

Context Statement

National Science Foundation
Directorate for Biological Sciences (BIO)
Division of Environmental Biology
Context Statement
Ecosystem Studies Program

Proposals submitted to the Ecosystem Studies Program are evaluated using a combination of ad hoc mail and panel review using the two NSF review criteria of intellectual merit and broader impacts as described in the NSF Grant Proposal Guide (NSF 07-140). Additional criteria are applied to proposals submitted in response to targeted solicitations, as specified in the program announcement for those solicitations. Based on their subject matter some proposals may be co-reviewed with other programs in BIO or other parts of NSF.

The 135 proposals submitted to the Ecosystem Studies Program for the 9 July 2008 target date were reviewed by the Ecosystem Studies Panel. The Ecosystem Studies Panel met October 15 - 17, 2008 at the National Science Foundation in Arlington, VA. Panel summaries are brief synopses written by the panelists of the salient points emerging from the panels discussion of your proposal. Verbatim copies of all the reviews and panel's summaries used in the decision making process are available to you and your co-investigator(s), if any, on the FastLane 'Proposal Status' screen.

The panel assigned each of the proposals to one of four categories with respect to priority for funding (category labels may vary between panels). The number and percentage of proposals placed in these four categories of priority for this panel were:

Outstanding 11
Superior 12
Meritorious 24
Do Not Fund 88

In reading the reviews, please keep in mind that the reviews are addressed to NSF, and not necessarily to you, the investigator. Reviewers may make comments and criticisms without documentation or without suggestions for improvement. Some reviews may contain irrelevant, non-substantive, erroneous or ad hominem statements. The advisory panel and the Program Directors disregard such statements in arriving at a recommendation for the proposal.

External reviews and panel evaluations are advisory. Decisions to fund or decline are made by NSF. While many projects warrant funding, because of budget limitations, many meritorious projects are declined. In the difficult decision-making process, Program Directors consider the relative strength of each proposal as well as other factors, such as award balance among sub-disciplines, geographic distribution, types of institutions and the potential contribution of each award to broadening the participation of individuals from groups traditionally underrepresented in science.

After considering these factors and based on available resources, funding recommendations are made by the program. In the FY2008 fiscal year, the Ecosystem Science Cluster funded 16% of submitted research proposals. Pending availability of funds, if the number of submitted proposals is similar, then a similar funding rate is likely in this fiscal year.

If you have questions regarding the review of your proposal, please contact your managing Program Director.

Panel Summary #1

Proposal Number: 0845166

Panel Summary:

Panel Summary

Ecosystem Science Cluster
Ecosystem Studies Advisory Panel Meeting, Fall 2008

Results of Prior NSF Support (If Applicable):
NA

If this a resubmission, how have previous criticisms been addressed?
NA

CRITERION I: [Intellectual Merit]:

This CAREER proposal focuses on applying newly available instrumentation to learn about the landscape scale fluxes of methane and the underlying ecological processes.

Intellectual Strengths: The ideas are innovative and the approach fresh; the work will materially advance understanding of key aspects of ecosystem metabolism that lie at the intersection of ecology and global change science. The PI demonstrates excellent knowledge of the technical details of the work.

Intellectual Weaknesses: There is no attempt to measure methane sources at the ecosystem level or to define the underlying biophysical controls and mechanisms. Studies along these lines are required to be able to understand the observed fluxes and thus to provide broadly applicable results.

CRITERION II: [Broader Impacts]:

Broader Impact Strengths: This proposal is truly outstanding in its approach to education and outreach. The proposal has the usual complement of curricular development and student support. But in addition, the PI has established links with Native American peoples and with a Tribal College, and has designed outreach and research activities specifically aimed at bringing students into ecological research from this woefully under-represented group. He has also made strong connections to a group working to increase educational opportunities for the South Asian community.

Broader Impact Weaknesses: NA

SYNTHESIS AND RECOMMENDATION

The PI proposes use new instrumentation to make landscape scale measurements of methane fluxes in in the forest-wetland mosaic of Northern Wisconsin. It is an interesting and novel project, which would be enhanced by companion studies of CH₄ sources and emission pathways at the small scale. The outreach and educational components are outstanding.

The panel recommendation is: superior

This summary was read by the assigned panelists and they concurred that the summary accurately reflects the panel discussion.

Panel Recommendation: Superior

Review #5

Proposal Number: 0845166
NSF Program: ECOSYSTEM STUDIES
Principal Investigator: Desai, Ankur R
Proposal Title: CAREER: Contrasting environmental controls on regional CO₂ and CH₄ biogeochemistry-Research and education for placing global change in a regional, local context
Rating: Multiple Rating: (Very Good/Good)

REVIEW:

What is the intellectual merit of the proposed activity?

The PI proposed to quantify CH₄ fluxes at a regional scale in the upper Midwest of USA using an already established tall tower (447 meters) in Wisconsin. The PI would analyze the CH₄ flux data in the context of environmental change such as declining water table and increasing air temperature. The PI would use the quite extensive data basis already obtained by others at the site. The main new component would be the addition of CH₄ measurements to the existing tall tower system. It seemed that CH₄ flux data from a tall tower would be interesting and useful, provided that adequate attention is being paid to methodological issues. Most would agree that much less is known about CH₄ fluxes than about CO₂ fluxes, especially true at spatial scales larger than a field plot. Because of this lack of information, the proposed research would be particularly valuable.

The PI has done quite a bit of work on CO₂ fluxes, but not much on CH₄. At a regional level, net CH₄ flux is determined not only by CH₄ generating sources but also by CH₄ consumption processes. Without considering the two sides separately, it may be difficult to interpret the net CH₄ flux only. Considering the similarity between the two trace gases in terms of the Eddy covariance approach, the PI should be capable of carrying out what being proposed here.

Scaling is a critical component in this kind of research. It would have been better if the PI had provided information about how to approach the issue of scaling.

The educational and outreach part of the proposal seemed fine. The 12 day summer plan would be interesting. The rest of the proposed activities would be of value too.

What are the broader impacts of the proposed activity?

This is a CAREER proposal. The research component will yield some interesting and valuable results about CH₄ fluxes at a regional spatial scale. The educational and outreach component of the proposal will likely generate positive impacts to local schools and communities.

Summary Statement

Overall, this is a solid proposal.

CAREER ELIGIBILITY CERTIFICATIONS

A. CAREER ELIGIBILITY CERTIFICATION

To be eligible for a CAREER award, you must meet the CAREER eligibility requirements as defined in the CAREER Program Solicitation (also refer to the CAREER FAQ for further explanations). To certify your eligibility, complete each section of the CAREER checklist below. The CAREER Eligibility Certification checklist will be included as part of the proposal and will be sent to reviewers.

I certify that by the relevant July deadline for submission of CAREER proposals, I will have met all of the following criteria.

- I will hold a doctoral degree in a field of science or engineering supported by NSF
- I will be untenured
- I will not have received an NSF PECASE or CAREER award
- I will not have competed more than two times in previous NSF CAREER Program Competitions

I certify that by October 1st following the relevant July deadline for submission of CAREER proposals I will

- be employed in a tenure-track position
- OR**
- be employed in a tenure-track equivalent position

- hold the title of assistant professor
- OR**
- hold a title that is equivalent to assistant professor

- be employed at an institution in the U.S., its territories, or possessions, or the Commonwealth of Puerto Rico that awards degrees in a field of science or engineering supported by NSF
- OR**
- be employed at an institution in the U.S., its territories, or possessions, or the Commonwealth of Puerto Rico that is a non-profit, non-degree granting institution such as a museum, observatory, or research lab

Project Summary

Magnitudes and future source/sink strengths of terrestrial ecosystem exchanges of carbon dioxide (CO₂) and methane (CH₄) to the atmosphere are highly uncertain, subject to large interannual variability, and responsible for a long term trajectory of the atmospheric greenhouse effect. While CO₂ has been extensively studied over the past several decades, research on CH₄ has been less exhaustive, especially at regional scales and in mixed upland-lowland landscapes. Atmospheric CH₄ has tripled since pre-industrial times and is a potent greenhouse gas. Moreover, regional interaction and concurrent changes of CO₂ and CH₄ surface-atmosphere exchange across landscapes confounds predictions of future radiative climate forcing and atmospheric chemistry/air quality.

The **goal** of this CAREER proposal is to initiate a novel study of regional (10s-100s of km) CH₄ exchange and incorporate it into an existing study of regional CO₂ exchange in the upper Midwest, USA. A multi-year trend in rising temperature and declining water table elevation have been observed. To test hypotheses on the effects of these and other environmental changes (e.g., precipitation, solar radiation) on CH₄ and CO₂ fluxes, I **propose** to quantify the regional exchange of these fluxes at a tall tower in Wisconsin, analyze their environmental controls, and predict sensitivity of regional biogeochemical cycling to climate and land use change with a next generation biogeochemical model.

To quantify the fluxes, I intend to build the first long-term tall-tower regional observatory of CH₄ ecosystem-atmosphere flux using a mix of boundary-layer tracer profiles and continuous eddy covariance with recently developed CH₄ instrumentation, complementing existing CO₂ flux observations occurring at a 447-m tower in N. Wisconsin. The tower is in a sub-boreal landscape with numerous small wetlands interspersed among northern hardwood forests. Tower measurements, plot-level CH₄ measurements, and a regional network of water table and micrometeorological measurements in upland and lowlands will be used to investigate moisture, temperature, and land use controls of regional CO₂ and CH₄ exchange at the diurnal to interannual timescale as well as be integrated into a place-based education and outreach plan.

Intellectual Merit

Studying the regional exchange of biologically-relevant trace gases straddles research in climate-relevant global flux/transport processes and ecologically-relevant local biogeochemical processes, and thus contains potential for significantly improving predictions of future carbon sources/sinks. Observing and modeling regional-scale surface-atmosphere exchange is difficult to do and consequently, has had only limited application, especially for CH₄. The environmental and anthropogenic controls on regional land-atmosphere exchange are poorly understood. Synergistic effects of these controls from interaction among landscapes can only be observed at the regional scale. This proposal addresses some of these issues with a combined observational and modeling study that will produce the first long-term record of both regional CH₄ and CO₂ exchange, investigations of regional environmental controls on them, and impacts on regional atmospheric chemistry and global climate.

Broader Impacts

Outreach activities are integral to this CAREER proposal and will be used to increase exposure of STEM disciplines and the local impacts of global change research to 1.) Native American community college students at the College of Menominee Nation via a 12 day global change summer program, 2.) high-school students and the general public in rural Wisconsin via hands-on activities and talks at a local field station, 3.) international undergraduate visitors from India as part of a recently initiated student lab exchange program at UW-Madison, and 4.) undergraduate non-science majors at the University of Wisconsin-Madison taking a global change class. A Ph.D. student will be recruited who is specifically interested in integration of education and research and therefore will participate in implementation of these activities of part of his or her graduate studies and professional development.

