Modeling the effects of climate change forecasts on streamflow in the Nooksack River basin

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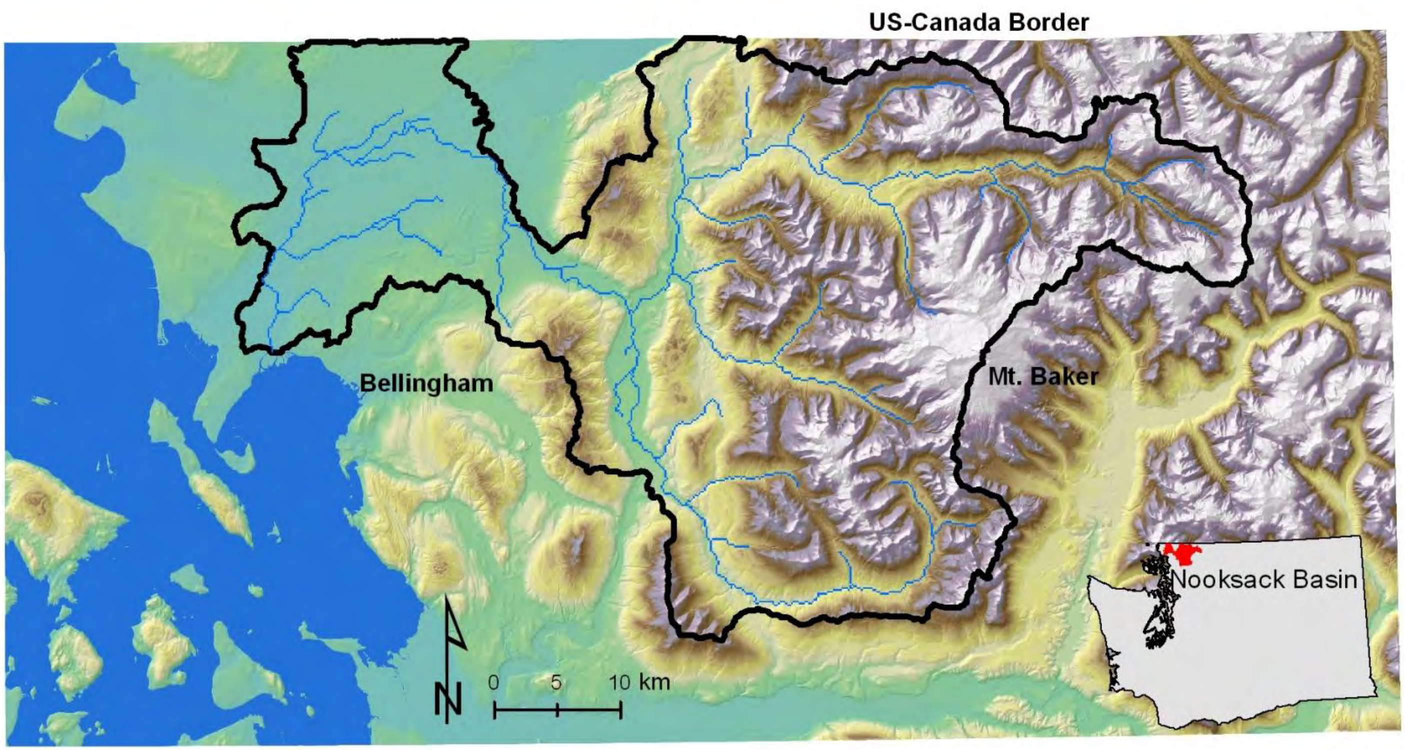
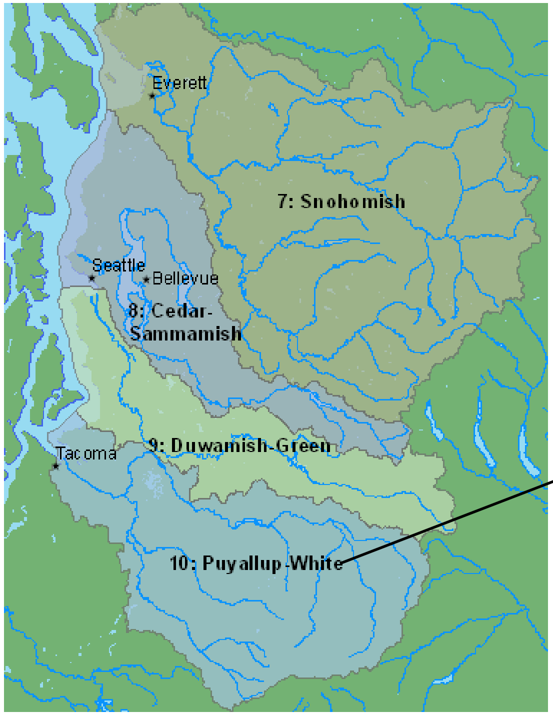
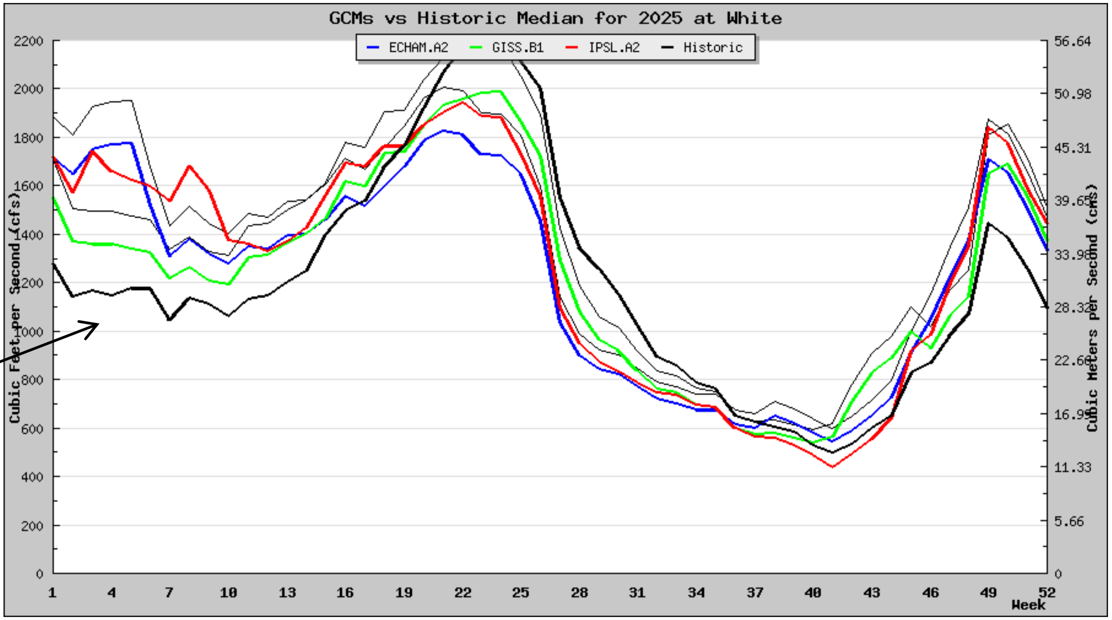
WESTERN WASHINGTON UNIVERSITY



Research Objective

To predict the timing and magnitude of streamflow in the Nooksack River basin under changing climate conditions

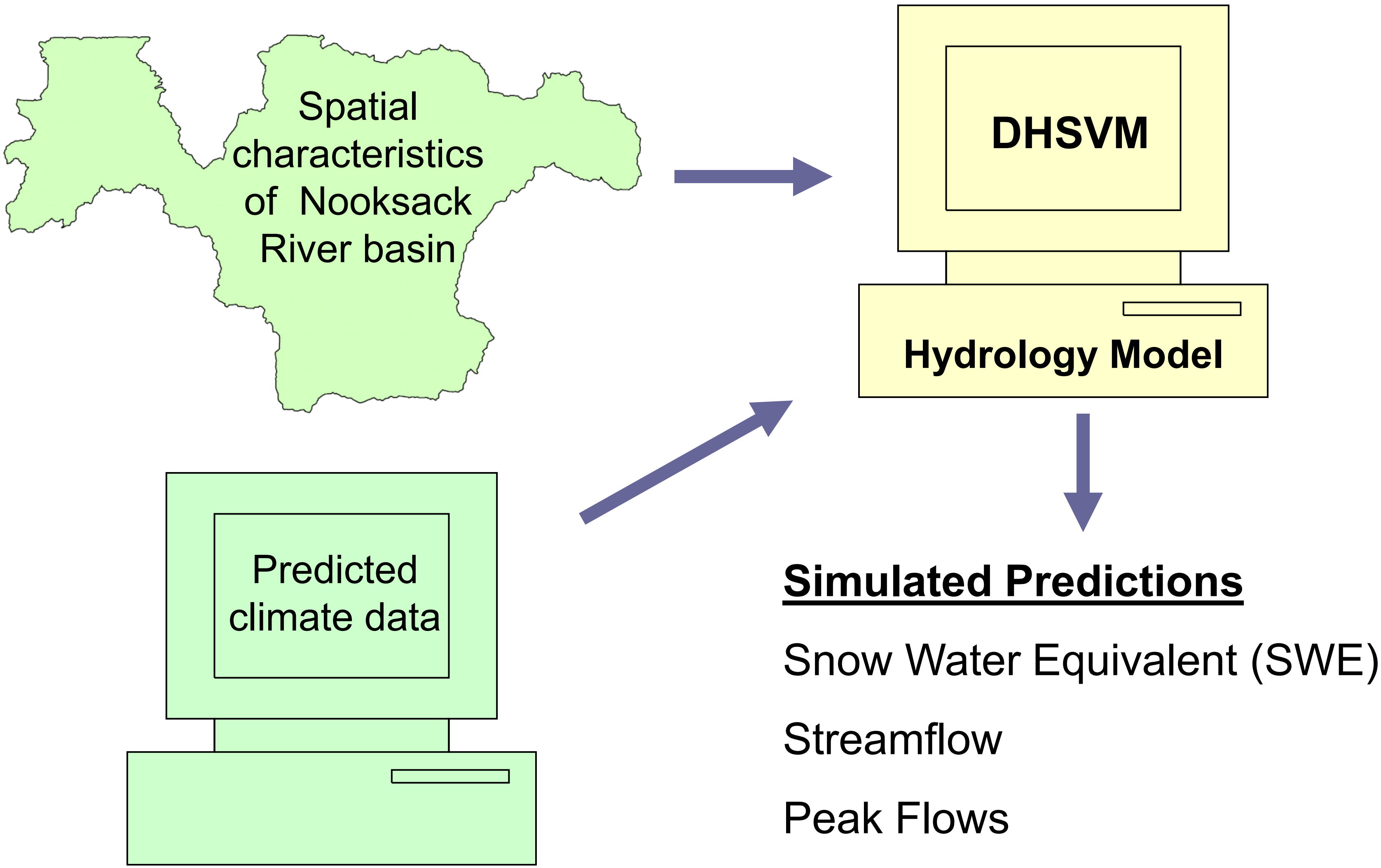




White River flow predictions (Palmer R.N., et al., 2007).

Climate Change Technical Committee - Regional Water Supply Planning Process

Nooksack Basin Approach



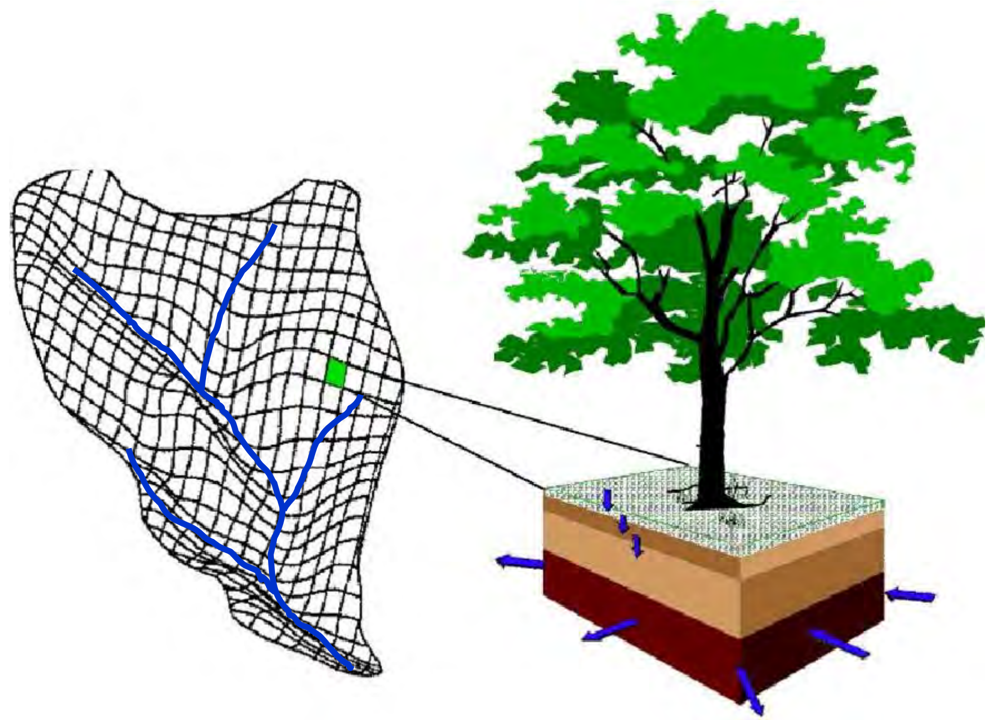
Methods

1. **Hydrologic Model Set-up, Calibration, & Validation**

2. Downscaling & Forecast Processing

3. Hydrologic Modeling

Distributed Hydrology Soil Vegetation Model (DHSVM)

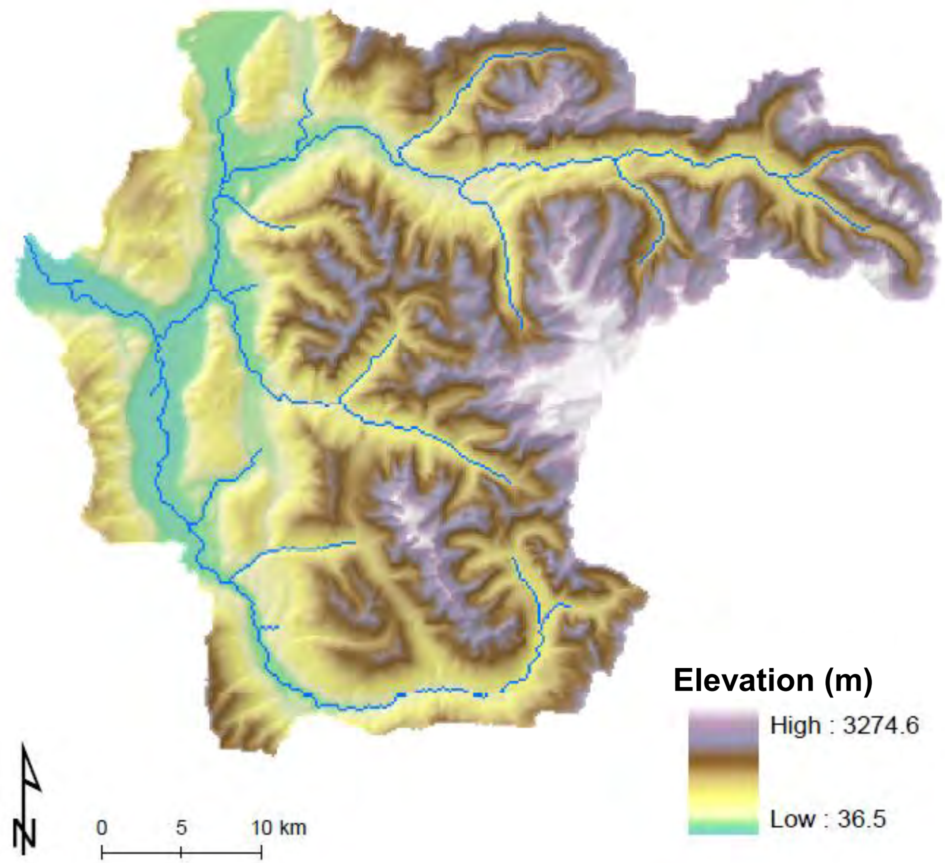


Spatially distributed, physically based model that calculates a water and energy budget at the grid cell scale for each time step (Wigmosta et al., 1994)

DHSVM Inputs

Spatial Inputs

- DEM
- Watershed Boundary
- Stream Network
- Soil Type
- Soil Thickness
- Landcover



DHSVM Inputs

Meteorological Inputs

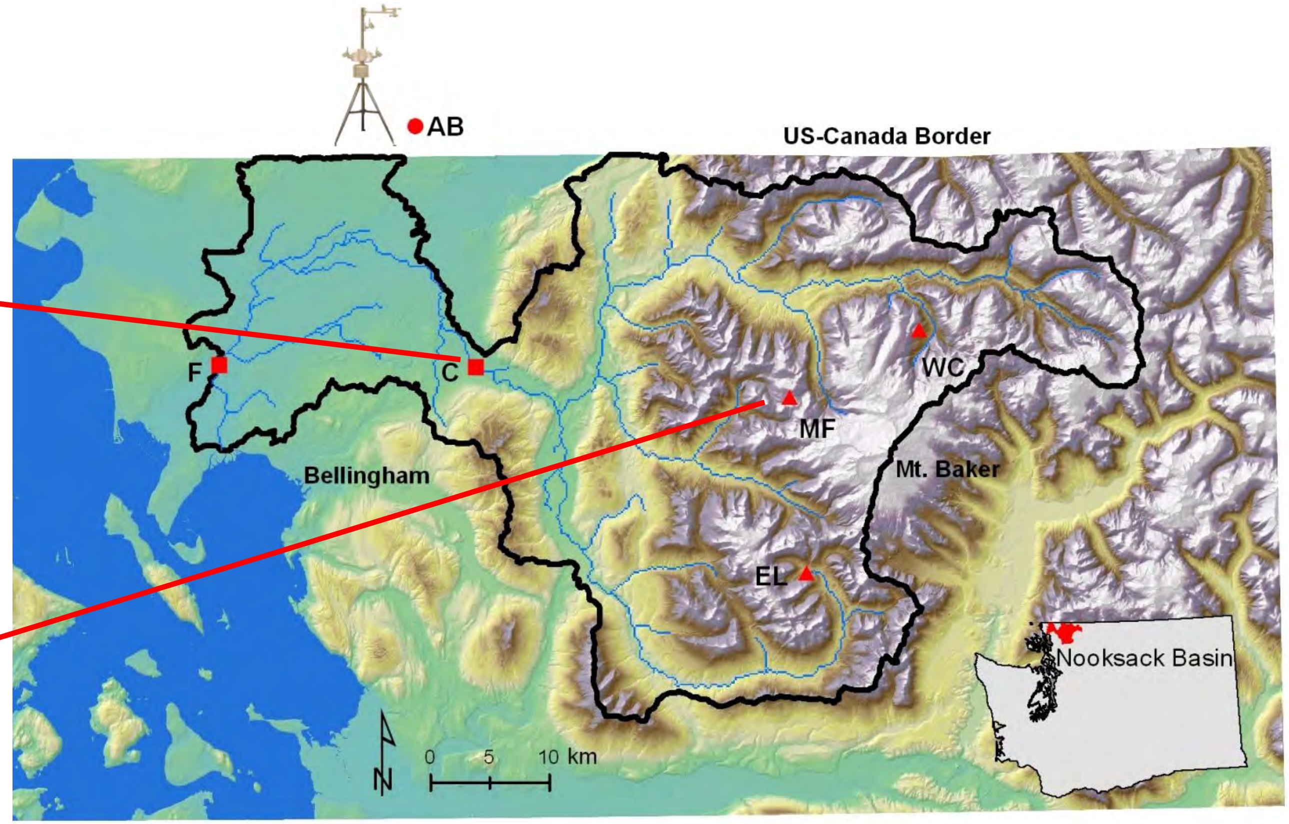
- Temperature
- Precipitation
- Wind Speed
- Relative Humidity
- Shortwave Radiation
- Longwave Radiation

Abbotsford Airport, British Columbia, CA

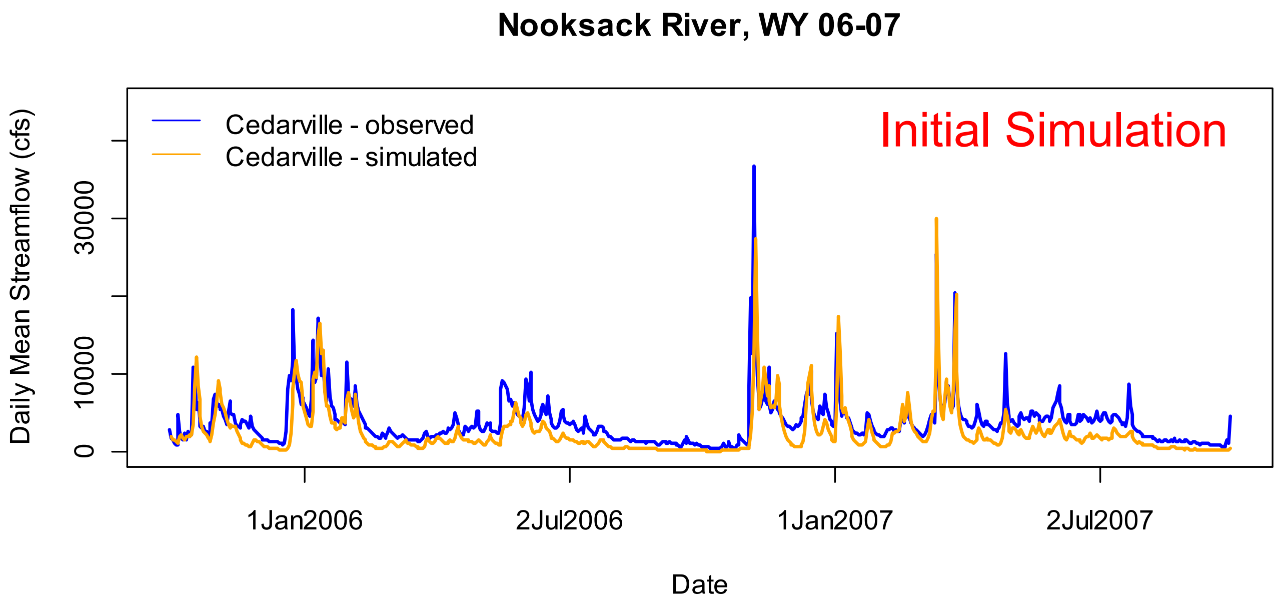
DHSVM Calibration – adjust model parameters until simulated values match observed measured values

