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Temperature Simulations and Analysis in Support of the Willamette Biological Opinion

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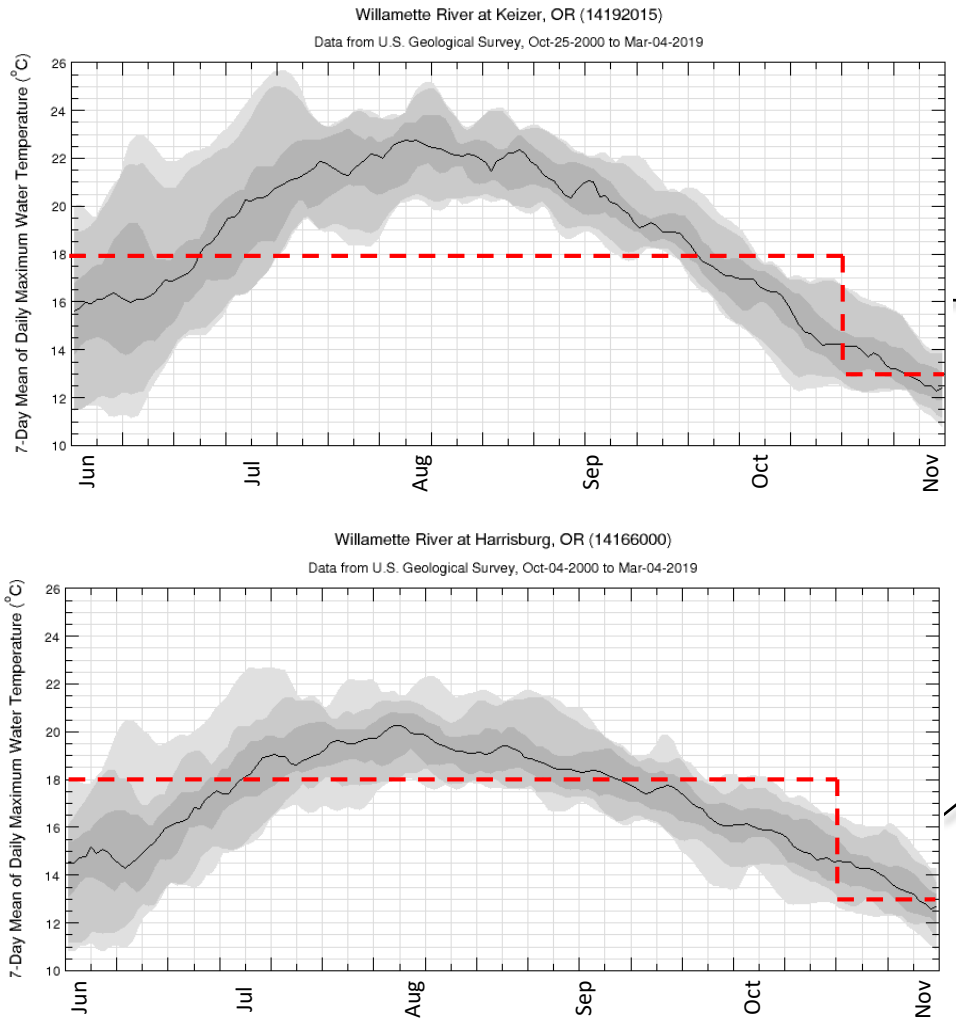
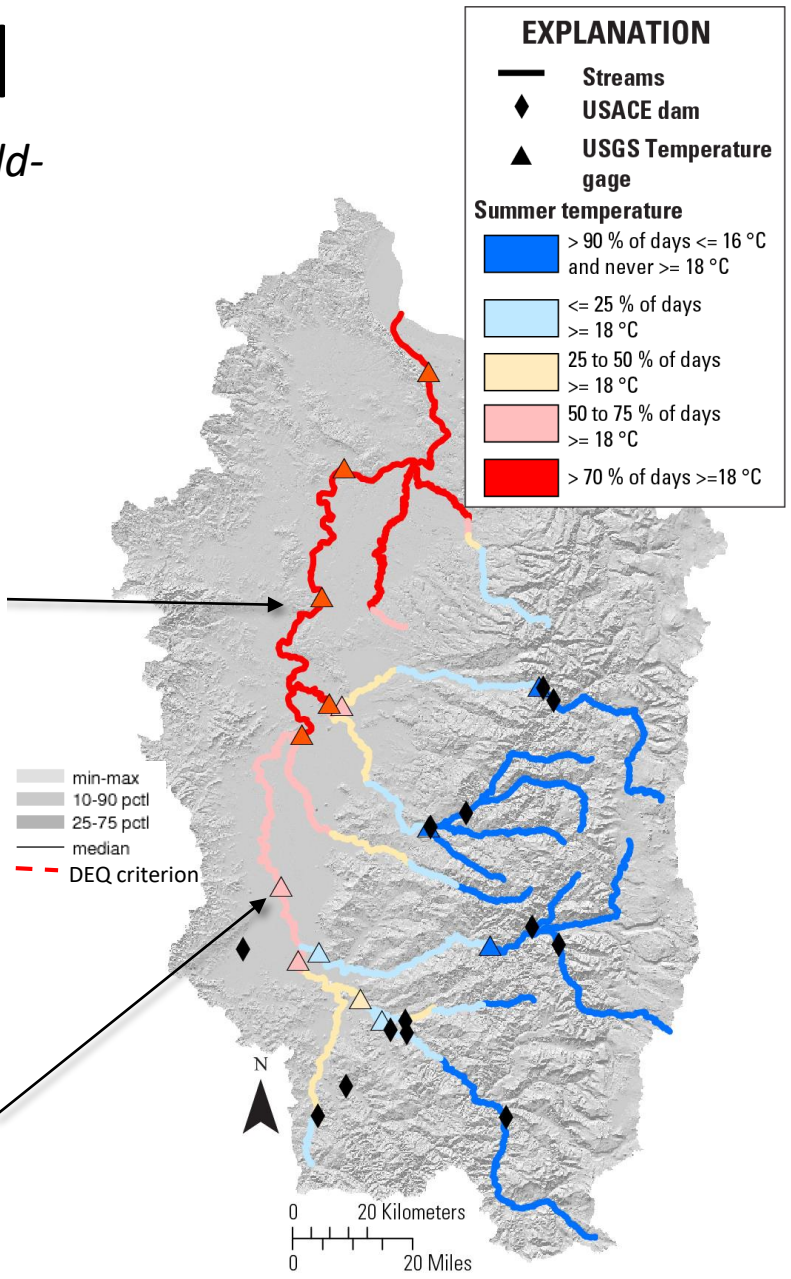
US Army Corps of Engineers, Portland District

Willamette Fisheries Science Review
March 13, 2019

U.S. Department of the Interior
U.S. Geological Survey

Willamette River thermal conditions: *Seasonally challenging for cold-water adapted species*





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USGS map by Gabe Gordon
Temperature plots from USGS Data Grapher

Willamette River thermal conditions: understanding temperature

Temperature ≈ the concentration of heat in the system

$$q \propto mC\,\Delta T$$

q = amount of heat added or removed from the system
m = mass of water
C = specific heat of water (approximately constant)

