



# Responding to Evolving Stakeholder Needs for 21<sup>st</sup> Century Hydrologic Scenarios:

## *An Overview of the Columbia Basin Climate Change Scenarios Project*

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*Climate science in the public interest*



Department of Civil and Environmental Engineering



# *Climate Change Planning Needs are Evolving*

## *Stakeholder requests:*

1. Address diverse stakeholder planning needs (terrestrial and aquatic ecosystems, water management, human health, energy, etc.)
2. Provide comprehensive coverage over large geographic areas using consistent methods
3. Increase spatial resolution
  - address both large-scale and small-scale planning efforts in a consistent manner
4. Increase temporal resolution
  - address changes at daily timescales and assess changes in hydrologic extremes
5. Quantify uncertainties in future projections

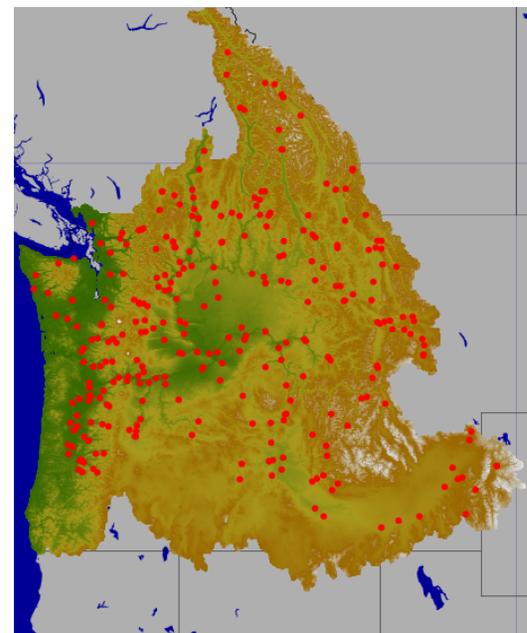


# The Columbia Basin Climate Change Scenarios Project

This 2-year research project (finalizing Spring 2010) is designed to provide a comprehensive suite of 21<sup>st</sup> century hydroclimatological scenarios for the Columbia River basin and coastal drainages in OR and WA.

## Collaborative Partners:

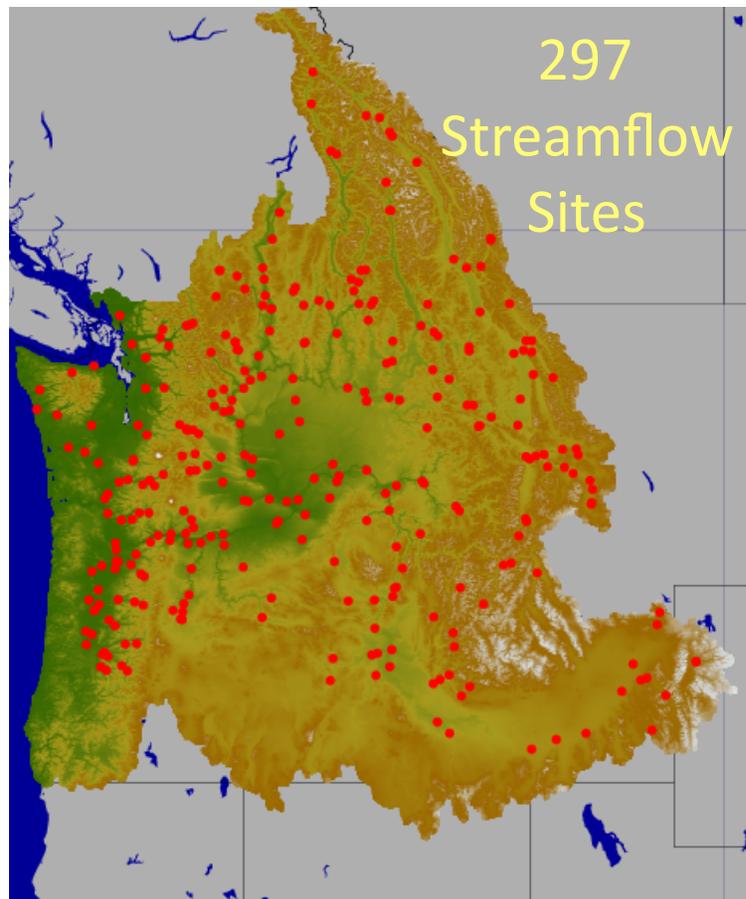
- WA State Dept. of Ecology (via HB 2860)
- Bonneville Power Administration
- Northwest Power and Conservation Council
- Oregon Water Resources Department
- BC Ministry of the Environment





# Project Goals and Objectives

- Provide a wide range of products to address multiple stakeholder needs
- Increase spatial and temporal resolution
- Provide a large ensemble of climate scenarios to assess uncertainties
- Address hydrologic extremes (e.g. Q100 and 7Q10)



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Reservoir Model  
Input Data

# Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages

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Pacific Northwest water resources are projected to be materially affected by a changing climate. This two-year collaborative project is designed to provide free public access to hydrologic scenarios needed to support long-range water planning for the 21st century. The menus to the left provide access to a comprehensive suite of climate change hydrologic data bases and summary products for approximately 300 streamflow locations in the Columbia River basin and selected coastal drainages west of the Cascades.

The hydrologic data produced by the study are based on climate change scenarios produced for the IPCC Fourth Assessment effort (link to climate scenarios at left). Information on the methods and modeling tools used in the study is provided in a summary report (link to project report at left). For new users of the site, a guide to the website and the data resources contained within it is also provided (link to introduction for new users).

