MONITORING EFFECTS OF INTERANNUAL VARIATION IN CLIMATE AND FIRE REGIME ON REGIONAL NET ECOSYSTEM PRODUCTION WITH REMOTE SENSING AND MODELING

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ABSTRACT
A spatially-distributed model of net ecosystem production (NEP) was run over western Oregon for the period 2001-2003 at the 1 km spatial resolution and daily temporal resolution. Inputs included MODIS-based FPAR, Landsat-based land cover and disturbance history, and distributed meteorology. Resulting NEP showed sensitivity to 1) areas of recent disturbance, such as a large forest fire in 2002, 2) areas of intensive management for timber production, 3) topographically-driven climatic gradients, and 4) interannual variation in climate. Validation measurements included a network of field plots and a chronosequence study.

INTRODUCTION

Regional estimates of terrestrial net ecosystem exchange using the inverse modeling approach provide information that generally does not allow for close examination of possible mechanism associated with the fluxes. Bottom-up flux estimates that take into account climate, as well as vegetation type, greenness, and disturbance history, can provide independent estimates of net ecosystem production that are informative with respect to mechanisms, but development of an appropriate model and assembling the relevant model inputs for spatial mode application are major research tasks. In this study, we developed and tested a bottom-up NEP modeling approach for use in comparisons with top down flux estimates.

OVERVIEW

The overall objective of the study was to simulate NEP over the western half of Oregon over a 3 year period. The approach relied on the application of a daily time step carbon cycle model in a spatially-distributed mode over a 1 km resolution grid. Model inputs included climate data interpolated from meteorological station data, MODIS-based FPAR (the fraction of incoming photosynthetically active radiation that is absorbed by the canopy), and Landsat-based surfaces for land cover, stand age, and disturbance history. The model parameters were optimized by cover type within ecoregions based on measurements at eddy covariance flux towers and site-level simulations over the course of succession with of a more detailed carbon cycle model (Biome-BGC).

THE CARBON CYCLE MODEL

A new model ("Fusion") was developed for this application. The gross primary production (GPP) component employs a light use efficiency (LUE) approach similar to the MOD17 algorithm currently used to produce the MODIS GPP product for NASA. In the case of forested cover types, a function for the effect of stand age on LUE was added to reflect observations of reduced GPP in older stands. The autotrophic respiration (Ra) algorithm uses a base rate and a Q_{10} function driven by average daily temperature. The Ra rate is scaled with FPAR to account for increasing biomass associated with increasing FPAR. The heterotrophic respiration algorithm likewise employs a base rate, and has functions for sensitivity to temperature and soil moisture (the latter simulated from water use efficiency, precipitation, and soil water holding capacity). As with GPP, a stand age function is used in the case of forested cover types to reflect the observation of higher Rh in recently disturbed stands. For model parameter optimization, measurements at eddy covariance flux towers provide the basis for specifying the daily time step parameters, and runs of the Biome-BGC model over the course of succession provide the basis for specifying the stand age effects on GPP and Rh.

SATELLITE AND CLIMATE DATA

The base land cover map and information on the stand age and disturbance history were from Landsat data (30 m). A majority rule filter was used to aggregate the fine resolution data to the 1 km resolution of the FPAR and climate data. Gaps in the standard MODIS FPAR at a 1 km spatial resolution and 8-day temporal resolution were filled by linear interpolation as needed. The climate inputs to the Fusion model are precipitation, minimum temperature, 24 hour average temperature, daytime mean vapor pressure deficit, and photosynthetically active radiation. For this application, 3 years of daily data were generated for a 1 km grid covering the study area based on observations at a network of meteorological stations. Interpolations were based on the DAYMET model.

RESULTS

Analyses of the FPAR data showed strong seasonality for cover types such as annual crops, and distinct interannual changes in response to large disturbance events such as a fire. The climatic data suggested that 2003 growing season was relatively dry over the region compared to 2001 and 2002. The stand age map indicated a relatively young mean stand age in the Coast Range ecoregion, where logging has been most extensive, compared to the other ecoregions. In 2003, the most recent disturbance type was fire for a significant proportion of the Klamath Mountains ecoregion because of the large fire there in 2002. The simulated NEPs showed the strong seasonality of daily NEP in agricultural areas, high annual NEPs associated with areas of young stands (ages 30-100) in the Coast Range ecoregion, and low (negative) annual NEPs in areas of the fires that occurred in 2002. There was significant interannual variation in regional NEP.

CONCLUSIONS

Independent assessments of terrestrial NEP at the regional scale are needed for evaluation of flux estimates based on spatial and temporal patterns in CO_2 concentration. Because stand age and disturbance history have significant effects on GPP, Ra, and Rh in forested regions, bottom-up scaling approaches must ideally include such information. Here we developed and tested a new NEP model that accounts for spatial and temporal patterns in vegetation FPAR, as well as for influences of stand age and disturbance history on Rh. The modeling approach will be used to test the sensitivity of bottom-up simulations to various assumptions (e.g. about the minimum scale of spatial heterogeneity), and will provide a basis for comparisons with flux estimates from the inverse modeling approach.