$$\Delta T \propto \frac{q}{mC}$$

$$water\ temperature \propto \frac{heat\ load}{discharge}$$

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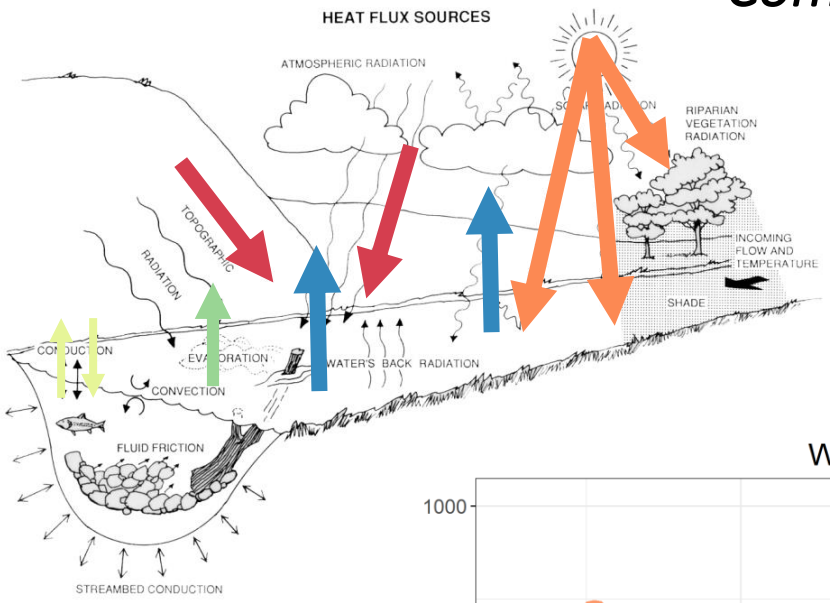
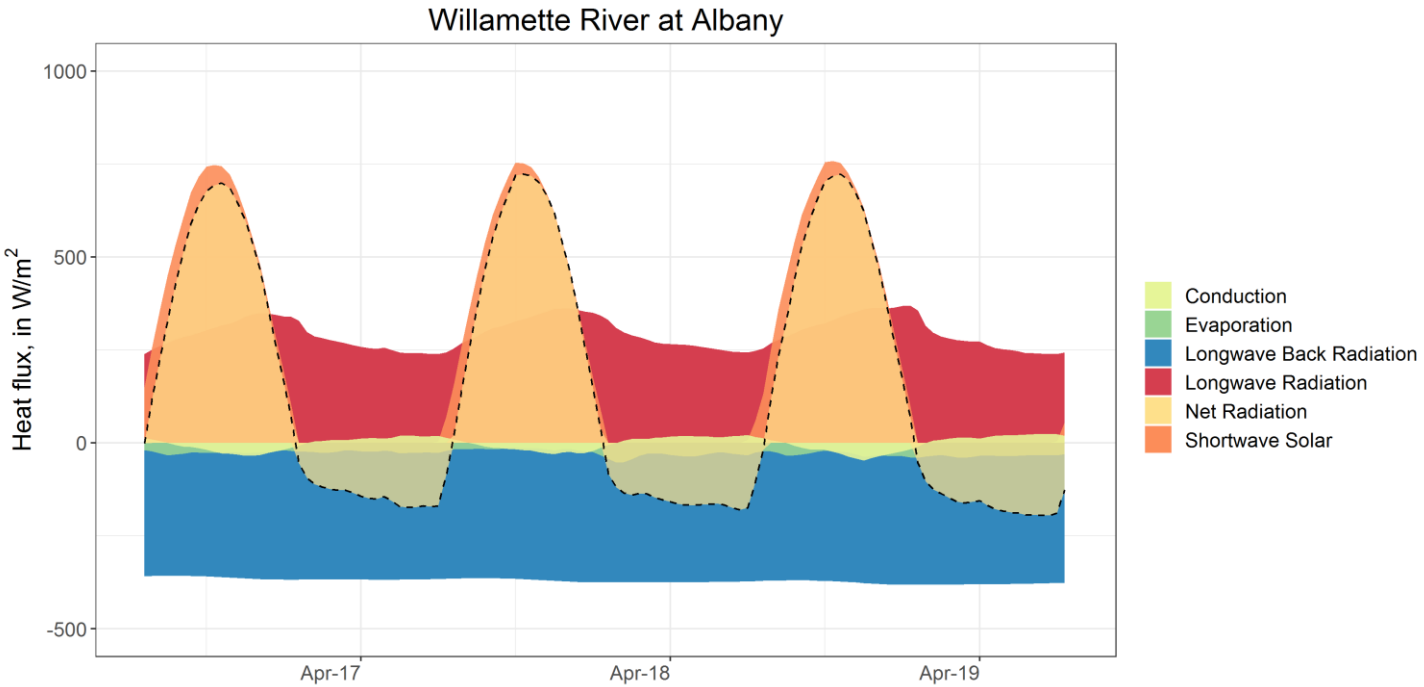
Discussion after Poole and Berman, 2001 and Caissie et al., 2006

Heat load to the Willamette River:

Comparing flux source and magnitude



$$water\ temperature \propto \frac{heat\ load}{discharge}$$



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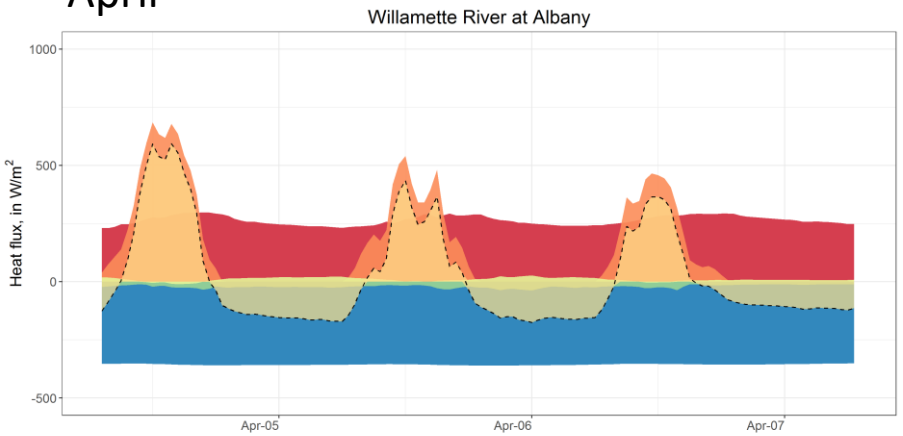
provisional results; subject to revision

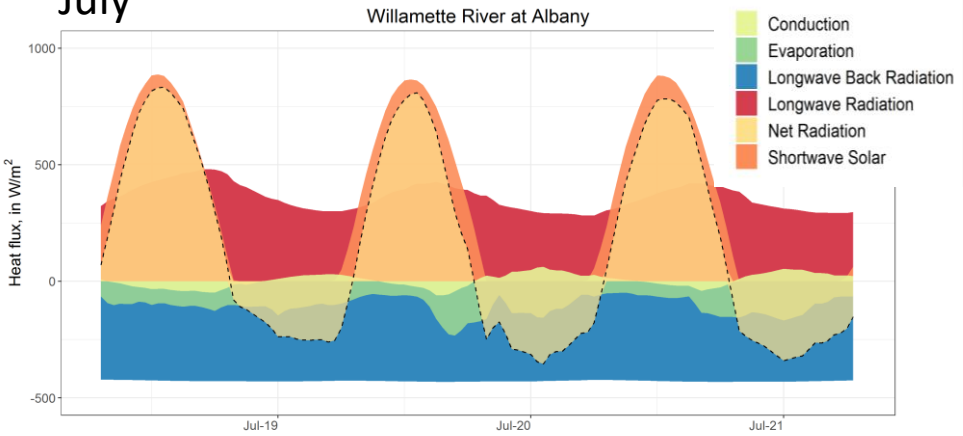
Relating heat load to temperature in the Willamette River

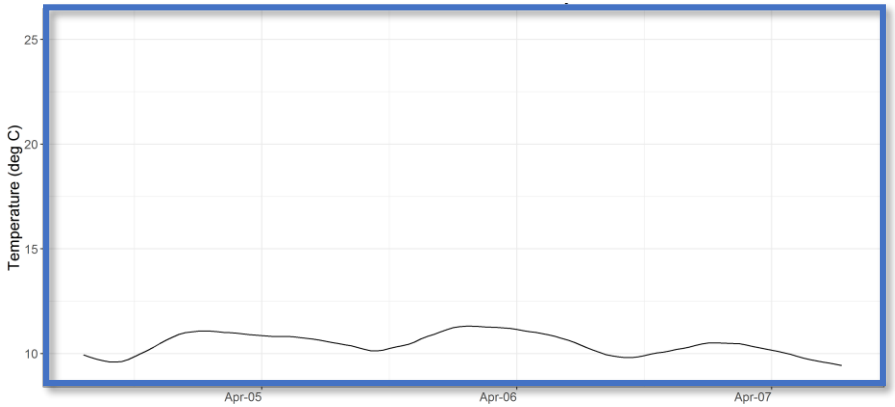
$$water\ temperature \propto \frac{heat\ load}{discharge}$$

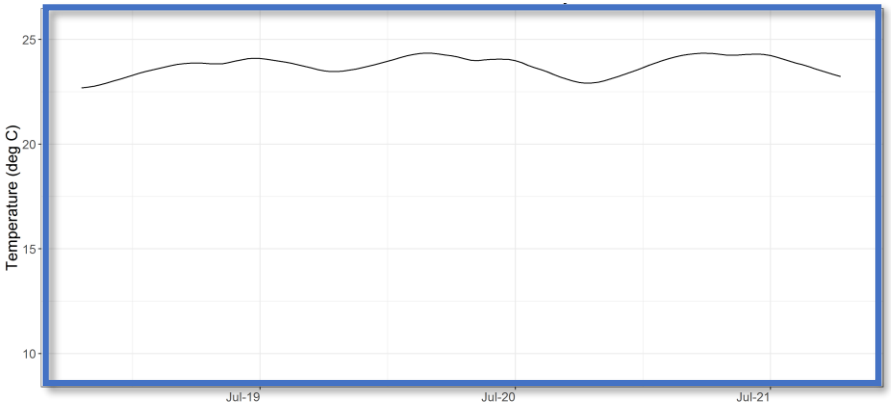
April



July







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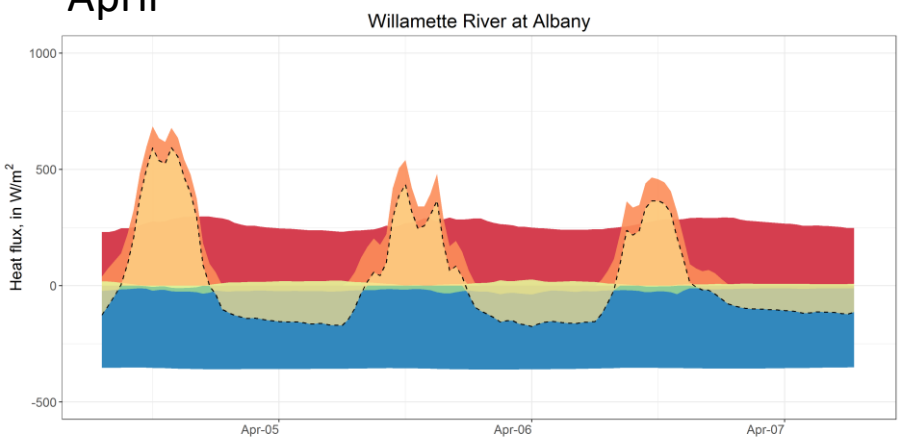

