A 500m WRF hindcast of a microburst event in The Netherlands

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1. Introduction

On 14 July 2010 a few high voltage pylons near Vethuizen (a small village in the east of The Netherlands, see Figure 1 for approximate location) were blown down. This day there were many reports of damaging wind gusts. The wind gusts were caused by a microburst area that moved in a north-east direction over the eastern part of the country.

Energy Consultant KEMA , who investigated the incident on behalf of the owner, grid-company TenneT, commissioned Meteo to perform a meteorological analysis.

Official meteorological observation sites are not present in the direct vicinity of Vethuizen. Therefore, the high resolution model WRF was used to simulate the weather of 14 July 2010, to investigate the strength of the wind gusts that could have occurred in this area.

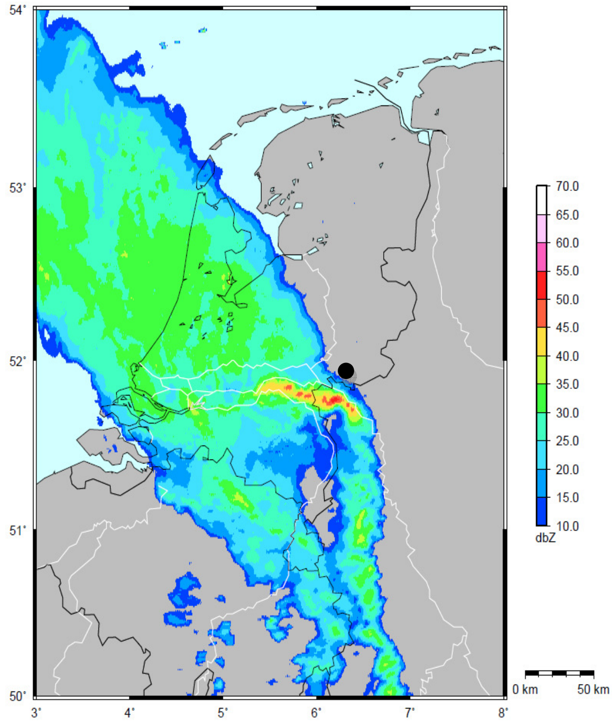

Figure 1: Radar image (radar reflectivity in dbZ) for 14 July 2010 16:30 UTC. The black dot indicates the approximate location of Vethuizen.

2. Weather situation 14 July 2010

The synoptic situation on 14 July consisted of a low pressure area over the British Isles. A southerly flow advected warm moist air from France northward. As temperatures rose during the day, this air became unstable. Together with strong winds in the upper air this caused an explosive situation. Over southern France the first shower systems already started to form during the morning. A squall line developed over the north of France in the afternoon, together with the first wind gusts [*Lankamp et al., 2010*]. The system travelled to the north-east at high speed, causing damage in the eastern parts of Belgium and The Netherlands. The radar image of 16.30 UTC (Figure 1) shows a typical bow echo near the Dutch-German border. A rear inflow jet is often found as part of a bow echo, strengthening the downbursts by inflow of air at the rear of the system at a few kilometers height. The strongest wind gusts were found at the curve of the front line of the precipitation [*Hamid, 2010*]. Over the north-east of The Netherlands the system lost strength, and around 19 UTC the remainder of the system had left the country.

3. Model and data

To simulate the weather on 14 July 2010, the WRF (Weather Research and Forecast) model (Advanced Research WRF v3.1.1) was used.

The model was ran at 9 km horizontal resolution, with 3 nests at higher resolution (500m, 1km and 3km) and 39 vertical levels. WRF was ran for a domain ranging from southern France to north of The Netherlands and from south-east England to western Germany (see Figure 2). This large domain size is necessary because the system that caused the wind gusts over eastern parts of The Netherlands originated in France. The model uses a variable timestep. Typical timesteps are 19 seconds at 3 km resolution, 5 seconds at 1 km and 2.5 seconds at 500 m horizontal resolution. Since the extreme weather event moved fairly fast, a 5 minute output interval was used.

