REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: Netherlands

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Project Title: EC-Earth climate simulation for AerChemMIP

If this is a continuation of an existing project, please state the computer project account assigned previously.		
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2017	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2015.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(units)	38,000,000	41,000,000	23,000,000
Data storage capacity (total archive volume)	(gigabytes)	40,000	41,000	29,000

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): 21 June 2016

Continue overleaf

[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.

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Within this special project, we will carry out climate simulations with the global climate model EC-Earth within the context of the Coupled Model Intercomparison Project Phase 6 (CMIP6). The simulations will be done with a model configuration with interactive aerosols and atmospheric chemistry, and will be part of the consortium's contribution to the Aerosols and Chemistry Model Intercomparison Project (AerChemMIP). The set of simulations will also include a selection of the CMIP DECK simulations (Diagnostic, Evaluation and Characterization of Klima) and the CMIP6 historical simulation for this model configuration.

Motivation

AerChemMIP is one of the 21 model intercomparison projects (MIPs) endorsed within CMIP6. The goal of AerChemMIP is to analyse the role of near-term climate forcers (NTCFs) and chemically reactive well-mixed greenhouse gases (WMGHGs) in past and future climate change. The set of NTCFs includes aerosols and ozone (O_3), and their precursors, and some halogenated species that are not WMGHGs. Reactive WMGHGs are nitrous oxide (N_2O) and various halogenated species. Methane (CH_4) is considered both a NTCF and a reactive WMGHG. AerChemMIP will contribute to CMIP6 by 1) diagnosing forcings and feedbacks involving these species, 2) documenting and understanding past and future changes in the chemical composition of the atmosphere, and 3) estimating the global-to-regional climate response from these changes. EC-Earth is one of the models participating in this MIP.

Model configuration

The modelling system used in this special project will be the CMIP6 version of EC-Earth with interactive aerosols and atmospheric chemistry. EC-Earth is a global climate model developed by a European consortium of climate research institutes (Hazeleger et al., 2010; 2011). EC-Earth 3, the latest version of the model, consists of an atmospheric circulation model based on ECMWF's Integrated Forecasting System (IFS) cycle 36r4, the NEMO3.6 ocean model, which also includes the LIM3 sea ice model, and the Cama-Flood run-off mapper. Aerosols and atmospheric chemistry are described using two-way coupling to TM5. Other Earth system components that have been integrated in EC-Earth, like dynamic vegetation, marine biogeochemistry, the carbon cycle, and ice sheets, will not be used for AerChemMIP. An earlier version of the IFS-NEMO-TM5 configuration has been described and evaluated by Van Noije et al. (2014). For AerChemMIP, the model will be run with the following component resolutions: T255 with 91 levels for IFS, ORCA1 with 75 levels for NEMO, and 3x2 degrees (longitude x latitude) with 34 levels for TM5. The exchange between the different components takes place through OASIS3-MCT.

The TM5 version used for AerChemMIP includes an advanced description of tropospheric aerosols as well as a comprehensive tropospheric chemistry scheme (see Van Noije et al., 2014 for details). Direct and indirect radiative effects of tropospheric aerosols in IFS will be calculated based on optical properties as well as mass and number concentrations simulated by TM5. Likewise, the radiative effects of tropospheric ozone will be based on concentrations simulated by TM5. The representation of stratospheric chemistry in TM5, on the other hand, is fairly limited. Stratospheric ozone will be largely imposed using the CMIP6 ozone concentration data set. The model can therefore not be used to analyse the role of stratospheric ozone depleting substances (ODS).

Work plan and simulations

The EC-Earth consortium has committed to the 1st tier of AerChemMIP simulations,[2] with the exception of those relating to the role of ODS. Participation to AerChemMIP also requires that the DECK and CMIP6 historical simulations will be carried out with the same model configuration. So far, three partners from the consortium, viz. KNMI, FMI and Helsinki University, have signed up for these simulations. According to the current plan, the computations will be about equally shared among these three institutes. Below we give an overview of the planned simulations, together with the estimated simulation length in number of years and storage requirements. Table 1 shows the coupled atmosphere-ocean simulations, table 2 the atmosphere-only simulations. The columns indicate the years in which the various simulations are expected to be carried out.

Table 1. Planned coupled atmosphere-ocean simulations

	2017	2018	2019
DECK (shared)			
Pre-industrial control	500 yrs / 57 Tb	-	-
Abrupt quadrupling of CO_2 concentration	-	-	150 yrs / 17 Tb
1% yr^{-1} CO_2 concentration increase	-	-	150 yrs / 17 Tb
Other (KNMI)			
CMIP6 historical simulation (1850-2014)	165 yrs / 17 Tb	-	-
HISTghg, Historical WMGHG concentrations, 1850 NTCF emissions (1850-2014)	-	165 yrs / 15 Tb	-
NTCFRESPSSP3-7, Reference: SSP3-7 (2015-2055)	-	-	41 yrs / 5 Tb
NTCFRESPSSP3-7ntcf , Perturbation: SSP3 with reduced NTCF (2015-2055)	-	-	41 yrs / 5 Tb
WMFORCch4, Same as CMIP6 historical but with CH4 at 1850 AOGCM (1850-2014)	-	165 yrs / 15 Tb	-
Estimated total (KNMI)	332 yrs / 36 Tb	330 yrs / 30 Tb	182 / 22 Tb

