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In this issue

GLOBAL IGBP CHANGE

A note From the New GAIM Co-Chair

By Colin Prentice

It has been exciting to participate in GAIM, and I'm expecting it to be even more exciting to work together with John Schellnhuber to jointly lead the task force into the new phase of IGBP. GAIM has evolved considerably during its decade-long existence, and I expect the evolution to continue as we now face very major new challenges.

GAIM's mandate is basically to promote integrative Earth System Science by whatever means are available to a small international task force. The "Waikiki Principles" that we formulated a few years ago (*Research GAIM, v. 3, #2*) encapsulated what GAIM had already been doing well, and it was sensible for us to continue along those lines. In other words: to identify new interdisciplinary challenges; to initiate new, feasible, fundable, cross-cutting projects by integrating the results produced within and beyond IGBP; and to promote the devel-

'Note from Co-Chair', p. 5

IGBP Fast-Track Initiatives

by Dork Sahagian

At the SC-IGBP meeting in Punta Arenas, the concept of formulating some focused projects that could produce tangible products on a reasonably short time frame (2-3 years) was proposed. IGBP/GAIM was charged with facilitating the Fast-Track Initiatives (FTIs), begining with a feasibilty study, identification of project leaders, expected results, and a time frame for completion. GAIM is initially launching three FTIs:

1. Fire: Focus on the non-linear effects and feedbacks of fire and ecosystem goods and services using an integrated research approach.
2. Iron: Focus on the role of iron in global biogeochemcial cycles, particularly where iron is a limiting factor, from an integrative review of the critical processes involved in iron mobilization and redistribution.
3. Nitrogen: Focus on the Nitrogen cycle in conjunction with ongoing and planned activities in SCOPE through the International Nitrogen Initiative.

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Fire

Fires are an intrinsic part of the dynamics of the Earth System. Fire regimes result from the interaction between biophysical factors and human land use, with varying weights across biomes and through time. Their impacts range across all scales from local to global, can be highly nonlinear, potentially affect all compartments of the Earth System, and can have large feedbacks to ecosystem goods and services and the human systems that depend on them. Fire research therefore requires an integrated approach across different IGBP projects in order to bring together human scientists, terrestrial ecologists and atmospheric scientists to tackle the complexity of interactions that are involved.

Previous integration efforts

Scientists from GCTE, LUCC and IGAC developed a conceptual framework for the study of regional vulnerability to fire (Lavorel et al.). This framework links the drivers of regional fire dynamics, fire-atmosphere-climate feedbacks, and fire -ecosystem services-human systems feedbacks. A first global map of fires regimes was produced.

A recent IGBP-GAIM-TRACES workshop in Isle-sur-la-Sorgue, France (22-26 October 2002) brought together 38 ecologists, palaeoecologists, climatologists, vegetation modellers, atmospheric chemistry and aerosol modellers, and remote sensing experts to discuss the role of fire within the earth system, and with a specific aim of developing priorities for improved simulation of fire within Earth System Models. The meeting emphasised the biological, physical and chemical dimensions of fire. Human activities in terms of ignition, suppression and land use change were discussed, but the socio-economic and institutional drivers of these activities were not.

Objectives for a fast track initiative

- To synthesis quantitative knowledge gained across IGBP projects and related research on impacts of changes in fire regimes worldwide on a range of ecosystem services
- To assemble global and regional data for fire-model development and testing; this data is also required to improve emission estimates

Products

- Global map of fire regimes – to be included in the Earth System Atlas (see back cover)
- Global compilation of parameters required for the calculation of emissions from plants and soils
- Synthesis publication in high profile journal on impacts of changes in fire regimes worldwide on a range of ecosystem services.

Operation

- Working groups on data – electronic communication
- Workshop for synthesis of impacts on ecosystem services prepared and followed by electronic communication.

Participating projects and groups

- Ecologists, palaeoecologists, climatologists, vegetation modellers, atmospheric scientists, and remote sensing experts identified for the 2002 workshops
- LUCC community involved in the analysis of drivers of fire regimes and of land transformations
- Broader IHDP community (e.g. institutions, GEHCS) and other human scientists (e.g. economists)

References

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A. Spessa, W. Cramer, S. P. Harrison, N. Mahowald & I. C. Prentice. The Burning Question: Report of a Workshop on the Role of Fire in the Earth System. EOS newsletter, *in press*.

Iron

The role of iron in the Earth system has risen to prominence in the past decade following the demonstration that addition of this element to certain areas of the ocean can lead to dramatic increases in marine productivity. This effect of iron has substantial implications for our understanding of how ocean biogeochemistry operates now and in the past, as well as how it may change in the future. Alteration in marine production has the potential to affect the amount of carbon dioxide transferred between the atmosphere and the ocean, the flux of carbon into the deep ocean and sediments, and the production of a range of gases important in atmospheric chemistry and climate. The importance of iron in nitrogen fixation in the ocean also has been recognized recently. In addition, there is commercial interest in and scientific concern over the proposal to fertilise the ocean with iron as a way to ameliorate increasing atmospheric carbon dioxide levels that will result from fossil fuel burning.

Marine (and possibly some terrestrial) ecosystems depend on dust supply for nutrients, particularly iron, but possibly also other elements. The major input of iron to the ocean is believed to be via atmospheric transport of dust and spoil from land. Dust comes predominantly from the arid and semi-arid areas, probably in a highly episodic process in dust storms. The terrestrial and atmospheric controls on dust storm activity are very poorly known. The incidence and nature of dust storms will change as climate changes and with societal response to climate change, and the dust in the atmosphere will itself influence climate. Atmospheric transport of dust storms now can be modelled and tracked with remote sensing.

Research on the global iron cycle has received a substantial boost in recent years because of its scientific and societal importance. However, the work has generally been conducted in rather distinct scientific disciplines. For example, research is pursued in virtually all of the programme elements of IGBP. This research ranges from studies of the production of dust (source of the iron) at land surfaces (Land-Use and Land-Cover Change [LUCC] and the new Land Project), how it is released into the atmosphere and transformed and transported therein (Integrated Land Ecosystem – Atmosphere Processes Study [ILEAPS] and IGAC), its deposition onto the ocean surface and effect on surface ocean biogeochemistry and nitrogen fixation (SOLAS), the importance of changes in ocean productivity on air-sea exchange of carbon dioxide and other trace gases (SOLAS), and, finally, the long-term sequestration of carbon in the deep ocean and sediments (Ocean Biogeochemistry and Ecosystems Analysis project, the Past Global Changes [PAGES] project, and the Global Carbon Project). The Iron Fast Track Initiative is a first attempt to bring these disparate research efforts together into a global framework. It will provide an opportunity to catalyse and focus scientific research across disciplinary boundaries to consider the role of iron in Earth system science.

Imperfect models exist for all parts of the iron cycle. The Iron Fast Track activity should produce well-defined research questions that modellers could address, which should help to (a) catalyse rapid improvements in the relevant models and their degree of coupling, and (b) advance the underlying science. The type of modelling-relevant questions that could be addressed in the proposed activity include

- Which chemical interactions between aeolian iron and other atmospheric constituents have significance for atmospheric composition?
- How much of the glacial-interglacial variation in atmospheric CO_2 concentration can be explained by changes in aeolian iron input to the ocean?
- Can we develop plausible scenarios for future changes in the iron cycle due to climate change and other human activities? What would be the implications of these scenarios for ocean biogeochemistry, atmospheric composition, and climate?

Modelling alone will not provide definitive answers, but it could sort out more-likely from less-likely speculations, and provide a preliminary quantification that might suggest key additional observations or experiments.

A workshop on the global iron cycle is being planned for early 2004. Participants wil include experts in the arease of desertification/climate change, dust generation/fluxes, atmospheric reactions, palaeo records (sedimentary and ice core), atmospheric transport and its potential change, deposition fluxes, ocean iron chemistry, biological uptake and utilization (ocean and land), nutrients/primary production/nutrient dynamics, nitrogen fixation and iron, iron-induced production
of greenhouse gases (e.g., dimethyl sulphide), remote sensing, modelling, and integration and synthesis. participants will be asked to prepare a short summary (2 or 3 pages) on the topic of their expertise, emphasising the major scientific questions and uncertainties in their topic area in relation to the global iron cycle. These summaries will be distributed before the workshop. A review paper will be produced and the workshop results will be synthesized for the Fast Track Initiative.

Nitrogen

Nitrogen is essential to the survival of all life forms, yet the natural abundance of useable nitrogen is so low that massive human alteration of the nitrogen cycle has been required to sustain the feeding of the world's population. The alteration has been made even greater by the release of nitrogen oxides to the atmosphere during fossil fuel combustion. These changes in the nitrogen cycle have exacerbated a number of environmental issues, including smog, acid deposition, climate change, coastal eutrophication, stratospheric ozone depletion, all of which have impacts on people and ecosystems on a regional and global basis. Delwiche (1970) voiced initial concern about global scale alteration of the N cycle. Over the intervening three decades since his seminal work, there have been steady advances in our understanding of various parts of The Nitrogen Fast Track will serve to help build on what has been learn at various scales to date, and develop a globally integrated approach to understanding the natural processes as well as the effect of the major anthropogenic alterations of the nitrogen cycle.

There have been two major international conferences on N over the last four years, with a third conference scheduled for 2004. The First International Nitrogen Conference, with a focus on Europe, was held in the Netherlands in March 1998 (van der Hoek et al., 1998). Three years later, the Second International Nitrogen Conference was held in the USA in October 2001 with a focus on North America and Europe (Galloway et al., 2002). The Third Conference, sponsored by the Chinese Academy of Sciences and other organizations, will be held in Nanjing, China in October 2004. The focus of the Third Conference will be Asia.

The Second Conference established as a goal *the development of a sustainable approach to manage nitrogen, and thus be able to provide food and energy to the world, yet minimize release of nitrogen to the environment.* Towards the realization of this goal, one of the recommendations of the Conference was to establish the International Nitrogen Initiative (INI). This goal was endorsed at a Workshop entitled "Nitrogen Management for Food Security and Ecosystem Security" held as part of the Science Forum associated with the World Summit on Sustainable Development in Johannesburg August 29, 2002. In December 2002, IGBP and SCOPE jointly became founding sponsors of the INI. The IGBP Fast Track has a counterpart in a SCOPE "Rapid Assessment Project" (RAP) on fertilizer.

