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 2021

Project Title: SIMULATIONS OF DIVERSE SUBTROPICAL CYCLONES AND TRANSITIONS TO TROPICAL CYCLONES IN THE EASTERN NORTH-ATLANTIC OCEAN

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: 01/01/2019

Expected end date: 31/12/2021

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)	900000	900000	900000	1100000
Data storage capacity	(Gbytes)	25000	25000	25000	25000

Summary of project objectives (10 lines max)

This project is the first special project that this team has in ECMWF. Our goal is to implement both Harmonie and WRF in ECMWF in order to simulate some STCs and compare differences between both kind of simulations. The key objectives in the project can summarized as follow:

- Simulation of different Subtropical Cyclones (STC) with the Harmonie model as well as the WRF.
- The simulated STCs will be analysed examining key variables in their genesis, developing and tracking.
- Warm seclusion transitions will be deeply analysed to elucidate physical mechanism favouring such cyclone formation.

Additionally, anomalous TCs, following unusual trajectories near Western Europe and experimenting tropical transitions (TT), are going to be studied in the last part of the Special Project SPESMART.

Summary of problems encountered (10 lines max)

As this special project is our first project, we have found some problems when Harmonie and WRF are implemented. Currently, we have simulated the STC of 2014 that landfall the Canary Islands, using both different parameterizations and no cumulus parameterization scheme.

Due to the COVID-19 situation, the WRF system setup has utilized more resources than we originally expected. Because of this, we have requested more resources which have been approved and the SBUs have been added to our account. Huge domains in Harmonie and moving nests in WRF in some simulations were needed to follow properly tracks of the cyclones. We have already simulated TTs such as Ophelia, Vince, Delta, Leslie and Theta Hurricanes and STC 2014 both with Harmonie and WRF.

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

- Due to the COVID-19 situation, the working methodology has been modified, maintaining regular meetings with the rest of the team members that in some occasions promoted delays in the final results. System setups have utilized more resources than we originally expected.
- Some problems with the huge domains used to simulated both TTs and STCs have been recently occurred. As soon as the problems with both models are fixed, more STC and/or transitions to TC will be simulated.
- Currently, both STC2014 and several TTS have been simulated in Harmonie and WRF. We hope in the rest of the year we will be able to simulate other cyclones using both models.
- Those simulated variables, key in the genesis and development of the STCs will be studied to analyse differences and similitudes between the performance of WRF and Harmonie.
- These high-resolution accuracy simulations will be studied in order to learn about the possible transitions form STCs to Tropical Cyclones.

List of publications/reports from the project with complete references

Papers

Bolgiani, P., Fernández-González, S., Valero, F., Merino, A., García-Ortega, E., Sánchez, J., Martín, M. (2018). Numerical Simulation of a Heavy Precipitation Event in the Vicinity of Madrid-Barajas International Airport: Sensitivity to Initial Conditions, Domain Resolution, and Microphysics Parameterizations. Atmosphere, 9(9), 329.

L.Quitián-Hernández, S.Fernández-González, J.J.González-Alemán, F.Valero, M.L.Martín (2018): Analysis of sensitivity to different parameterization schemes for a subtropical cyclone. Atmospheric Research, 204, 21-36.

S. Fernández-González, M. Sastre, F. Valero, A. Merino, E. García-Ortega, J. L. Sánchez, J. Lorenzana, M. L. Martín (2019): Characterization of Spread in a Mesoscale Ensemble Prediction System: Multiphysics versus Initial Conditions. Meteorologische Zeitschrift, 28 (1), 59 – 67. DOI: 10.1127/metz/2018/0918.

A. Manzano, M. A. Clemente, A. Morata, M. Y. Luna, S. Beguería, S. M. Vicente-Serrano, M. L. Martín (2019): Analysis of the atmospheric circulation pattern effects over SPEI drought index in Spain. Atmospheric Research, 230.https://doi.org/10.1016/j.atmosres.2019.104630.

Merino, A., E. García-Ortega, S. Fernández-González, J. Díaz-Fernández, L. Quitián-Hernández, M.L. Martín, L. López, J.L. Marcos, F. Valero, J.L. Sánchez (2019): Aircraft icing: in-cloud measurements and sensitivity to physical parameterizations. Geophysical Research Letters. https://doi.org/10.1029/2019GL084424.

Bolgiani, P., Fernández-González, S., Valero, F., Merino, A., García-Ortega, E., Sánchez, J. L., Martín, M. L. (2020). Simulation of Atmospheric Microbursts Using a Numerical Mesoscale Model at High Spatiotemporal Resolution. Journal of Geophysical Research: Atmospheres, 125(4), 1–23.

