SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2015
Project Title:	EFFECT OF THE SURFACE HETEROGENEITIES IN THE ATMOSPHERIC BOUNDARY-LAYER
Computer Project Account:	SPESTURB
Principal Investigator(s):	Joan Cuxart (1) and Maria A. Jiménez (2)
Affiliation:	(1) Universitat de les Illes Balears (UIB) (2) Institut Mediterrani d'Estudis Avançats (IMEDEA, UIB-CSIC)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	1st January 2015
Expected end date:	31st December 2017

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	150000	15000	150000	64500
Data storage capacity	(Gbytes)	200	200	200	100

Summary of project objectives

(10 lines max)

The current special project (2015-2017) is linked to the previous one (2012-2014) devoted to study the organization of the flow at lower levels in complex (topography) terrain regions. Now the attention is focused again in complex terrain regions but specially in areas with (surface) small-scale heterogeneities (related to temperature, soil moisture, vegetation or soil properties, among others). The aim of the project is to evaluate the impact of these small-scale heterogeneities in the spatial and temporal evolution of the atmospheric boundary layer, with special emphasis during the morning and evening transitions. The studied areas are the island of Mallorca and the Pyrenees, both taken as example of complex terrain regions with large surface heterogeneities.

Summary of problems encountered (if any)

(20 lines max)

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

This project is the continuation of a former one devoted to the study of the stably stratified boundary layer (SPESTURB, 2002-2011) which gradually evolved into the study of the Atmospheric Boundary Layer (ABL; SPESTURB, 2012-2014) over complex terrain in weak general pressure gradients, allowing to inspect the effect of the terrain-induced flows over the ABL characteristics. The analysis of atmospheric motions in complex terrain is made by our group through the combined use of experimental data (very often from campaigns that we organize or where we participate with our own instrumentation) and numerical modelling. The principal source of computing time for the very high-resolution simulations has been the SPESTURB project at ECMWF with the MesoNH model (Lafore et al., 1998).

The complexity of the studied regions has increased over time. Mesoscale runs made via the SPESTURB project has been focused on studying the organization of the flow at lower levels in:
(i) the Duero river basin: Low-Level Jet (using LES, Cuxart and Jiménez, 2007), cold pool formation (Martínez et al., 2010).
(ii) the island of Mallorca: nocturnal flows (Cuxart et al., 2007; Martínez and Cuxart, 2007; Jiménez et al., 2008) and breeze (Cuxart et al., 2014; Jiménez et al., 2015).
(iii) the Ebro river basin: fog formation (Cuxart and Jiménez, 2012), mesoscale simulations and remote sensing (Cuxart et al., 2012), surface energy balance (Cuxart et al., 2015).
(iv) the Pyrenees: characterization of the downslope winds (Jiménez and Cuxart, 2014), slope winds during BLLAST experiment (Jiménez and Cuxart, 2015, in preparation) or the temperature heterogeneities a different spatial scales (Cuxart et al., 2015, in preparation).
(**v) the Reuss valley**: characterization of the advective motions (Cuxart et al., 2015, in preparation).

From the beginning of this project, we have concentrated our efforts in: **(i)** the Sea Breeze (SB) and Land Breeze (LB) in the island of Mallorca and **(ii)** the organization of the flow in La Cerdanya, a E-W oriented valley in the south side of the Pyrenees about 20km long and 2km wide. Preliminary results are summarized in the following sections.

1) The sea and land breeze in Mallorca (MSB14 experimental field campaign).

The Mallorca Sea Breeze 2014 (MSB14) experimental field campaign took place in the Campos basin (at the south of Mallorca, Figure 1) from 26th May to 6th June 2014. Continuous measurements in Ses Covetes (red cross in Figure 1) were taken from a surface weather station (high-frequency sampling sensors, sonic), a multicopter and a tethered balloon during the 5 IOPs (see description in Figure 2). Due to the strength of the turbulence during the mature phase of the SB, only vertical soundings were sampled during the night-time and the morning and evening transitions. The temporal evolution of wind, temperature and TKE measured from the surface weather station (Figure 2) indicates that during these 5 IOPs morning and evening transitions were sampled.

