SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2015
Project Title:	An extreme wind climatology for Dutch Water Defences ……………………………………………………………
Computer Project Account:	spnlburg…………………………………………………
Principal Investigator(s):	Reinout Boers, since Sep 2013 [formally Gerrit Burgers]………………………………………… ……………………………………………………………
Affiliation:	Royal Netherlands Meteorological Institute (KNMI)…….
Name of ECMWF scientist(s) collaborating to the project (if applicable)	NA…………………………………………………… ……………………………………………………………
Start date of the project:	January 1, 2013……………………………………….
Expected end date:	December 31, 2015…………………………………….

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used until June 30
High Performance Computing Facility	(units)	3000000	all	3000000	0 [0%]
Data storage capacity	(Gbytes)	3000	all	3000	187TB

August 2015

Summary of project objectives

- The objective of the special project is to make high-resolution simulations of all major storms over the Netherlands from the period 1979-2012 using the Harmonie-Arome model (2.5km grid) for dynamical downscaling the ERA-Interim re-analysis.

- The special project contributes to a joint project of KNMI and Deltares that is funded by the Netherlands National Water Authority RWS and has the following objectives
    - Assessment how well high-resolution models can represent storm fields.
    - Production of a long-term (~ 30 year) storm data set that can be used for deriving extreme wind statistics needed for the design of Dutch water defenses.
    - Extreme value analysis of storm fields, including a proper space and time dependence.

Summary of problems encountered (if any)

None.

Summary of results up to 2015

R. Boers, with contributions from H. van den Brink.

Even though most work could be performed on KNMI computers this project has used [and is using] a considerable amount of storage at ECMWF, in fact much more than has been allocated [see resources above].

The present report summarizes the final report of Work Package 1 (WP1) of the Wind Modelling project. WP1 deals with assessing the high-resolution model and focusses on the spatial and temporal structures of the modelled wind fields. As such, the aim is to establish how well the high-resolution atmospheric model (i.c. HARMONIE) is capable of simulating realistic (open water) wind fields, including their variations in time and space.

The work of WP1 greatly benefitted from the computing power that has been made available under the SPNLBURG account at ECMWF in the previous year and from the storage capacity needed as a result from the vast amount of computing that was done the present year. The main thrust of WP2 has been the calculation of all hindcasts. This was completed and does not need further expansion in this summary as no problems were encountered.

Approach

To gain confidence in the high-resolution wind fields produced by the model, observed and modelled wind fields of test-set of 17 historical storms that occurred between 1979 and 2007 were analysed. Several model experiments were performed to establish the optimal modelling strategy for the Wind Modelling project. The resulting model set-up was used to perform hindcasts of the 17 test-set storms. The model results were compared with available station observations from KNMI, scatterometer winds from a satellite, and with tall mast observations. Not only the spatial and temporal evolution of the wind and surface stress fields was studied, but also the model's ability to represent land-water transitions and the influence of atmospheric stability. The added-value of high-resolution modelling is determined from a comparison with a much coarser atmospheric model. Since the modelled wind and stress fields are used as input for hydrodynamic models, the added value of the high-resolution model for the prediction of storm surges along the coast was also assessed.

Because HARMONIE is run on a finite domain, information on the state of the atmosphere must be provided at the boundaries. To this end, we use the ERA-Interim reanalysis dataset from the ECMWF (European Centre for Medium-Range Weather Forecasts, www.ecmwf.int). The strength of the ERA-Interim data set is that it combines one of the leading numerical weather prediction models (the ECMWF model) with an advanced data assimilation system (Dee *et al.* 2011). The resulting analyses can be considered a best-estimate of the state of the atmosphere because it is based on the very short term model forecast adjusted to match the observations of that moment in time. The grid-spacing of ERA-Interim is approximately 80 km. ERA-Interim analyses are available from 1979 onwards.

