Clean Lakes Alliance
Healthy Lakes • Healthy Community

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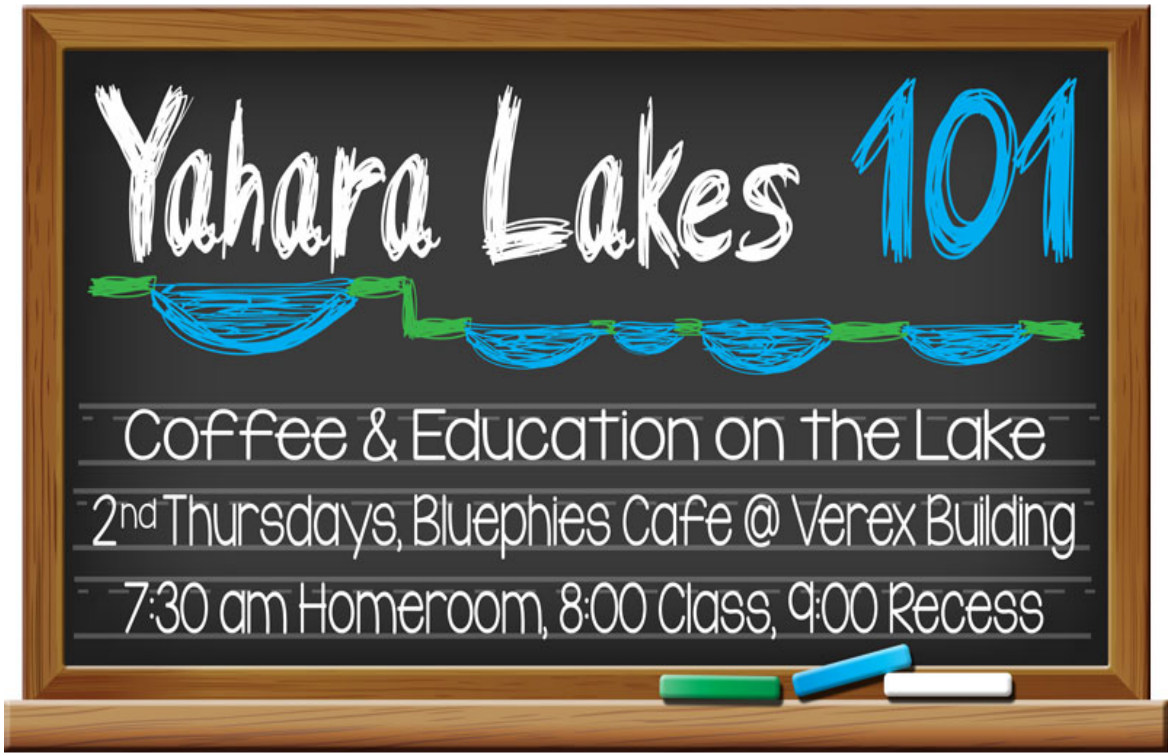

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CAN LAKES CHANGE THE GLOBAL CLIMATE?

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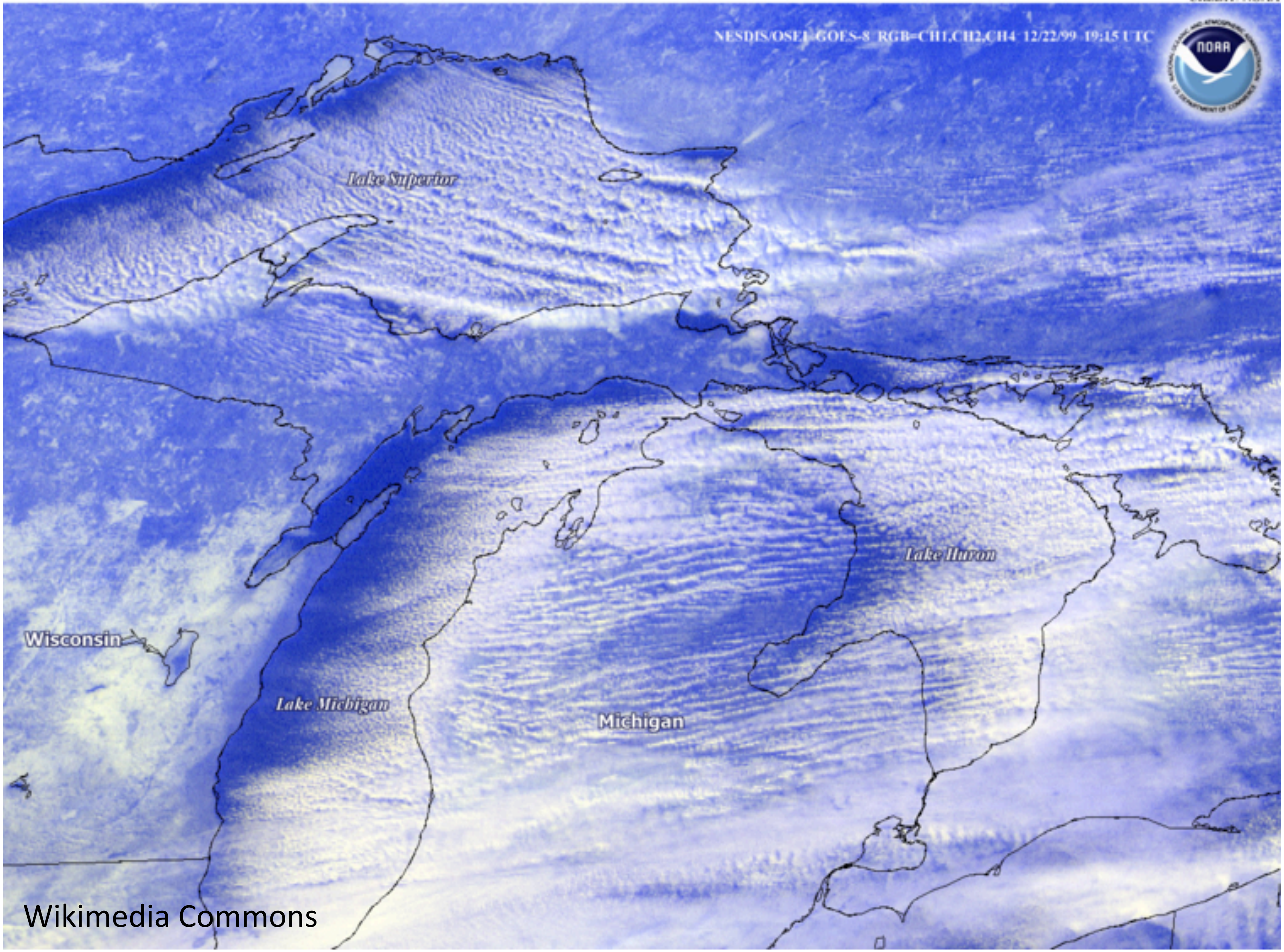
University of Wisconsin-Madison
Atmospheric and Oceanic Sciences

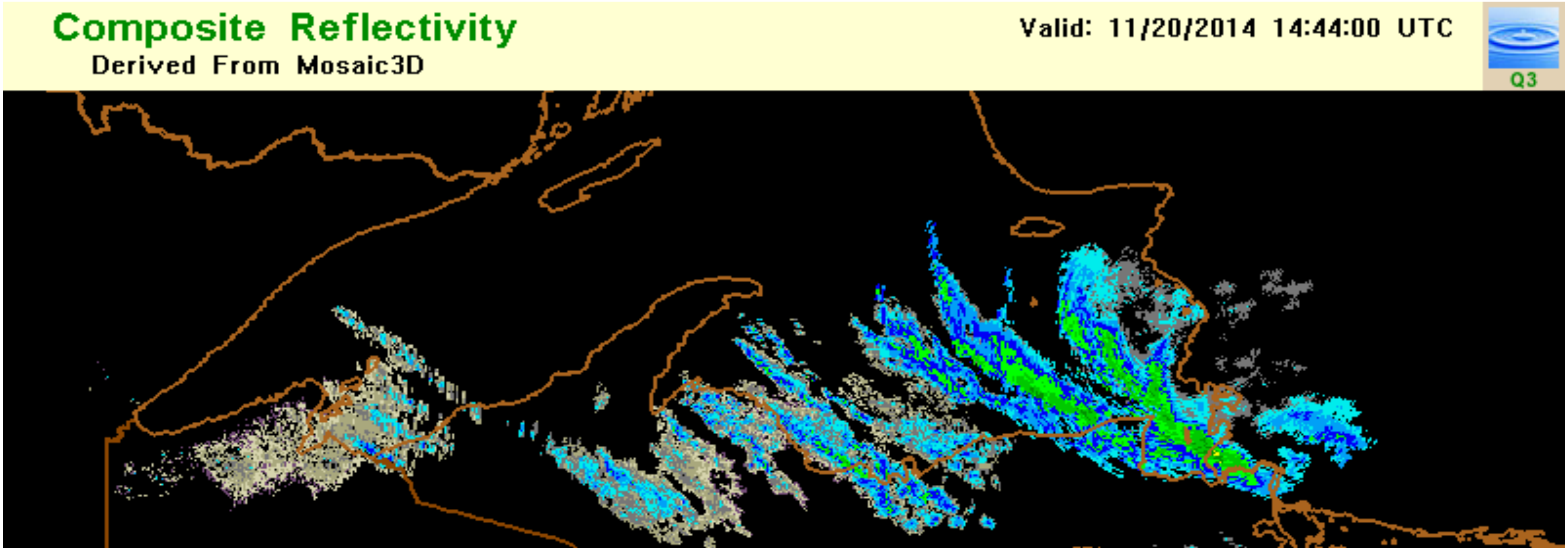
Clean Lakes Alliance
March 12, 2015

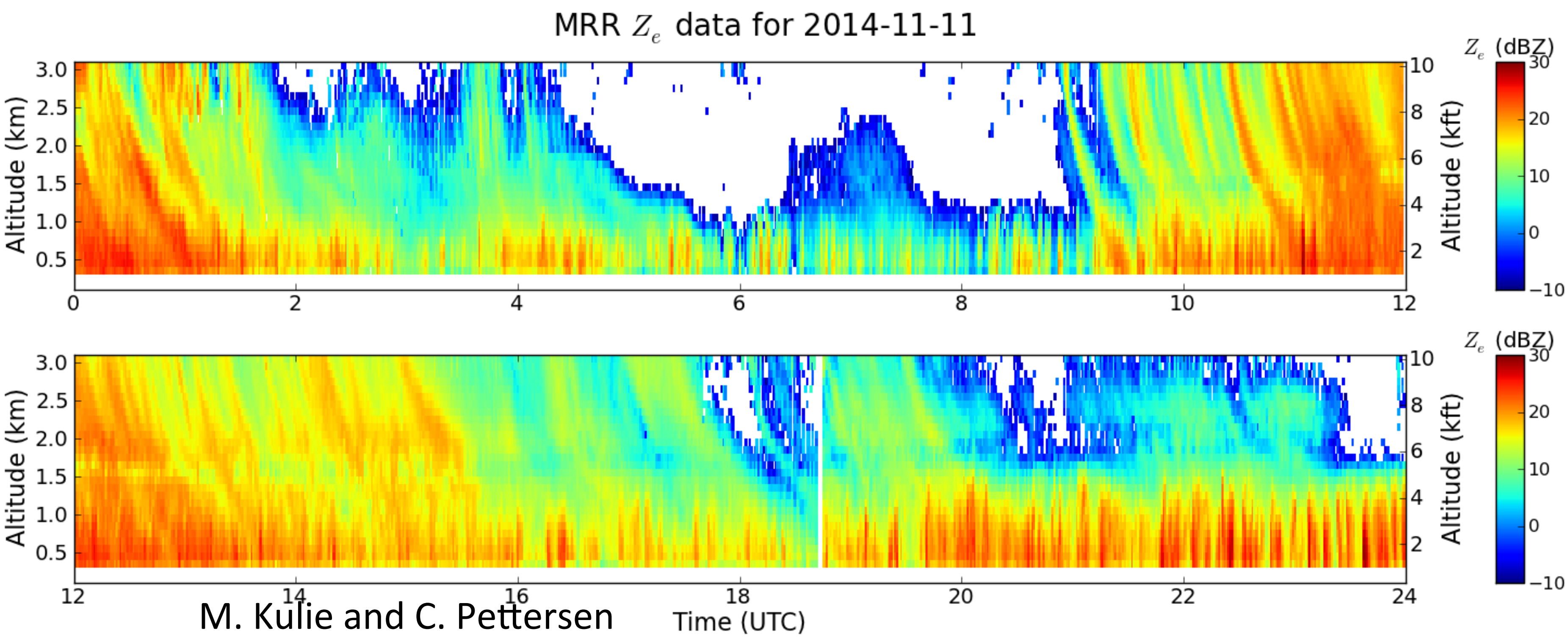
AGU/Flikr

Lake effect snow continues for the second day on the eastern shores of Lake Superior, Lake Michigan and Lake Huron. Lake effect snow occurs when cold air flows over the relatively warm surfaces of the lakes causing lifting and condensation.

