# REQUEST FOR A SPECIAL PROJECT 2015–2017

**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)

**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. | **SP** ___________________ | |
| Starting year:<br>(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:**<br>(The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.) | **2015** | **2016** | **2017** |
|---|---|---|---|
| High Performance Computing Facility (units) | 25 M | | |
| Data storage capacity (total archive volume) (gigabytes) | 15,000 | | |

*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):

16 July, 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:** 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 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.


## 1 Introduction

Weather extremes like very hot temperatures, extremes downpours, or heavy winds have a large impact on society. Often, such events are small scale 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 model, we propose to use Harmonie to downscale GCM output. Harmonie is a non-hydrostatic atmosphere model used operationally at KNMI. It has a horizontal resolution of 2.5 km and covers the region between 7°W and 10°E, and 48°N and 59°N, i.e., Great Britain, Denmark, the Benelux, large parts of northern France and north-west Germany, and nearly the whole North Sea. Henk van den Brink has recently shown that such a downscaling is technically and computationally feasible by downscaling 35 years of ERA-Interim data.

# 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. 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. A practical arrangement could be to perform ten years of each run first, and then extend them if preliminary results suggest a need to do so.

We have already performed a downscaling of the whole ERA-Interim period. However, the run has been performed by restarting the model every six hours from ERA-Interim output. The effect of these restarts is small for the wind (except low-level jets) but large for other parameters, like precipitation. Furthermore, not only the lateral boundaries conditions, but also the lower boundary conditions (soil moisture etc.) have been updated every six hours, preventing the model from generating its own climate. It is therefore advisable to repeat this run with only updating the conditions as the lateral boundaries.

# 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

From the experience of the aforementioned runs we expect that the three ten-year runs would take about six months to perform on C2a. They would require about 25 M SBU, and generate about 15 TB of data.

## 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. Stef▯anescu, 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.