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4th VALUE Training School
Validation of Regional Climate Change Projections

Pitfalls II

Douglas Maraun

Wegener Center for Climate and Global Change

Outline

Perfect Prognosis

Bias Correction

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Perfect Prognosis

Bias Correction

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Perfect Prognosis · The Perfect Prognosis Condition

Perfect Prognosis

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‘‘The following notation for the horizontal spatial scales can be adapted: the minimum scale is defined as the distance between two neighboring grid points of the GCM, whereas the skillful scale is larger than N gridpoint distanes. It is likely that $N \leq 8$ (Grotch and MacCracken, 1991). It is widely accepted that present-day GCMs are able to simulate the large-scale atmospheric state in a generally realistic manner, and it is believed that these models are the adequate tool to predict large-scale climate changes. Even though the GCMs produce values on the minimum scale, their implications on regional climate are questionable.” (von Storch et al., J Climate, 1993)

Validation of predictor fields

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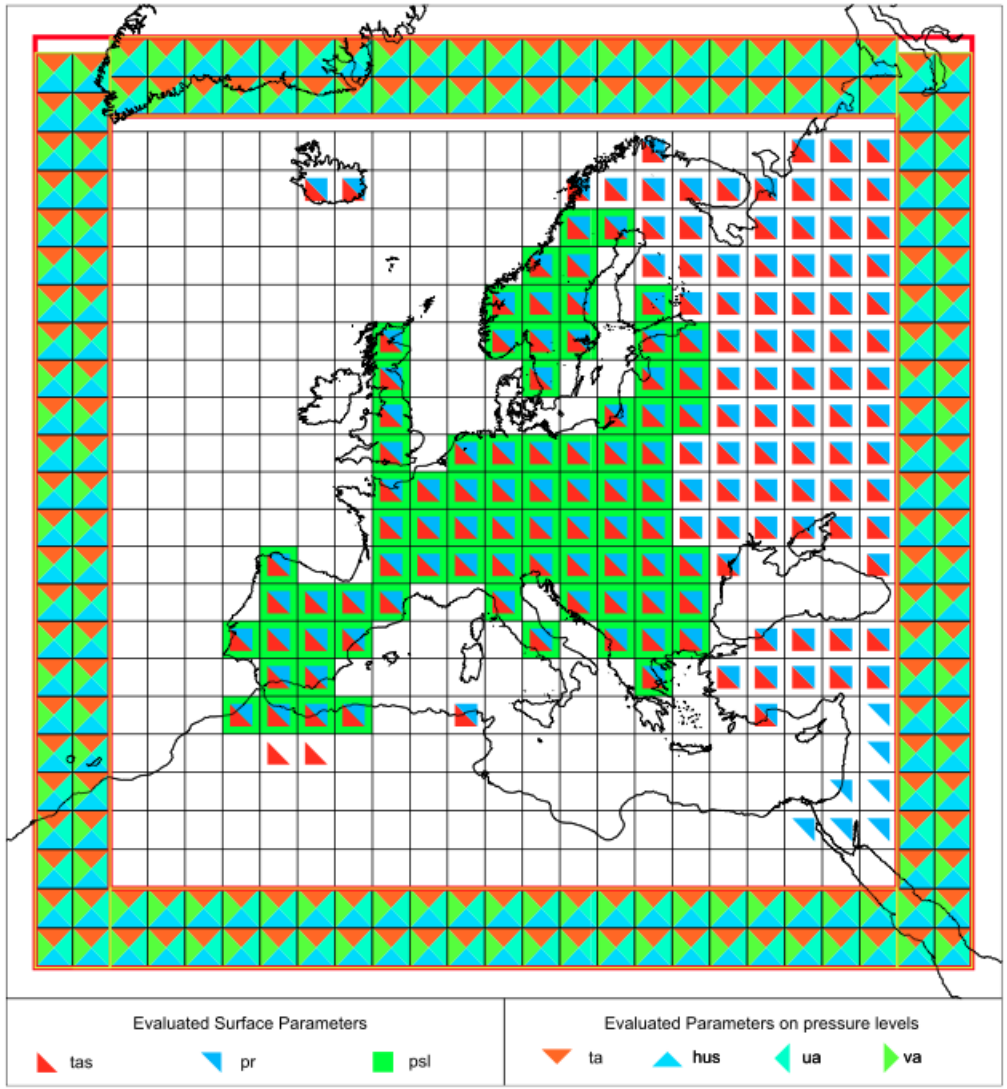
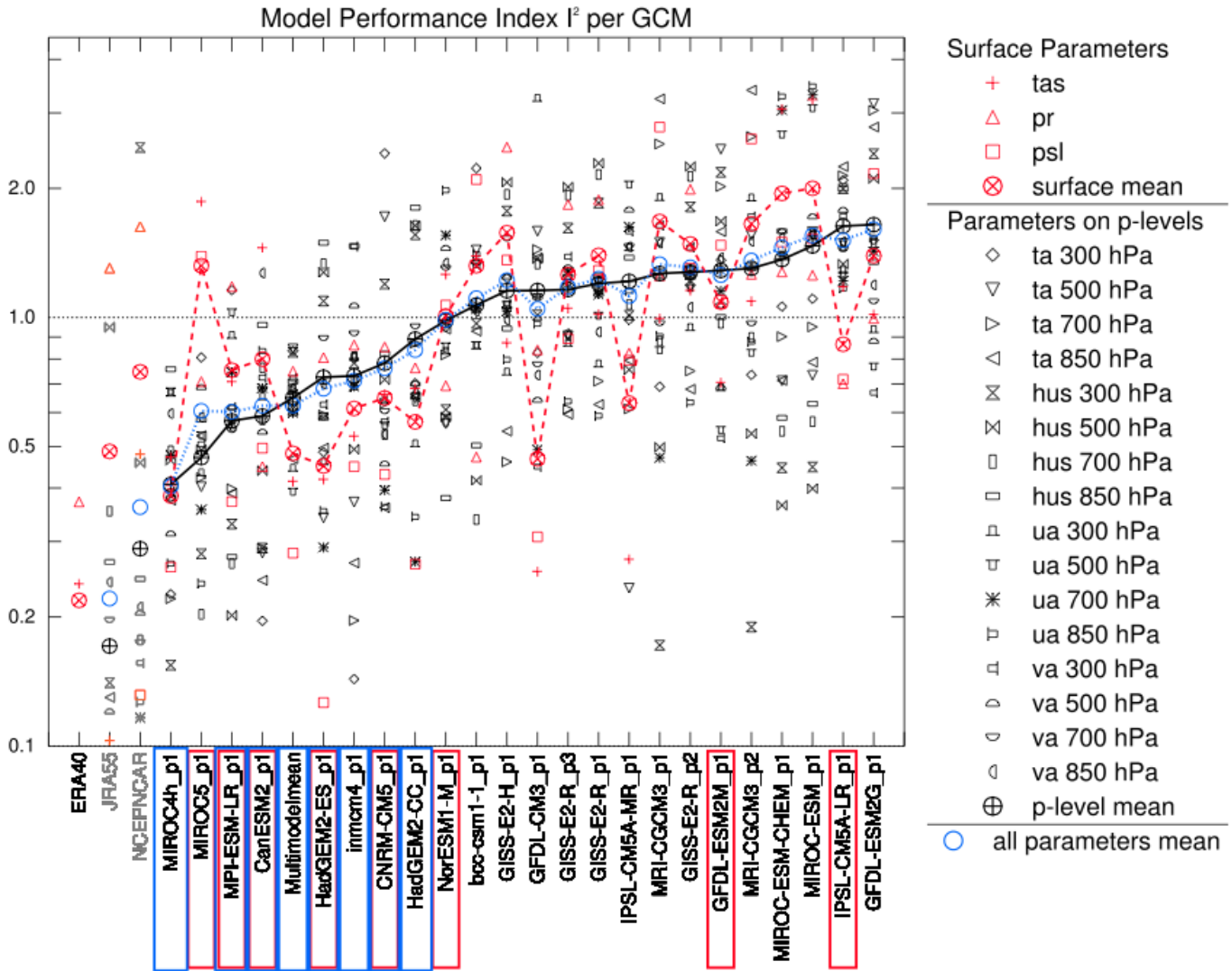


Jury et al., Clim. Dynam., 2015

Validation of predictor fields



Jury et al., Clim. Dynam., 2015

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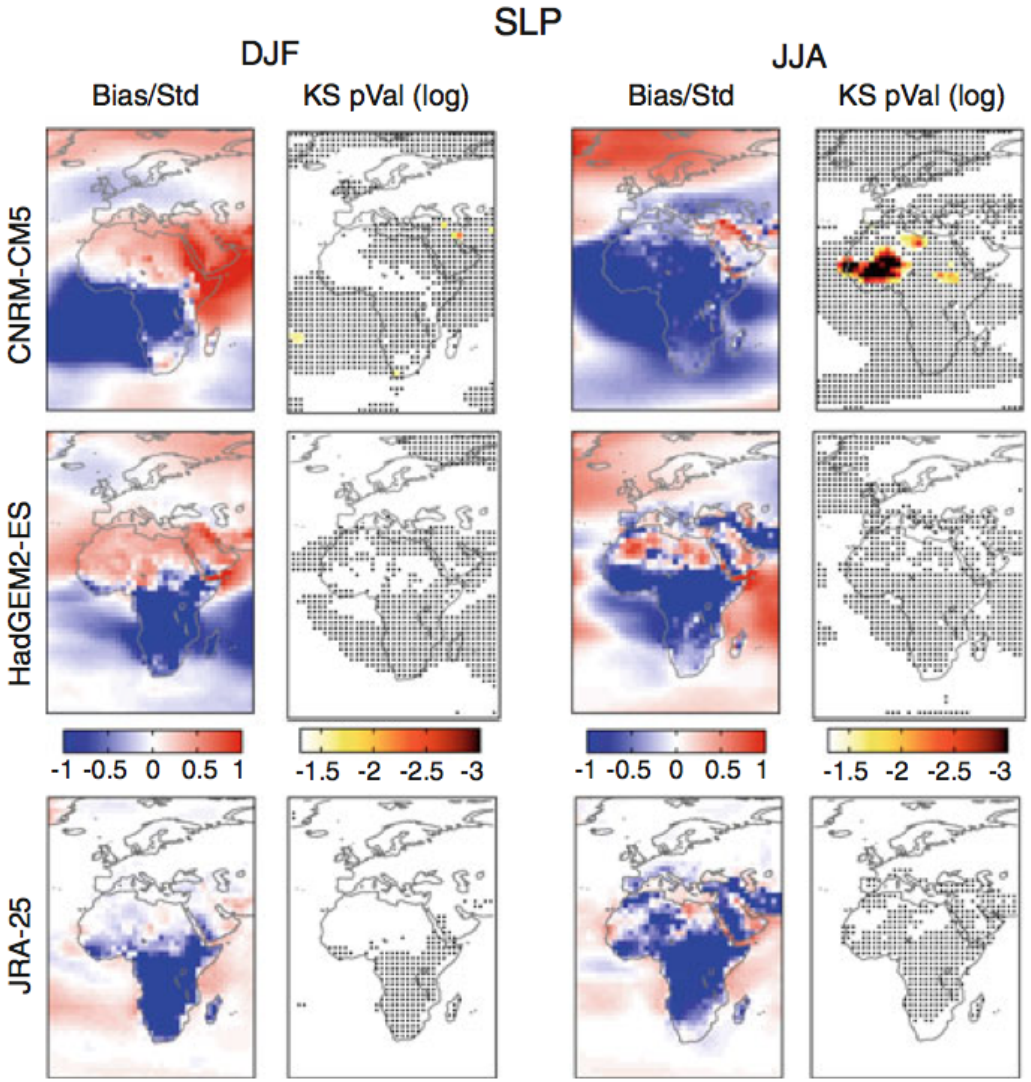

Brands et al., J Climate, 2013

Idea: normalise predictors

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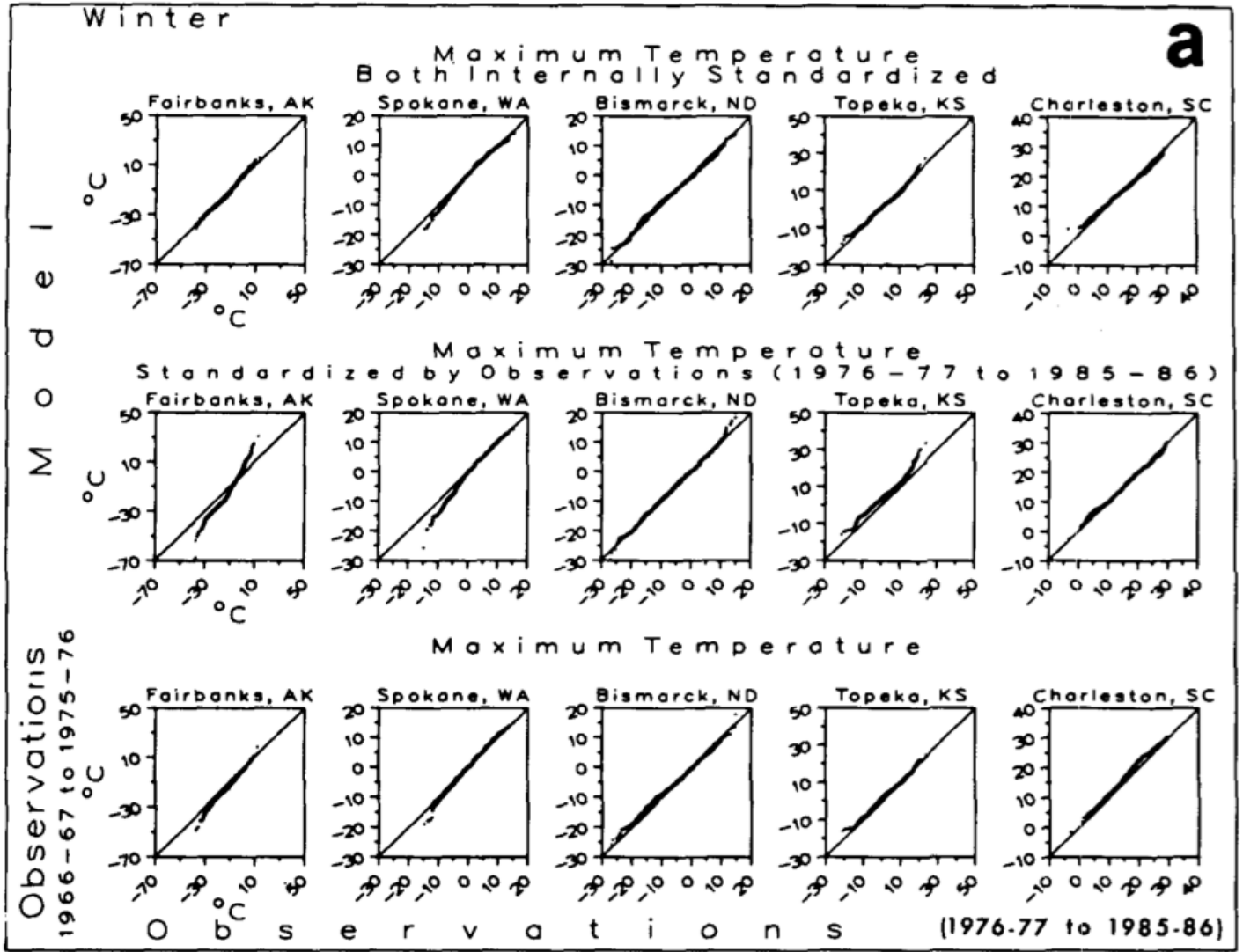
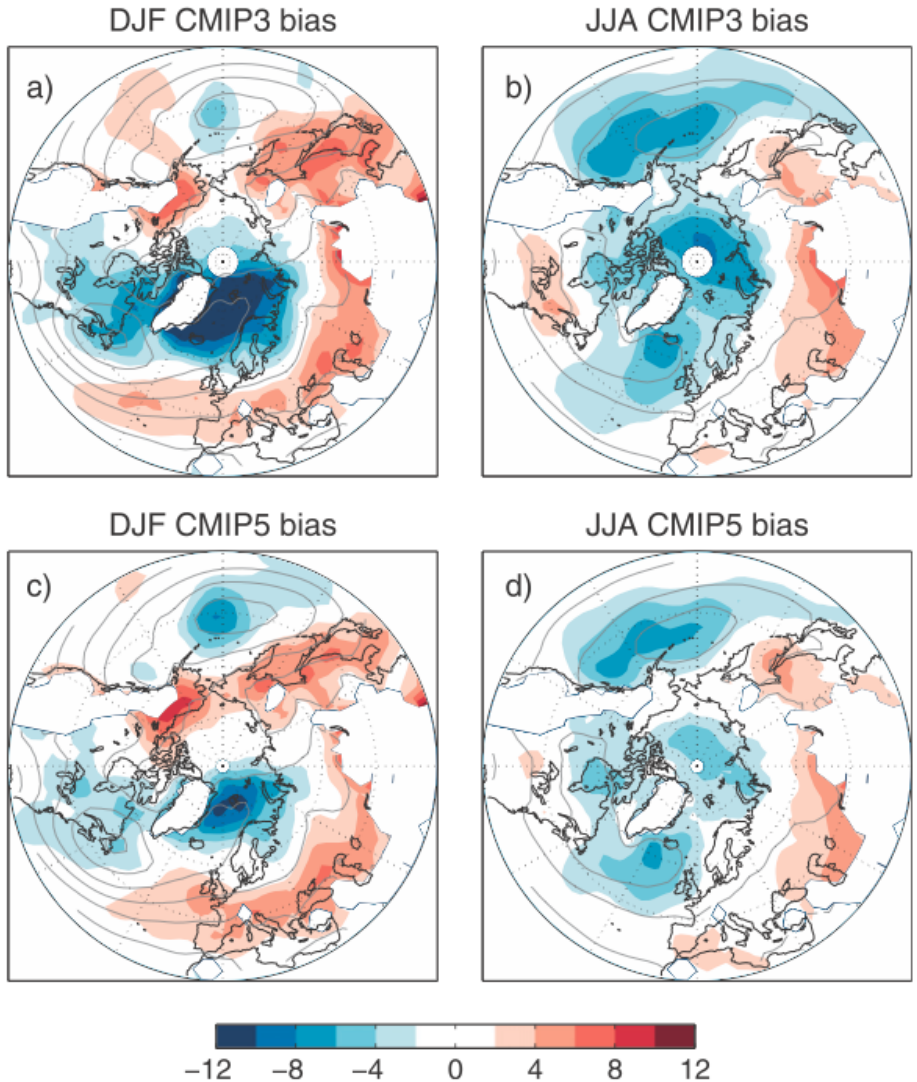
‘‘As Karl et al. (1990) demonstrated, regression-based downscaling methods also benefit from the standardization of the predictor variables (by their respective means and standard deviations) so that the corresponding distributions of observed and present-day GCM predictors are in closer agreement.” (Wilby et al., Env. Mod. Soft. 2002)

Influence of normalised predictors



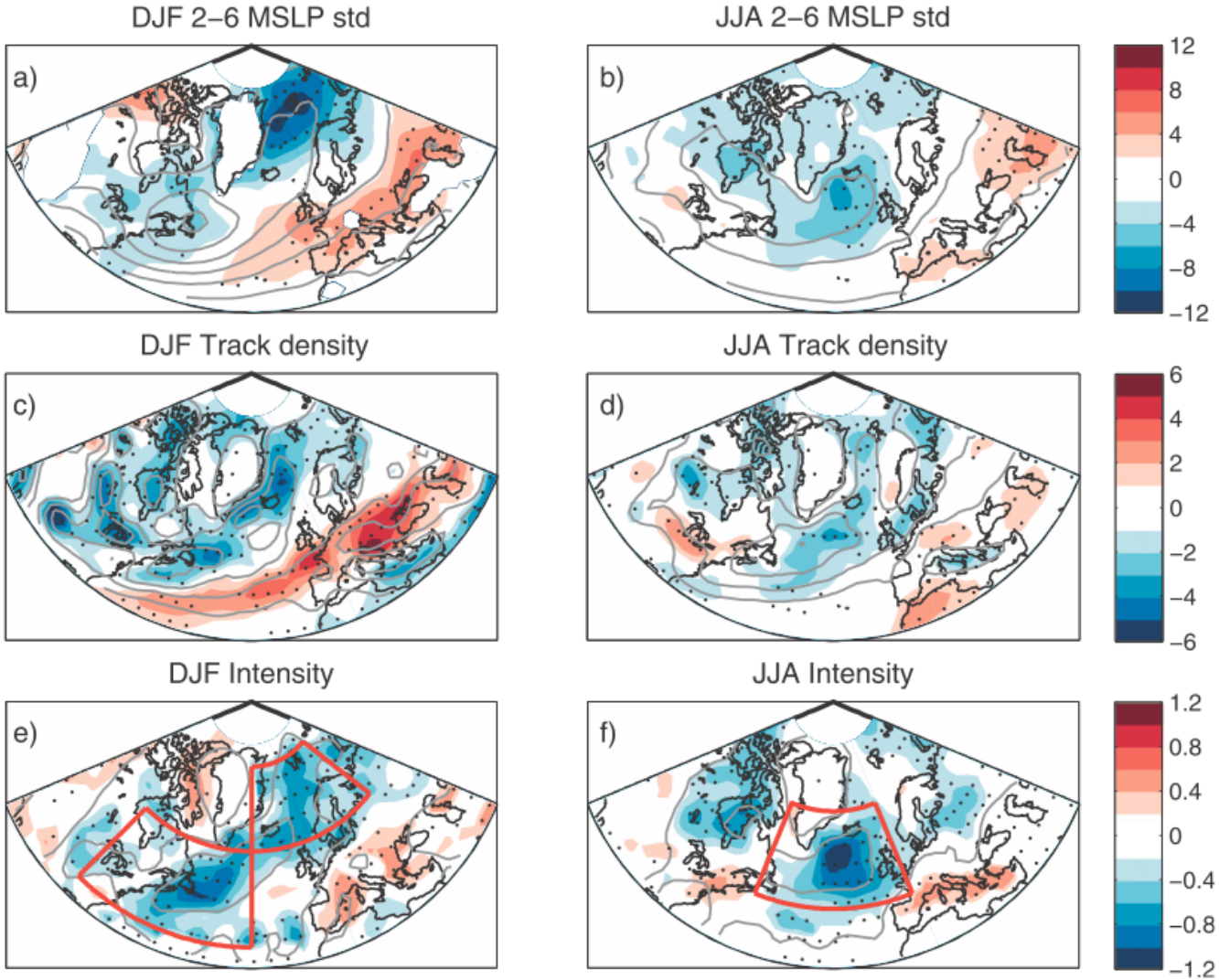
Karl et al., J Climate, 1990

Additionally process understanding



Zappa et al., J Climate, 2013

Additionally process understanding



Zappa et al., J Climate, 2013

Summary PP

- Use large-scale free atmosphere predictors;
- De-biasing by substracting mean;
- But: substracting means “hides” biases and therefore potential problems;
- Are the relevant processes simulated? (Garbage in, garbage out) This is more than comparing means and variances!

