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May 23, 1990

Dr. Roger Dahlman
U.S. Department of Energy
19001 Germantown Road
Germantown, MD 20767

RE: "Response of a Tundra Ecosystem to Elevated Atmospheric Carbon Dioxide and CO₂-induced Climate Change," Dr. Walter Oechel, Principal Investigator, San Diego State University

Dr. Dahlman:

Enclosed please find an original and two copies of a replacement proposal for the above reference proposal. The draft text was inadvertently forwarded to your office. Please retain the copies of the appendix materials for review.

Please feel free to contact me at (619) 594-5731, should you have any questions. Thank you for your assistance.

Sincerely,

Sandra D. Martinez
Development Services Associate

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ABSTRACT

This represents a continuation request for the second year of our current research program. Research to date and that proposed for the second year is on schedule and follows that presented in our original proposal, except for some reduction in scope dictated by budget availabilities. Funds are being requested from DOD to re-establish the work scope originally proposed.

PROGRESS REPORT

The current funding cycle was initiated on September 1, 1989. The first field season of this cycle will be initiated in summer 1990. Progress to date has been in two major areas: (a) data reduction, analysis, and interpretation, presentation, and publication of previous results and (b) revision of plans and preparation for the 1990 summer field seasons.

A. Analysis and Synthesis of Past Results

Significant effort has gone into the reduction, analysis, synthesis, and reporting of results from previous field experiments (1983-1985, 1987). This effort has been reported in publications (Grulke *et al.*, in press; Oechel and Billings, accepted; Oechel *et al.*, submitted, Oechel, in preparation) reports (Oechel, in revision), oral presentations, and national and international workshops (listed below).

Analysis of past data on net ecosystem carbon flux under current ambient conditions and the effect of elevated atmospheric CO₂ on net ecosystem CO₂ flux is fairly complete. Following are some of the major conclusions from these analyses.

Tussock tundra in the areas measured is currently losing carbon at the rate of 180 to 360 g C m² y. This may be a result of recent climate change which is reported to have occurred on the north slope of Alaska within the last several decades (Gulke *et al.*, in press; Oechel and Billings, accepted; Lachenbruch and Marshall 1986).

The observed pattern of net carbon loss differs from previous analyses of carbon uptake in tussock tundra which assumed carbon sequestering (net ecosystem carbon uptake) of about 23 g m² y⁻¹ (Miller, 1981; Miller *et al.*, 1984, 1983). If this shift from carbon sequestering to carbon loss has occurred over large areas of the tussock tundra, it may represent a decrease in carbon influx to tussock tundra of 0.1 Gt of C y⁻¹ and a decrease of up to 0.2 Gt of C y⁻¹ for both wet tundra and tussock tundra (Oechel and Billings, accepted). The research proposed here will determine the regional patterns of carbon sequestering and carbon loss from tundra ecosystems. Similar decreases in carbon uptake in other arctic tundra, boreal forest, and northern bogs may be occurring.

Our observed efflux of carbon from tussock tundra ecosystems is consistent with the results of Tans *et al.* (1990), since their calculations require a source for global carbon in the boreal regions (arctic and boreal forests) of up to 0.7 Gt of C y⁻¹. (They calculate a CO₂ sink in temperate forests).

Our analyses further indicate a rapid homeostatic adjustment (downward adjustment) of ecosystem flux to elevated CO₂. Some adjustment of net ecosystem CO₂ flux to elevated atmospheric CO₂ occurs within the first growing season's exposure to elevated CO₂. Complete homeostatic adjustment of net ecosystem carbon flux is reached within three seasons of elevated CO₂ treatment (Grulke *et al.*, in press). At three years, there is no difference in CO₂ flux in control vegetation and tussock tundra exposed to double atmospheric CO₂ concentration.

The combination of elevated CO₂ and temperature, however, results in overall, sustained enhancement of CO₂ uptake in tussock tundra (Oechel and Billings, accepted) for the three years of study.

The available data indicate complicated interactions of controls on net ecosystem carbon flux in arctic ecosystems where conditions leading to increased soil moisture and increased water table could result in greater net ecosystem carbon uptake, and conditions of decreased water table (from increased active layer development, loss of permafrost, decreased precipitation or thermokarst erosion) can result in increased soil decomposition and net carbon efflux from the ecosystem (Billings *et al.*, 1982, 1983, 1984; Post, 1990).

Based on our work and that of others it seems most probable that current loss of carbon from tussock tundra is the result of climate change (recent rises in mean annual temperature, Lachenbruch and Marshall 1986; Lachenbruch, Cladouhos, and Saltus 1988) resulting in decreasing soil water table and decreasing soil moisture content, rather than as a direct temperature effect. Further study is needed for confirmation, however.

B. Revised Summer Research Plans

Net ecosystem CO₂ flux

Emphasis during the summer field season of 1990 will be to determine net ecosystem CO₂ flux at three locations along the Haul Road (Toolik Lake, Happy Valley, and Prudhoe Bay/Kuparuk oil fields). The number of sites to be studied was reduced from the number in the original proposal to allow increased replication and measurement under diverse moisture conditions and to accommodate the available budget. Measurements will also be made at areas of increased and decreased moisture availability. These areas are provided up and down slope of existing structures such as roads and gravel pads. Measurements will be made from early June to late August.

Progress to date includes ordering necessary equipment and equipment upgrades, chamber design, materials purchase, and initial fabrication. This phase of the project is on track, and equipment and field crews will arrive on the north slope of Alaska in late May.

