

Impacts of climate change on stream temperature in the Pacific Northwest of USA



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Pacific Northwest (PNW) of USA?



Olympic Mountains

Seattle

Was

Long Beach

Range

Ric

Portland

Bend

Orego

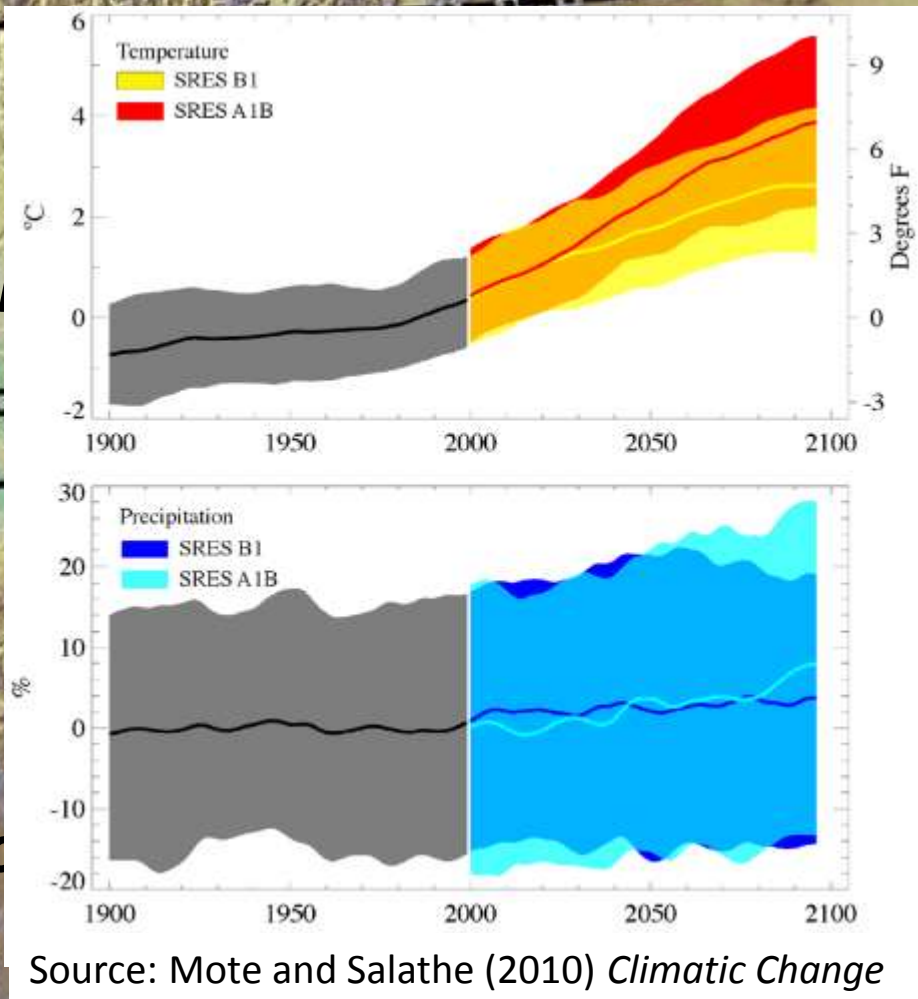
North Bend

Coast Range

Cascade

Kilometers

0 150



Vulnerability of water quality

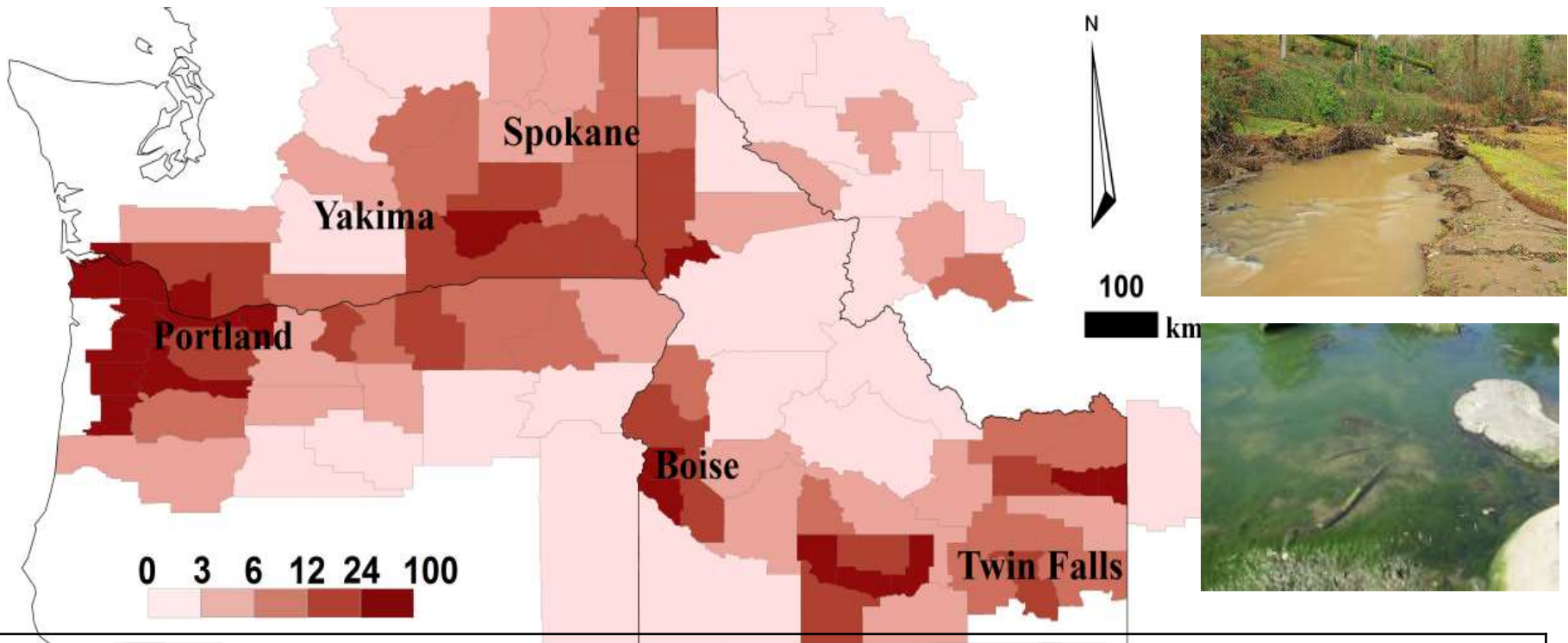


Table 1.

Vulnerability Index	Indicators (unit) (data period)	Source
Water quality vulnerability		
Physical	Mean annual stream temperature	this paper
	Erosion potential (K-factor)	USGS (2011)
Chemical	Total annual N loading potential	Wise and Johnson (2011)
	Total annual P loading potential	Wise and Johnson (2011)
Biological	Algal bloom probability	this paper

Source: Chang et al. *Atmosphere-Ocean* (2013)

What is the most significant WQ problem in the PNW of USA?

1) **Water temperature**



2) **Nutrient**



3) **Sediment**



4) **E-Coli**



Kilometers
0 150

Pollutants of concern in Tri-State

	Idaho	Oregon	Washington
1st Impairment	Sediment	Temperature	Temperature
Stream Length (km)	27,456	27,766	1,261
2nd Impairment	Temperature	Sediment	Fecal Coliform
Stream Length (km)	24,611	19,306	1,044
3rd Impairment	Phosphorous	Nutrients	D.O.
Stream Length (km)	8,664	18,142	624
4th Impairment	Impaired Biota	Eutrophication	Flow Alteration
Stream Length (km)	7,907	16,910	55
5th Impairment	Flow Alteration	pH	PCBs
Stream Length (km)	6,108	8,643	55
6th Impairment	Fecal Coliform	D.O.	DDE
Stream Length (km)	5,866	6,858	47
7th Impairment	Substrate Alterations	Fecal Coliform	Fish Habitat
Stream Length (km)	5,842	4,325	36
8th Impairment	Unknown	E. Coli	DDT
Stream Length (km)	3,987	3,796	29

Why Stream Temperature?

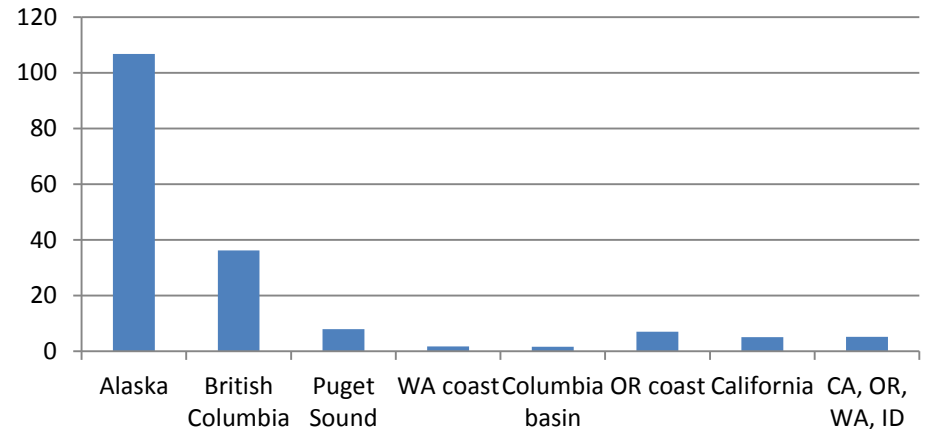
- Water quality indicator
 - Dissolved Oxygen
 - Rates of chemical reactivity
- Salmon and Trout require specific ranges of water temperatures for :
 - Smoltification: $<12^{\circ}\text{C}$
 - Spawning: 13°C
 - Core cold water habitat: 16°C
 - Rearing and Migration: 18°C

Source: Lackey (2000)

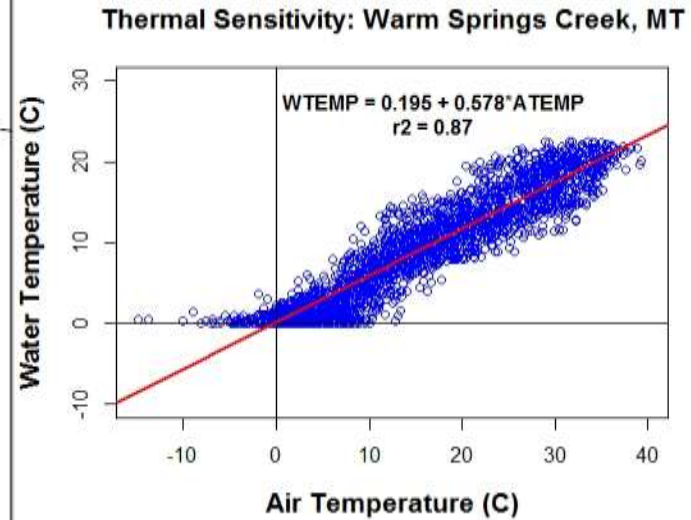
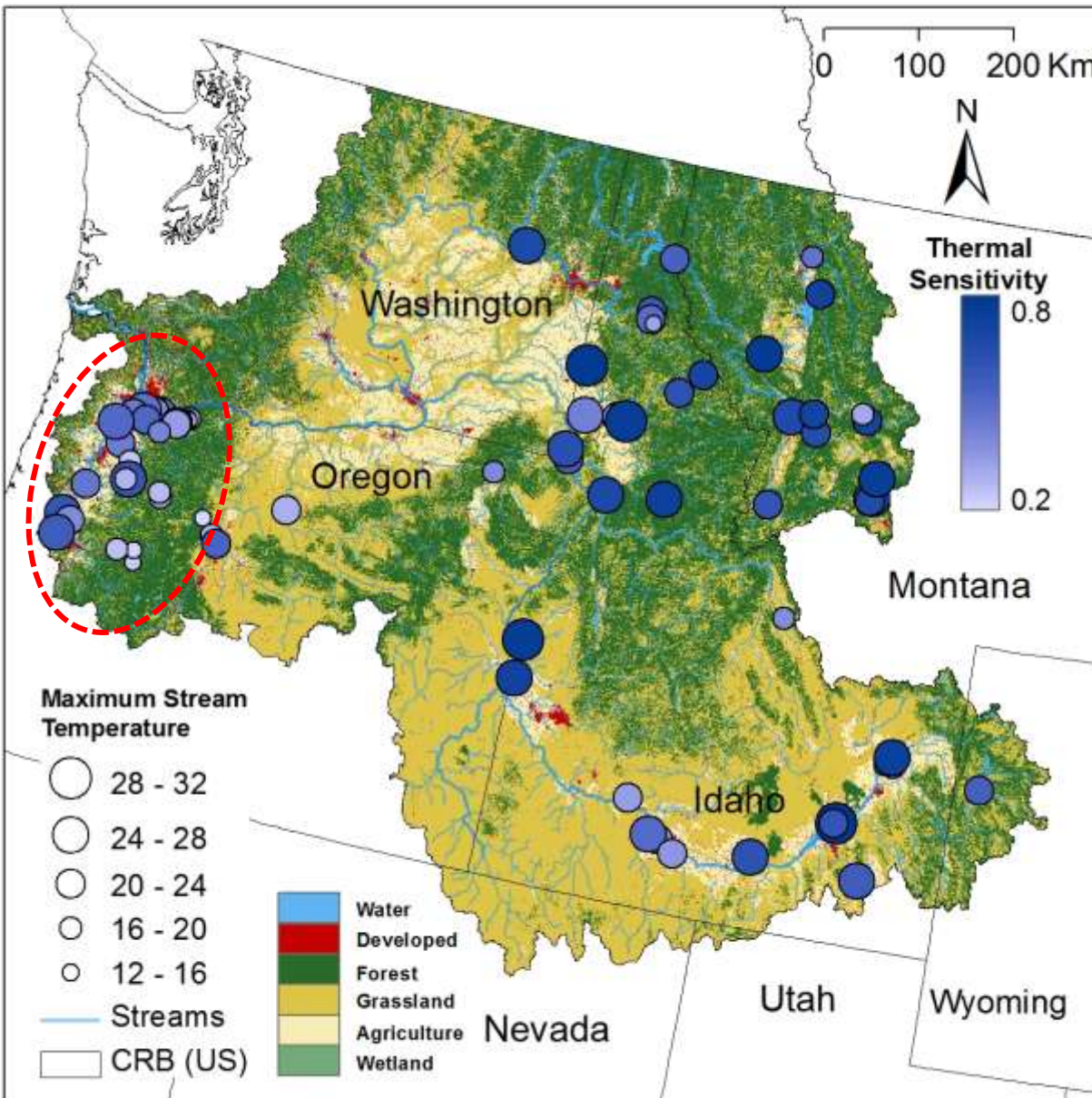


