North American Carbon Project (NACP) Spatial Model-Data Comparison Project (MDC) for regional and continental synthesis

1. Motivation

Available observations are localized and widely separated in both space and time, so we depend heavily on models to characterize, understand, and predict carbon fluxes at regional or global scales. The results from models differ from each other because they use different approaches (forward vs. inverse), modeling strategies (detailed process, statistical, observation based), boundary conditions, initial conditions, and driver data. We need an approach to identifying the causes of differences and deciding on which formulations and approaches best align with measurements, and why they may or may not agree with measurements.

Inverse or top-down analyses can provide estimates of carbon fluxes that are optimally consistent with measurements. Forward, or bottom-up ecosystem models can be used to test hypotheses concerning the attribution of processes in determining carbon fluxes and make projections using forcing scenarios. Examining and comparing results of inverse and forward model simulations with each other and with suitable measurements can help evaluate model strengths/weaknesses and utility, and provide multiple views of spatial and temporal patterns of fluxes, lead to understanding of processes involved, and provide a basis for making projections

Any interested party with a simulation model capable of calculating surface fluxes of carbon (also sensible and latent heat) either by employing an inverse or forward analysis (or both), at any spatial or temporal scale, for as much of the time period between 2000 to 2005 is welcome to participate. Each additional model provides information that can contribute to the analyses.

2. Specific regional hypotheses that can be addressed

The Spatial MDIP will identify and quantify spatial and temporal patterns of C fluxes, quantify model uncertainty and bias by comparing simulated or estimated surface fluxes and biomass to observed values at regional to continental scales for the period 2000-2005. Candidate “measurements” for regional comparisons include:

MODIS NPP, LAI (8 day, annual)
NASS crop yield (annual)
FIA based estimates of forest increment (annualized), biobass
AmeriFlux NEE (for those that haven’t used these for calibration) (half-hourly, daily)
Additional available measurements? EMDI- NPP data, LIDET, CIDET data, etc.?

Some specific hypotheses have been suggested by CASA and CarbonTracker results:

1. Do model results and observations show consistent spatial patterns in response to the 2002 drought? From measurements and model, can we infer what processes were affected by the 2002 drought?

2. What is the spatial pattern and magnitude of interannual variation in carbon sources and sinks? What are the components of carbon fluxes and pools that contribute to this variation?
3. What are the magnitudes and spatial distribution of carbon sources and sinks, and their uncertainties during the period 2000-2005?

Other questions are more diagnostic in nature and could be used to examine the magnitude of model uncertainty, such as

4. What are model sensitivities to model drivers?
5. How do similar model parameters vary across models?
6. How does process understanding vary among models, between regions, and across scales (site-region, region-continent)?

3. Project Management

The Spatial MDIP will have 2 related components – ecosystem (bottom-up) models for forward analyses, and similar models used for inversion analyses. The idea is that these are complementary approaches to analyzing the synthesis questions.

The inverse analysis models will provide model results at the spatial resolution of the North America TRANSCOM regions, and monthly temporal resolution. If results are available at finer spatial and temporal resolution (for example CarbonTracker) then these can also be provided since many of the bottom-up models will be at finer scales. Most inverse modeling groups have indicated that 1° spatial resolution is feasible.

The forward analysis or bottom-up models can provide analysis results at the temporal and spatial resolution of simulation runs more-or-less in hand. These will range from hourly to annual time steps with most probably being daily or twice daily (day vs. night), and 1km to county to 1° spatial resolution. MAST-DC, with help from the participants, will decide on spatial and temporal scales for aggregating/interpolating results for the planned analyses. One aggregation will be the TRANSCOM scales for comparison with inversion results. A finer target spatial resolution for comparing inverse model to forward/ecosystem models will be 1° with cells centered on half degrees. Both types of models will be asked to summarize monthly total terrestrial net ecosystem exchange at this spatial resolution, if possible. Forward ecosystem models compute many components of these net ecosystem exchange including GPP, NPP, Ra, Rh, and other diagnostic components that can be compared to observations such as LAI, aboveground biomass, crop yield, evapotranspiration, soil moisture, or soil carbon.

