10A.5 VARIABILITY IN THE KVÍSKER DOWNSLOPE WINDSTORMS

Hálfdán Ágústsson* and Haraldur Ólafsson
Institute for Meteorological Research, University of Iceland, Icelandic Meteorological Office and the Bergen School of Meteorology.

1. INTRODUCTION

Weather and climate play a very important role in the daily life in Iceland. Severe windstorms are frequent, especially during the winter months, and they often disrupt e.g. transportation on land and in air. The worst windstorms occur when deep cyclonic systems are near Iceland and the winds are locally enhanced due to the complex orography. Many such places are well known in Iceland and one of them is in Öræfi in Southeast-Iceland. The easterly Freysnes downslope windstorms, named after the farm at Freysnes in Öræfi on the western side of Mt. Öræfajökull, have been the subject of previous studies (Ólafsson and Ágústsson 2007) and were found to be related to breaking gravity waves aloft. Here we turn our attention to the windstorms on the eastern side of the mountain, near the farm at Kvísker (Fig. 1), where e.g. traffic is frequently disrupted due to very strong and gusty winds.

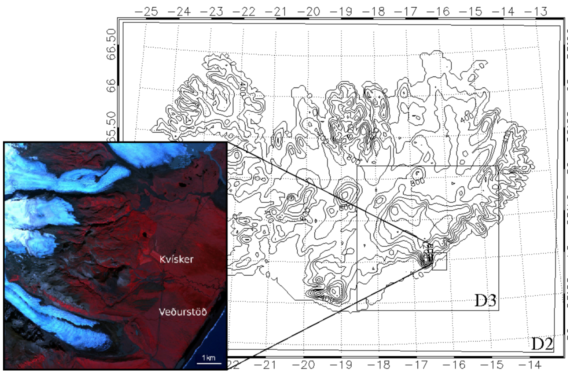

Figure 1: The location of the farm at Kvísker, as well as the Kvísker weather station and the numerical domains with a horizontal resolution of 3 and 1 km. Terrain contours with an interval of 200 m.

2. METHODOLOGY

The windstorms are studied using observations from the automatic weather station at Kvísker (Fig. 2) and with analysis from the ECMWF as well as from NCEP/NCAR.

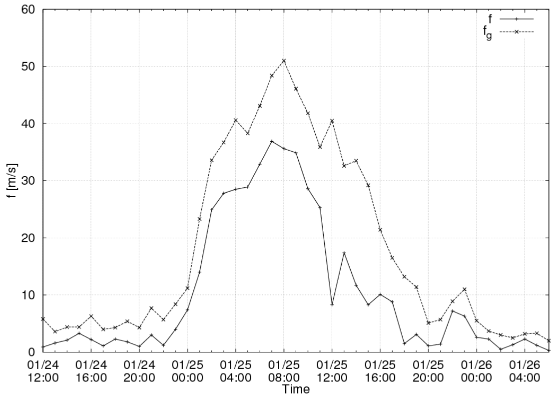

Figure 2: Observations at Kvísker of mean winds, f [m/s], and gusts, f_g [m/s], during the windstorm of 25 January 2007.

The observational data includes observations of the 10-minute mean wind and 3-second gusts at approx. 7 m above ground level. Additionally, data from other stations in Iceland are used for validating the simulations of the windstorms which are performed with the nonhydrostatic mesoscale model, MM5 (Grell et al. 1995). The model is initialized and forced with data from the ECMWF, and is run at a resolution of 9, 3 and 1 km (Fig. 1) with 40 σ-layers in the vertical for the real cases. A resolution of 2 km is used for the sensitivity tests with idealized flows.

The zonal and meridional wind components at 63°N 15°V on the 500 and the 850 hPa levels are extracted from the ECMWF-analysis, using the ERA-dataset for the years 1967-1999 and the operational analysis for 2000-2007. The NCEP/NCAR analysis is used to further investigate the windstorms observed at Kvísker but here we define an event as a windstorm if the observed gusts exceed 35 m/s.

3. THE WINDSTORMS

An investigation of the zonal and meridional wind components at the 500 and 850 hPa levels reveals two different types of windstorms ($f_g > 35$ m/s) at Kvísker (Fig. 3). The westerly windstorms (type A) are on average characterized by strong westerly winds throughout the troposphere as is shown in Fig. 4 for a sub-

*Corresponding author: Reiknistofa í veðurfræði, Grensásvegi 9, IS 150 Reykjavík, ICELAND; e-mail: halfdana@hi.is.

