REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: Spain

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Project Title: Simulations of different types of breezes and their interactions

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2025	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	400000	400000	400000
Accumulated data storage (total archive volume)[2]	[GB]	10000	10000	10000

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]			
Total memory	[GB]			

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Storage [GB]			
Number of vGPUs[3] [#]			

Continue overleaf.

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Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 10,000,000 SBU should be more detailed (3-5 pages).

Models still show significant errors in the simulation of meteorological variables when it comes to land-atmosphere interactions, particularly in complex terrain areas, whose ecosystems are, indeed, especially sensitive and vulnerable to climate change (Beniston, 2005). The lower atmosphere in these regions is generally affected by secondary mesoscale or sub-meso circulations (Rotach et al., 2008), being the most common ones the so-called mountainous or coastal breezes. These are thermally-driven flows developed under weak synoptic forcing conditions, due to temperature gradients and characterised by wind blowing from sea to land (from the plain to the mountain) in the day-time and from land to sea (from the mountain to the plain) in the night-time. Interactions of these phenomena with other atmospheric processes of smaller scales has a key impact on the evolution of relevant meteorological variables, such as near-surface wind, 2-m temperature, or relative humidity (Zardi and Whiteman, 2013). Since these interactions are not yet fully understood, they are not correctly represented in the models (Serafin et al., 2018), negatively impacting the simulation of the atmospheric variables (Holstlag et al., 2013). These errors affect the whole model performance, affecting the formation of mesoscale and weather systems, low-level winds (crucial for the wind energy industry), water, heat and CO_2 turbulent fluxes (important to investigate sinks or sources of carbon in the atmosphere), crop modelling (especially errors in near-surface minima temperatures) or fog formation and development, among others.

With this project we aim to better understand these thermally-driven mesoscale flows (mainly breezes) and their interaction with processes at different scales, including the surface turbulence and the energy exchanges between the soil-vegetation-atmosphere system (Cicuéndez et al., 2024). The study will be mainly carried out in heterogeneous and/or complex terrain in the Iberian Peninsula and at the foothills of the French Pyrenees. We have already built some high-quality experimental databases from different strategical observational areas in the aforementioned areas. Additionally, we need to perform numerical simulations with state-of-the art mesoscale models, which will allow us to achieve a better understanding of the influence of contrasting surface conditions, including land use, soil moisture, and possible changes in the context of the climate change, on the different phenomena and their interactions.

Firstly, we will study the surface turbulence and the processes that develop in the lower troposphere, which has traditionally been analysed over homogeneous and flat surfaces. These processes affect the local turbulent transfer, the advection (of scalars, heat or momentum) between different nearby sites, and the vertical divergence of the radiative flux (through temperature stratification), among others. All these processes are linked and give rise to particular vertical and horizontal fields of wind, temperature, humidity and trace gases. This complex behaviour of the lower atmosphere has two different consequences on model forecasts. On the one hand, some of these processes are not well parameterized in the numerical weather prediction (NWP) and climate models yet (such as gravity waves, shallow drainage flows, turbulence, or fog). On the other hand, they increase the uncertainty of the representativeness of the local measurements used for model validation. Ultimately, these two effects contribute to the observed low performance of model simulations, typically producing biases. Therefore, we plan to address this part of the study by confronting the high-quality observational data already collected from the experimental sites and high-resolution numerical model simulations to investigate the model ability and weaknesses simulating these processes. Particularly, we will use the Weather Research and Forecasting (WRF) model. Román-Cascón et al. (2021) showed the relevance of investigating the ability of WRF to represent land-atmosphere interactions in a heterogeneous area, particularly the surface heat fluxes, by using several possibilities for the surface representation of the land cover and the land surface models available.

In this project, for some particular events, also WRF with turbulence-resolving capability based on a large-eddy simulation (LES) approach (WRF-LES) will be used. Actually, using nested domains but also a grid resolution under 1 km would be desired to properly capture microscale phenomena.

In addition, as one of the high-quality observational datasets we have is close to a city, we will deep into the dynamic and thermal impacts of the thermally-driven flows in different zones of the city and their effects on the Urban Heat Island structure. Additionally, the heterogeneous influence of mountain and valley breezes together with urban breezes on air quality will be investigated. In all these cases, high-resolution numerical simulations will be needed.

Finally, among the future objectives of the project, there would also be the operational simulation of some periods of interest, in summer in coastal areas or in winter in stable situations where mountain breezes and their interactions with urban areas take place, automating WRF simulations in forecast mode.

This team does not currently have the required infrastructure to obtain such high-resolution simulations and we need enough computer resources in order to reach all these goals. Therefore, this SPECIAL PROJECT 2025–2027 will be the main source of computing time for the diverse simulations needed in the analysis of the different types of breezes. To conclude with, the SBUs and GBs indicated in the table are an estimation, as several previous tests will be required to obtain a model configuration which represents accurately the target phenomena in the respective areas of study.

References

- Beniston, M. "Mountain climates and climatic change: An overview of processes focusing on the European Alps." Pure and Applied Geophysics 162 (2005): 1587-1606.

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- Holtslag, A. A. M., et al. "Stable atmospheric boundary layers and diurnal cycles: challenges for weather and climate models." Bulletin of the American Meteorological Society 94.11 (2013): 1691-1706.

- Román-Cascón, C., et al. "Surface representation impacts on turbulent heat fluxes in the Weather Research and Forecasting (WRF) model (v. 4.1. 3)." Geoscientific Model Development 14.6 (2021): 3939-3967.

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