REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: ……Denmark…..……...…

Principal Investigator[1]: ……Shuting Yang ……..……

Affiliation: …… Danish Meteorological Institute ……..……

Address: …… Lyngbyvej 100, DK-2100 Copenhagen , Denmark ….……

……..……

……..……

E-mail: ……shuting@dmi.dk ……..……

Other researchers: ……..……

……..……

Project Title: …Simulating the climate in Last Millennium using EC-Earth ……

……..……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _____	
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 2017-2019: (To make changes to an existing project please submit an amended version of the original form.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(SBU)	2,250,000	2,250,000	
Accumulated data storage (total archive volume)[2]	(GB)	2 TB	2 TB	

***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):

……30 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.

[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.

Principal Investigator: … Shuting Yang ……

Project Title: … Simulating the climate of the Last Millennium using EC-Earth ……

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (1,000,000 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.

Scientific background

The Last Millennium (LM) before the industrial era is the period with well documented climate change of multi-decadal to multi-centennial time scales. Climate varies considerably with contrasting subperiods such as the Medieval Climate Optimum and the Little Ice Age, while the natural forcing external to the Earth's climate system was also characterised by variations in solar, volcanic and orbital factors during the period. The CMIP6-endorsed Paleoclimate Modeling intercomparison Project phase 4 (PMIP4) thus has proposed the LM experiment as one of the Tier 1 experiments, aiming at investigating the response to (mainly) natural forcing under climatic background conditions not too different from today". (Kageyama et al, 2016). Such investigation is crucial for improved understanding of climate variability, circulation and regional connectivity. It can also address the relative importance of natural fluctuations due to internal variability of the climate system and to variations in the external forcing.

The aims of the proposed project are thus two-fold:

1. to develop the transient climate in the last millennium (850-1849 CE) using climate model EC-Earth in response to mainly natural forcing (i.e., solar variations, volcanic aerosols, orbital parameters and the atmospheric concentration of well mixed greenhouse gases) as well as to a less extent the land use/land cover changes. This is to foster studies of characteristics and mechanisms of decadal to centennial climate variability.

2. to contribute to CMIP6-endorsed PMIP4 LM experiments so to foster multi-model intercomparison.

The LM simulation will also be used in the a number of national and international projects for investigations of, eg., the Greenland ice sheet changes resulting from the climate induced changes in surface mass balance; the long-term variability of atmospheric teleconnection patterns; evolution of deep ocean circulation, etc.

LM experiment plan

We will use the low resolution version of EC-Earth for CMIP6, **EC-Earth3-LR**, This version is based on a newer cycle of the ECMWF IFS atmospheric model (c36r4), the NEMO ocean model (v3.6), the LIM3 sea ice model and a river Runoff mapper. These model components are coupled together via the OASIS3-MCT coupler and use the XIOS for the (ocean variable) IO management. The orbital dependent solar irradiance have been implemented in the model, so that the model is able to facilitate paleoclimatological simulations in which astronomical parameters differ from present day. The **EC-Earth3-LR** is configured at horizontal resolution of T159 and 91 vertical layers for the atmosphere, and 1 degree and 75 layers for the ocean and sea ice.

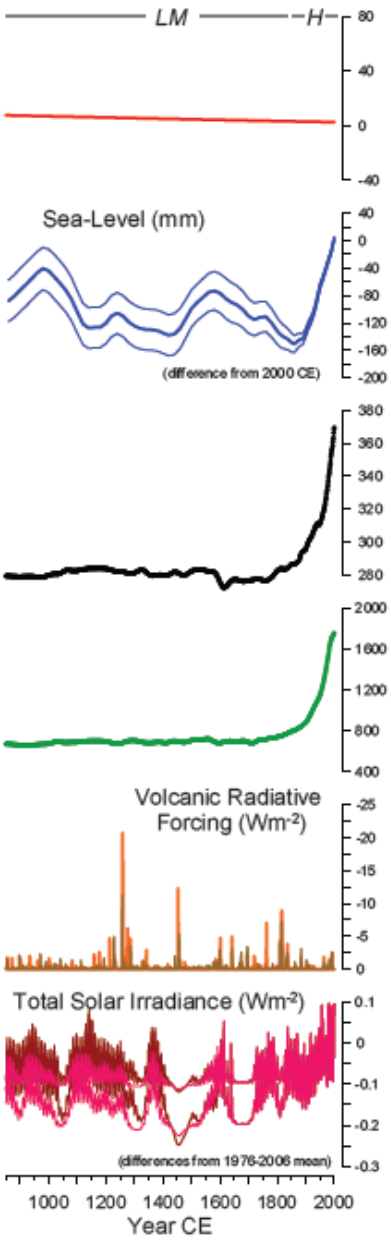

Figure 1. Context of the PMIP4-CMIP6 last millennium (LM) and CMIP6 historical simulations (H). From top to bottom: Insolation anomalies as differences from 1950 CE for July at 65°N (in W/m^2); Sea level (in mm); CO2 measurements (in ppm); CH4 measurements (in ppbv); Volcanic radiative forcing (in W/m^2); Total solar irradiance (in W/m^2). Figure from Kageyama et al (2016) Figure 1.

The boundary conditions for the LM simulation will follow the PMIP4-CMIP6 experiment protocol (Kageyama et al, 2016), which include time varying forcings of orbital parameters, greenhouse gases, radiative forcing due to stratospheric aerosols by volcanoes, solar activities, and land use (Figure 1). These forcings will be provided by the PMIP4-CMIP6 LM working group, and will be implemented into the model once they are available.

Transient simulations for 850-1849 will be carried out starting from the CMIP6 unforced equilibrium state, i.e., preindustrial control simulation (Eyring, et al, 2015). We will need to first prepare the model, model boundary and initial conditions for the LM experiment. Production run will start later 2017, and continue in 2018.

Justification of Computing Resources

The requested HPC resources in the following are based on the Eemian experiments with EC-Earth under the special project SPDKLANG led DMI researcher Dr. Peter L. Langen, which used an older version of EC-Earth (v3.1) at T159 and 1deg ocean resolution on the CCA cluster. The use of the new CMIP6 model version (i.e., EC-Earth-LR, which is under development now), and the latest upgrade of the HPC to Broadwell-based facility will influence the resource usage.

The experiments carried in SPDKLANG spent about 4500 SBUs per model year. A 1000 model years of LM simulation thus amounts to an estimated usage of 4,500,000 SBUs. We will archive mostly time means (monthly and annually) of atmospheric and oceanic variables. In some time period of particular interests more frequent model outputs may also be archived. These will make up to about 2 – 10 GB data per model year. We estimate a total amounts of about 4 TB storage will be needed.

2 year project 2017-18	
Total model years	1000 years
SBUs per model year	4,500 SBUs
Total SBUs requested	4,500,000 SBUs
Storage per model year	2 – 10 GB
Total Archive	4 TB

References

Eyring, V., Bony, S., Meehl, G. A., Senior, C., Stevens, B., Stouffer, R. J., and Taylor, K. E., 2015: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organisation, Geosci. Model Dev. Discuss., 8, 10539-10583, doi:10.5194/gmdd-8-10539-2015.

Kageyama et al, 2016: PMIP4-CMIP6: the contribution of the Paleoclimate Modelling Intercomparison Project to CMIP6. Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-106.