HIRLAM wind forecasts near the coastline

Priit Tisler
Division of Atmospheric Sciences, Department of Physical Sciences,
University of Helsinki, P.O. Box 64, FIN-00014 Helsinki, Finland
Finnish Meteorological Institute,
P.O. Box 503, FIN-00101 Helsinki, Finland

1 Introduction

An accurate prediction of weather would require detailed modelling of the atmospheric boundary layer, taking into account surface roughness, stability of atmosphere etc. Sudden changes in boundary conditions like roughness discontinuities and large temperature contrasts have significant effect on the development of weather in the coastal zone. Impacts on the cloudiness and precipitation (Alestalo and Savijärvi, 85, Roeloffzen et. al., 85) as well as on the characteristic features of the sea-land-breeze circulation (Arritt, 92, Zhong and Takle, 92, 93) have been cited in many studies. In addition, effects referred above depend on the ambient wind speed and direction near the coastline. The purpose of this study is to present a case study concerning operational HIRLAM wind field verification near the coastline of the Gulf of Bothnia.

2 Data

The FMI maintains about 600 weather observations in various parts of Finland. Unfortunately, offshore observations are very rare comparing with continental wind observations. On the other hand, coastal wind data is not fully representative in case of offshore wind situations when continental-like features are dominated. When wind is blowing from land, where the surface is essentially rougher, it takes a long way before a marine wind profile is established. Another point is that wind measurements at sea are taken from anemometers mounted at various heights on buoys, ships, towers and rigs. For example, at FMI the height of anemometers varies from 4.5m to more than 50m. Thirdly, the wind may not have a clear path from all firections. Nearby buildings and islands may cause the observed winds to deviate from truly representative upwind values at the measurement points.

In this study wind measurements from two well-qualified stations in the Gulf of Bothnia are used: Nahkiainen (latitude: 64°36‘, longitude: 23°54‘) and Raahe (latitude: 64°39‘, longitude: 24°25‘). Both of them have open surroundings. Nahkiainen lighthouse is approximately 20km from the Finnish coastline, Raahe is tower located exactly on the coastline. Weather measurements are carried out at both locations by Milos 500 automatic weather station. Wind measurements are performed at 31.6m (Nahkiainen) and 32.1m (Raahe) from sea level, which matches well with the HIRLAM lowest model height. The dataset considered here consists of observations of an ice-free period i.e. from September to November 2002, with relatively warm sea and cold land. Wind frequency analyses (wind roses) for Nahkiainen and Raahe are given in Figure 1.

The model data consist of FMI operational HIRLAM forecasts, based on the HIRLAM version 4.6.2. Detailed description of this operational routine is given in HIRLAM Newsletters (Eerola, 01, 02). At FMI, two integration areas of the model are used, with horizontal resolution of 0.4 and 0.2 degrees, respectively. The number of vertical levels is 31, ranging from 32 m at the lowest level up to approximately 30 km. Here, the data from the suite with the gridlength of 0.2 degrees are considered. The corresponding sea-land distribution for the Gulf of Bothnia is given in Figure 2 with locations of Nahkiainen and Raahe observation stations marked. As can be seen, Nahkiainen is located in a grid square with 100% of sea.

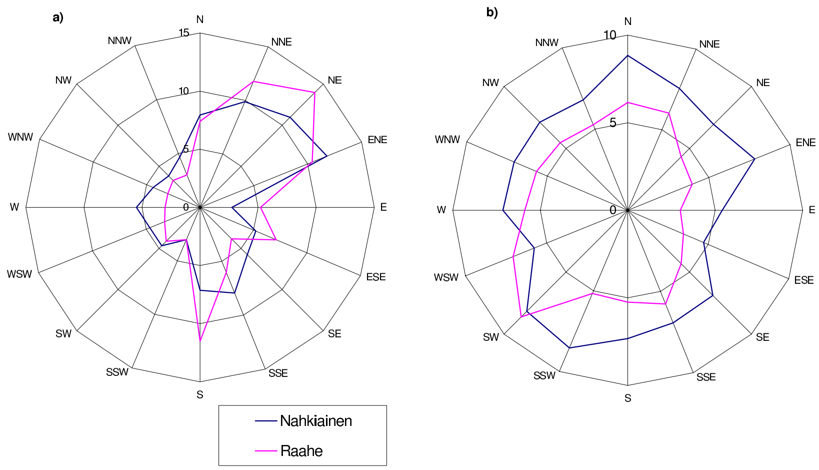

Figure 1: Wind direction frequency (a) and mean wind speed (b) distributions, measurements with 6h interval, September-November 2002 (n=365).

