REQUEST FOR A SPECIAL PROJECT 2016–2018

MEMBER STATE: Netherlands

Principal Investigator[1]: Andreas Sterl

Affiliation: KNMI (Royal Netherlands Meteorological Institute)

Address: P.O. Box 201
NL-3730 AE De Bilt

E-mail: sterl@knmi.nl

Other researchers: Henk van den Brink (henk.van.den.brink@knmi.nl)
Bert van Ulft (ulft@knmi.nl)

Project Title: Small-scale severe weather events: Downscaling using Harmonie

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPNLSTER**	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2016	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2016-2018: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2018.)		**2016**	**2017**	**2018**
High Performance Computing Facility	(units)	40 M	25 M	25 M
Data storage capacity (total archive volume)	(gigabytes)	30,000	45,000	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): 19 June 2015

Continue overleaf

1The 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: Andreas Sterl

Project Title: Small-scale severe weather events: Downscaling using Harmonie

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.

Abstract

We propose to use the non-hydrostatic Harmonie model to downscale climate model results. Such a downscaling has been shown to be technically and computationally feasible. It offers the possibility to investigate the effect of climate change on small-scale phenomena like convective rainfall and wind gusts. This is not only relevant from a scientific point of view, but has many applications. For example, wind turbines suffer from night-time low level jets that are not represented well in current climate models.

This request is to continue and extend the Special Project of the same name that has been granted for 2015. As described in detail in the 2015 Progress Report, one major conclusion of the work performed so far (half June 2015) was that the model domain had to be extended significantly, increasing the necessary computing time by nearly a factor of three. Furthermore, additional computing time was necessary to test new parametrizations that became available in the meantime, which resulted in large improvements. More details can be found in the 2015 Progress Report.

The present request is to accommodate for the increased computing time, while the aim of the proposal remains unaltered. The following description of the project is therefore a copy of the text in the original request, with only modest updates.

1 Introduction

Weather extremes like very hot temperatures, extremes downpours, or heavy winds have a large impact on society. Often, such events are small scaled and are not resolved by current global or regional climate models (GCM or RCM, respectively). For instance, RACMO2 (Van Meijgaard et al. 2008), the RCM used at KNMI, has a horizontal resolution of 11 km, while extreme precipitation events often have a scale of one kilometre or less, and wind gusts associated with them are even smaller. Furthermore, current GCMs and RCMs use the hydrostatic approximation, implying that the heaviest precipitation events, convective systems on hot summer days, are parameterized rather than modelled. This leads to well-known model deficiencies like a faulty daily cycle of summer precipitation.

Due to these resolution dependent problems with GCMs and RCMs, projections for extreme weather events in a warmer climate are associated with large uncertainties, and the magnitude of their change is likely underestimated. Comparing results from an 11 km RCM and a 1.5 km weather model, Kendon et al. (2014) recently showed that the latter projects significantly larger changes of heavy precipitation than the former over South England. Lenderink and Van Meijgaard (2008) showed that observed short-term amounts of heavy precipitation increase faster with temperature than the 7%/K suggested by the Clausius-Clapeyron relation. Responsible for this “super Clausius-Clapeyron” scaling is probably that warm and humid air is collected from a large area and then ascending in a narrow convective plume. Eventually, it condensates, leading to large precipitation amounts over a small area. As convection is not resolved in current RCMs, this process is, if at all, only rudimentarily captured. The same is true for the heavy wind bursts that accompany strong convective systems and that can cause a lot of damage.

To overcome the resolution-dependent shortcomings of current climate models, we propose to use Harmonie to downscale GCM output. Harmonie is the non-hydrostatic atmosphere model used operationally at KNMI. Preparatory experiments in the first half year of the project (see 2015 Progress Report) have shown that a domain encompassing most of France is necessary to allow convective systems developing over that country to be advected into the Netherlands. The corresponding model domain contains 800 x 800 grid points. Its boundaries are roughly (they do not follow lat-lon lines) at 42°N and 60°N, and at 10°W and 18°E. Running the model on this domain costs about 200 kSBU per month.

