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 TROPICAL TRANSITIONS IN THE EASTERN NORTH-ATLANTIC OCEAN: PAST, PRESENT AND FUTURE PROJECTIONS
Computer Project Account:	spesmart
Principal Investigator(s):	MARÍA LUISA MARTÍN
Affiliation:	ESCUELA DE INGENIERÍA INFORMÁTICA. UNIVERSIDAD DE VALLADOLID
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Daniel Santos (AEMET), Juan Jesús González-Alemán (Aemet), Lara Quitián-Hernández (UCM), Mariano Sastre (UCM), Pedro Bolgiani (UCM), Javier Díaz (UCM), Francisco Valero (UCM), Eloy Piernagorda (UCM), Carlos Calvo (UVA), Jose Ignacio Farrán (UVA) UVA: Universidad de Valladolid. Spain UCM: Universidad Complutense de Madrid. Spain AEMET: Agencia Estatal de Meteorología. Spain ……
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)	2000000	7917382	8000000	21370883
Data storage capacity	(Gbytes)	25000	25000	25000	25000

Summary of project objectives (10 lines max)

In the last years, tropical transitions (TT) have occurred very close to Iberia and surrounding areas. High-resolution simulations of TTs using improved models are needed to analyse the atmospheric dynamics of these systems. In this sense, in SPESMART several observed TTs (the strongest TTs > 90 percentile in wind speed) are simulated using the WRF and HARMONIE-AROME models. Moreover, simulations of these events using projections in areas nearby the Iberian Peninsula will provide knowledge about these atmospheric systems and their behaviour with respect to the Anthropogenic Climate Change (ACC). To do this, EC-Earth projections will be used. Thus, different climate scenarios will be analysed to study, simulate, and examine possible changes in frequency, tracking and intensity of several TTs.

Summary of problems encountered (10 lines max)

The request document specified three phases with the scientific plan:
The Phase 1 (Selection of TTs in ENA: study of the genesis and atmospheric dynamic) and Phase 2 (Assessment of the skill of the models in simulating the behavior of TTs) are fully developed. Phase 3 (Analysis of TTs in simulations of an advanced climate model) and Phase 4 (Analysis of TTs in future ACC projections) are not completed since the EC-Earth simulations nested in HARMONIE and WRF have provided unsuccessful results. Instead of using these simulations, another work perspective has been used. The pseudo global warning approach is used to study the genesis, development and intensity of selected TTs when ACC is considered. No special problems of technical nature we have had throughout the period of this Special Project. In the case of have them, the personal of the ECMWF has been kindly resolved them.

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

Because of the unsuccessful results obtained when using the EC-Earth simulations to be nest in HARMONIE and WRF for simulating TTs in future climate, a different approach is used to complete the Phases 3 and 4 of this project will continue. In this way, the relationship ACC - TTs will be assessed in this stage.

List of publications/reports from the project with complete references

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.

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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.

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C. Calvo-Sancho, L. Quitián-Hernández, P. Bolgiani, J. J. González-Alemán, D. Santos-Muñoz, M. L. Martín. Assessment of HARMONIE-AROME in the simulation of the convective activity associated to a subtropical transition using satellite data. Atmospheric Research, 290, 106794; https://doi.org/10.1016/j.atmosres.2023.106794. 2023.

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C. Calvo-Sancho, P. Bolgiani, A. Subías, M. Sastre, J.J. González-Alemán, M.L. Martín. Horizontal Kinetic Energy Analysis of Tropical Transition Simulations with the WRF and HARMONIE-AROME Models. Quarterly Journal of the Royal Meteorological Society. https://doi.org/10.1002/qj.4523.
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M. López-Reyes1, J.J. Gónzalez-Alemán, M. Sastre, D. Acosta-Insua, P. Bolgiani, M.L. Martín. On the impact of initial conditions in the forecast of Hurricane Leslie extratropical transition. Atmospheric Research. 295, 107020. https://doi.org/10.1016/j.atmosres.2023.107020. 2023.