Around Raahe the grid square contains both land and sea but the characteristics of the sea type surface dominate. As the typical near-surface output values in HIRLAM like 10m wind are given in unstaggered grid, the wind components at the model levels, used in the verifications, are also de-staggered. All the model data used is 6h forecasts.

3 Results of verification

3.1 Nahkiainen

Results of verification of HIRLAM wind data in Nahkiainen are presented in Figure 3. During the verification period, sea surface temperature SST (from HIRLAM analyses) was mostly higher than the observed temperature (25.9 m from sea level), except some days in the very beginning of September (panel a). The stratification is therefore unstable near the surface. Sea was ice-free for all the period. The scatterplot of HIRLAM windspeed vs. measured windspeed is given in panel b). Usually forecasts are given for a reference height, for wind 10 m above the surface is used. Here, instead, as the HIRLAM level 31 height is approximately 31-32m from the sea level, we used those model values directly to compare with the measured ones. Note that according to the Monin-Obukhov theory of similarity the 10m wind direction remains the same as at model lowest level. A tendency to slightly overpredict the windspeed can be observed in panel b) was more or less expected (Tisler, 02, Ansper and Fortelius, 01). Panel c) represents the scatterplot of measured and observed wind directions. As the spread of this data is relatively large, a more precise and closer look to wind direction is well-founded. Firstly, assuming that wind at HIRLAM level 24 (free atmosphere) can be considered as geostrophic wind, we have calculated the turning of the surface wind i.e. the cross-isobar angle. In panel d) the observed cross-isobar angle is given as the function of geostrophic wind direction. Overall, this angle, the wind veering, has positive values which is related to the typical behaviour of Ekman spiral. Note that Joffre, 82 got for a 0-500m layer over sea a mean value of wind veering of 17 degrees from pilot balloon soundings. However, we can see that 1) the scatter is large, and 2) for geostrophic wind from the sector 270-30 degrees, the scatter is essentially bigger and also negative values appear. Synoptically, these cold Northerlies and Northwesterlies over ice-free warm sea are quite often related to relatively strong cold advection with backing of winds with height (negative cross-isobar angles). From the point of view of operational forecasting it is desireable

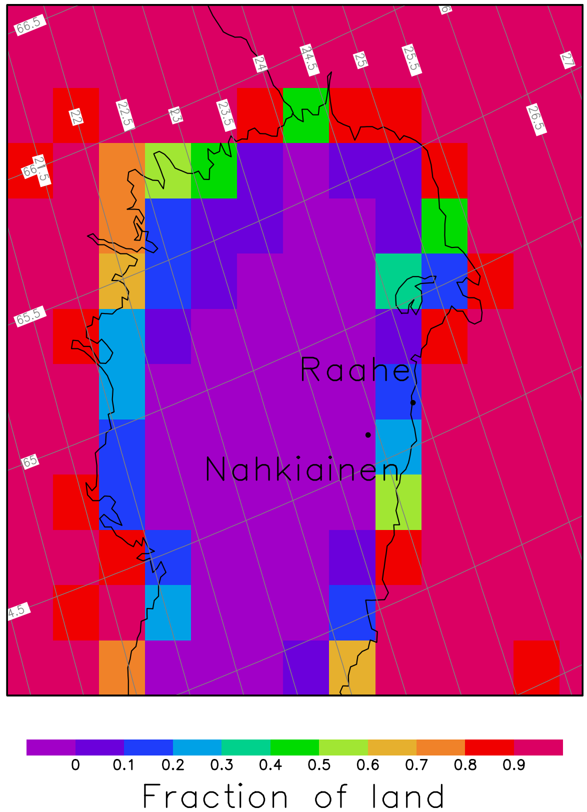

Figure 2: HIRLAM 0.2° sea-land distribution, Gulf of Bothnia.

that this wind veering or backing is well forecasted by the model. Unfortunately, noteable discrepancies are remain, see panel e). Some of them can probably be explained by weak synoptic activity, resulting in low windspeed, see panel f).

