Construction of regionalized scenarios for simulations of the urban area and buildings: present and future climate in the RCP8.5 scenario

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Overview

We analyze numerical simulations in high horizontal resolution (~20 km) for the metropolitan region of Sao Paulo (MRSP) with the RegCM4, forced by different global models (HadGEM2-ES and MPI-ESM-MR) until the end of the century, in order to build typical meteorological years (TMYs).

The TMYs should be used for modeling the urban areas (ENVI-met) and buildings (TAS/EDSL/UK, EnergyPlus/DOE/USA), seeking to develop strategies for mitigation and adaptation to climate change in the MRSP. That will make possible to propose strategies to be incorporated into the urban regulatory framework of Sao Paulo, in order to contribute to the adaptation of cities and buildings to climate change and also with the goal of zero carbon emissions by 2050, as established in the PlanClima2021 - the Sao Paulo Climate Action Plan.

The MRSP is the largest metropolis in South America and very economically relevant, it has ~20 million inhabitants and produces approximately 18% of Brazil's Gross Domestic Product per capita. Studies show that the MRSP has been experiencing an increase in extreme precipitation events and the incidence of days with intense precipitation in recent decades, and, in 2014-2015 the region experienced one of its worst droughts. The consequences were water shortages and economic losses. In this context, we understand not only the relevance of MRSP and its vulnerability to global warming, but also the need for studies that help decision makers in the development of mitigation and adaptation strategies to climate change.

Data, methods and results

Three climate simulations were performed with the RegCM4: one reference run (forced by the ERA-Interim, RegERai) and two forced by the CMIP5 global models (HadGEM2-ES, RegHad; MPI-ESM-MR, RegMpi) for the RCP8.5 scenario. Each climate projection is evaluated in the historical period (1980-2014), near future (2026-2060) and distant future (2064-2098).

Setup/parameterization	
Horizontal grid resolution	25 km
Microphysics	SUBEX
Cumulus	Tiedke/KF
Planetary boundary layer	UW-PLB
Radiation	CCSM
Surface atmosphere	CLM 4.5
Surface layer	CLM 4.5

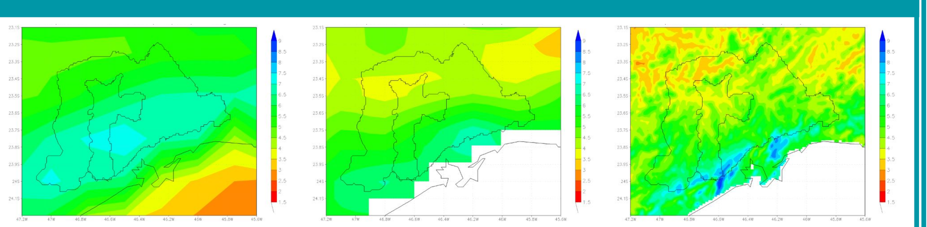

Figure 2: Average annual precipitation (mm/day) in present climate for RegErai, CHELSA and ERA5 (left, center, right).

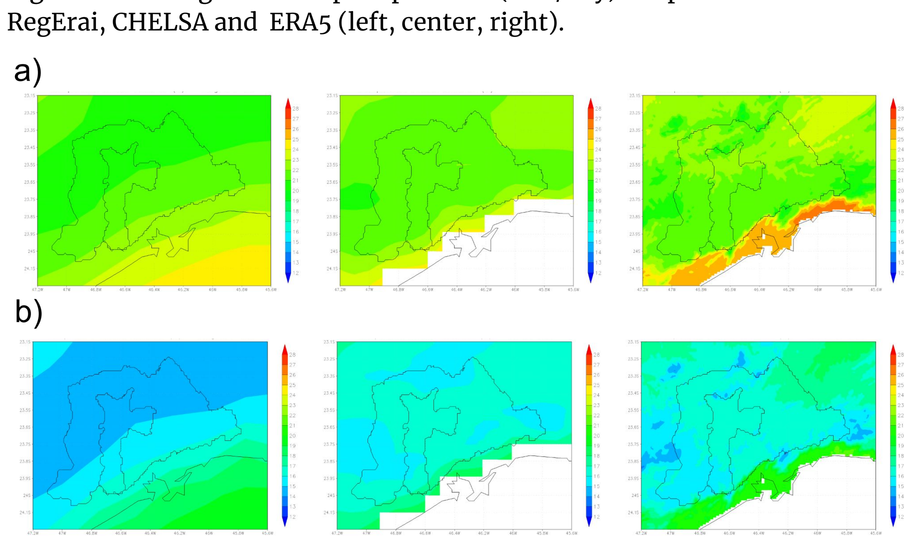

Figure 3: Seasonal mean temperature (°C) in present climate for: a) DJF and b) JJA for RegErai, CHELSA and ERA5 (left, center, right).

