Global records of lake surface temperature reveal a century of warming

John D. Lenters, Ph.D.
Senior Scientist, LimnoTech

Jordan S. Read, Sapna Sharma, Catherine M. O'Reilly, Stephanie Hampton, Derek Gray, Peter B. McIntyre, Simon J. Hook, Philipp Schneider, Piet Verburg, Peter D. Blanken, and GLTC Contributors

University of Colorado Boulder

GLTC
Global Lake Temperature Collaboration

GLTC Contributors

Sapna Sharma, Derek K. Gray, Jordan S. Read, Catherine M. O'Reilly, Philipp Schneider, Anam Qudrat, Corinna Gries, Samantha Stefanoff, Stephanie E. Hampton, Simon Hook, John D. Lenters, David M. Livingstone, Peter B. McIntyre, Rita Adrian, Mathew G. Allan, Orlane Anneville, Lauri Arvola, Jay Austin, John Bailey, Jill S. Baron, Justin Brookes, Yuwei Chen, Robert Daly, Martin Dokulil, Bo Dong, Kye Ewing, Elvira de Eyto, David Hamilton, Karl Havens, Shane Haydon, Harald Hetzenauer, Jocelyne Heneberry, Amy L. Hetherington, Scott N. Higgins, Eric Hixson, Lyubov R. Izmest'eva, Benjamin M. Jones, Küllli Kangur, Peter Kasprzak, Olivier Köster, Benjamin M. Kraemer, Michio Kumagai, Esko Kuusisto, George Leshkevich, Linda May, Sally MacIntyre, Dörthe Müller-Navarra, Mikhail Naumenko, Peeter Noges, Tiina Noges, Pius Niederhauser, Ryan P. North, Andrew Paterson, Pierre-Denis Plisnier, Anna Rigosi, Alon Rimmer, Michela Rogora, Lars Rudstam, James A. Rusak, Nico Salmaso, Nihar R. Samal, Daniel E. Schindler, Geoffrey Schladow, Silke R. Schmidt, Tracey Schultz, Eugene A. Silow, Dietmar Straile, Katrin Teubner, Piet Verburg, Ari Voutilainen, Andrew Watkinson, Gesa A. Weyhenmeyer, Craig E. Williamson, Kara H. Woo, Catherine M. O'Reilly, Sapna Sharma, Derek K. Gray, Stephanie E. Hampton, Jordan S. Read, Rex J. Rowley, Philipp Schneider, John D. Lenters, Peter B. McIntyre, Benjamin M. Kraemer, Gesa A. Weyhenmeyer, Dietmar Straile, Bo Dong, Rita Adrian, Mathew G. Allan, Orlane Anneville, Lauri Arvola, Jay Austin, John L. Bailey, Jill S. Baron, Justin D. Brookes, Elvira de Eyto, Martin T. Dokulil, David P. Hamilton, Karl Havens, Amy L. Hetherington, Scott N. Higgins, Simon Hook, Lyubov R. Izmest'eva, Klaus D. Jöhnk, Külli Kangur, Peter Kasprzak, Michio Kumagai, Esko Kuusisto, George Leshkevich, David M. Livingstone, Sally MacIntyre, Linda May, John M. Melack, Dörthe C. Müller-Navarra, Mikhail Naumenko, Peeter Nõges, Tiina Nõges, Ryan P. North, Pierre-Denis Plisnier, Anna Rigosi, Alon Rimmer, Michela Rogora, Lars G. Rudstam, James A. Rusak, Nico Salmaso, Nihar R. Samal, Daniel E. Schindler, S. Geoffrey Schladow, Martin Schmid, Silke R. Schmidt, Eugene Silow, M. Evren Soylu, Katrin Teubner, Piet Verburg, Ari Voutilainen, Andrew Watkinson, Craig E. Williamson, Guoqing Zhang, John D. Lenters, David M. Livingstone, Catherine M. O'Reilly, Martin T. Dokulil, Gesa A. Weyhenmeyer, Philipp Schneider, Sapna Sharma, Elvira de Eyto, Rita Adrian, Scott N. Higgins, Pierre-Denis Plisnier, Nico Salmaso, Dietmar Straille, Bo Dong, Piet Verburg, George Leshkevich, Peter B. McIntyre, Jordan S. Read, Silke Schmidt, Peeter Nõges, Tiina Nõges, Benjamin M. Kraemer, Mathew Allan, Martin Schmid, Geoffrey Schladow, Sally MacIntyre, David Hamilton, Alon Rimmer, Orlane Anneville, Stephanie E. Hampton, Claude Duguay, Amy L. Hetherington, Dendy D. Lofton, James A. Rusak, Nihar R. Samal, Noemi Barabas, Justin Brookes, Robert C. Wilson, Derek K. Gray, Simon Hook, Mehmet E. Soylu

Acknowledgements

- We would like to thank the **numerous scientists and institutions** that contributed data and expertise to the GLTC project (http://laketemperature.org/).
- Special thanks to the GLTC data analysis sub-group: Derek Gray, Stephanie Hampton, Peter McIntyre, Catherine O'Reilly, Jordan Read, Sapna Sharma, Noemi Barabas, Dendy Lofton, R. J. Rowley, Evren Soylu, and Piet Verburg
- We gratefully acknowledge NSF, NASA, and the University of Nebraska-Lincoln for funding the GLTC workshop, as well as other institutions for their support.

LimnoTech Water Environment | Scientists Engineers

NSF

NASA

University of Nebraska Lincoln

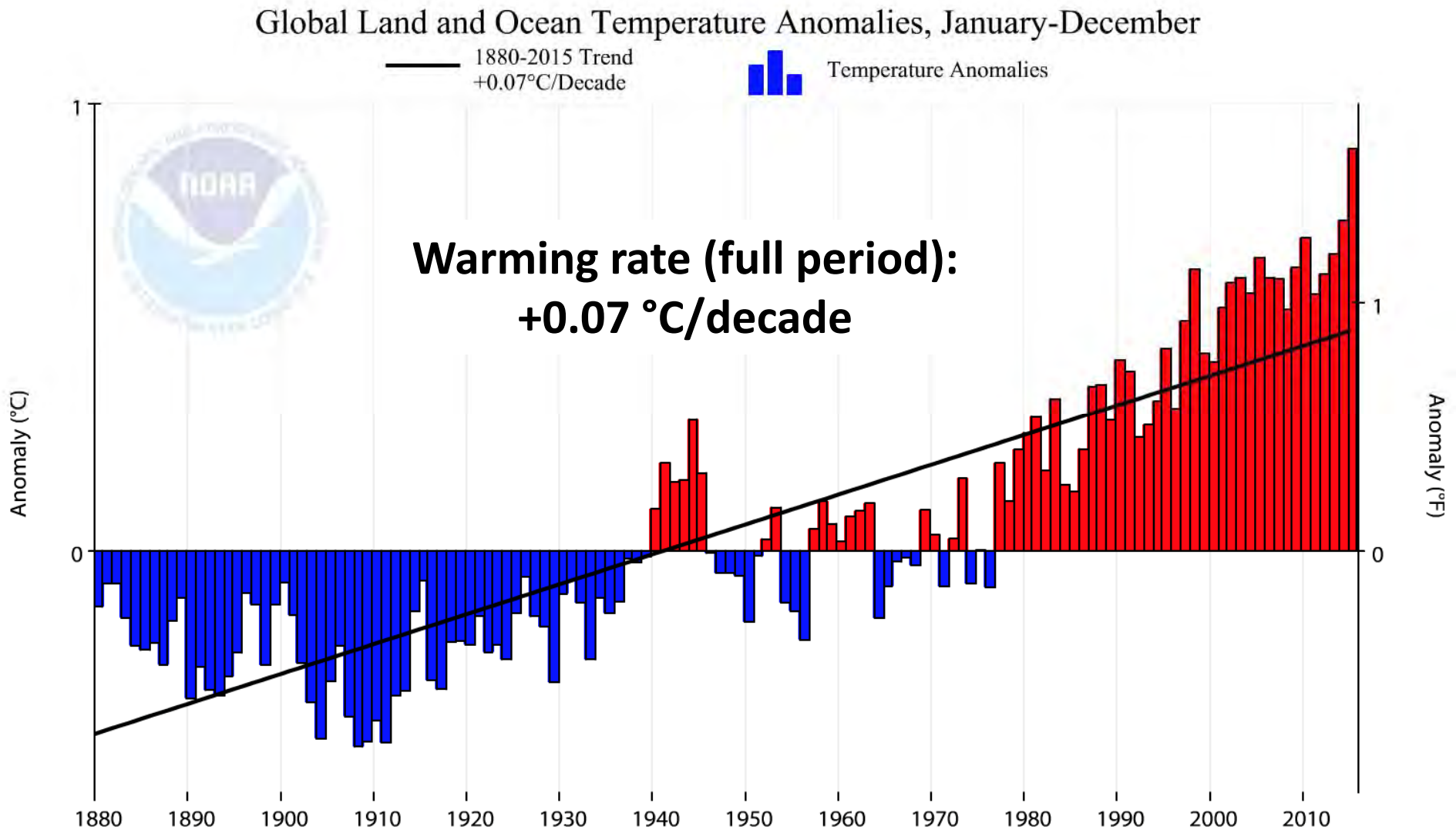
Talk outline

- Background and motivation
- Lake Superior: Big lake, big changes
- The “puzzle” of rapid lake warming
- Toward a solution: A new, global initiative
- Implications for evaporation, water levels
- Summary

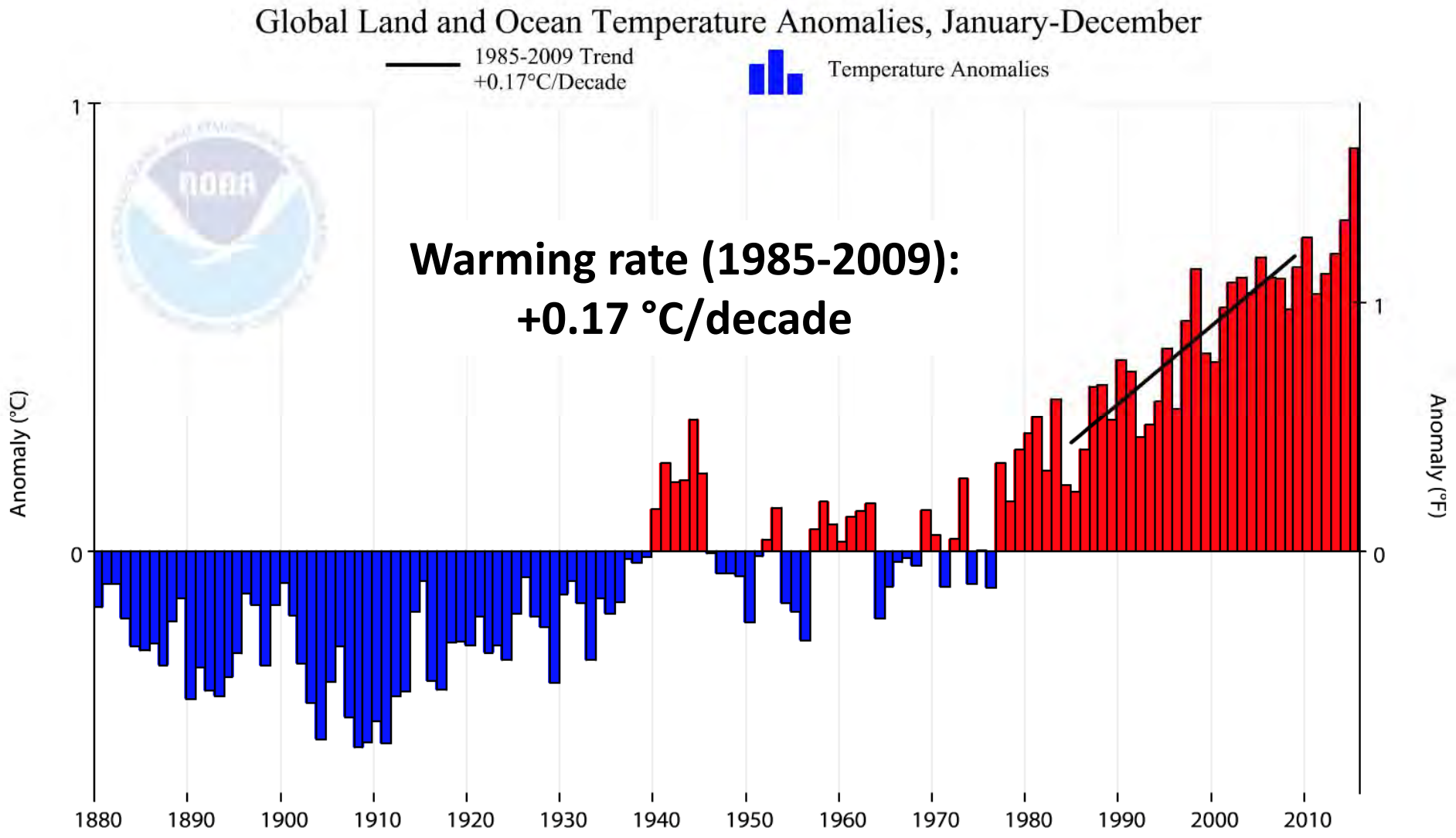
There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.

THANK YOU

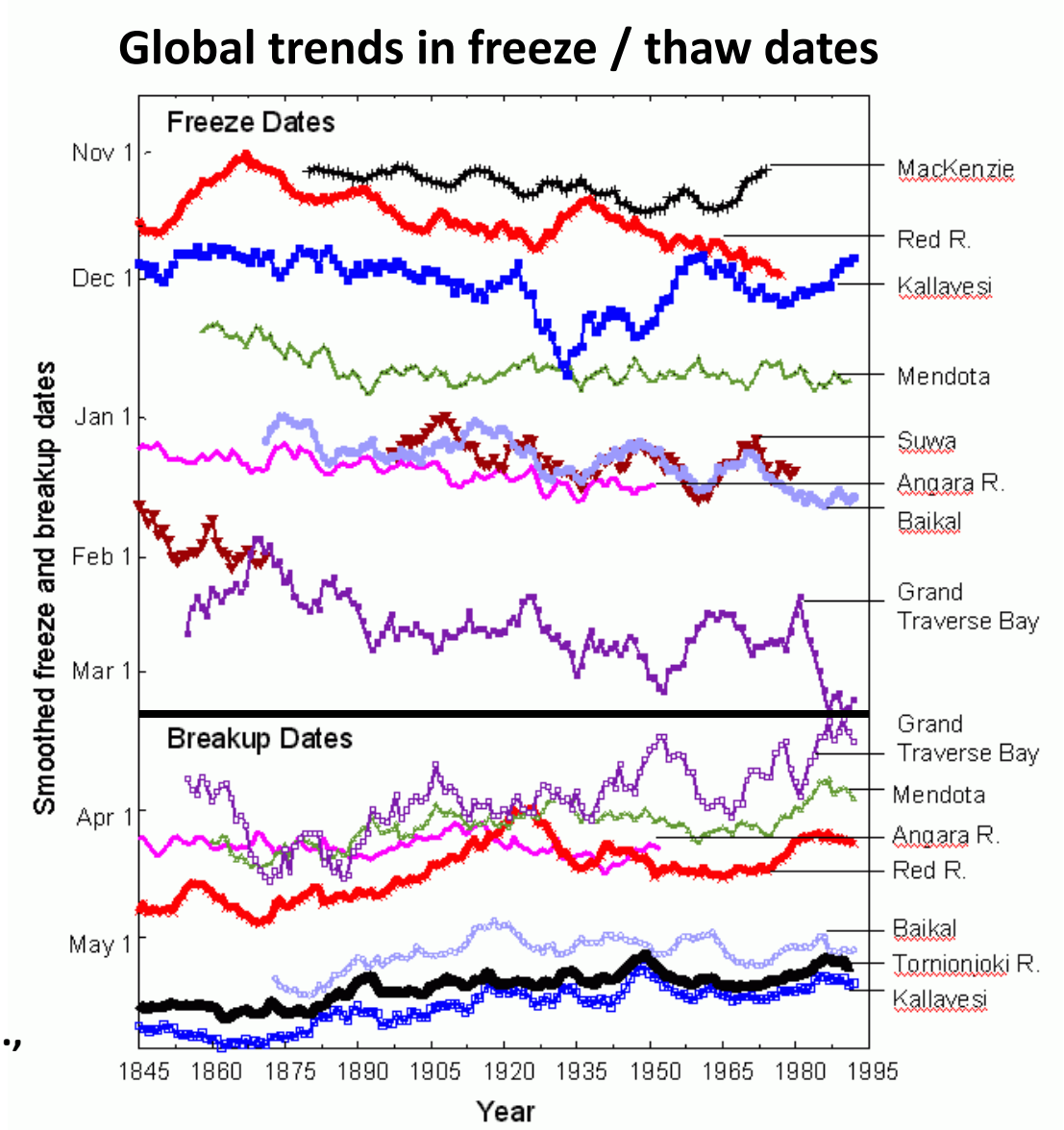
A known known: Our climate is changing



A known known: Our climate is changing

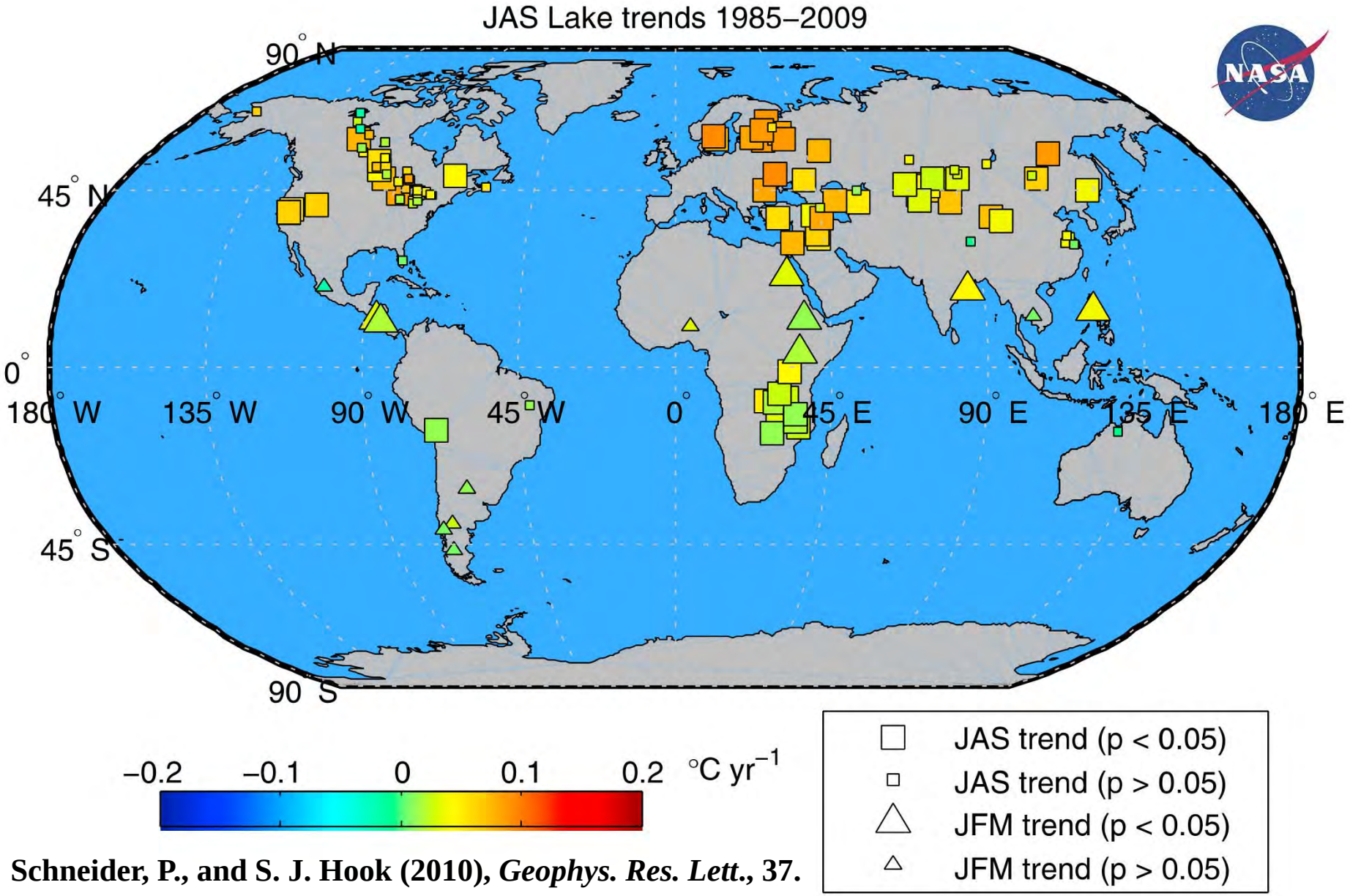


A known known: Lakes are losing ice



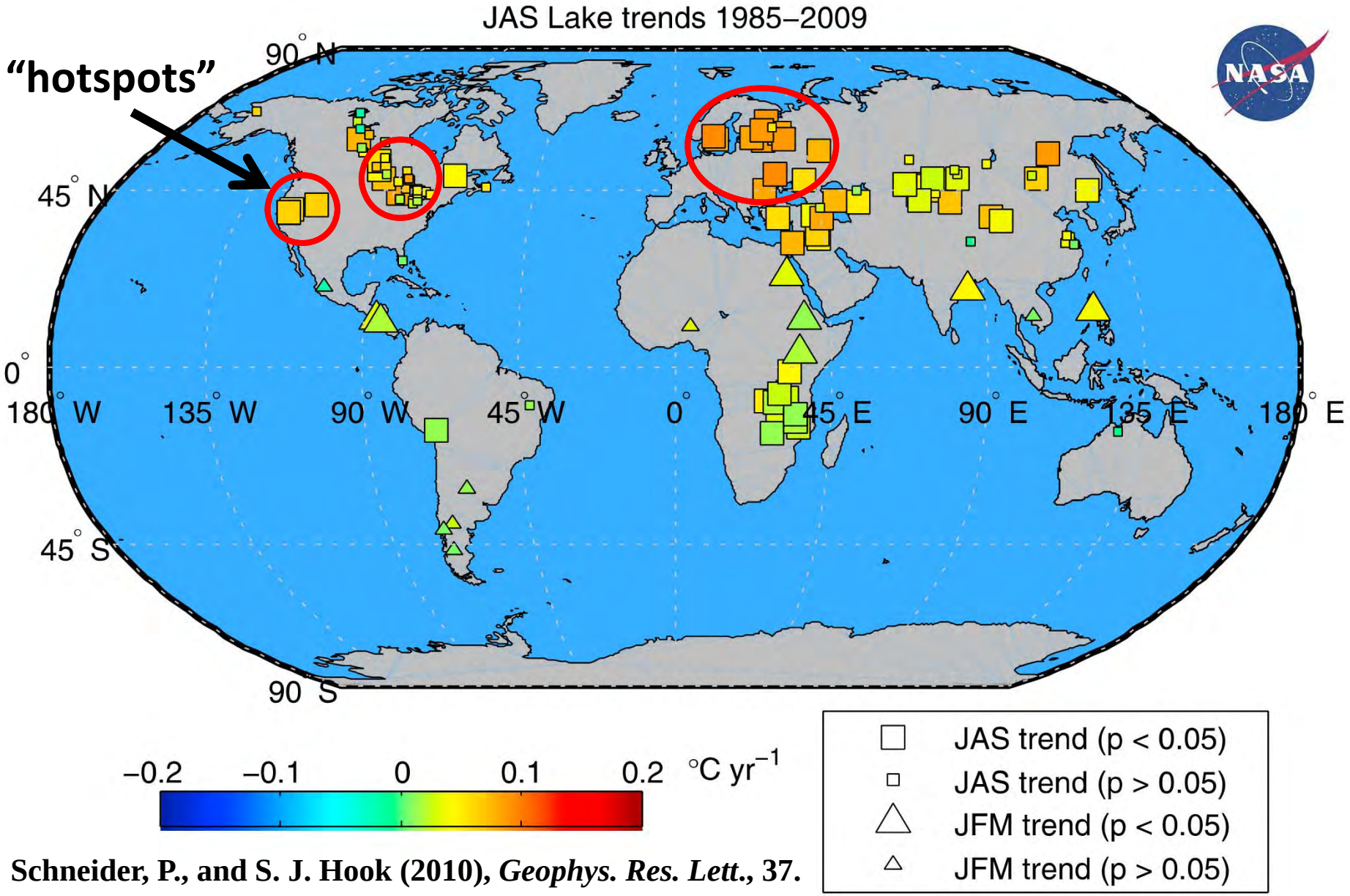
(Magnuson et al., 2000; *Science*)

A known known: Lakes are warming



Schneider, P., and S. J. Hook (2010), *Geophys. Res. Lett.*, 37.

A known known: Lakes are warming



Schneider, P., and S. J. Hook (2010), *Geophys. Res. Lett.*, 37.

