What Determines Water Temperatures in the Sacramento-San Joaquin Delta?

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Why Care About Water Temperature?

mpon

25 °C

(Bennett 2005)

+ Methodology:

1D Advection Dispersion Eq

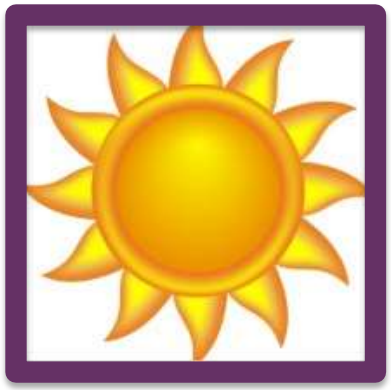
$$A(x)\frac{\partial T}{\partial t} - Q_f \frac{\partial T}{\partial x} = \frac{\partial}{\partial x} K(x)A(x)\frac{\partial T}{\partial x} - \frac{WH_f}{\rho c_p}$$

Unsteadiness

Advection

Dispersion

Atmospheric Heat Flux



Three Important Parameters Determine Temperature

$$A(x)\frac{\partial T}{\partial t} - Q_f\frac{\partial T}{\partial x} = \frac{\partial}{\partial x}K(x)A(x)\frac{\partial T}{\partial x} - \frac{W H_f}{\rho c_p}$$

Q_f

Flow

K

Dispersion

H_f

Atmospheric Heat Flux

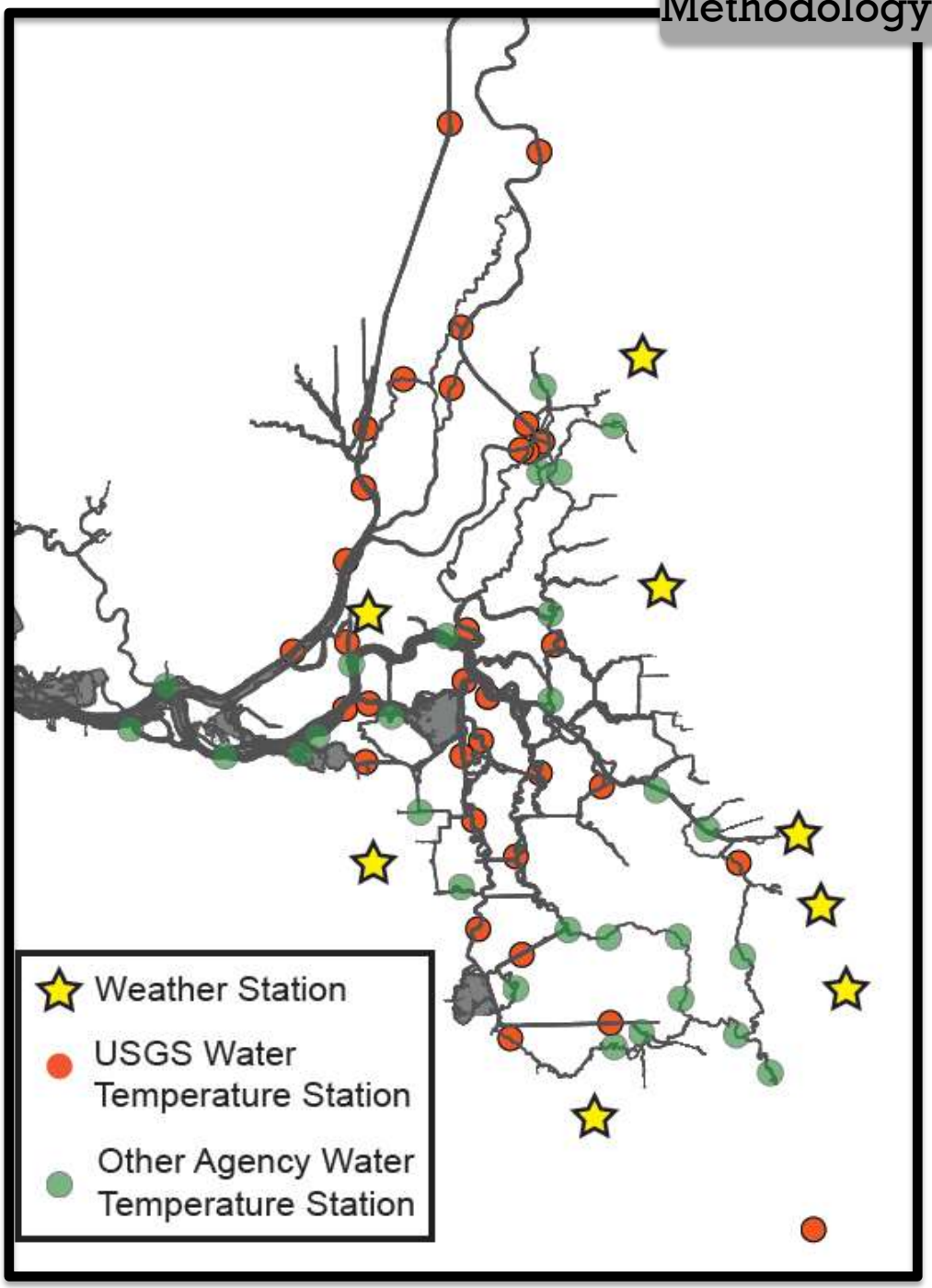
Data Sources

CDEC Water Stations

- Water temp
- Flow

CIMIS Weather Data

- Wind speed
- Air Temp
- Relative Humidity
- Solar Radiation



Case Study 1:

How Does Variation in Flow Affect Water Temperature?

$$A(x)\frac{\partial T}{\partial t} - Q_f\frac{\partial T}{\partial x} = \frac{\partial}{\partial x}K(x)A(x)\frac{\partial T}{\partial x} - \frac{WH_f}{\rho c_p}$$

