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	2024
Project Title:	PHYSICAL MECHANISM AT A BASIN SCALE IN COMPLEX TERRAIN REGIONS: PERSISTENT FOG AND SEA-BREEZE FRONT PROPAGATION
Computer Project Account:	spesturb
Principal Investigator(s):	Maria Antonia Jiménez Cortés
Affiliation:	Universitat de les Illes Balears (Spain)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	-
Start date of the project:	1st January 2024
Expected end date:	31st December 2026

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

(if applicable)
Please answer for all project resources

		Previous year (previous special project)		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	900,000	945,156	5,000,000	1,403,044
Data storage capacity	(Gbytes)	200	200	200	200

Summary of project objectives (10 lines max)

Two complex terrain regions are taken in this project following the results of the previous one. For the eastern Ebro subbasin, a combined study of in-situ observations and simulations will be carried out to better understand the physical mechanisms that take place during fog events (which are very frequent and can persist for several days), colder pooling within the basin and the propagation of the sea-breeze front (local wind known as *Marinada*). The runs will be based on observations started after the LIAISE campaign and still made at the site. For the island of Mallorca, simulations will be carried out to further understand the interactions between the sea/land breezes with the locally-generated winds of smaller scale and with the winds of larger scale (interactions between the sea/land breezes generated in the three main basins). The studied cases will be based on observations during the AGROWIND experimental field campaign (2021-24), organized by the members of the special project.

Summary of problems encountered (10 lines max)

None

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

Following the objectives of the special project, simulations over the island of Mallorca have been started. We plan to complete the runs of several cases in order to study in depth the propagation of sea breezes inland in the three main basins. At the same time, simulations of sea-breeze events during winter will be carried out.

List of publications/reports from the project with complete references

M.A. Jiménez, A. Grau, L. Marí, Ll. Cuadros, A. Serra, A. Maimó-Far (**2024**) Study of the physical mechanisms during sea breeze events in the Mallorca island through observations and simulations, European Meteorological Society meeting (Barcelona), EMS2024-838 (oral presentation)

Ll. Cuadros (**2024**) A numerical study to characterize the winter-time sea-breeze in the Alcúdia basin (Mallorca), Final degree thesis (supervised by M.A. Jiménez), Physics Degree at the University of Balearic Islands

A. Grau and M.A. Jiménez (**2024**) The importance of the surface features in the initiation and propagation of the sea-breeze front, *in preparation to submit to a journal*.

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.

During previous spesturb projects, mesoscale simulations were carried out over the island of Mallorca to better understand the organisation of the flow at low levels. Several simulations of some selected sea-breeze (SB) events in the Palma, Alcúdia and Campos basins have been performed, based on the filter proposed by Grau et al. (2021) and Grau and Jiménez (2024) to select these events. This statistical analysis, based on observations of the surface AEMET network, shows that most of the SB days occur during the warm months of the year (about 50% of these days), although the filter also selects 1-2 SB days per year during winter.

The results in the Palma basin (in the west of the island) show that the SB is stronger in summer than in winter, in accordance with the horizontal thermal gradient between the sea and land. The advection of the cold air from the sea is also more pronounced in summer because when it reaches a certain point in the basin, the radiative warming stops. The propagation of the SB front is clearly seen in summer but it is reduced to a coastal circulation in winter. Sensitivities in horizontal resolution also showed that resolutions of about 200m are needed to properly reproduce the organisation of the flow at low levels in the basin, as well as the interactions between the circulations of different scales (e.g. slope winds and SB).

The organisation of the flow at lower levels during the summer SB in the Alcúdia basin (in the northeast of the island) is completely different from that in the Palma basin. The lower parts of the Alcúdia basin are flat and mainly used for agriculture, whereas the Palma basin is smaller and the lower parts are mainly used by the airport and the city of Palma. Simulations for a summer SB event in the Alcúdia basin showed that this wind is from northeast, opposite to the general synoptical winds (westerlies at this latitude) and to the SB already generated in the Palma basin. Therefore, the interactions between the SB and larger/smaller scale winds in the Alcúdia basin are important.

At the beginning of the current special project the attention is focused on the further exploring of the SB in the Alcúdia basin. A winter SB case is taken (based on observations of the AGROWIND experimental field campaign). The simulation starts at 1800 UTC on 24th January 2022 and ends at 0000 UTC on 26th January 2022. The SB event takes place on the 25th January, when the spin-up of the simulation is completed.

Three nested domains are taken (Figure 1) and preliminary results are explored only analysed for the inner domain (at 250m of horizontal resolution). For the vertical domain, the resolution is 3m and stretched above to better include the physical processes that take place at lower levels. The simulation strategy is similar to the one used in the previous special project: initial conditions are taken from the ECMWF analysis and turbulence, advection and surface are the main parameterisations.

