Hydrologic sensitivities to climate change in the Columbia River Basin

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in collaboration with **Tapash Das[C], David Pierce[D], Daniel Cayan[D], and Alan Hamlet[A,B]**

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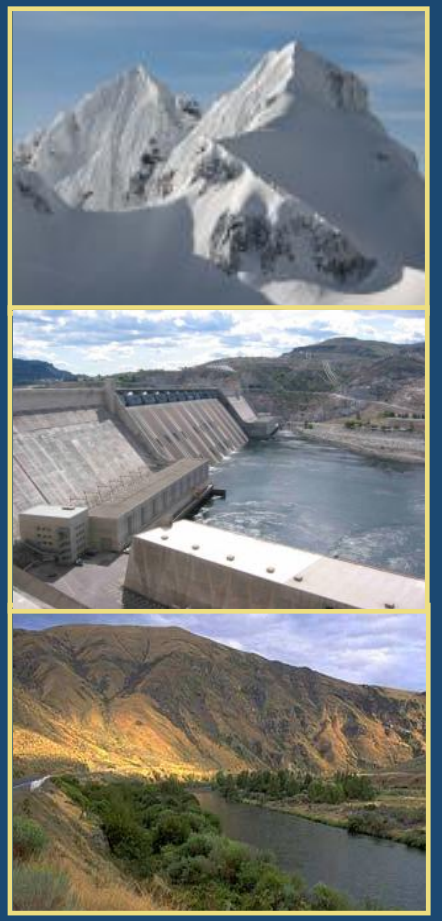
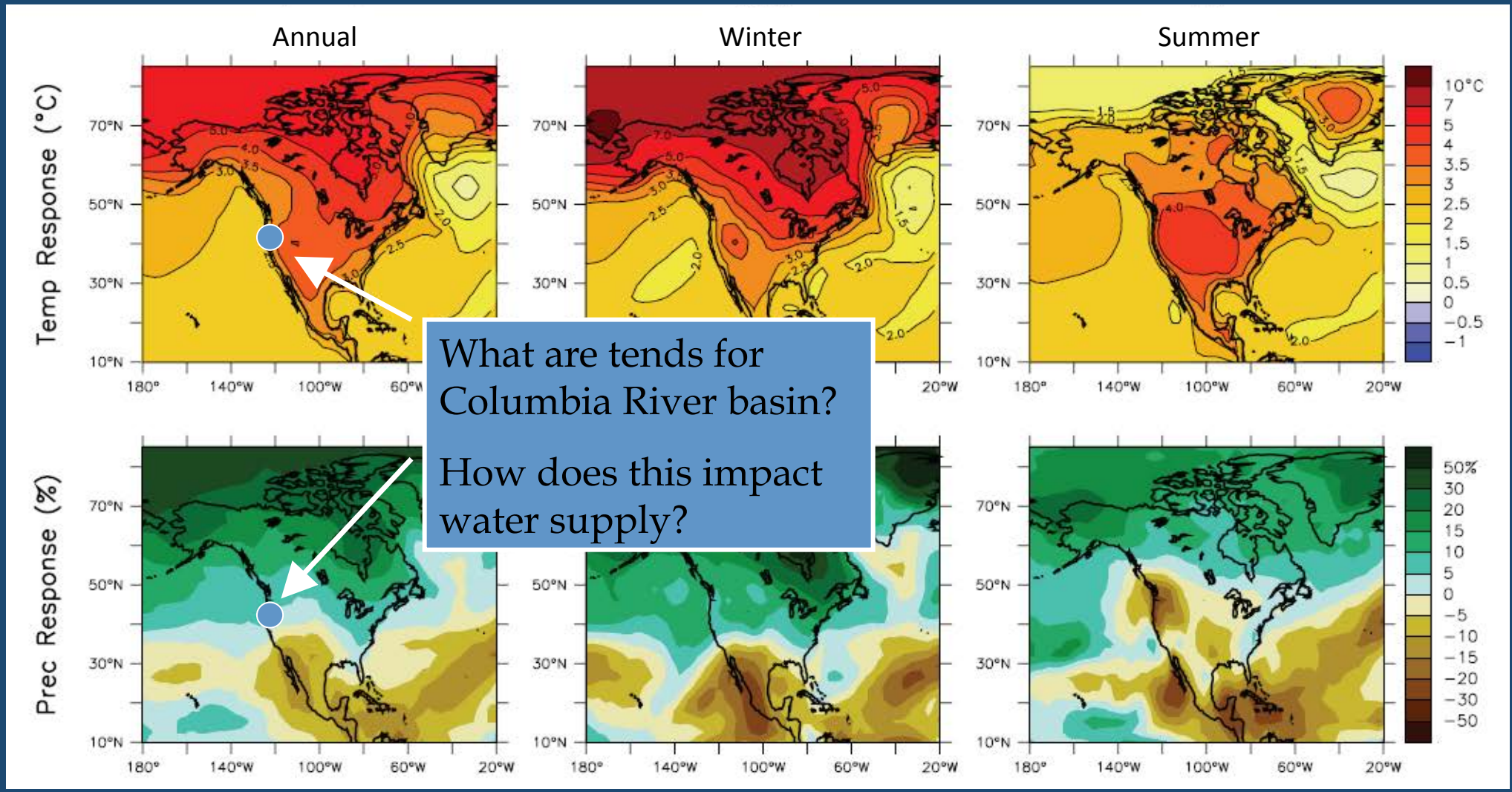