## Our Study Partners

- UW Climate Impacts Group
- WA State Department of Ecology
- Bonneville Power Administration
- Northwest Power and Conservation Council
- Oregon Department of Water Resources
- British Columbia Ministry of Environment

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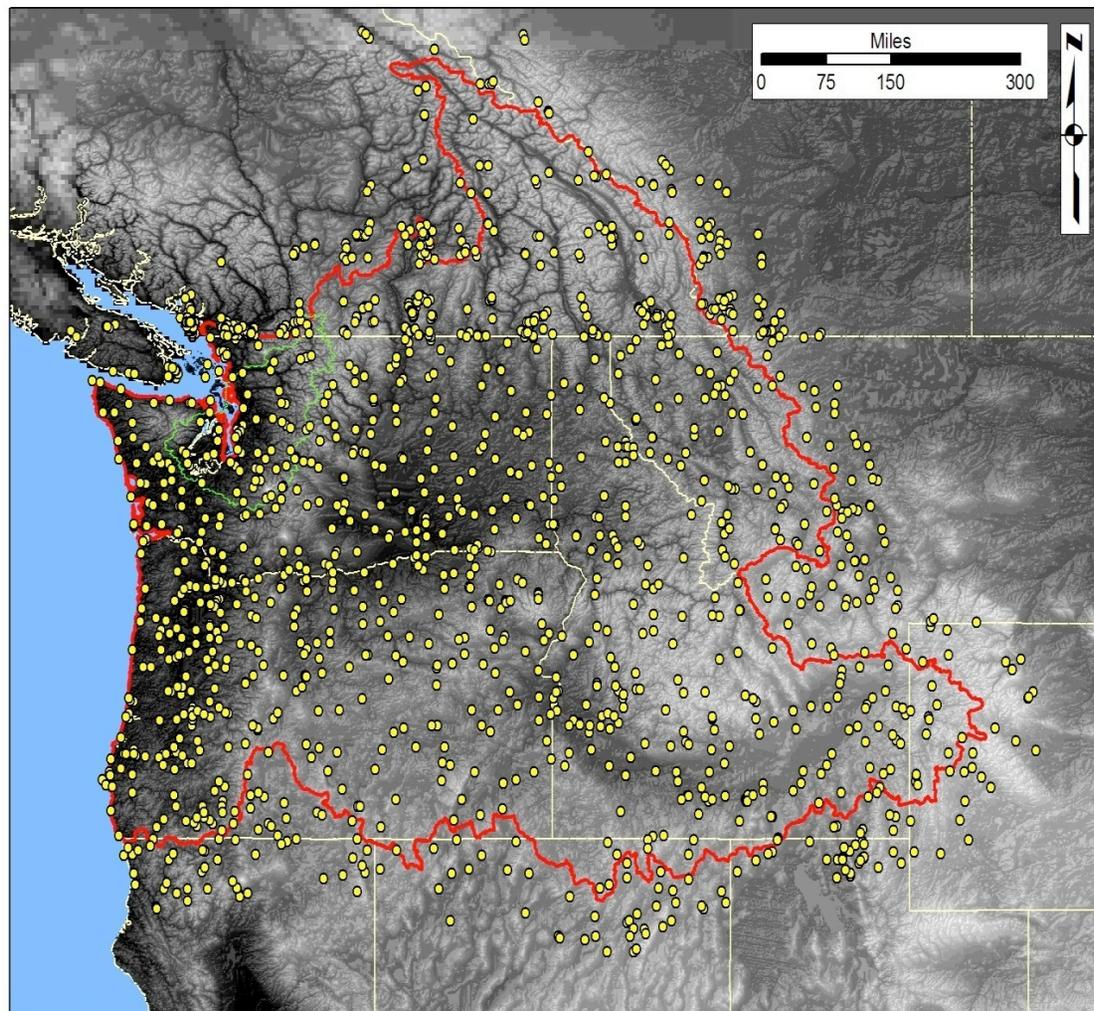
<http://www.hydro.washington.edu/2860/>



