Annual Report for Period: 08/2009 - 07/2010

Submitted on: 07/20/2010

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 CO2 and CH4 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:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Name: Thom, Jonathan

Worked for more than 160 Hours: Yes

Contribution to Project:

Jonathan Thom was supported 25% by this project to provide assistance in purchase and calibration of methane instrumentation, coordination with NOAA for planned installation, and fieldwork to maintain CO2 observations at the WLEF tower.

Other Participant

Research Experience for Undergraduates

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 CH4 profiling instrumentation. The CH4 instrument was sent to NOAA where Jonathan and others tested various ways to integrate instrument into the CO2 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.

USFS Northern Research Station

USFS Northern Research Station staff scientists Ron Teclaw and Mark Kubiske 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 continued discussion of the planned summer outreach program being supported by this project.

Other Collaborators or Contacts

Collaborators at:

Paul Wennberg and student Gretchen Keppel-Aleks at California Institute of Technology has
provided calibrated methane column and CO2 column FTIR abundances at the site. An undergraduate student funded from another grant is analyzing these data.

Bruce Cook at NASA GSFC is collaborating on analysis of methane chamber observations at nearby wetland sites.

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.

Activities and Findings

Research and Education Activities:

In year 1, I focused primarily on these research activities:

1) Acquisition, calibration and installation of CH4 flux sensor: Successful completion of bid comparison and purchase of a Envirosense CH4/CO2/H2O fast analyzer from Picarro, Inc. This sensor arrived in late June and is currently in the lab. A slight delay in aquisition as the company wanted to upgrade the electronics to a newer version. We will be one of the first to test the new electronics. Currently in lab testing. Deployment expected in early fall.

2) Operation of CH4 trace gas measurements: We shipped the Los Gatos, Inc. CH4 analyzer to NOAA to investigate optimal placement of CH4 observations into the existing CO2 and CO observation stream. This instrument was then shipped to Los Gatos, who upgraded the electronics to improve instrument stability. Instrument is now at NOAA for more testing. In the meantime, we assisted NOAA in replacing the instrument
trailer (shipping container) and upgraded racks for better room, throughflow, and instrument reliability. We hope to finally install CH4 profile observations in August.

3) Continued operation and maintenance of CO2 flux observation: Existing flux and micromet observations at the WLEF tower were continued. Code to compute CO2 fluxes from 2006 onward was rewritten in summer 2009 and quality control of these data will occur with undergraduate student support in summer 2010. A paper on analysis of regional flux estimates from this tower via a number of techniques was prepared, written, and published in JGR. A second paper combining flux tower observations with this tower and other nearby towers to assess phenological controls was also prepared and just accepted in JGR.

4) Data analysis: CH4 column observations were obtained from Paul Wennberg at CalTech, CH4 chamber data is being analyzed for a manuscript in preparation with Bruce Cook at NASA, water table depth sensors data were acquired from Paul Bolstad at UMN.

5) Personnel recruiting: A female, minority M.S. student from U Alabama was successfully recruited for Ph.D. studies in my lab and will start Fall 2010. She is excited about both the

research and outreach opportunities in this project. Jonathan Thom was retained as field site technician.

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

One paper was published and one was recently accepted and one just submitted based on activities in this project.
Findings from these are summarized below. Supporting figures are in the attached file.

1) Climatic controls of interannual variability in regional carbon fluxes from top‐down and bottom‐up perspectives

Observations of regional net ecosystem exchange (NEE) of CO_2 for 1997?2007 were analyzed for climatic controls on interannual variability (IAV) across the WLEF region. Four independent techniques estimated monthly regional NEE for 10^4 km2. These techniques included two bottom‐up methods, based on flux tower upscaling and forest inventory based demographic modeling, respectively, and two top‐down methods, based on tall tower equilibrium boundary layer budgets and tracer‐transport inversion, respectively. While all four methods revealed a moderate carbon sink, they diverged significantly in magnitude (Fig. 1). Coherence of relative magnitude and variability of NEE anomalies was strong across the methods (Fig. 2). The strongest coherence was a trend of declining carbon sink since 2002. Most climatic controls were not strongly correlated with IAV. Significant controls on IAV were those related to hydrology, such as water table depth, and atmospheric CO_2 (Fig. 3). Weaker relationships were found with phenological controls such as autumn soil temperature. Hydrologic relationships were strongest with a 1 year lag, potentially highlighting a previously unrecognized predictor of IAV in this region.

