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	2022
Project Title:	SIMULATIONS OF METEOROLOGICAL HAZARDS AFFECTING AVIATION SAFETY IN THE IBERIAN PENINSULA
Computer Project Account:	.....SPESVALE.....
Principal Investigator(s):	FRANCISCO VALERO
Affiliation:	FACULTAD DE CIENCIAS FÍSICAS. UNIVERSIDAD COMPLUTENSE DE MADRID PZA. CIENCIAS, 1. 28040 MADRID. SPAIN
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…… ……
Start date of the project:	01/01/2022
Expected end date:	31/12/2024

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	105000
Data storage capacity	(Gbytes)			10000	10000

Summary of project objectives (10 lines max)

Aviation is strongly dependent on meteorology, as flight plans and aviation safety are largely affected by a number of meteorological phenomena. To properly characterize aviation-related meteorological phenomena, it is desirable to use high-resolution numerical simulations. In SPESVALE, simulations of mountain waves and icing events near the Madrid Airport are carried out using the WRF-ARW and HARMONIE-AROME models. Atmospheric variables involved in the genesis of mountain waves are analysed, also focusing on the assessment of atmospheric turbulence. 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 to establish similitudes and differences between their behaviour in reproducing these meteorological phenomena related to aviation safety.

Summary of problems encountered (10 lines max)

Díaz-Fernández et al. (2021) studied the relevant thresholds involved in the mountain waves formation. Moreover, a decision tree was developed and evaluated to create a warning method, 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. To validate the results, satellite images were used. However, in the turbulence case, an observational data base is not available. It has been necessary to find turbulence reports related to mountain lee wave events in the study area, and the remainder. Finally, turbulence reports were extracted for the pilot reports (PIREPs), the Spanish commission for the investigation of civil aviation accidents and incidents reports (CIAIAC) and a turbulent and icing report occurred on 28 February 2017 and studied by Bolgiani et al. (2018). This fact has delayed obtaining of results.

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

A deep study of a derived variable which is very useful for aviation purposes, namely eddy dissipation rate (EDR), will be carried out to involve it as a key variable to be analysed and included in the decision tree and warning system. Moreover, other meteorological phenomena related to aviation safety, such as microbursts and supercells, will be also studied. To do this, simulations of such systems will be run using WRF-ARW and HARMONIE-AROME. The obtained results will be published.

List of publications/reports from the project with complete references

Journal Publications:

J. Díaz-Fernández, P. Bolgiani, D. Santos-Muñoz, L. Quitián-Hernández, M. Sastre, F. Valero, J. I. Farrán, J.J. González-Alemán and M.L. Martín. Comparison of the WRF and HARMONIE models ability for mountain wave warnings. Atmospheric Research, 265, 1-14. 105890. doi.org/10.1016/j.atmosres.2021.105890. 2022.

Bolgiani, P., Calvo-Sancho, C., Díaz-Fernández, J., Quitián-Hernández, L., Sastre, M., Santos-Muñoz, D., Farrán, J.I., González-Alemán, J.J., Valero, F., Martín, M.L. Wind Kinetic Energy Climatology and Effective Resolution for the ERA5 Reanalysis. Cimate Dynamics. https://doi.org/10.1007/s00382-022-06154-y. 2022.

Díaz-Fernández, J., Bolgiani, P., Sastre, M., Santos-Muñoz, D., Valero, F., Farrán, J.I. & Martín, M.L. Ability of the WRF and HARMONIE-AROME models to detect turbulence related to mountain waves over central Iberia. Atmospheric Research. 274, 1-8; https://doi.org/10.1016/j.atmosres.2022.106183. 2022

Calvo-Sancho, C., González-Aleman, J.J., Bolgiani, P., Santos-Muñoz, D., Farrán, J.I., Martín, M.L. An Environmental Synoptic Analysis of Tropical Transitions in the Central and Eastern North Atlantic. Atmospheric Research. Under review 2022.

Carlos Calvo-Sancho, Javier Díaz-Fernández, Yago Martín, Pedro Bolgiani, Mariano Sastre, Juan Jesús González Alemán, Daniel Santos-Muñoz, José Ignacio Farrán, María Luisa Martín, Supercell Convective Environments in Spain based on ERA5: Hail and Non-Hail Differences. Weather and Climate Dynamics. Under review. 2022

L. Quitián-Hernández, P. Bolgiani, D. Santos-Muñoz, M. Sastre, J. Díaz-Fernández, J. J. González-Alemán, J. I. Farrán, C. Calvo-Sancho, F. Valero and M. L. Martín. Analysis of the October 2014 subtropical cyclone using the WRF and the HARMONIE-AROME numerical models: assessment against satellite data. In preparation. 2022.

