ANALYSIS OF MODEL BIASES

ERT 474/574

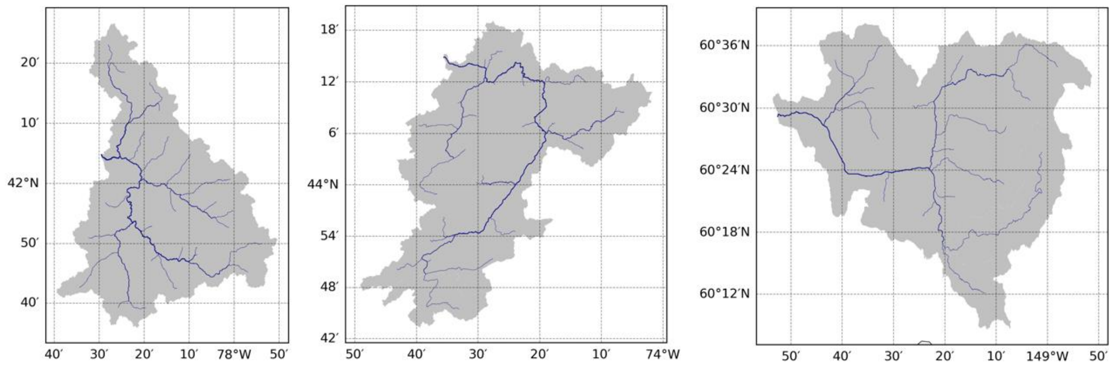
Open-Source Hydro Data Analytics

Nov 17th 2025

University at Buffalo The State University of New York

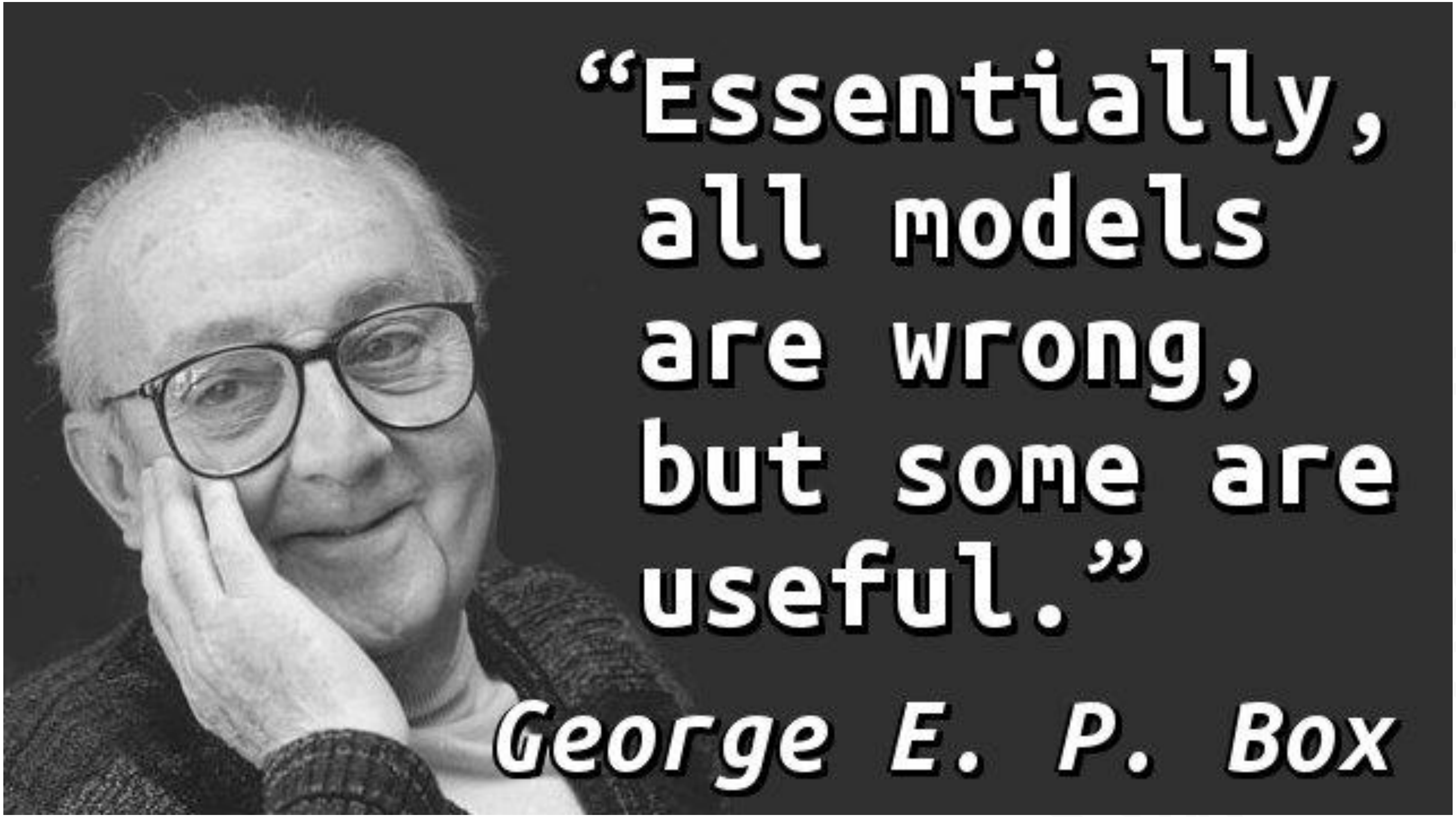
Final Project

- Set up the VIC and mizuRoute models for the targeted river basin
    - Evaluate the model performance by comparing it against the USGS observations
- Analyze the model biases and identify the potential source of errors
- Based on the analysis of potential errors, conduct a parameter sensitivity analysis for ONE parameter
    - Choose one updated parameter value and check whether modifying this parameter will improve the model performance for your model



Timeline:

- Nov 24: progress update (each group is expected to finish setting up VIC and mizuRoute models, and conducting initial evaluation against the USGS time series)
    - 5 min for each group
- Dec 8: Final presentation (30%)
    - 15 min for each group
- Dec 15: Final report (60%)
    - 10-page report for each group (including reference)