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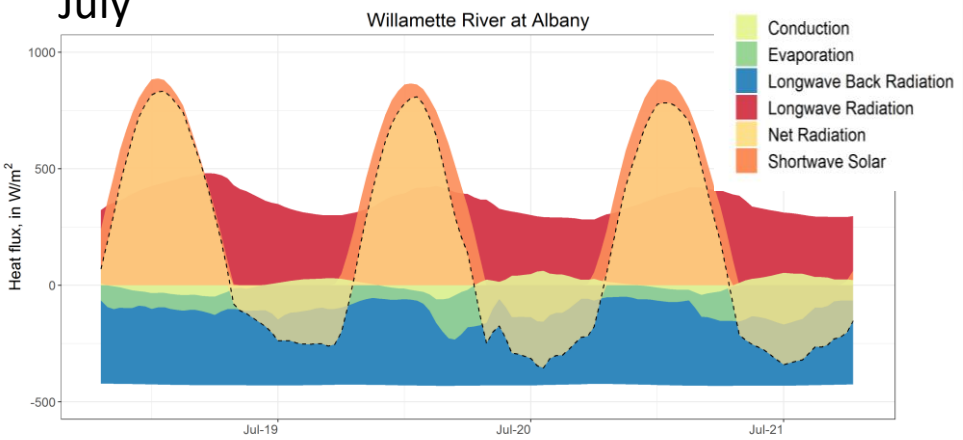

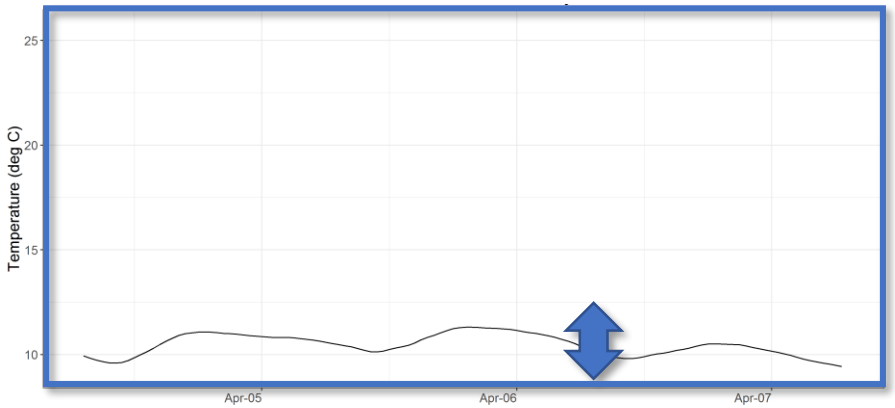

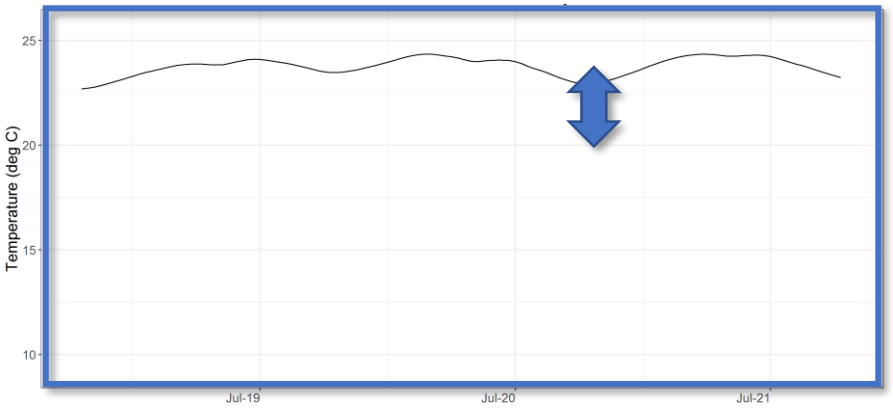

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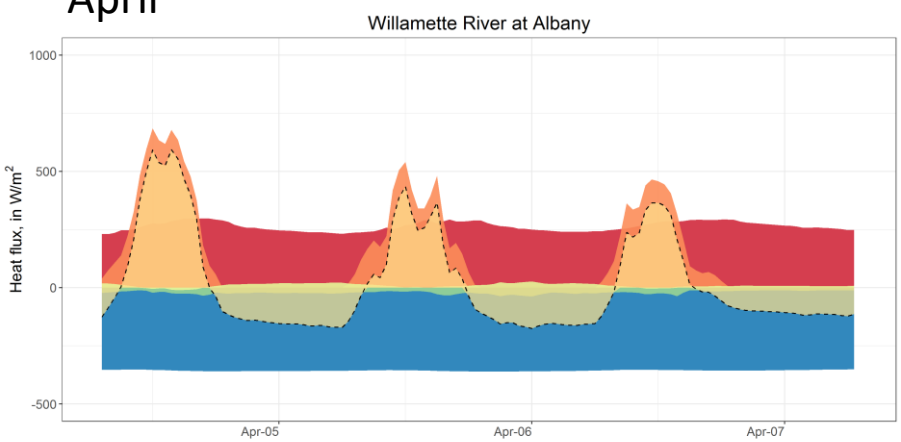

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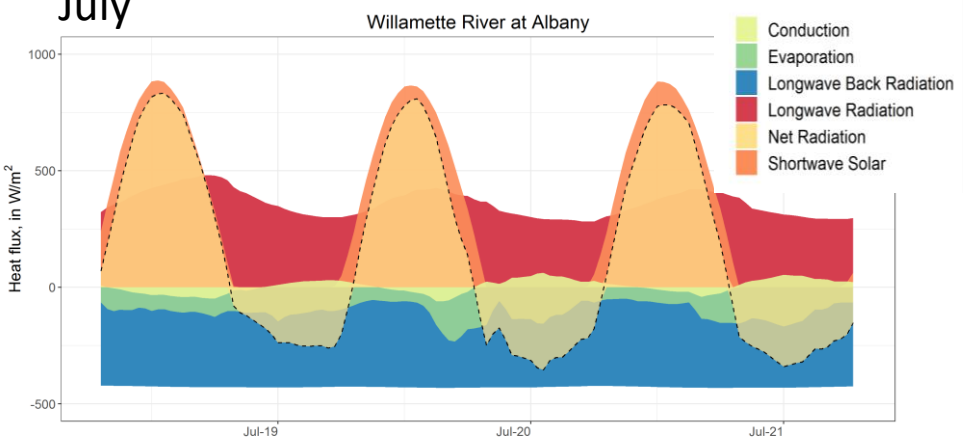

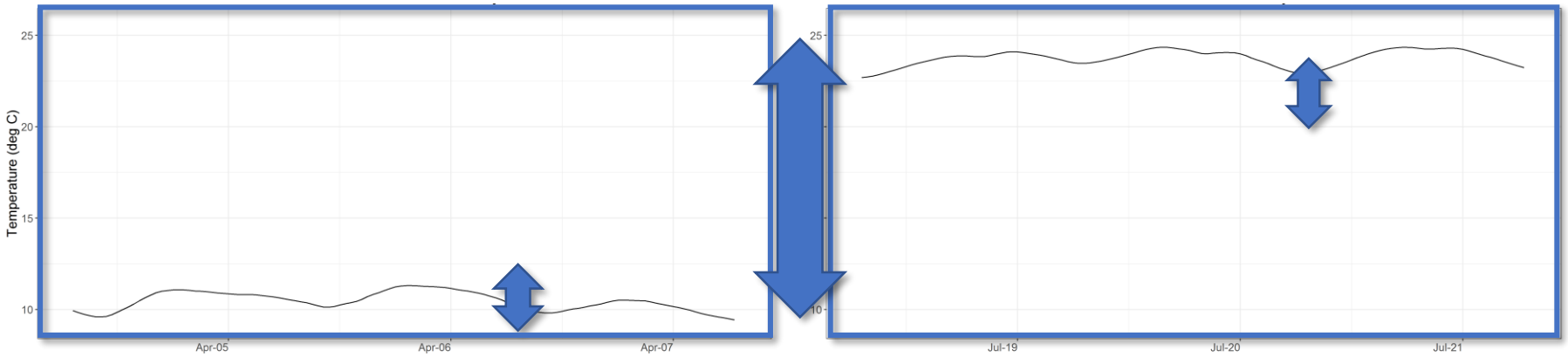

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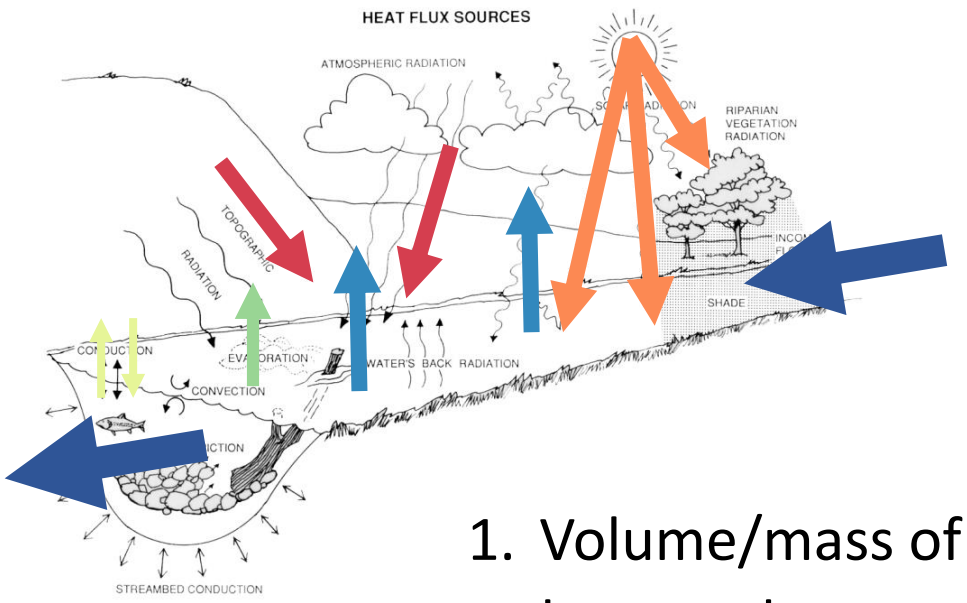
Temperature in the Willamette River: influence of discharge



