REQUEST FOR A SPECIAL PROJECT 2022–2024

MEMBER STATE: SPAIN

Principal Investigator[1]**:** FRANCISCO VALERO

Affiliation: FACULTAD DE CIENCIAS FÍSICAS. UNIVERSIDAD COMPLUTENSE DE MADRID

Address: PZA. CIENCIAS, 1. 28040 MADRID. SPAIN

Other researchers: 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

Project Title: SIMULATIONS OF METEOROLOGICAL HAZARDS AFFECTING AVIATION SAFETY IN THE IBERIAN PENINSULA
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If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPESVALE**	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2022	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2022-2024: (To make changes to an existing project please submit an amended version of the original form.)		**2022**	**2023**	**2024**
High Performance Computing Facility	(SBU)	300000	300000	300000
Accumulated data storage (total archive volume)[2]	(GB)	10000	10000	10000

Continue overleaf

[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.

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Extended abstract

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

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.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific Advisory Committee. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, and 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 asking for 3,000,000 SBUs or more should be more detailed (3-5 pages). Large requests asking for 10,000,000 SBUs or more might receive a detailed review by members of the Scientific Advisory Committee.

Aviation is strongly dependent on meteorology, as flight plans and aviation safety are largely affected by a number of meteorological phenomena. For instance, aircraft icing and turbulence are likely to be dangerous in departure and arrival operations in the vicinity of airports (Gultepe et al., 2019). Moreover, according to the National Transportation Safety Board (2014), meteorological conditions are the main reason for aviation accidents in 37% of the cases, being icing and turbulence associated with mountain waves the main causes in the 2000–2011 period in the US. Furthermore, weather hazards represented approximately 15% of the accidents and serious incidents in the European Risk Classification Scheme for 2019 (European Union Aviation Safety Agency, 2019).

Some previous studies from Fernández-González et al. (2014, 2015) analysed events of freezing drizzle in the Guadarrama range (in the middle of the Iberian Peninsula). Besides, Bolgiani et al. (2018) simulated an episode of mountain waves and ice conditions in the same area, which was actually reported by an airplane flying over that location. From those simulations it was suggested that clear air turbulence was found above the mountain wave cloud top. The results encouraged the use of mesoscale models and images from the Meteosat Second Generation (MSG) satellite to minimize aviation risks associated with such meteorological phenomena.

To properly characterize these and other aviation-related meteorological phenomena with numerical simulations, it is typically required very high-resolution simulations, both temporally and spatially. Thanks to a previous special project (SPESVALE), this research team is working on simulating several mountain waves events in the Guadarrama range area, with two well-known numerical weather prediction models, namely WRF-ARW (from now on, WRF) and HARMONIE-AROME (for short, Harmonie). These two models present different features, and therefore it is interesting to analyse how the aviation-related meteorological hazards are represented, considering their differences. With the current proposal, we aim to continue analysing this kind of events in the aforementioned zone. In addition to this, we would like to extend the study to focus on the assessment of atmospheric turbulence, which still needs to be better characterized. To this purpose, around 300 events in the period 2000-2020 have been identified, and these are the targets to be simulated with the two models. Using both models' simulations results, we aim to perform a comparison in order to establish similitudes and differences between their behaviour in reproducing mountain waves events and their features.

On the one hand, the Harmonie Reference system is maintained on the ECMWF HPC platform. This Reference System includes code, scripts and some other useful tools which may be required to run and postprocess the deterministic model. The previous Special Project (SPESVALE) aimed to obtain very high-resolution simulations of different variables: wind speed, temperature, liquid water content and other derived relevant variables, so that the mountain waves can be properly characterized.

On the other hand, for SPESVALE Special Project the WRF model was also implemented. Furthermore, different types of WRF settings have been extensively tested (Díaz-Fernández et al., 2020) to obtain a model configuration which represents accurately the formation of mountain waves in the Guadarrama range zone. These experiments included variations in the planetary boundary layer (PBL) schemes and surface model parameterizations. The best configuration from those experiments is expected to be the one considered for our future simulations. It includes for radiation, the Dudhia shortwave scheme (Dudhia, 1989) and RRTM longwave scheme (Mlawer et al., 1997), the Unified Noah land-surface model (Tewari et al., 2004), the revised MM5 (Jiménez et al., 2012) surface layer scheme, the Yonsei University (YSU) (Hong et al., 2006) PBL parameterization, and the Thompson (Thompson et al., 2008) microphysics scheme. Besides, initial and boundary conditions will be taken from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), with a temporal resolution of six hours and a horizontal spatial resolution of 0.5°. Each episode will be initialized at 00:00 UTC and independently run in periods of 24 h. A configuration with four nested domains will be considered (Figure 1), following a two-way nesting strategy. Each one will have 121 × 121 grid points in north-south and east-west directions, and 40 sigma vertical levels. The outer domain (d01) covers southwestern Europe and North Africa with 27 km of spatial resolution. Domain d02 approximately encompasses the Iberian Peninsula with 9 km resolution, whereas domains d03 and d04 are centred over the Guadarrama range covering the area of study at 3 and 1 km, respectively.

