Update on New Lake Model for CLM

CESM LMWG Meeting, NCAR
Mar 15, 2011, Boulder, CO

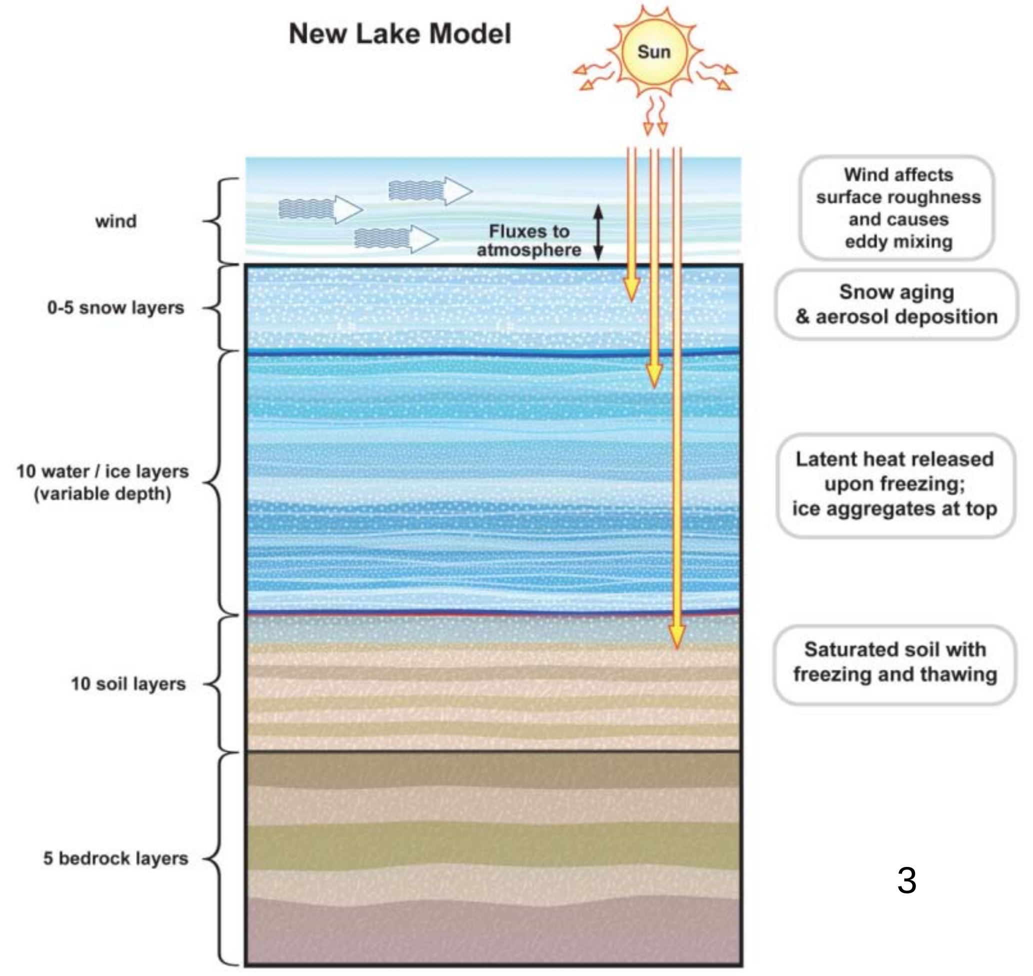
Zachary Subin
William Riley
Lisa Murphy
Fuyu Li
Celine Bonfils
Dmitrii Mironov

Outline

- Model Recap
- Site Evaluation
- Parameter & Process Sensitivity
- Climate Sensitivity to Lake Distribution

Model Improvements

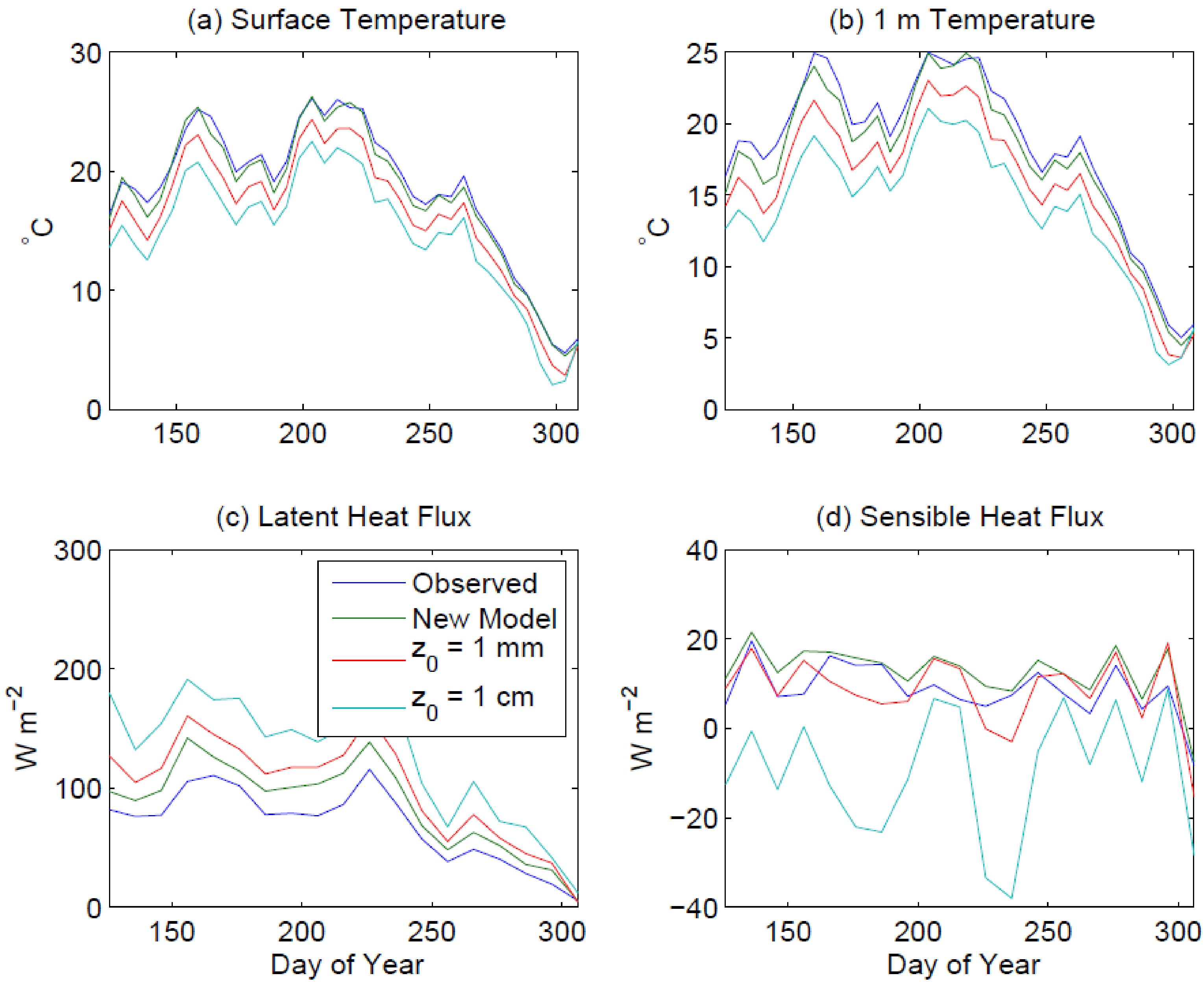
- Integrates CLM4 snow model
- Ice physics
- Underlying sediment
- Roughness lengths
- Enhanced mixing
- 3 bug fixes
- Depth, opacity, & fetch can vary spatially



