Evaluating large-scale models of terrestrial CH$_4$ emission with a very tall tower

Ankur R Desai*, Ke Xu, & Jonathan Thom, University of Wisconsin-Madison
Hanqin Tian & Bowen Zhang, Auburn University, and Lori Bruhwiler, NOAA ESRL
*desai@aos.wisc.edu  http://flux.aos.wisc.edu

- 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-PPa) with eddy covariance for CH$_4$ at 122m w/ Picasso 2301-F, H$_2$O fluxes from LI-6262 required for WPLI 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
- Flux footprint fetch is 2-5 km across a heterogenous upper Midwest USA models and developing quality-controlled CH$_4$ fluxes from LGR CH$_4$ LI-6262 required for WPL! Storage component
- Figure on right shows daily (+) and weekly (red) NEE, partioned
- Flux footprint fetch is 2-5 km across a heterogenous upper Midwest USA

- 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 degrees of freedom, which accounts for data autocorrelation at all lags (Breherton et al., 1999, J. Clim)
- Pearson correlation coefficient strongest for GPP and $R_{\text{eco}}$, 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

- 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 photosynthe, 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-$\sigma$ 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

- 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 Biogeoosciences open
- Seeking modelers and flux towers interested in evaluating larger scale models and developing quality-controlled CH$_4$ NEE and uncertainty

Acknowledgements: WLEF tall tower operations/analysis supported through funding by National Science Foundation (DEB-0845166 and DBI-1062204), tower operations by Wisconsin Educational Communications Board (J. Ayers), and technical assistance from D. Baumann, USGS, A. Andrews and J. Koffer of NOAA, and K. Davis at Penn State