REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: Netherlands

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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** NLSTER	
Starting year: (Each project will have a well-defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2017	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2017-2019: (To make changes to an existing project please submit an amended version of the original form.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(SBU)	25M	25M	25M
Accumulated data storage (total archive volume)[2]	(GB)	15,000	30,000	45,000

***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):

21 June 2016

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.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (1,000,000 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, and small-scale convective precipitation events can cause a lot of damage.

This request is to continue the Special Project of the same name that had been granted for 2015[1], 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

1 The extension of this project for the period 2016-2018 was initially rejected, but then granted for 2016 via a Late Request in April of this year.

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 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, no annual cycle in soil moisture). Part of the requested cpu-time will be used to further investigate these issues (see sec. 4).

Some 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 follow observations better 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.

The statistical properties of precipitation are simulated well in Harmonie. As an example Figure 3 (left) shows the accumulated sum of observed and modelled precipitation for the grid point corresponding to De Bilt (Netherlands), and the right panel the modelled and observed hourly precipitation amounts in the same point. Clearly, the statistical properties of observed and modelled precipitation are similar. The overestimation of the annual sum by the model is not limited to the grid point De Bilt but found over the whole model domain.

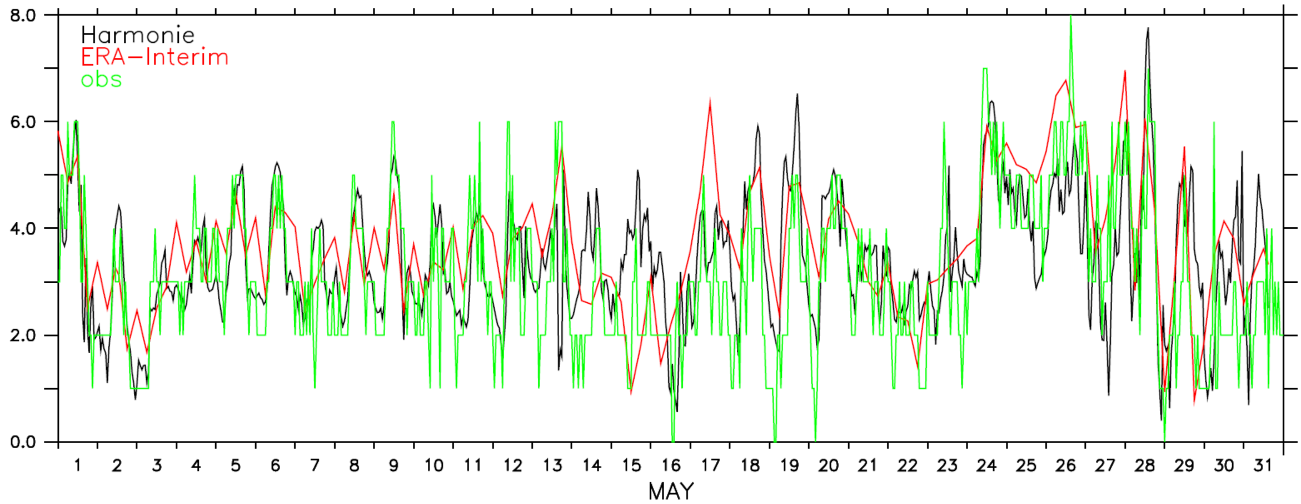

Figure 1: 10 m wind at grid point corresponding to De Bilt from Harmonie (black), ERA-Interim (red) and from the station observation (green) in May 2008.