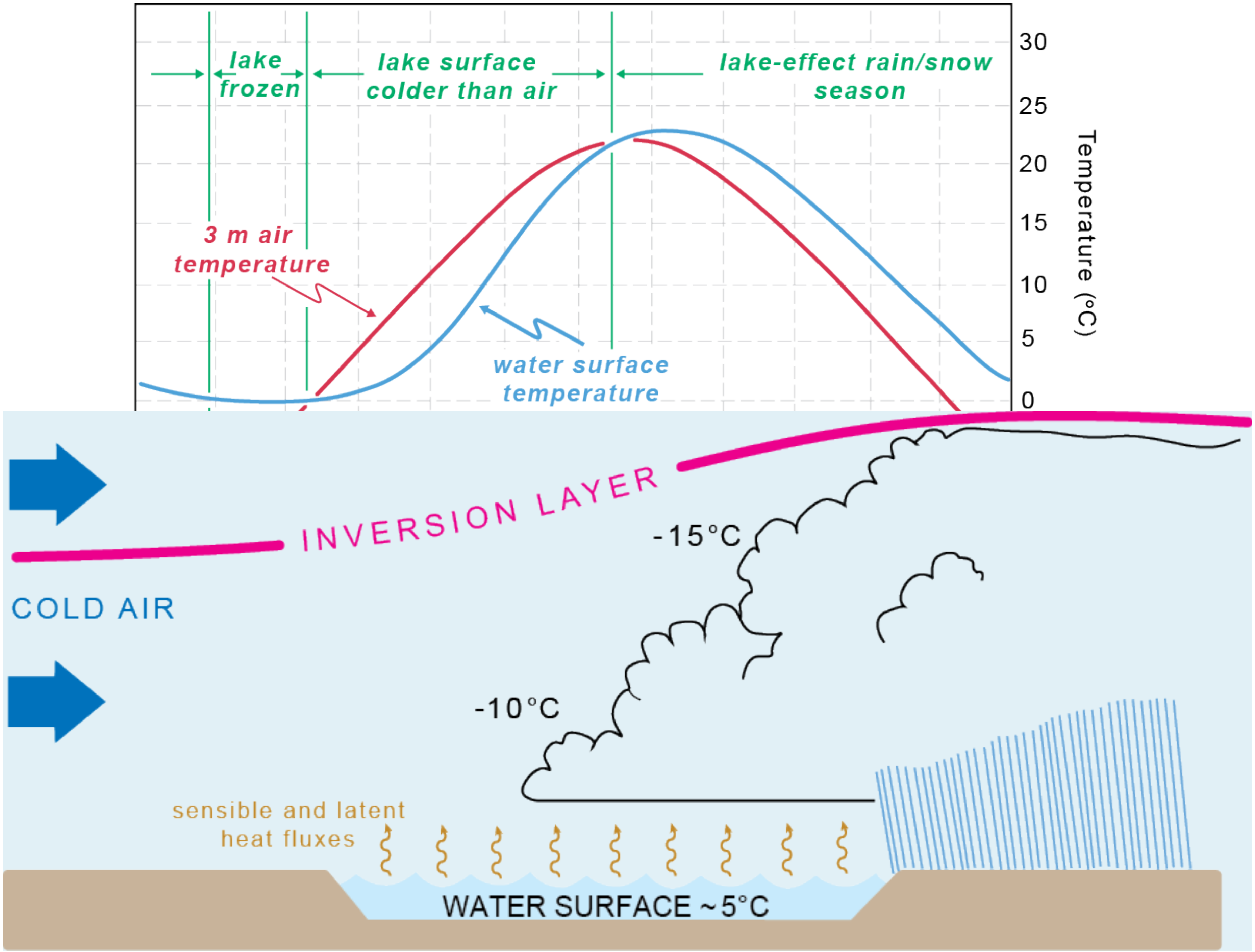
CREDIT: NOAA





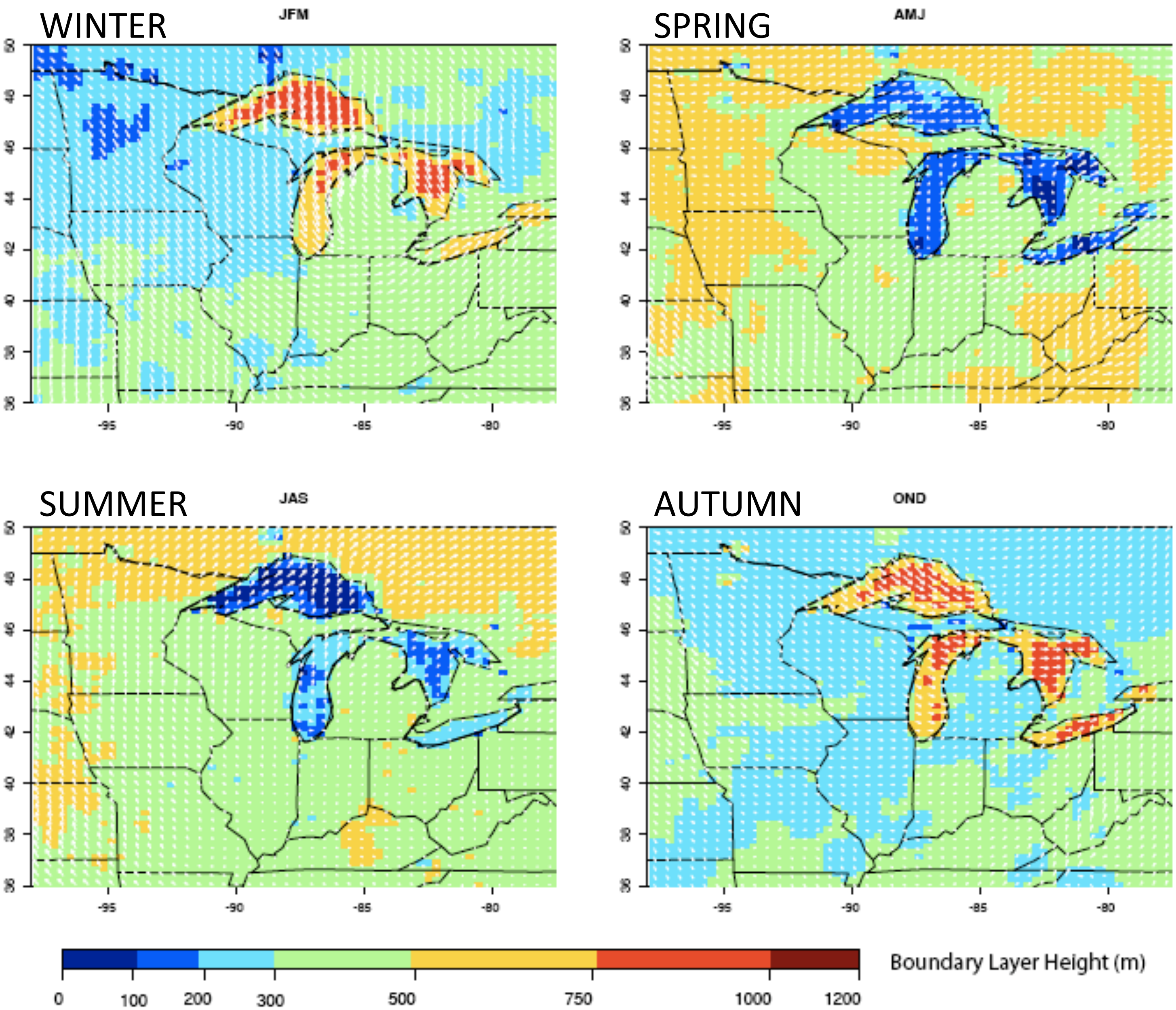


M. Kulie and C. Pettersen

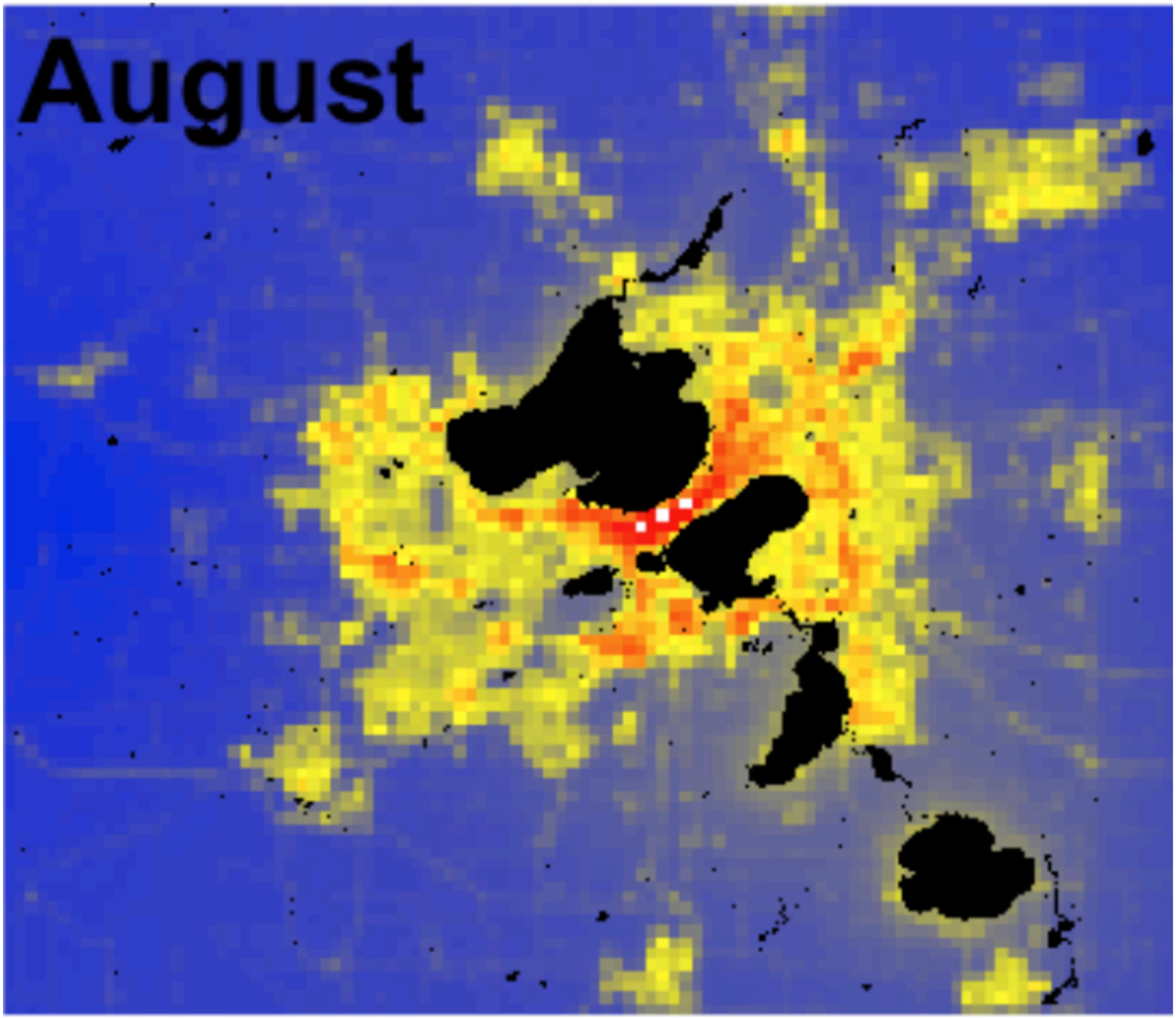


lake frozen
lake surface colder than air
lake-effect rain/snow season
3 m air temperature
water surface temperature
30
25
20
15
10
5
0
Temperature (°C)
INVERSION LAYER
COLD AIR
-15°C
-10°C
sensible and latent heat fluxes
WATER SURFACE ~5°C

Seasonal mean atmospheric boundary layer height (m) and 10 m winds in a 2002 MM5 simulation.
Adapted from Spak and Holloway (2008, in prep.).

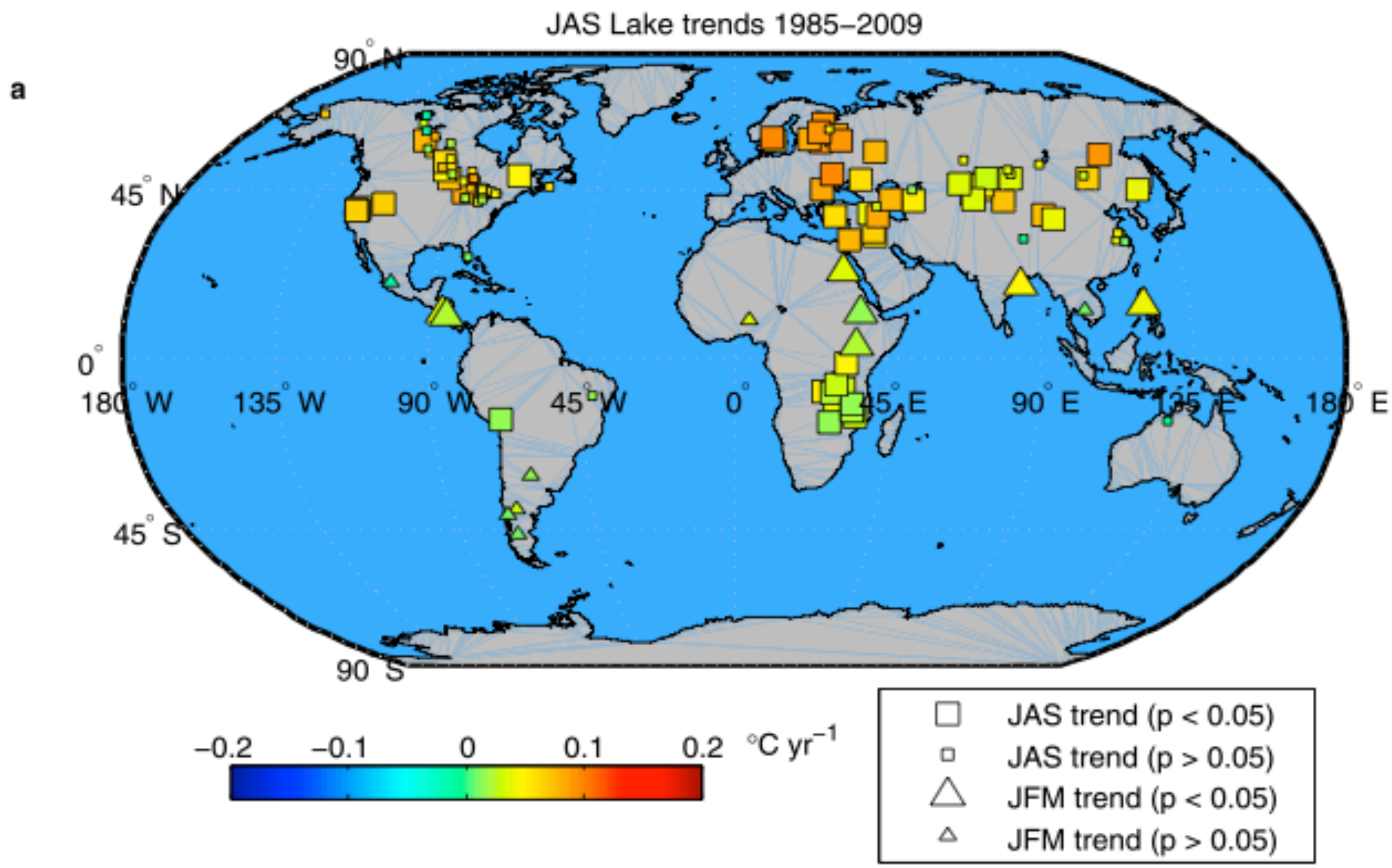


S.Spak

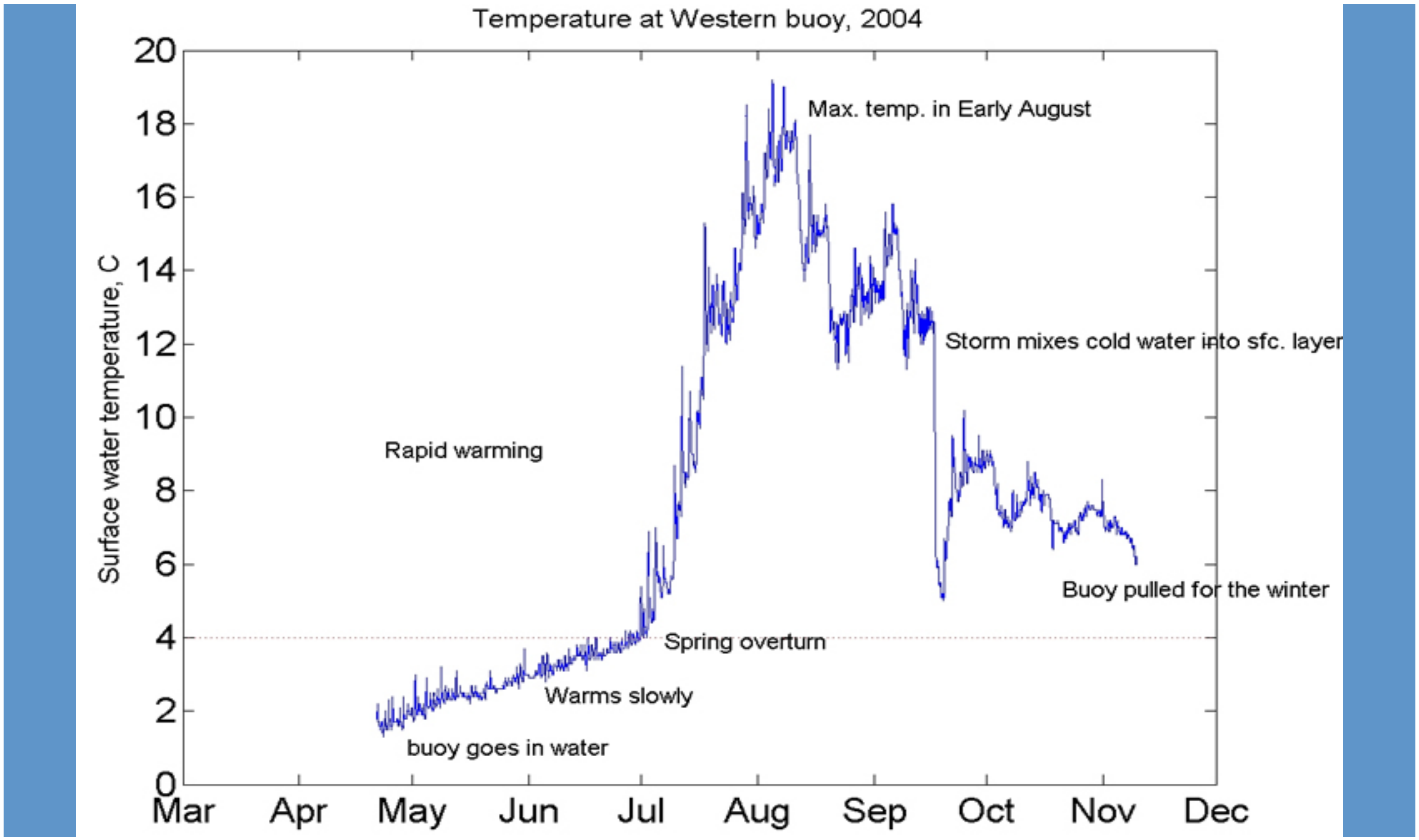


J. Schatz, 2014, JAMC

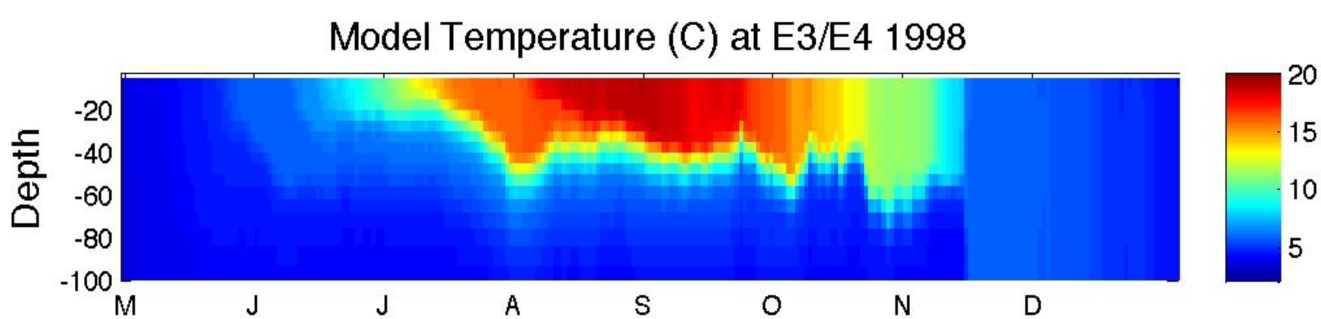
Globally, lakes of all sizes are warming faster than the air



