Selecting climate change scenarios using impact-relevant sensitivities

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Oregon State University

John Kim
U.S. Forest Service

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Table 1. CMIP5 Models Used in This Study and Some of Their Attributes

Model	Center
BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration
BCC-CSM1-1-M	Beijing Climate Center, China Meteorological Administration
BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University, China
CanESM2	Canadian Centre for Climate Modeling and Analysis
CCSM4	National Center of Atmospheric Research, USA
CESM1-BGC	Community Earth System Model Contributors
CESM1-CAM5	Community Earth System Model Contributors
CESM1-FASTCHEM	Community Earth System Model Contributors
CESM1-WACCM	Community Earth System Model Contributors
CMCC-CESM	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CMCC-CM	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CNRM-CM5	National Centre of Meteorological Research, France
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CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organization/ Queensland Climate Change Centre of Excellence, Australia
EC-EARTH	EC-EARTH consortium
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GISS-E2-R	NASA Goddard Institute for Space Studies, USA
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HadCM3	Met Office Hadley Center, UK
HadGEM2-AO	Met Office Hadley Center, UK
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INMCM4	Institute for Numerical Mathematics, Russia
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Lots of Global Climate Model output available

Rupp et al. JGR 2013

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Lots of Global Climate Model output available

Rupp et al. JGR 2013

To address this frustration…

Identify subset Global Climate Models that:

1) good performers, meaning they adequately simulate historical climate, providing plausible results for the region of interest
2) span the range of possible futures for the variables that are most important to the impact under investigation

Image from http://www.activatedesign.co.nz/blog/the-frustration-of-almost-perfect-websites/

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Global Climate Model ranking for Pacific Northwest by Rupp et al. JGR 2013

1. CESM1-CAM5
2. CCSM4
3. CNRM-CM5
4. HadGEM2-ES
5. HadGEM2-CC
6. CMCC-CM
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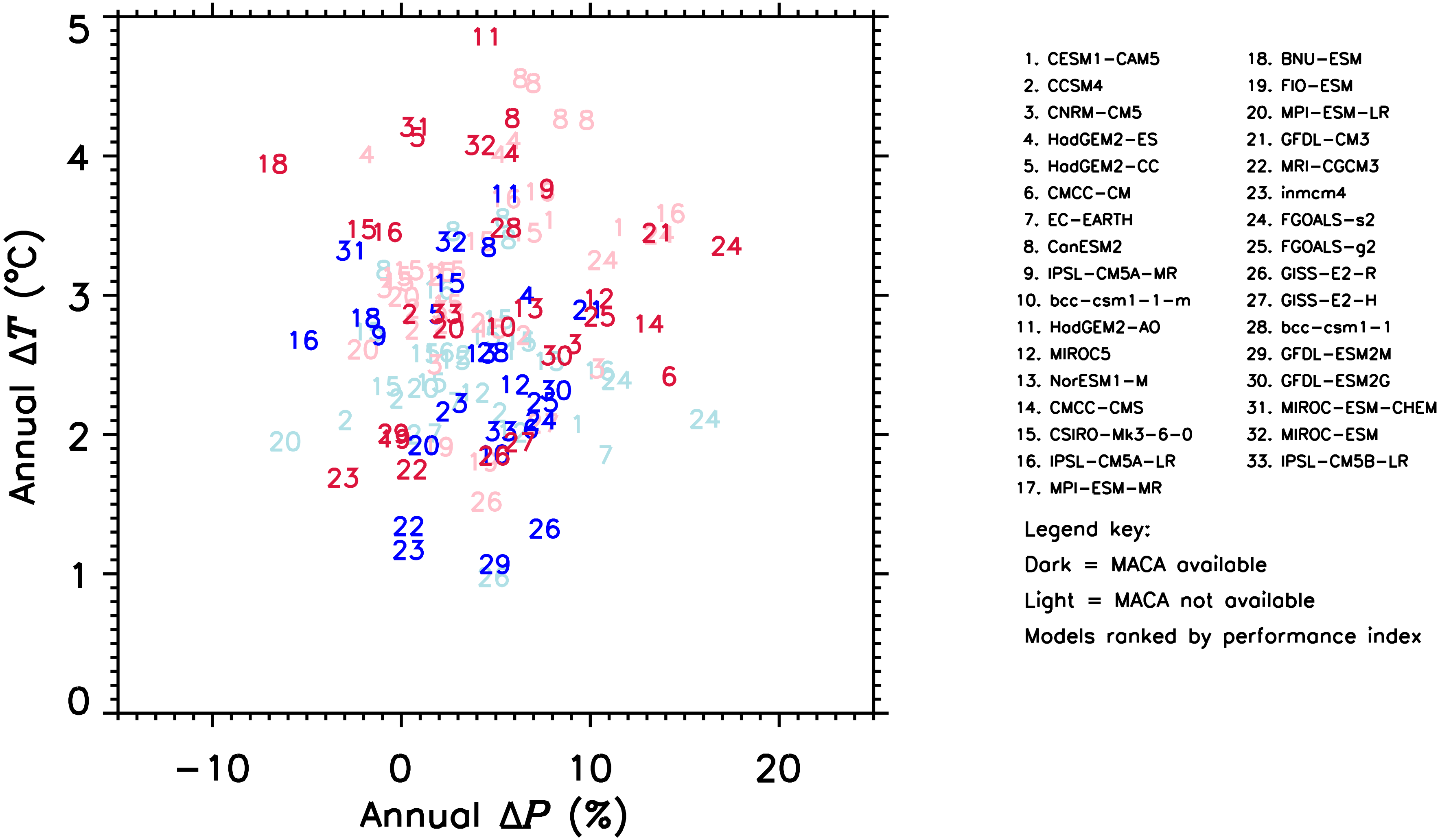
Global Climate Models precipitation and temperature responses



GCM ranking from Rupp et al. (JGR 2013), blue = RCP 4.5, red = RCP 8.5, Eastern Washington region 1970-1999 to 2041-2070

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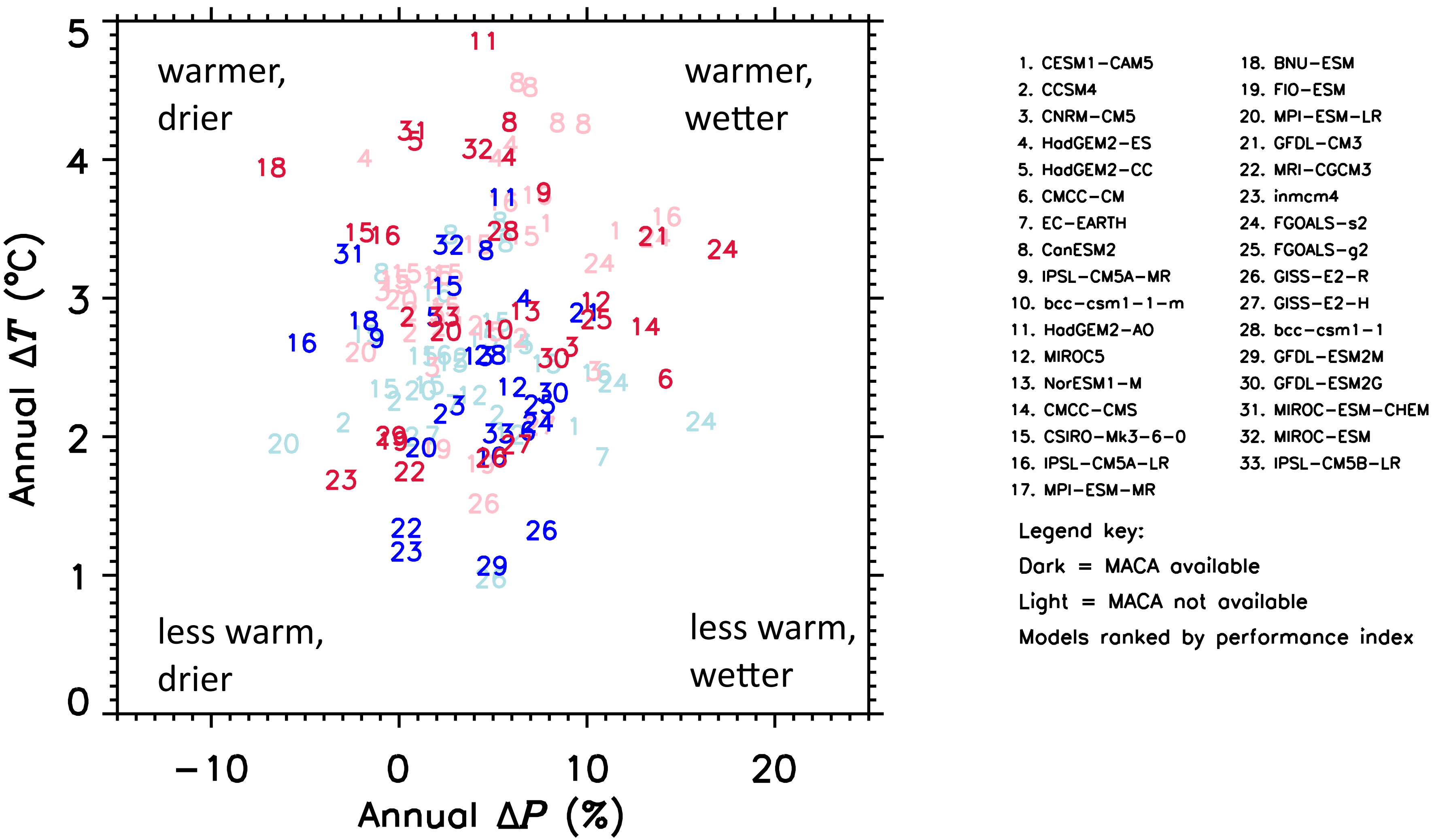

