Model-Data Synthesis of Ecosystem Responses to Elevated CO2: From Deserts to Temperate Forests of the U.S.

Anthony Walker (alp@ornl.gov) - ORNL, Richard Norby (PI).

There is a huge range in Earth-system model predictions of terrestrial ecosystem feedback on atmospheric CO_2 increase, and responses to elevated CO_2 (eCO_2) are a primary driver of this uncertainty [Friedlingstein et al., 2006; Arora et al., 2013]. The aims of the Free Air CO_2 Enrichment (FACE) model data synthesis (FACE-MDS) project are to evaluate terrestrial ecosystem models, focusing on the under-lying assumptions and hypotheses of the models, against data from eCO_2 experiments.

Six long-term, ecosystem-scale, eCO_2 experiments were simulated by a suite of 11 terrestrial ecosystem models. Initially the project simulated the evergreen needleleaf Duke Forest FACE experiment (NC) and the deciduous broadleaf Oak Ridge FACE experiment (TN). Recently we have included four additional sites - the evergreen broadleaf Kennedy Space Center Open Top Chamber (OTC) experiment (FL), the prairie heating and FACE experiment (WY), the Nevada desert FACE experiment and the deciduous broadleaf Rhinelander FACE experiment (MI). The presentation will focus on results from Duke and Oak Ridge.

Under ambient CO_2 conditions most models reproduced net primary productivity (NPP) with some degree of accuracy, though there were biases. Some models achieved a good fit to the observations but with compensating biases in component variables. In response to eCO_2, nitrogen (N) dynamics were the main constraint on simulated productivity. At Oak Ridge some models reproduced the declining response of C and N fluxes, while at Duke none of the models were able to maintain the observed sustained responses. C and N cycles are coupled through a number of complex interactions, which causes uncertainty in model simulations in multiple ways. Nonetheless, the major difference between models and experiments was a larger than observed increase in N-use efficiency and lower than observed response of N uptake. The results indicate that at Duke there were mechanisms by which trees accessed additional N in response to eCO_2 that were not represented in the models. Sequestration of the additional productivity under eCO_2 into forest biomass depended largely on C allocation assumptions.

In a conceptual study, using the models to simulate responses to eCO_2 over 300 years, N cycle assumptions caused the biggest variability in C sequestration across models, followed by C partitioning assumptions. A key difference between models, leading to qualitatively different responses of C sequestration, was whether N uptake was a function of N demand. By reducing N losses, demand based N uptake resulted in increased ecosystem N and sustained productivity responses to eCO_2.