Source: <http://www.ilovestickyrice.com/2010/03/02/fish-facts-salmon/>

Wild Salmon, % of historical run size



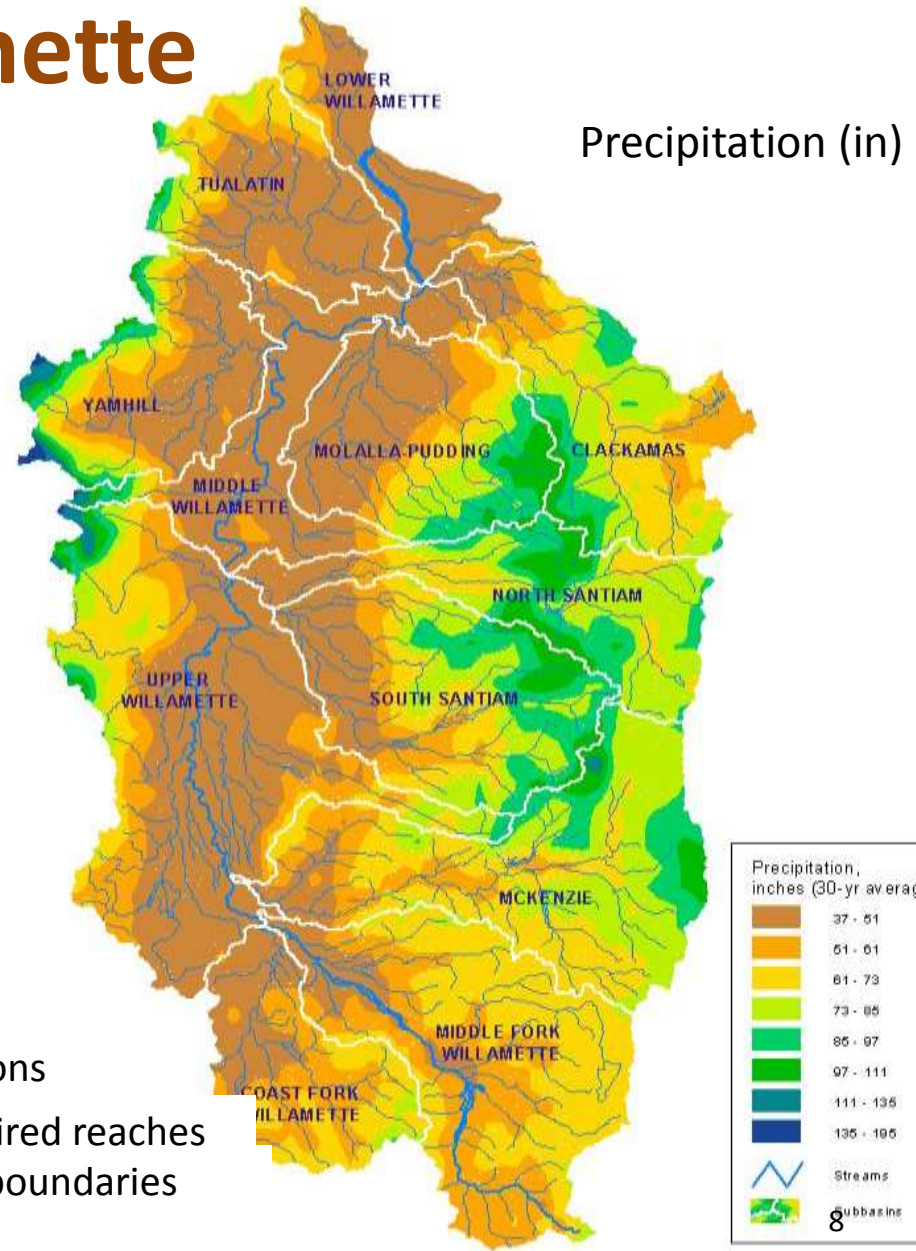
Spatial variations of stream temperature and thermal sensitivity (TS) in the Columbia River basin



$$TS = \frac{\Delta \text{ in water temp}}{\Delta \text{ in air temp}}$$

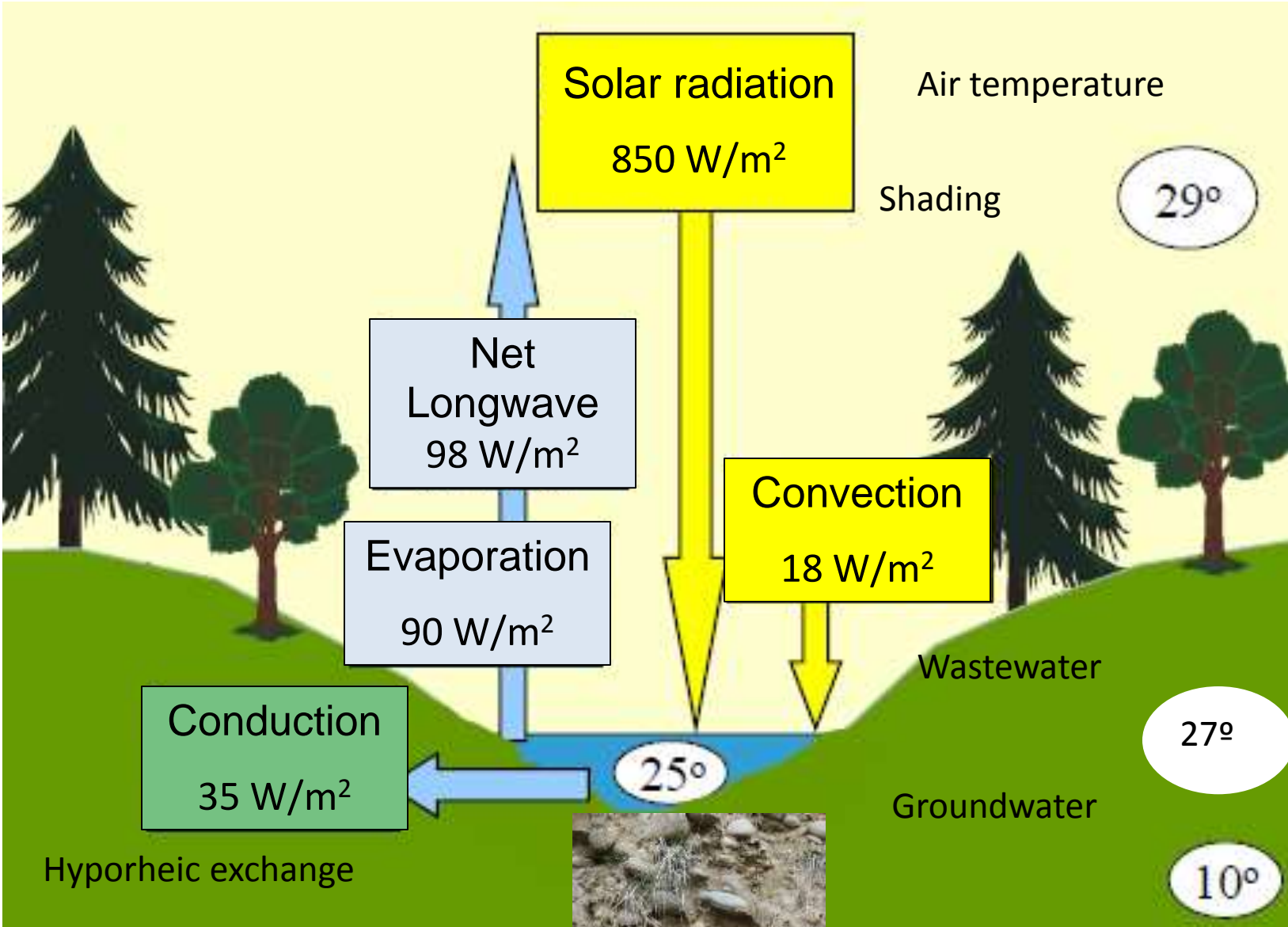
Source: Chang and Psaris (2013)
Sci. Tot. Environ.

Temperature Impaired Streams in the Willamette

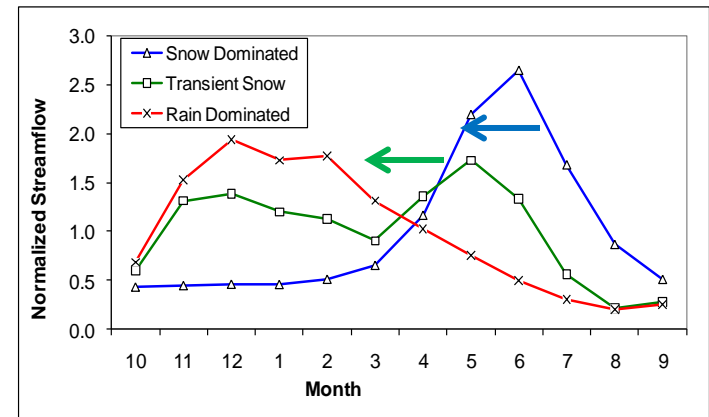
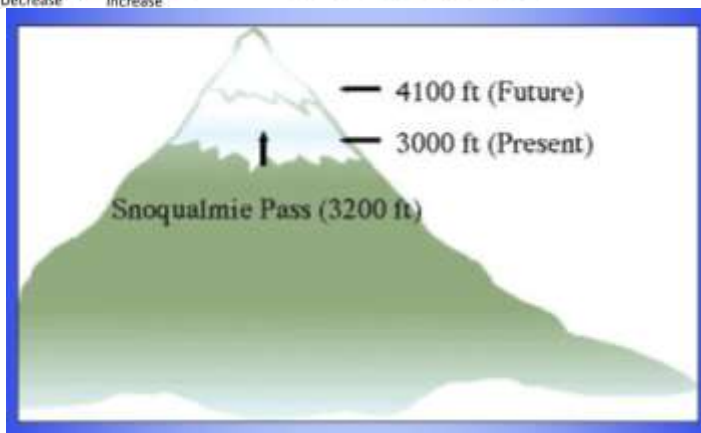
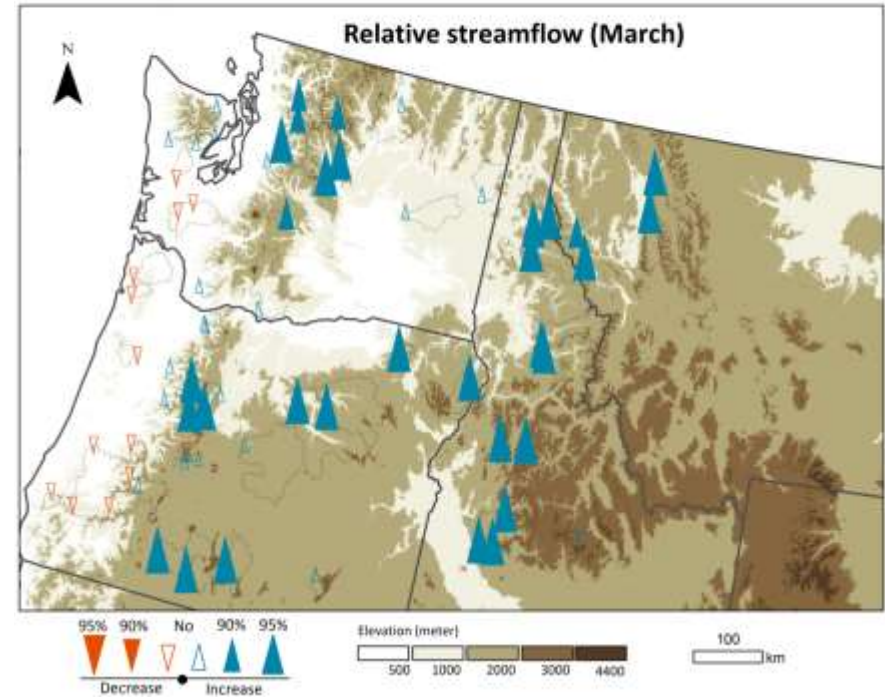
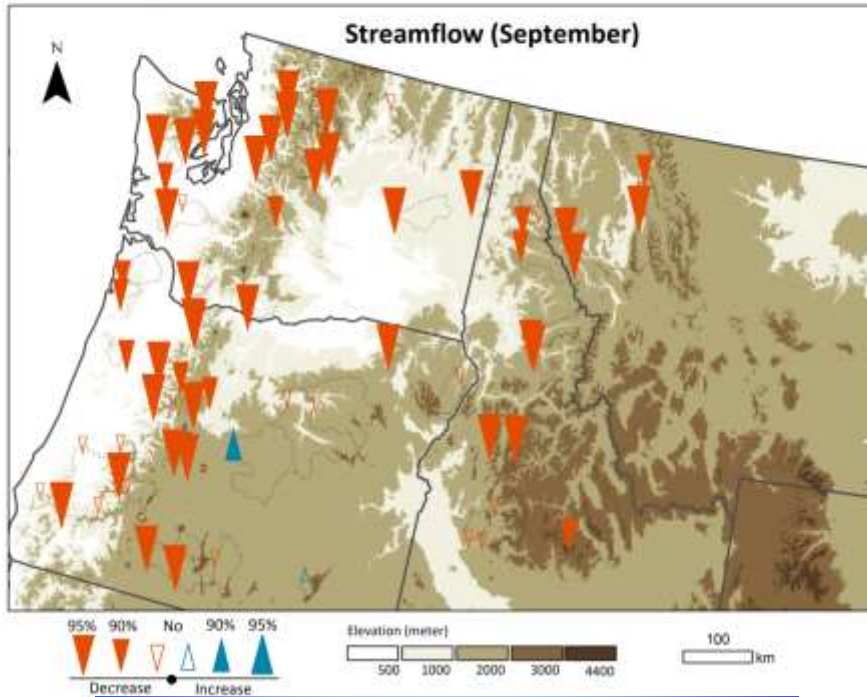


Source: ORDEQ

Major drivers of water temperature



Trends in September and March runoff, 1958-2008

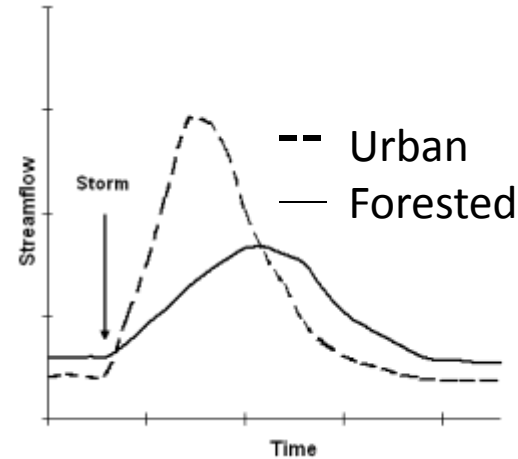
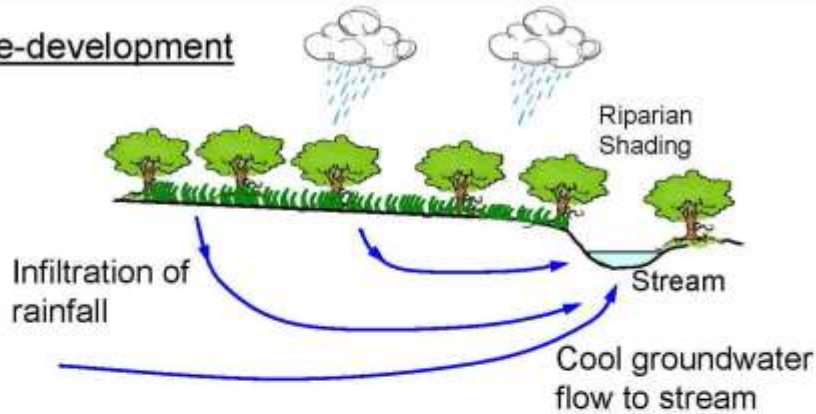


Source: Chang et al. (2012) *Geographical Analysis*

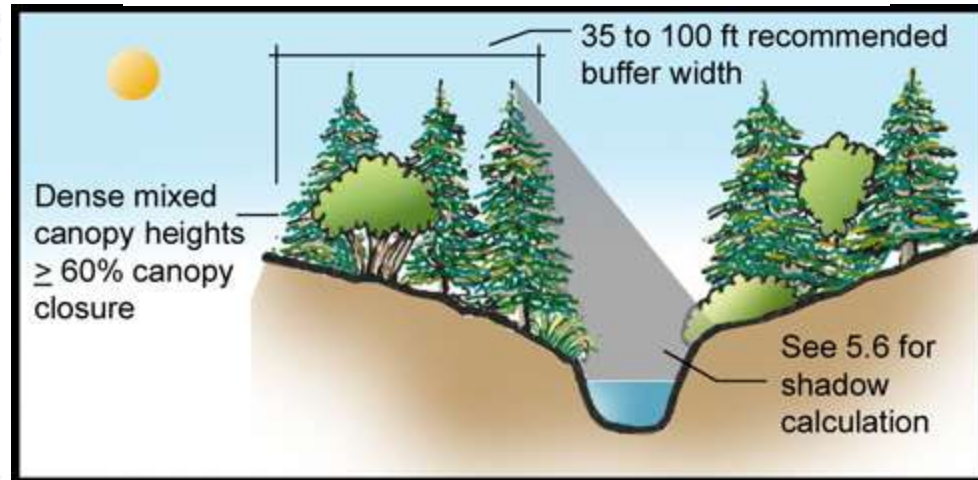
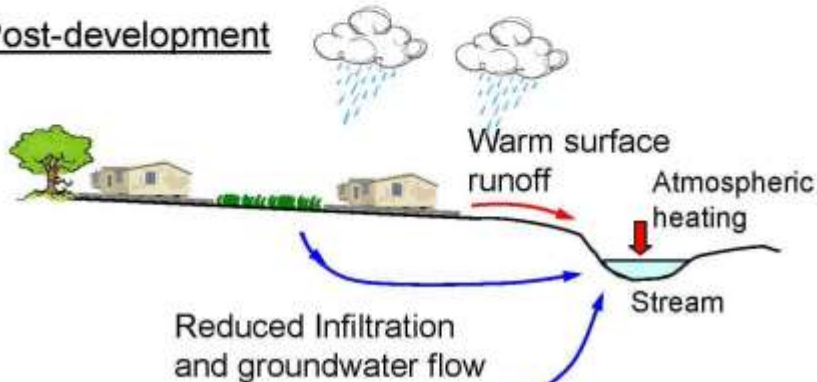
Source: Climate Impacts Group

