

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

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# Introduction

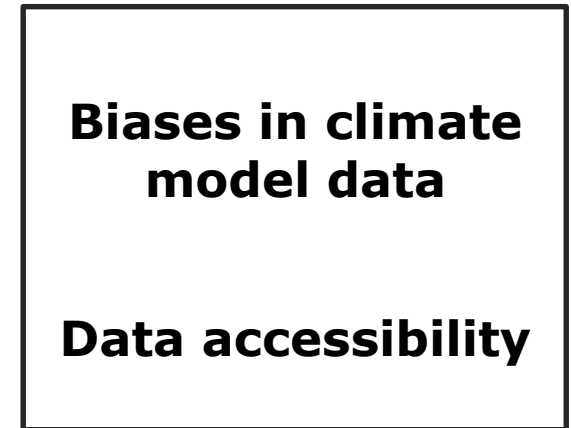
Increasing demand for climate  
change hydrologic impact  
studies



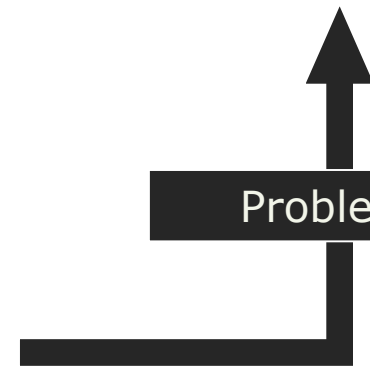
Sustainable management of  
water resources



Linking climate simulations  
with hydrological models



Problems



# Research Tasks

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(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

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- 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

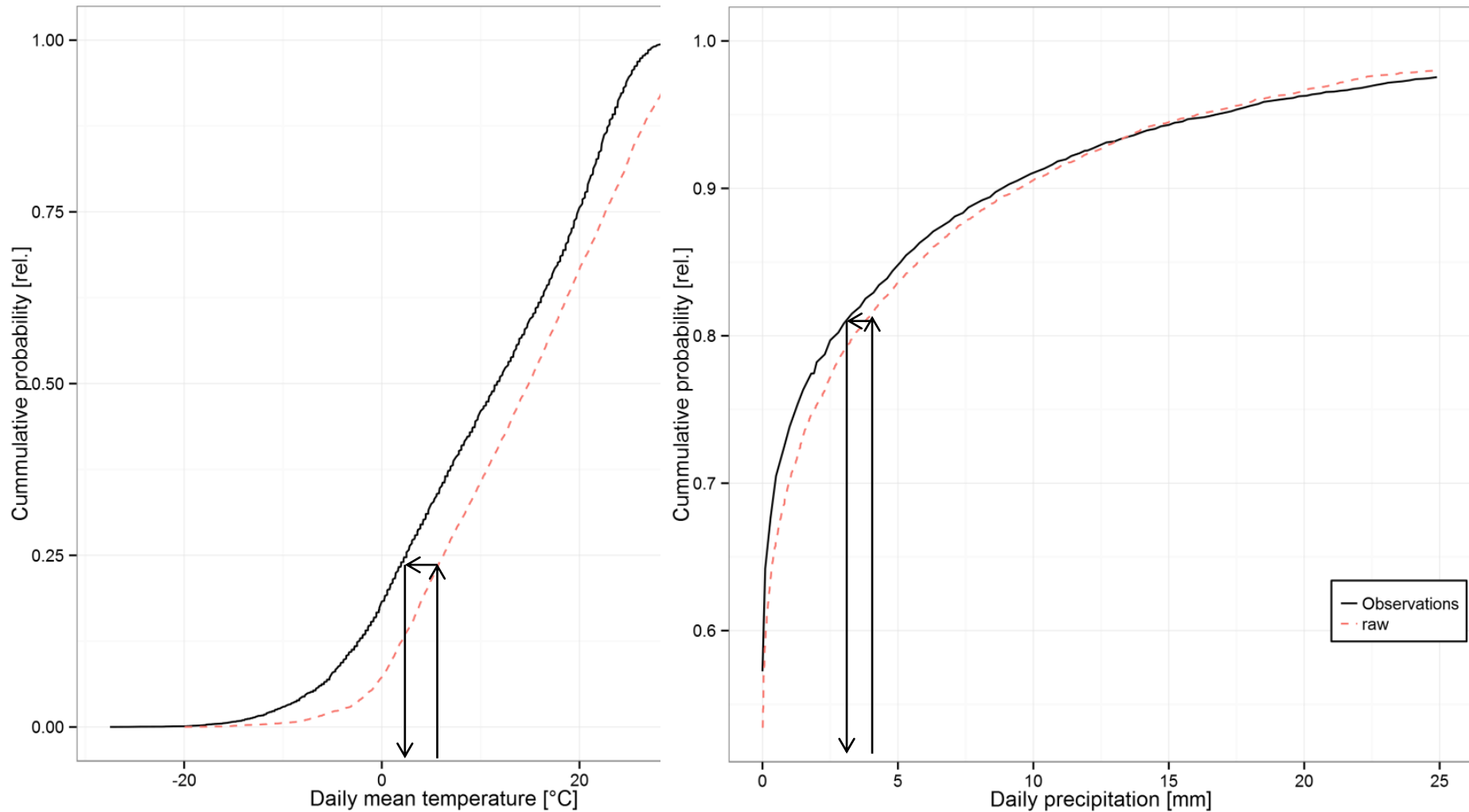
# Study area: Wildcat Creek watershed

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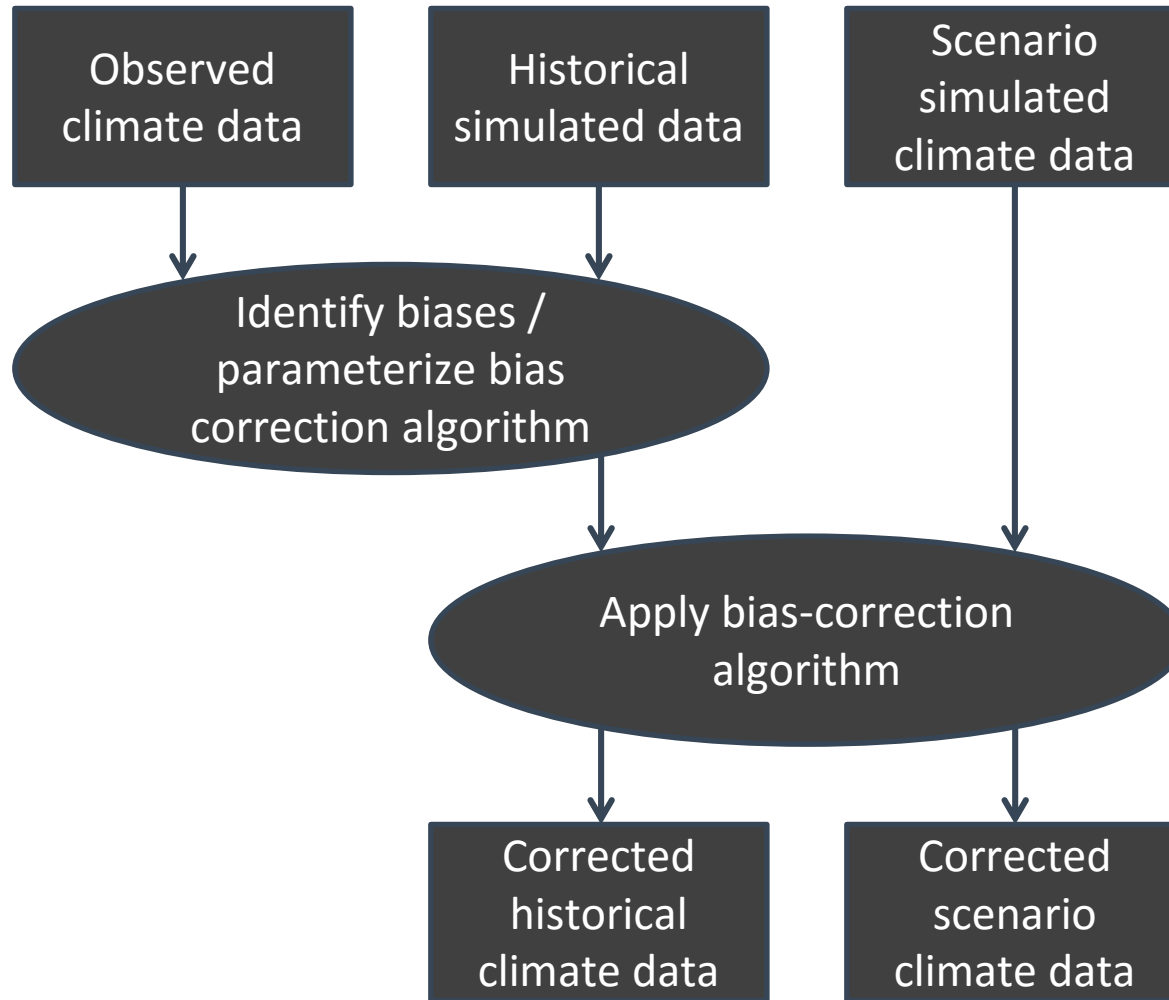
## Task 1:

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

# Bias-correction



# Bias correction



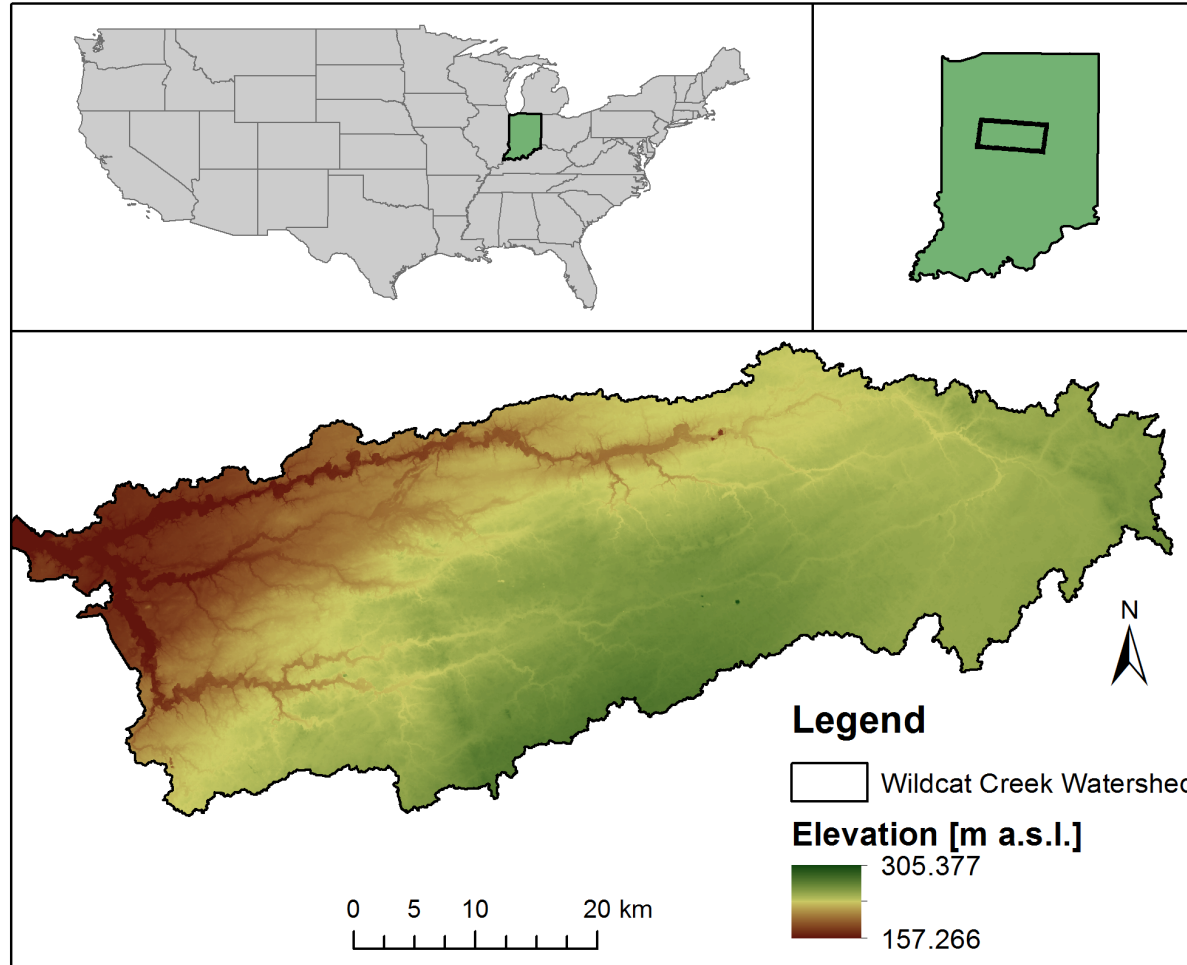
# Bias correction

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- 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

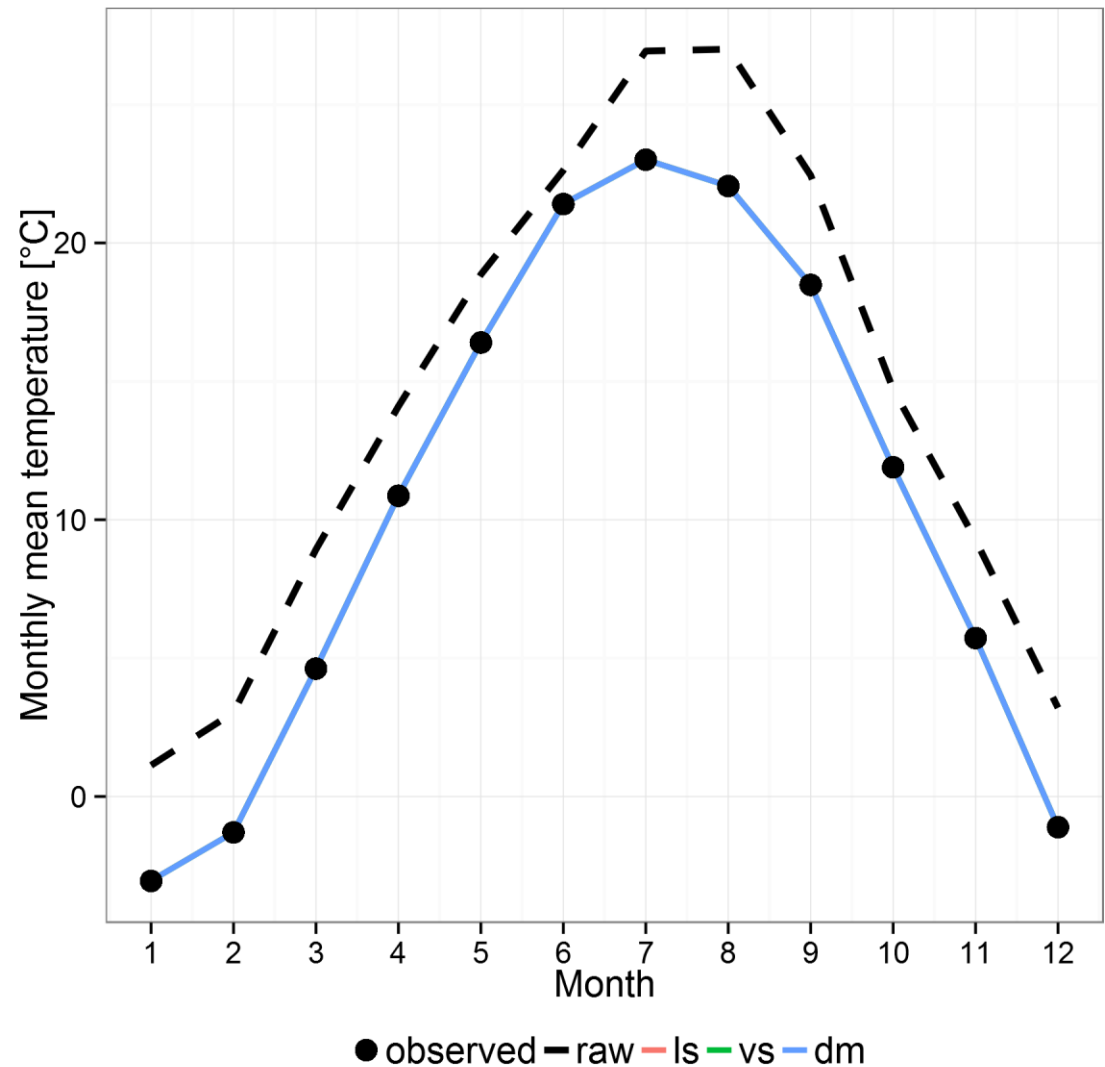
# Impact on SWAT simulations

- 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	Variance scaling
dm	Distribution mapping	Distribution mapping