Present climate - Simulation validation

The evaluation of the present climate (1980-2014) compare the annual cycles of temperature (T) and precipitation (Pr) from RegErai with local observations (IAG and INMET weather stations) and reanalyses (ERA5 and CHELSA).

RegErai captured observed local climate factors, showing good performance in simulating the characteristics of the annual cycles (Figure 1.a,b) in the RMSP: maximum of Pr and T in the austral summer, and minimums in the winter, although there is an overestimation of Pr and an underestimation of T. RegMpi underestimates and RegHad overestimates Pr in relation to RegErai. Annual, seasonal and monthly climatologies were calculated for both variables.

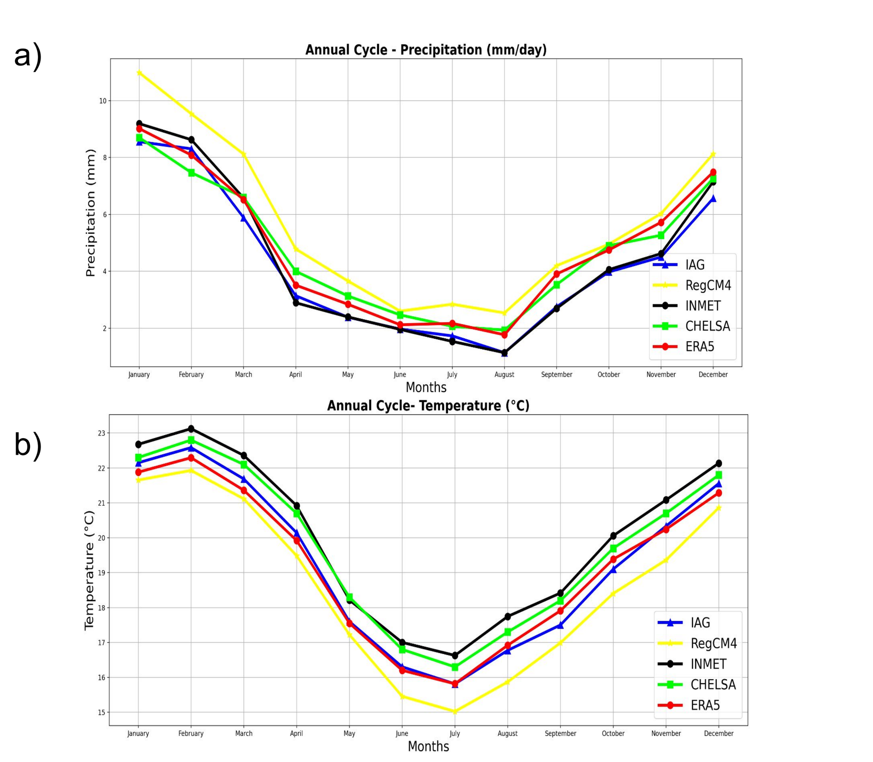

Figure 1: Annual cycle in the present climate of a) precipitation (mm/day) and b) temperature (°C) simulated by RegErai, and from CHELSA, ERA5, and IAG and INMET stations.

The spatial distribution of the annual mean Pr presents good correspondence between the simulation and the analysis (RegErai, ERA5 and CHELSA, Figure 2). Maximum rainfall is located in the southeastern region of MRSP, decreasing towards the northwest. Despite the overestimation, the maximums in the reanalysis are not reproduced by the RegErai.

Figure 3 shows the mean temperature (°C) for the austral summer and winter. The season with the best agreement between the RegErai and ERA5 is DJF, with the greatest bias occurs in JJA.

Future climate: projections for MRSP

Validation of the present climate makes the interpretation of future scenarios reliable. The annual precipitation and temperature cycles for the three simulations are shown in Figure 4.