Schneider and Hook, 2010 GRL

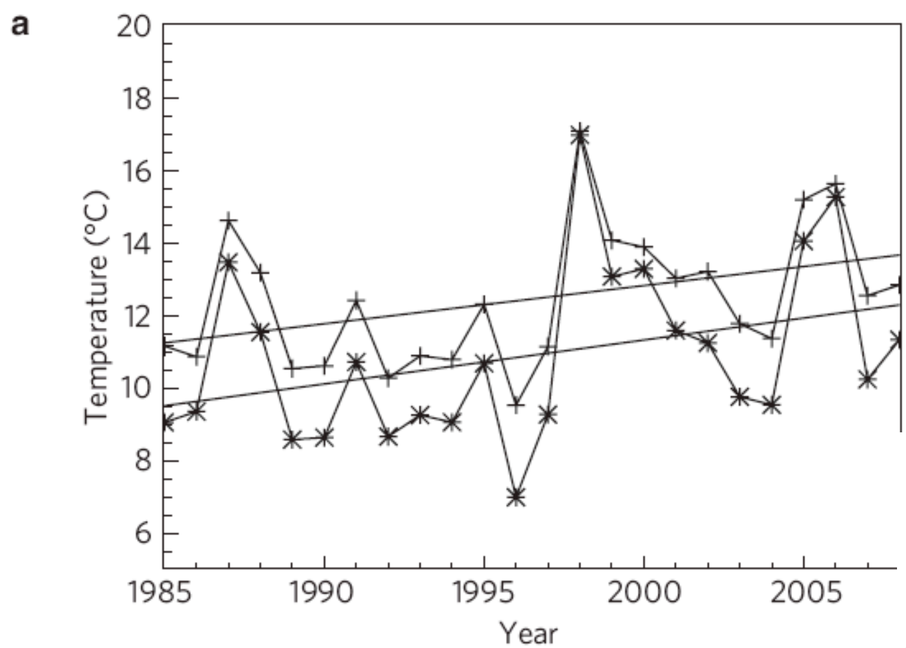


Temperature at Western buoy, 2004
Surface water temperature, C
Max. temp. in Early August
Storm mixes cold water into sfc. layer
Rapid warming
Buoy pulled for the winter
Spring overturn
Warms slowly
buoy goes in water
0
2
4
6
8
10
12
14
16
18
20
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



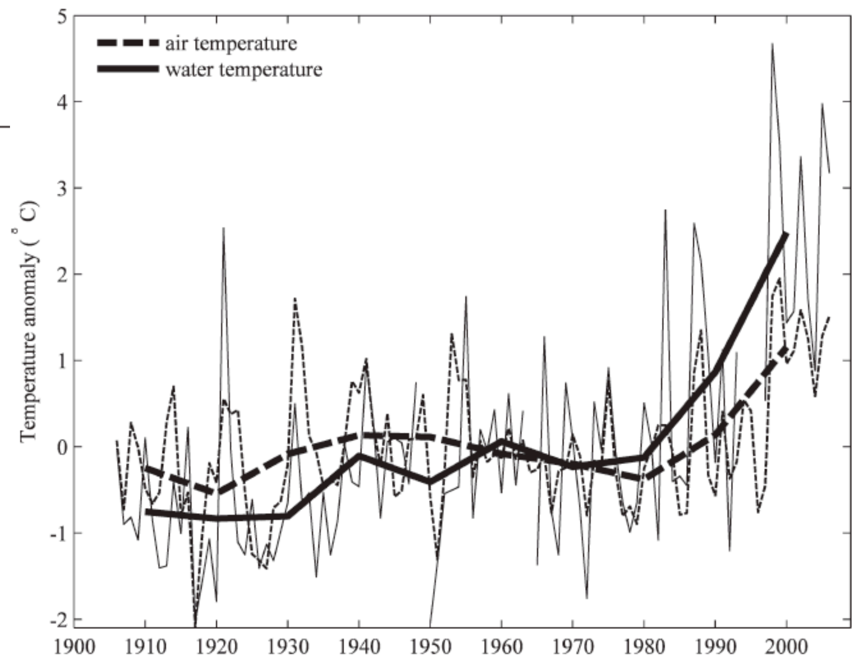
Model Temperature (C) at E3/E4 1998
Depth
-20
-40
-60
-80
-100
M
J
J
A
S
O
N
D
20
15
10
5

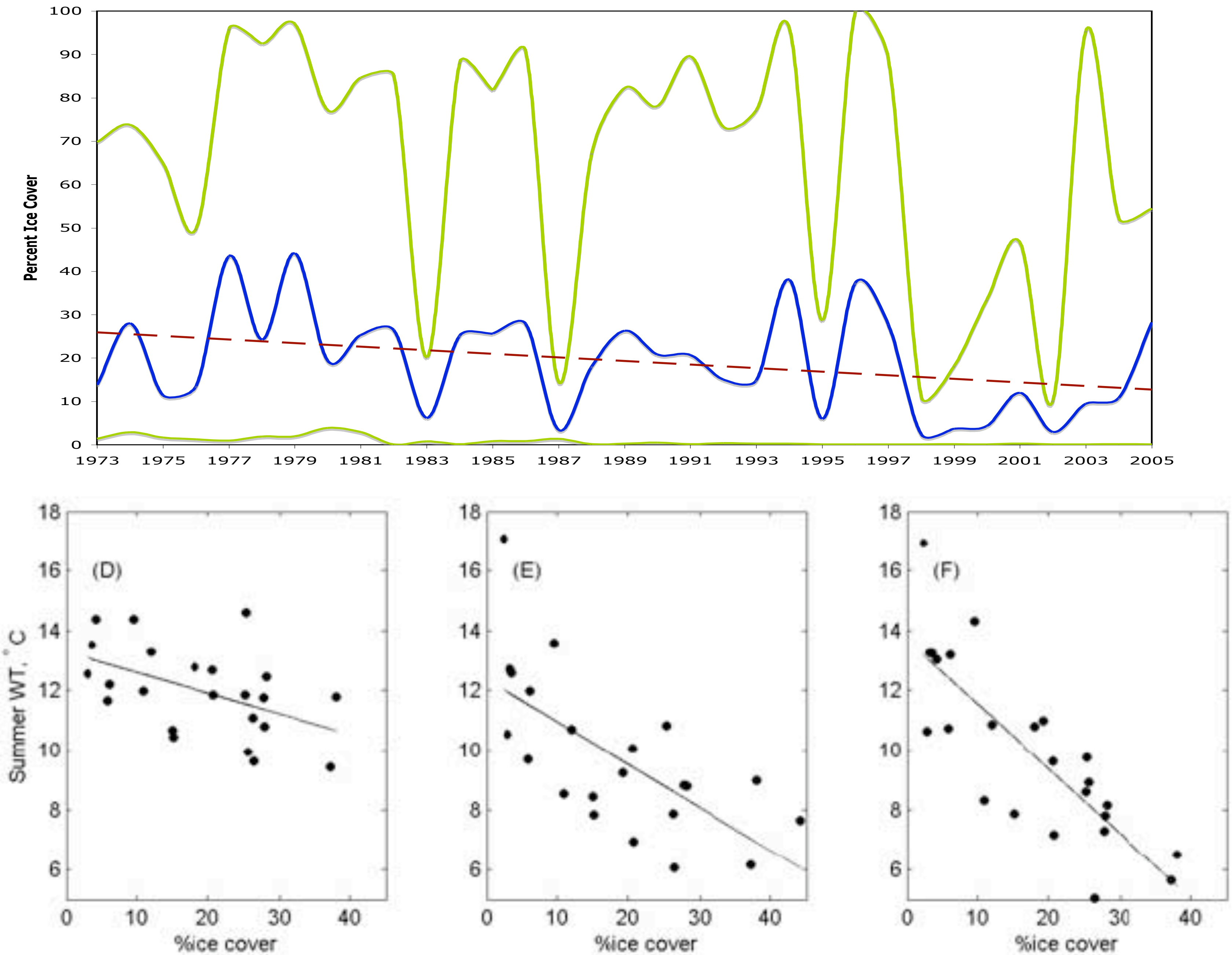
Air: 1.9 F $decade^{-1}$ vs Lake: 2.2 F $decade^{-1}$



Desai 2009

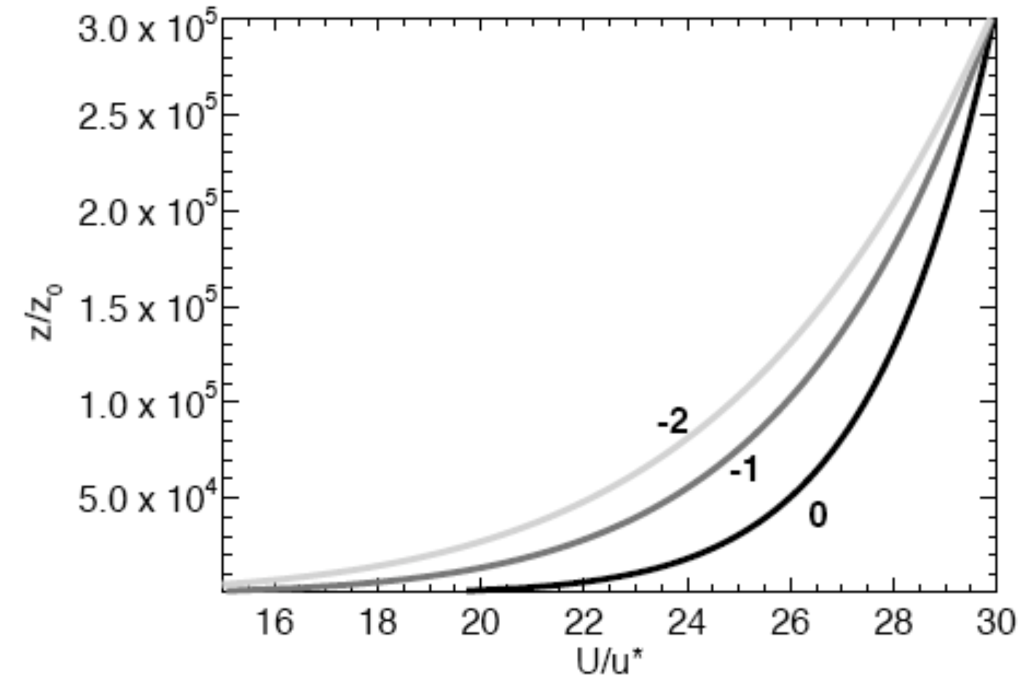
Austin and Colman 2008

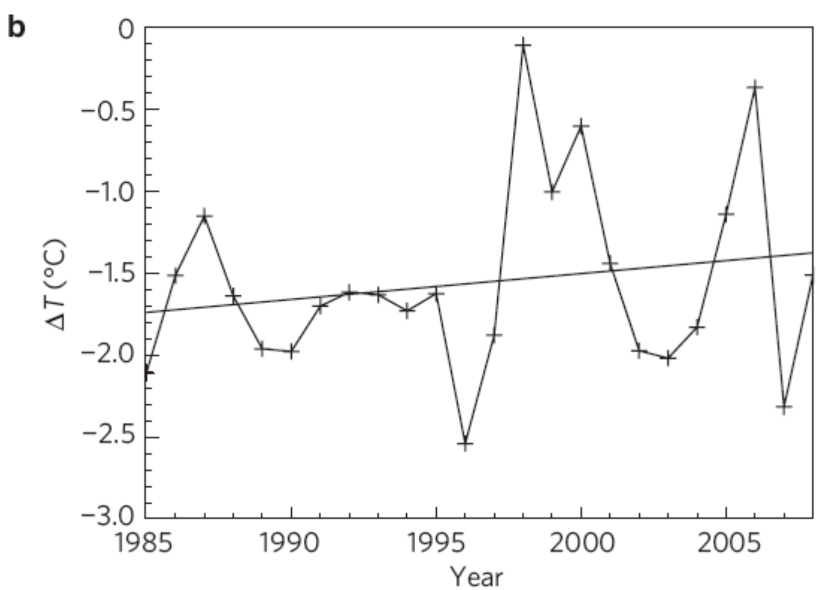


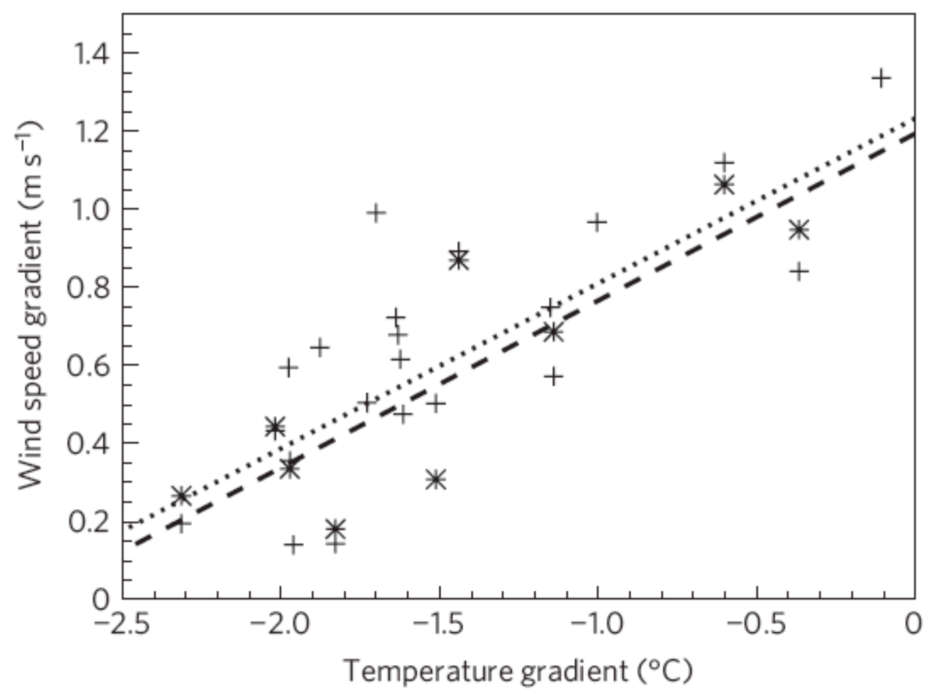


Percent Ice Cover
100
90
80
70
60
50
40
30
20
10
0
1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005
(D)
(E)
(F)
Summer WT, °C
18
16
14
12
10
8
6
0 10 20 30 40
%ice cover

