Hourly Temperature and Precipitation Time Series Characteristics in São Paulo with Urban Land Use Type of Convection-Permitting Model (CPM) outputs

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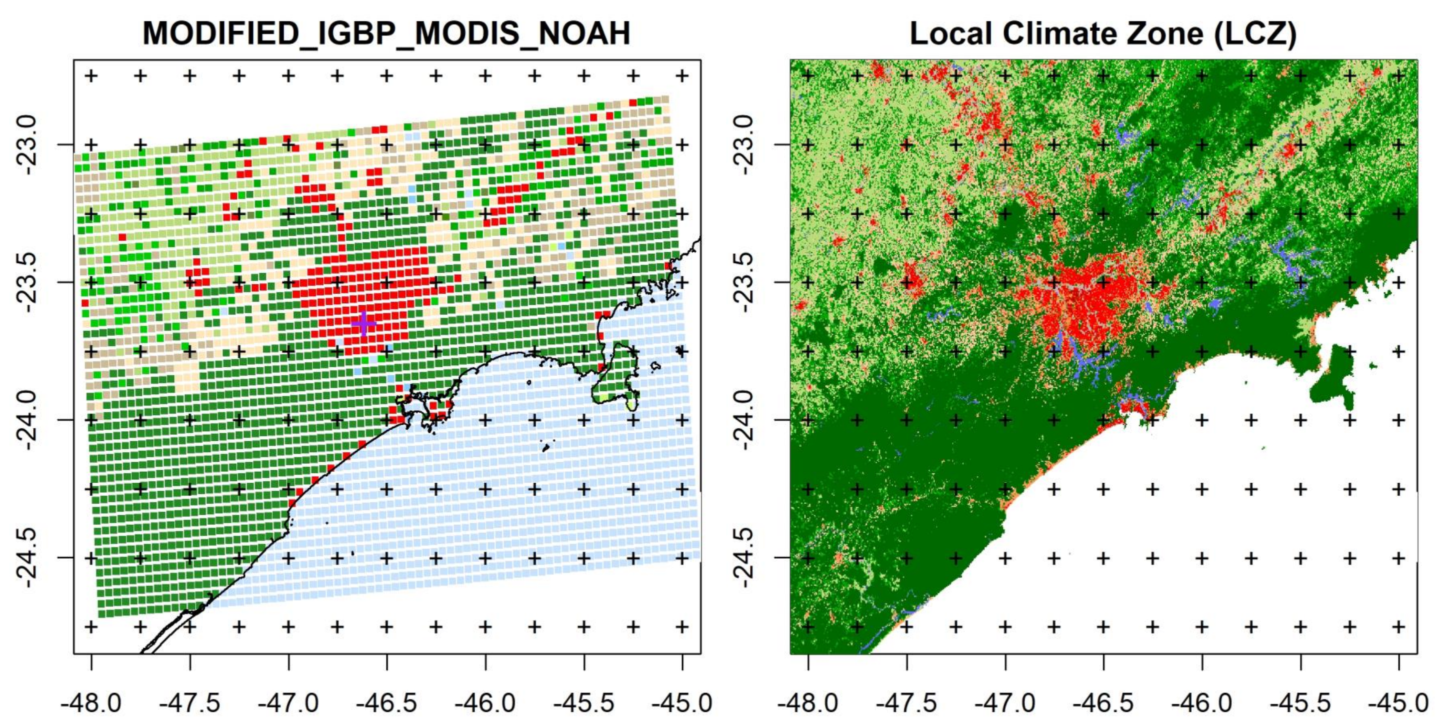
Introduction

Over São Paulo, the ERA5 data between 2000 and 2021 were dynamically downscaled by the South American Affinity Group (SAAG) using the Weather Research and Forecasting (WRF) model in a convection-permitting mode. Time series of temperature and precipitation were extracted from grid points of Urban & Built-up Lands (UBL) and Evergreen Broadleaf Forests (EBF).

