SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year ……2025……..……

Project Title: Investigations of climate change in post-CMIP6 EC-Earth3 simulations over the Mediterranean climate regions

Computer Project Account: ……SPITCHER……..……

Principal Investigator(s): ……Annalisa Cherchi ……

……..……

Affiliation: ……CNR-ISAC……..……

Name of ECMWF scientist(s) collaborating to the project (if applicable) ……n/a……..……

……..……

Start date of the project: ……01/01/2023……..……

Expected end date: ……31/12/2025……..……

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	8712800	8679872	11000000	492788
Data storage capacity	(Gbytes)	32700	18680	67000	29800

Summary of project objectives (10 lines max)

The main objective of this special project is to investigate the climate change response over the Mediterranean climate regions (MCRs), particularly sensitive and vulnerable to the process of subtropical drying and expansion, using the post-CMIP6 version of EC-Earth3 and considering newly available climate scenarios with the most recent climate policies.

Summary of problems encountered (10 lines max)

We have not encountered technical problems from July 2024 to present. Some changes are foreseen in the availability of scenarios to produce future simulations that might influence the plan for 2025 (see below more details on this aspect).

Summary of plans for the continuation of the project (10 lines max)

For 2025 the plan is to continue on the analysis of CMIP6 experiments to be used as benchmark for the evaluation of the historical and scenarios simulations produced. In terms of scenario simulations, the original plan was to produce two scenarios available within HE OptimESM project, one reflecting emission that realize the Paris agreement and the other failing because of delayed mitigation actions. In the meanwhile, new scenarios with more plausible range (ScenarioMIP project, 2024) have been developed. Following on this, either within OptimESM and within the international CMIP community it has been agreed to coordinate the use of these new scenarios that will likely be available in late 2025. In view of the timeline and objectives of this project the plan is then to consider, in case the scenarios will not be available on time to complete the simulations, to do idealized simulations to have different GWL to be considered in the analysis, or in alternative to perform sensitivity simulations even with off-line land surface models and/or AMIP-type simulations to test specific aspects of the hydrological properties of relevance for water-limited areas, like the Mediterranean climate regions.

List of publications/reports from the project with complete references

Cherchi A, Alessandri A, Lembo V, Gelsinari S, Possega M, Senigalliesi V, Renwick J (2025) Mediterranean climate regions in CMIP6 experiments: assessment of future changes and associated uncertainties. In preparation

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Since the 2024 progress report, we have been able to complete the historical simulation as we have been granted for the additional resources. The historical simulation covers the period 1850-2014, following the CMIP6 protocol (Eyring et al 2016) and it has been produced in emission-driven conditions. The simulation starts from initial conditions taken from long pre-industrial control simulation provided by SMHI in the framework of the HE OptimESM project. Fig 1 shows the timeseries (1850-2020) of the annual mean temperature at 2 m globally averaged. Some preliminary results are shown in the figures below and, where relevant, the outputs are compared with an historical simulation produced with a previous version of the EC-Earth3 model, specifically EC-Earth3-CC

(Doscher et al 2022) and with two available atmospheric reanalyses (ERA5, Hersbach et al 2020; NCEP, Kalnay et al, 1996). The temporal evolution is comparable with previous simulation but warmer, with the largest diversity between the two EC-Earth3 experiments during the first decades of the 20th century (Fig 1).

