OASIS Dedicated User Support 2009-2012: Synthesis

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"(...) Mais quand je suis, ou je l'ay peu marcher.
Haulsant les yeulx, je le voy loing s'estendre."
M. Scève

" (...) Jenes so oft
dir schon Gekommene scheint dir zu kommen
wieder wie Neues"
R.M. Rilke

Within IS-ENES, work package 4 "Strengthening the European Network on Earth System Modelling" proposed to provide technical help to implement new coupled models or improve existing configurations based on the OASIS coupler. Calls for applicants have been opened at the beginning of each year of the project (2009-2012). A total of 3 person-months were available each year. 31 applications, from 8 different countries, have been assessed by an IS-ENES Selection Committee.

Technical reports of the 12 OASIS Dedicated User Support (ODUS) are provided in the Appendix. Relying on their results, we propose to described our vision of the "multiple executable" coupling strategy adopted by the European climate community and how our project contributed to enhance it.

1. **Coupling strategies**

If we want to understand how important is "multiple executable" coupling for climate modelling in Europe, let's characterise how a coupler (OASIS) for MPMD (Multiple Program Multiple Data) is used and by which kind of laboratory.

The IS-ENES ODUS program has been organised in 7 different laboratories. If we look at the different granted institutions (see Table 1), we can notice that only 2 are national climate modelling centres (Rossby and Hadley centres, associated to SMHI and Met Office Meteorological agencies). Others laboratory activities are focused on ocean (AWI, LOCEAN, UBO), land surfaces (ETHZ and University of Bonn, also supported but outside the IS-ENES program) or atmosphere (BTU).

Laboratory	Models
SMHI (Sweden)	IFS (atmosphere) – NEMO (ocean), *Ec-Earth* RCA (atmosphere) – RCO (ocean) RCA (atmosphere) – NEMO (ocean)
LOCEAN-IPSL (France)	ECHAM (atmosphere) – NEMO (ocean) WRF (atmosphere) – NEMO (ocean)
AWI (Germany)	ECHAM (atmosphere) – FEOM (ocean)
ETHZ (Switzerland)	COSMO (atmosphere) – CLM/CESM (soil) – *Parflow (hydrology)*[1]
BTU (Germany)	COSMO (atmosphere) – ECHAM (atmosphere) – MPI-OM (ocean)
The Met Office (UK)	UnifiedModel (atmosphere) – NEMO (ocean) – WaveWatch (waves)

1 For COSMO community, in collaboration with Bonn University

UBO (France)	ARPEGE (atmosphere) – NEMO (ocean)

Table 1: Supported coupled models in IS-ENES granted laboratories

OASIS is used in climate laboratories to assemble the various climate model components developed inside or outside the institution. But in most of the specialized laboratories, it can be seen as a tool that allows to replace, in the laboratory main model, forcing boundary quantities by an exogenous model that produces those quantities.

This practice, facilitated by the community free movement of models, is widely spread in a European context, where national and continental scientific programs[2] encourage, organise and fund such activity. Furthermore, laboratories can share model development and support[3], which help creating communities: within those groups, additional components to the main model can also be exchanged.

But it is obvious that this or those additional models cannot be supported as the main model is. To support and develop a model is such an expensive task (which requires advanced competences) that it cannot be done with several components by all research groups, but only in bigger climate modelling laboratories.

To make possible the use of an extra model, without developing it, a modular interface is required. Most of the ODUS activity focused on writing, extend or improve performances of those interfaces in the targeted models. The reader can find in table 1 the various coupled systems implemented or enhanced during those 4 years. Initially implemented for two components, an interface can be extended for other exchanges[4]. When the coupling interface is modified by a model community member to allow the coupling with a new module, this module is theoretically made available for all the model community users: this highly increases the diffusion of a module through the community.

Let's immediately notice that to use a module in a coupled system does not necessarily imply to fully understand its how it works (even less its co-functioning with the main model).

2. **How is OASIS used ?**

One of the ODUS benefit is the transfer of knowledge about how a coupling is set and how a coupling interface is implemented.

Coupling is an exercise that must be considered complex. Its principle is simple. Its implementation is not. To split it into two parts, one theoretical (implementation of mathematical formula, mainly devoted to computing scientists) and one empirical (validation with observations comparison, mainly devoted to geophysical scientists) is an obstacle to its understanding.