Any individual or group with results to contribute for any sizable portion of the North America continent over any part of the period 2000 to 2005 or the present is welcome to participate.

Regional MDC Management Team

To ensure rapid and steady progress, several individuals to lead and organize the regional MDIP:

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Regional MDC Server

We will create a central data repository that will house model descriptions, documentation, codes, and analysis results. We will provide some standard software tools to help participants convert these inputs into formats required by their model and convert model output into the standard format for use in model-data comparison. We will incorporate standard security procedures to ensure only MIP participants can access the repository (or should we adopt a data policy and open it to the public?).

Regional MDC Email Lists

The Site MDC involves a large number of modelers, observationalists, program managers, and other interested parties widely distributed across North America. To facilitate effective communication, we will create participant email lists to disseminate information. As required, we will create smaller email lists consisting of subsets of the full participant list to focus on specific problems or research efforts (e.g. the inversion modeler list).

4. Model Simulation Protocols

Regional MDC participants fall into two, not necessarily distinct, groups: model participants and data providers. The description provided below is preliminary but will be distributed early in the project and will be modified as necessary following initial discussion by all measurement and modeling participants.

Information Provided by Participants

All potential model participants should provide general descriptive information about the model they intend to use. This includes a short model overview (1-2 paragraphs) with a brief description, basic structure, web pages, and associated references. Participants should also provide a primary point of contact and, if desired, secondary points of contact for each model. Lastly, we recognize that the required inputs for each model differ, so the participants should provide a list of all inputs used by their model. In particular, vegetation type or land cover classification should be provided. This will allow some subsetting of results for comparisons by vegetation types.

Data providers should provide a short overview of their measurements, a description of how they are derived, estimates of uncertainty, and associated references.

Inputs to Model

Initially we do not plan on prescribing model driver data. Weather, phenology, soil properties, N deposition, etc. will be left up to the modeling teams. For addressing the question of the absolute size of the carbon sources and sinks, initialization of carbon pools will be important and each participant should provide a description of their initialization technique. Those models with nitrogen or phosphorus biogeochemistry should initialize those variables as best suited for their model and provide a description.

Outputs from Model

Each model will save a core set of required variables and a secondary set of optional variables. Participants will convert their output to standard units and file format. Variable of interest include NEE for Inverse and forward ecosystem models. For the purposes of being able to diagnose the causes of C sources and sinks, forward ecosystems models should also provide GPP, Ra, NPP, and Rh if possible. Not all models calculate the full set of these but should provide what they can with NPP and NEE being the most important. If the models can provide sensible heat, and latent heat; and prognostic variables like soil temperature these should be saved and potentially contributed if they look like they are useful in an emerging analysis.

For each model, output the data at the finest time scale and the finest temporal scale the model provides. Having finer resolution up-front gives us more flexibility in the types of analysis we can do. It also provides the greatest amount of information. We expect that most comparisons will be made at monthly time step. For Inverse models TRANSCOM regions will be the nominal spatial scale. Most forward ecosystem models probably can produce results at a 1° spatial resolution, which for comparison to Inverse models, can be aggregated to TRANSCOM regions. Comparisons may be possible at finer spatial and temporal scales may be possible, although this should be decided before outputs are contributed. Finer temporal intervals are possible with most models and finer spatial scales of most data sets will be available for comparisons. Most of the towers estimate half-hour fluxes, so the models that can should save half hour averages for the tower pixels at least. Some observations are annual, such as crop biomass/yield or forest wood increment, so the models will output "snapshot" or instantaneous values at a particular time consistent with the observation time. The participant should convert all model output to Greenwich Mean Time (GMT).