September 13, 2012
WA-AWRA 2012 Annual Conference, Ellensburg, WA

Intergovernmental Panel on Climate Change (IPCC) 2007



Consensus Forecasts of Temperature and Precipitation Changes from AR4 GCMs

Climate Change in Columbia River basin

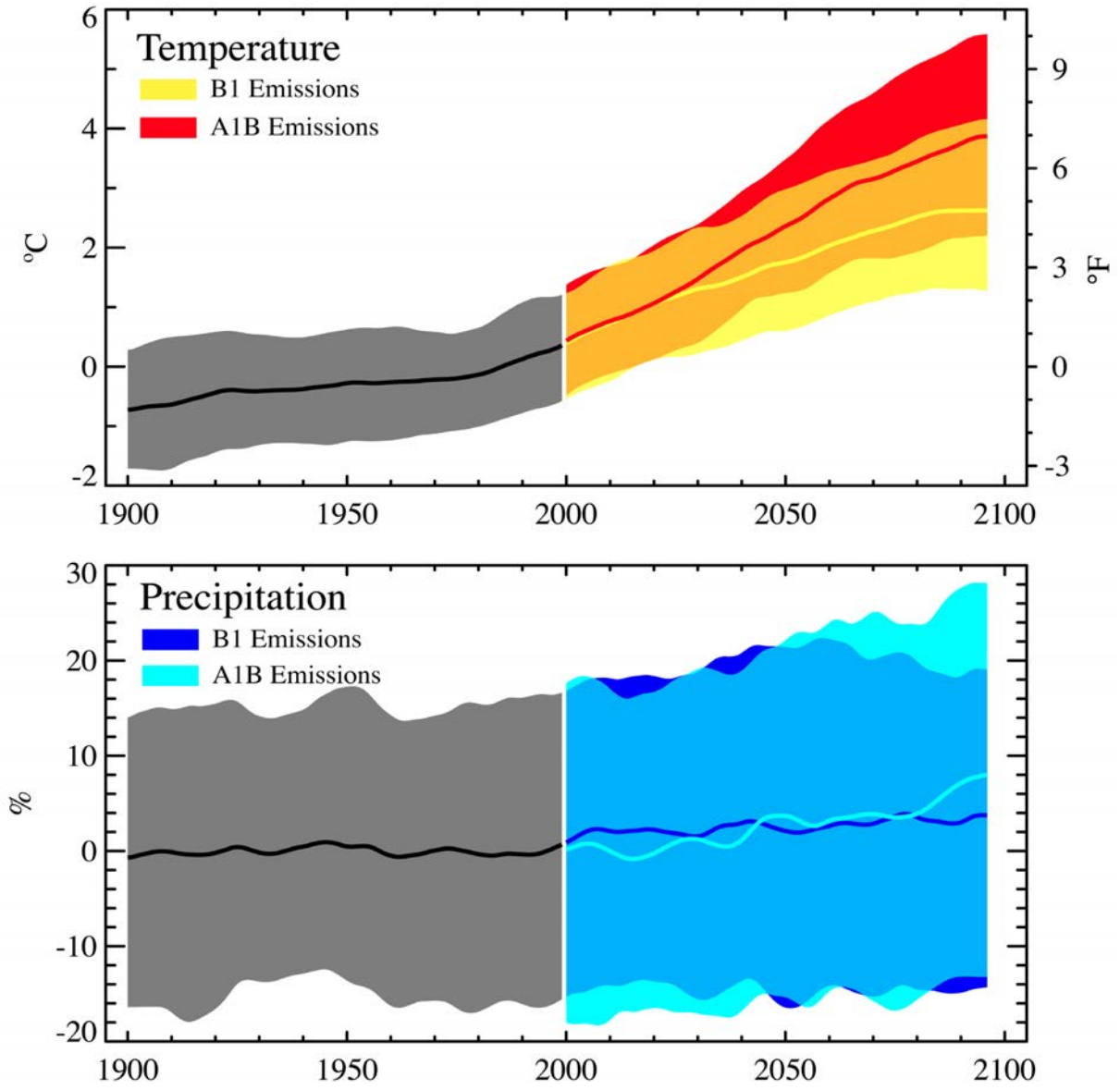


Figure from Washington State Climate Impacts Assessment Report, 2009. All changes are relative to 1970-1999 averages.

