Poster # H.new

An Integrated Terrestrial Carbon Model (ITCM) for North America: Constraining Process Models with Experiments and Measurements for Analysis and Projection

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Abstract

To further advance terrestrial carbon cycle science, observations and measurements must be integrated with spatially resolved, mechanistic process-based models of terrestrial ecosystems that represent scientific understanding from experiments and are validated and constrained by observations. Only through such integration may we produce reliable estimates of sources and sinks of CO_2 and extrapolation from observations in space and time to novel environmental conditions of the future. Thus the *overarching goal* is to develop and demonstrate an operational framework in which observational studies addressing different aspects of terrestrial carbon processes and modeling activities at different spatial and temporal scales are integrated in a mutually reinforcing relationship, and used to estimate and mechanistically explain current carbon sources and sinks and forecast their future behavior and influence on atmospheric CO_2 concentration and climate. We focus on North America, but the improved understanding and forecasting skill acquired through improved data-model integration have global applications.

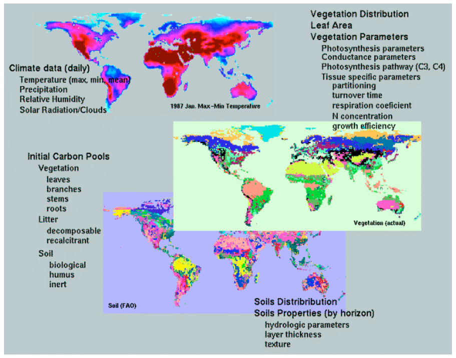

Figure 3. Data layers, model parameters, and compartment pool initial values required as input into a simulation of the GTEC model at site, regional, continental and global scales. This figure displays some data layers used in global runs of GTEC at 1° degree spatial resolution.

Progress to Date

The primary goal of our carbon cycle modeling activities under current TCP funding has been to investigate the global scale implications of physiological processes, especially those observed in field experiments, and to understand the sensitivity of the global carbon cycle to changes in atmospheric CO_2 concentration and climate. The global model GTEC (Global Terrestrial Ecosystem Carbon) developed under this funding is a geographically distributed model with the Earth's land surface partitioned by a grid (either 0.5° or 1° latitude by longitude) determined by the resolution of the gridded vegetation and soil maps used to characterize the land surface. A compartment model of carbon in vegetation and soil describes the carbon dynamics of each vegetated grid cell. When used in "stand-alone" ecosystem-scale applications this terrestrial plant and soil carbon model is known as LoTEC (Local Terrestrial Ecosystem Carbon).

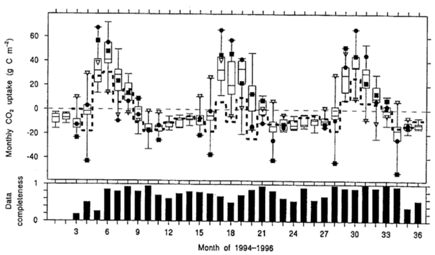

Figure 1. Model simulations of NEE plotted with measured NEE at the BOREAS Old Black Spruce site. Box and whiskers plot of monthly whole-ecosystem CO_2 uptake (top). The horizontal line inside each box represents the median model, the box shows the third smallest and third largest values (out of nine models), and the vertical whiskers show the range of all models. The dashed line shows monthly totals derived by binning all good and derived data each month according to the time of day to obtain the mean diurnal course of CO_2 exchange for each month. Simulations by LoTEC (inverted triangles), ecosys (circles), and TEM (squares) are shown for march-November each year (intermodel variation during December-February was small).

The processes of photosynthesis and stomatal conductance respond to hourly (or half-hourly, depending on the application) variations in photosynthetically active radiation, air temperature, relative humidity, wind speed, and leaf water potential. This plant carbon model is coupled to a daily version of the Rothamsted model of litter and soil carbon dynamics.

