



Assessment of a RegCM5 Convection-Permitting Simulation in a Complex Region of Southeast Brazil

*Michelle Simões Reboita
Rosmeri Porfírio da Rocha*

October, 2023



Introduction

Southeastern of Southeast Brazil is a complex region in terms of:

topography: a lot of hills such as Serra do Mar and Mantiqueira

land-sea interactions: it is bordered by the South Atlantic Ocean

land-use: forest, crops and urbanization

population: the 1st and 4th biggest metropolitan areas of South America: São Paulo and Rio de Janeiro

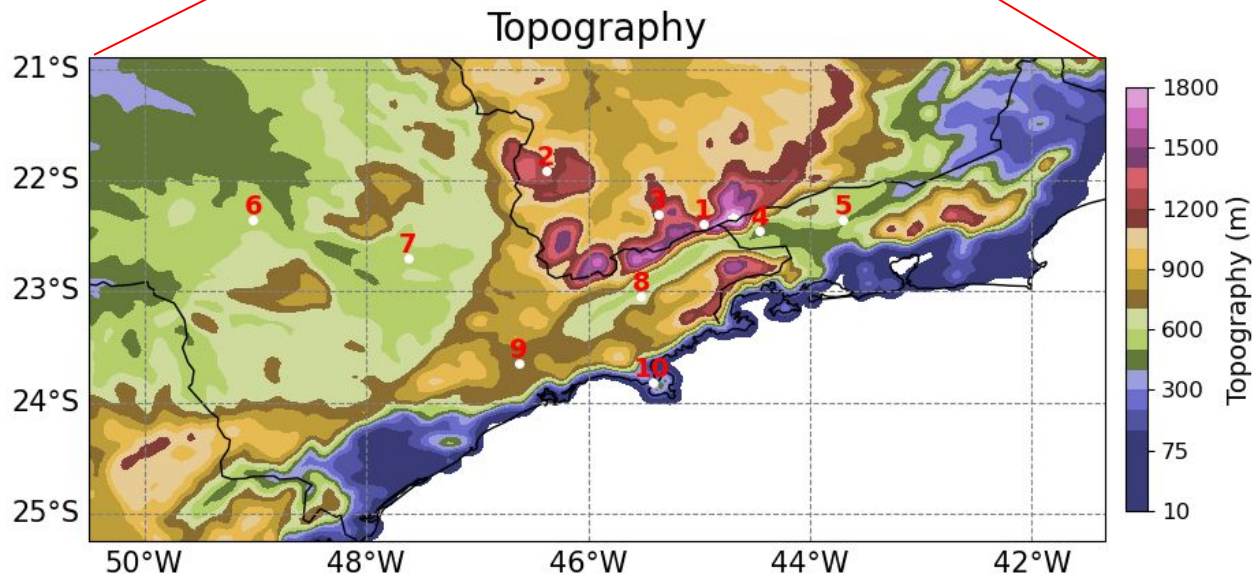


Objective

To assess a RegCM5 convection-permitting (CP) simulation over part of Southeastern Brazil in terms of:

- interannual variability
- annual cycle
- diurnal cycle
- extreme values

for precipitation (pr), 2-m air temperature (tas) and 10-m wind intensity (sfcWind).



Methodology

Model Configuration

Horizontal resolution: 4 km

Grid points: 250 x 140 x 41

Period: Dec 2009 - Dec 2020

Non-Hydrostatic: MOLOCH (Giorgi et al., 2023)

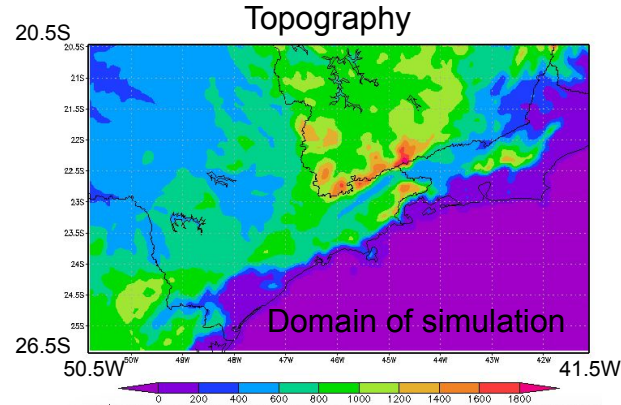
Microphysics: default - Noto scheme
(Nogherotto et al., 2016)

Land surface: CLM4.5 (urban model is off)
(Oleson et al., 2013)

PBL: Holtslag (1990)

Radiation: RRTM (Mlawer, 1997)

Ocean Fluxes: Zeng et al. (1998)



INITIAL & BOUNDARY CONDITIONS

atmosphere: ERA5

SST: ERA5



topo: GTOPO30

landuse: updated landuse from MODIS 2018
(urban areas are specified with an appropriated
code for RegCM5)
Source: Silva et al. (2023 - IJOC)

Processing time: 2 h 26 min per month

Methodology

Reference Datasets

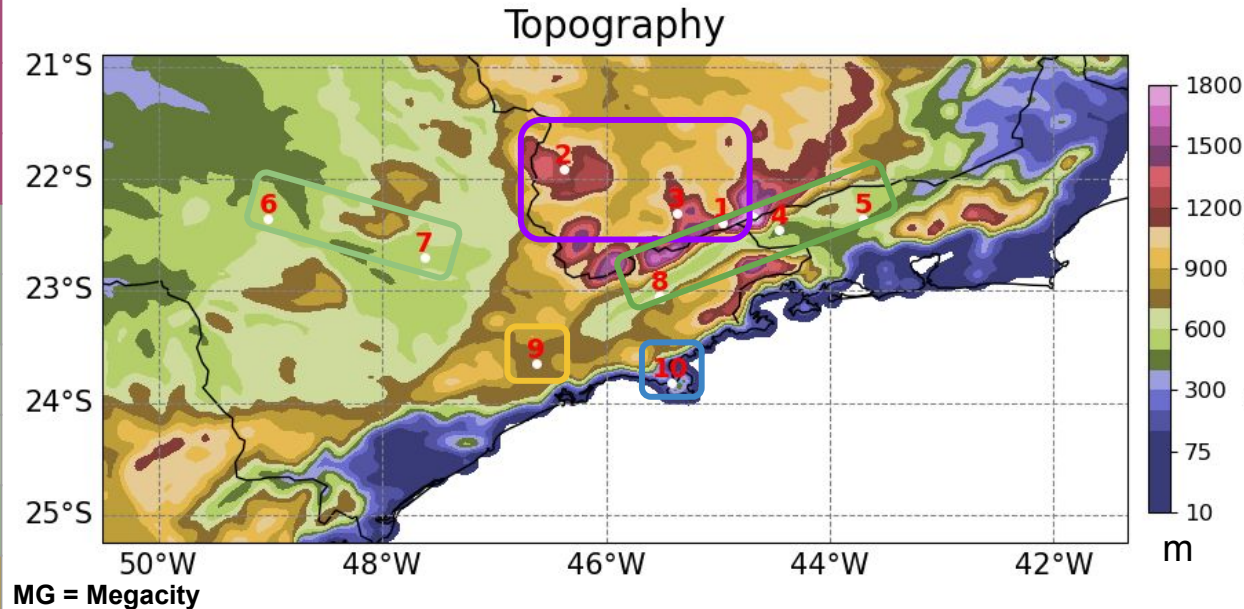
Dataset	Horizontal Resolution	Frequency	Variable	Additional Information	Links
GloH2O's Multi-Source Weather (MSWX)	1 x 1 km	3 h, daily and monthly <i>Only monthly data were downloaded → Connection Problems</i>	pr, sfcWind, tas	Combination of CHELSA and ERA5. Data from 1979 to present.	https://www.gloh2o.org/mswx/
Meteorological Brazilian Institute (INMET)	<i>in-situ</i> stations	hourly	pr, sfcWind, tas	Automatic stations Different dates of installation.	https://bdmep.inmet.gov.br/
IAG/USP	<i>in-situ</i> station	hourly	pr		http://www.estacao.iag.usp.br/
CEBIMar/USP	<i>in-situ</i> station	10 min	pr, sfcWind, tas 	Automatic station located in Ponta do Baleeiro, Praia do Segredo, São Sebastião, SP (23°49'25 S - 45°25'18 W, 18 m). Data from 2013 to present.	http://cebimar.usp.br/pt/acervo-e-comunicacao/estacoes-meteorologicas-e-oceanograficas/estacao-meteorologica-do-cebimar-usp

<https://www.monolitonimbus.com.br/cebimar/>

Methodology

Name and location of the 10 stations used in the study

	Id	State	City	Altitude (m)
Mantiqueira	1	MG	Passa Quatro	1040
	2	MG	Caldas	1150
	3	MG	Maria da Fé	1276
Valley	4	RJ	Resende	439
	5	RJ	Valença	367
Plateau	6	SP	Bauru	666
	7	SP	Piracicaba	573
Coast MG Valley	8	SP	Taubaté	571
	9	SP	São Paulo	799
	10	SP	São Sebastião	18



