P3.17 EXPERIMENTAL AND NUMERICAL ANALYSIS OF A MISTRAL CASE DURING MAP EXPERIMENT IN RELATION WITH THE PV BANNER OBSERVATION.

Aimé Druilhet[1] , Bruno Bénech[1] , Jean Luc Caccia[2] , Evelyne Richard[1], Bernard Campistron[1], Cyrill Flamant[3] , Marie Lothon[1] ,Frédérique Saï d[1], Cyril Caminade[1] and Vincent Guénard[2]
[1] Laboratoire d'Aérologie, UMR 5560 CNRS/UPS, 31400 Toulouse; France
[2] LSEET, Toulon, France
[3] SA, Paris, France

1. INTRODUCTION

During MAP IOP 15, a strong Mistral case has been well investigated experimentally and documented with the high resolution numerical simulations of Meso-nh model. Two UHF profilers, located respectively near Berre pond and Toulon, fulfilled the temporal evolution of the Mistral event, up to 3000 m height, in the two locations. On the 6 November, the three aircraft (Merlin, ARAT and P3), followed, at different levels above the Ligurian sea, an axis roughly perpendicular to the Mistral wind direction.

This study presents: (i) the time evolution of the Mistral wind structure as observed in St Chamas and Toulon by UHF profiler and its comparison with Meso-nh simulations, (ii) the spatial evolution of the Mistral wind in the vertical plan described by the aircraft compared to numerical simulation and (iii) the description of the PV as seen both by the model and by the aircraft data.

2. TIME EVOLUTION

The Mistral is a violent low-tropospheric northerly wind blowing along the Rhône valley. Such a wind regime is very well known in the South-Eastern France area, since it is a dominant meso-scale dynamical process during fall and spring. A well-marked Mistral occurred during the first part of IOP15, that is, from days 99/11/06 to 99/11/07. The time evolution of the wind profiles observed by the UHF profiler near the valley exit (location given in figure 2), at Saint-Chamas, north from Marseilles, is shown on Fig.1(upper). The beginning of the Mistral event appears at 0400 UT the 6 November and affects all the low troposphere between the ground and 3000 m. It is well predicted by Meso-nh numerical simulation. The wind direction is southward; a maximum wind speed of 35-40 m/s is observed at 1200 m ASL above Saint Chamas, the 6 November evening. The end of the Mistral event appears at 0400 UT the 7 November at 3000 m height. At low level, the Mistral wind lasts until the night of the 07 November. According to the model, the end of the Mistral wind occurs after 1800 UT, first in altitude and then near the ground. The flights took place during the middle of the 6 November, where the agreement between model and radar data are reasonably good. A comparison also made with the UHF radar located in Toulon south of the Alps chain gives similar results as reported by Caccia et al , 2001).

Correspondig author address : Benech B., Laboratoire d'Aérologie, UMR 5560 CNRS/UPS, 31400 Toulouse; France; email: benb@aero.obs-mip.fr