3.2 Raahe

Results of verification of model data versus measurements in Raahe are given in Figure 4. Raahe station is located exactly at the coastline and also quite near to the border of two neighbouring grid squares with different types of dominating surface (see Figure 2.). Verification is made for model data from both gridsquares. As we can see from panel a), HIRLAM so-called landgrid wind is slightly weaker comparing with forecasts from seagrid. This is expected considering the different surface roughnesses. Comparing with observations, forecasts from landgrid have a tendency to underestimate strong winds (> 12 m/s). Seagrid predictions, however, seem to systematically overestimate weak winds but strong windsspeeds correlate well with the observed.

Comparison of observed and predicted wind directions does not show any systematic difference, see panel b). Panel c) shows the larger cross-isobar angle over land than over the sea, as expected, especially for winds from the open sea sector (245-65 degrees). The turning of wind as the function of geostrophic (HIRLAM level 24) wind direction is given in panel d). Here, like in Nahkiainen, biggest differencies appear in the case of cold Northerlies and Northwesterlies. Note here that the sea-shore as well as the corresponding HIRLAM gridsquare were covered by ice in the end of November. Thus the verification period was shortened to November 20. From panels e) and f) were can see that the prediction of the near-surface wind direction has the same tendency as in Nahkiainen; relatively weak movement of cold air over warm sea causes difficulties in correct prediction of wind direction near coastline. This has been

