SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	SIMULATIONS OF TROPICAL TRANSITIONS IN THE EASTERN NORTH-ATLANTIC OCEAN: PAST, PRESENT AND FUTURE PROJECTIONS
Computer Project Account:	spesmart
Start Year - End Year :	2022- 2024.
Principal Investigator(s)	MARÍA LUISA MARTÍN
Affiliation/Address:	ESCUELA DE INGENIERÍA INFORMÁTICA. UNIVERSIDAD DE VALLADOLID
Other Researchers (Name/Affiliation):	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

The following should cover the entire project duration.

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, the effective resolutions of these models when simulating the TTs are investigated, analyzing the energetic spectral budget of the turbulence kinetic energy in each model.
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 are used with different climate scenarios to study, simulate, and examine possible changes in frequency, tracking and intensity of several TTs.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

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) 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. 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.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The experience with administrative aspects has been positive. No problems I have had in updating the progress reporting and I think the application procedure has been relatively easy.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

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.

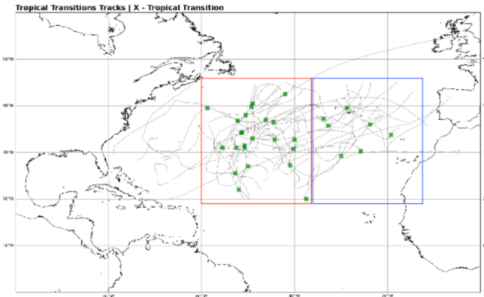


Figure 1: Tracks and transition time (green marks) of several TTs identified (1979 - 2019).

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.

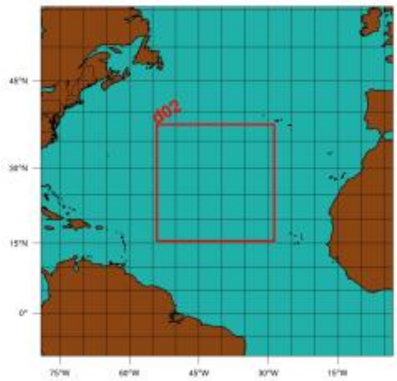


Figure 2: WRF domain configuration to simulate Hurricane Delta.

✓ 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.

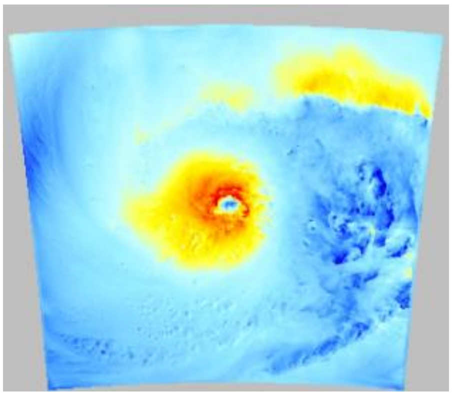


Figure 3: Simulations of wind speed with HARMONIE-AROME for the Hurricane Delta.

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.

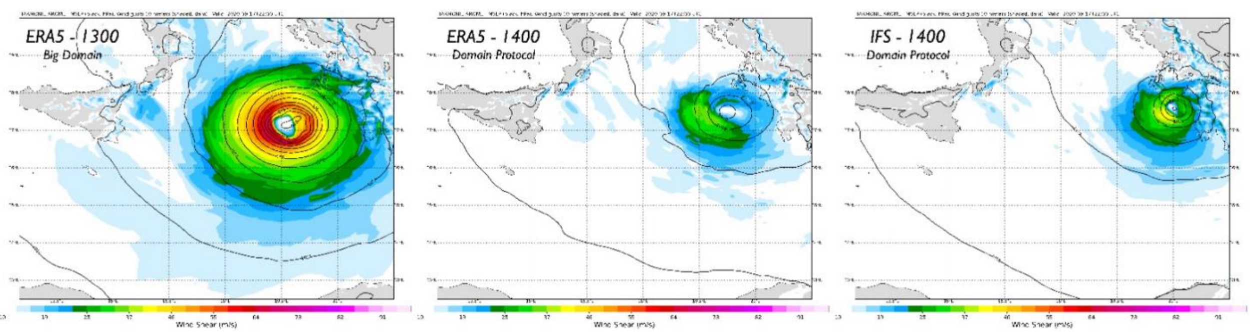


Figure 4: Simulations of wind speed with HARMONIE-AROME for the Medicane Ianos using different initial conditions.

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).

