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:	Simulations of Meteorological Hazards Affecting Aviation Safety in the Iberian Peninsula
Computer Project Account:	spesvale
Principal Investigator(s):	Francisco Valero
Affiliation:	Department of Earth Physics and Astrophysics, Faculty of Physics, Complutense University of Madrid, Plaza de las Ciencias 1, 28040 Madrid. Spain.
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Javier Díaz-Fernández (UCM), Pedro Bolgiani (UCM), Carlos Calvo (UVa), Lara Quitián-Hernández (UVa), Mariano Sastre (UCM), María Luisa Martín (UVa), Daniel Santos (DMI), José Ignacio Farrán (UVa), Juan Jesús González-Alemán (AEMET), Eloy Piernagorda (UCM) UCM: Universidad Complutense de Madrid. Spain UVa: Universidad de Valladolid. Spain DMI: Danish Meteorological Institute. Denmark AEMET: Agencia Estatal de Metorología. Spain
Start date of the project:	January 2022
Expected end date:	December 2024

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	1339837	300000	427283
Data storage capacity	(Gbytes)	10000	10000	10000	10000

Summary of project objectives (10 lines max)

Meteorology is essential in aviation since it has a significant impact on flight planning and safety. High-resolution numerical simulations are suggested for accurately characterising aviation-related meteorological events. SPESVALE simulates mountain waves and severe convective weather phenomena (such as supercells, thunderstorms, and downbursts) on the Iberian Peninsula using the WRF-ARW and HARMONIE-AROME models. The potential impact of global climate change on the precursor environments to mountain lee wave cloud episodes over central Iberia are examined. Moreover, the effect of complex orography in supercell and downburst development event in Spain were investigate using three different Weather Research and Forecasting numerical weather prediction model (WRF-ARW) orography experiments.

Summary of problems encountered (10 lines max)

We noticed some issues with the HARMONIE-AROME model related to domain size, increased temporal and horizontal resolutions, the establishment of nested domains... which produced running many times for testing such a model, and the usage of more SBUs than originally expected. No other problems of more technical nature have presented.

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

Related to severe convective weather phenomena, a selection of diverse global and regional climates will be analysed to identify the atmospheric conditions conducive to such events. This analysis will comprehend both historical data and future climate projections, with a particular focus on the SSP5-8.5 scenario, which represents a high greenhouse gas emissions trajectory. By examining these conditions, we aim to understand how the frequency, intensity, and distribution of severe convective storms might change in the future. Additionally, we will employ the pseudo global warming (PGW) approach, to isolate the impact of anthropogenic climate change on these phenomena. The PGW approach allows for a controlled comparison, providing insights into how human-induced warming influences severe weather patterns. Through this comprehensive study, we hope to establish clearer links between climate change and severe convective weather, aiding in future prediction and mitigation efforts.

List of publications/reports from the project with complete references

J. Díaz-Fernández, C. Calvo-Sancho, P. Bolgiani, J.J. González-Alemán, J. I. Farrán, M. Sastre, M.L. Martín. On the atmospheric conditions leading to mountain lee waves in central Iberia under CMIP6 projections. Atmosphere, 15 (1), 128. https://doi.org/10.3390/atmos15010128. 2024.

M.L. Martín, C. Calvo-Sancho, M. Taszarek, J.J. González-Alemán, A. Montoro-Mendoza, J. Díaz-Fernández, P. Bolgiani, M. Sastre, Y. Martín. Major Role of Marine Heatwave and Anthropogenic Climate Change on a Giant Hail Event in Spain. Geophysical Atmospheric Letters. 51, e2023GL107632. https://doi.org/10.1029/2023GL107632. 2024.

Meetings:

A. Montoro-Mendoza, C. Calvo-Sancho, J.J. González-Alemán, J. Díaz-Fernández, P. Bolgiani, M. Sastre, M.L. Martín. Influencia del cambio climático antropogénico en ambientes favorables para el desarrollo de transiciones tropicales en el Atlántico Norte. XXXVI Jornadas Científicas de la Asociación Meteorológica Española y el XXII Encuentro Hispano – Luso de Meteorología. Cádiz (España). 2024.