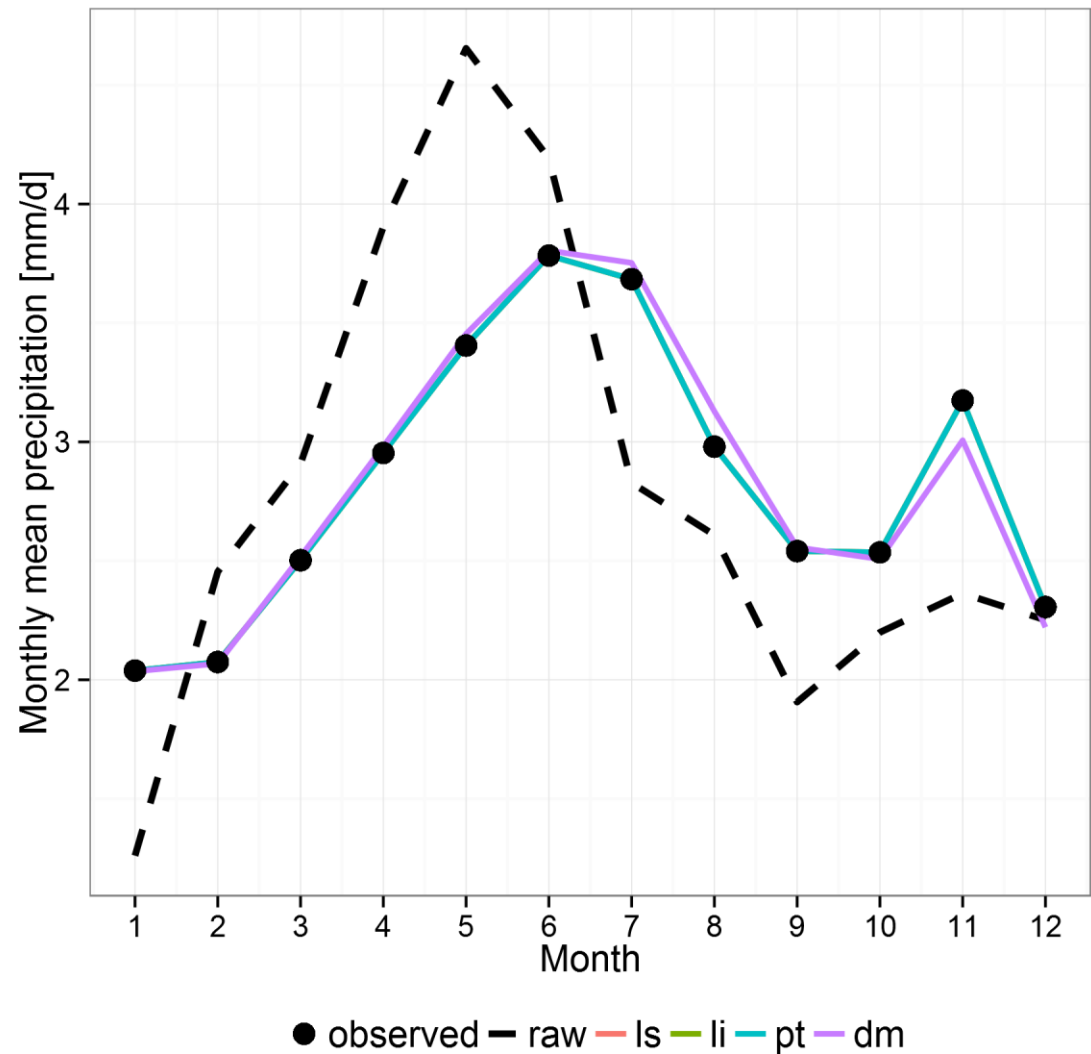
# Evaluation of bias correction methods

- Temperature: monthly mean



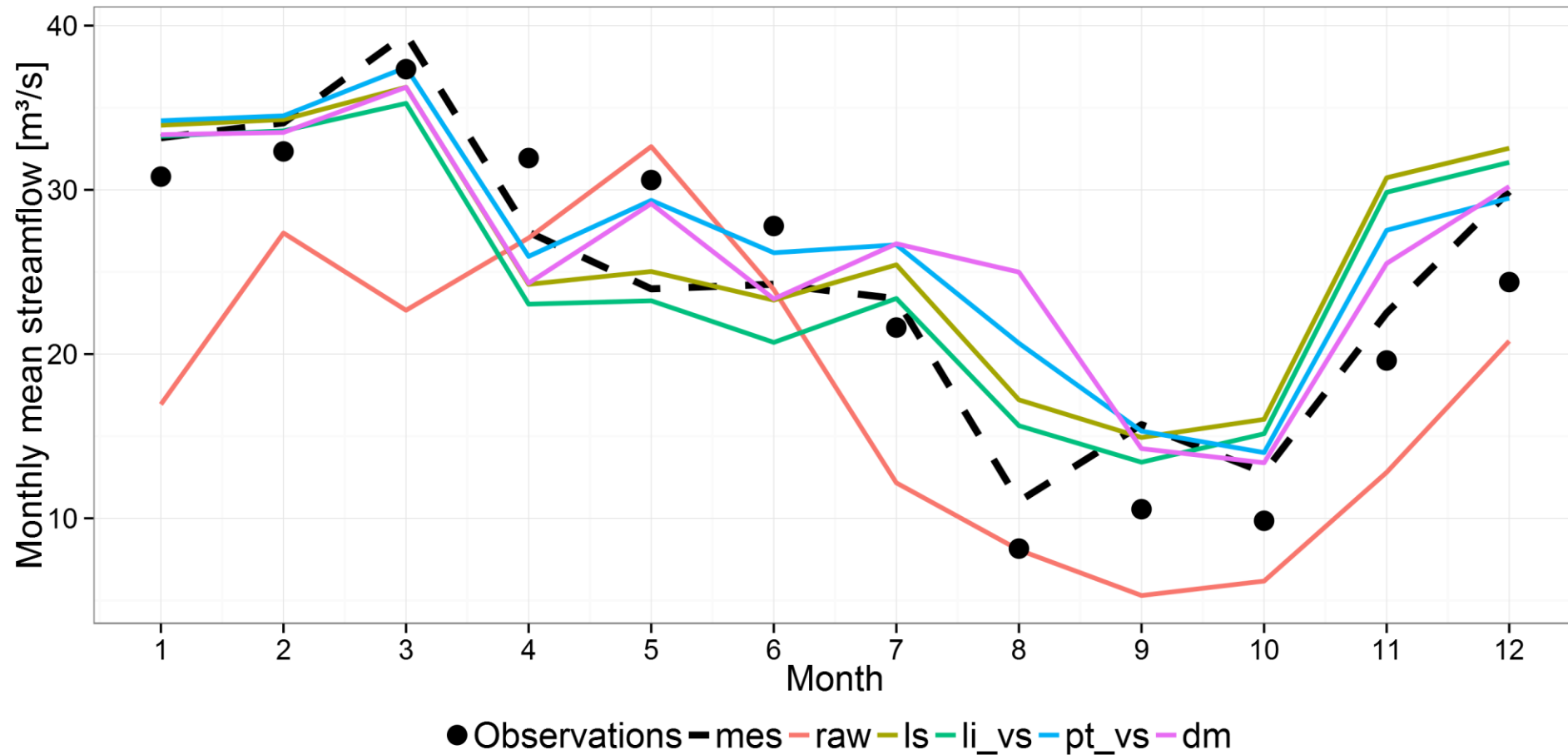
# Evaluation of bias correction methods

- Precipitation:  
monthly mean



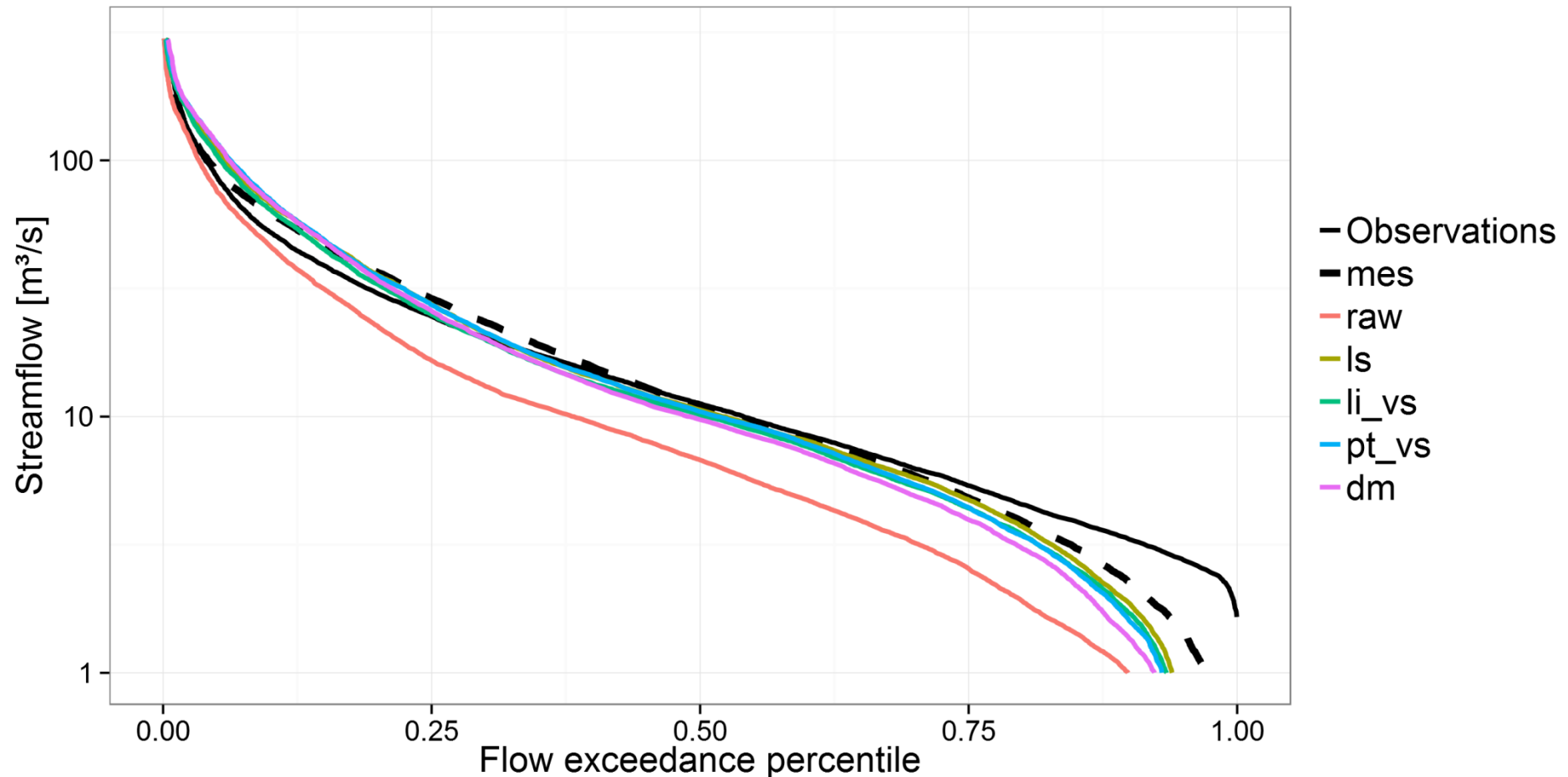
# Impact on SWAT simulations

## ■ Monthly mean streamflow



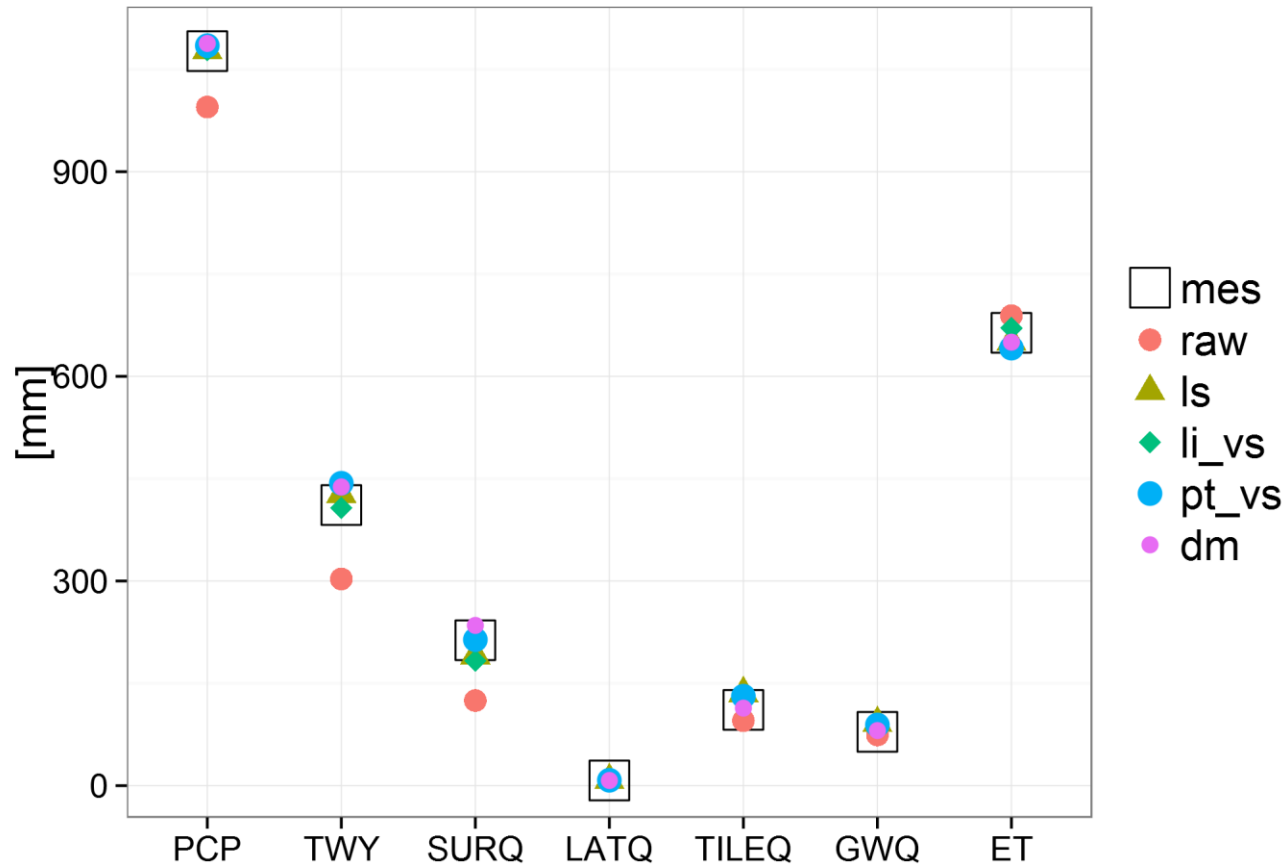
# Impact on SWAT simulations

## ■ Flow duration curve



# Impact on SWAT simulations

- Waterbalance and flow components





# Research Tasks

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## 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](http://www.globalweather.tamu.edu/cmip)

← → ↻ 🏠 [globalweather.tamu.edu/cmip](http://globalweather.tamu.edu/cmip) 🔍 ☆

### Step 1: Select your bounding box

Hold the **Shift** key and drag to select your bounding coordinates on the map. Or, type your latitude/longitude coordinates below. For quick response, bounding coordinates must not exceed 10 decimal degrees latitude and 10 longitude. You may submit a larger area, but it will be subject to approval by an administrator before running and make take several weeks to complete depending on the size and number of years requested.