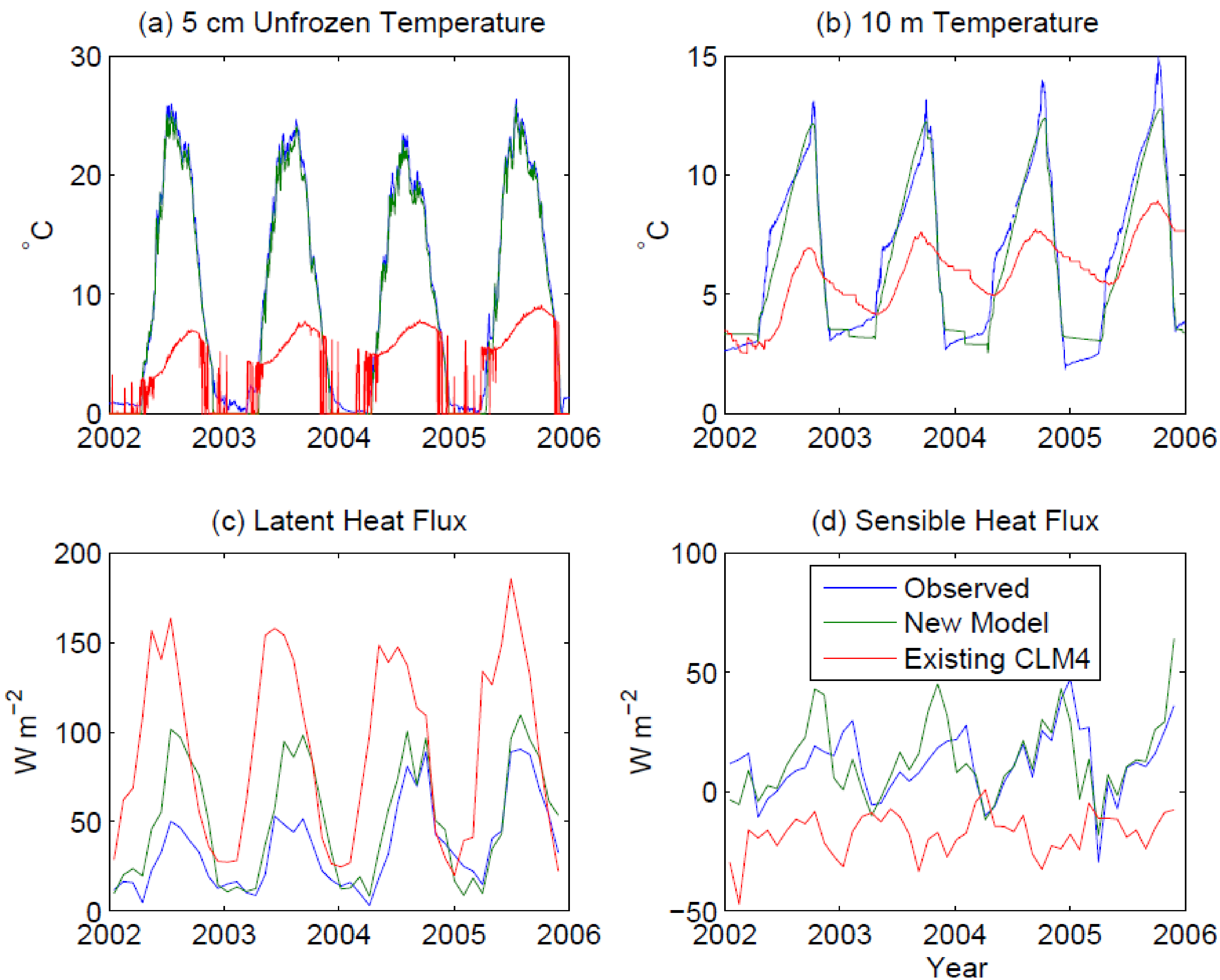
Roughness Lengths

- Waves move with wind!
- Mature waves → *less* momentum transfer
- CLM4 lake $z_0 = 10$ mm
- Literature: $z_0 \sim 0.1 – 1$ mm
- New model: $z_0 = f(u_*, \text{depth, fetch if avail.})$