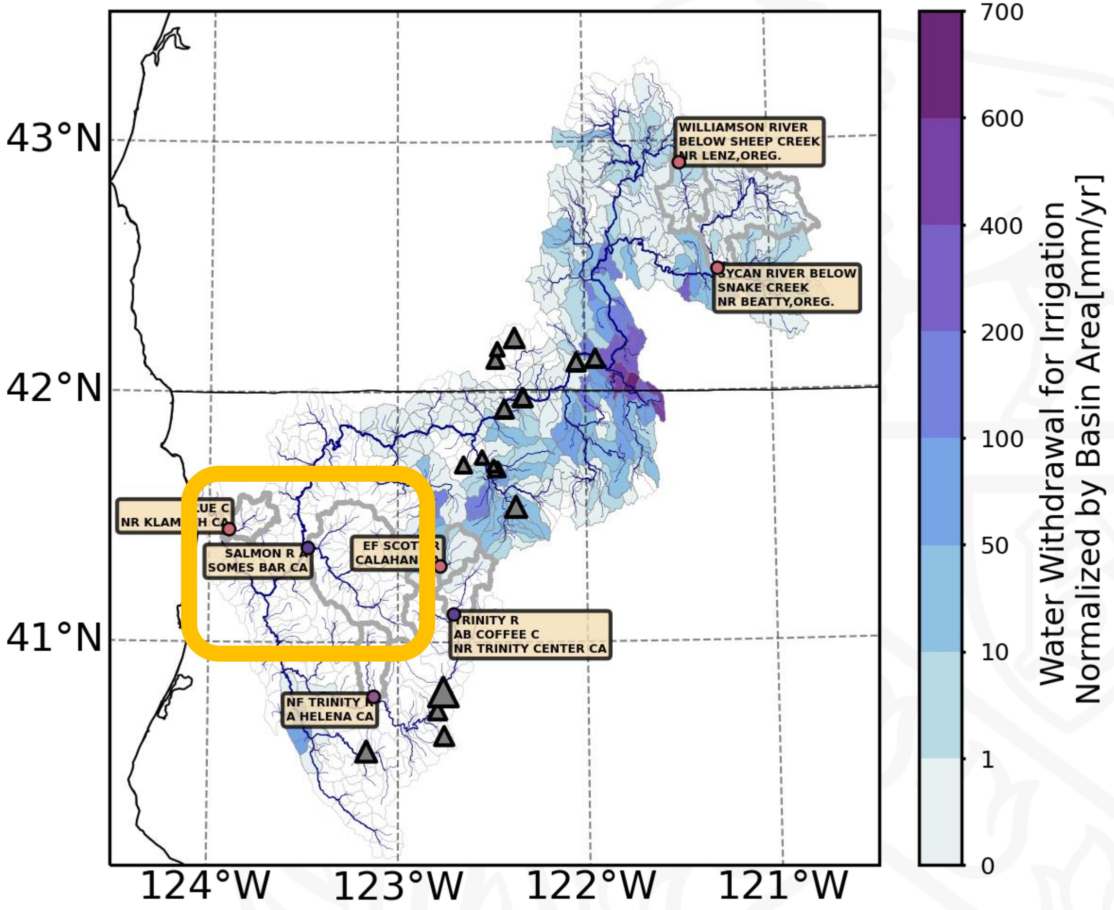

"Essentially, all models are wrong, but some are useful."
George E. P. Box

Outline

- Type of biases
- Source of biases
- Metrics for evaluating biases
- Case studies – Klamath River Basin
- Procedures to analyze the source of biases

Type of biases

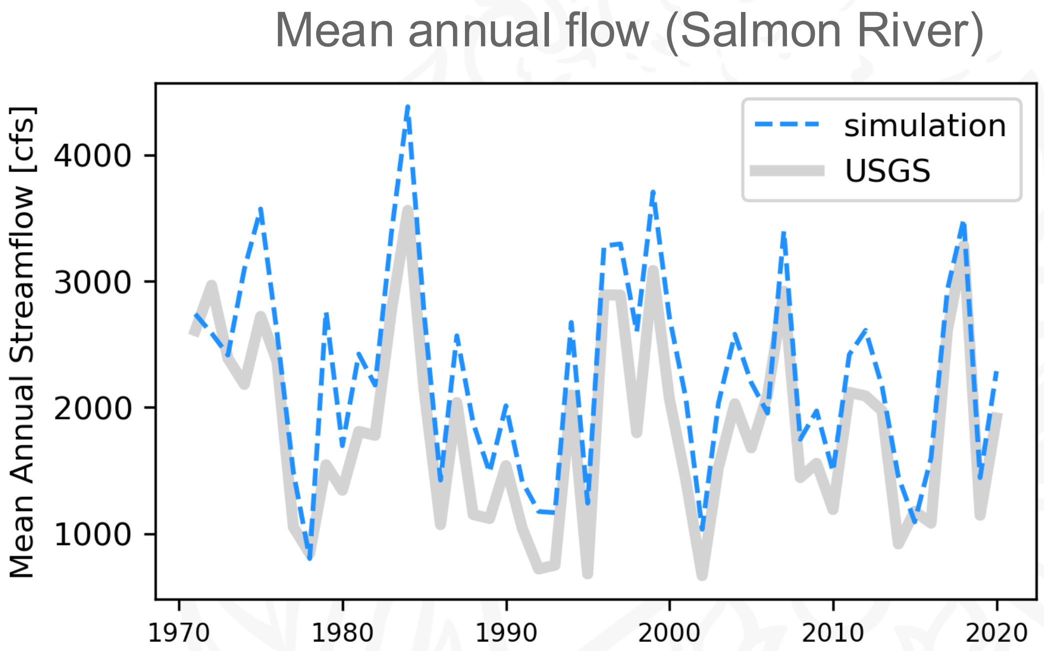
- Systematic Bias: Persistent over- or underestimation (e.g., streamflow).
- Seasonal Bias: Errors that vary by season (e.g., snowmelt timing).
- Event-Based Bias: Errors during extremes (e.g., floods, droughts).
- Spatial Bias: Differences across regions or catchments.