Effects of urban development on streamflow and stream temperature

Pre-development



Post-development

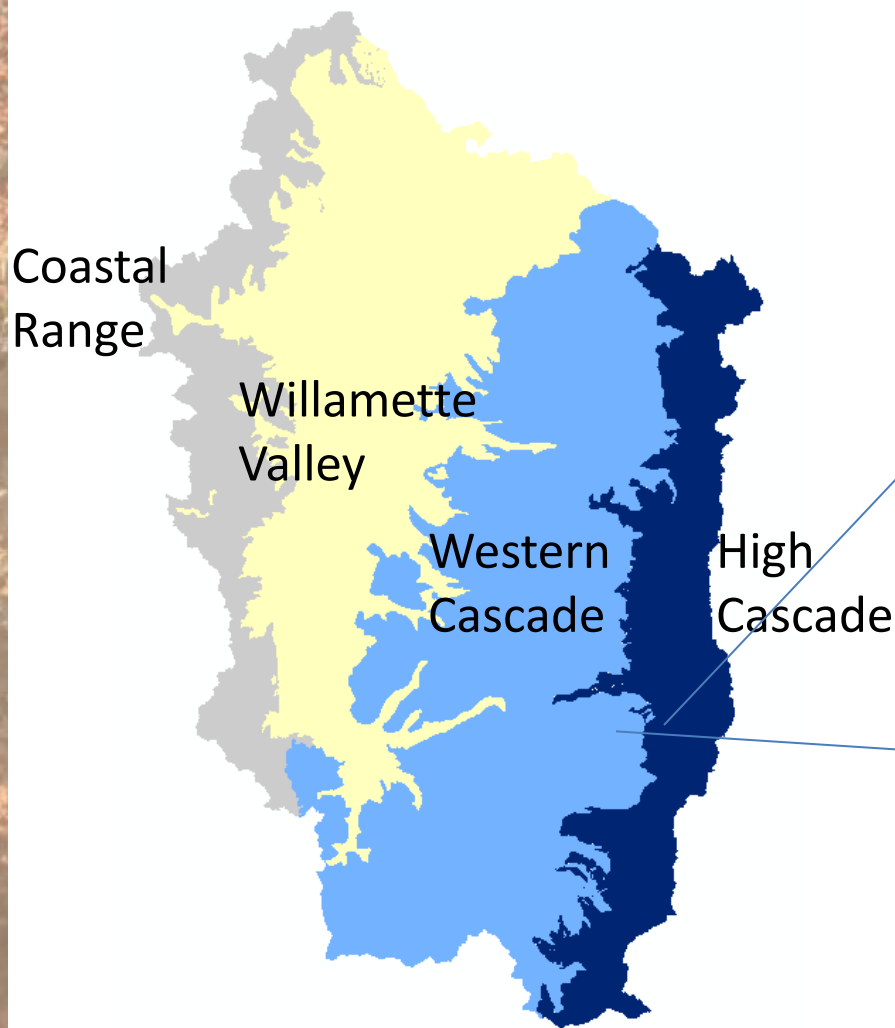


<http://troutstreamresearch.safl.umn.edu/>

http://nac.unl.edu/buffers/guidelines/2_biodiversity/12.html

Geology and streamflow regime

Geology



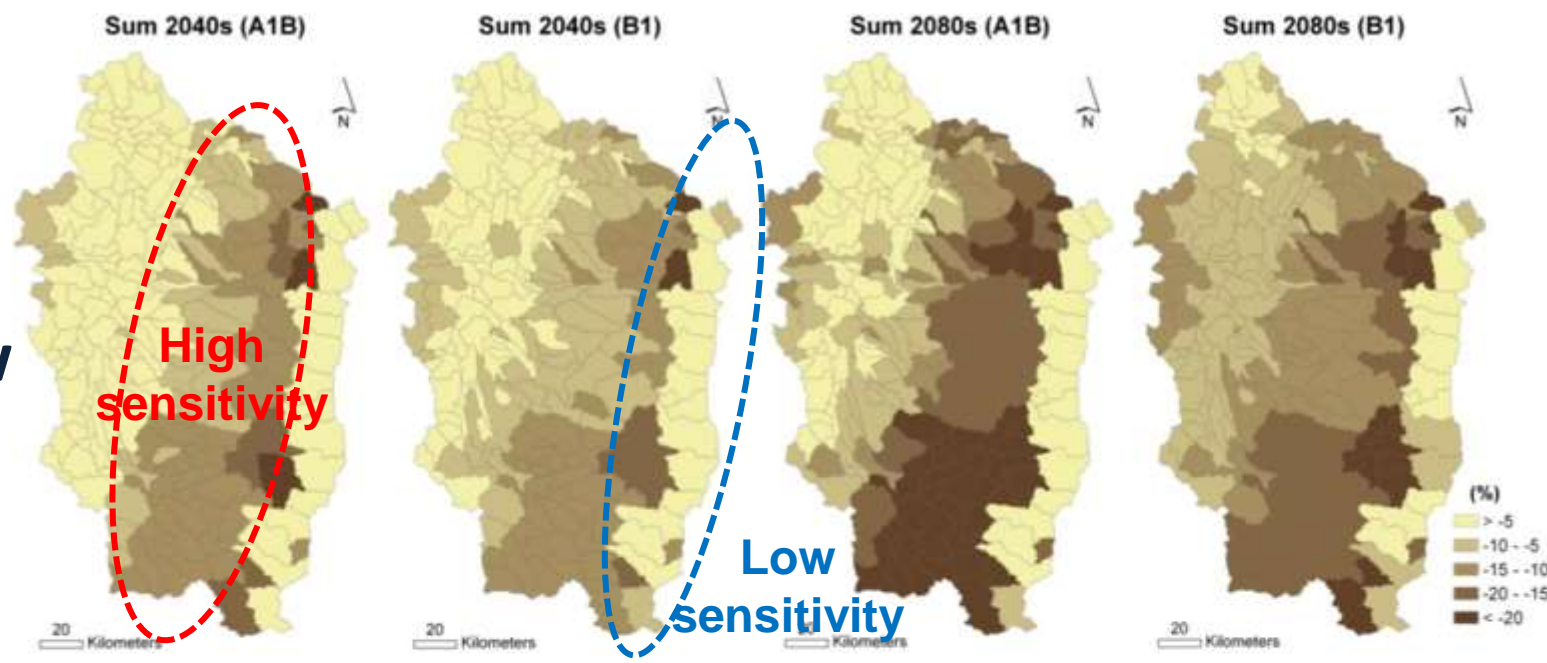
Groundwater-dominated



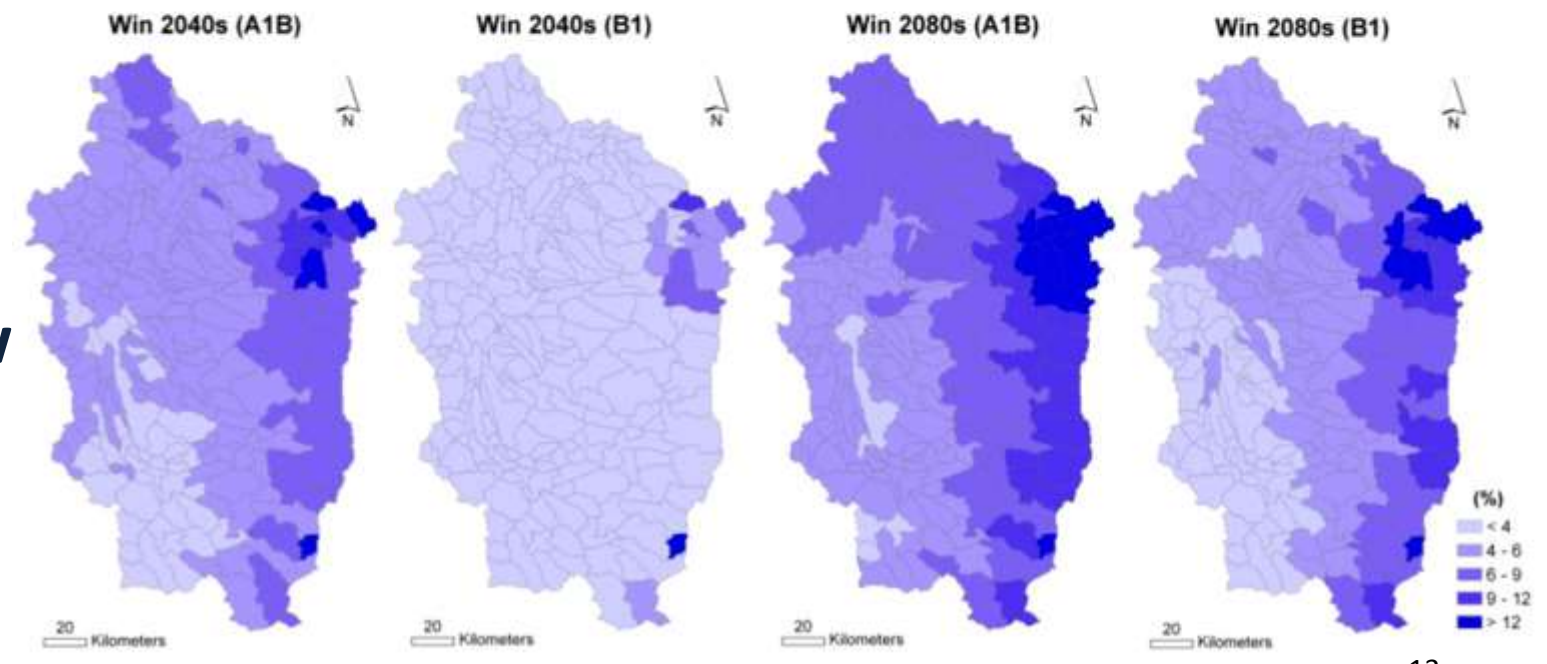
Surface flow-dominated



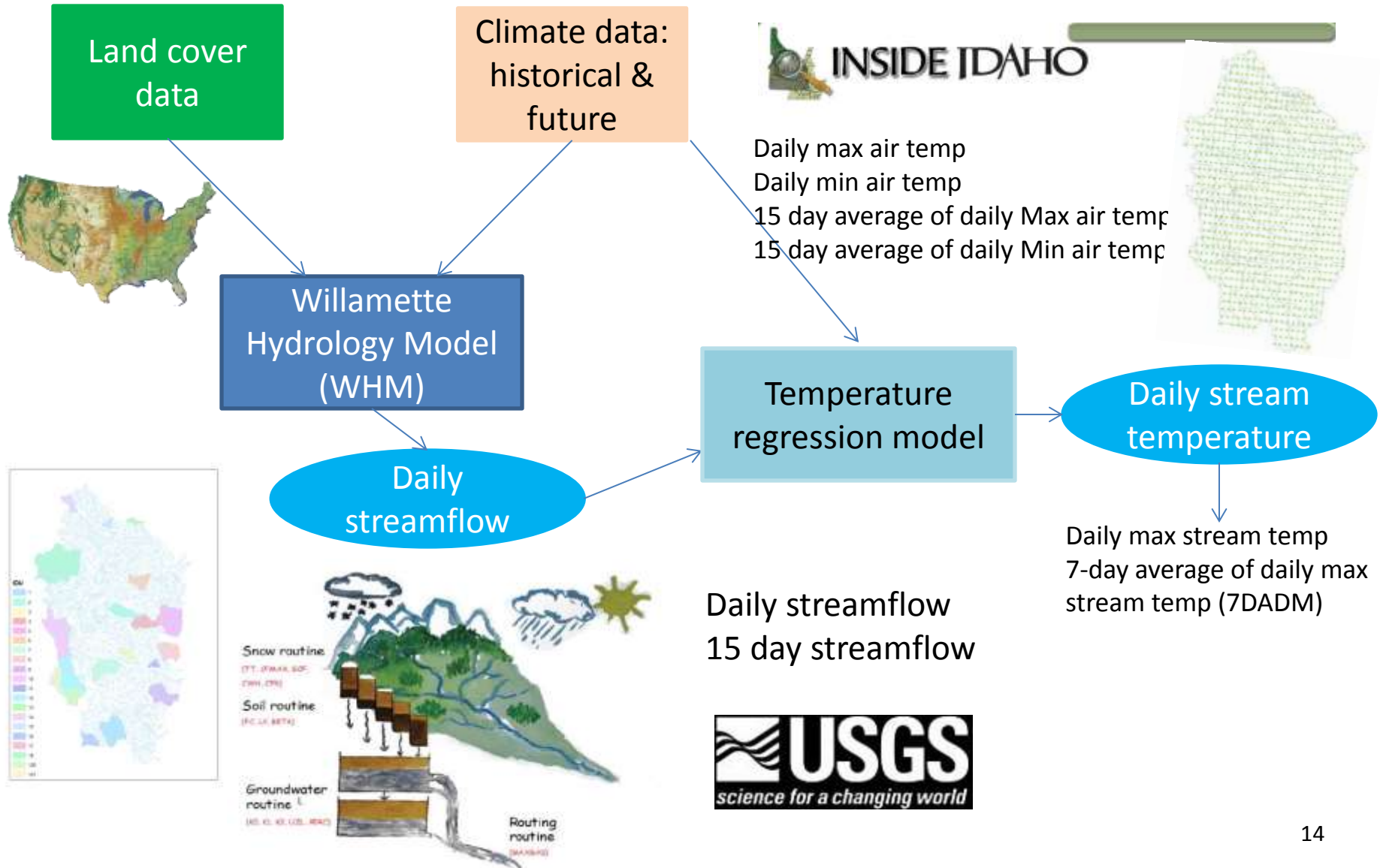
Changes in
summer
streamflow



Changes in
winter
streamflow



Case 1: Climate change impacts on stream temperature in the Willamette

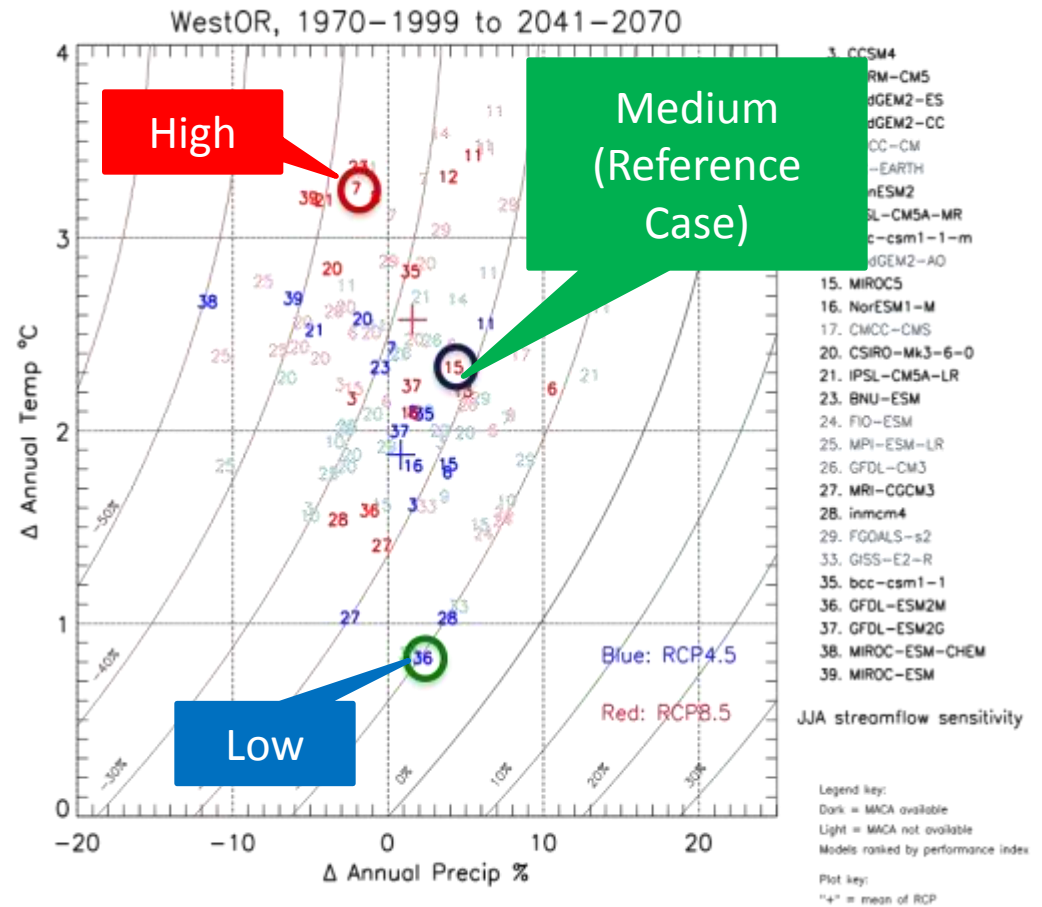


Climate Drivers

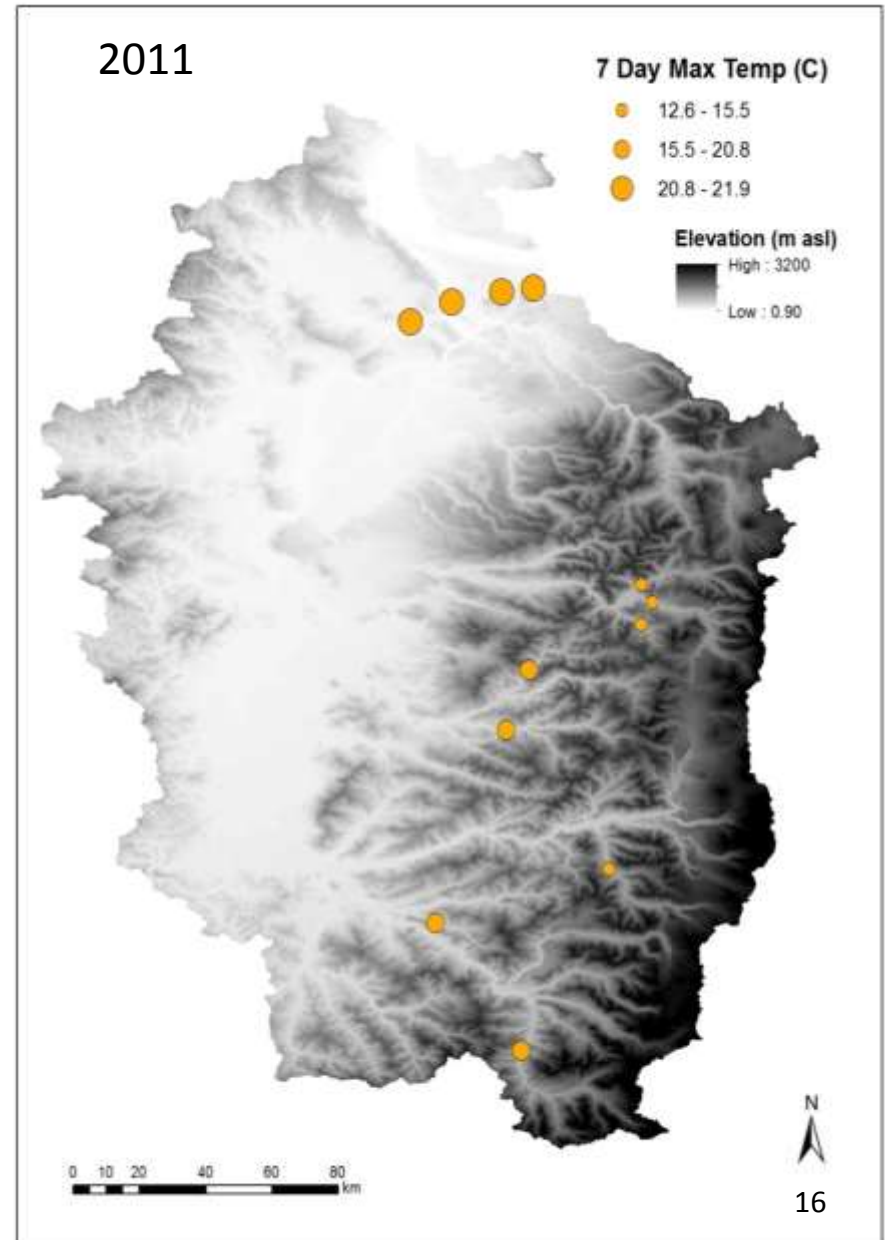
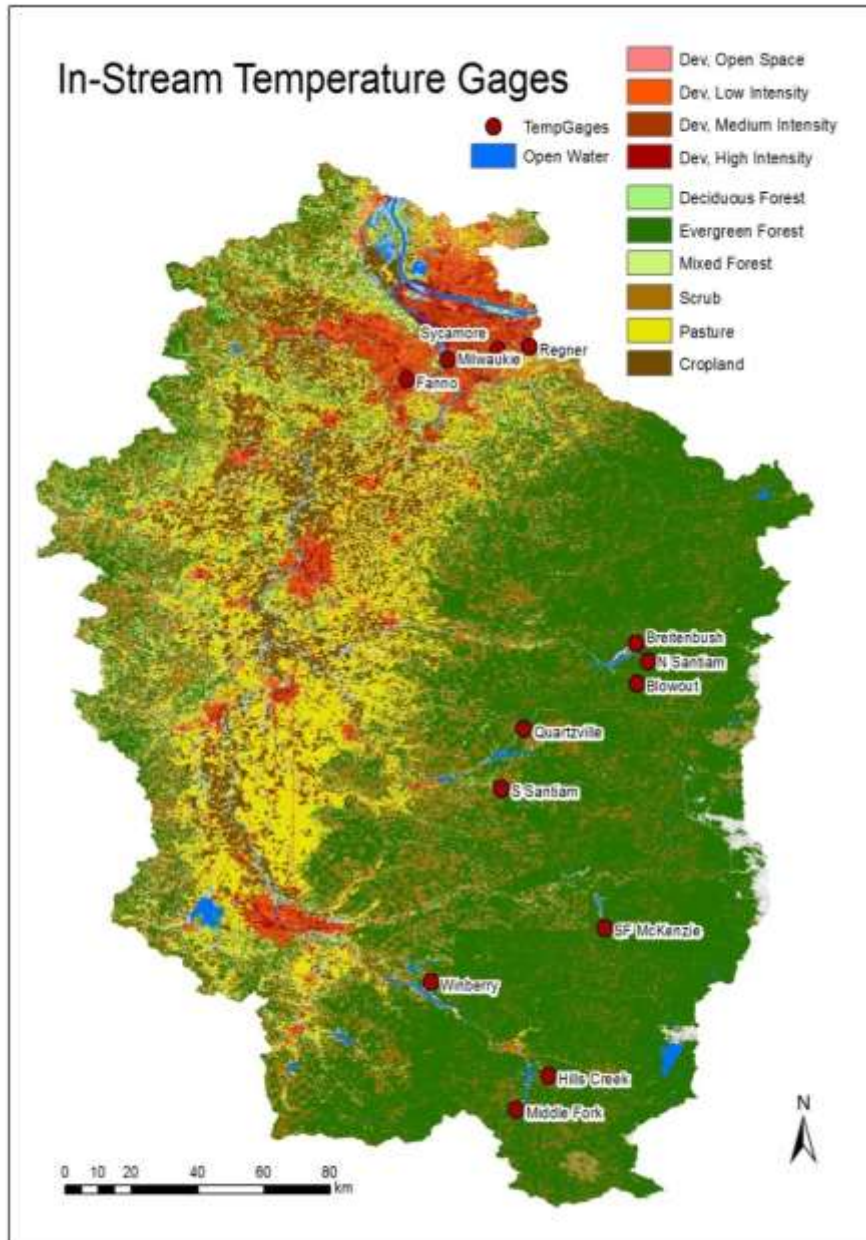