In order to further understand the observations, a high-resolution mesoscale simulation was done as in the SB study of Cuxart et al. (2014) using 2 nested domains (at 5 x 5 km covering the Balearic Islands and at 1 x 1 km centered in the island of Mallorca). However, a third domain is taken now, centered in the Campos basin at 250 x 250 m resolution (see Figure 1). The vertical grid is the same as in Cuxart et al. (2007; 2014) which is very fine at lower levels (3m resolution) and stretched above (for instance, 5m at 100m agl).

Preliminary results of the organization of the flow at lower levels for IOP3 are shown in Figure 3. It is found that during night-time the air flows out of the island due to the combined effect of the LB and downslope winds. Although all model domains behave similarly, the flow is better characterized at 250m where the topography is better reproduced.

The verification of the runs is a work still in progress but Figure 4 shows the first attempts to compare the multicopter and tethered balloon temperatures to those obtained from the model in Ses Covetes. It is found that the model is able to reproduce the thermal structure during the morning transition but it is not able to reproduce the strong surface cooling during night-time. This might be related to a too strong influence of the sea (Ses Covetes site is place about 500m away from the coastline). Comparing the model outputs to other sites in the Campos basin (Ses Salines, 1km inland and Porreres, 15km inland) it is seen that the model, specially the inner domain (D3, at 250m resolution) is closer to observations. Satellite-derived temperatures are also used to validate the model outputs, as it is seen in Figure 5. The model is able to reproduce the main observed SST and LST patterns but the verification is more difficult in coastal and mountain regions where satellite-derived temperatures might have larger errors.

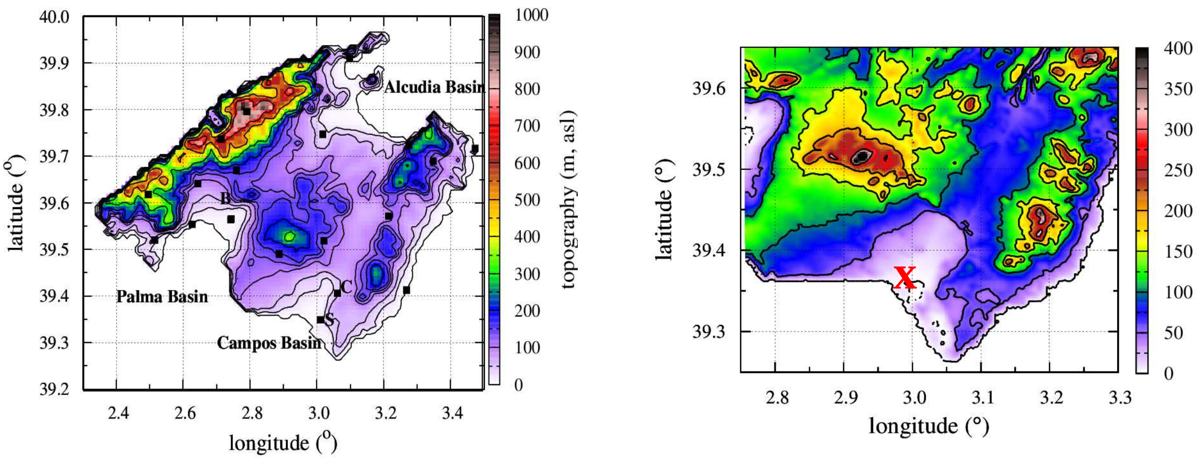
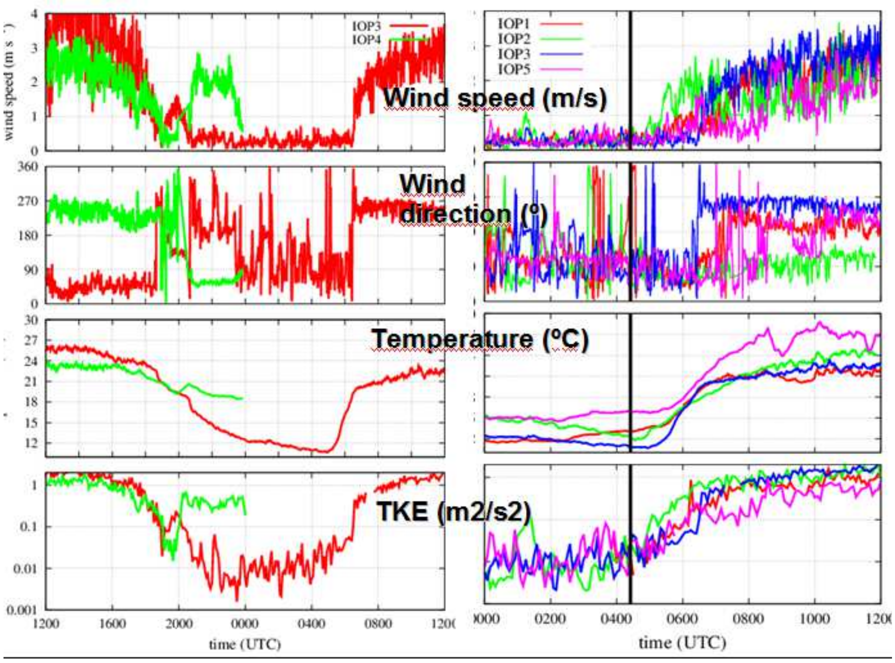