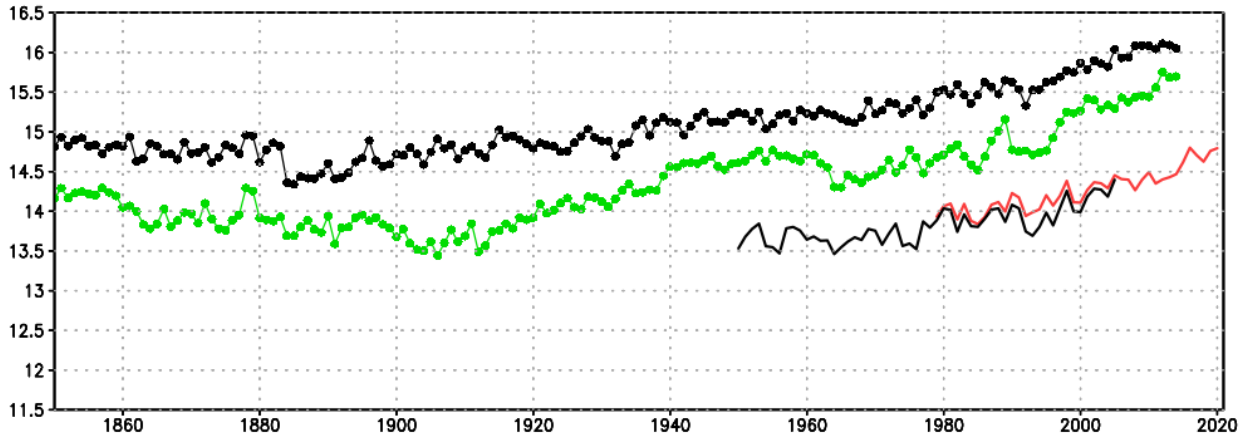

Fig. 1: Global mean surface temperature for the historical simulation with post-CMIP6 EC-Earth3 model (EC-Earth3-ESM-1, black line), for the similar simulation with previous version of EC-Earth3 (EC-Earth3-CC, green line), and for two atmospheric reanalyses (ERA5, red line; NCEP black solid line)

Focusing on the Euro-Mediterranean sector as one specific MCR of interest because of its projected changes as identified from CMIP6 simulations (Seager et al 2024), we see the timeseries of the temperature at 2 m average over the region (10°W-50°E; 35°-65°N) where the two EC-Earth3 experiments have larger differences during the first decades of the 20th century and then become highly comparable toward the end of the simulation (Fig 2).

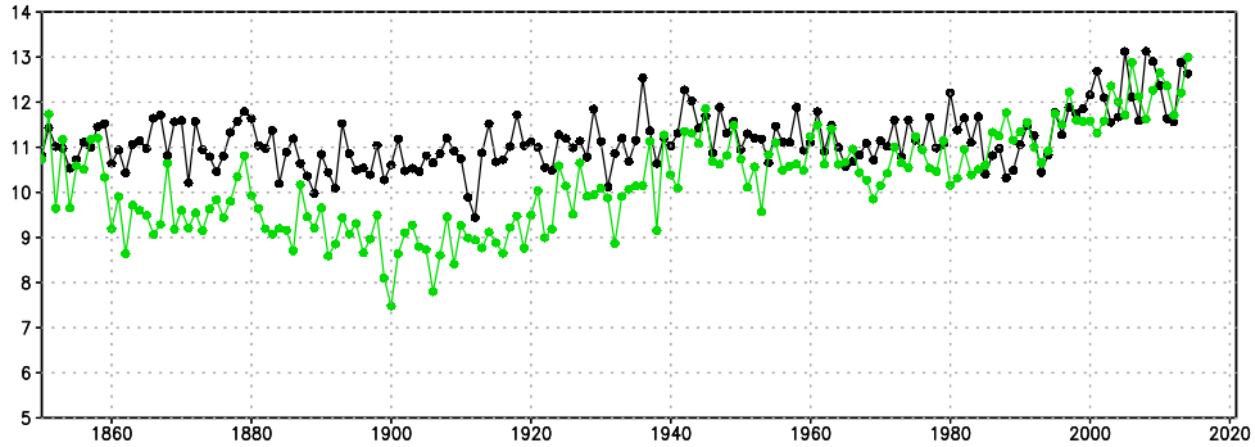

Fig. 2: Annual mean temperature at 2 m for the historical simulation with post-CMIP6 EC-Earth3 model (EC-Earth3-ESM-1, black line) and for the simulation with previous version of EC-Earth3 (EC-Earth3-CC, green line) averaged over the Euro-Mediterranean sector (10°W-50°E; 35°-65°N).

While waiting the availability of scenario simulation to verify the changes in future climate to be compared with the preliminary analysis started with CMIP6 simulations described in the previous report, we started an evaluation of the changes in MCR characteristics comparing the first part of the historical simulation with its end, i.e. comparing the 1860-1890 climatology with the 1984-2014 one. Figure 3 show the distribution of three types of climate (SNOW, MED and WARM TEMPERATE) based on the classification from Kottek et al 2006 but used also in more recent literature (i.e. Alessandri et al 2014) to compare the climatology at the beginning of the historical simulation (upper panel) and in the most recent period (lower panel). From this analysis we cannot appreciate large differences in the distribution of the MCRs over the Euro-Mediterranean region, as an example. This

imply that we need to consider future climates with largest changes represented by scenarios or idealized simulations. As described in the section above, the plan is to have available new future scenarios but in case of delays we could consider idealized simulations with adjustments to higher global warming level as an alternative. Alternatively, specific sensitivity experiments (either with off-line land or in AMIP-type configuration) to explore on the effects of specific hydrological properties relevant for these water-limited areas could be envisaged to complete the project.