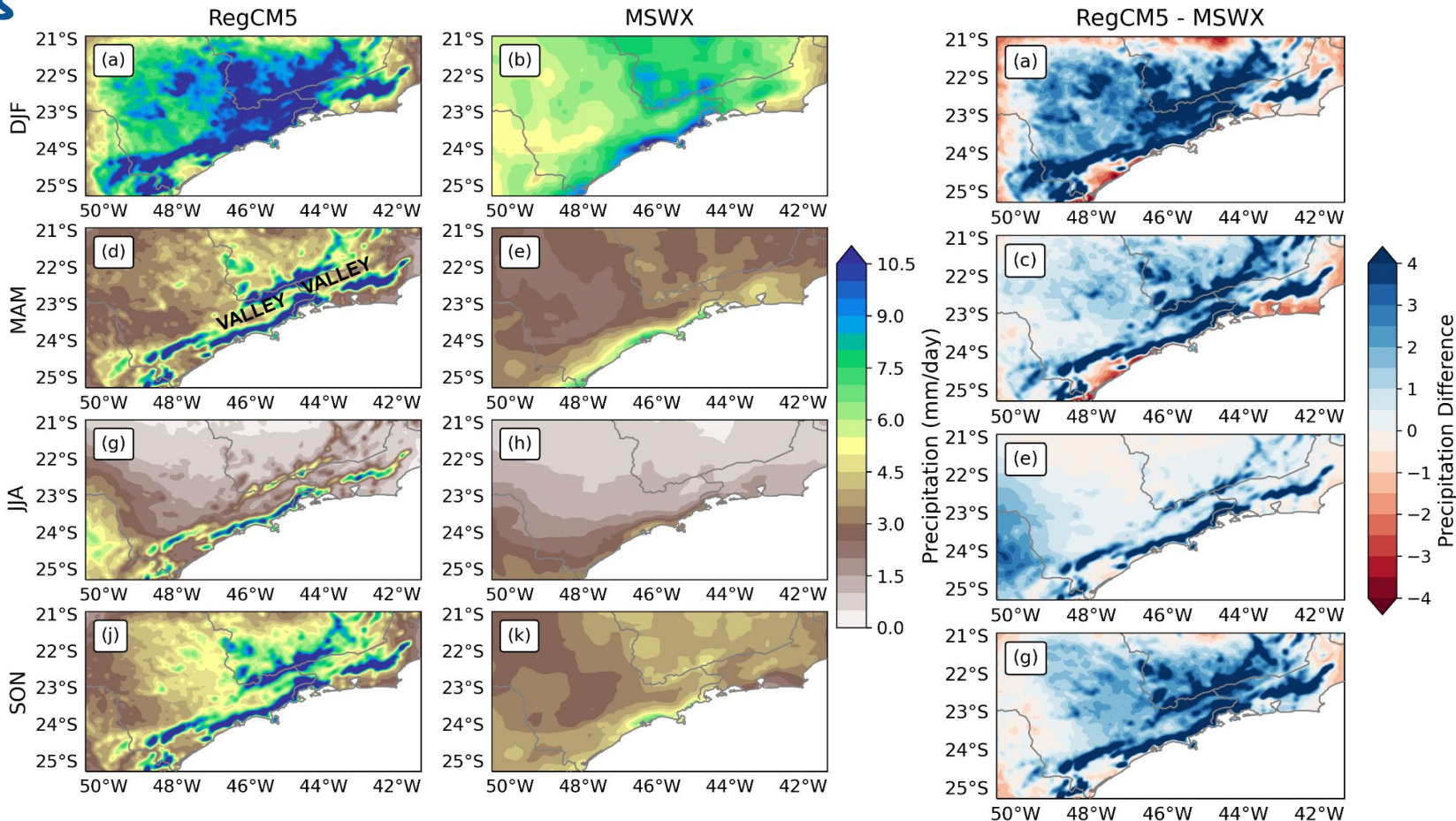
Results

Seasonal average: pr

Seasonal variability well captured

But

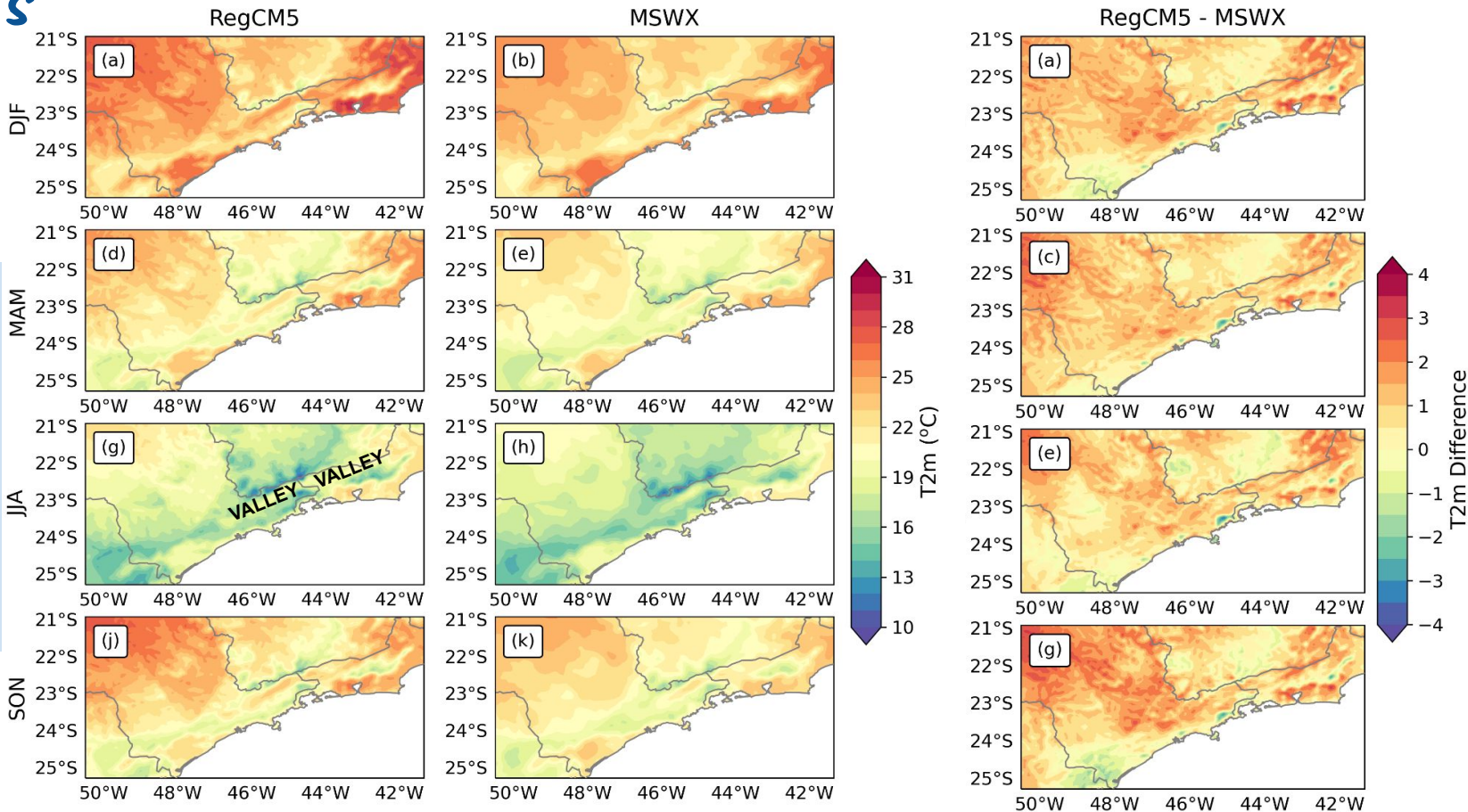
excessive pr over the mountains



Results

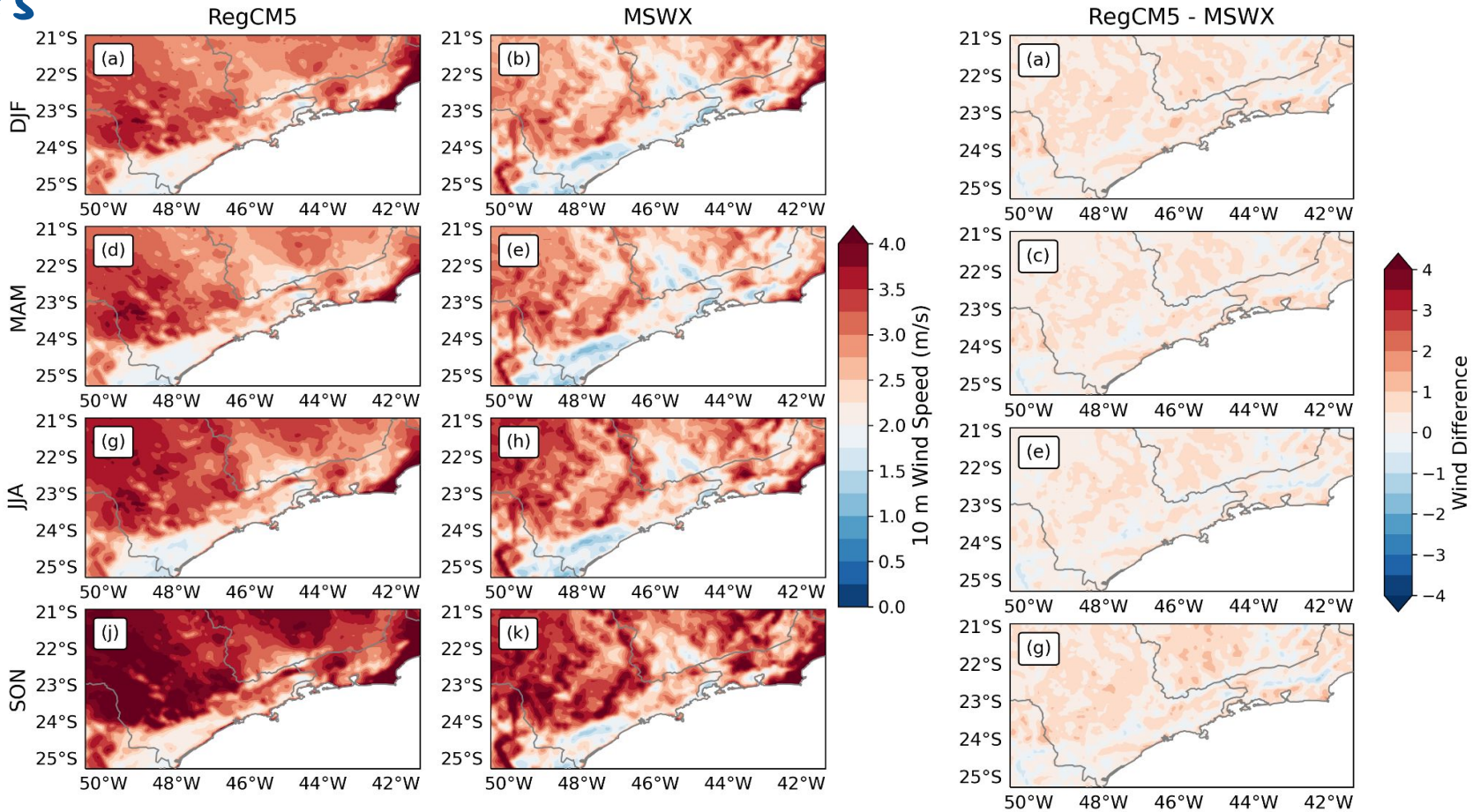
Seasonal average: tas

For all seasons, simulation captures very well the topographic effect in the air temperature: cold in the mountains and warm in the valleys



