

A simple OASIS interface
for CESM
E. Maisonnave
TR/CMGC/11/63

Index

Strategy.....	4
Implementation.....	6
Advantages.....	6
Current limitations.....	7
Annex 1: OASIS3 interface implementation on CESM.....	9
Annex 2: CESM/COSMO coupling fields	12

The Community Earth System¹ (version CESM1.0) NCAR Model embeds its own coupling system (CPL7). The component models, chosen during the compiling phase, are implemented on a single executable. Theoretically, this should complicate the work of any scientist curious to use separately one of the CESM component in another coupling system.

The Land-Climate Interactions² team from the Swiss Federal Institute of Technology (ETH Zurich) has been using for several years a mixed configuration made of the COSMO regional atmosphere model³ and the CCSM land model component (CLM). Traditionally, the CLM module was called as a subroutine within the COSMO code. This method implied several hard coded modifications on both COSMO and CLM FORTRAN sources.

Taking advantage of the IS-ENES OASIS Dedicated User Support program, a COSMO/CLM coupling framework has been implemented, first with OASIS4 using CLM3.5 version (December 2010), then with OASIS3 using CLM4 (part of CESM1.0 coupled system).

A few days were necessary to setup quickly a particularly non intrusive OASIS interface on the CESM1.0 code and plug in the previously OASIS interfaced COSMO model.

Based on a simple modification of the atmosphere data model (DATM), this coupling inherits its parallelization from the CESM architecture.

It also enables the use of several other CESM components (ocean, sea-ice and/or land-ice) by a simple change of CESM case configuration.

Strategy

Popularity of the OASIS framework mostly relies on its capacity to make the use of an external model as simple as the reading of a forcing dataset.

That is exactly the philosophy of this CLM-COSMO coupling.

Build from a CLM stand alone configuration case (I_TEST_2003), our CESM coupled model mainly consists on the driver, the prognostic land model and a “data models” (DATM for atmosphere). The main function of data models is to read forcing files. They are linked to the driver using the CPL7 internal coupler, which ensures remapping or interpolations, if necessary.

Modifications for OASIS coupling only consists in:

- defining DATM module grid on the original CLM grid, through a forcing file which holds variables not provided by COSMO atmosphere (aerosols)
- organizing OASIS exchanges through this DATM module

The CESM code coupled with OASIS still consists on its original components. Code modifications (communications with OASIS) mostly take place on DATM module. As

1 <http://www.cesm.ucar.edu>

2 <http://www.iac.ethz.ch/groups/seneviratne>

3 <http://www.clm-community.eu/>

shown on the following illustration, the red arrows, which represent the OASIS connections, only connect the atmosphere data model (DATM) rectangle.