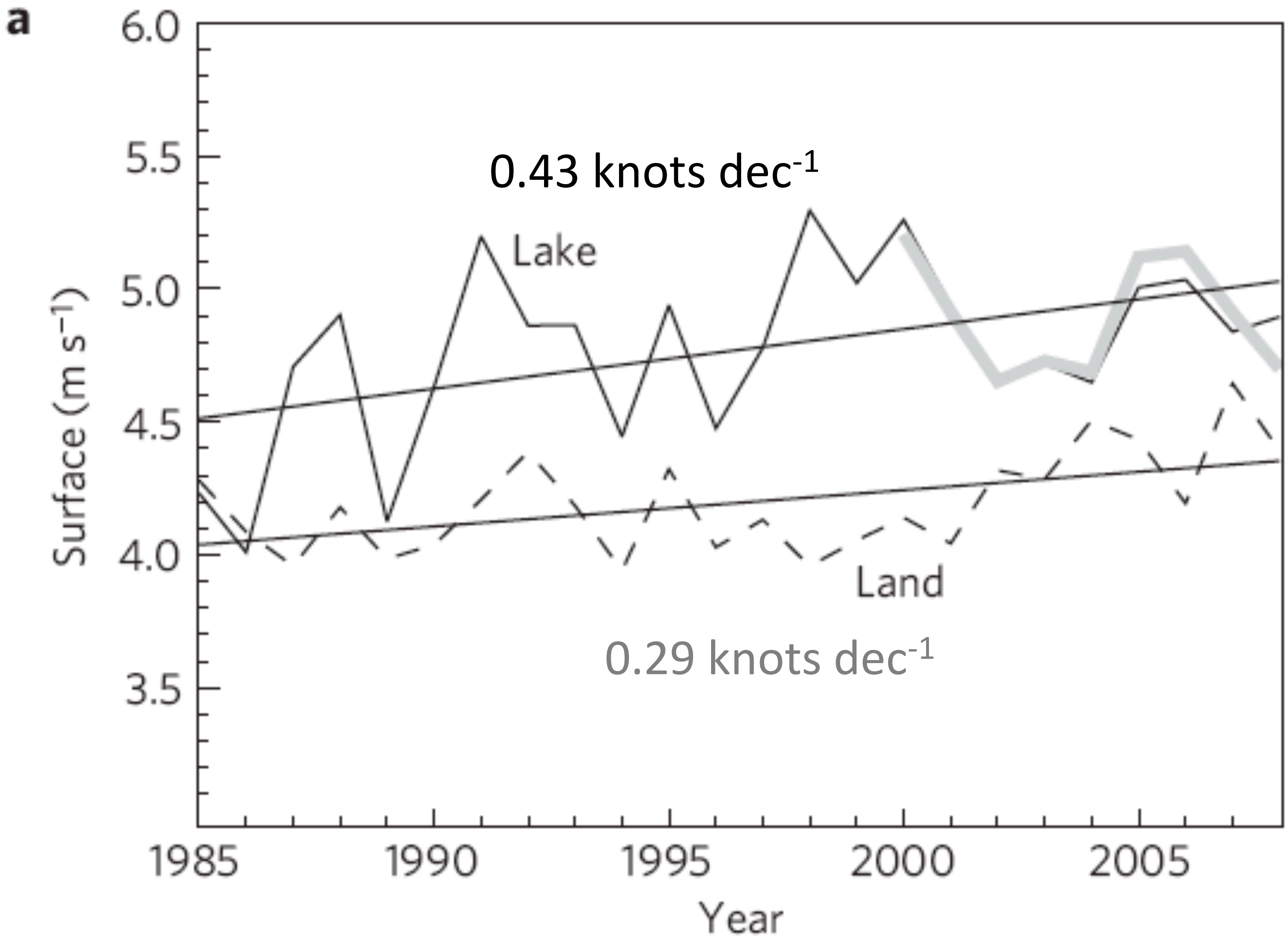
- DT = Lake temp – Air temp





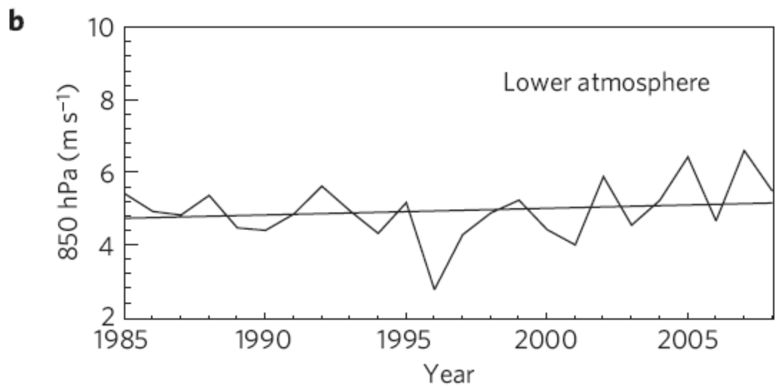


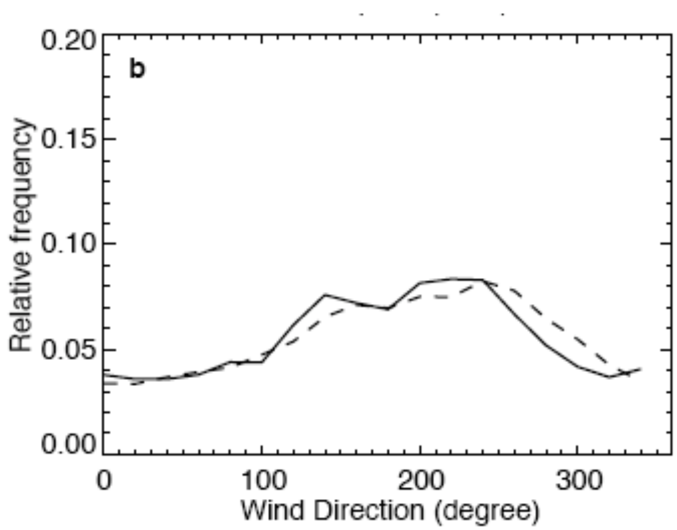
Desai et al., 2009

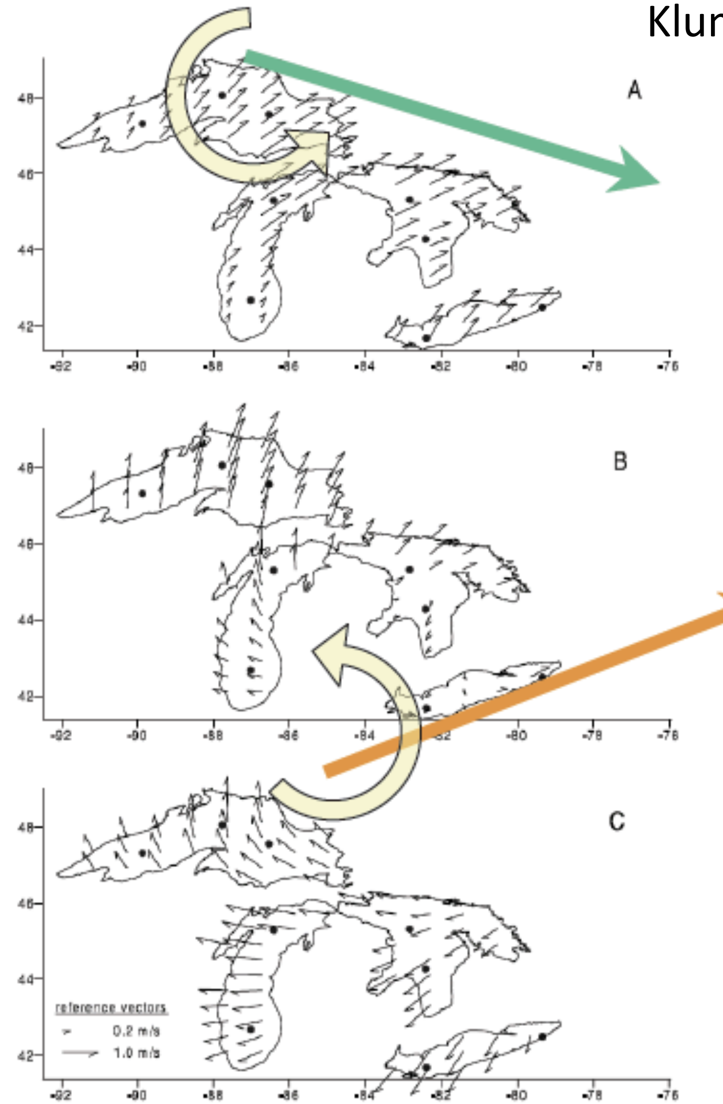


An Alternate Hypothesis

Klump 2002







What about small lakes?

Trout Lake(Oligotrophic)

Lake Mendota(Eutrophic)

The cumulative contributions to the Global Carbon Budget from 1870
Contributions are shown in parts per million (ppm)

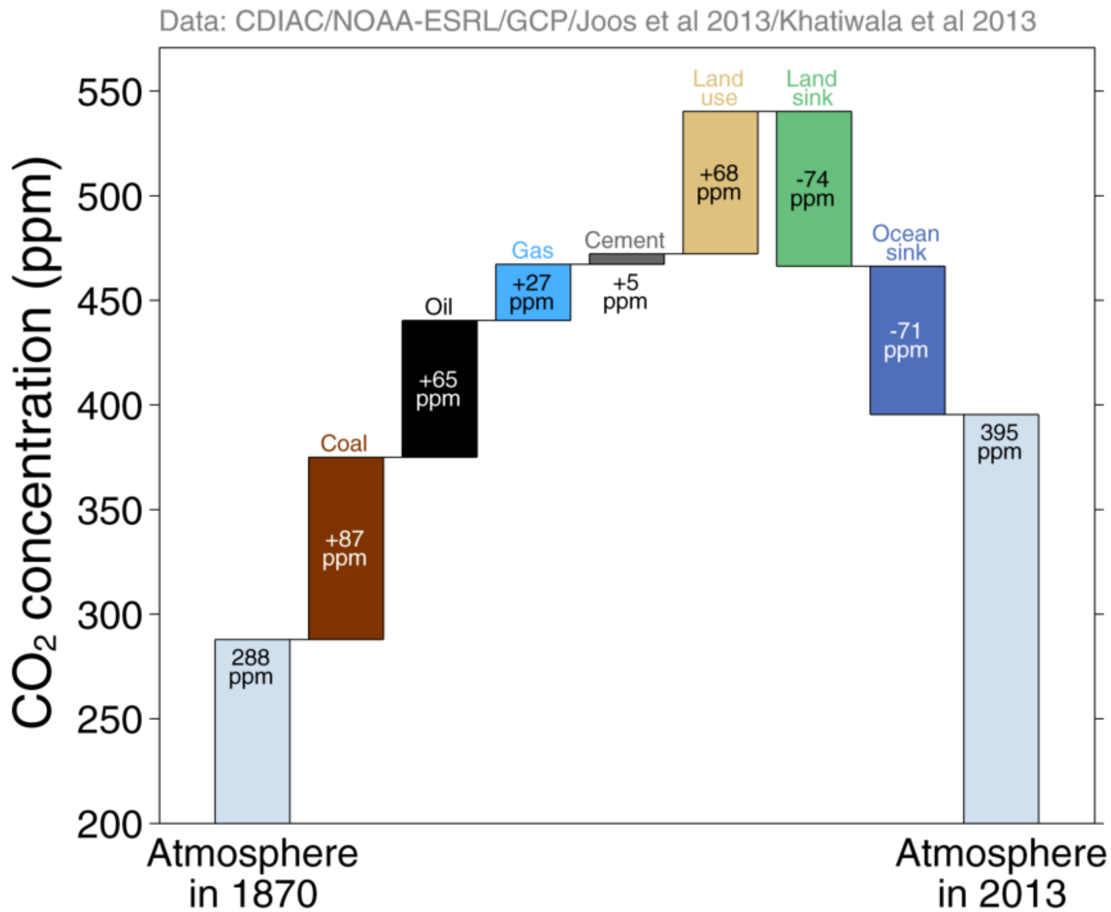
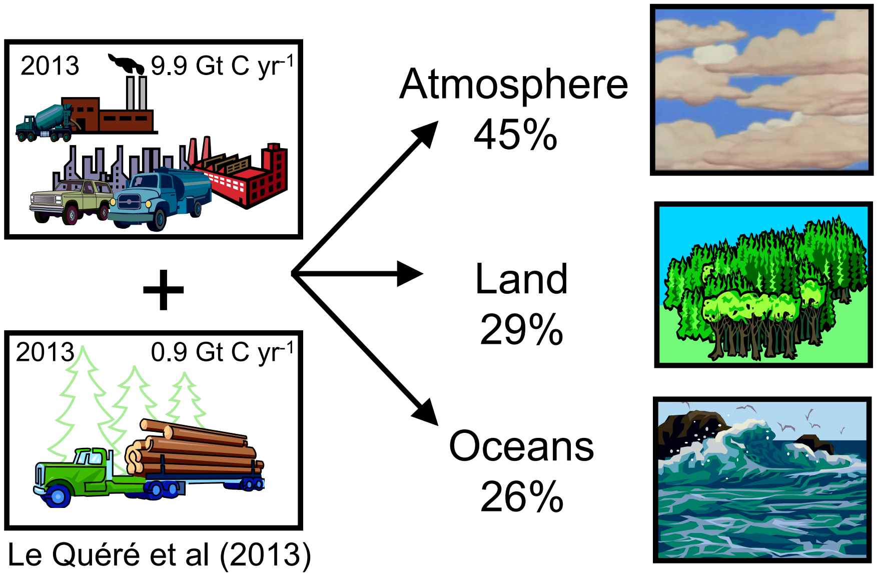
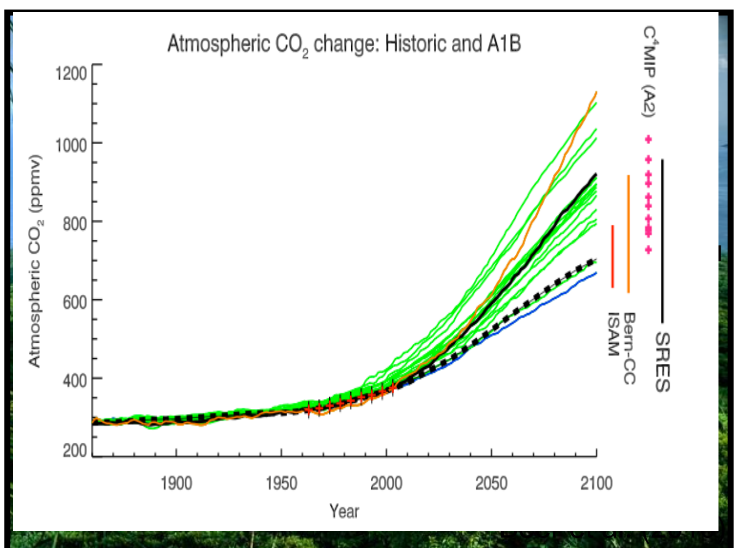


Figure concept from Shrink That Footprint
Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