Net Methane flux

Methanogenesis and methane oxidation are extremely important tundra ecosystem processes affecting global climate change and represent areas of major importance in understanding global land-atmosphere interactions. Despite the fact that several research groups are measuring or have measured methane

production in various areas of the tundra, it was decided to implement the original plan and measure net methane flux in the areas of net ecosystem CO₂ flux measurements. This was concluded after consultation with Bill Reeburg, University of Alaska, one of the principal individuals currently studying methane flux in the Alaskan tundra. The reasons for measuring methane flux concurrently with CO₂ flux were several fold and include recognition of the value of simultaneous measurements of both CO₂ and CH₄. This seems particularly important since CO₂ and CH₄ production are expected to vary in opposite directions with tundra wetting or drying and since conditions which favor the production of one gas tends to disfavor the production of the other. In addition, there exist relatively few measurements of methane flux in the tundra over the range of conditions and vegetation types which exist.

Current plans are to measure methane hourly during periods of net CO₂ flux measurements. Methane will be measured using separate cuvettes measuring 24 cm x 24 cm x 15 cm high and constructed following the current design used by Reeburg (Whalen and Reeburg, 1988). Gas samples will be taken hourly with gas tight glass barrel, butly rubber piston syringes, and measured in the field at Toolik Lake using a flame ionization detector equipped gas chromatograph (Shimadzu Mini-Z Gas Chromatograph).

The above plan is a modification of the original plan which was to use a second IRGA to measure methane flux from the clap cuvettes used for CO₂ flux measurements. However, the short exposure times

desired (< 3 min.) for use with the clap cuvettes precluded using the same chambers

Sampling and Analysis of Soil Samples

Soil cores will be sampled in early June 1990. A 9 cm ice-core auger, borrowed from the Cold Regions Research and Engineering Laboratory (CRREL), will be used to collect intact frozen peat samples. Three cores will be sampled in each experimental (vegetation-moisture) type at each location.

These peat samples will be analyzed for depth, carbon content, the stable isotopes of carbon (^{13}C) and oxygen (^{18}O), and for ^{14}C . Except for exploratory analyses, it is intended that samples will be analyzed in the next fiscal year. Funds are being requested under a new DOD project (see Appendix I).

CONTINUATION RESEARCH PLANS, 1990-1991

Net Ecosystem CO_2 and Methane Flux

Data acquired in the summer of 1990 will be reduced and analyzed in the subsequent Fall and Winter. Information gained from the field campaign and subsequent analysis of the resultant data will be used to modify equipment and approaches to be utilized in the summer of 1991. At the current time, the sites and locations suggested in the research proposal funded will be utilized. This represents a subset of 6 of the well sites studied by Lachenbruch and Marshall (1986) for permafrost temperature rise. These sites will allow us to correlate CO_2 and CH_4 gas fluxes with recent changes in

site temperature and possibly changes in sources of water (from ^{18}O) and recent changes in the patterns of peat accumulation (from ^{13}C and ^{14}C) data, (see below).

Soil Peat Samples

Soil cores will be collected from the locations described above in the manner described previously. These samples will be shipped to CRREL for further analysis. This portion of the program is requested to be funded by DOD, and the requisite budget is not included here.

Recently, G.M. Marion accepted a position in the Geochemical Sciences Branch of CRREL-DOD. DOD is in the process of developing a new global change program. A proposal was recently submitted to DOD requesting \$1.1 million for five years to examine stable isotopes as paleoecological indicators and ^{14}C for dating soil profiles to determine carbon accumulation rates. Additional details of the DOD project are found on the accompanying project description (Appendix II). The current scope of this DOE work has been constructed assuming that isotopic analysis of peat samples will be handled under the DOD project.

It is anticipated that a fruitful collaboration will develop between the DOE and DOD projects given the respective P.I.s' common interests in global change, arctic ecosystems, and fruitful past personal collaboration.

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CURRENT AND PENDING SUPPORT

Current Support for Walter Oechel

Funding Source: NSF, Ecosystem Studies
 Project Title: "Mechanism Controlling Resource Use, Community Organization and Succession in Fire Dominated Ecosystems"
 Award Amount: \$300,000
 Period Covered: 10/15/88-6/30/90
 % Effort: 10%
 Location of Research: California
 Co-Principal Invest.: D. Hilbert, G. Marion, P. Zedler, J. Kummerow

Funding Source: U.S. Department of Energy
 Project Title: "Response to a Tundra Ecosystem to Elevated Atmospheric Carbon Dioxide and CO₂-Induced Climate"
 Award Amount: \$244,000
 Period Covered: 9/1/89-8/31/90
 % Effort: 50%
 Location of Research: Alaska and California

Funding Source: The United States-Spanish Joint Committee for Cultural and Educational Cooperation
 Project Title: Factors and Mechanisms Controlling Postfire Resprouting of Spanish and Mediterranean-type Shrubs"
 Award Amount: \$8,250
 Period Covered: 4/25/91-4/24/92
 % Effort: 5%
 Location of Research: Spain and California
 Co-Principal Invest.: J. Moreno

Current Support for Giles Marion

Funding Source: NSF, Ecosystem Studies
Project Title: "Mechanisms Controlling Resource Use, Community
Organization and Succession in Fire Dominated
Ecosystems"
Award Amount: \$300,000
Period Covered: 10/15/88-6/30/90
% Effort: 25%
Location of Research: California
Co-Principal Invest: W. Oechel, D. Hilbert, P. Zedler, J. Kummerow

Pending Support

Funding Source: U.S. Army Cold Regions Research and Engineering
Laboratory
Project Title: Changing Rates of Carbon Accumulation in the
Arctic as a Result of Global Change
Award Amount: \$1,089,000
Period Covered: 10/1/92-9/30/97
% Effort: 25%
Location of Research: New Hampshire, Alaska

BUDGET AND BUDGET JUSTIFICATION

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