16.4 HIGH-RESOLUTION NUMERICAL SIMULATIONS OF WINDSTORMS IN THE COMPLEX TERRAIN OF ICELAND

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1. INTRODUCTION

In this study, two windstorms that hit Iceland in 2002 and 2003 are simulated numerically at high resolution. The results of the simulations are verified by comparison with meteorological observations made at both automatic and manned weather stations in Iceland.

The first windstorm hit Northwest-Iceland on 1 February 2002 and strong winds and heavy snowfall caused problems. The second storm (Fig. 1) hit East-Iceland on 17 February 2003, when strong southerly winds developed in accordance with the strong pressure gradient over the eastern part of Iceland. During the storm, wind gusts caused considerable damage to property, as well as personal injuries, in the small settlement of Seyðisfjörður. The gusts exceeded 50 m/s and were as great as 2.5 times the mean wind speed (Fig. 5).

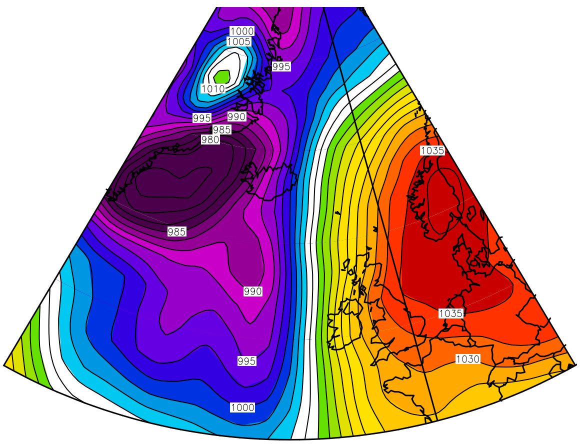

Figure 1: The mean sea level pressure [hPa] at 00 UTC on 18 February 2003. Based on data from NCEP acquired through NOAA/CDC.

In this paper, the latter storm is described in more detail than the first storm, but the study of both storms is extensively descibed in Ágústsson (2004).

Strong local windstorms were observed during both storms. They are presumably related to gravity wave activity aloft. A more detailed analysis of this is given in Ólafsson and Ágústsson (2004a,b).

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The simulations presented here are a part of preparations for operational high-resolution numerical weather prediction for Iceland.

2. THE SIMULATION SETUP

Both storms were simulated using the MM5 numerical weather prediction model (Dudhia et al. 2002). The simulations were performed using a horizontal resolution of 9, 3 and 1 km and 40 vertical levels. The high resolution is necessary to adequately resolve the complex terrain in Northwest and East-Iceland. The initial and boundary data was provided by the European Centre for Medium-range Weather Forecasts (ECMWF). The numerical domains, D1, D2 and D3, for the simulation of the storm on 17 February 2003 are shown in Fig. 2.

Fourteen, different simulations were performed for each storm. The sensitivity of the simulations to variable surface friction, four different planetary boundary layer (PBL) schemes, two moisture physics schemes and radiation parameterization was investigated.

3. SIMULATED WIND

Examples of the simulated wind at a resolution of 9 and 1 km for the storm of 17 February 2003, are given in Figures 2 and 3. The latter figure also shows observa-

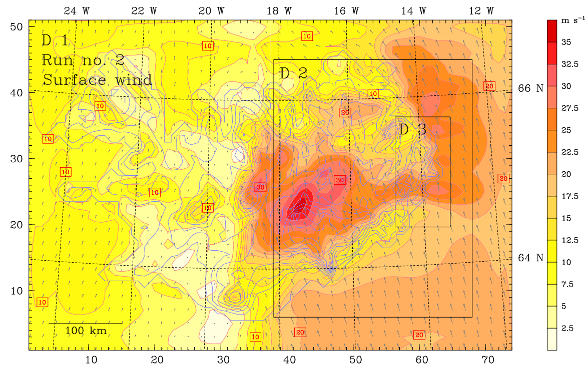

Figure 2: Simulated surface wind at low resolution (9 km) at 03 UTC on 18 February 2003. Terrain contours with a 200 m interval. The delineated domain marked D1 is enclosed by Fig. 3.

tions of the 10 minute mean wind speed, at 10 m above ground level at chosen automatic weather stations in East-Iceland.