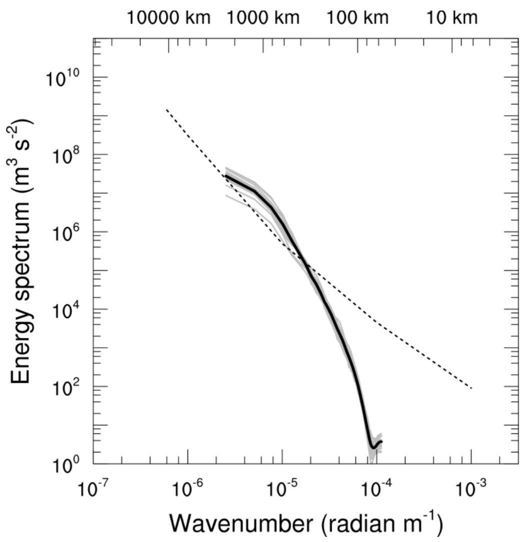
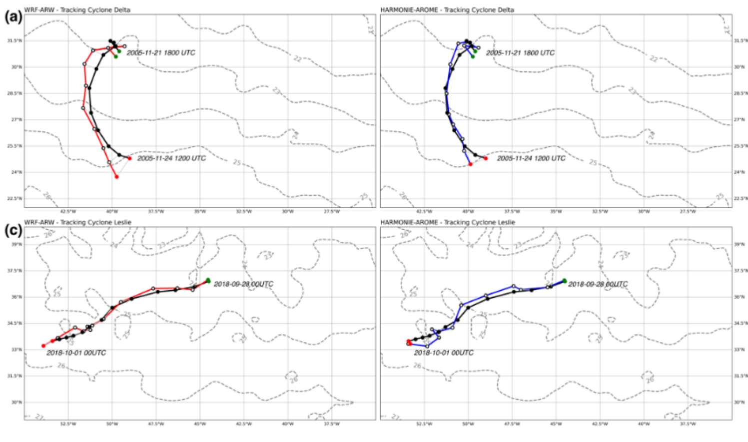


Figure 5: ERA5 wind kinetic energy spectrum at 500 hPa for the domain of storm Delta from 00:00 UTC 22 NOV 2015 to 00:00 UTC 25 NOV 2015. Grey lines are individual spectra, the black line is the average, the dashed line corresponds to the dissipation rate as per Lindborg (1999).

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.

During the second project year, several TT processes that lead to a hurricane structure [Delta (2005), Ophelia (2017), Leslie (2018), and Theta (2020)] are evaluated using two high-resolution numerical models (WRF and HARMONIE-AROME). Both tracks and intensities of the cyclones (Figures 6, 7) are assessed by comparing the simulated minimum sea level pressure and maximum wind speed to an observational dataset.



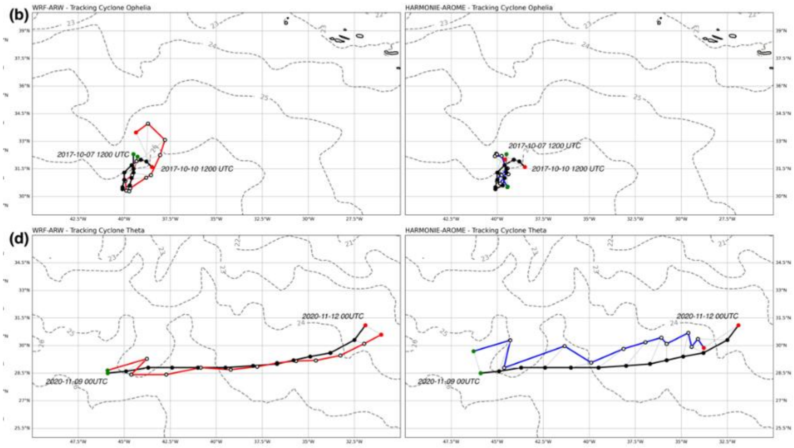


Figure 6: Simulated tracks for WRF (red) and HARMONIE-AROME (blue) models against the HURDAT database (black) for a) Delta, b) Ophelia, c) Leslie and d) Theta. Data is displayed every 6 h. A green circle indicates the beginning of the track, while a red circle marks the end.