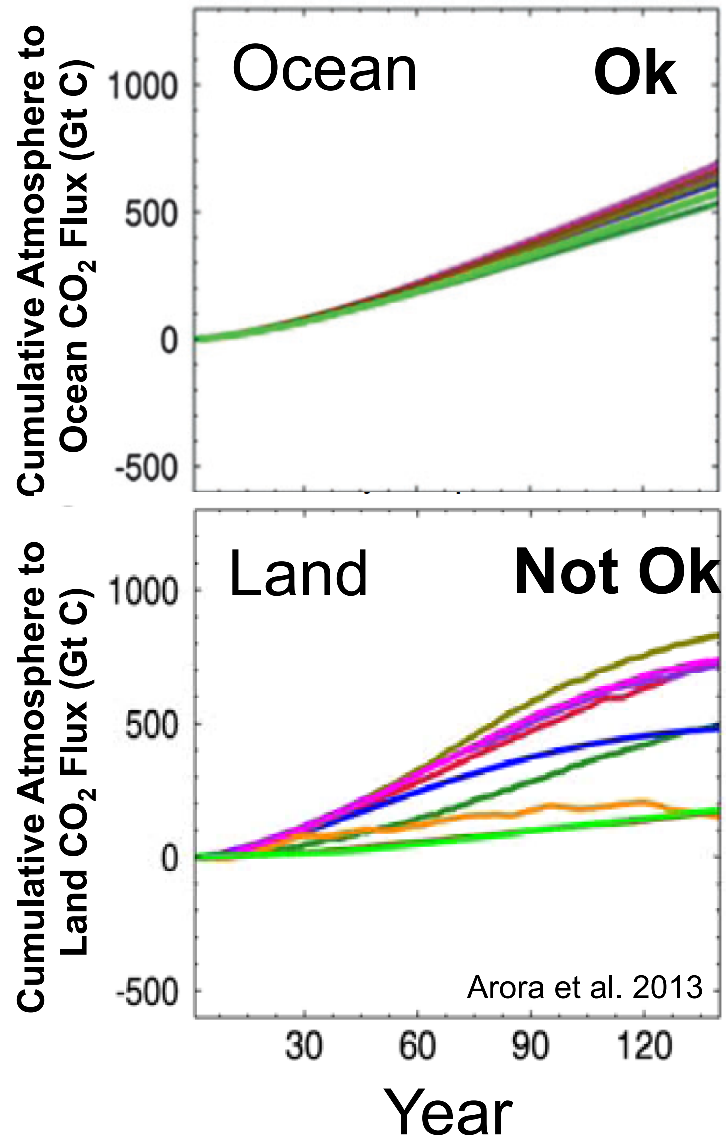
Terrestrial Biosphere CO_2 Flux Dominates Carbon Cycle Prediction Uncertainty



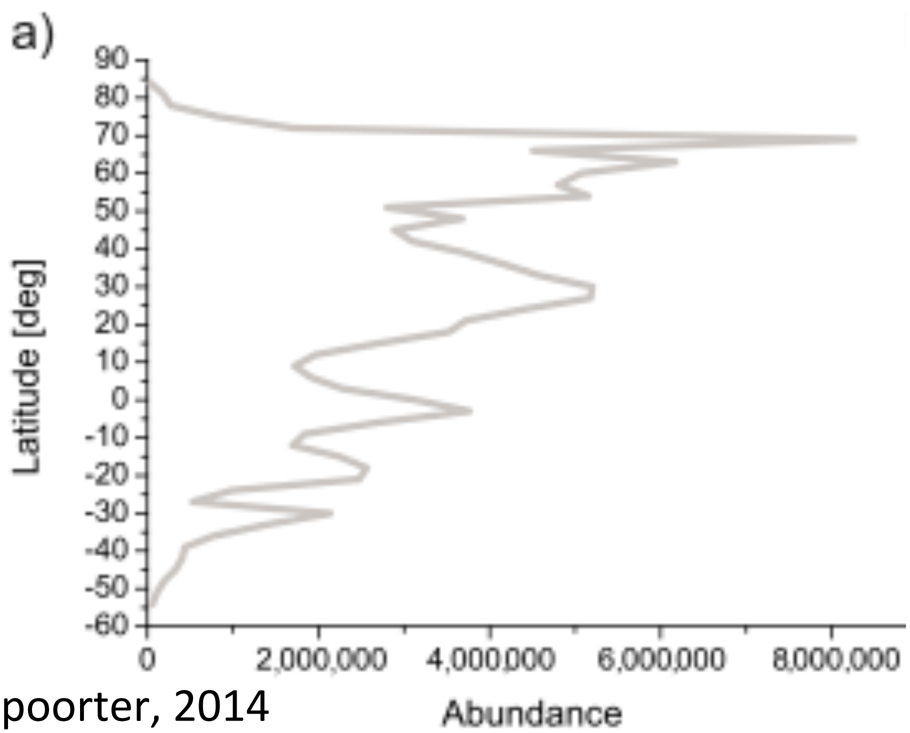
Le Quéré et al (2013)



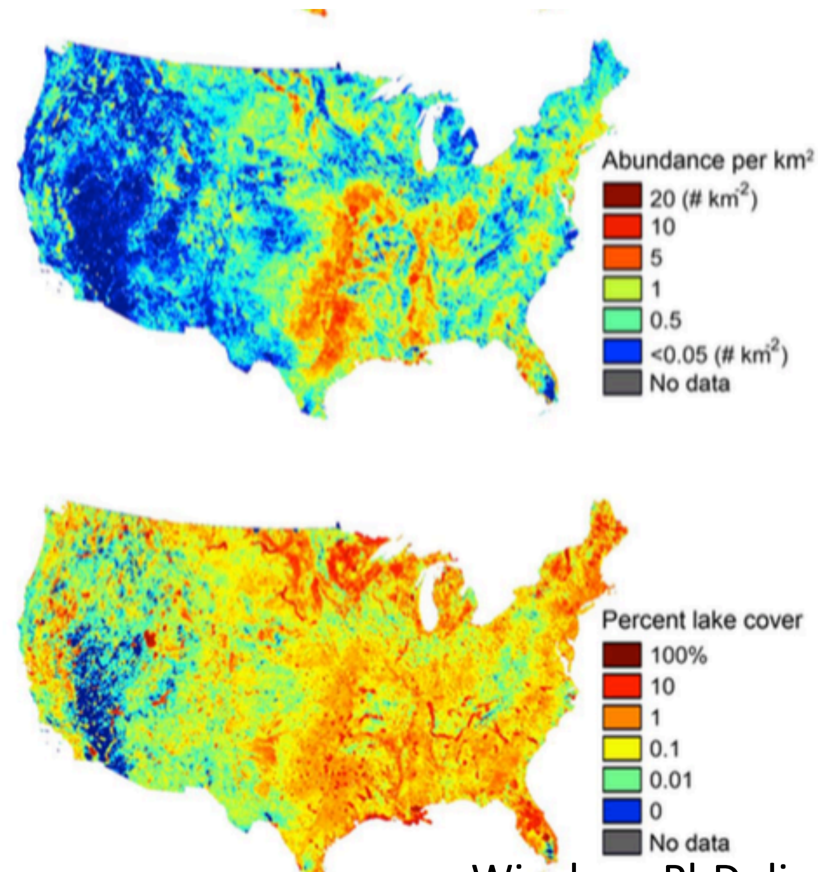
Booth et al, ERL, 2012



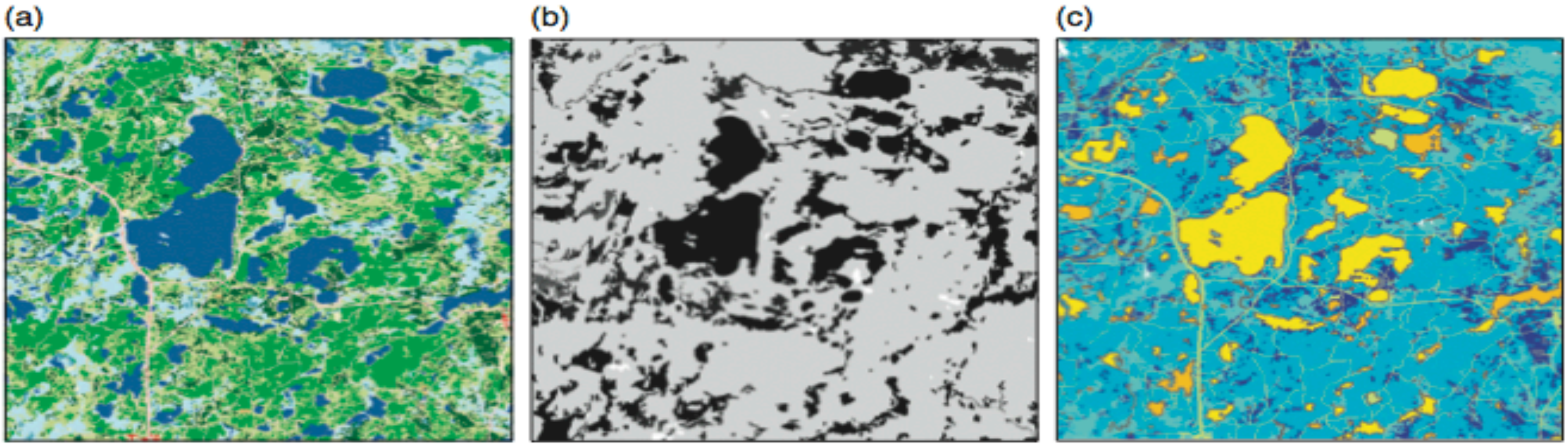
There are between 100-300 million lakes in the world
Taking up <0.5% of all terrestrial surfaces



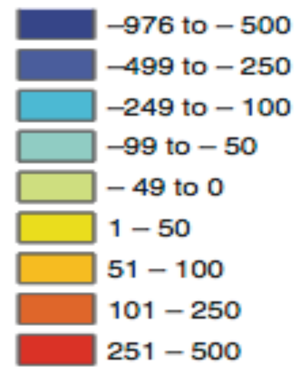
Verpoorter, 2014

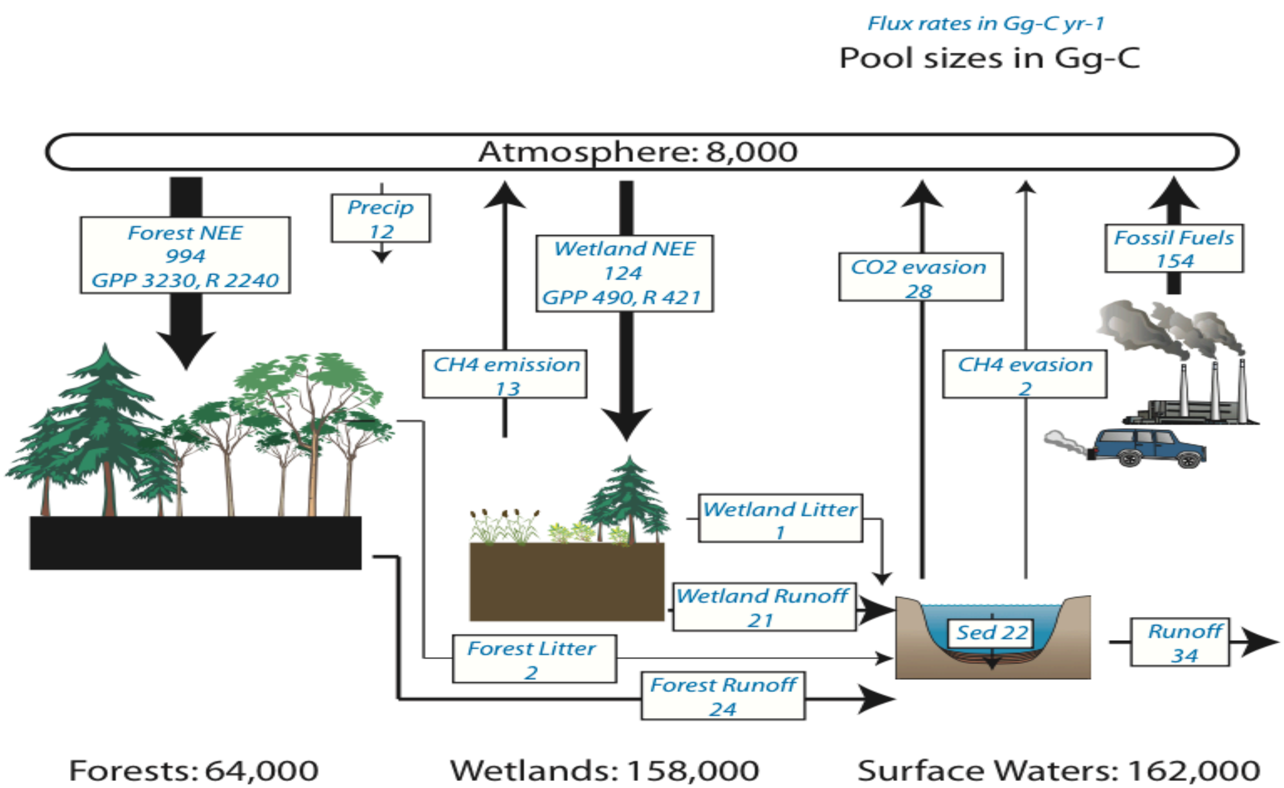


Winslow, PhD diss.



(a) Land cover (NLCD2001) Trout Lake region **(b)** Carbon pool density (kg C m^{-2}) **(c)** Annual surface-Atm. CO_2 exchange (g C m^{-2} yr^{-1})