Figure 1: Land use maps indicating urban areas (red)



Regional atmospheric drivers are hypothesised to control the joint distributions for multivariate precipitation and temperature from the CPM simulation. The cumulative Generalised Extreme Value (GEV) distribution function of a variable Y is

$$F(y;\mu,\sigma,\xi) = exp\left\{-\left[1+\xi\left(\frac{y-\mu}{\sigma}\right)\right]_+^{-1/\xi}\right\}, \qquad \sigma > 0$$

where the μ, σ and ξ are the location, scale and shape parameters. The subscript "+" means that $1+\xi\left(\frac{y-\mu}{\sigma}\right)$ should be positive. If $\xi < k^{-1}$, the kth moment about the mean for the GEV distribution exists. Provided the first and second moment exists, the mean and variance of the GEV distribution are expressed as $\mu + \sigma\left\{\frac{\Gamma(1-\xi)-1}{\xi}\right\}$ and $\sigma^2\frac{\{\Gamma(\xi)-\Gamma^2(1-\xi)\}}{\xi^2}$, respectively, where Γ is the gamma function.

Multivariate precipitation extremes are considered inside the domain, whereas $Y_{(1)},\dots,Y_{(r)}$ are the r largest observations from the grid in any particular year, such that $Y_{(1)} \geq \cdots \geq Y_{(r)}$.

For testing and modelling nonstationary signal from regional atmospheric drivers to precipitation extremes, the interannual variations of μ, σ and ξ are modelled by both the sea surface temperature indices from the Pacific and the Atlantic.

Results

Figure 2: Standardised Precipitation Index (SPI) time series and scatterplot with mean sea level (MSL) pressure