Q_f

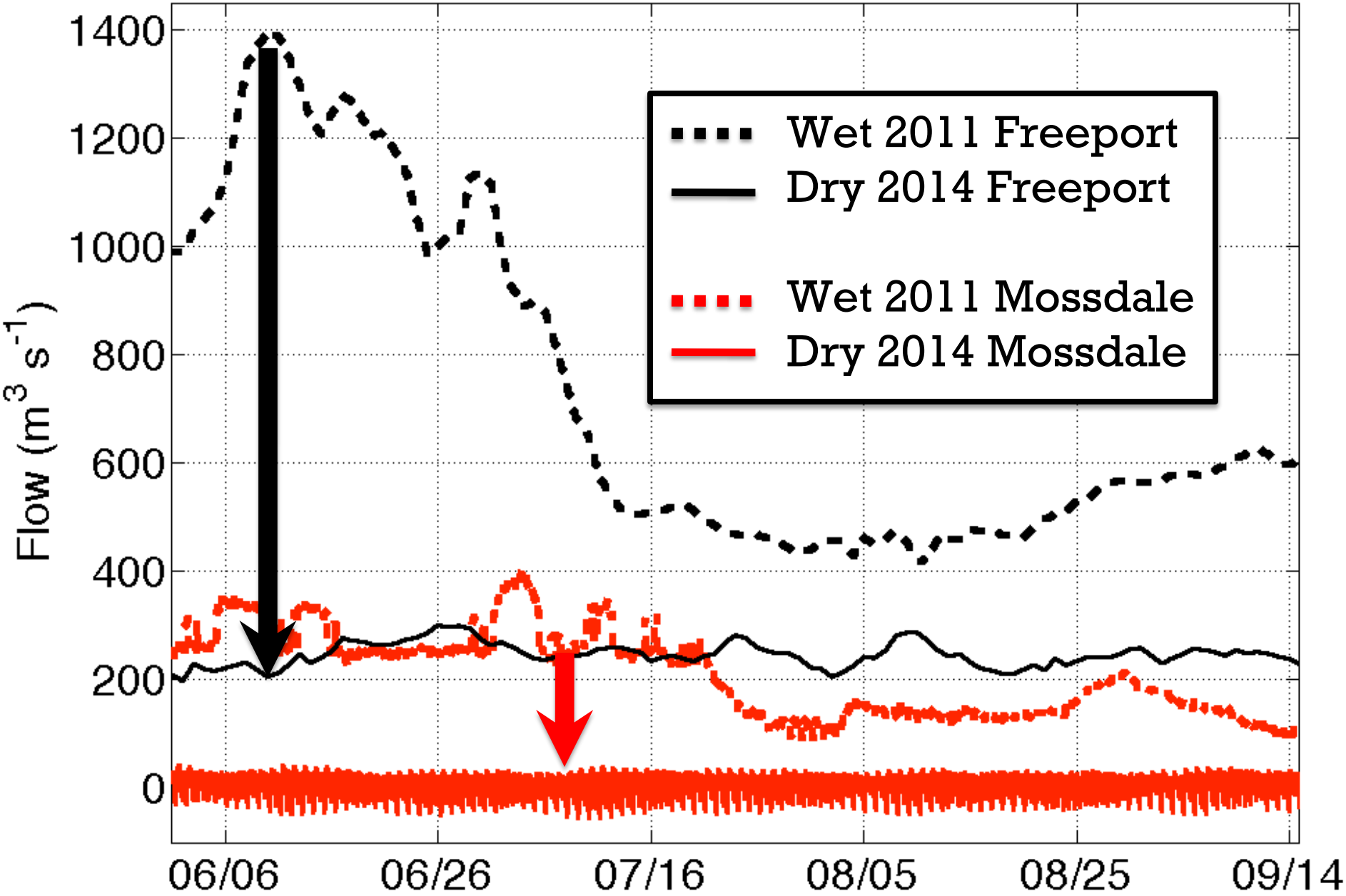
Flow

Summer June – Sept 15

Dry Year: 2014

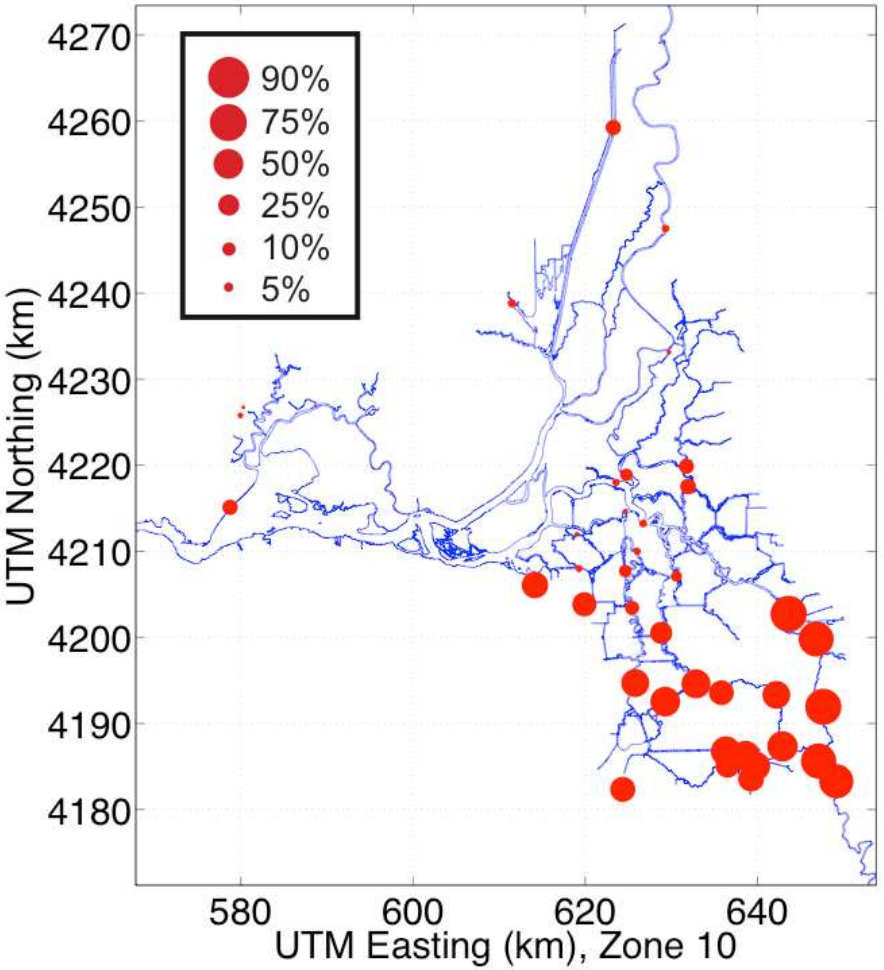
Wet Year: 2011

