MODELING PRECIPITATION OVER COMPLEX TERRAIN IN ICELAND

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ABSTRACT

An orographic precipitation model has been used to estimate the spatial distribution of precipitation in Iceland with a horizontal resolution of 1 km and time scales ranging from a day over the period 1958 to 2006. This model combines airflow dynamics with a simple parameterization of cloud physics (cloud water formation time, hydrometeor fallout time, condensed water advection and lee-side evaporation). The model is forced with large-scale atmospheric variables taken from the European Centre for Medium Range Weather Forecast (ECMWF) (Re-)analysis and the model parameters have been optimized using rain-gauge and glaciological data. The results suggest that the model behaves reasonably well in the complex terrain of Iceland and offers a suitable solution for providing detailed estimates of precipitation for various purposes ranging from hydrological and glaciological applications to climatology.

INTRODUCTION

Estimating the spatial distribution of precipitation in complex terrain remains a challenging problem. Traditional approaches based on a geo-statistical description of the spatial variability of precipitation are difficult to apply in Iceland because rain-gauge observations are sparse and affected by wind-induced undercatch. An alternative approach based on the linear model of orographic precipitation (LT-model) proposed by Smith and Barstad (2004) has been selected. This model includes crude representations of the main physical processes involved in orographic generation of precipitation, namely airflow dynamics and cloud physics. The LT-model is forced with large-scale temperature, wind and precipitation data obtained from the ECMWF (Re-)analysis, following a methodology defined in Crochet et al.

(2007) and further improved in Jóhannesson et al. (2007). The resulting 6-hourly precipitation estimates are then accumulated over a day or longer. The parameters of the LT-model were optimized over the period 1995-2000 using precipitation observations from a rain-gauge network and precipitation derived from mass-balance measurements made on 3 large ice caps. These parameters were then kept constant over the entire simulation period. Daily, monthly, annual and 30-year averaged gridded precipitation datasets have been produced with a horizontal resolution of 1 km over the period 1958-2006.

CASE STUDIES

As an example, Figure 1 shows the simulated precipitation field on 27 March 1994 when the main wind direction in Iceland was from the SE. Orographic enhancement of precipitation on the windward side of mountains and a precipitation shadow or dry areas on the lee side of mountains are clearly visible. The wet and dry areas are rather well detected despite the complexity of the precipitation pattern, especially in the northern part of Iceland. The comparison between simulated precipitation and wind-corrected rain-gauge observations is presented in Figure 2. Precipitation is systematically slightly overestimated for this day at most locations, and at a few locations where no precipitation is observed, rather large amounts are simulated, revealing the difficulty to delineate accurately the wet and dry areas in complex terrain.

Figure 3 shows simulated precipitation on 21 March 1998 when the main wind direction in Iceland was from the SW. The wet and dry areas are rather well detected but a lack of lee-drying is observed in a region located north of the Vatnajökull ice cap in SE Iceland. The comparison between simulated precipitation and rain-gauge observations is presented in Figure 4. Precipitation is rather well simulated for this day, but the largest amounts are underestimated.

A detailed verification of simulated daily precipitation fields over a 10-year period reveals that the model estimates agree quite well with observations in a large number of cases, but systematic over- and/or underestimation of precipitation may occur due to model shortcomings and to some aspects of the practical model implementation. Inconsistencies between the time windows of the large-scale forcing and the precipitation measurements have also an impact on the quality of the comparisons.

When precipitation is accumulated over a month or longer, the results indicate good model performances most of the time against both rain-gauge observations located in lowland areas and precipitation derived from mass-balance measurements on 3 large ice caps. As an example, Figure 5 presents a comparison between simulated and observed precipitation on the Hofsjökull ice cap, central Iceland, for the winter 2000-2001.