Columbia River Basin

Hydroclimate diversity:

- Precipitation varies with annual averages of less than 15 cm to more than 500 cm
- Vegetation and soil types vary
- Flow at Dalles varies from 36,000 to 1,240,000 cfs (1:34 ratio)

Unique management challenges:

- Most hydropower capacity in N. America (~37 GW)
- Flood control regulation problems
- International management, Columbia River Treaty Review 2014/2024
- Increasing environmental pressures

Information from presentation by Nancy Stephan, BPA and Matt Rea, USACE, 2014/2024 Review, Feb 2011

Multi-model approach

Global Climate Models

downscaling, bias correcting

Hydrology Models

stream routing, bias correcting

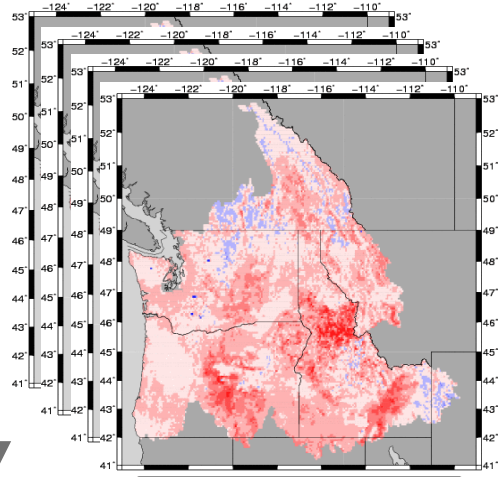
Water Supply Operations Models

Climate Impact

Hydrologic sensitivities approach

Global Climate Models

maps of sensitivities to temp & precip change



Changes in Central Tendencies

Climate Impact

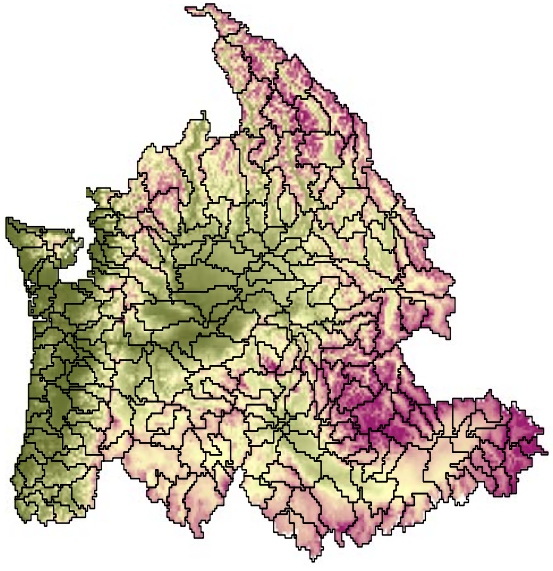
Hydrologic Sensitivity Method

Hydrologic Model

Variable Infiltration Capacity (VIC)
Unified Land Model (ULM)
Catchment Land Surface Model

Spatially…

1/16° lat-lon
226 subbasins



Measures of runoff (Q) change

$$\textbf{Precipitation Elasticity} = \frac{\frac{Q_{ref+\%\Delta} - Q_{ref}}{Q_{ref}}}{\%\Delta}$$

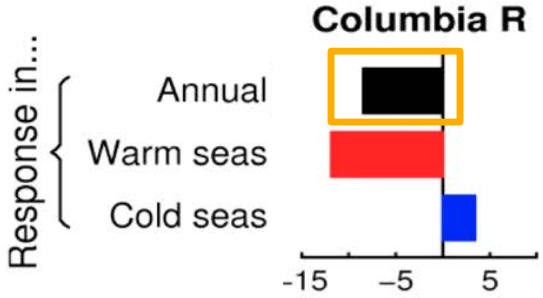
$$\textbf{Temperature Sensitivity} = \frac{\frac{Q_{ref+\Delta°C} - Q_{ref}}{Q_{ref}}}{\Delta°C}$$

Seasonally…

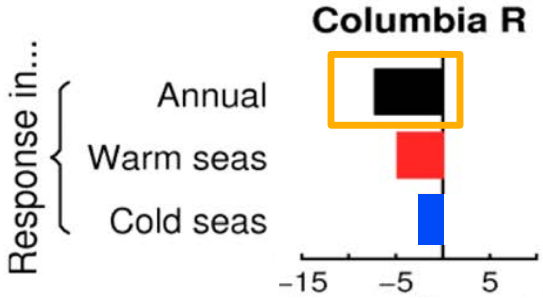
- warming applied annually
- warming applied in warm season only (Apr-Sep)
- warming applied in cool season only (Oct-Mar)

Seasonal differences (3°C warming) at the Dalles

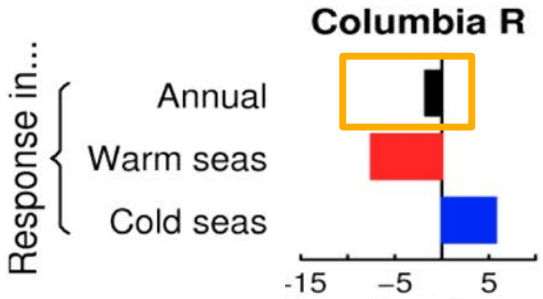
a) Warming applied year–round



b) Warming applied in warm season only (Apr-Sep)



c) Warming applied in the cool season only (Oct-Mar)



