Circulation Types and precipitation patterns over Southern Central America in the CORDEX-CORE Experiment 1 RegCM4.7 Simulations

Fernán Sáenz S
Universidad de Costa Rica
fernan.saenzsoto@ucr.ac.cr

Abstract:

Precipitation estimates from climate model simulations are characterized by biases in both the spatial and the temporal structures. Bias adjustment methods can improve the mean spatial structures; however, biases in the temporal structures relate to biases in simulated atmospheric circulation [1]. In Southern Central America (SCA)[2], Circulation typing has been used to characterize the atmospheric circulation in sets of circulation types with dynamics reflecting the complex physical interactions across spatial and temporal scales that control precipitation mechanisms [3].

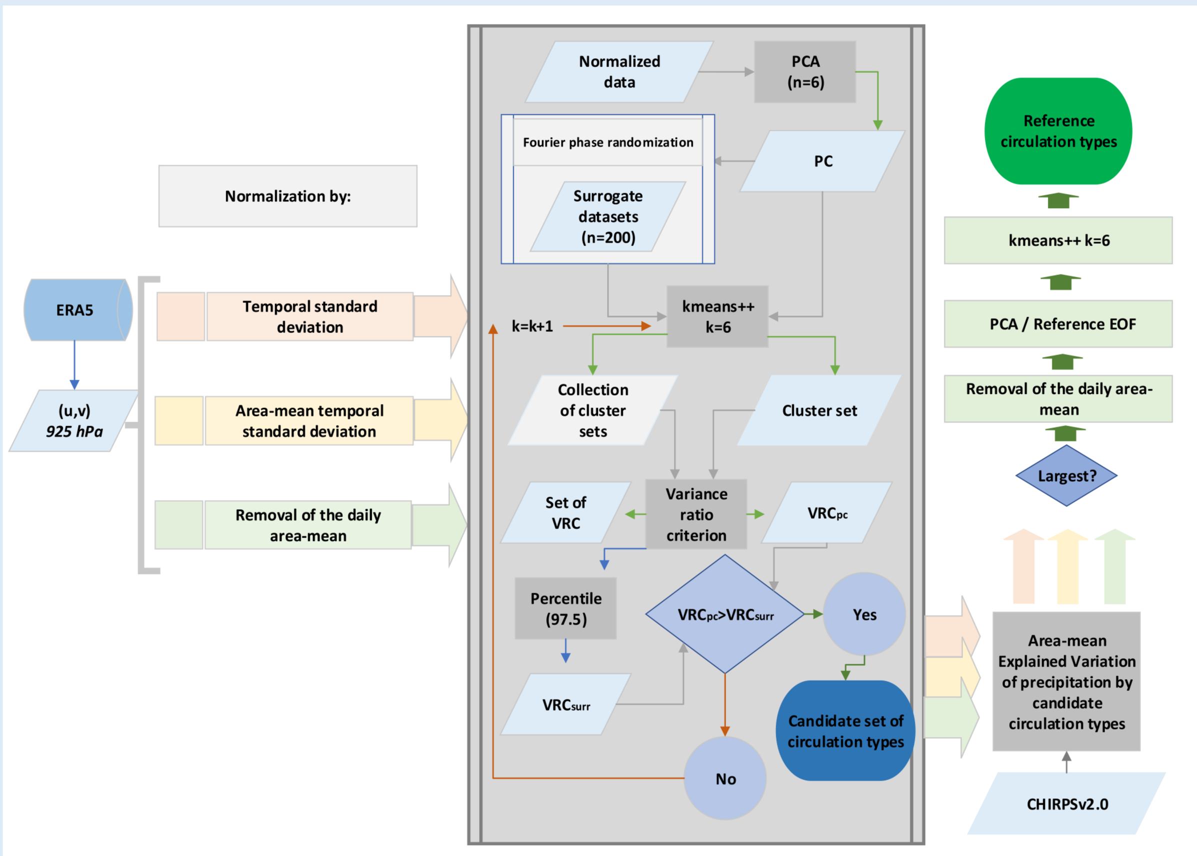
The objective of this work is to use Circulation Typing to establish relationships between the reference (ERA5 [4]) lower-tropospheric circulation and the precipitation estimates from CHIRPSv2.0 database [5], and project these relationships onto the simulated circulations from CORDEX-CORE Experiment 1 [6] and their respective boundary conditions from Coupled Model Intercomparison Project Phase 5 (CMIP5)[7], to produce circulation-adjusted precipitation estimates. This procedure enables a process-oriented diagnosis of simulated precipitation and its connection to simulated lower-tropospheric circulation.