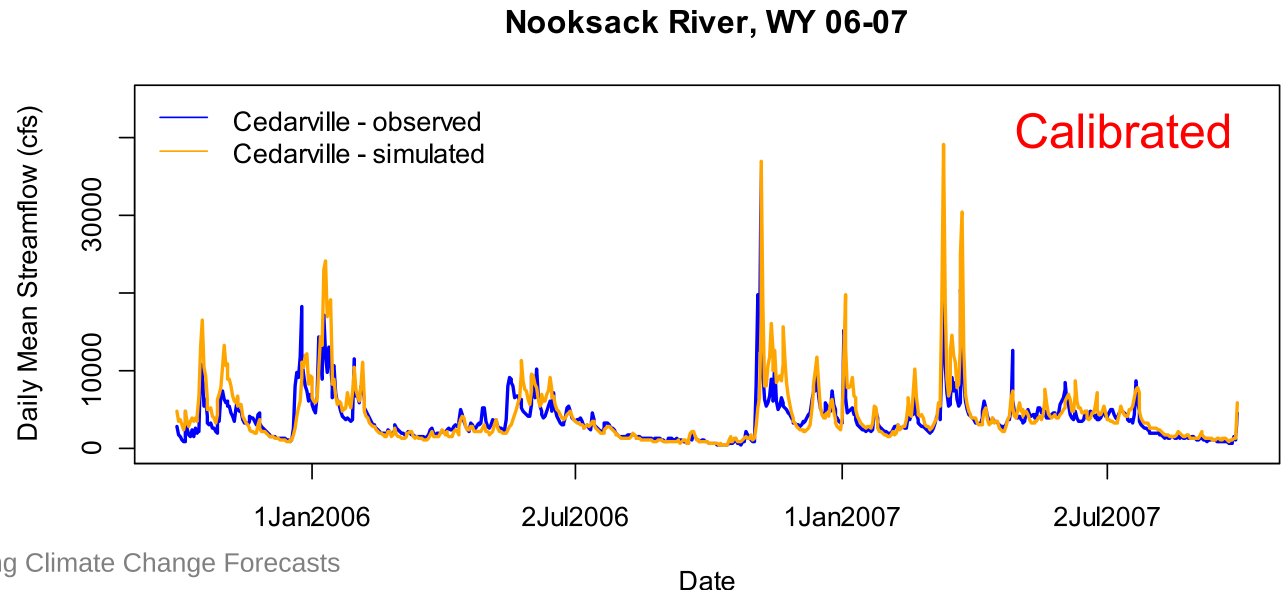
USGS stream gauge at Cerdarville

NRCS SNOTEL – Middle Fork



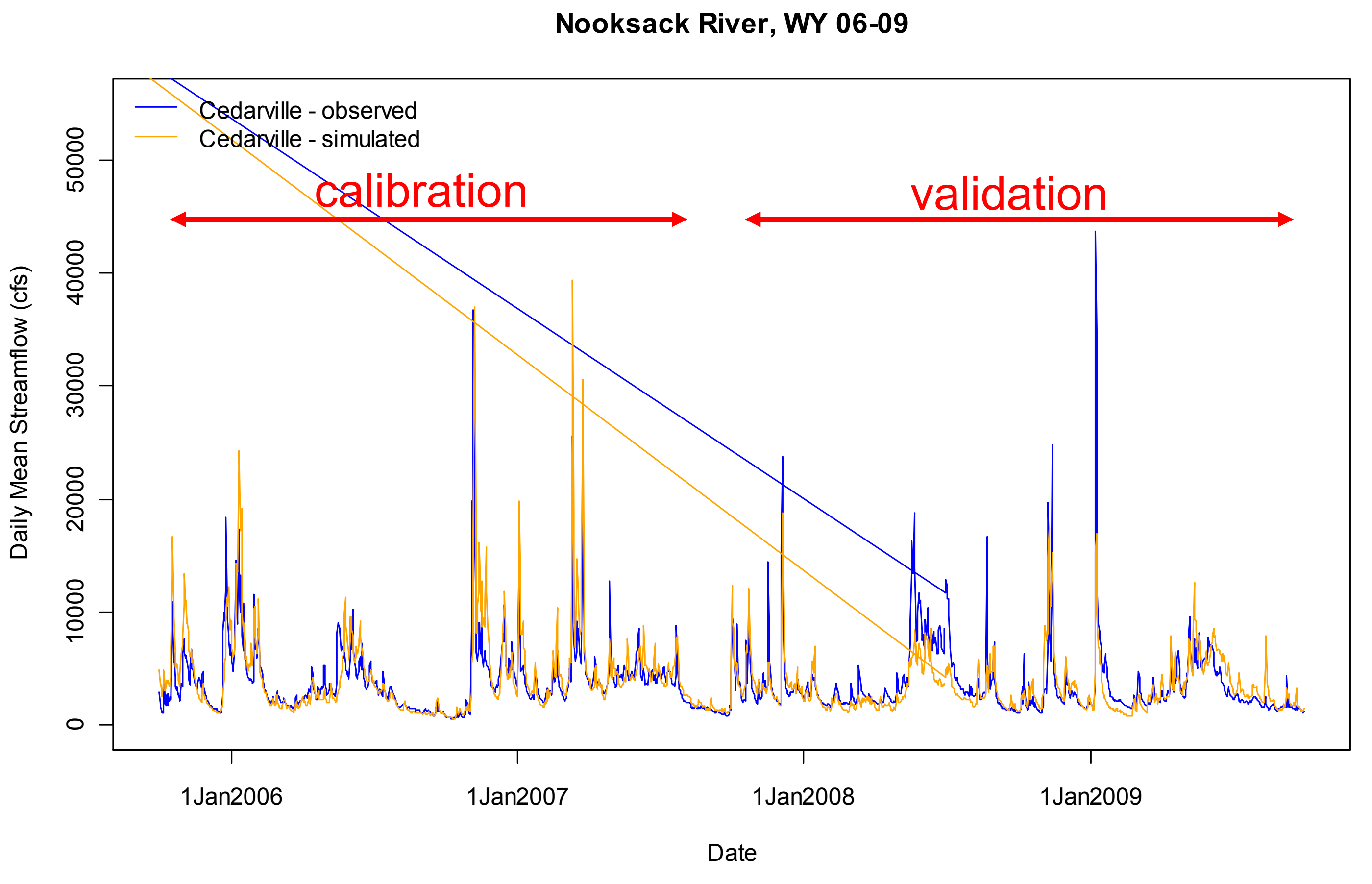
DHSVM Streamflow Calibration



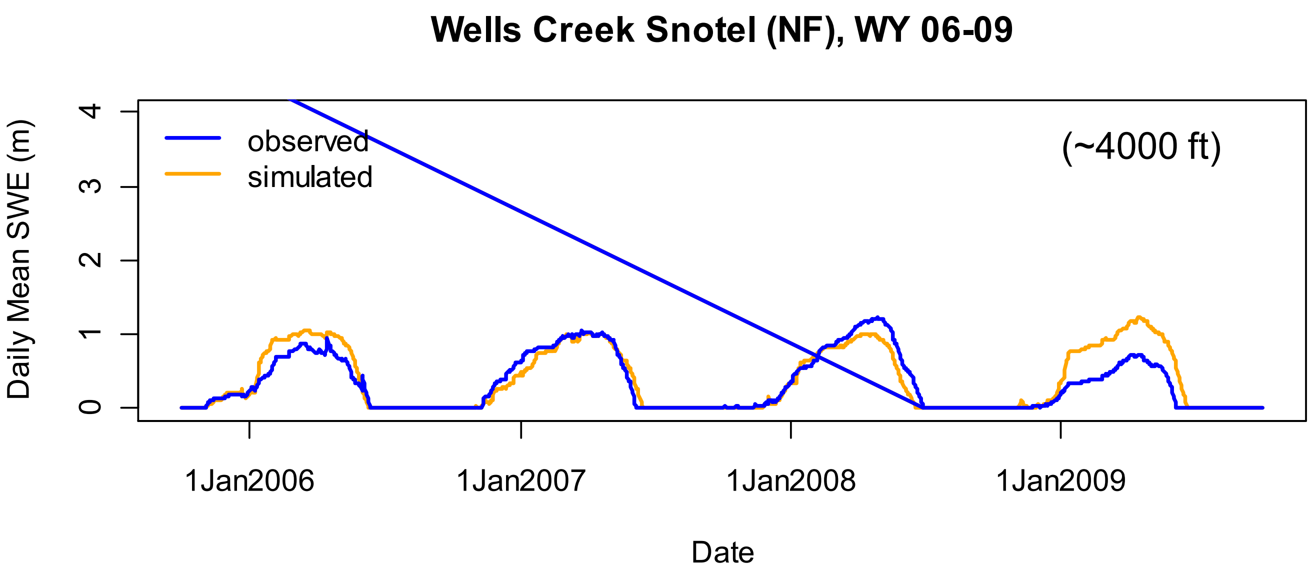


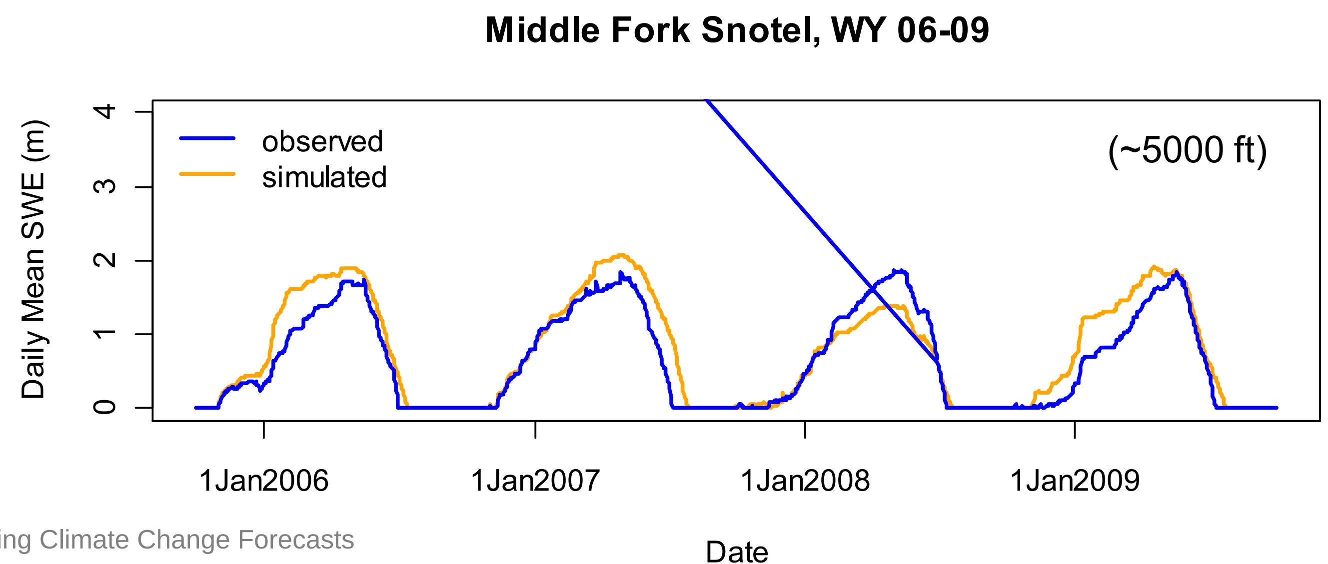
DHSVM Streamflow Validation

Validation – comparison of simulated data with observed data for a time period not included in the calibration



DHSVM SWE Calibration & Validation





Methods

1. Hydrologic Model Set-up, Calibration, & Validation

2. Downscaling & Forecast Data Processing

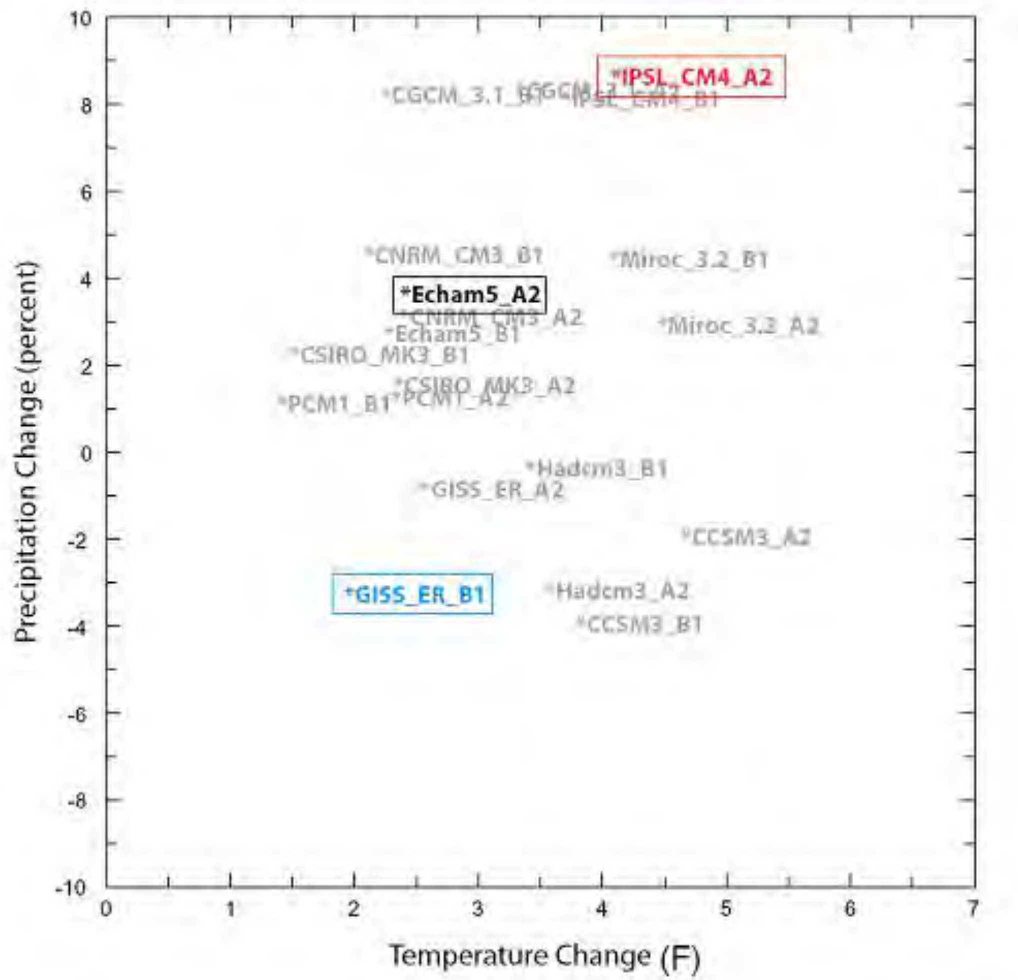
3. Hydrologic Modeling

General Circulation Models (GCMs)

1. IPSL_CM4_A2
Institut Pierre Simon Laplace (with A2)

2. Echam5_A2
Max Planck Institute for Meteorology (with A2)

3. GISS_ER_B1
Goddard Institute for Space Studies (with B1)

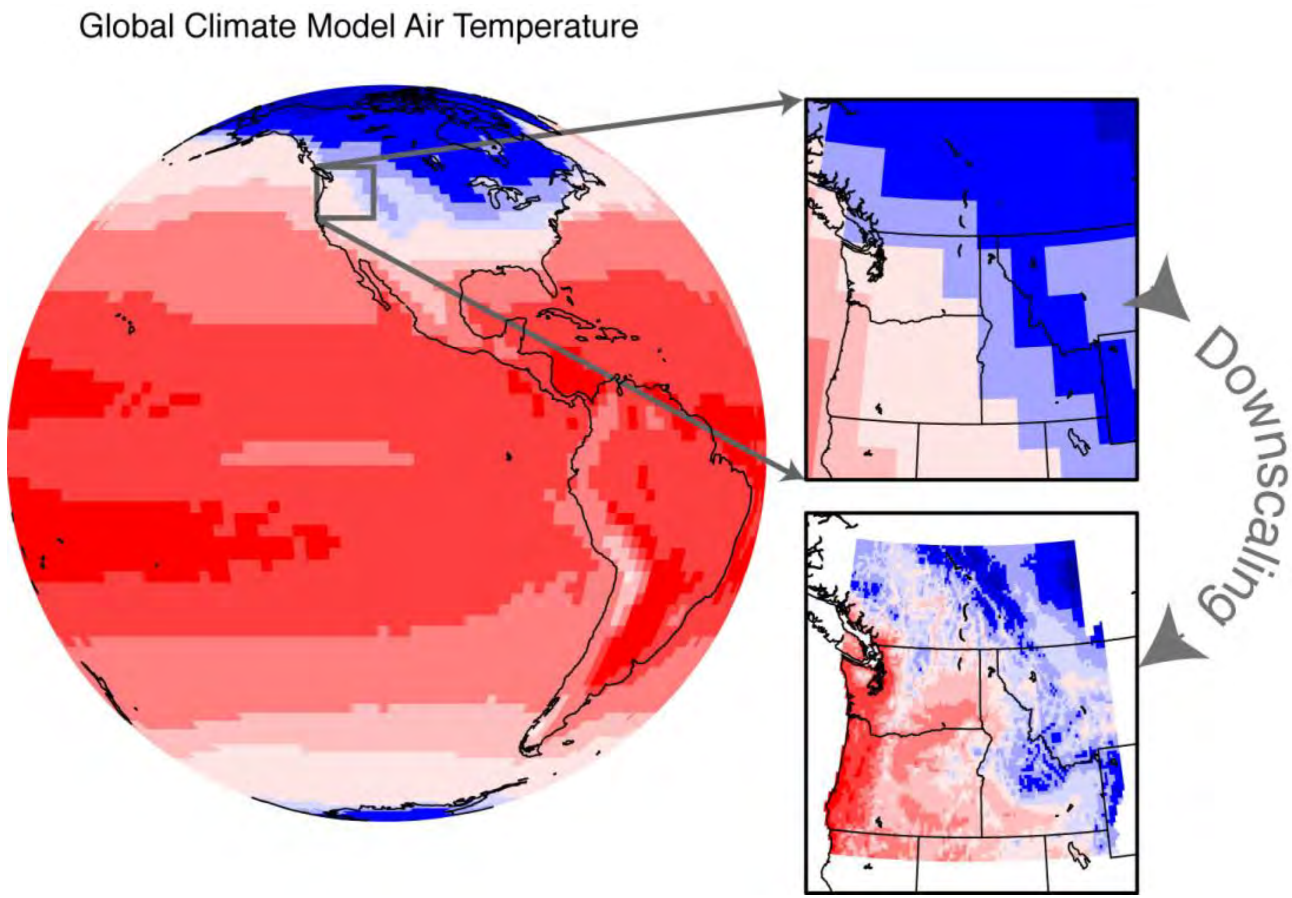


2040s Changes in Temperature and Precipitation

Mote and others, 2005

GCM Downscaling

GCM scale of 100s km → regional scale of 10s km → local station

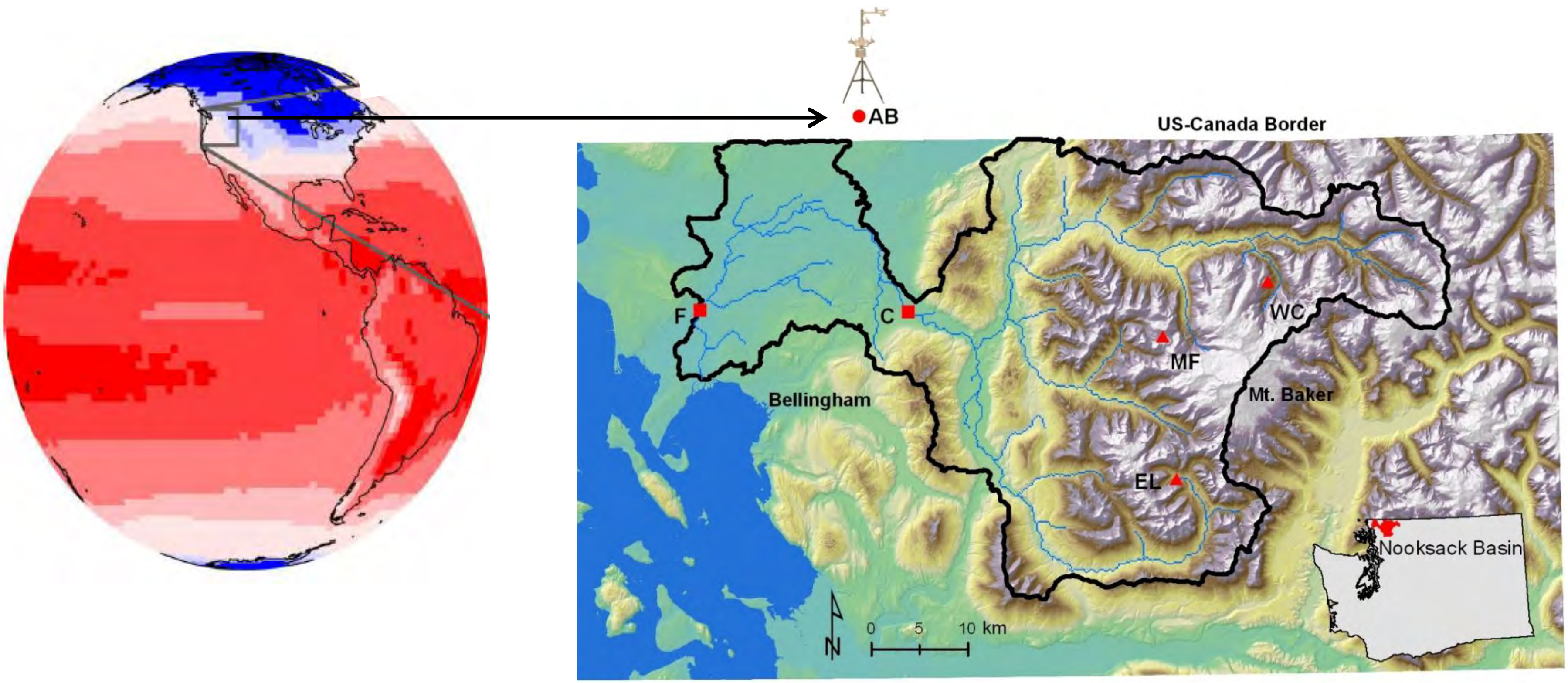


CIG, 2010

GCM Downscaling

Downscaling Technique:

Polebitski, A., M.W. Wiley, and R.N. Palmer, 2007. Technical Memorandum #2: Methodology for Downscaling Meteorological Data for Evaluating Climate Change.