Other impacts are becoming evident

- **Changes in lake evaporation, which also affects …**
  - Water balance
  - Temperature
  - Stratification
  - Lake chemistry
  - Vertical mixing
  - Lake ecology

Other impacts are becoming evident

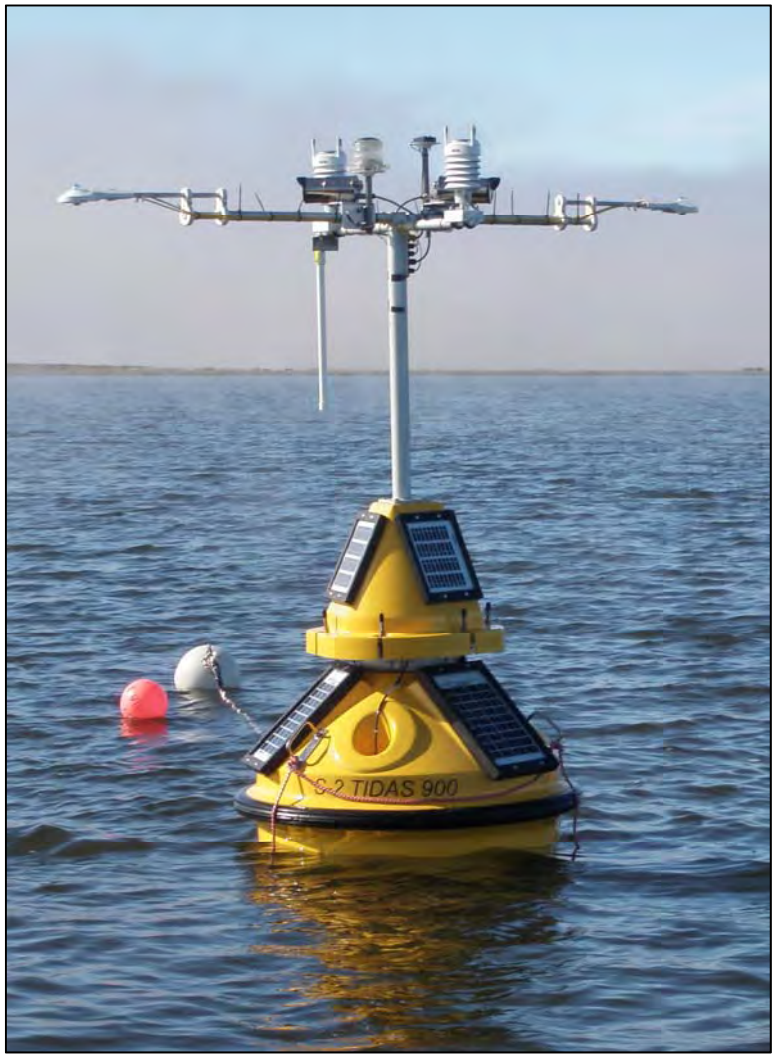
- **Variations in lake level, which also affects …**

  - Water quality / municipal water supplies
  - Recreational boating / fishing
  - Shoreline erosion / flooding
  - Commercial shipping
  - Lake ecology
  - Hydropower
  - Tourism

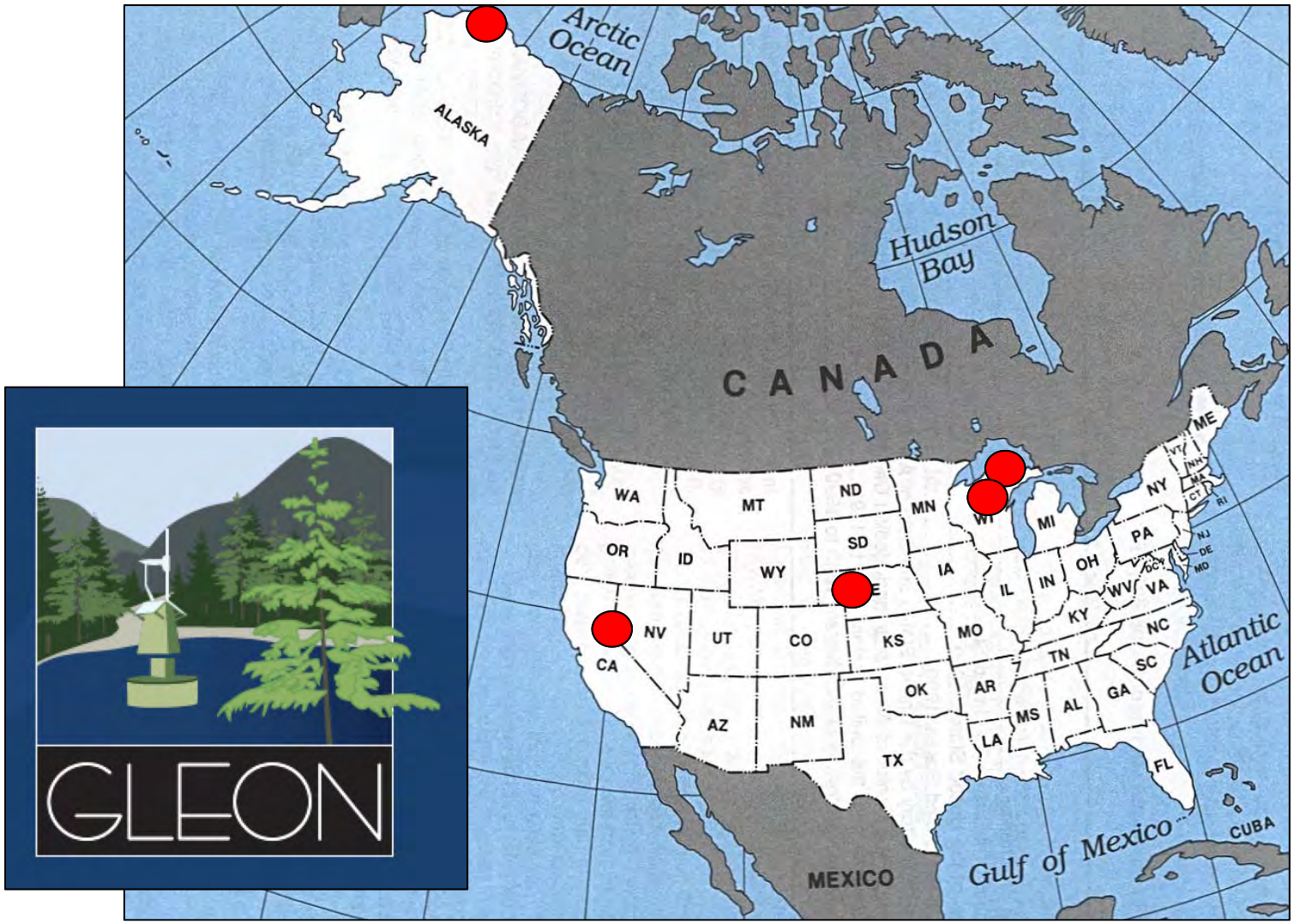
How do we know?

- **Measurements**
  - Field data
  - Satellite data
  - Long-term monitoring programs

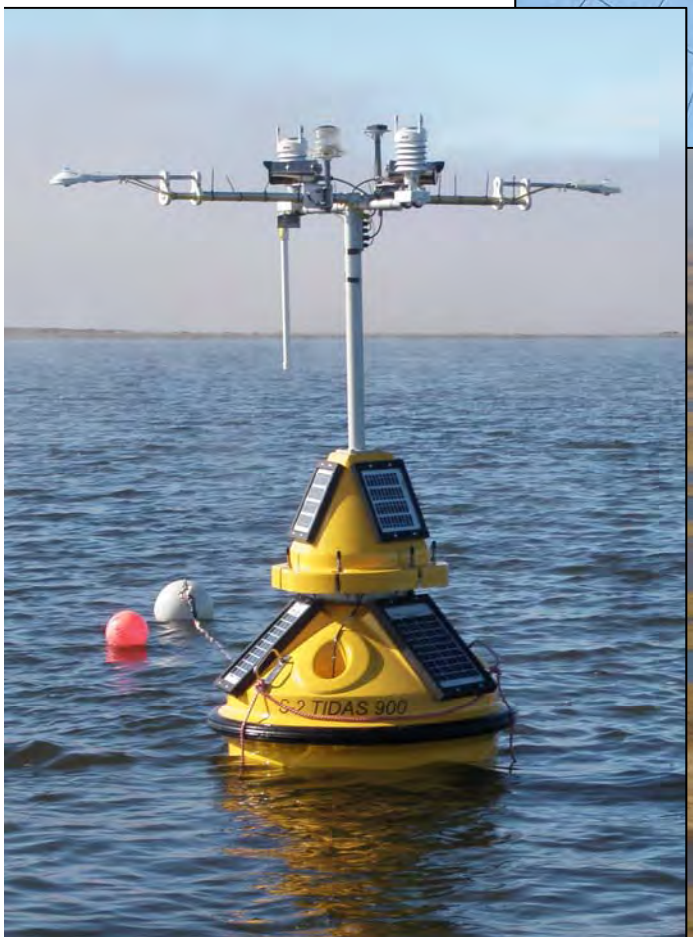
- **Models**
  - Physical, hydrological, biological
  - Climate models
  - Lake models



Examples of field sites

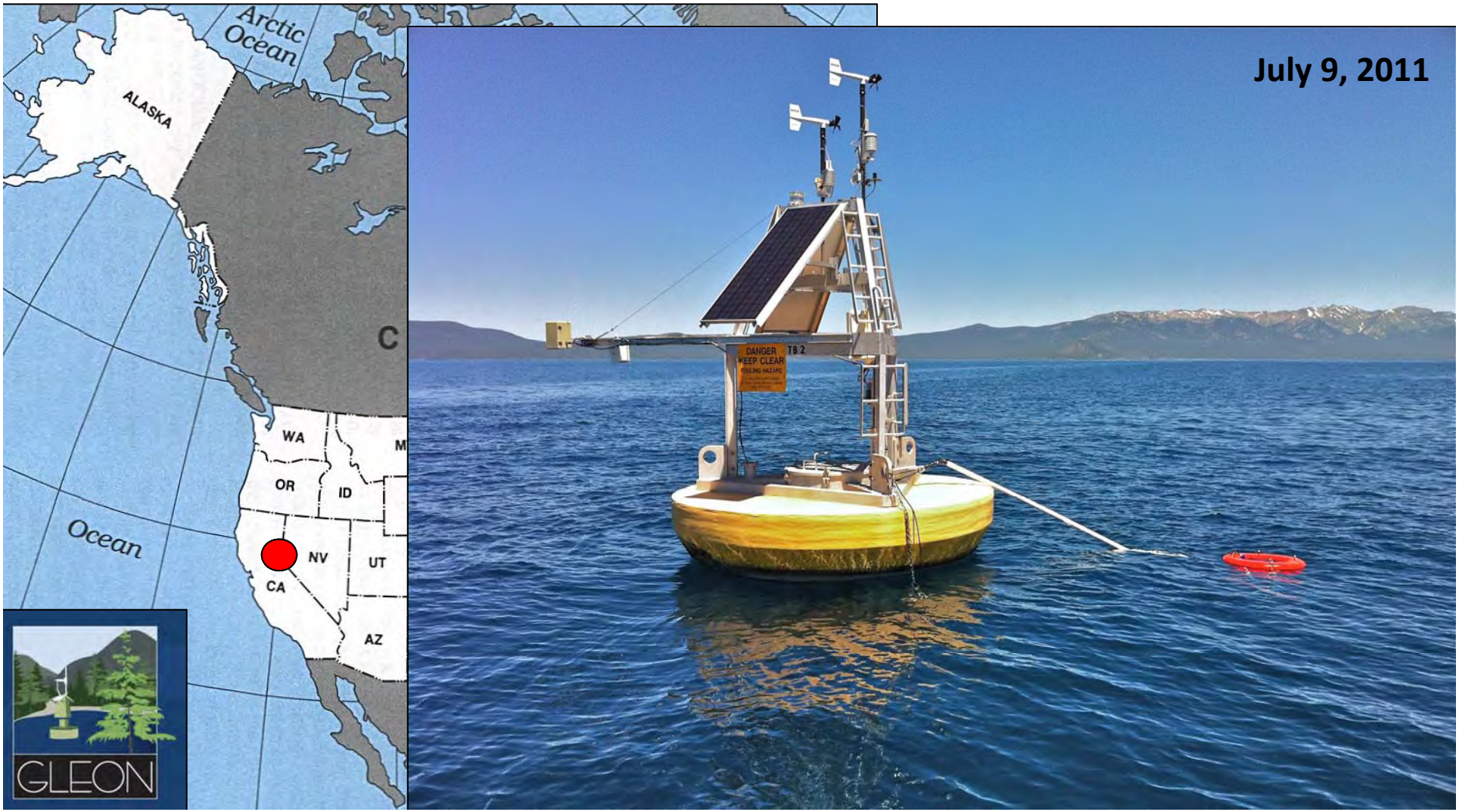


Arctic thermokarst lakes

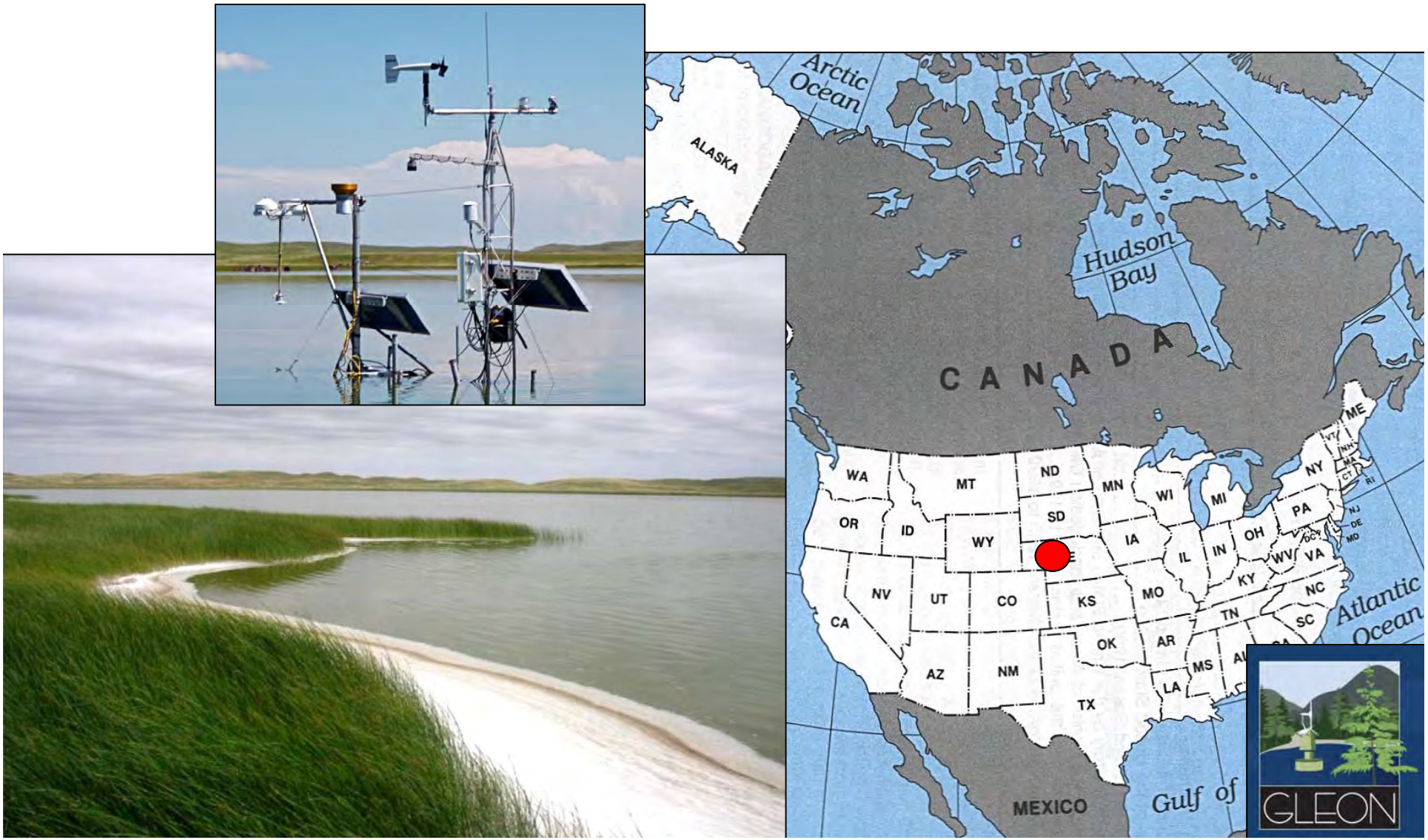


GLEON

Lake Tahoe


Arctic Ocean
ALASKA
C
WA
OR
ID
M
NV
UT
CA
AZ
Ocean
GLEON
July 9, 2011
DANGER
KEEP CLEAR
TB 2

Semi-arid western Nebraska



Sparkling Lake, Wisconsin

Available online at www.sciencedirect.com
SCIENCE DIRECT®

Journal of Hydrology 308 (2005) 168–195

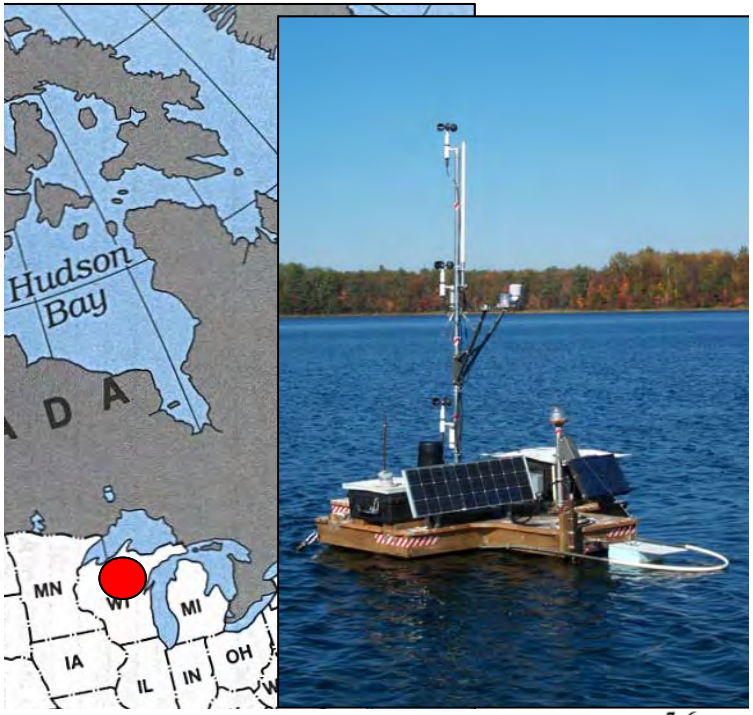
Journal of Hydrology
www.elsevier.com/locate/jhydrol

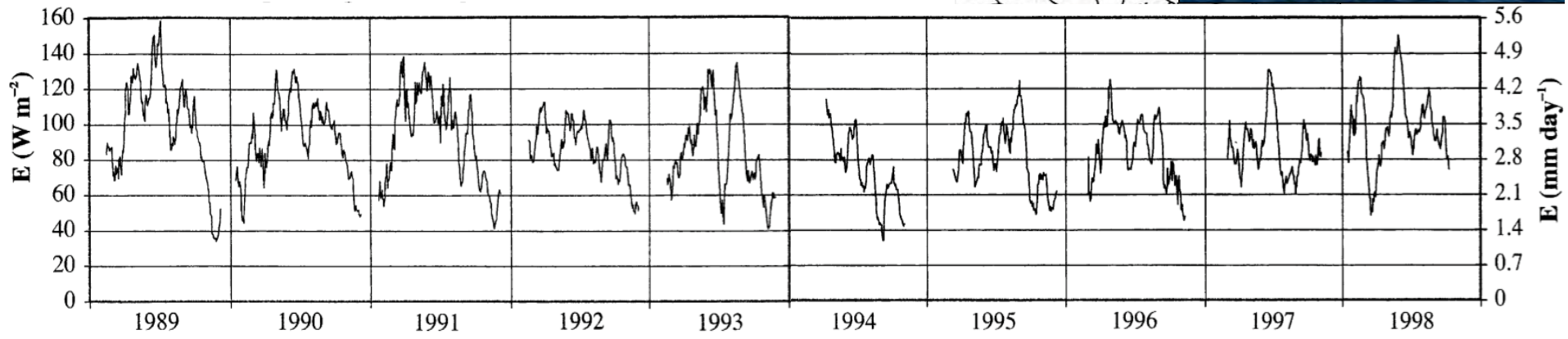
Effects of climate variability on lake evaporation: Results from a long-term energy budget study of Sparkling Lake, northern Wisconsin (USA)

John D. Lenters[a,*], Timothy K. Kratz[b], Carl J. Bowser[c]

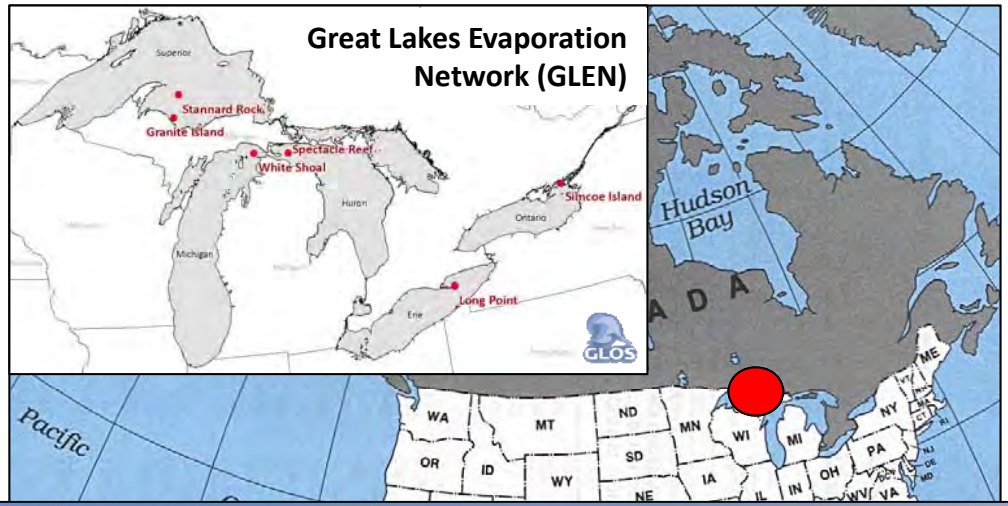
[a]*School of Environmental and Physical Sciences, Lake Superior State University, 650 W. Easterday Avenue, Sault Ste. Marie, MI 49783, USA*
[b]*Center for Limnology, University of Wisconsin-Madison, Madison, WI, USA*
[c]*Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI, USA*

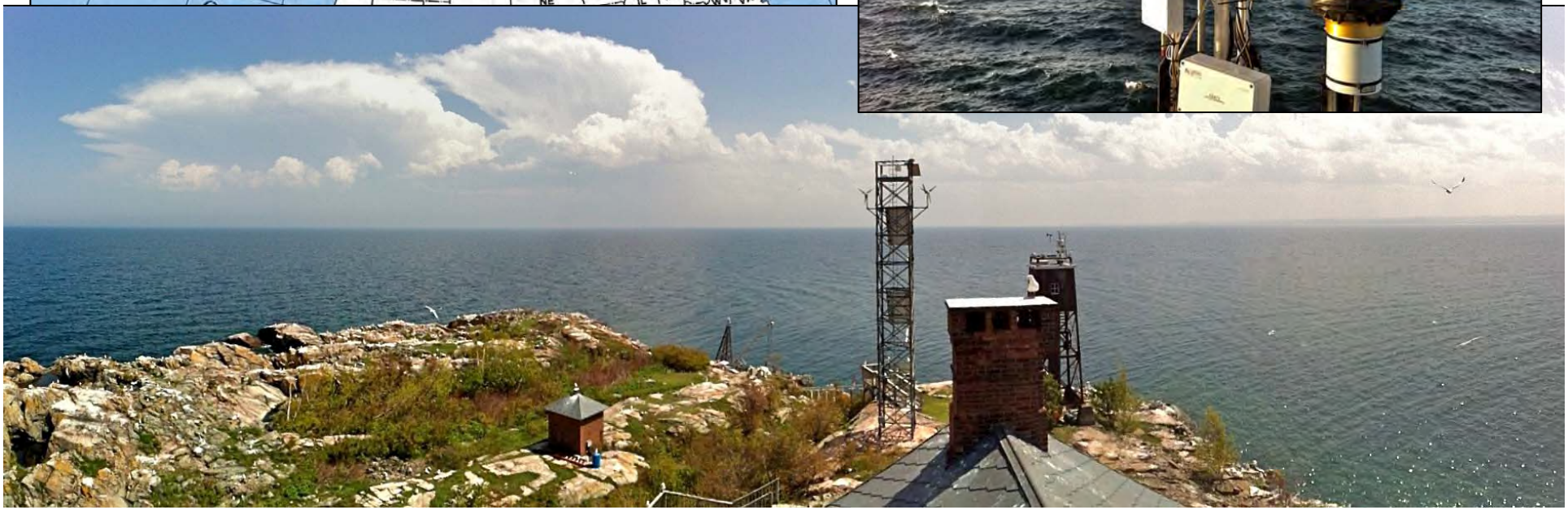
Received 7 October 2003; revised 20 September 2004; accepted 29 October 2004





