**P1.8** TEMPORAL OSCILLATIONS OF PRESSURE AND WIND SPEED IN A WINDSTORM OVER COMPLEX TERRAIN

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## 1. INTRODUCTION

On 17 and 18 February 2003, a strong southerly windstorm hit Iceland. The storm was particularly strong over the easternmost part of Iceland, where it caused signficant damage to structures in the small settlement of Seyðisfjörður. The magnitude of the winds and the gusts was very variable, as could be expected in the complex terrain where fjords and mountain ridges run perpendicular to the wind direction.

Here, the temporal evolution of the pressure and wind fields are analyzed. The flow is simulated numerically and an attempt is made to link the peak winds to vertically and horizontally propagating gravity waves.

## 2. THE SYNOPTIC DEVELOPMENT

Figures 1 and 2 show the mean sea level pressure and the geopotential height at 500 hPa, at 00 UTC on 18 February 2003. The winds are strong and the wind direction is approximately the same at both levels. The airmass is statically stable. These conditions are very favourable for creation and vertical propagation of gravity waves.

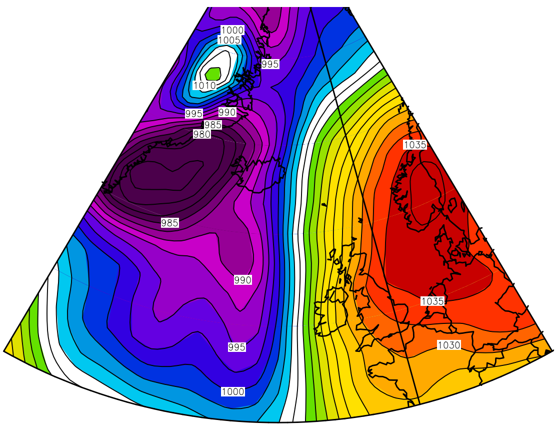


Figure 1: Mean sea level pressure [hPa] at 00 UTC on 18 February 2003. Figure is based on data from NCEP, acquired through NOAA/CDC.

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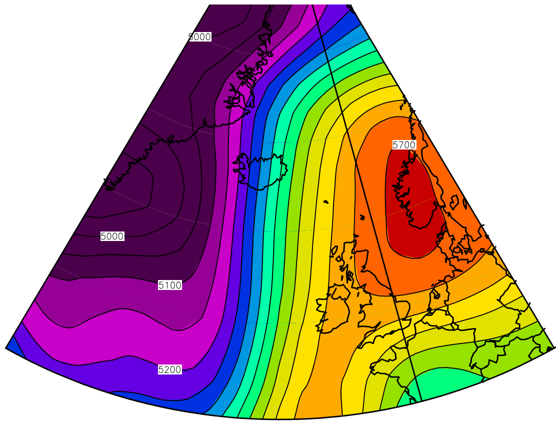


Figure 2: The 500 hPa geopotential height [$m^2/s^2$] at 00 UTC on 18 February 2003. Figure is based on data from NCEP, acquired through NOAA/CDC.

## 3. OBSERVATIONS OF A TRANSIENT PRESSURE ANOMALY AND MAXIMUM WINDS

The temporal evolution of the 10 minute mean wind speed, 3 second wind gust and mean sea level pressure at Seley is shown in Fig. 3. A temporary maximum can clearly be seen in the pressure curve between 21 UTC on 17 February and 03 UTC on 18 February, with

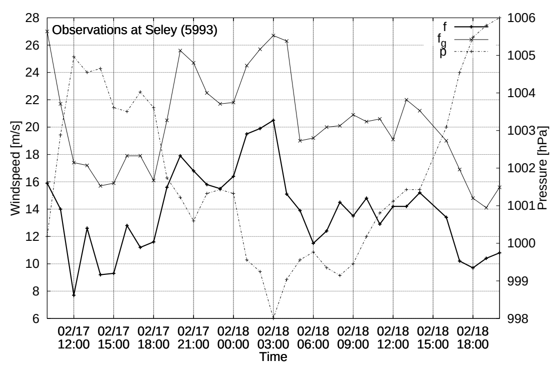


Figure 3: Time series of observed mean wind, $f$, wind gust, $f_g$ and mean sea level pressure, $p$, at Seley (Fig. 6) during the storm.

a maximum amplitude of approx. 2 hPa at 00 UTC on 18 February. The wind speed oscillates as if the pressure anomaly was moving upstream: there is a maximum shortly after the pressure anomaly has passed.

Similar pressure maxima as at Seley are observed at other locations in the region. The magnitude and the time of the pressure anomaly is shown schematically in Fig. 4. The anomaly moves southward with the speed of approximately 10 km/h and the maximum amplitude of more than 2 hPa is confined within a 50 km wide path.