$$water\ temperature \propto \frac{heat\ load}{discharge}$$

1. Volume/mass of water determines temperature response to given heat input (“buffering capacity”)

2. Velocity determines travel time from dam outflow or degree of river temperature adjustment to environmental fluxes

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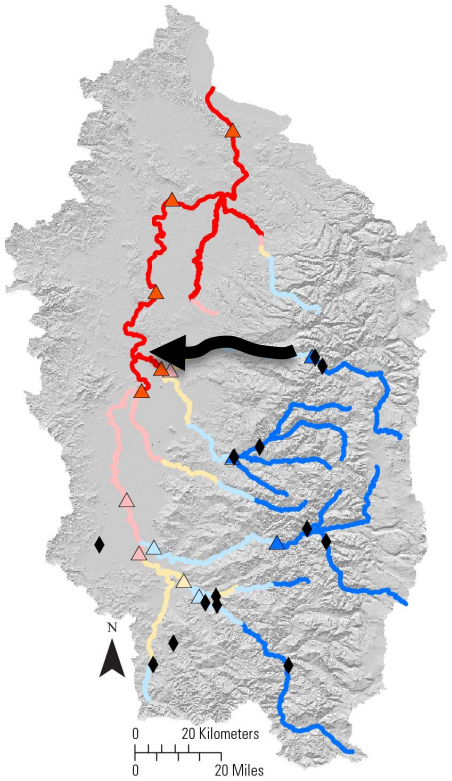
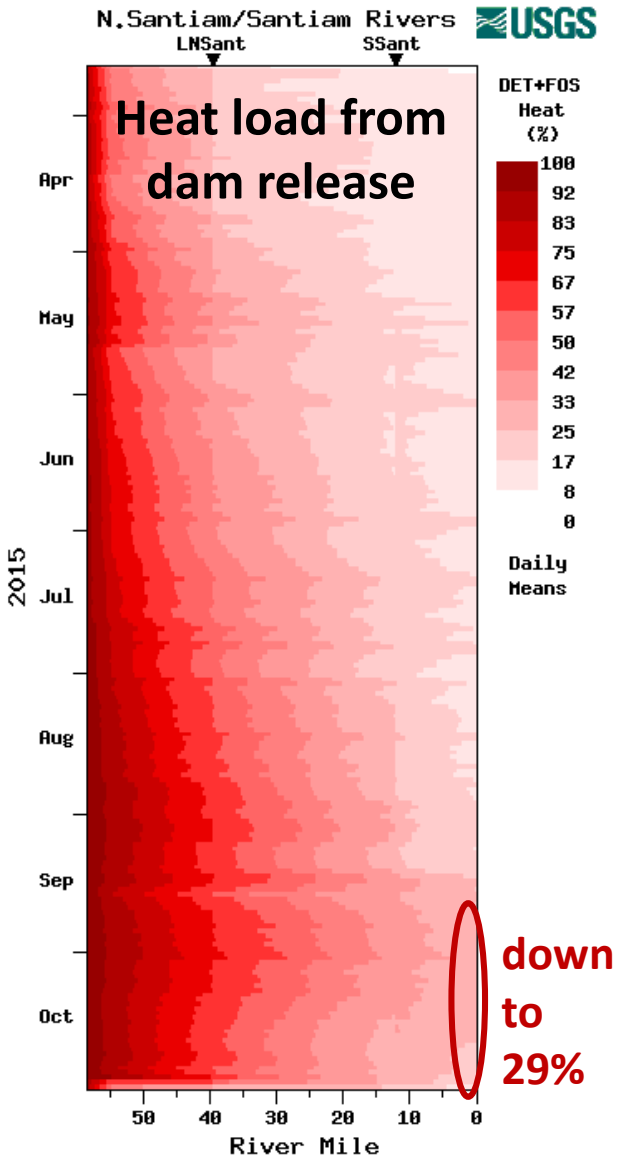
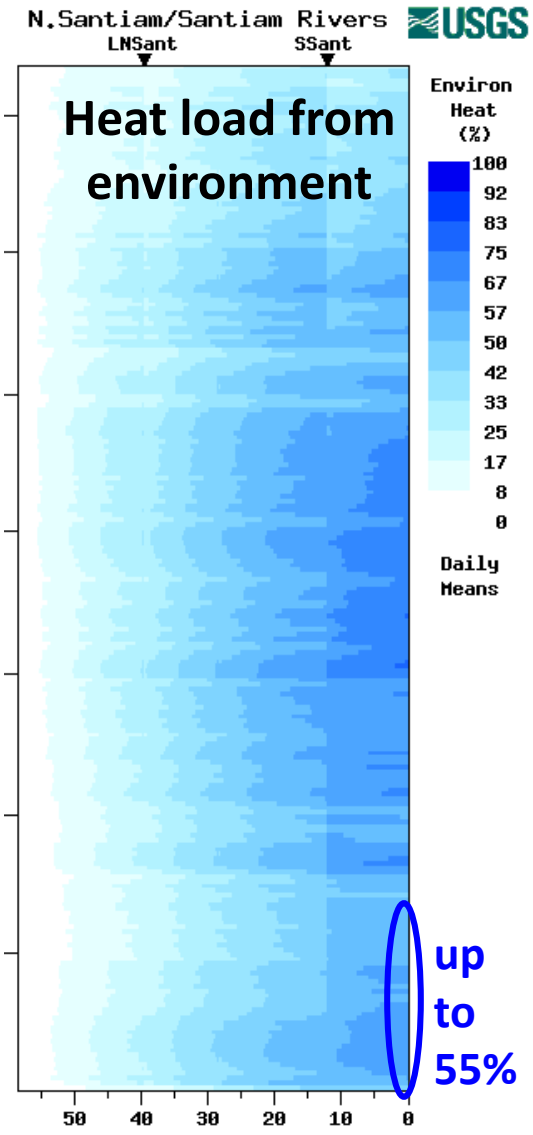
Evolution of dominant heat load sources with distance:

North Santiam and Santiam Rivers, Big Cliff Dam to Willamette River confluence



USGS graphic by Gabe Gordon





provisional results; subject to revision

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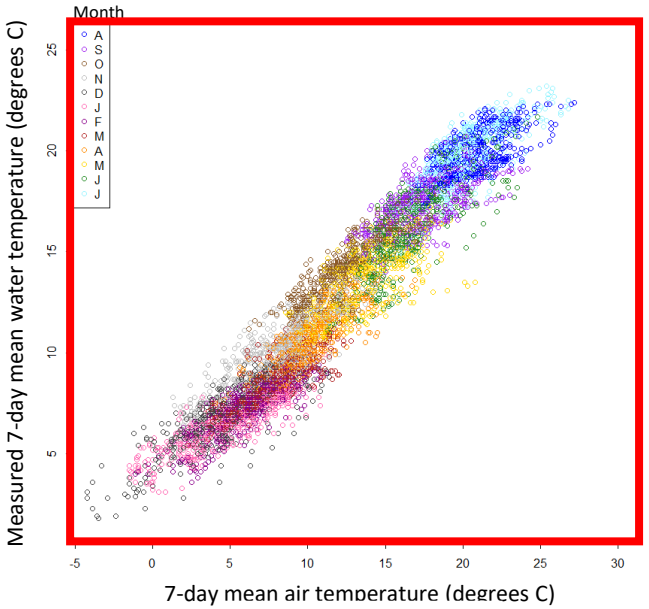
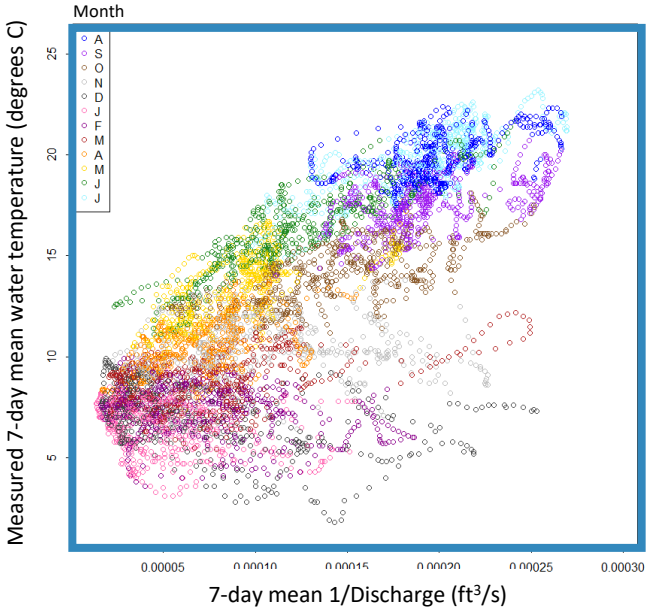
Predicting Water Temperature in the Willamette River

$$water\ temperature \propto \frac{heat\ load}{discharge}$$

- In the Willamette River, water temperature is approaching pseudo-equilibrium with environmental fluxes, allowing simple approximation of controlling processes:
  - Air temperature is reasonable proxy for environmental heat load
  - Discharge is reasonable proxy for travel time and thermal mass

