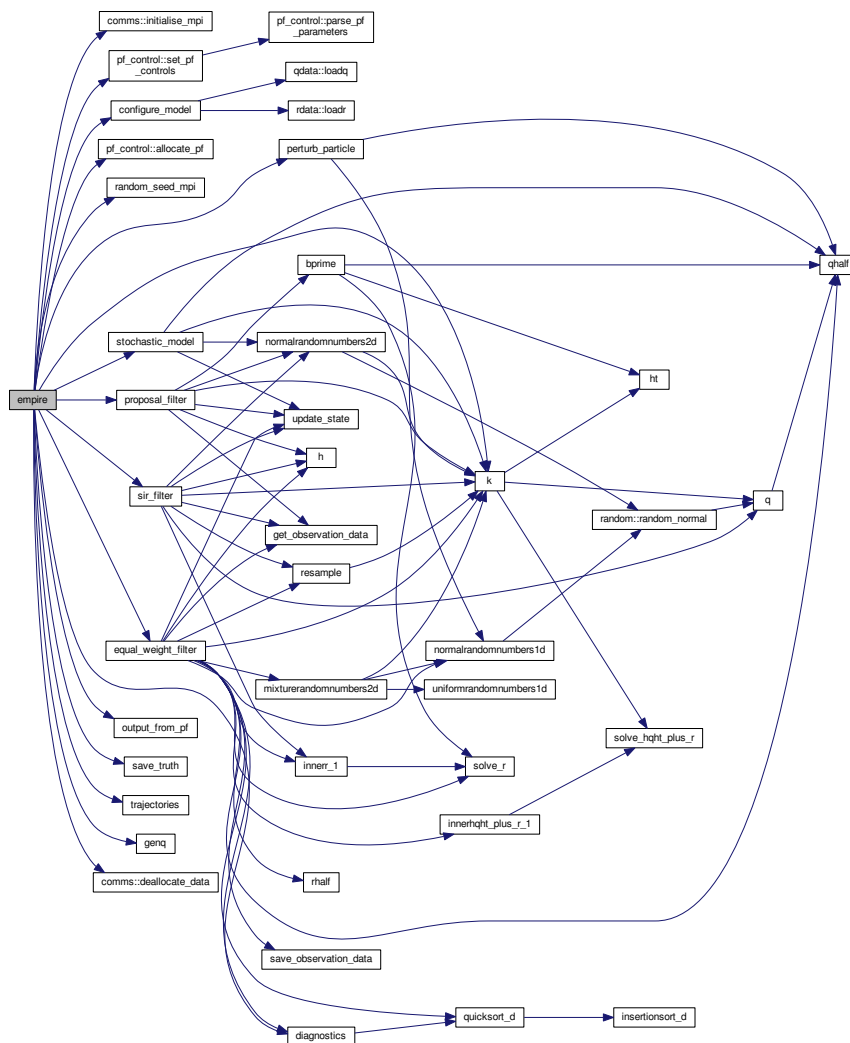
- program [empire](#)  
the main program

#### 5.4.1 Function/Subroutine Documentation

##### 5.4.1.1 program empire ( )

the main program

Here is the call graph for this function:



## 5.5 src/controllers/pf\_parameters.dat File Reference

## Variables

- &pf\_params `time_obs` =10
- &pf\_params `time_bwn_obs` =72
- &pf\_params `nudgefac` =0.5D3
- &pf\_params `gen_data` =.false.
- &pf\_params `nfac` =1.0D-5
- &pf\_params `ufac` =1.0D-5
- &pf\_params `keep` =0.95D0
- &pf\_params `Qscale` =1.0D3
- &pf\_params `human_readable` =1.0D3
- &pf\_params `use_talagrand` =.true.
- &pf\_params `use_weak` =.false.
- &pf\_params `use_mean` =.false.
- &pf\_params `use_var` =.false.
- &pf\_params `use_rmse` =.true.
- &pf\_params `gen_Q` =.false.
- &pf\_params `use_traj` =.true.
- &pf\_params `type` ='EW'

### 5.5.1 Variable Documentation

5.5.1.1 & pf\_params `gen_data` =.false.

5.5.1.2 & pf\_params `gen_Q` =.false.

5.5.1.3 & pf\_params `human_readable` =1.0D3

5.5.1.4 & pf\_params `keep` =0.95D0

5.5.1.5 & pf\_params `nfac` =1.0D-5

5.5.1.6 & pf\_params `nudgefac` =0.5D3

5.5.1.7 & pf\_params `Qscale` =1.0D3

5.5.1.8 & pf\_params `time_bwn_obs` =72

5.5.1.9 & pf\_params `time_obs` =10

5.5.1.10 & pf\_params `type` ='EW'

5.5.1.11 & pf\_params `ufac` =1.0D-5

5.5.1.12 & pf\_params `use_mean` =.false.

5.5.1.13 & pf\_params `use_rmse` =.true.

5.5.1.14 & pf\_params `use_talagrand` =.true.

5.5.1.15 & pf\_params `use_traj` =.true.

5.5.1.16 & pf\_params `use_var` =.false.

5.5.1.17 & pf\_params `use_weak` =.false.

## 5.6 src/controlers/sizes.f90 File Reference

### Data Types

- module [sizes](#)  
*Module that stores the dimension of observation and state spaces.*

## 5.7 src/data/Qdata.f90 File Reference

### Data Types

- module [qdata](#)  
*Module as a place to store user specified data for  $Q$ .*

## 5.8 src/data/Rdata.f90 File Reference

### Data Types

- module [rdata](#)  
*Module to hold user supplied data for  $R$  observation error covariance matrix.*
- module [hqht\\_plus\\_r](#)

## 5.9 src/DOC\_README.txt File Reference

## 5.10 src/filters/eakf\_analysis.f90 File Reference

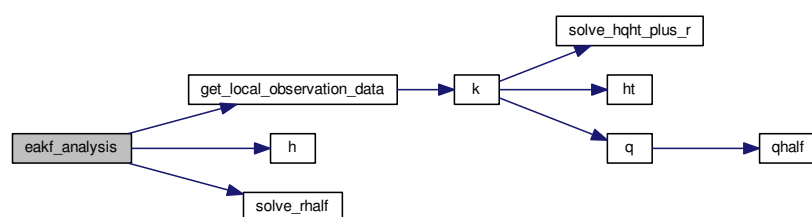
### Functions/Subroutines

- subroutine [eakf\\_analysis](#) (num\_hor, num\_ver, this\_hor, this\_ver, boundary, x, N, stateDim, obsDim, rho)

#### 5.10.1 Function/Subroutine Documentation

- 5.10.1.1 subroutine `eakf_analysis` ( integer, intent(in) *num\_hor*, integer, intent(in) *num\_ver*, integer, intent(in) *this\_hor*, integer, intent(in) *this\_ver*, integer, intent(in) *boundary*, real(kind=rk), dimension(statedim,n), intent(inout) *x*, integer, intent(in) *N*, integer, intent(in) *stateDim*, integer, intent(in) *obsDim*, real(kind=rk), intent(in) *rho* )

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.11 src/filters/enkf\_specific.f90 File Reference

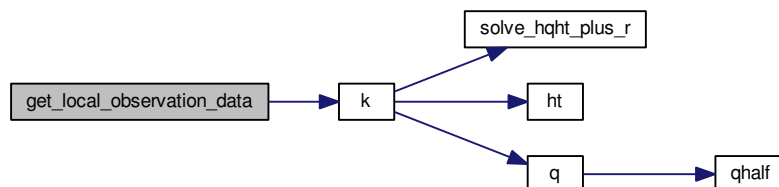
### Functions/Subroutines

- subroutine [h\\_local](#) (num\_hor, num\_ver, this\_hor, this\_ver, boundary, nrhs, stateDim, x, obsDim, y)
- subroutine [solve\\_rhalf\\_local](#) (num\_hor, num\_ver, this\_hor, this\_ver, boundary, nrhs, obsDim, y, v)
- subroutine [get\\_local\\_observation\\_data](#) (num\_hor, num\_ver, this\_hor, this\_ver, boundary, obsDim, y)
- subroutine [localise\\_enkf](#) (enkf\_analysis)