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Perfect Prognosis · Variance Inflation

Variance Inflation

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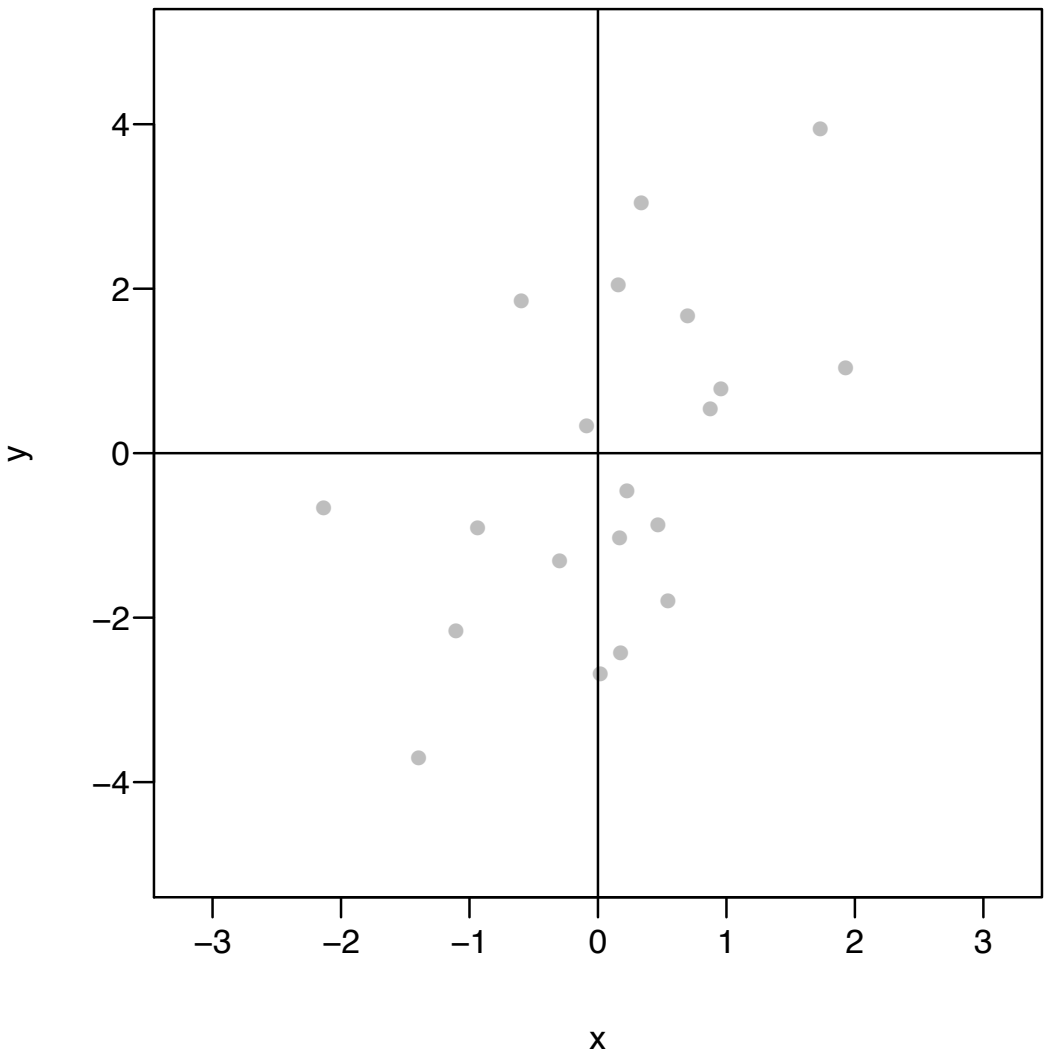
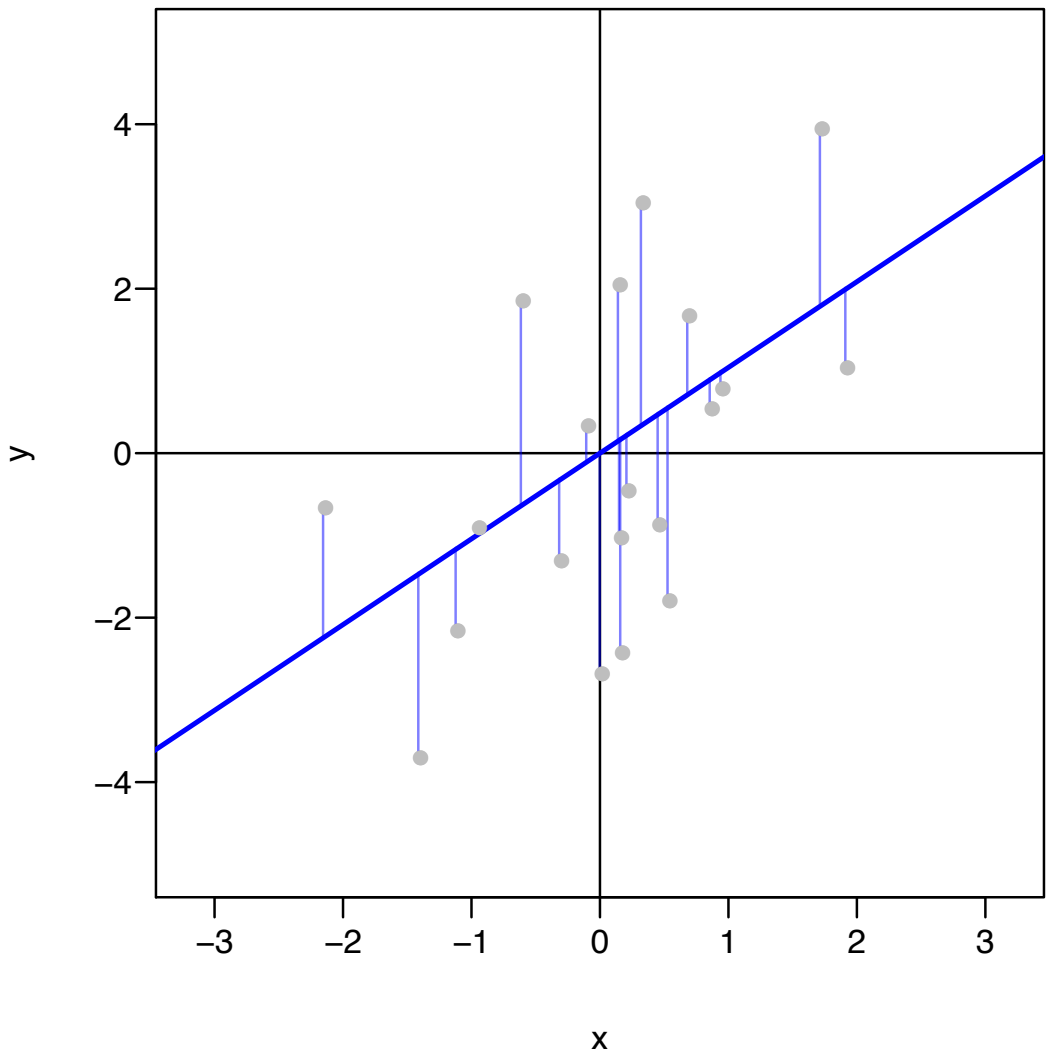
‘‘The method of inflation, developed by Klein et al. (1958) was used, since an important goal of this analysis was to reproduce the actual variance calculated in the observations from the free-atmospheric predictors.” (Karl et al., J. Climate, 1990)

Inflated regression



Maraun, J. Climate, 2014

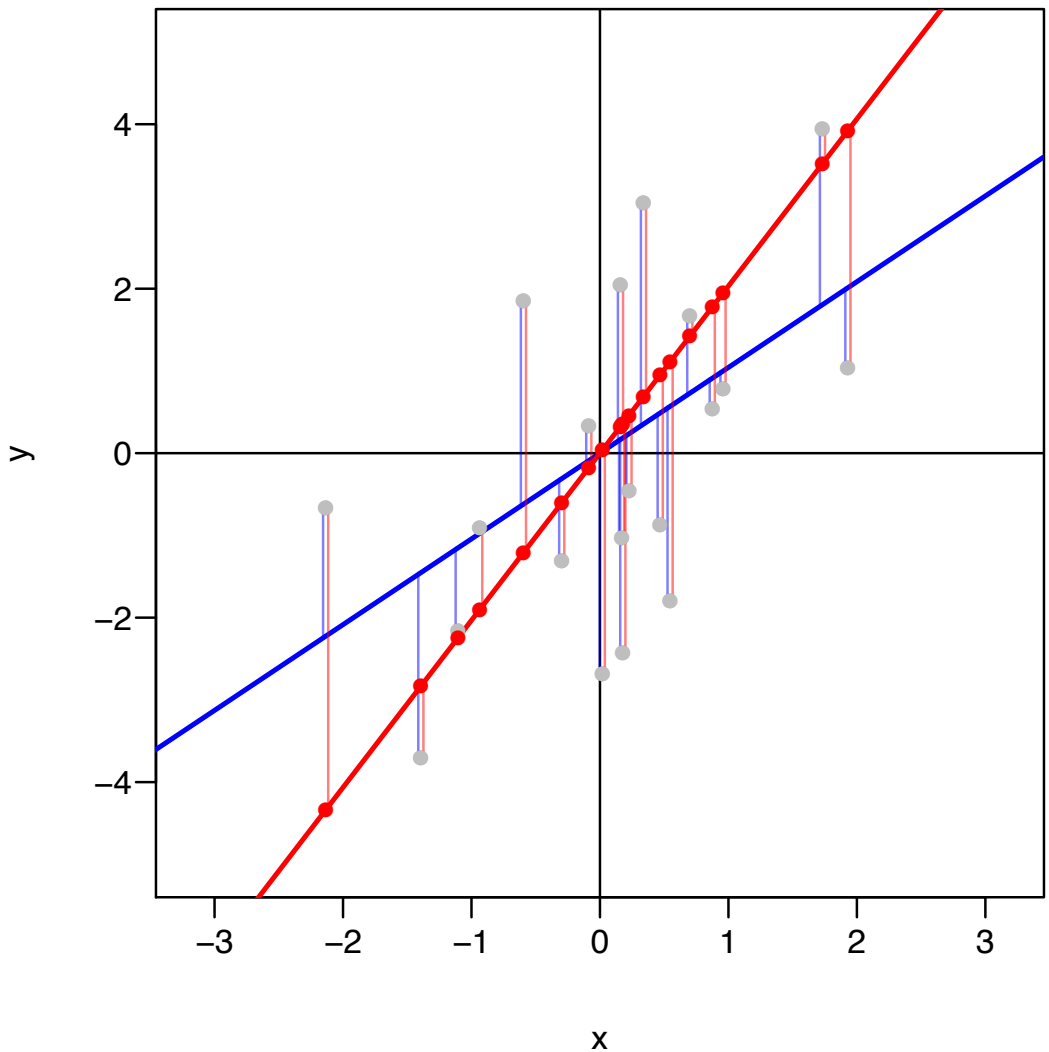
Inflated regression



- prediction underrepresents total variance

Maraun, J. Climate, 2014

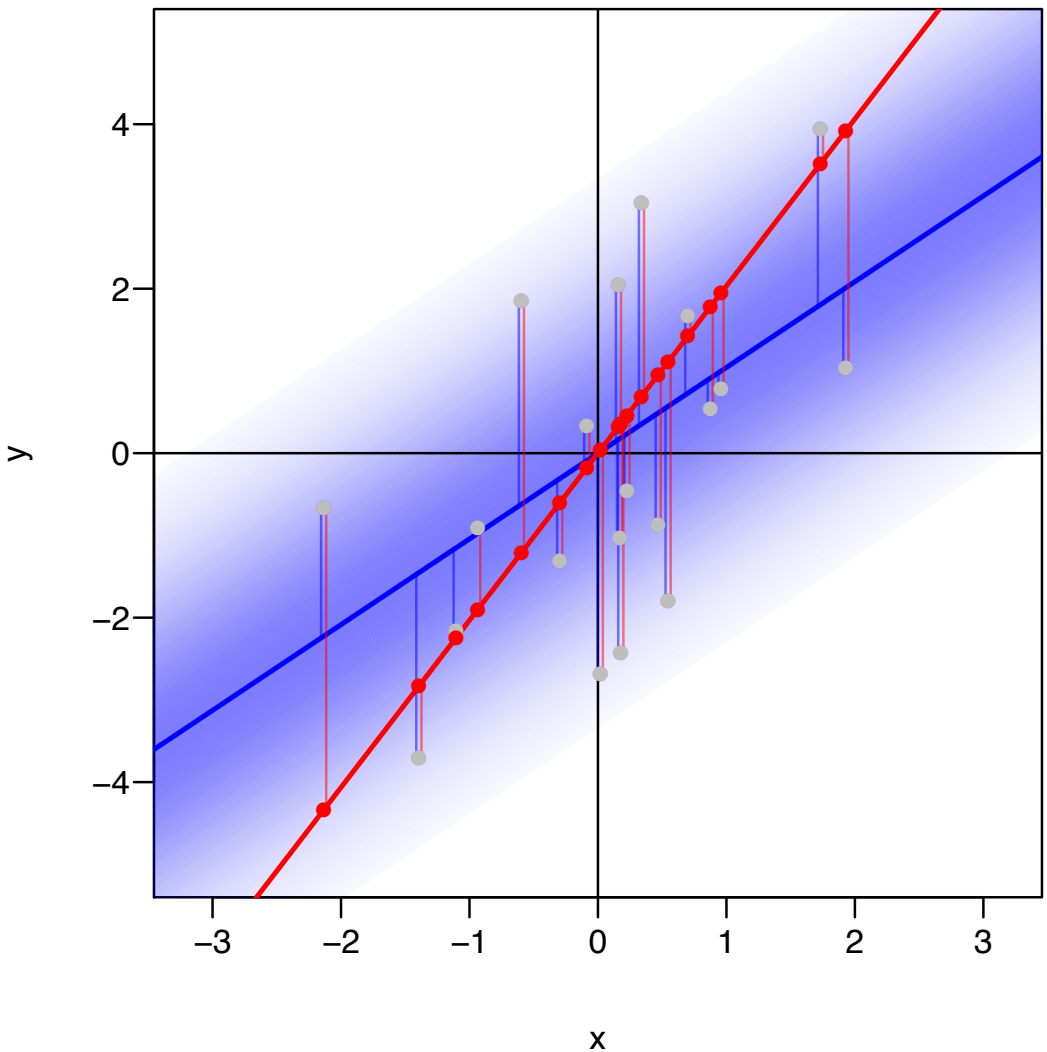
Inflated regression



- prediction underrepresents total variance
- inflate regression (Klein et al., 1958; Karl et al., 1990; Bürger, 1996

Maraun, J. Climate, 2014

Inflated regression



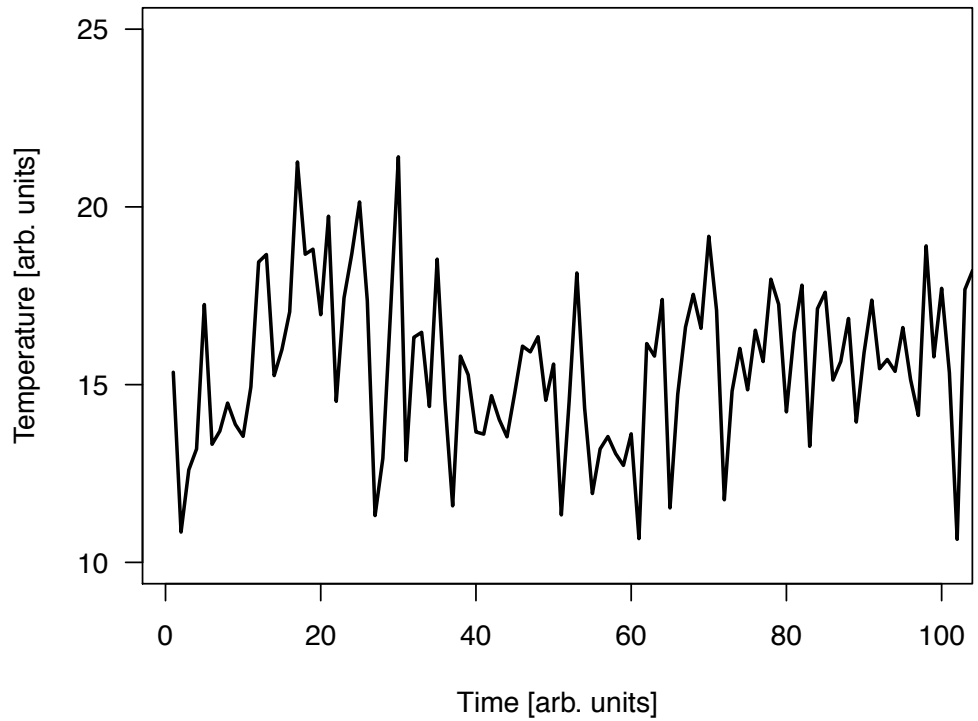
- prediction underrepresents total variance
- inflate regression (Klein et al., 1958; Karl et al., 1990; Bürger, 1996
- flawed concept (Glahn and Allen, 1966; von Storch, 1999; Maraun, 2013)

Maraun, J. Climate, 2014

Inflated time series

Simulated example:

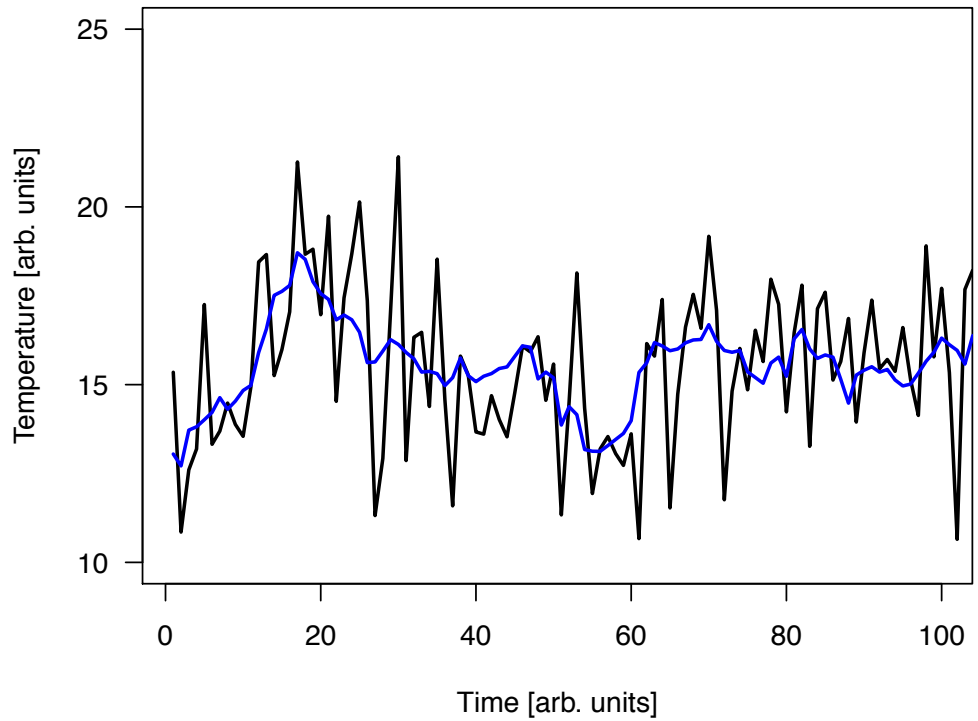
black: “observed” series;



Inflated time series

Simulated example:

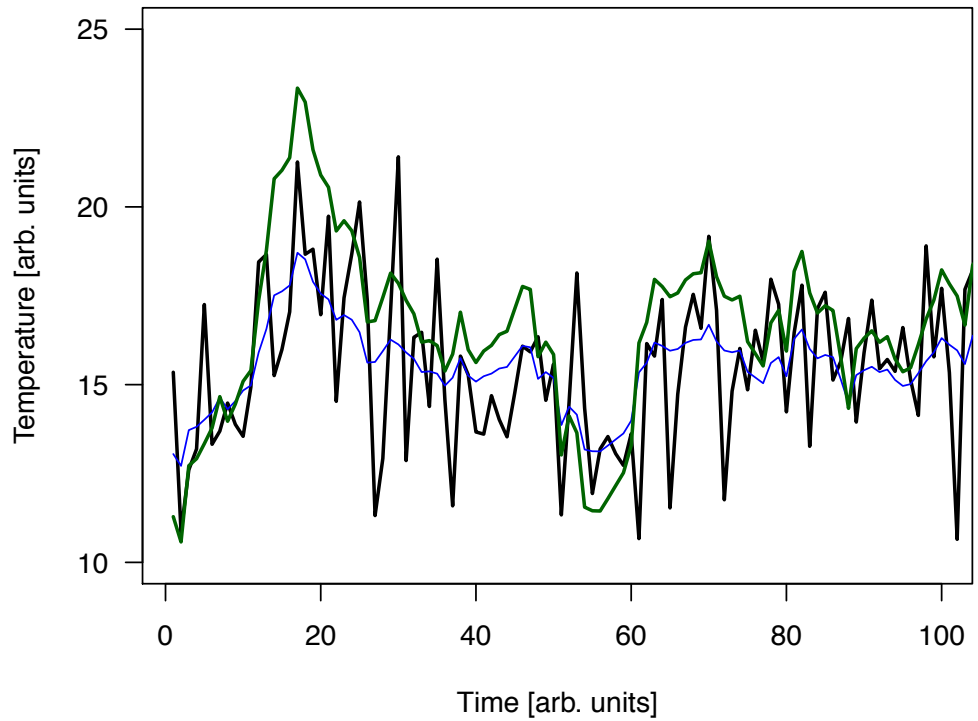
black: “observed” series;
blue: predicted mean of series;



Inflated time series

Simulated example:

black: “observed” series;
blue: predicted mean of series;
green: inflated result.



Inflated time series

Simulated example:

black: “observed” series;
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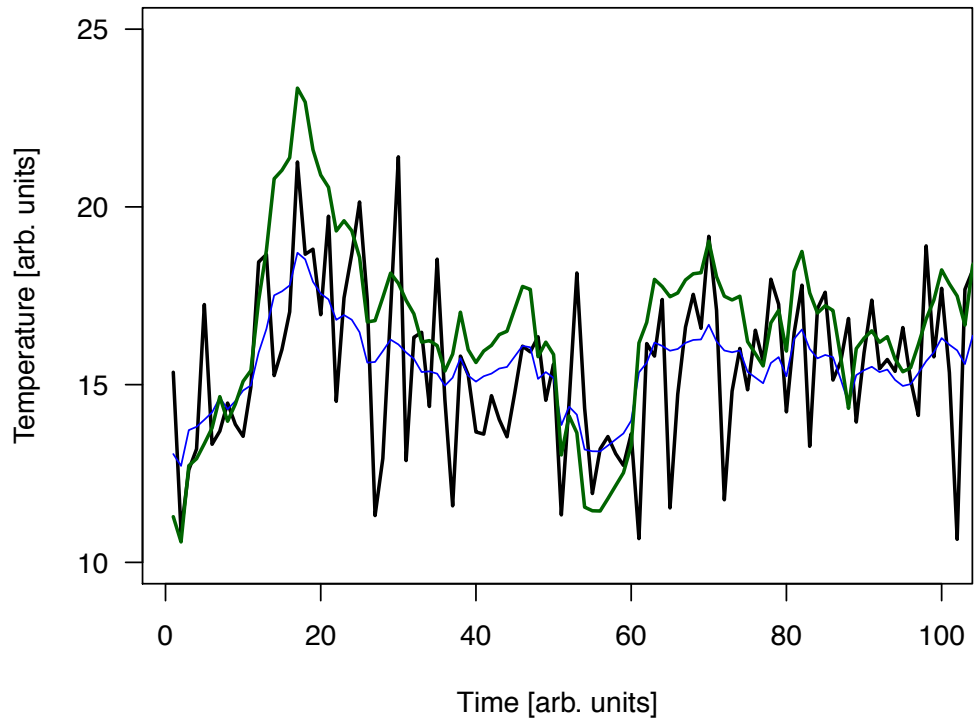
green: inflated result.