Results

Seasonal average:
sfcWind

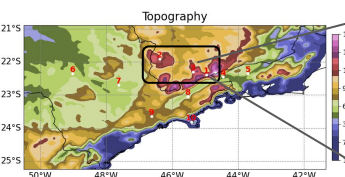


Results

Region:
Mantiqueira
Variable:
Pr (mm/day)

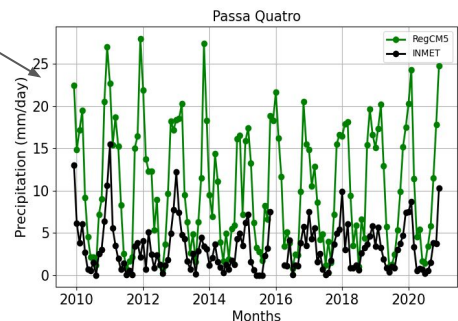
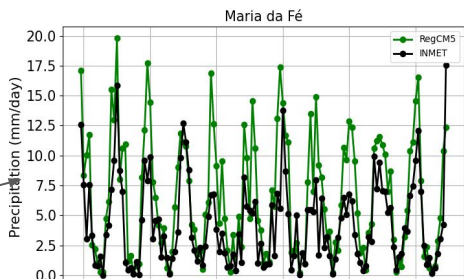
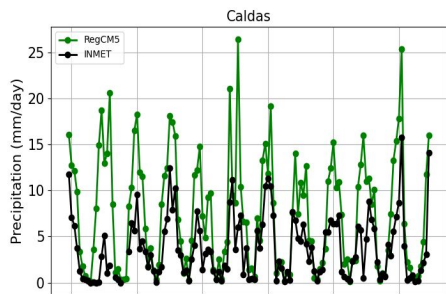
RegCM5
INMET
MSWX

LEGEND

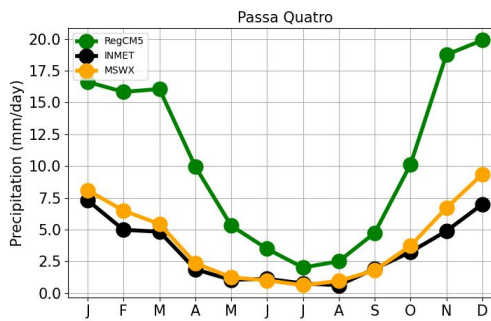
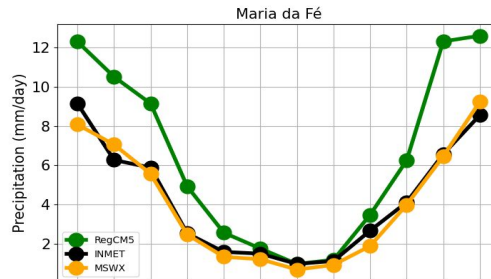
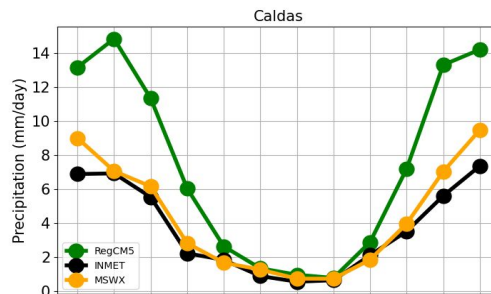


Diurnal Cycle: Great overestimation of nighttime rainfall over steep topography

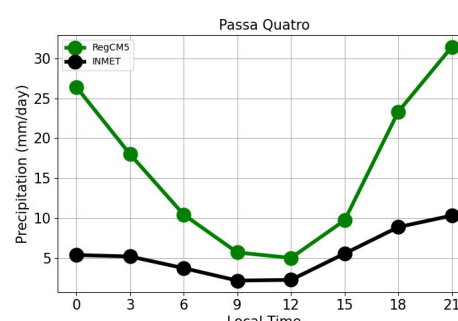
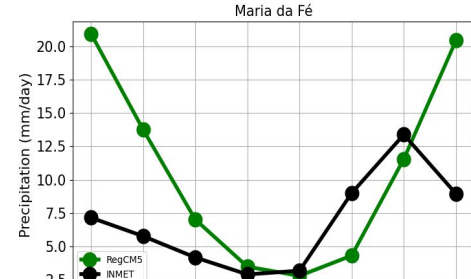
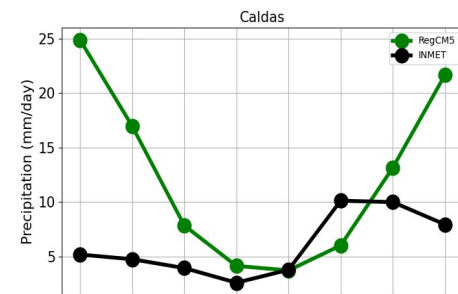
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)



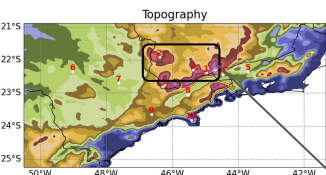
RegCM5 reproduces the variability in the different scales but with overestimates

Results

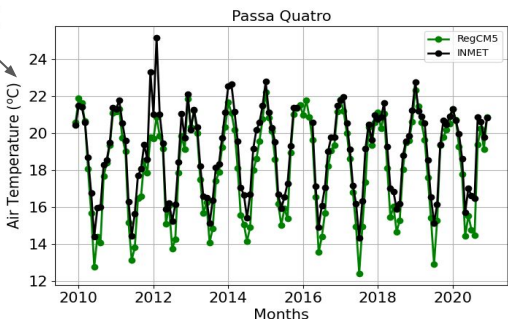
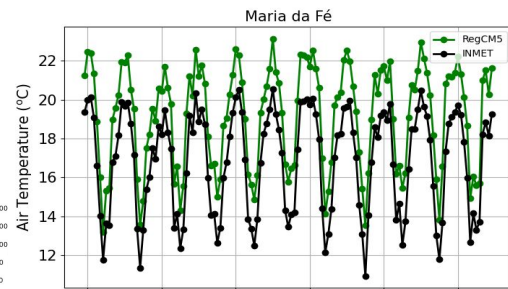
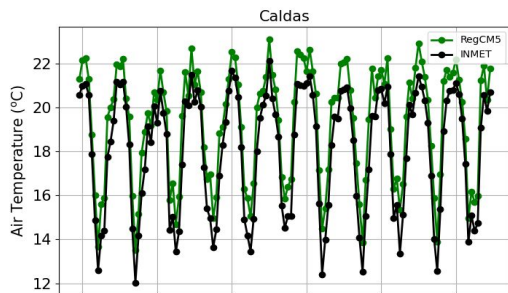
Region:
Mantiqueira
 Variable:
Tas (°C)

RegCM5
INMET
MSWX

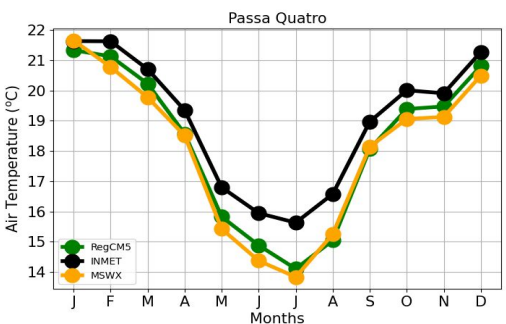
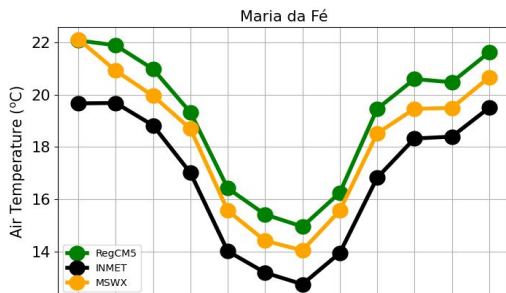
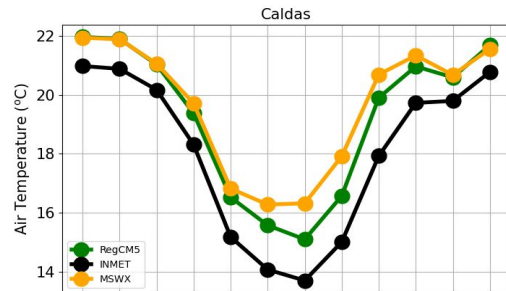
L
E
G
E
N
D



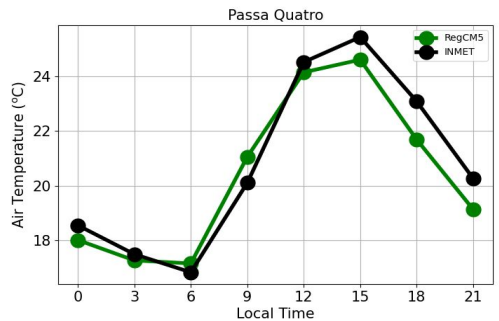
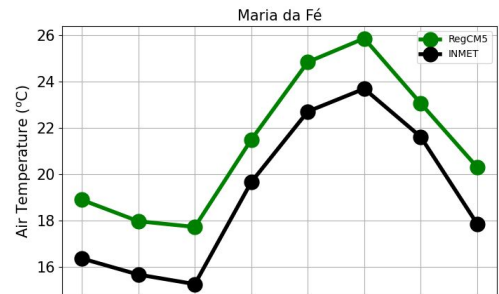
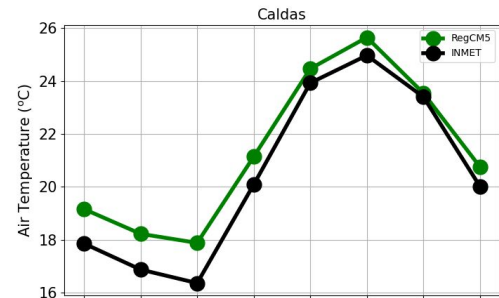
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)



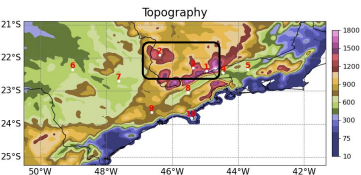
Pr is not well represented in Passa Quatro but Tas is better simulated compared to the other two sites.