2) Climate and phenology drive coherent regional interannual variability of carbon dioxide flux in a heterogeneous landscape

Multi-year eddy covariance carbon dioxide flux observations from five ecosystems in the Upper Great Lakes USA, located 400 km of each other and exhibiting coherent interannual variability (Fig. 4), were used to parameterize a simple ecosystem model. The model, when properly constrained with an interannual sensitive cost function, was able to explain a significant proportion interannual variation of carbon fluxes in all ecosystems except the old-growth forest (Fig. 5). The results reveal that spring or autumn climate thresholds impact annual carbon uptake, though the magnitude and strength varied by site (Fig. 6).

3) Implications of neglecting large lake carbon cycling for regional tracer transport inversions

Large lakes may be a significant component of regional surface-atmosphere fluxes, but few efforts have been made to quantify them. Tracer-transport inverse models that infer CO_2 flux from atmospheric concentration typically ignore large lakes. We made an attempt is made to determine the sensitivity of a tall tower in Wisconsin to CO_2 signatures from Lake Superior. Mesoscale transport model derived source-receptor sensitivity climatology revealed tower sensitivity to lake airmasses at nearly 20% of total 2004 nearfield sensitivity. Wind direction-segregated CO_2 observations confirm a lake signature. Sensitivity maps convolved with air-lake fluxes from a physical-biogeochemical lake model suggest that lake influence is likely detectable in late fall and late winter, when lake signal is strong and land signal is weak (Fig 7). These findings imply that inversions that neglect large lakes may underestimate dormant season land CO_2 emissions, and provide new insight into best doing boundary layer budgets as noted in the proposal.

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.

Two undergraduate students, funded on a different grants, worked on 1) WLEF flux quality control and column observations and 2) tracer-transport influence modeling of tower air masses.

Outreach Activities:

1) CMN: Continue discussion with College of Menominee Nation on workshop that we proposed to do in the next four years. A little slow to get off the ground, but I am now in contact with a faculty member and administrator and am preparing some of our initial plans for activities in summer 2011. The incoming Ph.D. student is very interested in participating.

2) Other outreach: Continue integration of research activities in my global change undergraduate course, including flux tower observations. Videoed presentation of climate change and greenhouse gases for UW Communications 5-minute Lectures iTunes U channel. Tour of WLEF flux tower for 15 journalists as part of the Society of Environmental Journalists post-conference tour. Collaboration on ecological forecasting and data assimilation on NSF RCN: FORECAST, part of Biogeochemistry Working Group. Inaugral member of the Climate Change Science Roundtable for the Chequamegon-Nicolet National Forest - working with land managers on climate impacts to northern forests.

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., "Climate and phenology drive coherent regional interannual variability of carbon dioxide flux in a heterogeneous landscape", Journal of Geophysical Research-Biogeosciences, p. , vol. , (2010). Accepted,

Vasys, V.N.; Desai, A.R.; McKinley, G.A.; Bennington, V.; Michalak, A.M.; Andrews, A.E, "Implications of neglecting large lake carbon cycling for regional tracer transport inversions", Geophysical Research Letters, p. , vol. , (2010). Submitted,

Books or Other One-time Publications

Desai, A.R., "Regional carbon fluxes in heterogenous 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.

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Findings to date on regional carbon fluxes have advanced the field in top-down and bottom-up comparisons, a key element of current diagnoses of continental carbon cycles. Interannual variability analysis has advanced field of ecological data assimilation and phenology modeling in ecosystem models. These advances are being noted in citations, invitations to workshops, and use by other researchers.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Recruitment of female, minority, Ph.D. candidate helps reach goals of improving diversity in STEM disciplines.

Contributions to Resources for Research and Education:

WLEF tower data is being used in educational contexts. All data is provided freely and via website.

Contributions Beyond Science and Engineering:

Purchase and testing of CH_4 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:

Any Web/Internet Site

Any Product

Contributions: To Any Other Disciplines

Any Conference

Figures for NSF Annual Report Year 1 Findings

Figure 1. Monthly NEE from the four models across the (a) entire time record (1997-2006) and (b) ensemble averaged across all years. Symbols are: Flux tower upscaling - IFUSE (filled circle), Ecosystem demography model - ED (gray diamond), Equilibrium tall-tower boundary layer budget - EBL (square), Carbontracker inverse model - CT (triangle). IFUSE model shows large uptake in the growing season. Both bottom-up methods (IFUSE and ED) show more uptake in the spring and autumn.

