Integrated Land Ecosystem - Atmosphere Processes Study

iLEAPS

Newsletter

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iLEAPS is
a core project
of IGBP

GLOBAL IGBP CHANGE

Editorial

Executive Director Anni Reissell

This fourth issue of the iLEAPS Newsletter includes several articles on vegetation fires, also generally referred to as biomass burning, as well as articles from iLEAPS recognized projects, AMMA and NEESPI. At the 22nd IGBP Scientific Committee (SC) meeting in beautiful Angra dos Reis on the coast of Brazil, hosted by SC chair Carlos Nobre, continuation of the very successful IGBP Fire Track Initiative (FTI, 2003-2006) was discussed. Based on suggestion by iLEAPS SSC member Sandy Harrison, iLEAPS will host the continuation of Fire FTI, for the moment called the Fire Task, in collaboration with other IGBP core projects GLP, IGAC, SOLAS, AIMES and PAGES. The topic of this newsletter is therefore timely and gives a brief overview of various aspects of fires: the fire-related articles range from measurements of gas phase compounds and particles in several wildland fuels to the role of fire in the Earth system.

As fire is an important process and has occurred throughout the history of life on land, it has changed and will continue to shape the landscape and vegetation structure, subsequently affecting water vapor fluxes, nutrient cycles, atmospheric composition in the troposphere and also in the stratosphere, properties of clouds as well as convective properties of the boundary layer, and ultimately climate, feeding back to the land surface by altering radiative properties, photosynthetic rate and carbon exchange. Also changes in deposition and erosion have an impact on land surface properties, vegetation and water quality.

Remote sensing allows for new global scale data on ignitions, burned areas and fire intensities, as well as measurements of trace gas and particle concentrations. Multispecies measurements both at the surface and aloft, in addition to measurement inter-comparisons and laboratory studies are of importance when determining atmospheric concentrations, transformation and deposition. Collaboration between observationalists and modellers as well as among a variety of disciplines is increasing and welcomed by iLEAPS.

Since the areas of biomass burning plumes are usually very large, the effects are important regionally, especially in the Southern Hemisphere, and also globally, as exemplified by several articles in this issue. In addition, simulations of global warming estimate that the largest temperature increases take place in the high latitudes, with projected increase in forest fire size and frequency affecting the boreal forest zone. The interactions between fire regimes, vegetation and climate are complex, especially as fire regimes are now largely controlled by humans; hence research benefits from using historical records. As stressed by the recent IPCC reports, reduction in tropical deforestation and biomass burning has important global implications as climate change will affect the extent of tropical forest area, and hence the carbon cycle and global hydrological cycle. Policy makers and fire management decision makers benefit from integration of improved measurements and modelling, from local to global scale.

Marie Curie – iLEAPS

Marie Curie Actions are part of the European Commission initiatives to facilitate mobility of researchers and Marie Curie – iLEAPS is part of this programme.
A number of travel grants are available for each event. Read criteria for eligibility, detailed information and updates at www.atm.helsinki.fi/ileaps/marie-curie-ileaps.

Conference Marie Curie – iLEAPS, Models

Towards a process-based description of trace gas emissions in land surface models

16–19 October 2007, Marina Plaza, Helsingborg, Sweden
Organizer: Dr. Almut Arneth, Lund University

The workshop contributes to the IGBP iLEAPS project and is supported by the European Commission via a Marie Curie workshops and conferences grant and by European Science Foundation activity VOCBAS. The main goal of the workshop is to facilitate exchange between observationalists and modellers; schedule and venue will allow for ample discussion after presentations or in front of posters. Presentations and discussions should concentrate on the following objectives:

- What is the state of the art of our process understanding and how well (if at all) is this reflected in surface emission models?
- Would an improved representation of the surface processes help to improve the description of atmospheric chemistry (or climate) models, if yes, how?
- What are the key vegetation-atmospheric chemistry-climate feedbacks that need to be quantified?
- What kind of data and observations are required (and from which region) to improve process descriptions in vegetation-emission models and/or to evaluate model output?
- Are there any unidentified feedbacks to be expected?

Deadline for abstract submission to this event has expired.

Training course Marie Curie – iLEAPS, Model-Data Assimilation

Model-data assimilation, recent progress and future needs

10–19 March 2008, Hyytiälä Field Station, Finland.
Organizer: Prof. Timo Vesala, University of Helsinki
3 ECTS

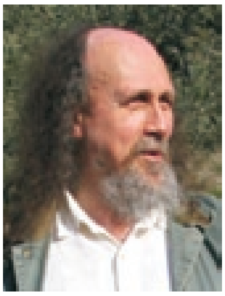
This training course will be merged with a similar course, Data Analysis, organized by the Nordic Graduate School, CBACCI. For continuous updates register to the iLEAPS e-mail list.

