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NOCTURNAL CIRCULATIONS UNDER WEAK PRESSURE GRADIENTS IN THE ISLAND OF MALLORCA

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1 INTRODUCTION

To study the local nocturnal circulations under weak pressure gradient conditions a winter clear sky night over Mallorca Island is simulated. Mallorca is the largest island (90 km from SW to NE) of the Balearic archipelago situated in the western Mediterranean sea. It has two main mountain ranges, one at the north with a mean elevation of 800 m and the other one at the east, with mean elevation of 400 m; at the center of the Island there is an elevated area of an elevation of about 200 m (see Figure 1). Three main bassins are between those mountain ranges: Palma at the southwest, Alcudia at the northeast and Campos at the south.

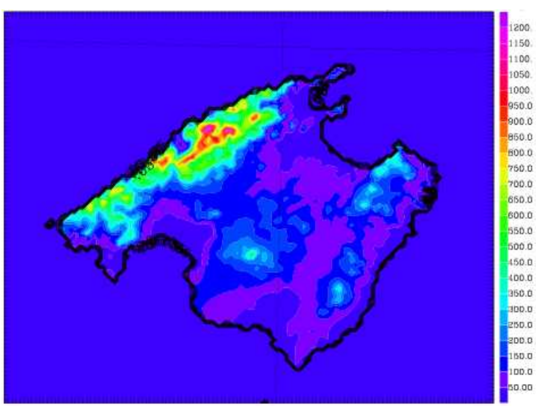

Figure 1: Inner domain and orography of the Island.

This study is focussed on the Palma bassin (Figure 5); vertical and horizontal cross-sections are used to identify the local effects such as the katabatic winds. The great variability of the boundary layer at very short horizontal scales will be shown. Finally, to evaluate the performance of the model for this case study, the surface temperature field is compared to the field provided by a NOAA satellite image and to the available automatic surface weather stations.

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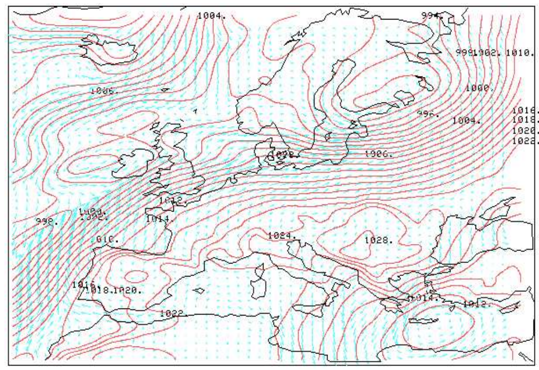

Figure 2: Synoptical situation at the beginning of the simulation: 5th January 1999 at 12UTC.

2 SETUP OF THE SIMULATION

The run has been done with the Meso-NH model (Lafore et al., 1998; Cuxart et al, 2000) with 2 nested domains: the largest has 5 km resolution and covers all the Balearic Islands whereas the smallest has 1 km resolution and it is centered in the Mallorca Island (see Figure 1). The vertical resolution is 3 m near the ground and a stretching factor is applied which produces 8 m resolution at Z=500 m until the top of the domain where the resolution is 600 m.

The simulation is initialized by the analysis of the European Center for Medium-range Weather Forecasts (ECMWF) and it is refreshed each 6 hours. It goes from 18UTC (18h local solar time) on January 5th, 1999 to the dawn of the next day. The pressure gradients were weak with SE winds (see the synoptical situation at 12UTC on January 5th, 1999 in Figure 2) and the sky was clear. The night was 15 hour-long allowing the nocturnal local circulations to develop completely.

