Report on CCSM Biogeochemistry Working Group Meeting
Sixth Annual CCSM Workshop, The Village at Breckenridge
Co-Chairs: Inez Fung and Scott Doney
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The Biogeochemistry (BGC) Working Group (WG) has invested the past 2-3 years on developing a community-based scientific agenda and a community-based model development strategy to meet that agenda.

The scientific agenda of the BGCWG is organized around a series of BGC-Climate experiments (termed the Flying Leap Series) using the CCSM. The identification of the scientific agenda helps focus the module development and scientific investigations.

1. **Coupled BGC-Climate Experiments**

The first experiment (termed Leap0) is led by Inez Fung and Scott Doney, and will have interactive land and ocean carbon cycles, so that the radiatively-important CO_2 in the atmosphere is a prognostic variable. It was decided that Leap0 would use existing codes, most importantly CCSM1. The ocean BGC component, developed by Doney and his group, predicts Dissolved Inorganic Carbon (DIC) and Alkalinity (ALK), and diagnoses marine productivity as that required to restore phosphate fields to those observed. Partial pressure of CO_2 in the surface water is diagnosed from DIC, ALK, temperature and other surface variables. Thirty years of coupled BGC-CCSM1 simulation have been completed by this meeting, and the simulation remains realistic and appears to be stable. Fung worries that since ALK is sensitive to salinity, imbalances in the freshwater budget of the upper ocean may lead to imbalances in the air-sea CO_2 exchange and a run-away effect. We are working to figure out a TALK companion to the freshwater flux correction. Progress has also been made in coupling land BGC to CCSM1. Since March 2001, Fung and her group have translated a version of the land biogeochemistry model CASA (Field et al.) into Fortran90 and have successfully implemented it in the CCSM1. The land BGC module takes as its starting point gross primary productivity (GPP), energy and soil water status calculated by the LSM already in the CCSM1. The code architecture is flexible, so that the modules (such as allocation, mortality) can be replaced with others from the community. In the version the land BGC component has three live carbon pools (leaves, roots, wood) and 9 dead carbon pools.

Leap1, the next coupled experiment in the series, to be led by Natalie Mahowald and Charlie Zender, will have, in addition, the dust cycle coupled through marine productivity to the carbon cycle. Mahowald has continued development and testing of the dust cycle module, and Keith Moore in Doney's group has developed a new marine ecosystem model that is sensitive to inputs of micronutrients such as iron and silica.

2. **Atmospheric Model Applications**

The tracer transport model MATCH (Rasch and Mahowald) is an off-line model that can use circulation statistics from any GCM. The past year saw multiple MATCH contributions to the IGBP-GAIM TransCom3 CO_2 inversions. Dargarville (NCAR), Chen (MIT), Bruhwiler (NOAA), and Baker (Princeton, NCAR) all used various atmospheric circulation inputs to MATCH and together proved that circulation differences are as important as source/sink differences to the interpretation of atmospheric CO_2 variations. A robust result from Transom3 is that the US is not a large carbon sink, as previously postulated by Fan et al.

Other applications of MATCH were in assimilation of AVHRR aerosol data (Collins and Rasch), forward modeling of dust cycle changes between the LGM and the 21st century (Mahowald), and forward modeling of SF6 to diagnose transport in the CCM (Dargarville).

Water-isotopes have been added to the atmospheric module (CCM3) by David Noone working with Jim Randerson (Caltech). Water isotopes will be very useful for understanding climate proxies, for diagnosing the water cycle, and for interpreting CO_{16}-O_{18} variations.

3. **Atmospheric Tracer Transport Model**

4. **Ocean BGC**

Development of ocean BGC has gone in several synergistic fronts. A new BGC model based on the algorithms used in the IGBP-GAIM Ocean Carbon Model Intercomparison Project (OCMIP2) has been migrated to POP, and will replace the diagnostic phosphate-restoring model (Lindsay).

