REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: Sweden.……………..…………………………………………...…

Principal Investigator[1]: Colin Jones..……………………………………………..……

Affiliation: SMHI……………………………………………………….……

Address: Folkborgsvägen 1……………………………………………….……
601 76 Norrköping..……………………………………………….……

E-mail: Colin.Jones@smhi.se……………………………………….……

Other researchers: David Lindstedt, Gunilla Svensson (Stockholm University), Petter Lind, Patrick Samuelsson, Christer Jansson, Ulf Hansson
…………..……….………………………………………….……

Project Title: High Resolution Regional climate projections at 2°C global warming thresholds

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.)	2013	
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.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	15 million	15 million	15 million
Data storage capacity (total archive volume) (gigabytes)	40 000	50 000	60 000

*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):
2012-04-30…………………………

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: Colin Jones

Project Title: High Resolution Regional climate projections at 2°C global warming thresholds

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.

The Rossby Centre at SMHI is partner in a new European Union FP7 project, IMPACT_2C (http://www.hzg.de/mw/impact2c). IMPACT_2C aims to assess the impacts associated with a 2°C increase in global mean temperatures relative to preindustrial levels, on a number of regions of the world and a range of natural ecosystems and societal enterprises. The primary region of interest is Europe, where the project will calculate high-resolution, regional climate change statistics, concurrent with global mean temperatures exceeding the 2°C threshold. These climate change estimates will then used to drive a range of sector and ecosystem specific impact models to gauge the impact on Europe of a global mean climate 2°C warmer. A similar procedure of high-resolution climate change projections and subsequent impact assessments will be made for a limited number of sectors in other, climate-vulnerable parts of the world. These include; west and east Africa, Bangladesh and the Maldives.

At the base of this effort are Global and Regional Climate Models (GCMs and RCMs) and the production of suitable climate projections. The Rossby Centre is presently performing a set of high-resolution, 30-year timeslice integrations for present climate conditions and for conditions representative of 2°C global warming. These integrations are being performed with the EC-Earth GCM (Hazeleger et al. 2011) at a spectral resolution of T511 (~40km) using prescribed daily sea surface temperatures (SST) and sea-ice concentrations (SIC) representative of present-day conditions and future conditions when global mean temperatures exceed the 2°C threshold.

To achieve this, we begin by identifying the time point when the simulated global mean temperature becomes 2°C warmer than pre-industrial values using 2 coupled EC-Earth, low-resolution (T159, ~1.125 resolution) CMIP5 projection runs. 30 years of daily SST and SIC values are then extracted from these simulations, centered on the time point of 2°C global warming. This is procedure is performed for two EC-Earth CMIP5 projection runs following, respectively, the RCP4.5 and RCP8.5 Reference Concentrations Pathways (RCPs), thereby sampling different rates of warming and time points in the future when the 2°C threshold is exceeded. From the historical EC-Earth CMIP5 simulation (covering 1860-2010) we also extract daily SST and SIC values for the period 1979-2009. The 30-year mean annual cycle of EC-Earth SSTs and SIC are then computed for this period and compared to observed SST and SIC for the same period. This allows the climatological annual cycle of EC-Earth simulated SSTs to be biased corrected to observations. The resulting mean annual cycle of monthly SST bias corrections is then added to the equivalent calendar months of the full 30-years of EC-Earth SST and SIC covering 1979-2009. The resulting global fields constitute bias-corrected SST and SIC that retain the inter-annual variability simulated by EC-Earth. The same monthly, annual cycle bias corrections are also applied to the 30-years of SST and SIC centered on 2°C global warming extracted from the EC-Earth RCP4.5 and RCP8.5 projections. This results in a set of SST and SIC global fields that retain the respective signatures of 2°C global warming simulated by the EC-Earth RCP4.5 and 8.5 runs, as well as retaining the model-simulated future inter-annual SST and

SIC variability. Furthermore, application of the observation-based bias correction removes the (present-day) systematic SST and SIC biases in the coupled model. The resulting sets of daily, bias-corrected SST and SIC global fields, one for the period 1979-2009 and two for the 30-year periods centered on 2°C global warming from the RCP4.5 and 8.5 runs are then interpolated to T511 resolution and used as prescribed lower boundary conditions for three 30-year timeslice simulations, one for 1979-2009 and two for the 30-year, 2°C global warming periods. We are also making the equivalent SST/SIC forced runs using the original T159 resolution of the EC-Earth atmosphere-land model.