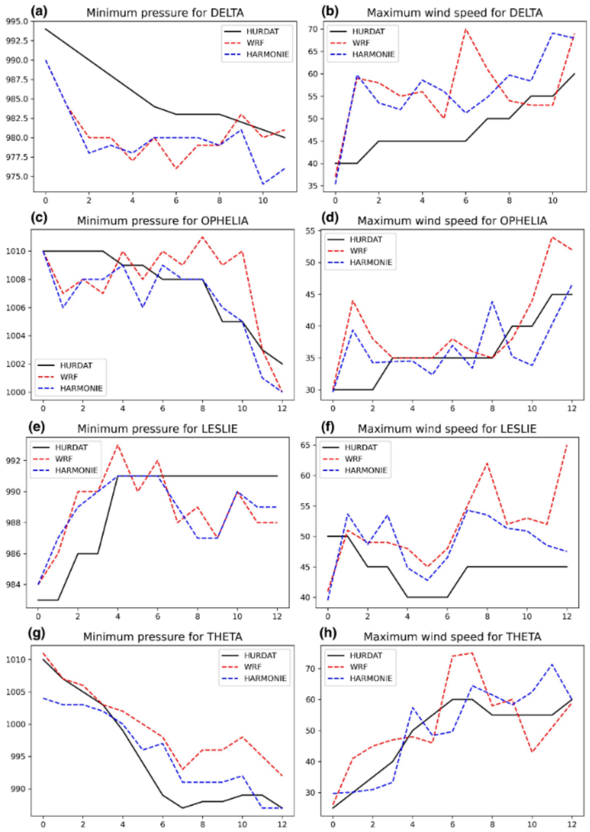


Figure 7: Simulated minimum SLP (left) and maximum SPD (right) by WRF (red) and HARMONIE-AROME (blue) for a), b) Delta, c), d) Ophelia, e), f) Leslie and g), h) Theta.

Moreover, a spatial verification is performed by comparing the MSG-SEVIRI brightness temperature (BT) and accumulated precipitation (IMERG) to the corresponding simulations accomplished by both models. Analyzing the track results, the WRF model, on average, outstands HARMONIE-AROME. However, it is the HARMONIE-AROME model that performs better than WRF when reproducing the intensity of these cyclones. Concerning the BT spatial validation, HARMONIE-AROME slightly outperformed WRF when reproducing the cyclone's structure but failed when simulating the BT amplitude. Besides, both models achieved a nearly perfect cyclone location (Calvo-Sancho et al., 2023). The SAL (Structure, Amplitude, Location) feature-based measurement is another verification method based on a direct attribution of forecasted objects to the observed ones (Wernli et al., 2008) and used to evaluate the level of quality of a particular field, taking into consideration its 'structure' (e.g. dispersed convective cells, frontal rain bands; Früh et al., 2007).

The systems are analysed considering two periods: pre-TT and post-TT times. Concerning BT, SAL results are relatively similar for both analysed periods (Figure 8). While smaller structures (S < 0) are generally obtained in comparison to the observation, the amplitude component is slightly underestimated (A < 0) for both models and periods (Figures 8a and 8b). The A and S medians have been computed for the WRF and HARMONIE-AROME models (red and blue dashed lines, respectively, depicted in Figure 8). Regarding median results of S during the pre-TT period (Figure 8a), while both models show a negative structure median value, the HARMONIE-AROME model performs slightly better. Similar results are observed for both models when analysing the amplitude median outcomes, with the WRF model outperforming the HARMONIE-AROME model. In terms of the location component, it is remarkable that both models have nearly perfect simulations (L-component median ~ 0.07) during the pre-TT and post-TT periods, with the HARMONIE-AROME model (L-component median ~ 0.07) slightly better than WRF (L-component median ~ 0.08) during the latter period. During the pure TT period (Figure 8b), the WRF model again yields slightly better median amplitude results. The structure median results are slightly worse than during the pre-TT period, but the behavior remains constant, i.e., both models simulate smaller structures (negative S values), and HARMONIE-AROME (blue dashed line) performs slightly better.

Concerning the statistical differences between the two models for the SAL components' distributions, it is outstanding that, while the A and L-components are statistically different (p-value < 0.05), the S-component shows no significant differences (p-value > 0.05). Besides, in general terms, both models depict a relatively symmetrical and concentrated distribution with few outliers (not shown). The WRF model depicts the range and a median closer to zero when simulating the A-component, implying a somewhat more accurate simulation than the one generated by HARMONIE-AROME; on the other hand, both models reproduce the S-component with similar results (not shown).