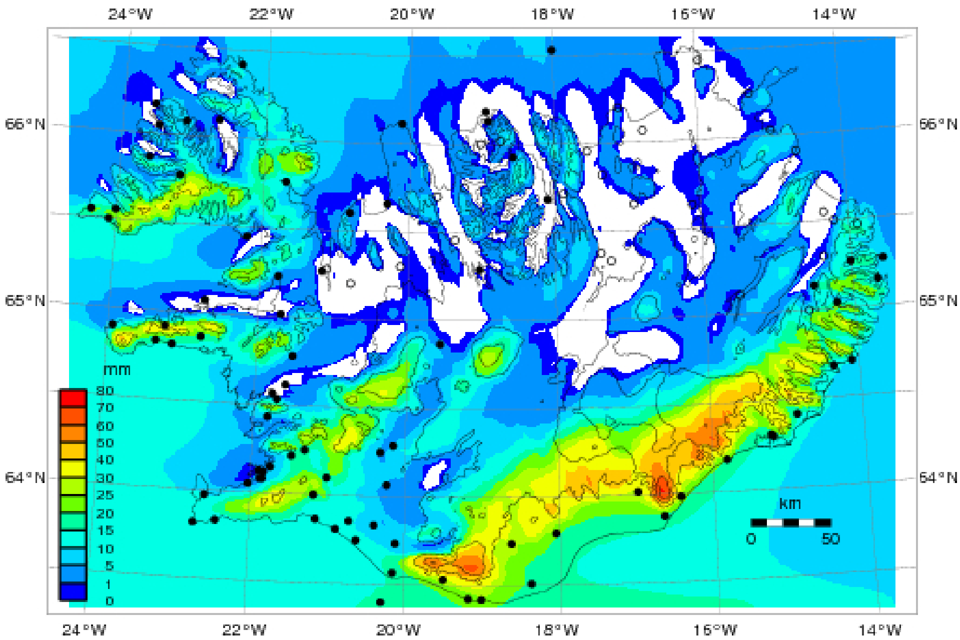

Figure 1. Simulated daily precipitation on 27 March 1994, when the main wind direction in Iceland was from the SE. Filled (open) symbols denote rain-gauge stations where precipitation was observed (not observed).

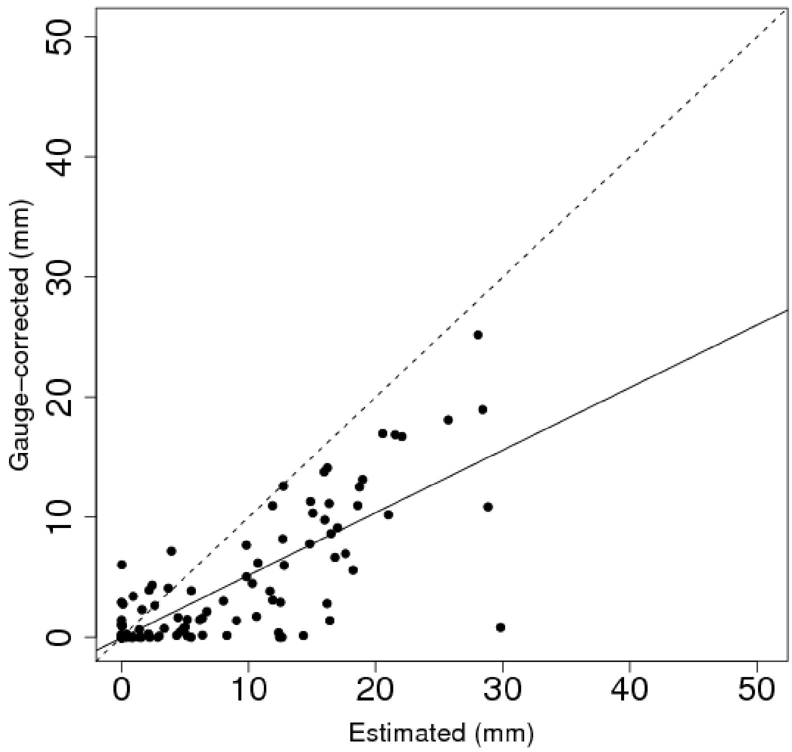

Figure 2. Estimated precipitation versus observed precipitation for 27 March 1994. The solid (dashed) lines are the regression (1:1) lines.

