3DVAR ASSIMILATION OF GPS AND METEOROLOGICAL OBSERVATIONS IN MM5 DURING THE DECEMBER 14TH SNOW STORM EVENT OVER THE WESTERN MEDITERRANEAN SEA.

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Introduction

The western Mediterranean is frequently affected by situations connected with heavy rainfalls over localized areas and during a short time. These events are mostly the result of mesoscale convective systems (Llasat and Puigcerver 1992; Romero et al. 1998) which are closely related to the land surface heat flux conditions and the topography of the area.

The Global Positioning System (GPS) technique is sensitive to the horizontal and temporal distribution of the precipitable water content in the atmosphere (e.g. Bevis et al. 1992; Rocken et al. 1995; Businger et al. 1996; Duan at al. 1996).

The aim of this study is to analyze the impact of the 3DVAR assimilation of GPS measurements and conventional meteorological observations for one of these convective episodes.

Meteorological situation

This experiment focuses on a storm event that took place between December 14th and December 15th 2001, and which produced a large amount of precipitation and snow cover over the western Mediterranean.

The meteorological situation was the result of the interaction of two atmospheric phenomena: low level advection of moist and warm air and a trough transporting cold air at upper levels. The Meteosat image for 12 UTC December 14th is shown in Figure 1.

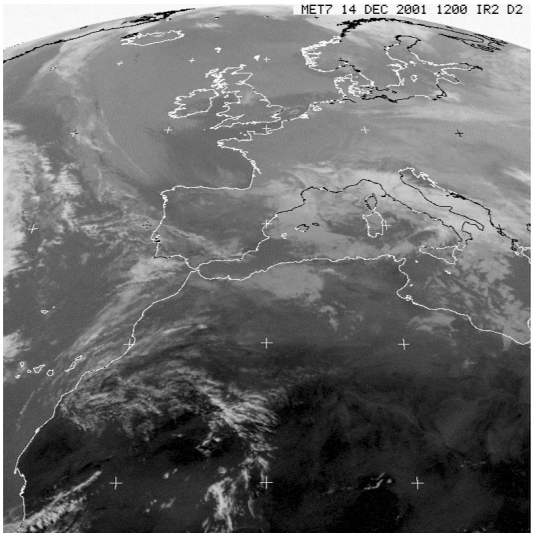

Fig 1. Meteosat Infrared image for 12 UTC 14th December 2001.

GPS and meteorological observations

The GPS receiver network ranges in length from about 30 to 2000 km and with a maximum altitude difference between the highest and lowest GPS sites of about 1500 m. The geographical location of these GPS sites samples quite equally the model domain, which roughly extends from 10W to 20E and from 30N to 50N (see Fig. 2).

The GPS sites are operated by the COST-716 'Exploitation of ground based GPS for Climate and Numerical Weather Prediction Applications' members (e.g. Brockmann et al. 2001).

From the entire available GPS data set, 17 stations are chosen for this case study. The GPS measurements are the Zenith Total Delays (ZTDs) gathered at those GPS receivers.

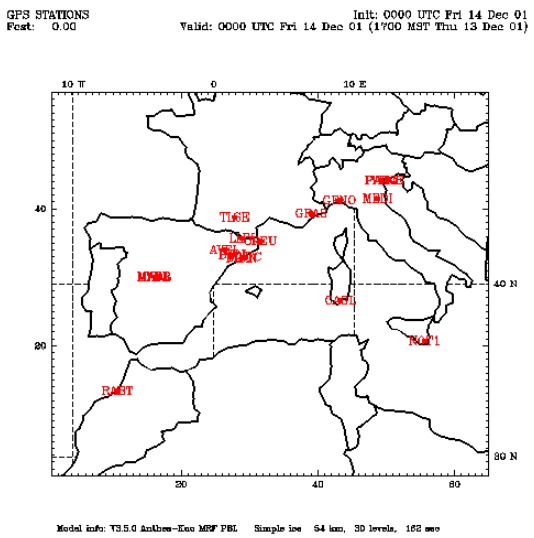

Fig. 2. Geographical location of the used GPS sites from the European permanent network.

When surface pressure measurements are also available at the location of the station, the hydrostatic contribution to the ZTD can be estimated and removed. This component is known as the Zenith Hydrostatic Delay (ZHD). The remaining term (Zenith Wet Delay) is associated with the atmospheric water vapor (Bevis at al. 1992).

