GEOMAR

4th VALUE Training School
Validation of Regional Climate Change Projections

Model Output Statistics and Bias Correction

Douglas Maraun

Wegener Center for Climate and Global Change

Outline

GEOMAR

Rationale

MOS in Climate Science

Delta Change Approaches

Distributionwise MOS

Pairwise MOS

GEOMAR

Rationale

MOS in Climate Science

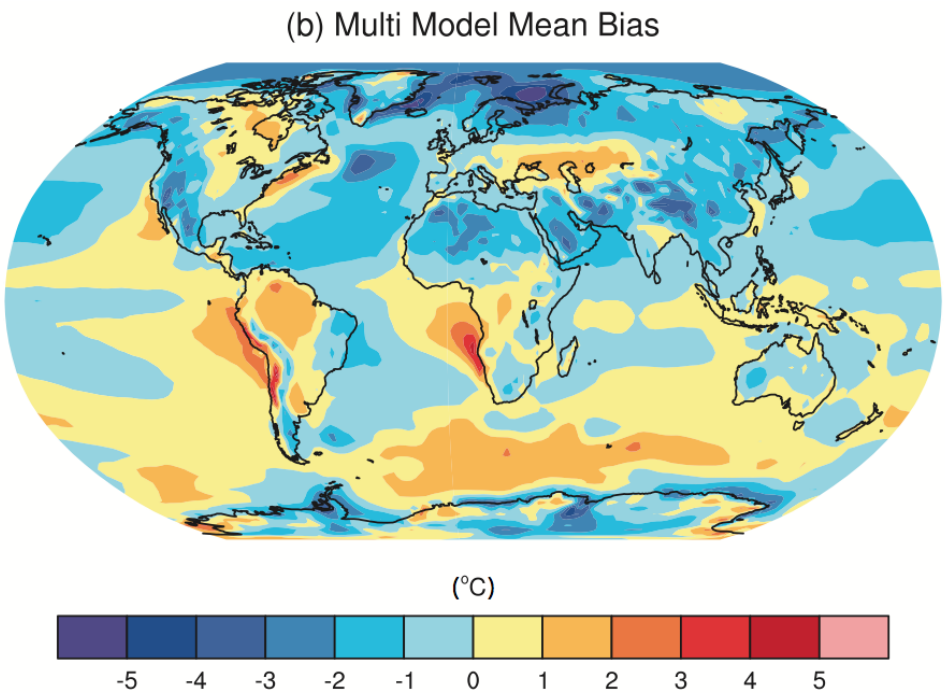
Delta Change Approaches

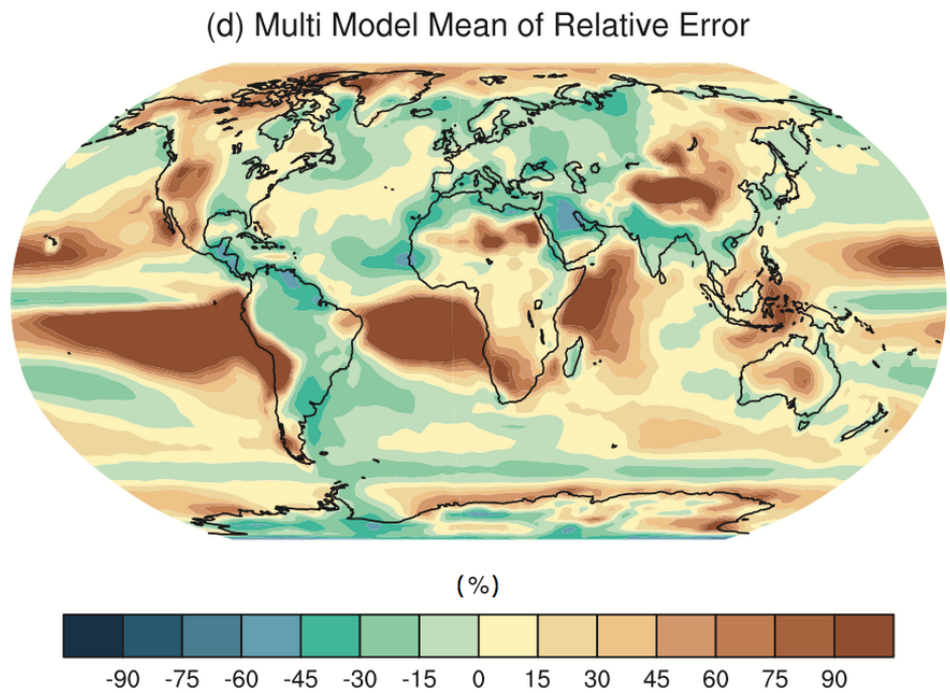
Distributionwise MOS

Pairwise MOS

Temperature and precipitation biases

CMIP5, multi-model mean

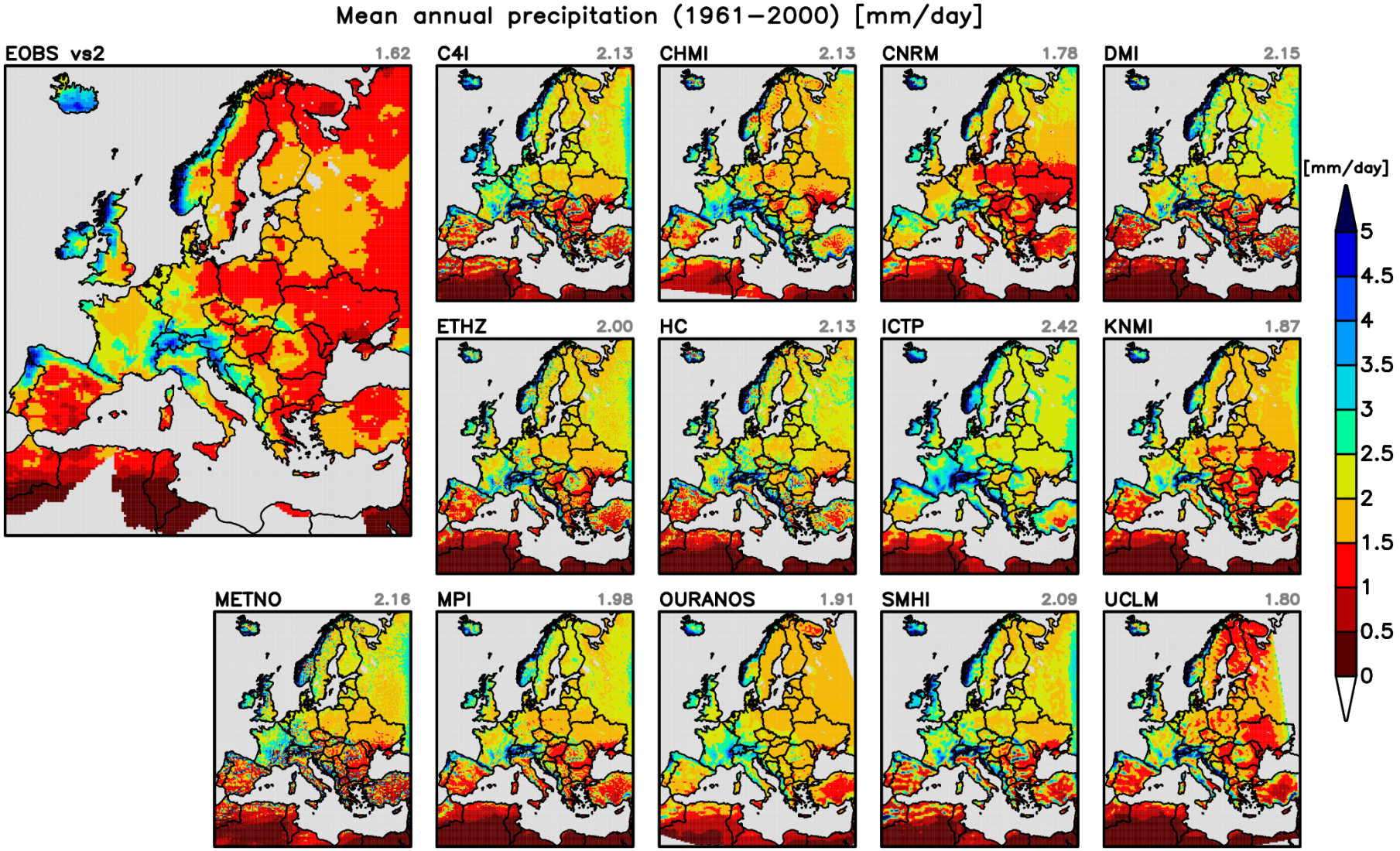




Impact modellers often desire to “correct” these biases.

