IS-ENES3 Deliverable D6.4

Report on new OASIS coupled models/interfaces

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ABSTRACT

This report describes the results of the Trans National Access activity performed with the OASIS coupler (Dedicated Support). It presents implementation details and best practices, as well as the new needs and improvements on OASIS software that have been induced by this activity.

Revision table			
Version	**Date**	**Name**	**Comments**
0	01/09/22	Initial draft	EM
1	01/10/22	Version for internal review	EM
2	16/10/22	Internal review	SJ
3		Version after internal review	EM
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PU	Public		X

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Table of contents

Executive Summary

In addition to services shaped for virtual accesses (online forums and supports, training session, etc), the Trans National Access Service (TNA) described in this document brings an on-site support for the use and improvements of the common coupling library OASIS as part of the IS_ENES3 services. The present OASIS dedicated support program wishes to extend, to strengthen and to popularise the best practices of this community. In that purpose, we visited eight laboratories for a total of eight person months during the 2019-2022 period. Rather than a standardisation, the present work has facilitated the development of new solutions, in three directions: (i) the set up of new coupled systems, (ii) the porting of existing frameworks and (iii) the use of new OASIS functionalities. Even though this program will be discontinued for several structural reasons, the benefits offered by our community coupler attest the necessity to keep its maintenance, strengthen its durability and extend its use by any further support program.

1- Objectives

The IS-ENES3 work package 6 (WP6/NA1) aims at facilitating the use of climate modelling community tools and model components. In particular, WP6/VA1 supports the spread of the common coupling library OASIS, which plays a crucial role for the development and efficient utilisation of climate models. The OASIS coupling library [Valcke et al. 2021], used by more than 70 climate modelling groups in Europe, USA, Canada, Australia and Asia, allows synchronized exchanges of coupling information between components of the climate system. In addition to services shaped for virtual accesses (online forums and supports, training sessions …), a Trans National Access Service (TNA) has proposed an on-site OASIS support. During this dedicated support to OASIS, a code coupling expert has visited laboratories to help designing, upgrading or enhancing the implementation of the OASIS library and set up a tailored and computationally efficient coupled system, though keeping in mind that such activity is really efficient when it supplements an existing local activity and not when it substitutes for a local missing manpower. This service was experienced with success through networking activity during IS-ENES1 [Maisonnave et al. 2013] and is resumed in this H2020 project to make the coupling library available on an even larger community.A now well established community in the surroundings of the OASIS library is perpetually recreating its coupled systems, and contributes to the coupling tool update. The new ODUS program we are presenting here wishes to strengthen and popularise the best practices of the community, and to facilitate the enhancement of the library/interfaces by communicating the program results to the community central entities (OASIS and model developers).

2. Methodology and results

2.1 Service allocation

Following on IS-ENES1 experience, a new TNA service was proposed in IS-ENES3 to expand this type of support to the community. Eight one month long dedicated supports were offered to climate research laboratories in Europe (see Fig. 1 and Appendix 1). A call was opened every year, published on the official IS-ENES and OASIS portals and notified to OASIS users and other Climate Modelling related mailing lists. The selection was validated by the OASIS Advisory Board and three grants allocated during 3 years (at M3, M27 and M39). The peer-review procedure was assigned to a selection panel consisting of members of the OASIS

Advisory Board, representing the main ENES institutions using the OASIS coupler but also people from outside the ENES community, chosen for their ability to provide valuable inputs and advices about OASIS related developments in models. The OASIS Advisory Board assessed all proposals received based on agreed selection criteria and recommended a short-list of the user groups that benefited from dedicated support. The evaluation was based on the following criteria:

- Originality of the problem: e.g. new physics (ice sheets, hydrology, atmosphere/ocean boundary layer ...), increased task parallelism (extraction and concurrent running of sub-components e.g. sea-ice) …
- Quality of the methodology proposed
- Development of cooperation with communities outside the global climat modelling community (regional modelling ...)
- Potential training aspects for new or young users
- Synergy with OASIS development plan

Figure 1: Location of the laboratories that took benefit from OASIS dedicated supports thanks to the IS-ENES3 Trans National Access program

Priority was given to participants who have not previously used the coupling library. A total of fourteen answers were received, most of them granted, with two supplementary grants attributed to MetOffice and NERSC through the Exascale oriented ESIWACE-2 project [Maisonnave & Bourdallé-Badie 2022; Maisonnave & Berthet 2022], and two laboratories (BTU Cottbus, HEREON Geesthacht and other laboratories of the COSMO community) deprived from the service by the pandemics and one last, outside of the EU limits, but helped independently from this program. Five hosts were newcomers in the OASIS community, although no new laboratory could be added to our list. This can be explained by the lack of international conference where ODUS could have been advertised during the project.

