Mesoscale Modelling in the Netherlands

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The installation of a new supercomputer has enabled KNMI to finally start running the mesoscale model HARMONIE on a regular basis. In this article we will describe the setup of the system, our first experiences with the model in severe weather conditions and some of the postprocessing designed to make optimal use of the possibilities of the mesoscale model.

The HARMONIE/AROME Mesoscale Model

The HARMONIE (HIRLAM ALADIN Research on Mesoscale Operational NWP In Euromed) model environment is a system which encompasses (amongst others) the AROME model and a script environment that enables the easy running of the model of choice. The mesoscale model is run on a Lambert grid of 800x800 points and has a resolution of 2.5 km with a timestep of 60 seconds. The model is currently driven by the regional model HIRLAM at the boundaries and uses 3D-Var for data-assimilation. Every three hours a forecast is made to 24 hours ahead. In the near future we will start making forecasts out to 48 hours, as the users of the model like to work with a single model for the whole forecasting period of 36 to 48 hours.

The main reason for running a high-resolution mesoscale model like HARMONIE is the ability of mesoscale models to represent severe convective weather well. As the most severe cases with deep convection over the Netherlands usually develop over France and Belgium, these countries have to be included in the model domain. If the model domain is too small, then the convection can already have some organization when the model domain is entered. In the model driving the mesoscale model the convection will be parameterized and the dynamic state of the convection will not be present. The convection and the organization of the convection will then start to build from the boundary, lagging behind the real development and organization by hours. This has a significant impact on the speed of advance of the convective complex and may cause the modelled convective complex to lag behind the real complex by hours, as an organized convective system can advance much quicker than the initial disorganized convection.

One example of such a case is the convective system that crossed the Netherlands on 14 July 2010. Very strong gusts associated with this convective system caused caravans to be blown over, causing two fatalities on a camping site in the small village of Vethuizen. When re-running this case on a small domain of 300x300 points the model showed very strong deep convection (see figure 1). The comparison with the radar, however, shows that the modelled convection lags behind the observed one by 3-5 hours. This is caused by the fact that this convective system already developed over France, outside of the model domain. Therefore the convective system was already in some state of development and organization, while the air mass containing the convection entered the domain through the boundary. But in the model the convection only started to develop when the unstable air entered the model domain, lagging behind the real development and organization. And it is this organization that makes the convective system develop and advance faster than individual cells, which develop initially in the model close to the boundary.

A second experiment, with the southern boundary moved south by about 500 km, provides a much better fit to the observed precipitation. Figure 2 shows the rain, cloud water and cloud ice distribution at the same time as figure 1. It shows that the rain in the HARMONIE experiment is still lagging behind the observed rain, but the distance between the observed and modelled rain is much smaller than with the small domain, and also the organization of the precipitation, with a bow echo on the most northeastern part of the convective system, is present in the run on the large domain.

The difference is large, especially at the back end of the convective system. In figure 1, the build-up of the convection starting close to the boundary is clearly visible with convective towers rising slowly from the southern boundary to the North. Figure 2