# *Overview of Methods*



# Primary Meteorological Stations Used to Create Spatial Dataset\* (1915-2006)



**\*1/16 spatial resolution & daily timestep**



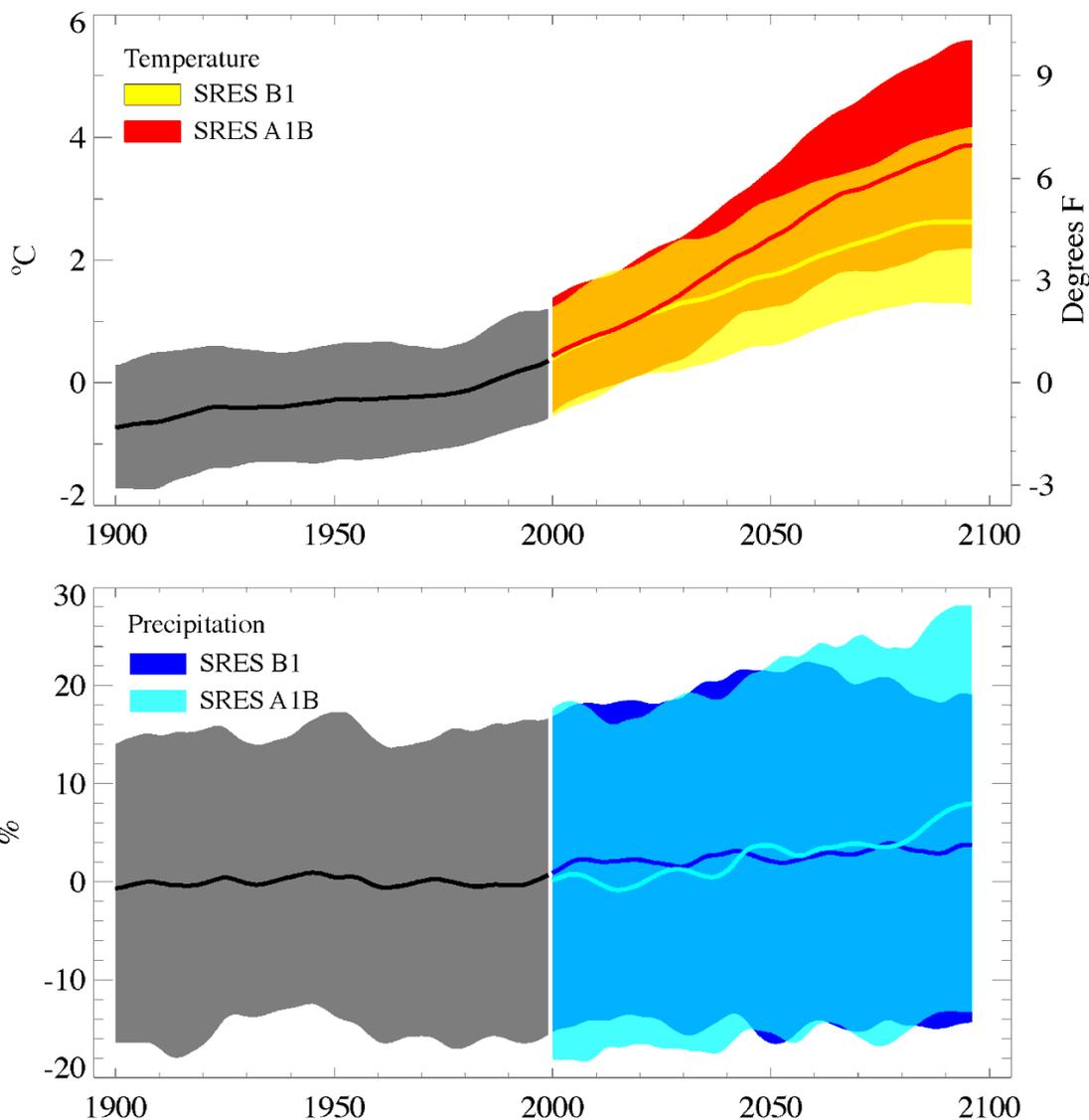
# Climate Change Scenarios

## IPCC AR 4 Emissions Scenarios:

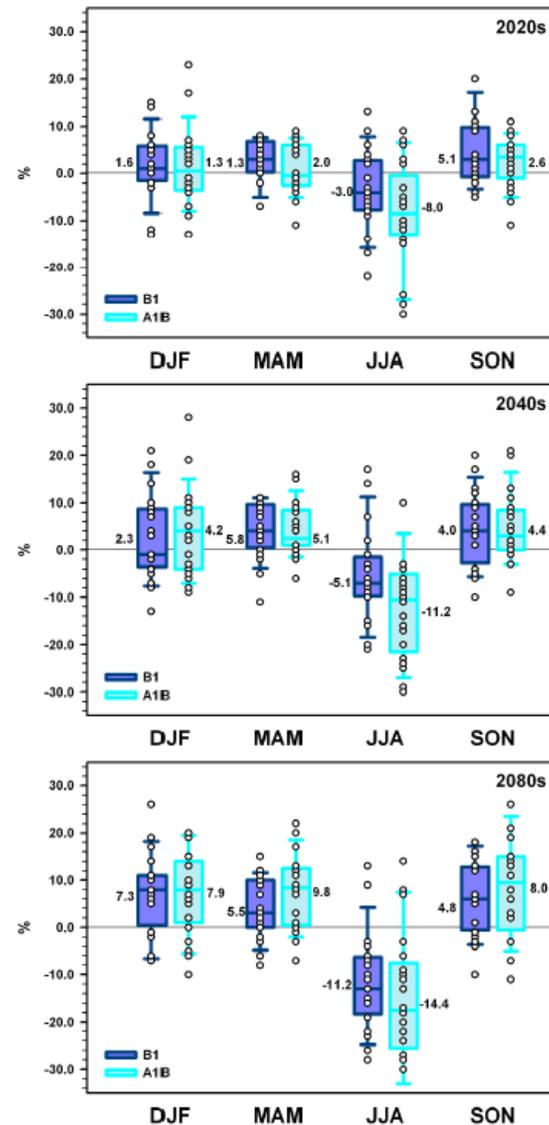
**A1B** Medium High

**B1** Low

Figure shows change compared with 1970 - 1999 average



# Seasonal Precipitation Changes for the Pacific Northwest



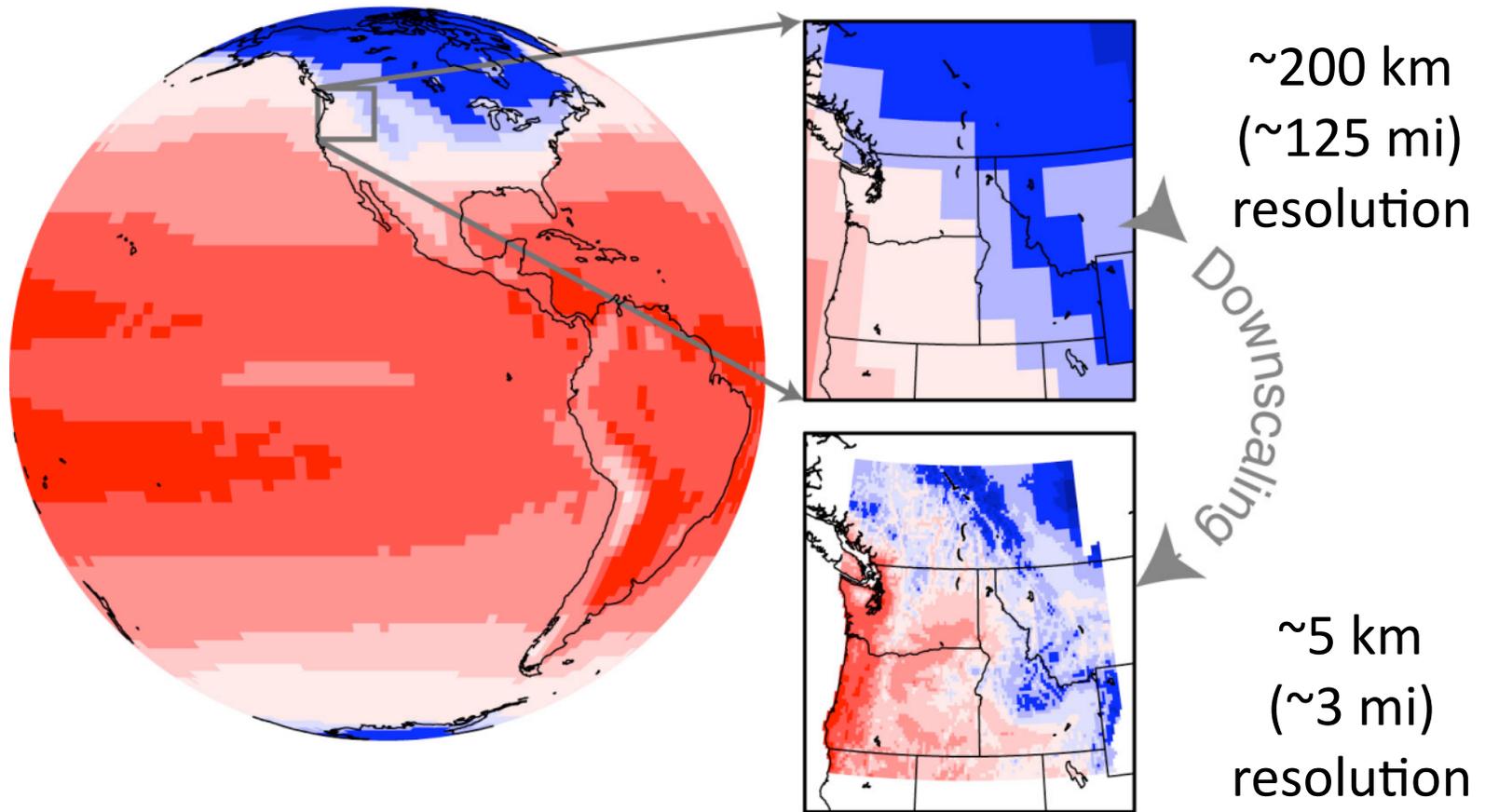
**Figure 10.** As in Figure 9, but for precipitation. The height of the bars indicates actual water precipitation but the percentages are calculated with respect to a reference value for that season, so that -11% in JJA is much less than -11% in DJF. The reference values for the extremes are that model's 20th century mean for that season (or annual mean), and for the REA average the reference is the all-model 20th century value. Unlike for temperature, for any season some models project increases and some project decreases, though the vast majority project decreases for summer and increases for winter by the 2080s.



