Annual 89'

DOE/ER/60490--T6

Proposed Supplemental to DOE Grant #DE-FG03-86ER60490
Period Covering 7/1/88 - 6/30/89

James F. Reynolds, P.I.

Development of simulation models of the effects of elevated CO_2 on plant physiological processes requires close cooperation between modelers and experimentalists. In particular, the detailed process-based, leaf-level photosynthesis model currently in development at San Diego State University requires parameterization data for different plant species, levels within the canopy, and growth conditions. Validation of model predictions will require additional data. The purpose of this supplemental is to initiate ways in which different groups involved in elevated CO_2 research can interact to advance the goals of both the individual research scientists and the CO_2 Research Program.

To be truly useful, models should serve as rich sources of information rather than solely as sinks for experimental data. The photosynthesis modeling activity provides several things of potential utility to experimentalists:

- The models can serve to posit specific, testable deductions from hypotheses about the mechanisms of photosynthetic response to CO_2 enhancement.

- Validated models allow extrapolation of limited experimental data to new sets of conditions.

- Analysis of the models reveals the important physiological parameters whose estimation accuracy must be increased to enhance the models' prediction accuracy. Thus, models can serve to emphasize the importance of collecting specific key data.

Clearly, opportunities exist for mutually beneficial working cooperation in the CO_2 research program for those individuals currently focusing on experimental and modeling work. We propose the following:

1) That there be increased exchange of personnel between SDSU and other institutions. Initially, this would involve sending two of the SDSU plant modelers, Peter Harley and Robert Dougherty, to Duke University, Harvard University and Bert Drake's lab, where they would present the models and interact with experimentalists whose expertise would aid greatly in assessing the validity of model assumptions and in further model development.

2) That the cooperative work beginning between SDSU and Harvard University in plant community response to CO_2 be expanded to incorporate photosynthesis model parameterization for species being used in this study. In this way, any direct physiological basis for the observed community effects might be more easily assessed.

3) That detailed physiological studies of salt marsh species under study in Maryland be undertaken with the aim of model parameterization. The salt marsh study is potentially an excellent system for validating both leaf and canopy model predictions under ambient and elevated CO_2 regimes, but model parameterization is a necessary precondition.

4) That, due to the critical role being played by plant physiologists at Duke University, Harley and Dougherty remain there for an extended period of time (on the order of weeks) interacting closely with Boyd Strain and co-workers and becoming involved in directing the collection of specific data necessary for model parameterization and validation. It is hoped that in addition to identifying areas of need for model development, the SDSU personnel might participate in actual data gathering, under the supervision of Duke personnel.

Although we are confident in the ability of the leaf photosynthesis model, when parameterized fully, to accurately predict net photosynthesis and leaf conductance over a wide range of environmental conditions, it has only been so tested for a few species and only under ambient CO_2 conditions. Ongoing experiments at the Duke Phytotron provide an excellent opportunity to extend these previous studies to include additional species and growth at enhanced CO_2. It would be unfortunate if data necessary for model parameterization, and relatively easy to collect, were not gathered simply due to lack of communication between research groups. The leaf-based physiological data required to parameterize the photosynthesis model are described fully in the accompanying Status Report, but of primary importance are:

- Sets of CO_2-saturated light response curves, over a range of temperatures, measuring carbon assimilation, stomatal conductance and dark respiration, and

- Sets of light-saturated CO_2 response curves, also over a range of temperatures. Ideally, responses should be determined at both 1% and 21% O_2, but data at only 21% O_2 should be sufficient.

Validation of the photosynthesis model will require diurnal courses of photosynthesis and conductance at ambient and elevated CO_2. Again, the growth chamber facilities of the Duke Phytotron would be ideal for this purpose (although for validation under field conditions, data from the salt marsh study would also prove invaluable.)

Parameterization of the photosynthesis model in a whole-plant or canopy context will require, for leaves in each canopy layer, the photosynthesis measurements mentioned above, along with data on plant morphology, including average leaf angles, leaf area, light absorptance, etc. Validation data for the canopy implementation should include:

- Diurnal courses of canopy photosynthesis and transpiration for an entire plant canopy.
- Temperatures of sunlit and shaded leaves in each layer.
- Average PPFD in each layer.

In addition to providing parameterization and validation data, the facilities and experimental expertise available at Duke will be invaluable for beginning to extend the utility of the model. There are may areas of leaf photosynthetic metabolism which the model does not incorporate at present, but which will ultimately have to be included. Among such problems which we propose to address, with the help of researchers from Duke and other institutions, are:

- How do source-sink relationships affect net photosynthesis?

- What is the relationship between dark respiration and photosynthetic capacity?

- To what extent does the proposed model of stomatal conductance (from Farquhar and Wong 1984), which is admittedly empirical due to our current lack of understanding of the physiological basis of stomatal behavior, mimic leaf responses to varying light, temperature, humidity and soil or leaf water potential?

- How do stresses, particularly water stress, affect model parameters?

- Finally, of overriding importance is the problem of assessing and subsequently dealing with the great degree of known genetic variability in photosynthetic/stomatal behavior, both within and between species.

It is important to stress that it is possible, and in our view extremely beneficial, to address these and other problems within the context of the proposed models, i.e., differences in photosynthetic behavior between species or changes over time or in response to stress can all be represented as changes in specific model parameters, providing a common framework which allows direct comparisons to be made. It is expected that many model parameters will prove to be relatively unvarying, and that three or perhaps four are of crucial importance in driving model performance[1]. The validily of this expectation however requires the kinds of modeler/experimentalist interactions which we propose to undertake.

1 The PROGRESS REPORT submitted with the renewal request outlines the photosynthesis model in detail along with some of its applications in a canopy context.