A climate community coupler: OASIS

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Abstract

A now well established and growing community in the surroundings of the OASIS climate model coupling library is perpetually recreating its coupled systems. The coupling library maintenance and upgrading activity, constant but modest, cannot alone explain this popularity. We assume that the constant growth of the OASIS-based model livestock is the consequence of a quasi organic development of climate models in a favourable direction. A three year long period of on-site dedicated supports to the OASIS coupling helped to understand how and why our coupler was used. We rely on this experience to better define the role that modularity is playing in the building of our community. We propose to call OASIS a community coupler, and examine how it partakes of an ethical politics of scientific research, which argues against its dismantling

1- Rationale

Used by more than seventy climate modelling groups in the five continents, the OASIS coupling library [Valcke et al. 2021] plays a crucial role for the development and efficient handling of climate models. The library allows synchronized exchanges of coupling information between components of systems which aims at representing earth climate. Recently, a set of on-site dedicated supports was organised within the IS-ENES-3 and ESIWACE-2 EU infrastructure projects. This gave us the opportunity to help designing, upgrading or enhancing the implementation of the OASIS library and setting up a tailored and computationally efficient coupled systems. But at the same time, this work was an opportunity to try to understand how and why our coupler was used. In this document, we propose to rely on this experience to try to better define the role that our coupler is playing in our community and to argue against its dismantling.

A dedicated support program was already led with success through a networking activity during the first fold of the IS-ENES project [Maisonnave et al. 2013]. The first twelve IS-ENES-1 OASIS dedicated user supports (ODUS) had facilitated the implementation and the use of coupled models in Europe, identifying or resolving practical issues during coding, or simply by discussion. Focusing and isolating the work of both model and coupler specialists on a given time period (one month), the ODUS gave enough time to precisely identify issues, sometimes involving more than one modelling group at the same time. Sometimes, a feedback effect of the work led to the library enhancement, with an added benefit for the whole community. This first ODUS program gave us a better idea about present and future model community requirements and contributed to tailor the OASIS following versions in that direction, diverting from trends driven by exogenous desires and futile fashions. The 2009-2013 ODUS program also contributed to disseminate OASIS coupling best practices through laboratories and created an onset of OASIS experts network. An extension of this activity, though lighter, was lonely sustained by CERFACS from 2013 onwards [Oouchi et al. 2015; Will et al. 2017].

Taking benefit of the same chain of infrastructure projects, the original 90's version of the coupler was enhanced, by adding interpolation (SCRIP) [Jones 1999] and parallel communication (MCT) [Jacob at al 2005] libraries. A comprehensive documentation was maintained. Access to beginners was facilitated by training sessions. The management of these activities at a continental level advertised the tool on a set of workshop and conferences.

But in our sense, this activity, constant but modest, cannot alone explain the success of our library. From our point of view, the constant growth of the OASIS-based model livestock is less the outcome of an imperialism whose tanks remain to be detected by the spy satellites, than the consequence of a quasi organic development of climate models in a favourable direction.

Of course, such a bold postulate needs to be corroborated but the full demonstration, if reachable, would require, in addition to our practical experience, a larger theoretical base in fields such as science epistemology, or even sociology. At our climate and computing scientist level, just let us stress a selected number of practical features of the OASIS software that should, in our sense, facilitate the climate modelling process and explain its success.

Climate modelling is fundamentally a process in motion. Mainly because climate research is a dynamical process per se, which modifies the object that it aims to represent, but also because of the nature of the representation tool: a computing code, sensible to the evolution of the underlying hardware. Climate is a complex topic, which has been studied for decades. The complexity of a climate model grows during time, since it is integrating more and more complex processes but also because it is costly to simplify it by rewriting the original code (legacy) too often[1].

One of the main benefit of the OASIS library lies in the initial assumption that has governed its conception: a climate system is made of more than a single atmosphere model, and more components need to be added at its interface rather than prescribing fixed boundary conditions. The modularity induced by this definition has its counterpart: the arbitrary concept of internal *limits* within the system, which makes more difficult to think and represent a continuum. The representation of any physical interface is made more complex because it is split between at least two models. These two drawbacks tend to dissuade from more detailed studies of the physical interface such as [Pelletier et al. 2021]. In our sense, this is the main limit of an OASIS induced representation of the climate system, which present document does not deny. But we assume that it is still possible to make progress in our science within this limit, which will not affect the main conclusions of this document.

The benefit of modularity is high regarding code development, since components developed on another laboratory are easily reusable, even more if these components are already endowed with an OASIS interface. In addition, updates in one module do not affect the whole system. These benefits reduce the development cost, limit duplicated developments in the community, thus save time for more precise and complementary studies using the same model (e.g. coupled systems using the same NEMO ocean propose a comprehensive understanding of this model behaviour in atmosphere coupled mode). Since the OASIS tool is long lasting[2], it is reliable and has incited the community to bet on the long term availability of the model they develop and of the paradigm on which it is based. This has strengthened the possibility of long term studies with the same model.

