REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE: Finland

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Project Title: AerChemMIP aerosol-specific simulations with EC-Earth

If this is a continuation of an existing project, please state the computer project account assigned previously.	spfiodon	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2019	
Would you accept support for 1 year only, if necessary?	**YES** ☒	NO ☐

Computer resources required for 2019-2021: (To make changes to an existing project please submit an amended version of the original form.)		**2019**	**2020**	**2021**
High Performance Computing Facility	(SBU)	30 500 000	27 400 000	20 300 000
Accumulated data storage (total archive volume)[2]	(GB)	57 000	104 000	138 000

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): 28 June 2018…………………………

Continue overleaf

Principal Investigator: Dr. Declan O'Donnell

[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.

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Extended abstract

Commented [HK1]: *All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.*
Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).
Following submission by the relevant Member State the Special Project requests will be evaluated by ECMWF as well as the Scientific and Technical Advisory Committees. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.
Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.
All accepted project requests will be published on the ECMWF website.

We propose to use the global climate model EC-Earth to carry out a set of targeted simulations that will provide insight into the role of atmospheric aerosols in historical and future climate change. These simulations will be performed within the context of the international model intercomparison project AerChemMIP (Collins et al., 2017), and will form a part of the EC-Earth consortium's contribution to CMIP6. The proposed simulations will investigate the aerosol forcing throughout the historical period and in the coming decades, study the effect of future air pollution controls on climate, and address the impact of uncertain natural emissions to the simulated forcing. These simulations cover the aerosol-specific part of AerChemMIP Tier 2 and 3 experiments, and will be carried out on top of the DECK and Tier 1 simulations for which computational resources have already been secured on national and ECMWF machines.

1. *Introduction*

Aerosol particles are an important regulator of the Earth's climate. Besides decreasing the permeability of the atmosphere to solar radiation (*aerosol direct effect*), a certain subset of the particles can act as initial formation sites for cloud droplets and ice crystals, and thereby modify the radiative properties and lifetime of clouds (*aerosol indirect effect*). On a global average, anthropogenic aerosols have increased the reflectivity of the planet and as a result masked some of the warming effect of greenhouse gases in the past centuries. However, the magnitude of especially the aerosol indirect effect is very uncertain; in fact it remains the single largest uncertainty in the current estimates of the drivers of climate change (Intergovernmental Panel on Climate Change, 2013). Furthermore, natural emissions of aerosol particles and precursor gases make a large contribution to the forcing uncertainty (Carslaw et al., 2013). This large uncertainty severely limits our understanding of the sensitivity of the climate system to CO_2 increase and thus causes significant uncertainties in the predictions of future climate.

AerChemMIP, which is one of the over 20 model intercomparison projects endorsed within CMIP6, has been specifically designed to quantify the climate impacts of aerosols and chemically reactive gases. It aims to answer the following scientific questions: 1) How have the anthropogenic emissions contributed to global radiative forcing and regional climate change historically?, 2) How might future policies on climate, air quality and land use affect their climate impacts?, 3) How do uncertainties in historical emissions affect forcing estimates?, and 4) How important are climate feedbacks due to the studied components? The EC-Earth model consortium has thus far committed to Tier 1 simulations of AerChemMIP. Unfortunately, these simulations will isolate only the impact of methane and halocarbons as well as the *total* impact of near-term climate forcers (NTCFs), i.e. the combined effect of methane, tropospheric ozone and aerosols. At the same time, all model experiments specifically targeting aerosol forcing and climate impacts have been placed on AerChemMIP Tiers 2 and 3, for which the EC-Earth consortium does not currently have sufficient computing resources. Given the high computational costs of aerosol-chemistry-climate models, a 'Tier 1 only' policy has an obvious attraction. The risk for CMIP6 is that, should too many modelling centres make such a choice, then the opportunity to advance knowledge on the role of aerosols in the climate system beyond the CMIP5 state of the science could be lost.

Therefore, we propose a special project which enables EC-Earth participation to a selected set of AerChemMIP Tier 2 and 3 simulations focusing specifically on aerosol impacts. Given the large uncertainty in historical aerosol forcing and its impacts on constraining the climate sensitivity, participation of EC-Earth modelling consortium to these experiments can be considered highly beneficial for the wider climate modelling community. The Finnish Meteorological Institute (FMI) and the University of Helsinki (UHEL), who partner in this proposed special project, have a long and strong experience in global-scale modelling of atmospheric aerosols and their climate impacts in the past, present and future.