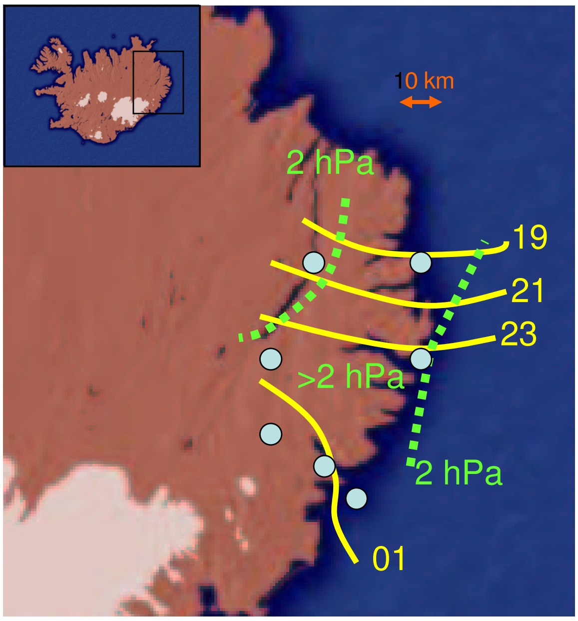


Figure 4: Schematic figure showing the magnitude of the pressure anomaly (green dotted lines) and its movement (yellow lines with time stamps).

## SIMULATION OF THE WINDSTORM

The windstorm has been simulated with the numerical model MM5 (Dudhia et al. 2002). The simulation is forced with boundaries from the European Centre for Medium-range Weather Forecasts (ECMWF). The flow is simulated in 40 vertical levels and with horizontal resolutions of 9, 3 and 1 km. The numerical domains, D1 (9 km), D2 (3 km) and D3 (1 km), used in the simulation, are shown in Fig. 5. For further information on the simulation, the reader is referred to Ágústsson and Ólafsson (2004) or Ágústsson (2004).

Figure 5 shows the simulated surface wind at a horizontal resolution of 9 km, in the outermost domain D1. There is not much detail in the simulated wind field, and there is worse correlation between the simulated and observed winds, than at a greater horizontal resolution (not shown). That is as expected, since the complex terrain in East-Iceland can not be properly resolved with a horizontal resolution lower than approx. 1 km.

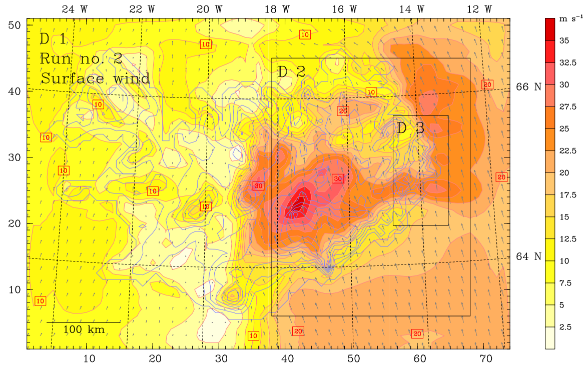


Figure 5: Simulated surface wind over Iceland at 03 UTC on 18 February 2003. Terrain contours with a 200 m interval. Shown are the numerical domains, D1, D2 and D3, used in the simulation.

Figure 6 shows the simulated surface wind in the innermost domain, at a horizontal resolution of 1 km. As can be expected, there is large spatial variability in the simulated surface winds and this variability represents observations reasonably well. The maximum wind speeds observed during the storm are however not well simulated by the numerical model, as is shown in Fig. 7 for the automatic weather station at Seyðisfjörður.

A cross section (Fig. 8) shows very strong wave activity over the region. The simulation reproduces a pressure anomaly as in the observations (Fig. 9), but the simulated anomaly is shifted forwards in time and its magnitude is smaller than the observed anomaly.

## DISCUSSION

The observed pressure anomaly is of a magnitude that can increase the winds locally by 10–15 m/s (Fig. 10). This is sufficient to turn a strong windstorm into a violent storm, causing widespread damage. The failure of the simulations to correctly simulate the severe winds during the storm's maximum, may therefore be related to the relatively poor simulation of the observed pressure anomaly.

