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Regional Characteristics of Statistically Bias-Corrected NARCCAP Data

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ABSTRACT

Climate model output often contains significant biases that must be removed before the data is used for impacts analysis or as a forcing input for other models. We apply statistical bias correction to monthly mean surface air temperature and precipitation data from the NARCCAP output archive and examine the characteristics of the distributions of these fields on a regional basis. Bias-correcting monthly data at the regional scale is the first step in developing a methodology for bias-correcting daily data at the gridcell level, and also will provide valuable information for studies of bias in these simulations.

First, we decompose the monthly average data into climatic regions, using the Bukovsky regionalization for North America. Operating on a regional basis, we then fit an appropriate statistical distribution (gaussian for temperature and gamma for precipitation) to RCM output. Next, we bias-correct model output by using quantile mapping (QM) to create a transfer function that adjusts the distribution of model data from the current-climate simulations to match the cumulative distribution function (CDF) of observed data (from the University of Delaware half-degree gridded observational dataset) for the same period. The same transfer function is then applied to output from the future-climate simulations. Finally, we fit the corrected data with an appropriate statistical distribution.

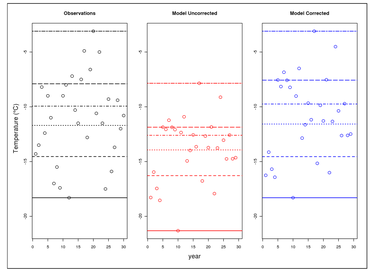
Because the statistical distributions are characterized by two parameters, we can then summarize the biases and the changes in the distributions due to bias-correction and due to climate change in terms of changes in those parameters. We examine these changes on a regional basis for the entire North American simulation domain and throughout the annual cycle.

QUANTILE MAPPING

1) Calculate quantiles for observations and model data
   $N_{bins} = 1 + \log_2(N_{points})$ [Sturges' formula]

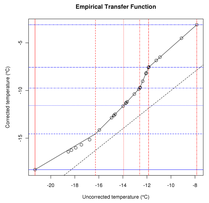
2) Apply a linear transformation (scale + offset) to each quantile in the current-period model data to adjust its range to match the corresponding quantile in the observed data

3) Apply the same correction to the quantiles of the future data

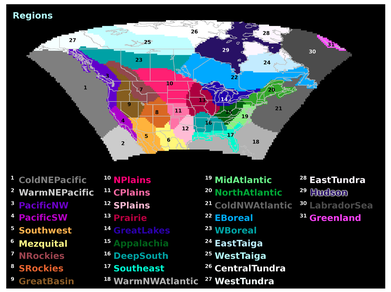


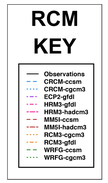
Because our observational dataset is monthly, we apply bias-correction by month over the Bukovsky regions. Quantile mapping is performed using `fitQmapQUANT()` from the `qmod` library for R. $N_{bins} = 15$.

Simple bias correction only shifts the mean of the data (equivalent to adjusting σ or θ for normal and gamma distributions, respectively). By construction, quantile mapping corrects all moments of the data.



BUKOVSKY REGIONS

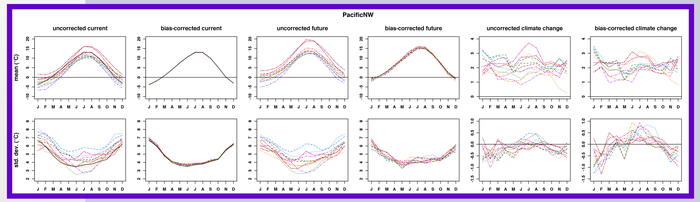


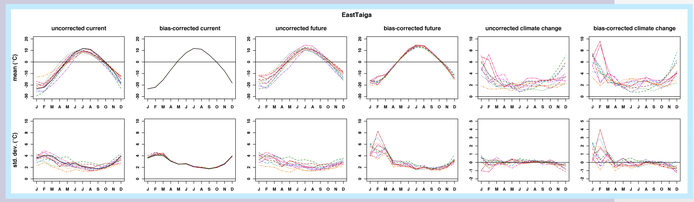


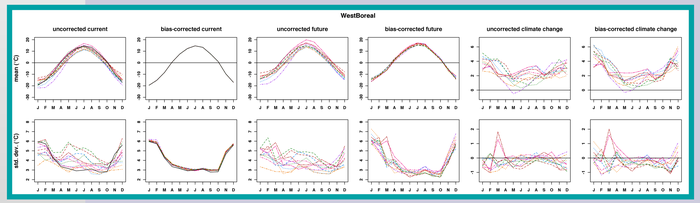
THE GAMMA DISTRIBUTION

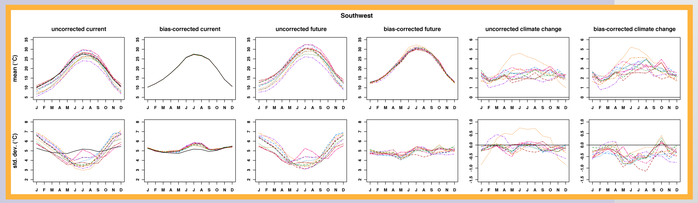
Precipitation intensity on wet days is characterized by a gamma distribution. This distribution has two parameters: shape (k) and scale (θ), both positive. The mean of the distribution is equal to $k\theta$ and the peak (mode) is located at $(k-1)\theta$. If k=1, the distribution behaves like a negative exponential. As k increases, the distribution behaves more like a Gaussian. If k increases while θ decreases in proportion, the mean will stay constant, but rainfall will become less frequent and more intense as the upper tail becomes fatter; if k decreases while θ increases, rainfall becomes more constant and drizzly.

