

# ASAGI User Manual

## 0.5

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## 1 Building and Installing ASAGI

### 1.1 Pre-requirements

#### 1.1.1 Compiler

ASAGI requires at least GCC 4.7 or Intel Compiler 12.1

#### 1.1.2 MPI

ASAGI makes use of the RMA (Remote Memory Access) API of the MPI-2 standard to transfer data. An MPI library that supports the new standard is required.

#### 1.1.3 NetCDF

ASAGI uses the NetCDF library (<http://www.unidata.ucar.edu/software/netcdf/>) to load data files.

#### 1.1.4 POSIX Threads (optional)

The PThreads library is required if ASAGI is compiled with NUMA support. If available it is also used to guaranty thread safety as an alternative to `std::mutex`.

#### 1.1.5 NUMA policy library (optional)

ASASGI uses the NUMA library to detect NUMA domains. This library is required if ASAGI should be compiled with NUMA support.

### 1.2 Compilation

To generate the Makefiles, CMake is used. For CMake it is recommend to keep source and build directory apart:

```
mkdir build
cd build
cmake <path/to/asagi_sources>
```

Several environment variables affect the behavior of CMake. They must be set before running "cmake".

- **Compiler** The compiler can be selected by setting `CC` (C compiler), `CXX` (C++ compiler) and `FC` (Fortran compiler) environment variables. C and Fortran compiler are only required for C and Fortran examples and tests.
- **Libraries** The `CMAKE_PREFIX_PATH` is used when searching for the MPI, NetCDF, POSIX Threads and NUMA library. If NetCDF was configured with `-prefix=<install_dir>` for example, set `CMAKE_PREFIX_PATH=<install_dir>`.

Besides the environment variables, you can change the behavior by setting internal CMake variables. They can be configured by adding one or more `-D<variable>=<value>` options when running "cmake". These variables can also be changed later with the following command:

```
ccmake <path/to/asagi_build>
```

The important variables are listed below. Most of the variables are ASAGI specific and will not work with other CMake projects.

- **CMAKE\_BUILD\_TYPE = Debug | Release** When set to "Debug", additional run-time checks are enabled as well as debug messages. [Release]
- **CMAKE\_INSTALL\_PREFIX** Installation directory for ASAGI. [/usr/local/]
- **SHARED\_LIB = ON | OFF** Build shared library. [ON]
- **STATIC\_LIB = ON | OFF** Build static library. [OFF]
- **FORTRAN\_SUPPORT = ON | OFF** Compile with Fortran support. [ON]
- **MAX\_DIMENSIONS** Maximum number of dimensions supported by ASAGI [4]
- **THREADSAFE = ON | OFF** If enabled all ASAGI functions are thread-safe. This is required, for example, if ASAGI is used in hybrid MPI/OpenMP programs. [ON]
- **THREADSAFE\_COUNTER = ON | OFF** Make access counters thread-safe. This may lead to a performance loss but makes sure, counters are accurate. [OFF]
- **THREADSAFE\_MPI = ON | OFF** Make MPI calls thread-safe. This is required if the MPI library is not thread-safe by itself. [ON]
- **NOMPI = ON | OFF** Do not compile with MPI support. All algorithms that require MPI communication will be disabled. [OFF]
- **NONUMA = ON | OFF** Do not compile with NUMA support. All intra-node communications will be turned off. [OFF]
- **TESTS = ON | OFF** Compile tests. [OFF]
- **EXAMPLES = ON | OFF** Compile example programs. [OFF]

### 1.3 Tests

If you have enabled the tests, you can run them with the following command:

```
make test
```

## 1.4 Installation

To install ASAGI simply run:

```
make install
```

This will install the (static and/or shared) library as well as the header files. If pkg-config was found, this command will also install a pkg-config configuration file for ASAGI in `CMAKE_INSTALL_PREFIX/lib/pkgconfig`

You can install ASAGI with and without MPI support on your system. The version with MPI will be called `asagi` and the version without MPI `asagi_nompi`. Use the same include file for both libraries, but if you do not compile your program with MPI, make sure to define `ASAGI_NOMPI` before including the ASAGI header:

```
#define ASAGI_NOMPI
```

## 2 Using ASAGI

### 2.1 Minimal examples

These are minimal C, C++ and Fortran examples that load a 2-dimensional grid and print the value at (0,0). In each case the grid contains floating point values.

C example:

```
#include <mpi.h>
#include <asagi.h>
#include <stdio.h>

int main(int argc, char** argv)
{
    MPI_Init(&argc, &argv);

    asagi_grid* grid = asagi_grid_create(ASAGI_FLOAT);
    asagi_grid_set_comm(grid, MPI_COMM_WORLD);
    // with threads, set number of threads
    asagi_grid_set_threads(grid, 1);

    if (asagi_grid_open(grid, "/path/to/netcdf/file.nc", 0) != ASAGI_SUCCESS) {
        printf("Could not load file\n");
        return 1;
    }

    double pos[] = {0, 0};
    printf("Value at (0,0): %f\n", asagi_grid_get_float(grid, pos, 0));

    asagi_grid_close(grid);

    MPI_Finalize();

    return 0;
}
```

C++ example:

```
#include <mpi.h>
#include <asagi.h>
#include <iostream>

using namespace asagi;

int main(int argc, char** argv)
{
    MPI_Init(&argc, &argv);

    Grid* grid = Grid::create();
    grid->setComm(MPI_COMM_WORLD);
    // with threads, set number of threads
    grid->setThreads(1);

    if (grid->open("/path/to/netcdf/file.nc") != Grid::SUCCESS) {
```

```

    std::cout << "Could not load file" << std::endl;
    return 1;
}

double pos[] = {0, 0};
std::cout << "Value at (0,0): " << grid->getFloat(pos) << std::endl;

// The same as: "Grid::close(grid);"
delete grid;

MPI_Finalize();

return 0;
}

```

Fortran example:

```

! You have two options:
! - Include the module file _once_ in your project:
!include 'asagi.f90'
! - Compile and link the module file as any other file in your project

program minimal
  use mpi
  use asagi
  use, intrinsic :: iso_c_binding
  implicit none

  integer :: grid_id
  real( kind=c_double ), dimension(2) :: pos
  integer :: error

  call mpi_init( error )

  grid_id = asagi_grid_create( )
  call asagi_grid_set_comm( grid_id, mpi_comm_world )
  ! with threads, set number of threads
  call asagi_grid_set_threads( grid_id, 1 );

  if( asagi_grid_open( grid_id, "/path/to/netcdf/file.nc" ) /= asagi_success ) then
    write (*,*) "Could not load file"
    call exit(1)
  end if

  pos(:) = 0
  write (*,*) "Value at (0,0):", asagi_grid_get_float( grid_id, pos )

  call asagi_grid_close( grid_id )

  call mpi_finalize( error )
end program minimal

```

## 2.2 Grid types

ASAGI distinguishes between three different grid types:

- **FULL** The whole grid will be loaded during the initialization. The file is not accessed during runtime. (default)
- **CACHE** ASAGI is used as a cache. After initialization, the cache will be empty. Each access to an element, will put the corresponding block into the cache for later usage.
- **PASS-THROUGH** ASAGI will pass each access to the underlying file system without any caching, etc.