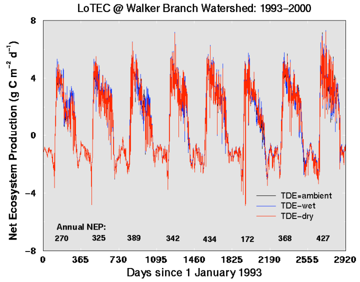

Figure 2. Daily summary of LoTEC simulations at the ORNL Throughfall Displacement Experiment (TDE).

North America Results

The GTEC modeling results for North America with a 1° grid show features that have important implications for the NACP. They offer hypotheses to be examined and tested with model-data assimilation at site and regional scales. These model based bottom-up analyses also need to be confronted with top-down inferences based on fine spatial and temporal resolution atmospheric CO_2 concentration measurements as outlined in the NACP Science Plan.

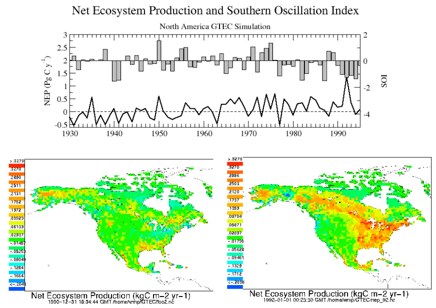

Figure 4. The impact of ENSO cycles on NEP of North America terrestrial ecosystems indicated by the simulations of GTEC. In particular, during the unusual El Niño of the early 1990's when Mount Pinatubo erupted, there is a large increase in the simulated North America carbon sink. Maps of the modeled NEP summed for each of these years indicate an increased carbon uptake by nearly all terrestrial ecosystems with the largest changes occurring in the eastern and boreal forests.

North America shows strong and distinct patterns of net CO_2 uptake and release (NEP) based on global weather patterns associated with ENSO. The cause of this result can be explained by examining the relative response of photosynthesis (GPP) and heterotrophic soil respiration (R_H). Simulations indicate that the large increase in NEP from 1991 to 1992 is attributed to a reduced rate of decomposition in 1992 especially in New England and Great Lakes region.

The response to rising CO_2 is not as apparent as at the global scale indicating other factors limiting the CO_2 fertilization response for this continent.

Future Plans

The logical progression of research tasks in Figure 5 begins a the bottom left and flows toward increasingly complex integration at the upper right, the research tasks are structured to allow progress on all three components nearly simultaneously. Site-scale data assimilation with computationally intensive FAPIS is already underway with previous funding. For regional data assimilation we will use the computationally less demanding LoTEC model combined with DAYCENT for natural ecosystems, and Agro-IBIS for agricultural systems. By starting with models that are fundamentally complete in terms of primary process representations and available, we can proceed at regional scales with parameter identification and parameter uncertainty estimation using data assimilation methods, integrate with regional data bases and perform bottom-up carbon cycle analyses for timely use in NACP synthesis activities. Finally, the integrated data-modeling system can be combined with CO_2, climate, and other environmental forcings (N deposition, O_3 concentration) to make continental to global scale carbon cycle forecasts. The integration framework considers that the proposed ITCM can be integrated into a land-surface component for utilization in Earth System Models (ESMs).

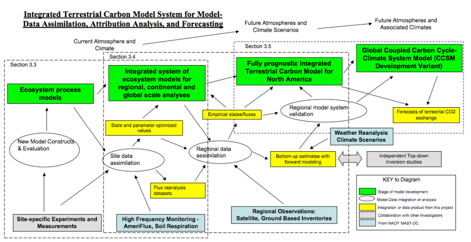

Figure 5. Overall outline for the development of the proposed Integrated Terrestrial Carbon Model system for North America. Flows of information and data required for model development, testing, parameter and initial state optimization, integration with spatial data layers, regional evaluation, and forecasting are highlighted. The flow of research activities include database assembly, hypothesis testing, model calibration through data assimilation, integration of data and models for regional scale analysis and forecasting.

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