Lake Superior

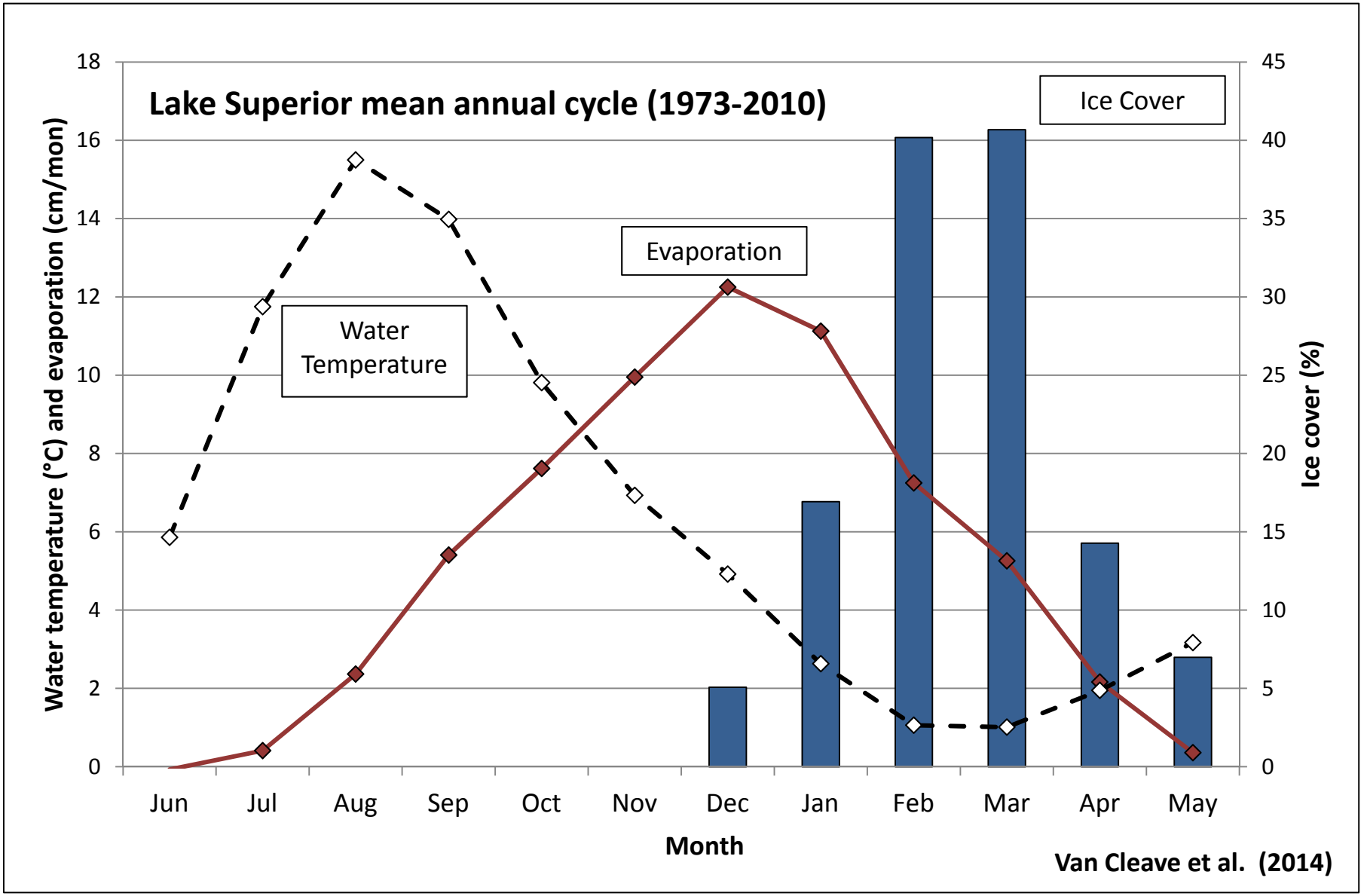




Talk outline

- Background and motivation
- **Lake Superior: Big lake, big changes**
- The “puzzle” of rapid lake warming
- Toward a solution: A new, global initiative
- Implications for evaporation, water levels
- Summary

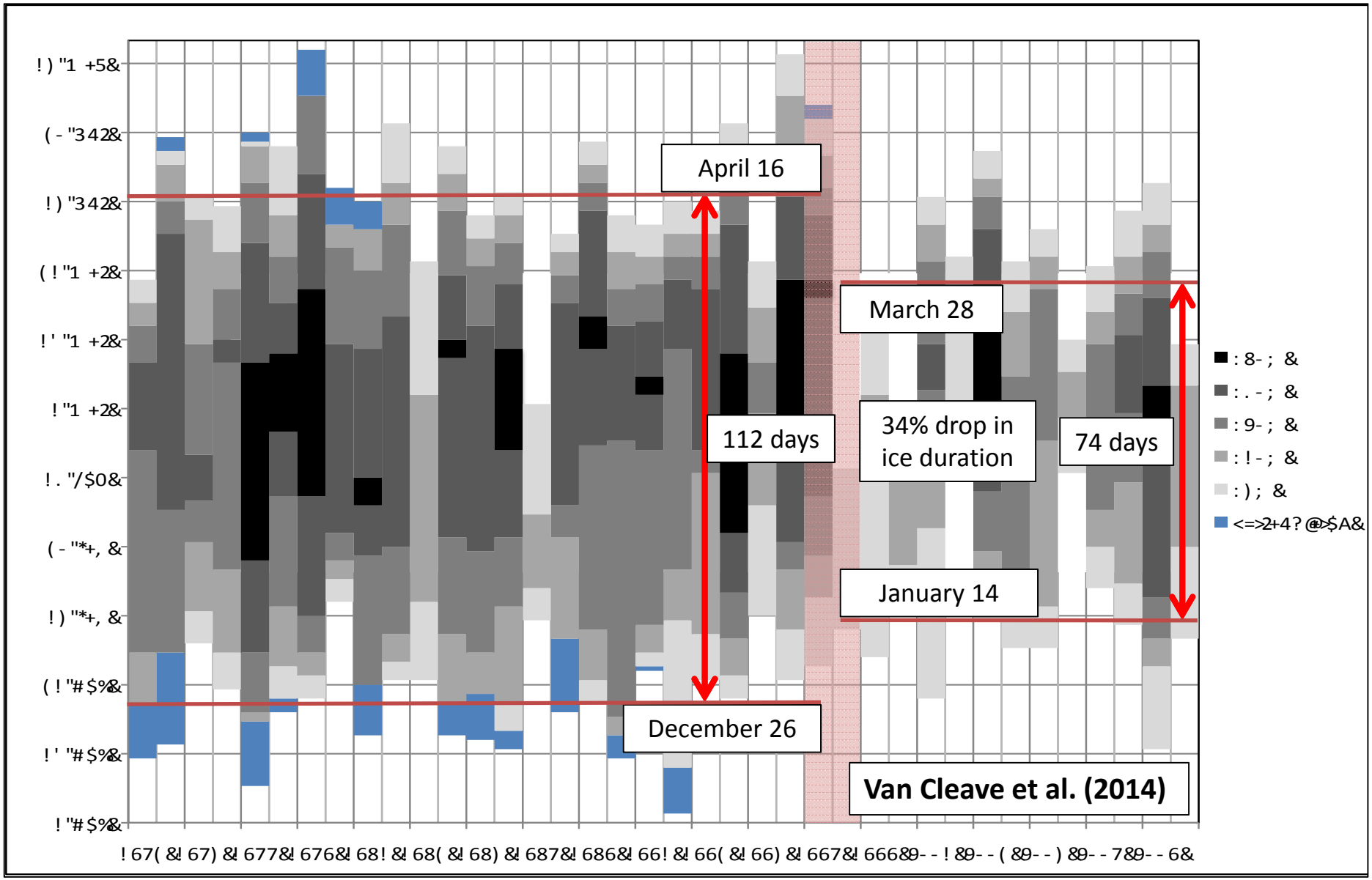
Seasonal interactions: Lake Superior



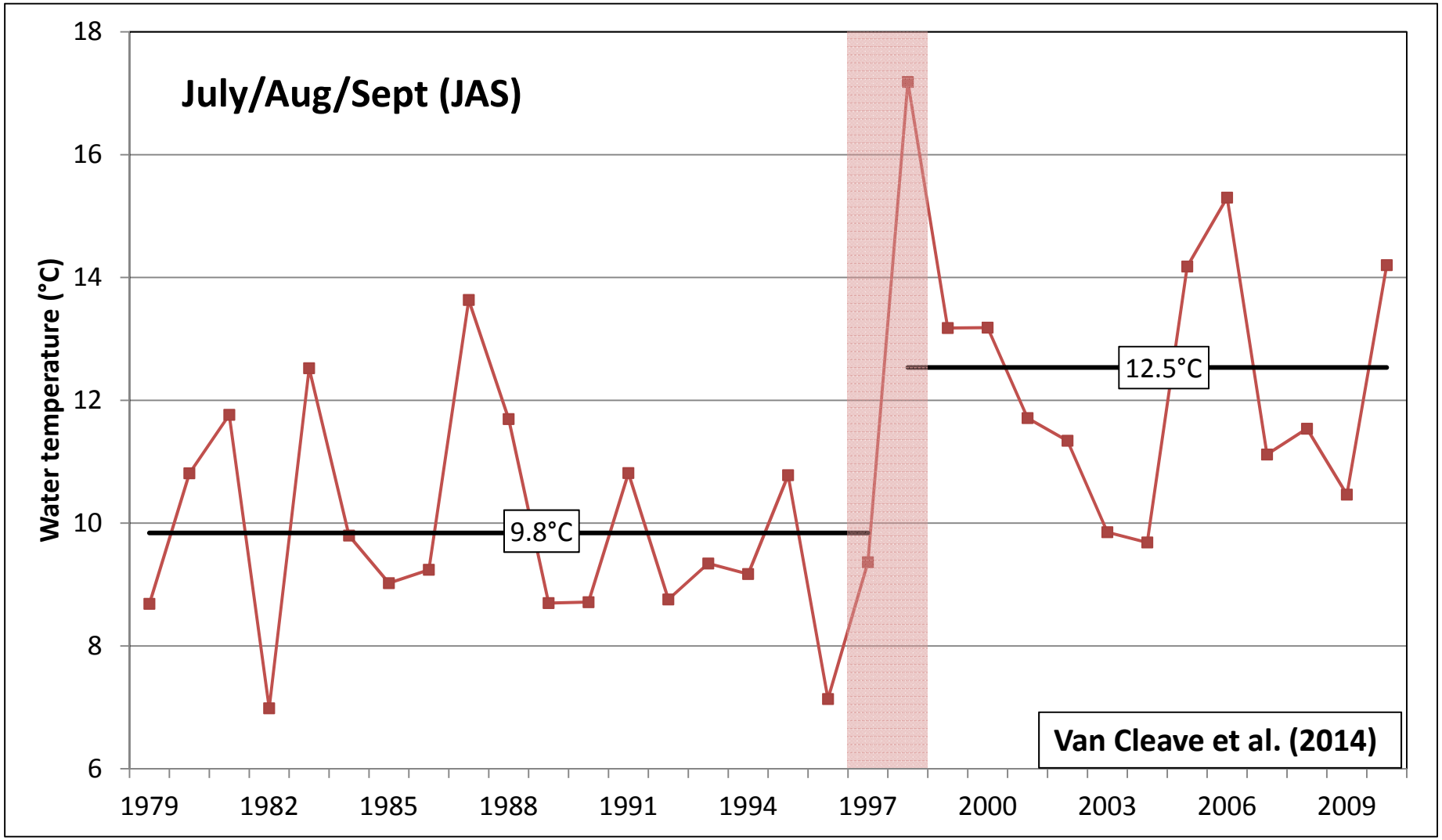
Lake Superior: Highly variable ice cover

Lake Superior: Highly variable ice cover

Lake Superior is losing ice

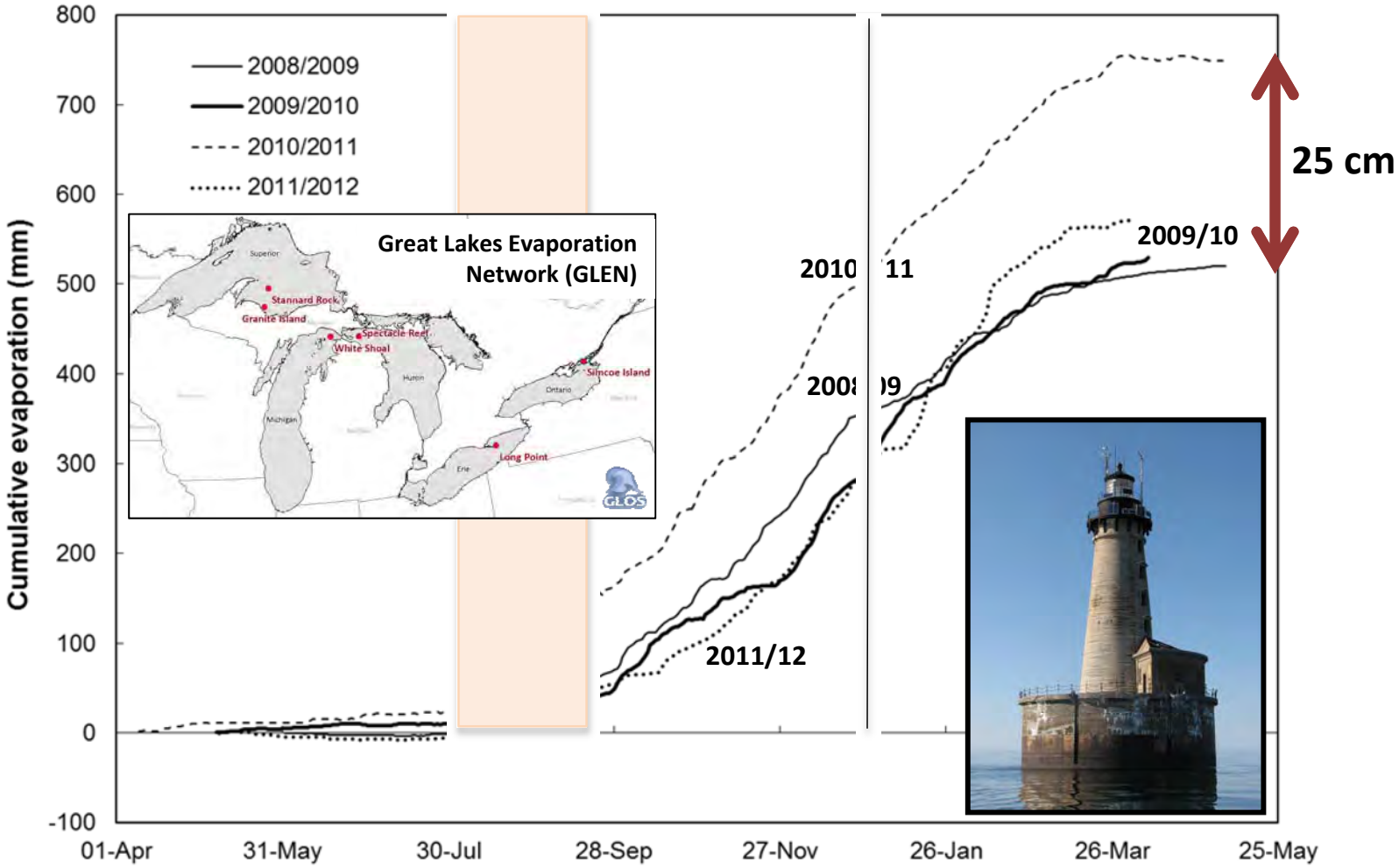


Lake Superior is warming rapidly



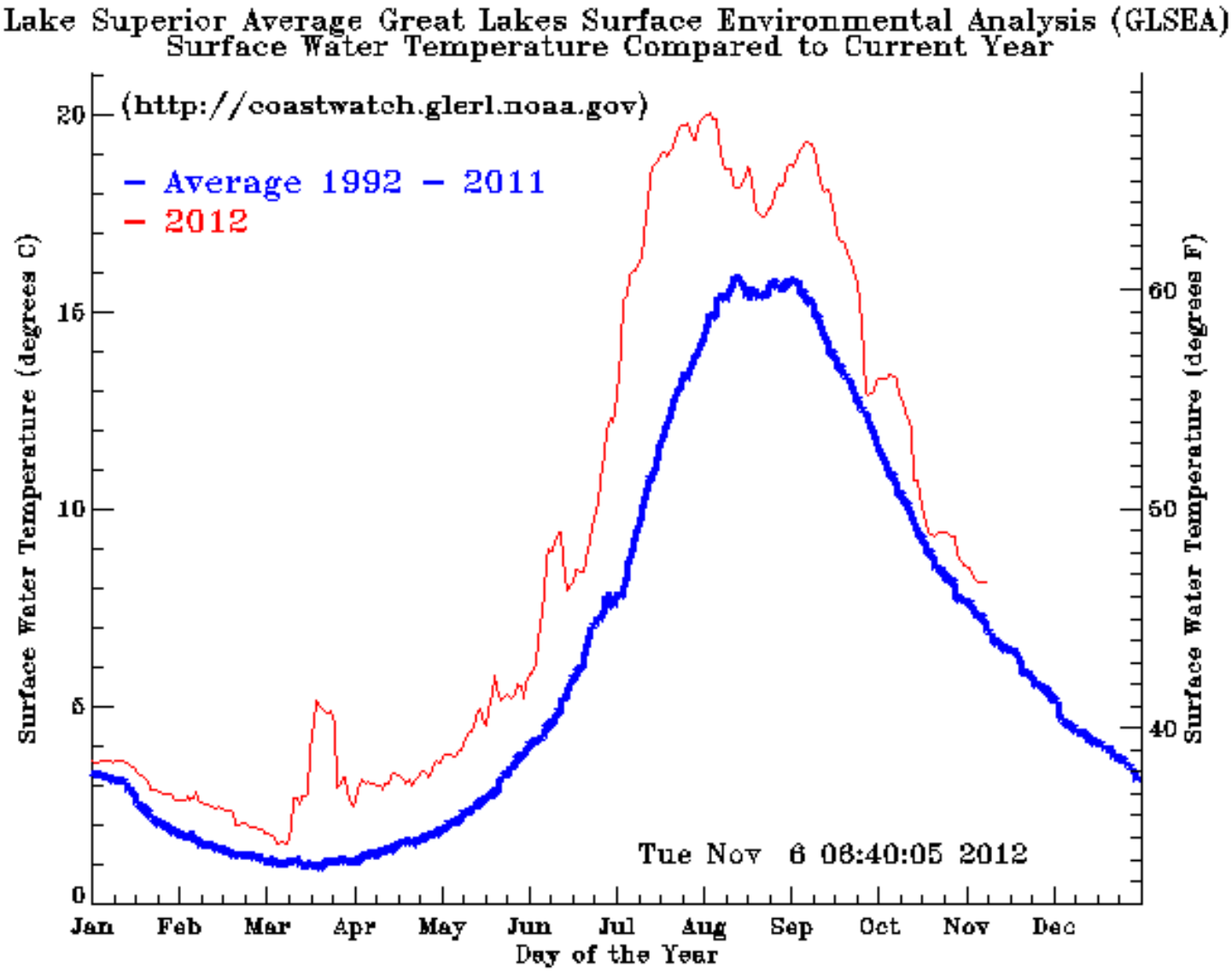
Lake Superior evaporation

(direct measurements at Stannard Rock Lighthouse)

