THE IMPACT OF MOUNTAINS ON THE PRECIPITATION CLIMATE OF ICELAND

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Abstract: Flow over a flat Iceland has been simulated with the MM5 numerical model for one water-year and the results are compared to a simulation with true orography. Overall, the mountains contribute to about 40% increase in precipitation in Iceland. The mountains lead to dryness at low elevations in the north of Iceland. A precipitation shadow to the north of Iceland extends as far as the simulation domain and this is also the case with an area of increased precipitation to the south of Iceland. There is a temporal variability in the total orographic enhancement of precipitation in Iceland which can be related to atmospheric flow patterns.

Keywords: *precipitation, mountains, orography, climate, Iceland, orographic enhancement*

1. INTRODUCTION

In the windy climate of Iceland, vertical motions in the vicinity of mountains are strong and mountains have a large impact on the spatial distribution of precipitation on short as well as long time scales. This can be seen for instance in Rögnvaldsson et al., (2004, 2007). So far, a direct comparison between precipitation over Iceland and the surrounding waters with mountains present and with no mountains has not been carried out, apart from a test in Rögnvaldsson et al., (2007), which is presented in this paper together with a preliminary flow analysis. Simulations of precipitation over Iceland have been thoroughly validated in the papers mentioned above, inviting to simple comparison between precipitation with the mountains being present and precipitation without the mountains. Here, a one-year simulation with a flat Iceland is presented and the results are compared to a reference simulation with the mountains present.

2. NUMERICAL SIMULATIONS

The water year 2001-2002 has been simulated with and without the mountains of Iceland with the primitive equation numerical model MM5 (Grell et al., 1994). The horizontal resolution is 8 km and there are 23 vertical levels. The simulations are forced with boundary values from the ECMWF. Further details on the numerical setup and the simulations can be found in Rögnvaldsson et al., (2007).

3. RESULTS

Figure 1(a) shows the precipitation of the reference simulation (control). The 12-months precipitation ranges from being less than 1000 mm in the lowlands in N-Iceland to almost 8000 mm in the mountains in S-Iceland. Accumulated precipitation during the same period simulated with no mountains is shown in Fig. 1(b). There is a large-scale precipitation gradient from the southeast to the northwest. Some local maxima are located along the coast in the southeast and in the northeast of Iceland. The difference between precipitation with the mountains present and precipitation over flat Iceland (Fig. 1(a) minus Fig. 1(b)) is presented in Fig. 2 and this difference, normalized with the reference precipitation in Fig. 1(a), is shown in Fig. 3. It is clear from Figs. 2 and 3 that low-level inland areas in the northern part of Iceland, and also to some extent areas in the west, receive a net reduction in precipitation because of the mountains, while the lowlands in the southwest receive a moderate increase because of the mountains. As expected, mountainous regions receive a substantial increase in precipitation when the mountains are present. The impact of the mountains appears to extend far offshore. There is a precipitation shadow as far as the domain extends to the north and more than a 20% increase in precipitation because of the mountains as far as the domain extends in the south. Figure 4 shows the seasonal variability in the impact of the mountains on the average accumulated monthly precipitation over the whole of Iceland. The simulation with mountains gives on the average 40% greater precipitation than the simulation with flat Iceland. Overall, the difference is greater in the winter than in the summer, but there is a substantial variability from one month to another.

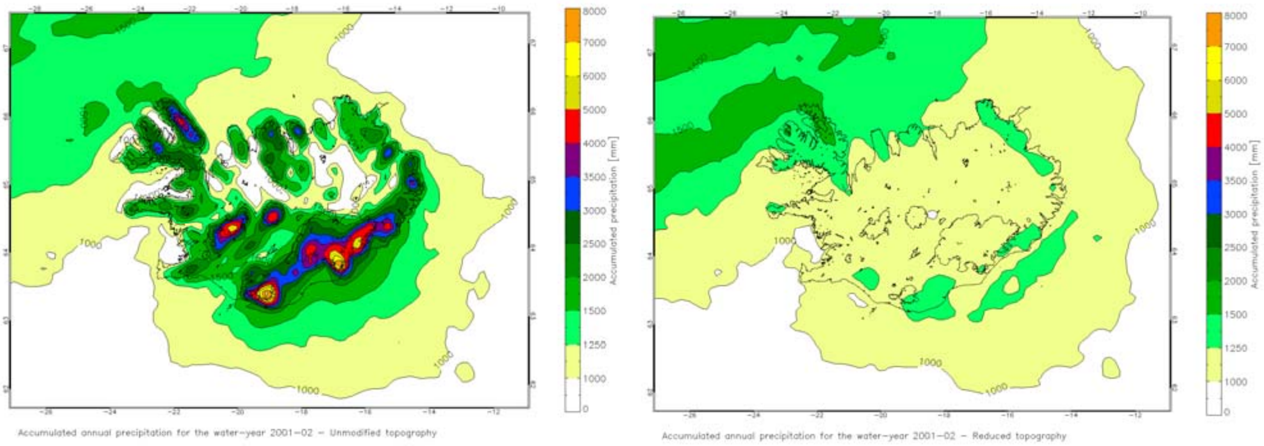

Figure 1: Simulated precipitation [mm] for 1 September 2001 to 31 August 2002. Left (a): With the mountains present. Right (b): With a flat Iceland (topography = 1 m)

