IMPACT OF THE SCANDINAVIAN MOUNTAINS ON A HIGH-IMPACT CYCLONE IN AUGUST 2003

Ragnhild Bieltvedt Skeie[1], Jón Egill Kristjánsson [1], Haraldur Ólafsson [2, 3]

[1] Department of Geosciences, University of Oslo, P.O.Box 1022 Blindern, N-0315 Oslo, Norway.
[2] Icelandic Meteorological Office, Bústadavegi 9, IS-150 Reykjavik, Iceland
[3] University of Iceland and Institute for Meteorological Research
E-mail: *r.b.skeie@geo.uio.no*

Abstract: In August 2003, Central Norway was hit by extreme precipitation. The cyclone that caused the precipitation has been simulated with a high-resolution model, and several sensitivity studies have been carried out. The simulations reveal that the release of latent heat had a major impact on the development of the cyclone. The cyclone occurred during a period of anomalously high sea surface temperatures (SST). Numerical tests show however that the development of the cyclone and the extreme precipitation are fairly insensitive to the SST. Removing the orography of Scandinavia leads to a deformation of the cyclone; when the orography is present a lee trough is formed over SE-Norway and the pressure gradient to the west of the low as it moves over SE-Norway is stronger than in the run with no mountains. The results will be helpful in analysing similar events in coarse-resolution climate simulations, where the mountains are poorly resolved.

Keywords – *Scandinavian mountains, extreme precipitation, orographic enhancement, lee trough*

1. INTRODUCTION

An intense cyclone over Scandinavia in August 2003 is investigated to determine atmospheric factors contributing to its development. The cyclone led to unusually heavy precipitation and flooding in central parts of Norway, near the city of Trondheim. Locally more than 100 mm of precipitation fell in a 24 hour period and more than 150 mm in 48 hours in areas where the average monthly precipitation for August is well below 100 mm. The estimated return period for such an event is more than 100 years, according to the Norwegian Meteorological Institute (http://met.no/aktuelt/nyhetsarkiv/2003/ekstrem_nedbor.html). As discussed by Einarsson et al. (2004), the event was rather well forecasted in the short range (1-2 days), while in the medium range the precipitation was greatly underestimated.

2. MODEL

The numerical model used in this study is the PSU/NCAR mesoscale model, MM5. The case is run with a 36 km horizontal grid resolution, 100 x 100 grid points in the horizontal and 23 sigma layers in the vertical. The model domain is centered at 58°N, 5°W. The following physical parameterization schemes were used: Grell cumulus parameterization scheme, MRF PBL scheme, "simple ice" explicit moisture scheme and "cloud radiation" scheme (MM5 User's Guide, 2003). The initial and boundary conditions are derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis, and the lateral boundary conditions are changed every 6 hours. The model is run for 72 hours starting at 13 August 00 UTC.

3. SIMULATIONS

In addition to a control run (CONTROL), the following sensitivity experiments have been conducted: a run without latent heat release (NOLAT), a simulation without the Scandinavian mountains (NOSCAN), a run with reduced sea surface temperature (RED-SST) and a run with increased albedo

(SNOW). In the NOLAT run, the latent heat release is excluded from the parameterization schemes. In the NOSCAN run the mountains in Scandinavia, Finland and the part of Russia in the domain are set to 1m. The model then extrapolates the atmospheric conditions from ECMWF reanalysis down to sea level. The RED-SST run is conducted with the initial SST reduced by 5 degrees. The albedo is increased in the SNOW run by changing the land use category to snow/ice.

4. RESULTS

In connection with a deep upper level trough over the North Atlantic, a surface low gradually deepens over southern Norway on 13 August 2003. This low subsequently moves very slowly to the east. The low is a few hPa weaker in the CONTROL run than in the analysis, but the location is well simulated. The central pressure at sea level for the different simulations and the analysis is given in Fig. 1. The 500 hPa low is a few tenths of meters deeper in the analysis than in the CONTROL run, but the location of the low in CONTROL is good. Behind the low a cold-air outbreak from the northwest wraps around the low.

