# Coupling an icosahedral model with OASIS

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*Abstract*

*An icosahedral grid atmosphere (NICAM) was coupled to NEMO ocean using OASIS3-MCT. The implemented interface was validated by a successful one month long simulation. Total cost of NICAM-NEMO exchanges (excluding initialisation) was evaluated at high horizontal resolution (12Km) to 2 to 3 order of magnitude faster than model time step duration.*

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## Models

Technically speaking, novelty of the presented configuration lies in atmosphere model horizontal discretisation: NICAM[1] v-2013.08.13 calculations are performed on an icosahedral grid. As far as we know, this is the first attempt to interpolate and exchange coupling fields with OASIS3-MCT from/to this kind of grid.

NEMO v-3.4 ocean model (with climatological ice) currently in use on CURIE supercomputer[2] has been configured to exchange a simplified (no ice related fields) set of coupling fields with NICAM. As already mentioned[3], the comprehensive NEMO-OASIS interface allows quick and safe plug of any kind of atmosphere model. Once again, no modification were necessary on NEMO to exchange coupling information with a new atmosphere model (coupling fields number/characteristics are simply parametrizable via FORTRAN namelist) which confirms the interface implementation robustness.

## Configuration

During implementation step, code modifications must be quickly tested, which limits atmosphere and ocean grid size. On CURIE supercomputer, the existing NEMO ORCA025 configuration (30Km) has been re-used on 64 cores, together with NICAM gl05-rl01 (225Km) configuration on 8 cores. A gl09 (14Km) would satisfy resolution balance requirements, but heavy input files were impossible to transfer to this machine[4]. This configuration has been launched for tests more than 50 times with instantaneous results.

## OASIS auxiliary files

Latitude, longitude and land sea mask of both ocean an atmosphere grid points have to be described in NETCDF file, on the global grid and excluding halos. It was necessary to develop conversion programs to transfer information from NICAM input files (grid.rgn* and landmask.rgn*) to masks.nc and grids.nc OASIS auxiliary files.
NICAM grid point shape could be hexa- or pentagon. At this stage, corners coordinates are not provided (as long as conservative interpolation is not required).

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1 Satoh, M., T. Matsuno,T., H. Tomita, H. Miura, T. Nasuno, S. Iga, (2007) Nonhydrostatic Icosahedral Atmospheric Model (NICAM) for global cloud resolving simulations. Journal of Computational Physics, doi:10.1016/j.jcp.2007.02.006

2 Maisonnave, E., Cassou, C., Coquart, L., Déqué, M., Ferry, N., Guérémy, J.-F., Piédelièvre, J.-P., Terray, L. and Valcke, S., 2012: PRACE Project Access for Seasonal Prediction with a high ResolUtion Climate modEl (SPRUCE) ,Working Note, **WN/CMGC/12/29**, SUC au CERFACS, URA CERFACS/CNRS No1875, France

3 Maisonnave, E., Valcke, S. and Foujols, M.-A., 2013: OASIS Dedicated User Support 2009-2012, Synthesis ,Technical Report, **TR/CMGC/13/19**, SUC au CERFACS, URA CERFACS/CNRS No1875, France

4 A 100KB/s transfer rate between France and Japan prevents GB file movement, as it is necessary with gl09 input files

NICAM interface

An OASIS interface was coded into atmosphere model to allow coupling quantities exchange at ocean surface.

Standard procedure was applied as follow:

1- *MPI communicator*

To switch from stand alone mode to coupled mode, disabling of MPI_COMM_WORLD communicator for internal parallelisation purpose and its replacement by local OASIS-provided communicator (mod_adm.f90, ADM_proc_init subroutine) were necessary. Call to OASIS_init subroutine was done at the same place.

2- *Partition/coupling fields definition*

As for any other model, NICAM grid points are split into as many partitions as MPI processes. Developer's work consists in linking, per MPI process (locally), all grid point in the same order as they appear in local arrays with their corresponding latitude, longitude and land-sea mask, as they appear in OASIS auxiliary files. A future work that would simplify this definition would consist in writing OASIS auxiliary files on the fly, using grid data file routines (see Chapter 2.3 of OASIS user guide[5]).