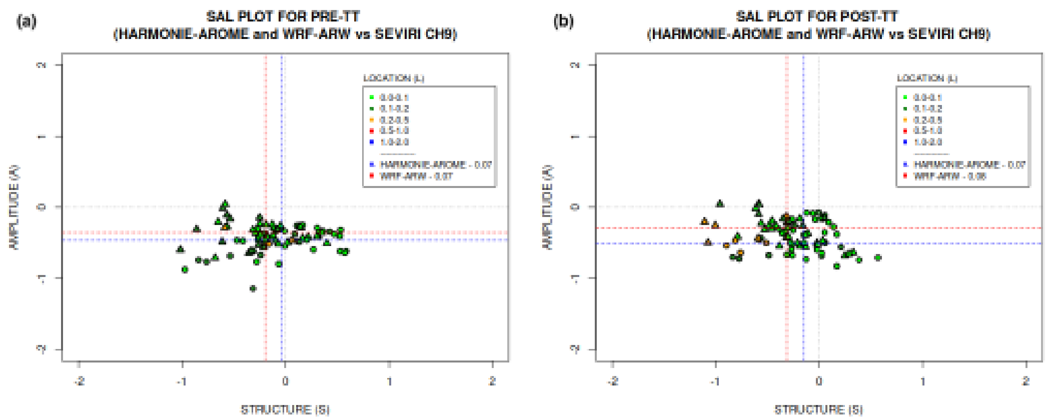


Figure 8: HARMONIE-AROME (triangles) and WRF (circles) model SAL results for the BT field during the a) pre-TT and b) post-TT periods. The medians are displayed in dashed lines for HARMONIE-AROME (blue) and WRF (red).

In terms of accumulated precipitation results, the HARMONIE-AROME model overestimates the larger structures while underestimating the smaller ones, whereas the WRF model underestimates the bigger structures, being poorly located by both models. Although it is difficult to establish which numerical model performs better, the overall results show an outstanding of the HARMONIE-AROME model over the WRF model when simulating TT processes.

In a similar way as done for BT, the accumulated precipitation amplitude and structure medians have also been computed for both models and displayed in Figure 9. During the pre-TT period (Figure 9a), despite both models showing higher median structure values, HARMONIE-AROME performs slightly better than WRF. Moreover, in terms of amplitude, both models display relatively higher median values, with again the HARMONIE-AROME model outperforming the WRF. These results agree with the results obtained in the probability density function (not shown). Finally, concerning the location median outcomes, both models yield similar values (L-component median ~ 0.08).

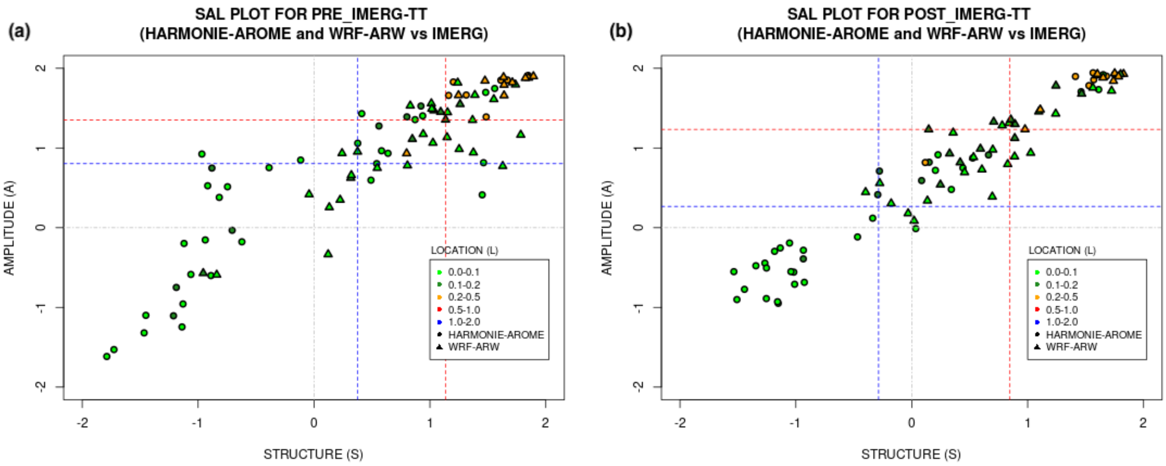


Figure 9: HARMONIE-AROME (triangles) and WRF (circles) model SAL results for the accumulated precipitation field during the a) pre-TT and b) post-TT periods. The medians are displayed in dashed lines for HARMONIE-AROME (blue) and WRF (red).

Additionally, these 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 10). 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.

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.

