REQUEST FOR A SPECIAL PROJECT 2025–2027

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

Principal Investigator[1]: Virgílio A. Bento ……………………………………………………………………

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: On fire risk projections throughout the XXI century and its relationship with new climate extremes with a spotlight on the design of storylines for adaptation strategies ………………………………………………

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	100000000
Accumulated data storage (total archive volume)[2]	[GB]	120000	160000	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: Virgílio A. Bento ………………………………………………………………………

Project Title: On fire risk projections throughout the XXI century and its relationship with new climate extremes with a spotlight on the design of storylines for adaptation strategies

Project Description

Wildfires have been a major threat to ecosystems and societies in the last decades, demanding an improved understanding of their drivers and mechanisms to mitigate their impacts. Climate change greatly enhances the need for fire knowledge. The Fire Weather Index (FWI) has been commonly used in real-time monitoring tools and in academic research. This index builds upon meteorological variables such as daily temperature, precipitation, humidity, and wind speed. However, fire risk is also sensitive to other parameters such as the presence of burn-prone vegetation and the existence of human settlements. Few works have explored the multidisciplinary trivariate relation between fire, vegetation, and human factors, and even fewer have studied the evolution and the interlinks of the three variables in the future. This is mainly due the difficulty of including dynamic vegetation and demography within the processes accounted in most climate models. With this project I propose to take advantage of regional climate models with dynamic vegetation, forced by global climate models (GCMs) under different scenarios (e.g., SSP1-2.6, SSP3-7.0) that consider the greenhouse gas trajectories and different shared socioeconomic pathways (SSPs) to study how fire risk may change until the end of the 21st century. Furthermore, spatially explicit population scenarios are expected to be used to quantify changes in population. This is a state-of-the-art project with several innovation factors, such as (1) the use of a new fire risk index enhanced with atmospheric instability (FWIe), (2) the use of the first CMIP6 regional climate model runs (with dynamic vegetation models included), (3) taking advantage of the increasingly used machine learning techniques to find relations between these variables, (4) the inclusion of wind direction on risk assessment, (5) the use of the emergent “storyline” approach to improve risk awareness, strengthen decision-making, providing a physical-basis for uncertainties, and to explore the boundaries of plausibility, by framing risk in an event-oriented manner that corresponds directly to how people perceive and respond to risk. A characterization of FWI, vegetation, and population density for different climate and socioeconomic scenarios is endeavoured. This is expected to be a time-consuming but valuable effort, which may result in several of the project’s outcomes being published in high visibility refereed journals. It is also expected to bring new perspectives to the understanding of fire risk that may be beneficial to society. This work will be developed for a region encompassing the Iberian Peninsula, which may be extended to the entire Mediterranean Europe, which are regions generally affected by large wildfires and further viewed as hot spots to frequent and intense wildfires in the future.

Motivation

Wildfires are one of the most important threats to people, forests, and the economy in the Iberian Peninsula [1] and in the Mediterranean Europe [2]. A striking example is the fire season of 2017 in Portugal [1], which resulted in more than 100 fatalities, and losses of more than a billion euros in the country’s economy. Hence, the characterization and understanding of wildfires and its components has been a major scientific endeavour in the last decades. Studies that show changes in fire season characteristics [3] or the development of indices that map the risk of fire occurrences solely based in meteorological variables are some [4]. Nowadays, the Canadian Forest Fire Weather Index (FWI) System [5] is a commonly used index that is both applied in real time monitorization (IPMA, IDL) and used in research to better understand fire mechanisms. A new enhanced FWI

(FWIe), which accounts for atmospheric instability was recently developed [4]. A leading branch of research is that linked with climate change and its effects in forest fires. Several studies [6] have addressed this topic, using Regional Climate Models (RCMs) forced with different greenhouse gas concentration trajectories to assess future fire risk. However, these studies were performed assuming vegetation as a static parameter, which may severely influence future fire risk patterns and thus have serious implications for policy and management resource allocation [7]. Few works focused on how climate change may affect wildfires by assuming dynamic vegetation, being either global or specific to local regions of interest [8,9]. Moreover, fire risk is not confined to meteorological variables and available fuel (vegetation). Some studies pointed to an increase in fire occurrences near to settlements and roads, while other studies used remote sensing to conclude that increase in human population lead to less fire occurrences [9,10]. Compound [11] and cascading [12] events related with fire regimes and other climate extremes such as droughts, heatwaves, floods, are increasingly studied due to their importance in societies. An emerging alternative to the probabilistic representation of uncertainty in climate change is the "storyline" approach [13], which offers a powerful way of linking physical with human aspects of climate change. This proposal relies on the new generation of regional earth system models, which incorporates vegetation and evolving aerosols, to overcome and answer open questions in climate science: understand the relationship between observed fire occurrences, burned area and population density; assess the fire risk patterns linked to changes on vegetation and population density in the context of a changing climate. These topics are crucial to increase our understanding of fire risk and its impacts, emphasizing the climate change interplay on this phenomenon, which is vital to the design of mitigation and adaptation strategies and avoid regional disasters.