Examples will be shown for the Salmon River in the Klamath River Basin

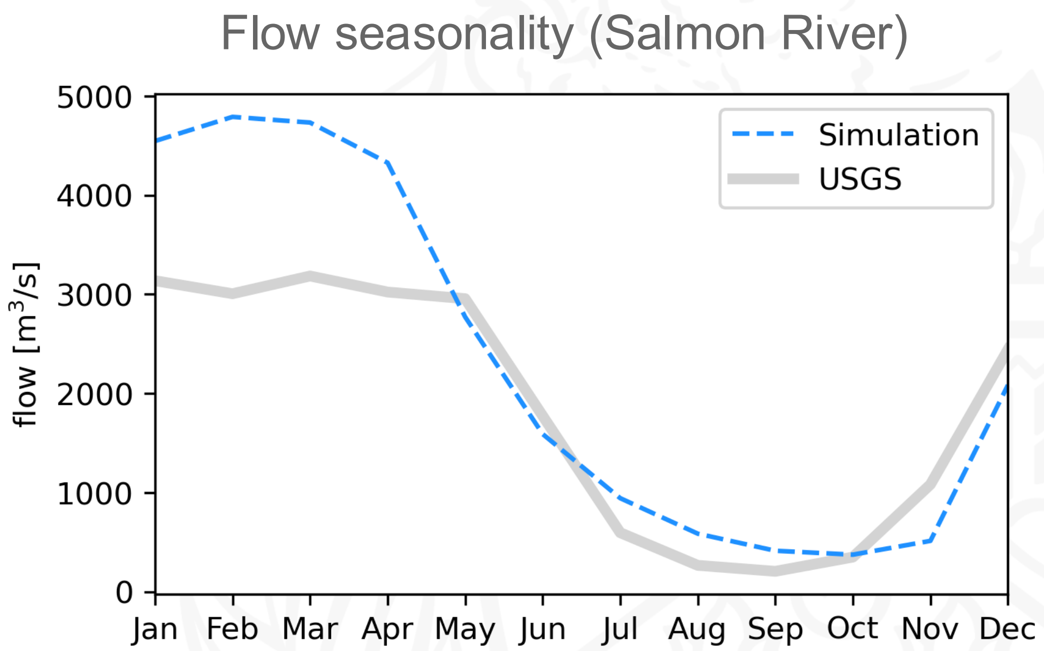
Type of biases

- **Systematic Bias: Persistent over- or underestimation (e.g., streamflow).**
- Seasonal Bias: Errors that vary by season (e.g., snowmelt timing).
- Event-Based Bias: Errors during extremes (e.g., floods, droughts).
- Spatial Bias: Differences across regions or catchments.



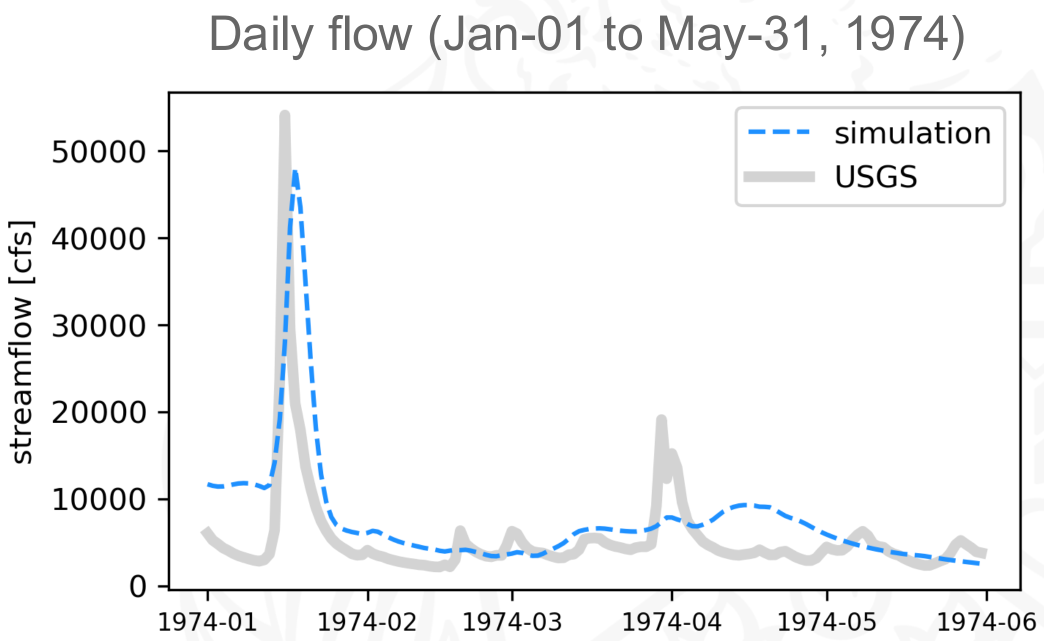
Type of biases

- Systematic Bias: Persistent over- or underestimation (e.g., streamflow).
- **Seasonal Bias: Errors that vary by season (e.g., snowmelt timing).**
- Event-Based Bias: Errors during extremes (e.g., floods, droughts).
- Spatial Bias: Differences across regions or catchments.



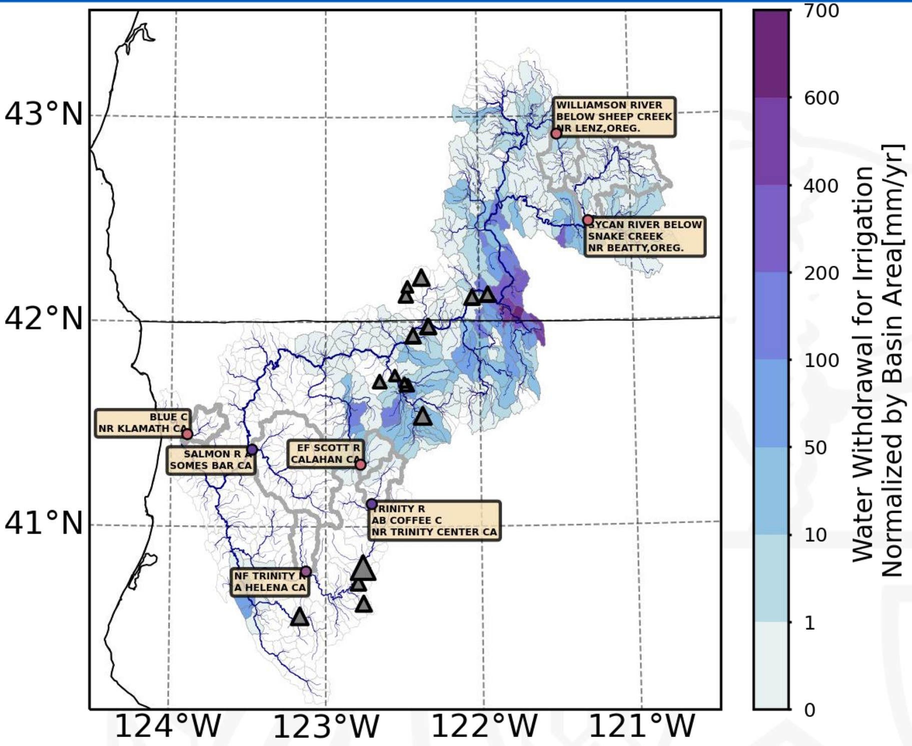
Type of biases

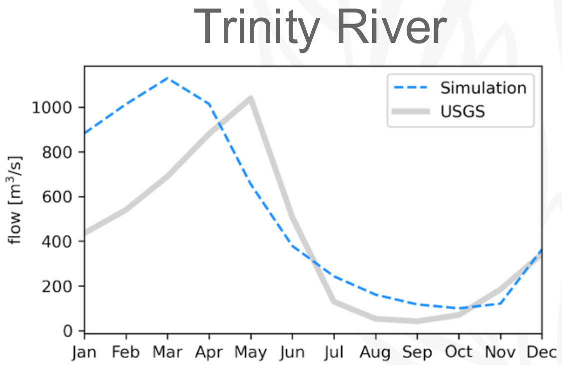
- Systematic Bias: Persistent over- or underestimation (e.g., streamflow).
- Seasonal Bias: Errors that vary by season (e.g., snowmelt timing).
- **Event-Based Bias: Errors during extremes (e.g., floods, droughts).**
- Spatial Bias: Differences across regions or catchments.