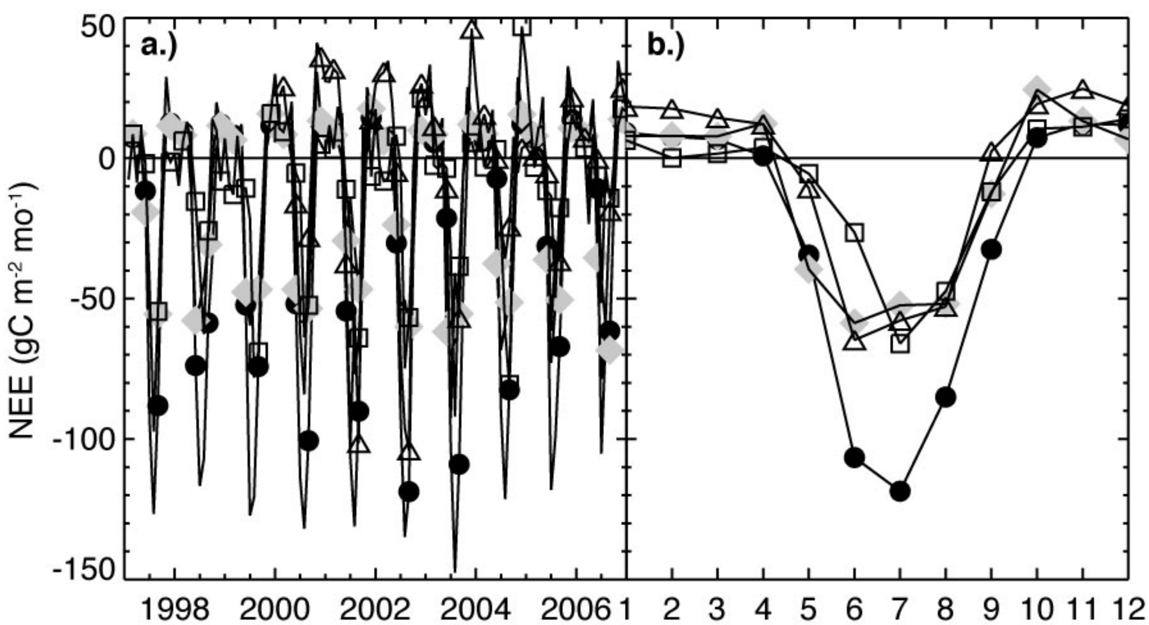

Figure 2. (a) Annual NEE and (b) annual NEE anomaly for each method. Symbols are: IFUSE (filled circle), ED (gray diamond), EBL (square), CT (triangle). 1-σ uncertainty for annual NEE is also shown. While there is large variation on magnitude of NEE, trends in NEE are coherent across several years and especially in the last five years of the record.

