Report: CCSM Biogeochemistry Working Group Meeting
UC Berkeley
March 29-30, 2001

Scott Doney, Inez Fung, Gordon Bonan, Steve Running (VEMAP), Peter Thornton, Jerry Melillo (CCMLP), Tim Kittel, Dennis Ojima, Tony King, Dave Erickson, Jim Randerson, Bill Riley, Starley Thompson, Phil Duffey, Lydia Gates, Roger Dargarville, David Noone, Natalie Maholwad, Joerg Kaduk, Chris Still (apolgies to anyone not Listed).

I. General discussion

1. Progress in the atmosphere/ocean components of the CCSM:
   a) NCAR is participating in the IGBP-GAIM TransCom3 project (inversion for carbon sources/sinks) via several versions of MATCH (off-line tracer transport model developed by P. Rasch and N. Mahowald) using 12 months, but from different years, of NCEP and ECMWF circulation statistics. This NCAR contribution establishes that differences in circulation (rather than in model construct; e.g., vertical convection computation) are a major source of variation among model simulations of tracer concentrations in the atmosphere.
   b) Dargarville has derived a version of MATCH that uses 27 years of NCEP circulation statistics. This is the first study of CO2 that uses interannual variations in the circulation. Preliminary results using a repeat seasonal cycle of land net CO2 fluxes show significant interannaul variability in measures such as the interhemispheric gradient and seasonal cycle driven strictly by year to year variation in transport.
   c) Keith Moore in Doney's group has developed and tested an ocean ecosystem model with different sizes of phytoplankton and zooplankton, iron, silica and other limitations on productivity, and specific geochemical functional groups (e.g., N2 fixation, calcification).
   d) Johanna Balle-Beganton in Fung's group has implemented a carbon-13 module into the ocean BGC model.
   e) Fung's group has coupled the atmosphere-ocean models with active ocean carbon module. The spin-up is ongoing.
   f) Fung's group has "cut-and-paste" the terrestrial BGC model CASA onto the LSM.

2. CLM.
   a) The LSM has been merged with the Common Land Model (Zeng, Dickinson et al) to yield the new CLM (Community Land Model). The CLM and LSM have very different behavior at high latitudes. New features include plant functional types (PFT's), river routing and the appropriate links for biogeochemistry.
   b) Bonan's group has built a new framework for the CLM based on an existing dynamic vegetation model (LPJ) but folding in the processes/dynamics already present in the CLM. The new module provides for dynamic, temporal variation of PFTs which will allow for the study of issues such as the invasion of woody

species. Spin-up of the new dynamic PFT/CLM version is underway, and preliminary results are encouraging.

c) It is important for the community to think in terms of providing "modules" and "subroutines" that can hooked into Bonan's architecture. It is impossible and impractical to couple an independent BGC model to the new CLM.

3. Coupled climate-BGC experiments (the Flying Leap Series):
   a) Leap0 has prognostic CO2 in the atmosphere. The fossil fuel CO2 source is specified. This will use existing codes. Per the March 2000 meeting, Leap1 will include dust/iron/marine productivity/CO2 interactions.
   b) A new experiment was proposed at this meeting (tentatively termed Leap0.5):
      - fossil fuel and land use forcing – perhaps scenario from Millenium Assessment project.
        Natural vegetation → agriculture → recovered vegetation
        Forest harvest and regrowth
        Action: Melillo to be in touch with the Millenium Assessment project to come up with forcing scenario.
      - New atmosphere, ocean physical GCM's
      - Ocean BGC with Moore/Doney eocsystem model
      - new Community Land Model with BGC architecture (Bonan schematic) with runoff, plant functional types (PFT)'s, …
      - Additional feedbacks that should be included (needed for model development): Nitrogen availability effects on mineralization, heterotrophic respiration, plant growth, net ecosystem production…; Dynamic vegetation interaction; Disturbance transients and trends; Snow/permafrost/soil BGC
      - Such runs can be used to address questions such as the effect of longer growing seasons (enhancement at high latitudes versus water stress at low latitudes), constancy of Bowen ratios.

4. Land BGC model development – see detailed discussion in section II below.

5. Assessment of BGC modules in the CLM should take advantage of the existing organization of VEMAP (represented by Running) and CCMLP (represented by Melillo) and the runs that have been done already by various land BGC groups. Action: Kittel (with Running) will investigate how to get the VEMAP and CCMLP atmospheric forcing fields adapted to CLM time steps (sub-diurnal) for forcing CLM off-line. Proposal to Jay Fein to get this going? This is a one time investment to get the forcing so that CLM can participate in these ongoing intercomparsion efforts.

