Slope and Valley flows at the Cerdanya valley in the Pyrenees

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(1) INTRODUCTION

The **Cerdanya valley** is the largest of the Pyrenees and one of the widest in Europe. Its distinct NE-SW orientation stands out among the rest of the valleys, generally oriented in the N-S direction on both sides of the range. In order to get a **preliminary characterization of local circulations** in view of future experimental campaigns, a **four-year statistical study** is performed using data from six automatic weather stations (AWS) belonging to the meteorological services of France, Spain and Catalonia (2). In addition, a 48-hour case is selected for an analysis in depth, combining observational data, satellite information and a **high-resolution simulation** for the valley (3).

(1.1) VALLEY DESCRIPTION

The Cerdanya valley is a graben 35 km long and 15 km wide, bounded to the north by the main axis of the Pyrenees (peaks above 2900 m asl(*)) and to the south by the Cadí mountain range (maximum height 2648 m asl). Valley bottom (1000 m asl) is covered essentially by pastures, with forests of conifers over the southern slopes and pastures with trees covering the less steep northern side. Several smaller tributary valleys oriented in the N-S direction are distributed around the main valley.

(*)Above sea level.

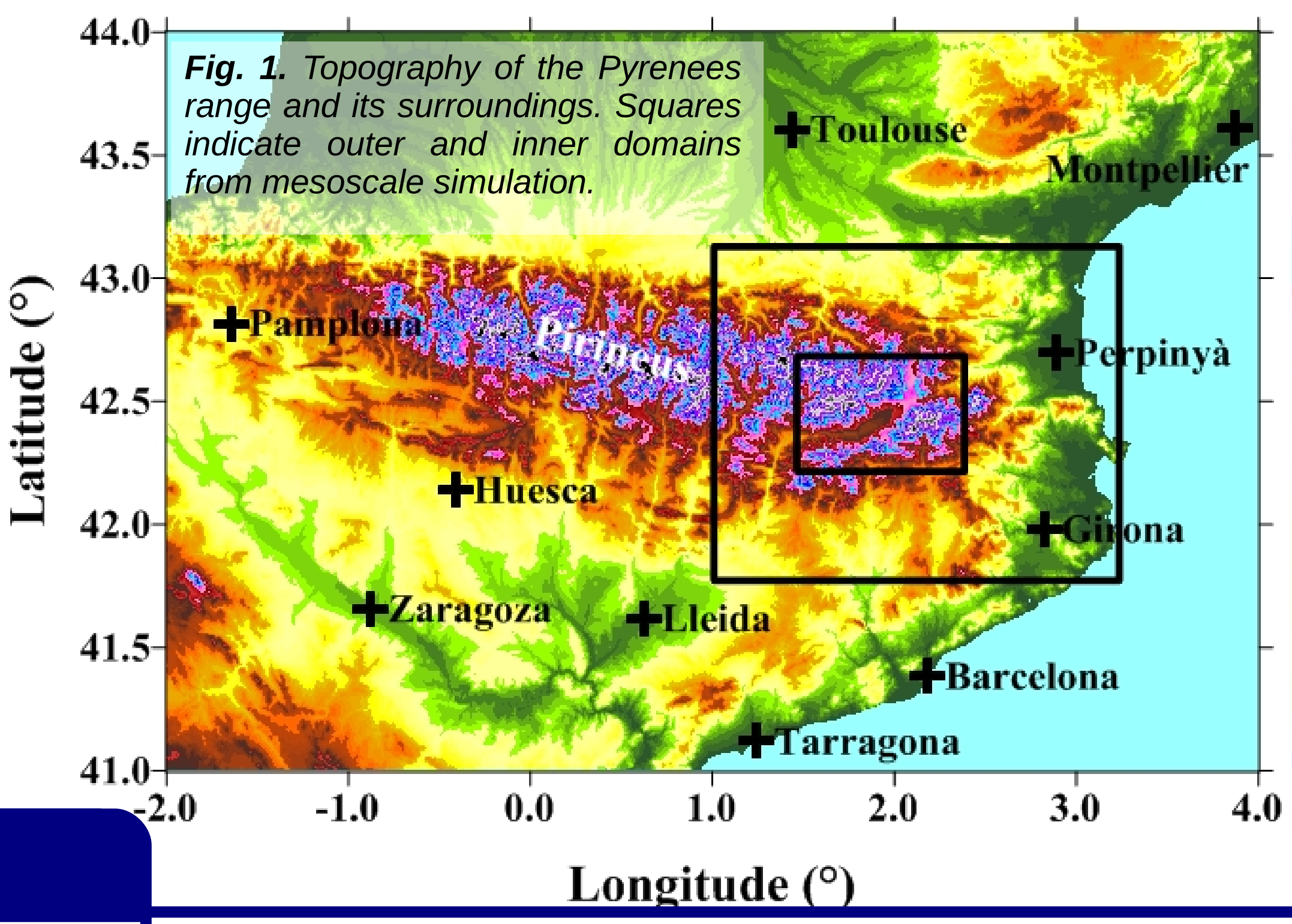

Fig. 1. *Topography of the Pyrenees range and its surroundings. Squares indicate outer and inner domains from mesoscale simulation.*