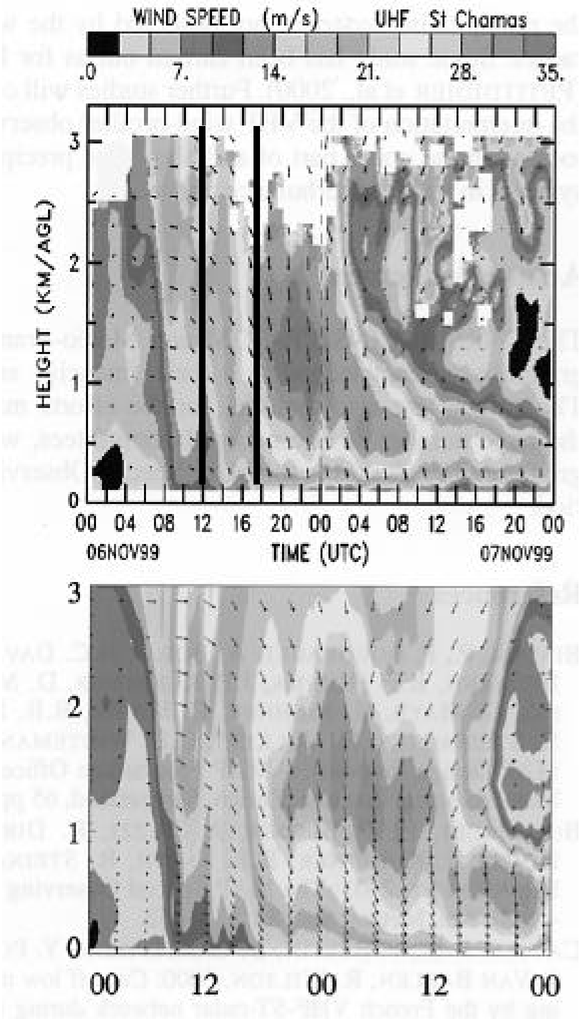


Figure 1: At the location of Saint Chamas, the radar (upper) and meso-NH model (lower) wind profiles are represented with grey colour scale with superimposed arrows indicating the wind direction, during the 6 and 7 November 1999. The same wind speed scale, i.e. 0-35 m/s, time scale and altitude range, i.e. 0-3 km-AGL, are used in the two figures. The vertical lines, on upper figure, represents the flight time of the tree aircraft.

In conclusion, as shown in figure 1, aircraft flew when the Mistral was well established, adapted to the analysis of its mean and turbulent structure and the estimation of the Alps wake generating the PV banners.

3. SPATIAL EVOLUTION ABOVE THE MEDITERRANEAN SEA

The numerical simulation (8 km horizontal resolution) of the horizontal structure of the Mistral during the 6 November at 1500 TU, near the aircraft flight time, shows clearly the main characteristics of the Mistral wind, that is a strong channeling effect within the Rhone valley and a large divergence above the Mediterranean sea (figure 2). During this event, a convective area was located above the ligurian sea, with many convective clouds identified with the aircraft data and also correctly observed by Meso-nh. These convective clouds affect a part of the flight axis near the point A represented on figure 2 and modify the dynamic flow in this area which are not only linked to the Alps wake.

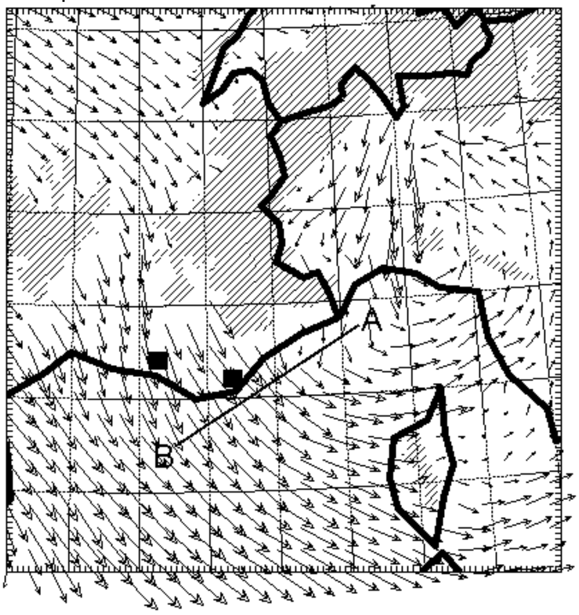


Figure 2: wind field at 800m height deduced from Meso-nh simulation the 6 November at 15 TU at the same time where is performed the aircraft flights. The black line located above the Mediterranean sea indicates the flight axis. The black squares indicate the location of the UHF profiler (St chamas at west, Toulon at east)

The flight track located near the French coast has been described at different levels with the three aircaft. The two french aircraft flew between 1300 and 1700 UT and described respectively the level 980 hPa and 900 hPa for the Merlin and 750 and 695 hPa for the ARAT. The P3 flew later between 1700 and 1800 TU at 800 hPa. A large horizontal pressure gradient is observed along the flight axis with a pressure increase of about 12 hPa from east to west. The flight axis is well located in the area where appears also a large horizontal gradient of winds presented in details in the following section.

4. MISTRAL STRUCTURE OBSERVED ALONG THE FLIGHT AXIS

The general features of the flights observed with the Merlin at the lower level, within the marine atmospheric boundary layer, are characterized by a strong wind reaching 58 kt near the point B as indicated in figure 2. These horizontal wind structure is also observed at the four other levels described by the three aircraft which seems also in accordance with the radar observations (figure 1).

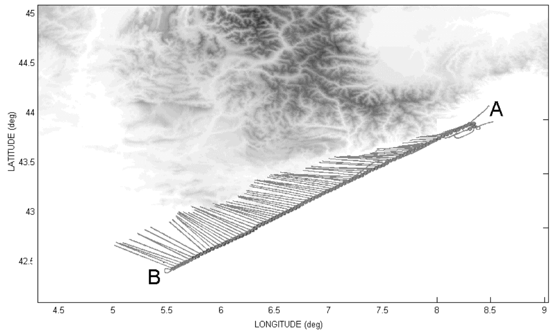


Figure 3: Evolution of the wind along the flight axis during the IOP 15 at 15 TU at 300 m height.

