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 2020

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	0
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 processes in the surface-atmosphere interface through a combined inspection of simulations and observations from the campaigns in which we have participated. Firstly, the plan is 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 northern part of the Pyrenees. These runs are intended to study the cold air pooling and the organization of the flow at lower levels in a complex mountainous terrain region, taking into account 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 in the Eastern Ebro valley in zones with extensive irrigated areas, linked to the LIAISE effort from HyMeX.

Summary of problems encountered (10 lines max)

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 CCP15 and CCP17 experimental field campaigns to evaluate the effect of the snow cover in the evolution of the cold pool reported in the bottom of the basin. During the last year of the special project, the focus will be to study the circulations at lower levels in the irrigated area in the eastern Ebro subbasin in order to prepare an experimental field campaign during 2020.

List of publications/reports from the project with complete references

M.A. Jiménez, A. Grau, J. Cuxart, 2020. Generation of Chilling Hours maps using Surface Observatons and Satellite data. Atmospheric Research, 236, 104807 https://doi.org/10.1016/j.atmosres.2019.104807

A. Grau, M.A. Jiménez, J. Cuxart, 2020. Statistical characterization of sea-breeze physical mechanisms through in situ and satellite observations. Int J Climatol. 2020; 1– 14. https://doi.org/10.1002/joc.6606

M.A. Jiménez, J. Cuxart, A. Paci, L. Conangla, D. Martínez-Villagrasa, and B. Martí, **2020**. Surface thermal inversion evolution in the bottom of a Pyrenean valley studied by observations and mesoscale simulations, *EGU 2020 General Assembly*

A. Paci, M.A. Jiménez, J. Cuxart, M. Lothon, O. Clary, Y. Seity, D. Martínez-Villagrasa, A. Dabas, T. Rieutord, and C. Román-Cascón, **2020**. Exit jet in a narrow Pyrenean valley: the Aure Valley 2018 field experiment, *EGU 2020 General Assembly*

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

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

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).