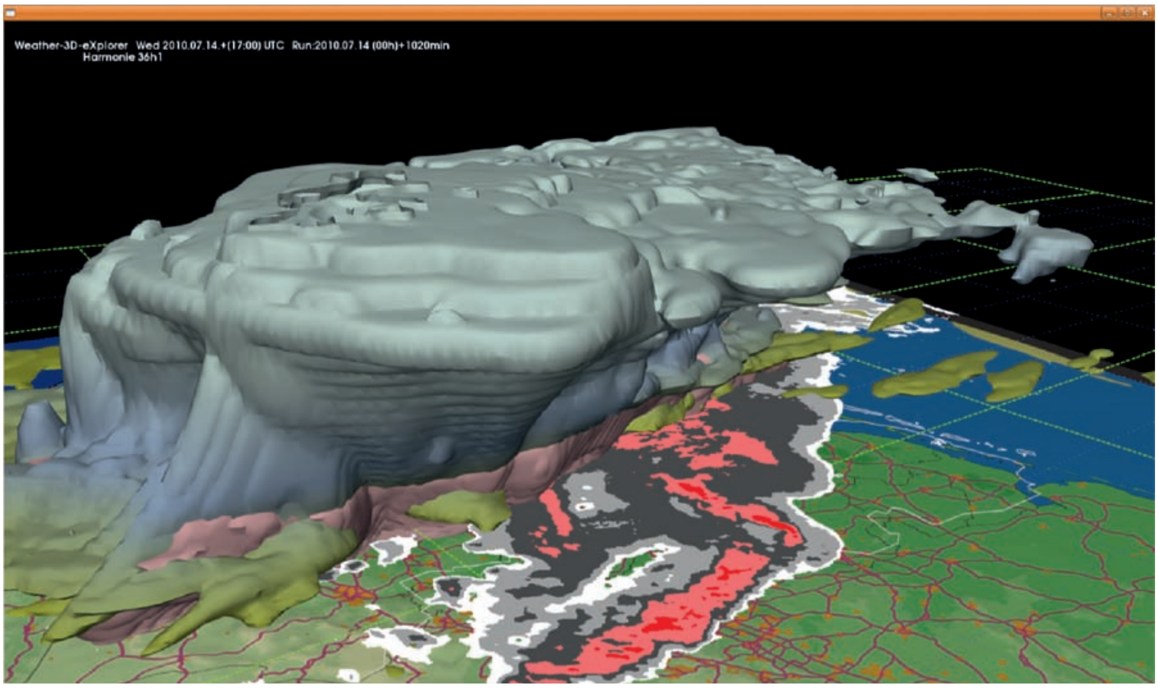

Figure 1

Observed radar precipitation and forecast cloud ice (grey), cloud water (yellow) and rain (pink) at 17 UTC on 14 July 2010 for the 300x300 points experiment. The plot comes from a 3D visualization tool. The southern boundary is situated on the bottom left corner of the image

