MULTI-SCALE OROGRAPHIC FORCING OF THE ATMOSPHERE LEADING TO AN EROSION EVENT

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Abstract: A satellite image of blowing dust is compared to a simulation of winds during a major erosion event in Iceland. There is large spatial variability in the wind speed and this variability is attributed to the topography. The atmosphere responds particularly stongly to the mountains because of a low-level inversion which is a result of synoptic-scale descent from the Greenland ice cap. The simulation is a part of the new MM5-based forecast system in Iceland (HRAS) and comparison with the patterns revealed by the dust image indicates that all main features of the flow are correcty reproduced by the forecast system. This case study indicates that local enhancment of the wind may be important for erosion.

Keywords *– sandstorm, erosion, Greenland, Iceland, inversion, corner wind, Nh/U, inverse Froude number*

1. INTRODUCTION

Erosion is considered to be a major problem in Iceland. Frequent strong winds and volcanic soil lead regularly to sandstorms that can have devastating impact on vegetation (Arnalds, 2004). On 5 October 2004 a sandstorm event took place in a northerly windstorm in S-Iceland. The dust was carried several hundreds of kilometers over the ocean and could be clearly detected on satellite images. Here, the role of orography in enhancing the winds during the sandstorm will be examined and the performance of the operational forecast system in predicting the event will be discussed.

2. THE SANDSTORM AND THE WIND FORECAST

Figure 1 shows the dust from the south coast of Iceland being blown several hundreds of kilometers to the south. At the coast, areas of high concentration of sand or dust can be detected and in between there is less erosion or none at all. The southernmost part of the coast with the greatest concentration of sand and dust is immediately to the east of a major glacier and the wind acting here is a corner wind, enhanced by the mountain. Further to the east, downstream of the large Vatnajökull glacier (below a broken cloud cover), there are streamers of sand and dust, but somewhat less than immediately east of the southernmost glacier. To the south of the southernmost glacier, there is no erosion at all, but to the west of the glacier there are small streamers of sand and dust.

Currently, a forecast system based on the MM5 model (Grell et al., 1995) is run for this region with a horizontal resolution of 9 km. Figure 2 shows the 48 hr wind forecast from this system valid at 06 UTC on 5 October. The forecast features very clearly a local maximum in the wind speed where there is greatest concentration of blowing soil in Figure 1. This is the aforementioned corner wind, enhanced by the topography of the southernmost glacier. The sheltering or the wake from this very same obstacle is visible in the wind forecast and so is the strong wind at the foothills of the Vatnajökull glacier. These strong winds do not extend far away from the topography and they are most likely related to gravity waves or downslope flow over Vatnajökull. The cloud pattern above does indeed indicate amplified waves. Further downstream, there is a wake with trailing vortices with very weak winds in the simulations. The vortex-like dust pattern in Fig. 1 indicates that the numerical simulation is most likely correct here too.

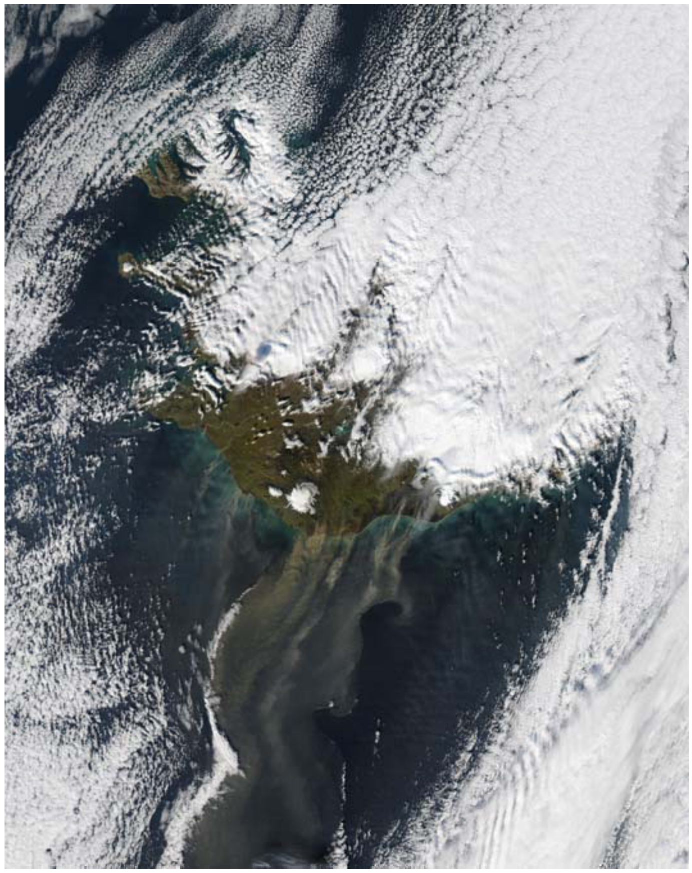

Figure 1. Modis satellite image taken at 13.40 UTC on 5 October 2004 (Courtesy of NASA)