Data:

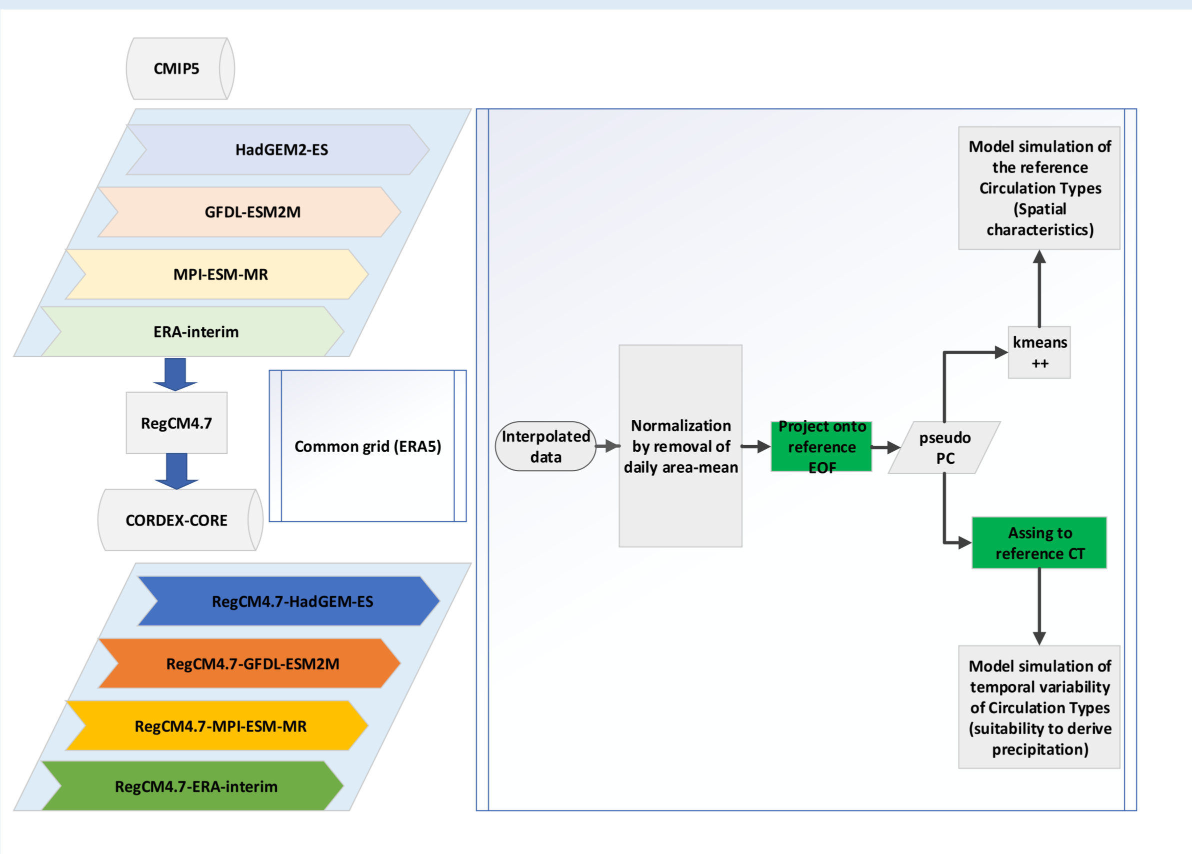
CORDEX-CORE Experiment 1 (CAM domain [6]) RegCM4.7 simulations (historical+rcp8.5) from 1979-2015 downloaded from the Earth System Grid Federation (ESGF; https://esgf-data.dkrz.de/search/cordex-dkrz/). Boundary conditions from CMIP5 [7] models: GFDL-ESM2M [8], MPI-ESM-MR [9] and HadGEM2-ES [10].
ERA5 [4] for 1979-2015, extracted from Copernicus Climate Change Service (C3S).
CHIRPS v2.0 (Climate Hazards group InfraRed Precipitation with Station data) [5].
GPCC Version 2018. Interpolated to CHIRPS grid using conservative remapping.

