Online Supporting Material – Supplementary Data

S.1 Methods

S.1.1 CO_2 observations

CO_2 concentrations at 396 m above ground were measured at the WLEF 447-m tall tower, located 14 km east of Park Falls, WI, USA (Bakwin *et al* 1998) using a non-dispersive infrared gas analyzer calibrated against known standard gases. These tower-observed CO_2 concentrations in units of ppm were compared to mid-latitude (45^o N) Pacific Ocean marine-boundary-layer (MBL) CO_2 concentrations to assess the relative influence of continental sources and sinks on tower CO_2 – MBL anomalies. MBL CO_2 was acquired from the NOAA ESRL Globalview dataset, which is interpolated from the global CO_2 flask observation network.

S.1.2 Influence functions and lake contribution

The well-tested Stochastic Time-Inverted Lagrangian Transport (STILT) particle tracking model (Gerbig *et al* 2003, Lin *et al* 2003, Michalak *et al* 2004) was used to compute influence functions for this study. STILT derives these functions by tracing ensembles of particles released in a model of wind fields. Wind fields used by STILT were provided by high-resolution mesoscale transport fields obtained using the National Center for Atmospheric Research (NCAR) Weather Research and Forecating (WRF) model (Gourdji *et al* 2010).

Both models were run for Feb-Dec 2004. January was not included due to WRF model output not being available at the time of analysis, but the results from February and December should be comparable to January. The transport model was run in a nested grid with the highest resolution of 2 x 2 km in the region surrounding WLEF. WRF model output showed high fidelity in reproducing both large-scale transport fields and local transport near the tower. The STILT model released 500 virtual particles from the 396-m level of the tower every hour. Trajectories of these particles through the WRF wind fields were tracked for 10 days backward in time and locations of particles in latitude, longitude, and altitude were recorded every 15 minutes. To generate particle dispersion among the particles, positions of particles were randomly perturbed from the release location and a subgrid model of random fluctuations was applied to the wind fields. WRF-STILT output is available online at http://puorg.engin.umich.edu/. It is likely that there were transport model biases owing to the difficulty of modeling lake-land boundary layer transitions, internal boundary layers along coastlines, and step changes in mixing depths, and these require further investigation. Still, previous studies have shown the large-scale synoptic transport of trace gases is well simulated by this model (Lin *et al* 2003).

Gridded influence function maps were computed by summing mass-conservation corrected (Gerbig *et al* 2003) boundary-layer particle mass across both a regional 0.375° grid, and a lake-specific 10-km grid. A primary assumption here is that particles, in the modeled boundary layer were influenced by fluxes emitted at the surface over which they transited, though we also accounted for particle height in this calculation by scaling contribution of an individual particle by the height of the particle relative to modeled boundary layer depth. Total lake influence was subset from these maps by applying a water mask to the grid and summing influence over all pixels identified as water.

S.1.3 Lake modeling

A three-dimensional gridded hydrodynamic-ecosystem model of Lake Superior (Bennington *et al* 2010, Desai *et al* 2009, Bennington *et al* in prep.) was run for 2004. Net primary productivity (NPP), respiration, carbon cycling and lake-air fluxes were calculated on a 2-km x 2-km grid and output in units of μmol m^{-2} s^{-1}. The model included daily carbon loads from the lake's nine largest tributaries, and seasonal variations of pCO_2 compared well to observations (Atilla *et al* 2011). The contribution of the lake fluxes to tall-tower CO_2 was computed by convolving the previously-described influence functions (ppm/(μmol m^{-2} s^{-1})) with these gridded hourly fluxes (μmol m^{-2} s^{-1}), and summing those values across all lake grid cells and over each month of analysis to produce CO_2 influence at the tower in units of ppm.

To compare contributions of the lake to those of the surrounding terrestrial ecosystems, the contribution of regional land fluxes to tall-tower CO_2 was also approximated, over a domain defined by a 600 km by 300 km box circumscribing Lake Superior. A typical CO_2 flux was assumed across the based on eddy covariance observed fluxes at the WLEF tall tower (Davis *et al* 2003) and convolved with the influence functions in the same manner as for the lake. The tower footprint samples a representative forest-wetland landscape (Desai *et al* 2010), and so this is a reasonable first guess of typical land surface CO_2 flux.

Supplementary References

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