CORR(obs,pred)=0.60
CORR(obs,inflate)=0.60



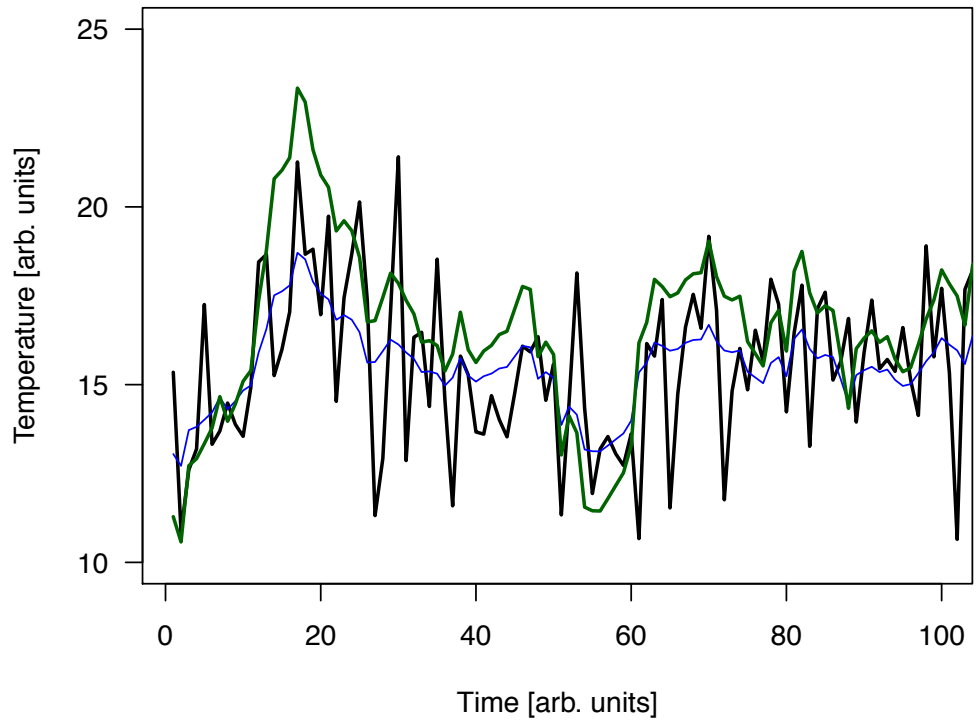
Inflated time series

Simulated example:

black: “observed” series;
blue: predicted mean of series;
green: inflated result.

CORR(obs,pred)=0.60
CORR(obs,inflate)=0.60

RMSE(obs,pred)=2.02
RMSE(obs,inflate)=2.64



Skill for inflated regression

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TABLE 1. Brier skill score for forecasts of the median and 95th percentile of Y, for different strengths of the correlation (corr) between predictor and predictand. Predictions are based on the predicted mean of the regression (PM), inflated regression (inf), and the correct probabilistic interpretation of the regression (prob). As a reference forecast, the climatology has been used: that is, a stationary normal distribution.

	Median			95th percentile		
Corr	PM	Inf	Prob	PM	Inf	Prob
0.9	0.43	0.43	0.60	0.31	0.25	0.49
0.7	−0.02	−0.02	0.32	−0.01	−0.28	0.20
0.5	−0.32	−0.32	0.16	−0.05	−0.61	0.07

Maraun, J Climate, 2014

Summary inflated regression

- Inflated regression is flawed and should not be used.

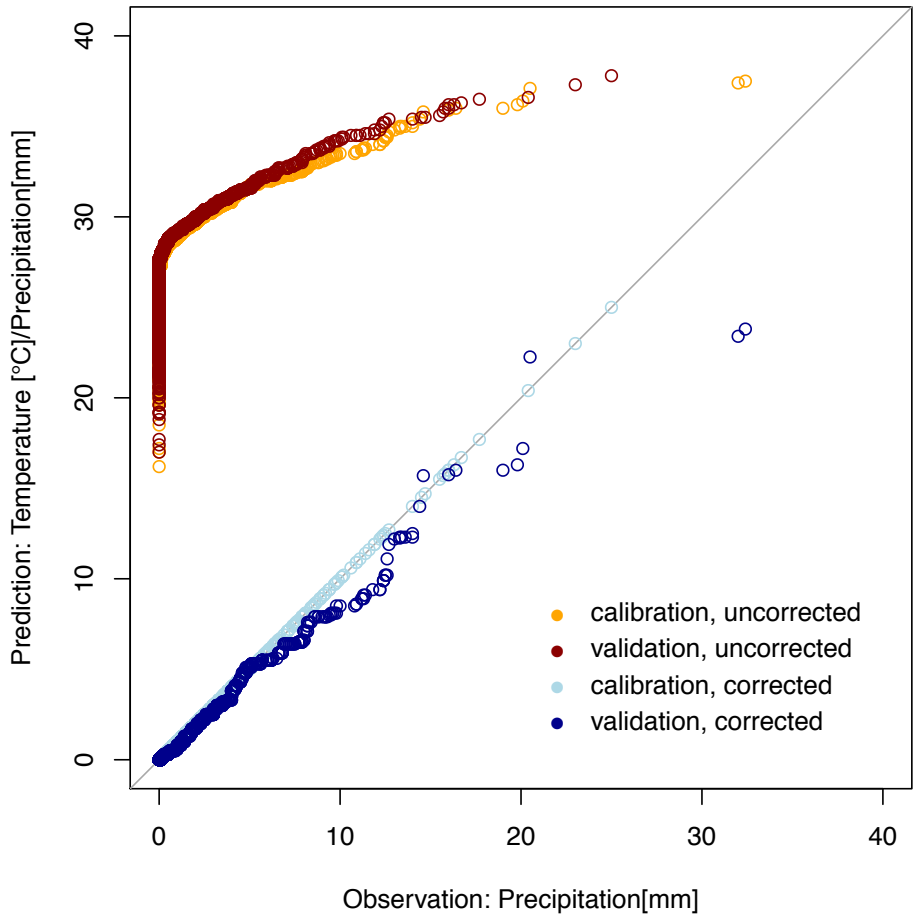
Perfect Prognosis

Bias Correction

Bias Correction · Validation problem

Problem: naive validation does not help

Map Buenos Aires daily temperature on Cambridge daily precipitation (DJF)
Calibration: 1961-1980; validation: 1981-2000

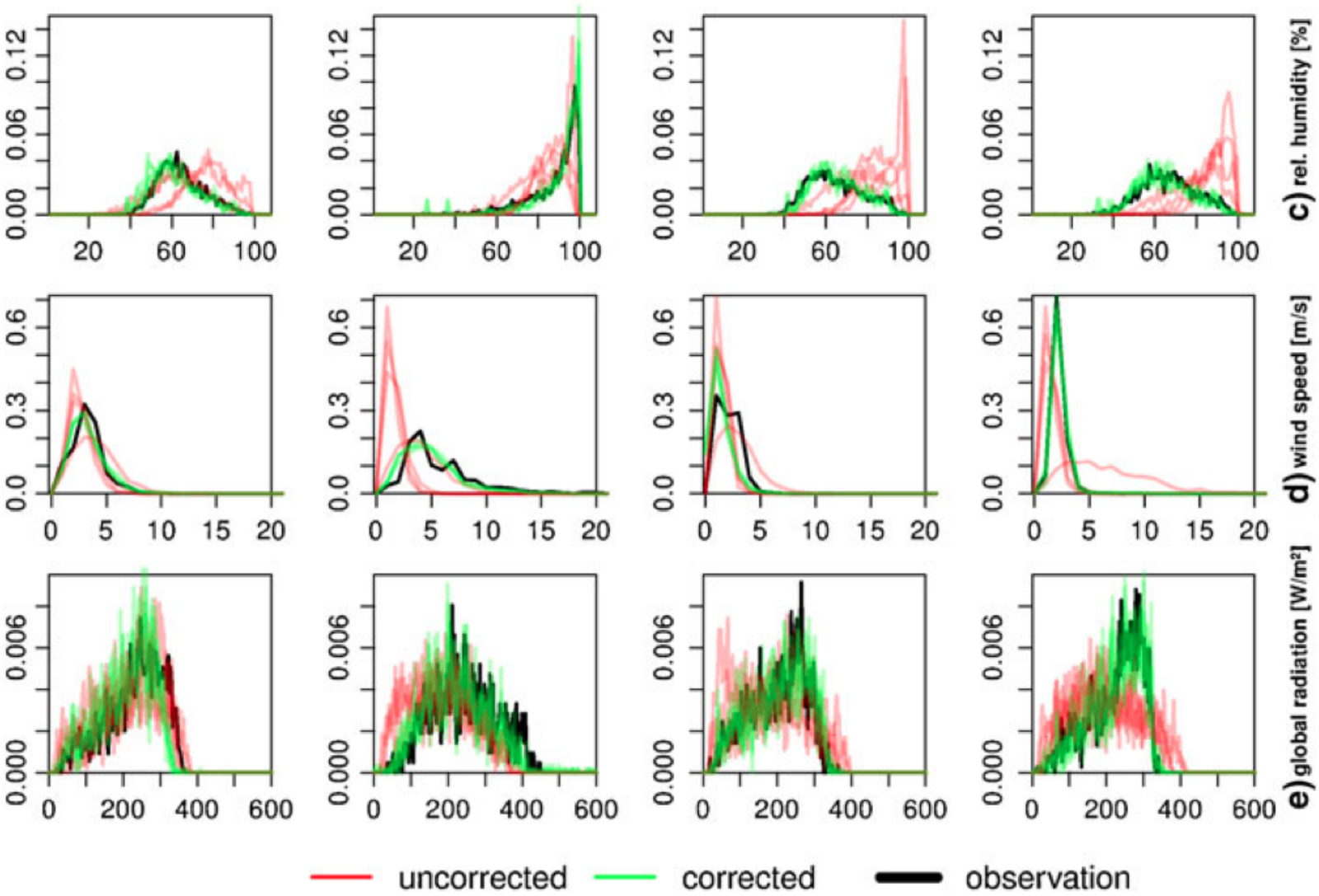


Summary validation

- Cross validation and qq plots (etc) is not suffient to assess whether a bias correction is meaningful.

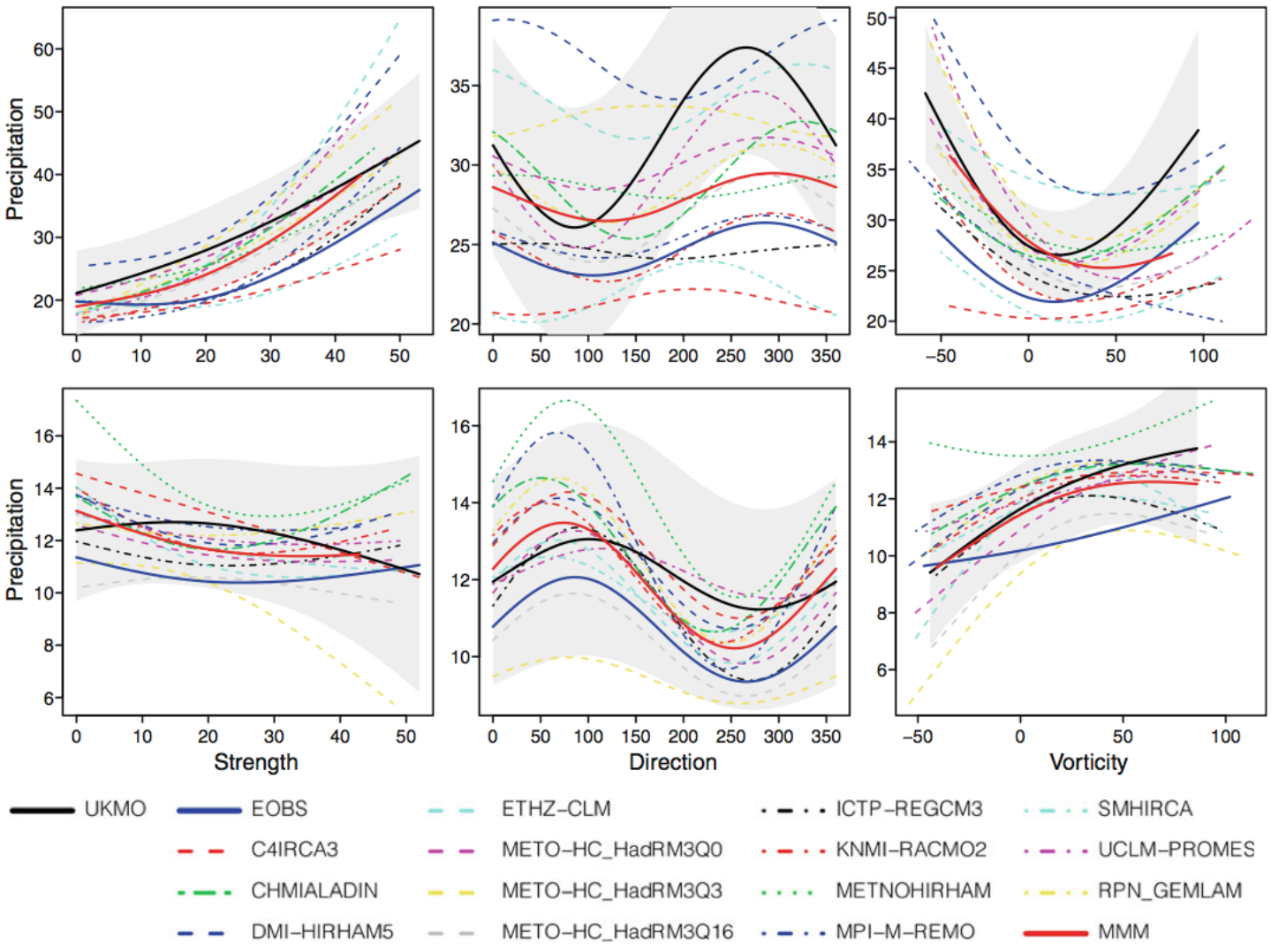
Bias Correction · Representativeness

Bias correction only if the model represents what we are interested in!



Wilke et al., Clim. Change, 2013

Bias correction only if the model represents what we are interested in!



Maraun et al., Clim. Dynam., 2012

Summary representativeness

- Bias correction should only be carried out if the dynamical model represents the local variable.
- Assessment, e.g., by means of correlation analysis.

Maraun and Widmann, Hydrol. Earth Syst. Sci., 2015

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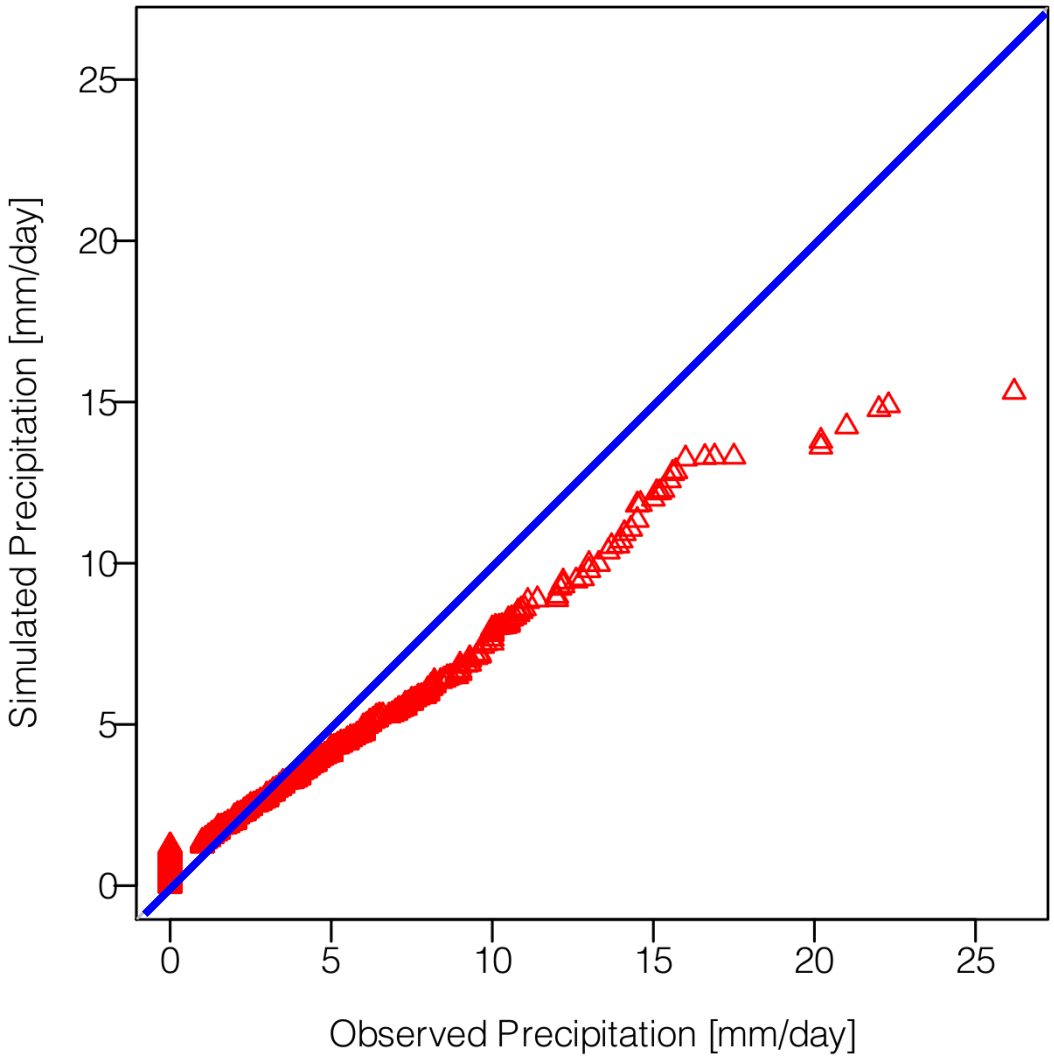
Bias Correction · Bias Correction and Inflation

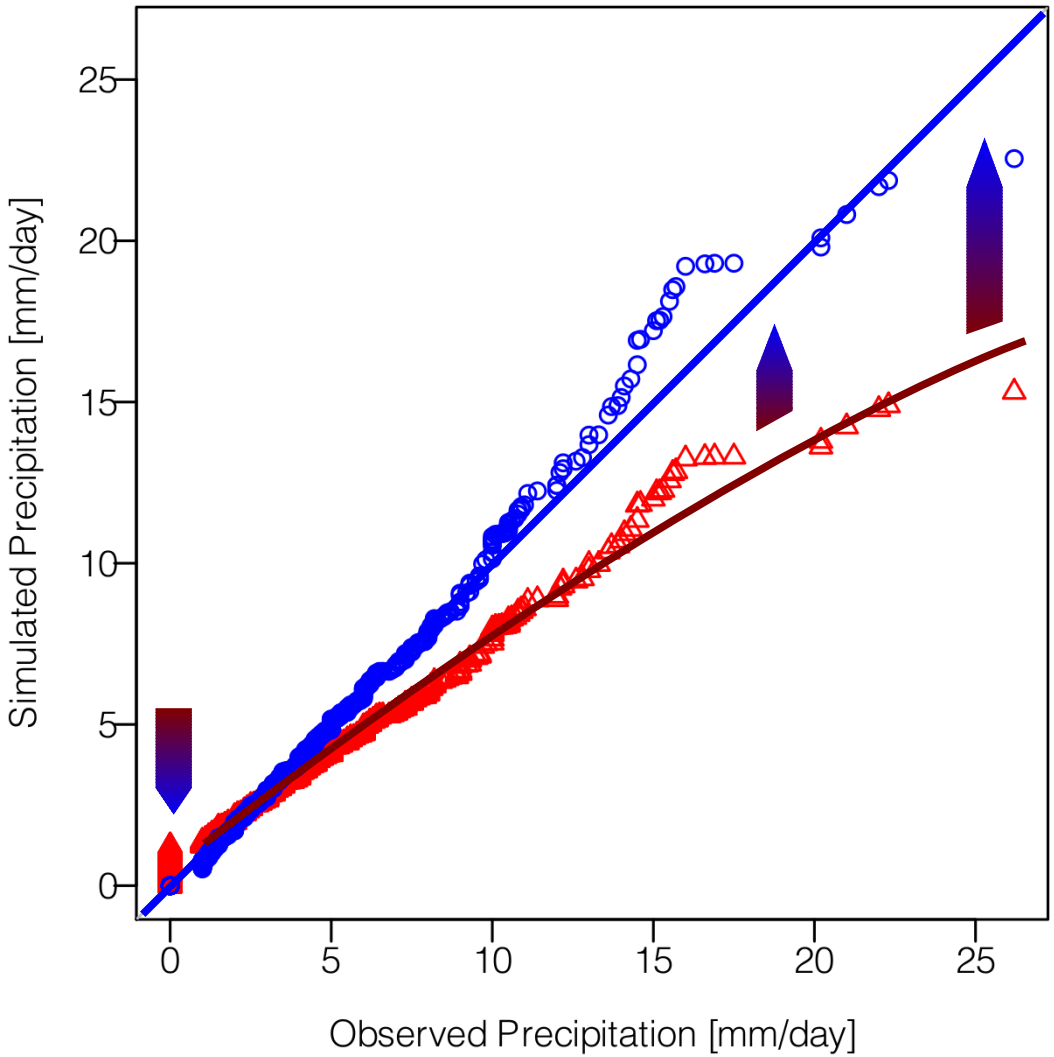
Popular approach: quantile mapping (QM)



- adjust intensities;
- adjust number of wetdays.

e.g., Piani et al., T.A.C., 2010; Maraun, J. Climate, 2013

Popular approach: quantile mapping (QM)



- adjust intensities;
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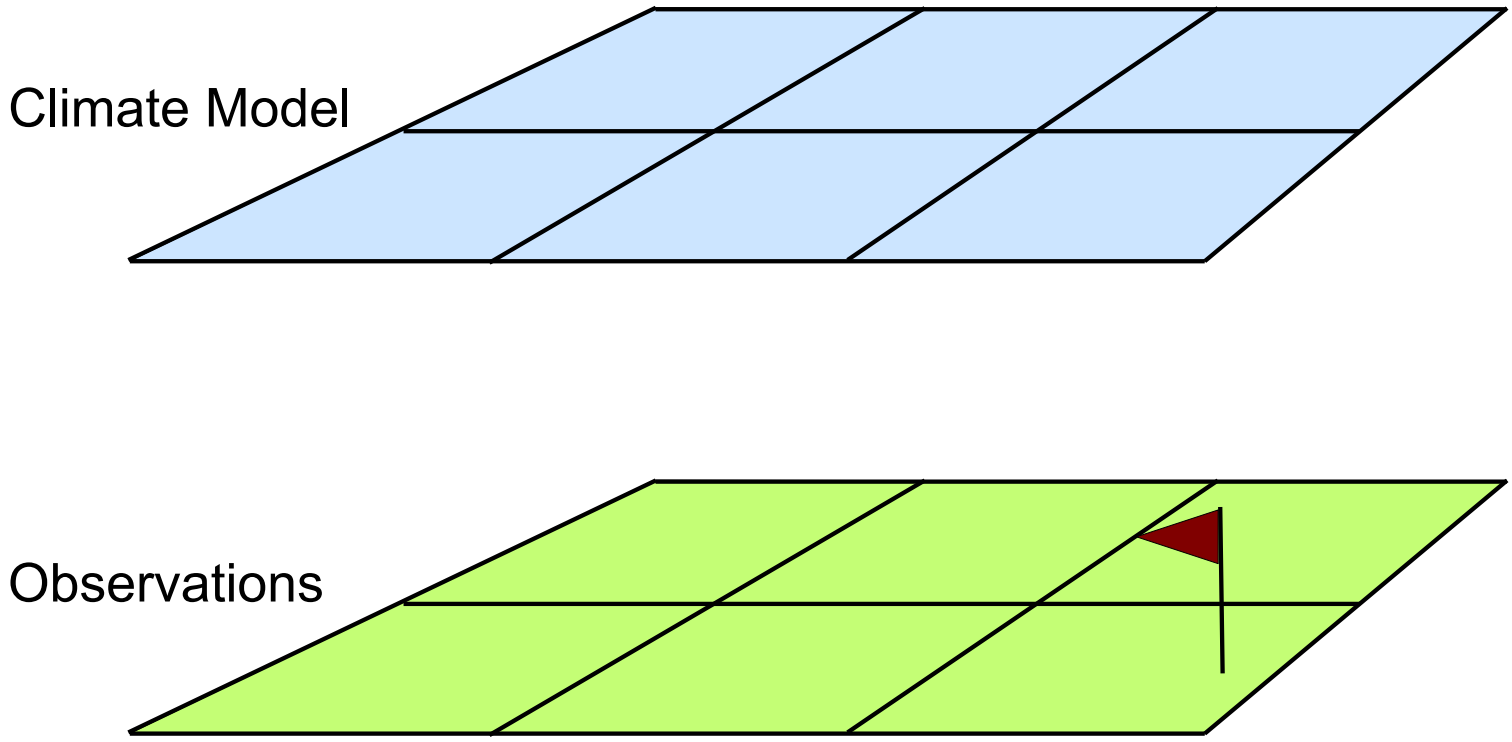
Bias Correction Settings