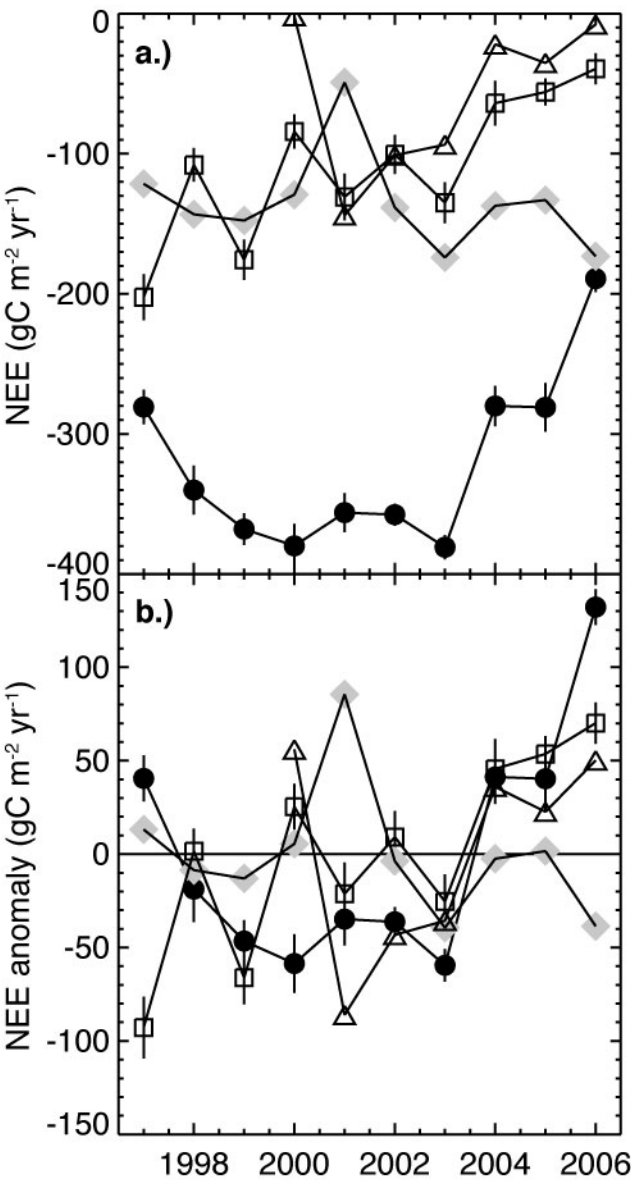

Figure 3. Scatter plot of annual NEE anomaly to (a) lag 1 year Q_{table}, (b) lag 1 year $[CO_2]$, (c) SON soil temperature, and (d) MAM PAR for bottom-up (left panels) and top-down (right panels) methods. Symbols are: IFUSE (filled circle), ED (gray diamond), EBL (square), CT (triangle). Top-down methods and IFUSE agree on slope of correlation, while ED generally differs.