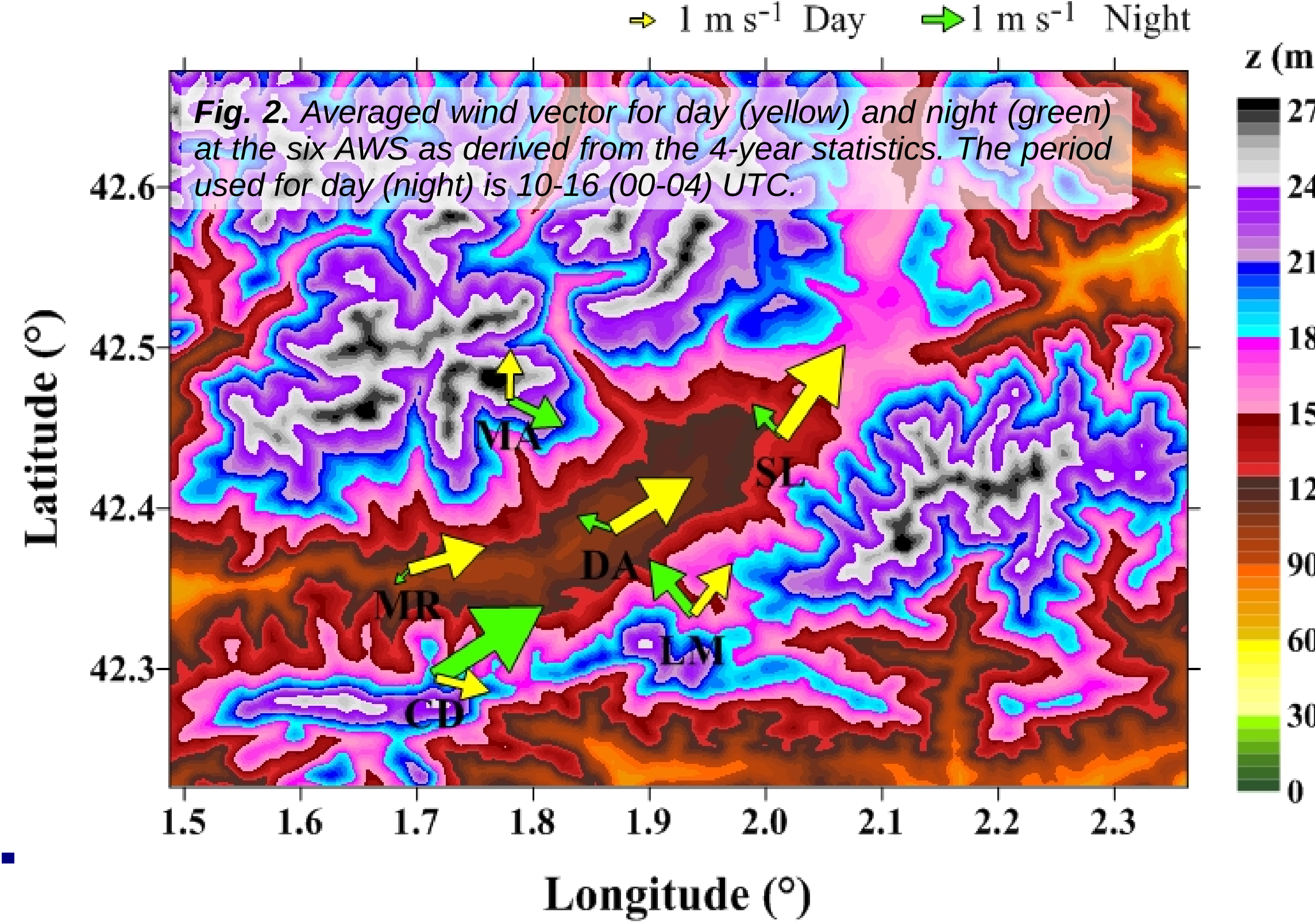

Fig. 2. *Averaged wind vector for day (yellow) and night (green) at the six AWS as derived from the 4-year statistics. The period used for day (night) is 10-16 (00-04) UTC.*

(2) OBSERVATIONS

AWS at DA.

Period: 01/09/2010 — 31/08/2014

Source: 6 AWS (fig 2):

- ✓ 3 AWS along the main valley axis: Martinet (**MR**), Das (**DA**) and Santa Llocaia (**SL**).
- ✓ 1 AWS at the upper part of a tributary valley (south-east of DA): La Molina (**LM**).
- ✓ 2 AWS at valley crests: Cadí Nord (**CN**) and Malniu (**ML**).

Variables: time series of temperature (*T*), relative humidity (*RH*) at 1.5 m height, wind speed (*WS*) and wind direction (*WD*) at 10 m height (6 m for ML) + insolation (*Q*) at DA.

(2.1) SELECTION OF CASES WITH PREVAILING LOCAL CIRCULATIONS

Three parameters applied to DA time series allow to select those cases with clear skies and weak synoptic pressure gradients (Martinez et al., 