In utilizing higher resolution (~40km (T511) compared to ~125km (T159), as used in the coupled CMIP5 simulations), we aim to more accurately simulate important higher time frequency weather variability, embedded within the mean climate, and thus provide more reliable estimates of potential changes in this variability as global mean warming exceeds 2°C. This variability includes features such as tropical and extra-tropical cyclones, African Easterly Waves, convective storms and blocking anticyclones, associated with heatwaves and droughts in the summer and extended cold periods in winter. Systematic changes in either the frequency, intensity, duration or geographic location of such weather variability will impact society and natural ecosystems far more significantly than a gradual change in the mean climate. It is therefore critical that GCMs accurately represent this underlying weather variability in order to provide credible estimates of its potential change in the future as input to downstream impact models applied in IMPACT_2C. The EC-Earth runs described above are presently being run on a large linux-cluster in Sweden. These simulations will be completed in the fall of 2012. In all simulations, six-hourly model level data is being archived for subsequent dynamical downscaling. This downscaling is the subject of our computer application.

While T511 (~40km) is an extremely high-resolution for a global climate model, in order to provide increased regional detail and data at spatial resolutions required by impact models, we plan to investigate a number of dynamical downscaling steps using the T511 EC-Earth simulations as lateral and surface boundary forcing. We will make two downscaling steps using a new Regional Climate Model (Harmonie-Climate (Niemelä, 2007; Lindstedt, 2012), hereafter referred to as H-CLIM), under development at the Rossby Centre and based on the combined Numerical Weather Prediction (NWP) models Hirlam (Undén et al. 2002) and Aladin/Arome (Yessad, 2011; Seity et al. 2011). In the first and primary downscaling step H-CLIM will be run for the 30-year timeslice 1979-2009 period and one of the future 2°C 30-year periods, forced by the respective EC-Earth T511 data at the lateral and surface boundaries. H-CLIM will be configured on the same geographical domain as used by Euro-CORDEX groups performing regional climate projections within the WCRP-sponsored CORDEX activity (http://wcrp.ipsl.jussieu.fr/SF_RCD_ CORDEX.html). This domain is the same as that used in the EU FP6 project ENSEMBLES, the primary difference being that Euro-CORDEX simulations are now performed at 0.11° (~12.5km) resolution. While we will run H-CLIM on the same geographical domain as Euro-CORDEX, we plan to investigate the benefits of further increased resolution, by making the downscaling runs here at a spatial resolution of ~5-8km. This resolution range is often referred to as the 'grey-zone' with respect to physical parameterization, in particular being a resolution where many of the fundamental assumptions underpinning convective parameterizations begin to break down. H-CLIM uses the physical parameterization package developed for the ALARO model (Wittmann 2009; Yessad 2011), which has been specifically developed targeted for application to NWP at the ~5-10km range. In particular, the convection scheme in ALARO (Gerard 2005) has been developed to address application at 'grey-zone' resolutions.

These Euro-CORDEX H-CLIM simulations will provide: (i) ~5-8km resolution downscaling of the bias-corrected T511 EC-Earth simulation covering 1979-2009. (ii) ~5-8km resolution downscaling of the bias-corrected T511 EC-Earth 30-year simulations, centered on 2°C global warming from one of the coupled EC-Earth CMIP5 projection runs. For each of the ~5-8km H-CLIM runs we will save six-hourly model level data, allowing further downscaling in selected regions using H-CLIM at convective resolving resolutions (~2km). The ~5-8km H-CLIM simulations made in this project will be compared to equivalent runs made on SMHI computer systems at lower resolution, using both H-CLIM and the 4th version of the Rossby Centre model RCA (Samulesson et al. 2010). Depending on the availability of complementary computer resources, the 2nd EC-Earth 2°Cn timeslice may also be downscaled using H-CLIM.

We have recently tested H-CLIM run at ~2km resolution and forced by output from a 15km H-CLIM simulation over Europe. For these tests 2 domains were configured at ~2km resolution. One centered on the Luleå river catchment in Northern Sweden, an important area for hydropower generation and a second domain over the Alps, where we aim to evaluate the benefits of increased model resolution in complex terrain using a high-resolution precipitation data set available for the Alpine region (Wüest,. et al. 2010). Depending on the computer time available, short periods (of order 1 season) of the ~5-8km H-CLIM timeslices will be downscaled to ~2km over these two regions, with further domains also considered, depending on the benefits arising from the increased resolution, particularly in relation to extreme weather events, the amount of computer time available and the specific needs of the impact groups in the project. Our primary aim with these short integrations is to gauge the benefit of going to convection-resolving resolution in simulating higher time-frequency precipitation variability. Comparison of the convection-resolving simulations with the driving 5-8km H-CLIM model will also help in evaluating the performance of H-CLIM in the 'grey-zone' resolution, with a particular emphasis placed on comparison of simulated extreme precipitation events. All the planned H-CLIM simulations will follow the CORDEX output specifications and be made available through the Euro-CORDEX archiving system.

