Statistical downscaling in the Tropics and Mid-latitudes: a comparative assessment for generating regional information on climate change.

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Motivation

- AEMET is responsible for the elaboration of downscaled climate projections over Spain to feed the National Plan of Adaptation to Climate Change (PNACC)

- AEMET participates in the elaboration of downscaled climate projections over Central America through the EUROCLIMA+ programme (https://euroclimaplus.org/)

- The limited number of CORDEX simulations in Central America and their coarse spatial resolution makes statistical downscaling necessary.

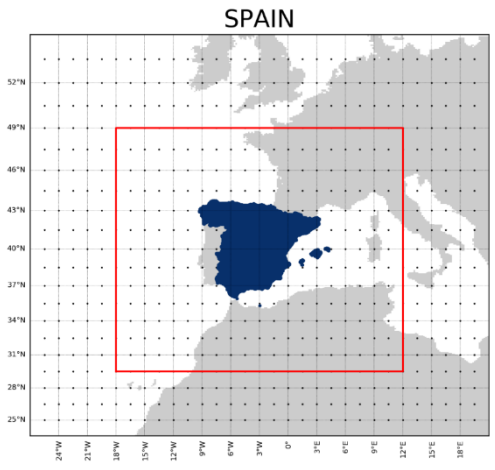
- **Extratropics:**
  - Statistical Downscaling (SD) widely evaluated and applied.
  - Comprehensive intercomparison of different SD approaches (see the EU COST Action VALUE; Maraun *et al.*, 2015)
- **Tropical regions:**
  - Few evaluation studies.

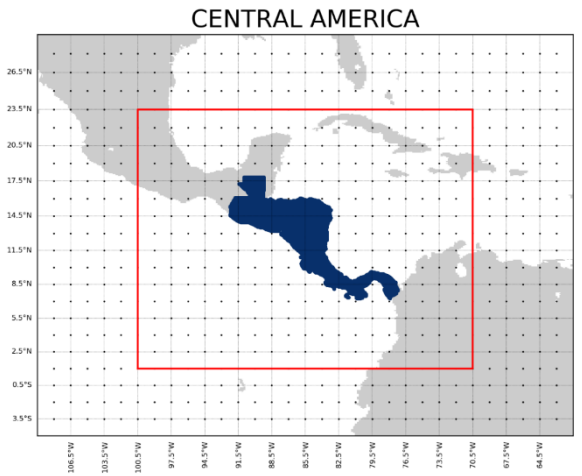
Summary

Results of two different ongoing studies:

- Part I: comparison two regions, few methods, only temperature and precipitation.

- Part II: only Central America, more methods, more variables (winds, humidity…)





Data

Predictors:

- reanalysis **ERA5** (Hersbach *et al.*, 2020) at 1.5º
- **10 (part I) / 7 (part II) GCMs from CMIP6** (Eyring *et al.*, 2016) interpolated to 1.5º

Predictands:

Part I (tmax, tmin, pcp):

- Spain: high resolution grid (0.05º) developed by AEMET (Peral *et al.*, 2017)
- Central America:
  - Temperature: reanalysis ERA5 at 0.25º
  - Precipitation: CHIRPS rainfall dataset (Funk *et al.*, 2015), with a spatial resolution of 0.05º

Part II (only Central America):

- Temperature, precipitation, wind, humidity, cloud cover.
- reanalysis ERA5 at 0.25º

Model	Institution	References
ACCESS-CM2	Commonwealth Scientific and Industrial Research Org. (CSIRO) and Bureau of Meteorology (BoM), Australia	Bi *et al.* (2020)
CanESM5	Canadian Centre for Climate Modelling and Analysis, Canada	Swart *et al.* (2019)
EC-Earth3	EC-Earth consortium, Europe	Döscher *et al.* (2021)
INM-CM5-0	Institute of Numerical Mathematics, Russia	Volodin *et al*. (2017)
INM-CM4-8	Institute of Numerical Mathematics, Russia	Volodin *et al*. (2013)
IPSL-CM6A-LR	Institute Pierre Simon Laplace (IPSL), France	Boucher *et al.* (2020)
MIROC6	Research Center for Environmental Modeling and Application, Japan	Tatebe *et al.* (2019)
MPI-ESM1-2-LR	Max-Planck-Institut (MPI) for Meteorology, Germany	Mauritsen *et al.* (2019)
MPI-ESM1-2-HR	Max-Planck-Institut (MPI) for Meteorology, Germany	Müller *et al.* (2018)
MRI-ESM2-0	Meteorological Research Institute, Tsukuba, Japan	Yukimoto *et al.* (2019)

Methods

Part I (comparison both regions)

Name	Family	Description
RAW	-	No downscaling. Nearest grid point.
QM	MOS	Empirical Quantile Mapping, over detrended series for temperature.
ANA	Analog (PP)	Multiple Linear Regression based on analogs days for temperature / Best analog for precipitation
MLR / GLM	Transfer Function (PP)	Multiple Linear Regression for temperature / Generalized Linear Model for precipitation
WG	Weather Generator	Weather Generator conditioned on monthly statistics

