REQUEST FOR A SPECIAL PROJECT 2012–2014

MEMBER STATE: The Netherlands

Principal Investigator[1]: Prof. Dr. W. Hazeleger

Affiliation: Royal Netherlands Meteorological Institute (KNMI)

Address: Wilhelminalaan 10
3732 GK De Bilt
The Netherlands

E-mail: Wilco.Hazeleger@knmi.nl

Other researchers: ECMWF: Simona Stefanescu.
KNMI: Camiel Severijns, Frank Selten, Richard Bintanja, Bart van den Hurk, Andreas Sterl.
And EC-EARTH consortium representatives: SMHI: Klaus Wyser; Met Éireann: Tido Semmler; IM: Pedro Viterbo; MISU: Annica Ekman; BSC: Jose Baldasano; AEMET: Jose Parodi; DMI: Shuting Yang; IC3: Fransisco Doblas-Reyes

Project Title: EC-EARTH: developing a European Earth System model based on ECMWF modelling systems.

Computer resources required for 2011-2013:	**2012**	**2013**	**2014**
High Performance Computing Facility (units)	15,000,000	15,000,000	
Data storage capacity (total archive volume) (gigabytes)	20 TB	40 TB	

Is this a continuation of an existing project?	YES X	NO
If YES, please state the computer project account assigned previously	**SP** NLTUNE_____	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

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): 26 April 2011

[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.

Continue overleaf

Principal Investigator: Prof. Dr. W. Hazeleger

Project Title: EC-EARTH (SPNLTUNE)

Extended abstract

EC-EARTH: developing a European Earth System model based on ECMWF modelling systems

Introduction

Climate and forecasting applications share a common ancestry and build on the same physical principles. Nevertheless, climate research and forecasting are commonly seen as different applications. The concept of "seamless prediction" (cf. WCRP) has emerged to forge forecasting and climate change into a joint topic. This concept extends the focus of the physical climate system toward a comprehensive view of the Earth System in which the various climate feedbacks (including climate-biosphere) are included. This enables one to combine short-term 'weather' physics and long-term climate/earth-system feedbacks in assessing long-term changes, with specifically including those that are 'weather-related' (such as extremes).

The need for an Earth System model was recognized by various ECMWF Member States (MS). A consortium with representatives from 11 MS is formed in which the seasonal forecast system of ECMWF (system 3) is developed into an earth system model. The project, which is named EC-EARTH, has as general objective to develop a global Earth System model consisting of a state-of-the-art atmospheric general circulation model, a state-of-the-art ocean general circulation model, a sea-ice model, a land model, and an atmospheric chemistry model (see http://ecearth.knmi.nl). This objective has been realised, as we now have a fully tested version of EC-Earth (Version 2) to be used for answering research questions, for near-term predictions and for climate scenario related work.

Version 2 of EC-EARTH has been released in 2010, and is based on System 3 of ECMWFs Seasonal Forecast System. The version consists of IFS cycle31r1 (with aspects of c33r1, T159L62 resolution), the NEMO ocean model (1 degree horizontal resolution), OASIS3 coupler and the LIM sea ice model. Also, the H-TESSEL land module has been merged back from cycle32 in cycle31. This well-tested version of EC-Earth (V2) has been used to run for 440 years under perpetual year 2000 conditions (http://ecearth.knmi.nl/index.php?n=PmWiki.PresentDayControlRun). Using objective metrics it has been established that V2 generally performs well when compared to CMIP3 models. Moreover, Version 2 was found to represent very well the internal dynamics of the coupled climate system, as manifested by the excellent agreement with observed patterns of e.g. ENSO, NOA and various monsoonal characteristics. Version 2 is currently used in a number of research applications. A special issue in Climate Dynamics is coming up with studies on various aspects of the model.

The consortium has therefore chosen Version 2 of EC-EARTH as backbone version for EU FP7 projects (partners collaborate in e.g. COMBINE, THOR, EUCLIPSE, EMBRACE) and CMIP5 (World Climate Research Program) projects. A long spin up of the coupled system under preindustrial conditions has been completed (1000 years in total) for year 1850 conditions. This serves to render initial states for historical (1850-2005) and future (2005-2100) runs that will be carried out in the framework of CMIP5. These CMIP5 runs are currently underway, and we expect to submit the output data from thes runs to the CMIP5 database later this year. For both the historical and future experiments 5-10 members will be realised, with the various consortium members contributing. Decadal hindcasts and forecasts initialized from ECMWFs NEMOVAR analysis (also multi-member) have also been carried out with Version 2 as part of the collective CMIP5 effort by the consortium. Finally, high-resolution atmosphere-only runs have been carried out (T511 and T799). Apart from these collaborative efforts, a large number of studies have started by the different groups that are part of the EC-Earth consortium.