2011 and 2014 Freeport and Mossdale Flow

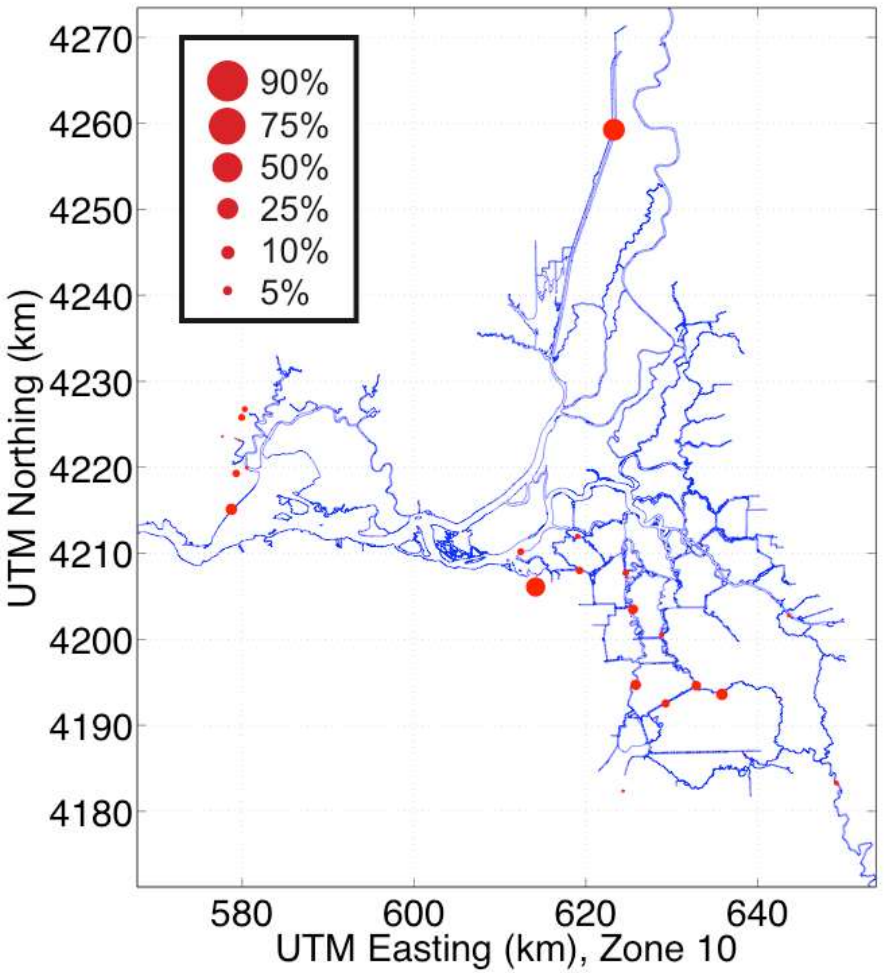


% Water Temp > 25°C

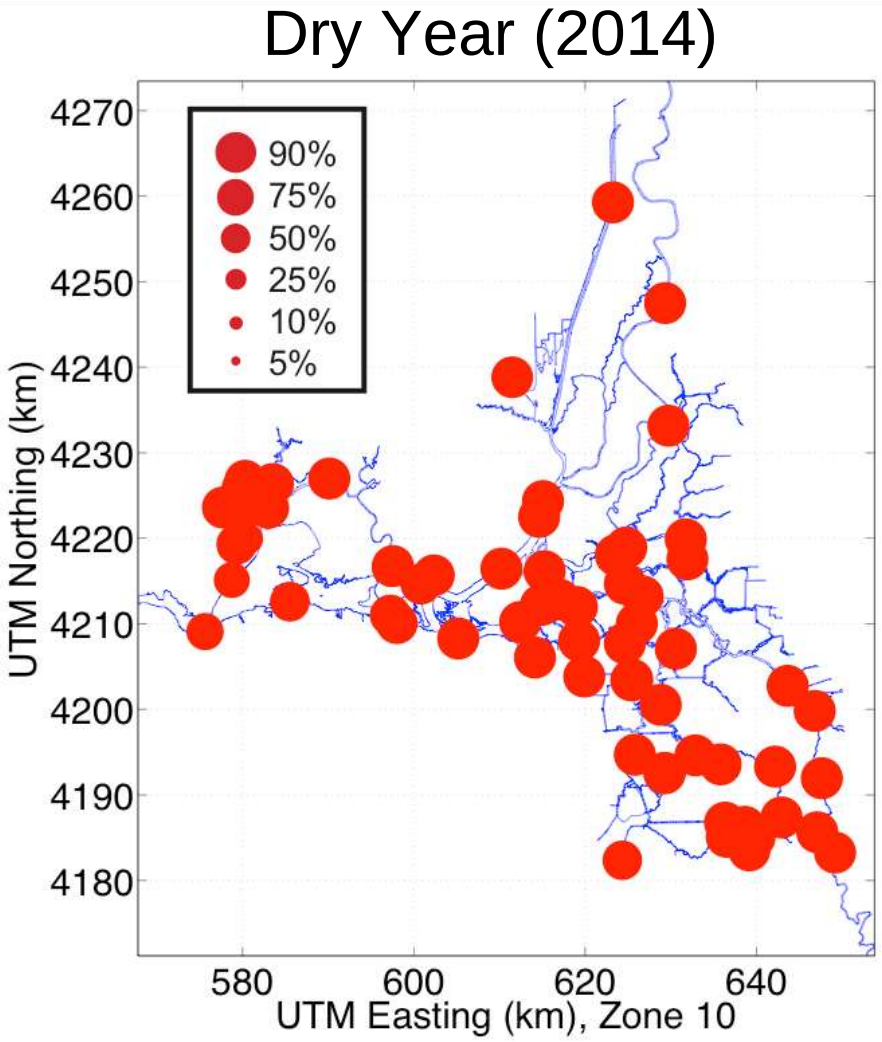
Dry Year (2014)

