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STUDY OF THE CONVECTION OVER MONTE ROSA USING S-POL OBSERVATIONS AND FINE SCALE MESO-NH SIMULATIONS

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1. INTRODUCTION

The Monte Rosa is the major peak inside the massif located in the Alpine orography concavity on the southern slopes (see map in Fig. 1). This area is associated to a climatological maxima of autumn rainfall (Frei and Schär 1998) . The polarimetric S-Pol radar from NCAR and the French doppler Ronsard radar have been deployed in the valley just at the foothills of Monte Rosa together with the operational Swiss radar Monte Lema in order to provide dual-Doppler data of the initial conditions and the evolution of the rainfall situations during the MAP (Mesoscale Alpine Programme) special observation period (September to November 1999).

The present study validate a fine-mesh simulation using the various radar data collected during the two days of the IOP2B (19 and 20 September 1999). The mechanisms at different scales linked to the convective episodes are then detailed.

2. SYNOPTIC SITUATION

The selected case is the IOP 2B (19 and 20 September 1999) because its chronology is classical and a large rain amount has been measured in the Lago Maggiore target area (LMTA thereafter). The synoptic situation is characterized by a deep cyclone located to the west of Ireland, and moving to France, a powerful stationary anticyclone over the eastern Europe (40°E), which extends by a ridge even to the south of the Mediterranean Sea east of the 20°E. In North-Africa, a second cyclone (located at 10°E) moves from Morocco to Tunisia during the IOP 2B.

An active cold front is associated to the Atlantic cyclone. At 0000 UTC, it extends along an approximately North-South axis from British Isles to Portugal. It crosses France during 19 September and reaches the alpine orography during the night. The eastwards evolution across the Po Valley during the 20 September is slowed down by the stationary high pressure over the eastern Europe.

The altitude analysis shows a cut-off low associated to the deep surface Ireland cyclone. The potential vorticity anomaly elongates along a meridional direction on 19 September, rotates eastwards and northwards during the second day. The surface cold front and the upper-level jet keep their S-N axes and move eastwards across Po Valley during the second day of the IOP.

3. NUMERICAL SET-UP

The numerical simulation is performed with the anelastic non-hydrostatic meso-scale model Meso-NH (Lafore*et al.*(1998). This model allows the simulation of multi-scale atmospheric features from a few thousand kilometers to a few tens of meters. In order to simulate the synoptic features over Alpine region and the detailed fine-scale structure of the convective cells, we use 2 nested models. The different horizontal meshes are 10 km (200x160 points) and 2.5 km (200x200 points). The two simulation domains are shown by solid line rectangles in Figure 1. The simulation starts at 0000 UTC on 19 September 1999 and lasts 48 hours. The initial conditions and lateral boundary conditions linearly interpolated in time between 6 hourly analyses are given by the French operational analysis Action de Recherche Petite Et Grande Echelle (ARPEGE). The microphysical scheme includes the three water phases with five species of condensed water. For the 10km mesh model, the subgrid-scale convection is parametrized by a mass flux convection scheme (Bechtold *et al.*2001). For the 2.5km mesh model, the convection is explicitly resolved and the convection scheme is switched off.

4. VALIDATION

4.1 Rainfall

We use the RAIN product of Monte Lema radar to validate our 2.5 km mesh simulation with a continuous evolution at a higher temporal frequency than

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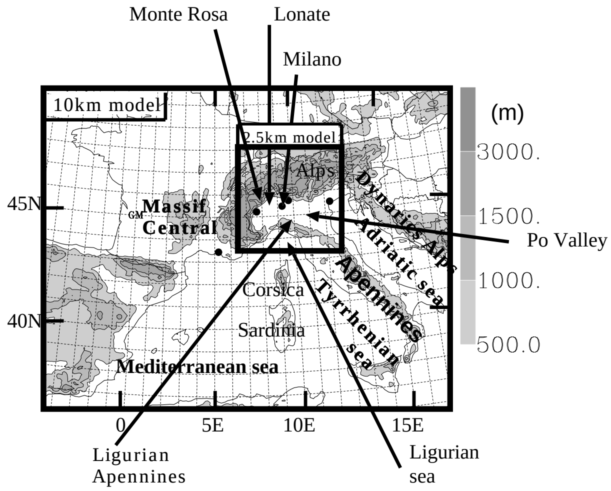

Figure 1: *Nested models domains used in numerical simulation and topographic map. The orography is represented in grey scale.The solid line rectangle represents the 2.5km mesh model domain.*

