SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2019
Project Title:	EFFECT OF SURFACE HETEROGENEITIES AND EVAPOTRANSPIRATION CHANGES ON THE ATMOSPHERIC BOUNDARY LAYER
Computer Project Account:	spesturb
Principal Investigator(s):	Maria A. Jiménez and Joan Cuxart
Affiliation:	Universitat de les Illes Balears
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	1st January 2018
Expected end date:	31st December 2020

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)	300000	300000	300000	171643
Data storage capacity	(Gbytes)	250	250	250	100

Summary of project objectives (10 lines max)

The aim of the special project is to increase the current knowledge of the surface-atmosphere interface through a combined inspection of simulations and observations from the campaigns that we have organized/participated. Firstly, we plan to continue performing high-resolution mesoscale simulations of observed cases during the Cerdanya Cold Pool experiments in 2015 and 2017 and the 2018 data in the Aura valley at the French side. This is intended to study the cold air pooling and the organization of the flow at lower levels in a complex mountainous terrain region, also considering the presence of snow. Secondly, the interactions between heterogeneous surfaces and the atmosphere will be explored through simulations based on observational campaigns held in Mallorca dealing with surface heterogeneities (Subpixel in 2016) and the in Eastern Ebro valley in zones with extensive irrigated areas, linked to the LIAISE effort from HyMeX.

Summary of problems encountered (10 lines max)

We have to install the lastest MesoNH model version in order to have an adequate representation of the surface processes (update the SURFEX model) and we had some difficulties related to the options of the compiler. With the collaboration and support of the MesoNH and ECMWF teams this issue was resolved.

Summary of plans for the continuation of the project (10 lines max)

The first part of the current special project has been devoted to the study of the organization of the flow in La Cerdanya valley. Several runs have been made based on selected IOPs during the CCP17 experimental field campaign to evaluate the effect of the snow cover in the evolution of the cold pool. By the end of this year, runs based on the Aura Experimental field campaign (summer 2018) will be performed to evaluate if the model is able to reproduce the observed features of the valley exit jet. At the end of the special project the main focus will be to study the circulations at lower levels in the irrigated area in the center of the Ebro river valley in order to prepare an experimental field campaign during 2020.

List of publications/reports from the project with complete references

Conangla; Cuxart; MA Jiménez; Martínez-Villagrasa; Miro; Tabarelli; Zardi. **2018**. Cold-air pool evolution in a wide Pyrenean valley. *International Journal of Climatology,* 38: 2852-2865. https://doi.org/10.1002/joc.5467

Jiménez, MA, Cuxart, J, Martínez-Villagrasa, D. **2019**. Influence of a valley exit jet on the nocturnal atmospheric boundary layer at the foothills of the Pyrenees. *Q J R Meteorol Soc*., 145: 356- 375. https://doi.org/10.1002/qj.3437

Cuxart, Conangla, Martínez-Villagrasa, Jiménez. **2019**. Surface thermal inversion evolution in the bottom of a Pyrenean valley studied by single-column modelling forced with observed surface fluxes. 7th International Conference on Meteorology and Climatology of the Mediterranean (MetMed)

Martínez-Villagrasa, Cuxart, Simó, Jiménez, Martí, Miró, Conangla, Wrenger, Paci, Picos. **2019**. The Cerdanya Cold Pool programme (CCP1x): an integrated study on cold-air pooling and drainage flows in the largest Pyrenean valley. 7th International Conference on Meteorology and Climatology of the Mediterranean (MetMed)

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

This project is a continuation of previous SPESTURB special projects. Between 2002 and 2011 the special project was focused on study the stably-stratified atmospheric boundary layer of ideal (Large-Eddy Simulations) and real (mesoscale simulations) cases. Later (2012-2014) the aim of the project was to study the atmospheric boundary layer over topographically complex regions. Afterwards, the previous special project (2015-2017) was more focused in study the atmospheric boundary layer features related to the surface heterogeneities (temperature or soil moisture, among others). During the last 8 years all the simulations made at the ECMWF are based on observations (experimental field campaigns) or they are made before an experimental field campaign to help in the finding of the locations to perform the measurements. All the runs are made with the MesoNH model (Lafore et al, 1998).