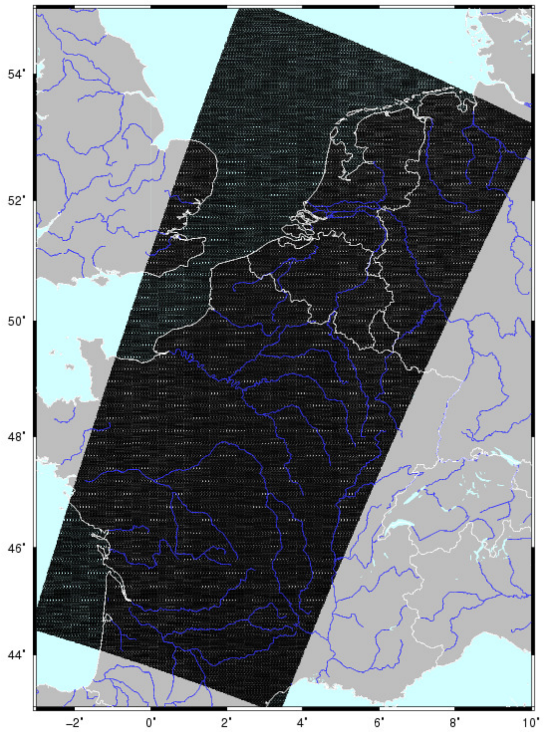

Figure 2: The black area indicates the domain of the 500 m WRF run.

For processes that take place within a gridbox, different parameterization schemes are used: the WSM6 microphysics scheme *[Hong et al., 1998, Hong et al., 2004, Skamarock et al., 2005]*, Yonsei University boundary layer scheme *[Skamarock et al., 2005]*, Noah landsurface model *[Chen et al., 2001]*, Monin-Obukhov surface scheme *[Monin et al., 1954]*, RRTM longwave radiation scheme *[Mlawer et al., 1997]* and the Goddard shortwave radiation scheme *[Chou et al., 1994]*. A cumulus parameterization is not needed since convection is explicitly solved by the model.

For the initialization of the WRF model, the 14 July 2010 00 UTC analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) model is used. Furthermore, ECMWF forecasts are used to feed WRF at the boundaries of the domain during the simulation.

The simulated radar reflectivity, wind direction and maximum wind speed in the past 5 minutes are studied. Instead of using the instantaneous wind speed at 5 minute intervals, the maximum wind speed in the past 5 minutes is determined in the model based on the model timestep. A wind gust is defined as the maximum 3-second wind speed. Since the timestep in the model is several seconds (at 1 km and 500 m resolution), the maximum model wind gives an indication of a wind gust. The wind speed is examined at 10 meter, 35 meter and 70 meter height.

Beside the model simulations also radar images provided by the Royal Netherlands Meteorological Institute (KNMI) have been used (see Figure 1). These radar images are based on measurements of the radars in De Bilt and in Den Helder. It should be noted that the Dutch radar product tends to underestimate the amount of precipitation, especially in cases of heavy precipitation [*Holleman, 2007*]. Blocking by heavy precipitation and hail hinder a good quantitative determination of the precipitation amounts from the radar. The radar images are however suitable to determine the location of the precipitation.

4. Wind results

The wind gusts are part of a large precipitation area passing over The Netherlands from the southwest. The maximum wind speeds are found in the eastern parts of this precipitation system, where also the highest reflectivity is found in the radar (Figure 1).