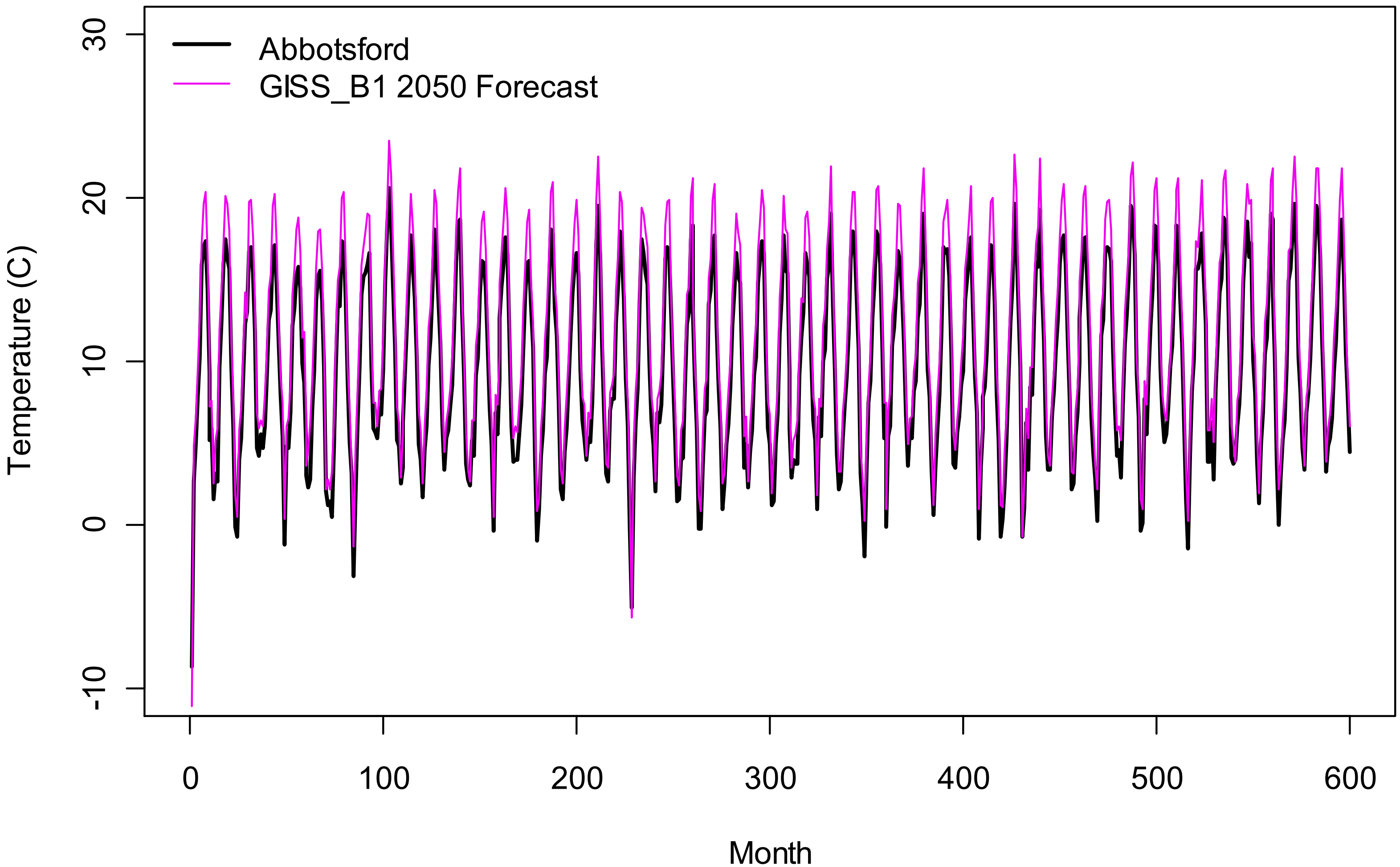


The technique is similar the hybrid approach (Hamlet et al., 2010, Statistical downscaling techniques for global climate model simulations of temperature and precipitation with application to water resources planning studies)

GCM Downscaling

Each forecast incorporates local variability

Monthly Mean Temperature, 1950-1999



GCM Downscaling

GMC Forecasts $\xrightarrow{\text{downscaled}}$ Nooksack Basin Forecasts

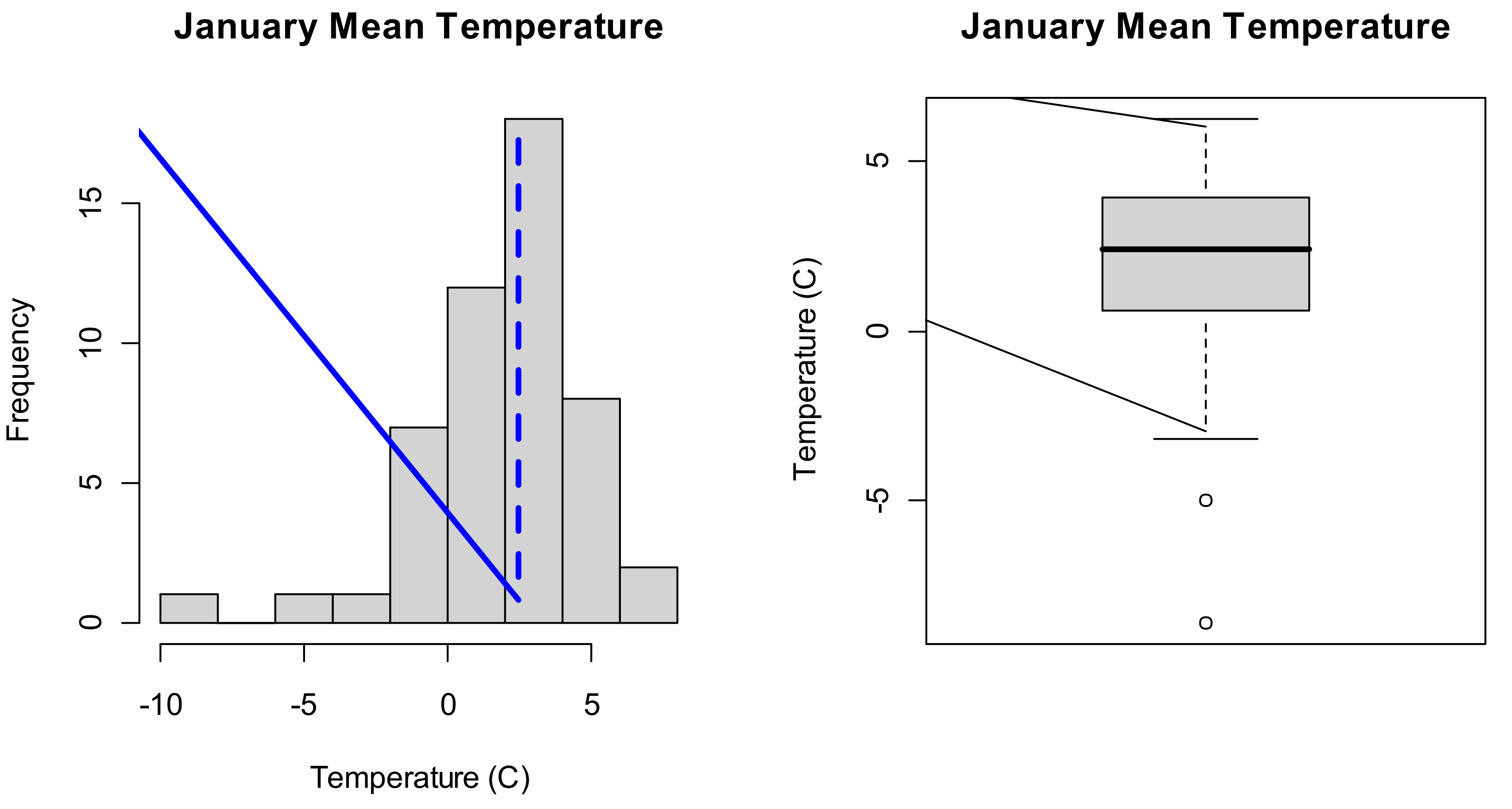
GISS_B1 → 2000, 2025,2050,2075

IPSL_A2 → 2000, 2025,2050,2075

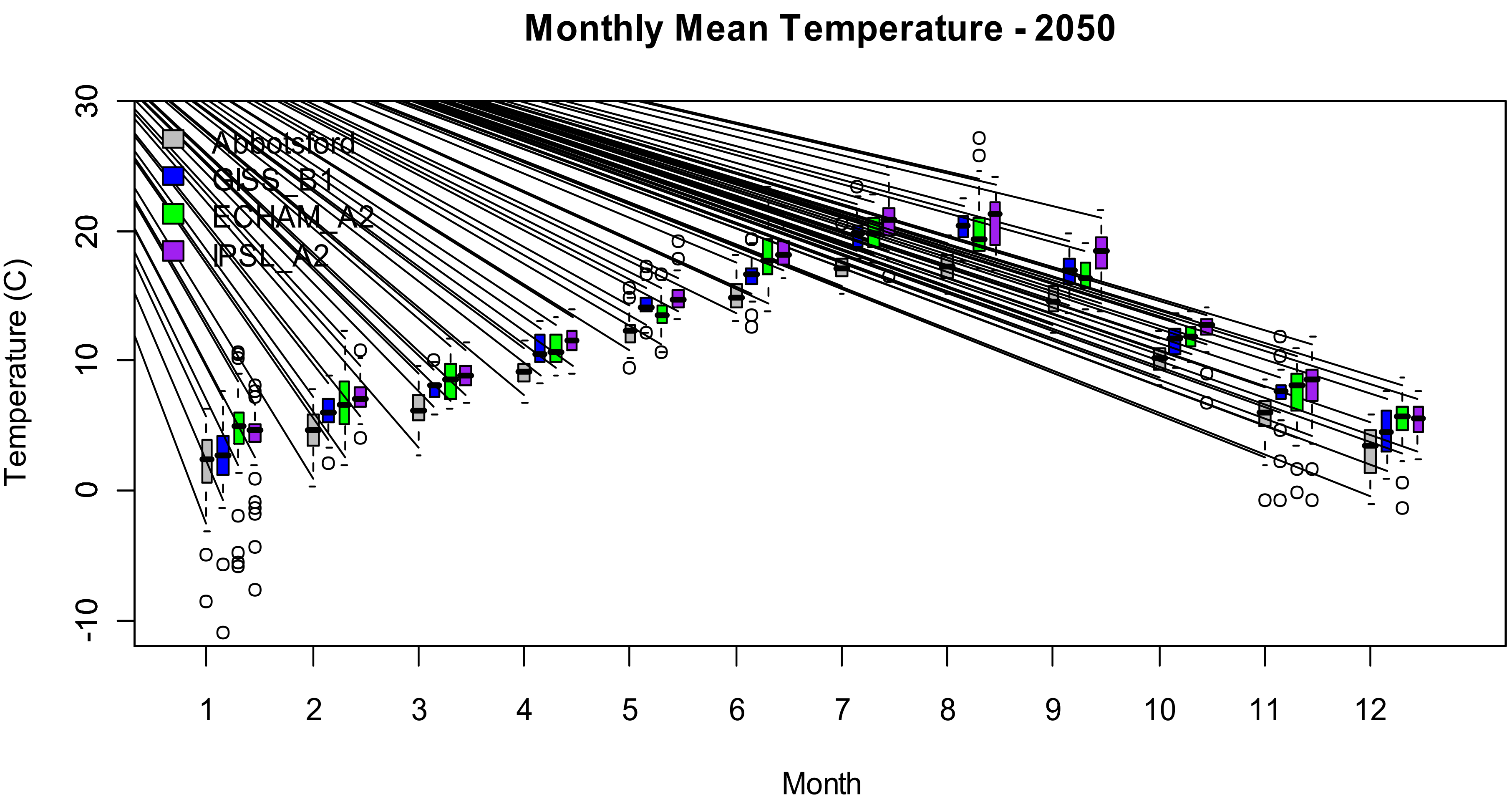
ECHAM_A2 → 2000, 2025,2050,2075

Downscaling Technique:

Polebitski, A., M.W. Wiley, and R.N. Palmer. 2007. Technical Memorandum #2: Methodology for Downscaling Meteorological Data for Evaluating Climate Change.

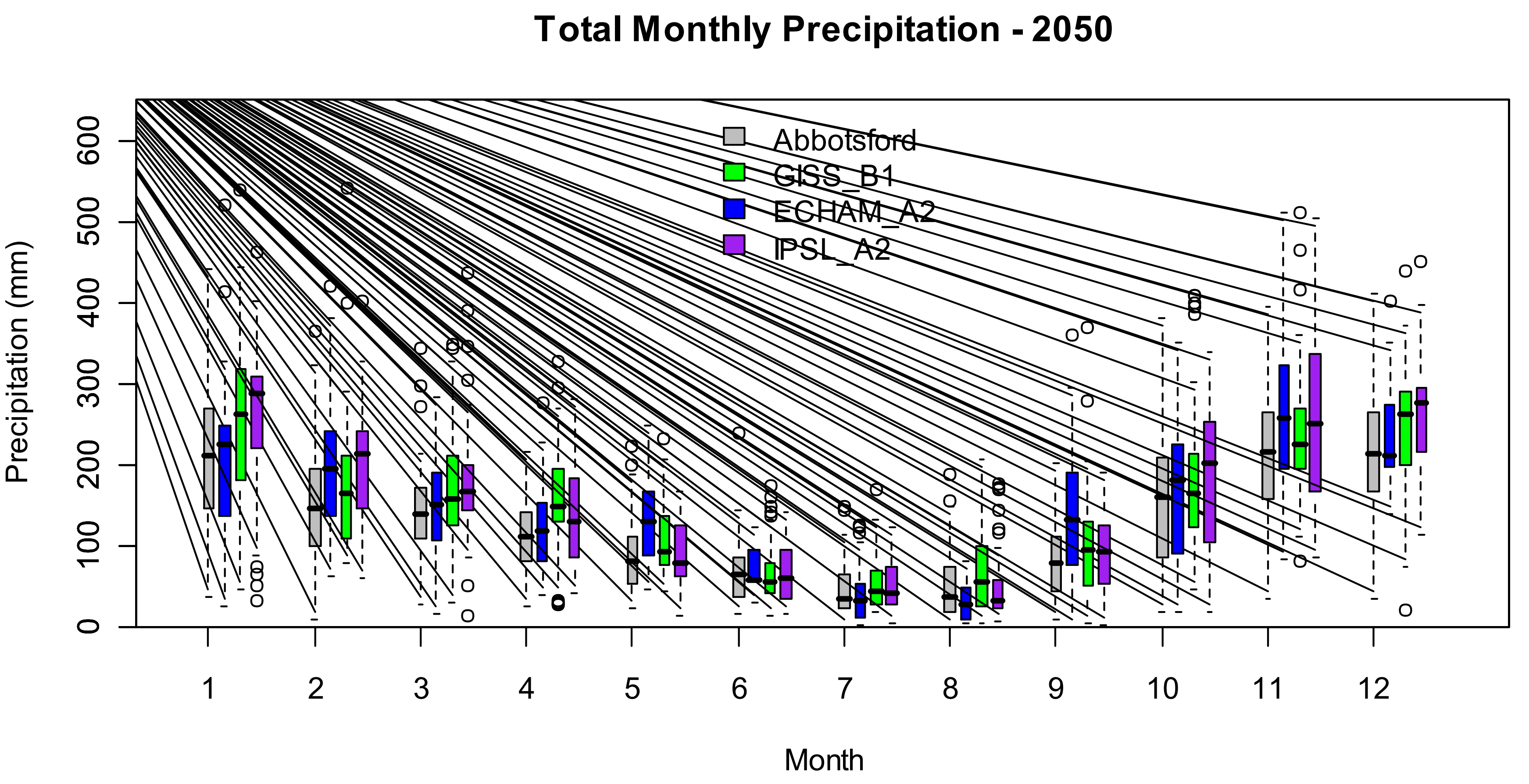

January Mean Temperature
Frequency
0
5
10
15
-10
-5
0
5
Temperature (C)
January Mean Temperature
Temperature (C)
-5
0
5

Downscaled Local Forecasts



Monthly Mean Temperature - 2075

Downscaled Local Forecasts



Total Monthly Precipitation - 2075

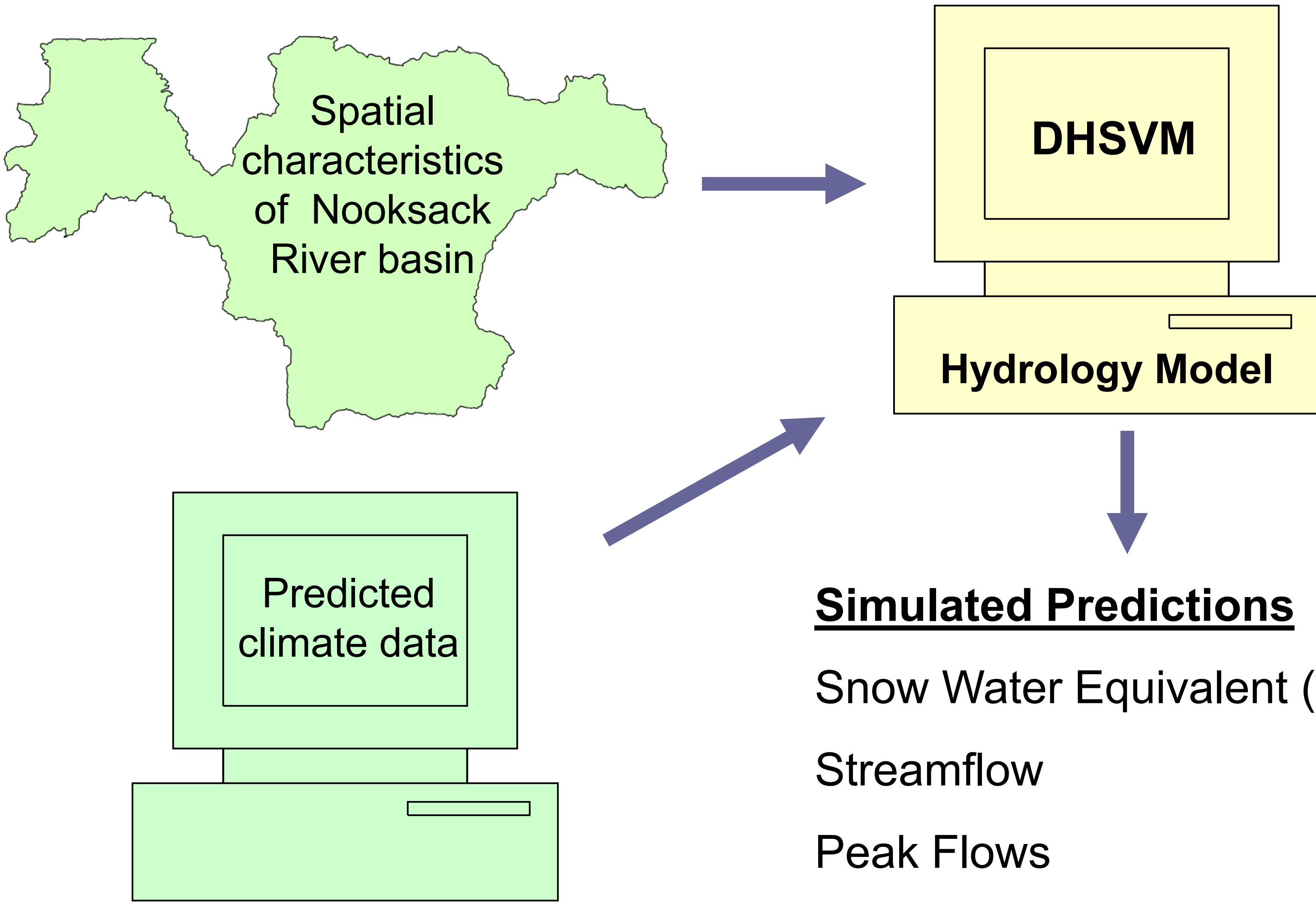
Methods

1. Hydrologic Model Set-up, Calibration, & Validation

2. Downscaling & Forecast Processing

3. **Hydrologic Modeling**

Nooksack Basin Approach



<u>Simulated Predictions</u>

Snow Water Equivalent (SWE)