2.2 Service description

2.2.1 COVID related adaptations

COVID19 pandemics sensibly disturbed the service. First, only eight out of nine supports originally planned were delivered (one of the allocated person month was re-directed towards Small Private Online Course (SPOC) training design, as agreed in the 3rd amendment of the project). Activity planned in 2020 was spread until end of 2021, which delayed the last round of services and the present report. The last round call was also slightly modified to make possible and as efficient as possible a remote provision of the service. Two supports were delivered remotely (NERSC, DWD) to avoid unnecessary travelling. Of course, the efficiency of the service was altered: the support was precisely organised on-site to foster the implementation of an OASIS based coupled model by concentrating the work during a short period of time and by tightly involving not only the OASIS expert and the host user, but also other laboratory collaborators in the task.

2.2.2 Service summary

The reader will find the comprehensive description of the eight ODUS provided in the three yearly reports made available in the course of the project [Maisonnave 2019 ; Maisonnave & Kjellsson 2021; Maisonnave 2022]. A shorter description of the achieved work is available in Appendix 1. In this paragraph, we try to evaluate the ODUS impact, from both community and software development points of view, rather than to provide the full implementation details.

During the first year of the project, we could upgrade the OASIS3-MCT library owned by the users to the current version 4 and make available new coupler functionalities in their coupled systems, such as the parallel computing of interpolation weights. Interfaces were modified to allow single precision computations (ETHZ), concurrent coupling of ocean and sea-ice (MetOffice) or full ocean zoom coupling (GEOMAR). The result was always a significant performance improvement. During a period that unintentionally covered the second plus the third

project year, we modified the call of OASIS API routines in models (ocean-ice and runoff mapper-ocean), to enhance the physical interface (NERSC) or make the most of new OASIS functionalities, e.g. the locally conservative interpolation (GEOMAR). Computing performance was checked, with more accuracy since the new OASIS event timeline [Maisonnave et al 2020] is made available. Finally, during the last year, a complex and computationally efficient coupled system, involving the XIOS I/O server, was ported on a non scalar processor (DWD) but the ODUS also helped to validate interpolation choices (at DWD and SMHI), to check the functioning of the newly developed pyOASIS API (SMHI) and to design an interface in a component (wave model) recently made available in the community (Météo-France).

Laboratory, Country	Main tasks	Coupled system components (Regional or Global)	Coupler
ETHZ, CH	Model upgrade, porting	Atmosphere – Land (R)	V
MetOffice, UK	Interface design, performance	Ocean – Sea Ice (G)	F
GEOMAR, DE	Interface design, performance	Atmosphere – Ocean (G/R)	V,F
NERSC, NO	Interface design	Ocean – Sea Ice (R)	none
GEOMAR, DE	Interpolation setup	Atmosphere-Ocean-Runoff (G/R)	V
DWD, DE	Porting	Atmosphere – Ocean (R)	V, F
Météo-France, FR	Interface design, porting	Ocean -Wave (G)	none
SMHI, SE	Workflow upgrade, interpolation setup	Atmosphere-Ocean-Runoff (G)	E

Table 1: Granted laboratories, task, coupled system implemented or modified and interaction with coupling library (E: Enhanced, F: bug Fixed, V: Version upgraded on existing model)

2.2.3 Task classification

A rough classification of theses tasks would discriminate between (i) the set up of new coupled system, (ii) the porting of an existing framework and (iii) the use of new OASIS functionalities.