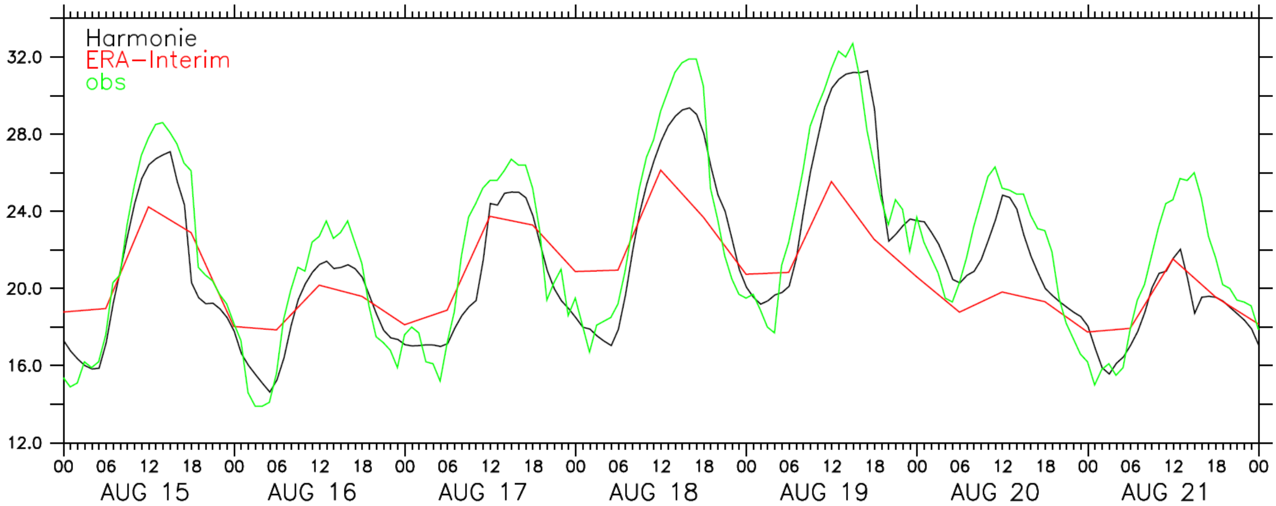

Figure 2: 2-metre temperature in De Bilt in during the hottest days of 2012 from Harmonie (black), ERA-Interim (red) and from the station observation (green).

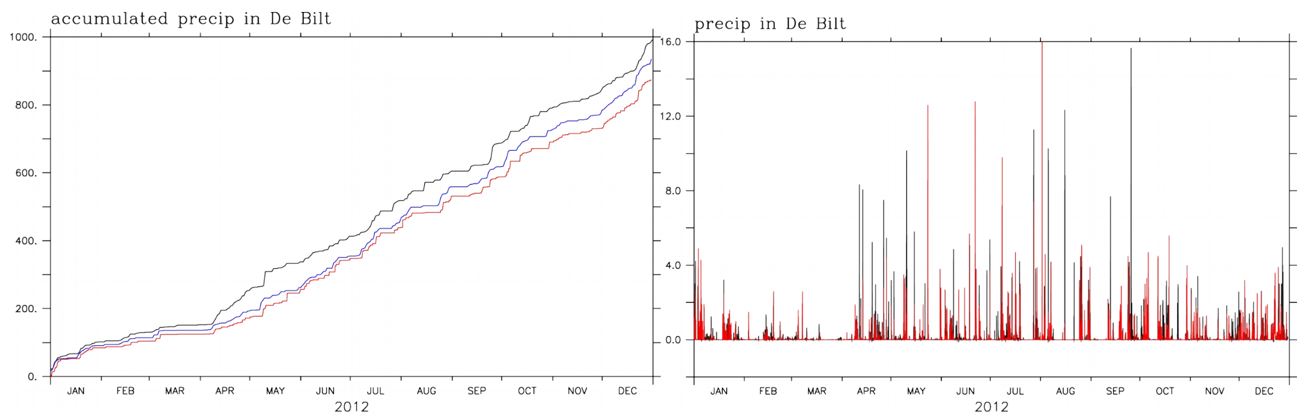

Figure 3: Precipitation at grid point corresponding to De Bilt from station observations, E-OBS and Harmonie. Left: Accumulation of hourly (daily for E-OBS) precipitation; black: Harmonie, red: station, blue: E-OBS). Right: Hourly precipitation according to Harmonie (black) and station observation (red).

Figure 4 shows an example of a parameter that is not well simulated by Harmonie, namely soil moisture. The figure compares simulated soil moisture at the Cabauw observation site in the Netherlands to observed i*n-situ* soil moisture values and to the satellite-based soil water index (SWI). Clearly, simulated values do not reproduce the observations well. There is nearly no annual cycle in the simulation, with values being much too low in winter and much too high in summer, and differences between layers are much too low. However, during summer simulated soil moisture values in the second model layer (red) and those measured a 8 cm depth (magenta) compare well. Comparison with SWI shows that the lack of an annual cycle is a general feature of the model and not restricted to the one location (Cabauw) investigated here (not shown).