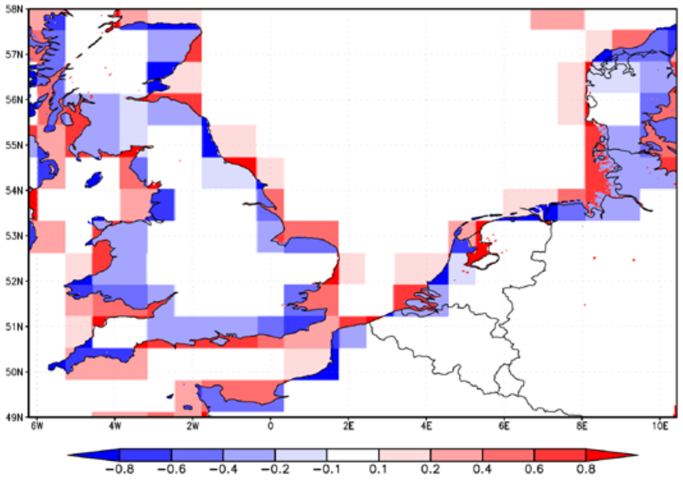

Figure 1: Difference in water fraction between HARMONIE and ERAInt

Figure 1 shows the difference in water fraction between HARMONIE and ERA-Interim. This difference is most pronounced in the coastal zone. The larger the difference in water fraction, the greater the benefit of using HARMONIE instead of ERA-Interim. Especially the coastal zone and Lake IJssel will benefit from the high resolution of HARMONIE. For instance, this leads to 25% higher wind in HARMONIE than in ERA-Interim for all wind speed classes. This implies that modelled surges will be order 50% higher (assuming a quadratic relation between the wind and surge). Water bodies such as the Frisian Lakes, Veluwse Randmeren, and rivers are too small to be explicitly resolved by the 2.5 x 2.5 km HARMONIE grid.

One could argue that increasing the horizontal resolution is nothing more than bringing more detail in the land-sea mask. However, by demonstrating that HARMONIE is able to represent a) direction-dependent wind speed patterns over Lake IJssel and b) the impact of atmospheric stability on the wind field (at least in a qualitative way), it becomes clear that the physical and dynamical processes are also modelled more realistically in the higher resolution HARMONIE compared to the coarser ERA-Interim.

Main results and conclusions

1. Based on verification with observations, we conclude that the wind fields produced by the HARMONIE model are realistic. Temporal and spatial characteristics of the storms are generally well-captured. Discrepancies with observations are largest for small and quickly developing storm depressions that pass close to The Netherlands.

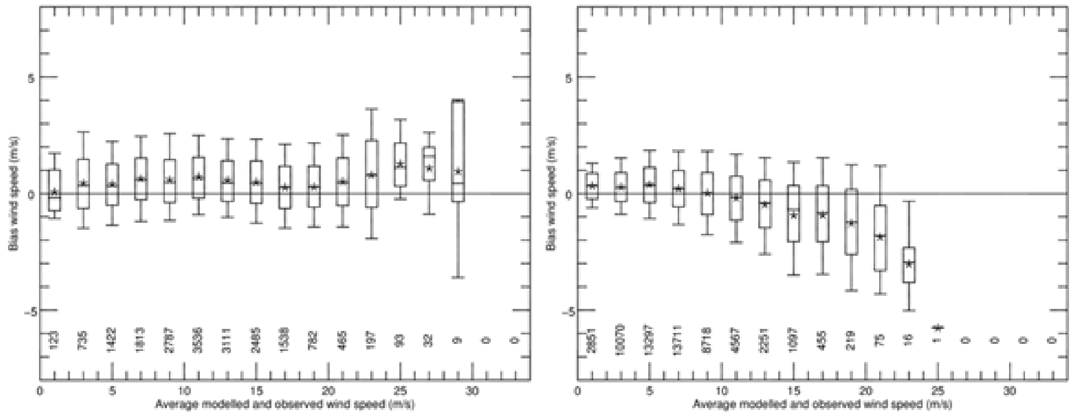

Figure 2. Bias (model – observations) in the 10-m wind speed as a function of wind speed for all stations over sea (left) and over land (right).

2. At sea, modelled wind speeds show a positive bias of about 0.5 m/s. For most stations, the root mean square (rms) difference between model and observations is between 1.5 and 2.0 m/s. For wind speeds over 17.2 m/s (8 Bft or higher) these values are almost the same. The bias in wind direction is a few degrees, rms differences range from 15° when all data are taken into account to about 10° for winds of 8 Bft and higher. These numbers compare well to those encountered when using HARMONIE in an operational setting. Note that the error in the observations is about 1 m/s for wind speed and 10° for wind direction. Bias and rms scores based on Quickscat satellite winds over open water agree with scores derived from station observations. Temporal correlation between modelled and observed wind speed is 0.95 over sea.

3. On land, the wind speed bias is mainly close to zero with rms differences between 1.0 and 1.5 m/s. For wind speeds over 8 Bft there is however a negative bias of about 2 m/s with rms differences varying from 1.5 to 4 m/s. Spatial characteristics are generally well-captured. Spatial correlation between observations valid at the

same time amounts to 0.87 on average. HARMONIE represents spatial gradients in 10-m wind speed between a selection of stations rather well.

4. Wind speeds over Lake IJssel and the Wadden Sea are overestimated by HARMONIE. This conclusion is based on a comparison of model output with data from measuring locations operated by Rijkswaterstaat. For wind speeds of 8 Bft and higher, modelled wind speeds over Lake IJssel are 5-10% higher than the observed ones. For the Wadden Sea this difference is 0-5%.