Moore presented the new ocean ecosystem model that is sensitive to inputs of Fe and Si. Model is computationally not unreasonable, and its results show that 50% of the world ocean is Fe-limited.

Diagnostic tracers will be an integral part of the ocean BGC work. C14 and CFC are carried as routine tracers in the ocean BGC.   Fung has successfully implemented C-13 into the ocean carbon module to diagnose the competition among various ocean exchange processes in determining CO_2 of the surface waters. Other tracers are also planned, with Britt Stephens leading the oxygen effort.

5. **Land BGC**

Bonan has developed a flexible architecture for BGC modules in CLM2 for coupling into the CCSM-2. The flexible architecture is crucial for community development and assessment of the BGC modules. It is important to note that while the architecture is patterned after existing codes (e.g. dynamic vegetation in LPJ), sub-modules developed by the community can be readily implemented.

In March 2001, the BGCWG held its annual meeting in Berkeley and focused the meeting on the development of the land BGC module for coupling to the CCSM. This has been reported previously. In sum, there is broad community enthusiasm for development and applications of the CLM2-BGC. In particular, Thornton (UMt, now NCAR) has an interactive land nitrogen-carbon module ready for CLM2.   Thornton and Bonan will lead (with community input) the incorporation of disturbance component into CLM2. This module will include frequency and intensity of disturbance as well as recovery dynamics. Thornton and Bonan will also lead the incorporation of dynamic vegetation into the CLM2 so that both the fast and slow changes in land cover will affect both the biophysics and biogeochemistry in an internally consistent manner. Mahowald and Zender are continuing to develop the interactive dust module, and Bonan's CLM2 has incoroporated soil properties to anticipate the dust effort. Bonan's CLM2 has incorporated a river-routing scheme. However, at the moment, the CLM2 is running distilled water into the oceans. There is a need to include biogeochemistry in the runoff (Sundquist has volunteered) and to incorporate a coastal ocean model (e.g. McWilliams effort) to take advantage of this aspect.

6. **Issues**

The BGCWG is busy in model development, model diagnostics and model application. There is a concern that there is asynchroneity between BGC efforts and efforts in the other Working Group's. In particular, the BGCWG would like to be kept abreast of model developments in the atmosphere and ocean arenas, and to participate in the evaluation of these modules for the CCSM-2.

We recommend the addition of a standard suite of tracers in CAM2 and COM2 to diagnose transport. For CAM-2, the tracers would be SF6 (interhemispheric transport), radon (convective transport), "simple strat O3" (for strat-trop exchange), and tracers blobs at low, mid and upper troposphere. For COM-2, the tracers would include CFC (10^1 – 10^2 years), 14C (10^2-10^3 years).

We recommend the addition of a "Constrained Transport Module" into the CCSM for diagnosing land or ocean sources/sinks.

We need a procedure for community access to "beta" versions of CAM2, CLM2, COM2 codes for BGC development. Code documentation would be crucial. Also, we recommend that the SSG endorse a procedure wherein a prospective BGC code developer would email the BGCWG co-chairs stating the scientific plan. The prospective developer should also state his/her promise not to distribute the code and to share the new codes with the CCSM community.

The BGC community is concerned about how we keep with the fast evolution in computer codes, platforms, and how we find the computer time to carry out our runs. In general, the BGC components are added after the CCSM-n has been spun up and evaluated, hence the lag.

Potential growth areas for BGC are in carbon/BGC data assimilation. There are several hopeful CO2 satellites proposed. CCSM is the only comprehensive C-climate model in the U.S. Collaboration with the NASA Data Assimiliation Office (DAO) is desired to position the CCSM at the front of a new endeavor.