3. THE OROGRAPHIC FORCING

The strong corner wind to the east of the southernmost glacier and the wake formations revealed by the dust in the satellite image and the numerical forecast are characteristic of flow with high value of the Nh/U (where N is the Brunt-Väisälä frequency or static stability, h is mountain height and U is the wind speed). With h only about 1500 m and U about 20 m/s within the boundary layer, N needs to very high to get a high Nh/U and this is indeed the case. The Keflavík sounding (Fig. 3) shows a strong inversion just below 1500 meters. Such an inversion does not only contribute to the corner wind and the wakes, it is also particularly favorable for the generation of mountain waves, which are quite obviously present, not only over the lee slopes of Vatnajökull glacier, but over the whole of Iceland.

A remaining question is what created the strong low-level inversion. The answer to this lies in the trajectories calculated in Fig. 4. The flow above the inversion comes directly from the North-Greenland ice cap. Once the flow has passed Greenland, it descends rapidly and according to the trajectory calculations, an air parcel at about 3700 m height at 00 UTC on 4 October has descended down to 2000 m at 12 UTC on 5 October. The associated adiabatic warming leads inevitably to stable stratification at low levels.

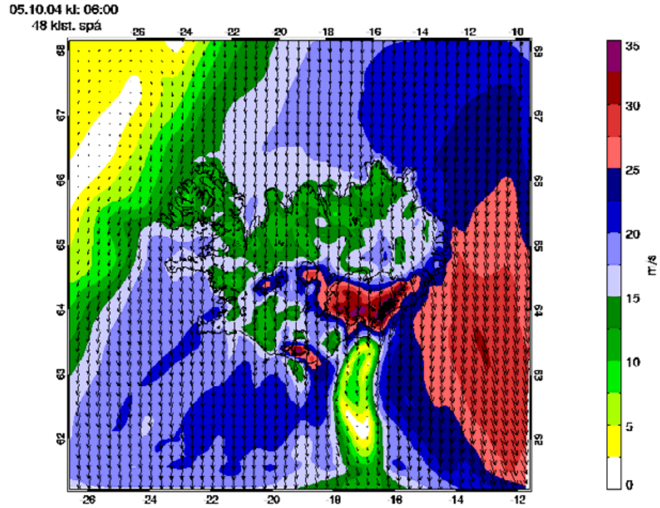

Figure 2. A 48 hour forecast of surface winds from the HRAS project (http://www.os.is/~or/vedurspa) valid on 5 October 2004 at 06 UTC

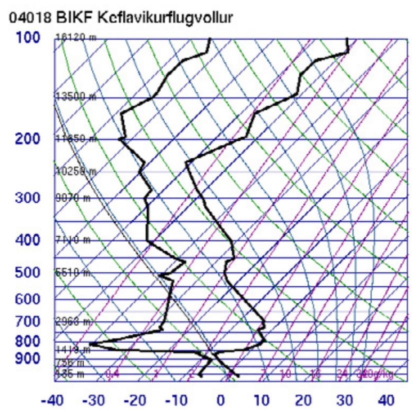

Figure 3. The radiosounding from Keflavíkurflugvöllur (SW-Iceland) on 5 October 2004 at 12 UTC (Provided by the University of Wyoming)

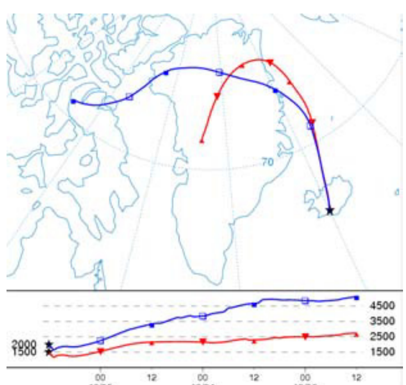

Figure 4. Backtracing of trajectories ending over S-Iceland on 5 October 2004 (12 UTC) at 1500 m and 2000 m height (HYSPLIT ARL/NOAA)

4. DISCUSSION

The windstorm presented here is a good example of how a low-level inversion in strong winds gives the flow the characteristics of a high Nh/U with corner winds and wakes and at the same time produces amplified gravity waves. The wind structures revealed by the satellite image correspond well with the forecasted winds giving credibility to the ability of the forecasting system being able to reproduce correctly the local orographic winds.

The inversion contributes not only the local enhancement of the winds, leading to the extreme erosion, but it also contributes to limiting the vertical dispersion of the dust once it is over the ocean. In fact, most of the dust must be concentrated below the inversion where it enables the indirect observation of the wake flow far downstream of Iceland.

5. CONCLUSIONS

This study indicates that local orographic effects may be important for erosion and it also demonstrates the ability of the MM5-based HRAS forecast system to predict all the main features of orographic modification of a northerly windstorm in Iceland. The usefulness of satellite images of blowing soil for validation of numerical simulations is confirmed.

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