What is Lake Analyzer?

- Computer program used to calculate indices of stratification and mixing
- Lake physical stability indices, surface mixing depth and thermocline depth are calculated according to established literature definitions
- Processed data are returned to the user in time series format, which can then be analyzed in R, Matlab, Excel, etc.
- Designed for analyzing high-frequency buoy data

Brief history

- The Lake Analyzer project started in 2007
- Developed through the Global Lake Ecological Observatory Network (GLEON) - based on original set of codes developed at the University of Waikato, New Zealand.
- Objective was to automate the processing of lake observational data from around the world
- Similar data format files to Lake Heat Flux Analyzer

What can Lake Analyzer calculate?

Output options and definitions.

Output	Units	Description
Ln	–	Lake Number
metaB	m	Bottom of the metalimnion depth (from the surface)
metaT	m	Top of the metalimnion depth
N2	s^{-2}	Buoyancy frequency
SLn	–	Seasonal Lake Number
SmetaB	m	Bottom of the seasonal metalimnion depth
SmetaT	m	Top of the seasonal metalimnion depth
SN2	s^{-2}	Seasonal buoyancy frequency
St	$J\ m^{-2}$	Schmidt stability (Idso, 1973)
ST1	s	Seasonal mode-1 vertical seiche period
SthermD	m	Seasonal thermocline depth
SuSt	$m\ s^{-1}$	Seasonal u-star
SW	–	Seasonal Wedderburn number
T1	s	Mode-1 vertical seiche period
thermD	m	Thermocline depth
uSt	$m\ s^{-1}$	u-star (water friction velocity due to wind stress)
W	–	Wedderburn number
wndSpd	$m\ s^{-1}$	Wind speed
wTemp	$m\ s^{-1}$	Water temperature

- The inputs required vary depending on the specified output variables
- See user manual for 'how to' guide

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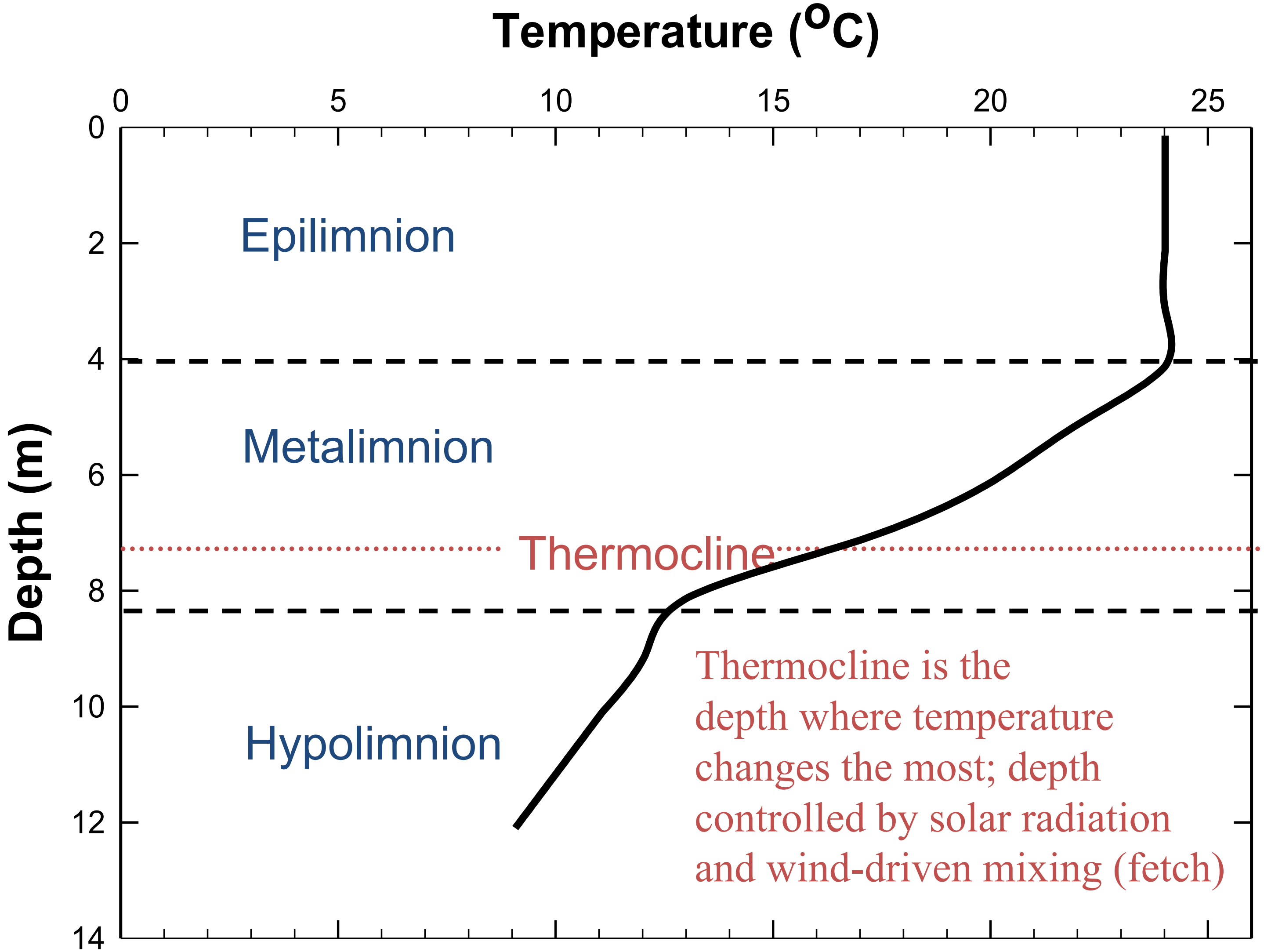
Thermal layering



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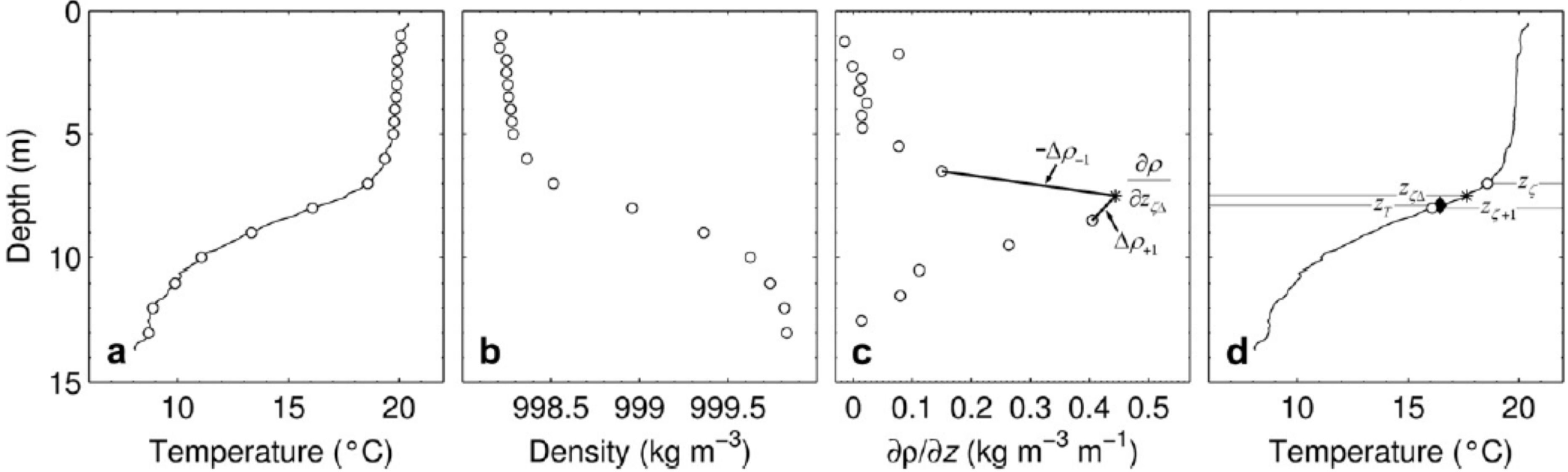
Thermal layering

