Evaluating large-scale models of terrestrial CH_4 emission with a very tall tower

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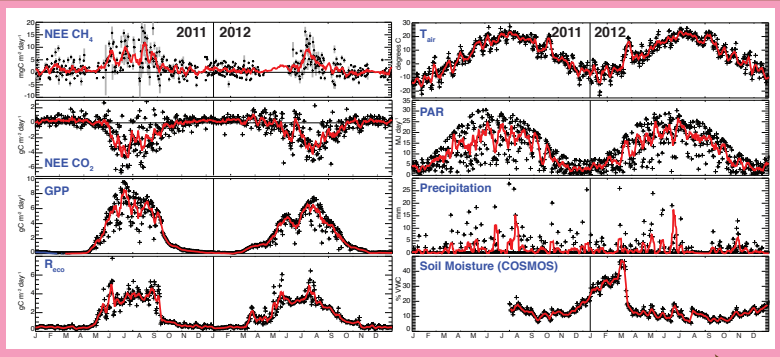
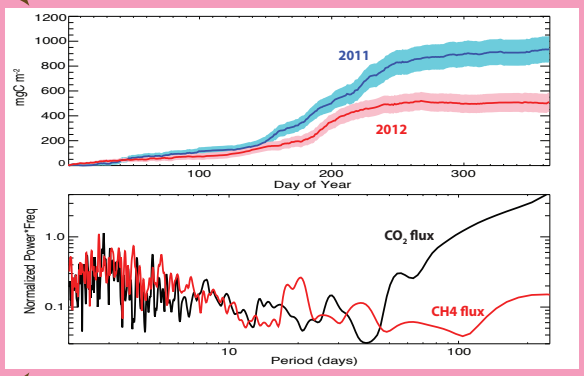
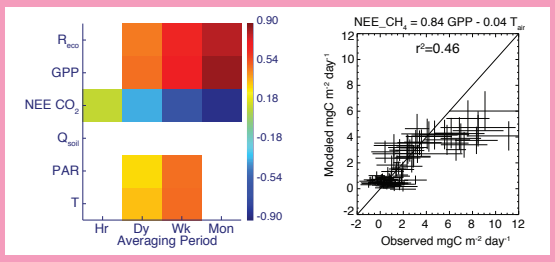
- Biogenic methane emissions are poorly constrained globally!
- Most CH_4 field studies are at small-scale, making regional model evaluation difficult
- In 2010, we instrumented the WLEF Park Falls very tall tower (US-PFa) with eddy covariance for CH_4 at 122m w/ Picarro 2301-f. H_2O fluxes from LI-6262 required for WPL! Storage fluxes from LGR CH_4 analyzer profile.
- Flux footprint fetch is 2-5 km across a heterogenous upper Midwest USA landscape of wetlands (30%) and temperate hardwood forest (70%)
- Figure on right shows daily (+) and weekly (red) NEE, partioned component fluxes, and meteorological conditions.
- CH_4 random flux uncertainty (gray lines) based on deviations of flux from successive filtering of blocks of flux data (Salesky *et al*., 2012, *BLM*). Errors are less heteroskedastic that CO_2. Mean error is 1.8 +/- 4.1 nmol m^{-2} s^{-1}

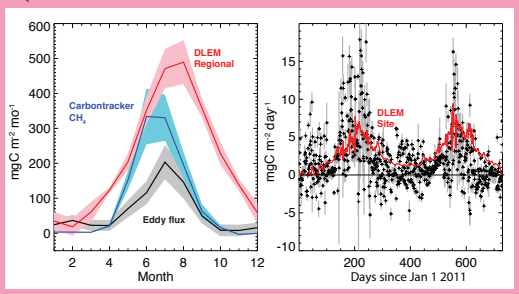




- Methane fluxes gap-filled at daily level with simple polynomial fit to air temperature. Have not been very successful with hourly gap-filling!
- Annual cumulative methane emissions on left show reduced emissions during warm, drought conditions in late 2012 (red line, 510±77 mgC m^{-2}) compared to more average conditions in 2011 (blue line, 935±105 mgC m^{-2}). CO_2 fluxes show similar reduction, primarily in GPP, suggesting regional CH_4 fluxes are primed by photosynthate, though reduced moisture may also suppress anaerobic emissions in wetlands
- Cumulative uncertainty based on quadrature sum (with autocorrelation correction) on random flux error and 2-σ parameter fit errors for gap-filled days. Regional methane fluxes are small (mean 2.8 nmol m^{-2} s^{-1}), and annual random uncertainty is 10% of total.
- A challenge of CH_4 fluxes is greater high-frequency variability as shown in Hilbert empirical model decomposition power spectrum in bottom figure on left (red line) compared to CO_2 fluxes (black line), which have greater monthly and seasonal variability

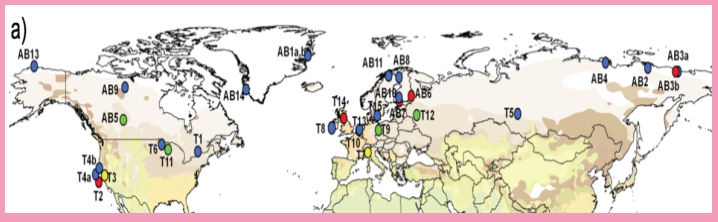
- Environmental control analysis on right based on simple linear correlation between NEE of CH_4 and observed forcing factors at four smoothing timescales (hourly, daily, weekly, monthly). Only significant correlations shown after correcting for effective degress of freedom, which accounts for data autocorrelation at all lags (Bretherton *et al*., 1999, *J. Clim*)
- Pearson correlation coefficient strongest for GPP and R_{eco}, leading to negative correlation with NEE at greater than hourly scale. Weaker correlation to temperature and no significant correlation to regional soil moisture from COSMOS neturon scattering probe
- Most parsimonious model of weekly fluxes (far right) includes GPP and temperature
- Linear model strongly underpredicts periods of high emission and also poor in winter





- Far left: regional scale 5x5 degree cutouts of top-down inversion (Carbontracker-CH4, blue line) and ~1x1 degree cutout of bottom-up ecosystem model (DLEM, red line) from 2000-2010 with monthly 10-yr standard deviation in shading show similar seasonal pattern to flux tower (black line with uncertainty in gray), but greater emissions. Top-down shows more efflux in spring while bottom-up has more in fall.
- Left: DLEM model parameterized for site (red line, daily fluxes) has much closer agreement to flux tower, but still overpredicts methane emission in fall. Also has weak interannual variability with no suppression of methane fluxes in dry year (2011). Net result is 40% overprediction on average.
- Primary difference between site and regional DLEM is increased fraction of wetland in latter.
- All models miss episodic large emissions in winter and middle of summer, hinting at other high-frequency processes important to methane flux.

- Clearly, evaluation of biogenic methane emissions is still in infancy and many questions remain unanswered at high and low frequencies
- Initial work on building a Fluxnet-CH_4 network for eddy covariance sites with CH_4 flux or autochambers started at a workshop last fall. See Dario Papale or Timo Vesala for more
- Global wetland CH_4 flux tower synthesis underway (Petruscu *et al*., in prep) focusing on growing network of auto chambers and towers in wetlands as shown on right. Also special issue in *Biogeosciences* open
- Seeking modelers and flux towers interested in evaluating larger scale models and developing quality-controlled CH_4 NEE and uncertainty



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