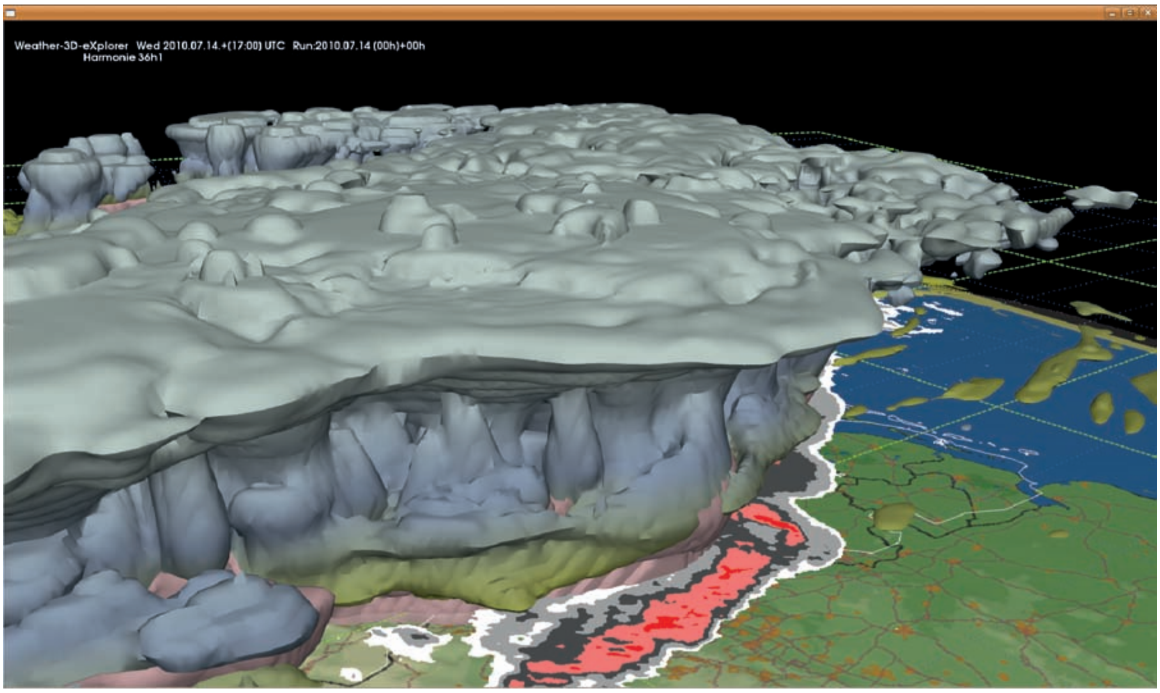

Figure 2

Observed radar precipitation and forecast cloud ice (grey), cloud water (yellow) and rain (pink) at 17 UTC on 14 July 2010 for the 500x500 points experiment.

shows a full-grown and organized system already at the place where the boundary is in the first experiment. It is this organization, - present in the experiment on the large domain whereas it clearly is not on the small domain - that shows that you cannot make the model domain too small, else you may miss or erroneously represent cases where the convection is already present in reality at the boundary of the mesoscale model domain.

First Operational Experiences With HARMONIE

From 7 December 2011 HARMONIE has been running on a regular schedule with 24-hour forecasts every three hours. During this time a few interesting situations have arisen, showing the potential of the model and the additional value for the forecasts of KNMI. Three of these situations involved the passage of a cold front with line convection, something that usually happens once or twice every year, but in this case occurred three times in one month.

Line convection is very interesting as it produces a very narrow band with intense precipitation that can be accompanied by strong wind gusts. In this article we describe one of these cases, 3 January 2012. On this day a deep cyclone moved over Scotland and the northern part of the North Sea to the East (see figure 3). The cold front associated with this system passed the Netherlands between 13 and 17 UTC. A narrow band with strongly forced convection, the line convection, was clearly visible in the radar images over the UK. It was forecast by HARMONIE to break up when it approached the Netherlands, but it was still intact at 13 UTC.

However, between 13 and 14 UTC it did start to break up and figure 4 shows the situation around 14 UTC. The line convection, or what is left of it, is situated over the Northwest of the Netherlands. Some extreme wind gusts were observed on this system with maximum gusts of 94 knots at the Dutch West coast (IJmuiden) and 80 knots observed at one of the Wadden Isles (Vlieland).

HARMONIE forecast the breakup of the line convection quite well in a qualitative way, and the model also forecast that the strongest gusts would be associated with the line convection that was breaking up. But the maximum gusts were forecast to be close to 70 knots, well below the maximum observed gusts of 80 and 94 knots. These extreme gusts were probably very localised, as these gusts are among the strongest ever reported in the Netherlands and widespread significant damage was not reported.

One of the issues with the output of mesoscale models is the very small-scale features that are present in these runs. These are so small that it is sometimes hard to distinguish in the plots that are used in the forecasting office, even when zoomed in on a small country like the Netherlands. Therefore we now also have another way of plotting the wind gust forecasts. For this we divide the country into three areas, water (sea), the coastal area ranging from the coastline to approximately 50 km inland, and the inland area. Then we plot the maximum instantaneous gust at each output time step for these areas. To compare with the observations we also plot all the observations, color coded in the same way as in the three areas.