Results

Region:
Mantiqueira
 Variable:
SfcWind
 (m/s)

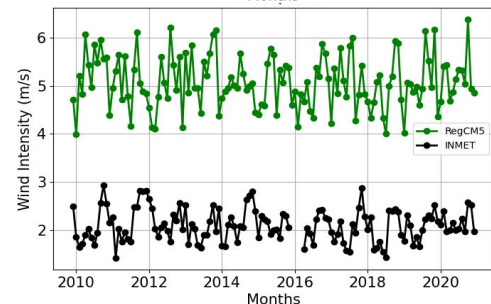
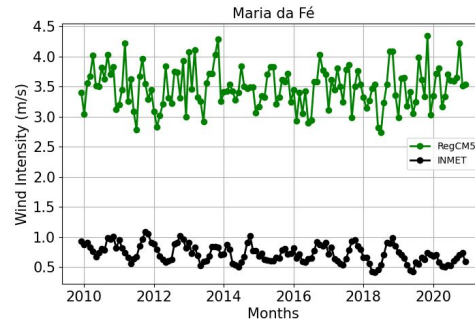
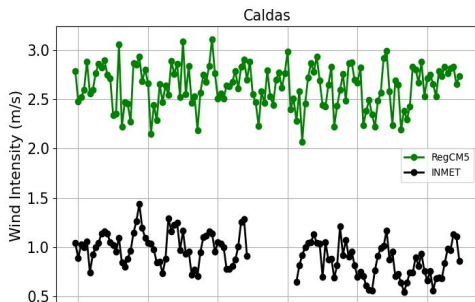
LEGEND

RegCM5
INMET
MSWX

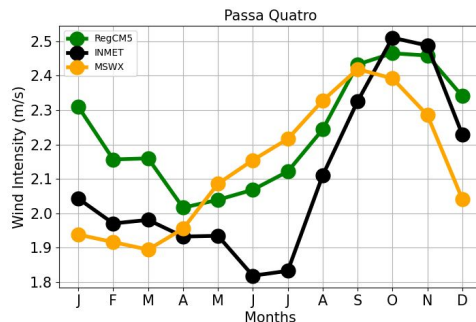
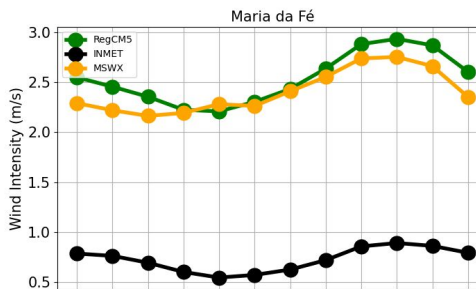
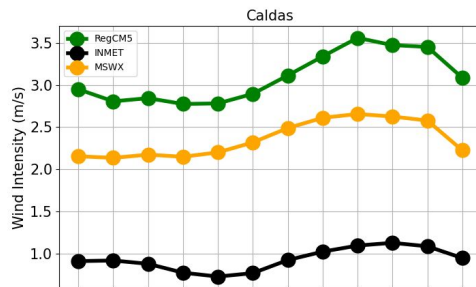


Wind intensity is not well reproduced in the mountains.

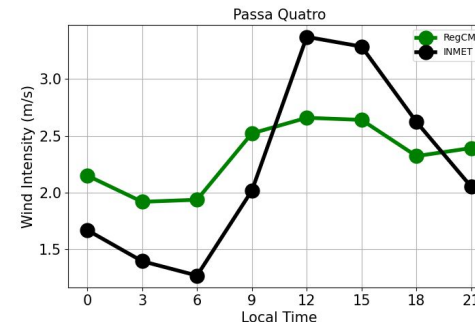
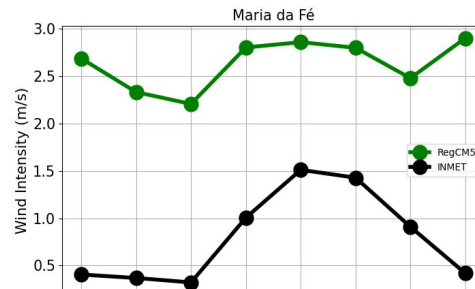
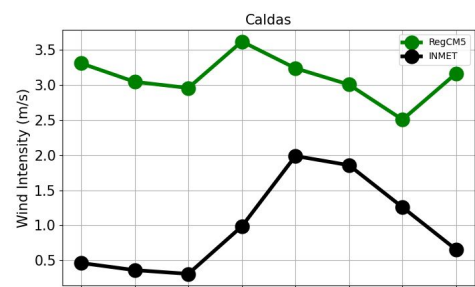
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)

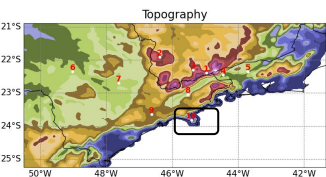


Results

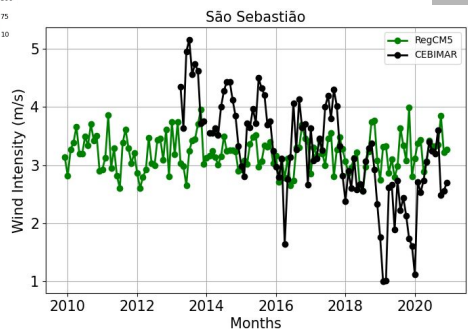
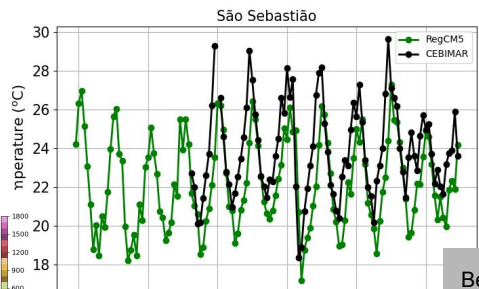
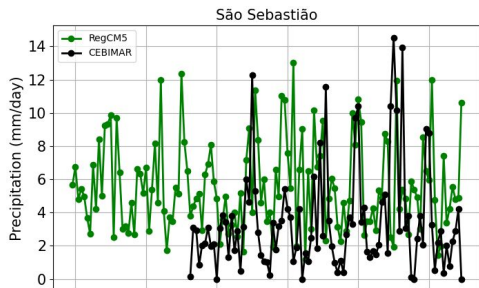
Region:
Coast

RegCM5
INMET
MSWX

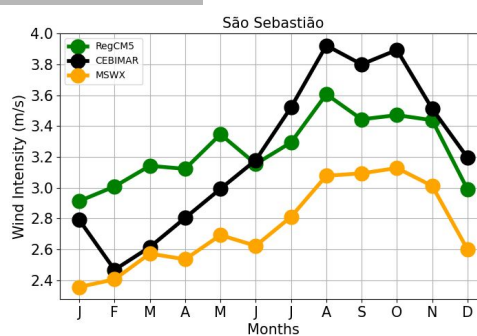
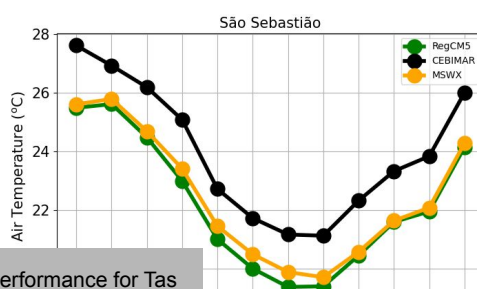
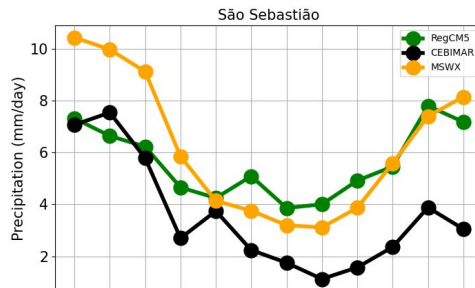
LEGEND



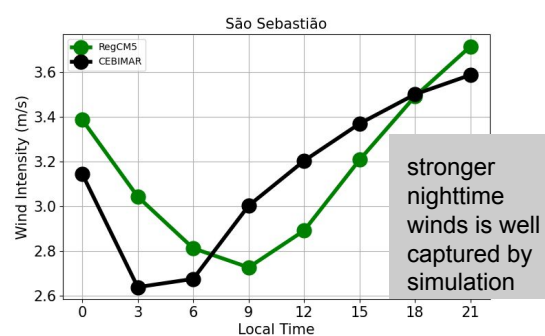
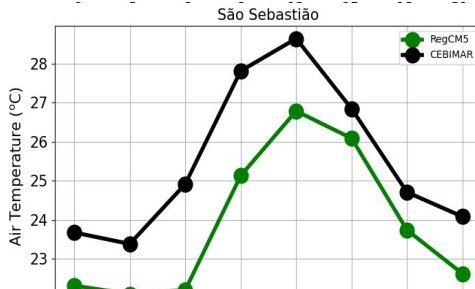
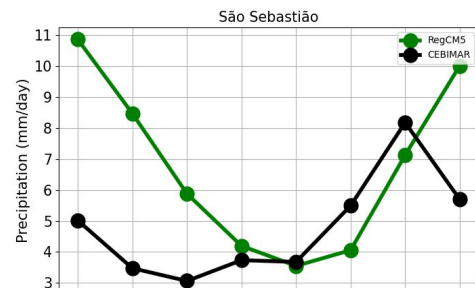
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)