Willamette River at Albany, OR (USGS Gage 14174000)





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provisional results; subject to revision

Predicting Water Temperature in the Willamette River

$$water\ temperature \propto \frac{heat\ load}{discharge}$$

$$WT_{7d} = A * AT_{7d} + \frac{B}{Q_{7d}} + C$$

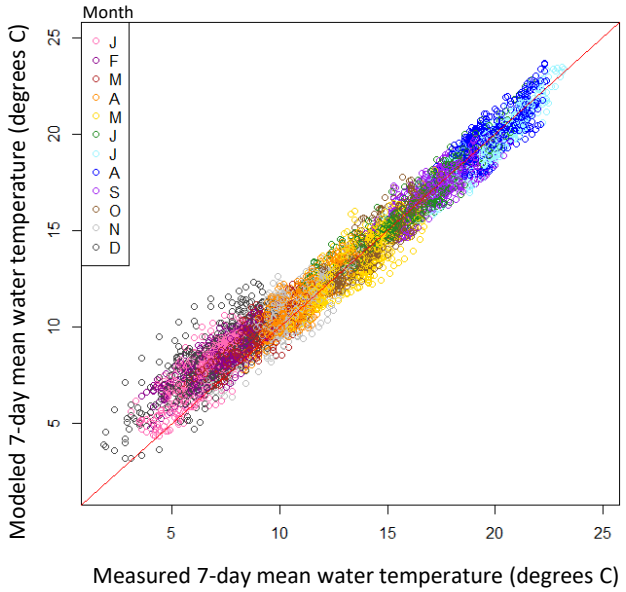
WT_{7d} = Stream Temperature, as 7-day moving average of the daily mean/max

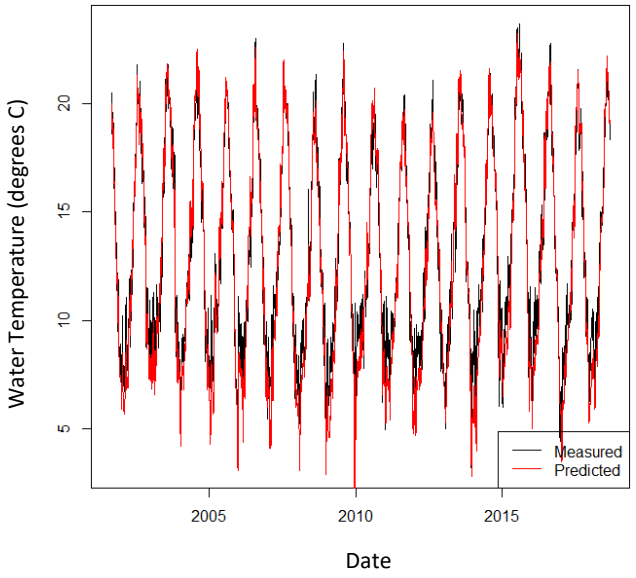
AT_{7d} = Air Temperature, as 7-day moving average of the daily mean/max

Q_{7d} = 7-day moving average discharge

A,B,C = regression coefficients

Willamette River at Albany, OR (USGS Gage 14174000)





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provisional results; subject to revision

Predicting Water Temperature in the Willamette River

Willamette at Willamette Falls (RM 27)

Willamette at Newberg (RM 50)

Willamette at Salem (RM 85)

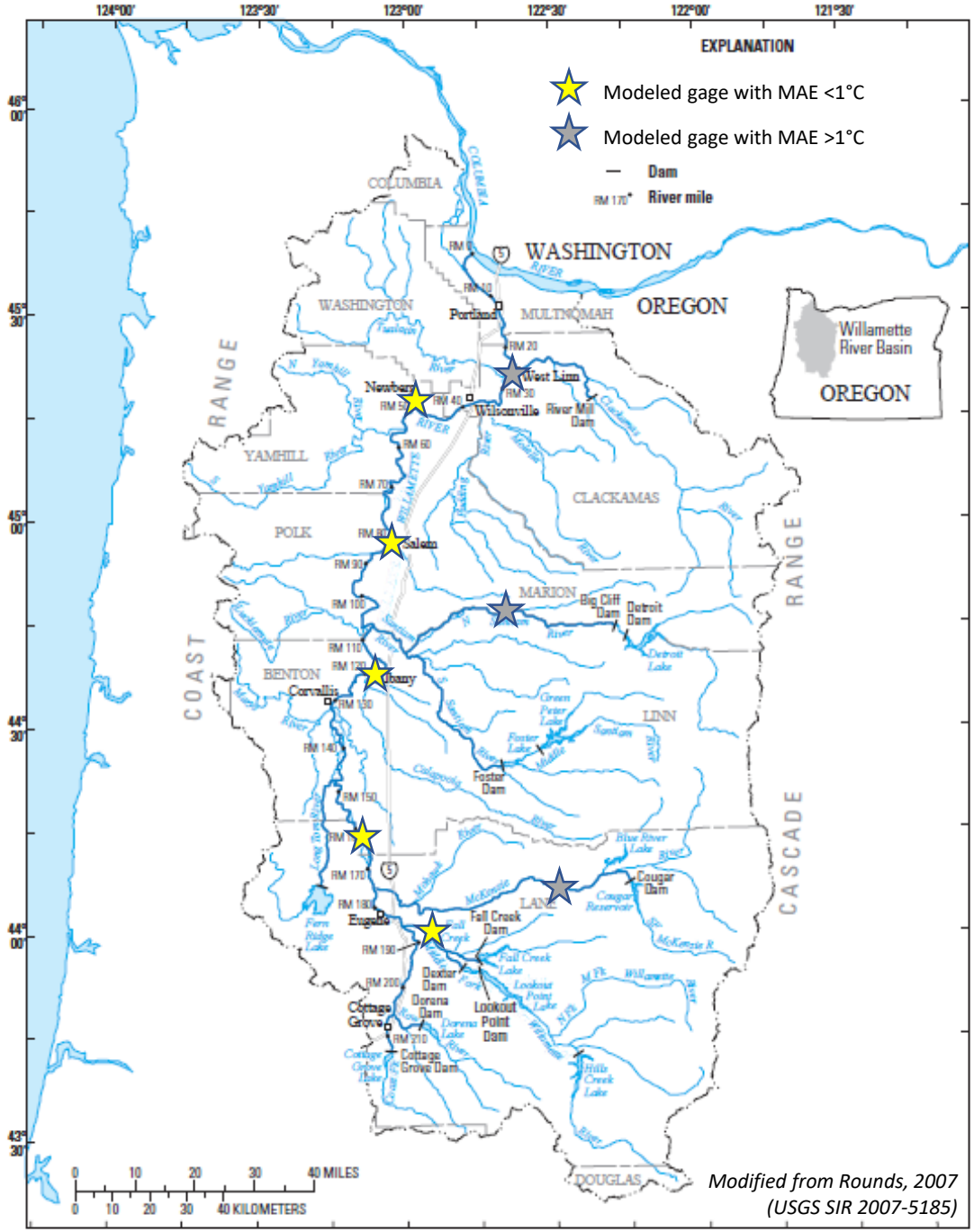
Willamette at Albany (RM 120)

Willamette at Harrisburg (RM 162)

McKenzie at Vida (RM 50)

Middle Fork Willamette at Jasper (RM 8)

North Santiam at Mehama (RM 39)



Modified from Rounds, 2007 (USGS SIR 2007-5185)

Base map modified from U.S. Geological Survey and other digital data sets (1:2,000,000; 1:100,000). Projection: Oregon Lambert Conformal Conic, NAD1983, NAVD1988.