Figure 5 shows the forecast of the maximum instantaneous

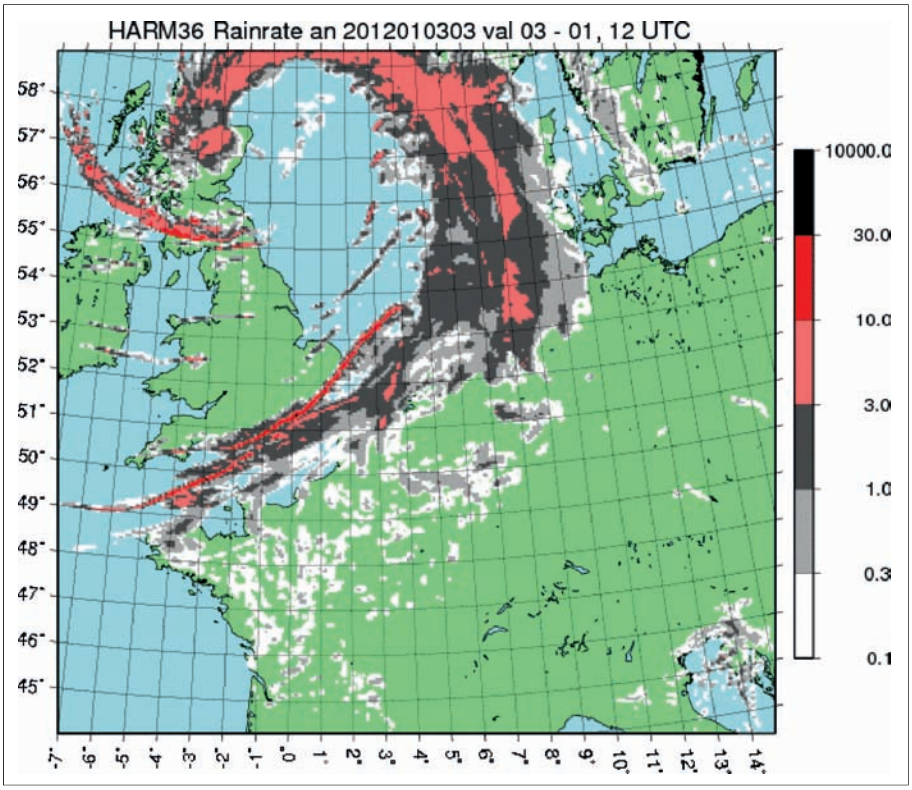

Figure 3

HARMONIE rain rate on 3 January 2012 at 12 UTC

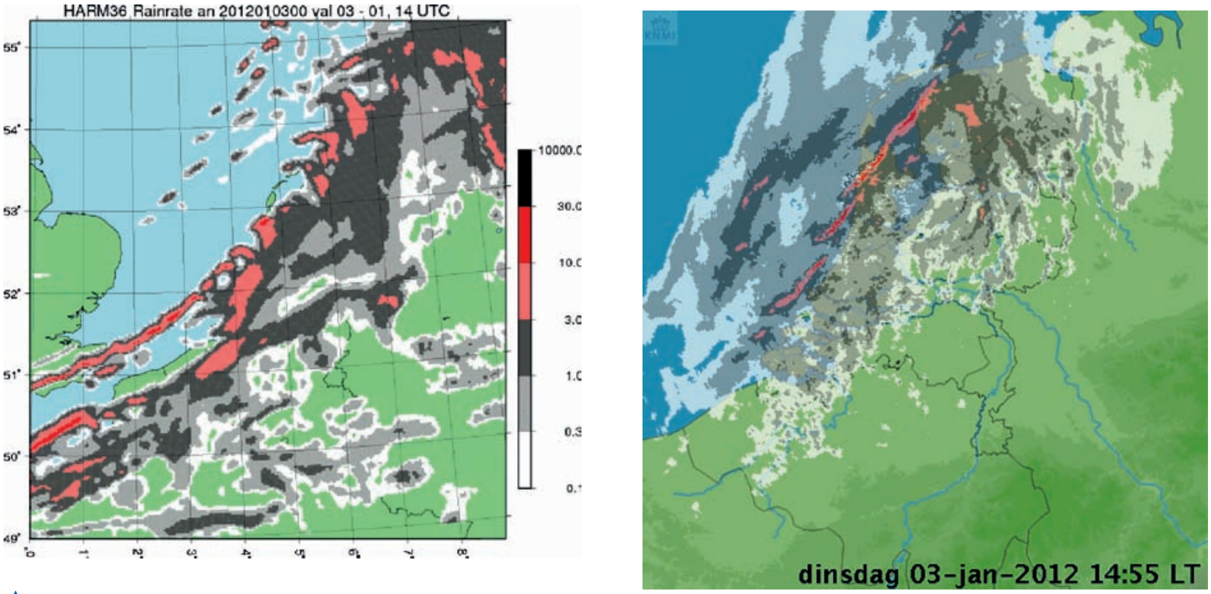

Figure 4

HARMONIE +14h forecast of precipitation intensity (left) valid at 14 UTC and the observed radar image (right) at 13.55 UTC (14.55 local time) on 3 January 2012

