REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: ……………………………ITALY…………………………………..…

Principal Investigator[1]: ………………………………Annalisa Cherchi…………………………………

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Project Title: Future droughts in Mediterranean climate regions

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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.)	2026	
Would you accept support for 1 year only, if necessary?	YES x	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	24500000	8400000	
Accumulated data storage (total archive volume)[2]	[GB]	53400	74200	

EWC resources required for project year:		**2026**	**2027**	**2028**
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.

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Project Title: ……… Future droughts in Mediterranean climate regions ………

Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 5,000,000 SBU should be more detailed (3-5 pages).

The Institute for the Atmospheric Sciences and Climate at the National Research Council of Italy (CNR-ISAC) is member of the EC-Earth consortium (http://www.ec-earth.org/). The consortium is aimed at building a European community Earth System Model (ESM) combining efforts of different research institutes from 10 European countries. In the EC-Earth consortium, CNR-ISAC coordinates the *Land and Vegetation* working group and the *CMIP and Tuning* working group. Moreover, it contributes to the *Ocean* working group and the *Prediction* working group. CNR-ISAC is a partner in several international efforts including HE projects and new emerging initiatives, like the proposal for a GEO pilot initiative aimed at exploiting latest land observations to improve and better constrain Earth System predictions (https://earthobservations.org). Within WCRP, CNR-ISAC is actively involved in novel Lighthouse Activities, like Explaining and Predicting Earth System Change (https://www.wcrp-climate.org/epesc) and Global precipitation experiment (https://www.wcrp-climate.org/gpex-overview).

In this special project we will consider the newly available future climate scenarios with the most recent climate policies to investigate how droughts are projected to change in the future over the Mediterranean climate regions. Available literature indicates that droughts in Mediterranean climate regions have become more frequent and severe over the past several decades due to rising temperatures, changes in atmospheric patterns and hydrological properties. For the future, these trends and changes are projected to continue and to further intensify, with potential significant consequences for water resources, ecosystems, and human livelihoods. We will use the most updated and recent version of the EC-Earth model developed to contribute to the CMIP7 framework. Insights into aridification and dynamical causes aid in tailoring policies for climate adaptation planning and is of relevance for the Mediterranean climate regions of the world.

Droughts over the Mediterranean climate regions in future projections

Mediterranean climate regions (MCRs) are characterized by temperate wet winters and warm (or hot) dry summers and they are located on the western edge of continents in the subtropics to mid-latitude thus being overall transition areas between wet and dry climates (Alessandri et al 2014; Seager et al 2019; Urdiales-Flores et al 2024). Over the world there are five main locations with these characteristics, that are the Mediterranean region, the west coast of North America, central Chile in South America, the far southwest tip of Southern Africa and southwest Australia. These regions currently correspond to approximately 2% of the Earth's land surface but are home to more than 700 million people corresponding to nearly 10% of the global population (Urdiales- Flores et al., 2023). Due to their temperate environmental characteristics, MCRs are biodiversity hotspots and among the most desired climatic zones for human inhabitation and tourism (Myers et al., 2000; Vogiatzakis et al., 2016). Viticulture, an example of cultivars of significant economic and cultural value, is concentrated in MCRs due to their distinctive climate characteristics (Hannah et al. 2013).

During the past century, MCRs have warmed similarly to the global mean, except for the Mediterranean Basin, which has experienced accelerated warming (nearly two times faster than the global mean rates), mainly during the last four decades (Urdiales-Flores et al. 2023; Zittis et al. 2022). Since 1901, all regions (except North America) have experienced drying, and this trend is projected to intensify in the future (Seager et al 2019). The North Atlantic Oscillation (NAO) is identified as clear large-scale driver in shaping winter precipitation in Europe and over the Mediterranean: positive NAO brings moist advection northward (UK, Scandinavia), while causing drying in continental Europe and the Mediterranean, with storm track shifts that account for regional nuances (Seager et al 2020). Hydroclimate changes across MCRs evidence radiatively-driven drying in Chile and southwest Australia in winter. Over the Mediterranean, observed winter drying exceeds what models (radiative and SST-forced) can explain, suggesting other dynamic processes at play. Future projections confirm continued year-round drying in the Mediterranean (Seager et al 2024). Ongoing investigations of water resources over the MCRs evidence important declines mostly in the Northern Hemisphere sectors (Senigalliesi et al 2025, in preparation). A probabilistic analysis CMIP5 projections evaluate future distribution of Mediterranean-type of climate (MED) and evidence a significant northward/eastward shifts of MED zones projected across Euro-Mediterranean regions and western North America, while southern boundaries (equatorward margins) of MED zones are expected to translate into arid (desert-like) climates (Alessandri et al 2014).