Methods:

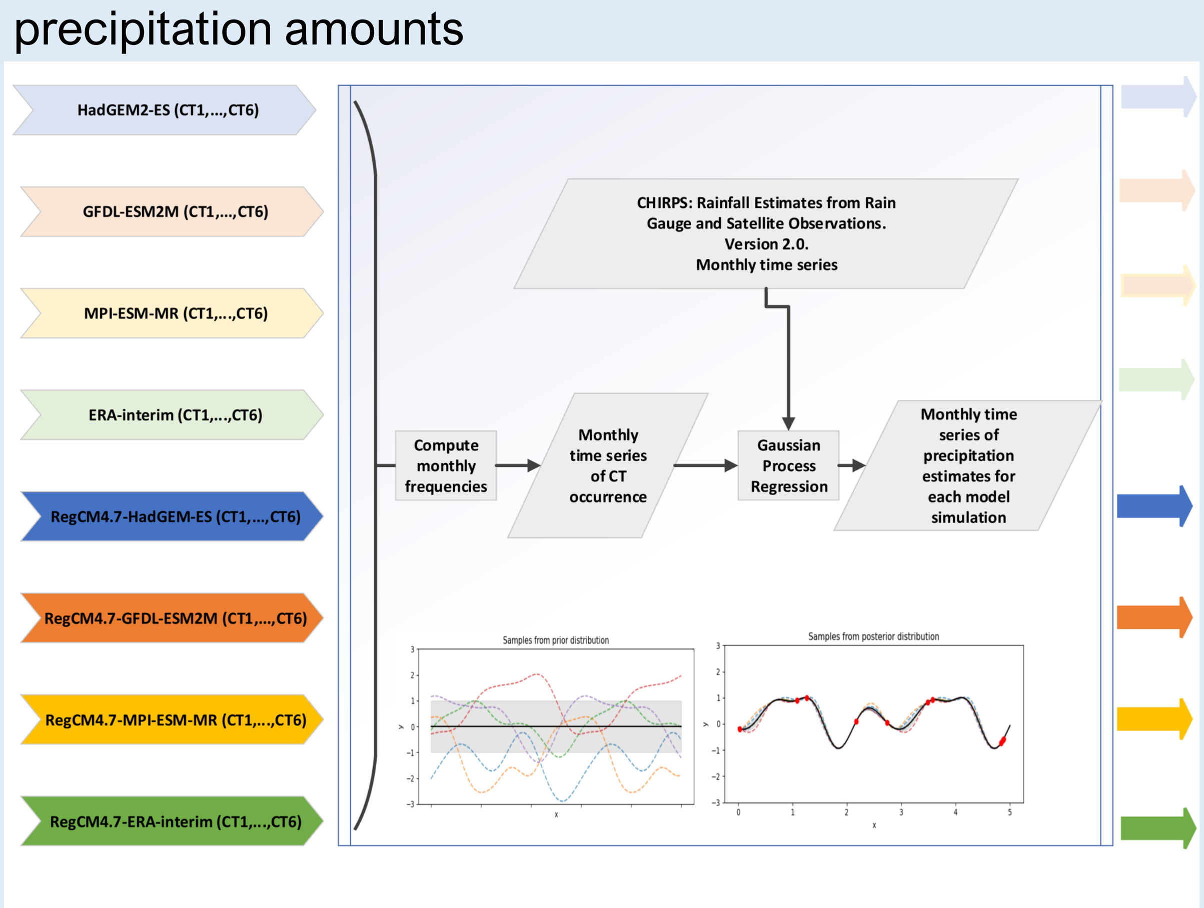
Step 1: Definition of the normalization method, reference EOFs and circulation types (CT) based upon maximization of the explanatory power CT have on regional precipitation (explained variation)[11].