The Nitrogen Fast Track will focus on both sides of the nitrogen cycle, and will begin with two initial workshops- The first is being planned for early 2004 and

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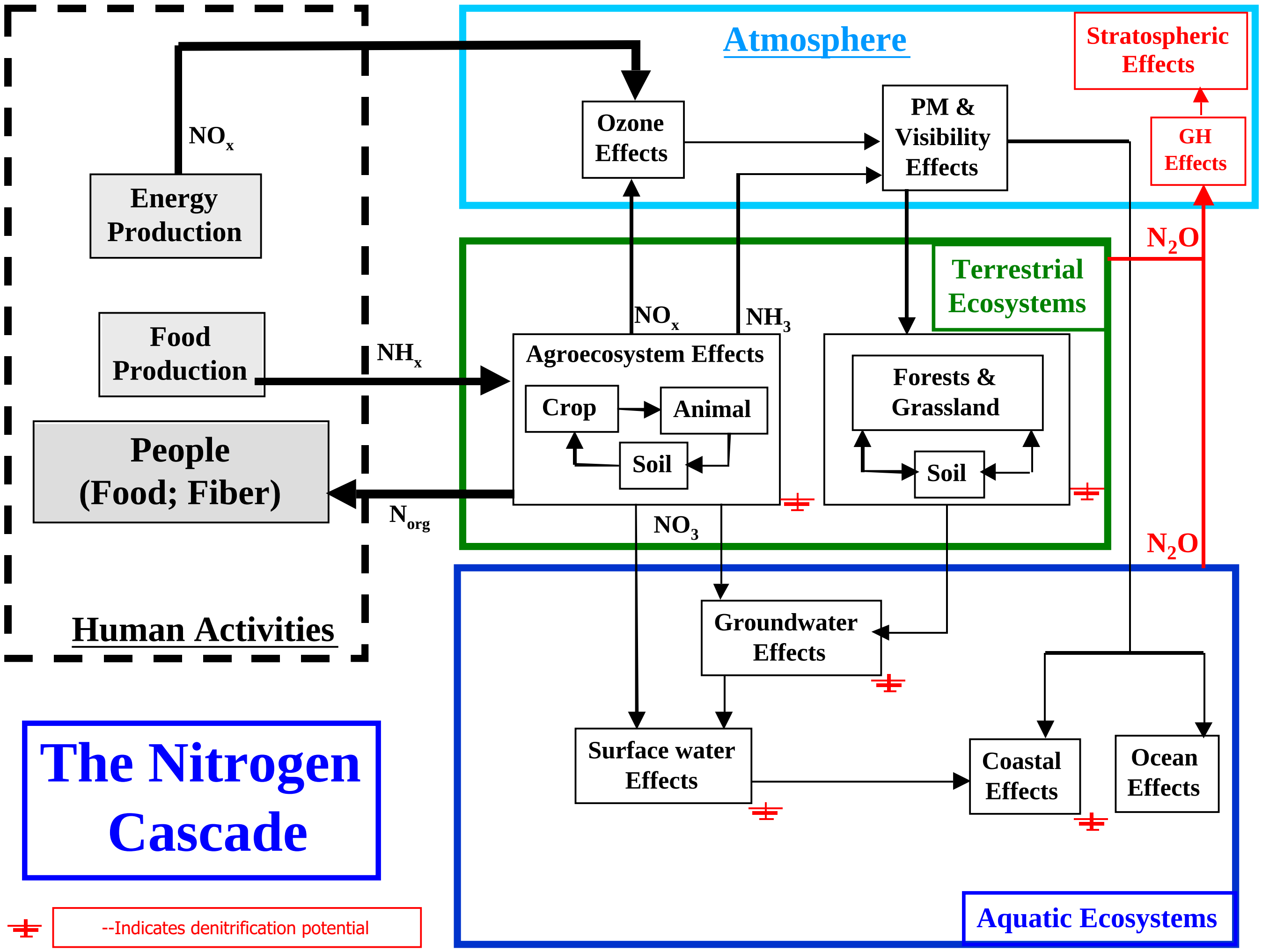

'Nitrogen'-

will involve fertilizer and its intended and unintentionanl effects. There are still major uncertainties regarding the fate of fertilizer nitrogen (N) added to agricultural soils and the potential for reducing emissions to the environment through soils, ground and surface water as well as the atmosphere. Enhancing the technical and economic efficiency of fertilizer N is seen to be a win-win situation for both agricultural production and the environment. This has provided much of the impetus for a detailed examination or fertilizer. The intial Fertilizer workshop will focus on

(i) developing a better understanding and quantification of the fate of fertilizer N added to different farming systems in diverse environments (a regional need)

(ii) elaborating the concept of 'reactive' N in agricultural systems and putting this in context with other sources of N to waters and the atmosphere (a conceptual and a contextual need)

(iii) identifying and assessing the technological and management strategies for enhancing the agronomic efficiency of fertilizer N and reducing emissions to the environment, with positive benefits to the economic efficiency of fertilizer N (a management and societal need).

The other side of the Nitrogen cycle involves denitrification, and a workshop will focus on this in Spring of 2004. By far the largest uncertainty about the human domination of the N cycle on all scales is the amount of reactive N that is converted back to N_2 during the last step of denitrification. Without this knowledge, it is impossible to determine the rate of accumulation of reactive N in most environmental reservoirs, and thus impossible to assess its long-term consequences. In addition to improved technologies in agriculture, industry, and transportation, an improved understanding of where, when, and how much reactive N is denitrified could contribute to finding solutions to the problems created by excessive reactive N in the environment. We have a good understanding of the environmental conditions under which denitrification occurs, but reliable quantification of N_2 production in the field is still relatively rare. There are three primary reasons for lack of knowledge about N_2 production: (1) it is difficult to measure due to the high atmospheric background concentrations; (2) N_2 production rates are very heterogeneous in space and time; and (3) there is a lack of synergy between the scientific communities that determine N_2 production rates. The workshop will focus on ways of improving our scientific understanding of the N cycle toward finding solutions to society's concerns about eutrophication of the biosphere.

opment, evaluation and wise use of Earth System Models. Our experience has been that these things don't happen by themselves, or not as fast as we would like, because of "cultural" inertia in the various communities that perform and fund science. By articulating and pursuing clear long-term visions, GAIM can and does make a difference. In this field of science, the need to improve understanding and predictive ability is extraordinarily urgent. Most of the world's governments and other organizations now recognize the implications of anthropogenic changes with regard to atmosphere and climate. Yet, quantitative scientific understanding of the complex system of which we are a part is by no means at the level needed to adequately inform decision making in public life. Much of the difficulty of making progress in Earth System Science is said to be caused by the extremely interdisciplinary nature of the system. I prefer to say that the boundaries between the existing scientific disciplines are unhelpful for the purpose of studying the Earth. We can't fix this problem, but we are always grappling with it. Even IGBP itself has, for practical reasons, been structured along lines that to some degree reflect conventional subject boundaries, and this will continue to be in so far as oceanographers study oceans, ecologists usually study either marine or terrestrial ecosystems, and so on. GAIM however is expected to routinely cross these boundaries. That's what we do.

At the start, GAIM had a major focus on the carbon cycle, which was not considered as a whole anywhere in the IGBP projects. Today the carbon cycle is a mainstream concept and there are multiple national programmes and a unified international project (the Global Carbon Project of the Earth System Science Partnership, ESSP) dedicated to it. The biggest new challenges we face now are on new frontiers, most importantly the reciprocal interactions between the geosphere, biosphere, physical climate system, and the human system. To clarify and quantify these interactions we need to achieve a still higher level of integration between different scientific communities. In practical terms this means we need to work much more closely with IGBP's partner organizations in the ESSP. In scientific terms it means, among other things, we will certainly need to develop new analytical approaches and modelling tools that somehow combine elements from disparate fields.

The GAIM Task Force has recently expanded to achieve a more broadly representative membership including people whose main research interests are in the physical or human dimensions of Earth System Science. The newly expanded Task Force will determine GAIM's new directions, but we can assume that these will include the further development of coupled physical-chemical-biological models (for land, ocean, and indeed the whole planet), and new approaches to modelling the interactions of environment, resources and human society. There will surely be a major emphasis on model evaluation, and on the use of historical and palaeodata to test the predictive abilities of models.

Above all, GAIM will need to "think outside the box" and promote activities that might well be considered impossibly ambitious by the criteria of "normal" science. I believe that the very disciplinary boundaries that can frustrate progress in Earth System Science paradoxically represent a fantastic opportunity in the form of the breakthroughs that can occur when people from different scientific cultures and disciplines are brought together and encouraged to work together in an effective and sustained manner. Our task is to encourage these breakthroughs to occur.

Nitrogen Fast-Track References

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'Fast Track', p.24

The Earth System Atlas:
A Platform for Access to Peer-Reviewed Information about the Earth System

by Dork Sahagian and the GAIM Task Force

A great deal of time, effort and resources have been expended on global change research to date, but there is as yet no single compendium describing the state of the art of in our understanding of the Earth system and how it has responded to and is likely to respond to natural and anthropogenic perturbations. Toward that end, a new effort is being launched by IGBP/GAIM to compile an Earth System Atlas that will include maps and time series (including the underlying data) of all the relevant parameters that drive or are driven by changes in the Earth System at various time scales. The Earth System Atlas represents an initiative of the International Geosphere Biosphere Programme (IGBP) in conjunction with its Earth System Science Partners (ESSP), the World Climate Research Programme (WCRP), the International Human Dimensions Programme (IHDP), and the International Programme for Diversity Science (DIVERSITAS). As such, it will be a product of the entire research community rather than that of a single agency or institute. As an effort by the entire community, there will be much stronger quality controls than would be possible within a single research entity.

There are two basic functions for the proposed Atlas. The first is effective and convenient dissemination of global change research results to the broad scientific, educational, lay, and policy sectors. The marked increase in recent decades of public concern in global environmental change issues adds renewed importance to ensuring that research results are made available as broadly and conveniently as possible. This Atlas should help in this regard. The second basic function is directed back to the global change research community itself, defining one access point for current, quantitative state-of-the-art data about the Earth System, coming from either historical reconstructions, "now-casting" (i.e. spatial assimilation of observed data) and scenarios for future developments. This will serve to provide existing data to the community, but also will help to highlight data gaps that may hinder our understanding of critical components of the Earth system. A brief introduction to the Atlas concept was presented in the *IGBP Global Change Newsletter* v.50, September 2002 , and the nature of the Atlas is explained in more detail here. In addition, an on-line "prototype" has been constructed to demonstrate a few of the intended data manipulation and display tools.

The Atlas will be much more than a collection of pre-made maps posted on the web. Rather, it will be a tool for assembling, manipulating, and displaying specific data as selected and customized by the user. Maps are created "on the fly" according to user-specified instructions. A "proof of principle" prototype has been developed and can be viewed, along with example "exercises" at http://EarthSytemAtlas.sr.unh.edu

The initial development of Atlas will focus on various data sets related to the global carbon cycle. These include a growing number of marine, terrestrial and atmospheric data, and the integrated approach being pursued by the Global Carbon Project (GCP) as well as various national initiatives. In subsequent phases of Atlas development, additional areas will be covered.

The Earth System Atlas will be unique in several ways. It will provide explanations to all types of audiences; data will be peer-reviewed as would be for a prestigious journal; data will be managed by the user so that custom maps and time series can be made using web-based tools developed specifically for the Atlas.

A few key aspects of the Atlas in both content as well as process and function are:

1. The Atlas will take a long-time perspective on Earth System information, from as far back in the past as data are available, to model-based projections into the future. This long-term perspective is often missing in discussions of global change, and the general public has historically found it difficult to grasp concepts involving geologic time scales. The juxtaposition of modern rates of change with natural rates from various paleo records will place the user in a much better position to understand the place of human perturbations and impacts in the Earth system.

2. The Atlas will draw on extensive international networks of scientists and institutions. It will represent a community effort rather than that of just one or a few institutions. It will be sponsored by the four international global change research programs, collectively the Earth System Science Partnership (ESSP).

3. Review process. All data sets to be included in the Atlas will be peer reviewed to ensure data quality, documentation of collection methodology, and assessment of comparable related data sets. The user will know why a particular data set was selected, how the data were collected, for what applications the data would be appropriate, and what other alternative data sets are available.

4. Targeted explanations. Each data set (and the maps to be generated from each) will have explanatory text included that is tailored to the needs of audiences at various levels.

5. Projection. All data will be displayed using a common projection so that data can be superimposed for comparison and analysis.

6. Data manipulation tools. Web-based tools for the manipulation of data using a number of arithmetic and algebraic algorithms will be developed so that the data can be used in broader calculations by the user, both for mapping and display, and for analysis of the data itself.