New developments

New Earth system components are being coupled to the model. The chemistry transport model TM5, including an M7 aerosol scheme, has been coupled to EC-Earth Version 2. Also, alternative components are

in preparation (new sea-ice modules, PISCES ocean biogeochemistry, and LPJ dynamic vegetation scheme) to enter forthcoming EC-Earth versions. Furthermore, improvements of the atmospheric component are being developed, such as indirect aerosol effects.

In fall 2011, ECMWFs Seasonal Forecast System 4 will become operational. Since EC-Earth follows a seamless strategy, the consortium will update the atmospheric and oceanic components of EC-Earth in accordance. Version 3 of EC-Earth will be tested technically and will be released later in 2011. Just as Seasonal Forecast System 4 it will be based on IFS cycle36r4 and NEMO3. Currently, stable fully coupled runs have been made with IFSc36r1-NEMO3-LIM2-OASIS3, but this version needs to be updated to include IFSc36r4 after which it will be rigorously tested and tuned before it can be used for research applications. Version 3 will be used for further research (e.g. in EU EMBRACE). We anticipate that TM5 will also be coupled to this version.

A summary of the most important improvements in EC-Earth Version 3 over Version 2:

– IFS: a new shortwave radiation scheme (RRTM–SW) including McICA cloud-radiation interactions
– IFS: retuned convection
– IFS: new microphysics scheme (with prognostic and falling hydrometeors)
– IFS: new gravity drag treatment (important for the stratosphere)
– IFS: revised subgrid-orography scheme
– NEMO: new TKE scheme
– NEMO: new surface module
– General: several technical improvements

Later, biogeochemical components will be added to a Version 4. Additionally, initiatives are under way to couple integrated assessment models (such as IMAGE) to EC-Earth.

An overview of the various versions of EC-Earth:

- V2: IFS c31r1 (with aspects of c33)-HTESSEL-NEMO2/LIM2-OASIS3; released in March 2009
- V3: IFS c36r4 – HTESSEL- NEMO3/LIM2 – OASIS3; expected release later in 2011 (the atmosphere and ocean model version will be identical to that of Seasonal Forecast Version 4).
- V4: IFS c36+ - HTESSEL – NEMO3/LIM3- TM5- LPJ – PISCES – OASIS3; expected release in 2012/3 (possibly with IMAGE components).

Workplan

Three activities are currently carried out in a distributed fashion (in 2010/11 based on Version 2, later in 2011 based on Version 3, from 2012/13 possibly on Version 4)

- The consortium is actively running with V2 of the model system to contribute to CMIP5
- The consortium will be tuning the V3 model system to reduce biases in the simulated climate
- The consortium is developing new components to be added to the EC-EARTH System in a coordinated fashion

A standard version of the fully coupled atmosphere-ocean-seaice-land EC-EARTH system is maintained at ECMWF in a central repository using ECMWFs version management system Perforce. Modifications from different MSs are collected and, if approved, combined into new versions. A new version management is then being set up to include EC-Earth as a branch of IFS, to facilitate merging of model versions. This requires extensive experimentation to merge the modifications and additional tuning to reduce the biases and to optimize the code. Prime biases which are addressed are (see http://ecearth.knmi.nl/index.php?n=PmWiki.Experiments for results) :

- temperature biases over midlatitude continents in winter
- sea surface temperature bias in the Southern Ocean
- bias in precipitation over the warm pool regions.

These biases can also be found in ECMWFs seasonal forecast system. A typical run that is needed for testing impact of modifications is at least 10-years long (to rule out internal variability) when the sea surface temperature is prescribed and much longer when the system is coupled to an ocean model and sea ice model. The biases are quantified and assessed objectively using published performance indices (e.g. Reichler and Kim, BAMS 2008) for the RMS error and Taylor diagrams for the variability (such as the seasonal cycle). Starting late 2011, we will perform the same rigorous testing and (if necessary) tuning to Version 3 as that

we did with Version 2. For that purpose we may decide te redo certain CMIP5-type experiments with Version 3.