Conference Marie Curie – iLEAPS, Feedbacks Land-Climate Dynamics – Key Gaps

Current understanding of how integrated land ecosystem-atmosphere processes influence climate dynamics

Fall 2008, La Badine, France.
Organizer: Dr. Nathalie de Noblet, CEA-CNRS, France

Science
on biomass burning



Colin Prentice is Professor of Earth system science at Bristol University and leader of the UK Natural Environment Research Council programme Quantifying and Understanding the Earth System (NERC QUEST) research programme. He has broad research interests in biosphere-climate interactions, the carbon cycle, and climate change, and is a pioneer in the global modelling of ecosystems. He was the co-ordinating lead author for carbon cycle science in the IPCC's Third Assessment Report (2001). He has long been active in IGBP and currently co-chairs the AIMES (Analysis, Integration and Modelling) core project.

Fire in the Earth system and the IGBP

Colin Prentice[1], Sandy P. Harrison[2], Patrick Bartlein[3], Mike Flannigan[4] and Sandra Lavorel[5]

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Fire is an extraordinarily important process in the Earth system and has occurred throughout the long history of life on land. Today, people use fire for many purposes, including forest clearance, restoration, and land and wildlife management. They also start fires accidentally or deliberately; unfortunately, arson is becoming more prominent in a number of regions like California and the Mediterranean. There are often similarities in the time and place of natural and human-caused fires (Fig. 1) – because vegetation always has to be dry enough to burn. However, humans also cause fires during seasons or locations when lightning is rare. In fact, in some regions of the world as many as 90% of all fires are started by people – so it's easy to forget that fire is also a natural process with lightning strikes still accounting for many of the largest fires, including those that have had the most destructive effects in terms of human life and property. Indeed, the evolution of boreal, savanna and dry forest plants and ecosystems has been shaped to a large extent by this prevalent natural force. As is so often the case in global change science, the scientific community has stumbled rather late on the importance of understanding both a highly complex natural process and one in which a human imprint is by now almost ubiquitous.

Fortunately, tools to advance the scientific study of fire are at hand, or at least undergoing rapid development. The detailed records of fires kept by some government agencies during recent decades can now be supplemented by increasingly reliable remote-sensed data on ignitions, burned areas and fire intensities that are global in coverage. Remotely sensed concentration data on atmospheric trace gases, such as carbon monoxide, also provide powerful evidence of the global impact of wildfires. On the other hand, recent advances in the modelling of ecosystem processes have allowed modelling of climate-fire-vegetation interactions to progress beyond statistical correlations, and into the realm of explicit ecological and biophysical processes (see Fig. 2). Mod-

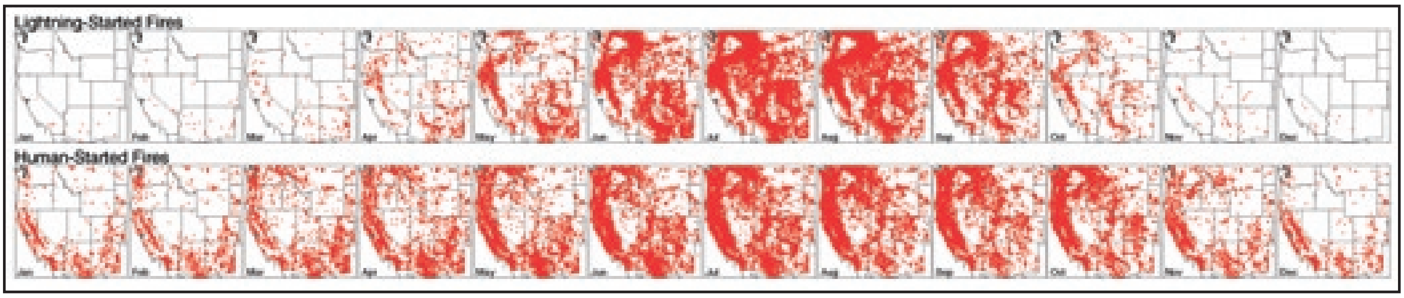

Figure 1. Natural and human-set fires in the western Unites States from January to December, a multi-year time series (1986–1996) of US Forest Service fire statistics (USFS Rocky Mtn. Research Station, http://www.fs.fed.us/fire/fuelman/).

