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CHARACTERIZATION OF THE 28 JUNE 2001 MISTRAL EVENT DURING THE ESCOMPTE FIELD EXPERIMENT

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1*. INTRODUCTION

When a northerly flow characterized by a low Froude number impinges on the Alpine range, it is deflected west and accelerated by the Coriolis force as well as the pressure build-up on the northern edge of the range. In addition to these large-scale forcings, the flow experiences channelling in the Rhône valley between the Massif Central and the Alps which leads substantial acceleration (Pettre 1982, Drobinski et al. 2001a) (see Fig. 1). The acceleration gives birth to a local wind called the Mistral. The role of orographic forcing and blocking induced by the Alpine range and channelling in the Rhône valley are prominent mechanisms leading to the onset of the Mistral.

One intriguing aspect of the Mistral is that it maintains its characteristics over large horizontal distances above the Mediterranean with a sharp wind shear line separating the Mistral from a sheltered area behind the Alps.

This violent wind is well known in France but has been inadequately explained up to now. Recent study by Flamant (2002) shows the impact of the Mistral on air-sea exchanges which drive both atmospheric and oceanic circulations and mesoscale turbulent heat flux fields over coastal waters.

In this paper, the analysis focuses on the 28 June 2001 Mistral event which has been documented in the Fos-Berre/Marseille region (south french coast) in the framework of the ESCOMPTE program (http://medias.obs-mip.fr/escompte). An important instrumental device has been unfold in a range of about 200 km around Marseille, using lidars, radars, a GPS network, rawinsondes stations... In particular, a ground-based Doppler lidar (Drobinski et al. 2001b) and the French-German airborne Doppler lidar WIND (Werner et al. 2001), developed by CNRS, CNES and DLR and first validated during the MAP experiment (Reitebuch et al. 2001), have been used to investigate the sea breeze along the South French coast at Marseille. This instrumentation allows to make the retrieval of the three-dimensional wind field as a function of time. The combination of these instruments provide complementary data which are essential to determine the different parameters (return flow height, land-sea breeze penetration distance,...), which characterize the sea breeze phenomenon.

These data provide detailed information on (1) the channeling region by the Rhone valley; (2) a zone of strong deceleration at the land-sea transition where the Mistral vertical extent decreased and (3) the region over the Mediterranean where the Mistral speed increased and deepened again. The across-Mistral axis leg evidences the lateral extent of the Mistral and the shape of the smooth transition between the jet and the the sheltered zone. The structural characteristics in time and space are discussed with respect to the vertical stratification (temperature, humidity,...) and intensity of the turbulence.

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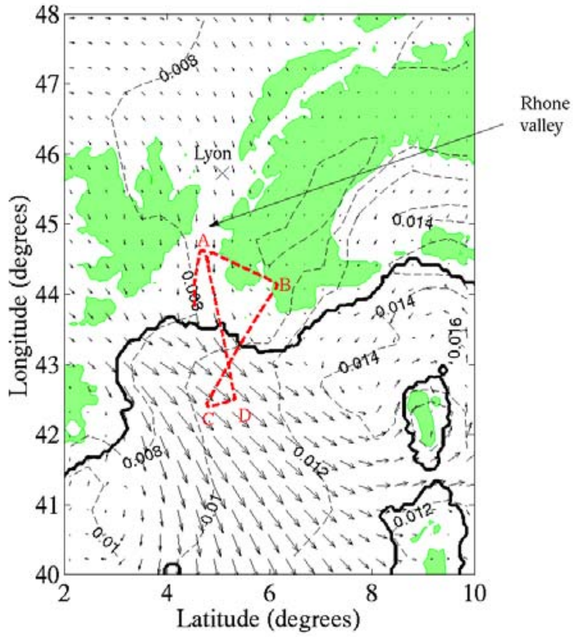

<u>Figure 1</u>: Topography of the ESCOMPTE target area. The arrows represent the ECMWF surface wind vectors and the dashed isocontours indicate the specific humidity (kg/kg). The shaded area indicate the zones where the topography is higher than 700 m. Thick dashed lines follow the aircraft trajectory made 28 June 2001 from 0930 to 1045 UTC.