Software:
https://github.com/ahernanzl/pyClim-SDM

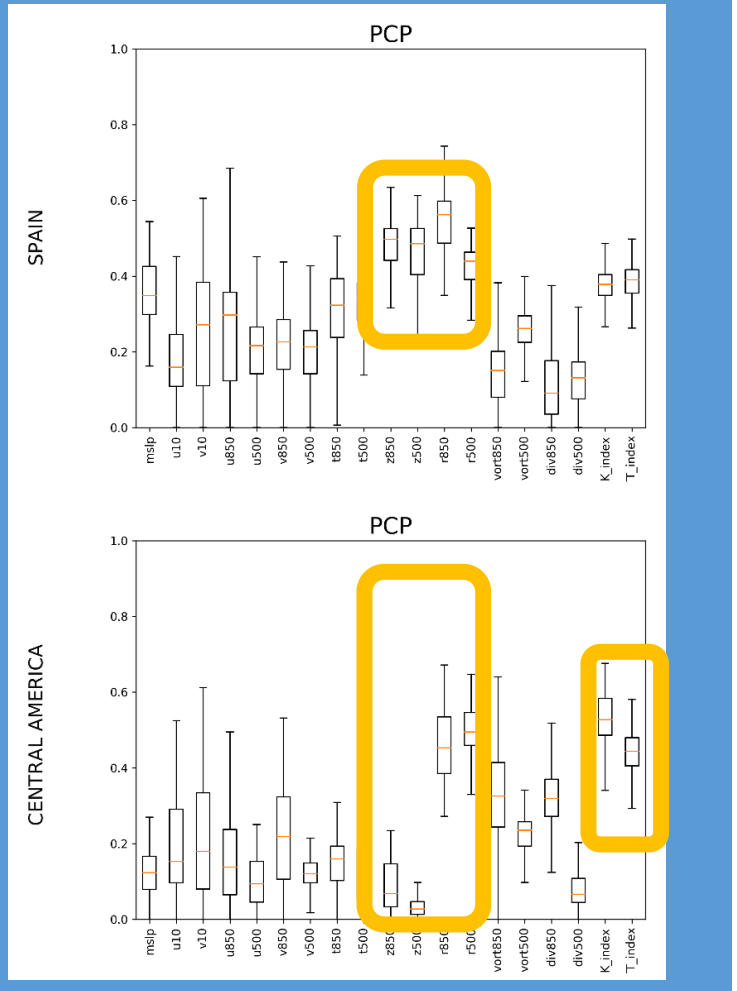
Part II (Central America, different variables)

Family	Description
RAW	2 methods: nearest vs. bilinear interpolation
Quantile Mapping	4 methods: parametric/non-parametric, trend preserving, etc
Analogs	9 methods: synoptic vs. local analogy, best analog vs k-best analogs, etc.
Linear methods	3 methods
Machine Learning	6 methods: support vectors, random forest, neural networks
Weather Generator	2 methods

Part I: comparison both regions

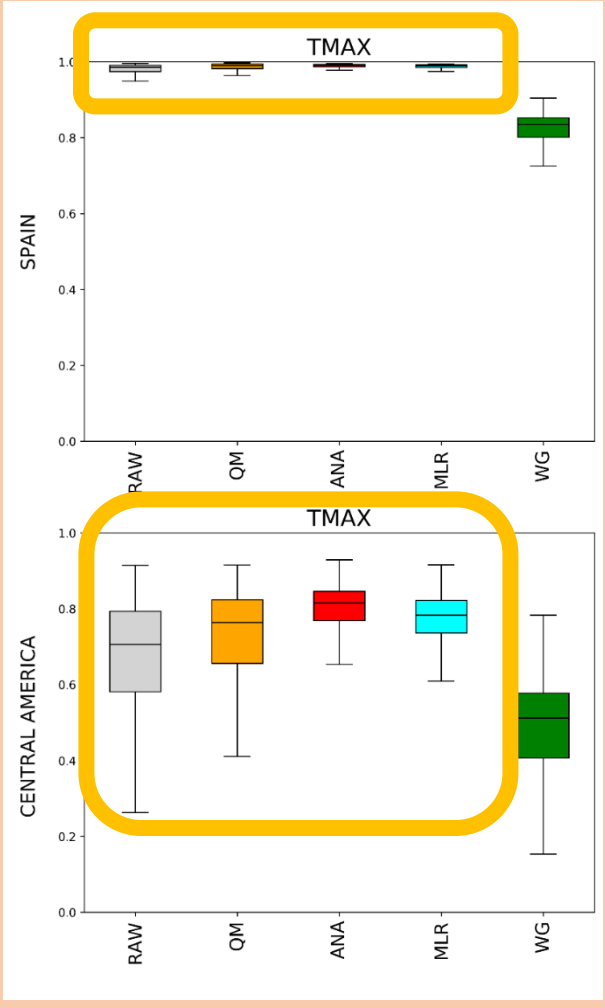
Different key predictors:

- Spain: geopotential and humidity
- Central America: humidity and instability indexes