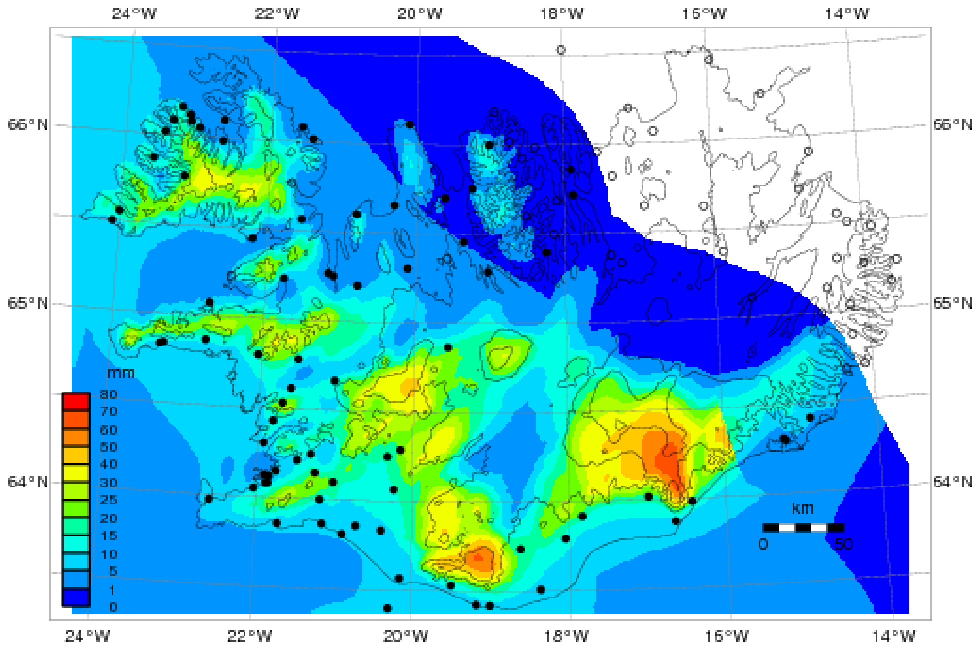

Figure 3. Simulated daily precipitation on 21 March 1998, when the main wind direction in Iceland was from the SW. Filled (open) symbols denote rain-gauge stations where precipitation was observed (not observed).

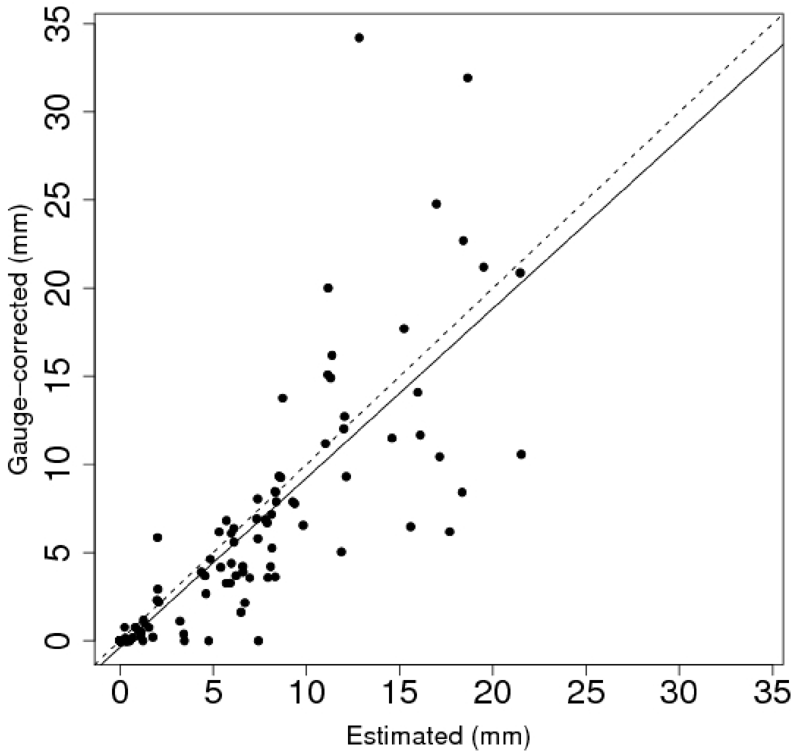

Figure 4. Estimated precipitation versus observed precipitation for 21 March 1998. The solid (dashed) lines are the regression (1:1) lines.