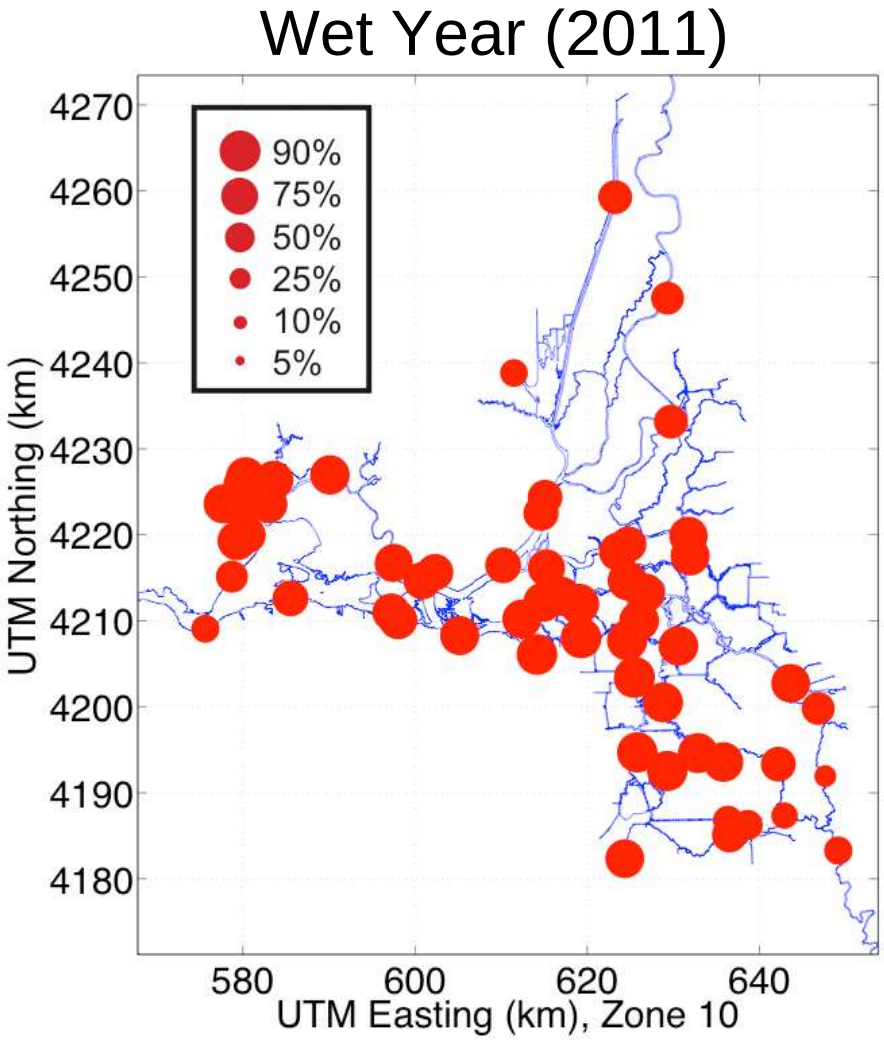


Wet Year (2011)

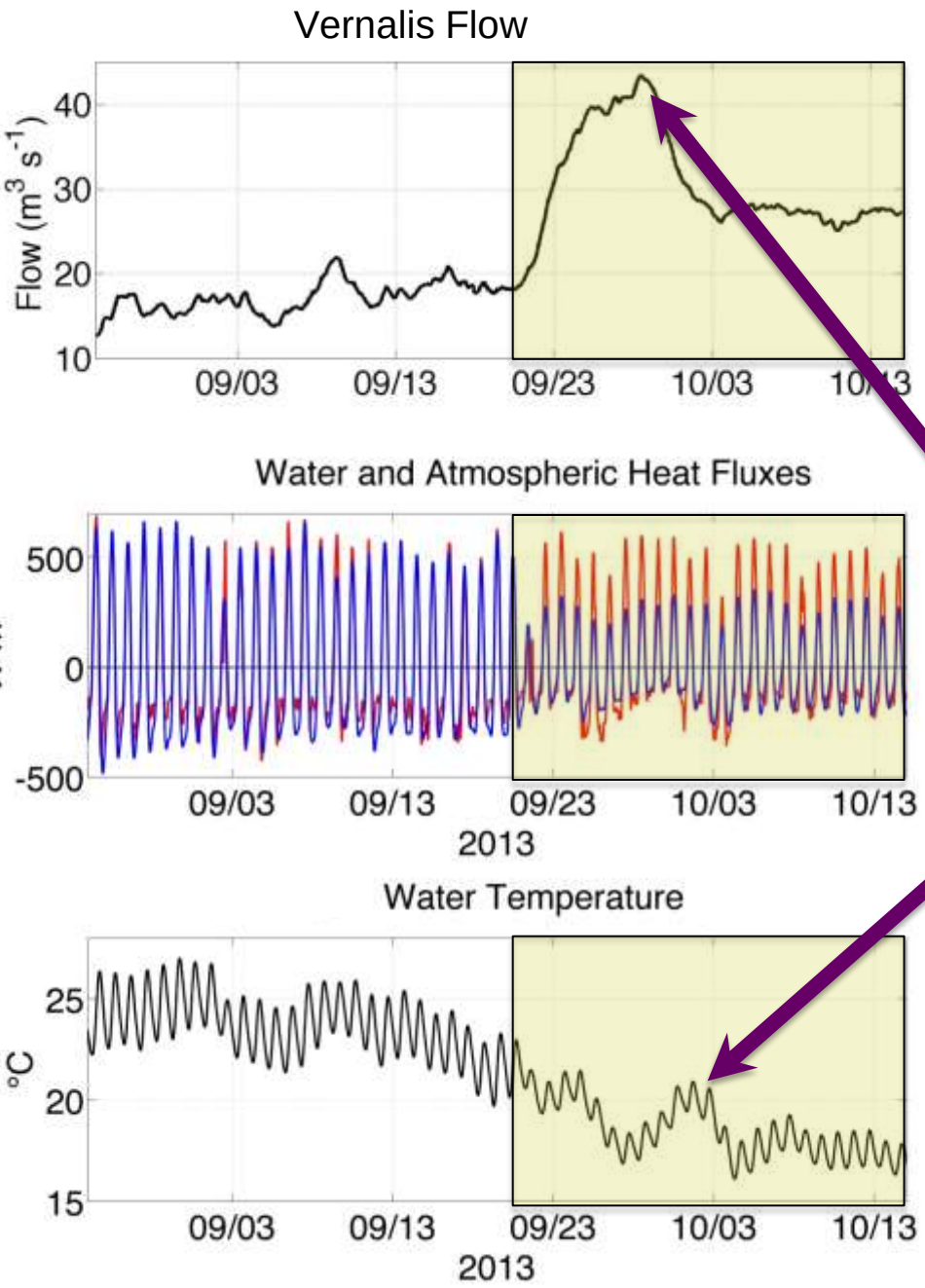


% Water Temp > 20°C





Changes in Operations Change Water Temperature



Flow Pulse

=

Lower water temperature

Case Study 2:

How Does Dispersion Affect Water Temperature?

