NEMO/neXtSIM-DG preliminary coupling interface

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Abstract

In this document, after having previously defined a new two-hemispheric grid in the NEMO ocean model, a preliminary OASIS interface implementation in the neXtSIM-DG global Eulerian grid sea ice model is described. In the perspective of comprehensive ocean-ice global long-term simulations, the ice model is ported on the Météo-France (MF) research supercomputer. The OASIS interface is added to the existing slab ocean routines of the neXtSIM-DG model, thanks to the new pyOASIS version of the library, including a C API. A simple one day long coupled simulations validates the first exchange and use of coupled quantities via OASIS between NEMO and neXtSIM-DG. However, several technical improvement are still missing, and the physically realistic atmosphere-ocean-ice (climate) configuration, which always requires a tuning of a magnitude that should never be underestimated is out of reach without a comprehensive extra human resource effort

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In the framework of the international SASIP[4] project, higher order finite element discretizations for the momentum equation and higher order discontinuous Galerkin (DG) methods for the advection are implemented [Richter et al. 2023] in the neXtSIM ice model [Rampal et al. 2016]. The OASIS [Valcke et al. 2021] coupling library was already used to interpolate field from/to the original Lagrangian grid to/from ocean models (e.g. with HYCOM in Maisonnave & Kjellsson 2021). In this project, a coupling with the NEMO model [Madec at al. 2008] is considered, taking into account the new characteristics of the neXtSIM-DG global Eulerian grid. In a first step [Maisonnave & Bourdallé-Badie 2022], the NEMO global model was split into two hemispherical grid models, with intention to follow the same spatial discretisation in the new DG ice model, so that no interpolation would be necessary at the ocean-ice interface and no complex boundary condition exchanges (coming with a full global tripolar grid) at model MPI sub-domain would be required in neXtSIM-DG.

In this document, the second step of this interface implementation is described: a first technical OASIS interfacing in neXtSIM-DG (chapter 1), followed by a short description of a preliminary coupled experiment (chapter 2).

1. neXtSIM-DG integration into a coupled system

A working version of the neXtSIM-DG model is made available by Bergen NERSC, in addition to a running environment, tested on the Norwegian UNINETT supercomputer. In the perspective of comprehensive ocean-ice global long-term simulations using NEMO-neXtSIM-DG and led by the CERFACS team, a porting of the ice model on the Météo-France (MF) research supercomputer (`belenos`) is set up.

1.1 Running on MF machine

Even though a full compiling environment is provided by MF, like on many other supercomputing facilities, several usual C++ related libraries are missing from the list, mainly because C++ is not the main programming language of the MF users community.

For that reason, some extra effort was required from the MF administration to install, with the appropriate compiler version (Intel 2018.5.274), the `boost` library. `Eigen` was already available, the same for the C++ compatible version of the `netCDF` file handling library. Notice that a comprehensive modification of the `Cmake` configuration file was required, because of the MF library installation procedure misfit with this unusual compiling toolkit. For similar reasons, a header of the `catch2` library has to be manually added to the model directory.

4 https://sasip-climate.github.io

1.2 OASIS interface

The last missing piece was the OASIS coupling library itself, already installed in `belenos`, but never used here for his C language interface. In previous successful attempts, the new set of Python/C API was implemented: in an interpolation file generator [Maisonnave 2022] or in machine learning small scales predictors. For the needs of our work, the pyOASIS version of the library is generated and linked to the neXtSIM model using the C API, while the FORTRAN API is used to call, as usual, the OASIS routines in the NEMO model.

The most time consuming work lies of course on the design of the OASIS interface in the neXtSIM-DG model. An OASIS interface already exists in the Lagrangian model, but a brand new implementation is necessary here to fit the new parallelisation (fully parallel exchanges) and DG discretisation requirements. The starting point is the current slab ocean configuration of the code. We duplicate here the use of arrays coming/going from/to the slab ocean by arrays going/coming to/from the NEMO ocean via the OASIS interface. This modified slab ocean version is published in a special branch of the `github` neXtSIM-DG repository[5]. Notice that the `netCDF` file that defines the slab ocean grid[6] also defines the ice model grid. Our initial technical test occurs on a simple coarse rectangular grid which covers the Arctic region. In theory, it would be possible to generate the model prognostic variables and geographical coordinates on a ORCA grid (final target of our work) by modifying the `init_topaz128x128.py` building script. But it would also necessary to produce the atmosphere boundary conditions and slab ocean damping variables by modifying the `era5_topaz4_maker.py` script. In this intermediate step of our implementation, we prefer to avoid the interpolation definition in this preparatory phase and use a discretisation that is not the final one (the ORCA hemispherical grid), by letting OASIS perform the interpolation at runtime.

In an initialisation step, the OASIS communications are setup[7]. The OASIS coupling definition is done during the slab ocean variable initialisation[8]. In the slab ocean array update routine[9], not all the coupling quantities that NEMO requires are available (wind stress components and module, E-P, salt, solar and non solar fluxes, ice fraction). Zeros are sent to the ocean model if the information is not available at this stage (this is currently the case except for E-P, non solar flux, wind stress module and ice cover). On the other way round, sea surface temperature and salinity are received from NEMO[10]. A termination signal is finally sent to the coupler on the same main routine than for communication setup.