Kossenblatter (Germany): old z_0 bias



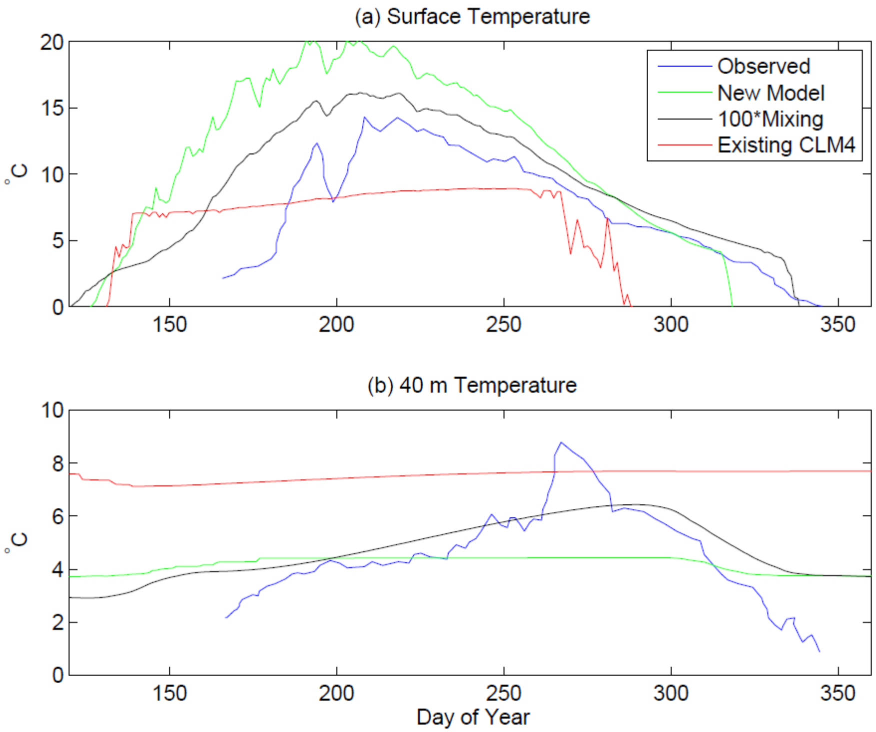
Sparkling Lake (WI): CLM4 Comparison

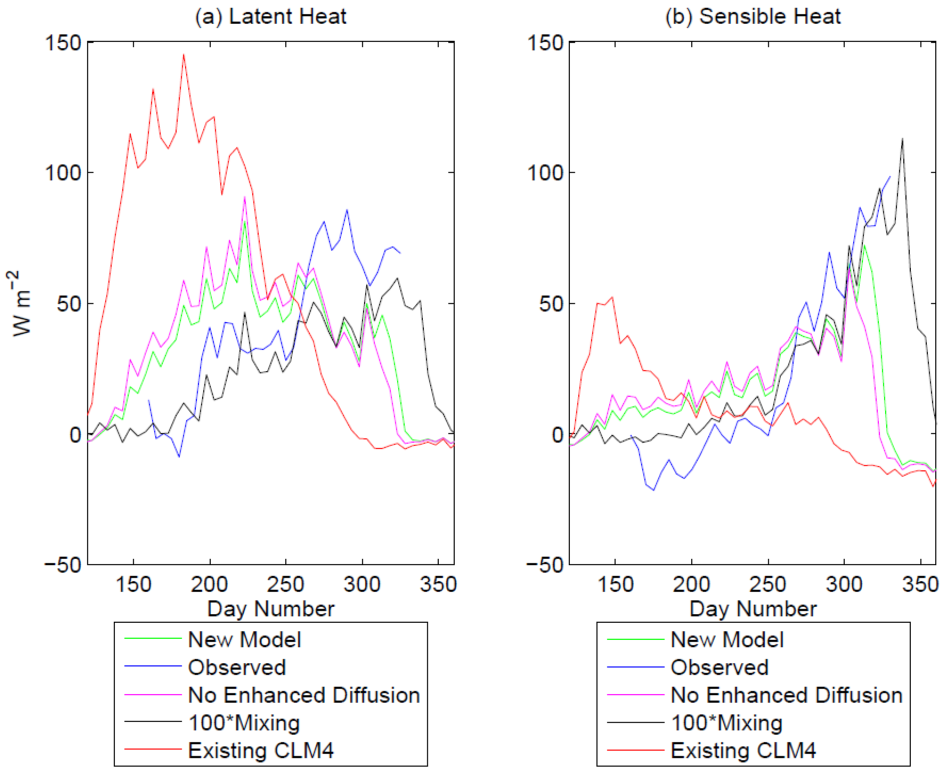


Model Evaluation

- 13 lakes
  – Varying size, geometry, & climate
- Small lakes + forcing obs. → new model performs well
- Large lake simulation usually improved w/ increased mixing
- Snow, ice, & sediment OK but scarce data
- CLM4 model performs poorly

Great Slave Lake (Canada)





- Large, deep (90 m at measurements)
- Hostetler wind-driven eddy mixing ~100 times too weak

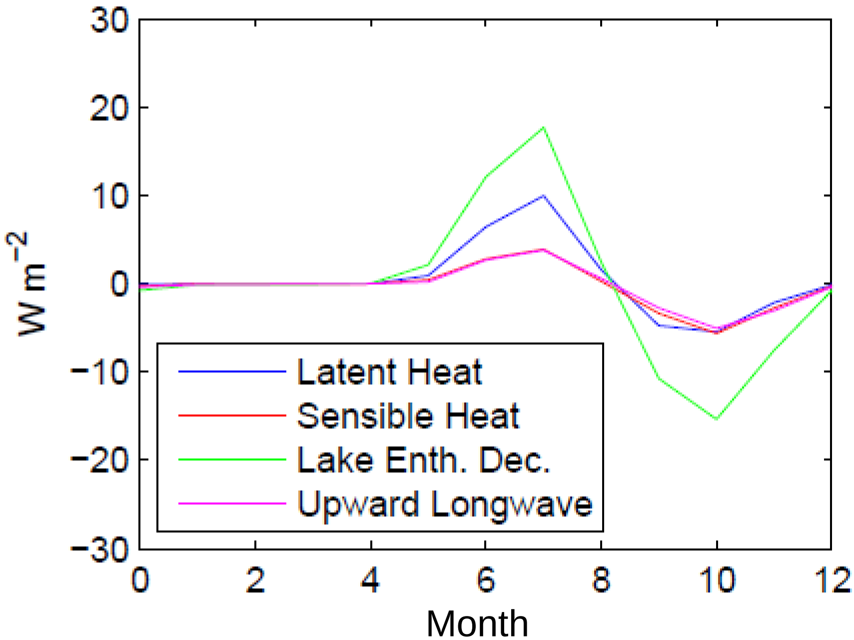
More mixing

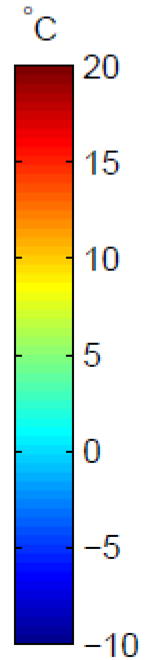
- New lake model retains core Hostetler parameterization
- Mild enhanced diffusion from Fang & Stefan (1996) not enough
- 3D convection must be dominating
- More sophisticated turbulence models parameterize large lakes well, but over-predict mixing in small lakes…
- Hybrid approach needed?