Figure 4 (next page) shows the evolution of the potential temperature, mixing ratio and horizontal wind along the flight axis between the points A (right) and B (left) and at the five levels flown by the aircraft. Figure 5 shows the same evolution along the flight axis and at the same levels deduced from Meso-nh simulations at 2 km horizontal resolution.

The large variations of the different parameters observed by the aircraft are in agreement with the numerical results, in particular the warming appearing into the marine boundary layer near the point B where the Mistral wind is strong. Concerning the wind intensity, the simulations underestimate the real wind speed of 2 to 3 ms^{-1}, and smooth it between the Mistral area and the convective area observed above the ligurian sea . The humidity variations are also correctly reproduced, in particular the increase of humidity near the level 800 hPa.

Concerning the turbulent momentum, the experimental data show moderate to high turbulence with in particular strong latent heat fluxes reaching 500 Wm^{-2} (figure 6). The simulated surface heat fluxes (continuous line on figure 6) seem to agree with the experimental data, and reproduce correctly the spatial evolution of the marine boundary layer which is submitted to large wind and strong surface heat fluxes in the west domain. The decrease of the surface heat fluxes in the East part of the domain is also well reproduced in the simulation. 10% of the differences of heat fluxes can be explained by the vertical divergence linked to the flight level of Merlin which is about 300m.

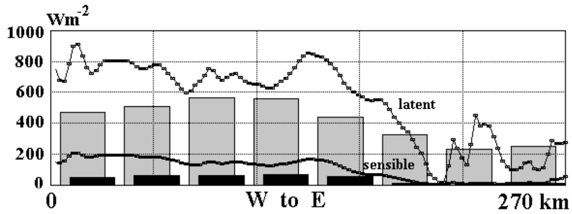
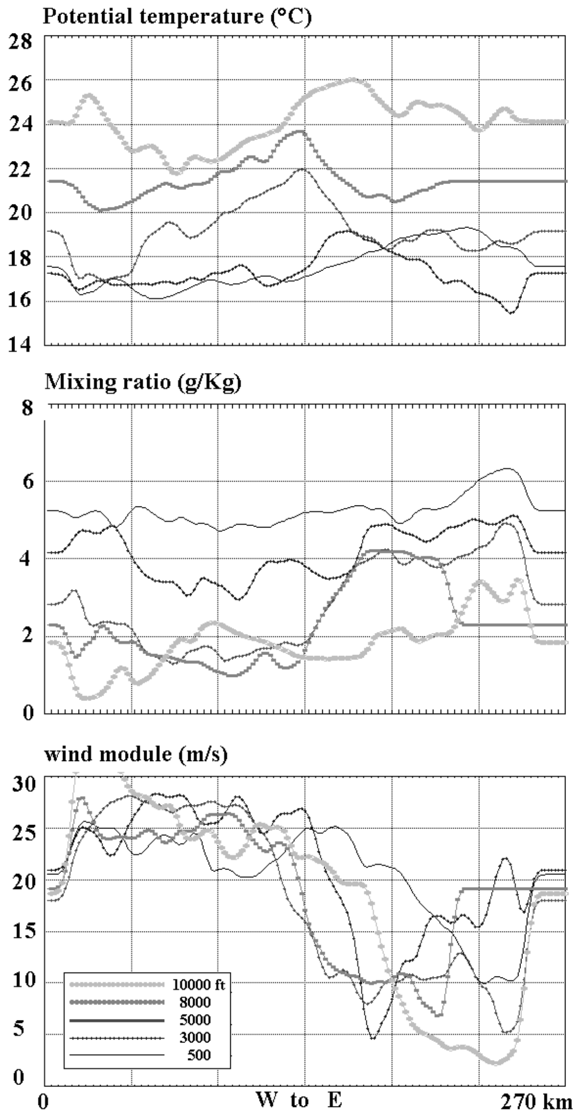


Figure 6: Evolution of the latent and sensible heat fluxes observed along the flight track by Merlin aircraft (rectangles) and calculated with Meso-nh model (lines).



