MARITIME CONVECTIVE INITIATION OF THE SEVERE THUNDERSTORM OF 4 OCTOBER 2007 IN MALLORCA: NUMERICAL EXPERIMENTS

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(15 September 2009)

I. INTRODUCTION

The Mediterranean basin is regularly affected by severe weather associated with deep convection. Even if they are usually tied to coastal orography, some severe thunderstorms develop and mature over the sea. A good and recent example is the severe thunderstorm that crossed the island of Mallorca in the afternoon of 4th October 2007. Generated early in the morning offshore of Murcia (southeastern Spain), this storm organized progressively into a squall line structure with a northeastwards movement. Arriving in Palma city, this squall line was accompanied by severe gusts, heavy rain and several F2-F3 tornadoes, leading to significant damages in the southwestern part of the island and eventually to one fatality.

An observational study of weather patterns favourable to such squall line development is presented in Ramis et al, (2009). The triggering and evolution of convection in these kind of events depend on both synoptic and mesoscale features. Representing such interaction is a real challenge for numerical models used in weather forecasting, all the more since the squall line was triggered over the sea.

II. PRESENTATION OF RESEARCH

In order to better identify mechanisms responsible for the initiation and evolution of this severe thunderstorm, three mesoscale numerical models have been used (Méso-NH, WRF and MM5) combined with several initial and boundary conditions (from ECMWF, ARPEGE and ALADIN). All the experiments were achieved with a fine resolution mesh (between 2 and 2.4 km) centred over Mallorca and no deep convection parameterization was activated. Analyses rather than forecasts were used to provide the most realistic initial and boundary conditions available.

The best simulations are expected to provide interesting comprehensive elements of squall lines dynamics and structure. This study also allows assessing initial and boundary conditions influences as well as model parameterization impacts on the modeling framework. Another objective is to test simulation improvements by assimilating synthetically generated observations corresponding to mesoscale features, in order to remedy the lack of data over the sea. The idea is to assimilate pseudo-observations of plausible structures that are believed to be necessary for convective initiation.

III. RESULTS AND CONCLUSIONS

Méso-NH simulations have been performed with several initial conditions from ECMWF, ARPEGE and ALADIN, and confirm the crucial effects of initial state on the numerical modeling. Failure of experiments initialized with ALADIN data is clearly due to an incorrect representation of the environment over the Mediterranean Sea. Experiments fed with ECMWF and ARPEGE present more accurate low-level flows and achieve simulations with more realistic evolutions. However, differences in the low-level temperature fields lead to a best convective triggering with ARPEGE experiments, in which the front is associated with a stronger convergence of winds. Moreover, differences pointed out in experiments performed with Méso-NH, WRF and MM5 with the same initial conditions indicate the benefits of a multi-model approach, since each one is characterized by its own physical and dynamical parameterizations.

The analysis of the ensemble of experiments leads to the conclusion that the low-level convergence appears to be in this case the key element to explain the triggering of deep convection. The position of a low-pressure area to the south of the Balearic archipelago in the lower troposphere is an important factor that improves the triggering location of the simulated storm. The experiment performed with WRF forced by ECMWF analysis succeeds in reproducing the squall line evolution with the best spatiotemporal representation. In the morning, this simulation triggers a convective cell to the south of Murcia, over an area with significant wind convergence and characterized by a pronounced convective instability. Later on, this thunderstorm organizes in a linear structure and moves over the sea along a thermal boundary to reach Mallorca around 16 UTC (15:30 UTC in reality). The high sheared environment resulting from an easterly low-level flow overlain by strong southerly winds appears to be necessary to sustain the squall line.

Of particular importance is that the MM5 model is not able to trigger a convective cell offshore of Murcia, as opposed to the other models. In order to attempt to remedy this failure to correctly simulate the event, two different approaches have been considered. Since in the MM5 experiment, the lack of low-levels convergence seems to avoid an efficient convective triggering, the first improvement was to assimilate pseudo-observations in order to synthetically generate a convergence line. Such observations are inspired from an experiment with Méso-NH forced by ARPEGE analyses in which initial stages of the convective cell are well captured. Only wind pseudo-observations are provided in the morning, at several levels in the planetary boundary layer, in order to initiate convection. Data assimilation of these pseudo-observations by the nudging method results in a well located convective triggering necessary to the further realistic evolution of the squall line. Although the simulated squall line is slightly off to the west of Mallorca,the signature is very similar to observed radar reflectivities.