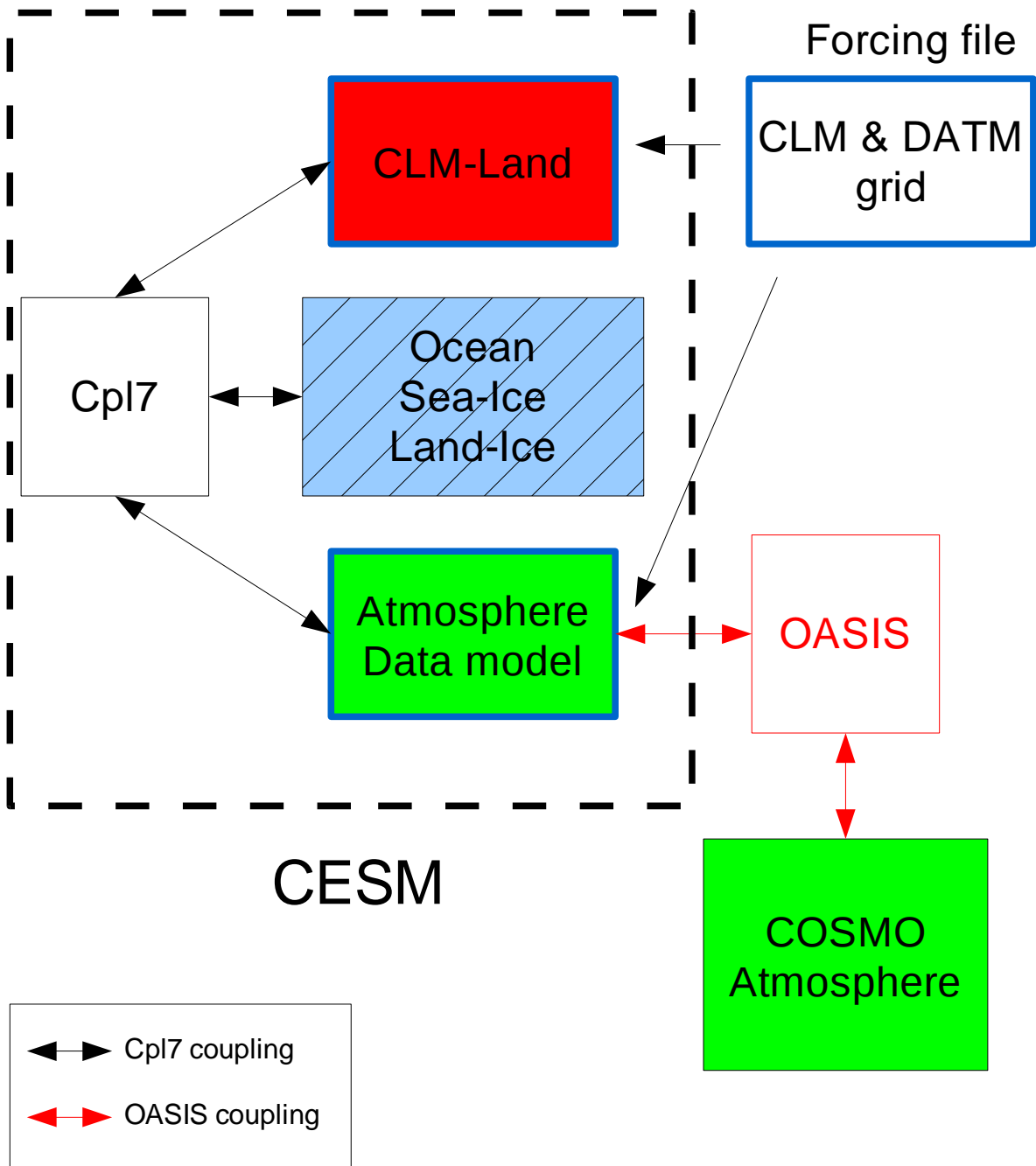


Illustration 1: Description of CLM (CESM) / COSMO coupling using OASIS

Implementation

An exhaustive description of our Fortran interface implementation and input files modification/addition is given in annex 1. This paragraph only summarizes the principle of the CESM modifications needed to build the OASIS interface.

We choose to start from a CLM stand alone CESM configuration (I_TEST_2003).As a first step of the OASIS interface implementation, we modify the file which contains the atmospheric forcing fields. We interpolate the input file variables, describing them on the CLM original grid. Aerosols (not given by COSMO) are the only variables actually used by the model: the other variables will be overwritten by the OASIS coupling fields.

In this way, the DATM module has now the same spatial discretization than the CLM land model (it defines its own grid according to the dimensions read on the forcing files). Then, the CPL7 functions will be limited to the remapping (no interpolation between land and data atmosphere models) and only if decompositions of both components (CLM and DATM) are different.

The OASIS interpolations (with atmospheric grid) are defined for the CLM discretization:

- On an initialization phase, mask and coordinates of this grid are communicated to OASIS, at the same time than the names of the exchanged coupling fields.
- On the main temporal loop, and at each time step, the OASIS “send” and “receive” primitives are called through the DATM module. To convey land model variables there, a driver modification is necessary (interpolation and remapping of those variables have to be done as if the prognostic atmosphere model was active).

