PRECIPITATION DOWNSCALING ON THE WEST COAST OF NORWAY: COMPARISON WITH OBSERVATIONAL NETWORK

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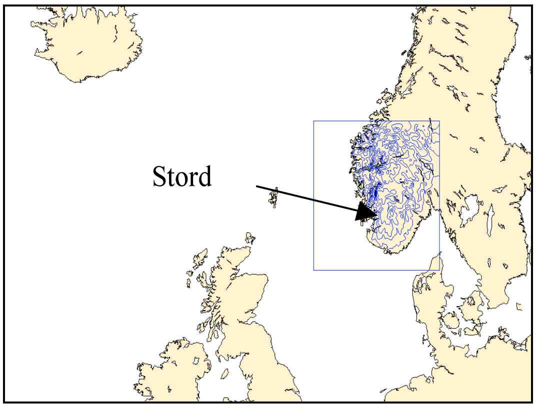
Abstract: High frequency observations from a field campaign have been compared with time-step precipitation in the WRF regional climate model. Two microphysical schemes of different levels of sophistication have been tested. Both of the schemes generally reproduce the observed precipitation, yet the produced level of wetness is somewhat high, and the intensities rather low. Typical simulated intensities are about 9mm/hr, as opposed to the observed values of approximately 15mm/hr. The simpler scheme performs better in complex terrain. Both schemes show limited skill on flat land.
Keywords: *WRF, mp-schemes, time-step precipitation, evaluation, STOPEX.*

1 INTRODUCTION

The WRF model offers a few different microphysical schemes, which differ by the level of sophistication and by their computational cost. In this extended abstract we will investigate the skill of performance between a simple and a more sophisticated microphysical scheme - towards the precipitation intensity on time scales comparable with the model time step. The skill will be measured against data from an observational network. We will further discuss the performance of these schemes in resolving the precipitation over mountainous terrain.

2 EXPERIMENTS AND RESULTS

The island of Stord was chosen as an experimental site for the STord Orographic Precipitation EXperiment (STOPEX 1; Reuder et al. (2007)). Stord is located on the south-west coast of Norway. It has mountains of about 600 m high and it is 20 km long and 10 km wide (see Figure 1 for geographical information). The prevailing winds in the area are southwesterly. During the autumn 2005 (7 weeks) numerous rain gauges were deployed across the island, and several automatic weather stations (AWS) surveyed the weather situation. The stations used in this study are shown in Figure 1.



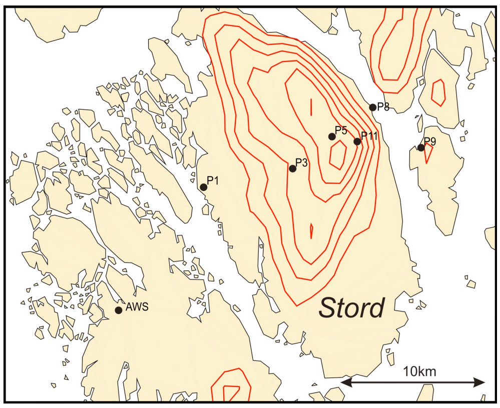


Figure 1. Left: The two nested model domains (10 km and 3.3 km). Right: The terrain (every 100 m starting at 100 m elevation) shown by 1 km grid spacing. Precipitation stations investigated in this study are shown.

WRF V3.0.1.1 was set up with two nested domains (10 km and 3.3 km) and the boundaries were orchestrated by the ECMWF-analysis. A standard set-up was used with 40 vertical layers. Two different microphysical schemes, "mp3" - a simple 3-class scheme (Hong et al. 2004), and "mp10" - a more sophisticated multi-class scheme (Morrison and Pinto, 2006) were tested. The more sophisticated scheme, "mp10", required approximately 30-40% more CPU time than the simpler scheme, "mp3". The model time-step used was 20 s in the higher resolution domain. A four-dimensional data assimilation (FDDA) nudging was used with 6-hour relaxation time outside of the planetary boundary layer.

Table 1 shows the performance of the two schemes for 6 stations across the island, from west to east. ‘Rain vs. no-rain’ cases are shown in % for various accumulation periods and the total accumulated precipitation for STOPEX 1 period is indicated. From the table, we find that the simulated 10-min cases are far too wet, particularly at the upwind flat land station (P1). The "mp3" simulation performs weakly compared with the "mp10" case. Longer accumulation periods camouflage this effect improving the results, which is in agreement with the findings of Barstad and Smith, (2005). The total accumulated precipitation amounts show a dry bias in simulated precipitation in elevated terrain, and a wet bias on flat land. The "mp3" simulation produces higher accumulated precipitation than "mp10" in all of the stations.