Within this Special Project we will thus perform the following activities:

- 2012a: Test and optimize fully coupled EC-EARTH Version 3 and comparison to EC-Earth Version 2 and to ECMWF's Seasonal Forecast Version 4 (note, same resolution will be used as System 4).
- 2012b: Test modifications, merging and testing new components:
    - LIM3 new sea ice
    - LPJ and H-Tessel (including new anthropogenic components as urbanization, irrigation, seasonal and interannual variations in land use)
    - PISCES ocean biogeochemistry
    - Full coupling TM5 (including M7 aerosol scheme online coupled to radiation scheme).
- 2013 and later: Test and optimize fully coupled EC-EARTH Version 3 and development towards Version 4, including atmospheric chemistry, dynamic vegetation, ocean biogeochemistry and integrated assessment models (IMAGE).

Justification resources

A T159L62 IFS cycle31r1 run without the ocean component for 10 years costs 15000 SBU. Including the ocean makes the model twice as expensive: 30000 SBU for 10 years. Running at T255 (NEMO3 at ORCA1 as in V2), which is the resolution that ECMWF's Seasonal Forecast System 4 will be using, EC-Earth Version 3 will take up roughly 5 times as much SBU's per model year compared to Version 2. We found out, comparing to earlier special project request, that tuning is needed in the fully coupled model, and that every new module added will require extensive retuning of the coupled system. Experiences with the preindustrial control run show that at least 100 years is needed to see an effect of changes made to the code. For 800 years of simulation with Version 3 at T255, 12 MSBU will be needed (some changes may be tested at lower resolution). Including atmospheric chemistry makes the model even 3.5 times more expensive. EC-Earth including TM5 is expected to be used only for time slices. Since TM5 developments go fast, we expect already a need for these runs in early 2012. For 10 slices of 10 years, about 3 MSBU will be needed in addition. After 2012, increased resolution and increasing use of the full EC-Earth model, including chemistry, will raise the computational costs. The Global Climate Division of KNMI, which leads the project, has 6 MSBU of Member State resources at its disposal and will use part of these resources as well for this project. We expect to run the EC-EARTH Version 3 (based on ECMWFs seasonal forecast system 4) as new base version of EC-EARTH from fall 2011 onwards.

It is expected that the efforts will be beneficial for the performance of later cycles of the ECMWF modelling system. New developments (e.g. snow parameterization, lakes, sea ice, aerosol effect, irrigation) developed by the EC-EARTH community have already been discussed with ECMWF and in case of snow, they have already been implemented. Also, new physical aspects will be brought into the ECMWF system by the MS through developing EC-EARTH. New components for EC-Earth will be developed in the EU FP7 project COMBINE as well, while within FP7 EMBRACE major biases will be addressed. The project is leading to a truly seamless earth system model. Version 2 of EC-Earth, which has been optimized using resources from this project, is described in an article which has been published by BAMS in 2010 – Hazeleger, W. et al. EC-Earth: a seamless Earth system prediction approach in action. *Bull. Am. Meterol. Soc*. **91**, 1357-1363, doi:10.1175/ 2010BAMS2877.1 (2010).

The EC-EARTH consortium consists of the following partners (signed Letter of Intent of EC-EARTH): DMI, Denmark; University Utrecht, The Netherlands; Instituto de Meteorologia, Portugal; Centro de Geofísica,University of Lisbon, Portugal; KNMI, The Netherlands; Meteorologisk Institutt, Norway; Unité ASTR, Belgium; Met Éireann, Ireland; University College Dublin, Ireland; Vrije Universiteit Amsterdam, The Netherlands; Meteorologiska Institutionen, Stockholm, Sweden; Lund University, Sweden; ICTP, Italy; ISAC-CNR Italy; SMHI, Sweden; AEMET, Spain; ETH/C2SM, Switzerland; BSC, Spain; Universiteit Wageningen, The Netherlands; IRV, Sweden; ICHEC, Ireland; IC3, Spain; Niels Bohr Institute, University of Copenhagen, Denmark; IfM Geomar, Germany; SARA, The Netherlands; NTNU, Norway