2 One can cite, non exhaustively, Pulsation (France), TR32 (Germany), EMBRACE, SPECS and other IS-ENES WPs (FP7)

3 COSMO (atmosphere), Ec-Earth (climate), NEMO (ocean) ...

4 For example, COSMO regional atmosphere, initially coupled to CLM land model is now connected to NEMO ocean, ECHAM global atmosphere, MPI-OM ocean and Parflow hydrological model. Other example: NEMO can be coupled to different atmosphere models (UM, ECHAM, LMDZ, ARPEGE, WRF, COSMO ...)

To simplify, we can report from ODUS two kinds of coupling management. When it is an integrative activity of the laboratory (Climate centres) or of an (even single) scientist long term research program. And when it is an exploratory activity (like trying, for the first time, to switch from fixed boundary conditions to coupled quantities).

In the first case, most of the time, the OASIS functioning is well known. ODUS has served to extend its use or performances of new configurations on new supercomputers. The knowledge of external modules depends on the research program maturity.

In the other case, a time limited project is often the occasion of the interface implementation. The laboratory takes benefit of ODUS to set up a single configuration of the model, that will serve to provide scientific results in a restricted study. Even though few things are known of the exogenous module, non intrusiveness and simplicity of OASIS coupling theory leads to fast results (it is the goal) but also to weak implementations[5].

3. How to enhance coupled model implementation ?

There is no clear solution that can be recommended to any kind of project. Nevertheless, any partner in a coupling implementation, from coupling implementers and laboratory institutions to OASIS developers, should avoid some basic traps, that we will mention. In conclusion, we will suggest how an extended ODUS could contribute to this.

It is generally admitted that the theoretical (implementation) part of a coupling is completed when a given number of coupling time steps[6] has been achieved successfully (without obvious drifts). Coupling implementers should take care not to entrust anyone with the task of starting coupling validation[7] at this point but to carry out by themselves.

All details of the initial implementation are important and some of them will necessarily be modified during validation (or when the model will be later used in another configuration). They can not be easily changed by a third party because (i) they are spread on different parts of, at least, two different (and, most of the time, legacy) programs, (ii) their parametrization is difficult[8] and sometimes depends on different sets of parameters (one per coupled model) and (iii) the relative simplicity of use and adaptability of OASIS could lead to subtle but esoteric implementations that get documentation work more expensive.

Unsurprisingly, the author strongly suggests that both computing and geophysical validation skills were associated to coupling implementation work. He still does not lose hope that an even better solution, the double skills for the same person, would be, at last, efficiently encouraged at any level of our institutions.

More practical aspects can also be enhanced when a model coupling implementation is considered. First, it is important to consider it as a complex operation, that must be organised and which requires adequate tools.

5 For example, OASIS gives the possibility to exchange coupling fields through the single master processor. If user does so, it won't be necessary for him understand models parallelism strategy and but this would lead to dramatically slow down performances when his model resolution will increase
6 For an ocean-atmosphere coupling, a one month long run meets the needs of a simple validation
7 For example with observation comparison
8 OASIS namcouple gathers some (but not all) of them. For example, how to simply parametrize the length of the boundary zone between parent and child grid coupling fields, in an coupling model including a zoom (see ODUS #12)

When an exogenous model is added, it implies that the existing workflow is modified. This technical aspect of a coupling operation is neglected, although it can be highly time consuming. It is usually a strong reason of frustration for coupling implementers. We suggest to consider workflow adaptation as a work *per se*. Enabling an OASIS coupling on models is complex enough for being done separately from the workflow modification.

In a first step, it is crucial to work in a simplified environment. To start with a workflow already set for production is definitely not a good idea. Once completed a first coupling validation run, the merging of modules workflow could be done accordingly to this initial simplified environment.

Performance tuning can also be a crucial part of the work and can even be the condition for production[9]. Sometimes, model results can be changed by this tuning. For example, when the sequence of coupling exchanges is modified. The impact of this change must then be evaluated[10].