# Downscaling

## Relates the “Large” to the “Small”

Global Climate Model Air Temperature



# Statistical Downscaling Approaches

## Composite Delta Method

### Strengths:

- Simple, easy to explain “snapshot” of average future conditions
- Incorporates realistic historical daily time series and spatial variability
- Provides 91 years of historical variability combined with changes in T and P for each future time frame and emissions scenario
- Projections are easily relate to stakeholder knowledge of historical impacts

### Limitations:

- Incorporates only average changes in mean monthly T and P, not extremes
- Changes are assumed to be the same throughout the region

# Statistical Downscaling Approaches

## Bias Corrected and Spatially Downscaled (BCSD)

### Strengths:

- Incorporates more information from the monthly GCMs, including altered monthly T and P variability in space and time
- Produces a transient (i.e. continually varying) daily time series for 150 years (1950-2098+)
- Simulates rates of change in hydrologic variables
- Offers flexible time period of analysis (one run gives all future time periods)

### Limitations:

- Quality of downscaled realizations is dependent on GCM performance – ***What you get out is only as good as what you put in!***
- Ensemble analysis needed to account for decadal P variability due to relatively small sample size in future time slices (~30 years)
- Daily time series characteristics are not suitable for some kinds of analyses (e.g. analysis of hydrologic extremes)

# Statistical Downscaling Approaches

## Hybrid Delta Method

### Strengths:

- Combines the strengths of the Composite Delta and BCSD methods, while avoiding most of the weaknesses of both
- Incorporates more information from the monthly GCMs, including altered spatial patterns of T and P changes
- Incorporates realistic historical daily time series and spatial variability
- Provides 91 years of historical variability combined with changes in T and P for each future time frame and emissions scenario
- Arguably the best method for evaluating hydrologic extremes (floods and low flows)

### Limitations:

- Quality of downscaled realizations is dependent on GCM performance (spatial patterns only)
- Constrained by the time series behavior in the historic record



# Available PNW Scenarios

Downscaling Approach		A1B Emissions Scenario	B1 Emissions Scenario	
Hybrid Delta	hadcm cnrm_cm ccsm3 echam5 echo_g cgcm3.1_t47 pcm1	2020s	10	10
	miroc_3.2 ipsl_cm4 hadgem1	2040s	10	10
		2080s	10	10
Transient BCSD	hadcm cnrm_cm ccsm3 echam5 echo_g cgcm3.1_t47 pcm1	1950-2098+	7	7
Delta Method	composite of 10	2020s	1	1
		2040s	1	1
		2080s	1	1

