IS-ENES model interface updates for compliance with new OASIS coupler

E. Maisonnave, L. Coquart, U. Fladrich,
P.-G. Fogli, R. Hill, Ø. Seland, A. Voldoire

TR/CMGC/16/29506

Table of Contents

Laboratories using highly scalable models such as high resolution CGCM and participating to the IS-ENES2 WP9 had to face an important change at project start. Used as a standard by most of the European laboratories involved in CMIP5 [1], the coupling software OASIS evolved to provide a satisfactory scalability on top end supercomputers (i.e. PRACE). Originally driven by a separate executable (OASIS3), the coupling operations are now achieved by a coupling library (OASIS3-MCT) that proved its efficiency on more than O(10,000) computing cores. Some performance comparisons of the two coupling techniques have been already published [2].

This document focuses on the upgrade impact on three models participating to the multi-model multi-member activities described in IS-ENES2 WP9: the Met Office Global Coupled model [3], EC-Earth and CNRM-CM. The initial interfaces (model code routines where are located the calls to the OASIS API) needed to be adapted to the new coupling routines. Groups took this opportunity to rethink or extend their coupling strategy: grid to grid interpolations were changed, more model component added to the coupled system (ESM).

Towards CMIP6, and particularly HiResMIP experiments, these WP9 participants made the choice of OASIS3-MCT. Others (CMCC, Met.no) decided to switch to (or keep) the NCAR CPL7 coupler, adapting to their needs the CESM infrastructure.

Description of interface updates

Switch from OASIS3 to OASIS3-MCT

An important care to the OASIS API backward compatibility was taken during OASIS3-MCT developments. Logically, a few amount of modifications on model code were necessary to simply switch from OASIS3 to OASIS3-MCT in the existing coupled systems. Let's mention (i) the declaration of a single FORTRAN module to be able to use the OASIS API, instead of dedicated modules to each coupling step (initialisation, declaration, exchange and ending) and (ii) the renaming of OASIS parameter variables accessed in the code (optional).

Such compatibility promoted a quick switch between the two coupling techniques. Consequently, the transitory phase was shortened: only Met Office still feels necessary to offer OASIS3 and OASIS3-MCT coupling choice to their users. EC-Earth consortium, Météo-France (ARPEGE) and IPSL (NEMO) rapidly removed OASIS3 calls from their newly released interfaces (ARPEGE6, NEMO3.6_stable).

Due to the high scalability of OASIS3-MCT, the master-process-only coupling capability becomes obsolete. It was withdrawn from the Met Office interface components. At the opposite, a new functionality (2nd order conservative remapping) was adopted by this laboratory. The coupling interface was modified to provide coupling field gradients explicitly.

More flexibility in coupling field choice also lead to interface adaptation. NEMO and ARPEGE interface rewriting anticipates all possible coupling fields that could be provided to or received from other models. Choice is done through model namelist, that must fit to the OASIS parameter file (namcouple). Met Office preferred a slightly different option, making some local changes to OASIS3-MCT code, e.g. to ensure a non-zero return code from OASIS_ABORT (MPI_ABORT) and to ignore the check for redundant fields. The parameter file contains all potential coupling fields, and components are able to switch each field on/off reading an "additional instrumentation" included in this parameter file. The EC-Earth model has implemented a new coupling interface for its atmospheric component, IFS, which is build on top of OASIS3-MCT.

No other OASIS code modification were reported by WP9 OASIS users.

New OASIS3-MCT interpolations

As previously said, the 2nd order conservative interpolation was elected by Met Office, and components interface modified accordingly. Unfortunately, providing coupling field gradient (on an MPI parallel grid) is not always straightforward in any component. The IFS and ARPEGE gaussian grid strongly complicates an easy implementation in EC-Earth and CNRM-CM coupled systems. The distance weighted nearest-neighbour (DISTWGT) and gaussian weighted nearest-neighbour (GAUSWGT) rescue interpolations are not fully satisfactory in case of varying resolution ratio between source and target grids. It is the case for coupled system which includes the NEMO global grids (ORCA). The 1st order conservative interpolation also shows limitations in case of mismatches between coast line represented in source and target grid. In this case, the best solution considered by Météo-France is a redefinition of ARPEGE model land-sea mask to fit NEMO one. This solution implies strong choices that could not satisfy all coupled system users.