Projected increasing temperature and decrease in precipitation, exacerbated by increased evapotranspiration, become unavoidable sources of stress for water resources, hence driving more intense and more severe droughts. Droughts are complex natural hazards that strongly depend on the interaction between atmosphere, land surface processes, and hydrology. They are among the most devastating climate hazards, with potential wide-ranging consequences on water supply, agriculture, ecosystems, and economies. Future climate projections using CMIP6 models indicate a significant increase in the frequency, duration, and severity of droughts (IPCC, 2021). For example, over the Euro-Mediterranean region, CMIP6 models project consistent drying trend, especially in summer, with greater risk of prolonged agricultural and hydrological droughts under intermediate to high emission scenarios (SSP2-4.5 and SSP5-8.5), with significant impacts on agriculture, biodiversity and hydropower (Zittis et al., 2021; Cramer et al., 2018). On top of anthropogenic forcing and direct effects on increasing temperature, increased evapotranspiration and possible decrease in precipitation, changes in droughts and how they relate with increasing global warming levels largely depend also on natural climate variability and large-scale drivers (Seager et al 2024; Cook et al 2014; Naumann et al 2018). Newly available future climate scenarios and improved state-of-the-art coupled climate models are key to investigate further these changes to provide guidance and information relevant for long-term adaptation planning.

Towards a CMIP7 version of EC-Earth

In this special project, we will use the available evolution of the current version of EC-Earth (Döscher et al. 2022) that is under development in preparation of the CMIP7 coordinated experiments. Compared to v3.x the newly available v4.x version is based on OpenIFS 48r1, NEMO4.2.2, XIOS 2.5 and OASIS3-MCT 5.2 (https://ec-earth.org/ec-earth/ec-earth4/). As planned, the CMIP7 versions (v3.4.x and v4.x) of EC-Earth include improved process representation (improved treatment of aerosols and aerosol-cloud interactions, land vegetation, permafrost and hydrological processes) as well as the inclusion of novel components (such as dynamical ice sheets) that are relevant for the representation of climate feedbacks and the related risk of triggering fast and abrupt climate transitions. Furthermore, the components of the EC-Earth model are routinely upgraded to incorporate improved numerical schemes and revised encoding, enhancing high-performance computing (HPC) performances. The developments and improvements towards the CMIP7 version of EC-Earth are under development and during this special project we will use the most recently available version.