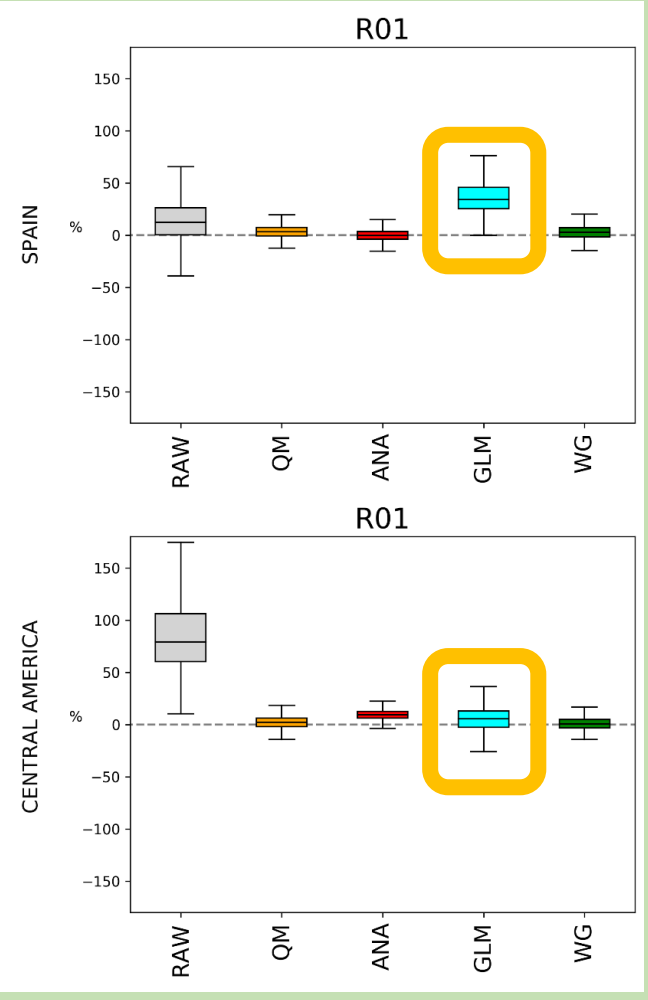
SD less skillful in Central America

Correlations of the downscaled daily series for tmax

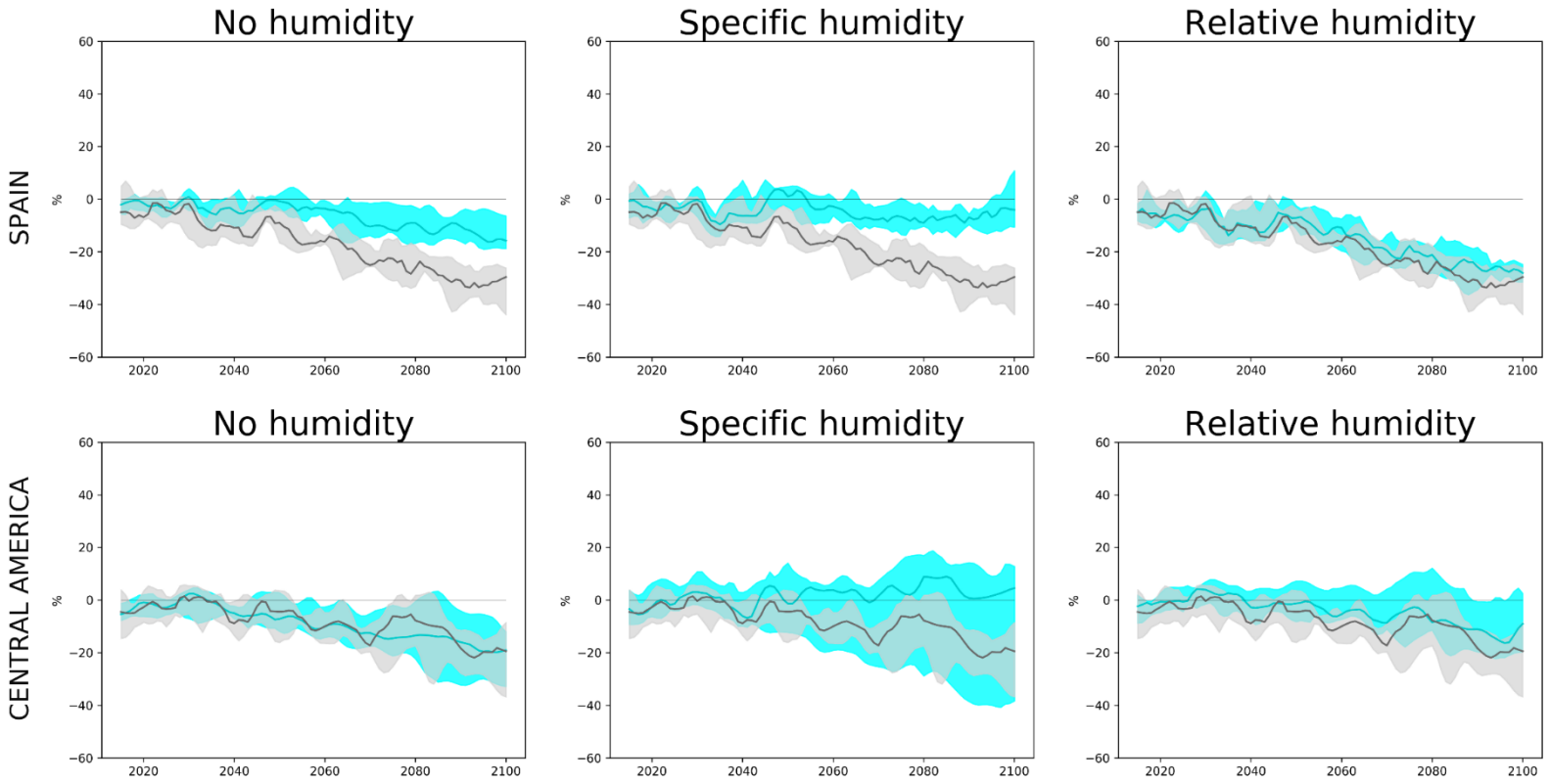


Some methods behave differently

Bias in the number of wet days



How does humidity affect trends?



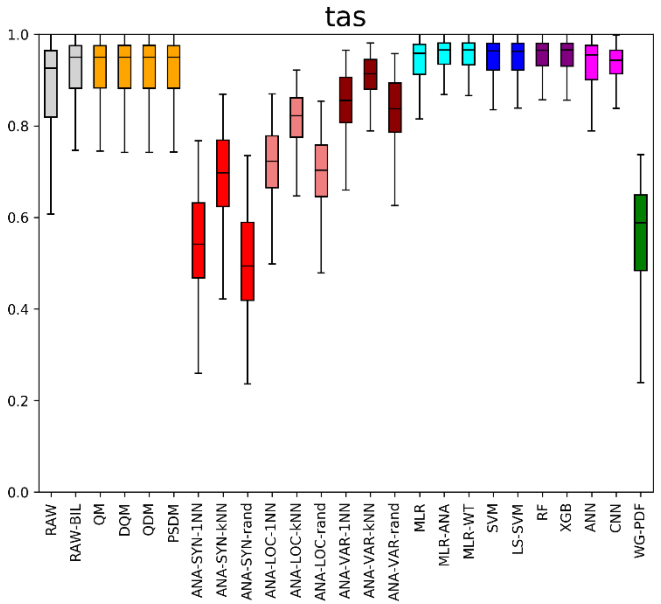
Change in total precipitation (PRCPTOT)% by RAW (gray) and GLM with different sets of predictors, under SSP5-8.5, spatially averaged. The shaded area expands over the interquartile range around the median of the multimodel ensemble.