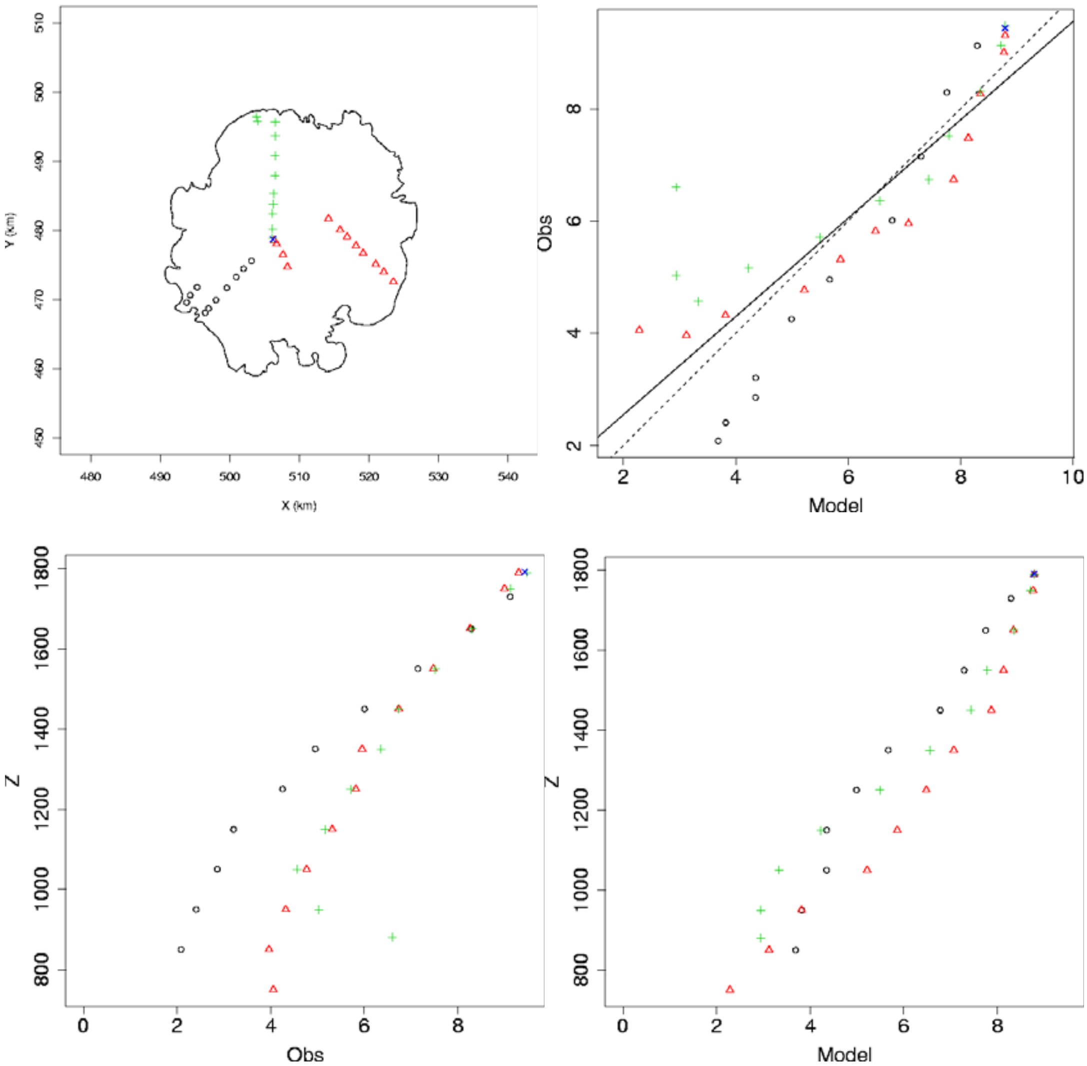

Figure 5. Precipitation on Hofsjökull ice cap from October 2000 to April 2001. Top left: snow-stakes location. Top right: averaged observed precipitation versus simulated precipitation (mm/day). The solid (dashed) lines are the 1:1 (regression) lines. Bottom left: stake elevation (m.a.s.l) versus averaged observed precipitation (mm/day). Bottom right: stake elevation (m.a.s.l) versus averaged simulated precipitation (mm/day).

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