Full storage does not automatically mean, that the full grid is stored on every CPU. If `asagi::Grid::setComm()` and/or `asagi::Grid::setThreads()` are called, the initial grid will be distributed among all nodes resp. CPUs. If the cache-grid is used and `asagi::Grid::setThreads()` and/or `asagi::Grid::setComm()` are set, ASAGI will copy the data from other NUMA domains and/or other MPI processes. Only if it is not available in another cache, the data will be fetched from the file.

## 2.3 Dimensions

ASAGI supports grids with up to `MAX_DIMENSIONS` dimensions. (`MAX_DIMENSIONS` is 4 by default, but can be changed during compilation of ASAGI.) The number of actual dimensions in the grid cannot be specified by calling an ASAGI function but depends on the netCDF input file.

### Remarks

The order in the dimension in the netCDF file is in Fortran style (column-major, see [NetCDF files](#)) but the ASAGI interface uses C/C++ ordering (row-major).

## 2.4 Level of detail

A grid can have multiple resolutions. Each resolution is identified by a level id (level of detail). If the number of levels is not specified when creating a grid, the grid will contain only one level of detail. In this case you can also omit the level id in all other functions, since level 0 will be used by default. (C does not support default arguments or overloading, therefore omitting arguments is not possible when using the C interface.)

For grids with multiple levels `asagi::Grid::open()` must be called once for each level. Several levels can be stored in a single NetCDF file with different variable names. (Use `asagi::Grid::setParam()` to specify the variable name.) The coarsest resolution should have the level id 0. With ascending level id, the resolution should get finer. When accessing values with any `get` function, the level of detail can be selected with the last argument. The function `asagi::Grid::close()` has to be called only once for the whole grid.

## 2.5 Coordinate mapping

ASAGI distinguishes between actual coordinates and internal array indexes. All functions, that return a grid value, expect actual coordinates. ASAGI maps each coordinate to an array index using the coordinate variables from the NetCDF file (see section [NetCDF files](#) on how specify coordinate variables in NetCDF files). If no coordinate variable is available, the mapping is omitted. After the mapping, the coordinate is rounded to the nearest array index. ASAGI does not interpolate between array values.

The actual range of the grid can be obtained with `asagi::Grid::getMin()/asagi::Grid::getMax()`. They also return coordinates, not array indexes. It is erroneous to access values outside range of the grid.

The range of a dimension can be  $(-\infty, \infty)$ . This is the case if the size of the dimension in the netCDF file is one.

## 2.6 Value position

ASAGI supports cell-centered and vertex-centered grids. The value position can be switched with `asagi::Grid::setParam()`.

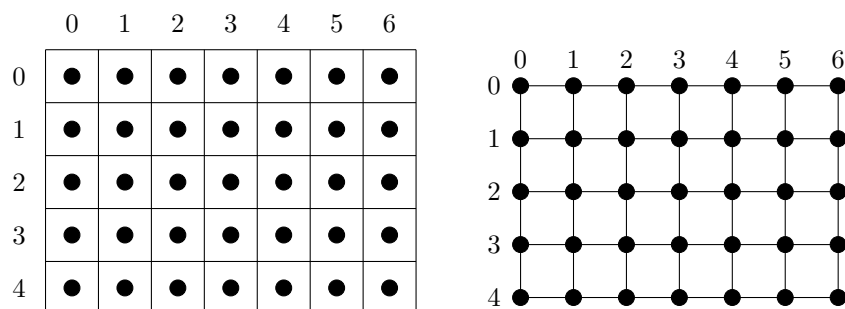


Figure 1: Cell-centered and vertex-centered grids

## 2.7 NetCDF files

All NetCDF files opened with ASAGI should respect the COARDS conventions ([http://ferret.wrc.noaa.gov/noaa\\_coop/coop\\_cdf\\_profile.html](http://ferret.wrc.noaa.gov/noaa_coop/coop_cdf_profile.html)). However, ASAGI has some further limitations:

- The attributes `scale_factor` and `add_offset` are ignored. Besides conversion between data types, ASAGI does not modify the values.
- Since ASAGI does not change the NetCDF file, all values have to be present in the file. Attributes, like `_FillValue` and `missing_value`, are not supported.
- ASAGI is not aware of any units. It is up to the user of the library to interpret the values correctly.
- Variables with more than three dimensions are not supported.

It is possible to open a NetCDF file by different grids or levels at the same time. This allows you, for example, to store all levels of one grid in a single NetCDF file. In this case the levels must be distinguished by the variable names.

## 2.8 Multi-thread support

When compiled with `THREADSAFE=ON` (see section [Compilation](#)) all functions are thread-safe. However, there are some restrictions due to MPI implementations. If your MPI library is not thread-safe, you have to add the additional flag `THREADSAFE_MPI=ON` which will make sure that ASAGI does not call MPI functions from different threads at the same time. However, in this case, you are not allowed to call MPI **and** ASAGI functions at the same time.

Multi-thread support is required if you want to use ASAGI's NUMA functionality (see [NUMA](#)).

## 2.9 NUMA

ASAGI is able to detect the NUMA domains of your node. If more than one NUMA domain is detected, ASAGI will place a cache on each NUMA domain to increase locality. To enable the NUMA detection, call `asagi::Grid::setThreads()` with the **total** number of threads you are using. In this case, `asagi::Grid::open()` has to be called by all threads and is a collective operation.