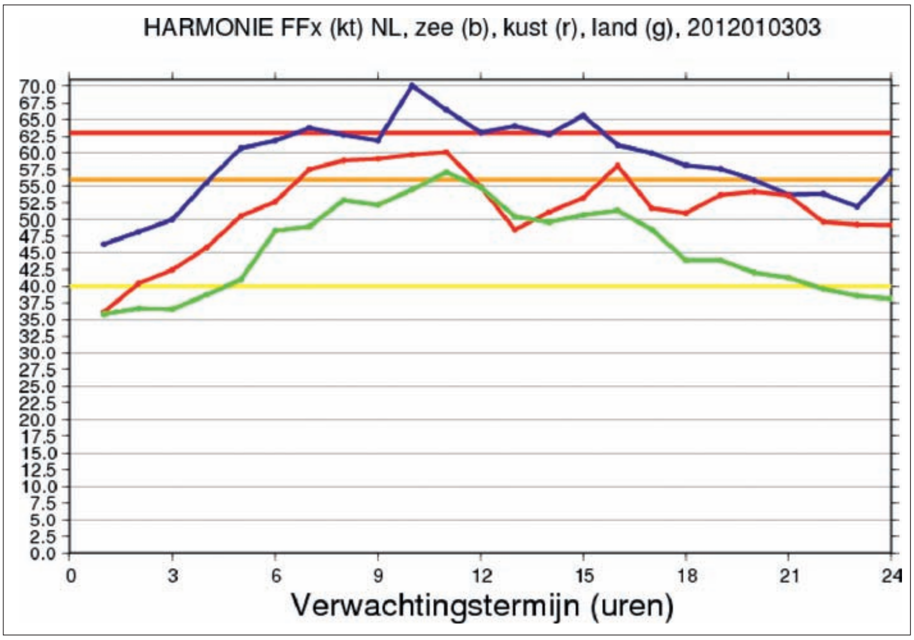

Figure 5

Maximum wind gust forecast by HARMONIE in the 03 UTC run on 3 January 2012 for the sea points (blue), coastal points (red) and the points over land (green) in and close to the Netherlands. Also shown are the warning criteria (yellow, orange, which is the weather alert criterion inland, and red, the weather alert criterion at the coast)

wind gust based on the forecast from 03 UTC on 3 January 2012. It shows that the maximum gust is forecast over the sea (close to the coast, not shown here) around 13 UTC (03 UTC + 10 hours). In the observations it is shown that the maximum gusts are observed on 13.30 and 14.00 UTC, so about one hour later than was forecast.

Forecasting Lightning Intensity With HARMONIE

The hydrometeors in HARMONIE, prognostic rain, snow and graupel, which are not present in HIRLAM, have the advantage that new forecasting tools can be developed based on these parameters. Until