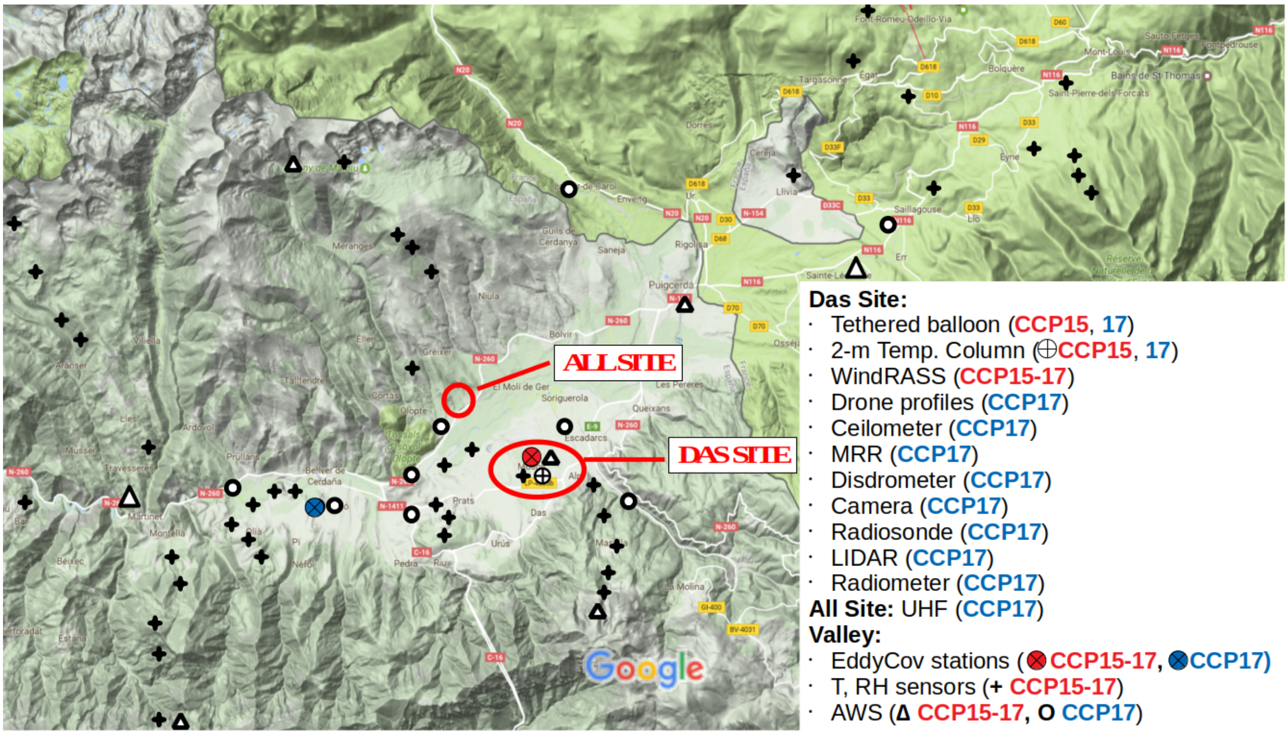

Figure 1. Location of the measurement sites during CCP17. The main site was Das where there are measurements of the surface, the lower layer and the vertical structure of the atmosphere. Besides, different surface weather stations were placed at different sites along the valley (see triangles, circles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

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 analyse 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 is activated to include the physical processes that take place in snow-covered regions. Besides, the microphysical scheme has been activated (no rain was present in the CCP15 simulations) to allow precipitation (rain and snow) in the simulated domain.

Three IOPs have been selected to further analyse them through mesoscale modelling:
* **fresh snow covering the whole valley, bottom included** (18 – 19 January 2017),
* **strongly stratified conditions in the bottom of the valleywithout snow** (24 – 30 December 2016),
* **after a snowfall that covered the whole valley, with areas already melted having a heterogenous snow cover** (28 January – 2 February 2017).

These runs are validated with the observations taken during the CCP17 experiment, 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 the simulations is to 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 campaign (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 observations 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.

All the runs show that the organization of the flow at low levels under clear-sky conditions is strongly influenced by the slope winds (upslope and downslope during day and night, respectively). During night-time mesoscale runs (Figure 2) show that down-valley and downslope winds are present, in agreement with the observations. Nevertheless, larger scale winds can modify the intensity of the thermally driven winds; especially in the cases when a channelled wind from the Gulf of Lyon reaches the basin from the northeastern sector (see Figure 2, middle).

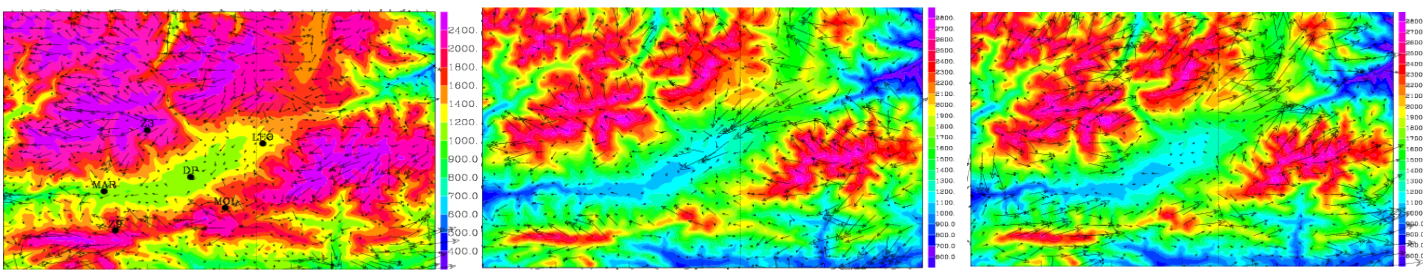

Figure 2. Organization of the flow at low levels (wind vectors at 50 m above the ground) at 0400 UTC for (LEFT) the non-snow case (28 December 2016), (MIDDLE) partially covered by snow (19 January 2017) and (RIGHT) totally covered by snow (31 January 2017).

