Title: The use of a high resolution model in the private sector

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The private organisation MeteoGroup uses WRF-ARW for multiple purposes. WRF is used in the operational environment of several MeteoGroup companies across Europe. It is also used in hindcast studies, for example hurricane tracking, wind climate computation and deriving boundary conditions for air quality models.
A great deal of effort is put into the development and improvement of the pre- and post-processing of the model.
In this paper we describe how we fix a skin surface temperature initialisation problem. Furthermore, we describe how we change the land use data and how we use model level initialization. Also the calculation of cloud fractions is described.

Skin surface temperature

During a cold situation WRF computes too low skin surface temperatures near the coast. This results in cold areas and fog areas near the coast. It is even more extreme when night temperatures are below zero. Then WRF computes sea ice instead of water for various coastal areas in Europe.

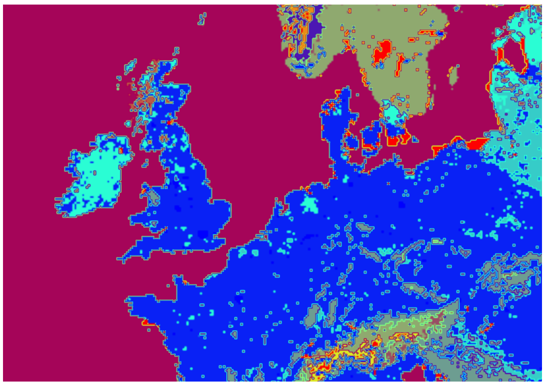

Figure 1: Land use in WRF input. Red is sea ice, purple is water.

Some places, such as small lakes in Sweden can indeed be frozen. Most other areas e.g. some spots near the coast of Denmark, the East Seats and near the French coast, are definitely not frozen, as can be verified by (sea water) temperature observations. These spots can been seen in figure 1.

The horizontal interpolation program, metgrid, has a possibility to horizontally interpolate the temperature near the coast using a landmask restriction. For instance, don't interpolate a water point with grid points that have a land mask of one. Only this does not work with a fractional landmask. Our input data, ECMWF, use fractional landmask. It can occur that a grid point has a 60% land cover and a low skin surface temperature, for instance -4.4 ^{o}C . Using the landmask restriction above, this point would still be used for the interpolation of a water point. Therefore the WRF sea surface temperature can fall below 0 ^{o}C. It even can get under the sea threshold and become a sea ice point.

To solve this problem an algorithm is made which checks all the sea points which are near the coast. If one of those sea points differs more than a certain threshold from the surrounding average sea surface temperature (the yellow area in figure 2), it will be replaced by the surrounding average sea surface temperature. This check is done several times, because during the first iteration the erroneous values can still have a large influence on the average sea surface temperature.

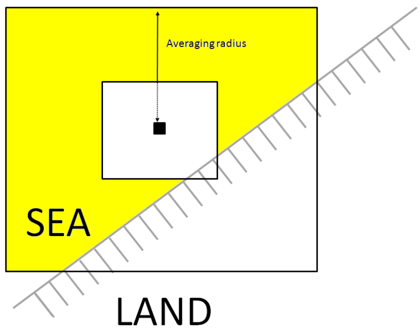

Figure 2: Schematic overview of the fix for the erroneous sea surface temperatures. The temperature of the grid point is compared to the surrounding average sea surface temperature (calculated for the yellow area).

The effect of this algorithm is clearly visible in figure 3a and 3b. Figure 3a shows cold spots near the cost. In figure 3b the cold spots have disappeared.

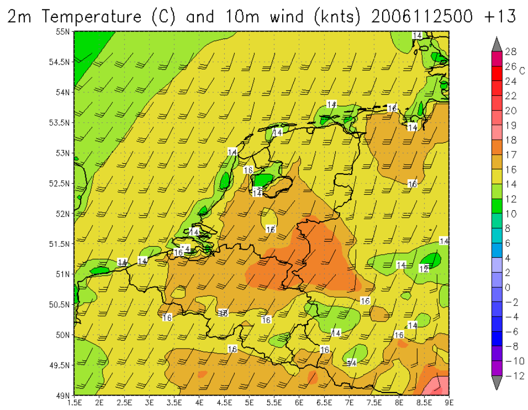

Figure 3a: Output of the WRF model without the use of the fix for the erroneous sea surface temperature.

