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 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)	……………………………………………………….…… ……………………………………………………….……
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	891726
Data storage capacity	(Gbytes)			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) is fully developed. In Calvo-Sancho et al. (2022) a climatology (1979-2019) of TTs in which 30 TT events were identified over the central and eastern North Atlantic basin have revealed differences between TTs formed in the two Atlantic basins. The Phase 2 (Assessment of the skill of the models in simulating the behavior of TTs) is developed. Several TTs have been simulated using both HARMONIE and WRF models. The SPESMART team is analyzing intensity, track and model skillful of the simulated TTs. The Phase 3 (Analysis of TTs in simulations of an advanced climate model) is not completed. The BSC supported us EC-Earth simulations to nest HARMONIE and WRF. However, the simulations did not consider the whole variables needed to run both models. Therefore, the BSC is going to generate new simulations.

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

As soon as the tracking method is adapted to the simulations facilitated by the BSC, the Phase 3 of the project will continue. A modified tracking method, using the cyclone-space method (CPS) of Hart (2003) of Phase 1, will be applied to select probable cases of TTs of the EC-Earth.

Once the TTs are identified in the present climate of the climate model (EC-Earth CTRL) and HARMONIE and WRF are nested, the models will be evaluated considering the obtained TTs in EC-Earth CTRL. The next steep consists of the analysis of TTs in future ACC projections generated by the BSC. Relationship ACC - TTs will be assessed in this stage.

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.

During the first project year, a climatology of TTs has been carried out, analysing the synoptic and environmental characteristics of the TTs. The results have shown that there is two different group of TT considering the genesis of the systems: the TTs developed in central Atlantic Ocean and the TTs generated in eastern Atlantic basin. This work has been made using the ERA5 data base.

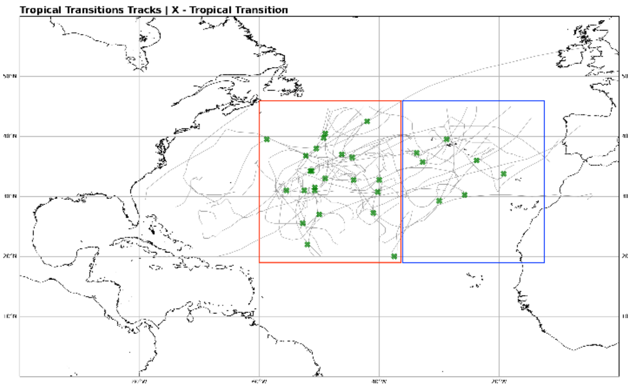

Figure 1: Tracks and transition time (green marks) of several TTs identified (1979 - 2019).

Figure 1 shows tracks of the identified TTs from 1979 to 2019. Simulations of this systems are needed to study during the time before their genesis the possible precursors that can be useful in forecasting and warning this kind of catastrophic events. All this information is shown in the scientific manuscript, currently under review, of Calvo-Sancho et al. (2022).

In this way, hurricanes such as Vince, Ofelia, Delta, Theta, Leslie, selected from Calvo-Sancho et al. (2022) and presenting wind speed values greater than the 90-percentile value, have been simulated with WRF and HARMONIE-AROME. After different test, the configuration of both models is as follows:

- ✓ The WRF numerical model for analysing TTs has been configured with two domains: the outer domain with 7.5 km of grid resolution and the high resolution one with 2.5 km (Figure 2), using 1000 grid points in the west-east direction, 1000 grid points in the south-north direction and 65 sigma levels unequally spaced, with a greater number of levels in the lower troposphere for a better representation of the convective planetary boundary-layer processes. Adaptative time steps are used. The WRF physics options used in this study are those defined as the default for Hurricane research mode. Among them, it is worth noting the WRF Single-Moment 6-class (WSM6) (Hong and Lim, 2006) parameterization scheme for microphysics, YSU for the planetary boundary layer (PBL), and Dudhia (Dudhia, 1989) and RRTM for short and longwave radiation, respectively. No cumulus parameterization scheme is used in this study, being cloudiness explicitly computed by the model. Finally, the initial/boundary conditions are obtained from the ERA5 Reanalysis of the ECMWF with 0.31° horizontal resolution every 6 hours.

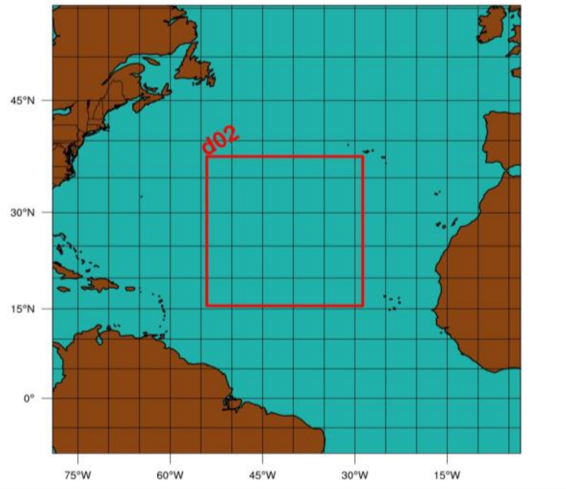

Figure 2: WRF domain configuration to simulate Hurricane Delta.