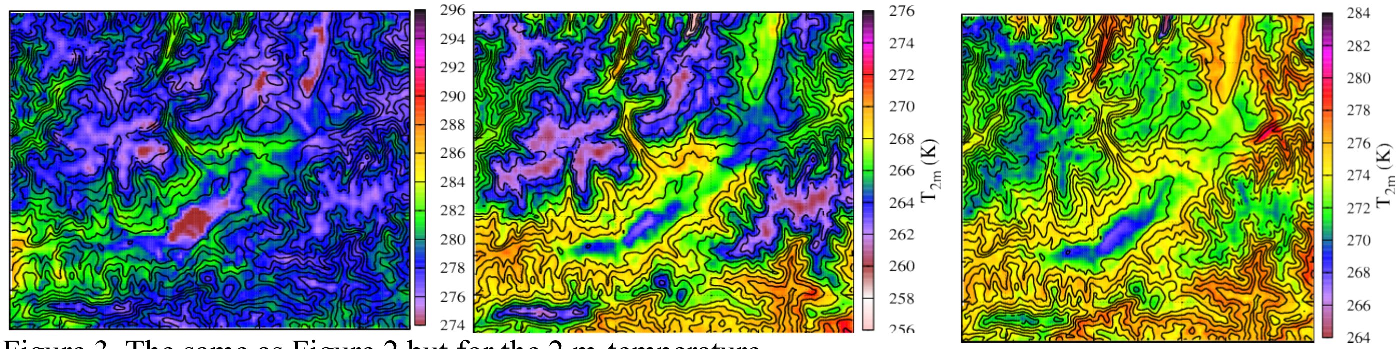

Figure 3. The same as Figure 2 but for the 2 m-temperature.

Regarding the cold pool features, when no snow is present the cold pool is clearly placed at the bottom part of the basin (Figure 3, LEFT). Instead, the presence of snow tends to homogenise the 2-m temperatures in the bottom parts of the basin resulting in a cold pool region less defined and with lesser strength than for the no-snow case.
Figures 4, 5 and 6 show the validation of the model results with some of the observations during the CCP17 experimental field campaign (surface observations, surface energy balance and WindRass, respectively).

Figure 4 shows that the model is not able to properly reproduce the strength of the cold pool reported during the case of 24-30 December 2016. The differences between the modelled and observed 1.5m might be related to a wrong representation of the processes at the surface (Figure 5), 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.

Results also show that when snow partially covers the valley the 2 m-temperature is better captured than for the cases of totally covered snow or without snow (Figure 6). This might suggest that the presence of snow tends to homogenise the temperature patterns avoiding a strong radiative cooling of the (flat) surfaces.

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 7) is overestimated due to the presence of north-easterly winds from the Gulf of Lyon that are channelled in La Cerdanya valley. If the same simulation is done but using Arpege as lateral boundary conditions this mesoscale wind in the Gulf of Lyon is weaker and the channelling effect does not take place.

The initial and boundary conditions are better captured for the case of 18-19 January 2017 (Figure 4, 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 4 right). The differences between the model and observations for this case are 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 that the model tends to overestimate.

We are still working on the analysis of these simulations but results confirm that the surface features (vegetation and partially and totally covered by snow) strongly condition the organization of the flow at low levels and the cold pool features (duration, strength, extension and height).

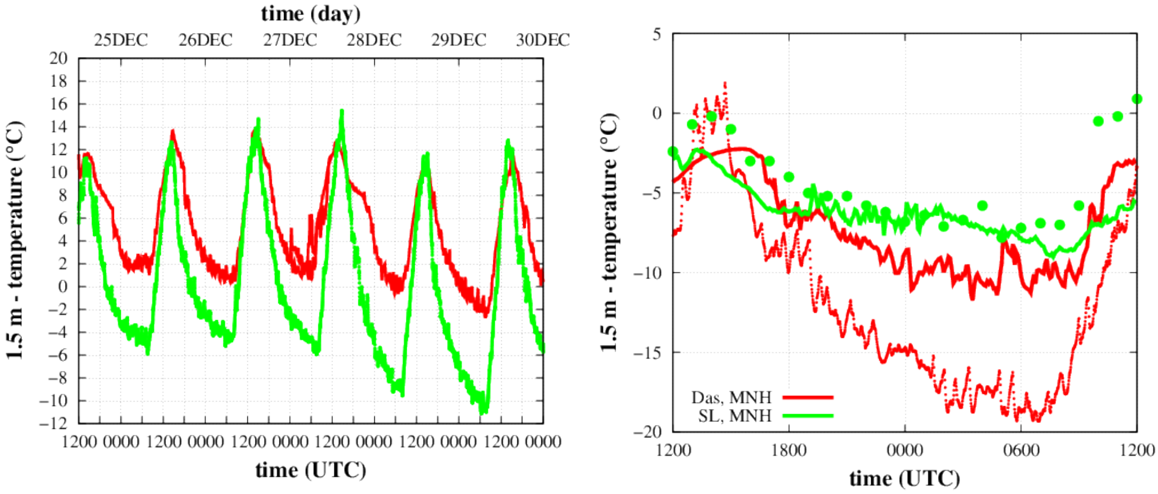

Figure 4. (LEFT) Comparison of the modelled (in red) and observed (in green) temperatures for the strongly-stratified case (24-30 December 2016) in Das. The same in (RIGHT) for the case with the valley covered by snow (18-19 January 2017) for two locations: in the bottom of the valley (Das, in red) and in the upper north-east side (Sainte-Leocadie, in green). Observations are in dots and model results in lines.