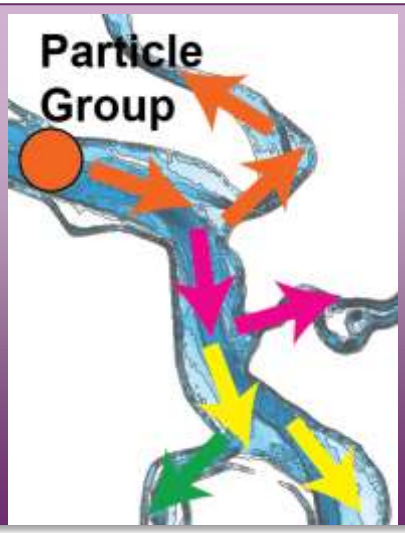
$$A(x)\frac{\partial T}{\partial t} - Q_f \frac{\partial T}{\partial x} = \frac{\partial}{\partial x} K(x) A(x) \frac{\partial T}{\partial x} - \frac{WH_f}{\rho c_p}$$

K

Dispersion

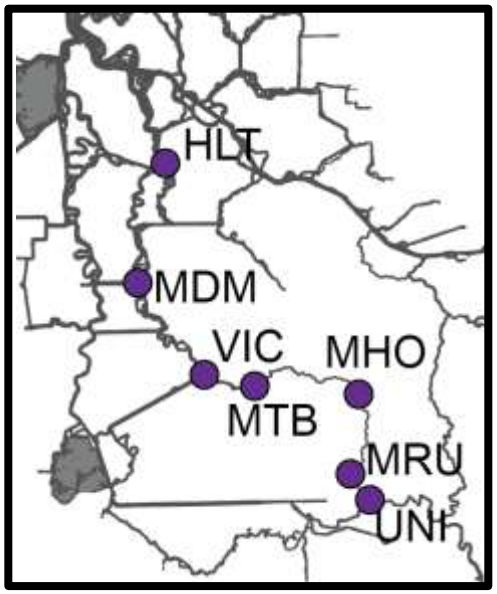
Track along-channel temps

Link to junction dispersion

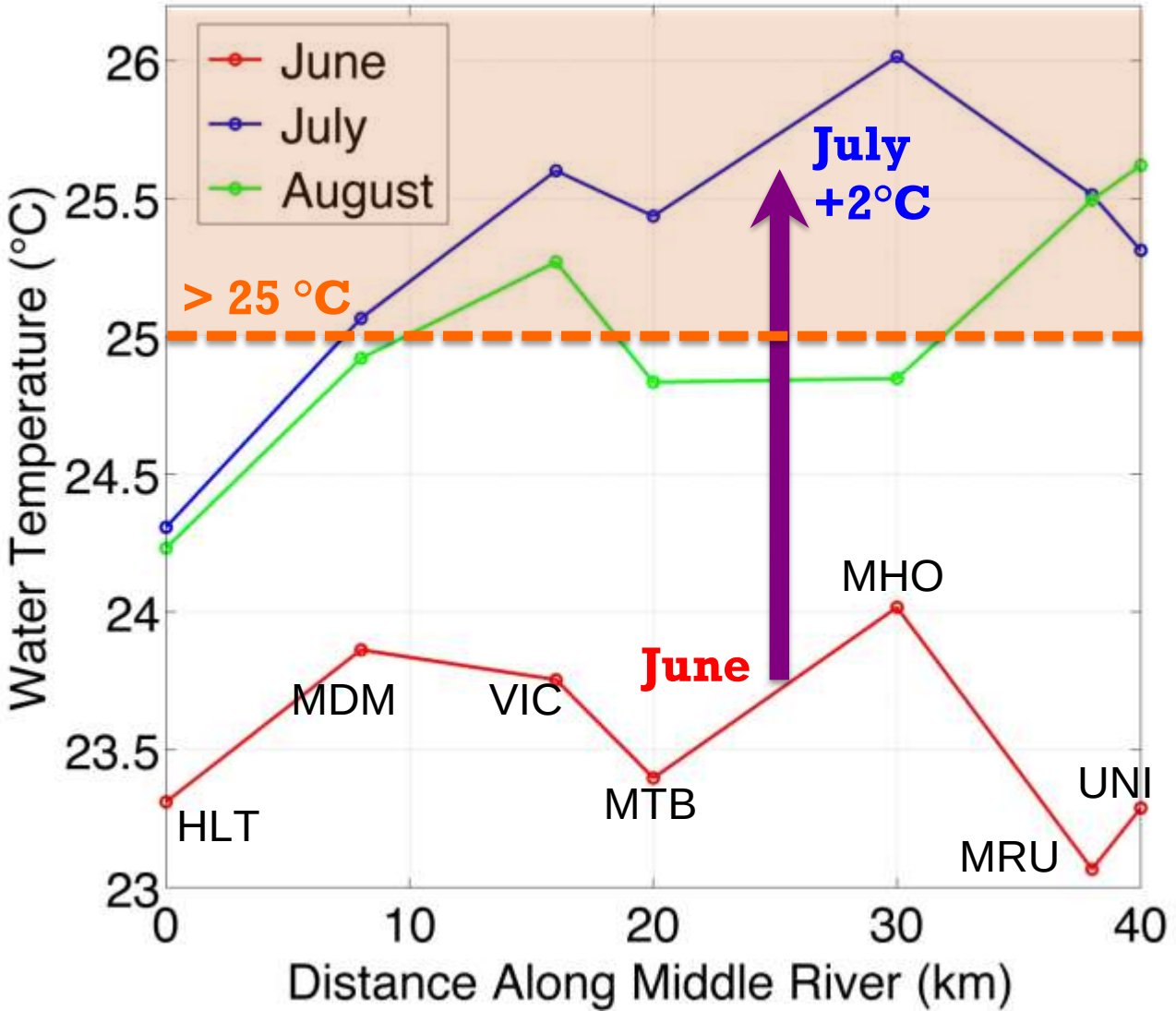


2014 Middle River Along Channel Temps

Many Junctions ➡ Dispersion ➡ Heat Transport

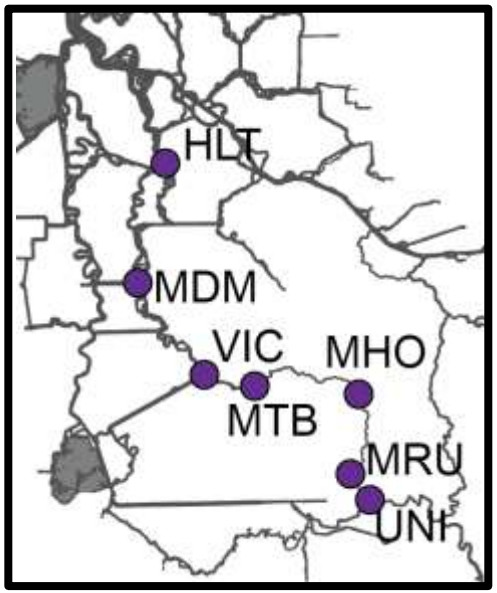