WW2100 employs three climate scenarios, representing a range of temperature and precipitation responses

- High:** HadGEM2-ES RCP 8.5
- Reference:** MIROC5 RCP 8.5
- Low:** GFDL-ESM2M RCP 4.5

Reference Case scenario based on MIROC (Medium) climate change projection

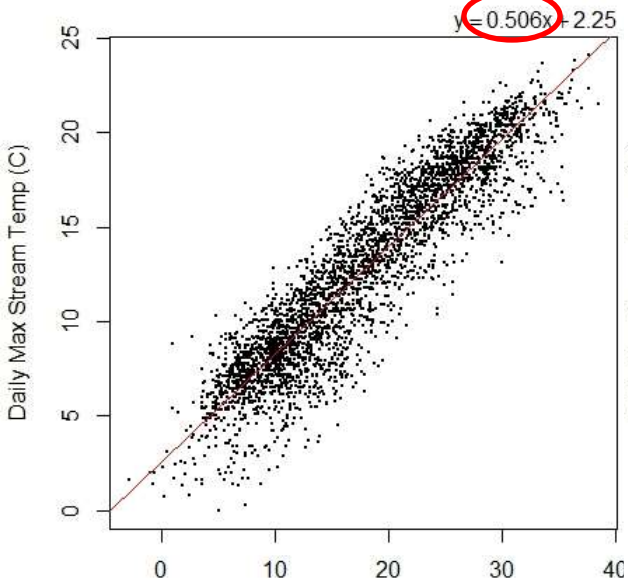


Study monitoring stations

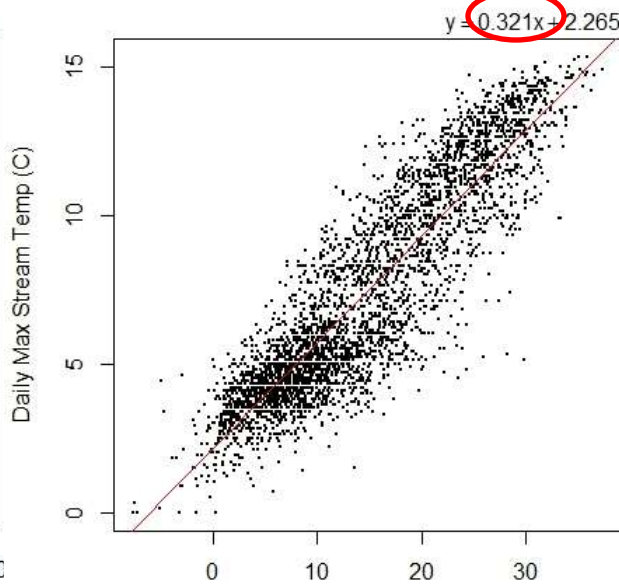


Thermal Sensitivity

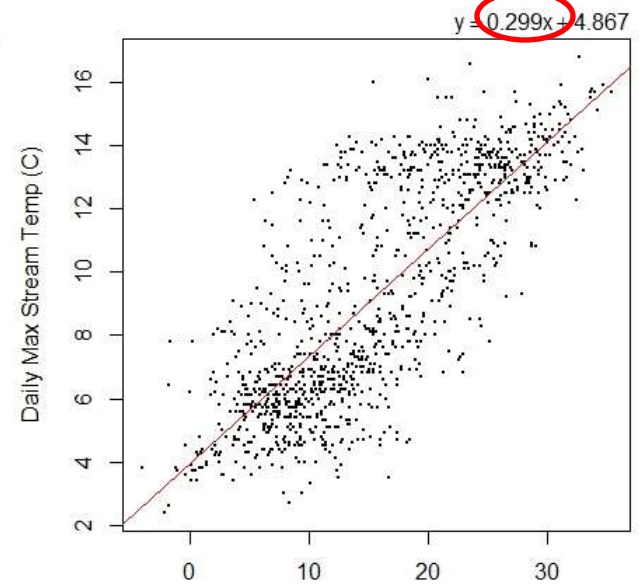
Johnson Milwaukie



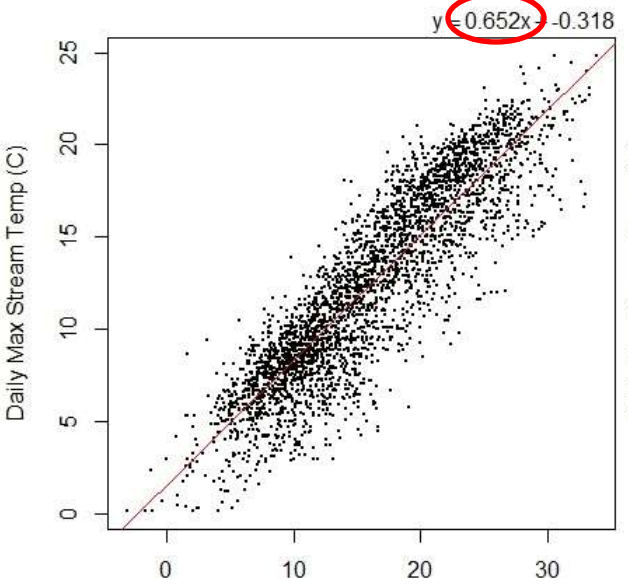
N Santiam



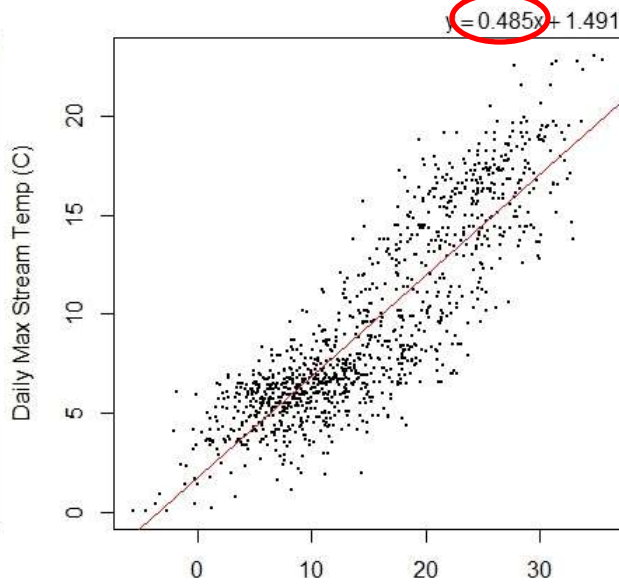
Middle Fork



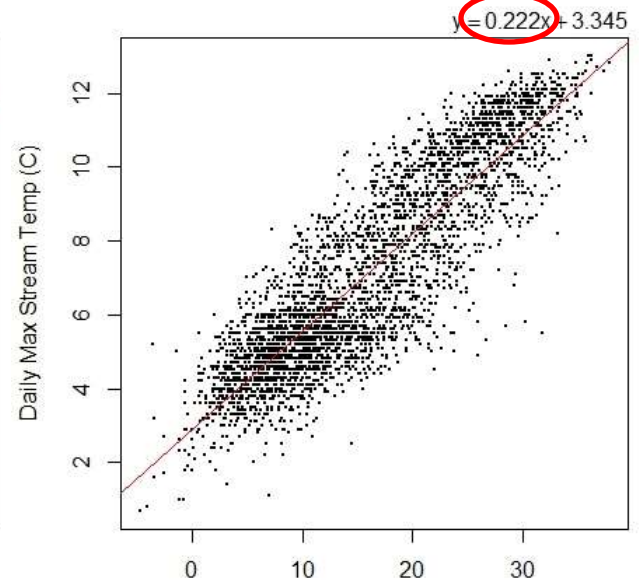
Fanno



S Santiam



South Fork

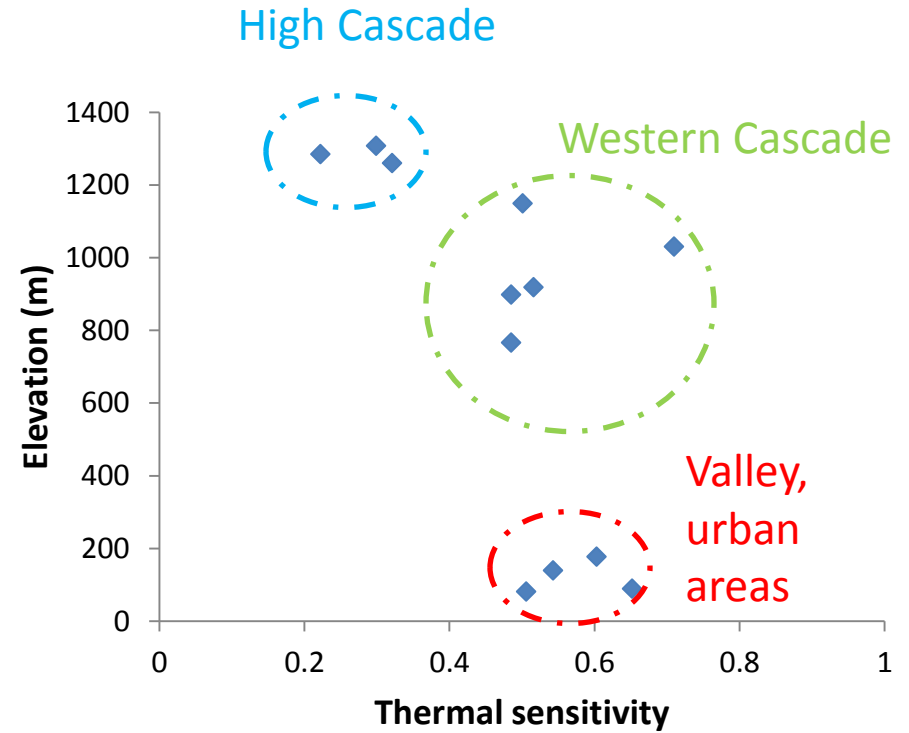
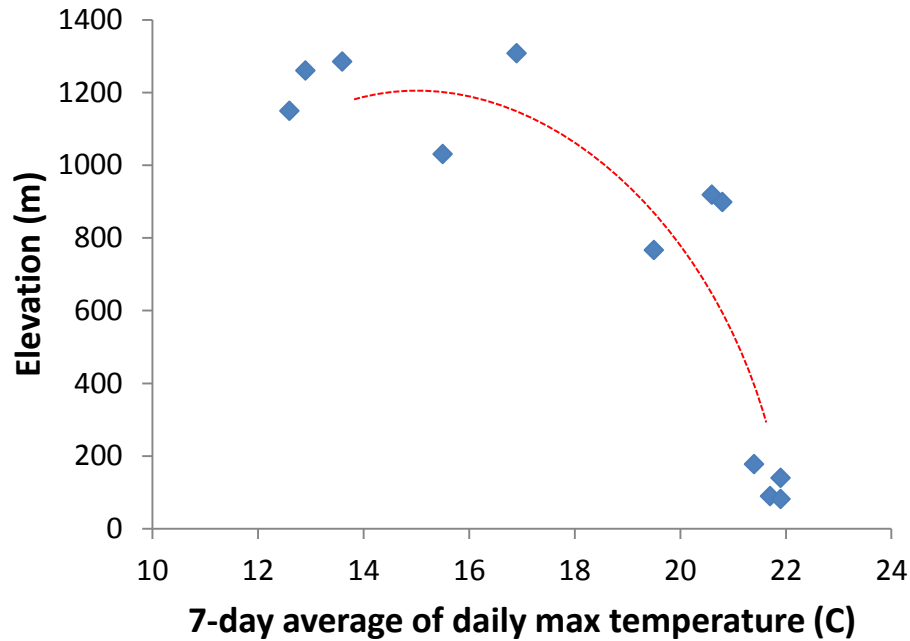