Figure 1. Topography of (a) the inner domain (at 1km resolution) of the run and (b) the 3rd nested domain and 250m resolution (only for MSB14 runs). The location of the main site during MSB14 (Ses Covetes) is indicated with a red cross.



IOP	period
1	30/May 0400 - 0900 UTC morning SB initiation with clouds after the turning
2	31/May 0300 - 0700 UTC nocturnal cooling with a high katabatic. SB initiation with strong wind
3	2/June 1800 UTC - 3/June 0700 UTC nocturnal cooling (katabatic) followed by SB initiation polluted with strong wind
4	4/June 1600 - 2000 UTC evening transition of SB with strong winds at the end that do not allow development of katabatic winds
5	6/June 0300 - 1200 UTC nocturnal cooling (katabatic) followed by SB initiation polluted with strong wind and clouds

Figure 2. Observations in Ses Covetes during the 5 IOPs of the MSB14 experiment.

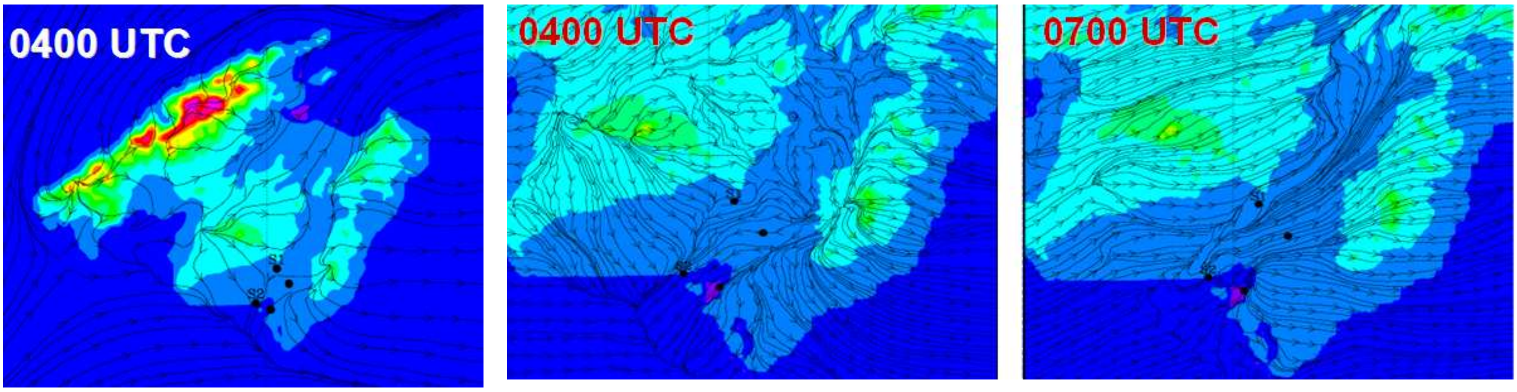


Figure 3. Streamlines at 10m (agl) during IOP-3 (3rd June 2014) at 0400 UTC and at 0700 UTC, for the land and preparatory phases of the diurnal cycle of the SB, respectively.

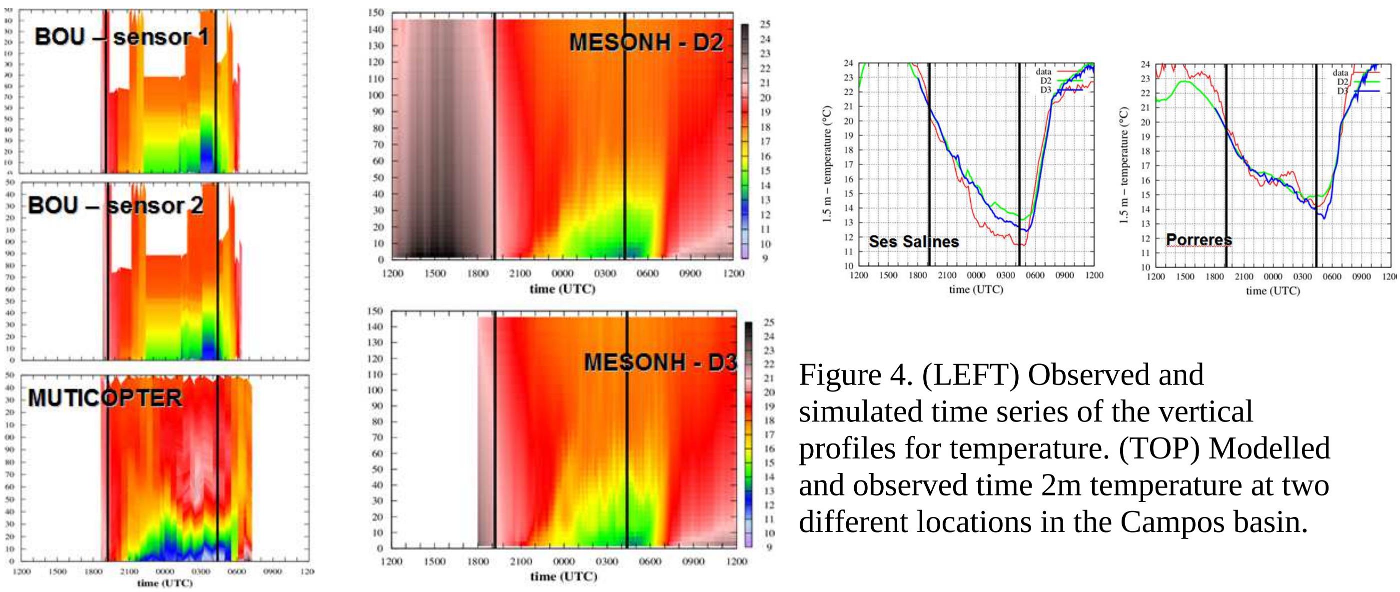


Figure 4. (LEFT) Observed and simulated time series of the vertical profiles for temperature. (TOP) Modelled and observed time 2m temperature at two different locations in the Campos basin.