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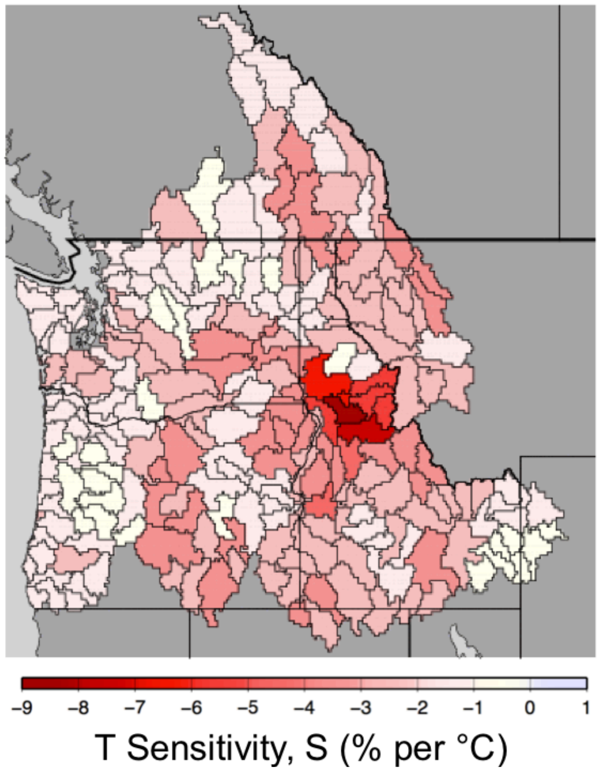
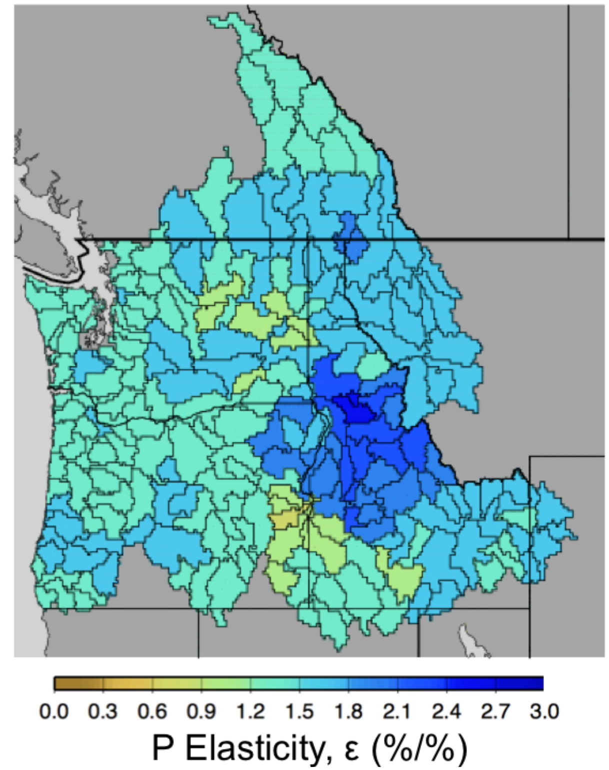
Impact-relevant concept:
Hydrologic Sensitivities from Vano et al.





$$\text{Temperature Sensitivity } (S) = \frac{\dfrac{Q_{ref+\Delta°C} - Q_{ref}}{Q_{ref}}}{\Delta°C}$$

$$\text{Precipitation Elasticity } (\varepsilon) = \frac{\dfrac{Q_{ref+\Delta\%} - Q_{ref}}{Q_{ref}}}{\Delta\%}$$

Figures from Vano et al. (WRR, in review)

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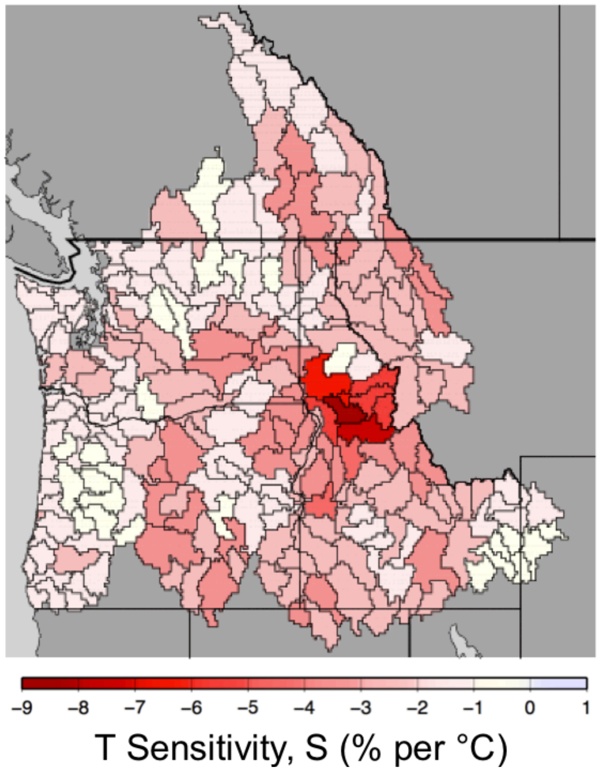

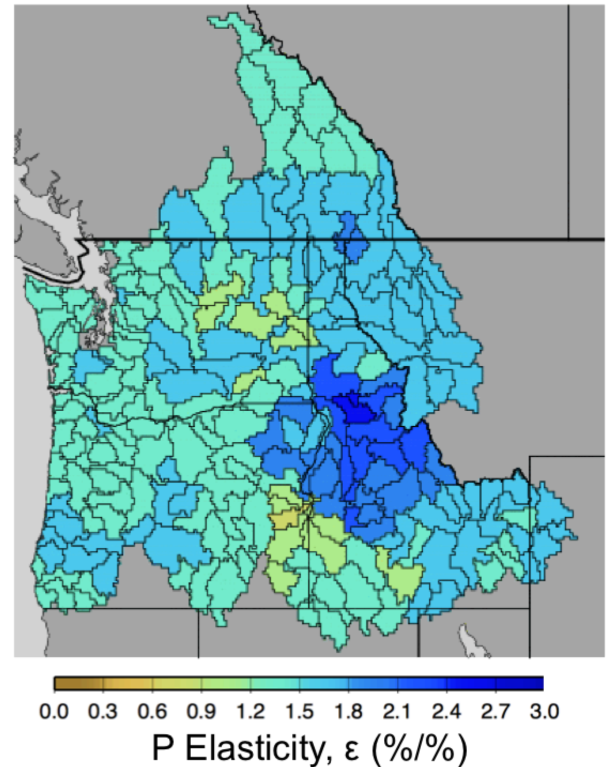

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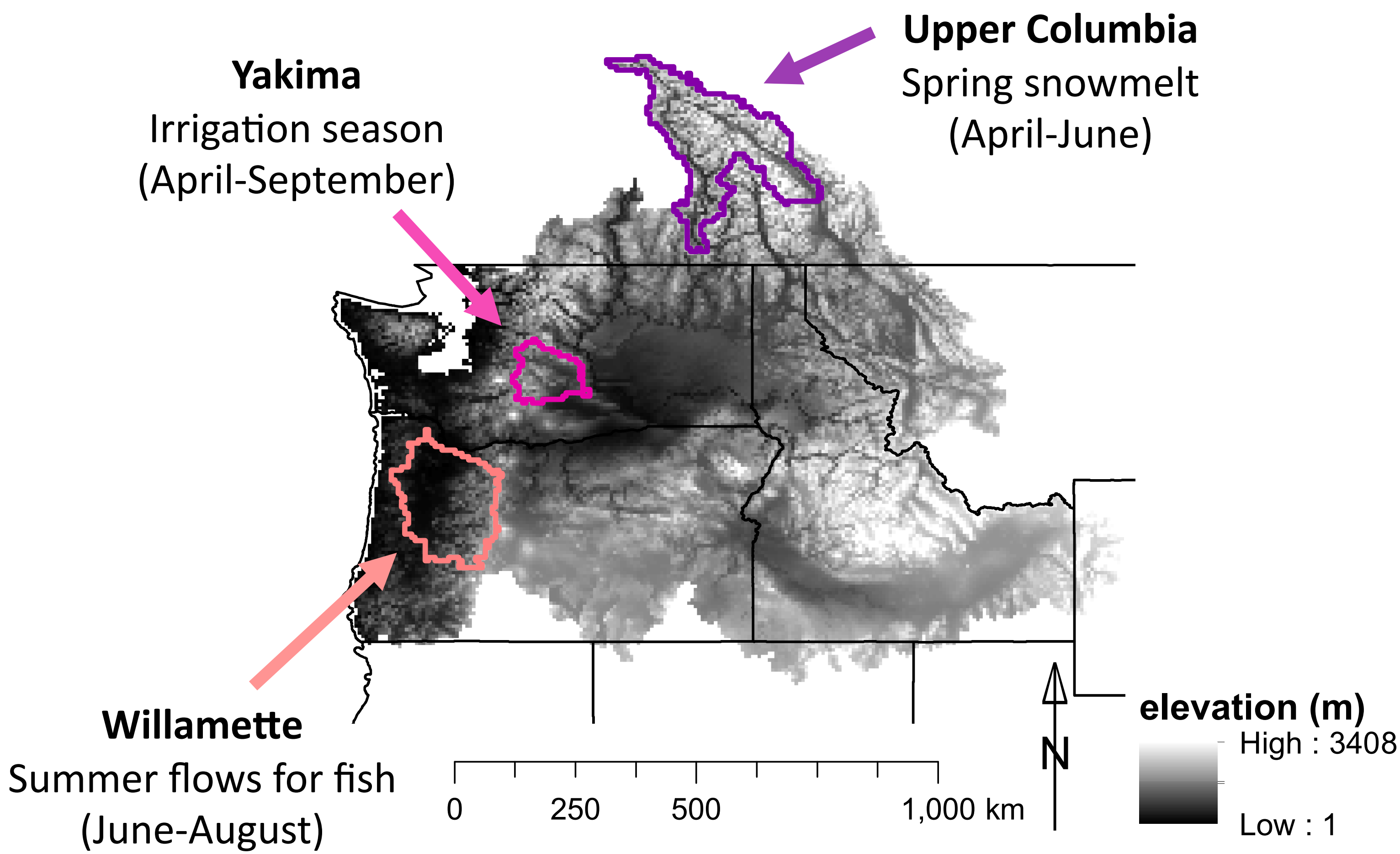
$$\text{Streamflow Change} = S(\Delta T)\,\Delta T + \varepsilon(\Delta P)\,\Delta P$$