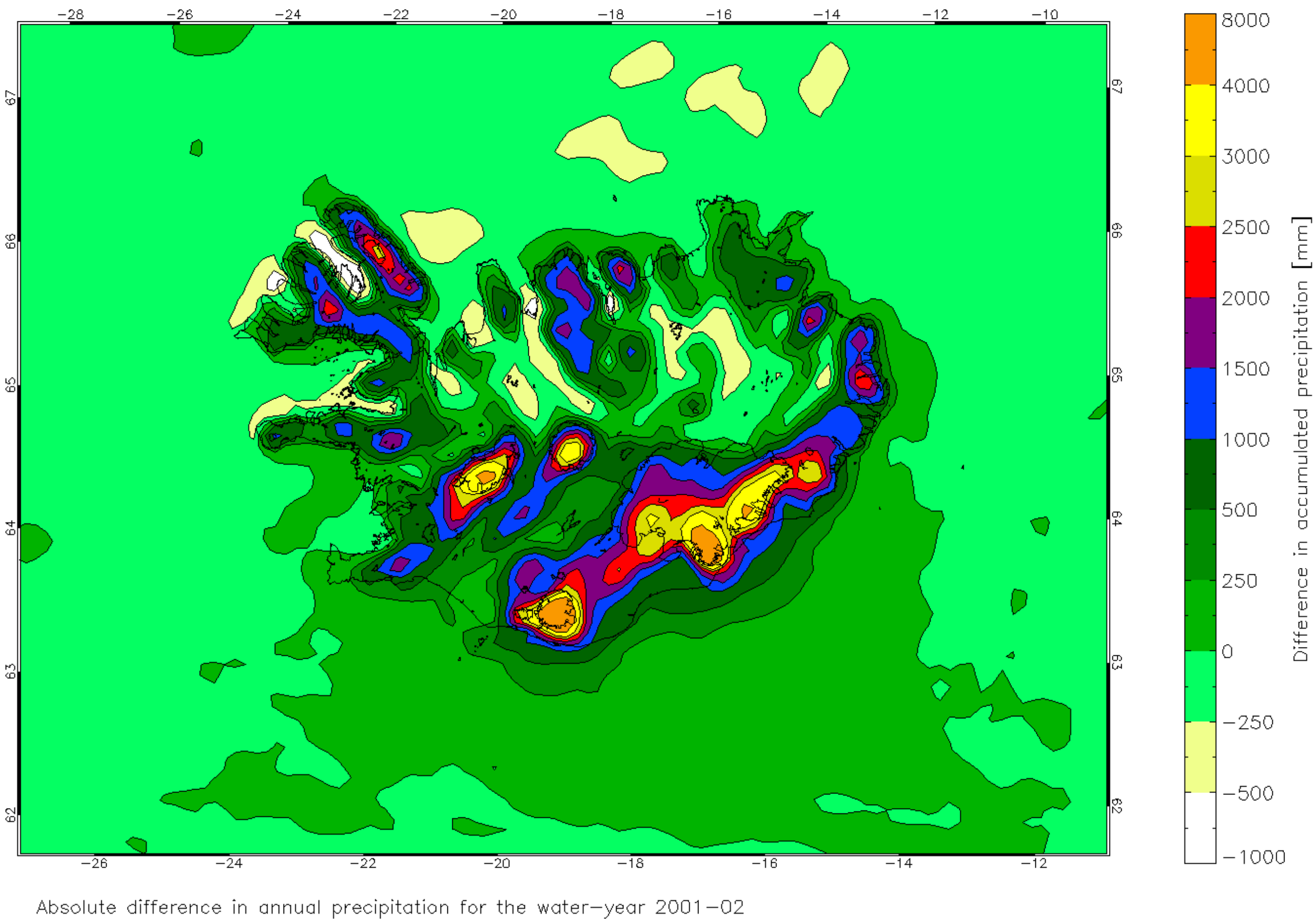

Figure 2: Figure 1(a) minus Figure 1(b).