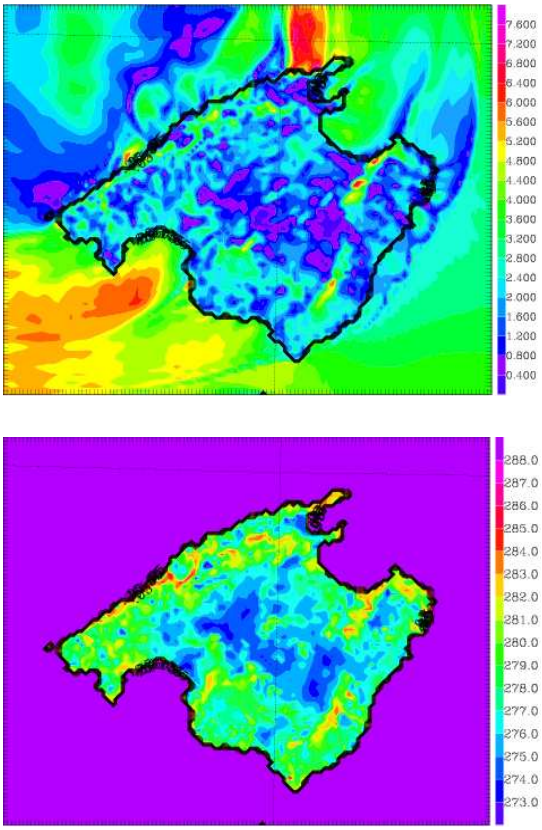

Figure 3: Module of the wind (top) in ms^{-1} and surface radiative temperature in K (bottom) near the surface (10 m) at 04UTC.

3 GENERAL DESCRIPTION OF THE FLOW

As the night advances, the air near the ground cools down, specially in the valleys, that have gentle slopes towards the sea. The air flows out of the Island specially through the centers of the bassins, generating wind maxima near the coast up to 7 m s^{-1} at 04UTC, whereas the wind are almost calmed in the center of the Island (Figure 3). The return currents take place at a height of about 700 m, as it will be shown later. The radiative temperature patterns follow the orography and the air is colder in the valleys than in the higher levels. At a height of 1000 m, there is no hint of the presence of the Island except for the effects of the main mountain range on the mean flow (Figure 4).

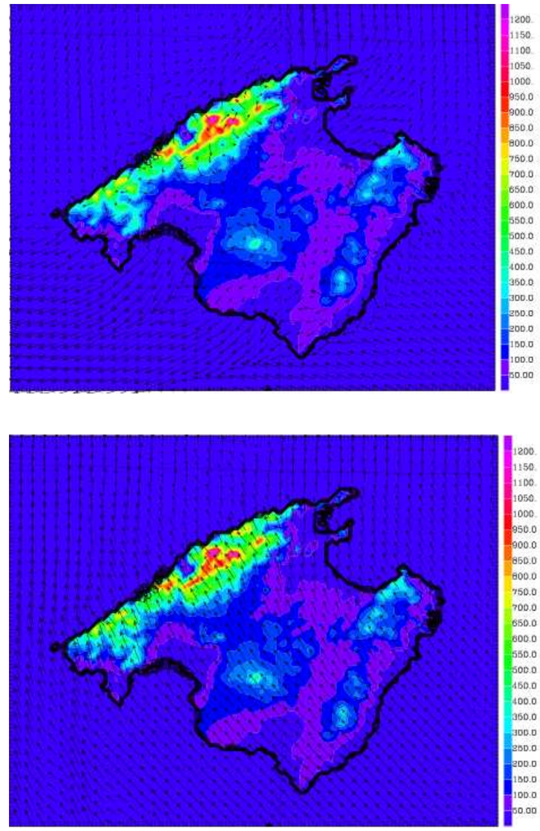

Figure 4: Wind direction (04UTC) at 10 m (top) and 1000 m (bottom). There is one arrow each 3 points of the domain and in colours, the orography.

4 STUDY OF THE PALMA BASSIN

The Palma bassin (Figure 5) has been chosen to study the local effects since it is the bassin where they are more significant. The city of Palma is located at the coast and the airport and Indioteria correspond to two suburban locations distant 7 km each other, at the east and the north of the town respectively. Their locations are shown in Figure 5, as well as the selected vertical cross-sections that will be shown in Figures 6 and 7 to study the vertical structures. The differences that exist between two points -distant only 7 km in the center of the same bassin- will show that the mesoscale effects related to the orography produce important changes in the respective surface and profile measurements.