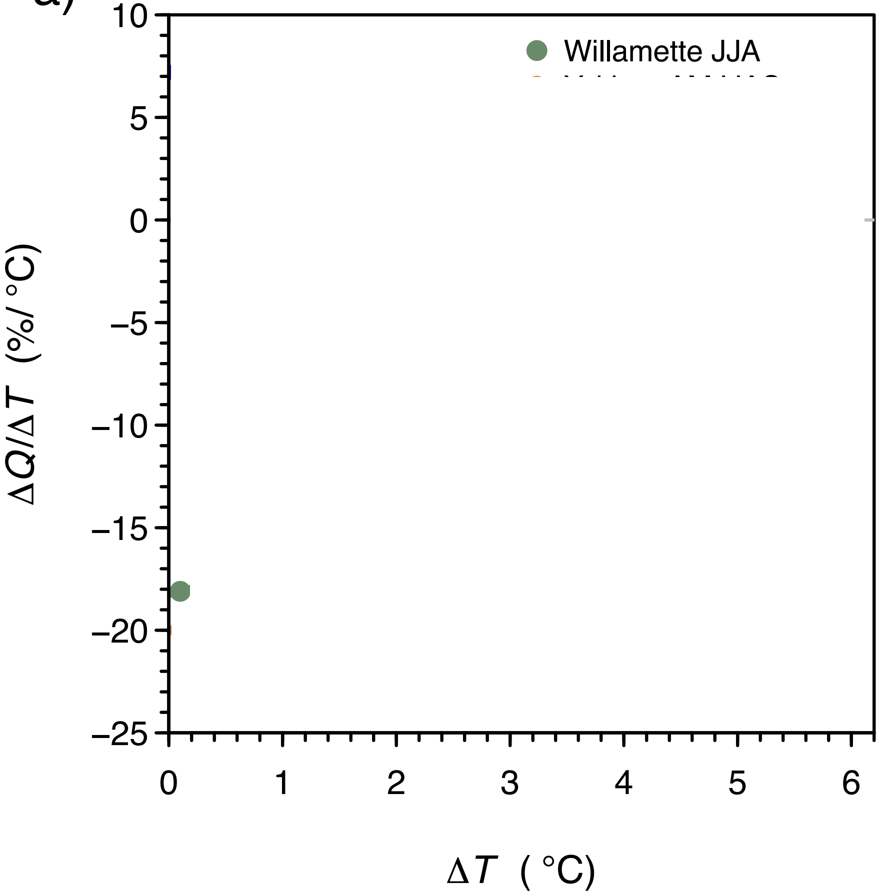
Figures from Vano et al. (WRR, in review)

Impact:

Seasonal Streamflow



a)



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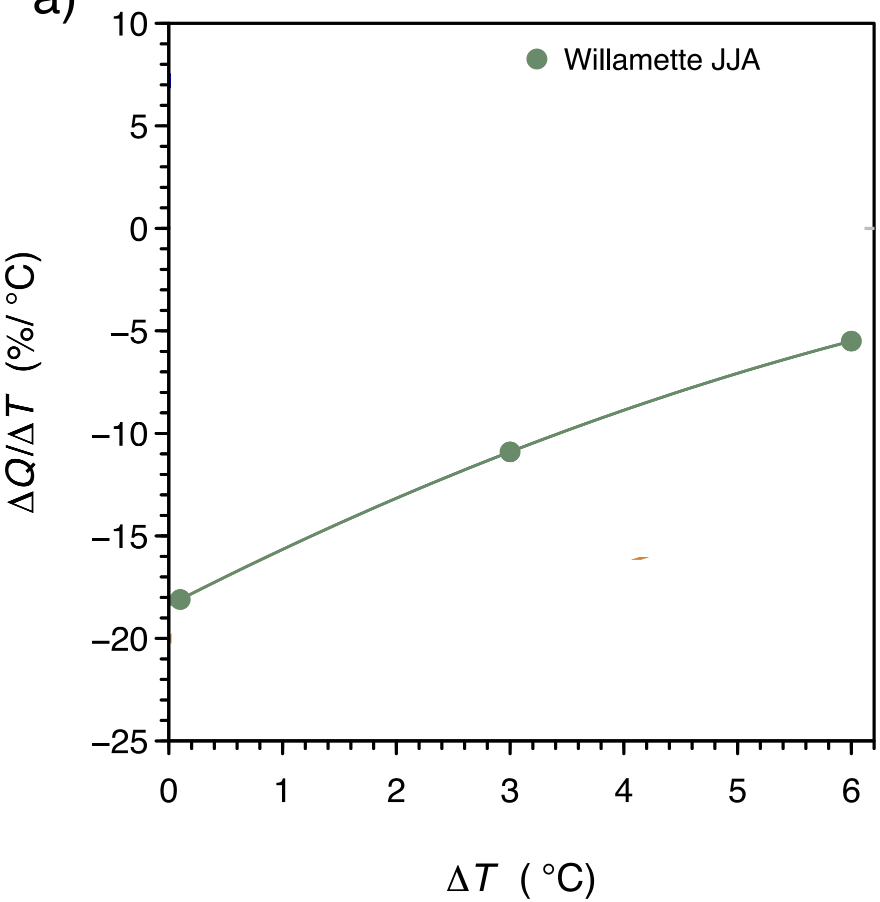

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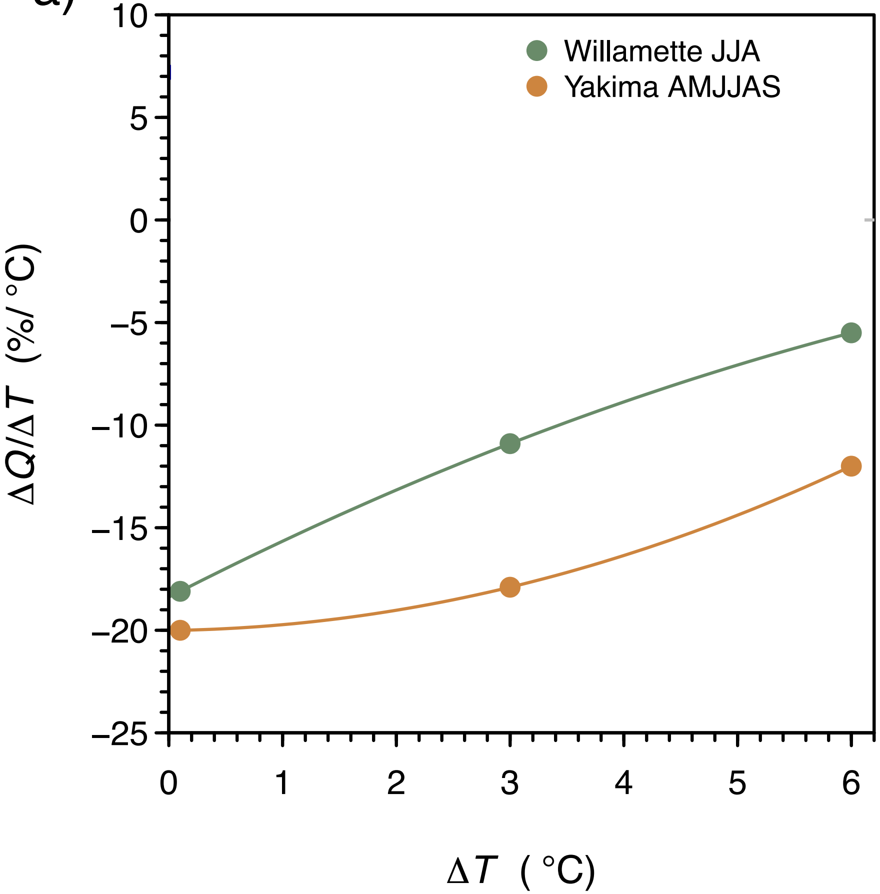

