LATE REQUEST FOR A SPECIAL PROJECT 2016–2018

MEMBER STATE: Netherlands

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Project Title:

Small-scale severe weather events: Downscaling using Harmonie

Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2016-2018: (The project duration is limited to a maximum of 3 years, agreed at the beginning of the project.)		**2016**	**2017**	**2018**
High Performance Computing Facility	(units)	25M		
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):

04 February 2016

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 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 that are not resolved in global climate models. 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 the Special Project of the same name that has been granted for 2015, and In which the basic model set-up has been established and one year (2012) of ERA-Interim has been downscaled. The assessment of these runs has shown excellent agreement between model output and observations for some parameters (e.g., the vertical profiles of longwave radiation and wind, especially at night-time), but also some deficiencies (e.g., a cold temperature bias). Part of the requested cpu-time will be used to further investigate these issues.

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) 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 rudimentary 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. Its model domain contains 800 x 800 grid points with a distance of 2.5 km. 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.

In a preceding Special Project (spnlster) the basic model set-up has been established and different parameterization options have been tested, and one year (2012) of ERA-Interim has been downscaled. The assessment of these runs so far has shown excellent agreement between model output and observations for some parameters (e.g., the vertical profiles of longwave radiation and wind, especially at night-time), but also some deficiencies (e.g., a cold temperature bias). Part of the requested cpu-time will be used to further investigate these issues (see sec. 4).

Two examples are given in the figures. In Figure 1 the 10 m wind in De Bilt (Netherlands) from Harmonie and from ERA-Interim is compared with the station observations for May 2008. In most instances the Harmonie results better follows observations than ERA-Interim. This is remarkable as the Harmonie runs are only forced at the lateral boundaries, which are 1000 km away from De Bilt, while ERA-Interim is forced everywhere due to the data assimilation. In the same way Figure 2 compares the 2-metre temperatures. The Harmonie values are closer to the observations than are the ERA-interim ones (which are representative for a larger area), but clearly underestimate the observations.

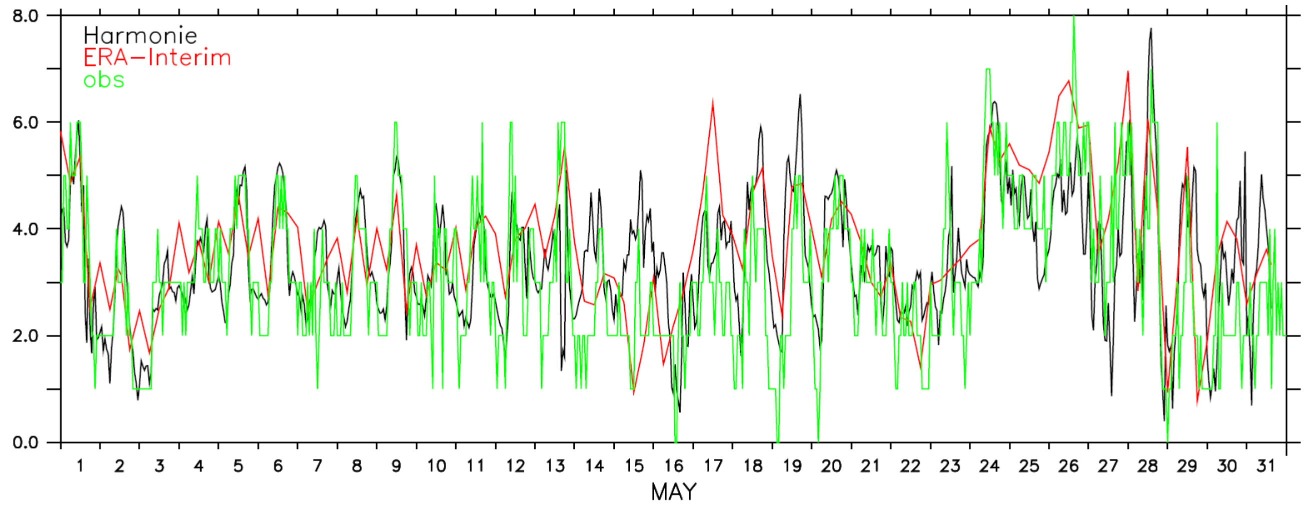

Figure 1: 10 m wind at grid point corresponding to De Bilt from Harmonie (black), ERA-Interim (red) and from the station observation (green) in May 2008.