## 2.10 Parameters

ASAGI supports several parameters for each grid:

Name	Values	Description	Grid-global (*)
GRID	FULL   CACHE   PASS-THROUGH	The grid type (see <a href="#">Grid types</a> )	yes
NUMA-CACHE	YES   NO	For full-grids, try local caches before using MPI	yes
MPI_COMMUNICATION	THREAD   WINDOW	Use a communication thread or MPI RMA (windows) for MPI communication (default: WINDOW, see <a href="#">MPI Communication</a> )	yes



VALUE-POSITION	CELL-CENTERED   VERTEX-CENTERED	The value position (see <a href="#">Value position</a> )	yes
TIME-DIMENSION	int	The dimension that holds the time (default is -1 which means no time dimension exists). ASAGI treats time dimension specially.	yes
VARIABLE	string	The variable name in the netCDF file. (default: z)	no
BLOCK-SIZE-X	int	The size of a block in dimension X. Use a negative value to set the block size equal to the total number cells in this dimension.	no
CACHE-SIZE	int	The size of the cache (in blocks) on each CPU.	no
CACHE-HAND-SPREAD	int	ASAGI uses the clock algorithm to approx. LRU. This parameter specifies the difference of the 2 hands in the clock. Lower values result in a faster algorithm but a worse approximation.	no

(\*) If yes, the parameter can only be set for all levels at the same time. Set the parameter `level` in `asagi::Grid::setParam()` to 0 to change value.

### 2.10.1 MPI Communication

ASAGI supports two different MPI communication patterns: Via MPI remote memory access (MPI windows) or a separate communication thread. The MPI windows are used by default since they do not have any special requirement and are easy to use. However, in some MPI libraries, RMA is poorly tested and does not work well, especially with hybrid parallelization.

Therefore, you can use the communication thread. In this mode, a separate thread is required which is responsible for answering remote requests. You have to start the thread with `asagi::Grid::startCommThread` **before** any grid using the communication thread is opened. Multiple grids will share one communication thread does you must not start more than communication. However, you have to make sure that the MPI communicator for the communication thread includes all grid communicators. Once the last grid using the communication thread is closed, you should stop the additional with `asagi::Grid::stopCommThread`. To use the communication thread it is also necessary to have a thread-safe MPI implementation.

## 2.11 Access counters

ASAGI supports several access counters to measure the throughput of the library and get information about effectiveness of the caches:

Name	Description
accesses	Total number of data accesses
numa_transfers	Number of blocks transfered between CPUs
mpi_transfers	Number of blocks transfered between processes
file_load	Number of blocks loaded from file (after initialization)
local_hits	Number values that where already in local NUMA domain
node_hits	Number values that where already on the local node
local_misses	Number of values that where not already in local memory

#### Remarks

If more than one thread is used and ASAGI is not compiled with `THREADSAFE_COUNTER=ON`, the counters might be inaccurate.

## 3 Troubleshooting

### 3.1 CMake does not find MPI

On some platfforms, CMake has problems finding MPI. Try to set the environment variable `CMAKE_PREFIX_PATH` (see section [Building and Installing ASAGI](#)) or select the MPI compiler before running CMake by setting the enviroment variable `CXX`.

### 3.2 The program hangs

#### 3.2.1 Intel MPI

Due to a bug (<http://software.intel.com/en-us/forums/showthread.php?t=103456>) in the Intel MPI library (version 4.0 update 3 and probably earlier versions) the remote memory access in ASAGI does not work properly. This only happens when fabric is set to "ofa" or "shm:ofa". Selecting a different fabric by changing the environment variable "I\_MPI\_FABRICS" solves the problem.

#### 3.2.2 OpenMPI

OpenMPI windows also have a bug that might create deadlocks if more than one thread is used.

The bug could be reproduced with the following example with OpenMPI 1.8.7:

```
#include <mpi.h>
#include <unistd.h>
#include <iostream>

int main(int argc, char* argv[]) {
    int provided;
    MPI_Init_thread(&argc, &argv, MPI_THREAD_SERIALIZED, &provided);
    //MPI_Init(&argc, &argv);

    int rank;
    MPI_Comm_rank(MPI_COMM_WORLD, &rank);

    MPI_Win window;
    int* data;
    MPI_Alloc_mem(sizeof(int), MPI_INFO_NULL, &data);
    *data = 0;

    MPI_Win_create(data,
        sizeof(int),
        sizeof(int),
        MPI_INFO_NULL,
        MPI_COMM_WORLD, &window);

    if (rank == 0) {
        sleep(3);
    }
}
```

```

std::cout << "Start rank 0" << std::endl;

MPI_Win_lock(MPI_LOCK_SHARED, 1, 0, window);
int mydata = 1;
MPI_Put(&mydata, 1, MPI_INT, 1, 0, 1, MPI_INT, window);
MPI_Win_unlock(1, window);

char signal = 0;
MPI_Send(&signal, 1, MPI_CHAR, 1, 0, MPI_COMM_WORLD);

std::cout << "End rank 0" << std::endl;
} else {
std::cout << "Start rank 1" << std::endl;

char signal;
MPI_Recv(&signal, 1, MPI_CHAR, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);

std::cout << "End rank 1" << std::endl;
}

MPI_Win_free(&window);
MPI_Free_mem(data);

MPI_Finalize();

return 0;
}

```

This bug seems to be fixed in version 1.10.0.

### 3.3 The program fails with "PMPI\_Win\_create: Assertion

'winptr->lock\_table[i]' failed" or "function:MPI\_WIN\_LOCK, Invalid win argument"

The SGI Message Passing Toolkit uses a special mapped memory for one-sided communication. For large grids the default size of mapped memory may be too small. It is possible to increase the size by setting the environment variable `MPI_MAPPED_HEAP_SIZE`.

