

**Annual Report for Period:**08/2011 - 07/2012**Submitted on:** 05/04/2012**Principal Investigator:** Desai, Ankur R.**Award ID:** 0845166**Organization:** U of Wisconsin Madison**Submitted By:**

Desai, Ankur - Principal Investigator

**Title:****CAREER:** Contrasting environmental controls on regional CO<sub>2</sub> and CH<sub>4</sub> biogeochemistry-Research and education for placing global change in a regional, local context

### **Project Participants**

#### **Senior Personnel**

**Name:** Desai, Ankur**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Desai is lead PI and oversaw project management. Desai conducted research activities in Year 3 on footprint modeling, land cover analysis, CH<sub>4</sub> flux data processing, and the Menominee Nation outreach project. He supervised one associate scientist, one graduate student, and two undergraduate students.

#### **Post-doc**

**Name:** Hua, Dong**Worked for more than 160 Hours:** No**Contribution to Project:**

Dong Hua is a new post-doctoral scholar in the Desai lab who will be partially supported here to continue flux tower data processing and ecosystem modeling.

#### **Graduate Student**

**Name:** Jimenez, Kristine**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Kristin left graduate school in spring 2011 to pursue other opportunities and was not supported in year 3.

**Name:** Sulman, Benjamin**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Sulman is a finishing PhD student whose work on his final dissertation chapter was supported here in year 3. He worked on integration of hydrological variability and peatland succession on landscape carbon flux variability in the study area.

#### **Undergraduate Student**

**Name:** Welch, Jennifer**Worked for more than 160 Hours:** Yes**Contribution to Project:**

A combination of NSF and DOE funding supported a 10-week internship for Jennifer Welch in summer 2010 to work on processing and analysing WLEF tall tower fluxes and total column CH<sub>4</sub> observations.

#### **Technician, Programmer**

**Name:** Thom, Jonathan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Jonathan, Thom was supported 20% by this project to provide continued assistance in site maintenance, operations, data ingest, and lab work.

**Other Participant**

**Research Experience for Undergraduates**

**Name:** Harp, Ryan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Ryan Harp was hired in summer 2011 for a 10-wk REU. He is working on analyzing soil moisture relationships to regional and site level fluxes and assisting in collection of soil respiration and 14C observations with DOE LLNL collaborators.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2011

**REU Funding:** REU supplement

**Name:** Gumber, Amanda

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Amanda is an REU supported student for summer 2012 who will work on development of a calibration protocol for CH<sub>4</sub> and CO<sub>2</sub> cylinder gases and micro met spatial variation characterization.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2012

**REU Funding:** REU supplement

**Name:** Thomas, Austin

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Austin is an REU supported student for summer 2012 who will work on development of a survey chamber for CH<sub>4</sub> soil flux measurement and test it on the study area landscape.

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2012

**REU Funding:** REU supplement

**Organizational Partners**

**NOAA/Office of Atmospheric Research/Earth Systems Research Lab**

Arlyn Andrews and Jonathan Kofler of NOAA ESRL coordinated with Jonathan Thom and the PI

on installation of CH<sub>4</sub> profiling instrumentation. The CH<sub>4</sub> instrument was sent to NOAA where Jonathan and others tested various ways to integrate instrument into the CO<sub>2</sub> profiling rack. This in-kind support of testing and calibration facility is essential for proper observations. We continued our long standing collaboration on research with data at the site and sharing of facility space in the instrument trailer, which NOAA provides and we maintain. NOAA helped install the profile system.

#### **USFS Northern Research Station**

USFS Northern Research Station staff scientist Mark Kubiske and Dan Baumann coordinate on collection of data at the WLEF tower site. Weekly data collection and maintenance visits, funded partly by NOAA and eventually by this grant, ensure high uptime.

#### **College of Menominee Nation**

Outreach partner College of Menominee Nation worked with this project on our community college field course.

#### **University of Arizona**

COSMOS soil moisture sensor (NSF-supported) installed at WLEF site by University of Arizona collaborators (Trenton Franz, Rafael Soloem, Jim Shuttleworth), with a second sensor planned for year 3. Also at Arizona, Dave Moore is planning to install at WLEF a high-resolution multi-angle digital camera for phenology analysis at the tower site.

### **Other Collaborators or Contacts**

Collaborators at:

Paul Wennberg and student Gretchen Keppel-Aleks at California Institute of Technology has provided calibrated methane column and CO<sub>2</sub> column FTIR abundances at the site.

Bruce Cook at NASA GSFC is collaborating on analysis of methane chamber observations at nearby wetland sites and remote sensing land cover analysis.

Anna Michalak, University of Michigan, provided WRF-STILT transport model influence function data for the tower, which we can use to assess the air mass sampling footprint of the tower.

Karis Macfarlane and Claire Phillips from Dept of Energy Lawrence Livermore Laboratory has funding from DOE to measure <sup>14</sup>C flasks at WLEF and soil respiration across forest sites nearby. We have assisted in their setup and measurement. REU student Ryan Harp is also working with them.

Diego Riveros-Iregui is a soil ecologist at U Nebraska. He visited some wetlands in the region to conduct some organic carbon density and microbial analysis, that we hope to build on in the future with our soil survey work.

### **Activities and Findings**

#### **Research and Education Activities:**

In year 3, we focused squarely on the proposed tasks, made new discoveries on seasonal patterns of methane emissions, and gained significant attention locally from our outreach field course.