Streamflow change (%) for 3°C warming

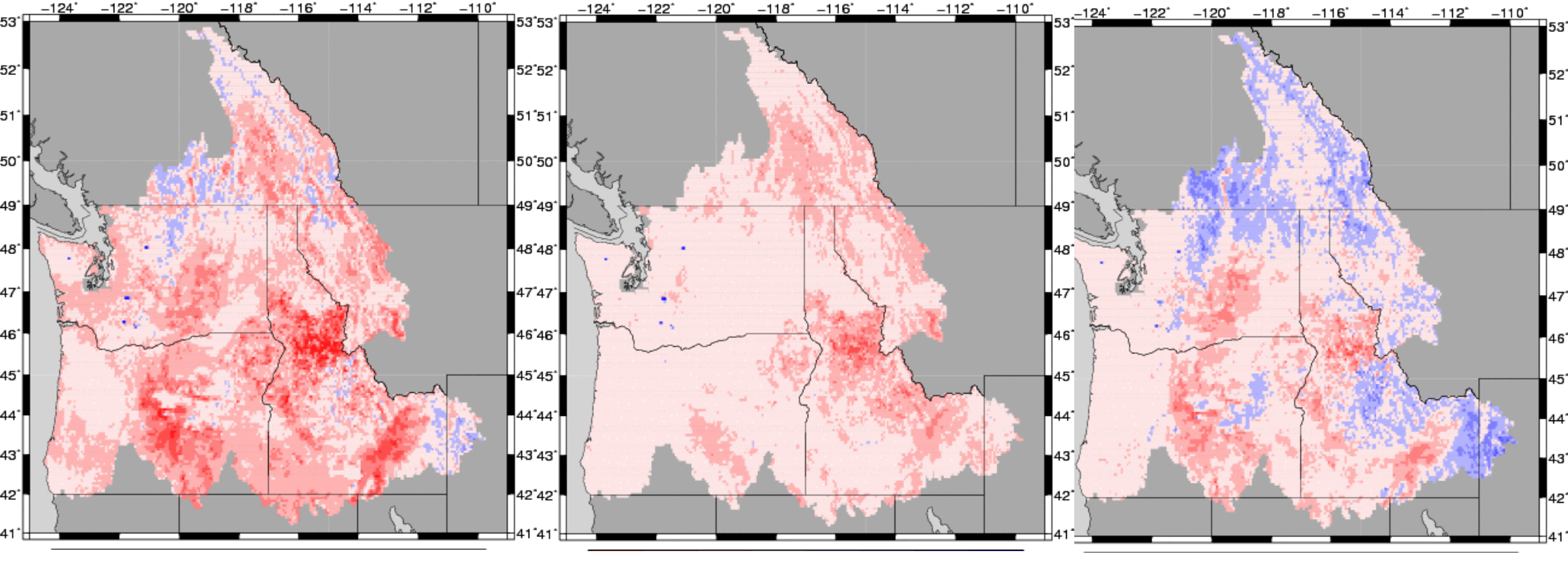
Figures from Das et al., 2011 in Geophysical Research Letters, color scheme modified

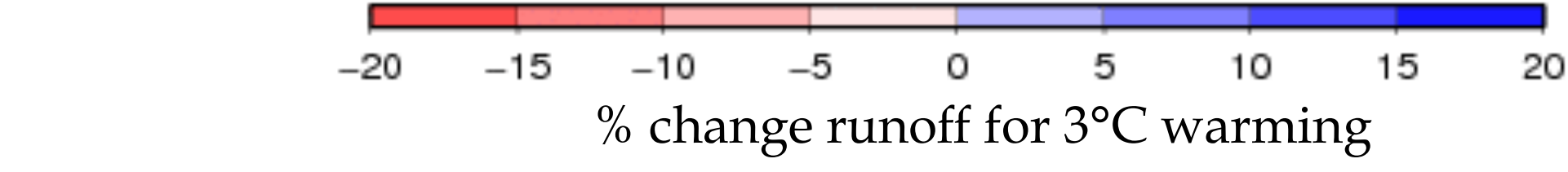
Columbia Basin at 1/16th degree Annual Responses (VIC)

