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Poster #66

Lake Superior's John Hancock: Unique Atmospheric Signature in Tall Tower CO2

Victoria Vasys[1], Ankur Desai[1], Galen McKinley[1], and Anna Michalak[2]

[1]Atmospheric and Oceanic Sciences, University of Wisconsin – Madison, Madison, WI
[2]Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, MI

Abstract

The Great Lakes have a large impact on regional climate, yet their carbon cycles are under-studied. This investigation attempts to determine whether the atmosphere can depict a carbon signature from Lake Superior and further, whether it can be used to calculate accurate fluxes from the lake. Particle influences on the tower are resolved from an atmospheric transport model and particles that have traveled over Lake Superior are identified. Lake fluxes extracted from a novel coupled 3D lake ecosystem and circulation model are applied to the transport model and the expected CO2 measurements at the tall tower are calculated and compared. Seasonal patterns of lake fluxes are evident in the atmospheric observations, however, further research is needed to identify the accuracy of the methodology.

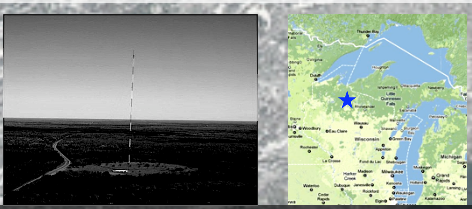

Figure 1. The WLEF 447-m tall tower a) viewed from afar, b) located 14 km east of Park Falls, WI in the Chequamagon National Forest, as indicated by the blue star. CO_2 is measured continuously at 396 m and periodically at a total of six heights.

Introduction

- Great Lakes carbon cycle uncertainty, confirmed by:
    - Urban, et al. in situ measurements
    - McKinley, et al. model calculations
    - Atilla, et al. EPA pCO_2 evaluation
- Useful tall tower network, but largely ignores large lakes
    - Gerbig, et al. regional- scale constraint of fluxes
    - Desai, et al. terrestrial CO2 fluxes in upper midwest
- Lake Superior impact on WLEF tall (447 m) tower
    - Discernable signal from L. Superior
    - Former wind direction approach inadequate
- Transport models now able to resolve flow
    - High-res WRF model applied to STILT particle model to project air masses arriving at WLEF tall tower
    - Michalak, et al. small scale surface flux estimations

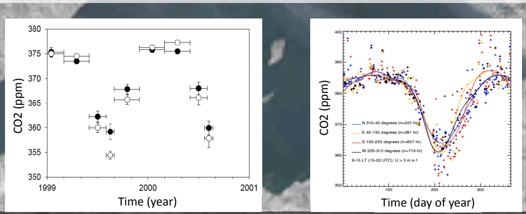

Figure 2. CO_2 concentrations from the 396-m level of the WLEF. a) Open (closed) circles represent periods when wind was blowing over the land (Lake Superior). b) Concentrations divided into four wind direction bins. The blue line indicates winds approaching the tower from the north, where Lake Superior is located.

Methods

- Obtained STILT inverse model (see conceptual model) outputs with particles released from WLEF
- Investigated annual influences on WLEF tower
- Computed transit times from particle data to evaluate flux influence from L. Superior on a 60x30 10-km grid

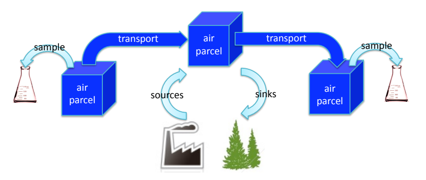

Figure 3. Traditional inverse modeling conceptual model. CO_2 concentrations are measured at two sampling locations. Changes in CO_2 among the two samples provide information about sources and sinks between the locations.

Results

- Particle trajectories and annual accumulation of particles released backward reveal Lake Superior, especially the western arm, does have an influence on WLEF
- Modeled lake fluxes are small and thus induce a small influence at the tower; model does not yet include riverine inputs. Increasing the flux by an order of magnitude would induce up to a 2ppm hourly influence on the WLEF tower.