(i) New coupled system set up

The coupled systems we had to study were mainly built with well established components. The ODUS work may consist in adding a new interface, if the component is a newcomer in the OASIS zoo (e.g. MFWAM at Météo-France). It may also require an upgrade of the existing interface, if the model is used in a new configuration (e.g. a two way coupled AGRIF zoom, GEOMAR). The ODUS also contributes to test, validate or enhance the capacity of the coupling library itself. Depending on how independent from or integrated in other framework the components are, the ODUS also gives a better idea how powerful the OASIS modularity can be.

(ii) Porting and enhancements of existing coupled systems

Porting (that can be done in conjunction to a task of the first class during the same ODUS period) was particularly challenging when made on non CPU architectures. Not because of the compatibility of the library itself, not used on GPU and already compatible with vector machines, but because of the heterogeneity of the computing units that the coupled system were gathering on the supercomputers (e.g. IO servers on CPU and computing processes on vector engines at DWD). Assuming that the trend of hardware manufacturing will keep favouring, in the near future, the assembling of specialised chips, the ODUS has helped validating the hypothesis that a modular system (i) can be ported on such architectures and (ii) makes the most of the heterogeneous computing power by distributing each element of the modular system on the kind of hardware where it is the most efficient.

(iii) Implementation of new OASIS library functions

The third class of ODUS tasks we can identify gathers (i) the use of new OASIS functionalities, related to the core features of the library, such as its interpolations (locally conservative interpolation for runoff, GEOMAR [Voldoire 2019, Maisonnave 2020]) or additional tools (new load balancing tool, MetOffice) and (ii) the use of existing functionalities, but in innovative ways : parameter tuning of the Gaussian distance weighted interpolation (GEOMAR), joint use of heterogeneously (scalar/vector machines) compiled OASIS libraries (DWD), validation of the pyOASIS API in a simplified coupled system, used during a post-processing step to calculated in parallel (OpenMP) weights and addresses (SMHI). Doing that, we contribute to test functionalities of the library not often used by the community, and make sure that the last OASIS version can handle them (bug reports, commits into the repository).

2.2.4 Impact on community

The modular design of OASIS made coupled systems greatly improves the collaboration of laboratories. It is easier to work on the same component, though on different coupled architectures (e.g. OpenIFS-NEMO in global or regional mode, with or without AGRIF zoom, with or without a bio-geo-chemistry component …) In that perspective, the IS-ENES3 ODUS program contributed to make available a set of new components (or upgrade of existing components) by updating or even creating the OASIS interface that will facilitate their redeployment to other laboratories (see Table 2). In a second level, the ODUS also popularises coupling solutions or best practices that are not necessarily well spread (locally conservative runoff, ocean/seaice coupling in NEMO, load balancing measurement …)

Ocean	Atmosphere	Others
NEMO v3.6	COSMO-CLM v5	CLM v5 (land)
NEMO v4	OpenIFS cy40	SI3 v4 (sea ice)
NEMO v4.2	OpenIFS cy43r3	neXtSIM (sea ice)
HyCOM v2.2	ICON-NWP v2.6.4	**MF-WAM** (waves)

Table 2: List of OASIS compatible models which interface was upgraded or **created** during the ODUS

Complementing this function of component/best practice exchange facilitator, the ODUS also aims at reporting library bugs that slows down, sometimes prevent, the implementation of a coupled system. During this project, a modest number of bug/improvements were reported (less than a dozen) but it could have its importance regarding to the overall reliability of the coupler and the trust that the community can award to it.

Finally, we hope that the ODUS has facilitated the diffusion of new OASIS versions in the community, but has also convinced new users through the various means of communication invested: 8 reports related to the ODUS tasks published (see list in References), meetings in laboratories, internal IS-ENES workshop for HPC or Coupling technologies, participation to the EGU conference [Kjellsson et al. 2020].

3. Conclusions and Recommendations

The IS-ENES3 ODUS program has led to several important results from which:

- the spreading of a newly developed river-runoff-oriented interpolation (@GEOMAR & SMHI), made possible by a former national collaboration[1],
- the upgrade of ocean-ice interfaces (NEMO-SI3 @ MetOffice & HyCOM-neXtSIM @ NERSC), also facilitated by a previous national funding[2] and extended thanks to an international collaboration[3],
- the compliance of OASIS libraries and OASIS interfaces with heterogeneous hardware (GPU-CPU @ ETHZ & Vector-CPU @ DWD),
- the checking of the pyOASIS API (@SMHI) and the contribution to the development of a Python tool aiming at efficiently produce OASIS interpolation weights and addresses in a pre-production phase.