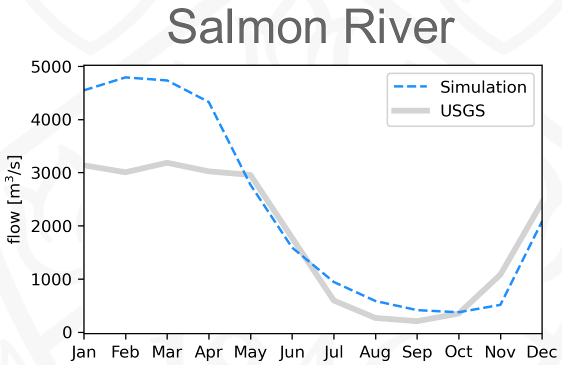


Type of biases

- Systematic Bias: Persistent over- or underestimation (e.g., streamflow).
- Seasonal Bias: Errors that vary by season (e.g., snowmelt timing).
- Event-Based Bias: Errors during extremes (e.g., floods, droughts).
- **Spatial Bias: Differences across regions or catchments.**







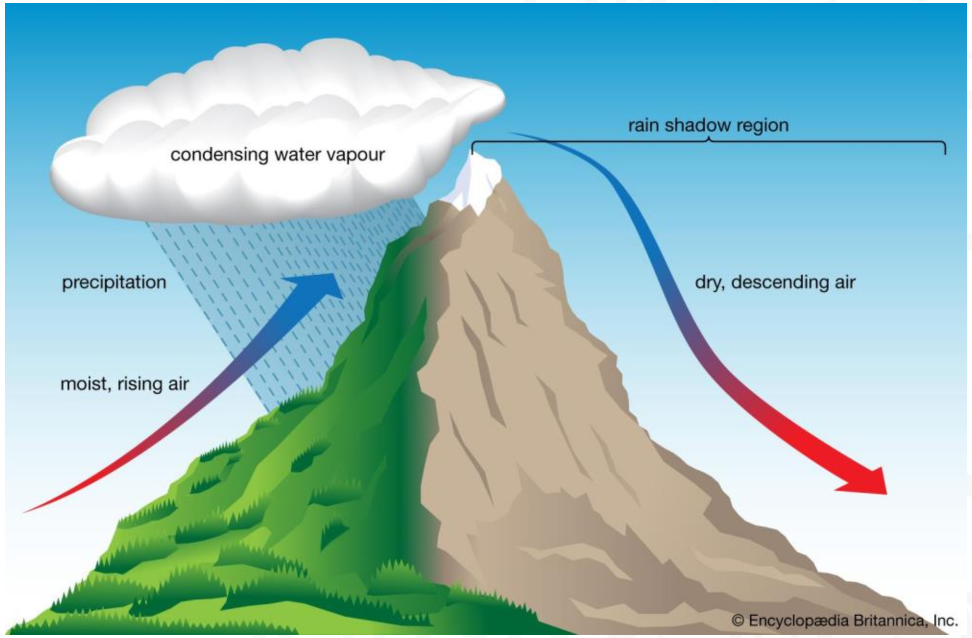
Source of biases

- Meteorological forcing: Precipitation undercatch, coarse spatial resolution.
- Parameter Uncertainty: Infiltration and baseflow parameters are often used in VIC model tuning.
- Model Structure: Simplifications in snowmelt or infiltration processes.
- Land Surface Data: Land use, soil properties.

Source of biases

- **Meteorological forcing: Precipitation undercatch, coarse spatial resolution.**
- Parameter Uncertainty: Infiltration and baseflow parameters are often used in VIC model tuning.
- Model Structure: Simplifications in snowmelt or infiltration processes.
- Land Surface Data: Land use, soil properties.

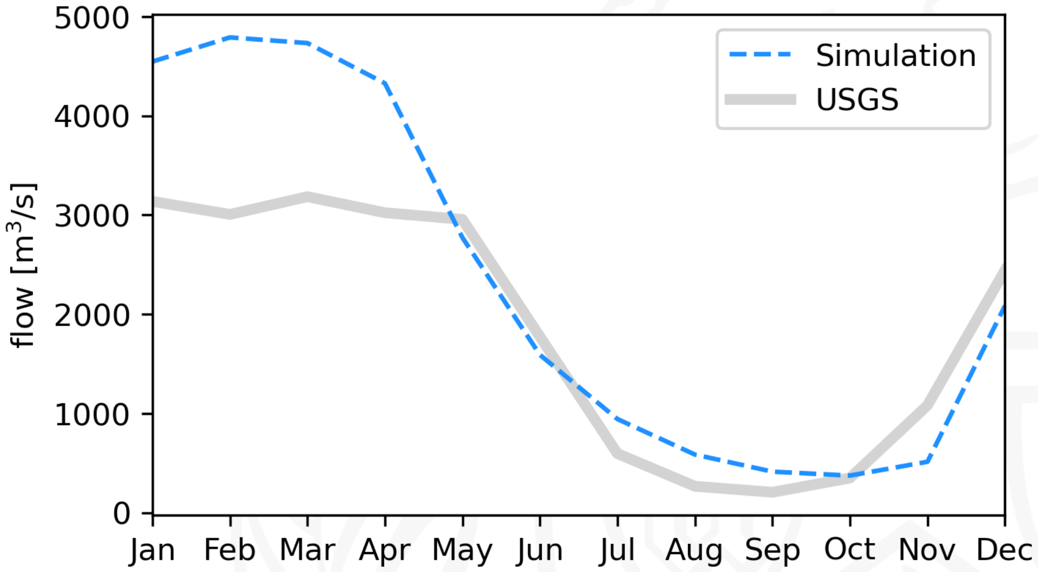
Why would coarse spatial resolution of met forcing be a problem?



Because of the topographic precipitation.