Quitián-Hernández, L., J. J. González-Alemán, D. Santos-Muñoz, S. Fernández-González, F. Valero, M. L. Martín (2020): "A subtropical cyclone formation via warm seclusion development: The importance of surface fluxes". Journal of Geophysical Research: Atmosphere (accepted). https://doi.org/10.1029/2019JD031526.

Díaz-Fernández, J., Quitián Hernández, L., Santos-Muñoz, D., García-Gago, A., Bolgiani, P., Fernández-González, S., Valero, F., Merino, A., García-Ortega, E., Sánchez, J. L., Sastre, M. and Martín, M. L. (2020). Mountain waves analysis in the vicinity of the Madrid-Barajas airport using the WRF model. Advances in Meteorology, 1-17, https://doi.org/10.1155/2020/8871546.

Bolgiani, P., Santos-Muñoz, D., Fernández-González, S., Sastre, M., Valero, F., Martín, M. L. (2020). Microburst Detection with the WRF Model: Effective Resolution and Forecasting Indices. Journal of Geophysical Research: Atmospheres, 125(14), 1-13. https://doi.org/10.1029/2020JD032883.

Díaz-Fernández, J., P. Bolgiani, D. Santos-Muñoz, M. Sastre, F. Valero, L.I. Sebastián-Martín, S.Fernández-González, L. López and M.L. Martín (2021). On the characterization of mountain waves and the development of a warning method for aviation safety using WRF forecast. Atmospheric Research (accepted).

Quitián-Hernández, L., P. Bolgiani, D. Santos-Muñoz, M. Sastre, J. Díaz-Fernández, J. J. González-Alemán, J. I. Farrán Martín, L. Lopez, F. Valero and M. L. Martín (2021). Analysis of the October 2014 subtropical cyclone using the WRF and the HARMONIE-AROME numerical models: assessment against observations. Atmospheric Research (accepted). doi.org/10.1016/j.atmosres.2021.105697.

Díaz-Fernández, J. P. Bolgiani, D. Santos-Muñoz, L. Quitián-Hernández, M. Sastre, F. Valero, J. I. Farrán, J.J. González-Alemán and M.L. Martín (2021). Comparison of the WRF and HARMONIE models ability for mountain wave warnings. Atmospheric Research (submitted).

Meetings

Mariano Sastre, Sergio Fernández-González, Francisco Valero, and María Luisa Martín
Quantification of uncertainty in wind prediction: towards a climatology for the Iberian Peninsula.
European Meteorological Society (EMS) Annual Meeting Abstracts
Copenhagen, Denmark,

Oral presentation.
09-13 September 2019

Javier Díaz-Fernández, Lara Quitián-Hernández, Daniel Santos Muñoz, Sergio Fernández-González, Francisco Valero, Andrés Merino, Eduardo García-Ortega, José Luis Sánchez, Mariano Sastre, María Luisa Martín.
Mountain wave episodes using the high-resolution HARMONIE-AROME model in Spain.
American Geophysical Union (AGU)
San Francisco, CA, USA.
Poster.
9-13 December 2019

Lara Quitián Hernández, Daniel Santos-Muñoz, Juan Jesús González Alemán, Javier Diaz-Fernandez, Sergio Fernández-González, Pedro Bolgiani, Mariano Sastre, Francisco Valero, Maria Luisa Martin (2019):
Analysis Of Several Subtropical Cyclones By Means Of The High-Resolution HARMONIE-AROME Model.
Congress of American Geophysical Union (AGU). General Assembly Conference.
San Francisco, USA.
Poster.
7-11 December 2019.

Javier Díaz Fernández, Lara Quitián Hernández, Pedro Bolgiani, Daniel Santos-Muñoz, Mariano Sastre, Francisco Valero and María Luisa Martín.
Modelización de ondas de montaña en las proximidades del aeropuerto de Barajas.
Seminario Final de la Red Temática Winter Precipitation and Strong Winds: Observational Studies (WiPSWis).
UCM, Madrid, España.
Oral presentation.
17 June 2019

María Luisa Martín, Mariano Sastre, Sergio Fernández-González, Daniel Santos-Muñoz, Francisco Valero
Incertidumbre y predictibilidad del viento en la Península Ibérica.
Seminario Final de la Red Temática Winter Precipitation and Strong Winds: Observational Studies (WiPSWis).
UCM, Madrid, España.
Oral presentation.
17 June 2019

L. Quitián-Hernández, M. L. Martín, Javier Díaz Fernández, Pedro Bolgiani, Mariano Sastre, J.J. González-Alemán, Daniel Santos-Muñoz, S. Fernández-González
Análisis del viento en un ciclón subtropical: uso de diferentes parametrizaciones en WRF.
Seminario Final de la Red Temática Winter Precipitation and Strong Winds: Observational Studies (WiPSWis).
UCM, Madrid, España.
Oral presentation.
17 June 2019