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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:

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.

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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-Hemández, 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.

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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.

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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.

Additional to the exposed results in the previous Special Project reports, four TT events, simulated with WRF and HARMONIE-AROME, are selected to study the main features of the horizontal kinetic energy (HKE) spectra of this kind of high-energetic atmospheric systems. Though most of the times similar results are obtained with both models, HAR shows a more intense filtering and numerical dissipation, whereas WRF tends to represent over-energized spectra in the synoptic scale and especially at smaller wavelengths (Figure 1). Predictability is dissimilar for the four TTs studied due to the different spectral curve slope obtained for each case, ranging from unlimited to very poor predictability at synoptic scale. Additionally, an increased HKE is presented in the middle-upper troposphere spectra due to vorticity and convection, which are characteristic features of tropical cyclones.

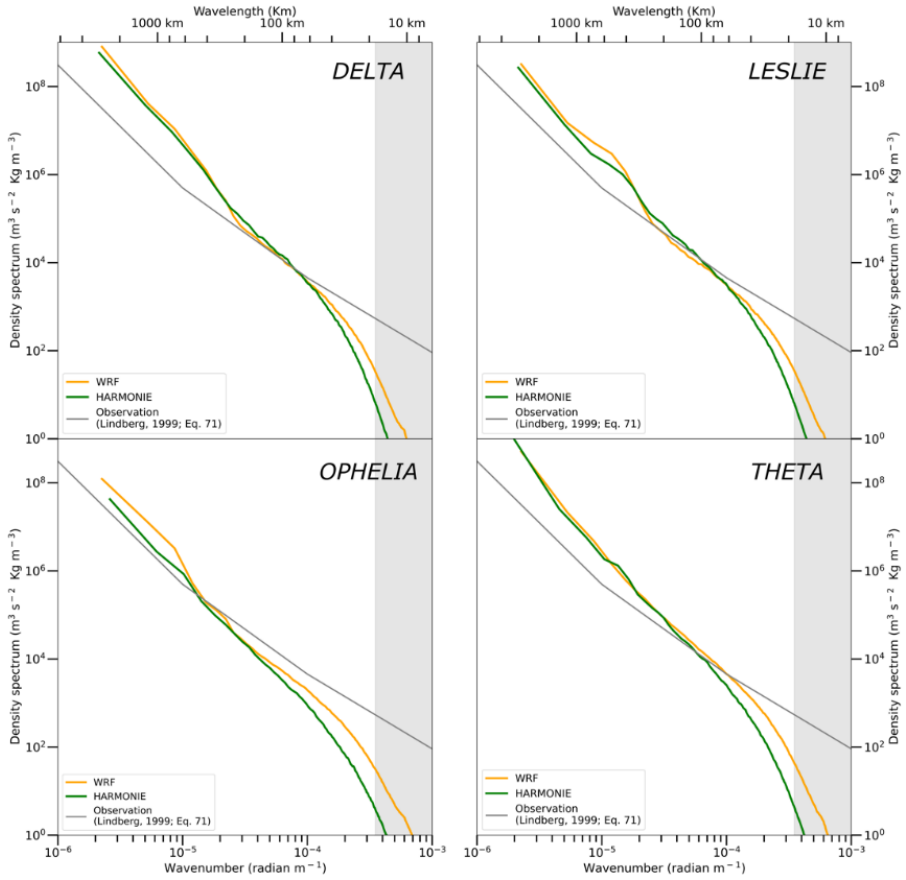

Figure 1: 500 hPa wind HKE spectra for the TTs selected, simulated with WRF and HARMONIE-AROME. The observed energy horizontal wavenumber spectral curve is shown for reference. The shaded area corresponds to the wavelengths below the theoretical effective resolution of the models.