Read et al., 2011

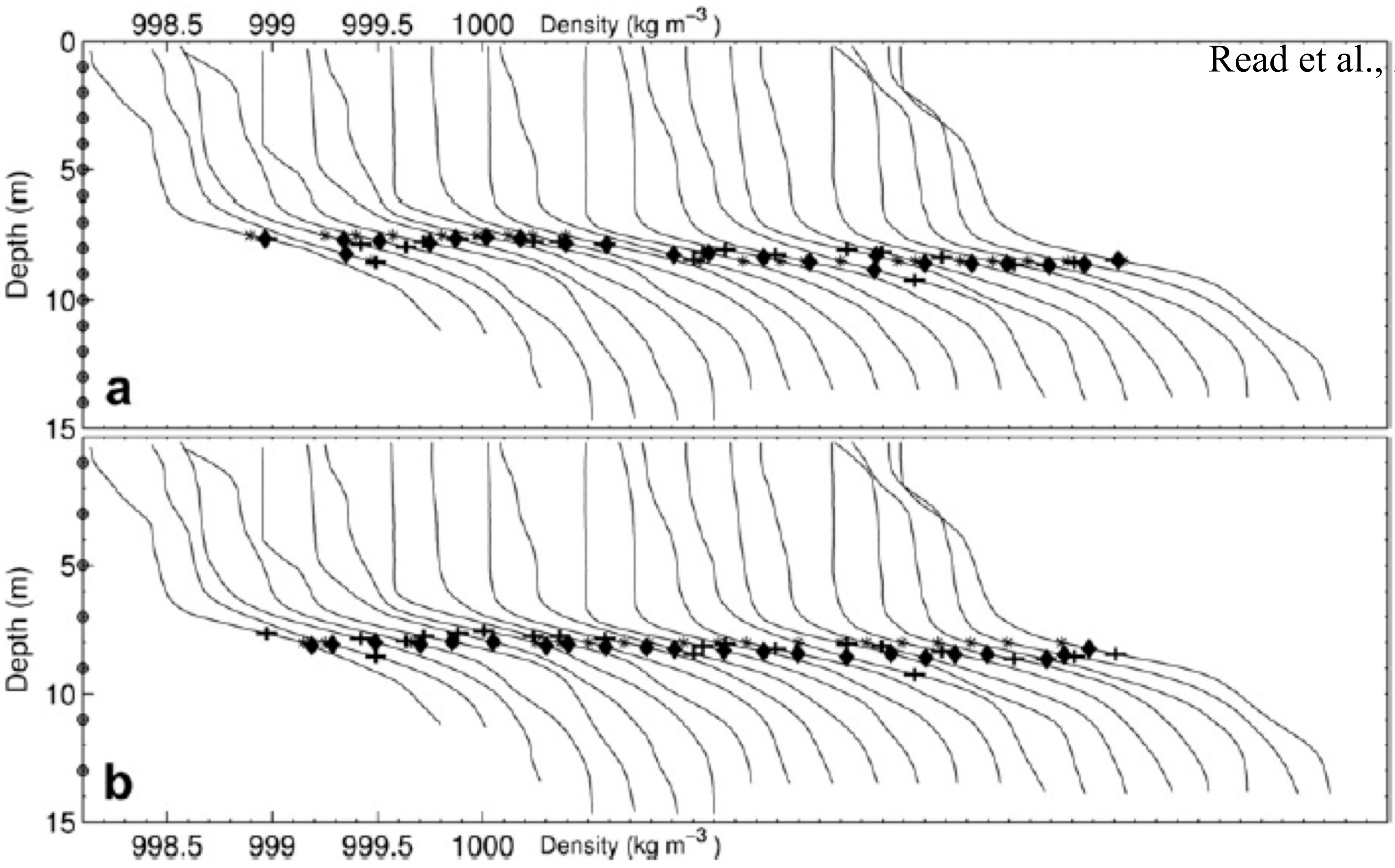


$$\frac{\partial\rho}{\partial z_{i\Delta}} = \frac{\rho_{i+1} - \rho_i}{z_{i+1} - z_i},$$

$$z_T \approx z_{\zeta+1}\left(\frac{\Delta\rho_{+1}}{\Delta\rho_{-1} + \Delta\rho_{+1}}\right) + z_\zeta\left(\frac{\Delta\rho_{-1}}{\Delta\rho_{-1} + \Delta\rho_{+1}}\right)$$

Thermal layering

Read et al., 2011



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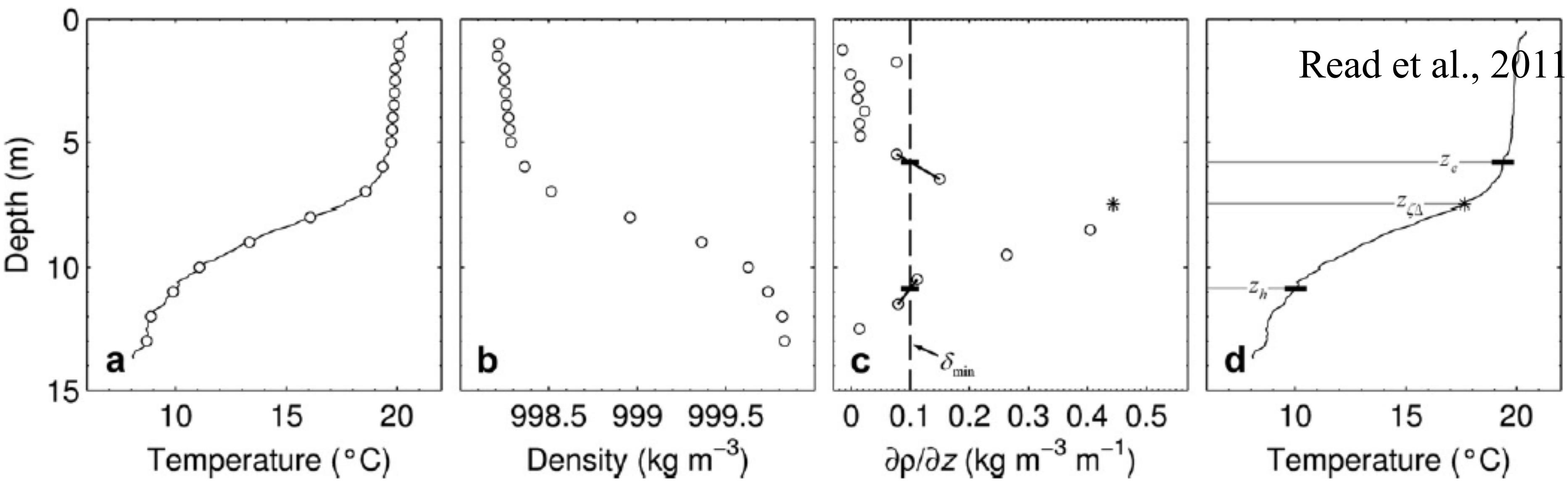
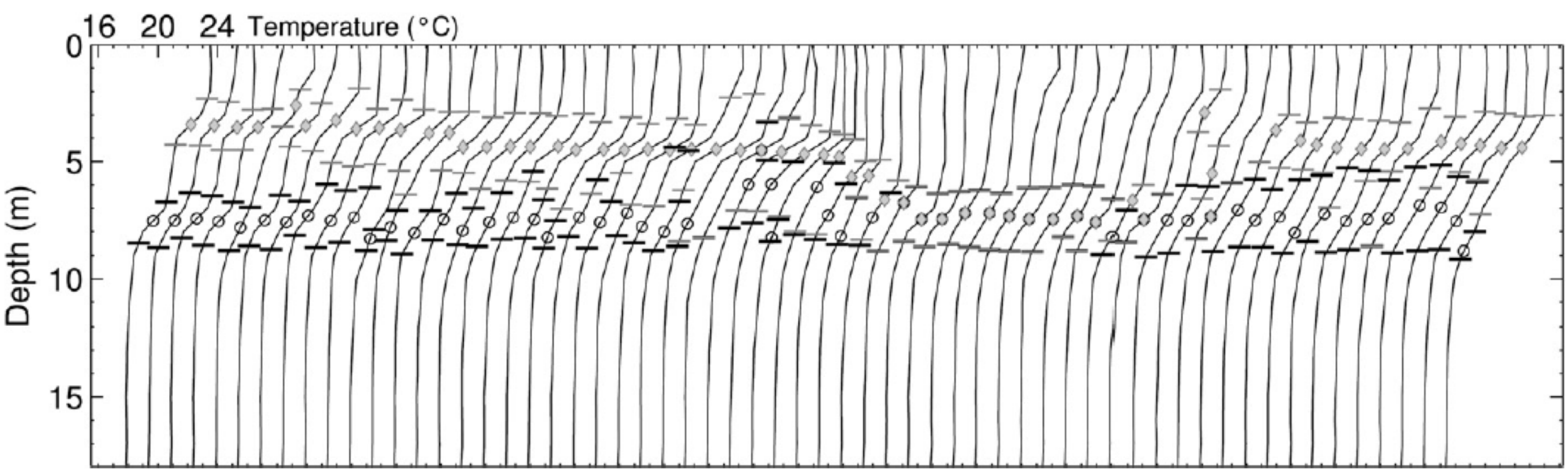
Thermal layering



Can be used to calculate the depth of each of the three main vertical layers of lakes



Thermal layering

Lake Analyzer is a useful tool for analyzing the variability in lake thermal structure and temperature dynamics

Stability

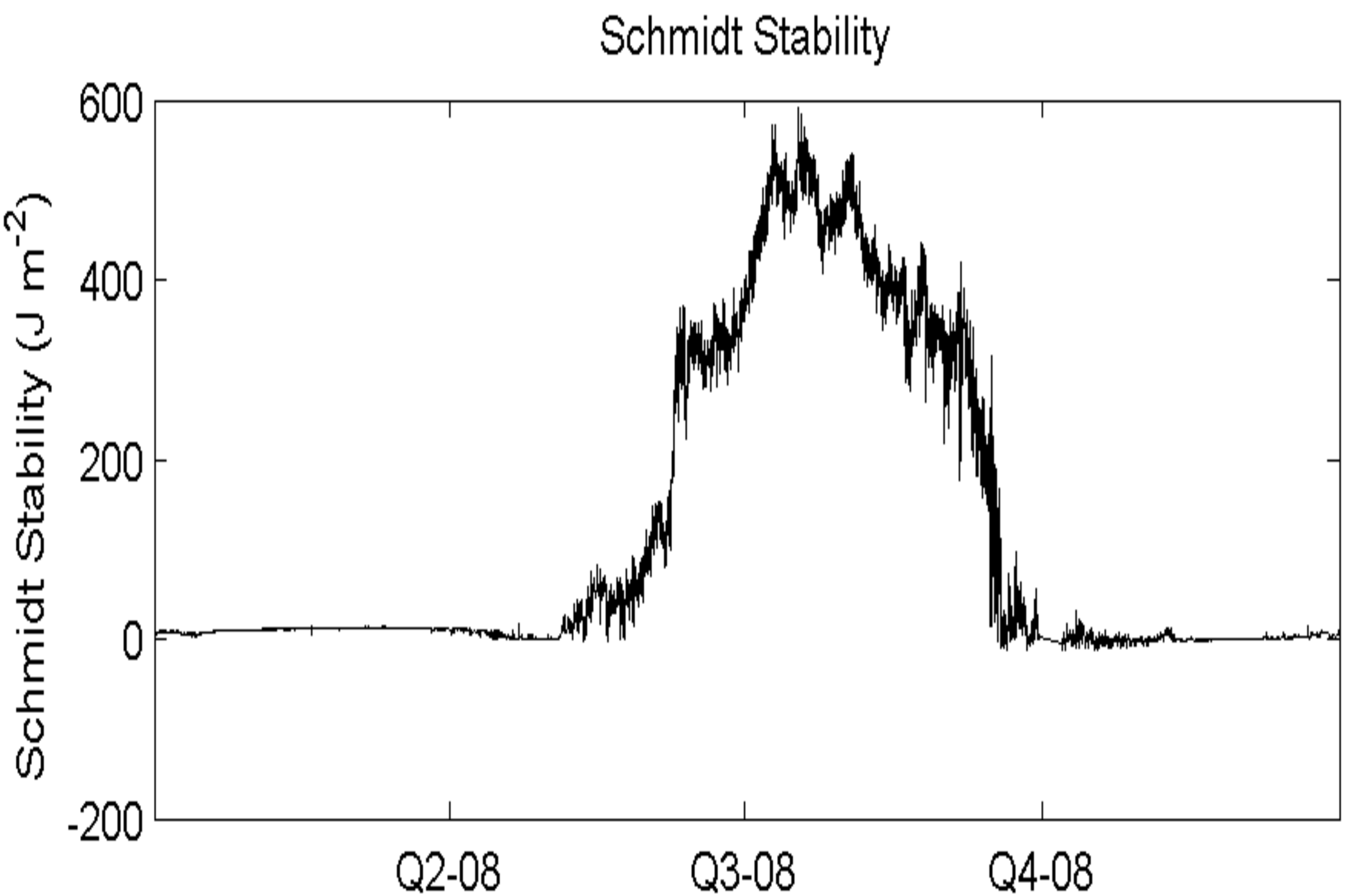
- the degree to which lake stratification resists mixing by the wind
- Stability depends on the difference in density between layers

$$S_T = \frac{g}{A_s} \int_0^{z_D} (z - z_v)\rho_z A_z \partial z$$

Schmidt stability

- quantity of work required to mix the entire volume of water to a uniform temperature
- How much wind energy is needed to mix the lake?