## 4 Module Documentation

### 4.1 Fortran Interface

#### Data Types

- module [asagi](#)

#### Functions/Subroutines

- integer(kind=c\_int) function [asagi::asagi\\_grid\\_create\\_struct](#) (count, block\_length, displacements, types)
- subroutine [asagi::asagi\\_grid\\_set\\_comm](#) (grid\_id, comm)
- subroutine [asagi::asagi\\_grid\\_set\\_threads](#) (grid\_id, threads)
- integer(kind=c\_int) function [asagi::asagi\\_grid\\_dimensions](#) (grid\_id)
- real(kind=c\_double) function [asagi::asagi\\_grid\\_min](#) (grid\_id, n)
- real(kind=c\_double) function [asagi::asagi\\_grid\\_max](#) (grid\_id, n)
- integer(kind=c\_int) function [asagi::asagi\\_grid\\_var\\_size](#) (grid\_id)
- subroutine [asagi::asagi\\_grid\\_close](#) (grid\_id)
- integer(kind=c\_int) function [asagi::asagi\\_start\\_comm\\_thread](#) (sched\_cpu, comm)
- subroutine [asagi::asagi\\_stop\\_comm\\_thread](#) ()
- integer(kind=c\_int) function [asagi::asagi\\_node\\_local\\_rank](#) (comm)
- integer function [asagi::asagi\\_grid\\_create](#) (type)
- integer function [asagi::asagi\\_grid\\_create\\_array](#) (basictype)
- subroutine [asagi::asagi\\_grid\\_set\\_param](#) (grid\_id, name, value, level)

- integer function [asagi::asagi\\_grid\\_open](#) (grid\_id, filename, level)
- real(kind=c\_double) function [asagi::asagi\\_grid\\_delta](#) (grid\_id, n, level)
- character function [asagi::asagi\\_grid\\_get\\_byte](#) (grid\_id, pos, level)
- integer function [asagi::asagi\\_grid\\_get\\_int](#) (grid\_id, pos, level)
- integer(kind=c\_long) function [asagi::asagi\\_grid\\_get\\_long](#) (grid\_id, pos, level)
- real function [asagi::asagi\\_grid\\_get\\_float](#) (grid\_id, pos, level)
- real(kind=c\_double) function [asagi::asagi\\_grid\\_get\\_double](#) (grid\_id, pos, level)
- subroutine [asagi::asagi\\_grid\\_get\\_buf](#) (grid\_id, buf, pos, level)

#### 4.1.1 Detailed Description

#### 4.1.2 Class Documentation

##### 4.1.2.1 module asagi

ASAGI Fortran Interface.

##### Public Member Functions

- integer(kind=c\_int) function [asagi\\_grid\\_create\\_struct](#) (count, block\_length, displacements, types)
- subroutine [asagi\\_grid\\_set\\_comm](#) (grid\_id, comm)
- subroutine [asagi\\_grid\\_set\\_threads](#) (grid\_id, threads)
- integer(kind=c\_int) function [asagi\\_grid\\_dimensions](#) (grid\_id)
- real(kind=c\_double) function [asagi\\_grid\\_min](#) (grid\_id, n)
- real(kind=c\_double) function [asagi\\_grid\\_max](#) (grid\_id, n)
- integer(kind=c\_int) function [asagi\\_grid\\_var\\_size](#) (grid\_id)
- subroutine [asagi\\_grid\\_close](#) (grid\_id)
- integer(kind=c\_int) function [asagi\\_start\\_comm\\_thread](#) (sched\_cpu, comm)
- subroutine [asagi\\_stop\\_comm\\_thread](#) ()
- integer(kind=c\_int) function [asagi\\_node\\_local\\_rank](#) (comm)
- integer function [asagi\\_grid\\_create](#) (type)
- integer function [asagi\\_grid\\_create\\_array](#) (basictype)
- subroutine [asagi\\_grid\\_set\\_param](#) (grid\_id, name, value, level)
- integer function [asagi\\_grid\\_open](#) (grid\_id, filename, level)
- real(kind=c\_double) function [asagi\\_grid\\_delta](#) (grid\_id, n, level)
- character function [asagi\\_grid\\_get\\_byte](#) (grid\_id, pos, level)
- integer function [asagi\\_grid\\_get\\_int](#) (grid\_id, pos, level)
- integer(kind=c\_long) function [asagi\\_grid\\_get\\_long](#) (grid\_id, pos, level)
- real function [asagi\\_grid\\_get\\_float](#) (grid\_id, pos, level)
- real(kind=c\_double) function [asagi\\_grid\\_get\\_double](#) (grid\_id, pos, level)
- subroutine [asagi\\_grid\\_get\\_buf](#) (grid\_id, buf, pos, level)

#### 4.1.3 Function/Subroutine Documentation

##### 4.1.3.1 subroutine [asagi::asagi\\_grid\\_close](#) ( integer( kind=c\_int ) *grid\_id* )

See also

[asagi::Grid::close\(asagi::Grid\\*\)](#)

##### 4.1.3.2 integer function [asagi::asagi\\_grid\\_create](#) ( integer, intent(in), optional *type* )

See also

[asagi::Grid::create\(\)](#)

4.1.3.3 integer function `asagi::asagi_grid_create_array` ( integer, intent(in), optional *basictype* )

See also

[asagi::Grid::createArray\(\)](#)

4.1.3.4 integer( kind=c\_int ) function `asagi::asagi_grid_create_struct` ( integer( kind=c\_int ) *count*, integer( kind=c\_int ), dimension(\*), intent(in) *block\_length*, integer( kind=c\_long ), dimension(\*), intent(in) *displacements*, integer( kind=c\_int ), dimension(\*), intent(in) *types* )

See also

[asagi::Grid::createStruct\(\)](#)

4.1.3.5 real( kind=c\_double ) function `asagi::asagi_grid_delta` ( integer, intent(in) *grid\_id*, integer, intent(in) *n*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getDelta\(\)](#)

4.1.3.6 integer( kind=c\_int ) function `asagi::asagi_grid_dimensions` ( integer( kind=c\_int ) *grid\_id* )

See also

[asagi::Grid::getDimensions\(\)](#)

4.1.3.7 subroutine `asagi::asagi_grid_get_buf` ( integer, intent(in) *grid\_id*, type( c\_ptr ) *buf*, real( kind=c\_double ), dimension(\*), intent(in) *pos*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getBuf\(\)](#)

4.1.3.8 character function `asagi::asagi_grid_get_byte` ( integer, intent(in) *grid\_id*, real( kind=c\_double ), dimension(\*), intent(in) *pos*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getBytes\(\)](#)

4.1.3.9 real( kind=c\_double ) function `asagi::asagi_grid_get_double` ( integer, intent(in) *grid\_id*, real( kind=c\_double ), dimension(\*), intent(in) *pos*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getDouble\(\)](#)