Present Proposal

The present project aims at contributing to a detailed assessment of meteorological fire risk projections throughout the 21st century and a detailed characterisation of its relationship with new climate extremes with a spotlight on the design of storylines for adaptation strategies. Additionally, this proposal will seek an improved understanding of the trivariate relation between wildfires, dynamic vegetation, and changes in population density, focusing on the Iberian Peninsula (but also extended to the Mediterranean Europe). It will be integrated in the CORDEX Flagship Pilot Study LUCAS (Land Use and Climate Across Scales), an initiative of the World Climate Research Programme, and in the DHEFEUS project (financed by FCT). In addition to these projects, the cooperation with the National Roadmap for Adaptation XXI (RNA 2100) team will provide a valuable partnership through the collaboration with several Portuguese and Norwegian institutes.

This is to be achieved taking advantage of the new generation RESMs, which couple atmosphere interactively with other earth system's components (e.g., ocean, dynamic vegetation, variable aerosols), crucial to the development of this proposal. The new multi-model ensemble from the CORDEX Flagship Pilot Study LUCAS at 0.11º, in which the RCMs (with static and dynamic vegetation) are downscaled from global climate models (GCMs) from CMIP6, is expected to be used. This is possible due to the inclusion of my host institute in the Euro-CORDEX and the Flagship teams. The cooperation with the CORDEX international consortia will allow the assembly of high-quality dataset of the region's climate and allow the appraisal of the climate projection uncertainties which is paramount for robust impact assessments and the drafting of mitigation/adaptation strategies.

Work plan

Target questions (TQ):

TQ1 What is the expected meteorological wildfire risk in a changing climate?

TQ2 Is this risk going to drift to new regions due to changes in the vegetation cover?

TQ3 What is the influence of larger population clusters and the migration of people to previously human free regions?
TQ4 What to expect from compound (heatwaves, drought, fires) and cascading events (e.g., fire – desiccated soil – precipitation – landslides – floods) with the projected new extremes?
TQ5 Which storylines can be written in the context of linking new extremes and new fire regimes uncertainties to better mitigate their impacts in society?

Tasks (T):
T1 Analyse the relationship between wildfire risk and the number of occurrences and/or burned area in current climate. Development of new statistical models through artificial intelligence methods.
T2 Assess the trivariate relation between population density, wildfire risk, and vegetation in current climate.
T3 Investigate the evolution of wildfire risk, considering the changes in vegetation under different mitigation future scenarios.
T4 Assess the influence of different mitigation scenarios of future demography in wildfire risk. Quantify the human influence in fire risk in the future.
T5 Quantify the relationship between future fire regimes and compound/cascading events under a warming climate.
T6 Fire risk assessment analysis on the impacts of future climate change in several economic sectors. Build of storylines of new extremes and fire regimes.

Methods
Taking advantage of the new set of high-resolution simulations at 12km that will downscale ERA5 reanalysis using the WRF model for the European domain, the wildfire risk over Iberian Peninsula will be assessed through the analysis of FWI and FWIe. New statistical models will be developed using deep learning (artificial intelligence techniques) to assess the relationship between wildfire risk and the number of occurrences and/or burned area in current climate (T1). The simulations will incorporate static/dynamic vegetation, aerosols aware microphysics and radiation parametrizations, crucial to characterise the changes on vegetation and its impact on wildfire risk. A full characterization and broad comparison between static and dynamic vegetation is fundamental to understand the impacts of LUC in the climate system. The Global Fire Assimilation System from ECMWF will be used as an input of the emissions from vegetation fires to obtain the aerosols information, crucial to obtain accurate fire results. The trivariate relationship between wildfire indices (FWI, FWIe, fire occurrences and/or burned area), population density, and vegetation dynamics will be investigated through the development of a new statistical method through deep learning artificial intelligence technique (T2). Regional climate scenarios for historical (1960-2015) and future periods (2016-2100), in agreement with the new scenarios MIP - SSP1-2.6, SSP2-4.5, and SSP3-7.0, that will downscale CMIP6-GCMs, will be used to pursue an analysis of the effects of climate change on wildfire risk and its associated impacts (T3-6). Similar analysis to T1-2 will be performed, using the statistical models developed. The changes on vegetation will allow the characterisation of the evolution of wildfire risk (T3), and to understand the influence of different scenarios of future demography based on the Shared Socioeconomic Pathways in wildfire risk (T4). The application of the new fire/vegetation/demographic statistical model will be crucial to combine human influence in fire risk in the future climate. Compound and cascading events will be investigated to assess the relationship between new extremes of fires, heatwaves, and droughts (T5). The influence of wind direction and orographic slope on fire risk will be investigated and its introduction on risk models will be pursued. The assessment of uncertainties based on an emerging alternative to the traditional probabilistic one, i.e., through the so-called "storyline" approach, will offer a powerful way of linking physical with human aspects of climate change (T6). The building of

storylines of new extremes and fire regimes will improve the risk awareness and consequently how people perceive and respond to risk, to strengthen decision-making and address compound risk and promote appropriate stress tests and explore the "boundaries of plausibility" preventing false prediction and surprise. The climate change information that will be obtained will be valuable to strategic decisions on economic sectors, by revealing the project impacts of climate change in sectors like forests, agriculture. The link between this proposal and RNA 2100 project will be crucial for the development of mitigation strategies for forests management.

Resources

The simulations for all the tasks will be performed in three years. A total of 100.000.000 SBUs in the first year, 100.000.000 SBUs in the second year, and 100.000.000 SBUs in the third 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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