REQUEST FOR A SPECIAL PROJECT 2025–2027

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

Principal Investigator[1]: Daniela C.A. Lima ………………………………………………………………

Affiliation: Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa …

Address: Faculdade de Ciências, 1749-016, Lisboa…………………………………………

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Other researchers:

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Project Title:

Land-atmosphere-ocean coupling along the Atlantic Eastern Boundary Current Systems ……………………………………………….

To make changes to an existing project please submit an amended version of the original form.)

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.)	2025	
Would you accept support for 1 year only, if necessary?	YES X☐	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	100000000	100000000	
Accumulated data storage (total archive volume)[2]	[GB]	120000	160000	

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

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.

[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: Daniela Catarina André Lima…………………………………………………………

Project Title: Land-atmosphere-ocean coupling along the Atlantic Eastern Boundary Current Systems

Project Description

According to the Sixth Assessment Report of the IPCC, observed and projected rates of climate change indicate an increase in the severity and frequency of both wet and dry extreme events across the Iberian Peninsula and southwestern Africa, along the eastern Atlantic [1-3]. A general warming trend is highly likely to persist throughout the 21st century leading to an expected increase in agricultural and ecological drought affecting local populations.

Climate systems along the Atlantic Eastern Boundary Current Systems (EBCS) regions, as Iberia-Canaries and Benguela, are characterized by highly coupled climate regimes, exhibiting complex interactions between the land, atmosphere and ocean [4-13]. The coupling between atmosphere and surface is particularly intricate, and improving its representation in climate models is crucial for the better understanding of regional-to-local climate change impacts.

Earth Systems Models (ESMs) have been developed to enhance the representation of land-atmosphere-ocean physical mechanisms, including physical, chemical and biological processes [14-18]. Therefore, reaching far beyond their predecessors, the Global Climate Models (GCMs), which just have the atmospheric and oceanic components [19-21]. ESMs have these two components, but also have the representations of the dynamic vegetation, atmospheric chemistry, global carbon cycle, ocean bio-geo-chemistry and continental ice sheets. However, these ESMs typically have relatively coarse horizontal resolutions, appropriate for representing large-scale dynamics, but insufficient for capturing physical processes at regional or local scales. Conversely, Regional Climate Models (RCMs), which downscale ESMs, provide a higher level of detail in resolving physical processes at finer resolutions, offering improved representation of regional and local circulations [4,13,22,23]. However, most state-of-the-art RCMs poorly represent interactions between the atmosphere and other Earth system components [24,25].

The overarching objective of this project is to quantify in a detailed manner the main physical mechanisms associated with land-atmosphere-ocean interactions along the Atlantic EBCS, contributing deeply to enhance the understanding of the coupling mechanisms. A comprehensive and robust characterisation of these coupled physical mechanisms and their impacts on regional climate is crucial for addressing the effects of climate change on this complex climate system.

The use of a new generation of RCMs (Regional ESMs), which interactively couple the atmosphere with other earth system components (e.g., ocean, vegetation), and allow for land use/land cover changes (LUC), will enable the generation of high-quality climate projections. Incorporating an ocean model is important for reducing significant biases exhibited by most ESMs when simulating the sea surface temperature (SST) along the Atlantic EBCS [26,27]. Additionally, integrating vegetation dynamics will allow us to quantify the evolution of forests and savannas under different climate change scenarios. These high-resolution coupled simulations are expected to improve the representation of mesoscale circulation and processes, leading to a better description of land-atmosphere-ocean interactions.

The project framework encompasses two main general goals: quantify the climate sensitivity of land-atmosphere-ocean processes in present climate and under future climate and assess the impact of these processes on extreme weather events and economic sectors through risk assessment under a climate change framework. This will be accomplished based on methodological approaches developed by the team members (e.g. multi-model evaluation [28], coastal low-level jets (CLLJs) [29], moisture transport [10], wildfires [30], compound events [31]) and new methods developed during the project, supported by Reanalysis data, ESMs simulations from CMIP6,

observational datasets, and a set of regional simulations conducted during the project. A set of WRF reanalysis driven simulations will be performed, considering static and transient vegetation. This will contribute to understanding the impact of LUC on regional climate. Additionally, historical and future simulations with similar features will be conducted. These high-resolution simulations may improve the representation of mesoscale circulation and processes, allowing a better description of land-atmosphere-ocean interactions, which is crucial to the project goals.
Results, for both present and future climates, will yield several key benefits focusing on the Atlantic EBCS regions (Iberia-Canaries and Benguela): 1) providing a crucial tool to evaluate the significant role of land-atmosphere-ocean interactions in Atlantic EBCS, specifically the feedbacks between low-level clouds, upwelling, CLLJs, vegetation, moisture transport, and aerosols; (2) providing a quantitative assessment of the effects of land use/land cover changes; (3) offering enhanced insights into how climate change might impact different physical mechanisms that drive regional climate patterns; and (4) making a valuable contribution to risk assessment and adaptation studies, tailored specifically for end-users. These results will be an important asset in identifying robust climate change impacts under different levels of global warming, contributing to a framework for multi-scale earth system analyses which allow tailoring mitigation and adaptation strategies.
We expect that the project will contribute to: (1) fill the scientific gap by providing robust information on the upwelling systems and biophysical feedbacks of LUC in Atlantic EBCS regional climate; (2) identify potential biases arising from missing ocean and land use dynamics in regional climate change projections and help improve simulated impacts; (3) better constrain the further strategic development of coupled land-atmosphere-ocean and Regional ESMs; and (4) support decision-making in several economic sectors by revealing the projected impacts of climate change across different sectors. Namely, through risk assessment related to extreme events associated with water and land management, as well as renewable energy, and food security.