Station/measure	Wet (%) – 10min (mp3/mp10)	Wet (%)- 1hr (mp3/mp10)	Wet (%)- 3hr (mp3/mp10)	Wet (%) – 24hr (mp3/mp10)	Total accumulated (mm) (mp3/mp10/**obs**)
P1 upwind-flat land	525/443	283/252	200/189	122/122	787/729/**333**
P3 upwind-slope	360/311	215/200	156/150	115/113	927/766/**768**
P5 top	307/266	199/185	149/143	105/102	927/766/**1120**
P11 leeside-top	284/234	169/152	130/123	100/100	864/700/**1220**
P8 leeside-slope	357/286	224/199	170/161	116/116	856/676/**838**
P9 leeside-flat land	362/289	220/194	167/159	113/116	804/634/**640**

Table 1. Simulated precipitation across the Stord island in autumn 2005. Wet events (100% means as observed) for various accumulation periods (column 2-5) and total accumulated amounts during the campaign (last column). “mp3” and “mp10” refer to two different microphysical schemes used. Underlined value indicates the simulation with better skill.

In order to have a closer look at the intensities ‘hidden’ inside various accumulating periods (10 min, 1 hr, 3 hr and 24 hr), we take a look at the tipping bucket measurements and to the comparison with the model time-step precipitation. Figure 2 shows the typical time between each tip (0.2 mm amount) as observed and simulated. Neither one of the schemes is able to reproduce the highest intensities. The observed intensity is about 15 mm/hr whereas the simulated one is closer to 9 mm/hr. The "mp3" simulation, in particular, shows too many weak intensity cases (200 s - 400 s in Figure 2). This is in agreement with the general picture that the model is too wet (Table 1).

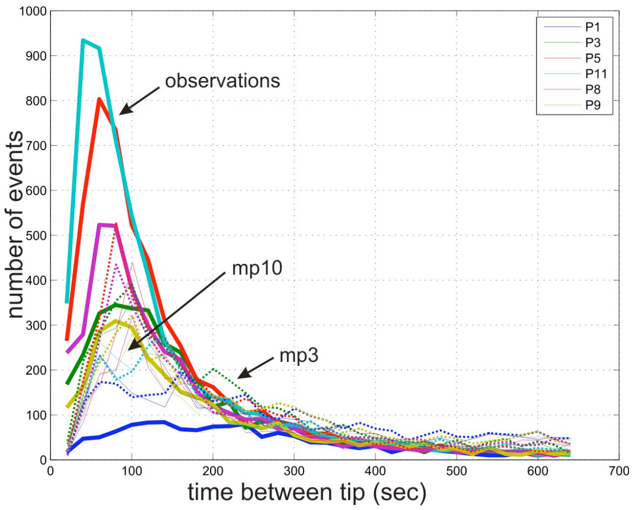


Figure 2. Tipping-bucket vs. modelled values for STOPEX 1. 6 stations are shown, cf. Table 1. Thick solid line represents the observations, dotted line the "mp3" simulation, and thin line the "mp10" simulation.

An important case is that of November 5th, 2006. The winds were steadily from the west throughout the day. Some of the rain gauges received as much as 100mm of precipitation. Simulation of this case with identical model set up as used in this report but including an additional nest of a grid spacing of 1.1 km shows that the maximum precipitation intensity in the 1.1 km grid was about 15-20% larger than in the 3.3 km grid. This indicates that the precipitation results in the 3.3 km grid should ideally be a bit lower than the observed values.

We then investigated the impact of the wind direction to the amount of precipitation and the skill of the two microphysical schemes. Figure 3 shows the accumulated precipitation across the Stord island for the prevailing southwesterly winds (direction 150°-270°) for both microphysical schemes. It shows that the "mp3" simulation is generally wetter across Stord than the "mp10" simulation during southwesterly wind conditions. This finding is in agreement with the accumulated precipitation averaged over all wind directions (Table 1).