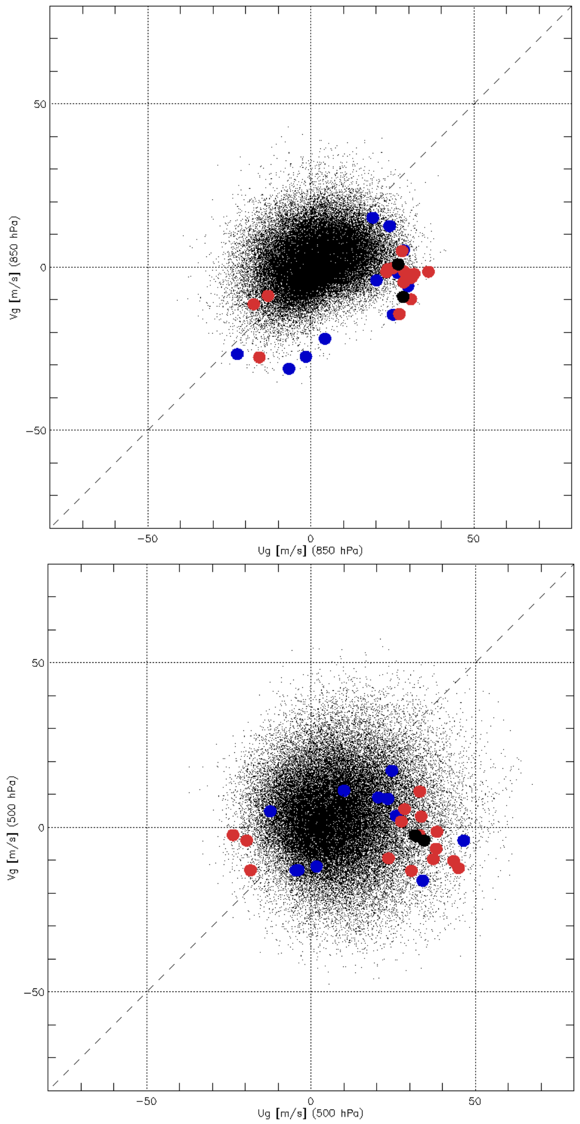

Figure 3: Zonal and meridional wind components at 63°N 15°V at 850 (above) and 500 hPa (below) in the ECMWF-analysis (1967–2007). Blue, red and black dots correspond to observations of gusts at Kvísker exceeding 35, 40 and 50 m/s, respectively

set of the storms with gusts exceeding 40 m/s. These windstorms are more common than the other type, and are also the strongest with gusts exceeding 50 m/s, e.g. during 25 January 2007 (Fig. 2). The northerly windstorms of type B are in general not as strong but are characterized by strong northerly winds at lower levels and a reverse and directional wind shear with slightly weaker and more easterly winds aloft.

Simulations of the strongest northerly windstorm on 18 October 2004 show strong winds in a large region on the leeslopes and downstream of the mountains,

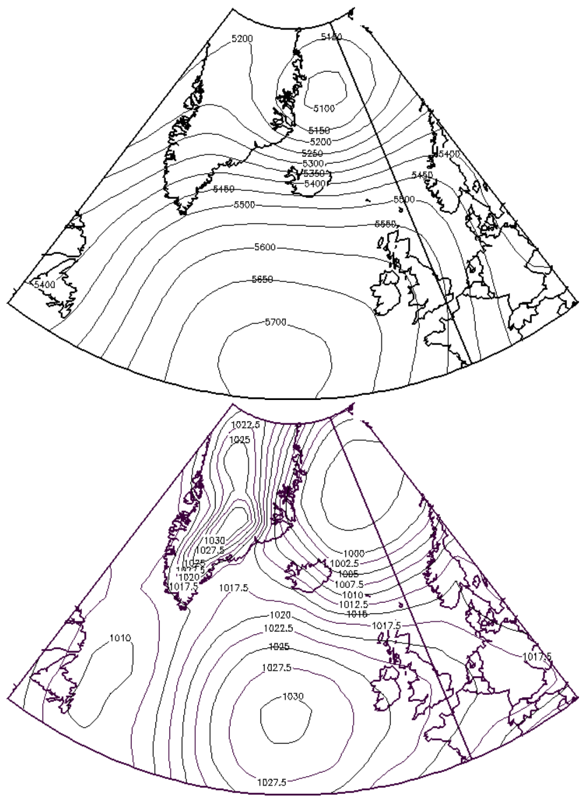

Figure 4: Mean geopotential [m] and sea level pressure [hPa] at Kvísker during westerly windstorms when observed gusts at Kvísker exceed 40 m/s (data from NOAA/CDC).