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Biographical Sketches (Not to exceed 2 pages each)	2	_____
Budget (Plus up to 3 pages of budget justification)	9	_____
Current and Pending Support	1	_____
Facilities, Equipment and Other Resources	2	_____
Special Information/Supplementary Documentation	0	_____
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Appendix Items:		

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

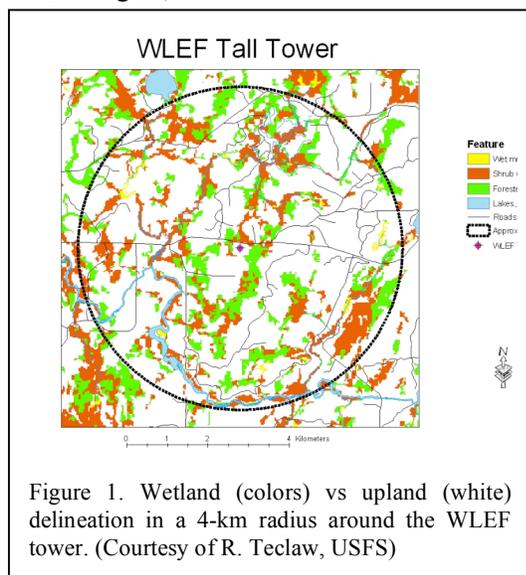
Introduction

We are in the midst of a grand global experiment that presents unprecedented challenges for ecosystem science and environmental policy. To fully understand the impacts on ecosystems of ensuing global changes in climate and land use, we need to link global climatic process affecting atmospheric composition, chemistry, and radiative balance to local ecological processes affecting biosphere-atmosphere interaction. The emerging subfield of regional (10s-1000s of km) biogeochemistry has arisen to meet this need (Blankinship *et al.*, 2008), developing new methodologies to bridge the gap from meteorology to ecology and in process discovering new insights into functions of ecosystem-atmosphere interaction (Baldocchi, 2003). While significant progress has been made to this end in carbon dioxide (CO₂), the same cannot be said other greenhouse gases, including methane (CH₄) (Beswick *et al.*, 1998; Wofsy and Harris, 2002). Similarly, carbon balance studies to date have been generally focused on forested uplands, with limited research in lowland and wetland regions.

Quantifying carbon balance, estimating net radiative forcing, and predicting future changes in vegetated landscapes with significant quantities of wetlands requires understanding *both* CO₂ and CH₄ cycles. In addition, the interaction of carbon cycles with the hydrologic cycle cannot be neglected in these landscapes. Complex upland-lowland landscapes are characteristic across temperate latitudes, especially in sub-boreal and boreal regions. **This CAREER proposal addresses the scientific need to understand the joint regional balance of CO₂ and CH₄ in these sub-boreal landscapes, their environmental controls, and future trajectories in the face of global change.** Additionally, I seek to integrate this research into education activities that emphasize local ecological impacts of global change and prepares next generation environmental scientists and managers to bridge local and global concerns.

Though global level carbon cycle inversions have largely been successful (e.g., Chen and Prinn, 2006), even with the added complexity of OH chemistry for CH₄, these inversions are limited in their application at the regional scale (Bousquet, 2006); a similar argument can be made for plot level studies (Potter *et al.*, 2006). There are many reasons to suspect that studying the interaction of CO₂ and CH₄ at regional scales can reveal subtleties in earth system biogeochemistry that are not captured by simple scaling of plot level data or downscaling of global data. Emergent regional properties such as CO₂ and CH₄ emissions from lake sediments (e.g., Bastviken *et al.*, 2008; Repo *et al.*, 2007), CH₄ ebullition in saturated landscapes (e.g., Sachs *et al.*, 2008; Strack and Waddington, 2008), CO₂ or CH₄ hot spots (e.g., Flessa *et al.*, 2008), or ecological and micrometeorological edge effects at forest-wetland boundaries are likely to be missed.

I propose to adapt an existing tall tower regional observatory (WLEF, Park Falls, WI) for simultaneous observations and analysis of regional CO₂ and CH₄. To adequately constrain CH₄ and CO₂ budgets, I will utilize what Mike Goulden of UC-Irvine has coined “method-hopping”– the



integration of multiple observation techniques at multiple scales (Blankinship *et al.*, 2008). I will instrument the first long-term tall-tower observatory of regional CH₄ using recently developed high-precision, fast response, self-calibrating CH₄ analyzers and a combination of innovative footprint-weighted eddy covariance flux tower (Desai *et al.*, 2008; Wang *et al.*, 2007b), surface layer Bowen ratio similarity (Werner *et al.*, 2003), and convective boundary layer tracer budget techniques (Helliker *et al.*, 2004). These analyses, along with the existing nearly decade long CO₂ observations, plot level CH₄ observation, and soil, hydrologic, and meteorological regional observation networks will be used to analyze and contrast the regional environmental controls on CO₂ and CH₄ exchange and parameterize and test sensitivity of a next-generation hydrological-biogeochemical model of regional carbon exchange (Mackay *et al.*, 2003a,b, 2007).

There are several compelling reasons to conduct this study at the WLEF site. First, the existence of the 447-m WLEF tall flux tower, operating since 1996 and studies occurring in the region have provided a rich existing database on landscape properties and atmospheric trace gases (Chen *et al.*, 2008). Second, the footprint of the tower is a complex, mixed landscape, that is more than 30% wetland, ideal for this study (Fig. 1). Finally, a long term decline in water table elevation has been observed at several pizeometers around the region and corroborated by stream flow and precipitation records (Mackay *et al.*, 2007) (Fig. 2). This trend has been shown to affect stand scale wetland CO₂ flux (Cook *et al.*, 2008; Sulman *et al.*, 2008). The water table effect provides a natural regional scale manipulation that can be analyzed for its effects on regional carbon balance and hypothesized shifts from CH₄ flux to CO₂ flux.

Relevance

Natural emission of methane from wetlands is the largest source of uncertainty in quantifying sources/sinks of atmospheric CH₄ (Mikaloff Fletcher *et al.*, 2004), contributing 25-40% of global CH₄ emissions and dominating the interannual variability signal (Bousquet *et al.*, 2006; Chen and Prinn, 2006; Crill *et al.*, 1992) Significant anthropogenic warming is predicted to dominate natural variability in the climate signal in as little as 5-10 years (Smith *et al.*, 2007). These climate changes are bound to affect regional water tables and wetland soil temperatures (Roulet *et al.*, 1992). Given the close coupling of CH₄ to CO₂ and H₂O cycles and the sensitivity of wetlands to hydrology and climate, wetlands are expected have regional and global significance in future atmospheric trajectories of CH₄ and CO₂.

To date, based on review of the literature, only a few other continuous annual CH₄ eddy covariance flux measurements has been made, and only at short towers (Rinne *et al.*, 2007; Will *et al.*, 2008). Shorter term CH₄ flux observations have also been made (e.g., Fowler *et al.*, 1995; Friberg *et al.*, 2003; Kim *et al.*, 1998; Shurpali and Verma, 1998; Suyker *et al.*, 1996). None of these measurements have been made at the regional scale from a tall tower and few have had simultaneous CH₄, CO₂ and H₂O flux measurements. This proposal also targets the aims of the U.S. Carbon Cycle Interagency Working Group North American Carbon Program (NACP) to develop infrastructure for long-term surface fluxes of CO₂ and CH₄ and improve the next generation of ecosystem models to assimilate data from these observational platforms to derive regionally resolved fluxes of CH₄ (Wofsy and Harriss, 2002).

Next-generation research will be tied to next-generation place-based education. Outreach activities are integral to this CAREER proposal and will be used to increase exposure of STEM disciplines and the local impacts of global change research with programs aimed at Native American community college students, high-school students, the general public, international undergraduate lab interns, non-science major students in my global change class, and a Ph.D. student to be recruited to work on this project. Detailed descriptions of these activities are noted in the *Broader Impacts* section below.

I believe this proposal has potential to be transformative to the field of regional biogeochemistry by moving beyond a CO₂-only to a more inclusive greenhouse gas perspective and with better consideration of complexity in landscapes. Innovations in regional observation methods will also help shape the future of the emerging tall tower network. This CAREER proposal also strengthens my existing ties with the network of ecologists, hydrologists, meteorologist studying carbon and water cycles in the upper Midwest and with whom I have been acquainted for the past seven years. I have been building expertise in observing and modeling regional CO₂ cycles in heterogeneous regions and have identified the need to better understand wetlands, hydrologic cycles, and CH₄. Since starting at the University of Wisconsin-Madison (UW-Madison), I have started on this latter path by starting new collaborations in wetland observation and CH₄ modeling and incorporating elements of such into my education and outreach. Funding this proposal would significantly jumpstart these efforts in both my research and education.

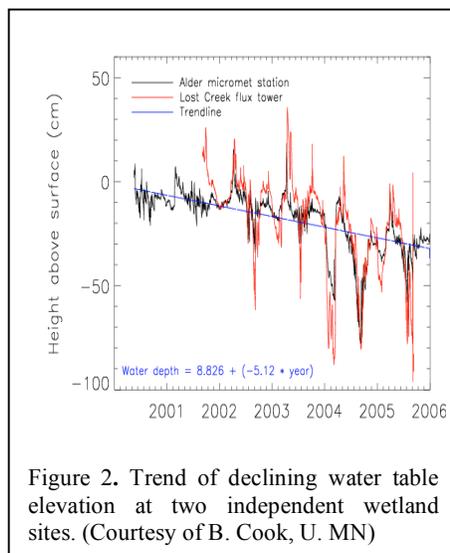
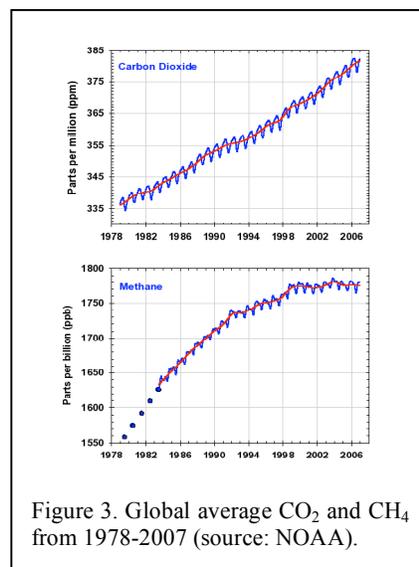


Figure 2. Trend of declining water table elevation at two independent wetland sites. (Courtesy of B. Cook, U. MN)

Background

Global Atmospheric View: CO₂ and CH₄

Magnitudes and future source/sink strengths of terrestrial ecosystem exchanges of carbon dioxide (CO₂) and methane (CH₄) to the atmosphere are highly uncertain, subject to large interannual variability, and responsible for a long term trajectory of the atmospheric greenhouse effect (Friedlingstein *et al.*, 2003, 2006; Shindell *et al.*, 2004; Zhuang *et al.*, 2004). Atmospheric CH₄ has tripled since pre-industrial times (Houghton *et al.*, 2001). In addition to being a potent greenhouse gas with 62x greenhouse gas warming potential at 20 year times scales and 23x at 100 year time scales when compared to CO₂ (Houghton *et al.*, 2001; Lelieveld, 2006), CH₄ is also an important sink for atmospheric OH and plays an important role in tropospheric water vapor and stratospheric ozone chemistry (Keppler *et al.*, 2006).