Planned experiments and analysis

The set of experiments with the EC-Earth full ESM as latest available for this special project will consist of an historical simulation covering the period 1850-2020 with CMIP7 forcing (here identified as HIST), and five scenarios based on new sets of emissions following the latest climate policies being developed in the framework of CMIP7. The overall goal of ScenarioMIP is the identification of new plausible futures, connecting various research communities and exploring the broad relationships between the main drivers of climate change and the resulting climate outcomes (Van Vuuren et al 2025). In this respect, new scenarios are organized into high-end scenario to explore risks in case the world does very little to combat climate change, a pair of medium scenarios to explore the impact of current policies remaining 'frozen' or mitigation actions are delayed, and on the low side of the temperature spectrum, the importance to explore the temperature range that has been associated with the Paris climate goals (UNFCCC, 2015; Rogelj et al 2016; IPCC, 2018; IPCC, 2021). Within this plethora of planned emission scenarios under CMIP7 ScenarioMIP (Van Vuuren et al 2025), for this special project we select three scenarios in the low emissions range, one scenario in the medium emission range and one scenario in the high emission range. In the low emission range, we intend to consider the low emission scenario (here identified as LOW), as well as the other two scenarios with low emissions but with two different options of overshoot (here identified as VLHO and VLLO). LOW is designed to remain low as plausible given feasibility constraints (staying as close as can still be plausible to 1.5°C at the time of peak warming and limiting warming to 1.5°C by the end of the century), hence being relevant for the low end of the Paris range (Van Vuuren et al 2025). VLHO (Very Low after High Overshoot) is a scenario with a higher overshoot of the 1.5°C goal, followed by stringent climate policies (including Carbon Dioxide Removal) to return to lower levels, thus supporting research into the reversibility of climate outcomes and their consequences, while VLLO (Very Low with Limited Overshoot) is a scenario designed to be consistent with the pursuit of holding warming to levels likely below 2°C at all times, without returning to 1.5°C before the end of the century (Van Vuuren et al 2025). In the medium emission range, we select the medium emission scenario (here identified as MEDIUM) that is designed to explore the consequences of continuing current policies without modification (Van Vuuren et al 2025). Finally, in the high emission range we will consider the high emission scenario (here identified as HIGH) that assumes developments, like high demographic growth and slow development of mitigation technologies and diffusion, to explore high-end climate risks. The five scenario simulations will cover the period 2021-2100. Overall, these new experiments could be also compared with the SSP scenarios already produced within CMIP6 to explore the changes projected over the Mediterranean climate regions and the related sensitivity to the different scenarios considered.
The analysis of the set of CMIP7 experiments performed with the latest available version of EC-Earth ESM will be focused on the identification of differences in the climate response over the Mediterranean climate regions across different scenarios. We will investigate how the occurrence and the characteristics of droughts will change depending on the time evolution and intensity of emissions in the scenarios. Diverse drought indices (i.e. meteorological, agricultural or hydrological) and diversified droughts characteristics (i.e. frequency, duration and severity) will be considered, including the investigation of potential emergence of abrupt transitions in the different scenarios used. In terms of the expected changes in the statistics in future climate projections compared to historical simulation, interesting aspects of analysis include investigations in potential changes in the persistence of droughts, changes in the recurrence of droughts of a given intensity and changes in the season most prone to droughts.
A summary of the planned experiments, with details about the resources needed and how they are distributed within the duration of the special project are summarized in Table 1.

Configuration and justification of resources

For the core set of historical and scenario simulations, we will use the state-of-the-art version of EC-Earth4 in its full ESM configuration (with a closed carbon cycle) available. The resolution to consider for this special project is the standard one, corresponding to T255 with 91 vertical levels in the atmosphere, and ORCA1 with 75 vertical levels in the ocean. Based on the preliminary evaluation performed in the framework of the EC-Earth consortium, the expected optimal configuration on Atos is obtained considering the following components and related dedicated CPUs: IFS (768), NEMO (with PISCES activated; 372), XIOS (2), LPJG (120), and other shared between runoff and ISM mappers, and the activated chemistry for a total of around 10 nodes (1280 total cores). With this configuration, we estimate that the model requires on Atos about 50000 SBUs per simulated year. About 50 years of simulation with the full ESM are added to account for the need to test the updates and improvements toward stable configurations. Overall, the total resources estimated for the project are rounded to 32.9 million SBUs (Table 1), which includes a buffer of 5% to account for failing jobs or additional short tests needed.

In terms of storage, the requirement is about 130 GB per year of historical and scenarios simulations, considering raw data and monthly means for the different model components and higher-frequency (i.e. 6-hours or 1-hour) atmospheric variables. The "cmorization" procedure via the ece2cmor3 tool will be used to reduce the raw output volume in case of exceeding storage output. Therefore, the total storage required for the project is 74.2 TB.

Experiment name	Description	kSBU/ year	#YEARS	Year 1 kSBU	Year 2 kSBU
HIST	CMIP7 Historical simulation (1850-2020)	50	171	8550	
VLLO	Future scenario with low emission and limited overshoot (2021-2100)	50	80	4000	
VLHO	Future scenario with low emission and high overshoot (2021-2100)	50	80	4000	
MEDIUM	Future scenario with medium-range emissions (2021-2100)	50	80	4000	
LOW	Future scenario with low emissions (2021-2100)	50	80		4000
HIGH	Future scenario with high emissions (2021-2100)	50	80		4000
Testing resources configuration (ESM framework)			50	2500	
~5% buffer				1150	400
Total				24500	8400

Table 1: Experiment planned in this project, total years of simulation and details of the resources needed.

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