SIMULATIONS OF A NOVEMBER THUNDERSTORM EVENT BY TWO MESOSCALE MODELS IN THE SOUTH ALPINE REGION

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Abstract: Two numerical models have been used to investigate the development of a thunderstorm event that took place on November 7th , 2004, in the northern Italy. A cold air mass moved from the northeast to the Alps and the Po valley, while the temperature in the lower layers was quite warm. A thunderstorm with rain and hail developed in the central and eastern part of Italy's subalpine region. In this work it's analyzed some aspects of the thunderstorm dynamics at the mesoscale using two different models. The first one is the semi-implicit, semi-lagrangian non-hydrostatic mesoscale spectral model of CEM (SISL-MSM); the second one is the Meso-NH anelastic nonhydrostatic numerical model by the french Laboratoire de Aerologie and MeteoFrance. Both are nested into our European Spectral Model which provides the boundary conditions. In this study, different horizontal resolutions have been considered both for SISL-MSM and Meso-NH. The work is focused on the comparison of the results obtained from the different runs, including a test-case without orography to examine the role played by the Alps in the development and evolution of the thunderstorm.

Keywords *– Numerical simulation, influence of orography, mesoscale model, thunderstorm*

1. INTRODUCTION

Thunderstorms have never been an usual phenomenon in the northern Italy during autumn, especially if these events produce hail and strong winds. The complexity of the Alpine orography and environmental flow (fronts, moisture, etc.) motivates the present study in which it's also attempted to better understand the behaviour of two mesoscale models. When an air mass impacts against the Alps, orographically modified flows have some effects on the total rainfall and are determined by the environmental static stability, Coriolis effect, and air velocity, and by height and shape of orography. The impact of orography upon airflow and precipitation has been extensively investigated (Smith 1979; Smith 1989). There is a relationship between the airflow response to topographic effects and non-dimensional parameters: Nh/U and the Rossby number ($Ro=U/fL$), where N is the buoyancy frequency, h is the height of mountain, U is the speed of the free airstream, f is the Coriolis parameter and L is the mountain half-width scale. Low-level flow can be blocked by an obstacle when $Nh/U > 1$ (Smith 1979) and if Nh/U is very large, flow stagnation may be present on the upwind and lee sides with lateral deflection persisting downstream to form a wake region (Smith 1980; Smith and Smith 1995).

For mesoscale mountains ($L \ll U/f$) the maximum mountain height primarily determines the character of the barrier effects (Pierrehumbert 1984). Davies (1984) deduced an analytical solution for a front moving over topography and showed that the character of the flow governing the topographic retardation of a cold front in neutral stratification is determined by a rotational Froude number and a front-aspect ratio. In some theoretical works it's documented that fronts have a tendency to weaken on the windward side of mountains and strengthen again on the lee slopes (Williams et al. 1992) and other observational studies have indicated that the marked deformation effects of orography upon fronts includes blocking and splitting of low-level airflow, gravity wave generation and foehn-type flows (Kurz 1990; Volkert et al. 1991; Hoinka and Volkert 1992). If an east-west idealized Alpine mountain ridge with a western flank is considered, the flow regimes is defined "go around" and "go over" in the presence of a finite-width southerly jet (Schneideret and Schar, 2000) and it is also influenced by the horizontal moisture gradient (Rotunno and Ferretti, 2001).

2. MODELS AND DATA

In this work, two numerical models have been used to simulate a thunderstorm event occurred over northern Italy on November 7th, 2004 from 15 UTC to 19 UTC.

Simulated values of temperature and other parameters have been also compared with data measured by Automatic Weather Stations (AWSs) in selected location over the Po Valley.

Of course, observed data are not readily comparable with the modeled grid-box values. It's interesting to simulate this case and compare the results with observations because it's statistically unusual the development of a thunderstorm over northern Italy during this season. In fact, as it's shown in Tab.1, the number of thunderstorm days in autumn is not so rilevant and most of days are in September.

During the day, a mass air came from north-east, the flow channelled through Adige's Valley and converged in the Po Valley (Fig.1).

All the simulations have used the initial conditions at 12UTC of November 6th, 2004 and at 00UTC of 7 November 2004. Also, tests with and without the Alps were performed by both models.