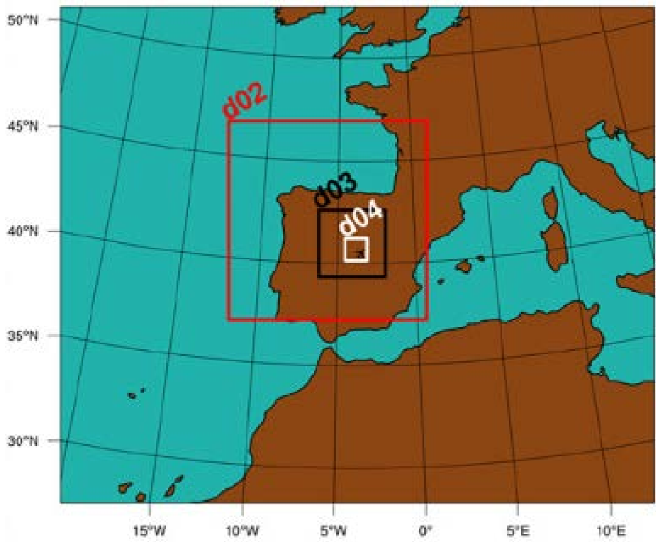

Figure 1: WRF domain configuration. Outer boundary corresponds to outermost domain.

Díaz-Fernández et al. (2021) studied the relevant thresholds involved in the mountain waves formation. The research strategy consisted of focusing on several simulation grid points with three different categories: in the windward side, over the Guadarrama mountains, and in the leeward side. A similar approach will be done in the upcoming studies we aim to perform.

Moreover, Díaz-Fernández et al. (2021) sketched a decision tree (Figure 2). It has been also evaluated to create a warning method which is able to detect these potentially dangerous events. This decision tree allows us to forecast a warning for mountain waves, wave clouds and icing with at least 24 h in advance. After validating the results against satellite images, good skill scores are found. Additionally, when the decision tree is applied in this area to a particular case study, the warnings yielded are in accordance with the reported observations.

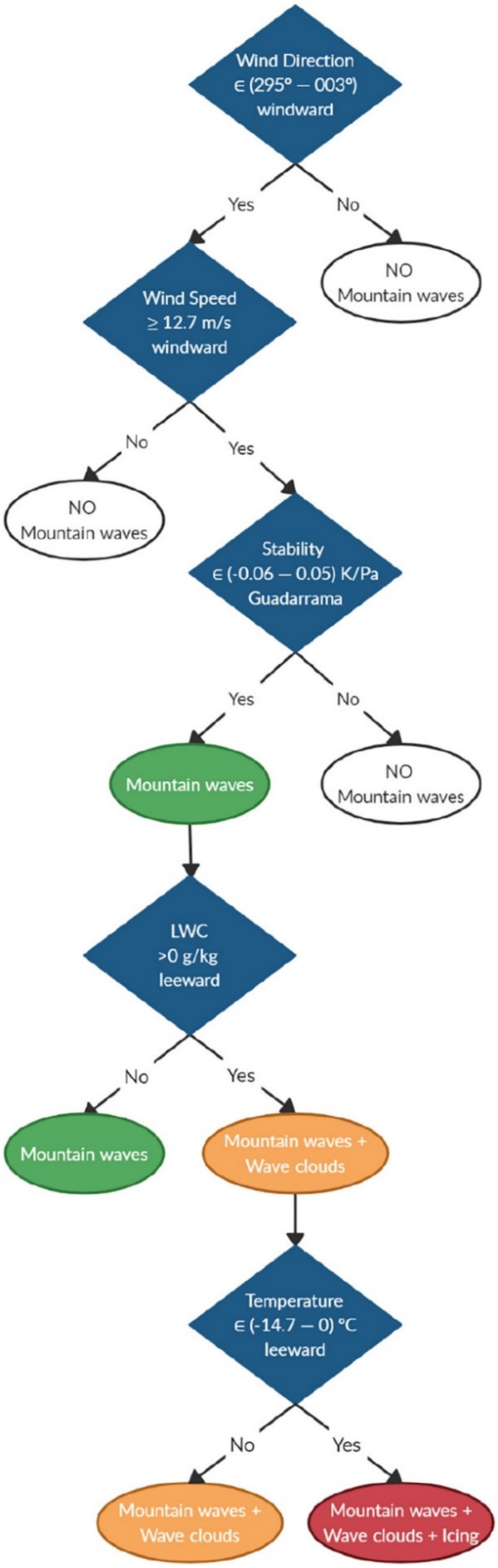

Figure 2: Decision tree for mountain waves, wave clouds, and icing risk warning.

As we will focus on, but not restrict to mountain waves, the scientific goals of this project can be summarized as follows:

- Assessment of the mesoscale atmospheric situations, as well as the synoptic factors, which are directly related to icing risk conditions and mountain waves, focusing in the area surrounding the Guadarrama range.
- Application of machine learning techniques in order to improve the decision tree and warning system.
- Deep study of a derived variable which is very useful for aviation purposes, namely eddy dissipation rate, in order to include it as a key variable to be analysed and included in the decision tree and warning system.

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