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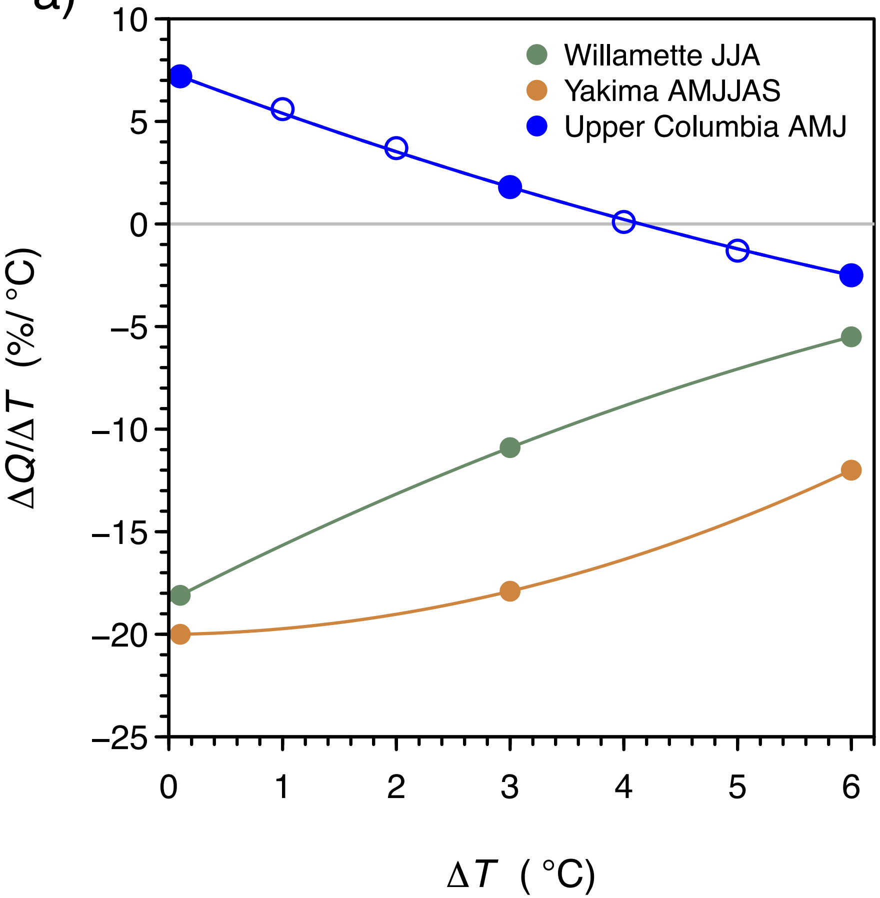

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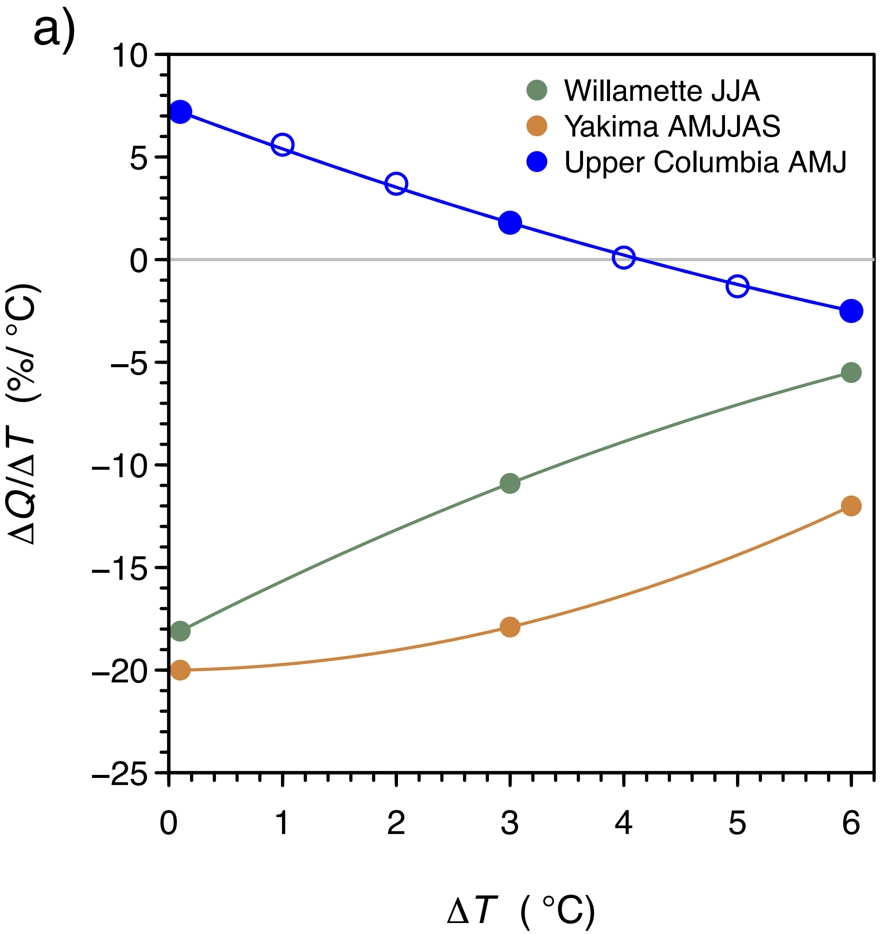
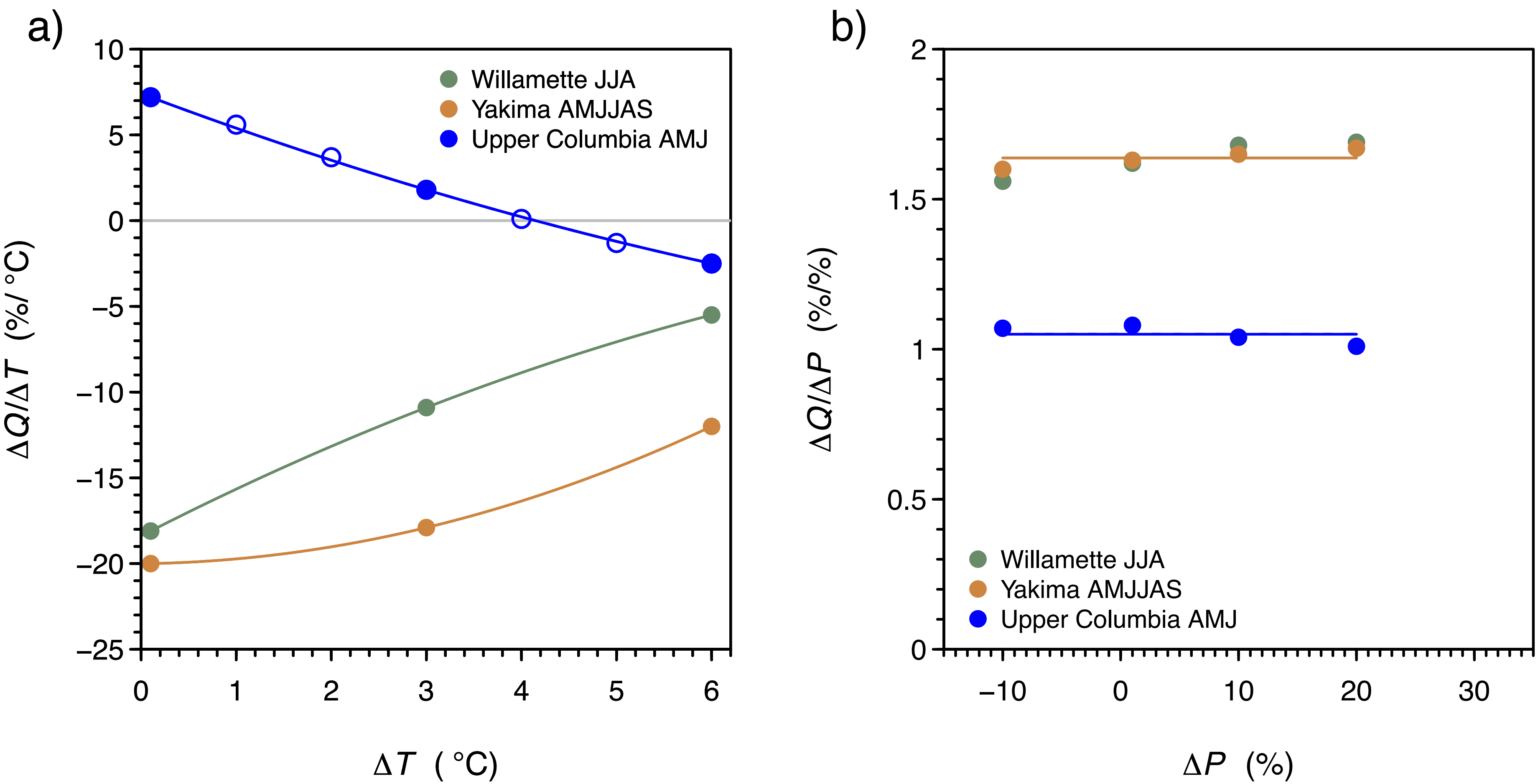
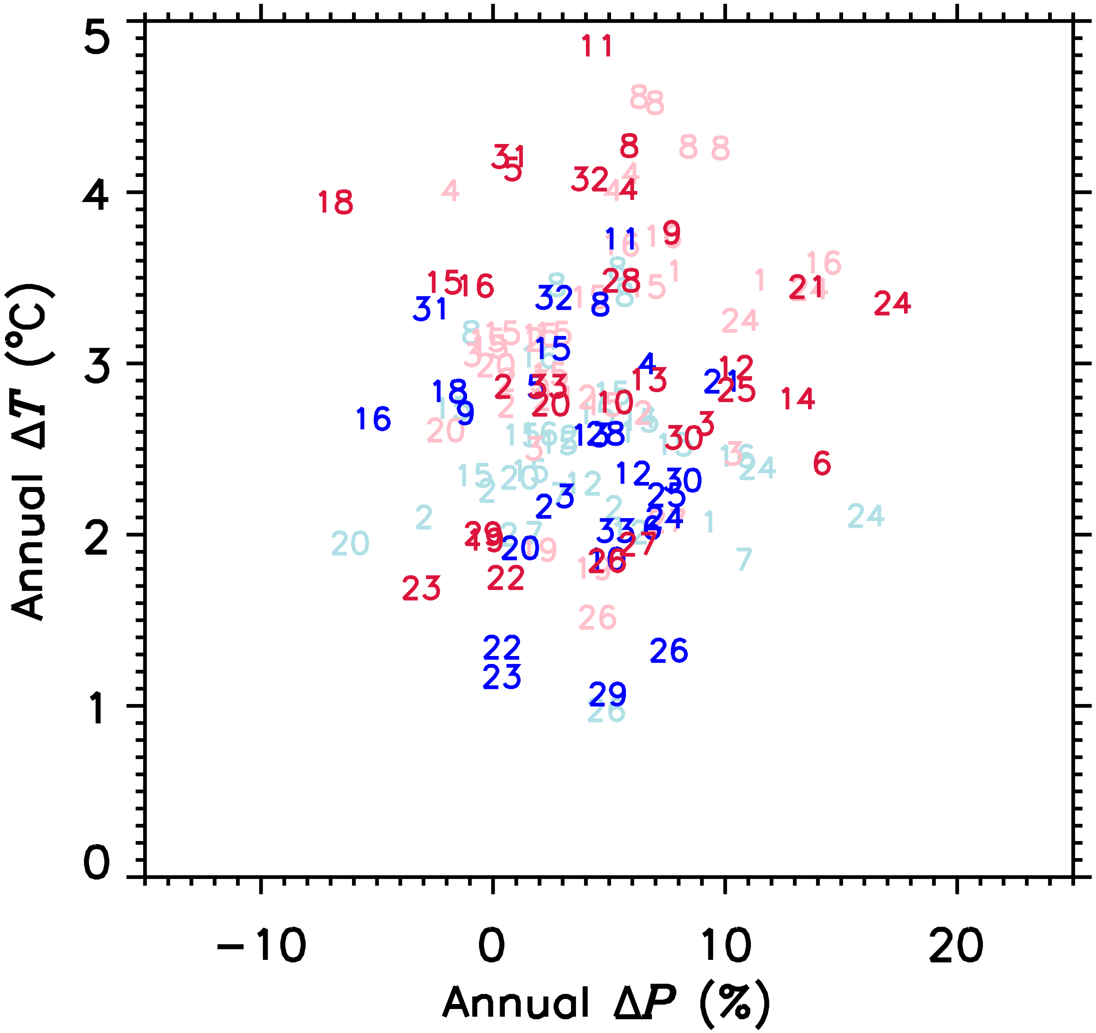