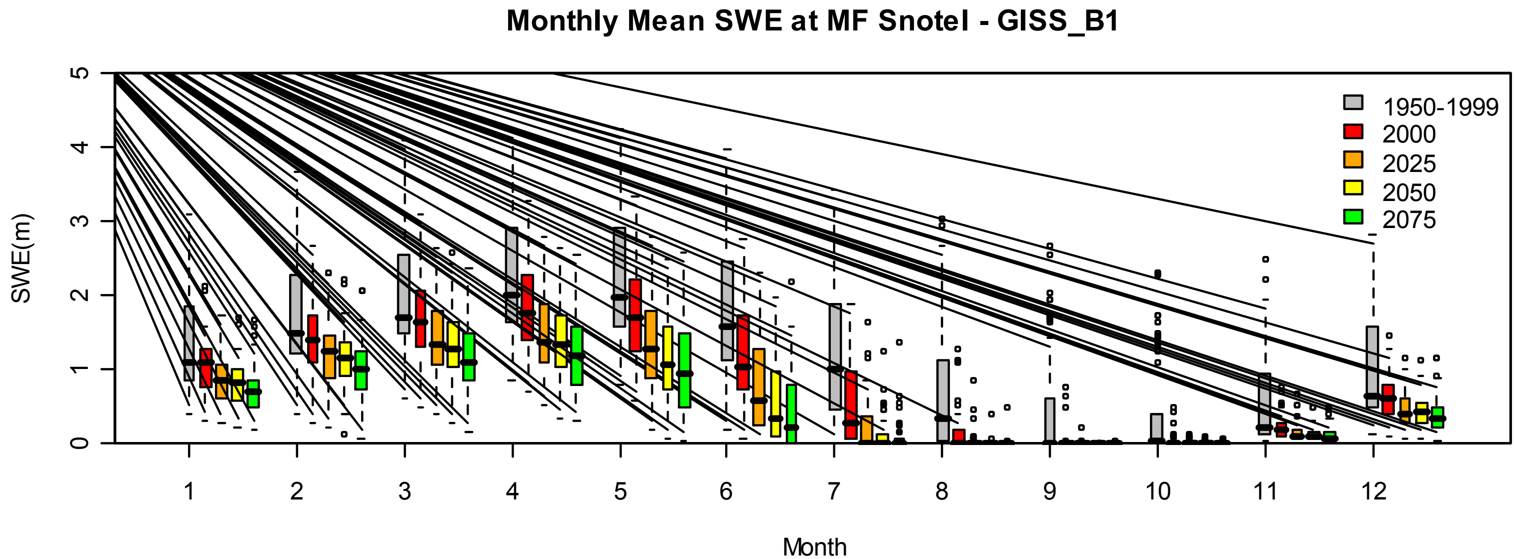
Streamflow

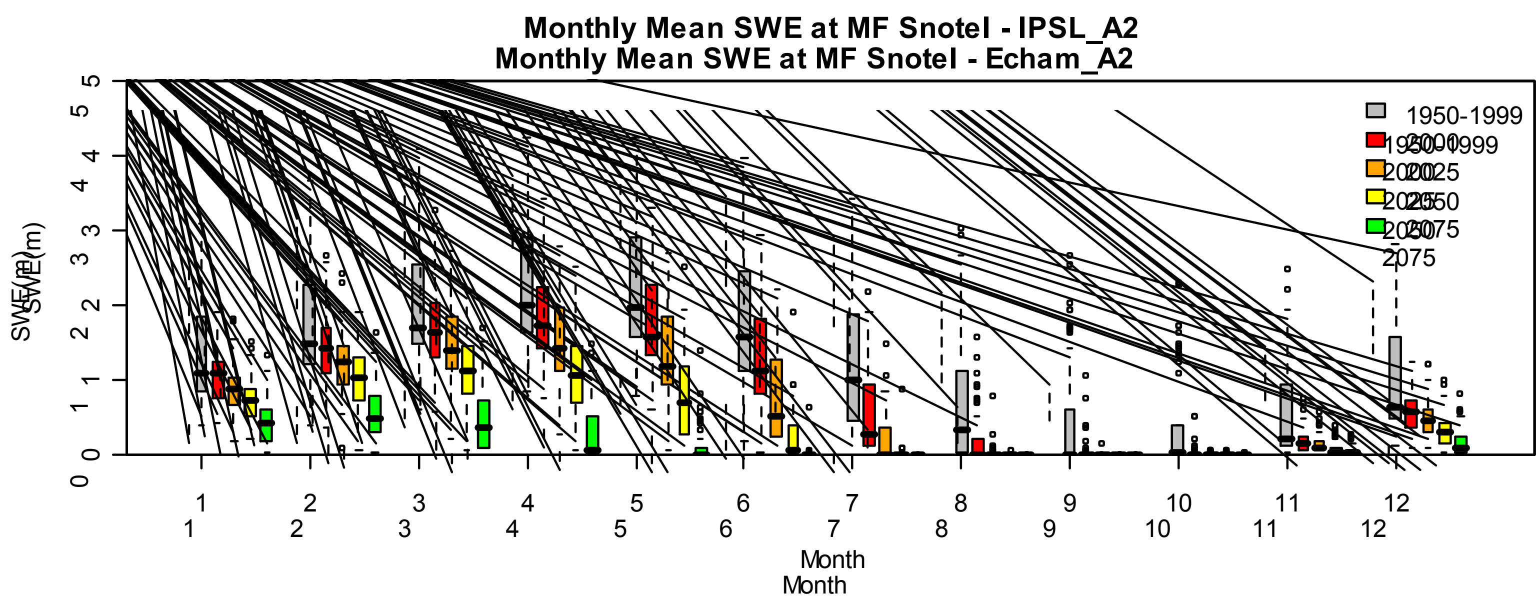
Peak Flows

1 2 3 4 5 6 7 8 9 10 11 12

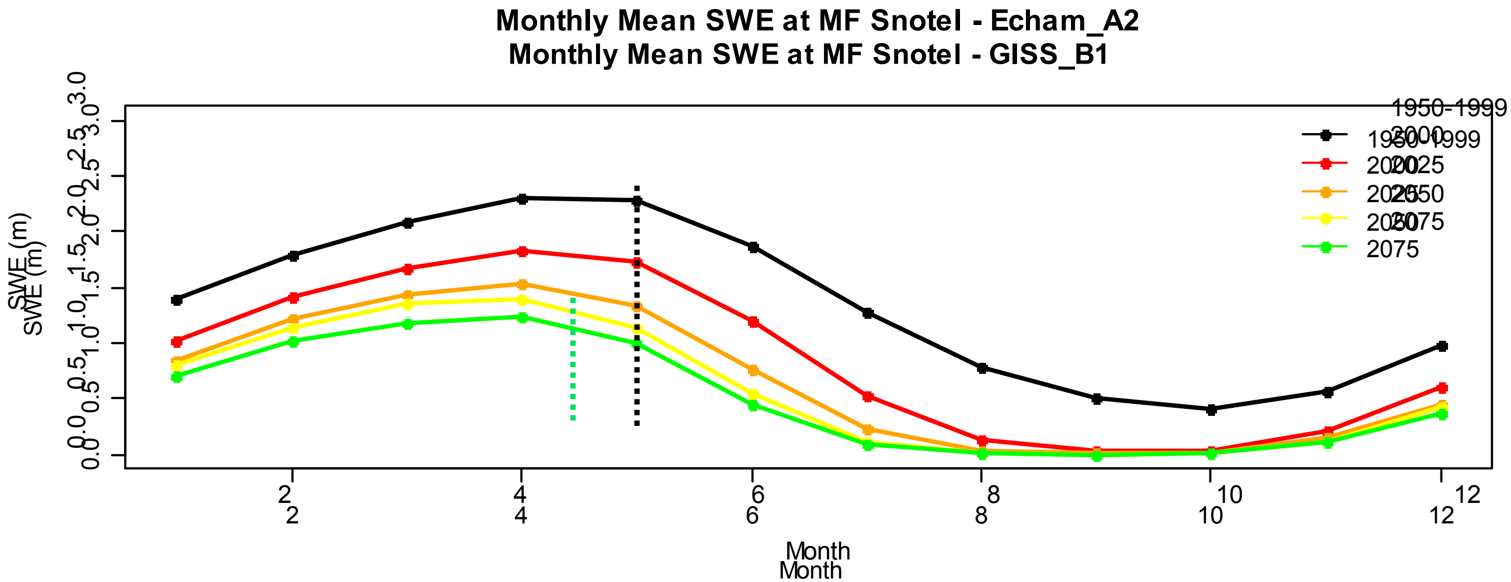
Month

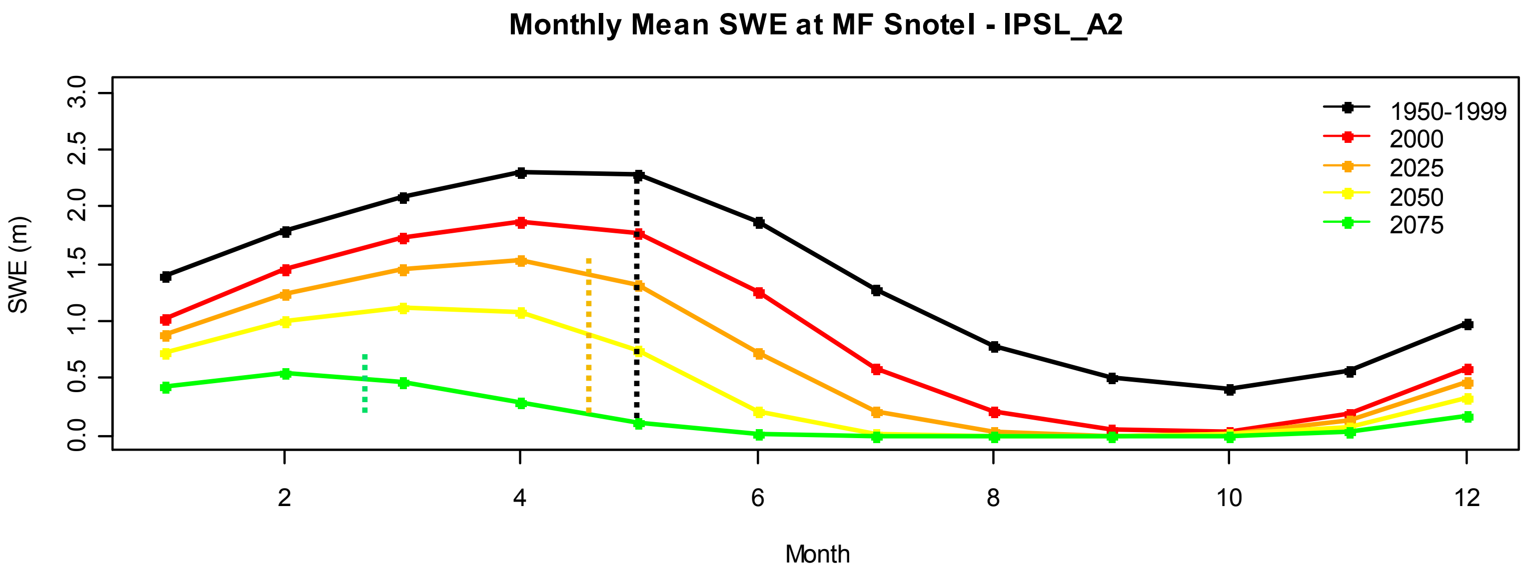
Results: Snow Water Equivalent



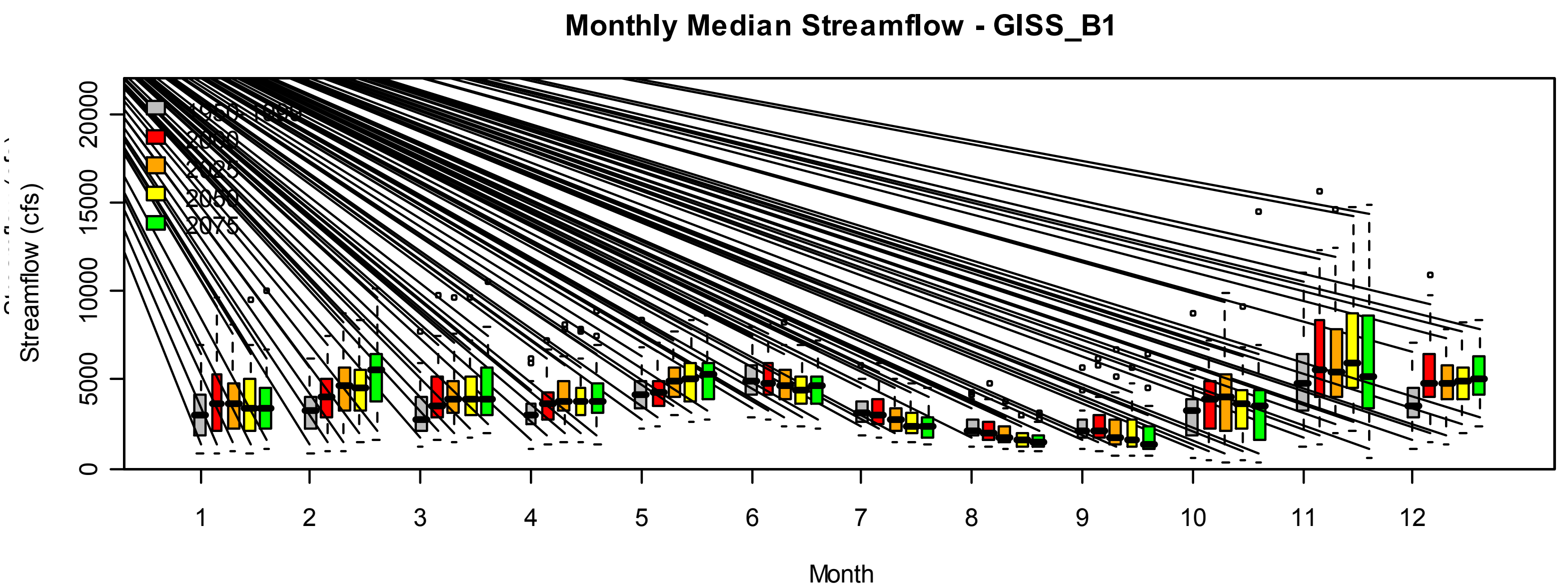


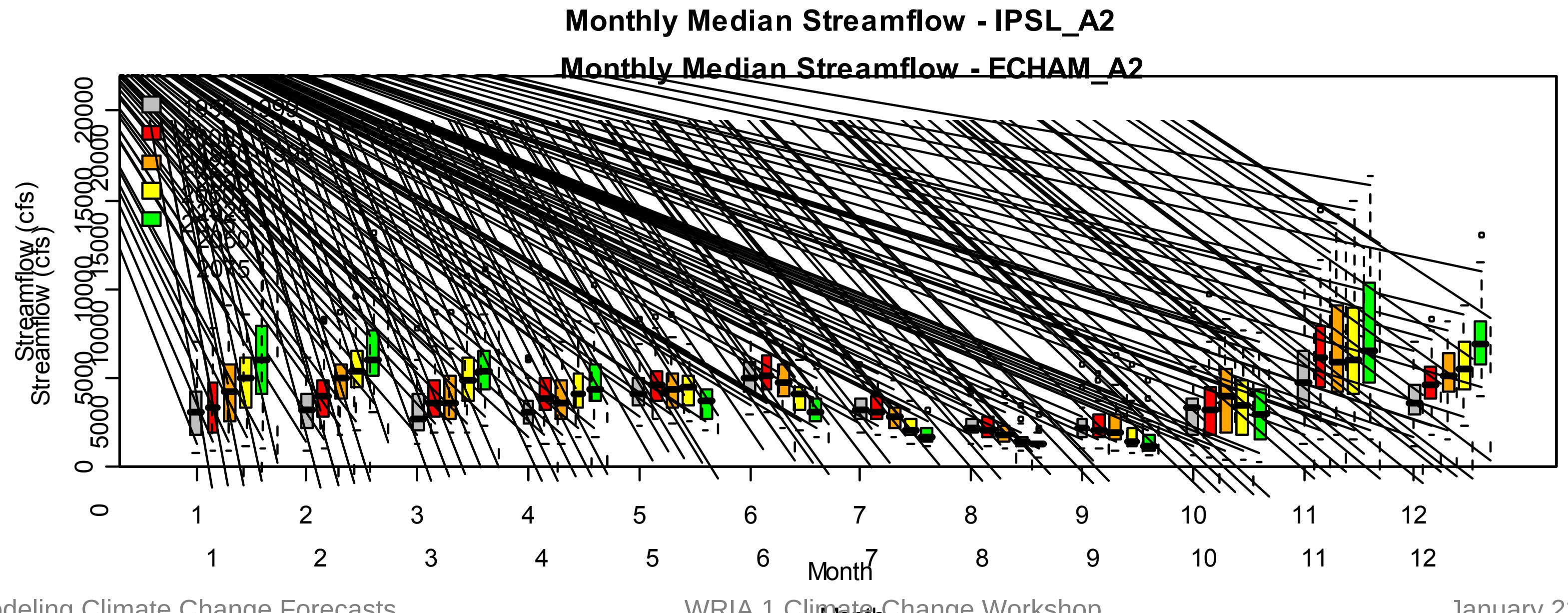
Results: Snow Water Equivalent



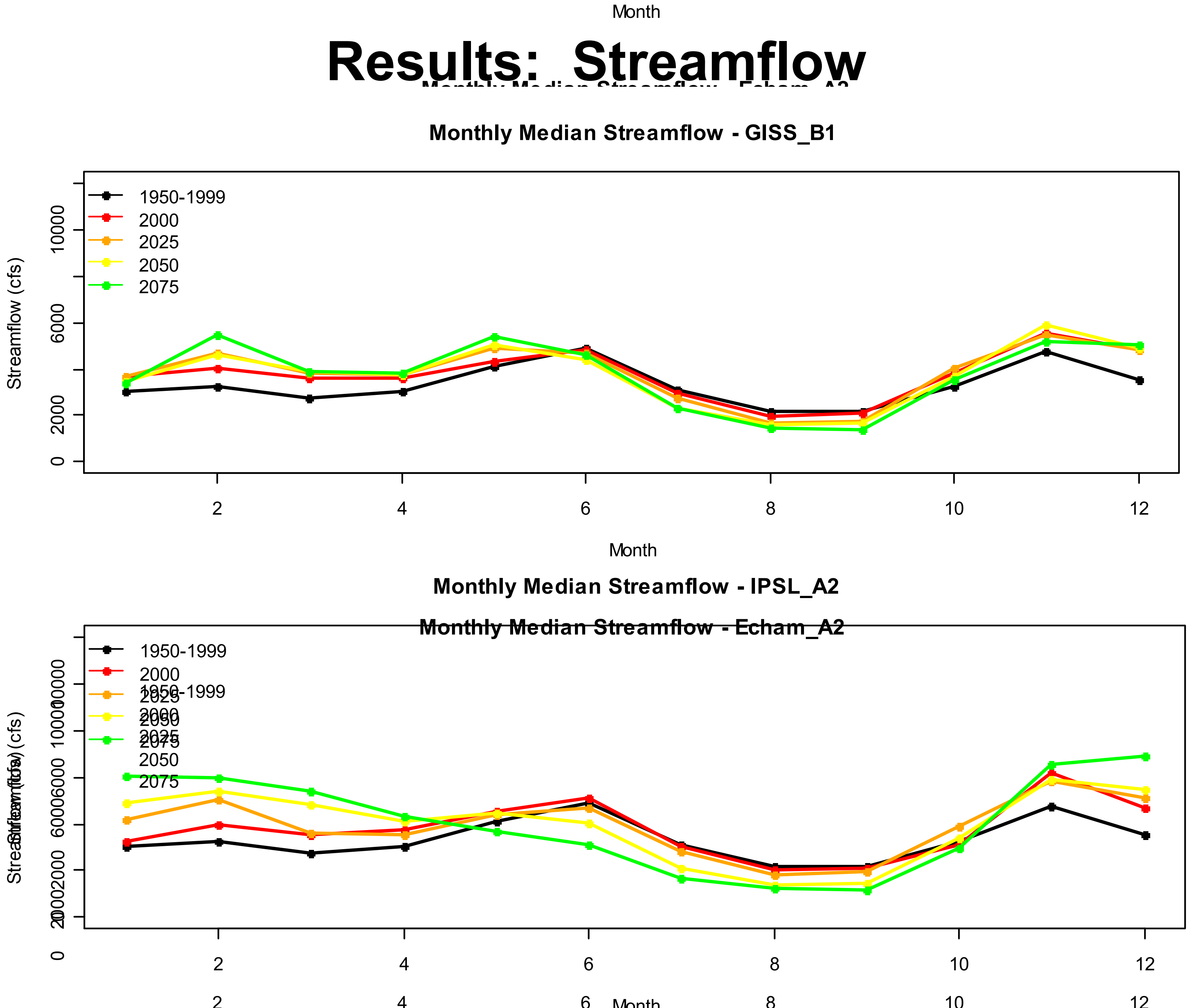


Results: Streamflow





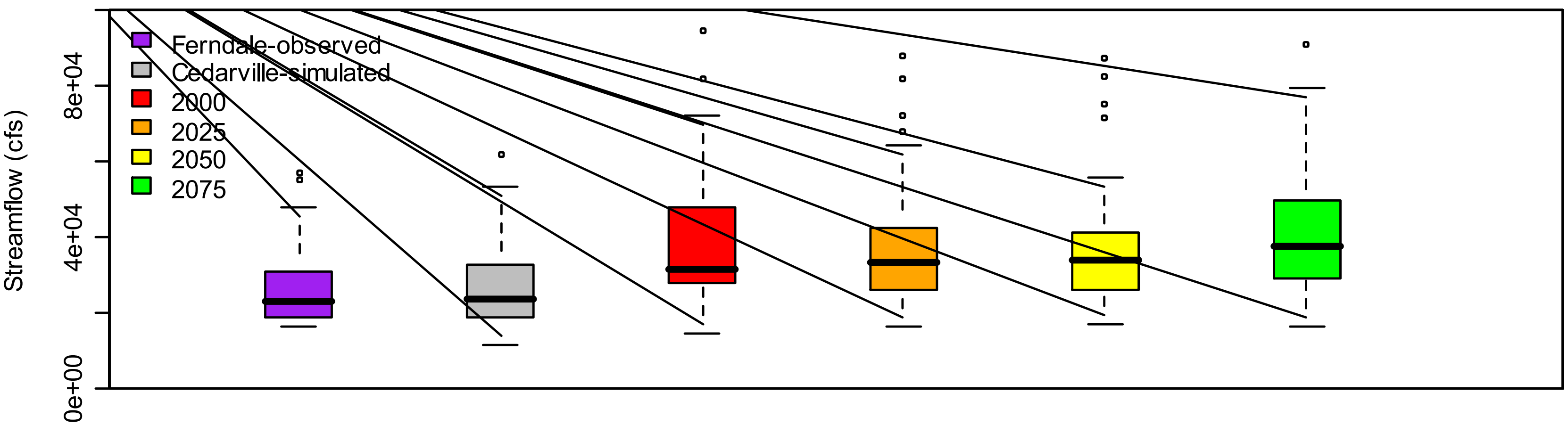
Results: Streamflow



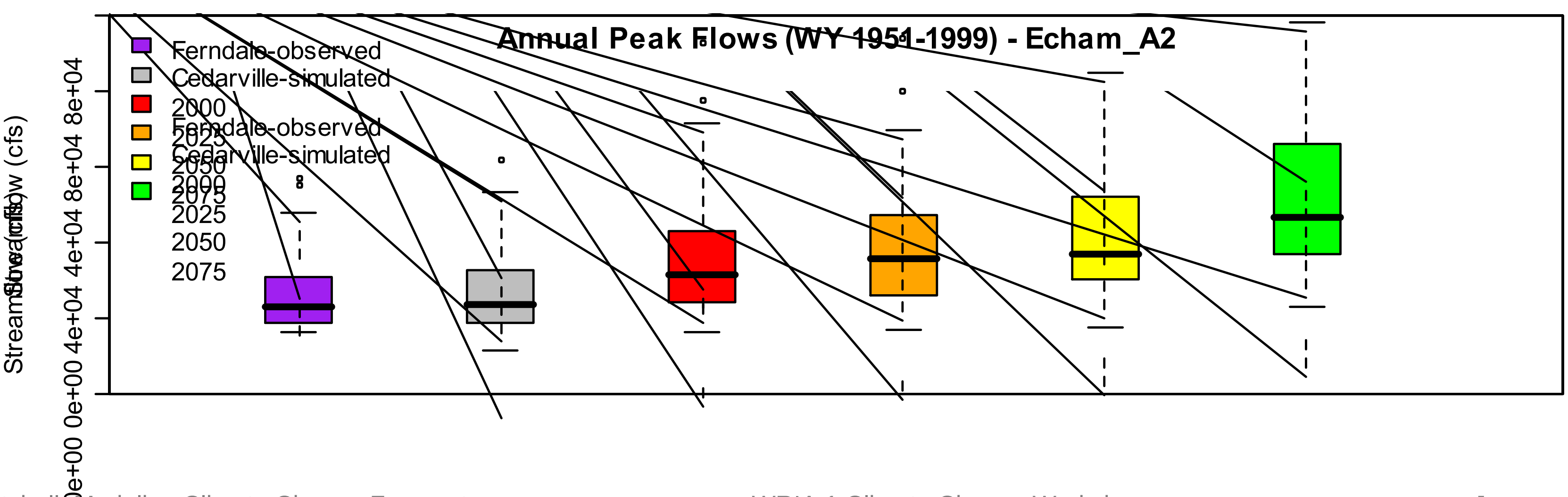
Results: Peak Flow Events

Annual Peak Flows (WY 1951-1999) - Echam A2

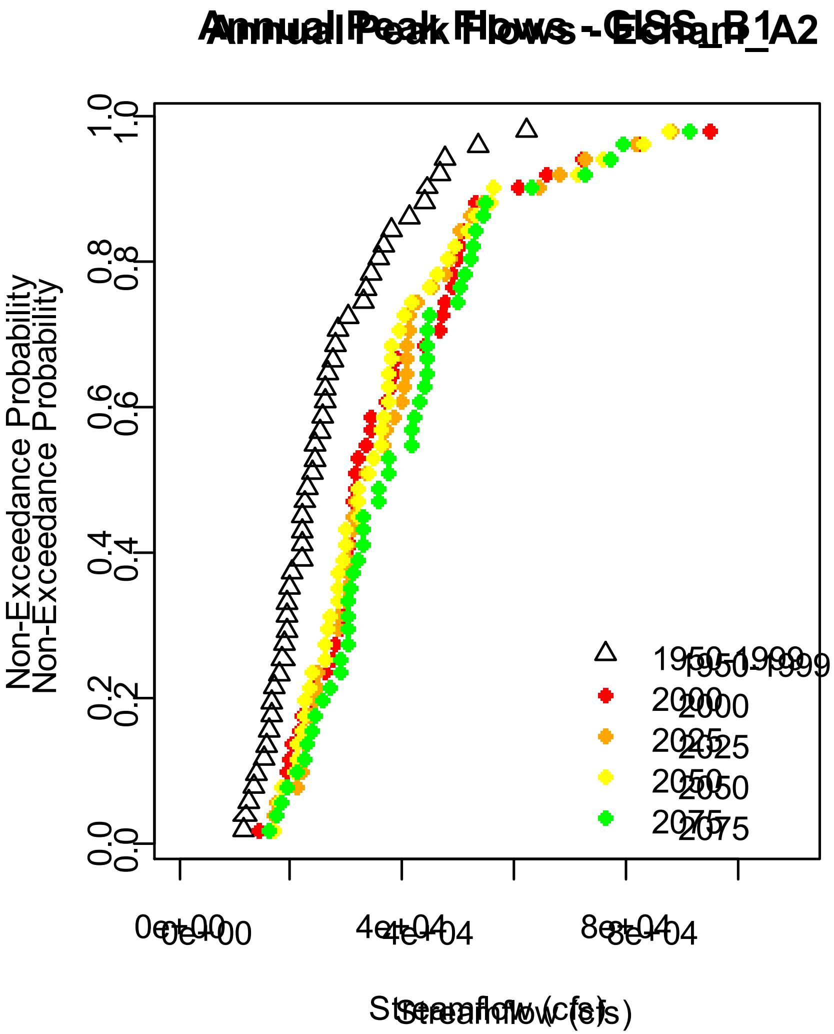
Annual Peak Flows (WY 1951-1999) - GISS_B1