4. DISCUSSION

The one-year pattern in Fig. 1 resembles the 15 year mean in Rögnvaldsson et al., (2007). We therefore consider the results of the experiment to give a reasonably good picture of the impact of the mountains on precipitation in Iceland, even though only one year has been simulated. However, there is considerable

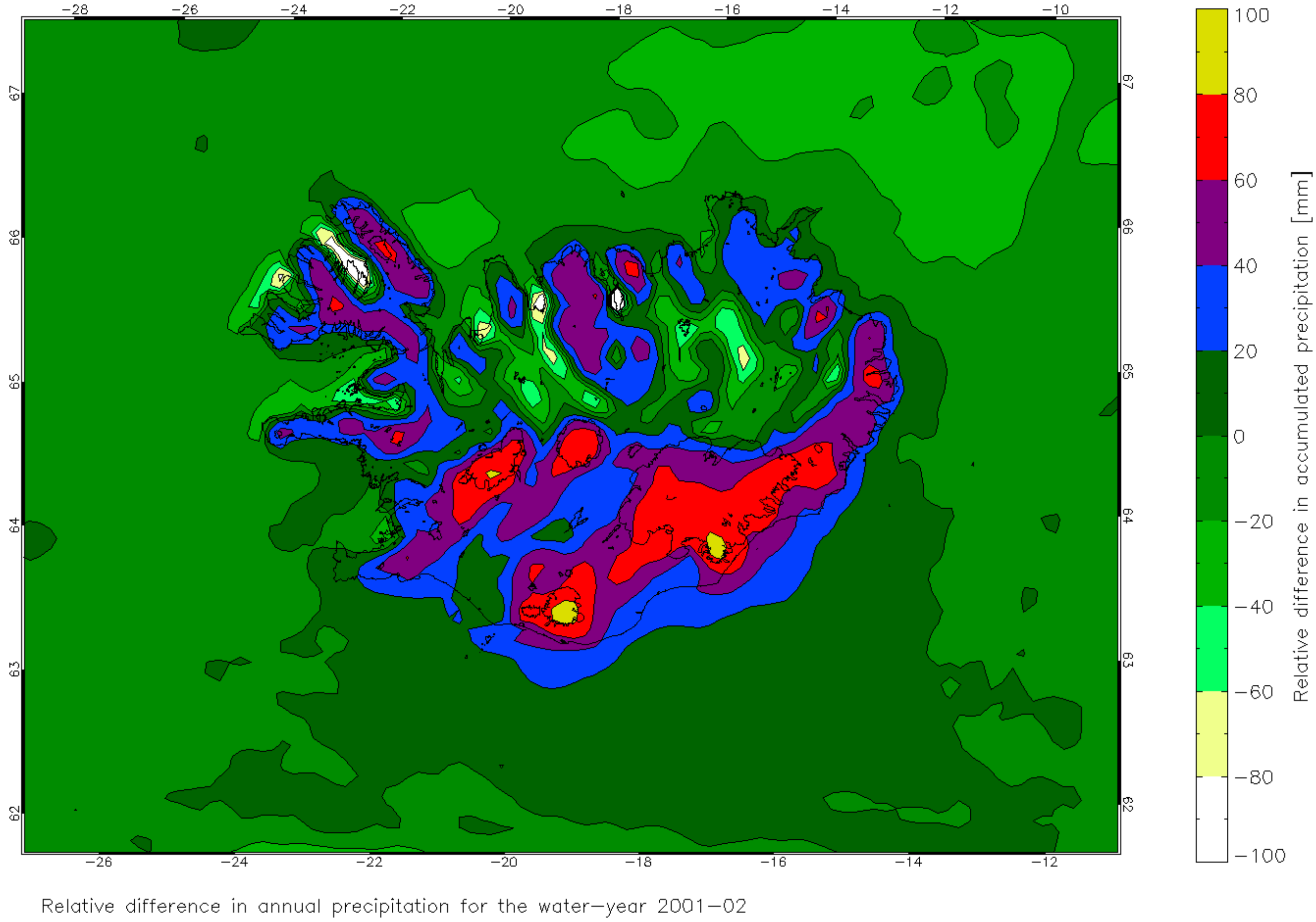

Figure 3: Figure 2 normalized with Figure 1(a) ([control-flat]/control).