Daily Max Air Temp (C)

Daily Max Air Temp (C)

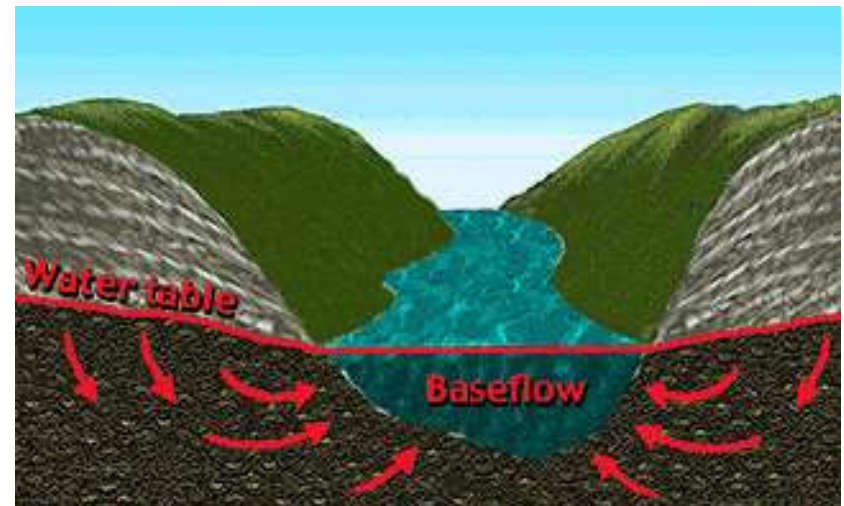
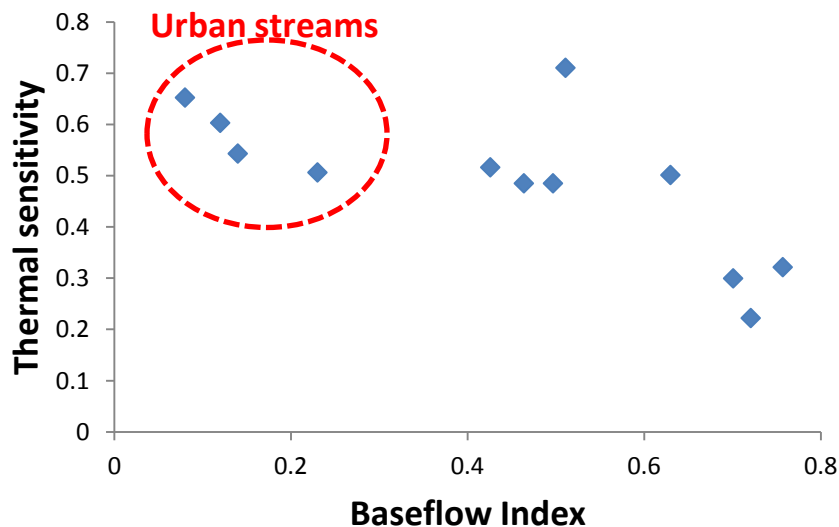
Daily Max Air Temp (C)

Stream temperature and elevation



Baseflow and thermal sensitivity

- Baseflow: The component of streamflow originating as subsurface flow.
- Baseflow Index: $BFI = \frac{\min(\text{Daily Flow})}{\text{ave}(\text{Annual Daily Flow})}$ (Poff 1996)



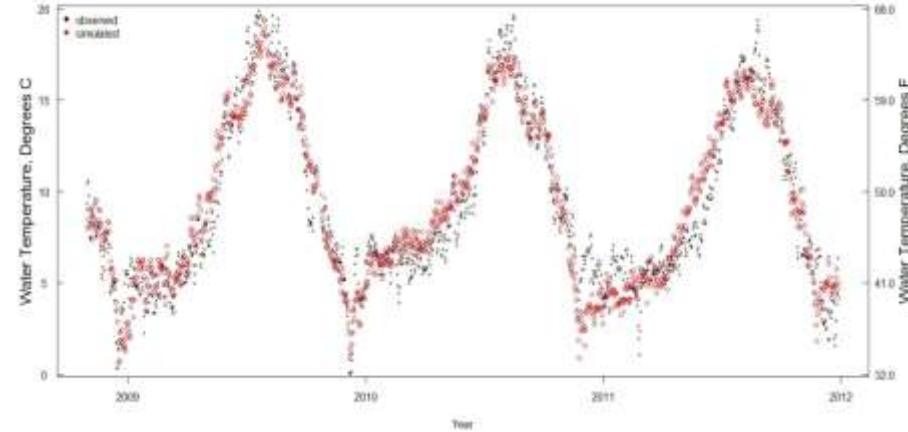
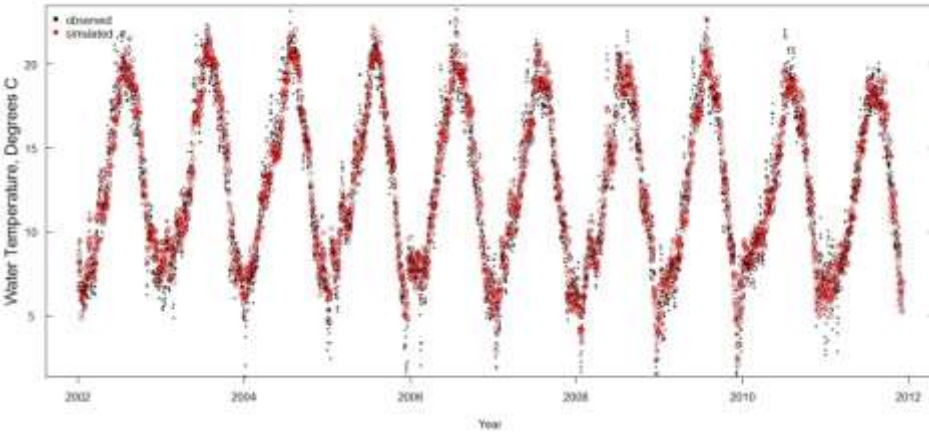
http://www.bigelow.org/virtual/water_sub2.html

Observed vs. simulated stream temperature

Johnson Creek

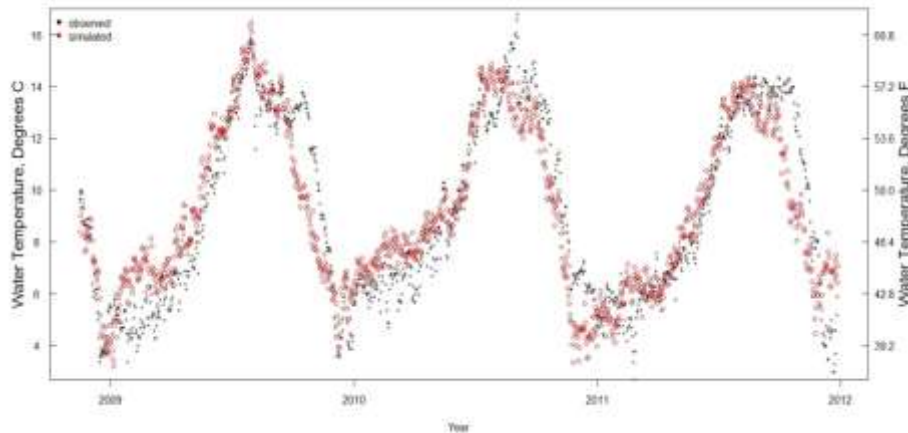
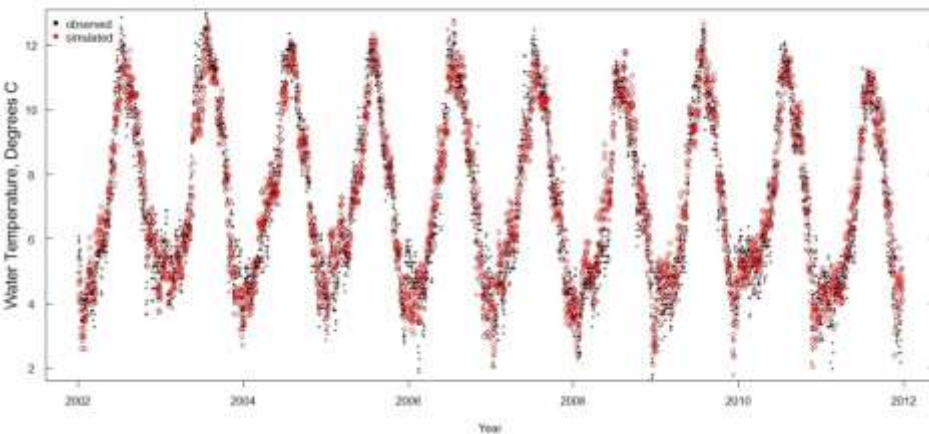
$R^2 = 0.92$

South Santiam



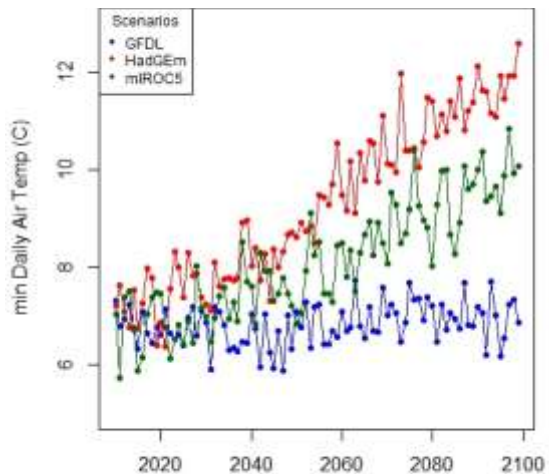
South Fork

Middle Fork

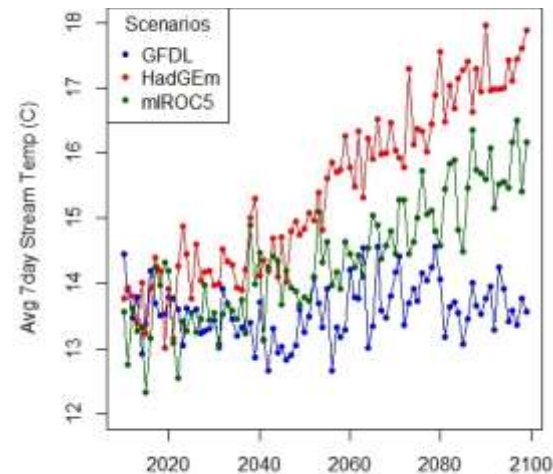


Change in air temperature, streamflow, and stream temperature, Johnson Creek

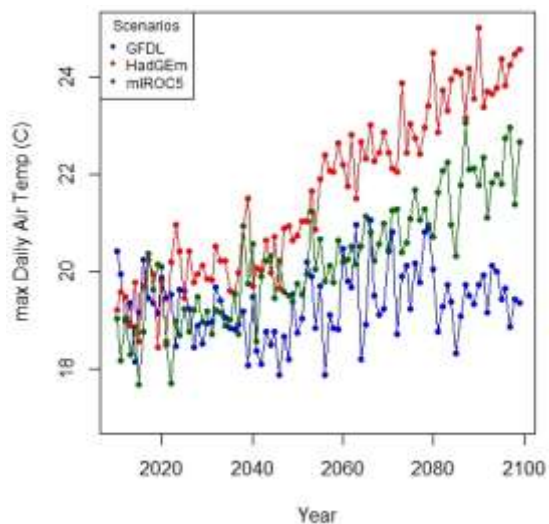
Air temp (min daily)



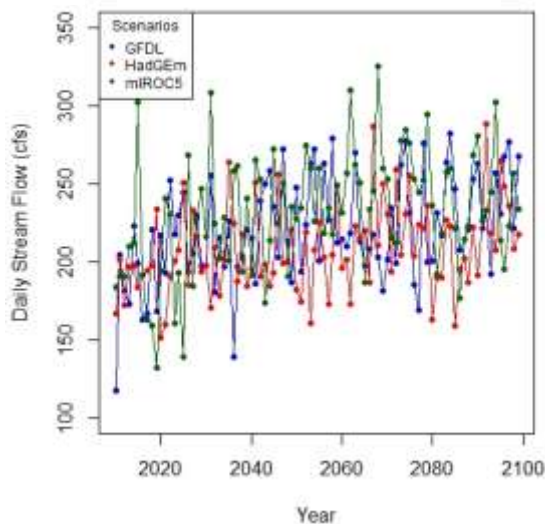
Stream temp (average 7DADM)



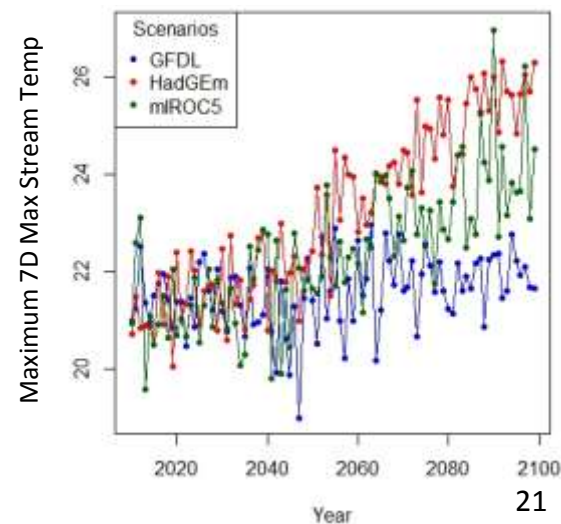
Air temp (max daily)



Streamflow

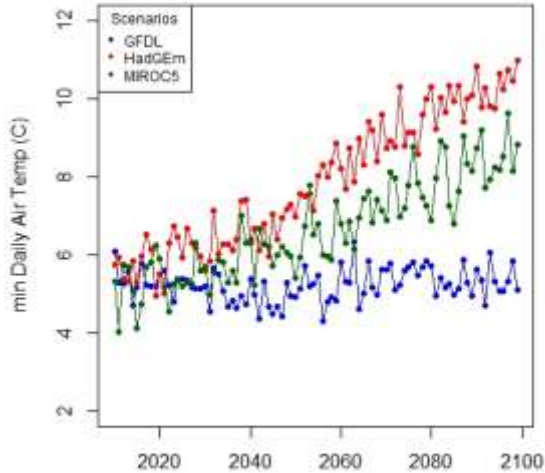


Stream temp (Max 7DADM)

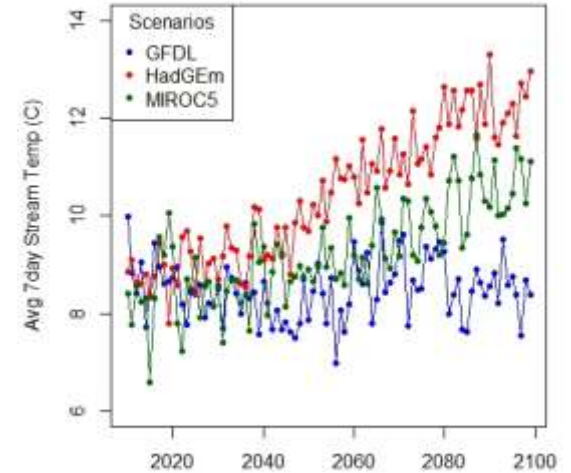


Change in air temperature, streamflow, and stream temperature, South Santiam

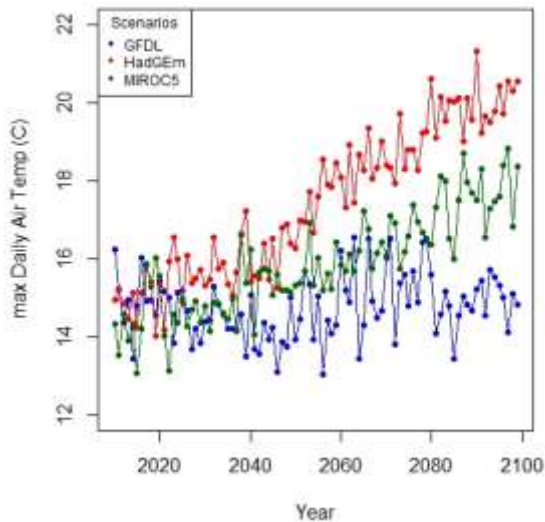
Air temp (min daily)