including at Kvísker (Fig. 5). Above the leeslopes, the flow descends and accelerates until it reaches a hydraulic jump slightly downstream of the mountain. In the westerly windstorm of 25 January 2007, the windstorm at Kvísker is very localized and confined to the slopes of the mountain. Section A across Mt. Öræfajökull reveals large amplitude gravity waves aloft and Kvísker is located below the first descending wave where the winds are strongest. The winds are much weaker only slightly further downstream. There are significant amounts of turbulence kinetic energy (TKE) aloft in both storms, which is not unexpected given the strong gustiness which is observed and predicted at Kvísker using a method based on Brasseur (2001) (Fig. 6). It should be noted that during both storms there is evidence of gravity waves in satellite images (not shown).

An investigation of the origin of the airmasses reveals that the airmass in the northerly windstorm is of arctic origin but boundary layers of such airmasses tend to deepen when traveling southward over warmer seas. It has therefore a relatively deep neutral boundary layer below an inversion well above the mountain tops. The westerly windstorm is related to an airmass

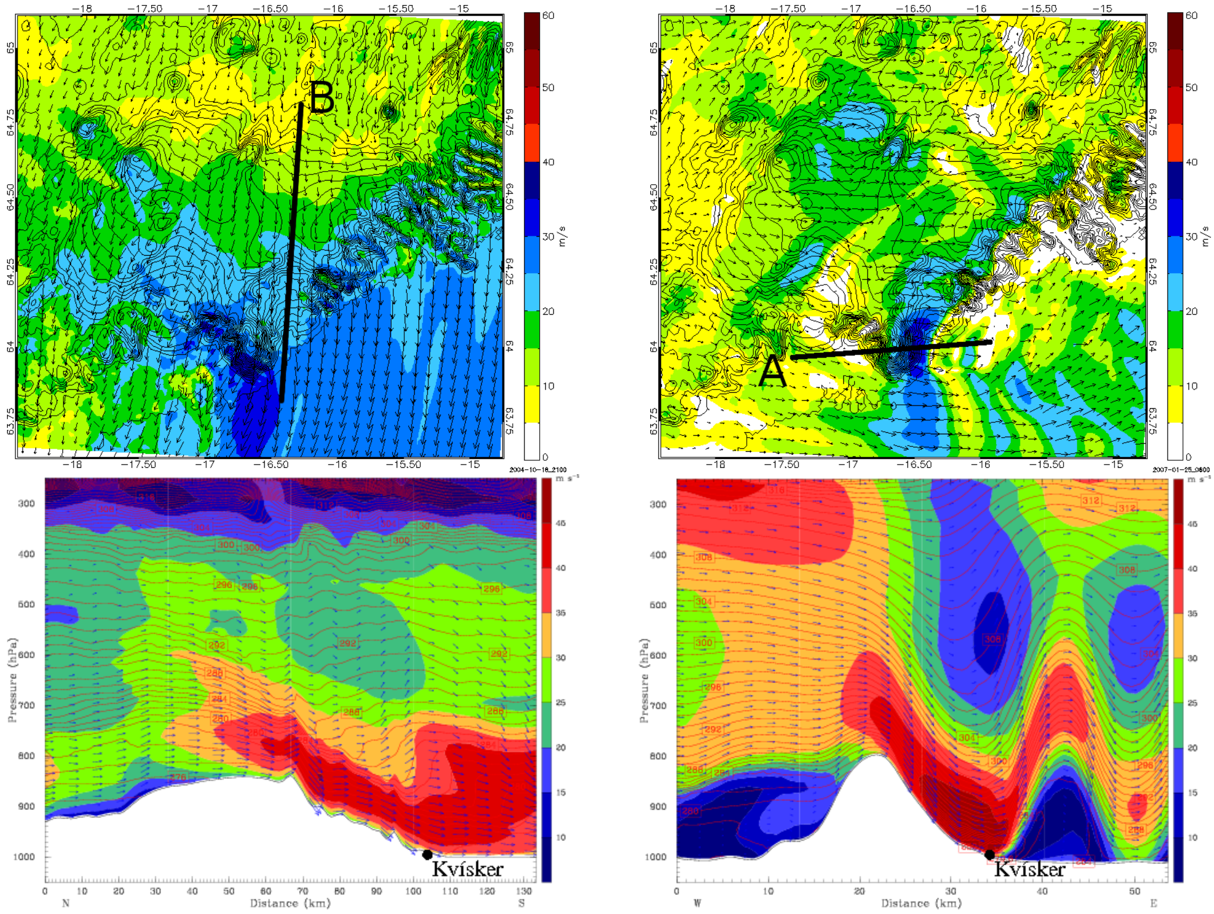

Figure 5: Surface wind speed [m/s] and vectors, as well as terrain contours with a 100 m interval (above) and wind speed [m/s] and potential temperature [K] in sections A and B (below) at a resolution of 1 km at 21 UTC 18 October 2004 (left) and at 06 UTC on 25 January 2007 (right).