Step 2: Projection of simulated wind fields onto reference EOFs, independent clustering and assignment to reference clusters



Step 3: Using Gaussian Process Regression (GPR) to relate monthly frequencies of CT occurrence to grid-point precipitation amounts



Results:

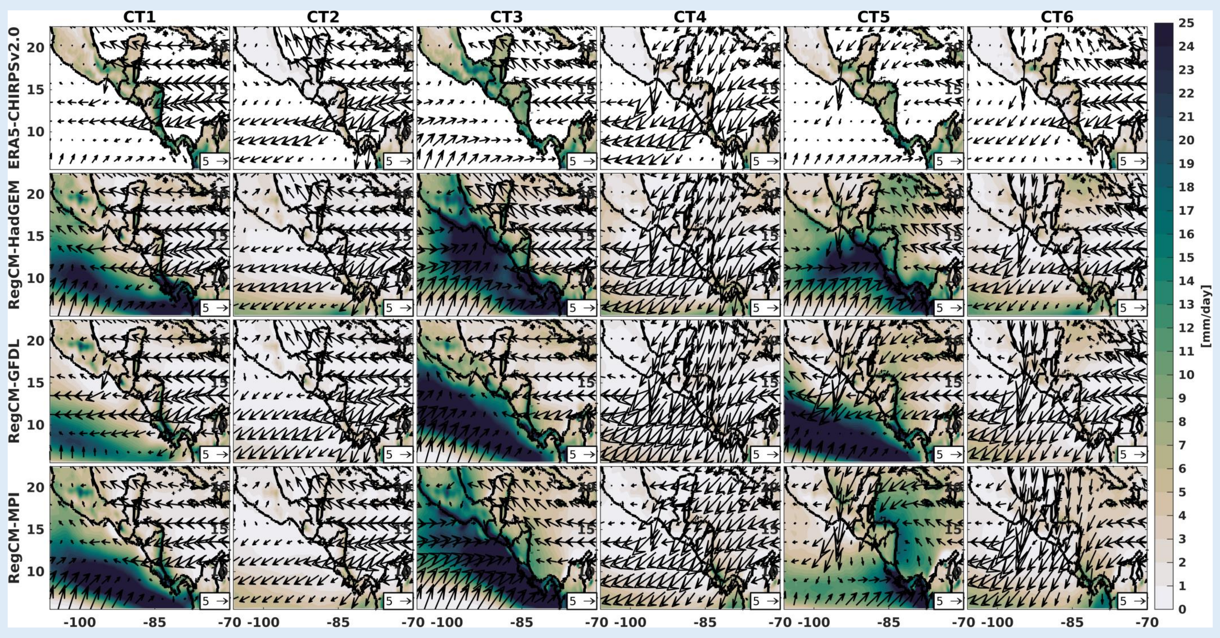


***Figure 1.** Composites of 925-hPa wind fields (vectors) and daily precipitation (shaded) for the reference CT and the RegCM4.7 simulated CT. CMIP5 models present indistinguishable spatial structures (not shown). Reference CT were ordered in decreasing frequency and simulated CT numbered minimizing root mean squared distances.*

Spatial patterns in Figure 1 come from independently clustered simulations. CORDEX-CORE simulations correctly represent the relevant features from the reference CT: CT characterized by drier conditions (2,4 and 6), feature northeasterly wind crossing the SCA isthmus extending across the domain, while CT characterized by wetter conditions (1,3 and 5) feature zones of confluence between the dominant easterlies and westerly flow. The multivariable integrated skill score [12] computed for CORDEX-CORE and CMIP5 suggest that HadGEM2-ES (both CMIP5 and downscaled) simulations better represent the spatial characteristics of CT.