## Year 3 activities:

- 1) Relevant to Task 1, we continued measurement of long-term CH<sub>4</sub> and CO<sub>2</sub> fluxes and atmospheric profiles from the WLEF-TV tall tower. We also begun collaboration on our footprint-weight land cover analysis, having deploying the flux footprint code and acquired high-resolution hand analyzed species level land cover maps. These results were presented at the December AGU meeting and the upcoming May AMS Biogeosciences meeting. We have developed automated file transfer and are working on automating flux processing to acquire near-realtime fluxes at the site.
- 2) To help decompose the regional flux into its constituents, we also, as proposed, developed and applied a convective boundary layer flux footprint algorithm to the 2011 time series of CH<sub>4</sub> flux, with collaboration from Weiguo Wang at NOAA. Bruce Cook at NASA provided hand-analyzed high-resolution (30m) land cover maps which were then used to convolve flux and land cover to solve for local flux. This analysis will be presented at the AMS Biogeosciences meeting in May.
- 3) To further test for environmental controls on fluxes, we conducted some initial correlation analysis and have started collected automated CO<sub>2</sub> soil respiration data at a hardwood forest (in collaboration with Claire Phillips at DOE LLNL), collected peatland cores along a topographic gradient and are awaiting lab analysis for <sup>15</sup>N, <sup>13</sup>C, and pyrosequence and DNA based analysis for microbial functional community (in collaboration with Diego Riveros-Iregui at U Nebraska).
- 4) Some initial work on regional-modeling (as outlined in the proposal) started through the PhD work of Ben Sulman, who has extended a forest succession model from Dave Mladenoff at UW (LANDIS-II) to include peatland succession and showed the importance of hydrologic processes in driving vegetation dynamics and ultimately carbon uptake. These processes are further coupled to short-term processes occurring at the inter annual scale within wetland communities, which show increased productivity and respiration in drier years, opposite the regional response, and poorly resolved in current generation ecosystem models (as published in Sulman et al., 2011).
- 5) The WLEF tower site and the ChEAS flux tower mesonet continue to serve as a international testbed for regional ecosystem-atmosphere interaction, with model development and evaluation presented in several papers by Bagley et al. (2011) on boundary-layer dynamic models, Richardson et al. (2012) on modeling of phenology, Schafer et al (accepted) on modeling of GPP, Gower et al (in review) on CO<sub>2</sub> fluxes of old-growth forests, Wu et al. (in review) on inter annual variability, and Grant et al (submitted) on peatland CO<sub>2</sub> and CH<sub>4</sub> modeling. Additional collaborations for new cosmic ray atmospheric humidity sensing (via the COSMOS project), regional webcam phenology are under work.
- 6) In Year 2, we worked extensively on the trace gas and column CH<sub>4</sub> budget. The lead PhD student working on that left the graduate program, so this research has been stalled for the moment. A new graduate student Ke Xu, will start this summer and hopefully pick up this work and couple it to our activities on flux tower measurement and ecosystem modeling. Year 4 activities will focus on coupling the trace gas budget and flux footprint analysis, expanding on the soil chamber and microbial/stable isotope analysis, and developing ecosystem modeling of CH<sub>4</sub> emissions.

**Findings: (See PDF version submitted by PI at the end of the report)**

Our two biggest findings to date are a) the strong role of regional water balance on regional carbon fluxes, even outside of wetlands (as published in prior years) (Fig. 1), and b) our newest finding on the significant role of winter-time episodic methane emissions on the annual methane budget (Figs 2 and 3). The long-term CO<sub>2</sub> fluxes reveal a pattern of

declining uptake over a period of water table decline, and in 2011, a dramatic shift to large uptake in a year with significant water table increase. This result contrasts what we see in the wetlands, where flux towers show concomitant increases in GPP and respiration with lower water table. Wetter conditions, regionally, drive larger uptake, for reasons we are still investigating.

The methane fluxes are showing patterns that are quite unique. Winter time  $\text{CH}_4$  fluxes are of the same magnitude as winter, but more episodic. There is a clear regime shift inside and outside the growing season (Fig. 2). Growing season  $\text{CH}_4$  fluxes are of the same magnitude as wetland chamber emissions (Fig. 3) suggesting that growing season  $\text{CH}_4$  emissions are primarily driven by wetland emission. This is supported by stronger relationship of  $\text{CH}_4$  flux to temperature (Fig. 4a) then to NEP in the summer (Fig. 4b). In contrast, winter time  $\text{CH}_4$  fluxes are strongly coupled to the smaller magnitude (relatively)  $\text{CO}_2$  fluxes, implying a common source for both. We are continuing statistical analysis of environmental controls.

To better understand the source of  $\text{CO}_2$  and  $\text{CH}_4$  fluxes from the tall tower, we have begun analyzing specie-level land cover maps around the tower (Fig. 5), which reveal the patchy and near-fractal like nature of upland and lowland in the tower footprint. We have applied a novel convective layer footprint model to connect the fluxes measured at the site to this land cover map. The mean footprints reveal a fetch for the 122m  $\text{CH}_4$  fluxes of 5 km for the e-folding sample depth (Fig. 6). So far, however, when we couple the footprint model to the land cover map and flux measurements, no clear relationship is observed between large  $\text{CH}_4$  emissions and particular land cover type (Fig. 7). However, we are continuing this analysis using some more sophisticated statistical tools.

Beyond flux tower analysis, we have also started on the path toward testing and improving ecosystem models of regional biogeochemical fluxes. PhD student Ben Sulman chose to focus squarely on the role of peatlands in mixed landscapes. His initial work, just recently published in JGR-G, reveals a wide range of ecosystem model performance versus wetland flux tower sites (Fig. 8), but a consistent relationship of worse model performance in wetter conditions, leading to overestimation of productivity, and to a lesser extent respiration. These overestimates are driven by model soil moisture mechanisms that we have identified and are working on testing this with one particular model (ecosys). Additionally, Sulman recently focused more on the role of hydrologic variability driving peatland succession via affectation processes. The LANDIS-II forest dynamic model was modified to incorporate peatland cover types and a hydrology model was applied to allow peatlands to grow or be colonized depending on regional mean water table. The initial results from this model, to be submitted soon for publication, show that time-scale strongly matters for how peatland succession influences landscape carbon uptake, but in general, drying leads in the decadal timescale to carbon gains in the landscape, but long-term loss of recalcitrant carbon eventually switches the landscape to carbon source, but the process could take more than 400 years (Fig. 9).

### **Training and Development:**

Jonathan Thom continued to gain lab skills in methane and carbon dioxide flux analyzer equipment and has consulted extensively with personnel at NOAA ESRL. He also is working on data management and automated processing.

In year 3, we supported two undergraduate REU students on soil methane efflux measurement and atmospheric trace gas calibration. In previous years, two undergraduate students (Jennifer Welch and Ryan Harp) worked on 1) WLEF flux quality control and column observations and 2) soil moisture and flux relationships, and soil respiration sampling.

One graduate student (Kristine Jimenez), supported in year 2, worked on trace gas

boundary layer budgeting, flux data processing and outreach management.

PhD student Ben Sulman, supported in year 3, gained training in wetland process modeling and landscape scaling and recently successfully defended his Ph.D.

New post-doc scholar Dong Hua is being trained in flux tower data processing.

New Ph.D. student Ke Xu begins fall 2012.

