Gust Factors

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ABSTRACT

Gust factors are analyzed for wind speeds greater than 10 m/s in a large set of data from 13 automatic weather stations in Iceland. The average gust factors appear to be independent of the stability of the atmosphere, but there is strong dependency on wind speed and the nearby topography. The mean gust factor decreases regularly with increased wind speed. High mountains close to the weather stations give strong gusts and the data suggests that to get an average gust factor of 1.7 or more in stable flows, a mountain within 6 km upstream of the weather station must rise at least 600 m above the station.

1. Introduction

In this study, data from selected automatic weather stations in Southwest-Iceland (marked in fig. 1) is used to investigate gust factors. The gust factors are calculated and compared to the stability of the airmass, wind speed and the topography surrounding the station. For more detailed information on the study than is given here, a paper is available on the web at http://www.vedur.is/∼haraldur/artikel.pdf.

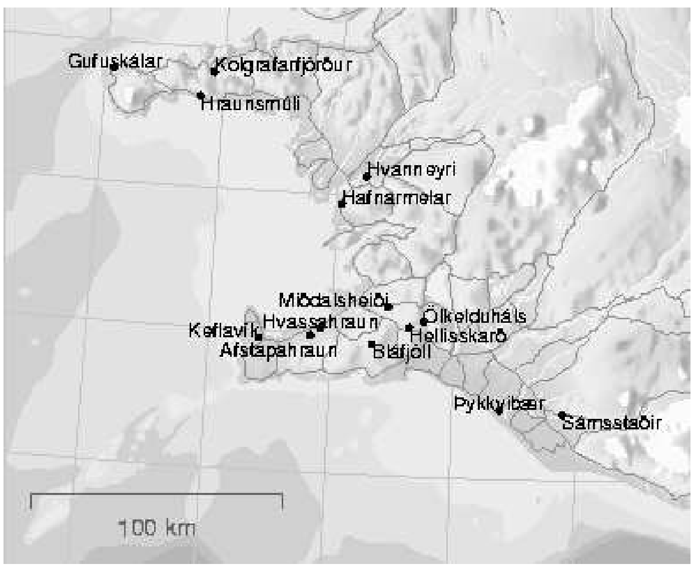

Figure 1: *Weather stations used in the study.*

2. Data

The wind data used in the study was collected from 13 automatic weather stations, shown in figure 1. The 10 min mean wind speed, f, maximum 3 second gust, f_g, and wind direction, d, were collected from the years 1999, 2000 and 2001. In order to limit the volume of data, only observations with $f > 10$ m/s were considered.

Radiosoundings from the Keflavík (WMO 4018) upper-air station are used to determine the stability of the airmass, but they are considered to represent well the stability of the airmass over Southwest-Iceland. Apart from the study of the connection between atmospheric static stability and the gust factors, unstable and near neutral situations are not considered in this study.

With help of topographic maps and photographs, the directions, d_m, to nearby hills and mountains were found. The height of the mountains above the weather station, H, and the distance, D, to the mountains are also determined for each station for mountains up to 20 km away from the station.

3. Calculation of Gust Factors

The gust factor G is defined as $G = f_g/f$. For all the stations, the average gust factor G_{avg} was calculated using all wind speeds above 10 m/s. The gust factor G_f is calculated for 2.5 m/s intervals in wind speed. A gust factor G_d is also calculated for each wind direction with 10° intervals.

3.1 Gust Factors and Static Stability

Figure 2 shows the entire dataset plotted against the temperature difference between 850 hPa and 925 hPa as observed in Keflavík.The figure reveals very little dependence of the mean gust factor on static stability of the airmass, as it remains close to 1.4 for unstable as well as very stable air.

