

Review of King County's Continuous Lake Temperature Monitoring Data

29th Annual Washington Lake Protection Association Conference

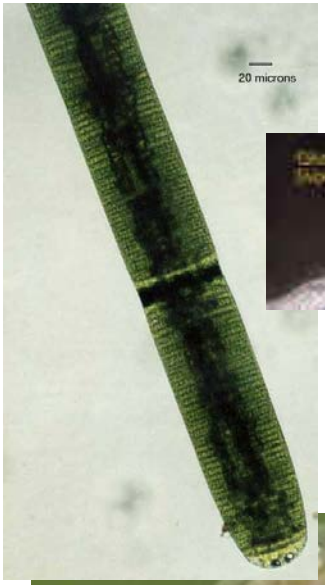
Curtis DeGasperi
King County Water and Land Resources Division

October 6, 2016

Why care about water temperature?

- Distribution and abundance of organisms
- Life history timing
- Metabolic processes
- Chemical reaction rates and gas fluxes

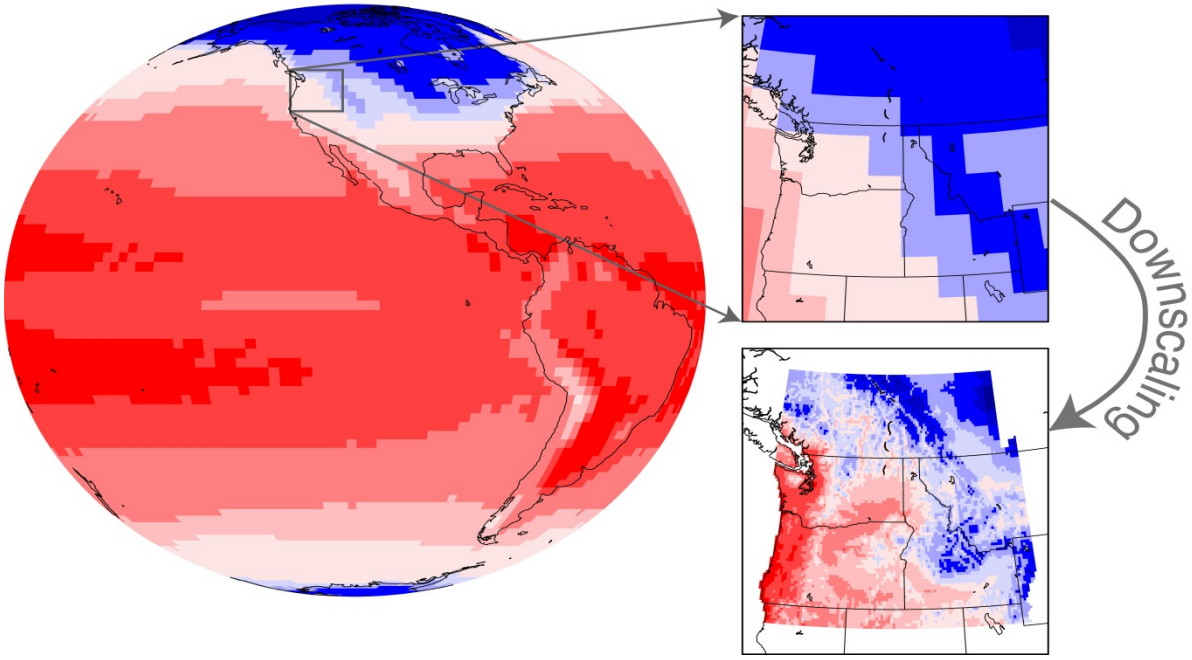








Global Climate Model Air Temperature



Various Temperature Monitoring Methods







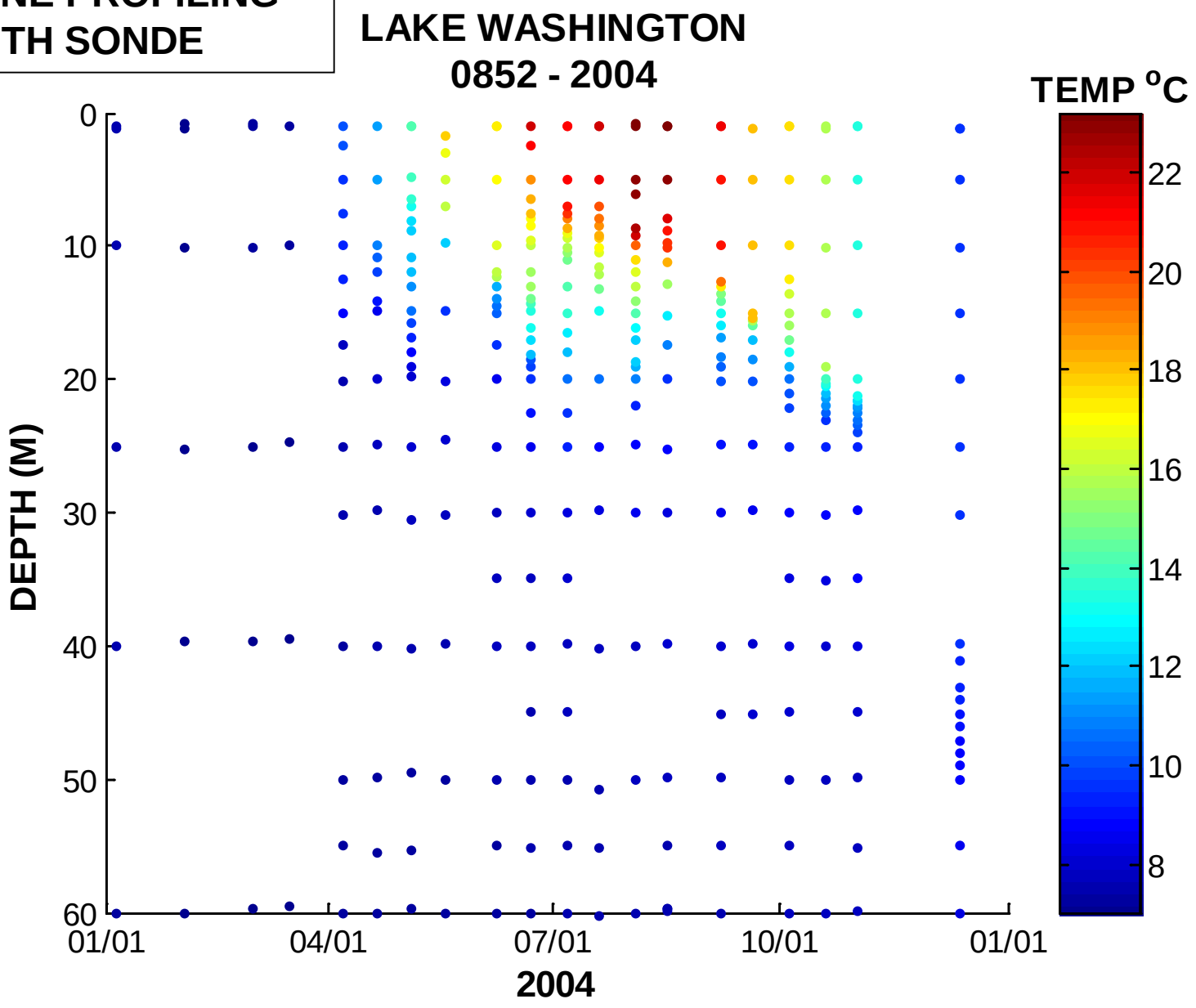




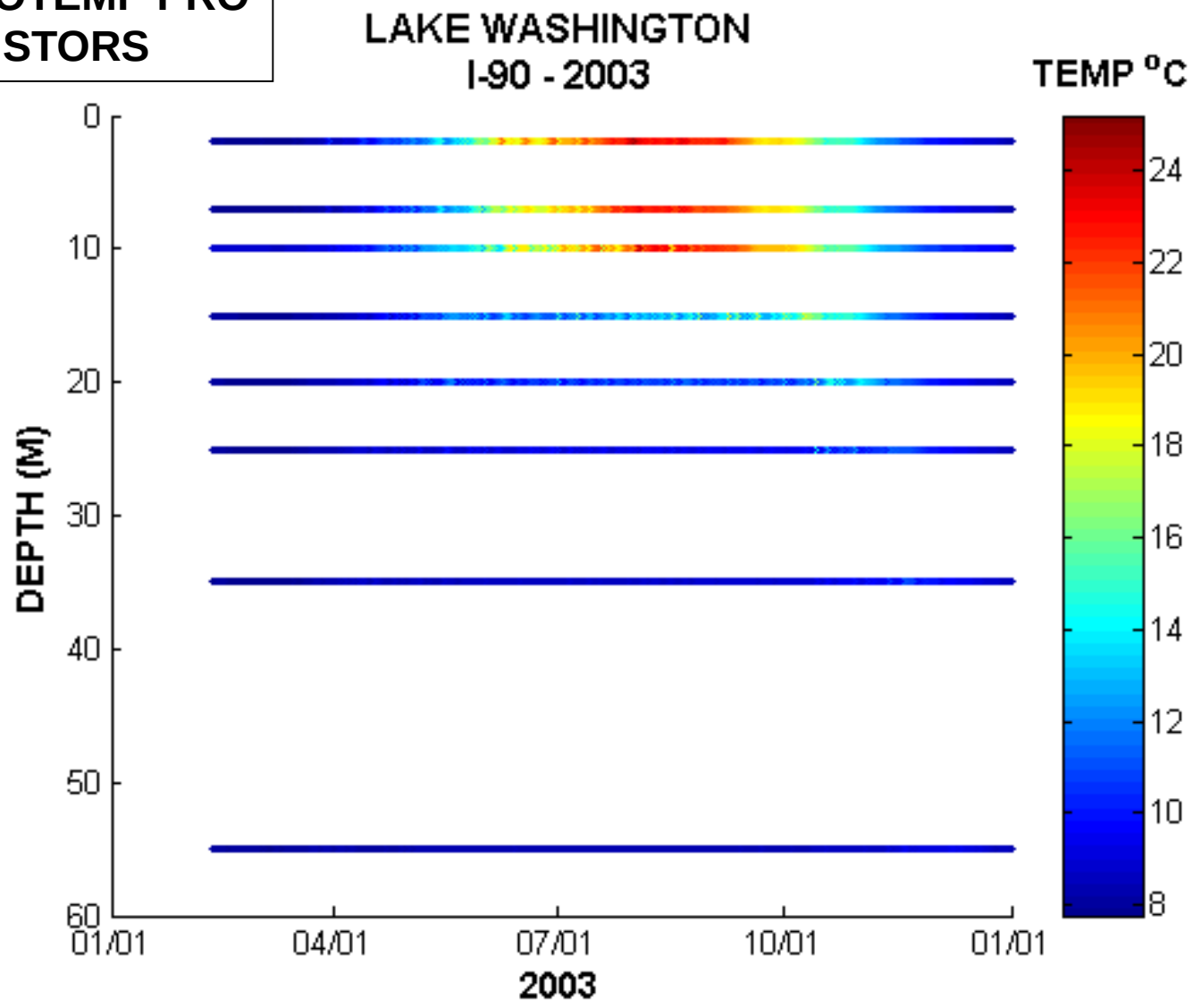




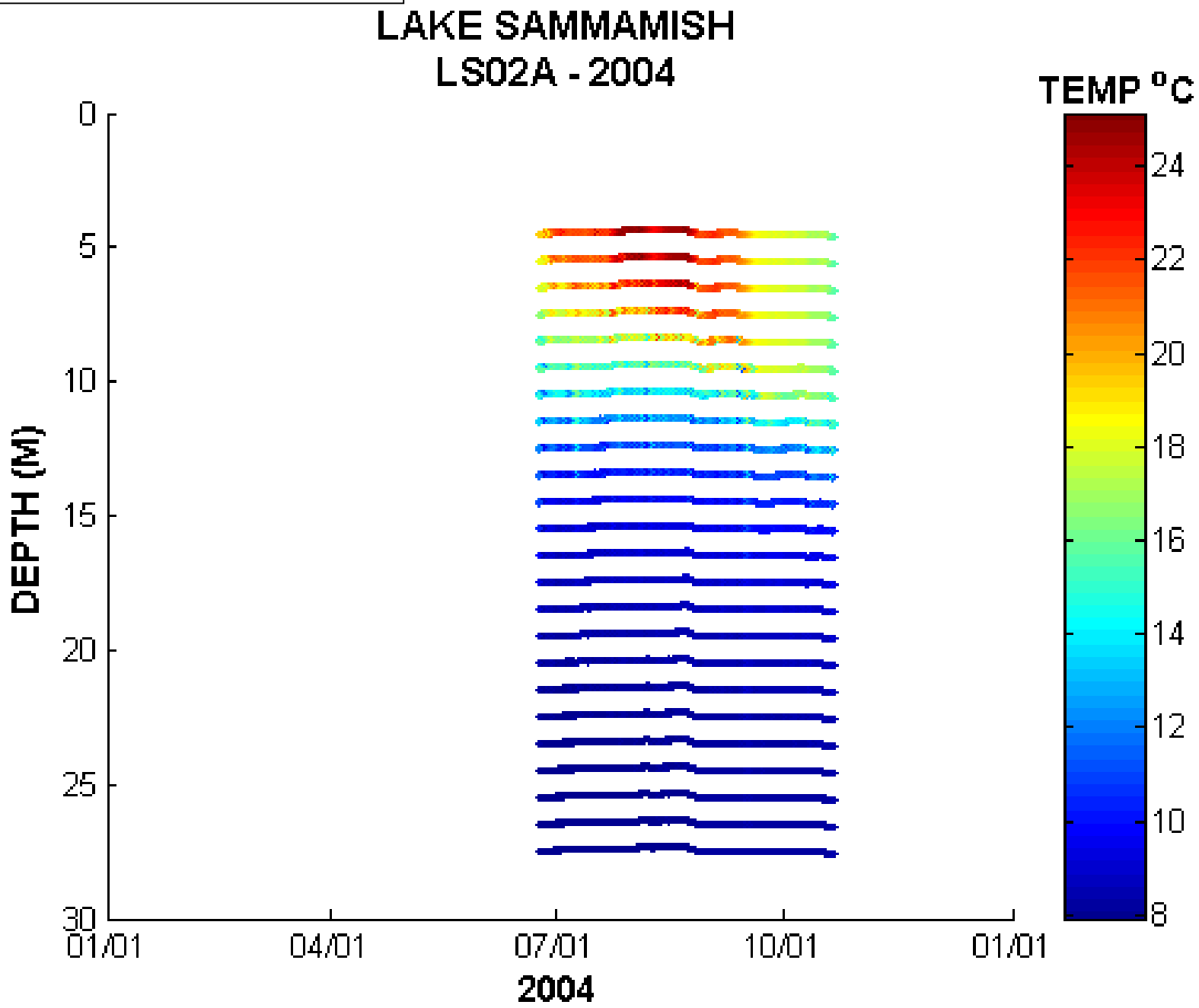
ROUTINE PROFILING WITH SONDE



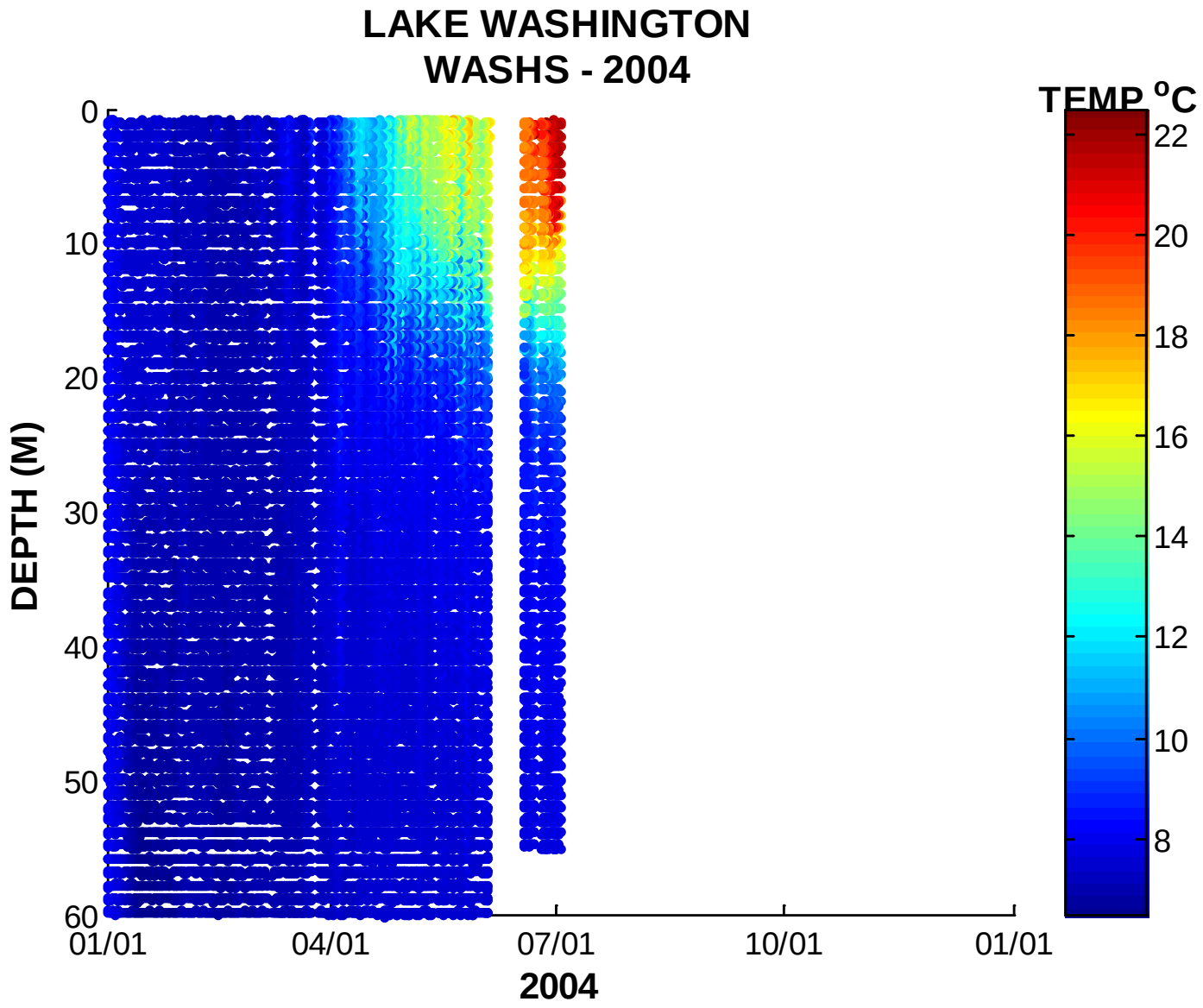
ONSET HOBOTEMP PRO THERMISTORS



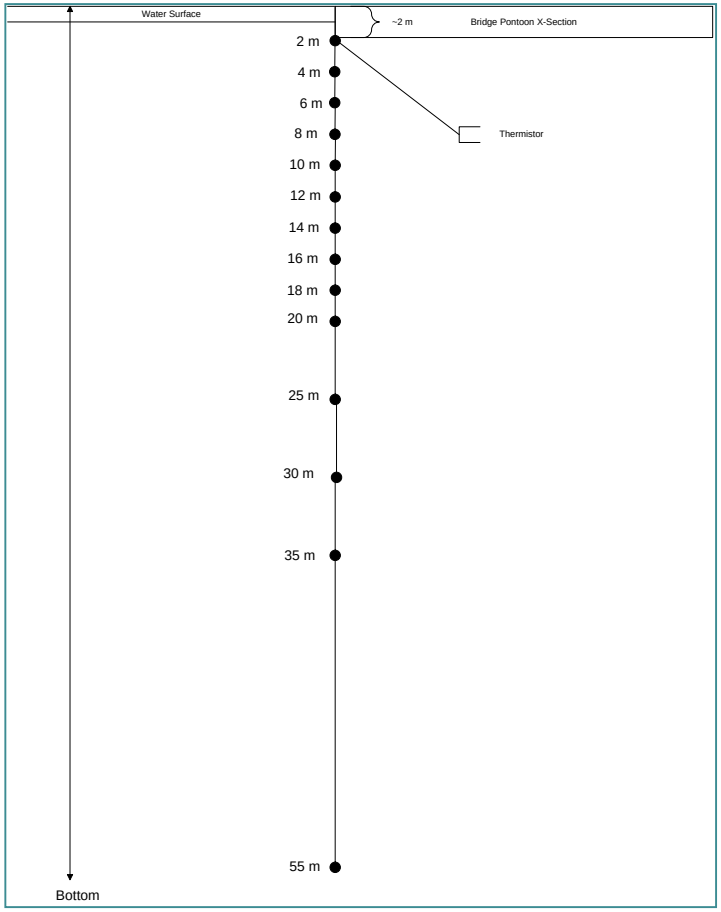
RBR THERMISTORS