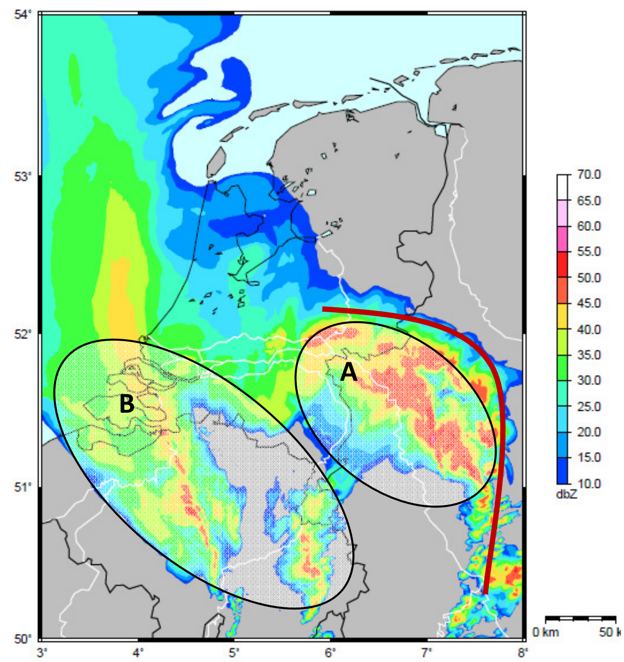

Figure 3: Simulated radar image (radar reflectivity in dbZ) for 14 July 2010 16:30 UTC, for WRF at 500 m resolution. See text for further explanation.

The high reflectivity in the east of The Netherlands is captured well by the simulated radar images (area A in Figure 3). A similar pattern is found for all horizontal resolutions. The WRF model is capable to simulate the typical bow structure in the radar images (red line in Figure 3). Compared to reality, the location of the southerly part of the bow is more towards the east in the model. The bow is less sharp in the model than in the measured radar images. The intensity is somewhat stronger in WRF than in reality, possibly related to the underestimation of the Dutch radar. The simulated images show a second system with heavy precipitation (area B in Figure 3), which is less intense and rotated somewhat more to the north in reality. However, this second system is not accompanied by strong winds, which makes it less relevant for the present study.

To examine the timing of the system, the passage of maximum wind speeds at 10 meter height in the surroundings of Vethuizen is studied. This passage is around 16.15 UTC. The radar reflectivity over Vethuizen also attains a maximum around 16.15 UTC in the model, while this is around 16.40 UTC in the measured radar images.

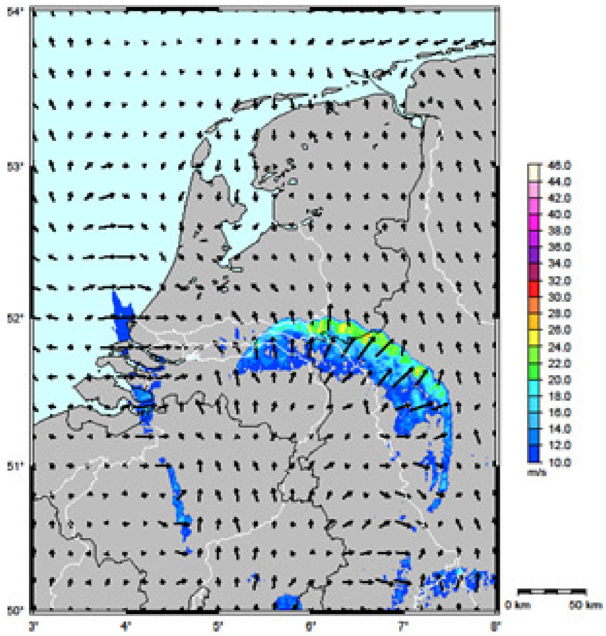

Figure 4: Wind direction (vectors) and maximum wind speed (in m/s, colors) during the last 5 minutes for 14 July 2010 16.15 UTC at 10 meter height for WRF at 1 km resolution.

The occurrence of a certain precipitation system or wind field in the WRF model should not be seen as an exact solution for the weather on 14 July 2010. The occurrence of certain weather phenomena within a large scale structure in WRF gives an indication of the physical possibility of these phenomena, but not of the exact location. Small changes in the initial condition or land use and topography could cause a shift in time or space of a certain system.

The structure of the system is also seen in the model wind speed, which shows high values in a narrow band at the front of the precipitating system (see Figure 4). For a certain location the duration of the passage with highest wind speeds is limited to a few minutes. These maximum wind speeds can be quite local, and seem to be organized in lines.