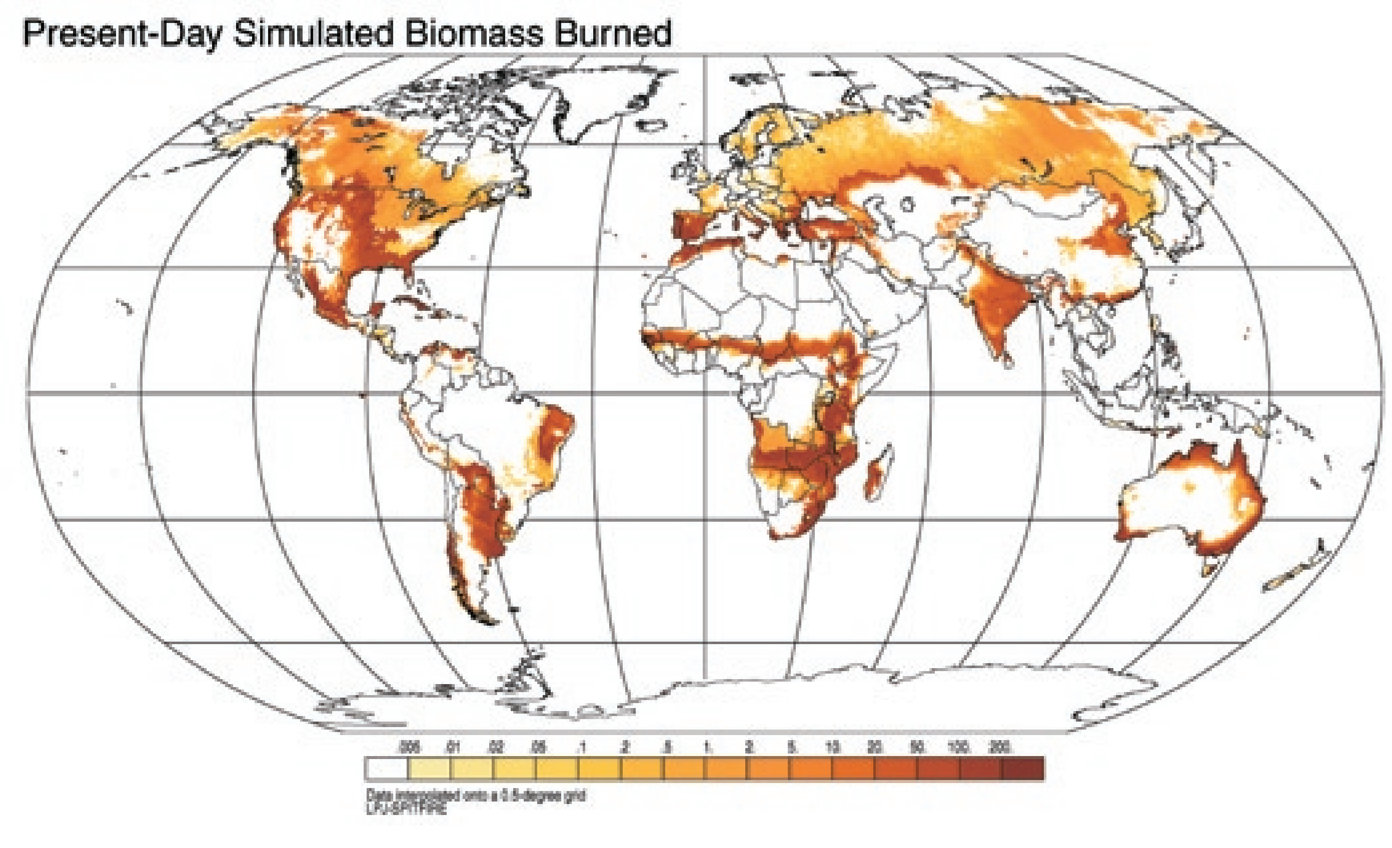

Figure 2. An example of a process-based simulation of the fire regime including the interaction of terrestrial ecosystems and fire. The model used is LPJ-SPITFIRE, developed by Kirsten Thonicke (Bristol) and Allan Spessa (Reading). Data provided by Kirsten Thonicke.

els of the fate of reactive pyrogenic compounds (such as carbon monoxide, nitrogen dioxide and hydrocarbons) in the atmosphere, which can predict the implications of fire for air quality and greenhouse gases such as methane and tropospheric ozone, are relatively well developed. With good observational and modelling tools, the time should be ripe for collaboration – among ecologists, climatologists, atmospheric chemists, carbon cycle scientists and wildfire experts – to develop a quantitative, predictive understanding of fire and its Earth system consequences.