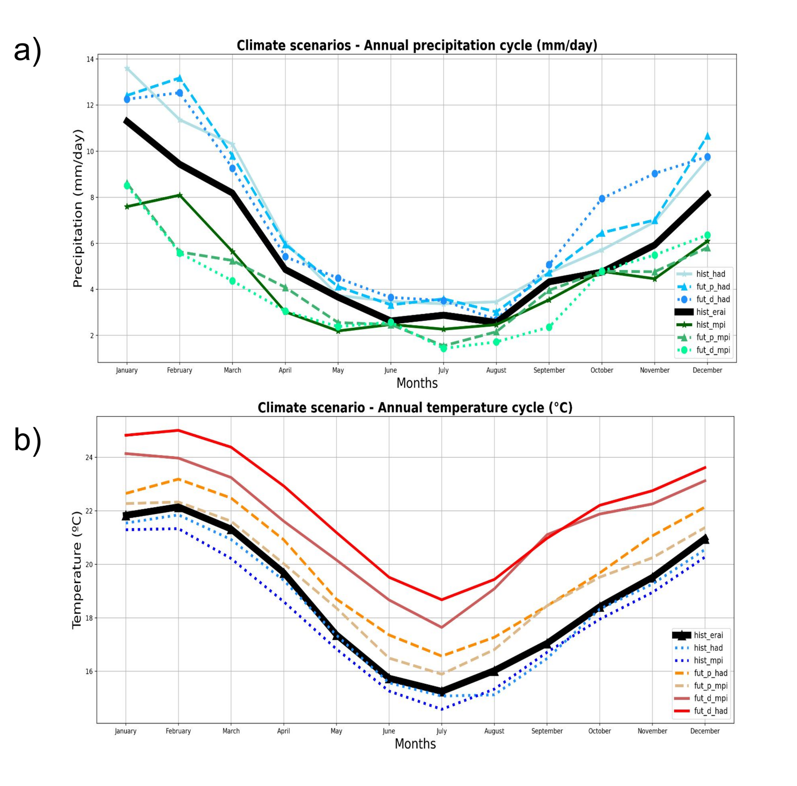

Figure 4: Annual cycle of a) precipitation (mm/day) and b) temperature (°C) simulated by RegErai, RegMpi, RegHad (present, near future and distant future climates).

For the future, there is not agreement in relation to precipitation projections. RegHad projects a drier climate between February-March and June-September, while RegMpi indicates an increase in Pr mainly in February and September-November. Both experiments project a progressive temperature increase in the near and distant futures, with RegHad indicating an increase of up to 4°C (Figure 5).

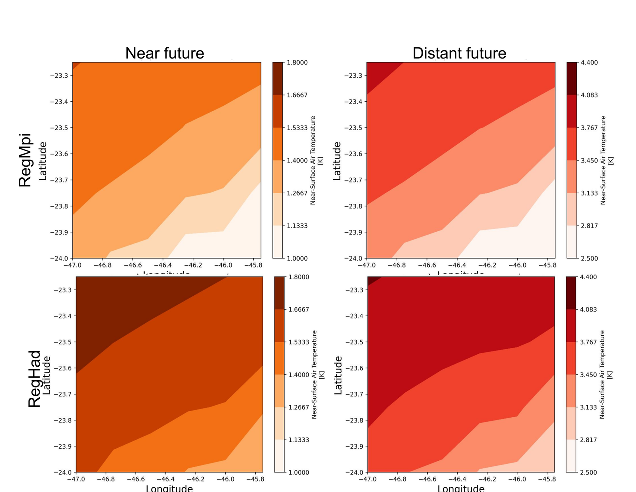

Figure 5: Temperature trends (°C) for the near and distant future climates (left and right, respectively) projected by RegMpi (top) and Reghad (bottom).

Typical meteorological year

Classic methods of building TMY individually evaluate each month of a period and, through statistics, select the most representative month to compose the TMY (Sandia method), while modern methods filter data to approximate them to climatology. Here we propose a new method that considers hourly values of each day of the year are grouped and hourly averages are calculated.

The difference between the TMY elaborated from Sandia method and the new method can be seen in Figure 6, for air temperature. The main difference refers to the extreme values, which are smoothed by the hourly climatology method, since it involves average values.