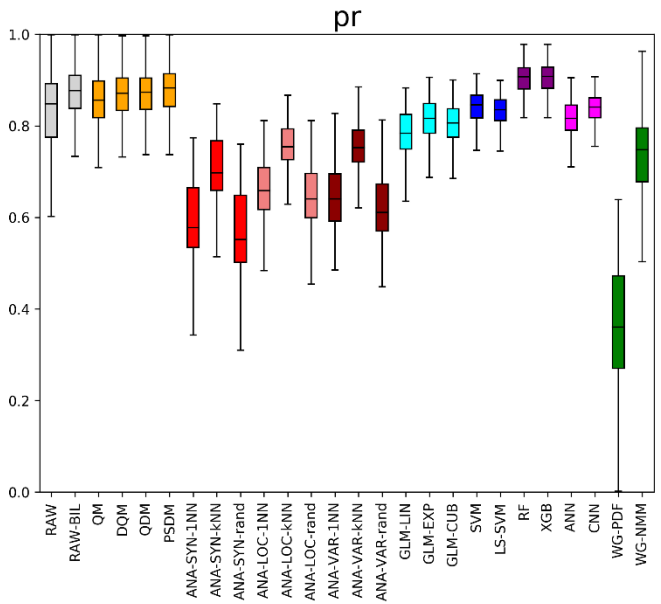
Important concerns about the use of specific humidity:

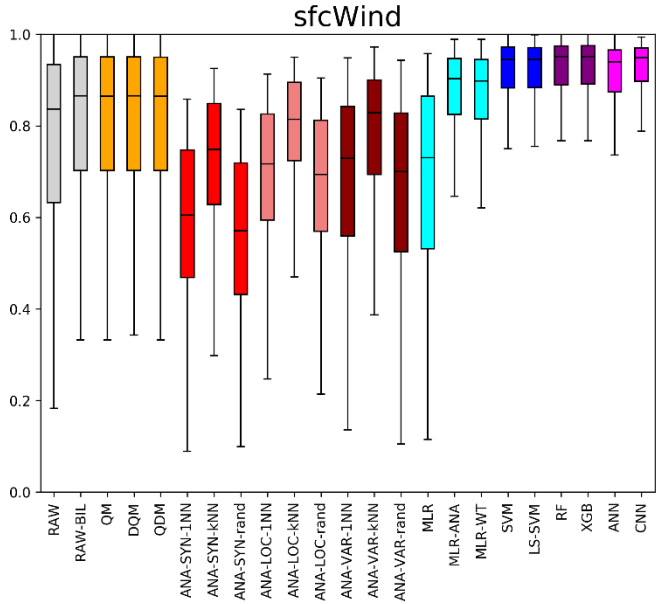
- ✓ It adds information on the water vapor content (important for precipitation intensity)
- ✗ Warmer atmosphere can hold more water vapor without saturation
- ✗ Future values out of the observed range (confusing for statistical methods)

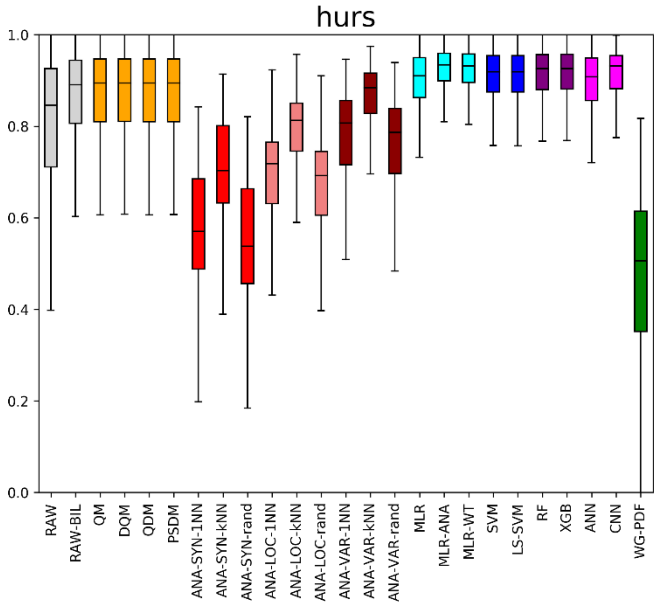
Part II: Central America, different variables

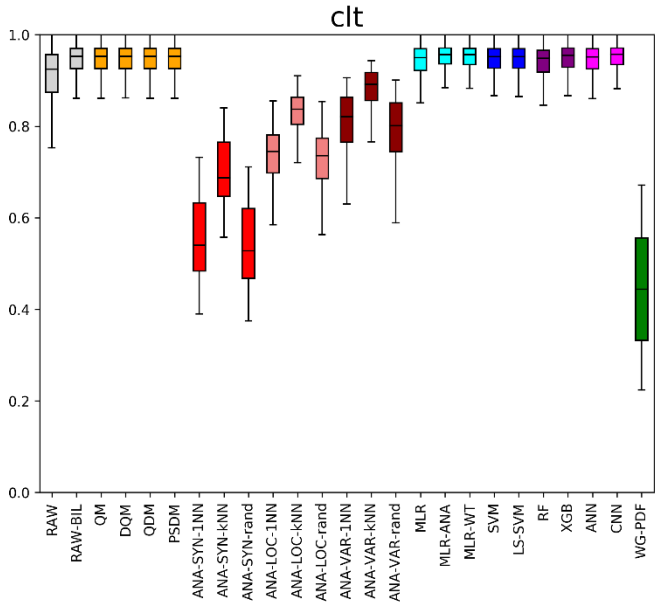
Correlation downscaled daily series











RAW (interpolatioin)

