Ensemble bias correction of climate simulations: preserving internal variability

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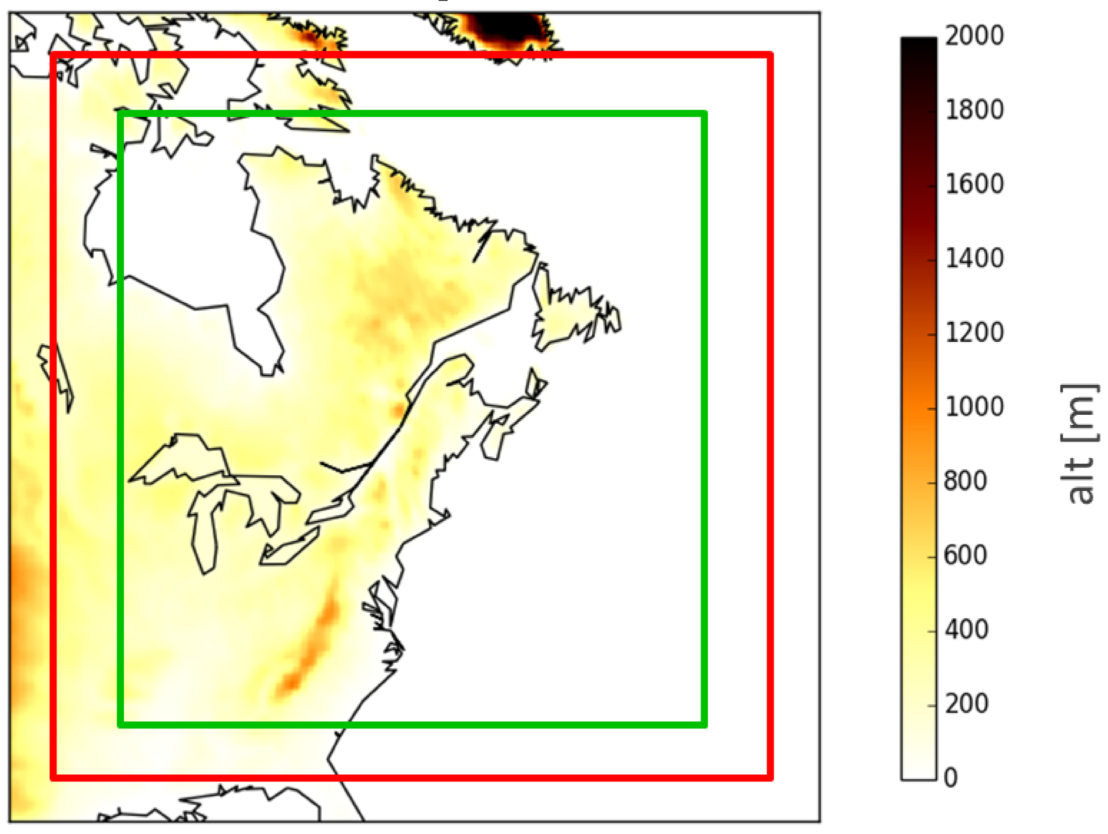
Abstract

Climate simulations often need to be adjusted (i.e., corrected) before any climate change impacts studies. However usual bias correction approaches do not differentiate the bias from the different uncertainties of the climate simulations: scenario uncertainty, model uncertainty and internal variability. In particular, in the case of a multi-run ensemble of simulations (i.e., multiple runs of one model), correcting, as usual, each member separately, would mix up the model biases with its internal variability. In this study, two ensemble bias correction approaches preserving the internal variability of the initial ensemble are proposed. These "Ensemble bias correction" (EnsBC) approaches are assessed and compared to the approach where each ensemble member is corrected separately, using precipitation and temperature series at two locations in North America from a multi-member regional climate ensemble. The preservation of the internal variability is assessed in terms of monthly mean and hourly quantiles. Besides, the preservation of the internal variability in a changing climate is evaluated. Results show that, contrary to the usual approach, the proposed ensemble bias correction approaches adequately preserve the internal variability even in changing climate. Moreover, the climate change signal given by the original ensemble is also conserved by both approaches.

