Impacts of ocean-atmosphere coupling on precipitation in small islands: a case study of the Cape Verde archipelago

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Background and Objective

Small islands are recognized as being particularly at risk to climate change (Thomas et al., 2020). Therefore, enhancing tailored climate information for small islands is vital. Ocean-atmosphere interaction is expected to plays a major role in small islands climate (Weber et al., 2022). This study main objective is to evaluate the impact of a regionally atmosphere-ocean coupled model (ROM) to simulate historical precipitation over the Cabo Verde Archipelago.

Study Area

Cabo Verde archipelago climate is driven by a complex combination of large processes (including ocean-atmosphere interactions) and local topography (Fig.1). The local precipitation annual cycle, with a peak in September, is mainly driven by the ITCZ seasonal displacement and West African Monsoon. Given the limitation of global climate models to reproduce small islands rainfall features regional downscaling is required.

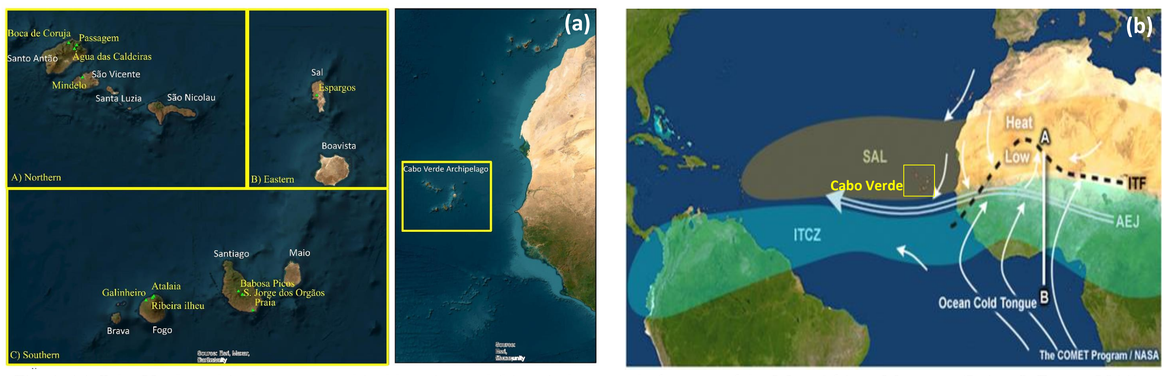

Fig. 1: (a) Cabo Verde archipelago geographical location and (b) main large-scale features of the West African Monsoon (Laing & Evans, 2011)

Data and Methods

We used the results from the simulations for Africa and adjacent oceans (Fig. 2) using the regionally-coupled model ROM and the atmospheric regional climate model REMO (Weber et al., 2022) from 1981 to 2010. Since REMO(uncoupled) is the atmospheric component of ROM(coupled), by comparing both the impact of atmosphere–ocean coupling is assessed. The lateral boundary forcing was prescribed using ERA-INTERIM reanalysis.

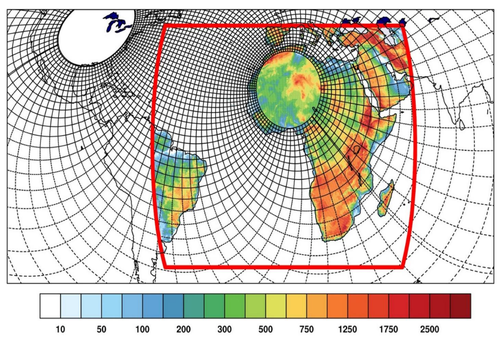

Fig 2: ROM and REMO domain and orography [m] for Africa continent and adjacent oceans (Weber et al., 2022)

The impact of the regional atmosphere–ocean coupling was evaluated using the added value (AV) metric (Dosio et al., 2015) :

$$AV = \frac{(REMO-REF)^2-(ROM-REF)^2}{Max\left((REMO-REF)^2,(ROM-REF)^2\right)}$$

To evaluate the coupled and the uncoupled simulations we used precipitation from ERA5 reanalysis and from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS).