1.3 NEMO component

The NEMO model code does not require any modification. Thanks to its parametric interface,

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5 `issue240_oasis_interface` branch

6 `run/init_topaz128x128.nc`

7 `oasis_c_init_comp` in `core/src/main.cpp`

8 `oasis_c_def_partition`, `oasis_c_def_var` & `oasis_c_enddef` in `physics/src/SlabOcean.cpp (SlabOcean::setData)`

9 `SlabOcean::update`

10 They replace the existing `sstSlab` and `sssSlab` values

the same `namelist` fits, for the moment, both SI3 and neXtSIM-DG external coupling requirements. Adjustments should be easy when realistic experiments will start. The NEMO configuration we use comes from the definition of the two hemisphere grid experiments (4.0.6 release). For the purpose of this technical setup, the whole global ORCA2 grid is used, but a switch to the two-hemisphere configuration will only require changes in NEMO input files (already available and successfully tested with SI3) and OASIS parametrisation (`namcouple` file, to be easily modified).

2. Coupled experiment

2.1 OASIS files setup

A coupled experiment is launched on `belenos` (MPI MPMD mode, neXtSIM-DG on a single process). Due to the geographical extension mismatch between the neXtSIM slab ocean grid (Arctic region) and the NEMO global ORCA2 grid, the internal SCRIP interpolation package is required to ensure that a value is provided to all the non masked grid point of the two models. In that purpose, grid descriptions have to be provided to the coupler (auxiliary files), which come from the NEMO `meshmask` file in one hand and from the neXtSIM slab ocean grid definition on the other hand.

2.2 First results

As mentioned, some coupling fields required by the ocean model were not provided (zeroed) or exaggeratedly extrapolated outside the Arctic region, which rapidly lead to fatal inconsistency in the model. However, it was possible to check that the surface variables were correctly received and used (then output by the model) in neXtSIM (see Figure 1).

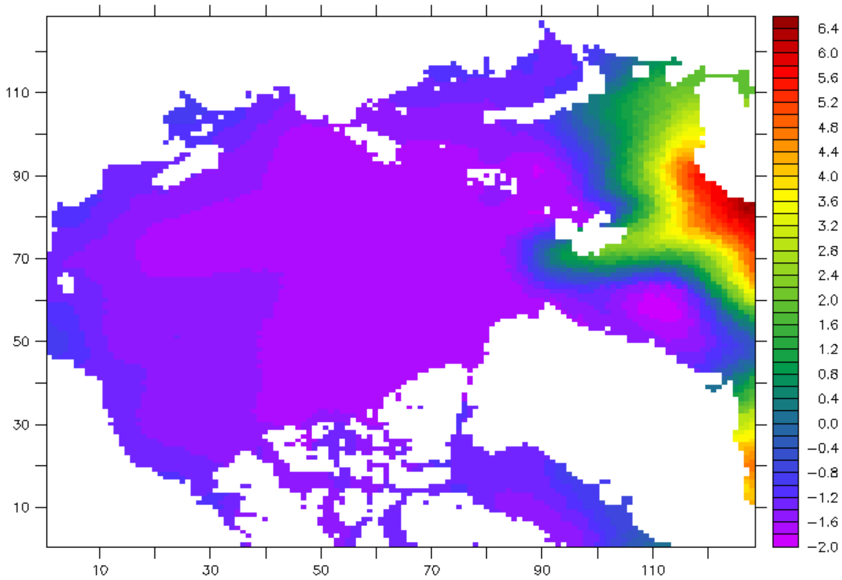

Figure 1 : NEMO sea surface temperature (C°) coupling field as seen on neXtSIM-DG regular 128x128 regional Arctic grid, as simulated after a one day integration (one way coupling)

Again, in the ice model, the mismatch between the two coupled quantities (SST and SSS) and the other forcing variables of the slab ocean quickly leads to produce unrealistic values. But we now can say that coupled quantities exchanges via OASIS between NEMO and neXtSIM-DG are possible, what was the main goal of this work.

3. Next steps

Several changes are now necessary to make neXtSIM-DG ready for a short realistic coupled simulation with our ocean model. The missing quantities have to be defined and provided to the OASIS interface. In that perspective, quantities only used by the still in progress dynamical core would have to be temporarily provided to the slab ocean. In a second step, the computations of the slab ocean should be avoided and a proper module developed to define an OASIS interface only in these routines. The question of the grid definition (deduced from a dedicated file or NEMO input ?) is still open. At this stage, the use of the two (or even only one) ORCA hemisphere grid would have the advantage to avoid any interpolation error. A single Arctic grid would fit our minimal need, assuming that the Southern Hemisphere zone could be covered by the existing SI3 model.

After this last technical improvements, even without dynamics and MPI parallelisation, the ice model would be ready for starting the painful work of parametrisation in coupled mode. A start, without presuming of the number of the following steps. CERFACS and NERSC technical staff are gathering the necessary knowledge and working force to modify their current stand-alone implementations of neXtSIM-DG and NEMO and achieve a technically fitted coupled configuration. But needless to say that a physically realistic atmosphere-ocean-ice (climate) configuration, which always requires a tuning of a magnitude that should never be underestimated [Hourdin et al. 2017], is out of reach without a comprehensive extra human resource effort.

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