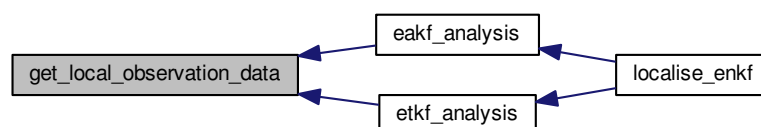
### 5.11.1 Function/Subroutine Documentation

5.11.1.1 subroutine `get_local_observation_data` ( integer, intent(in) *num\_hor*, integer, intent(in) *num\_ver*, integer, intent(in) *this\_hor*, integer, intent(in) *this\_ver*, integer, intent(in) *boundary*, integer, intent(in) *obsDim*, real(kind=rk), dimension(obsdim), intent(out) *y* )

Here is the call graph for this function:

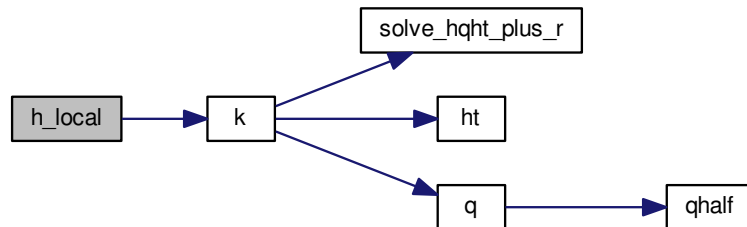


Here is the caller graph for this function:

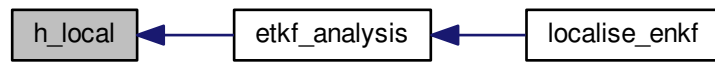


5.11.1.2 subroutine `h_local` ( integer, intent(in) *num\_hor*, integer, intent(in) *num\_ver*, integer, intent(in) *this\_hor*, integer, intent(in) *this\_ver*, integer, intent(in) *boundary*, integer, intent(in) *nrhs*, integer, intent(in) *stateDim*, real(kind=rk), dimension(*statedim*,*nrhs*), intent(in) *x*, integer, intent(in) *obsDim*, real(kind=rk), dimension(*obsdim*,*nrhs*), intent(out) *y* )

Here is the call graph for this function:

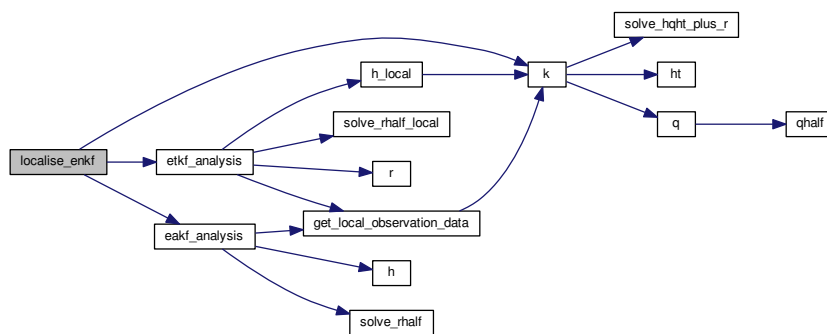


Here is the caller graph for this function:



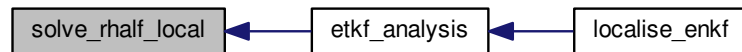
5.11.1.3 subroutine `localise_enkf` ( integer, intent(in) *enkf\_analysis* )

Here is the call graph for this function:



5.11.1.4 subroutine solve\_rhalf\_local ( integer, intent(in) num\_hor, integer, intent(in) num\_ver, integer, intent(in) this\_hor, integer, intent(in) this\_ver, integer, intent(in) boundary, integer, intent(in) nrhs, integer, intent(in) obsDim, real(kind=rk), dimension(obsdim,nrhs), intent(in) y, real(kind=rk), dimension(obsdim,nrhs), intent(out) v )

Here is the caller graph for this function:



## 5.12 src/filters/equivalent\_weights\_step.f90 File Reference

### Functions/Subroutines

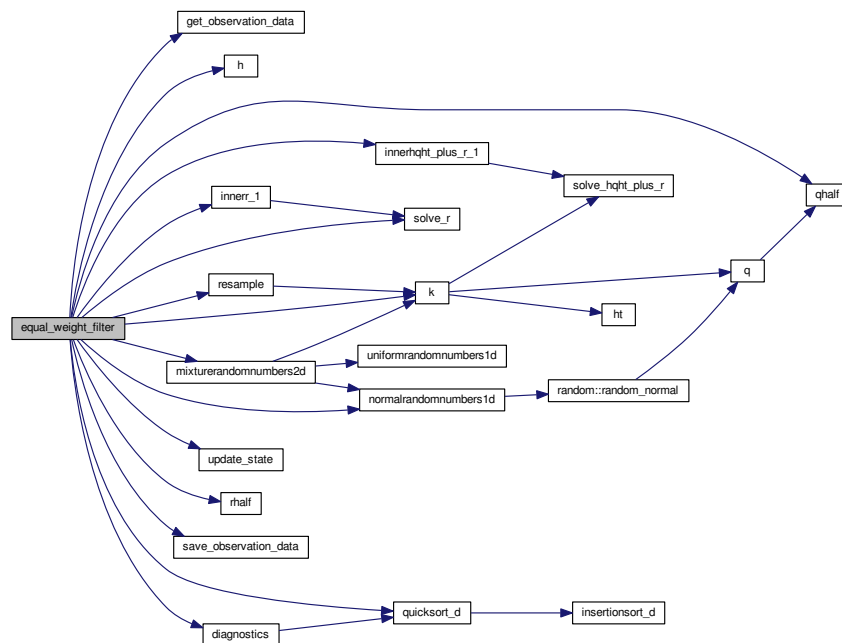
- subroutine [equal\\_weight\\_filter](#)  
subroutine to do the equivalent weights step

### 5.12.1 Function/Subroutine Documentation

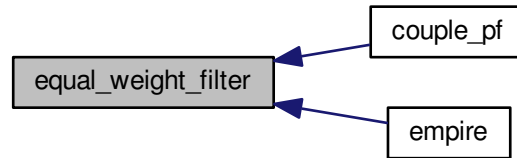
#### 5.12.1.1 subroutine equal\_weight\_filter ( )

subroutine to do the equivalent weights step

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.13 src/filters/etkf\_analysis.f90 File Reference

### Functions/Subroutines

- subroutine [etkf\\_analysis](#) (num\_hor, num\_ver, this\_hor, this\_ver, boundary, x, N, stateDim, obsDim, rho)

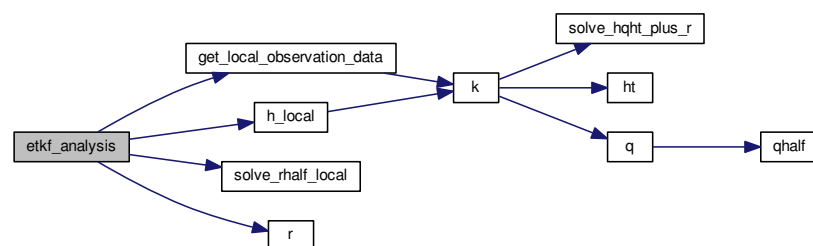
*subroutine to perform the ensemble transform Kalman filter*

### 5.13.1 Function/Subroutine Documentation

**5.13.1.1** subroutine `etkf_analysis` ( integer, intent(in) *num\_hor*, integer, intent(in) *num\_ver*, integer, intent(in) *this\_hor*, integer, intent(in) *this\_ver*, integer, intent(in) *boundary*, real(kind=rk), dimension(statedim,n), intent(inout) *x*, integer, intent(in) *N*, integer, intent(in) *stateDim*, integer, intent(in) *obsDim*, real(kind=rk), intent(in) *rho* )

subroutine to perform the ensemble transform Kalman filter

Here is the call graph for this function:





Here is the caller graph for this function:



## 5.14 src/filters/letkf\_analysis.f90 File Reference

### Functions/Subroutines

- subroutine [letkf\\_analysis](#) (x, N, stateDimension, obsDim, y, rho, len, t)

