REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: Sweden

Principal Investigator[1]: Qiong Zhang

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Project Title: Simulations with climate model 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.)	2015	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2015-2017: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)	**2015**	**2016**	**2017**
High Performance Computing Facility (units)	25000000	25000000	25000000
Data storage capacity (total archive volume) (gigabytes)	50000	50000	50000

*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, 2014

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.

Principal Investigator: Qiong Zhang

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Extended abstract

1. Climate model EC-Earth

EC-Earth is a global coupled climate model, which integrates a number of component models in order to simulate the earth system. It is developed by a consortium of European research institutions, which collaborate in the development of a new Earth System Model (ESM). The goal of EC-Earth is to build a fully coupled Atmosphere-Ocean-Land-Biosphere model, usable from seasonal to decadal climate prediction and climate projections (Hazeleger et al. 2010). The atmospheric component of EC- Earth is based on the modelling systems i.e. Integrated Forecasting System (IFS) which is developed at the European Centre for Medium-Range Weather Forecasts (ECMWF) and the ocean component is based on Nucleus for European Modelling of the Ocean (NEMO) which is a global ocean circulation model.

EC-Earth is our main tool in studying the climate from past, present to future. The model is today used in a number of applications here at the Bolin Centre for Climate Research at Stockholm University. As part of the EC-Earth consortium, we, here at the Bolin Centre in collaboration with the Rossby Centre at Swedish Meteorological and Hydrological Institute (SMHI), have implemented the EC-Earth model on various super computer platforms and have made a number of model integrations, such as historic simulations (e.g. 1850 to 2005 with known climate forcings such as greenhouse gas, volcanic, aerosol etc.) and scenarios of future possible climates taking into account an increased amount of greenhouse gases (e.g., RCP45, RCP85 etc.). These results contribute to CMIP5 (Climate Model Intercomparison Project Phase 5) experiments, which form an essential part of the IPCC Fifth Assessment Report. An evaluation of EC-Earth for the Arctic shows the model simulates the 20th century Arctic climate reasonably well (Koenigk et al. 2013). Most of the CMIP5 modelling groups have provided both the paleo simulations together with historic and future simulations, in order to show a systemic picture of climate variation along the time. However, the EC-Earth has not been used for paleo climate modelling extensively yet. We know the climate models are built from the knowledge of present day and the physical parametrisations are based on present-day observation. But we don't know if such a model is valid for another unknown climate condition, i.e. the future and the past. Fortunately, natural archives such as tree-ring, ice-core, stalagmite etc., have recorded the past climate information and thus it is possible to validate the climate model for other climate conditions that differ from today. If the model is well tested for past climate, we will have more confidence for its ability to project the future climate.

On the other hand, paleoclimate scientists have seen climate variability recorded in proxy data and they have different hypotheses to interpret the data. Climate model is the only tool that can test these hypotheses. Due to the limitation of computer recourses, most paleoclimate experiments have been performed with simple models like Energy Balance Model or intermediate complexity climate model. However, many important climate feedbacks cannot be reflected in these highly simplified models and thus difficult to compare with the paleo proxy data. Now with availability of the high performance computational (HPC) resources, it is possible to simulate the past climate with more sophisticated climate model such as EC-Earth, to meet the needs of paleoclimate community. Therefore using EC-Earth on paleoclimate modelling is one of our major focuses in Bolin Centre. Our aim is to provide the paleo simulation results to the whole research community via open database.

2. Scientific plans according to on-going projects and applied projects

2.1 Paleo simulations with EC-Earth 3.1

Being a new paleo-climate modelling group supported by the Bolin Centre for Climate Research at Stockholm University, we aim to perform paleo simulations with the latest version of EC-Earth, i.e. version 3.1. The first step is to follow the PMIP (Paleoclimate Modelling Intercomparison Project) protocols. The standard PMIP simulations include the time slice simulations for Mid-Holocene (MH, 6000 years before present) and Last Glacier Maximum (LGM, 21,000 years before present), as well as a transient simulation for Last Millennium (LM, 850 AD to 1850 AD). We will not perform all the simulations listed in the PMIP protocols right now due to limited computer resources. The first plan is to perform simulations during period of LGM. Such simulations have never been run with EC-Earth, therefore it is very important to assess the model performance under such a different conditions as compared to present-day. Our modelling group recently have implemented the important physical processes such as orbital forcing, as well as modifying the topography, ice sheet etc. in EC-Earth within a collaboration with Shuting Yang in Danish Meteorological Institution (DMI). Some test runs and tuning of the model are ongoing. Moreover, the coupling of other components such as dynamical vegetation model (e.g. LPJ), snow model (e.g. CROCUS) and ice-sheet model (e.g. PISM) are also planned to be applied with low resolution (T159L62) of EC-Earth. The results will be evaluated against the paleo observations and other climate models results in PMIP database and later we will run more specified experiments according to scientific questions.

As mentioned above, for the first step, the planned feasible simulations include long spin-up simulations at LGM condition and two LM simulations. Therefore, ECMWF computing resources are requested to perform these experiments, see the budget below for detailed information. We will choose low-resolution configuration T159L62ORCA1L46 which corresponds to 1.125 degree for atmosphere and 1 degree for ocean. The total simulation year for LGM is estimated to be about 1000 years in which 500 years are for spin-up and another 500 years will be used for analysing results. Such a long spin-up time (i.e. 500 years) is needed especially for the ocean to adjust to the cold LGM conditions and reach a steady state. This will be the most demanding experiment by far, but it should be noted that 500 model years is a realistic but conservative estimation of such type of simulation. For the transient LM runs, the actual run will be 1000 years with varied external forcings from 850AD to 1850AD, and about 500 years are needed for spin up as well.