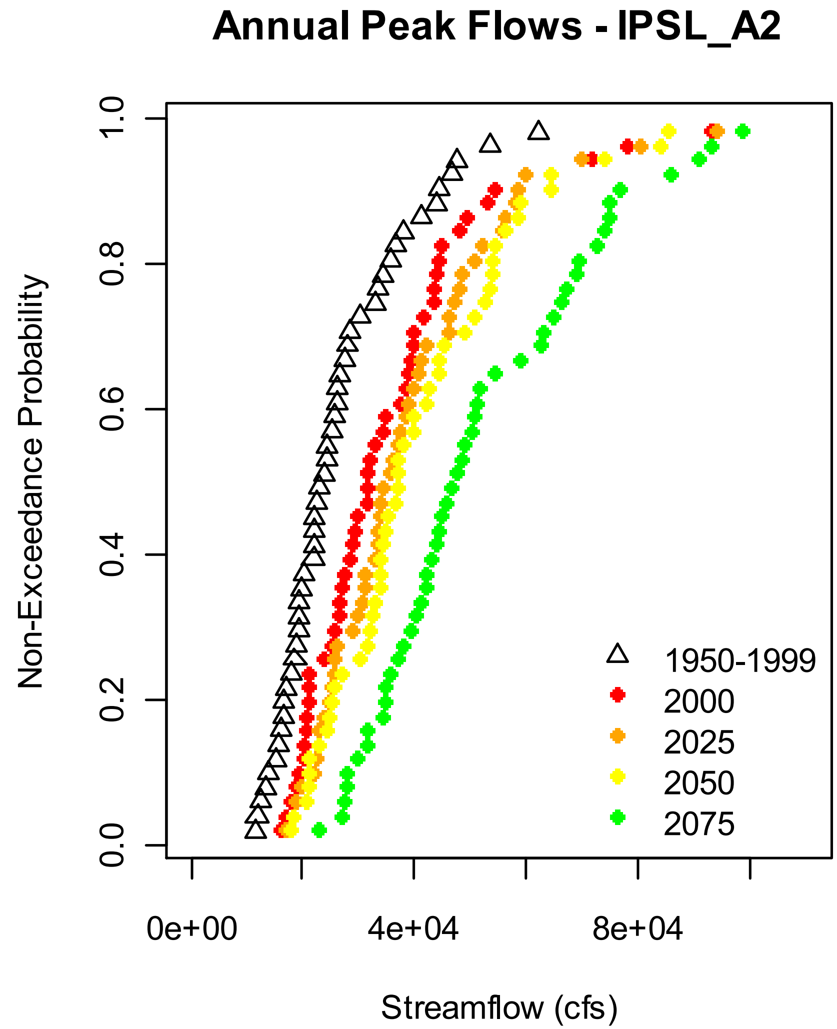


Annual Peak Flows (WY 1951-1999) - IPSL_A2



Results: Peak Flow Events





Conclusions

- Winter streamflow will increase
- SWE will decrease and is more sensitive to temperature rather than precipitation changes
- Timing of SWE and melt peak will occur earlier in the year
- Summer streamflow will decrease
- Peak flow events will increase in magnitude and frequency

Acknowledgements

Funding Provided By:

Whatcom County Flood Control Zone District

Alcoa Foundation

Assistance From:

Climate Change Technical Committee:

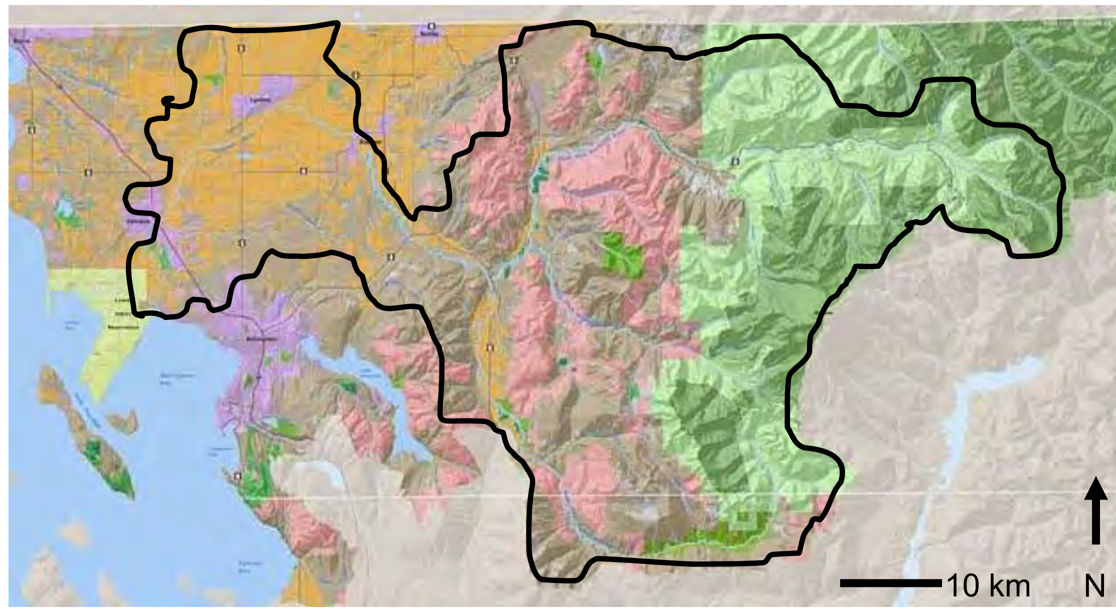
Matt Wiley & Austin Polebitski

Thank you!

Background: The Nooksack River

Photo: Bellingham Herald

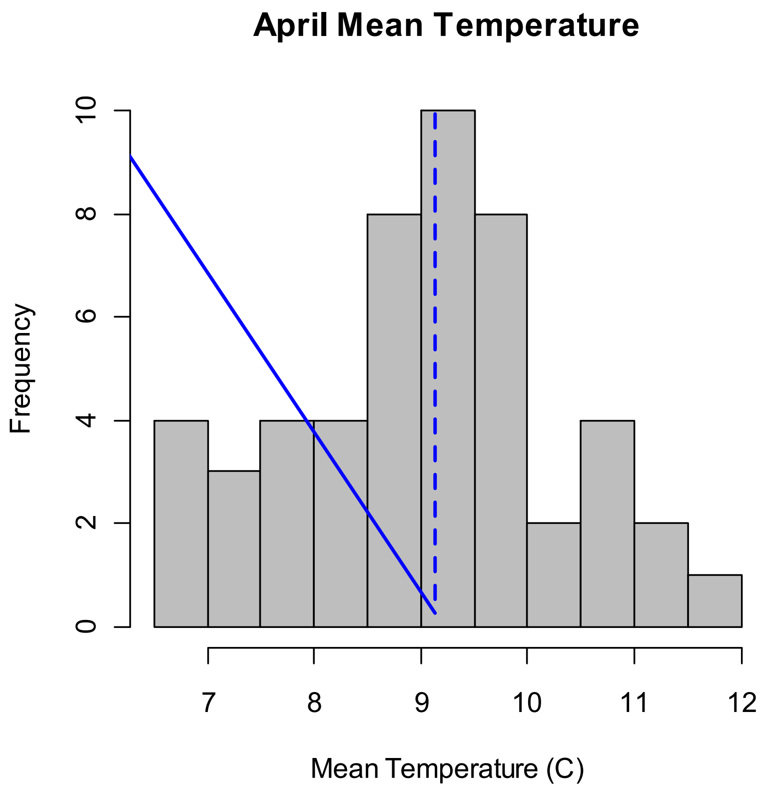
Photo: Becca Gjertson

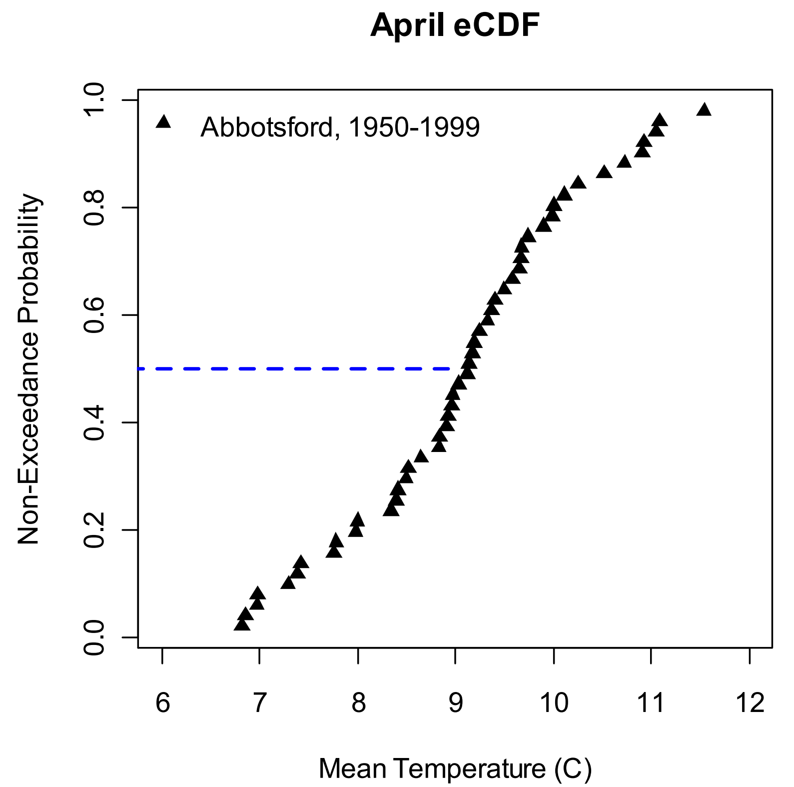


Shared Strategy for Puget Sound

Methods: GCM Downscaling

Empirical Cumulative Distribution Functions (eCDF

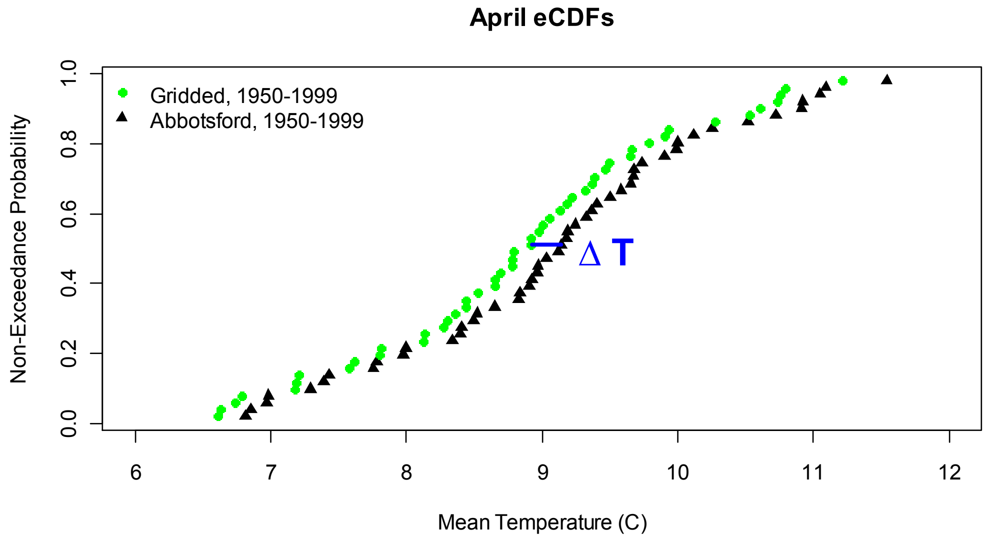


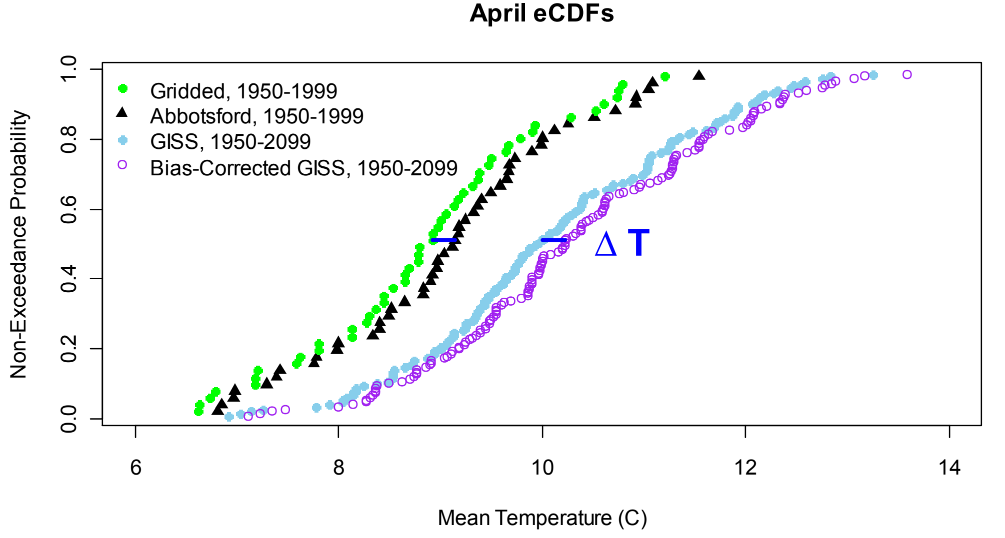


Methods: GCM Downscaling

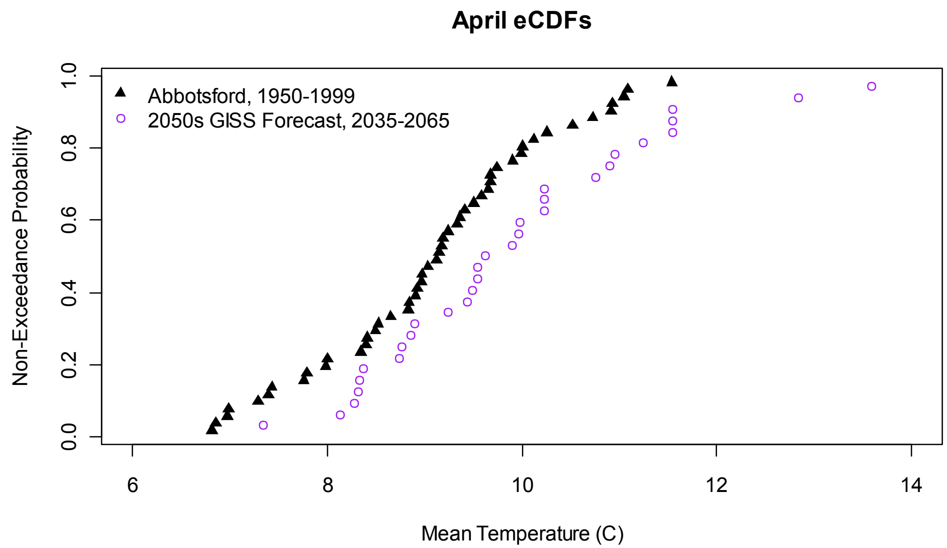
Bias-correct between spatial scales

1/8° ⟶ Station



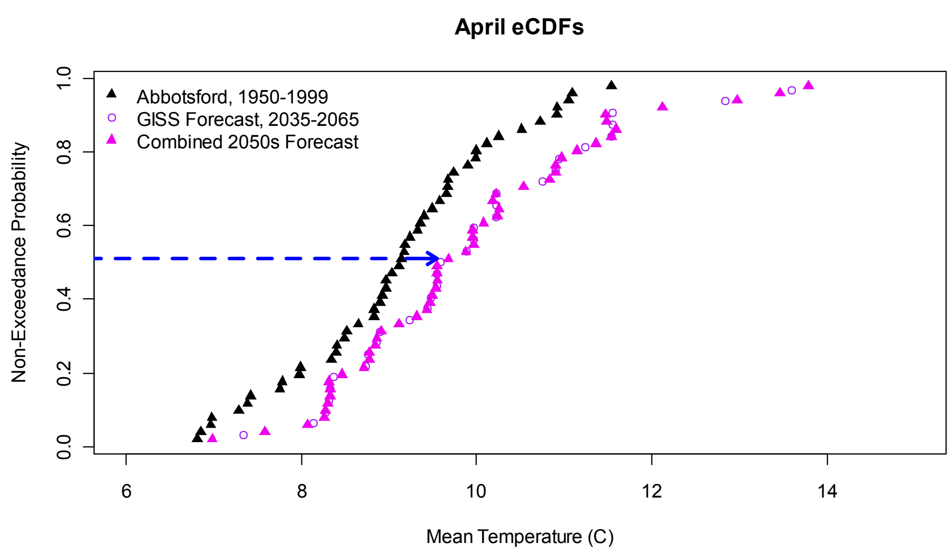


Methods: GCM Downscaling

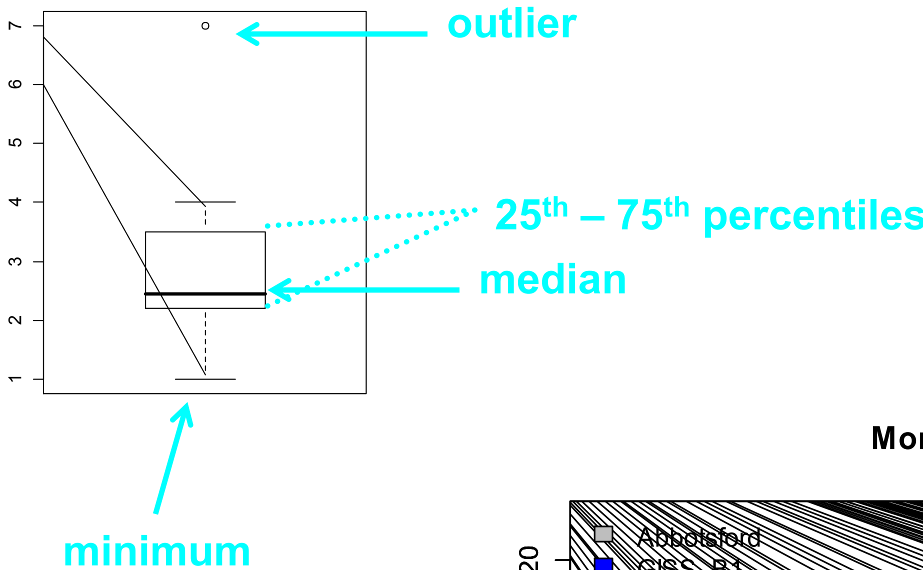


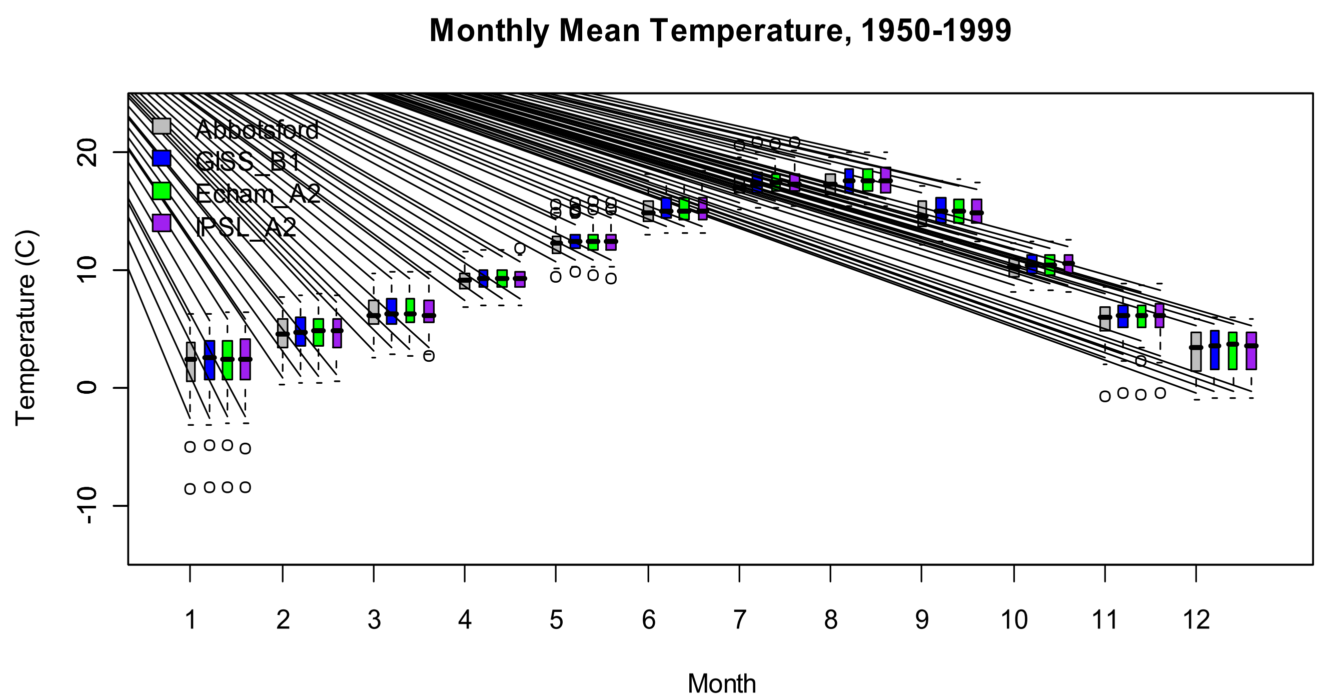
Shift 50-year historical time series based on 31-year forecast period