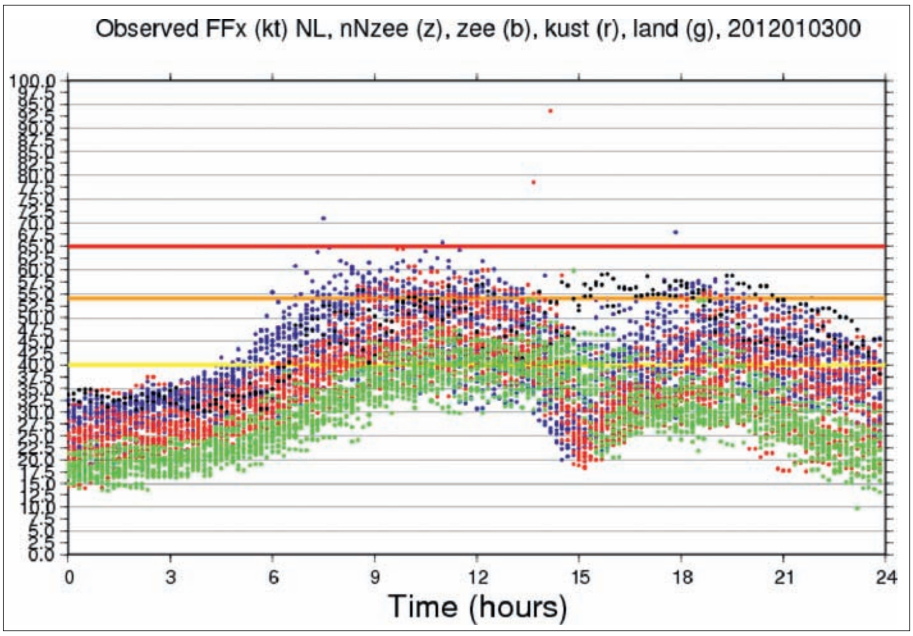

Figure 6

Observed gusts at all Dutch stations from 00 to 24 UTC on 3 January 2012 for the sea stations (blue, black dots for the stations on the Northern North Sea), coastal stations (red) and inland stations (green)

now the forecasting of, for example, the chance of lightning or the chance of reaching a certain lightning intensity threshold was based on statistical methods that needed a significant number of cases to get the correct probabilities. Also, these methods had the drawback that they included the model errors (differences in timing and placement of convection), meaning that the maximum thresholds for which the forecasts could be made was less than what was needed. In the Netherlands the weather alert criterion for lightning is 500 discharges in 5 minutes over an area of 50x50 km^2, or smaller, but the statistical methods can only be derived for lightning thresholds of 200 discharges in an area of 60x90 km^2.

The addition of graupel to the prognostic model parameters enables us to use this parameter, which is one of the most important factors responsible for charge separation in thunderstorms, to make forecasts of lightning intensity. Eight cases with thunderstorms were used to find a relation between the lightning intensity and the graupel. Four of these cases were with very intense thunderstorms and four with limited lightning intensity. For all these cases a whole day was used in deriving the relation, so periods with no or only a small amount of graupel are included in the derivation of the relation.

By first trying to find a relation between the total graupel in the model over the lightning observation area, and then trying to make it applicable on the smaller areas that are used in the issue of weather alert, we were able to find a relation between the forecast graupel and the lightning intensity for areas of 25x25 km^2. In this derivation we have excluded the cases where there was a clear difference between the model and the observations and tried to account for changes in phase. By doing this a very clear relation can be found between the vertical integrated graupel and the lightning intensity.

Figure 7 shows the result of this relation for the case of 30 April 2012. On this day warm air was present over the Netherlands, Belgium and Germany, causing the destabilization of the atmosphere. Thunderstorms, developing on a cold front over France and Germany, moved into Belgium and the first very intense thunderstorms of the convective season 2012 started to form. The model forecast these thunderstorms in more or less the right place and time, indicating that the lightning intensity could be as high as 150 discharges per 5 minutes in a 25x25 km^2 area.