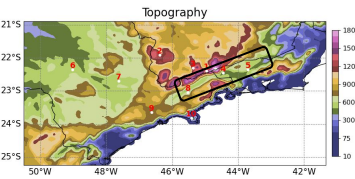
Best performance for Tas

Results

Region:
Valley
Variable:
Pr (mm/day)

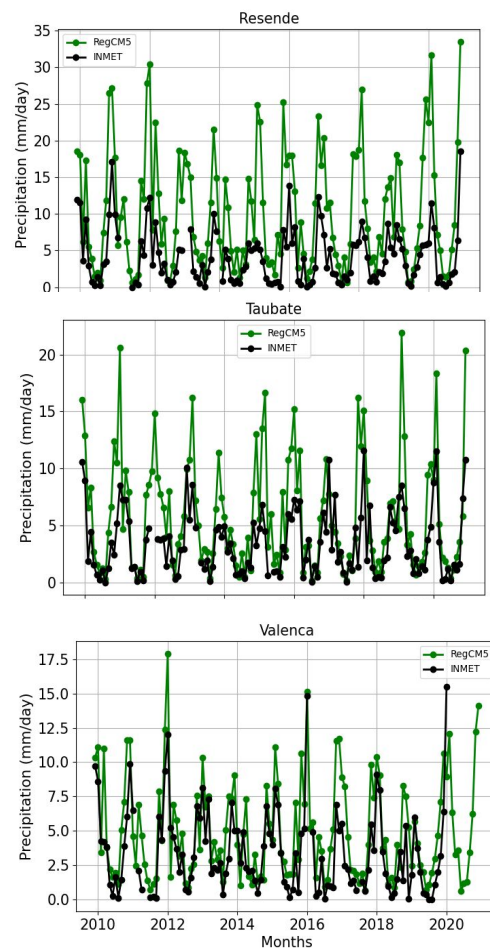
RegCM5
INMET
MSWX

L
E
G
E
N
D

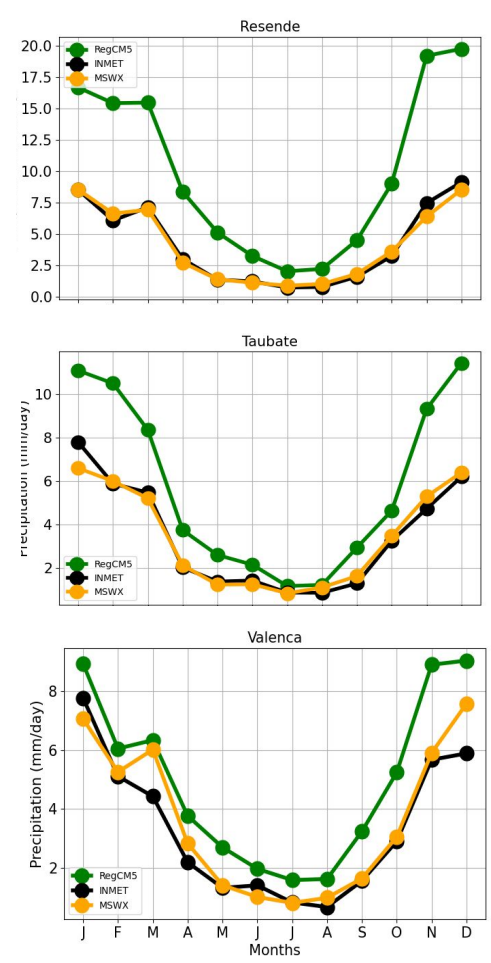


RegCM5 reproduces the variability in the different scales but with overestimates

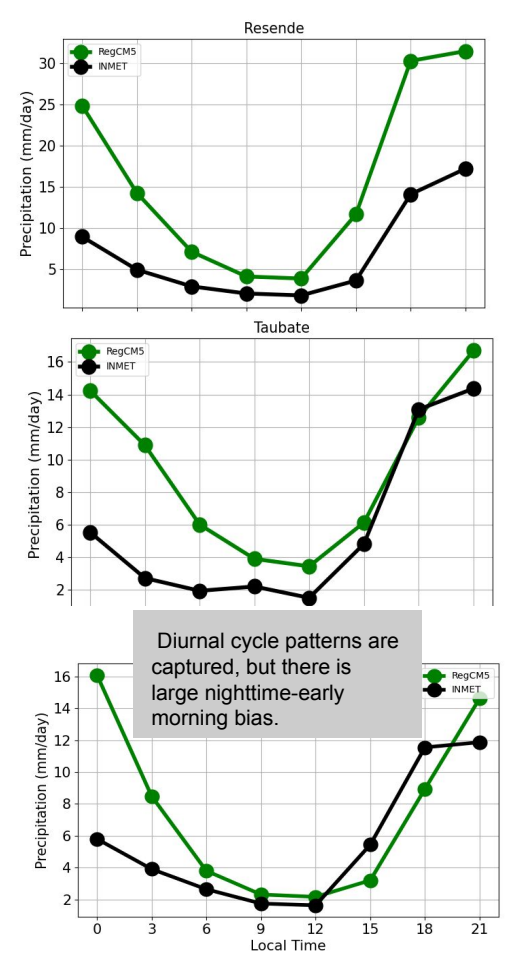
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)



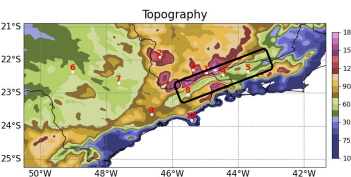
Diurnal cycle patterns are captured, but there is large nighttime-early morning bias.

Results

Region:
Valley
Variable:
Tas (°C)

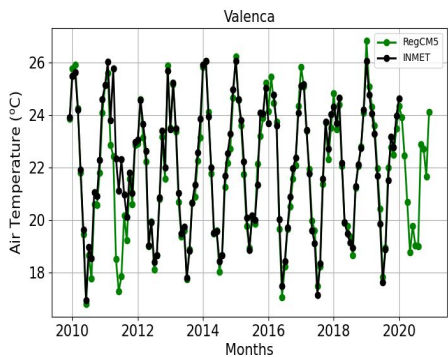
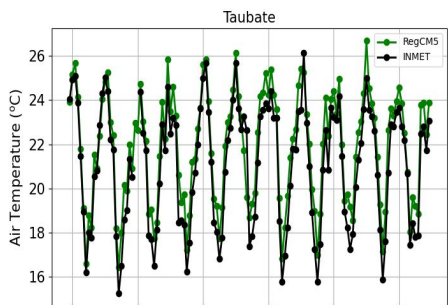
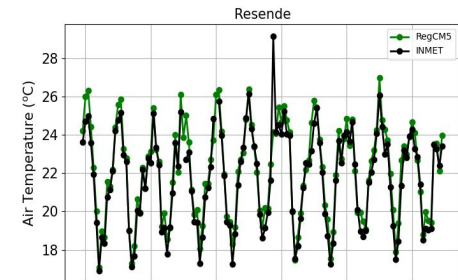
RegCM5
INMET
MSWX

L
E
G
E
N
D

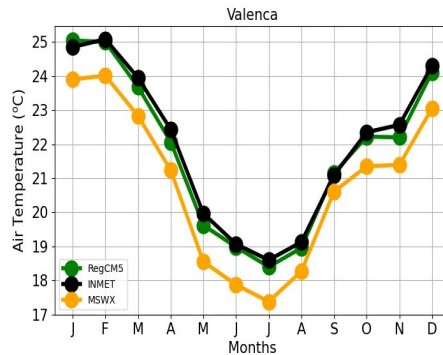
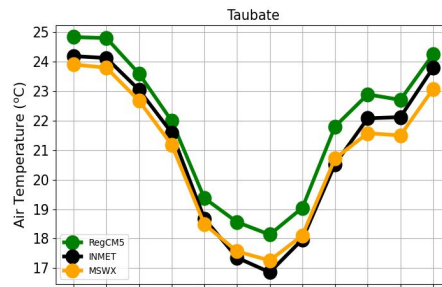
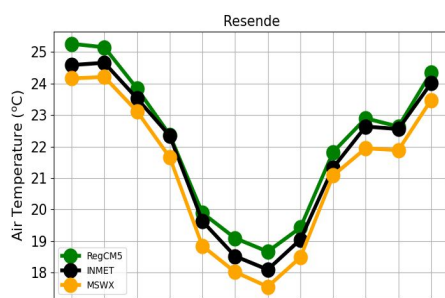


RegCM5 performed an excellent job here!