Models	Interpolation choice
CNRM-CM	1st order conservative
EC-EARTH	SCRIP/GAUSWGT (other options under investigation)
Met Office GC	2nd order conservative

Table 1: Interpolation of main flux coupled fields for three WP9 models

New improvements in coupling interface

The increasing complexity of geophysical models can also be observed on coupling interfaces. A link between increasing complexity and coupler upgrade cannot be clearly established. However, the OASIS fully parallel coupling library performances probably stimulates the new developments in OASIS coupling that can be seen in the presented interfaces.

It is now obvious that the number of exchanged coupling fields is no more an issue for our developers. For example, at Météo-France, water flux coupling is decomposed in 7 separate coupling fields, i.e. evaporation, rain, snow, runoff on ocean, runoff on lakes (spread over open oceans), calving from Antarctic (spread over Southern Ocean) and calving from Greenland. For the same reasons, the TRIP river routing and SURFEX land models are coupled in the 2 directions. At Met Office, even 3D coupling is possible between atmosphere and chemistry transport.

The existing interface is the same for different configurations of the coupled system. At Météo-France, the regional coupled model (ALADIN-Climat) uses the same interface than the original global configuration. In this same laboratory, it is possible to enable internal components (like atmosphere chemistry) and increase the number of exchanged coupling fields with ocean components; these was made possible by a complete transfer of the ARPEGE interface, from atmosphere to land surface (SURFEX) part of the code.

Inexpensive coupling exchanges also favour coupling between different grids included in a single model. For example, the NEMO interface was modified at IPSL to allow coupling between ocean and atmosphere zooms [4]. At the same time, a possibility of partial coupling was implemented: only a portion of the global domain receives boundary conditions from a coupled component, the rest is filled with fixed boundary conditions read in file (forced mode). This last improvement replaces the former OASIS3 FILLING functionality not offered anymore by OASIS3-MCT.

We also clearly observe an increase in coupled system components coupled via OASIS. This coupling mode can be preferred to an internal by-subroutine coupling, even if components share the same grid. Table 2 below summarizes the new component already added to some ESM configurations and possible OASIS coupling in a near future.

Models	Initial	Additional	Possible
CNRM-CM	ARPEGE-SURFEX (atmosphere-land) NEMO-GELATO (ocean) TRIP (river routing)	Wave Watch (waves)	LIM, GELATO (sea ice)
EC-EARTH	IFS (atmosphere) NEMO-LIM (ocean-sea ice) Runoff-mapper	TM5 (atm chemistry), LPJ-GUESS (vegetation)	Ice-sheet model
Met Office GC	GA-JULES (atmosphere-land)	UKCA (atm chemistry)	Land ice

	NEMO-CICE (ocean-sea ice)		

Table 2: OASIS coupled components (former, present and possible) for three WP9 ESM

The Met Office atmosphere chemistry is used at lower resolution than the atmosphere it is linked with, which requires fast interpolations and exchanges. In CNRM-CM, the WW wave model shares the same grid than the corresponding SURFEX land model, but coupling is ensured by OASIS, for modularity reasons.

Finally, let's mention the possibility to couple via OASIS a component that was formerly a subroutine. This is the case between NEMO and its surface interface, including sea ice models [5].

CPL7 interfaces

The coupled systems of two WP9 participants (Met.no and CMCC) are not based on OASIS but CPL7 [6], a coupler that controls the execution of the NCAR CESM model and the data flow between its constituents. In both cases, the CESM original ocean components (POP) is disabled and replaced by another ocean model, but without modifying the CESM driver structure. At CMCC, the NEMO ocean model component replaces the original POP component, and CPL7 is ensuring coupling with the newly added model [7]. Like others groups [8], Met.no originally tried another solution, using OASIS to replace the ocean component of the CESM coupled system (by NCC-MICOM). Build with OASIS4, this technical solution did not survive to the coupler withdrawal and Met.no went back to CPL7.