2008) that favour local circulations within the valley. Indexes' thresholds have been adapted to valley dynamics. Only days from **March to October** are considered:

Insolation deficit index:	Humidity index:	Mean-nocturnal wind velocity:
$$Q_d=\frac{Q_{th}-Q_e}{Q_{th}}\leq 0.3$$	$$HUM=\frac{RH_d-RH_s}{RH_d}\geq 0.28$$	$$V_{na}=\sum_{i=t}^{t+n}\frac{v_i}{n}\leq 2\ m\ s^{-1}$$
Q_{th}: Daily-mean theoretical insolation. Q_e: Daily-mean measured insolation.	RH_d: Daily-mean relative humidity. RH_s: Average of the relative humidity during daylight.	

The filtered dataset contains **163 days** from a total of 980 (17%).

(2.2) STATISTICAL VALLEY CIRCULATIONS

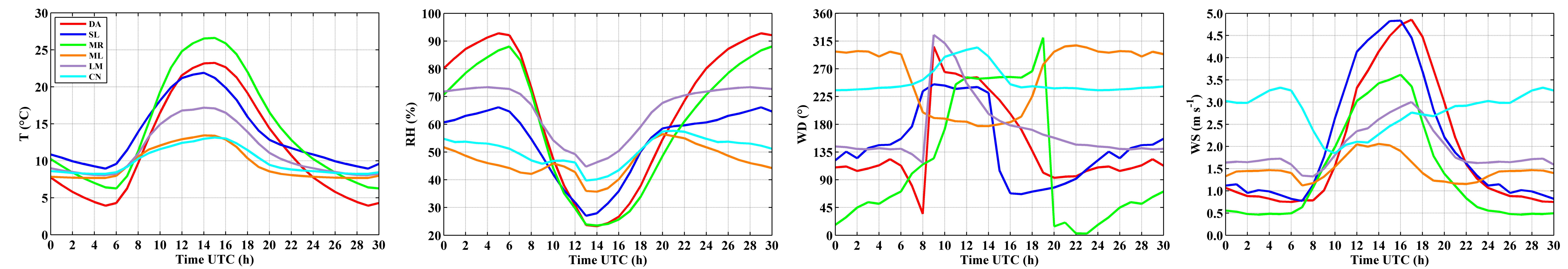

Fig. 3. *Daily cycle of the average temperature, relative humidity, wind direction and speed measured at the six AWS for the selected 163 days. The hours 0-6 UTC have been added again after 24 UTC for better interpretation of nocturnal dynamics.*

