Regional Fluxes: Challenges and Opportunities

Ankur R Desai
Dept. of Atmospheric & Oceanic Sciences
University of Wisconsin-Madison

AMS 29th Conference on Agricultural & Forest Meteorology
Keystone, CO, Aug 5, 2010
Regional Fluxes?

• Anthropogenic climate change has global forcing but regional impacts

• These impacts require assessment of response of regional surface-atmosphere fluxes of trace greenhouse gases, water, and energy to climate variability and change
So What?

- Fundamentals of ecology and micrometeorology have been mostly studied at the plot scale.

- Fundamentals of surface-atmosphere flux influence on climate mostly studied globally.

- Regions (landscapes, watersheds, continents) are where climate-ecosystem interactions are least understood and likely to hold the most surprises.
  - It’s also the relevant scale for ecosystem management.

- A couple of examples in carbon cycling...
Example 1: Northern Wetlands

- NEE (Net Ecosystem Exchange of CO2): negative = carbon uptake

Sulman et al. (2009) BG; Sulman et al. (in press) GRL
The Region

- Does the region respond similarly?
Methods

- Bottom-up (scaling)
  - IFUSE – Interannual Flux-Tower Upscaling Experiment
  - 12 regional flux tower upscaling using simple regional model and data assimilation (Desai et al., 2008 AgForMet; accepted, JGR-G)

Desai et al (2008) AgForMet; Desai, accepted, JGR-G
Methods

- Bottom-up (scaling)
  - IFUSE – Interannual Flux-Tower Upscaling Experiment
  - ED – Ecosystem Demography Model v1.5
  - Height-and-age cohort succession model tuned to Forest Inventory and Analysis (FIA) data (Desai et al., 2007, JGR-G)

Methods

- Bottom-up (scaling)
- Top-down (atmospheric budgets)
  - EBL – Equilibrium Boundary Layer
    - 1-D boundary layer budget inferred from tall tower CO₂ and reanalysis subsidence rates (Helliker et al, 2004, JGR-D)

\[
\text{NEE} = \rho W (C_t - C_m) + \rho h \frac{\partial C_m}{\partial t}
\]

Methods

- Bottom-up (scaling)
- Top-down (atmospheric budgets)
  - EBL – Equilibrium Boundary Layer
  - CT – CarbonTracker v2009
    - Global, nested-grid inverse tracer-transport model using Kalman filter assimilation of atmospheric CO$_2$ *(Peters et al., 2007, PNAS)*

Methods

• Bottom-up (scaling)
  – IFUSE – Interannual Flux-Tower Upscaling Experiment
    • 12 regional flux tower upscaling using simple regional model and data assimilation (Desai et al., 2008 AgForMet; accepted, JGR-G)
  – ED – Ecosystem Demography Model v1.5
    • Height-and-age cohort succession model tuned to Forest Inventory and Analysis (FIA) data (Desai et al., 2007, JGR-G)

• Top-down (atmospheric budgets)
  – EBL – Equilibrium Boundary Layer
    • 1-D boundary layer budget inferred from tall tower CO$_2$ and reanalysis subsidence rates (Helliker et al, 2004, JGR-D)
  – CT – CarbonTracker v2009
    • Global, nested-grid inverse tracer-transport model using Kalman filter assimilation of atmospheric CO$_2$ (Peters et al., 2007, PNAS)

Desai et al (2010) JGR-G
Regional Flux

- Magnitudes vary, but variability is similar

Desai et al (2010) JGR-G
Regions and Water

- Unlike wetland sites, water table strongly influences anomalies in regional NEE

Desai et al (2010) JGR-G
Example 2: Montaine Conifer Forests

- NEP = Net Ecosystem Production
  - Positive = More productivity

Courtesy of R. Monson, CU-Boulder
Interannual Response

- Niwot Ridge Ameriflux subalpine fir/spruce
  - 3050m elevation

Hu et al. (2010) GCB, Sacks et al. (2006) GCB
Is It Regional?
Airborne Carbon in the Mountains Experiment – ACME 2007

Is It Regional?

## Summary

<table>
<thead>
<tr>
<th>Site Level</th>
<th>Regional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperate-boreal wetland/forest (WISCONSIN)</strong></td>
<td></td>
</tr>
<tr>
<td>Wetland annual NEE weakly related to water table</td>
<td>Annual NEE strongly sensitive to water table and regional drying</td>
</tr>
<tr>
<td>Large forest sinks</td>
<td>Moderate forest sinks</td>
</tr>
<tr>
<td>Large interannual variability</td>
<td>Smaller interannual variability</td>
</tr>
<tr>
<td><strong>Evergreen montaine forest (COLORADO)</strong></td>
<td></td>
</tr>
<tr>
<td>Peak uptake after snowmelt (Apr-May)</td>
<td>Peak uptake in mid-June</td>
</tr>
<tr>
<td>Drought stress 2 months later</td>
<td>Weaker drought stress response</td>
</tr>
<tr>
<td>Weak secondary peak</td>
<td>Stronger secondary peak?</td>
</tr>
</tbody>
</table>
Challenges and Opportunities

• Methods to quantify regional fluxes require continued research
  – But rich networked datasets now allow us to test these

• Emergent climate-surface flux interactions are apparent at regional scale and call into question parameterizations from on site or global scale
  – But new model-data assimilation techniques allow us to develop regional assimilations

• Carbon and water cycling are intimately connected in multiple ways in regions
  – Ecosystem and climate model testbeds can test range of responses, level of complexity required
Challenges and Opportunities

Buffam et al (in press) GCB
Acknowledgments

• **Northern wetlands:** B Sulman, J Thom (UW), D S Mackay (SUNY-Buffalo), B. Helliker (Penn), A. Andrews (NOAA), P Moorcroft (Harvard), flux tower techs and PIs, NACP model-data synthesis participants

• **Montaine forests:** W. Ahue, B Brooks (UW), R Monson (CU), D Moore (King’s College), D Schimel (NEON), B Stephens, T Campos (NCAR), S deWekker (U.Va), ACME07 team

• **Funding:**
  – NSF Biology Directorate DEB-0845166.
  – DOE NICCR Midwestern Region 050516Z19
  – NOAA CPO NA09OAR4310065
  – UCAR (NSF)
  – UW Alumni Research Foundation