Meetings:

EGU

Calvo-Sancho, C., González-Alemán, J. J., Bolgiani, P., Santos-Muñoz, D., Farrán, J. I., Sastre, M., and Martín, M. L.: A Climatology of Tropical Transitions in the North Atlantic Ocean, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-2395, https://doi.org/10.5194/egusphere-egu22-2395, 2022.

Díaz Fernández, J., Bolgiani, P., Santos Muñoz, D., Sastre, M., Valero, F., Farrán, J. I., González Alemán, J. J., and Martín Pérez, M. L.: Characterization and warnings for mountain waves using HARMONIE-AROME, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-2471, https://doi.org/10.5194/egusphere-egu22-2471, 2022.

Calvo-Sancho, González-Alemán, J.J., Díaz-Fernández, J., Quitián-Hernández, L., Bolgiani, P., Santos-Muñoz, D., Farrán, J.I., Sastre, M., Calvo, J., and Martín, M.L.: Ianos in the HARMONIE-AROME model, I MedCyclones Workshop and Training School, MedCyclones Cost Action, Athens, Greece, 27 June - 2 July 2022.

Díaz-Fernández, J., Calvo-Sancho, C., González-Alemán, J.J., Bolgiani, P., Santos-Muñoz, D., Farrán, J. I., Sastre, M., Quitián-Hernández, L., and Martín, M. L.: WRF vs HARMONIE-AROME: A Comparison in a Supercell Event, Online Mini-European Conference on Severe Storms (mini ECSS), European Severe Storms Laboratory, Online, 27-28 September 2022.

Calvo-Sancho, C., Díaz-Fernández, J., Bolgiani, P., González-Fernández, S., González-Alemán, J.J., Santos-Muñoz, D., Farrán, J. I., Sastre, M., Quitián-Hernández, L., and Martín, M. L.: Microburst and Supercell Analysis - A study of 1 July 2018 Severe Weather Event over Zaragoza's Airport, Online Mini-European Conference on Severe Storms (mini ECSS), European Severe Storms Laboratory, Online, 27-28 September 2022.

J. Díaz-Fernández, M.Y. Luna, P. Bolgiani, D. Santos-Muñoz, M. Sastre, F. Valero, J.I. Farrán, JJ. González-Alemán, L Quitián-Hernández, M.L. Martín (2022). Climatología de ondas de montaña en la sierra de Guadarrama: caracterización con el modelo meteorológico de alta resolución WRF. XII Congreso Internacional de la Asociación Española de Climatología (AEC): Retos del Cambio Climático: impactos, mitigación y adaptación. Santiago de Compostela (Spain), October 2022.

C. Calvo-Sancho, J.J. González-Alemán, M.Y. Luna, P. Bolgiani, D. Santos-Muñoz, L. Quitián-Hernández, M.Sastre, F.Valero, J.I. Farrán, J.Díaz-Fernández, L. López, M.L. Martín. Identificación y Distribución Temporal de Transiciones Tropicales en el Océano Atlántico Norte. XII Congreso Internacional de la Asociación Española de Climatología (AEC): Retos del Cambio Climático: impactos, mitigación y adaptación. Santiago de Compostela (Spain), October 2022.

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.

A characterization of turbulence associated to mountain lee waves in the vicinity of the Adolfo Suarez-Madrid Barajas International Airport was carried out using WRF-ARW and HARMONIE-AROME models. The vertical wind speed and the EDR (Figure 1) have been successfully evaluated to know the turbulence intensity associated to these events. Also, the results show the ability of the models to detect clear air turbulence when lenticular clouds are not present. Moreover, based on probability density functions of the maximum EDR, the highest values of EDR were obtained when lenticular cloud bands associated to mountain lee waves are diagnosed in the leeward of the mountain range. Differences in results from WRF-ARW and HARMONIE-AROME are discussed in Díaz-Fernández et al. (2022).