- ✓ Statistical data show a valley regime with a diurnal cycle within the Cerdanya valley.
- ✓ Large amplitudes of *T* and *RH* for those AWS at the valley floor (MR, DA), smaller at the valleys head (SL and LM) and smallest at valley crests (CN, ML).
- ✓ Statistical data for Summer season reflect identical cycle patterns than the general statistics with a longer daylight regime (not shown).
- ✓ Both transitions between up- and down-valley regimes generally occur during daylight hours.
- ✓ Up-valley regime starts earlier at the upper valley (SL), followed by the middle part (DA) and the valley end (MR). Steady wind period is much shorter at DA, probably very influenced by the southern tributary valley of La Molina (LM). Up-valley regime lasts longer at the valley end (MR).
- ✓ Steady down-valley winds at DA, while the nocturnal wind turns at the valley end (MR) and head (SL) due to other valleys' influence.
- ✓ LM reflects the dynamics of down-valley at night and up-valley at the beginning of daylight. Afterwards, it turns counter-clockwise for the rest of the day until down-valley regime starts again.
- ✓ At high-altitudes (CN, ML), westerly wind has an in-(out-)valley component at night (day).
- ✓ Wind speed is minimum during the night-day transition regime for all stations. CN shows maximum winds at night.

(3) CASE STUDY

The 48-h long case study **(12 UTC 30/09/2011 – 12 UTC 02/10/2011)** is extracted from the list of 163 days. Observations reflect a similar pattern to the statistics (section 2), with wind speeds generally very low at night and a **strong temperature inversion** generated within the Cerdanya valley.