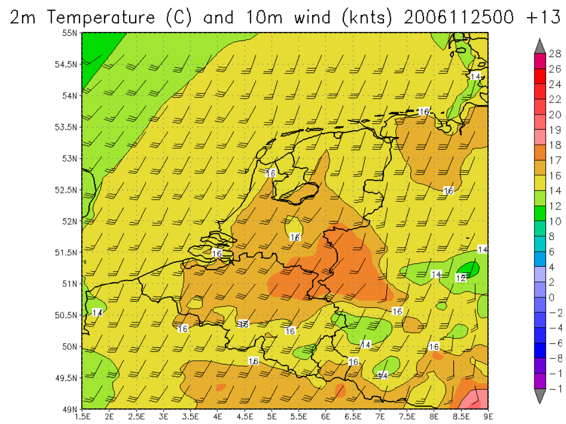

Figure 3b: Output of the WRF model with the use of the fix for the erroneous sea surface temperature.

Land use data

Land use information determines physical quantities such as surface roughness length and albedo. Improving the land use information will therefore have a positive effect on meteorological quantities such as boundary layer wind speed and temperature.

The default USGS land use data has been replaced with GlobCover data from the European Space Agency (ESA). The ESA GlobCover project, led by MEDIAS-France, provides land use data at a 250m spatial resolution based on the MERIS instrument onboard ENVISAT. Apart from a higher spatial resolution, the GlobCover land use data is more up-to-date and contains more categories than the USGS data set.

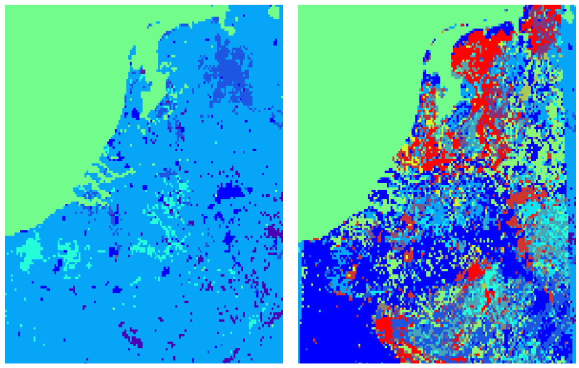

Figure 4 USGS land use information (left) compared with GlobCover land use information (right), both interpolated to 3 km spatial resolution, for an area over the Netherlands, Belgium and Luxembourg. Water bodies are colored green.

An independent dataset of surface roughness lengths (a product of the EO-windfarm project of ESA) was used to assign a typical roughness length to each GlobCover land use category. Some categories are split in order to be able to vary roughness length within one land use type.

Figure 4 shows the default USGS land use information and the GlobCover equivalent, both interpolated to a 3km resolution to be used by WRF. One can clearly see the extra detail present in the GlobCover product.

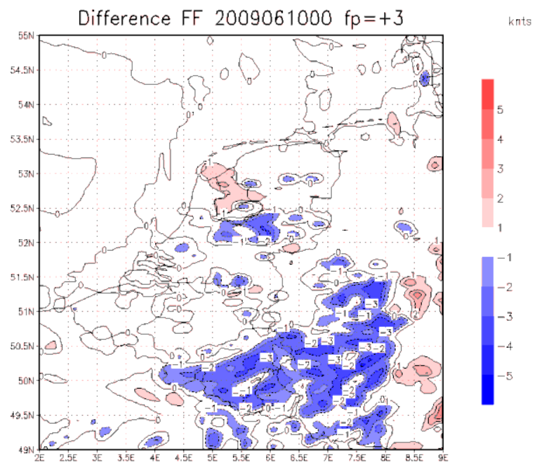

Figure 5 Difference in wind speed (knots) between a run with USGS land use data and a run with GlobCover land use data.