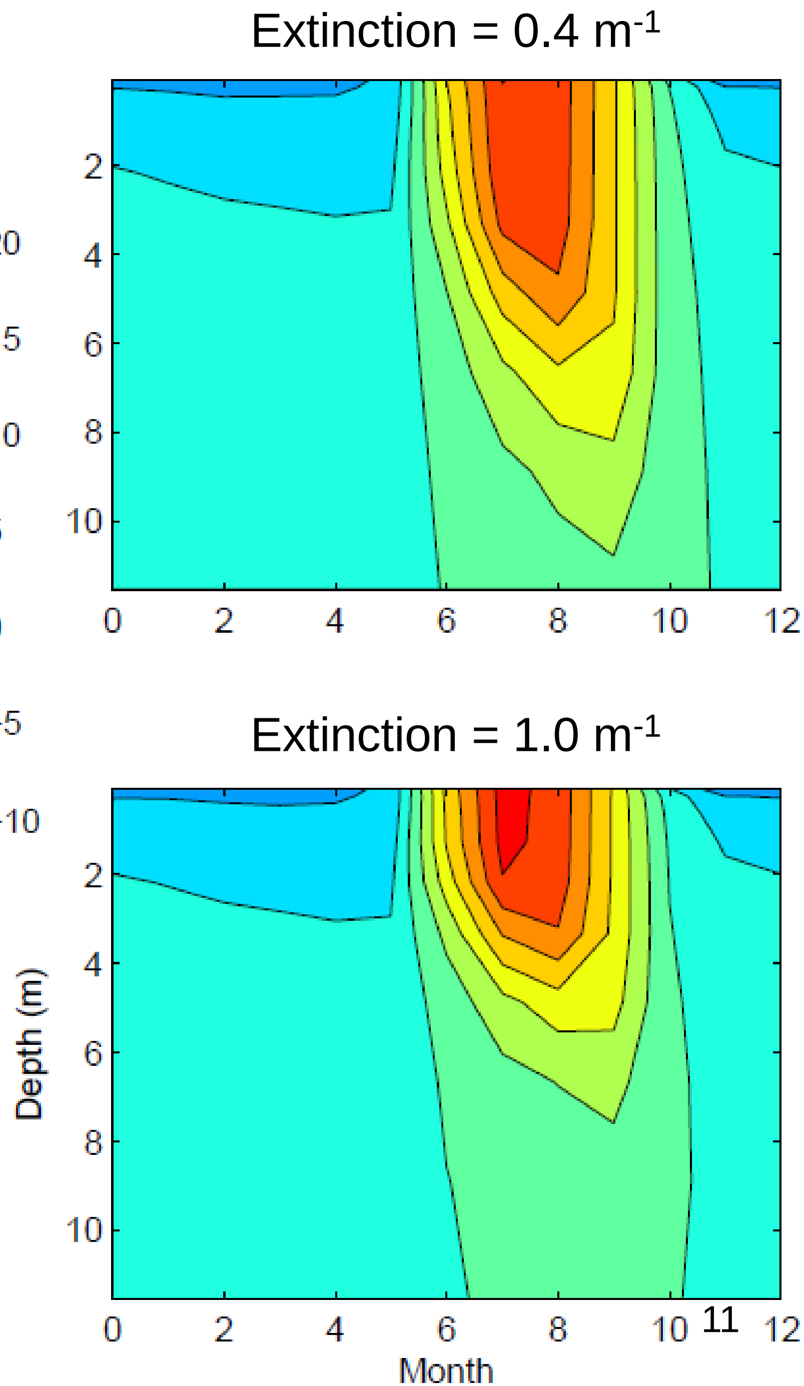
Surface Flux Sensitivity

- 14 cases, processes & parameters
- Key controls (seasonal 15 – 30 W m^{-2}):
  - Snow insulation
  - Phase change
  - Depth
  - Opacity (range of 0.05 to 7 m^{-1} just for 13 lakes!)
  - Melting lake albedo
  - Mixing strength (if large range)
- For global simulations, errors in depth, mixing strength, & opacity are ~equally important.

Example: Opacity





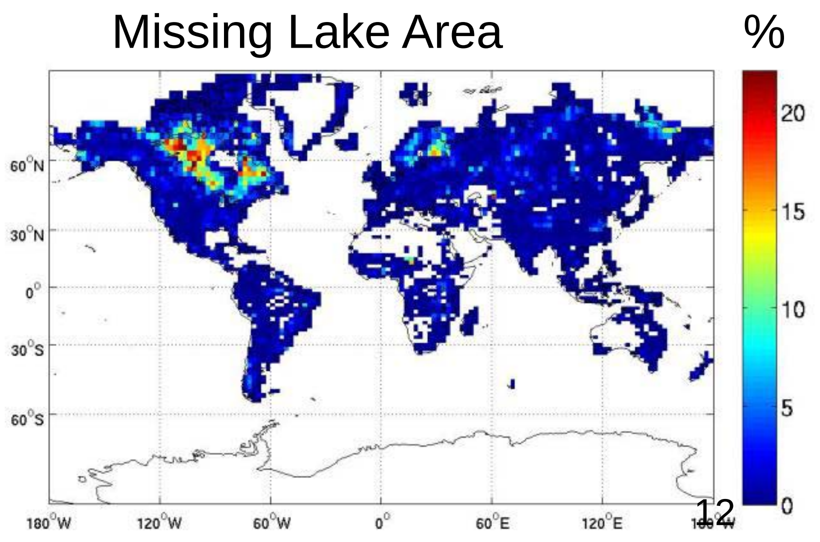


- A turbid lake acts like a shallow lake.
- Remote sensing could constrain this.

