Linking regional climate simulations and hydrologic models for climate change impact studies – A case study in central Indiana (USA)

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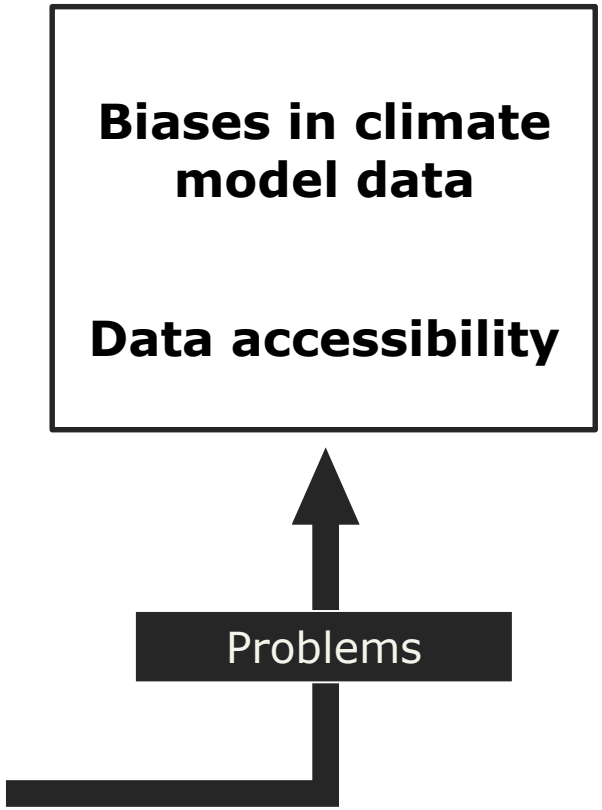
Introduction

Increasing demand for climate change hydrologic impact studies

→ Sustainable management of water resources

→ Linking climate simulations with hydrological models



Research Tasks

(1)

Evaluate bias correction methods for simulated precipitation and temperature and **assess their influence on resulting streamflow simulations**

(2)

Automate climate model **data extraction** and **bias correction**

Overview

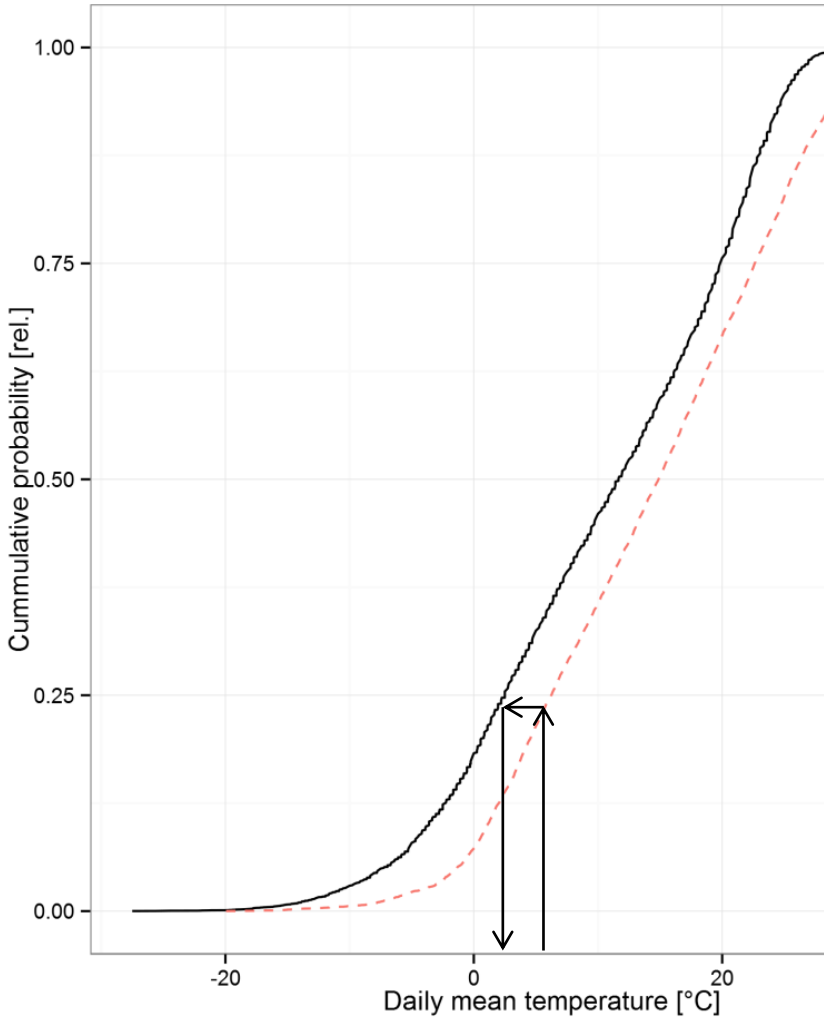
- Evaluation of bias correction methods
  - (Comparing measured and simulated climate data)
  - Assessing the impact of bias correction methods on SWAT simulations
- Automate data extraction and bias-correction
  - Web service for data extraction
  - Desktop application bias-correction and data extraction

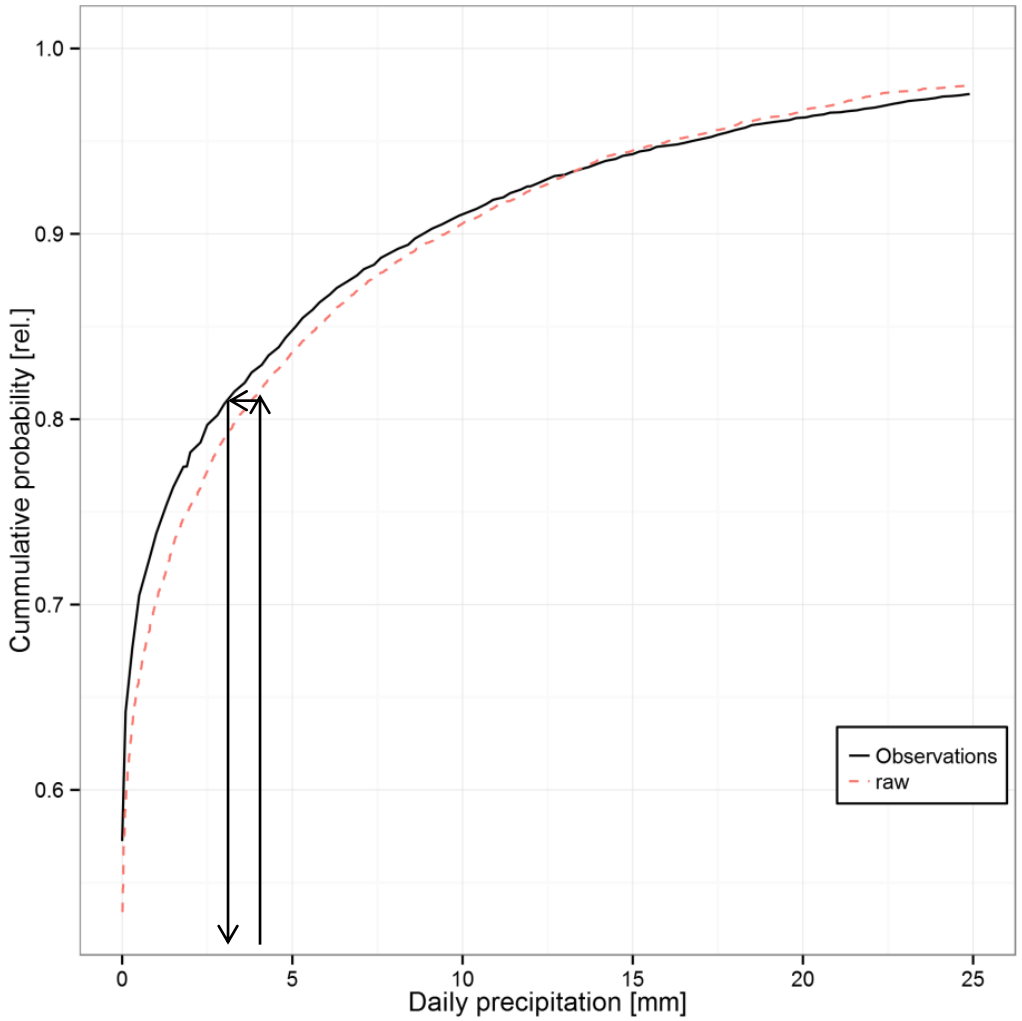
Study area: Wildcat Creek watershed

Task 1:

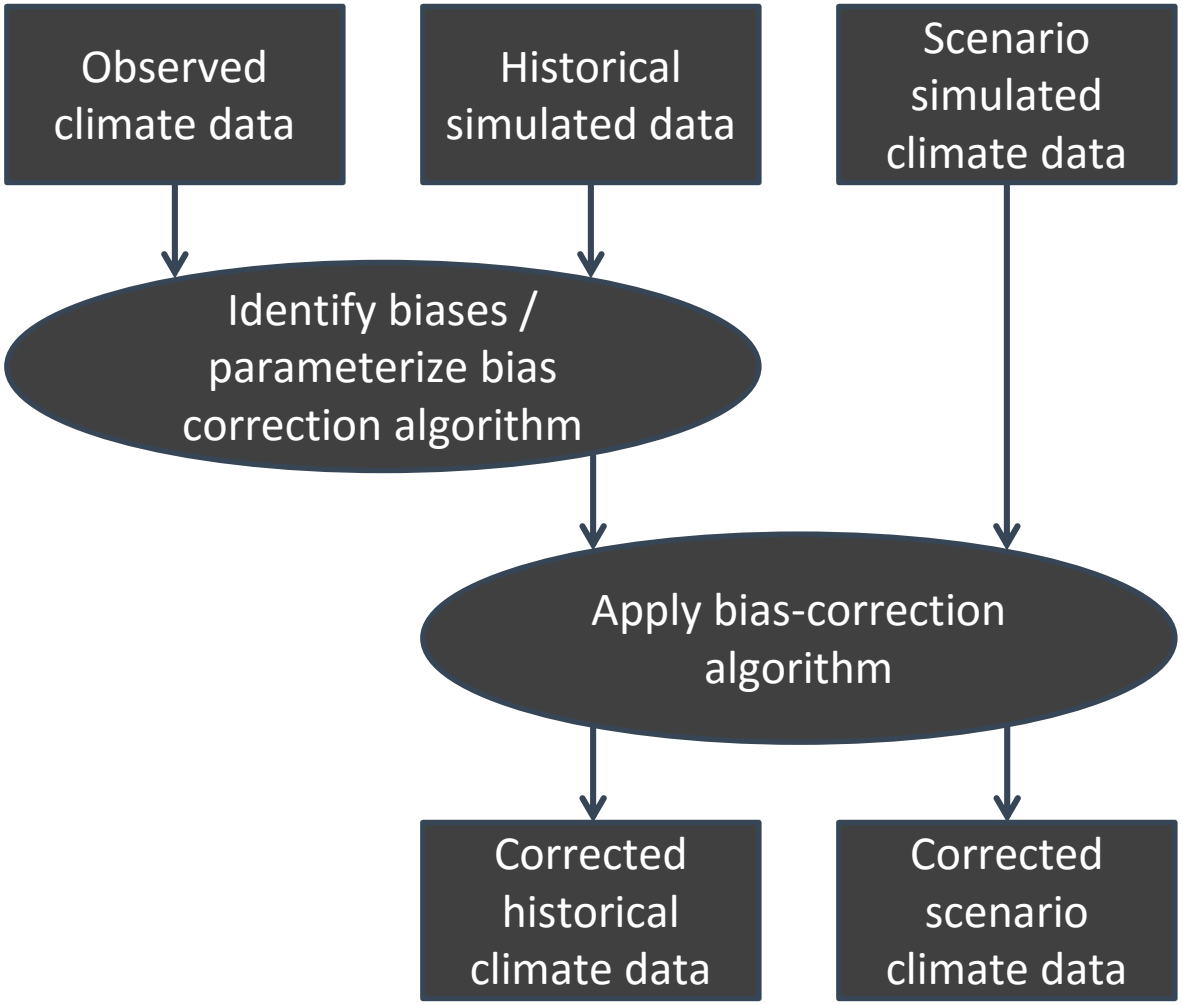
Evaluate bias correction methods for simulated precipitation and temperature and to assess their influence on resulting streamflow simulations

Bias-correction





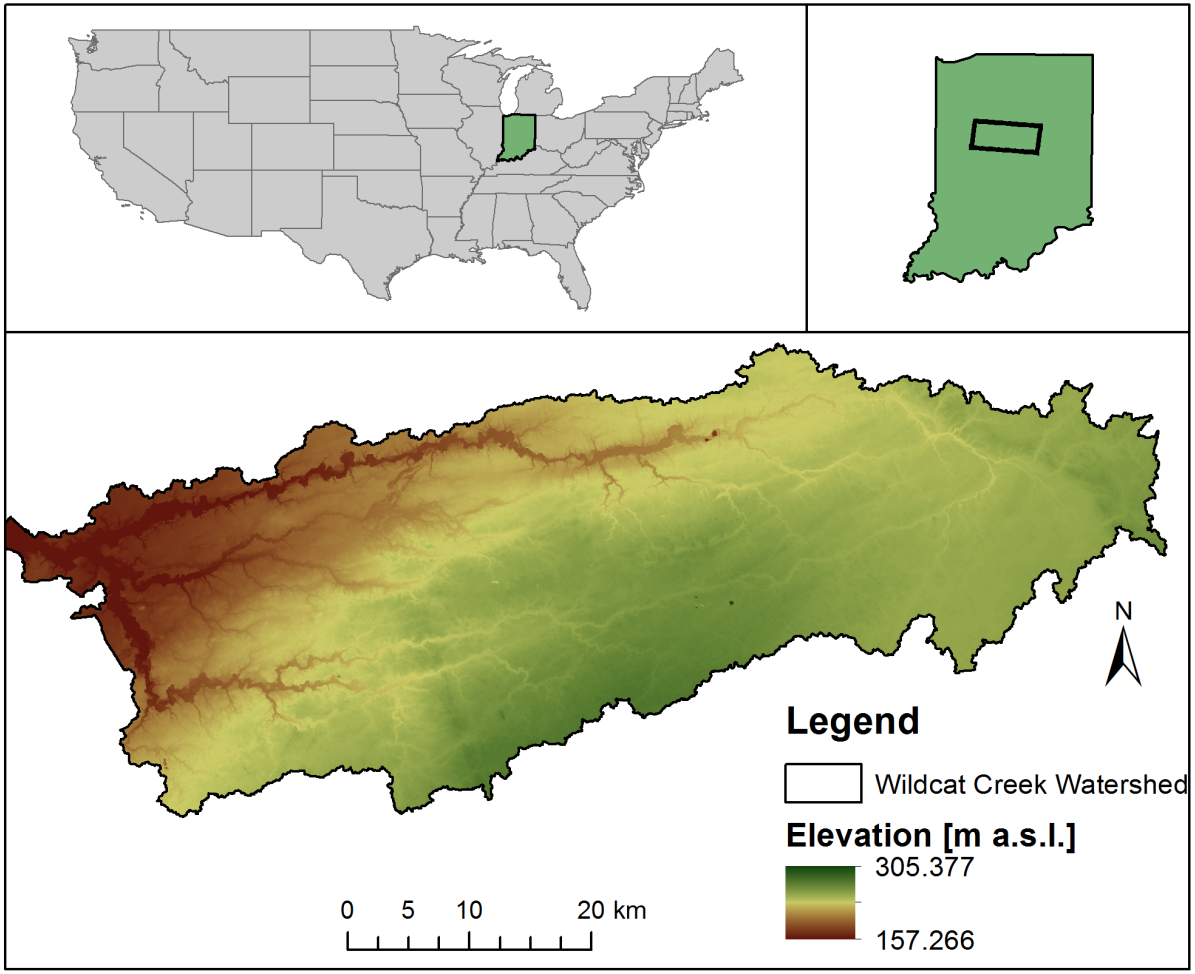
Bias correction



Bias correction

- Bias-correction methods
  - Linear scaling for temperature and precipitation
  - Local intensity scaling for precipitation
  - Power transformation of precipitation
  - Variance scaling of temperature
  - Distribution mapping of precipitation and temperature

Study area: Wildcat Creek watershed



- Precipitation:
  - 969 mm / year
  - 9 gages
- Mean annual temperature:
  - 10.5 °C
  - 8 gages

Model framework

- Models:
  - RCM: RCA4 (Rossby Centre Regional Atmospheric model, version 4)
  - Hydrology: SWAT (Soil and Water Assessment Tool)
- Assessing the impact on SWAT simulations
  - Daily Nash-Sutcliffe efficiency: 0.72, R^2: 0.75
  - Impact on SWAT results: 1990 – 2009

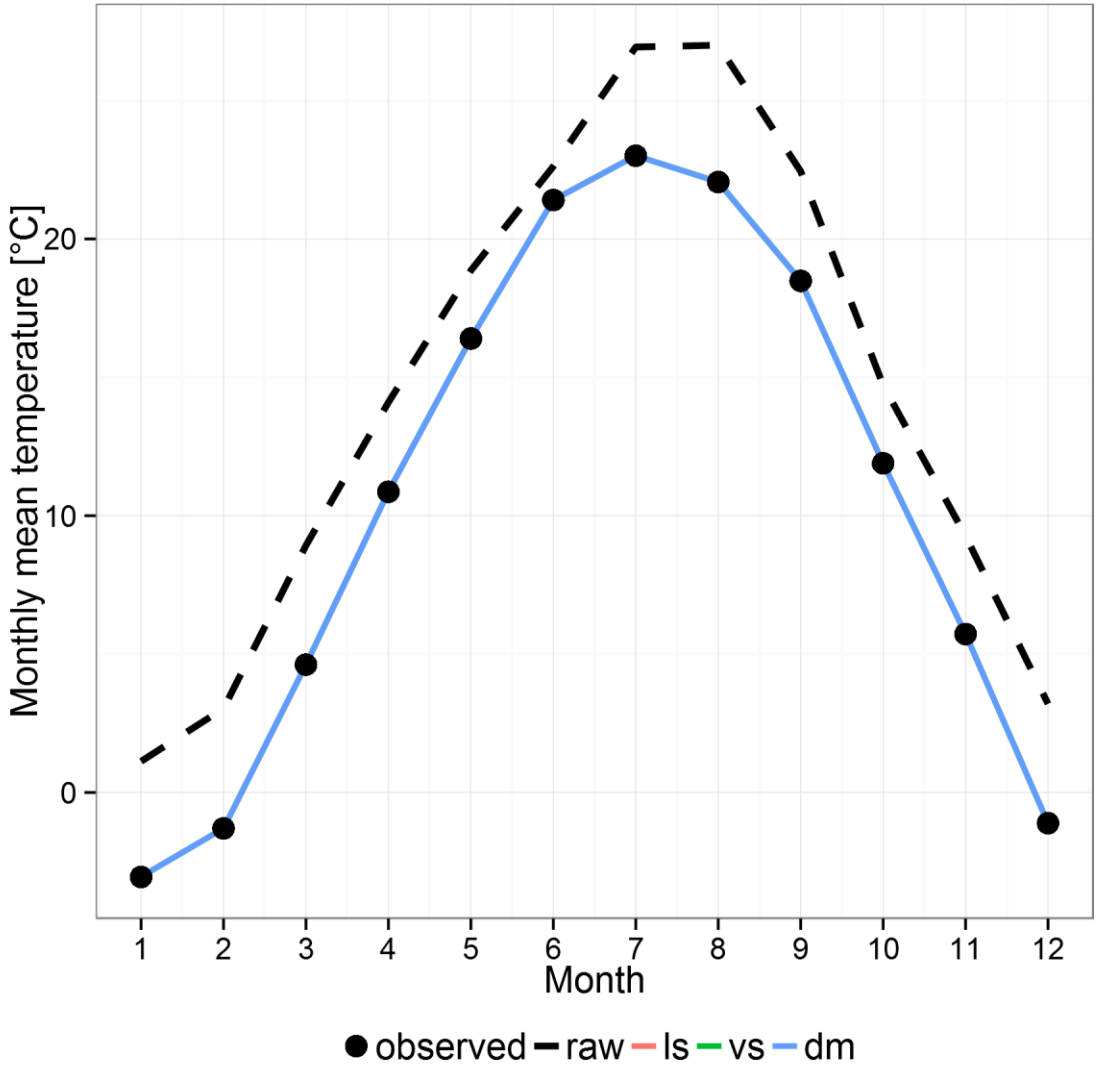
Impact on SWAT simulations

- Comparison of SWAT models driven by observed and simulated climate data:

Model run	Precipitation	Temperature
mes	Observed	Observed
Raw	Simulated (raw)	Simulated (raw)
ls	Linear scaling	Linear scaling
li_vs	Local intensity	Variance scaling
pt_vs	Power transformation	Vairance scaling
dm	Distribution mapping	Distribution mapping

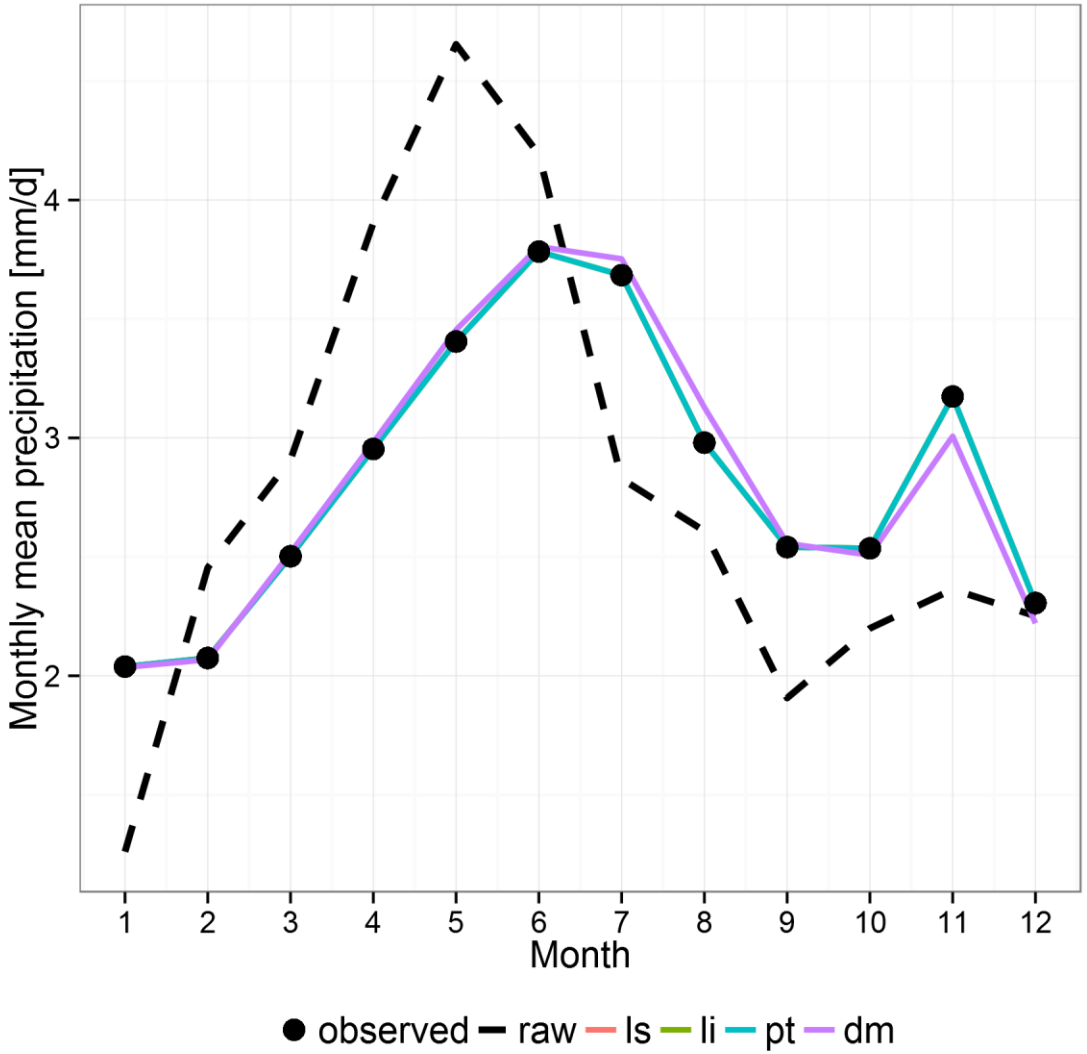
Evaluation of bias correction methods

- Temperature: monthly mean



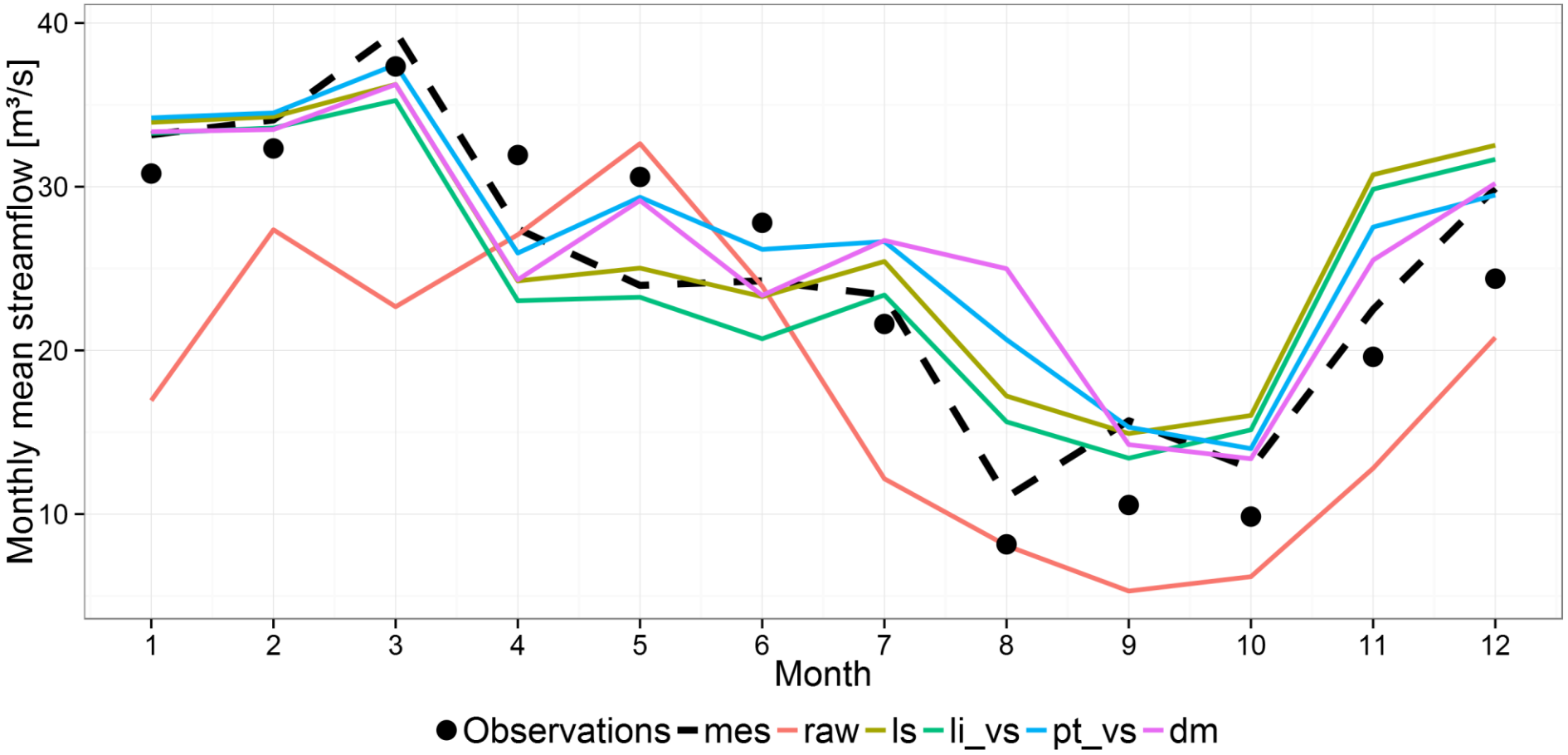
Evaluation of bias correction methods