**South Latitude**  
37.9962

**West Longitude**  
-90.1318

**North Latitude**  
40.9799

**East Longitude**  
-85.4297

### Step 2: Define your time period for collecting data

Select the type of data  
Historical data (1961-2000) ▼

### Step 3: Select climate change models

- ☒ CCCMA CGCM3.1 - [More information](#)
- ☒ CNRM-CM3 - [More information](#)
- ☐ GFDL CM2.0 - [More information](#) [wiki](#)
- ☐ GFDL CM2.1
- ☐ IPSLCM4 - [More information](#)
- ☐ MIROC3.2 (medres) - [More information](#)
- ☐ MIUB ECHO-G - Meteorological Institute University of Bonn (MIUB), ECHO-G, Germany
- ☐ MPI ECHAM5 - [More information](#)
- ☐ MRI CGCM2.3.2 - [More information](#)

### Step 4: Select what data to collect

- ☒ Temperature (°C)
- ☒ Precipitation (mm)

### Step 5: How should we deliver your data?

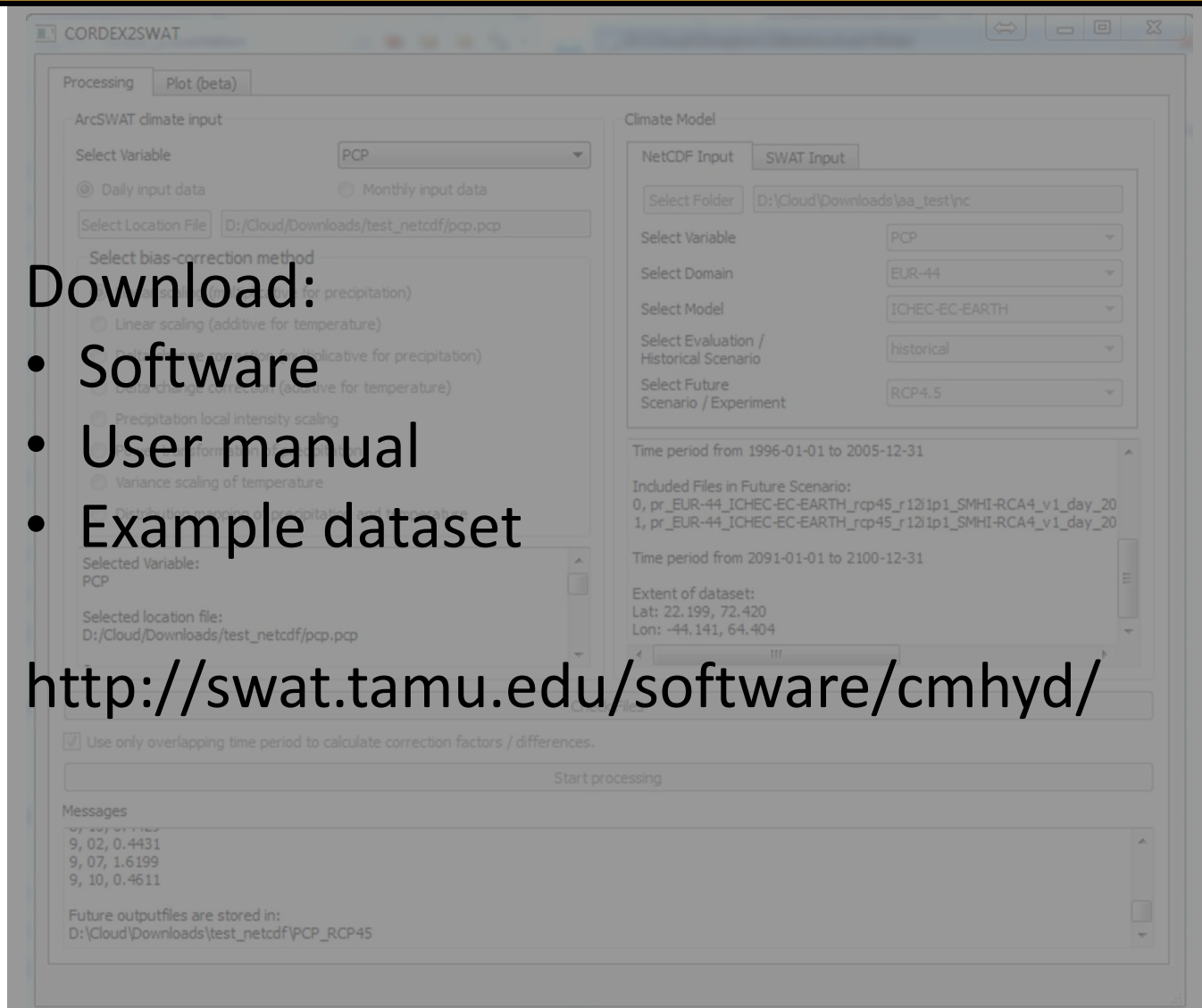
Depending on the size of your region, it may take several hours to compile your data. We will email you with a link to download a zip file containing your data when it is complete.