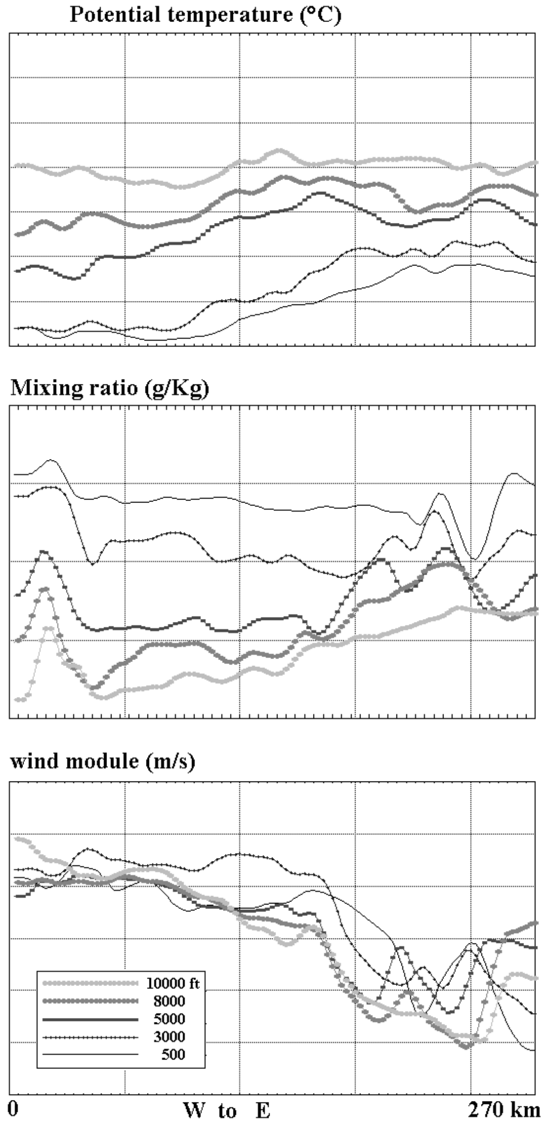


Figure 4: Evolution of the temperature, mixing ratio, wind intensity along the flight track at the five levels described by the three aircraft. The mean values along the flight track are also indicated.

Figure 5: same as Fig. 4 from the meso-NH numerical simulation, with the same scale for each parameter than in Fig. 4.

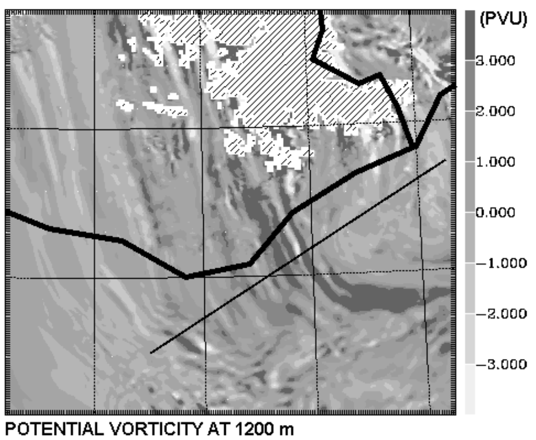


Figure 7: Potential vorticity field at 1200 m height (dashed line on figure 8). The black line represents the flight axis.

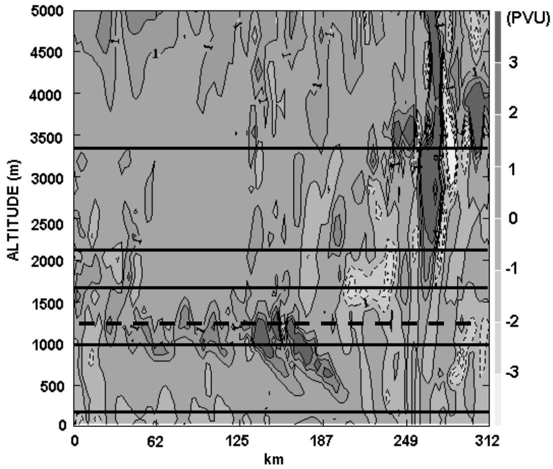


Figure 8: Vertical plan of potential vorticity along the flight axis. The dashed line represents the altitude of the horizontal plan given in figure 7. The continued line the altitude of the flight tracks of the three aircraft.

5. RELATION WITH THE PV BANNERS

One goal of our analysis is to diagnose the presence of PV banners downstream of the Alps from the aircraft data. As a first analysis, we use the Meso-nh simulations to detect the PV banners, and to describe the intensity of the potential vorticity observed in the vertical plan described by the three aircraft. Second, we evaluate the potential vorticity along the flight track with the model and third, we compute the terms of potential vorticity which are accessible by the aircraft data. Because the aircraft describe only a vertical plan, vorticity along the aircraft flights tracks can only be computed with a simplified relation taking into account only the vertical component (dv/dx-du/dy).