- Precipitation: monthly mean



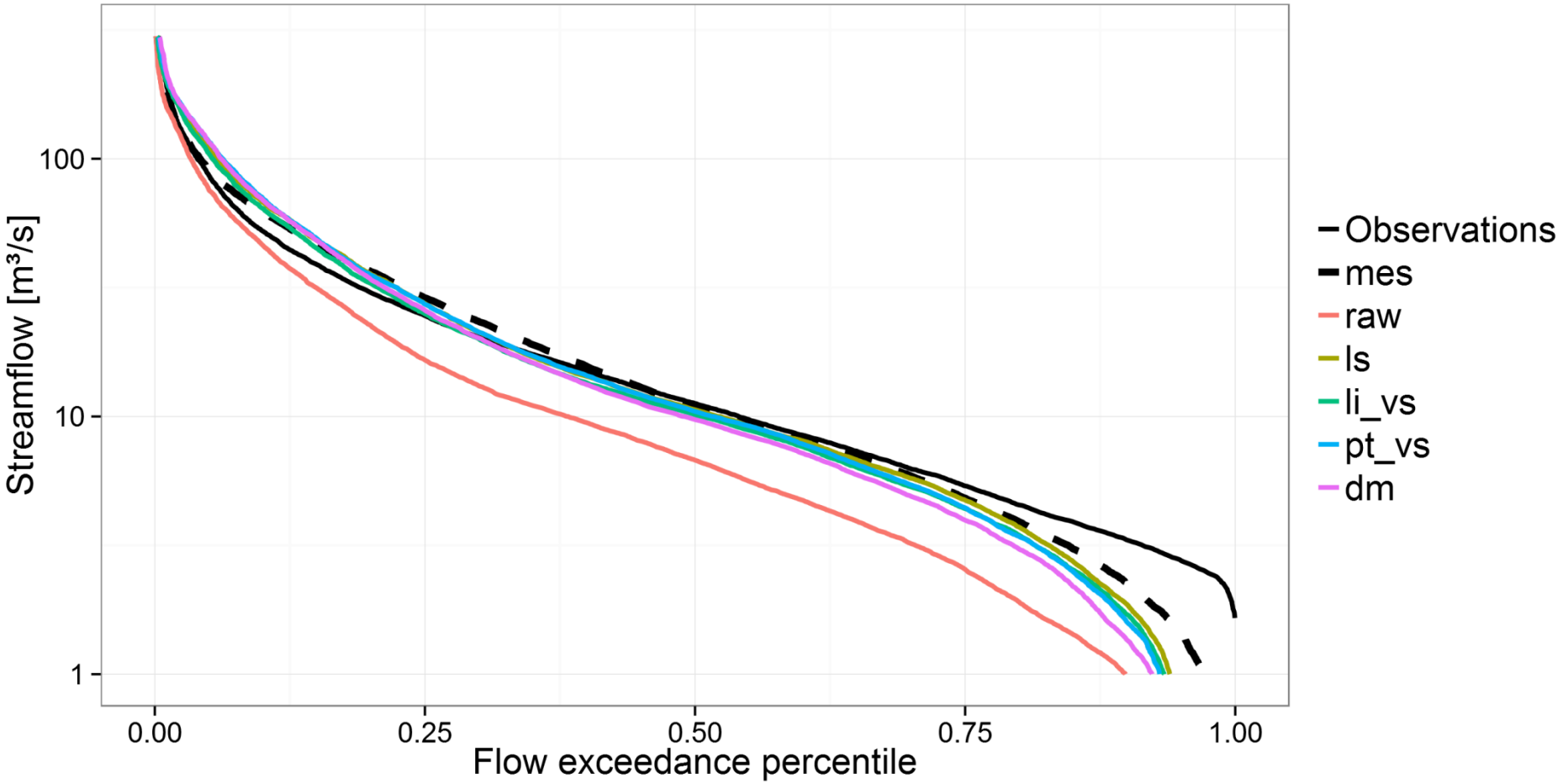
Impact on SWAT simulations

- Monthly mean streamflow



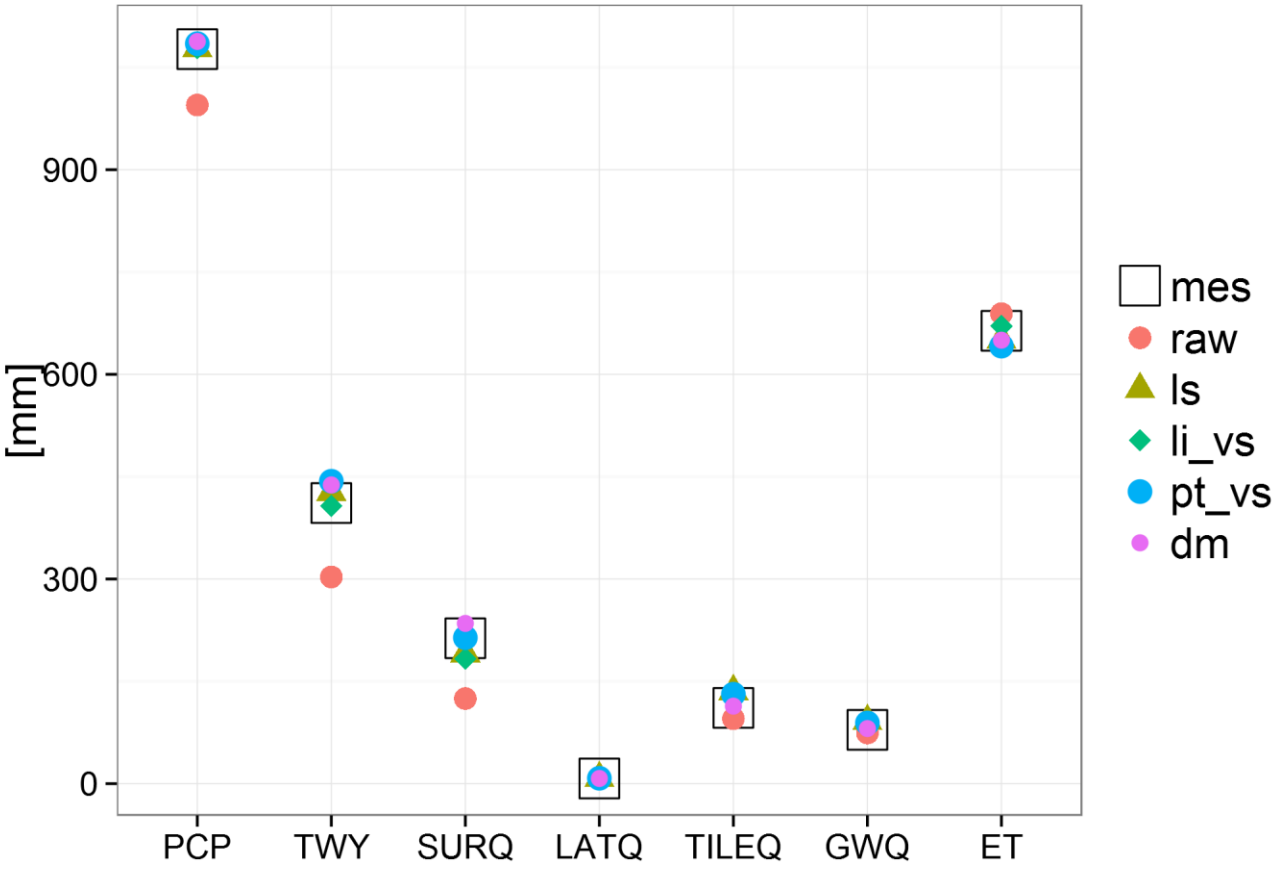
Impact on SWAT simulations

- Flow duration curve



Impact on SWAT simulations

- Waterbalance and flow components



Research Tasks

Task 2:

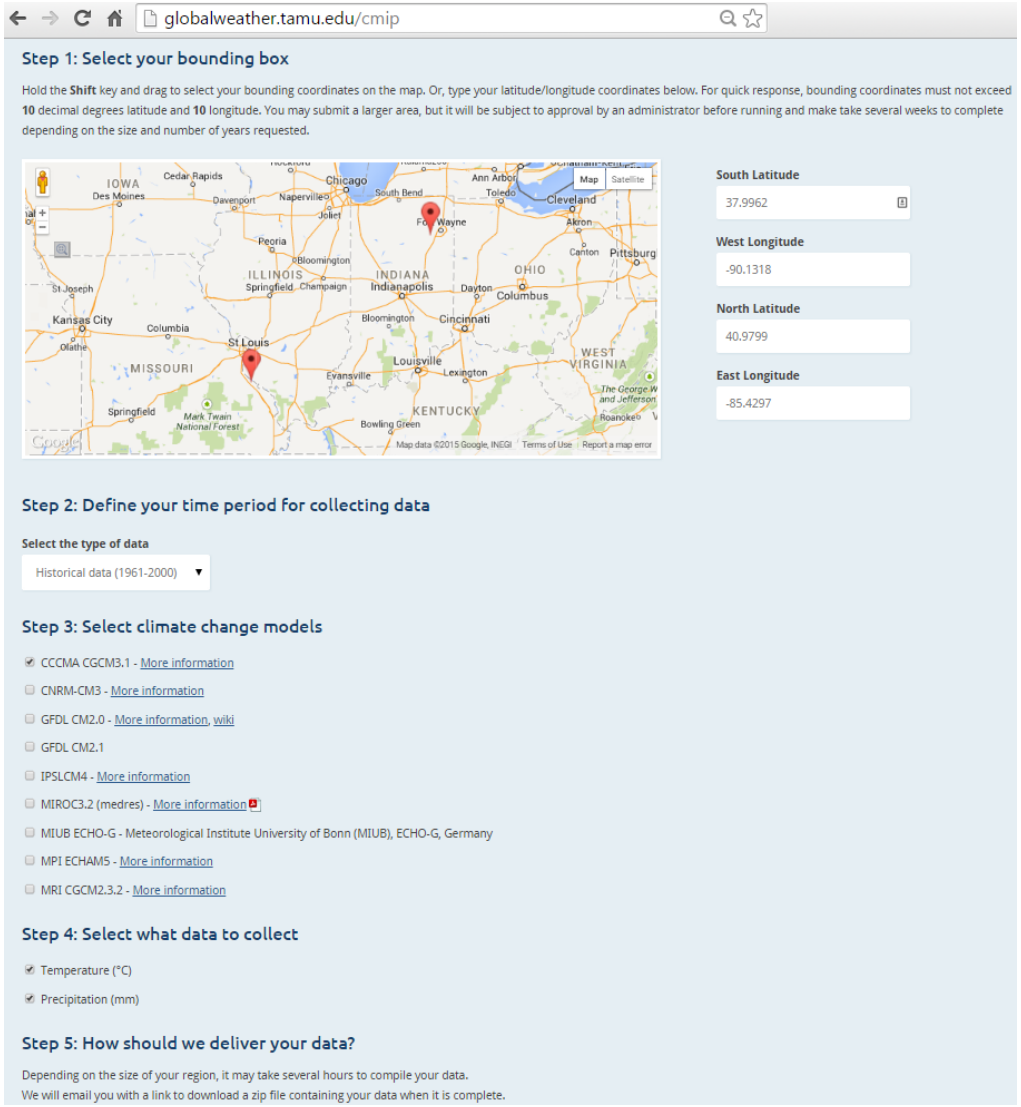
Automate climate simulation data extraction and bias correction