In the run with no latent heat release, the surface low is significantly weaker than in CONTROL, especially during the first 30 hours of the simulation (see Fig. 1). Latent heating is found to contribute about 40% of the deepening. The surface low in NOLAT has a track that lies south of the track for the low pressure center in the CONTROL run, in agreement with the rule of thumb about deeper lows being deflected to the left. The low center in the NOLAT run moves more rapidly to the east over Scandinavia.

Reducing the SST by 5 K did not affect the deepening of the cyclone significantly. The average pressure in the domain rose by ~1hPa, since the pressure over the oceans increased when the temperature decreased. After the first 30 hours of the simulation the pressure in the center of the low level cyclone rose by a few hPa (see Fig. 1). This may be because in the beginning of the simulation the low is mainly affected by the air already present in the atmosphere. Later the low is affected by the reduced evaporation when SST is lowered.

The removal of the Scandinavian mountains did not affect the deepening of the cyclone significantly (Figure 2), but it greatly reduces the precipitation over the area hit by flooding, as will be discussed in the next paragraph. The simulations also indicate that the mountains push the isobars closer together over southern Norway, comparing the control run to the NOSCAN run. A trough appears over SE Norway (see Fig. 2) in the control run but not in NOSCAN. Relating this to onshore winds from the northwest that ascend the mountains in southern Norway indicates that this trough is a lee-trough. A run with increased albedo (SNOW) was conducted to determine the significance of thermal effects for the trough formation. The lee low was somewhat weakened in this simulation, but in general the impact of surface albedo was much weaker than that of mountain effects.

The most intense stage of precipitation was during 14 August. The 24 hour accumulated precipitation on 15 August 0600 UTC from the CONTROL run is shown in Fig. 3a. The model captures well the observed precipitation amounts (Figure 4), which exceeded the monthly average for August in several locations. To see the orographic enhancement of precipitation more clearly, we show in Figure 5 the difference in vertical motions due to orographic lifting, as well as the resulting rain water production.

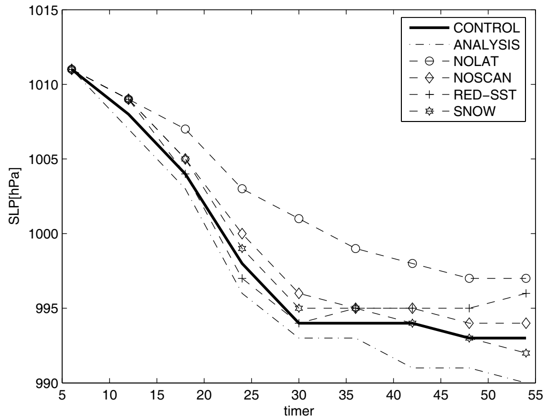

Figure 1. Central pressure at sea level for the different simulations and the analysis

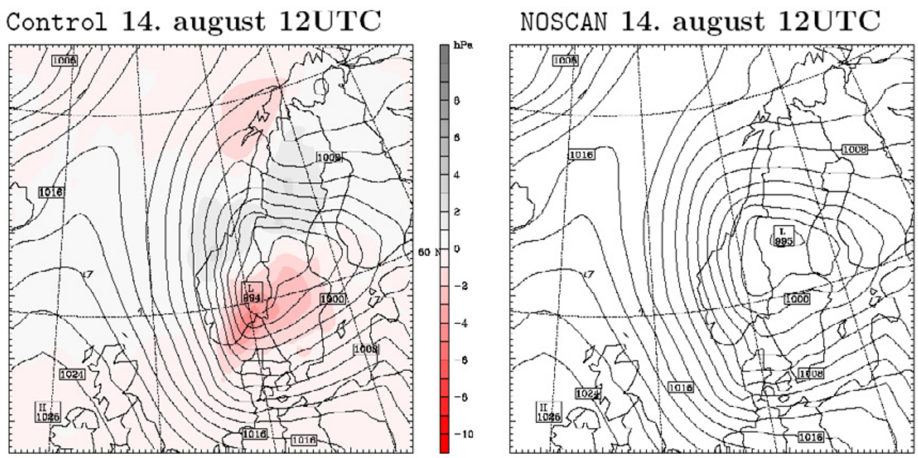

Figure 2. Sea-level pressure (hPa), CONTROL run (left panel) and NOSCAN run (right panel). Color scale shows the pressure difference NOSCAN-CONTROL

