# SIMULATION OF HEAVY PRECIPITATION EVENTS WITH THE COSMO MODEL: RESULTS WITHIN THE PREVIEW PROJECT

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**Abstract:** Three heavy precipitation events in the Piedmont and Cévennes region are simulated using the COSMO model at 2.2km grid mesh. The model captures the predominantly convective events quite well regarding position and shape of the precipitation area. But the precipitation amount is generally overestimated by the model at 7km grid mesh as well as at 2.2km grid mesh. The overall structure of precipitation is the same at 7km and 2.2km grid size, but smaller structures like the position of the maximum are improved using the higher resolution. Thus, the simulations suggest that increased horizontal resolution improves the forecast of convective events and consequently also flood forecast.

Sensitivity studies show that the vertical resolution does not have a major impact on the precipitation simulation for the Piedmont cases. First results suggest that precipitation simulation is slightly improved by using z coordinates instead of terrain following coordinates. Additionally, a significant improvement is achieved by using the Runge-Kutta scheme instead of Leapfrog and by calculating prognostic precipitation. Improved initial conditions from assimilation pre-runs result in a better representation of the position as well as the shape of the precipitation region for the Cévennes test case.

Comparing the results of Meso-NH, MM5 and COSMO model reveals strong differences of the amount and shape of simulated precipitation. The comparison of threat scores shows similar result quality for the different models – the latter might be affected by using point-by-point comparison for the verification with rain gauges. Verification methods taking into account the temporal and spatial uncertainty on this scale are applied in order to approve the results.

**Keywords**: *PREVIEW, heavy precipitation, high resolution atmospheric modelling*

## 1. MOTIVATION

The improvement of flash flood forecast is one of the aims within the EU project PREVention, Information and Early Warning (PREVIEW). An overview of the work done in the flash flood working group is given in the presentation by B. Vincendon. The term ‘flash floods’ describes fast rising floods due to heavy precipitation events with typical timescales of several hours and typical spatial scales between 100 and 1000 km$^2$. Flash floods are dangerous, because they combine the destructive power of a flood with rapid rise of water and difficulties to forecast the events. An important reason for the latter is the limited quality of precipitation forecast on short timescales and small domains. Thus, the increased resolution of new generation weather forecast models promises a step forward. Several flash flood episodes are simulated with the high-resolution atmospheric models COSMO (formerly known as LM), MM5 and Meso-NH using mesh sizes between 2 and 3 km. The aim is to determine the most suitable configuration with respect to forecasting heavy precipitation events.

## 2. TEST CASES AND MODEL SETUP

Three periods of heavy, mainly convective precipitation events in the Piedmont and the Cévennes region are selected for case studies. During the period of 4 and 5 June 2002 heavy precipitation and thunderstorms affected the north-western zones of Piedmont. Landslides, erosions and floodings occurred in the area. Maximum values of up to 400 mm were measured. During the period 1 and 2 September 2002 thunderstorms with heavy localized precipitation affected the province of Turin. Precipitation maxima of around 100 mm were measured in the Turin area. Between 5 to 9 September 2005, several precipitating systems affected the south-eastern part of France, the Cévennes region. Accumulated precipitation from 5 to 8 September 2005 reached values above 300 mm.

The simulations are performed with the Swiss implementation of the COSMO model (formerly known as Lokal Modell). It is a non-hydrostatic limited-area atmospheric model developed for applications on the meso-ß and meso-γ scale. A full description of the model is available at http://www.cosmo-model.org/public/documentation.htm. The model is based on non-hydrostatic, fully compressible hydro-thermodynamical equations in advection form. Generalized terrain-following height coordinates with rotated geographical coordinates are used. The model equations are solved on an ARAKAWA C-grid with user-defined vertical grid staggering. The prognostic variables are horizontal and vertical wind components, pressure perturbation, temperature, specific humidity, cloud water and ice content, specific water content of rain, snow and graupel (at 2.2km grid mesh) and turbulent kinetic energy. Three-dimensional transport of rain and snow is calculated. Moist convection is parameterized using a mass-flux scheme based on moisture convergence following Tiedtke for simulations with 7 km grid size. For simulations with 2.2 km moist convection is not parameterized except for shallow convection. Data at the lateral boundaries are prescribed using a Davies-type one-way nesting.