Source of biases

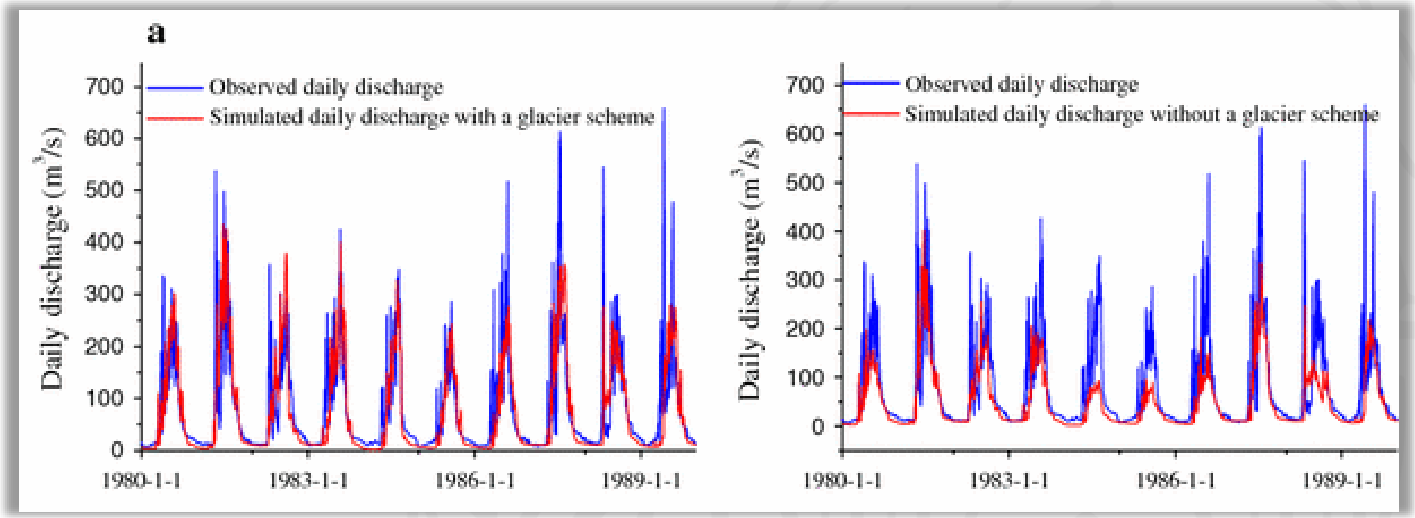
- Meteorological forcing: Precipitation undercatch, coarse spatial resolution.
- **Parameter Uncertainty: Infiltration and baseflow parameters are often used in VIC model tuning.**
- Model Structure: Simplifications in snowmelt or infiltration processes.
- Land Surface Data: Land use, soil properties.



During the summer, when the model simulation consistently overestimates the streamflow, it is highly possible that it results from the baseflow parameters

Source of biases

- Meteorological forcing: Precipitation undercatch, coarse spatial resolution.
- Parameter Uncertainty: Infiltration and baseflow parameters are often used in VIC model tuning.
- **Model Structure: Simplifications in snowmelt or infiltration processes.**
- Land Surface Data: Land use, soil properties.

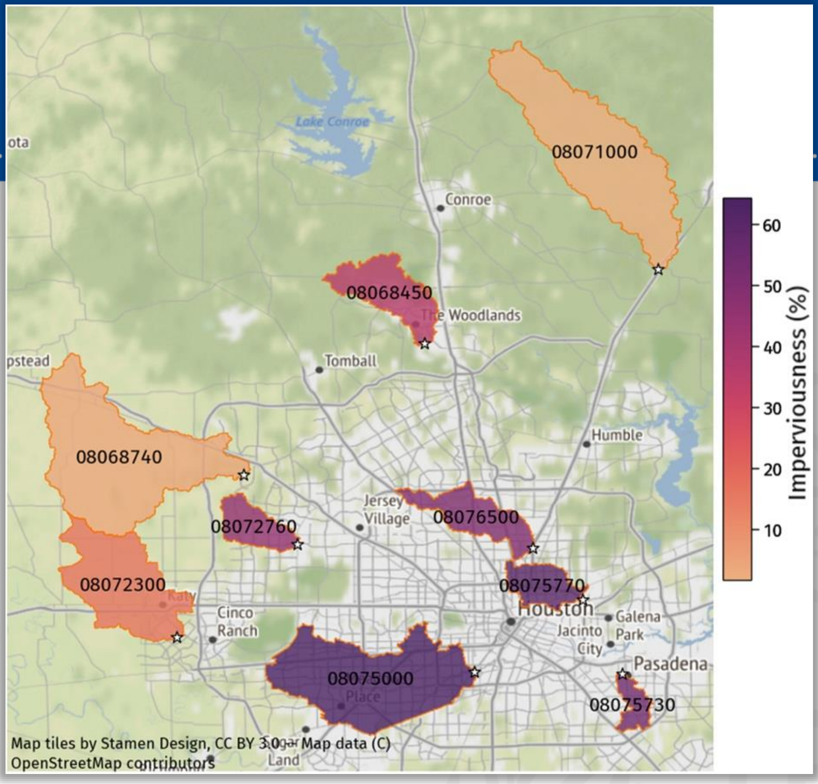


[Coupling a glacier melt model to the Variable Infiltration Capacity (VIC) model for hydrological modeling in north-western China](https://link.springer.com/article/10.1007/s12665-012-1718-8)

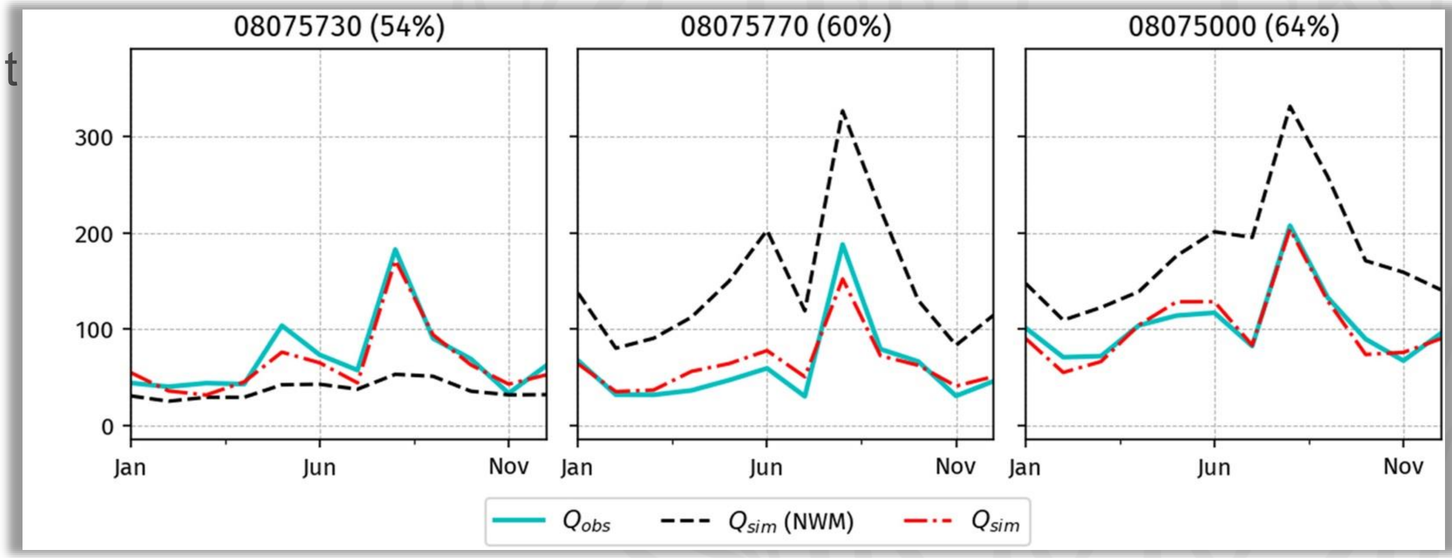
Source: https://link.springer.com/article/10.1007/s12665-012-1718-8