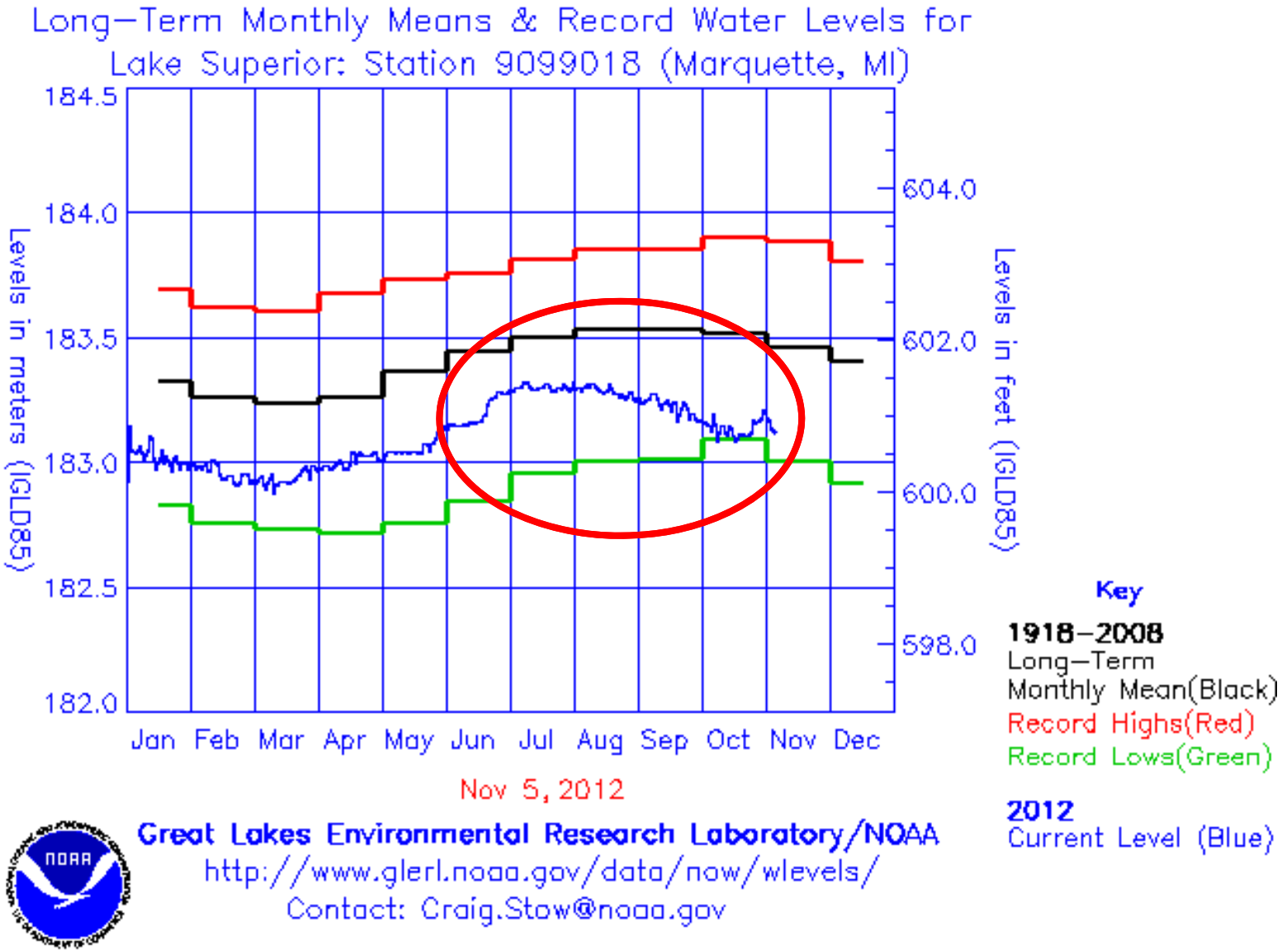


Spence et al. (2013) *Journal of Hydrometeorology*

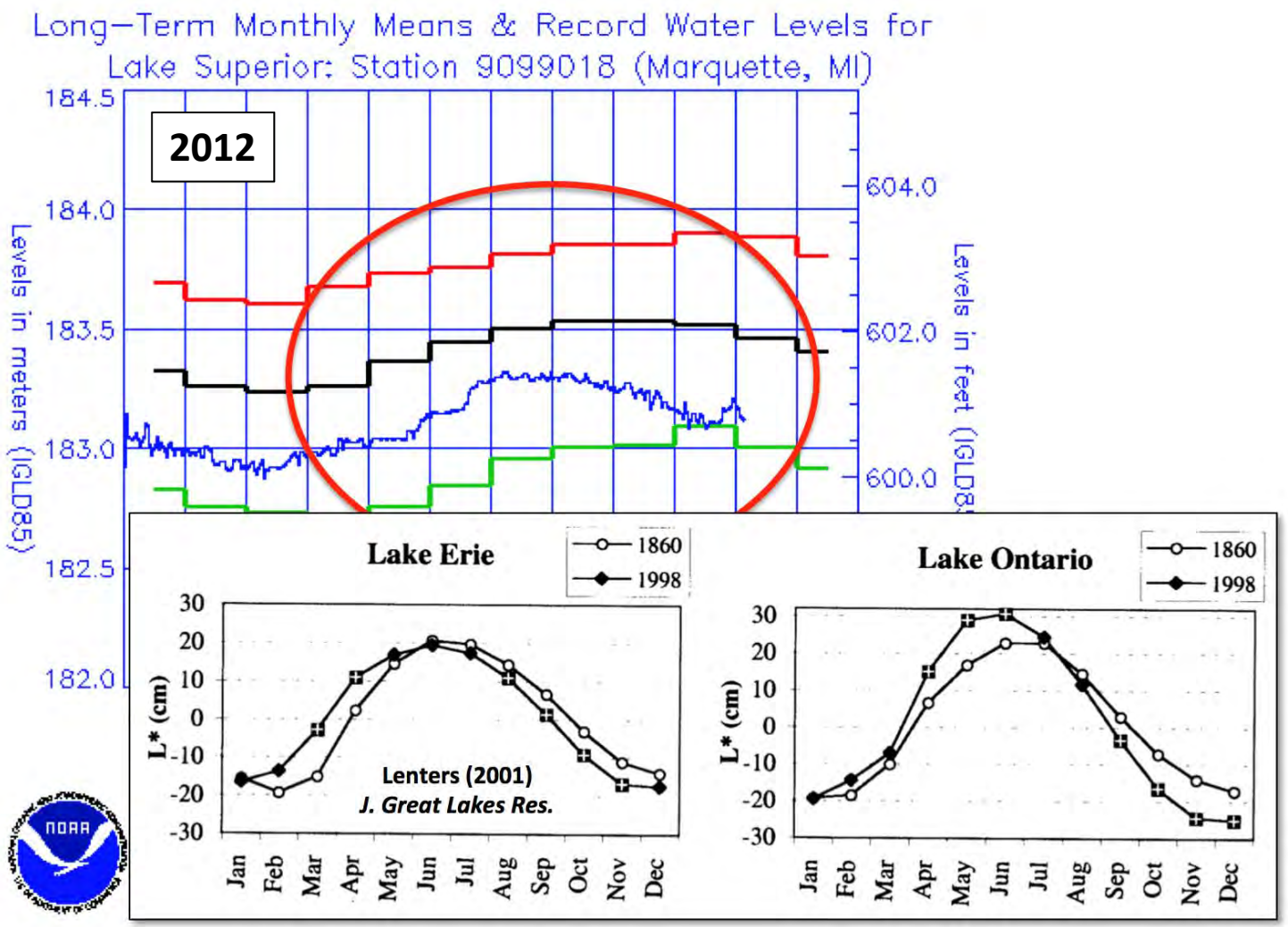
Record warmth in 2012



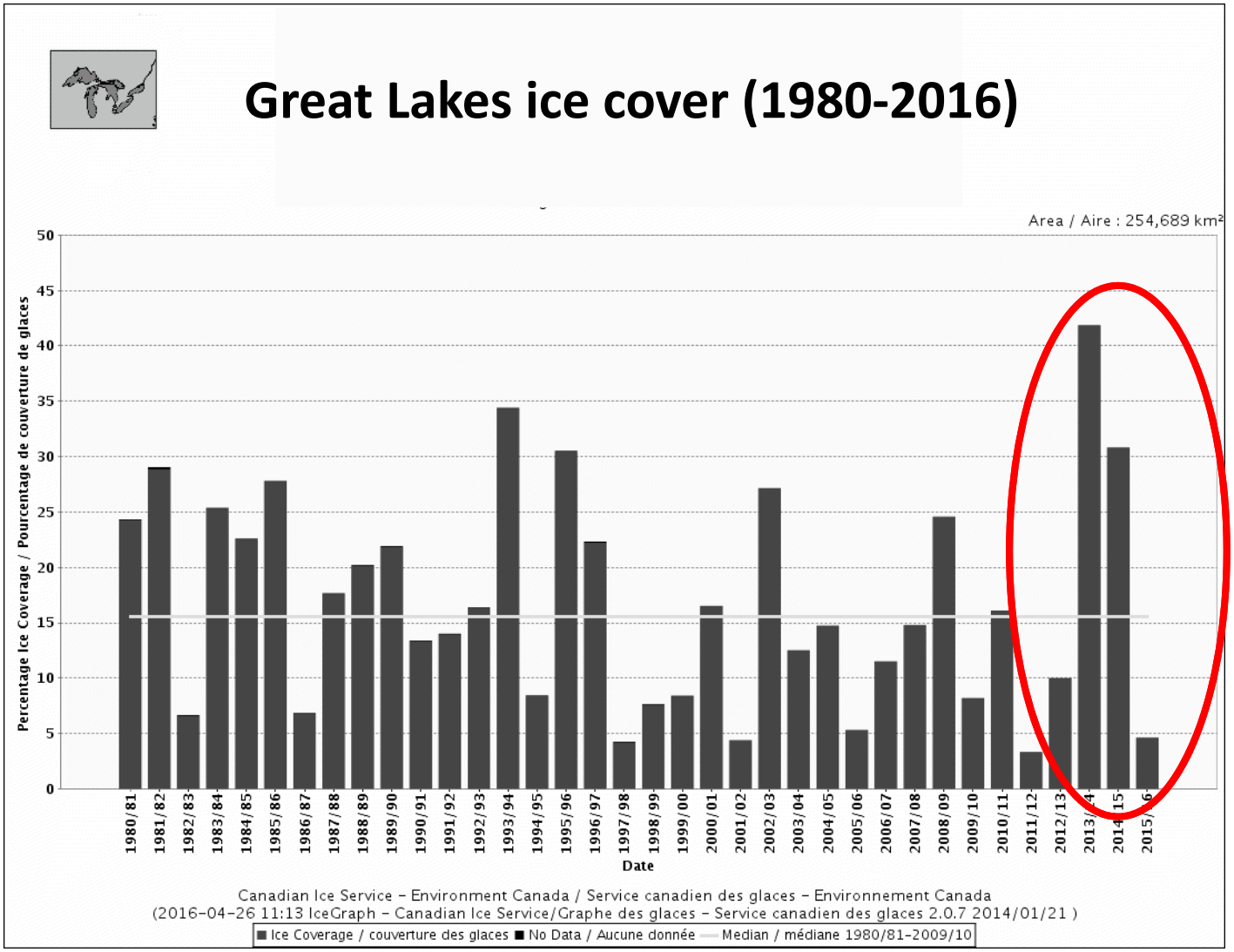
Low water levels, shifting seasons



Shifting seasons



High variability

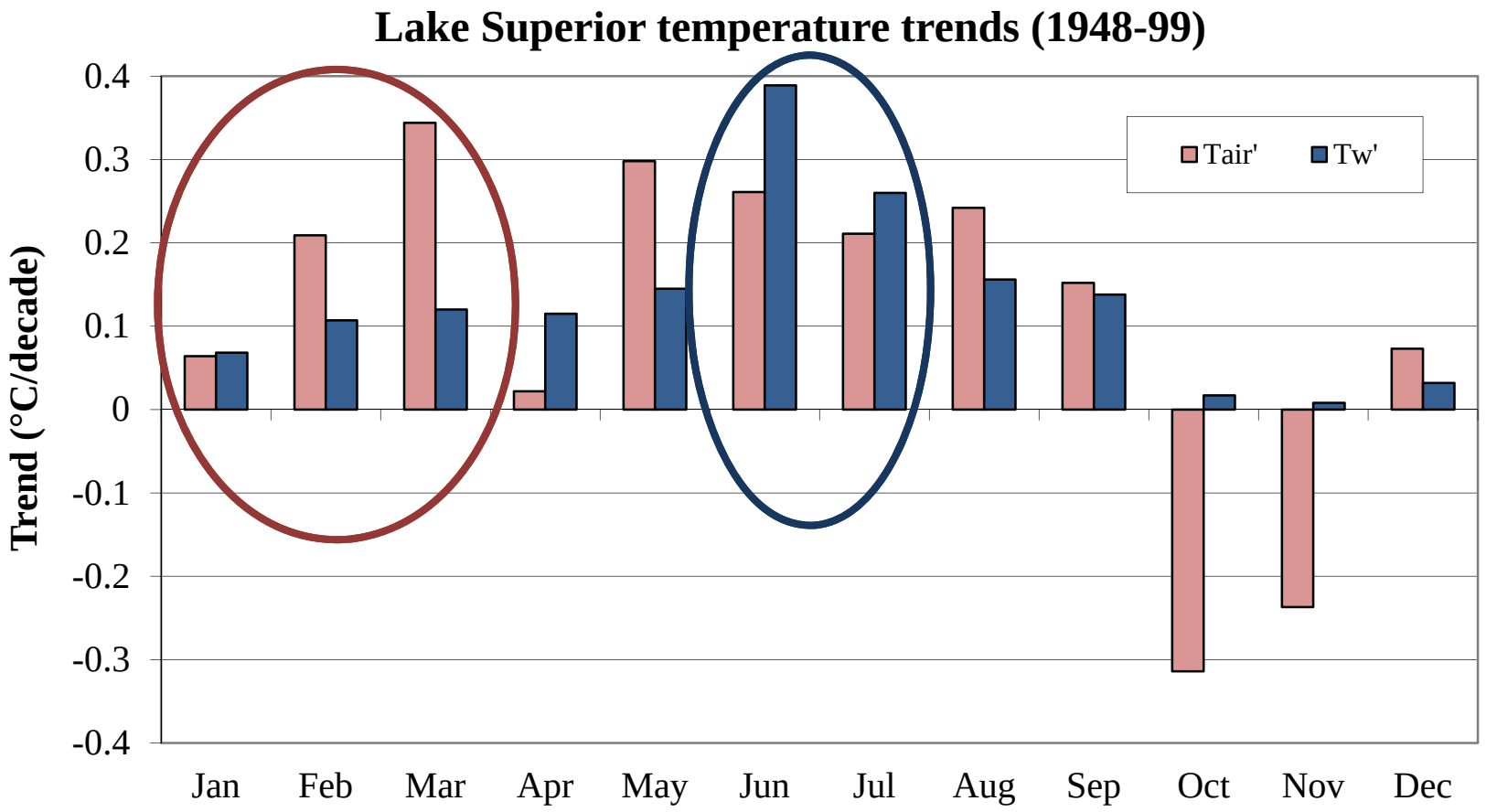


Talk outline

- Background and motivation
- Lake Superior: Big lake, big changes
- **The “puzzle” of rapid lake warming**
- Toward a solution: A new, global initiative
- Implications for evaporation, water levels
- Summary

Why the rapid warming of Lake Superior?

Is it a summer response to winter warming?



Lenters (2004) – *J. Great Lakes Res.*

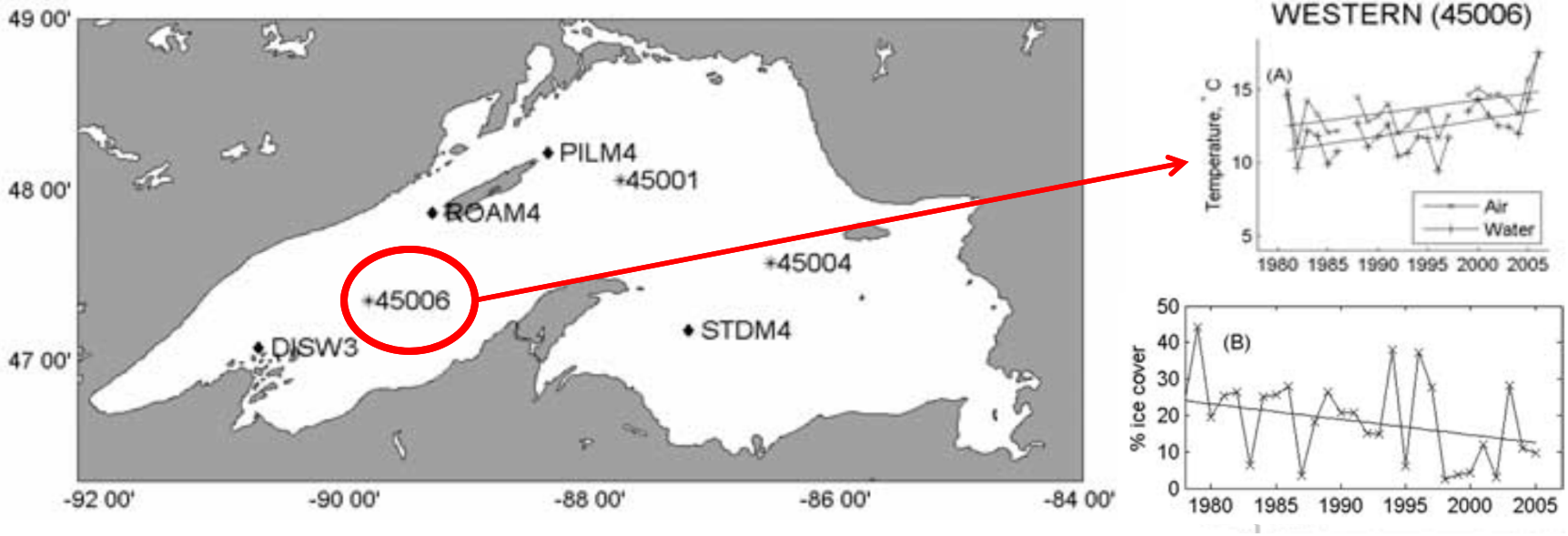
Why the rapid warming of Lake Superior?
Is it an ice-albedo feedback?

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L06604, doi:10.1029/2006GL029021, 2007

Lake Superior summer water temperatures are increasing more rapidly than regional air temperatures: A positive ice-albedo feedback

Jay A. Austin[1] and Steven M. Colman[2]

Air: dT_{air}/dt ~ +0.5 °C/decade
Water: dT_s/dt ~ +1.1 °C/decade



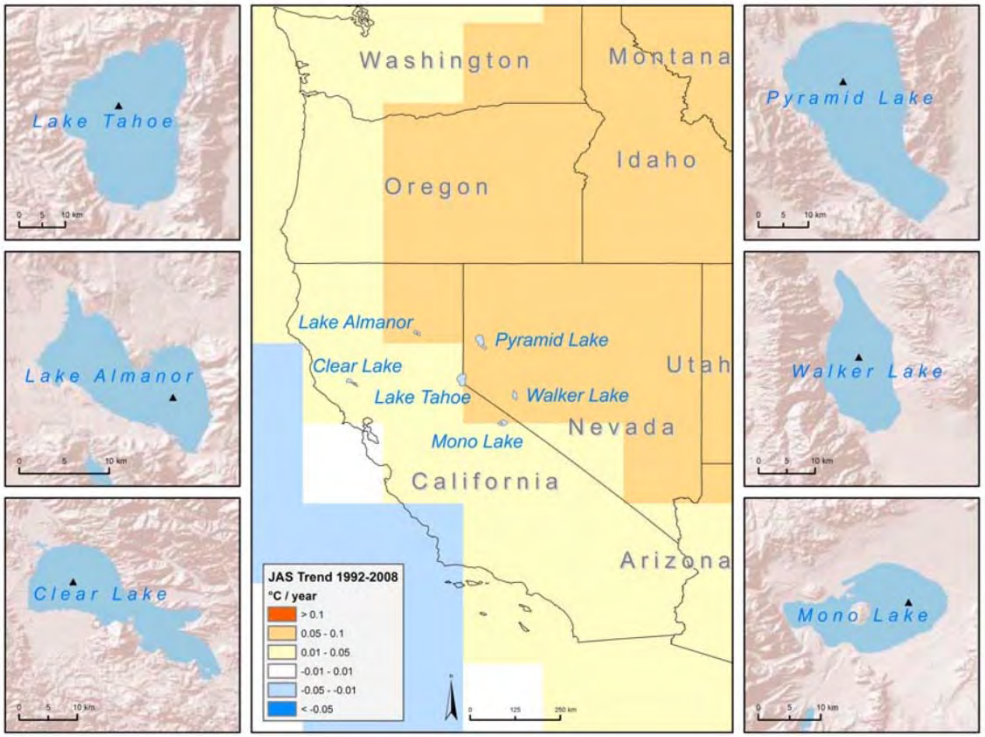
Ice-albedo feedback? Not for these lakes …

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L22402, doi:10.1029/2009GL040846, 2009

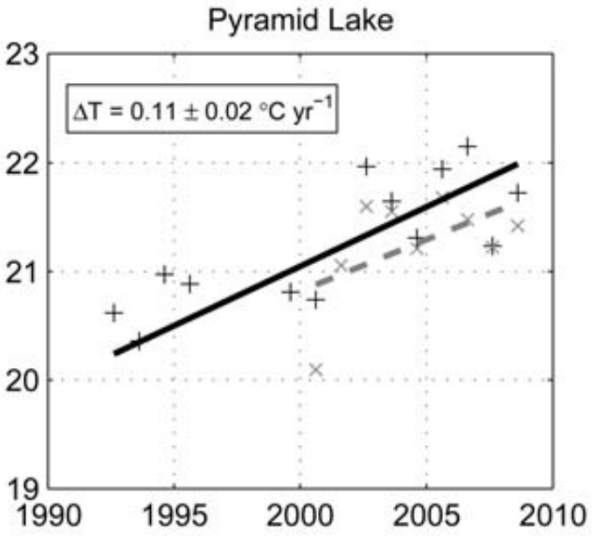
Satellite observations indicate rapid warming trend for lakes in California and Nevada

P. Schneider,[1] S. J. Hook,[1] R. G. Radocinski,[1] G. K. Corlett,[2] G. C. Hulley,[1] S. G. Schladow,[3] and T. E. Steissberg[3]

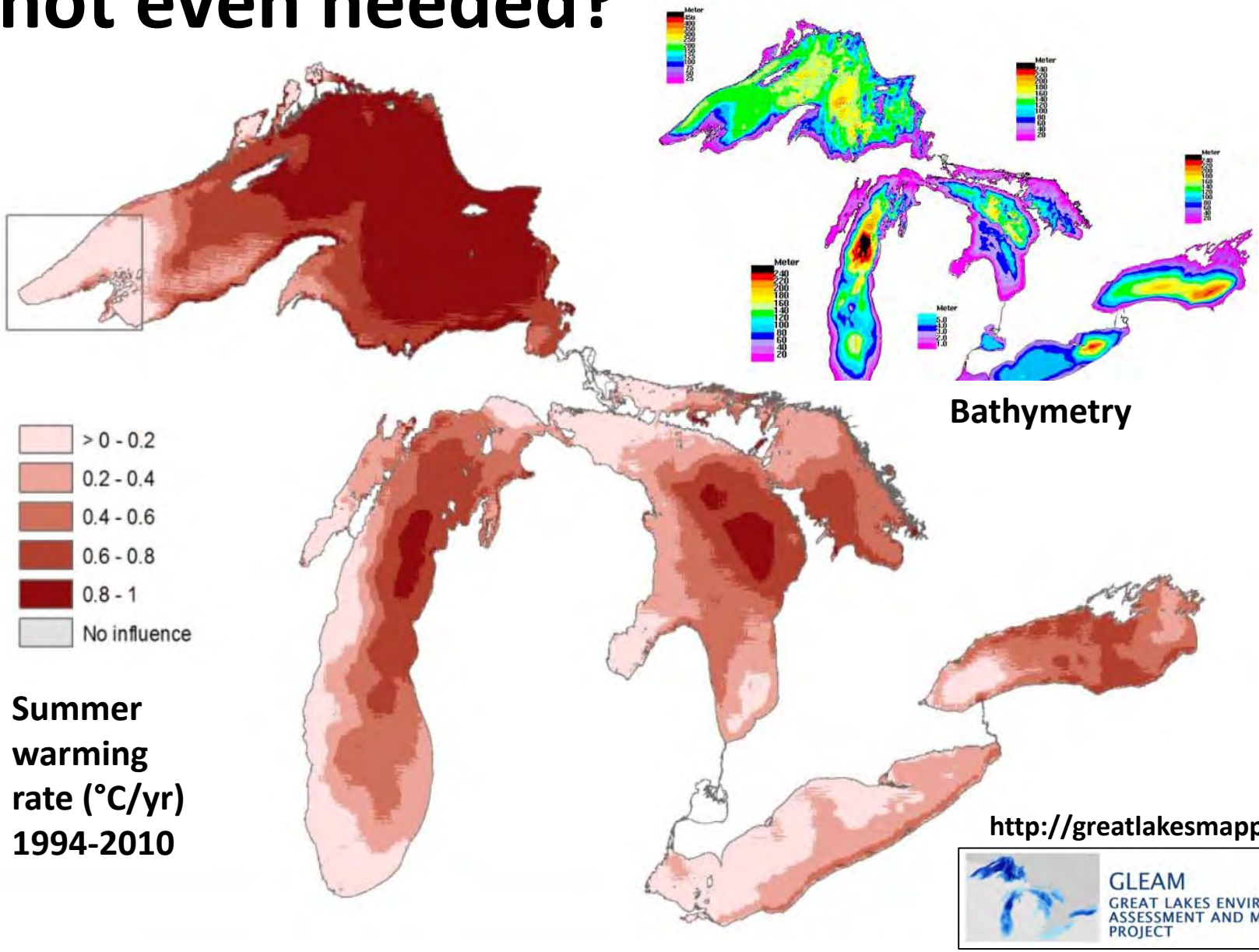
Received 10 September 2009; revised 21 October 2009; accepted 26 October 2009; published 25 November 2009.



Air: dT_{air}/dt ~ +0.5 °C/decade
Water: dT_s/dt ~ +1.1 °C/decade



Maybe an ice-albedo feedback is not even needed?



Bathymetry

Summer warming rate (°C/yr) 1994-2010

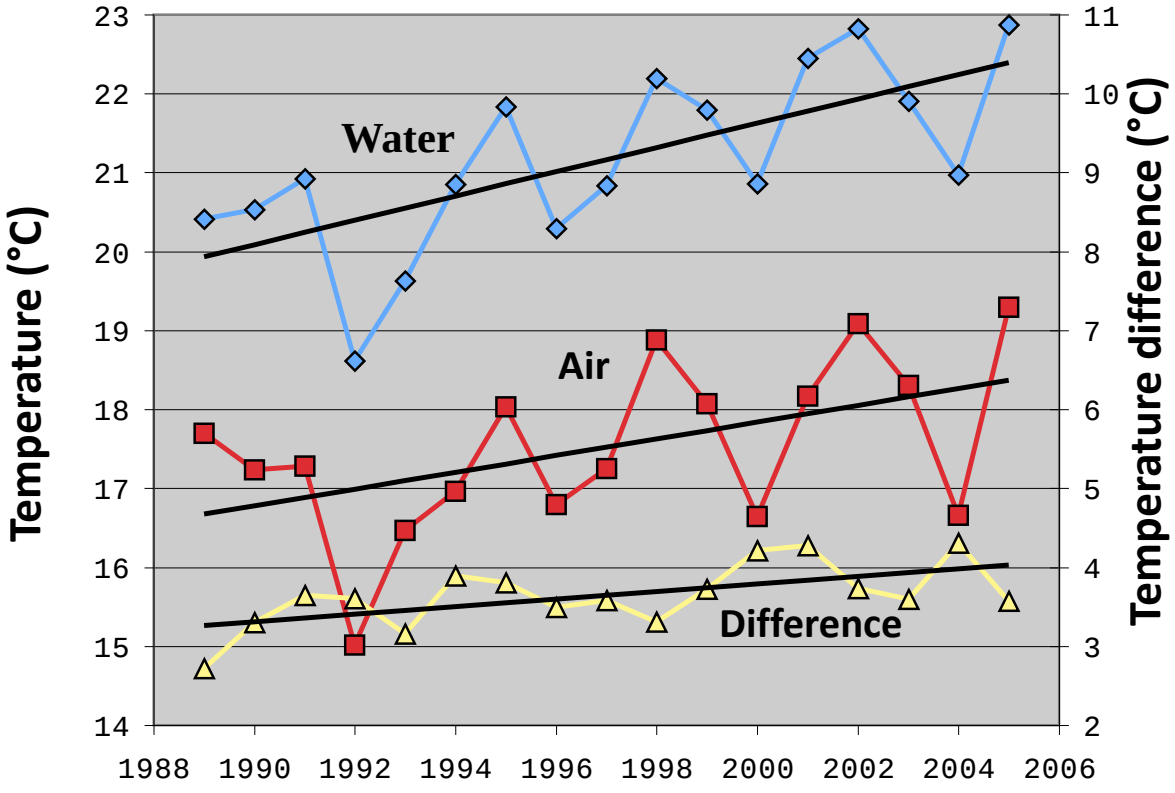
http://greatlakesmapping.org

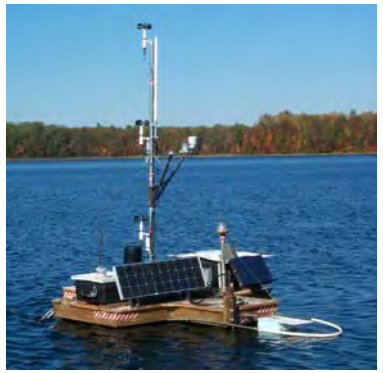
GLEAM
GREAT LAKES ENVIRONMENTAL ASSESSMENT AND MAPPING PROJECT

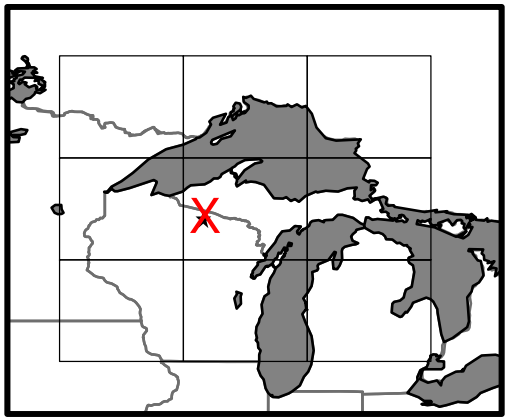
Is the rapid warming just a “deep lake” phenomenon? Nope.