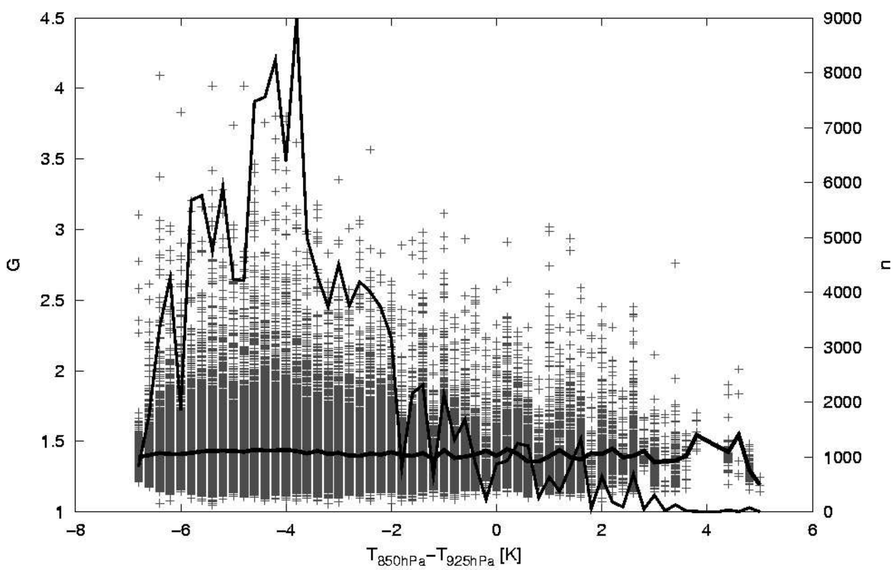

Figure 2: *Crosses show measurements of G, jagged line the number of measurements, n, and relatively horizontal line average G, all as a function of* $T_{850hPa} - T_{925hPa}$.

3.2 Gust Factors and Wind Speed

The gust factor G_f was plotted as a function of wind speed f, for all 13 stations (figure not shown here). For low and moderate wind speeds the gust factor decreased regularly with increasing wind speed. For every 5 m/s increase in mean wind speed, with f between 10 and 22 m/s, there was a reduction of about 0.03 in the gust factor. At higher wind speeds an irregular behaviour was observed that is presumably related to a limited amount of data.

3.3 Gust Factors and Surrounding Topography

The gust factor G_m is calculated for wind blowing from nearby mountains (direction d_m). It is assumed that for most of the data the wind direction at the weather station correctly indicates airflow coming off the mountain. Figures were made to investigate the behaviour of G_m as a function of mountain height, H, and distance to mountain from weather station, D.

Figure 3 shows two examples, with G_m as a function of D for 200 m < H < 600 m. Each dot on the graphs corresponds to wind coming from the direction of a certain mountain. The horizontal lines correspond to $G_m = 1.4$, but the straight, sloping, lines indicate best fit using the least squares method and serve only to highlight a possible trend in the data. Figure 3 shows that G_m increases as D decreases. Similar figures for

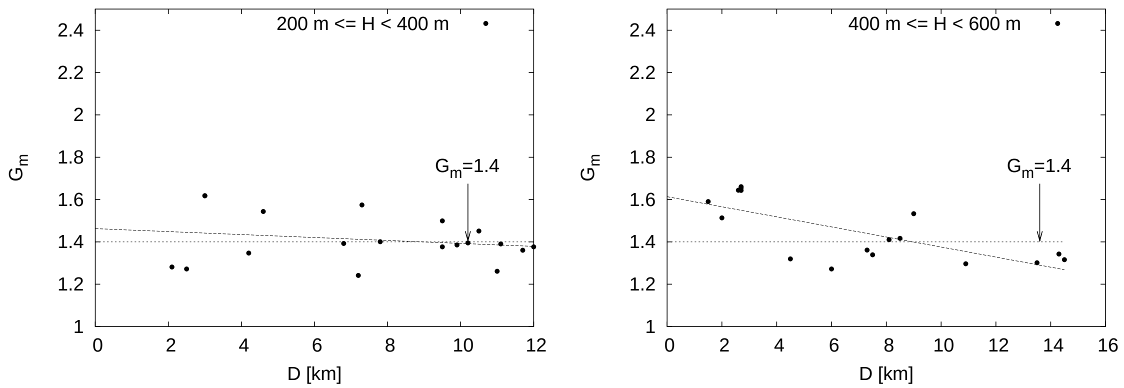

Figure 3: *G_m in the direction of mountains of height H and in the distance D.*

other mountain heights indicate that the average gust factor grows with the mountain height and the influence of the mountains extends further away as the mountains get higher. Figure 4 is similar to figure 3, except D and H have been interchanged.