of southern origin and has a shallower neutral layer due to the cooling of the warm surface flow over the colder sea. However, the strong winds ensure some mixing and there is an inversion near mountain level.

4. Sensitivity to inversion height

To further investigate the sensitivity of the windstorms to the thickness of the neutral layer a series of sensitivity tests were carried out using a smooth mountain defined with the "Witch of Agnesi" function. Only the height of the inversion was varied between the tests and Fig. 7 shows the case with the inversion height at 800 hPa which is identical to the height of the mountain.

In general, all the tests show an upstream deceleration of the flow with accelerated flow on the shoulders of the mountain. Gravity wave activity aloft is observed in all cases as well as downslope windstorms on the leeside of the mountain (Fig. 8). The extent of these downslope windstorms has relatively little dependance on the inversion height and in fact appears linearly related to it (Fig. 9). However, on the shoulders of the mountain there is a strong dependance on the inversion height with the greatest increase when the inversion is at mountain level. The pattern is slightly asymmetric due to the Coriolis-force while the symmetric pattern downstream is related to a secondary wave on the wake which is reminiscent of a bow wake behind a boat.

5. Concluding remarks

Here we present an investigation of downslope windstorms at Kvísker in Iceland. The windstorms are of two different types, westerly and northerly, and the main difference at the surface is the horizontal extent of the windstorms. The northerly windstorm is slightly weaker and not as gusty but has a large horizontal extent while the westerly windstorm is on the other hand, stronger and very localized as it is limited

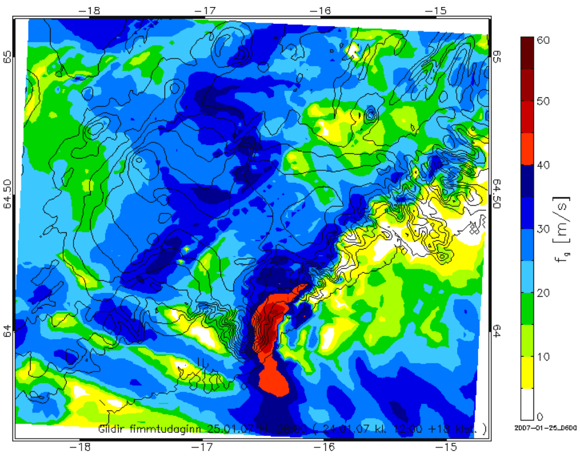

Figure 6: Predicted gust strength [m/s] and 100 m terrain contours every at a resolution of 1 km at 06 UTC on 25 January 2007.

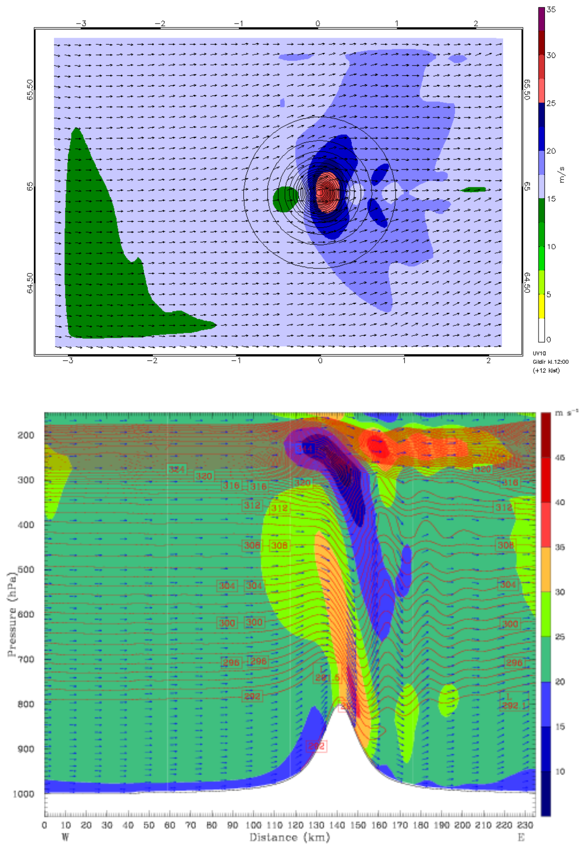

Figure 7: Surface wind speed [m/s] as well as the wind speed [m/s] and potential temperature [K] in a section over the mountain with the inversion height at 800 hPa.

to the leeslopes of Mt. Öræfajökull.