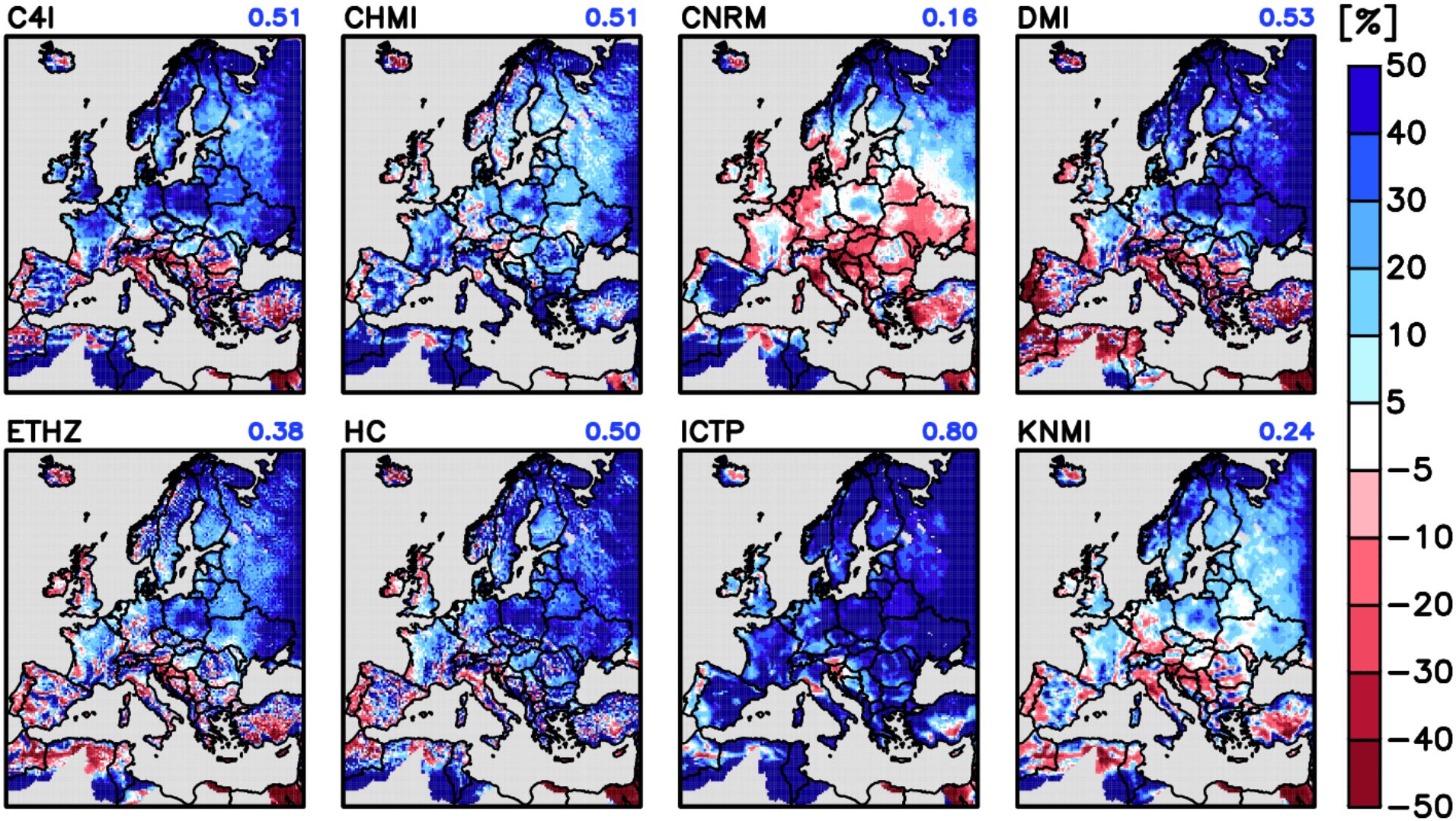
Flato et al., IPCC AR5, 2013

Also RCMs are biased



Kotlarski, unpublished

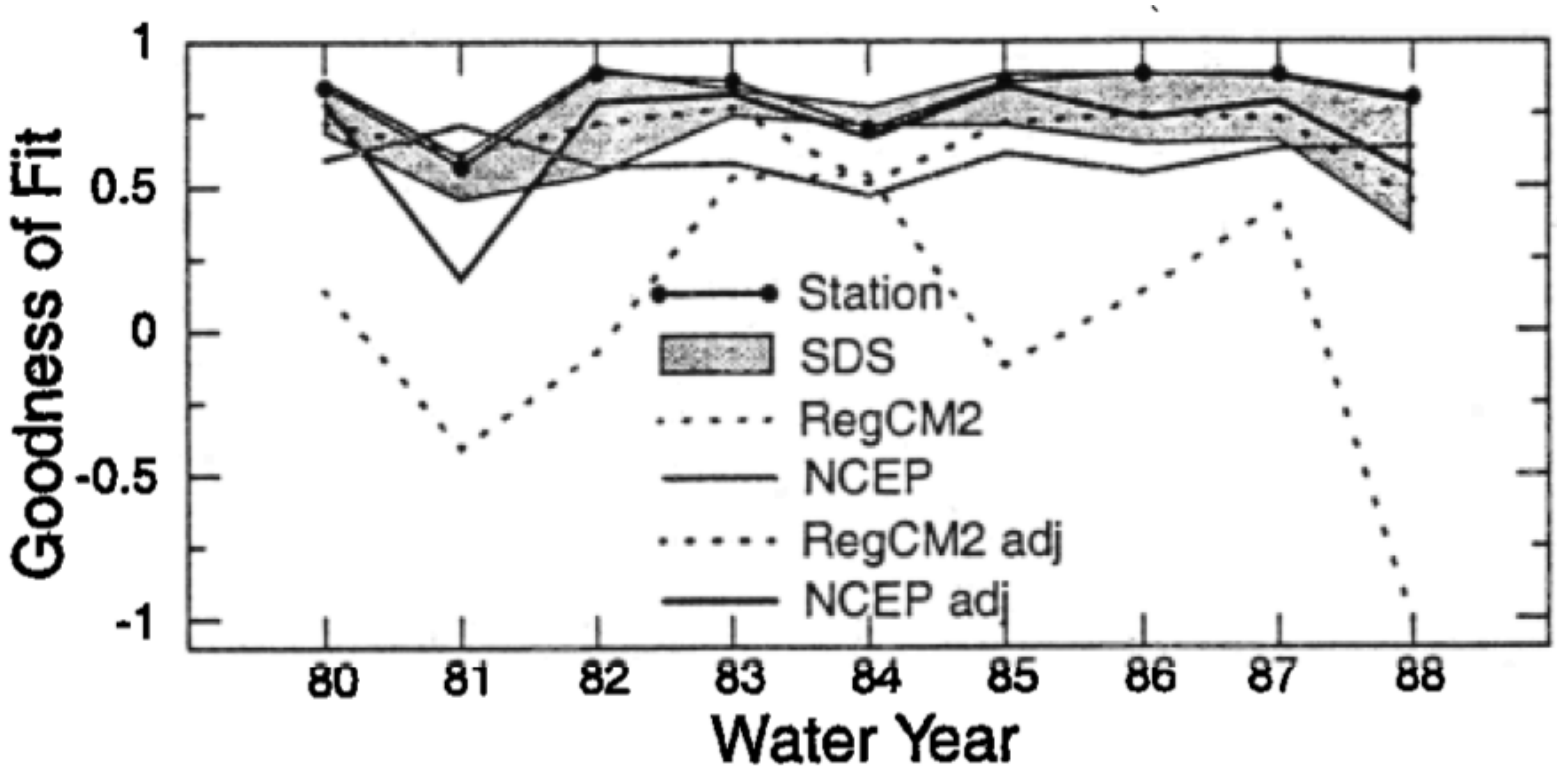
Also RCMs are biased



Kotlarski, unpublished

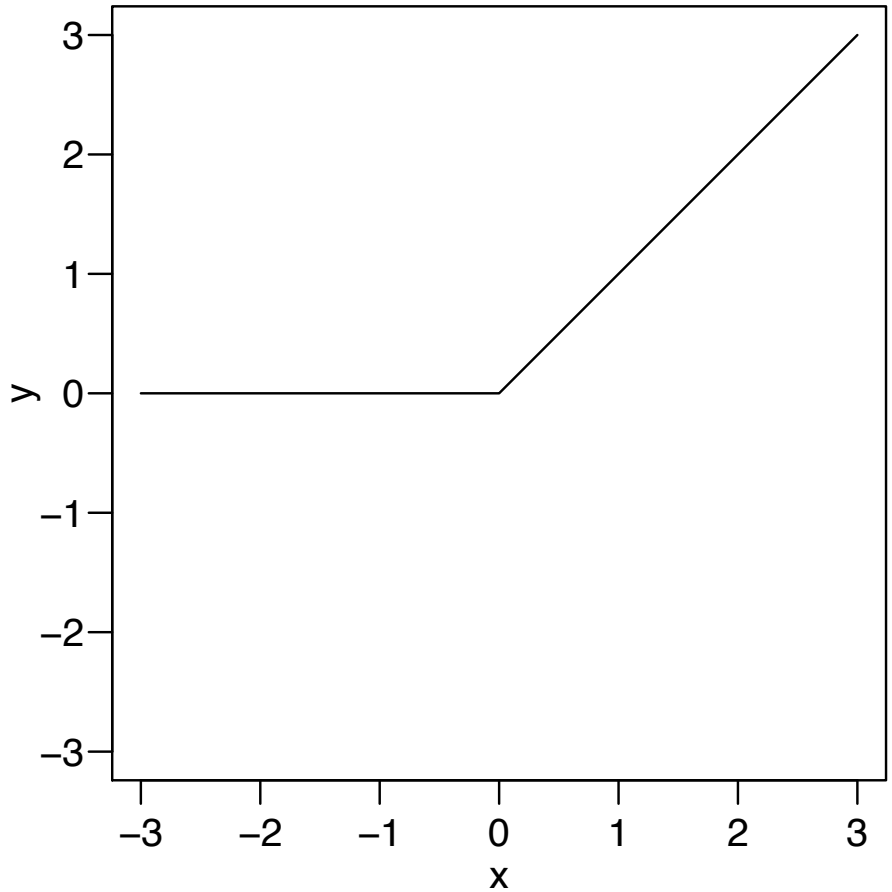
Example: Driving Hydrological Model

Goodness of fit of hydrological model simulation driven with different input data