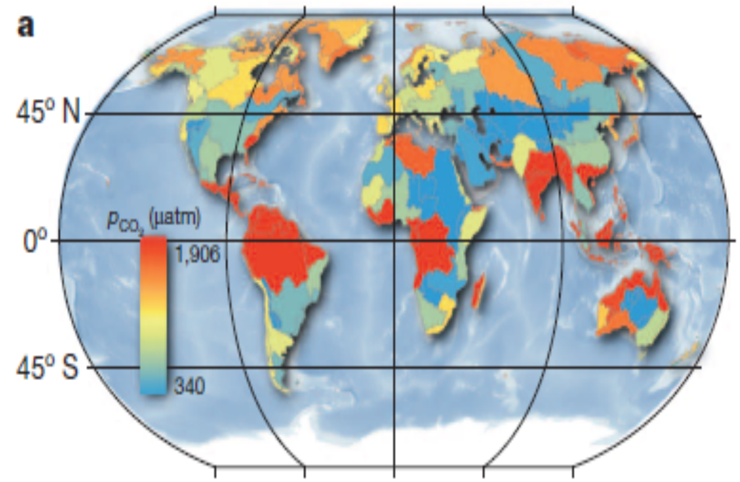


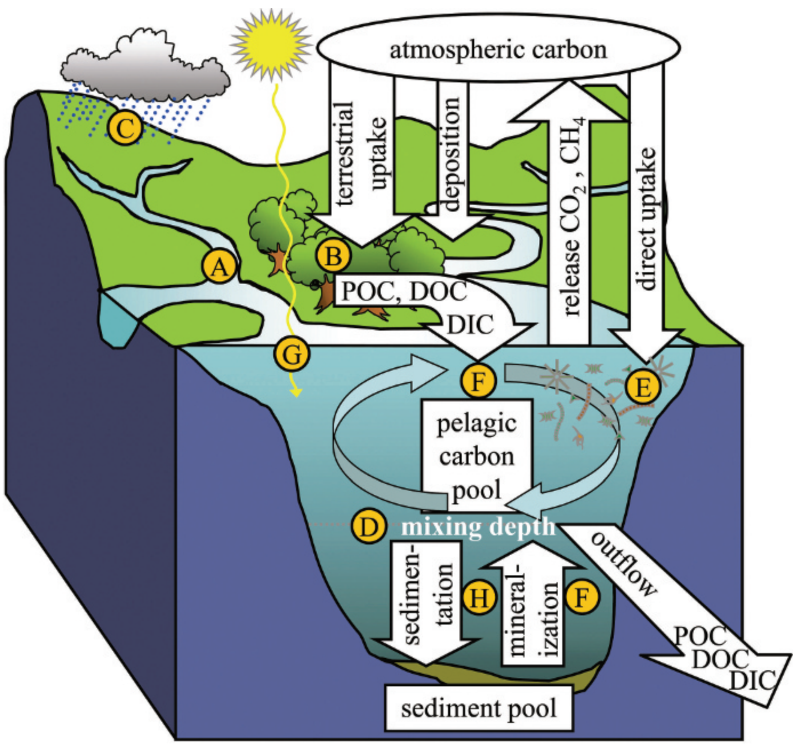


Buffam et al., 2011, GCB

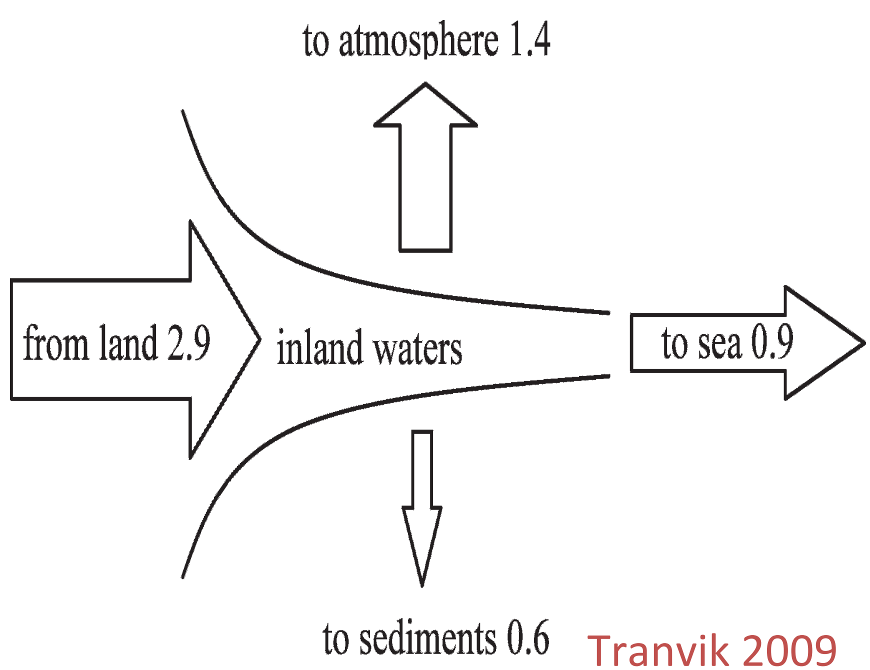
Lakes and riverine systems process a lot of carbon

Raymond et al., 2013



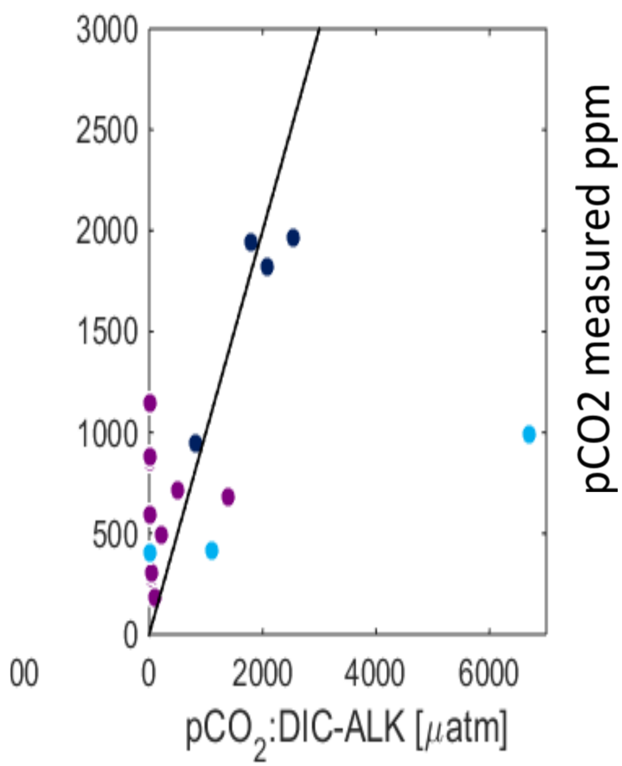


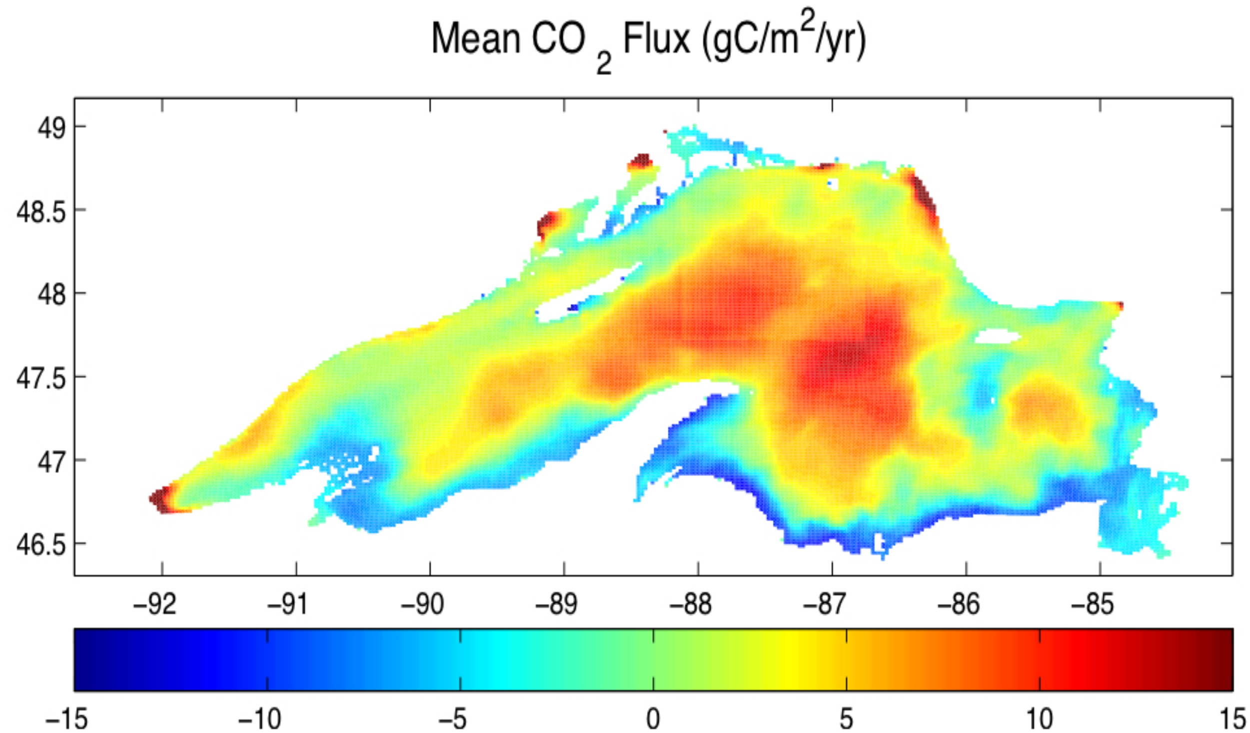
Adrian et al 2009



Tranvik 2009

Significant uncertainties in these global estimates owing to methogological and spatial sampling issues