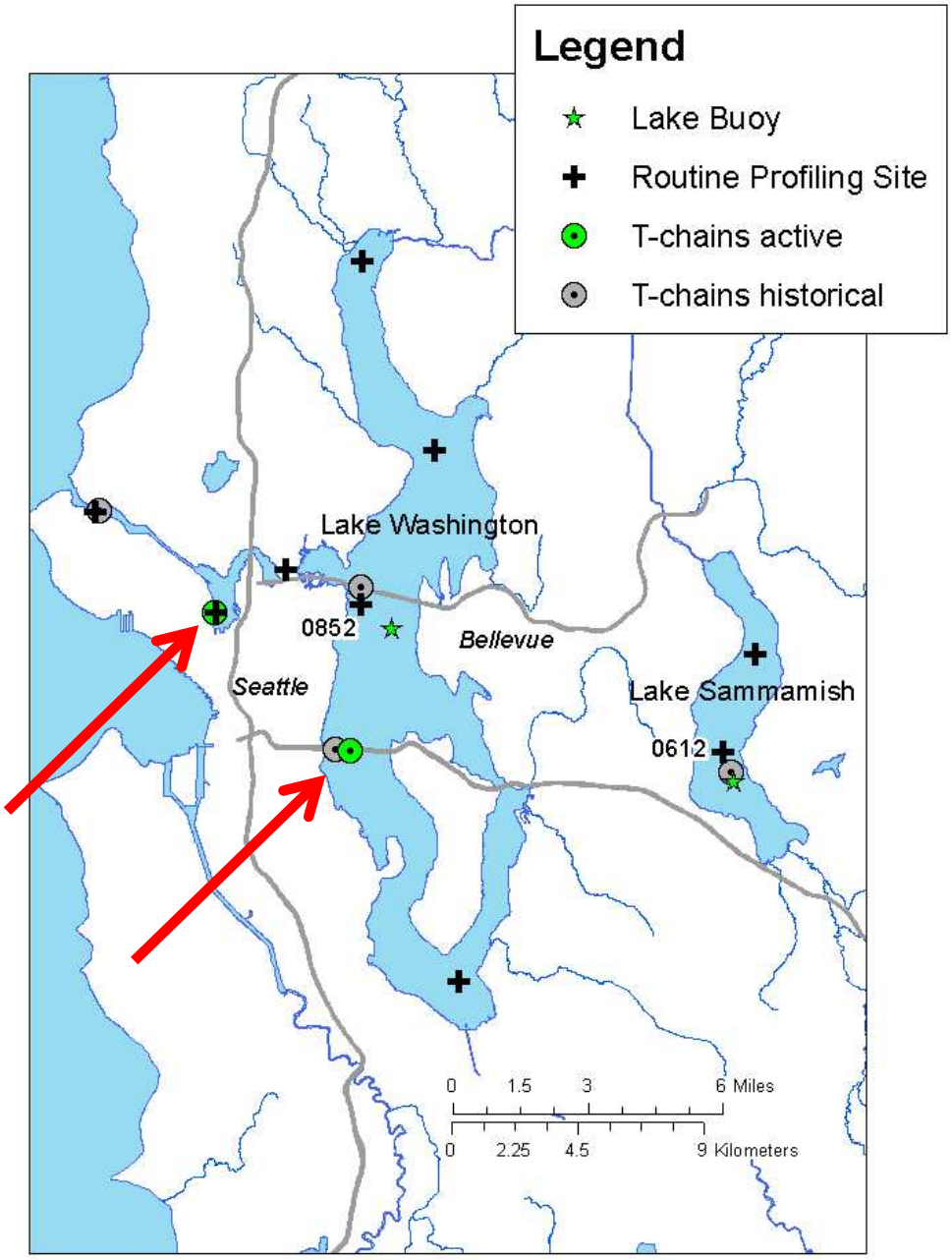


RUSS BUOY PROFILER



Locations

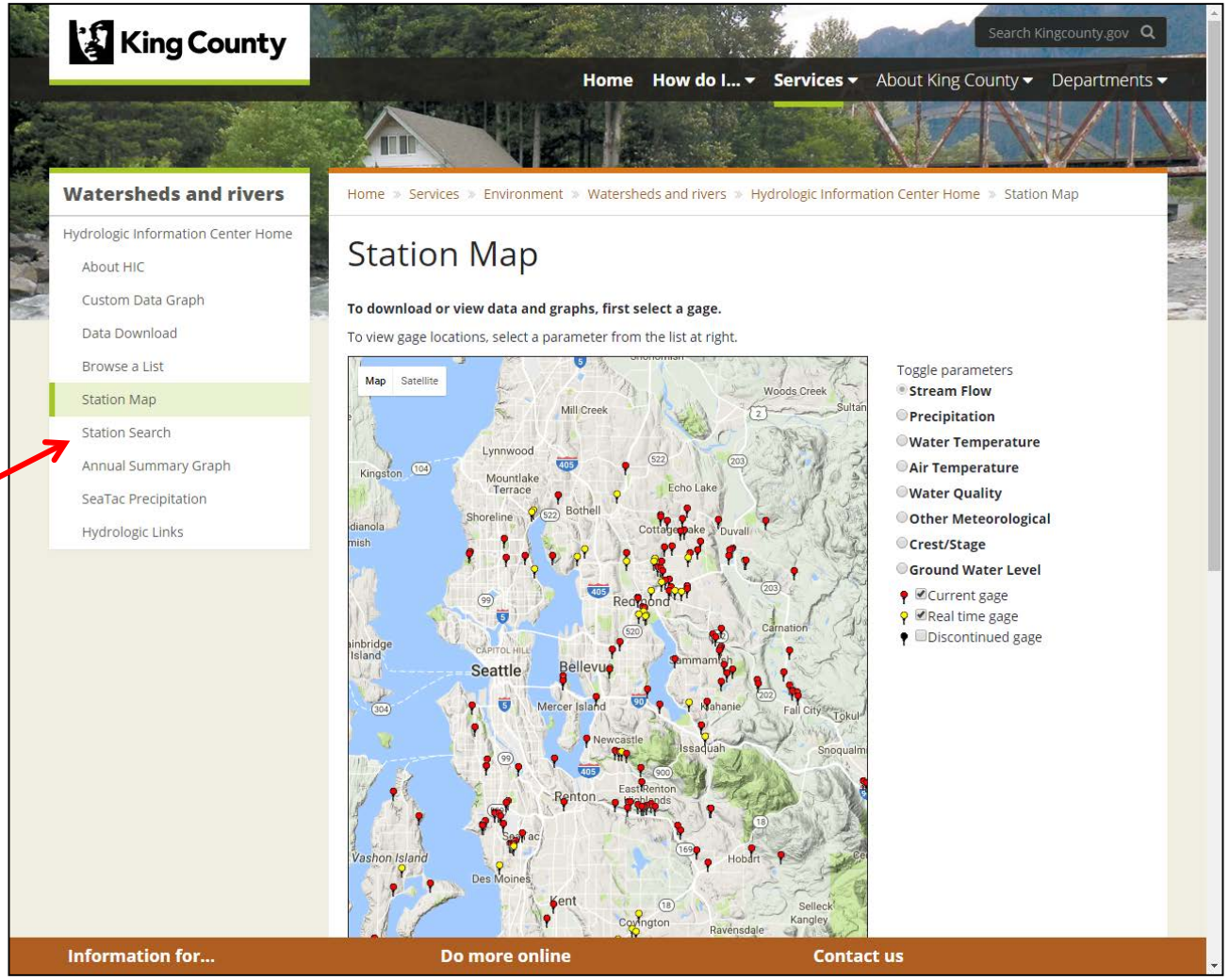

Water Surface
~2 m
Bridge Pontoon X-Section
2 m
4 m
6 m
8 m
10 m
12 m
14 m
16 m
18 m
20 m
25 m
30 m
35 m
55 m
Thermistor
Bottom


Legend
Lake Buoy
Routine Profiling Site
T-chains active
T-chains historical
Lake Washington
0852
Bellevue
Seattle
Lake Sammamish
0612
0 1.5 3 6 Miles
0 2.25 4.5 9 Kilometers