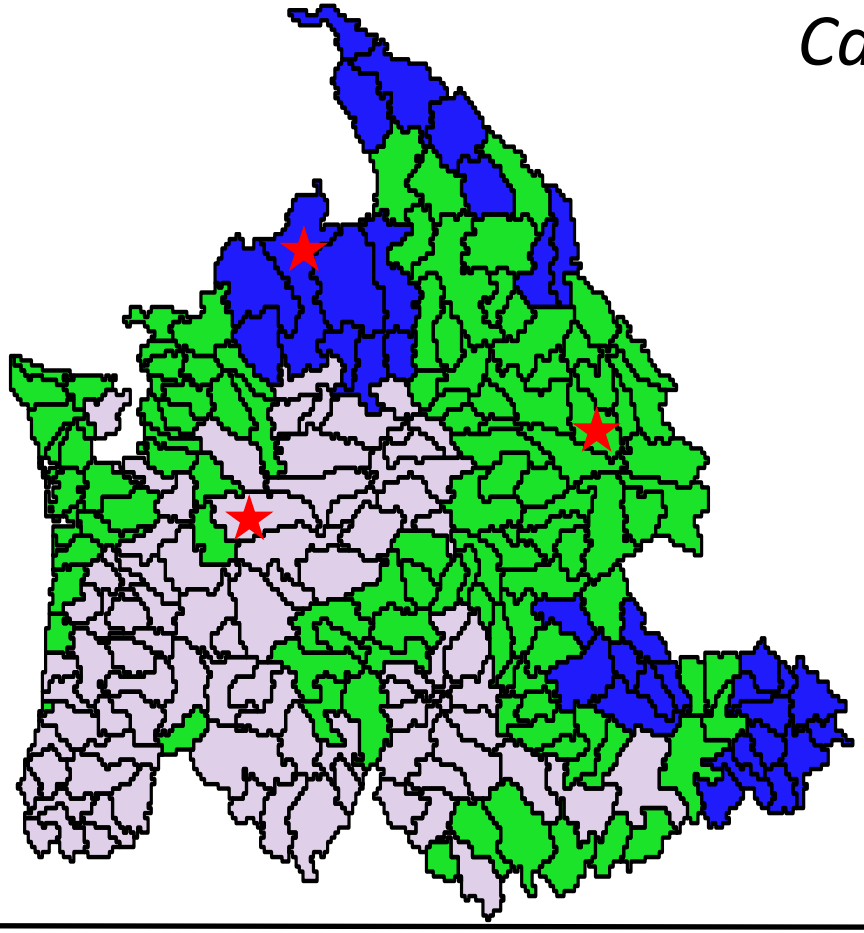
Year-Round Warming

Warm-Season Warming

Cool-Season Warming







*Categories of Sub-basin Responses to changes in **annual** flow (VIC)*

LEGEND

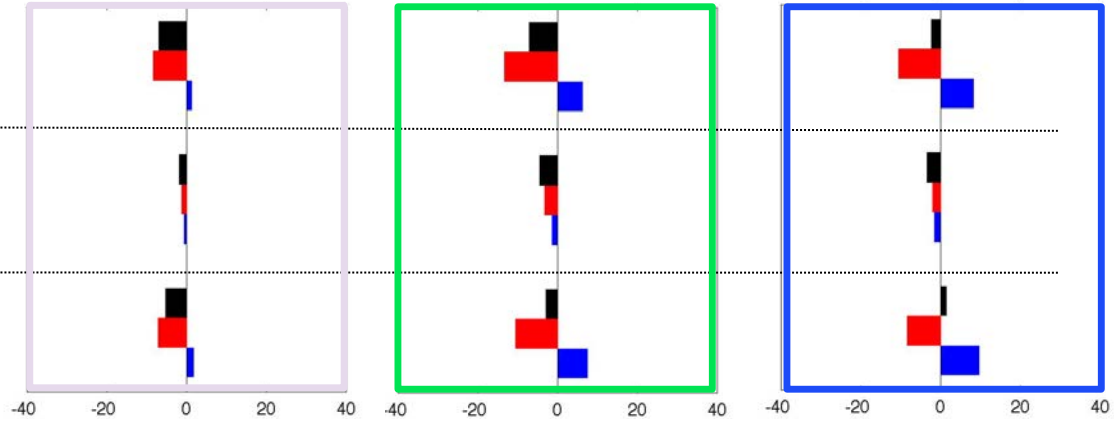
- Watershed units
- More sensitive to cool season warming
- More sensitive to warm season warming
- Cool season warming positive
- Example watersheds (below)

Example watersheds:

Warm applied year-round

Warming applied in warm season only

Warming applied in cool season only

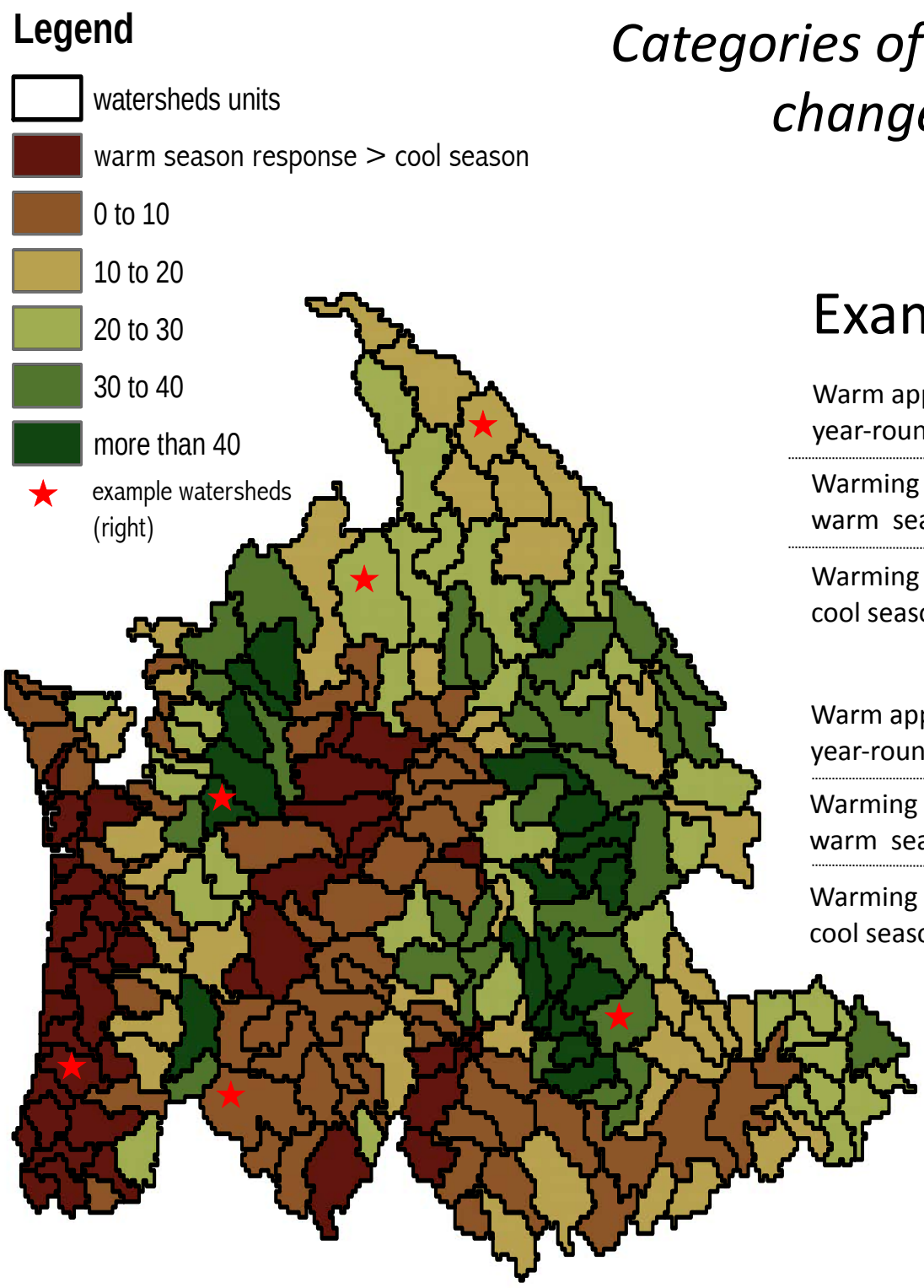


Streamflow change (%)

Responses in:

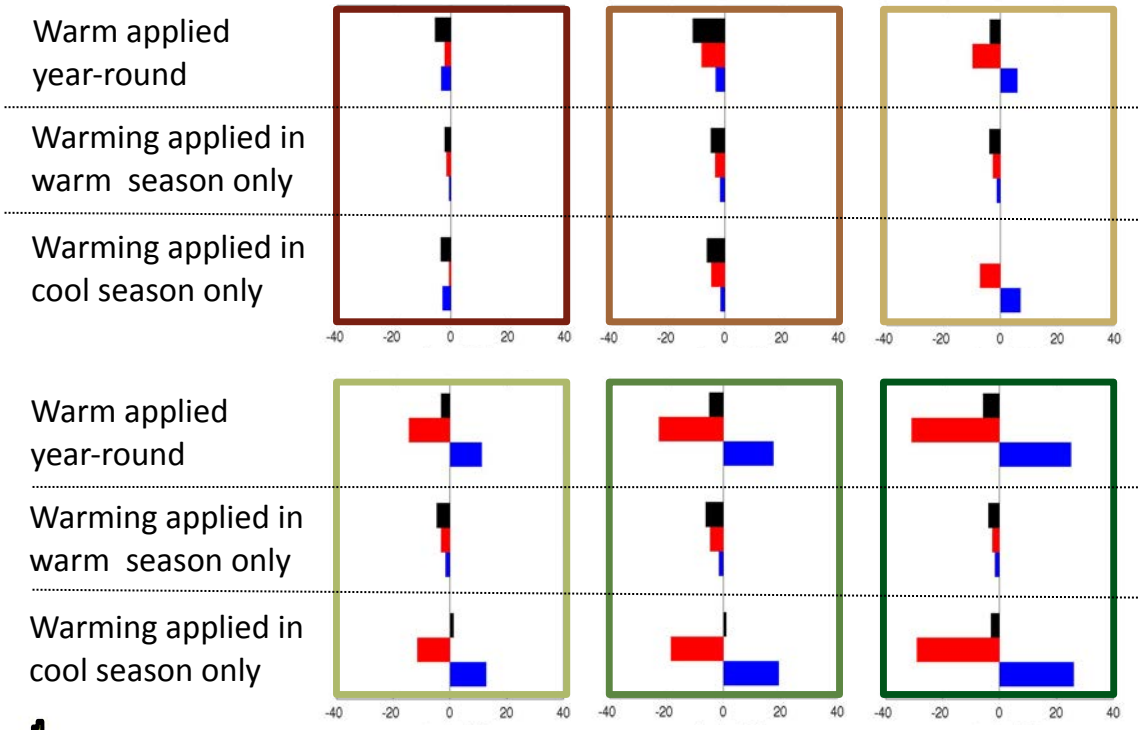
- annual flow
- warm season flow
- cool season flow