2. SYNOPTIC SCALE CONDITIONS

The 28 June 2001 Mistral (and Tramontane) event was intimately linked to the existence of an upper-level trough (and its associated cold front) progressing towards the Alps (not show) and the presence of a shallow vortex over the Tyrrhenian Sea (between Sardinia and Continental Italy) (Fig. 1) similar to the situation investigated by Flamant (2002).

3. UPSTREAM CONDITIONS

The 1200 UTC vertical sounding in Lyon shows that on the windward side, the Rhône valley is filled with a stably stratified, relatively cool air mass (Fig. 2). The stability is concentrated in an inversion layer around 1600 m. Figure 2 displays a north-westerly upper-level flow which veers to the north below the inversion evidencing blocking by the barrier and channelling in the valley. The Mistral jet fills the planetary boundary layer (PBL) depth.

A review by Smith (1989) have shown from linear theory, that the splitting of the flow around mountains occur when a stagnation point exists and when the Froude number, $Fr = U(gh\Delta\theta/\theta)^{-1/2}$ (U is the mean upstream wind, θ a representative potential temperature and $\Delta\theta$ the change in potential temperature from near the surface to above the ridge height h upwind of the ridge) is sufficiently small. Mesoscale observations by Manins and Sawford (1982) suggest that below Fr = 1.6 blocking occurs. In the present case, on 28 June 2001, we find U = 7 m s^{-1}, θ = 296 K and $\Delta\theta/\theta$ = 9. These values lead to Fr = 0.25 for an orography height h = 2500 m. Laboratory experiments (Hunt and Snyder, 1980) lead to the derivation of an equation to estimate the height z_s of the splitting point for low Froude number flows: $z_s = h(1-2Fr)$. On 28 June 2001 at 1200UTC, the values of Fr and h give z_s = 1250 m which is in agreement with the observations shown in Fig. 2.

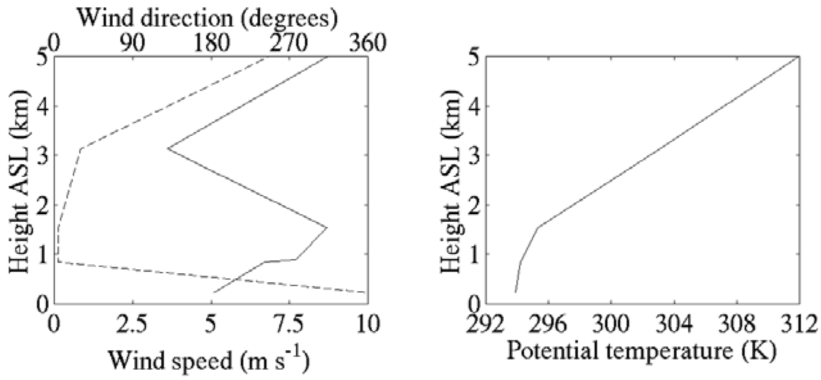

Figure 2: Upstream 1200 UTC sounding in Lyon (see Fig. 1). Left panel displays the wind speed (solid line) and direction (dashed line). Right panel displays the vertical profile of potential temperature.

4. MISTRAL FLOW AT THE RHONE VALLEY EXIT

The aircraft, in which the airborne french-german Doppler lidar WIND has been emplaned, flew over the region to be documented on 28 June from approximately 0930 to 1045 UTC. The track flown on 28 June is represented in Fig. 1. The aircraft has investigated a part of the Rhone and Durance valleys. The wind has been measured with an horizontal resolution of 4 km and a vertical one of 250 m.

Figure 3 displays the wind field measured along leg D-E in the Rhône valley (see Fig. 1, upper panel) between 1016 and 1041 UTC. Arrows indicate the horizontal wind direction as a function of height and the superimposed color map the wind strength. Observations clearly show the existence of a north-westerly synoptic wind blowing at about 10 m s^{-1}. In a 1000 m depth layer, the Mistral flow, confined within the PBL depth and experiencing the Rhône valley constriction, blows parallel to the valley axis with an intensity of about 25 m s^{-1} inland (down to 43.7°N). As the Mistral reaches the Rhône valley exist, it decelerates as the Rhône valley enlarges (15 m s^{-1} between 43.2°N and 43.7°N). Further investigation has to be conducted to analyze this abrupt transition with respect to the Tramontane case studied by Drobinski et al. (2001c) which displayed similar behaviour. Over the Mediterranean (up to 43.2°N), the Mistral accelerates. The horizontal wind field shown in Fig. 1 provides evidence of horizontal convergence over the sea (as the Tramontane and the Mistral flows merge) which results in an acceleration of the Mistral flow over the sea. Other processes such as the change of dynamical roughness associated with the land-sea transition could be responsible for accelerating the Mistral flow over the sea.