2. *Model configuration*

The modelling system used will be the CMIP6 version of EC-Earth with interactive aerosols and atmospheric chemistry. EC-Earth 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. An earlier version of the IFS-NEMO-TM5 configuration has been described and evaluated by Van Noije et al. (2014). 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. 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.

3. Work plan and simulations

The proposed simulations are summarized in Table 1 together with the estimated simulation length in model years as well as storage requirements. The unshaded rows indicated Tier 2 and the shaded rows Tier 3 experiments.

It should be noted that the corresponding DECK and historical simulations with the same model configuration as well as AerChemMIP Tier 1 simulations needed will be carried out with previously secured national and ECMWF resources in collaboration by FMI, UHEL, The Royal Netherlands Meteorological Institute (KNMI) and Barcelona Supercomputing Centre (BSC).

Table 1. Planned simulations

	2019	2020	2021
Coupled atmosphere-ocean simulations			
hist-piAer (1850-2014); aerosol precursors set to 1850 values; 3 ensemble members	14 000 000 SBU 23 TB	14 000 000 SBU 23 TB	14 000 000 SBU 23 TB
Atmosphere only simulations			
histSST-piAer (1850-2014); aerosol precursors set to 1850 values	11 500 000 SBU 21 TB	-	-
ssp37SST-lowAer (2015-2055); aerosol reductions due to air quality policies	2 900 000 SBU 5.1 TB	-	-
ssp37SST-lowBC (2015-20155); black carbon reductions due to air quality policies	-	2 900 000 SBU 5.1 TB	-
PiClim-aer; 30 year timeslice with 2014 aerosol; other forcers use pre-industrial climatology	2 100 000 SBU 3.7 TB	-	-
PiClim-BC; 30 year timeslice with 2014 black carbon; other forcers use pre-ind. climatology	2 100 000 SBU 3.7 TB	-	-
PiClim-SO2; 30 year timeslice with 2014 SO2; other forcers use pre-industrial climatology	-	2 100 000 SBU 3.7 TB	-
PiClim-OC; 30 year timeslice with 2014 organic carbon; other forcers use pre-ind. climatology	-	2 100 000 SBU 3.7 TB	-
piClim-2xdust; 30 year timeslice with doubled dust emissions	-	2 100 000 SBU 3.7 TB	-
piClim-2xss; 30 year timeslice with doubled sea spray emissions	-	2 100 000 SBU 3.7 TB	-
piClim-2xDMS; 30 year timeslice with doubled DMS emissions	-	-	2 100 000 SBU 3.7 TB
piClim-2xfire; 30 year timeslice with doubled wildfire emissions		2 100 000 SBU 3.7 TB	-
piClim-2xVOC; 30 year timeslice with doubled biogenic VOC emissions	-	-	2 100 000 SBU 3.7 TB
piClim-2xNOx; 30 year timeslice with doubled lightning NOx emissions	-	-	2 100 000 SBU 3.7 TB

Estimated total	30 500 000 SBU 57 TB	27 400 000 SBU 104 TB	20 300 000 SBU 138 TB

4. Explanation of the requested resources

The computational resources requested for this special project have been estimated based on test simulations performed by KNMI on the CCA Cray XC30 system (personal communication with Philippe le Sager). 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 180 CPUs for IFS and 135 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 69.6 kSBU in atmosphere-only mode and 83.5 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 that these numbers are based on test runs performed on CCA with the Intel compiler, and with the Intel Ivy-Bridge processor technology.

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.[2] 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. We have also used our own experience and data volumes from existing simulations. The data volumes are given as raw model data volumes, without any data compression. Post-processing and eventual publication of the model results will be performed outside of ECMWF facilities.

5. Relationship with other Special Projects

This request is additional to, and is coordinated with, the special project 'EC-Earth climate simulation for AerChemMIP'. There are no duplicated simulations between the two projects. The figures for SBU per simulated year differ due to model developments in the intervening period, which improve the model scalability and allow us to efficiently run the model with a higher number of cores. This allows us to run simulations more quickly, and to complete the full set of simulations without running them in parallel, resulting in an even load distribution throughout the project lifetime.

References

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2 https://earthsystemcog.org/projects/wip/CMIP6DataRequest