Pseudo–Global Warming climate projections at convection-permitting resolution in the Macaronesia region

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In territories with complex orography such as the Macaronesian archipelagos of Madeira, Azores, Canary Islands, and Cape Verde, the spatial resolution of the Coupled Model Intercomparison Project Phase 6 (CMIP6) simulations is not sufficient to account for all the atmospheric phenomena that occur in such a complex microclimatic structure. This research presents a climatic dataset at a spatial resolution of 3x3 km² in all the Macaronesian archipelagos derived from high-resolution regional climate simulations performed with Weather Research and Forecasting (WRF) model, applying the pseudo-global warming (PGW) method. The dataset is focused on the following variables: temperature, precipitation, solar radiation, wind, and cloud cover. Meteorological stations (ECAD and METAR) and reanalysis ERA5 data were used for the validation of the model results in the recent past period (1982–2019). We worked with two periods for future projections (2030–2059 and 2070–2099) under two representative scenarios (SSP2.6 and SSP8.5). Annual and seasonal statistics and variability for each variable have been analyzed. The dataset aims to support regional climate adaptation strategies, contributing to the broader scientific understanding of climate in insular environments.

• Objectives

- High-resolution dataset will provide valuable insights into future climate projections across the Macaronesian archipelagos.
- This study will support future research, planning, and decision-making by providing detailed projections for multiple climate variables under different emissions scenarios.
- The dataset addresses a critical gap in regional-scale information for insular environments and its open availability will foster scientific collaboration and adaptation strategies.

• Introduction:

- In territories with complex topography, such as the Macaronesian archipelagos, global models do not resolve local climatology well.

- Coupled Model Intercomparison Project Phase 6 (**CMIP6**) model outputs provide climatological information with spatial resolutions lower 30x30 km², similar to the most of the Macaronesian island's size.

- This study, using the pseudo–global warming (**PGW**) method (Kimura and Kitoh, 2007) has been used to perform climate regionalization for the Macaronesian archipelagos using WRF.

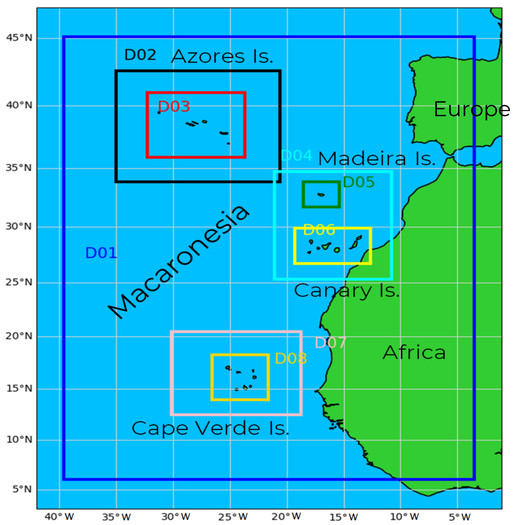

Figure1: Location of Macaronesian region and domains used in the WRF simulations. The coarse domain in blue (D01) 45x45 km² spatial resolution, -D02, D04 and D07- a nested domain of 15x15 km² resolution, and an innermost domain -D03, D05, D06 and D08. with a 3x3 km² resolution.

• Methodology

- The Weather Research and Forecasting (**WRF**) non-hydrostatic model has been used as a Regional Climate Model (RCM) to simulate atmospheric processes at high spatial resolutions. Downscaling to different nested domains was applied with spatial resolutions from 45x45 (D01), 15x15 (D02, D04 and D07), to 3x3 km² (others) (see **Fig 1**).

- From the 2-hourly and cumulative daily outputs of the model, values for the different variables are obtained:, maximum temperature (**TX**), mean temperature (**TG**), humidity (**HU**), mean wind speed (**FG**), precipitation (**RR**), and radiation (**QQ**) for seasonal, annual and total averages outputs were generated.

- Ground station data were used to validate the model in the recent past simulations driven by ERA-5 data (source: **ECAD** (https://www.ecad.eu/), **IPMA** (https://www.ipma.pt/pt/) , and **METAR** from Iowa State University (https://mesonet.agron.iastate.edu/request/download.phtml).

- Once the model was validated in the recent past, PGW was used to generate climate projections based on Shared Socioeconomic Pathways (**SSP**) scenarios 1 and 5 (SSP1-2.6 and SSP5-8.5) for 2030 to 2059 and 2070 to 2099 periods.

• Model Evaluation:

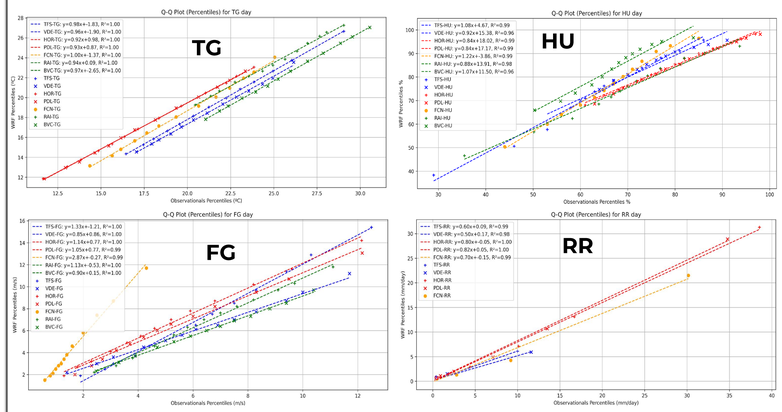

Figure2: QQplot (percentiles) daily averaged data WRF vs Ground Stations: Canary Island (ECAD-blue), Azores (IPMA-red), Madeira (IPMA-orange) and Cape Verde (METAR-green, no RR data) adding its fitting.

• Results and Discussions:

- Previously published studies, conducted only for the Canary Islands (Sosa et al., 2024), with lower resolutions (5x5 km) (Carrillo et al., 2022 and 2023) or other scenarios (RCP) (Expósito et al., 2015 and Pérez et al., 2014 and 2022), indicated an increasing trend in temperature and a decrease in humidity and precipitation (for all scenarios).

- The results obtained in this study reinforce these trends for the Canary Islands with higher resolutions and extend them for the rest of the Macaronesian archipelago in some cases or reveals minor signals in others.

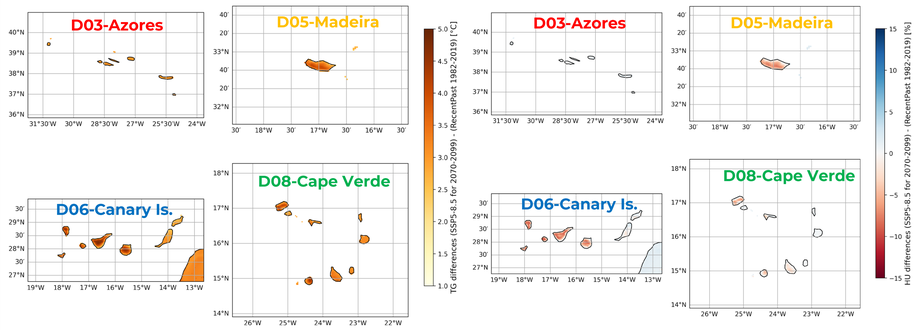

Figure3. left) Differences for the TG variable (°C) between the simulations for the future projections (SSP5-8.5 end of the century) and the Recent Past (1982-2019), and **right)** Humidity.

• Future Works

- This study will cover more than 10 main climatological variables in monthly, seasonal and annual values.
- Encourage collaboration with other centers to generate a broader set of simulations to reduce uncertainty in the projections.

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