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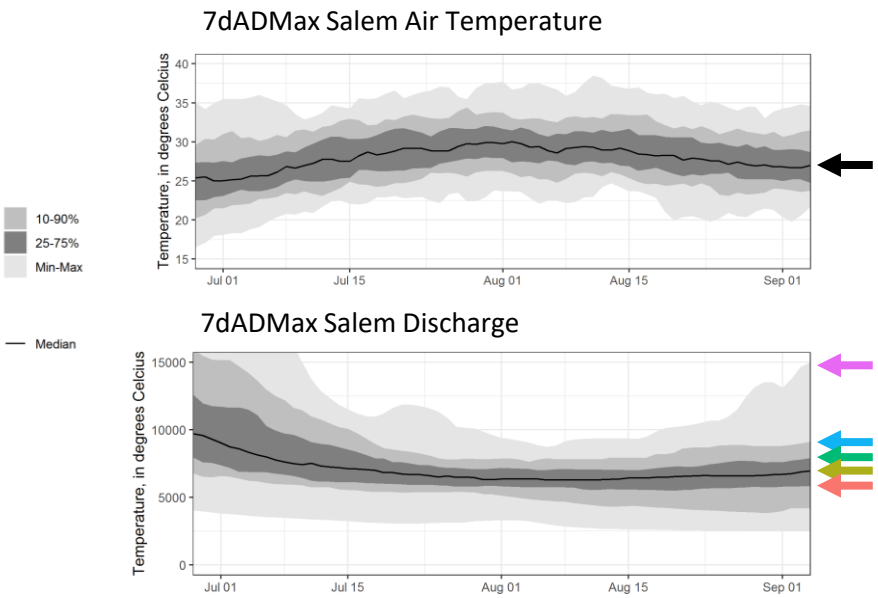
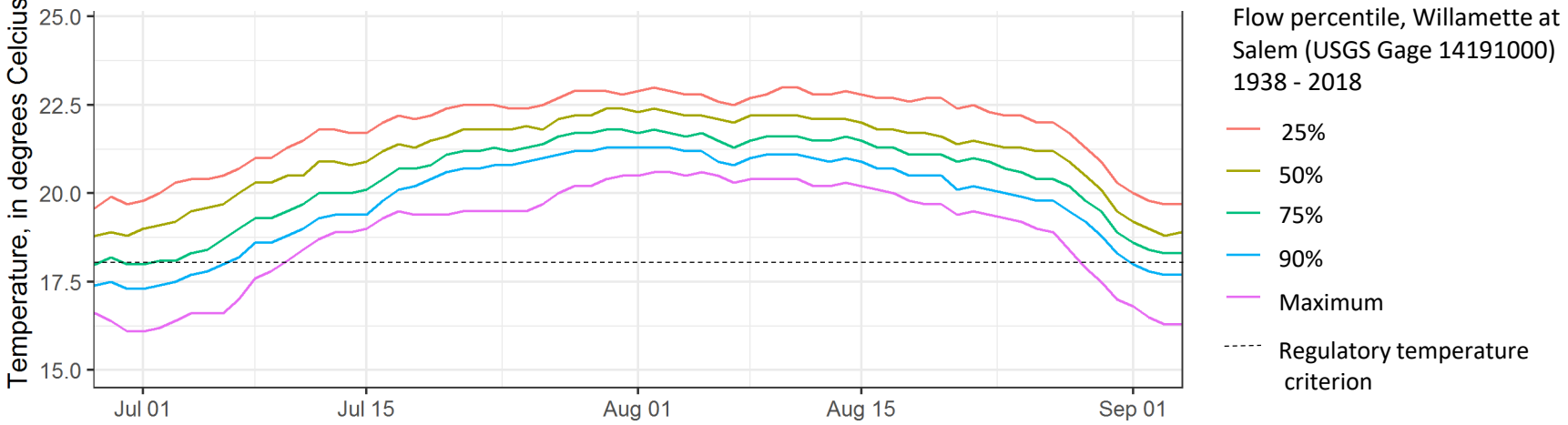
provisional results; subject to revision

Exploring the influence of flow on stream temperature:

Estimated stream temperature response to variation in flow given median air temperature conditions



Predicted 7dADMax Temperature, Willamette at Keizer (USGS Gage 14192015)
Assuming Median 7dADMax Air Temperature at McNary Field Salem, 1948 - 2018



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7dADMax = 7-day running average of the daily maximum
provisional results; subject to revision

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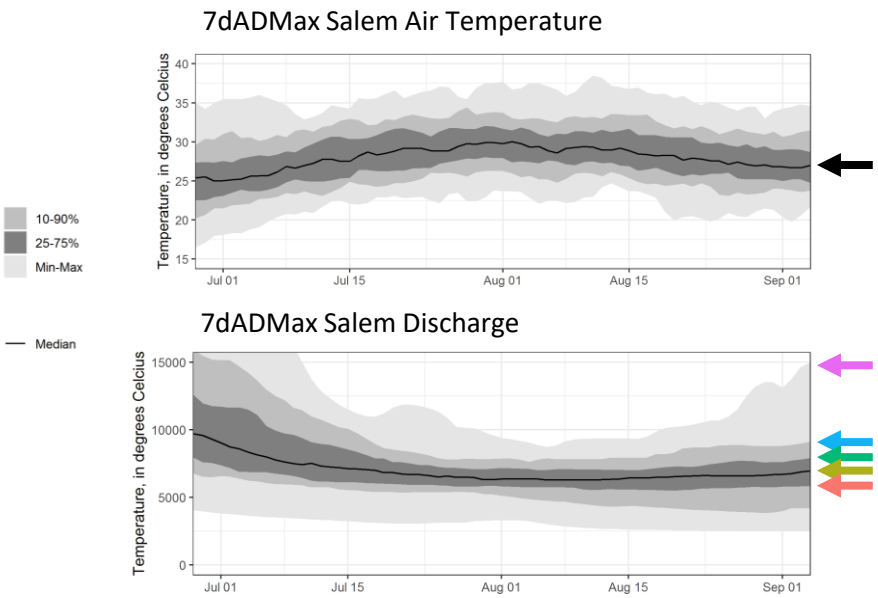

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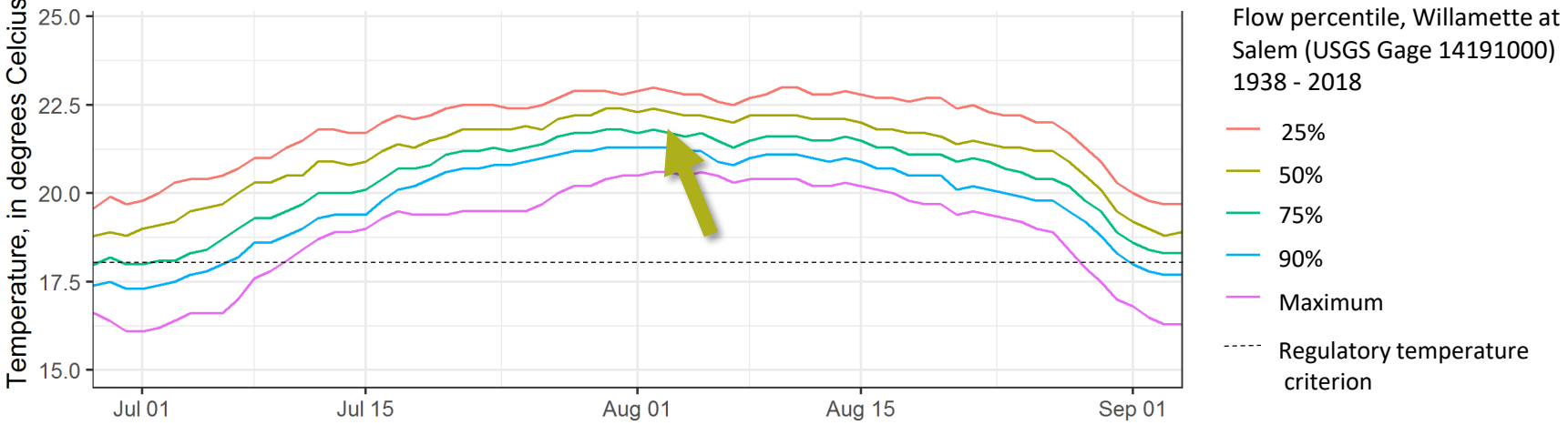

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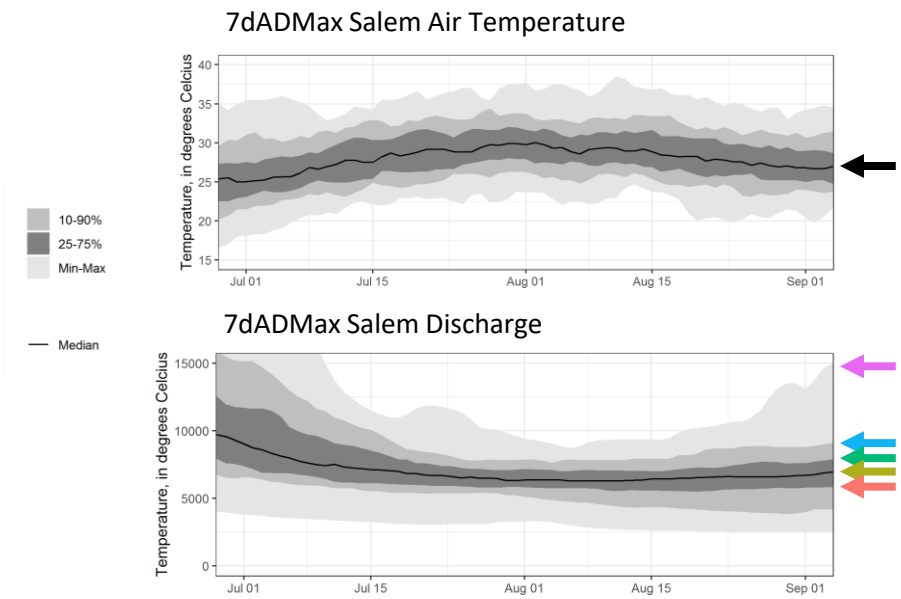