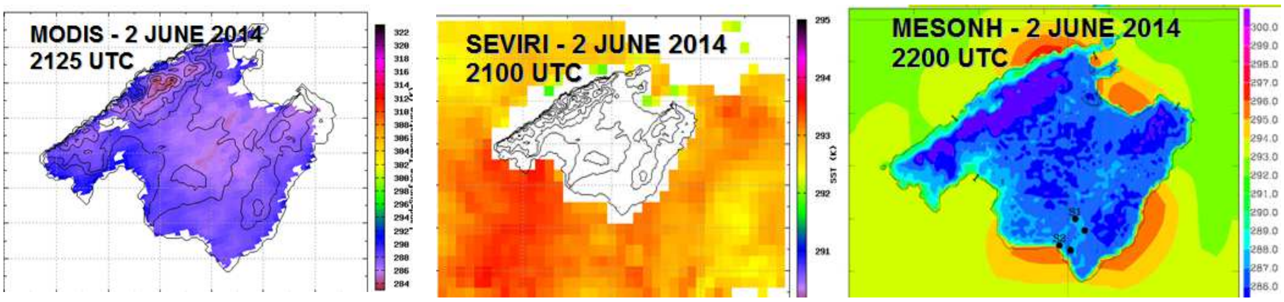


Figure 5. Satellite-derived surface temperatures compared to those obtained from the model during the evening of IOP-3.

2) Organization of the flow at lower levels in a complex terrain valley in the south side of the Pyrenees (La Cerdanya)

La Cerdanya is a valley located in the south side of the Pyrenees 30 km long and 9 km wide oriented to the NE to SW directions. It is taken in this study as an example of complex terrain valley, in terms of topography but also covered by hetereogeneous surfaces (forest, no vegetation, snow, …). A climatology study of this area using surface weather observations is under progress. In order to further understand the organization of the flow at lower levels, a representative case during fall (snow still not present at the mountains top) with a clear diurnal cycle is taken (weak pressure gradient conditions and clear-skies). A period of 48 hours, starting on September 30th 2011 is simulated with the MesoNH model with two nested domains at 2 x 2 km and 400 x 400 m resolution (see Figure 6).

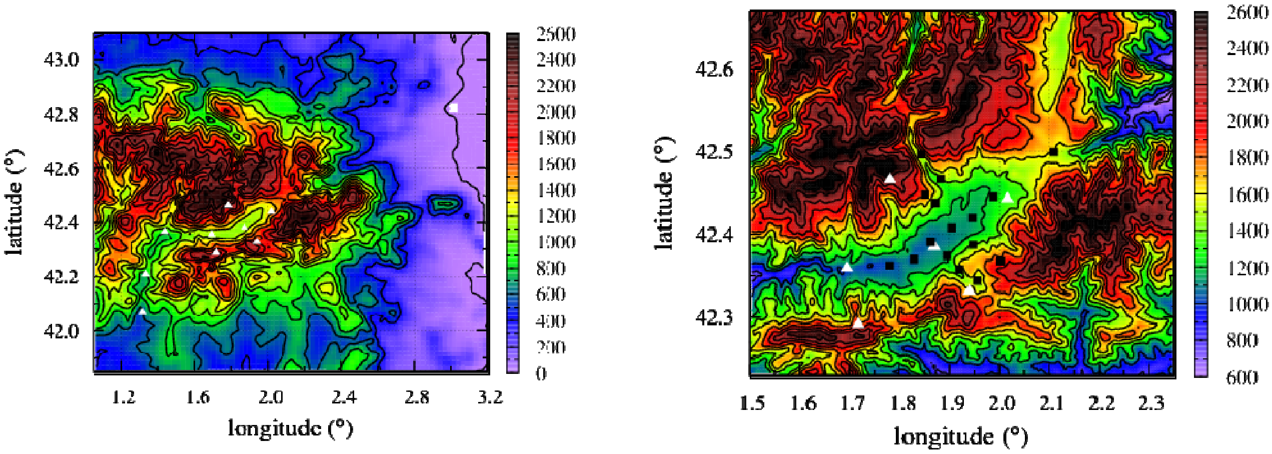


Figure 6. Topography of the two nested domains at (LEFT) 2 x 2 km and (RIGHT) 400 x 400 m resolution, respectively. The locations of the AEMET and MeteoFrance automatic weather stations are indicated in white triangles and some interesting points that we are further exploring are in black dots.