Source of biases

- Meteorological forcing: Precipitation undercatch, coarse spatial resolution.
- Parameter Uncertainty: Infiltration and baseflow parameters are often used in VIC model tuning.
- Model Structure: Simplifications in snowmelt or infiltration processes.
- **Land Surface Data: Land use, soil properties.**



A Scale-Adaptive Urban Hydrologic Framework: Incorporating Network-Level Storm Drainage Pipes Representation



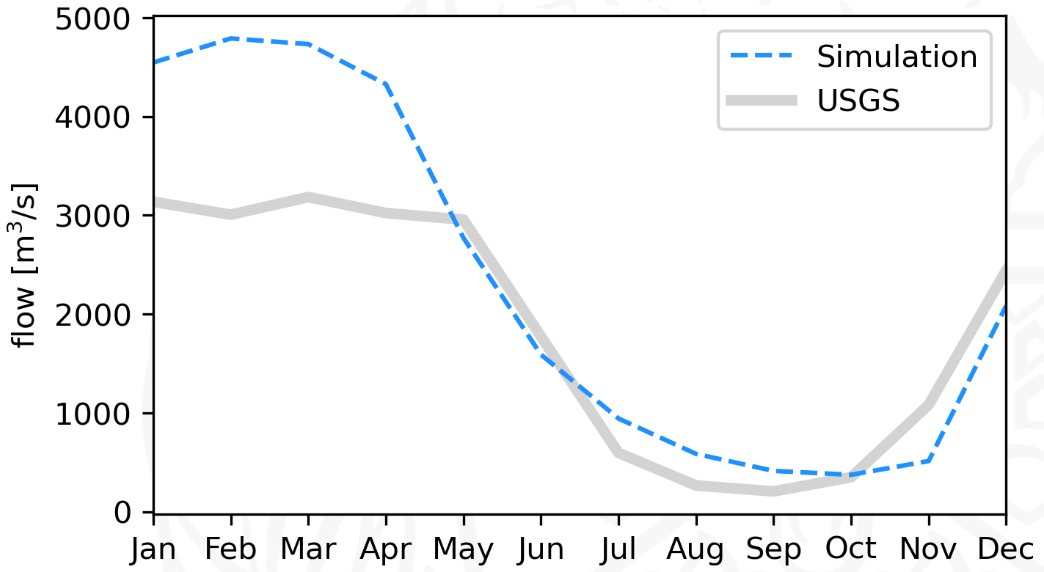
Source:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2024WR037268

Metrics for evaluating biases

- Mean Bias Error (MBE)
- Percent Bias (PBIAS)
- Root Mean Square Error (RMSE)
- Nash-Sutcliffe Efficiency (NSE)
- Kling-Gupta Efficiency (KGE)

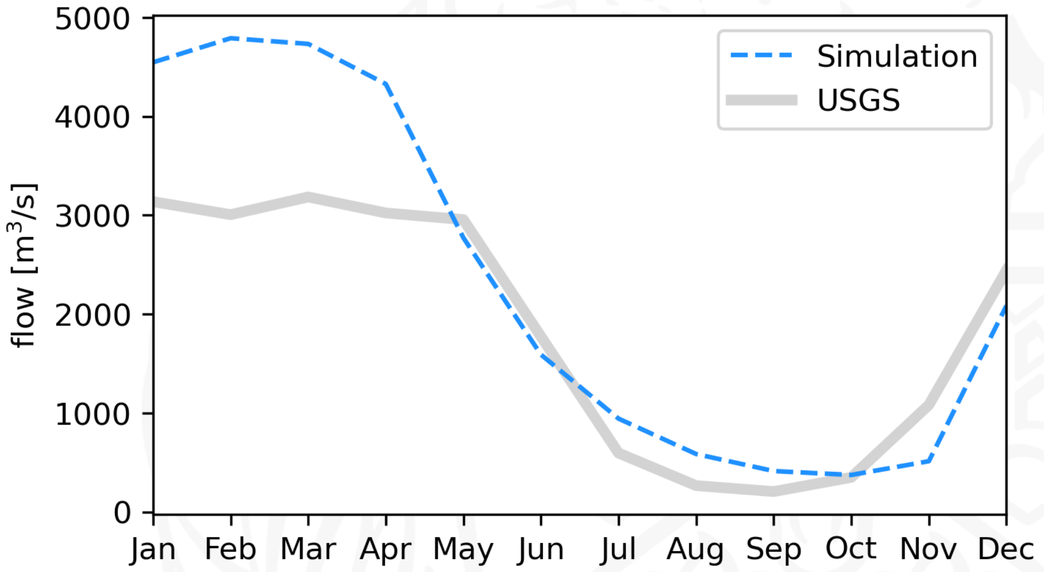
Metrics for evaluating biases

- Mean Bias Error (MBE)
- Percent Bias (PBIAS)
  - For MBE and PBIAS, we can use it to calculate not only mean annual values, but also seasonal biases.
- Root Mean Square Error (RMSE)
- Nash-Sutcliffe Efficiency (NSE)
- Kling-Gupta Efficiency (KGE)