West Africa: Spatial and seasonal mean precipitation

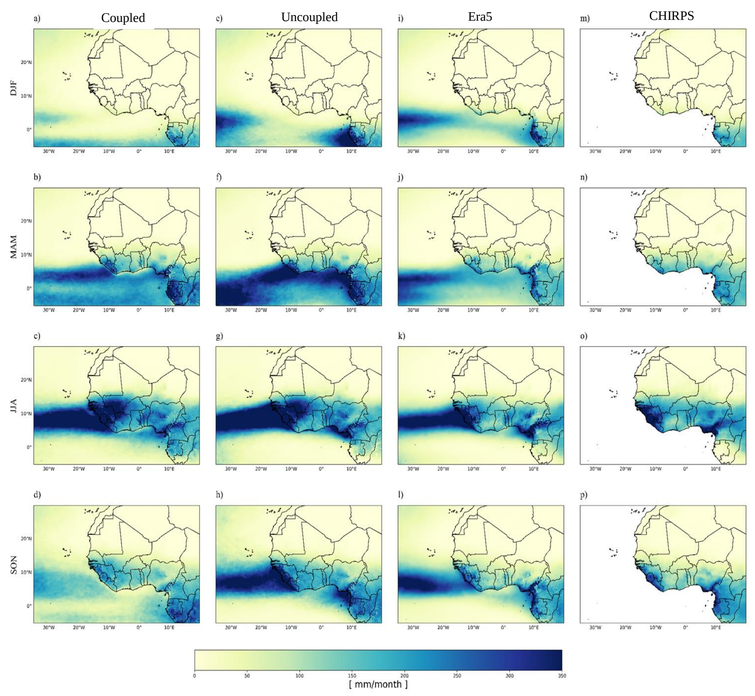

Fig. 3: Mean seasonal cycle of precipitation over West Africa (1981 -2010) as simulated by ROM(coupled) and REMO(uncoupled) and estimated by CHIRPS and ERA5.

- Both coupled and uncoupled reproduce the seasonal march of precipitation over West Africa
- The precipitation peak is observed during the boreal summer (JJA), consistent with ERA5 and CHIRPS.
- However, uncoupled simulate higher amount of rainfall compared to coupled.

Cabo Verde: Spatial and seasonal mean precipitation

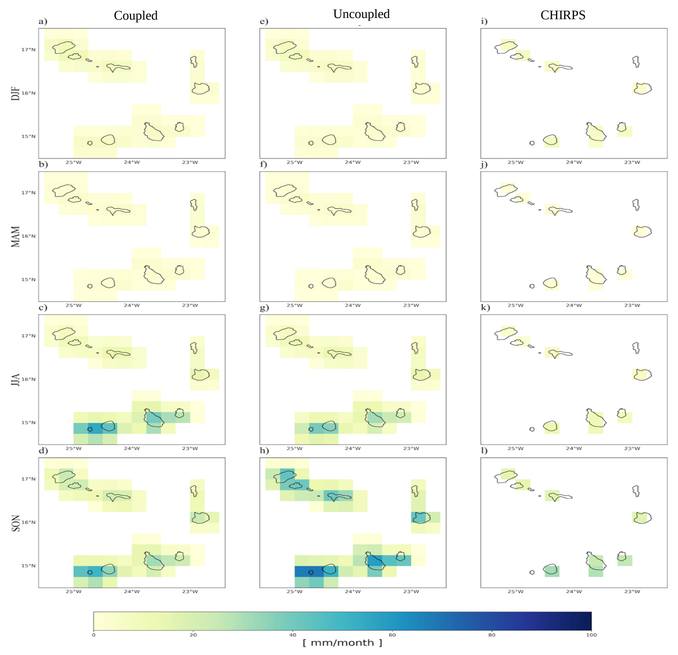

Fig. 4: Mean seasonal cycle of precipitation over Cabo Verde for ROM (coupled), REMO (uncoupled) and CHIRPS for the period from 1981 to 2010.

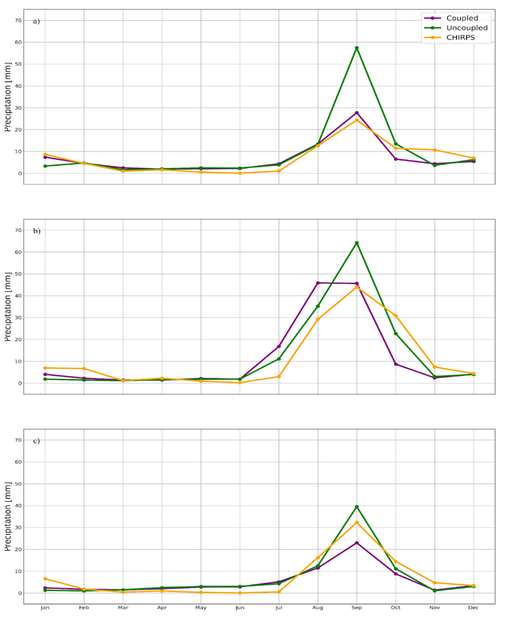

Fig. 5: Monthly mean variation of precipitation over Cabo Verde subregions as described in Fig. 1:: Northern Islands (a), Southern Islands (b), Eastern Islands (c)