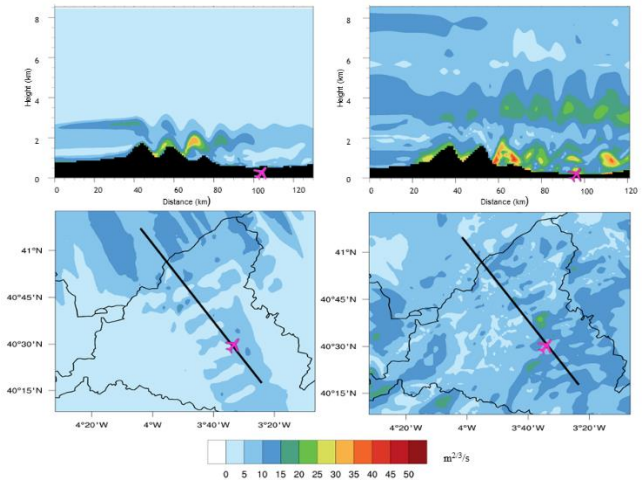

Figure 1: EDR ($m^{2/3}/s$) on 06 November 2009 at 13:00 UTC. (a) HARMONIE-AROME Cross section. (b) WRF-ARW Cross section. (c) HARMONIE-AROME at 2800 masl. (d) WRF-ARW at 2800 masl. Aircraft symbols correspond to Barajas Airport location and the black line indicates the cross section used.

Considering the EDR-P10 as threshold, a decision tree based on Díaz-Fernández et al. (2021) methodology, is developed to establish a warning (Figure 2). The turbulence warning associated with mountain lee waves events has been validated against turbulence reports of pilot reports and accidents and incidents reports, showing that EDR skill scores for the WRF model seem to be better than those obtained with HARMONIE.

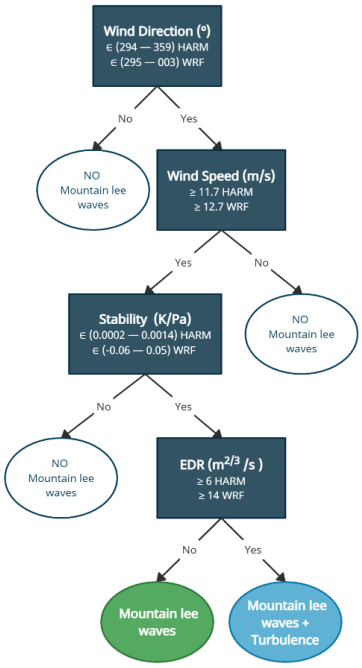

Figure 2: Decision tree created for HARMONIE-AROME (HARM in the rectangles) and WRF-ARW (WRF in the rectangles) highlighting the 10th and 90th percentiles used as thresholds.

Other meteorological systems related to aviation are severe convective storms, in particular supercells. They are occasionally responsible for many losses of property and damages in Spain as well as being a possible safety aviation issue. From a dataset of 262 supercells during 2011-2020 in Spain, the synoptic configurations and pre-convective environments has been analysed in Calvo-Sancho et al. (2022, under review). The events are grouped into supercells with hail (SP-HAIL, diameter larger than 5 cm) and without hail (SP-NONHAIL) and the results are compared. ERA5 reanalysis data are used to study the synoptic configurations and soundings related to the supercell events at the initial and centroid time (as an example, Figure 3). Moreover, mesoscale setting is analysed studying temperature, convective available potential energy, convective inhibition, lifting condensation level, level of free convection, height of freezing level, wind shear and storm-relative helicity for each event. The results show that supercells are more frequent in the Mediterranean coast during the warm season. There are statistically significant differences between hail and non-hail events in the mentioned thermodynamic and kinematic-related parameters analyzed, such as SP-HAIL environments characterized by higher median values of most-unstable convective available potential energy than SP-NONHAIL.