1 One could also mention here, as a possible explanation of the code growing intricacy, our proclivity to add new parametrisations to the model, for the only reason that they are supposed to enhance its realism. In that representation, the removal of any part of the code would take away the model from some kind of truth

2 The reusability is increased by the backward compatibility of the OASIS interface

Another benefit of the OASIS interface is its distributed writing and maintenance. Users of one or several modules are defining the needs, and can participate to the coding of the interface but also of parts of the OASIS library itself, all written in an accessible and standard language: FORTRAN. A guarantee of the library continuous developments is ensured by the conceiver's laboratory (CERFACS), while the community involvement ensures adequacy to the needs. A "weak" copyleft, induced by the GNU Lesser General Public License that governs the OASIS use, secures the possibility for the community to freely adapt the library to their needs while preventing the (benign) risk of seizures.

Last but not least, OASIS gives you the possibility to build your own coupled system. As stated by Michel de Montaigne in his "Essais", "*j'y veux pouvoir quelque chose du mien*": I would have a power of introducing something of my own[3]. This freedom that our tool offers is granted back by a willing participation to the tool development and the community permanence. With a better knowledge of the tool, freedom of development increases. In interaction with a community, possibilities widen. One would see a positive feedback to this mechanism, and another possible element of this supposed quasi organic process that led the development of the OASIS community.

Apparently, a now well established community in the surroundings of the OASIS library is perpetually recreating its coupled systems, spreading them on a larger extend, and also contributes to the coupling tool update, thus its relevance and its ability to convince more users. Can we say more about the mechanisms at work behind this development ?

2- A community coupler

The 2019-2021 OASIS dedicated support program was the ideal view point to try to identify our community needs and practices. The reader will find the comprehensive description of the eight ODUS provided in the three yearly reports made available during the IS-ENES-3 project [Maisonnave 2019 ; Maisonnave & Kjellsson 2021 ; Maisonnave 2022], jointly with the two reports of the ESIWACE-2 funded supports [Maisonnave & Bourdallé-Badie 2022; Maisonnave & Berthet 2022]. The description is intentionally reduced in this document, where we focus on summarising the practices that help to understand how OASIS is used, and then try to deduce from that how it can be adopted by a larger community.

3 Translated by Charles Cotton

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
NERSC, NO	Model upgrade, interface design	Ocean- Sea Ice (G)	none
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
MetOffice, UK	Interface design, interpolation development	Ocean-Biogeochemistry (G)	E

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

2.1- Usage

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 ice (MetOffice) or full ocean zoom coupling (GEOMAR), with a significant performance improvement. During the 2020-2021 period, 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 a 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] was 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 functionning 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). More advanced coupling were prepared for a Eulerian version of the neXtSIM sea-ice model (NERSC) and the coarsening of the TOP-MEDUSA bio-geo-chemistry model (MetOffice). In the first case, the ORCA global grid was split into two independent hemispheric components, as a simplified basis of the neXtSIM future discretisation, having an interpolation-less coupling with the NEMO ocean in mind. In the second case, an exact coarsening of the NEMO ocean tracers was implemented in the OASIS library to allow performing the future BGC component computations at a lower resolution.

A rough classification of these tasks we achieved during the ODUS could give a rather comprehensive view of the coupling library potentialities. The classification would discriminate between (i) the set up of new coupled system, (ii) the upgrade of the porting of an existing framework and (iii) the use of new OASIS functions.

(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. adding the MFWAM wave model to NEMO ocean for a future Météo-France weather forecast system. It may also consist in an upgrade of the existing interface, if the model is used in a new configuration, e.g. a two way coupled AGRIF zoom included in the original OpenIFS-NEMO ocean-atmosphere model at GEOMAR. More exceptionally, an existing model can be split into independent pieces, that are coupled in a second step with an OASIS interface. Computing performance is the key motivation to such operation. This was done at MetOffice, for both SI3 sea-ice and TOP-MEDUSA bio-geo-chemistry (BGC) modules of the NEMO framework.

The extreme case of the neXtSIM sea-ice coupling at NERSC is worth to be noticed. The discretisation of the existing NEMO ocean model was simplified (removal of the tri-polar folding zone) and proposed as a new sea-ice model grid, the coupling of the two models being ensured, without error prone interpolation, by the existing NEMO ocean interface.