4.1.3.10 real function `asagi::asagi_grid_get_float` ( integer, intent(in) *grid\_id*, real( kind=c\_double ), dimension(\*), intent(in) *pos*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getFloat\(\)](#)

4.1.3.11 integer function `asagi::asagi_grid_get_int` ( integer, intent(in) *grid\_id*, real( kind=c\_double ), dimension(\*), intent(in) *pos*, integer, intent(in), optional *level* )

See also

[asagi::Grid::getInt\(\)](#)

4.1.3.12 `integer( kind=c_long ) function asagi::asagi_grid_get_long ( integer, intent(in) grid_id, real( kind=c_double ), dimension(*), intent(in) pos, integer, intent(in), optional level )`

See also

[asagi::Grid::getLong\(\)](#)

4.1.3.13 `real( kind=c_double ) function asagi::asagi_grid_max ( integer( kind=c_int ) grid_id, integer( kind=c_int ) n )`

See also

[asagi::Grid::getMax\(\)](#)

4.1.3.14 `real( kind=c_double ) function asagi::asagi_grid_min ( integer( kind=c_int ) grid_id, integer( kind=c_int ) n )`

See also

[asagi::Grid::getMin\(\)](#)

4.1.3.15 `integer function asagi::asagi_grid_open ( integer, intent(in) grid_id, character*(*) , intent(in) filename, integer, intent(in), optional level )`

See also

[asagi::Grid::open\(\)](#)

4.1.3.16 `subroutine asagi::asagi_grid_set_comm ( integer( kind=c_int ) grid_id, integer( kind=c_int ) comm )`

See also

[asagi::Grid::setComm\(\)](#)

4.1.3.17 `subroutine asagi::asagi_grid_set_param ( integer, intent(in) grid_id, character*(*) , intent(in) name, character*(*) , intent(in) value, integer, intent(in), optional level )`

See also

[asagi::Grid::setParam\(\)](#)

4.1.3.18 `subroutine asagi::asagi_grid_set_threads ( integer( kind=c_int ) grid_id, integer( kind=c_int ) threads )`

See also

[asagi::Grid::setThreads\(\)](#)

4.1.3.19 `integer( kind=c_int ) function asagi::asagi_grid_var_size ( integer( kind=c_int ) grid_id )`

See also

[asagi::Grid::getVarSize\(\)](#)

4.1.3.20 `integer( kind=c_int ) function asagi::asagi_node_local_rank ( integer( kind=c_int ) comm )`

See also

[asagi::Grid::nodeLocalRank](#)

4.1.3.21 `integer( kind=c_int ) function asagi::asagi_start_comm_thread ( integer( kind=c_int ) sched_cpu, integer( kind=c_int ) comm )`

See also

[asagi::Grid::startCommThread](#)

4.1.3.22 subroutine asagi::asagi\_stop\_comm\_thread ( )

See also

[asagi::Grid::stopCommThread](#)

## 4.2 C Interface

### Typedefs

- typedef [asagi::Grid](#) [asagi\\_grid](#)

### Enumerations

- enum [asagi\\_type](#)
- enum [asagi\\_error](#)

### Functions

- [asagi\\_grid](#) \* [asagi\\_grid\\_create](#) ([asagi\\_type](#) type)
- [asagi\\_grid](#) \* [asagi\\_grid\\_create\\_array](#) ([asagi\\_type](#) basic\_type)
- [asagi\\_grid](#) \* [asagi\\_grid\\_create\\_struct](#) (unsigned int count, unsigned int blockLength[], unsigned long displacements[], [asagi\\_type](#) types[])
- void [asagi\\_grid\\_set\\_comm](#) ([asagi\\_grid](#) \*handle, MPI\_Comm comm)
- void [asagi\\_grid\\_set\\_threads](#) ([asagi\\_grid](#) \*handle, unsigned int threads)
- void [asagi\\_grid\\_set\\_param](#) ([asagi\\_grid](#) \*handle, const char \*name, const char \*value, unsigned int level)
- [asagi\\_error](#) [asagi\\_grid\\_open](#) ([asagi\\_grid](#) \*handle, const char \*filename, unsigned int level)
- unsigned int [asagi\\_grid\\_dimensions](#) ([asagi\\_grid](#) \*handle)
- double [asagi\\_grid\\_min](#) ([asagi\\_grid](#) \*handle, unsigned int n)
- double [asagi\\_grid\\_max](#) ([asagi\\_grid](#) \*handle, unsigned int n)
- double [asagi\\_grid\\_delta](#) ([asagi\\_grid](#) \*handle, unsigned int n, unsigned int level)
- unsigned int [asagi\\_grid\\_var\\_size](#) ([asagi\\_grid](#) \*handle)
- unsigned char [asagi\\_grid\\_get\\_byte](#) ([asagi\\_grid](#) \*handle, const double \*pos, unsigned int level)
- int [asagi\\_grid\\_get\\_int](#) ([asagi\\_grid](#) \*handle, const double \*pos, unsigned int level)
- long [asagi\\_grid\\_get\\_long](#) ([asagi\\_grid](#) \*handle, const double \*pos, unsigned int level)
- float [asagi\\_grid\\_get\\_float](#) ([asagi\\_grid](#) \*handle, const double \*pos, unsigned int level)
- double [asagi\\_grid\\_get\\_double](#) ([asagi\\_grid](#) \*handle, const double \*pos, unsigned int level)
- void [asagi\\_grid\\_get\\_buf](#) ([asagi\\_grid](#) \*handle, void \*buf, const double \*pos, unsigned int level)
- void [asagi\\_grid\\_close](#) ([asagi\\_grid](#) \*handle)
- [asagi\\_error](#) [asagi\\_start\\_comm\\_thread](#) (int sched\_cpu, MPI\_Comm comm)
- void [asagi\\_stop\\_comm\\_thread](#) ()
- int [asagi\\_node\\_local\\_rank](#) (MPI\_Comm comm)

#### 4.2.1 Detailed Description

#### 4.2.2 Typedef Documentation

##### 4.2.2.1 typedef struct [asagi\\_grid](#) [asagi\\_grid](#)

A handle for a grid

#### 4.2.3 Enumeration Type Documentation

##### 4.2.3.1 enum [asagi\\_error](#)

See also

[asagi::Grid::Error](#)



#### 4.2.3.2 enum `asagi_type`

See also

[asagi::Grid::Type](#)

