REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: SWEDEN.……...…

This form needs to be submitted via the relevant National Meteorological Service.

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Project Title:

EC-Earth in CMIP6 (SPSEECCMIP)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPNLTUNE**	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2020:
(To make changes to an existing project please submit an amended version of the original form.)

		2018	**2019**	**2020**
High Performance Computing Facility	(SBU)	50000000	60000000	50000000
Accumulated data storage (total archive volume)[2]	(GB)	70000	140000	140000

An electronic copy of this form must be sent via e-mail to: *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

June 29, 2017……

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

[2] 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.

Continue overleaf

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Extended abstract

The Earth System Model EC-Earth needs further tuning of the physical and earth system components in various configurations. New tuning targets are, among others, teleconnection patterns. After the tuning, models configurations need to run a standardised set of simulations with idealized forcing and with historical forcing. Those runs will be a precondition for participation in Model Intercomparison projects under the umbrella of the Climate Model Intercomparison Project (phase 6).

Scientific plan

The Earth System Model (ESM) EC-Earth has been developed during the last three years with the goal to run Climate Model Intercomparison Project (CMIP6) simulations. EC-Earth is based on the ECMWF system 4 seasonal prediction system (IFS cy36r4) and has been adjusted to run as a climate model, using the capacities of ECMWF HPC resources during 2015-2017 under the SPNLTUNE project. A paper describing tuning of EC-Earth for CMIP6 is in preparation.
During 2017, a well-tuned Earth-System-Model in its GCM configuration (atmosphere, ocean, sea ice) is to be expected. Starting late 2017 and early 2018, the EC-Earth consortium will carry out simulations within the framework of the Coupled Model Intercomparison project (CMIP6) including the mandatory DECK simulations and several Model Intercomparison Projects (MIP) simulations. Throughout 2018, tuning of ESM configurations will be carried out and applied during 2019 and 2020. Long coupled runs of ESM-coupled model configurations will be needed.
As a longer term activity, EC-Earth will start developing a future version of the EC-Earth system.

The major objectives of this special computing project are

- to tune several ESM configurations of EC-Earth
- to run DECK simulations with selected configurations
- to run a choice of MIP simulations
- to develop a future version of the EC-Earth system based on OpenIFS

Tuning GCM and ESM configurations:

Tuning efforts for EC-Earth so far have focussed mainly at AMIP tuning of the standard and high-resolution versions of the model and initial tuning of long coupled runs at standard resolution. The focus has been energy and mass conservation in the model and achieving realistic radiative fluxes (TOA and surface, cloud forcing). The next three years will see the need for re-tuning the full coupled model with all final CMIP6 forcing fields finally available. In particular a series of long coupled model runs will need to be performed at standard and at high resolution, in preindustrial and present-day runs, in order to tune the equilibrium surface temperatures and the climatology of wide range of other fields of interest. Additionally tuning efforts will be aimed at verifying and possibly improving the physical model's ability in representing realistic spatio-temporal variability, such as QBO, ENSO, teleconnection patterns, regimes, northern hemispheric blocking and troposphere-stratosphere coupling.

In addition to the physical (GCM) model, including atmosphere, land surface and the ocean/sea-ice system, specific model tuning will be needed for all the new Earth-System configurations of EC-Earth which are being implemented in the framework of CMIP6. The planned EC-Earth configurations are:

Model configuration	description
EC-EARTH3:	IFS cy36r4 NEMO 3.6 LIM3 (T255L91/ORCA1L75)
EC-EARTH3-HR:	EC-EARTH3 at high resolution (T511L91/ORCA025L75)
EC-EARTH3-LR:	EC-EARTH3 at low resolution (T159L62/ORCA1L75)
EC-EARTH3-CC:	EC-EARTH3 with coupled carbon cycle (IFS+NEMO+TM5+LPJ-GUESS+PISCES)
EC-EARTH3-CC-LR:	EC-EARTH3 with coupled carbon cycle at low resolution (IFS+NEMO+TM5+LPJ-GUESS+PISCES)
EC-EARTH3-GrIS:	EC-EARTH3 with coupled Greenland ice sheet model (IFS+NEMO)
EC-EARTH3-AerChem:	EC-EARTH3 with interactive aerosols and atmospheric chemistry (IFS+NEMO+TM5)
EC-EARTH3-Veg:	EC-EARTH3 with interactive vegetation module (IFS+NEMO+LPJ-GUESS)

For each of these configurations a specific tuning effort will be necessary, with different protocols. For example for high-resolution tuning (which has already started), shorter runs of 50 years in given reference periods (fixed-year 1950) are being used to achieve, through the use of Gregory plots (net fluxes vs. surface temperature), an estimate of reasonable net equilibrium fluxes at the ocean surface for that period and a realistic equilibrium ocean temperature.

The model configurations including LPJ-Guess will require specific tuning to make sure that changes in the land-surface component (albedo, roughness) still provide realistic energy fluxes and pre-industrial equilibrium temperatures, both through modifications of the atmospheric tuning parameters and through adjustments of parameters in the routines mapping LPJ-Guess vegetation to HTESSEL vegetation types.

