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

Regional net ecosystem production (NEP) was monitored over a 10.9 x 10^4 km^2 forested area in western Oregon USA for 3 years (2001-2003) using a combination of remote sensing, distributed meteorological data, and a carbon cycle model. High spatial resolution satellite data (Landsat, 30 m) provide information on land cover and the disturbance regime. Coarser resolution satellite imagery (MODIS, 1 km) provided estimates of vegetation absorption of photosynthetically active radiation. A spatially-distributed (1 km) daily time step meteorology was generated for model input by interpolation of meteorological station data. This monitoring approach detected spatial patterns in NPP associated with climatic gradients, temporal variation in NEP associated with interannual variation in climate, and changes in NEP associated with recovery from disturbances such as the large forest fires in southern Oregon in 2002. Comparisons of outputs with those from a more detailed process-based modeling approach, and with flux estimates from US Forest Service inventory plots, showed good agreement.

Introduction

Regional estimates of terrestrial net ecosystem production using the inverse modeling approach or boundary layer budget approaches 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 NEP 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 develop and test a bottom-up modeling approach for regional monitoring of NEP for use in comparisons with top down flux estimates.

Methods

The overall objective of the study was to simulate NEP over a large area of western Oregon (Figure 1) over a 3 year period. The approach relied on the application of a daily time step carbon cycle model ("Fusion") 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, Figure 2), and Landsat-based surfaces for land cover, stand age (Figure 3), and disturbance history. The processes of gross primary production (GPP), autotrophic respiration (Ra), and heterotrophic respiration (Rh) are treated separately in the model (Figure 4). The model parameters were optimized (e.g. Figure 5) by cover type within ecoregions based on measurements at eddy covariance flux towers or site-level simulations of a more detailed carbon cycle model (Biome-BGC).

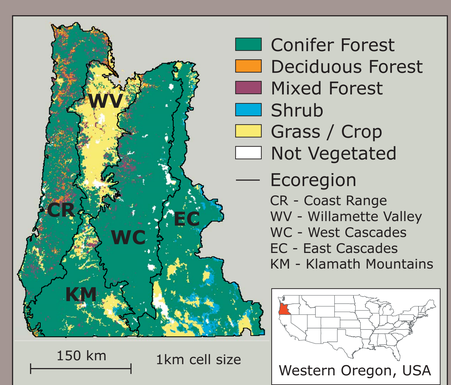

Figure 1: Land Cover

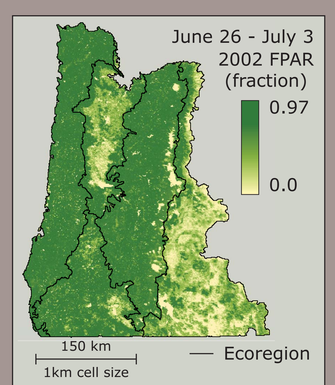

Figure 2: MODIS Filled FPAR

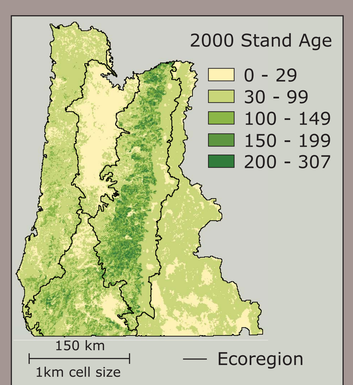

Figure 3: Stand Age

Figure 4: Fusion model processes

$GPP = \downarrow PAR * FPAR * e_g * S_{sa}$

GPP = gross primary production
$\downarrow PAR$ = incoming PAR (MJ d^{-1})
FPAR = fraction of PAR absorbed
e_g = light use efficiency (gC MJ^{-1})
S_{sa} = stand age factor (0-1)

$R_h = f(R_{h\text{-}base}, FPAR, Tsoil, SW, SA)$

R_h = heterotrophic respiration
$R_{h\text{-}base}$ = base rate of respiration
FPAR = fraction of $\downarrow PAR$ absorbed
Tsoil = soil temperature
SW = soil water content
SA = stand age factor (0-1)

$R_a = f(R_{a\text{-}base}, Tair, FPAR)$

R_a = autotrophic respiration
$R_{a\text{-}base}$ = base rate of R_a
Tair = air temperature
FPAR = fraction of PAR absorbed

$NPP = GPP - R_a$

NPP = net primary production
GPP = gross primary production
R_a = autotrophic respiration

$NEP = NPP - R_h$

NPP = net primary production
R_h = heterotrophic respiration

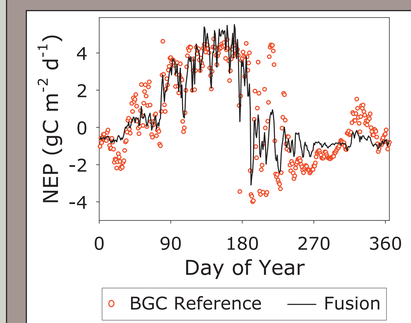

Figure 5: Fusion parameters were optimized to Biome-BGC results.