*subroutine to perform the ensemble transform Kalman filter as part of L-ETKF*

### 5.14.1 Function/Subroutine Documentation

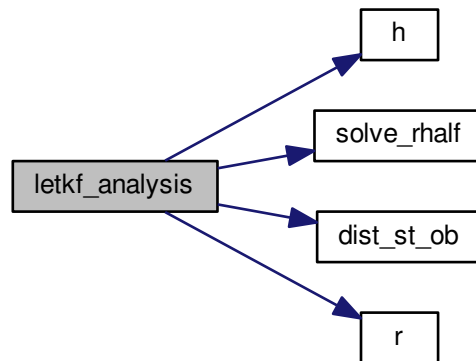
**5.14.1.1** subroutine `letkf_analysis` ( `real(kind=rk)`, `dimension(statedimension,n)`, `intent(inout) x`, `integer, intent(in) N`, `integer, intent(in) stateDimension`, `integer, intent(in) obsDim`, `real(kind=rk)`, `dimension(obsdim)`, `intent(in) y`, `real(kind=rk)`, `intent(in) rho`, `real(kind=rk)`, `intent(in) len`, `integer, intent(in) t` )

subroutine to perform the ensemble transform Kalman filter as part of L-ETKF

#### Parameters

<code>in</code>	<code>n</code>	number of ensemble members
<code>in</code>	<code>statedimension</code>	current size of state dimension
<code>in</code>	<code>obsdim</code>	total number of observations
<code>in, out</code>	<code>x</code>	Forecast ensemble on entry, analysis ensemble on exit
<code>in</code>	<code>y</code>	The observation
<code>in</code>	<code>rho</code>	Inflation parameter; forecast perturbations will be scaled by 1+rho
<code>in</code>	<code>len</code>	Localisation length scale
<code>in</code>	<code>t</code>	the timestep

Here is the call graph for this function:



## 5.15 src/filters/proposal\_filter.f90 File Reference

### Functions/Subroutines

- subroutine [proposal\\_filter](#)

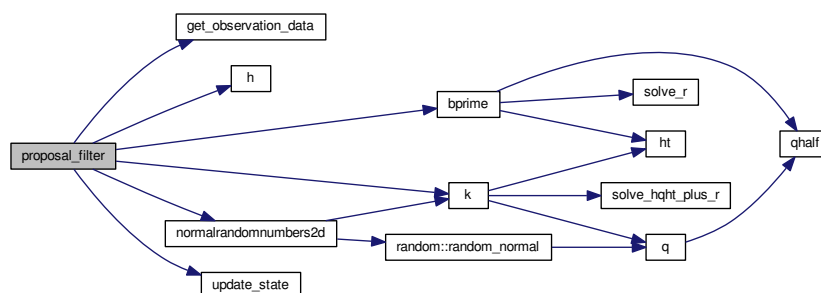
*Subroutine to perform nudging in the proposal step of EWPF.*

### 5.15.1 Function/Subroutine Documentation

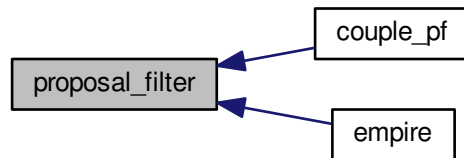
#### 5.15.1.1 subroutine `proposal_filter` ( )

Subroutine to perform nudging in the proposal step of EWPF.

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.16 src/filters/sir\_filter.f90 File Reference

### Functions/Subroutines

- subroutine [sir\\_filter](#)

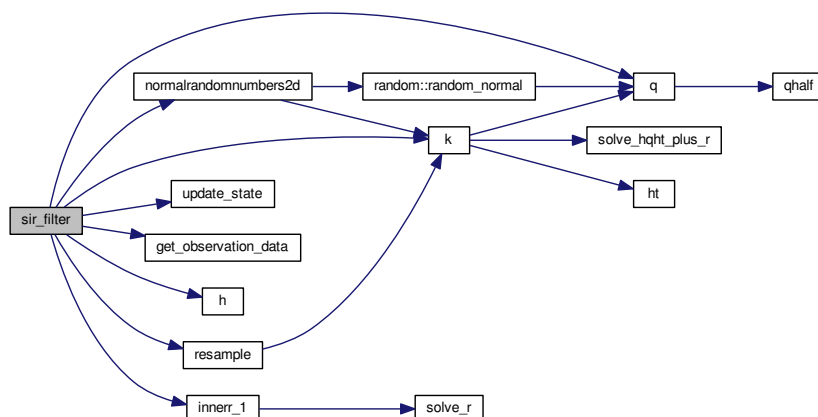
*Subroutine to perform SIR filter (Sequential Importance Resampling)*

### 5.16.1 Function/Subroutine Documentation

#### 5.16.1.1 subroutine sir\_filter ( )

Subroutine to perform SIR filter (Sequential Importance Resampling)

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.17 src/filters/stochastic\_model.f90 File Reference

### Functions/Subroutines

- subroutine [stochastic\\_model](#)  
*subroutine to simply move the model forward in time one timestep PAB 21-05-2013*
- subroutine [check\\_scaling](#) (x, fx, b, scales)

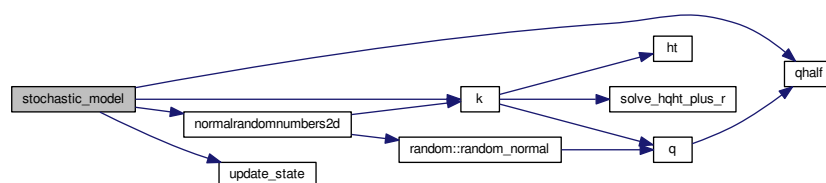
### 5.17.1 Function/Subroutine Documentation

5.17.1.1 subroutine `check_scaling` ( `real(kind=rk)`, `dimension(state_dim)`, `intent(in) x`, `real(kind=rk)`, `dimension(state_dim)`, `intent(in) fx`, `real(kind=rk)`, `dimension(state_dim)`, `intent(in) b`, `real(kind=rk)`, `dimension(9)`, `intent(inout) scales` )

5.17.1.2 subroutine `stochastic_model` ( )

subroutine to simply move the model forward in time one timestep PAB 21-05-2013

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.18 src/operations/gen\_rand.f90 File Reference

### Functions/Subroutines

- subroutine [uniformrandomnumbers1d](#) (minv, maxv, n, phi)  
*generate one dimension of uniform random numbers*
- subroutine [normalrandomnumbers1d](#) (mean, stdev, n, phi)  
*generate one dimension of Normal random numbers*
- subroutine [normalrandomnumbers2d](#) (mean, stdev, n, k, phi)  
*generate two dimensional Normal random numbers*
- subroutine [mixturerandomnumbers1d](#) (mean, stdev, ufac, epsi, n, phi, uniform)  
*generate one dimensional vector drawn from mixture density*
- subroutine [mixturerandomnumbers2d](#) (mean, stdev, ufac, epsi, n, k, phi, uniform)  
*generate two dimensional vector, each drawn from mixture density*
- subroutine [random\\_seed\\_mpi](#) (pfid)  
*Subroutine to set the random seed across MPI threads.*

### 5.18.1 Function/Subroutine Documentation

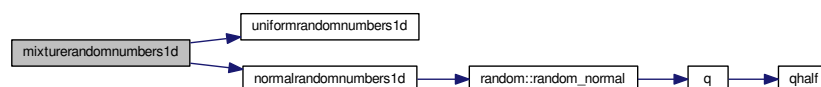
**5.18.1.1** subroutine [mixturerandomnumbers1d](#) ( [real\(kind=kind\(1.0d0\)\)](#), intent(in) *mean*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *stdev*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *ufac*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *epsi*, integer, intent(in) *n*, [real\(kind=kind\(1.0d0\)\)](#), dimension(n), intent(out) *phi*, logical, intent(out) *uniform* )

generate one dimensional vector drawn from mixture density

#### Parameters

in	<i>mean</i>	Mean of normal distribution
in	<i>stdev</i>	Standard deviation of normal distribution
in	<i>ufac</i>	half-width of uniform distribution that is centered on the mean
in	<i>epsi</i>	Proportion controlling mixture draw. if random_number > epsi then draw from uniform, else normal
in	<i>n</i>	size of output vector
out	<i>phi</i>	n dimensional mixture random numbers
out	<i>uniform</i>	True if mixture drawn from uniform. False if drawn from normal

Here is the call graph for this function:



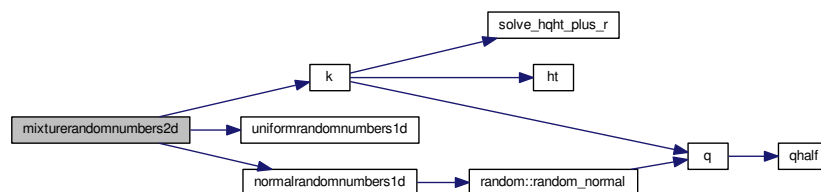
**5.18.1.2** subroutine [mixturerandomnumbers2d](#) ( [real\(kind=kind\(1.0d0\)\)](#), intent(in) *mean*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *stdev*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *ufac*, [real\(kind=kind\(1.0d0\)\)](#), intent(in) *epsi*, integer, intent(in) *n*, integer, intent(in) *k*, [real\(kind=kind\(1.0d0\)\)](#), dimension(n,k), intent(out) *phi*, logical, dimension(k), intent(out) *uniform* )

generate two dimensional vector, each drawn from mixture density

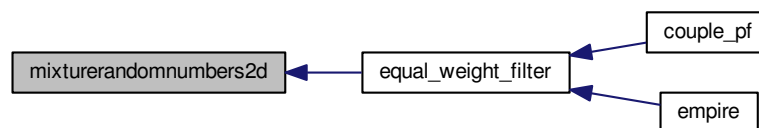
## Parameters

in	<i>mean</i>	Mean of normal distribution
in	<i>stdev</i>	Standard deviation of normal distribution
in	<i>ufac</i>	half-width of uniform distribution that is centered on the mean
in	<i>epsi</i>	Proportion controlling mixture draw. if random_number > epsi then draw from uniform, else normal
in	<i>n</i>	first dimension of output vector
in	<i>k</i>	second dimension of output vector
out	<i>phi</i>	n,k dimensional mixture random numbers
out	<i>uniform</i>	k dimensional logical with uniform(i) True if phi(:,i) drawn from uniform. False if drawn from normal

Here is the call graph for this function:



Here is the caller graph for this function:



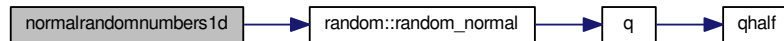
**5.18.1.3** subroutine normalrandomnumbers1d ( real(kind=rk), intent(in) *mean*, real(kind=rk), intent(in) *stdev*, integer, intent(in) *n*, real(kind=rk), dimension(n), intent(out) *phi* )

generate one dimension of Normal random numbers

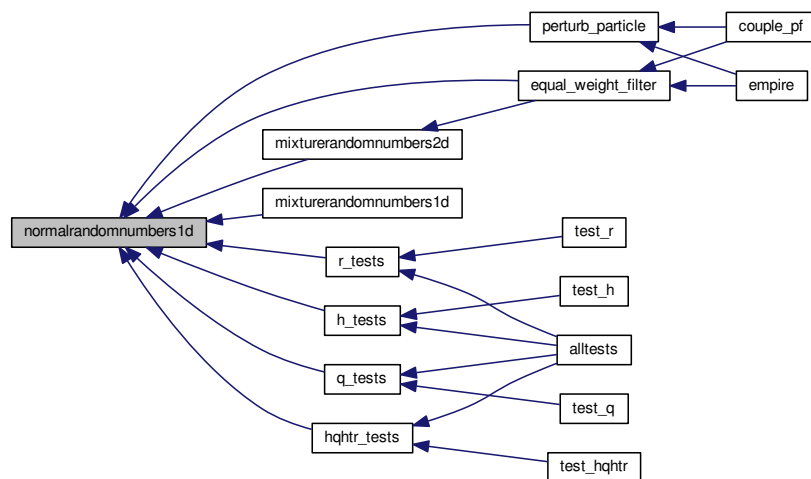
## Parameters

in	<i>n</i>	size of output vector
in	<i>mean</i>	mean of normal distribution
in	<i>stdev</i>	Standard Deviation of normal distribution
out	<i>phi</i>	n dimensional normal random numbers

Here is the call graph for this function:



Here is the caller graph for this function:



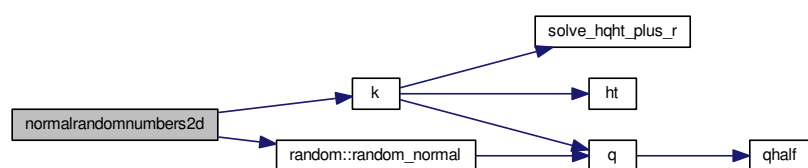
**5.18.1.4** subroutine `normalrandomnumbers2d` ( `real(kind=rk)`, intent(in) *mean*, `real(kind=rk)`, intent(in) *stdev*, integer, intent(in) *n*, integer, intent(in) *k*, `real(kind=rk)`, dimension(*n*,*k*), intent(out) *phi* )

generate two dimensional Normal random numbers

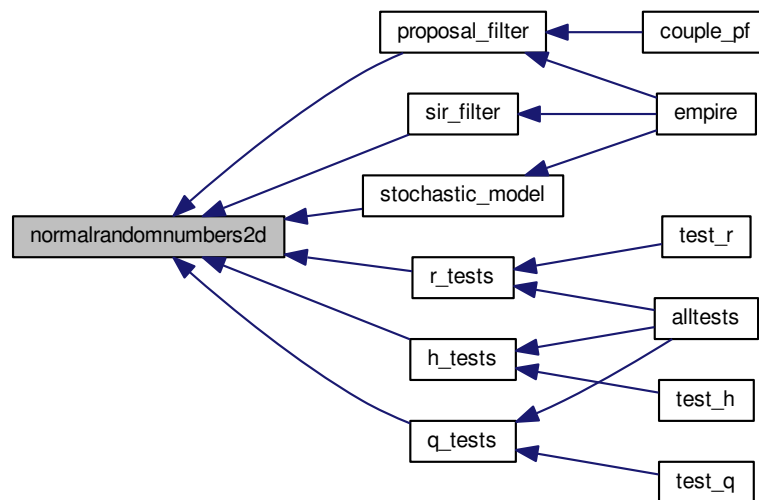
#### Parameters

in	<i>n</i>	first dimension of output vector
in	<i>k</i>	second dimension of output vector
in	<i>mean</i>	mean of normal distribution
in	<i>stdev</i>	Standard Deviation of normal distribution
out	<i>phi</i>	<i>n</i> , <i>k</i> dimensional normal random numbers

Here is the call graph for this function:



Here is the caller graph for this function:



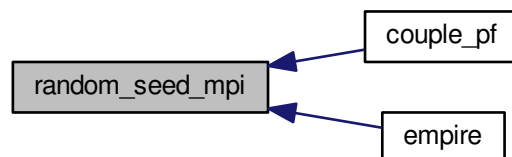
#### 5.18.1.5 subroutine `random_seed_mpi` ( integer, intent(in) *pfid* )

Subroutine to set the random seed across MPI threads.

Parameters

<i>in</i>	<i>pfid</i>	The process identifier of the MPI process
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Here is the caller graph for this function:



#### 5.18.1.6 subroutine `uniformrandomnumbers1d` ( real(kind=rk), intent(in) *minv*, real(kind=rk), intent(in) *maxv*, integer, intent(in) *n*, real(kind=rk), dimension(*n*), intent(out) *phi* )

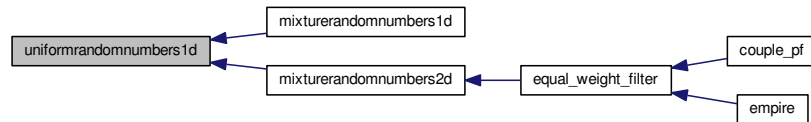
generate one dimension of uniform random numbers



## Parameters

in	$n$	size of output vector
in	$minv$	minimum value of uniform distribution
in	$maxv$	maximum value of uniform distribution
out	$phi$	n dimensional uniform random numbers

Here is the caller graph for this function:



## 5.19 src/operations/operator\_wrappers.f90 File Reference

## Functions/Subroutines

- subroutine [k](#) ( $y, x$ )  
Subroutine to apply  $K$  to a vector  $y$  in observation space where  $K := QH^T (HQH^T + R)^{-1}$ .
- subroutine [innerr\\_1](#) ( $y, w$ )  
subroutine to compute the inner product with  $R^{-1}$
- subroutine [innerhqht\\_plus\\_r\\_1](#) ( $y, w$ )  
subroutine to compute the inner product with  $(HQH^T + R)^{-1}$
- subroutine [bprime](#) ( $y, x, QHtR_1y, normaln, betan$ )  
subroutine to calculate nudging term and correlated random errors efficiently

## 5.19.1 Function/Subroutine Documentation

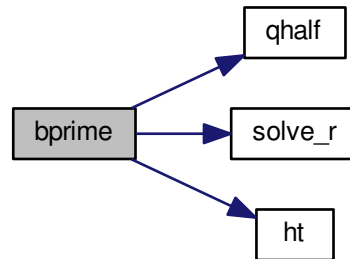
- 5.19.1.1 subroutine [bprime](#) (  $real(kind=rk)$ , dimension(obs\_dim,pf%count), intent(in)  $y$ ,  $real(kind=rk)$ , dimension(state\_dim,pf%count), intent(out)  $x$ ,  $real(kind=rk)$ , dimension(state\_dim,pf%count), intent(out)  $QHtR_1y$ ,  $real(kind=rk)$ , dimension(state\_dim,pf%count), intent(in)  $normaln$ ,  $real(kind=rk)$ , dimension(state\_dim,pf%count), intent(out)  $betan$  )

subroutine to calculate nudging term and correlated random errors efficiently

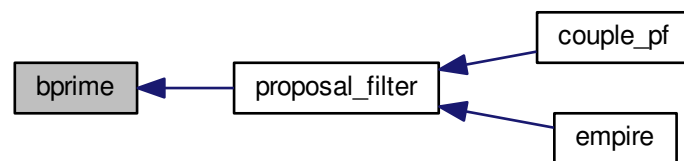
## Parameters

in	$y$	(obs_dim,pf%count) vectors of innovations $y - H(x^{n-1})$
out	$x$	(state_dim,pf%count) vectors of $pH^T R^{-1}[y - H(x^{n-1})]$
out	$QHtR_1y$	(state_dim,pf%count) vectors of $pQH^T R^{-1}[y - H(x^{n-1})]$
in	$normaln$	(state_dim,pf%count) uncorrelated random vectors such that $normaln(:,i) \sim \mathcal{N}(0, I)$
out	$betan$	(state_dim,pf%count) correlated random vectors such that $betan(:,i) \sim \mathcal{N}(0, Q)$

Here is the call graph for this function:



Here is the caller graph for this function:



5.19.1.2 subroutine `innerhqht_plus_r_1` ( `real(kind=rk)`, `dimension(obs_dim)`, `intent(in) y`, `real(kind=rk)`, `intent(out) w` )

subroutine to compute the inner product with  $(HQH^T + R)^{-1}$

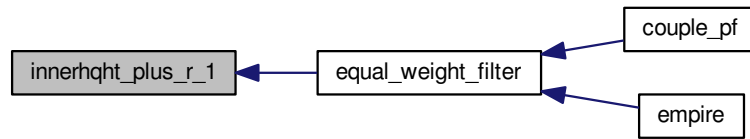
Parameters

<code>in</code>	<code>y</code>	vector in observation space
<code>out</code>	<code>w</code>	scalar with value $y^T R^{-1} y$

Here is the call graph for this function:



Here is the caller graph for this function:



**5.19.1.3** subroutine `innerr_1` ( `real(kind=rk)`, `dimension(obs_dim,pf%count)`, `intent(in) y`, `real(kind=rk)`, `dimension(pf%count)`, `intent(out) w` )

subroutine to compute the inner product with  $R^{-1}$

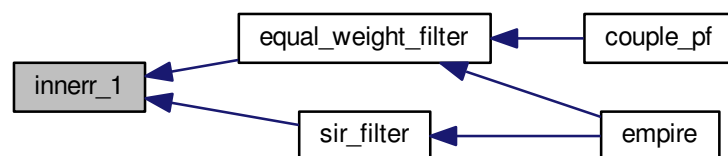
#### Parameters

<code>in</code>	<code>y</code>	multiple vectors in observation space ( <code>pf%count</code> of them)
<code>out</code>	<code>w</code>	multiple scalars ( <code>pf%count</code> ) where <code>w(i)</code> has the value $y(:,i)^T R^{-1} y(:,i)$

Here is the call graph for this function:



Here is the caller graph for this function:



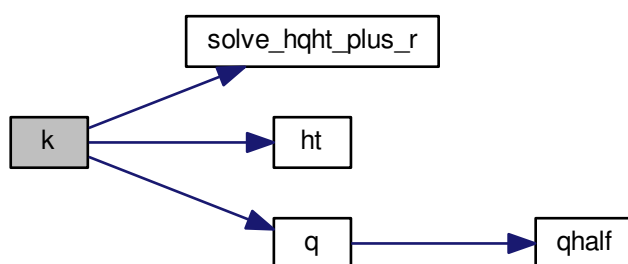
**5.19.1.4** subroutine `k` ( `real(kind=rk)`, `dimension(obs_dim,pf%count)`, `intent(in) y`, `real(kind=rk)`, `dimension(state_dim,pf%count)`, `intent(out) x` )

Subroutine to apply  $K$  to a vector  $y$  in observation space where  $K := QH^T (HQH^T + R)^{-1}$ .

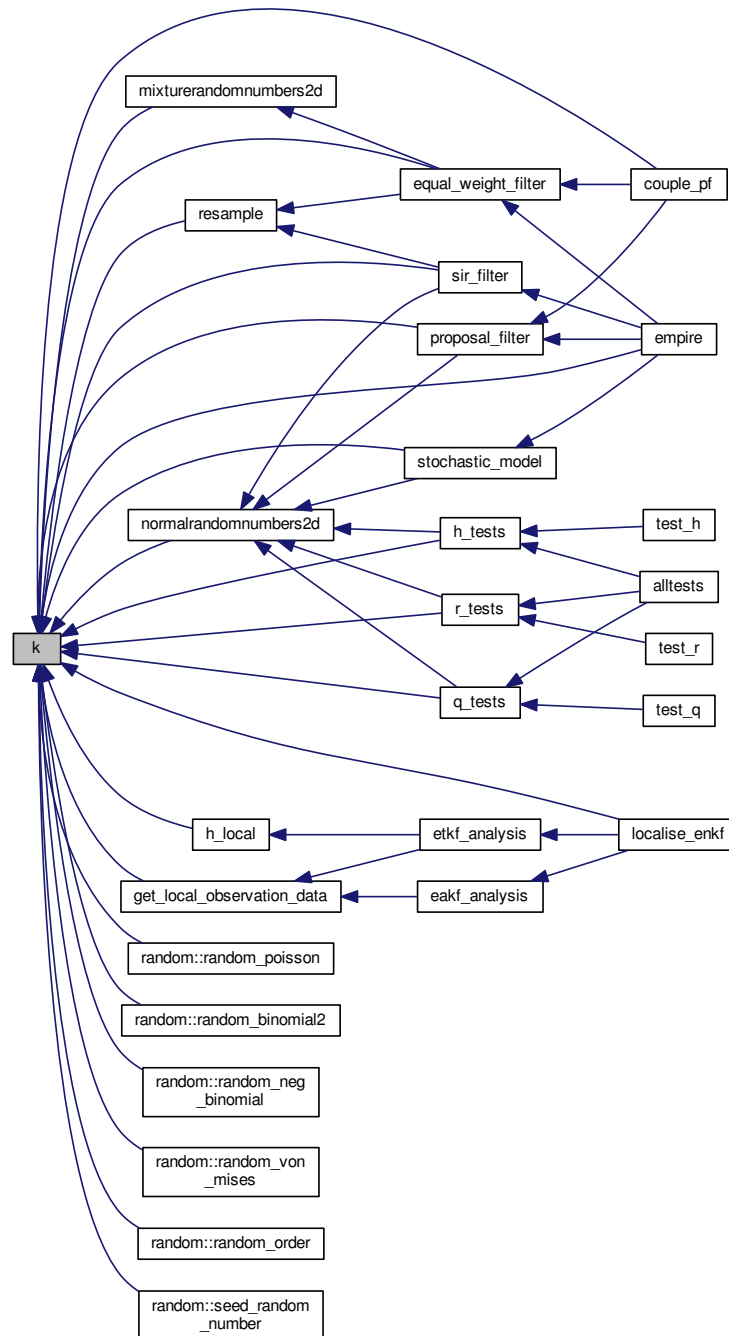
## Parameters

in	y	vector in observation space
out	x	vector in state space

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.20 src/operations/perturb\_particle.f90 File Reference

### Functions/Subroutines

- subroutine `perturb_particle` (x)

Subroutine to perturb state vector with normal random vector drawn from  $\mathcal{N}(0, Q)$ .