Advices for interface implementation are expressed in the exhaustive OASIS documentation. Let's emphasize again on the necessity to call OASIS exchange routines (prism_put and prism_get) at each time step. Interface implementers are reluctant to let OASIS calculate averages or accumulations. We remind that those operations are performed locally (no need of MPI exchanges, then no extra cost). The advantages strongly appear when more than two models are coupled with different coupling time steps. For the same reason, when necessary, it is recommended to let OASIS save coupled fields on separated restart files.

Other benefits of this program arose through collaborations with computing centres (organized, on the last 2 years, in the PRACE IP programs). It gave us the possibility to emphasize the importance of different MPI characteristics for climate modelling in Europe such as:

- MPMD mode (several executables launched on the same MPI execution environment)
- multi-threading (more than one MPI process can be run on a single resource) that can be interesting when models are running sequentially
- mapping (to explicitly choose the position of a given process on a particular resource)
- mixed OpenMP-MPI mode

and any combination of those 4 features, that most of the time require a particular and subtle MPI parametrization from supercomputer administrator.

4. **How to enhance OASIS ?**

When one start testing his recently implemented interface, the first question is always: which module of my coupled system has failed ? The difficulty is that we cumulate at least three problems: the lack of model error handling (sometimes), the lack of model error handling on coupling interface (it depends on the interface implementer himself) and the lack of coupler error handling.

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9 To be convinced, the author will have a look to the different performances of the same ECHAM-COSMO model as observed during ODUS #10

10 See ODUS ## 7 and 9

During the recent writing of OASIS3-MCT, a more precise error handling has been included. The ODUS program gave the opportunity to intensively test the coupler on a lot of different configurations and a lot of easy-to-do mistakes has been reported. However, to imagine new mistakes is one of our civilization favourite activities and preventing them all is such an important work that its implementation in a FORTRAN software like OASIS could lead to multiply line code number by a factor 2 or 3 and definitely darken its algorithm.

We noticed that OASIS3-MCT embed a much better error handling than on past OASIS versions. Nevertheless, an extra effort would be appreciated to avoid that people wrongly attribute bugs to coupler and not to their own coupling implementation[11].

To conclude this chapter, one can observe during the past 4 years the increasing importance of regional modelling. Naturally, OASIS has been selected to set up numerous European regional configurations.

As we proved it, OASIS can be used for regional coupled modelling. Nevertheless, some missing important features would be very useful to simplify the definition of coupled region boundaries[12].

5. How ODUS could contribute to OASIS better use ?

The purpose here is not to propose enhancements to the ODUS (mostly because this program stopped) but to make an assessment, made by its main contributor.

This one person.year work has produced the implementation of HPC compliant interfaces (ECHAM for NEMO and FEOM), interfaces for regional modelling (COSMO-CLM-Parflow), an interface with already integrated Earth-system (COSMO-CESM), an interface for 3D regional/global two way nesting (COSMO-ECHAM) and an interface for global model with zoom (NEMO/ERNA-ARPEGE).

Fact reports were produced on OASIS4 and OASIS3-MCT behaviour and performances on HPC configurations. It helps to optimise climate model performances on supercomputers (Ec-Earth, COSMO-CLM), developing a specific tool for performance measurement (“lucia”).

As expected, the ODUS program served IS-ENES partners, other community laboratories and CERFACS, via bug reports and coupler enhancement suggestions based on practical experiments.

Within the limits of the previously described community means and common practices, it helped to facilitate the implementation and the use of coupled models in Europe, identifying or resolving practical issues during coding, or simply by discussion[13]. Focusing and isolating the work of both model and coupler specialists on a given time period, these

11 That could lead to the complete implementation withdrawal

12 Most of the time, there is a geographic mismatch between regional grid extensions of the two models. This could at least, slow down coupling performances, but, sometimes, even forbid interpolation weight computations

13 Only a few hours have been necessary to help Bonn University people setting up their own coupling interfaces.

one month long format of each ODUS gave enough time to precisely identify issues, sometimes with more than one modelling group. One month to complete a coupled model implementation from A to Z is clearly not enough[14]. But ODUS target was clearly to bring an help and not to deliver a ready-to-use coupled system.

Sometimes, it has been possible to collaborate with an host laboratory to develop tools that should benefit to the whole community. This is what happened with the load balancing tool “lucia”, even though its lack of robustness and the work overload of the OASIS development team still defers its official release jointly with OASIS.