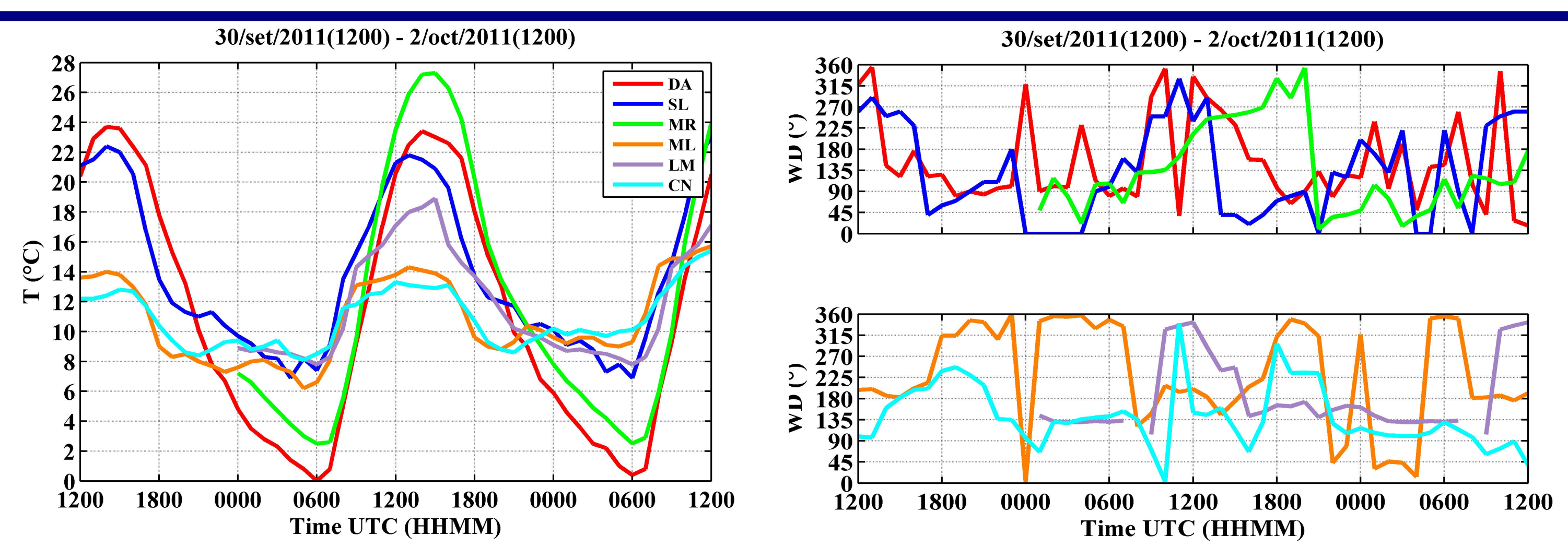

Fig. 4. Time evolution of air temperature (left) and wind direction (right) at the six AWS for the case study.