*Categories of sub-basin responses to changes in **seasonality***



Responses in:
- annual flow
- warm season flow
- cool season flow

Example watersheds:



Differences in warm and cool season responses when warming applied in cool season only

Multi-model approach

Global Climate Models

downscaling, bias correcting

Hydrology Models

stream routing, bias correcting

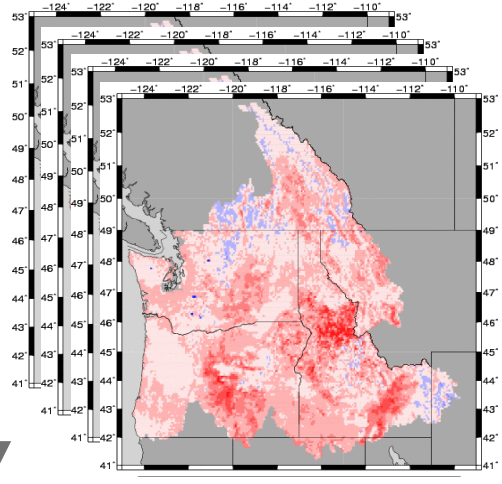
Water Supply Operations Models

Climate Impact

Hydrologic sensitivities approach

Global Climate Models

maps of sensitivities to temp & precip change



Changes in Central Tendencies

Climate Impact

Multi-Model Approach in the Yakima

Global Climate Models

2 emission scenarios x 20 GCMs, for the 2020s, 2040s, 2080s

downscaling, bias correcting

Hydrology Models

Variable Infiltration Capacity (VIC) model

stream routing, bias correcting

Water Supply Operations Models

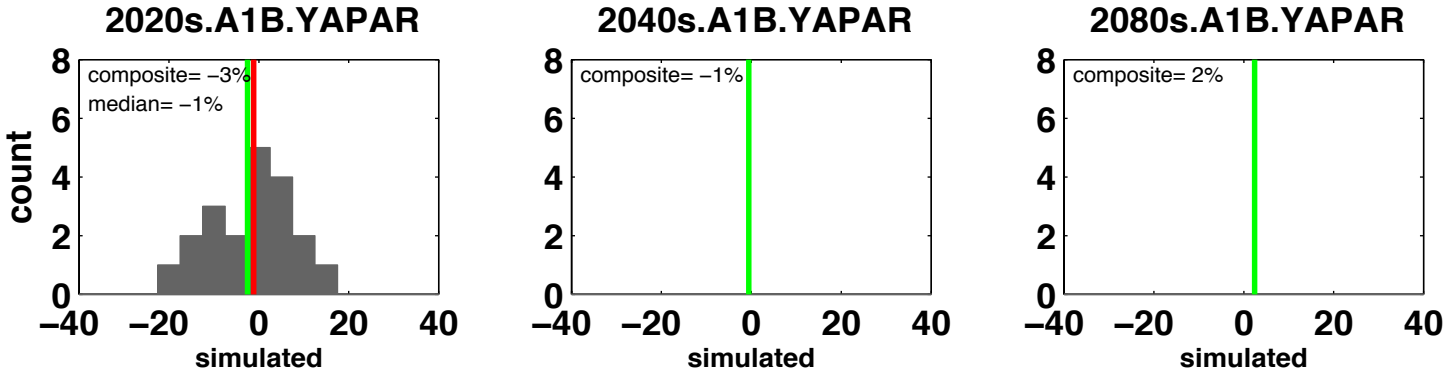
Riverware, USBR Operations model

Climate Impact

Computationally intensive

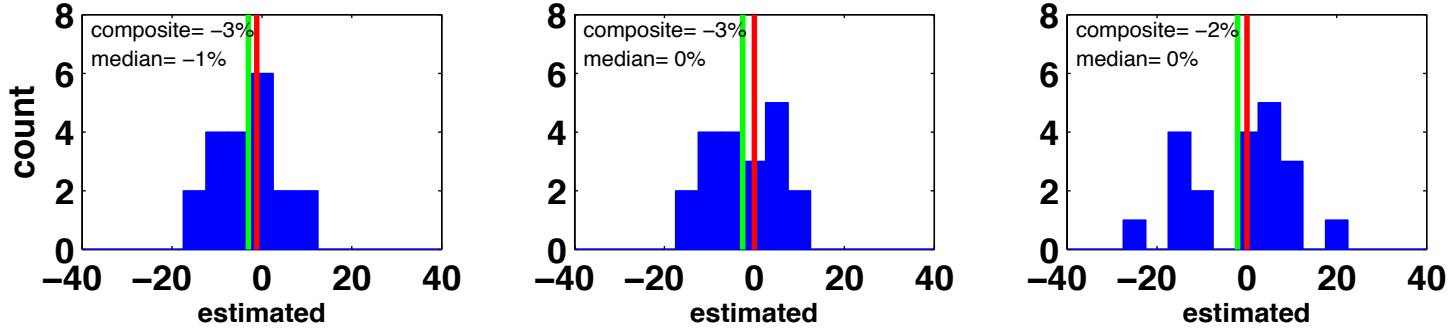
Future scenarios: Long-term annual average