# 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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United States Department of Agriculture  
Agricultural Research Service

**TEXAS A&M**  
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# 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-linear 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 frequency 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:

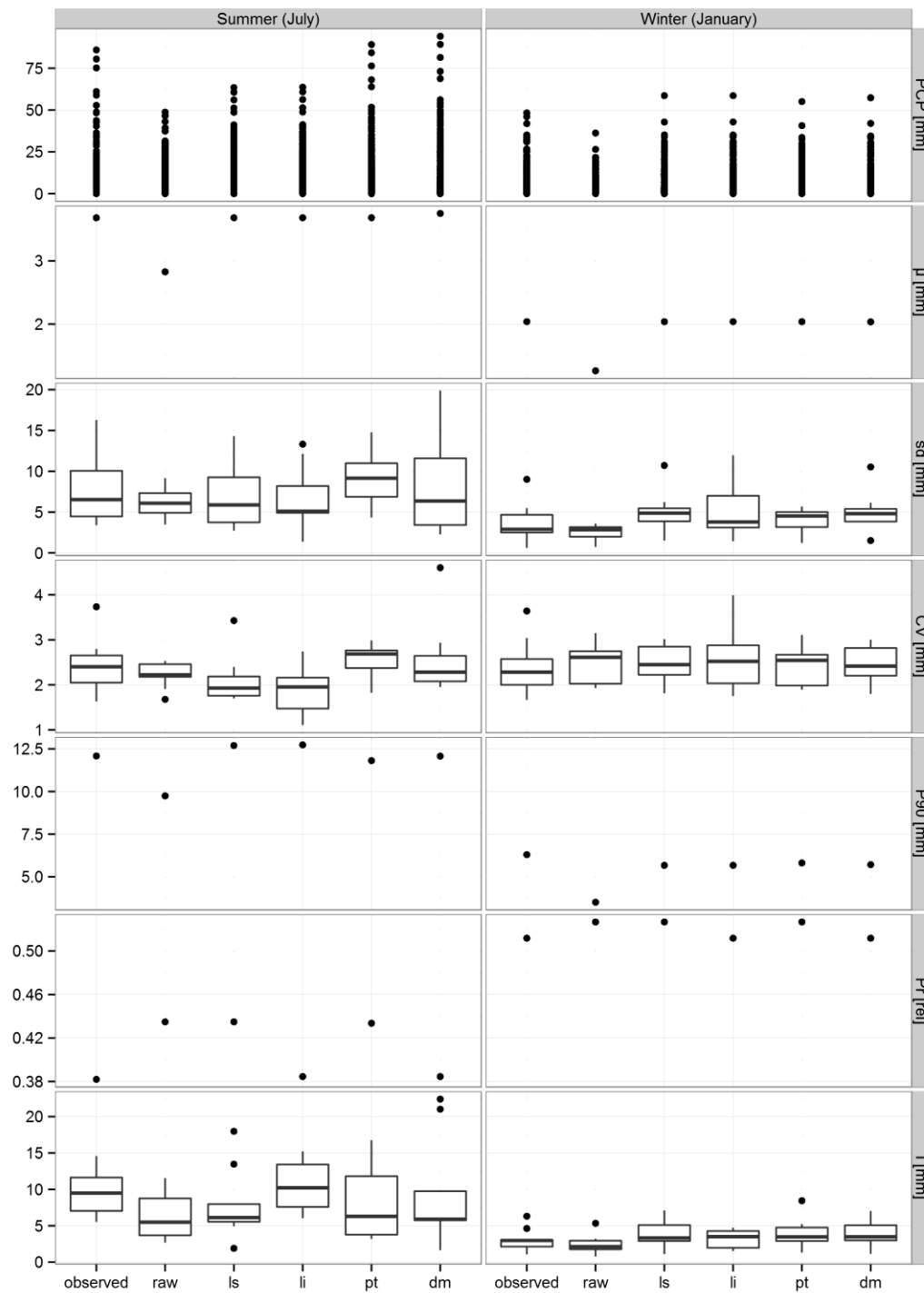
$$P_{eva}^*(d) = P_{obs}(d)$$
$$P_{sce}^*(d) = P_{obs}(d) \cdot \frac{\mu_m(P_{sce}(d))}{\mu_m(P_{eva}(d))}$$

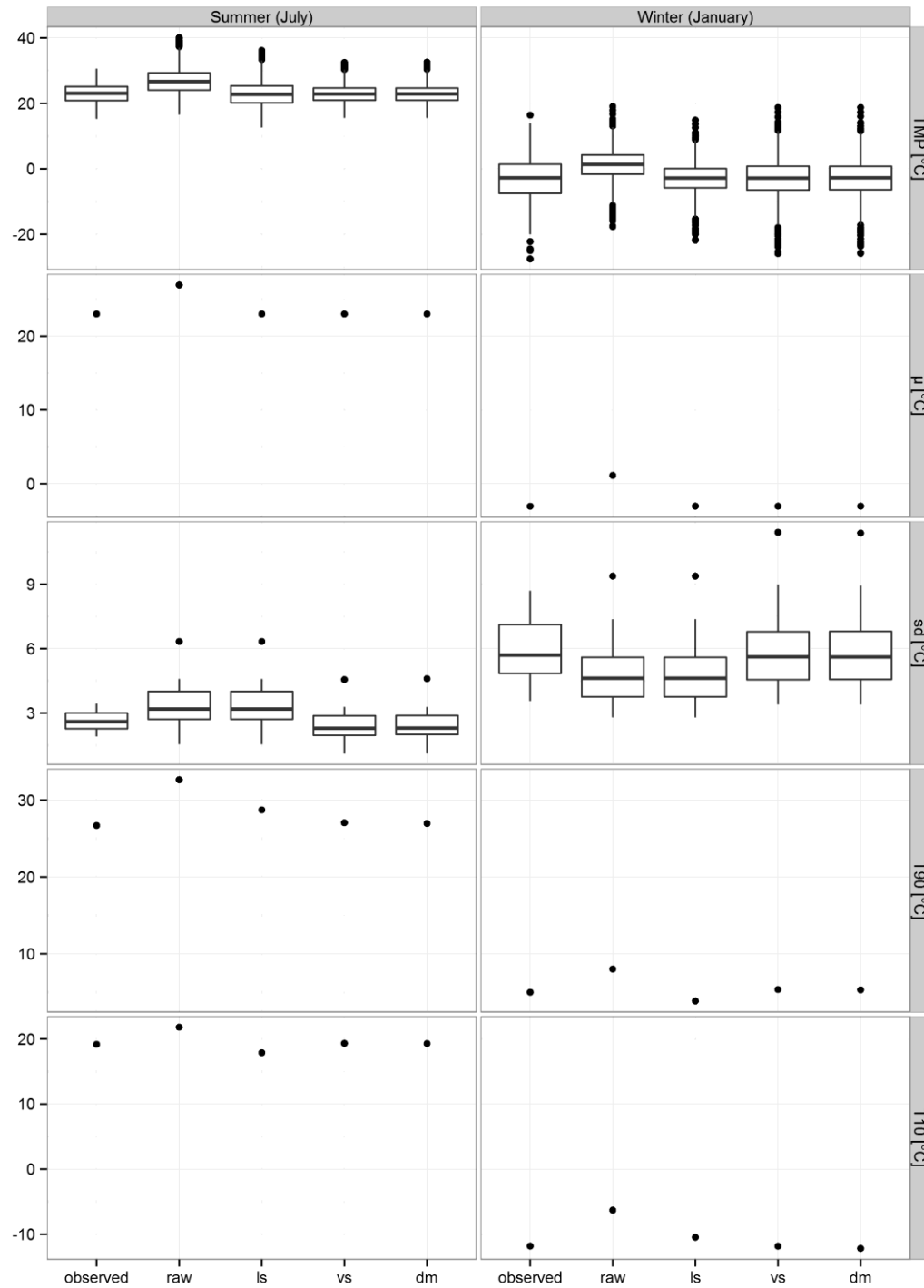
- Temperature:

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

# Evaluation of bias correction methods

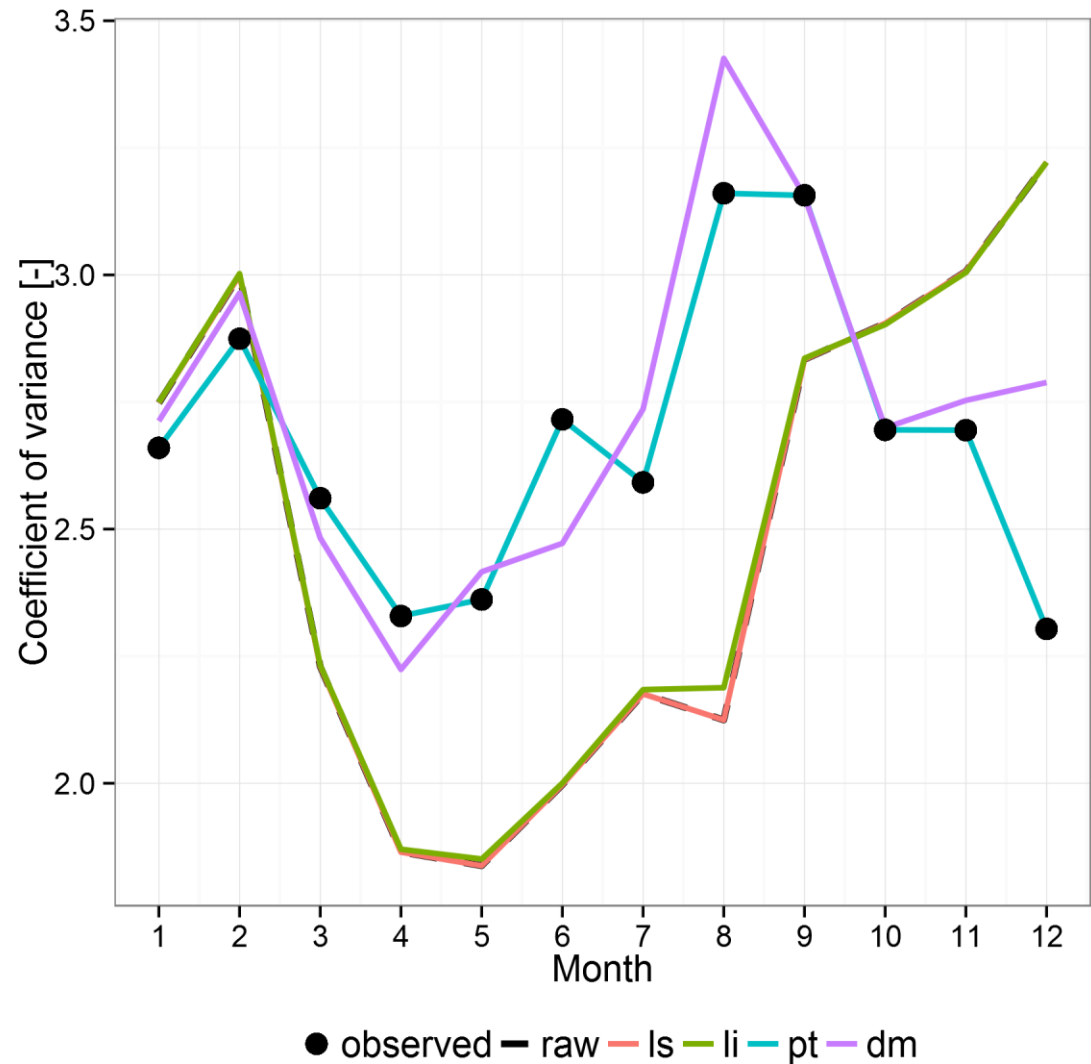
- Comparing observed and modeled data on a monthly basis:
  - Precipitation:  
mean, standard deviation, coefficient of variation, 90th percentile, probability of wet days, intensity of precipitation
  - Temperature:  
mean, standard deviation, 10th percentile, 90th percentile





# Evaluation of bias correction methods

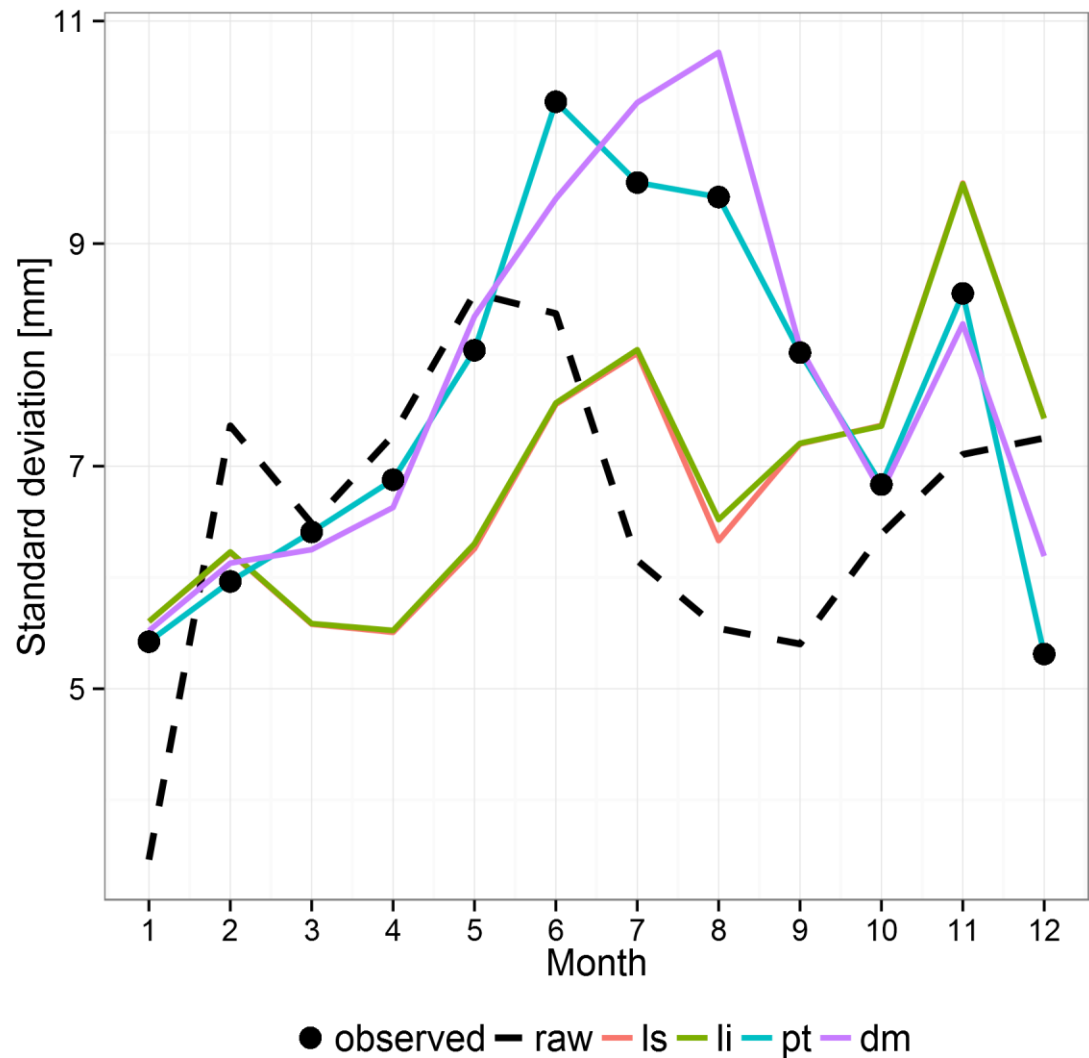
- Precipitation: monthly coefficient of variation