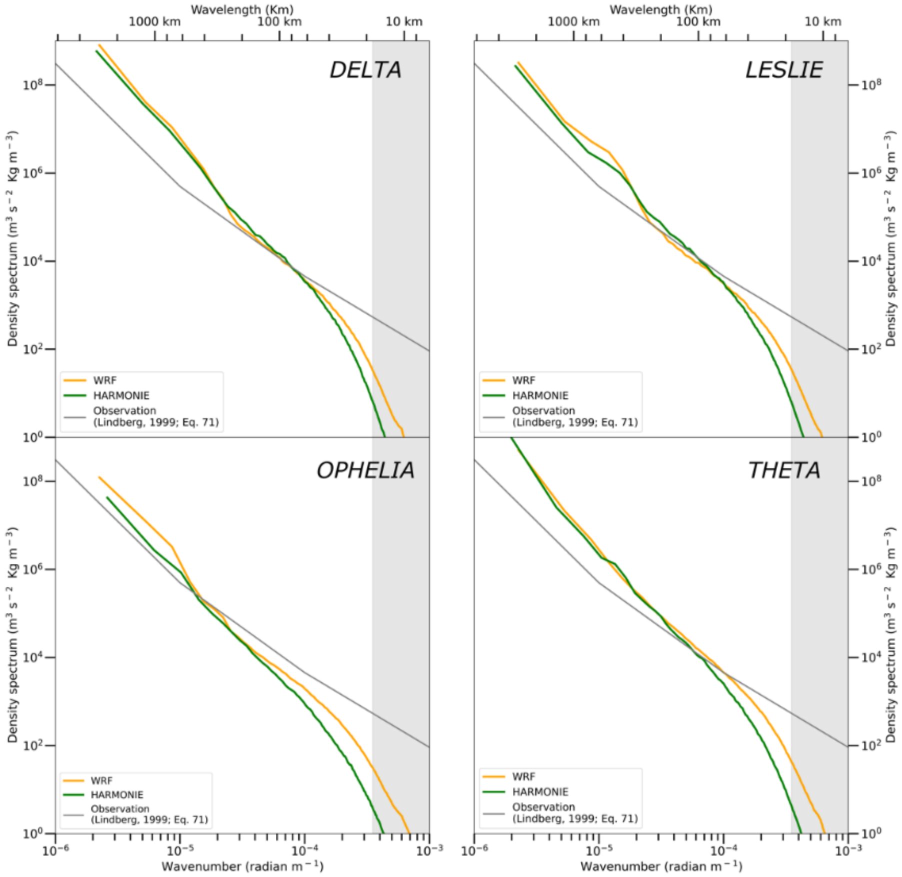


Figure 10: 500 hPa wind HKE spectra for the TTs selected, simulated with WRF and HARMONIE-AROME. The observed energy horizontal wavenumber spectral curve is shown for reference. The shaded area corresponds to the wavelengths below the theoretical effective resolution of the models.

Additionally, 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 λ_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 $C_{A\rightarrow h}$, $\partial_z F_{h\uparrow}$ 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.

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. 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 score used in this special project is more than 10000000 SBUs.

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.

Früh, B., J. Bendix, T. Nauss, M. Paulat,A. Pfeiffer, J. W. Schipper, B. Thies, and H. Wernli, 2007: Verification of precipitation from regional climate simulations and remote-sensing observations with respect to ground-based observations in the upper Danube catchment. Meteor. Z., 16, 275–293.

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.

Sun, Y.Q., Rotunno, R., Zhang, F., 2017. Contributions of Moist Convection and Internal Gravity Waves to Building the Atmospheric −5/3 Kinetic Energy Spectra. Journal of the Atmospheric Sciences 74, 185–201. https://doi.org/10.1175/JAS-D-16-0097.1

Wang, G., Yang, F., Wu, K., Ma, Y., Peng, C., Liu, T., Wang, L.-P., 2021. Estimation of the dissipation rate of turbulent kinetic energy: A review. Chemical Engineering Science 229, 116133. https://doi.org/10.1016/j.ces.2020.116133

Wernli, H. and Sprenger, M. (2007). Identification and ERA-15 Climatology of Potential Vorticity Streamers and Cutoffs near the Extratropical Tropopause. Journal of the Atmospheric Sciences, 64(5), 1569-1586. https://doi.org/10.1175/JAS3912.1

Zheng, H., Zhang, Y., Wang, Y., Zhang, L., Peng, J., Liu, S., Li, A., 2020. Characteristics of Atmospheric Kinetic Energy Spectra during the Intensification of Typhoon Lekima (2019). Applied Sciences 10, 6029. https://doi.org/10.3390/app10176029.

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.