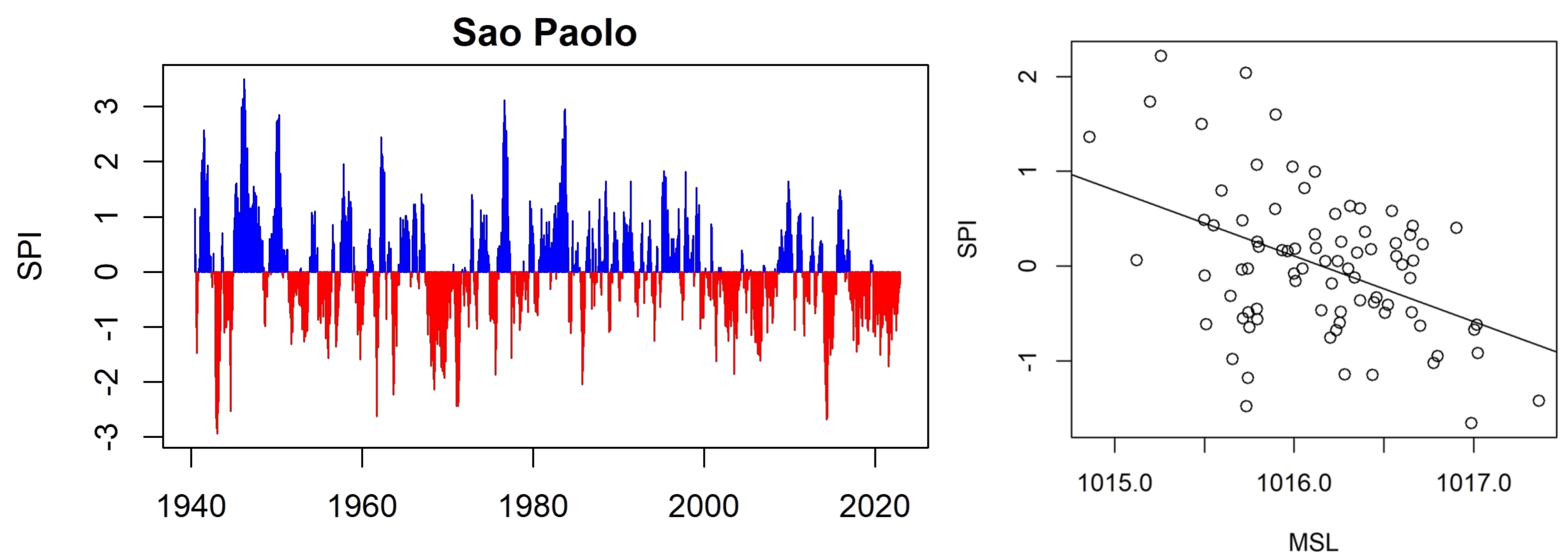
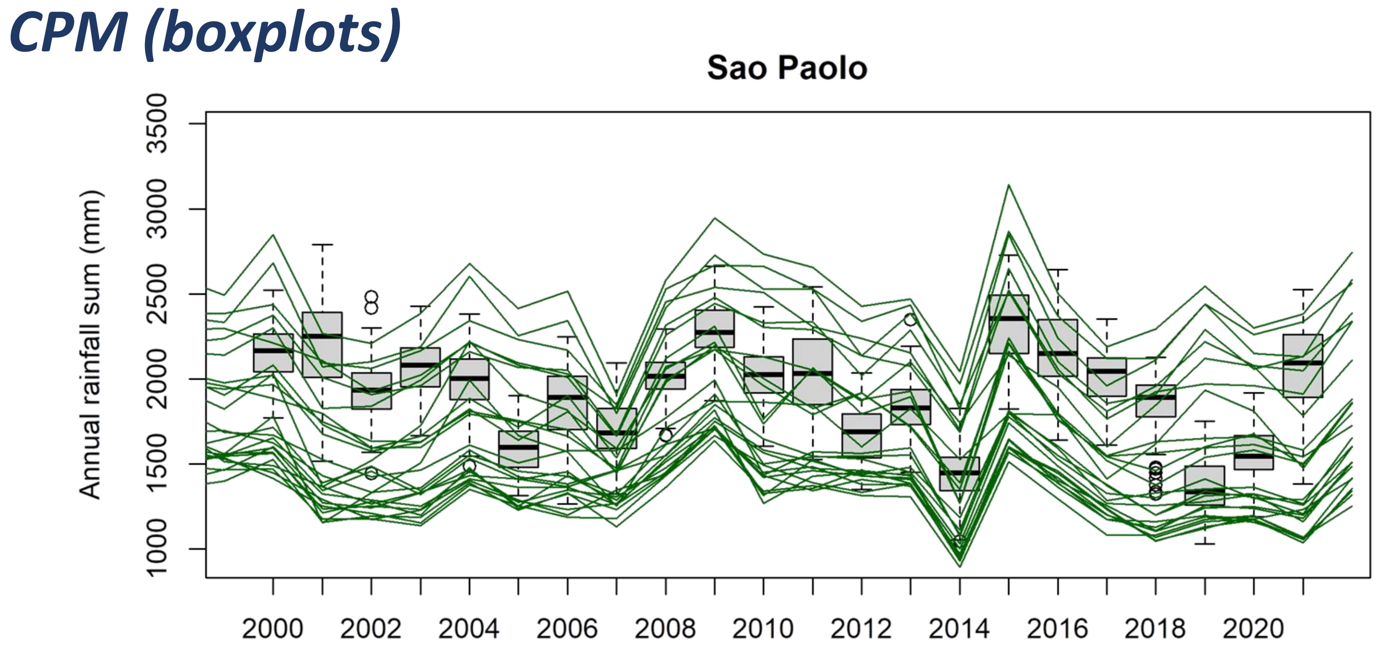