Pure bias correction vs. bias correction plus downscaling



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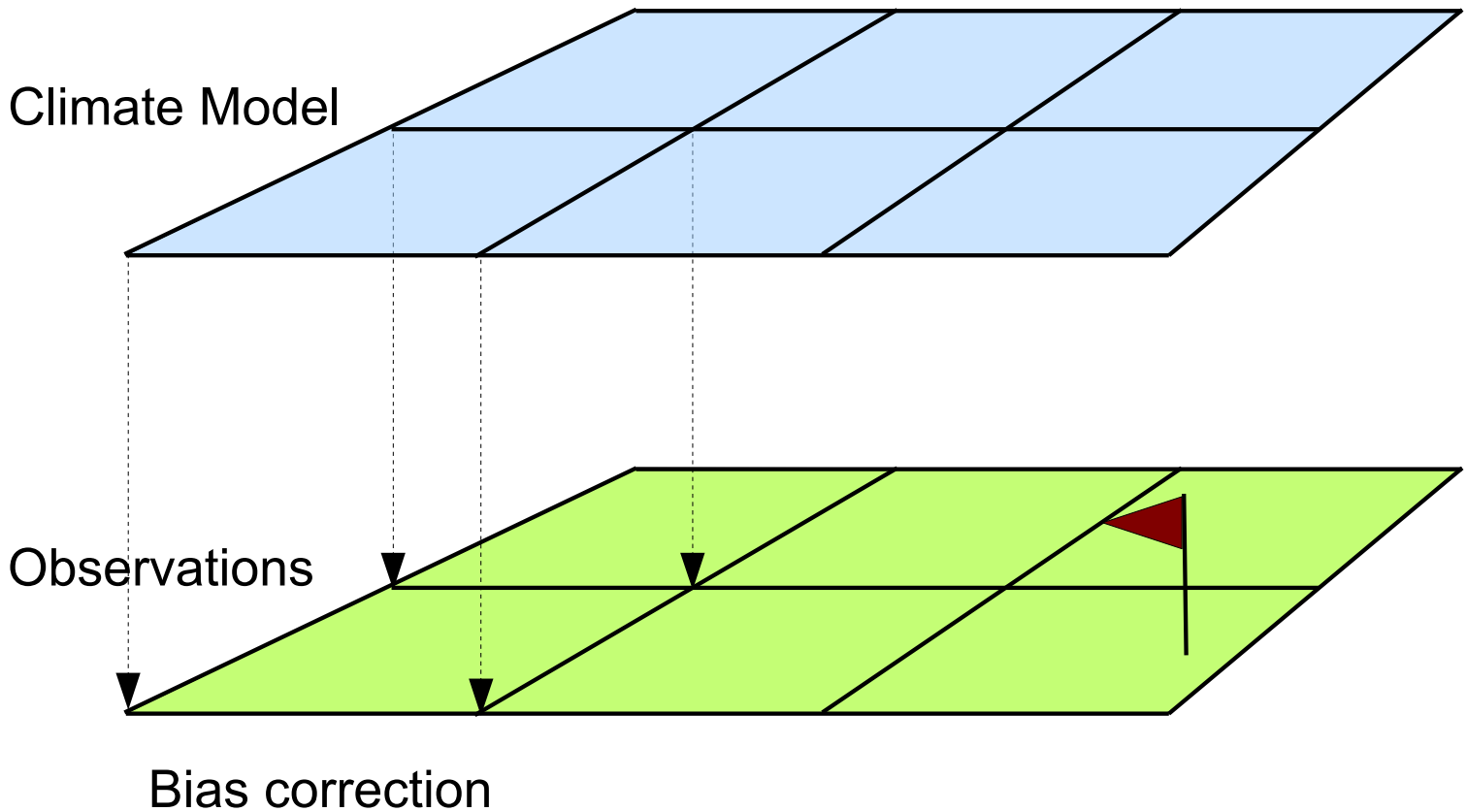

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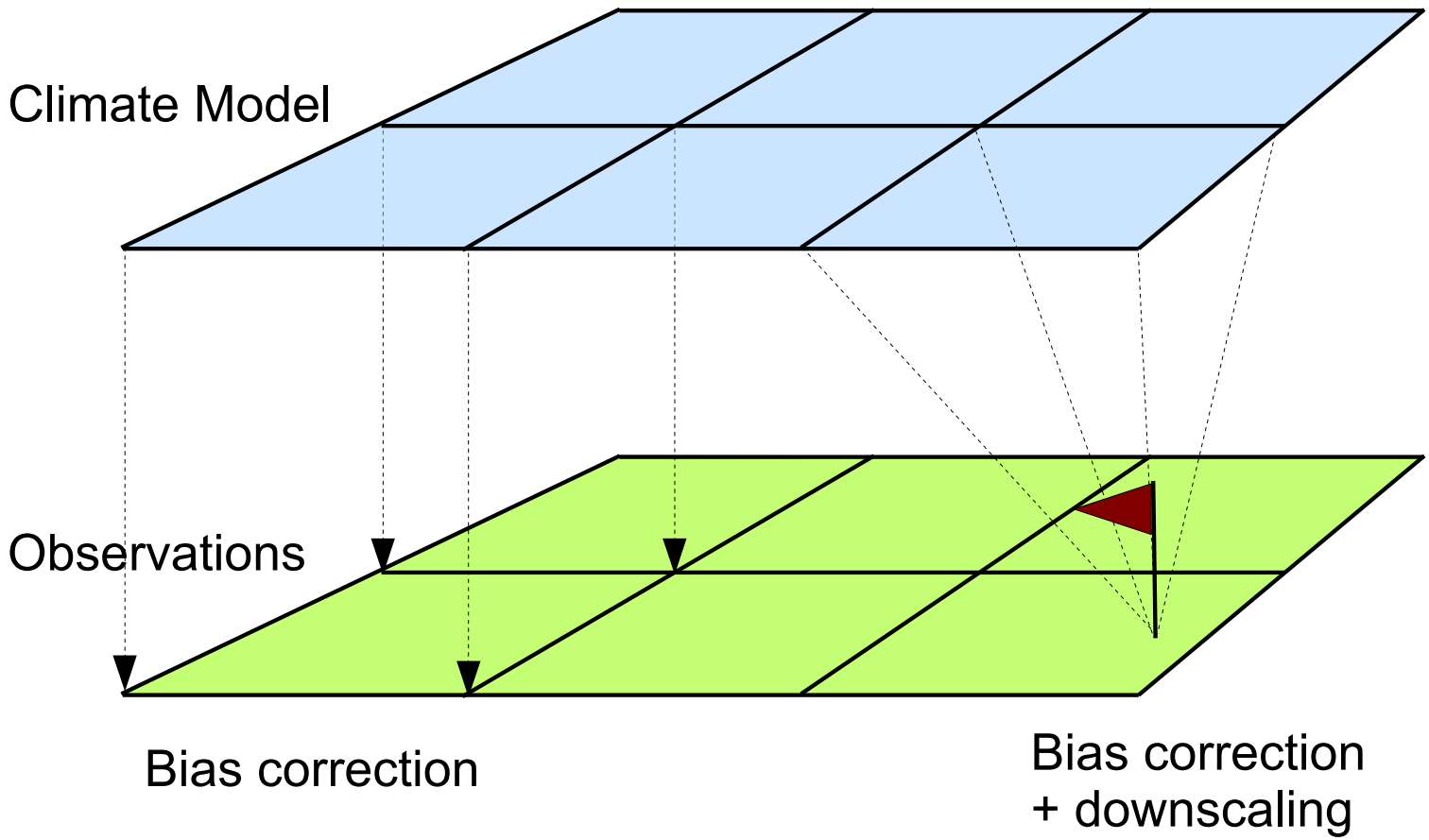

One Grid Box State $\leftrightarrow$ Several Local States

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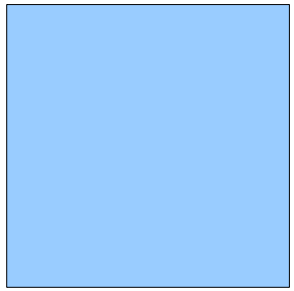
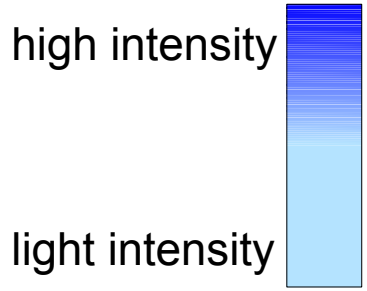
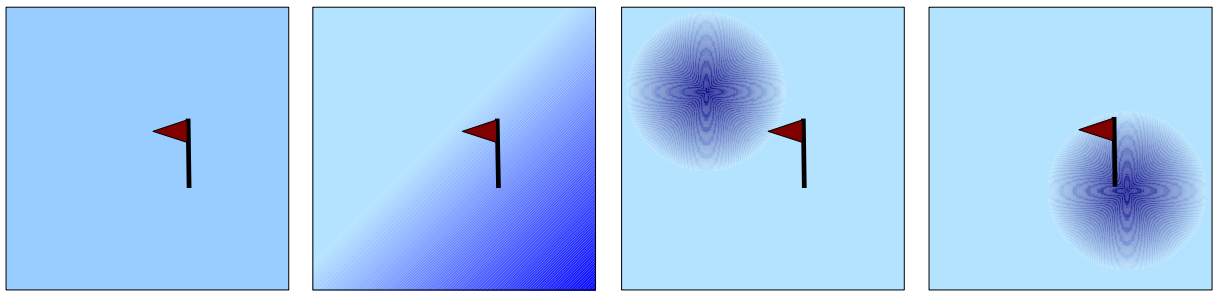
Climate Model



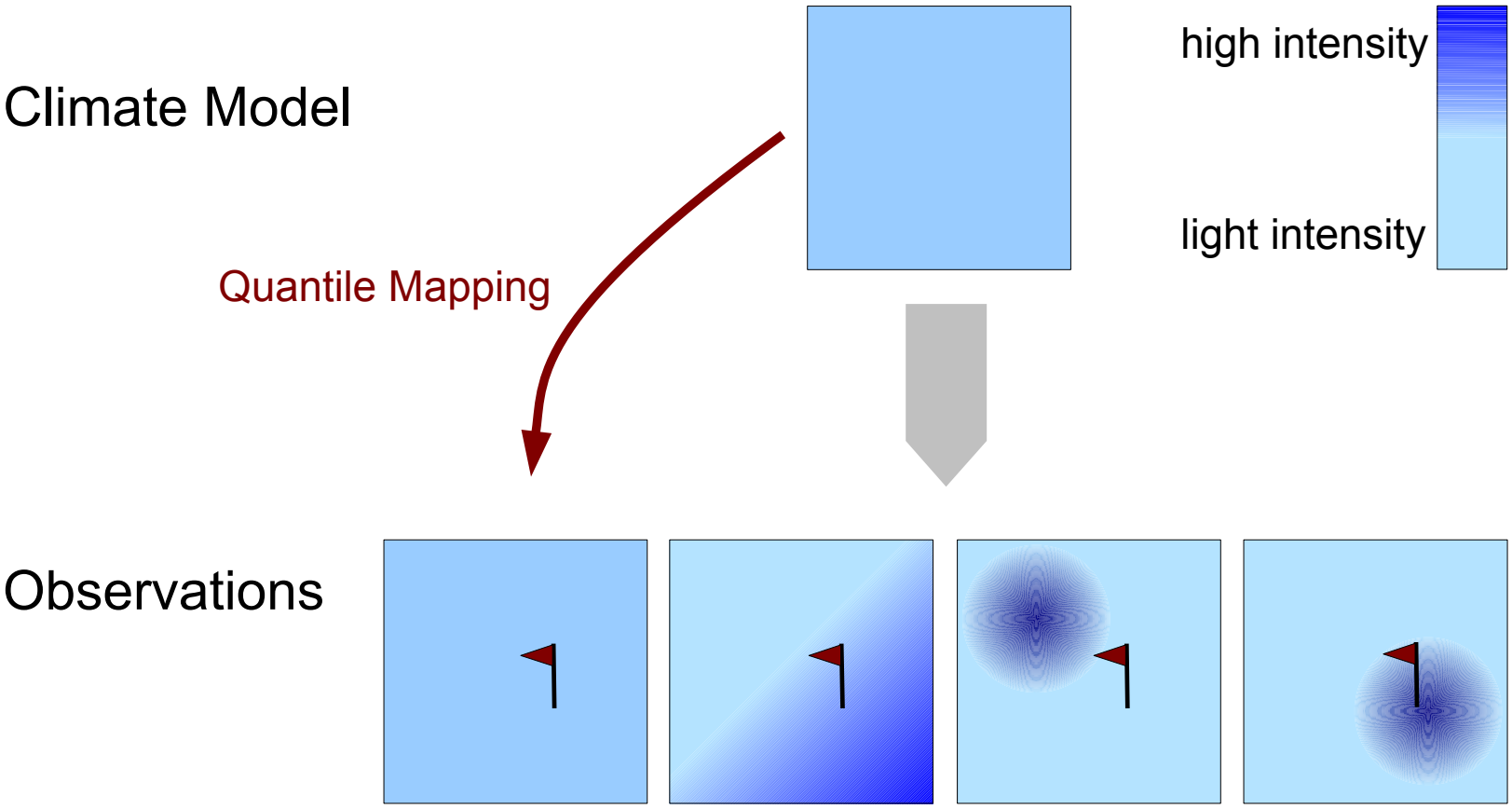


Observations



Grid box variability does not explain all local variability

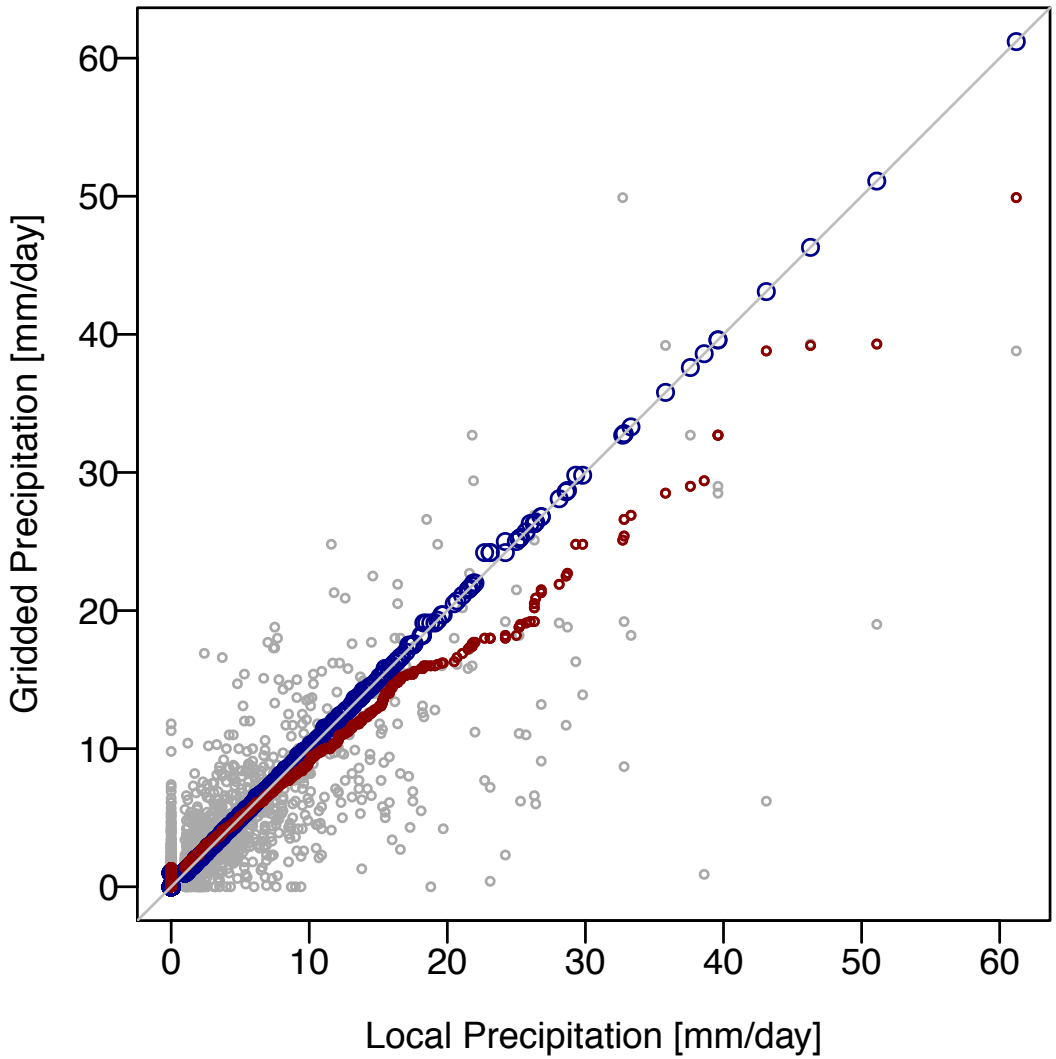
QM does not add Random Variability



Quantile Mapping is deterministic

Local variability not explained by grid-box

EOBS gridded data → rain gauge data; Hasselfelde, Harz mountains; summer

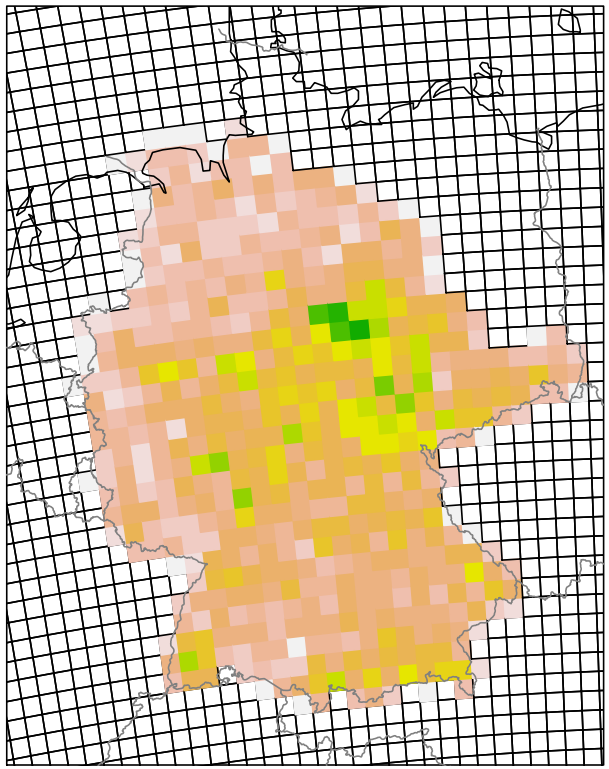


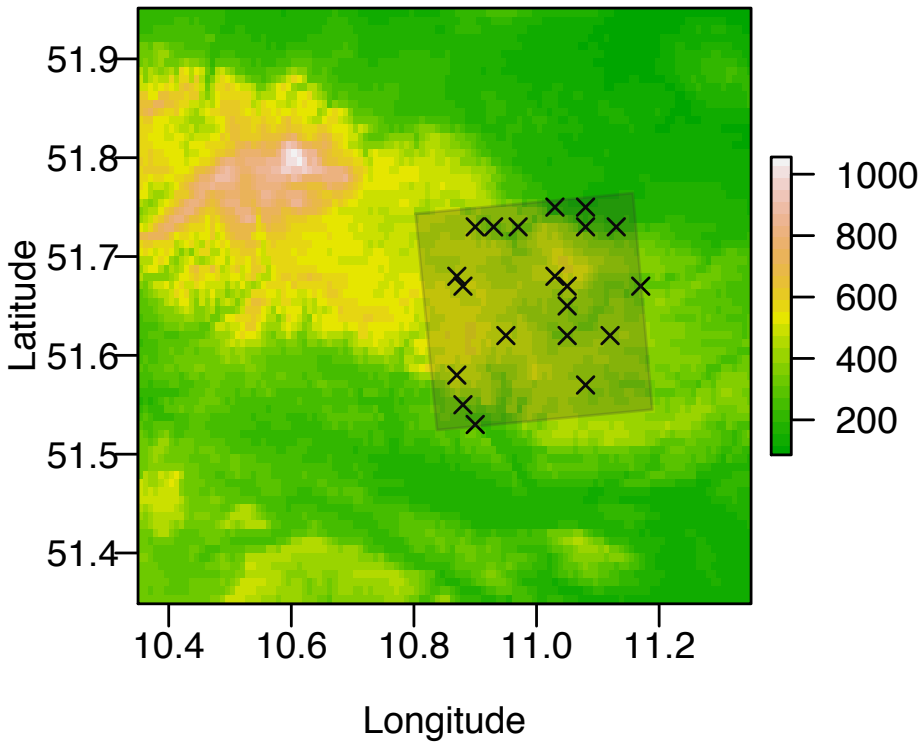
- raw data
- quantiles
- corrected with quantile mapping

after Maraun, J Climate, 2013

Example Study

20 rain gauges within one grid box in Harz mountains





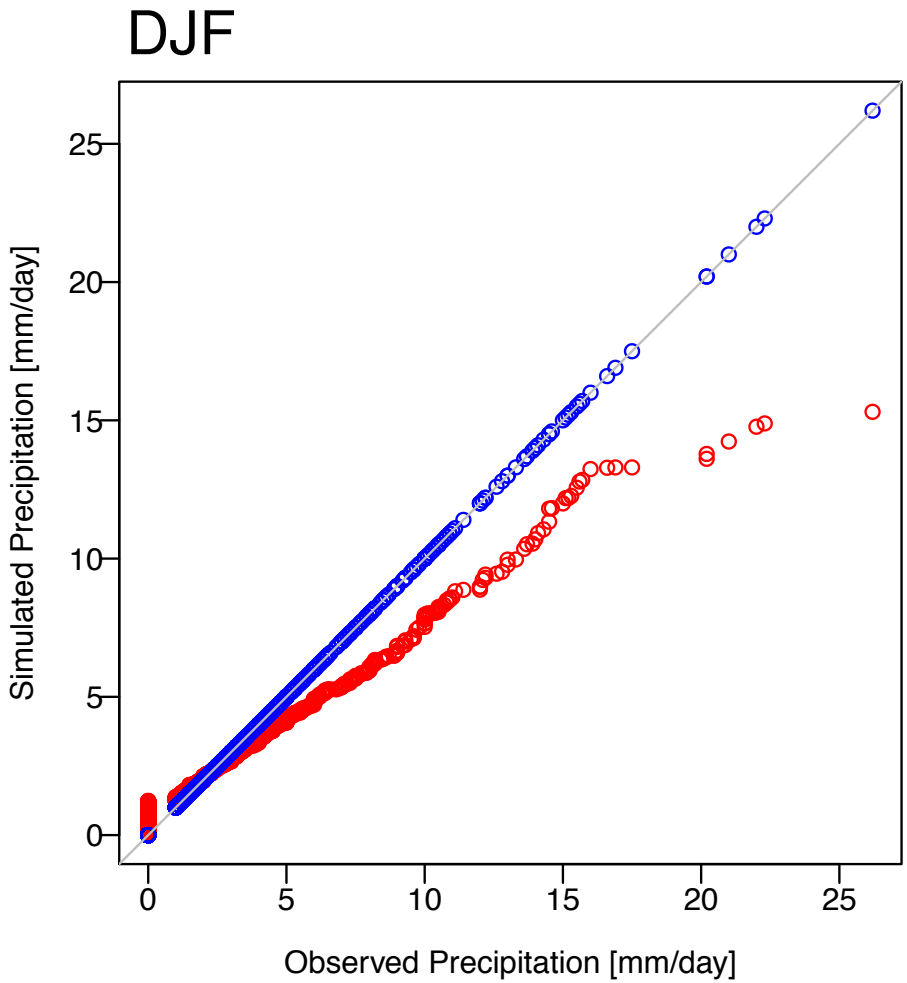
gauge density:

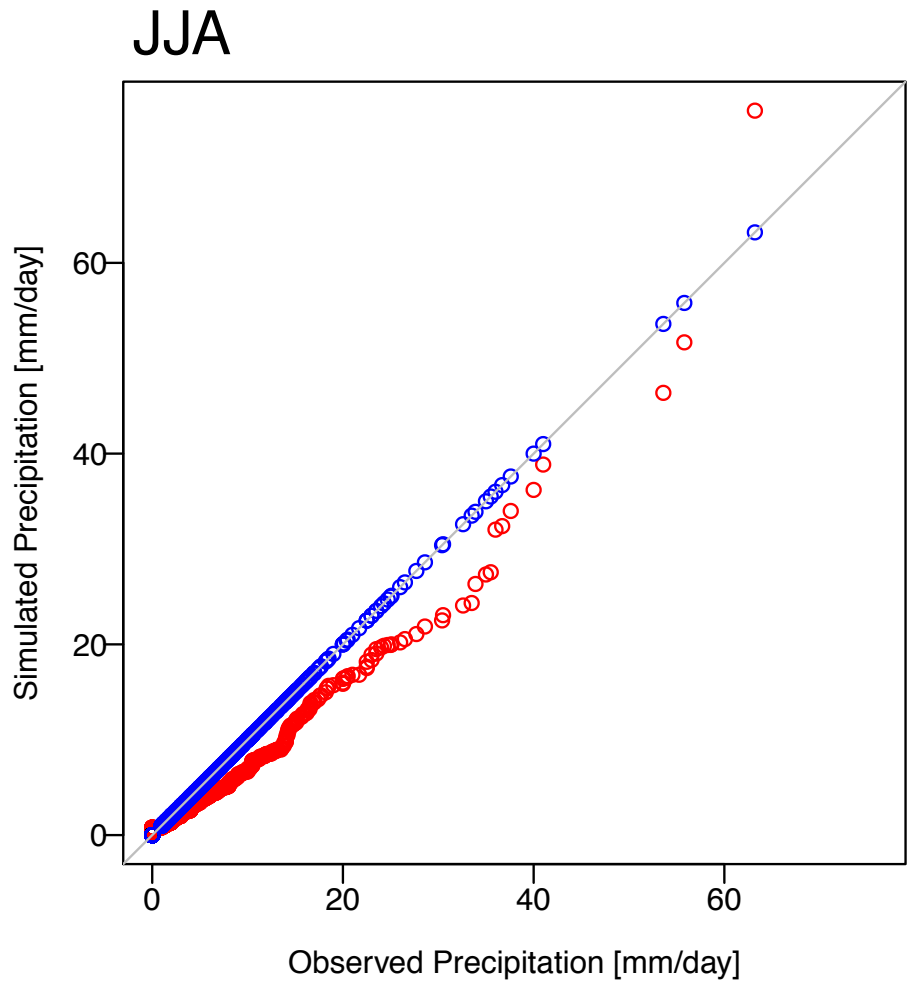
white: low, green: high

Maraun, J. Climate, 2013

Quantile mapping

applied to RACMO2 and 20 gauges within one gridbox in Harz mountains



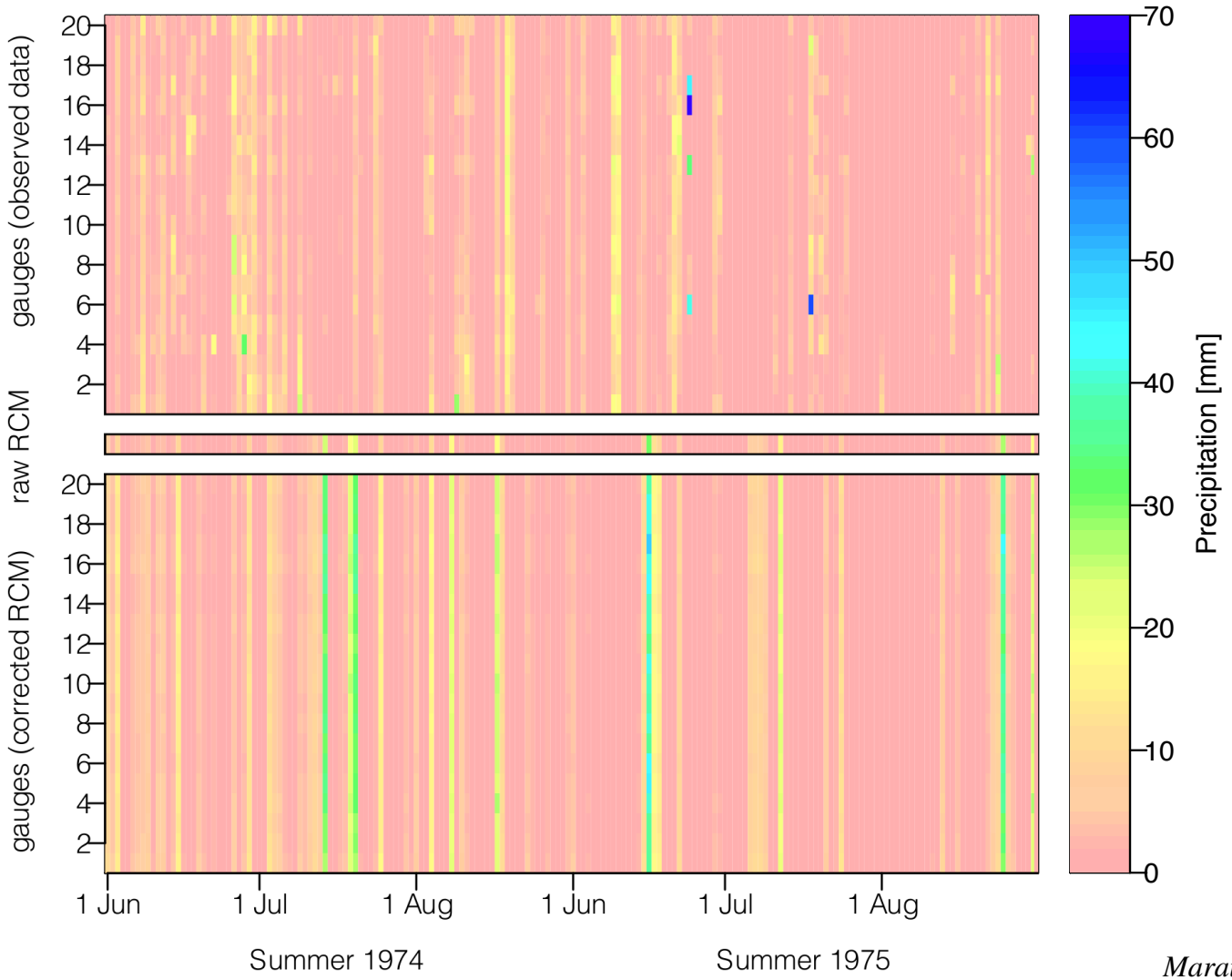


red: uncorrected, blue: corrected

Maraun, J Climate, 2013

Illustrating the Problem

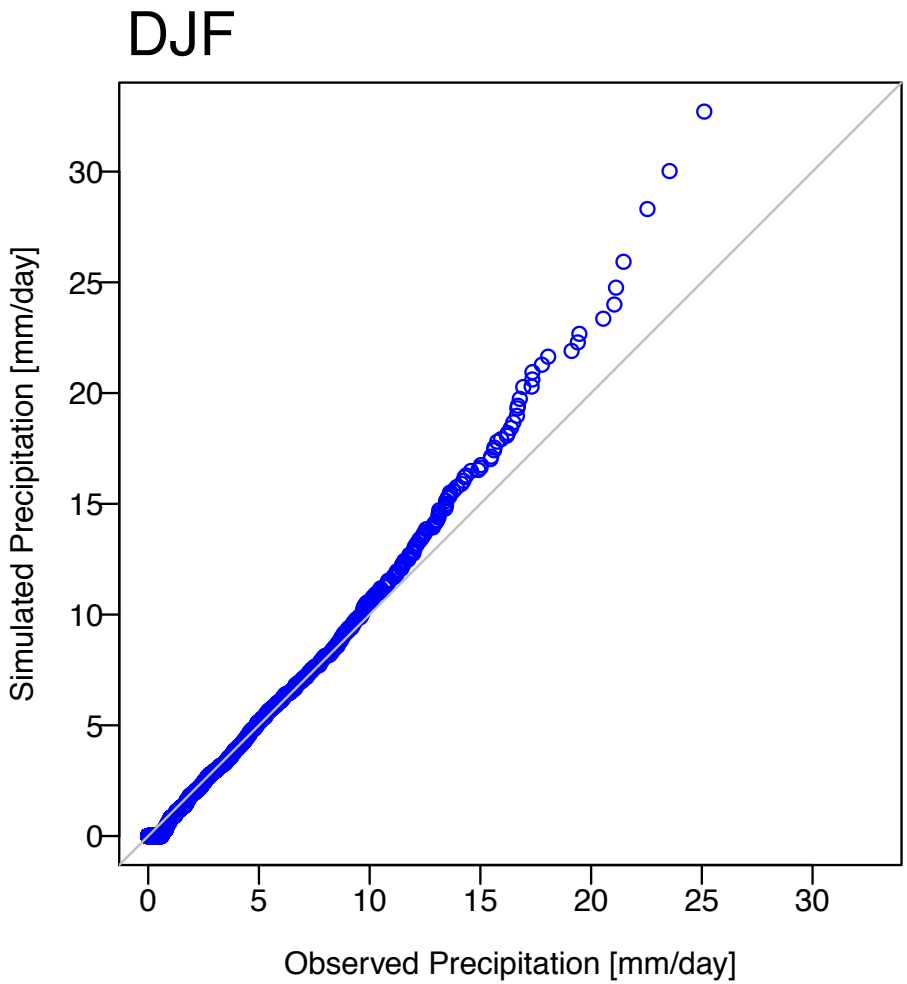
REMO grid box precipitation mapped onto 20 rain gauges

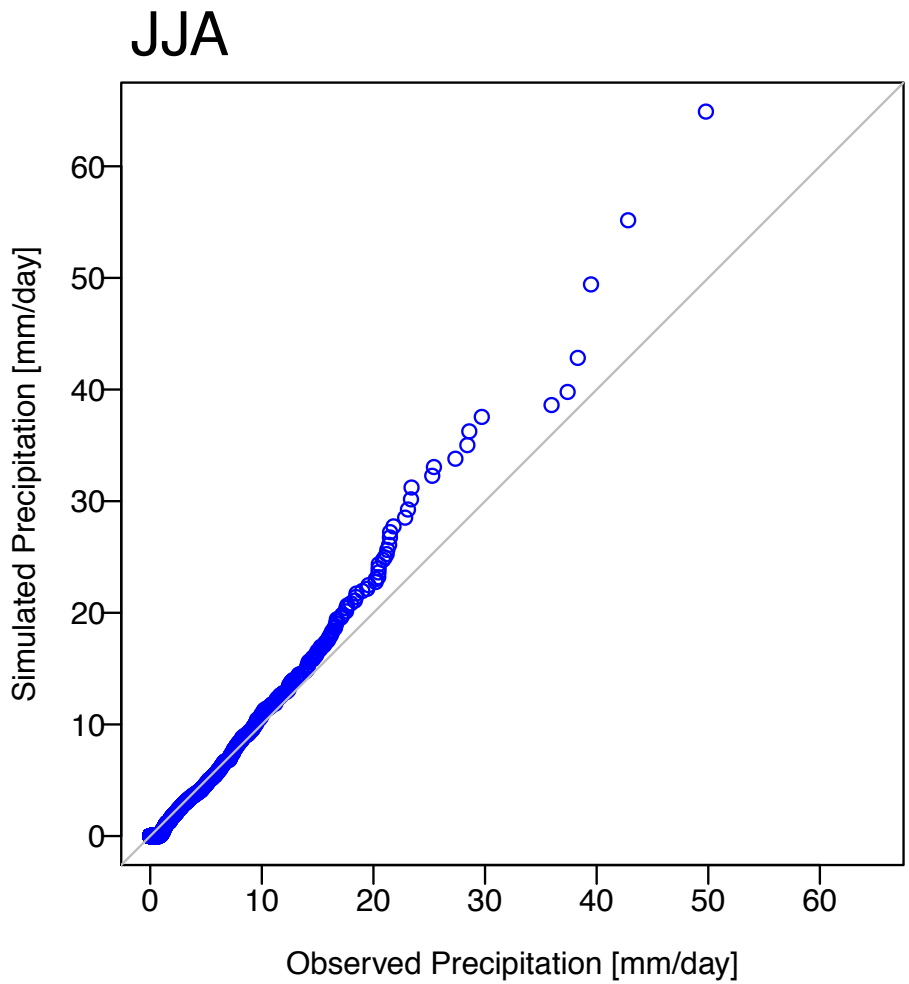


Maraun, J. Climate, 2013

QM Effect at Grid Scale

QM overcorrects the area drizzle effect and inflates area extremes





Maraun, J Climate, 2013

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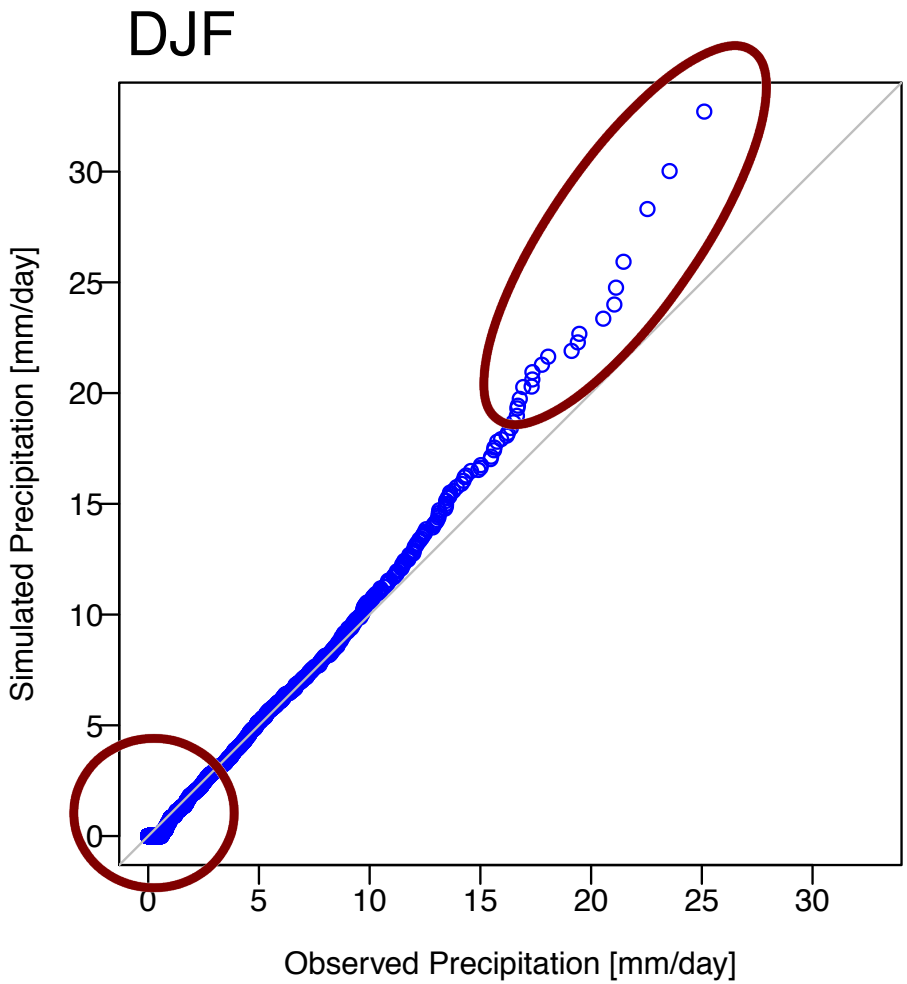
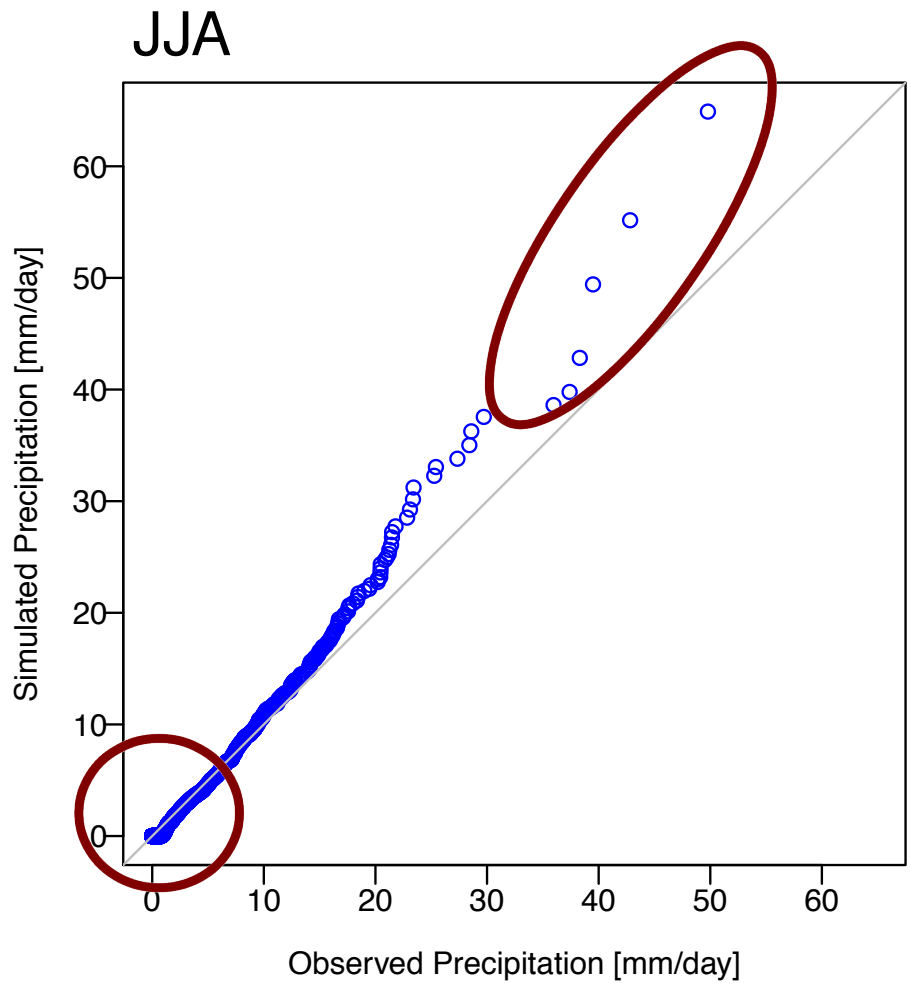
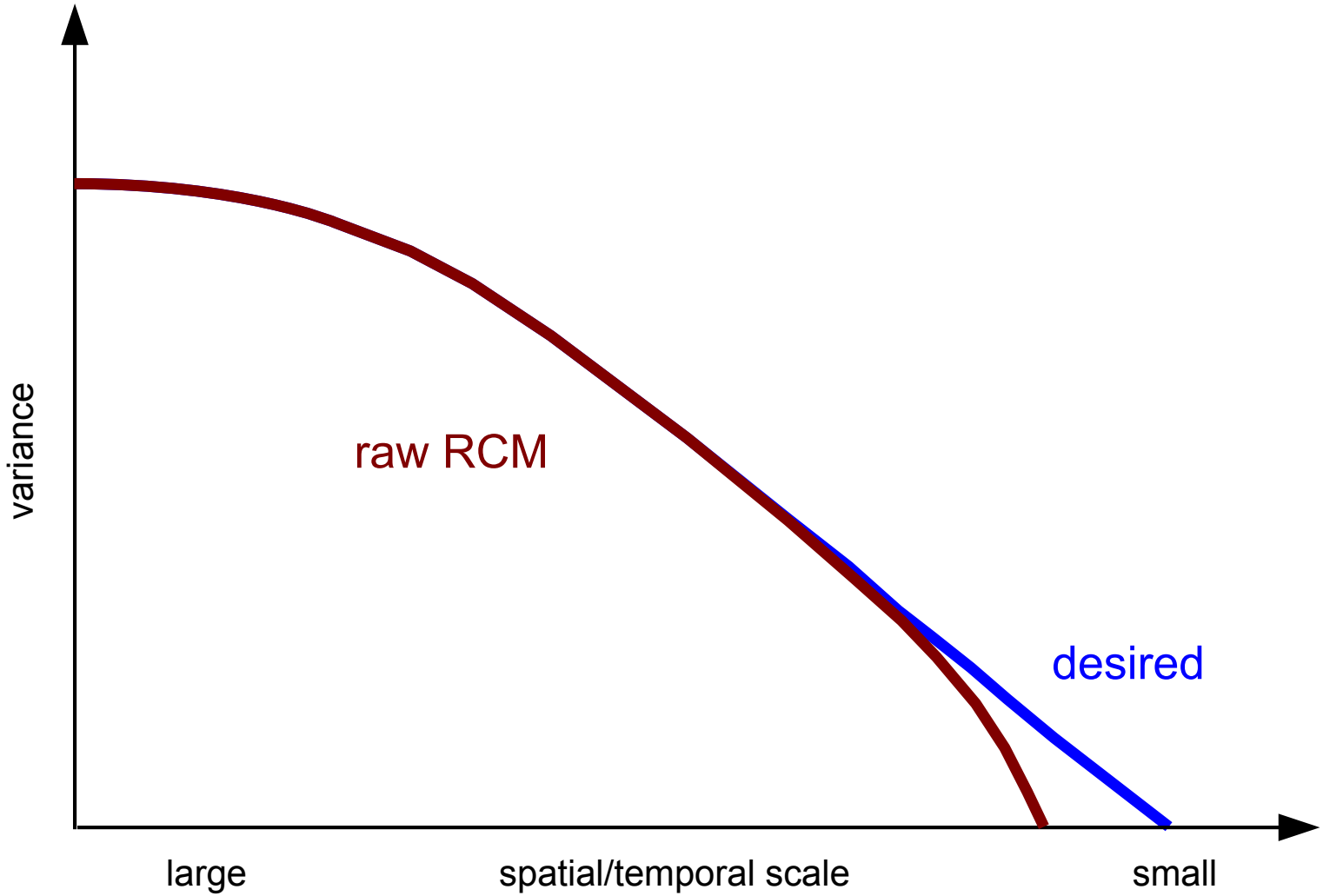