Sparkling Lake temperature trends (July–September mean)

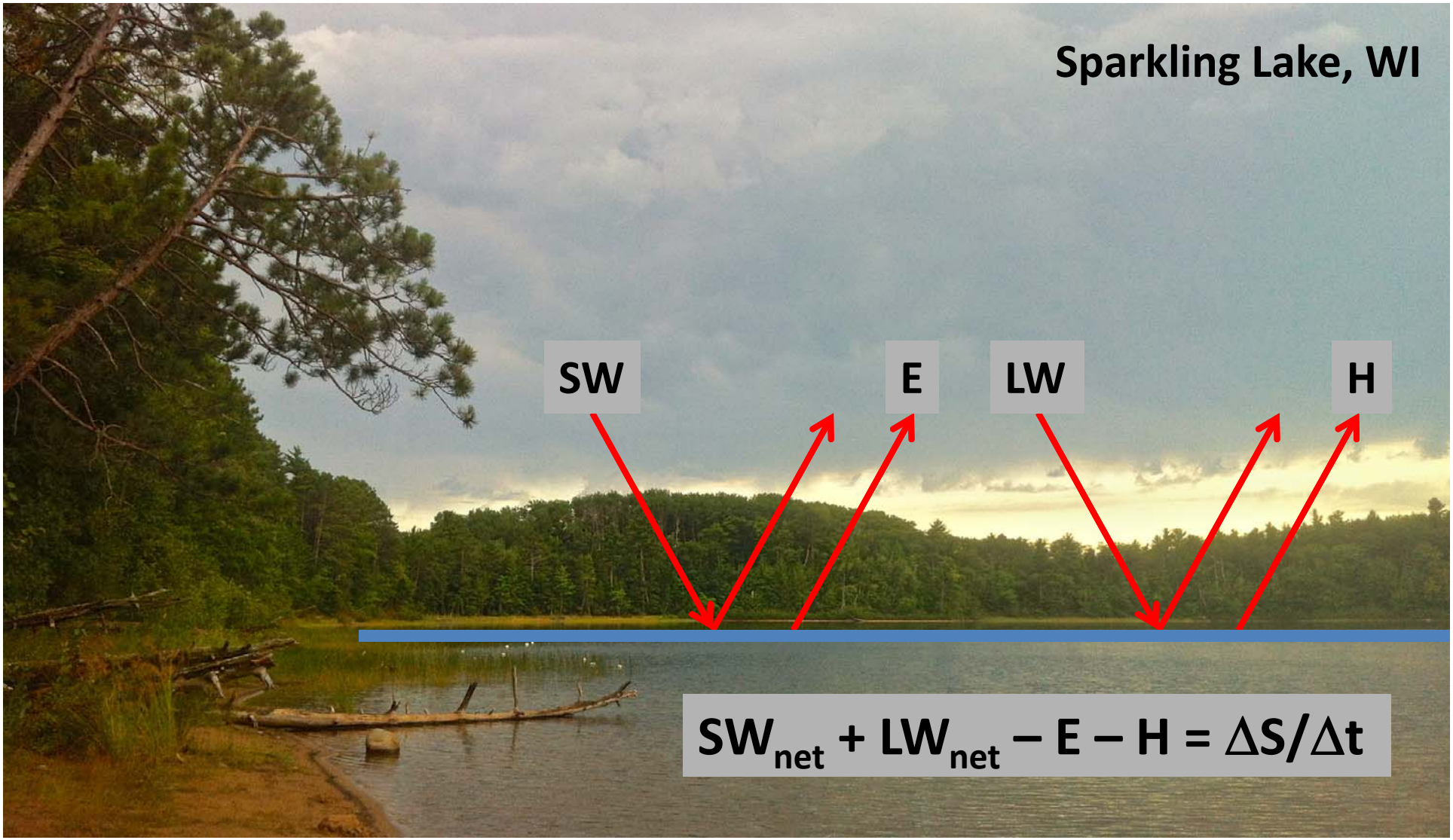
Air: dT_{air}/dt ~ +1.0 °C/decade
Water: dT_s/dt ~ +1.5 °C/decade



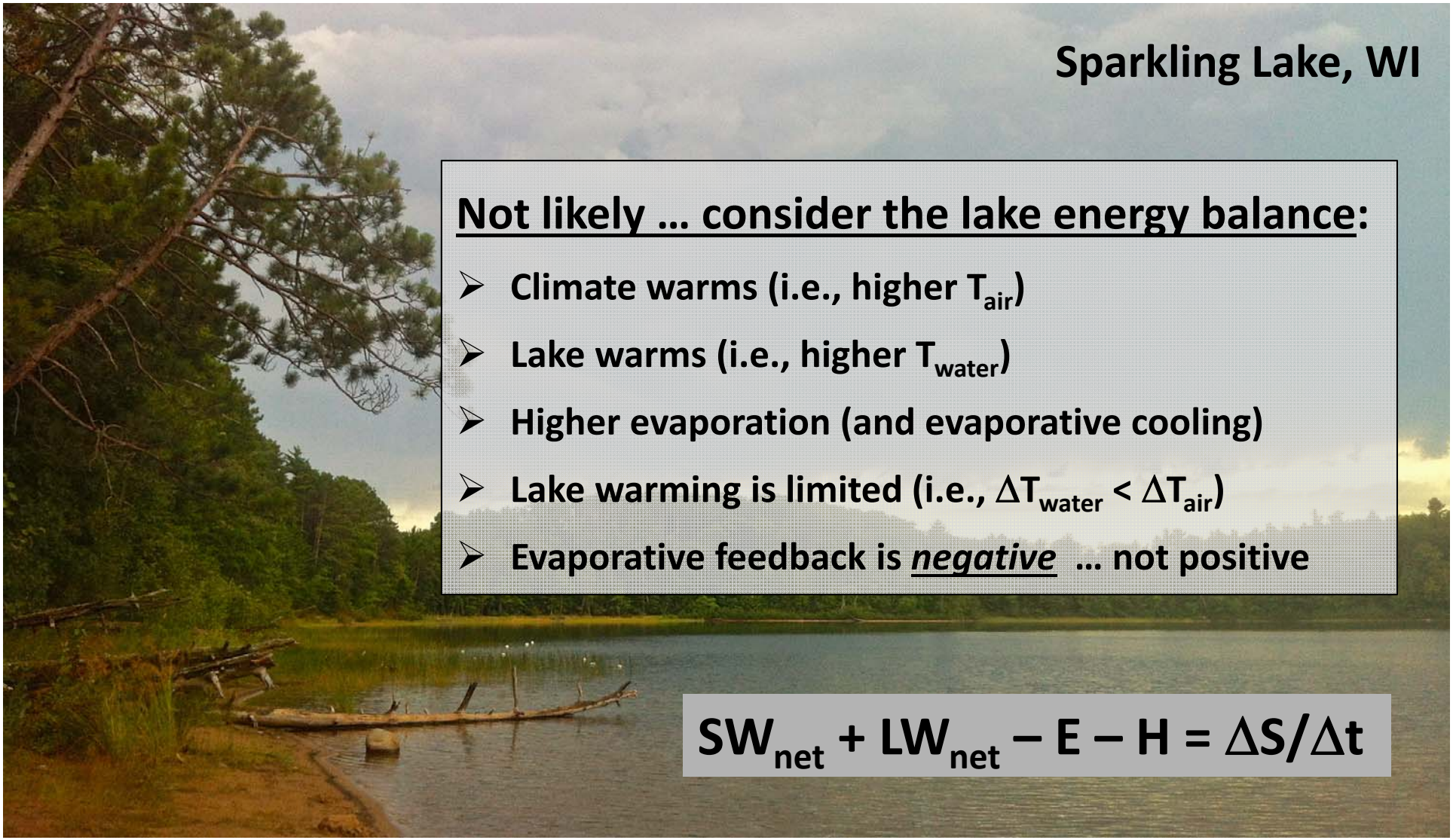




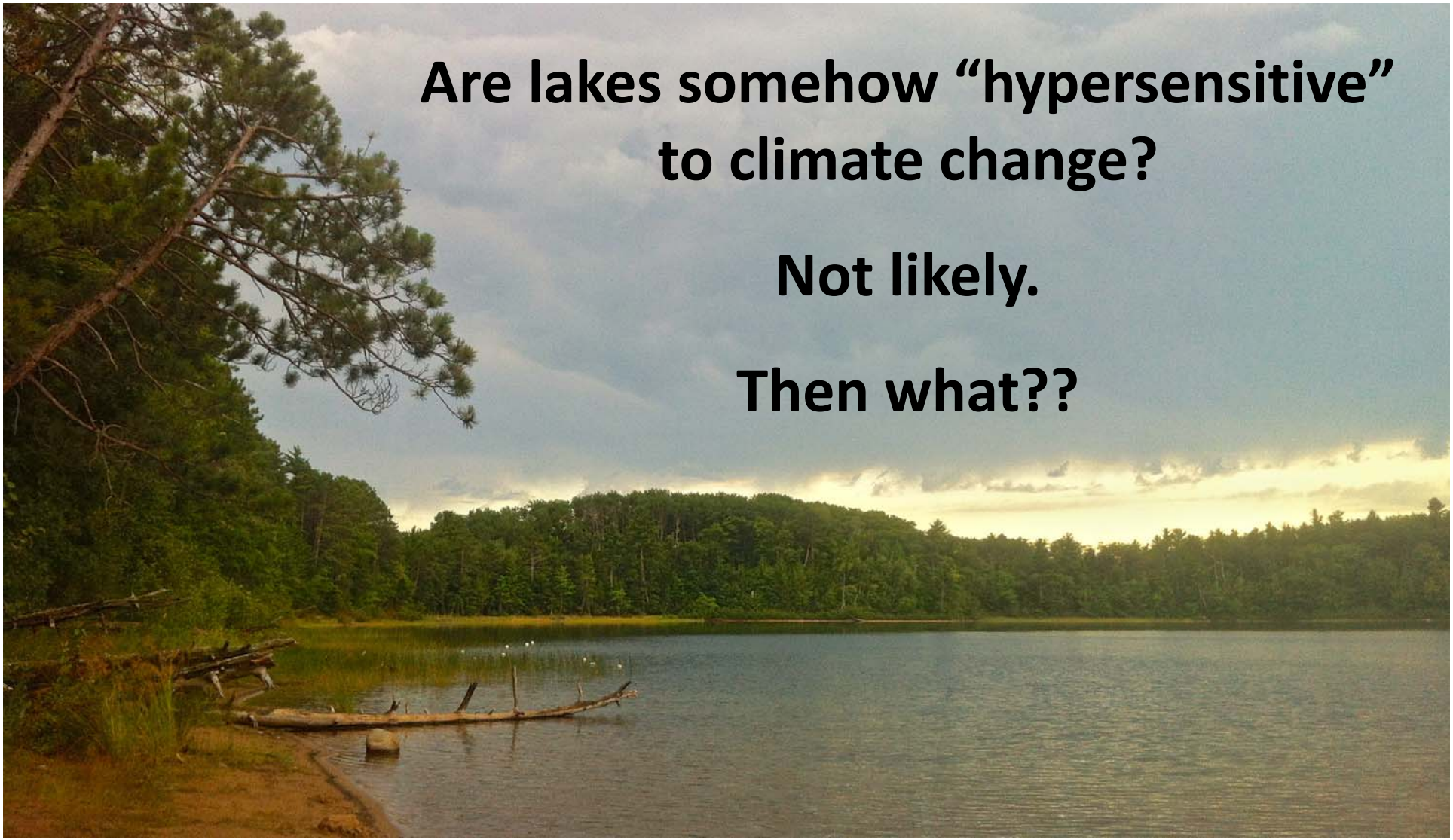
Are lakes somehow "hypersensitive" to climate change?



Are lakes somehow "hypersensitive" to climate change?



Ice-albedo feedback? Not for some lakes. Only a “deep lake” phenomenon? No.

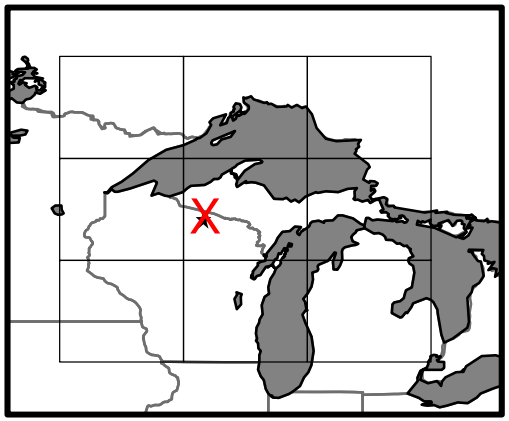


Talk outline

- Background and motivation
- Lake Superior: Big lake, big changes
- The “puzzle” of rapid lake warming
- **Toward a solution: A new, global initiative**
- Implications for evaporation, water levels
- Summary

Origins of a new global initiative:

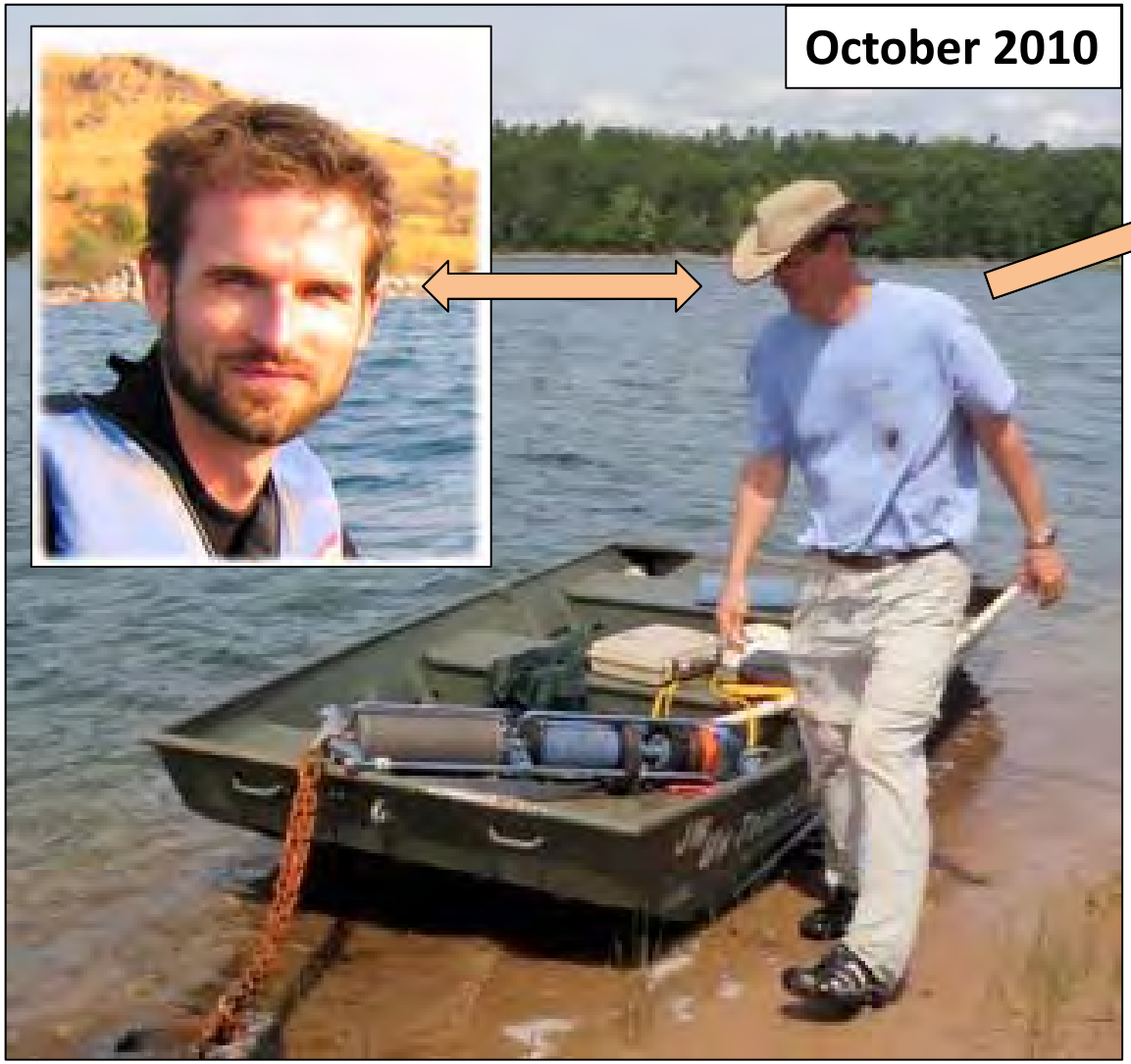
The Global Lake Temperature Collaboration (GLTC)



GLTC

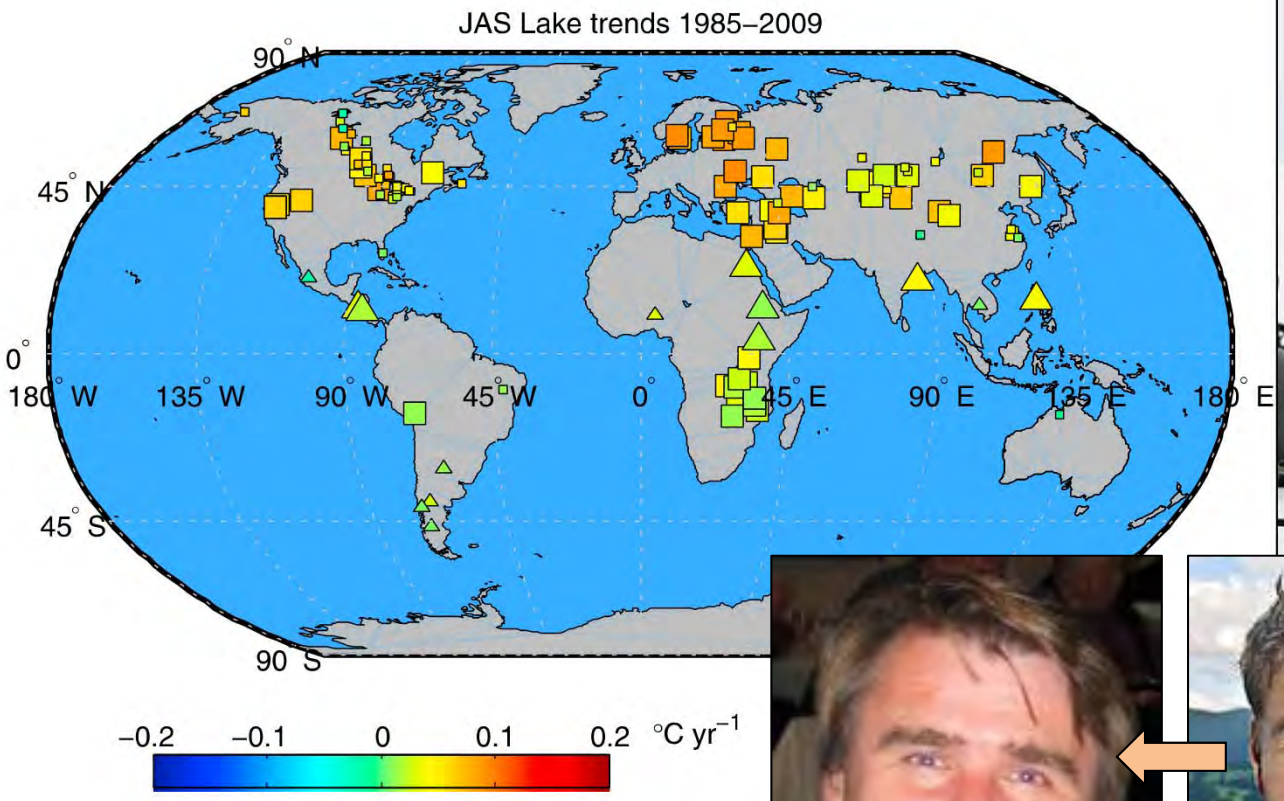
Global Lake Temperature Collaboration – http://laketemperature.org/

Origins of the GLTC initiative

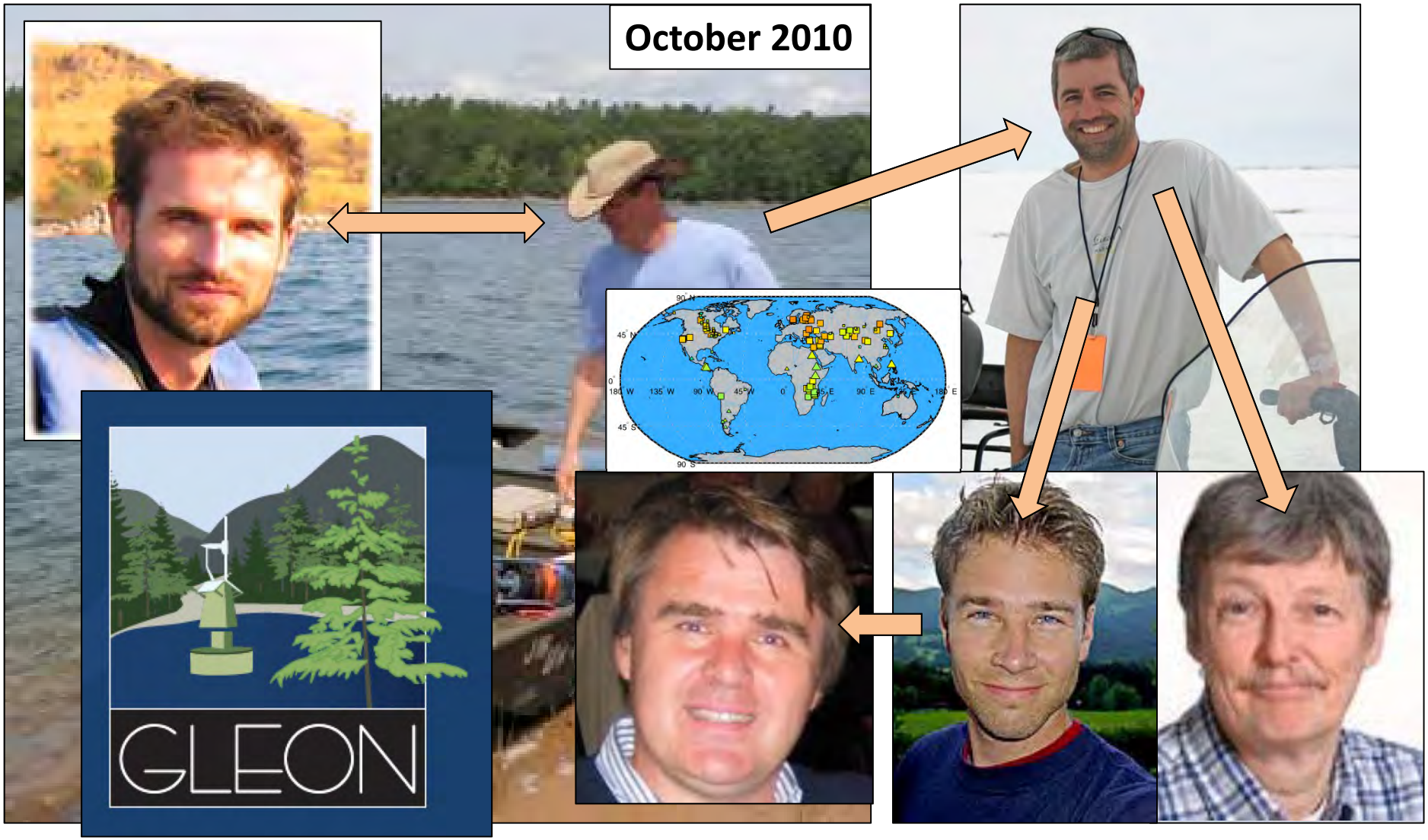


Origins of the GLTC initiative

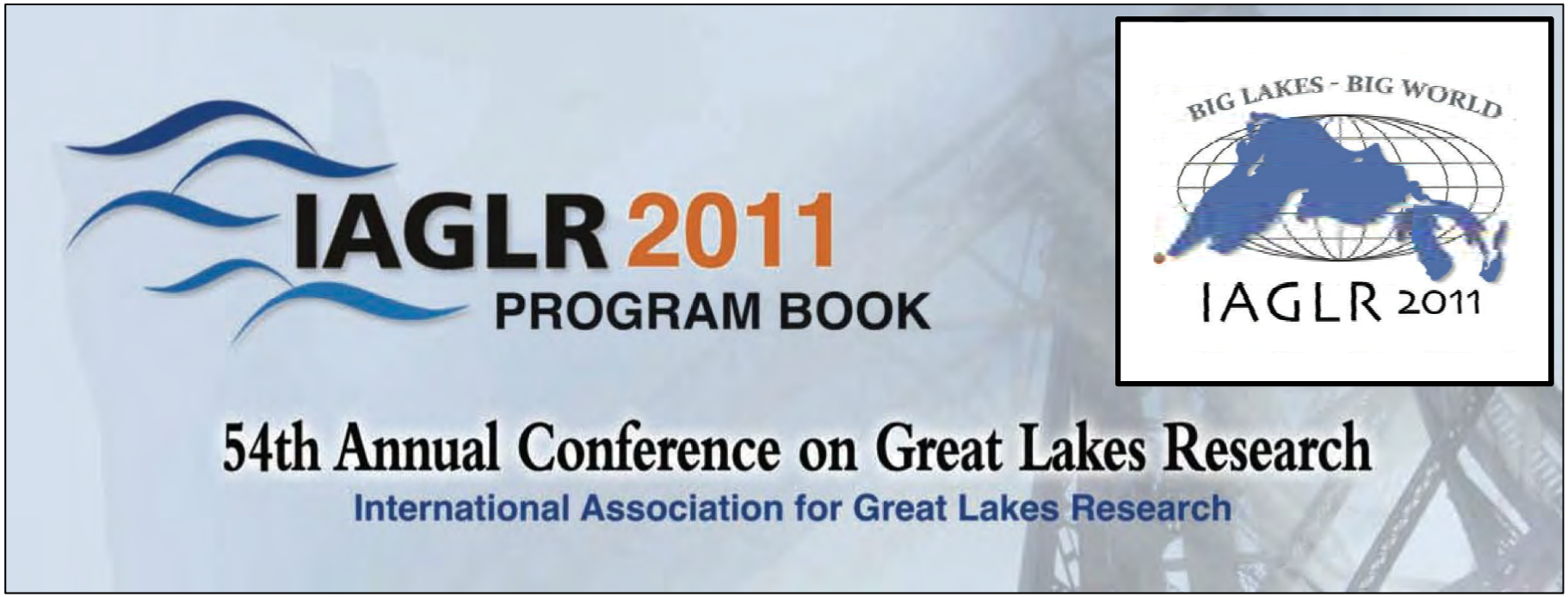
Schneider, P., and S. J. Hook (2010), *Geophys. Res. Lett.*, 37.