Web-service for CMIP3 data

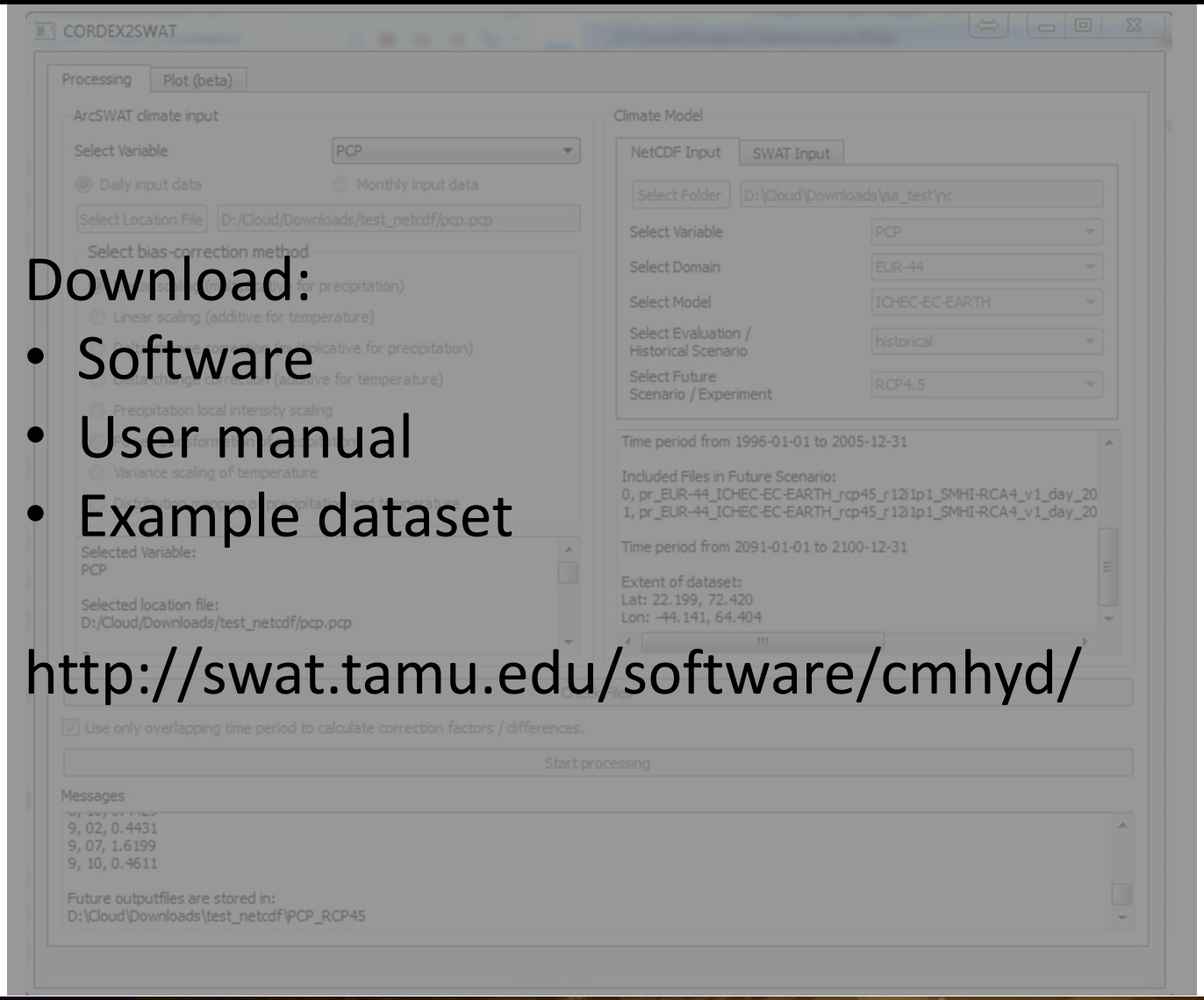
Web service

- Precipitation and temperature
- 9 climate models
- Historical data
- Future data (3 scenarios)

www.globalweather.tamu.edu/cmip



Bias-correction tool



Download:

- Software
- User manual
- Example dataset

http://swat.tamu.edu/software/cmhyd/

Research Conclusions

- Evaluation of bias correction methods
  - An improvement was achieved with all approaches
  - The choice plays a large role in assessing hydrological change

- Climate model data extraction and bias correction
  - Web service (data extraction)
  - Desktop application (data extraction and bias-correction)

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USDA ARS United States Department of Agriculture Agricultural Research Service

TEXAS A&M UNIVERSITY

End of presentation

Appendix

Bias-correction

Linear scaling

- Perfect agree in monthly mean
- Step 1: Adjust monthly mean
  - Precipitation:
  - Temperature:

-

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Bias-correction

Local intensity scaling for precipitation

- Perfect agree in monthly mean, wet-day frequency, intensity
- Step 1: Adjust wet-day frequency

$$\hat{P}_{eva}(d) = \begin{cases} 0, & \text{if } P_{eva}(d) < P_{thres} \\ P_{eva}(d), & \text{else} \end{cases}$$

$$\hat{P}_{sce}(d) = \begin{cases} 0, & \text{if } P_{scen}(d) < P_{thres} \\ P_{scen}(d), & \text{else} \end{cases}$$

- Step 2: Adjust wet-day intensities

$$s = \frac{\mu_m(P_{obs}(d) \mid P_{obs}(d) > 0)}{\mu_m(P_{eva}(d) \mid P_{eva}(d) > P_{thres}) - P_{thres}}$$

$$P^*_{eva}(d) = \hat{P}_{eva}(d) \cdot s$$

$$P^*_{scen}(d) = \hat{P}_{sce}(d) \cdot s$$

Bias-correction

Power transformation of precipitation

- Agree in the monthly mean and variance
  - Non-linar correction in an exponential form:
- Step 1: Estimate by matching the monthly coefficient of variation (ratio between and)

- Step2: Adjust monthly mean

Bias-correction

Variance scaling of temperature

- Agree in monthly mean and variance
- Step 1: Adjust by linear scaling: ,
- Step 2: Shift the mean-corrected time series to a zero mean

- Step 3: Match standard deviation

- Step 3: Shift the time series back to the corrected mean

Bias-correction

Distribution mapping of precipitation and temperature

- Agree in monthly frequeny distribution
- Step 1: Calculate monthly observed and RCM distribution parameters
  - Precipitation: Shape of Gamma distribution
  - Temperature: Standard deviation of Gaussian distribution
- Step 2: Adjust cumulative distribution
  - Precipitation:
  - Temperature:

Bias-correction

Delta change correction

- Use observed data as database
- Step 1: Adjust monthly mean
  - Precipitation:

$$P^*_{eva}(d) = P_{obs}(d)$$

$$P^*_{sce}(d) = P_{obs}(d) \cdot \frac{\mu_m(P_{sce}(d))}{\mu_m(P_{eva}(d))}$$

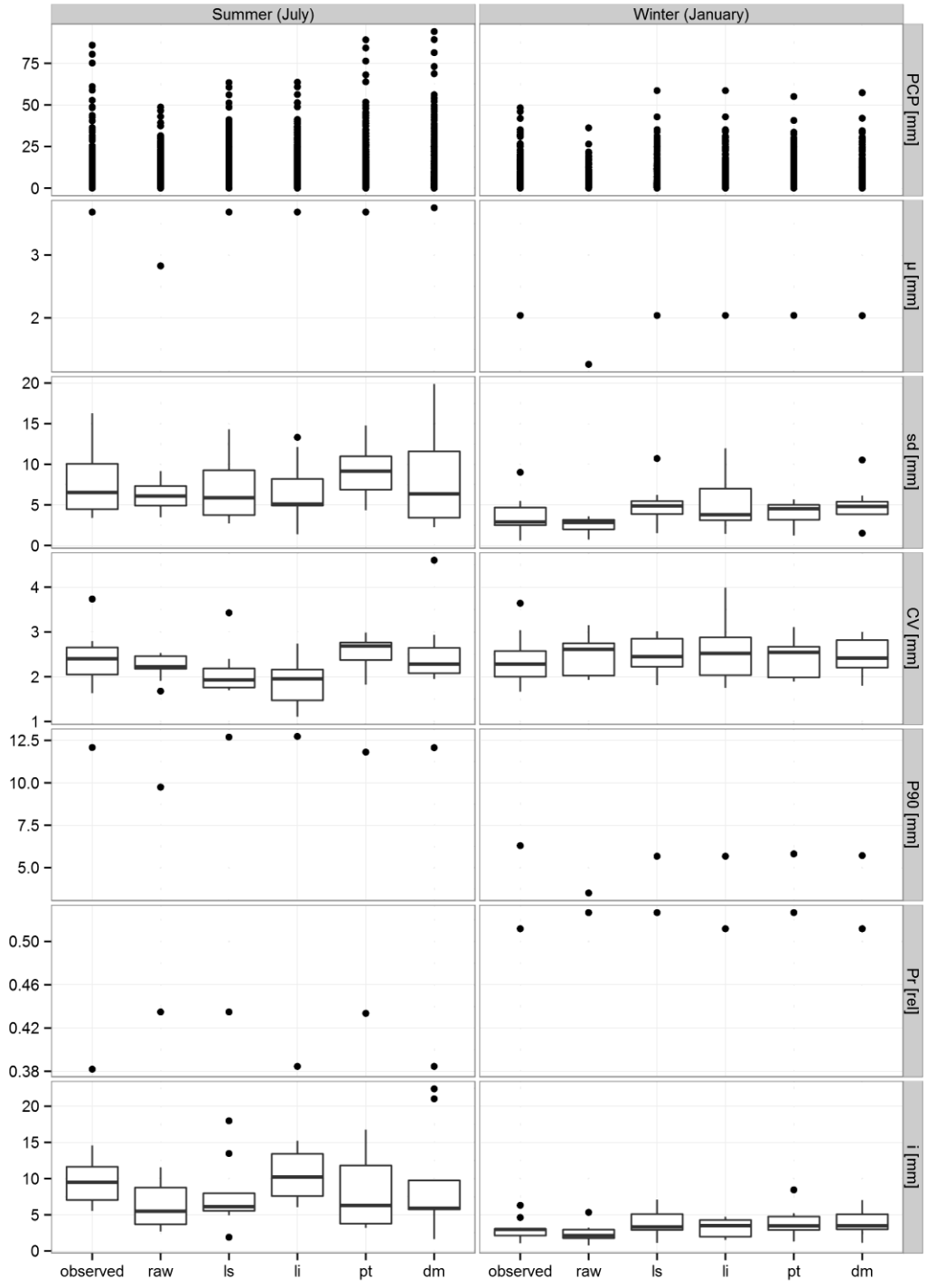
  - Temperature:

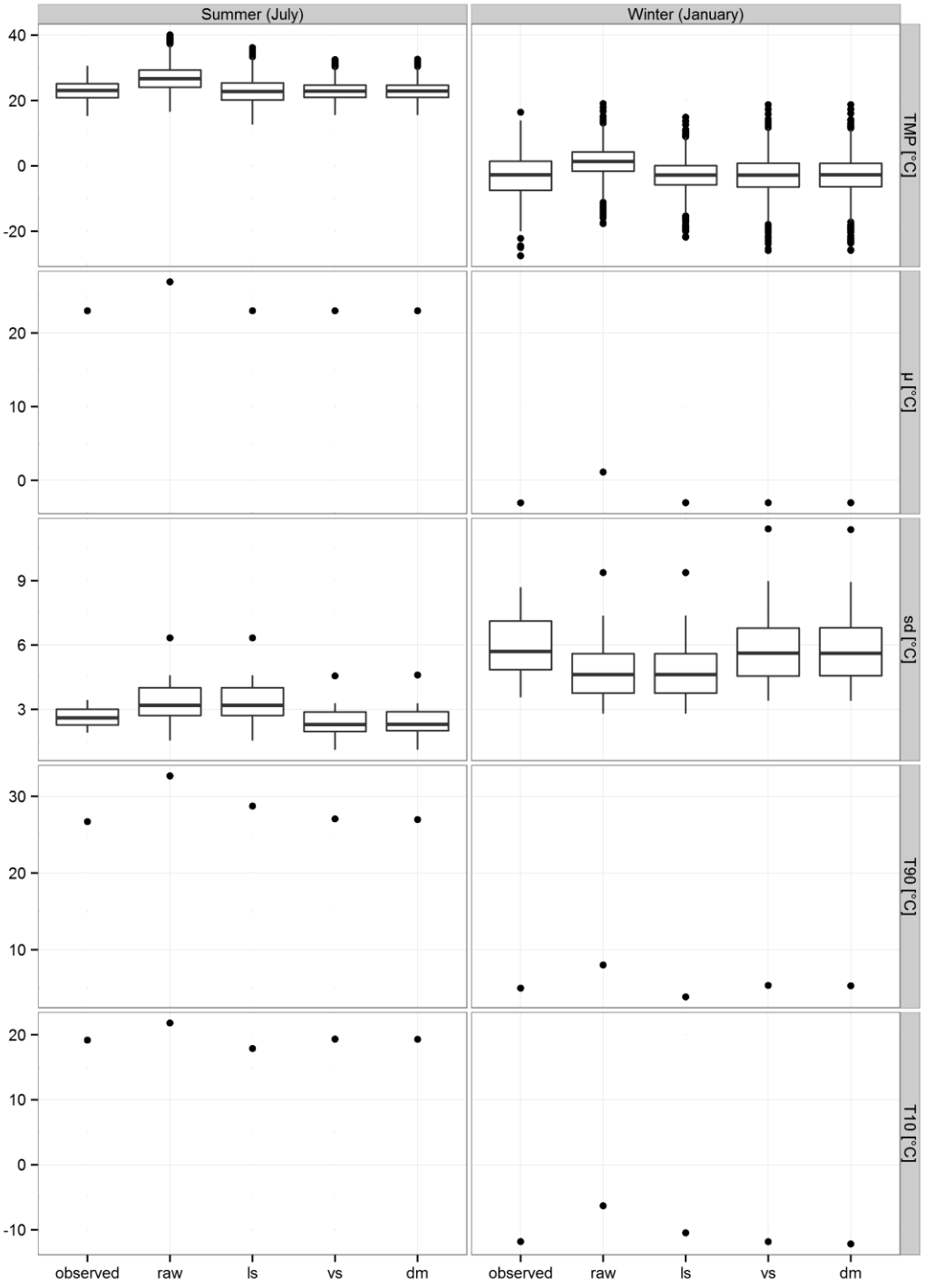
$$T^*_{eva}(d) = T_{obs}(d)$$

$$T^*_{sce}(d) = T_{obs}(d) + \mu_m(T_{sce}(d)) - \mu_m\big(T_{eva}(d)\big)$$

Evaluation of bias correction methods

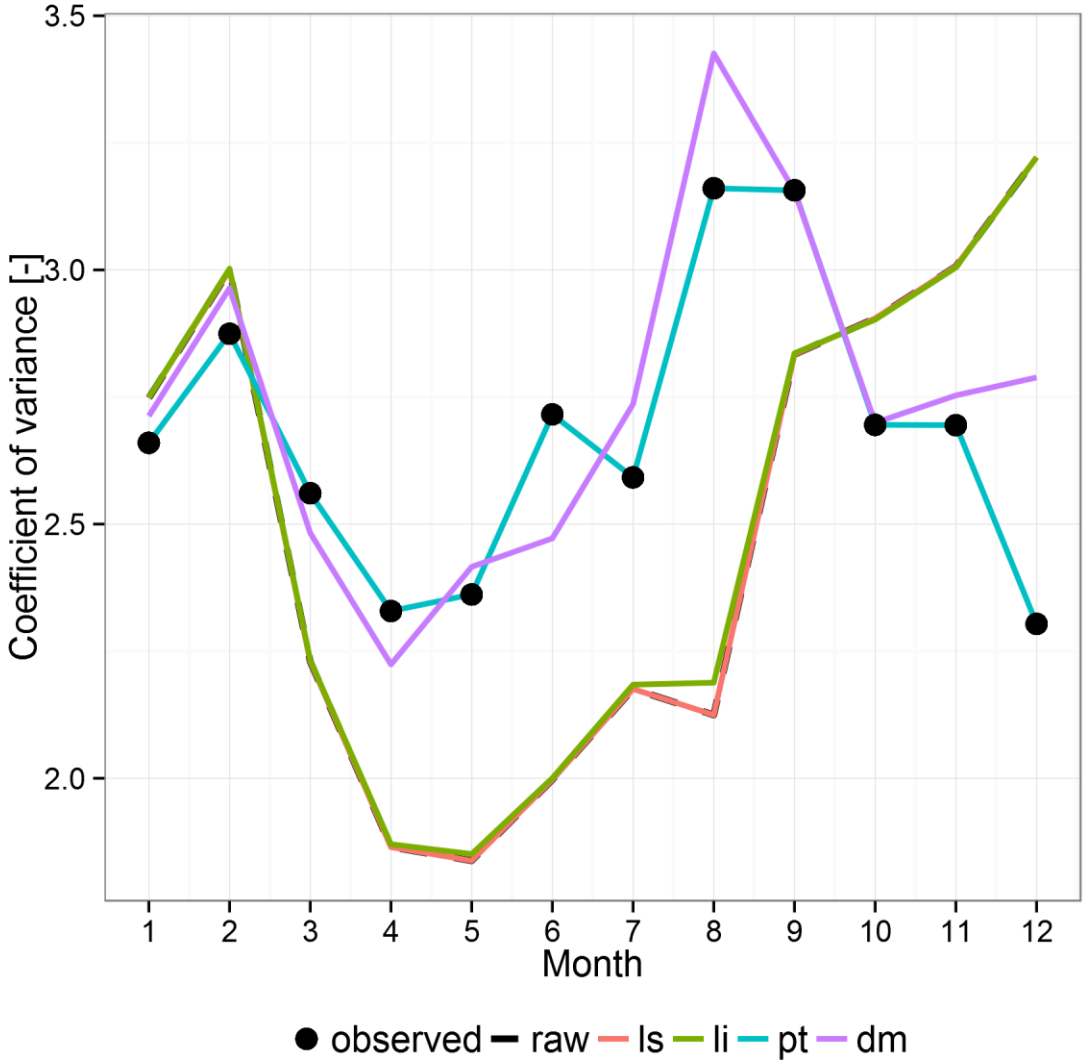
- Comparing observed and modeled data on a monthly basis:
  - Precipitation:
    mean, standard deviation, coefficient of variation, 90th percentile, probability of wet days, intensity of precipipation
  - Temperature:
    mean, standard deviation, 10th percentile, 90th percentile