While the growth rate of atmospheric CO₂ has been a positive trend of 1-2 ppm yr⁻¹ (Conway *et al.*, 1994), the growth rate for CH₄ is less defined, slowing from 10-15 ppb yr⁻¹ in the 1980s to 0-5 ppb yr⁻¹ in the 1990s (Dlugokencky *et al.*, 2003) (Fig. 3). Currently, CH₄ is increasing 0.5% per year and responsible for 15% of the 2.5 W m⁻² increase in atmospheric longwave radiative forcing (Chen and Prinn, 2006; Collins *et al.*, 2006). Globally, atmospheric CH₄ concentration is approximately 4850 Tg (doCarmo *et al.*, 2006) with a typical net annual emission to the atmosphere of 600 Tg CH₄ yr⁻¹ (Prather *et al.*, 2001).

Local Ecological View: CH₄ and The Role of Wetlands

North temperate regions play a large role in the wetland carbon cycle, given their relatively large area and carbon in wetlands (Dahl, 2006) and significant expected regional climate change (Heitmann *et al.*, 2007; Urban *et al.*, 1989); moreover, these emissions are poorly constrained and highly variable (Cao *et al.*, 1998, Panikov *et al.*, 1999). Much activity has focused on the large carbon stores under thawing permafrost in wetlands north of the 0C isotherm (Christensen *et al.*, 2004; Johansson *et al.*, 2006), though carbon release is also likely to be significant in warming and drying temperate mid-latitudes.

Two pathways exist to convert buried organic carbon into the form of major greenhouse gases. CO₂ is produced mainly due to aerobic oxidation of organic matter; CH₄ is produced only in anaerobic environments (Segers, 1988) from a balance of production and consumption in the soil due to reduction of CO₂ (Heitmann *et al.*, 2007) or fermentation of acetate. Controlling factors on this balance are the difference in rates of methanogenesis and methanotrophy and modes of transport (Conrad, 1995; Holzapfelschorn *et al.*, 1985; Oremland & Culbertson, 1992; Schimel & Gullede, 1998; Zinder, 1993).

Water table and temperature have both been shown to be controlling environmental factors for CO₂ and CH₄, but results on their dominance have been inconclusive. Thus, changes in water table are expected to have strong impact on temperate wetland CH₄ and CO₂ emission ratios, though with great uncertainty (Davidson and Janssens, 2006). Numerous studies have attempted to correlate CH₄ observations to environmental parameters such as water table depth, temperature, vegetation type, CO₂ fixation/respiration rates, atmospheric O₃, and/or microbe/organic matter quality (e.g., Aerts and Ludwig, 1997; Bellisario *et al.*, 1999; Blodau *et al.*, 2007; Bubier *et al.*, 1995; Christensen *et al.*, 2003; Dunn *et al.*, 2007; Freeman *et al.*, 1992; Friborg *et al.*, 2000; Girardin *et al.*, 2001; Grant and Roulet, 2002; Gullede and Schimel, 2000; Hargreaves *et al.*, 2001; Kettunen *et al.*, 1996; King *et al.*, 2002; Kruger *et al.*, 2001; Laine *et al.*, 1996; Lelieveld, 2006; Moore and Roulet, 1993; Mörsky *et al.*, 2008; Shannon *et al.*, 1996; Shaver *et al.*, 2006; Strack and Waddington, 2007; Updegraff *et al.*, 2001; vonFischer and Hedin, 2007; Whalen and Reeburgh, 2000), but these plot-level chamber, modeling, or meta-analysis based studies have had mixed results. A review paper noted that most studies point to water table and temperature as strong controlling factors, and the authors note that latitudinal trends show that anaerobic and aerobic decomposition are both important in boreal regions (Jungkust and Fiedler, 2007).

Moving Forward To Regional CO₂/CH₄ Biogeochemistry

Lessons learned from regional CO₂ studies

My collaborators and I have conducted several studies attempting to primarily understand regional CO₂ balance in upper Midwest upland ecosystems. Before discussing how I will incorporate CH₄ and wetlands into this picture, I review major findings relevant to this proposal.

Regional CO₂ fluxes

We have attempted to quantify regional CO₂ net ecosystem exchange (NEE) flux around the WLEF tall tower using several independent techniques (Desai *et al.*, 2006), including tall tower eddy covariance (Davis *et al.*, 2003), a forest inventory based model (Desai *et al.*, 2007), biometric budgets (Tang *et al.*, 2008), an ecosystem model tuned to 16 nearby flux towers (Desai *et al.*, 2008; Wang *et al.*, 2006b), and CO₂ boundary layer budgets (Bakwin *et al.*, 2004; Helliker *et al.*, 2004) (Fig. 4). Unlike upscaling of forest evapotranspiration (Ewers *et al.*, 2007, 2008; Mackay *et al.*, 2002, 2007; Tang *et al.*, 2006), there is not strict convergence of upscaled CO₂ fluxes among the methods due to differences in region footprints, error in model inputs, and error in model processes. Nevertheless, the results are encouraging and suggest that regional flux quantification is possible if errors and footprints are properly accounted. For example, we've learned that footprint "bias" in the raw WLEF EC data requires a model to deconvolve the EC sampled landcover against the true regional landcover, which significantly improves comparison against the multiple flux tower model (Desai *et al.*, 2008).

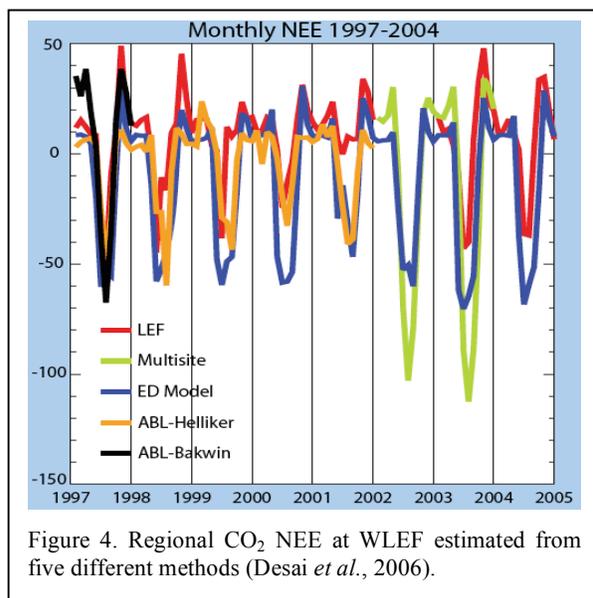


Figure 4. Regional CO₂ NEE at WLEF estimated from five different methods (Desai *et al.*, 2006).

Environmental controls of CO₂ exchange

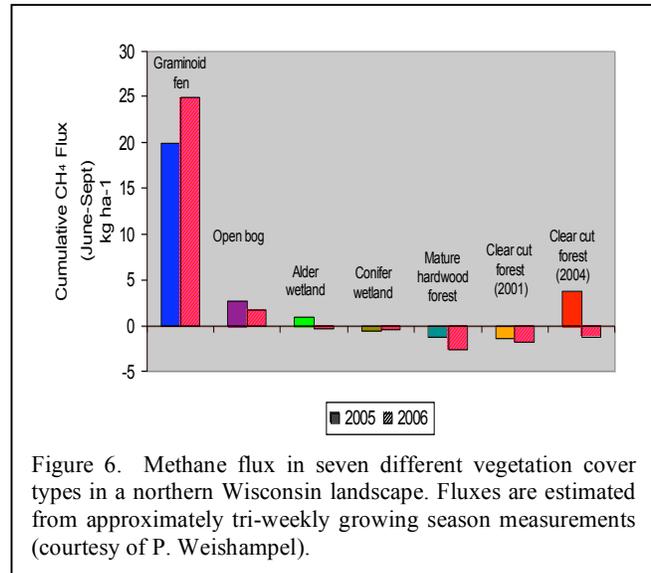
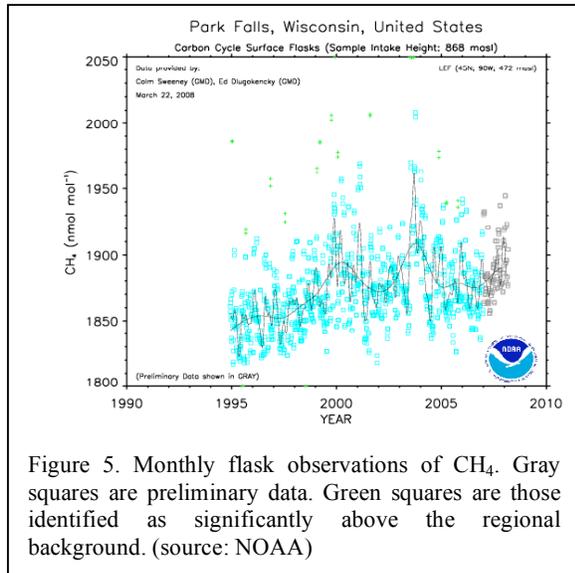
A number of studies in the region, focused mostly on the stand-scale flux towers have studied environmental and anthropogenic controls on upland CO₂ ecosystem respiration (ER) and gross primary production (GPP) (e.g., Bolstad *et al.*, 2004; Cook *et al.*, 2004; Desai *et al.*, 2005; Yi *et al.*, 2004) and more recently wetland CO₂ GPP or ER (Cook *et al.*, 2008; Sulman *et al.*, 2008). Short-term controls on flux are largely temperature, shortwave radiation, and for wetlands, water table elevation. Longer-term controls vary by site, but typically include site age and growing season length. Interannual variability is notoriously hard to model (Ricciuto *et al.*, 2008). Lags in biogeochemical responses to environmental controls exist and need to be accounted when regressing or modeling fluxes. The region-wide declining water table and trends in temperature and precipitation provide a natural experiment for testing these controls. These studies have led to installation of significant infrastructure in water table elevation pizeometers and micrometeorological and soil observations systems that are currently in operation.

Flux modeling and prediction

A number of ecosystem models and parameter estimation techniques have been successfully applied at individual tower sites (E.g., Pridhoko *et al.*, 2008), but short-term (years) prediction of CO₂ fluxes using tuned ecosystem models have generally been confounded by the difficulty in capturing interannual variability. I have done some initial work suggesting that incorporating a dynamic start of growing season and site disturbance history can significantly improve this. Long-term regional prediction has mostly focused on forest succession (e.g., Gustafon *et al.*, 2000), and less on biogeochemical cycling. Emerging ecological data assimilation and parameter optimization techniques have potential for providing a better picture of future regional carbon cycle (Ricciuto *et al.*, 2008; Sacks *et al.*, 2006). Linking CO₂, CH₄, and H₂O cycles for regional biogeochemistry has not been done.

Some initial findings on wetlands and CH₄

Preliminary findings by my lab and collaborators on CH₄ and the role of water table in the upper Midwest form my basis for suspecting that a better picture of controls on regional biogeochemistry can be had by simultaneous observations of CH₄ and CO₂ fluxes from a regional perspective. Some of these findings are briefly reviewed here.