1 ANR COCOA (air-sea interactions), https://anr.fr/Projet-ANR-16-CE01-0007

2 ANR PULSATION (resolution effect on ocean-atmosphere coupling), https://anr.fr/Projet-ANR-11-MONU-0010

3 SASIP (sea ice modelling), https://sasip-climate.github.io/

Moreover, developments produced during the support period were (or are planned to be) distributed from the hosting laboratories towards larger communities:

- FOCI from GEOMAR,
- Copernicus from Météo-France via Mercator Ocean,
- COSMO-CLM from ETHZ & DWD,
- EC-Earth from SMHI,
- NEMO from GEOMAR, Météo-France, MetOffice, SMHI & DWD,
- neXtSIM from NERSC.

Despite its persistant community of users and its growing popularity, OASIS is mainly relying on a code, which is itself at risk. From at least the end of the EU PRISM infrastructure project onwards [Valcke et al. 2006], a centripetal force contrives to multiply the number of couplers or coupling frameworks. Based on the present experience, we would recommend to maintain one of these couplers, and complement it with a comprehensive user support.

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To conclude, thank you to Uwe Fladrich, leader of the WP6 workpackage, who has facilitated our work at several levels: coordination within the project, selection procedure and even support hosting. Tak, tak, Uwe.References

- Maisonnave, E., Valcke, S. & 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
- Maisonnave, E. & Bourdallé-Badie, R., 2022: Coupling NEMO global ocean with hemispheric Arctic and Antarctic ice models , Technical Report, **TR/CMGC/22/18**, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E. & Berthet, S., 2022: Biogeochemistry coarsening in NEMO 4.2, Technical Report, TR/CMGC/22/86, CECI, UMR CERFACS/CNRS No5318, France
- Valcke, S., Guilyardi, E. and Larsson, C., 2006: PRISM and ENES: a European approach to Earth system modelling. *Concurrency Computat.: Pract. Exper.*, **18**: 247-262. https://doi.org/10.1002/cpe.915
- Valcke, S., Craig, T., Maisonnave, E., & Coquart, L., 2021: OASIS3-MCT User Guide, OASIS3-MCT 5.0 , Technical Report, **TR/CMGC/21/161**, CECI, UMR CERFACS/CNRS No5318, France
- Voldoire, A., 2020: River to ocean models interpolation. [Research Report] CNRM, Université de Toulouse, Météo-France, CNRS meteo-02986574

Directly related work (IS-ENES funded):

- Maisonnave, E., 2019: OASIS Dedicated Support, 4th annual summary , Technical Report, **TR/CMGC/19/149**, CECI, UMR CERFACS/CNRS No5318, France
- Kjellsson, J., Park, W., Martin, T., Maisonnave, E., & Latif, M., 2020: Greatness from small beginnings: Impact of oceanic mesoscale on weather extremes and large-scale atmospheric circulation in midlatitudes , in EGU General Assembly Conference Abstracts (p. 17899)
- Maisonnave, E., 2020: Locally conservative OASIS interpolation using target grid nearest neighbours , Technical Report, TR/CMGC/20/166, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E., Coquart, L., & Piacentini, A., 2020: A better diagnostic of the load imbalance in OASIS based coupled systems , Technical Report, TR/CMGC/20/176, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E., 2021: NEMO performance optimisation on NEC SX-Aurora TSUBASA , Working Note, WN/CMGC/21/37, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E. & Kjellsson, J., 2021: OASIS Dedicated Support, 5th annual summary , Technical Report, TR/CMGC/21/150, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E., 2021: How to interpolate atmosphere fluxes to an AGRIF zoom ? The ECHAM & OpenIFS test case (in French) , Technical Report, TR/CMGC/21/200, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E., 2022: NEMO performance on pre-Exascale processors : NEC SX-Aurora TSUBASA and Fujitsu PRIMEHPC FX700 , Working Note, WN/CMGC/22/22, CECI, UMR CERFACS/CNRS No5318, France
- Maisonnave, E., 2022: OASIS Dedicated Support, 6th annual summary , Technical Report, TR/CMGC/22/139, CECI, UMR CERFACS/CNRS No5318, France