The overarching goal of the Atlas will be to publicize as broadly as possible the results of recent global change research efforts.

The purpose of the Atlas will be to provide a wide range of users with the tools with which to construct in real time a series of Global Change related digital maps and time series, along with access to the underlying data from which they were constructed, and text explanation of data collection, analysis, and other pertinent information. The target audiences are:

- the Global Change science community (both within and outside the ESSP),
- the general public and policy community
- K-12 education community.

The initial effort will be focused on the needs of the scientific community, but as the Atlas develops additional resources will be devoted to the outreach and educational aspects to disseminate global change information as broadly as possible.

Specific *objectives* include:

- Establishing a well-known, single source of global change information;
- Presenting research results in an easily understandable format;
- Creating a format that can be updated as new results and refine ments emerge;
- Enabling superposition of different aspects of global change for comparison, assessment, and interpretation;
- Linking maps and time series with original data;
- Enabling user-defined zoom, overlay, and snapshot/time interval;
- Producing data manipulation tools for custom map generation by the user;
- Identifying conceptual and data gaps that will help direct subsequent work within the research community.

The Earth System Atlas will contain pertinent information regarding changes in climate, atmosphere, land surface and ocean, as well as socio-economic factors. Maps would be created from ground-based and satellite-derived data, conceptual and numerical models, census, economic, and additional relevant databases. The Earth System Atlas will include, in addition to data at global scale, products at a broad regional scale of particular interest (e.g. the Amazon or the Antarctic). Users of the Atlas will be able to zoom in and out as needed, with map resolution depending on scale. An important feature of the Earth System Atlas will be that maps will be developed in such a way that past conditions may be compared visually with the present, and also with future environmental conditions predicted on the basis of current models and forcing scenarios. Underlying data will be made available in electronic format.

The free and open data exchange policy of the International Council of Scientific Unions (ICSU) will apply to all aspects of the Atlas.

The Earth System Atlas will consist of an evolving collection of internally-consistent Global Change related data sets covering a range of space and time scales. Maps can be displayed in layers allowing the juxtaposition of any number of factors to provide a contextual framework from which the reader can draw his/her own conclusions regarding trends, cause and effect, and the myriad relations between changes in the various parts of the Earth system. Maps will be constructed on the basis of data sets (updated as appropriate) centrally housed and maintained at the IGBP/GAIM Office. Users will be able to define the parameters of each map using web-based tools for data selection and manipulation.

The data from which each map is constructed will be available to the user both in tabular form, and also interactively as the cursor is dragged across the map. This allows not only for point-by-point analysis, but also can be used as an indication of data density and interpolation.

The Atlas will be an important tool for the broad dissemination of data-linked graphical representations of global change research results. As such, it will serve as a cross-pollinator through which diverse research communities can obtain, share, compare, and assess a wide range of data products and interpretations. This will enable scientists to draw on information from very different “disciplines” to enhance their own research and place it in better context within the Earth system.

A second, and perhaps more critical long-term service that the Atlas will provide to the research community will be that of identifying conceptual and data gaps. The procedure of compiling a table of contents for the Atlas amounts to determining those aspects of global change within the Earth system that warrant display on the basis of interacting in a significant way with the rest of the Earth sys-

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temic behavior. Once such a table of contents is produced and graphics and their underlying data are compiled, it will soon become apparent where gaps exist (and there are surely many). These can then be articulated, prioritized, and addressed in subsequent research throughout the community.

An important criticism of the scientific community has traditionally been that it does not adequately communicate with the general citizenry that supports it and depends on its productivity for technologic innovation on the one hand, and environmental problem solving on the other. The Atlas will represent a major effort to alter that tradition and provide the broadest possible dissemination of global change scientific results that are policy-relevant, environmentally timely, and understandable to any reader with basic education (not necessarily scientific). The Atlas will be a useful educational resource for K-12 classrooms, college classes, and graduate study. Elementary classroom teachers may be most interested in the utility of the Atlas for demonstrating basic concepts such as land use/land cover, sea level change, or CO_2 emissions. High school teachers may wish to explore the details of ocean circulation, the hydrologic cycle, or the carbon cycle. College professors could exploit the capabilities of the Atlas in superposing multiple data sets, thus highlighting cause and effect relationships to enhance classroom teaching and labs. Finally, graduate students could use the Atlas to investigate the factors that control Earth system behavior, as they delve into their thesis research.

The growing body of scientific results emerging from the efforts of the global change research community is become increasingly policy-relevant, particularly in view of the growing international recognition of the influence of human activities on the Earth system. As such, the Atlas will provide a useful resource for policy makers in viewing and assessing the state of the art in global change and Earth system science. While the Atlas will not have any political implications or offer policy suggestions, the science presented therein can readily be used by the policy sector in developing sound science-based policy at the local, national, and international levels.

One of the primary unique features about the proposed Earth System Atlas is the fact that all data will be peer reviewed for quality. This will involve two phases. The first will be evaluation of any data set for appropriateness and relevance. Once a data set is selected for consideration for the Atlas, the second aspect of quality control will involve review to scrutinize each data set for completeness, functionality, isolated errors, mismatches, etc. An Editorial Board will utilize the full peer-review process in evaluating potential data sets for the Atlas. In addition, all accompanying text will be reviewed for accuracy, writing style (for each intended audience), and appropriate context. Prior publication in the peer-reviewed literature will be neither a necessary nor sufficient criterion for inclusion in the Atlas. The Atlas will engage in its own peer-review process to ensure the highest quality and topical fit. Conversely, inclusion in the Atlas will not constitute formal "publication" of material, so authors will be free to publish their own contributions to the Atlas in regular journals and books.

Tools for manipulation data in the Atlas will enable the user to select user-defined geographic frames (not necessary to download or display entire global data sets), zoom and crop, click on data points to obtain source and references, download data in user-selected formats (e.g. lat-long-value; Arc-info grid; NET-CDF, etc.), and display animations of geographic data for which time series exist. In addition, the user will be able to perform a variety of mathematical operations on the data using arithmetic operations on a single data set or by formulating relations involving multiple data sets. This will enable data sets to be critically compared, allow new data to be generated using existing data sets, and create a graphical environment through which new insights can emerge regarding the relationships between the functional parameters related to the data included in the Atlas.

The Atlas will enable the user to analyze data sets in some specific ways. A few examples are:

- Framing and cropping so that entire data sets need not be displayed or downloaded
- Use of mathematical operations on data sets such as +,-,*,/, <,>, if, or, abs, trig, etc.
- Operation of one data set upon another (e.g. Dataset1 - sqrt[Dataset2])
- Superposition of two data sets for direct comparison
- Statistical analysis of displayed data
- Downloading gridded data (before or after use of various operators) in user-specified format

A "guide" in the form of a set of exercises is included in the box (next page). This will help the reader explore the various preliminary tools and get a better idea of the capabilities we have in mind when we begin development of the full Atlas. A section will be included for on-line submission of user comments and suggestions. In this way the Atlas can respond to the evolving needs and capabilities of the user communities.

A few preliminary tools are already developed in a partial prototype of the Atlas which can be explored at http:EarthSytemAtlas.sr.unh.edu

Earth System Atlas DEMONSTRATION

A prototype for the Earth System Atlas has been developed by GAIM for demonstration of a limited set of planned data manipulation tools and display options. This is ONLY a functional prototype in that it demonstrates the types of functions that will be included the Earth System Atlas. It is by no means a final (or even initial) product. These will be developed during the actual Atlas project in consultation with an Executive Committee and professional artists/designers. Only a few example data sets are included for this prototype demonstration. Note that the Atlas is not a "normal" web page, but rather is an application that is accessible through the web.

1. Access the Atlas at **http://EarthSystemAtlas.sr.unh.edu/** This access page is left blank until placing artwork, logos, programmatic links, etc.

2. Go to "Atlas Maps" link. The Atlas has three major sections on the web page. The first section is a dataset chooser (a bluish background row with dataset drop-down menus), to be explained below. The second section is a set of map navigation tools. It looks like a wide row with gray background and a small navigation map on the left side of the gray row. The lower (third) section of the page is the map itself with its legend below and data manipulation tools adjacent.

3. **Panning and zooming.** You can change map zoom by clicking a radio button or entering a custom box size. Clicking on the global map centers the blue box. Now you can click a button below named "Update Map Below to Your Selection". You can also try adding or deleting information layers at the far right.

4. **Changing main dataset.** The top section of the page has two dropdown menus. The first dropdown menu is named "Choose Dataset". The default value is Elevation. Try changing the dataset in the menu and you see that both navigation and main maps are updated to your choice. There are a few simple demonstration datasets to choose from. The full Atlas will have many data sets listed in this menu. Dataset explanations appear to the right- See the one for NPP, for instance. You can display a second dataset simultaneously by choosing it from the second dropdown menu. It will be shown in contour lines. Contour line color corresponds to the dataset legend shown under the main map. We recommend removing country borders from the information layers to reduce the number of lines on the map. Data values can be read directly from the map by clicking the boxes to the right of the main map to load the data, and then moving the cursor over the map.

5. **Histogram.** You can see the data histogram of the displayed map area by checking the radio button to the right of the main map. You can switch back to the map at any time.

6. **Download data.** You can download data as an ArcInfo ASCII formatted file for any map by clicking the button to the right of the main map.

7. **Calculations with data for the map area.** For any displayed map area you can perform dataset calculations by going to the calculation tool. Click the big button named "Data Manipulation" located to the right of the main map. "No calculations requested" will be displayed. Below the table of data sets you can type in the equation you want to execute. Try clicking the "help" link for definitions and operators.

   Example 1. Type in "data1/1000" in the "Enter equation…" box at the bottom of the page and press "Run Equation" button. You will get the elevation of your selected map area in kilometers.

   Example 2. To see the difference between summer and winter temperatures type in the equation "data4-data3" then press "Run Equation".

   Example 3. To see a simple relation between NPP and precipitation, type in the equation "data6/data5" then press "Run Equation" button. To improve the display, force the range by typing "0" and "2" in the "Min" and "Max" input box respectively and "Run Equation". Look at the histogram- NPP (in g C m-2) has a peak at about half the precipitation (in mm). Is this true of other continents, or globally? (It is not true of Indonesia, for instance.) You can find out later by "return to Atlas maps" to change the map area.

   Example 4. You can use "if" statements in the equation field. Try "data1>1000" as an equation and "Run Equation". That will show you the area where the condition is true (blue or resulting value of 1). If you want to see both true and false results of the "if" statement, type data1>1000?1:0" and Run Equation- Red will show the high elevation (true if) and black will show the low elevation (false if). To explore various examples of operators, go to "help" link just under the equation line. All standard operators (POSIX) are allowed in the prototype. You can also display other data while satisfying this condition by typing "data5 if data1>1000" as an equation. This will show you precipitation at elevations over 1000 m only. If you want to see precipitation only over continents, type "data5 if data1" and Run Equation.

8. **Compare data sets** You can explore the quality of data by comparing similar datasets. For example, you can subtract elevation data from elevation/depth data to check for any inconsistency. Type "data1-data2" in the equation input field and force the value range by setting "Min" to -100 and "Max" to 100. Run Equation.