Global meteorological observations in WMO Global Telecommunication System (GTS) format are also assimilated into the model.

MM5 3DVAR system

The Penn State/NCAR Mesoscale Model (MM5) (Grell et al. 1994) using its three-dimensional variational assimilation (3DVAR) system is used to analyze the impact of the ZTD and meteorological observations. Details on the MM5 3DVAR system can be found in the NCAR/MMM 3DVAR web site (http://ww.mmm.ucar.edu/3dvar).

Fig. 3 shows the domain configuration used to simulate the meteorological situation under study. We set up three (2-way nested) domains with grid distance ranging from 54 km down to 6 km.

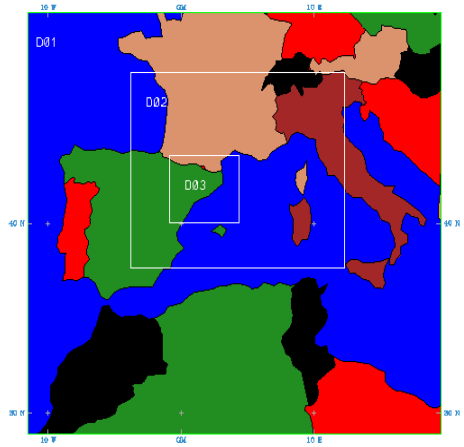

Fig. 3. Domain configuration for the model simulation.

Since the ZTD observations are not model variables, the development of a forward operator (and its linear and adjoint versions) to convert model variables into ZTD at the location of the GPS sites is needed.

We have used a bilinear interpolation on the horizontal to interpolate the ZTD model values from the grid points of the domain to the location of the GPS sites.

A more accurate treatment is needed for the interpolation in the vertical because the station pressure (and consequently the ZHD) strongly depends on the height of the GPS sites and these are not corrected modeled by MM5 due to the topography resolution used. (See, e.g., Cucurull et al. 2002).

The method used to interpolate the model surface pressure to the location of the GPS station is based on the methodology developed by Pondeca and Zou (2001). Depending on the elevation of the GPS site with respect to the model surface, three different cases are considered:

- Station elevation above model topography: the surface pressure of the GPS site is found from the two sigma levels above and below the station. The interpolation assumes an exponential

dependence for pressure as a funcion of height.

- Station elevation lower than the model topography: the ground pressure at the GPS site is interpolated from the sea level pressure and the model ground pressure.
- Station elevation coincides with the model topography: the surface pressure at the ground-based receiver is provided by the model pressure.

In the model simulation, initial and boundary conditions are provided by the AVN model.

Fig. 4 shows the temperature analysis at 00 UTC December 14th for the finest domain when the 3DVAR technique is used. In this case, only meteorological data is assimilated into the model.

When comparing to the results obtained by applying the objective analysis scheme (Fig. 5), the 3DVAR analysis shows a decrease of the temperature field in the northern part of the domain. These results from the 3DVAR analysis agree better with the observations available over the same area and at the same time (Fig 6).

The assimilation of the ZTD measurements along with the WMO observations are also found to have an impact on the model forecasts.

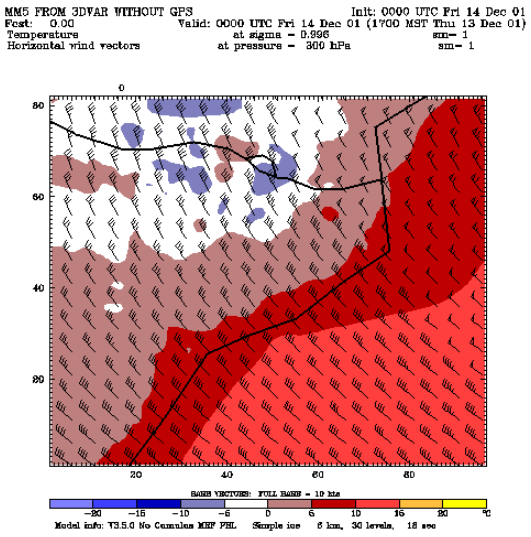

Fig. 4. 3DVAR analysis of the temperature field for December 14th 2001 at 00 UTC.