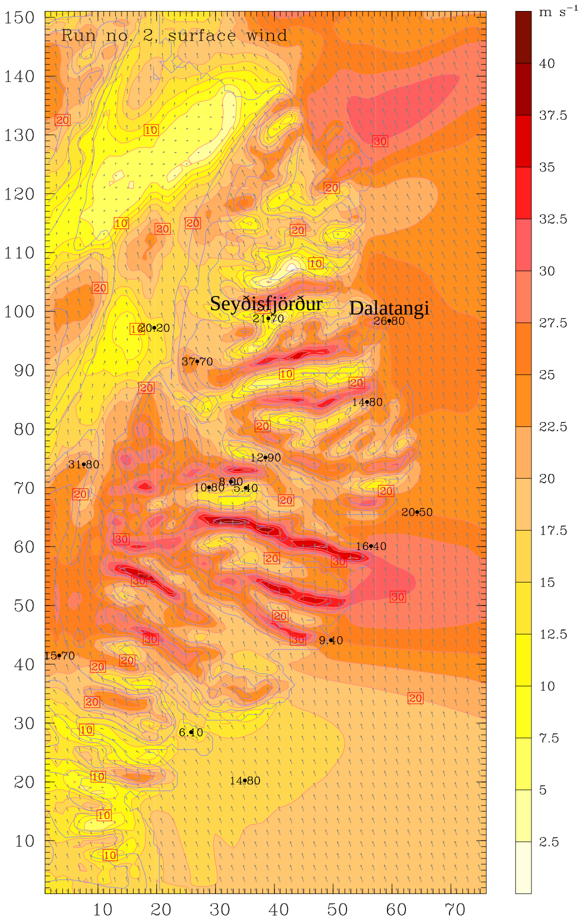

Figure 3: Simulated surface wind at high resolution (1 km) at 03 UTC on 18 February 2003. Terrain contours with a 200 m interval. Shown are mean wind speed observations (numbers) at chosen weather stations.

All detail in the simulated surface wind field is lost at the low resolution in Fig. 2. The results are somewhat better for domain D2, at a resolution of 3 km (figure not shown here). In Fig. 3, there is on the other hand large spatial variability in the simulated surface wind field. Where available, meteorological observations verify this variability, and are in most cases in good agreement with the simulated surface wind. At a few locations, there is significant difference between the simulated and observed winds, but this difference can be related to sub-grid topography.

Figure 4 shows the mean difference between the simulated and observed wind speeds at the stations marked in Fig. 3. The mean difference is shown

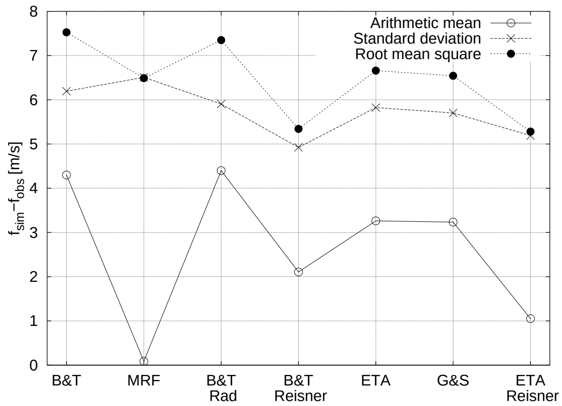

Figure 4: Arithmetic mean, standard deviation and root mean square of the difference between simulated and observed wind, $f_{sim} - f_{obs}$, for chosen simulations (horizontal axis) and at all stations marked in Fig. 3.

for seven different simulations, which use four different PBL schemes, available in the MM5 numerical model. Namely; the Burk & Thompson PBL scheme (B&T), the MRF PBL scheme, the ETA PBL scheme and the Gayno & Seaman PBL scheme (G&S). The mean difference is also shown for one simulation which included radiation processes (Rad), and two simulations which used a more sophisticated moisture physics scheme (Reisner), than the other simulations (Dudhia). For a description of these different schemes, the reader is referred to Dudhia et al. (2002).

The four different PBL schemes give somewhat similar results for the simulated wind speeds, but the MRF PBL scheme simulated the observed wind direction much worse than the other schemes (not shown here). The inclusion of radiation processes had nearly no impact on the simulated wind field, while a more sophisticated moisture scheme had a large positive impact on the performance of the simulations.

4. WIND GUST PREDICTION

An attempt was made to predict wind gusts using the method of Brasseur (2001). The method has been shown to perform well over both simple and complex topography (Goyette et al. 2003). The method is based on numerical considerations of turbulence and mean wind in the planetary boundary layer.