Case study 1 – Lake Sunapee



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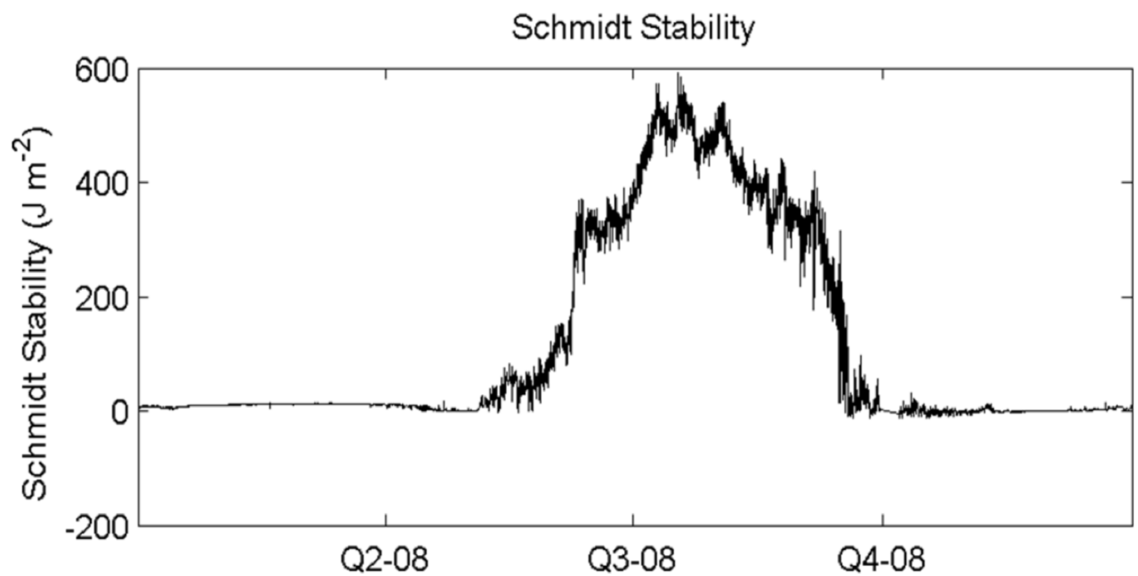
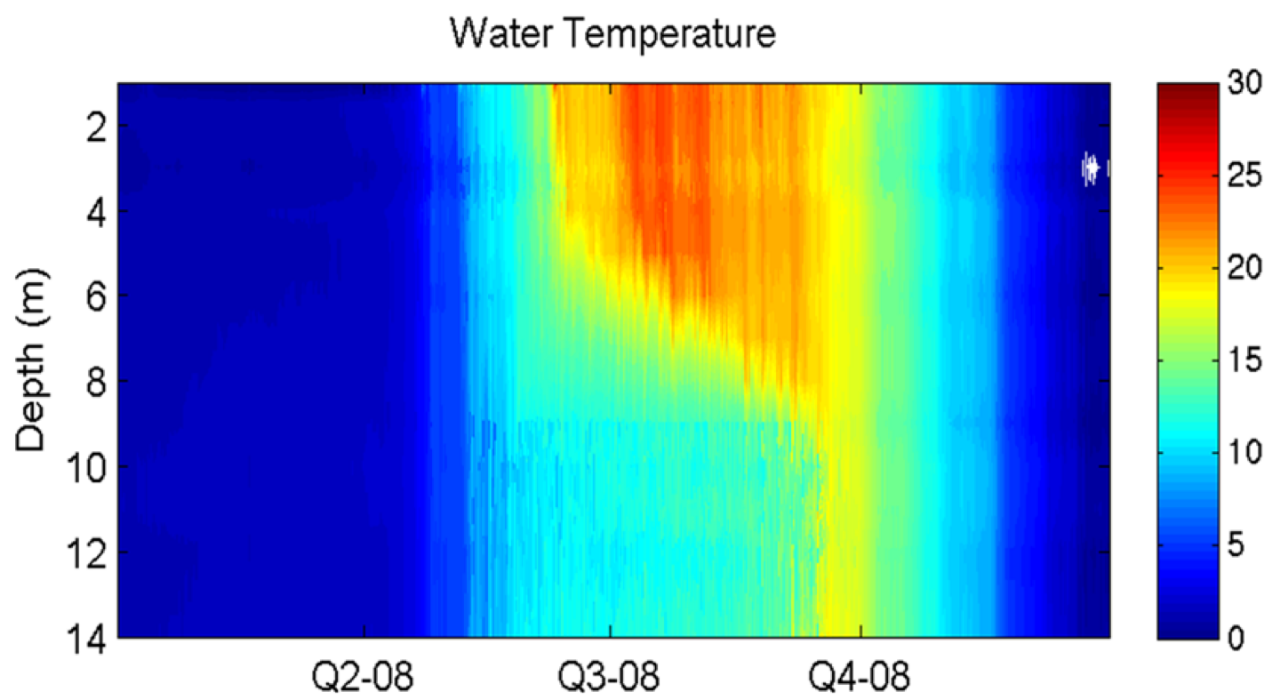
Comparison of Schmidt Stability to temperature profile heat map



What factors might explain variation in Schmidt Stability during summer stratification?



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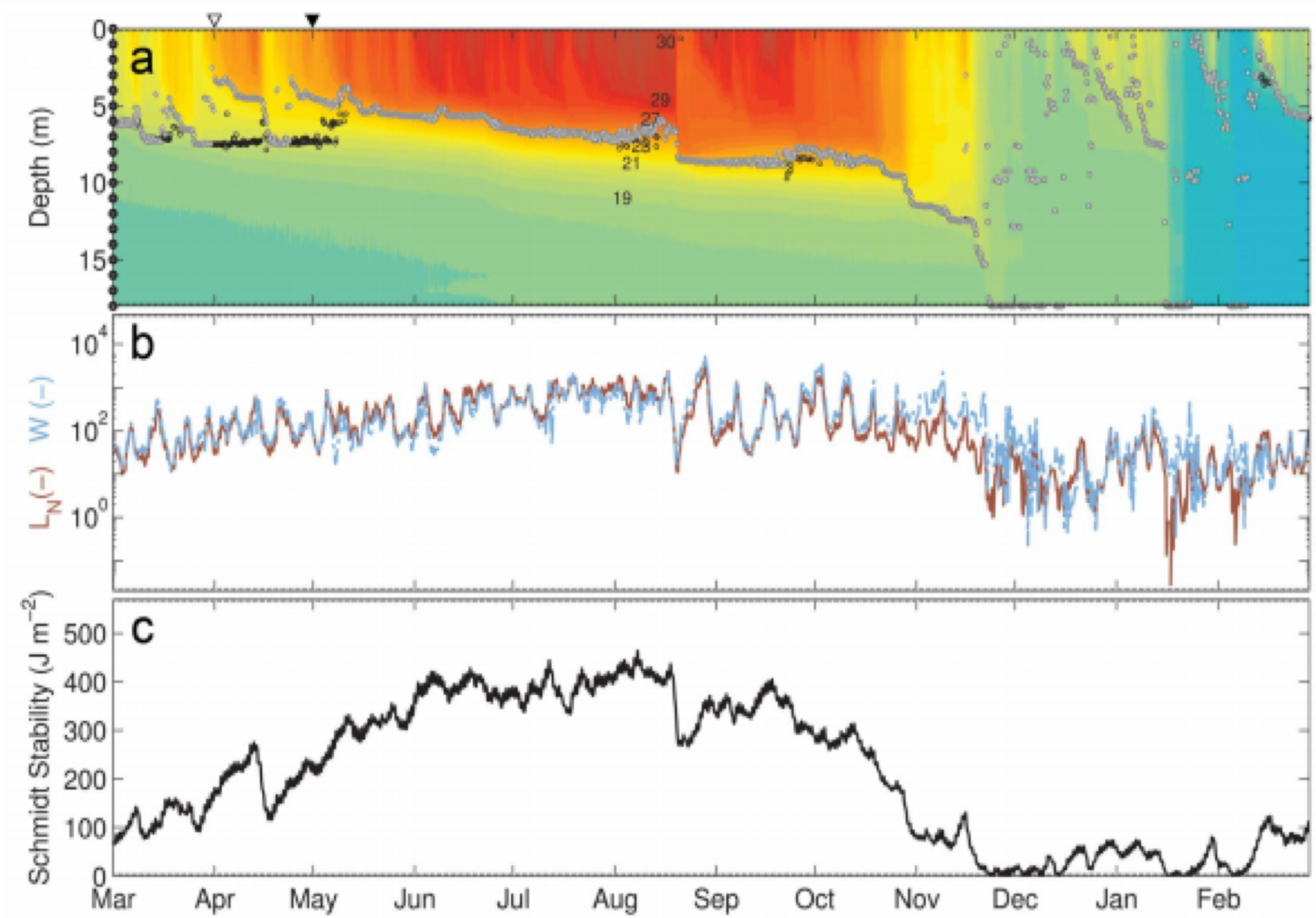
Case study 2 – Lake Mendota



Can you see the short-lived wind mixing event?

