ERROR ANALYSIS IN DYNAMIC DOWNSCALING OF PRECIPITATION IN THE COMPLEX TERRAIN OF ICELAND

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Abstract: The analysis of the ECMWF for 15 years has been downscaled over Iceland with the numerical model MM5 run at a horizontal resolution of 8 km. A systematic comparison with observed precipitation has been carried out. Undercatchment of solid precipitation in the cold and windy climate of Iceland is dealt with by looking only at days when precipitation is presumably liquid or by considering the occurrence and non-occurrence of precipitation. Away from non-resolved orography, the long term means (months, years) of observed and simulated precipitation are often in reasonable agreement. This is partly due to a compensation of the errors on a shorter timescale (days). The proportion of precipitation falling in events of little precipitation is systematically underestimated at many stations, but there is no clear connection between the wind speed and model error and temperature and model errors, for temperatures above 2°C. The simulations show better skill in SW-Iceland than in N-Iceland and modelled precipitation in N-Iceland is of a relatively poor quality in southerly (downstream) flow.

Keywords: precipitation, Iceland, mm5, dynamical downscaling, error analysis

1. INTRODUCTION

The 6-hourly analysis of the ECMWF (European Centre for Medium-Range Weather Forecasts) have been dynamically downscaled for a period of 15 years using the numerical model MM5 (Grell et al., 1994). The MRF boundary layer scheme was employed as well as the Reisner2 microphysical scheme. The horizontal resolution is 8 km and 23 sigma levels were used (Rögnvaldsson et al., 2004).

Climatological downscaling of precipitation is of use for hydrological purposes. The MM5 model, using a similar setup as described above, is in operational use in Iceland for production of short to medium range weather forecasts. Although a hydrologist and a weather forecaster would both like to be able to predict precipitation, their interests lie on different timescales.

The aim of this study is to evaluate the quality of the simulations by comparing them to measurements. This can be done by comparing long term means (months, years) of simulated and observed precipitation. Such a comparison would be of use to a hydrologist but of somewhat limited value for a forecaster. We therefore set out to making comparisons that would assess strong and weak points of the simulations to aid forecasters. We want to know how the errors in the simulated precipitation relate to other meteorological factors and if the performance depends on the temporal resolution of the data and geographical location. The work should shed a light on which aspects need improving. Increased understanding of the limitations of the simulations on a short timescale will also be beneficial for their use in hydrological purposes.

2. DATA

In the comparison the period 1987-2002 is used. There are just under 60 synoptic weather stations with useful amount of data in that period, see Fig. 1. Precipitation is measured twice per day on synoptic stations in Iceland, at 09 and 18 UTC. The MM5 output was saved every 6 hours, at 00, 06, 12 and 18. The shortest comparison period is therefore 24 hours (from 18 to 18). That period will from now on be referred to as an “event” in this paper.

The model output from a grid point can be considered as an area averaged precipitation on an area of 64 km². Therefore we do not expect the simulations to agree with measurements in areas with topography that is not resolved by the model.

When comparing simulated and observed precipitation we must also bear in mind the general problems of precipitation observations. The most significant of these is the large undercatchment of solid precipitation in...
Figure 1: A map of Iceland. The height above sea level in meters is denoted by the colours on the colourbar to the left. Each coloured circle corresponds to a synoptic weather station. Station names are included at the stations referred to in this paper. The colour of the circle denotes the relative error in the simulations (colourbar to the right) for the summer months June, July and August (JJA). The blue boxes enclose a few stations on flat land in S-Iceland where the observations and simulations are in reasonable agreement. The red boxes draw attention to stations in N-Iceland where the model overestimates precipitation, despite these stations being on flat land. Stations that have huge overestimation, which is almost certainly due to non-resolved orography, are enclosed in black boxes.

Figure 2: Left: Data from Bergstaðir, N-Iceland. The horizontal axis shows bins of 24 h mean temperature and on the vertical axis is the sum of precipitation [mm] in each bin (observed or simulated). Right: Data from Raufarhöfn, NE-Iceland. Horizontal axis shows bins of 24 hour mean wind speed [m/s]. The vertical axis shows precipitation sum in each bin as a percentage of the total observed or simulated precipitation.