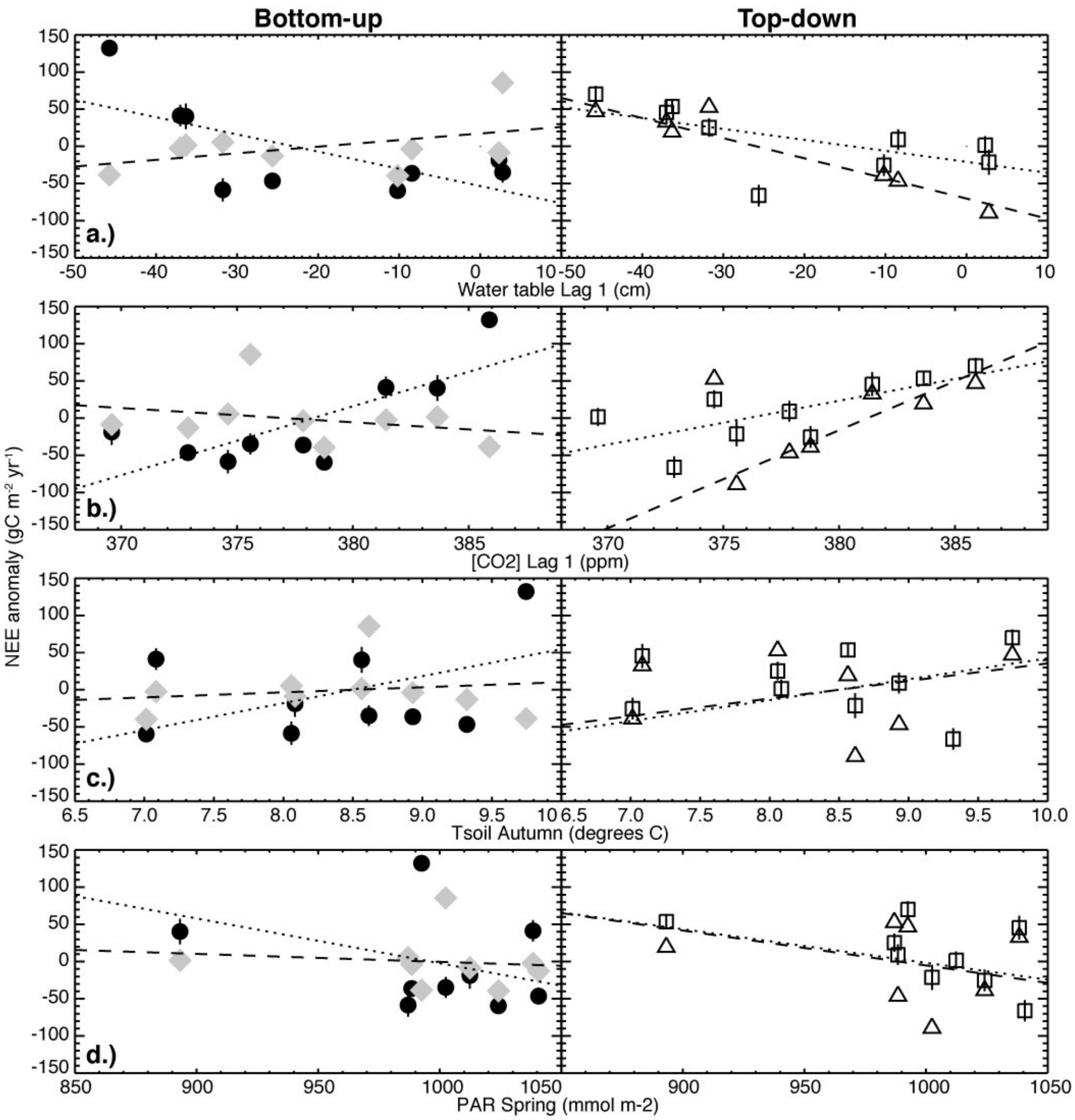

Figure 4. Observed standardized interannual variability in NEE at the five study sites. Strong coherence in variability in NEE was observed across the time period, even though absolute magnitudes in NEE variability varied widely. Observational uncertainty in NEE is noted by the horizontal bars.

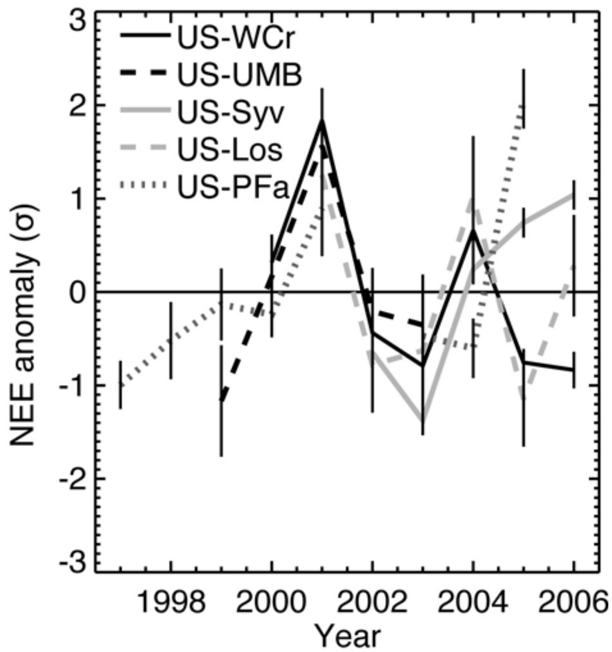

Figure 5. Correlation of anomalies in observed and modeled annual NEE using a) the traditional A_H cost function parameters (Table 4) and b) the interannual sensitive A_I cost function parameters (Table 5). Significant improvement in simulation of interannual variability was found for all sites in the latter.