The comparison of CMCC coupling interface implementation, via CPL7, with OASIS based interfaces gives interesting comparison about modularity, intrusiveness and efficiency of both coupler. Since the CESM CICE model is used in place of the LIM original NEMO component, the ocean/sea ice model splitting leads to, like in [5], an increase of coupling fields number. To keep NEMO calculation on the original ORCA grid implies the use of CPL7 interpolation functions.

Towards CMIP6 (HiResMIP)

Towards CMIP6, and particularly HiResMIP experiments, three WP9 participants (EC-Earth, Met Office and Météo-France) made the choice of OASIS3-MCT. Others (CMCC, Met.no) decided to switch to (or keep) the NCAR CPL7 coupler, adapting the CESM infrastructure to their needs. The OASIS interface update did not lead to any particular issue, excepting the interpolation choice, made difficult by the withdrawal of automatic gradient calculation for the bicubic interpolation. WP9 groups took benefit of the interface update to enhance its possibility (more components, flexible coupling field choice, etc). The newly developed interfaces are designed for highly parallel models such as WP9 HR ESMs. Deliverable 9.2, "HR ESM performance resulting from OASIS updates" will summarize the impact of such choice on the model performances.

Glossary

API: Application Programming Interface
CESM: Community Earth System Model
CMCC: Centro Euro-Mediterraneo sui Cambiamenti Climatici
CMIP: Coupled Model Inter-comparison Project
CNRM: Centre National de la Recherche Météorologique
ESM: Earth System Model
Met.no: Meteorologisk Institutt
MICOM: Miami Isopycnic Coordinate Ocean Model
POP: Parallel Ocean Program
PRACE: Partnership for Advanced Computing in Europe
SURFEX: Surface Externalisée
WW: Wave Watch

References

[1] Valcke, S. (2013): The OASIS3 coupler: a European climate modelling community software, Geoscientific Model Development, 6, 373-388, doi:10.5194/gmd-6-373-2013

[2] Gasper, F., Goergen, K., Shrestha, P., Sulis, M., Rihani, J., Geimer, M., and Kollet, S. (2014): Implementation and scaling of the fully coupled Terrestrial Systems Modeling Platform (TerrSysMP v1.0) in a massively parallel supercomputing environment – a case study on JUQUEEN (IBM Blue Gene/Q), Geoscientific Model Development, 7, 2531-2543, doi:10.5194/gmd-7-2531-2014

[3] Williams, K. D., Harris, C. M., Bodas-Salcedo, A., Camp, J., Comer, R. E., Copsey, D., Fereday, D., Graham, T., Hill, R., Hinton, T., Hyder, P., Ineson, S., Masato, G., Milton, S. F., Roberts, M. J., Rowell, D. P., Sanchez, C., Shelly, A., Sinha, B., Walters, D. N., West, A., Woollings, T. and Xavier, P. K. (2015): The Met Office Global Coupled model 2.0 (GC2) configuration. Geoscientific Model Development, 8 (5). pp. 1509-1524. ISSN 1991-9603

[4] Masson, S., Hourdin, C., Benshila, R., Maisonnave, E., Meurdesoif, Y., Mazauric, C., Samson, G., Colas, F., Madec, G., Bourdallé-Badie, R., Valcke, S., Coquart, L. (2012): Tropical Channel NEMO-OASIS-WRF Coupled simulations at very high resolution , 11.4. 13th WRF Users' Workshop – 25-29 June 2012, Boulder, CO

[5] Maisonnave, E. and Masson, S. (2015): Ocean/sea-ice macro task parallelism in NEMO Technical Report, TR/CMGC/15/54, SUC au CERFACS, URA CERFACS/CNRS No1875, France

[6] Craig, T. (2011): CPL7 User's Guide

[7] Fogli, P. G., & Iovino, D. (2014): CMCC–CESM–NEMO: Toward the New CMCC Earth System Model. CMCC Research Paper, (248).

[8] Maisonnave, E. (2011): A simple OASIS interface for CESM ,Technical Report, TR/CMGC/11/63, SUC au CERFACS, URA CERFACS/CNRS No1875, France