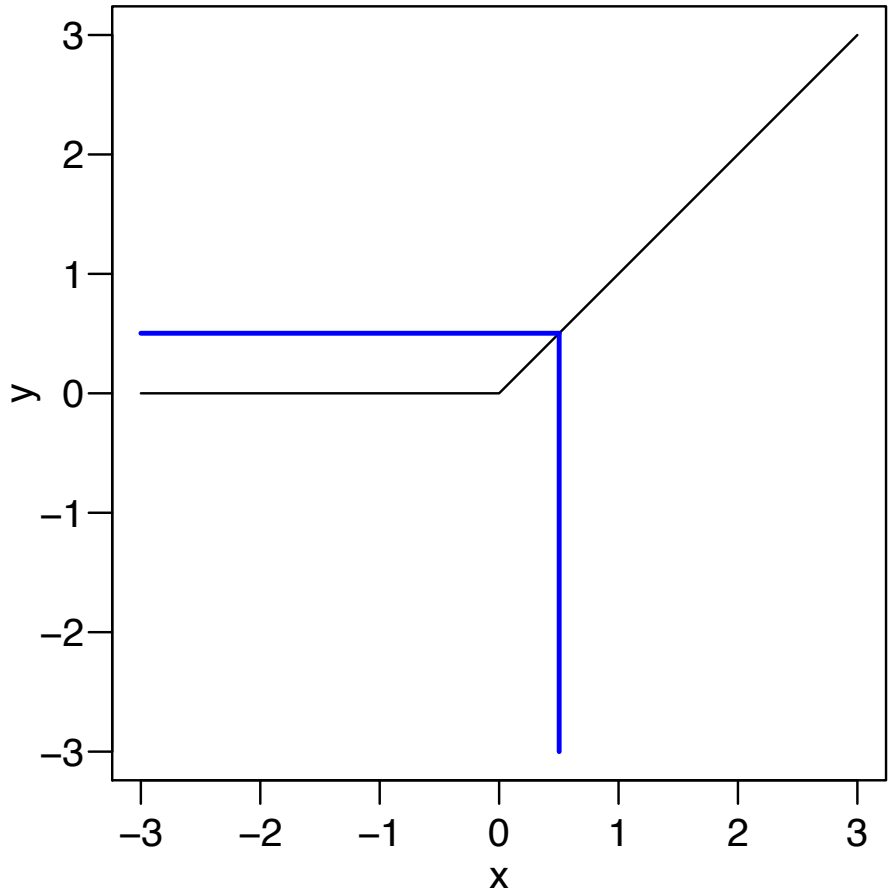
Wilby et al., Geophys. Res. Lett., 2000

MMEs do not Solve the Bias Problem



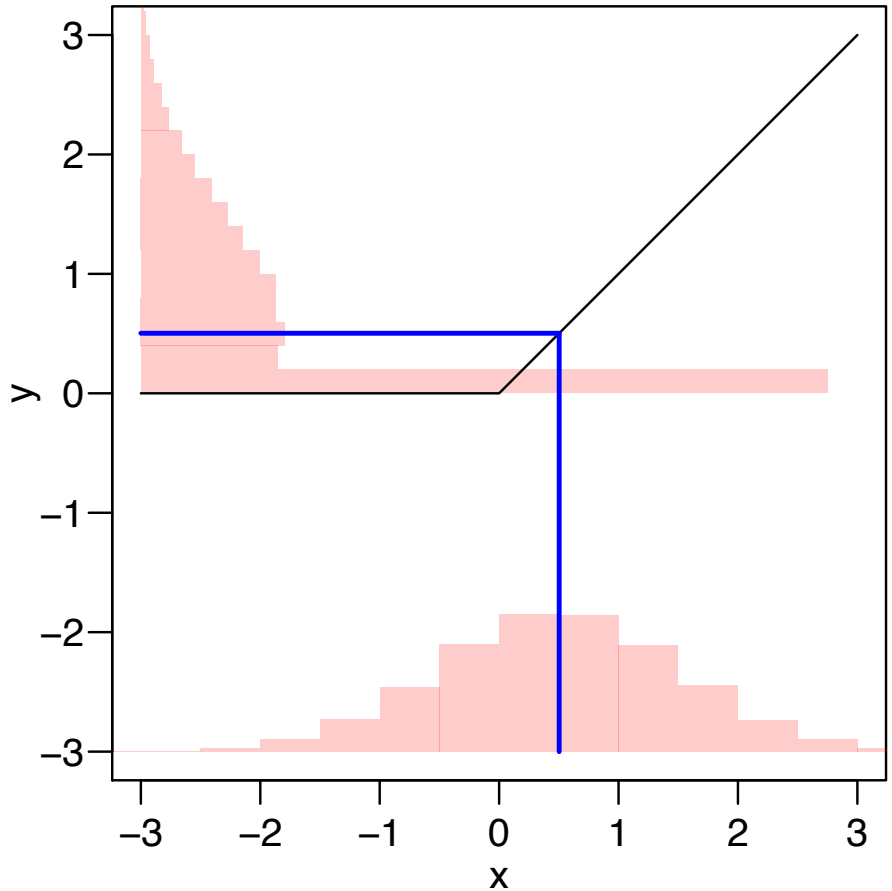
black: transfer function; blue: true value; red shading: model ensemble; red line: ensemble mean.

MMEs do not Solve the Bias Problem



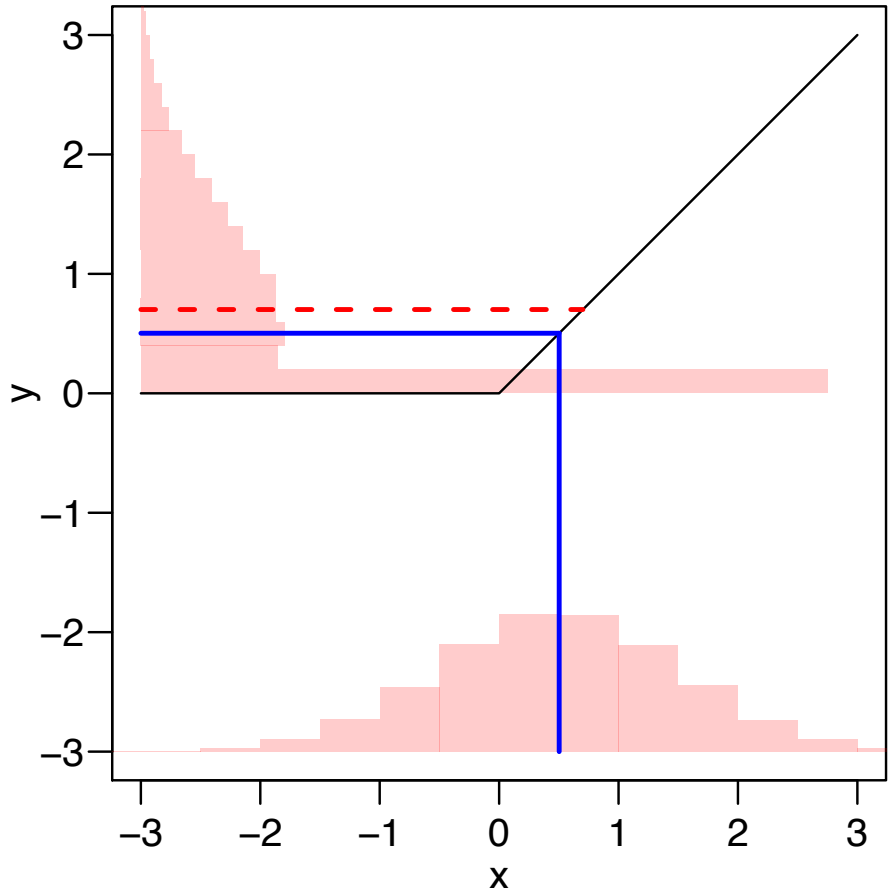
black: transfer function; blue: true value; red shading: model ensemble; red line: ensemble mean.

MMEs do not Solve the Bias Problem



black: transfer function; blue: true value; red shading: model ensemble; red line: ensemble mean.

MMEs do not Solve the Bias Problem



black: transfer function; blue: true value; red shading: model ensemble; red line: ensemble mean.

GEOMAR

NWP vs. Climate Projections?

What is different between the two?

NWP vs. Climate Projections?

What is different between the two?

- time scales of calibration and prediction/projection
- extrapolation requirements
- validation data availability
- **synchronicity**

Pairwise vs. distributionwise calibration

GEOMAR

Pairwise (NWP)

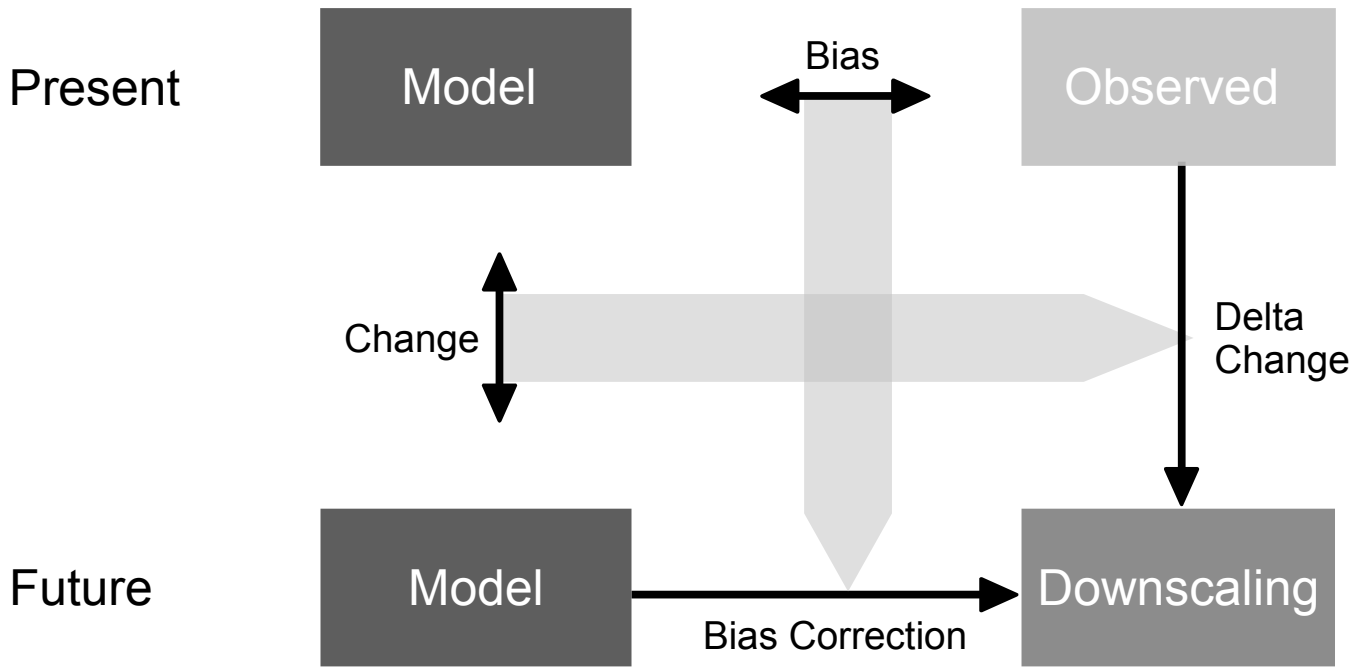
- simulated and observed series in sync.
- regression model possible
- skill evaluation possible

Distributionwise (typically climate)

- independent climate simulation
- no simple regression (with time as index) possible
- skill evaluation difficult
- typically homogeneous!

Delta change vs. bias correction

Do we take series/parameters from obs or model?



Maraun et al., Rev. Geophys., 2010

GEOMAR

“Delta” Method

shifting/rescaling observed rainfall by change “factors”

Temperature:

$$y^f_{i+T} = x^p_{\mathrm{obs},i} + \bar{y}^f_{\mathrm{mod}} - \bar{x}^p_{\mathrm{mod}}$$

Precipitation:

$$y^f_{i+T} = x^p_{\mathrm{obs},i} \frac{\bar{y}^f_{\mathrm{mod}}}{\bar{x}^p_{\mathrm{mod}}}$$

Note: this method

- does not use the RCM time series, but only the climate change signal;
- does not account for dynamical changes;

Change Factor Weather Generators (WGs)

GEOMAR

- Calibrate WG in present day climate against observations;
- derive changes of WG parameters from RCM;
- run the WG with changed parameters.