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Atlas Explanatory Text

Each data set included in the Atlas will be accompanied by explanatory text describing the data a well as the meaning of the selected display within the Earth system. The text will have the form of extended "figure captions" and will be written specifically for each of three target audiences for the Atlas. The text will be fully referenced including data source(s), published literature, and links to data-specific websites, as appropriate. The text will be written in three versions for each of the target audiences as follows:

• *Scientific community-*
This will be the full, technical version, with the least contextual explanation (no need to be pedantic for the scientists who use the Atlas data). The explanation will focus on data collection methodology, error bounds and reliability, interpretive procedures, and related issues directed to the scientists who would be downloading and using the data in their own research. In addition, an explanation of the data review procedure would be included along with a list of other similar data sets (if any) that were not selected for inclusion in the Atlas and why. Links would be provided to web sites of each original data source. This full version will be the initial focus of the Atlas, but other versions for other audiences will be added subsequently.

• *Educated lay public and policy community-*
This version will omit the technical details, but rather, provide sufficient contextual explanations so that the reader can understand the purpose of the data, how it fits into Earth system science, and the interpretations drawn from the data by the scientific community. The explanation will include the value of the data in understanding the operation of the Earth system, and will highlight the relevance of interpretations of the data to policy, social systems, and contemporary ecological and socioeconomic issues.

• *K-12 educational community-*
This version will be tailored to the needs and understanding of school children, aimed at upper middle school to high school level. It will be designed so that teachers can use it as a classroom resource in lesson planning, demonstrations, and homework assignments. Students will use it as the basis for school projects, homework assignments, and general background information in support of a variety of classroom subject units. The text will be the most elementary of the three versions in the Atlas, and will be coordinated with the "public and policy" version so that a seamless transition can be made from one to the other by high school students and others who require the background provided by the K-12 version. This version will represent one of the most significant educational and outreach activities of IGBP, and it is anticipated that it will become a heavily used resource.

"MIPs" Catalog

At the 2002 joint meeting between IGBP/GAIM and WCRP/WGCM, it was acknowledged that there are a great many model intercomparison projects (MIPs) ongoing, and that each would benefit from enhanced communication with others regarding methods, protocols, and results. Consequently it was agreed that a compilation of the various MIPs should be posted as a first step toward constructing a "toolbox" of techniques for model intercomparison to be made available to the community at large. The list below is an initial draft of such a compilation. Additional details can be found on the GAIM web site at **http://gaim.unh.edu** at the bottom of "GAIM Projects". If there are any major Earth system related model intercomparison activities that you can add to this compilation, or that are listed but have evolved to something else, please contact the GAIM office.

Asian-Australian Monsoon Atmospheric GCM Intercomparison Project(AMAMIP)
The main foci of this program are intercomparing intraseasonal oscillation, monsoon dynamics and hydrology, atmosphere-ocean interaction, and global heat budget at the top of atmosphere and the surface in atmospheric GCMs.
In-Sik Kang (kang@climate.snu.ac.kr)
http://climate.snu.ac.kr/clivar/index.htm

Atmospheric Model Intercomparison Project (AMIP)
AMIP is a standard experimental protocol for global atmospheric general circulation models (AGCMs). It provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access.
Peter Gleckler (gleckler1@llnl.gov)
http://www-pcmdi.llnl.gov/amip/

Arctic Ocean Model Intercomparison Project (AOMIP)
The Arctic Ocean Model Intercomparison Project (AOMIP) is an international effort to identify systematic errors in Arctic Ocean models under realistic forcing. The main goals of the research are to examine the ability of Arctic Ocean models to simulate variability on seasonal to interannual scales, and to qualitatively and quantitatively understand the behaviour of different Arctic Ocean models.
Andrey Proshutinsky (aproshutinsky@whoiu.edu)

Arctic Regional Climate Model Intercomparison Project (ARCMIP)
An international intercomparison of regional model simulations in the Arctic has been organized under the auspices of the WCRP GEWEX Cloud System Studies Working Group on Polar Clouds and the ACSYS Numerical Experimentation Group.
Judy Curry (curryja@eas.gatech.edu)
http://paos.colorado.edu/~curryja/arcmip/index.html

Carbon-Cycle Model Linkage Project (CCMLP)
CCMLP has brought together several research groups to study the role of the terrestrial biosphere in the Earth system using TBMs. Four models were run in parallel for the period 1920-1992.
Martin Heimann (martin.heimann@bgc-jena.mpg.de)
http://w3.bgc-jena.mpg.de/~martin.heimann/ccmlp/

Coupled Model Intercomparison Project (CMIP)
CMIP was to compare simulations from global coupled climate models with components describing atmosphere, ocean, sea ice and land surface. Several phases and activities include CMIP1,CMIP2, CMIP2+,20C3M, CMIP Coordinated Experiments.
Gerald Meehl (meehl@ncar.ucar.edu)
http://www-pcmdi.llnl.gov/cmip/

Coupled Carbon Cycle Climate Model Intercomparison Project (C^4MIP)
C^4MIP is designed to compare and analyze the feedbacks between the carbon cycle and climate in the presence of external climate forcing.
Pierre Friedlingstein (pierre@lsce.saclay.cea.fr)
http://www.atmos.berkeley.edu/c4mip/home.html

International Climate of the TwentiethCentury Project (C20C)
C20C project is a WMO/CLIVAR activity to address climate by imposing the observed atmospheric forcing functions of the last century or more on state-of- the-art atmospheric general circulation models (AGCMs) to determine primarily the extent to which these seasonal to interdecadal variations are reproducible and also to serve as a validation of the AGCMs themselves.
Chris Folland (chris.folland@metoffice.com)
Jim Kinter (kinter@cola.iges.org)
http://www.iges.org/c20c

Potsdam DGVM Intercomparison Project (DVGM)
The possible responses of ecosystem processes to rising atmospheric CO2 concentration and climate change are illustrated using six dynamic global vegetation models that explicitly represent the interactions of ecosystem carbon and water exchanges with vegetation dynamics.
Wolfgang Cramer (wolfgang.cramer@pik-potsdam.de)

Ecosystem Model-Data Intercomparison (EMDI)
The goals of the EMDI are to compare model estimates of terrestrial carbon fluxes (NPP and net ecosystem production (NEP), where available) to estimates from ground-based measurements, and improve our understanding of environmental controls of carbon allocation.
Kathy Hibbard (kathy.hibbard@oregonstate.edu)
http://gaim.unh.edu/Structure/Intercomparison/EMDI/

ENSO Intercomparison Project (ENSIP)
ENSIP is aimed to document the El Nino simulations in coupled ocean-atmosphere models. Outputs from about 20 rather different coupled models have been collected so far, including regional and global models, as well as coarse-resolution and high-resolution models, flux-corrected and freely running coupled models.
Mojib Latif (latif@dkrz.de)

GEWEX Cloud System Study (GCSS)
GCSS will develop better parameterizations of cloud systems for climate models by an improved understanding of the physical processes at work within four types of cloud systems.
Steve Krueger (skrueger@met.utah.edu)
http://www.gewex.org/gcss.html

Global Land-Atmosphere Coupling Experiment (GLACE)
The great majority of AGCM land-atmosphere interaction studies appear to take a given model's implicit coupling strength on faith, not addressing either its realism or how it compares with that in other models. The goal of GLACE is to quantify and document the coupling strength across a broad range of AGCMs.
Randy Koster (randal.d.koster@nasa.gov)
http://glace.gsfc.nasa.gov

Global Soil Wetness Project (GSWP)
GSWP is an ongoing environmental modeling research activity of the Global Land-Atmosphere System Study (GLASS) and the International Satellite Land-Surface Climatology Project (ISLSCP), both contributing projects of the Global Energy and Water Cycle Experiment (GEWEX).
Paul Dirmeyer (dirmeyer@cola.iges.org)
http://www.iges.org/gswp/

Ice Shelf - Ocean Model Intercomparison Project (ISOMIP)
ISOMIP is currently being proposed as an international effort to identify systematic errors in sub-ice shelf cavity ocean models. ISOMIP will bring together the international modeling community for a comprehensive evaluation and validation of current sub ice shelf cavity ocean models.
David Holland (holland@cims.nyu.edu)
http://fish.cims.nyu.edu/project_oisi/isomip/overview.html

Potsdam Net Primary Production Model Intercomparison Project (NPP)
Seventeen global models of terrestrial biogeochemistry have been compared with respect to annual and seasonal fluxes of net primary productivity (NPP) for the land biosphere.
Wolfgang Cramer (wolfgang.cramer@pik-potsdam.de)

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Ocean Carbon-Cycle Model Intercomparison Project (OCMIP)
OCMIP was initiated by GAIM in 1995 as a means to develop international collaboration to jointly improve the predictive capacity and accelerate development of global-scale, three-dimensional, ocean carbon-cycle models through standardized model evaluation and model intercomparison.
Jim Orr (orr@lsce.saclay.cea.fr)
http://www.ipsl.jussieu.fr/OCMIP

Ocean Model Intercomparison Project (OMIP)
OMIP aims to assess the general performance of ocean and ice model components used in coupled models to study climate and tracer uptake; assess the quality of the forcing fields and improve understanding of the sensitivity of ocean/ sea ice models to parameterisations and forcing aspects.
Tony Hirst (tony.hirst@csiro.au)
http://www.clivar.org/organization/wgomd/pomip.htm

Project for Intercomparison of Landsurface Parameterization Schemes (PILPS)
PILPS is an element of GLASS under the auspices of GEWEX and the World Climate Research Programme and it is designed to improve the parameterization of the continental surface, especially hydrological, energy, momentum and carbon exchanges with the atmosphere.
Ann Henderson-Sellers (ahssec@ansto.gov.au)

Project to Intercompare Regional Climate Simulations (PIRCS)
PIRCS is a community-based project that seeks to evaluate the strengths and weaknesses of regional climate models and their component procedures through systematic comparative simulations. The first series of experiments used a North American domain, but future experiments will seek to assess transferability of regional models to other domains.
William J. Gutowski (gutowski@iastate.edu)
Gene S. Takle (gstakle@iastate.edu)
Raymond W. Arritt (rwarritt@bruce.agron.iastate.edu)
http://www.pircs.iastate.edu/

Paleoclimate Model Intercomparison Project (PMIP)
Partly inspired by AMIP, PMIP was initiated in order to coordinate and encourage the systematic study of atmospheric general circulation models (AGCMs) and to assess their ability to simulate large changes of climate such as those that occurred in the distant past.
Sylvie Joussaume (sylvie.joussaume@cnrs-dir.fr)
Andy Pitman (apitman@penman.es.mq.edu.au)
Jan Polcher (Jan.Polcher@lmd.jussieu.fr)
http://www-pcmdi.llnl.gov/pmip/

Regional Climate Model Inter-comparison Project for Asia (RMIP)
RMIP for Asia was established in 1999 to evaluate and improve regional climate model (RCM) simulations of monsoonal climate. RMIP operates under joint support of the Asia-Pacific Network for Global Change Research (APN).
Congbin Fu (fcb@tea.ac.cn)
http://rmip.tea.ac.cn/

Sea-Ice Model Intercomparison Project (SIMIP)
SIMIP is an international effort to develop an improved representation of sea ice in climate models. SIMIP is carried out by co-ordinated numerical experiments with contributions from several institutes in the framework of the Arctic Climate System Study (ACSYS) within the World Climate Research Programme (WCRP).
Greg Flato (greg.flato@ec.gc.ca)
http://www.cccma.bc.ec.gc.ca/acsys/simip2/SIMIP2_intro.htm
http://www.ifm.uni-kiel.de/fb/fb1/me/research/Projekte/SIMIP/simip.html