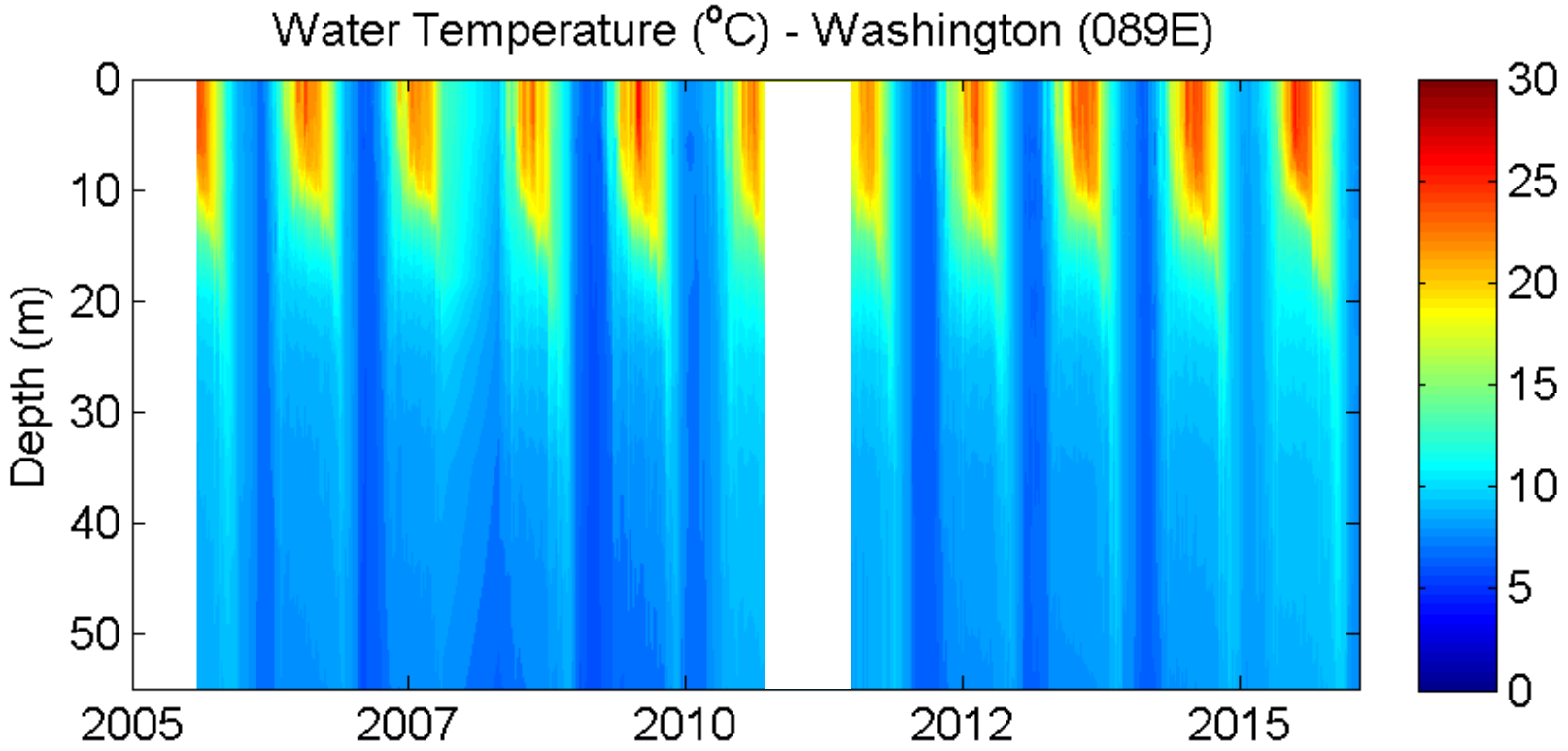
King County Hydrologic Information Center

Station Search:

0641
0852
0890
0522
0512
0890

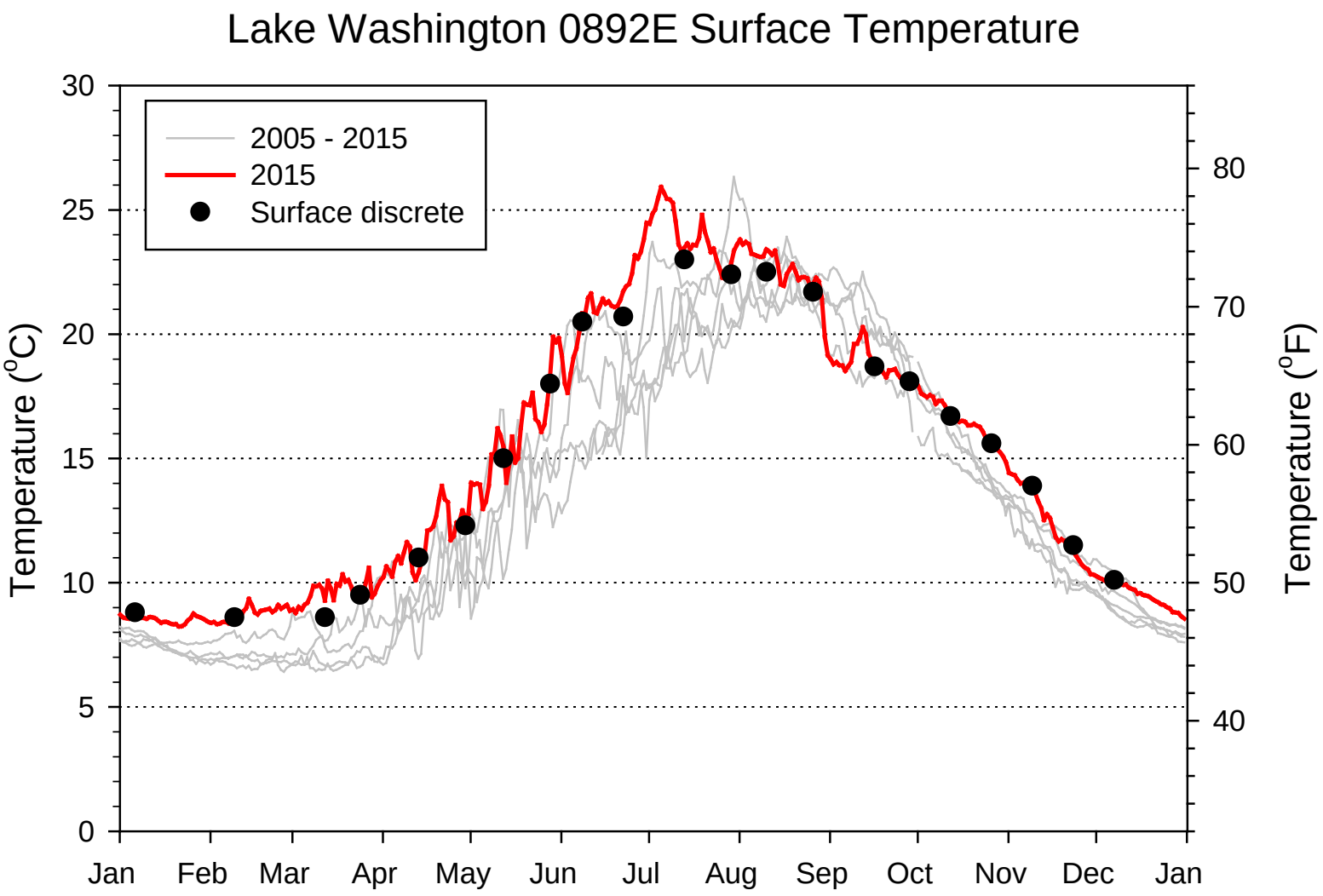


Lake Analyzer

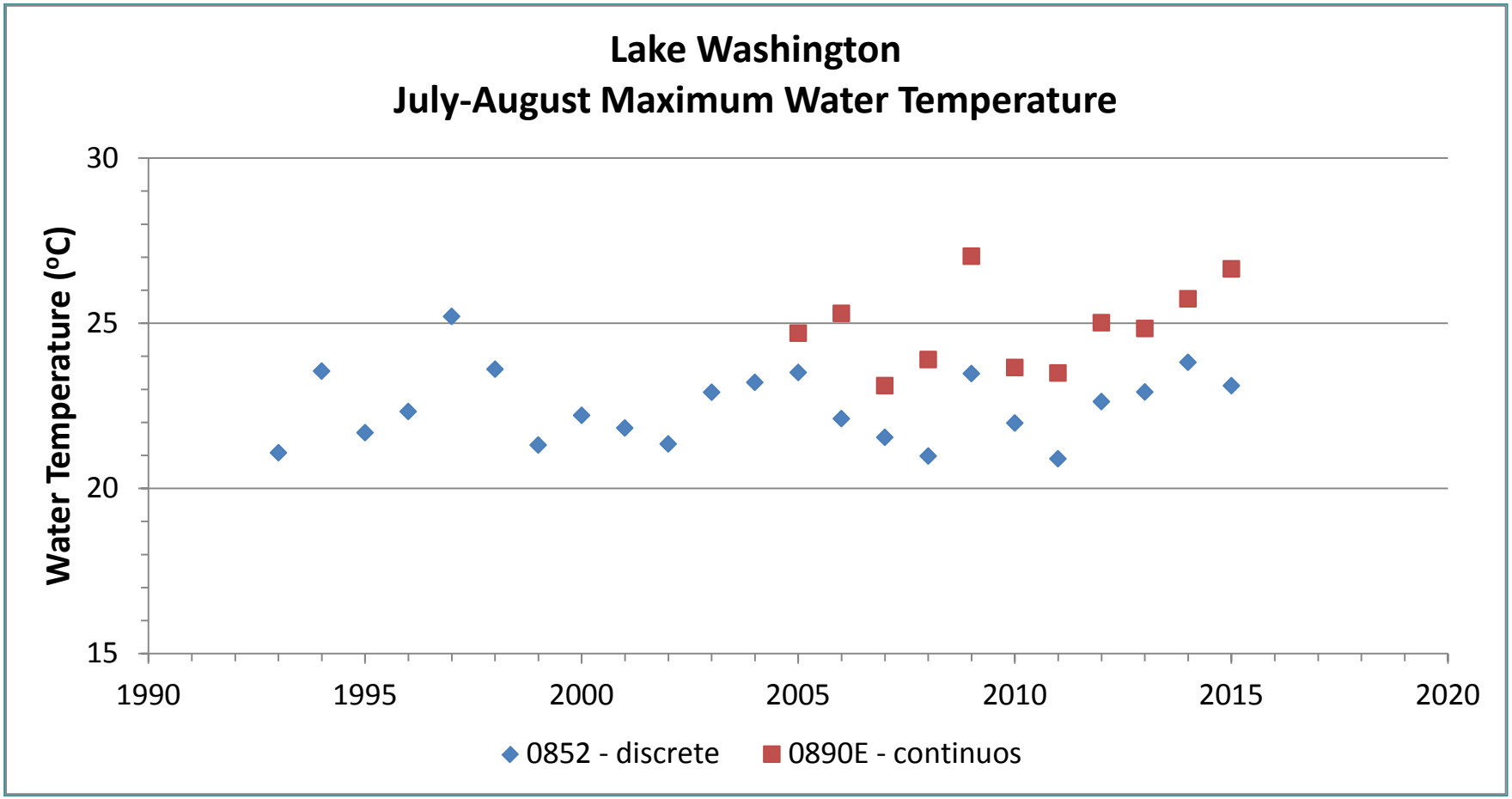


- Schmidt Stability
- Thermocline Depth
- Stratification Onset
- Etcetera

Year-to-year Comparisons



Trends in Summer Maximum Temperatures



Continuous temperature monitoring may be even more important in small lakes

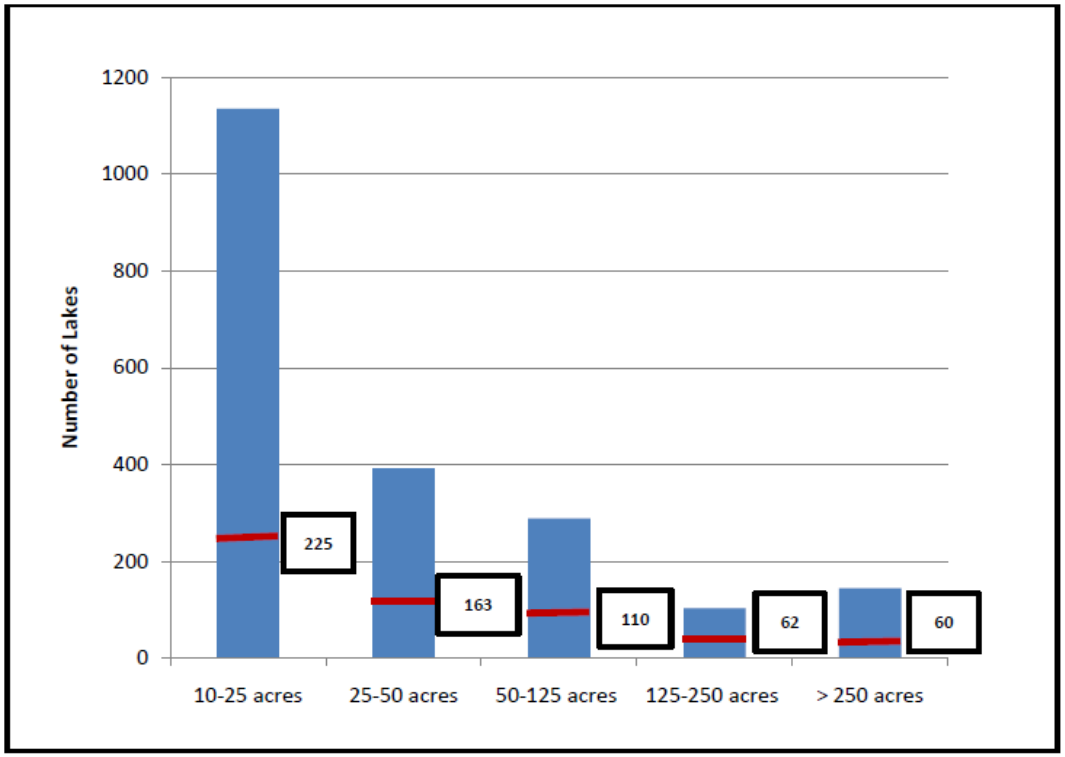


Figure 2. Total number of lakes in Washington and final lake sample population in the various lake size categories.

The blue bars show the number of lakes in Washington in each size class. The red lines within the blue bars and the numbers in the boxes both indicate the number of lakes (out of the 620 lakes which make up the final lake sample population) which the NLA data results are applied to.

Bell-McKinnon (2010) Ecology Publication No. 10-03-029

Diel temperature range appears to scale with lake area

~0.25 ~2.5 ~25 ~250~2500~25000 acres

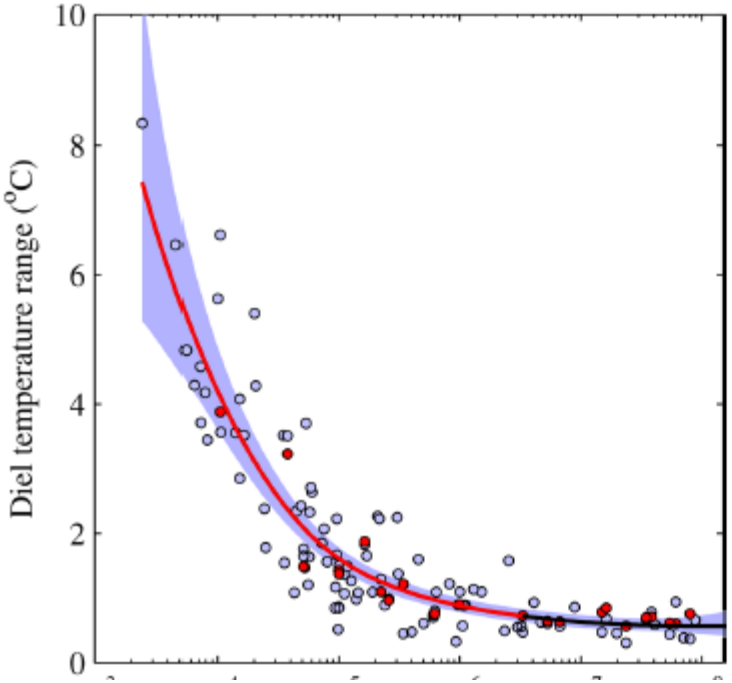


Fig 3. Relationship between the diel range in lake surface water temperature and surface area. Relationship between the observed (light violet circles) and theoretical (red circles) diel surface temperature range with lake area during summer, with the solid line illustrating the fitted generalised additive model with 95% confidence interval shown by the shaded region; lake surface areas where the diel temperature range changes significantly ($P < 0.001$) are shown with a red line.

doi:10.1371/journal.pone.0152466.g003

Woolway et al. (2016) PLoS ONE

Waughop

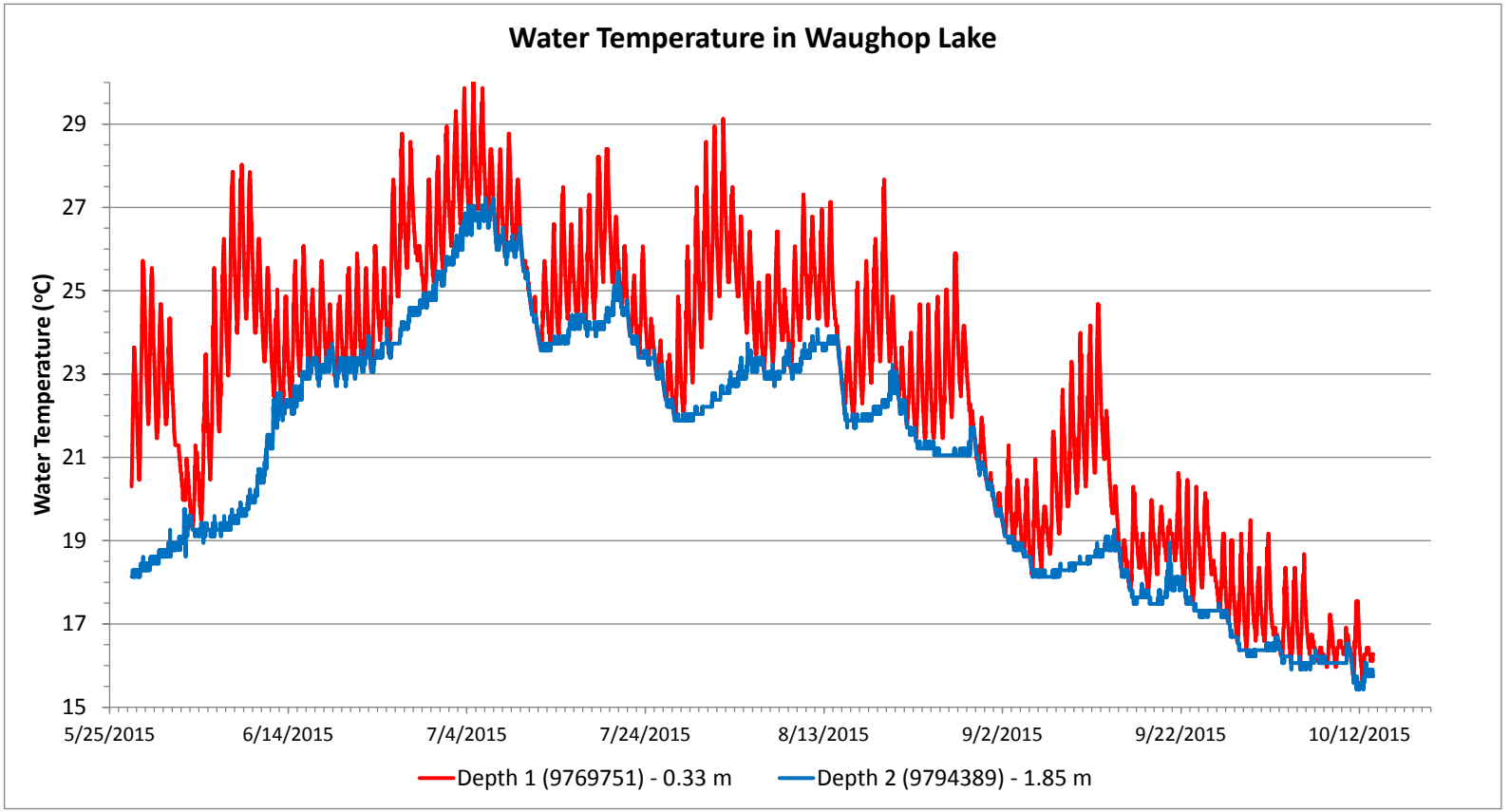


Surface area: 33 ac (0.13 km^2)

