Testing the Community Land Model (CLM 4.5) ^{13}C isotope simulations for a subalpine forest at Niwot Ridge, Colorado

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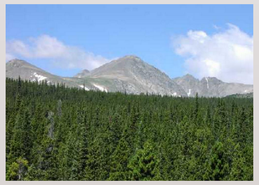
INTRODUCTION

Terrestrial biosphere models are an important tool to diagnose and predict land-atmosphere exchanges of carbon and energy. This is critical in order to quantify the land-carbon feedback into the climate system. Ecological observations are extremely important in order to quantify model skill and to improve techniques in which to simulate ecosystem behavior. Recently, carbon isotope behavior has been incorporated within CLM and we test simulated ^{13}C behavior against site level observations of biomass and carbon fluxes measured at Niwot Ridge.

OBJECTIVES

- Initialize CLM through a spinup procedure to approximate the ecosystem state (e.g. biomass, soil carbon) as observed at present day Niwot Ridge
- Calibrate the model to obtain reasonable simulation of carbon, sensible and latent heat fluxes as observed through flux tower observations
- Test if the CLM photosynthetic ^{13}C discrimination sub-model can reproduce the observed behavior in ^{13}C biomass and carbon fluxes

METHODS



- Site: subalpine conifer forest, subalpine fir (46%), Engelmann spruce (28%), lodgepole pine (26%). last disturbance: ~1905 logging clearcut
- Location: 40.03ºN 105.55ºW, elevation: 3050 meters, mean annual temp: 1.5 ºC, mean annual precip: 800 mm.
- Observations: Carbon Flux: 1998-present, ^{13}C flask: 1990-present, ^{13}C (high resolution): 2006-present

- Model version: CESM 1.2.1 (Dec. 2013) Compsets: I1850CLM45, I20TRCLM45
- Spinup phase: 1000 years accelerated decomposition mode, 1000 years normal mode, atm. CO_2=284.7 ppm, atm. $\delta^{13}C$ = -6 ‰, loop 1998-2007 local meteorology
- Transient phase: 1850-2007, loop 1998-2007 local meteorology, transient atm. CO_2

Simulation of biomass pools

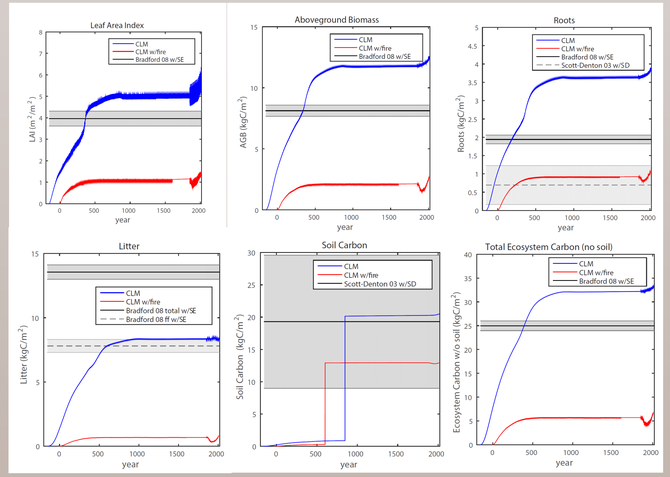


Figure 1: Simulation of biomass state variables initialized from near bare ground state. Spinup phase is 2000 years and transient phase with increasing atmospheric CO_2 is from years 1850-2007. Black lines are the mean observed values and the shaded gray regions represents uncertainty as standard error of site measurements. 'ff'= forest floor.

- CLM simulation without prognostic fire is more accurate, but overestimates biomass for most state variables
- The parameter controlling soil respiration rate with depth (decomp_depth_efolding) was adjusted (0.5->20) to reduce soil depth and total soil carbon within observed bounds

Simulation of Carbon Fluxes

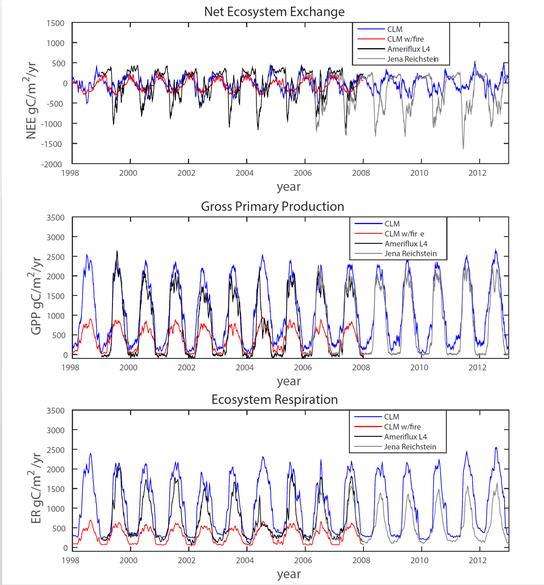


Figure 2: Comparison of CLM simulation vs. flux tower 'observations' with and without the prognostic fire module turned on. Ameriflux data is from 1998-2008 and Jena* fluxes from 2008-2013. Both sets of flux data are calculated with gap-filling and partitioning methods based upon Reichstein et al. 2005. The observed and simulated data are a 15 day moving average to remove noise and display seasonal trends. *Max Planck Institute: http://www.bgc-jena. mpg. de /~MDIwork/eddyproc/

- CLM simulation with prognostic fire significantly underestimates GPP and ER. This is an artifact of the underestimated biomass pools. (Figure 1) Removing fire improves simulated carbon fluxes significantly.
- The seasonal cycle of simulated GPP is captured well. The model incorrectly predicts winter-time GPP. Observations suggest GPP does not start until spring thaw.
- The model consistently underestimates the magnitude of the carbon sink as a result of overestimated growing season respiration fluxes.