There are also abundant data on past fires, stretching back well beyond documentary archives, through centuries (e.g. tree ring and fire scar records) and millennia (e.g. sedimentary charcoal counts). Palaeoecologists have been studying fire for decades and this knowledge should also form a crucial part of an integrative science of fire, throwing light on long-term fire regimes, the effects of natural climate change on fire, and the interactions of fire, vegetation and people in prehistory. But here is another familiar scenario: whereas huge amounts of data have been collected, there has previously been no systematic attempt to gather these data (with quality- and dating-control information) in a form suitable for large-scale scientific analysis. This requires collaboration among palaeoecologists, and with climate modellers who study ancient climates.

The Fire Fast Track Initiative

Following a ground-breaking workshop on fire, involving all of the relevant natural science disciplines, held at Isle-sur-la-Sorgue, France under the auspices of the Max Planck Institute for Biogeochemistry, Sandra Lavorel in 2003 proposed an IGBP Fast Track Initiative (FTI) on Fire. The overarching goal of the Fire FTI was to synthesize quantitative data and understanding of fire-related processes at a global scale. This proposal was accepted by the IGBP Scientific Committee and formed the start of a highly productive activity during an extended (2003-2006) FTI period. The work of the Fire FTI has been described in a series of reports and publications, and more are in the pipeline; it has produced a special issue of the International Journal of Wildland Fire, five additional published papers, and at least an equal number of papers in preparation. This iLEAPS newsletter article summarizes the highlights of the FTI's work, and outlines a follow-on programme of cross-project fire research in IGBP.

Historical and palaeo fire regimes has been the subject of one major strand of the FTI, initiated through a workshop organised by Cathy Whitlock, Tom Swetnam and Mike Flannigan in Boulder, Colorado in 2004. The initial aim of this workshop was to bring together contemporary fire ecologists and climatologists with experts on tree ring, fire scar and sedimentary charcoal records, with an initial focus on the western USA in order to share data and ideas. This effort was built on the International Multiproxy Palaeofire Database that began operation in 2003 and was hosted by NOAA at http://www.ncdc.noaa.gov/paleo/impd/paleofire.html. Subsequent work on this focus was reported at the December 2004 AGU meeting in multiple sessions on "Fire, Climate, and Ecosystems", and in an April 2005 workshop on "Fire History and Climate Synthesis in Western North America" in Flagstaff.

The availability of quantitative sedimentary charcoal records, either archived in databases or provided by co-operating authors, along with hundreds of publications in which sedimentary charcoal is described, provides a critical mass of information for summarizing the global patterns of charcoal deposition since the Last Glacial Maximum. These data also gave the opportunity to relate these fire patterns to the changing climatological, ecological, biogeochemical, and anthropogenic controls of fire. Initial attempts to informally develop a global database provided the springboard for a larger palaeofire data gathering exercise in connection with a workshop co-sponsored by QUEST (the UK Natural Environment Research Council programme Quantifying and Understanding the Earth System) and held at Dartington Hall, UK late in 2006. More information about this activity can be found in a companion article "Palaeofires and the Earth System" by Sandy Harrison, Mitch Power and William Bond. Following up this workshop, palaeofire data and modelling will form the basis of a lecture session and a techniques session at the forthcoming INQUA (International Union for Quaternary Research) Congress in Cairns in July 2007. Palaeofire-vegetation-human interactions are also the subject of an Australian Research Council/New Zealand Landcare Research Network on Vegetation Function working group called QUAVIDA (http://www.bridge.bris.ac.uk/projects/quavida), whose aims include elucidating the complex interplay of these factors in regions that have been occupied by humans for very different lengths of time.

Fire regime mapping was a second FTI objective, which proceeded in two stages. A first stage developed a three-way classification of fire regimes, according to broad classes of recurrence interval, predominant cause (human versus natural fires) and type (crown versus ground fires), and used expert knowledge to generate the very first published global fire regime map. In a second phase, remote sensing data are being used in an attempt to construct the first observational, pixel-based regime map using a similar classification. Satellite data cannot distinguish the causes of fire, but remotely-sensed data products now available can indicate fractional burnt areas over time (used here as a proxy for fire recurrence time), and fire radiative power, which can distinguish the (more intense) crown fires from ground fires. The use of remote sensing data in this way is just beginning, but is certain to catalyse major advances in our understanding of the controls on fire regimes worldwide.

Landscape fire modelling was a third FTI focus, culminating in the Global Change and Terrestrial Ecosystem (GCTE) Fire Modelling Waterton Workshop led by Geoff Cary, Mike Flannigan and Bob Keane in 2005. A first phase of this work produced a first classification of such models, and applied it to analyse model sensitivity to climate and weather as compared to terrain features. The second phase devised a common modelling experiment and intercomparison of six models. Major findings were that: 1) across all models weather and climate effects dominate over terrain effects, and 2) weather and ignition management are more important determinants of area burned than fuel management - a conclusion with has important practical consequences for fire management, not least in the USA and Australia (see Cary e al., this issue).