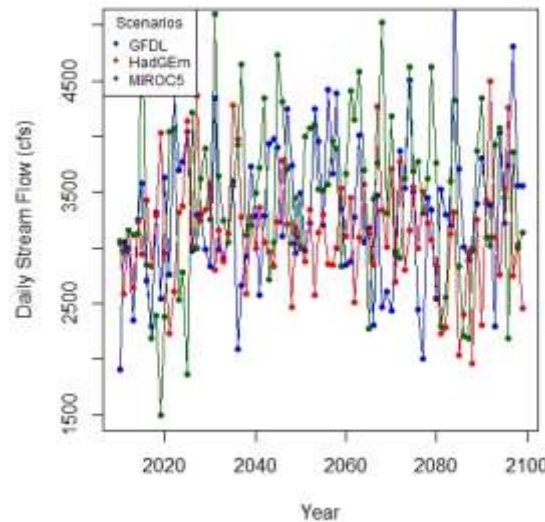
Stream temp (average 7DADM)



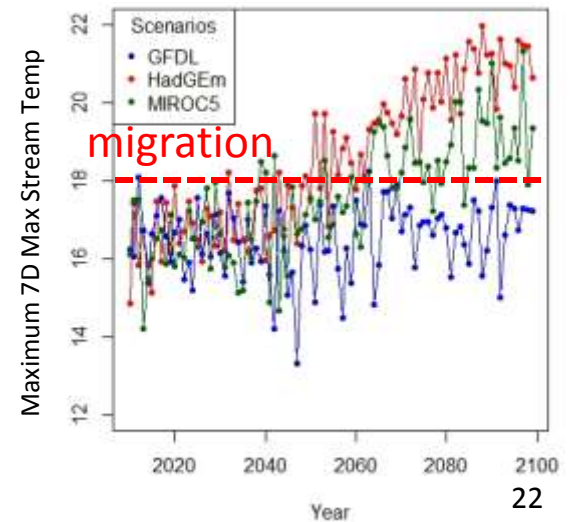
Air temp (max daily)



Streamflow

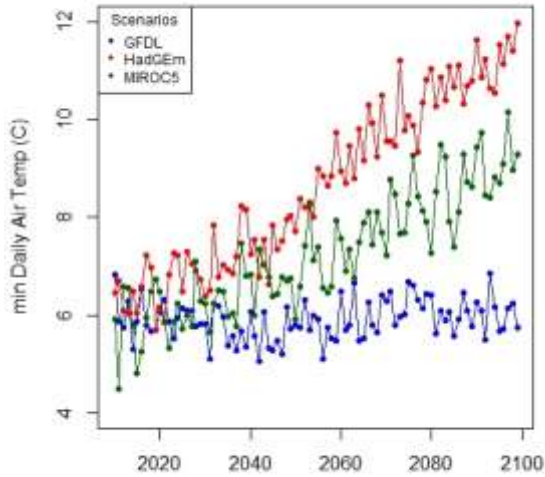


Stream temp (Max 7DADM)

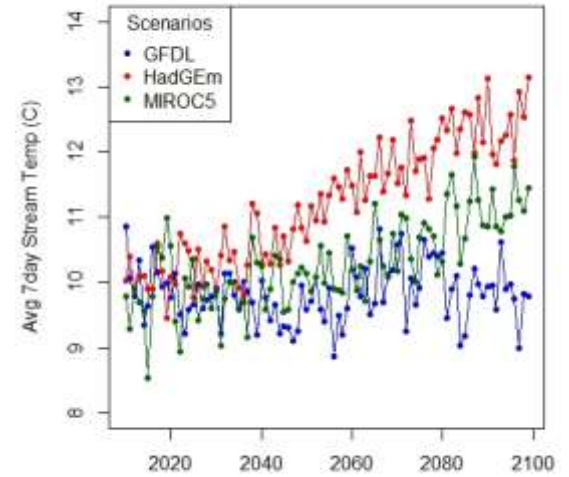


Change in air temperature, streamflow, and stream temperature, Middle Fork

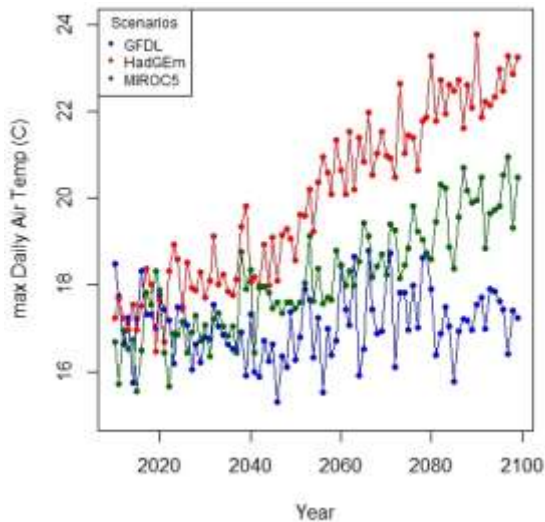
Air temp (min daily)



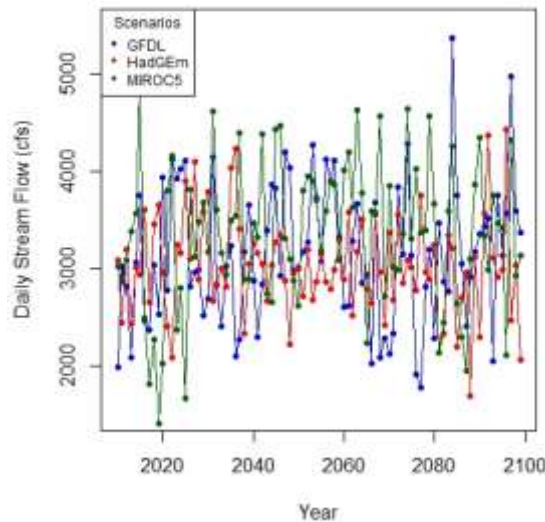
Stream temp (average 7DADM)



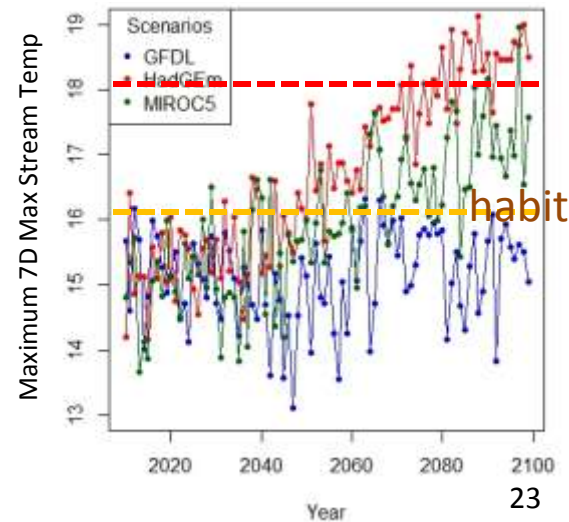
Air temp (max daily)



Streamflow



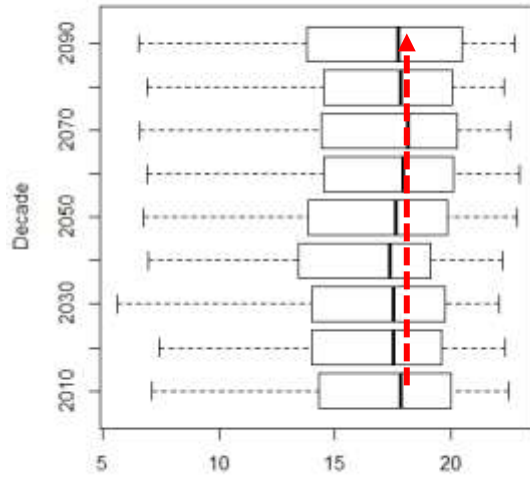
Stream temp (Max 7DADM)



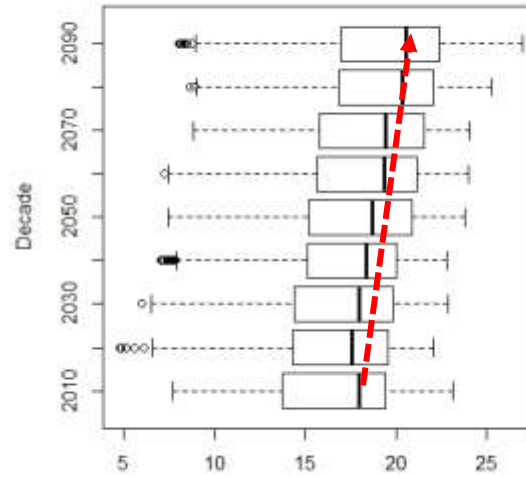
Change in 7DADMAX stream temperature by decade, Johnson Creek & Middle Fork

Johnson

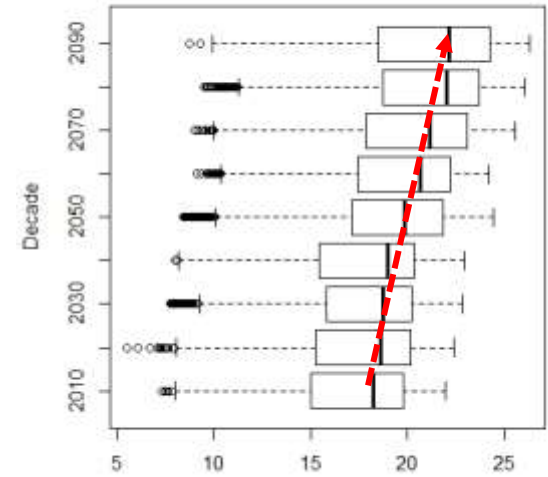
GFDL



MIROC5

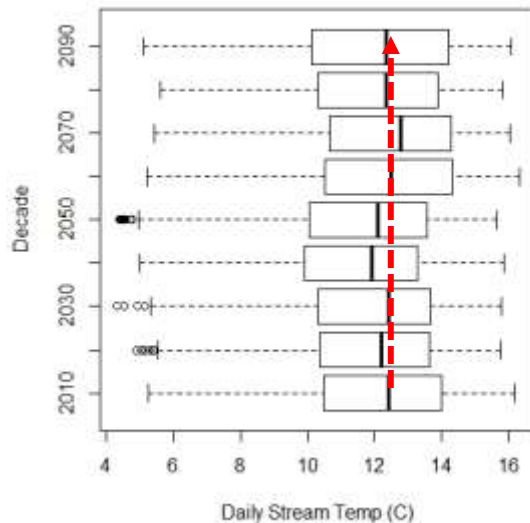


HadGEM

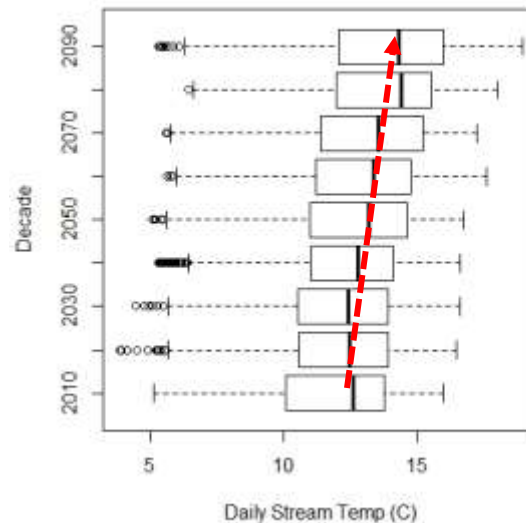


Middle Fork

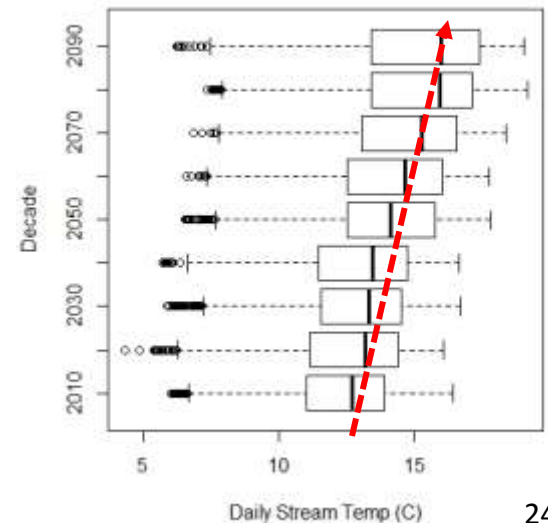
middle fork-GFDL (Summer-7d max)



middle fork-MIROC5 (Summer-7d max)



middle fork-HadGEM (Summer-7d max)

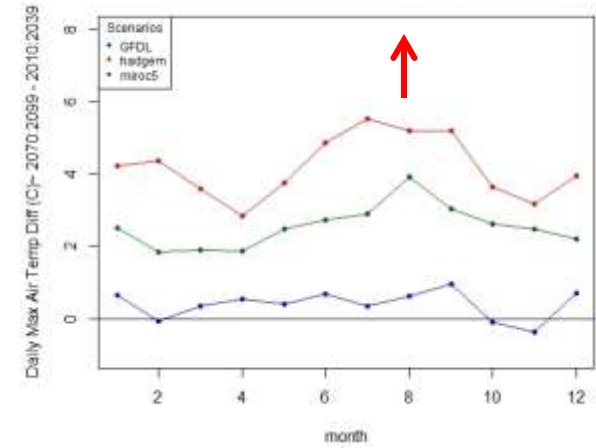
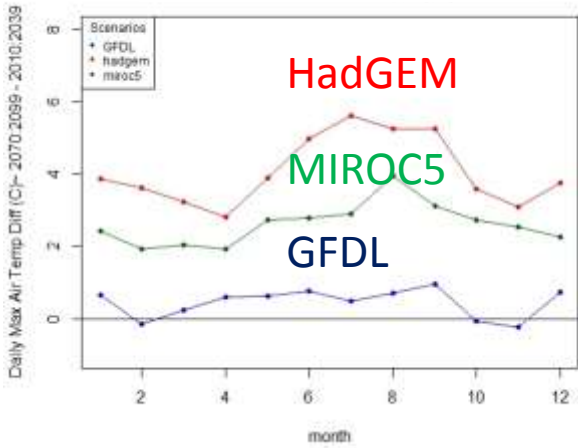
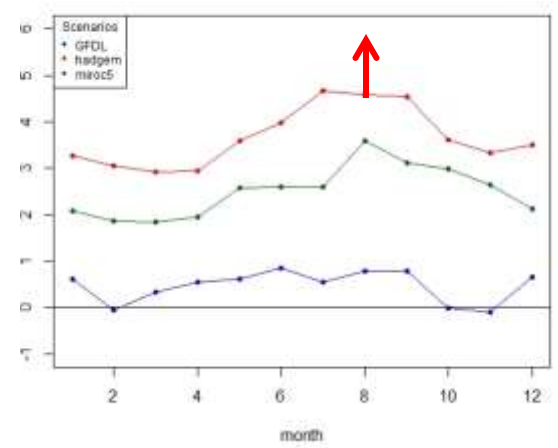


Johnson

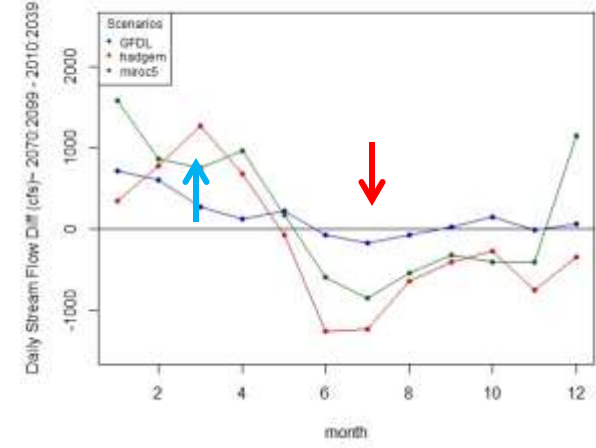
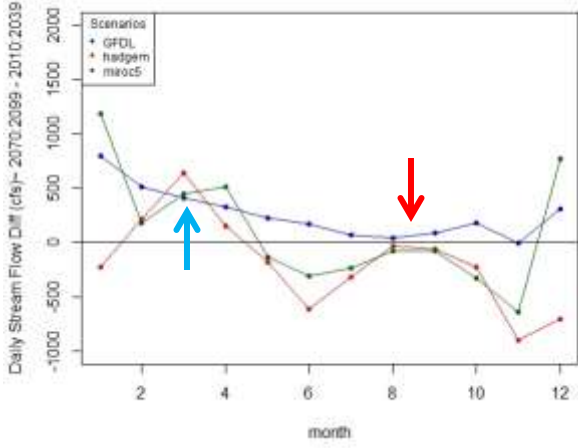
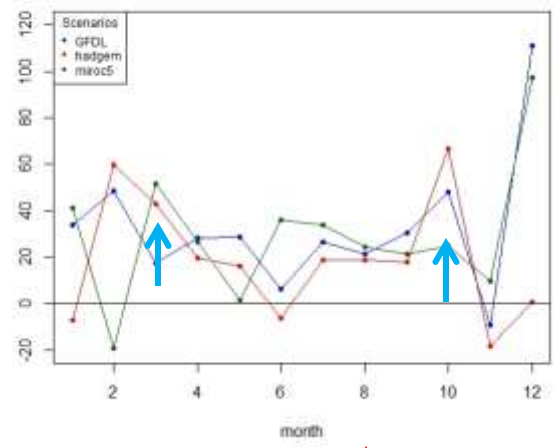
S Santiam