According to Eq. 28c in Smith (1980), the vertical

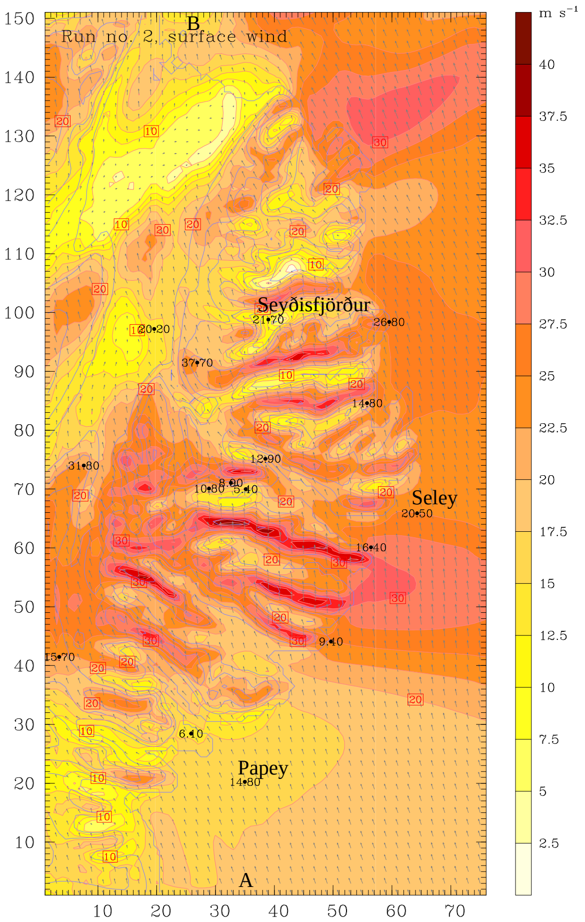


Figure 6: Simulated surface wind over East-Iceland at 03 UTC on 18 February 2003. Terrain contours with a 200 m interval. Shown are observations (numbers) of the 10 minute mean wind at 10 m a.g.l. at chosen weather stations in East-Iceland.

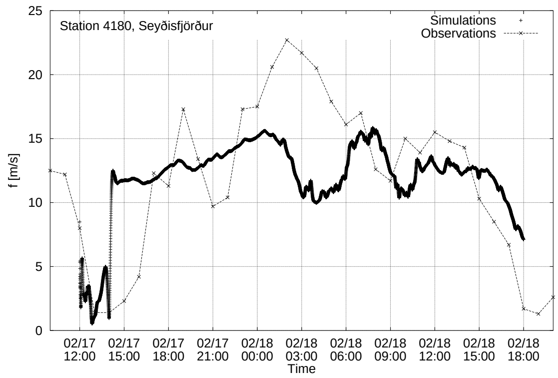


Figure 7: Simulated and observed surface winds during the storm at Seyðisfjörður (Fig. 6).

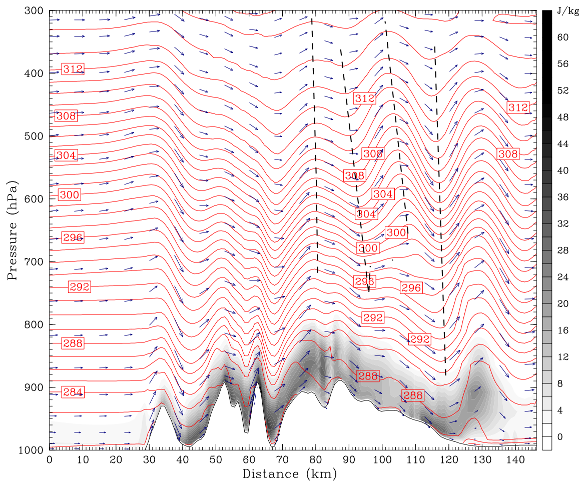


Figure 8: A cross section showing potential temperature [K] and wind vectors. The position of the cross section is from A to B in Fig. 6.

component of the wave group velocity is given by

$$C_{gz} = \frac{U^2k^2}{N(k^2+l^2)^{1/2}}, \tag{1}$$

where $U$ and $N$ are the mean wind and the Brunt-Väisäilä frequency. The horizontal components of the total wavenumber vector are given by $k$ and $l$. By applying (1), and assuming $k$ to be $1/L$ where $L$ is a characteristic length scale of the mountains in the direction of the flow (10 km) and $l = 0$, we obtain a vertical group velocity of about 16 km/h. Estimating the slope of the phase lines of the waves in Fig. 8 gives a 0–10 km upstream tilting with height in the lowest 8 km of the atmosphere. As the wave propagates from the ground up to about 300 hPa in about 30 minutes, it should in other words reach 0–5 km upstream. This horizontal speed is of the same sign and the same order of magnitude as the movement of the observed pressure anomaly. This supports that the upstream propagation of the pressure anomaly may be associated with a vertically propagating gravity wave created by the interaction between the mountains and the airflow.

## 4. ACKNOWLEDGEMENT

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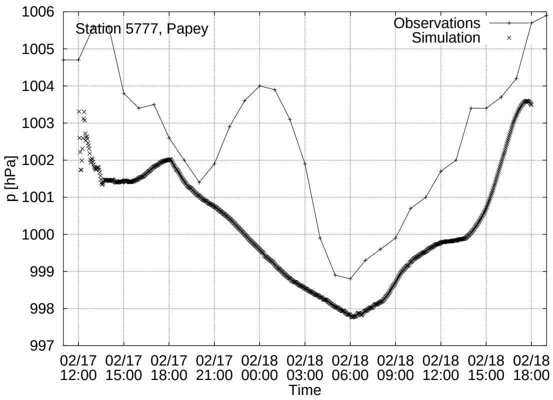


Figure 9: Time series of observed and simulated mean sea level pressure during the storm, at the automatic station at Papey (Fig. 6).


Figure 10: A schematic figure of the observed pressure anomaly, showing the winds (yellow arrows) generated by the anomaly and the direction (green arrow) in which the anomaly moves.

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