REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Portugal……………………………………………………….…….

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João António Martins Careto……………………………………….

Project Title:

Convective phenomena at high resolution over Europe and the Mediterranean……………………………………………………

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2020-2022: (To make changes to an existing project please submit an amended version of the original form.)		**2020**	**2021**	**2022**
High Performance Computing Facility	(SBU)	9.500.000	9.500.000	9.500.000
Accumulated data storage (total archive volume)[2]	(GB)	1000	1000	1000

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

Principal Investigator: Pedro Matos Soares…...…………………………………………

Project Title: Convective phenomena at high resolution over Europe and the Mediterranean…………………………………………………

Abstract

Atmospheric convective phenomena might generate damaging extreme events. In a changing climate, the paradigm of convective events and its consequences, could change in terms of intensity, duration and spatial scale. We propose that by running a Regional Climate Model, at a very high resolution, will enable a better assessment of these type of events for present day climate, and how these phenomena will evolve in a transient climate. The study of convection based on very high resolutions will improve our knowledge, allowing a better assessment and projection of these events, by reducing the uncertainty of climate models. This project will focus into two main components: (i) assessment of the model ability to reproduce convective phenomena, together with an assessment of its consequences for the current climate, and (ii) assessment of future climate conditions regarding convection inhibition or intensification, together with a characterization of changes in intensity, spatial and temporal scale of convective related weather extremes. These simulations will be performed with the WRF model forced by ERA5 and ERA-Interim and by the CMIP5 and CMIP6 version of the EC-Earth global model.

Motivation

Convective precipitation phenomena are often associated with extreme weather events (Ducroq et al., 2014), such as flash floods, windstorms, landslides, hail or lightning (Carvalho et al., 2002; Beniston, 2006; Stucki et al., 2015). This type of phenomena occurs over areas of rapid moisture convergence and over regions of conditionally unstable atmospheric stratification. Convective cells can form anywhere, from homogenous plains to orographic regions or even as response to land/sea or urban/rural contrasts. Over the tropics or mid-latitude regions, convection is the predominant type of precipitation, where it can influence the general circulation of the atmosphere. A changing climate interferes with convective phenomena generation, by modifying the large-scale conditions which could impact precipitation extremes (Kendon et al., 2014; Prein et al., 2017). Prein et al, 2017 also showed that precipitation increases in energy limited regions, contrasting with a significant reduction over water limited areas, for the U.S. Thus, a study about this phenomena is needed in this context, as these changes could lead to an increase of damaging extreme weather events.

The Alps is one of the most active regions for convective phenomena generation. Since it is a mountainous region, the Foehn effect occurs, namely during winter, which generates persistent precipitation over a week period. On the other end, during the Mediterranean storm season, storms generated over the Mediterranean Sea could be advected into the alps, potentially intensifying the consequences, such as flash floods or landslides. Over Europe, another location for convective storm generation is the Iberian Peninsula, where during late summer and autumn, due to persistent heating, local shallow convective phenomena could evolve into deep convection, creating dangerous and damaging windstorms, lightning, hail and very intense precipitation over a short period (Coppola et al., 2019).

Today, our only tool to assess future climate conditions, in response to an increase of greenhouse gases in the atmosphere, are the Global Circulation Models (GCMs). GCMs can reproduce the large-scale circulation of the atmosphere and ocean, as well their decadal to centennial variability (Randall et al. 2007). However, the spatial and temporal scales of GCMs are insufficient to study local weather, such as convection and land-ocean-atmosphere interactions. Thus, leading to the development of Regional Climate Models (RCMs). RCMs constitute an increasingly sophisticated method, since they can reproduce physically consistent regional and local circulations (Giorgi and Mearns, 1991; Laprise, 2008; Soares et al, 2012; Soares et al, 2017). Over the years, the increase of computational power has enabled higher resolution RCMs runs for larger domains. An example is the 0.11^{o} resolution of the Word Climate Research Program Coordinated Regional Downscaling Experiment (WCRP-CORDEX), which encompasses the full European continent (Giorgi et al, 2009). EURO-CORDEX consists in a set of simulations where RCMs are forced by CMIP5 (Coupled Model Intercomparison Project, Phase 5) GCMs, enabling the study of both current climate and the evolution of climate over the 21st century. The gains of RCMs against GCMs are commonly known as added value.