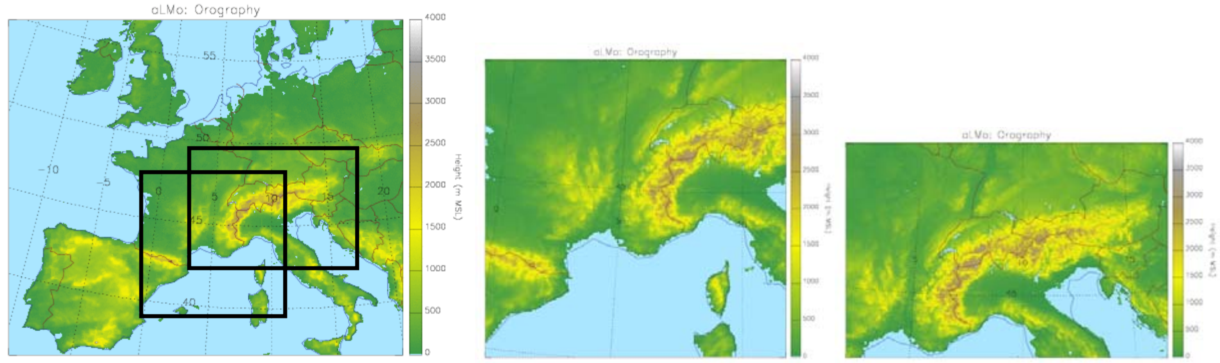


**Figure 1**: Orography of the model domains for the Cévennes and Piedmont cases : Model domain at 7km grid mesh covering Europe (left), at 2.2km grid mesh for the Cévennes case (middle) and at 2.2km grid mesh for the Piedmont cases (right). The rectangles denote the positions of the model domains for the Cévennes and Piedmont cases (middle, right) in the coarse model domain (left).

Two model domains at 2.2km grid mesh are one-way nested into a model domain covering Europe at a grid mesh of 7km (Figure 1). Forty five levels are used in the vertical. 24 hour forecast runs are initialised at 0000 UTC and 1200 UTC and provide hourly model outputs: 4 simulation are performed for the June 2002 Piedmont case study (4 June, 00 - 5 June, 12), 2 simulations for the September 2002 Piedmont case study (1 Sept., 00 and 12) and 11 simulations for the September 2005 case study (4 - 9 Sept., 12). Initial conditions and boundary conditions for the outer domain are taken from interpolated European Centre for Medium range weather forecasting (ECMWF) global gridded forecast fields at 0.5-degree lat/lon horizontal grid increments. No spin up period or assimilation of additional observations is used for the reference set.

## 3. RESULTS

### 3.1 Comparison of results with different horizontal resolution

Results for the Piedmont test cases show that the simulations at 7km and 2.2km grid mesh describe the precipitation event quite well, although the amount of precipitation is overestimated. The overall characteristics of the precipitation event are similar in the simulations at 7km and 2.2km grid mesh. Still, details are improved in the simulations at 2.2 km grid size by shifting the precipitation area to the east and, thus, improve the agreement with the measurements (Figure 2). The comparison of measured and simulated accumulated rain for the 5 -8 September 2005 in the Cévennes region shows a very good agreement (Figure 3). The COSMO model captures the location, the shape as well as the amount of precipitation.

### 3.2 Results at different vertical resolution and with different vertical coordinates

Sensitivity studies regarding vertical resolution are performed for the Piedmont case studies. The simulations are set up using 60 levels at 7 km and 2.2km grid mesh and 60 levels at 7km grid mesh and 100 levels at 2.2km grid mesh, respectively. The differences between the simulations remain negligible. The impact of vertical resolution on precipitation forecast is small for these cases.