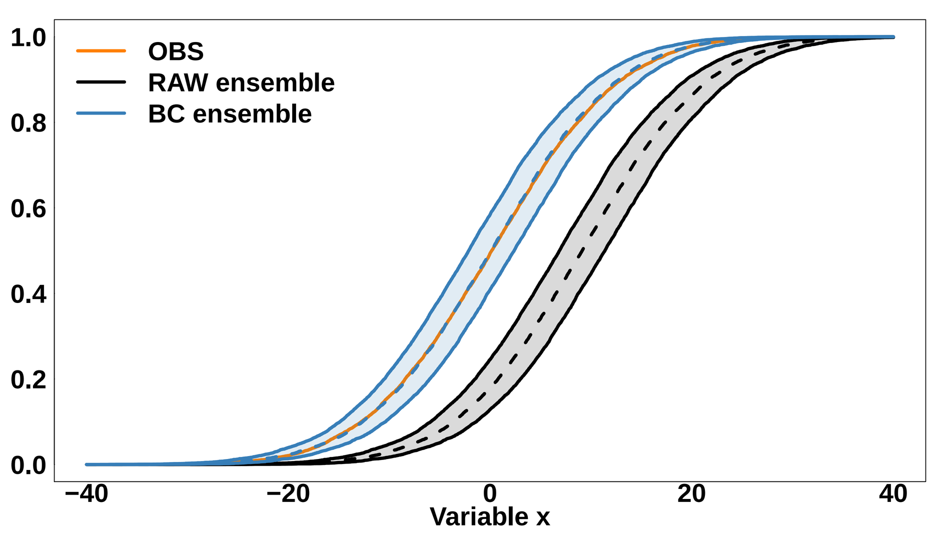
Study area and Datasets

Canadian Regional Climate Model Large Ensemble [**CRCM5-LE**, Leduc et al., 2019] : 50 hourly simulations at 0.11° of spatial resolution under RCP 8.5.



1. **Observations** from two hourly weather stations [HadISD database , Dunn et al., 2016] over the period 1961-1990 calibration period : Chicago O'Hare and New York LaGuardia airports.
2. **Precipitation and temperature** from CRCM5 grid-cell containing the stations are extracted.

Methods



CDF-t - Vrac et al. [2012]

- Transformation T applied to RCM CDF
- F_{S_C} Verifies by definition $T\left(F_{M_C}(x)\right) = F_{S_C}(x)$ (1)
- Assumption: Eq. (2) remains valid in the future

	Present (calib.)	**Futur** (proj.)
RCM	$F_{M_C}(x)$	$F_{M_P}(x)$
	$\Downarrow T$	$\Downarrow T$
Station	$F_{S_C}(x)$	?? $F_{S_P}(x)$

$$x = F_{M_C}^{-1}(u) \text{ with } u \in [0,1] \rightarrow T(u) = F_{S_C}\left(F_{M_C}^{-1}(u)\right) \quad (2)$$

$$\widehat{F}_{S_P^{(m)}}(x) = F_{S_C}\left(F_{M_C^{(m)}}^{-1}\left(F_{M_P^{(m)}}(x)\right)\right). \quad \text{(BCIND)}$$

Bias-corrected quantile: $\widehat{x}_{S_P^{(m)}} = \widehat{F}_{S_P^{(m)}}^{-1}\left(F_{M_P^{(m)}}(x_{M_P^{(m)}})\right)$ (3)

Avantage: Changes of the large-scale CDF accounted for

Question: How to preserve the Internal Variability (IV)?

Use of F_{M-Ens_C} to account for the IV.

1. F_{M-Ens_C} replace $F_{M_C^{(m)}}^{-1}$ in (BCIND)

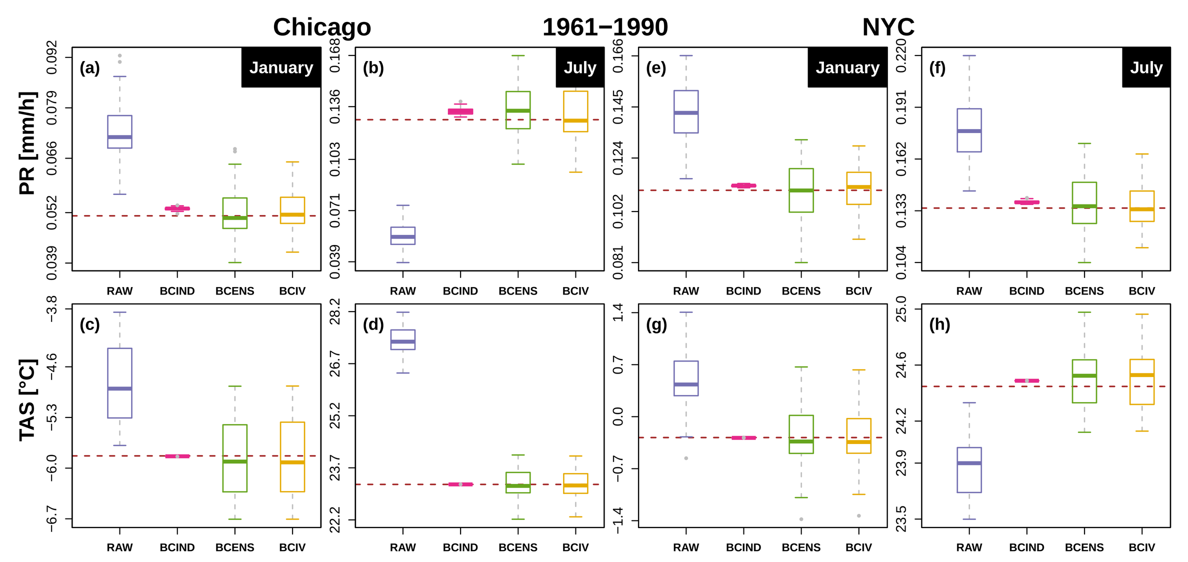
$$\widetilde{F}_{S_P^{(m)}}(x) = F_{S_C}\left(F_{M-Ens_C}^{-1}\left(F_{M_P^{(m)}}(x)\right)\right). \quad \text{(BCENS)}$$