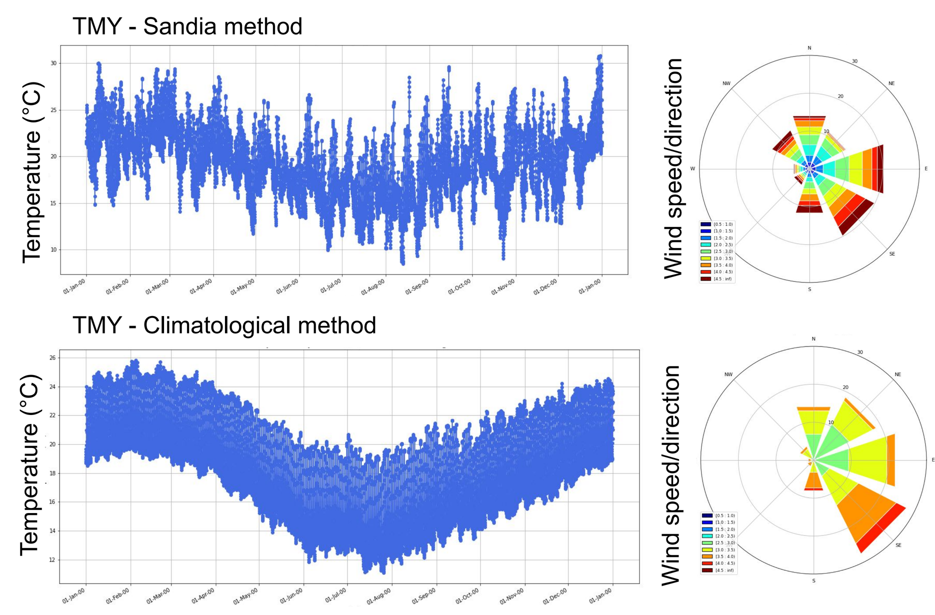

Figure 6: Comparison between the TMY built from the Sandia (top) and climatological (bottom) methods for temperature and wind (right).

Bias correction

The annual bias of each simulation varies, as well as its distribution over the year (Fig.7). The annual cycle of T, for example, has a negative bias throughout the year but, although the annual bias of RegErai is -0.6°C and RegMpi -1.2°C, they are distributed differently throughout the year (Fig.7).

Thus, a technique was developed to correct the simulations considering the average monthly diurnal cycle of variables. In this way, the biases (difference between the simulated and observed average diurnal cycles) are removed from the simulations on the hourly scale for each TMY day.

The impact of diurnal cycle correction in RegErai for the typical year of T can be seen in Fig.7. We note a shift of the annual cycle curve towards higher temperature values.

The bias correction directly impacts the TMY, as seen in the density curves of variables such as temperature, relative humidity, wind direction and speed (Fig.8). It is observed that the density curves of the TMY years simulated are close to the reference (IAG-USP) after correction.