Participants

David F. Baker
NCAR/ASP/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1666 Fax:
Email: dfb@ucar.edu

Gordon Bonan
NCAR/CGD
P.O. Box 3000

Boulder, CO 80307
USA
Phone: 303-497-1613 Fax: 303-497-1324
Email: bonan@ucar.edu

Michael G. Bosilovich
NASA GSFC
Data Assimilation Office
NASA GSFC Code 910.3
Greenbelt, MD 20771
USA
Phone: 301-614-6147 Fax: 301-614-6297
Email: mikeb@dao.gsfc.nasa.gov
URL: http://dao.gsfc.nasa.gov/

Francis P. Bretherton
University of Wisconsin
Atmospheric and Oceanic Sciences
1225 W. Dayton St
Madison, WI 53706
USA
Phone: 608-262-7497 Fax: 608-262-5974
Email: fbretherton@ssec.wisc.edu

Lori M. Bruhwiler
NOAA Climate Monitoring and Diagnostics Laboratory
Carbon Cycle Group
325 Broadway R-CG1
Boulder, CO 80303
USA
Phone: 303-497-6921 Fax: 303-497-6290
Email: lbruhwiler@cmdl.noaa.gov

William D. Collins
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1381 Fax: 303-497-1324
Email: wcollins@ucar.edu

Alan Condron
Climate System Research Center
Geosciences
Morrill Science Center
University of Massachusetts Amherst, MA

USA
Phone: 413-545-0659 Fax: 413-545-1200
Email: alanc@geo.umass.edu

Yong-Jiu Dai
Georgia Institute of Technology
School of Earth and Atmospheric Sciences
221 Bobby Dodd Way
Atlanta, GA 30332-0340
USA
Phone: 404-385-1665 Fax: 404-894-1779
Email: dai@eas.gatech.edu
URL: http://climate.eas.gatech.edu/dai/dai.htm

Roger J. Dargaville
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1732 Fax: 303-497-1695
Email: rjd@ucar.edu

Robert M. DeConto
University of Massachusetts
Department of Geosciences
233 Morrill Science Center
University of Massachusetts Amherst, MA 01003
USA
Phone: 413-545-3426 Fax: 413-545-1200
Email: deconto@geo.umass.edu

Gilles Delaygue
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307-3000
USA
Phone: 303-497-2695 Fax: 303-497-1348
Email: delaygue@ucar.edu

Scott Denning
Colorado State University
Department of Atmospheric Sciences Fort Collins, CO 80523-1371
USA
Phone: 970-491-6936 Fax: 970-491-8449
Email: denning@atmos.colostate.edu

Robert E. Dickinson
Georgia Institute of Technology
Earth and Atmospheric Sciences Dept
221 Bobby Dodd Way
Atlanta, GA 30332-0340
USA
Phone: 404-385-1509 Fax: 404-385-1510
Email: robted@eas.gatech.edu

Noah S. Diffenbaugh
University of California - Santa Cruz
Earth Sciences Santa Cruz, CA 95064
USA
Phone: 831-459-3504 Fax:
Email: suresh@es.ucsc.edu

David J. Erickson
Oak Ridge National Laboratory
Computer Science and Mathematics Division
P. O. Box 2008
Oak Ridge, TN 37831
USA
Phone: 865-574-3136 Fax: 865-574-0680
Email: ericksondj@ornl.gov

Inez Fung
U.C. - Berkeley
Center for Atmospheric Sciences
307 McCone Hall, MC 4767
Berkeley, CA 94720-4767
USA
Phone: 510-643-9367 Fax: 510-643-9377
Email: inez@atmos.berkeley.edu
URL: http://www.atmos.berkeley.edu

Matthew W. Hecht
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1714 Fax: 303-497-1700
Email: hecht@ncar.ucar.edu
URL: http://www.cgd.ucar.edu/oce/hecht

Michael Herzog
University of Michigan

Department of Atmospheric, Oceanic, and Space Sciences
2455 Hayward Street
Ann Arbor, Michigan 48109
USA
Phone: 734-936-0491 Fax: 734-764-5137
Email: herzogm@umich.edu
URL: http://aoss.engin.umich.edu/faculty_staff/faculty/Herzog.html