Table 1. ISTAT statistics

Weather stations	N. of thunderstorm days per month
Milan	4
Brescia	7
Piacenza	5

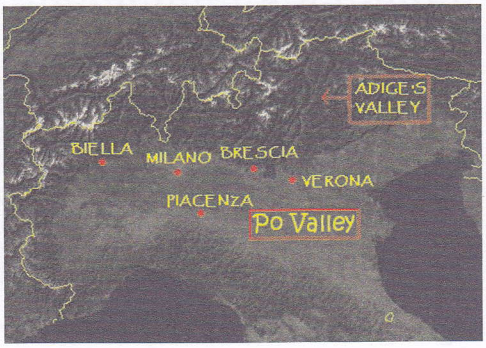

Figure 1. Northern Italy

3. SIMULATION WITH OROGRAPHY AND WITHOUT OROGRAPHY

3.1. The numerical models

Two numerical models have been used in this study. The first one is the CEM's Italian Spectral Model (ISM) based on the non-hydrostatic primitive equations (for smaller-scale applications) used in the operational mode run. This model is nested into a larger european-scale model (ESM) which is also nested in the Global Circulation Model (GCM).

The model domain was chosen to be large enough to encompass the entire Alps and northern Italy. The horizontal resolution in the operational mode is 16 Km, with 28 sigma levels. The time integration is semi-implicit and semi-Lagrangian. Lateral boundary relaxation is considered. Since non-zero boundary conditions may cause difficulties with semi-implicit time schemes, the perturbation method is applied for the resolution of the equation, because zero lateral boundary condition can be satisfied and diffusion can be applied to perturbation only (Juang, 1992). The model can use a type of dynamical initialization, which can be considered whenever there is a doubt about the balance state of the initial conditions, or when a field such as vertical motion is not given in the initial analysis. Flux computation in the surface layer follows the Monin-Obukhov similarity profile (Arya, 1988) with a multi-layer soil model in which different classes of vegetation and soil types are considered. Deep convection has been treated with a relaxed Arakawa-Schubert scheme (Moorthi and Suarez, 1992, 1999; a modified Grell scheme and Kain-Fritsch (1993) parameterization are available). The microphysics treatment employs five prognostic species including water vapour, cloud water, cloud ice, snow and rain (Rutledge and Hobbs, 1989).

The second one is the Meso–NH, a mesoscale nonhydrostatic model joined developed at the Centre National de Recherches Meterologiques (Meteo-France) and the Laboratoire d'Aerologie (CNRS).

Meso-NH is a numerical model able to simulate atmospheric motions at different scales, from the large meso-alpha scale down to the micro-scale. Meso-NH is a grid point model and makes use of an Arakawa C-grid both for the horizontal and the vertical grid. For this work, the quasi-operational horizontal grid resolution was of 10 km, nearly comparable to the other one.

The model makes use of the anelastic approximation in the resolution of the equations of motion. In this approximation the fluid is virtually incompressible or pseudo-incompressible. The time scheme is explicit.

Meso-NH was initialized with real case data: the initial conditions for dynamic and thermodynamic variables are derived from a larger scale model that was, in this case, ESM. Six microphysical variables are used (vapour water, cloud water, rain, ice, snow, graupel, hail and pristine ice). We used the Kessler cloud scheme for warm clouds and the Kain-Fritsch scheme for deep convection. Turbulence was treated one-dimensionally because only the vertical turbulent fluxes have been considered.

3.2. Results and observations

From satellite (no images are shown here), it could be evident that a cold air mass in the middle troposphere moved towards northern Italy and propagated over the Alps.

In the simulations started at 00UTC 7 November 2004, about 15 hours before thunderstorm developed, fig.2 shows how the orographic shape of Alps forced the flow to cross the Adige's Valley.

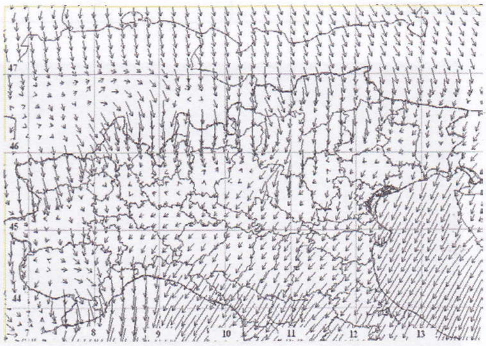

Figure 2. Wind at 10m over surface at 15 UTC

After 12 hours of simulation, the temperature difference between 850 and 500 hPa was 24°C in the western Po Valley and 30°C in the eastern part. During the next 4 hours, the temperature at the surface falled about 2 °C, fairly well in agreement with those measured by surface stations, except for Brescia where the temperature dropped 5 °C. Moreover, the temperature difference between 850 and 500 hPa became 31°C in the western Po Valley and 29°C in the eastern part. Looking at the fig. 3 the movement of the cold air mass may be inferred even by the wind and the temperature at 850 hPa only.