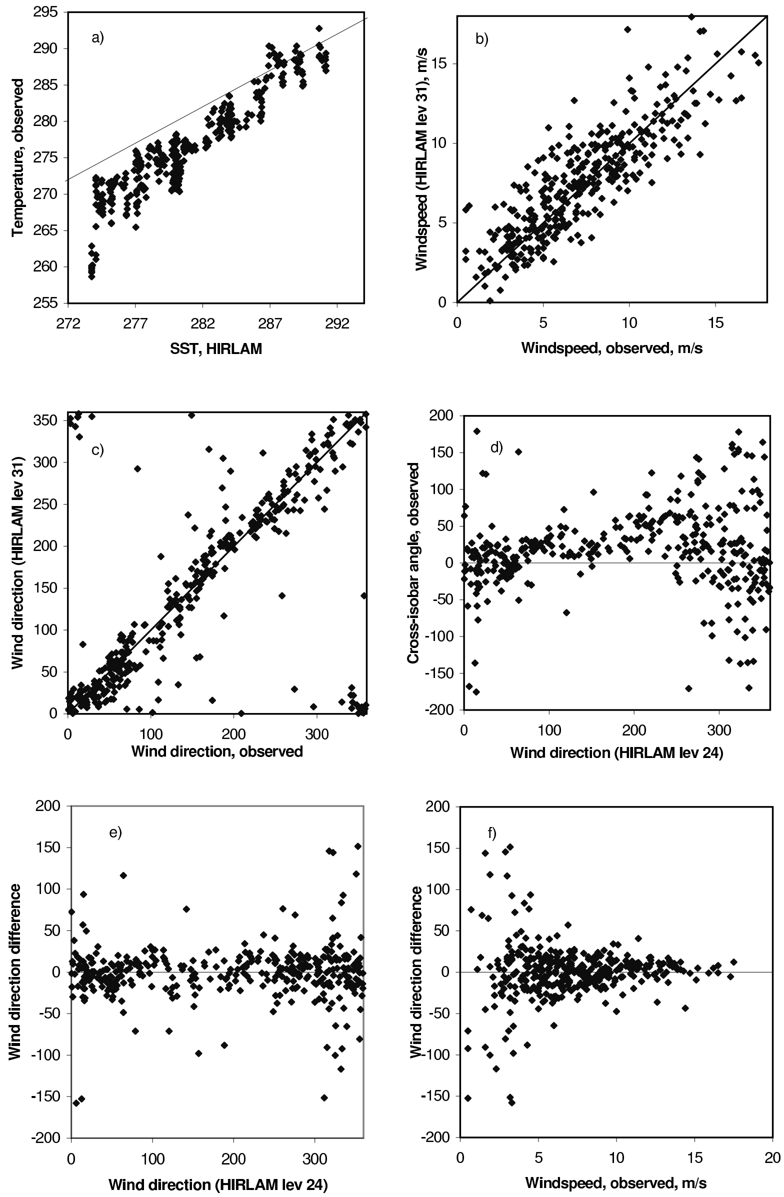

Figure 3: Verification of HIRLAM data at Nahkiainen, September-November 2002, see text.

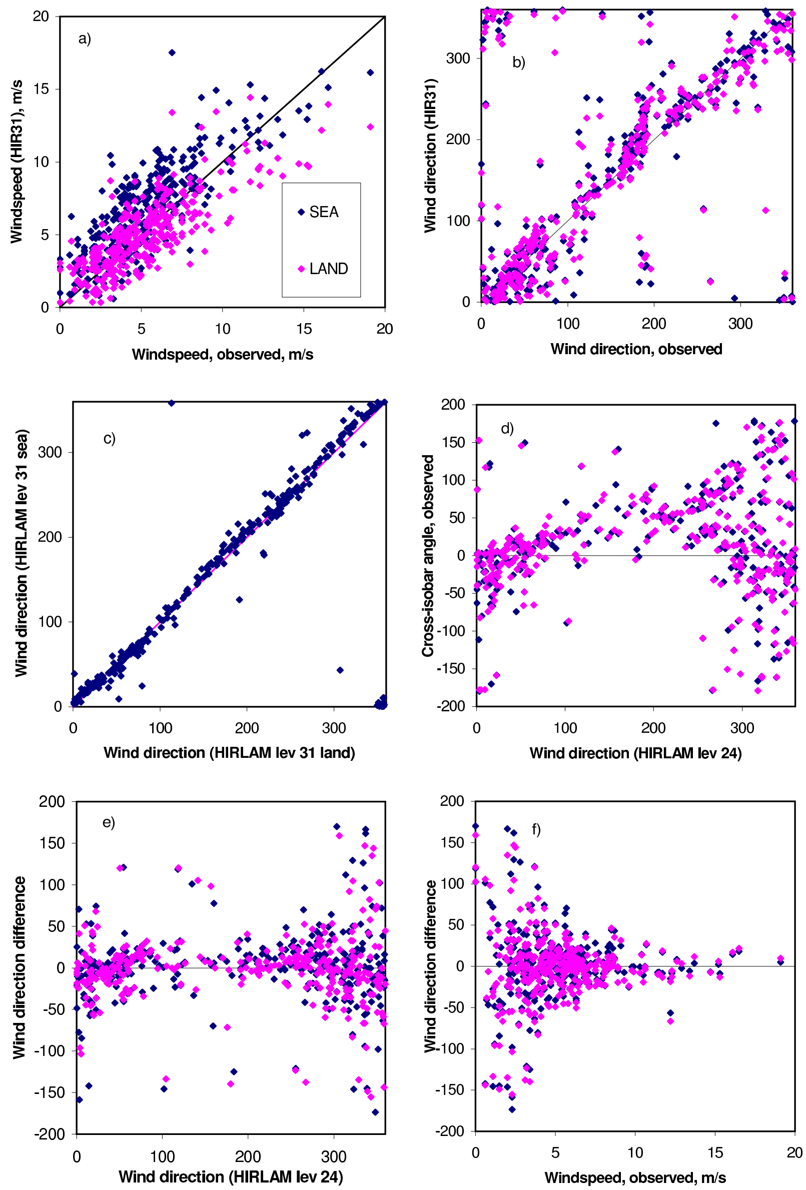

Figure 4: Verification of HIRLAM data at Raahe, September 01 - November 20, 2002, see text.

a problem also in the ECMWF forecasts for many years, so it is worth a closer look in future work.

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