The first numerical works of the current special project correspond to some selected IOPs during the Cerdanya Cold Pool experiment2017 (CCP17) that took place in La Cerdanya valley from January to April 2017 (see measurement sites in Figure 1). This valley (about 30km long and 9km wide) is located in the central Pyrenees, oriented along the NE-SW direction. It is a clear example of complex terrain region in terms of topography and soil properties because it is covered by heterogeneous surfaces (forest, grass, rock, heterogeneous distribution of snow, etc). The same area was taken during the previous special project to analyze some selected IOPs during the CCP15 experimental field campaign (October 2015). Now the simulation strategy is similar (2 nested domains at 2km and 400m resolution with a vertical grid of 3 m close to the surface and stretched above), except that during CCP17 snow was present at the mountain peaks but also in the bottom areas of the Valley. In this sense, the snow pack of the model will be activated to include the physical processes that take place in snow-covered regions. Besides, the microphysical scheme will be activated (no rain was present in the CCP15 simulations) to allow the precipitation (rain and snow) in the simulated domain.

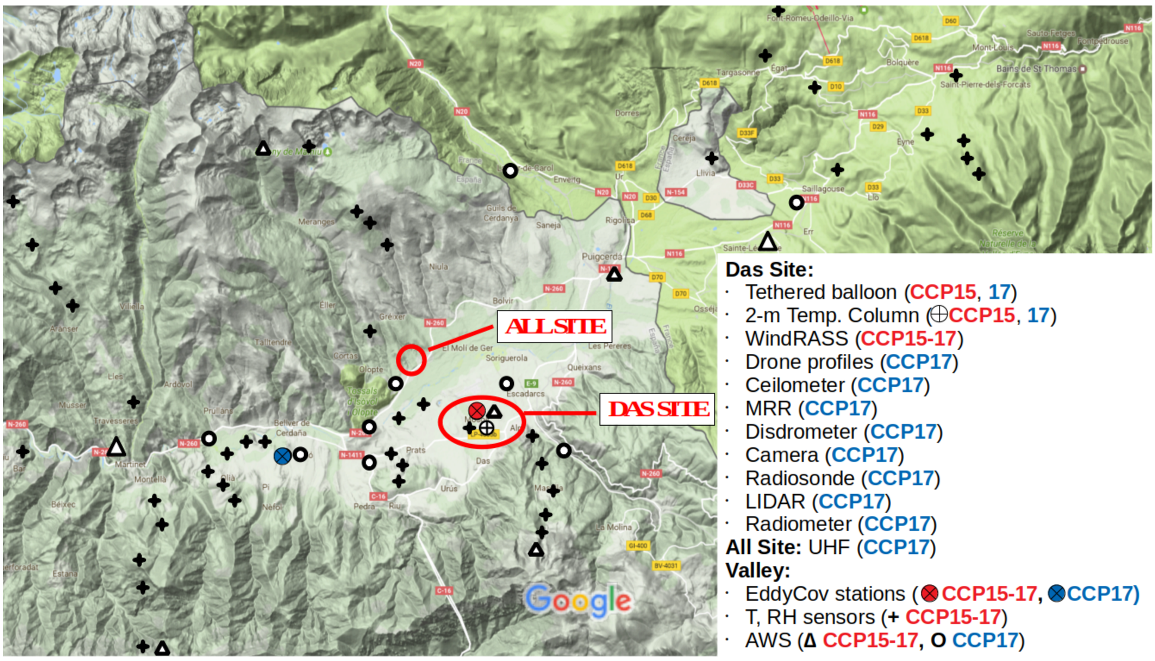

Figure 1. Location of the measurement sites during CCP17. The main site was Das where there are measurements of the surface, the lower layer and the vertical structure of the atmosphere. Besides, different surface weather stations were placed at different sites along the valley (see triangles, circles and crosses).