[2] http://www.wcrp-climate.org/images/modelling/WGCM/CMIP/CMIP6_ConsolidatedExperimentList_150408_Sent.xls

Table 2. Planned atmosphere-only simulations

	2017	2018	2019
DECK (KNMI)			
AMIP (1979-2014)	36 yrs / 4 Tb	-	-
AerChemMIP (shared)			
RFDOCcntrl, Perturbation from 1850 control using 1850 aerosol and ozone precursor emissions (1850)	-	20 yrs / 3 Tb	-
RFDOCntcf, Perturbation from 1850 control using 2014 aerosol and ozone precursor emissions (1850)	-	20 yrs / 3 Tb	-
HISTsstghg+ntcf1850, Historical WMGHG concentrations, 1850 NTCF emissions (1850-2014)	-	165 yrs / 14 Tb	-
HISTsstghg+ntcf+hc1950, Historical WMGHG concentrations and NTCF emissions (1950-2014)	-	65 yrs / 6 Tb	-
NTCFRESPcntrl, Control: SSP3-7 using SST from NTCFRESP-SSP3-7 (2015-2055)	-	41 yrs / 5 Tb	-
NTCFRESPbc, Perturbation: Only black carbon emissions as in NTCFRESP-SSP3-7ntcf (2015-2055)	-	-	41 yrs / 5 Tb
NTCFRESPnox, Perturbation: All aerosol precursor emissions (but not NOx) as in NTCFRESP-SSP3-7ntcf (2015-2055)	-	-	41 yrs / 5 Tb
NTCFRESPo3, Perturbation: All ozone precursors except methane kept the same as in NTCFRESP-SSP3-7ntcf (2015-2055)	-	-	41 yrs / 5 Tb
NTCFRESPo3Cch4, Perturbation: All ozone precursors kept the same as in NTCFRESP-SSP3-7ntcf (2015-2055)	-	-	41 yrs / 5Tb
Estimated total (KNMI)	36 yrs / 4 Tb	104 yrs / 11 Tb	55 yrs / 7 Tb

Explanation of the requested resources

To estimate the computational resources needed for this project, we have performed a number of test simulations on the CCA Cray XC30 system. These simulations indicate that, for the EC-Earth configuration to be applied in this project, the optimal balance between computational performance and costs is obtained using 144 CPUs for IFS and 45 for TM5, and in addition 72 CPUs for NEMO in atmosphere-ocean coupled mode. With these numbers of CPUs, a one-year simulation costs about 55 kSBU in atmosphere-only mode and 106 kSBU with coupled ocean. Multiplying these estimates with the total number of simulation years planned in the different years of the project, we arrive at the SBU numbers indicated in the table above.

Note, however, that these numbers are based on test runs performed on CCA with the Intel compiler, and with the Intel Ivy-Bridge processor technology. A recent performance analysis by Boussetta et al. (2016) has shown that “the use of the Cray compiler can result in an increase in the system performance up to 34%”, with an average of 17% for the standard EC-Earth model. Due to the limited amount of cores that IFS and NEMO can efficiently use when coupled to TM5, the potential gain for our project is more likely to be about 10%. The standalone TM5 model also performs better with the Cray compiler: preliminary tests on the new Cray-Broadwell architecture show a speed up of 8% for a decrease in SBU of 8%.

Boussetta et al. (2016) also mention that EC-Earth can profit from a forking configuration, where idle cores are avoided. This is even more important when coupling to TM5, since the amount of idle cores in a standard (i.e. non forking) configuration is proportionally larger than in the GCM model. Although forking is still being tested, the TM5 coupled configuration is likely to benefit from the 7% SBU decrease being reported.

To summarize, switching to the Cray compiler leads to performance increases in GCM (10%) and in TM5 (7%). The promising forking configuration could bring an additional 7% improvement. All combined, we can reasonably lower our request by 15%.

The data storage amounts indicated in the tables are estimates based on the CMIP6 data requests and software tools published by the WGCM Infrastructure Panel.[3] We applied these tools to estimate the amount of data corresponding to the output requested for the various simulations at the resolutions of the EC-Earth model configurations.

[3] https://earthsystemcog.org/projects/wip/CMIP6DataRequest

References

Boussetta, S., C. Simaro, and D. Lucas, Exploring EC-Earth 3.2-Beta performance on the new ECMWF Cray-Broadwell, ECMWF Technical Memorandum No. 779, 2016.

Hazeleger, W., et al. (2010), EC-Earth: A seamless Earth-system prediction approach in action, Bull. Amer. Meteor. Soc., 91, 1357-1363.

Hazeleger, W., et al. (2011), EC-Earth V2.2: description and validation of a new seamless earth system prediction model, Clim. Dyn., 10.1007/s00382-011-1228-5.

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