

GAIM/AIMES MEETING MINUTES
Frontier Research Center for Global Change
24-27 October, 2004

Monday

Opening Roadmap

Colin opened the meeting with a charge to the group for communication and brainstorming towards a better understanding of the coupled Earth System AND the future of GAIM into AIMES. Expected outcomes and future plans was presented by Will. Translating from ideas to products in a roadmap from GAIM to AIMES was emphasized. The evolution of coupled Earth's System projects began with the Global Carbon Project (GCP) in 1998 and the transfer of carbon-cycle research activities from GAIM to the GCP. An Earth System Science Partnership (ESSP) was formed in 2001 with co-partners DIVERSITAS, the IHDP, IGBP and WCRP. The fundamental discussion for AIMES include its relationship with the ESSP, other IGBP projects, types of research AIMES should undertake and IPO funding.

With regard to AIMES and the ESSP, at this time AIMES will be sponsored by the IGBP only but will have 'hooks' to the other ESSP partners and not let programmatic get in the way of good science. AIMES will continue with a mix of existing 'traditional GAIM' activities (e.g., C⁴MIP) and the newer 'visionary AIMES' activities (e.g., IHOPE). At this time, the relationship between AIMES and other IGBP projects is unresolved. For instance, interactions with PAGES and IGBP Integration panels. The challenge will be to develop collaborative partnerships between AIMES and IGBP/ESSP projects through open communication and mutually beneficial research activities. Resources and funding are also unresolved. Dave Schimel reported that funding for the IPO is encouraging, however venture capital to initiate an institutional and post-doctoral network as well as funding for workshops would be a primary focus of the Boulder IPO.

EARTH SYSTEM PROCESSES

Dust as an Earth System Component

Natalie Mahowald presented results from the NCAR Community Climate System Model (CCSM) to model the variability of dust and its associated feedbacks on climate and biogeochemistry. Dust sources were modelled as a function of the LGM, pre-industrial, current and with 2X CO₂. Previous studies have shown that humans can impact dust through direct modification of soils and vegetation (land use, water use, CO₂ fertilization) and indirect modification of climate. Future dust was predicted to be 20-60% lower than current climate in Mahowald and Luo (2003) for 2100

or $\pm 20\%$ from Tegan et al. 2004 in 2050. Differences between these simulations include differences in models and methodology and are not well understood.

Models include direct radiative forcing of mineral aerosols, but there are large uncertainties due to the optical properties of dust, surface albedo and particle size distributions. Indirect forcing through cloud-aerosol interactions may be important, but are poorly understood.

Iron is thought to be important for ocean biogeochemistry, but the bioavailability of iron in dust is not well understood (e.g., what state of Fe is bioavailable in the ocean?).

Spinup for coupled Earth System models with dust are in place with C⁴MIP. Natalie reiterated the problems of error propagation from small scale observations to global grids and the notion that contemporary dust plumes are now interacting with anthropogenic forcings (e.g., Asian dust moving east and interaction with urban and other aerosol inputs).

Role of Phytoplankton and Global Biogeochemistry

Paul Falkowski provided the group with a primer on phytoplankton and their evolutionary history. Marine phytoplankton biomass accounts for less than 1% (ca 1Pg) and track climate change perfectly with no hysteresis. There are two oceanic carbon cycles: silicate transformation to carbonates (slow) on timeframes of hundreds of millions of years and fast carbon cycles as Redox reactions (e.g., photosynthesis) that occur on microscopic and global scales. Coupled redox reactions begs the question: are photosynthesis and respiration globally balanced?

Coupling O₂, N₂ and C cycles are problematic. The historic rise of oxygen altered the nitrogen cycle resulting in a big flip, or shutdown of the thermohaline circulation (THC) resulting in N loss from oceans (this has happened many times in the Earth's history). Paul presented model results of linked oceanic nutrient cycles suggesting that the (1) rise of O₂ is critically dependent on the N cycle, (2) time delay between the evolution of oxygenic photosynthesis and oxidation of Earth's atmosphere is sensitive to the areal extent of shallow seas, but not physical mixing, (3) concentration of O₂ in the atmosphere, and to a small extent the timing of oxidation, is sensitive to the initial PO₄ concentration (4) given an initial PO₄ concentration of ca. 0.2 mM the atmosphere would not become oxidized within 150 Myr- WITHOUT SINKS! Modeled feedbacks that have not yet been considered include iron and the effect of O₂ concentrations on nitrogenase and the nitrogen cycle.

The nitrogen cycle and ocean biogeochemistry is further impacted through a seasonal asymmetry of Fe flux (dust) by latitude and shifts in the distribution of aerobic vs. anaerobic processes with depth. As such, over the past 200M years, the oceans' nitrogen, carbon and oxygen cycles have been out of equilibrium.