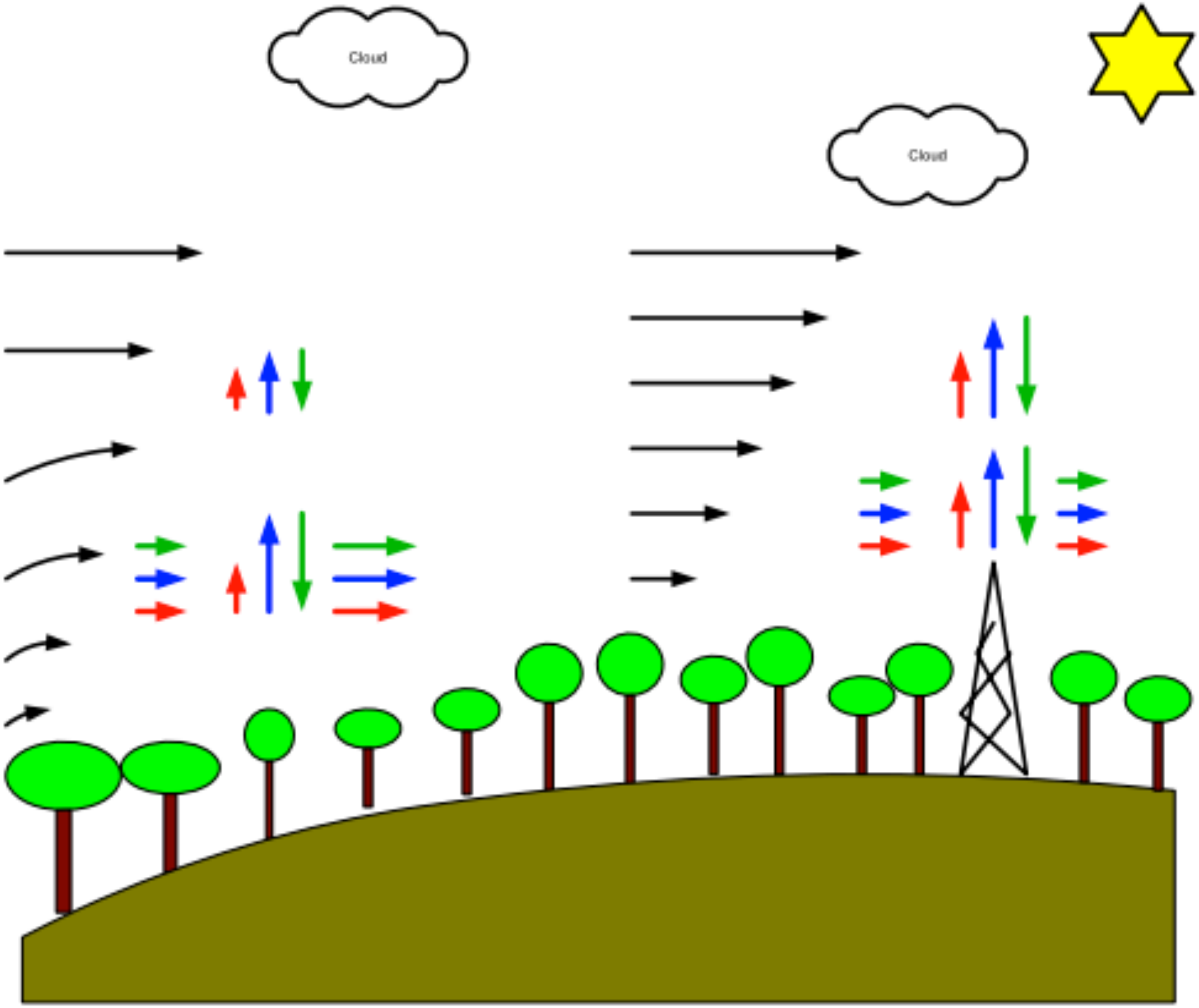




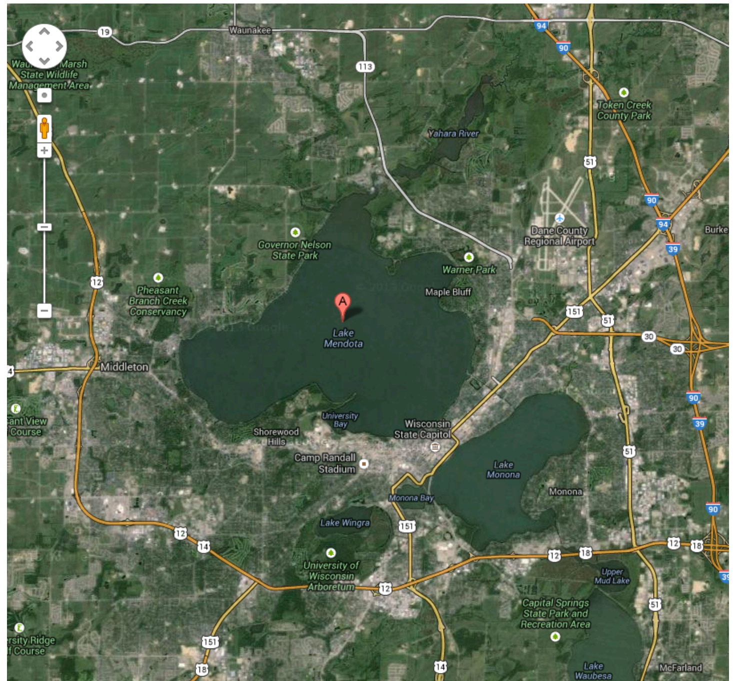
V. Bennington

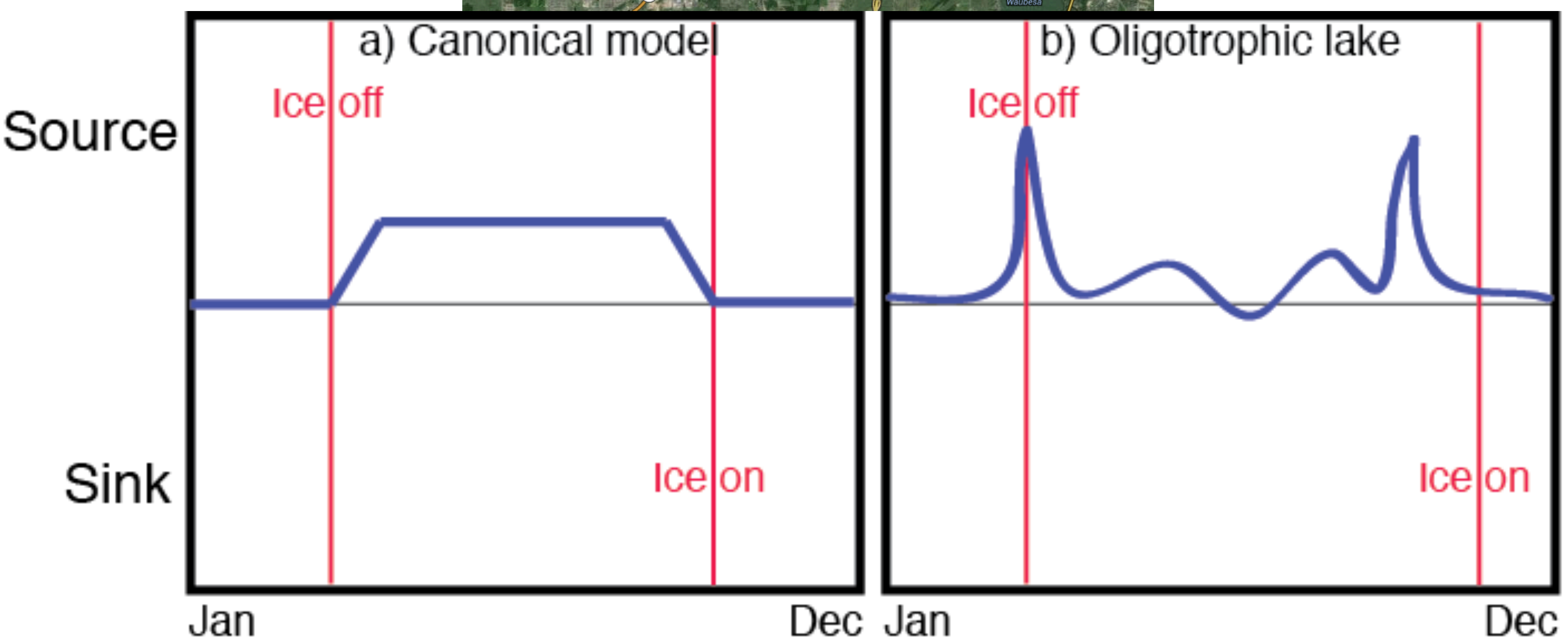
RMSE = 1484 uatm

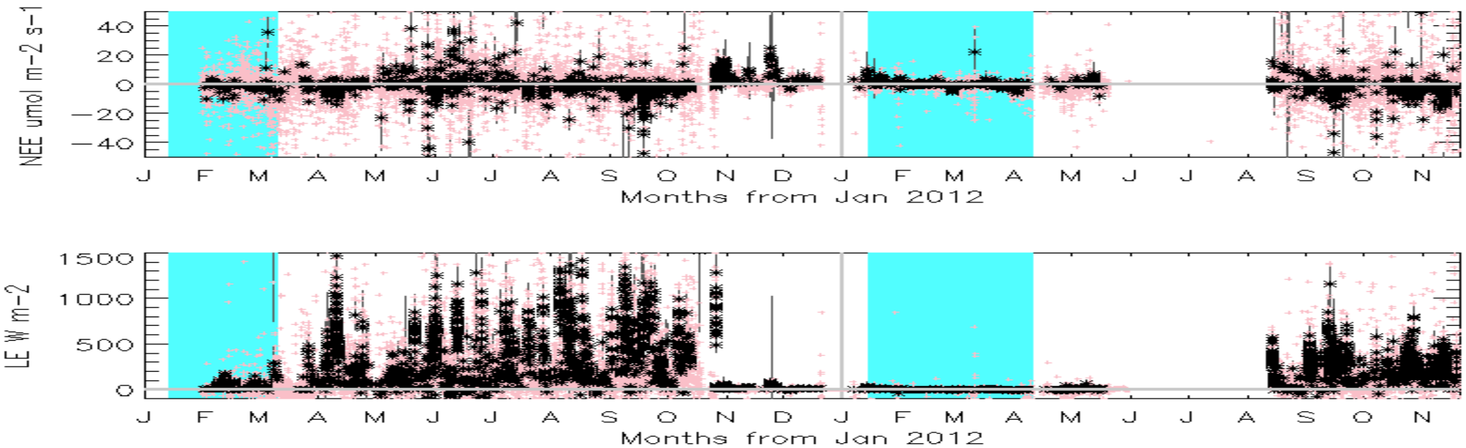
M. Golub, UW

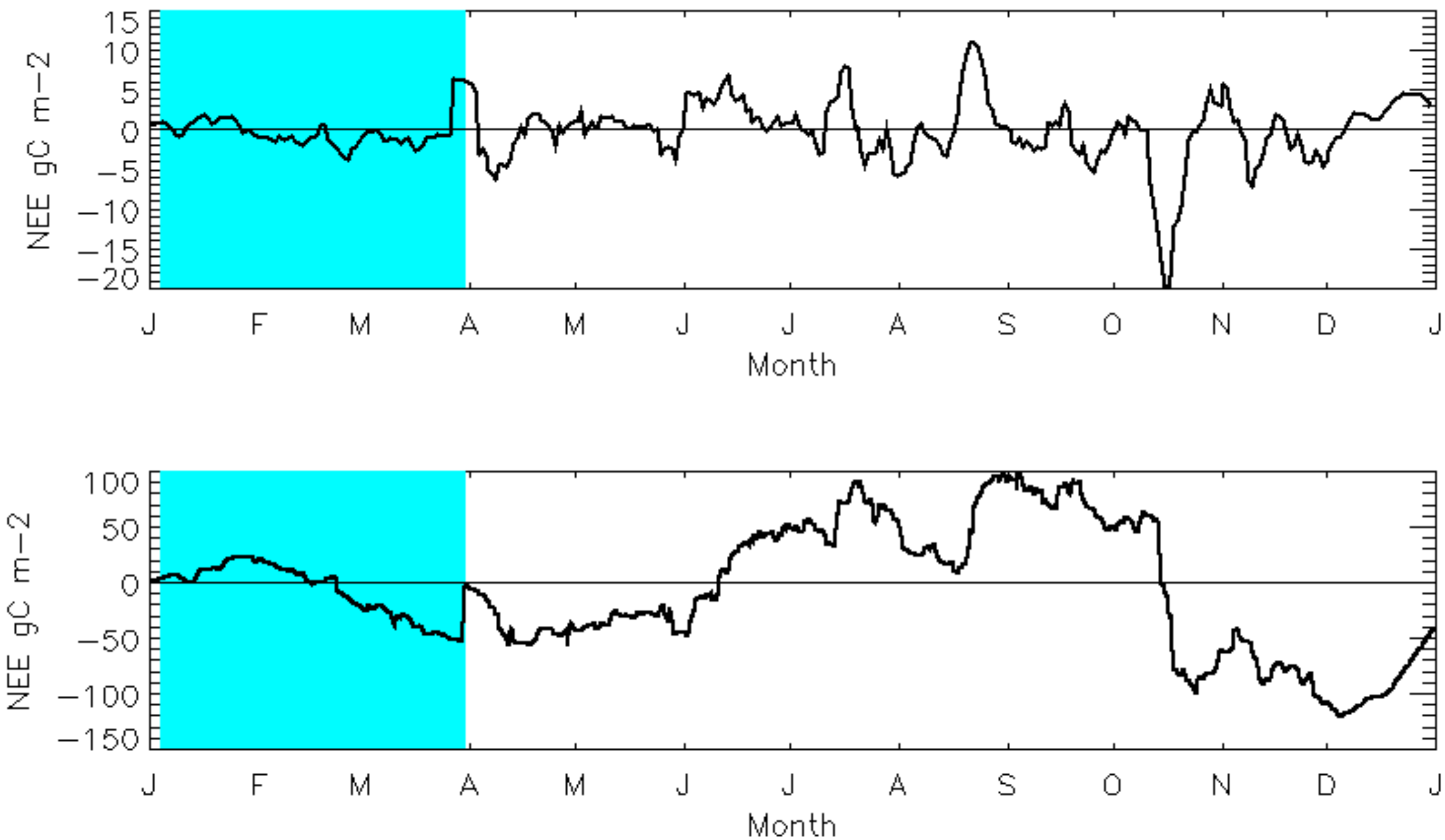


D. Baldocchi


Waunakee
Yahara River
Token Creek County Park
Dane County Regional Airport
Governor Nelson State Park
Warner Park
Maple Bluff
Pheasant Branch Creek Conservancy
Lake Mendota
Middleton
University Bay
Wisconsin State Capitol
Shorewood Hills
Camp Randall Stadium
Lake Monona
Monona Bay
Monona
Lake Wingra
University of Wisconsin Arboretum
Upper Mud Lake
Capital Springs State Park and Recreation Area
Lake Waubesa
McFarland
Burke

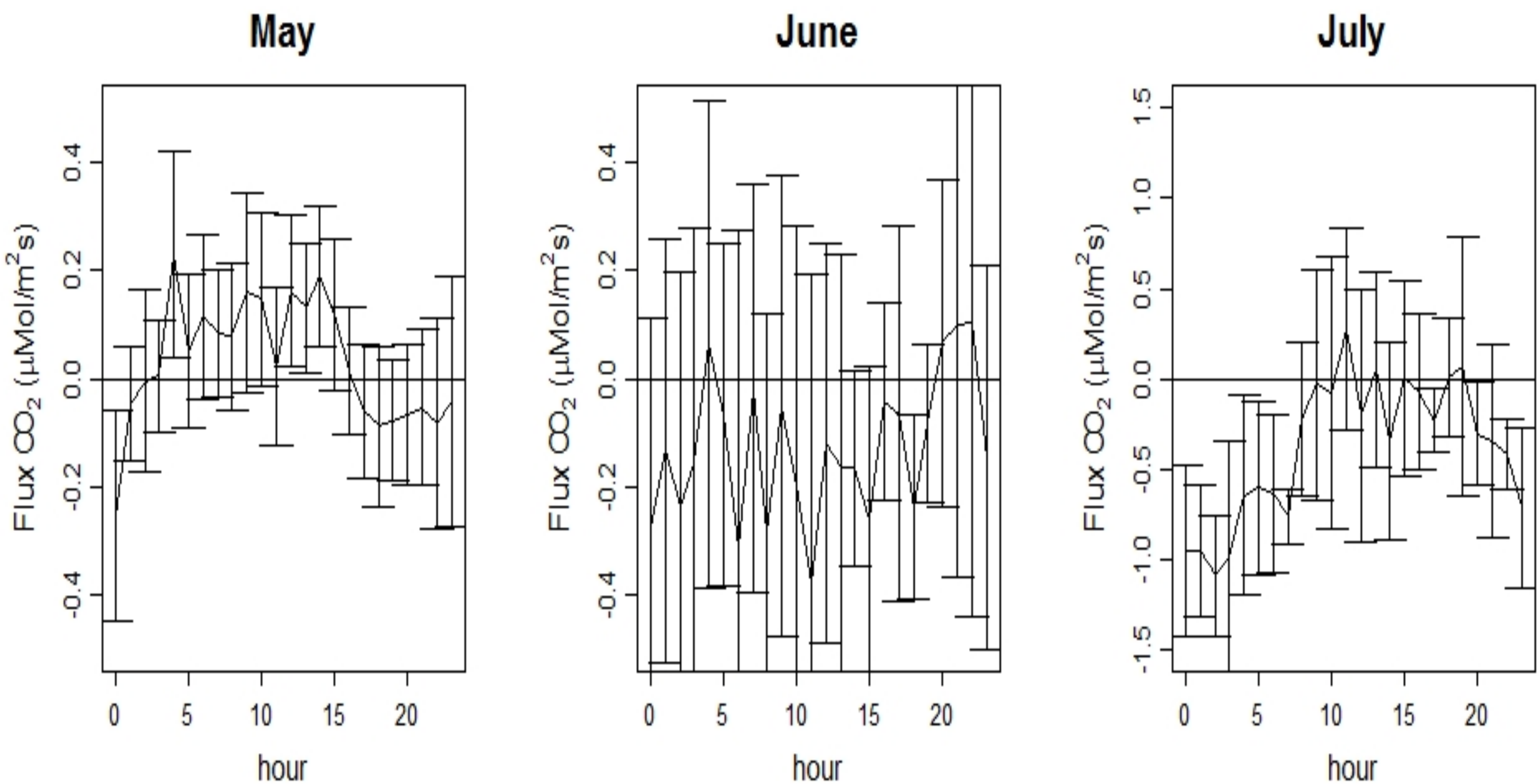

a) Canonical model
b) Oligotrophic lake
Source
Sink
Ice off
Ice on
Ice off
Ice on
Jan
Dec
Jan
Dec


NEE umol m-2 s-1
Months from Jan 2012
LE W m-2
Months from Jan 2012


NEE gC m−2
Month
NEE gC m−2
Month

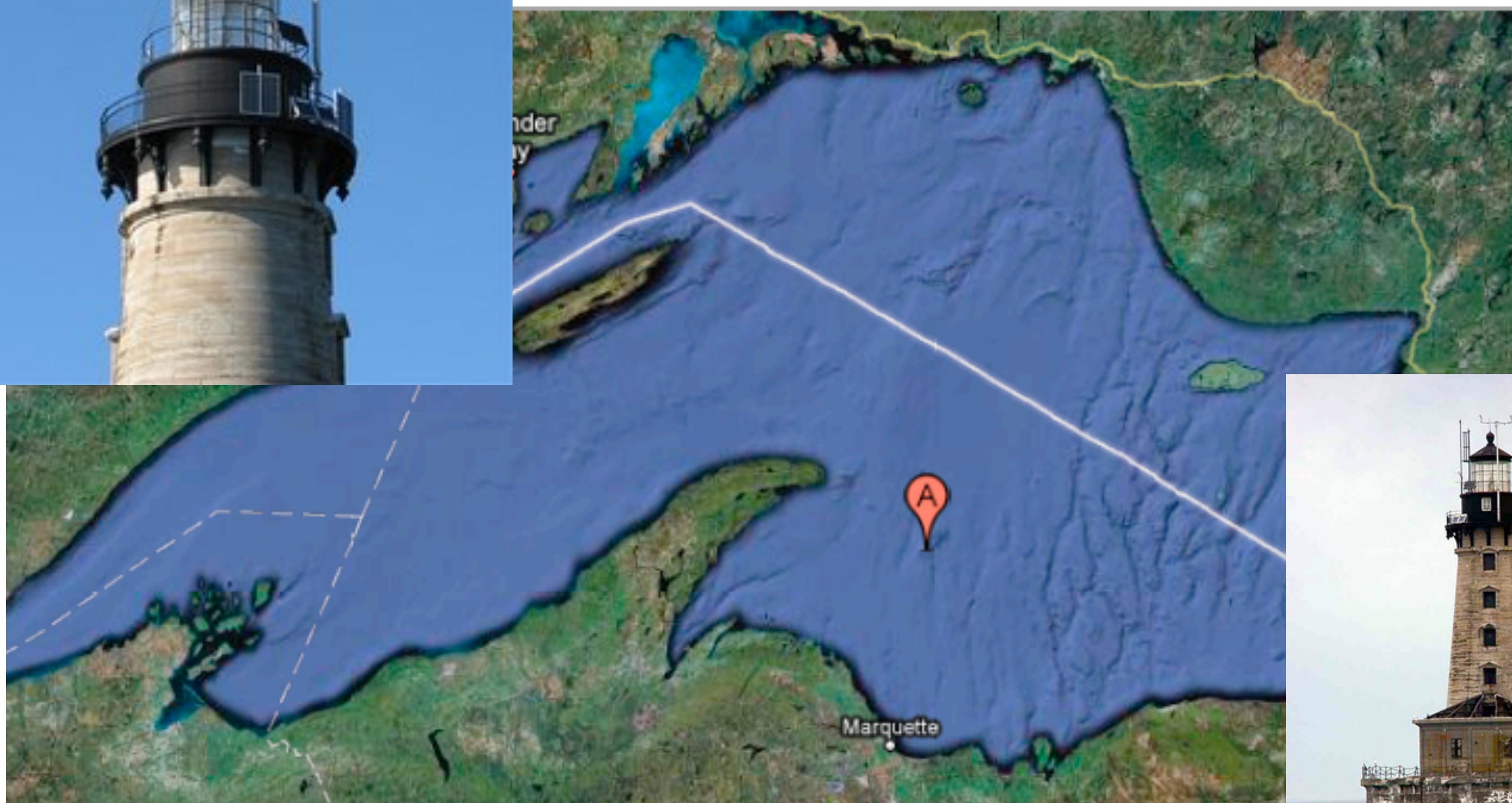

Arctic Ocean
Greenland
Iceland
Canada
United States
Mexico
North Pacific Ocean
North Atlantic Ocean
Sweden
Norway
United Kingdom
Poland
Germany
France
Italy
Spain
Ukraine
Russia
Kazakhstan
Mongolia
Turkey
China
South Korea
Japan
Iraq
Iran
Afghanistan
Pakistan
India
Thailand
Algeria
Libya
Egypt
Saudi Arabia
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
DR Congo
Tanzania
Angola
Namibia
Botswana
Madagascar
South Africa
Venezuela
Colombia
Peru
Brazil
Bolivia
Chile
Argentina
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Indonesia
Papua New Guinea
Australia
New Zealand
Google