Origins of the GLTC initiative



Origins of the GLTC initiative



<u>Special session</u>: Global Trends in Lake Temperature and Associated Impacts on Lacustrine Systems

GLTC Workshop (June 2012)

GLTC Workshop (June 2012)

Eos, Vol. 93, No. 43, 23 October 2012

MEETINGS

Workshop Examines Warming of Lakes Worldwide

First Global Lake Temperature Collaboration (GLTC) Workshop; Lincoln, Nebraska, 1–5 June 2012

GLTC

Global Lake Temperature Collaboration

http://laketemperature.org/

Home | Background | Participants | Lakes | 2012 Workshop | Education / Outreach | Publications | Links

Lake Superior, USA (photo courtesy of John Lenters)

Welcome

The Global Lake Temperature Collaboration (GLTC) began in the fall of 2010 to assemble an international group of investigators with interest in and access to global lake temperature records (both *in situ* and satellite-based). The GLTC group has since grown to over 50 investigators and has recognized the need for a workshop to bring together all international project participants in a common location to share data, examine patterns and trends, perform comparative analysis, compile a global lake temperature database, and publish results from the GLTC project.

NEW publications from the GLTC project

Download the GLTC Informational Poster:

English

French

Italian

Upcoming Events:

SIL

July 31 - August 5, 2016
Turino, Italy Website »

European Geosciences Union, General Assembly

April 17 - 22, 2016
Vienna, Austria Website »

American Geophysical Union, Fall Meeting

December 14 – 18, 2015
San Francisco, California, USA
Website »

News:

December 16, 2015 – Climate Change Rapidly Warming World's Lakes

AGU Press Release Story »
AGU Press Release Video »

November 19, 2015 – On Thin Ice: Big Northern Lakes Are Being Rapidly Transformed

Read more »

Fundamental question:

What are the patterns, mechanisms, and impacts of global lake warming / cooling?

(from both satellite and *in situ* measurements)

GLTC

Global Lake Temperature Collaboration – http://laketemperature.org/

Figure 1: Map of the lakes included in the GLTC dataset.

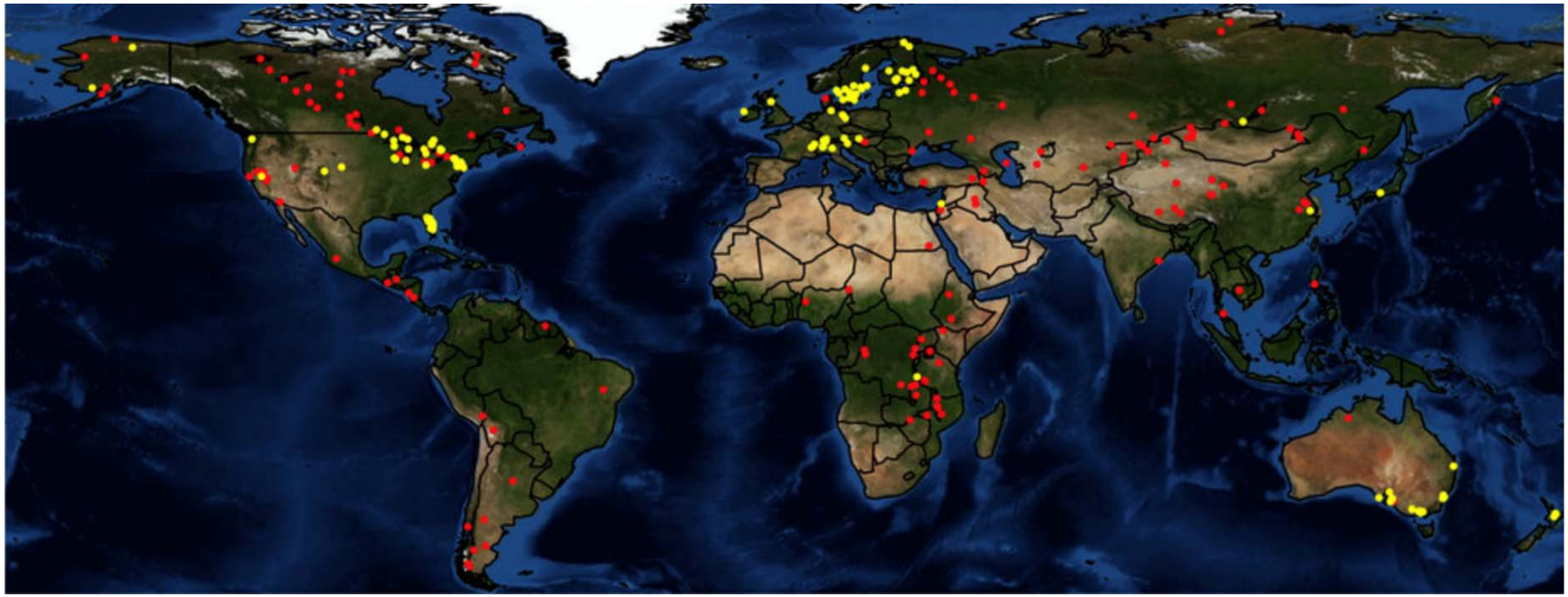
From

A global database of lake surface temperatures collected by *in situ* and satellite methods from 1985–2009

Sapna Sharma, Derek K Gray [...] Kara H Woo

Scientific Data **2**, Article number: 150008 (2015) | doi:10.1038/sdata.2015.8

Received 17 November 2014 | Accepted 13 February 2015 | Published online 17 March 2015



Yellow—*in situ* sampled lakes; Red—satellite sampled lakes.

Figure 1: Map of the lakes included in the GLTC dataset.

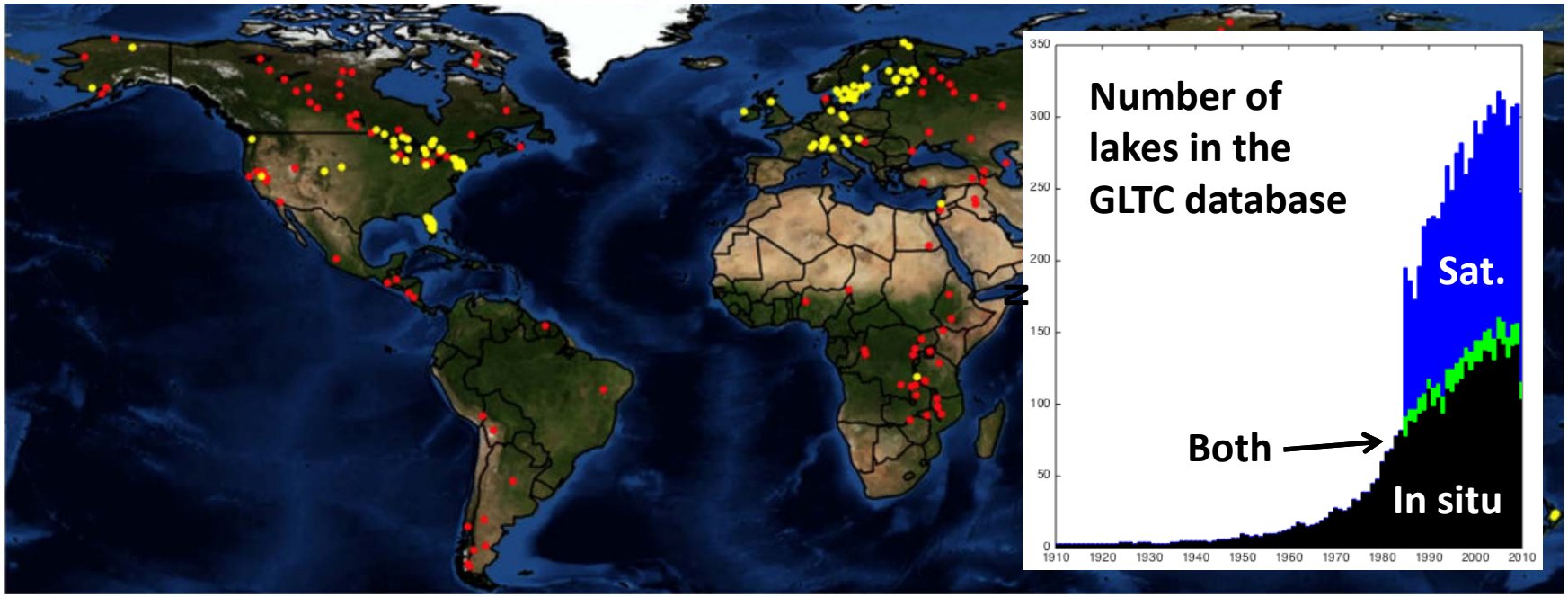
From

A global database of lake surface temperatures collected by *in situ* and satellite methods from 1985–2009

Sapna Sharma, Derek K Gray […] **Kara H Woo**

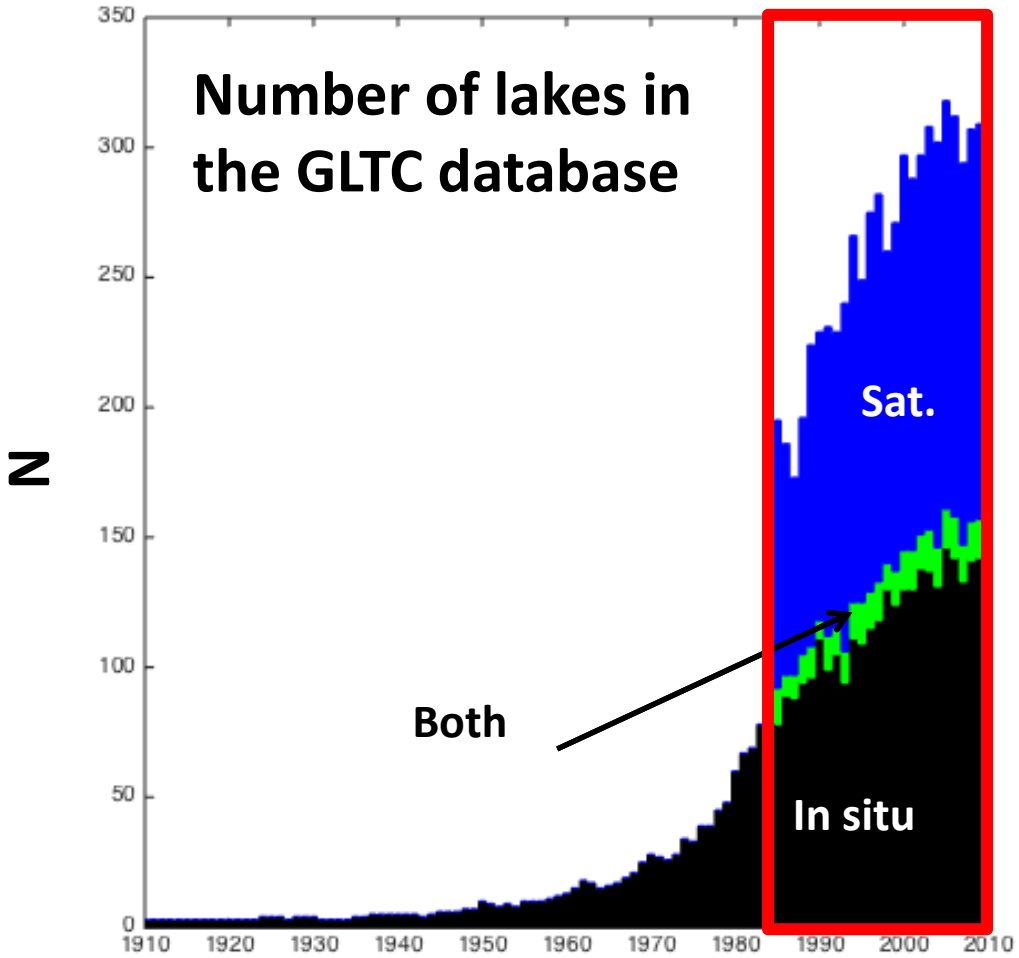
Scientific Data **2**, Article number: 150008 (2015) | doi:10.1038/sdata.2015.8

Received 17 November 2014 | Accepted 13 February 2015 | Published online 17 March 2015

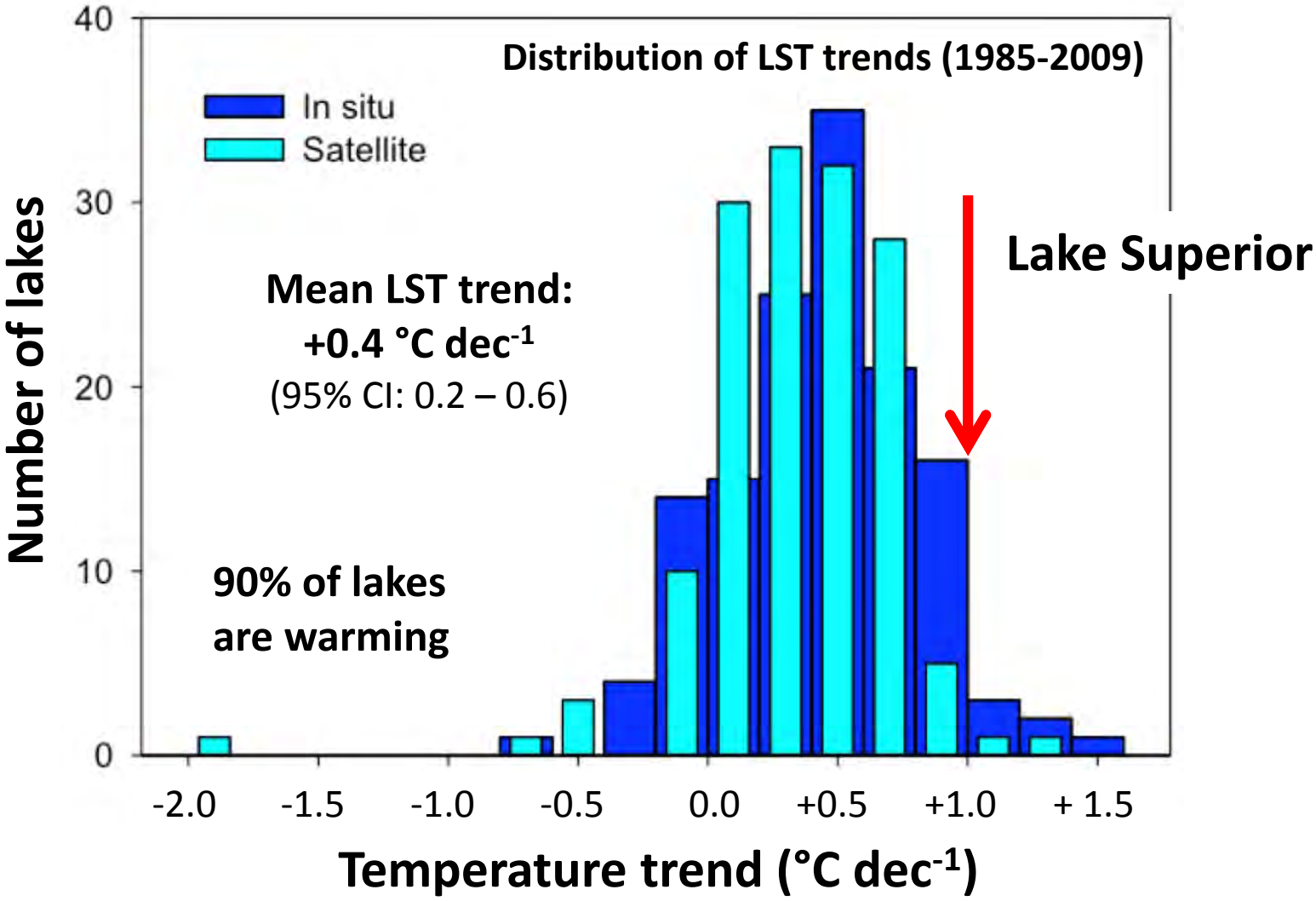


Yellow—*in situ* sampled lakes; Red—satellite sampled lakes.

Recent warming rates (1985-2009)



Distribution of LST trends (1985-2009)



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL066235

Catherine M. O'Reilly, Sapna Sharma, Derek K. Gray, and Stephanie E. Hampton joint first authors

Key Points:
- Lake surface waters are warming rapidly but are spatially heterogeneous
- Ice-covered lakes are typically warming at rates greater than air temperatures
- Both geomorphic and climate factors influence lake warming rates

Supporting Information:
- Figures S1–S4 and Tables S1–S4

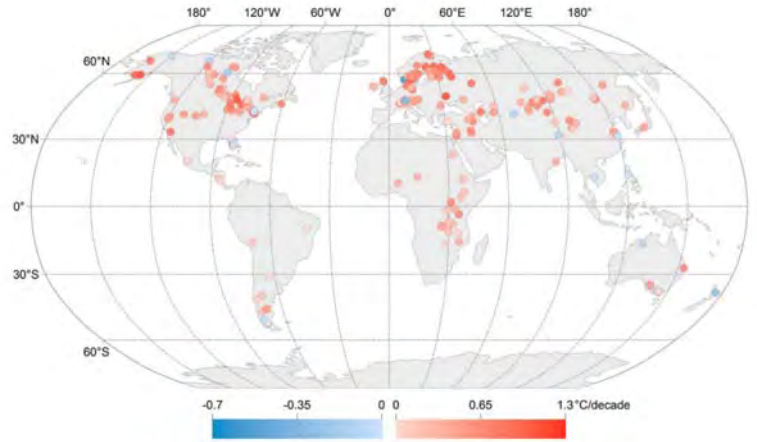
Correspondence to:
C. M. O'Reilly,
oreilly@ilstu.edu

Citation:
O'Reilly, C. M., et al. (2015), Rapid and highly variable warming of lake surface waters around the globe, *Geophys. Res. Lett.*, *42*, doi:10.1002/2015GL066235.

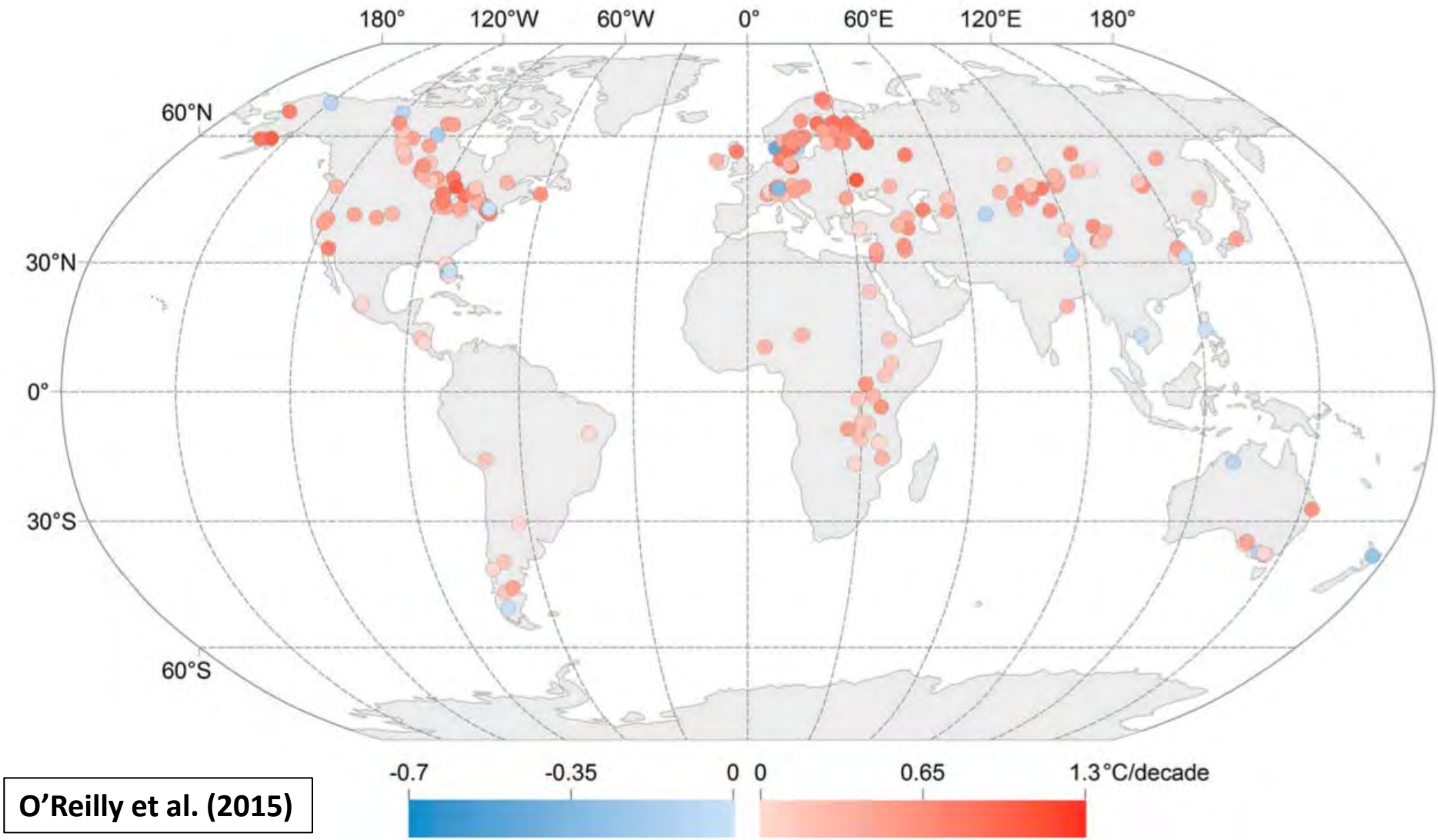
Received 16 OCT 2015
Accepted 14 NOV 2015

Rapid and highly variable warming of lake surface waters around the globe

Catherine M. O'Reilly[1], Sapna Sharma[2], Derek K. Gray[3], Stephanie E. Hampton[4], Jordan S. Read[5], Rex J. Rowley[1], Philipp Schneider[6], John D. Lenters[7], Peter B. McIntyre[8], Benjamin M. Kraemer[8], Gesa A. Weyhenmeyer[9], Dietmar Straile[10], Bo Dong[11], Rita Adrian[12], Mathew G. Allan[13], Orlane Anneville[14], Lauri Arvola[15], Jay Austin[16], John L. Bailey[17], Jill S. Baron[18], Justin D. Brookes[19], Elvira de Eyto[20], Martin T. Dokulil[21], David P. Hamilton[22], Karl Havens[23], Amy L. Hetherington[24], Scott N. Higgins[25], Simon Hook[26], Lyubov R. Izmest'eva[27], Klaus D. Joehnk[28], Kulli Kangur[29], Peter Kasprzak[30], Michio Kumagai[31], Esko Kuusisto[32], George Leshkevich[33], David M. Livingstone[34], Sally MacIntyre[35], Linda May[36], John M. Melack[37], Doerthe C. Mueller-Navarra[38], Mikhail Naumenko[39], Peeter Noges[40], Tiina Noges[40], Ryan P. North[41], Pierre-Denis Plisnier[42], Anna Rigosi[19], Alon Rimmer[43], Michela Rogora[44], Lars G. Rudstam[24], James A. Rusak[45], Nico Salmaso[46], Nihar R. Samal[47], Daniel E. Schindler[48], S. Geoffrey Schladow[49], Martin Schmid[50], Silke R. Schmidt[12], Eugene Silow[27], M. Evren Soylu[51], Katrin Teubner[52], Piet Verburg[53], Ari Voutilainen[54], Andrew Watkinson[55], Craig E. Williamson[56], and Guoqing Zhang[57]