Multi-model approach



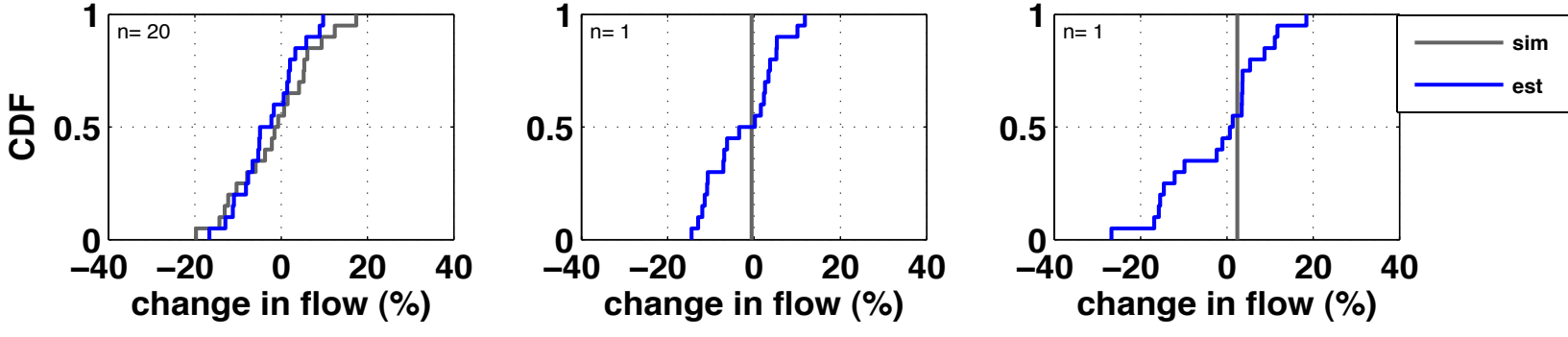
$$\%\Delta Q_{simulated} = (Q_{sim}-Q_{hist})/Q_{hist}$$

Hydrologic Sensitivities approach

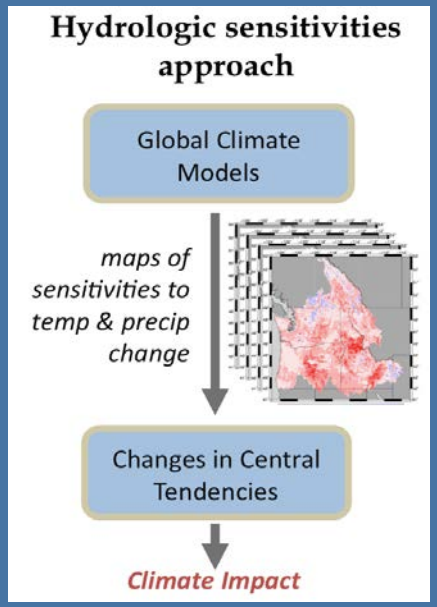


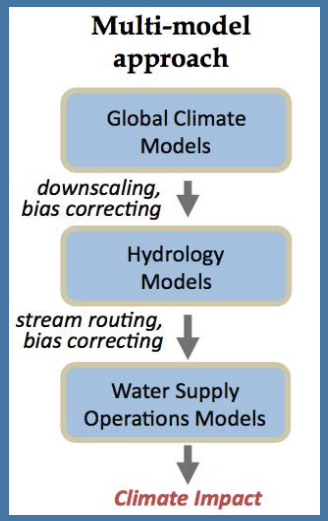
$$\%\Delta Q_{estimated} = \Delta T * T_{sensivity} + \%\Delta P * P_{elastcity}$$

Comparison of approaches for LONG-TERM annual change in streamflow (Q)



Summary





Hydrologic sensitivities approach:

- Provides insights on how the land surface will respond spatially to changes in temperature and precipitation independently
- Quick calculations, provide an estimate of long term average runoff change, can use multiple hydrology models
- When future changes applied, results more conservative and do not capture seasonality

Multi-model approach, in contrast:

- More computationally-intense
- Provides daily values to run through operation models
- Results have precipitation and temperature combined in land surface processes, more realistic seasonality

Together they provide complimentary methods to understanding future uncertainties in Columbia River water supply.

Acknowledgements

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Questions? Suggestions?

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