AGU Fall 2010

B31E-351

Climatic Controls on Carbon Exchange in the US Mountain West at Multiple Scales

A.R. Desai*, W. Ahue, B. Brooks, D.J. Moore, T.L. Quaife, R.K. Monson, S. De Wekker, T.L. Campos, B.B. Stephens, P. Wilkes, D. Schimel

*Corresponding author: Ankur R Desai, Dept of Atmospheric & Oceanic Sciences, University of Wisconsin-Madison, desai@aos.wisc.edu, http://flux.aos.wisc.edu

1) Site: Niwot Ridge

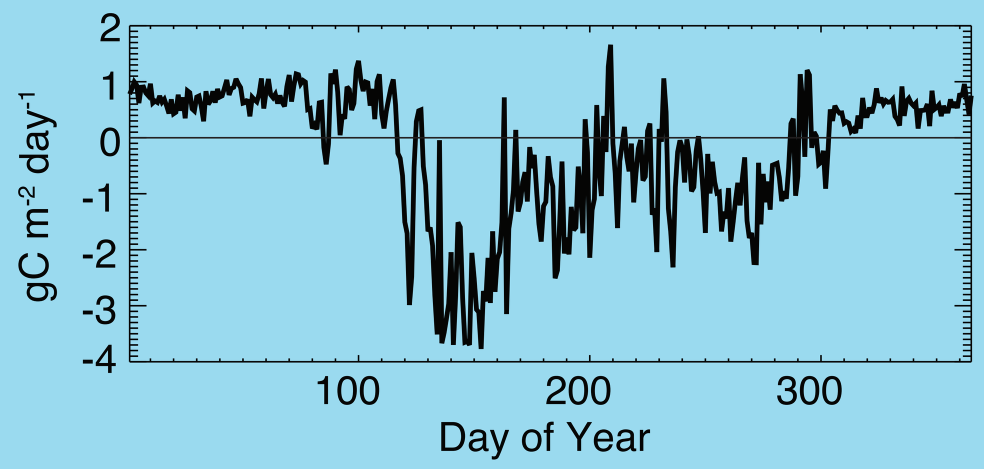

Figure 1. Daily NEE at flux tower site in 2007 shows a primary and secondary peak uptake typical of most years.

- Niwot Ridge eddy covariance tower samples footprint of sub-alpine forest in Colorado (Monson et al., 2002)

- Peak uptake in June is strongly a function of timing of snowmelt (Hu et al., 2010) (Fig. 1)

- Drought stress in July is followed by period of additional uptake in August, coincident with return of North American monsoon, with reduced uptake in late August (Fig. 2)

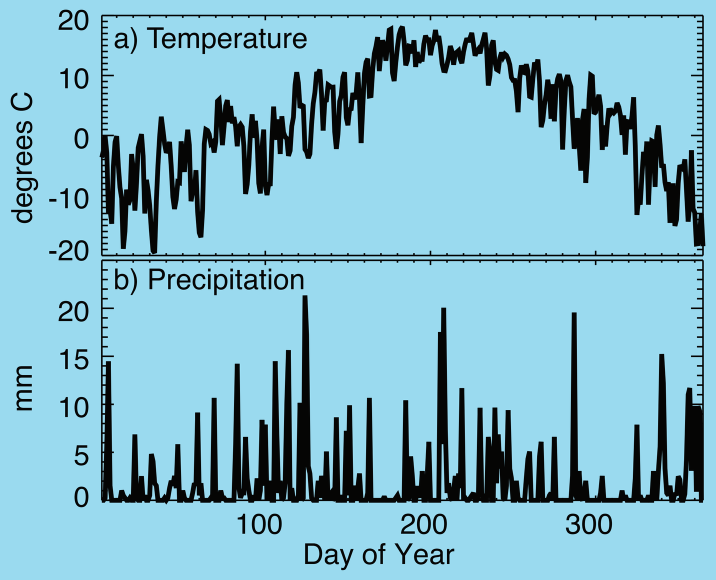

Figure 2. Daily a) average temperature and b) total precipitation at the flux tower site. Carbon uptake occurs when T > 0 C. Mid-summer drought is evident.