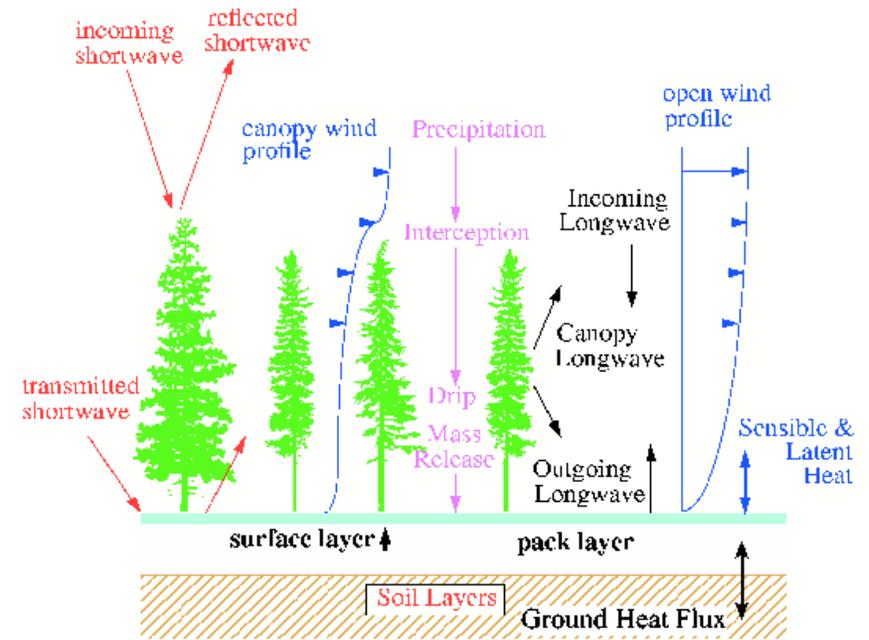
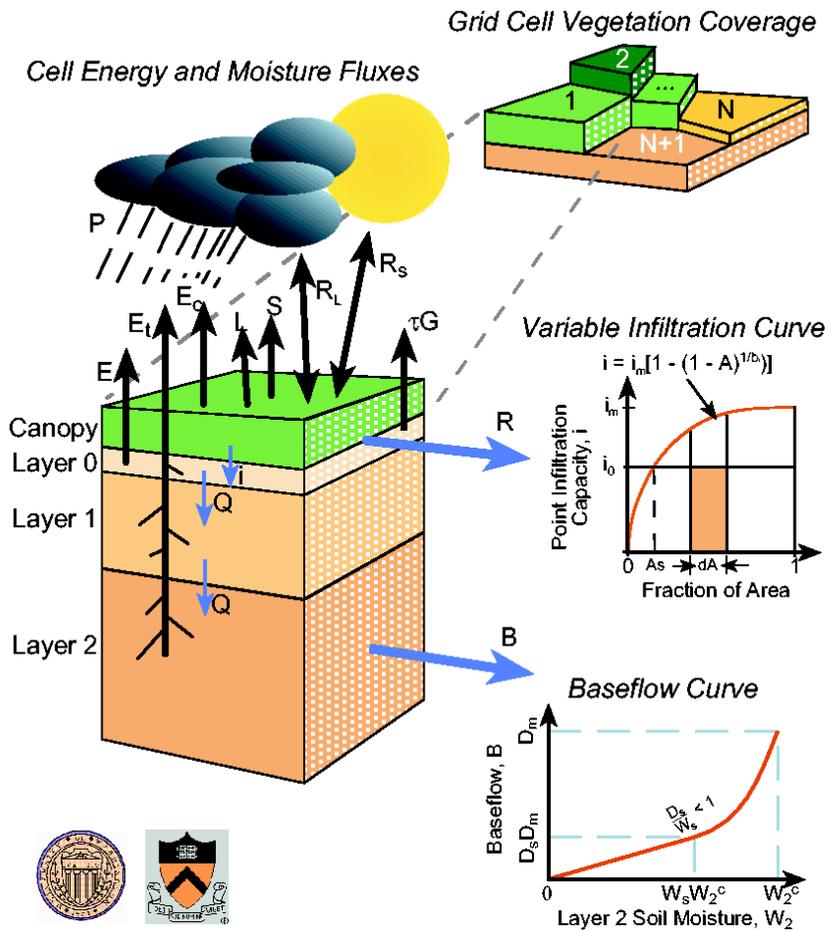
*2020s – mean 2010-2039; 2040s – mean 2030-2059; 2080s – mean 2070-2099*



# Schematic of VIC Hydrologic Model

**Variable Infiltration Capacity (VIC)  
Macroscale Hydrologic Model**

- Sophisticated, fully distributed, physically based hydrologic model
- Widely used globally in climate change applications
- 1/16 Degree Resolution  
(~5km x 6km or ~ 3mi x 4mi)



**General Model Schematic**

**Snow Model**



***Sample Results Using  
Different Statistical  
Downscaling Approaches***

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## ***Hydrologic Products***