Middle Fork

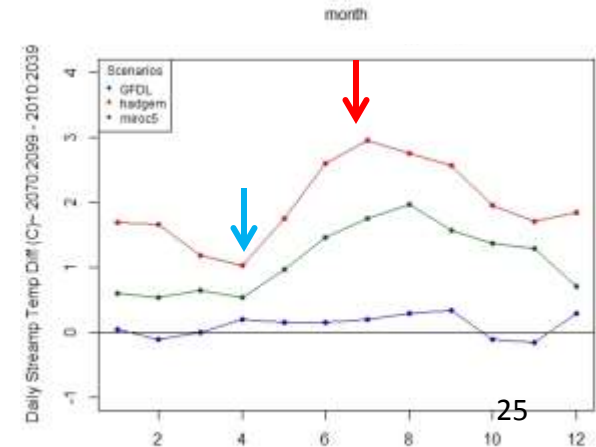
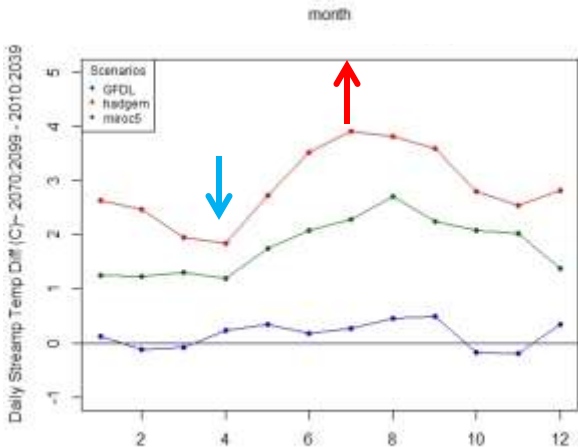
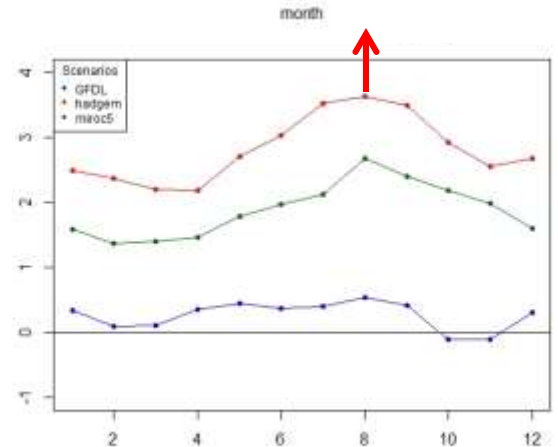
Δ in daily max air temp (C)



Δ in daily flow (cfs)



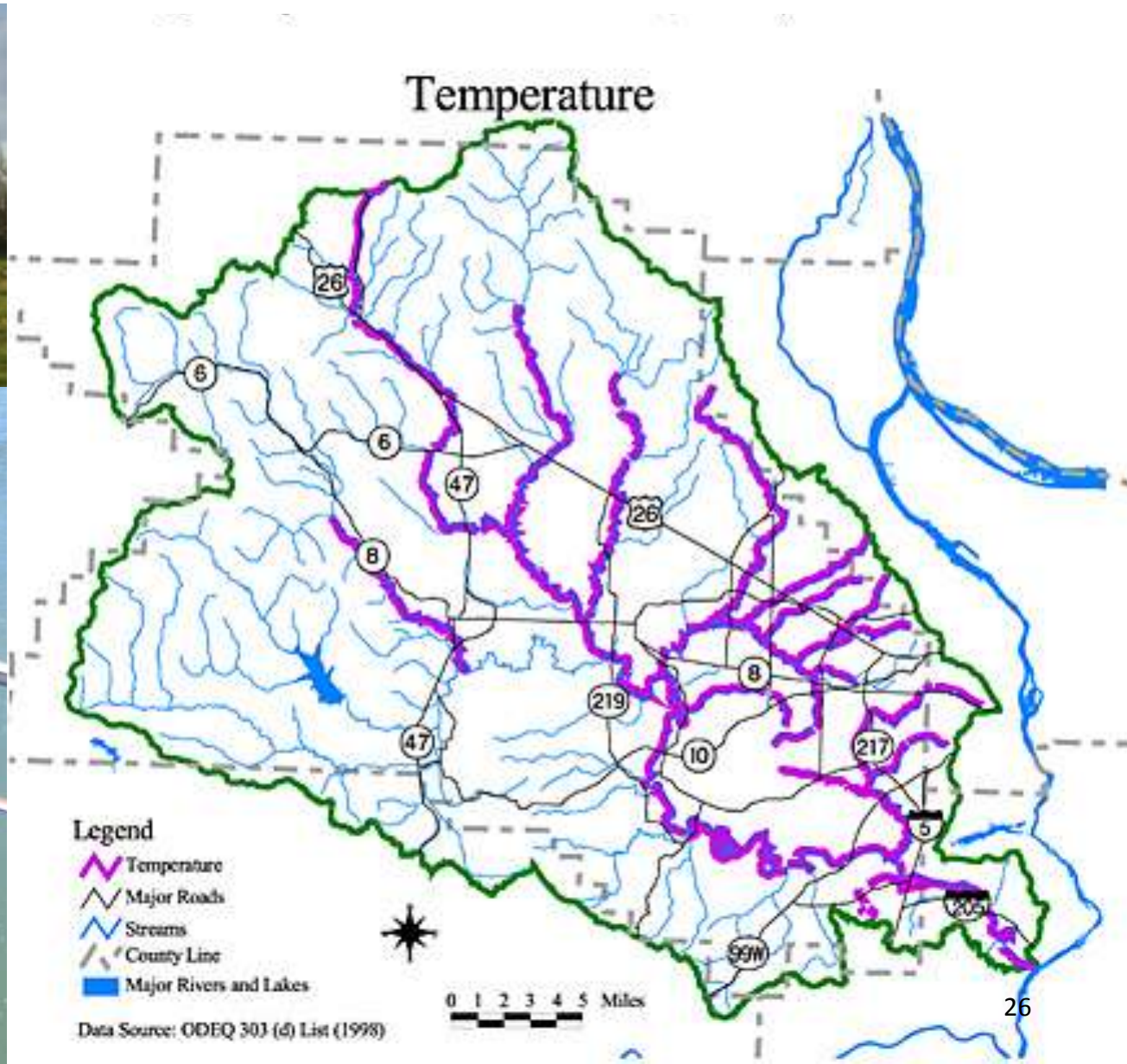
Δ in 7DADM stream (C)



Case 2: Stream temperature in the Tualatin River

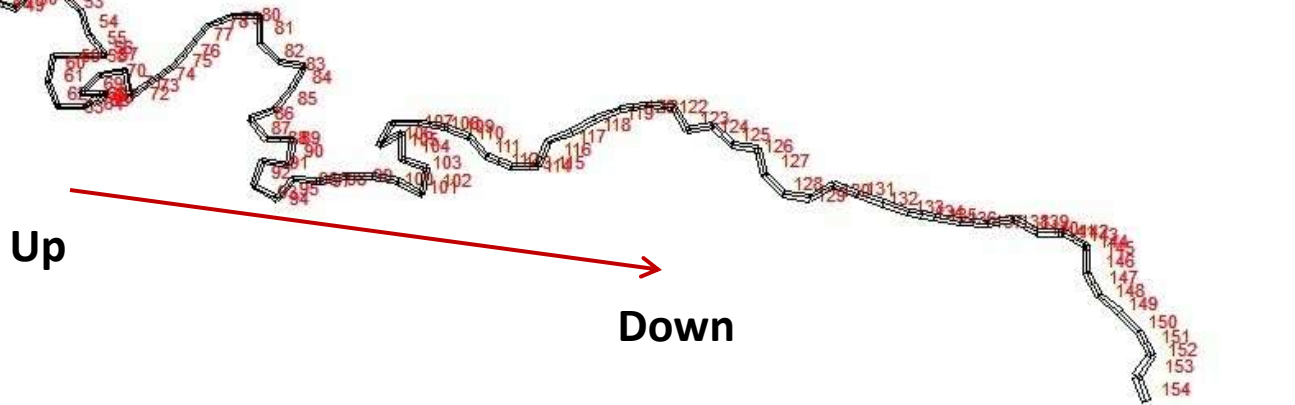
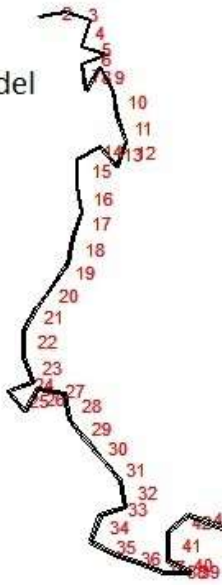


GROUND LEASE
OR
BUILD TO SUIT
JACK GALLAGHER
NORRIS
HIGGINS &
SIMPSON
223-7181



Modeling lower Tualatin water temperature using CE-QUAL-W2

-> from upper model



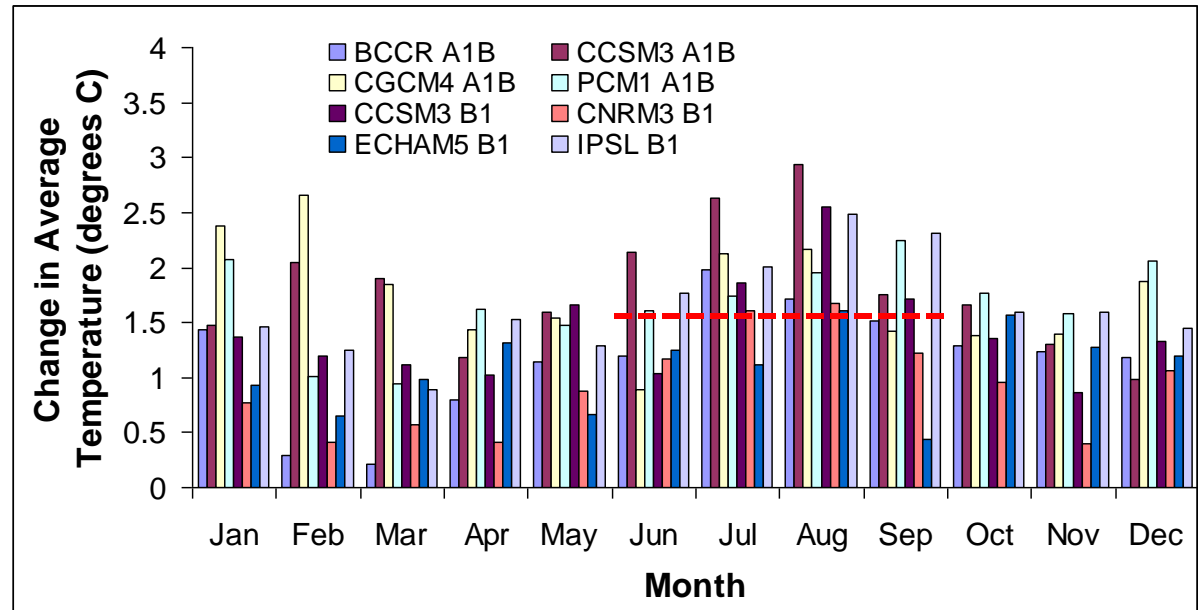
Lake Oswego Diversion Dam

Change in air temperature and streamflow

2040s

**Approximately
1.5 °C warmer**

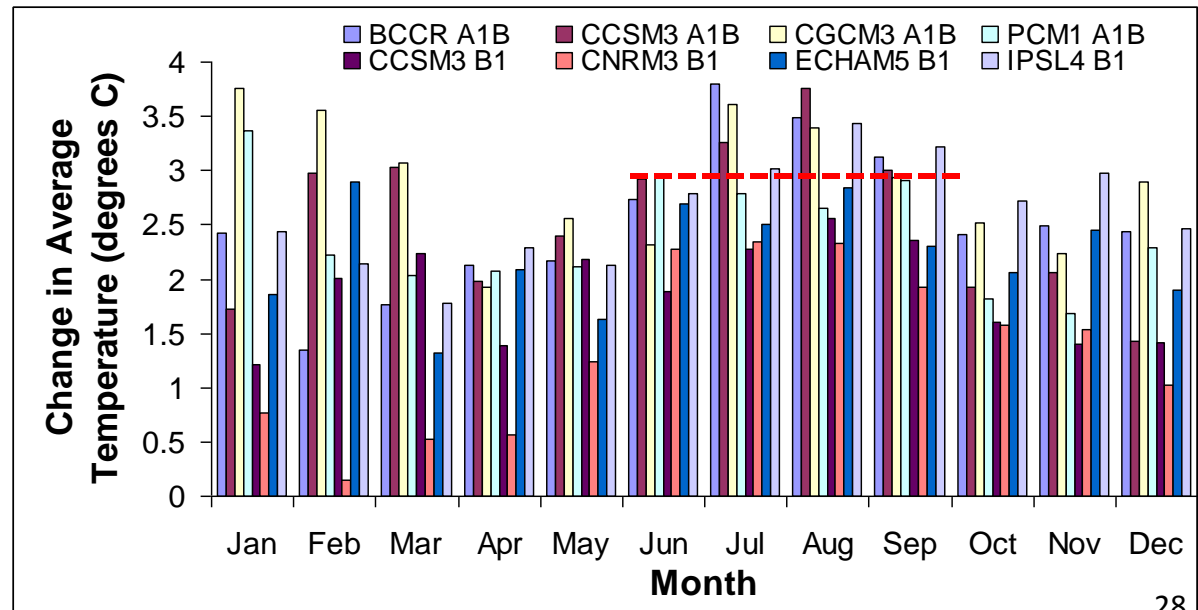
**5% reduction in
flow**



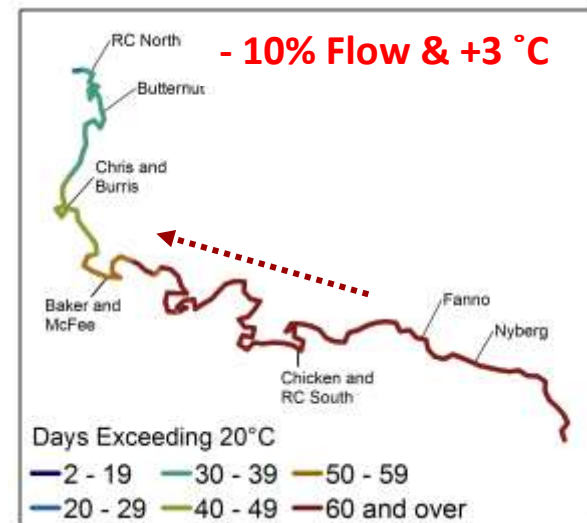
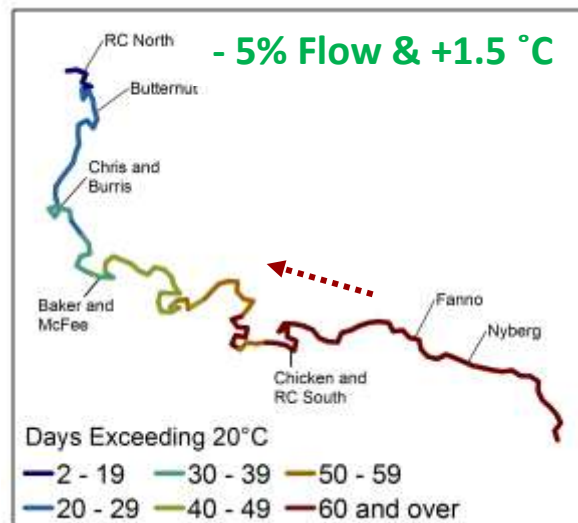
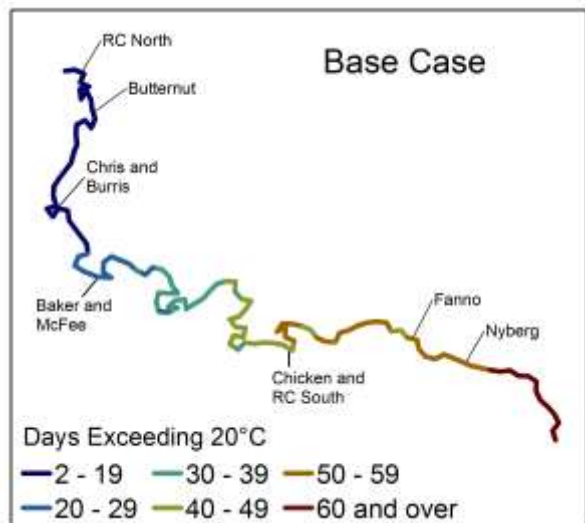
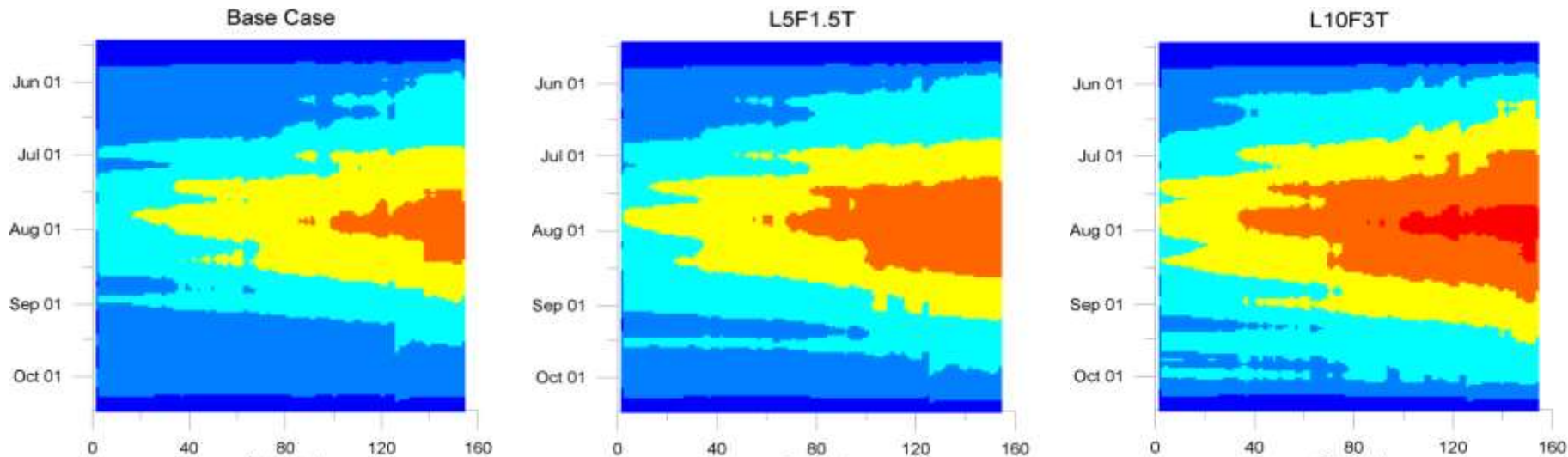
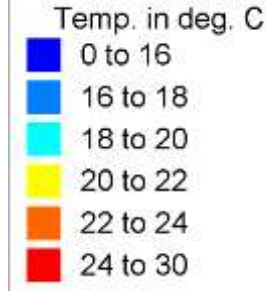
2070s