Middle River CDEC Stations

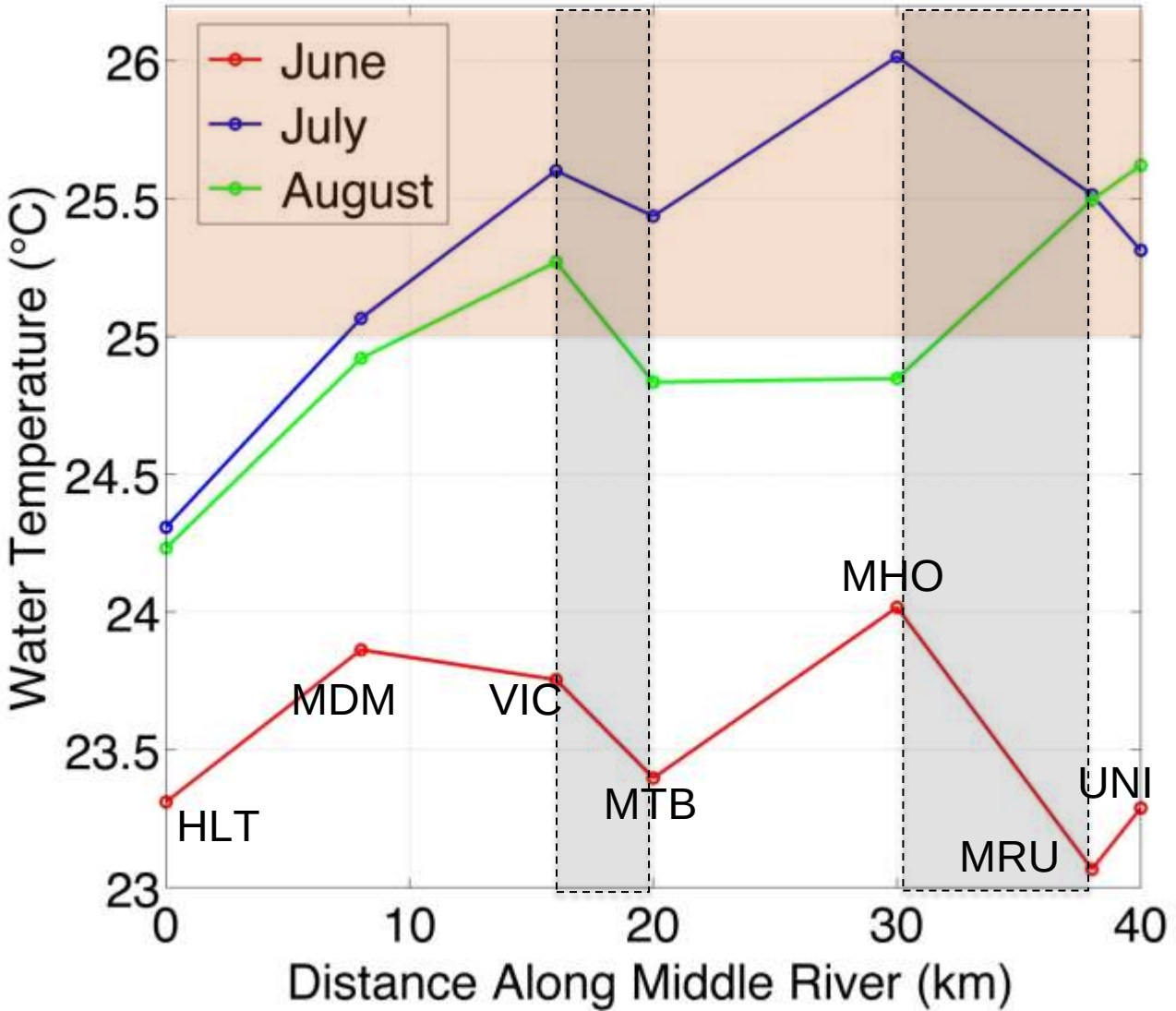


2014 Middle River Along Channel Temps

Many Junctions ➡ Dispersion ➡ Heat Transport



Middle River CDEC Stations



Case Study 3:

How Does Atmospheric Forcing Affect Water Temperature?

$$A(x)\frac{\partial T}{\partial t} - Q_f \frac{\partial T}{\partial x} = \frac{\partial}{\partial x} K(x) A(x) \frac{\partial T}{\partial x} - \frac{W H_f}{\rho c_p}$$

H_f

Atmospheric Heat Flux

1) Atmospheric Heat Flux = ?