Tall tower CH₄ flask observation

The National Oceanic Atmospheric Administration (NOAA) Earth Systems Research Lab (ESRL) monitors greenhouse gases at the WLEF tower including weekly single level flask observations of CH₄. These observations show periods of higher than background CH₄ concentrations in the region (Fig. 5). Given the small amount of anthropogenic CH₄ emissions, these data suggest a significant natural flux of CH₄ in the region with large temporal variability. Werner *et al.* (2003) attributed these emissions to wetlands based on a simple land cover analysis, but uncertainty on this remains high.

Soil chamber observations of CH₄ flux

A colleague (P. Weishampel, see letter) recently made some CH₄ chamber flux observations in the footprint of the WLEF tower to complement the larger number of CO₂ chamber flux observations made in the past (e.g., Bolstad *et al.*, 2004). These measurements were made with standard static chamber techniques (Healy *et al.*, 1996; Hutchinson *et al.*, 2000; Livingston and Hutchinson, 1995) and deployed over soil, low-growing vegetation, or floated on water. Measurements made at various times over the growing season in 3 lowlands and 3 uplands showed the largest CH₄ emissions in a fen, smaller in a bog, neutral in forested wetlands and generally methane consumption in forests (Fig. 6). Results also showed pulses of CH₄, such as a large pulse of CH₄ in the recent clear cut in one year but not the following. Only continuous observations, such as those from eddy covariance, will be able to regularly observe pulses of CH₄ (e.g., after a rainstorm or during ebullition events (Strack and Waddington, 2008) along with non-growing season fluxes, which may also be substantial (Pelletier *et al.*, 2007; Yu *et al.*, 2007).

Water table-carbon interaction in wetlands

My graduate student and I have recently analyzed six years of shrub wetland eddy covariance CO₂ and water table data to reveal a strong relationship of water table elevation to ER, but a weak relationship to GPP (Sulman *et al.*, 2008). We also found preliminary evidence of changing water use efficiency (WUE) at the site in the face of a deepening water table elevation, possibly hinting at plant succession.

Fig. 7 shows that depending on soil temperature, CO₂ emissions have a sharp decline as water table approaches the surface, at roughly -20 to -40 cm. This result has been corroborated at two other wetland EC sites. The picture for GPP to date has been more mixed. Without CH₄ observations, however, the total carbon balance of this wetland with change in water table is unknown.

Lingering questions and proposal objective

The initial findings suggest that there are significant CH₄ sources in the region that have large spatiotemporal variability and potentially share environmental controls with CO₂ fluxes, in both uplands and wetlands, for decomposition and photosynthesis. These findings provide motivation for my **objective of observing and analyzing regional (10s-100s km) CH₄ flux and understanding the combined carbon-climate feedbacks of CO₂ and CH₄ under conditions of declining water table elevation and rising temperature.** I ask:

1.) How is our understanding of regional controls on greenhouse gas uptake/emissions by natural vegetation skewed by our lack of observation of the fuller carbon cycle beyond CO₂?

2.) Are there emergent regional responses in CO₂ and CH₄ cycling that are not observed by plot-level and stand-scale observations?

I intend to meet our objective by quantifying regional CO₂ and CH₄ flux in a mixed upland-wetland landscape, investigating environmental controls on them, and parameterizing these results in ecosystem models to test sensitivity of regional biogeochemistry to future climate. These goals can be subdivided into the these questions and hypotheses:

1.) Can we quantify regional CO₂ and CH₄ flux?

Hyp. 1: Independent observations of regional CO₂ and CH₄ flux will converge on magnitude, trends, and interannual variability within the estimated uncertainty for each technique.

2.) Is there a simple way to estimate CH₄ fluxes from CO₂ fluxes?

Hyp. 2: Interannual variability of CO₂ and CH₄ are correlated, thus allowing for derivation of a region CH₄ emission:CO₂ uptake ratio useable for remote sensing of regional CH₄ (e.g., Potter *et al.*, 2006), similar to the global scale ratio proposed by Whiting and Chanton (1993).

3.) What are the primary environmental controls on CO₂ and CH₄ flux and the implication for climate sensitivity?

Hyp 3a: Land cover distribution (upland vs wetland), water table elevation, soil/air temperature, soil moisture, and photosynthetic active radiation (PAR) explain most of the diurnal, season, and interannual patterns in regional CO₂ and CH₄ flux.

Hyp 3b: The net effect on carbon fluxes from increasing air/soil temperature is a smaller CO₂ sink and greater CH₄ emission, due to increased soil aerobic and anaerobic decomposition and reduced net primary production of vegetation.

Hyp 3c: The net effect on carbon fluxes from a decreasing (deeper) water table is a smaller CO₂ sink and smaller CH₄ emission, due to increased ER of CO₂ and decreased ER of CH₄ in wetlands, decreased CH₄ consumption in uplands, and decreased GPP in uplands.

The confounding effects of CO₂ and CH₄ will be considered together using CH₄ and CO₂ climate forcing factors to assess the net radiative and chemistry impacts of these changes in regional carbon cycling.

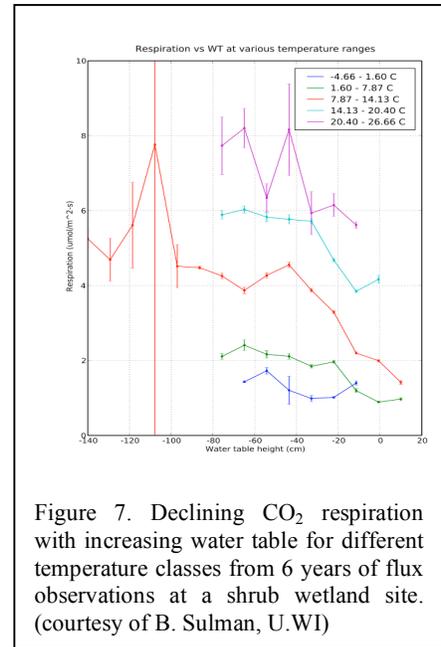


Figure 7. Declining CO₂ respiration with increasing water table for different temperature classes from 6 years of flux observations at a shrub wetland site. (courtesy of B. Sulman, U.WI)

Research Methods

General approach

To answer my questions and test my hypotheses on the differences in environmental controls of regional CO₂ and CH₄ fluxes, I intend to intensively observe regional biogeochemical cycling across a mixed upland-wetland landscape in northern Wisconsin using a number of innovative techniques, analyze their environmental controls, and adapt a joint CO₂-CH₄-H₂O model to test regional carbon cycle sensitivity to climate, hydrology, and land management. I propose to:

- 1) Quantify regional CH₄ and CO₂ flux: I intend to produce the first long-term record of continuous regional CH₄ observations in a mixed landscape using both tall tower eddy covariance and boundary layer budget techniques. These observations complement the existing long-term records of CO₂ flux at the field site. The five-year funding cycle will allow generation of a sufficiently long dataset so as to analyze both short-term and interannual controls on CH₄ and CO₂ flux. Regional flux will be computed using 1.) “footprint weighted” tall tower eddy covariance, 2.) single tower convective boundary layer budget technique, and 3.) a modified Bowen ratio technique. **Applies to questions 1, 2, and 3.**
- 2) Analyze environmental controls of CH₄ and CO₂ flux: The regional fluxes will be used to test hypotheses on how CO₂ and CH₄ regional carbon fluxes are simultaneously affected by changes in water table, temperature, PAR, etc... at hourly to interannual timescales. The existing water table elevation network and previously collected plot-level chamber and flux data will be used to clarify and identify processes leading to the observed results. **Applies to questions 2 and 3.**
- 3) Predict future CH₄ and CO₂ flux: The quantified regional flux and the analyzed environmental controls will be used to refine an existing hydrological and biogeochemical model that a collaborator and I are currently building for a wetland site. Parameter and model optimization techniques will be employed and simple scenarios of future climate, hydrology, and land use will be applied to this model to quantify future changes in biogeochemical cycling and net radiative forcing and atmospheric chemistry effects of regional landscapes. **Applies to question 3.**

Details of the site and the approaches are provided below.

Site description

The proposed area of study is the region surrounding the WLEF-TV tall tower in Park Falls, WI USA. The tower is located with the Chequamegon-Nicolet National Forest. This region is lightly populated and heavily forested. The terrain is characterized by undulations in elevation of about 20m forming a heterogeneous landscape of wetlands and uplands. The region was heavily logged in the early 20th century and is currently managed for hardwoods, red pine, aspen, and forest wetlands (e.g., alder, cedar) (Mackay *et al.*, 2002).

The 447-m tall WLEF TV tower is an Ameriflux eddy covariance site producing eddy covariance observations of CO₂, H₂O, temperature and momentum flux at 30, 122 and 396 m since mid-1996 (Bakwin *et al.*, 1998; Davis *et al.*, 2003). The heterogeneous flux footprint provides direct observations of regional flux. A large database of ecological *in situ* and remotely sensed data are also available for the tower footprint. My lab is involved in operating the flux and CO₂ tracer instrumentation at this site in collaboration with NOAA and The Pennsylvania State University.

The measurements and analysis conducted to date has fallen mostly under the auspices of the Chequamegon Ecosystem-Atmosphere Study (ChEAS; <http://cheas.psu.edu>), a multi-investigator consortium of investigators studying carbon and water balance in the region. Plot, stand and regional data, primarily focused on CO₂ fluxes, H₂O fluxes, carbon stocks, and land cover, have been collected by nearly one dozen independently funded investigators.

Task 1: Quantify Regional Flux of CH₄ and CO₂

I will use three independent techniques, described below, to quantify the regional fluxes of CH₄ and CO₂ in the region. All three rely on the existing infrastructure of the WLEF tower. Installation of a recently acquired high-precision CO₂/CH₄ analyzer and the acquisition of a fast-response CH₄ analyzer will be initiated under this proposal to allow for CH₄ flux analysis. Previously collected plot-level chamber flux and stand-scale flux tower (as many as 16 in the region in the past) data will be scaled and compared to these fluxes for comparison.

Task 1a: Footprint weighted eddy covariance from a very tall tower

The eddy covariance technique relies on transport of scalars in the turbulent atmospheric surface layer. By conservation of mass, measuring the sum of scalar advective flux, below sensor scalar accumulation, and most importantly the turbulent covariance of vertical wind velocity and scalar yields the net flux into or out of the surface (Loescher *et al.*, 2006). Typically, the advective flux is ignored, which is a reasonable assumption in flat terrain with homogenous landcover (Goulden *et al.*, 1996). Thus, single tower measurements of scalar profile and high frequency (>5 Hz) vertical wind and scalar can be used to yield NEE. High frequency wind velocity is typically measured with an ultrasonic anemometer, which uses pulses of ultrasonic sound to gauge wind velocity. There are many sensor related corrections related to measuring the flux (Berger *et al.*, 2001). An advantage of the tall tower is that the homogenous landcover requirement is relaxed, given the mixing in the boundary layer. My collaborators and I have successfully measured CO₂, H₂O, temperature, and momentum fluxes on the WLEF tall tower and several other sites in this way for the past decade (Davis *et al.*, 2003).

