Precipitation across a mesoscale mountain ridge - The Reykjanes Experiment (REX)

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ABSTRACT

A dense network of raingauges is operated across a 700 m high mountain ridge in SW-Iceland in the autumn of 2002. The mountain ridge is oriented perpendicular to the main wind direction during precipitation. The maximum precipitation is found immediately in the lee of the mountain crest and it amounts to about 350% of the precipitation in the lowlands upstream of the mountains and 600% of the precipitation in the lowlands in the lee of the mountains. The stronger the winds are, the more difference there is between precipitation in the mountains and on the lowlands. This is particularly clear for the upstream side.

1. Introduction

Precipitation is known to be up to several times greater in mountains than on nearby flat land. A key factor in increasing the precipitation in mountains is undoubtedly linked to the forced ascent of the airmass as the horizontal wind impinges the mountains. Other processes such as differential heating leading to local enhancement of convection and local ascent in gravity waves may also be of importance.

The main purpose of the Reykjanes Experiment (REX) is to investigate and explain the precipitation pattern in the mountainous Reykjanes peninsula, SW-Iceland. In order to do this, the precipitation has been measured at several locations during a period of about 5 weeks in the autumn of 2002. The Reykjanes mountain range is about 700 m high, 10 km wide and the observation network of 17 gauges extends about 30 km from the south coast to the north coast of the peninsula (Fig. 1). The precipitation was observed as soon as possible after each precipitation event in order to investigate the variability of the precipitation gradients and how the precipitation pattern is linked to the synoptic weather conditions.

Spatial distribution of precipitation in complex terrain can be even more complex than the terrain itself. It is inevitably dependent upon the nature of the precipitating systems whose characteristics vary from one place to another. All mountains are also unique, and consequently, it is difficult to apply results obtained in one place to another. However, the relatively uniform structure of the Reykjanes mountain ridge and the fact that it runs perpendicular to the main wind direction during precipitation, add a general value to the results of this study

2. The precipitation observations

The precipitation observations took place from 7 September to 16 October 2002. The precipitation gauges were located approximately 20 cm above the ground and the precipitation during this period was almost exclusively liquid. There are consequently relatively small errors due to wind loss. The precipitation was measured manually during periods between precipitation events. The 5 week observation period consisted of 6 cases or events that have been analyzed individually. Automatic wind observations in Bláfjöll are used as a proxy for the wind in the region.