Note: as the delta change method, these WGs do not use the RCM time series, but only the climate change signal

e.g., Kilsby et al., Env. Mod. Soft., 2007

GEOMAR

Direct Method

GEOMAR

correcting regional climate model output by a correction term or scaling factor

Temperature:

$$y_i^f = x_{\mathrm{mod},i}^f + \bar{y}_{\mathrm{obs}}^p - \bar{x}_{\mathrm{mod}}^p$$

Precipitation:

$$y_i^f = x_{\mathrm{mod},i}^f \frac{\bar{y}_{\mathrm{obs}}^p}{\bar{x}_{\mathrm{mod}}^p}$$

y_i^f: corrected simulated future series

$x_{\mathrm{mod},i}^f$: uncorrected simulated future series

$\bar{y}_{\mathrm{obs}}^p$: observed present mean

$\bar{x}_{\mathrm{mod}}^p$: simulated present mean

Correction of mean and variance

$$y_i^f = \frac{x_{\mathrm{mod},i}^f - \bar{x}_{\mathrm{mod}}^p}{sd_{\mathrm{mod}}^p / sd_{\mathrm{obs}}^p} + \bar{x}_{\mathrm{obs}}^p$$

sd_{mod}^p present simulated variance

sd_{obs}^p present observed variance

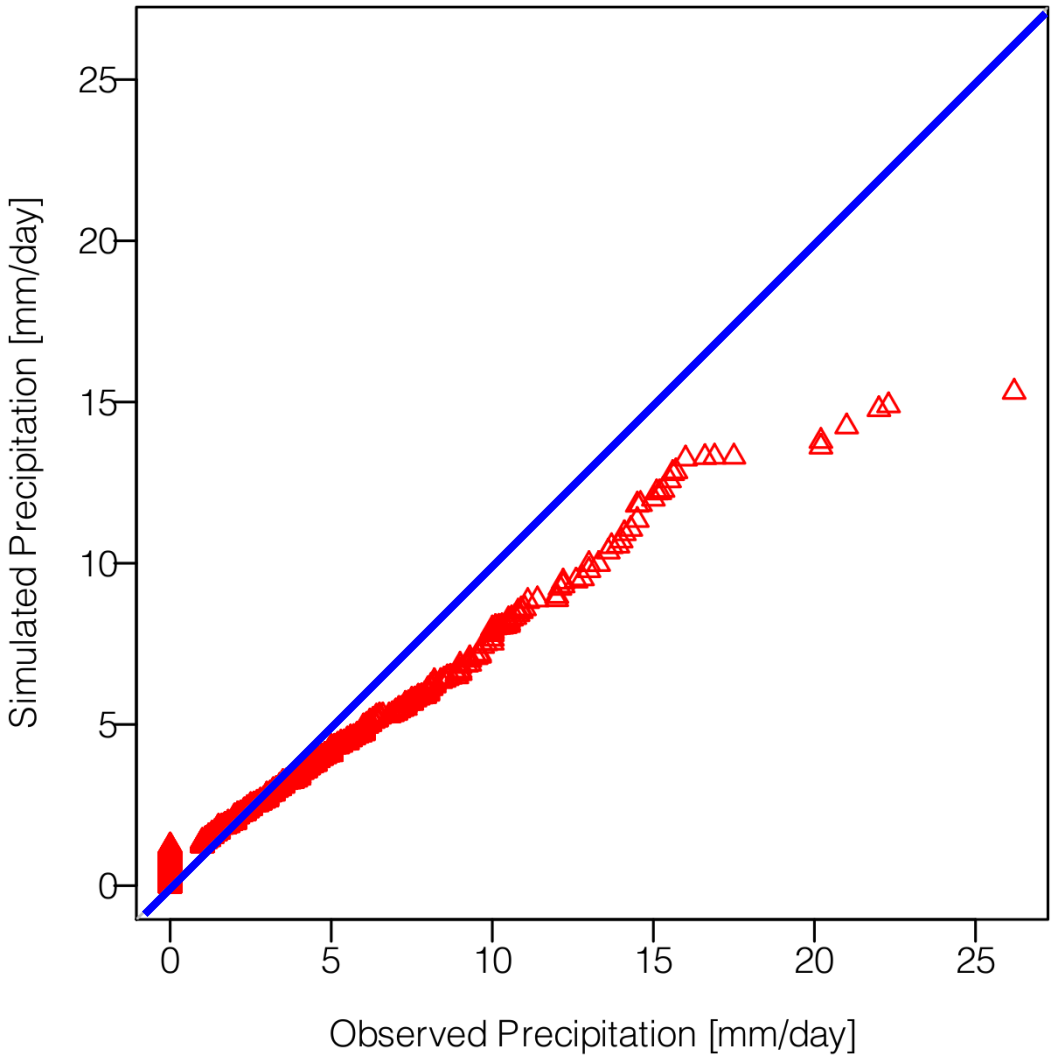
Quantile (-Quantile) mapping

quantile dependent mapping

$$PDF(y_i^f) = T_{cal}(PDF(x_{\mathrm{mod},i}^f))$$

x modelled grid box rainfall; y observed (grid box) rainfall

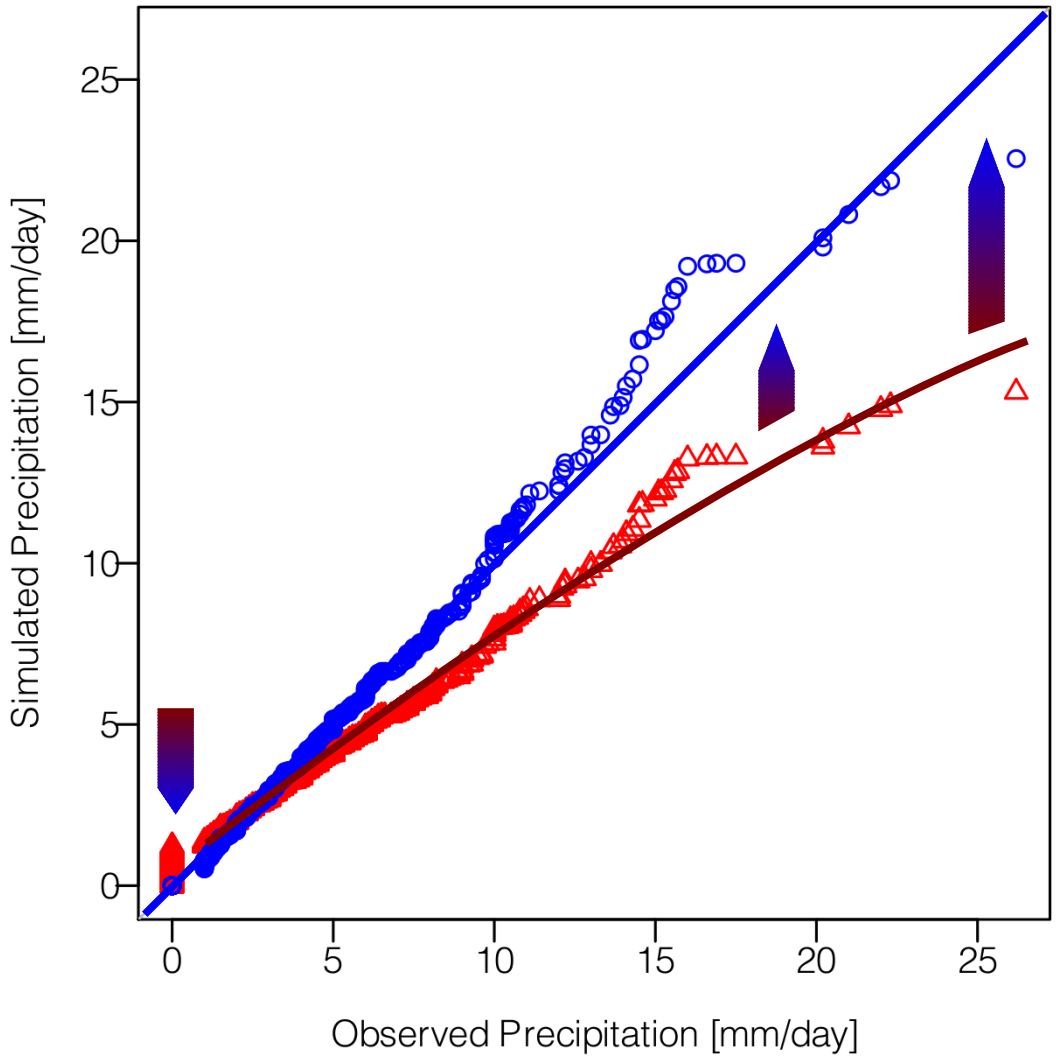
Quantile mapping



- adjust intensities;
- adjust number of wetdays.