Introduction of interactive aerosols and chemistry with TM5 will also require specific re-tuning of the model's atmosphere. A limited set of tuning experiments will therefore be performed with EC-Earth3-AerChem in atmosphere-only configuration, both for pre-industrial and present-day conditions. The focus of these runs is 1) to get a net energy flux at the ocean surface sufficiently close to zero, when pre-industrial conditions (incl. SSTs) are applied, and 2) to obtain realistic global mean surface and TOA energy fluxes and optimize climate performance indices under present-day conditions.

Running DECK and historical simulations with selected model configuration

Participation in CMIP6 requires standardized simulations that characterize the specific model. "Diagnostic, Evaluation and Characterization of Klima" (DECK) experiments (Eyring et al. 2016) will be carried out for each model configuration. The DECK comprises four baseline experiments including a historical atmosphere-standalone simulation, a pre-industrial control simulation, a simulation forced by an abrupt quadrupling of CO2 and a simulation forced by a 1 % yr −1 CO 2 increase. CMIP also includes a historical simulation from 1850 to the present.

MIP simulations

The EC-Earth consortium plans to participate in the majority of MIPs. In SPSEECCMIP we focus on a limited selection:

- ScenarioMIP: This MIP is the primary activity within CMIP6 that will provide multi-model climate projections based on alternative scenarios of future emissions and land use changes (O'Neill et al., 2016). EC-Earth plans to carry out tier-1 simulations of four different Shared Socio-economic Pathways (SSPs) including one SSP with a ensemble 9 members at the most

- DAMIP: The primary goals of the Detection and Attribution Model Intercomparison Project (DAMIP) are to facilitate estimation of the contributions of anthropogenic and natural forcing changes to observed global warming to contribute to the estimation of how historical emissions have altered and are altering contemporary climate risk; and to facilitate improved observationally constrained projections of future climate change (Gillet et al., 2016)

OpenIFS

The EC-Earth consortium has decided to integrate OpenIFS based on IFS cycle 43r1 as the future atmospheric model component into their next generation ESM. Work on the implementation of OpenIFS into the EC-Earth framework will be intensified during 2018 and 2019. The ability to perform long climate simulations, the infrastructure for coupling OpenIFS to other ESM components, and interfaces for reading CMIP6 climate forcing data are necessary extensions to be implemented in OpenIFS. The new model version will undergo thorough testing and tuning in atmosphere-only, atmosphere-ocean coupled and full ESM configurations, for different spatial resolutions. The goal at the end of the project is to repeat CMIP6 DECK simulations and possibly a few selected scenarios from ScenarioMIP with the new model system. An important aspect will be the analysis and improvement of the model's computational performance, particularly for high resolution configurations and on massively parallel systems.

Justification of the computer resources requested

Most simulations included in this project will be carried out with the GCM version of the model (EC-Earth3). The costs associated with this model version is estimated around 30 and 22 kSBU per simulation year for the coupled atmosphere-ocean and atmosphere-only configurations, respectively.

The overall tuning effort is estimated to take 1000 simulated years (coupled) + 450 years (AMIP), corresponding to a cost of about 40 MSBU

The DECK experiments, comprising a long pre-industrial control, an AMIP and a two climate sensitivity experiments totals in 910 simulation years. The entry card for CMIP6 is a historical simulation (156 yrs) which will then be followed by climate scenario experiments (95 yrs). Four different socio-economic scenarios with different climate forcing are requested for Tier 1 of ScenarioMIP which results in 156+(4*95)=536 simulation years. We plan to do at least 3 members of the historical and of one specific scenario simulation (SSP3/7) to capture the climate variability. The grand total (DECK+historical+ScenarioMIP) becomes then (910+536+(2*156)+(2*95) = 1948 simulated years, requiring approximately 58 MSBU.

The corresponding coupled atmosphere-ocean simulations are part of DAMIP (Gillett et al., 2016). Also for DAMIP, three-member ensembles are requested. The tier-1 historical simulations of DAMIP (hist-nat, hist-GHG, and hist-aer), which cover the period 1850-2020, amount to a total of 1539 simulation years or ca. 46 MSBU. These simulations are planned for 2020.

For the development of the OpenIFS-based version of EC-Earth, we estimate an initial need of 500 simulated years, corresponding to 15 MSBU

Technical characteristics of the code to be used.

The EC-Earth system consists of the atmosphere model IFS cy36r4 (including the land surface model H-Tessel), the ocean model NEMO3.6, the sea ice model LIM3 and optional models for atmospheric composition, dynamical vegetation, ocean bio-geo-chemistry and for the Greenland ice sheet. The component models are coupled via the OASIS-MCT coupler. The system is configured for several HPC systems including CRAY XC-40, such as installed at ECMWF.

The IFS, being a major EC-Earth component, has been developed at ECMWF and is extensively tested and optimised for the Centre's machines, a performance advantage that carries over to the EC-Earth model. Furthermore, the EC-Earth consortium has been using ECMWF's Cray systems (as well as similar platforms at other institutions) in the past to analyse and optimise the computational performance of the coupled configurations, which have shown very good scalability and efficiency.

References

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937-1958, doi:10.5194/gmd-9-1937-2016, 2016.

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O'Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.-F., Lowe, J., Meehl, G. A., Moss, R., Riahi, K., and Sanderson, B. M.: The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6, Geosci. Model Dev., 9, 3461-3482, doi:10.5194/gmd-9-3461-2016, 2016.