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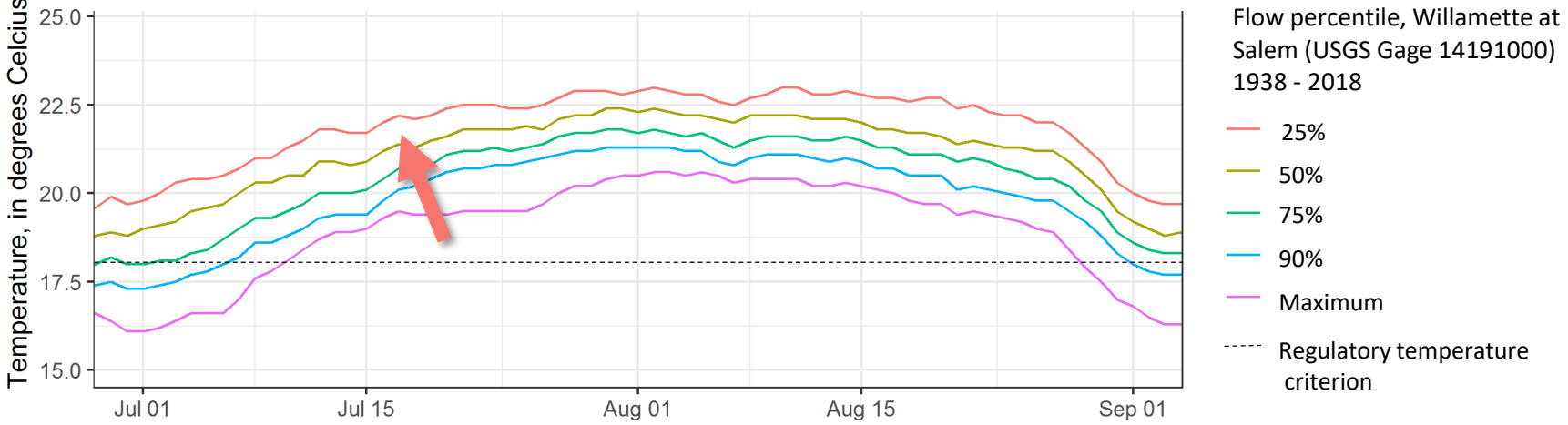

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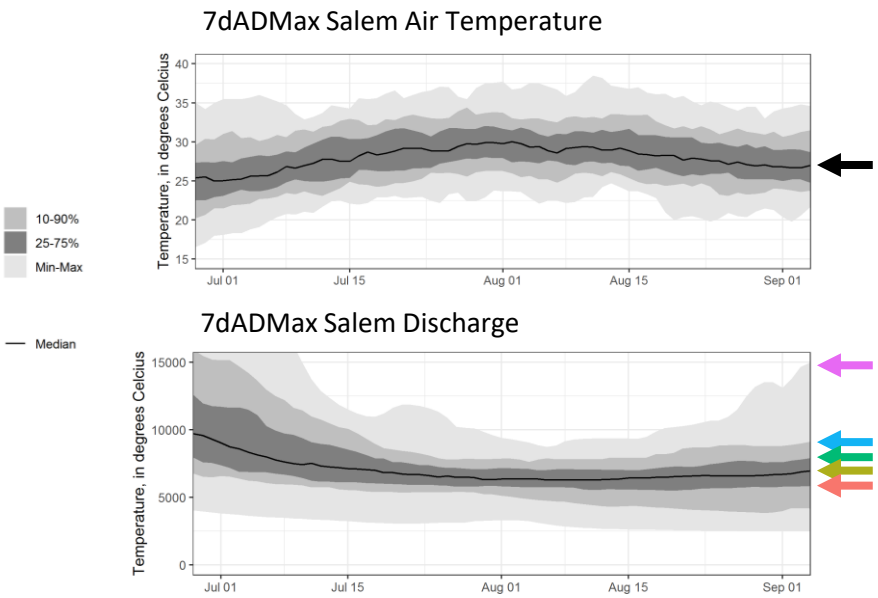

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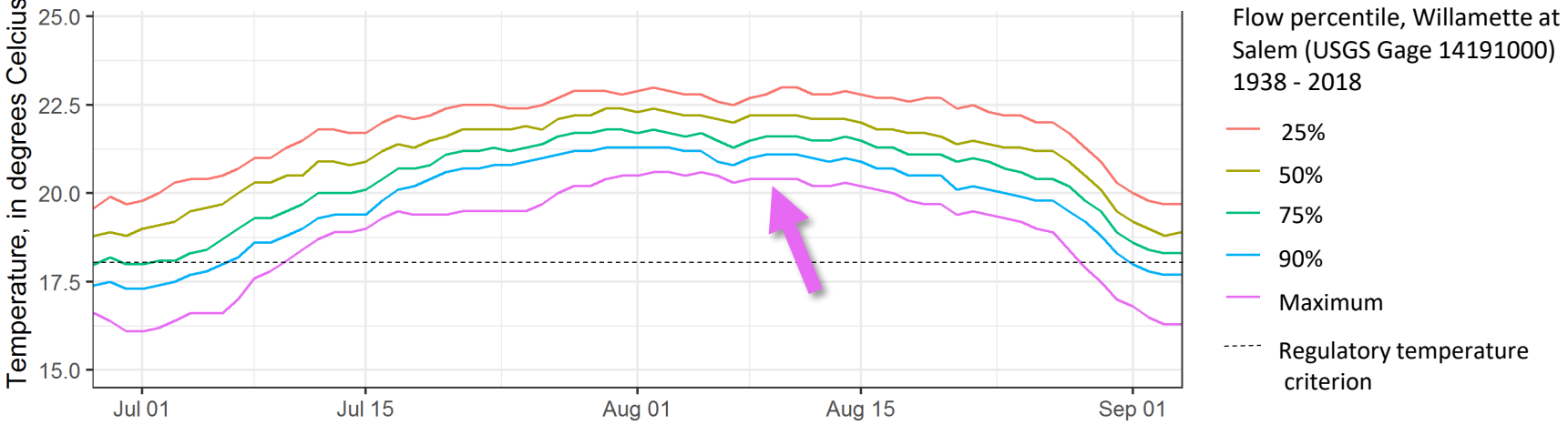

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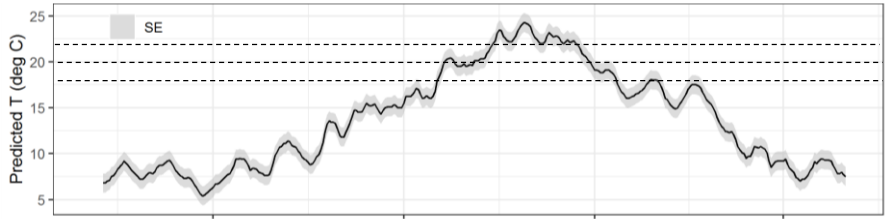
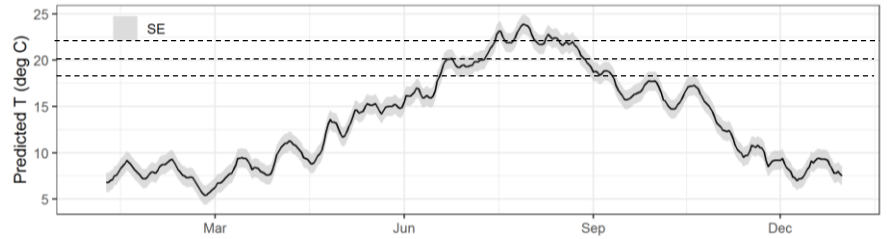
Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge



July 2018
17 Days > 22 °C
27 Days > 20 °C
31 Days > 18 °C

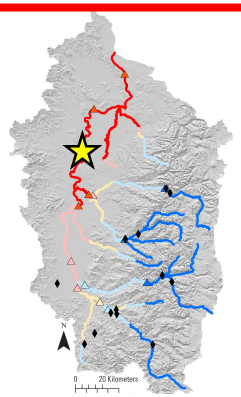
August 2018
19 days > 22 °C
29 Days > 20 °C
31 Days > 18 °C

Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge + 500 cfs



July 2018
13 days > 22 °C
22 Days > 20 °C
31 Days > 18 °C

August 2018
11 days > 22 °C
28 Days > 20 °C
31 Days > 18 °C



Potential influence of additional 500 cfs discharge on modeled 7dADMax stream temperature at Keizer (USGS Gage 14192015):

July Temperatures
> 18°C: 0 day reduction
> 20°C: 5 day reduction
> 22°C: 4 day reduction

August Temperatures
> 18°C: 0 day reduction
> 20°C: 1 day reduction
> 22°C: 8 day reduction

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7dADMax = 7-day running average of the daily maximum
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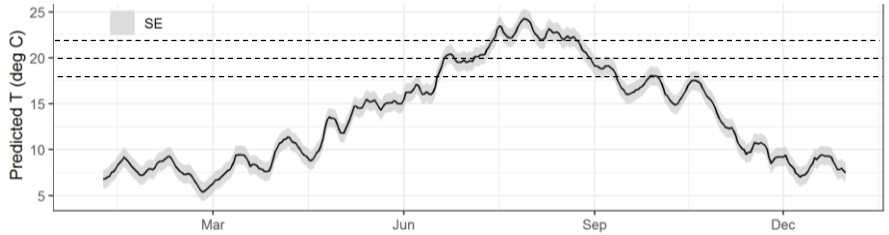