When the transversal section is inspected (Figure 6), it can be seen that close to the limit of the bassin with the sea (where the city of Palma is), the

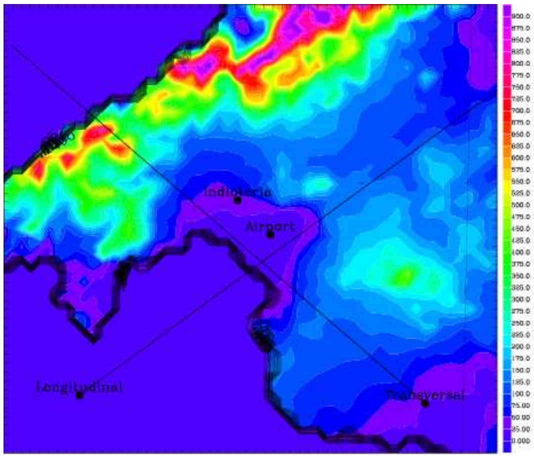

Figure 5: Longitudinal and transversal vertical cross-sections displayed in figures 6 and 7. The Airport and Indioteria are two points where vertical profiles are taken. The city of Palma is located inside this bassin near the coast, and the Airport and Indioteria correspond to the outskirts.

module of the wind is maximum near the ground and comes from the north, flowing out to the sea as illustrated in Figure 4. The wind gradually veers towards southeast with height and reaches this synoptic direction at 700 m. However, the wind speed varies significantly with height, with the maximum of 5 m s^{-1} at low levels (up to 100 m) from the north and a secondary maximum of 4 m s^{-1} from the northeast at 300 m and the southeastern return current of 6 m s^{-1} at 700 m.

Similar results are found for the longitudinal vertical cross-sections (Figure 7). The Palma bassin is located in the left side of the Figure 7 whereas the right side corresponds to the Alcudia bassin, located in the north-east bay (Figure 1). Near the ground, the maxima of the wind are located above the sea in front of the bassins due to the air outflow. However, in a large area at the center of the Island there is a minimum of the wind speed; in this area the air diverges to the bassins at the north and the south. The convergence of the orographically generated low level winds is larger in the Palma bassin due to its more closed configuration giving stronger outflow winds.

The vertical profiles for the wind module and direction, the temperature and the turbulence kinetic energy are shown in Figure 8 for the two selected locations within the Palma bassin: the airport and Indioteria. Indioteria has a very low (the

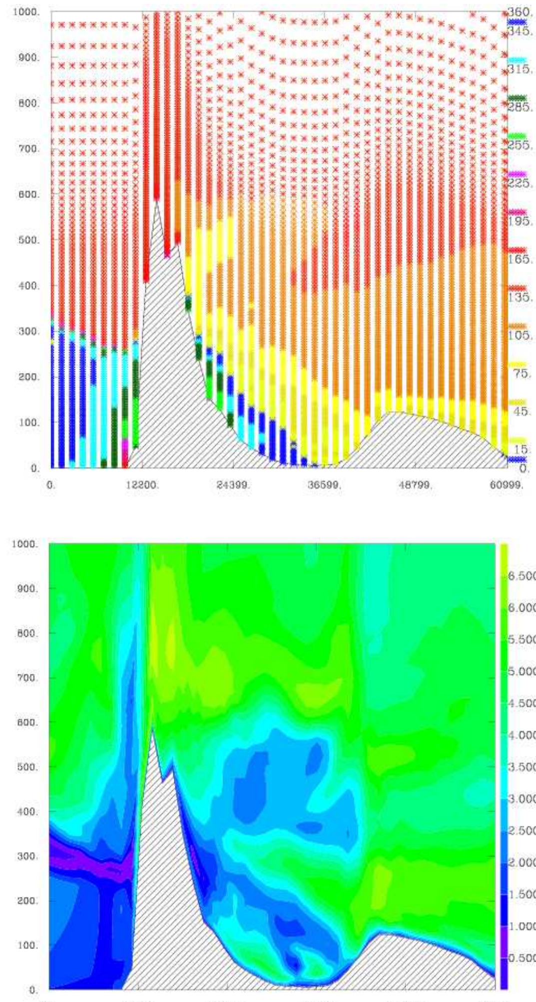

Figure 6: Transversal vertical cross-section at 04UTC. Top: Wind direction in degrees (north is 0 °); Bottom: module of the wind in m s^{-1}.