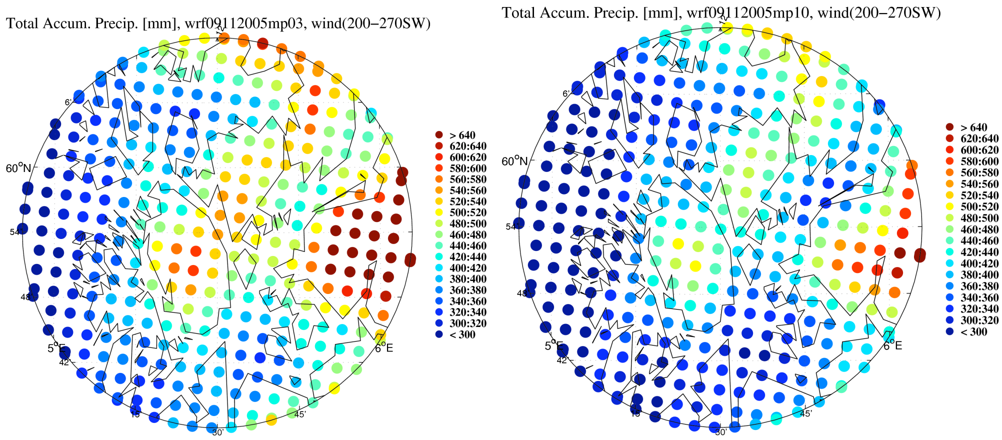


Figure 3. Total accumulated precipitation [mm] when the wind direction was between 200° and 270°. Plots are shown for the microphysical schemes "mp3" and "mp10".

Table 2 shows the accumulated precipitation at the investigated stations for the wind directions of 150°-200°, 200°-270° and 270°-300° separately. We see that the "mp10" simulation shows better skill at all stations for the wind directions from to 150°-200°. The schemes differ more for the wind direction of 200°-270°: the more sophisticated scheme "mp10" performs better on the slope and the lee side stations. Both schemes fail to reproduce enough precipitation on the top and leeside/top stations. In this case the "mp3" performs better because it is generally wetter. At the upwind ‘flat land’ station both schemes produce too much precipitation, the "mp10" showing the better skill - but still too high by several factors. In the case of wind direction of 270°-300° the precipitation is less orographic by nature but more convection is involved. The "mp3" scheme performs slightly better in these conditions.

Wind direction	150-200°	200-270°	270-300°	All directions
Station/measure	(mp3/mp10/**obs**)	(mp3/mp10/**obs**)	(mp3/mp10/**obs**)	(mp3/mp10/**obs**)
P1 upwind-flat land	124/<u>122</u>/**45**	501/<u>452</u>/**224**	<u>65</u>/80/**25**	787/<u>729</u>/**333**
P3 upwind-slope	190/<u>164</u>/**122**	581/<u>486</u>/**446**	66/<u>61</u>/**60**	927/<u>766</u>/**768**
P5 top	190/<u>164</u>/**161**	<u>581</u>/486/**692**	<u>66</u>/61/**95**	<u>927</u>/766/**1120**
P11 leeside-top	190/<u>155</u>/**166**	<u>531</u>/444/**783**	<u>65</u>/57/**106**	<u>864</u>/700/**1220**
P8 leeside-slope	169/<u>130</u>/**107**	<u>546</u>/437/**514**	<u>63</u>/57/**77**	<u>856</u>/676/**838**
P9 leeside-flat land	172/<u>139</u>/**90**	492/<u>406</u>/**385**	73/<u>48</u>/**59**	804/<u>634</u>/**640**

Table 2. Simulated precipitation across the Stord island (autumn 2005). Accumulated precipitation (mm) for various wind directions (columns 2-4) and total accumulated precipitation during the campaign (last column). "mp3" and "mp10" refer to the two different microphysical schemes used. Underlined value indicates the scheme with the better skill. The stations P3 and P5 are seen as the same grid point in WRF (Fig. 2).

3 CONCLUSIONS

This study shows that a simulation by a mesoscale model with a 3.3 km grid spacing still does not solve the standard problem for numerical models; it rains too often and too little. Of the two microphysical schemes used, the simpler one performs better than the sophisticated one in complex terrain in reproducing the precipitation intensity. On flat land the more sophisticated scheme is better but still both schemes are too wet. A case study (not shown) indicates that higher intensities (15-20% increase) can be expected if a 1.1 km grid is nested inside the 3.3 km grid. We also found differences in the schemes when comparing the accumulated precipitation from different wind directions. When winds were from the main direction (southwesterly) the more sophisticated scheme performs better, especially in complex terrain. The simpler scheme is generally wetter than the more sophisticated one. The model is not able to reproduce the highest level of precipitation in the mountain top stations. Because the "mp3" simulation generally produces more precipitation it performs better in these stations.

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