Javier Díaz Fernández, Lara Quitián Hernández, Pedro Bolgiani, Daniel Santos-Muñoz, Mariano Sastre, Juan Jesús González-Alemán, Francisco Valero, L.I. Sebastián-Martín, L. López, J.I. Farrán and María Luisa Martín
Sensitivity analysis to WRF parameterizations for mountain waves near Madrid airport (Spain)
EGU

Vienna, Austria.
Oral presentation, On line.
19-30 April 2021

Bolgiani, P., Díaz-Fernández, J., Quitián-Hernández, L., Sastre, M., Santos-Muñoz, D., Farrán, J.I., Gonzalez-Alemán, J.J., Valero, F., Martín, M.L.
On the effective resolution of WRF simulations at microscale grid resolution.
EGU
Vienna, Austria.
Oral presentation, Online.
19-30 April 2021

Lara Quitián Hernández, Ángel García Gago, Javier Díaz Fernández, Pedro Bolgiani, Daniel Santos-Muñoz, Juan Jesús González-Alemán, Mariano Sastre, Francisco Valero, J.I. Farrán and María Luisa Martín
Analysis of the hurricane Ophelia using two high-resolution numerical weather prediction models.
34th Hurricane and Tropical Meteorology Conference; American Geophysical Union (AGU)
New Orleans, USA.
Oral presentation, Online.
9-14 May 2021

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.

The Harmonie model was implemented to simulate some STCs (detailed in the original request). Additional anomalous TCs, that have followed unusual trajectories near Western Europe and have experimented tropical transitions (TT), are going to be studied in the last part of the Special Project SPESMART in 2021. Hurricane Vince (Tapiador et al., 2007; Beven et al., 2008), and Tropical Storm Delta in 2005 (Beven et al., 2008), Hurricane Alex in 2016, Hurricane Ophelia in 2017, or recently Hurricane Leslie in October 2018 have affected different European domains (Figure 1). Their intensification after the extratropical transition (Evans and Hart, 2003) have caused injuries, casualties, and huge economical losses along their tracks. Therefore, the analysis of these systems is one of the most important studies on the domain of the Northeastern Atlantic.

Figure 1: Anomalous tracks of (left) Hurricane Ophelia (2017) and (right) Hurricane Leslie (2018).

Quitián-Hernández et al. (2020) have studied the October 2014 STC. They have simulated this event using the WRF model and highlighted the importance of heat fluxes in the genesis and development of this atmospheric system. Moreover, Quitián-Hernández et al. (2021) have analysed the behaviour of both WRF and Harmonie models in simulating such STC, finding significant differences between both simulations. These two papers have been possible thanks to the Special Project SPESMART.

Until June 2021 and once different testing experiments have been needed to set up the WRF model, systems such as Vince, Ofelia, Delta, Theta, Leslie have been simulated using both WRF, and also with the Harmonie model. The configuration of both models is as follows:

- The WRF numerical model in studying STCs has been configured with a single domain of 2.5 km of grid resolution using 813 grid points in the west-east direction, 647 grid points in the south-north direction and 65 sigma levels unequally spaced, with a greater amount 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 Integrated Forecasting System (IFS) analysis of the National Meteorological Archival and Retrieval System (MARS) of the ECMWF with a 0.25° horizontal resolution every 6 hours.

- 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. Same physical schemes have been selected in the TT studies with initial/boundary conditions obtained from the ERA5 Reanalysis of the ECMWF with a 0.31° horizontal resolution every 6 hours.

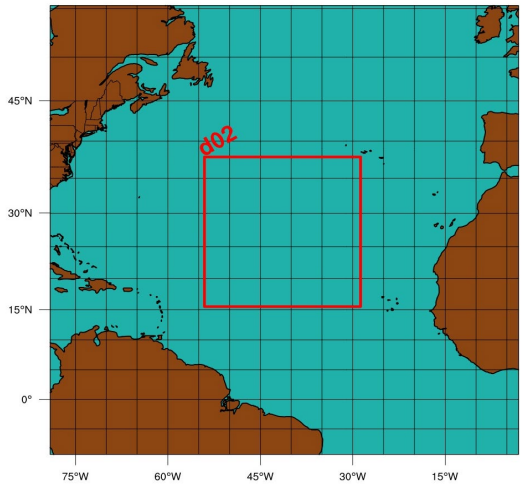

Figure 2: Example of WRF domain configuration to simulate Hurricane Delta.