Seasonal Prediction Model Intercomparison (SMIP)
WGSIP has initiated two experimental protocols using atmospheric general circulation models to investigate SMIP-2) using observed SST, and (2) actual predictability using forecast SST (SMIP-2/HFP). Modeling groups may participate in either or both protocols. The basic experiment calls for ensembles of integrations, differing only by their initial conditions, for each season for 1979-2000.
Ken Sperber (sperber1@llnl.gov)
http://www-pcmdi.llnl.gov/smip/

Snow Models Intercomparison Project (SnowMIP)
The project aims at comparing snow simulations at four sites (middle elevation temperate, high elevation temperate, eastern US site, arctic site) from various models.
Eric Martin (Eric.Martin@meteo.fr)
http://www.cnrm.meteo.fr/snowmip/

STOIC: Study of Tropical Oceans In Coupled models (STOIC)
STOIC aims to identify common strengths and weaknesses of coupled models in tropical ocean regions. It is complementary to another WGSIP project (ENSIP) that concentrated on ENSO and the equatorial Pacific.
Mike Davey (mike.davey@metoffice.com)
Ken Sperber (sperber1@llnl.gov)

Atmospheric Tracer Transport Model Intercomparison Project (TransCom)
The TransCom 3 CO_2 inversion intercomparison is aimed at quantifying the components that contribute to uncertainty in inverse estimates of carbon sources and sinks.
Kevin Robert Gurney (keving@atmos.colostate.edu)
http://transcom.colostate.edu

WCRP Transport MIPs (WCRP)
WCRP is to provide a foundation for establishing the credibility of stratospheric models usedin environmental assessments of the ozone response to chlorofluorocarbonds, aircraft emissions, and other climate-chemistry interactions.
Natalie Mahowald (mahowald@ncar.ucar.edu)
Jae H. Park (park@jaedec.larc.nasa.gov)
http://www.wmo.ch/web/wcrp/wcrp-home.html

IGBP CONGRESS SESSIONS HIGHLIGHT GAIM ACTIVITIES

The IGBP Congress in Banff, Canada was a landmark meeting of the entire IGBP community in which numerous plenary and parallel sessions addressed issues pertaining to various aspects of Earth system analysis. This article summarizes some of the key issues that emerged from a few of the parallel sessions in which GAIM was directly involved. These results will serve to help guide GAIM and the broader research community in IGBP-II projects directed to understanding the connections within the Earth system.

Development of Earth System Models to Assess the Predictability of Non-Linearity in the Earth System (Working Group A2)

Conveners: John Schellnhuber and Roger Pielke Sr.
Rapporteur: Dork Sahagian

The goals of this session were to devise strategies for further investigation of hotspots of vulnerability and potential switches in the Earth system, toward improving the predictability of the Earth system as a whole. The threat of excursions into intolerable domains caused by exceeding thresholds was discussed, as well as systemic changes such as those associated with a long term, major alteration in the ocean circulation. Temporally, spatially, and functionally small perturbations, which result in long term, large magnitude, and large spatial scale changes were explored. These events would be abrupt and surprising, and could result in devastating and unmanageable consequences to society.

Recognized hot spot effects where such catastrophic results could occur include Amazon deforestation, changes in the Asian monsoon due to aerosols and/or land use change, fresh water fluxes which effect Atlantic deep water formation, and aerosols which are windblown from dry lakes such as the Bodele depression. Reliable prognostic Earth system models are needed so that it may be possible to enhance global adaptive capacity, as well as identify possible mitigation strategies. Policymakers can use these models to assist in developing the most appropriate management options.

Participants in the session recognized that skillful prediction of information of use to policy makers may not be possible with our present understanding of the system, or indeed with any conceivable model, regardless of complexity . While a GAIM goal is to assess predictability, a complementary approach is to assess the vulnerability of components of the Earth System to human and natural perturbations. With this approach, thresholds and risk need to be evaluated.

The climate system also needs to be recognized as a component of the Earth System, and not an external driver. Examples were presented at the session which documented the inability of the existing models to skillfully predict the evolution of the Earth system over the last several decades, which further exemplifies the complex, nonlinear character of the Earth System. Climate itself needs to be recognized as a coupling between the atmosphere, oceans, land and continental ice sheets.

Appropriate metrics need to be chosen to monitor the evolution of the Earth system. In the context of the climate system, the use of Joules was suggested as the metric to assess "global warming". The spatial variations in heating and cooling, in addition to the global average of this quantity was proposed as an additional metric to monitor. Examples were presented for other components of the Earth system, including the monitoring of the thermohaline circulation, the response of plants to increased CO_2 and to changes in precipitation, and documentation/prediction of land use change. In the assessment of the Earth system, humans need to be studied as a part of the Earth system, rather than distinct from it. This greatly increases the complexity of the Earth system, but is a necessary condition to assess vulnerability and predictability.

The Vostok challenge: Science overview and implementation issues (Working Group B3)

Conveners: Colin Prentice, Dominique Raynaud, Thomas Stocker.
Rapporteur: Dork Sahagian

The records from Vostok and other ice cores from Antarctica and Greenland have provided unique information about the Earth system. From the vast body of information now available, some generalizations can be made which are crucially important for our understanding of Earth system dynamics and the possible impacts of human activities on the Earth. These issues were discussed in the session, and new questions inspired by the Vostok record were contemplated. A few of the major points are as follows:

1. Rapid climate changes, between multiple quasi-stable states, can and do occur.

2. Abrupt changes in the thremohaline circulation (indicated in part by a comparison of Antarctic and Greenland ice-core records) have taken place, associated with large and rapid changes in climate.

3. There are strong linkages between the physical and biogeochemical aspects of the Earth system. These are manifested by covariations of key atmospheric trace constituents such as CO_2, CH_4, N_2O and aerosols with indicators of the physical climate.

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4. Mineral dust plays an important but not fully understood role in the carbon cycle as a supplier of essential nutrients to terrestrial and marine ecosystems. Glacial times have included phases when the global redistribution of mineral elements through dust has greatly exceeded that of today.

5. The Earth system is characterized by both positive and negative feedbacks, as illustrated by the occurrence of both rapid changes and more-or-less stable "end stops" in CO_2 concentration in the Vostok record.

There remain very many open questions and research issues. The session highlighted a few of them:

- What mechanisms underlie the glacial-interglacial changes of atmospheric CO_2 content? (A general consensus among participants was that a solution to this long-standing problem may be in our grasp, provided we recognize that no single mechanism can be a full explanation.)

- What exactly is the role of enhanced dust delivery to the ocean with respect to changes in the carbon cycle? (Several studies converge on assigning a significant but limited role for dust in glacial-interglacial CO_2 changes. There remain large uncertainties in the magnitude and details of operation of this process.)

- Can we identify periods warmer than today in the palaeorecord? If so, what can we learn from them about the future? (This question needs to be qualified with the observation that climate anomalies typically have a strong spatial pattern, so the question cannot be meaningfully studied from the perspective of one region alone.)

- What controls the intensity and duration of interglacials, in the absence of human interference with the atmosphere? (Marine isotope stage (MIS) 11 is an interesting case because orbital conditions were then quite similar to those of the Holocene.)

- What are the mechanisms behind rapid changes in trace gases, aerosols and climate? (This is still a highly speculative field, made more difficult by synchronization problems between ice and trapped gases, and between marine, terrestrial and ice records.)

- How do the linkages between northern and southern hemisphere climates vary through glacial-interglacial cycles? (This issue is crucial to understanding the role of ocean circulation changes.)

- What is the contribution of CH_4 clathrates in permafrost and the sea floor to the ice-core record of CH_4? (This is highly controversial, yet of vital importance to understanding the possibility of unpleasant surprises associated with possible large CH_4 releases in the future.)

The subsequent discussion centered on the issue of how most effectively to use palaeorecords (of all types, from all regions) to unravel the causes of changes in atmospheric composition, especially CO_2, shown by the ice core records. This issue is crucial because there are potentially many ways in which a given change in CO_2 concentration could happen, but different causes are expected to leave different spatial and temporal "fingerprints" in terrestrial and marine sediment archives. Some of the required information exists but still needs to be put together in accessible form. Other information may be lacking or deficient, suggesting a need for new data collection and/or the development of new proxies. Key regions and variables include Southern Ocean sea ice, and tropical palaeoenvironments generally over one or more glacial-interglacial cycles.

The role of modelling in helping to understand the palaeorecord was discussed. A strong case was made for utilizing models in "data assimilation" mode. It was also emphasized that modelling of past environments must, sooner rather than later, progress from time-slice approaches toward transient modelling. This has been done by Earth system models of intermediate complexity, but needs to be done by general circulation models as well. It was recognized that a number of practical problems remain to be solved e.g. about how to handle time-dependent sea-level changes in coupled atmosphere-ocean GCMs.

A challenge was proposed to modellers: to make model-based predictions, now, about what will be found in the EPICA ice core when the record is extended back beyond the past half-million years or more and into the "41 ka era" before the onset of the 100 ka glacial-interglacial cycle that has dominated recently. Similarly, modellers could usefully try to hindcast stable isotope ratios (such as $\delta^{13}C$ in CO_2 and in CH_4) when these become measurable in ice cores with sufficient precision.

An additional topic proposed for study was the "superdeglaciation" (massive, rapid melting of the Greenland ice sheet) which may have occurred during the last interglacial and may be forced to occur due to anthropogenically increased greenhouse gas concentrations during the present one. This topic could be approached through a combination of ice-sheet modelling with palaeodata from the last and earlier warm interglacials. A further focus on MIS 11 is also well justified.

International Nitrogen Initiative (Working Group C6)

Chairs: Sybil Seitzinger, Mary Scholes
Rapporteur- Dork Sahagian

This session aimed to stimulate interaction and integration of IGBP Core Projects with the new IGBP Fast-Track Initiative (see article on pg. 1) related to the International Nitrogen Initiative (INI). The working group participants included people (~25) from many IGBP core projects and from both developed and developing countries. Mary Scholes opened the session with a brief overview of INI and the goals of the workshop. She also reviewed the concept of Fast-Track Projects as integrative across IGBP Core Projects, relatively short-term (~3 years), and producing products that feed back into IGBP core projects. Sybil Seitzinger made a short presentation on the history and goals of INI, and the 3-phase approach being undertaken to achieve those goals. The three phases include: I. Assessment of knowledge on N flows and problems; II. Development of region-specific solutions; and III. Implementation of scientific, engineering and policy tools to solve problems. The participants made suggestions, raised questions (summarized below), and provided input on past/current/planned IGBP projects addressing N issues.

The participants expressed strong positive responses to the goals and approach of INI. It was noted that almost all past, current and planned IGBP projects include some N component. The Chairs of those IGBP projects should be contacted to obtain more detailed information on the N studies and data availability associated with those projects. Potential products of INI within the time frame of this Fast-Track project could include: 1) books and scientific papers from the cross-cutting topical workshops (e.g., fertilizer workshop; denitrification workshop) that summarize the state of the science and research/data gaps; 2) a white paper policy brief on N; and 3) a short-term focused study on integration of science and policy.

The recurring themes in the working group discussion were policy and regional centers.

Policy: Engage policy-makers at the beginning of the project rather than trying to bring them on board after the program structure has been defined. There are three potential ways to accomplish this:

- Modify the stated INI goal to put the policy up-front (e.g., Provide scientific, engineering, and policy tools to the research community right from the start).
- Determine what the policy community wants to know. If policy-makers ask INI for information, INI is more likely to have an impact.
- Develop a white paper (policy brief) that includes: a) data on emissions/sources of N, b) relevance of N to policy, human health, environment, recreation, etc., and c) what information/tools are needed to address these issues. A "road show" to present this policy brief in various world regions could assist with engaging, identifying, and providing INI products that will be relevant to the "stakeholders" in INI.