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. 278, 10635, 1-16. https://doi.org/10.1016/j.atmosres.2022.1063532022. 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. 3, 1021–1036. https://doi.org/10.5194/wcd-3-1021-20222022. 2022.

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.

Calvo-Sancho, C., Quitián-Hernández, L., González-Aleman, J.J., Bolgiani, P., Santos-Muñoz, D., Martín, M.L. Assessing the performance of the HARMONIE-AROME and WRF-ARW numerical models in North Atlantic Tropical Transitions. Atmospheric Research, 291, 106801; https://doi.org/10.1016/j.atmosres.2023.106801. 2023.

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. 2023.

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.

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:

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.

Díaz-Fernández, J., Calvo-Sancho, C., Quitián-Hernández, L., Bolgiani, P., Santos Muñoz, D., Luna, M.Y., González Alemán, J. J., Sastre, M., Valero, F., Farrán, J. I. & Martín, M. L. (2022). Análisis del evento supercelular del 31 de julio de 2015 en España con el modelo WRF-ARW. 10ª Asamblea Hispano Portuguesa de Geodesia y Geofísica. Toledo (Spain). 2022

Quitián-Hernández, L., J., Calvo-Sancho, C., Díaz-Fernández, Bolgiani, P., Santos Muñoz, D., Luna, M.Y., González Alemán, J. J., Sastre, M., Valero, F., Farrán, J. I. & Martín, M. L. Análisis de un ciclón subtropical en el Océano Atlántico Norte mediante el modelo numérico HARMONIE-AROME. 10ª Asamblea Hispano Portuguesa de Geodesia y Geofísica. Toledo (Spain). 2022

Calvo-Sancho, C., Díaz-Fernández, J., González Alemán, J. J., Martín, Y., Quitián-Hernández, L., Bolgiani, P., Santos Muñoz, D., Farrán, J. I. Sastre, M., & Martín, M. L. Numerical Analysis of a Spanish Supercell Outbreak. European Geosciences Union (EGU) 2023. Vienna (Austria). 2023

Calvo-Sancho, C., González Alemán, J. J., Martín, Y., Calvo, J., Martín, M. L., Martín Pérez, D. & Viana Jiménez, S. (2023). Testing very high-resolution simulations in a high-impact static convective system in Spain using HARMONIE-AROME model. European Conference on Severe Storms (ECSS) 2023. Bucarest (Rumanía). 2023

Calvo-Sancho, C., Díaz-Fernández, J., González Alemán, J. J., Martín, Y., Quitián-Hernández, L., Bolgiani, P., Santos Muñoz, D., Farrán, J. I. Sastre, M., & Martín, M. L. (2023). Supercell synoptic configurations and pre-convective environments in Spain. European Meteorology Society (ECSS) Annual Meeting 2023. Bratislava (Eslovaquia). 2023.

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

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

Future plans are to apply for a new Special Research Project. It will deal with the study of tropical cyclones in the eastern North Atlantic. This project will carry out the dynamic analysis and risk assessment of future climate conditions. We expect that with this new project future knowledge about the genesis, development and evolution of tropical cyclones in both present and future climates will be obtained. In fact, the objectives of the new project will be:

1. To establish a robust climatology of the atmospheric environments related to African eastern wves (AEWs) and tropical transitions (TTs) genesis and evolution over the eastern North Atlantic (eNATL) basin under present and future climate conditions.
   - To identify and classify TTs and AEWs with anomalous tracks within the eNATL in ERA-5 reanalysis (1940-present).
   - To comprehensively characterize the environmental conditions that promote the development of AEWs and TTs over the eNATL under present climate.
   - To analyze the changes in the above environments under future climate conditions.

2. To apply, for the first time, the pseudo global warming methodology to simulate, at very high resolution, cyclones with tropical characteristics in the vicinity of Spanish territory.
   - To simulate, at very high resolution (500m - 3km), selected AEWs and TTs with HARMONIE-AROME, WRF and MPAS mesoscale atmospheric models under present climate conditions.
   - Same as SO-2.1, but under perturbed anthropogenic climate change (ACC) conditions through pseudo global warming, to fulfill the next goal.

3. To evaluate how ACC conditions will affect eNATL AEWs and TTs meteorological behavior.
   - To assess the influence of ACC on the dynamics and meteorological evolution of selected events that may pose a threat to Spanish territory.
   - To assess the influence of ACC on the meteorological impacts (wind gusts, precipitation, etc.) of these events.
   - To assess the influence of ACC on their associated economic losses in Spain.