Present Proposal
The present project aims to contribute to a detailed quantification and improved understanding of the influence of land-atmosphere-ocean coupling in the main physical mechanisms and systems governing the regions along the Atlantic EBCS: Iberian Peninsula-Morocco and southwestern Africa's climate. This project will seek a better and detailed characterization of the impacts of climate change on regional climate, with special attention on specific socio-economic sectors, like agriculture, energy, and water resources.
The current proposal will be part of the ongoing inter-comparison projects, as stated in the Description section.

Specific Objectives:
- To better understand the relative contribution of LUC to the past climate evolution in Iberian Peninsula and in southwestern African (from South Africa to Angola).
- To quantify the relative contribution of the oceanic upwelling systems (Iberia-Canaries and Benguela) to climate.
- To make an inter-comparison of simulated land-ocean-atmosphere interactions and evaluation of model performance against multi-variable observations.
- To investigate local scale feedback of ocean, land use and water table dynamics on climate; focusing on feedback between low-level clouds, upwelling, coastal low-level jets, vegetation dynamics, moisture, and energy transport.
- To Identify robust climate change impacts under different levels of global warming: downscaling coupled global climate simulations with WRF forced by different potential future scenarios.
- To contribute to a framework for multi-scale earth system analyses to provide mitigation and adaptation strategies to climate change.

Target questions (TQ):

The main TQ that this proposal aims to answer are as follows:
TQ1 How do the physical mechanisms, from low-level clouds to coastal low-level jets and upwelling, feedback in the regional climate?
TQ2 How large is the influence of LUC in the land-atmosphere interactions?
TQ3 What are the contributions of the feedback in the coupled land-atmosphere-ocean system to current and future climate?
TQ4 In what sense the changes on the coupled regional system may impact on the occurrence and intensity of extreme events?
TQ5 What are the implications of climate change in the coupled regional system to agriculture, fisheries, and renewable energy?
These TQ are focused on the Atlantic EBCS regions of Iberian Peninsula-Morocco and southwestern Africa.

Work Plan

The main objective of this task is to conduct a set of regional climate simulations to investigate the impact of interactions between the atmosphere, land and ocean on the regional climate. Additionally, we will incorporate climate simulations conducted in other project efforts into our analysis.

1) High-resolution climate simulations for southwestern Africa:

We will conduct two WRF high-resolution simulations at 0.11^{o} covering southwestern Africa, from Angola to the Cape of Good Hope, and the southern Atlantic Ocean up to 15^{o}W. These simulations will downscale 40 years of the global reanalyse ERA5, considering static (assuming 2015's vegetation distribution) and transient vegetation. The second one will incorporate the new harmonized reconstructed land use data from ESACCI (with yearly evolving vegetation distribution). Furthermore, we will downscale the ESM MPI-ESM-HR from the CMIP6 framework, which has increased spatial resolution and a better representation of the land-atmosphere-ocean physical mechanisms, for future climate analysis. These simulations will incorporate transient vegetation, allowing us to quantify the contribution of LUC to climate change. The historical period considered is 1980-2015, while future climate simulations span 2016-2100 in agreement with the SSP3-7.0.
The new set of emissions and land-use scenarios were produced based on new future societal development pathways, the Shared Socioeconomic Pathways (SSPs), and connected to the Representative Concentration Pathways (RCPs). Although the radiative forcing in CMIP6 and CMIP5 are similar, the climate projections will differ between them. For CMIP6, the climate models have updated versions, and the future scenarios include SSPs. This will create new climate sensitivities across CMIP6 models. These new climate scenarios are crucial for climate change mitigation, adaptation, and impact assessments, aligning with the goals of our project.

2) High-resolution climate simulations for Iberian Peninsula:

Simulations with similar settings will be performed covering the Iberian Peninsula (Europe).

Resources

The two tasks will be performed in two years. A total of 100.000.000 SBUs in the first year and 100.000.000 SBUs in the second year.
The storage will be managed to keep the relevant output of these simulations while temporary testing and extra output will be removed after the analysis.

References

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