Figures 7 and 8 (previous page) present respectively the horizontal plan at 1200 m of PV and the vertical plan along the flight axis, deduced from the Meso-nh simulations. The intensity of the PV remains in general positive. It becomes sometimes negative along the flight axis, so that one pair of PV banners can be observed on this axis at 1200 m (fig 7). This level is the one where the PV fluctuates the most (figure 8). The large values at 3500 m near the point A are may be due to convective clouds. The axis described by the Merlin at 1000 m seems well located as regard this PV field. .

Figure 9 presents the evolution of the vertical potential vorticity component along the flight axis deduced from the aircraft data (upper) and Meso-nh simulations (lower). Low values are observed at the West part corresponding to Mistral, and large fluctuations appears in the east part.

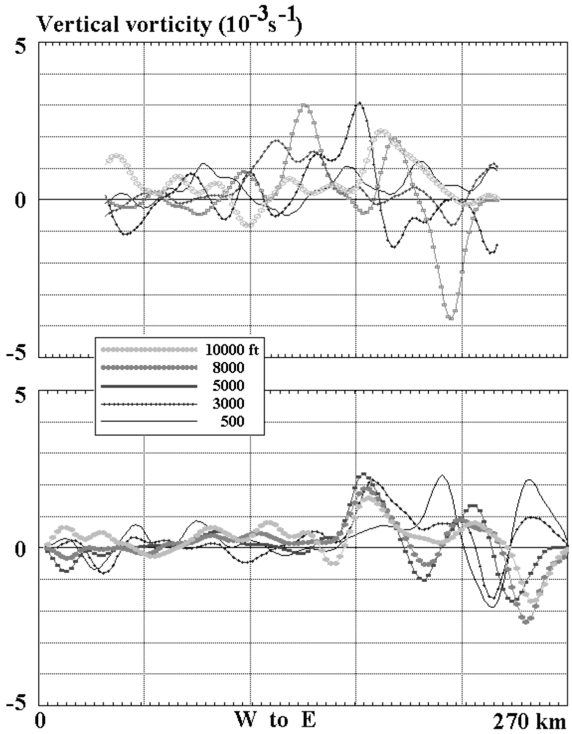


Figure 9: Component of vertical rotational at different altitude along the flight axis, calculated from (a) the aircraft data and (b) the numerical simulation.

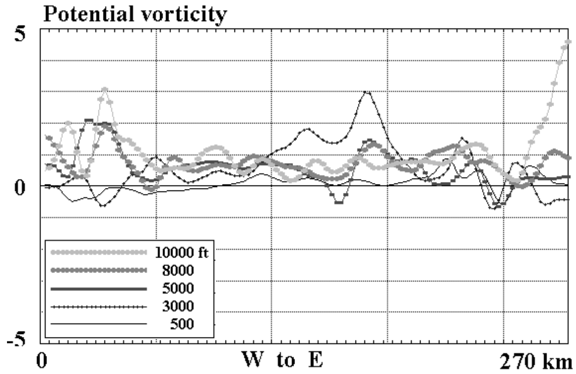


Figure 10: Total potential vorticity calculated along the flight axis with Meso-nh model.

The experimental and simulated data are in average positive and relatively well correlated despite the fact that the wind intensity decreases behind the Alps more westerly in the experimental measurements than in the simulated data.

The figure 10 gives the total potential vorticity which is positive with local variations not in relation with the vertical components presented figure 9, in particular near the point B. In our case, the potential vorticity is not dependant of the vertical component only as it was observed in the Bora case (Grubisic, 2000).

6. CONCLUSION

We have presented the Mistral case of the IOP15 observed by UHF radar, aircraft and Meso-nh simulations. This case is characterized by a strong wind in the Rhône valley and Mediterranean sea reaching 3000 m the 6 November and decreasing in height the 7 November. The aircraft flight occured during the phase of well established Mistral. The simulations seems in accordance with the mean experimental data with an underestimation of the wind intensity. The surface fluxes are also correctly simulated in particular the latent heat fluxes.

The diagnose of the PV with aircraft data seems difficult and well linked with the precision to evaluate the terms of first order derivation from the wind data. The evaluation of the vertical component of the vorticity along the flight axis gives a mean value in agreement for experimental and simulated data. The total PV showed figure 10, seems to indicate that the vertical component is not sufficient to explain the PV intensity.

7. REFERENCES

Grubisic V., 2000: Bora Driven PV banners on the Adriatic: Preliminary results, MAP newsletter, 13.

Caccia et al, 2001: The french ST-radar network during MAP: Observational and scientific aspects. Meteorologische Zeitschrift, 10, 6, 469-478.

ACKNOWLEDGMENTS

The authors acknowledge Météo-France/CNRM for operating the Merlin IV aircraft during MAP experiment, as well as EDF for their contribution to the UHF measurements.