Maraun, J Climate, 2013

A Spectral Perspective

Downscaling requires adding small scale variability



A Spectral Perspective

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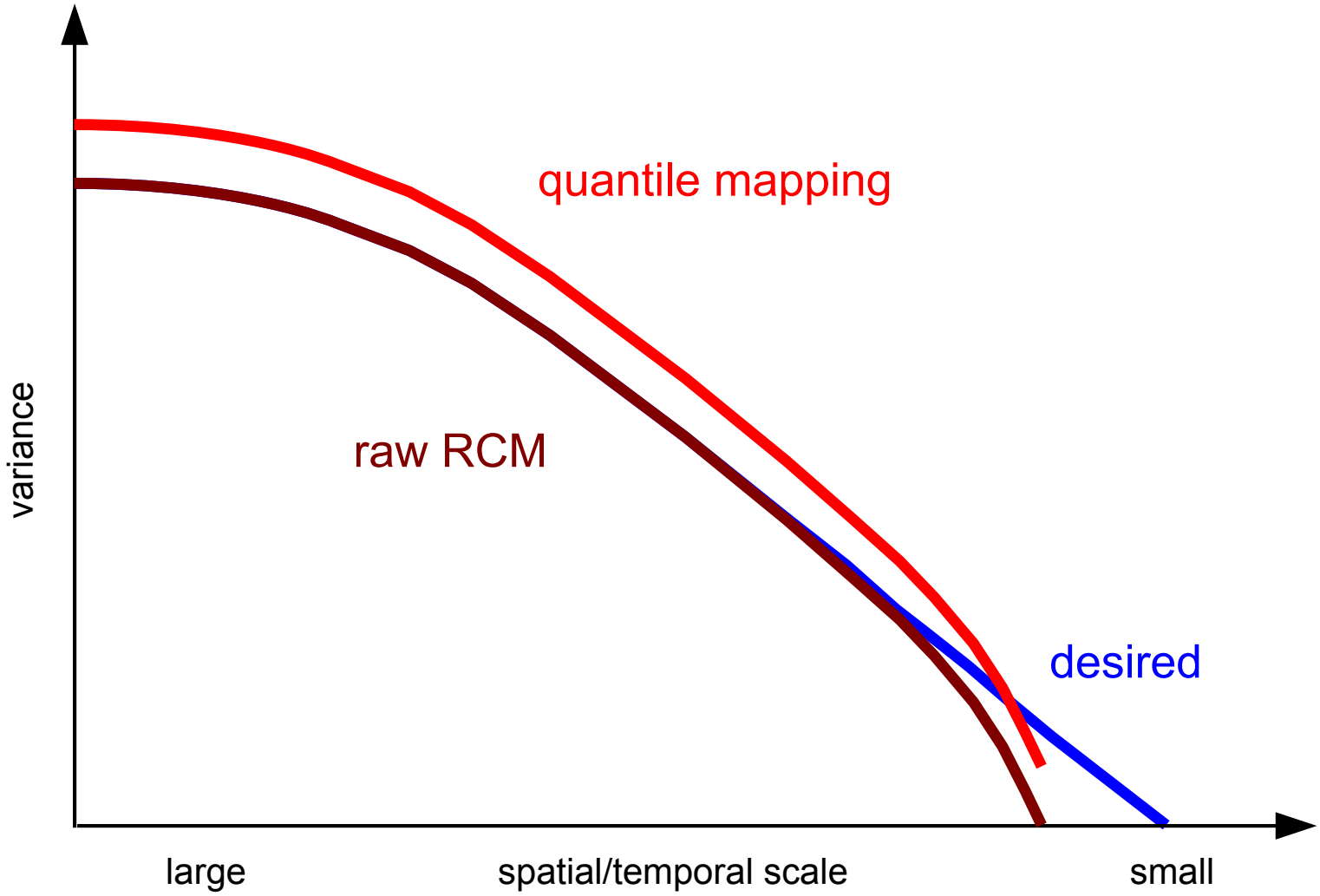
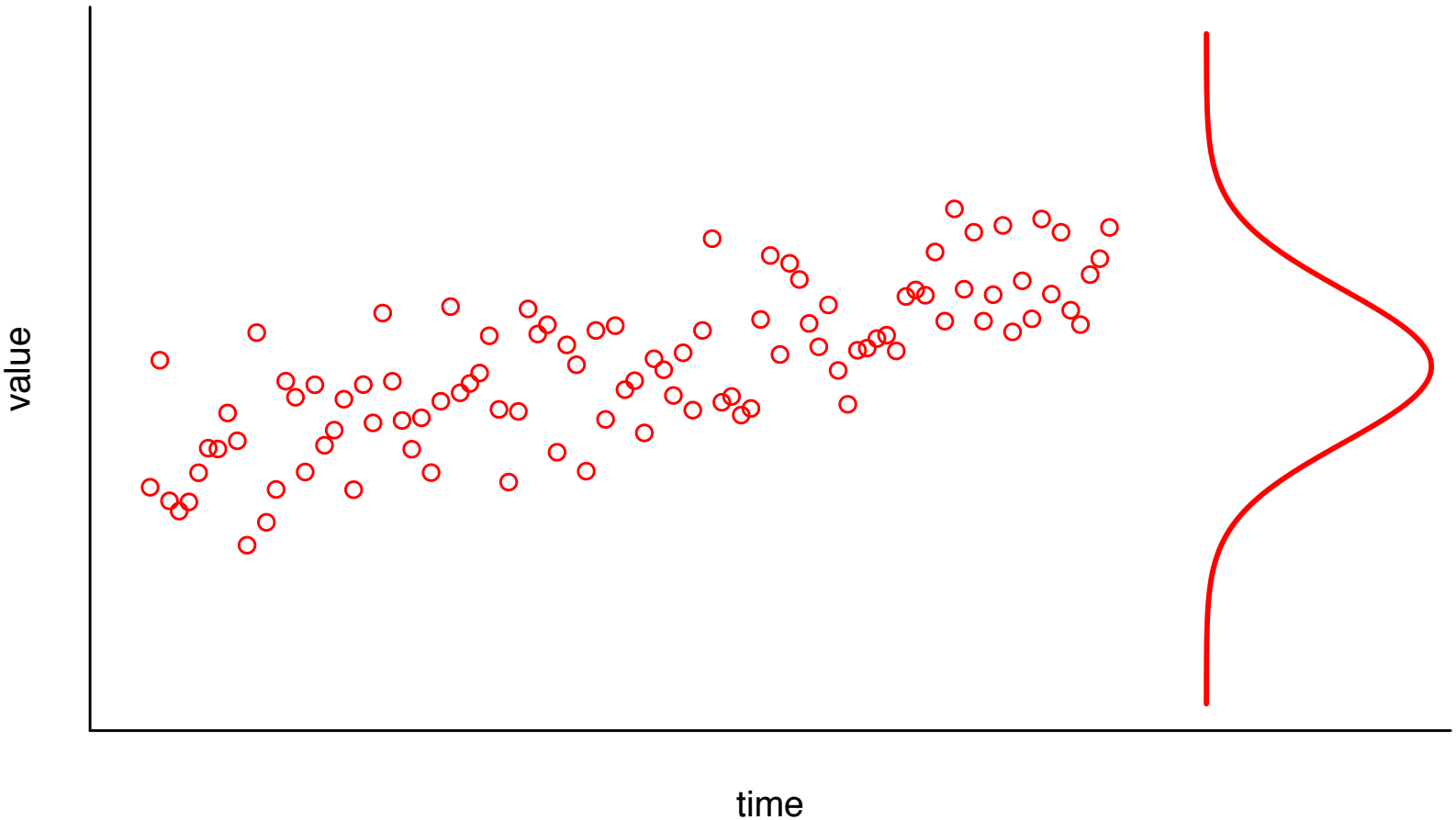


Quantile Mapping Inflates Trends



Maraun, J Climate, 2013

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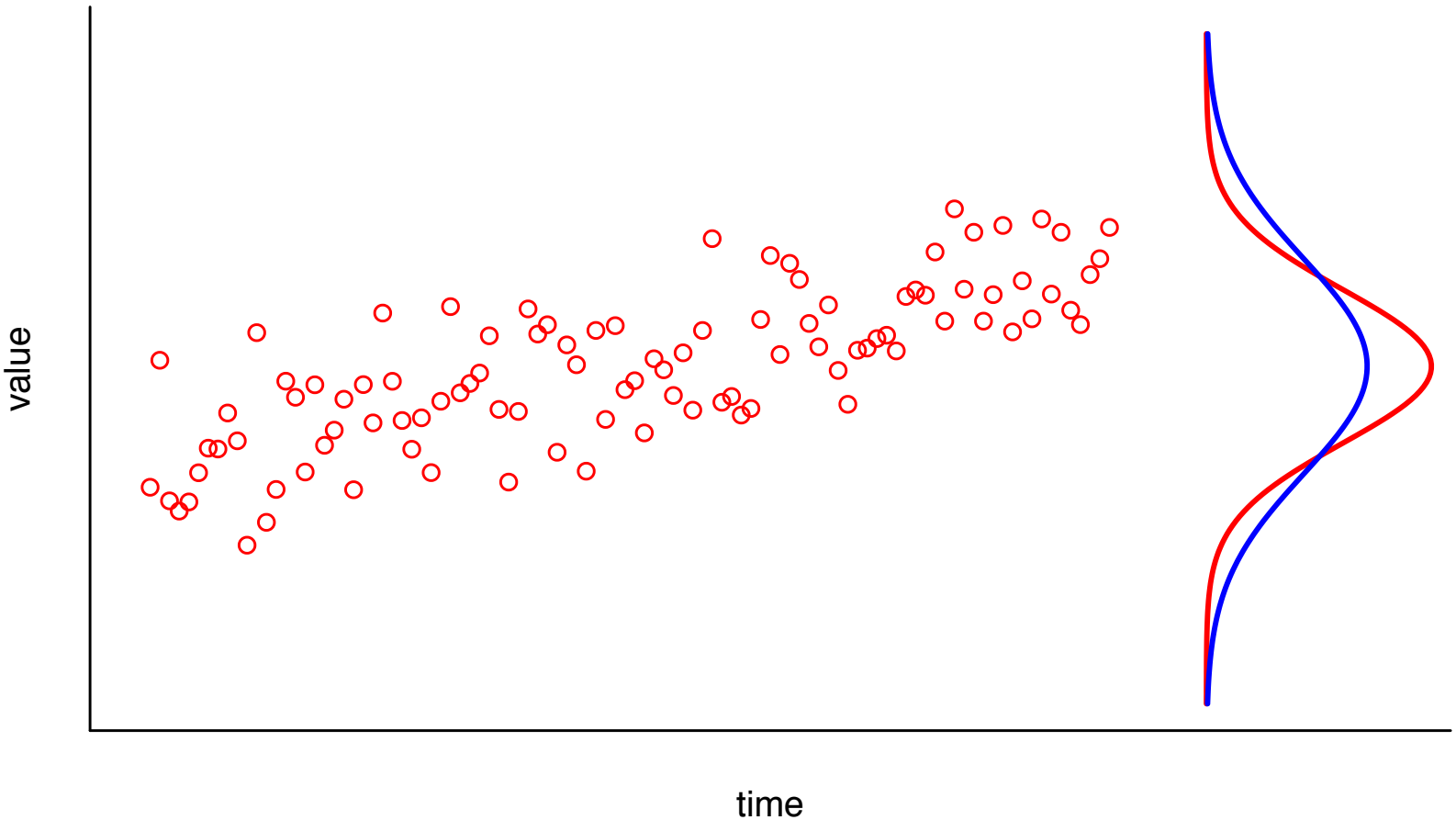

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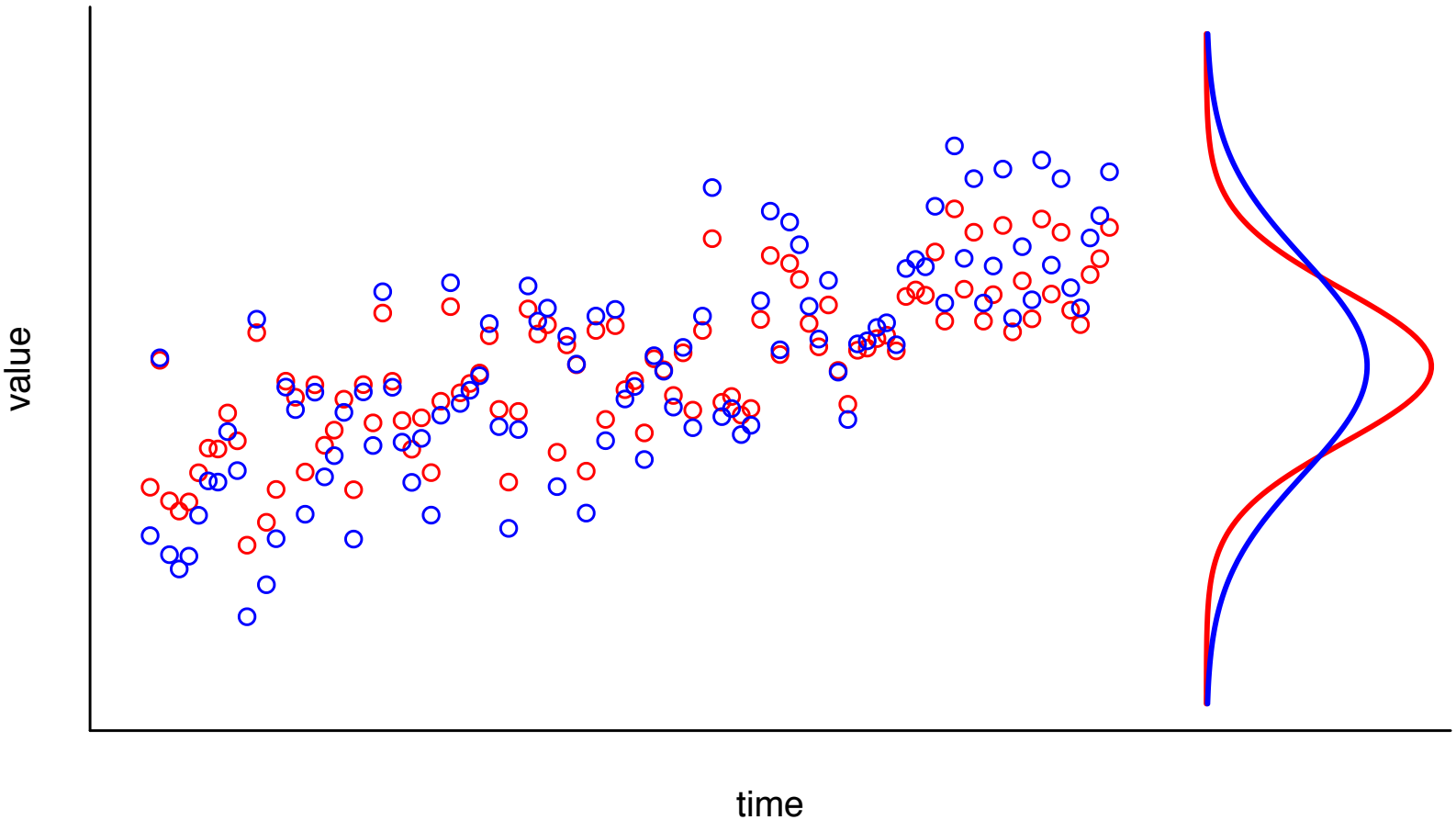

Maraun, J Climate, 2013

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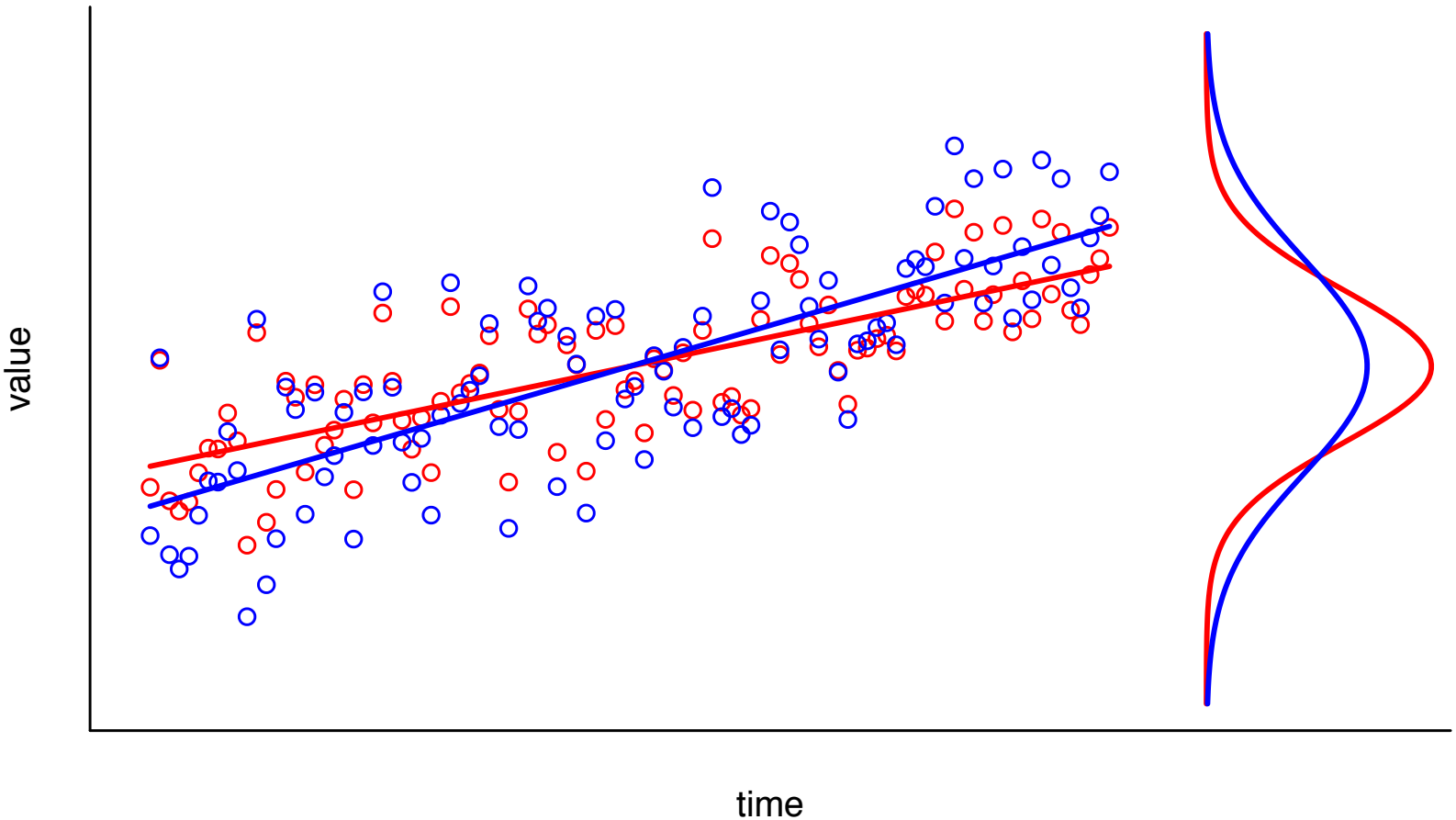

Maraun, J Climate, 2013

Stochastic model output statistics

New research avenue in climate science

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Idea: Regression Model

observed precipitation = corrected RCM precipitation + noise

Requirement for any regression model:

- a day to day correspondence between predictor and predictand. Ensured by ERA40 boundary conditions and spectral nudging

Wong et al., J. Climate, 2014

Summary QM-Downscaling

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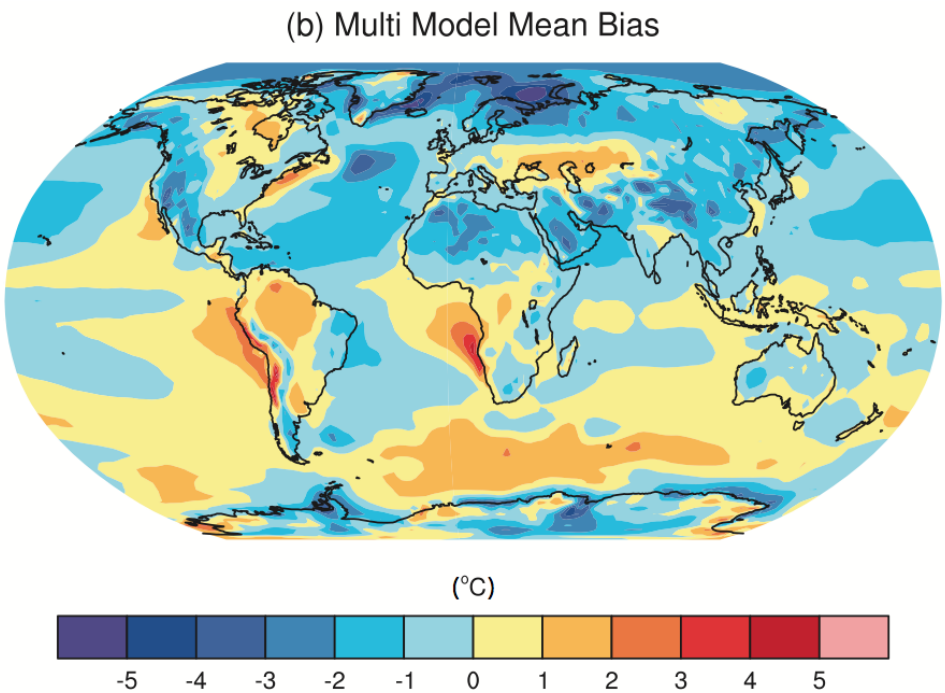
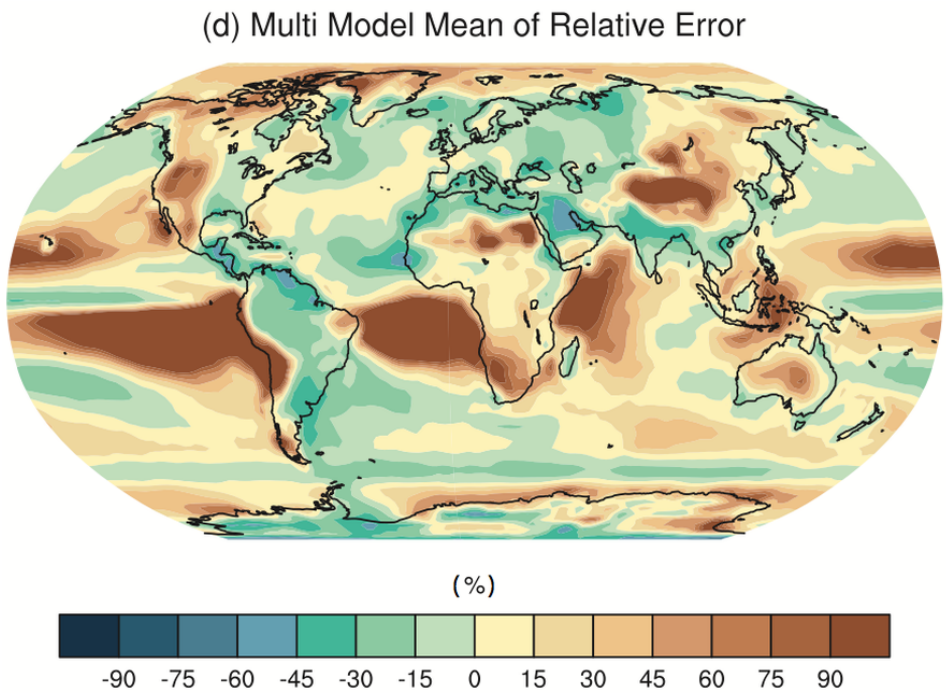
- QM (and variance correcting BC) cannot be used to downscale processes, that exhibit large random variability at local scales;
- Idea: use stochastic bias correction approaches.