Non-linear temperature response



Non-linear temperature response and linear precipitation response

Selecting climate scenarios using hydrologic sensitivities



irrigation season (Apr-Sep) streamflow sensitivity in the Yakima River basin, WA

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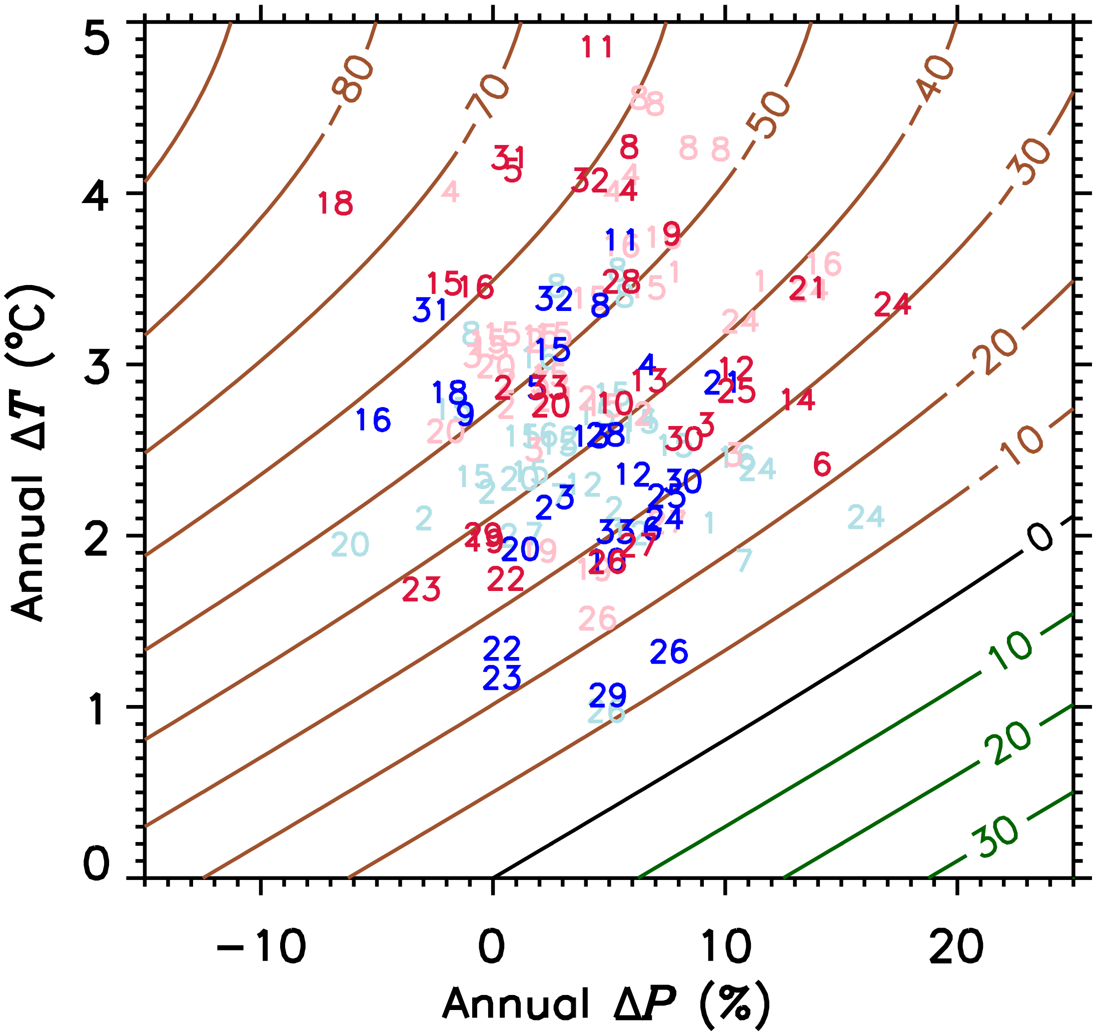
Legend key:
Dark = MACA available
Light = MACA not available
Models ranked by performance index

GCM ranking from Rupp et al. (JGR 2013), contours of streamflow change derived from S and ε values, blue = RCP 4.5, red = RCP 8.5, Eastern Washington region 1970-1999 to 2041-2070