- Two different versions of the HARMONIE model have been used to simulate both STCs and TTs. In a first step, HARMONIE model configuration (v40h1.1.1 version) has been used to study the STCs. With this version we have been learning the setup of this model, studying its postprocessing procedures.

- Once the STCs were simulated with this version of HARMONIE, another model configuration (43h2.1 version) was compiled to analyse 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 (1000x1000) in the west-east and south-north directions (domain in Figure 3, left) 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, such as the STC events.

- We have applied for more resources in this Special Project because some needed different experiments previous to the final simulations, that is, WRF set-up, and some proofs with different HARMONIE versions, were needed. The requested additional resources have recently been approved and the SBUs have been added to our account that can be noted in table of High Performance Computing Facility.

- The huge domains that cover these atmospheric systems boost the SBUs used in each simulation. Thus, 93000 units approximately have been used using WRF and, around 40000 units have cost using HARMONIE in each simulated STC or TT. This is the reason why we have exceeded the original request. Figure 3 shows an example of the simulated wind using both WRF and Harmonie for the TT Delta.

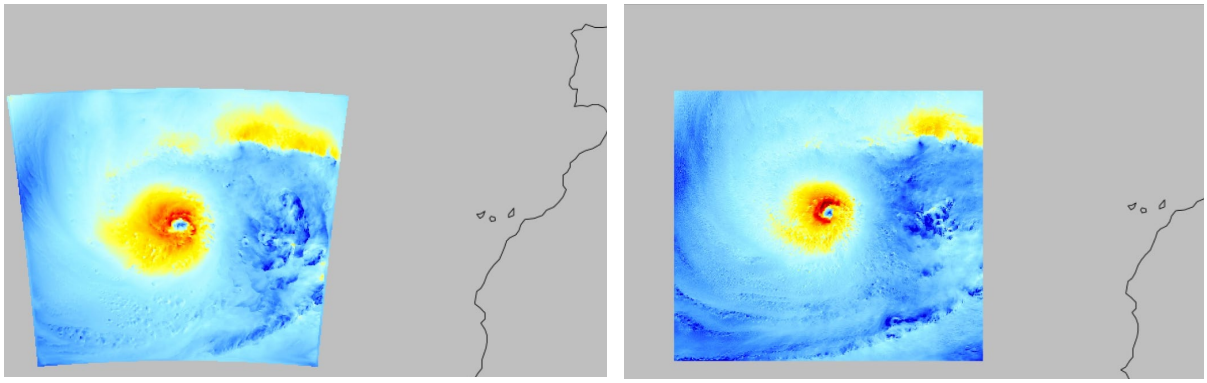

Figure 3: Simulations of wind speed with (left) Harmonie and (right) WRF for the Hurricane Delta.

In the first months of 2021, we have found more TTs using ERA5 data base. Figure 4 shows tracks of additional identified TTs from 1979 to 2019. We need to simulate them with both models to study during the time previous to their genesis and analyse possible precursors that can be useful in forecasting and warning this kind of catastrophic events.

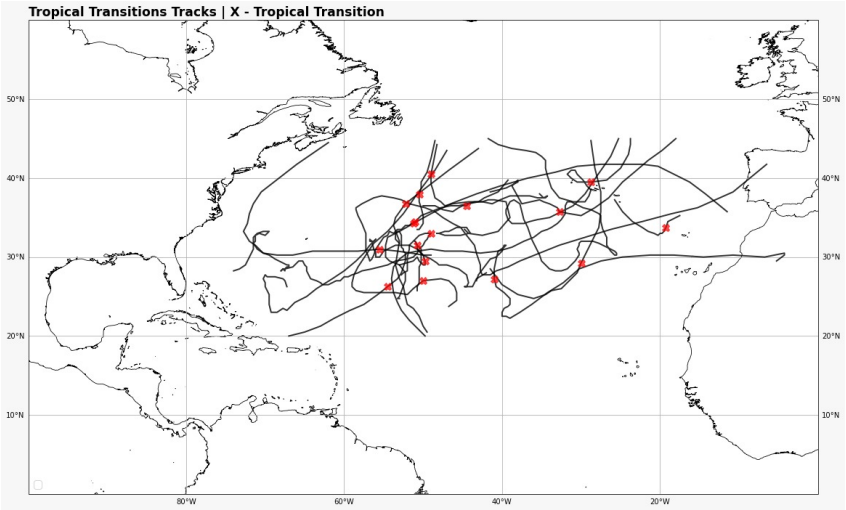

Figure 4: Tracks of several TTs identified (1950 - 2019).

We hope that throughout the remainder of the year, the WRF and Harmonie models will be used to simulate more TTs 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

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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.

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