The best file format for providing spatial model output is CF compliant netCDF. An example will be provided. Instructions for producing such a file from ASCII files and appropriate meta-data will be developed if necessary. These instructions provide additional guidance on what information will be required for model output. Software tools for most computer platforms for producing and viewing netCDF files is available. See http://www.unidata.ucar.edu/software/netcdf/ for general information and http://cf-pcmdi.llnl.gov/ for the CF convention for netCDF files. As a concrete example, please see ftp://ftp.cmdl.noaa.gov/ccg/co2/carbontracker/regions.nc. This CF-1.0 and COARDS-compliant netCDF file not only defines the grid but also gives Transcom 22 region definitions on that grid.

Measurements

There are many types of measurements that can be compared against model output. Example include MODIS-NPP, MODIS-LAI, EMDI-NPP, crop yield, forest inventory based biomass and growth, NEE at AmeriFlux locations, soil respiration measurements, etc. Investigators compiling and maintaining these observations and measurements will be invited to participate in the project planning, execution, and publication of findings. Spatial data should be prepared in the same fashion as model output described in the previous section.

5. Intercomparison Methods and Analysis

Model-data comparison

Comparisons between model spatial patterns and data spatial patterns are often examined visually. Difference plots can also be useful. One very useful diagrammatic form, termed "Taylor diagram", can convey information about the pattern similarity between a model and observations. This same type of diagram can be used to illustrate the relative accuracy among a number of model variables or different observational data sets. One additional advantage of the "Taylor diagram" is that there is no restriction placed on the time or space domain considered. A good description of the Taylor diagram can be found at
http://www.ipsl.jussieu.fr/~jmesce/Taylor_diagram/taylor_diagram_definition.html

Variograms, EOFs, Getis statistic of spatial autocorrelation (Wulder and Boots 1998, Int. J. Remote Sens. 19, 2223–2231), etc., for examining the spatial scale of synoptic patterns will also be considered.

Other model data comparisons have used a wide variety of point-by-point comparison statistics. There is a large literature in other disciplines on comparing models and data. Some references are: Janssen and Heuberger 1995, Ecol Modelling 83:55-66; Legates and McCabe 1999, Water Resources Research 35:233-241; Wilmott 1982 BAMS 63:1309-1313; Fox 1981 BAMS 62:599-609.

Model-Model comparisons

While the emphasis will be on model data comparisons, there is much to be learned by comparing models directly. In addition to comparing the performance of each model to flux measurement or observations, there is an analysis of how models compare with one another. This will be of particular interest for comparing forward ecosystem models with inverse models. The output can be aggregated up into biome types or regions (similar to CarbonTracker) and then the compared. Do they agree? Is there more agreement between models for particular biome types? etc. This would also allow for the inclusion of regional scale models into the study (i.e., included in the comparison of certain sub-regions). The variograms would also be a useful in comparing the spatial variability included in the different models.