Regional Centers/Regional Assessments: Regional centers were considered essential to the success of INI developing products of use to policy. Specific issues raised included:

- How can assessment procedures be standardized across regions? Consider differences in the technological capabilities and financial resources among regions. Consider ways to include "local knowledge" that may not conform to the "standardized assessment" procedures.
- Identify at what scale policy is made in each region in order to determine how the regional centers can most effectively interact with the national-level policy makers.
- Identify who the "stakeholders" are in INI. Who wants to know about N at the regional level?

Future plans for INI include two workshops in 2004. The first will focus on Fertilizer (Kamapala, Uganda, January, 2004). The second will examine denitrification (Woods Hole, Spring, 2004). These workshops should serve to mobilize the community on the two sides of the nitrogen cycle to takes steps toward closing the global nitrogen budget.

Introducing the Dynamic Biosphere into Earth System Models (Working Group D3)

Conveners: P. Friedlingstein, I.C. Prentice

The introduction of a more realistic biosphere into Earth System Models (ESMs) is an ongoing activity. Several recent studies showed the importance of the biosphere (both on land and in the ocean) on the control of the major greenhouse gases and reactive species in the context of future or past climate change. A static representation of such exchanges is clearly not satisfactory anymore; there is a need for a dynamic representation of the land and ocean biosphere in climate models.

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The level of maturity of such dynamic models is not equivalent between the land and the ocean. The development of land biosphere models started over a decade ago and is reaching a level of relative maturity (although many processes are still unaccounted for or poorly represented). On the other hand, ocean biosphere modelling is still in its infancy. The "Green Ocean" activity can be seen as a brainstorming activity to initiate such development. This unbalanced level of development translated into an unbalanced land/ocean ratio of participants at the present working group. Therefore the subjects approached are biased toward the land.

The coupling of the dynamic land biosphere to the GCMs is already going on. Nine modelling groups have, or will have soon, a GCM coupled to a dynamic land biosphere (Hadley, IPSL, MPI, NCAR, LLNL, GFDL, CSIRO, CCSM and Frontier). In addition, there are two modelling intercomparison projects that will help to validate components of such new models (see 'MIPs Catalog' on pg. 10). The first is PILPS-C1, a GEWEX activity that aims to test the ability of GCM land surface schemes to simulate the land atmosphere exchanges of energy, water and carbon dioxide at the diurnal to interannual frequency as well as the growth of the forest biomass and soil organic matter of a FLUXNET site (Loobos, Netherlands). The second project is C^4MIP, where the aim of the first phase is to use the coupled atmosphere-land GCM, forced by historical sea surface temperature, to simulate, among others, the atmospheric concentration of carbon dioxide. All modelling groups are encouraged to participate in these intercomparisons, but other benchmarks may have to be initiated in order to validate other components of the coupled land-atmosphere system. These may include the following:

a) The forest/grass transition in dynamic vegetation models when coupled to GCMs. The Hadley coupled simulations highlighted the potential importance of such transition in the future. We clearly need to better test such transitions looking for example at the dynamics of tropical precipitation on seasonal and interannual time-scales, and at some recorded transitions in Africa. It would be important to assess the realism of GCMs in simulating the precipitation regimes and of the biospheric models in simulating tree/grass competition.

b) Can these coupled climate-dynamic vegetation models simulate a collapse of the "Green Sahara" as occurred during the Holocene?

c) Fires are important drivers of vegetation dynamic, carbon and trace gases fluxes, the Fast Track Initiative on Fire (See article on pg. 1) should provide the means to test the ability of these coupled models to reproduce fire frequency, extension of area burned, amount of carbon, reactive species and aerosols released.

It would be extremely valuable if the information of such benchmarks (existing and future) could be centralized. GLASS was suggested as a potential candidate for such a central point.

Regarding the inclusion of dust in ESMs and its role on ocean productivity and therefore on atmospheric CO_2, key obstacles were identified. A realistic representation of wind speed distribution (especially the higher tail of the PDF) in ESM is needed; there is obviously a scaling issue here. The exchange of dust at the air-sea interface needs to be better represented in ocean biogeochemistry models. There is also a need to better understand the interaction between iron supply and the growth of phytoplankton (diatoms in particular) and N_2 fixers.

Regarding the biogenic sources, as mentioned above, an effort is needed on understanding of fire in terms of frequency, extension, and emission factors. Recent increases in understanding of the processes driving natural biogenic emissions of reactive species need to be introduced in ESMs. Nitrogen emissions for soils are relatively well understood, however, the current dynamic vegetation models that are embedded in GCMs do not account for the nitrogen cycle.

Emissions of methane by land is currently not accounted for in dynamic vegetation models. What is needed is a good representation of (seasonal and permanent) wetland distribution. This requires solution of the hydrologic budget at very high resolution, incompatible with the current GCM resolution. Asynchronous coupling is therefore required. Models of methane emissions from wetlands do exist, and their incorporation into ESMs does not seem to present major problems. However, other natural sources of methane, such as the ones from herbivores, have not been addressed so far in a prognostic way. Also, there is a lack of a comprehensive methane emission dataset needed to validate methane emission models.

The Earth System Atlas (Working Group D4)

Convener- Dork Sahagian

The session on the Atlas was directed to engage the broader IGBP and ESSP community in the Atlas effort, as well as to bring all interested parties up to date with recent developments and solicit suggestions for further refinement and future directions. A more complete description of the Atlas is included in a separate article (pg. 6), so will not be repeated here.

Modelling is not programming:
The argument for a declarative modelling approach in Earth System modelling

By Robert Muetzelfeldt (r.muetzelfeldt@ed.ac.uk)
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Modelling is a knowledge-rich, collaborative design process. This is especially true in the emerging field of Earth System modelling, where it necessarily draws on a wide range of research results, involving the efforts of many scientists working on different parts of the earth system, and making a great number of design decisions for appropriate model design at a variety of scales.

Computers have considerable potential to help in this process. They can link between research knowledge and model elements, they can help scientists to share models and parts of models, and they can support the model-design process. However, at the moment this potential is barely recognised, let alone realised, for two related reasons: we seem to think that the role - the only role - of computers is to run simulations; and that the only way to represent research-grade models on a computer is as a computer program. Unless we can break this mindset, and adopt a fundamentally different way of representing models on computers, we will fail to benefit from the support that computers can provide for the modelling process.

What's wrong with implementing models as programs?

- Programs for research-grade models are costly to develop and maintain, often running into many thousands of lines of code and requiring specialist programming skills.
- Debugging is difficult. It is hard to put probes in a model to (e.g.) plot some arbitrary variable, and it is difficult to test submodels in isolation.
- Re-use of models, submodels and model support tools is difficult and thus rare.
- Programs, and thus the models they embody, frequently become obsolete at the end of the research project within which they were developed.
- It can be very hard for others to comprehend a model from its program.
- There is no enforced correspondence between a model-as-program and the documentation (e.g. metadata, comment blocks or journal paper) that describes the model. Variables cannot have metadata attached to them.
- An equation in a conventional programming language is actually an assignment statement. It is possible to read the statement

```
temperature = 20 - 0.01*altitude
```

  as a functional relationship, but its meaning is:

  Calculate the expression on the right, and assign it to the variable on the left.

  So there is nothing to stop us adding, by mistake, another equation for temperature later on. This means that, while it is possible to write principled programs to implement a model, the language does not enforce this.
- There is a considerable conceptual gap between the constructs provided by a programming language, and those in the head of modellers when they design a model. The design statement "Every pixel contains a model of vegetation dynamics" translates into something like an iterative loop, calling the vegetation model for each pixel.

Currently, we are seeing a rash of 'integrated frameworks' (aka 'integrated environments') for modelling being developed. However, these mainly address the 're-use' issue. In principle, they reduce the need to re-develop support tools (e.g. simulation engines, graphical display tools), and they allow submodels to be re-used. In practice, the mere fact that we are getting so many 'integrated frameworks' being developed suggests that their use is limited to the controlled environment of a particular research programme, rather than being a global solution. Also, they almost all still see the individual model components (submodels) as being programmed in a conventional programming language, so do not address most of the problems identified above.

The essence of the solution

To overcome the problems of implementing a model as a computer program, we need to separate the representation of the mathematical structure of the model from the tools we use for reasoning with the model. This approach is termed declarative modelling, since the model is represented as a set of statements that define the structure of the model, and do not constitute instructions in a conventional procedural ('imperative') programming language.

*"Perspectives"is a forum for thoughts from the broader community. GAIM invites comments, responses and different perspectives for future issues.

continued on next page

'Modelling' -

You'd probably be pretty horrified if you asked someone to work out the total of some numbers, and they came up with the following program:

```
a(1)=27.1; a(2)=53.2; a(3)=41.9...... a(157)=19.2
sum=0; for i = 1 to 157; sum = sum+a(i); next i
print sum
```

Why? Because this one document contains both the data and the program for analysing it. Separating data and program gives huge benefits: the same data can be analysed by different programs; and the same program can be applied to different data sets. Of course, the data do not have to be numeric. The following could be 'data' for an electronics simulator:

```
resistor(r1,220).
capacitor(c3,100pF).
connected(r1,c1).
```

Again, it is obvious that it is far better to separate out the representation of the circuit from one particular form of reasoning we might wish to do with it.

And yet, when we come to modelling, what do we do? We produce a single entity (the computer program) that merges two quite different concepts: the design of the model, and the calculations we need to do to simulate its behaviour. Separating the design from the simulator would yield huge benefits:

- the same model could be run by a variety of simulators;
- the same simulator could be applied to many different models.

The same benefits can, in some cases, be obtained using conventional programming techniques, by separating out the programmed model component from various support tools (input/output, numerical integrators, etc), and indeed a number of modelling environments would make this claim. The true benefits of a declarative modelling approach become apparent when we start to consider all the other ways computers can support the modelling process.

Use-case scenarios: what we can do with declaratively-represented models

- Enable the same model on different computing systems: a single PC, a cluster of workstations, and a high-performance computer.
- Automatically generate metadata and model descriptions, in a variety of formats, from the model representation. These can be tuned to suit different types of user, from a specialist scientist to the general public.
- Interrogate model structure ("Find all variables influenced by temperature.").
- Search a model catalogue (or the internet) for models with desired characteristics.
- Two groups take the same model and work on it. After 6 months, automatically compare the two versions. Automatically merge the two versions into a new, composite version.
- Model transformation. In GAIM, you may want to take a complex Earth System model and automatically collapse it down to an EMIC (Earth Model of Intermediate Complexity); or take an EMIC and produce a roughly-equivalent Daisyworld version. There is a growing body of theory concerning perfect and imperfect (approximate) model aggregation, plus heuristics developed by modellers themselves, which could be applied to Earth System models.
- Link model elements (variables, functional relationships) to equivalent elements in conventional experimental or field-based research, using ontologies common to research and modelling.

Is it achievable?

Yes: there are numerous indicators suggesting that declarative modelling is a feasible approach.

- Computer-aided design (CAD) systems are commonplace in other design areas - e.g. architecture, electronics. These are based on an absolute distinction between the representation of the design and the tools available for processing designs. Thus, a building is designed once, then the design passed to a 3D visualisation package, to a 2D plan producer, a tool for costing its construction, and perhaps another for simulating the heat balance of the building.
- Simulation languages (such as CSMP, ACSL and Dynamo), visual modelling environments (such as Stella, Vensim, Modelmaker and Powersim) and spreadsheets all embody the declarative modelling concept to some extent. However, they do not encourage others to develop tools that are compatible with their model-representation language; and the expressiveness of these systems is in general inadequate for the needs of modelling in ecosystem research.
- The last few years have seen the emergence of XML as the standard format for representing information on the web, and of XML-based markup languages for representing information within specific disciplines (see Box 1).