Figure 5 shows an example of wind speed difference when USGS or ESA land use data. Positive means using ESA data gives higher wind speed. The forested areas are clearly visible (blue areas). The roughness and land use of these forested areas are better represented in the ESA data. The roughness is much higher than in the USGS table, therefore WRF produces a lower wind speed .

Model level initialisation

Initially WRF used only four ECMWF pressure levels in the lower atmosphere (1000, 925, 850 and 700 hPa) for initialisation. Problems occurred with thin cloud layers that were not detected. This has been solved by introducing ECMWF model levels instead of the standard pressure levels. This way WRF is initialized based on 14 levels between 1000 and 700 hPa instead of the original 4.

The effects of this modification can be seen in figure 6. With the new levels, thin low cloudiness over the North Sea has become visible and the model output corresponds much better to the satellite image as shown in figure 7.

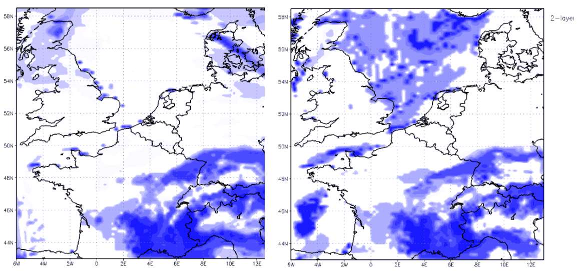

Figure 6: Total cloud cover calculated by WRF. Initialisation time: 3 May 2007, 0 UTC, T+12 forecast. Left: pressure level initialisation Right: model level initialisation

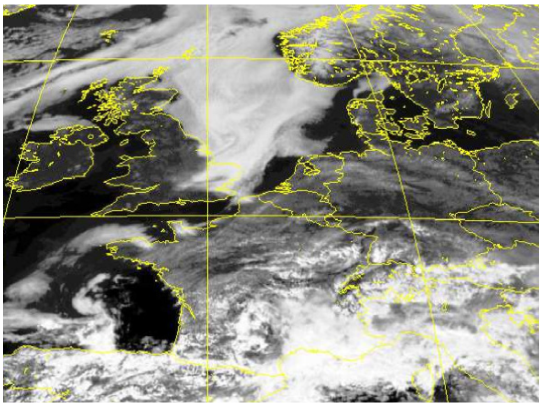

Figure 7: Satellite image (visible light) 3 May 2007, 12 UTC

Advanced cloud fraction

Cloud fraction is an important variable for forecasters and for users. It is also a variable used by our model derived weather codes algorithm. Therefore MeteoGroup developed an algorithm that computes cloud fractions

