REQUEST FOR ADDITIONAL RESOURCES IN THE CURRENT YEAR FOR AN EXISTING SPECIAL PROJECT

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

Project account: **SPESMART**

Additional computer resources requested for		**2021**
High Performance Computing Facility	(units)	1100000
Data storage capacity (total)	(Gbytes)	25000

[1] The Principal Investigator is the contact person for this Special Project

Continue overleaf

Technical reasons and scientific justifications why additional resources are needed

This project is the first one of two special projects 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 the differences between both types of simulations. The key objectives in the project can be summarized as follows:

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

The key simulated variables for Harmonie and WRF in the genesis and maturity of the STCs are compared in order to analyse differences and similitudes. These high-resolution simulations have been studied in order to know the possible transitions form STCs to Tropical Cyclones.

Additionally, 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 North Eastern 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.

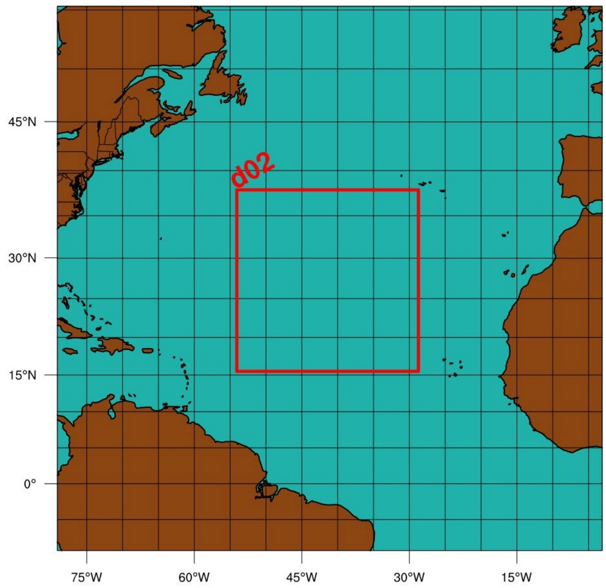

Figure 2: Example of WRF domain configuration to simulate Hurricane Delta.

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 set up 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.

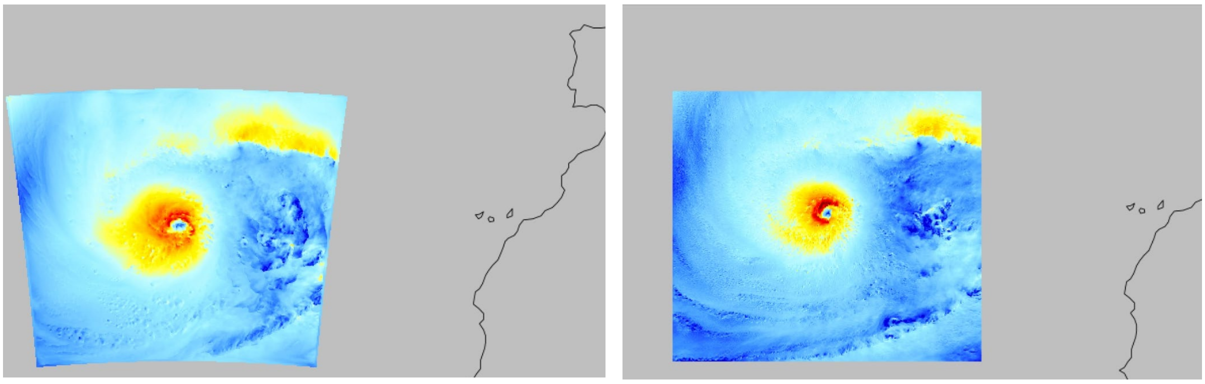

Figure 3: Simulations of wind speed with (left) Harmonie and (right) WRF for the Hurricane Delta.

For each atmospheric system, 93000 units approximately have been used using WRF and, around 40000 units have cost using HARMONIE. Considering the needed different experiments previous to the final simulations, that is, WRF set-up, and some proofs with different HARMONIE versions, that they have cost around 800000 units, we have also consumed additional 1000000 units in simulating 10 TTs. 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.

It is worth noting that the huge domain and high resolution used to simulate TTs require previous needed tasks which means additional USBs. Due to the COVID-19 situation, the system setup has utilized more resources than we originally expected. Currently, the setup has been fixed and therefore in this project step we consider that the new estimation of USBs we may need is realistic. We are learning about the technical features (High Performance Computing Facility and Data storage capacity) we need, and we should have requested at the very beginning of this Special Project.

Figure 4 shows tracks of additional identified TTs by this research team from 1950 to 2019, that we need to simulate with both models to study during the time previous to their genesis, analysing possible precursors that can be useful in forecasting and warning this kind of catastrophic events.

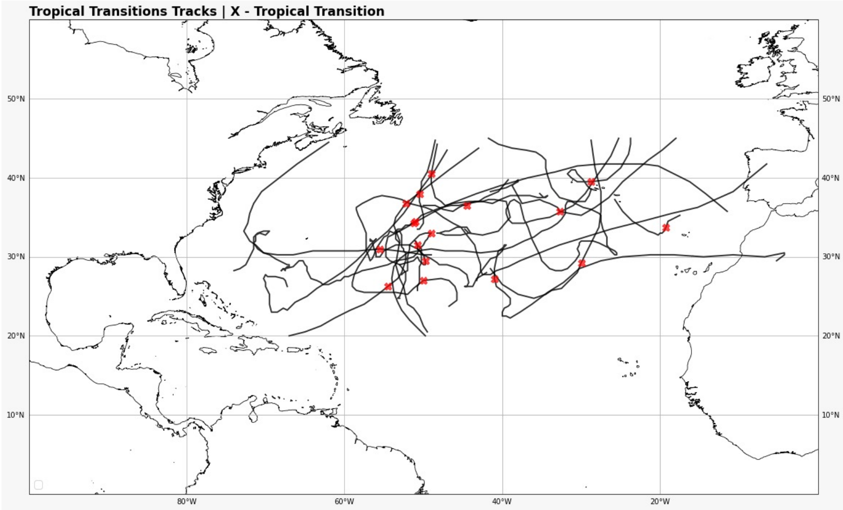

Figure 4: Tracks of several TTs identified (1950 - 2019).

To sum up, to continue simulating these TTs, we would need additional SBUs because these experiments require additional resources that in the original request, we did not expect to need.

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