Notice that the standard MPI management has to be slightly changed at initialization phase: CESM is not supposed to use the MPI_COMM_WORLD communicator, and its driver is forced to work with a local communicator (provided by OASIS). Consequently, a predefined OASIS routine is called by the CESM driver to let it switch off MPI.

Advantages

1. Simplicity: As previously said, rapidity and non-intrusiveness of implementation are a strength of OASIS. To call a set of the standard initialization, declaration, sending, catching and ending OASIS interface routines adapted to CESM, we only had to modify 2 driver subroutines (ccsm_driver.F90 and ccsm_comp_mod.F90) and 1 DATM file (datm_comp_mod.F90).
2. Modularity: No other modification is required on COSMO and OASIS code or on their input files (in use on the previously set up CLM3.5 / COSMO / OASIS coupled model).
3. Scalability: taking advantage of the internal DATM parallelization (which could be adjusted independently of the CLM one, just changing a namelist parameter), OASIS exchanges could be made on a variable number of PE. Illustration 2 shows that the OASIS exchanges cost remains constant with parallelization (but expected to grow significantly at higher resolution with decomposition of more than 100 sub domains). On the contrary, it appears much more efficient to parallelize the DATM module (less than 0.01s on 122 PE but 0.3s when DATM runs on only 1 PE). Slowing down (reducing parallelism) occurs on remapping between CLM and DATM through the driver (driver_l2c, driver_a2c, driver_c2l, driver_c2a) but, above all,

during DATM reading (“strdata_advance”) and scattering (“datm_scatter”).

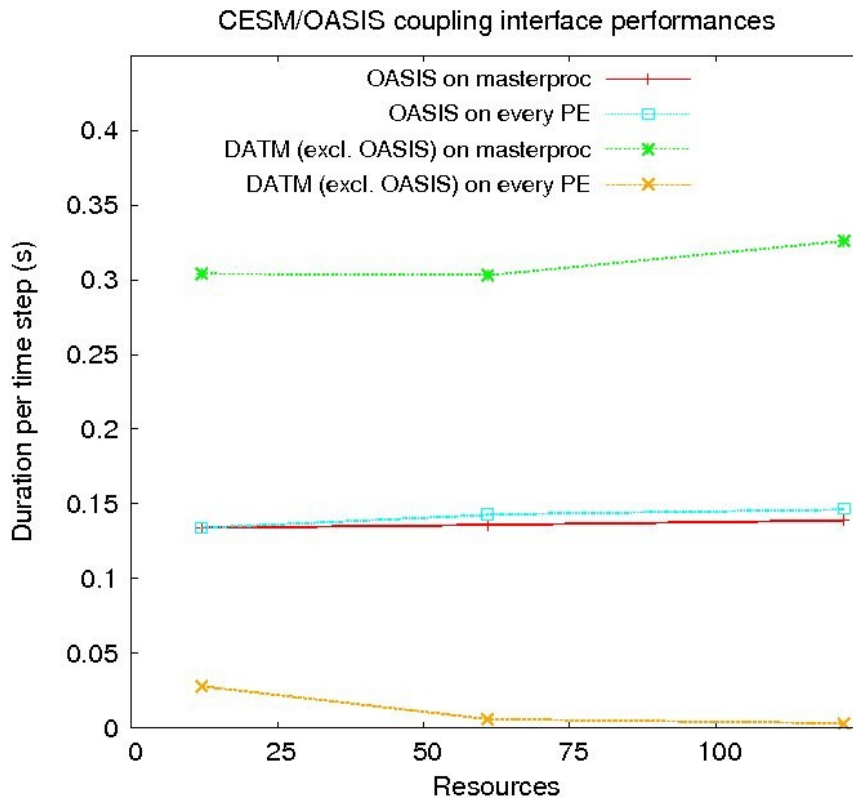


Illustration 2: Performances of OASIS exchanges (communications + interpolations, two ways) and of DATM routines (excluding OASIS send/receive calls)

4. Extensibility: on illustration 1, a blue box represents different CESM modules, disabled in the present configuration. Theoretically, the same OASIS coupling interface (on DATM module) should allow us to exchange, with COSMO, information coming from (and given to) ocean, sea-ice or land-ice modules. To go further, the same interface may be implemented on other data modules (like DOCN) to ensure the OASIS coupling of the only CESM module that could not be plugged in the present configuration: the CAM atmosphere model.