#### 4.2.4 Function Documentation

##### 4.2.4.1 void `asagi_grid_close` ( `asagi_grid * handle` )

See also

[asagi::Grid::close\(asagi::Grid\\*\)](#)

##### 4.2.4.2 `asagi_grid*` `asagi_grid_create` ( `asagi_type type` )

See also

[asagi::Grid::create\(\)](#)

##### 4.2.4.3 `asagi_grid*` `asagi_grid_create_array` ( `asagi_type basic_type` )

See also

[asagi::Grid::createArray\(\)](#)

##### 4.2.4.4 `asagi_grid*` `asagi_grid_create_struct` ( unsigned int *count*, unsigned int *blockLength*[], unsigned long *displacements*[], `asagi_type types`[] )

See also

[asagi::Grid::createStruct\(\)](#)

##### 4.2.4.5 double `asagi_grid_delta` ( `asagi_grid * handle`, unsigned int *n*, unsigned int *level* )

See also

[asagi::Grid::getDelta\(\)](#)

##### 4.2.4.6 unsigned int `asagi_grid_dimensions` ( `asagi_grid * handle` )

See also

[asagi::Grid::getDimensions\(\)](#)

##### 4.2.4.7 void `asagi_grid_get_buf` ( `asagi_grid * handle`, void \* *buf*, const double \* *pos*, unsigned int *level* )

See also

[asagi::Grid::getBuf\(\)](#)

##### 4.2.4.8 unsigned char `asagi_grid_get_byte` ( `asagi_grid * handle`, const double \* *pos*, unsigned int *level* )

See also

[asagi::Grid::getBytes\(\)](#)

##### 4.2.4.9 double `asagi_grid_get_double` ( `asagi_grid * handle`, const double \* *pos*, unsigned int *level* )

See also

[asagi::Grid::getDouble\(\)](#)

4.2.4.10 `float asagi_grid_get_float ( asagi_grid * handle, const double * pos, unsigned int level )`

See also

[asagi::Grid::getFloat\(\)](#)

4.2.4.11 `int asagi_grid_get_int ( asagi_grid * handle, const double * pos, unsigned int level )`

See also

[asagi::Grid::getInt\(\)](#)

4.2.4.12 `long asagi_grid_get_long ( asagi_grid * handle, const double * pos, unsigned int level )`

See also

[asagi::Grid::getLong\(\)](#)

4.2.4.13 `double asagi_grid_max ( asagi_grid * handle, unsigned int n )`

See also

[asagi::Grid::getMax\(\)](#)

4.2.4.14 `double asagi_grid_min ( asagi_grid * handle, unsigned int n )`

See also

[asagi::Grid::getMin\(\)](#)

4.2.4.15 `asagi_error asagi_grid_open ( asagi_grid * handle, const char * filename, unsigned int level )`

See also

[asagi::Grid::open\(\)](#)

4.2.4.16 `void asagi_grid_set_comm ( asagi_grid * handle, MPI_Comm comm )`

See also

[asagi::Grid::setComm\(\)](#)

4.2.4.17 `void asagi_grid_set_param ( asagi_grid * handle, const char * name, const char * value, unsigned int level )`

See also

[asagi::Grid::setParam\(\)](#)

4.2.4.18 `void asagi_grid_set_threads ( asagi_grid * handle, unsigned int threads )`

See also

[asagi::Grid::setThreads\(\)](#)

4.2.4.19 `unsigned int asagi_grid_var_size ( asagi_grid * handle )`

See also

[asagi::Grid::getVarSize\(\)](#)

4.2.4.20 `int asagi_node_local_rank ( MPI_Comm comm )`

See also

[asagi::Grid::nodeLocalRank\(MPI\\_Comm\)](#)

4.2.4.21 `asagi_error asagi_start_comm_thread ( int sched_cpu, MPI_Comm comm )`

See also

[asagi::Grid::startCommThread\(int, MPI\\_Comm\)](#)

4.2.4.22 `void asagi_stop_comm_thread ( )`

See also

[asagi::Grid::stopCommThread\(\)](#)

## 4.3 C++ Interface

### Classes

- class [asagi::Grid](#)

### Enumerations

- enum [asagi::Grid::Type](#) {  
[asagi::Grid::BYTE](#), [asagi::Grid::INT](#), [asagi::Grid::LONG](#), [asagi::Grid::FLOAT](#),  
[asagi::Grid::DOUBLE](#) }
- enum [asagi::Grid::Error](#) {  
[asagi::Grid::SUCCESS](#) = 0, [asagi::Grid::MPI\\_ERROR](#), [asagi::Grid::THREAD\\_ERROR](#), [asagi::Grid::NUMA\\_](#)←  
[\\_ERROR](#),  
[asagi::Grid::UNKNOWN\\_PARAM](#), [asagi::Grid::INVALID\\_VALUE](#), [asagi::Grid::NOT\\_INITIALIZED](#), [asagi::](#)←  
[Grid::ALREADY\\_INITIALIZED](#),  
[asagi::Grid::NOT\\_OPEN](#), [asagi::Grid::VAR\\_NOT\\_FOUND](#), [asagi::Grid::WRONG\\_SIZE](#), [asagi::Grid::UNS](#)←  
[UPPORTED\\_DIMENSIONS](#),  
[asagi::Grid::INVALID\\_VAR\\_SIZE](#) }