Quantile Mapping

Analogs

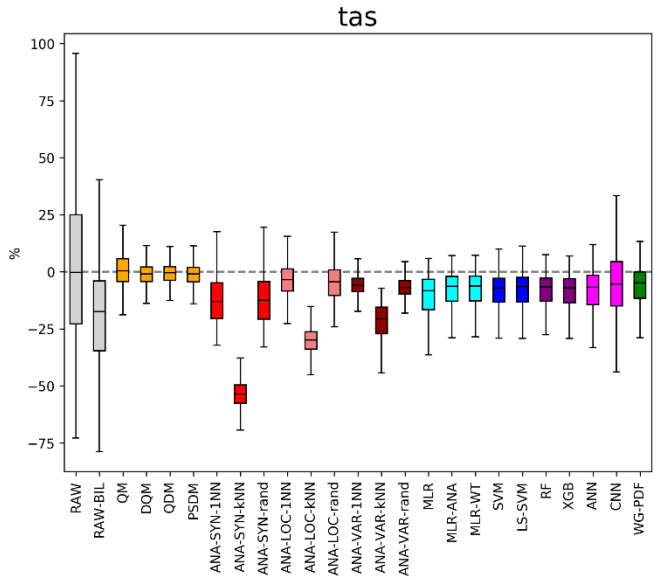
Linear

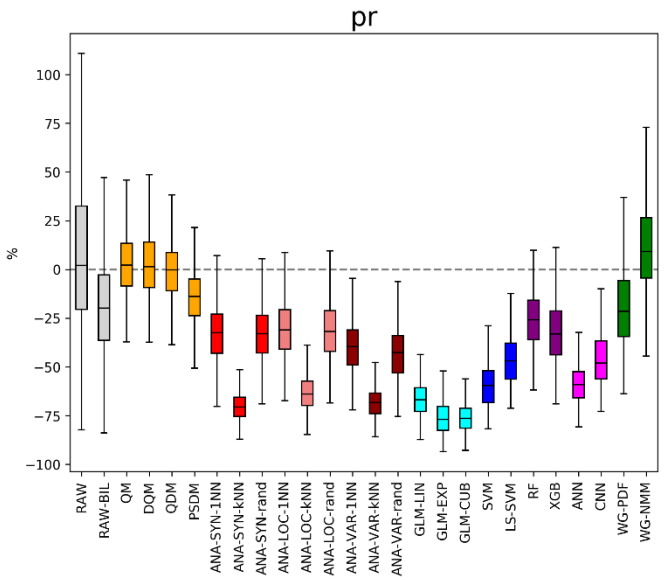
Machine Learning

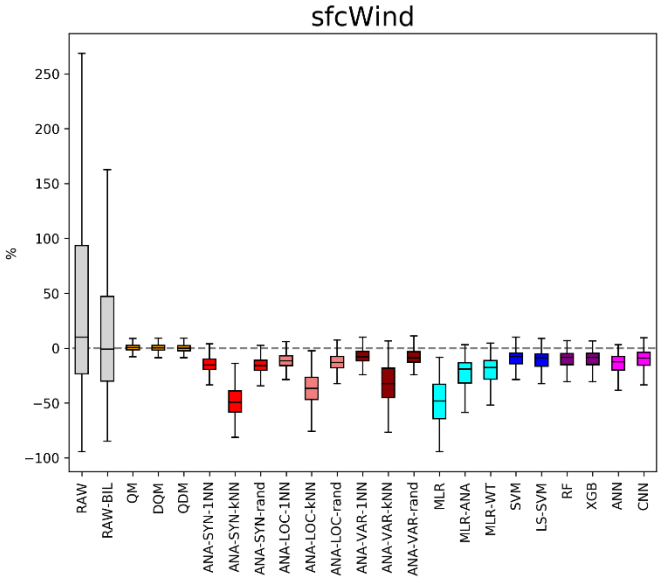
Weather Generators

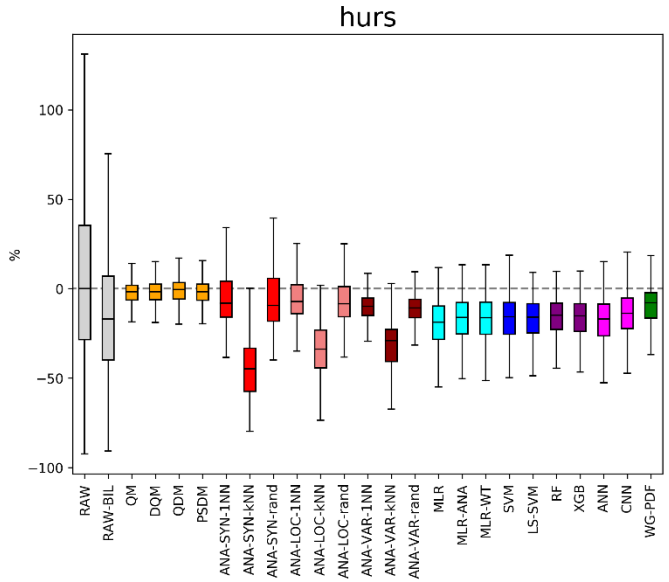
Part II: Central America, different variables