What about the upwelling event in January

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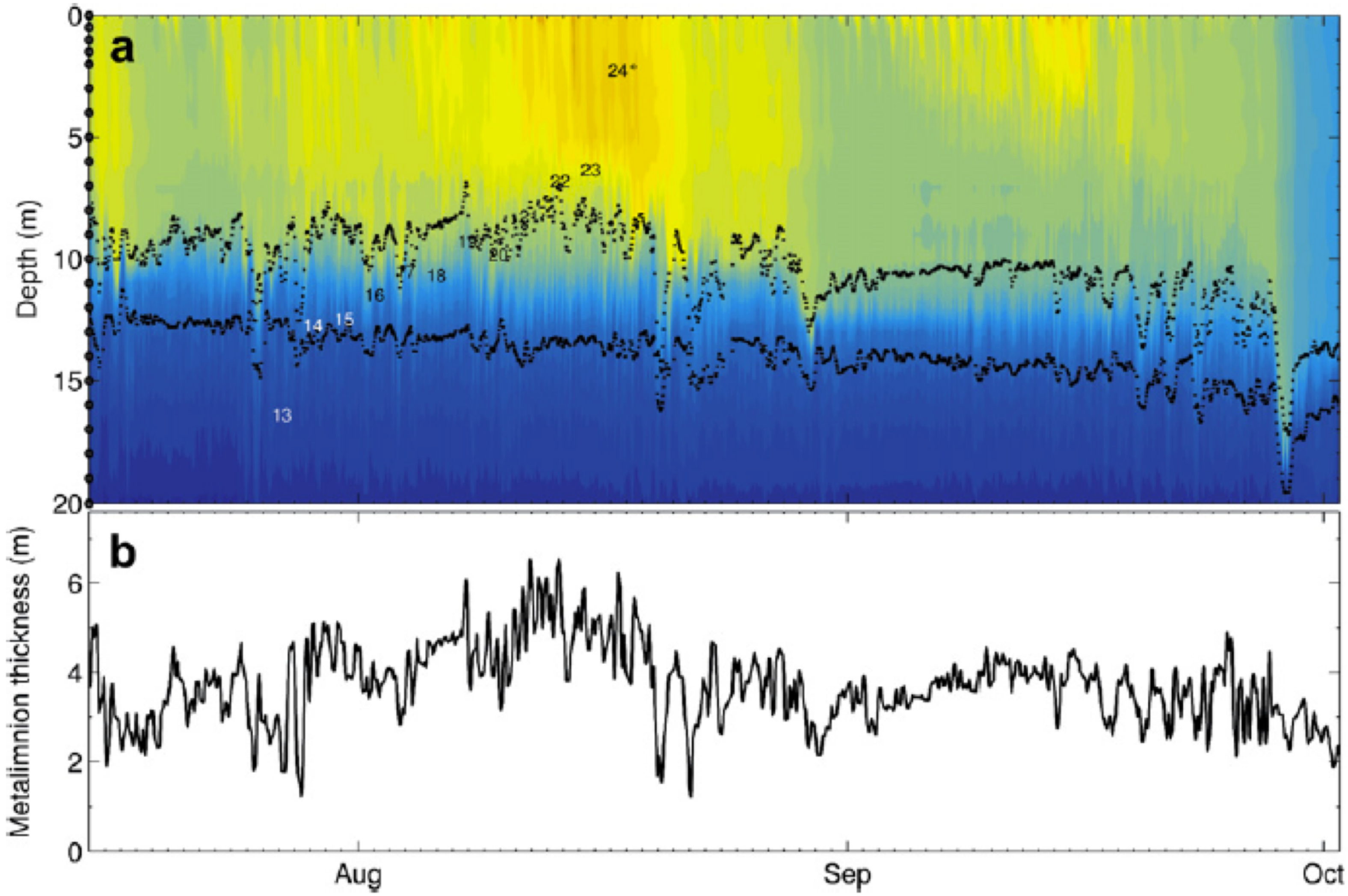
Case study 2 – Lake Mendota



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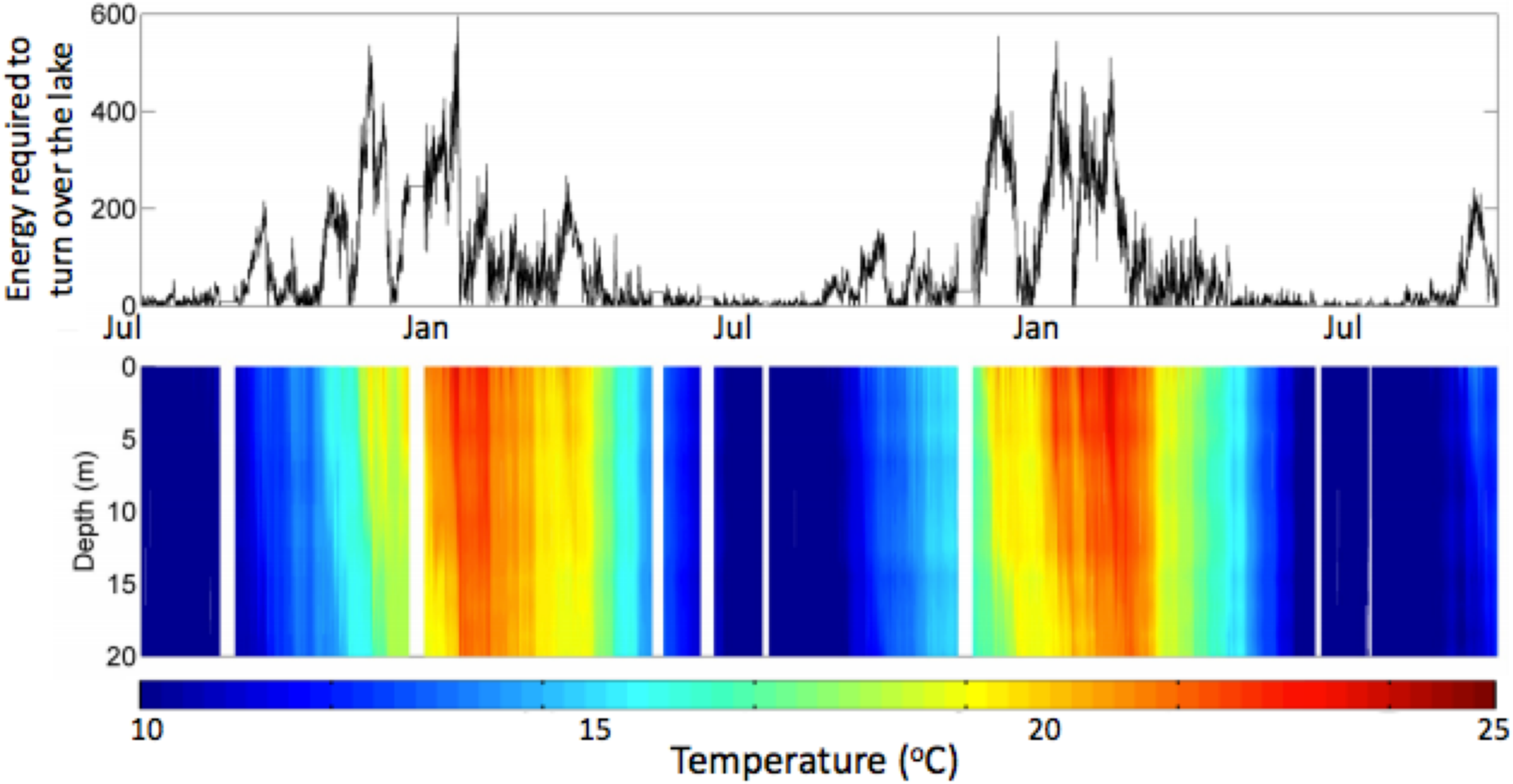
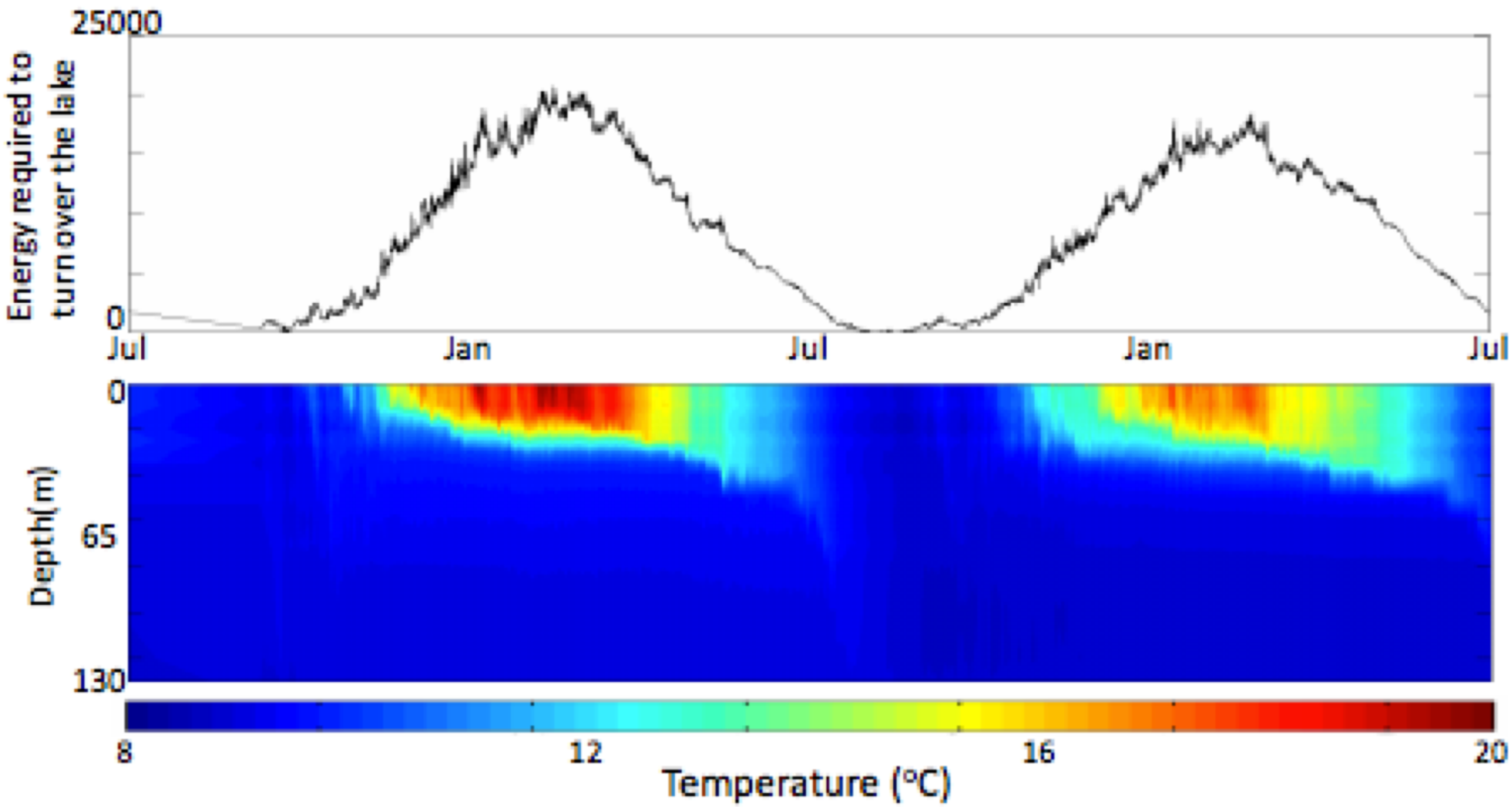
Case study 3 – Lake Rotorua