2. Assuming a stationary climate over the 30-year reference period: Δ is added to Eq.3 : $\widehat{x}_{S_P^{(m)}} = \widehat{F}_{S_P^{(m)}}^{-1}\left(F_{M_P^{(m)}}(x_{M_P^{(m)}})\right)$

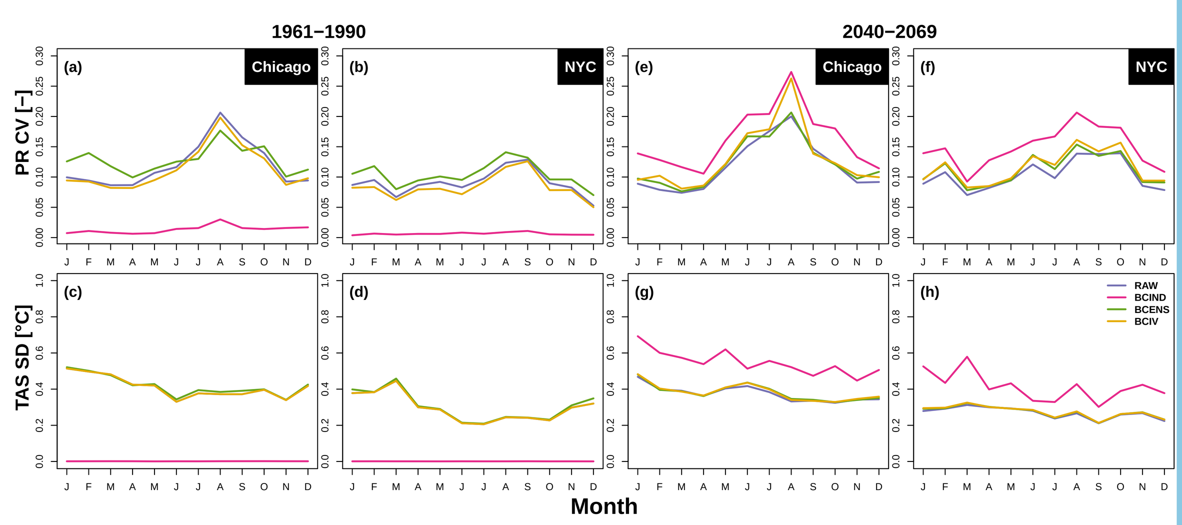
$$\text{(BCIV)} \begin{cases} \widetilde{x}_{S_P^{(m)}} = \widehat{x}_{S_P^{(m)}} + \Delta \\ \Leftrightarrow = \widehat{F}_{S_P^{(m)}}^{-1}\left(F_{M_P^{(m)}}(x_{M_P^{(m)}})\right) \\ + F_{M_C^{(m)}}^{-1}\left(F_{M_P^{(m)}}(x_{M_P^{(m)}})\right) - F_{M-Ens_C}^{-1}\left(F_{M_P^{(m)}}(x_{M_P^{(m)}})\right) \end{cases}$$