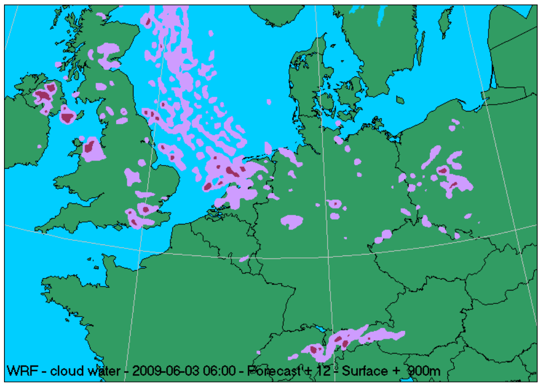

Figure 8a: cloud water at 900m

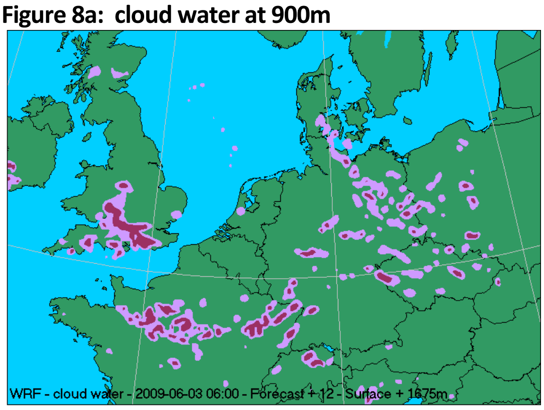

Figure 8b: cloud water at 1675m

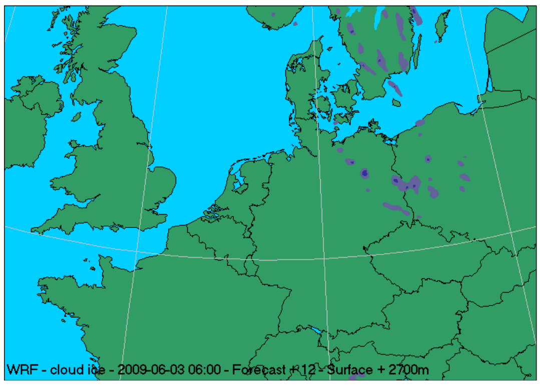

Figure 8c: cloud ice at 2700m

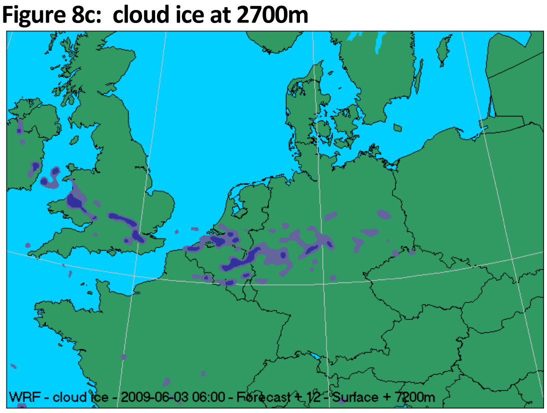

Figure 8d: cloud ice at 7200m

using direct model output.
The model output contains cloud water and cloud ice. These variables represent the amount of actual clouds in the model. Figure 8 shows an example of both variables at different heights.

To get from cloud water and cloud ice to a cloud fraction the first step is to compute the saturated mixing ratio. Therefore the saturated water vapour pressure needs to be computed.
The total amount of cloud water and cloud ice are weighted against the saturated mixing ration, this results in a cloud on each model level. To get a cloud fraction over multiple levels a random overlay is assumed.

In figure 9a an example of the total cloud fraction using our algorithm. This figure corresponds with figure 9b which is a satellite image of the same time. Above southern France WRF computes to much clouds. Above Germany there are to less clouds. Therefore the algorithm still needs to be tuned and this process is ongoing.

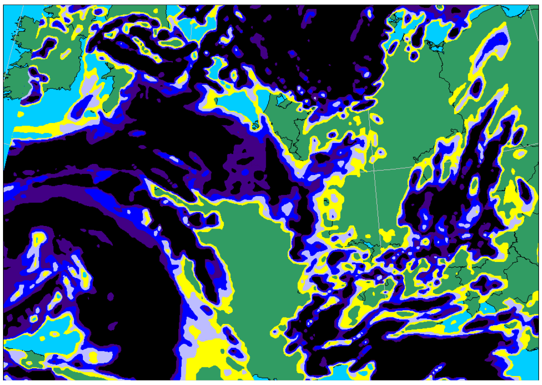

Figure 9a: Total cloud fraction in WRF 10 June 2009 9UTC (T+9)

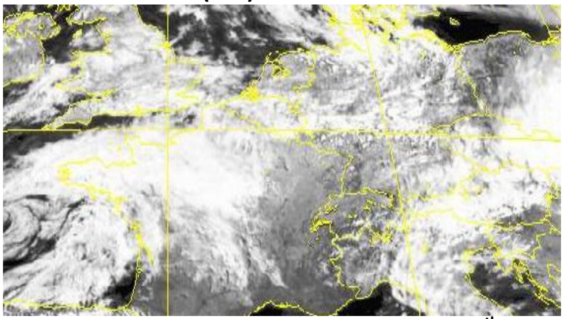

Figure 9b: Satellite image (visible light) June 10th 2009, 9 UTC