The top levels (122m and 396m) of the tower sample a mixed landscape of uplands and lowlands that is representative of the larger region as a whole, “seeing” roughly 2 km² in unstable conditions, larger in stable conditions (Desai *et al.*, 2007a; Wang *et al.*, 2006a). The 122m and 396m level have similar flux footprints, but the 122m is also more likely to be in the nocturnal boundary layer, increasing its usability at night. However, because the heterogeneous landscape sampled changes with wind direction and atmospheric stability, the hourly flux “footprint” is not always measuring the same regional flux. To overcome this issue, my colleague, Weiguo Wang, developed a novel technique to deconstruct the flux use a micrometeorological footprint model (e.g., Horst and Weil, 1992) for the convective boundary layer (Wang *et al.*, 2006a) that is then convolved with a land cover map, an empirical minimal parameter ecosystem model, and the observed fluxes. Though the problem is nonlinear and underconstrained, there is sufficient oversampling to solve for land cover based fluxes at monthly and seasonal timescales with acceptable uncertainty. By sampling many hours and applying the footprint model, a consensus (by multivariate optimization such as Monte Carlo simulation) emerges on the net fluxes (specifically, emission/uptake factors) from each land cover type.

I have applied this method and developed a reconstruction technique to then observe the regional “footprint-weighted” flux (Desai *et al.*, 2008). Initial use of this technique will be improved in this proposal by using a more recent landcover map with detailed wetland delineation (a deficiency noted by Wang *et al.* (2006b)), a better ecosystem model (with water table consideration), and run over a longer (interannual) time periods. Additionally, the joint use of CO₂ and CH₄ flux in this optimization should significantly improve detection of wetland fluxes as the covariance between the two fluxes is likely to change with amount of wetland in the footprint. Finally, this technique may be valuable for detecting any possible sources of hypothesized CH₄ production from upland vegetation (Frankenburg *et al.*, 2005; Houweling *et al.*, 2006; Keppler *et al.*, 2006;).

This proposal supports the acquisition of one of the recently developed fast-response, high-precision, self-calibrating, continuous CH₄ analyzers (Kroon *et al.*, 2007). The analyzer will be calibrated and installed at the WLEF tower to acquire CH₄ fluxes at the 122m level. Using the existing sonic anemometer and data acquisition system at the WLEF tower reduces costs. Storage flux will be computed using the high-precision CH₄ profiling analyzer (see Task 1b). These observations will allow for direct observation of regional scale continuous CH₄ over interannual timescales, which has never been done before.

Typical CH₄ turbulent fluxes at WLEF are expected to be 1 mg m⁻² h⁻¹ (0.5 ppb m s⁻¹) (Werner *et al.*, 2003), which requires that eddies with deviations of 2 ppb must be detected by the sensor at hourly averaging scales. The instrument I plan to acquire that can accomplish this is the Picarro, Inc. EnviroSense 3000f high frequency cavity ringdown CH₄/CO₂ analyzer, currently in the final phase of testing and slated for sale in late summer 2008 (E. Crosson, 2008, pers. comm.). Unlike traditional single-pass infrared gas analyzers, as are used for CO₂, this analyzer relies on integrating the decay curve (ringdown) as photons are lost from the highly reflective cavity and subsequently counted. Thus, the sensor is very precise and does not require reference calibration. Line and pressure broadening effects are minimized by scanning and integrating across the entire absorption spectra of interest. The lines being scanned by the Picarro sensor also includes CO₂, allowing for an additional measure of CO₂ flux at the site. The instrument will collect 10 Hz CH₄ flux data at 122m by drawing down air from that level to a trailer located at the WLEF base. Eddies at this height are large, therefore relaxing the frequency response required to ~0.1 Hz. However, the higher altitude increases the averaging time needed to capture the largest eddies to one hour (Berger *et al.*, 2001). Drawing air samples down to the surface via long tubes at high flow rates has been shown to have little effect on fluxes because mixing of the eddies that transport scalars is minimized by turbulent flow in the tubes. High-frequency spectral losses for CO₂ fluxes at 122m are roughly 5% (Berger *et al.*, 2001). Errors due to systematic advection are modest (Davis *et al.*, 2003; Ricciuto *et al.*, 2008; Yi *et al.*, 2000). Some research will be needed on applying Webb-Pearman-Leuning density corrections to CH₄ (Webb *et al.*, 1980). These potential systematic errors primarily influence flux magnitude, and have little influence on temporal variability; therefore, questions that hinge on temporal variability can be addressed with great confidence via micrometeorological flux measurements.

Task 1b: Trace gas boundary layer budget

I have recently acquired a Los Gatos, Inc. high-precision CO₂/CH₄ analyzer with my University start-up funding. The instrument is currently in use for lab calibration of CO₂ and CH₄ gas standards. I plan to install this instrument at the WLEF tower and sample the existing high-precision CO₂ profiling lines (Bakwin *et al.*, 1998) to acquire six-level two-minute average samples of CH₄ concentration. The instrument is based on integrated cavity output spectroscopy (ICOS). ICOS is a multi-path cavity-enhanced absorption spectroscopic technique with a precision of < 0.7 ppbv CH₄ and < 0.2 ppm CO₂ at 0.5 Hz (Bear *et al.*, 2002). The unique cavity uses high reflectivity mirrors to create an effective path length of ~10km within a 40cm cavity, significantly increasing detection of CH₄ in the near IR at room temperature. The device is also relatively insensitive to vibration, small changes in cavity length, temperature and alignment. The device is calibrated and line locked against a reference cell and a baseline loss value from a cavity ringdown measurement at the end of each scan.

Several papers have shown that, when averaged over synoptic cycles, CO₂ mixing ratio time rate of change, corrected for boundary layer entrainment, is strongly correlated to the tall tower CO₂ flux as measured by eddy covariance (Bakwin *et al.*, 2004; Helliker *et al.*, 2004). Entrainment at the boundary layer top is estimated by 1) extracting vertical velocity measurements from reanalyzed meteorology models and applying a zero-order jump model to tower and NOAA weekly aircraft profiles or 2) relying on a water vapor similarity approach that relates water vapor vertical derivatives, water vapor eddy covariance flux, and NOAA water vapor soundings to free troposphere entrainment. I propose to extend this analysis to the continuous CH₄ observations that will be acquired by the CH₄ profiling system. This tracer approach also has a larger footprint (10-100 km upwind fetch) than the tall tower flux (1-10 km fetch) and so will be investigated for extrapolating from the tower footprint to the larger region.

Task 1c: Modified bowen ratio

An alternative approach to estimating large region CH₄ flux from CH₄ tracer profile has also been tested at the tall tower for a short time period (Werner *et al.*, 2003). This method, termed the Modified Bowen Ratio (MBR) technique relies on similarity of diffusion for CO₂ and CH₄. By combining first-order diffusion equations for CO₂ and CH₄ and equating the diffusion coefficients, one can derive an equation for CH₄ flux as a function of CH₄ tracer profile, CO₂ tracer profile, and CO₂ flux. This method was tested on two growing seasons at the tall tower. In this proposal, I will extend the analysis to the entire data record of available CH₄ profiles and compare to the eddy covariance and tracer budget techniques.

Task 2: Understand Environmental Controls of CH₄

Regional fluxes from Task 1, the network of meteorological and hydrological observations, nearby stand-scale fluxes towers, and plot-scale chamber fluxes will be analyzed at the diurnal, monthly, seasonal and annual timescales for patterns and correlations of CO₂ and CH₄ emissions in the region and the mechanisms responsible for these patterns. Correlation analysis, both direct and lagged, will be performed at the hourly, daily, synoptic (weekly), monthly, seasonal, and interannual timescales as appropriate for each measurement. Primary environmental variables that will be tested are soil and air temperature, water table elevation, precipitation, soil moisture, and PAR. CH₄ pulse fluxes will be compared to atmospheric pressure and turbulence variables to test for ebullition effects (e.g., Sachs *et al.*, 2008). ANOVA and related tests will be used to test for significant interactions across the entire regional observation network.

Of particular interest is whether there is consistency in relationships of environmental variables to CO₂ and CH₄ flux, even if the magnitude of regional flux varies among the methods (which is likely given the different spatial/temporal scales of measurement). The goal is to provide more confidence that observed correlations are robust against flux uncertainty. Interannual analysis will also be valuable to estimate regional CH₄:CO₂ emission factors and their spatiotemporal variability.

Another compelling way to analyze these is to use the footprint weighting model mentioned in Task 1a and essentially run it in reverse. The key here is recognizing that the patterns and parameters derived from the simple ecosystem model embedded in the footprint model can be used to test hypotheses on the sensitivity of wetland and upland GPP and ER to water table, temperature, moisture, light, and cover type. Model selection, tuning, and sensitivity tests will be the primary activities used to test the hypotheses.

Task 3: Predict Future CH₄ and CO₂ Flux

While the simple model to be developed for the footprint model of Task 1a and the environmental control analysis of Task 2 can be used for interpreting data, it does not have value for extrapolation and prediction. A biogeochemical process model is needed for this task. While several wetland and CH₄ models exist (e.g., Cao *et al.*, 1996; Petrescu *et al.*, 2008; Potter *et al.*, 1997; Sonnentag *et al.*, 2008; Walter *et al.*, 2001; Zhang *et al.*, 2002; Zhuang *et al.*, 2004), many only weakly constrain hydrology, only a few also include upland biogeochemistry, and therefore most are not suited for regional application. Here, I propose to remedy that by building on work being done by a collaborator (D. Scott Mackay, SUNY-Buffalo) and I on an independently funded proposal (see “Current Support” and letter). We are adapting the Terrestrial Regional Ecosystem Exchange Simulator (TREES) ecohydrology model (Mackay *et al.*, 2003a,b; Ewers *et al.*, 2008) to incorporate wetland biogeochemistry and hydrology. The TREES model has been successfully used to model transpiration and leaf level CO₂ fluxes across the region (Mackay *et al.*, 2003). Non-vascular plant processes and peatland respiration models will be added to TREES to incorporate wetland CO₂ and CH₄ biogeochemistry. Regional processes will be connected by a hydrology model based on a finite difference groundwater model and constrained by the water table piezometer network and previously collected canopy LiDAR ground return data that will be used to construct a high resolution hydraulic gradient map.

CH₄ regional flux data to be collected by this proposal will be synthesized and provided as constraint to the TREES model. A Markov Chain Monte Carlo (MCMC) parameter estimation routine is being implemented for TREES (Samanta *et al.*, 2007) to constrain model parameters with CO₂ flux tower assimilation. Here, I will investigate data assimilation of CH₄ flux into this framework after the TREES model CH₄ biogeochemistry and wetland hydrology have been incorporated. The constrained model can then be fed a variety of scenarios on future temperature and water table to test the effects on upland, wetland, and regional variability in biogeochemical cycling and land-atmosphere exchange.

Once regional flux predictions are produced, simple analyses can be done on the climate impact on CH₄ versus CO₂ fluxes using radiative balance models (Frolking *et al.*, 2006) and tracer transport/chemistry models. For example, tradeoffs in CH₄ emissions versus CO₂ respiration with a changing climate can be quantitatively examined by comparing across years with different mean temperatures and precipitation. This kind of analysis would provide added insight at the large region impact and role that subboreal regions play in carbon balance, air quality, and climate.