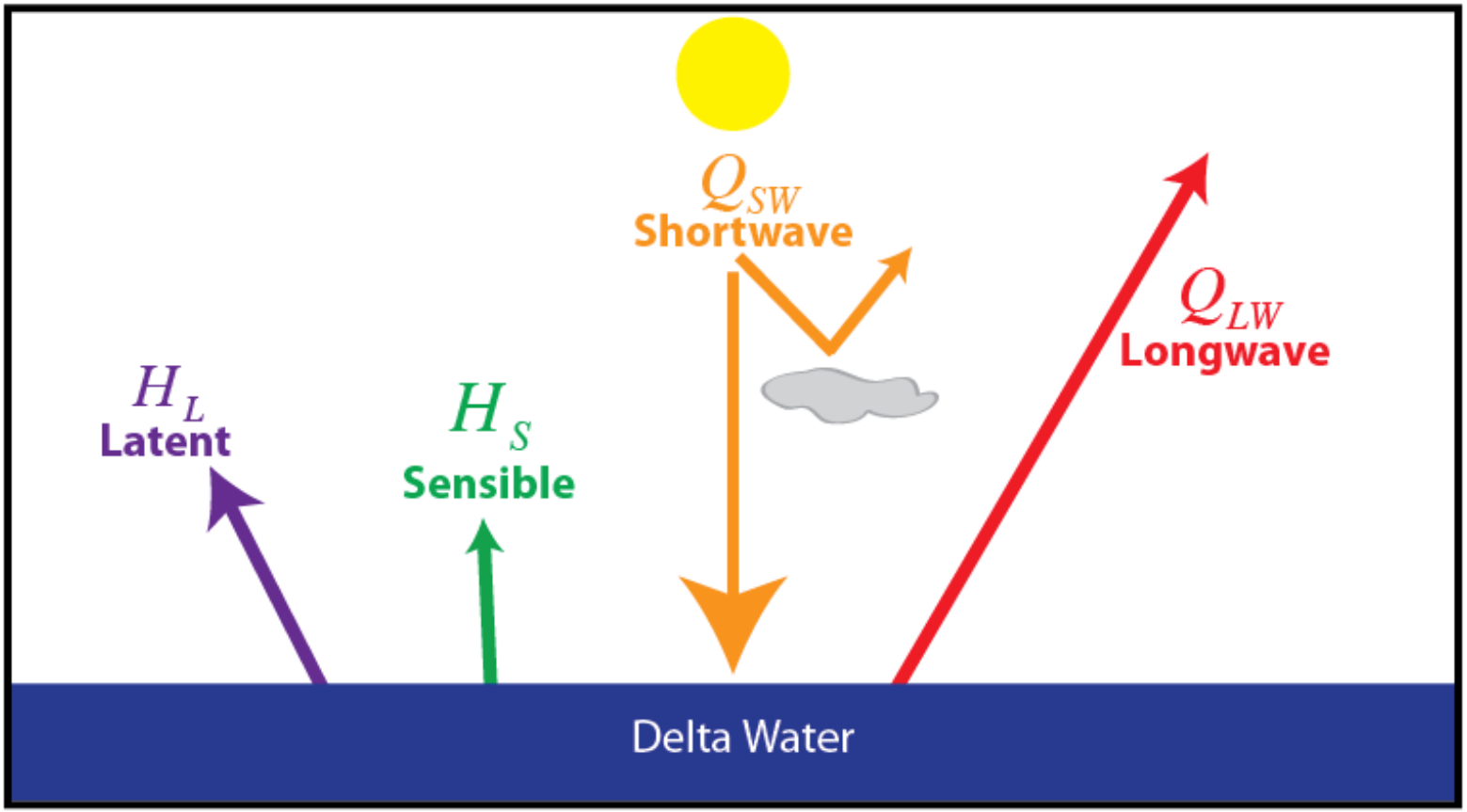
2) Perform heat balance over Delta

- Track heat transport

+1) Atmospheric Heat Fluxes

H_f
Atmospheric Heat Flux

$$H_f = H_{Latent} + H_{Sensible} + QW_{Longwave} + QW_{Shortwave}$$



2) Perform Heat Balance of Delta

$$A(x)\frac{\partial T}{\partial t} - Q_f\frac{\partial T}{\partial x} = \frac{\partial}{\partial x}K(x)A(x)\frac{\partial T}{\partial x} - \frac{W H_f}{\rho c_p}$$

Q_f Flow

K Dispersion

H_f Atmospheric Heat Flux

2) Perform Heat Balance of Delta

$$A(x)\frac{\partial T}{\partial t} - Q_f\frac{\partial T}{\partial x} = \frac{\partial}{\partial x}K(x)A(x)\frac{\partial T}{\partial x} - \frac{W H_f}{\rho c_p}$$

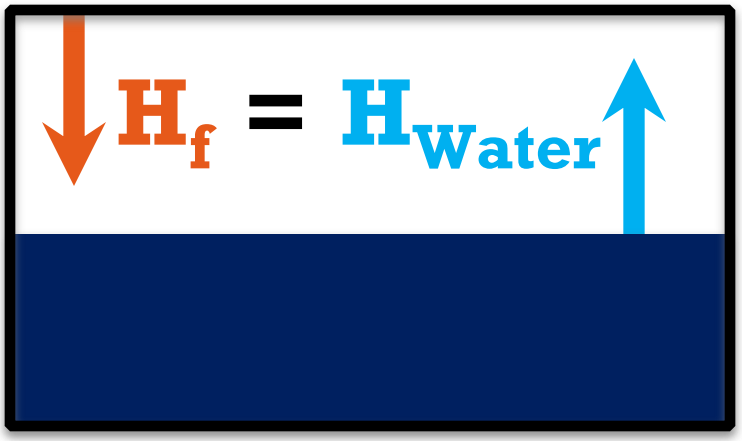
$$H_f = \frac{\partial}{\partial t}(\rho c_p \int_H^0 T_{Water}(z,t)dz)$$

$$H_{Water}$$

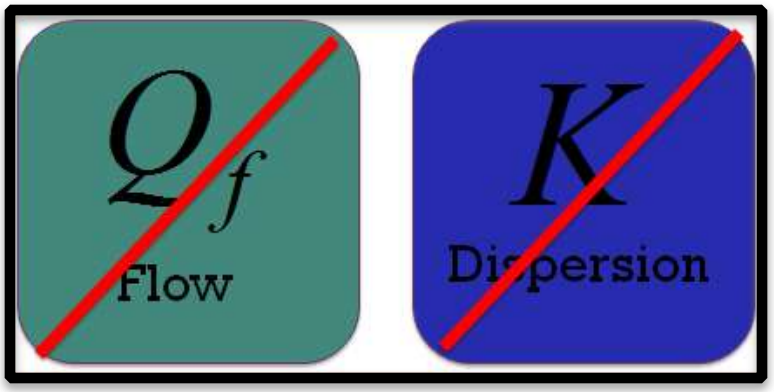
Air and Water in Equilibrium

$$H_f = \frac{\partial}{\partial t}\left(\rho c_p \int_H^0 T_{Water}(z,t)\,dz\right)$$

$$H_{Water}$$



Assuming:



+ However, if…

$$H_f \neq \frac{\partial}{\partial t}\left(\rho c_p \int_H^0 T_{Water}(z,t)dz\right)$$