6. Coordination with other CCSM working groups:
   a) Land working group: Discuss in June the issue sub-grid scale variability. BGC needs it, for among other things, mortality. Also if the land can have higher resolution than the atmosphere, then we can geo-reference PFT, rather than have statistical representation, and pursue more dynamics/interesting

hydrology experiments. If we go for 5-minute resolution, what would be the impact of computer architecture and distributed computing environments. Action: Fung and Doney

b) Climate Variability WG: We need extremes, especially for nonlinear BGC dynamics (floods) and mortality (e.g. wind throw). Need high-resolution parameterization for strong winds, intense rainfall, hurricane/storm tracks. Action: Fung and Doney

c) Action: Fung/Doney/Bonan et al. to coordinate with Warren Washington and Impacts and Assessment group.

7. Synergistic efforts at DOE:
   a) Dave Erickson – ORNL climate dynamics group and computing and mathematics section. John Drake is the group leader. GCM has been running at ORNL for 8 years. Now have CCM 3.3.6, fully MPI compliant. An NCAR contingent, Bob Malone (LANL) and others went to Oak Ridge to figure out how to run CCSM on distributed machines. 3-4 Tflops in 1-2 years. Close collaboration with IBM and Com? to figure out how to run a GCM. Manual queueing – you get the whole machine for a month.
   b) Starley Thompson – Livermore. CCM3-IBIS runs. AMIP-style, carbon uptake.
   c) DOE folks are encouraged to report this meeting to their management, and to discuss collaboration between NCAR and DOE in June.

8. Outstanding issues
   a) Need coastal coastal model to link riverine fluxes to the open ocean (Doney).
   b) Run-off right now is distilled water. Need to include BGC in runoff. Invite Charlie Vorosmarty to June meeting (Fung).
   c) Flooding – river routing model – not much analyzed. Sundquist – explore collaboration with USGS via USGS post-docs located in Woods Hole to interact with arctic LTER group at MBL. Jan 15 deadline to start in Fall.
   d) Develop an MPI capable version of MATCH, the off-line atmospheric transport model (Action: Mahowald and Dargaville to determine programming needs)

II. CLM-BGC Development

BGC Mechanisms important for the Leap problem: - several of these have to be treated as a package to maintain internal consistency. Development and enhancement of ach module is discussed separately below. Modules:

A. Lifecycle on shorter and seasonal time scales
   i. Integrated photosynthesis and transpiration – N interaction, acclimitization
   ii. Growth and maintenance respiration
   iii. Dynamic leaf/stem/root allocation
   iv. Leaf/root growth phenology
   v. Seasonal litterfall and mortality

B. Soil decomposition and N mineralization

C. Disturbance triggers, mortality triggers
D. Lifeform (PFT's) on interdecadal time scales – competition for light/water/N

These are described separately below, but should be thought of as packages/modules.

1. Growth respiration:
    a. Stoichiometry – worked out from basic bonding chemistry. Very stable
    b. 0.3 * new carbon…. - not temperature driven
2. Maintenance respiration – temperature driven. Q10 logic. Need to be separated from growth respiration. %live cells versus % dead cells. N concentration as surrogate of cytoplasmic activity. What about physiological acclimation – adjust Q10? Lots of plot level data. Need to generalize to a single mathematical function. Has place-holder algorithm. Q10 value may be dependent on time step of model.

3. Labile photosynthate: depletion of this pool is how plants really die. E.g. insect infestation. Can be a mechanistic trigger of mortality. Size of reserve pool needs research/justification. Where to do this? In allocation subroutine – or elsewhere?

4. Leaf phenology
5. Summer green – degree days to trigger leaf-drop
6. Winter green – existing 6-month stuff unacceptable even in constant climate.
7. Leaf-off in temperate zones – how? turn off leaf photosynthetic capacity before leaves drop.

8. Root phenology – very crude treatment. Fine root allocation seasonal. Easier to track leaf area. Fine root flux in evergreen. More important is the amount of carbon to fine roots. Continuous investment in fine roots in all directions in search of water and nutrients (in that order). The ones that find water stay, else die.

9. Root distribution – there is root profile. Tough to do root depth since water table not specified. Soil 3.5 meters thick. Light/water/nutrient for allocation good enough for global models.