Prior, Current, and Future Support

Carbon and water cycle studies have been funded in the ChEAS-region for over a decade, though none have focused on the entire region across water, CO₂, and CH₄ interactions. The most relevant funded project was a NASA Carbon Cycle project (PI: P. Bolstad) that focused extensively on collecting high resolution land cover data around the tall tower corroborated with many intensive biometric sampling plots, LiDAR based tree canopy mapping, roving portable flux tower wetland CO₂ fluxes, and mechanistic modeling with a modified Biome-BGC model (Bond-Lamberty *et al.*, 2006). These data are available and provide a thorough snapshot of the state of the regional landscape that will be used to initialize the proposed mechanistic models.

Currently, I am funded on two projects relevant to this proposal. I have recently initiated a project to measure and model wetland carbon fluxes funded by a Department of Energy (DOE) National Institute of Climate Change Research (NICCR) Midwest region grant (Lead PI: Ankur Desai, UW-Madison; co-PI: D. Scott Mackay, SUNY-Buffalo). The goal of that proposal is to understand water table controls on wetland CO₂ flux and develop a hydrological-biogeochemical model for wetlands. This CAREER proposal builds on the expertise gained here and extends the TREES model developed by the NICCR grant to incorporate CH₄ and regional landscape hydrology.

I am also currently funded by NSF as co-PI on collaborative proposal OCE-0628560 (with lead PI G. Mckinley, C. Wu, UW-Madison; and N. Urban, Michigan Tech.), 10/1/06-9/31/10, *Carbon balance of Lake Superior*. This project is in year 2. We have successfully built a biological and physical model of Lake Superior and estimated initial regional atmospheric CO₂ emission rates. I have focused on incorporating atmospheric CO₂ observations into the model and comparing results to land flux towers in the region. Presentations have been made at the American Geophysical Union and the American Society of Limnology and Oceanography. We have also recruited and trained a minority post-doc and a female Ph.D. candidate. A workshop on the Lake Superior carbon cycle is planned for August 2008.

This proposal helps tie my current research and education activities, and potential future projects into a coherent whole focused on understanding wetland biogeochemistry, atmospheric CO₂/CH₄ variability, and carbon-climate interaction in regional settings using micrometeorological and ecological techniques. At UW-Madison, I have formed new collaborations with Frank Keutsch (see letter) on methane instrumentation; Ishi Buffam, Monica Turner, Jon Foley, and Tim Krantz to better understand regional carbon cycling in the lake-studded Northern Highlands region of Wisconsin and the North Temperate Lakes Long Term Ecological Research Site (LTER); and Phil Townsend and Shawn Serbin on biomass and wetland cover sampling from high-resolution hyperspectral remote sensing. I have submitted an NSF proposal with Chuixiang Yi, CUNY-Queen's, to investigate advection across wetland-upland gradients.

Research initiated by this proposal also has potential for generating new collaborations and projects. I have currently initiated discussions with Randy Kolka, USFS (see letter) on comparing methane eddy covariance observations; Peter Weishampel, U. Minnesota (see letter) on scaling plot-level chamber CH₄ observations; Dylan Millet, U. Minnesota on the potential for VOC eddy covariance at the WLEF tall tower; Gregg Starr, U. Alabama on open-path methane sensors and water table studies, and Nic Saliendra, USFS and D. Scott Mackay, SUNY-Buffalo on how to model human behavior and incorporate land and water management actions into biogeochemical models. Support of this proposal would significantly improve the likelihood of converting these discussions into new formal collaborations.

It is likely that other projects and new research questions will also emerge from continued analysis of the wealth of data from the WLEF tall tower observatory and the newly acquired methane instrumentation. The CH₄ instrumentation will form a significant new facility for the Desai lab and the Ameriflux flux tower network. I also foresee future acquisition of a currently in-development low-power open-path CH₄ flux sensors (e.g., Li-Cor, Inc. LI-7700) to do targeted studies at wetland sites in the tower footprint that lack A/C power. Finally, I note that the NSF-support National Ecological Observatory Network (NEON, Inc.) has located its Great Lakes core facility at the nearby (< 100 km) University of Notre Dame Environmental Research Center (UNDERC) and based on my discussions and site visits with them, they are planning to leverage the data collected by ChEAS (including this proposal if funded) to understand spatiotemporal variability of carbon cycling and local future sensing platforms or sites for this region.

Broader Impacts

Global climate change is a topic on many people's minds today. Of course, local weather and climate are always a topic of interest. However, much misinformation is passed around when the latter is attempted to be tied to the former (e.g., recent extreme weather, frequency of hurricanes, change in planting dates). In my research, I am fundamentally interested in making both global change and local observations relevant to regional scale concerns about ecosystems. Consequently, I believe, as University faculty, that my education and outreach should also be similarly directed. I would like to use this CAREER proposal to further some of my current efforts and establish new ones, in the realm of tying together global change, local observations, and regional ecological change. Moreover, I prefer that these education and research activities do not stand alone, but form an integrated whole. Here, I outline several broader impact activities that connect the research in this proposal to education and outreach activities, and vice versa.

The activities below target 1.) community college science students at a Wisconsin tribal college seeking more knowledge about 4-yr degrees in STEM, 2.) Wisconsin rural high school students and the local public interested in learning about local impacts of global change, 3.) UW undergraduate non-science majors interested in global change, and 4.) international undergraduates considering attending graduate school in the U.S. A graduate student interested in education and outreach activities will also be recruited to assist in these activities. Although this is an ambitious list, it should be noted that only the first two activities will be completely new endeavors, with the majority effort focused on the tribal college.

Each of the plans share some common goals and themes. For each group, I want to **motivate interest in the sciences and global change by appealing to the research we are doing in their backyards**, namely northern Wisconsin. Too often, as scientists, we gain greatly by doing research in various field locations, but for the local populace, the reverse is not necessarily true. I have been working on research in northern Wisconsin for almost a decade, and I would like to ameliorate my own deficiency here. Moreover, local outreach is well received by the University of Wisconsin due to the enshrinement of the Wisconsin Idea, which states that "the boundaries of the university should be the boundaries of the state, and that research conducted at the University of Wisconsin System should be applied to solve problems and improve health, quality of life, the environment and agriculture for all citizens of the state". The idea is well tied to the NSF CAREER program aim to integrate research and education.

The proposed activities are also aligned with recent calls to improve STEM education, provide teacher education, and develop summer institutes as noted in the recent National Academy of Science document, "Rising Above the Gathering Storm" (National Academy of Sciences, 2007). The education plans here are aimed to promote STEM careers, provide hands-on activities that utilize STEM skills, and propagate STEM awareness in underserved populations. To do this, activities also need to follow published national guidelines on science standards, incorporating research into education, and assessment (e.g., National Research Council, 1996, 2001, 2002). The outreach here targets national science standards on the state of current local, national and global Earth system scientific and technical challenges.

Preparing for college degrees in STEM: College of Menominee Nation

Through a collaborative opportunity with the NSF-supported multi-college consortium Wisconsin Alliance for Minority Participation (WiscAMP, see letter), I intend to develop, implement, and assess a 12 day summer science inquiry and career exploration program for 2-yr college students at the College of Menominee Nation (CMN), in cooperation with their VP of Academic Affairs, Donna Powless (see letter). The **goal** of this activity is to provide greater exposure to research careers in STEM to students. The **expected outcome** is to increase enrollment in 4-yr STEM degrees, which will be **assessed** by longitudinal tracking through WiscAMP.

CMN is an accredited 2-yr tribal college on the Menominee Reservation in Keshena, WI. Menominee County is the poorest county in the state of WI, located within the same general region as the proposed field study, and less students here pursue STEM careers. At the same time, the Menominee Tribe have been pioneers (since before the 20th century) in the development of sustainable forestry techniques (Davis, 2000; Pecore, 1992; Wood and Dewhurt, 1998) and consequently CMN offers AA degree programs in Natural Resources, Sustainable Development, and Biology & Physical Sciences. I intend to target this

pool of students, introduce them to topics on global change and regional biogeochemistry via inquiry-based projects at our field sites, and attempt to interest some to pursue baccalaureate and graduate degrees in the sciences. CMN also has some connections with the Menominee Indian School District, and the opportunity to recruit advanced high school students into the program will also be considered in consultation with CMN.

WiscAMP is committed to increasing the pipeline of underrepresented minority students who receive bachelor's degrees in STEM fields. Native Americans do not receive a share of degrees in STEM in proportion to their share of population (age 20-24) at any degree level (Babco, 2003, 2005). Though Native Americans have now increased to 0.7% of all STEM degrees in 2000, compared to 0.4% in 1987 (Babco, 2003), poverty, poor educational systems, and lack of exposure of science research continues limit the appeal of STEM degrees (Lin *et al.*, 2007). I would like to increase exposure to the breadth of global change research that can provide viable careers and an opportunity to improve the livelihoods (e.g., forestry in a changing climate) of the local community. Summer science enrichment programs with other tribes have been done (Dalbotten *et al.*, 2004; Lin *et al.*, 2006, 2007) and lessons learned here on unique cultural, family, and educational backgrounds of many Native American students places additional requirements on what should be included in an educational program.

The summer program will take place at CMN, a field station, and the field study site. The first part (2 days) at CMN will take place during the day, and will focus on basic earth system science topics such as biogeochemical cycling, climate change, and energy. Much of these materials will be adapted from an undergraduate global change class that I currently teach (see below). For the last two parts, participants will be transported to Kemp Natural Resources Station (NRS) and reside there for the remainder of the project. Kemp NRS is an experimental field station run by the University of Wisconsin-Madison, College of Agriculture and Life Sciences. I have had a long relationship with Kemp NRS, since it is my primary base for research studies in northern Wisconsin. In addition to lab, lodging, and kitchen space for researchers, classroom and outdoor meeting space are available for outreach and Kemp NRS encourages researchers who utilize the facility to also conduct outreach (see letter). Kemp NRS provides affordable dormitory lodging (\$12/pp/night), classrooms, lab facilities, and a computer lab with internet access.

In the second part (5 days), participants will visit field sites, learn about local land-atmosphere datasets and dataset tools. Simple measurements will be made at the field sites to demonstrate scientific measurement techniques. Students, in teams of three, will then meet with me and other colleagues. Each student group will develop a short, simple inquiry-based project on regional land-atmosphere change based on the existing data (with possible limited opportunity for more data collection). National Research Council (2002) provides insight into how to incorporate scientific research into education, and the guidelines there on education of research conduct, presentation, and ethics will be incorporated here.

After students have selected projects, the final portion (5 days) of the class will consist largely of free time dedicated to pursuing the project in close cooperation with my lab and other colleagues available for consultation. Typically, many field researchers also stay at Kemp in the summer, and a few will be recruited to assist in research mentoring. At the end of the program, each group will write a scientific abstract describing their project and produce a 20-minute presentation with graphics as part of a mini-conference. Particularly compelling projects may possibly lead to incorporation into the proposed research or used as a motivator to recruit participants to UW-Madison and my lab.