### **Outreach Activities:**

The primary outreach component has been our training course with the College of Menominee Nation (CMN) tribal college. We successfully ran our first course last year, whose results can be seen at : <http://flux.aos.wisc.edu/twiki/bin/view/Main/ForCLIMATE> . A significant number of research partners worked with the students to explore concepts in global change research and tutor students in hands-on research at the flux tower sites. Some outcomes are already being realized, as two of the students are already planning to enroll in 4-year colleges to get degrees in sciences. The course also generated local media coverage, including the front page of the U Wisconsin website for one week at: Barnard, C. and Rychter, B., 2011 Northwood's Partners: Studying a landscape's carbon diet UW News, October 17, 2011. <http://www.news.wisc.edu/slideshows/59/slides/447>

To further build a research community on regional biogeochemical cycles in managed landscapes, I am organized a workshop with 20 scientists to be held at the Kemp field station. These scientists will focus on the particular role of human land management on regional carbon cycling, and how to best incorporate them into ecosystem models. More details at: <http://flux.aos.wisc.edu/twiki/bin/view/Main/ChEASMeeting2012>

As in previous years, Desai intends to help organize, attend, and lecture at the 25-graduate student 2-week flux measurements and modeling course in Colorado. A new tutorial that further emphasizes the role of data assimilation in ecosystem modeling is being developed jointly with Mike Dietze at University of Illinois.

### **Journal Publications**

Desai, A.R.; Helliker, B.R.; Moorcroft, P.R.; Andrews, A.E.; Berry, J.A., "Interannual variability in regional carbon fluxes from top-down and bottom-up perspectives", *Journal of Geophysical Research-Biogeosciences*, p. G02011, vol. 115, (2010). Published, 10.1029/2009JG001122

Desai, A.R., "Climatic and phenological controls on coherent regional interannual variability of carbon dioxide flux in a heterogeneous landscape", *Journal of Geophysical Research-Biogeosciences*, p. G00J02, vol. 115, (2010). Published, 10.1029/2010JG001423

Vasys, V.N.; Desai, A.R.; McKinley, G.A.; Bennington, V.; Michalak, A.M.; Andrews, A.E., "Influence of large lake carbon exchange on regional tracer transport inversions", *Environmental Research Letters*, p. 034016, vol. 6, (2011). Published, 10.1088/1748-9326/6/3/034016

Yi, C.X.; Ricciuto, D.; Li, R.; Wolbeck, J.; Xu, X.Y.; Nilsson, M.; Aires, L.; Albertson, J.D.; Ammann, C.; Arain, M.A.; de Araujo, A.C.; Aubinet, M.; Aurela, M.; Barcza, Z.; Barr, A.; Berbigier, P.; Beringer, J.; Bernhofer, C.; Black, A.T.; Bolstad, P.V.; Bosveld, F.C.; Broadmeadow, S., "Climate control of terrestrial carbon exchange across biomes and continents", *ENVIRONMENTAL RESEARCH LETTERS*, p. , vol. 5, (2010). Published, 10.1088/1748-9326/5/3/03400

Buffam, I., Turner, M.G., Desai, A.R., Hanson, P., Rusak, J., Lottig, N.R., Stanley, E.H., Carpenter, S.R., "Integrating aquatic and terrestrial components to construct a complete carbon budget for a north temperate lake district", *Global Change Biology*, p. 1193, vol. 17, (2011). Published, 10.1111/j.1365-2486.2010.02313.x

Schwalm, C., Williams, C., Schaefer, K., et al. (43 other co-authors including Desai, A.R.), "A model-data intercomparison of CO<sub>2</sub> exchange

across North America: Results from the North American Carbon Program Site Synthesis", *Journal of Geophysical Research-Biogeosciences*, p. G00H05, vol. 115, (2010). Published, 10.1029/2009JG001229

Zobitz, J., Desai, A.R., Moore, D.J.P., and Chadwick, M.A., "A primer for data assimilation with ecological models using Markov Chain Monte Carlo (MCMC)", *Oecologia*, p. 599, vol. 167, (2011). Published, 10.1007/s00442-011-2107-

Keppel-Aleks, G., Wennberg, P.O., Washenfelder, R.A., Wunch, D., Schneider, T., Toon, G.C., Andres, R., Blavier, J.-F., Connor, B., Davis, K.J., Desai, A.R., Messerschmidt, J., Notholt, J., Roehl, C.M., Sherlock, V., Stephens, B.B., Vay, S.A., Wofsy, S.C., "The imprint of surface fluxes and transport on variations in total column carbon dioxide", *Biogeosciences*, p. 875, vol. 9, (2011). Published, 10.5194/bg-9-875-2012

Sulman, B.N., Desai, A.R., Schroeder, N.M., Ricciuto, D.M., Barr, A., Richardson, A.D., Flanagan, L.B., LaFleur, P.M., Tian, H., Chen, G., Grant, R.F., Poulter, B., Verbeeck, H., Ciais, P., Ringeval, B., Baker, I.T., Schaefer, K., Luo, Y., and Weng, E., "Impact of hydrological variations on modeling of peatland CO<sub>2</sub> fluxes: results from the North American Carbon Program site synthesis.", *Journal of Geophysical Research-Biogeosciences*, p. G01031, vol. 117, (2011). Published, 10.1029/2011JG001862

Bagley, J., Desai, A.R., West, P.C., and Foley, J.A., "A simple, minimal parameter model for predicting the influence of changing land cover on the land-atmosphere system.", *Earth Interactions*, p. 1, vol. 15, (2011). Published, 10.1175/2011EI394.1

Richardson, A.R., Anderson, R.S., Altaf Arain, M., Barr, A.G., Bohrer, G., Chen, G., Chen, J.M., Ciais, P., Davis, K.J., Desai, A.R., Dietze, M.C., Dragoni, D., Garrity, S., Gough, C.M., Grant, R., Hollinger, D.Y., Margolis, H.A., McCaughey, H., Migliava, "Terrestrial biosphere models need better representation of vegetation phenology: results from the North American Carbon Program Site Synthesis.", *Global Change Biology*, p. 566, vol. 18, (2012). Published, 10.1111/j.1365-2486.2011.02562.x

Wu, C., Chen J.M., Black, A., Gonsamo, A., Jassal, R.S., Desai, A.R., Gough, C.M., Dragoni, D., Bohrer, G., Herbst, M., Gielen, B., Berninger, F., Kurz, W., Price, D.T., Pilegaard, K., and Blanken, P.D., "Interannual variability of net ecosystem productivity in forests is explained by growing season and net carbon uptake phenology in autumn.", *Global Ecology and Biogeography*, p. , vol. , (2012). Submitted,

Schaefer, K. et al. (50 co-authors including Desai, A.R.), "A model-data comparison of gross primary productivity: Results from the North American Carbon Program Site Synthesis", *J. Geophys. Res.*, p. , vol. , (2012). Submitted,

Grant, R.F., Desai, A.R., Sulman, B.N., "Modelling contrasting responses of wetland productivity to changes in water table depth", *Biogeosciences*, p. , vol. , (2012). Submitted,

Gower, S.T., Peckham, S.D., Desai, A.R., Black, T.A., McCaughey, J.H., Margolis, H.A., Dunn, A., Wharton, S., Paw U, K.T., Goulden, M.L., Bond- Laberty, B., Barr, A.G., Magnani, F., and Chen, J., "North American old- growth forests are not carbon sinks", *Nature*, p. , vol. , (2012). Submitted,

### **Books or Other One-time Publications**

Desai, A.R., "Regional carbon fluxes in heterogeneous landscapes: Challenges and opportunities", (2010). Conference Proceeding, Published  
Bibliography: 29th Conference on Agricultural and Forest Meteorology, American Meteorological Society, Abstract 6.4, Keystone, CO, Aug 2-6, 2010.