Finally, *Fire as an Earth System Process* was the theme of two QUEST-sponsored workshops held under the FTI banner. The first workshop, held in late 2005, brought together a large group of experts in different aspects of fire science to exchange latest results – including topics that have not otherwise been covered by the FTI, such as new findings on the implications of fire-related particulate emissions for cloud condensation nuclei and convective precipitation in the tropics. The second, smaller workshop was held in late 2006. The principal aim was to develop a high-profile scientific article outlining the multiple roles of fire as a process cutting across different Earth system compartments. For example, as a process originating in terrestrial climate-vegetation interactions, fire strongly influences the reactive chemistry of the troposphere, while plant nutrients volatilized by fire can fertilize terrestrial and marine ecosystems in areas remote from the fire. Products under development as part of this article (in preparation) include the fire regime map mentioned above, a modelling exercise to quantify the effects of fire-generated NO_x emissions on marine ecosystems, and a model-based analysis of the possible nature of a "world without fire".

The next stage: Fire in the IGBP

It has become abundantly clear, through the activities of the Fire FTI, that there is a great deal of cross-cutting research to be done on the topic and, furthermore, that this work cannot be done without intensive collaboration – both internationally, and involving several IGBP core projects. Accordingly, at its March 2007 meeting in Brazil, the IGBP Scientific Committee approved the founding of a cross-project Fire activity led by iLEAPS as land-atmosphere interactions are a major focus of interest in fire. The Fire activity also potentially involves GLP (Global Land Project) especially for human dimensions of fire, SOLAS (Surface Ocean – Lower Atmosphere Study) for marine ecosystem consequences of the atmospheric transport of fire-derived trace substances, IGAC (International Global Atmospheric Chemistry) for atmospheric chemistry consequences, AIMES (Analysis, Integration and Modeling of the Earth System) for modelling and analysis of total Earth system implications, including ecosystem services and PAGES (Past Global Changes) for continued co-operation on modelling and data analysis of fire during past millennia. Key proposed activities of this new initiative are given below.

Quantifying and understanding past and present fire regimes, continuing both the historical fire regimes and fire regime activities of the FTI. This work will encompass the continued development of a palaeofire data base, quantifying spatial and temporal relationships between natural and human-set fires, and the continued development (and wider application) of remotely sensed data to increase knowledge and understanding of contemporary fire regimes.

Modelling past, present, and possible future fire regimes. Given much recent effort to develop global process-based models of the interdependence between ecosystems and fire, there is now a need to compare and evaluate modelling approaches and outcomes both under contemporary and palaeo conditions. The continuing intercomparison of landscape-scale vegetation-fire models is equally important and should provide valuable information for the global models, in which many processes have to be simplified. A significant challenge here is to integrate humans into fire modelling, e.g. through land-use and land-management models with dynamic vegetation-fire models. With better-tested models, there will be a stronger basis to assess the potential consequences of global changes – in human development and population as well as changes in CO_2 and climate – under alternative scenarios of the 21st century.

Earth system dimensions of fire, including better modelling of emissions (CO_2, reactive compounds and particulates) and their role as radiative forcing agents, aerosol precursors, and cloud condensation nuclei. Field campaigns, including the Fire-Land-Atmosphere Regional Ecosystem Studies (FLARES) programme within iLEAPS, will allow improved quantification of emissions and facilitate more explicit treatment in models. Issues including human dimensions, the feedback loop from fire to ecosystem services and to land use, and back again to fire have barely been addressed in research up to now. More broadly there is an urgent need for a typology of human-influenced fire regimes which could be the start of a better predictive understanding of how social change and economic development may influence the type and scale of human-induced fires. This is proposed as a potential key topic for integrated land research in the spirit of the GLP.

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Related literature

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2. Keane R.E., Cary G.J., Davies I.D., Flannigan M.D., Gardner R.H., Lavorel S., Lenihan J.M., Li C. and Rupp T.S. 2006. Understanding global fire dynamics by classifying and comparing spatial models of vegetation and fire dynamics. In: Canadell J., Pitelka L.F. and Pataki D. (eds). Terrestrial Ecosystems in a Changing World. Springer-Verlag, p. 139-146.
3. Keane R. E., Cary G., Davies I.D, Flannigan M.D., Gardner R.H., Lavorel S., Lennihan J.M., Li C. and Rupp T.S. 2004. A classification of landscape fire succession models: spatially explicit models of fire and vegetation dynamic. Ecological Modelling 256, 3-27.
4. Kitzberger T., Brown P.M., Heyerdahl E.K., Swetnam T.W. and Veblen T.T. 2007. Contingent Pacific-Atlantic ocean influence on multi-century wildfire synchrony over western North America. Proceedings of the National Academy of Sciences 104, 543-548
5. Lavorel S., Flannigan M.D., Lambin E.F. and Scholes M. 2007. Regional vulnerability to fire: feedbacks, nonlinearities, and interactions. Mitigation and Adaptation Strategies for Climate Change 11, 33-53.