A second area where high-resolution downscaled data is required in IMPACT_2C is East Africa. In this region researchers will assess the potential impacts of 2°C global warming on agriculture, food security and health. We will use the same set of EC-Earth T511 boundary condition data to force H-CLIM at ~5-8km resolution on a domain covering a region of East Africa. Once again model level data will be saved for a number of targeted second downscaling steps using the ~2km configuration of H-CLIM. The latter domains and periods to be simulated will be decided after careful analysis of the lower resolution H-CLIM simulations and consultation with impact groups working in the region. The primary emphasis for the convection-resolving simulations, will be a case-study evaluation of the representation of extreme precipitation and comparison with the driving ~5-8km driving model.

The Rossby Centre already has some experience performing dynamical downscaling over Africa, with the principal investigator being the co-chair of the CORDEX activity (http://wcrp.ipsl.jussieu.fr/SF_RCD_CORDEX.html) and the group having made a large ensemble of Africa-CORDEX projections with our present RCM (RCA4). The principal investigator will therefore ensure all H-CLIM simulations, over both Europe and Africa, are made fully available to the CORDEX research community. Furthermore, the group is part of the EU FP7 project, Healthy-Futures (http://www.healthyfutures.eu) investigating the potential impacts of climate and environmental change on vector borne diseases in East Africa. The 2°C simulations outlined in this application will also be provided to researchers in the Healthy-Futures project.

References

- Gerard, L. and Geleyn, J.-F., 2005:, Evolution of a subgrid deep convection parametrization in a limited-area model with increasing resolution. Q.J.R. Meteorol. Soc., 131, 2293–2312.
- Hazeleger, W., Wang, X., Severijns, C., Ştefănescu, S., Bintanja, R., Sterl, A., Wyser, K., Semmler, T., Yang, S., van den Hurk, B., van Noije, T., van der Linden, E., van der Wiel, K., 2011: EC-Earth V2.2: description and validation of a new seamless earth system prediction model., Clim. Dyn., 38, 1-19.
- Lindstedt, D., 2012: Development of a high resolution regional climate model, Rossby Centre Newsletter., Available at: http://www.smhi.se
- Niemelä, S., 2008: The HARMONIE system, In the 2nd AROME training course, Lisbon, 4-7 March 2008, Available at: http://www.cnrm.meteo.fr/gmapdoc

- Samuelsson, P., Jones, C. G., Willen, U., Ullerstig, A., Gollvik, S., Hansson, U., Jansson, C., Kjellström, E., Nikulin, G. and Wyser, K., 2011: The Rossby Centre Regional Climate model RCA3: model description and performance., Tellus A, 63: 4–23.
- Seity, Y., Brousseau, P., Malardel, S., Hello, T., Bénard P., Bouttier, F., Lac, C., Masson, V,. 2011: The AROME-France Convective-Scale Operational Model. Mon. Wea. Rev., 139, 976–991.
- Undén P, Rontu L, Calvo J, Cats G, Cuxart J, Eerola K, Fortelius C, Garcia-Moya JA, Gustafsson N, Jones C, Jarvenoja S, Jarvinen H, Lynch P, McDonald A, McGrath R, Navascues B, Odegaard V, Rodriguez E, Rum-mukainen M, Room R, Sattler K, Savijarvi H, Sass BH, Schreur BW, The H, Tijm S., 2002: HIRLAM-5 Scientific Documentation., SMHI: Norrköping, Sweden. http://hirlam.org.
- Wittmann, C., 2009: Evaluation of ALARO-0 5km over Madeira., http://www.rcLace.eu
- Wüest, M., Litschi, M., Altenhoff, A., Frei, C., Hagen M., Schär, C., 2010: A gridded hourly precipitation dataset for Switzerland using rain-gauge analysis and radar-based disaggregation., Int. J. Clim., 30, 1764-1775.
- Yessad, K., 2011: Basics about ARPEGE/IFS, ALADIN and AROME in the cycle 38 of ARPEGE/IFS., Available at: http://www.cnrm.meteo.fr/gmapdoc