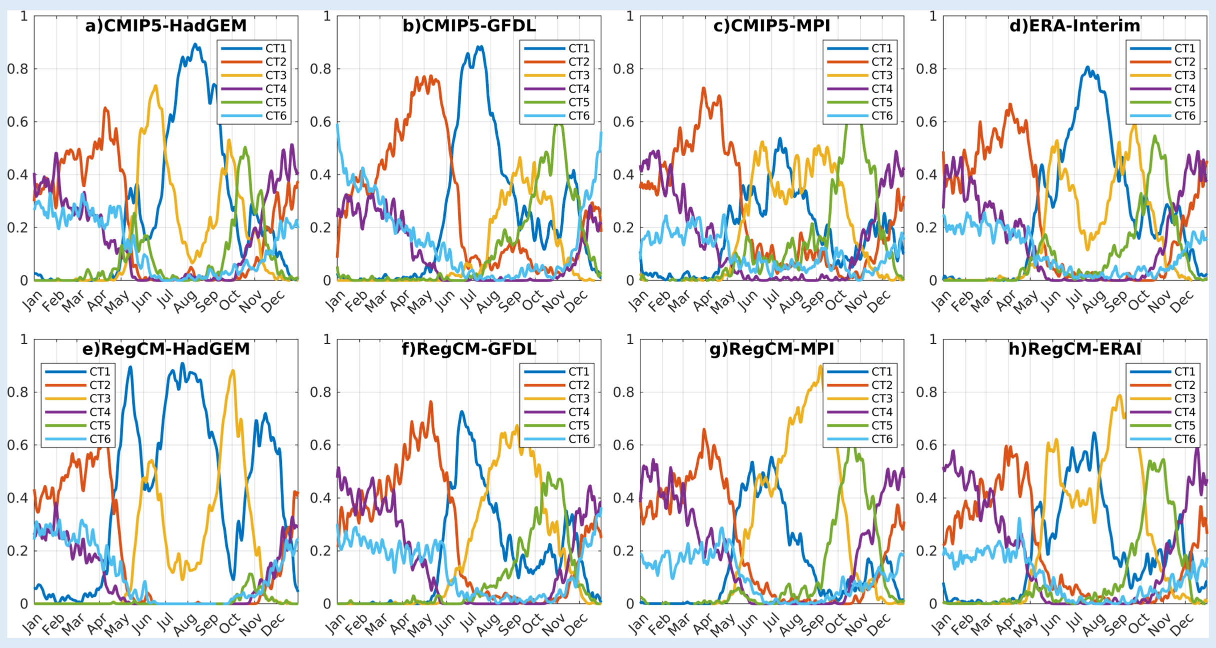


***Figure 2.** Climatology of occurrence probabilities for each CT. Each line represents the probabilities of occurrence of each CT on each Julian day. Reference are not shown because of their similarity with ERA-interim (panel d).*

In Figure 2, the climatological annual cycles correspond to CT drawn from the assignment of pseudo-PC from simulations to reference CT, however, their spatial structures are indistinguishable from those in Figure 1. This would be the procedure employed to compute CT for future projections.
The most challenging feature for simulations to represent are the temporal patterns of CT1 and CT3, which are associated with the midsummer drought (enhancement of the Caribbean low-level jet) and the bimodal annual cycles of precipitation in the Pacific slopes of SCA.