Forrest M. Hoffman
Oak Ridge National Laboratory
Environmental Sciences Division
Building 1505, Room 216
Mail Stop 6036
P.O. Box 2008
Oak Ridge, Tennessee 37831-6036
USA
Phone: 865-576-7680 Fax: 865-576-3989
Email: forrest@esd.ornl.gov
URL: http://research.esd.ornl.gov/~forrest

Paul R. Houser
NASA Goddard Space Flight Center
Hydrological Sci.
Code 974
Greenbelt, MD 20771
USA
Phone: 301-614-5772 Fax: 301-614-5808
Email: Paul.Houser@gsfc.nasa.gov

Jasmin G. John
U.C. - Berkeley
Earth and Planetary Science
Center for Atmospheric Sciences
307 McCone Hall, #4767 Berkeley, CA 94720-4767
USA
Phone: 510-643-8336 Fax: 510-643-9377
Email: jjohn@uclink4.berkeley.edu

Anthony W. King
Oak Ridge National Laboratory
Environmental Sciences Division
Bldg 1509, MS 6335
PO Box 2008 Oak Ridge, TN 37831-6335
USA
Phone: 865-576-3436 Fax: 865-574-2232
Email: kingaw@ornl.gov

Samuel Levis
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1627 Fax: 303-497-1324
Email: slevis@ucar.edu

Shian-Jiann Lin
NASA GSFC
DAO
Code 910.3
Greenbelt, MD 20771
USA
Phone: 301-614-6161 Fax:
Email: lin@dao.gsfc.nasa.gov

Keith T. Lindsay
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307-3000
USA
Phone: 303-497-1722 Fax: 303-497-1700
Email: klindsay@cgd.ucar.edu
URL: http://www.cgd.ucar.edu/oce/klindsay/klindsay.html

Qing Liu
Georgia Institute of Technology
Earth and Atmospheric Sciences
221 Bobby Dodd Way
Atlanta, GA 30332
USA
Phone: 404-894-1512 Fax:
Email: gte710s@prism.gatech.edu

JoAnn A. Lysne
Los Alamos National Laboratory MS B296
Los Alamos, NM 87545
USA
Phone: 505-665-7563 Fax: 505-667-5921
Email: jlysne@lanl.gov

Natalie M. Mahowald
U.C. - Santa Barbara
Bren School Santa Barbara, CA 93106

USA
Phone: 805-893-7234 Fax: 805-893-7612
Email: natalie@bren.ucsb.edu

Pamela A. Martin
University of Chicago
Geophysical Sciences
5734 S. Elllis Ave
Chicago, CA 60637
USA
Phone: 773-83-42788 Fax: 773-702-9505
Email: pmartin@uchicago.edu

Rebecca McKeown
Colorado State University
Natural Resource Ecology Laboratory Fort Collins, CO 80523
USA
Phone: 970-491-1623 Fax: 970-491-1965
Email: beckym@nrel.colostate.edu

Jose Milovich
Lawrence Livermore National Laboratory
Atmospheric Science Division
7000 East Ave. L-103
Livermore, CA 94550
USA
Phone: 925-423-6689 Fax: 925-422-6388
Email: milovich1@llnl.gov

Jefferson K. Moore
NCAR/CGD/ASP
P.O. Box 3000
Boulder, CO 80307-3000
USA
Phone: 303-497-1692 Fax: 303-497-1646
Email: jkmoore@ucar.edu
URL: http://www.cgd.ucar.edu/oce/jkmoore

Ana L. Mosor
University of Arizona
Atmospheric Sciences
1118 E 4th Street
Tucson, Arizona 85721
USA
Phone: 520-620-0043 Fax: 520-621-6833
Email: mosor@atmo.arizona.edu

Norikazu Nakashiki
CRIEPI
Environmental Science Dept.
1646 Abiko
Abiko, Chiba 270-1194
JAPAN
Phone: 471-82-1181 Fax: 471-83-2966
Email: nakasiki@criepi.denken.or.jp