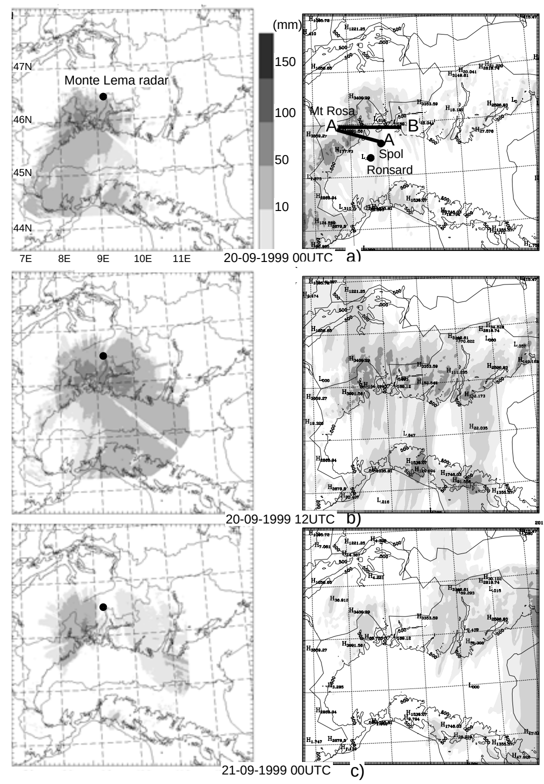

Figure 2: *6 hours accumulated rain (mm) during a pre-frontal period (a), the frontal passage (b), and post-frontal period (c): the 2.5km model on the right side, the Monte-Lema radar on the left side*

the available rain-gauges data. The RAIN estimations of the rainfall precipitation are deduced from the radar reflectivities over the western side of the Po Valley. The 6 hours accumulated rain in Figure 2 gives a good synthesis of the observed precipitation chronology for this scale. The eastwards displacement of the frontal system is accurately reproduced by the model.

4.2 Vertical structures

In order to confirm the successful representation of the rain and convection evolutions over LMTA, Figure 3 compares the reflectivity measured by the S-Pol radar (Fig. 3 a,c,e,g) along a vertical cross section AA (see Fig. 2a) extending until the Monte-Rosa and the reflectivity computed from the explicit clouds of the 2.5km model . The horizontal and vertical extensions of the cells are similar in the simulation and in the observations during the three periods (pre-frontal, frontal and post-frontal). The height of the cells is 4km except during the frontal passage where 10km is exceeded. The radar gives a width of 5km for the cells observed along the AA cross section. This scale is recovered by the simulation even if it is close to the limit of resolution of the model. In summary, the rain upstream the Alpine crest follows the same temporal evolution in the S-Pol observations and in the simulation. Downstream the Alpine crest, the model shows a less intense convection but no S-Pol data are available to confirm this point.

4.3 Wind

The vertical cross-section AB (Fig. 4) along the Alpine foothills (see Fig. 2a) gives a depth of 2 km for an easterly low level jet . This jet follows the orography and some flow passes over the Monte Rosa crest. This easterly flow, named the barrier wind, results from the eastern deviation by the Coriolis force of the southerly incident synoptic flow slowing down when it approaches the alpine orography . It is rather stationary in direction as observed by the UHF radar in Lonate but its intensity varies during the two days of the IOP2B.

5. DIFFERENT FEATURES LINKED TO CONVECTIVE EPISODE OVER MONTE-ROSA

5.1 Barrier Wind

This easterly low-level jet produces therefore a strong orographic forcing for the convection over Monte-Rosa eastern slopes. Figure 5 shows that this wind is strongly correlated to the rain evolution over LMTA during the whole IOP. The maximum rain rate occurs during the night and the value of 7 mm/h is of course a mean value of very stronger local rates which exceed 100 mm/h.