10. Root turnover – need sensitivity calculation.

11. Root-leaf allocation – something in place. Need to quantify sensivity to soil moisture gradient.

12. Tony King – physiological acclimation.

13. **Decomposition**: most logic seems to be BGC based. Running - Worry. In tropics, termite mounds. Randerson – herbivory is a function of NPP – as much as 30% of above-ground NPP.

14. **N mineralization**: Peter Thornton – C-N plant linkages code to Gordon.
15. How to define Vcmax (in Bonan's model):
16. Vcmax = area-based leaf N conc = 1/(SLA C:N_leaf)
17. x fraction of leaf N in Rubisco (determined from Assim – Ci observations)
18. x fnc (det'd from protein structure)
19. x act (Rubisco activity, f (Tleaf)
20. (umol CO2/m2. s) =
21. (g N_leaf/m2) (g N_Rub/g N_leaf) (g Rub/g N_Rub)(umol CO2/g Rub s)
22. TEM and Biome-GBC have very similar treatment.
23. C:N_leaf – specified constant. No evidence of change with changing environment
24. Century has dynamic allocation for N as well as for C.

25. **Fire models** – triggers, mortality, recovery, BGC… Thornton, Ojima, Randerson, McGuire. Wild fire – meterology well understood. Exact ignition point of wild fire not well known – study area. Cloud top temperature works a lightning indicator in the tropics. Dennis is tasked to contact Ron Nielson and his collaborators and report in June to figure out how to implement a climate-fire trigger in the GCM. Fires – need to put in darkening of soils. Existing models have modifications to live→ dead transfers, additions to CWD etc.

26. **Mortality other than by fi**re.
    a. NPP → 0, soil water stress. Probably there already. Want mortality from freeze events.
    b. Nutrient translocation before mortality ??? Good agreement that it is necessary and how to treat this. Tweak – standing dead – do we need to deal with this explicitly?
    c. Consequence of subgrid scale/cohort mortality on the hydrology, GBC in the rest of the gridbox – Ojima to report in June.
    d. Subgrid scale variability directly affects competition – how to deal with this? Need to coordinate with Land working group.
    e. Need to include also windthrow, and grazing
    f. Bugs jump on trees when negative carbon balance. Need to include parameterization of insect infestation as a function of climate – mild winters allow insect infestation, etc.

27. **Wetland PFT's**. What to do with flooding. Mike Coe's river routing model does transient wetlands … Carbon BGC associated with wetlands is important. Now wetlands have no vegetation, just flooded. Need to incorporate wetlands into PFT.

28. **Agricultual PFT's**.

a. Missing agricultural models – 4 of 5 classes of crop functional types - maize ... different management types. Need to track carbon removed, and export/transport of carbon.
b. Food import/export – Melillo to contact Cynthia Rosenzweig. Wood fiber import/exports– Linda Joyce, Forest service in Ft Collins

29. **Subgrid variability in PFT** – Bob Dickinson / Andrea H. Inez/Scott. Dennis

30. **River** organics, and sensitivity for atmospheric transport - Sundquist, Stallard, and Dargarville.

31. **Biogeography**. First generation biogeography models use climate thresholds. 6K and other PMIP – dynamic vegetation crucial for albedo and climate feedbacks. Number of biome boundaries were tricky – e.g. one of the forest/grassland rules. In LPJ: for each climate space → potential PFT's that can exist. Then compete to see who can survive. Need to evaluate bake off (ala LPJ) versus migration logic. How to get the timing of boreal forest migration into the tundra? Do we need to deal with timberlines going up and down mountains? How to interpret pollen data: presence on site versus abundance of pollen? Low abundance may mean disturbance has not had time to wipe out. Rik Leemans has a paper in GC Biology on seed dispersal rates.
32. VEMAP to test sensitivity of bake-off versus migration. VEMAP and CCMLP as test-bed for these ideas of bake-up, seed disperal, and migration time scale; and their impact on carbon budgets.
33. Peter Thornton to provide update on dynamic vegetation in June.

34. Millenium assessment – Jerry to report after their April meeting. We need to define what we need in terms of BGC development in order to fully exploit the CCSM runs forced by scenarios of human modifications – Melillo and group

35. IGBP-IHDP – LUCC global dataset biome. Lydia Gates to explore.

36. Software – to run on LINUX. Get info out to University community.

37. Need an MPI version of MATCH. Right now Dargarville's experiments - 27 years take 2 months.

Distributed memory machines.
High resolution atm modeling – T239 (50 km) test simulations as global downscaling techniques.
Long-term plans for C4MIP. Using Warren Washington's model. Works well.