Paul concluded that the nitrogen cycle constrains the timing of the rise of oxygen on

Earth, and provides a major feedback that constrains the O₂ concentration in Earth's atmosphere. In the modern ocean, over 50% of the nitrogenase in cyanobacteria is inactive at any moment in time and the global N, C, and O cycles are constantly fluctuating. Variability in ocean biogeochemistry is on time scales of hundreds of millions of years to thousands of years. Finally, humans have made a major impact on the N and C cycle over the past 200 years – and the effects on oceanic ecosystems are only just beginning to be understood.

Tim Jickells: The Iron Cycle

Tim opened with the concept that iron is a biogeochemical valve or 'pinch point' and iron limitation on land far less critical than in ocean. Tim presented results from 3 of models on global iron fluxes into the oceans from the iron fast track initiative that were consistent with satellite imagery. About 25% of dust emissions are deposited in oceans (global = 1700 Tg/y). As Natalie mentioned earlier, the bioavailability of iron, particularly in oceans is poorly understood. Dust interacts with ocean biogeochemistry through primary production, and alleviates iron stress. It allows macronutrient utilization and CO₂ uptake in regions including high nutrient/low chlorophyll (HNLC) and other Fe limited areas. The effects of Fe on Ocean biogeochemistry include primary production and nitrogen fixation. The controls on export production include species composition, ballast effect and the biogeochemistry of dimethylsulfide (DMS), nitrous oxide (N₂O), methane (CH₄), hydrogen sulfide (H₂S), halocarbons, alkyl nitrates and ozone (O₃), isoprene, and carbon monoxide (CO). The key species to focus on the biogeochemistry of export production is on diatoms.

Tim suggested that research priorities should emphasize dust fluxes and bioavailability of dust to the ocean and biogeochemistry beyond C fixation. These process studies should be both as a prelude to and in association with inclusion of dust/iron in earth system models. From these priorities, impacts on the global system carbonate flux vs. organic flux might be a good first question or issue to address.

Tim's presentation sparked productive discussion from Paul Falkowski regarding science questions that might drive an iron fast track including:

1. Do we use nutrients efficiently? Look at HNLC regions and response to inputs over decadal time scales; clearly Fe is limiting. What controls Fe in these regions is key. Whether the sign of the change is positive or negative is unclear
2. Questions with regard to N₂-fixation: most of the global ocean N₂ fixation limited by iron. There has been NO experiment and this is a huge uncertainty.
3. The PIC/POC fluxes and their controls – perhaps doable but NOT on a fast-track schedule.

Dork Sahagian – Nitrogen

Dork Sahagian reported on progress of the nitrogen fast track for Pam Matson. Regions include Africa, Asia, Europe, Latin America where many export budgets are largely

unknown. Riverine and denitrification fluxes (budgets) are also highly uncertain – especially for Africa. It may be a doable activity to focus on Africa, particularly S. Africa, perhaps riverine systems in W. and S. Africa. How can/does IGBP play a role in INI – centers supposed to have a ten-year lifetime. This project has been ‘inherited’ by the International Nitrogen Initiative (INI - <http://www.initrogen.org>) and is not necessarily a fast track in the IGBP time domain. AIMES participation could be to identify Earth Systems questions that would be complimentary to INI goals, for instance N-transformations where there are still large uncertainties, nitrogen to phosphorous ratios from high latitudes to tropics. There was some discussion of INI collaboration with GAIM/AIMES, for instance C4MIP models that integrate nitrogen, or collaboration with other activities such as GEIA or IGBP projects (e.g., LAN D).

Colin Prentice – Fire

Colin Prentice summarized the fire fast track to date. A workshop has been proposed for Spring 2005 by Sandra Lavorel and Colin with a strong modeling emphasis. The goal of the workshop would be to understand the human and natural drivers of biomass combustion. Colin identified three goals of the Fire Fast Track: (1) To ensure we have good information from observation and modeling fire communities, (2) Enable communication between managers and modelers; and (3) to produce at least one prognostic model of fire that incorporates human activities.

Jonathon Foley – Consequences of Global Land Use

Jonathon discussed the variable time scales of managed systems on land ranging from ca. 30 to 1000 years (Amazonia and China/Japan, respectively) and land use associated with water use. Fully one-third of the terrestrial biosphere has been ‘replaced’ with croplands and pastures and land use is a major carbon source (ca 1/3 of emissions). Human actions, primarily fertilizers have doubled flow of nitrogen through biosphere and irrigation has caused major disruptions to the water cycle. These land use impacts have swamped any effect of climate change.....so far.