Partition definition (oasis_def_partition subroutine) is done immediately after local array dimension calculation (mod_adm.f90, ADM_setup subroutine). OASIS exchange arrays exclude halos. These 1D arrays are dimensioned as :

**ADM_lall * nmax²**

i.e. inner size of local array excluding halo (**nmax²)** times number of local regions (**ADM_lall**).

A standard set of coupling fields (assuming no sea-ice model) are defined at the same place:

– received by NICAM: SST, (climatological) ice cover
– sent by NICAM: Evaporation minus precipitations, Solar and non-solar flux, wind stresses. Be careful that 3 wind stress components are given on Cartesian grid (x,y,z), interpolated by OASIS on NEMO T-grid and automatically projected by NEMO onto its local U,V grids.

3- *Boundary conditions reception*

Following the standard strategy, routines involved in surface boundary condition reading are identified on NICAM code. Basically, two kinds of routine can be activated :

– or _sst routines to force surface temperature read on files,
– or _mixedlayer routines to simulate SST calculation with a simplified ocean.

We decided to preferentially modify “reading SST on file” subroutines and substitute oasis_get subroutine to file reading (mod_oceanvar_sst.f90, subroutines oceanvar_sst_setup and oceanvar_sst_update). SST reading has to be selected on

5 Sophie Valcke, Tony Craig, Laure Coquart, 2013: OASIS3-MCT User Guide, OASIS3-MCT 2.0, Technical Report, TR/CMGC/13/17, CERFACS/CNRS SUC URA No 1875, Toulouse, France

NICAM namelist (nhm_driver.cnf file, OCEAN_TYPE = 'SST'). For an future inclusion of sea-ice in the coupled system, mixed layer subroutines functioning will have to be investigated to calculate appropriate sea-ice fluxes, as it is done in this case.

4- *Fluxes export*

Even though fluxes are probably calculated sooner in temporal loop, we preferred to wait the end of the loop, at diagnostic stage, to send fluxes information to OASIS (oasis_put subroutine): at this stage, all information needed is available at the same place and can be easily detected (clear comments, arrays content visualizable on diagnostics files).

<u>Interpolation</u>

As a first guess, a N nearest-neighbour interpolation weighted by their distance and a gaussian function is chosen in both direction (NICAM to NEMO: 4 neighbours, NEMO to NICAM: 25 neighbours). Due to large ratio between grid resolutions and N nearest-neighbour interpolation rusticity, poor quality results are transmitted to both models. As shown on Fig 1, icosahedral shape is visible on ORCA grid. Nevertheless, interpolations do not provide out of range values and simulation can be performed normally.