These runs are just made and we are currently analysing them. Preliminary results are shown in the following figures. It is found that during night-time downslope and down-valley winds are generated and the temporal evolution of them in La Cerdanya valley strongly depends on the slope winds generated in the tributary valleys at the north and south (Figure 7, left). An opposite behaviour is found during day time (Figure 7, right). Upslope winds are present in the northern mountains of La Cerdanya whereas those at the south are strongly influenced by the strong upslope winds generated at the south side, outside La Cerdanya. The interactions between the slope winds in La Cerdanya with those generated outside (tributary valleys or other topographically disconnected) is under progress.

The model results are verified with satellite observations (MODIS, land-surface temperature, Figure 8) and the surface weather observations (Figure 9). It is found that the model is able to reproduce the main observed surface temperature patterns by the MODIS. However, it is not able to reproduce the small cold pool in the lower valley (Figure 9), close to the exit (Das, labelled as DP in Figure 7). Modelled 1.5m temperatures are better reproduced in the upper valley (Figure 9, indicated as LEO in Figure 7). The model tends to overestimate the wind speed although it is capturing the turning of the wind.

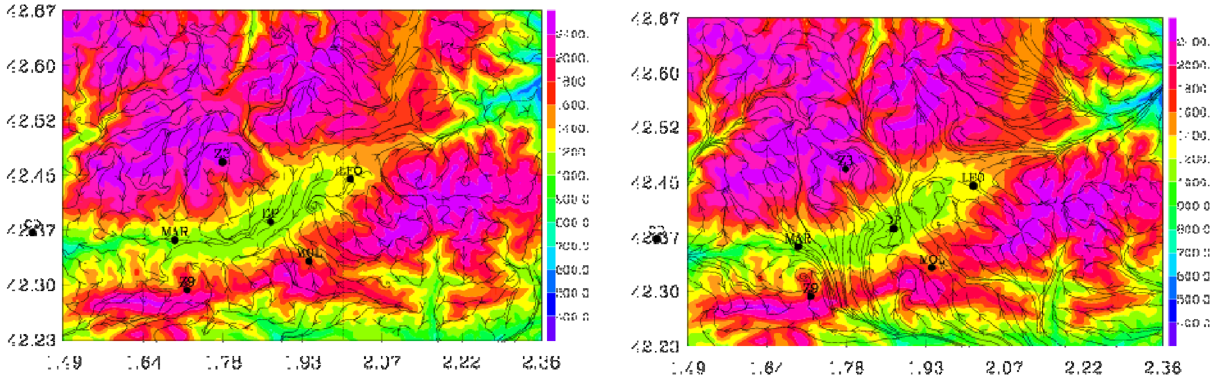


Figure 7. Streamlines at 25m (agl) together with the topography obtained from the inner domain on 1st October 2011 at (LEFT) 0200 UTC and (RIGHT) 1300 UTC.