2) Sub-Region: ACME07

- Airborne Carbon in the Mountains Experiment 2007 used University of Wyoming King Air to construct paired upwind-downwind boundary layer budgets on 7 days in north-central Colorado (Desai et al., in prep)

- Compared to models at same space and time scale and the flux tower, daytime uptake from aircraft is similar, if slightly higher, in magnitude, and drought stress effect is less clear (Fig. 3)

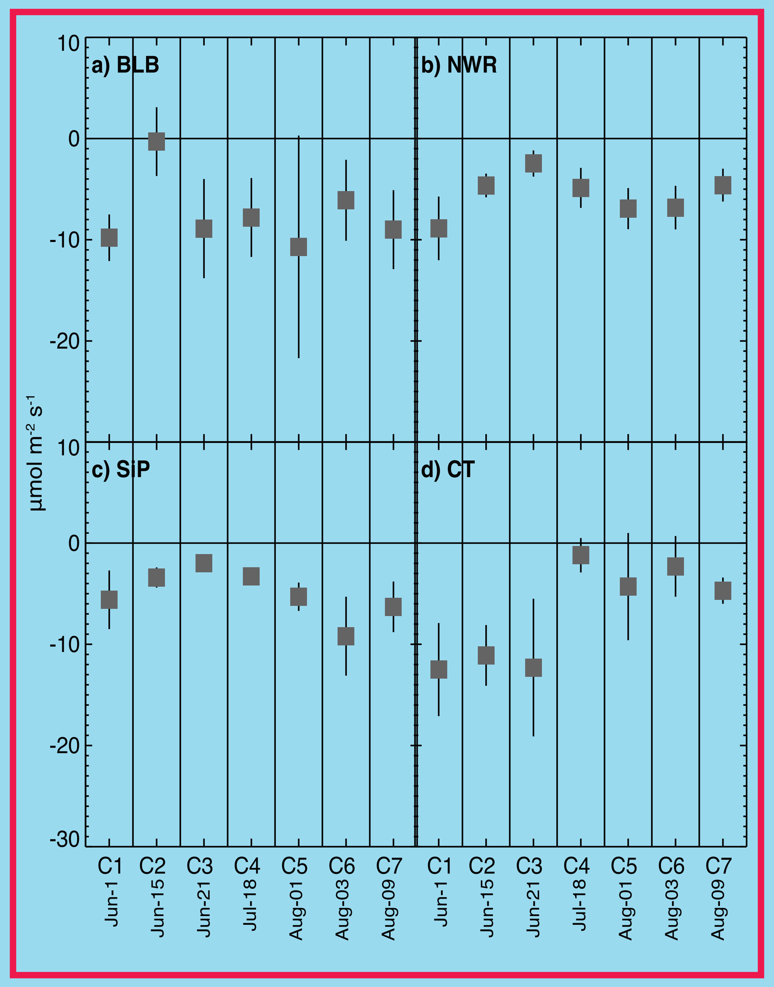

Figure 3. Comparison of daytime NEE (10-14 LT) at a) airborne boundary layer budget (BLB), b) flux tower (NWR), c) ecosystem model (SiP), and d) atmospheric inversion (CT) for 7 flight days of the ACME07 experiment. Error bars reflect propagation of uncertainties of BLB and spatiotemporal variability for the others. The primary and secondary carbon-uptake peaks are captured by NWR, SipNET, and possibly BLB, however at the regional scale, the secondary uptake peak vanishes for CT.

Questions

Complex terrain adds challenges to measuring regional net ecosystem exchanges (NEE) of carbon dioxide. The U.S. Mountain West is experiencing significant climatic changes and abiotic and biotic stresses. To better understand impacts to carbon cycling, we compare sub-regional (left) and regional (right) NEE at four different scales and ask:

1. What is the magnitude of regional NEE at each scale?

2. How similar are relationships between patterns of seasonal NEE and climate at each scale?

3. Where are the major sources and sinks of NEE in the US Mountain West?

Methods

Four approaches compared *at the scale* they best represent processes: (1) flux tower, (2) airborne budget, (3) ecosystem model, and (4) atmos-pheric inversion. Daily NEE for each was computed for 2007. Maps are for July.

Answers

- Pattern of primary and secondary uptake is seen at site and regional scale across central Rockies, less apparent in airborne sub-regional budget or in sub-continental inversion, where monsoon rains are less important.

- Higher carbon uptake is seen at high elevations with most methods, with later peaks in timing of the uptake, as might be expected.

- Quantifying NEE in mountain areas is difficult to achieve, but the four methods do reveal the importance of moisture stress and elevation in determining NEE magnitude and timing. Significant sinks of carbon do exist in the Mountain West.