iLEAPS at IUGG

International Union of Geodesy and Geophysics XXIV General Assembly 2–13 July 2007 in Perugia, Italy

iLEAPS is organising/co-sponsoring sessions:

MS014 Interactions of Land Cover and Climate
Thursday, 5 July, at 9.30–12.30 hrs.
Convener: Meinrat O. Andreae, Co-Convener: Pavel Kabat

JHW001 Interactions between Snow, Vegetation and the Atmosphere
Tuesday, 10 July, at 9–12 hrs.
Convener: Richard Essery
Co-Coveners: Robert Baxter, John Pomeroy, Matthew Sturm, Takeshi Yamazaki

JMS007 Stable Water Isotopes: from Basin to Global Scale
Thursday, 5 July, at 9–12 hrs.
Convener: Kendal McGuffie, Co-Conveners: Ann Henderson-Sellers, John Gibson

MS012 Impacts of Biosphere-Atmosphere Interaction on Atmospheric Composition from Synoptic to Annual and Decadal Timescales
Monday, 9 July, at 9–12 hrs.
Convener: Dylan Jones, Co-Convener: Parvadha Suntharalingam

More information at http://www.iugg2007perugia.it

Sandy Harrison is Professor of Climate Dynamics Reader in Geography at Bristol University. She is a palaeoclimate diagnostician, with a special interest in the role of the land-surface, terrestrial biosphere and hydrological processes on modulating regional climate changes in the past and the future. She is a member of the Terrestrial Observation Panel for Climate (TOPC) of the Global Climate Observing System (GCOS) and Global Terrestrial Observing System (GTOS), Vice-President of the International Union for Quaternary Research (INQUA) Commission on Palaeoclimatology, on the Scientific Steering Committee for the Palaeoclimate Modelling Intercomparison Project (PMIP), and on the Scientific Steering Committee of iLEAPS. In addition to the Palaeofires Working Group presented here, she has coordination roles in several palaeoclimate synthesis initiatives sponsored by IGBP including BIOME6000, the Global lake Status Data Base, DIRTMAP, 21ka TROPICS and SNOWLINE.

Palaeofires and the Earth system

Sandy P. Harrison[1], Mitchell Power[2] and William Bond[3]

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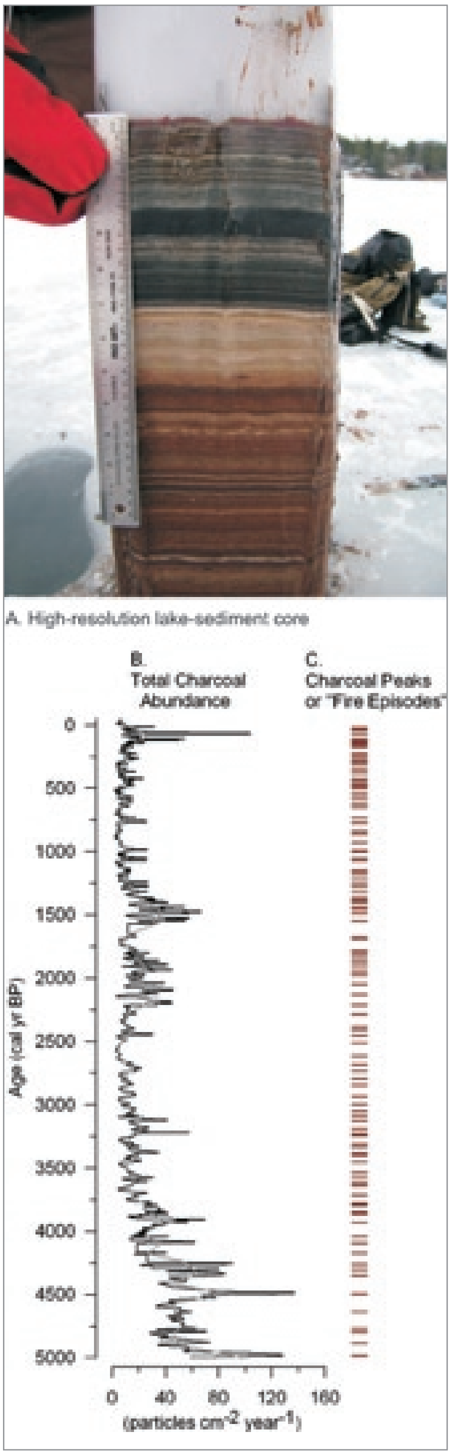
[2] Institute of Geography, School of Geosciences, University of Edinburgh, Edinburgh, UK
[3] Botany Department, University of Cape Town, Rondebosch, South Africa