2 Runs to be performed

To investigate basic relations between small-scale weather elements, one run for the present climate would be enough. To investigate the effect of climate change, a similar run for a future climate is needed. However, current climate models have certain biases that are transferred to the downscaling model. For instance, EC-Earth (Hazeleger et al. 2012) is known to be have a cold and therefore dry bias at low latitudes and a wet bias at higher latitudes. Through the lateral boundary conditions that are provided from the driving climate model, such biases are transferred to the downscaling model. To assess the bias, a parallel run using ERA-Interim or any other reanalysis is needed. Due to their assimilation of observations, reanalyses are much less affected by biases than free-running climate models. We therefore propose the following runs:

- **ERA-Interim** The lateral boundary conditions for Harmonie are taken from ERA-Interim. This run serves as reference for the Present Day run, but can also be used to perform processes studies.
- **Present Day** The lateral boundary conditions are taken from an EC-Earth run for the same period as the ERA-Interim run is performed (historical run in CMIP6 parlour). This run forms the basis from which to derive changes as simulated in the Future run.
- **Future** Here the boundary conditions are taken from an EC-Earth scenario run. Which scenario and which period have to be determined.

To obtain enough events for a thorough statistical analysis, each run should last for at least ten years, with 20 or even 30 years being preferable. As a practical arrangement we plan to perform ten years of each run first, and then extend them if preliminary results suggest a need to do so.

3 Scientific questions and applications

The results of these runs can be used to analyse a variety of scientific questions, but they also have important applications. The following is a list of scientific questions and applications that can be dealt with the model output. It is non-exhaustive, but guided by expertise and interest available at KNMI. The data will be available for non-KNMI researchers.

The wind-related products are especially important for wind-farm operations which at present suffer from incomplete knowledge of the wind climate and its variability in the lower 200 m of the atmosphere. Both wind and precipitation related products are important for safety considerations.

- climatology of low-level jets
- climatology of gusts at 100 m (incl extremes)
- climatology of vertical wind shear (incl extremes)

- effects of stability on wind(shear)
- impact of climate change on heavy precipitation
- impact of climate change on wind and wind gusts
- impact of climate change on temperature extremes. The resolution of Harmonie is high enough to distinguish urban and rural areas, or clay and sand grounds
- waves (off-line forced)
- floodings (off-line forced hydrological model)
- process studies of small-scale weather systems, especially those that are highly impacted by the relaxation of the hydrostatic approximation.
- local feedbacks in the hydrological cycle - how do water availability (soil moisture) and convective activity (rainfall) influence each other?
- coincident events

4 Computational requirements

As mentioned above, one model month costs about 200 kSBU. For a 10-year downscaling run this is 25 MSBU, and 75 MSBU for the three runs planned. These runs will generate about 45 TB of data. The need for further testing, and allowing for necessary re-runs due to, e.g., runs crashing or bugs discovered, leads us the requested resources (90 MSBU and 60 TB, including the 15 TB granted in the original project).

References

Kendon, E.J., N.M. Roberts, H.J. Fowler, M.J. Roberts, S.C. Chan, and C.A. Senior (2014), Heavier summer downpours with climate change revealed by weather forecast resolution model. Nature Clim. Chang., 4, 570-576, 10.1038/NCLIMATE2258.

Hazeleger, W., X. Wang, C. Severijns, S. Ştefănescu, R. Bintanja, A. Sterl, K. Wyser, T. Semmler, S. Yang, B. van den Hurk, T. van Noije, E. van der Linden, and K. van den Wiel (2012), EC-Earth V2: description and validation of a new seamless Earth system prediction model. Clim. Dyn., 39, 2611-2629, doi: 10.1007/s00382-011-1228-5.

Lenderink, G., and E. van Meijgaard (2008), Increase in hourly precipitation extremes beyond expectations from temperature changes. Nature Geosci., 1, 8, 511-514, doi:10.1038/ngeo262.

Van Meijgaard, E., L.H. van Ulft, W.J.van de Berg, F.C. Bosveld, B.J.J.M. van den Hurk, G. Lenderink, and A.P. Siebesma, (2008), The KNMI regional atmospheric climate model RACMO, version 2.1. KNMI Technical Report TR-302, http://www.knmi.nl/bibliotheek/knmipubTR/TR302.pdf.