Keppel-Aleks, G.; Washenfelder, R.A.;  
Toon, G.C.; Desai, A.R.; Davis, K.J.;  
Wennberg, P.O., "Net ecosystem exchange inferred from eddy covariance flux and total column measurements", (2010). Poster, Published  
Bibliography: NASA Terrestrial Ecology Science Team

Meeting, Abstract 89, La Jolla, CA, Mar 15-17, 2010.

Pressel, K.G.; Collins, W.D.; Desai, A.R., "Variance scaling in water vapor measurements from a tall tower.", (2010). Conference Proceeding, Published Bibliography: 13th Conference on Cloud Physics, American Meteorological Society, Abstract P1.77, Portland, OR, June 28-July 2, 2010.

Zobitz, J., D.J.P. Moore, A.R. Desai, "A hitchhiker's guide to data assimilation in the ecological sciences", (2010). Conference Proceeding, Published Bibliography: MathFest 2010, Mathematical Association of America, Pittsburgh, PA, Aug 5-7, 2010.

McKinley, G.A., V. Bennington, N.R. Urban, C.P. McDonald, N. Atllia, A.R. Desai, D. Pilcher, and V. Vasys, "The carbon cycle of Lake Superior and its influence on regional carbon budgeting", (2010). Conference Proceeding, Published Bibliography: American Geophysical Union Fall Meeting, Abstract B13A -0455, San Francisco, CA, Dec 13-17, 2010

Desai, A.R., "Climate change and regional carbon fluxes in heterogeneous landscapes", (2010). Conference Proceeding, Published Bibliography: 2nd Science in the Northwoods workshop, U Wisconsin Center for Limnology, Boulder Junction, WI, Sep 29-Oct 1, 2010.

Xiao, J. et al., "Advances in Upscaling of Carbon and Water Fluxes from Towers to Regional, Continental and Global Scale", (2011). Conference Proceeding, Published Bibliography: Ameriflux Science Meeting and 3rd North American Carbon Program (NACP) All-Investigators Meeting, New Orleans, LA, Jan. 31- Feb 4, 2011

V. Bennington, G.A. McKinley, V. Vasys, A.R. Desai, and N.R. Urban, "Lake Superior within the Regional Carbon Budget", (2011). Conference Proceeding, Published Bibliography: ASLO Aquatic Sciences Meeting: Limnology and Oceanography in a Changing World, San Juan, Puerto Rico, Feb. 13-18 2011

Schwalm, C.R., et al., "Evaluating Terrestrial Biosphere Models: Comparing Simulated and Observed Net Ecosystem Exchange", (2011). Conference Proceeding, Published Bibliography: Ameriflux Science Meeting and 3rd North American Carbon Program (NACP) All-Investigators Meeting, New Orleans, LA, Jan. 31- Feb 4, 2011.

McKinley, G.A., A.R. Desai, V.



Bennington, V. Vasys, A.E. Andrews, and A.M. Michalak, "Lake Superior's influence on regional carbon budget", (2011). Conference Proceeding, Published  
Bibliography: Ameriflux Science Meeting and 3rd North American Carbon Program (NACP) All-Investigators Meeting, New Orleans, LA, Jan. 31- Feb 4, 2011.

Desai, A.R., J.C Welch, B. Brooks, K. Jimenez, G. Keppel-Aleks, D. Wunch, P.O Wennberg, B.D Cook, "Novel approaches to estimating regional CH<sub>4</sub> fluxes from a very tall tower", (2011). Conference Proceeding, Published  
Bibliography: Ameriflux Science Meeting and 3rd North American Carbon Program (NACP) All-Investigators Meeting, New Orleans, LA, Jan. 31- Feb 4, 2011

Pressel, K.G., W. Collins, and A.R. Desai,, "A Comparison of the Scale Invariance of the Water Vapor Field Observed by the Atmospheric Infrared Sounder to the Scale Invariance of In Situ Observations from a Very Tall Tower", (2011). Conference Proceeding, Published  
Bibliography: AGU Chapman Conference on Remote Sensing of the Terrestrial Water Cycle, Kona, HI, Feb 19-22, 2012. (poster)

Desai, A.R., "Seasonal controls on regional methane and carbon dioxide exchange observed from a very tall eddy covariance tower in a wetland-rich landscape", (2011). Conference Proceeding, Published  
Bibliography: Abstract B13J -03 presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5-9 Dec.

Phillips, C.L., K.J. McFarlane , A.R. Desai, and D.A. Risk, "Using 14C as a high-frequency tracer of forest CO<sub>2</sub> emissions sources: preliminary results from a Northern Wisconsin case study", (2011). Conference Proceeding, Published  
Bibliography: Abstract B31A -0314 presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5-9 Dec.(poster)

Pressel, K.G., W. Collins, and A.R. Desai,, "Scaling of water vapor in the meso-gamma (2-20km) and lower meso-beta (20-50km) scales from tall tower time series", (2011). Conference Proceeding, Published  
Bibliography: Abstract A54A -01 presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5-9 Dec.

Pressel, K.G., W. Collins, and A.R. Desai, "A comparison of scaling

in satellite and in situ water vapor measurements", (2011). Conference Proceeding, Published  
Bibliography: 64th Annual Meeting  
of the American Physical Society  
Division of Fluid Dynamics, Baltimore,  
MD, Nov. 20-22, 2011.

Sulman, B.N., A.R. Desai, and N.M. Schroeder, "Ecosystem Model Performance at Wetlands: Results from the North American Carbon Program Site Synthesis", (2011). Conference Proceeding, Published  
Bibliography: Abstract B51R -10  
presented at 2011 Fall Meeting, AGU,  
San Francisco, CA, 5-9 Dec.

### **Web/Internet Site**

#### **URL(s):**

<http://flux.aos.wisc.edu/twiki/bin/view/Main/LabResearchMethane>

#### **Description:**

Primary project website, with links to official ChEAS data repository for flux, meteorology, and biological data for WLEF tower and other sites, outreach project, media coverage, project reports, and workshop link.