◄**Figure 1.** (a) An example of a high-resolution lake-sediment core from the northern Rocky Mountains, USA from which charcoal is extracted and used to reconstruct palaeofire activity. Total charcoal abundance (b) is represented as number of charcoal particles per cm^{-2} year^{-1}. A smoothed moving average (gray line) represents the level of background charcoal or amount of biomass burned through time. The positive deviations above the background are charcoal peaks (c), representing specific fire events (occurring every 30-50 years at this site).

Fire has direct and important effects on the global carbon cycle, atmospheric chemistry, and terrestrial ecosystems. Disturbance by fire helps to maintain vegetation diversity, productivity and nutrient cycling. However, vegetation structure and productivity influence the occurrence and magnitude of fires [1]. The interactions between climate, vegetation and fire regimes are complex and difficult to unravel – particularly under modern conditions when fire regimes are largely controlled by humans. Fire is used to clear land, improve grazing and control weeds in agricultural areas. Beyond this, there are a significant number of accidental fire-sets and arson events. Humans also modify the natural fire regime through suppression of wildfires. Thus, the best approach to understanding the controls on, and impacts of, changing fire regimes is to exploit historical [e.g. 2] and geological [e.g. 3] records of fire.

Charcoal, preserved in sedimentary sequences (Fig. 1a) from lakes, bogs and soils, can be used to reconstruct the occurrence of fires on palaeo-timescales [4]. The extent of fires (or total biomass burned) in a particular region is registered in such sedimentary sequences through the total charcoal abundance (Fig. 1b). In high-resolution sedimentary records, individual fires are identified as peaks in charcoal accumulation (Fig. 1c).

Charcoal particles are preserved for millions of years: the earliest known charcoal record of vegetation fires is from the late Silurian (~ 420 million years ago). The importance of fire has varied throughout Earth's history, with e.g. extensive fires during the Permian (~ 250-300 million years ago) possibly associated with the high levels of oxygen (ca 30%) present in the atmosphere [5] and apparently very little fire during the early Cenozoic (~65 million years ago) when contemporary vegetation was evolving [6]. Fire has been implicated in the rapid spread of C4 tropical grasslands [7], which occurred simultaneously in Africa, Asia and the Americas around 8 to 7 million years ago [8]. Fire has also been implicated in the shaping of the modern vegetation of Australia, though here the high incidence of fires indicated by charcoal records between ca 60,000 and 45,000 years ago has been traditionally associated with the widespread use of fire for vegetation clearance during the initial phase of human colonization of the continent [9]. It has even been suggested that this anthropogenic modification of the vegetation cover through fire resulted in sufficiently large changes in land-surface properties to promote a shift towards