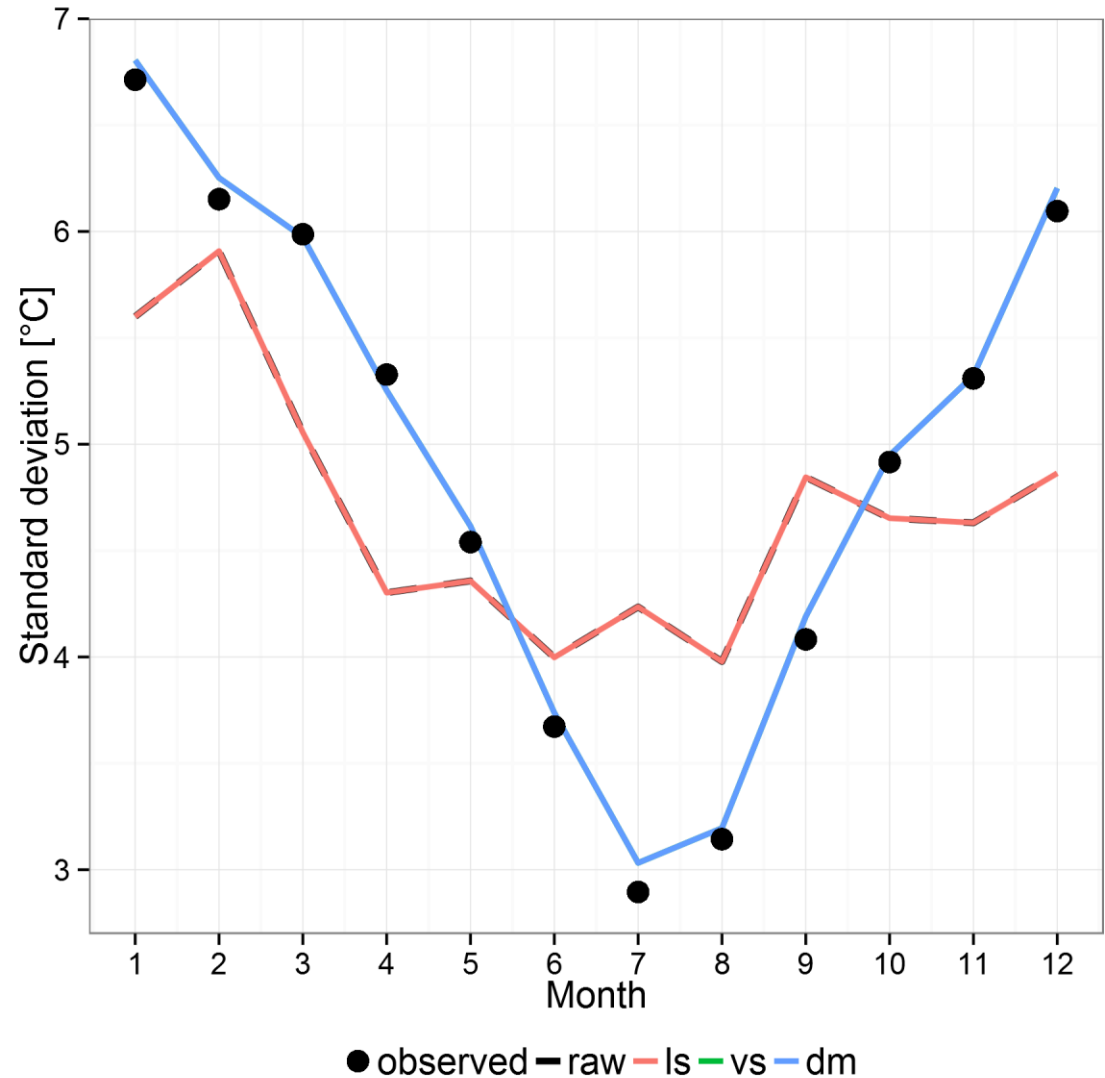
# Evaluation of bias correction methods

- Precipitation:  
monthly standard  
deviation



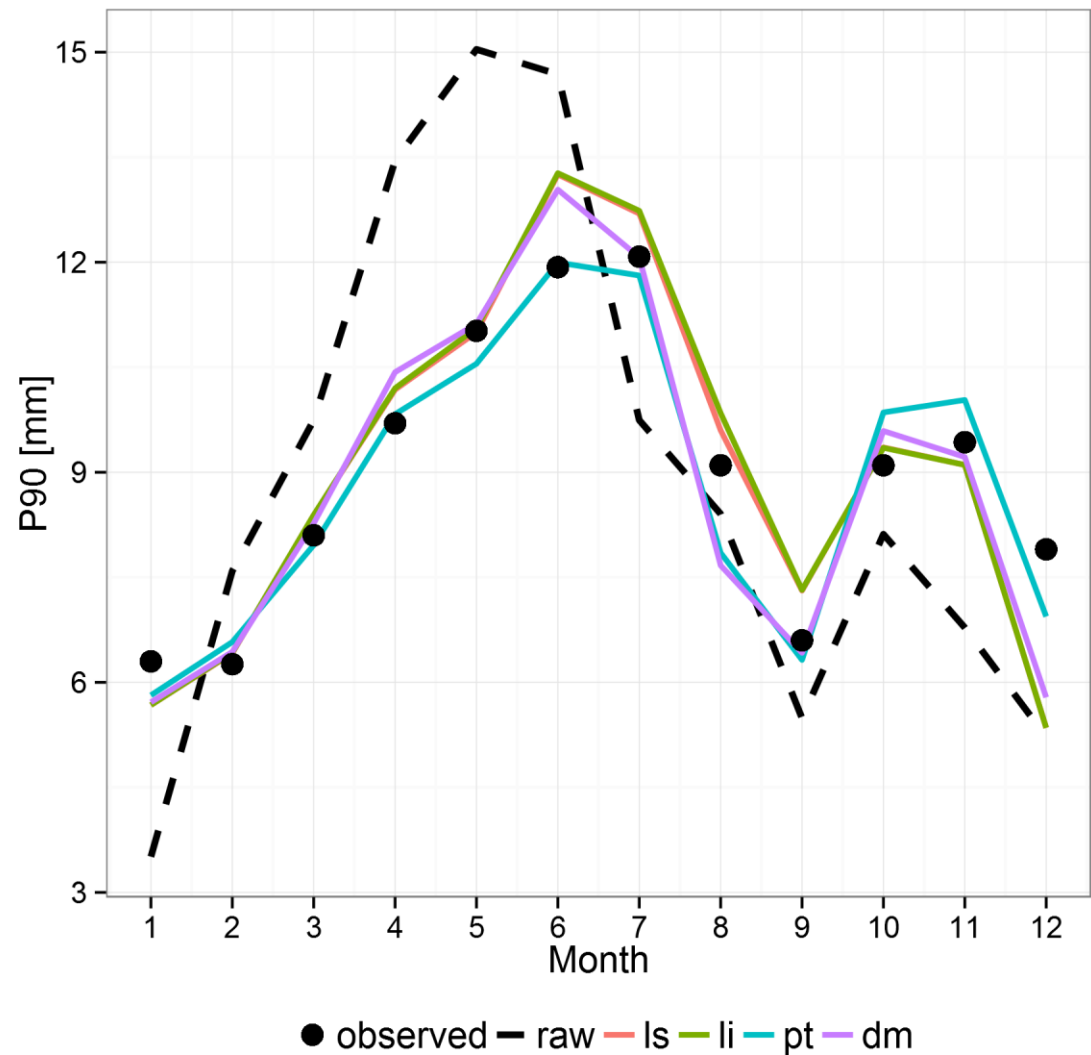
# Evaluation of bias correction methods

- Temperature:  
monthly standard  
deviation



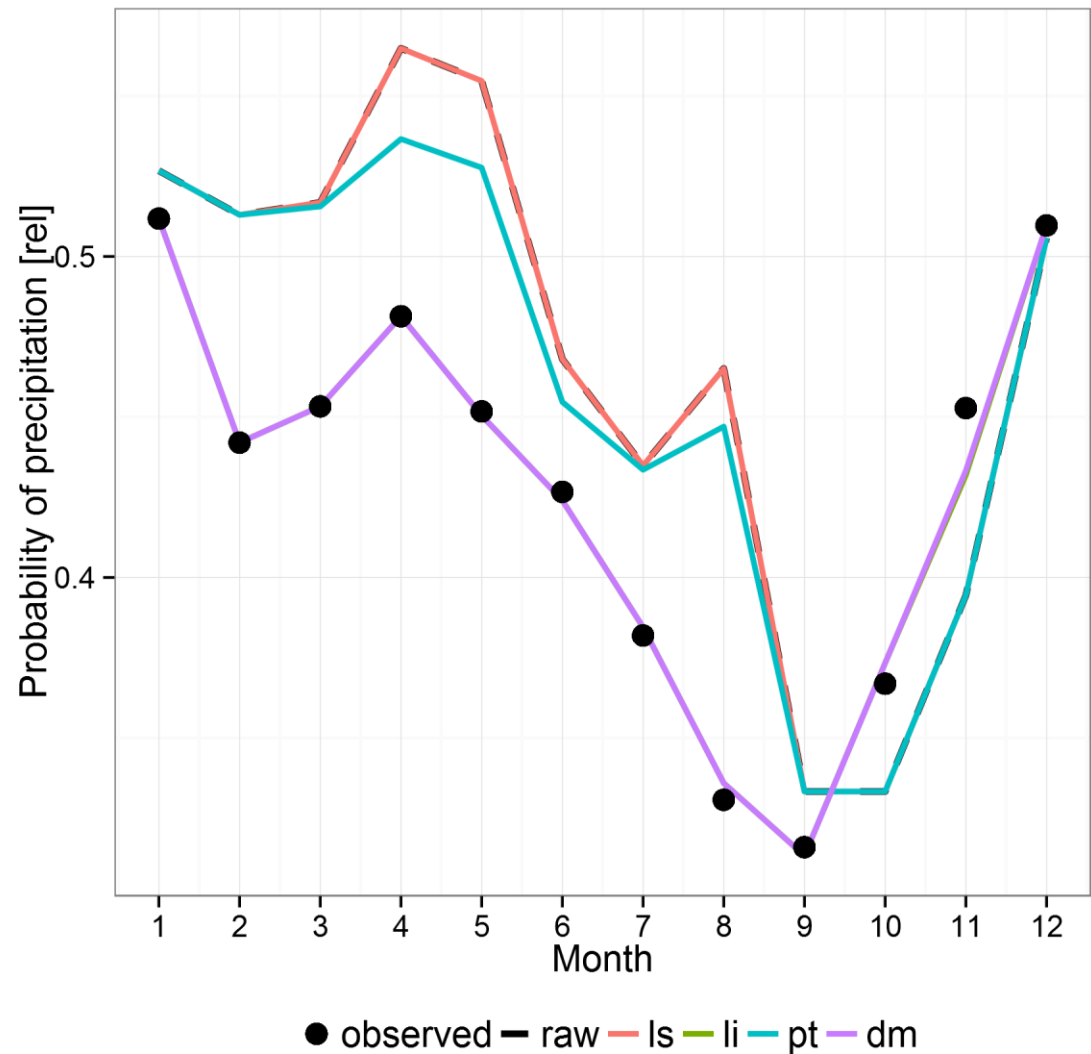
# Evaluation of bias correction methods

- Precipitation: monthly 90th percentile



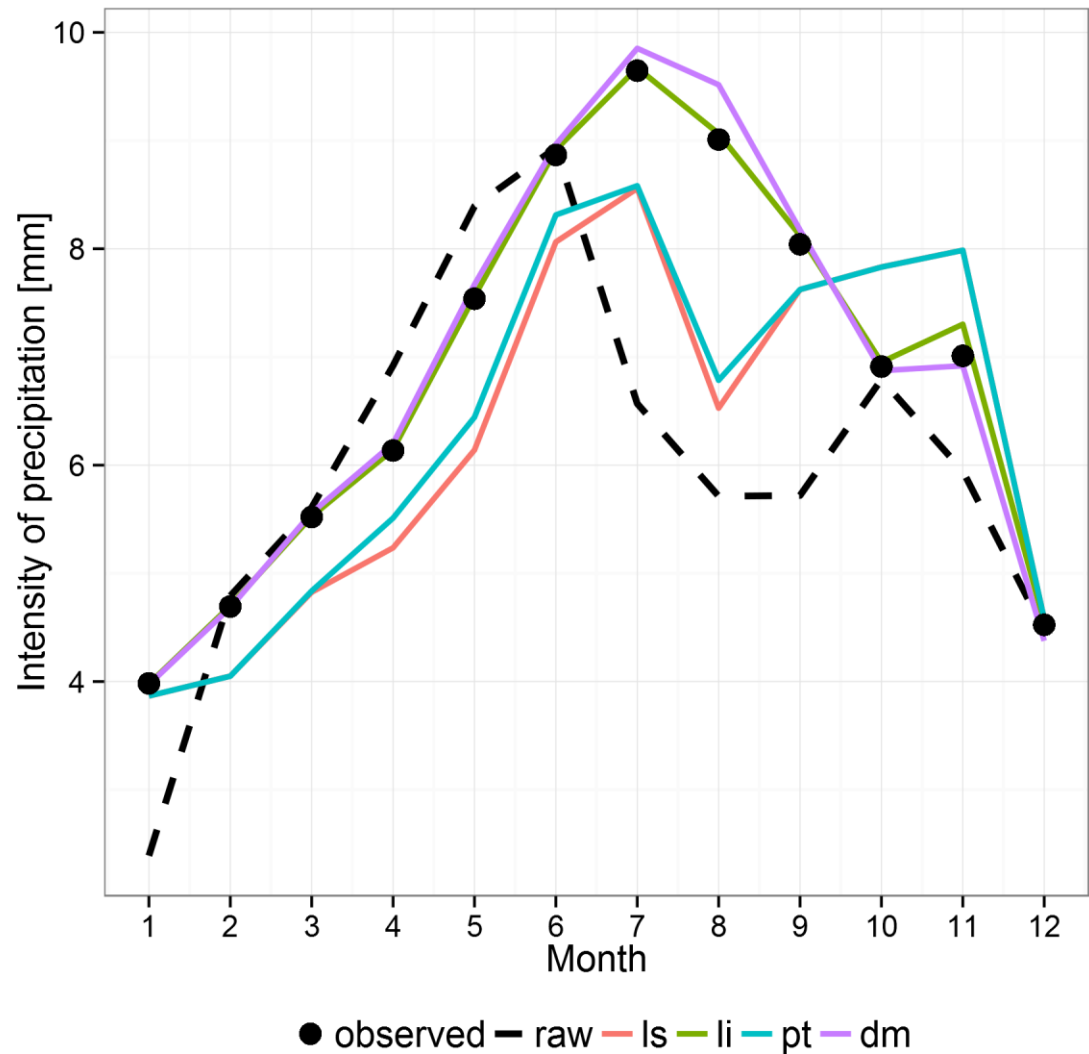