Assessment and evaluation are integral to any educational endeavor. The National Research Council (2001) notes that assessment in science needs to gauge student cognition, observation, and interpretation skills. Timely feedback is needed to improve student metacognition (reflecting and direction one's own thinking). I extensively use "clicker" instant-response classroom technology in my undergraduate courses and I will investigate the potential to use these in the course. Student evaluation will be driven by use of a pre-test prior to start of the program, short self-graded quizzes and journaling activities during the course, and post-course evaluation and self assessment. A rubric and written assessment will be provided for the presentations. Evaluation of the overall program logistics and content will be scrutinized to improve future runs of the course. These assessments will be used by Kemp NRS and CMN as part of its review process of outreach programs. The potential to offer CMN credit for this class will also be considered.

To optimize the time commitment of this activity, the first year of this proposed activity will be devoted entirely to course development and recruitment of the first class in collaboration with WiscAMP, CMN, Kemp NRS, and my lab. The graduate student to be supported by this proposal will be recruited with express notice that an education component involving assistance to this course will be part of professional development (see below). Thus, a side benefit of this course is to provide instructional experience for a graduate student, something that is typically lacking in most science Ph.D. programs. Additionally, there is a Menominee student currently considering majoring in Atmospheric & Oceanic Sciences at UW-Madison. Supplemental NSF REU, minority participation funding, or UW internal grants will be used to recruit him or other interested undergraduates to work on both research and education components. In years 2-5, a program for 15-20 students will be held. Selection will be by application. This proposal includes funding to cover transport, lodging (\$12/pp/night at Kemp), meals, and incidentals to all participants. The possibility of stipends (which may be necessary for many or most participants) will be explored through internal WiscAMP grant competition and other funding mechanisms.

K-12 and public outreach on STEM careers at Kemp NRS

Kemp NRS routinely welcomes researchers who are lodging at Kemp to present research to the public. I will present two talks per year at Kemp NRS targeted to high school students from the surrounding mostly rural school districts and the general public. The **goal** of this activity is to disseminate knowledge about global change, local impacts, local research to residents in the area, and provide education about science careers and STEM degrees to high school students. The **expected outcome** is increased understanding about local research and science careers which will be **assessed** by participant evaluation and follow-up surveys. I will develop two sessions per year. One will likely focus on global climate change and the connection to local land use, biogeochemical cycling, and environmental science careers. The other will focus our local research activities and provide hands-on access to instrumentation that we use to measure land-atmosphere exchange and micrometeorology by installing these sensors at the Kemp property. Access to research grade instrumentation is one way to engage people on how science actually works and connecting the message scientists communicate with the methods they develop to acquire the results. Publicity and school district contact for these events will be coordinated with Kemp NRS.

Undergraduate global change course development

I currently teach an undergraduate course in the Atmospheric & Oceanic Sciences department (and cross listed in Environmental Studies) at UW-Madison titled “Global Change: Atmospheric Issues”. This undergraduate introductory level elective has fulfills a University writing intensive course requirement needed by all undergraduates, most of whom are from Wisconsin. I cover topics on climate change, stratospheric ozone, acid rain, and basic earth system science. Regional climate and land-atmosphere data generated by this proposal will be incorporated into existing written homework assignments that currently rely on article response papers to include more analysis and discussion of *in situ* data. Student evaluations in the past have shown that the data-driven writing assignments were the most well received. The **goal** of this activity is to connect the relatively abstract concepts of global change to regional change and scientific data analysis. The **expected outcome** is increased understanding of global change as **assessed** by tracking expected improved results on final exams and the final term paper.

International student lab exchanges: The Khorana Program

The Khorana Program for Scientific Exchange has been recently established at UW-Madison and is focused on increasing interaction and research between universities in India and UW-Madison (see letter). Every year, undergraduates from top institutions in India are accepted into a summer lab internship program via the program. I am currently listed as a faculty mentor and if this proposal is funded, I plan to leverage the funding to recruit an undergraduate from India to work in my lab via the Khorana program. The proposed research lends naturally to many opportunities for lab, computational and/or field research. The **goal** of this activity is to build a pipeline for future Indian environmental scientists and increase opportunities for international collaboration with India. The **expected outcomes** are increased enrollment in graduate programs in biogeosciences by participants and future international research proposals, which will be **assessed** by participant tracking through Khorana and reporting on research collaborations by me.

Graduate student education

A graduate student will be funded on this proposal and will focus on the burgeoning fields of regional biogeochemistry, land-atmosphere interaction, and carbon cycle. The student will also be directly involved in the education activities outlined here as part of his or her professional development. To assist this, I will leverage the Delta program, the UW-Madison implementation of the NSF-funded Center for the Integration of Research, Teaching, & Learning (CIRTL) (see letter). Delta offers courses in instructional materials development and classroom diversity. These courses will be taken by the student. The student will also have the opportunity to engage in a "teaching-as-research" internship and obtain a certificate offered by Delta which acknowledges this student as a next generation scholar committed to integration of teaching and research, the **goal** of this activity. The **expected outcome** is that the Ph.D. student will not just participate but lead some of the proposed education activities and upon graduation, have better career opportunities, which will be **assessed** by student follow-up.

Management Plan

Personnel

I (Ankur Desai), will be the PI and am in my 2nd year as Assistant Professor of Atmospheric & Oceanic Sciences at University of Wisconsin-Madison. I have extensive experience in eddy covariance flux measurement, trace gas calibration, and scaling land-atmosphere fluxes. I also have significant ecosystem modeling experience. This proposed project, if funded, will help broaden my current CO₂ and upland focused research to CH₄ and wetlands. I will supervise the technician and graduate student on the project and oversee project management. Also, I will interact with the numerous outreach partners identified in this proposal. Last year, I organized an NCAR/NSF sponsored 50 graduate student summer regional biogeochemistry colloquium in Boulder, CO and have organized other workshops in the past. Thus, I feel I have the experience necessary to develop, implement, and assess the proposed education programs.

This proposal supports an associate researcher who will act as lead field technician and will be trained in maintenance of eddy covariance flux towers, micromet stations, and water table depth stations and continue to provide these services for the WLEF tall tower and the surrounding sensors. This person will also lead purchase, calibration, installation and data collection of the CH₄ flux instrumentation and work with colleagues at the U.S. Department of Agriculture (USDA) U.S. Forest Service (USFS) Northern Research Station in Rhineland, WI who will visit sites weekly to collect data, perform simple maintenance, and troubleshoot problems (see letter).

This proposal supports training of a Ph.D. student in Atmospheric & Oceanic Sciences. He or she will work with me to develop a Ph.D. thesis around the research topics proposed here. The student will also collaborate on field measurement and on the education component as part of his or her professional development as previously described.

Timeline

Year 1: *Research:* Acquisition, calibration and installation of CH₄ flux sensor; continued operation and maintenance of CO₂ flux observations and CH₄ trace gas measurements; acquisition and maintenance of existing water table, soil temperature, land cover data; analysis of CH₄ chamber data; recruiting of personnel; presentation at regional meeting. *Education:* One Kemp NRS presentation and contact of local schools; Khorana student recruiting; meeting with CMN and WiscAMP to develop course.

Years 2-4: *Research:* Continued operation of CH₄ and CO₂ systems; grad student training; flux tower data analysis; regional flux computation; CH₄/CO₂ model development, data assimilation, and sensitivity study; development of proposals to support supplementary observations (e.g., targeted CH₄ fluxes); publication and presentation at national meetings. *Education:* Two Kemp NRS talks, undergraduates in the lab; operation of summer course; global change course improvement.

Year 5: *Research:* In addition to above, a decommissioning of systems if needed; and regional workshop on CH₄ and CO₂ biogeochemistry and dissemination of data. *Education:* Continuation of programs plus overall assessment of outreach program and evaluation of opportunities for sustaining them.

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BIOGRAPHICAL SKETCH FOR ANKUR R DESAI

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EDUCATION

Oberlin College, B.A., Computer Science, 1997
Oberlin College, B.A., Environmental Studies, 1997
University of Minnesota, M.A., Geography, 2000
Pennsylvania State University, Ph.D., Meteorology, 2006

ACADEMIC EMPLOYMENT

2008- Faculty affiliate, Center for Climatic Research, Nelson Institute for Environ. Studies
2007- Assistant Professor, Dept. of Atmospheric & Oceanic Sciences, University of Wisconsin
2006-2007 Postdoctoral Fellow, Advanced Study Program, Nat'l Center for Atmospheric Research
2002-2006 Graduate Research Assistant, Dept. of Meteorology, Pennsylvania State University
2000-2001 Research Fellow, Dept. of Forest Resources, University of Minnesota
1998-2000 ICGC MacArthur Scholar Fellow, Dept. of Geography, University of Minnesota

5 RELEVANT PUBLICATIONS

- Desai, A.R.**, Bolstad, P.V., Cook, B.D., Davis, K.J., Carey, E.V., 2005. Comparing net ecosystem exchange of carbon dioxide between an old-growth and mature forest in the upper Midwest, USA. *Agricultural and Forest Meteorology* 128(1-2): 33-55, doi:10.1016/j.agrformet.2004.09.005.
- Desai, A.R.**, Moorcroft, P.R., Bolstad, P.V. and Davis, K.J., 2007. Regional carbon fluxes from a biometrically-constrained dynamic ecosystem model: Impact of disturbance, CO₂ fertilization and heterogeneous land cover. *Journal of Geophysical Research - Biogeosciences*, 112(G01017), doi:10.1029/2006JG000264.
- Desai, A.R.**, Noormets, A.N., Bolstad, P.V., Chen, J., Cook, B.D., Davis, K.J., Euskirchen, E.S., Gough, C.M., Martin, J.G., Ricciuto, D.M., Schmid, H.P., Tang, J.W. and Wang, W., 2008. Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the Upper Midwest, USA: Implications for regional scaling, *Agricultural and Forest Meteorology*, 148(2): 288-308, doi:10.1016/j.agrformet.2007.08.001.
- Desai, A.R.**, Richardson, A.D., Moffat, A.M., Kattge, J., Hollinger, D.Y., Barr, A., Falge, E., Noormets, A., Papale, D., Reichstein, M., and Stauch, V.J., 2008. Cross site evaluation of eddy covariance GPP and RE decomposition techniques, *Agricultural and Forest Meteorology*, 148(6-7): 821-838, doi:10.1016/j.agrformet.2007.11.012.
- Heinsch, F.A., Zhao, M., Running, S.W., Kimball, J.S., Nemani, R.R., Davis, K.J., Bolstad, P.V., Cook, B.D., **Desai, A.R.**, Ricciuto, D.M., Law, B.E., Oechel, W.C., Kwon, H., Luo, H., Wofsy, S.C., Dunn, A.L., Munger, J.W., Baldocchi, D.D., Xu, L., Hollinger, D.Y., Richardson, A.D., Stoy, P.C., Siqueira, M.B.S., Monson, R.K., Burns, S. and Flanagan, L.B., 2005. Evaluation of remote sensing based terrestrial productivity from MODIS using regional tower eddy flux network observations, *IEEE Transactions on Geosciences and Remote Sensing*, 44(7): 1908-1925, doi:10.1109/TGRS.2005.853936.

