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Wind field numerical forecasts at high dynamic of pressure field changes

Ireneusz A. Winnicki, Janusz M. Jasiński, Krzysztof A. Kroszczyński
Sławomir A. Pietrek

Military University of Technology, Faculty of Civil Engineering and Geodesy
00-908 Warszawa, ul. S. Kaliskiego 2
e-mails: {ireneusz.winnicki; janusz.jasinski; kkroszczynski; spietrek}@wat.edu.pl

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Abstract
The paper presents an analysis of a rapid atmospheric process which in the beginning of December of 2013 moved over Europe from NNW in the form of a deep cyclone. The analysis aim is to verify the Weather Research & Forecasting Model results of daily numerical weather forecasts of extremely dynamic atmospheric processes. The applied spatial resolution of the computational grid of 36.3 km does not reveal the sub-grid processes. In case of the Xaver cyclone development and movement, the spatial step may be of significant importance. It is planned to analyze the case using data computed at better resolutions.

Introduction

The paper presents an analysis of a rapid atmospheric process which in the beginning of December of 2013 moved over Europe from NNW in the form of a deep cyclone. Scientists, media and meteorological services gave it the name of Xaver. The previous such a deep cyclone developed in Europe in 1953. In December 2013, meteorological stations in Scotland reported wind speeds reaching 300 km/h, and in inhabited areas – 228 km/h. This is an equivalent of a fourth category hurricane in the Saffir-Simpson scale developed in the National Hurricane Center NOAA, USA in 1969 and applied only to processes in the Atlantic and North Pacific Oceans. The presented description of the synoptic situation covers two days from December 5 at 00 UTC through December 7 at 00 UTC. The analysis aim is to verify the WRF model (the Weather Research & Forecasting Model [1, 2]) results of daily numerical weather forecasts of extremely dynamic atmospheric processes. The analysis does not concern the physical background of the low pressure system with intensive atmospheric fronts, nor the losses caused by the element so rare in Europe. All presented figures are the WRF model products of the 36.3 km or 12.1 km resolution. The paper supplements analyses of the storm situation over the southern Baltic Sea using direct hydrometeorological and remote sensing measurements results [3, 4] with the WRF model data which is operationally run in the Faculty of Civil Engineering and Geodesy of the Military University of Technology, Warsaw, Poland.

Diagnostic data of December 5, 2013 at 00 UTC

The data of the meteorological fields (atmospheric profiling [5]) come from the international network of measurement stations. They are then interpolated into a regular computational grid. An example of such diagnosis, i.e. real pressure and wind fields at the Earth surface on December 5, 2013 at 00 UTC is presented in figure 1. Black labels depict wind speed at the surface, and blue ones – atmospheric pressure. Areas with winds exceeding 30 m/s were observed in the northern part of the Atlantic – north-east of Iceland and near western coast of Scotland – at night on Wednesday

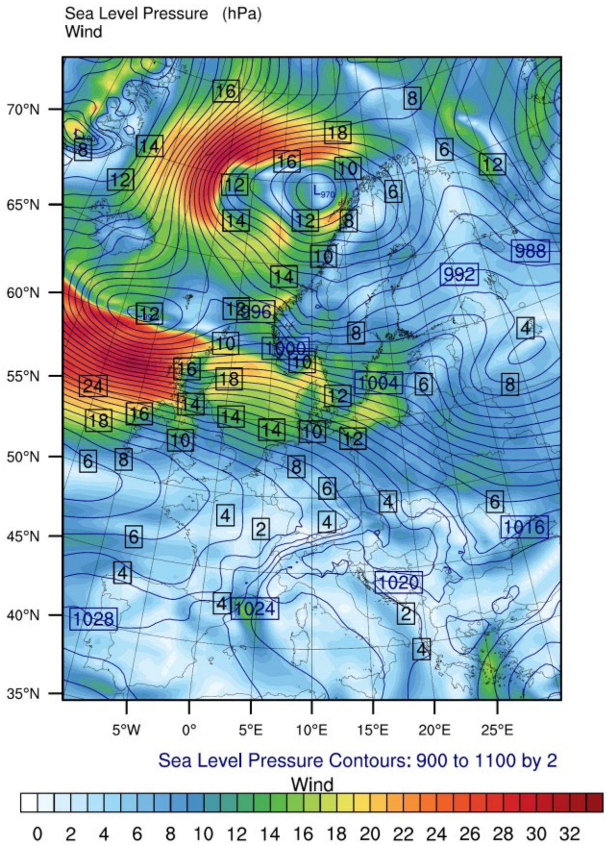

Fig. 1. Surface pressure and wind speed chart on December 5, 2013 at 00 UTC, WRF model data at 36.3 km resolution

and Thursday (December 04/05, 2013). The legend with the color scale representing appropriate isovels below the chart helps analyze the values properly because the maxima are not always printed in charts.