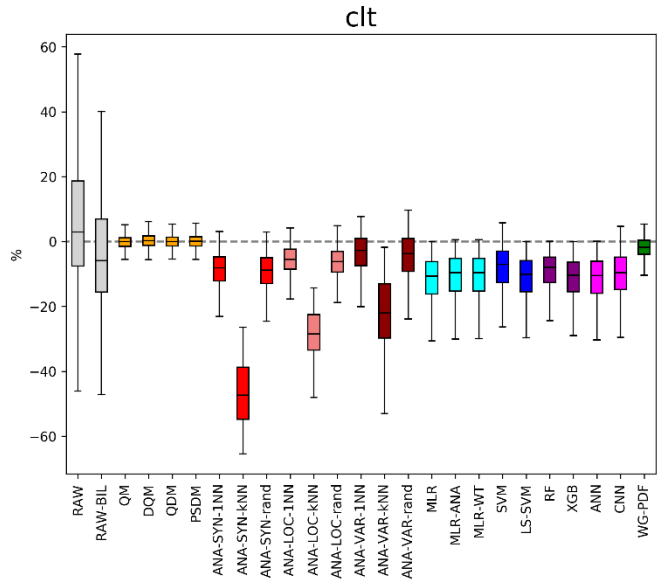
Bias variance daily series











RAW (interpolatioin)

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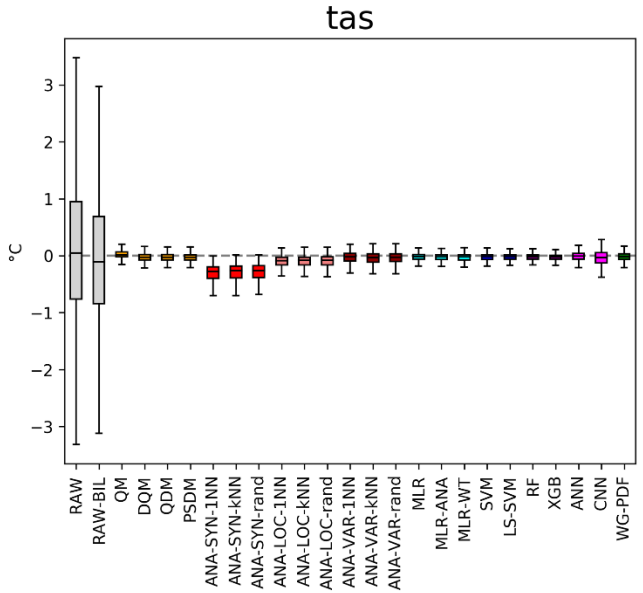
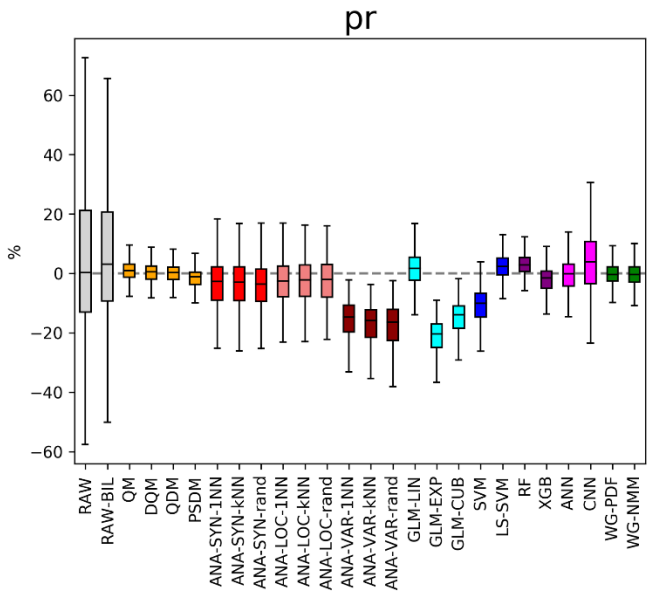
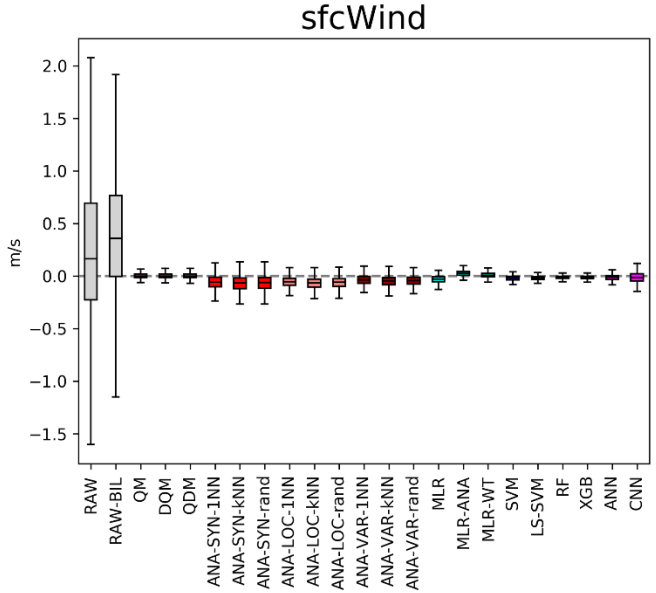
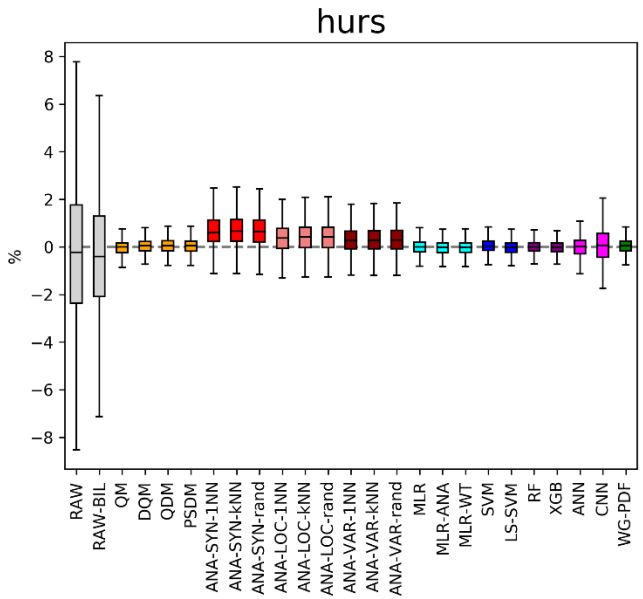
Part II: Central America, different variables