To start with, 4 IOPs have been selected:
* fresh snow covering all the bottom parts of the valley (18-19 January 2017)
* strongly stratified conditions in the bottom of the Valley (24-30 December 2016)
* the same as before but less stable and with a large number of measurements of the lower atmosphere (25-27 February 2017)
* after a snowfall that cover the whole valley but meting starting in the bottom parts (28 January – 2 February 2017)

All of these runs have to be validated with the observations taken during CCP17, that included an enhanced surface network of stations, two locations with the surface energy budget and profiles of the lower atmosphere by remote sensing and balloon soundings. The aim of these runs is to further explore the organization of the flow in the valley at lower levels and to evaluate the impact of the presence of the snow in the evolution of the atmospheric boundary layer. In the main site of the campaing (Das, see Figure 1) during clear-sky and weak-wind conditions cold pools are frequently reported (Conangla et al., 2018) and with a combined inspection of the CCP15 and CCP17 simulations and obervations it is possible to determine which are the mechanisms involved and the impact of the snow in the cold pool formation or in the organization of the flow at lower levels. Besides, these datasets are useful to validate the model outputs and understand the processes that the model is able to capture, as well as those misrepresented.

Figures 2, 3 and 4 show the validation of the model results with some of the observations during the CCP17 experimental field campaing (surface observations, surface energy balance and WindRass, respectively). This work is still in progress but preliminary results show that the model is not able to properly reproduce the strength of the cold pool reported during the case of 24-30 December 2016 (Figure 2). The differences between the modelled and observed 1.5m might be related to a wrong representation of the processes at the surface (Figure 3), among other factors. The net radiation is well captured by the model but it overestimates the latent heat (H) and ground (G) fluxes. It is important to recall that the observed imbalance for this case is large (the same order of magnitude of the net radiation at some time) whereas in the model it is assumed as zero.

The large values of modelled H are related to a strong shear at lower levels. The inspection of the vertical structure of the atmosphere indicates that the modelled wind at about 100 m above the ground in Das (Figure 4) is overestimated due to the presence of north-easterly winds from the Golf of Lyon that are channeled in La Cerdanya valley. If the same simulation is done but using Arpege as a lateral boundary conditions this mesoscale wind in the Gulf of Lyon is weaker and the channeling effect does not take place.

The initial and boundary conditions are better captured for the case of 18-19 January 2017 (Figure 2, right) were all the valley was covered by snow. However, the model still have some difficulties in reproducing the evolution of the temperature at lower levels (inside the cold pool) but it has a realistic behaviour for the temperature above the cold cool (in a surface weather station at the mountain slopes of the north-east side of the valley, in green in Figure 2 right). The differences between the model and observations for this case might be related to the representation of the snow in the model. It is important to mention that the presence of the snow is responsible of the low values of the surface energy balance terms (maybe because they are sampling under snow conditions) that the model tends to overestimate.