Selecting climate scenarios using hydrologic sensitivities



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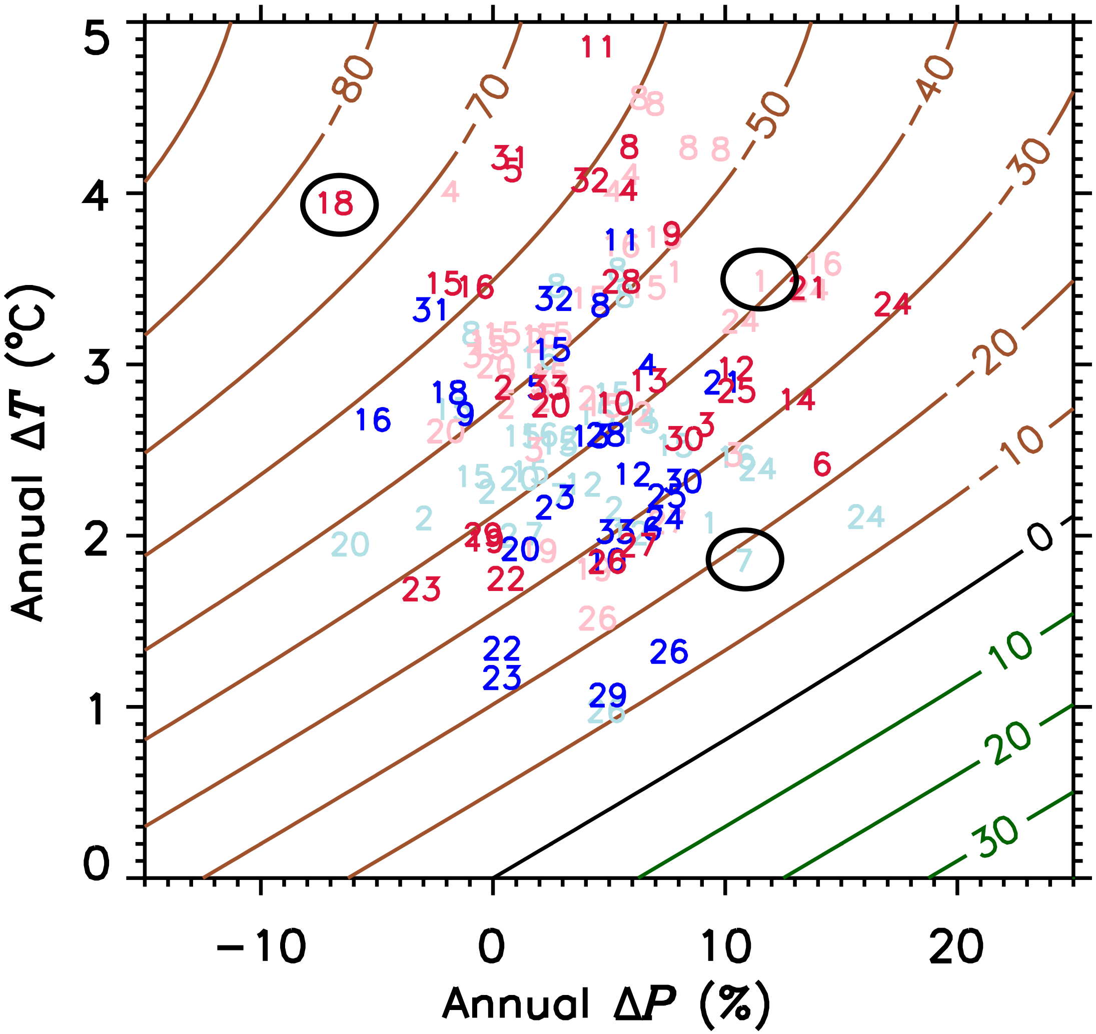

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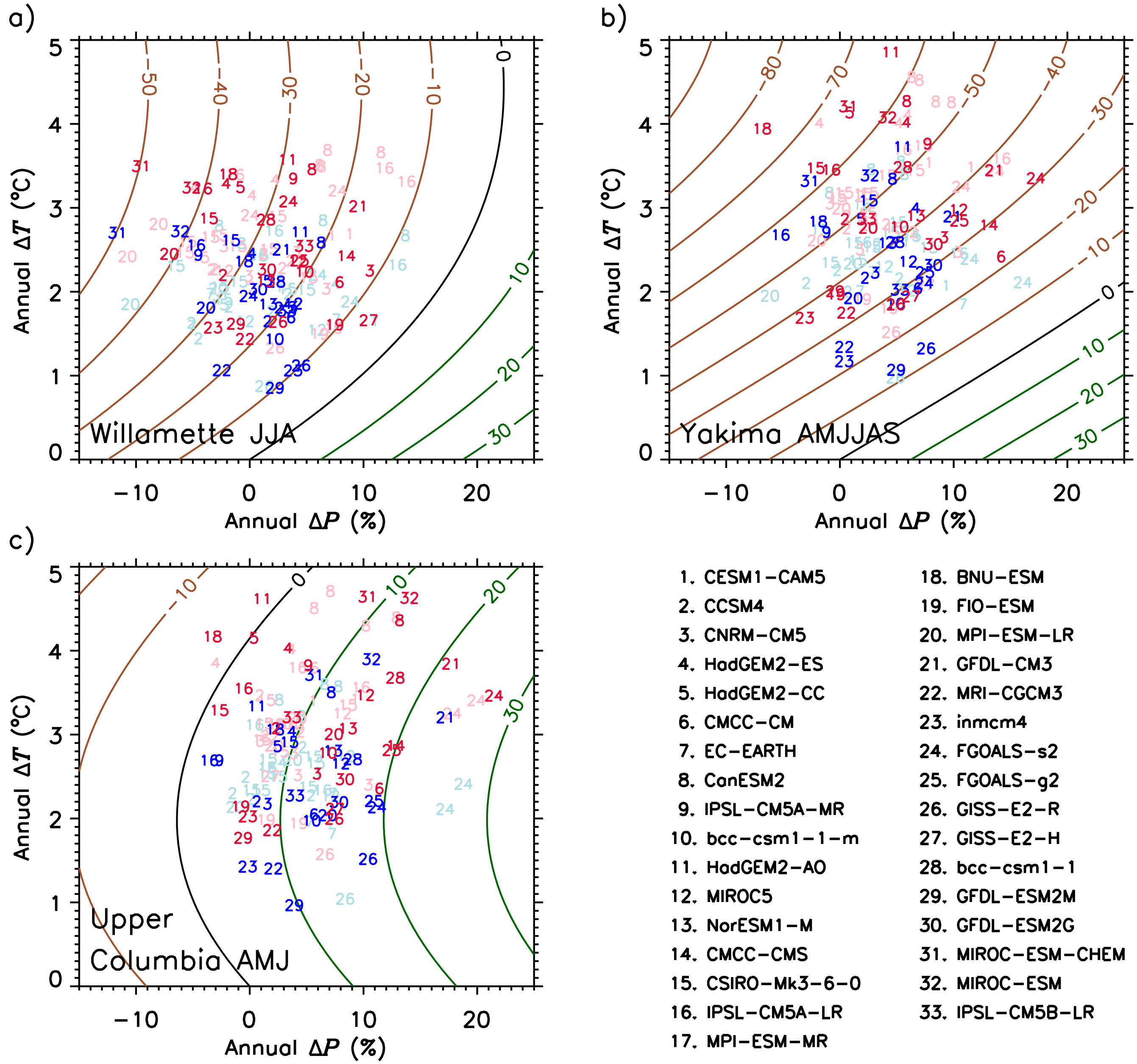
Selecting climate scenarios in three river basins and seasons

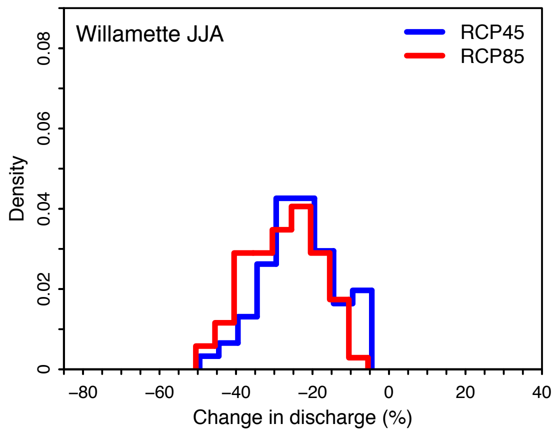


Contours based on Variable Infiltration Capacity hydrologic model derived sensitivities

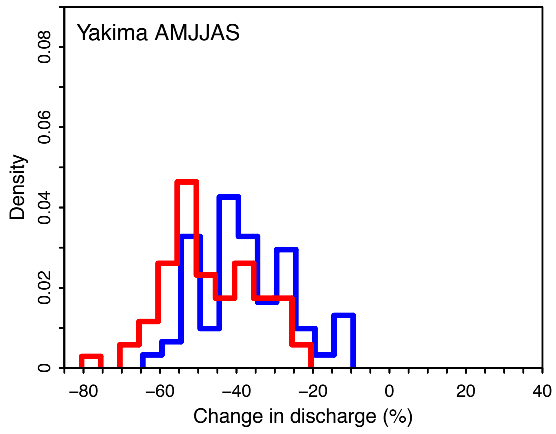
Distribution of global climate models for specific seasons