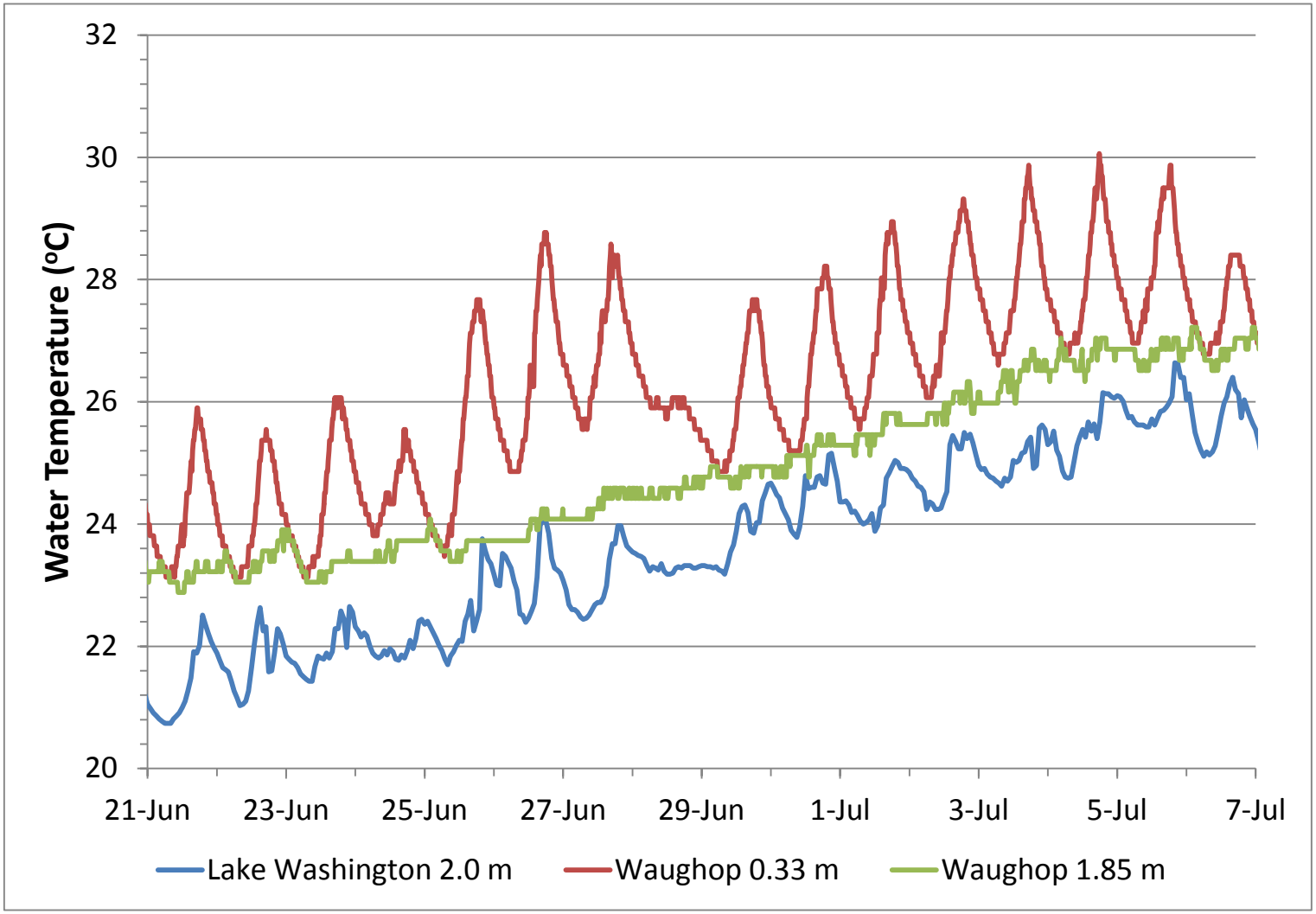
Mean depth: 7 ft (2.1 m)



Data courtesy of Jim Gawel, UW Tacoma



Compare Small vs Large Lake

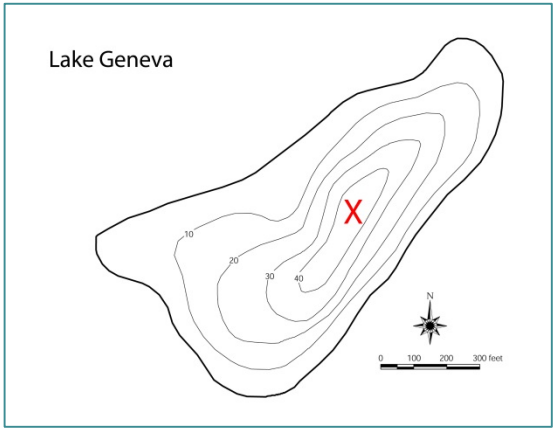


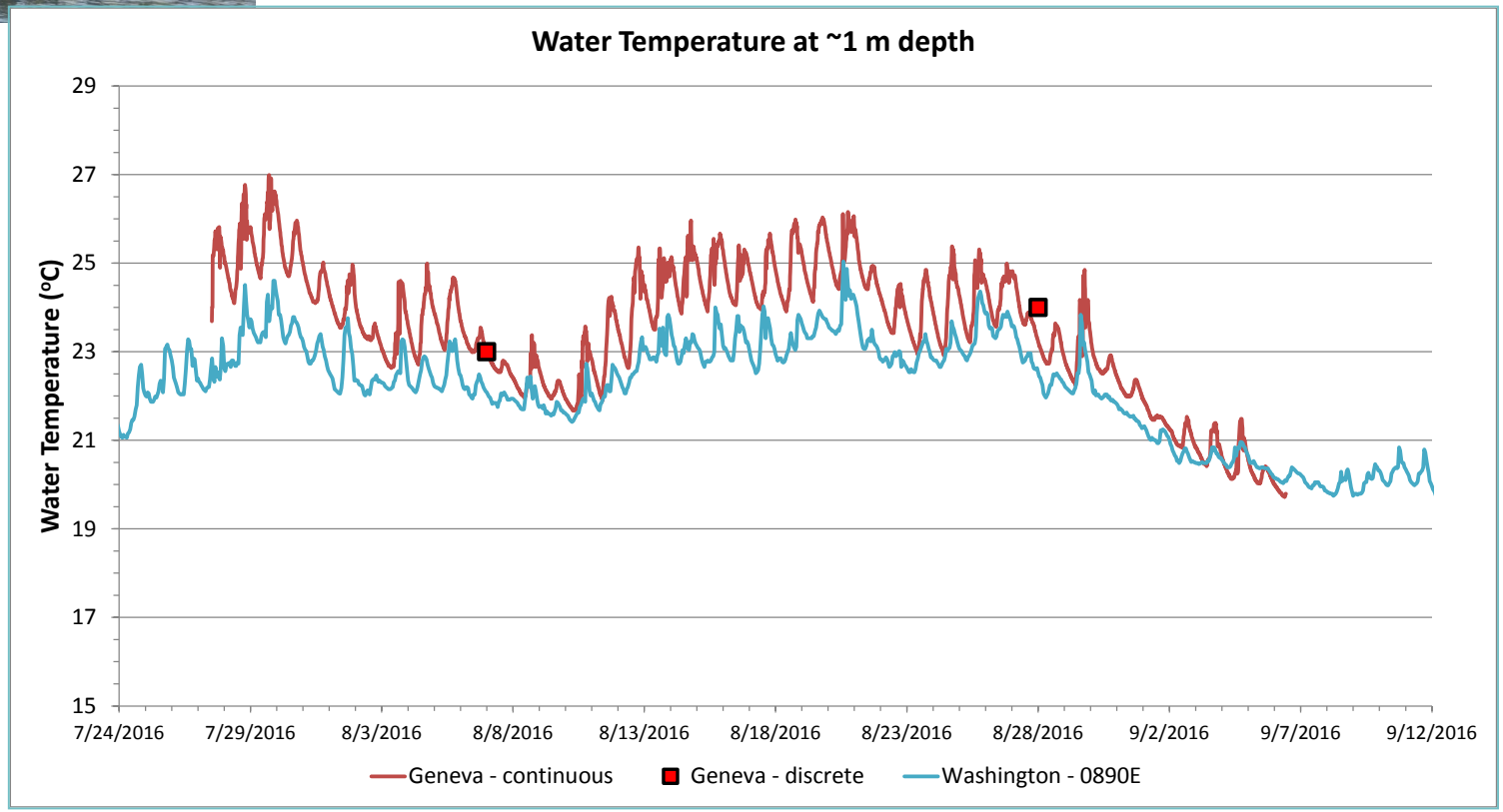
Lake Geneva



Surface area: 29 ac (0.12 km^2)