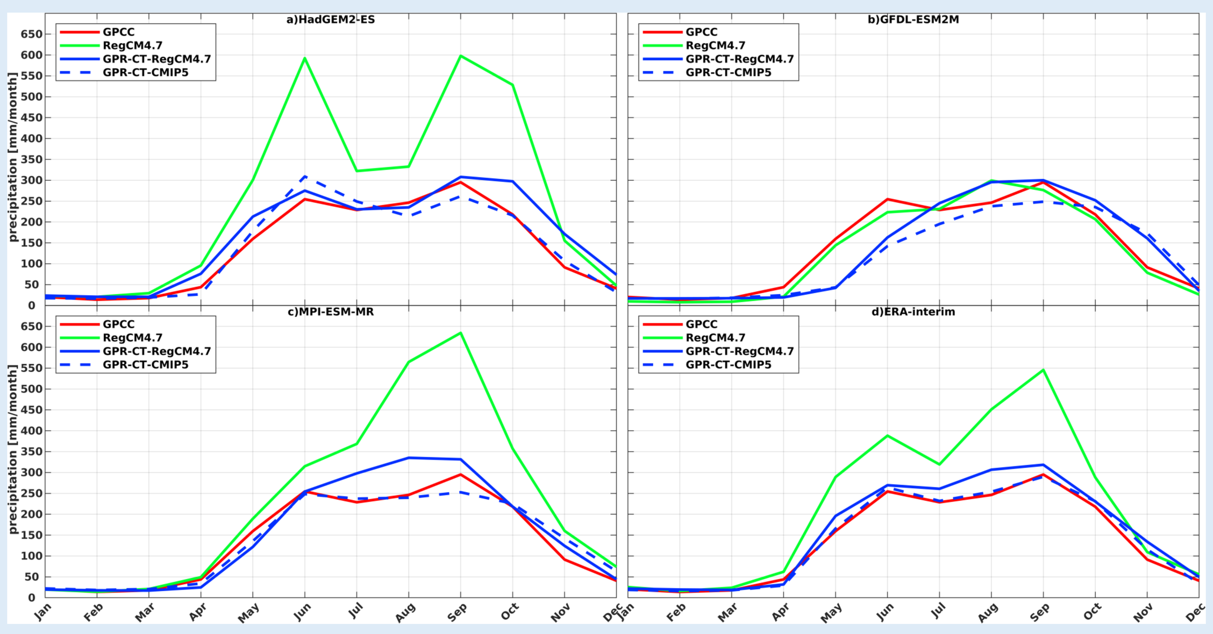


***Figure 3.** Area-mean annual cycle of precipitation over the pacific slope of SCA. GPCC (red), RegCM4.7 simulation (green), GPR-RegCM-CT (solid blue) and GPR-CMIP5-CT (dashed blue) for each model.*

Figure 3 shows that the monthly precipitation estimates generated from CT frequencies by GPR improve the climatological annual cycles in an area where the temporal variability of precipitation is connected to that of the atmospheric circulation. The performance is better for models that simulate the bimodality of the climatology of CT3 (both HadGEM2-ES and MPI (CMIP5). This results hold for smaller areas localized along the Pacific slopes. Furthermore, the procedure reduces the spatial bias for every RegCM4.7 simulation (not shown).

Concluding remarks:

All model simulations from CMIP5 and CORDEX-CORE successfully simulate the spatial structures associated with the CT, however, the temporal structures present a major challenge. Overall, the best performing simulation is HadGEM2-ES from CMIP5, followed by its downscaled simulation.
From the results here presented, plus other not shown (total frequencies, persistence, cluster quality, etc.), it is concluded that for using Circulation Typing to estimate precipitation, the downscaling step adds no value. However, more analysis is needed, specifically, doing a CT-conditional bias adjustment [13] of simulated precipitation from downscaled simulations could produce more accurate results and with daily resolution, which is the next step for this research.

References

[1] Addor N and coauthors, J. Geophys. Res. Atmos., 121(5), (2016).
[2]Iturbide M and coauthors. Earth System Science Data, 12(4), 2020.
[3] Sáenz F, Hidalgo G., Muñoz Á.G., Alfaro EJ., Amador J.A. and Vázquez-Aguirre JL. Int.J.Clim, 43(1), (2023).
[4] Hersbach H and coauthors. Q J R Meteorol Soc, 146 (730), (2020).
[5] Funk C and coauthors. Sci data, 2(1), (2015).
[6] Giorgi F and coauthors. Bull. Amer. Meteor. Soc., 103, (2022).
[7] Taylor KE, RJ Stouffer and GA Meehl. Bull. Amer. Meteor. Soc., 93, (2012)
[8] Dunne JP and coauthors. J. Climate, 25(19), (2012).
[9] Giorgetta MA and coauthors. J. Adv. Model. Earth Syst., 5(3). (2013)
[10]Jones CD and coauthors. GMD,4(3),(2011).
[11] Beck C, Philipp A and Streicher F.
[12] Zhang MZ, Xu Z, Han Y and Guo W. GMD, 14(5), (2021). Int J.Clim,36,(2013).
[13]Maraun D., Truhetz, H. and Schaffer, A. JGR Atmospheres. 126(6).(2021)