The Alps influence is clear in the fig.3, which shows the simulations of wind and temperature at 850 hPa by ISM with ("a" image) and without ("b" image) orography. It's also clear from the part a) of the figure that the flow, coming from north-east, is forced to go around the mountains.

The simulations of vertical velocity by MESO-NH with and without mountains are presented in fig.4. In these vertical cross sections over latitude (44N-47N) and longitude (9.9 E) it could be deducted the influence of the orography for the development of convective motions.

The observations over the considered area described also an increase of the wind speed and fluctuations of humidity in the period between 14 and 21 UTC.

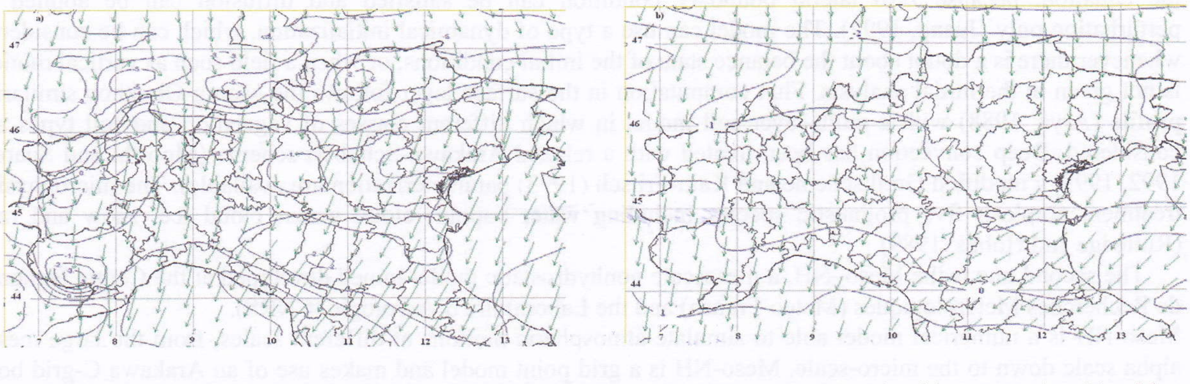

Figure 3. Simulations by ISM of temperature and wind at 850 hPa at 16UTC: a) with orography; b) without orography.

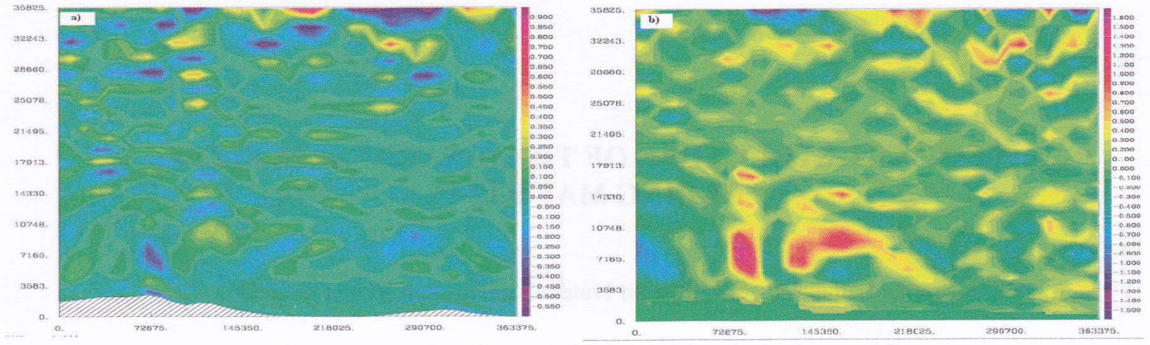

Figure 4. Simulations by MESO-NH of vertical velocity at 16UTC: a) with orography; b) without orography.

4 CONCLUSION

In this study, two models have been used with different mesh grid sizes. Simulations have been carried out to study some aspects of the models and to understand the influence of topography in in the development and strenght of the thunderstorm. By the models results compared to observations, some errors in the simulations have been evidenced. From the dynamical point of view, ISM was fairly well consistent with observations. The analyses of temperatures indicate that their variations are almost close to observations, but they are too cold in the lowest layers, keeping from the fast development of convective motions and decreasing their global strenght. The presence of orography, however, has allowed warmer air to stay into the Po Valley, increasing the difference of temperature with the middle troposphere and enhancing the convection respect to the simulations without the mountains.

This is a preliminary work made by simulations over Alps using ISM and MESO-NH at various resolutions. In the future, other and more detailed studies will be done in order to improve the understanding of models simulations and performance.

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