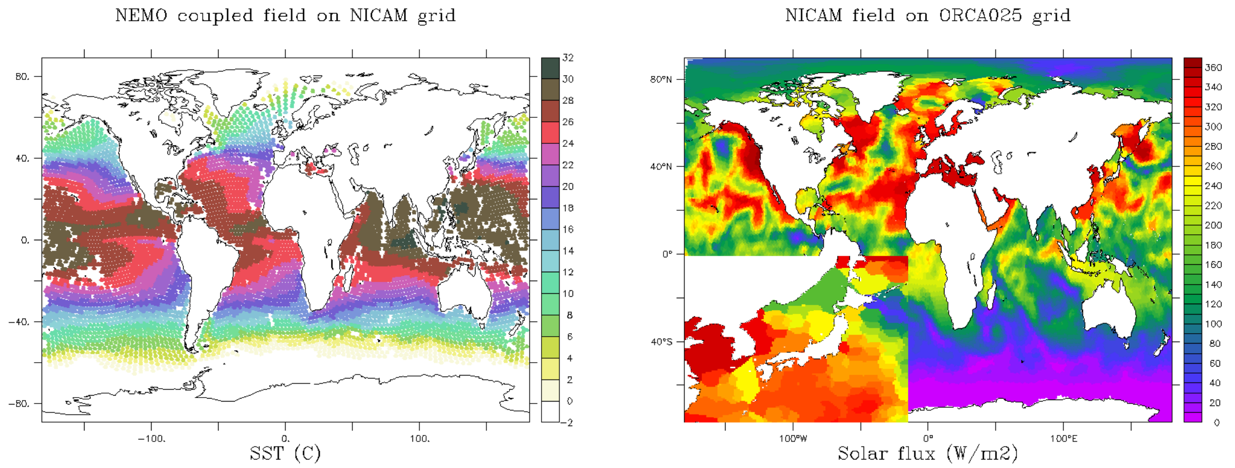


Fig 1: Interpolated fields (with zoom over Japan for solar flux)

For internal purpose (NICAM/COCO coupling), Tokyo University team already develops smarter (conservative ?) interpolations to link icosahedral and lat-lon tri-polar grids. A simple format conversion of weight files to OASIS format should allow to re-use these better quality interpolations with our coupler.

<u>Important remark</u>: land-sea mask as provided through NICAM landmask.rgn* input files includes too many land points (visible in Pacific ocean on Fig 1, left). One diagnostic could be that a NICAM grid point is considered here as a land point if a non zero portion of the total grid area is covered by land. But it seems that some of those NICAM abnormal land points are supposed to receive SST information. For that reason, missing values are temporarily provided at SST receiving stage in NICAM. Obviously, this issue has to be solved finding the right NICAM land-sea mask values and correcting them on OASIS

masks.nc auxiliary file.

OASIS performances

How OASIS could efficiently remap information from/to icosahedral grid is an important question that this work allows to investigate.

To efficiently estimate OASIS performances, a higher NICAM resolution is required (gl09, 14Km). Such resolution is difficult to handle and too expensive with a full model. Toys models which mimic grid and MPI partitioning are developed to simplify the tests. As expected, interpolation weight calculations (sequential) last 2.5 and 6 hours from/to gl09 and orca05 grids. Hopefully, this operation only need to be performed once for a given geometry.

Fig 2 (left) shows total time needed to perform 6 NICAM/NEMO and 2 NEMO/NICAM OASIS interpolations (during simulation, at each 3 hours coupling step). This total is always lower than 50 ms, which is 2 to 3 order of magnitude less than model time step durations. More than 10,000 cores has been used without any evidence of non scalability, even with largest grid point number (gl09 NICAM, orca05 NEMO resolutions). Other coupler operations (averages, communications) appeared less expensive than interpolation cost. This result has to be mitigated regarding initialisation time: on Fig 2 (right), cost of communication pattern definition, performed only once at initialisation step, seems to increase linearly with core number (but this scalability issue has already been reported and is independent of icosahedral grid or partitioning characteristics).

Consequently, our preliminary conclusion is that OASIS is able to perform interpolations and remapping operations from/to icosahedral grid, without any over-cost compared to standard spatial discretisation ones.