The wind field measured along leg B-C is displayed in Fig. 3 (lower panel). It evidences the core of the Mistral and the location of the zone of maximum shear that separates the mistral flow from the sheltered zone (43.1°N in Fig. 3, lower panel)..

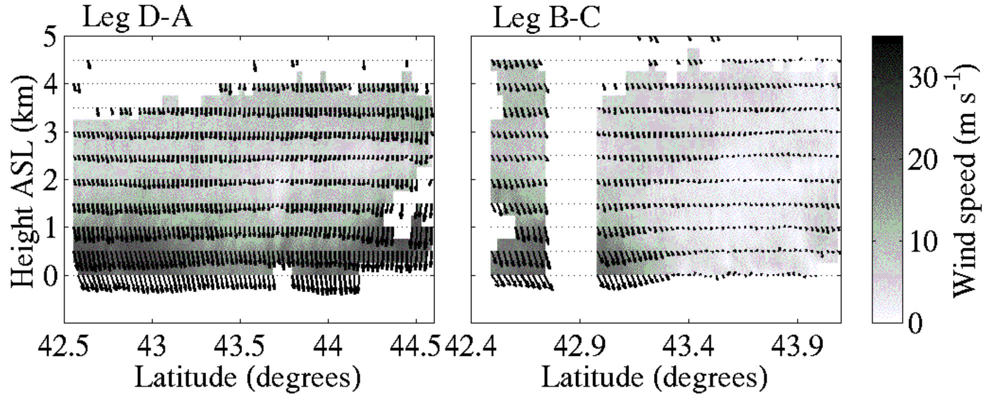

Figure 3: Wind field measured by the airborne Doppler lidar along the legs shown in Fig. 1.

Figure 4 displays the comparison between the surface winds measured by the airborne Doppler lidar WIND and those extracted from the ECMWF analyses. The transition between the Mistral and the sheltered area is well located in the ECMWF analyses whereas the ECMWF analyses underestimate the Mistral flow intensity and overestimate the wind rotation towards the east over the Mediterranean.

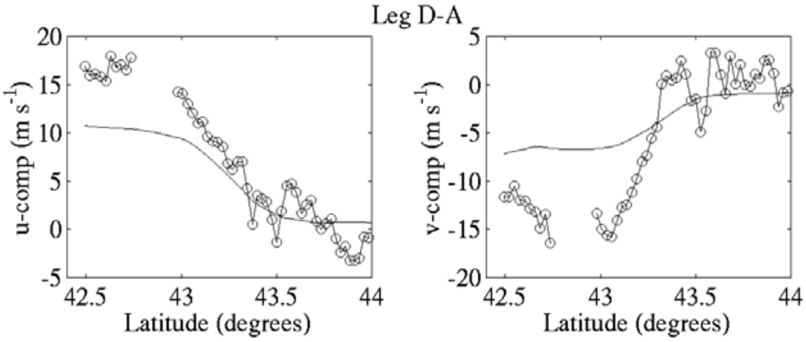

Figure 4: Comparison between ECMWF analyses (solid line) and WIND measurements (circles) of the zonal (left panel) and the meridional (right panels) surface winds for leg D-A (see Fig. 1).

5. CONCLUSION AND FUTURE PROSPECTS

The structure of the Mistral flow will be explored in more details through the use of the important network of local data and non-hydrostatic mesoscale numerical simulations. In fact, lots of questions need to be answered : can the location of the zone of maximum shear that separates the mistral flow from the sheltered zone be diagnosed beforehand? What drives the 3D structure of the Mistral flow offshore?

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