CCSM 4 Sensitivity to Lake Area

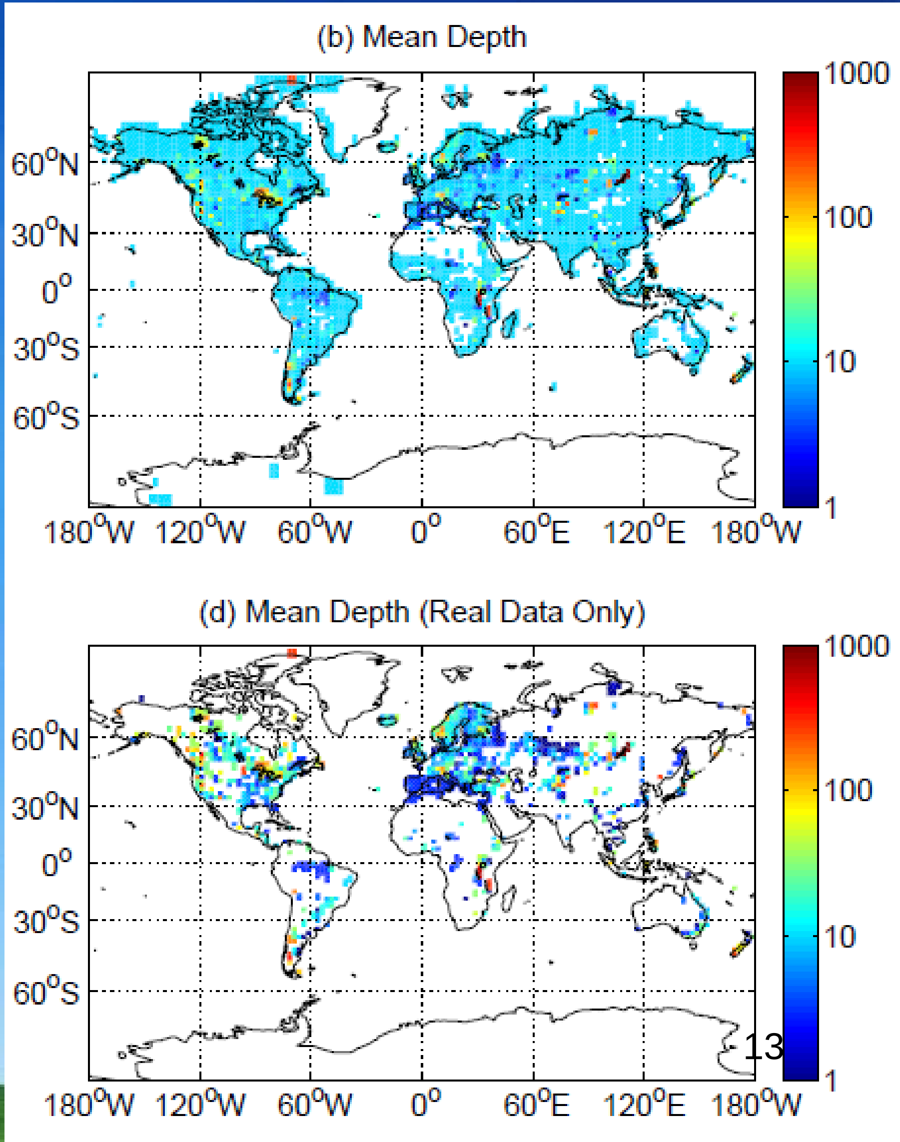
- 2° CLM4: 0.7 million km^2 (Cogley 1991)
- 2° GLWD: 2.3 million km^2 (Lehner & Döll, 2004)
- Mostly missing in N. Canada