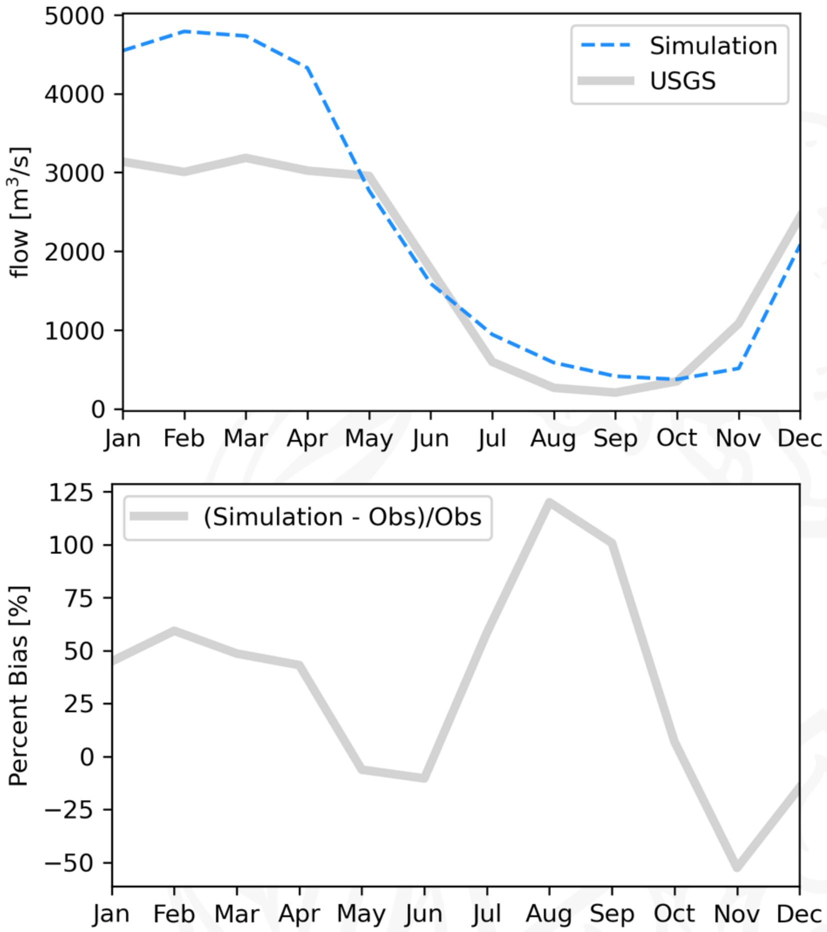
Metrics for evaluating biases

- Mean Bias Error (MBE)
- Percent Bias (PBIAS)
- Root Mean Square Error (RMSE)
- Nash-Sutcliffe Efficiency (NSE)
  - For both RMSE and NSE, they are both biased towards high-flow biases
- Kling-Gupta Efficiency (KGE)



Metrics for evaluating biases

- Mean Bias Error (MBE)
- Percent Bias (PBIAS)
- Root Mean Square Error (RMSE)
- Nash-Sutcliffe Efficiency (NSE)
  - For both RMSE and NSE, they are both biased towards high-flow biases
- Kling-Gupta Efficiency (KGE)

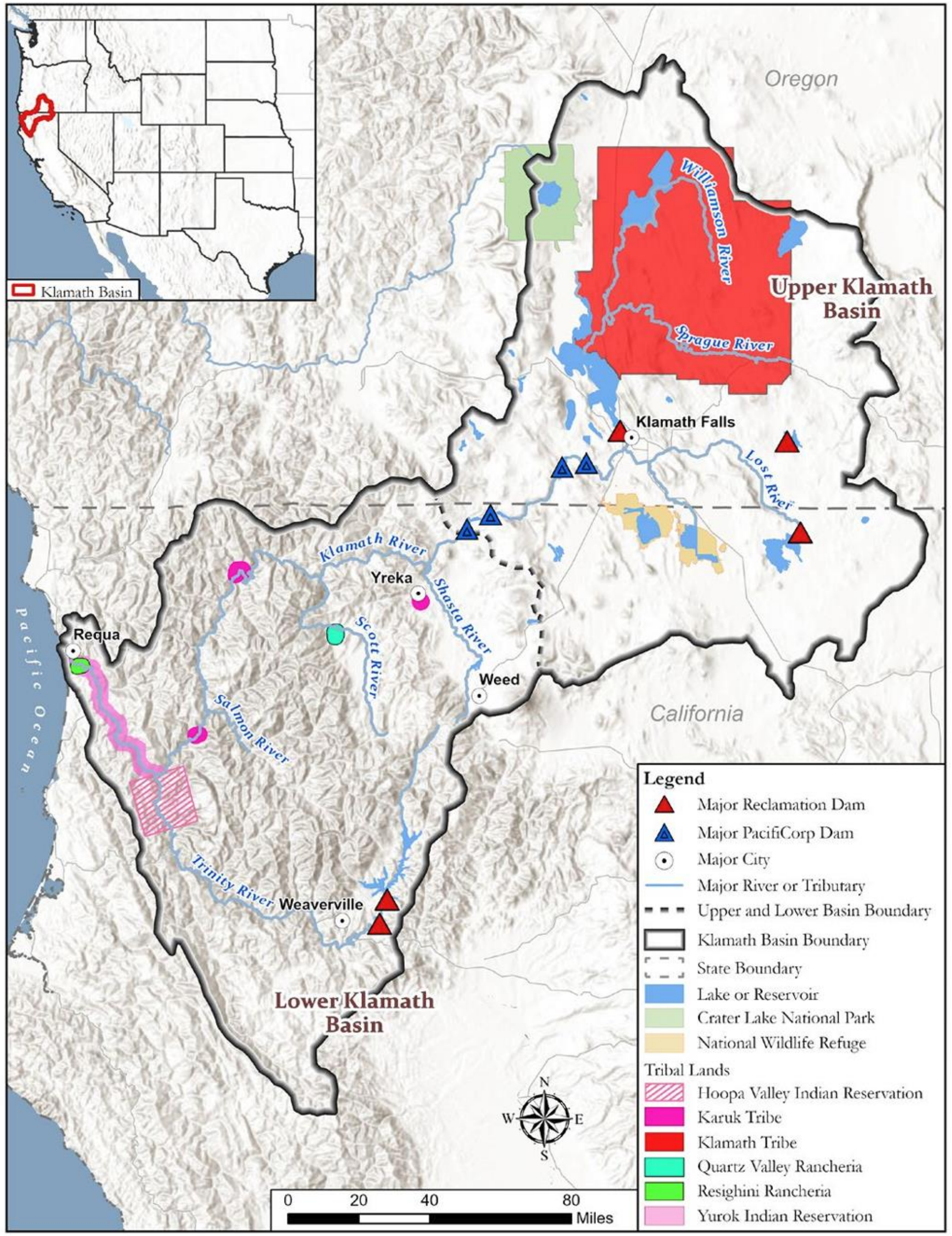


Even though the largest absolute bias occurred in winter, the largest relative bias occurred in the summer.