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

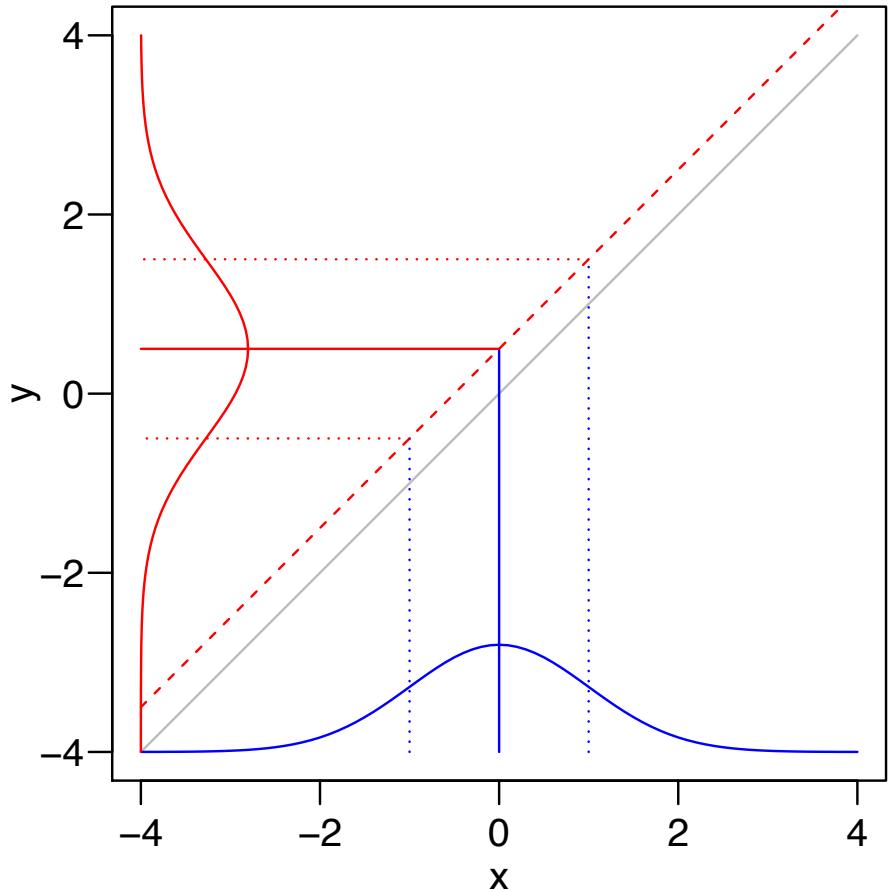
Quantile mapping



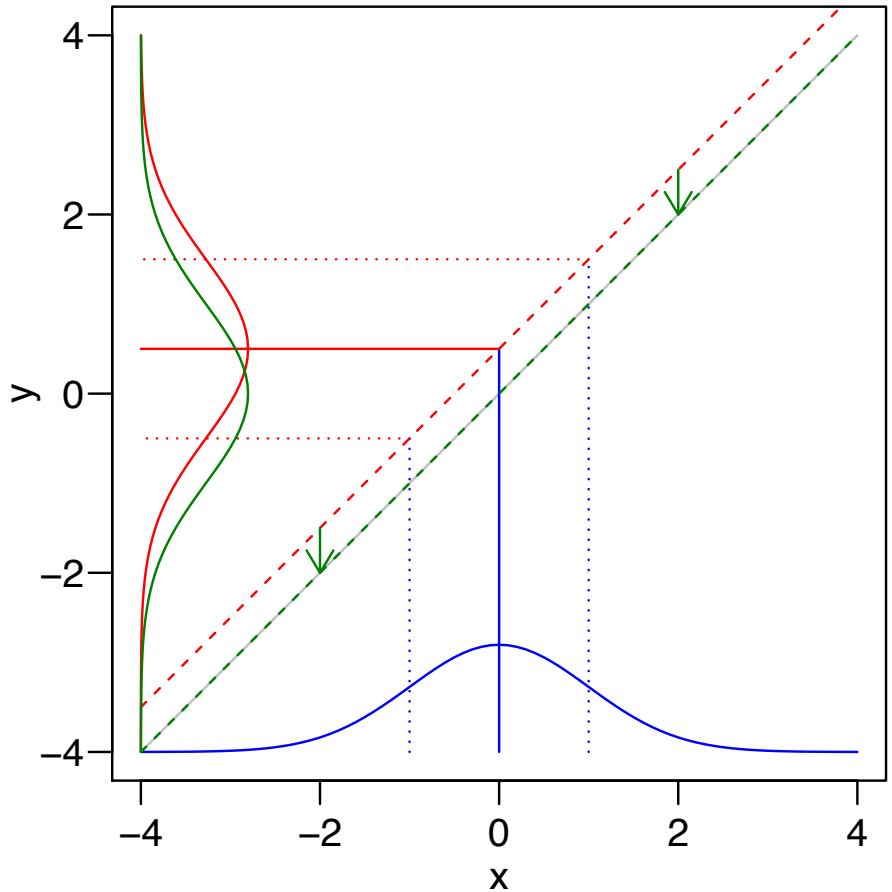
- adjust intensities;
- adjust number of wetdays.