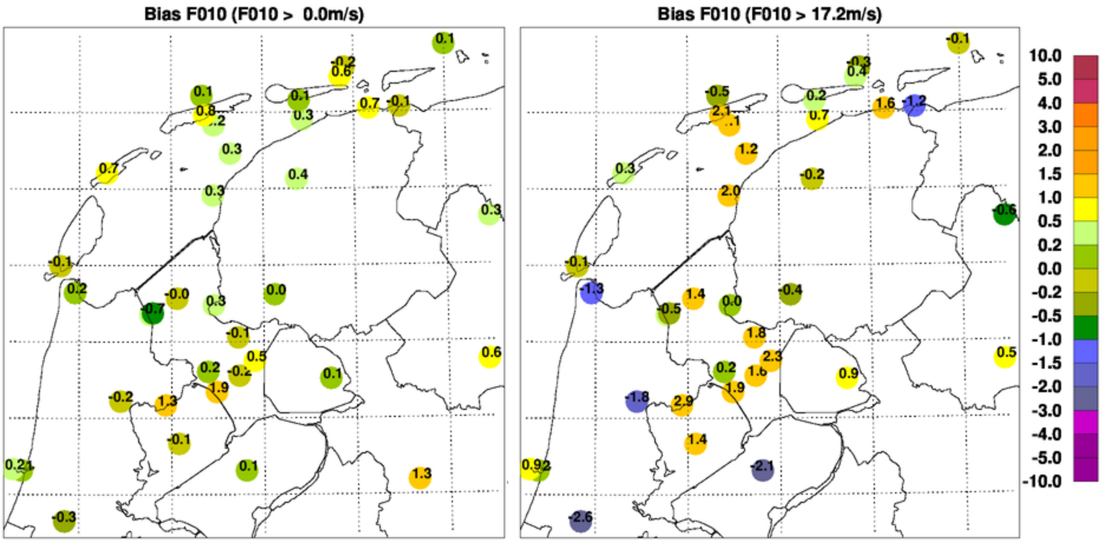

Figure 3. Wind speed bias for the Lake IJssel and Wadden Sea area based on the production runs. The left panel is based on all data (at least 240 data points per station), the left panel includes only data which exceeds the 8 Bft threshold (at least 12 data points per station).

5. The spatial patterns of the wind speed over Lake IJssel are accurately reproduced by HARMONIE. A cross-section of modelled and observed wind speed shows that HARMONIE reproduces transitions from land to water realistically, including the impact of stability on the near-surface wind speed .

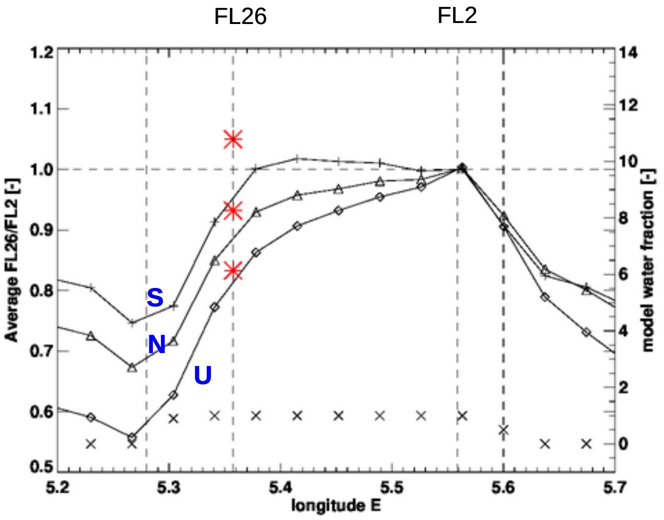

Figure 4. Cross-section over Lake IJssel of 10 m wind for three stability classes (right panel) for westerly winds. Diamonds indicate the unstable case, triangles the neutral case, and plusses the stable case. The asterisks indicate the observed wind speed ratio for the three stability classes; the crosses indicate the modelled water fraction (right axis).