Appendix 1

Summary of ODUS achievements

ETH Zürich (Switzerland), Land-Climate Dynamics group: To take a maximum benefit of the GPU compliant COSMO model, the last version of OASIS and ClandM were included in the coupled system, the existing OASIS interface in COSMO was modified to allow single precision compiling, and a coupling between heterogeneously (PGI/Intel) compiled components was set up successfully. All together, this upgrade leads practically to the multiplication by a factor 1.5 of the COSMOCLandM coupled system speed
MetOffice Exeter (UK), Climate Science IT Applications: Coming with the new NEMO 4.0 version, the recent upgrade of the sea-ice component from LIM to SI3 makes necessary a check up of the ocean/surface_module coupled interface. Few code modifications, included in a development branch for later trunk update, were necessary to perform test simulations at ORCA1 and ORCA12 resolution and roughly check its validity. Improvement of NEMO speed and cost is real but limited to 10 to 20% and observed with sufficiently high decomposition only. At its best, our coupled configuration is faster (x2) and cheaper (-25%), but, since it is spread on a larger number of resources, it could reduce the actual speed (simulation + scheduling time) of production runs
GEOMAR Kiel (Germany), Marine Meteorology team: The necessary removal of the on-disk coupling procedure of the ocean zoom surface fields in the GEOMAR OpenIFS-NEMO-AGRIF coupling (FOCI) required the upgrade of both NEMO and OpenIFS interfaces. The inexpensive OASIS coupling that has been set up allowed to increase the OpenIFS horizontal resolution to 25Km. The CPU cost of the coupled system, that includes the North Atlantic zoom AGRIF, is estimated to approximately 30 time less than the CPU cost of the corresponding global ORCA12 based configuration
Nansen Environmental and Remote Sensing Center, Bergen (Norway), Ocean modelling group: The coupling interface of the HYCOM model is modified to allow the exchanges at surface with the neXtSIM ice model. A first order validation is performed in a stable one year long simulation and its computing performance optimise by reducing the components load imbalance.

GEOMAR, Kiel (Germany), Marine Meteorology team:
A new runoff interpolation algorithm is introduced in the existing OpenIFS-NEMO coupled model. It relies on the new locally conservative method implemented recently in OASIS3-MCT v5. The number of debouch grid points per basin is tuned to avoid numerical instabilities while keeping a realistic spatial spread in the global ORCA05 grid as well as in the North Atlantic 10Km resolution AGRIF zoom

German Meteorological Service, DWD, Offenbach (Germany):
The NEMO-ICON coupled model, including ICON internal and XIOS external I/O servers, is ported on the new DWD vector machine (NEC SX-Aurora TSUBASA). The ICON I/O processes and the NEMO IO servers are pinned on the scalar hosts of the machine, while the computing processes are running on the vector cores. Interpolations are parametrised to better conserve fluxes and minimise errors, including along the coast line, for which the definition is modified in the ICON interface. A first performance evaluation, performed with the OASIS3-MCT v5 library, confirms the modest extra-cost of our coupled interface

Météo-France, PREVIMER, Toulouse (France):
A support is given to the PREVIMER R&D team to ensure the efficient exchange of OASIS coupling fields between the NEMO ocean and MFWAM wave models. After a training period, the user was able to develop its own toy models, which were gradually replaced by the final models. Small standard adaptations (MPI internal communicator) were necessary to deliver a fully functional NEMO-MFWAM system

SMHI, Rossby center, Norrköping (Sweden):
Several enhancements have been proposed for both SCRIP interpolation file generation in a pre-processing phase and interpolation parametrisation. A parallel version of the rdy2cpl tool is set up and its scaling checked, while better conservative parameters are proposed in the future version of the EC-Earth4 coupling system (ice temperatures of the sea-ice edge). The rdy2cpl tool modifications were the occasion to test the new pyOASIS interface and establish the efficacy of Python based coupled toys. Easily configurable, this tool has the potential to serve a broader community