To gain more insight into the dynamics of the HKE spectra, the different processes that contribute to the tropospheric energy evolution and transference in the TT Delta are also analyzed, as an example. Summarizing, it can be noted that globally WRF and HARMONIE-AROME present similar spectra. However, WRF results are consistently more energetic than HAR, specially at the smaller wavelengths, denoting a steeper numerical dissipation by HAR. Moreover, the spectral budget of the TT Delta is investigated considering both models. The results of the Delta spectral budget are also similar for both models, and the differences are mainly located in the stratosphere, most probably due to the differences in vertical resolution. The HKE spectral budget is mainly governed by t_h, D_h and H_h, i.e., the non-linear spectral transfer term, the spectral tendency due to three-dimensional divergence and the spectral tendency due to diabatic processes, respectively, mainly above $\lambda_h > 1000$

km. While D_h and H_h present positive contributions, $t_h$is negative for λ_h < 2000 km, but presenting a large positive pool for λ_h > 2000 km. The combined contributions partially explain the over-energetic spectrum. This is also assisted by the synoptic flow of t_h inhibiting the direct cascade at tropical-storm-size wavelengths. The contributions of $C_{A\to h}$, $\partial_z F_{h\uparrow}$ and $\partial_z F_{p\uparrow}$, i.e., the spectral conversion from APE to HKE, $\partial_z F_{h\uparrow}(\mathbf{k})$ and $\partial_z F_{p\uparrow}(\mathbf{k})$ the vertical flux divergence terms of HKE and pressure, respectively. These terms greatly affect the spectrum at the synoptic scale and mesoscale, highlighting that the roles of moist convection and latent heat can exceed the energy cascade and other energy transfer processes. $F_{h\uparrow}$ is predominant at synoptic scale and $F_{p\uparrow}$ is predominant at mesoscale. At mesoscale, the contribution of each term seems to be dependent on the vertical levels. However, at synoptic scales the terms have a much more complex behaviour, which seems to be dependent on the wavelengths (Calvo-Sancho et al., 2023).

Overall, it is clear that a high-energetic system, such as a TT, can notably affect the atmospheric energy spectrum. The energy budget of TT events shows a very complex behaviour far from the simple energy cascade theory, presenting a three-dimensional transfer and contribution of energy, in line with the results of the Sun et al. (2017), Wang et al. (2018) and Zheng et al. (2020). Moreover, the energy transfer is very dependent of the strong links existing between vertical levels. Both, WRF and HAR models are coincident in most of the results; however more research is required to fully grasp the energetic configuration of TTs and how each process affects the building of the HKE spectrum.

In the remainder project time, the WRF and Harmonie-Arome models have been used to simulate more TTs and medicanes in the vicinity of the Iberian Peninsula at very high-resolution. Differences and similitudes between key simulated variables (for Harmonie-Arome and WRF) in the genesis, developing and tracking of these systems are studied. As it is abovementioned, the Phase 3 (Analysis of TTs in simulations of an advanced climate model) and Phase 4 (Analysis of TTs in future ACC projections) are not completed since the EC-Earth simulations nested in HARMONIE and WRF have provided unsuccessful results. Instead of using these simulations, another work perspective has been used. Martin et al. (2024) shows the different methodology used to study the ACC effect on the development of supercells affecting the northeastern Spain. Such approach will be used to study the genesis, development and intensity of selected TTs when ACC is considered. In the rest of the year, some simulations using this new approach will be run for some studied cases of TTs.

It is worth to note that for each atmospheric system, 93000 units approximately have been used using WRF and, around 600000 units have cost using the very-high resolution in HARMONIE. Numerous tests have been needed to finally simulate the TTs with very high-resolution. Such resolution is necessary to properly study the mesoscale processes involved in the genesis and development of these events. Considering the numerous needed different experiments before the final simulations and the very high resolution used to properly simulated TTs (500m with the second version of the HARMONIE model), the final SBU usage in this special project is much more than the requested initial SBUs. We are sorry for having made a mistake in the initial figure requested.

References

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