Case Study #1 – Klamath River Basin

Local hydrology summary

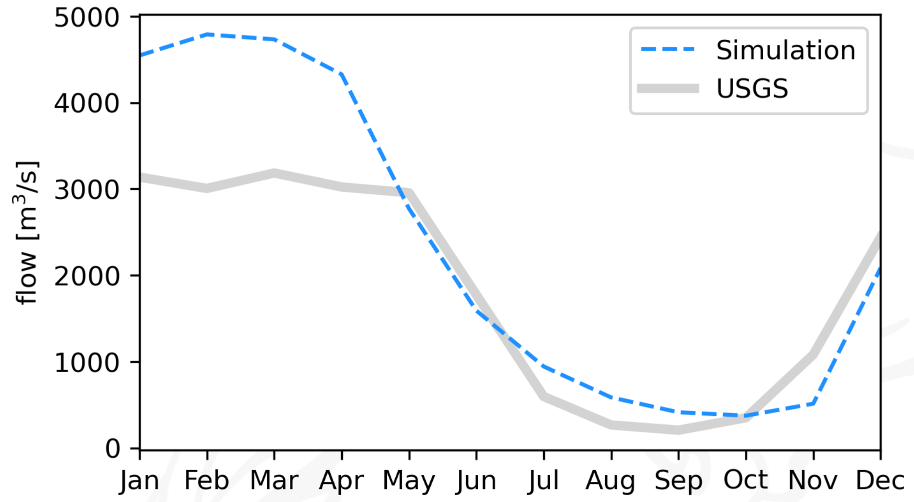
- Cold and wet winter, hot and dry summer
- Winter precipitation may accumulate temporarily as snowpack in the Klamath Mountains and the Cascade Range,

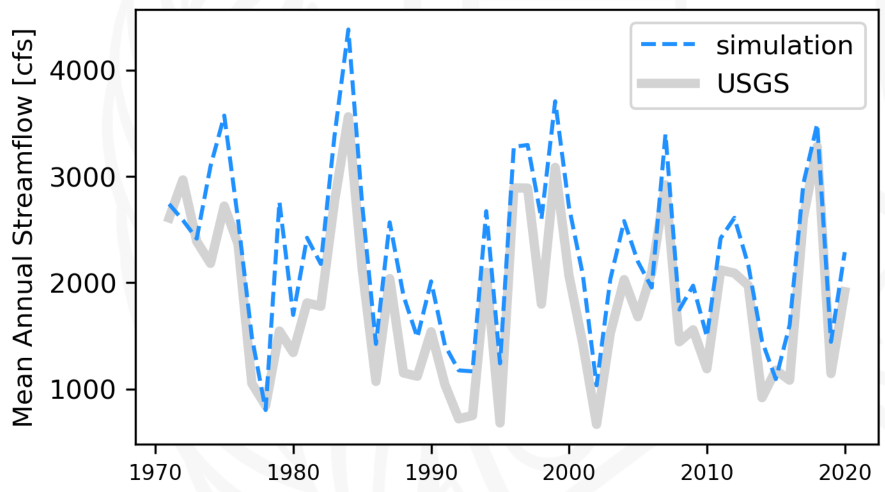


Case Study #1 – Klamath River Basin

Bias identification for Salmon River

- Consistent overestimation of mean annual streamflow
- Overestimation of winter streamflow
- Overestimation of summer streamflow





Case Study #1 – Klamath River Basin

Bias identification for Salmon River

- Consistent overestimation of mean annual streamflow

Precipitation bias

Parameters that partition runoff/ET

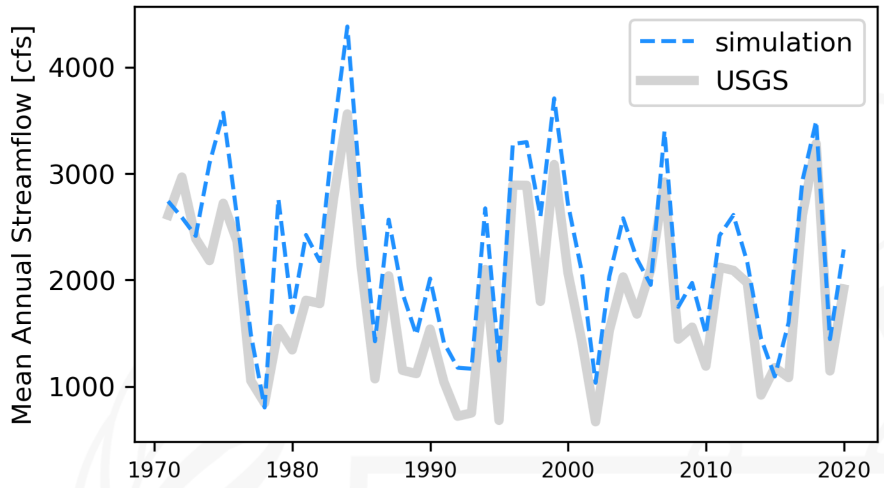
- Overestimation of winter streamflow

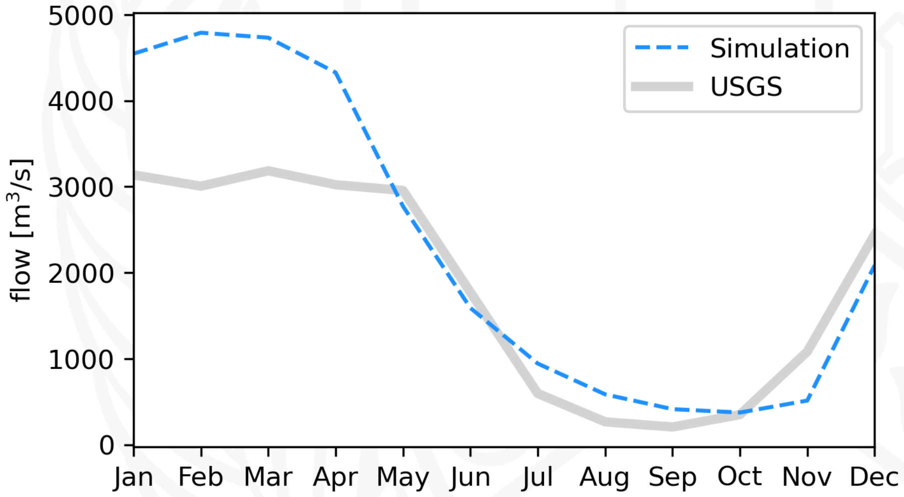
Precipitation did not stored in snow

Temperature bias (too hot)

- Overestimation of summer streamflow

Parameters related to ET and Baseflow





Procedures to analyze the bias in hydrologic modeling

- First, learn the hydrology in this region.
  - What type of climate is in this region (dry/humid, precipitation/temperature seasonality)?
  - Does this area snow?
- Second, identify the type of biases.
  - Consistently overestimation or only certain seasons have large biases.
  - Postulate certain hypotheses
- Third, conduct follow-up analyses to test your hypotheses

For example:

If consistently overestimating/underestimating streamflow, check whether there are biases in 1) model forcing data, such as too much/too little precipitation, and 2) parameters that affect the partition of runoff/evapotranspiration.

If the seasonality of streamflow is off during the spring/summer seasons, check whether there is snow and snow-related parameters.

If the flow in the low-flow season is consistently underestimated, check the baseflow parameters.

Questions?