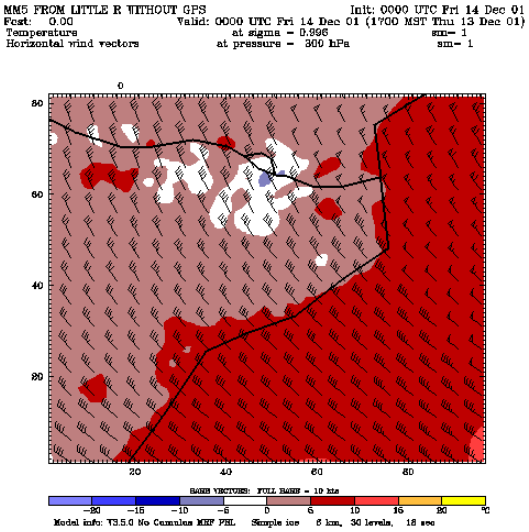

Fig. 5. Objective analysis of the temperature field for December 14th 2001 at 00 UTC .

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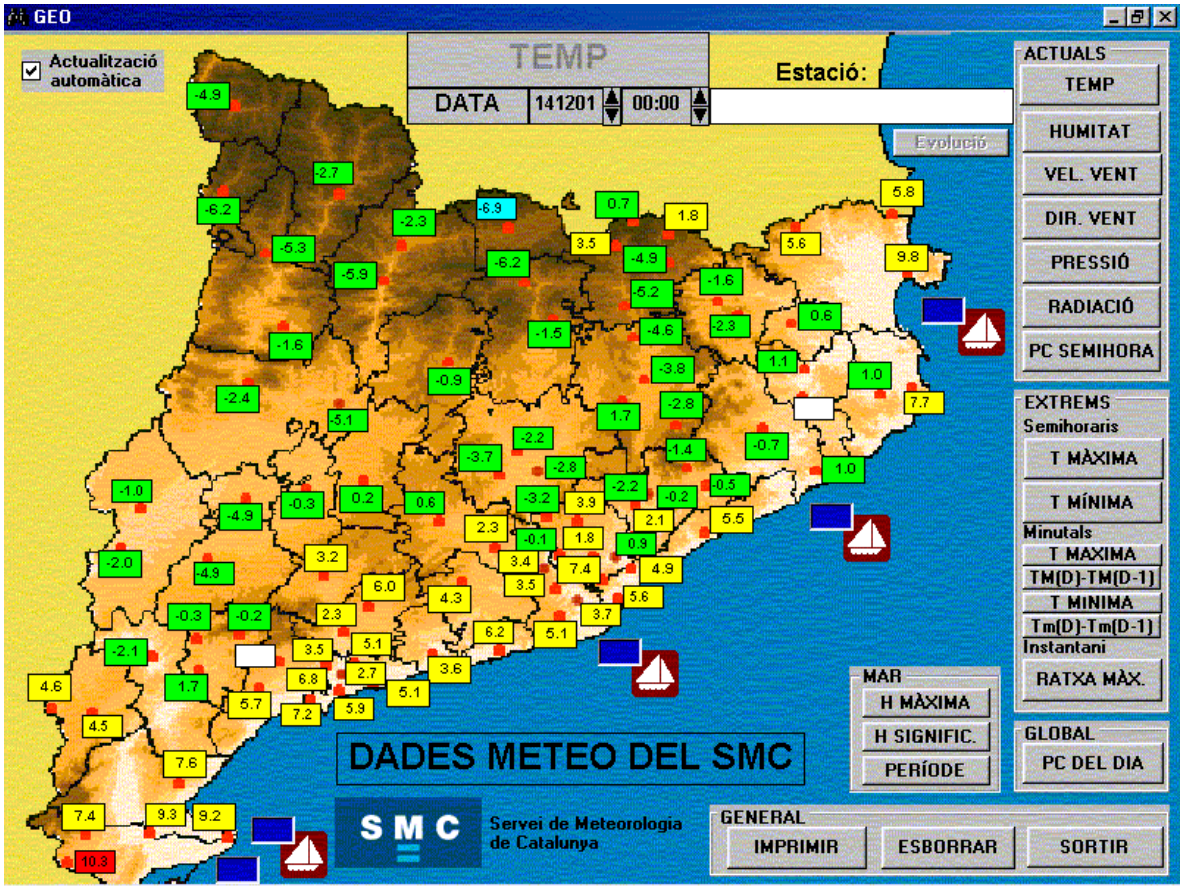

Fig. 6. Observations of the temperature variable for December 14th 2001. The geographical location of the data covers from around 0.3W to 3.1W and from 40.5N to 42.7N.