Jon presented land use and landscape changes as a tradeoff: before and after with regard to infectious disease mediation, crop, forest and pasture production, irrigation, etc. Tradeoffs could, for example, relate to yield versus water quality for crop yields and nitrogen fertilizer use. Global significant tradeoffs may be different for various systems, landscapes, or regions. Global land use and ecosystem resilience must confront the possibility of surprises and abrupt change. How are we to understand and quantify system vulnerability?

Jon proposed to enhance our portfolio of land use and diversity by using Earth System models to analyze scenarios. He presented a tentative proposal: an adaptive land management strategy, “Athena”, as a network, or a conceptual framework that integrates human actions, land use practices, terrestrial ecosystems (managed and natural), coastal oceans, terrestrial hydrosystems and the atmosphere. Athena could feedback to human welfare, ecosystem goods and services. Athena would develop a common synthetic data product, new community modeling frameworks and a common framework for assessing

tradeoffs. Candidate regions include: LBA, Southeast Asia, Yaqui Valley, ATEAM Arctic, GEWEX, US Midwest (in collaboration with NACP). AIMES would emphasize the global, intersecting with LAND, iLEAPS, LOICZ. This activity would also speak to the ESSP (GCP, Water, GECHS).

Will Steffen/Rik Leemans - IHOPE

Will and Rik challenged the group with the need for a new view of history that moves us towards an integrated human/environmental history. IHOPE will set in motion a reconceptualization of our history. Long-term goals of IHOPE are to map the human record over the last 10,000, last 1000 and last 100 years. The first major activity for IHOPE is a Dahlem conference, to be held in Berlin on 12-17 June 2005. The conference will follow the usual Dahlem format, with four working groups organized by a time slice: (1) millennial, over 10,000 years, capturing the transition from hunter-gathering to agriculture (2) centennial, over the last 1000 years, encompassing the industrial revolution: (3) decadal, over the last 100 years, picking up the “1950s discontinuity”; and (4) the future, looking ahead to the evolution of the human-environment relationship through this century and beyond. The product of the Dahlem IHOPE conference will be a book published by Island Press that includes a series of background papers encompassing concept papers (e.g., causation/modeling; abrupt transitions), case studies (e.g., Mayan, Australasian); and both chronologies of natural and social change on a range of timescales, as well as the synthesis papers of the four working groups at the conference. Participants will include archeologists, historians, anthropologists, sociologists, ecologists, palaeo scientists, applied mathematicians, economists, geographers and atmospheric chemists. Workshop participants will be charged to identify databases required to understand the evolution of the human-environment relationship through time and to test linked narrative, agent-based and quantitative prognostic models.

Marko Scholze - Earth Observation Data and Carbon Cycle Modeling

Marko presented recent results from the June, 2004 TransCom workshop held in Tsukuba, Japan. He presented the results as anomalies from the mean: both seasonal forward and inverse calculations (mean of 1992-1996) and interannual results 1988-2003. Interannual results suggested that variability of the land fluxes were larger than the ocean and interannual changes were more robust than seasonal. With regard to model-data synthesis activities, an inverse ocean modeling project from a recent ocean dissolved organic carbon survey (ca. 60,000 observations). Suggested a southerly carbon transport of 0.37 PgC/y for pre-industrial times with northerly present-day transport ca -0.06 PgC/y.

Marko also presented results from monte carlo simulations on priors from the FluxNet observing network (<http://daacsti.ornl.gov/FLUXNET/>) to show how uncertainties may be reduced for NEE flux observations. A carbon cycle data assimilation system was presented using the BETHY biosphere model and TM2 transport model. A two-stage assimilation system from: (1) AVHRR data (Knorr 2000); and (2) atmospheric CO₂ data.

The upper bound of biosphere parameters were derived from eddy covariance calculations. The number of free parameters with eddy covariance 5 or 2 parameters, or all parameters that govern the fast, seasonal and diurnal fluxes. Marko's approach can only provide constraints on light use efficiency, etc. and are not expected to match observed growth rates which incorporate long-term processes. The residuals were much more interesting than the fit, in that they tell you which processes are missing. Error reduction in parameters driving heterotrophic and autotrophic respiration were as much as 90% (e.g., based on temperature dependence).