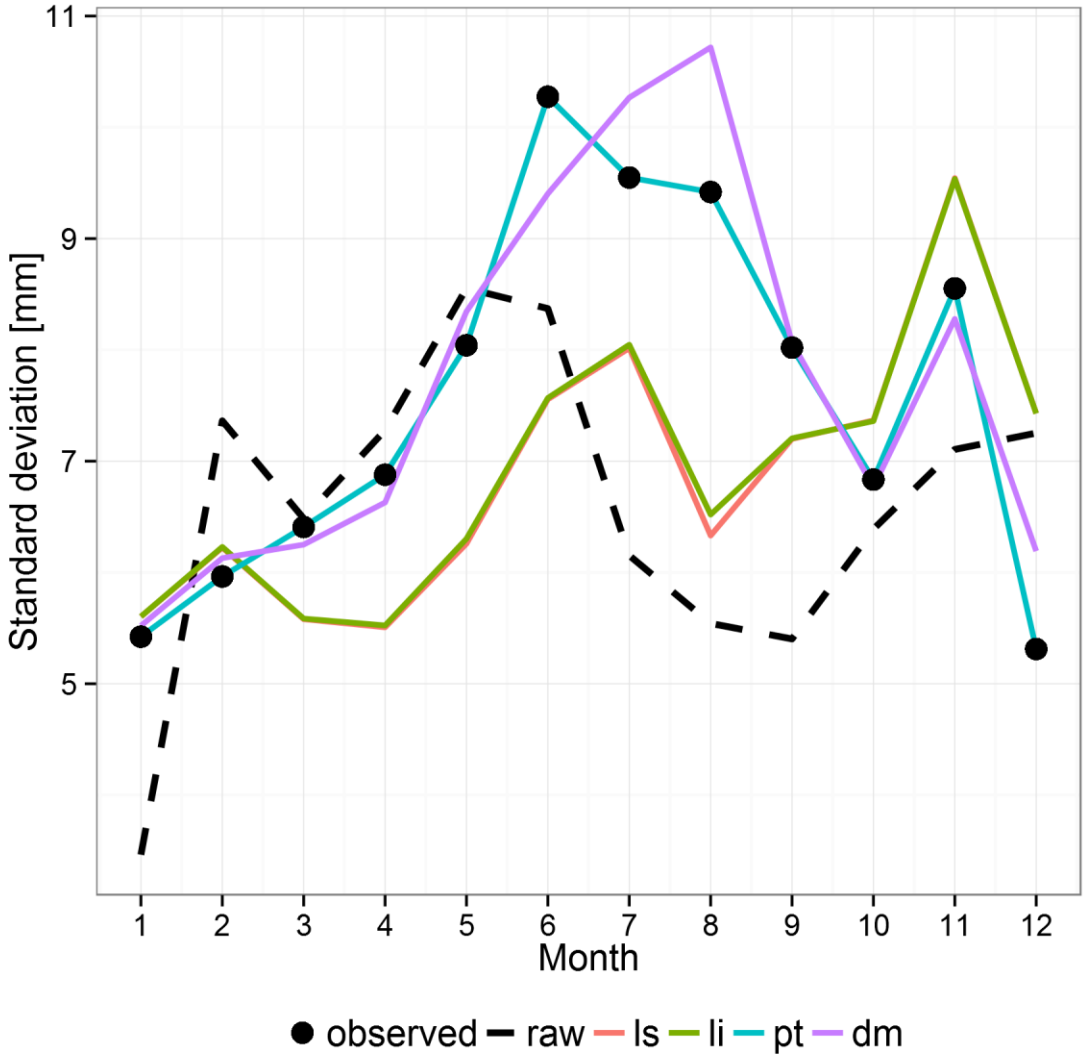
Evaluation of bias correction methods

- Precipitation: monthly coefficient of variation



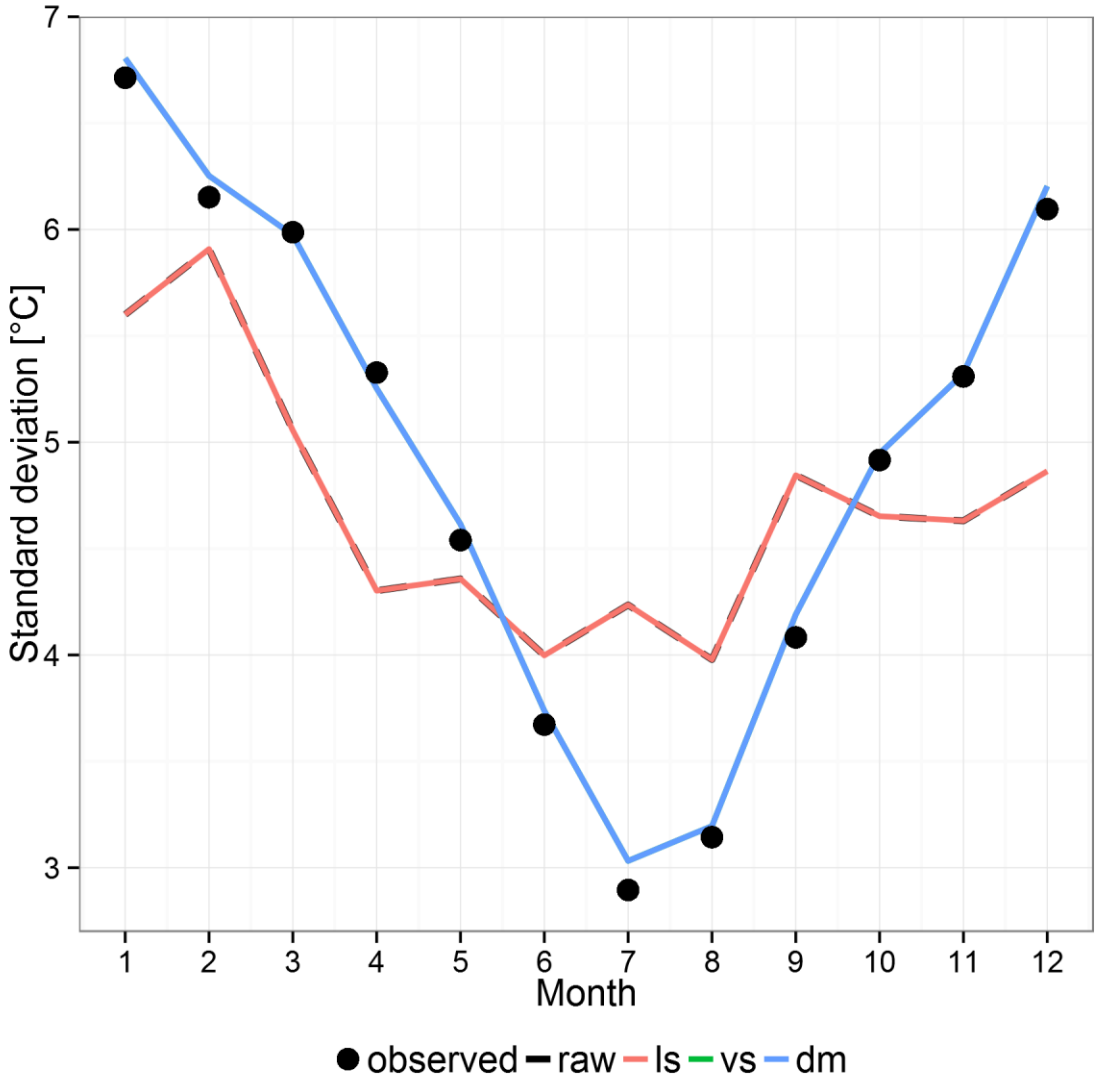
Evaluation of bias correction methods

- Precipitation: monthly standard deviation



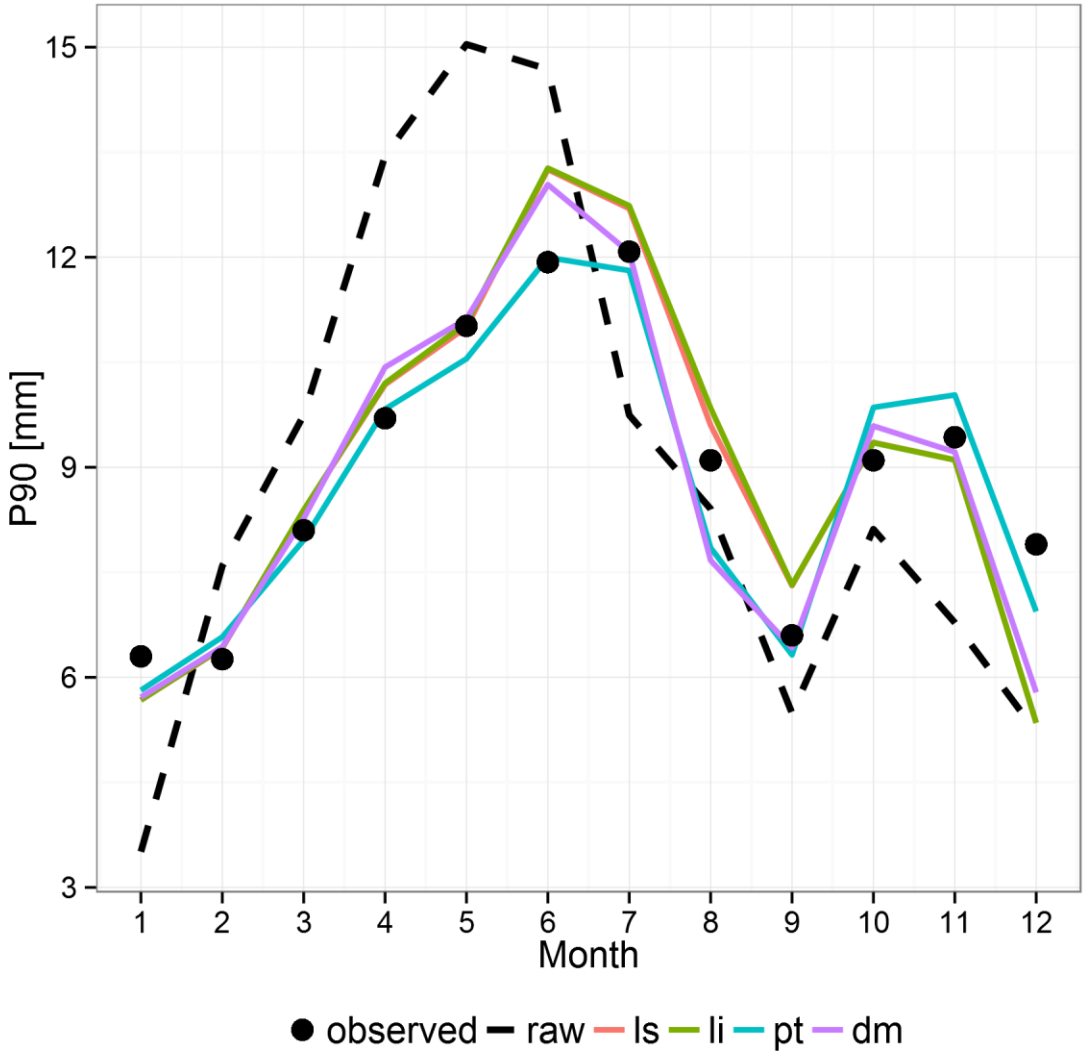
Evaluation of bias correction methods

- Temperature: monthly standard deviation



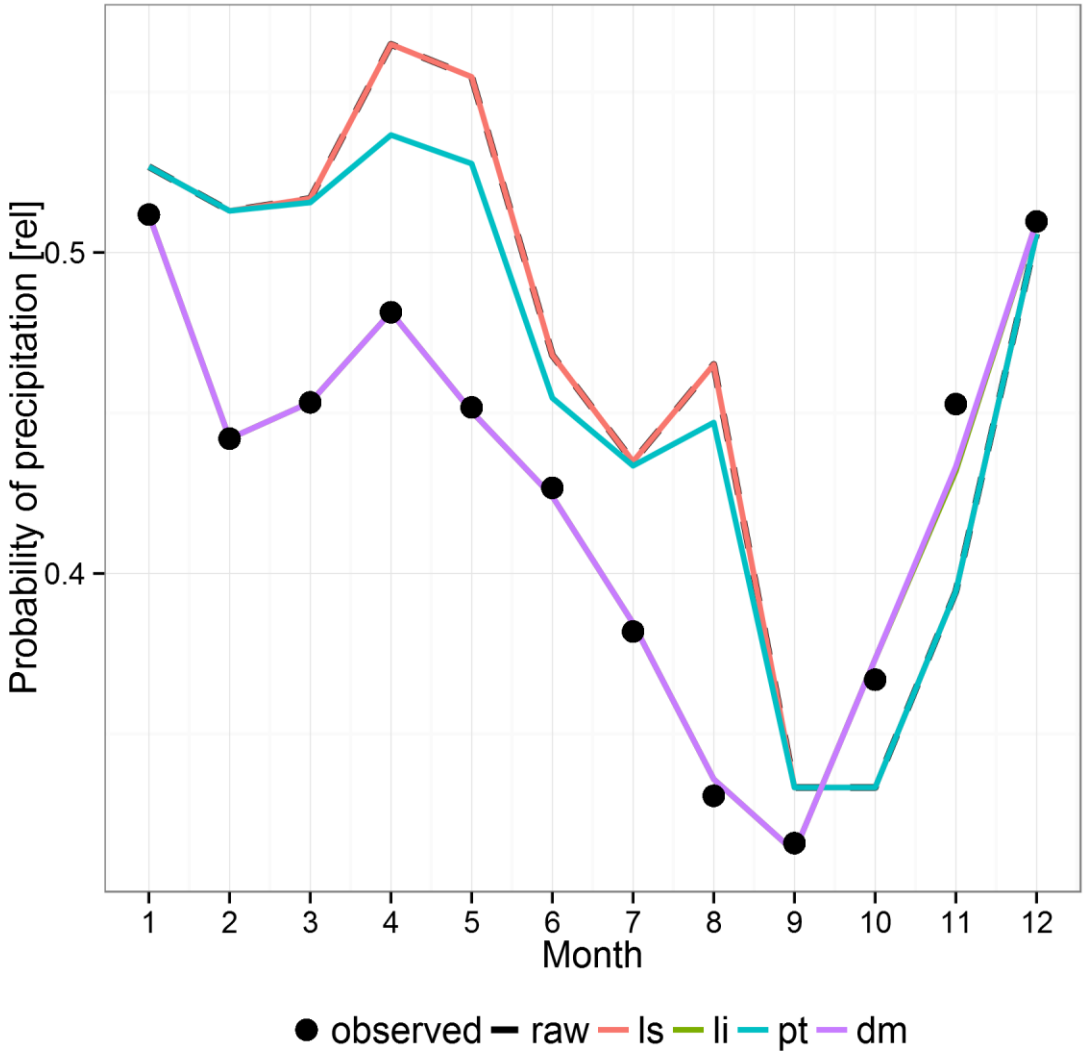
Evaluation of bias correction methods