**Approximately
3.0 °C warmer**

**10% reduction in
flow**



Spatial and temporal change in water temperature under climate change

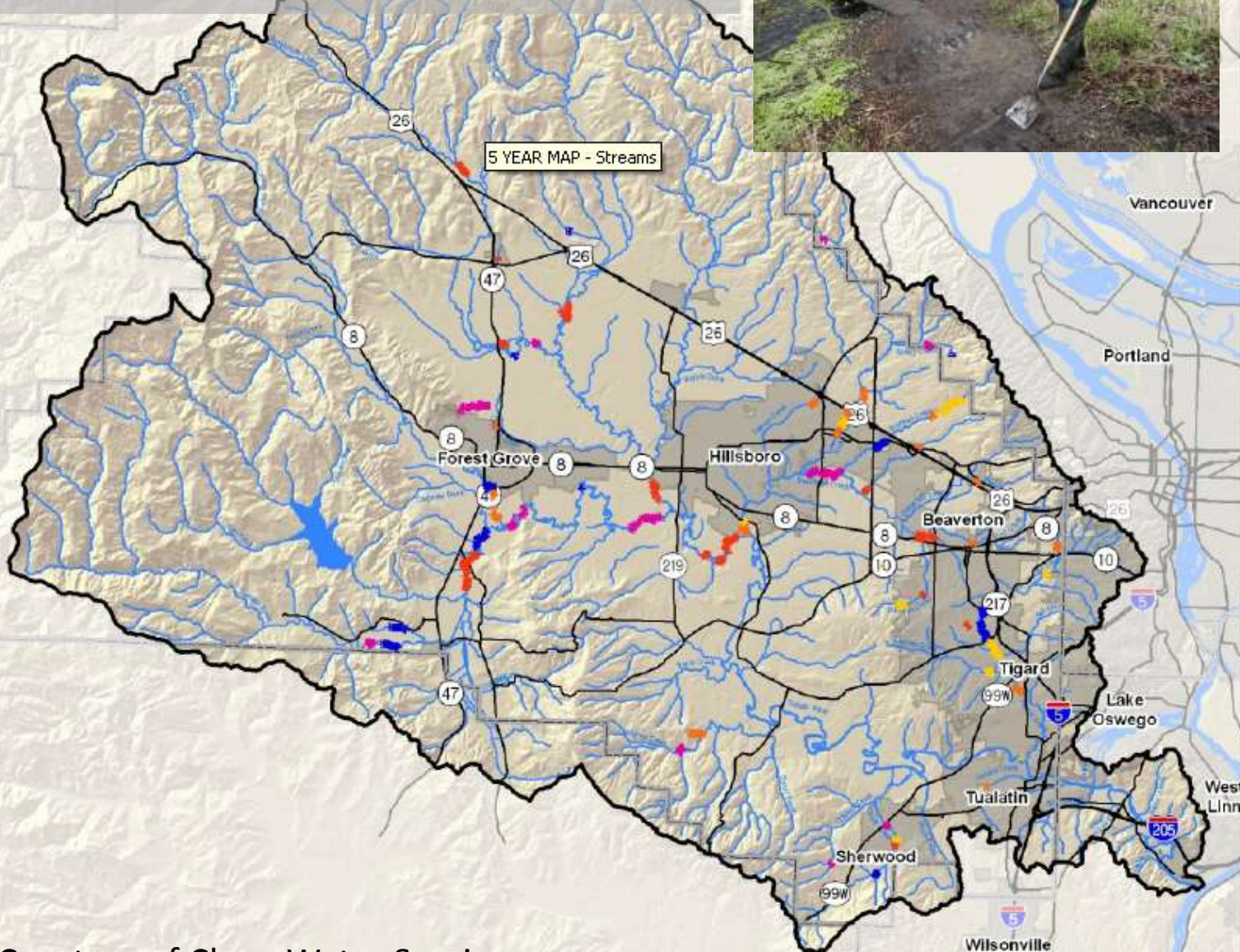


Can riparian vegetation reduce stream temperature? If so, how much and where?



05.16.2009

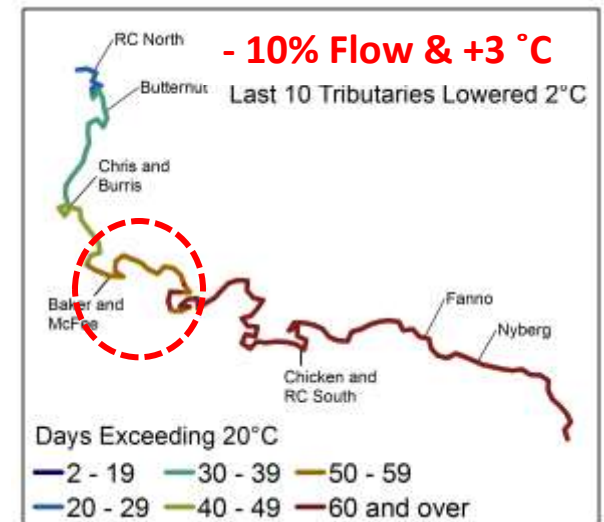
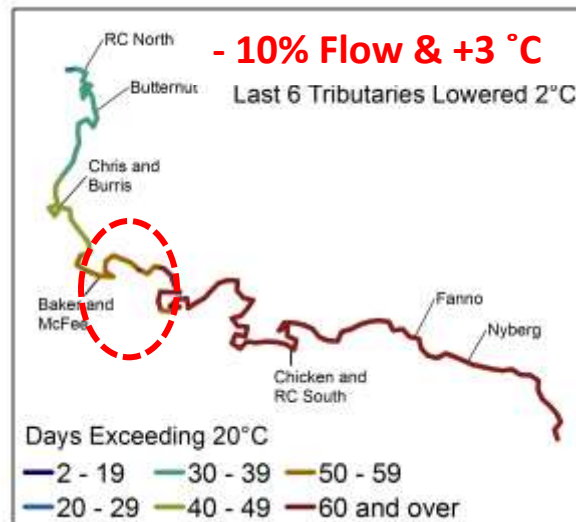
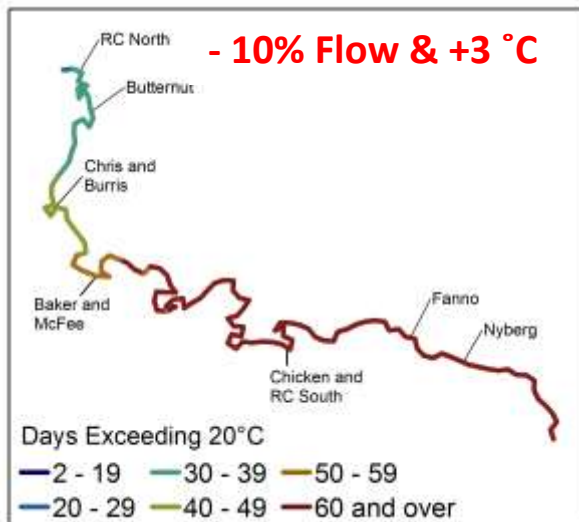
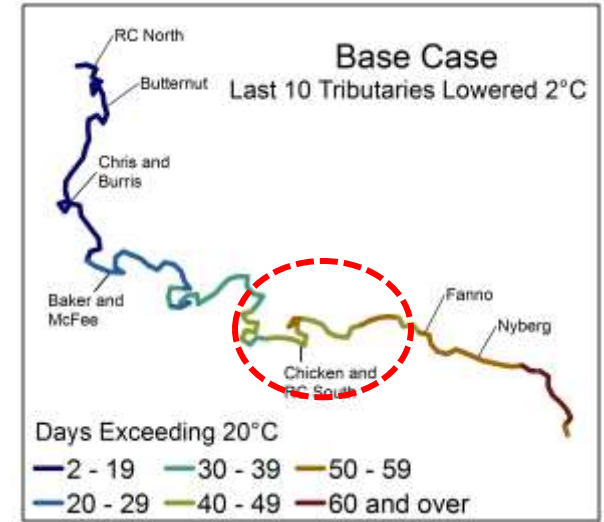
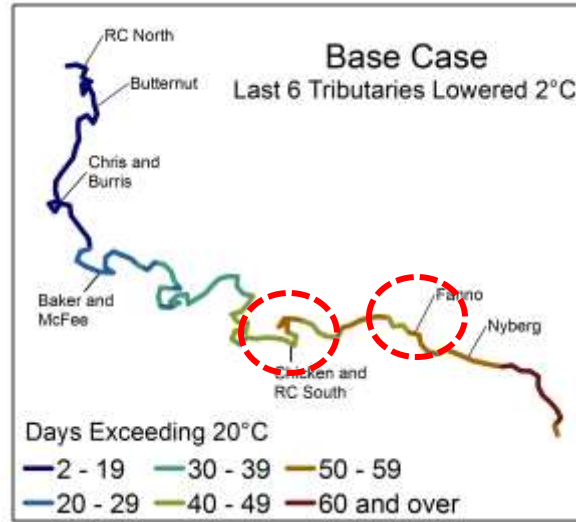
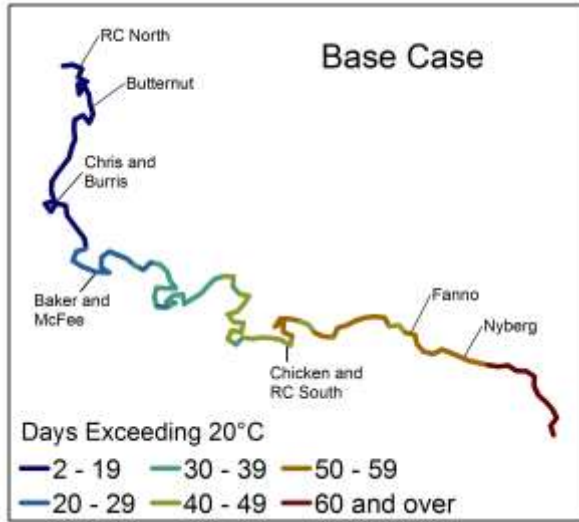
Stream enhancement project in the Tualatin

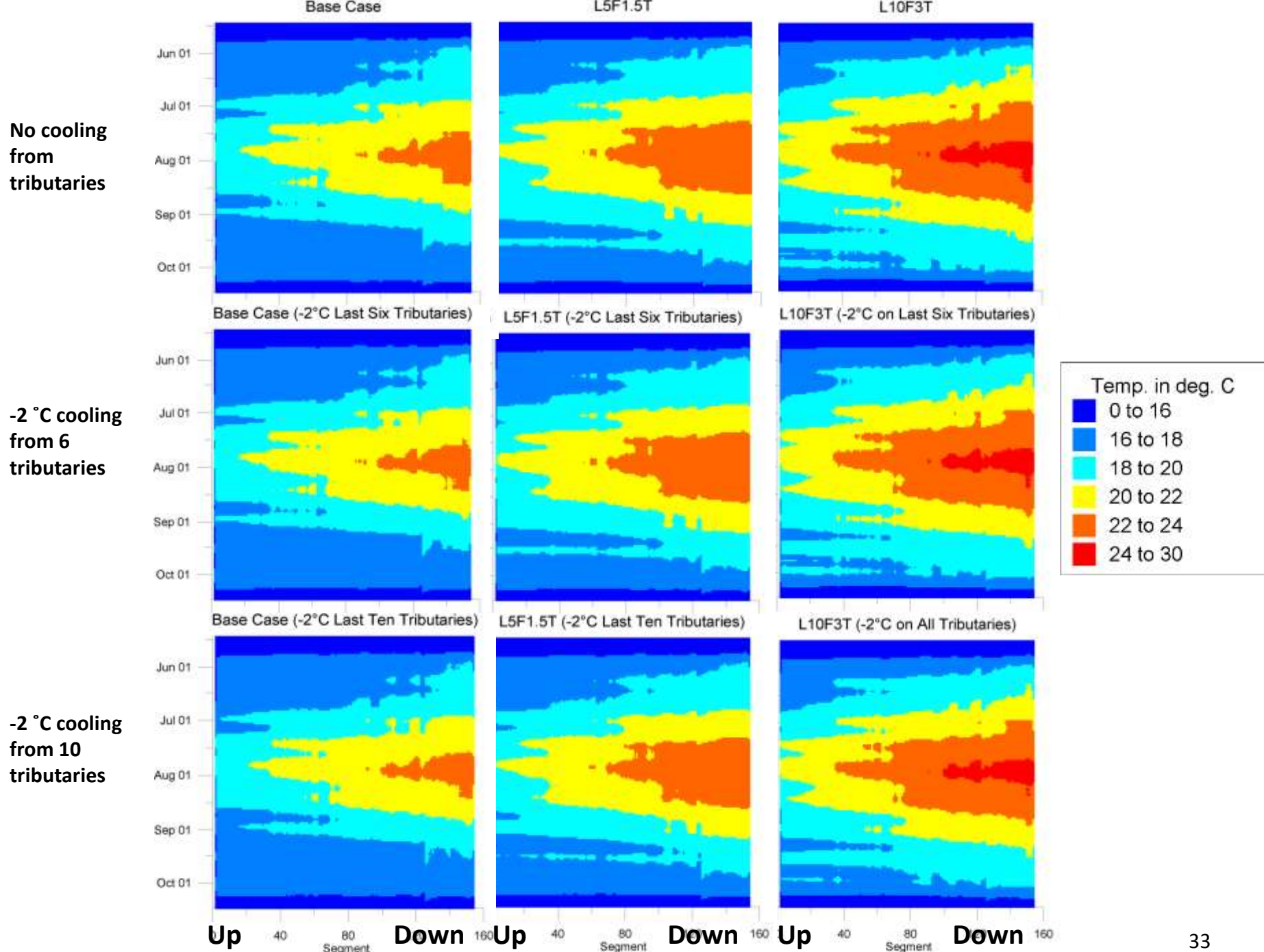


- 2004
- 2005
- 2006
- 2007
- 2008
- Tualatin Basin
- Major Urban Areas

Not intended as definitive property description. All users of this information should perform a separate investigation of conditions before commencing any plan, design, construction, watershed enhancement activities, or other work. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, concerning the information.

Number of days that water temperature exceeds 20° C under base and **high** climate change scenarios





Source: Chang and Lawler (2011) IAHS publication

Summary

- Thermal sensitivity varies over space (High thermal sensitivity in lowland, urban streams with low BFI).
- Daily maximum stream temperature is highly associated with daily maximum air temperature (+) and daily streamflow (-).
- Stream temperature is projected to increase more in summer than in spring in PNW streams due to changes in flow regime.
- Surface water-fed streams in mid-elevation respond to changes in climate more abruptly than ground water-dominated streams.
- Climate change will further expand the spatial and temporal extent of thermal regime.
- Riparian vegetation reduces stream temperature in small streams, but has limited effects on reducing mainstem stream temperature.

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Questions?

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