Post-field Season Work Plan

for

"Response of a Tundra Ecosystem to Elevated Atmospheric Carbon Dioxide and CO2-Induced Climate Change"

DOE Grant No. DE-FG03-86ER60479

For the Period

September 1, 1994 to November 30, 1994

Recent Progress

Aircraft flux measurements and scaling

In 1993 eddy correlation flux measurements of CO2, energy, and water vapor were made at Barrow, Prudhoe Bay, and Toolik Lake, Alaska. Dr. Yoshi Harazono of the National Institute of Agro-Environmental Sciences in Tsukuba, Japan collaborated on the eddy correlation studies. Tower and chamber flux measurements were made and compared. The results showed good correlation between both methods, and indicated the utility of eddy correlation for measuring regional fluxes of CO2, water vapor, and energy. The IBP sites at Barrow, Alaska were remeasured. Flux data from sites at Barrow were compared to those measured at US IBP sites in the early 1970s. A paper has been written comparing contemporary and historical CO2 fluxes at the same sites in Barrow, AK (Oechel et al., in press).

In 1993, NOAA aircraft flew north-south transects to conduct CO2 flux measurements. These data indicated the feasibility of CO2 flux measurements with good spatial resolution over the tundra. Twenty north-south transects were flown, extending from the Arctic Ocean north of Prudhoe Bay to near Toolik Lake, and twelve east-west transects were flown from south of Prudhoe Bay to south of Barrow. The flux initial analyses were very promising, however, low flux rates suggested improvements to instrumentation and data handling. The campaign also indicated more efficient means of data collection in 1994 and the future.
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In situ manipulations

Our initial hypothesis stated that within both normal climatic variation and bounds of anticipated climate change, soil moisture has greater significance than temperature in controlling net ecosystem flux from the arctic. This response is primarily due to changes in soil aeration with drying. However, there is an optimum water content for soil respiration. Soils drier than this optimum will have lower rates of respiration with drying. Elevated temperature alone has little effect on net flux and respiration; warmer temperature with similarly water-logged soil results in increased net carbon sequestering. Elevated temperature has a greater stimulation effect on NPP than on soil respiration in water-logged soils.

In wet tundra, gross primary productivity (GPP) in drained plots exposed to elevated temperature was markedly lower than under ambient conditions. This may be due to an increase in desiccation and mortality of non-vascular plants. In tussock tundra ecosystems, warmer and drier soils were found to lead to enhanced C accumulation. Elevated temperature increased soil decomposition relative to GPP, while reduced soil water content increased both respiration and GPP. These results suggest that under drier soil conditions, higher decomposition rates result in increased rates of mineralization. Since the C:N ratio is much larger in plant material than it is in soil organic matter, an increase in soil mineralization results in a greater increase in CO₂ uptake in GPP than CO₂ loss in respiration.

Scaling between the patch and landscape

Chamber flux can be calculated using models recently developed by Drs. Tagir Gilmanov and Viktor Nosov (SDSU). These models are based on a hyperbolic relationship between photosynthesis and incident PAR (Johnson and Thornley, 1984), and an exponential relationship between respiration and soil surface temperature (Flanagan et al., 1980). Using this methodology, analysis of preliminary data collected during the 1993 field season in Barrow, Alaska indicates that, in many cases, the fluxes at the patch and landscape levels are similar. Some deviation between patch and landscape level flux estimates is inevitable, due to variation between the patch and landscape footprint, and consistent differences in scale-specific controls on net CO₂ exchange (e.g. effects of aerodynamic resistance; Jarvis and McNaughton, 1986).

Daily flux totals, calculated by integrating half-hourly estimates over a diurnal cycle, indicate a larger disparity between the patch and landscape flux measurements. This
disparity is undoubtedly due to variation in both scale-specific environmental controls, and landscape surface types integrated at the patch and landscape scales.

1994 Summer Field Season

Aircraft, tower, and chamber flux measurements and scaling

Scaling between the landscape and the regional spatial scales will involve analyses of atmospheric and spatial effects on net CO$_2$ flux. Regional flux measurements will be made using eddy correlation technology from an aircraft platform (Crawford et al., 1990). Aircraft flux flights will occur between June 16 and July 18 during the 1994 field season. During the flux campaigns, north to south (N-S) regional transects will be made between the Prudhoe Bay eddy correlation tower to the north and the Happy Valley tower to the south at various times of the day. These runs will be used to characterize the latitudinal pattern of net CO$_2$ flux. Since time and space vary during an aircraft flux sampling run, special considerations must be made to ensure that the aircraft flux footprint and the tower flux footprint correspond to each other. This will be carried out through a series of "astrix" flight patterns over each tower during various times of the day. Using this methodology, aircraft flux measurements can be calibrated to the tower flux measurements.

Dr. Yoshi Harazono and his colleagues will participate in our research efforts. They will conduct CO$_2$ flux measurements at West Dock and will also measure methane flux using aerodynamic methods.

In situ manipulations

The results currently in hand are preliminary. In 1994 we will conduct full season manipulations of temperature (with both ITEX cones and heating through the use of solar panels). We will also undertake full season manipulation of increased and decreased water table in combination with temperature. We will seek to obtain data for an entire season from these manipulations which will permit analysis of temperature and soil moisture effects at each stage of ecosystem development throughout the growing season. This will provide a greater understanding of the role of temperature and soil moisture in controlling net CO$_2$ flux, and give us greater confidence in our ability to generalize about the future effects of CO$_2$-induced climate change.
1994 Post-field Season Research Activities

Scaling

This application requests funds for post-field season data reduction, synthesis, publication, and reporting. Completion of DOE-supported scaling efforts is planned. These include aircraft, tower, and manipulation measurements. Detailed analysis of scaling net CO₂ flux across patch (0.5 m²), landscape (2.5-3 ha), and regional scales (ca. 5 km²) will be undertaken. A major initiative will include rectifying data from CO₂ flux measurement from chambers, through eddy correlation towers, to aircraft. We will investigate methods and requirements for extrapolation of this information across spatial scales. Results of CO₂ flux measurements on the Alaskan north slope based on all three scales of measurement will be prepared for submission to scientific journals.