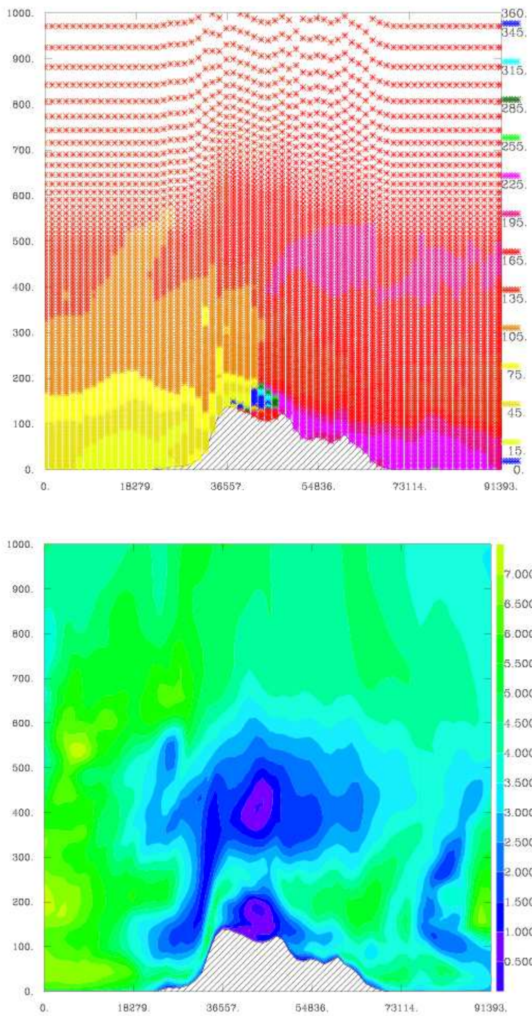

Figure 7: Same as Figure 6 for the longitudinal vertical cross-section.

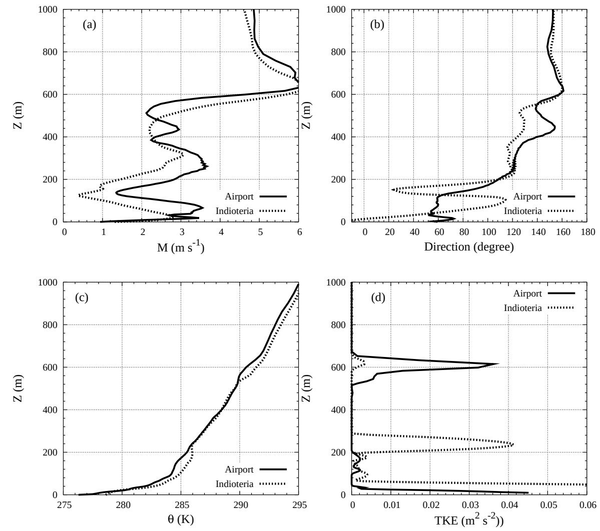

Figure 8: Vertical profiles at 04UTC of (a) wind speed, (b) direction, (c) potential temperature and (d) turbulence kinetic energy at the Palma Airport and at Indioteria.

maximum at a height of 10 m) northern low-level jet (LLJ) corresponding to a local gravity current and two other maxima at 300 m (120 °, 3 m s^{-1}) and at 650 m (160 °, 6 m s^{-1}). These structures can be related to a katabatic flow coming from the mountain at the center of the Island (the first) and to the return flow above. At the airport, the lower maximum is also very close to the ground but it comes from 70 °, the direction of the nearby mountain, and the above features are similar. The stratification is stronger at the airport and the first level temperatures differ as much as 3 K. At Indioteria there is a litlle turbulence near the ground - maybe associated to the local gravity current- that prevents a too strong cooling, where at the airport the turbulence is negligible. Hints of upper turbulence are given by the model close to the upper wind maxima, but none is significant.

