North American Carbon Project (NACP) Regional Model-Model and Model-Data Intercomparison Project

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Participants: Dozens of modeling teams and data providers, Canada, USA, Mexico, Europe
Interim Synthesis of Regional and Continental Models and Data

- Initiated by MAST-DC and NACP investigators in 2008
- In-hand model simulations & data
- 2000-2005
- 1° spatial resolution
- Monthly temporal resolution
- 14 forward/ecosystem models
- 24 inversion models


http://nacp.ornl.gov/int_synth_contreg.shtml
Motivation: Bridge the Gap

Atmospheric Inversions
Forward Models
Flux tower sites
CO₂ Flux (NEE)
Survey Data
MODIS
Flux footprint size
Soil C, Crop NPP, Forest Biomass
GPP

University of Michigan
Modeling Approaches: Inversions

Ocean fluxes
NEE
Fossil fuel emissions
Modeling Approaches: Inversions

Inversion

Surface Flux

Ocean fluxes
NEE
Fossil fuel emissions
Modeling Approaches: Forward/Ecosystem

- Spatially extrapolate site scale data to model C exchange at regional scales
- Multiple fluxes, including Net ecosystem exchange (NEE) and component fluxes (GPP, R, NPP), etc.
- Test hypotheses and make projections
- Different model formulations/parameterizations
- Different boundary conditions
  - Soil properties
  - Vegetation type
  - Land management
- Different forcing data
  - Weather
  - Nutrient inputs
  - Disturbances
  - Land-use/land cover changes
Overall Science Questions:

- **Identification of Sources/Sinks**
  - What are the magnitudes and spatial distribution of carbon sources and sinks, and their uncertainties during 2000-2005?

- **Interannual Variation**
  - What is the spatial pattern and magnitude of interannual variation in carbon fluxes during 2000-2005?
  - What are the components of carbon fluxes and pools that contribute to this variation?

- **2002 Drought**
  - Do model results and observations show consistent spatial patterns in response to the 2002 drought?
  - From measurements and ecosystem models, can we infer what processes were affected by the 2002 drought?
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Identify Sources/Sinks: Spatial Patterns

Forward Models

Net C Flux
June 2002

(+) source to atmosphere
(-) uptake from atmosphere
Identify Sources/Sinks: Inter-Model Variability

2002

Across Model Mean

Across Model Standard Deviation

Forward Models
N=12

Inverse Models
N=4

Note:
Only a small subset of inversion models report 1°x1° fluxes

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Identify Sources/Sinks: Inter-Model Variability

2004

Across Model Mean

Across Model Standard Deviation

Forward Models
N=12

Inverse Models
N=4

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Inter-Model Variability: Component Fluxes

2002

Forward Models

Across Model Mean

Across Model Standard Deviation

Gross Primary Production

Ecosystem Respiration

$\text{gC/m}^2/\text{year}$

$\text{gC/m}^2/\text{year}$
Identify Sources/Sinks: Long-Term Mean

Inverse Models

Forward Models

Boreal North America
Identify Sources/Sinks: Long-Term Mean

![Graph showing net carbon exchange for different models in Temperate North America.](Temperate_North_America_map.png)
Identify Sources/Sinks: GPP

Boreal North America

Gross Primary Production, PgC/month

(6 – 20 PgC/yr)

Temperate North America

Gross Primary Production, PgC/month

(12 – 30 PgC/yr)
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Interannual Variation: Net Annual Flux

**Temperate North America**

<table>
<thead>
<tr>
<th></th>
<th>Inverse</th>
<th>Forward</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boreal</strong></td>
<td>-0.07 (-0.3, 0.2)</td>
<td>-0.05 (-0.01, 0.02)</td>
</tr>
<tr>
<td><strong>Temperate</strong></td>
<td>-0.9 (-0.4, -1.4)</td>
<td>-0.07 (-0.04, 0.01)</td>
</tr>
</tbody>
</table>
Interannual Variation: Mean Deviated

Temporal Patterns

Temperate North America
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2002 Drought: Inter-Model Variability

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2002 Drought: Inter-Model Variability

2004

Across Model Mean  
Across Model Standard Deviation

Forward Models  
N=12

Inverse Models  
N=4

Note:  
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![Maps showing model variability over time.](image)
2002 Drought: Interannual Variation

Mean Deviated

Temperate North America
Conclusions:

- **Identification of Sources/Sinks**
  - Forward models predict significantly different magnitudes and spatial patterns of flux across NA.
  - Spread in forward model predictions due, *in part*, to differences in model purpose, inputs, and model formulation.

- **Interannual Variation**
  - Inversions predict more seasonality, **uptake**, and IAV over N. America than forward models.
  - We can make broad statements of agreement among different models/approaches, but cannot identify mechanisms responsible for disagreement.

- **2002 Drought**
  - Both forward and inverse models do predict less uptake (greater source) of C during 2002.
  - Cannot make inferences about what processes were affected by the 2002 drought.
Steps Forward

- Continue analysis:
  - Component fluxes (e.g., NPP, Ra, Rh);
  - Satellite indices (e.g., LAI, FPAR, NDVI, EVI); and
  - Inventory data (e.g., Soil C, Biomass, crop NPP) at monthly or annual times

- NACP Multi-Scale Terrestrial Model Intercomparison Project (MsTMIP)
  - Site, regional, global scales
  - Detailed protocol
  - Consistent set of model input and driver data
    - Place focus on differences in model formulation and help improve model performance

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