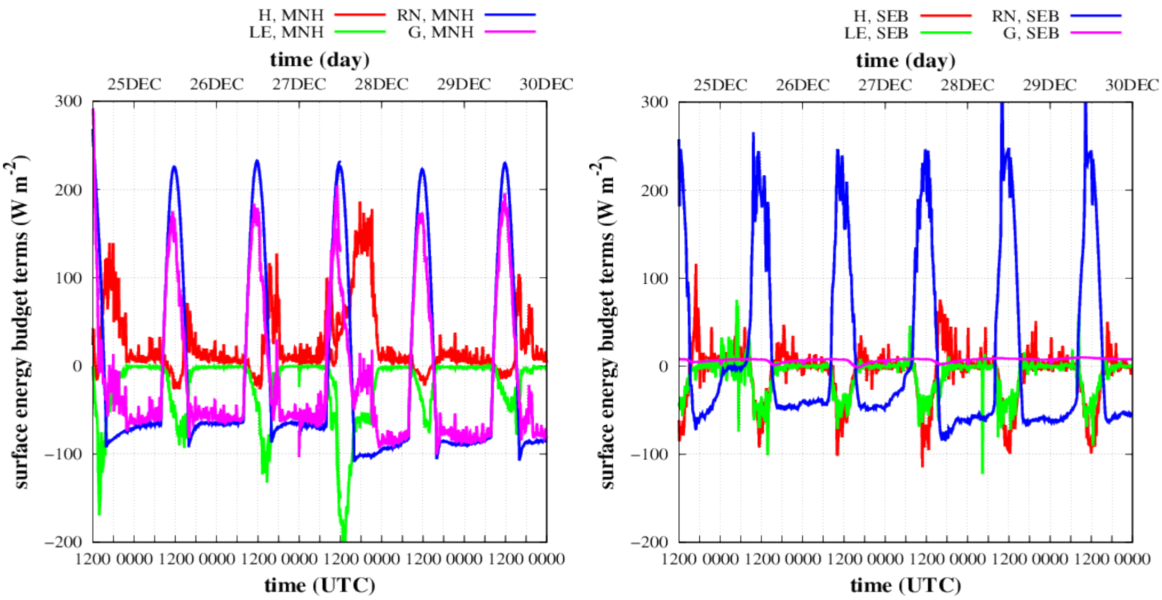

Figure 5. Modelled (LEFT) and observed (RIGHT) surface energy balance in Das during the period 24-30 December 2016.

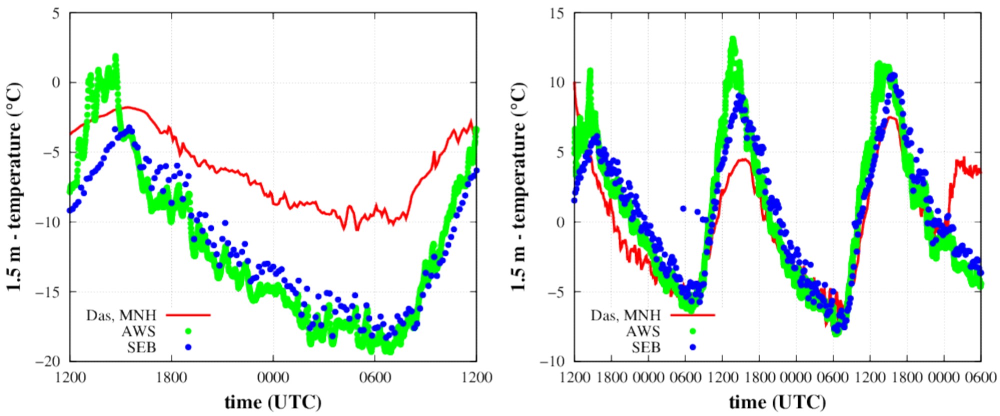

Figure 6. Comparison of the modelled (in red) and observed (in green and blue) temperatures for (LEFT) the snow case (18-19 January 2017) and (RIGHT) the partially covered snow case (30-31 January 2017).