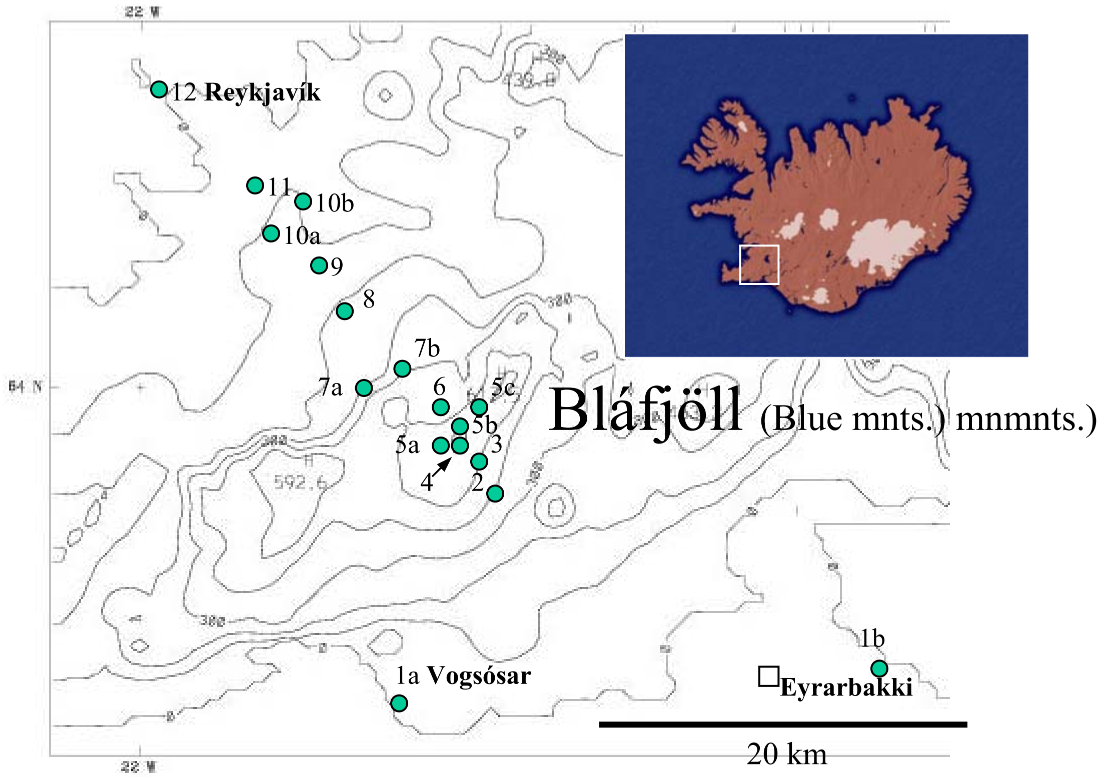

Figure 1. The observation network in the Reykjanes experiment (REX), SW-Iceland. The terrain is with 100 m intervals.

3. Observational results

The total observed precipitation at all of the stations is shown in Fig. 2. The total precipitation at the mountain stations (no.2-6) is typically 700-800 mm with a maximum of about 850 mm. The corresponding values are about 260 mm at the south coast and about 140 mm at the north coast (Reykjavik). The maximum is observed immediately in the lee of the highest part of the mountain range, but there are relatively small differences between the stations close to the highest part of the mountain range. There is a local minimum at the very top of the mountains (no. 4), but that is presumably related to wind loss. The steepest gradient in the precipitation is at a distance of 2-7 km downstream of the mountains. Figure 3 shows the proportion of precipitation in the mountains to precipitation in the lowlands at different wind speeds. It is evident that the stronger the wind is, the greater is the precipitation gradient on the upstream side of the mountains. The data also indicates a similar gradient in the lee, but the results are not as clear on this. The number of cases is too small for solid statistical analysis, but the slope of a best-fit regression for the upstream cases suggests that for an increase in wind speed from 6 to 12 m/s the precipitation in the mountains may increase from about 200% to about 500% of the lowland values.

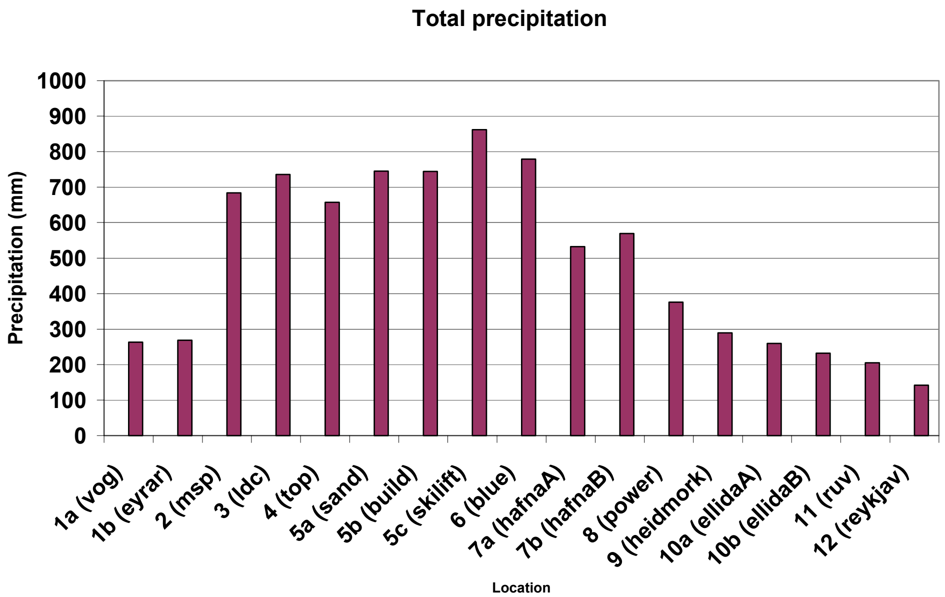

Figure 2. Total observed precipitation in the Reykjanes Experiment from 7 September – 16 October 2002.

