Novel approaches to estimating regional CH_4 fluxes from a very tall tower

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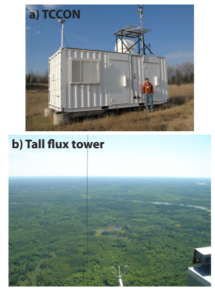
Introduction

Can we estimate regional CH_4 land surface flux with:

(a) Column CO_2 and CH_4 observations from the Total Carbon Column Observatory Network (TCCON) solar spectroscopic FT-IR instrument?

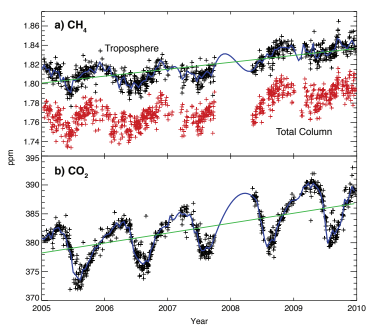
(b) Tall eddy covariance flux tower (WLEF) net ecosystem exchange (NEE) of CO_2 observations?

in a heterogeneous upland-wetland-lake landscape where CH_4 fluxes are likely to be significant but poorly constrained?



Photos courtesy of: a) G. Keppel-Aleks, b) B.D. Cook

Observations



Daytime averaged column observations of CO_2 and CH_4 from 2005-2009 in Park Falls, WI USA reflect global and regional sources and sinks (left).

Total column CH_4 observations (red points) were corrected for stratospheric influence to estimate troposphere-only CH_4 (black points) using HF column (Washenfelder *et al.*, 2003)

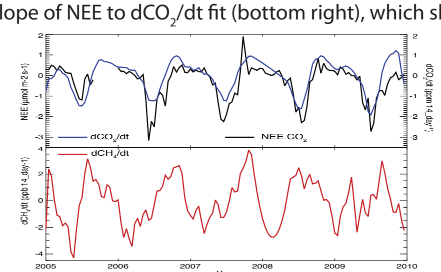
Fossil fuel signal was removed by simple linear fit (green line) and gaps filled with spline interpolation (blue line) for both CO_2 and CH_4.

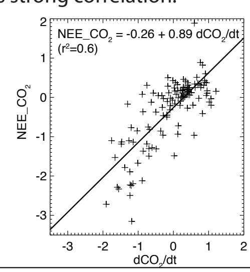
Methods

Neglecting entrainment, the time rate of change in atmospheric column should be proportional to flux. Assuming this proportion is the same for CO_2 and CH_4, we can write a simple equation for NEE CH_4:

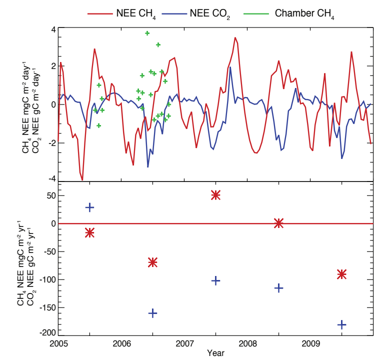
$$\frac{NEE\_CH_4}{NEE\_CO_2} = \frac{k_{CH_4}\frac{dCH_4}{dt}}{k_{CO_2}\frac{dCO_2}{dt}} \longrightarrow NEE\_CH_4 = \left[\frac{NEE\_CO_2}{\frac{dCO_2}{dt}}\right]\frac{dCH_4}{dt}$$

Entrainment can be neglected when averaged over multiple synoptic cycles (Helliker *et al.*, 2004) and by using total column observations. Time derivative of 14-day average CO_2 (bottom left) shows pattern that reflects flux. Term in bracket above was estimated from slope of NEE to dCO_2/dt fit (bottom right), which shows strong correlation.





Results



Estimated regional CH_4 flux (right, red line) has a seasonal pattern of uptake in winter and emissions in late summer, in contrast to NEE CO_2 (blue line).

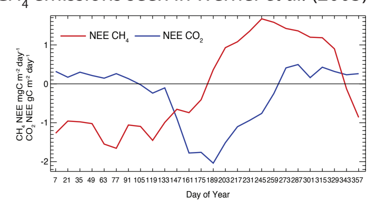
CH_4 fluxes are of similar magnitude to chamber observations of CH_4 efflux (green crosses) measured at three wetlands in tower footprint in 2006-2007, but seasonality is offset.

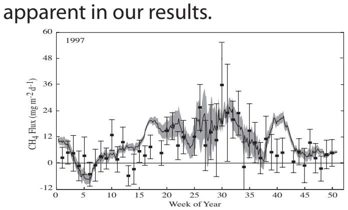
Annual CH_4 flux (right, red stars) has high interannual variability, alternating from sink to source, but is positively correlated to CO_2 flux interannual variability (blue crosses).

Discussion

Seasonal uptake of CO_2 NEE (bottom left, blue line) appears to lag CH_4 NEE uptake (red line) by 3-6 months and CH_4 maximum efflux occurs in late summer. While seasonal NEE of CO_2 and CH_4 are anti-correlated, annual fluxes of CO_2 and CH_4 are positively correlated. These results imply complex biogeochemical mechanisms occuring at regional scale.

CH_4 flux magnitudes were at lower bounds of those estimated by modified-Bowen ratio technique (bottom right, black line) and nocturnal column accumulation (black dots) from tower GC observations of CH_4 and CO_2 in 1997 (Werner *et al.*, 2003). Dual peak pattern of CH_4 emissions seen in Werner *et al.* (2003) not apparent in our results.





Conclusion

Future work is needed to test sensitivity of method to assumptions on averaging, fossil fuel estimate, entrainment, linearity of ratio of NEE to column change, difference in footprint between tall tower NEE, column and chamber observations, and observation error.

New measurements of tall tower eddy covariance CH_4 initiated in fall 2010 and ongoing model-based upscaling of chamber observations will provide independent estimates of magnitude and pattern of regional methane flux and applicability of our technique.

Citations: Helliker *et al.* (2004) *J Geophys. Res*; Washenfelder *et al.* (2003) *Geophys. Res. Lett.*; Werner *et al.* (2003) *Global Change Biol.*

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