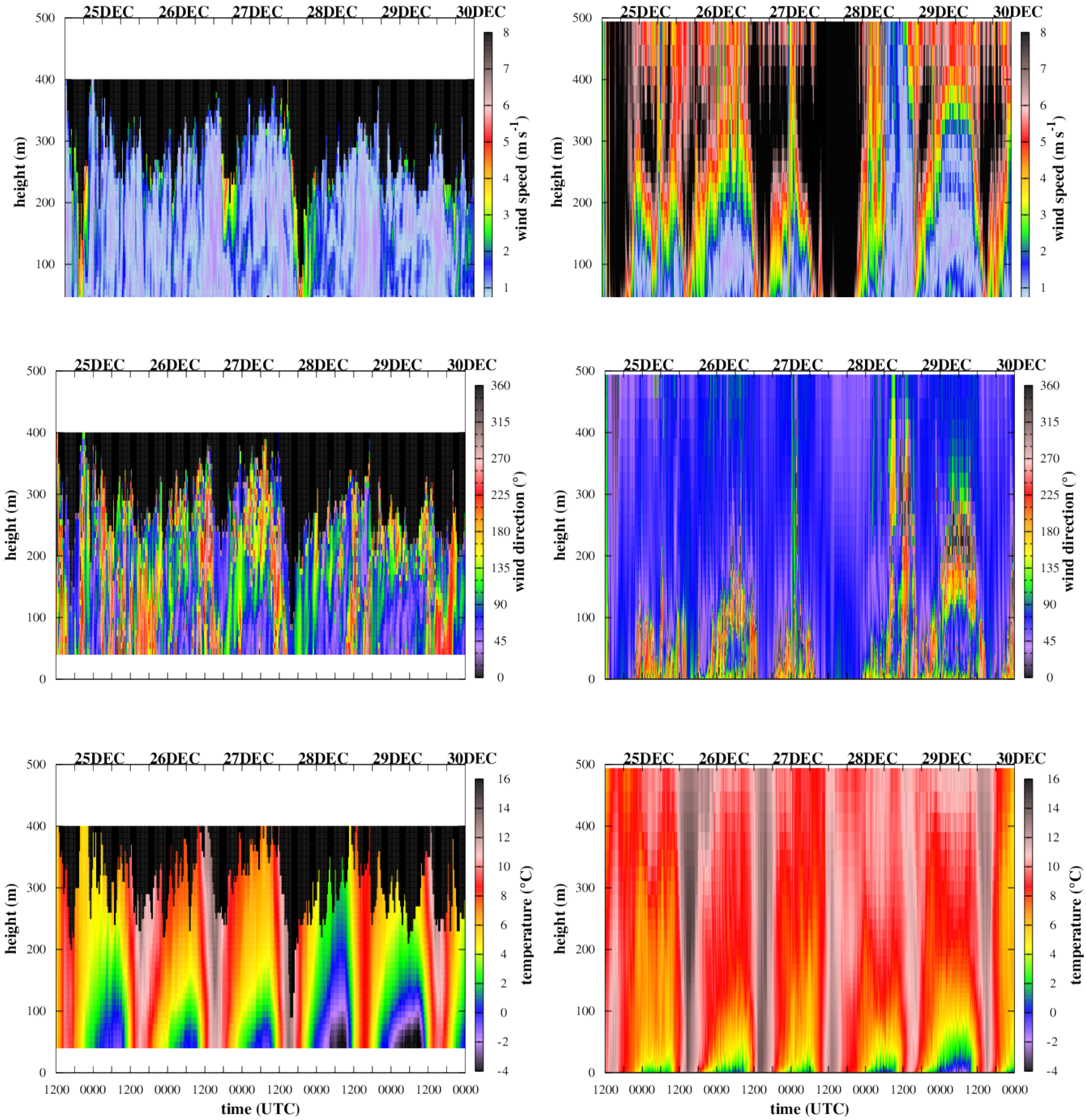

Figure 7. Comparison of the vertical structure observed by the WindRass in Das (LEFT) together with the one obtained by the model (RIGHT) during 24-30 December 2016.