Bias Correction · Large-Scale Errors

Temperature and precipitation biases

CMIP5, multi-model mean



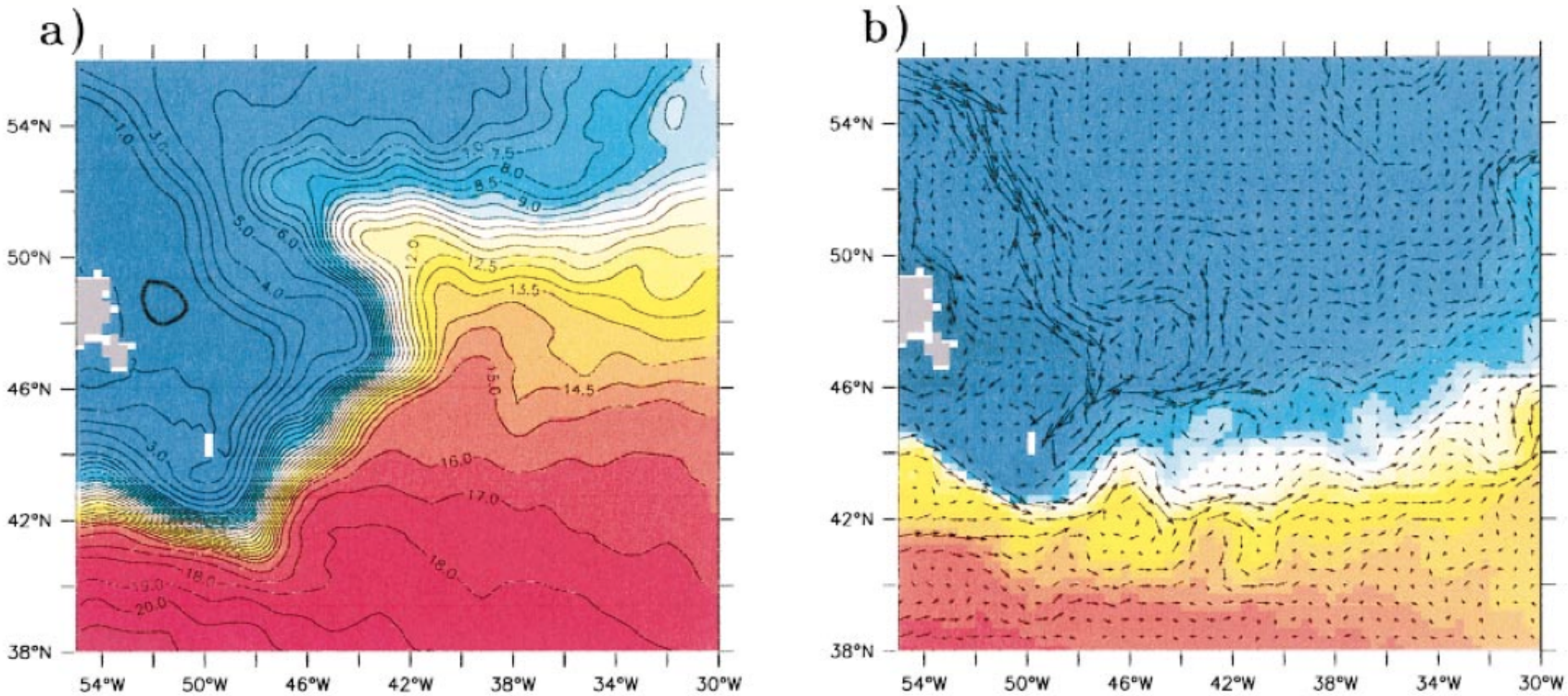


Impact modellers often desire to “correct” these biases.

Flato et al., IPCC AR5, 2013

Cause: too little meridional heat transport

Temperature at 50m depth east of Newfoundland

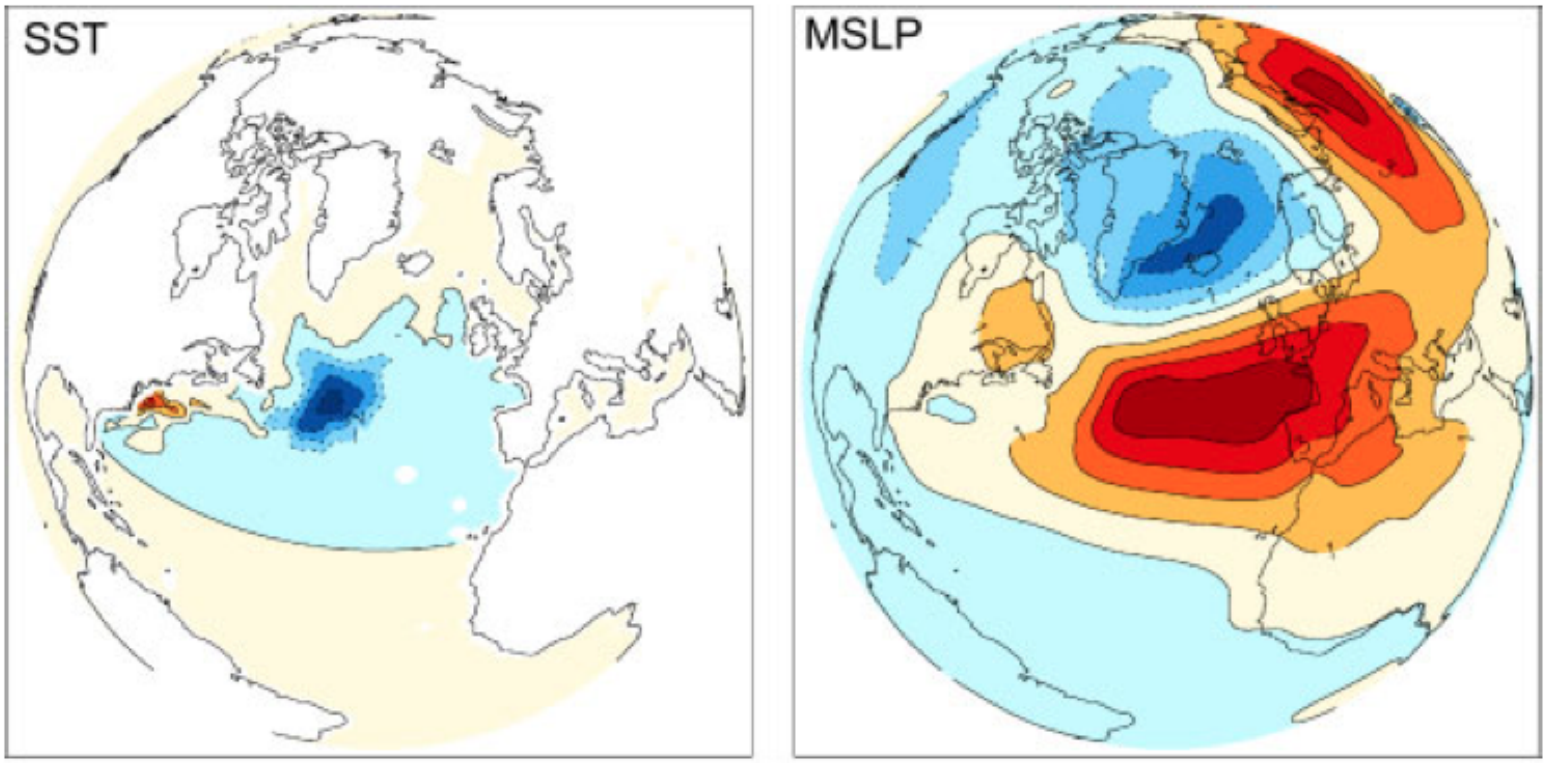


left: observations; right: typical resolution ocean model

- eddies not resolved;

Eden et al., J. Phys. Oceanography

Impacts of GCM biases on large-scale circulation



left: imposed SST anomaly; right: DJF SLP response

Keeley et al., QJRMS, 2012

Displaced storm tracks

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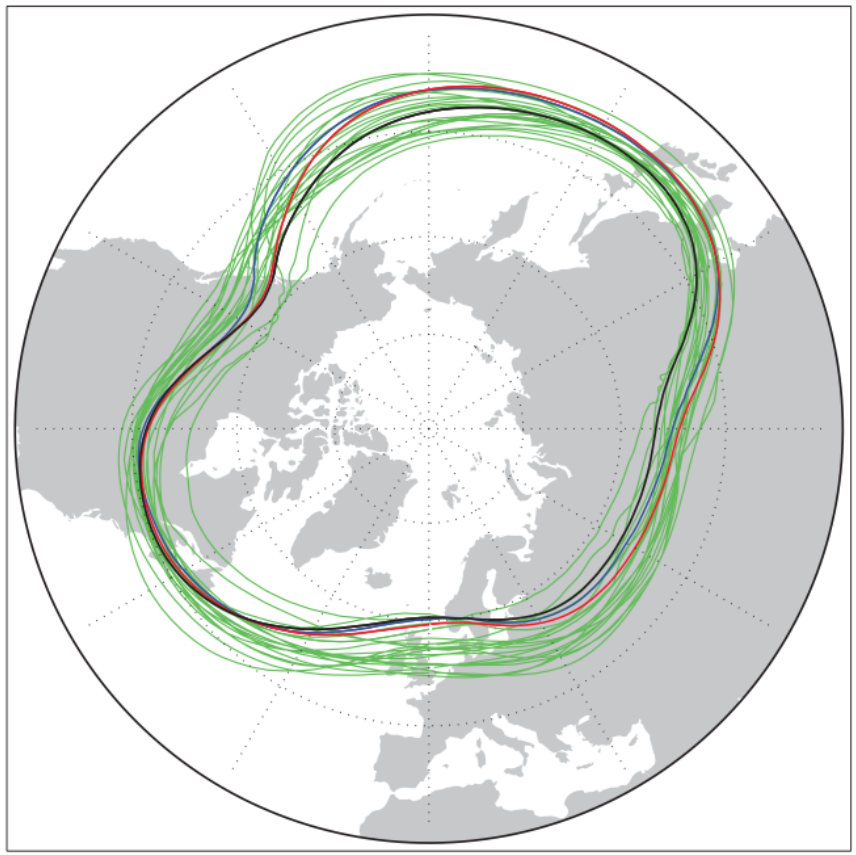

black: ERA40; green: CMIP3 models; red, blue: two high resolution models

Woollings, Phil Trans R. Soc, 2010

Typical impact modeller statement

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"We just need a reference state that agrees with observations."

But how do we get a correct reference state if the model simulates the wrong dynamics?

A step back: Gedankenexperiment

- Bias correction attempts to correct model misspecifications
- Increase misspecifications as far as possible

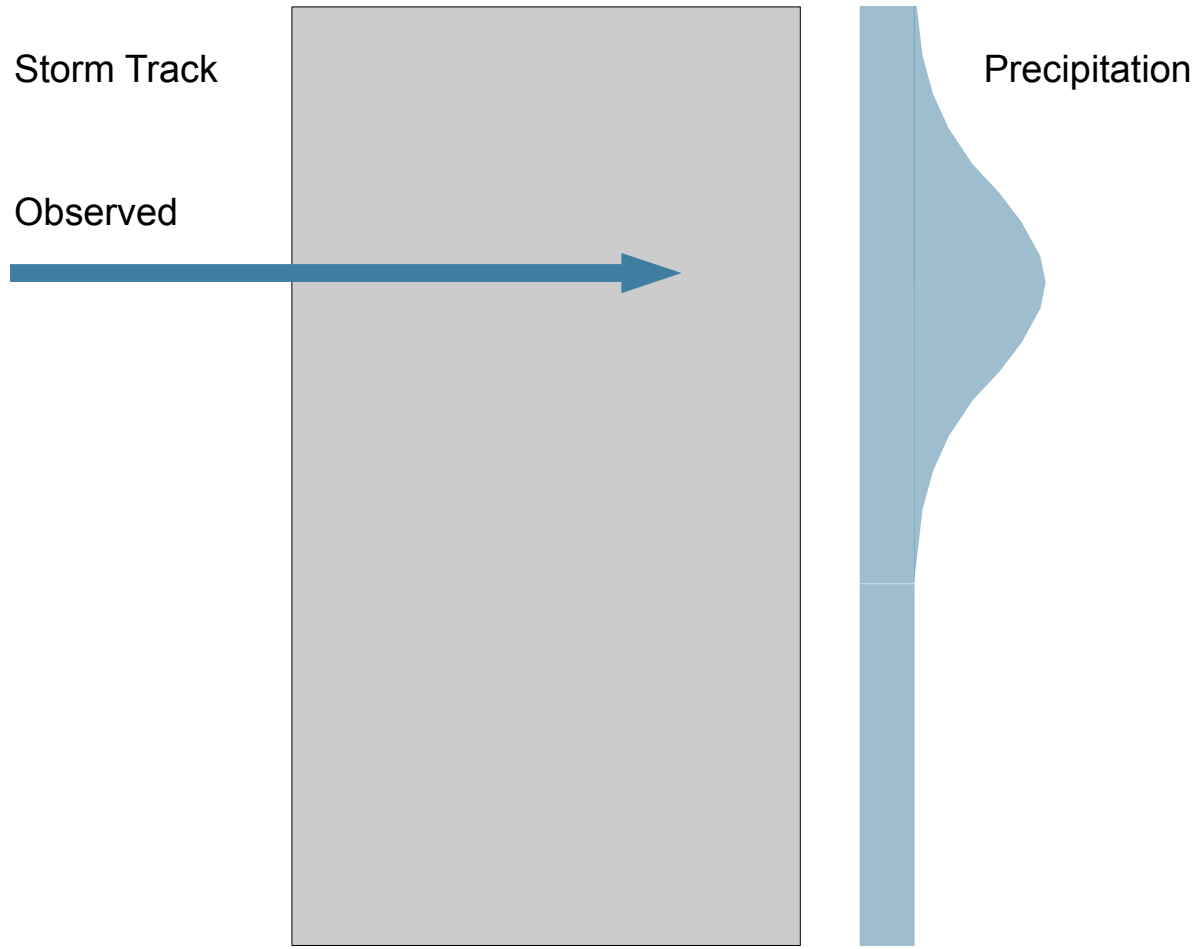
$$\Downarrow$$

energy balance model

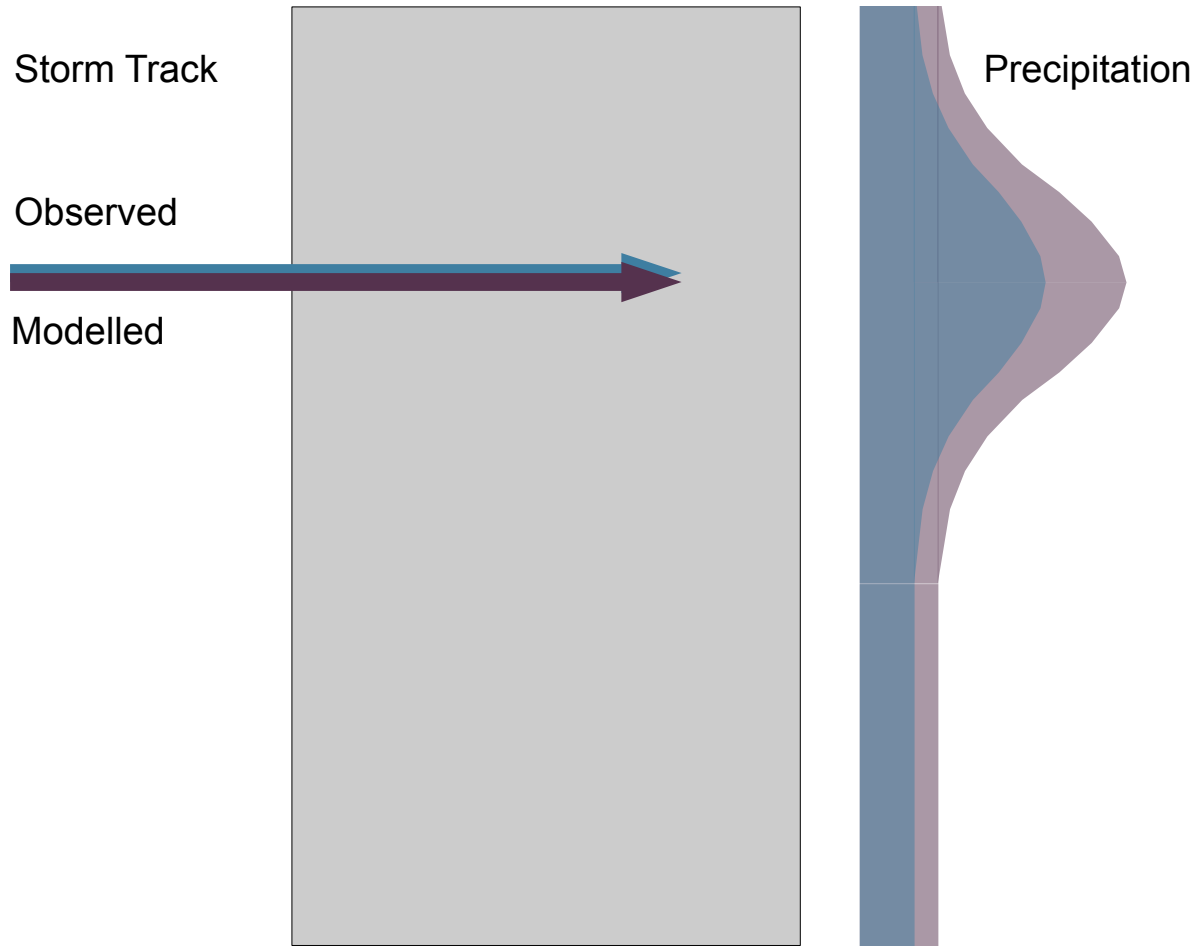
Bias correcting an energy balance model to infer regional changes obviously doesn't make sense.

So, where are the limits?