### Functions

- virtual [asagi::Grid::~~Grid](#) ()
- virtual Error [asagi::Grid::setComm](#) (MPI\_Comm comm=MPI\_COMM\_WORLD)=0
- virtual Error [asagi::Grid::setThreads](#) (unsigned int threads)=0
- virtual void [asagi::Grid::setParam](#) (const char \*name, const char \*value, unsigned int level=0)=0
- virtual Error [asagi::Grid::open](#) (const char \*filename, unsigned int level=0)=0
- virtual unsigned int [asagi::Grid::getDimensions](#) () const =0
- virtual double [asagi::Grid::getMin](#) (unsigned int n) const =0
- virtual double [asagi::Grid::getMax](#) (unsigned int n) const =0
- virtual double [asagi::Grid::getDelta](#) (unsigned int n, unsigned int level=0) const =0
- virtual unsigned int [asagi::Grid::getVarSize](#) () const =0
- virtual unsigned char [asagi::Grid::getBytes](#) (const double \*pos, unsigned int level=0)=0
- virtual int [asagi::Grid::getInt](#) (const double \*pos, unsigned int level=0)=0
- virtual long [asagi::Grid::getLong](#) (const double \*pos, unsigned int level=0)=0
- virtual float [asagi::Grid::getFloat](#) (const double \*pos, unsigned int level=0)=0
- virtual double [asagi::Grid::getDouble](#) (const double \*pos, unsigned int level=0)=0
- virtual void [asagi::Grid::getBuf](#) (void \*buf, const double \*pos, unsigned int level=0)=0
- virtual unsigned long [asagi::Grid::getCounter](#) (const char \*name, unsigned int level=0)=0
- static [asagi::Grid \\* asagi::Grid::create](#) (Type type=FLOAT)
- static [asagi::Grid \\* asagi::Grid::createArray](#) (Type type=FLOAT)
- static [asagi::Grid \\* asagi::Grid::createStruct](#) (unsigned int count, unsigned int blockLength[], unsigned long displacements[], Type types[])
- static void [asagi::Grid::close](#) ([asagi::Grid \\*grid](#))
- static Error [asagi::Grid::startCommThread](#) (int schedCPU=-1, MPI\_Comm comm=MPI\_COMM\_WORLD)
- static void [asagi::Grid::stopCommThread](#) ()
- static int [asagi::Grid::nodeLocalRank](#) (MPI\_Comm comm=MPI\_COMM\_WORLD)

#### 4.3.1 Detailed Description

#### 4.3.2 Class Documentation

##### 4.3.2.1 class [asagi::Grid](#)

C++ Interface for ASAGI grids.

## Public Types

- enum `Type` {  
    `BYTE`, `INT`, `LONG`, `FLOAT`,  
    `DOUBLE` }
- enum `Error` {  
    `SUCCESS` = 0, `MPI_ERROR`, `THREAD_ERROR`, `NUMA_ERROR`,  
    `UNKNOWN_PARAM`, `INVALID_VALUE`, `NOT_INITIALIZED`, `ALREADY_INITIALIZED`,  
    `NOT_OPEN`, `VAR_NOT_FOUND`, `WRONG_SIZE`, `UNSUPPORTED_DIMENSIONS`,  
    `INVALID_VAR_SIZE` }

## Public Member Functions

- virtual `~Grid` ()
- virtual `Error setComm` (MPI\_Comm comm=MPI\_COMM\_WORLD)=0
- virtual `Error setThreads` (unsigned int threads)=0
- virtual void `setParam` (const char \*name, const char \*value, unsigned int level=0)=0
- virtual `Error open` (const char \*filename, unsigned int level=0)=0
- virtual unsigned int `getDimensions` () const =0
- virtual double `getMin` (unsigned int n) const =0
- virtual double `getMax` (unsigned int n) const =0
- virtual double `getDelta` (unsigned int n, unsigned int level=0) const =0
- virtual unsigned int `getVarSize` () const =0
- virtual unsigned char `getByte` (const double \*pos, unsigned int level=0)=0
- virtual int `getInt` (const double \*pos, unsigned int level=0)=0
- virtual long `getLong` (const double \*pos, unsigned int level=0)=0
- virtual float `getFloat` (const double \*pos, unsigned int level=0)=0
- virtual double `getDouble` (const double \*pos, unsigned int level=0)=0
- virtual void `getBuf` (void \*buf, const double \*pos, unsigned int level=0)=0
- virtual unsigned long `getCounter` (const char \*name, unsigned int level=0)=0

## Static Public Member Functions

- static `asagi::Grid * create` (Type type=FLOAT)
- static `asagi::Grid * createArray` (Type type=FLOAT)
- static `asagi::Grid * createStruct` (unsigned int count, unsigned int blockLength[], unsigned long displacements[], Type types[])
- static void `close` (asagi::Grid \*grid)
- static `Error startCommThread` (int schedCPU=-1, MPI\_Comm comm=MPI\_COMM\_WORLD)
- static void `stopCommThread` ()
- static int `nodeLocalRank` (MPI\_Comm comm=MPI\_COMM\_WORLD)

## 4.3.3 Enumeration Type Documentation

## 4.3.3.1 enum asagi::Grid::Error

Possible errors that could occur

## Enumerator

- `SUCCESS`** No error
- `MPI_ERROR`** An MPI function failed
- `THREAD_ERROR`** A pthread function failed
- `NUMA_ERROR`** An error in the NUMA detection code
- `UNKNOWN_PARAM`** Unknown configuration parameter
- `INVALID_VALUE`** Invalid configuration value

**NOT\_INITIALIZED** Function is not yet initialized  
**ALREADY\_INITIALIZED** Function already initialized  
**NOT\_OPEN** Could not open input file  
**VAR\_NOT\_FOUND** netCDF variable not found  
**WRONG\_SIZE** Wrong variable size in the file  
**UNSUPPORTED\_DIMENSIONS** Unsupported number of dimensions input file  
**INVALID\_VAR\_SIZE** Variable size in the input file does not match the type

#### 4.3.3.2 enum asagi::Grid::Type

The primitive data types supported by ASAGI

Enumerator

**BYTE** signed byte  
**INT** signed 4-byte integer  
**LONG** signed 8-byte integer  
**FLOAT** 4-byte floating point value  
**DOUBLE** 8-byte floating point value

#### 4.3.4 Function Documentation

##### 4.3.4.1 static void asagi::Grid::close ( asagi::Grid \* *grid* ) [inline],[static]

Frees all memory resources associated with *grid*. After a grid is closed you cannot access any values and you can not reopen another NetCDF file.