- Simile (Box 2, next page) is a visual modelling environment based on an open declarative language (http://www.simulistics.com). I initiated its development specifically to demonstrate that a very broad range of ecological and environmental simulation models could be built within a single design environment. It is capable of representing complex models, with many hundreds of equations and complex forms of disaggregation, including spatial and individual-based models. To undertake simulations, Simile generates and compiles C++ code, so complex models can be run at similar speeds to hand-crafted code. Simile supports modular modelling, so matches the abilities of current component-based integrated modelling environments. However, potentially the most important feature of Simile is that models can be saved in an XML-based model-representation language, enabling many other groups to develop software tools for handling Simile models (including simulation engines) completely independently of Simile itself.

What is required to achieve this vision?

First, and most important, we need a change in mindset: from model-as-program to model-as-design.

Second, we need to develop a standard, XML-based model-representation language. There are many precedents for this, both within the World Wide Web Consortium (W3C), and for the many markup languages that have been or are being developed. This process should involved a consortium with 3 types of member: people with experience in the standards process and the design of a markup language; people with experience of developing model-representation formats for simulation modelling (there are a number of relevant initiatives to draw on); and practitioners - i.e. modellers - to ensure that the things they want to express in their models are handled by the language.

Third, we need to re-cast a number of representative Earth System models in the model-representation language. This proceeds in parallel with the design of the language itself, and serves to ensure that the language is capable of handling actual models. In my experience, the work involved in doing this is not great (perhaps weeks) for well-programmed models.

Box 1. XML and related technologies

XML - the eXtensible Markup Language - is the standard way for representing information on the web. Like HTML (the HyperText Markup Language), an XML document is a text file with information enclosed between tags in triangular brackets. However, whereas in HTML the tags are predefined and relate generally to appearance, in XML the tags have no pre-defined meaning and relate to information content.

One use of XML is to represent structured data. Thus, the following could be a (greatly simplified) extract from a document on stocks and flows of carbon in a biosphere model:

```
<model>
    <pool name="ocean">39000</pool>
    <pool name="atmos">750</pool>
    <flow name="uptake" from="atmos" to="ocean">90</flow>
    .......
</model>
```

Note that all the element names (`model`, `stock` and `flow`), the attributes (`name`, `from`, `to`) and the syntax (e.g. `stock` is inside `model`) are defined by a particular community. This constitutes a markup language for this particular domain.

XML documents can be processed in two ways. First, all the major programming languages are able to read, process and generate XML documents. Second, there is an XML-based language called XSLT (eXtensible Stylesheet Language for Transformation) which can be used to transform any XML document into different XML, into HTML (for display in a browser), or into plain text. Thus, an XSLT document could be used to transform the above information into the following HTML:

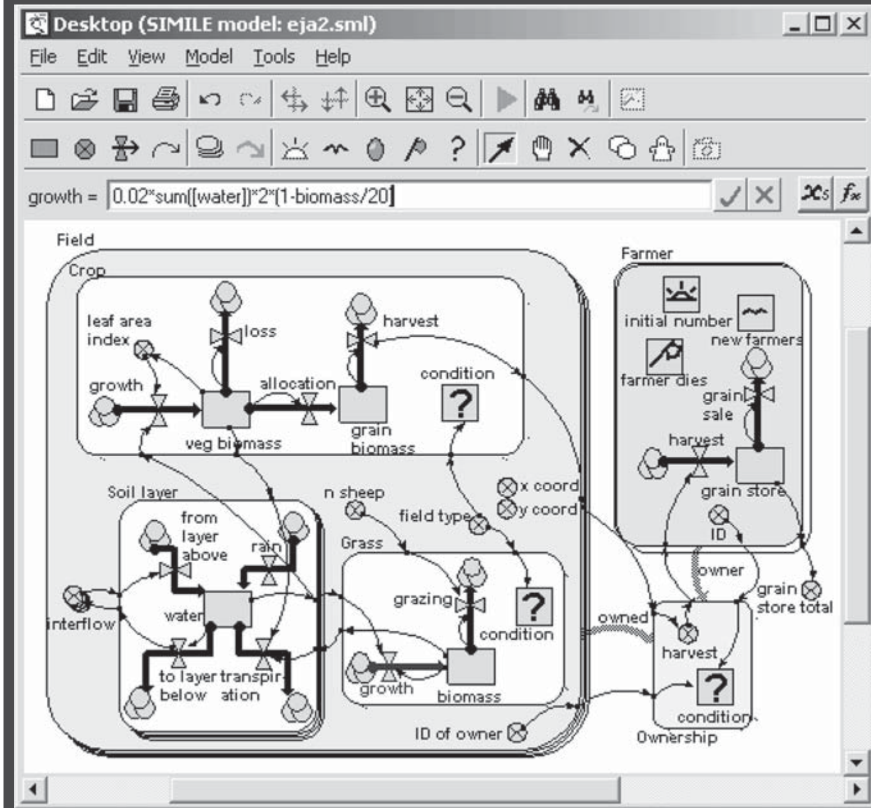
```
<body>
 <b>ocean</b>: pool value = <b>39000</b>
 <b>atmos</b>: pool value = <b>750</b>
 flow <b>uptake</b> from <i>atmos</i> to <i>ocean</i> = <b>90</b>
 .......
</body>
```

which would be displayed in a browser as:

ocean: pool value = **39000**
atmos: pool value = **750**
flow **uptake** from *atmos* to *ocean* = **90**

continued on next page

Box 2. The Simile visual modelling environment



This screen dump illustrates the expressiveness and intuitiveness of model-representation language in Simile. (The example has been chosen to be readily understandable and illustrative, rather than for any direct relevance to Earth System modelling.)

It represents a fixed number of spatial units ("fields") and a dynamically-varying population of farmers (note the difference in the boundary of the two submodels). Fields are spatially referenced with x, y coordinates; they include a multi-layer soil water submodel, and may have either a crop submodel or a grass submodel, depending on the field type.

The farmers are represented as individuals, which may be created and die, and which have a grain store. The ownership of fields by farmers is represented, through the Ownership submodel, and this is used to channel the grain harvest from all the fields owned by a farmer into his or her's grain store. The total grain store of all farmers is calculated.

Simile's visual design interface allows the diagram, and the underlying equations, to be readily edited, simulations to be run (using an automatically-generated C++ program), and results displayed in a variety of graphical and tabular formats.

Fourth, we need to develop a reference collection of tools for handling models expressed in this language. As an absolute minimum, this will include tools (both visual and text-based) for building and editing models; tools for simulating the behaviour of models expressed in the language and displaying the results of simulations; and tools for displaying model structure in a variety of formats (e.g. as an HTML document).

Note that, unlike every other current 'integrated framework' initiative, this approach has absolutely no software core. The only core is a standards document defining the syntax and semantics of the model-representation language. All software tools are independently-developed units, sharing only the ability to read and/or write models expressed in the standard language.

Further development will take place on a piecemeal basis. Existing models will be converted into the declarative model-representation language and published on the web. Individual groups will decide to add specific tools, to meet their own requirements or to contribute to the global toolbase. These could include, for example, the development of program generators for simulating model behaviour on computer clusters or parallel computers; the development of improved run-time environments (e.g. for backcasting, parameter estimation); or tools for automatic comparison of two similar models.

Final thoughts

In the near future, numerous ecosystem models, implemented in Simile and other open modelling environments built around declarative modelling principles, will be 'published' on the web, as XML documents. You will be able to enter a URL or click on a hyperlink to load and run the models; or load several and make a composite model with a few mouse clicks. You will be able to select a model with one URL, and some tool with another, to have the same model displayed diagrammatically, mathematically, or as a prose document. I encourage other groups to develope approaches with similar functionality.

This will revolutionise the way we model, so that programmed models may rapidly come to be seen as technological dinosaurs. The key concern, for the Earth System community amongst others, is that this will result in the emergence of one or more *de facto* model-representation standards. The challenge is to join this revolution now, and have some chance of molding it to the particular needs of Earth System modelling rather than sit back and fit in with whatever standard emerges.

TransCom Update

by Kevin Gurney and Peter Rayner

May of 2003 saw the last formal meeting of the TransCom 3 (T3) experiment. The meeting, held in Jena, Germany at the Max Planck Institute for Biogeochemistry, was an opportunity for many of those involved in this global carbon cycle atmospheric inversion intercomparison experiment to share their latest work. In addition to the core TransCom 3 inversion results, new projects using TransCom 3 experimental output and carbon cycle research related to the TransCom experiment were presented. By the end of the four day meeting, it became clear that this community has a great desire to continue working with the voluminous TransCom experimental products, occasionally meeting to share results and plan progress. In addition, there was keen interest in broadening the purview of the group to include investigators working on all aspects of inverse modeling of carbon species and involve to a greater extent the many different measurement communities whose observations form the foundation for the inverse calculations. This activity is being pursued with the IGBP Global Carbon Project and may come under the broader focus of “model-data fusion”.

TransCom commenced in 1993 as a project to explore the role of differences in simulated atmospheric transport in explaining the differences in CO_2 inversion results. In its first phase it considered the simulated concentrations arising from the dominant drivers of north-south gradients and seasonal cycles in observed CO_2. In the second phase it posed the question of how much of the spread in transport could be judged implausible by considering tracers with more or less known sources and distribution, namely SF_6. In its third and most ambitious phase, TransCom designed a precise protocol in which many different models provided transport fields for use in the same inversion algorithm and the same data. The first inversion set-up was necessarily simple to maximize the

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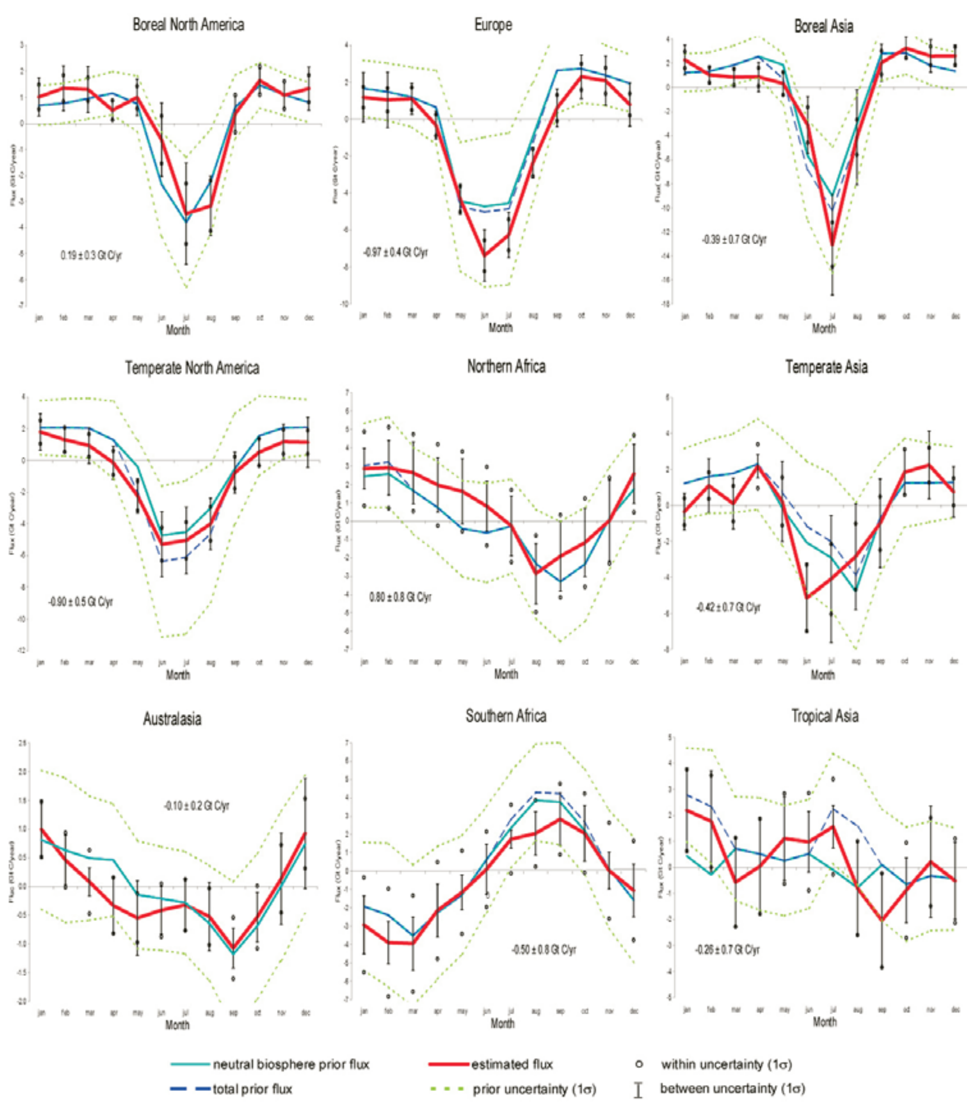