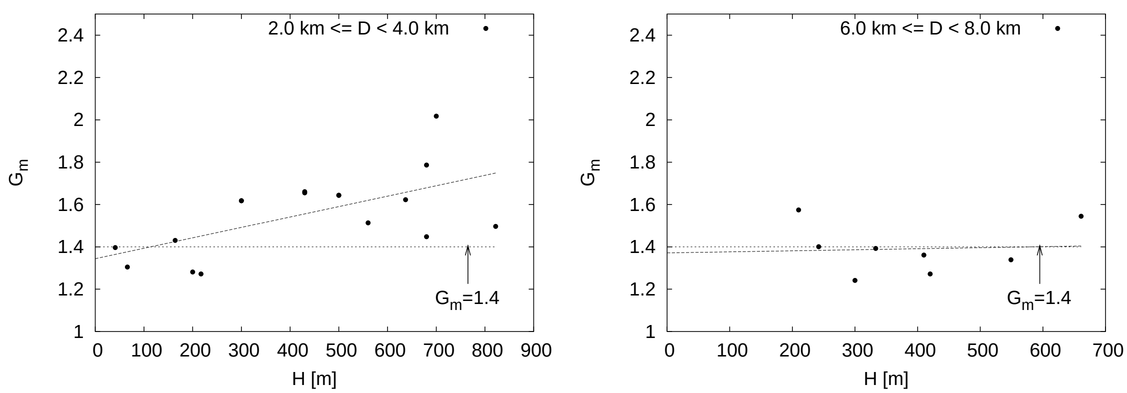

Figure 4: *G_m in the direction of mountains of height H and in the distance D.*

A closer look at figures similar to figures 3 and 4 leads to the suggestion that to influence the flow at a distance of approximately 6 km, a mountain needs to be at least 600 m high. For smaller distances lower mountains appear to be able to have strong effect on the gust factor, but mountains lower than 200 metres do however only have a minimal effect on the gust factor.

An attempt to summarize the effect of topography is made in fig. 5 where the gust factors are plotted against distance from mountain and mountain height. Not unexpectedly, gust factors greater than 1.7 are only found in the upper left corner of the graph. All have a mountain of at least 600 m height within a distance of less than 6 km. Lower gust factors scatter all over the figure, but there is a trend towards higher density of low-G at the lower end of the figure.

4. Summary and Conclusions

A large collection of data from automatic weather stations has been analyzed in an attempt to investigate gust factors and parameters influencing the gust factors. Only data with mean wind speed greater than 10 m/s has been considered in this study.

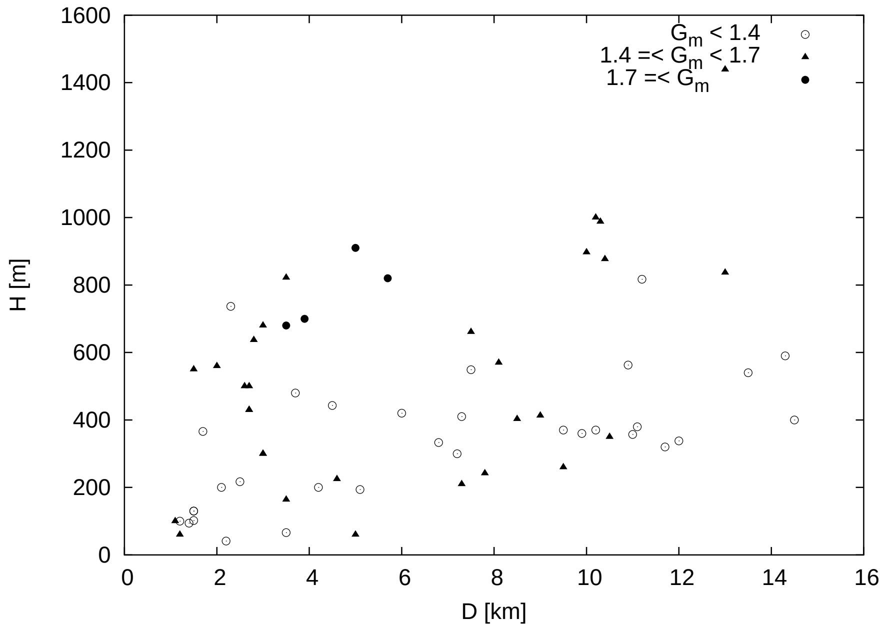

Figure 5: *Three series of G_m, plotted with H as a function of D.*

The average gust factor in the dataset is close to 1.4, and appears to be quite independent of atmospheric stability. The explanation of the gusts at different ends of the stability curve may however be quite different. In unstable air, turbulent eddies can give strong gusts, while in a stable airmass there is less turbulence, except where the airflow interacts with topography. In such a case, strong gusts can be produced, in particular downstream of the mountains. The data in this study suggests that the gust-producing effect of topography may compensate for damping of gusts by static stability.

An attempt has been made to create a parameter space for stably stratified flows where mountain height and distance from the weather station are key parameters. To have a gust factor of 1.7 in this space, the data indicates that mountains must in general reach at least 600 m above the weather station and not be further away than approximately 6 km from the station.

Finally, the data indicates a regular decrease in the gust factor for increased wind speed. The reduction of gust factor in stable flows is about 0.03 for every 5 m/s increase in 10 min mean wind speed for the wind speed range between 10 and 22 m/s.