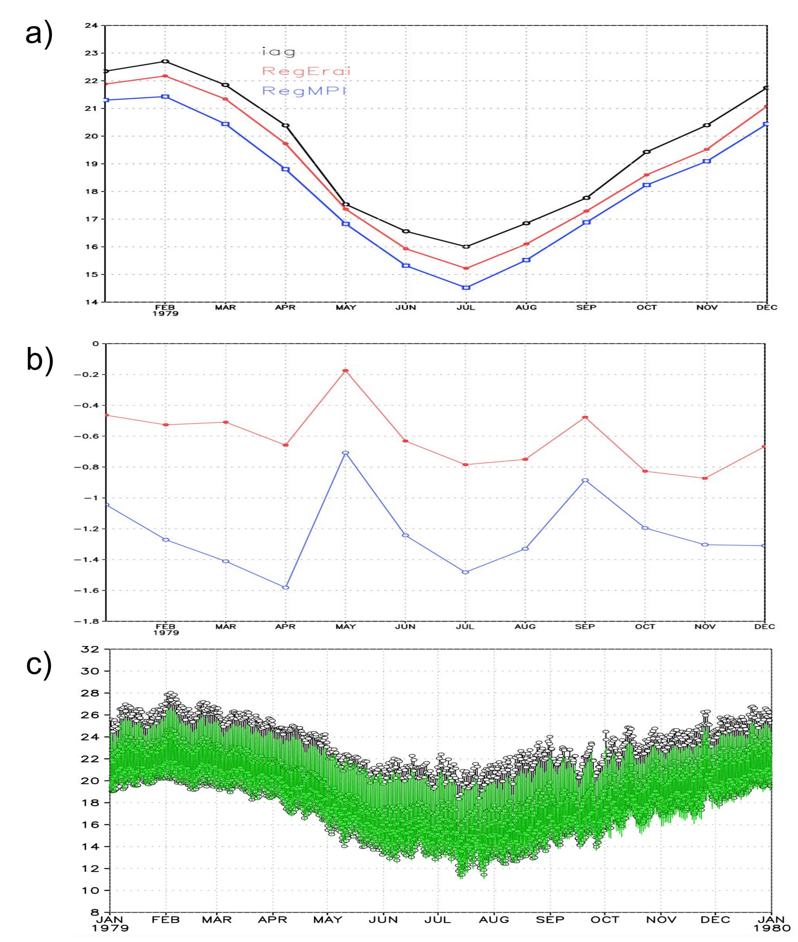

Figure 7: For the present climate: a) annual T cycle for the IAG-USP station (black), RegErai (red) and RegMpi (blue line); b) Monthly bias between RegErai and IAG-USP (red) and between RegMpi and IAG-USP station (blue), c) typical year of T before (green) and after (black) bias correction.

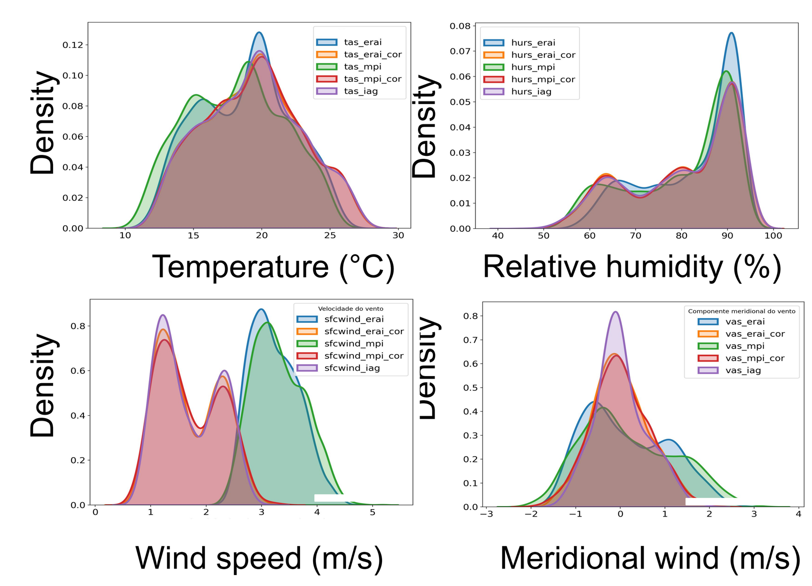

Figure 8: Frequency distribution of the TMY year, before and after (subindice cor) bias correction, for a) temperature, b) relative humidity, c) wind speed, d) meridional wind.

Conclusion

The RegErai reference simulation was validated for the current climate (1980-2014) through comparisons of T and Pr series with observations at meteorological stations and reanalysis. It shows good performance in simulating the characteristics of the MRSP climate, providing confidence in the interpretation of future scenarios.

For distant future projections RegHad and RegMpi disagree: RegHad projects drier climate most the year, while predominates rainfall increases. Both experiments project a progressive increase in T in the near and distant futures, with RegHad being the more alarming, with an increase of more than 4°C by the end of the century.

Modern TMY construction methods filter input data by bringing them closer to the climatology. Therefore we propose an hourly climatology method to construct the TMY.

The annual bias of each simulation varies, as well as its distribution over the day and year. Thus, a technique was developed to correct the simulations considering the observed average monthly diurnal cycle c. In this way, the biases are removed from the simulations on the hourly scale for each TMY day. The bias correction has a direct impact on the TMY, providing density curves for variables (such as T, relative humidity, wind direction and speed) much closer to those observed than before the correction.

Acknowledgements

The authors would like to thank the University of Sao Paulo and the National Council for Scientific and Technological Development (CNPq), for the financial support for the development of this research. The first author is especially grateful to the Abdus Salam International Center for Theoretical Physics (ICTP), for funding her trip to the International Conference on Regional Climate ICRC-CORDEX 2023.

WCRP CORDEX 25-29 SEPTEMBER 2023 TRIESTE, ITALY
ICRC-CORDEX 2023
International Conference On Regional Climate
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