### **Other Specific Products**

### **Contributions**

#### **Contributions within Discipline:**

Research on methane fluxes is growing and new collaborations are in the works on global synthesis. The work on winter-time CH<sub>4</sub> fluxes and influence of regional hydrology on regional carbon cycling has led to new discussions, conference presentations, and publications. Workshops on forest management and biogeochemistry and outreach on model data assimilation are helping strengthen the ecosystem modeling community. Students in the lab have recently started postdoctoral fellowships that are expanding on research here. Ben Sulman will start a post-doc at Princeton University/GFDL to focus on incorporation of wetland biomes into global climate models. Justin Bagley, who conducted some research at the tall tower site, is a post-doc at U Illinois with Carl Bernacchi, working on applying his ecosystem-atmosphere influence techniques to bioenergy crops.

#### **Contributions to Other Disciplines:**

The world's tallest flux tower continues to be an internationally reputed test bed for regional scale biogeochemical and boundary layer research, with ongoing collaboration in ecology, atmospheric science, remote sensing.

#### **Contributions to Human Resource Development:**

Graduate and undergraduate student training of domestic and international students, including underrepresented groups.

#### **Contributions to Resources for Research and Education:**

WLEF tower data is being used in educational contexts. All data is provided freely and via website. Outreach projects lesson plans have been posted on the web.

#### **Contributions Beyond Science and Engineering:**

Purchase and testing of CH<sub>4</sub> analyzer by small startup company in California (Piccaro) supports continued development of high-tech analyzers for greenhouse gas, air pollution, and medical applications by U.S. businesses.

**Conference Proceedings**

**Special Requirements**

**Special reporting requirements:** None

**Change in Objectives or Scope:** None

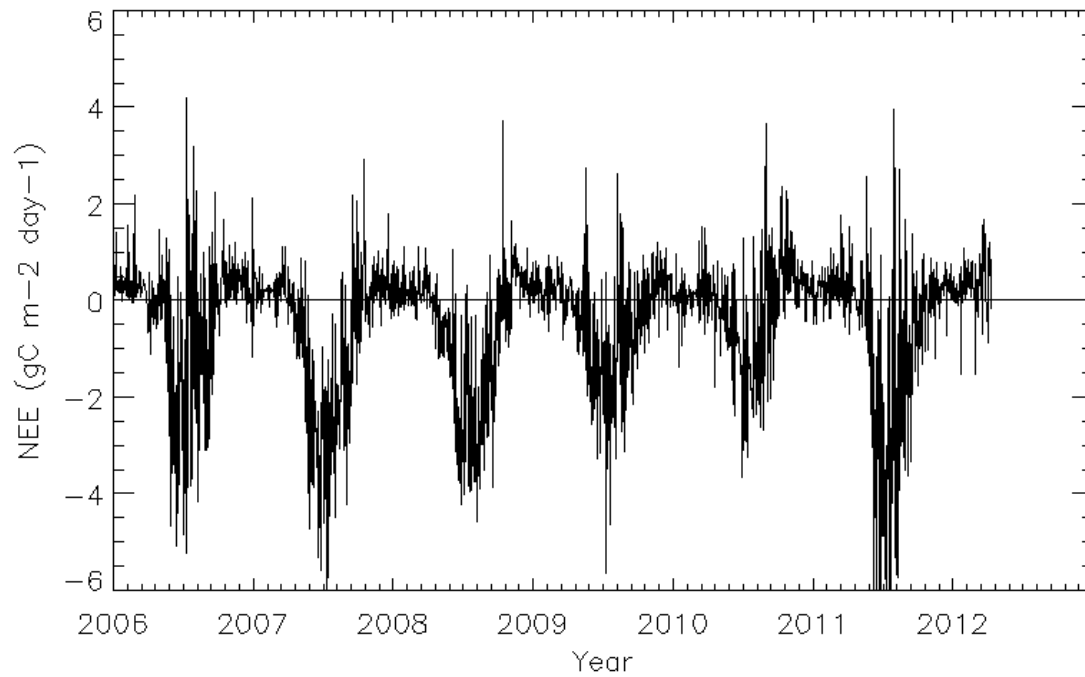
**Animal, Human Subjects, Biohazards:** None

**Categories for which nothing is reported:**

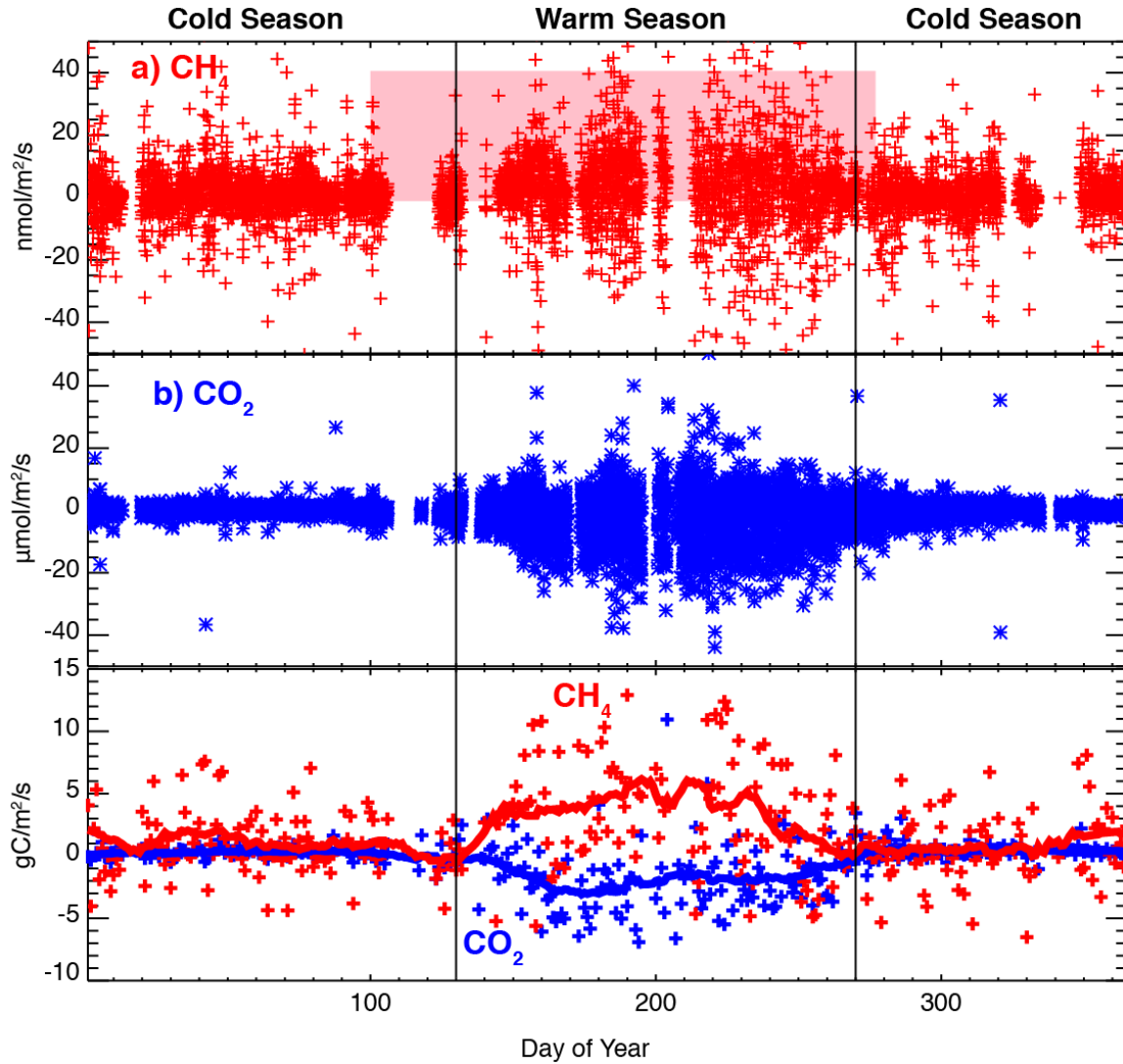
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Any Conference