Both cases of strong winds are related with two low pressure systems. In the former pretty deep low (north-west coast of Norway, approx. 70°N), the pressure decreased to 970 hPa, and in the latter rather shallow low (between Scotland and Iceland, approx. 60°N) the pressure decreased to 992 hPa. Both cyclones developed over the ocean surface significantly warmer than the land surface at the time of the year. Warm water is for these dynamic pressure systems an additional source of energy – the so called Convective Available Potential Energy.

The Baltic Sea area and the route to the North Sea are important from the point of view of the Polish fishing fleet, shipping industry and touristic activities. They are also important from the point of view of short term hydro-meteorological support. Near the eastern and southern coasts of Norway, in the Danish Straits – Skagerrak and Kattegat – and over the Western Baltic the wind speed reached the values of 14–18 m/s. Wind speeds of such values are not surprising there, however, low pressure systems with increasing wind speed approaching from north and west put the hydro-meteorological operational services on alert.

Upper fields charts presenting the layout of air currents steering the processes of flow in the atmosphere are also important from the point of view of navigation. An example of such field at the model 18th level (at the altitude of 5 140 m above ground) is presented in figure 2. At the level, the wind speed (steering current) reaches the value of 60 m/s (over 200 km/h). The chart in figure 2 is prepared in a better resolution where the spatial step is 12.1 km. Such a chart contains more important details and it is more useful for analyzing hazardous atmospheric processes.

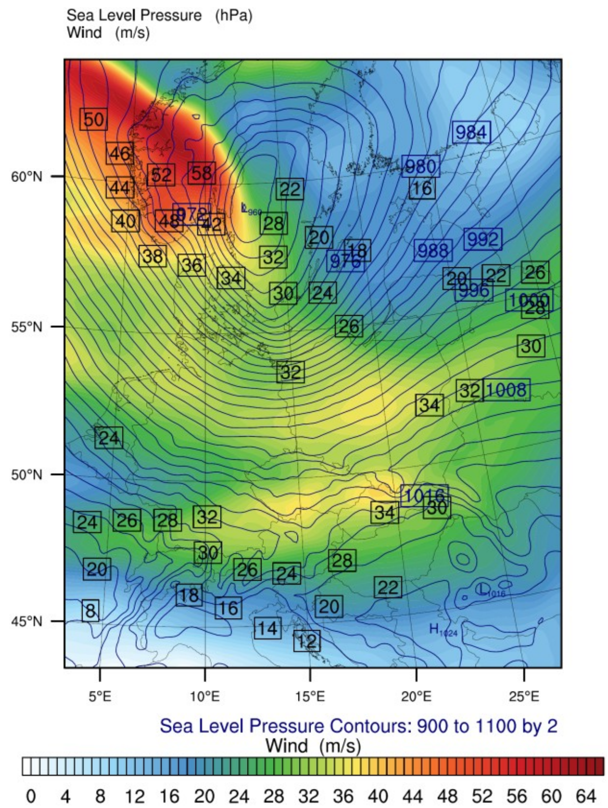

Fig. 2. Surface pressure and wind speed at level 18 chart on December 5, 2013 at 00 UTC, WRF model data at 12.1 km resolution

24-hours forecast based on data of the December 5, 2013 at 00 UTC

Analysis of the forecast chart on December 6, 2013 at 00 UTC (Fig. 3) shows that the cyclones would combine into one with a common area of strong winds. From the synoptic point of view it cannot be unambiguously forecasted which of the cyclones would develop and which would decay. It would be a problem without a forecast chart.