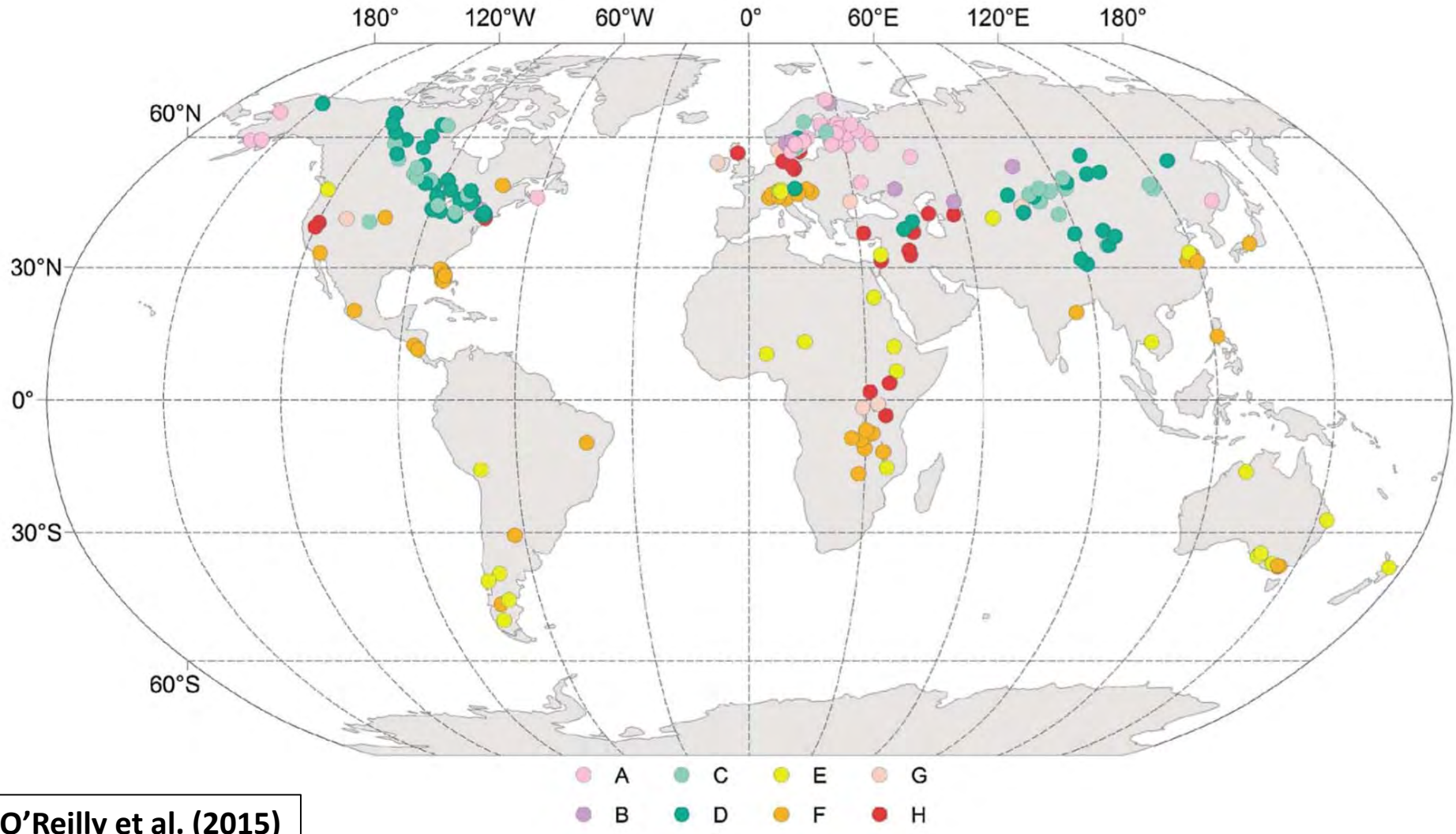


Lake surface temperature (LST) trends
(1985-2009; summer only)



O'Reilly et al. (2015)

Many factors influence warming rates



O'Reilly et al. (2015)

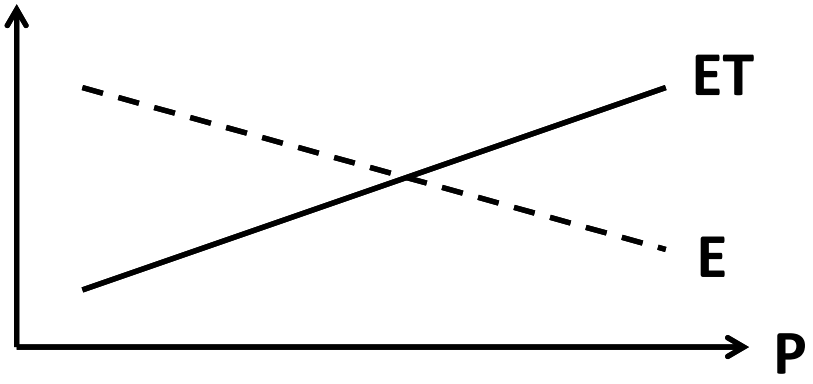
Talk outline

- Background and motivation
- Lake Superior: Big lake, big changes
- The “puzzle” of rapid lake warming
- Toward a solution: A new, global initiative
- **Implications for evaporation, water levels**
- Summary

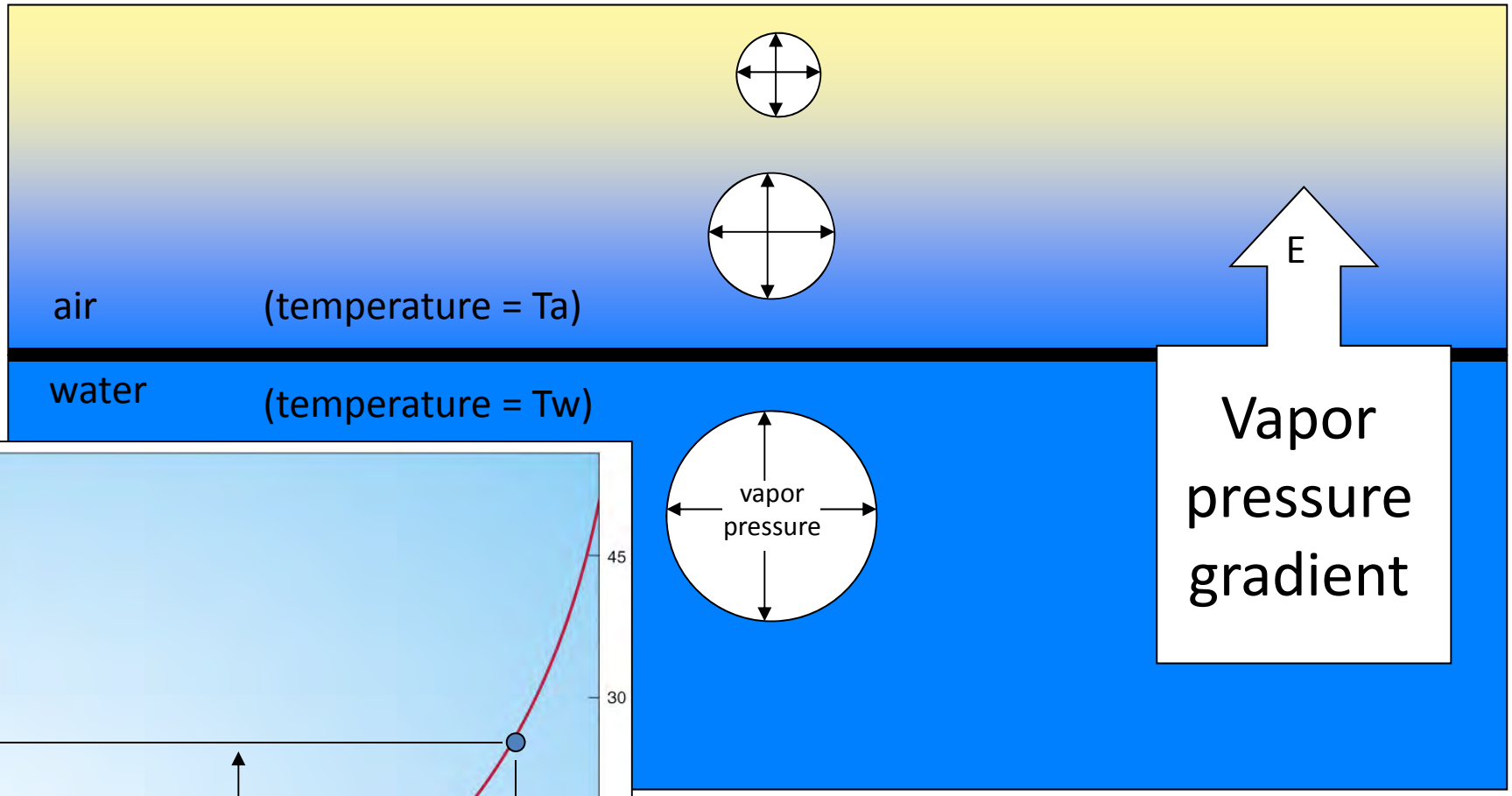
Implications for evaporation

- **Open-water evaporation can be very different from terrestrial evapotranspiration (ET)**

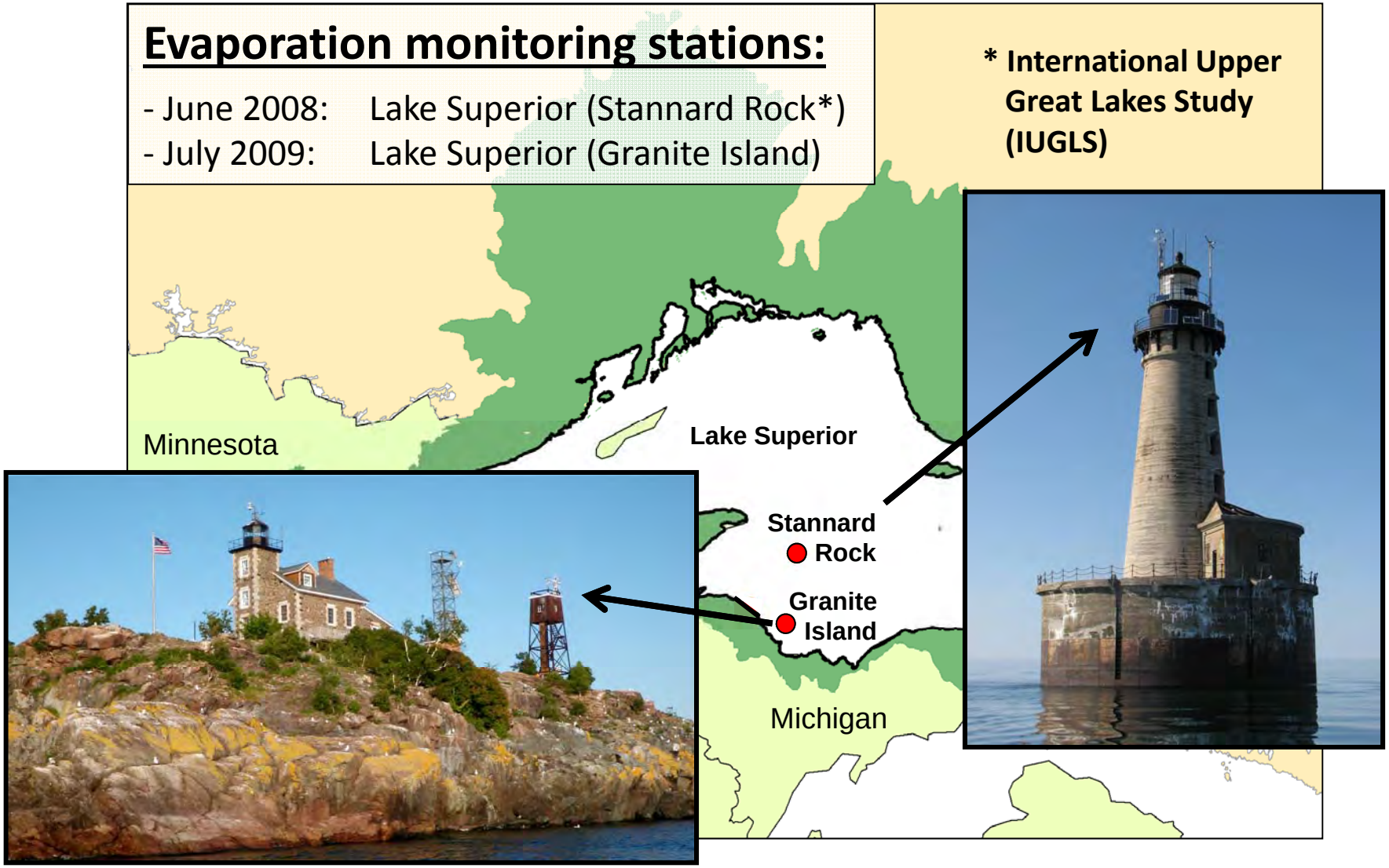
  - Different drivers
  - Different variability
  - Different impacts



Implications for evaporation



Measuring evaporation on large lakes



Instrumentation

Real-time data and imagery

Evaporati

- June 2008:
- July 2009:

Current Conditions | Wind & Pressure | Temperature | Humidity & Rain | Radiation | Evaporation

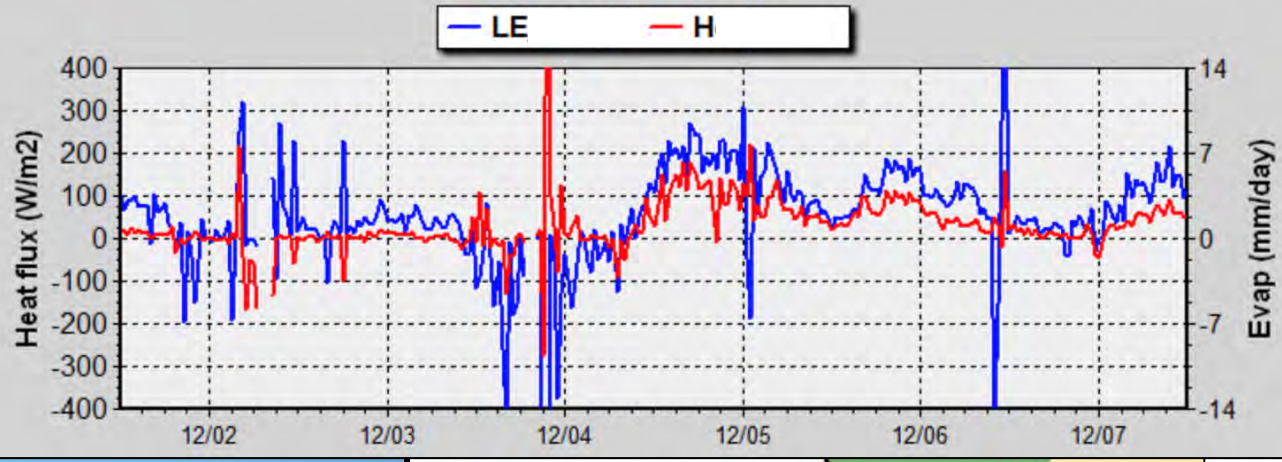
Flux-Diag | Flux-Evap | Flux-Wind | Flux-Kh | Flux-Li | Obukhov L | Table (10 min)

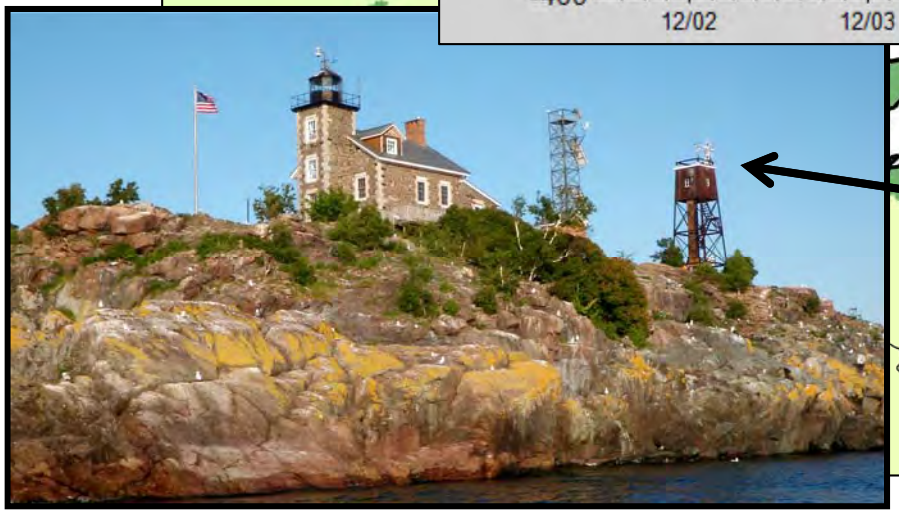
University of Nebraska Lincoln

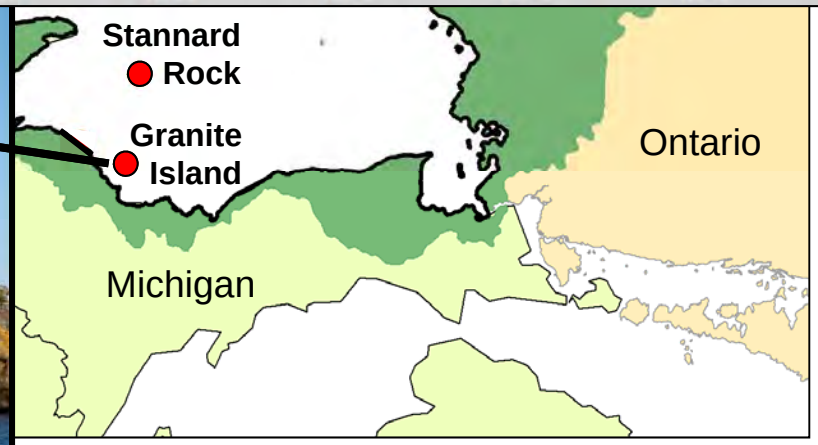
Granite Island weather conditions

(30-minute averages updated every 3 hours)