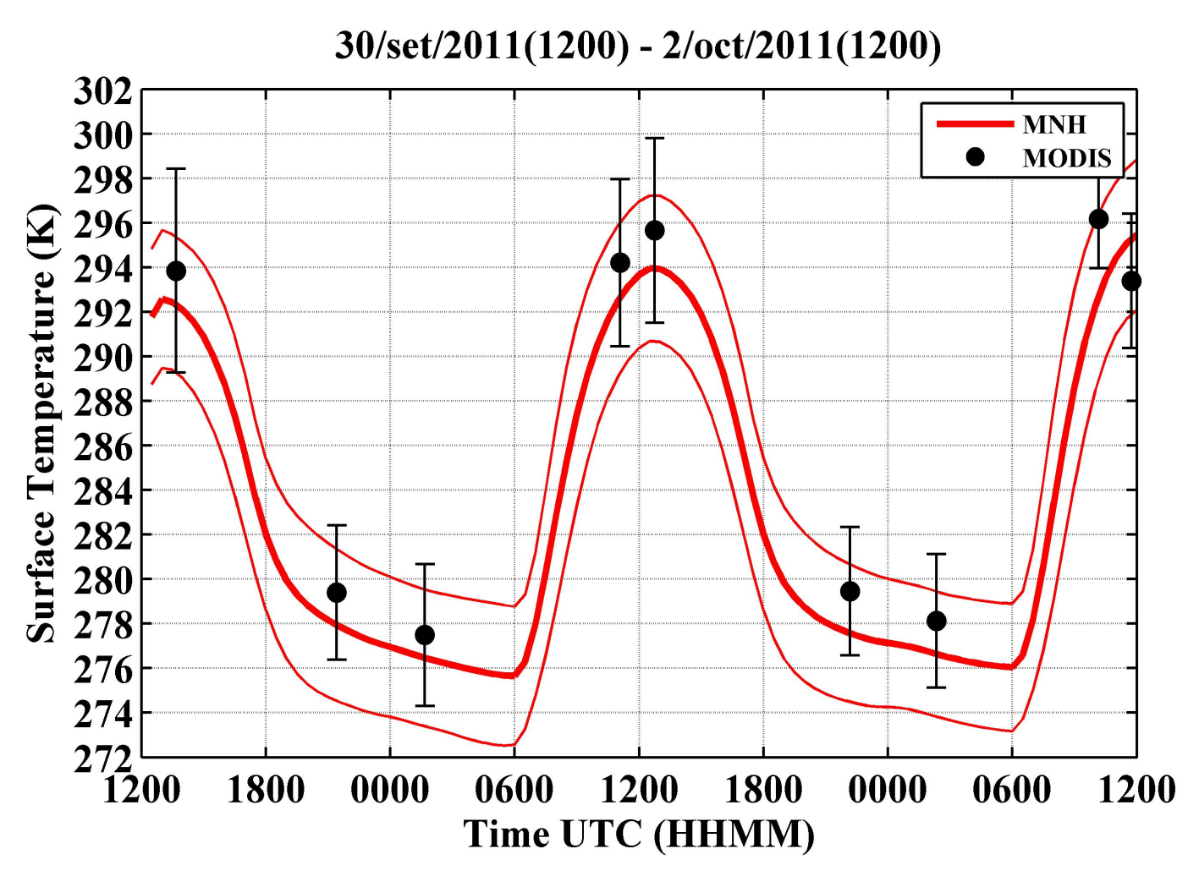

Fig. 5. *Domain-averaged surface temperature evolution for the 48-h cycle obtained from the model output every 30 minutes (and the respectively standard deviation) compared to the values obtained from MODIS satellite images at 9 instants. Both averaged fields agree despite of local differences.*

(3.1) MESOSCALE SIMULATION

- ✓ **Meso-NH model** (Lafore at al., 1998) with **two nested domains** (2 km and 400 m, respectively).
- ✓ Stretched vertical resolution: **3 m close to the ground** and 8 m at 500 m height.

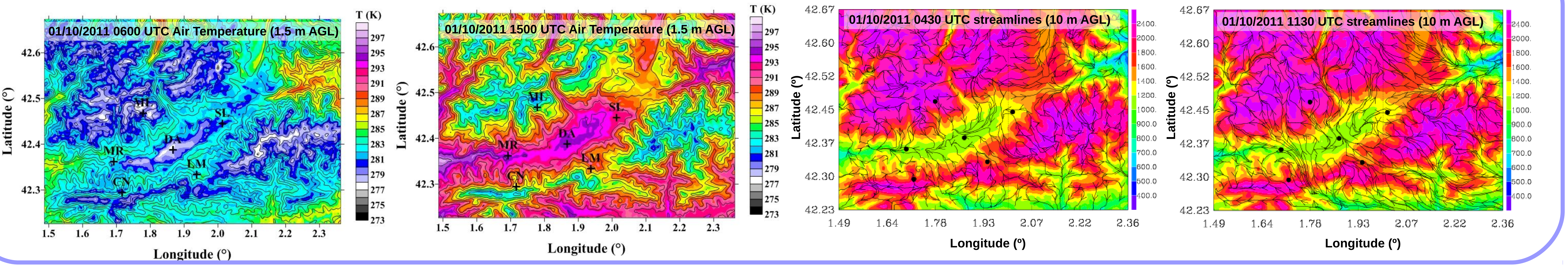

Fig. 6. *Outputs from the high-resolution mesoscale simulation.*

- ✓ Max. and min. 1.5-m temperatures develop at the valley floor during day and night. A **cold pool** with the lowest temperatures at the vicinity of DA is deployed. However, the simulation is not able to reproduce the observed values at MR and DA (**5 K warmer than observations**, fig. 4,6).
- ✓ Simulated surface temperature field matches with observations on average, despite of local differences (fig. 5).
- ✓ Streamlines (fig.6) confirm the influence of tributary valleys at the valley floor (northern tributaries at MR, and southern tributaries at DA and SL) that disturb the down-valley regime. During up-valley regime, a 'suction effect' produced by the northern mountain range generates mesoscale circulations that affect distinctly MR than DA and SL.
- ✓ Simulation at 400 m horizontal resolution is able to reproduce the wind dynamics within the Cerdanya valley, specially regarding the tributaries influence.

CONCLUSIONS

- ✓ The main features of the valley regime can be described statistically after applying a filter to observed 4-year time series.
- ✓ The simulation of a particular case gives more details (in agreement with observations) and shows its limits in reproducing the cold pool strength.

FUTURE

Experimental campaign (05-17 October 2015):

- ✓ **WindRass**: analysis of valley circulations above 10 m height.
- ✓ **Energy balance station**: Cold pool formation and evolution. Why mesoscale simulations do not reproduce its intensity?

References

Lafore, J. P. et al. (1998). The Meso-NH atmospheric simulation system. Part I: Adiabatic formulation and control simulation. *Ann. Geophys.* **16**, 90-109.

Martínez et al. (2008). Conditioned Climatology for Stably Stratified Nights in the Lleida Area. *Tethys*, **5**, 13-24.

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