✓ The HARMONIE-AROME configuration (43h2.1 version) was compiled to simulate the different TTs. The final set up used to simulate TTs resembles WRF's one as much as possible to maintain the consistency of the study. Defined with the HARMONIE default physics options (Bengtsson et al., 2017), the model also has a main domain with 2.5 km resolution and the same grid dimensions (1000 x 1000) in the west-east and south-north directions (domain in Figure 3) with 65 hybrid sigma-pressure levels in the vertical. The initial/boundary conditions are the same as those used for WRF. In this case, the model is configured with a temporal resolution of 75 s (Bengtsson et al., 2017). Operated at 2.5 km resolution this model has a convection-permitting configuration and uses a non-hydrostatic spectral dynamical core with a semi-Lagrangian and semi-implicit discretization of the equations. In this way, more realistic results are obtained (Bengtsson et al., 2017) compared to other models, which may provide an added value to the study of TTs.

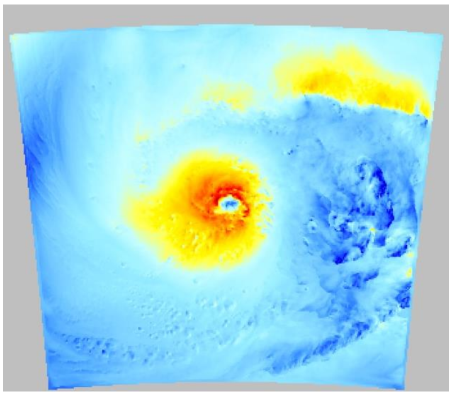

Figure 3: Simulations of wind speed with HARMONIE-AROME for the Hurricane Delta.

On the other hand, tests with other related systems, such as medicanes, have been also carried out using the abovementioned HARMONIE-AROME configuration. In this way, Figure 4 shows the Ianos system simulated using different initial conditions (ERA5 and IFS). The notable differences obtained in the system simulation will be subsequently analyzed.

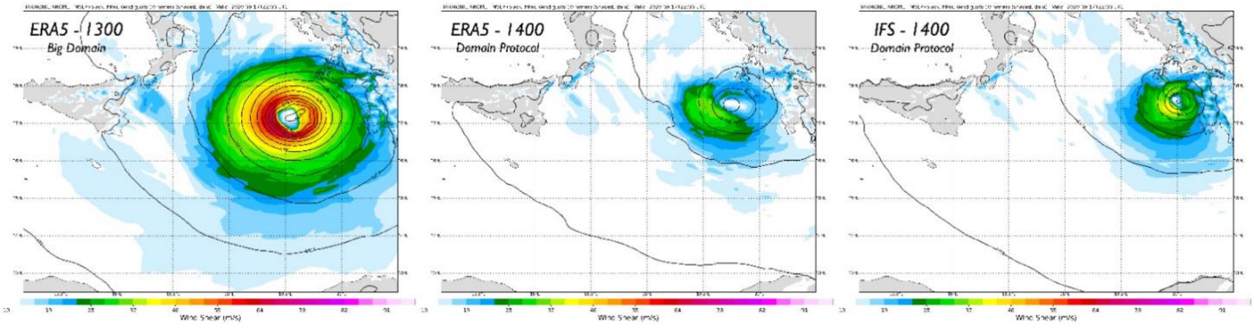

Figure 4: Simulations of wind speed with HARMONIE-AROME for the Medicane Ianos using different initial conditions.

Moreover, from the WRF and HARMONIE-AROME simulations, studies related to the spectrum energy of the different TTS have been analysed and compared to a spectrum energy climatology generated by the SPESMART team using the ERA5 data base and published in Bolgiani et al. (2022).

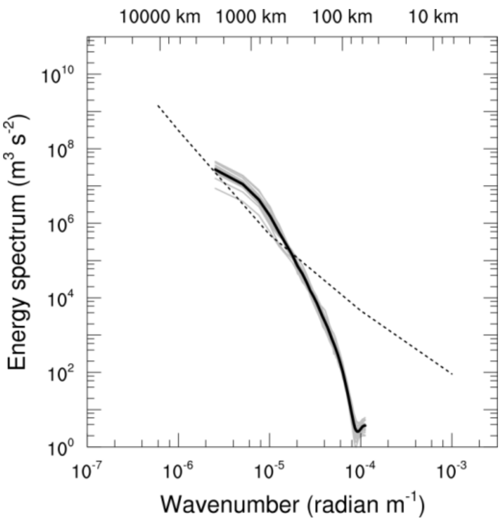

Figure 5: ERA5 wind kinetic energy spectrum at 500 hPa for the domain of storm Delta from 00:00 UTC 22 NOV 2015 to 00:00 UTC 25 NOV 2015. Grey lines are individual spectra, the black line is the average, the dashed line corresponds to the dissipation rate as per Lindborg (1999).

Comparisons and differences between the climatology spectrum energies of the selected TTS (as an example, Figure 5) with those obtained from the high-resolution simulations from the models are being currently analysed.

We hope that throughout the remainder of the year, the WRF and Harmonie models will be used to simulate more TTs and medicanes in the vicinity of 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 (for Harmonie and WRF) in the genesis, developing and tracking of these systems.

References

Bengtsson, L., et al., 2017. The HARMONIE–AROME Model Configuration in the ALADIN–HIRLAM NWP System. Mon. Wea. Rev., 145, 1919-1935, https://doi.org/10.1175/MWR-D-16-0417.1

Beven, J. L., and Coauthors (2008): Atlantic hurricane season of 2005. Mon. Wea. Rev., 136, 1109–1173.

Dudhia, J., 1989: Numerical study of convection observed during the Winter Monsoon Experiment using a mesoscale two–dimensional model. J. Atmos. Sci., 46, 3077-3107.

Hong, S.–Y., and Lim, J.–O. J., 2006: The WRF single-moment 6–class microphysics scheme (WSM6). J. Korean Meteor. Soc., 42, 129-151.