Results

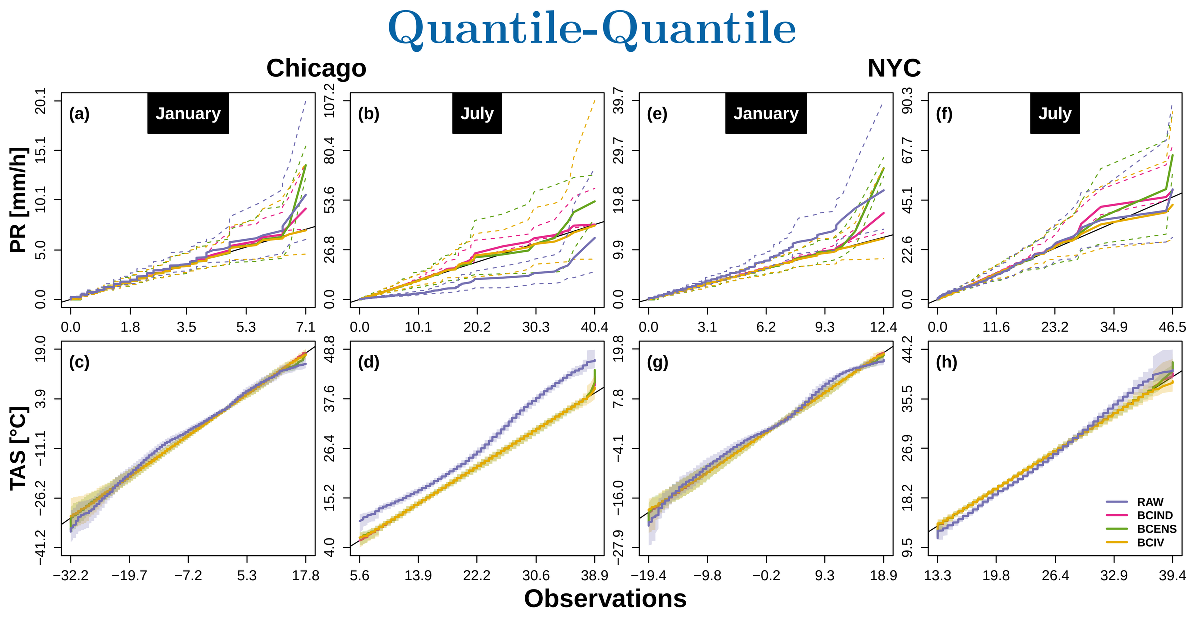
Monthly mean



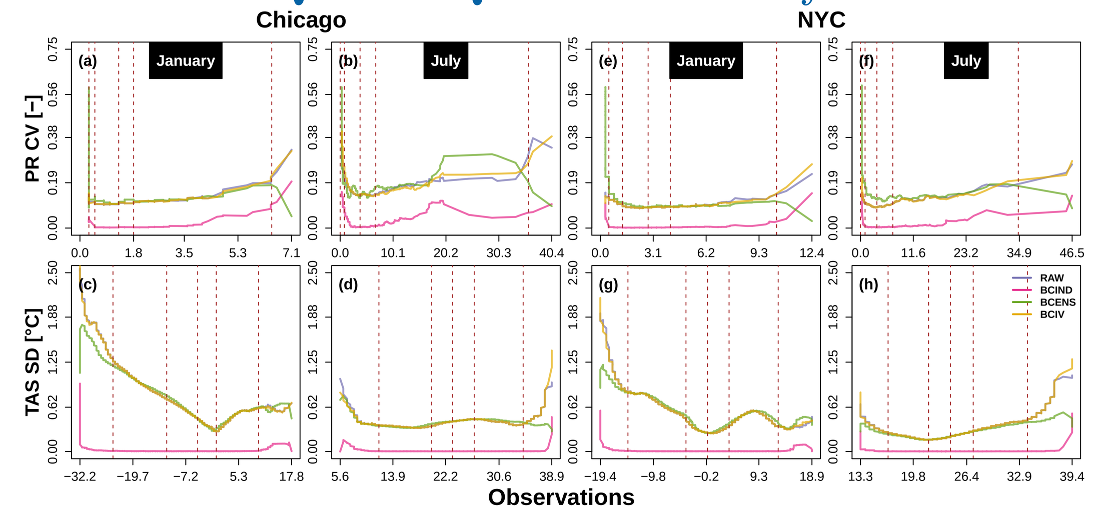
Monthly mean variability CV=$\frac{\text{sd}}{\text{median}}$