- subroutine `update_state` (state, fps, kgain, betan)

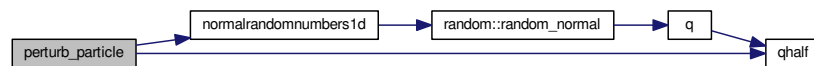
Subroutine to update the state.

## 5.20.1 Function/Subroutine Documentation

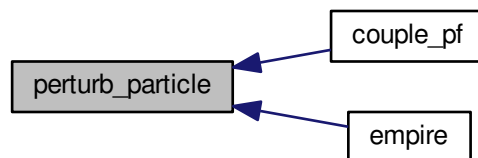
### 5.20.1.1 subroutine `perturb_particle` ( real(kind=rk), dimension(state\_dim), intent(inout) x )

Subroutine to perturb state vector with normal random vector drawn from  $\mathcal{N}(0, Q)$ .

Here is the call graph for this function:



Here is the caller graph for this function:



### 5.20.1.2 subroutine `update_state` ( real(kind=rk), dimension(state\_dim), intent(out) state, real(kind=rk), dimension(state\_dim), intent(in) fps, real(kind=rk), dimension(state\_dim), intent(in) kgain, real(kind=rk), dimension(state\_dim), intent(inout) betan )

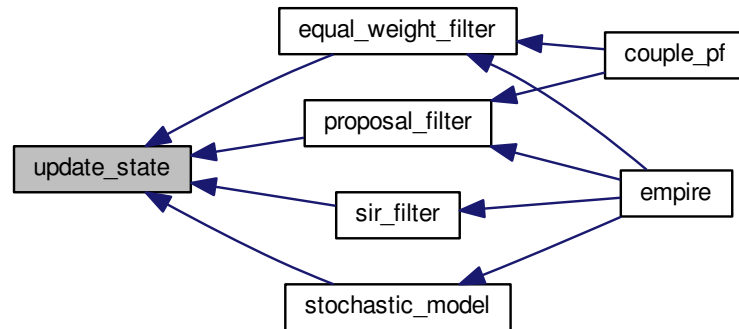
Subroutine to update the state.

This can be changed for the specific model if it needs to be

#### Parameters

in	<i>fps</i>	deterministic model update $f(x^{n-1})$
in	<i>kgain</i>	nudging term
in, out	<i>betan</i>	Stochastic term
out	<i>state</i>	The updated state vector

Here is the caller graph for this function:



## 5.21 src/operations/resample.f90 File Reference

### Functions/Subroutines

- subroutine [resample](#)

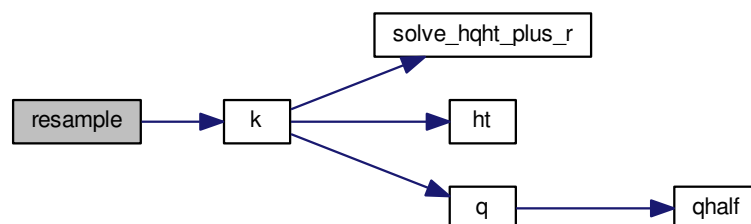
*Subroutine to perform Universal Importance Resampling.*

### 5.21.1 Function/Subroutine Documentation

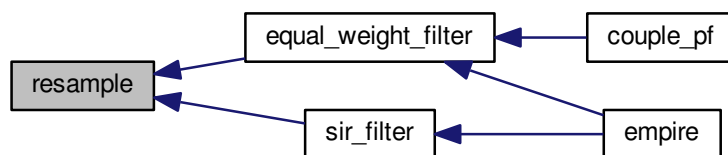
#### 5.21.1.1 subroutine `resample ( )`

Subroutine to perform Universal Importance Resampling.

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.22 src/tests/alltests.f90 File Reference

### Functions/Subroutines

- program [alltests](#)

*program to run all tests of user specific functions*

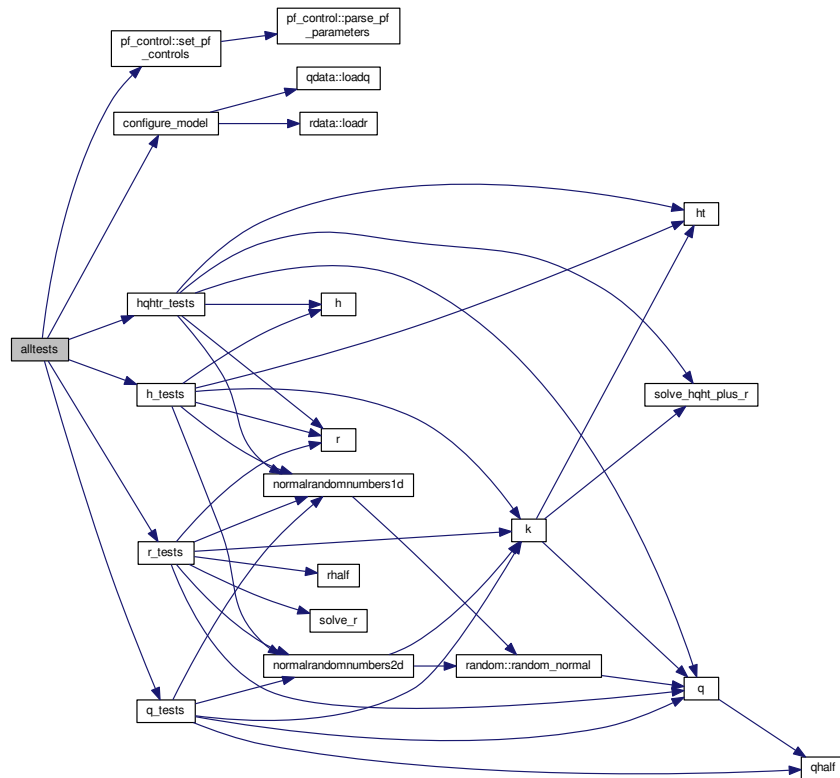
### 5.22.1 Function/Subroutine Documentation

#### 5.22.1.1 program alltests ( )

program to run all tests of user specific functions



Here is the call graph for this function:



## 5.23 src/tests/test\_h.f90 File Reference

### Functions/Subroutines

- program [test\\_h](#)

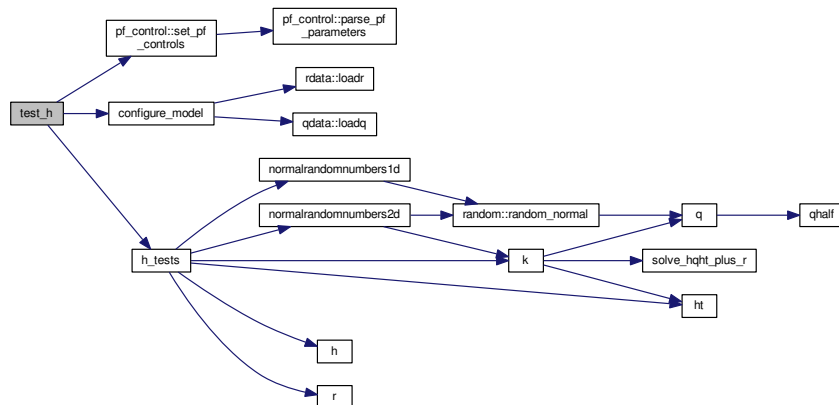
*program to run tests of user supplied observation operator*

#### 5.23.1 Function/Subroutine Documentation

##### 5.23.1.1 program test\_h ( )

program to run tests of user supplied observation operator

Here is the call graph for this function:



## 5.24 src/tests/test\_hqht.f90 File Reference

### Functions/Subroutines

- program [test\\_hqht](#)  
program to run tests of user supplied linear solve

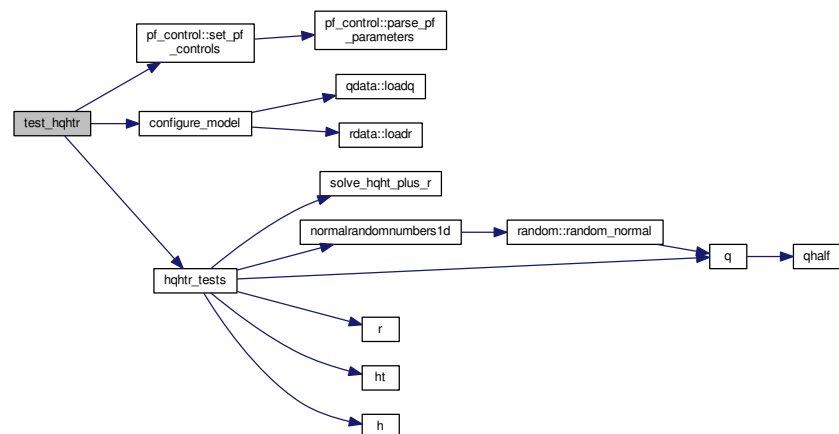
#### 5.24.1 Function/Subroutine Documentation

##### 5.24.1.1 program test\_hqht ( )

program to run tests of user supplied linear solve

$$(HQH^T + R)^{-1}$$

Here is the call graph for this function:



## 5.25 src/tests/test\_q.f90 File Reference

### Functions/Subroutines

- program [test\\_q](#)

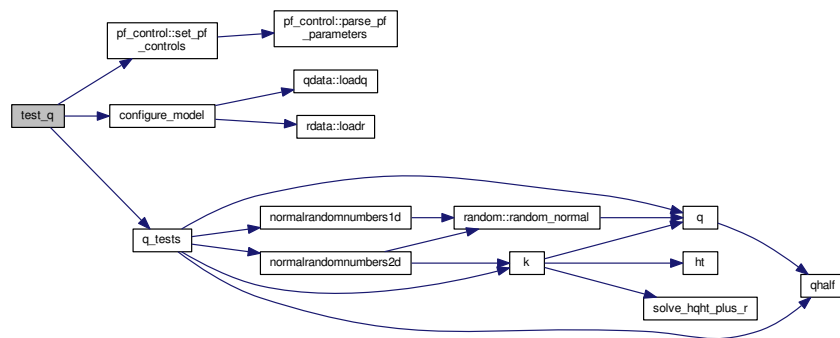
*program to run tests of user supplied model error covariance matrix*

#### 5.25.1 Function/Subroutine Documentation

##### 5.25.1.1 program test\_q ( )

program to run tests of user supplied model error covariance matrix

Here is the call graph for this function:



## 5.26 src/tests/test\_r.f90 File Reference

### Functions/Subroutines

- program [test\\_r](#)

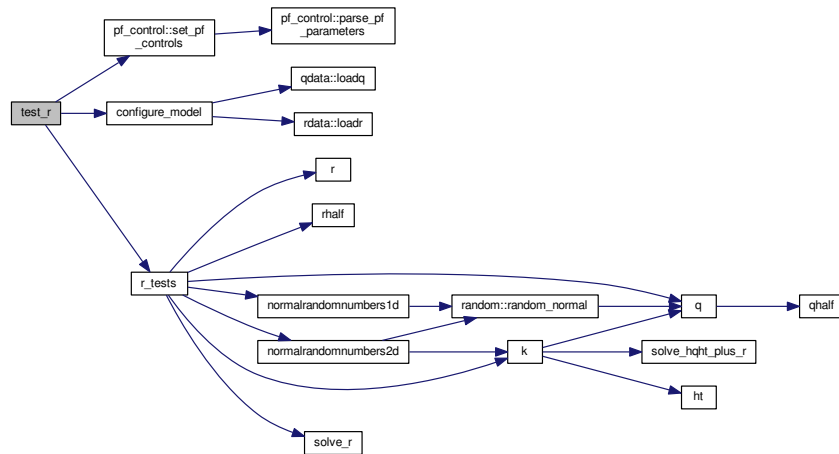
*program to run all tests of user supplied observation error covariance matrix/*

#### 5.26.1 Function/Subroutine Documentation

##### 5.26.1.1 program test\_r ( )

program to run all tests of user supplied observation error covariance matrix/

Here is the call graph for this function:



## 5.27 src/tests/tests.f90 File Reference

### Functions/Subroutines

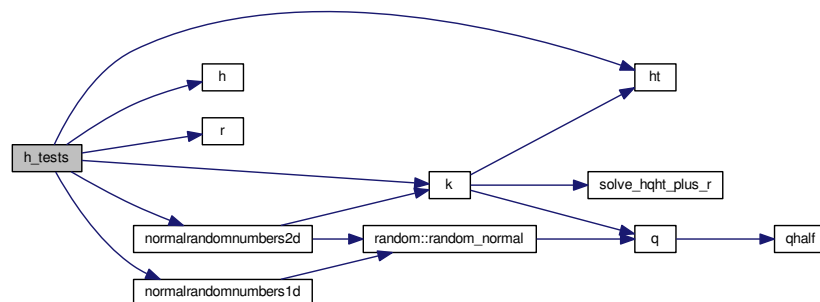
- subroutine [h\\_tests](#) ()
- subroutine [r\\_tests](#) ()
- subroutine [q\\_tests](#) ()
- subroutine [hqhtr\\_tests](#) ()

### 5.27.1 Function/Subroutine Documentation

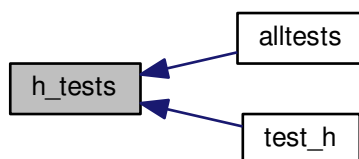
#### 5.27.1.1 subroutine `h_tests` ( )

These are some tests to check that the observation operator is implemented correctly

Here is the call graph for this function:



Here is the caller graph for this function:

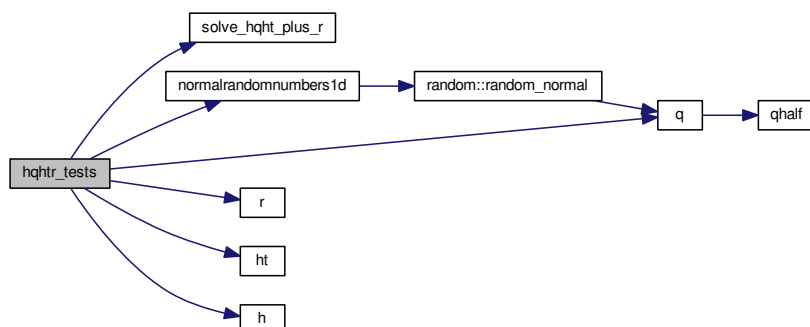


### 5.27.1.2 subroutine hqhtr\_tests ( )

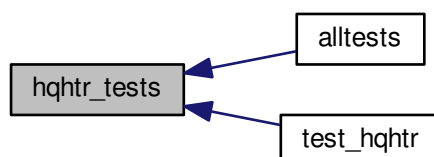
These are some tests to check that the linear solve operator is implemented correctly

This should check the operation  $(HQH^T + R)^{-1}$  is working

Here is the call graph for this function:



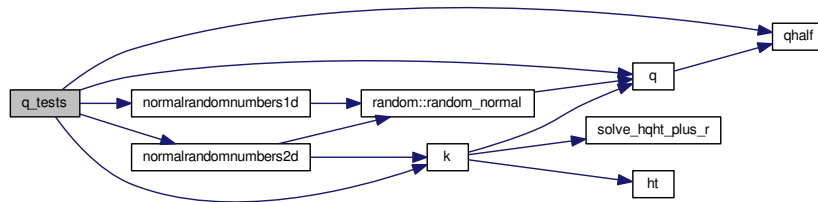
Here is the caller graph for this function:



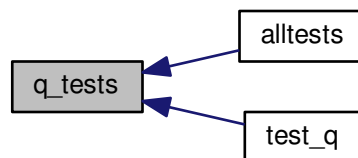
### 5.27.1.3 subroutine q\_tests ( )

These are some tests to check that the model error covariance matrix is implemented correctly