# Evaluation of bias correction methods

- Precipitation: monthly probability of precipitation



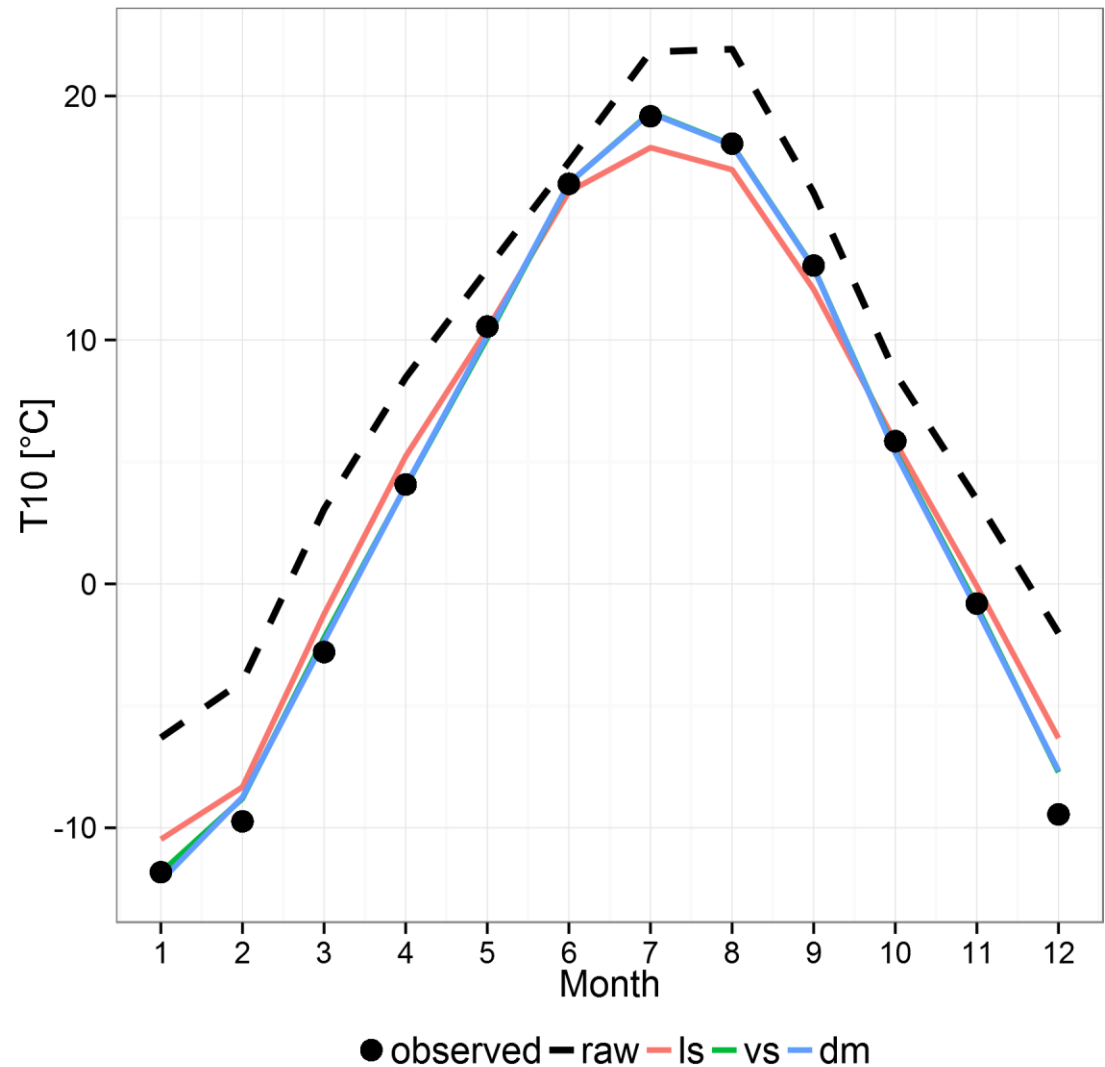
# Evaluation of bias correction methods

- Precipitation:  
monthly intensity  
of precipitation



# Evaluation of bias correction methods

- Temperature: monthly 10th percentile



# Evaluation of bias correction methods

- Temperature: monthly 90th percentile