The results obtained have been validated with observations from the surface weather stations of the AEMET network and data from the AGROWIND experimental field campaign. The model is able to reproduce the diurnal cycle of the SB (see for example Figure 2 for a site close to the coast). The diurnal cycle of temperature and specific humidity is also well captured, although it fails to reproduce the temperature and humidity during the night. This fact could be related to the poor spatial resolution to reproduce the surface heterogeneities but also to the fact that the turbulence scheme reaches its limits when winds are weak and nocturnal coolings are strong (weak and intermittent turbulence). The same run is performed with 3D turbulence, starting at 1200 UTC to represent the night cooling of the previous SB day. The results do not change significantly (see the thin line in Figure 2), suggesting the difficulties in the model parameterisations to properly reproduce the organisation of the flow at lower levels.

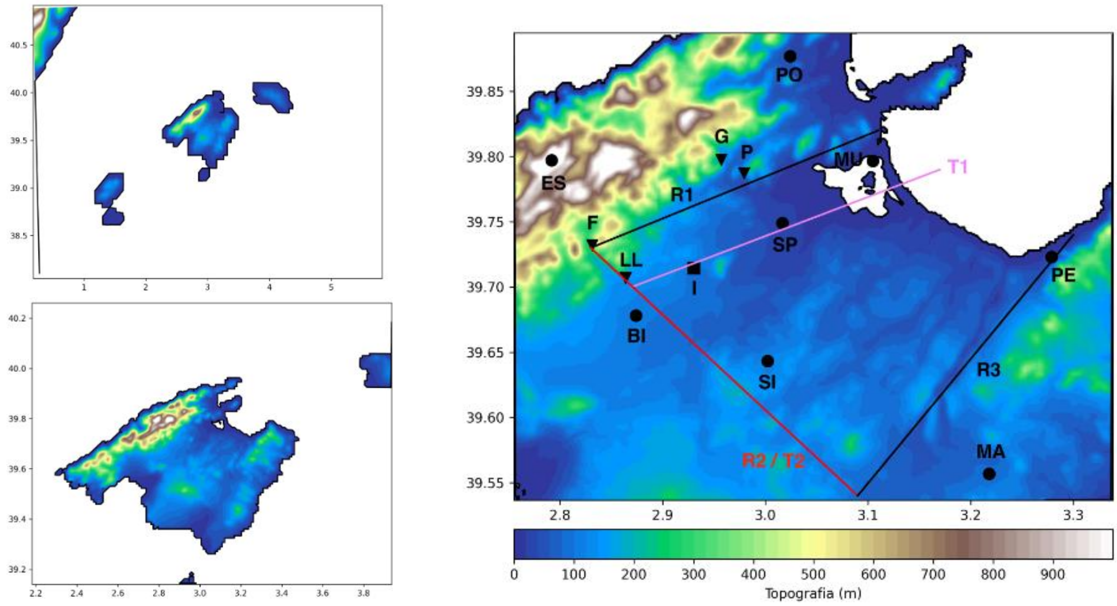

Figure 1. Topography of the nested domains of the simulation increasing the horizontal resolution: (top.left) 5km x 5km; (bottom.left) 1km x 1km; (right) 250m x 250m. In the latter, the locations of the surface observation network are indicated by a symbol and a label. The dots and squares indicate the AEMET stations, while the triangles represent the observations made during the AGROWIND experimental field campaign by the members of the special project.

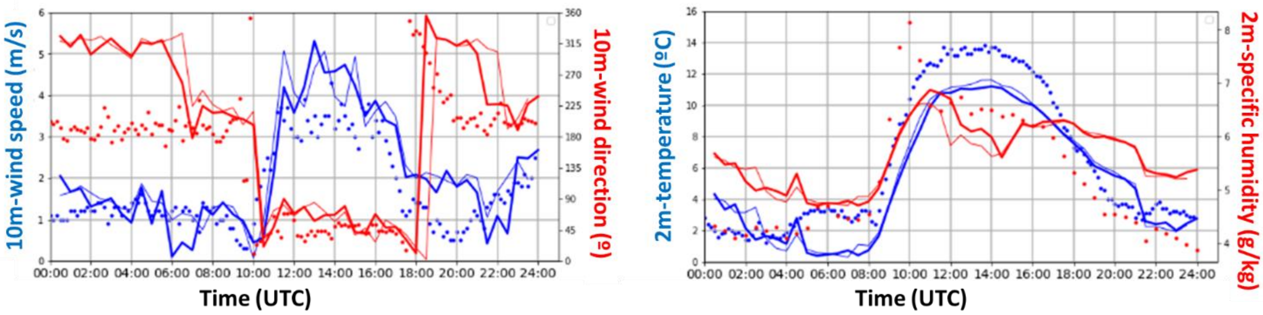

Figure 2. Temporal evolution of 10m wind speed and direction and 2m temperature and humidity for a site near the coast (SP in Figure 1.right). Observations are shown as points and simulations as lines. The thinner line shows the model output using the 3-D turbulence scheme and initiated at 1200 UTC of the previous day.

Inspecting the horizontal cross-sections (Figure 3) at several instants it is found that winds are from the western sector and weak during the night (corresponding to the land-breeze, 0700 UTC, Figure 3.left) and a maximum wind speed is found over the sea in the middle of the bay while the wind is weaker over the land. At 1000 UTC, the land breeze becomes weaker and is opposite to the larger scale wind over the sea (Figure 3.middle). One hour later (at 1100 UTC) the wind veers and it has the SB wind direction over the land, enhanced by the eastern larger scale wind (Figure 3.right).