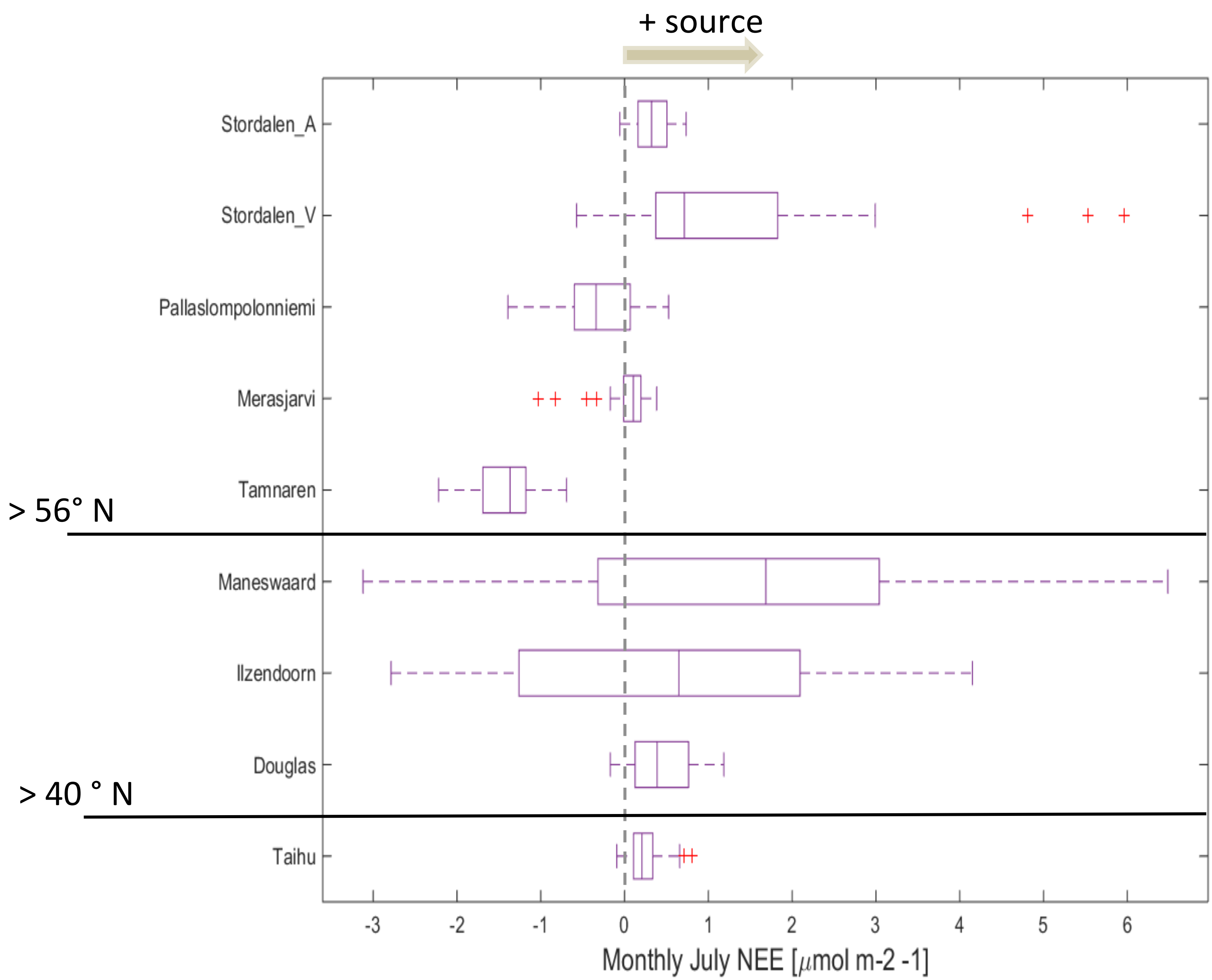
Trout Lake

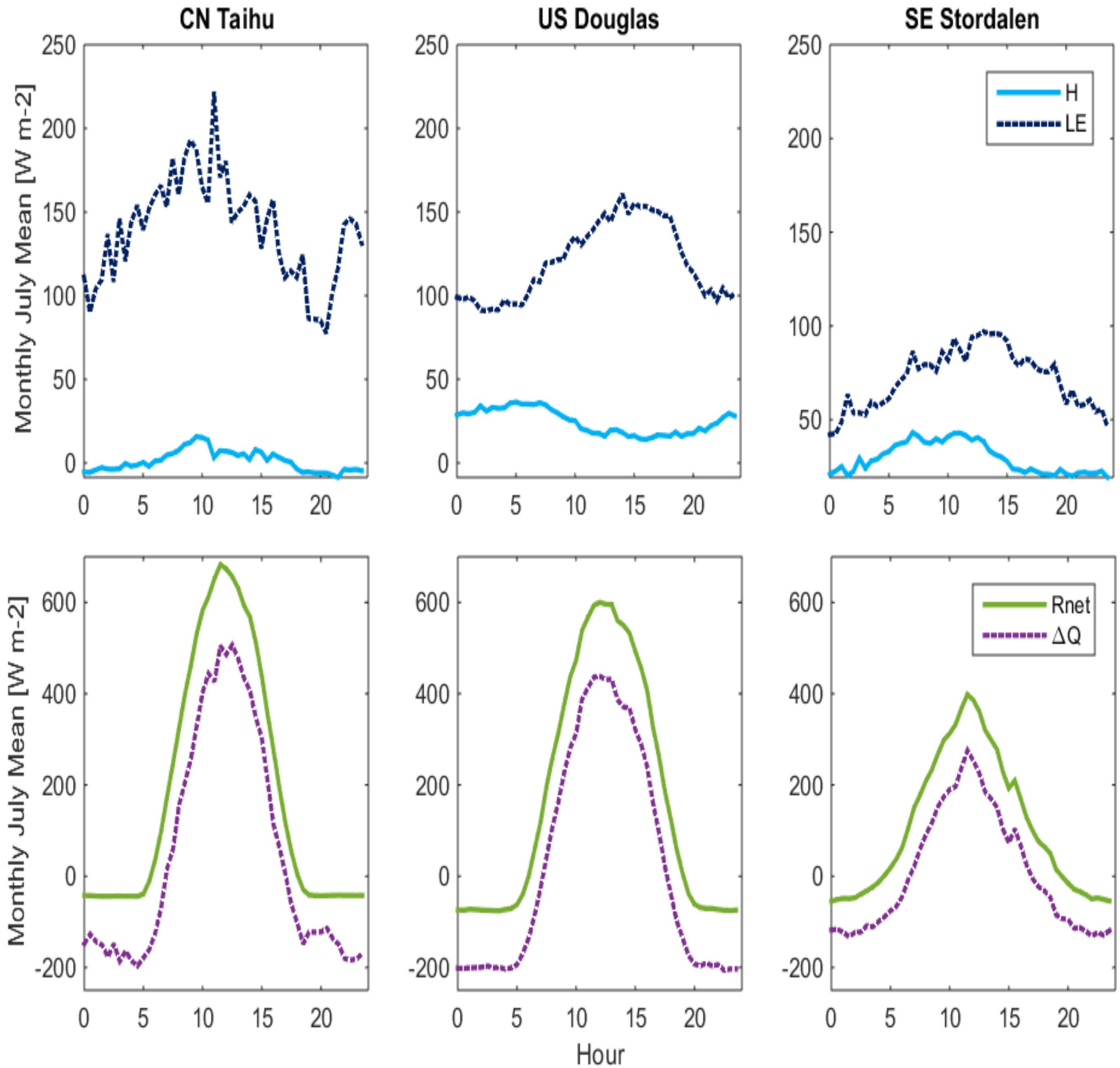


M. Balliett, UW

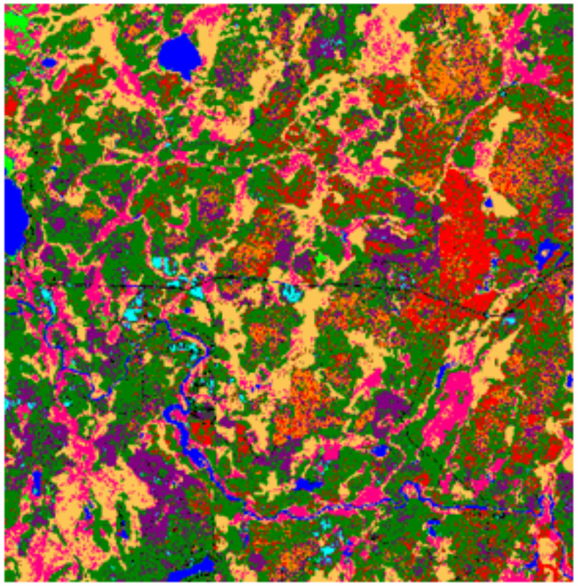
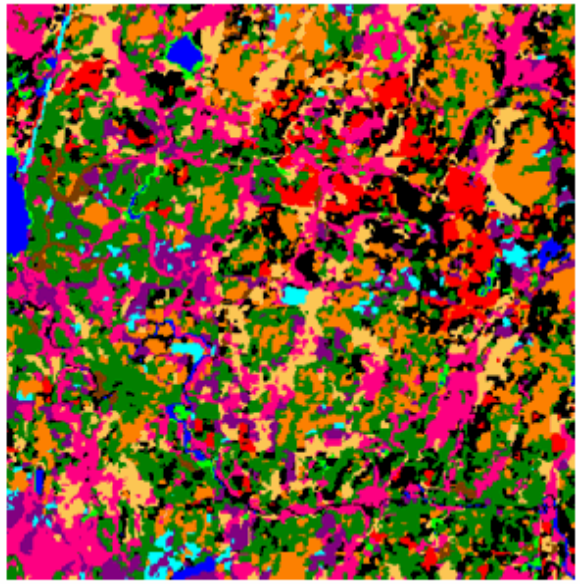
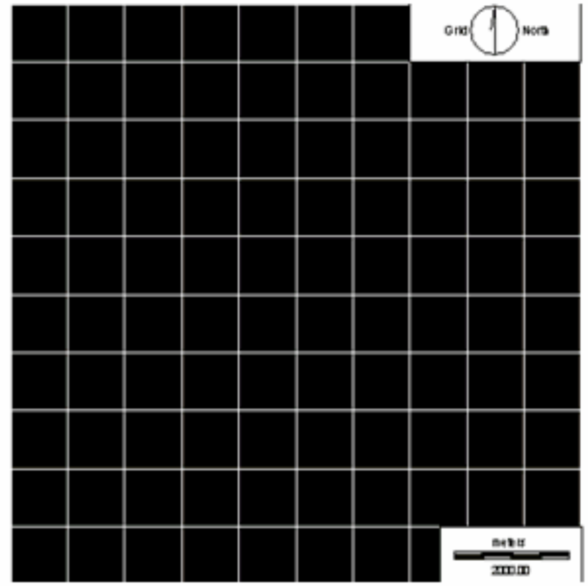
P. Blanken and J. Lenters

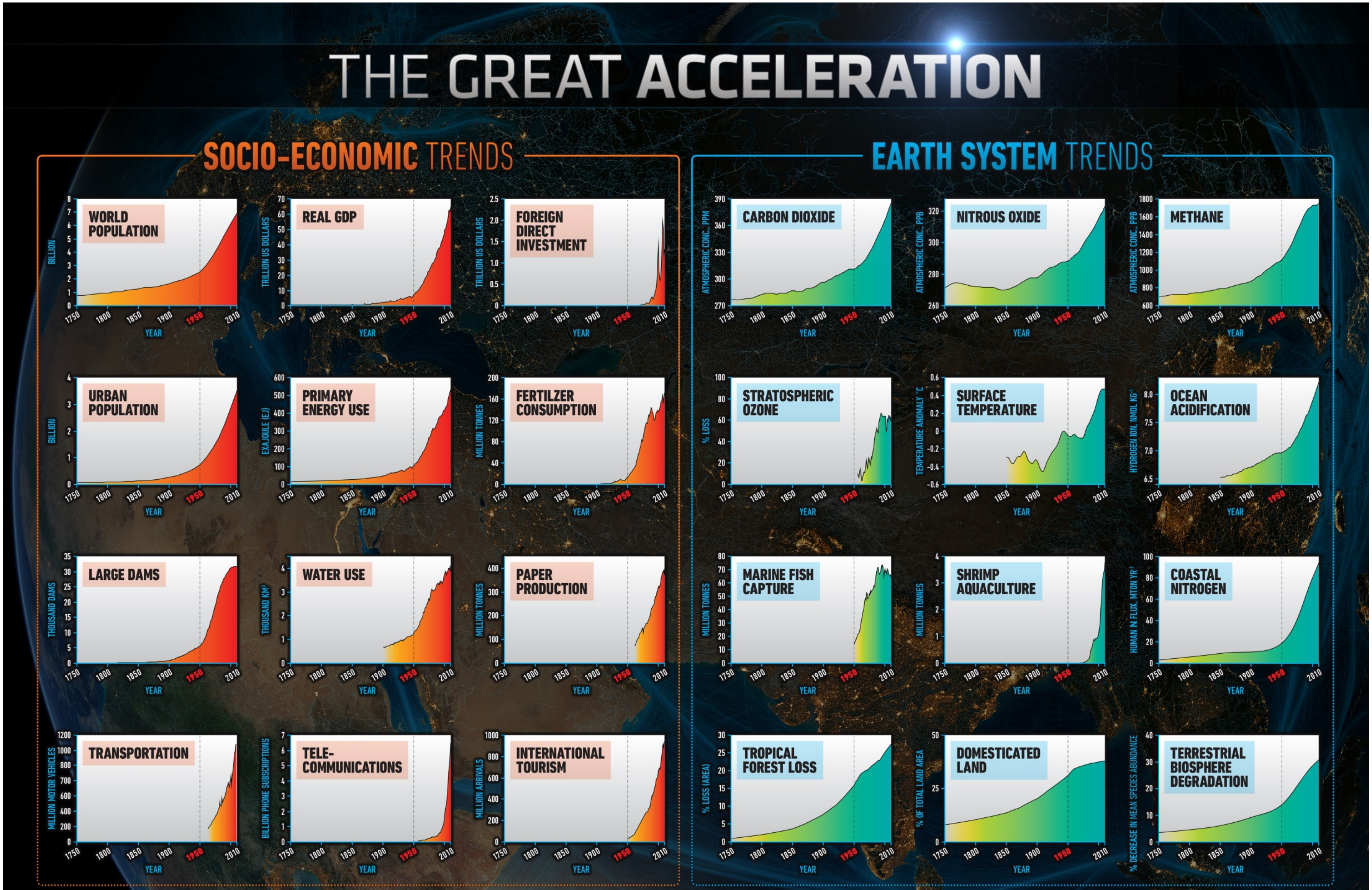



+ source
Stordalen_A
Stordalen_V
Pallaslompolonniemi
Merasjarvi
Tamnaren
> 56° N
Maneswaard
Ilzendoorn
Douglas
> 40 ° N
Taihu
-3
-2
-1
0
1
2
3
4
5
6
Monthly July NEE [μmol m-2 -1]



subtropical temperate boreal

a) IKONOS.	b) WISCLAND.	c) MODIS-UMD and IGBP.
		
— Mixed Forest 13.3% Upland Conifer 34.8% Aspen-Birch 5.7% Upland Hardwood 12.0% Upland Opening/Shrub 0.9% Grassland 17.8% Lowland Conifer 0.7% Lowland Deciduous 10.6% Lowland Shrub 0.6% Wet Meadow 2.6% Open Water 1.0% Road	7.1% Mixed Forest 13.0% Upland Conifer 25.3% Aspen-Birch 14.6% Upland Hardwood 6.8% Upland Opening/Shrub 1.8% Grassland 10.7% Lowland Conifer 1.9% Lowland Deciduous 16.3% Lowland Shrub 1.0% Wet Meadow 1.6% Open Water — Road	100% Mixed Forest



REFERENCE: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig (2015), The Trajectory of the Anthropocene: the Great Acceleration, Submitted to *The Anthropocene Review*.

MAP & DESIGN: Félix Pharand-Deschênes / Globaïa

- Land cover type and temperature of different surfaces changes properties of the air above
- Lakes of many sizes generate their own micro or even macro climates and trends in lake properties can alter these
- While lakes cover a small portion of the globe, they could be a major player in the global carbon cycle that drives current and future climate change

Thank you!

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UW-Madison & The Wisconsin Idea

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