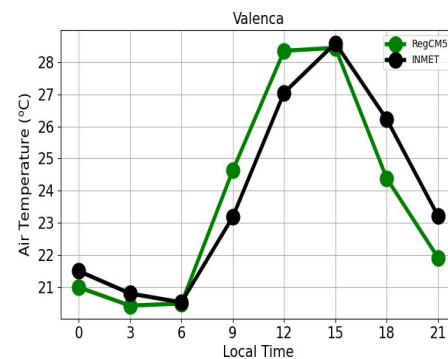
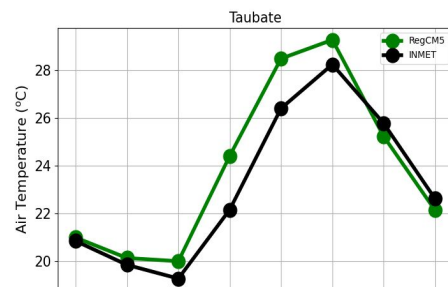
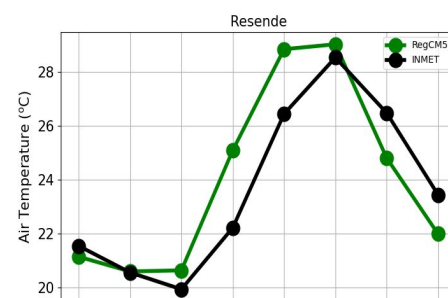
Monthly Means



Annual Cycle



Diurnal Cycle (Oct-Mar)

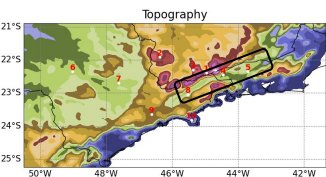


Results

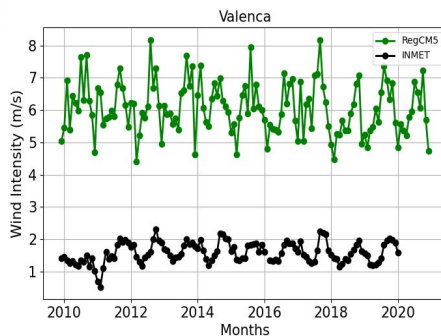
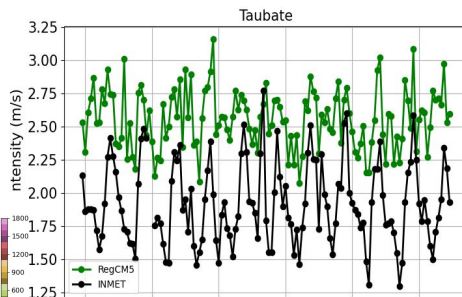
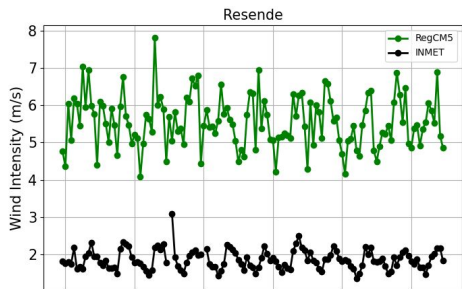
Region:
Valley
SfcWind
(m/s)

RegCM5
INMET
MSWX

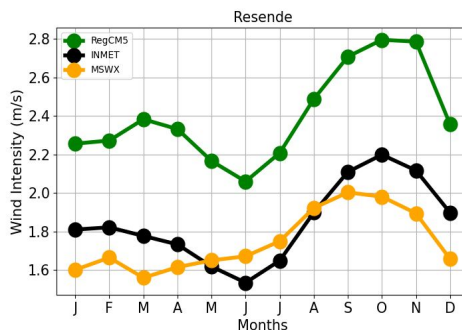
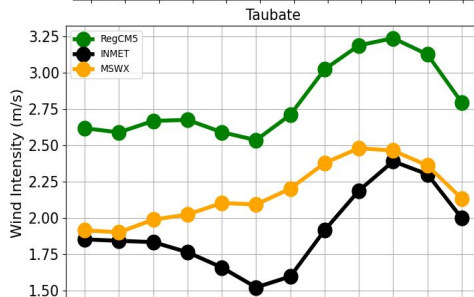
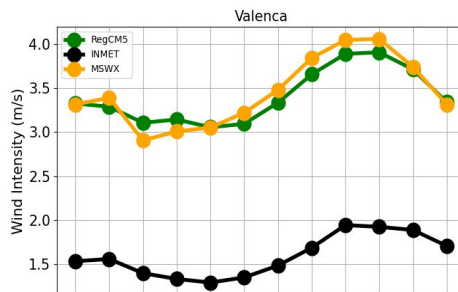
L
E
G
E
N
D



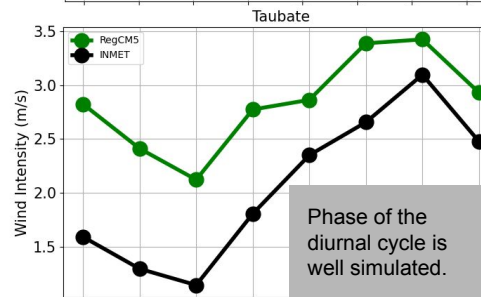
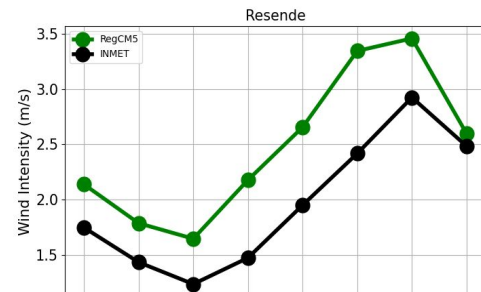
Monthly Means



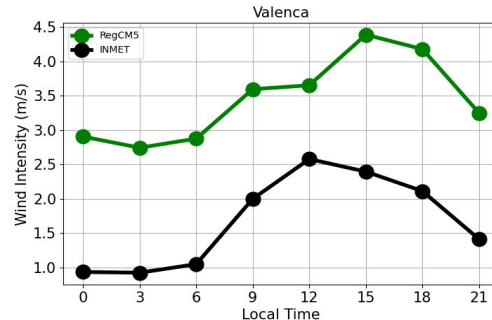
Annual Cycle



Diurnal Cycle (Oct-Mar)



Phase of the diurnal cycle is well simulated.



Even in Valley, RegCM5 has difficulty to reproduce winds.

Results

Monthly Means

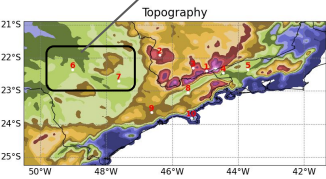
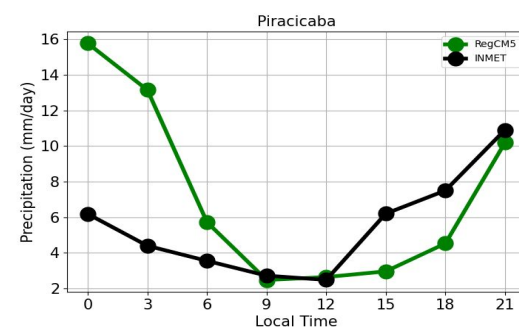
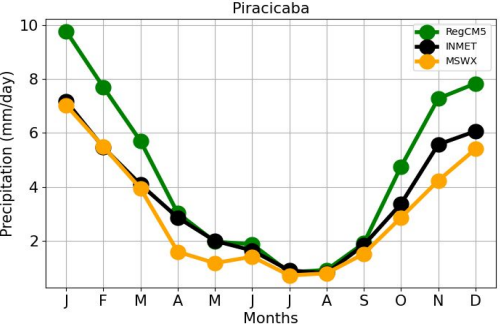
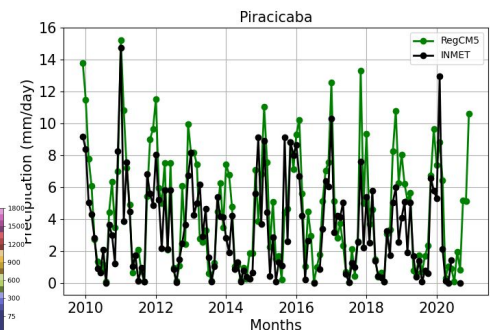
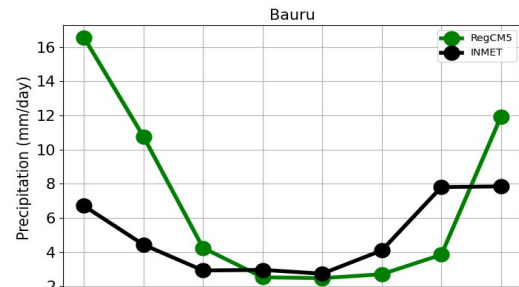
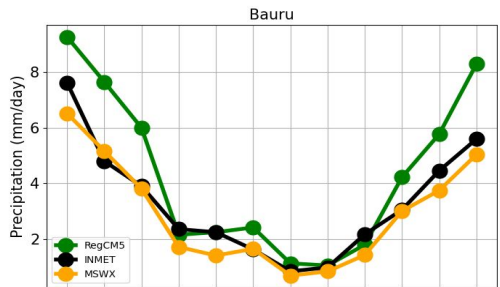
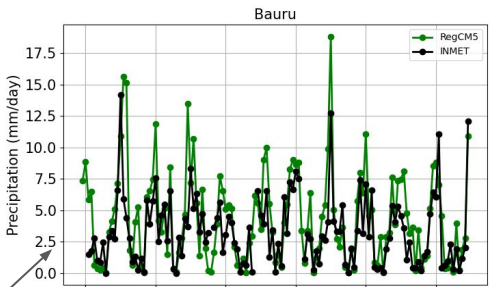
Annual Cycle

Diurnal Cycle (Oct-Mar)

Region:
Plateau
Pr (mm/day)

RegCM5
INMET
MSWX

L
E
G
E
N
D



Good performance in representing the variability of precipitation even to diurnal cycle.