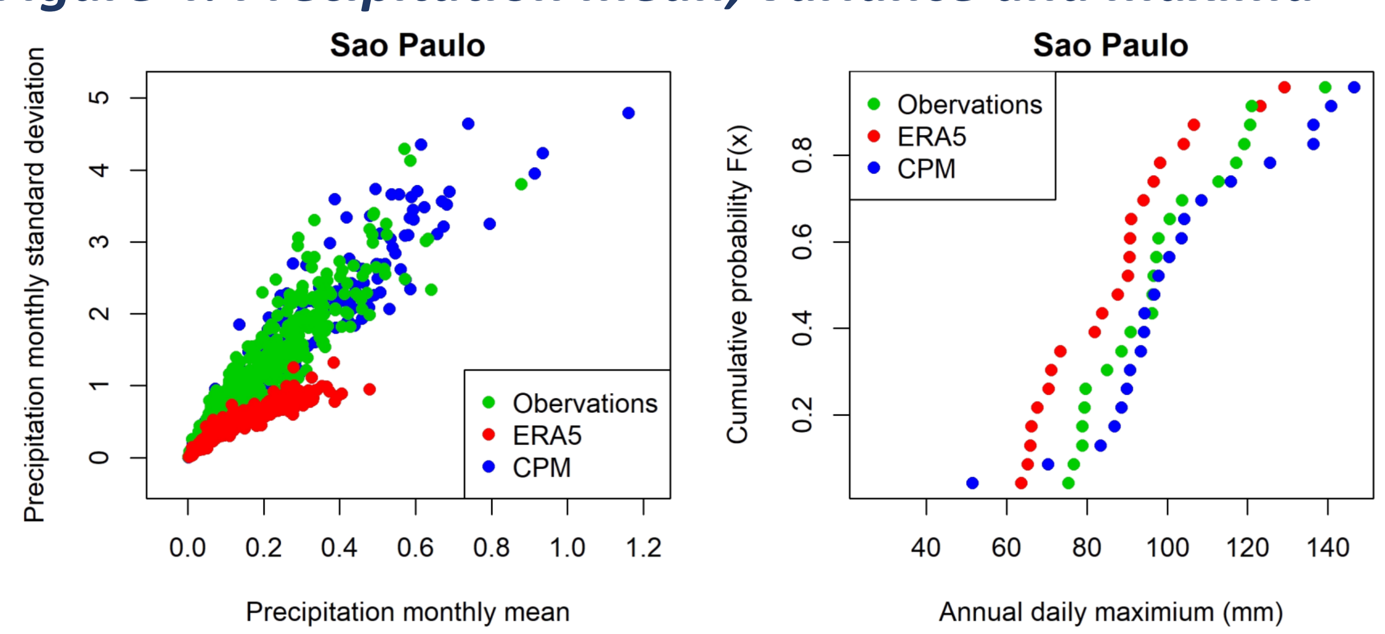
Figure 3: Rainfall annual sum from ERA5 (green lines) and CPM (boxplots)



The extracted hourly time series of temperature and precipitation were aggregated into daily, monthly, and annual time series for both maximum and mean values. These time series data were compared to the ERA5 reanalysis data and station observations.

The CPM outputs have higher and more intermittent precipitation than the ERA5 reanalysis. Additionally, the CPM outputs are more consistent with the station observations in terms of the tail of extreme precipitation distributions.