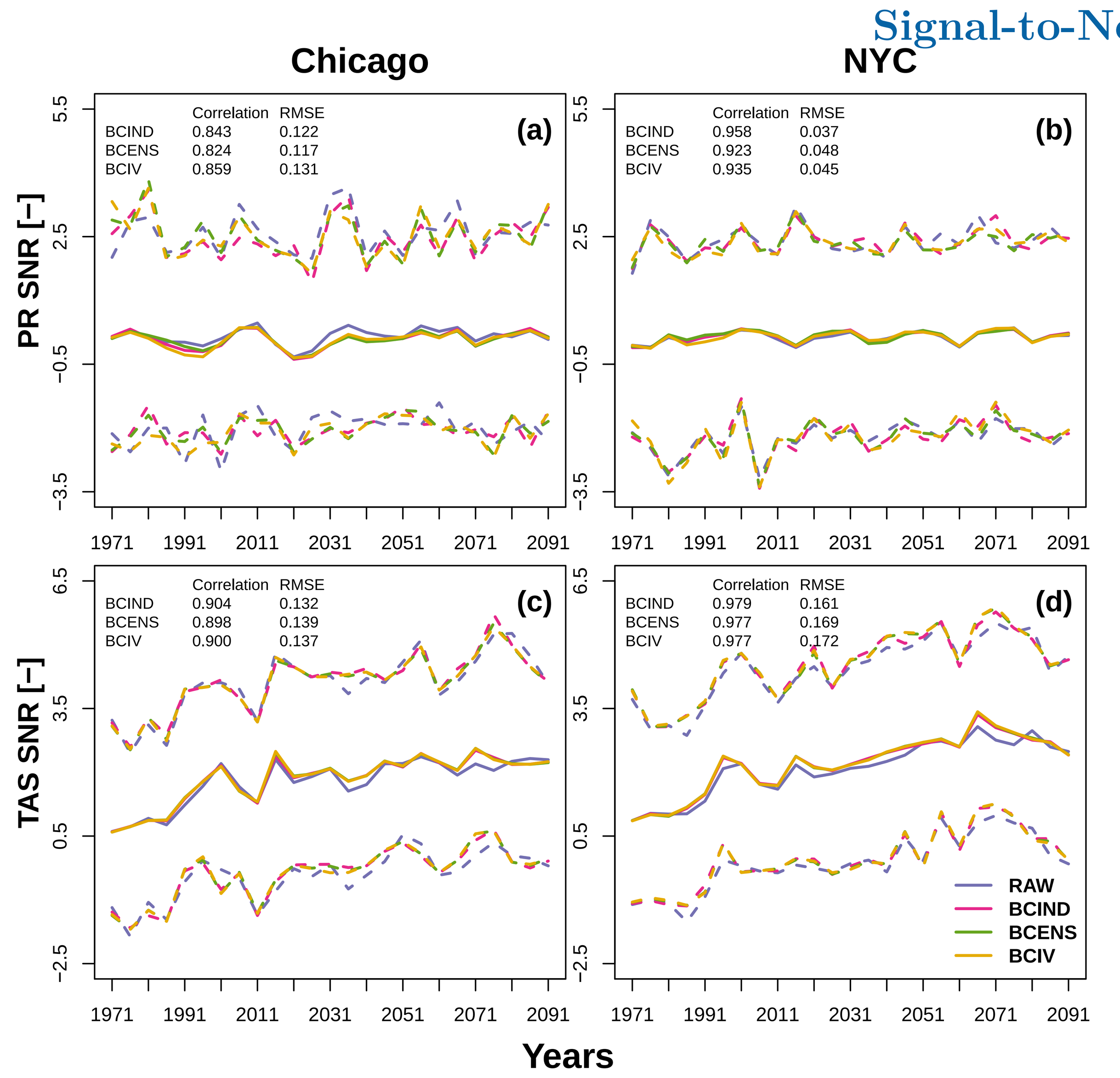
Quantile-Quantile



Quantile-Quantile variability



Signal-to-Noise Ratio



Measure the contribution of the IV to climate change signal

$$\text{SNR} = \frac{\text{mean(trends)}}{\text{sd(trends)}}$$

SNR estimated for each 20-year sliding window (shifted every five years)

Conclusions& Perspectives

1. Conclusions

- Usual BCIND: completely fails in the preservation of the raw ensemble IV.
- BCENS and BCIV are successful to provide bias corrections respecting the raw ensemble IV.
- BCIV has a clear advantage regarding the preservation of the variability of extremes
- All approach preserve the raw ensemble IV contribution to the climate change signal

2. Perspectives

- Test robustness of the findings for other univariate and multi-variate BC approaches [cf., François et al., 2020, and reference therein].
- The question is still open for the inter-model variability in the case of a multi-model ensemble.
- Evaluation of EnsBC through ensemble variability partitioning and estimation though "analysis of variance".
- EnsBC methods can be assessed through impact modelling.

Reference

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