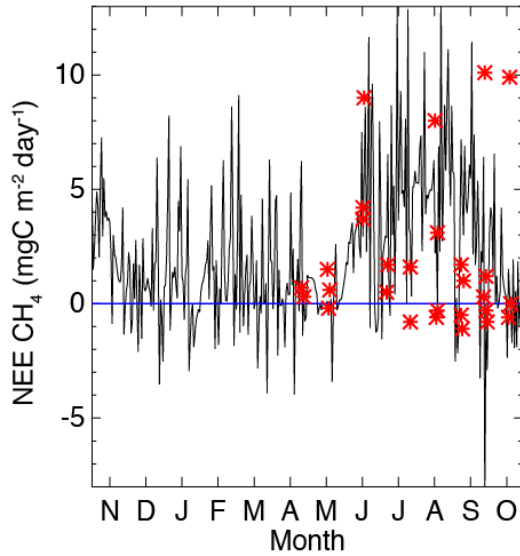
**Figure 1.** Net ecosystem exchange of CO<sub>2</sub> for the WLEF Park Falls tower from 2006-2012 shows significant growing season variability in uptake. A declining trend in uptake linked to water table declines appears to have reversed course in 2011, a year when water table heights increased.



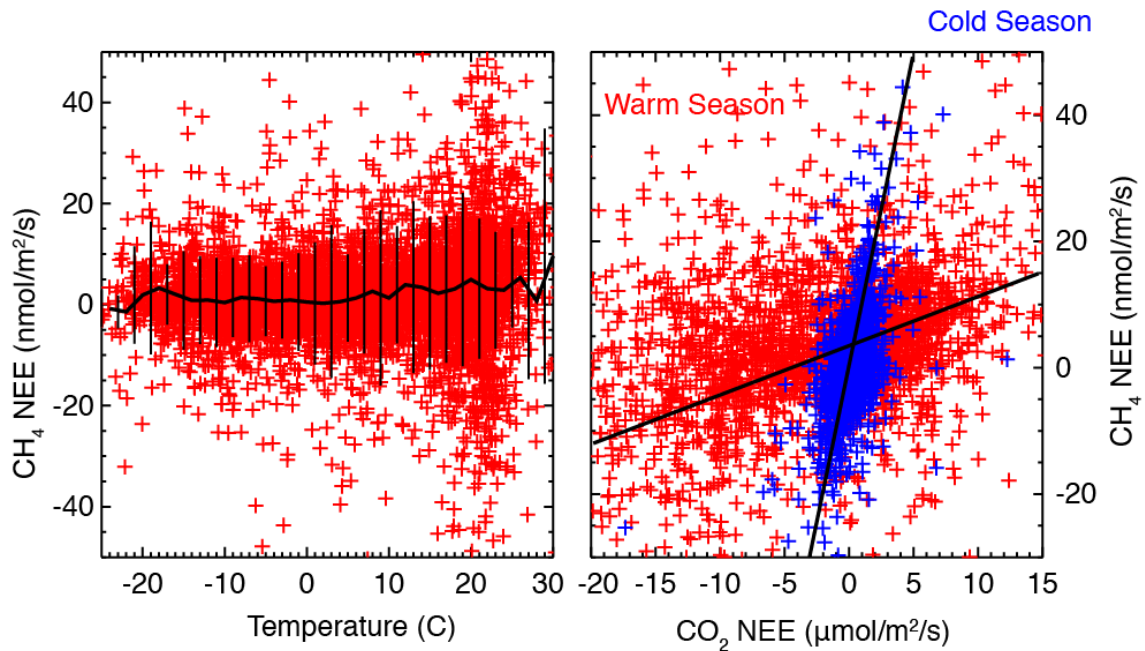
**Figure 2.** Comparison of daily CH<sub>4</sub> and CO<sub>2</sub> net ecosystem exchange in 2011 reveals high relative magnitude CH<sub>4</sub> fluxes year round and shift in seasonal pattern between warm and cold season. Pink box shows range of chamber flux estimates of warm season CH<sub>4</sub> fluxes in nearby wetlands.