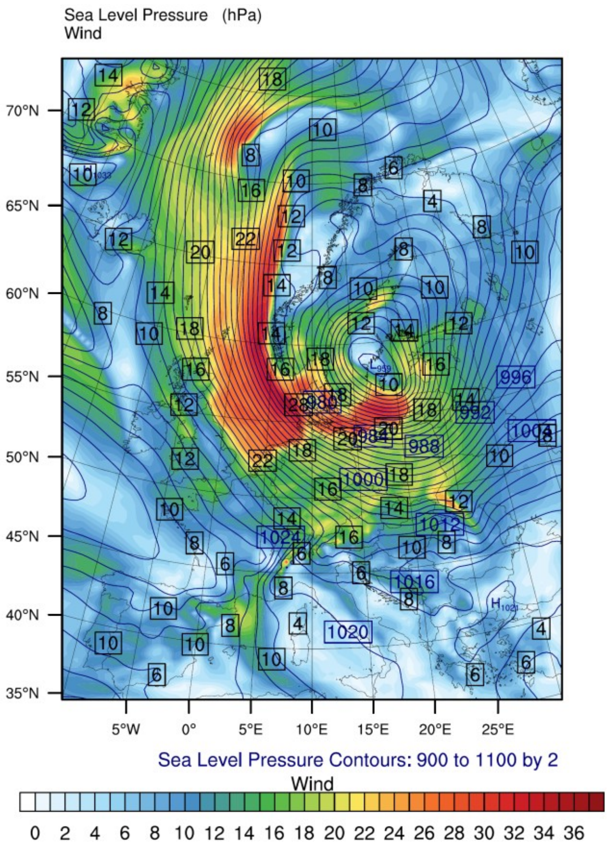

Fig. 3. Forecast chart on December 6, 2013 at 00 UTC, WRF model data at 36.3 km resolution

The forecast chart shows also that the surface wind speed increases. In a wide latitudinal zone between Scandinavia and the British Isles the wind speed exceeds 30 m/s.

The WRF numerical model weather forecast for December 6, 2013 at 00 UTC presented in figure 3 shows significant qualitative and quantitative changes in the atmospheric fields within a short time of twenty four hours.

Analysis of the chart of December 5, 2013 at 00 UTC (Fig. 1) and 12-hours forecast (Fig. 4) and 18-hours forecast (Fig. 5) shows that the deep cyclone near the north-west coast of Norway started to decay so rapidly at 12 UTC that at 18 UTC only a trough was observed (Fig. 5).

The cyclone north-west of Scotland with pressure of 992 hPa in the center moved very quickly (almost longitudinally) in the direction of southern part of Norway and deepened. The pressure in its center reached 964 hPa at 12 UTC and 961 hPa at 18 UTC. These rapid changes in the pressure field were accompanied by significant increase of the surface wind speed – according to 12- and 18-hours forecasts – up to 38 m/s. At the time, the Xaver cyclone influenced the western part of the Baltic Sea and north-western part of Poland.

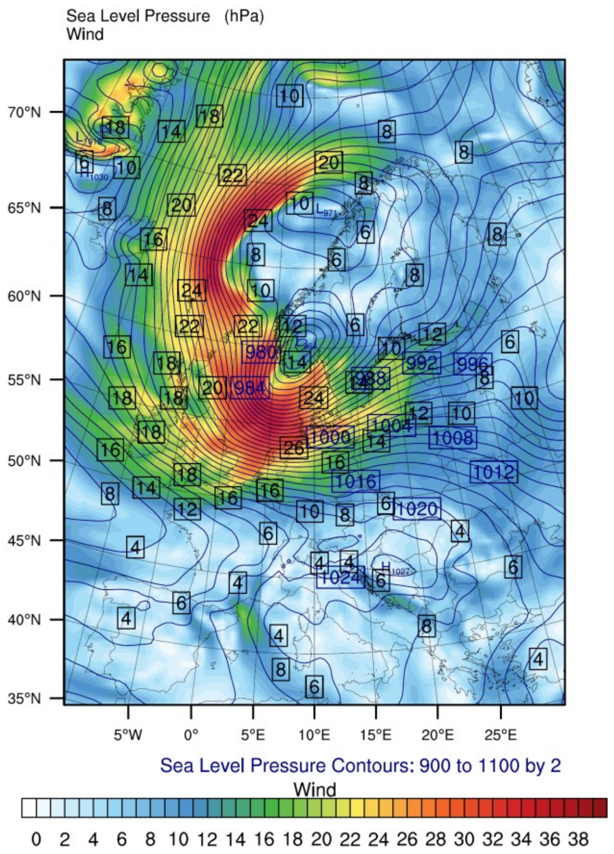

Fig. 4. Forecast chart on December 5, 2013 at 12 UTC, WRF model data at 36.3 km resolution