Mean depth: 19 ft (5.8 m)



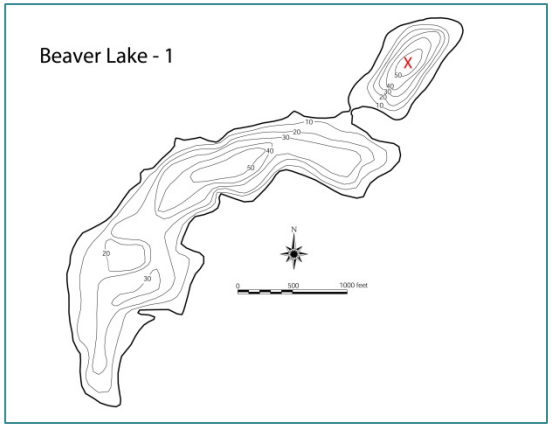


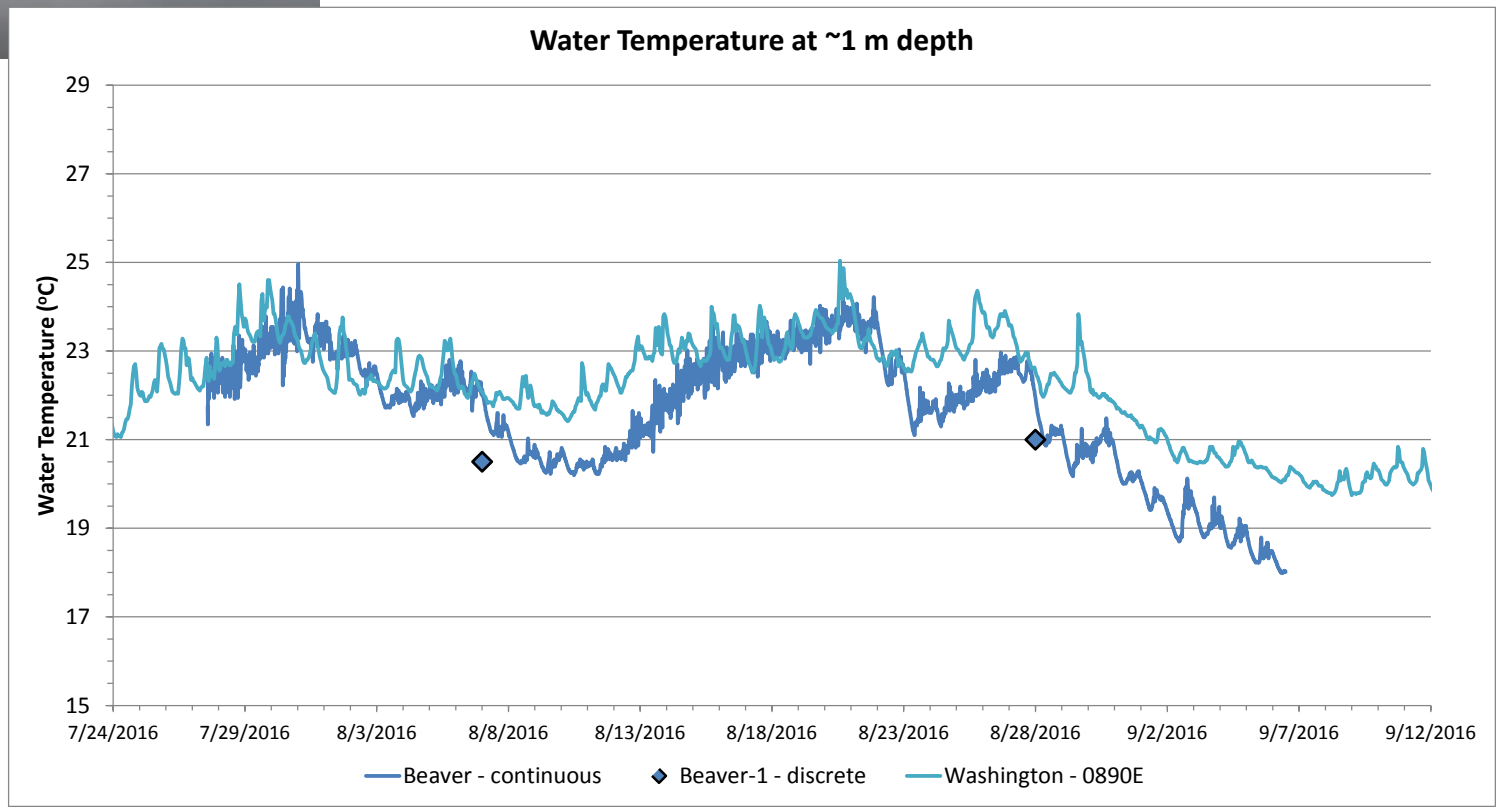
Beaver-1



Surface area: 12 ac (0.05 km^2)

Mean depth: 22 ft (6.7 m)





Estimating the timing of the onset of stratification

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE
10.1002/2013WR014975



A novel method for estimating the onset of thermal stratification in lakes from surface water measurements

R. Iestyn Woolway[1,2], Stephen C. Maberly[1], Ian D. Jones[1], and Heidrun Feuchtmayr[1]

[1]Lake Ecosystems Group, Centre for Ecology & Hydrology, Lancaster Environment Centre, Lancaster, UK, [2]Environmental Change Research Centre, University College London, London, UK

Key Point:
- Stratification onset in lakes can be estimated from surface water temperature measurements

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Citation:
Woolway, R. I., S. C. Maberly, I. D. Jones, and H. Feuchtmayr (2014), A novel method for estimating the onset of thermal stratification in lakes from surface water measurements, *Water Resour. Res.*, *50*, 5131–5140, doi:10.1002/2013WR014975.

Received 29 OCT 2013
Accepted 6 JUN 2014
Accepted article online 10 JUN 2014
Published online 25 JUN 2014

Abstract High-frequency surface water temperature measurements were analyzed for 17 annual data series from seven lakes to assess whether the onset of thermal stratification can be determined from time series of surface water temperature measurements alone. Current methods for estimating the start of thermal stratification require depth-resolved temperature measurements, whereas many existing high-frequency measurements are often limited only to the lake surface. In this study, we show that the magnitude of the diel surface water temperature range can be used to estimate the onset of thermal stratification. We assess the accuracy of using the diel range as an estimate of the onset of thermal stratification by applying two methods based on the calculation of (1) the absolute difference in the diel surface temperature range and (2) the magnitude of the diel range from wavelet analysis. Our study shows that the onset of thermal stratification can be accurately estimated by wavelet analysis with a root mean square error of 2.1 days and by the observed diel temperature range method with a root mean square error of 11.8 days. This approach enables existing, and future, high-resolution surface water data sets to be used to estimate the onset of lake stratification. Furthermore, the continuously increasing observational powers of satellites may eventually result in surface water temperature being measured at a sufficiently high temporal resolution at the spatial scales of small lakes to allow the onset of thermal stratification to be estimated remotely.

HeatFluxAnalyzer Web

This is the web front end to Lake HeatFluxAnalyzer, a tool that allows users to calculate derived heat flux information for lakes.

Code and Other versions

The HeatFluxAnalyzer Matlab code is availble on github.

If used, please cite

Woolway, RI, ID Jones, DP Hamilton, SC Maberly, K Muraoka, JS Read, RL Smyth, and LA Winslow. 2015. *Automated calculation of surface energy fluxes with high-frequency lake buoy data.* Environmental Modelling & Software 70: 191–198.

Documentation

Additional information can be found in the User Manual.

Web Submit

Please zip up your input files and upload them to run. An input example set is provided to help you create input of your own.

Input files (zipped): Choose File No file chosen

Submit

Input file format

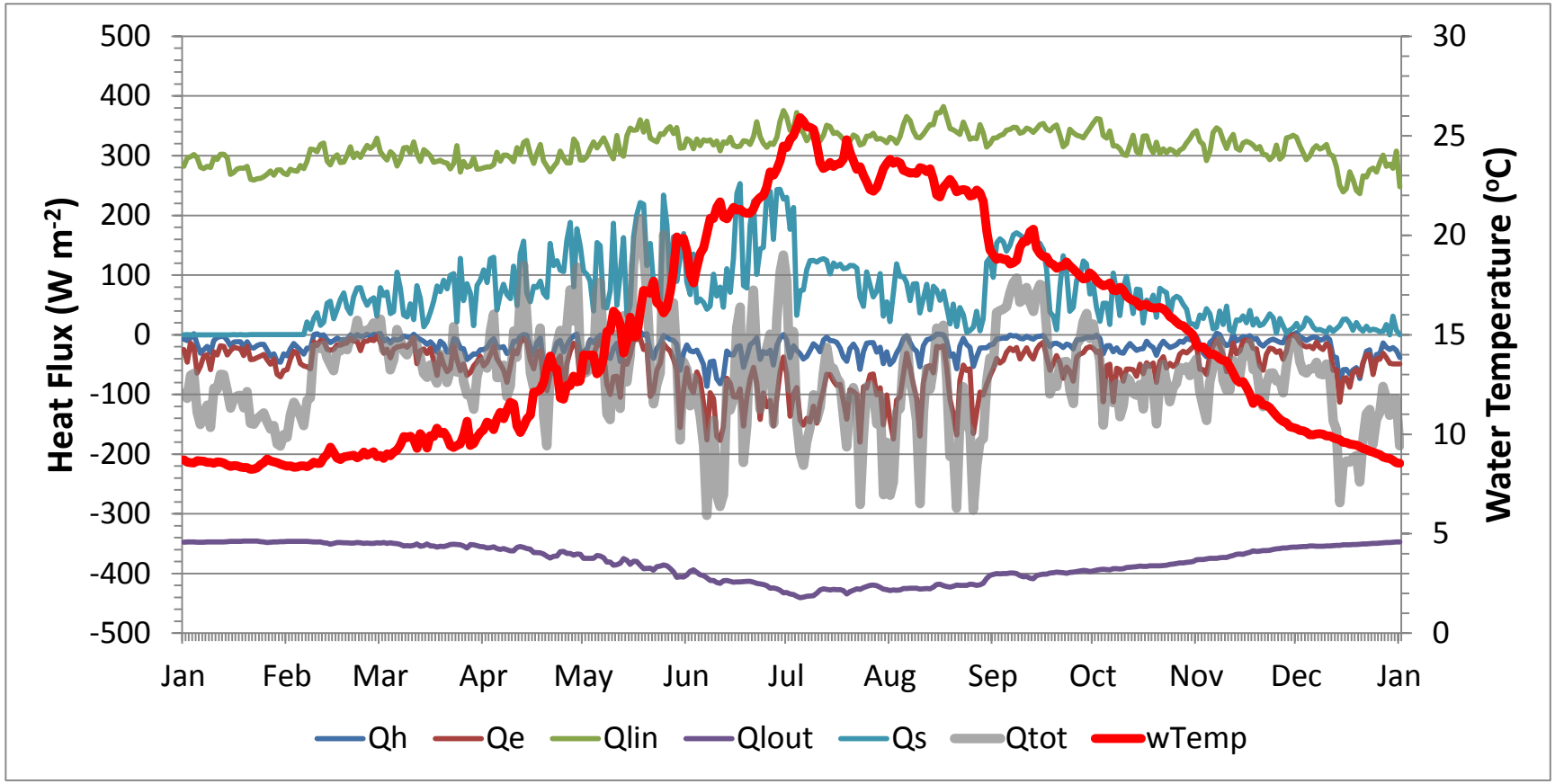
The input files need to be in the format as described below.