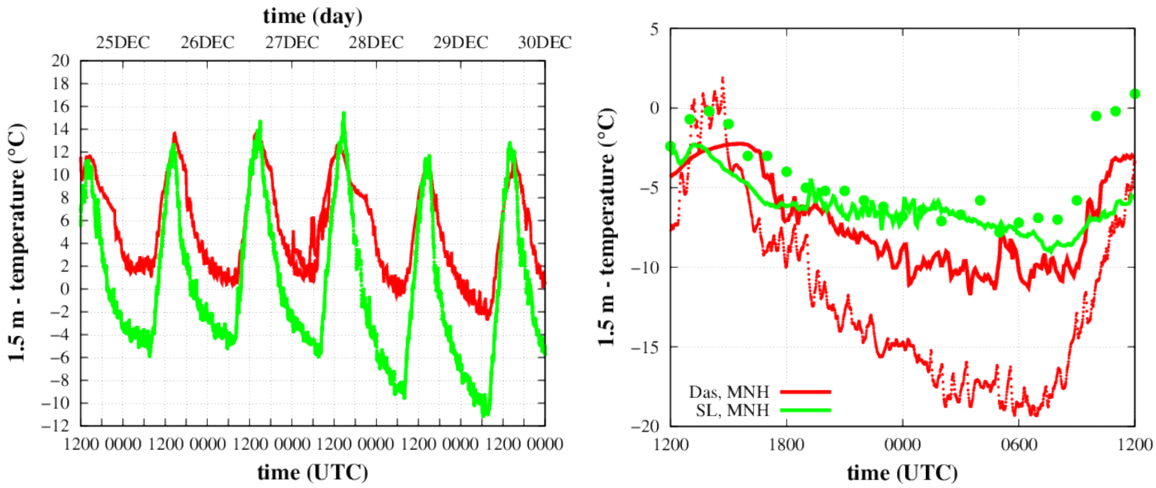

Figure 2. (LEFT) Comparison of the modelled (in red) and observed (in green) temperatures for the strongly-stratified case (24-30 December 2016) in Das. The same in (RIGHT) for the case with the valley covered by snow (18-19 January 2017) for two locations: in the bottom of the valley (Das, in red) and in the upper north-east side (Sainte-Leocadie, in green). Observations are in dots and model results in lines.

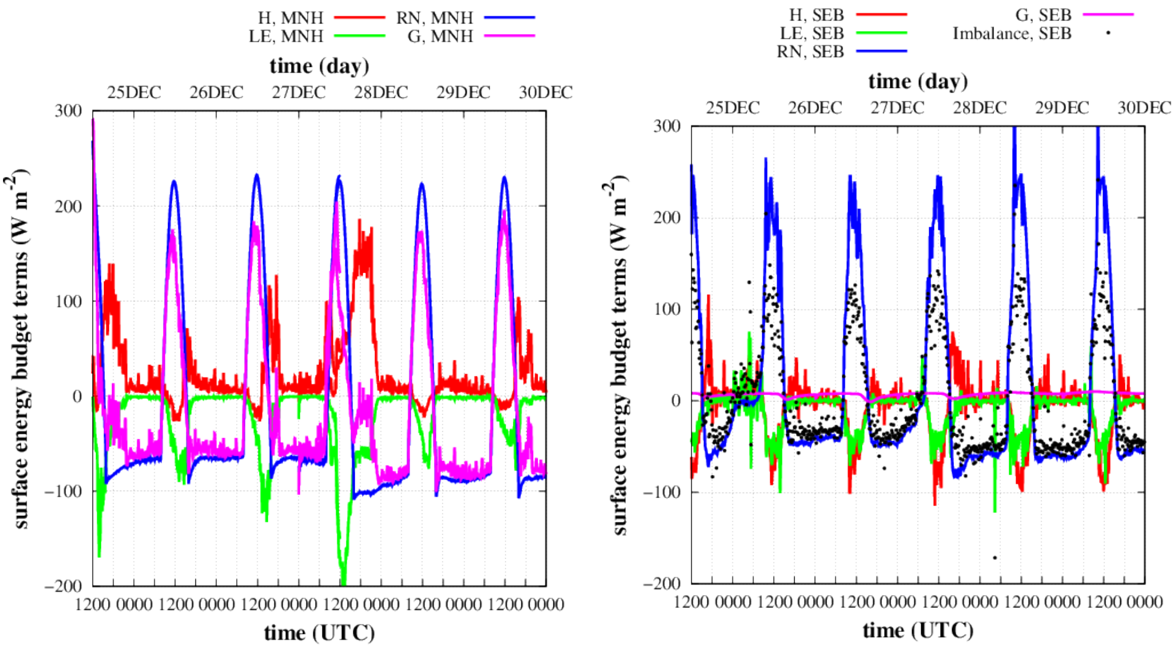

Figure 3. Modelled (LEFT) and observed (RIGHT) surface energy balance in Das during the period 24-30 December 2016.