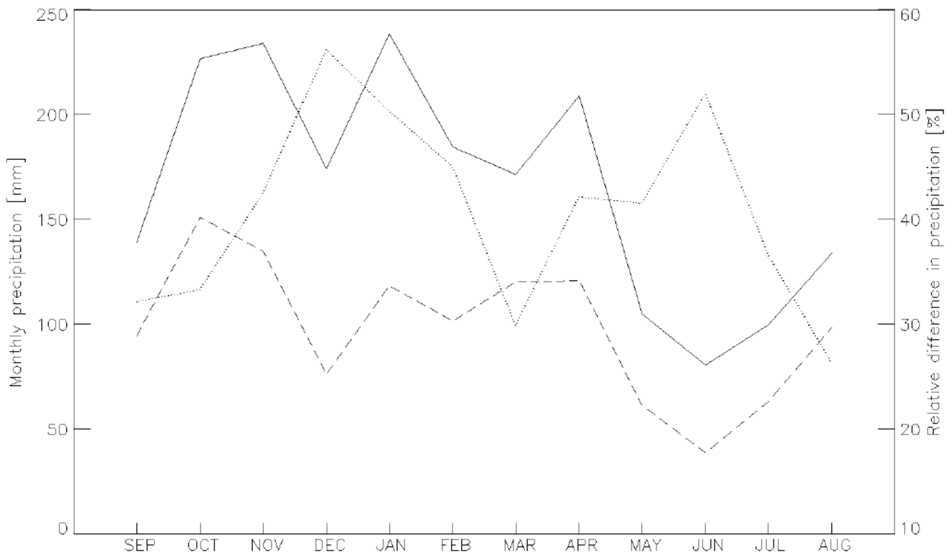

Figure 4: Accumulated mean monthly precipitation over the whole of Iceland simulated in the control simulation as in Fig. 1 (solid line). The dashed line shows the corresponding value for a flat Iceland (Fig. 1(b)) and the dotted line shows the relative difference as defined in Fig. 3 ([control-flat]/control).

variability in the orographic enhancement on the monthly scale. This variability is most likely related to the variability in frequency of weather patterns. To shed some light on this we may compare the mean surface pressure in September 2001 and in December 2001 (Fig. 5). September with mean southeasterly geostrophic winds has much less orographic enhancement of precipitation than December which has mean flow from the southwest . This is presumably related to the precipitation shadow from the high mountains in the southeast extending towards northwest over a much greater land areas in the southeasterly flow than if the flow is predominantly from the southwest as in December.

The results on the dryness in inland areas in N-Iceland confirm the general view of the climate of Iceland and the role of mountains in keeping the north dry. This has however not been confirmed before, partly because of difficulties in estimating true precipitation quantities when a large part of the precipitation falls as snow in strong winds.

Finally, the orographic enhancement in the south and the shadow effect in the north do both extend very far away from the mountains. The limits of this impact coincide in fact with the limits of the model domain and consequently, the true impact may reach even further than we see here.

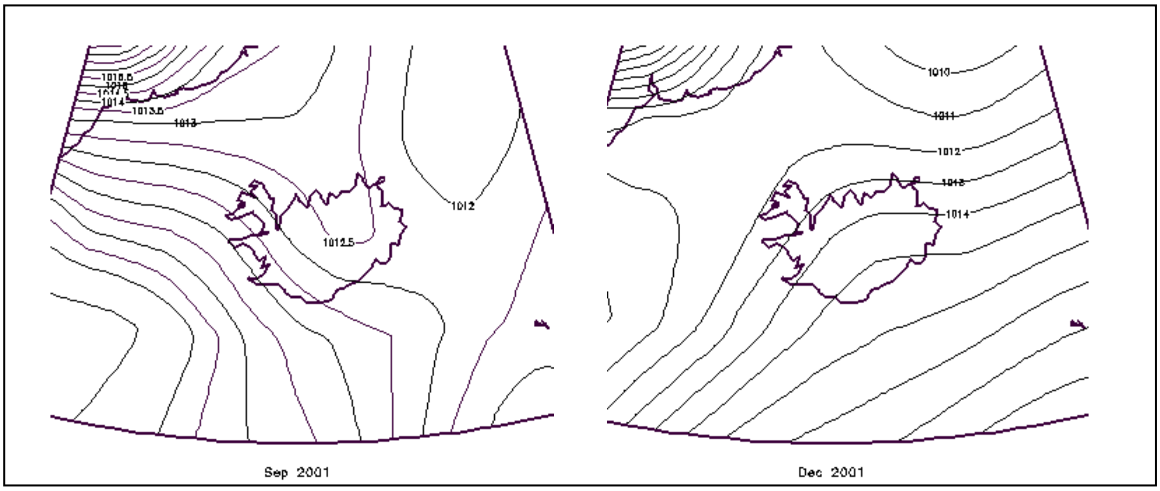

Figure 5: Mean sea level pressure in September 2001 and in December 2001 (1 hPa intervals). Retrieved from NOAA/ESRL.

5. FUTURE WORK

The results presented here and in Rögnvaldsson et al., (2007) call for a further study of the role of mountains in determining the precipitation pattern in Iceland and in other mountainous regions in the world on even finer scales. In this context it is of interest to investigate the variability of the mountain impact on precipitation in different weather patterns in past and future climate.

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