REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Germany

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Project Title:

DECK Simulations with an alternative EC-Earth v4 prototype based on OpenIFS-43r3 coupled to FESOM2

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _____
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020
Would you accept support for 1 year only, if necessary?	YES ☒ NO ☐

Computer resources required for 2020-2022: (To make changes to an existing project please submit an amended version of the original form.)		**2020**	**2021**	**2022**
High Performance Computing Facility	(SBU)	25.000.000		
Accumulated data storage (total archive volume)[2]	(GB)	5.500		

Continue overleaf

1The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

Jan Streffing
DECK Simulations with an alternative EC-Earth v4
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June 27, 2019

1 Scientific plan

The proposed experiments would serve as a benchmark and validation of an alternative prototype version of the next generation earth system model EC-Earth v4. After the successful completion of the special project the published results would qualify the newly developed coupled configuration of EC-Earth v4 containing the Finite VolumE Sea-ice Ocean Model (FESOM2) to answer advanced scientific questions.

Status quo   Quite a number of projects use the current EC-Earth v3, which is based on IFS cy36r4 coupled to NEMO 3.6 for decadal to millennial climate prediction. For ease of licensing and to stay more up do date with model improvements developed at the ECMWF, the EC-Earth community has decided to adapt OpenIFS, first cy40r1 then cy43r3, as the atmospheric component of EC-Earth v4. The Alfred Wegener Institute is currently using AWI-CM, based on the Finite Element Sea-ice Ocean Model (FESOM-1.4) coupled to ECHAM6, for the majority of it's scientific computing. Because the end of the development cycle for ECHAM6 approaches with CMIP6, AWI has been looking to couple it's next generation OGCM FESOM2 to another AGCM for a while. Within the new and more flexible legal framework the EC-Earth community has chosen to implement a new modular technical coupling framework into OpenIFS. The Climate Science Department of the AWI has followed this development with interest and subsequently coupled the FESOM2 to the EC-Earth-modified version of OpenIFS cy40r1. First results of this coupled model, such as figure 1 were shown at the EC-Earth meeting in Lisbon 2018 [1].

FESOM2   FESOM2 is an unstructured mesh OGCM which employs a finite volume dynamical core and is formulated using the arbitrary Lagrangian Eulerian (ALE) vertical coordinate [2]. Unstructured mesh ocean models provide the possibility to locally increase resolution in areas of high interest without nesting a regional model. They also allow for more complex approaches such as mesh resolution following the local Rossby radius [3] or sea surface hight variability [4]. FESOM2 is one of the first unstructured mesh ocean models where such flexibility no longer comes at the price of state of the art computational performance [5]. The time to solution for a given number of wet surface nodes and processors is similar to that of NEMO. Having one structured

and one unstructured ocean model available under the umbrella of EC-Earth widens the range of scientific questions that can be explored with the earth system model.

Towards the start of the project While the EC-Earth community has in the past years mainly focused their attention on the CMIP6 version of EC-Earth v3, some work has been done with OpenIFS cy40r1 already, including implementation of the OASIS3MCT coupling interface, a CMIP6 greenhouse gas and solar forcing reader, and of code to modify the solar insolation based on orbital parameters. These efforts are currently being ported from OpenIFS cy40r1 to cy43r3 before test runs can begin. OpenIFS cy43r3 v0.9 has been shown to compile and run as standalone on CCA. Once the stability of the new coupled model has been proven and the sensibility of the results of decadal climate prediction runs has been established, the model is ready to be put through it's paces and complete the proposed experiments.

2 Experiments and required resources

The Diagnostic, Evaluation and Characterization of Klima (DECK) simulations by design serve as the entry card for coupled climate models into CMIP6. Here they shall serve as the entry card of the alternative EC-Earth v4 configuration with FESOM2 into scientific service. Therefore three of the four DECK experiments [6], as well as a historical run shall be performed. The AMIP experiment is not planned here, since the standalone OpenIFS 43r3 atmosphere will likely be thoroughly tested by other members of the EC-Earth community. The full list of experiments together with the projected SBU cost is shown in Table 2.

Planned experiments The pi-control run would serve as a spinup to ensure that the upper and some degree the middle layers of the ocean are in equilibrium. The analysis done on the pi-control run would focus on the description of inherent model biases compared to reanalysis data as well as natural variability patters (stability & strength of AMOC & ACC, ENSO & NAO frequency and extends). Thus these can verify whether the model behaves in a sensible way and quantify the impact of natural variability on the results of future experiment setups. The historical, abrupt-4xCO_2 and the 1%-CO_2 runs would initialize from the final restart files of the pi-control experiment.

The abrupt-4xCO_2 experiment can be used to quantify the fast responses of the model and to determine the equilibrium climate sensitivity (ECS) of the coupled system. Preliminary results of CMIP6 have shown an increase of ECS in many of the participating models when compared to their respective CMIP5 versions. EC-Earth v3 also exhibits this behaviour when compared to EC-Earth v2, putting an additional focus on this run.

The experiment with 1%-CO_2 increase per year is a standardized setup to measure the transient climate response (TCR) to an idealized gradual CO_2 increase and has been performed ever since CMIP2.

The historical run would determine whether the OpenIFS43-FESOM2 configuration of EC-Earth v4 can accurately reflect the historical transient climatic behaviour as observed directly during the years from 1850 to 2014. Key parameters to analyze are the global mean surface temperature rise, opposing sea ice area developments in northern and southern hemisphere as well as tropical precipitation patterns.