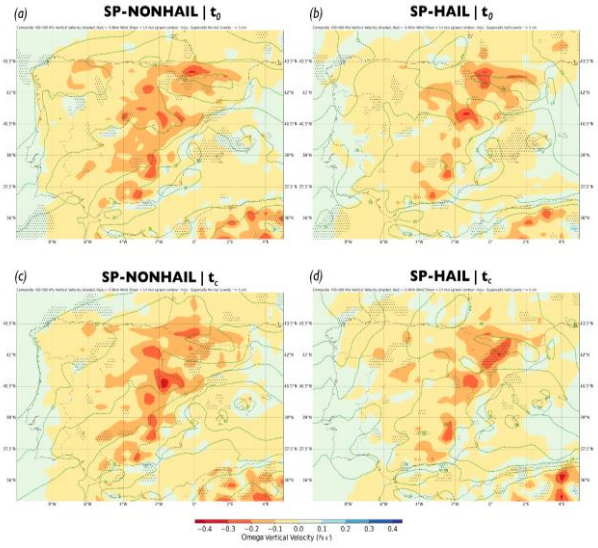

Figure 3: 700-400 hPa omega vertical velocity (contours; Pa s^{-1}), 0-6 km WS (green lines; m s^{-1}) composites for (a) SP-NONHAIL at t_0, (b) SP-HAIL at t_0, (c) SP-NONHAIL at t_c and (d) SP-HAIL at t_c. Black points denote statistically significant differences (p-value < 0.05) in omega vertical velocity.

In order to continue the study of this kind of systems, in SPESVALE several supercells are going to also be simulated with HARMONIE-AROME and WRF-ARW. First results are currently obtained. Conclusions will be assessed in the remainder of this part of the special project.

Additionally, some resources have used to simulate microbursts generated near airports in the Iberian Peninsula (as an example, Figure 4). This last research line force us to continue using SBUs to better simulate this kind of phenomena, like supercells, so destructive and dangerous for aeronautics.

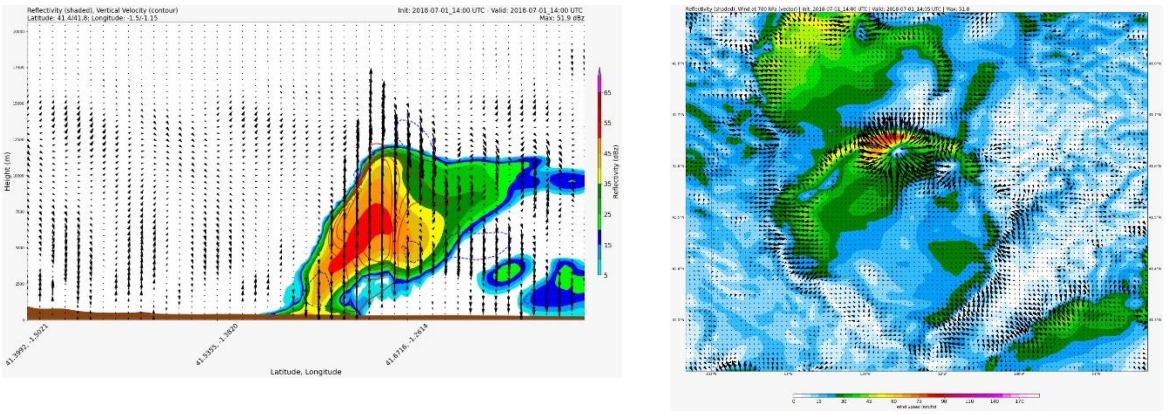

Figure 4: Simulations with WRF for the microburst on 1st July 2018 in vicinity of Zaragoza Airport: (left) reflectivity (shadow) and vertical velocity (contours); (right) wind speed (shadow) and wind vectors at 700 hPa.

We hope that throughout the remainder of the year, the WRF-ARW and HARMONIE-AROME models will be used to simulate more microbursts and supercells in the Iberian Peninsula. As soon as the runs are finished, we will be able to analyse the simulations to study differences and similitudes between key simulated variables.

References

Bolgiani, P., S. Fernández-González, M.L. Martin, F. Valero, A. Merino, E. García-Ortega, J.L. Sánchez (2018). Analysis and numerical simulation of an aircraft icing episode near Adolfo Suárez Madrid-Barajas International Airport Atmos. Res., 200, 60-69. http://dx.doi.org/10.1016/j.atmosres.2017.10.001.

Díaz-Fernández, J., L. Quitián-Hernández, P. Bolgiani, D. Santos-Muñoz, Á. García-Gago, S. Fernández-González, F. Valero, A. Merino, E. García-Ortega, J.L. Sánchez, M. Sastre, M.L. Martín (2020). Mountain waves analysis in the vicinity of the Madrid-Barajas airport using the WRF model. Advances in Meteorology, Article ID 8871546, 17 pp. https://doi.org/10.1155/2020/8871546.