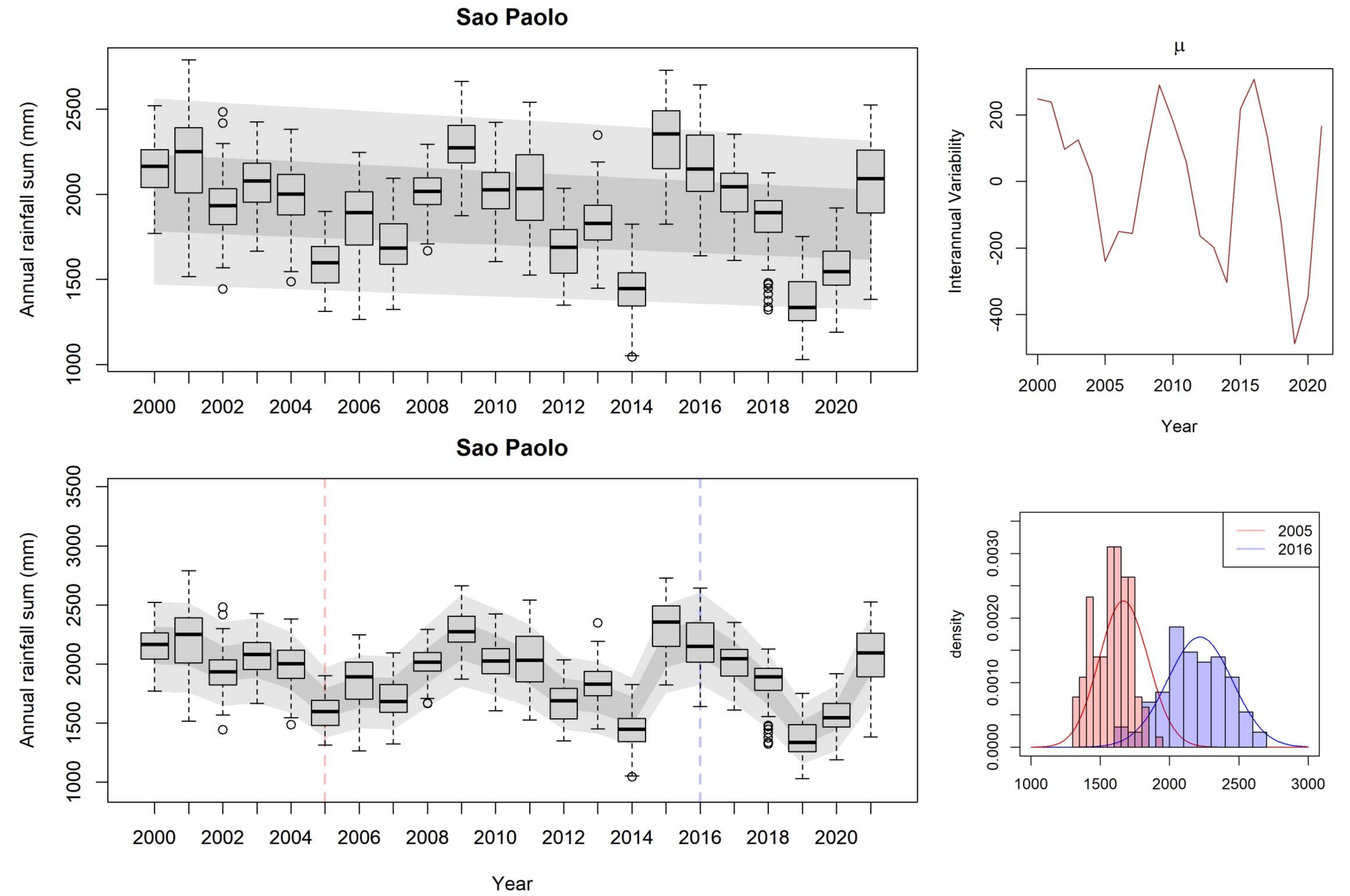
Figure 4: Precipitation mean, variance and maxima



The Atlantic Meridional Mode (AMM) has been significantly related to the interannual variation of the location parameter (μ) of the GEV distribution. The multifaceted El Niño–Southern Oscillation (ENSO) index is related to temperature and annual variations of precipitation. As the AMM signals are related to both temperature and precipitation, more precise capturing of the AMM signal could enable better modelling of extreme temperature and precipitation occurrences based on their joint distribution.

Discussion & Conclusions

Figure 5: Nonstationary models for annual rainfall sum based on linear time co-variates and nonlinear interannual variations



In this study, a nonstationary approach for temperature and precipitation is presented to analyse multiscale relationships of dynamically downscaled convection-permitting simulation. The outcomes of this research are anticipated to offer significant insights for regional planning in different parts of Brazil and other countries in South America simultaneously, particularly regarding the pursuit of Sustainable Development Goals 11 and 13, which pertain to climate action and reforestation in both urban and rural settings.

Acknowledgement: The corresponding author is the awardee of the Accelerator Programme (AP) 2022–24 in the University of the West of England (UWE), Bristol. This study is also supported by the seedcorn fund from the Centre for Water, Communities and Resilience (CWCR). The analysis method is developed from the Royal Scoeity International Exchanges 2022 scheme (IEC\NSFC\223132).