Untangling the dominant controls on seasonal vegetation dynamics and carbon uptake in semi-arid ecosystems of the southwestern US

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Background

Recent studies have suggested that semi-arid ecosystems play a dominant role in the interannual variability and long-term trend in the global carbon sink, citing the response of gross carbon uptake to moisture availability as the primary mechanism². However, the terrestrial biosphere models (TBMs) used in these studies have often performed poorly in comparison to a variety of observed data in semi-arid Ecosystems³ (and see fig. inset, J. Biederman et al. pers. comm.)

Objectives

In this study we perform an evaluation of the ORCHIDEE TBM, which is the land component of the French IPSL earth system model, against site-based eddy covariance fluxes in the semi-arid SW USA, with the aim of answering:
1. Is ORCHIDEE able to reproduce the annual net CO₂ budget and the magnitude and sign of the interannual variability (IAV)?
2. Does ORCHIDEE capture the mean seasonal cycle seen in the data?
3. Does vegetation type (PFT map) contribute to significant spread in the annual NEE?
4. Which processes are responsible for model-data misfit?

Methods

- ORCHIDEE terrestrial biosphere model⁶
- Flux site met forcing from FLOXNET 2015 database
- 4 simulations per site based on different vegetation fractions: 2 typical plant functional type (PFT) maps (ESA and IPCC) and 2 prescribed vegetation (Table 1)

Results

Fig. 1: Comparison of model and flux site ann. NEE across sites for the SITE VEG Evergreen veg. frac.

Fig. 2: Comparison of model and flux site ann. NEE for US-srm for different veg. types (Table 1)

Fig. 3: C flux monthly mean seasonal cycle averaged across sites

Fig. 4: LAI profiles simulated by ORCHIDEE at US-whs for the dominant PFTs plus total LAI (top 4 panels) driven by different vegetation fractions (Table 1) compared to green chromatic index from the phenocam website (bottom panel) (phenocam.sr.unh.edu/webcam/sites/luckyhills/)

Table 1: 4 simulations based on different vegetation fractions, 9-day means, + analogous, from current ORCHIDEE v3.7.2 (2015), ORCHIDEE v3.3.1 (2015) and new PFT (2015).

Conclusions

- ORCHIDEE underestimates the magnitude of the NEE IAV (Fig. 1)
- Different vegetation type can result in switch between source and sink (Fig. 2)
- Weak or negative correlation can exist for NEE IAV, dependent on vegetation type and site (Fig. 1, 2)
- Mean seasonal cycle not well-captured by the model (Fig. 3): Monsoon peak not captured
- Spring green up too early
- Model LAI temporal profile does not correspond to phenocam gcc index for any PFT (Fig. 4)

Future directions

- Better understand the cause of model-data discrepancy in ORCHIDEE
- Investigate patterns at other sites/biomes > particular issues in monsoon regions?
- Assess coupled C-water relations with new version of ORCHIDEE incl. mechanistic plant hydraulic architecture vs empirical plant water stress function
- Likely new semi-arid phenology models needed, incl. lag limitation on photosynthesis before monsoon rains
- Assess impact of model-data discrepancy on role of semi-arid regions in global C budget & SW US contribution.

References:
  ¹Poulter et al. (2014) Nature 509:600
  ²Ahlström et al. (2015) Science 348:6237
  ³MacBean et al. (2015) Biogeoisci. 12:7185
  ⁴Traore et al. (2014) Remote Sens. 6:8923

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