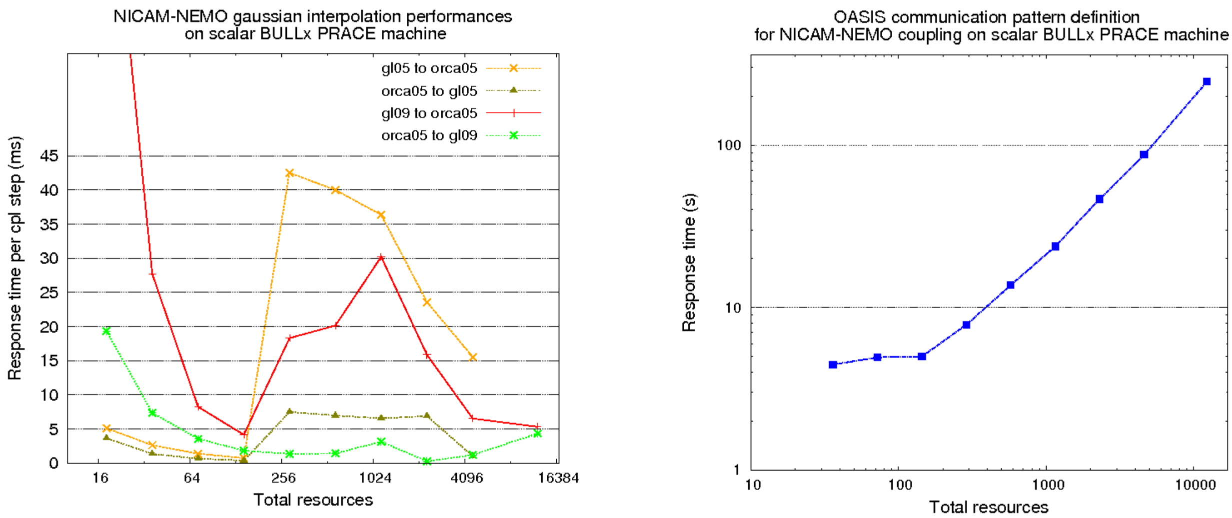


Fig 2: OASIS scalability for interpolations and communication pattern definition

Validation

As any other OASIS based coupled model, MPI MPMD mode is required to launch NICAM and NEMO executables at the same time.

A one month long simulation was performed and successfully achieved on CURIE supercomputer. Fig 3 shows reasonable SST and SSS anomalies (compared to GLORYS[6] climatology), that roughly validates the OASIS interface implementation.

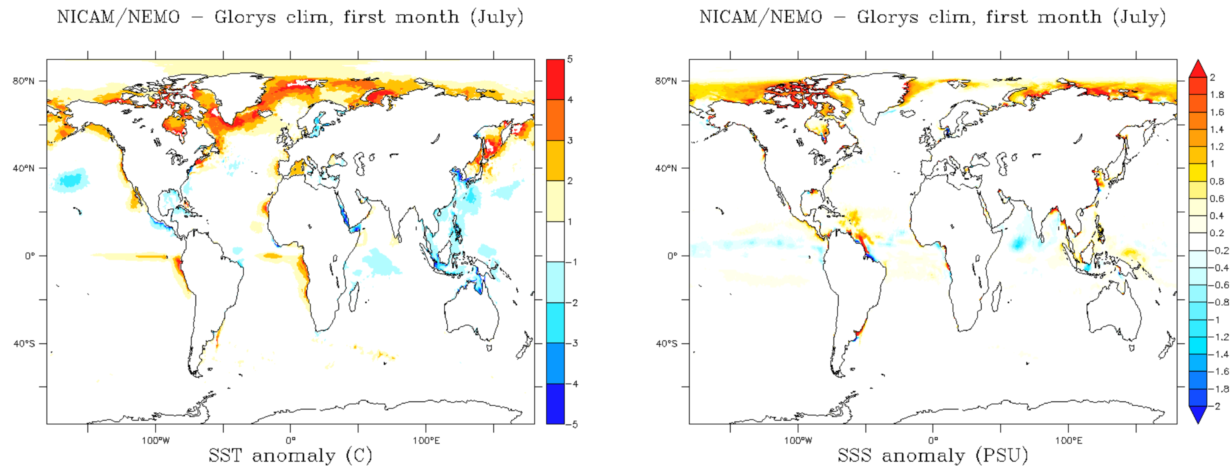


Fig 3: SST and SSS anomalies of a one month long simulation

6 Ferry, N., Parent, L., Garric, G., Bricaud, C., Testut, C.-E., Le Galloudec, O., Lellouche, J.-M., Drévillon, M., Greiner, E., Barnier, B., Molines, J.-M., Jourdain, N. C., Guinehut, S., Cabanes, C., Zawadzki, L., 2012: GLORYS2V1 global ocean reanalysis of the altimetric era (1992-2009) at meso scale. Mercator Quarterly Newsletter 44, January 2012, 29-39. available at http://www.mercator-ocean.fr/eng/actualites-agenda/newsletter.