2.2 Tuning effort within EC-Earth working group

Starting from the summer in 2014, there will be a new working group (WG) titled “Low resolution climate model development and studies” in EC-Earth consortium lead by Department of Physical Geography & Quaternary Geology (INK) at Stockholm University modelling group. The proposed tasks for this WG include:

- Develop and maintain a T159-ORCA1-LIM3 version following the v3 code development for the purpose of long climate simulations
- Carry out tuning of the final CMIP6 code v3.x for the low resolution version
- Coordinate lower resolution activities within EC-Earth
- Line out CMIP-6 activities on paleo modelling

We foresee that along the progress of these tasks, plenty of modelling activities and collaboration will happen besides our specific paleo-simulation plan. Thus it is important for all our modelling activities that we continue to have access to HPC resources.

2.3 Applied climate modelling projects

We have submitted two scientific research applications as main/co applicant this year. Our role in these proposed projects is climate modelling with EC-Earth. Note that our current application

will not cover all the computer resources for these projects and we may apply additional computer resource in National Supercomputer Centre in Sweden if we succeed in research grant application.

Main applicant for a research project "Greenland in a warming Arctic" on Swedish-French collaboration in climate and environment from Swedish Research Council, applied for 2015-2017, coordinated by Qiong Zhang from SU and Masa Kageyama from LSCE, France. Decision will be made in November 2014.

Co-applicant for a research project with high scientific potential "Variation and predictability of high impact climate events in Northern Europe" from the Wallenberg Foundations in Sweden, applied for 2015-2018, coordinated by Deliang Chen from the Regional Climate Group at University of Gothenburg. Other participate includes Rossby Centre colleagues in SMHI. Decision will be made in December 2014.

3. Researchers and their roles in project

The main applicant Qiong Zhang is a senior lecturer on climate modelling in Department of Physical Geography and Quaternary Geology. She is the co-leader of research area 5 on "Centennial to millennial climate variability" in Bolin Centre for climate research. She will lead the EC-Earth working group "Low resolution climate model development and studies" once the working group tasks are approved by EC-Earth steering board in July 2014.

Dr Qiang Li is our scientific programmer, employed by Bolin Centre and has been dedicated in model experiment setting up and running, as well as the model data management and analysis.

Dr Maxime Ballarotta is a postdoc researcher in Bolin Centre, he is assisting Dr. Qiang Li on ocean part of LGM experiment setup, as well as analysing the model results.

4. Estimation of computer resource on Cary XC30

Within collaboration with Shuting Yang in DMI, we have recently accessed ECMWF new computer Cary XC30 and installed latest version of EC-Earth 3.1. Here we show the computer resource estimation from our test runs (log is attached in the end of this application).

Model configuration: EC-Earth V3.1, IFS resolution T159L62, NEMO resolution ORCA1L42
Coupling frequency: 3h
One year of simulation using 23 nodes, 552 MPI tasks, 256 MPI tasks for IFS, 256 for NEMO, 20 for OASIS
Runtime for one year simulation: 2376 seconds
SBU: 5931 units

If we use half nodes, the runtime for one simulation year is 5172 seconds and SBU is 7297 units.

5. Resources requirement budget

Sum of model simulation years: 3500 years
Billing units per model year: 6000-7000 units
Total billing units required: 25 million units
Storage per model year: 15 GB
Total storage required: 50 TB

Due to the fact that the code needs to be tuned in the beginning and it can crash sometimes due to unpredictable reasons, about 15% more billing units are required.

The above estimation is for our specific planned simulations in 2015, we foresee there will be more modelling tasks in 2016-2017 and expect to be able to apply additional resource from ECMWF or elsewhere.

Reference

Hazeleger, W., and Coauthors, 2010: EC-earth: a seamless earth-system prediction approach in action. *Bulletin of the American Meteorological Society*, **91,** 1357-1363.

Koenigk, T., and Coauthors, 2013: Arctic climate change in 21st century CMIP5 simulations with EC-Earth. *Climate Dynamics*, **40,** 2719-2743.

Attach: sh.epilog.ecmef-INFO

```
## INFO ----------------------------------------------------------------------------
## INFO  This is the ECMWF job Epilogue. Please report problems to calldesk, cdk@ecmwf.int
## INFO ----------------------------------------------------------------------------
## INFO
## INFO Run at Wed Jun  4 10:34:42 2014 on CCT
## INFO Job Name               : ec310test
## INFO Job ID                 : 7856256.sdb
## INFO Queued                 : Wed Jun  4 09:54:12 2014
## INFO Dispatched             : Wed Jun  4 09:55:06 2014
## INFO Completed              : Wed Jun  4 10:34:42 2014
## INFO Waiting in the queue   : 54 seconds
## INFO Runtime                : 2376 seconds
## INFO Exit Code              : 0
## INFO Account                : seuniv
## INFO Queue                  : np
## INFO Owner                  : suzk
## INFO STDOUT                 : /home/ms/se/suzk/qiang/ec310/runtime/q.out
## INFO STDERR                 : /home/ms/se/suzk/qiang/ec310/runtime/q.err
## INFO Hyperthreads           : 1
## INFO SBU                    : 5931.323276 units
## INFO Logical CPUs           : 1104
```