5.2 Influence of the surrounding orography

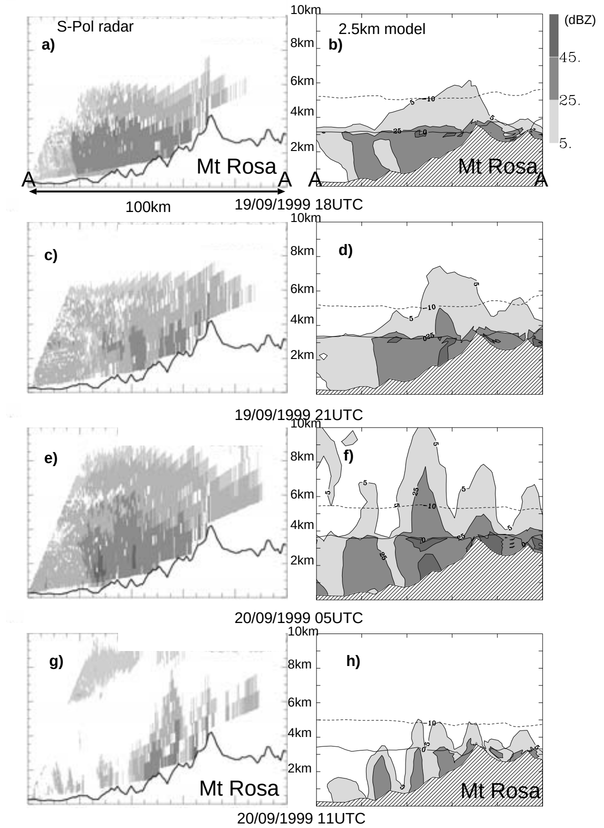

Figure 3: *Temporal evolution of the clouds along the cross section S-Pol-Monte Rosa. Reflectivity (dBZ) in the same grey scale observed by S-Pol radar on the left side, simulated in the 2.5km model on the right side. The iso 0° and iso -10° are represented with respectively solid and dashed lines.*

To study the history of the air mass convecting over Monte Rosa, we follow two layers of this air mass located inside a square of 50x50km^2 centered on S-Pol radar. A first layer above 2km in the south-westerly flow depicted in Figure 4 and a second layer beneath 2km inside the easterly low-level jet. The backward trajectories of the upper-level layer (not shown) reveal a stationary origin from Mediterranean and Ligurian sea. The backward trajectories of the boundary layer (ending points at 500m above S-Pol radar) in Figure 6 describe different origins depending on the temporal evolution of the meso-scale flow around the Po valley. At the beginning of the IOP 2B (Fig. 6a), the LMTA is inside the blocked region and the air comes from the Adriatic Sea. Then, a second origin adds to it, with air coming from the Ligurian Sea (Fig. 6b) advected by the jet east of Sardinia. This second air origin is displaced ahead of the front (Fig. 6 c and d) at 0500

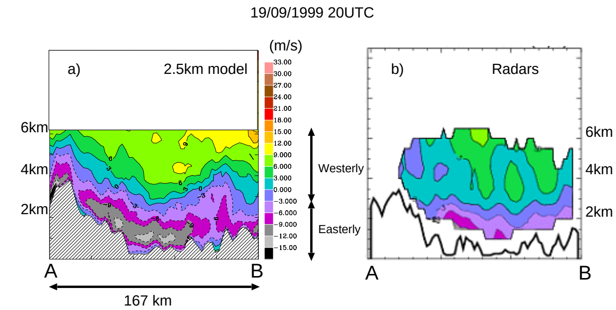

Figure 4: *Barrier wind (ms^{-1}) along the cross section AB in grey scale:(a) simulated in the 2.5km model, (b) calculated from Ronsard-S-Pol-Lema observations*

UTC and 1100 UTC. Later, the Adriatic origin ends and is replaced by a direct Ligurian origin advected by the southerly post-frontal flow (Fig. 6d). Two gaps inside the Apennines localized to the south of Venezia along the 11.5°E and 12.5°E favor the entry over the Po Valley of maritime air coming from the Ligurian Sea.

5.3 Meso-scale structures: dry anomaly and upper level clouds

In spite of very high CAPE values over the Ligurian Sea (> 2000 J/kg), the boundary layer over the Po Valley presents an equivalent potential temperature 10K weaker than the maritime one. CAPE values observed in Milano keep rather weak (300 J/kg) during the whole IOP. A vertical cross section CC along the Ligurian entry (identified in Fig. 6b) explains this decrease of the CAPE when southerly air mass cross the Apennines (Fig. 7). The maritime boundary layer feeds the convection on the coastal mountain which partly consumes its CAPE, with small convective developments (4km height). Then the convective cells are trailed with the southwesterly upper-level flow and the subsidence at the lee of the Apennines stops their evolution. On an other hand, on the Alpine orography the vertical developments are greater than expected according to the instability structure.

A possible explanation of this low height of convective cells above Apennines is based on the presence of a mid-troposphere dry anomaly , which inhibits the convective developments by entrainment of very dry air in the convective updrafts. And the upper-level clouds ahead the frontal system contribute to the enhancement of the convection above the Alpine orography.

5. CONCLUSION

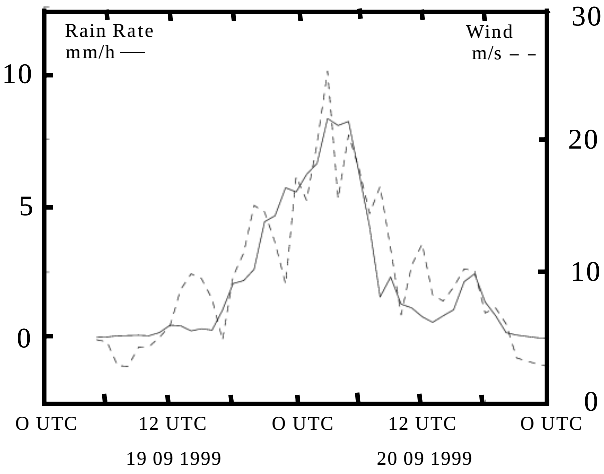

Figure 5: *2.5km model. Temporal evolution of the intensity of the barrier wind at S-Pol location and the rain rate over a 100kmx100km^2 area centered on Monte Rosa: Rain rate (mm/h) in solid line, Wind (ms^{-1}) in dashed line along the cross section AA*