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

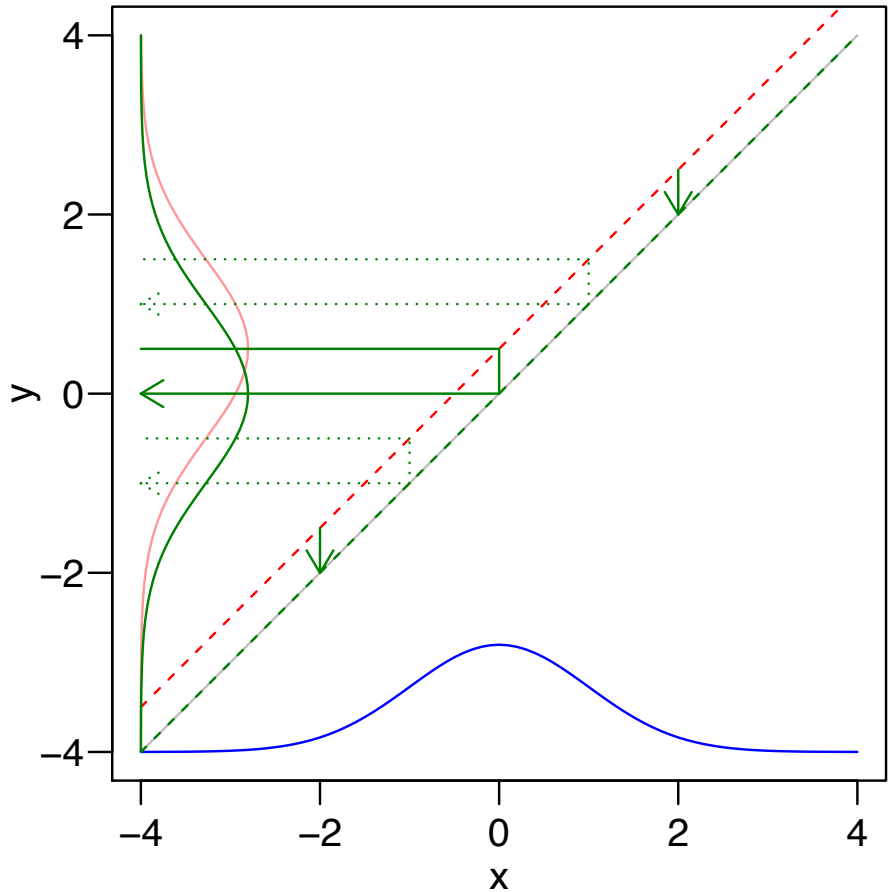
Correction of mean



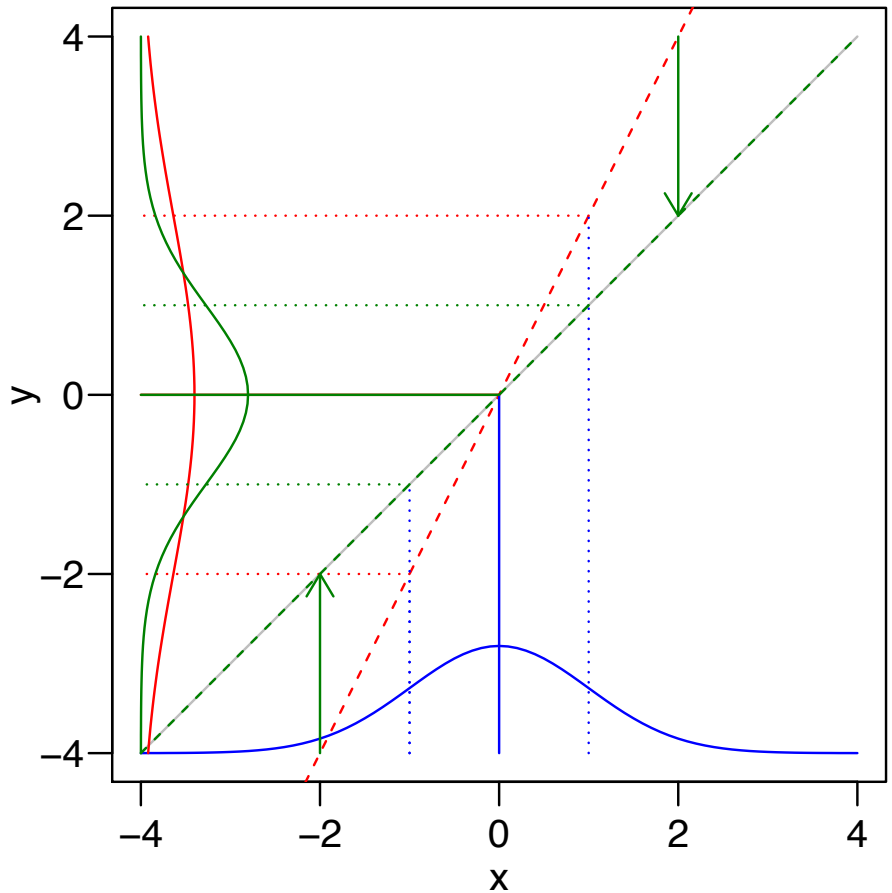
Correction of mean



Correction of mean

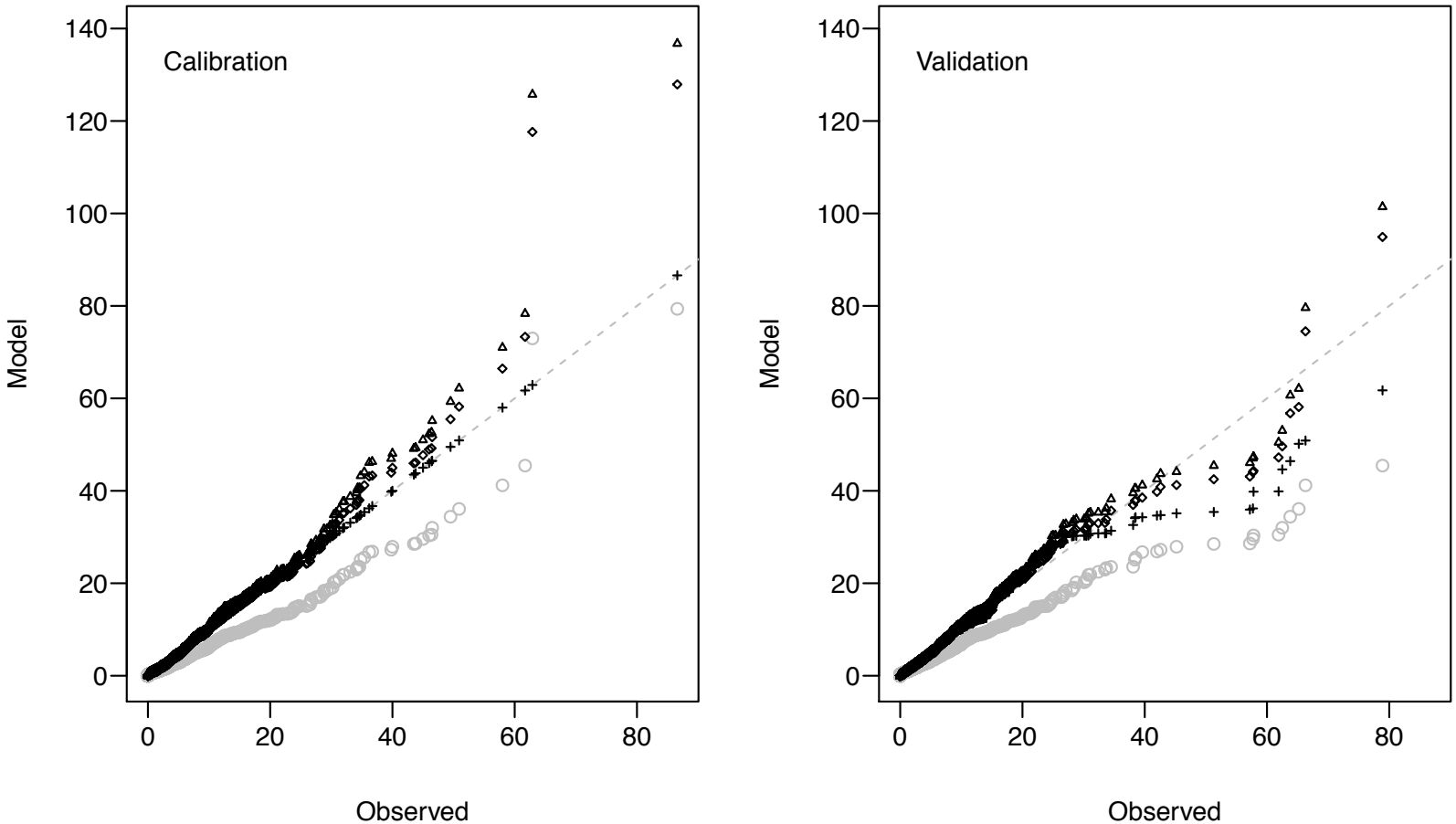


Correction of variance



Comparison of methods

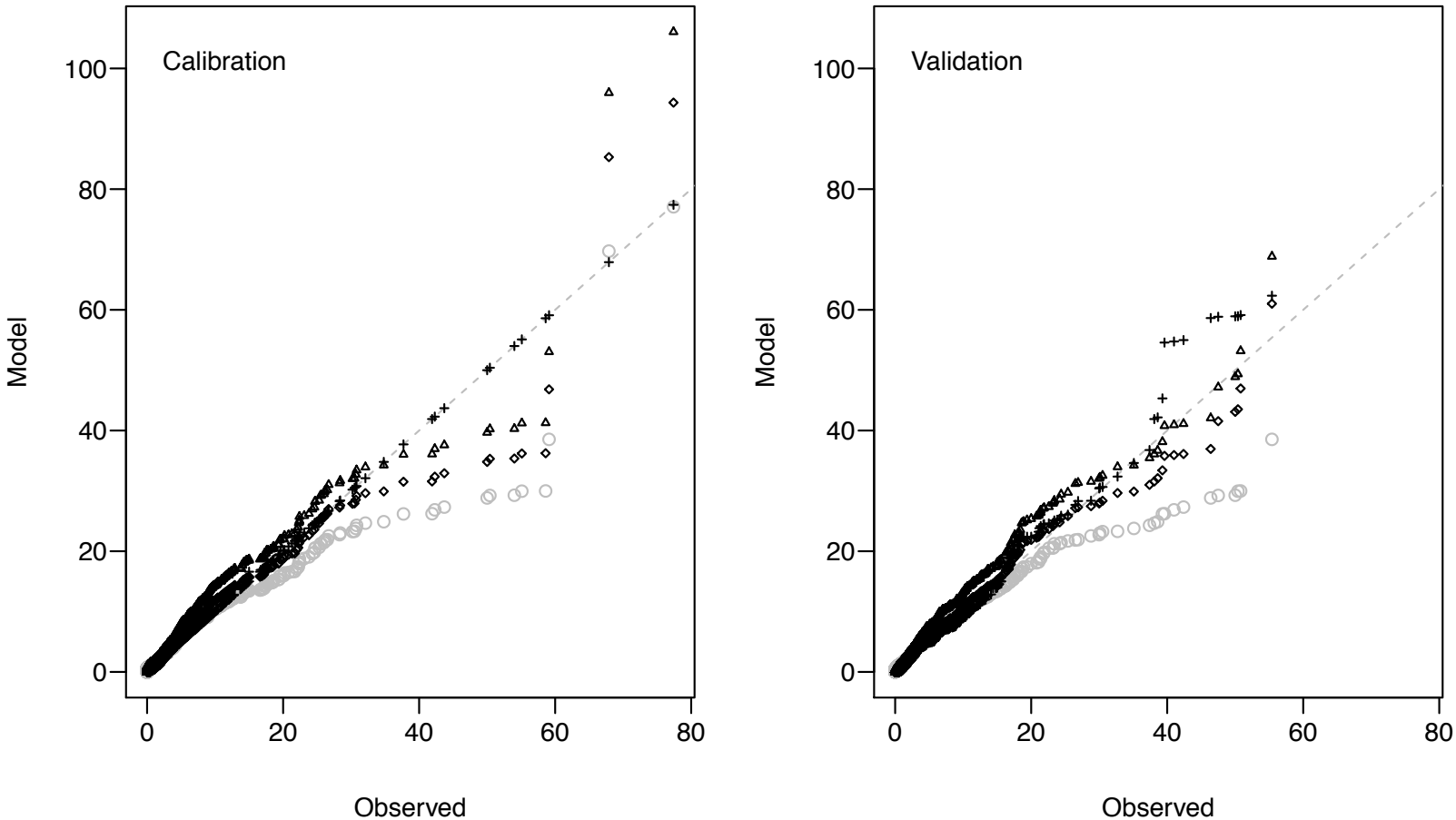
Example 1: daily summer precipitation at Clausthal-Zellerfeld-Erbprinzentanne (Id: 862)



Top: Clausthal-Zellerfeld-Erbprinzentanne (Id: 862), bottom: Eckertal (Id: 1117)
Left: Calibration period, right: validation period
Grey circles: uncorrected RCM, triangles: scaling, diamonds: parametric quantile mapping, crosses: non-parametric quantile mapping.

Comparison of methods

Example 2: daily summer precipitation at Eckertal (Id: 1117)



Left: Calibration period, right: validation period
Grey circles: uncorrected RCM, triangles: scaling, diamonds: parametric quantile mapping, crosses: non-parametric quantile mapping.

GEOMAR

Rationale

MOS in Climate Science

Delta Change Approaches

Distributionwise MOS

Pairwise MOS

GEOMAR

Pairwise MOS · Multipredictor methods

Pairwise MOS

GEOMAR

MOS as in Forecasting:

- re-analysis driven RCM, potentially spectrally nudged;
- synchronicity;
- predictors other than the variable itself are possible.

But: can only correct RCM biases!
(Discuss: how could one define pairs other than by temporal indexing?)

Themessl et al., Int. J. Climatol., 2010

GEOMAR

Pairwise MOS · Stochastic methods

Stochastic model output statistics

GEOMAR

Idea: regression model in pairwise MOS

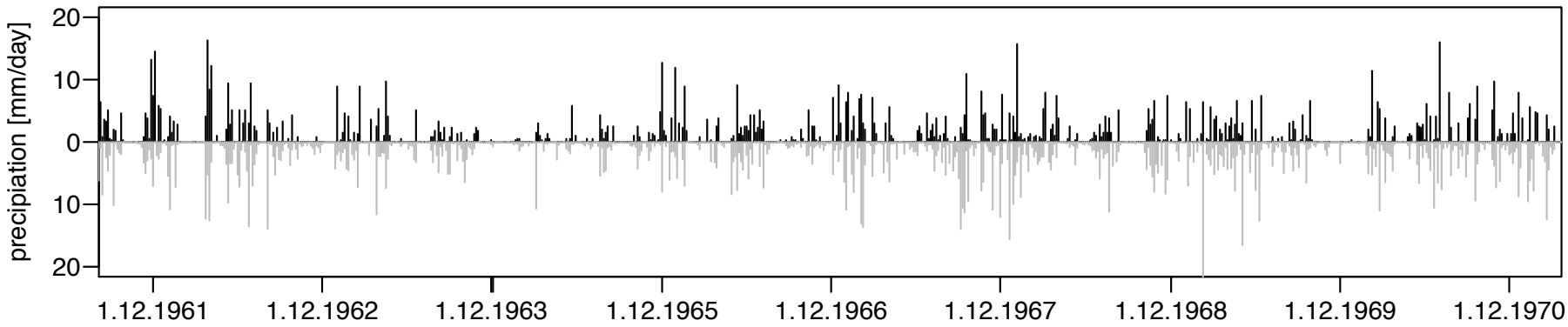
observed precipitation = corrected RCM precipitation + noise

Requirement for any regression model:

- a day to day correspondence between predictor and predictand.

Perfect boundary setting

Cambridge, CEE England (Station Id. 454)



Synchronicity ensured by ERA40 boundaries + nudging

Wong et al., J Climate, 2014.