Result: 50-year forecast



Methods: Validation of Downscaling

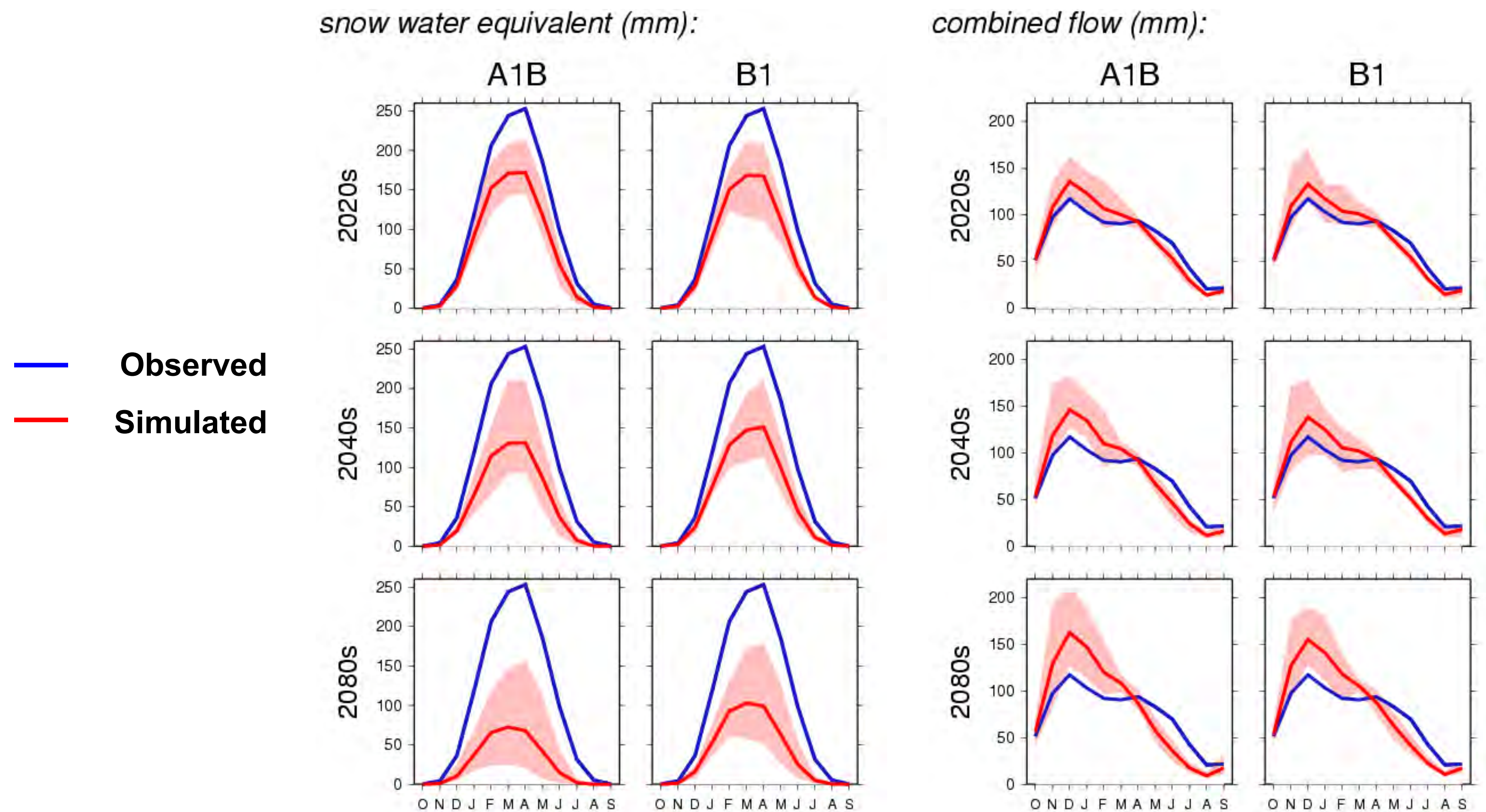




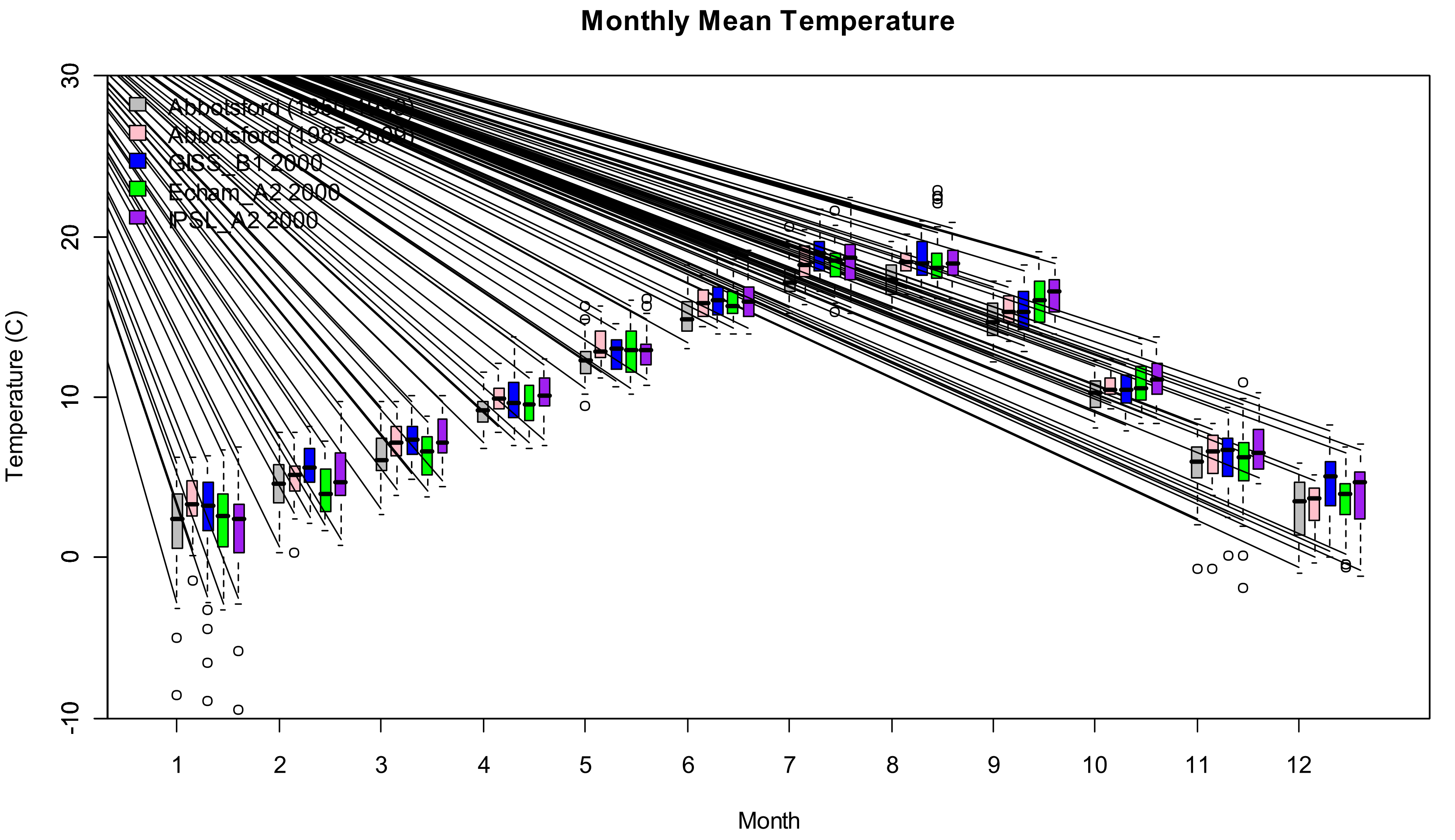
Comparison: Climate Impacts Group Results

Columbia Basin Climate Change Scenarios Project, 2010

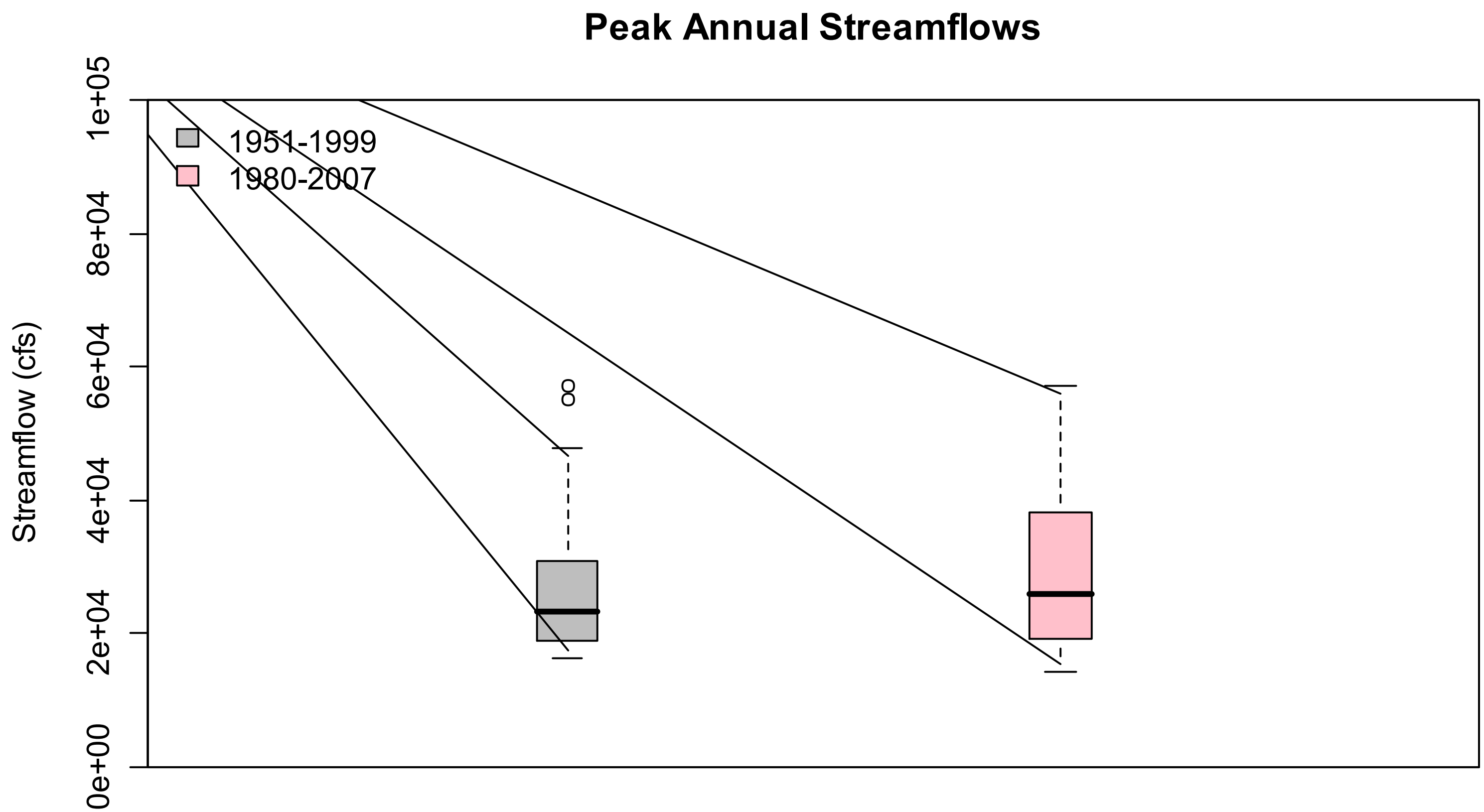
Nooksack River Basin, 1/16° resolution hydrology model