Alonso García-Miguel, Carlos Calvo-Sancho, Javier Díaz-Fernández, Ricardo Castedo, José J. Ortega, María Yolanda Luna, Ana Morata, María Luisa Martín. Evaluación del impacto climático en el recurso eólico en la península ibérica. XXXVI Jornadas Científicas de la Asociación Meteorológica Española y el XXII Encuentro Hispano – Luso de Meteorología. Cádiz (España). 2024.

Carlos Calvo-Sancho, Yago Martín, Juan Jesús González-Alemán, María Luisa Martín. Atribución a ola de calor marina y cambio climático antropogénico de un evento de granizo gigante en agosto de 2022. XXXVI Jornadas Científicas de la Asociación Meteorológica Española y el XXII Encuentro Hispano – Luso de Meteorología. Cádiz (España). 2024.

Mauricio López-Reyes, J.J. González-Alemán, M. Martín-Pérez, C. Calvo-Sancho, P. Bolgiani. Incertidumbres en la predicción del huracán leslie: caso de estudio con el modelo MPAS. XXXVI Jornadas Científicas de la Asociación Meteorológica Española y el XXII Encuentro Hispano – Luso de Meteorología. Cádiz (España). 2024.

Redaelli, Gianluca, Calvo-Sancho, & Martín, M. L. Exploring how a warmer Mediterranean Sea affects the origin and development of destructive Tropical-Like Cyclones IANOS and DANIEL. European Geophysical Union Annual Meeting (EGU). Viena (Austria). 2024

Javier Díaz-Fernández, García-Miguel, Alonso, Calvo-Sancho, Carlos, Ricardo Castedo, José J. Ortega, Pedro Bolgiani, Mariano Sastre, María Yolanda Luna, María Luisa Martín. A wind energy resource analysis in the iberian peninsula under climate projections. European Geophysical Union Annual Meeting (EGU). Viena (Austria). 2024

Ana Montoro-Mendoza, Carlos Calvo-Sancho, Juan Jesús González-Alemán, Javier Díaz-Fernández, Pedro Bolgiani, José Ignacio Farrán, Ana Morata and María Luisa Martín. Anthropogenic Climate Change Attribution to a Giant Hail Event in August 2022 in Northeastern Spain. European Geophysical Union Annual Meeting (EGU). Viena (Austria). 2024.

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.

Several results related to mountain lee waves and severe convective weather phenomena were obtained during the last year, thanks to the SPESVALE special project.

Atmospheric conditions leading to mountain lee waves in central Iberia under CMIP6 projections were analysed obtaining statistically significant variations and trends in precursor environments

between historical data and future climate scenarios, with a particular focus on the expansion of the Azores High towards the Iberian Peninsula, resulting in increased zonal winds throughout the Iberian Peninsula in the future. However, the increase in zonal wind is insufficient to modify the wind pattern, so future mountain lee wave cloud events will not vary significantly. Moreover, the risk of icing precursor environments connected with mountain lee wave clouds is expected to decrease in the future, due to rising temperatures. Our results highlight that the EC-EARTH3 Global Climate Model reveals the closest alignment with ERA5 data, and statistically significant differences between the historical and future climate scenario periods are presented, making EC-EARTH3 a robust candidate for conducting future studies on the precursor environments to mountain lee wave cloud events, among the remainder used CMIP6 climate models.

On the other hand, on July 1, 2018, many supercells were spotted near the Zaragoza Airport (Spain), and at least one of them generated a downburst that affected the airport, causing significant damage in the surrounding area. This event was simulated using the Weather Research and Forecasting (WRF-ARW) numerical weather prediction model using three different orography experiments to investigate if the region's complex orography has an important role in supercell and downburst development. One of the three experiments uses the default orography as control; another one uses a 90% smoothed orography, and the third experiment is configured with a high-resolution dataset. Several atmospheric and convective variables are compared for each orography experiment. Results show that the smoothing process leads to a more uniform wind flow, contributing to the formation of numerous supercells. However, supercells channel through valleys and mountains in the control and high-resolution orography experiments, where the surface wind divergences are uniquely reproduced, and the highest reflectivity values are observed. Moisture advection from the Mediterranean Sea is essential in the process, reaching more deeply into the study region in the smoothed orography experiment due to the lack of orographic barriers. Orography affects dynamic and thermodynamic features, which have considerable effects on the formation and development of downbursts.