Results

Monthly Means

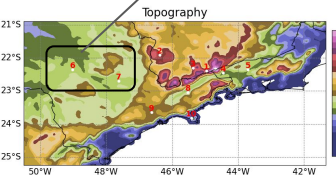
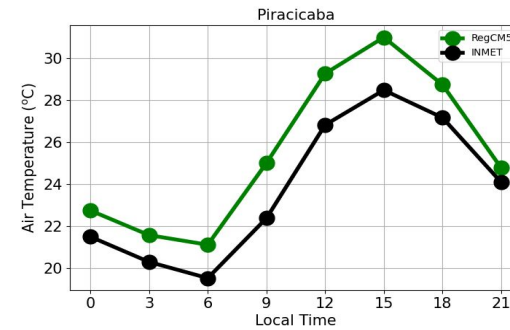
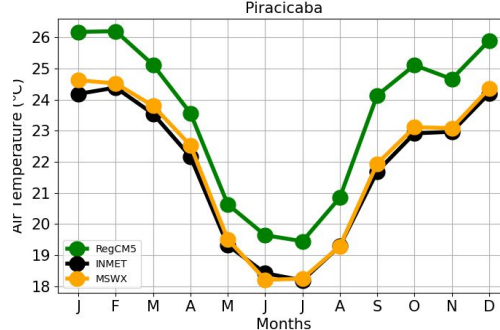
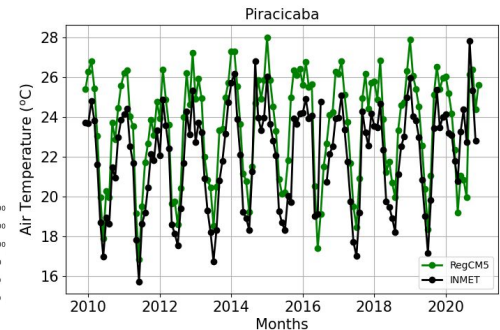
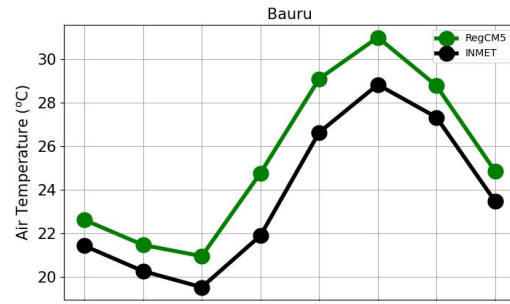
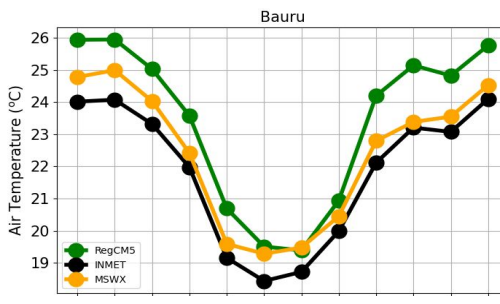
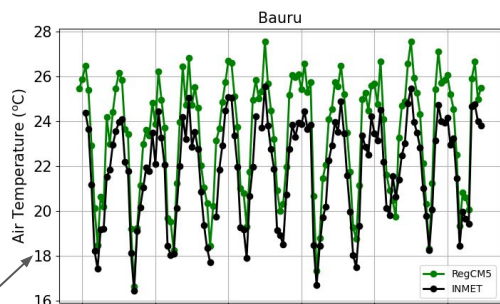
Annual Cycle

Diurnal Cycle (Oct-Mar)

Region:
**Plateau
Tas (°C)**

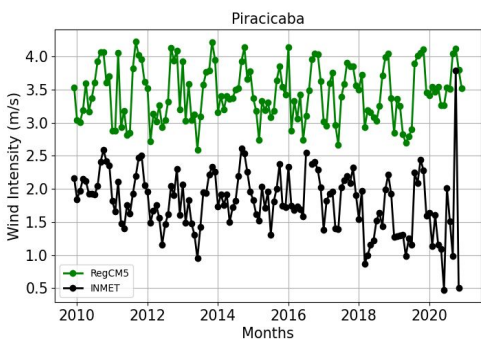
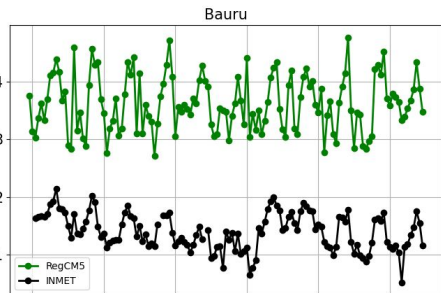
RegCM5
INMET
MSWX

L
E
G
E
N
D

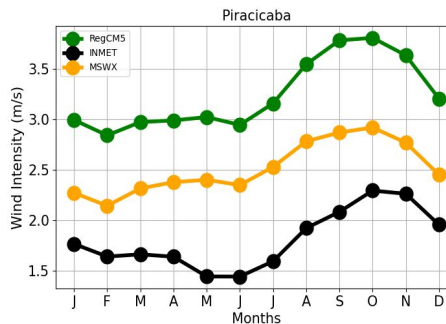
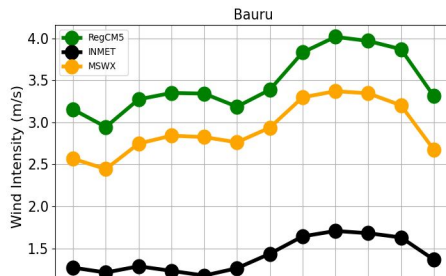


Results

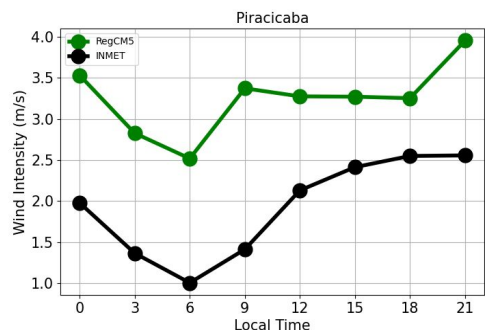
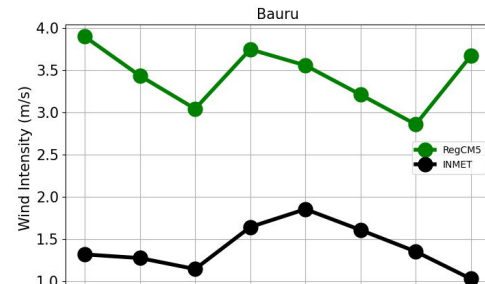
Monthly Means



Annual Cycle



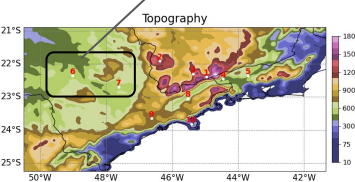
Diurnal Cycle (Oct-Mar)



Region:
Plateau
SfcWind
(m/s)

RegCM5
INMET
MSWX

LEGEND



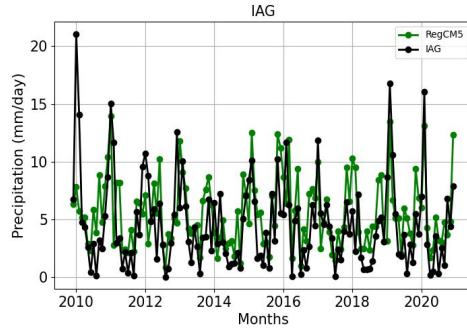
Results

Region:
Megacity

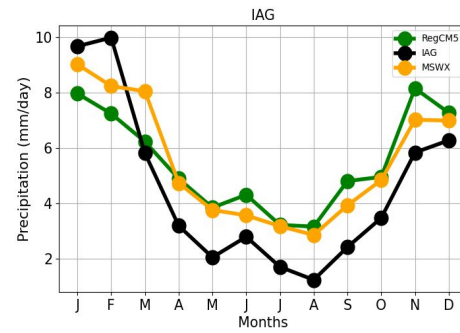
RegCM5
INMET
MSWX

L
E
G
E
N
D

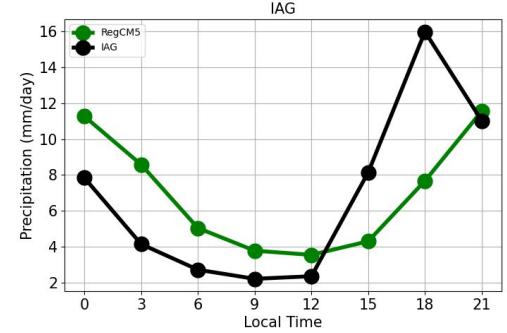
Monthly Means



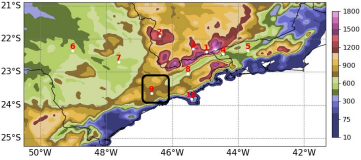
Annual Cycle



Diurnal Cycle (Oct-Mar)



Topography



Results

Frequency distribution of daily precipitation (whole year) (values are grouped by integer bins)

It is another way to show the distribution of the daily precipitation.

In general, in all places, the quantity of daily precipitation is higher in RegCM5

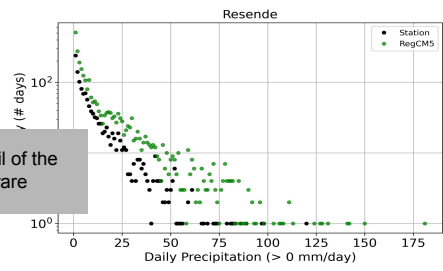
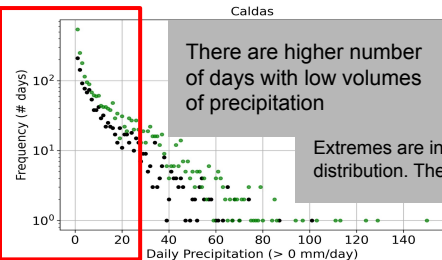
y axis = frequency (number of days)