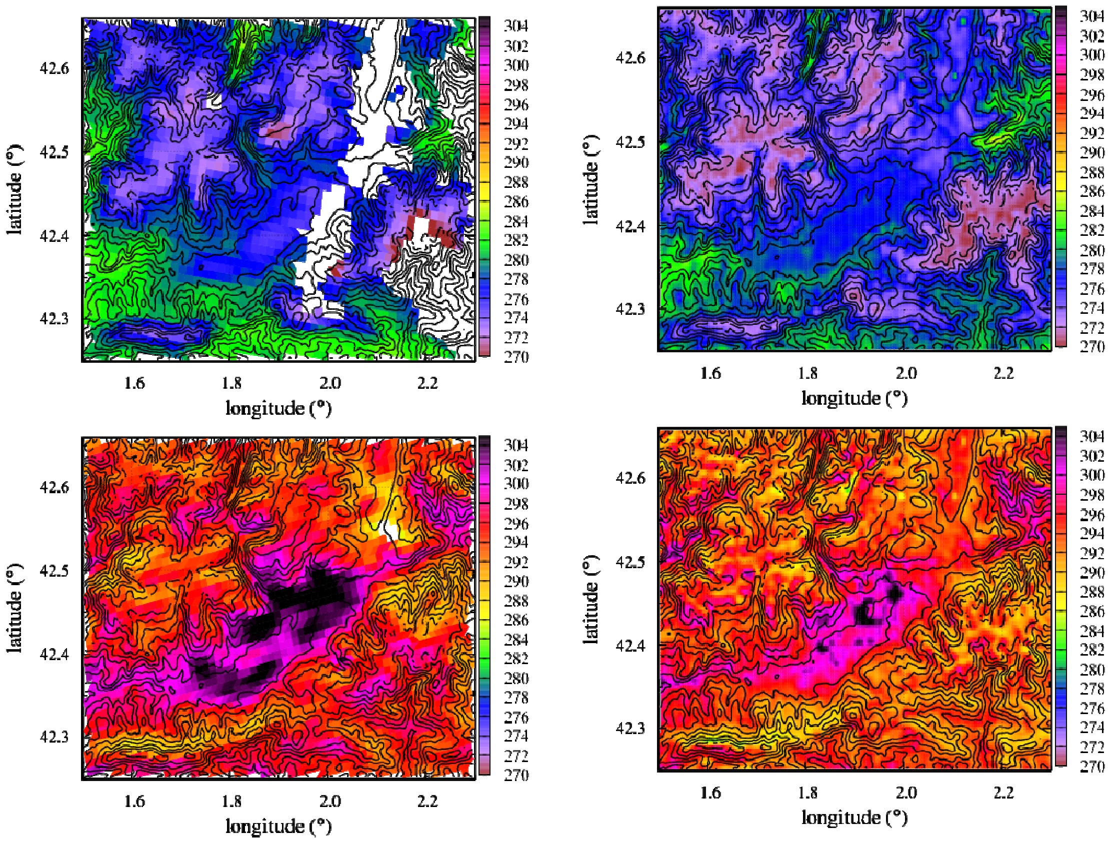


Figure 8. Land-surface temperature observed by MODIS (left) and obtained from the inner domain (right) at 0200 UTC (top) and 1300 UTC (bottom) together with the topography (black lines).