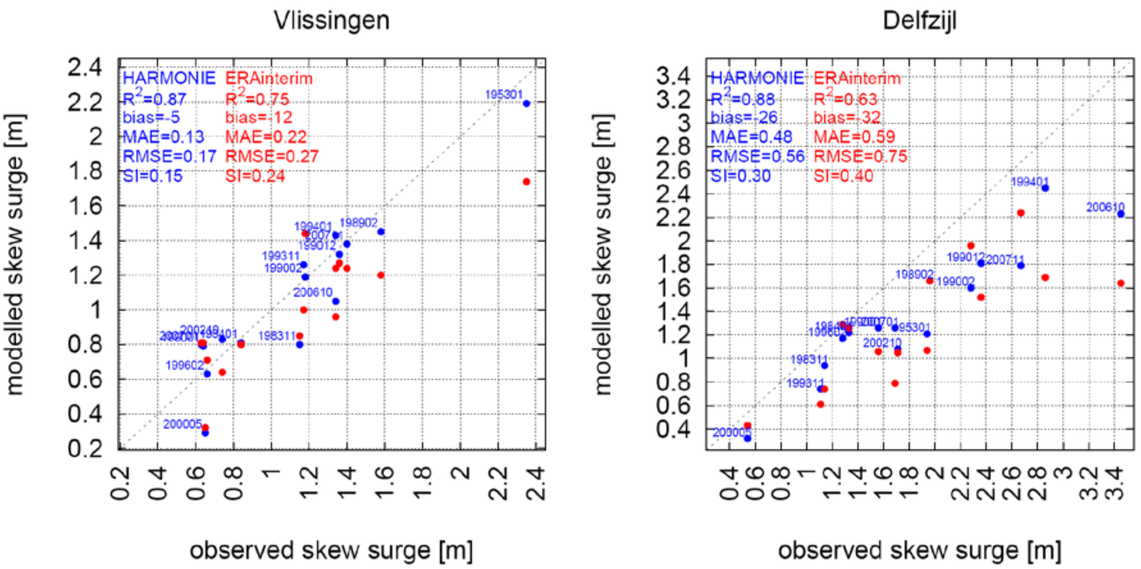

Figure 5. Scatter plots of the maximum skew surge at Vlissingen (left) and Delfzijl (right) for the 17 events as modelled by HARMONIE (blue) and ERA (red).

6. The 2LM method (2LM stand for 2 Layer Model) which is currently used to transform wind speeds from one site to another only takes differences in roughness length into account. It turns out however that for westerly winds the observed wind speed ratio between IJmuiden (sea) and Schiphol (land) show a significant daily and yearly cycle. Around noon, this ratio between the wind speed over sea and over land varies by as much as 25% between its minimum in April and its maximum in November. This suggests that the 2LM methodology is prone to errors as it does not take into account variations in atmospheric stability.

7. Storm surge calculations with the WAQUA model indicate that water levels calculated with HARMONIE wind speeds are consistently closer to the observed water levels than the ones calculated with ERA-Interim wind speeds. To avoid a mismatch between drag relations used by the different models, we use the surface stress to drive the WAQUA model rather than the wind speed.

8. Overall, we rate the model results as good. As such, we conclude that, although further improvements can be made, the model as it is now is adequate for use in Work Packages 2 and 3 of the Wind Modelling project and for the rest of the WTI program.

Recommendations

To establish the value of the high-resolution model for the determination of the HBCs in more detail, we suggest the following:

1. The HARMONIE model is suitable to be used as it is in Work Packages 2 and 3 of the Wind Modelling project. It provides a solid basis for further work.

2. When using the HARMONIE wind fields to drive hydrodynamical models, special attention should be paid to the consequences of the overestimation of the wind speed over Lake IJssel.

3. The underestimation of extreme wind speeds over land remains an intriguing topic for further research. Model development, focusing on the representation of the boundary layer and the air-surface interaction, is needed to better understand the causes of this general model problem.

4. In many cases, differences exist in the modelling of the air-sea interaction of hydro-dynamic models and atmospheric models that are used to drive those. This mismatch may lead to ambiguous results. It would be more consistent to drive the hydro-dynamic models with the surface-stress of the atmospheric models rather than with the 10-m wind. In the long term, we advocate the use of coupled models in which the interaction between the atmosphere and the water surface is explicitly taken into account.

List of publications/reports from the project with references

Scientific papers:

The results of WP1, which has now been completed, have been compiled into a KNMI-scientific report that can be downloaded using the link below:

http://www.knmi.nl/bibliotheek/knmipubWR/WR2014-02.pdf

Journal articles:

1. Baas P., Bosveld F. C., and Burgers G. (2015) The impact of atmospheric stability on the near-surface wind over sea in storm conditions, Wind Energ., doi: 10.1002/we.1825.

2. The paper 'A verification of the high-resolution NWP model HARMONIE for 18 historical storms' by Peter Baas was accepted in 'Journal of Wind Engineering and Industrial Aerodynamics', precise ref. not yet available

Conference papers:

1. The paper 'High resolution modelling improves the simulation of extreme winds in the coastal zone' by Boers, Baas, vd Brink, Barkmeijer, Bosveld, Wijnand, Groeneweg en Caires was presented on 26 September last year at the conference 'Deltas in a time of climate change II' in Rotterdam.
2. The paper " by Peter Baas and Fred Bosveld was presented on 07 October, 2014 at the 14th European Meteorological Society annual meeting in Praag.

Summary of plans for the continuation of the project

At present the required 100% of hindcasted days is complete. It is not expected that a lot of ECWMF time will be used the rest of this current year.