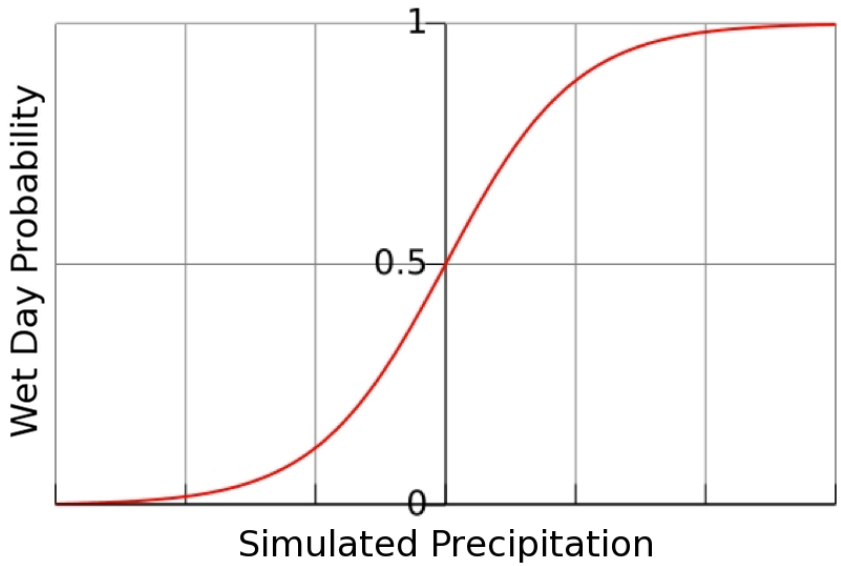
Wet day probabilities

GEOMAR

Logistic Regression

$$p_i = \frac{\exp(a + bx_i)}{1 + \exp(a + bx_i)}$$

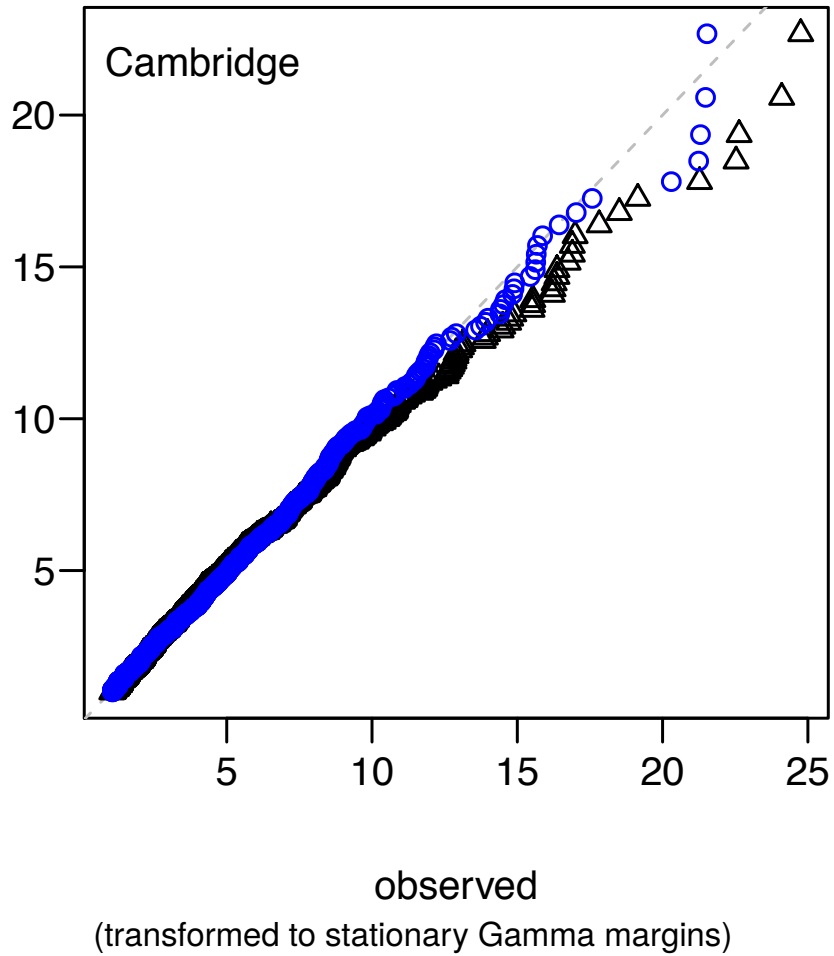
p_i: wet day probability
x_i: simulated precipitation
a, b: parameters



Wong et al., J Climate, 2014.

Biases are effectively corrected (DJF)

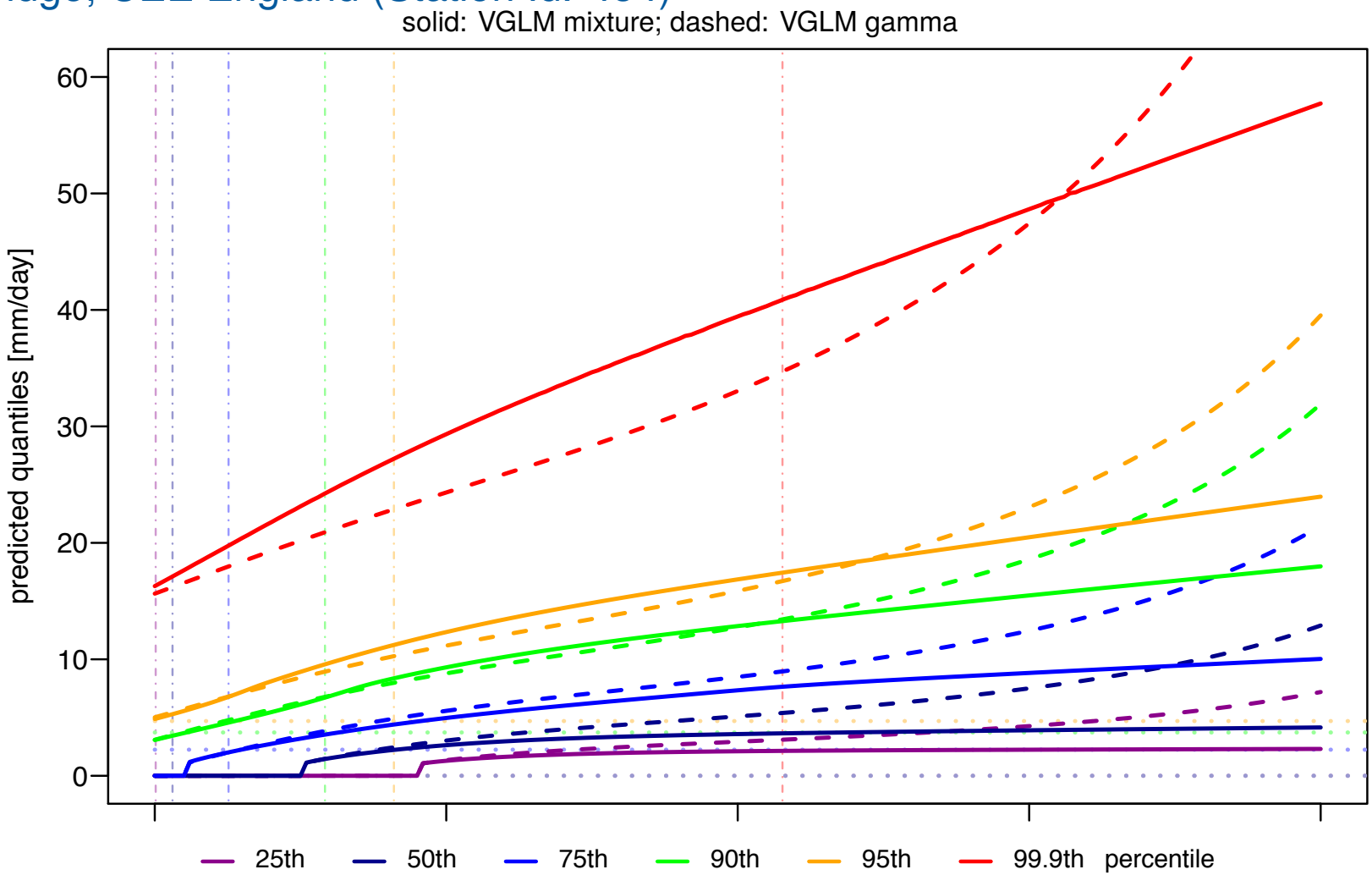
Cambridge, CEE England (Station Id. 454)



- VGLM mixture model
- VGLM gamma model

Predicted quantiles (DJF)

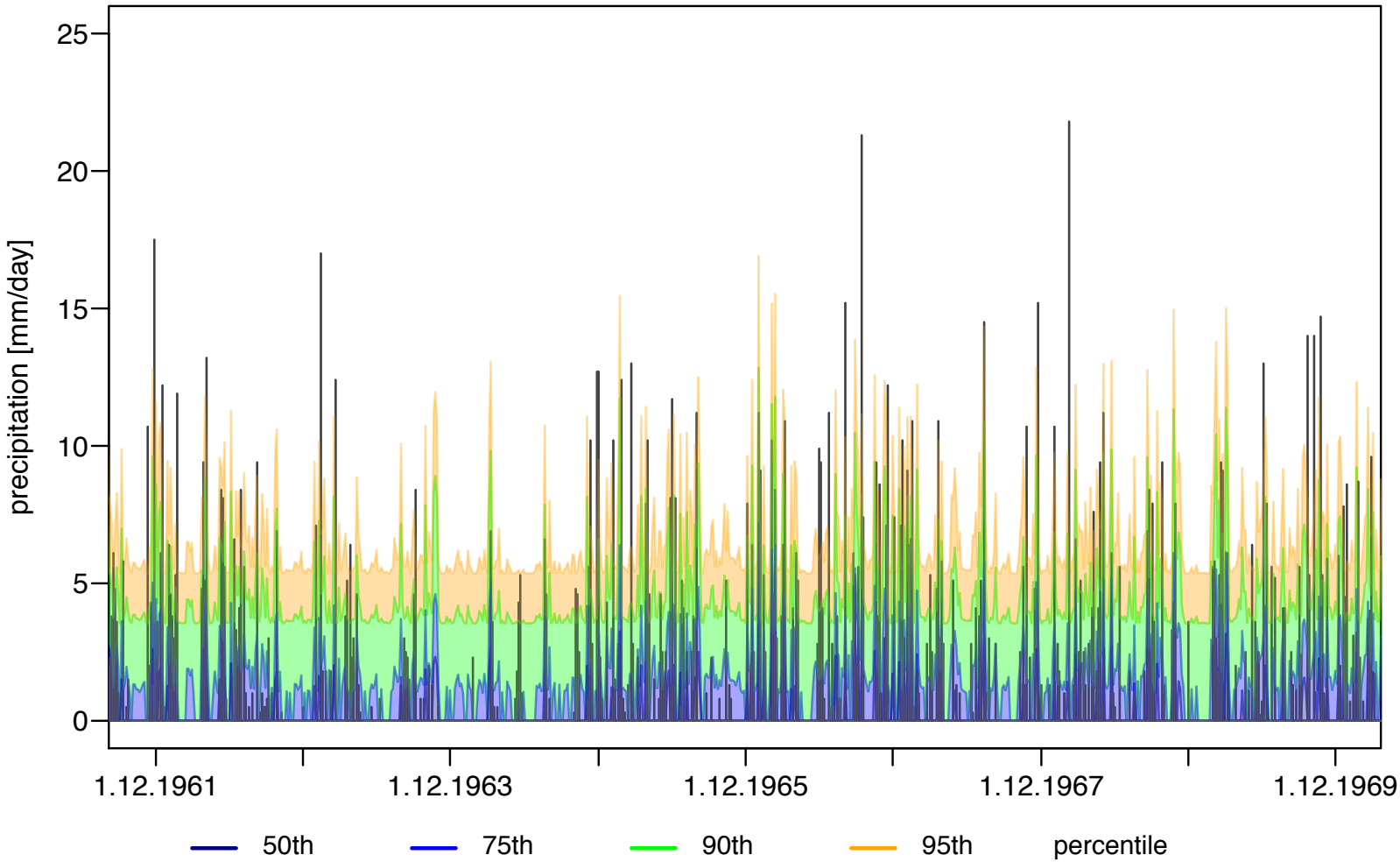
Cambridge, CEE England (Station Id. 454)



Wong et al., J Climate, 2014.

