REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: UK………………………………………………………………………..

Principal Investigator[1]: Kevin Hodges…………………

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Other researchers:

Adrian Champion, Lennart Bengtsson

Project Title:

Changes in Precipitation Extremes Associated with Extra-tropical Cyclones: System Centered Dynamical Downscaling

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPGBHODG**	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2012	
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)	500000	500000	
Data storage capacity (total archive volume) (gigabytes)	500	500	

*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):

……………………………………………

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: Kevin Hodges

Project Title: Changes in Precipitation Extremes Associated with Extra-tropical Cyclones: System Centered Dynamical Downscaling

Extended abstract

We have only just been allocated this project, but we repeat the original abstract below.

It is well understood that one of the main consequences of a warmer climate is an enhancement of the hydrological cycle. The global atmospheric water vapour increases ~6%/K according to the Clausius-Clapyron (CC) relation but precipitation increases only by ~1-2%/K (Held and Soden, 2006). However, it also follows that the convergence of water vapour also scales with the CC-relation implying that changes in precipitation are expected to be more pronounced in the vicinity of storms, even approaching the scale of change seen for the water vapour (Bengtsson et al., 2009). Previous climate change studies have clearly shown a change in precipitation associated with extra-tropical storms, which is larger than seen in the global mean change in precipitation, these changes also have a seasonal character to them (Bengtsson et al, 2009; Champion et al, 2011).

The likely enhancement in extreme precipitation associated with storms in a warmer world will have a strong impact on the likelihood of extreme pluvial and fluvial flooding events. However, current climate simulations are still not at sufficiently high enough resolution to fully simulate the extreme precipitation associated with storms, for this resolutions more typical of Numerical Weather Prediction are required (<10km). Although, limited area models (LAM) can address the issue of resolution to some extent, past downscaling studies of climate model data have been limited to resolutions ~10's km due to the computation expense of downscaling long time periods, although this will depend on the domain size. Also, the downscaling domains have tended to be tied to particular regions so that storms moving into these regions may only be partially captured where they intersect with the LAM boundaries resulting in biases at the boundaries. Of coarse the domain can be made large enough to reduce this effect but then the resolution versus computational cost becomes an issue. Also, making the domain size large results in the boundary conditions exerting less constraint towards the centre of the domain and the LAM then generates its own weather systems, spectral nudging can be used to partially alleviate this issue.

In the PhD work of Adrian Champion particular extra-tropical cyclones that have resulted in flooding in the UK have been downscaled to resolutions of 12 and 4km using the Met Office LAM applied to the UK region with the boundary condition data from the ECMWF operational analyses. In order to capture the intense precipitation realistically when compared with rain gauge data it was found that the lead time of the short range forecast was also important with an optimum lead time of ~12hrs. However, as this was for a fixed domain, problems were still experienced at the boundaries.

One solution to the use of static domains, previously used in case studies of storms and in particular for tropical cyclones, is to use a limited area for downscaling moving with the storm. This has the benefits that a smaller region can be downscaled allowing higher resolutions to be achieved and there is less of a problem with the boundaries as the storm is always in the centre of the domain and well away from the boundaries. This has the potential to also allow transient systems to be downscaled to high resolution over their whole lifecycle and so better capture when the extreme precipitation occurs, which for a fixed LAM may occur outside of the region. It also offers the potential to more efficiently downscale a large number of systems which would provide better statistics of more realistic extreme precipitation associated with storms than is the case with global models or with current LAM usage. The Weather Research and Forecasting (WRF) limited area model (Michalakes et al, 2004) has the facility to use a moving mesh.

The aim of this project is to use previously determined cyclone tracks obtained from ERA-Interim (Hodges et al, 2011) and climate model simulations with the ECHAM5 model (Bengtsson et al, 2009, Champion et al 2011) and apply the WRF moving mesh downscaling to resolutions ~1-5km over as many storms as we can. In the first instance this would be based on identified extreme precipitating storms in the re-analyses and model simulations. This would provide a much more detailed and accurate view of extreme precipitation associated with extra-tropical cyclones in both the current and future climates. The downscaled data will also be made available for use in hydrological models. This work would be closely associated with several existing projects such as the NERC Storm Risk Mitigation program and its sub-programs, TEMPEST and DEMON. A related issue is whether the increased precipitation in storms in the future will lead to an increase in the release of latent heat and thus result in dynamically more intense storms with stronger winds. Studies so far, at resolutions ~10's km's, have shown no particular change in the dynamical intensity, at least during winter, though the situation can be different during summer and autumn when this might be complicated by more intense tropical cyclones migrating into the extra-tropics (Champion et al., 2011; Bengtsson et al, 2009). It would be interesting to see if this is still the case with the downscaled storms obtained from the WRF fully non-hydrostatic model.

L. Bengtsson, K. I. Hodges, and N. Keenlyside, 2009, Will Extratropical Storms Intensify in a Warmer Climate? , J. Clim., **22**, pp 2276-2301.

A. J. Champion, K. I. Hodges, L. O. Bengtsson, N. S. Keenlyside, M. Esch, 2011, Impact of increasing resolution and a warmer climate on extreme weather from Northern Hemisphere extratropical cyclones, Tellus A , **63A**, 893-906.

Held, Isaac M., Brian J. Soden, 2006: Robust Responses of the Hydrological Cycle to Global Warming. *J. Climate*, **19**, 5686–5699.

K. I. Hodges, R. W. Lee and L. Bengtsson, 2011, A Comparison of Extratropical Cyclones in Recent Reanalyses ERA-Interim, NASA MERRA, NCEP CFSR, and JRA-25, J. Clim. , **24**, 4888-4906.

Michalakes, J., J. Dudhia, D. Gill, T. Henderson, J. Klemp, W. Skamarock, and W. Wang, 2004: "The Weather Reseach and Forecast Model: Software Architecture and Performance,"to in proceedings of the 11th ECMWF Workshop on the Use of High Performance Computing In Meteorology, 25-29 October 2004, Reading U.K. Ed. George Mozdzynski