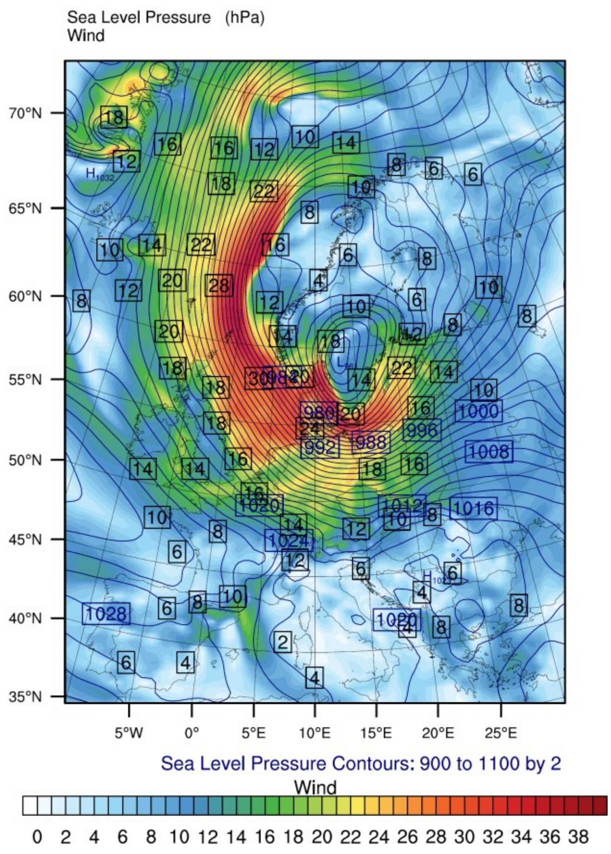

Fig. 5. Forecast chart on December 5, 2013 at 18 UTC, WRF model data at 36.3 km resolution

Diagnostic data of December 6, 2013 at 00 UTC

The main part of the research concerned the reliability of the WRF model in situations related with rapidly developing atmospheric processes. Analysis of the 24-hours forecast chart on December 6, 2013 at 00 UTC (Fig. 3) and the weather chart of December 6, 2013 at 00 UTC (Fig. 6) shows that the general layout of the pressure field is well forecasted and the centers of the forecasted and diagnosed low pressure centers match satisfactorily in the southern part of Sweden.

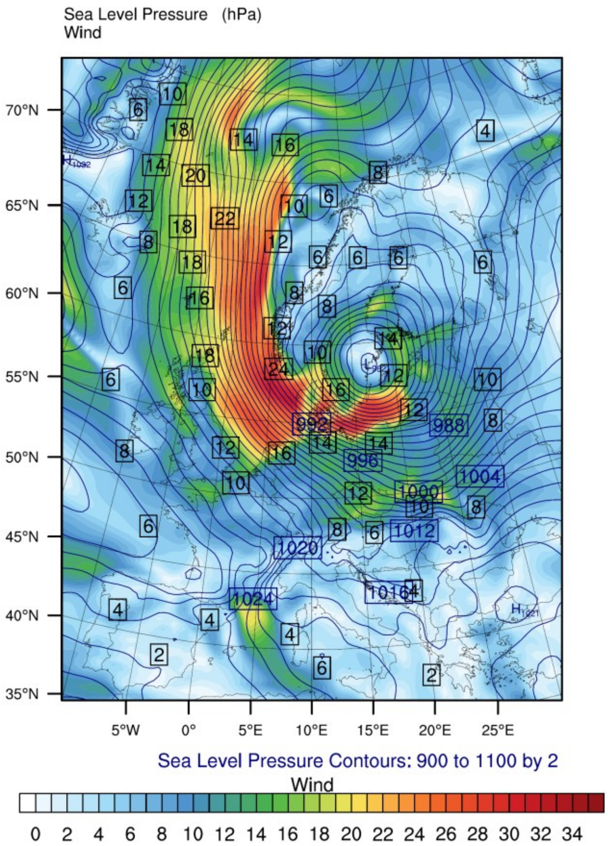

Fig. 6. Surface pressure and wind speed chart on December 6, 2013 at 00 UTC, WRF model data at 36.3 km resolution

The differences observed in the charts concern the pressure in the center of the lows and the location of the trough. The forecasted pressure value was 959 hPa, and the real equaled to 962 hPa. These differences are acceptable for the resolution of 36.3 km of the WRF model and prove its applicability to such rapidly developing pressure systems.