### **Key Partners**

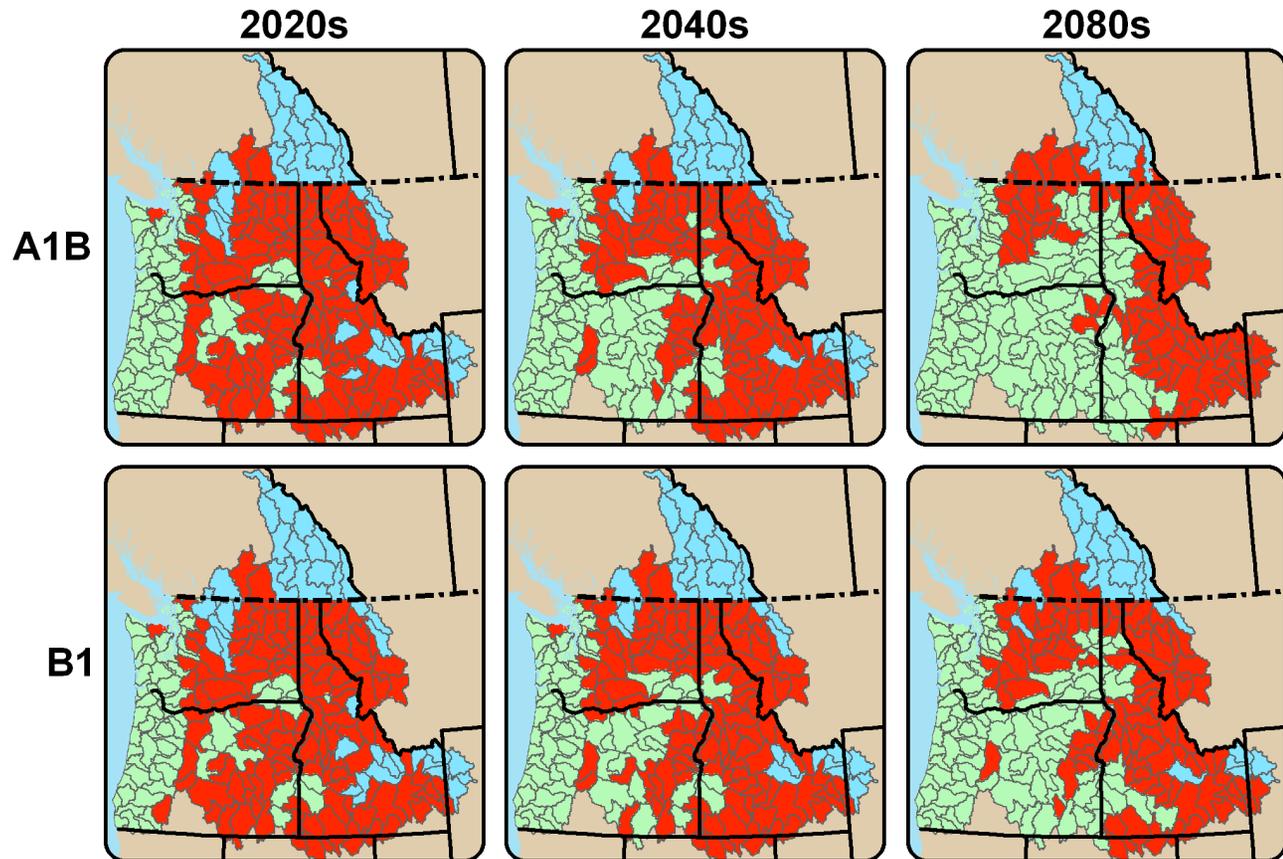
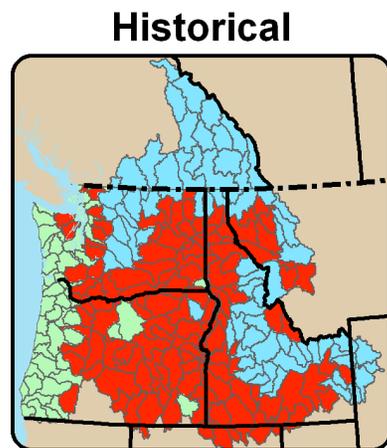
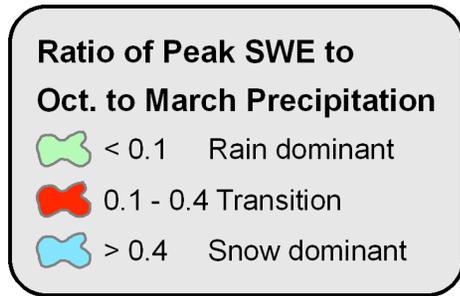
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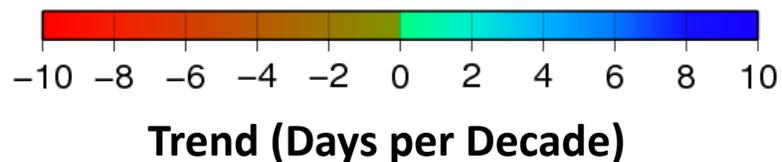
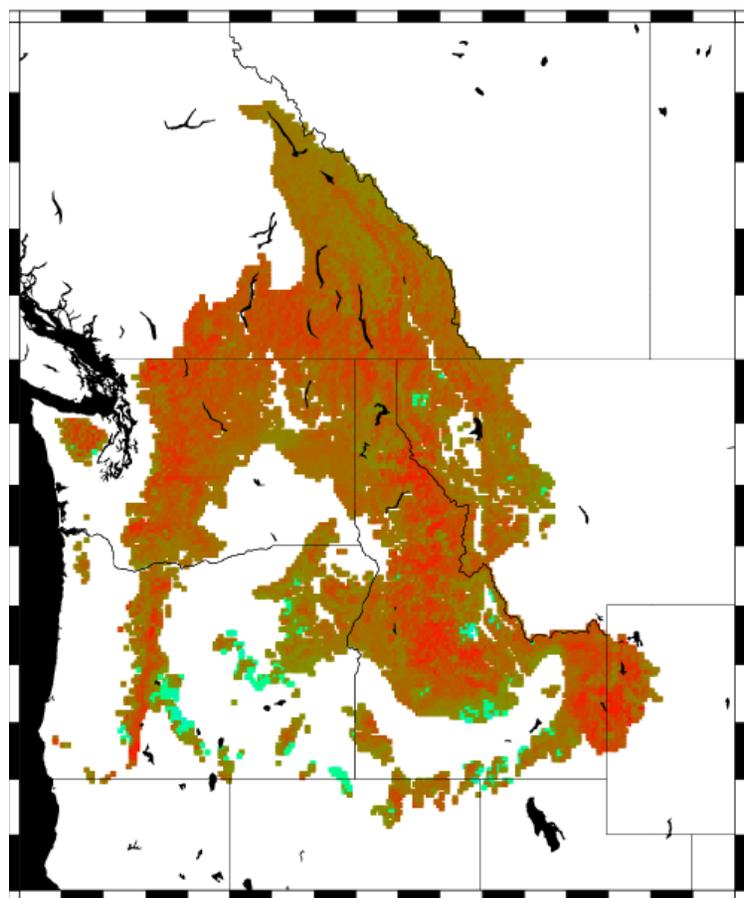
# Changing Watershed Classifications: *Transformation From Snow to Rain*



**\* Based on Composite Delta Method scenarios (multimodel average change in T & P)**



# Trends in Date of Peak SWE



Linear trend for the  
**ECHAM 5 A1B Scenario**  
downscaled using the  
transient **BCSD**  
**Downscaling Method**

\* **50mm SWE Plotting Threshold**



## Site Specific Data

[Research Site Data Spreadsheet](#)

Site: SWAN RIVER NEAR BIGFORK

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### SWAN RIVER NEAR BIGFORK

#### Site Info: SWANR (3031)

USGS Id: [12370000](#)

Latitude (DMS): 48 01 28

Longitude (DMS): 113 58 44

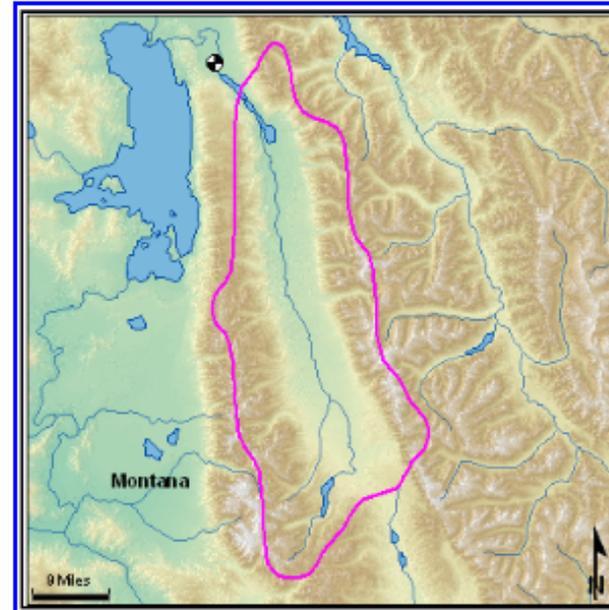
Latitude (Decimal): 48.0244

Longitude (Decimal): -113.9789

Area: 671 miles<sup>2</sup>

Nash Sutcliffe Efficiency = 0.8

[General FTP directory](#)



#### Raw Data

- [vic streamflow daily dt 2020.dat](#)
- [vic streamflow daily dt 2040.dat](#)
- [vic streamflow daily dt 2080.dat](#)
- [vic streamflow daily hd 2020.dat](#)
- [vic streamflow daily hd 2040.dat](#)