These examples, experienced within the ODUS program, make clear that modularity is the primary need that favours the use of the library OASIS. The addition of a new component is done quickly, thanks to the low intrusiveness of the OASIS API. When it is done, the prime core model boundary conditions can be provided from static data or coupled fields. They are ready to be filled by coupling fields coming from a future component, if this should have been interfaced with OASIS API routines.

(ii) Upgrading and porting of an existing coupled system

As already noticed, the non intrusiveness of the OASIS API facilitates the standard exchange of one component, particularly when a new version has to be included in the user system, as it was experienced at NERSC or ETHZ. Porting of the whole coupled system can be much more challenging, particularly 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 [Thompson & Spanuth 2018], 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) Use or implementation of new OASIS 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 functions, 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 functions 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).

More scarcely, bug can be corrected and new functions can be added by users to the OASIS library itself. And this is particularly facilitated by the readiness of the FORTRAN language and the profusion of the inlined commentaries. Our implementation of an efficient 3D coupling (without vertical interpolation) and the replacement of the average weighting operation by a maximum between source grid points, shows at least that adapting the library to user needs is possible. Of course, this was done by experienced users and we have to admit that, in history, only a few number of users are at the origin of OASIS modifications. And no new experimental observation can corroborate the assumption that the opportunity to modify the OASIS library is intensively taken in the community.

2.2- Impact on community

The modular design of OASIS made coupled systems is what greatly improves the collaboration of laboratories willing to share the same modules. Rather than developing an new model, it is easier to work on a component developed elsewhere by better specialists, even if this was done on different coupled architectures, e.g. OpenIFS-NEMO in global or regional mode, with or without AGRIF zoom, with or without a BGC component, etc. During the IS-ENES-3 ODUS program, we observed that the OASIS interfacing of a set of new components, or the upgrade of this interface in existing components (see Table 2) has facilitated their redeployment to another laboratory of the community (see Table 3).

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)
		TOP-PISCES (bio-geo-chemistry)

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

Models are not the only things which exchanges are facilitated by the modularity. The ODUS program may have speed up the spreading of coupling solutions or best practices that are not currently well known (locally conservative runoff, ocean-ice coupling in NEMO, load balancing measurement …) but we guess that this diffusion is implicit in the communities we visited for the reason that coupling techniques are exchanged at the same time that new components or component versions.

Source laboratory	*Community*
GEOMAR	FOCI
Météo-France	Copernicus
ETHZ & DWD	COSMO-CLM
GEOMAR, Météo-France, MetOffice, SMHI, NERSC & DWD	NEMO
NERSC	neXtSIM & Hycom
SMHI	EC-Earth

Table 3 : Communities benefitting of the interfaced components developed during the ODUS

The last axis of what could be considered as a community effect is the enhancement of the coupling library by its users. The existence of this axis remains unclear, since the library upgrade mechanism is centralised and marginally affected by user contributions. However, user questions are compiled and addressed in the library website forum, and the users and steering committees are consulted by the OASIS development head. During our ODUS experience, library bugs that slows down, sometimes prevents, the implementation of a coupled system, were reported. But their number is modest (less than a dozen), even though they could have there importance regarding to the overall reliability of the coupler and the trust that the community can award to it. Most of them are ready to be integrated to the next release. However, the inclusion of library deeper modifications (3D coupling, source maximum, single precision computations) is less certain.

Despite this restriction, that will have an importance for the future of the OASIS library, the ODUS experience has confirmed that both an ensemble of intrinsic properties and an ensemble of usages (which proceed from these intrinsic properties) allows to call our coupler a *community coupler*. In that multiple sense that (i) it is a widely spread tool for building (coupled systems), (ii) that this technical building must be done in a community, (iii) that the built product can be adapted to other needs for a larger community, (iv) that this sharing also propagated building techniques that also contributes to build an even larger community, (v) that finally forms a meta-community which participates to the tool enhancement.

3- Recommendations

The maintenance of the OASIS framework itself may be subject to a weakening in the years to come. The main CERFACS' contribution is languishing, and its planed partition from EU infrastructure projects will necessarily reduce the development and maintenance effort. We hope to have convinced the reader of the importance of maintaining a community coupler. In our opinion, this requires to focus our attention and some part of our working efforts in prospective actions.

Despite its evergreen community of users and its growing popularity, OASIS is materially relying on a code which is at risk. As previously emphasised, the endogenous code development by the community itself is the weak link in the chain of subtle actions and feedbacks that sustains the library success. Ways of empowering this feedback must be found to have a chance to adapt the code to our science evolution. But in case of failure, can the solution come from another coupling software developed in the community ?