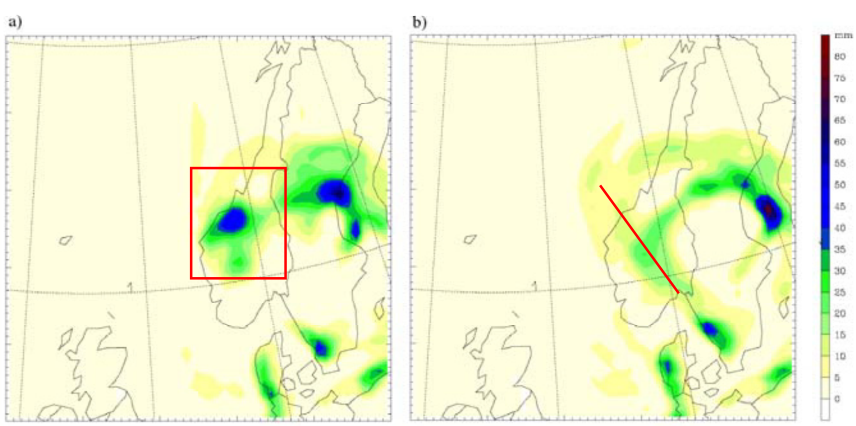

Figure 3. Simulated precipitation over the 24 hours ending at 06 UTC on 15 August from a) CONTROL, b) NOSCAN

5. CONCLUSION

Simulations of the extreme precipitation event in Norway on 14 August 2003 have shown a crucial role played by orographic lifting over southern Norway. Frontal lifting alone is unable to account for the heavy precipitation, where in some areas more than twice the monthly average precipitation fell in 48 hours. The mountains form a lee-trough over SE Norway. Lowering of the SST in the August case had no significant influence on the deepening of the cyclone. On the other hand, latent heat release contributed about 40% of the cyclone deepening.

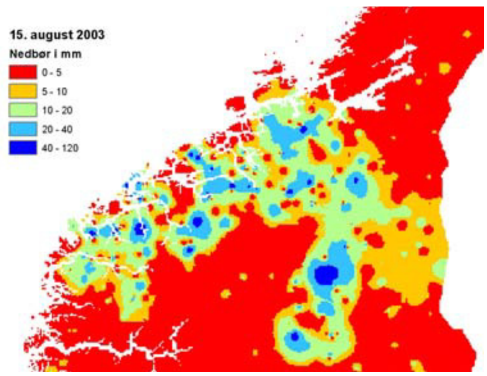

Figure 4: Observed precipitation from 06 UTC 14 August to 06 UTC 15 August 2003. Area shown is indicated by rectangle in Figure 3a.

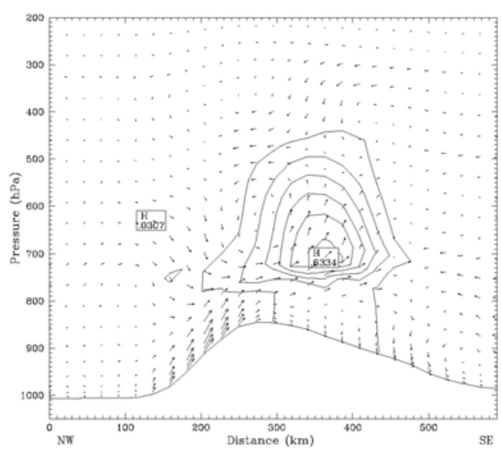

Figure 5. Vertical cross-section over southern Norway, showing the wind difference between CONTROL and NOSCAN (wind vectors), as well as rain water mixing ratio (solid lines) from CONTROL at +36 hours, corresponding to 12 UTC 14 August 2003. Location of cross-section is shown by red line in Figure 3b.

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