Simulation of ^{13}C for biomass pools

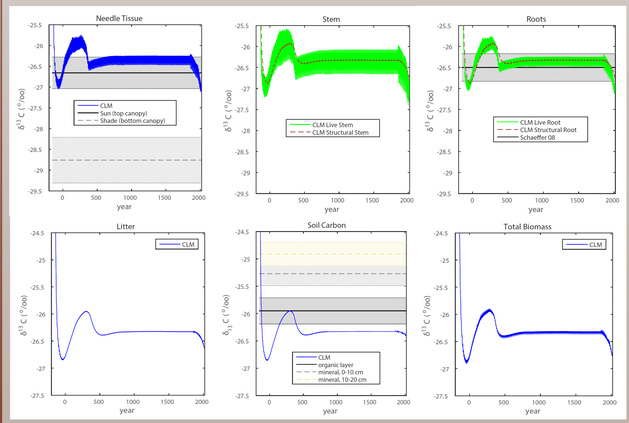


Figure 3: Simulation of $\delta^{13}C$ isotope concentrations of biomass pools. Observations are from Schaeffer et al. 2008. Black lines are the mean observed values and shaded gray regions are uncertainty as standard error.

- Simulated needle tissue and root $\delta^{13}C$ generally agree with observations. Simulated soil carbon is slightly depleted in $\delta^{13}C$ compared to observations.
- Currently the model assumes a constant atmospheric $\delta^{13}C$ = -6 ‰, and only considers photosynthetic fractionation.
- All biomass pools experience a depletion in $\delta^{13}C$ during the transient phase (year 1850 and on) as a result of increased photosynthetic discrimination from increasing atmospheric CO_2. Suess effect is not included here.

Simulation of ^{13}C for carbon fluxes

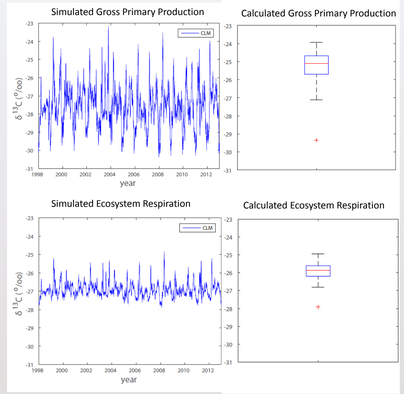
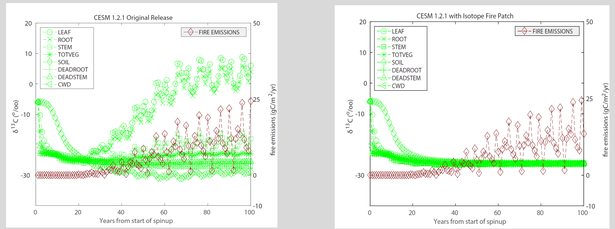


Figure 4: Calculated values are from an isotopic mixing model using carbon and ^{13}C flux tower data from 2007-2012 (Bowling et al. 2014). Simulated ^{13}C values are 15 day moving averages from CLM.

- In general, simulated ER ^{13}C values are more enriched than GPP ^{13}C values. Calculated values suggest the opposite.
- Higher variation in GPP ^{13}C values results from high sensitivity to environmental conditions (changes to stomatal conductance)

CESM 1.2.1 Fire Isotope Bug Fix



- Fire influences vegetation within CLM by direct burning and by mortality in which dead biomass is transferred to the litter pool
- The original CESM 1.2.1 release did not calculate a ^{13}C flux from the bulk carbon litter flux from fire mortality (CNCIsoFluxMod.F90). This caused an artificial ^{13}C enrichment of the surviving vegetation pools (left figure)
- A code patch has been successfully tested (right figure) See: http://bugs.cgd.ucar.edu/, Bug 2116. Artificial ^{13}C enrichment of biomass pools has been eliminated.

CONCLUSIONS

- More accurate biomass pools may be attained by reducing fire severity during spinup phase, then turning off fire during transient run.
- The overestimation of summertime respiration warrants further investigation of respiration-temperature dependence for each respiring carbon pool.
- Isotope simulations are encouraging: future runs will include 1) improvements to bulk carbon model performance, 2) inclusion of a dynamic atmospheric $\delta^{13}C$.
- These improved model simulations will determine if post-photosynthetic ^{13}C fractionation processes are necessary to reproduce observed behavior.

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