Model mean estimated flux, total prior flux, neutral biosphere prior flux, prior uncertainties, and posterior uncertainties for selected land regions. Numerical estimate of annual mean flux is provided in each figure. Note that the vertical scale varies. The fluxes do not include fossil fuel emissions.

number of participating models. Here long-term mean data were used to infer long-term averaged sources. A smaller subset of models also computed the relation between monthly averaged sources and monthly averaged concentrations, allowing the inference of seasonally or interannually varying sources. Inversions for both these cases have also been carried out and either published or in preparation. The studies also featured a large number of sensitivity tests to all the other details of such an inversion, e.g. spatial resolution, data uncertainty, prior constraint etc.

The most recent centralized TransCom results to date include the publication of the seasonal inversion flux estimates for the eleven land and eleven ocean regions, forthcoming in the journal *Global Biogeochemical Cycles*. Compared to a seasonally-balanced biosphere prior flux generated by the CASA model, the T3 results show significant changes to the carbon exchange in the European region with greater growing season net uptake which persists into the Fall months (see figure, previous page). Both Boreal North America and Boreal Asia show lessened net uptake at the onset of the growing season with Boreal Asia also exhibiting greater peak growing season net uptake. Temperate Asia shows a dramatic Springward shift in the peak timing of growing season net uptake relative to the neutral CASA flux while Temperate North America exhibits a broad flattening of the seasonal cycle. In most of the ocean regions, the inverse fluxes exhibit much greater seasonality than that implied by the ΔpCO_2 derived fluxes though this may be due, in part, to misallocation of adjacent land flux. In the Southern Ocean, the Austral Spring and Fall exhibits much less carbon uptake than implied by ΔpCO_2 derived fluxes. Sensitivity testing indicates that the inverse estimates are not overly influenced by the prior flux choices.

Considerable agreement exists between the model mean, annual mean results of this study and that of the previously published TransCom 3 annual mean inversion (Gurney et al., 2002). The differences that do exist are in poorly constrained regions and tend to exhibit compensatory fluxes in order to match the global mass constraint. The differences between the estimated fluxes and the prior model over the northern land regions could be due to the prior model respiration response to temperature. Significant phase differences, such as that in the Temperate Asia region, may be due to the limited observations for that region. Finally, differences in the Boreal land regions between the prior model and the estimated fluxes may be a reflection of the timing of Spring thaw and an imbalance in respiration versus photosynthesis.

Future TransCom 3 work includes completion of the interannually varying inversion and the "level 3" portion of the experiment in which investigators compare inverse results produced through their own inverse procedure and transport model. This phase and a synthesis of the previous

Carbon Cycle Model Intercomparison Projects Transition to GCP

Three projects that were the mainstay of GAIM's early phase of model intercomparison are now being transitioned to the Global Carbon Project (GCP) (http://www.globalcarbonproject.org), as GAIM focuses increasingly on Earth system issues. With the inception and growth of the GCP, a natural "home" is provided for the intellectual and logistical support of these three projects. These include:

- Ocean Carbon-cycle Model Intercomparison Project (OCMIP)(http://www.ipsl.jussieu.fr/OCMIP/)
- Atmospheric Tracer Transport Intercomparison Project (TransCom) (http://transcom.colostate.edu/)
- Ecosystem Model-Data Initiative (EMDI)(http://gaim.unh.edu)

Each of these projects has evolved since it began, with OCMIP going through its various phases, EMDI metamorphosing from the original Net Primary Productivity intercomparison (NPP), and TransCom ending its original task and considering new directions and emphases. The latest information and project details, as well as references can be found at each of the projects' individual websites, and linked from the GAIM website http://gaim.unh.edu work should be a useful addition to the next IPCC report on climate change. A number of additional research activities are continuing that use the TransCom output including network optimization studies, sensitivity testing, and inclusion of other species such as $\delta^{13}C$.

In addition to producing leading research results in the area of inverse carbon flux estimates, TransCom has formed a broad community of researchers interested in this approach to characterizing the global carbon cycle. Through its success, TransCom has served a crucial educational role as new investigators avail of the inverse approach. In the future this group plans to broaden research efforts to include the use of remotely sensed, continuous observations, coupled Earth System inverse modeling, assimilation techniques, and multi-consituent inversions. Links to the atmospheric chemistry community and the surface flux and biospheric modelling communities should serve to enhance and broaden the original TransCom goals.

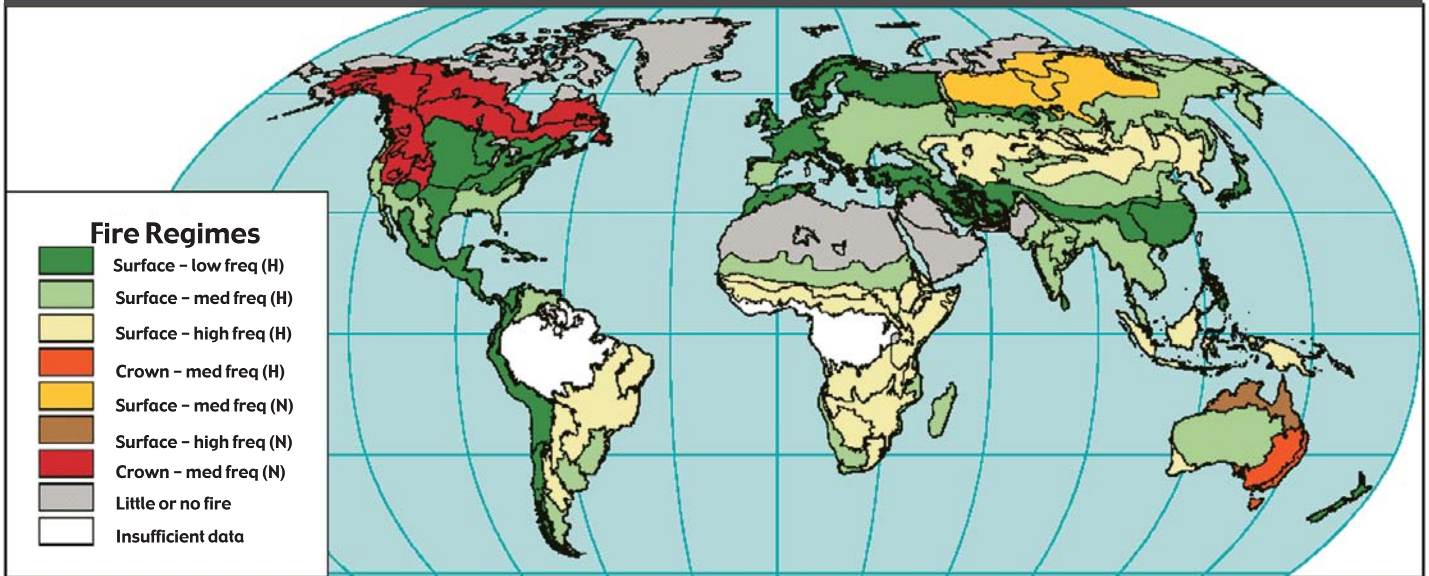
GAIM Launches New Post-Doc Network

GAIM has been conducting a number of modelling activities in recent years, and the complexity and number of activities has grown to the point that a concerted effort is needed to take the next major steps in integrated model development and assessment. Toward that end, GAIM is launching a program to create a number of post-doctoral positions for young scientist who can work in a coordinated manner in support of Earth system models, their applications, and assessment of results. Each of the young scientists in the network will conduct specific projects, while contributing to a broader whole within the context of IGBP/GAIM. Each young scientist (post-doctoral level) will be supported and supervised by a primary sponsor and each project will stand upon its own merit. However, by coordination of the various projects within IGBP/GAIM, the results can be placed in the broader context of Earth system analysis and begin to address some of the exceedingly complex questions facing the global change research community in the 21st century. At the same time, this will also help to train young scientists and increase their involvement in leading international research efforts.

Earth system modelling is being conducted at various levels, from simplified, stylized models that focus on whole system behavior, to highly detailed, high-resolution models that include the myriad processes involved within the various subsystems of which the Earth system is composed. In the coming years, most emphasis will be placed on the "upper half" of the spectrum of model complexity, including models of intermediate complexity and full-complexity AOBGCMs. The role of the young scientists would be in the development of analytical and numerical formulations of the highly coupled system. They will work toward elucidating some of the key aspects including non-linearities, switch and choke points, "hotspots" in which the system is particularly sensitive to perturbations or impacts, and relative performance of suites of models of comparable complexity.

It is anticipated that the result of the proposed network of young scientists will be the creation of a strong base of new expertise that can be applied to pressing global environmental problems and broader questions as identified in the "23 Earth System Questions" posed by GAIM in 2002. While each project is expected to lead to concrete results that would be of interest to a significant community in isolation, when coordinated within the context of IGBP/GAIM, they can contribute to the broader questions now being posed regarding the Earth system as an entity.

The first step has already been taken, and 2-3 post-docs will be supported at NCAR in conjunction with their own support of young scientists. GAIM encourages additional members aof the broader community who wish to participate in the coordinated network to contact the GAIM office.



Global map of fire regimes. This map shows present day regimes, although data are being collected for various times in the past. Ultimately, it may be possible to produce a series of global maps to describe specific aspects of the fire regime such as intensity, frequency, cause, seasonality, type and severity (e.g. amount of organic material consumed). In addition, such maps could be developed for future time slices on the basis of models using 2x and 3x present atmospheric CO_2 concentrations.

These first three Fast Track Initiatives should serve to catalyze integration of research in these critical areas, and lead to broader research efforts to determine the detailes of the roles of Iron, Nitrogen, and Fire within the Earth system. These initial “Fast Tracks” will set the stage for subsequent inititatives as additional areas are identified that stand in the way of progress in our understanding of the operation of the Earth system, humanity’s role in it, and how it will evolve in the future.

Research GAIM

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