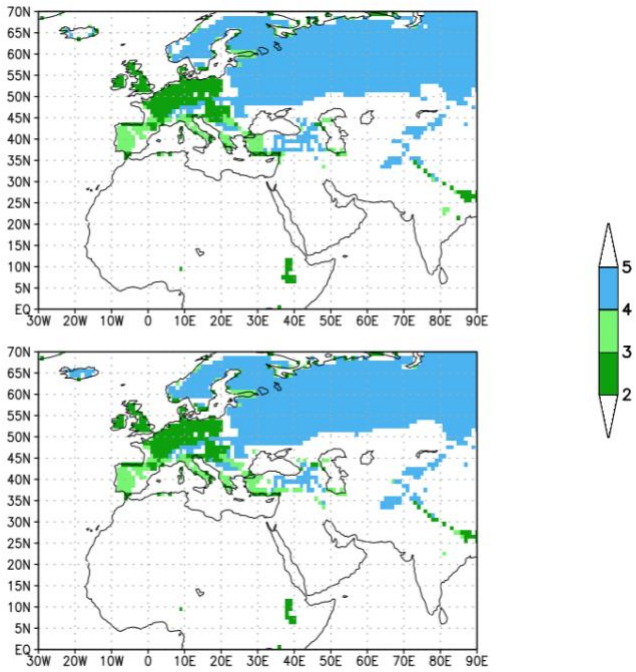

Fig. 3: Climate-type classification in the EC-Earth3-ESM-1 historical simulation. Upper panel show the climatology of the period 1860-1890, while the lower panel show the climatology of the period 1984-2014. Grid-points where there is no correspondence with an observed climatology are not shown. Blue stands for point characterized by SNOW type of climate, light green stands for MED type of climate and dark green stands for WARM TEMPERATE type of climate. The classification corresponds to the one used in Alessandri et al 2014.

References:

Alessandri et al (2014) Robust assessment of the expansion and retreat of Mediterranean climate in the 21st century. Sci Reports https://doi.org/10.1038/srep07211

Döscher, R., Acosta, M., Alessandri, A., Anthoni, P., Arsouze, T., Bergman, T., Bernardello, R., Boussetta, S., Caron, L.-P., Carver, G., Castrillo, M., Catalano, F., Cvijanovic, I., Davini, P., Dekker, E., Doblas-Reyes, F. J., Docquier, D., Echevarria, P., Fladrich, U., Fuentes-Franco, R., Gröger, M., v. Hardenberg, J., Hieronymus, J., Karami, M. P., Keskinen, J.-P., Koenigk, T., Makkonen, R., Massonnet, F., Ménégoz, M., Miller, P. A., Moreno-Chamarro, E., Nieradzik, L., van Noije, T., Nolan, P., O'Donnell, D., Ollinaho, P., van den Oord, G., Ortega, P., Prims, O. T., Ramos, A., Reerink, T., Rousset, C., Ruprich-Robert, Y., Le Sager, P., Schmith, T., Schrödner, R., Serva, F., Sicardi, V., Sloth Madsen, M., Smith, B., Tian, T., Tourigny, E., Uotila, P., Vancoppenolle, M., Wang, S., Wårlind, D., Willén, U., Wyser, K., Yang, S., Yepes-Arbós, X., and Zhang, Q.(2022) The EC-Earth3 Earth system model for the Coupled Model Intercomparison Project 6, Geosci. Model Dev., 15, 2973–3020, https://doi.org/10.5194/gmd-15-2973-2022

Eyring et al (2016) "Overview of the coupled model intercomparison project phase 6 (CMIP6) experimental design and organization" GMD https://doi.org/10.5194/gmd-9-1937-2016

Hersbach et al (2020) The ERA5 global reanalysis. Quart J Royal Meteor Soc https://doi.org/10.1002/qj.3803

Kalnay et al. (1996) The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470

Kottek et al (2006) World map of the Koppen-Geiger climate classification updated. Meteor Zeitsch https://doi.org/10.1127/0941-2948/2006/0130

ScenarioMIP project (2024): The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP7. ScenarioMIP SSC and task groups https://wcrp-cmip.org/wp-content/uploads/2024/04/24-04-15_ScenarioMIP-CMIP7-proposal_final.pdf

Seager R, Wu Y, Cherchi A, Simpson IR, Osborn TJ, Kushnir Y, Lukovic J, Liu H, Nakamura J (2024) Recent and near-term future changes in impacts-relevant seasonal hydroclimate in the world's Mediterranean climate regions. Int J Climatol 44(11) 3792-3820 https://doi.org/10.1002/joc.8551