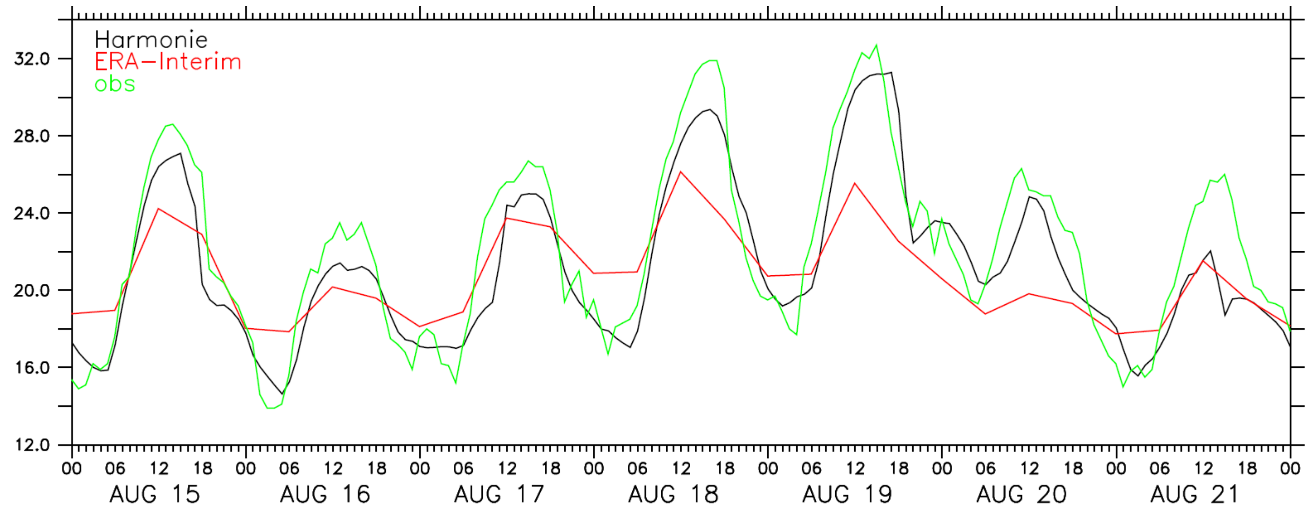

Figure 2: 2-metre temperature in De Bilt in during the hottest days of 2012 from Harmonie (black), ERA-Interim (red) and from the station observation (green).

3 Scientific questions and applications

The focus of research are phenomena that cannot be resolved in a global climate model. Basic questions to be investigated are

- Are the phenomena well represented by Harmonie when forced by ERA-Interim (verification against observations)?
- What is the climatology of these phenomena?
- What is the bias resulting from using EC-Earth as the forcing?
- What is the climate-change signal?

The following list of such phenomena is not exhaustive, but guided by expertise and interest available at KNMI. The wind-related parameters 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 parameters are important for safety considerations, and (extreme) temperatures for human comfort and well-being.

- low-level jets
- wind gusts in the lower 200 m (incl extremes)
- vertical wind shear in the lower 200 m (incl extremes)

- effects of stability on wind(shear)
- temperature extremes. The resolution of Harmonie is high enough to distinguish between urban and rural areas, or between 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

The data will be available for non-KNMI researchers to pursue their own research.

4 Computational requirements

We aim at performing additional test runs an a first 5-year chunk of the ERA-Interim run in 2016. For the test runs we anticipate an equivalent of five model years. As mentioned above, one model month costs about 200 kSBU, resulting in 25 MSBU for a total of ten model years. The corresponding amount of output data is 15 TB.

References

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