TEMPERATURE









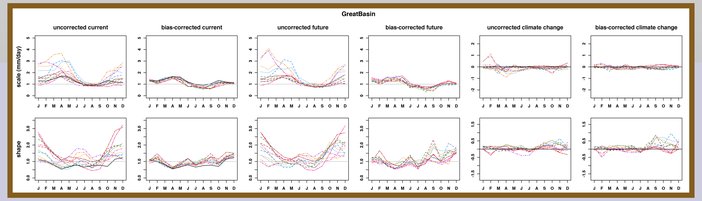
PacificNW: Although bias correction improves agreement between the models dramatically, there is **no clear overall effect** on the climate change signal.

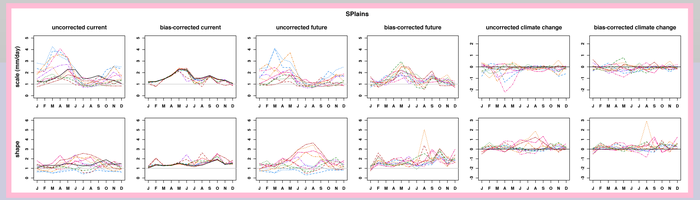
WestBoreal: After bias correction, most models show an **increase in the change in the mean** during winter months. A similar pattern is exhibited in the WestTundra and NPlains regions.

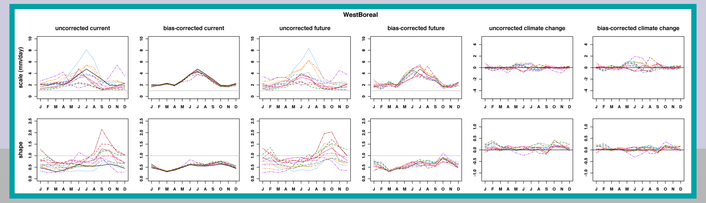
EastTaiga: After bias correction, most models show a significant **increase in interannual variability (std.dev.)** during winter months. A similar pattern appears in the EastBoreal and EastTundra regions.

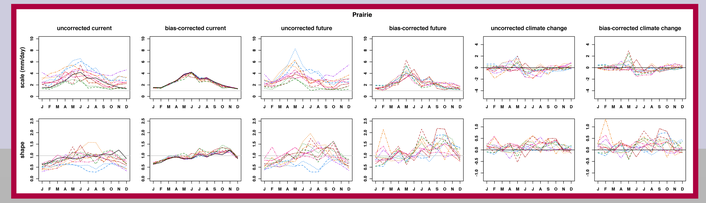
SouthWest: In summer, **bias correction enhances both an increase in the mean and a decrease in the variance**. The Mezquital and PacificSW regions show similar patterns.

PRECIP









GreatBasin: Although bias correction significantly improves model agreement and reduces bias in this region, there is **minimal effect on the climate change signal**. This is typical for precipitation in most regions.

WestBoreal: Bias correction **amplifies the climate change signal** in summer, increasing scale while leaving the shape parameter unchanged. A similar pattern appears in the WestTaiga and WestTundra regions.

SPlains: Bias correction **diminishes the climate change signal**, reducing scale decrease in spring and shape increase in summer. A similar pattern appears in the CPlains, NPlains, and SRockies regions.

Prairie: In this region, bias correction **clarifies a complex change signal**, with an increase in scale in late spring, followed by a decrease in scale but increase in shape in summer as precipitation intensifies.

CITATIONS

NARCCAP: Mearns, L.O., et al., 2007, updated 2011. *The North American Regional Climate Change Assessment Program dataset*, NCAR Earth System Grid data portal, Boulder, CO. Data accessed 2011-01-07. http://www.earthsystemgrid.org/project/NARCCAP.html

QMAP: Lukas Gudmundsson, 2012: *qmap: Quantile-mapping for post-processing climate model output*, R package version 1.0-0. http://CRAN.R-project.org/package=qmap

UDEL: Matsuura, K. , and C. Willmott, 2009: *Terrestrial Air Temperature and Precipitation: 1900-2008 Gridded Monthly Time Series (V 2.01)*, Center for Climatic Research, Department of Geography, University of Delaware. Downloaded April 2010. http://climate.geog.udel.edu/~climate/html_pages/archive.html

CONCLUSIONS

- Bias correction can amplify or diminish climate change signals.
- Effects of bias correction vary by season and region.
- Correction of the mean will not correct all significant biases.