Multiple mixing events (as shown by the Schmidt stability)

Case study 4 – Lake Waikaremoana



Strong seasonal variation in stratification and stability in this deep lake

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Case study 5 - Model comparison

- One other extremely useful 'use' for Lake Analyzer is in validating numerical model outputs
- One can simulate the temperature profile of a lake using a model and then use Lake Analyzer to calculate different metrics such as thermocline depth, and then compare to observations
- This forms another set of validation compared to simple statistical metrics such as the Nash Sutcliffe Efficiency Index or R2 values

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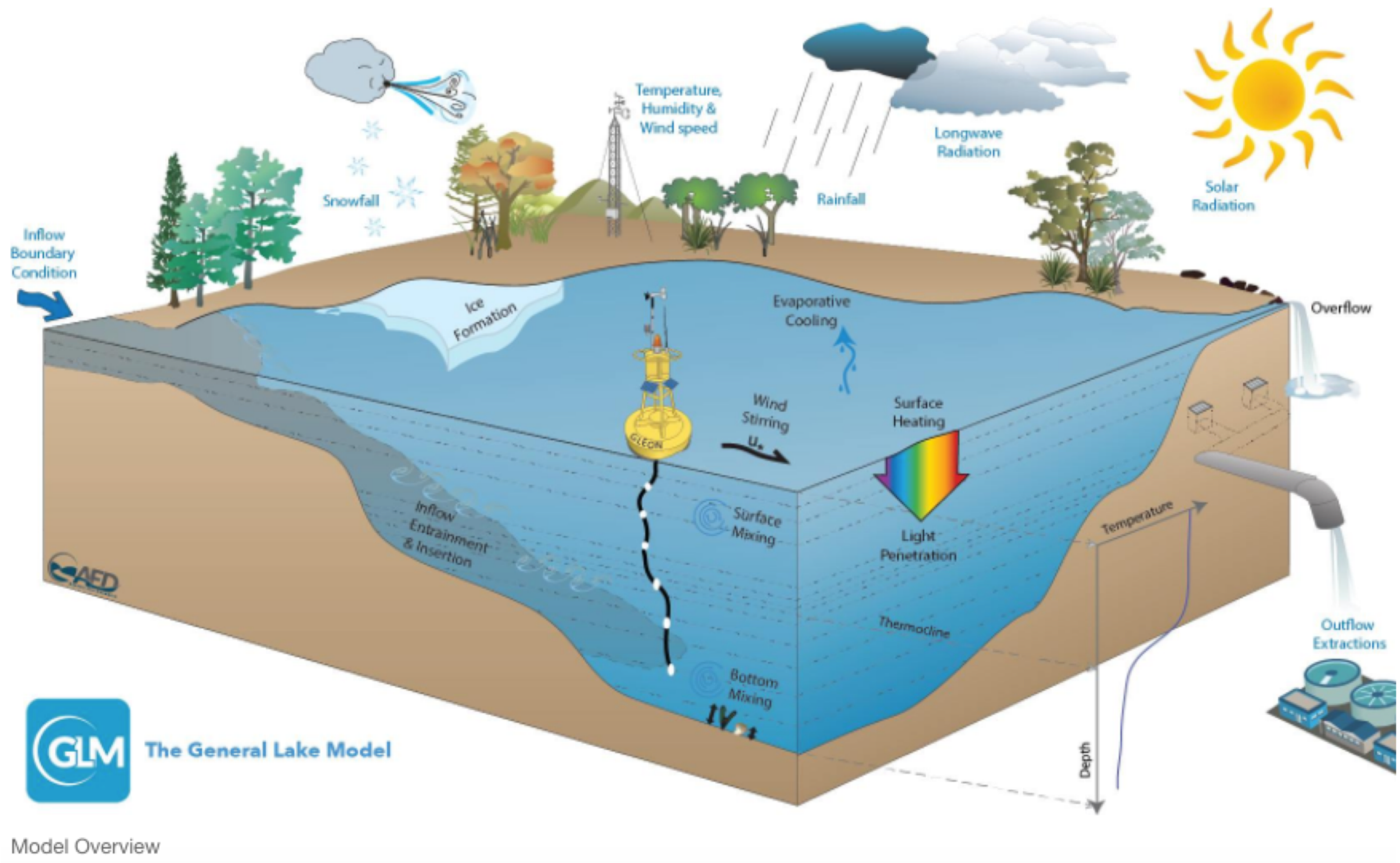
Case study 5 - Model comparison



http://aed.see.uwa.edu.au/research/models/GLM/overview.html

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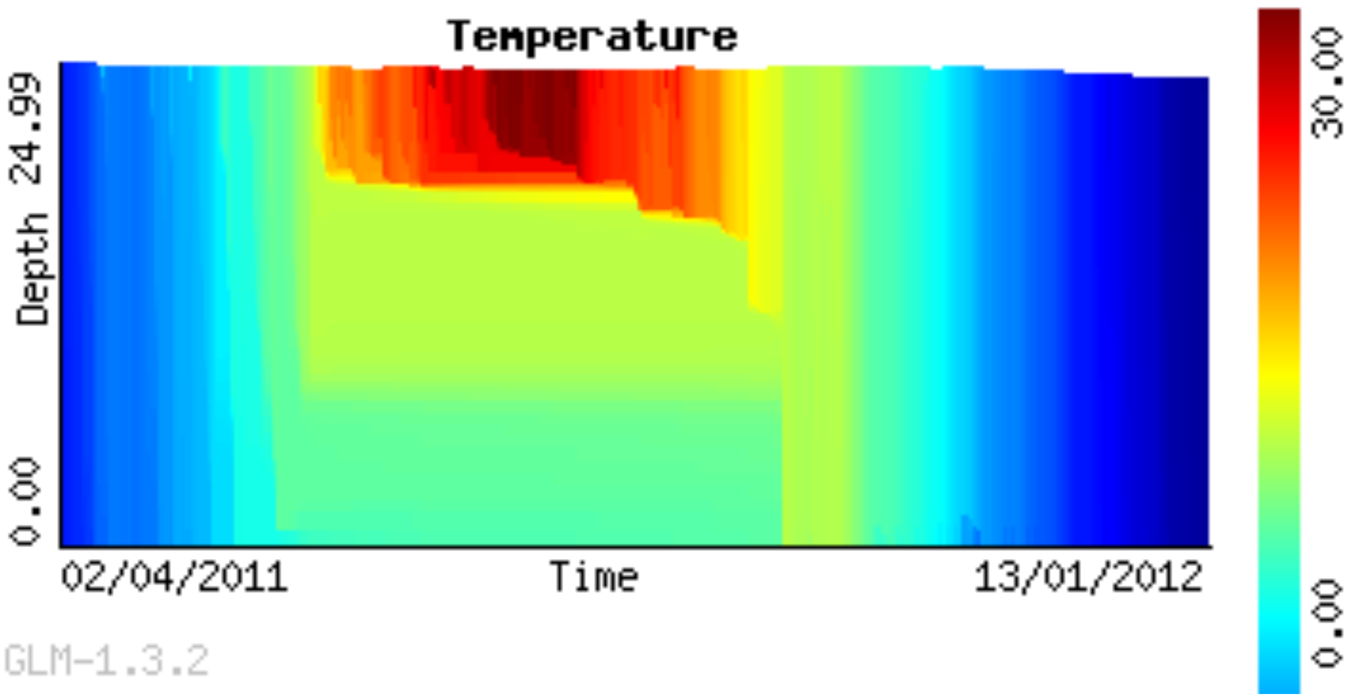
GLM: General Lake Model

- **Authors**: Matt Hipsey, Louise Bruce, and David Hamilton
- **Location**: http://aed.see.uwa.edu.au/research/models/GLM/
- **Overview**: The *General Lake Model* (GLM) is an open-access model developed for simulating lake dynamics. It simulates vertical stratification and mixing and accounts for the effect of inflows/outflows, surface heating and cooling.
- GLM has been designed to be an open-source community model developed in collaboration with members of the Global Lake Ecological Observatory Network (GLEON) to integrate with lake sensor data.

Case study 5 - Model comparison



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Available versions

- LakeAnalyzer is open-source software
- The program was developed for Matlab and R environments and there is also an easy-to-use web version
  - **Matlab**: The original version (Read et al., 2011)
  - **Web**: An online version not requiring any installation
  - **R package**: A version for R program users (Winslow et al., 2017) – a product of the GLEON fellowship program

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Program Location

http://lakeanalyzer.gleon.org/

lake analyzer web

This is the web front end to Lake Analzyer, a tool that allows users to calculate common metrics for lake physical states.

Code and Other versions

Lake Analyzer is available in both Matlab and R versions.
Matlab code on GitHub.
R version available through CRAN. Code on GitHub.