Streamflow change = $S(\Delta T)\,\Delta T + \varepsilon\,\Delta P$

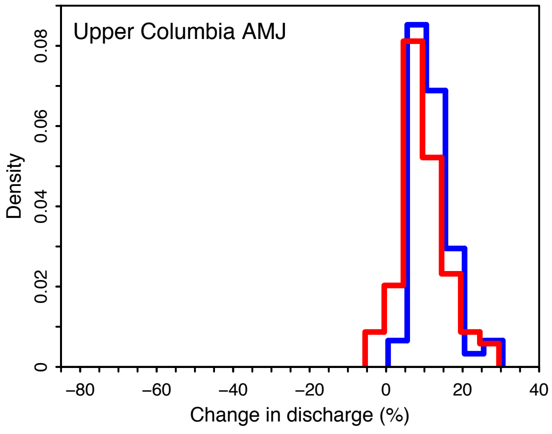
Willamette



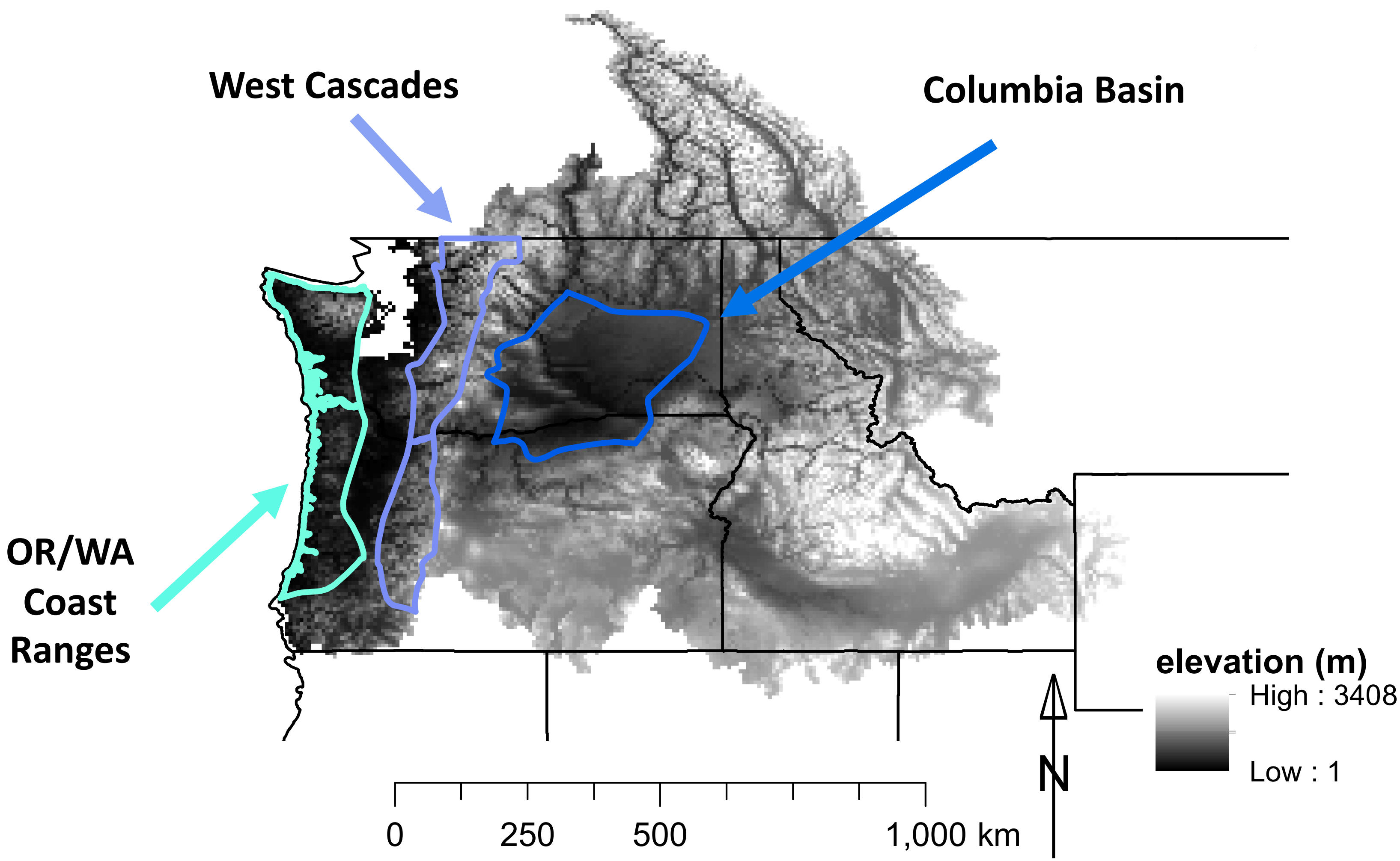
Yakima



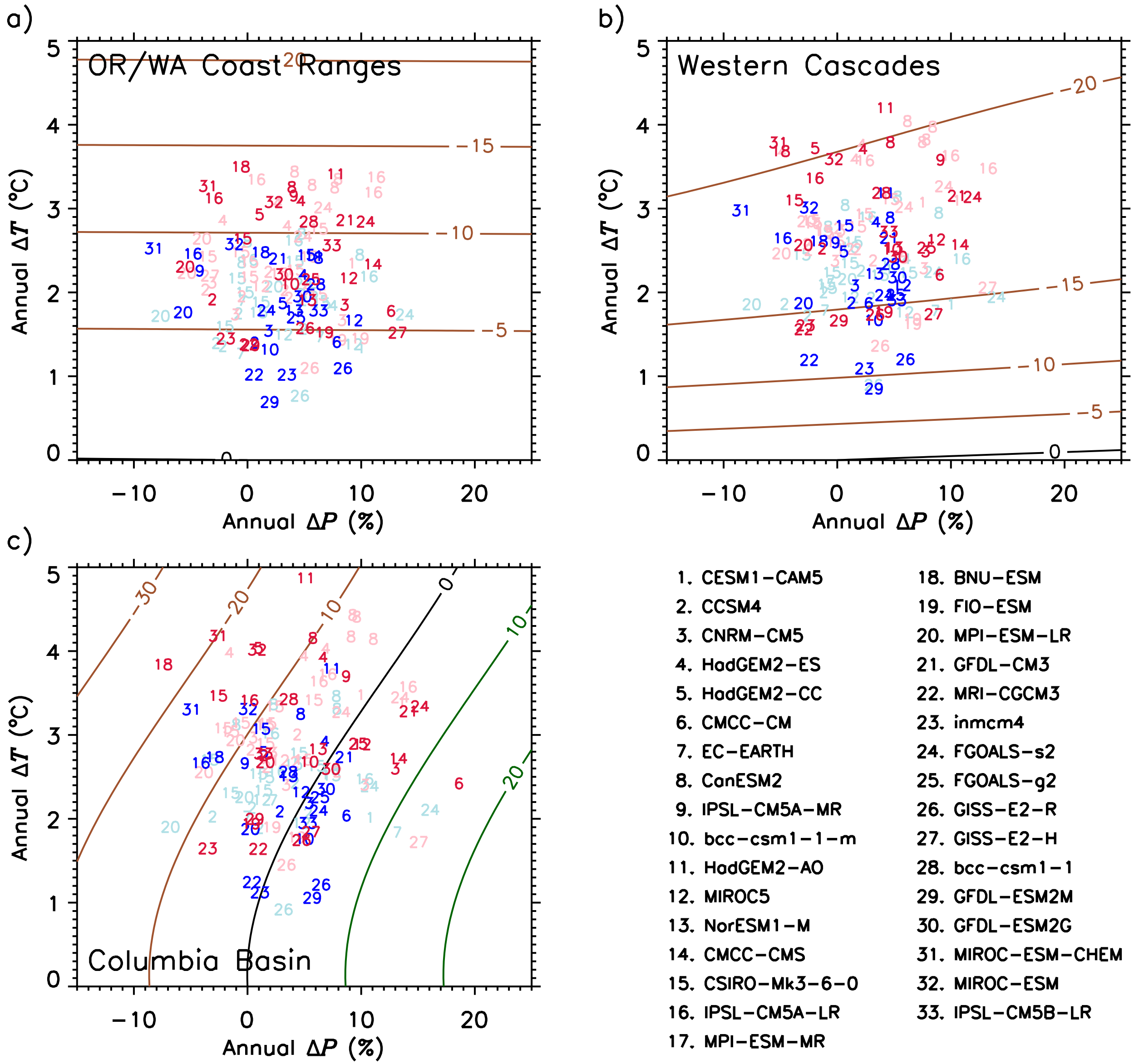
Upper Columbia



Impact:
Total Vegetation Carbon



Total vegetation carbon for three ecoregion

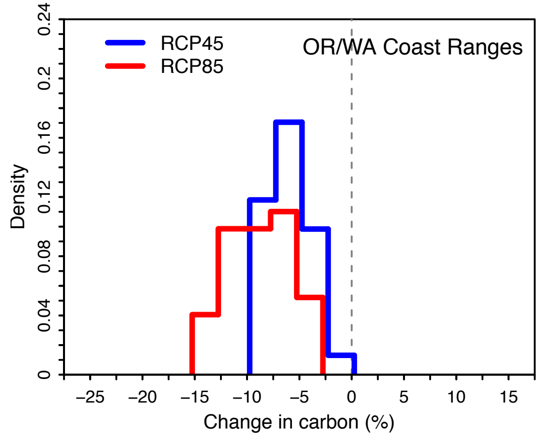


Contours based on MC2 dynamic general vegetation model derived sensitivities

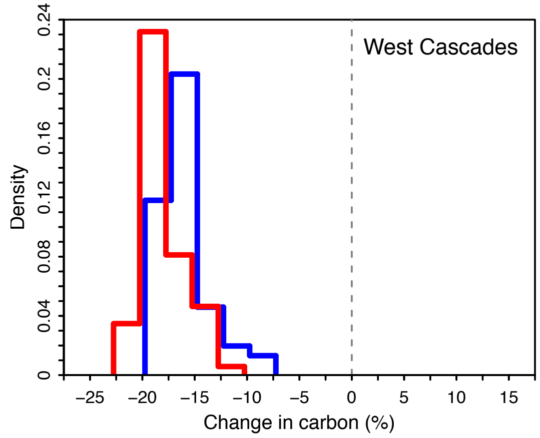
Distribution of global climate models for total vegetation carbon for three ecoregion