The second approach was to explore the sensitivity of the MM5 reference simulation to the planetary boundary layer scheme, since on the whole domain, the convection develops later than with other models. The substitution of MRF scheme (Hong and Pan, 1996) -daily used in the Universitat de les Illes Balears forecasts- by ETA scheme (Janjic, 1994) leads to significant improvements in the simulation. With this later scheme, using a 1.5 order of closure and a prognostic equation to compute Turbulent Kinetic Energy, convection is favoured and the triggering of the squall line takes place with rather accurate spatiotemporal features. The lower diffusion of vertical velocity patterns and a better representation of the moisture vertical profile in the lowest levels are crucial factors to this success.

Given the successful results of the Méso-NH experiment fed with ECMWF analysis -which simulates the squall line in remarkable agreement with remote sensing observations, despite a time lag-, further experiments have been carried out. An analysis of the internal structure and dynamics of convection confirms the squall line organization of the simulated convective system. In addition, a very high resolution simulation with a grid size of 600 meters, performed on a domain surrounding the squall line already formed, points out a bow-echo in reflectivities located in the southern sector of the squall line arriving to Mallorca (FIG. 1).

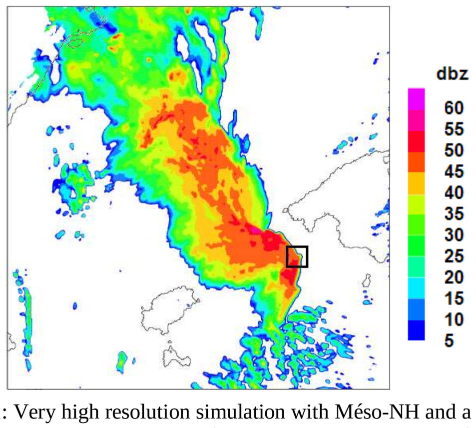

FIG. 1: Very high resolution simulation with Méso-NH and a 600 m grid size at 12:30 UTC: Reflectivities and indication of FIG.2 domain.

Near the bow apex and in other undulations of the squall line leading edge, where the rear inflow jet is severe, the highly detailed simulation allows highlighting individual vertical mesovortices. Their respective location, with the positive vortex to the north, indicates that they are enhanced by updrafts ahead of the gust front (FIG. 2). The theory of such vortices genesis by updrafts is extremely recent and is described in Atkins and St Laurent, (2009). The presence of this couplet of mesovortices demonstrates the favourable environment to the tornadogenesis.

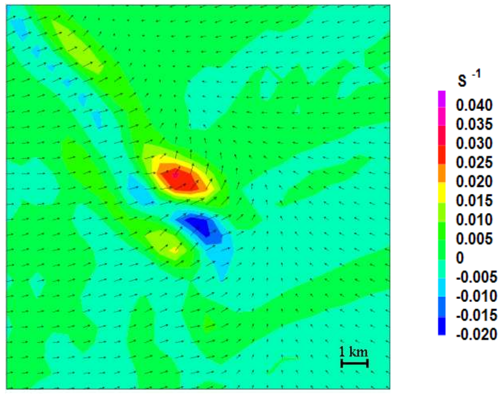

FIG. 2: Vertical vorticity and horizontal wind at 200 *m* on domain indicated on FIG.1.

To conclude, the success of a numerical simulation to capture a severe convective event with a maritime initiation closely depends on a conjunction of factors from distinct scales. On the 4th October 2007 event, in a favourable synoptic environment which has been identified, a mesoscale circulation was necessary to lead to the squall line triggering. Finally, the ability of mesoscale numerical models to reproduce such maritime convective event is highly dependent on initial condition accuracy at small scales, an ever-present challenge over the data-void Mediterranean Sea.

IV. AKNOWLEDGMENTS

The authors would like to thank Juan Escobar from the Laboratoire d'Aérologie whose help was essential to succeed in running Méso-NH at the UIB. Thanks are also due to Regina Guilabert and Jose Arrecio for their software assistance. At least, UIB authors acknowledge support from MEDICANES/CGL2008-01271/CLI project, from the Spanish Ministerio de Ciencia e Innovacion.

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