Examples of simulated and observed gusts, at two stations during the storm of 17 February 2003 are shown in Fig. 5. The locations of the stations are marked in Fig. 3. Seyðisfjörður is located in a relatively deep and narrow fjord, while Dalatangi is located

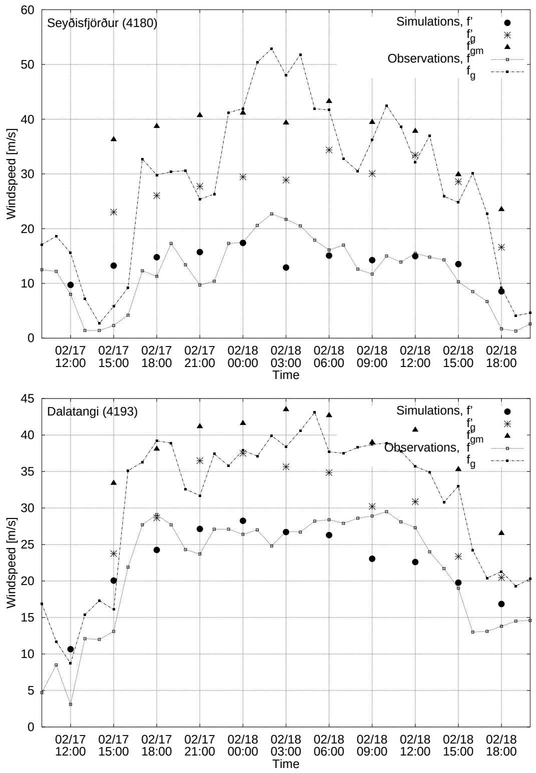

Figure 5: Simulated gusts, f'_g, upper and lower bound on simulated gusts, f'_{gm} and f', as well as observations of the 10 minute mean wind speed, f, and the 3 second gust strength, f_g.

at the tip of a peninsula and near the open sea.

The performance of the gust prediction is greatly dependent on the correlation of the simulated and observed mean winds. With overestimated surface winds, the observed gusts also tend to be greatly overestimated. Although the quality of the simulated wind is similar at Dalatangi and Seyðisfjörður, the accuracy of the wind gust prediction is somewhat greater at Dalatangi than at Seyðisfjörður.

Figure 6 is similar to Fig. 4, but it compares simulated and observed wind gusts, as opposed to simulated and observed mean surface winds. The figure does not take into account the width of the bounding interval, $f'_{gm} - f'$, or whether the observed gust lies within the interval, or not. The width of the gust bounding interval, $f'_{gm} - f'$, is a measure of the accuracy of the method, and the accuracy can be considered greater when the interval is shorter. The MRF PBL scheme does not predict TKE, and therefore the method of Brasseur can not be used for calculating the wind gusts when the MRF PBL scheme is used.

There is a slight difference in the performance of

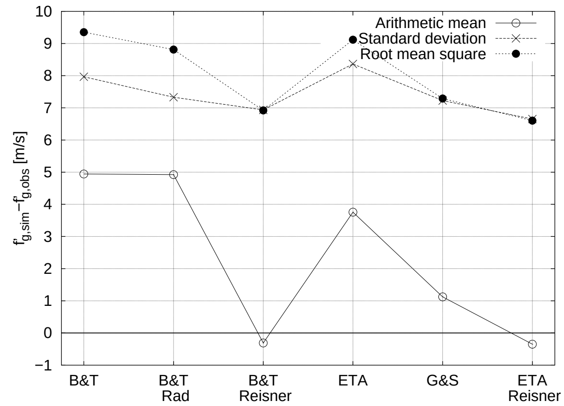

Figure 6: Arithmetic mean, standard deviation and root mean square of the difference between simulated and observed wind gust, $f_{g,sim} - f_{g,obs}$, for chosen simulations (horizontal axis) and at all stations marked in Fig. 3.

the different PBL schemes, with the G&S PBL scheme performing slightly better than the ETA and B&T schemes. The use of a more sophisticated moisture physics scheme (Reisner) has a much greater impact on the simulated gusts, giving on average, considerable better results than with a simpler moisture scheme (Dudhia). Weaker gusts are simulated with the first scheme, as it predicts lower TKE and weaker winds in the planetary boundary layer.

5. SUMMARY AND CONCLUSION

In this study, two storms have been succesfully simulated at high resolution, and the results of the simulations are verified by comparison with meteorological observations. For further information on the study, the reader is referred to Ágústsson (2004).

Some of the most important results of the study can be summarized as follows below.

- The observed surface wind is on average slightly overestimated at most locations.
- There is less dependence on the method to parameterize surface friction, i.e. PBL scheme, than was expected.
- A resolution of 9 km is far to low to realistically simulate the effects of the complex topology, in the region of interest, on the surface wind field.
- Local effects such as downslope windstorms and lee-side sheltering are in general well reproduced at a resolution of 1 km. In some cases, orographic

blockings seem however to be poorly predicted, leading to overestimated surface winds.

- Significant difference between observed and simulated winds at some locations can in many cases be attributed to sub-grid topography.
- Wind gusts were simulated using the method of Brasseur. At locations where the surface mean wind was well simulated, the observed wind gusts were generally also well simulated.
- The study clearly indicates that high-resolution simulations can aid when forecasting winds in complex terrain.

6. ACKNOWLEDGEMENT

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