- Hi – Lo area experiments
  - 25 yr offline
  - 200 yr slab ocean

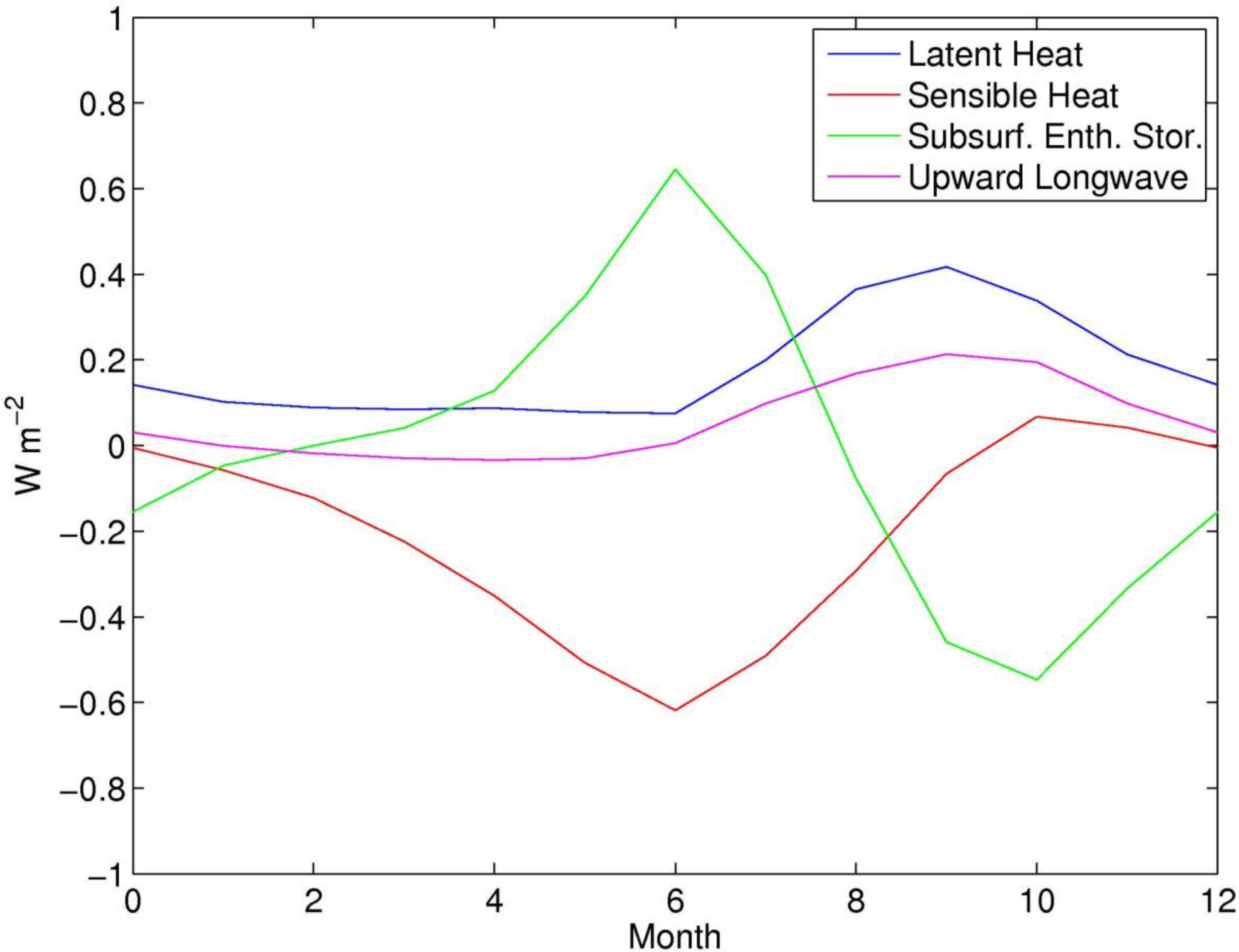


New Gridded Lake Depth Data

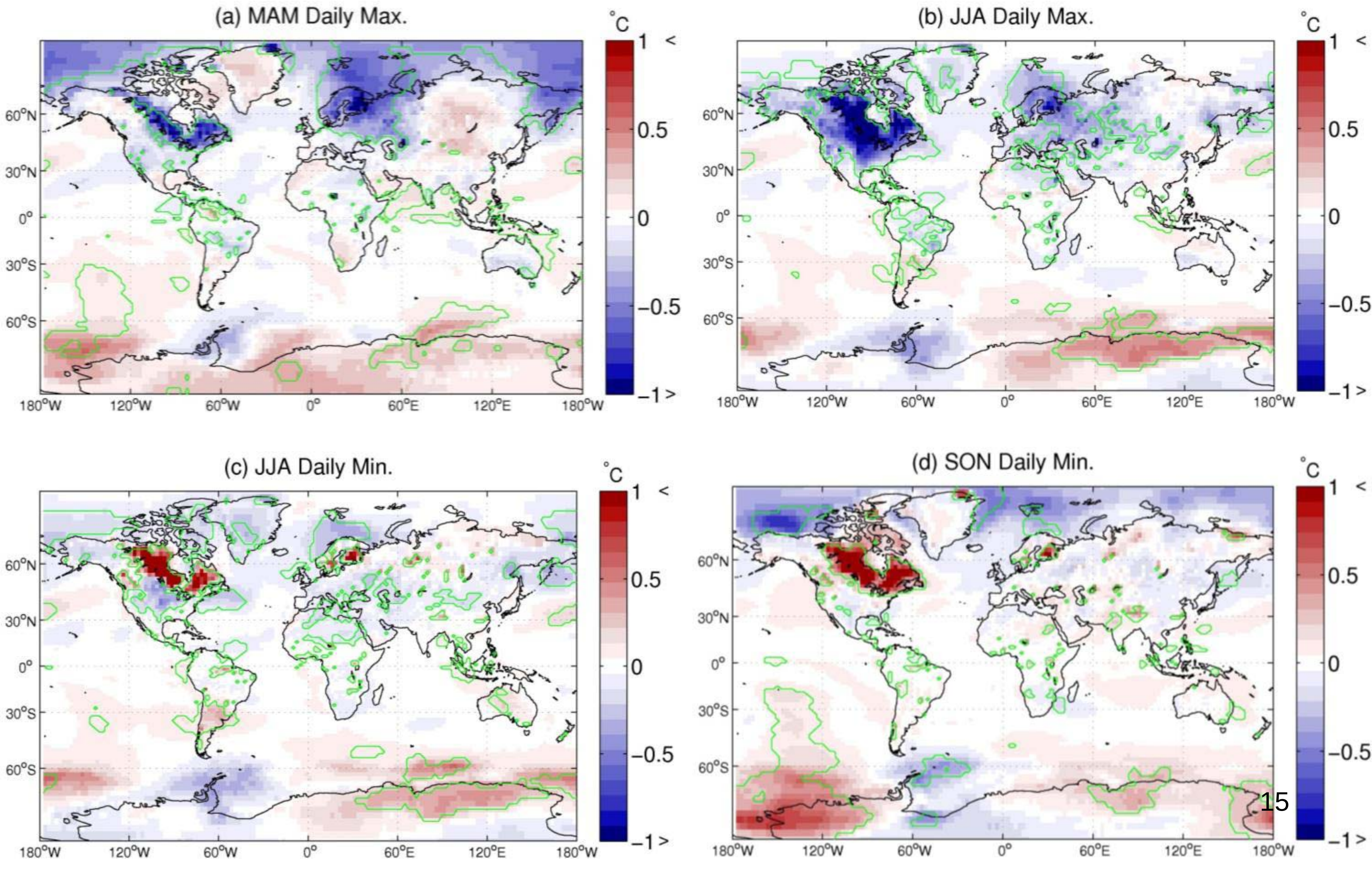
- First dataset
  - (Kourzeneva et al., 2010)
- Interpolation to 2° is crude