Inspecting the hourly evolution of the horizontal cross-sections for the 10m-wind (not shown), it is found that this simulated winter SB is strongly influenced by the larger scale wind from the eastern sector. It is important at higher levels, while it weakens at lower levels, allowing the SB to form in the lower parts of the Alcúdia basin. Once the SB is formed, it is reinforced by this larger scale wind, since both have the same wind direction.

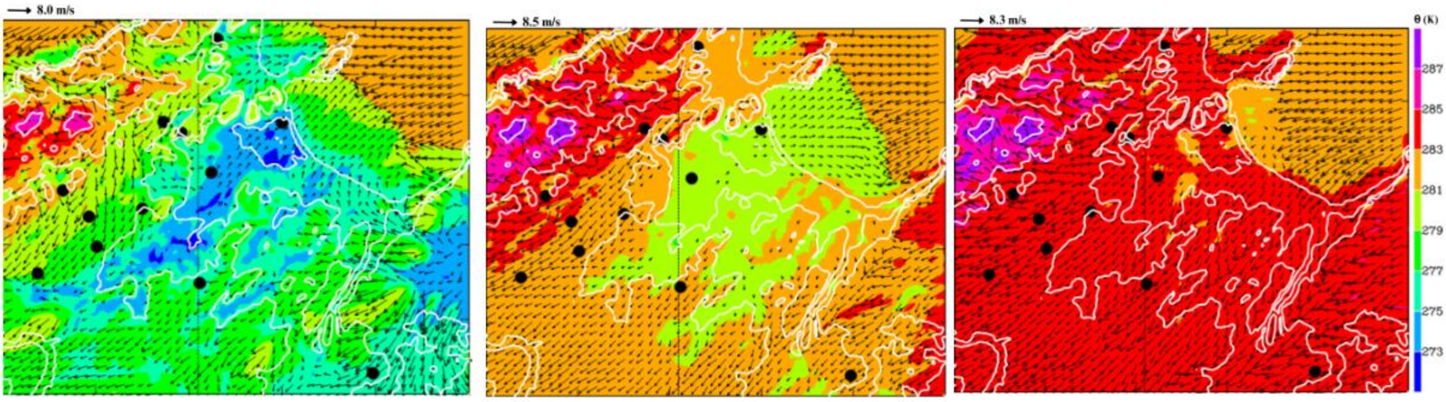

Figure 3. Potential temperature fields at 2m (in colours) together with the 10m wind vectors for the inner domain of the simulation at (left) 0700 UTC, (middle) 1000 UTC and (right) 1100 UTC for the sea breeze event of 25th January 2022.

The results of this winter case were also compared with those of a summer breeze case studied in the previous special project (Figure 4). Preliminary results show that the SB is weaker in winter than in warm months and consequently the temperature and humidity advection are less intense. The results suggest that the horizontal thermal gradient is important for SB occurrence, but other factors, such as the larger scale winds, are crucial for describing the diurnal evolution of the SB.

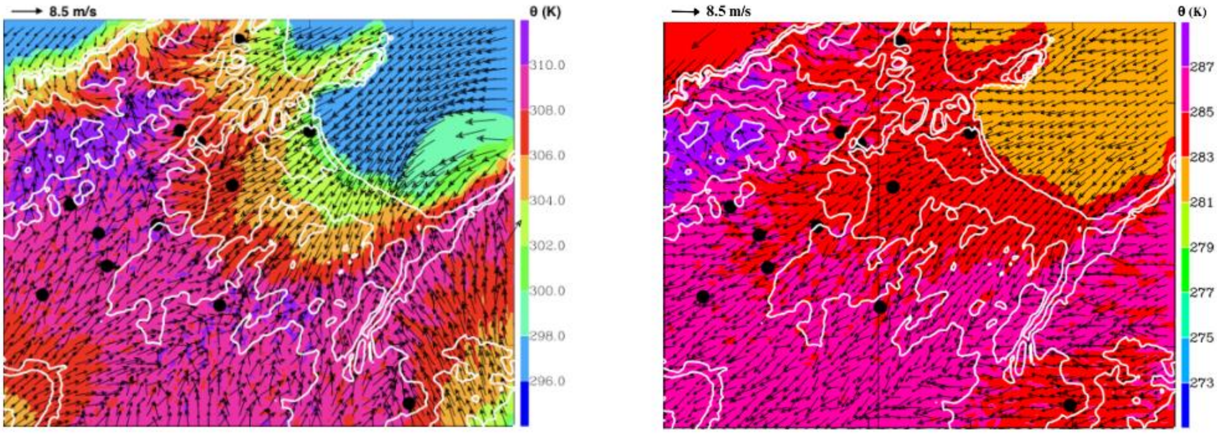

Figure 4. Potential temperature fields at 2m (in colours) together with the 10m wind vectors for the inner domain of the simulation at 1300 UTC for 2 simulated sea breeze events (left) during summe (21st July 2021) and (right) during winter (25th January 2022).