Dominique Raynaud– Ice cores and the European Project for Ice Coring in Antarctica (EPICA) Challenge

Dominique provided the group with a review of the ca. 420,000 year Petit et al. (1999) Vostok record and presented some exciting results from a new core that extends the Vostok record up to 8 glacial cycles, or ca. 750kyr from the 'Dome C' site (EPICA Members 2004). The first 420,000 years from Dome C are very similar to the Petit et al. (1999) Vostok record. To construct a timescale they used an ice flow model with snow accumulation history. An inverse method looks for best fit of this dating model with independent control age windows. The top 800m were constrained to be close to existing European Dome C (EDC1) timescale, also further constraining 'doors' were used from glacial terminations II, III, IV, VII and VIII. On the EDC2 time scale, the deuterium values (a temperature proxy) remains above the -403 (the minimum value over the Holocene) for 28 kyr. Over the Holocene, δD remains over this same values for 12 kyr and the rate of change is similar in both terminations. Thus, our current interglacial could extend for another 15 kyr WITHOUT taking into account human activities. The period between 750,000 and 430,000 years ago is characterized by less pronounced warmth in interglacial periods. Still to come, the new EDC2 may reach up to 960kyr. Some of the driving questions that the EDC cores pose include whether CH₄ and CO₂ maintain fixed glacial/interglacial levels before the mid-Brunhes Event (MBE; ca. 430 kya) or parallel closely the temperature, and what drives the transition between the 40 and 100kyr world? Finally, Is there any trend in average CO₂ that could have forced the mid-Pleistocene Revolution (MPR; ca. 900 kya) or MBE?

The EPICA-EDC record will be the new gold standard for global climate over the last 800 kyr, perhaps longer and ideas for future Antarctic projects include arrays of "coastal" cores covering at least the last glacial maximum. The ice core community will also search for a site with older ice in each of Antarctic and Greenland. Dominique concluded that the challenge for the Vostok/Dome C EPICA project will be to investigate the (1) controls of the CO₂-temperature relationship (before and after Mid Bruhnes Revolution), (2) oceanic CO₂ carbon cycle and its relationship to deglaciation and the impacts of iron and nitrogen cycles with regard to dust, nitrous oxide and nitrate; and (3) what is driving the transition between the 40 and 100k year worlds.

The group queried whether methane from ice cores could be a proxy for soil moisture? Dominique responded that methane changes are largely due to wetland emissions from both tropics and boreal regions, but the question remains to know to what extent it can also be used as a proxy for soil moisture.

Claire Granier and GEIA: Global Emissions Inventory Activity

Clair presented a short history of the Global Emissions Inventory Activity (GEIA). Detailed activities of GEIA are to include: new inventories, model and data intercomparison and evaluation, to prioritize observations, develop temporal datasets, and develop initialization schemes for chemical exchange models. The challenge of GEIA will be to develop the databases for intercomparisons rather than the models themselves with IGBP projects such as ILEAPS and AIMES to provide regional to global modeling structures. GEIA also has strong linkages with ocean and humans with a broad programmatic scope that could include coastal zones, oceans and social sciences.

Integrating GEIA with the new AIMES project will require an understanding of the complicated blend of models and observations that comprise the global emissions databases as there are no databases for either global emissions or deposition fluxes. It was proposed that detailed meta data on gridded products be provided by GEIA and AIMES. For instance, information on emission models, factors, etc. can be extracted and inserted into coupled modeling framework.

Colin Prentice and the Earth System Atlas

Colin presented a summary of the current status of the Earth System Atlas as Summary: one-stop shopping for Earth System datasets. The Earth Systems Atlas will contain 3 components: (1) content, (2) technical infrastructure; and (3) explanatory context for broad availability (policy, teaching, science). Fundamentally, content will be determined by peer-review process and the majority of the work to be contributed by the scientific community. The primary stumbling block (funding) for the Earth System Atlas has been made available from the NRC for parts 2 and 3. Funding for content (#1) are available from Lehigh University (Dork) and the University of Bristol (Colin) for initial startup. 'Sister' international programs to GAIM/AIMES incited this Atlas; the group agreed that it is time to open a dialogue with a host country about the possibility of a long-term financial commitment with the World Data Center identified as a possible central repository.

Summary

It is clear that it is important to solicit for funds in areas that the agencies will support. There are very few pockets and the global community must speak with a unified voice and thematic focus. Paul talked about biogeochemical cycles that beat on variable time scales. The way our research priorities are laid out should provide a sense of what might happen on the next hundred years. A focused AIMES research activity may reach out to SOLAS, etc. to initiate field campaigns. The role of AIMES is to determine key research priorities with a broad conceptual target (e.g., perhaps a C₄MIP for iron). What

observational and model needs are required for an iron-C₄MIP? Natalie's scenarios or the coupling of Fe and ocean biogeochemistry across all time scales would be useful. Further, derive modeled sensitivity predictions over the next 100 years that contradicts the paleo record would not be productive. Contemporary modeling needs to be complimentary with the paleo record as well as current observations.

A definable difference between GAIM and AIMES is the need to understand the why of change and not just a budget. For instance, optimizing fertilizer yield and ecosystem health or urbanization issues including emissions and the change in urban environmental temperature. Modeling activities from AIMES would test the sensitivity of tradeoffs in vulnerability and resilience in terms of economics and ecosystem consequences. AIMES is at the beginning of a process, not at the end.