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. This objectively contributes to divide and weaken a common effort, and to forever defer the possibility of a worldwide models interoperability. From now on, these softwares are devoted to the coupling of a dedicated number of models, following national or laboratory coopted criteria of choice. This latter promotes integrated coupled models, making practically impossible any change in the laboratory pre-defined module list. Some of these softwares, making use of object oriented languages, jeopardise their source openness. And to crown it all, a lingering trend towards high performance, which now verges on gigantism, darkens the climate model computing codes (computing oriented languages, opaque libraries, etc), thus their tied proprietary coupled libraries.

Though justified at short term, these *deliberate* choices denies some long term tendencies and recent scientific clarifications that should make us ruling such dangerous policies out :

1- It is now obvious that the CPU multi purpose era is ending and most of the computers and supercomputers available include specialised processors such as GPU [Thompson & Spanuth 2018]. This heterogeneity, and the short lifetime of this market guided hardware, necessarily suppose the adaptability and portability of our software and should prevent to orient the community corpus towards esotericism. At the opposite, a legible and simple coding syntax must facilitate the involvement of the climate scientists in their software library development and upgrading, including for couplers.

2- Despite the unquestionable media coverage of the Global Warming Issue, external societal trends strongly suggests that the expansion phase of our community is also behind us. The conjunction of the rarefaction of public investment to poorly profitable sciences[4], from one hand, but also from the now multi-decadal summons to energy savings and more recent stresses on raw material production, thus semiconductor industry, on the other hand, should stimulate more imaginative approaches of climate model development, less blindly grounded on cheap labour force and unlimited computing power.

3- Despite our thirst of explicit phenomena representation, tradeoff with parametrisation in climate models is not questionable, because of *the absence of any target resolution where one could argue that everything of interest to climate is resolved* [Balaji et al. 2022]. The race to more resolution, thus uncontrolled growth of computing resources, encouraged by GPU migration, is unsustainable, converges to make our codes and couplers opaque and reserved to a selected number of trustee laboratories. This finally sends most of our scientists away from their models understanding and evolution.

At the opposite, modularity that our community coupler brings can be the pivotal concept for sustainability. First because a standardly interfaced code is more easily shared or recycled, which should contribute to save labour force, if correctly organised. But modularity also makes the component choice more accurate, thus less expensive, by tuning (i) the number of component in the system, e.g. from GCM to ESM in [Séférian et al. 2019], (ii) the component complexity, e.g. full atmosphere model or simple boundary layer [Lemarié et al. 2021], or (iii) the component resolution, e.g. by coarsening the resolution of the BGC of the NEMO ocean [Maisonnave et al. 2021].

Metaphors can sometimes help to understand more quickly. So let forgive us the a priori strange comparison of the OASIS community coupler to the solution designed by [Dietel 1986] during times of more severe restrictions in the German Democratic Republic (GDR), and for a totally different purpose. Motorbikes conceived by this Bauhaus follower were built in such a way that the maintenance, the repairing and the component replacement (particularly in case of significative technical innovation) were facilitated. Focused on function, not fashion, the conception was combining standardisation (of the components) and variety of choice (of the overall system). Tunable, the vehicle was fitting the users needs at its best possible. Despite the unsteadiness of the GDR economy, it remained in production for decades and some specimen are still in use today[5].

This is this kind of modularity that a coupling library should reflect to make it more durable. For that, the involvement of the user in the model maintenance and evolution is of paramount importance. To face limitations that will totally redefine our working habits, an *Openness*. Rather than a *Weltanschauung* that self consistent systems implicitly carries. To avoid as much as possible preconceived ways of thinking, to facilitate implementation by and for scientists,

4 See e.g. in our community the growing importance of Climate Change impact and mitigation studies compared to model infrastructure support

5 Although one of our reviewers questioned the possibility to offer us a ride on one of these Bauhaus inspired motorbike which is rusting in his garage. "*Arcs triomphaux, pointes du ciel voisines / qui de vous voir le ciel même étonnez / Las, peu à peu cendre vous devenez / fable du peuple et publiques rapines !*"

this is what has to be constantly stimulated. To favour a practice, a pedagogy, instead of the passive use of an object, which maintenance is untrusted to its authors and which comprehension is more and more out of reach of its users. A practice is made possible by the modularity at the basis of the concept of community coupler, which facilitates module switch and comparison, freedom of choice, in the path of fulfilling true needs by the comprehension of means. A continuous back and forth between practice and theory founds, not a topic, but a *subject*: *manners* of defining climate complex systems and their module interfaces.

This idea makes possible to think a seamless poetics[6]-ethics-politics: a community coupler is the place where points of view are put together, and selected by the community itself in a visible process, through an informed self selection, in short, an ethical politics of scientific research. At the opposite of a Research of Prestige. A modernity, against all obscurantisms, and despite all difficulties. Though this latter was the only reason to do it, we would recommend to maintain, by any mean, our community coupler.

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6 "Poetics" to be understood in its classical sense of production of works

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