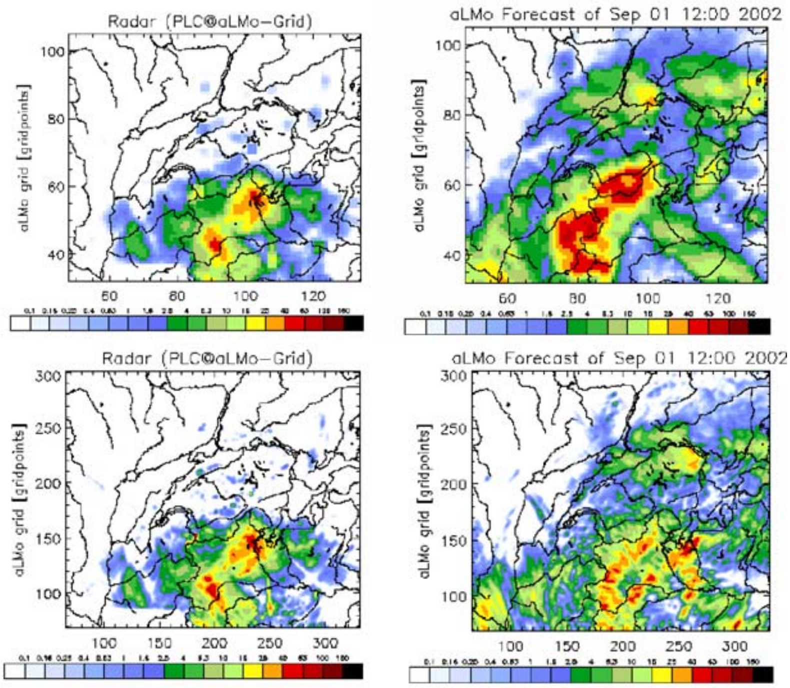


**Figure 4**: 24h accumulated precipitation (01 - 02.09.2002, 12) from radar data interpolated on the 7km (upper panel, left) and 2.2 km grid (lower panel, left) and model results at 7km (upper panel, right) and 2.2km grid mesh (lower panel, right).

A sensitivity study is performed using z coordinates instead of terrain following coordinates. Z coordinates use model layers that are parallel to the surface of the sphere and consequently intersect the orography. The purpose of using z coordinates is a more accurate representation of the flow field in mountain regions, since terrain following coordinates get more inaccurate the steeper orography gets. The simulations require some configuration changes: Leapfrog scheme for time integration, no prognostic calculation of rain, reduced time steps and a slightly different orography since v valleys are filled up.

The simulations using z coordinates and terrain following coordinates show significant differences. The results with z coordinates show a more pixel-like structure compared to the more band-like structure with terrain following coordinates. The results with z coordinates show also a higher amount of area average precipitation. The evaluation with rain gauge measurements shows that the results of the terrain following version agree significantly better with the measurements than those with z coordinates. An additional set of simulations is performed using the settings of the z coordinate runs but terrain following coordinates. First results suggest that using Runge-Kutta and prognostic precipitation strongly improves the precipitation forecast and that z coordinates improve the simulation of precipitation if the same setting is used.

### 3.3 Results using initial data from interpolated large-scale data and assimilation

An additional set of simulations is performed taking initial values from a 12-hour assimilation run with 2.2 km grid size instead of interpolated ECMWF data. Data assimilation is based on observation nudging. The atmospheric observations that are hourly assimilated are: radiosonde (wind, temperature, humidity), aircraft (wind, temperature), surface level data (SYNOP, SHIP, BUOY: pressure, wind, humidity).

For the Piedmont cases initial conditions from assimilation increase the threat score for higher precipitation amounts but decrease it for lower precipitation amounts. Thus, the effect of assimilation is contradictory. The results for the Cévennes cases are significantly improved by using the assimilation (Figure 3). The position and shape of the precipitation area are in better agreement with the measurements. Further studies are performed trying to reach further improvement by using latent heat nudging.

