Climate and disturbance effects on gross ecosystem fluxes assessed by model-data fusion

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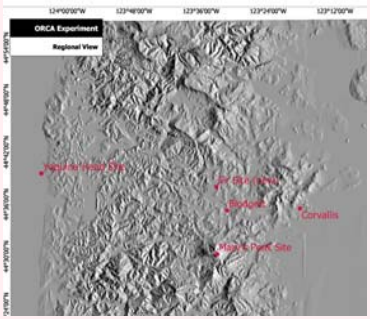
BOX B: Characterizing the CO_2 concentration of the ABL in the Oregon coast range

Three new CO_2 measurement sites are being installed in the Oregon coast range (see figure below):

- The Yaquina Head site is located on the coast. This site aims to capture the CO_2 concentration of air flowing inland from the Pacific Ocean, free from terrestrial influences and representing the free tropospheric concentration.
- The Mary's Peak site is on the tallest peak in the coast range at 1240m. This site aims to capture the CO_2 concentration of the well-mixed ABL during the daytime and be representative of the vegetative influence of the whole coast range. At night, this site will often sample air above the nocturnal boundary layer, capturing either the residual layer concentration or the free troposphere.
- The fir site is at a lower elevation (260m) in the coast range in typical Douglas fir forest. This site aims to capture the CO_2 concentration of both the daytime and nighttime ABL over the forest, helping to distinguish within and above ABL concentrations measured on Mary's Peak. Eddy covariance flux measurements will also be made here.

Together these sites will give a picture of the CO_2 concentration within and above the ABL over the coast range, and an indication of its dynamics.



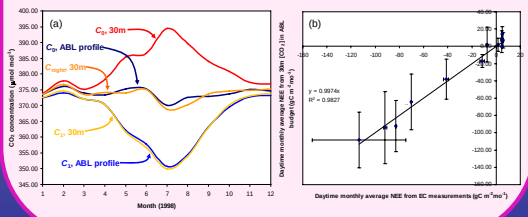
BOX A: ABL budget

CO_2 concentration measured at forest sites within the study region will be interpreted within a simple atmospheric boundary layer (ABL) budget to infer daytime NEE (see equation below). The ABL model was tested at the WLEF tall tower to validate approximations and methods to account for the near-surface gradient:

- Figure (a) shows that the 30m nighttime average concentration is close to the morning nocturnal boundary layer concentration, and the afternoon 30m and vertical ABL profile concentrations are similar.
- Figure (b) shows that the monthly average daytime NEE inferred from the ABL budget using 30m concentration data agrees well with eddy covariance flux measurements.

$$\frac{\langle F_c \rangle \tau}{\rho h_1} = \left(c_1 - \langle c_+ \rangle\right) - \frac{h_0}{h_1}\left(c_0 - \langle c_+ \rangle\right) - \langle w_+ \rangle \langle c - c_+ \rangle \tau / h_1$$

Air density CO_2 concentration
Surface CO_2 flux Boundary layer height Mean vertical velocity
Sub 0: Time t_0 in the morning Sub 1: Time t_1 in the afternoon Sub +: Above the ABL



BOX 1: Modeling gross flux components

The models for GPP and R_A were based on the MODIS algorithms but incorporating additional influences such as increased photosynthetic efficiency in diffuse light, and the response of R_A to GPP and leaf area index. R_H was formulated to incorporate influences of soil temperature, soil moisture and stand age. An alternate model for R_A will be considered that follows the form of the GPP and R_H models.

Gross flux component algorithms are shown below. Parameters are given by $\{a_i,\ i=1,\ldots,15\}$. Parameters in blue are optimized with observational data (see **Box 3**). Other parameters are taken from Biome-BGC results, the literature or varied slightly from their prior estimates in an initial optimization.

$$GPP = -a_1 T_{scalar} VPD_{scalar} APAR(1 + a_4 cloud_effect)$$

$$T_{scalar} = \frac{1}{1+\exp\left(\frac{-(T_{min}-a_6)}{a_7}\right)}$$

$$VPD_{scalar} = 1 - \frac{1}{1+\exp\left(\frac{-(VPD_{kgtime}-a_{10})}{a_{11}}\right)}$$

$$R_A = a_2\left(a_{15}^{(T-a_{14})/10} + a_7\right)\left[1 + a_5\left(-GPP/a_1\right)\right]\frac{1}{-k}\log(1 - fPAR)$$

$$R_H = a_3 f(age) g(T) h(sw)\ fPAR$$

$$f(age) = 0.321\left[1 + 2\exp\left(-0.206 * age\right) + 0.5\left(1 - 0.979^{age}\right)\right]$$

$$g(T) = \exp(a_{13} T_{soil})$$

$$h(sw) = (1 - 0.86\exp(a_{12} sw))/0.7486$$

$$ALTERNATE: R_A = GPP \times \left[1 - (NPP/GPP)_{max}\ f_2(age) g_2(T) h_2(soil_moisture)\right]$$