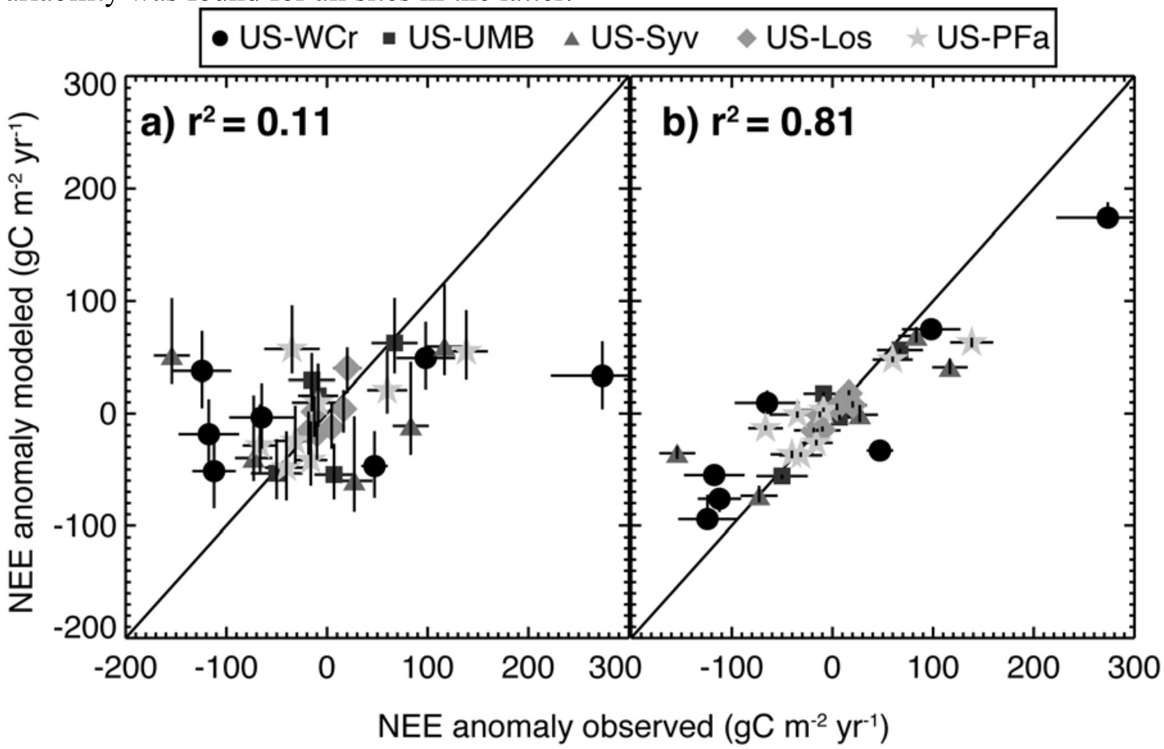

Figure 6. Linear regression derived slope of the relationship between annual NEE and anomaly in dates of leaf on (L_{ON}), leaf off (L_{OFF}) and growing season length (G_{SL}) as quantified from IFUSE model output using A_I cost function parameters (Table 5) plotted against linear correlation of this relationship at all sites. Dotted line indicates p<0.1 significance level.

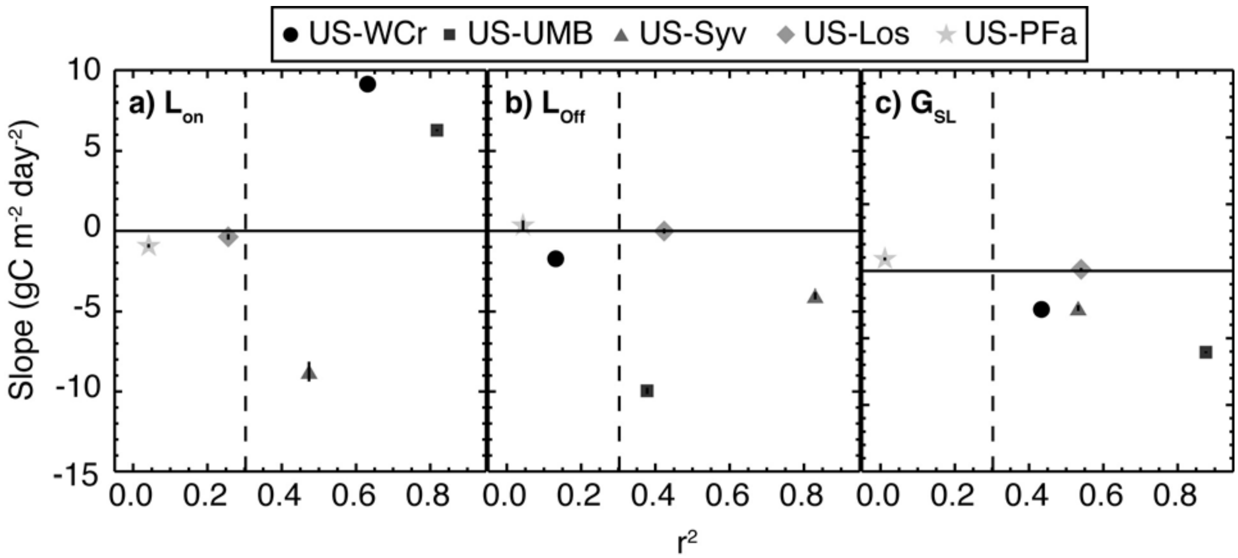

Figure 7. a) Model-based estimates of daily total CO_2 fluxes of the western arm of Lake Superior, with positive values indicating efflux to the atmosphere. b) Fluxes convolved with sensitivity functions produce a time series of daily influence of flux on tall tower CO_2. c) When summed to monthly influence, lake influence (gray line) is a large fraction of monthly change in observed CO_2 (black line), especially in Dec-Mar.