Exp. Name	Type	Length [y]	SBU	Data[TB]
Pi-Control	Equilibrium	500	12500000	2.750
Historical	Transient	164	4100000	0.902
Abrupt-4xCO$_2$	Equilibrium	150	3750000	0.825
1%-CO$_2$	Transient	150	3750000	0.825
Sum		964	24100000	5.302

Table 1: Experiments and computational resources

Required resources The exact number of required SBUs per year of coupled simulation are as of yet unknown, so OpenIFS cy40r1 - FESOM2 CORE2 values are standing in for cy43r1. The OpenIFS development team stated in conversation that the T$_{co}$159L91 grid for c43r3 is approximately 1.5 as costly to run as T$_l$255L91. Previous special project applications estimated EC-Earth v3 T255L91 - ORCA1 to use between 16.600[7] and 19.500[8] SBUs per simulated year. The computational cost of the FESOM2 CORE2 mesh is comparable to NEMO ORCA1L75 so the cost of the new coupled setup are estimated at 25.000 SBU/Year. Experiments with cy40r1 T$_l$255L91 coupled to FESOM2 CORE2 after post-processing occupied 5.5 GB of disk storage per year. Between the lower resolution spherical harmonic and the higher resolution grid point output T$_{co}$159L91 should have similar data storage requirements. The calculated requirements have been endued with a small ~4% safety margin for testing and crashed runs and well as uncertainties about actual cost leading to the requested 25 MSBU and 5.5 TB.

3 Relevance to ECMWF

The validation of the alternative version of EC-Earth v4 containing FESOM2 would increases the potential user-base OpenIFS. AWI is already loosely cooperating with the Stockholm University to implement stable water isotopes in OpenIFS. Efforts in this direction could be intensified with a fully tested coupled model containing FESOM2.

At times it is not at all clear if a modelled behaviour stems from the particularities of a statistical parameterization in ocean or atmosphere, might be rooted in model resolution of either component, or even indicative of a bug in either code base. For the EC-Earth community a coupled and validated second ocean model would allow experiments that can determine the origin of biases and errors in a rapid small model component intercomparison. For example EC-Earth v3 exhibits a bi-stability in the pi-control experiments regarding deep-water formation in the Labrador Sea. Depending on whether a check experiment with a second ocean model shows similar behaviour, the root cause can either be traced to OpenIFS or common ocean features on one hand, or determined to be in a specific ocean model or the other. Such experiments could lead to improvements of all model components, but first require a buildup of trust in the new coupled configuration.

In a separate project, FESOM2 has been inserted as a subroutine into the finite volume prototype of the integrated forecast system IFS-FVM. These two radically different coupling strategies, single executable vs modular OASIS3MCT coupling will become subject of future research at AWI.
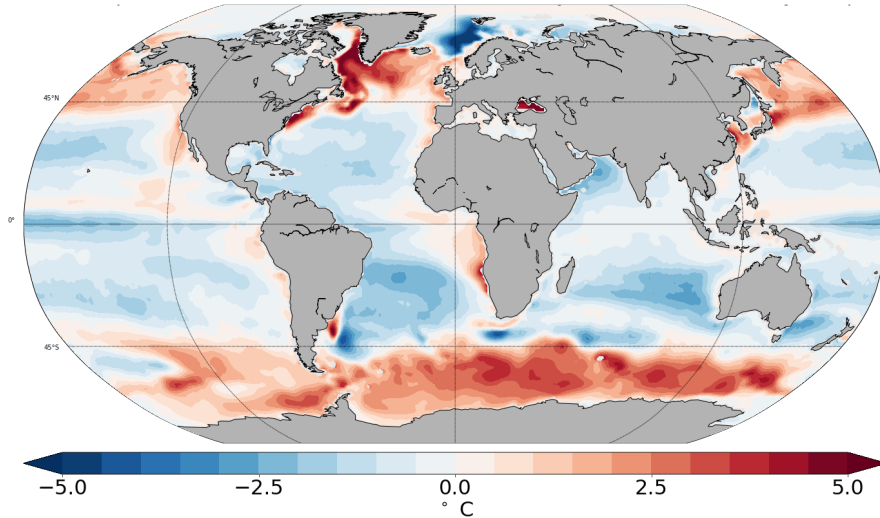
Figure 1: 20 year mean of SST bias against PHC3 after 130 year spinup of OpenIFS cy40r1 T_l255L91 - FESOM2 CORE2. The coupled model was forced with pre-industrial greenhouse gas conditions.

4 Fallback options

Should OpenIFS cy43r3 against current estimates of a release in August 2019 not be ready for centennial coupled simulations at project start, it is possible to run the described experiments with OpenIFS cy40r1 coupled to FESOM2. Preliminary results from a shorter 150 year pi-control run of this configuration are already available. Figure 1 shows the last 20 year mean SST bias of this configuration compared to PHC3 ocean temperatures. Should the computational cost estimation for cy43r3 T_{co}159L91 from section 2 be substantially too low, the cost-wise better constrained T_l255L91 could be used instead. In case the data storage requirements have been underestimated, it is possible to modify the post-processing to store fewer vertical levels of 6hourly 3D data, the main driver of storage volume.

References

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