Vegetation carbon change	$= S(\Delta T)\,\Delta T + \varepsilon\,\Delta P$

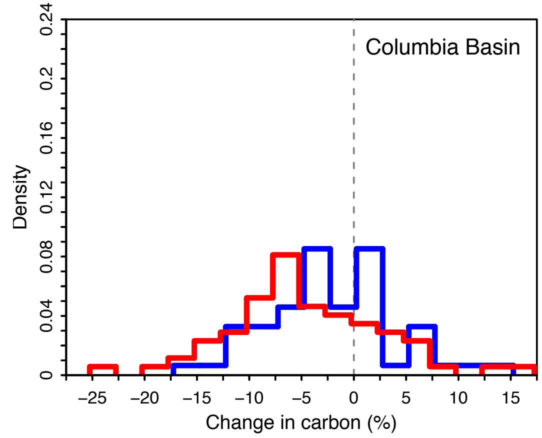
OR/WA Coast Range



West Cascades



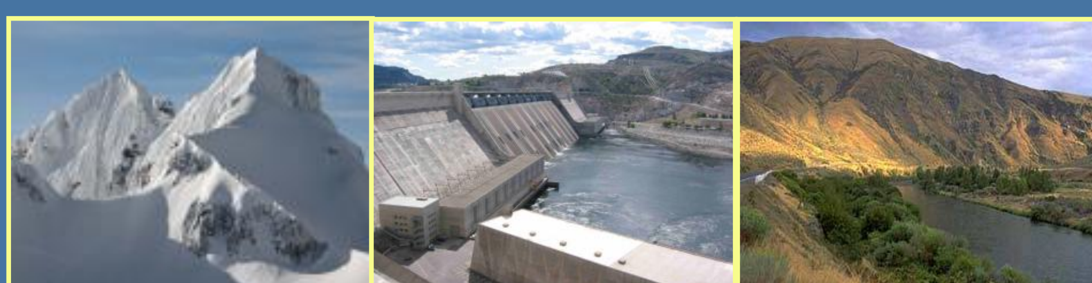
Columbia Basin



Summary

The approach:

- Allows impacts to guide GCM selection rather than T and P changes
- Is computationally efficient
- Provides defensible GCM selection for publicly scrutinized decision-making, ideally frees up resources
- Provides both qualitative and more technical evaluations
- Is transportable, can be applied to multiple impacts



Acknowledgements

GCM precipitation and temperature changes where calculated from data downloaded at http://cmip-pcmdi.llnl.gov/cmip5. Support for this work was provided by the National Science Foundation under Awards No. EAR-1250087 and EAR-1039192, by the U.S. National Oceanic and Atmospheric Administration, Grant NA10OAR4310218, and by USGS, Grant #G12AC20495

NSF

CIRC
Climate Impacts Research Consortium

Feedback, questions??

contact Julie Vano, jvano@coas.oregonstate.edu

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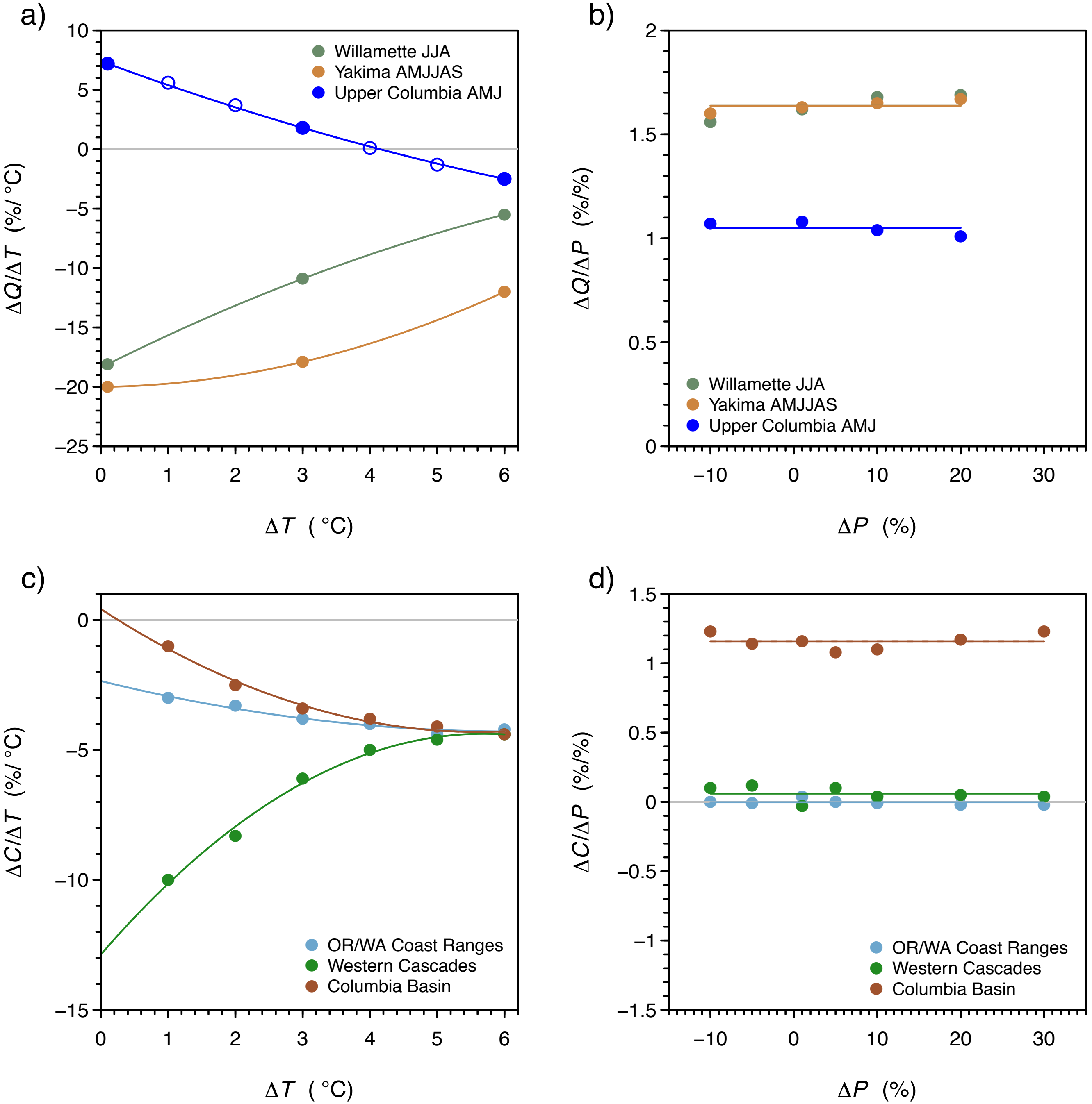
The approach:

- Allows impacts to guide GCM selection rather than T and P changes
- Is computationally efficient, e.g., in the Yakima we evaluated 142+ GCM runs using only 9 impact model simulations
- Provides defensible GCM selection for publicly scrutinized decision-making, ideally frees up resources to understand nature of change instead of data management
- Provides information to those interested in both qualitative and more technical evaluations
- Is transportable, can be applied to multiple impacts. We demonstrate with one hydrologic model and vegetation model, but could be applied to other impacts or employed using other simulation models.

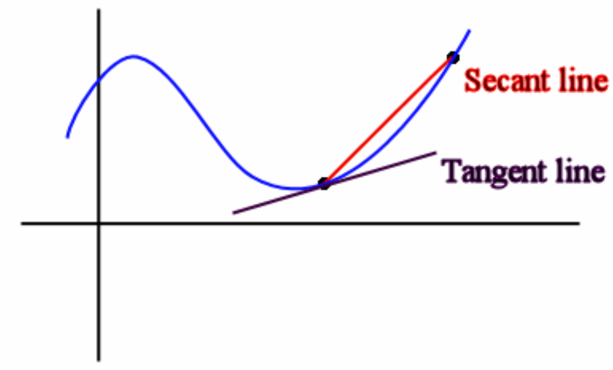


Extra Slides


a)
Willamette JJA
Yakima AMJJAS
Upper Columbia AMJ
ΔQ/ΔT (%/ °C)
ΔT (°C)
b)
Willamette JJA
Yakima AMJJAS
Upper Columbia AMJ
ΔQ/ΔP (%/%)
ΔP (%)
c)
OR/WA Coast Ranges
Western Cascades
Columbia Basin
ΔC/ΔT (%/ °C)
ΔT (°C)
d)
OR/WA Coast Ranges
Western Cascades
Columbia Basin
ΔC/ΔP (%/%)
ΔP (%)

Considerations

(1) **Linearity**, the extent to which a small change (e.g., 0.1 ºC), which provides a reasonable approximation of the tangent of the change, is proportional to a larger change (e.g., 3 ºC) which captures the secant



(2) **Superposition**, the extent to which hydrologic sensitivities identified through independent simulations can be added together to equal the same value as changes applied within the same simulation.

$$\Delta Q_{1\%P} + \Delta Q_{1°C} \stackrel{?}{=} \Delta Q_{1°C \,\&\, 1\%P}$$

$$\Delta Q_{3°C \text{ warm season}} + \Delta Q_{3°C \text{ cool season}} \stackrel{?}{=} \Delta Q_{3°C \text{ year round}}$$