Current limitations

The present implementation only addresses problems of version update, allowing ETHZ to keep using their CLM model in an OASIS coupled system though the new CLM version cannot be used without the whole CESM framework.

Considering the low size of the targeted configuration, we prefer to focus on implementation facility rather than on performances, in order to facilitate management, by user, of next version updates.

Consequently, the system general design (presented in illustration 1) strongly suggests that an further increase of parallelism (with higher resolution model) would lead to a lack of

performances.

1. OASIS3 restricted parallelism (one OASIS process per coupling field) is not sufficient when problem size increases
2. CLM/DATM internal coupling, though efficient, increases the total time needed to exchange information between CLM and COSMO
3. As on any other OASIS coupling, MPI process (from the different executables) mapping on the reserved resources could significantly affect the performances, which makes mandatory a fine and, possibly, difficult tuning
4. In addition, OpenMP could not be used, at least without code and/or MPI launcher settings modification

It is obvious that extra developments are necessary to be able to increase resolution and parallelism of the system. Will they be sufficient ? This question is the concern of the larger debate of compared advantages of integrated/composite coupling.

Anyway, the OASIS capacity to make the *use* of an external model as simple as the reading of a forcing dataset should not hide that, once a technically validated configuration is available, a substantial work, including modifications of models parametrization, is then necessary to take into account the newly created coupled phenomena.

This work has been supported by the IS-ENES FP7 European project (OASIS Dedicated User Support) and ETHZ. The author is extremely grateful to Sonia Seneviradne and Edouard Davin for their financial support and their cordial help. The CESM project is supported by the National Science Foundation and the Office of Science (BER) of the U.S. Department of Energy.

Annex 1: OASIS3 interface implementation on CESM

Added routines

oas_clm_vardef.F90	CLM/OASIS interface global variable definition
oas_clm_init.F90	Let OASIS organize MPI initialization
oas_clm_define.F90	Communicate model information to OASIS at initial step
oas_clm_finalize.F90	Let OASIS organize MPI ending
send_fld_2cos.F90	Fill arrays with coupling fields and call oas_clm_snd for each coupling field sending
oas_clm_snd.F90	Send one coupling field to OASIS
receive_fld_2cos.F90	Call oas_clm_rcv for each coupling field catching and fill model arrays
oas_clm_rcv.F90	Receive one coupling field from OASIS

Modified routines

To find these modifications on the code, see CPP key "COUP_OAS "

<u>ccsm_driver.F90</u> - Let OASIS close MPI communications , calling oas_clm_finalize
<u>ccsm_comp_mod.F90</u> - Let OASIS define local MPI communicator (instead of MPI_COMM_WORLD) , calling oas_clm_init - Launch internal coupling routines to bring information to DATM module from other modules (force the prognostic atmosphere case) and particularly from land model to be able to use this information, sending it to OASIS
<u>datm_comp_mod.F90</u> - Communicate model characteristics (grid lat/lon and mask, subdomain distribution per process) to OASIS, calling oas_clm_define - Prepare coupling fields and send coupling field to OASIS (through send_fld_2cos routine) - Receive coupling fields from OASIS (through receive_fld_2cos routine) after reading complementary forcing fields (aerosols) and overwrite appropriate arrays with corresponding information

Compiling on CSCS system

Change CSCS batch_script (/project/s193/emaision/cesm1_0_3/scripts/batch_cscs.sh)

1. start from "I_TEST_2003" CLM configuration
2. indicate 2 new include directory and library (OASIS) to the CESM compile script:

```
export USER_FFLAGS="-DCOUP_OAS -I/users/emaision/oasis3/CRAYXT/build/lib/psmile.MPI1"
export USER_LDFLAGS="/users/emaision/oasis3/CRAYXT/lib/libpsmile.MPI1.a
/users/emaision/oasis3/CRAYXT/lib/libmpp_io.a"
```