3) Region: SipNET

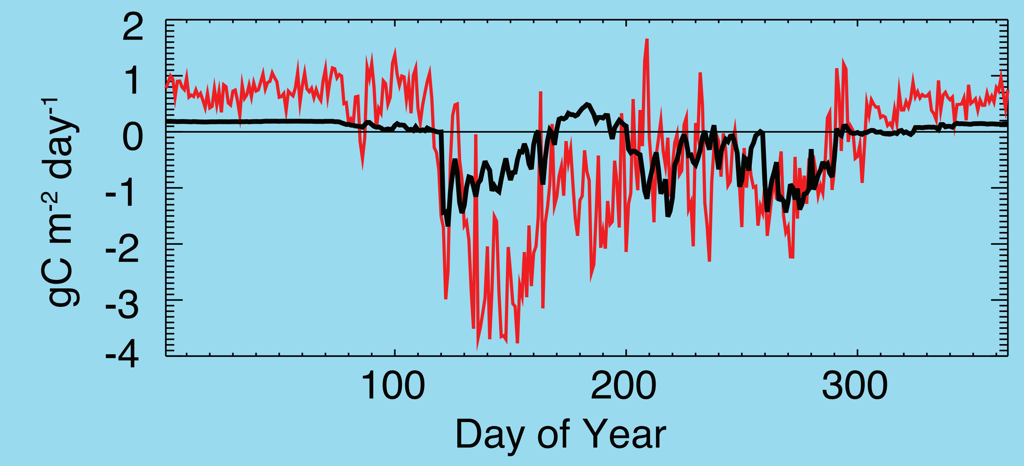

Figure 4. 2007 mean daily NEE from SipNET for Western Colorado region (black line), compared to NWR flux tower (red line). Pattern is similar, though magnitudes and timing differ given mix of deciduous, conifer, and grassland. Late August drought stress is strong, leading to a three peak pattern.

- SipNET Ecosystem model (Sacks et al., 2006) was paramterized against representative flux towers and spatialized with remotely sensed leaf area and interpolated meteorology.

- Daily NEE pattern (Fig 4) is similar to flux tower, but peak uptake is shifed earlier in time and much smaller in magnitude, while relative drought stress is smaller.

- July NEE shows a strong SE to NW gradient of increasing NEE.

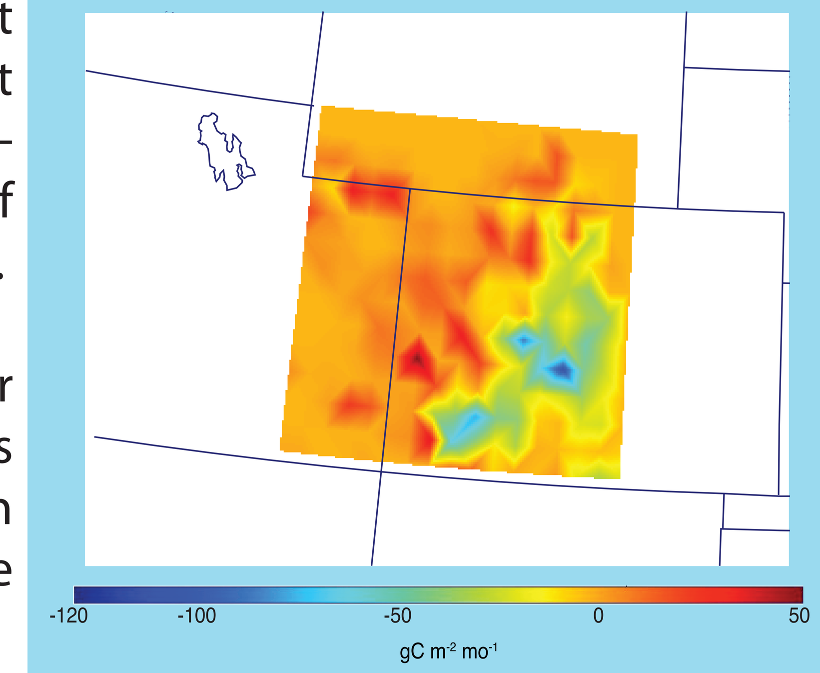

Figure 5. Spatial map of SipNET NEE in July 2007 shows high uptake (shaded green and blue) at high elevation across central Colorado and carbon sources throughout much of W Colorado / E Utah.

4) Sub-Continent: CarbonTracker

- CarbonTracker atmospheric inversion (Peters et al., 2007) best represents continental scale NEE.

- Spatial patterns show strongest July sinks in northern Rockies, though discrepancies exist with SipNET over Colorado (Fig. 6)

- Temporal pattern shows a later peak uptake than SipNET and lack of secondary peak uptake suggesting climate sensitivity of uptake varies across the Rockies (Fig. 7)