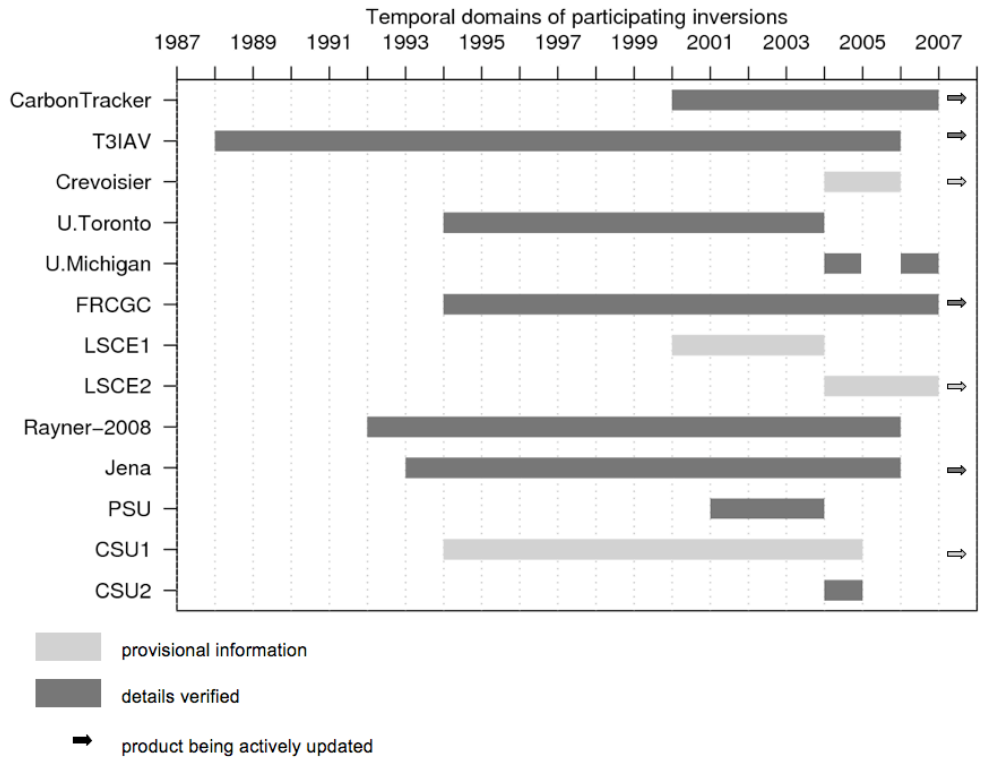
Model Participants

Tables 1 and Figure 1 list the potential models participating in the NACP Regional MDC, including lead contact and appropriate references.

Table 1. Potential participants in the NACP Regional/Continental model data comparison project – ecosystem or forward models.

Model	**Contact**	**Region**
SiBCASA	Denning/Shaeffer	NA, MCI
TECOR	Luo/Zhou	NA
VEGAS	Zeng	NA, MCI
CLM-CN	Thornton	NA
CLM-CASA'	Hoffman/Thonton	NA
DAYCENT	Parton/Ojima	MCI. NA
EDCM	Liu/Bliss	NA, MCI
Biome-BGC	Turner/Law	Oregon-California
AgroIBIS	Kucharic	MCI
ISAM	Jain	NA
EPIC	Izaurralde	MCI
ED	Moorecroft	New England
CASA	Potter	NA, MCI
TOPS/Biome-BGC	Nemani	NA, MCI
SimCYCLE	Ito	NA
ECOSYS	Grant	MCI, NA
CN-CLASS	Altaf Arain	NA
GTEC/LoTEC	Post/King/Gu	MCI, NA
CANVEG	Novick/Katul	Eastern US
Biome-BGC	Gower	Great Lakes Forest
CENTURY+MODIS	Ogle	MCI
PnET	Ollinger/Aber	MCI
GFDL Land Surface	Pacala/Golaz/Hurt	NA
ORCHIDEE	Piao	NA
ORCHIDEE	Viovy	NA
OTHERS???		

Figure 1. Potential participants in the NACP Regional/Continental model data comparison project – inverse models.



Invitations to NACP investigators including modelers and data providers to join in this project will be sent in early February by the coordinators (the inverse modelers have already been contacted) and posted on the NACP website. All investigators, even those not formally part of the NACP, are welcome to participate and do not have to wait for an invitation to contact the project coordinators to be included in the planning and execution of the project.

Schedule

Synthesis Protocol send to participants – February 2008

Prospectus to NACP for Funding – February 2008

Observational data sent to MAST-DC – May 2008

Model results sent to MAST-DC – May 2008

Analysis of model-data comparison – June through September 2008

Regional MDC Workshop – September 2008

Draft papers for publication – September through December 2008

Present results at NACP All-Scientist meeting – January 2009

Finalize papers for publication, submit – February 2009

References

Fox 1981 BAMS 62:599-609.

Janssen and Heuberger 1995, Ecol Modelling 83:55-66.

Legates and McCabe 1999, Water Resources Research 35:233-241.

Wilmott 1982 BAMS 63:1309-1313.

Wulder, M., Boots, B., 1998. Local spatial autocorrelation characteristics of remotely sensed imagery assessed with the Getis statistic. Int. J. Remote Sens. 19, 2223–2231.