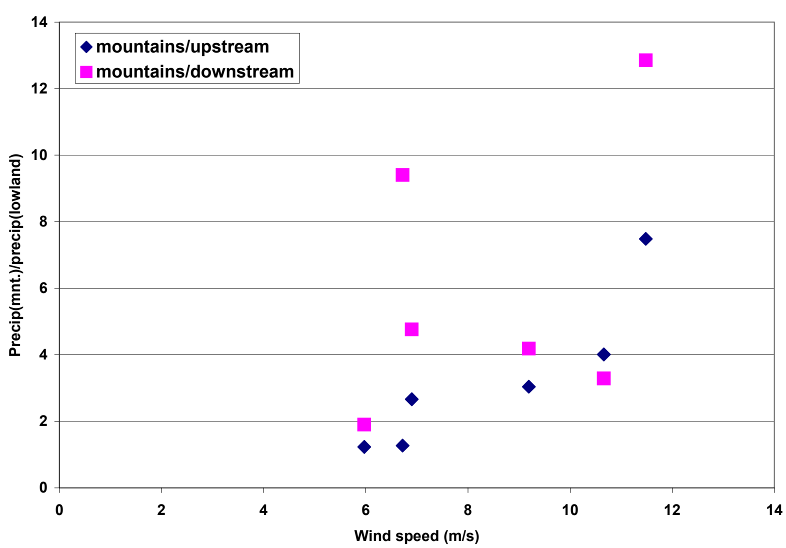

Figure 3. Ratio of precipitation in the mountains and precipitation in the lowlands for different wind speeds. The precipitation ratio is defined as the average of 4 stations giving most precipitation in the mountains divided by a) the two stations 1a and 1b upstream of the mountains and b) the two stations furthest downstream of the mountains (11 and 12). The wind speed is the average wind speed as observed in Bláfjöll during precipitation.

5. Discussion

In this study we find the mean precipitation to be 6 times greater in the Reykjanes mountains than in Reykjavik, some 20 km downstream. A large precipitation gradient in this region is certainly not a surprise and for the area close to Reykjavik it corresponds well with previous observations, indicating that the mean precipitation in Heiðmörk (no.9) is about 100% greater than in the central part of Reykjavík (Sigurðsson, 1964). The relatively high precipitation values observed in the mountains are however greater than expected. The corresponding factor between the precipitation in the mountains and at the south coast is 3-4, which is also a little more than expected (Einarsson, 1976). The data indicates that strong precipitation gradient on the upstream side is associated with strong winds. This is undoubtedly related to greater vertical velocity upstream of the mountains and more advection of moist air. The corresponding signal for the downstream precipitation is not as clear, suggesting that greater spillover may to some extent compensate for more precipitation production in the mountains than over the downstream lowland.

During a large part of the year, mean wind speeds during precipitation are greater than in this experiment. The observed sensitivity of the precipitation gradient to the wind speed suggests that the difference between precipitation in the mountains and at the upstream coast may be even greater than observed here.

One of the reasons why little is, so far, known about precipitation in the Reykjanes mountains is that there is practically no runoff on the surface of the earth. Significant fluctuations of groundwater have been observed, but they have been attributed to changes in waterways below the surface of the earth. The sensitivity of the precipitation gradient to wind speed study suggests that when investigating the role of precipitation in the groundwater budget, the precipitation observed at the coast may not be a sufficient indicator for precipitation in the entire catchment and that variations in wind speed should be considered as well.

The data presented here will be used for validation of high-resolution numerical simulations of precipitation.

Acknowledgments

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