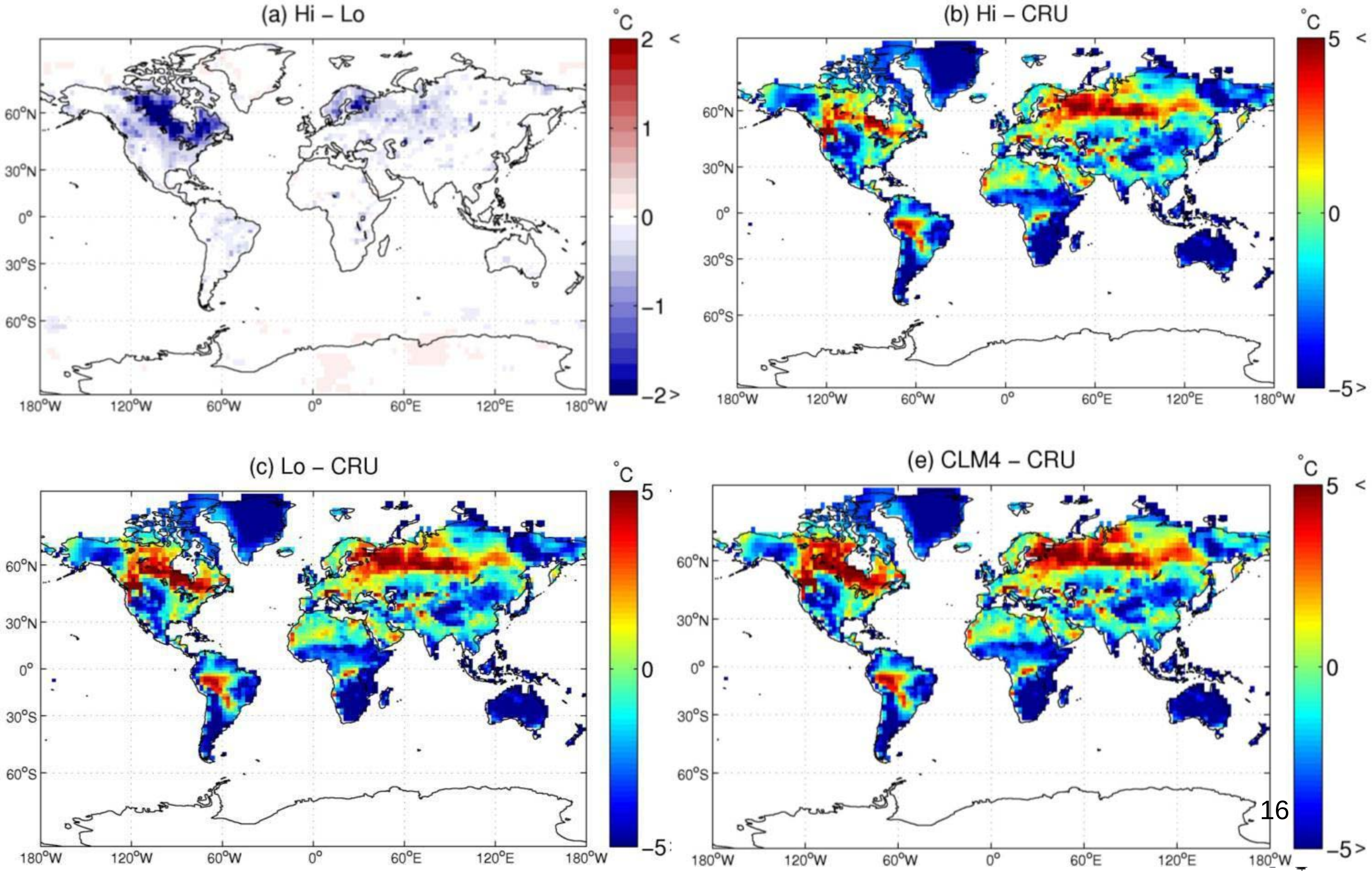
Hi-Lo Canadian Flux Anomalies



Hi-Lo Surf. Air Temp.

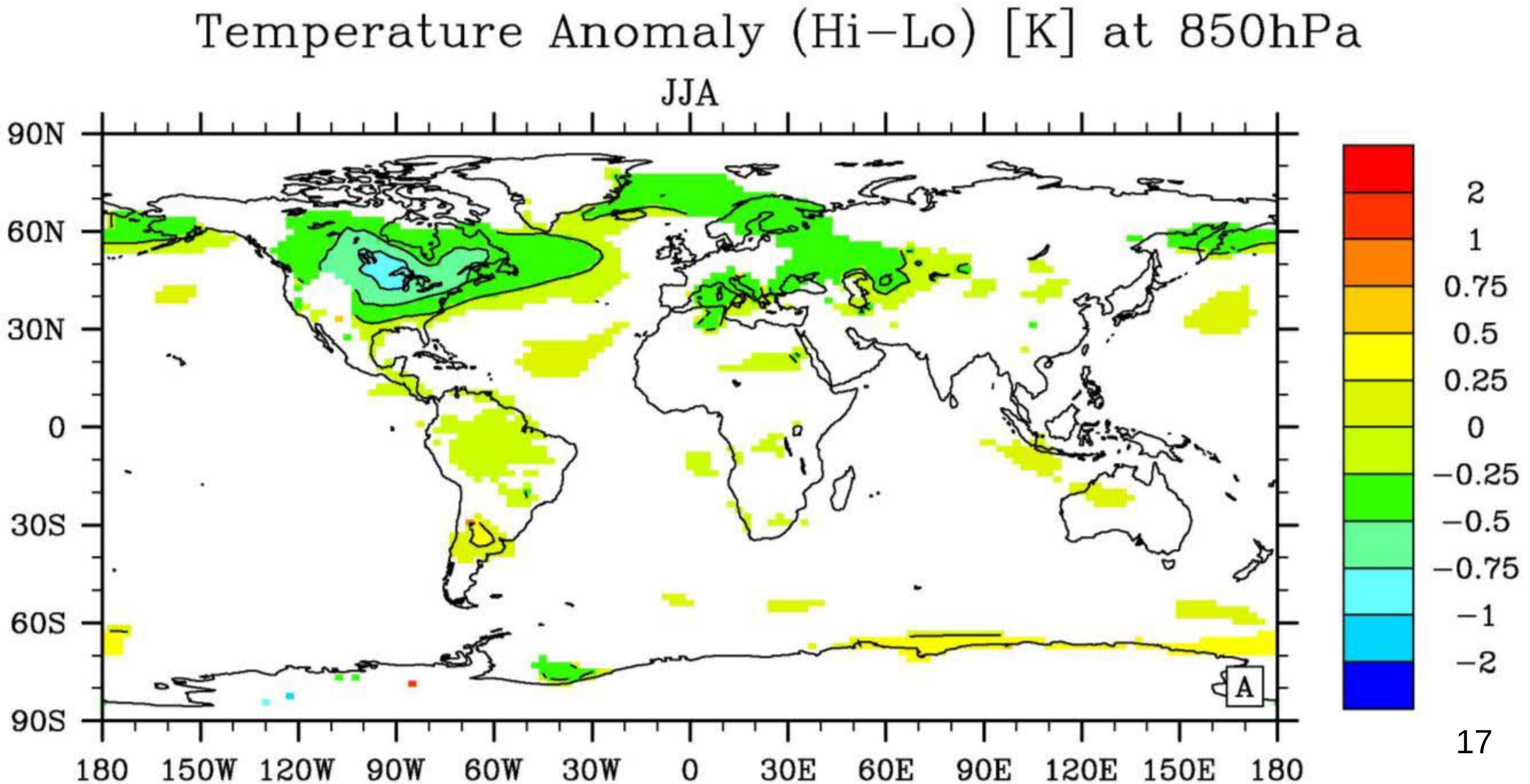


JJA Diurnal Temp. Range



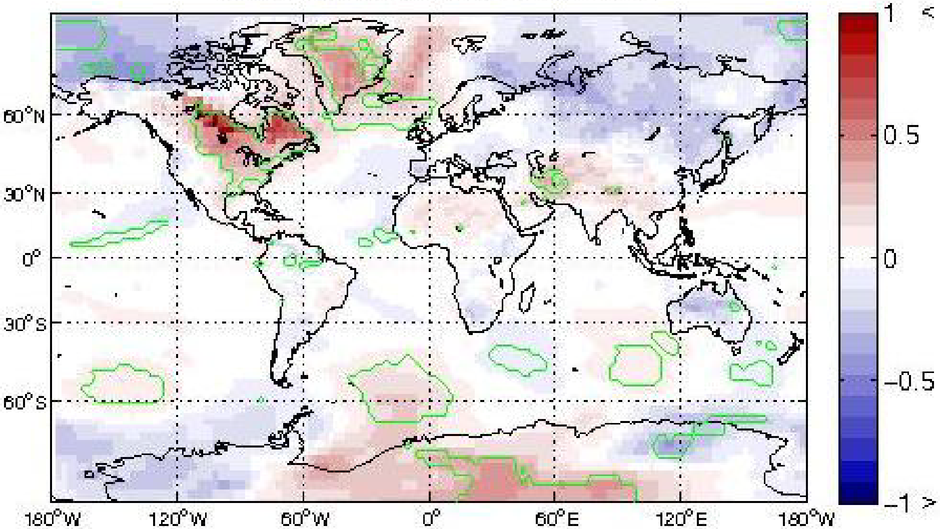
Atmospheric Response

- Lower atm. responds more to daytime SH
- Remote changes / modes of variability?