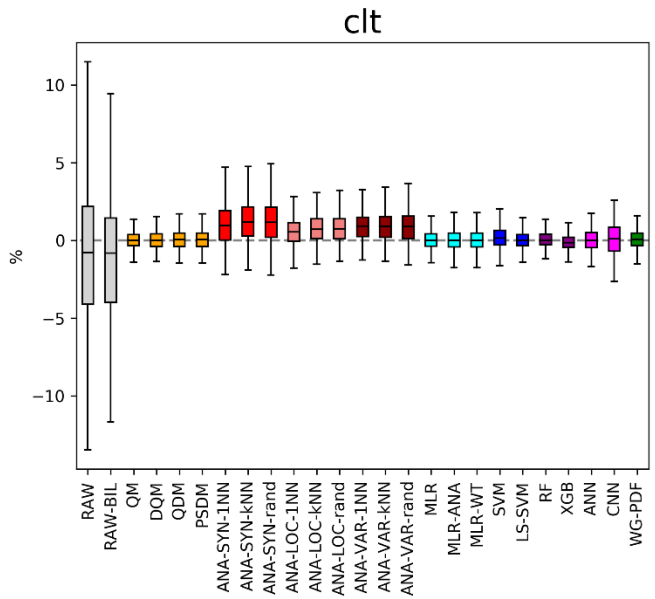
Bias mean/accumulated values











RAW (interpolatioin)

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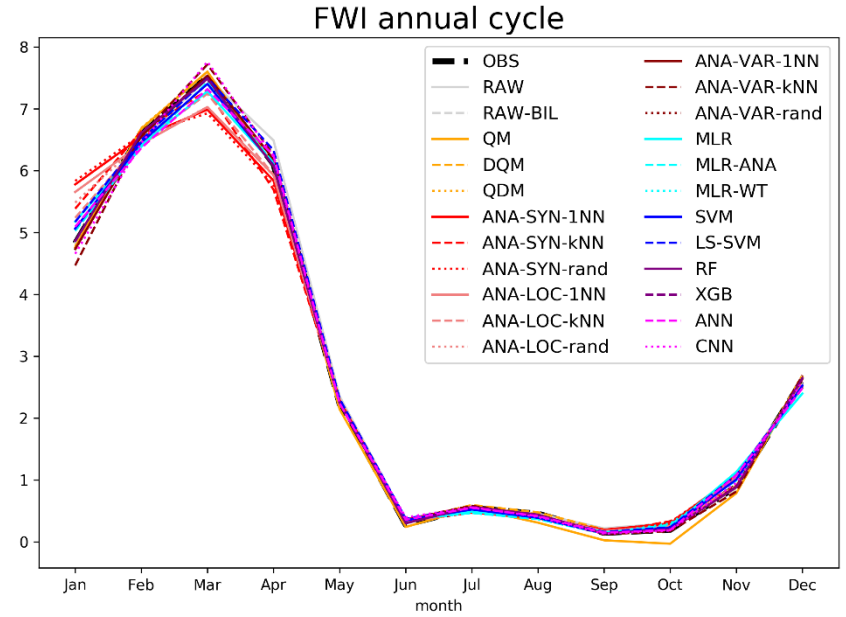
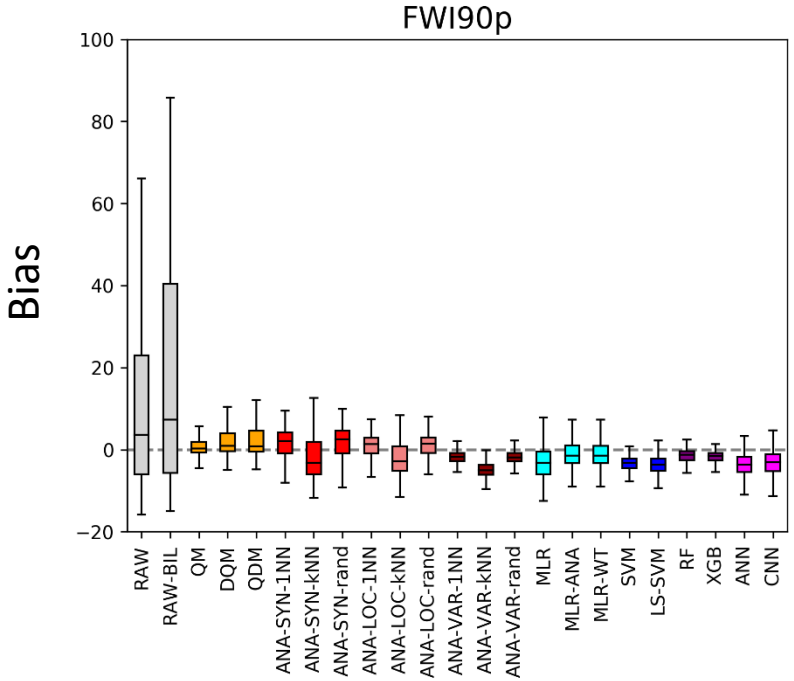
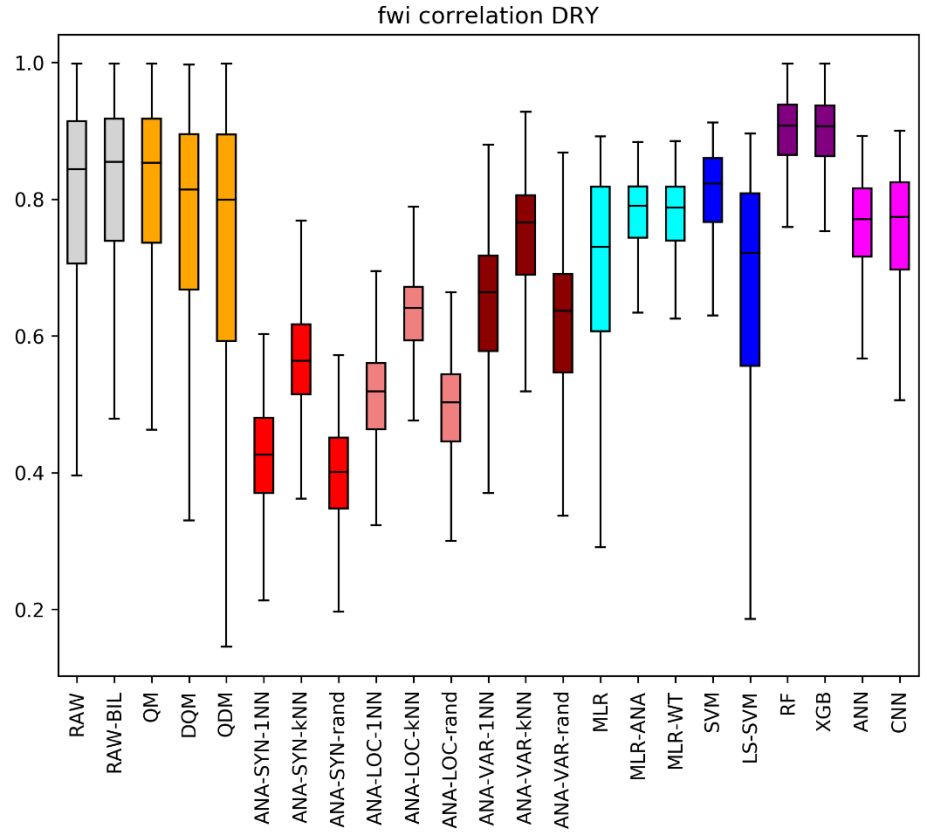