5 VERIFICATION

Verifying a high-resolution mesoscale simulation is a very difficult task. The comparison for two different points in the Palma bassin where automatic surface weather stations are available shows that point to point comparison is extremely sensitive to the very small-scale orographical features. For instance at the airport the temperature sensor is located in a small topographic depression of less

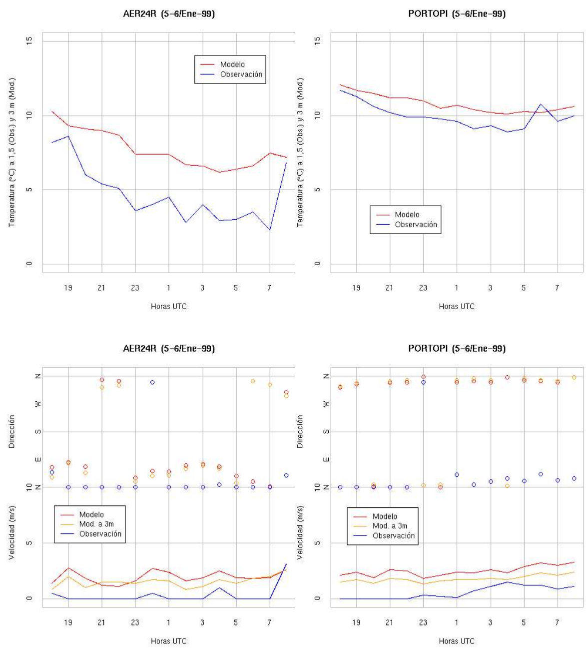

Figure 9: Temperature and module of the wind time series obtained by the model and those observed by automatic surface weather stations.

than 1 km of diameter that the model cannot see and therefore, the temperature is overestimated in that point. For another point in the Palma harbour the error in the temperature is much smaller. The wind direction is better captured in general and the winds are slightly overestimated.

If a global verification is aimed to, the satellital information is a possible issue. In Figure 10 the radiative surface temperature as seen by NOAA at 04 UTC (the same time that the model output in Figure 3) is shown. The cold and warm areas approximately match, specially the top of the mountain ranges (warm) and the cold areas in the center of the Island. It is clear that both fields can be compared and several conclusions might be reached once objective methods are developed.

6 CONCLUSIONS

The Island, of a characteristic size of 90 km, is able to generate important low-level local circulations during the night related to its mountainous configuration. The outflows over the sea can reach values up to 7 m s^{-1} at some spots and the return circulations are at heights of about 700 m.

Within one single bassin of a characteristic size

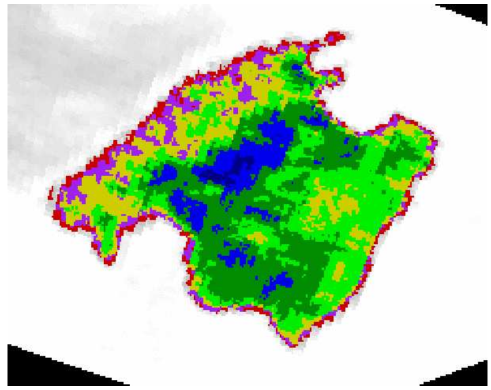

Figure 10: Surface radiative temperature at 04UTC obtained from a NOAA image.

of 25 km -all limited by mountain ranges except the Palma bay- the local circulations are very different depending on the location inside the valley. Points distant only 7 km may have differences of 3 K in the temperature and 70 ° in the wind direction due only to the low level wind patterns.

The point verification of the simulation with the weather stations is difficult due to the influence of the very small scale topographic features affecting the measurements. To overcome this issue the use of satellite images is suggested.

References

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