CLIMATE VARIABILITY IN THE PACIFIC NORTHWEST, USA AND THE IMPACT ON CARBON EXCHANGE IN AN OLD-GROWTH FOREST

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ABSTRACT

Long-term micrometeorological measurements (1998-2004) show high interannual variability in the atmosphere-ecosystem exchange of carbon for a Pacific Northwest coniferous old-growth forest. Earlier work [*Wharton et al.* 2004] has shown that net ecosystem exchange of carbon (NEE) in this forest is highly sensitive to any perturbations in climate, and in particular, in precipitation and temperature anomalies. Here we present results from the ACASA (Advanced Canopy Atmosphere-Soil Algorithm) model to investigate NEE as it relates to various climate forcings, including a shift in precipitation pattern and increase in air temperature.

INTRODUCTION

The Wind River Canopy Crane Research Facility (WRCCRF) in southern Washington State, USA provides a unique opportunity to study the exchange of carbon between an old-growth (~500 yr old) forest ecosystem and the atmosphere in a region that experiences a significant amount of historical climate variability. Eddy covariance instrumentation (Solent Gill 3-D sonic anemometer and fast-response LiCor 6262 infrared gas analyzer) mounted at 67m on the canopy crane has generated half-hourly flux estimates of carbon dioxide, water vapor, and energy above the tall forest canopy since July 1998. Details on instrument methodology and the calculation of NEE can be found in Paw U *et al*. 2004.

REGIONAL CLIMATE VARIABILITY

The climate is strongly seasonal with most precipitation confined to the winter and drought occurring during the summer. Regional climate variability is forced predominately by El-Niño-Southern Oscillation and Pacific Decadal Oscillation phase-events. Time series analysis showed significant coherencies ($P < 0.01$) between historical (1919-2004) rainy-season precipitation and oscillation phase at periodicities of ~ 27 yr, 5 yr, and 2.2 yr. Coherencies between historical temperature and oscillation phase indicate similar periodicities, though are less significant.

OBSERVED AND MODELED NET ECOSYSTEM EXCHANGE

Observed data show that the forest assimilated carbon at relatively high rates under favorable climatic conditions (such as a delayed summer drought) during the 1998/1999 la Niña year but released carbon to the atmosphere under climatic stress from higher temperatures in 2003. To further investigate the sensitivity of the old-growth forest to climate variability, we ran a multi-layer canopy-surface-layer model, ACASA, using meteorological data from the site. ACASA showed excellent agreement between model and observed cumulative NEE (Fig. 1), with annual totals falling well within observational uncertainty. Observed and simulated monthly cumulative NEE values were compared using linear regression, with an r^2 of 0.89 for the period. Both model and observations reflect high seasonal and year-to-year variability in NEE, driven by moisture and temperature variations and to a lesser extent winter dormancy in some species at the site. To address the question of whether the observed interannual variability in NEE could be explained by year-to-year differences in respiration, photosynthesis, or a combination of the two fluxes, we partitioned NEE into its two components: gross primary productivity (GPP) and total ecosystem respiration (TER). TER was empirically derived based on temperature; GPP is the residual of NEE and TER. Observed data show that reduced soil respiration rates in 1999 were instrumental for the overall gain in carbon by the ecosystem that year. NEE changes arising from shifting winter rains by one or two months in ACASA are relatively subtle and in some cases show the forest to be a stronger sink of carbon (Table 1). These modeled results are more subtle than the changes in NEE indicated by the observed flux data. Both observed and ACASA values show 2001, 2003, and

2004 to be either near equilibrium or are net sources largely due to high respiration rates from anomalous warm temperatures. Modeled and measured data show that changes in respiration/photosynthesis rates in early summer are very sensitive to climatic anomalies as the ecosystem suddenly switches from a highly productive mode to a period of respiratory loss. This short but vital transition can determine whether the forest will be net carbon source or sink.

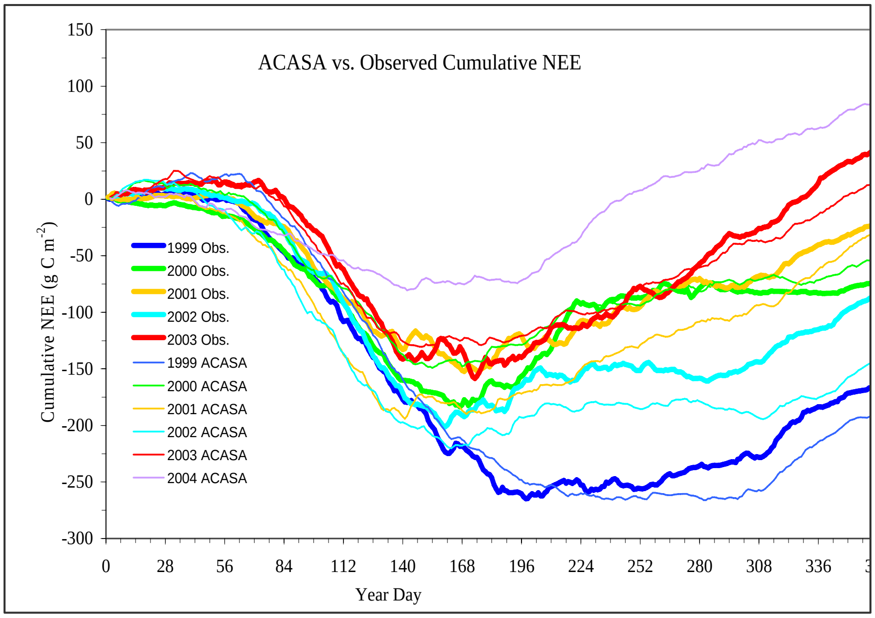

Fig.1. ACASA and observed cumulative NEE for each year (1999-2004).

	control	28 days earlier	56 days earlier	28 days later	56 days later
1999	-191	-197	-208	-234	-234
2000	-32	-53	-3	-44	-86
2001	-29	-35	-28	-33	-22
2002	-139	-148	-150	-178	-207
2003	18	-28	26	-55	-67
2004	87	75	70	-2	-34

Table 1. Modeled NEE estimates based on shifting precipitation. (gC m^{-2} yr^{-1})

CONCLUSIONS

Our results show the current potential for large carbon storage within an old-growth forest under favorable climatic conditions. While GCM’s predict overall regional warming in the Pacific Northwest, the impact of climate change on NEE will depend on the precise nature of changes in seasonal temperature as well as shifting precipitation patterns. Such results should have significant implications on future policy and management decisions for old-growth ecosystems as the interest in using North American forests for carbon sequestration increases.

REFERENCES

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