Note the method that is used here is a 'perfect prog' method. This means that it does not take into

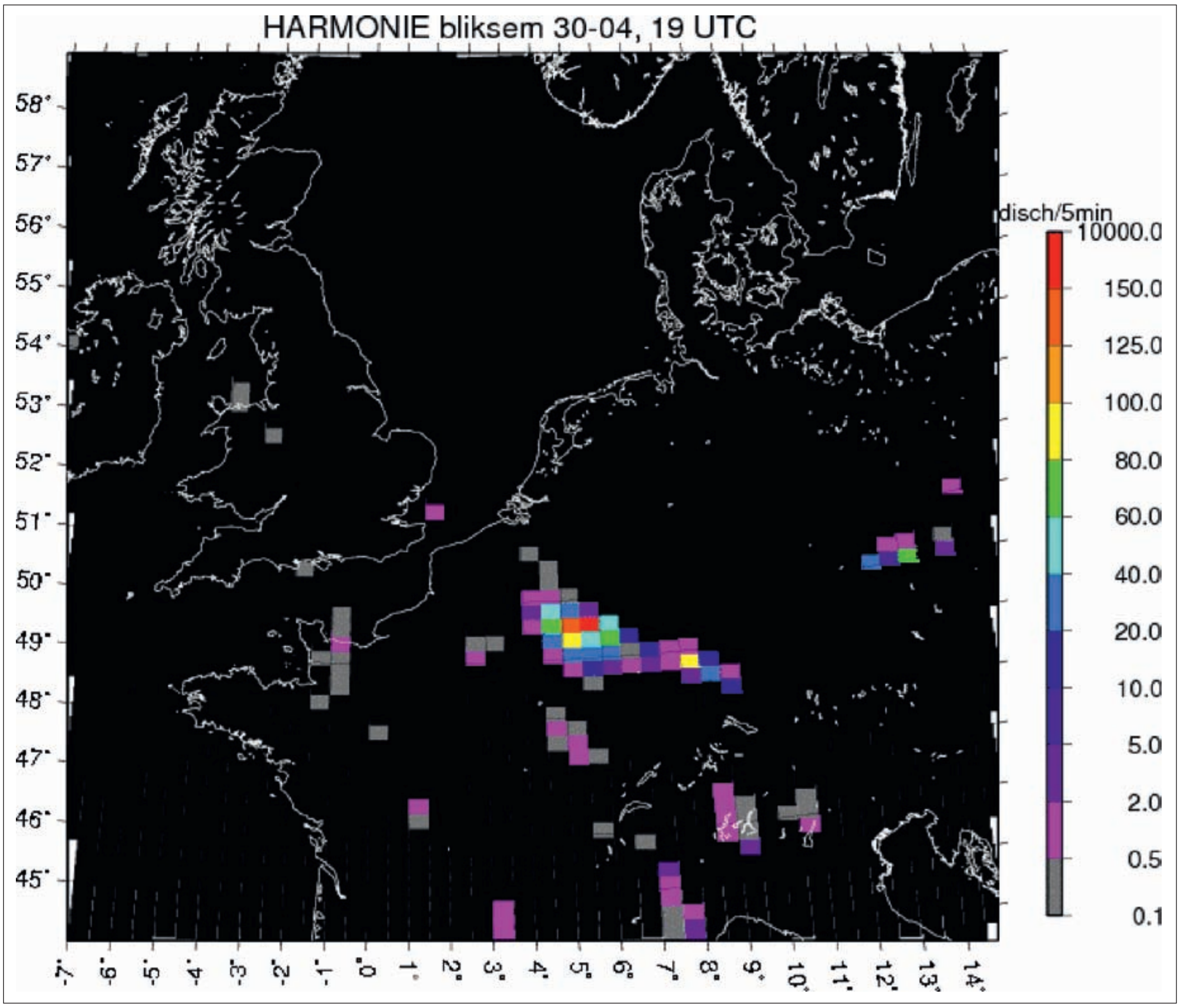

Figure 7

Lightning intensity forecast from 00 UTC on 30 April 2012, valid time 19 UTC, based on the vertically integrated graupel in HARMONIE

account the cases where the model convection forecast is bad (where showers develop in reality but not in the model, or the other way around). So when the forecast of convection is bad, this method will give a bad lightning forecast, whereas a statistical method will still give some signal that should point in the right direction. One other issue that has to be raised is the fact that the relation is only valid for HARMONIE. The method can be used for any model (it was first used on WRF) but our experience suggests that the graupel is very differently represented in the different mesoscale models.