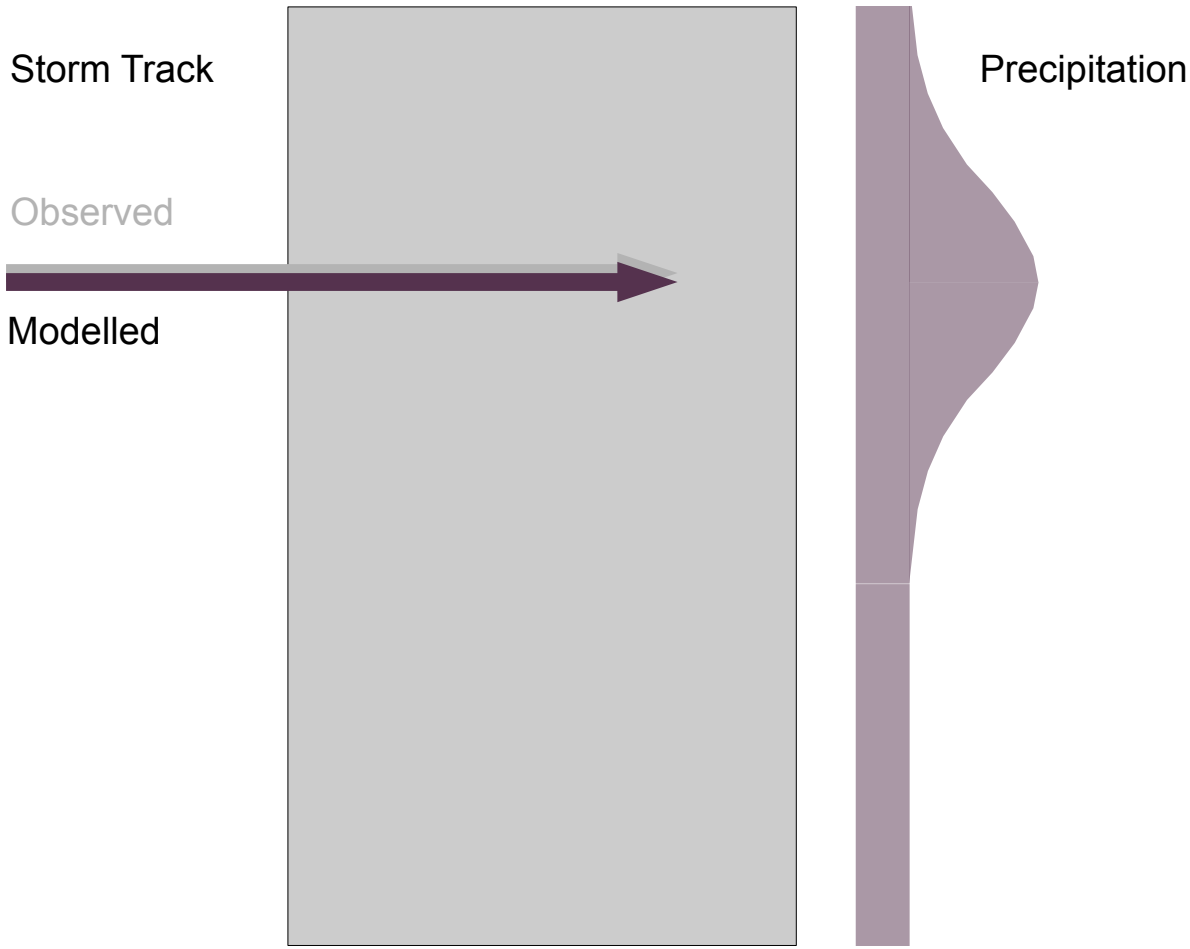
Origins of BC in weather forecasting



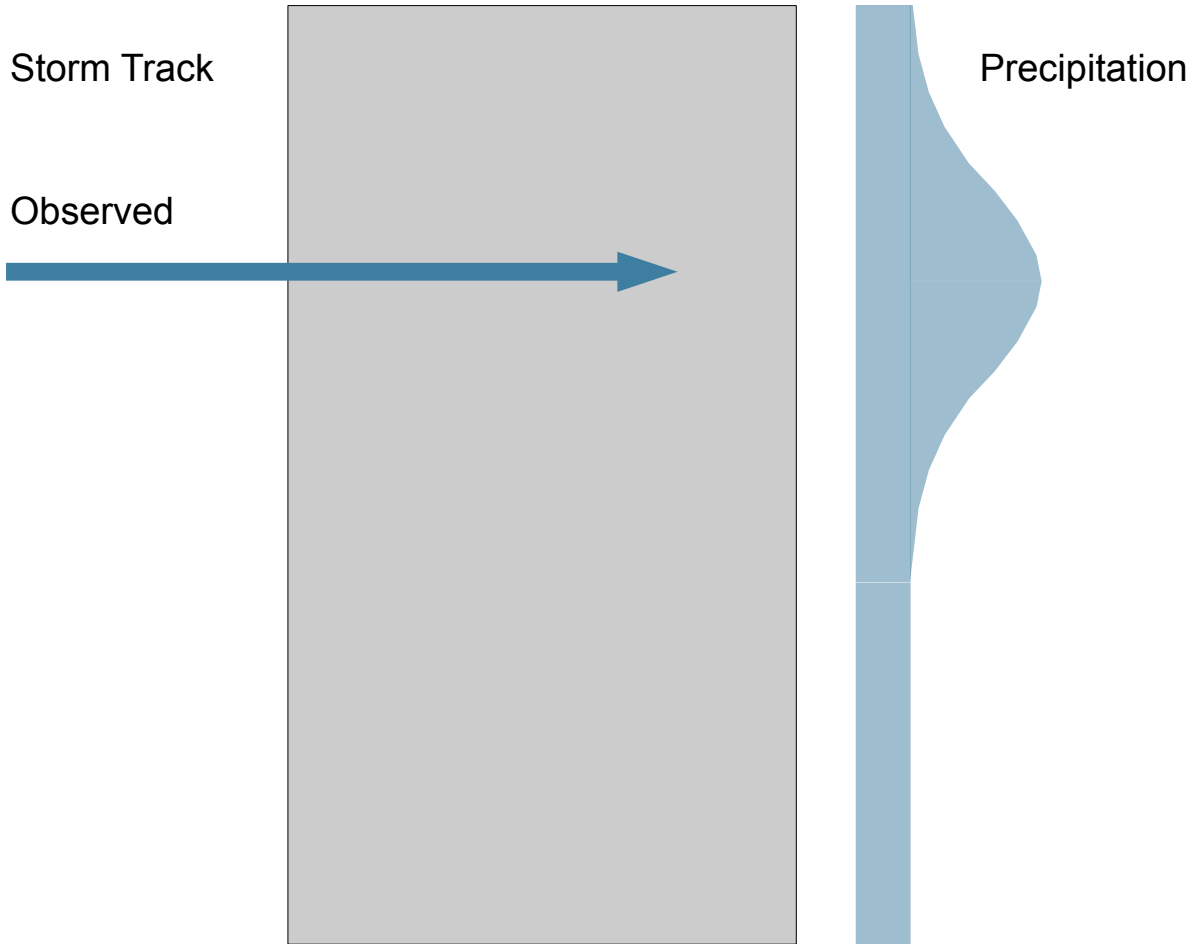
Origins of BC in weather forecasting



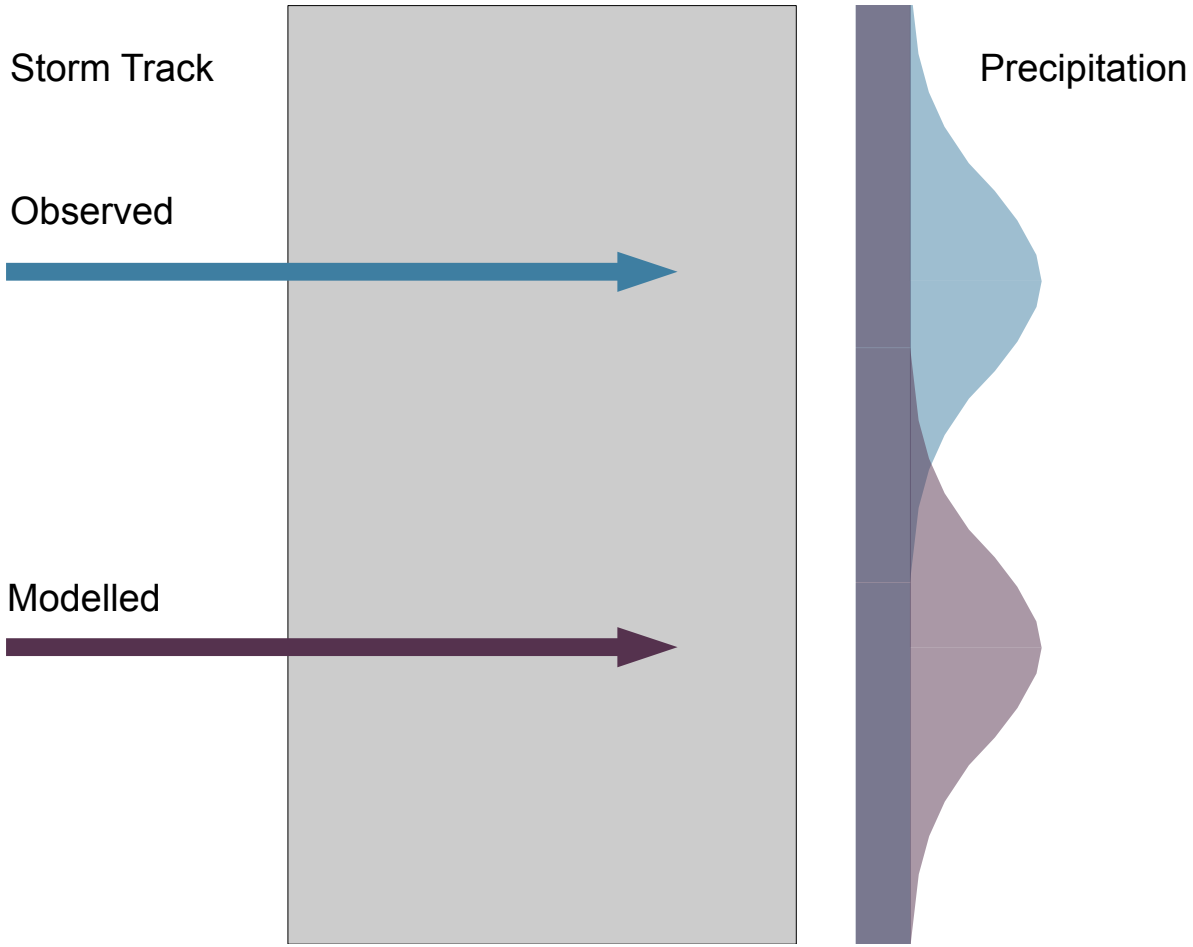
Origins of BC in weather forecasting



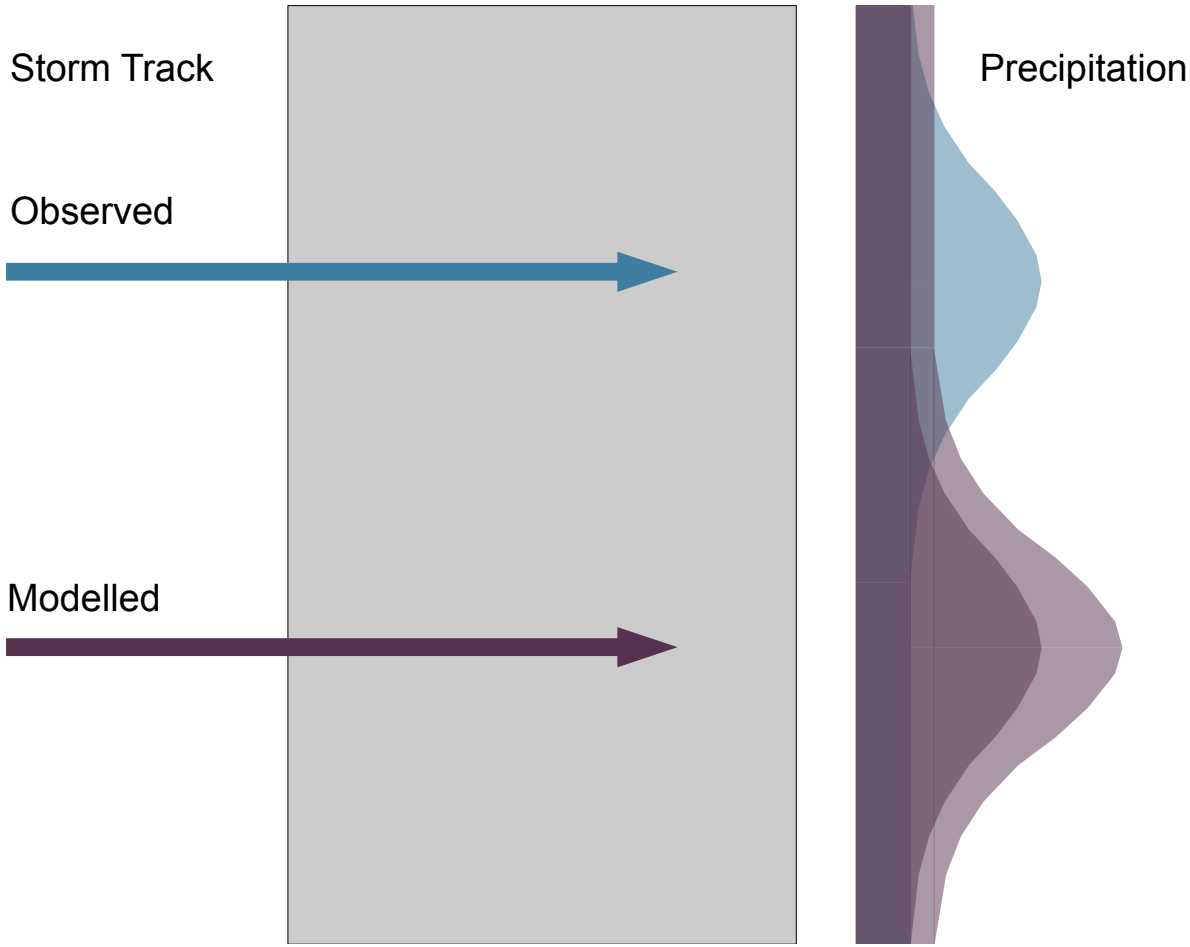
In climate modelling, things are different



In climate modelling, things are different



In climate modelling, things are different



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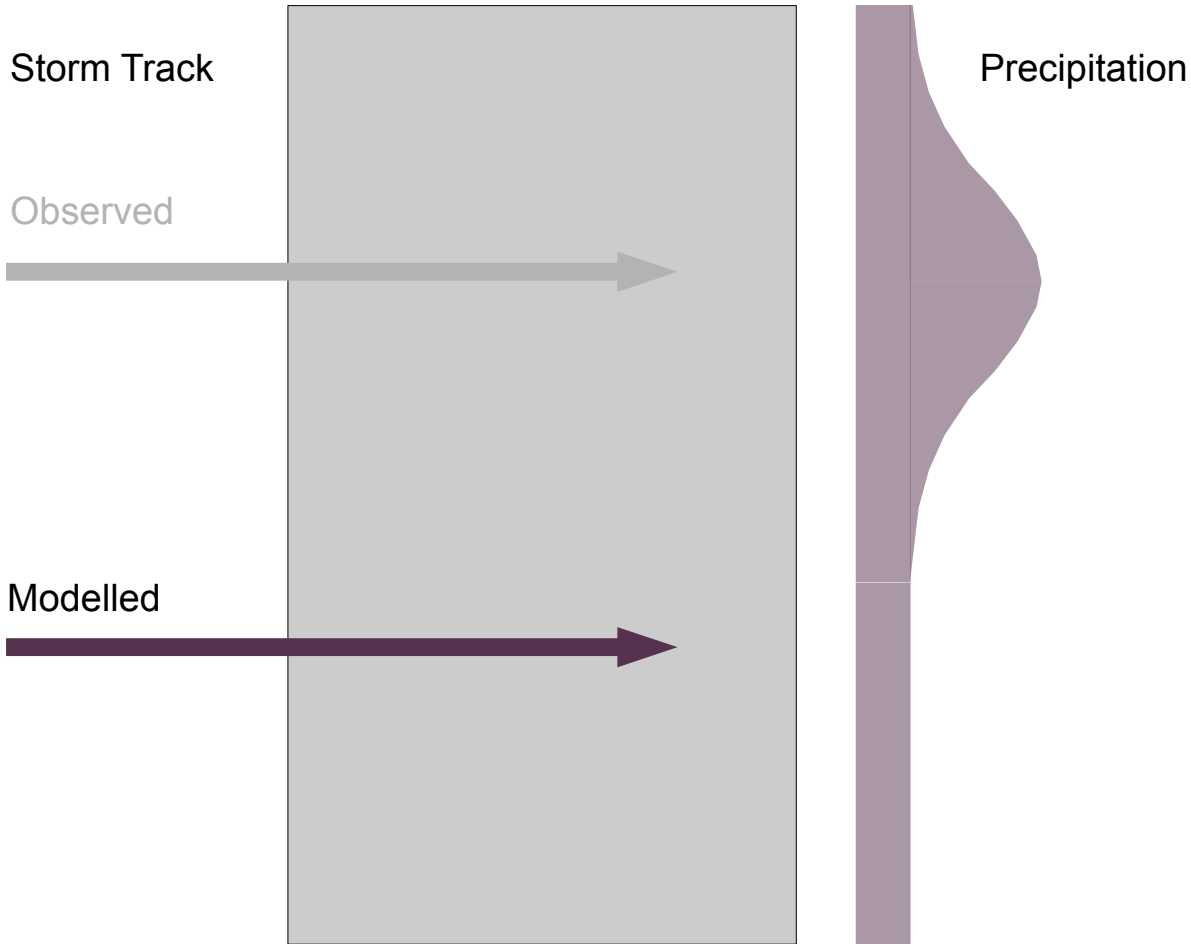
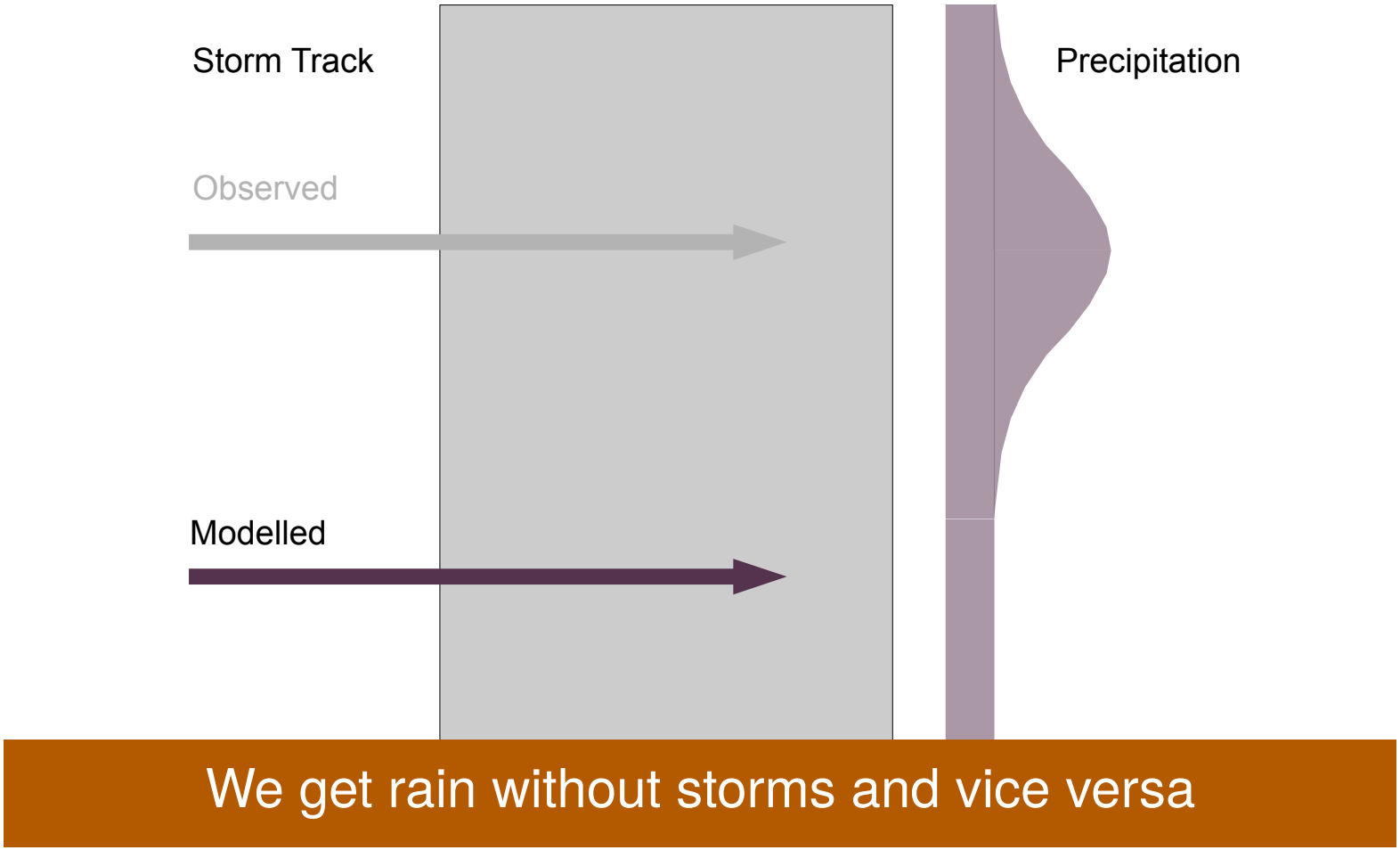
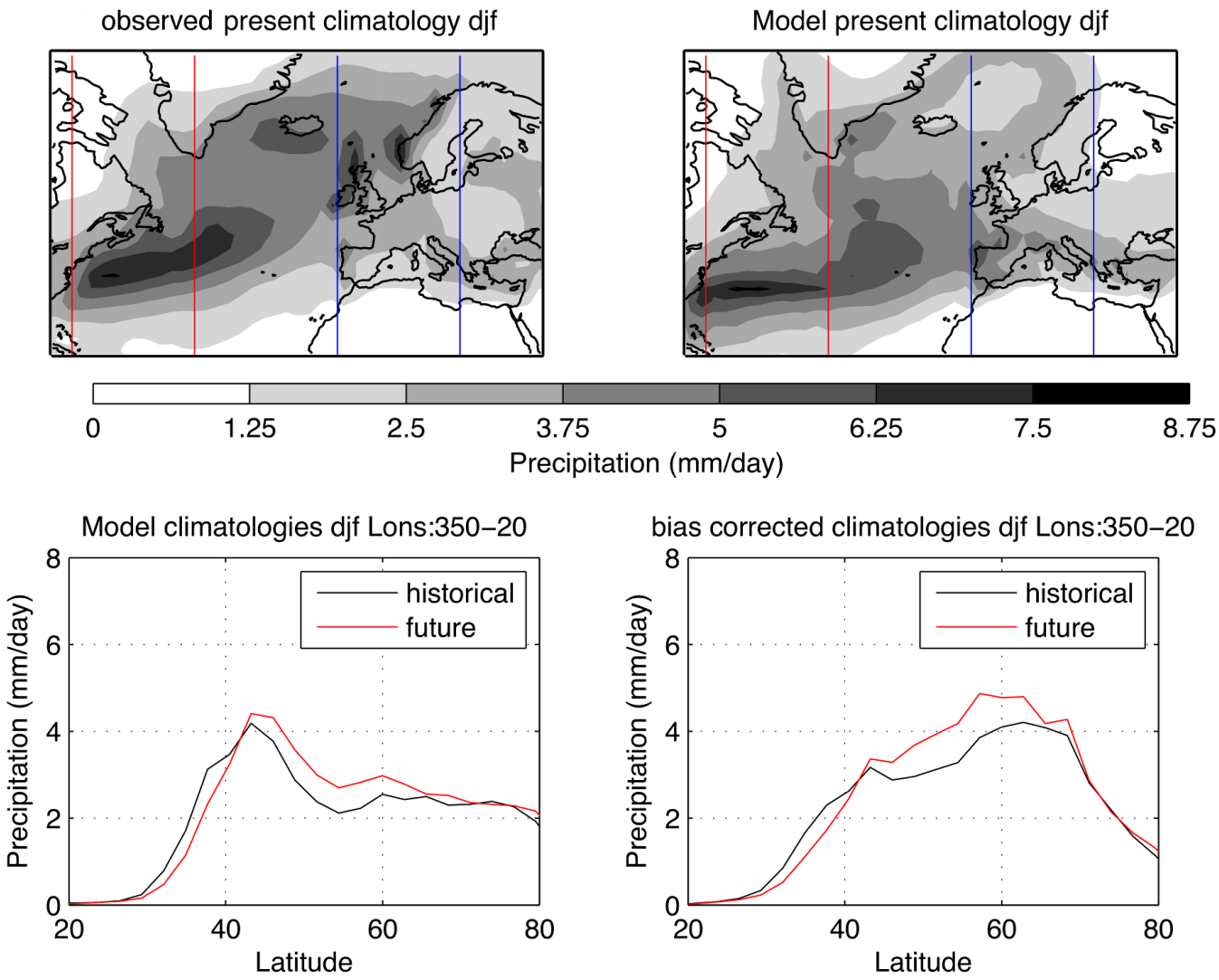


In climate modelling, things are different

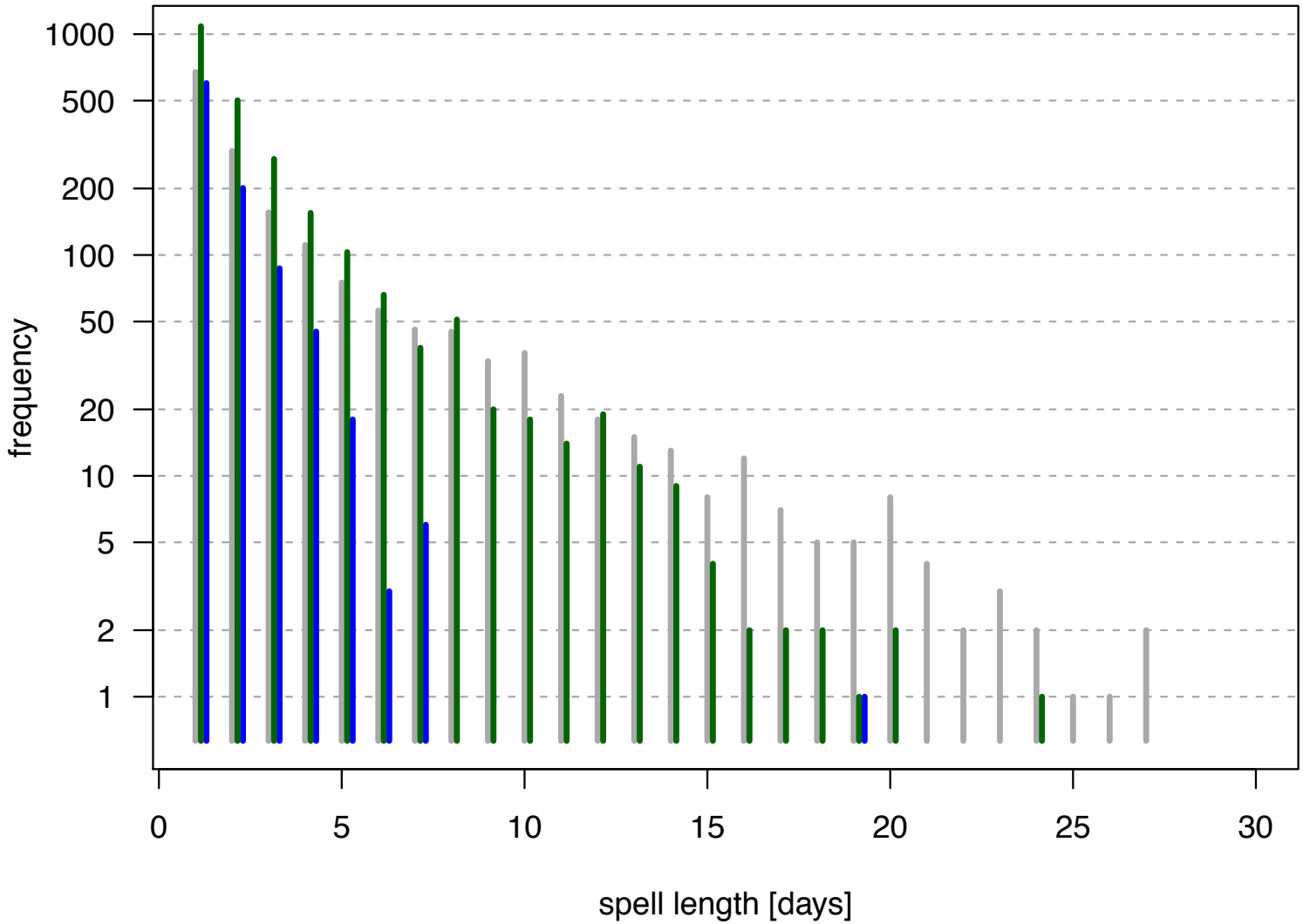


Bias Correction under storm track bias



Maraun et al., in prep.

Quantile mapping under “blocking bias”



Maraun et al., in prep.

Summary large-scale errors

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- GCMs have substantial large-scale circulation errors;
- these errors cannot sensibly be corrected by current methods;
- prior to any bias correction, a pre-selection of suitable GCMs is required.
- If key processes are not simulated, a GCM should not be downscaled.

How to mitigate GCM biases?