Jason C. Neff
US Geological Survey
Geologic Division
MS 980
Denver Federal Center Lakewood, CO 80225
USA
Phone: 303-236-1306 Fax: 303-236-5349
Email: jneff@usgs.gov

David C. Noone
California Institute of Technology
Geological and Planetary Sciences
Mail Stop 170-25
1200 E. California Blvd. Pasadena, CA 91125
USA
Phone: 626-395-6496 Fax: 626-568-0935
Email: dcn@caltech.edu

Keith W. Oleson
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1332 Fax: 303-497-1324
Email: oleson@ucar.edu

Bette L. Otto-Bliesner
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1723 Fax: 303-497-1348
Email: ottobli@ucar.edu

Steven Pawson
NASA GSFC

DAO and GEST
Code 910.3
Greenbelt, MD 20771
USA
Phone: 301-614-6159 Fax: 301-614-6297
Email: pawson@dao.gsfc.nasa.gov

Elisabetta Pierazzo
University of Arizona
Planetary Sciences
Lunar and Planetary Laboratory,
Tucson, AZ 85721
USA
Phone: 520-626-5065 Fax: 520-621-8364
Email: betty@lpl.arizona.edu
URL: http://www.lpl.arizona.edu/~betty/index.html

Philip Rasch
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307
USA
Phone: 303-497-1368 Fax: 303-497-1324
Email: pjr@ucar.edu

David Schimel
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307-3000
USA
Phone: 303-497-1610 Fax: 303-497-1695
Email: schimel@ucar.edu

Muhammad J. Shaikh
Georgia Institute of Technology
Earth and Atmospheric Sciences
221 Bobby Dodd Way
Atlanta, GA 30332-0340
USA
Phone: 404-385-1511 Fax: 404-385-1510
Email: shaikh@eas.gatech.edu

Britton B. Stephens
NOAA/CMDL
NOAA CMDL MC R-CMDL1
325 Broadway Boulder, CO 80305

USA
Phone: 303-497-6999 Fax: 303-497-5590
Email: bstephens@cmdl.noaa.gov

Eric T. Sundquist
U.S. Geological Survey 384 Woods Hole Road
Woods Hole, MA 02543
USA
Phone: 508-457-2397 Fax: 508-457-2310
Email: esundqui@usgs.gov

Peter E. Thornton
NCAR/CGD
P.O. Box 3000
Boulder, CO 80307-3000
USA
Phone:303-497-1727 Fax: 303-497-1348
Email: peter@ucar.edu

Wanli Wu
University of Colorado-Boulder
CIRES/216 UCB
Boulder, 80309
USA
Phone: 303-492-0281 Fax: 303-492-1149
Email: wanli@cires.colorado.edu
URL: http://cires.colorado.edu/~wwu

Wanru Wu
Georgia Institute of Technology
Earth and Atmospheric Sciences
221 Bobby Dodd Way
Atlanta, GA 30332-0340
USA
Phone: 404-385-2383 Fax: 404-385-1510
Email: wwu@eas.gatech.edu

Zong-Liang Yang
University of Arizona
Hydrology and Water Resources
1133 E. North Campus Dr.
P.O. Box 210011 Tucson, AZ 85721-0011
USA
Phone: 520-621-8922 Fax: 520-621-1422
Email: liang@hwr.arizona.edu
URL: http://www.hwr.arizona.edu/~liang

Hongbin Yu
Georgia Institute of Technology
Earth and Atmospheric Sciences
221 Bobby Dodd Way
Atlanta, GA 30332
USA
Phone: 404-894-1758 Fax: 404-894-1779
Email: yh11@prism.gatech.edu
URL: http://climate.eas.gatech.edu/yu/yu-cv.htm

Xubin Zeng
University of Arizona
Atmospheric Sciences
P.O. Box 210081
Tucson, AZ 85721
USA
Phone: 520-621-4782 Fax: 520-621-6833
Email: xubin@atmo.arizona.edu