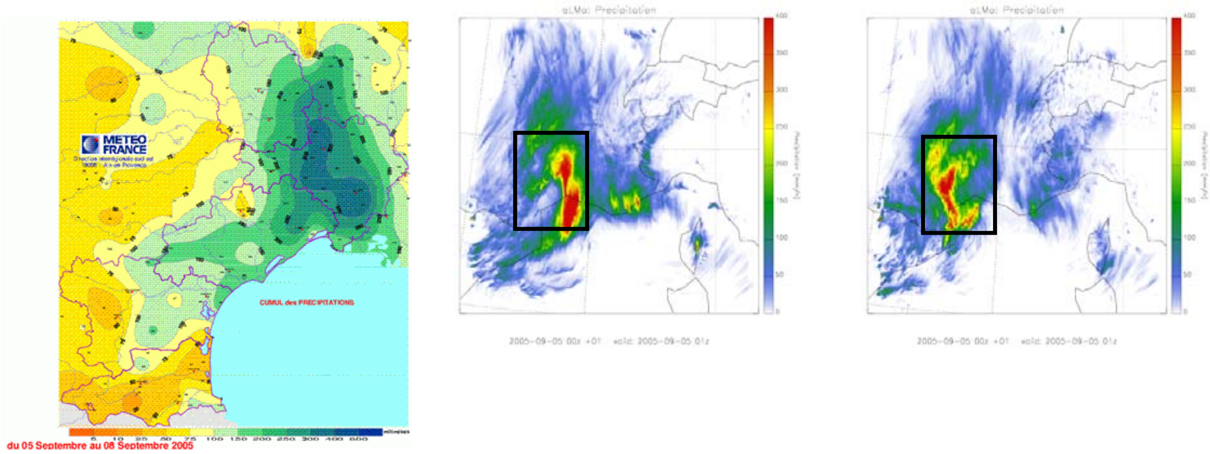


**Figure 5**: 3d accumulated precipitation from 05 - 08.09.2005, 06 in the Cévennes region from rain gauge measurements (left), in the results of the COSMO model using initial conditions from an assimilation (middle) and from interpolated large-scale data (right).

### 3.4 Results using COSMO model, Meso NH and MM5

The reference runs are performed with COSMO, Meso NH and MM5. The results differ significantly regarding precipitation amount and shape of the precipitation area (Figure 6). The threat scores averaged for all simulations show similar values for the models, meaning a similar result quality. A subjective verification confirms this. Still, the similarity of values might also be a shortcoming of the point-by-point comparison which is not an adequate comparison method at high resolutions. Other verification methods taking into account temporal and spatial uncertainties are applied. Simulated precipitation is also used for discharge forecasts. The results are discussed in the presentation of M. LeLay.

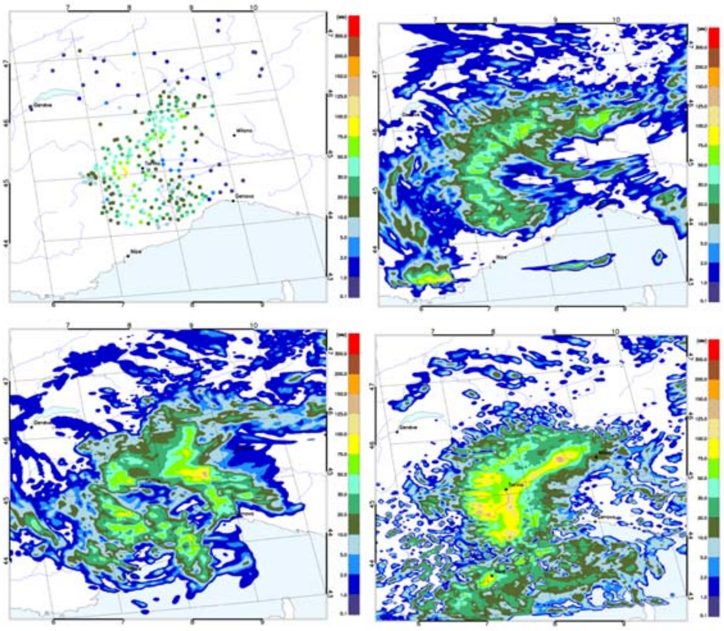

**Figure 6**: 12h accumulated precipitation from rain gauge observations (upper panel, left), in the results of the COSMO model (upper panel, right), of Meso NH (lower panel, left) and MM5 (lower panel, right).

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