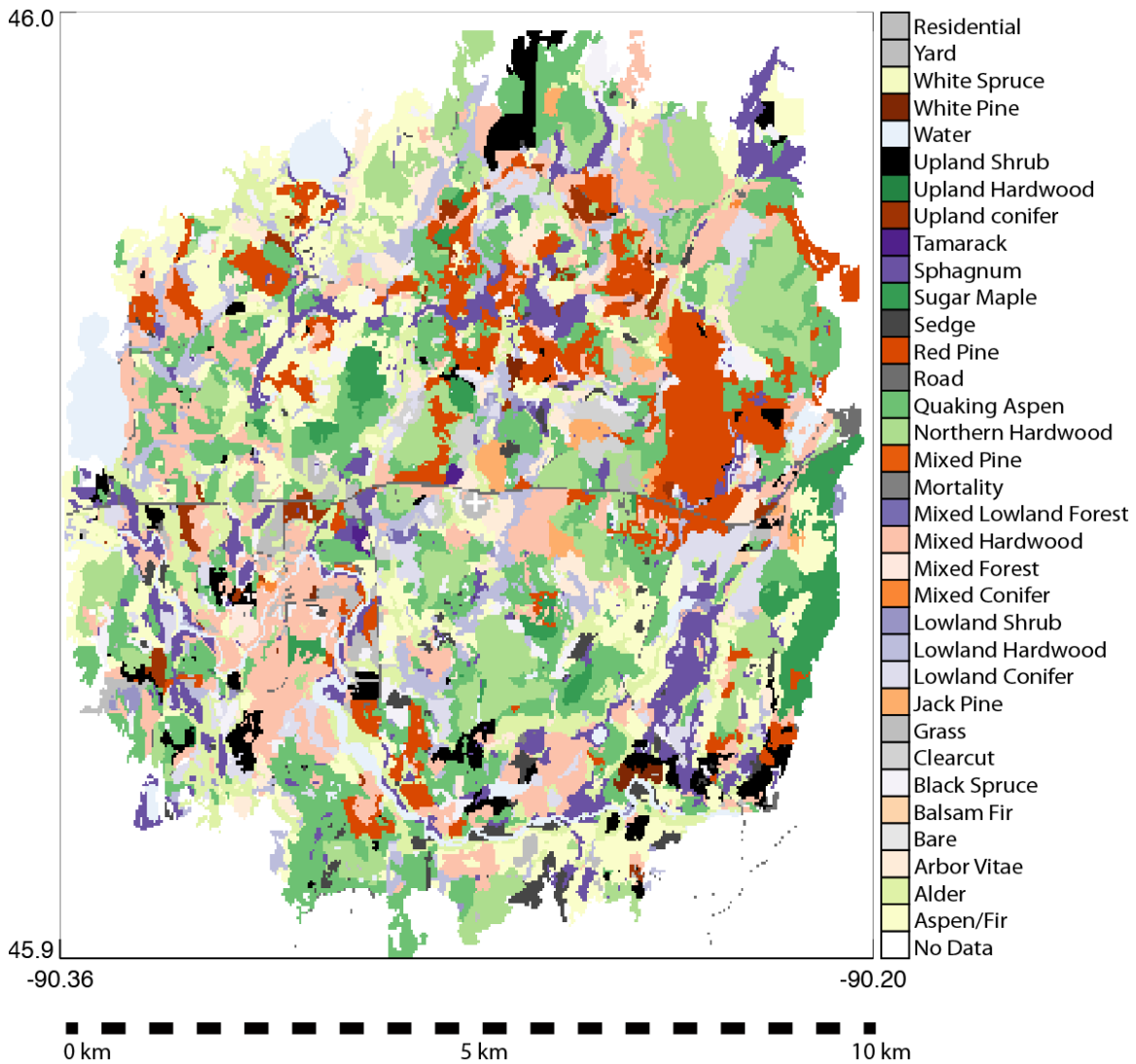
**Figure 3.** Further comparison of CH<sub>4</sub> fluxes from 2011 to survey CH<sub>4</sub> chamber of wetland site-averaged CH<sub>4</sub> emissions taken in 2006.



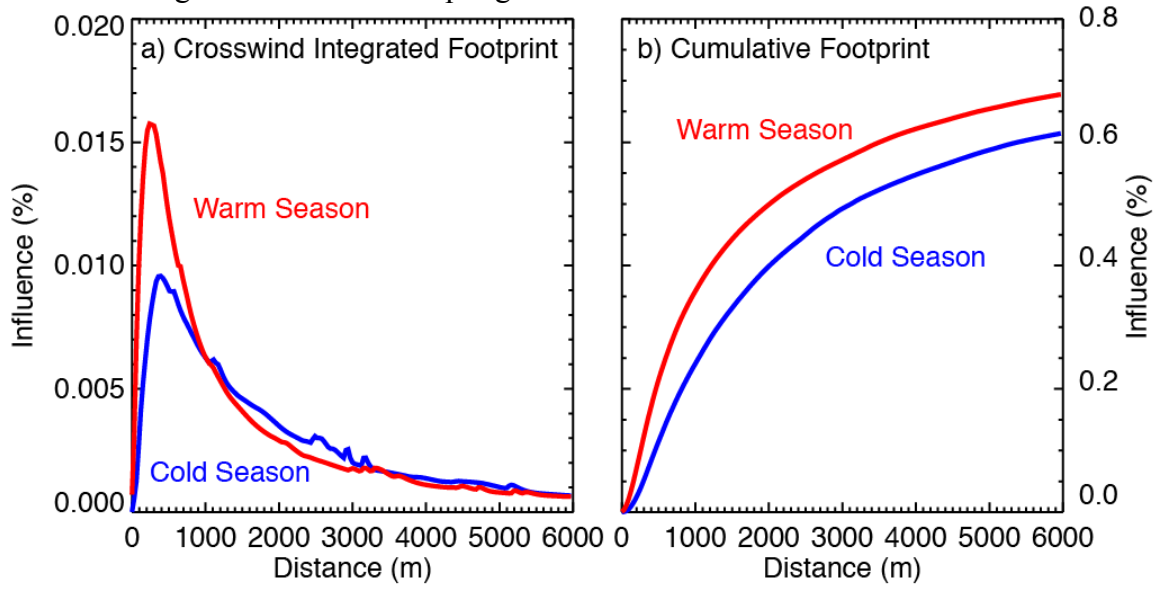
**Figure 4.** Correlation analysis of cool and warm season CH<sub>4</sub> fluxes shows a tight coupling of CO<sub>2</sub> and CH<sub>4</sub> emissions in winter, which weakens in summer, and shifts mainly to a weak correlation with temperature in growing season.



**Figure 5.** Hand-analyzed 30m resolution land cover in a 10x10 km box around WLEF tower, derived from Quickbird satellite imagery.