Last update: 12/7/2012 12:00:00 PM EST

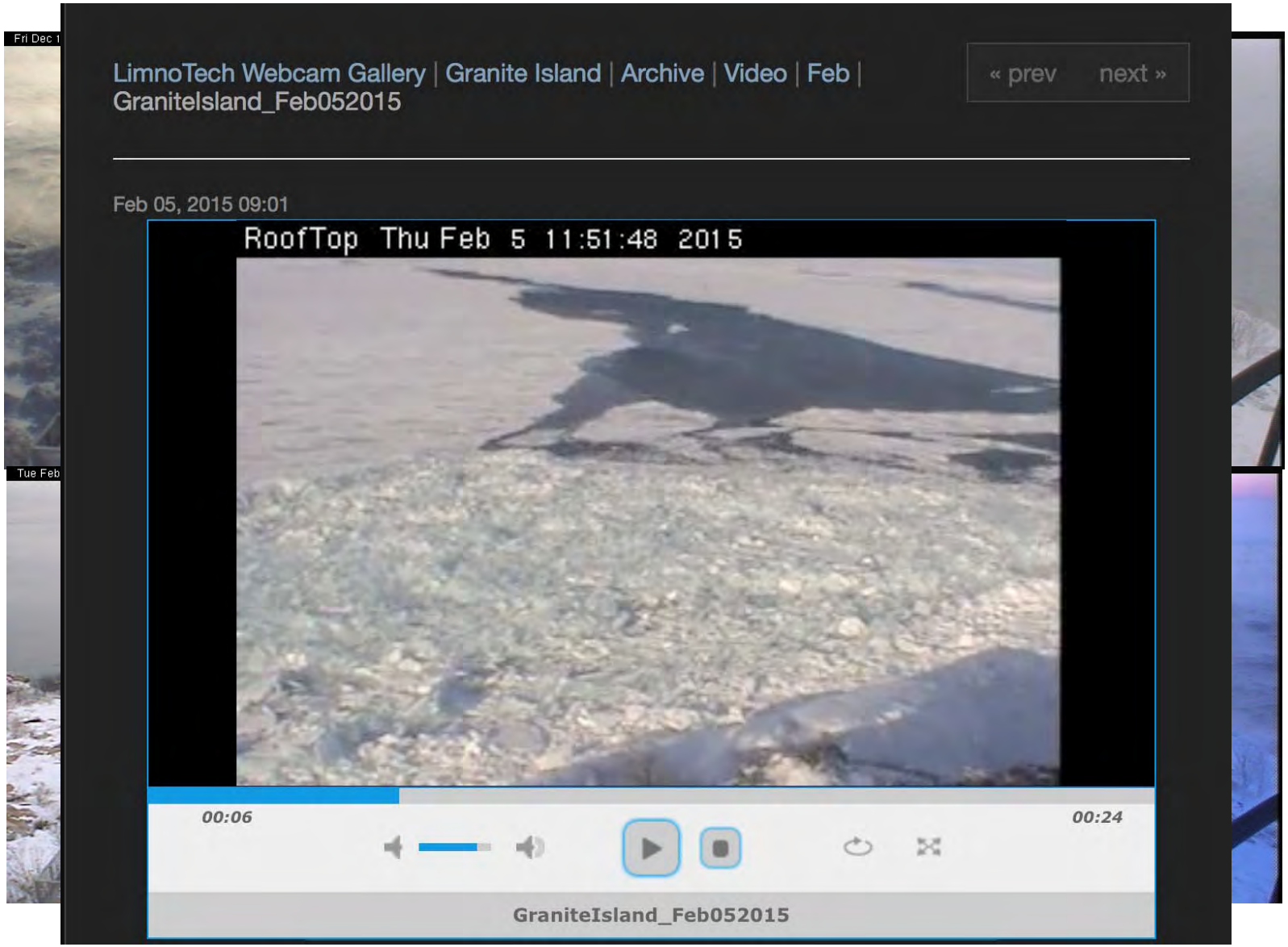




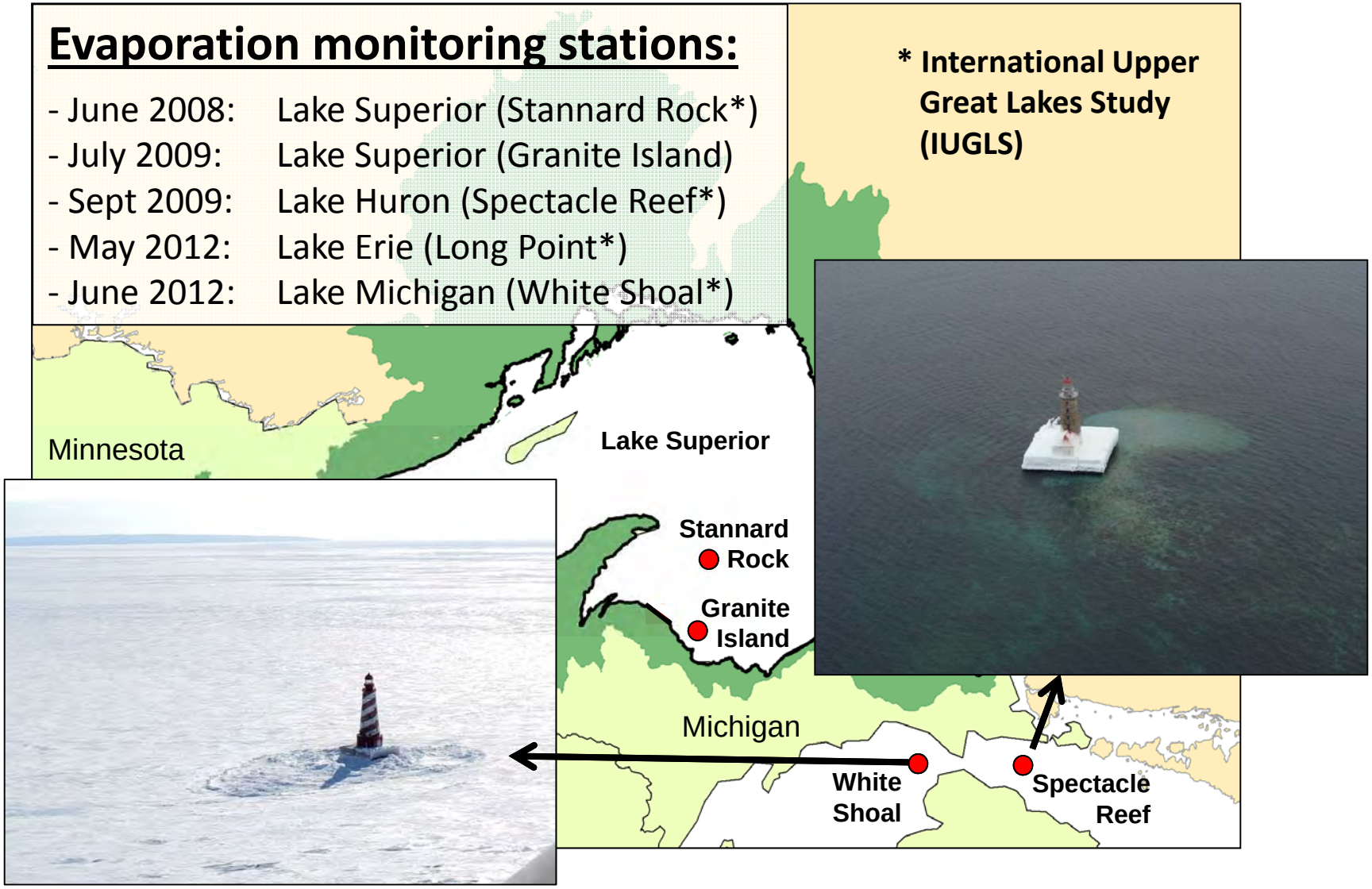


Real-time data and imagery

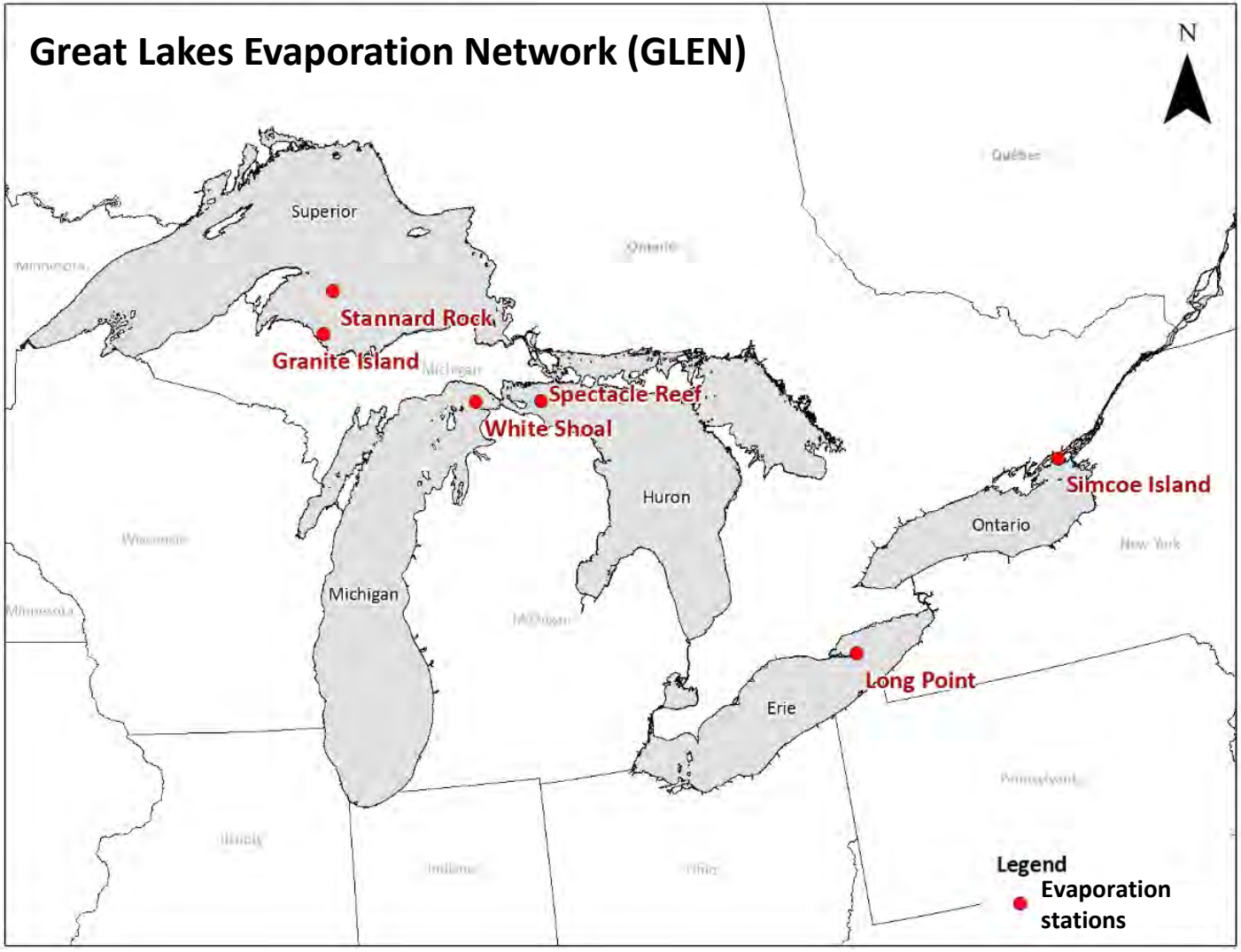
Time-lapse video



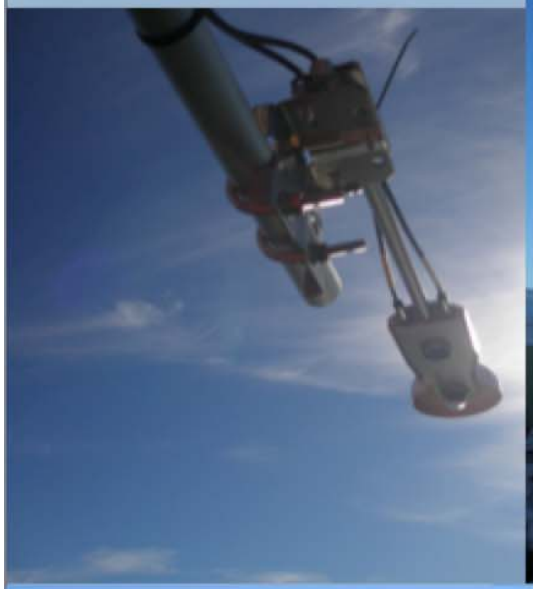
Growing the network



The current GLEN network



Fieldwork



More info on GLEN

Great Lakes Evaporation: Implications for Water Levels

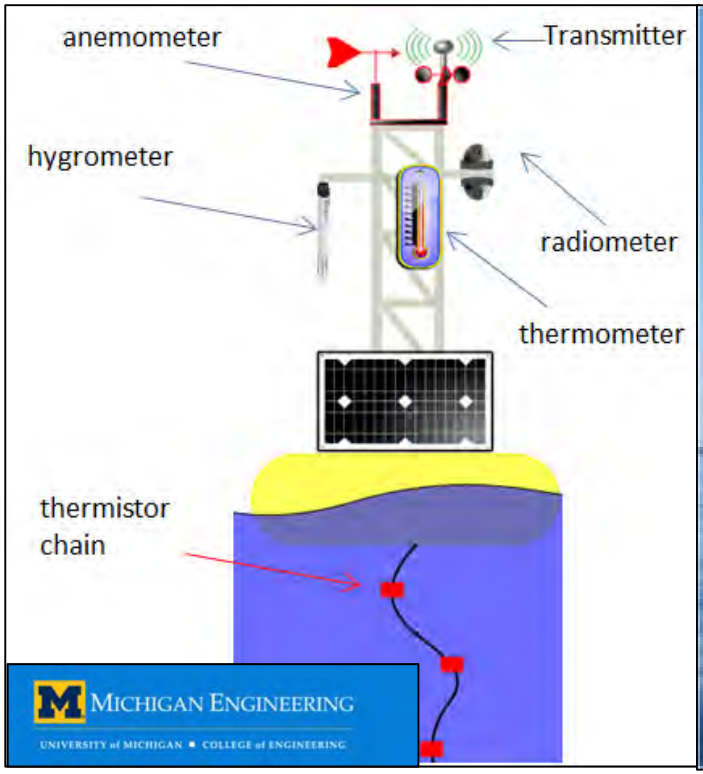
GLISA
GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS

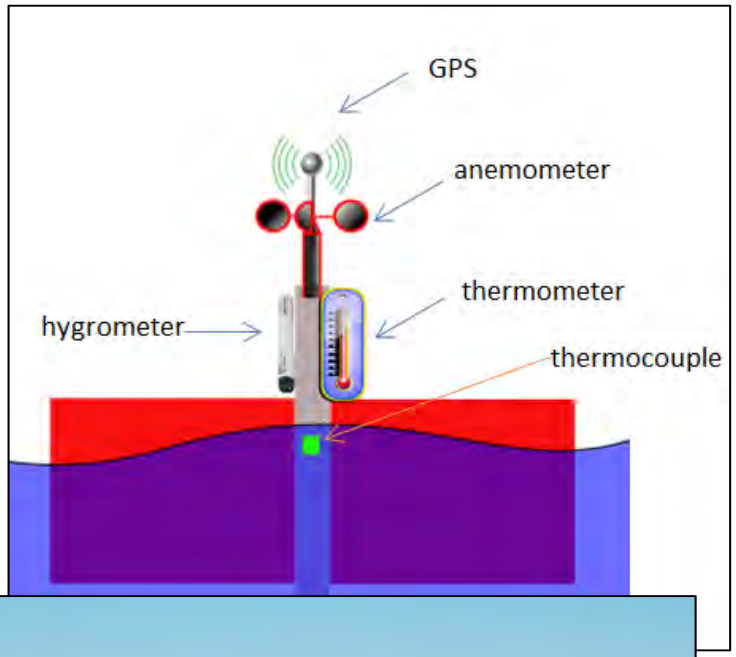
Assessing the Impacts of Climate Variability and Change on Great Lakes Evaporation:

Implications for water levels and the need for a coordinated observation network

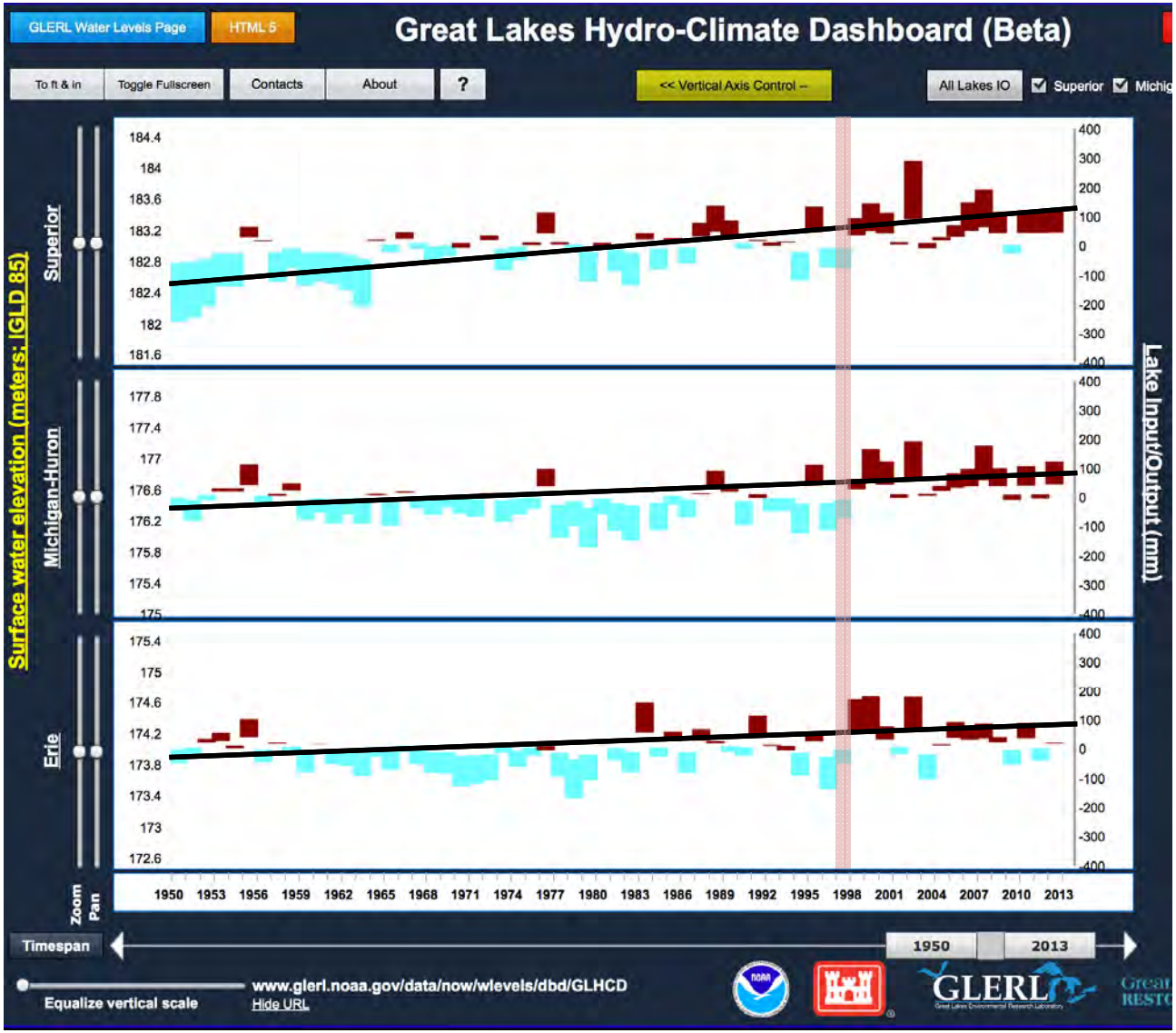
Lenters, J. D., J. B. Anderton, P. Blanken, C. Spence, and A. E. Suyker, 2013: *Assessing the Impacts of Climate Variability and Change on Great Lakes Evaporation.* In: *2011 Project Reports*. D. Brown, D. Bidwell, and L. Briley, eds. Available from the Great Lakes Integrated Sciences and Assessments (GLISA) Center: http://glisaclimate.org/media/GLISA_Lake_Evaporation.pdf

Expansion to buoys, drifters, and ships

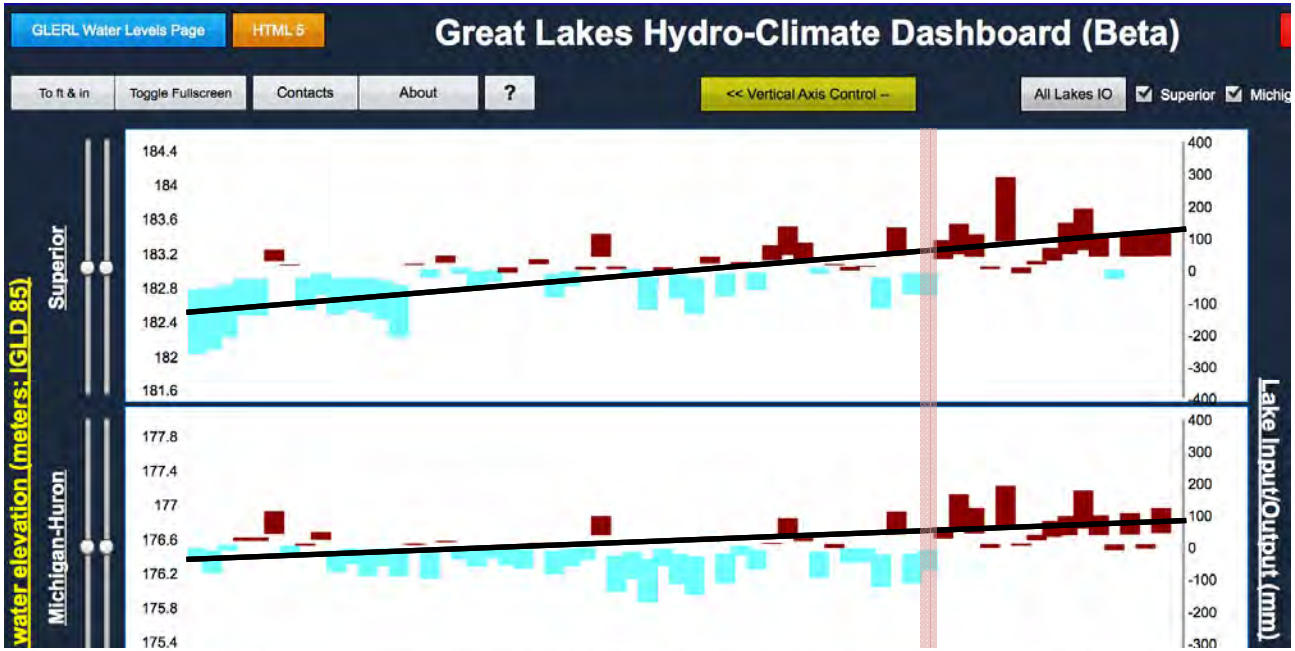


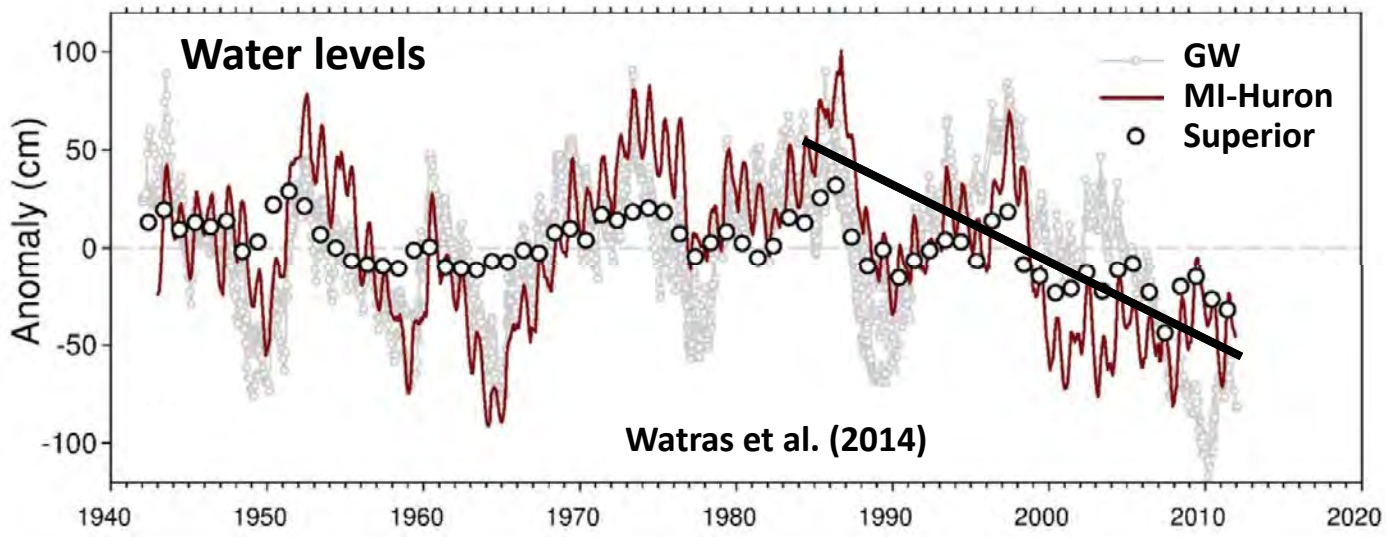


Model results show increasing evaporation



Model results show increasing evaporation





Summary

- First global compilation of satellite / *in situ* lake temperature data
- 250+ lakes in the GLTC database; most covering at least 25 years
- ~90% of the lakes in the database are warming (1985-2009)
- Satellite / *in situ* data show similar rates of lake surface warming
- “Global” LST has increased ~2 standard deviations since 1900
- Great Lakes are warming rapidly (esp. Superior and Huron)

Summary

- Most rapid warming is in recent decades (~0.4 °C dec^{-1})
- Some changes are non-linear (e.g., Lake Superior regime shift)
- Interdecadal variability in global LST is coherent with T_{air}, lake ice, and global patterns of solar dimming / brightening
- Important implications for lake evaporation, water levels
- **Long-term, global datasets provide valuable perspective**

Acknowledgements

- Many thanks to the **numerous scientists and institutions** that contributed data and expertise to the GLTC project (http://laketemperature.org/).
- Special thanks to the GLTC data analysis sub-group: Derek Gray, Stephanie Hampton, Peter McIntyre, Catherine O'Reilly, Jordan Read, Sapna Sharma, Noemi Barabas, Dendy Lofton, R. J. Rowley, Evren Soylu, and Piet Verburg
- We gratefully acknowledge NSF, NASA, and the University of Nebraska-Lincoln for funding the GLTC workshop, as well as other institutions for their support.

LimnoTech Water Environment | Scientists Engineers

NSF

NASA

University of Nebraska Lincoln

GLTC Contributors

Sapna Sharma, Derek K. Gray, Jordan S. Read, Catherine M. O'Reilly, Philipp Schneider, Anam Qudrat, Corinna Gries, Samantha Stefanoff, Stephanie E. Hampton, Simon Hook, John D. Lenters, David M. Livingstone, Peter B. McIntyre, Rita Adrian, Mathew G. Allan, Orlane Anneville, Lauri Arvola, Jay Austin, John Bailey, Jill S. Baron, Justin Brookes, Yuwei Chen, Robert Daly, Martin Dokulil, Bo Dong, Kye Ewing, Elvira de Eyto, David Hamilton, Karl Havens, Shane Haydon, Harald Hetzenauer, Jocelyne Heneberry, Amy L. Hetherington, Scott N. Higgins, Eric Hixson, Lyubov R. Izmest'eva, Benjamin M. Jones, Küllli Kangur, Peter Kasprzak, Olivier Köster, Benjamin M. Kraemer, Michio Kumagai, Esko Kuusisto, George Leshkevich, Linda May, Sally MacIntyre, Dörthe Müller-Navarra, Mikhail Naumenko, Peeter Noges, Tiina Noges, Pius Niederhauser, Ryan P. North, Andrew Paterson, Pierre-Denis Plisnier, Anna Rigosi, Alon Rimmer, Michela Rogora, Lars Rudstam, James A. Rusak, Nico Salmaso, Nihar R. Samal, Daniel E. Schindler, Geoffrey Schladow, Silke R. Schmidt, Tracey Schultz, Eugene A. Silow, Dietmar Straile, Katrin Teubner, Piet Verburg, Ari Voutilainen, Andrew Watkinson, Gesa A. Weyhenmeyer, Craig E. Williamson, Kara H. Woo, Catherine M. O'Reilly, Sapna Sharma, Derek K. Gray, Stephanie E. Hampton, Jordan S. Read, Rex J. Rowley, Philipp Schneider, John D. Lenters, Peter B. McIntyre, Benjamin M. Kraemer, Gesa A. Weyhenmeyer, Dietmar Straile, Bo Dong, Rita Adrian, Mathew G. Allan, Orlane Anneville, Lauri Arvola, Jay Austin, John L. Bailey, Jill S. Baron, Justin D. Brookes, Elvira de Eyto, Martin T. Dokulil, David P. Hamilton, Karl Havens, Amy L. Hetherington, Scott N. Higgins, Simon Hook, Lyubov R. Izmest'eva, Klaus D. Jöhnk, Külli Kangur, Peter Kasprzak, Michio Kumagai, Esko Kuusisto, George Leshkevich, David M. Livingstone, Sally MacIntyre, Linda May, John M. Melack, Dörthe C. Müller-Navarra, Mikhail Naumenko, Peeter Nõges, Tiina Nõges, Ryan P. North, Pierre-Denis Plisnier, Anna Rigosi, Alon Rimmer, Michela Rogora, Lars G. Rudstam, James A. Rusak, Nico Salmaso, Nihar R. Samal, Daniel E. Schindler, S. Geoffrey Schladow, Martin Schmid, Silke R. Schmidt, Eugene Silow, M. Evren Soylu, Katrin Teubner, Piet Verburg, Ari Voutilainen, Andrew Watkinson, Craig E. Williamson, Guoqing Zhang, John D. Lenters, David M. Livingstone, Catherine M. O'Reilly, Martin T. Dokulil, Gesa A. Weyhenmeyer, Philipp Schneider, Sapna Sharma, Elvira de Eyto, Rita Adrian, Scott N. Higgins, Pierre-Denis Plisnier, Nico Salmaso, Dietmar Straille, Bo Dong, Piet Verburg, George Leshkevich, Peter B. McIntyre, Jordan S. Read, Silke Schmidt, Peeter Nõges, Tiina Nõges, Benjamin M. Kraemer, Mathew Allan, Martin Schmid, Geoffrey Schladow, Sally MacIntyre, David Hamilton, Alon Rimmer, Orlane Anneville, Stephanie E. Hampton, Claude Duguay, Amy L. Hetherington, Dendy D. Lofton, James A. Rusak, Nihar R. Samal, Noemi Barabas, Justin Brookes, Robert C. Wilson, Derek K. Gray, Simon Hook, Mehmet E. Soylu


Questions?