SD can lead to intervariable inconsistencies…

Can we downscale multivariable derived indexes?



Example: Canadian Fire Weather Index, based on temperature, precipitation, wind and humidity

FWI90p: number of days over the 90th percentile

References:

Bi Daohua, et al. (2020). Configuration and spin-up of ACCESS-CM2, the new generation Australian Community Climate and Earth System Simulator Coupled Model. *Journal of Southern Hemisphere Earth Systems Science* **70**, 225-251. https://doi.org/10.1071/ES19040

Boucher, O., et al. (2020). Presentation and evaluation of the IPSL-CM6A-LR climate model. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS002010. https://doi.org/10.1029/2019MS002010

Döscher, R et al. (2021). The EC-Earth3 Earth System Model for the Climate Model Intercomparison Project 6, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2020-446, in review.

Eyring, V., et al. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937-1958, https://doi.org/10.5194/gmd-9-1937-2016

Funk, C., *et al.* (2015) The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Sci Data* **2,** 150066. https://doi.org/10.1038/sdata.2015.66

Hersbach, H, et al. (2020). The ERA5 global reanalysis. *Q J R Meteorol Soc*. 146: 1999– 2049. https://doi.org/10.1002/qj.3803

Maraun, D., et al. (2015) Value: a framework to validate downscaling approaches for climate change studies. *Earth's Future*, 3(1), 1– 14. https://doi.org/10.1002/2014EF000259

Mauritsen, T., et al. (2019). Developments in the MPI-M Earth System Model version 1.2 (MPI-ESM1.2) and its response to increasing CO_2. *Journal of Advances in Modeling Earth Systems*, 11, 998– 1038. https://doi.org/10.1029/2018MS001400

References:

Müller, W. A., et al. (2018). A higher-resolution version of the Max Planck Institute Earth System Model (MPI-ESM1.2-HR). Journal of Advances in Modeling Earth Systems, 10, 1383– 1413. https://doi.org/10.1029/2017MS001217

Peral, C., Navascués, B., and Ramos, P. (2017). Serie de precipitación diaria en rejilla con fines climáticos. Nota Técnica nº 24 AEMET. http://www.aemet.es/documentos/es/conocermas/recursos_en_linea/publicaciones_y_estudios/publicaciones/NT_24_AEMET/NT_24_AEMET.pdf

Swart, N. C., et al. (2019). The Canadian Earth System Model version 5 (CanESM5.0.3), Geosci. Model Dev., 12, 4823–4873, https://doi.org/10.5194/gmd-12-4823-2019

Tatebe, H., et al. (2019): Description and basic evaluation of simulated mean state, internal variability, and climate sensitivity in MIROC6, Geosci. Model Dev., 12, 2727–2765, https://doi.org/10.5194/gmd-12-2727-2019

Volodin, E.M., et al. (2013). Simulation and prediction of climate changes in the 19th to 21st centuries with the Institute of Numerical Mathematics, Russian Academy of Sciences, model of the Earth's climate system. Izv. Atmos. Ocean. Phys. 49, 347–366. https://doi.org/10.1134/S0001433813040105

Volodin, E.M., et al. (2017). Simulation of modern climate with the new version of the INM RAS climate model. Izv. Atmos. Ocean. Phys. 53, 142–155. https://doi.org/10.1134/S0001433817020128

Yukimoto, S., et al. (2019). The Meteorological Research Institute Earth System Model version 2.0, MRI-ESM2. 0: Description and basic evaluation of the physical component. Journal of the Meteorological Society of Japan. Ser. II. https://doi.org/10.2151/jmsj.2019-051

Thanks for your attention!

Questions?

Suggestions are welcome!