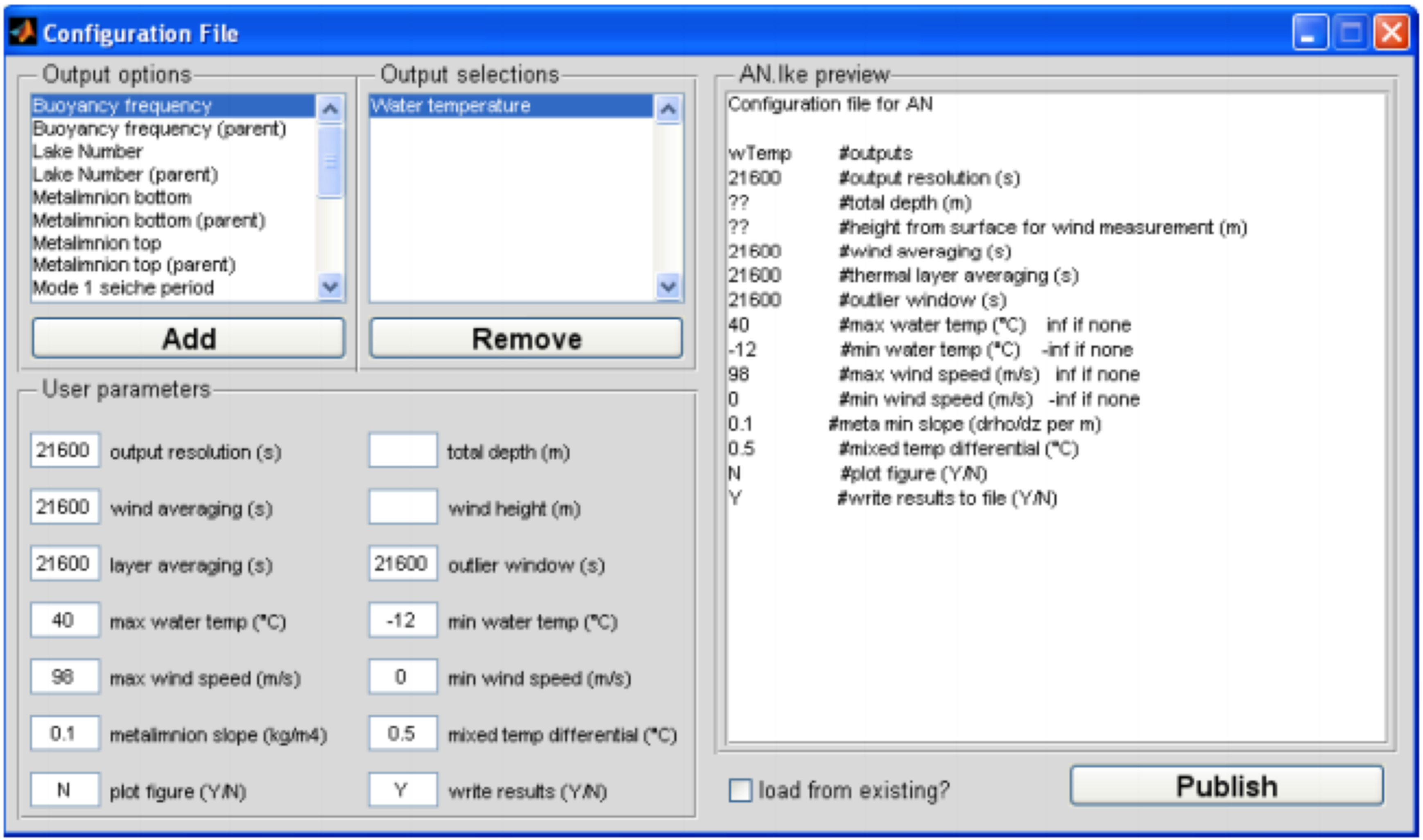
If used, please cite

Read JS, DP Hamilton, ID Jones, K Muraoka, LA Winslow, R Kroiss, CH Wu, E Gaiser. 2011. Derivation of lake mixing and stratification indices from high-resolution lake buoy data. Environmental Modelling and Software. 26: 1325-1336.

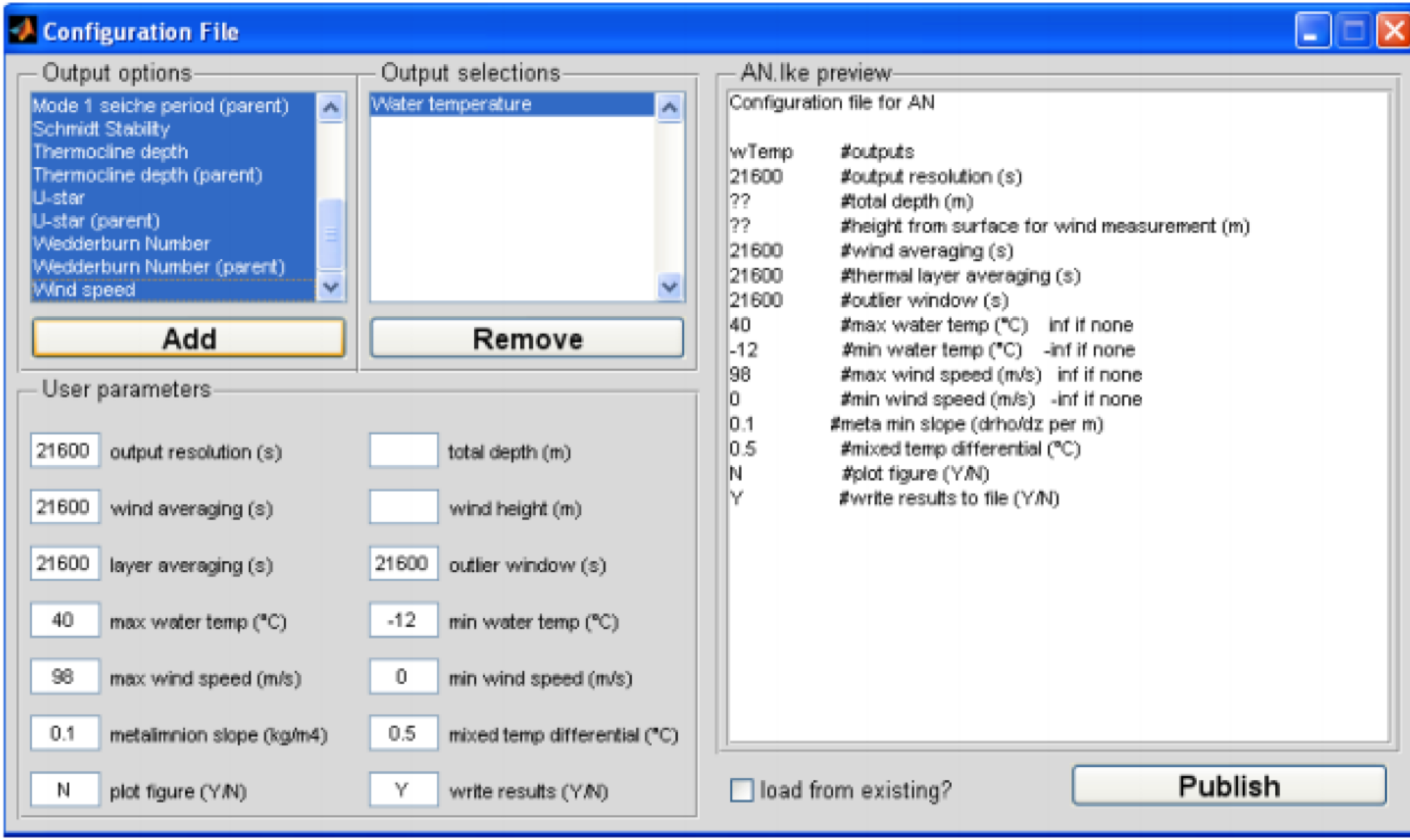
Documentation

Additional information can be found in the LakeAnalyzer Manual.

Matlab version



Matlab version



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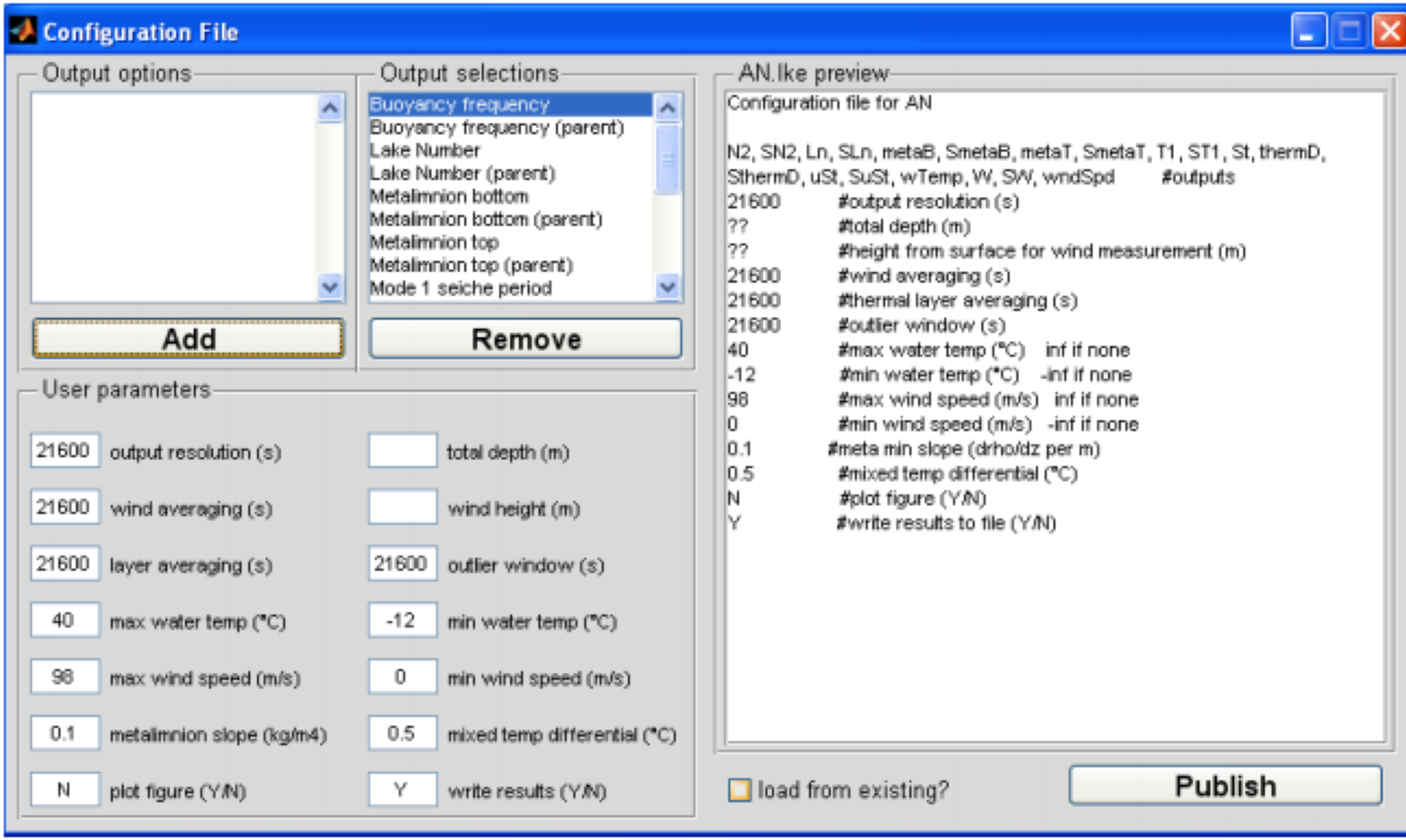
Matlab version