- Precipitation over Cabo Verde increases from north to south due to topography and the largest influence of ITCZ on the southern islands. Both coupled and uncoupled consistently capture this spatial pattern.
- The uncoupled model overestimates monthly precipitation during the rainy season peak.
- In general, coupled model improves rainfall for all regions during the wet season, however, for southern islands it simulates higher (lower) rainfall at the beginning (end) of the season.

Added value of seasonal mean monthly precipitation

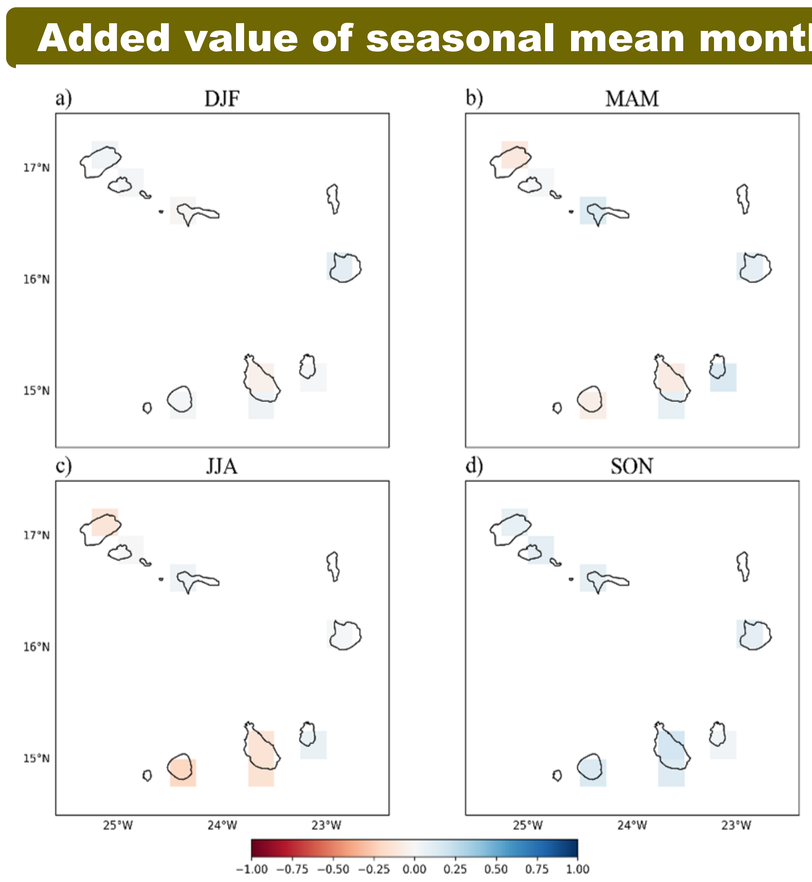

Fig. 6: Added values of seasonal mean precipitation over Cabo Verde Archipelago.

- Positive Added Value was found over all islands during SON, when the peak of the rainy season in Cabo Verde occur.
- This indicates that ROM tends to improve the rainfall over Cabo Verde during the most important period of the rainy season.

CONCLUSIONS

This study demonstrates that there is benefits of using a regional atmosphere-ocean coupling system to simulate precipitation over the Cabo Verde archipelago, which corroborate previous study (Weber et al., 2022) that regionally coupled atmosphere–ocean models can reduce the precipitation bias over the islands offshore the African continent.

REFERENCES

Janicot et al., (2011). Atmospheric Science Letters, 12(1), 58–66. https://doi.org/10.1002/asl.280

Laing, A., & Evans, J. L. (2011). The COMET Program, 8–10.

Thomas et al., (2020). Annual Review of Environment and Resources. https://doi.org/10.1146/annurev-environ-012320-083355

Weber et al., (2022). Climate Dynamics. https://doi.org/10.1007/s00382-022-06329-7

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