Introduction

This is part of a study to understand and quantify carbon stocks and fluxes in Oregon and north California. The steps involved are:

1. Develop algorithms for gross primary productivity (GPP), autotrophic and heterotrophic respiration (R_A and R_H) – **BOX 1**
2. Parameterize these models using a more sophisticated biogeochemical model – **BOX 2**
3. Optimize the base rates of these models with observational data (eddy covariance fluxes) – **BOX 3**
4. Incorporate CO_2 concentration measurements into the scheme and apply the models across the study region – **BOX 4**

Step 4 also involves:

A. Developing an atmospheric boundary layer budget using CO_2 concentrations measured at flux towers – **BOX A**

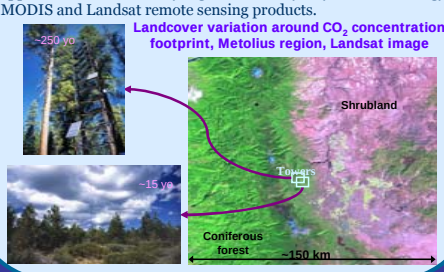
B. Setting up accurate CO_2 measurement stations, especially in complex terrain where concentrations may be difficult to interpret – **BOX B**

BOX 4: Future work- regional optimization and regional flux estimates

Final implementation will involve parameterizing the process models using regional daytime NEE estimates from ABL CO_2 concentrations as well as eddy covariance NEE measurements. The STILT model will be used to determine the footprint influencing CO_2 concentrations and distribute the flux among surrounding landcover types and ages (e.g. see figure below), This will enable the optimization to be more representative of the whole study site.

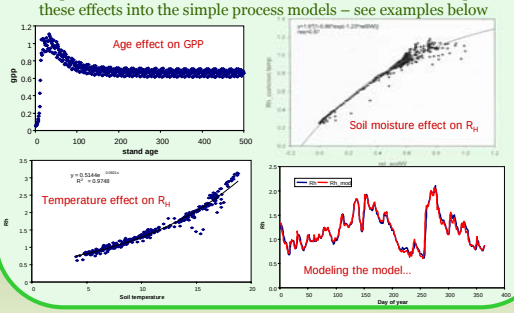
Once parameterized for each landcover type, the models will be applied to the whole study region, driven by Daymet meteorology, MODIS and Landsat remote sensing products.

Landcover variation around CO_2 concentration footprint, Metolius region, Landsat image

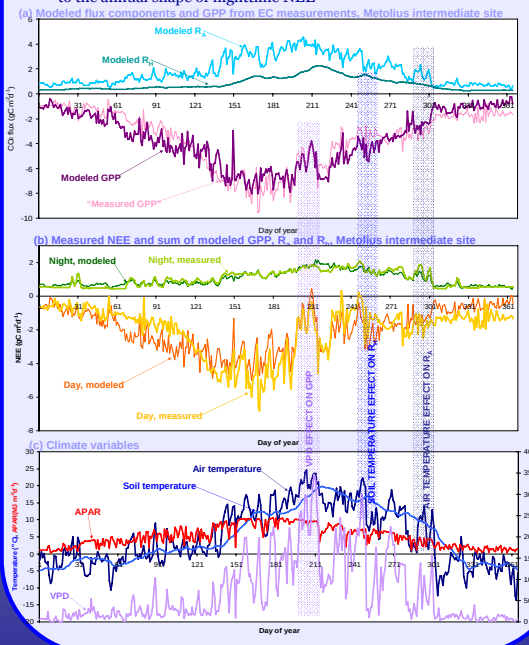


BOX 2: Parameterizing climate modulation with Biome-BGC

We use the Biome-BGC model to characterize response of GPP and respiration to climate variables and disturbance and incorporate these effects into the simple process models – see examples below



BOX 3: Parameter estimation and model results

Base rates for GPP, R_A and R_H were optimized by minimizing the difference between measured and modeled NEE, separated into daytime and nighttime components. Results show:

- Base rates for R_A and R_H were highly negatively correlated, but comparison of the figures below shows that R_A and R_H have very different sensitivities to climate variables, and daily fluctuations in nighttime NEE follow those in R_A, providing constraint on the two respiration base rates.
- The model was able to reproduce most of the daily variability and seasonal trend in GPP (figure (a)) and day and night NEE (figure (b)).
- The model reproduced climate influences (compare figures (a), (b), (c) in highlighted columns) such as:
  - reduction in GPP causing reduction in daytime NEE due to high vapor pressure deficit;
  - increase in R_A causing an increase in nighttime NEE due to unusually high fall temperatures;
  - bumps and dips in R_H following those in soil temperature, contributing to the annual shape of nighttime NEE