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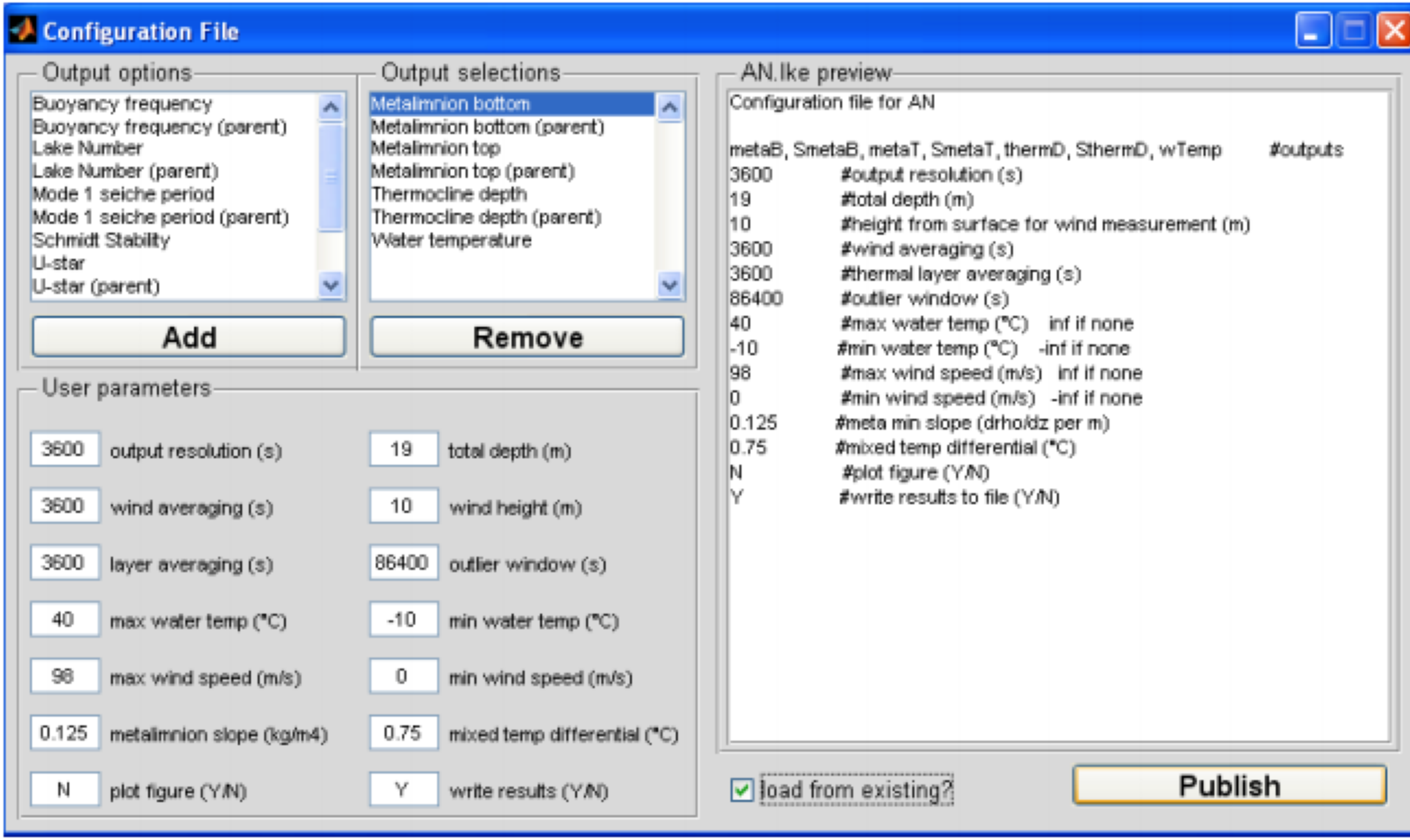
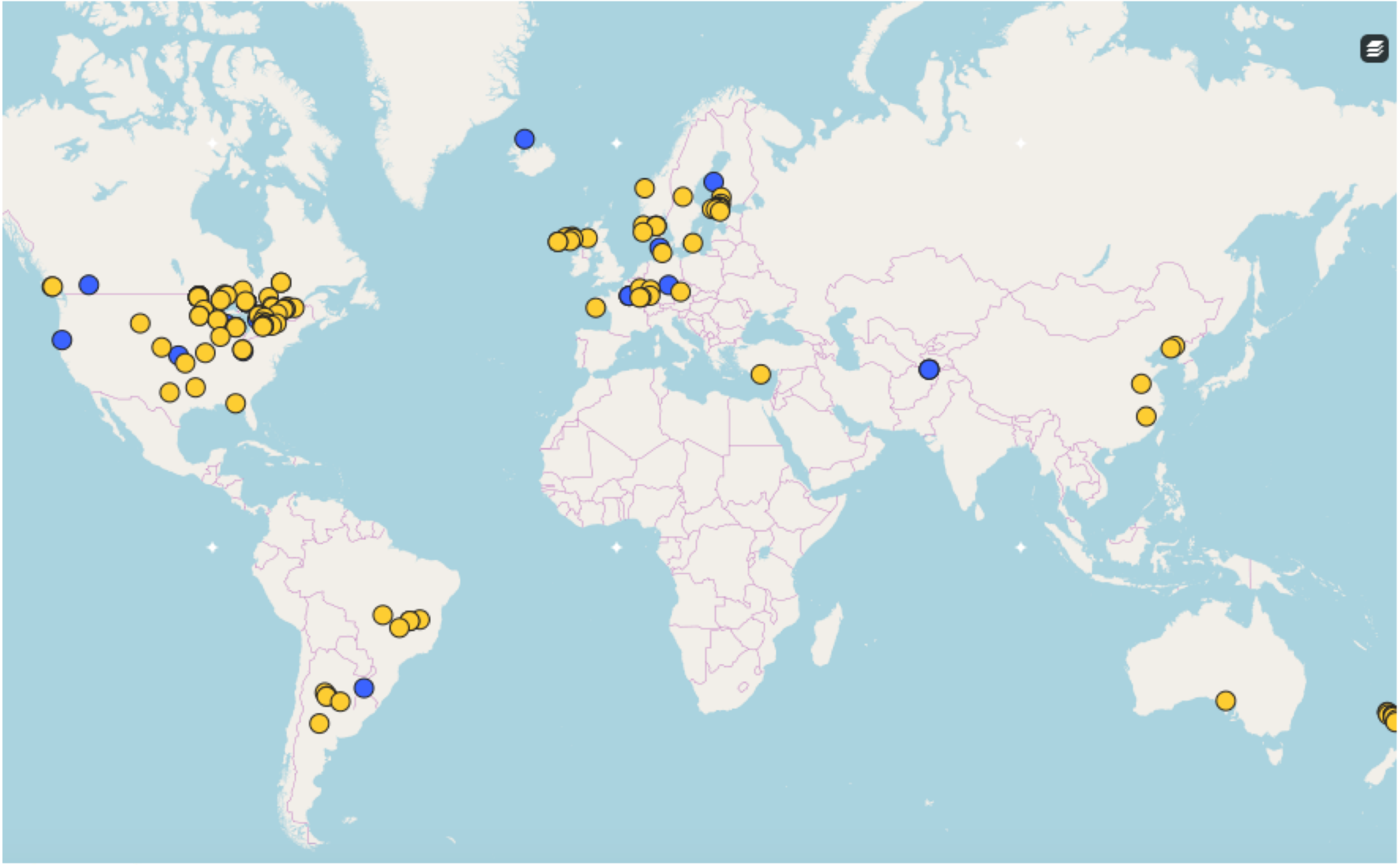
Matlab version



Benefits of these tools



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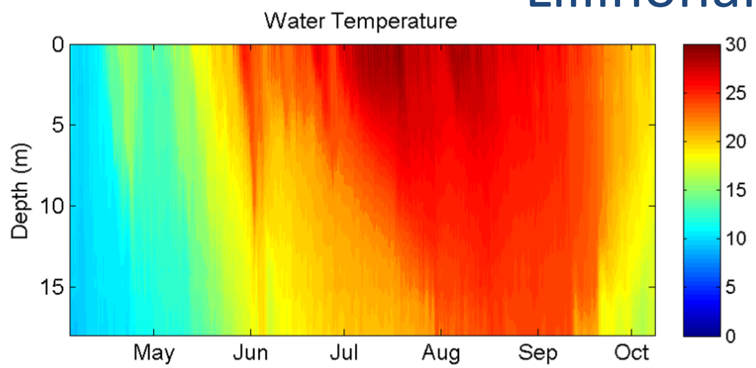

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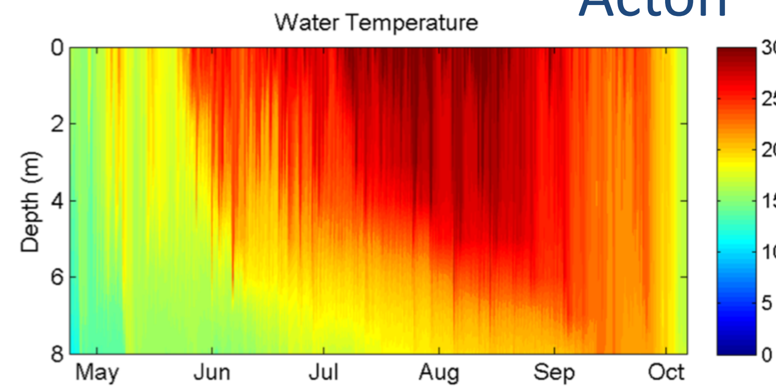