Here is the call graph for this function:



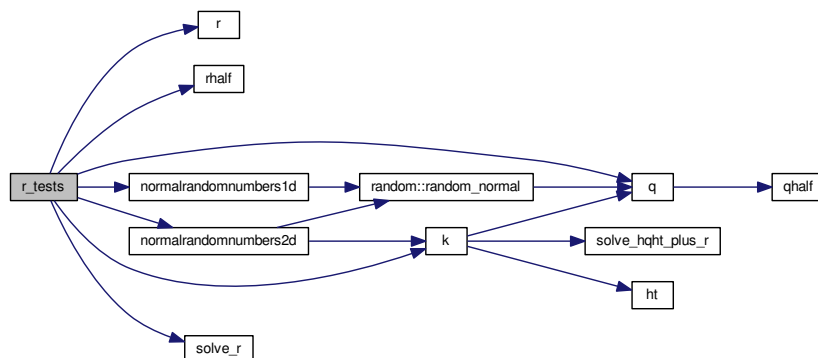
Here is the caller graph for this function:



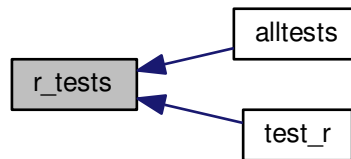
### 5.27.1.4 subroutine r\_tests ( )

These are some tests to check that the observation error covariance matrix is implemented correctly

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.28 src/utils/comms.f90 File Reference

### Data Types

- module `comms`  
*Module containing EMPIRE coupling data.*

## 5.29 src/utils/data\_io.f90 File Reference

### Functions/Subroutines

- subroutine `get_observation_data` (y)  
*Subroutine to read observation from a file  
Uses `pftimestep` to determine which observation to read.*
- subroutine `save_observation_data` (y)  
*Subroutine to save observation to a file  
Uses `pftimestep` to determine which observation to save.*
- subroutine `save_truth` (x)  
*Subroutine to save truth to a file*
- subroutine `output_from_pf`  
*subroutine to ouput data from the filter*

### 5.29.1 Function/Subroutine Documentation

#### 5.29.1.1 subroutine `get_observation_data` ( `real(kind=rk)`, `dimension(obs_dim)`, `intent(out) y` )

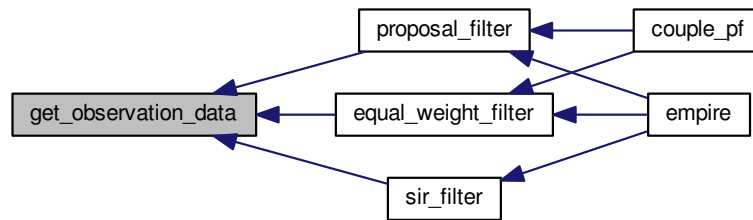
Subroutine to read observation from a file

Uses `pftimestep` to determine which observation to read.

#### Parameters

<code>out</code>	<code>y</code>	The observation
------------------	----------------	-----------------

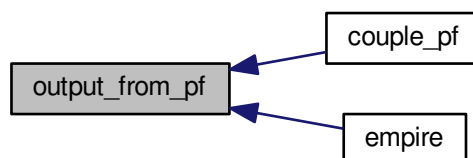
Here is the caller graph for this function:



#### 5.29.1.2 subroutine `output_from_pf ( )`

subroutine to output data from the filter

Here is the caller graph for this function:



#### 5.29.1.3 subroutine `save_observation_data ( real(kind=rk), dimension(obs_dim), intent(in) y )`

Subroutine to save observation to a file

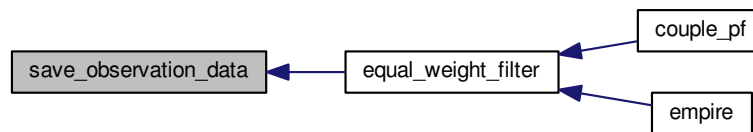
Uses `pftimestep` to determine which observation to save.

##### Parameters

<code>in</code>	<code>y</code>	The observation
-----------------	----------------	-----------------



Here is the caller graph for this function:



#### 5.29.1.4 subroutine `save_truth` ( `real(kind=rk)`, `dimension(state_dim)`, `intent(in) x` )

Subroutine to save truth to a file

.

##### Parameters

<code>in</code>	<code>x</code>	The state vector
-----------------	----------------	------------------

Here is the caller graph for this function:



## 5.30 src/utls/diagnostics.f90 File Reference

### Functions/Subroutines

- subroutine [diagnostics](#)

*Subroutine to give output diagnostics such as rank histograms and trajectories.*

- subroutine [trajectories](#)

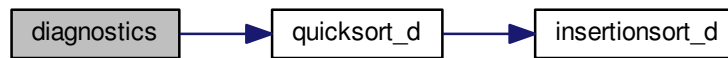
*subroutine to output trajectories*

### 5.30.1 Function/Subroutine Documentation

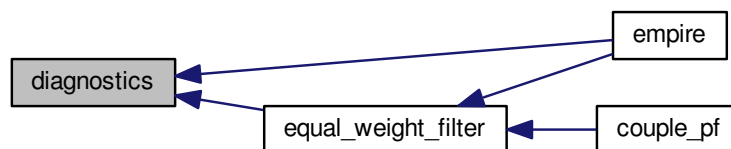
#### 5.30.1.1 subroutine `diagnostics` ( )

Subroutine to give output diagnostics such as rank histograms and trajectories.

Here is the call graph for this function:



Here is the caller graph for this function:



#### 5.30.1.2 subroutine trajectories ( )

subroutine to output trajectories

Here is the caller graph for this function:



## 5.31 src/utls/genQ.f90 File Reference

### Functions/Subroutines

- subroutine [genq](#)

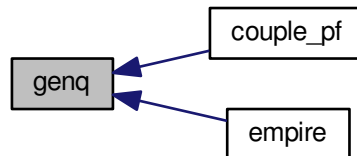
*Subroutine to estimate Q from a long model run.*

#### 5.31.1 Function/Subroutine Documentation

## 5.31.1.1 subroutine genq ( )

Subroutine to estimate Q from a long model run.

Here is the caller graph for this function:



## 5.32 src/utls/histogram.f90 File Reference

## Data Types

- module [histogram\\_data](#)

*Module to control what variables are used to generate rank histograms.*

## 5.33 src/utls/quicksort.f90 File Reference

## Functions/Subroutines

- recursive subroutine [quicksort\\_d](#) (a, na)

*subroutine to sort using the quicksort algorithm*

- subroutine [insertionsort\\_d](#) (A, nA)

*subroutine to sort using the insertionsort algorithm*

## 5.33.1 Function/Subroutine Documentation

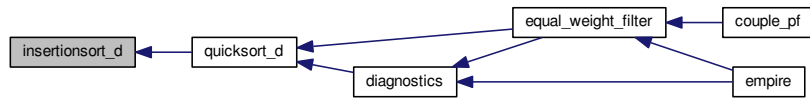
## 5.33.1.1 subroutine insertionsort\_d ( real(kind=kind(1.0d0)), dimension(na), intent(inout) A, integer, intent(in) nA )

subroutine to sort using the insertionsort algorithm

## Parameters

in, out	a	array of doubles to be sorted
in	na	dimension of array a

Here is the caller graph for this function:



#### 5.33.1.2 recursive subroutine `quicksort_d` ( `real(kind=kind(1.0d0))`, `dimension(na)`, `intent(inout) a`, `integer, intent(in) na` )

subroutine to sort using the quicksort algorithm

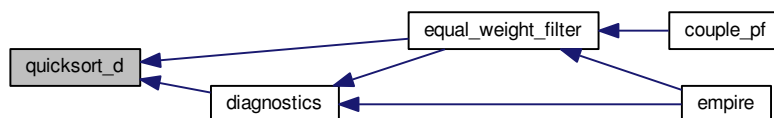
##### Parameters

<code>in, out</code>	<code>a</code>	array of doubles to be sorted
<code>in</code>	<code>na</code>	dimension of array <code>a</code>

Here is the call graph for this function:



Here is the caller graph for this function:



## 5.34 `src/utils/random_d.f90` File Reference

### Data Types

- module [random](#)

*A module for random number generation from the following distributions:*

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- allocate\_pf
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- alltests.f90
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