The Terrestrial Carbon Model Intercomparison Project (TCMIP)

**Motivation** (why another MIP?):

Large uncertainties exist in our understanding of terrestrial carbon sources and sinks and their variability, especially when compared to the atmosphere and ocean. For instance, the C4MIP project showed disturbingly large uncertainties in land carbon cycle response and feedback to future global climate change that need to be understood and narrowed.

A central problem in carbon cycle research over the last two decades has been the ‘missing’ carbon sink, but the question remains unsolved as major uncertainties exist on the importance of CO2 fertilization, land use, nitrogen limitation, and so on. On the other hand, the variability of contemporary CO2 sources and sinks is estimated at 5-6 Pg/y on interannual timescales and 1-2 Pg/y on decadal timescales, with land contribution dominating the shorter timescales. Thus, the size of the missing carbon sink (1-2 Pg/y) is comparable to decadal-scale variability, and significantly smaller than interannual variation.

The question of climate-related variability offers opportunities for major advances in our understanding of the carbon cycle. This is so for two important reasons: 1) the recent development and improvement in terrestrial carbon cycle models, but they tend to differ in many aspects such as ENSO and drought related amplitude and phasing, relative importance of NPP, respiration and fire; 2) the availability of 25 years of CO2 network and satellite observations, and recent flux measurements that provide key information on the variability in CO2 sources and sinks, but not easy to interpret on their own. A casual survey of the Seventh International CO2 Conference (ICDC7, Colorado, September, 2005) indicates that more than half of the presentations addressed the variability issue, yet there is currently no coordinated effort on the terrestrial side for modeling and model-data comparison. Such analysis will also be valuable for activities such as the North American Carbon Program (NACP) where seasonal-interannual variabilities are expected to dominate the observations.

**Objective** (phase 1)

The TCMIP project aims to bring together state-of-the-art terrestrial carbon cycle models and compare their ability at simulating interannual-to-interdecadal variability in carbon sources and sinks. Through extensive model-data comparison, these forward models will be constrained by atmospheric inversions, CO2 flux measurements, CO2 concentration, and satellite observations on one hand, and provide interpretation of the observations on the other hand. In doing so, we will provide mechanistic understanding of sensitivity of carbon cycle response to climate and validate the terrestrial carbon models.

The overarching goal of the project is:

- Using interannual-to-interdecadal variability as a testbed to understand the climate sensitivity of carbon cycle, and validate the models. It also provides the essential
background for understanding the fate of anthropogenic CO2 such as the ‘missing’ carbon sink.

Examples of scientific questions to be addressed:

- Why and how land dominates the ENSO-related interannual CO2 variability? What are the relative importance of underlying processes such as NPP, soil respiration, and fire? What caused exceptions such as the Pinatubo period?

- What caused the recent anomalous increase in atmospheric CO2? What is the role of midlatitude drought? To what degree this indicates possible direction of future climate-carbon change?

- What are the consequences of high-latitude warming in recent decades? Does the enhanced growth lead to a net carbon accumulation in spite of the enhanced soil respiration? What’s the relevance and implication to anthropogenic warming?

- How do other modes of climate variability such as NAO, NAM, PDO manifest themselves in carbon cycle?

**Relation to other projects** (more on why another MIP):

CCMLP: Ended in 2002, and it was essentially a predecessor of this project, but with a small number of and earlier terrestrial models. It showed the dominant but highly uncertain influences from CO2 fertilization and land-use change (McGuire et al. 2001), but the observed CO2 contain major climate-related variability not emphasized in that project. TCMIP will build on CCMLP’s experience and focus on understanding interannual to interdecadal variability. We expect to include updated versions of those models, as well as a number of more recently developed models.

C4MIP: Identified land as the major source of uncertainty in response to climate change. Many of the C4MIP terrestrial carbon models are expected to participate in TCMIP, which will serve as a major validation for the C4MIP predictions.

TRANSCOM: Several groups within TRANSCOM have produced over two decades of surface fluxes from inversion and expressed interest in joint forward-inverse model comparison.

OCMIP: Having compared climatology and anthropogenic CO2 uptake, OCMIP phase 3 is now looking at the interannual-interdecadal variability in the oceanic CO2 fluxes through NOCES and other projects. TCMIP will be its counterpart on the land side.

**Modeling strategy** (Phase 1)

- Terrestrial and oceanic carbon cycle forced by observed climate variability through the 20th century to present, focusing on two periods: a) last 50 years (Mauna Loa era), b) last 25 years (CO2 network and satellite era)
• Transport of surface fluxes, then compare with station CO2 (together with ocean, only needs one group)

**Modeling strategy (Phase 2)**
• Terrestrial and oceanic carbon cycle forced by observed climate variability through the 20th century to present, and by observed CO2, land use and fire management history. Some of these data are under rapid development or revision and will be more useful in the future.

**Model-Model comparison**

**Model-data comparison with:**
• Inversions: individual inversions; TRANSCOM models with uncertainty range; what regional scale is achievable?
• Satellite products such as NDVI, EVI, (future) OCO
• Station CO2: atmospheric transport model
• FluxNet site flux measurements: a) grid/site comparison; b) scatter plots

**Other issues**
Protocol (expansion of the strategy above)
Models: interested or might be interested
- LPJ (S. Sitch)
- TRIFFID (C. Jones)
- TEM (D. McGuire)
- VEGAS (N. Zeng)
- BETHY (W. Knorr)
- SIB3 (K. Schaeffer)
- Princeton (E. Shevliakova)
- IBIS (J. Foley)
- SLAVE/ORCHIDEE (P. Friedlingstein)
- CASA (J. Collatz)

Coordination; who does what analysis? Most groups only need to provide the simulation results. Each participating group will have access to all the data. Funding will also be thought for analyzing results for a couple of postdocs at some coordinating institutions.

Second draft Feb. 23, 2006 by N. Zeng, with input from D. McGuire, S. Sitch, C. Jones, M. Heimann and C4MIP participants