#### Bias-Adjusted Data

- [nat bias adjusted vic streamflow daily dt 2020.dat](#)
- [nat bias adjusted vic streamflow daily dt 2040.dat](#)
- [nat bias adjusted vic streamflow daily dt 2080.dat](#)
- [nat bias adjusted vic streamflow daily hd 2020.dat](#)
- [nat bias adjusted vic streamflow daily hd 2040.dat](#)

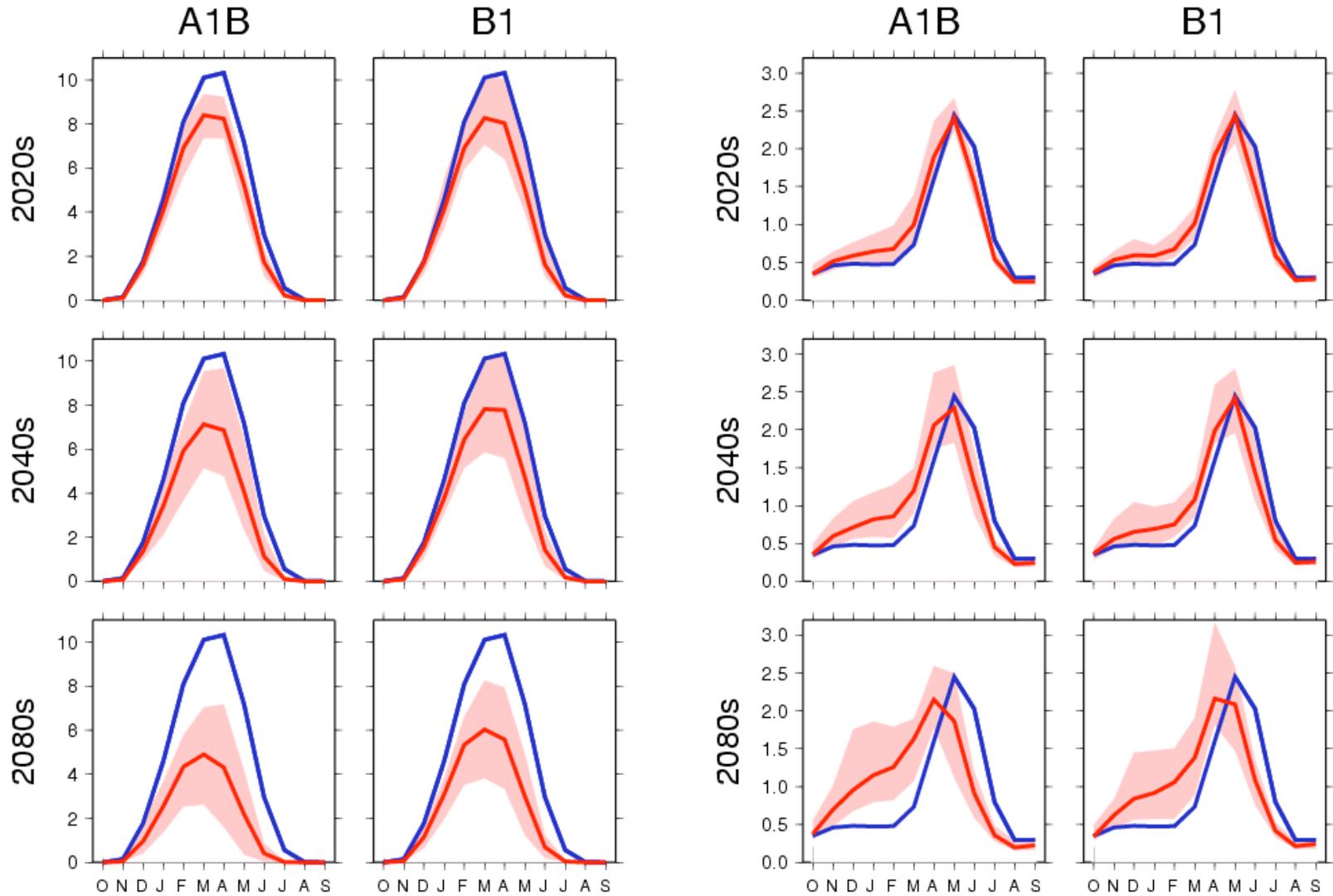
<http://www.hydro.washington.edu/2860/products/sites/?site=3031>



# Snow and Runoff Summary (Swan River Near Bigfork)

snow water equivalent (in):