The difference in the two types of windstorms is presumably partly related to the different structure of the airmasses and possibly to the height of the surface between the lower, neutral, layer and the upper, stable, layer. The idealized experiments reveal a somewhat linear dependance of the downslope windstorms on the height of the interface but no sudden change of character in the windstorms. This has to be studied in more detail to better explain the cause behind the difference in the surface extent of the windstorms. Such an investigation is for example of great importance for improving operational forecasting at locations in complex terrain, such as at Kvísker. Operational forecasting systems (e.g. the HRAS-system[1]) sometimes forecast windstorms in complex terrain and at the foot of big mountains while the windstorms are not observed on-site. This indicates that the horizontal extent of the windstorms may be incorrectly captured and that the windstorms are limited to the mountain slopes above the observation sites and that they do not reach down to lower levels.

The windstorms revealed here are in many aspects similar to the easterly windstorms at the nearby farm Freysnes (Ólafsson and Ágústsson 2007), however with the important difference that the waves in the easterly windstorm steepen and break above the leeslopes of Mt. Öræfajökull due to a reverse wind shear aloft. This is less likely to occur in the westerly windstorms investigated here as the wind shear is very weak or positive. Also, here as well as in previous studies of extreme windstorms in Iceland (e.g. Ágústsson and Ólafsson 2007), the strongest and gustiest winds are observed below descending gravity waves and turbulence aloft which is in accordance with the observed surface winds and gusts.

[1]http://belgingur.is

Acknowledgements

This study is partly funded by Kvískerjasjóður and is carried out in connection with the RÁV project which is supported by the Icelandic research fund (RANNÍS).

References

Ágústsson, H. and Ólafsson, H.: 2007, Simulating a severe windstorm in complex terrain, *Meteorol. Z.* **16**(1), 111–122.

Brasseur, O.: 2001, Development and application of a physical approach to estimating wind gusts, *Mon. Weather Rev.* **129**, 5 – 25.

Grell, G. A., Dudhia, J. and Stauffer, D. R.: 1995, A Description of the Fifth-Generation

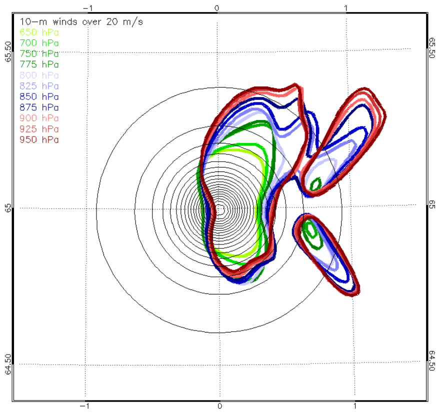

Figure 8: The 20 m/s windspeed isolines for the different inversion heights with 100 m terrain contours.

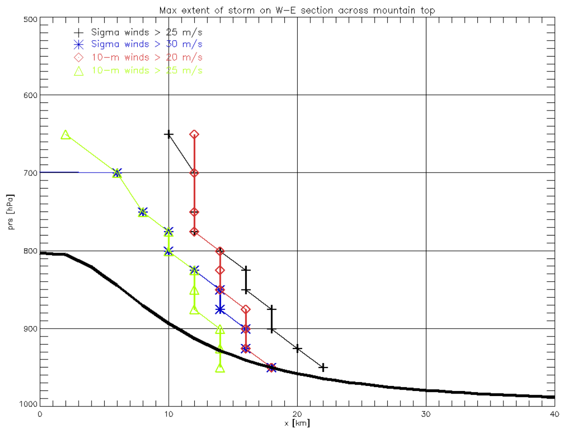

Figure 9: The largest extent of the windstorm in a WE-section over the mountain top for different inversion heights and different minimum 10-m and sigma-3 wind speeds.

PennState/NCAR Mesoscale Model (MM5), *Technical Report NCAR/TN-398+STR*, National center for atmospheric research. Available at http://www.mmm.ucar.edu/mm5/doc1.html (May 2004).

Ólafsson, H. and Ágústsson, H.: 2007, The Freysnes downslope windstorm, *Meteorol. Z.* **16**(1), 123 – 130.