- Precipitation: monthly 90th percentile



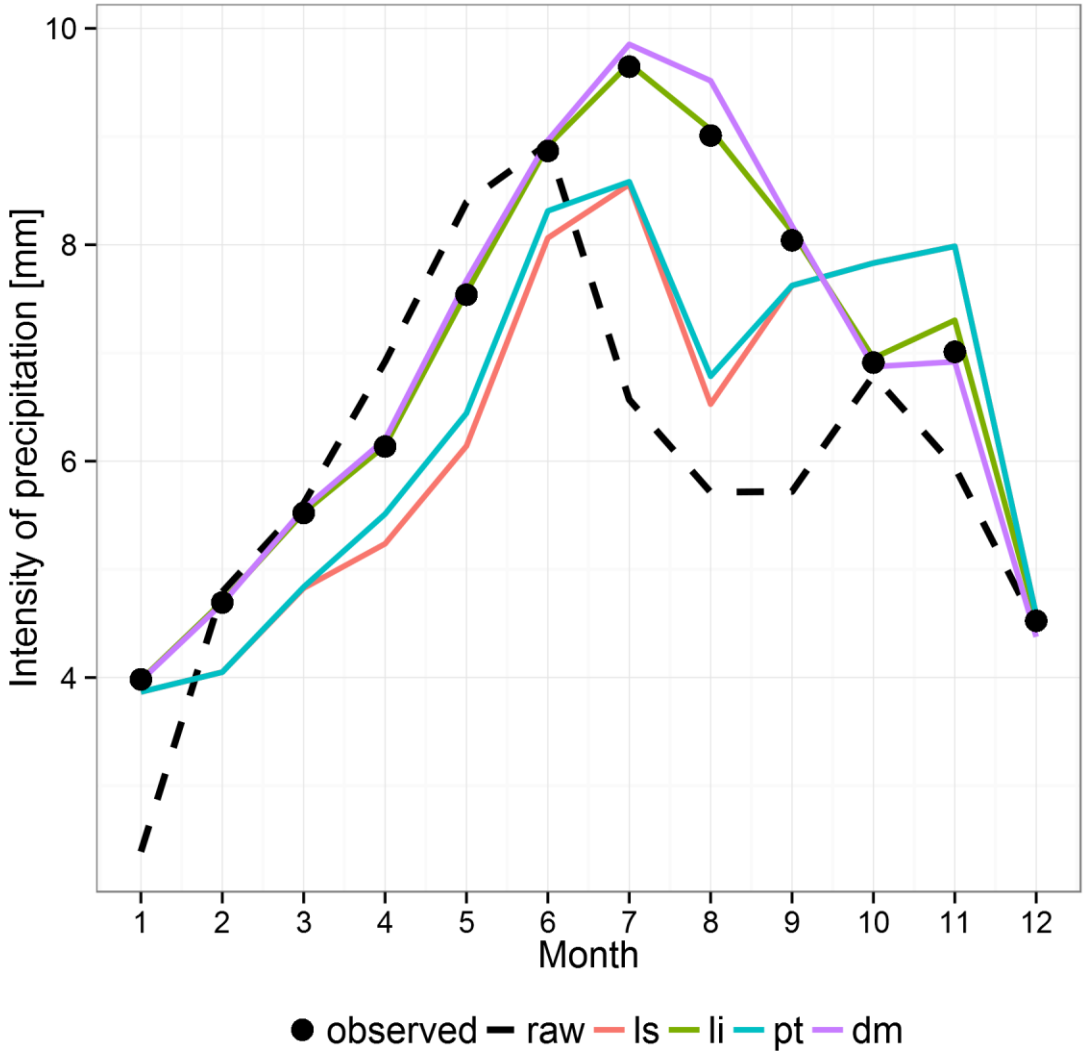
Evaluation of bias correction methods

- Precipitation: monthly probability of precipitation



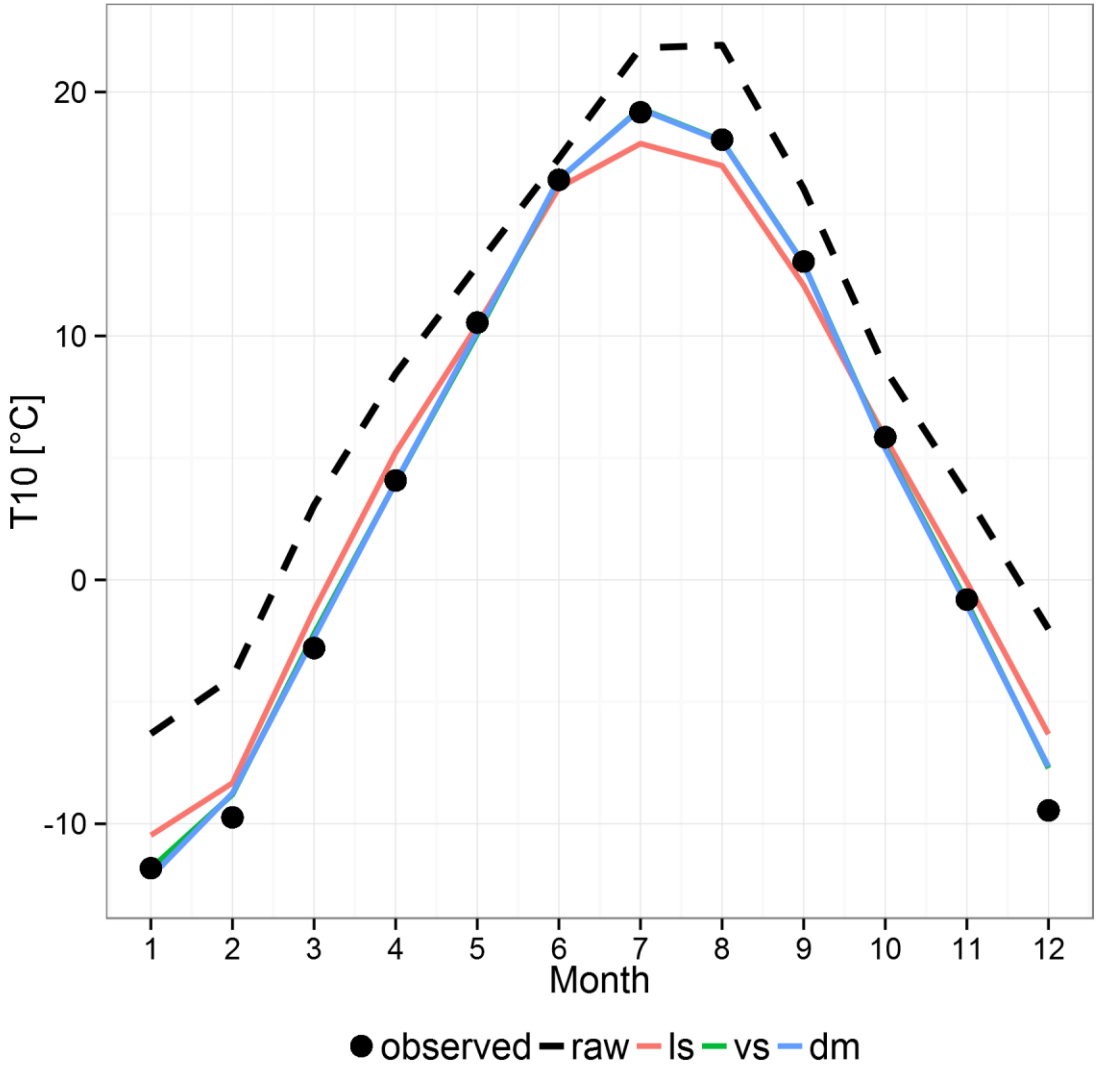
Evaluation of bias correction methods

- Precipitation: monthly intensity of precipitation



Evaluation of bias correction methods

- Temperature: monthly 10th percentile



Evaluation of bias correction methods

- Temperature: monthly 90th percentile