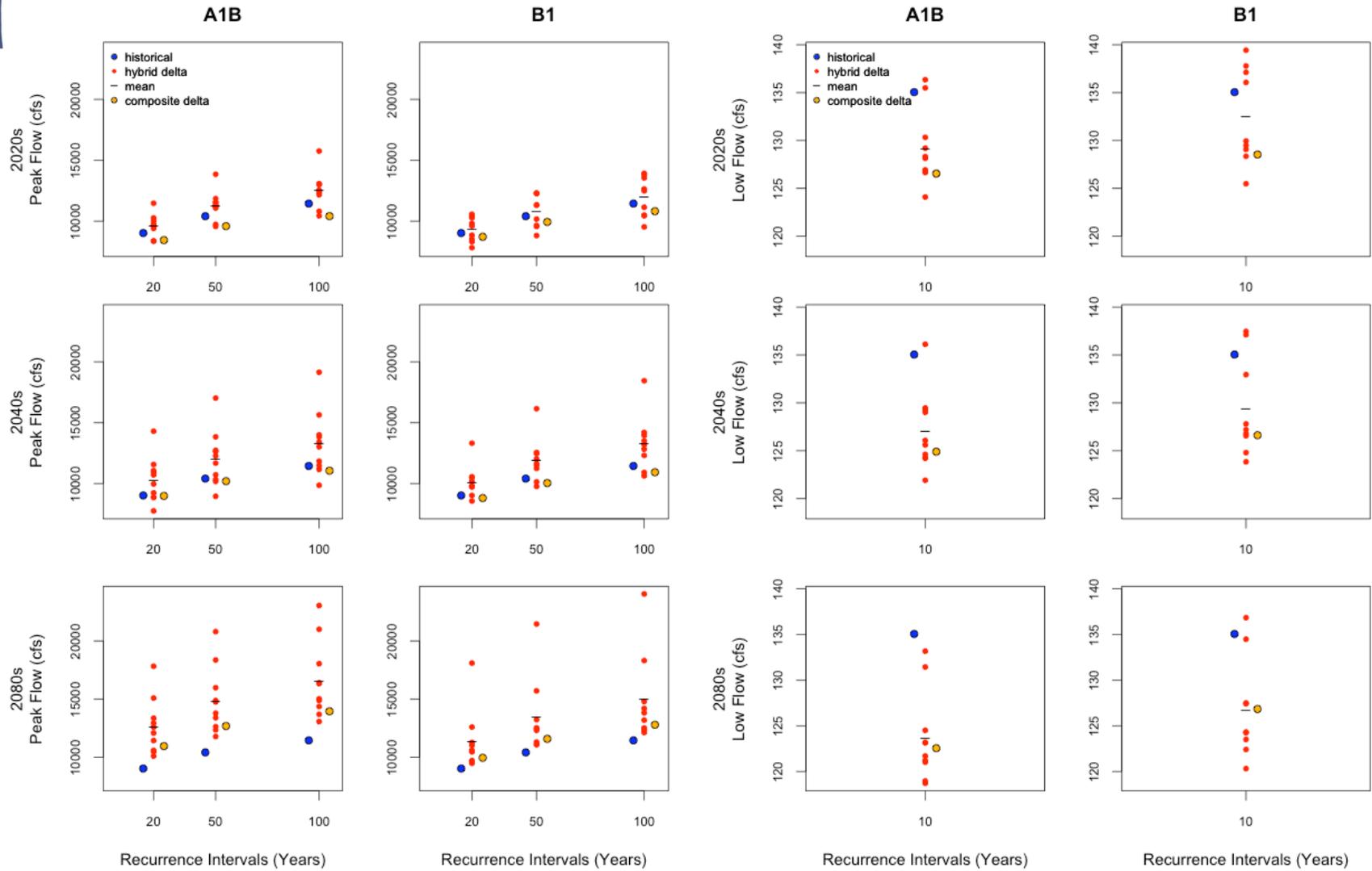
combined flow (in):



Scenario Ensembles Ensemble Mean Historical Mean



# Q100 and 7Q10 Summary (Swan River Near Bigfork)

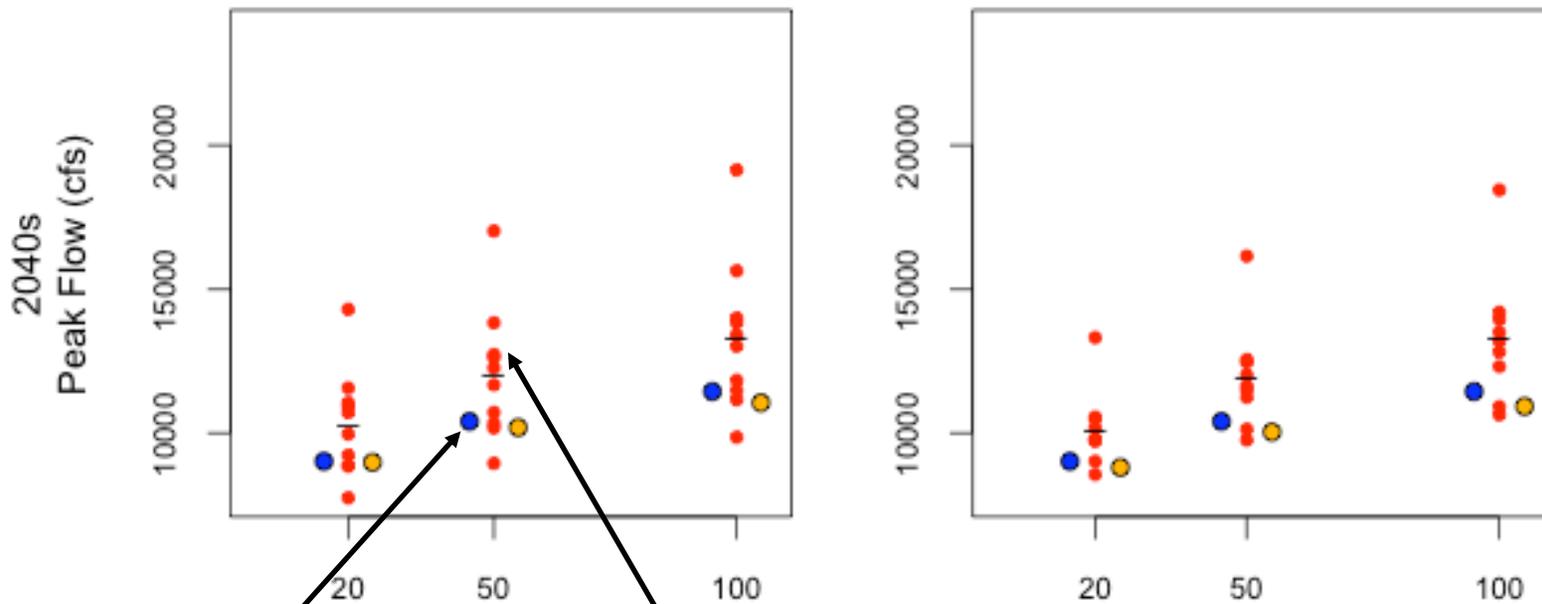


Scenario Ensembles    Ensemble Mean    Historical Mean

# 2040s Changes in Flood Risk Swan River Near Bigfork

A1B

B1



Historical

10 Member Ensemble  
Using the Hybrid Delta  
Downscaling Approach



# Who's Using the Data?

Draft study results (to be finalized Spring 2010) are already being used and evaluated by a wide range of stakeholders including:

- USGS
- Bonneville Power Administration
- U.S. Bureau of Reclamation
- U.S. Army Corps of Engineers
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- Boise Aquatic Research Laboratory
- National Marine Fisheries Science Center



## Next steps...

Extending the approach to additional western US watersheds in partnership with:

- US Forest Service
- US Fish and Wildlife Service
- Boise Aquatic Sciences Lab
- Trout Unlimited