Results

Preliminary analyses of the FPAR data showed seasonality for cover types such as annual crops and interannual changes in response to large disturbance events such as fire (Figure 6). NEP for 2002 averaged 197 gC m^{-2} yr^{-1} over the study area (Figure 7). The NEP difference map for 2002 vs. 2003 (Figure 8) shows the new heterotrophic respiration sources (lower NEP) associated with the Biscuit fire that occurred in 2002, a general decrease in NEP west of the Cascade Mountains, and a small increase in NEP east of the Cascade Mountains. Fusion 2002 NPP was compared with NPP estimates derived from plot-level US Forest Service inventory data (Figure 9) and Fusion 2002 NEP was compared to NEP estimates for the same region from the Biome-BGC model (Figure 10).

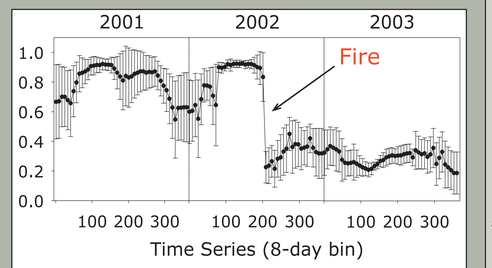

Figure 6: MODIS filled FPAR (fraction) from selected area within Biscuit fire.

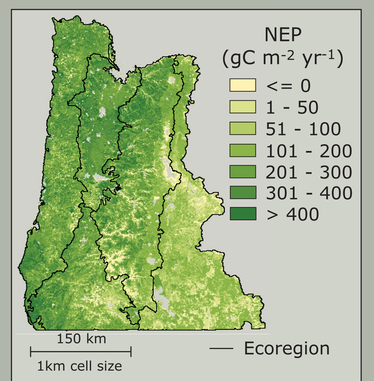

Figure 7: Fusion 2002 NEP

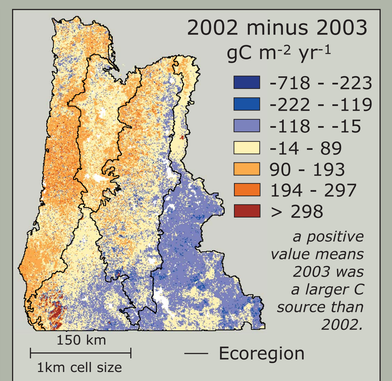

Figure 8: Fusion NEP Difference

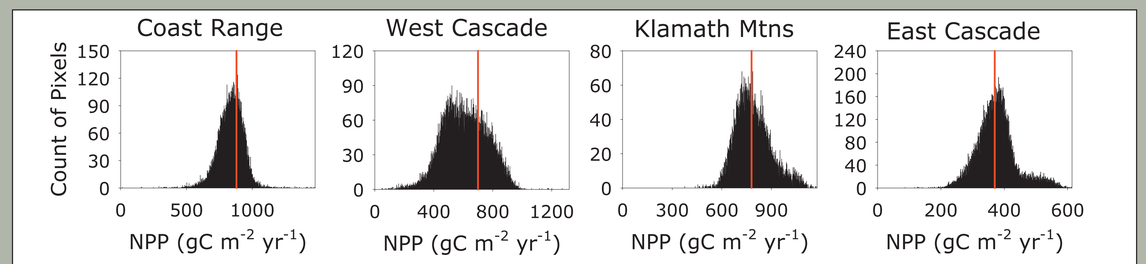

Figure 9: Histograms of Fusion 2002 NPP by ecoregion with red bars representing NPP estimates derived from U.S.Forest Service, Forest Inventory Analysis (FIA) Plots (conifer only) (Van Tuyl et al, 2005).

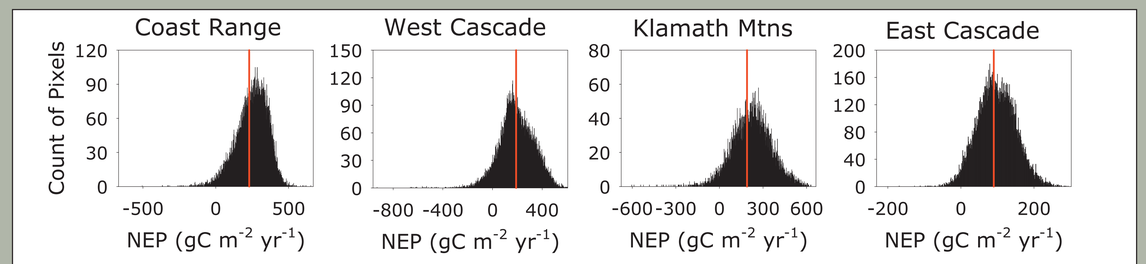

Figure 10: Histograms of Fusion 2002 NEP by ecoregion with red bars representing NEP estimates derived from Biome-BGC model runs (Law et al, 2004).

Conclusions

Average NEP over western Oregon is strongly positive (carbon sink).

Areas that have recently burned are associated with elevated heterotrophic respiration and introduce a significant offset to regional NEP.

Interannual variation in climate drives strong interannual variation in regional NEP.

References and Acknowledgements

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