These line structures are visible in Figure 5, which shows the maximum wind speed between 14 and 22 UTC in the 1 km run at 10 meter height. This figure basically gives an indication of the progression of the maximum wind speed in time, since the system passes over the country in a few hours. These line structures are also present in the 500 m run, but practically absent in the 3 km run. Apparently the highest wind speeds occur with individual showers within the system, that persist up to 2 hours and are not resolved by the model at 3 km resolution. A model at very high resolution is thus required to obtain an indication of the strength of wind gusts. WRF at 1 km or 500 m resolution is suitable for this.

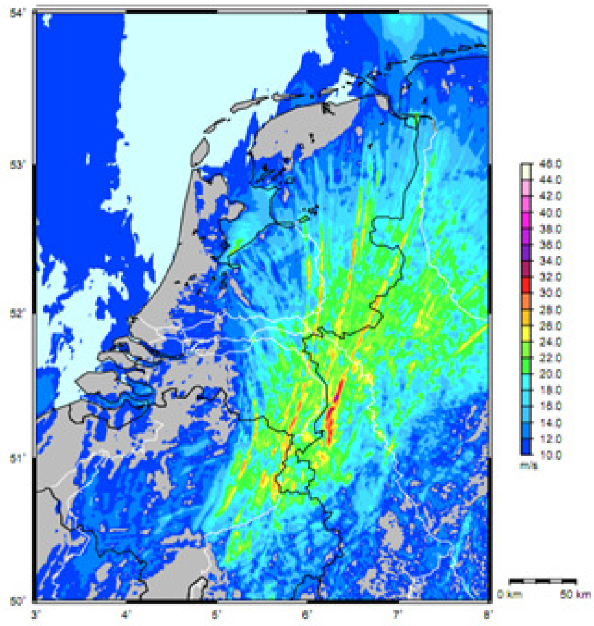

Figure 5: Maximum wind speed (in m/s) between 14 and 22 UTC at 10 meter height, for WRF at 1 km resolution.

The maximum wind speeds in the model are of comparable strength for the 1 km and 500 m runs, while lower maxima are obtained in the 3 km run. The maximum wind speed occurs in the 1 km run and amounts to 134 km/hour (~37 m/s) at 10 meter height. Turbulent structures at smaller scales than solved by the model, like mesovortices, could lead to additional local intensifications of the wind speed [*Hamid, 2010*]. That the maximum wind speed is found in the 1 km model run is probably related to different initial conditions and a different development of precipitating systems in the 1 km and 500 m runs. Similar wind speed maxima could however occur in the 500 m run. The present study does not indicate whether the results of the 500 m run are more realistic than those of the 1 km run.

During the passage of the highest wind speeds near Vethuizen, the wind direction varied from southwesterly in the east of the precipitation system to more south-southeasterly in the west of the system (Figure 4). This is typical for a downburst connected to a squall line. The southwesterly flow is perpendicular to the orientation of the high voltage line Doetinchem-Ulft (the pylons that were blown down belonged to this line).

The wind patterns that are found at 35 and 70 meter height are similar in structure to the pattern at 10 meter, but with higher wind speeds (maxima of 160 km/h at 35 m and 171 km/h at 70 m).

5. Summary and conclusion

WRF seems capable of simulating the complex weather of 14 July 2010. The shape (e.g. the bow echo structure), intensity and timing of the precipitation system were resolved quite well by WRF. Compared with the observed radar, the location of the extreme weather system was simulated a little more to the east. The simulation results showed a large area, spreading from west to east, with high wind speeds that moved rapidly towards the north east. The high resolution runs (500 m and 1 km) revealed micro-burst structures in combination with streaks of high wind speed.

The maximum simulated wind speed at 10 meter height is about 134 km/h. The wind patterns at 35 and 70 meter are similar in shape, only the wind speed increases with height. During the passage of the bow echo near Vethuizen, the simulated wind direction was south-southwest, and this is in agreement with the observed damage.

To conclude, WRF has proven its potential in resolving the complex weather system down to the scale of micro bursts. The maximum wind speed in the model exceeded 130 km/h at 10 meter height and 170 km/h at 70 meter height. It can thus be concluded that it is meteorologically possible that wind speeds of this order of magnitude occurred in the surroundings of Vethuizen on 14 July 2010.

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