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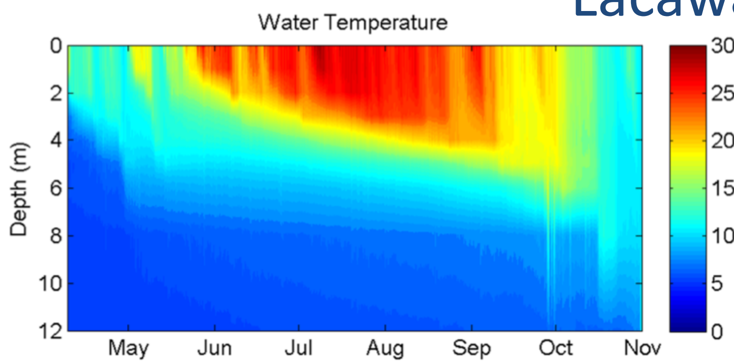
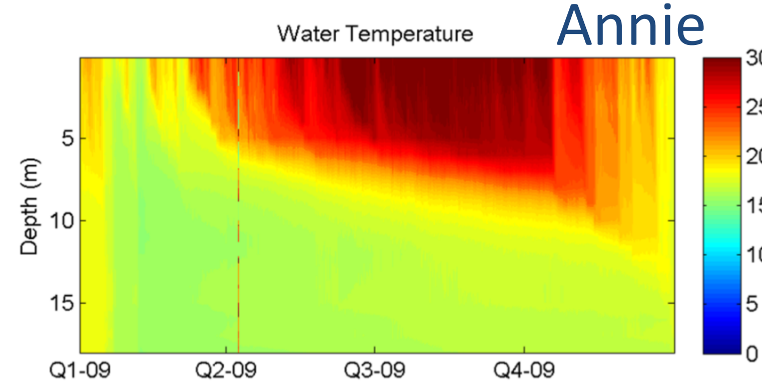


Annie



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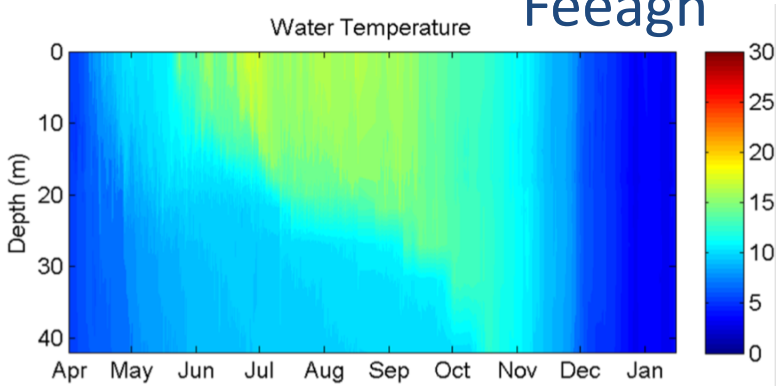

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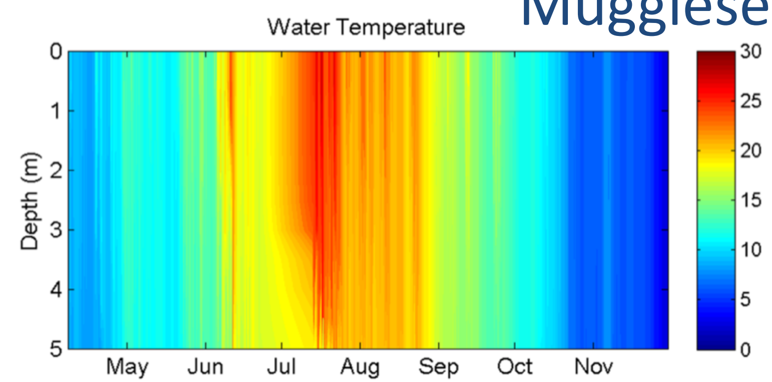
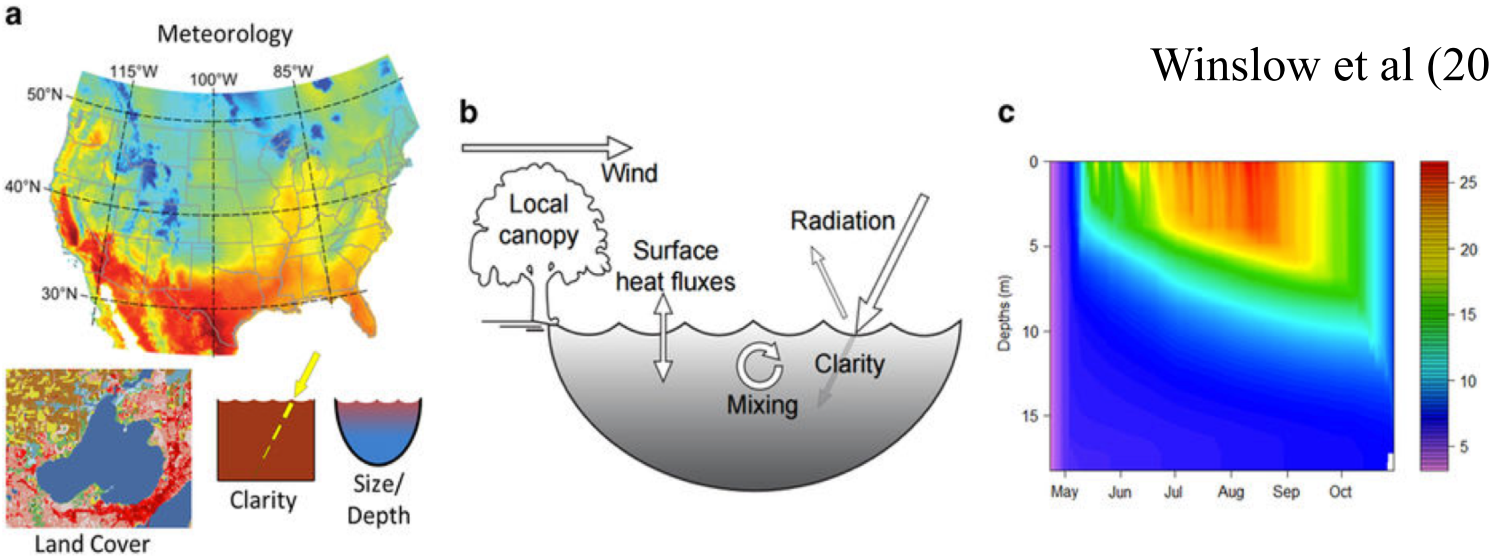


Benefits of these tools



Winslow et al (2017)

- They provide the ability to analyse and interpret data sets of tens of thousands of observations, including the ability to quickly visualize changes in a lake's water column and thermal stability through time.
- The benefits of this is that you can use exactly the same method to calculate the fluxes for many lakes
- Some examples…

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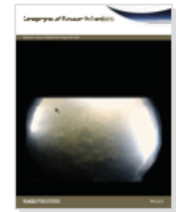

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Volume 39, Issue 9
May 2012

Hydrology and Land Surface Studies

Lake-size dependency of wind shear and convection as controls on gas exchange

Jordan S. Read, David P. Hamilton, Ankur R. Desai, Kevin C. Rose, Sally MacIntyre, John D. Lenters, Robyn L. Smyth, Paul C. Hanson, Jonathan J. Cole, Peter A. Staehr, James A. Rusak, Donald C. Pierson, Justin D. Brookes, Alo Laas, Chin H. Wu

First published: 10 May 2012 Full publication history

DOI: 10.1029/2012GL051886 View/save citation

Abstract

[1] High-frequency physical observations from 40 temperate lakes were used to examine the relative contributions of wind shear (u_*) and convection (w_*) to turbulence in the surface mixed layer. Seasonal patterns of u_* and w_* were dissimilar; u_* was often highest in the spring, while w_*increased throughout the summer to a maximum in early fall. Convection was a larger mixed-layer turbulence source than wind shear ($u_*/w_* < 0.75$) for 18 of the 40 lakes, including all 11 lakes <10 ha. As a consequence, the relative contribution of convection to the gas transfer velocity (k, estimated by the surface renewal model) was greater for small lakes. The average k was 0.54 m day^{-1} for lakes <10 ha. Because u_* and w_*differ in temporal pattern and magnitude across lakes, both convection and wind shear should be considered in future formulations of lake-air gas exchange, especially for small lakes.

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Research Letter

Latitude and lake size are important predictors of over-lake atmospheric stability

R. Iestyn Woolway, Piet Verburg, Christopher J. Merchant, John D. Lenters, David P. Hamilton, Justin Brookes, Sean Kelly, Simon Hook, Alo Laas, Don Pierson, Alon Rimmer, James A. Rusak, Ian D. Jones

First published: 5 September 2017 Full publication history

DOI: 10.1002/2017GL073941 View/save citation

Funding Information

Abstract

Turbulent fluxes across the air-water interface are integral to determining lake heat budgets, evaporation, and carbon emissions from lakes. The stability of the atmospheric boundary layer (ABL) influences the exchange of turbulent energy. We explore the differences in over-lake ABL stability using data from 39 globally distributed lakes. The frequency of unstable ABL conditions varied between lakes from 71 to 100% of the time, with average air temperatures typically several degrees below the average lake surface temperature. This difference increased with decreasing latitude, resulting in a more frequently unstable ABL and a more efficient energy transfer to and from the atmosphere, toward the tropics. In addition, during summer the frequency of unstable ABL conditions decreased with increasing lake surface area. The dependency of ABL stability on latitude and lake size has implications for heat loss and carbon fluxes from lakes, the hydrologic cycle, and climate change effects.

Future questions

- There is still a lot of global comparisons to be made
- Comparisons of lake mixing and stratification, different heat flux components (e.g., evaporation)
- What are the magnitude, frequency and duration of mixing (or stratification) events across lakes globally?
- How do evaporation rates vary among lakes globally?
- How does the transfer of heat/energy from the atmosphere to a lake vary among sites?
- And many more…