3. copy OASIS interface fortran files (and CESM modified routines) into scratch compiling directory from /project/s193/emaision/CLM4/src/ directory to /scratch/rosa/emaision/testclm4/SourceMods/

Running on CSCS system

Launching directory: /users/emaision/COSMO4.8-CLM11-CLM3.5/run/clm4_EXP

Prepare new input files:

1. No need to change any oasis and cosmo parameter and input files (could be the same as CLM3.5 coupling)

2. Change some values within input_clm/lnd_in parameter file:

```
finidat = ' ' -> no restart
fatmgrid      = 'data/surfddata_0122x0276.nc' -> CLM uses Europe grid, modified to match COSMO
mask
fatmInldfrc   = 'data/surfddata_0122x0276.nc'
fsurdat       = 'data/surfddata_0122x0276.nc'
```

3. Change values of oatm_input/datm_atm_in parameter file:

```
dataMode      = 'CLMNCEP' -> same option than initial CESM config
domainFile    = 'data/surf_datm.nc' -> read DATM data (= OASIS coupling fields) on the same Europe grid
than CLM, modified to match COSMO
streams       = 'OASIS.stream.txt 1 1 1 ' -> take same forcing information at any time step from parameter
file OASIS.stream.txt
vectors       = 'null'
mapmask       = 'nomask'
tintalgo      = 'linear' -> those last 3 info for CLM/DATM interpolations (should not be used).
```

4. Build the "oatm_input/OASIS.stream.txt" fake parameter file:

This file allows to:

- read aerosols forcing file
- read other forcing variables. Those forcing values will be replaced by the coupling fields: they could be a simple copy of aerosols (or zero).
- define DATM model grid reading this file

The aerosol file defines the DATM grid. OASIS cpl fields are exchanged following this grid: That means that aerosol file defines the CLM grid (as seen by OASIS).

5. Build netcdf input files:

oatm_input/surf_datm.nc: this file holds lat/lon information for DATM grid. It could be built copying CLM variables from file:

/project/s193/emaision/preproc_CLM/surfddata_0122x0276.nc

Original variables	LONGXY	LATIXY	LANDMASK	AREA	LANDFRAC
Copy	XC	YC	MASK	AREA (converted to radian squared, x2.464E-08)	FRAC

oatm_input/aero_dummy.nc: with correct aerosols data on CLM grid. WARNING: for the moment, aerosols values are not correct. Build them with NCAR tools.

6. Change some values on original drv_in parameter file:

- the start date start_ynd (WARNING: COSMO/CLM calendars could be inconsistent)
- the total duration (in time step and not in days)
- the total task for both CLM and DATM modules. DATM task number could be equal to CLM total tasks (every PE are involved in the OASIS coupling), or equal to 1 (only master PE exchanges information through OASIS). WARNING: the number of PE involved in the coupling must be changed consistently on namcouple parameter files.

Annex 2: CESM/COSMO coupling fields

Coupling field	OASIS naming rule (CESM interface)	Sent by
surface temperature	CLMTEMPE	COSMO
surface winds	CLMUWIND, CLMVWIND	COSMO
specific water vapor content	CLMSPWAT	COSMO
thickness of lowest level	CLMTHICK	COSMO
surface pressure	CLMPRESS	COSMO
direct shortwave downward radiation	CLMDIRSW	COSMO
diffuse shortwave downward radiation	CLMDIFSW	COSMO
longwave downward radiation	CLMLONGW	COSMO
total convective precipitations	CLMCPRE	COSMO
total gridscale precipitations	CLMGSPRE	COSMO
wind stresses	CLM_TAUX, CLM_TAUY	CESM
total latent heat flux	CLMLATEN	CESM
total sensible heat flux	CLMSENSI	CESM
emitted infrared (longwave) radiation	CLMINFRA	CESM
albedo	CLMALBED	CESM