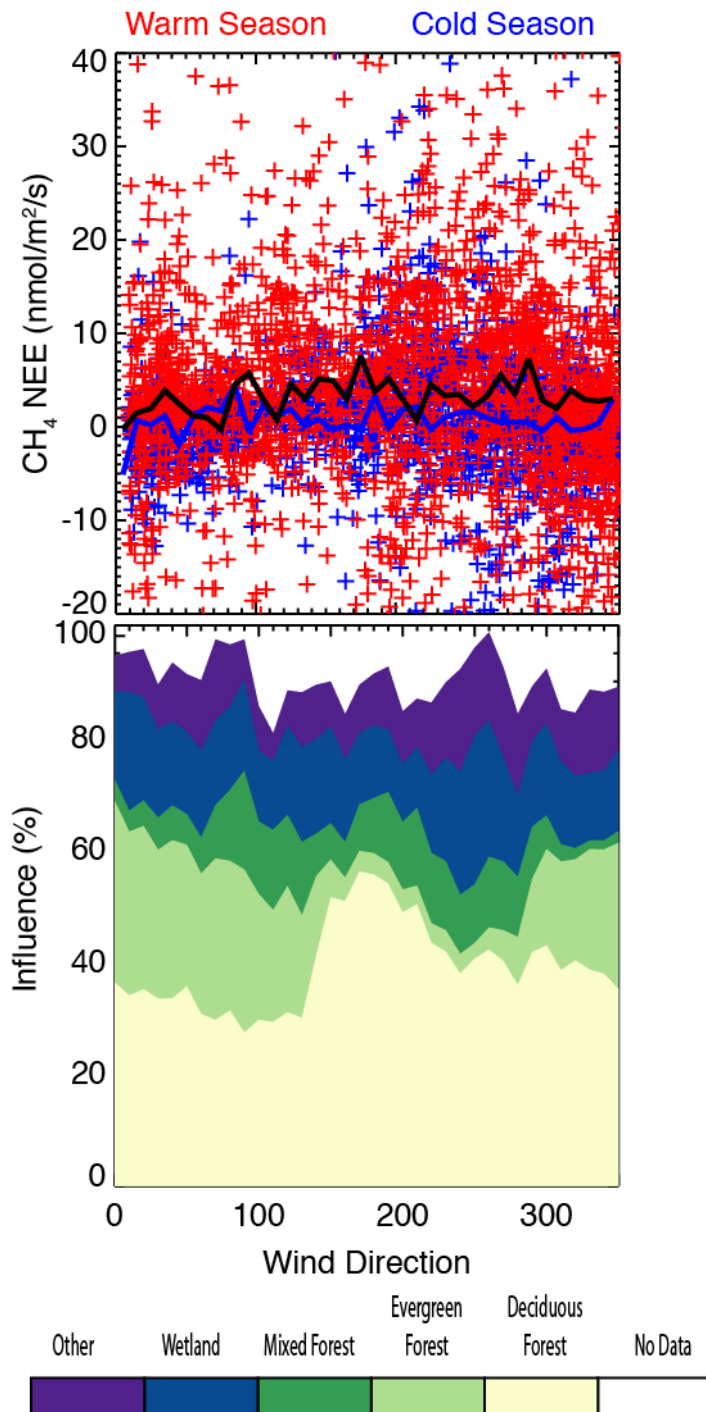


**Figure 6.** Analysis of 2011 mean cross-wind integrated flux footprint influence functions for 122m shows similar footprints year round, with a slightly larger sampling radii in the winter and a general ~5-6 km sampling radius.

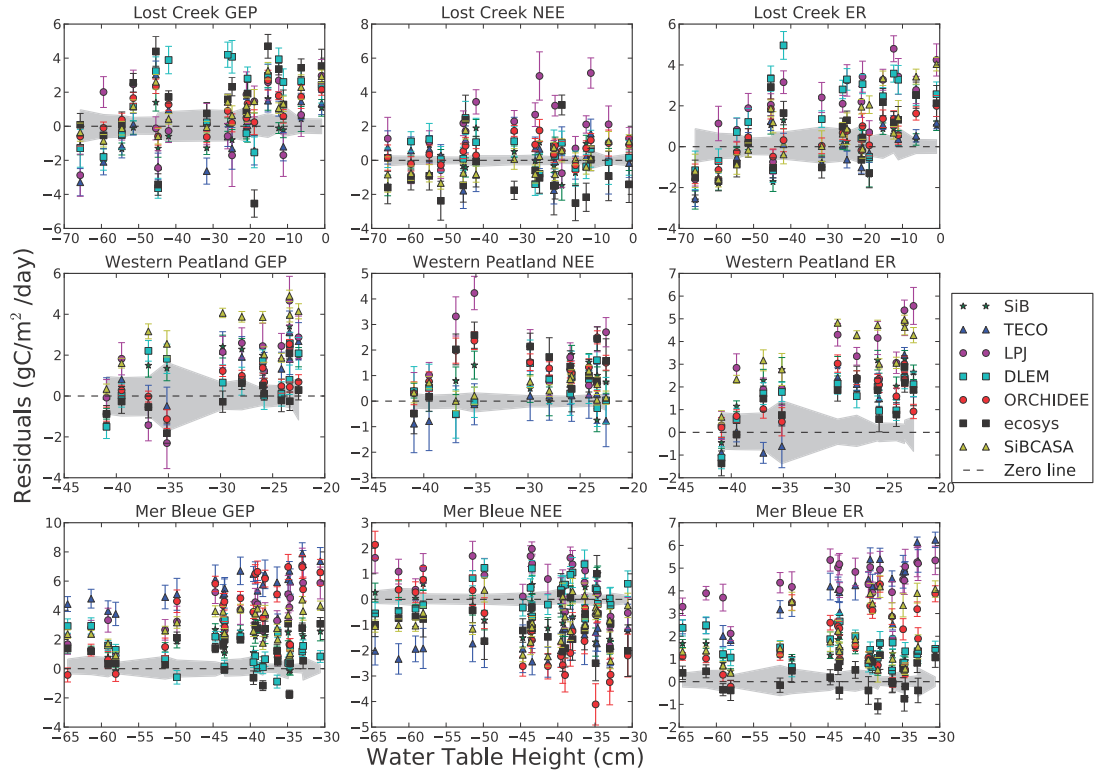




**Figure 7.** Flux-footprint land cover analysis of 122 m CH<sub>4</sub> fluxes against wind direction in warm and cool season. No apparent source of large CH<sub>4</sub> emissions in either season can be easily identified, even with greater wetland source emissions from the NW.



**Figure 8.** Comparison of ecosystem model wetland CO<sub>2</sub> fluxes against three peatland flux towers, including one near WLEF tower, shows a general overestimate of primary productivity and ecosystem respiration by all models at all wetlands, especially when observed water table is high.



**Figure 9.** Peatland succession analysis for WLEF region (Price Count) shows change in total carbon, biomass, and soil carbon (top, middle, bottom panels) for wetlands (left three panels) and landscape (right panel) over 400 years owing to a 40 year water table decline. Green and red lines show results with differing model mechanisms, while black line shows full effect of model relative to control (blue line) for deep peat (dotted) and shallow peat (dashed). Carbon gains are initially found, but these slowly decline as biomass gains and peatland conversion reaches a maximal extent.