ODUS program gave us a clearer idea about present and future model community requirements. One major result is the survey of the different OASIS version limits toward model parallelism increase. It contributes to drive OASIS supporting thousands of cores configurations, which actually satisfy the needs of the community in Europe.

Made on real models, coupler tests reveal present needs. Identification of more model characteristics impacting their coupling[15] helped to set-up more realistic toy models, used for coupler validation.

Mission	Date	OASIS version	Distribution (cores)	Supercomputer
LOCEAN-IPSL	10/2009	4	500	IBM P6
AWI	11/2009	4	n/a	IBM P6
SMHI	02/2010	3	50	HP Nehalem
SMHI	10/2010	3	1000	Cluster Opteron
ETHZ	11/2010	4	150	CRAY XT5
LOCEAN-IPSL	03/2011	4	150	IBM P6
ETHZ	07/2011	3	150	CRAY XT5
Bonn University	11/2011	3	n/a	n/a
SMHI	02/2012	3	1200	Cluster Opteron
BTU	08/2012	3-MCT	60	IBM P6
The Met Office	11/2012	3-MCT	2000	IBM P7
UBO	12/2012	3	140	IBM P6

Table 2: Observed coupled model infrastructure during ODUS program

ODUS program has increasingly contributed to disseminate OASIS best practice through laboratories. We hope that it will contribute too, within associated EU projects such as Embrace or IS-ENES2, to favour interactions between not only laboratory managers but also coupling implementers.

14 Its documentation has been problematic: more time was needed to report the different level of information to the laboratory user (implementation and user guide) and to IS-ENES community (coupling specificity, elements to share)

15 Representative decompositions, use of restart, high resolution ...

It has been easily carried on until its end, despite its length and its cost[16]. An extension of this activity, in a different framework, has been submitted to CERFACS direction.

6. **Conclusion**

ODUS successes are the results of a conjunction of efforts:

- from host laboratories, with personal involvement of laboratory applicants, sharing computing and other infrastructures means, with sometimes effective participation to lodging and food (ETHZ, AWI) and, always, the warm and friendly atmosphere that my hosts knew how to create.
- from OASIS developers, that bring an additional and real-time support to this program. It is important to emphasize that no OASIS enhancement could be possible without their goodwill.
- from CERFACS authorities, in addition to the standard OASIS development they offer to the community
- from IS-ENES selection committee who, again voluntarily, tried to estimate the scientific potentiality of each application. We notice that the difficulties associated to this aspect were also probably underestimated. It lead for example to grant important laboratories, that certainly offered good conditions for an efficient ODUS collaboration, to the detriment to the smallest ones.

Despite of this goodwill or, rather, because of it, it seems obvious that this activity cannot continue by its own. Our results are weak: a coupler (OASIS4) development has been forsaken, some coupled models still need to be set up (ETH, BTU, UBO) by their users and a new support could be necessary for that.

Laboratory	Year	Title
AWI	2009	OASIS3-OASIS4 coupling for FEOM
ETH/Meteo Swiss	2011	COSMO-CLM with OASIS
Bonn University	2011	COSMO-CLM with OASIS
DWD	2012	IS-ENES OASIS Dedicated Support
BTU	2012	COSMO-ECHAM with OASIS3-MCT
NCAR	2013	OASIS Dedicated Support

Table 3: Seminar list

Even though it is clear that a lot of contemporaneous European collaborations are including such long dedicated missions, it seemed not possible to rely on larger existing European infrastructures[17], for things as different (but essential) as lodging or expertise networking[18].

16 What it involved for the main contributor: journey length, activity interruptions at CERFACS ...

17 Except the EU terrestrial and maritime transport infrastructure, but mostly composed of independent national networks. Allowing to prepare and document the different missions, the convoying between laboratories (with adequate connection times) has been always punctual and nice. It demonstrated (if needed) the continental aerial network pointlessness

18 or even simple wireless connections in laboratories like Eduroam

Generally speaking, an activity such as ODUS is efficient when it supplements and enriches existing activities and not when it substitutes for a local missing manpower. However, we hope that we contributed to identify and strengthen the existing network of OASIS implementers.

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Estimated carbon emissions for 12 continental journeys by terrestrial and collective means of transport: 1110 KgEqCO2

Fig 1: Cloud cover record, November 2012