OTHER PUBLICATIONS

- Barkley, M.P., Monks, P.S., Hewitt, A.J., Mchida, T., **Desai, A.R.**, Vinnichenko, N., Nakazawa, T., Yu Arshinow, M., Fedoseev, N., and Watai, T., 2007. Assessing the near surface sensitivity of SCIAMACHY atmospheric CO₂ retrieved using (FSI) WFM-DOAS. *Atmospheric Chemistry and Physics*, 7(13), 3597-3617.

- Cook, B.D., Bolstad, P.V., Martin, J.G., Heinsch, F.A., Davis, K.J., Wang, W., **Desai, A.R.**, and Teclaw, R.M., 2008. Using light-use and production efficiency models to predict forest production and carbon exchange during canopy disturbance events, *Ecosystems*, 11: 26-44, doi:10.1007/s10021-007-9105-0.
- Desai, A.R.**, Davis, K.J., Senff, C., Ismail, S., Browell, E.V., Stauffer, D.R., and Reen, B.P., 2006. A case study on the effects of heterogeneous soil moisture on mesoscale boundary layer structure in the southern Great Plains, USA. Part I: Simple prognostic model. *Boundary-Layer Meteorology*, 119(2): 195-238, doi:10.1007/s10546-005-9024-6.
- Yi, C., Davis, K.J., Bakwin, P.S., Denning, A.S., Zhang, N., **Desai, A.R.**, Lin, J.C., Gerbig, C. and Wofsy, S.C., 2004. Observed covariance between ecosystem carbon exchange and atmospheric boundary layer dynamics at a site in northern Wisconsin. *Journal of Geophysical Research*, 109(D08302), doi:10.1029/2003JD004164.

AWARDS AND HONORS

National Center for Atmospheric Research Advanced Study Program Fellowship (2006-2007); Pennsylvania Space Grant Consortium, NASA Space Grant Fellowship (2005-2006); Arnulf I Muan Graduate Fellowship, College of Earth and Mineral Science, Penn State Univ. (2004-2005); Centennial Research Award, Penn State Univ. (2004-2005); Inducted to Chi Epsilon Pi, Penn State chapter, 2003; John D. and Catherine T. MacArthur Scholars Fellowship, University of Minnesota (1998-2000)

SYNERGISTIC AND EDUCATIONAL ACTIVITIES

- Member, AGU Committee on Biogeosciences, 2008-
- Co-convener, AGU Fall 2007 Session B31: Observing, Modeling and Predicting Regional Carbon Exchange
- Lecturer, University Avenue Day Care, "Hurray for Spring!", preschool science demo, March 2008
- Lecturer, UW-Madison class AOS 171: Global Climate Change for primarily non-science majors and AOS 773: Boundary layer meteorology for graduate students
- Faculty mentor, Khorana Program for Scientific Exchange, undergraduate lab exchange program for science students in India, 2008-
- Organizer, *Regional-scale Biogeochemistry: Needs and Methodologies*, NSF-sponsored NCAR/ASP Summer Student Colloquium workshop, Boulder, CO, June 4-15, 2007
- Invited lecturer, *Flux Measurements and Modeling*, NSF graduate student workshop, Ward, CO, July 21, 2008.

COLLABORATORS (LAST 48 MONTHS)

M. Barkley (U. Leicester), E.V. Browell (NASA), E.V. Carey (JSA Consultants), J. Chen (U. Toledo), B.D. Cook (U. Minnesota), A.S. Denning (Colorado State U.), E.S. Euskirchen (U. Alaska), B.E. Ewers (U. Wyoming), C.M. Gough (Ohio State), F.A. Heinsch (U. Montana), S. Ismail (NASA), D.S. Mackay (SUNY-Buffalo), J.G. Martin (Oregon State), G.A. McKinley (U. Wisconsin), N. Miles (Penn State), A. Moffatt (Max-Planck BGC), P.R. Moorcroft (Harvard U.), A. Noormets (NC State), B. Reen (Penn State), A. Richardson (UNH), D.M. Ricciuto (Penn State), N. Saliendra (USDA), S. Samanta (Woods Hole Research Center), C. Senff (NOAA), J.W. Tang (Chicago Botanic Gardens), R.M. Teclaw (USDA), N. Urban (Michigan Tech), W. Wang (DOE), C. Yi (CUNY)

GRADUATE AND POST-DOCTORAL ADVISORS

David S. Schimel, National Center for Atmospheric Research (Postdoctoral mentor)
 Kenneth J Davis, Pennsylvania State University (Ph.D.)
 Howard Veregin, Rand-McNally, formerly University of Minnesota – Twin Cities (M.A.)

POSTDOCTORAL FELLOWS ADVISED None

GRADUATE STUDENTS ADVISED

Ben Sulman (current Ph.D. student), Will Ahue (current M.S.), Ruben Behnke (current M.S.)

Budget Justification

Budget Narrative

Cost Justification

Funding is requested for 5 years from 1/1/2009 to 12/31/2013. Justification of the costs are provided below. F & A rate is 48.5%. Tuition, permanent equipment over \$5,000, and participant costs are excluded from the F&A cost base.

Personnel

Ankur Desai is an assistant professor in Atmospheric & Oceanic Sciences at the University of Wisconsin – Madison and faculty affiliate of the Center for Climatic Research, Nelson Institute for Environmental Studies, University of Wisconsin-Madison. He will be responsible for overall project management, installation of field equipment, and analysis of data. Desai will supervise a graduate student and technician. Desai holds a 9-mo teaching position and this proposal requests 0.5-month summer salary annually primarily to support outreach and education activities. Fringe rate is 38.5%. All salaries and fringe rates are projected to increment 4% and 1% annually, respectively.

We also seek support for an associate researcher who will serve as the main field technician on the project. He or she will be responsible for purchase, installation, calibration, maintenance and removal of the CH₄ flux and trace gas sensor system as well as routine maintenance of the WLEF tall tower. We are requesting 25% (3 month) time in each year. Fringe rate is 38.5%

A 12-mo 50% graduate research assistantship will support a graduate student in her Ph.D. research in climate and biogeochemistry. She will work on both the research and education components of this proposal. Fringe rate is 20.5%. Tuition is budgeted as \$8,000/yr.

Permanent Equipment

A fast response methane sensor will be purchased and installed at the WLEF tall tower, to complement the existing CH₄ trace gas system. The sensor is the newly developed Picarro, Inc. EnvironSense 3000f, to be released for sale this late summer (E. Crosson, 2008, pers. comm.). This instrument is a high-uptime, self-calibrating, cavity-ring down based spectroscopic analyzer of CO₂ and CH₄ with a 10 Hz response time. Cost of the system with a dry scroll vacuum pump is \$75,000. Using the existing tall tower infrastructure (tubing, data lines, sonic anemometer, etc...) for the rest of the flux instrumentation provides significant costs savings. Desai lab startup funds have been used to purchase a Los Gatos, Inc. CO₂/CH₄ analyzer for trace gas profile observations at WLEF, which are also central to this proposal.

Materials, Supplies and Services

Field supplies are budgeted at \$3,000 in each year will be used to support operation costs of the flux tower, including but not limited to, tower climbs by OK Tower Company (\$1,000/yr) air sampling filters (\$500/yr), pump diaphragms and parts (\$500/yr), secondary gas standards (\$500/yr), data storage media, replacement parts, tubing, valves, fittings, and water table/micromet station batteries (remaining \$500/yr).

Weekly data collection, maintenance and troubleshooting visits will be coordinated by a long standing consultation contract with the U.S.D.A. U.S. Forest Service and continue to be supported by \$5,000/yr to be paid to the U.S. Forest Service Northern Research Station in Rhinelander, WI. These funds support their tower visit operation costs. These visits are critical to providing the high uptime required for the research proposed here.

Publications costs of \$1,000/yr are budgeted in years 2-5 when significant manuscript submissions are expected.

Travel

Field travel is budgeted at \$3,500 for seven 4-day trips in year 1 and \$1,000 for two 4-day trips in years 2-5 by the technician and an assistant (e.g., the graduate research assistant or the PI). Low cost lodging is provided at Kemp NRS, which also provides group kitchen, wet lab, truck rental, shipping/receiving and wireless internet facilities for free. Thus, significant travel cost savings are provided by staying at Kemp.

Meeting travel costs of \$2,200/yr are budgeted for presentation of research results at 1-2 national meetings such as fall AGU by the PI or the graduate student.

Education and outreach travel has been budgeted at \$2,000 in year 1 to conduct three meetings with the College of Menominee Nation, WiscAMP, and Kemp NRS to plan the summer course and talks to be run in years 2-5.

Field Travel:

Purpose: Research Technician and PI or Graduate Assistant travel to field sites

Number of People: 2

Departure/Arrival cities: Madison, WI to Woodruff, WI

Nights/Days: 4

Lodging: $(\$12/\text{night} * 4) * 2 = \96

Meals: $(\$19/\text{day} * 4 \text{ days}) * 2 = \152

Incidentals = \$52

Vehicle Rental (UW Fleet): \$200

Scientific Meeting:

Purpose: PI or Graduate Student to attend the American Geophysical Union (AGU) Meeting

Number of People: 1 (PI or Graduate Student)

Departure/Arrival cities: Madison, WI to San Francisco, CA

Nights/Days: 5

Lodging: $\$150 + 20\% \text{ tax/night} * 5 = \900

Meals: $\$40/\text{day} * 5 \text{ days} = \200

Airfare: \$600

Ground Transportation: \$50

Conference Registration Fee and Abstract: \$450

Education and Outreach Travel:

Purpose: PI and Graduate Student to coordinate summer course with College of Menominee, WiscAMP, and Kemp NRS. Meeting to be held at CMN or Kemp NRS.

Number of People: 2

Nights/Days: two 5-day trips

Lodging: $(\$12/\text{night} * 2 \text{ people}) * 5 \text{ nights} = \120

Meals: $(\$19/\text{day} * 2) * 5 \text{ days} = \190

Incidentals = \$60

Vehicle Rental (UW Fleet): \$280

Purpose: Staff from College of Menominee / Kemp NRS to meet with PI at UW-Madison

Number of People: 1

Nights/Days: 3 nights

Lodging: $(\$70/\text{night}) * 3 \text{ nights} = \210

Meals: $(\$34/\text{day}) * 3 \text{ days} = \102

Incidentals = \$38

Vehicle Rental: \$200

Meeting Space Rental: \$150

Participant Expenses

To conduct the summer course, we have budgeted funding to cover participant expenses at \$10,000/yr in years 2-5. This funding will be used to defray participants lodging, meal, and transportation expenses. For 20 participants, this amounts to \$2,400 total for lodging at Kemp NRS (\$12/pp/night for 10 days); \$5,280 total for group meals (\$264/pp = 33 meals over 12 days at \$8/meal in the Kemp NRS group kitchen); and the remaining \$2,320 (\$116/pp) to cover travel expenses to visit field sites and transport from CMN to Kemp NRS.