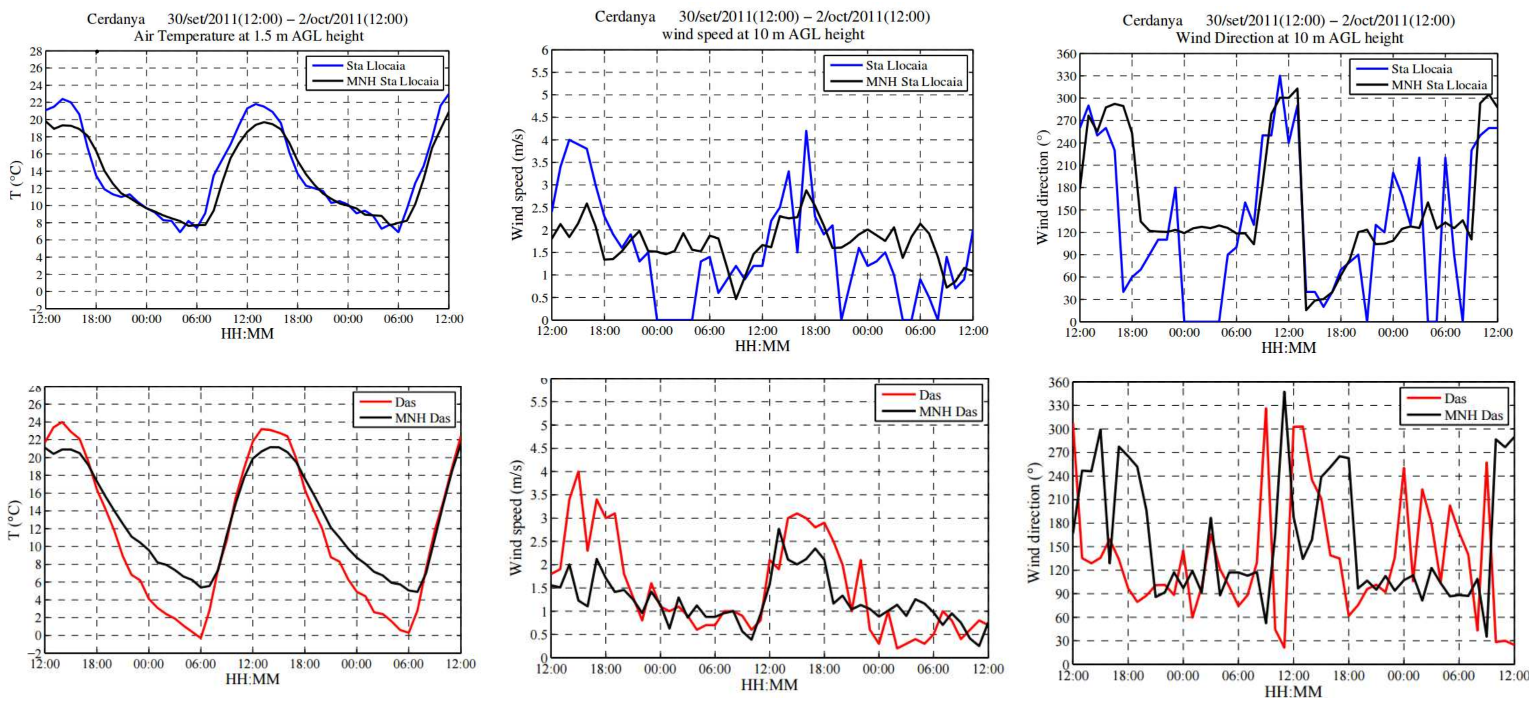


Figure 9. Modelled and observed time series (TOP) in the upper valley and (BOTTOM) in the lower valley, close to the narrow exit. These sites are indicated with LEO and DP in Figure 7, respectively.

List of publications/reports from the project with complete references

These are the works related to the previous project that will be submitted during 2015.

Cuxart, J.; B. Wrenger; J. Dünnermann; D. Martínez; J. Reuder; M.O. Jonassen; M.A. Jiménez; M. Lothon; F. Lohou; O. Hartogensis; A. Garai; L. Conangla, 2015: Sub-kilometric heterogeneity effects on the surface energy budget in BLLAST. To be submitted to *Atmospheric Chemistry and Physics*.

Jiménez, M.A. and Cuxart, J., 2015: Slope winds during the BLLAST experiment. To be submitted to *Atmospheric Chemistry and Physics*.

Jiménez, M.A., LeMoigne, P., Couvreaux, F., and Cuxart, J., 2015b: The land-atmosphere coupling seen by the MesoNH model for the DICE case. To be submitted to *J. Hydrometeor.*

Summary of plans for the continuation of the project

(10 lines max)

This is the first year of the project and the first runs are just made. Both are based on observations and further work is needed to complete the analysis and to understand the most relevant physical processes that take place in these complex areas.