July 2018
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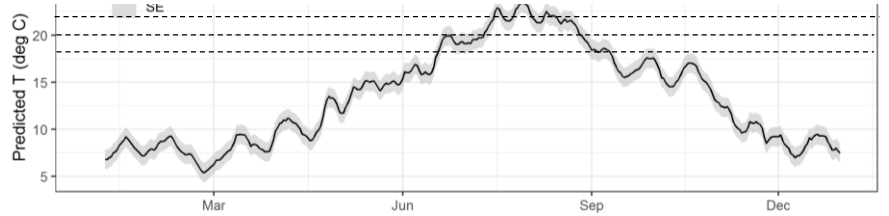
27 Days > 20 °C
31 Days > 18 °C

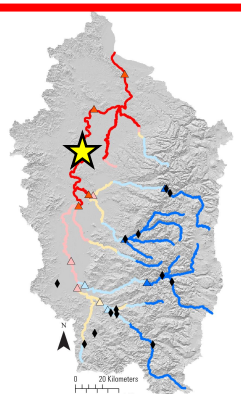
August 2018
19 days > 22 °C
29 Days > 20 °C
31 Days > 18 °C

Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge + 1000 cfs



July 2018
10 days > 22 °C
21 Days > 20 °C
31 Days > 18 °C

August 2018
6 days > 22 °C
26 Days > 20 °C
31 Days > 18 °C



Potential influence of additional 1000 cfs discharge on modeled 7dADMax stream temperature at Keizer (USGS Gage 14192015):

July Temperatures
> 18°C: 0 day reduction
> 20°C: 6 day reduction
> 22°C: 7 day reduction

August Temperatures
> 18°C: 0 day reduction
> 20°C: 3 day reduction
> 22°C: 13 day reduction

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7dADMax = 7-day running average of the daily maximum
provisional results; subject to revision

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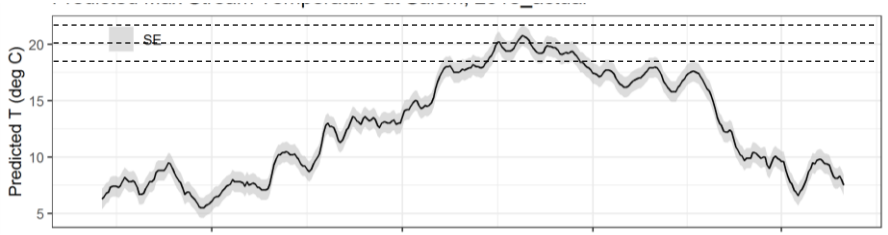
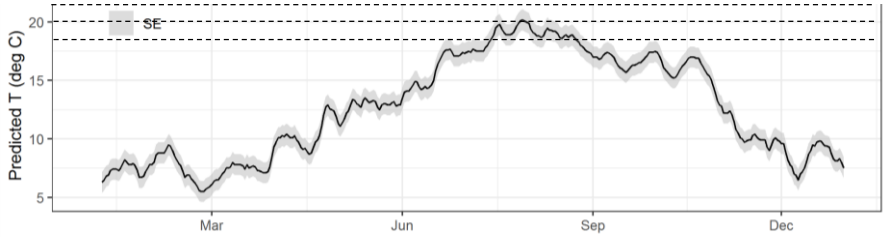
Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge



July 2018
0 Days > 22 °C
8 Days > 20 °C
23 Days > 18 °C

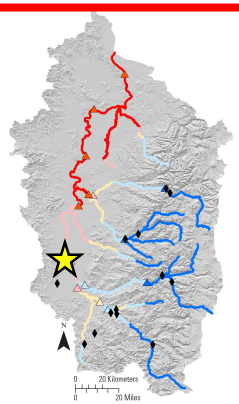
August 2018
0 Days > 22 °C
1 Days > 20 °C
28 Days > 18 °C

Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge + 500 cfs



July 2018
0 Days > 22 °C
3 Days > 20 °C
19 Days > 18 °C

August 2018
0 Days > 22 °C
0 Days > 20 °C
25 Days > 18 °C



Potential influence of additional 500 cfs discharge on modeled 7dADMax stream temperature at Harrisburg (USGS Gage 141166000):

July Temperatures
> 18°C: 0 day reduction
> 20°C: 4 day reduction
> 22°C: *NA*

August Temperatures
> 18°C: 3 day reduction
> 20°C: 1 day reduction
> 22°C: *NA*

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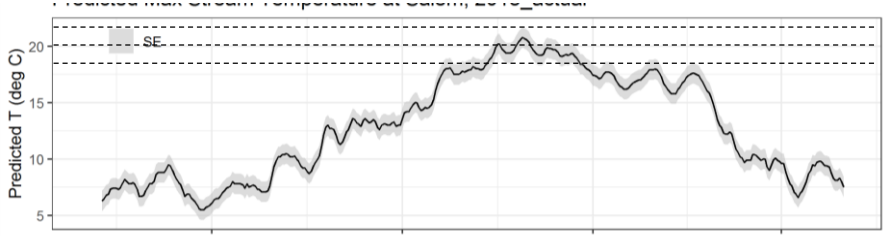

July 2018
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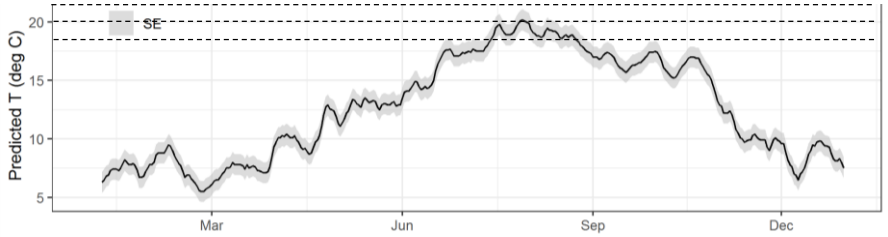
8 Days > 20 °C
23 Days > 18 °C

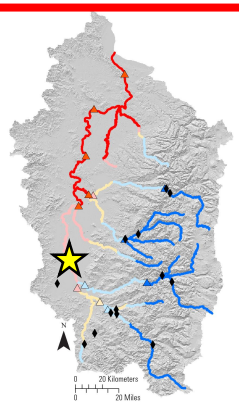
August 2018
0 Days > 22 °C
1 Days > 20 °C
28 Days > 18 °C

Estimated 7dADMax stream temperature assuming 2018 measured air temperature and 2018 measured discharge + 1000 cfs



July 2018
0 Days > 22 °C
0 Days > 20 °C
18 Days > 18 °C

August 2018
0 Days > 22 °C
0 Days > 20 °C
24 Days > 18 °C



Potential influence of additional 1000 cfs discharge on modeled 7dADMax stream temperature at Harrisburg (USGS Gage 141166000):

July Temperatures
> 18°C: 0 day reduction
> 20°C: 8 day reduction
> 22°C: *NA*

August Temperatures
> 18°C: 4 day reduction
> 20°C: 1 day reduction
> 22°C: *NA*

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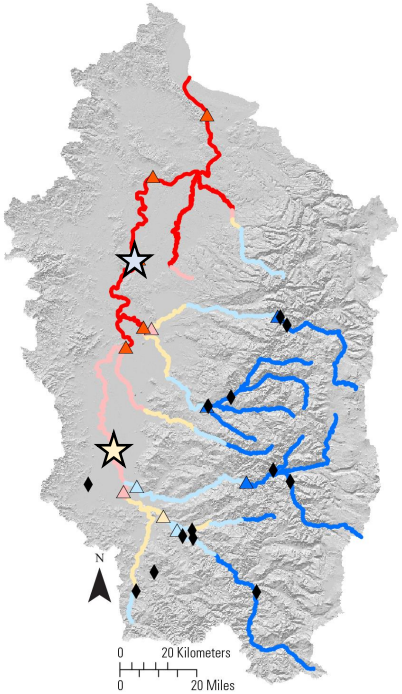
7dADMax = 7-day running average of the daily maximum
provisional results; subject to revision

Exploring the influence of flow on stream temperature:

Spatial variation in Willamette River potential temperature response to different flow augmentation volume during summer 2018



	Mean Change in 7dADMax (degrees C)	
Flow Augmentation: 500 cfs	**July**	**August**
Willamette at Harrisburg	**-0.5**	**-0.5**
Willamette at Keizer	**-0.3**	**-0.4**
Flow Augmentation: 1000 cfs		
Willamette at Harrisburg	**-0.9**	**-0.9**
Willamette at Keizer	**-0.6**	**-0.7**

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7dADMax = 7-day running average of the daily maximum
provisional results; subject to revision

Conclusions

- **Relative importance of heat source varies along river network**
  - On tributaries below dams, stream temperature is controlled by temperature of dam release
  - With distance from dam release, stream equilibrates to environmental heat loads
- **Flow augmentation can help mitigate high stream temperatures in Willamette River downstream of dam release-temperature influence; however:**
  - Temperature response to flow augmentation decreases downstream
  - Preliminary models suggest flow augmentation is inadequate to consistently meet, but could reduce number of days exceeding regulatory thresholds at Salem

USGS Photo
provisional results; subject to revision

Thank you!

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Photo: USGS