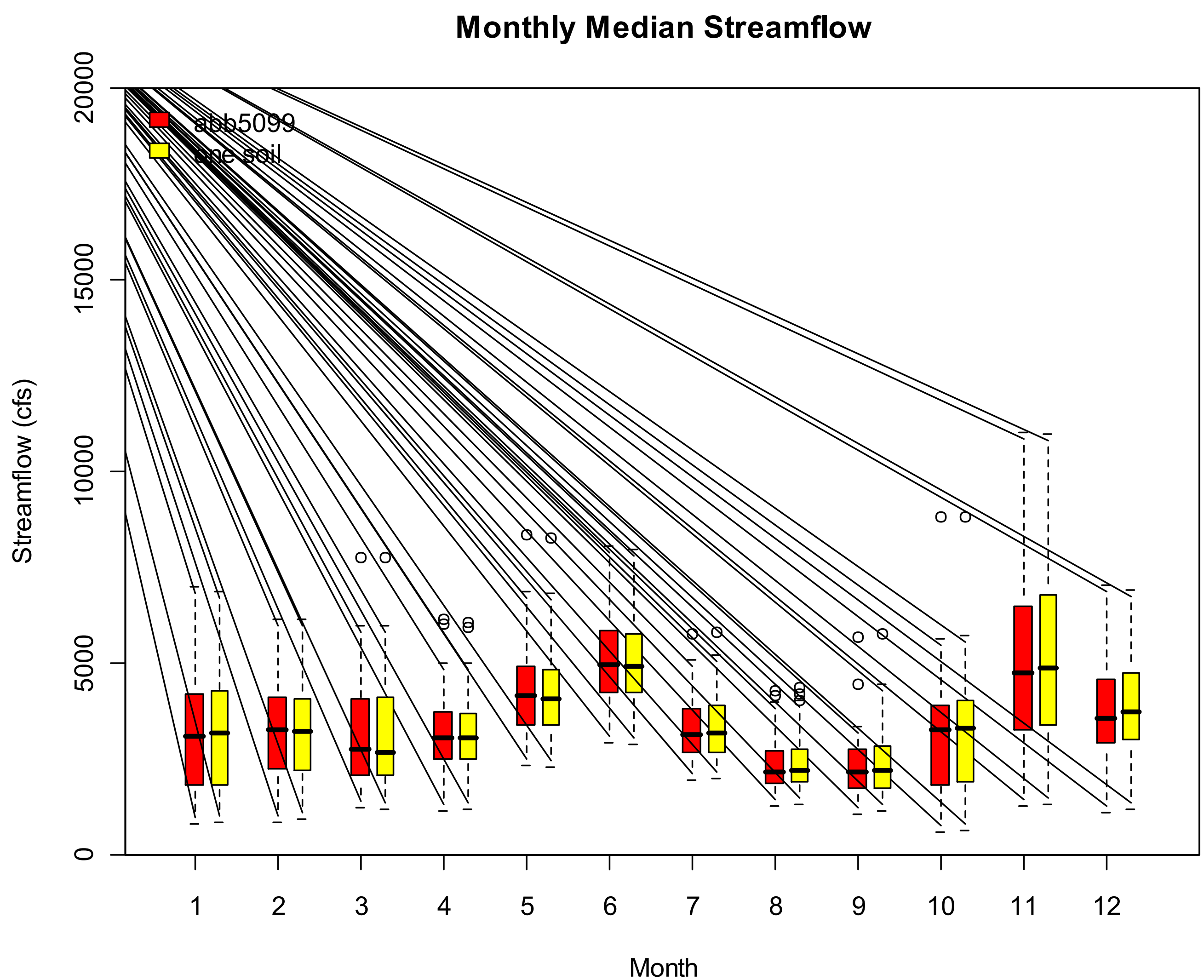
2000 simulation



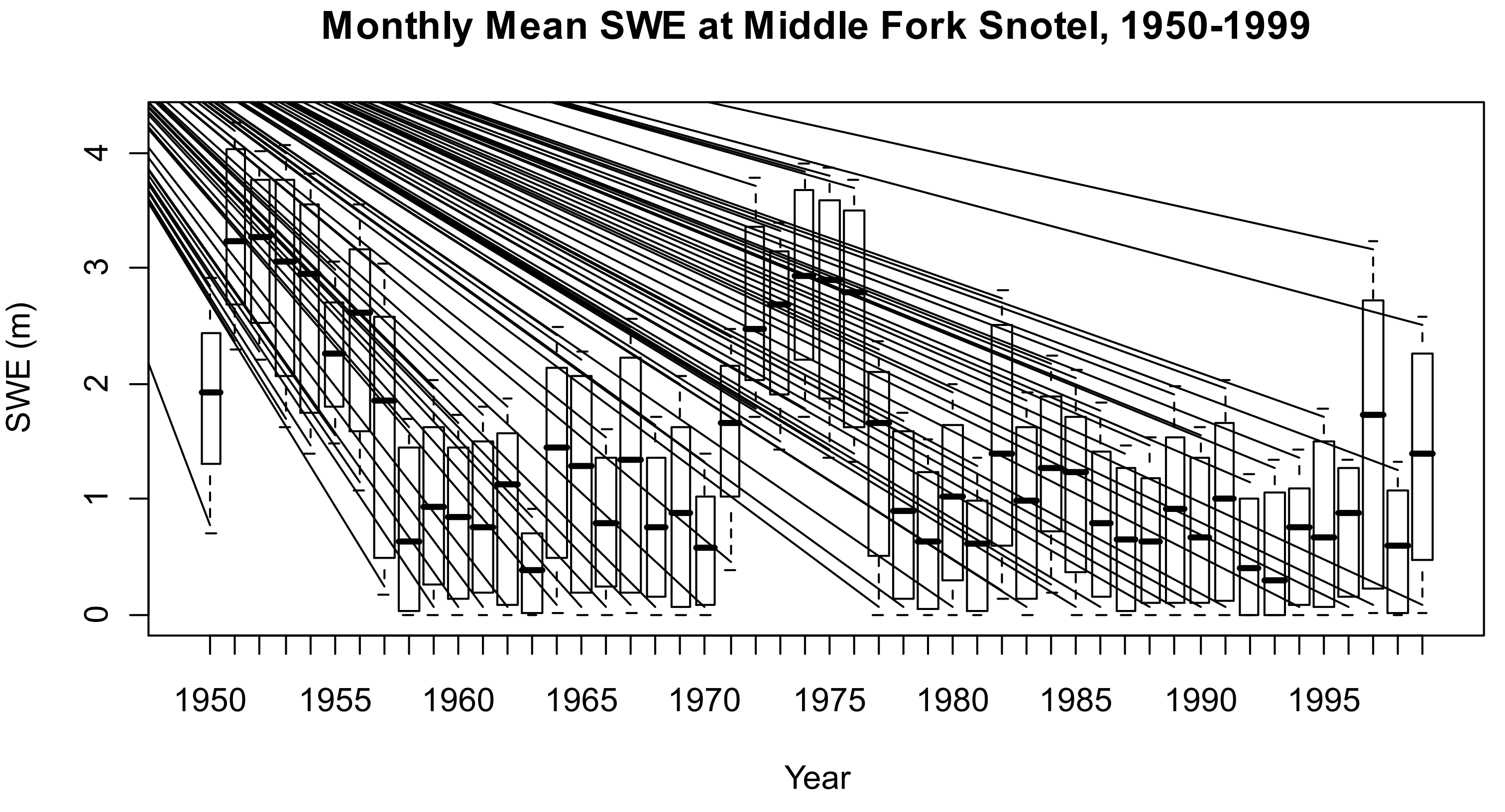
Results: Peak Flow Events



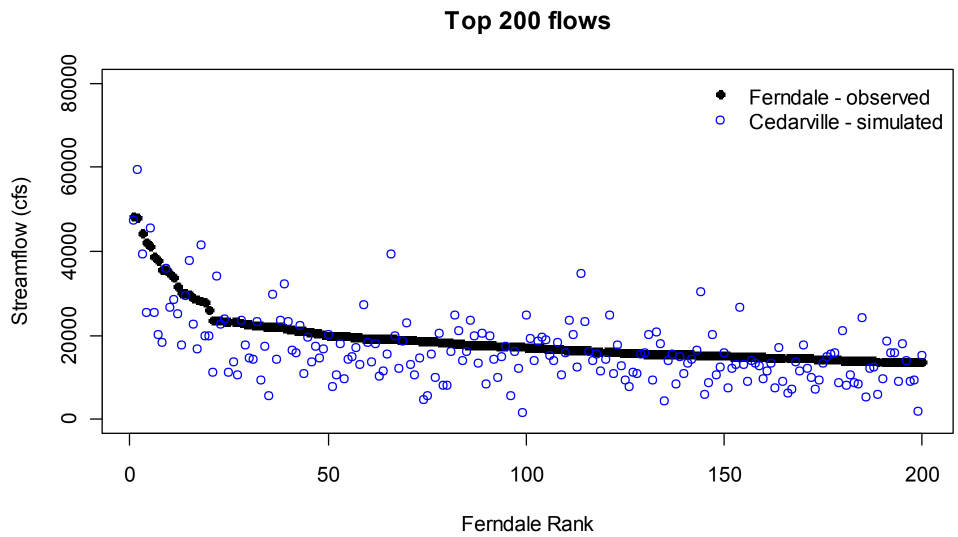
Soil Sensitivity Analysis

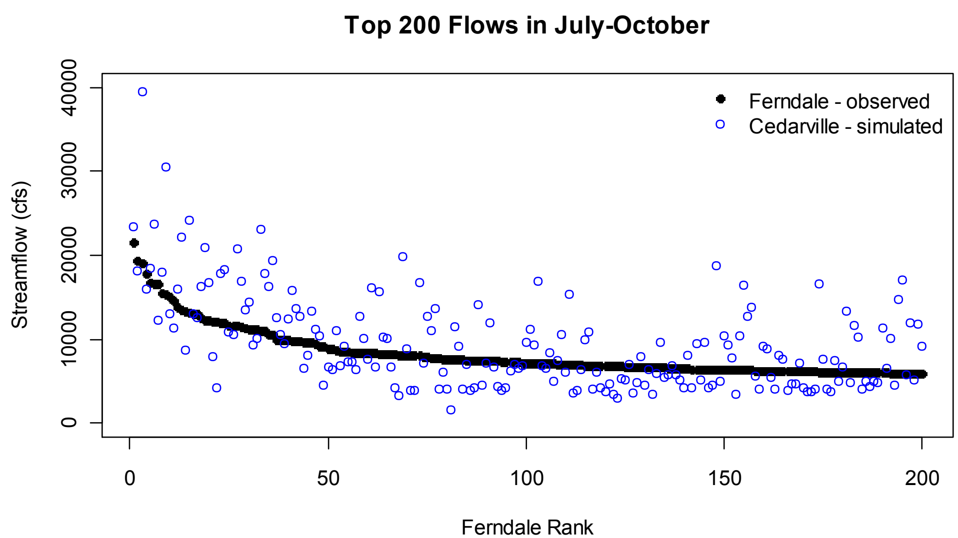


SWE and climate cycles



Results: Peak Flow Events





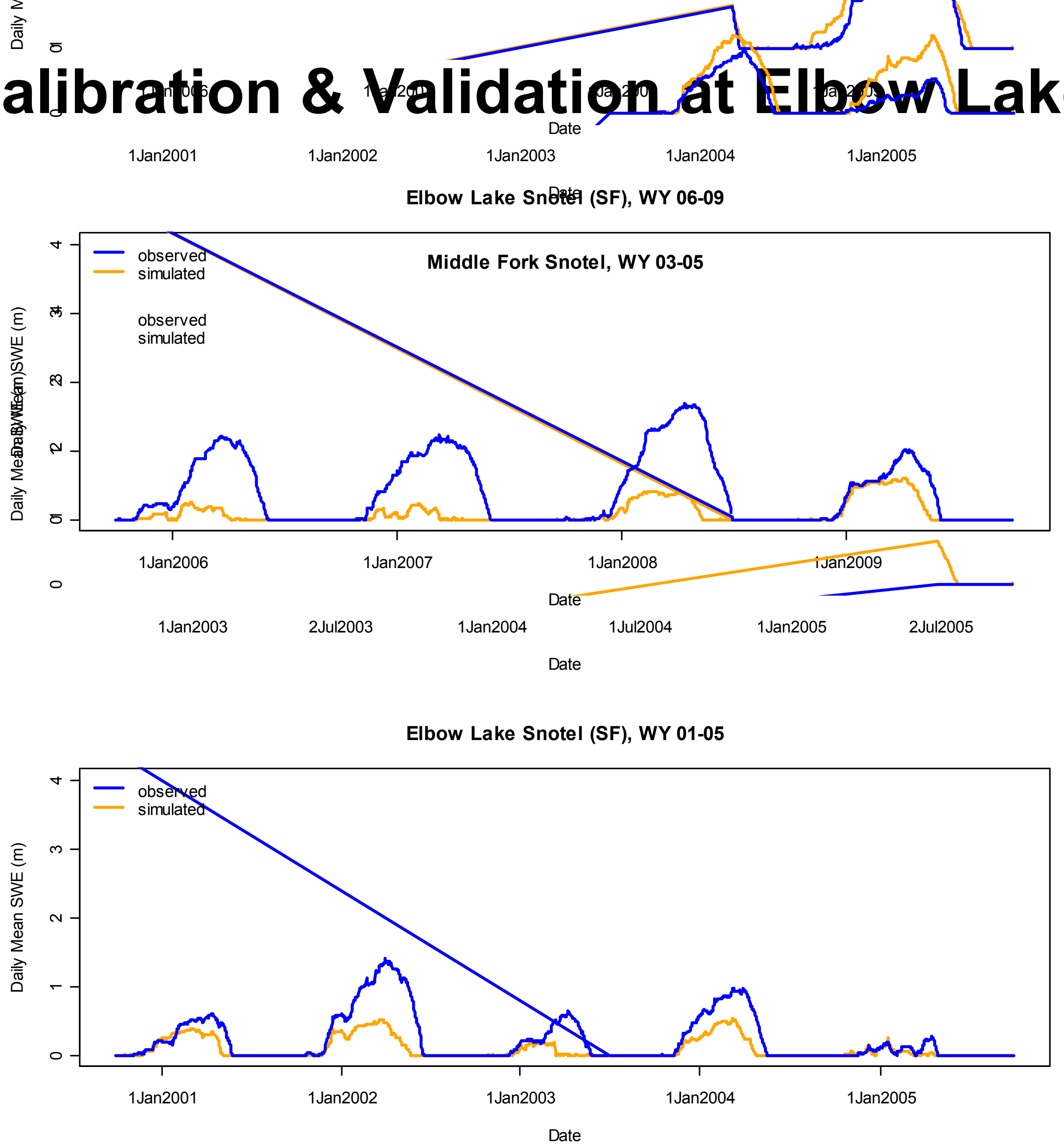
Methods: Processing of Forecasts

1. Apply **monthly** ΔT to **daily** Abbotsford data

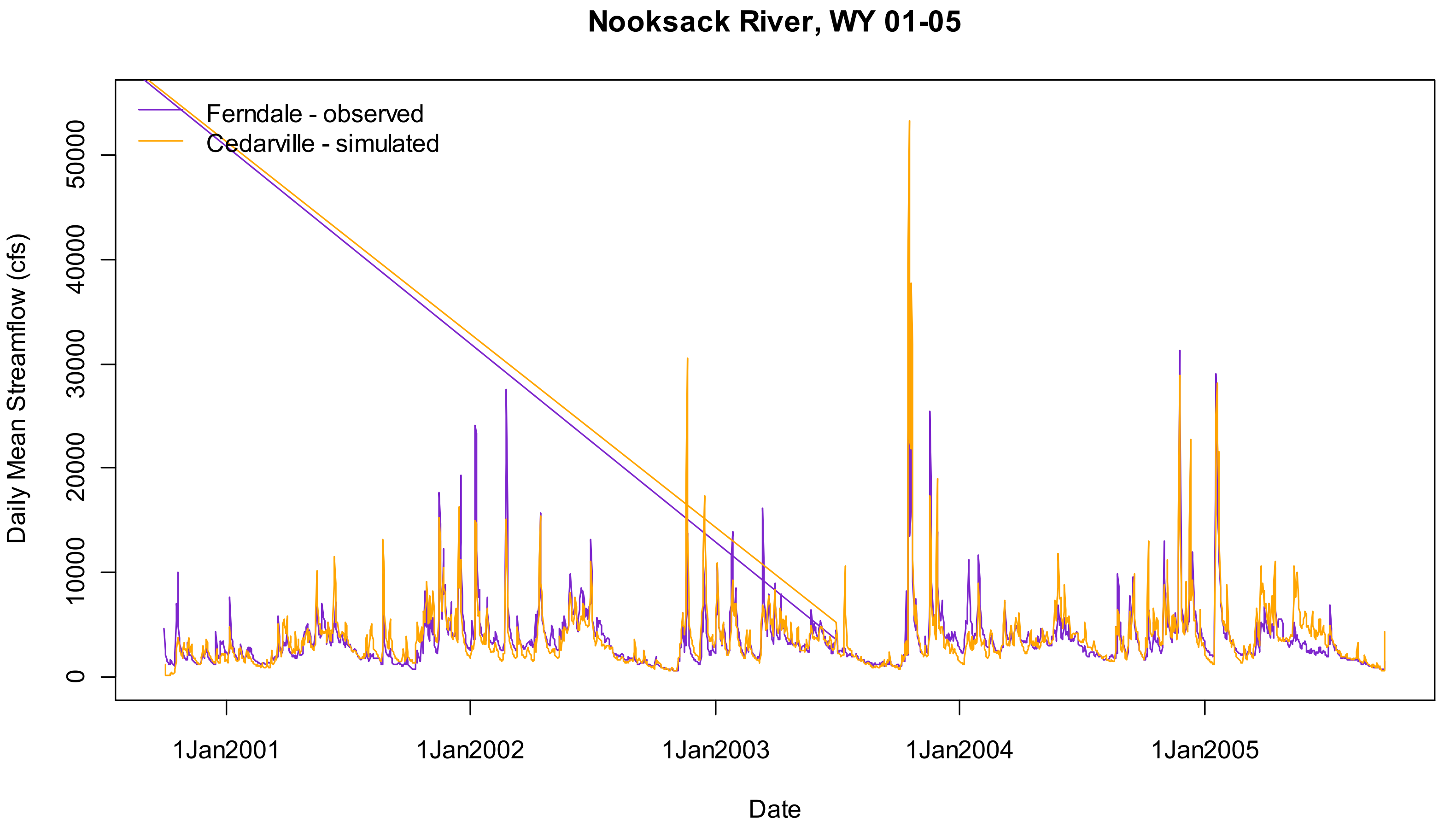
2. Disaggregate **daily** data to a **3-hour** time step

3. Derive other 3-hour meteorological input from temperature and precipitation
    - Shortwave Radiation
    - Longwave Radiation
    - Windspeed
    - Relative Humidity

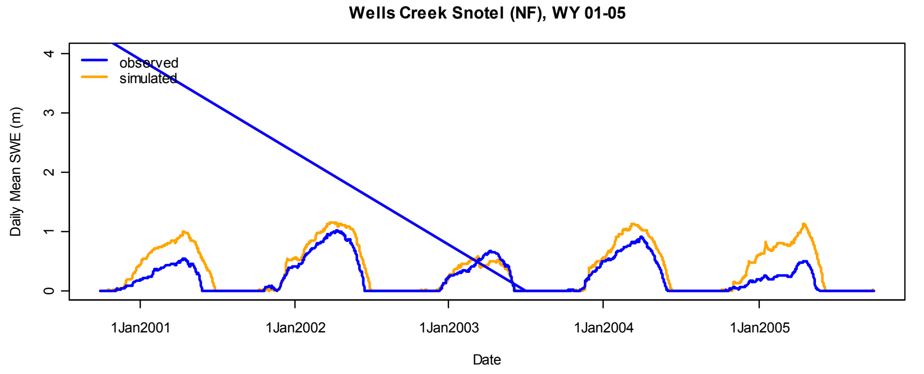
Calibration & Validation at Elbow Lake

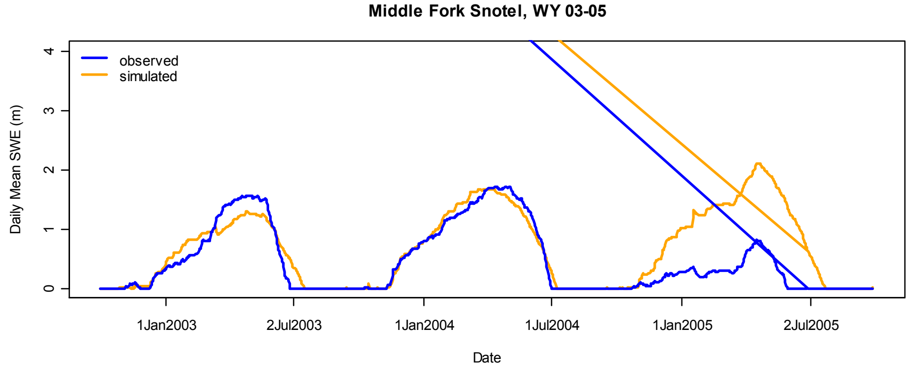


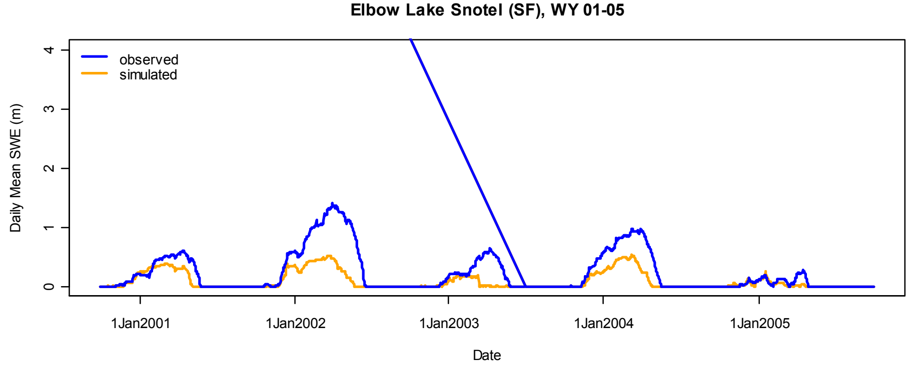
Further Validation: Streamflow at Ferndale



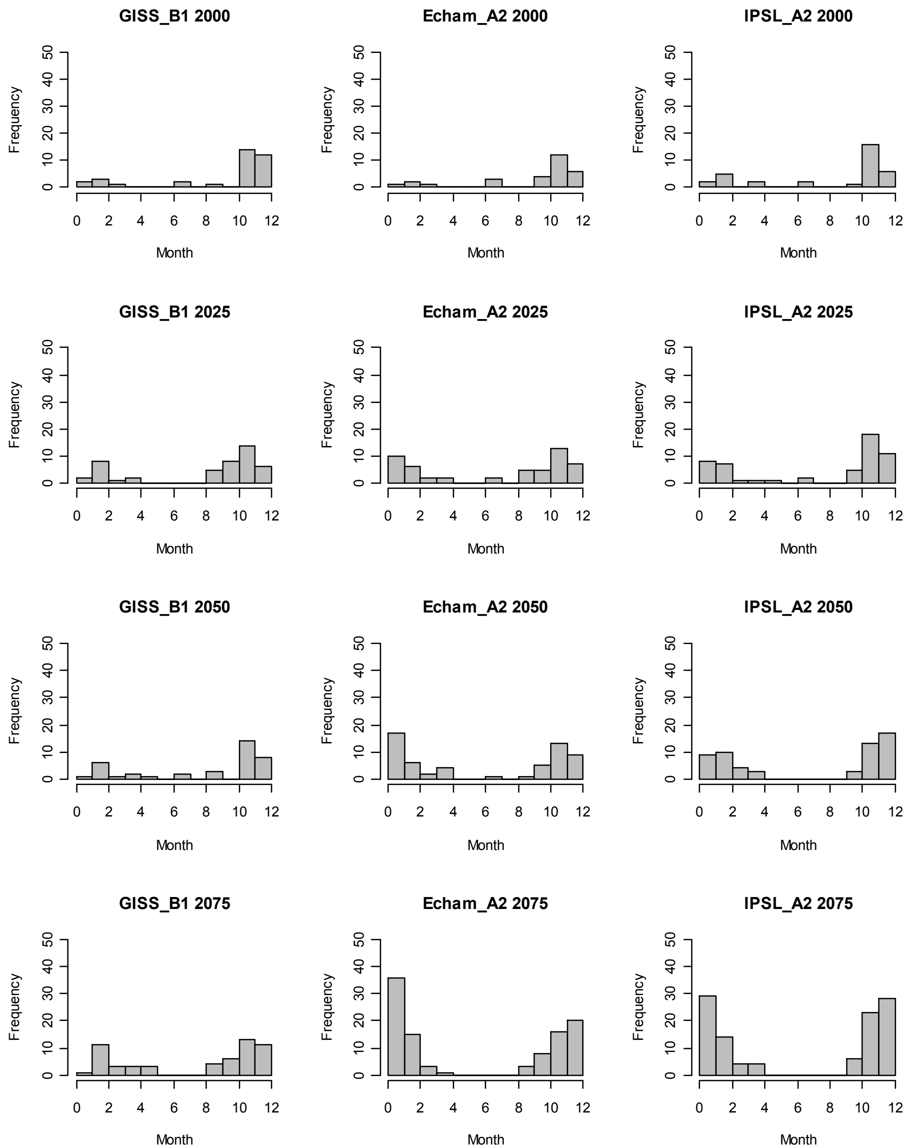
Further Validation: SWE



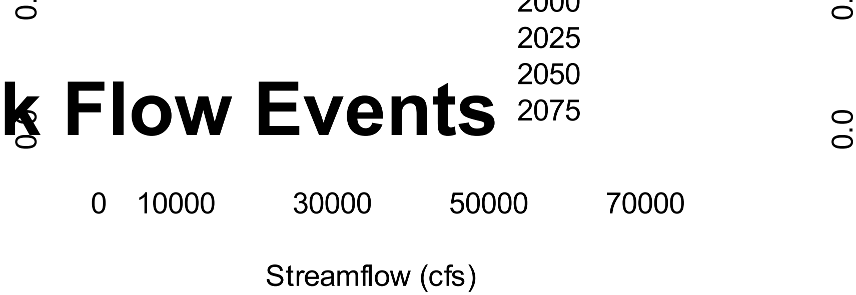




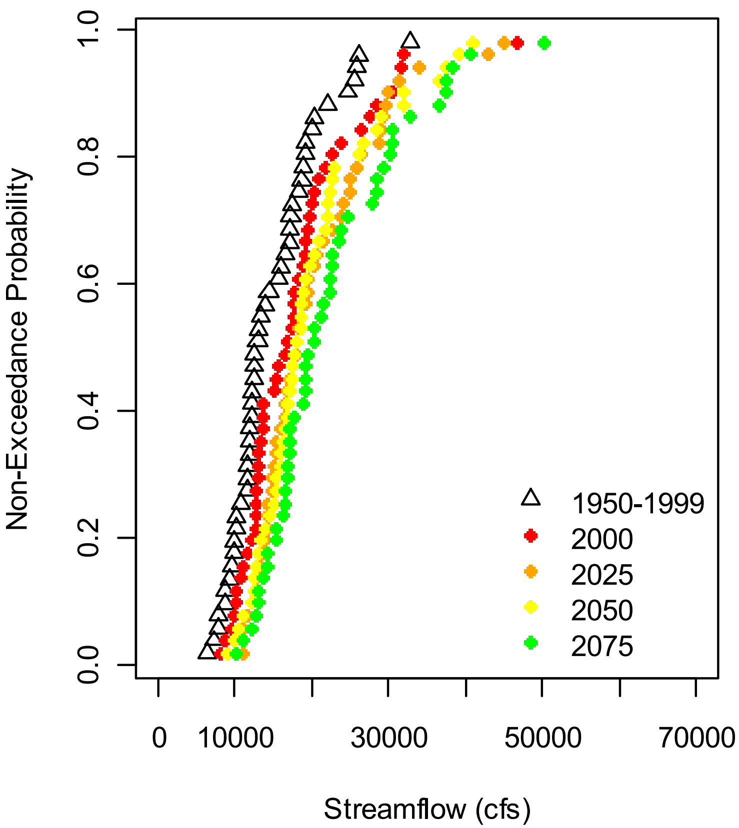
Results: Peak Flow Events



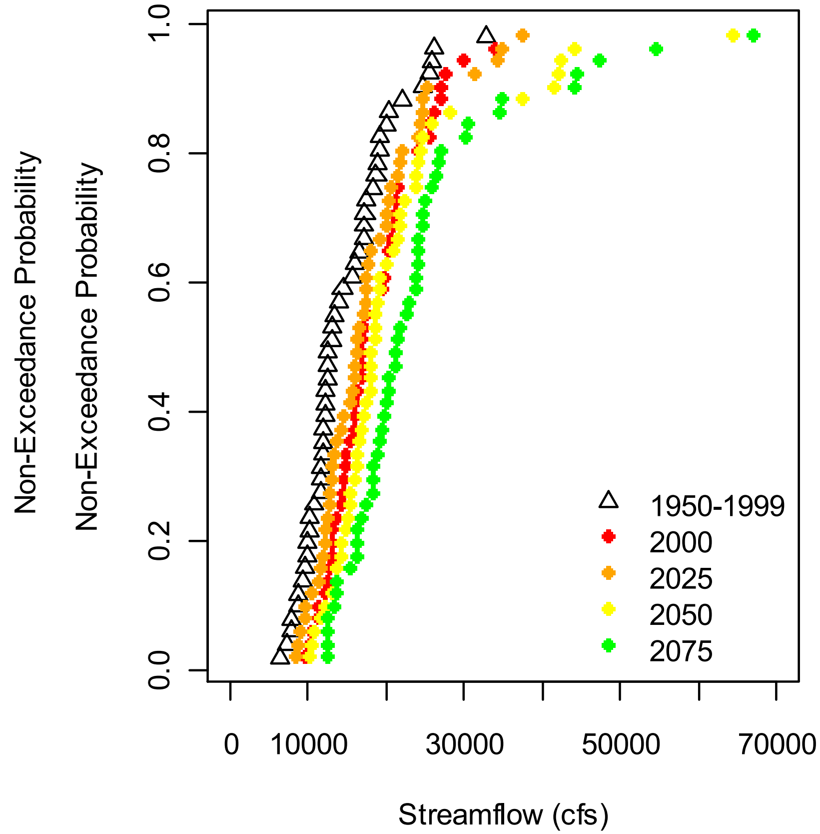
Results: Spring Peak Flow Events



Spring Peak Flows - GISS_B1

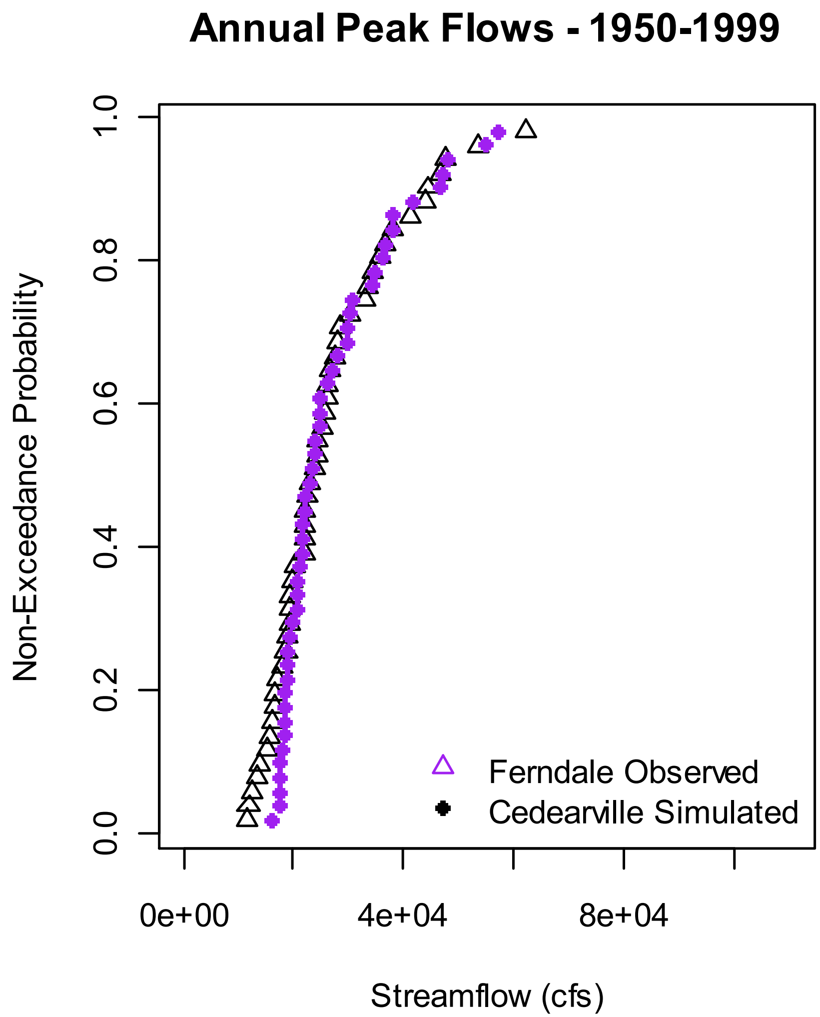


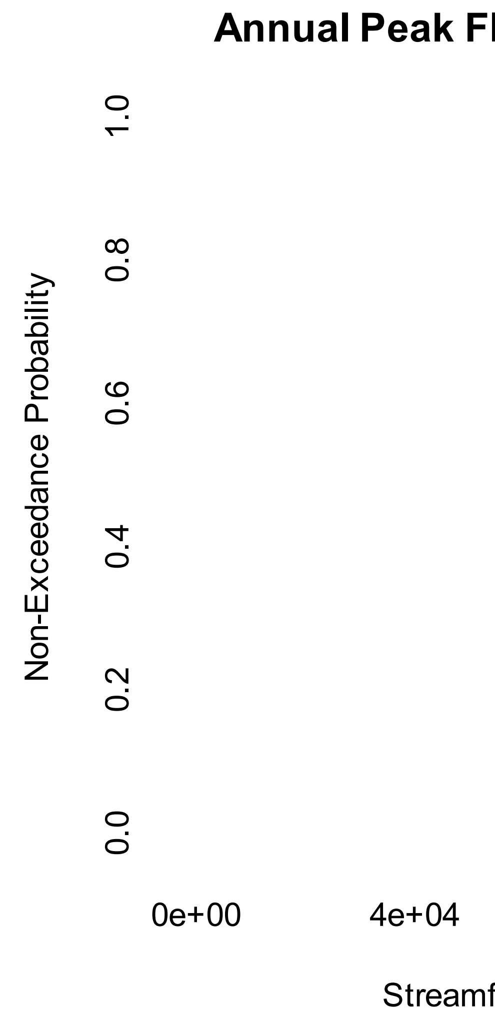
Spring Peak Flows - IPSL_A2



Spring Peak Flows - IPSL_A2

Results: Peak Flow Events - Validation





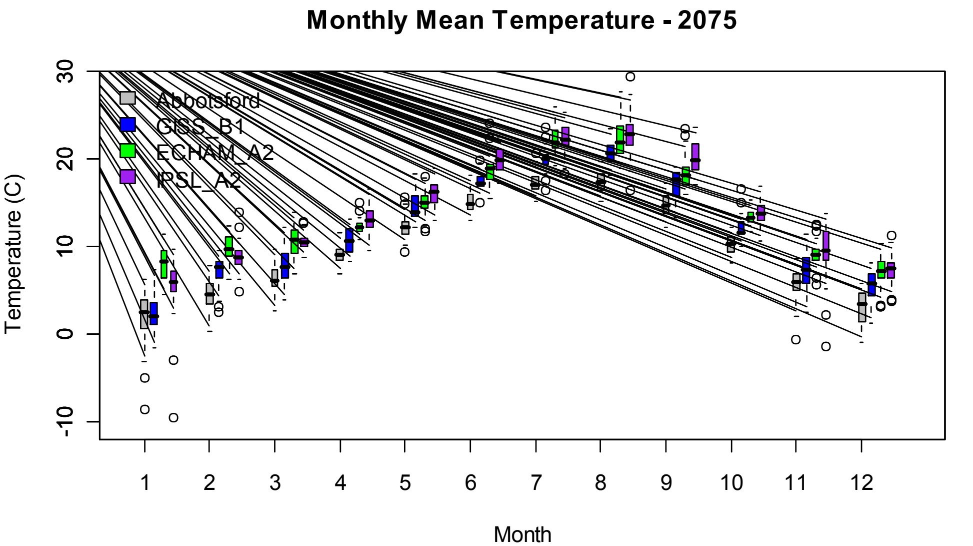
Annual Peak Flows - Echam_A2

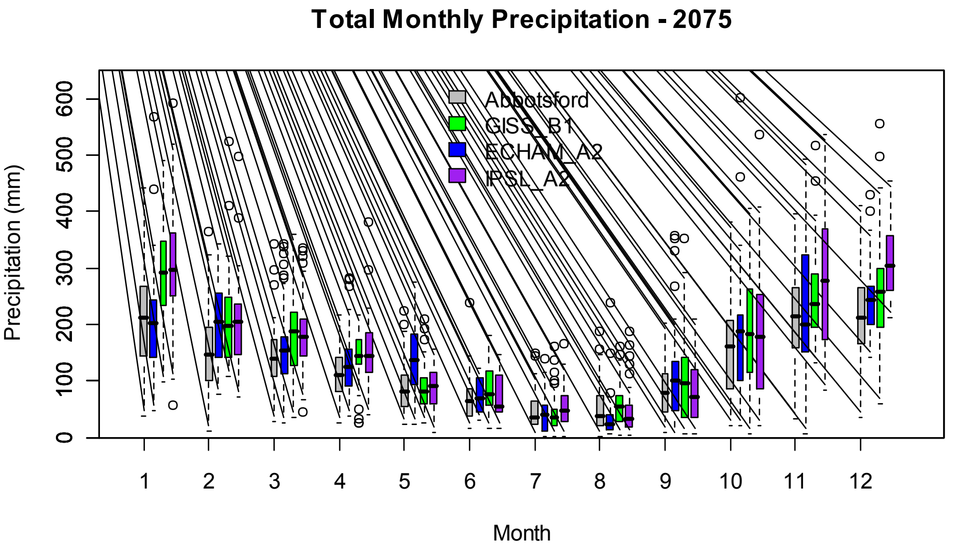
Annual Peak F

Temperature or Precipitation?