Figure 3: Left: Data from Reykjavík, SW-Iceland. The horizontal axis shows bins of 24 hour accumulated precipitation [mm]. The vertical axis shows the accumulated precipitation in each bin as a percentage of the total observed or simulated precipitation. Right: Data from Stórhöfði, S-Iceland, accumulated 24 hour precipitation [mm] (observed and simulated) for November 1992. Blue colour denotes the amount of mm5 underestimation and red denotes the mm5 overestimation.
cold and windy climate, as in Iceland (Førland et al., 1996). This effect is visible in Fig. 2 (left). It shows data from Bergstaðir, N-Iceland (see its location in Fig. 1). In the figure every 24 hour event has been grouped into bins according to observed temperature and then the precipitation in each bin has been added up. A sharp increase can be seen in the discrepancy between the simulations and observations below the temperature which precipitation is expected to be solid. This kind of behaviour can be seen on the majority of the stations under study. The undercatchment problem has been dealt with by looking only at liquid precipitation (summer or temperature criteria) or by comparing the occurrence and non-occurrence of precipitation.

3. ERROR ANALYSIS

In Fig. 2 (right) we see the classification of observed and simulated precipitation by wind speed for station Raufarhöfn in NE-Iceland. We see that the model reproduces accumulated precipitation equally well for all wind speeds. This is true for most of the stations in the study.

Classification of observed and simulated precipitation by precipitation amounts can be seen in Fig. 3 (left, data from Reykjavík, SW-Iceland). A larger portion of the observed total precipitation falls in small events than for the simulations. A similar behaviour can be seen in many stations, i.e. the model underestimating the number of small precipitation events.

Figure 1 shows the relative error of the simulations, (mm5-obs)/obs, for the summer months, JJA. It can be seen that the model behaves differently in N- and S-Iceland for stations in flat land (minimal effect of non-resolved orography). For stations on flat land in the South, the simulations and observations are in an
overall reasonable agreement (see stations in blue boxes in Fig. 1). The model does however underestimate precipitation in flows from the SE (not shown). The model overestimates the precipitation for flat land stations in the North (red boxes in Fig. 1). This is particularly true in northerly flow. For stations situated in orography that is obviously not resolved by the model (black boxes in Fig. 1), the somewhat expected result of huge relative errors is clearly visible.

The 24 hour precipitation amounts (observed and simulated) for November 1992 at Stórhöfði, S-Iceland, is shown in Fig. 3 (right). The sums of observed and simulated precipitation for this month are almost identical. It is however clear that the agreement of the monthly sums is in large part due to compensation of the errors on a daily timescale.

4. OCCURRENCE AND NON-OCCURRENCE OF PRECIPITATION

We define a “false alarm” event as a period of 24 hours (18-18) where there is some precipitation in the simulations ($r_{mm5}>0.1$) but the observations are dry ($r_{obs}\leq0.1$). Figure 4 (left) shows the percentage of events that fall into the false alarm category on each of the stations during the winter months December, January and February (DJF). Comparison with maps from the other seasons (not shown) reveals that there is increased probability of false alarms in winter, most notably for inland areas in N-Iceland. In Fig. 4 (right) all false alarm events at Staðarhóll have been categorized according to wind direction. We see that most of the precipitation during false alarm events falls in southerly wind directions.

A “missing” event is defined as a 24 hour period where the simulations are dry ($r_{mm5}\leq0.1$) but the observations are wet ($r_{obs}>0.1$). Figure 5 (left) shows the percentage of missing events during the summer months (JJA) at each of the observation stations. There is higher probability of missing events during summer than in winter (map not shown). In Fig. 5 (right) the precipitation during missing events (only observed precipitation) at Staðarhóll has been grouped into bins of different wind direction and the precipitation in each bin added up. Again we see that southerly wind directions (lee side) are the main culprit.

5. SUMMARY

The numerical model MM5 run at a horizontal resolution of 8 km has been used to downscale over Iceland the 6-hourly analysis of the ECMWF for 15 years. A systematic comparison with observed precipitation has been presented and the main results are:

a) Simulated precipitation is usually greater than observed for $T < 2^\circ \text{C}$, where precipitation is normally solid. This is attributed to undercatchment.

b) The model reproduces accumulated precipitation equally well for all wind speeds.

c) The number of small events is underestimated in many places.

d) Away from non-resolved orography, long term (months, years) sums of simulated precipitation are quite correct in the south but too high in the north. This is partly due to compensating errors on a smaller time scale (days).

e) Probability of false alarms (model predicts precipitation, but none is observed) is highest in N-Iceland, particularly during winter.

f) Probability of missing precipitation events is highest in the summer inland and on the lee side of Iceland in southerly flows.

g) Precipitation is underestimated in SE flows in SW-Iceland but precipitation is overestimated in northerly flows in N-Iceland. This cannot only be explained by non-resolved orography.

REFERENCES