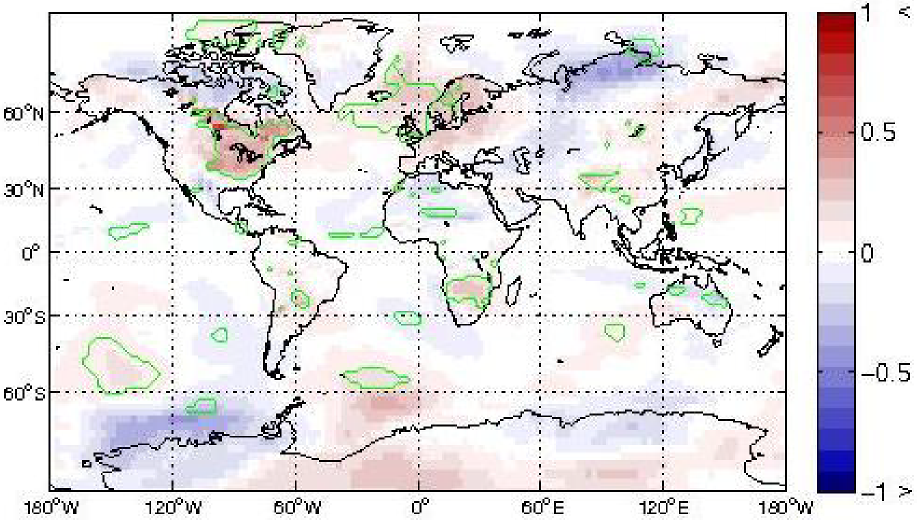


Future – Hi Area, 2 x CO_2

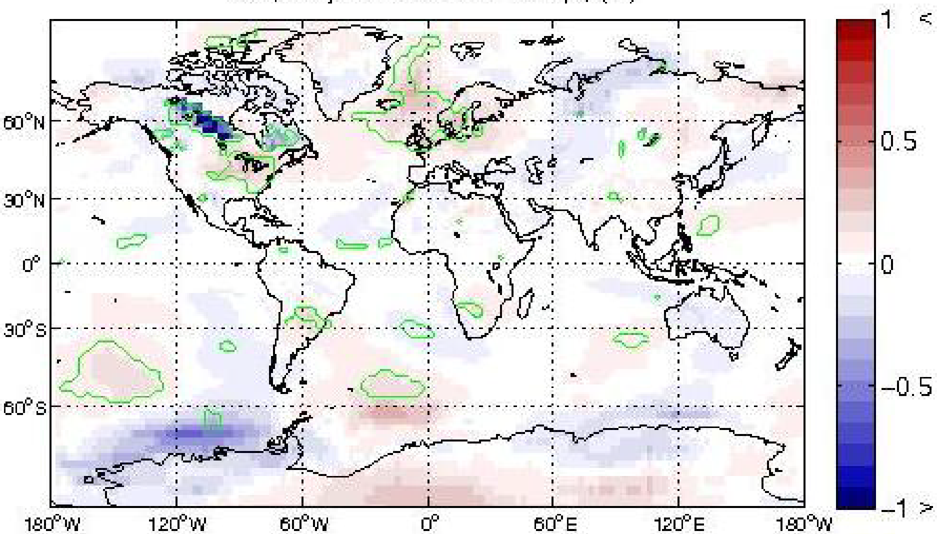
MAM,Daily Max. Surf. Air Temp., (C)



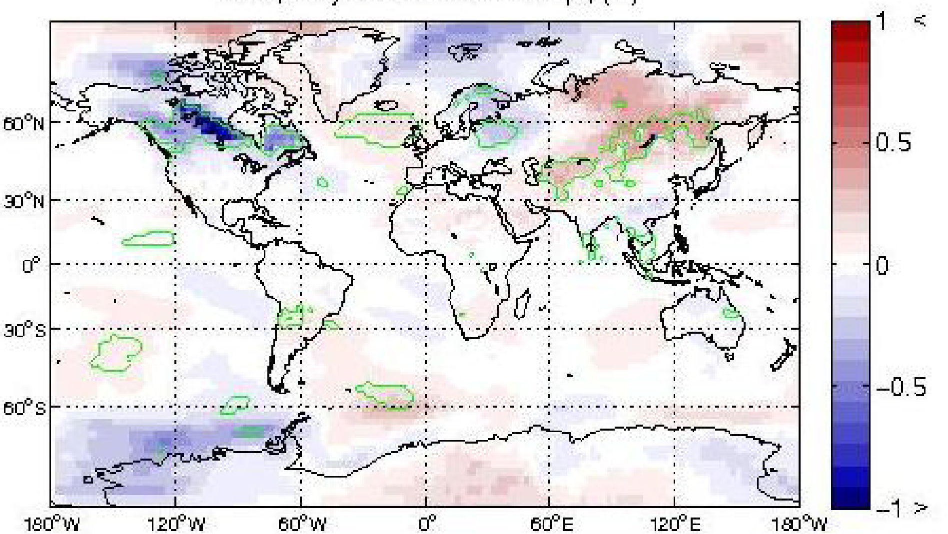
JJA,Daily Max. Surf. Air Temp., (C)



JJA,Daily Min. Surf. Air Temp., (C)



SON,Daily Min. Surf. Air Temp., (C)



Conclusions

- New lake model evaluated for 13 lakes
  - CLM4 model evaluated for 4 lakes
  - New model: large improvement in water temperature and surface fluxes
  - Increased mixing improves results for large lakes; more work needed
- 14 surface flux sensitivity cases
  - Snow & ice processes are important for climate.
  - Better data needed on opacity, depth, melting albedo

Conclusions, cont'd

- Lake area is currently under-estimated.
  - Correcting improves diurnal temp. range
  - Permafrost lake area changes likely much smaller in importance

Acknowledgments

- Victor Stepanenko (Moscow State University), Andrey Martynov (UQAM), Marjorie Perroud (NOAA)
- Margaret Torn (LBNL), David Lawrence
- Funding from DOE Office of Science, Biological & Environmental Research