In situ manipulations

Data on the effects on net ecosystem CO₂ flux of manipulating soil temperature and moisture will be reduced and interpreted. These interpreted results will give insight into the likely effects of climate change on future carbon budgets of arctic tussock and wet coastal tundra. Phenomenological models will be used to calculate diurnal and seasonal carbon dioxide fluxes under varying levels of temperature and soil moisture. The results will be published and therefore made available to individuals with interest in terrestrial carbon processes, especially in high latitude ecosystems, and those attempting to close the global carbon budget. More generally these results should provide insight to modellers who are working toward predicting the response of arctic ecosystems to climate change.

Scaling between the patch and landscape

Daily flux totals, calculated by integrating half-hourly estimates over a diurnal cycle, indicate a disparity between the patch and landscape flux measurements. This disparity is undoubtedly due to both differences in scale-specific environmental controls and in the landscape surface types integrated at the patch and landscape scales. For example, landscape-level flux estimates are affected by landscape surface variability in the tower footprint, and the spatially integrated flux measured by the tower may vary from the patch level estimate if trace gas flux from dominant patch types in the effective tower footprint are unaccounted for.
Analyses which specifically address these basic scaling questions will be performed during fall 1994. The summer data will allow for the determination of the atmospheric variables, such as aerodynamic resistance, which are important in controlling large-scale fluxes of material. Two methods will be used to scale patch-level fluxes at the landscape level. The statistical-dynamic approach outlined by Wetzel and Chang (1988) and Rastetter et al. (1992) will be used to estimate the landscape level fluxes. This method relates patch-level relationships, for example the relationship between flux and soil moisture, to a landscape-scale flux estimate by accounting for the variability of the different patch types encountered in the landscape. If the variation in soil moisture is assumed to be normally distributed within a given landscape (Rastetter et al., 1992), then the patch-level relationship for flux and soil moisture (Oechel and Vourlitis, in press; Oechel et al. unpublished data) can be recalculated to encompass the expected variability in the landscape (Wetzel and Chang, 1988).

A second approach will utilize the actual landscape level flux estimates for the calibration of patch-level flux estimates (Rastetter et al., 1992). If true distribution of the patch types can be estimated within the tower footprint, then the flux estimated at the patch level can be extrapolated to the landscape scale with a high degree of confidence by multiplying the patch-level fluxes by the area of the respective patch types. The landscape-level fluxes can then be used as a check of the extrapolated patch-level flux estimates, and to assess scaling hypotheses and methods such as the statistical-dynamic approach outlined above.

Scaling between the landscape and region

Tower and aircraft flux measurements typically produce large quantities of data. For example, a preliminary campaign between August 10-20, 1993 resulted in approximately 2.5 months of data reduction and analyses. This year, the actual field data collection period is about twice as long, and the resultant post-field season processing time will undoubtedly be more than 2.5 months. A primary goal is to shorten the time required for aircraft flux data reduction by placing more effort and resources into this task.
Summary

The preliminary data from the temperature and water table manipulations indicated that net CO$_2$ flux of both tussock and wet sedge tundra ecosystems is sensitive to changes in water table depth and soil temperature. The preliminary results from the patch, landscape, and regional flux measurements indicate that there are large deficiencies in our current ability to extrapolate from patch and landscape levels to the region. During fall 1994, our primary goals are to:

- Analyze a full season of net CO$_2$ flux from the *in situ* manipulations, and determine the effects of water table depth and elevated temperature on the C balance of arctic ecosystems. Once this task is complete, the data will be published in a form that discusses the importance of these environmental controls, and their relevance to future CO$_2$-induced climate change.

- Analyze tower- and aircraft-based eddy correlation flux data, and develop methods to reduce the time required to analyze these data.

- Determine the importance of environmental controls of the exchange of CO$_2$ at each spatial scale, and to develop the necessary routines that will permit the scaling of fine-scale flux data to landscape and regional scales.

- Prepare manuscripts for publication on 1) net CO$_2$ flux data for each spatial scale, 2) latitudinal flux pattern, and 3) on methods and considerations for scaling from point measurements to the landscape and regional scale.


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BUDGET AND JUSTIFICATION
BUDGET JUSTIFICATION

Senior Personnel

Salary (1.55 months) is requested for W. Oechel during the academic year for data analysis, interpretation, and report and manuscript preparation.

Other Personnel

Salary (3.1 months each) is requested for S. Hastings and George Vourlitis who will assist in data reduction and analysis and interpretation. Tagir Gilmanov and Victor Nosov are budgeted for .52 months each for phenomenological modeling, scaling, and computer programing. Kathleen Turner's time (1.55 months) is budgeted for report and manuscript preparation and typing.

Travel

U.S. Travel

One program meeting or national meeting for coordination and/or presentation of results from the research is budgeted.

Other Direct Costs

Material and Supplies

Office supplies including computer disks, toner cartridges, transparencies, envelopes, etc. are budgeted.

Publication costs

Publication costs for page charges, reprints, and associated data publishing costs are budgeted.

Communication Costs

Communication costs including xeroxing, phone, postage, and FAX are budgeted.