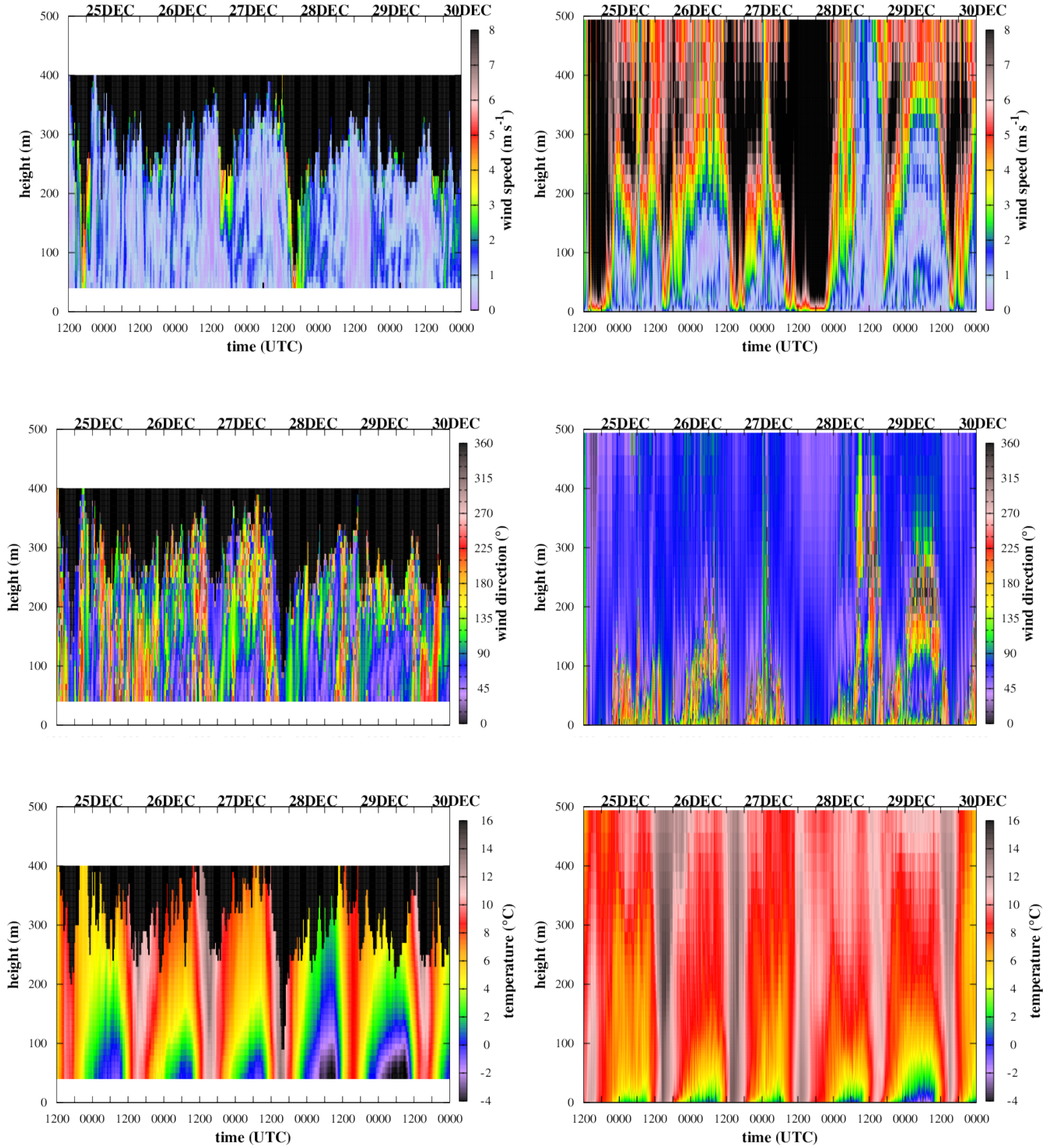

Figure 4. Comparison of the vertical structure observed by the WindRass in Das (LEFT) together with the one obtained by the model (RIGHT) during 24-30 December 2016.