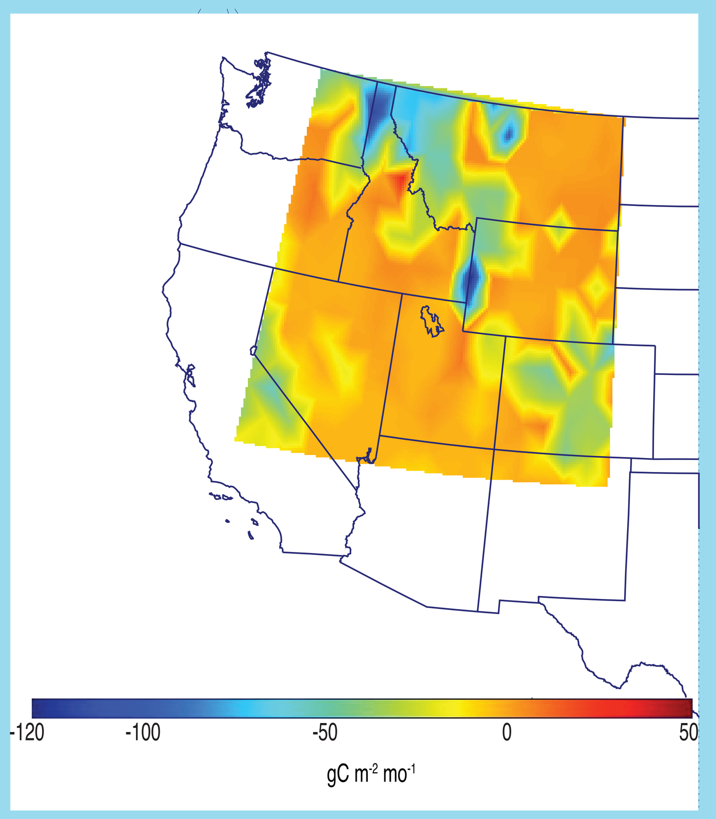

Figure 6. Spatial map of Carbontracker NEE in July 2007 similar to Fig. 5 showing pattern of high uptake at high elevation, while much of western U.S. is carbon neutral with largest sinks in Northern Rockies.

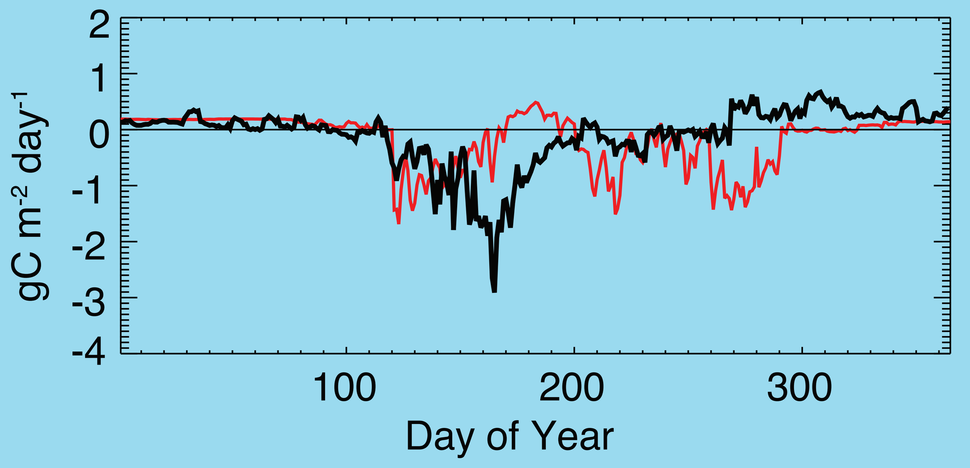

Figure 7. Temporal pattern of mountain west NEE (black line) and SipNET (red line). Peak uptake is larger in magnitude than SipNET. Note that SipNET shows carbon sources circa day 150-200, while the larger region does not become a carbon source until after day 200 and a lacks a secondary peak.

Citations:

Desai, A.R., et al. (in prep), Seasonal patterns of regional carbon balance in the Airborne Carbon in the Mountain Experiment 2007, *Journal of Geophysical Research-Biogeosciences*.

Hu, J., et al. (2010), Longer growing seasons lead to less carbon sequestration by a subalpine forest, *Global Change Biology*, 16, 771-783, doi:10.1111/j.1365-2486.2009.01967.x.

Monson, R.K., et al. (2002), Carbon sequestration in a high-elevation, subalpine forest, *Global Change Biology*, 8, 459–478.

Peters et al. (2007), An atmospheric perspective on North American carbon dioxide exchange: Carbontracker, *Proceedings of the National Academy of Sciences*, 104 (48), 18925–18930.

Sacks et al. (2007), Coupling between carbon cycling and climate in a high-elevation, subalpine forest: a model-data fusion analysis, *Oecologia* 151, 54-68.

Acknowledgments:

We acknowledge support of the various teams that collected these data for the Niwot Ridge Ameriflux tower, ACME07 field campaign, SipNET modeling team, and NOAA ESRL CarbonTracker inverse modeling group. We especially note support from Sean Burns (U.Colorado) for NWR, Jeffrey French (U.Wyo.) for ACME07, Bill Sacks (NEON,inc.) for SipNET, and Andy Jacobson (NOAA) for CarbonTracker. ACME07 field campaign was supported by the National Science Foundation (NSF) via the University Corporation for Atmospheric Research (UCAR). Analysis was further supported by National Oceanographic and Atmospheric Administration through the Office of Atmospheric Research (OAR) Climate Program Office (CPO) grant # NA09OAR4310065.