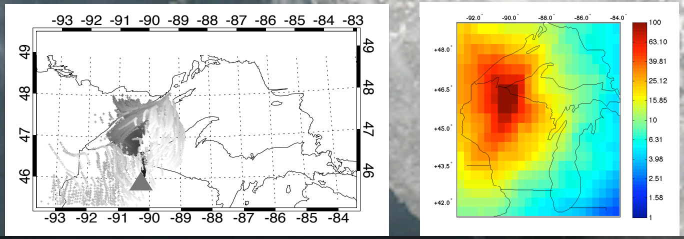

Figure 4. a) Particle trajectories as released from WLEF on 26 March 2004 using the STILT model. Darker colors indicate more recently released. b) Total annual influence (m^2s / mol) of particles on the WLEF.

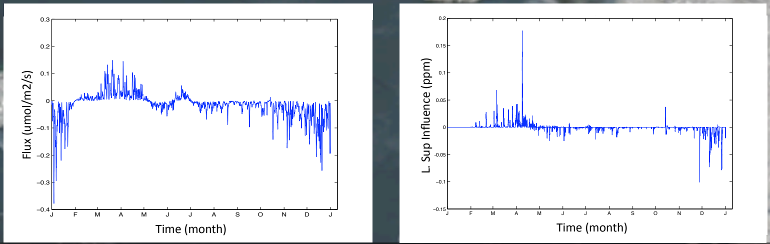

Figure 5. a) Hourly flux of CO2 at the surface of Lake Superior, according to the UW Lake Superior dynamic-ecosystem model. b) Influence of Lake Superior on WLEF tall tower, according to modeled lake fluxes and STILT influence functions.

Conclusions & Future Work

1. CO_2 fluxes from the lake impact CO_2 concentrations at the WLEF tower
2. Inverse modeling suggests the WLEF tower is influenced by Lake Superior
3. Small fluxes from the model induce a relatively small influence on the tower using inverse modeling

- Attempt to implement additional towers, such as Fraserdale, north of L. Superior
- Attempt top-down constraint on lake flux using an algorithm such as:

([C at WLEF] = [Farfield C] + [influence of land] * [flux of land] + [influence of lake] * [flux of lake])

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REFERENCES

Atilla, N., G. A. McKinley, V. Bennington, M. Baehr, N. Urban, M. DeGrandpre, A. R. Desai, C. Wu, 2010. Observed variability of Lake Superior pCO_2. *In Press*.

Bakwin, P. S., P. P. Tans, D. F. Hurst, and C. Zhao, 1998. Measurements of carbon diiioxide on very tall towers: results of the NOAA/CMDL program. *Tellus*, **50B**, 401-415.

Davis, K. J., P. S. Bakwin, C. Yi, B. W. Berger, C. Zhao, R. M. Teclaw, and J. G. Isebrands, 2003. The annual cycles of CO2 and H2O exchange over northern mixed forest as observed from a very tall tower. *Global Change Biol.*, **9**, 1278-1293.

Desai, A. R., A. Noormets, P. V. Bolstad, J. Chen, B. D. Cook, K. J. Davis, E. S. Euskirchen, C. Gough, J. G. Martin, D. M. Ricciuto, H. P. Schmid, J. Tang, and W. Wang, 2008. Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the upper midwest, USA: Implications for regional scaling. *Ag. and Forest Meteor.*, **148**, 288-308.

Gerbig, C., J. C. Lin, S. C. Wofsy, B. C. Daube, A. E. Andrews, B. B. Stephens, P. S. Bakwin, and C. A. Grainger, 2003. Toward constraining regional-scale fluxes of CO_2 with atmospheric observations over a continent: 2. Analysis of COBRA data using a receptor-oriented framework. *J. Geophys. Res.*, **108** (D24), doi: 10.1029/2003JD003770.

Lin, J. C., C. Gerbig, S. C. Wofsy, A. E. Andrews, B. C. Daube, K. J. Davis, and C. A. Grainger, 2003. A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model. *J. Geophys. Res.*, **108** (D16), doi: 10.1029/2002JD003161.

Michalak, A. M., L. Bruhwiler, and P. P. Tans, 2004. A geostatistical approach to surface flux estimation of atmospheric trace gases. *J. Geophys. Res.*, **109** (D14109), doi: 10.1029/2003JD004422.

Urban, N. R., M. T. Auer, S. A. Green, X. Lu, D. S. Apul, K. D. Powell, and L. Bub, 2005. Carbon cycling in Lake Superior. *J. Geophys. Res.*, **110** (C06S90), doi: 10.1029/2003JC002230.