The EURO-CORDEX simulations have been extensively evaluated (Kotlarski et al, 2014; Soares et al, 2017), showing important gains in precipitation, mainly associated with the enhancement in the representation of orographic features. However, for specific regions and variables, no added value was identified. In fact, there are regions where RCM projections disagree from GCM projections, for example over the Alps (Giorgy et al., 2016). Therefore, a large uncertainty of changes in regional processes remains, namely regarding the extremes (WCRP, 2015). One of the highest contributors to this uncertainty are the parametrizations of sub-grid processes (Prein et al., 2015), which interfere with extreme events and numerous feedback mechanisms at regional scales, such as the underestimation of hot days (Brockhaus et al., 2008), underestimation of hourly precipitation intensities (Prein et al 2013; Ban et al 2014) and overestimation of events of low-precipitation frequency (Berg et al., 2013). Therefore, increasing the resolution of regional climate models enables to explicitly represent process, which otherwise would be parametrized. Nevertheless, process level understandings and investigations are still required to fill knowledge gaps, improving current climate representation and future climate projections. Recently, a new set of simulations, the so-called convective permitting simulations (CP simulations) started to be devised, in hope of addressing some of these issues. Towards this end, the capabilities of RCMs have been extended to the CP scales, where convective parametrizations are able to be switched off (Weisman et al 1997), allowing a better assessment of the local climate, at an unprecedent high resolution. However, these CP simulations still needs information from large scale circulations, which are obtained from state-of-the-art GCMs.

Historically, a number of small-scale CP simulations have been performed (e.g. Benoit et al., 2002; Milovac et al., 2016; Schwitalla et al., 2017), in which have shown added value, due to resolving explicitly convective processes. Besides the improvement of CP simulations regarding the ability to explicitly resolve deep convection, a more detailed representation of land features is extremely beneficial in mountainous regions and areas of heterogeneous surfaces, such as the boundaries between coastal areas and urban to rural regions (Prein et al., 2013; 2015). Also, CP simulations have enabled a better assessment of weather extremes related to precipitation and to complex interactions with the orography (e.g. Weisman et al., 1997; Grell et al., 2000; Ducroq et al., 2002, 2008; Mass et al., 2002; Done et al., 2004; Davies et al., 2006, Khodayar et al., 2016; Pontoppidan et al., 2017). Besides these benefits, CP simulations also allow the study of fine scale aerosol-cloud-precipitation (Heinzeller et al., 2016), soil-moisture-precipitation (Hohenegger et al., 2016) and soil moisture-temperature (Argüeso et al. 2014) interactions. However, some limitations still arise for the CP simulations. For example, the shallow convection is not explicitly solved at these km scales (Soares et al., 2004; Khairoutinov and Randall et al 2006; Siebesma et al., 2007), which is critical in providing energy in moisture from the planetary boundary layer to the free atmosphere, which in turn sustains the development of deep convection (Holloway ad Neelin, 2009).

The increase in computational power over the years and the model's shortcomings regarding physical parametrizations of sub-grid processes motivated several modelling exercises at the CP scales (e.g. Ban et al., 2014). The reasoning behing the current proposal is to contribute with two simulations for an Alpine and a Iberian domains for the Flagship pilot study: "Convective phenomena at high resolution over Europe and the Mediterranean", which is an initiative supported by the WCRP CORDEX and GEWEX-GASS international program.

Workplan

The work will be organized into 6 tasks. For the first 3 tasks, a domain centred over the Alps will be considered and for the last 3 task another domain, centred over the Iberian Peninsula, will be contemplated. The purpose of the tasks is to perform the CP simulations, to evaluate the model performance in current climate and to assess the evolution of climate extremes in future climate, for the domains.

Task 1. In this first task the WRF (Weather Research and Forecast) model set-up will be developed performing a set of sensitivity runs. Afterwards the WRF-CP model will be run for the Alpine domain. The RCM model will be forced by the ERA-Interim reanalysis. For this simulation, two nested domains are considered: a mother domain at 15 Km resolution and a son high-resolution domain at 3Km resolution. On the highest resolution domain, the convection parametrizations will be switched off.

Task 2. For this task, the setup from the previous task is considered, however the WRF model is forced by the EC-Earth GCM for a historical period (CMIP5).

Task 3. In this third task, the same domain will be pursued but for a future period and therefore the WRF-CP model will be forced by the EC-Earth GCM results for the 21st century.

Task 4. In this fourth task the WRF model will be set-up for the Iberian Peninsula domain. In this case, the RCM model is forced by the recently available ERA5 reanalysis. For this simulation, two domains are considered: a larger domain at 15 Km resolution and a nested high-resolution domain at 3Km resolution. On the highest resolution domain, the convection parametrizations will be switched off.

Task 5. For this task, maintaining the setup from the previous task, the WRF model will be forced by the CMIP6 version of the EC-Earth GCM for a historical period.

Task 6. In this final task, with the same domain considerations from the previous two task, the WRF model will again be forced by the CMIP6 EC-Earth GCM, but for a future period.

Resources

The resources for each task are similar:

- A total of 11 years simulation per task.
- Approximately 4.750.000 SBU per task
- Approximately 4.9TB of data will be generated for each year of each task.

Two task per year will be performed, totalizing 9.500.000 SBUs each year. The storage will be managed to only keep the output of these simulations while temporary testing and extra output will be removed after the analysis.

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