The effect of erroneous forecast of the trough in the field of atmospheric pressure is well observed in figure 7. The center of the maximum differences in pressure (6.2 hPa) is observed near Liepai, Latvia. In the remaining area of Europe, the differences between the forecasted and measured pressure fields are much smaller. In majority of the

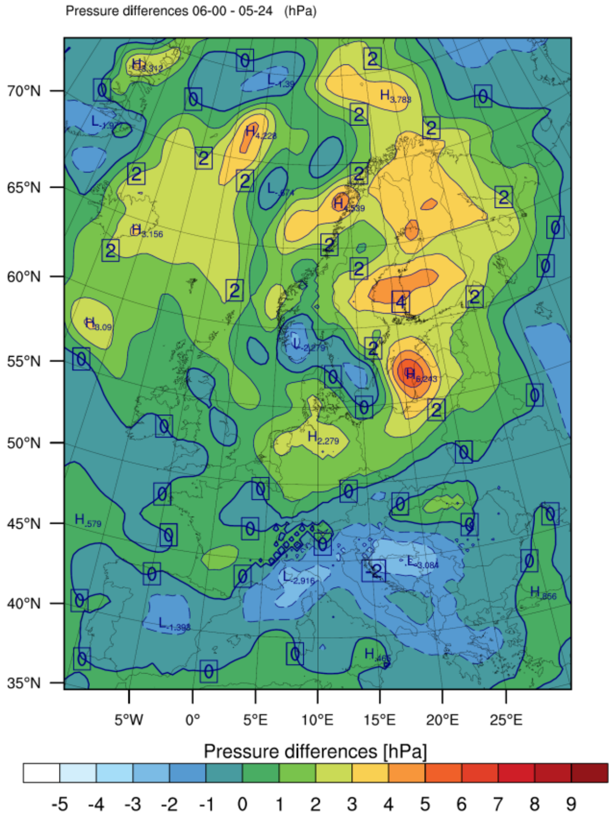

Fig. 7. Differences in pressure fields values between 24-hours forecast and measured data on December 6, 2013 at 00 UTC, WRF model data at 36.3 km resolution

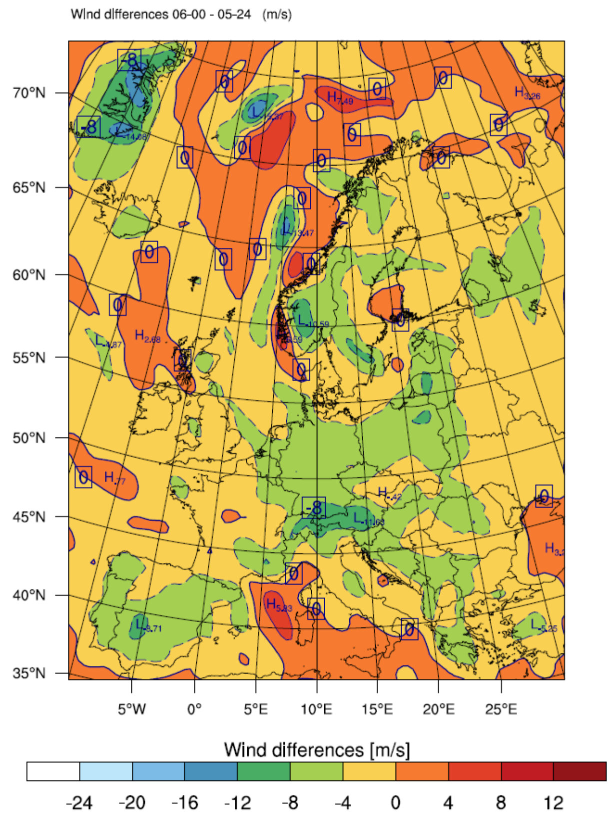

Fig. 8. Differences in wind speed fields values between 24-hours forecast and measured data on December 6, 2013 at 00 UTC, WRF model data at 36.3 km resolution

areas the absolute values of the differences do not exceed 2 hPa.

The forecasted and diagnosed areas of strong winds are located in the same part of Europe. Figure 8 presents a chart of the wind speed differences. Centers with differences in the range of –15 m/s to +7 m/s are observed. However, the information in this chart is rather of demonstrative nature with smaller practical importance. The wind speed field is the fastest changing field of meteorological elements, and the diagnostic charts are prepared using 10-minutes averages.

Conclusions

The authors are fully aware that an analysis of one case (one day of the Xaver cyclone) development is not enough for formulating conclusions of a general nature. However, this selection is related with an extremely untypical meteorological situation. A deep cyclone with vast frontal systems and extremely strong winds was discussed. The presented charts confirm the WRF numerical model's proper reaction to the selected initial conditions. It is worth mentioning that the applied spatial resolution of the computational grid of 36.3 km does not reveal to the user the sub-grid processes [6]. In case of the Xaver cyclone development and movement, the spatial step may be of significant importance. It is planned to analyze the case using data computed at better resolutions.

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