This function does the same as calling `delete grid`; and it is the C++ equivalent to [asagi\\_grid\\_close\(asagi\\_grid\\*\)](#) and [asagi::asagi\\_grid\\_close](#)

Parameters

<i>grid</i>	The grid that should be closed.
-------------	---------------------------------

##### 4.3.4.2 static asagi::Grid\* asagi::Grid::create ( Type *type* = FLOAT ) [static]

Creates a new grid containing values with a primitive data type

Parameters

<i>type</i>	The type of the values in the grid
-------------	------------------------------------

##### 4.3.4.3 static asagi::Grid\* asagi::Grid::createArray ( Type *type* = FLOAT ) [static]

Creates a new grid containing arrays

The length of the arrays is determined by the input file

Parameters

<i>type</i>	The type of the values in the arrays
-------------	--------------------------------------

##### 4.3.4.4 static asagi::Grid\* asagi::Grid::createStruct ( unsigned int *count*, unsigned int *blockLength*[], unsigned long *displacements*[], Type *types*[] ) [static]

Creates a new grid containing structured values

## Parameters

<i>count</i>	Number of blocks in the structure
<i>blockLength</i>	Number of elements in each block
<i>displacements</i>	Displacement of each block
<i>types</i>	Primitive types of the blocks

4.3.4.5 `virtual void asagi::Grid::getBuf ( void * buf, const double * pos, unsigned int level = 0 )` [pure virtual]

Copys the element at `pos` into `buf`. The buffer size has to be (at least) `getVarSize()` bytes.

## Parameters

<i>buf</i>	Pointer to the buffer where the data should be written
<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

4.3.4.6 `virtual unsigned char asagi::Grid::getBytes ( const double * pos, unsigned int level = 0 )` [pure virtual]

If the grid contains array values, only the first element of the array is returned

## Parameters

<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

## Returns

The element at `pos` as a char

4.3.4.7 `virtual unsigned long asagi::Grid::getCounter ( const char * name, unsigned int level = 0 )` [pure virtual]

Gets the current value of a counter for a grid level.

See [Access counters](#) for a list of all counters.

## Returns

The current counter value or 0 if the name is not defined

## Warning

The performance counters are by default not thread-safe for performance reason. You may get wrong result when using more than one thread.

4.3.4.8 `virtual double asagi::Grid::getDelta ( unsigned int n, unsigned int level = 0 ) const` [pure virtual]

## Parameters

<i>n</i>	The dimension
<i>level</i>	The level for which the difference is requested

## Returns

The difference of two coordinates in dimension `n`

#### 4.3.4.9 virtual unsigned int asagi::Grid::getDimensions ( ) const [pure virtual]

Returns the number of dimensions loaded from the file.

##### Returns

The number of dimensions of the grid

#### 4.3.4.10 virtual double asagi::Grid::getDouble ( const double \* *pos*, unsigned int *level* = 0 ) [pure virtual]

##### Parameters

<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

##### Returns

The element at `pos` as a double

##### See also

[getBytes](#)

#### 4.3.4.11 virtual float asagi::Grid::getFloat ( const double \* *pos*, unsigned int *level* = 0 ) [pure virtual]

##### Parameters

<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

##### Returns

The element at `pos` as a float

##### See also

[getBytes](#)

#### 4.3.4.12 virtual int asagi::Grid::getInt ( const double \* *pos*, unsigned int *level* = 0 ) [pure virtual]

##### Parameters

<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

##### Returns

The element at `pos` as an integer

##### See also

[getBytes](#)

#### 4.3.4.13 virtual long asagi::Grid::getLong ( const double \* *pos*, unsigned int *level* = 0 ) [pure virtual]



## Parameters

<i>pos</i>	The coordinates of the value, the array must have at least the size of the dimension of the grid
<i>level</i>	The level from which the data should be fetched

## Returns

The element at `pos` as a long

## See also

[getBytes](#)

4.3.4.14 `virtual double asagi::Grid::getMax ( unsigned int n ) const` `[pure virtual]`

## Parameters

<i>n</i>	The dimension
----------	---------------

## Returns

The maximum allowed coordinate in dimension `n`

4.3.4.15 `virtual double asagi::Grid::getMin ( unsigned int n ) const` `[pure virtual]`

## Parameters

<i>n</i>	The dimension
----------	---------------

## Returns

The minimum allowed coordinate in dimension `n`

4.3.4.16 `virtual unsigned int asagi::Grid::getVarSize ( ) const` `[pure virtual]`

## Returns

The number of bytes that are stored in each grid cell

4.3.4.17 `static int asagi::Grid::nodeLocalRank ( MPI_Comm comm = MPI_COMM_WORLD )` `[static]`

Computes the rank of the process on the node. This function can be used to determine the core, to which the communication threads should be pinned in [startCommThread](#).

## Parameters

<i>comm</i>	The communicator that should be used
-------------	--------------------------------------

## Returns

The node local rank

4.3.4.18 `virtual Error asagi::Grid::open ( const char * filename, unsigned int level = 0 )` `[pure virtual]`

Loads values from a NetCDF file.

This function must be called for each level of detail. If more than one thread is used, this is a collective function for all threads.

4.3.4.19 `virtual Error asagi::Grid::setComm ( MPI_Comm comm = MPI_COMM_WORLD ) [pure virtual]`

Call this function before [open\(\)](#) if the grids should exchange chunks via MPI.

4.3.4.20 `virtual void asagi::Grid::setParam ( const char * name, const char * value, unsigned int level = 0 ) [pure virtual]`

Changes a grid parameter.

This function allows you to change ASAGI's configuration. It must be called before calling [open\(const char\\*, unsigned int\)](#).

See [Parameters](#) for a list of supported parameters.

#### Parameters

<i>name</i>	The name of the parameter
<i>value</i>	The new value for the parameter
<i>level</i>	Change the parameter for the specified level of detail. Should be 0 when setting <b>value-position</b>

4.3.4.21 `virtual Error asagi::Grid::setThreads ( unsigned int threads ) [pure virtual]`

Sets the number of threads in the application.

This function must be called before [open\(\)](#). If it is not called, one thread is assumed.

4.3.4.22 `static Error asagi::Grid::startCommThread ( int schedCPU = -1, MPI_Comm comm = MPI_COMM_WORLD ) [static]`

Starts the communication thread. This must be done before a grid with the option `MPI_COMMUNICATION = THREAD` is opened.

This is a collective operation within `comm`.

#### Parameters

<i>schedCPU</i>	The id of the CPU on which the communication thread should run. Use negative values to select the last, second last, ... CPU. If the id is invalid, the thread will not be pinned to a CPU.
<i>comm</i>	The communicator specifying which processes will be involved in any communication

#### Returns

SUCCESS or an error

4.3.4.23 `static void asagi::Grid::stopCommThread ( ) [static]`

Stops the communication thread

4.3.4.24 `virtual asagi::Grid::~~Grid ( ) [inline], [virtual]`

See also

[close\(asagi::Grid\\*\)](#)

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