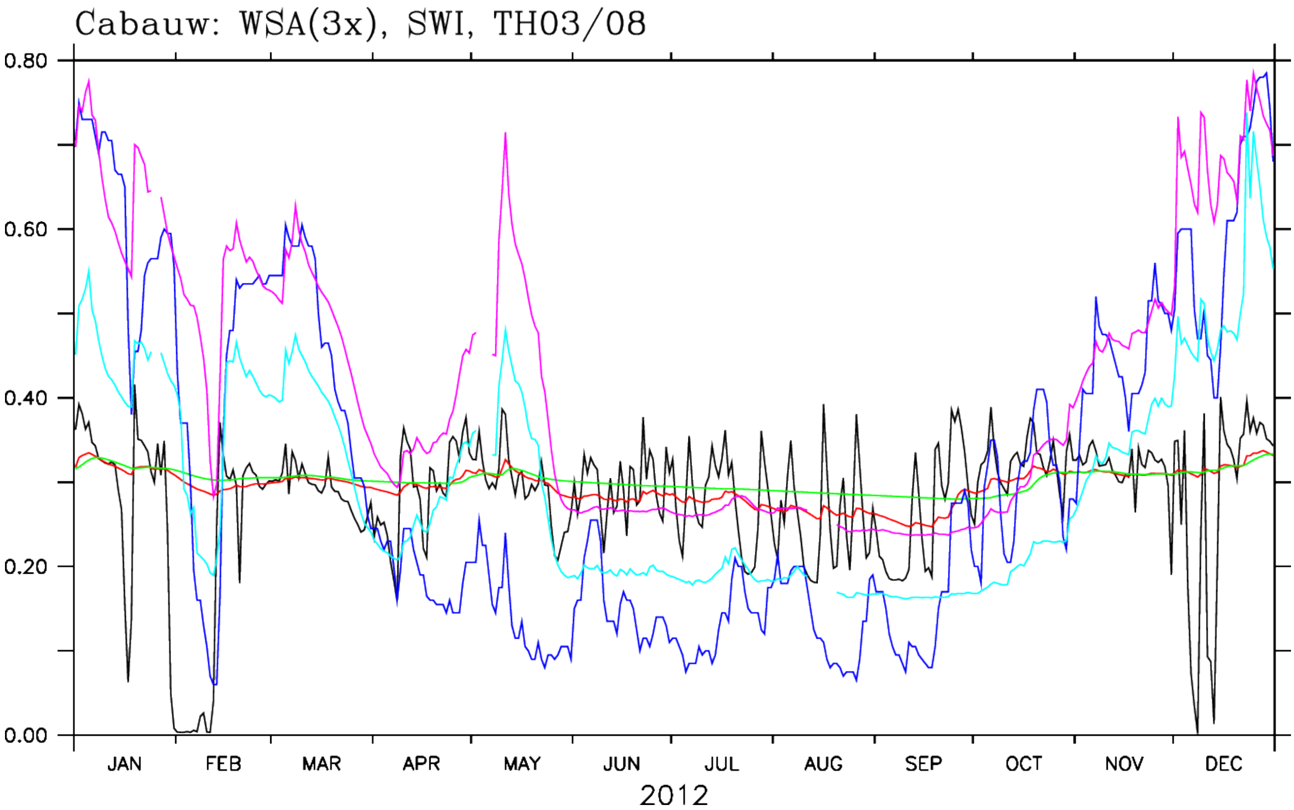

Figure 4: Soil moisture in Cabauw in first (black), second (red) and third (green) layer, SWI/100 (blue) and measured soil moisture at depths 3 cm (cyan) and 8 cm (magenta).

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 these phenomena well represented by Harmonie when forced by ERA-Interim (verification against observations)?
- What is their climatology?
- 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,

- convective events and accompanying precipitation and wind gusts
- temperature extremes. The resolution of Harmonie is high enough to distinguish between urban and rural areas, or between clay and sand grounds
- 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)
- 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 (extreme values occurring simultaneously for two variables)

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, while (extreme) temperatures are important for human comfort and well-being.

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

4 Computational requirements

We aim at performing additional test runs and a first 5-year chunk of the ERA-Interim run in 2016. The computational resources for this are granted, and the test runs underway. The second half of the ERA-Interim downscaling and the two EC-Earth driven runs are planned for the period 2017-2019. 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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