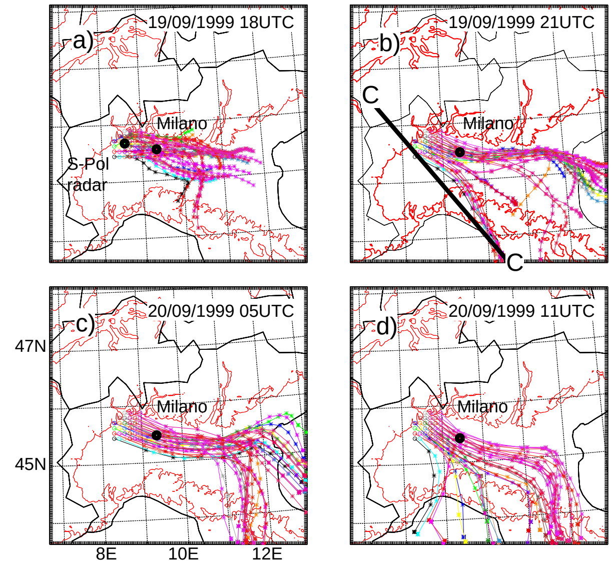

Figure 6: *Backward trajectories of air localized at 500 meters AGL around S-Pol location:(a) at 1800 UTC on 19/09/1999, (b) 2100 UTC, (c) 0500 UTC on 20/09/1999 (d) 1100 UTC. The stars show the hourly locations.*

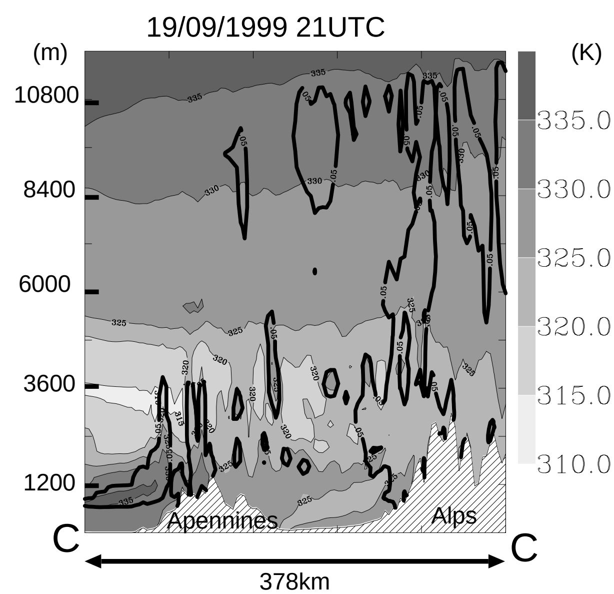

Figure 7: *2.5km model at 2100 UTC on 19/09/1999: vertical cross section CC of equivalent potential temperature in grey scale and clouds in solid line.*

The IOP2B is a typical situation for heavy precipitation over Alpine region. The maximum of precipitation observed in LMTA corresponds to a persistent rainfall during the two days of this IOP. The fine scale Meson-NH model has been successfully validated with the radar data over LMTA. The characteristics of the convection over Monte Rosa slopes differ from the coastal mountains ones. The barrier wind and the meso-scale structures (dry anomaly in middle troposphere, upper level clouds) control the evolution of rainfall. The boundary layer over the Po valley is a previous maritime boundary layer significantly modified by crossing the Apennines.

References

[1] P. Bechtold, J.S. Kain, E. Bazile, P. Mascart, and E. Richard. A mass flux convection scheme for regional and global models. *Quart. J. Roy. Meteor. Soc.*, 127:869–886, 2001.

[2] C. Frei and C. Schär. A precipitation climatology of the Alps from high-resolution rain-gauge observations. *Int. J. Climatol.*, 18:873–900, 1998.

[3] J.P. Lafore, J. Stein, N. Asencio, P. Bougeault, V. Ducrocq, J. Duron, C. Fischer, P. Héreil, P. Mascart, J.L. Redelsperger, E. Richard, and J. Vilà-Guerau de Arellano. The Meso-NH atmospheric simulation system. Part I : Adiabatic formulation and control simulations. *Annales Geophysicae*, 16:90–109, 1998.