- ***Lake Name***.hfx: Configuration file for Heat Flux Analyzer run
- ***Lake Name***.wtr: Time series of water temperature measurements (Celsius)
- ***Lake Name***.rh: Time series of relative humidity measurements (%)
- ***Lake Name***.airT: Time series of air temperature measurements (Celsius)
- ***Lake Name***.wnd: Time series of wind speed measurements (meters/sec)
- ***Lake Name***.sw: Time series of shortwave radiation measurements (W/m^2)
- ***Lake Name***.par: Time series of PAR measurements (µmol/m^2/sec)
- ***Lake Name***.lw: Time series of incoming longwave radiation measurements (W/m^2)
- ***Lake Name***.lwnet: Time series of net longwave radiation measurements (W/m^2)

© Richard W & Luke Winslow 2014

http://heatfluxanalyzer.gleon.org/

Estimated Heat Fluxes Lake Washington – 2015

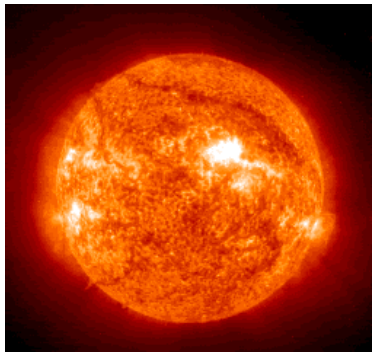


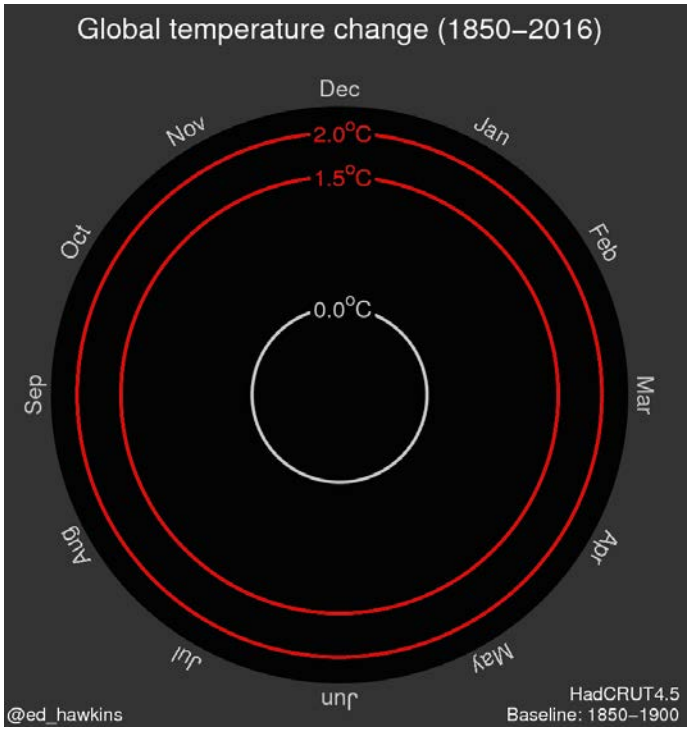
Heat Flux (Qtot) = Solar (Qs) + Incoming Longwave (Qlin) – Outgoing Longwave (Qlout) – Evaporation (Qe) – Conduction (Qh)

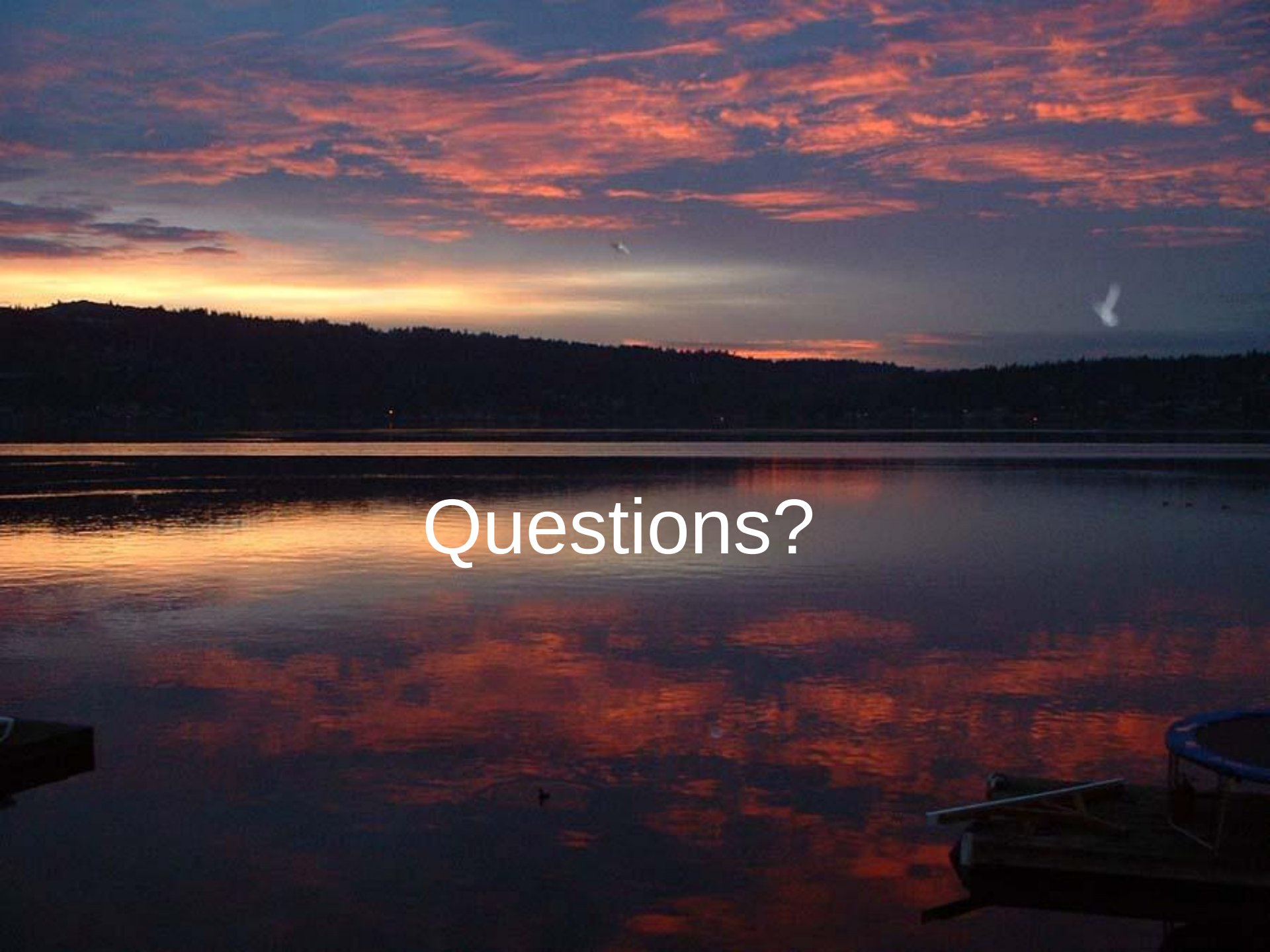
A couple of conclusions…



- High resolution temperature data may be needed if…
- You may just need a single sensor near the lake surface






Questions?

Some references

- Rode et al. (2016) Sensors in the stream: The high-frequency wave of the present. ES&T doi:10.1021/acs.est.6b02155.
- Woolway et al. (2016) Diel surface temperature range scales with lake size. PLoS ONE doi:10.1371/journal.pone.0152466.
- Woolway et al. (2015) Automated calculation of surface energy fluxes with high-frequency lake buoy data. Env. Model. & Soft. doi:10.1016/j.envsoft.2015.04.013
- HeatFluxAnalyzer Web http://heatfluxanalyzer.gleon.org/
- Woolway et al. (2014) A novel method for estimating the onset of thermal stratification in lakes from surface water measurements WRR doi:10.1002/2013WR014975.
- Read et al. (2011) Derivation of lake mixing and stratification indices from high-resolution lake buoy data. Env. Model. & Soft. doi:10.1016/j.envsoft.2011.05.006.