- Predicted increases in temperature and precipitation
- More agreement on temperature trends
- Previous regional studies indicate that temperature is the driving factor in changes to SWE

(Hamlet et al., 2005, Mote et al., 2005, Mote et al., 2008)

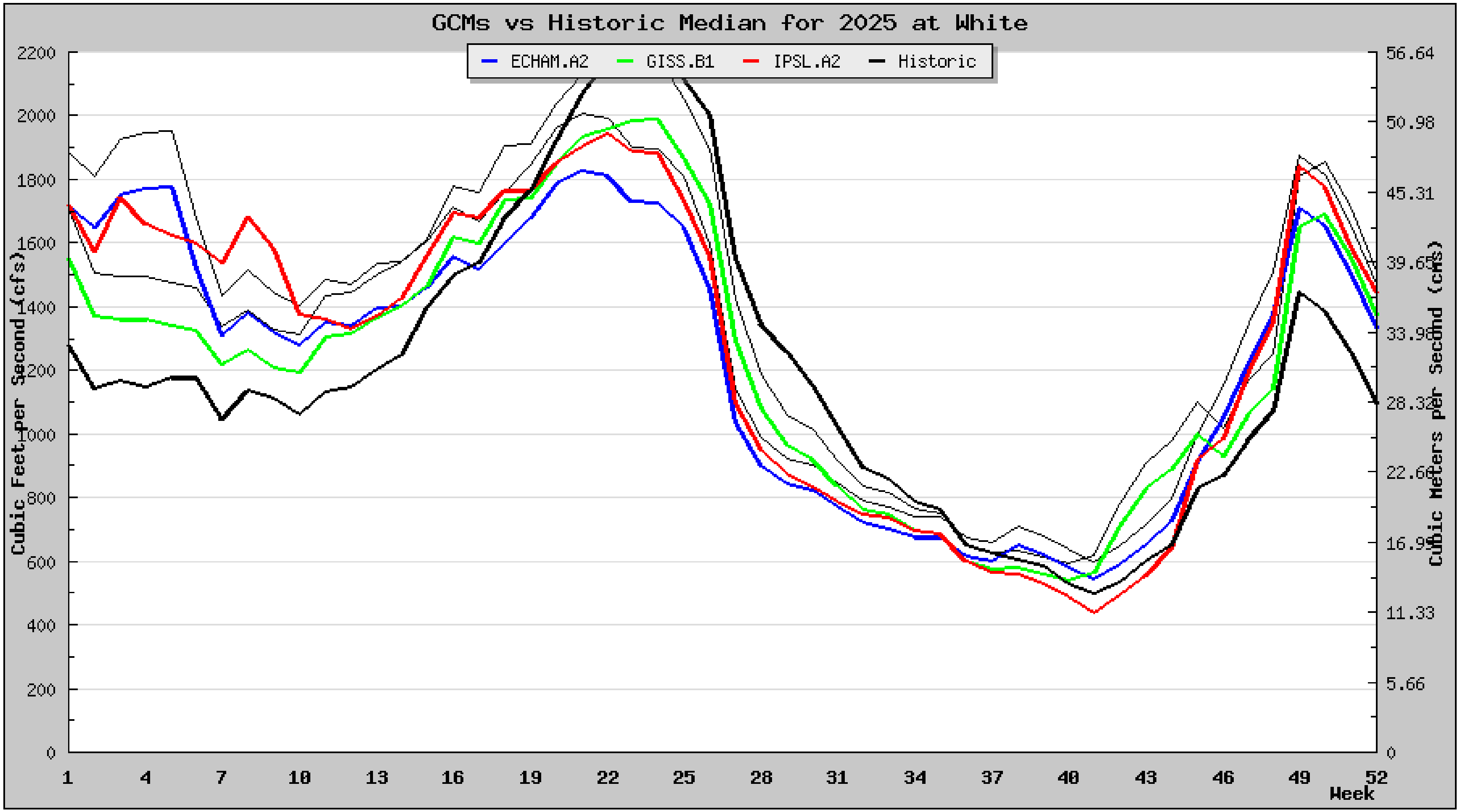




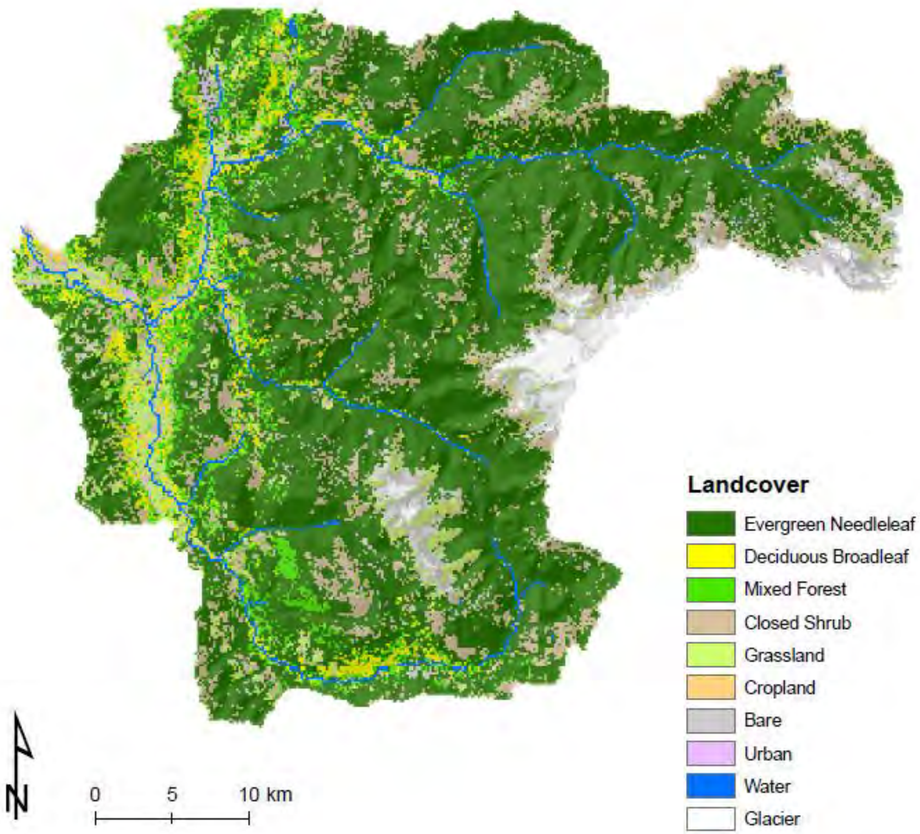
Discussion: CCTC Results

Climate Change Technical Committee

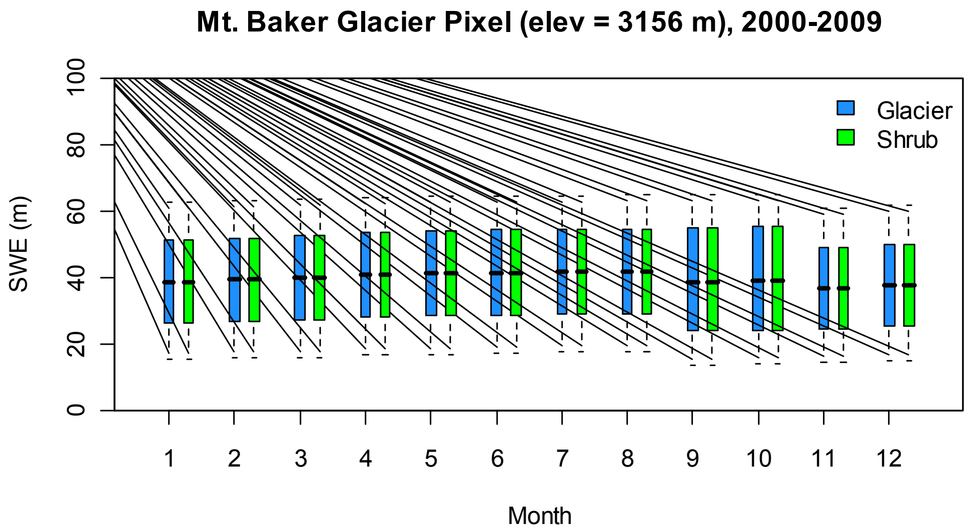
Discussion: CCTC Results

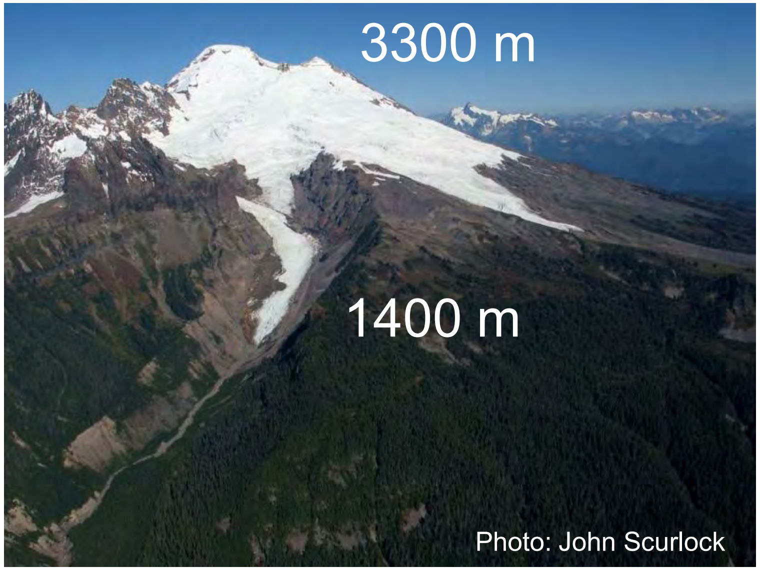


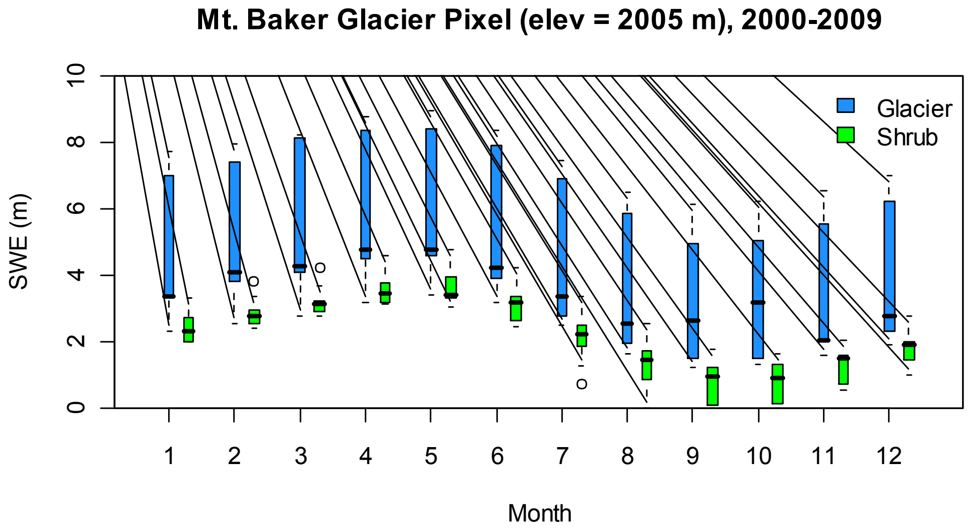
Methods: Glacial Contribution to Streamflow



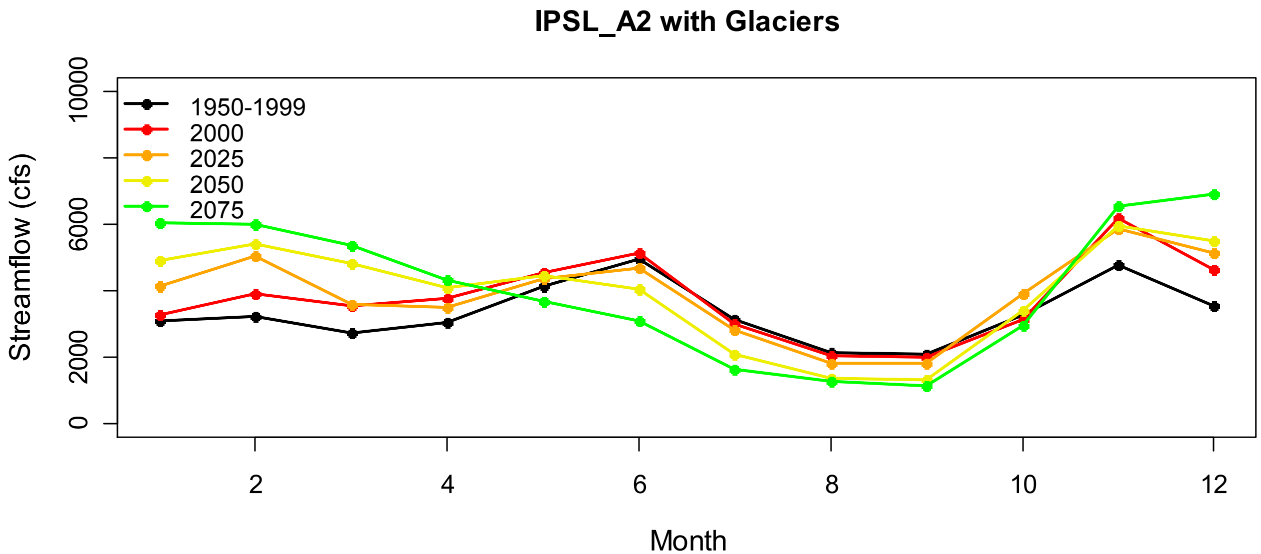
Results: Glacial Contribution to Streamflow

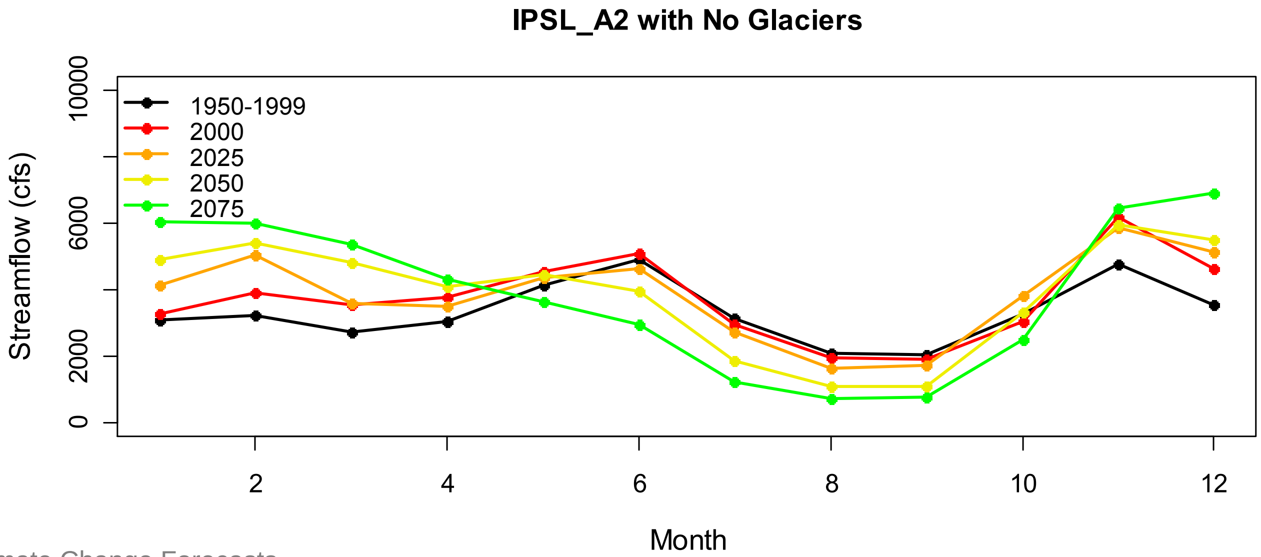




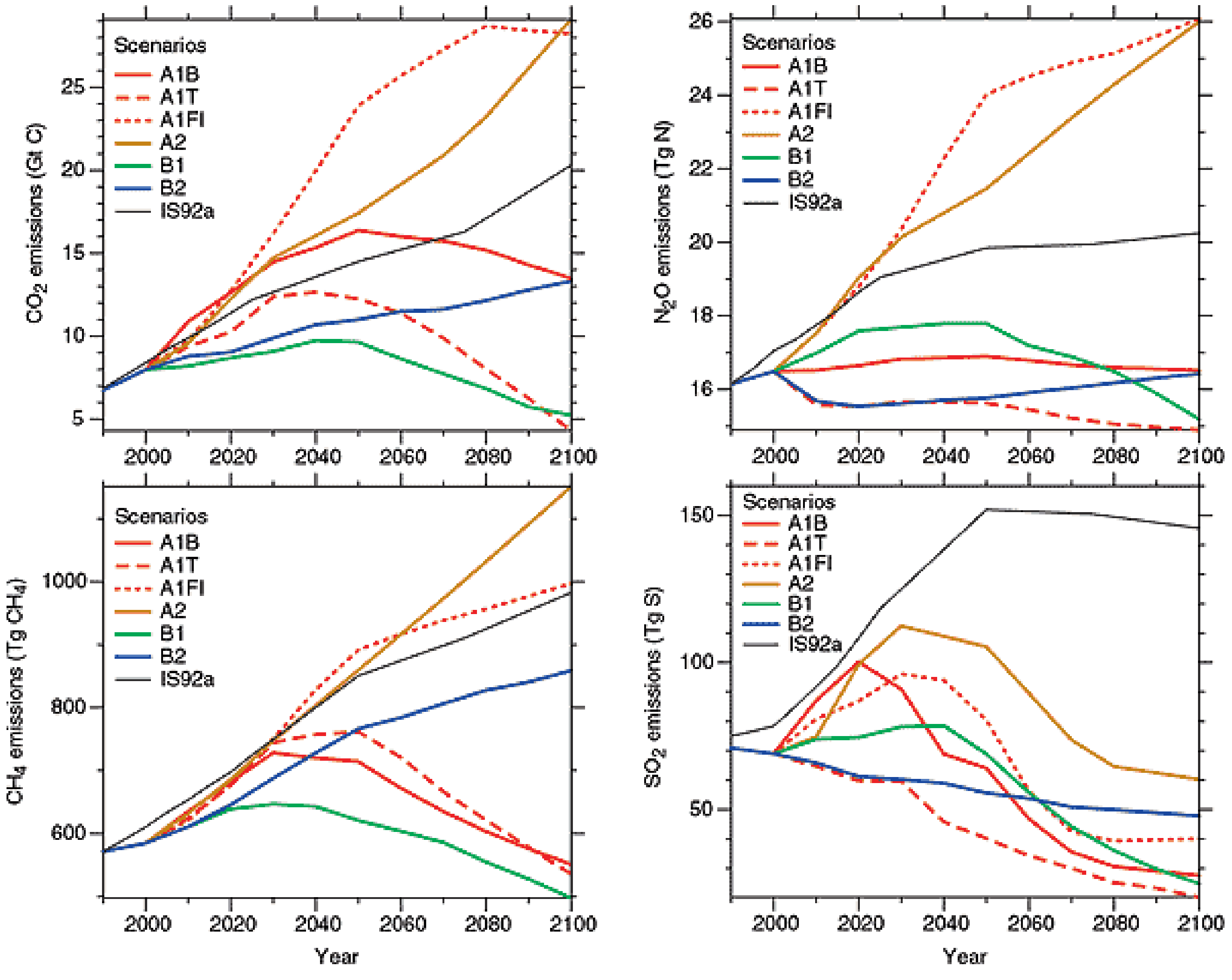


Results: Glacial Contribution to Streamflow





Emissions Scenarios



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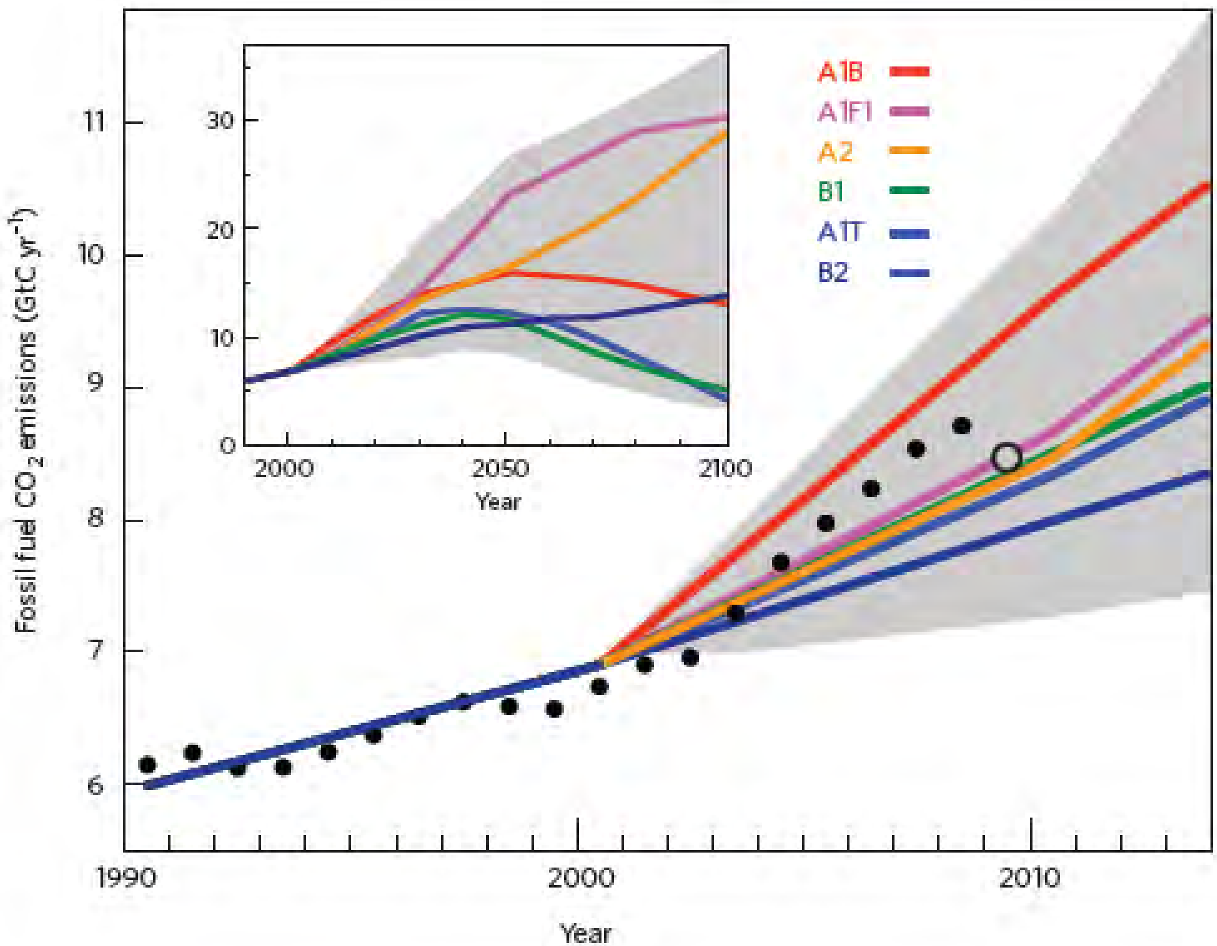
Emissions Scenarios



Manning et al., 2010

Results: Peak Flow Events