Mantiqueira

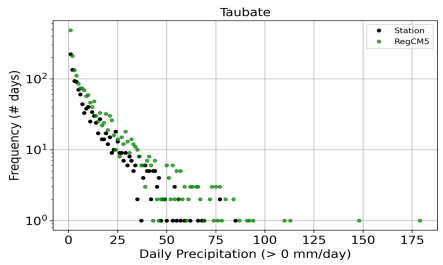
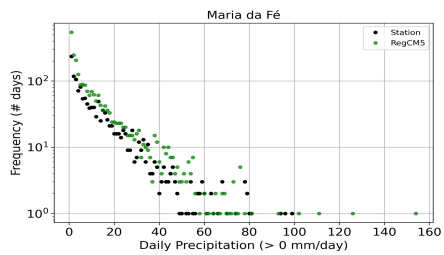
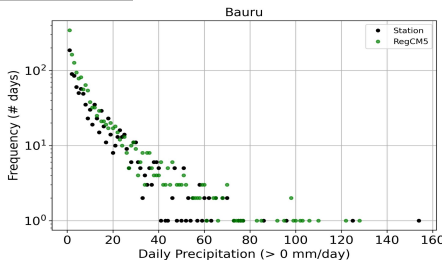
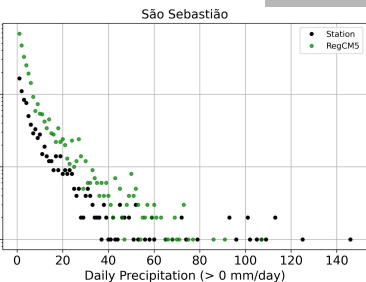
Valley

Coast

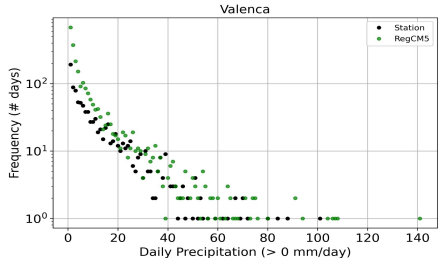
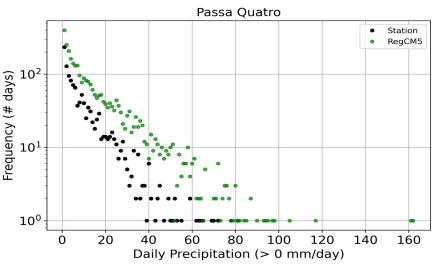
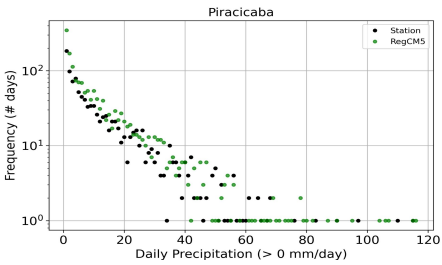
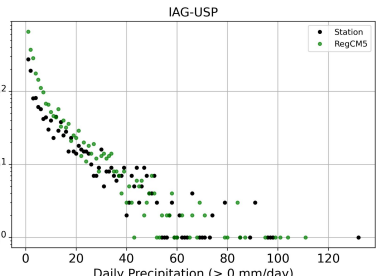
Plateau



x axis = daily precipitation (mm)



IAG-USP



Results

Frequency Distribution of Daily Precipitation > Threshold Extreme Events

São Sebastião

São Sebastião

Pr > 75%

RegCM has higher frequency of extremes with low precipitation

PS = 9.1
PR = 3.5

IAG-USP

IAG-USP

RegCM has higher frequency of extremes with low precipitation

PS = 11.3
PR = 6.1

Caldas

Caldas

RegCM has lower frequency of extremes with low precipitation

PS = 8.6
PR = 8.4

Maria da Fé

Maria da Fé

RegCM has higher frequency of extremes with low precipitation

PS = 10.0
PR = 7.6

Passa Quatro

Passa Quatro

RegCM has lower frequency of extremes with low precipitation

PS = 10.0
PR = 14.5

São Sebastião

Pr > 90%

PS = 21.4
PR = 15.7

IAG-USP

PS = 26.0
PR = 17.4

Caldas

PS = 22.0
PR = 24.9

Maria da Fé

PS = 22.8
PR = 20.4

Passa Quatro

PS = 21.4
PR = 30.5

São Sebastião

Pr > 95%

PS = 32.7
PR = 25.6

IAG-USP

PS = 39.3
PR = 28.1

Caldas

PS = 31.1
PR = 30.0

Maria da Fé

PS = 32.6
PR = 31.5

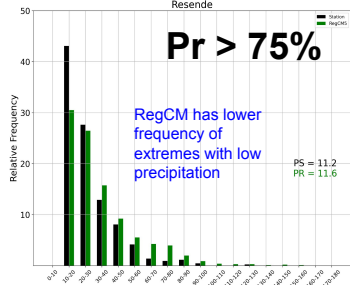
Passa Quatro

PS = 28.2
PR = 41.7

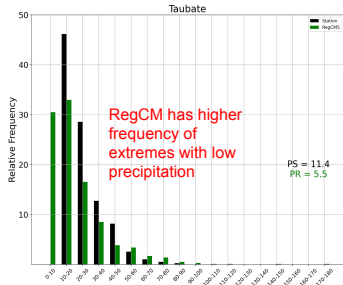
Results

Frequency Distribution of Daily Precipitation > Threshold Extreme Events

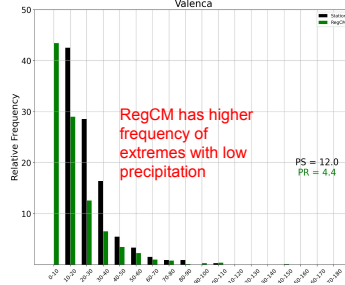
Resende



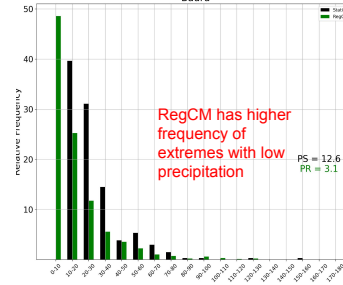
Taubaté



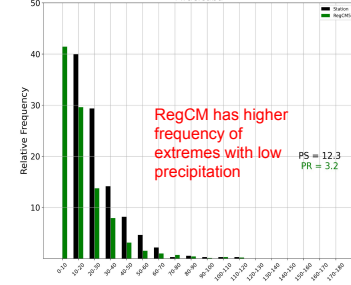
Valência



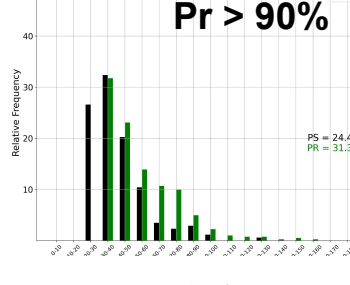
Bauru



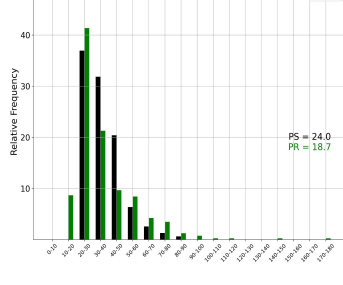
Piracicaba



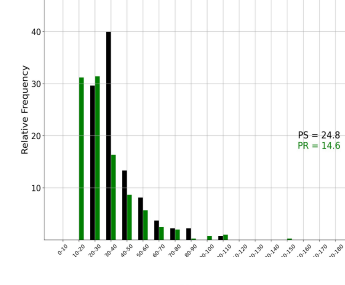
Resende



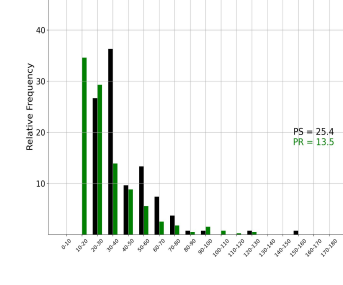
Taubaté



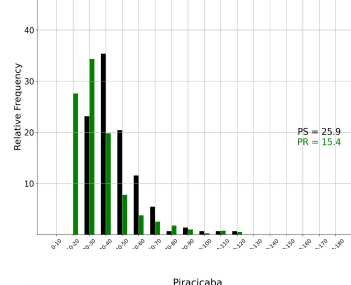
Valência



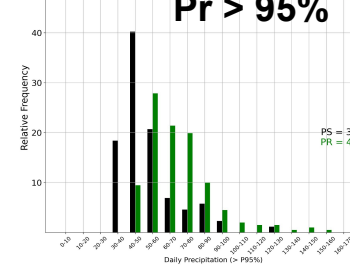
Bauru



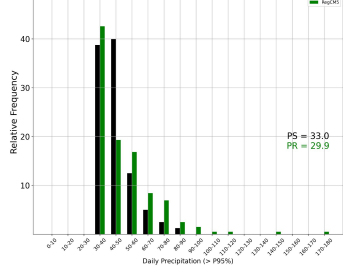
Piracicaba



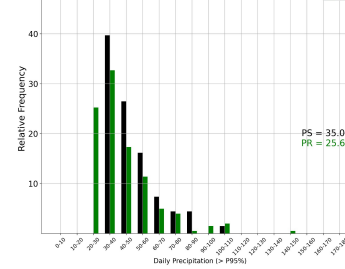
Resende



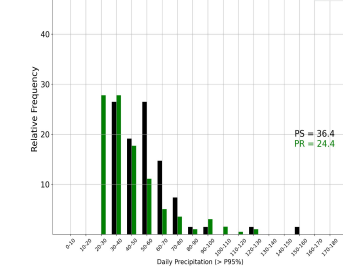
Taubaté



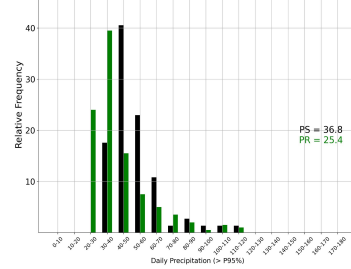
Valência



Bauru



Piracicaba



Conclusions

CP simulation improves the representation of the interannual variability, annual cycle and diurnal cycle of precipitation, air temperature and near-surface winds compared with coarser resolution simulations performed in the past to the same study region.

RegCM5 overestimates the precipitation over the mountains.
Suggestion: calibrate the Noto's microphysics scheme

Winds are the worst simulated variable.

Difficulties and challenges

- space to storage CP simulations
- missing reliable station observed data
- uncertainties among the grid-datasets (e.g. CPC, CHELSA, MSWX etc.)
- connection difficulties and downloading time to get higher resolution data for model's validation (e.g. satellite estimates)