$$H_{Water}$$

Heat is being transported downstream

Q_f Flow

K Dispersion

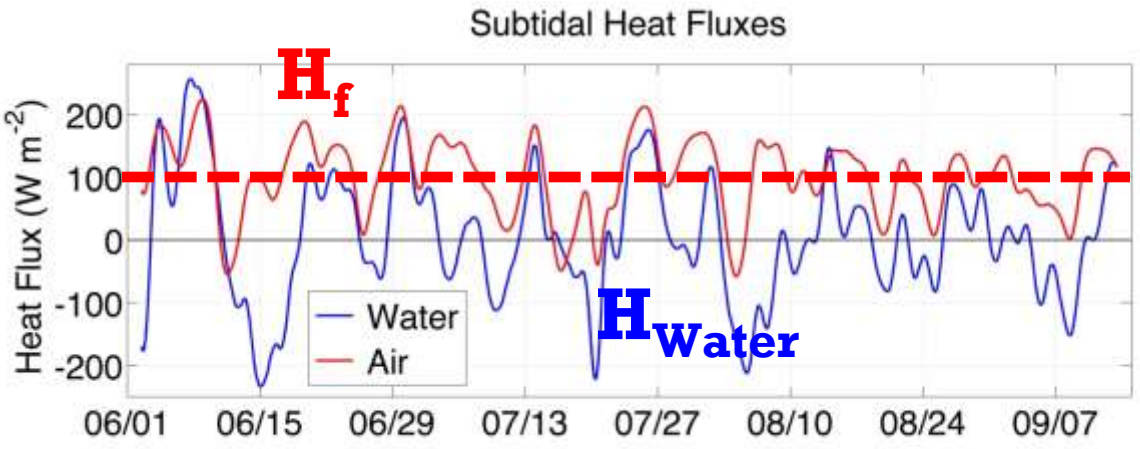
+ Heat Transport, $H_{Downstream}$

$$H_{Downstream} = H_f - H_{Water}$$

$$H_{Downstream} \propto Q_f \text{ (Flow)} \quad K \text{ (Dispersion)}$$

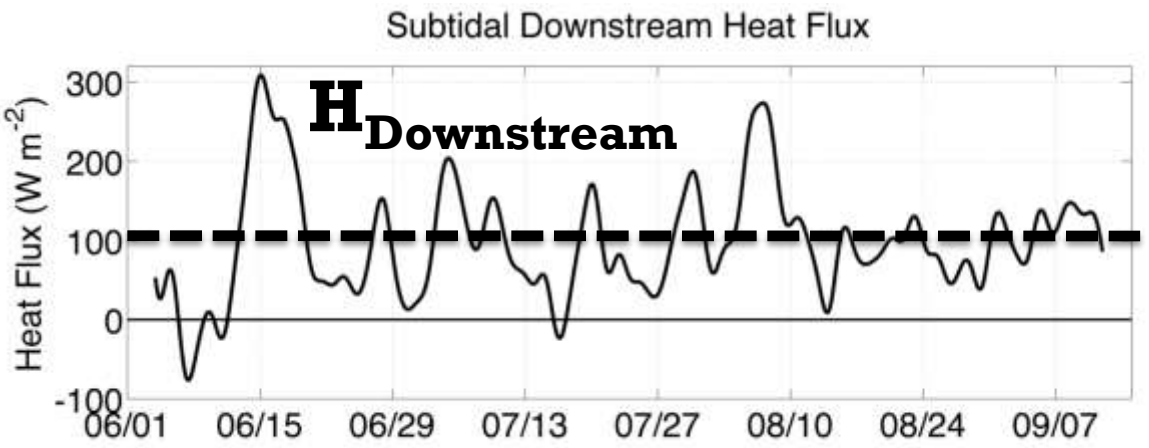
Downstream Heat Flux at GSS

$$H_{Downstream} = H_f - H_{Water}$$



H_f~100 W m^{-2}

=



$H_{Downstream}$ ~100 W m^{-2}

Downstream Heat Flux at GSS

$$H_{Downstream} \approx H_f \approx 100\ \mathrm{W\ m^{-2}}$$

Remember that

$$H_{Downstream} \propto Q_f \quad K$$

Q_f: Flow

K: Dispersion

Thus

$$H_{Downstream} \approx H_f \approx H_{Q_f} + H_K$$

What Can We Conclude?

$$H_f \approx H_{Q_f} + H_K$$

Water Temperatures Are Dictated By:

50% atmospheric forcing — H_f Atmospheric Heat Flux

50% advection and dispersion — Q_f Flow; K Dispersion

What Can We Conclude?

There is hope!

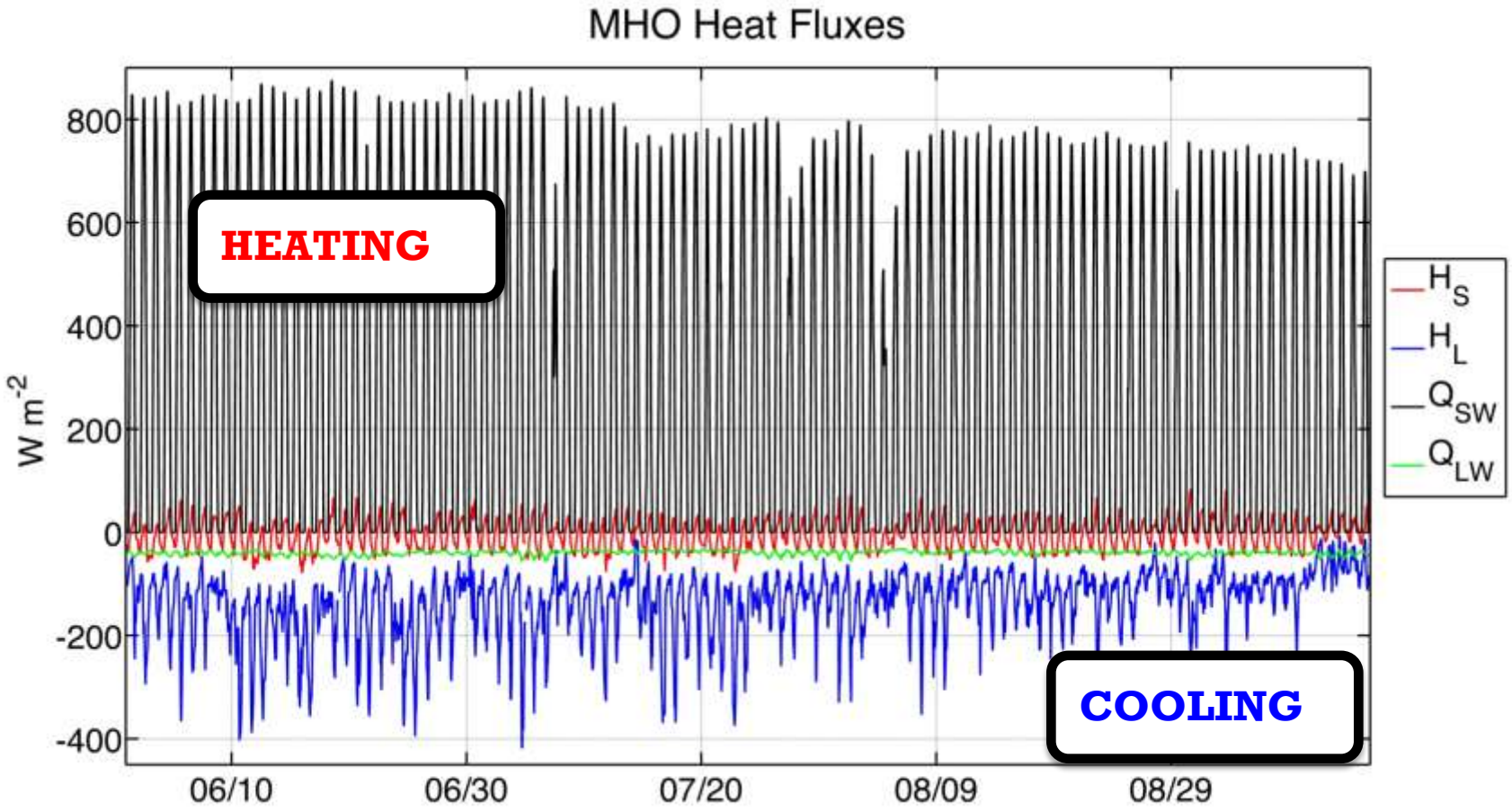
In the face of climate change, Delta flow operations have the capacity to effectively alleviate warm temperatures

Question Time!

Fear the Tree!

And please talk to me later or email me at:

kgleich@gmail.com


MHO Heat Fluxes
HEATING
COOLING
W m-2
800
600
400
200
0
-200
-400
06/10
06/30
07/20
08/09
08/29
HS
HL
QSW
QLW