Example series (DJF)

Cambridge, CEE England (Station Id. 454)



color: predicted quantiles; black: observations

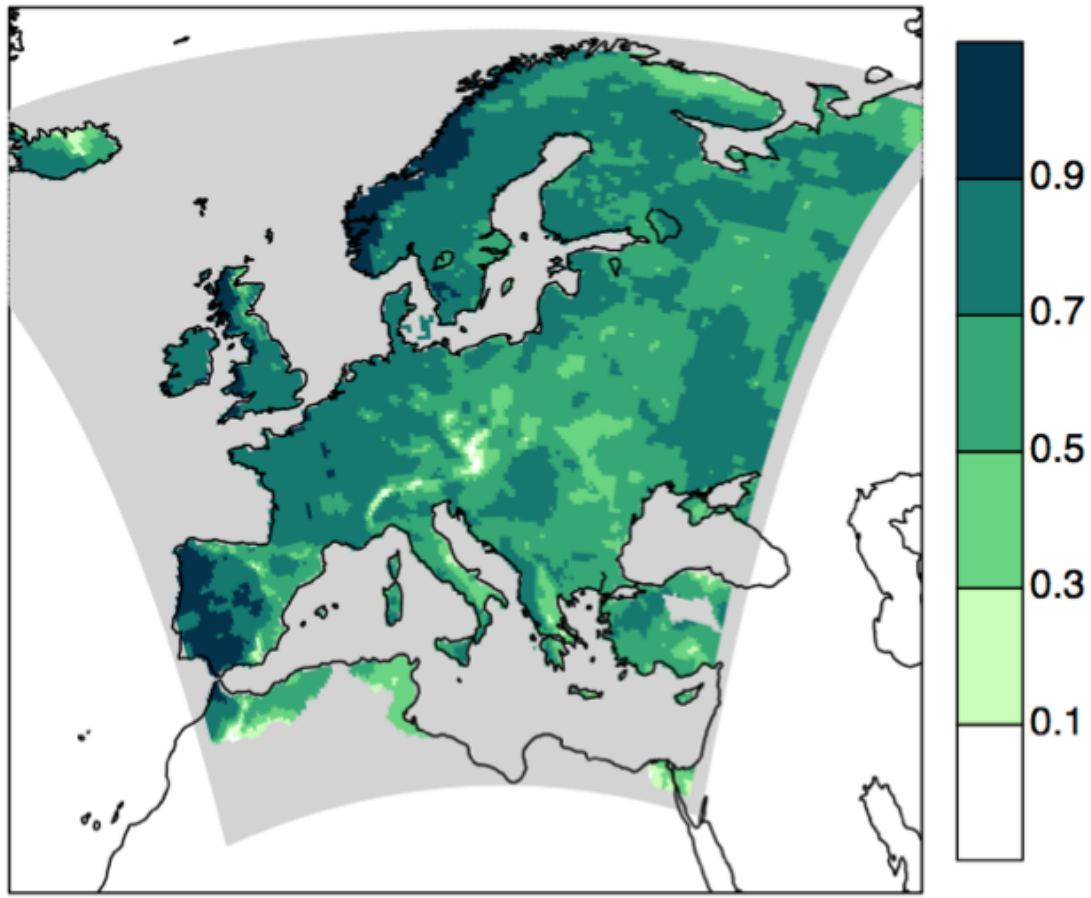
Wong et al., J Climate, 2014.

GEOMAR

Pairwise MOS · Location correcting methods

Do RCMs correctly represent location?

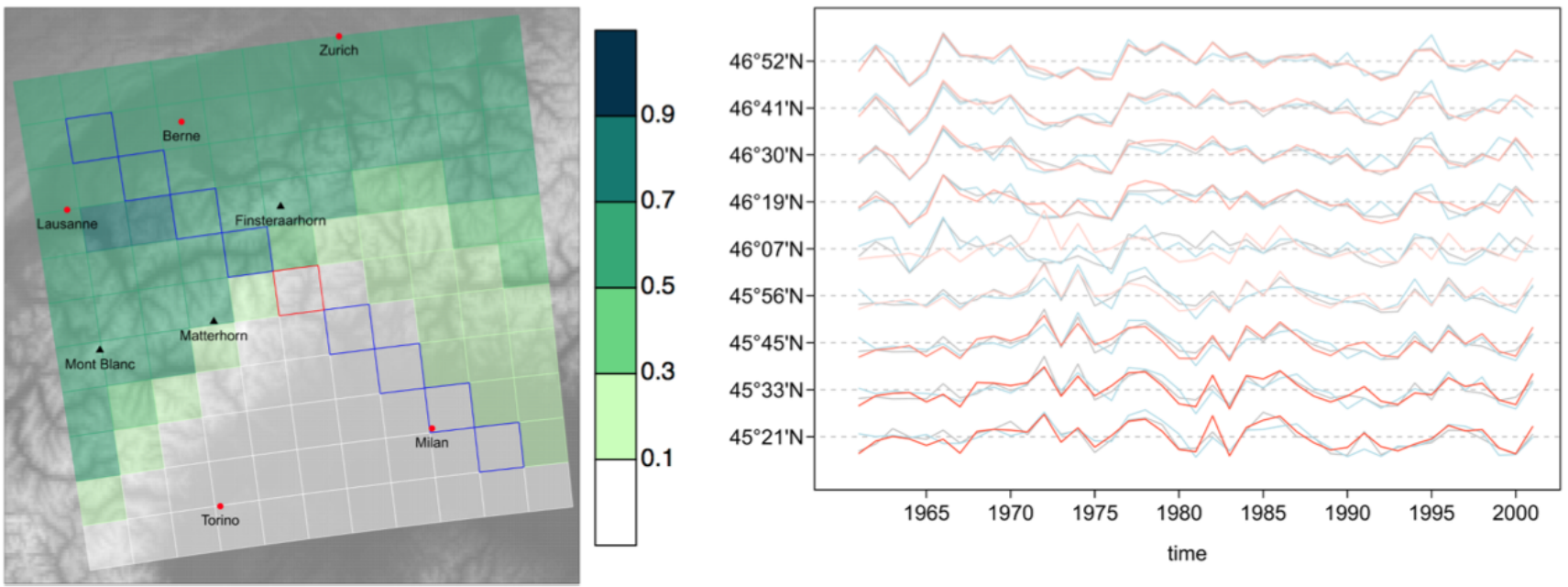
Correlation between observed/modelled seasonal winter precipitation



Maraun & Widmann, HESS, 2015

An example from the Alps

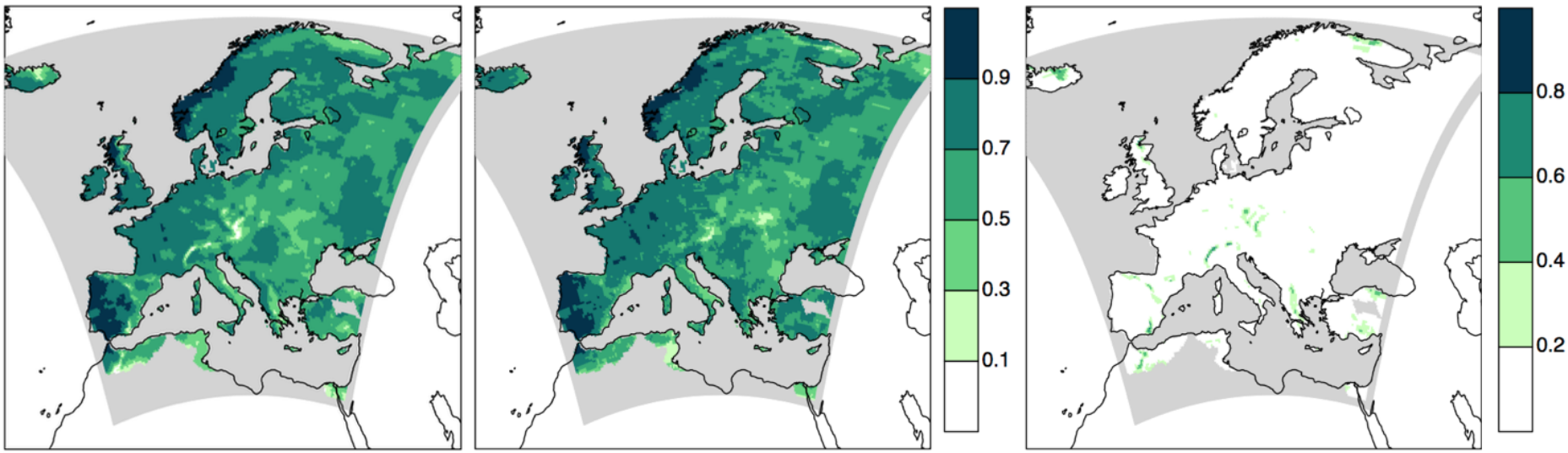
Left: correlation between observed precipitation at Domodossola (red square) and simulated precipitation.
right: time series; blue: observed; red: model at the same grid box; grey: model at optimal grid box



Maraun & Widmann, HESS, 2015

Non-local bias correction

Correlation between observed/modelled precipitation. Left: local correction; centre: non-local correction; right: improvement.



Maraun & Widmann, HESS, 2015