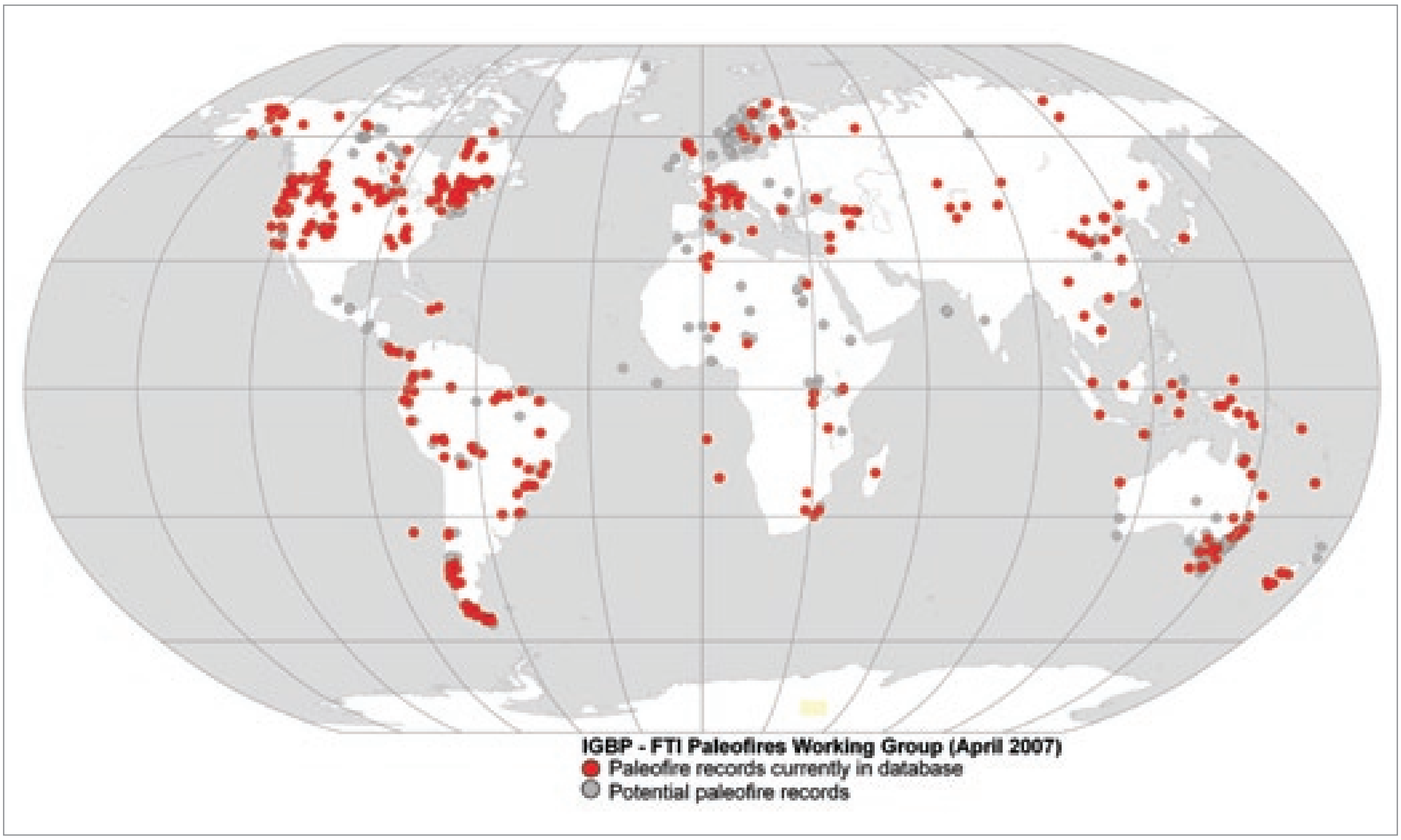


Figure 2. Distribution of the ~500 charcoal records (red dots) from radiocarbon-dated lakes, bogs and soil records in the current version of the global palaeofire database. This figure can be thought of as a snapshot of the development of the database; more sites are being added for Russia, Africa, Southeast Asia and India. As new sites are identified (gray dots), metadata (e.g. site type, basin size, landscape description, counting method) is gathered for each record and then the original charcoal counts are added.

more arid climates after ca 45,000 years ago [10].

Our knowledge of changing fire regimes during the longer-term geological past is derived from relatively few records. However, there are hundreds of records for the last glacial-interglacial cycle (i.e. the past ca 21,000 years). Synthesising and analyzing these records is the task of the Palaeofires Working Group (http://www.bridge.bris.ac.uk/projects/QUEST_IGBP_FTI_FIRE) of the IGBP Fire Fast Track Initiative. The Palaeofires Working Group has constructed a database which now includes charcoal records from nearly 500 sites from most regions of the world (Fig. 2). As several different methods are used for recording changes in sedimentary charcoal the database contains records from different settings (e.g. lakes, bogs, soils) with very different temporal resolution and dating control. To allow global analyses both of changes in fire regime and of the reconstruction methods, the database includes descriptive data about each site (e.g. information on site type and hydrology), about the individual charcoal samples from each site (e.g. sample size, sampling method, size of material counted), and about the site chronologies (including the radiocarbon dates) for each record in the database.

Preliminary analyses of these records show that global fire regimes varied continuously since the Last Glacial Maximum (LGM, ca 21,000 years ago) in response to long-term changes in global climate (Fig. 3). In eastern and western North America and western Europe, charcoal records indicate less fire activity than present from 21,000 to 9000 cal yr BP. In southern South America, there was less fire than today between 21,000 and 11,000 cal yr BP. In contrast, tropical Indochina and Australia had more fires from 18,000 to ~13,000 cal yr BP. Records of fires from tropical South and Central America indicate a brief period of greater-than-present fires between 19,000 and 17,000 cal yr BP, followed by a period of less fire than today until after 10,000 cal yr BP. During the last 10,000 years, many regions of the world experienced more fire than today including Africa, tropical South America and Europe. Only in eastern North America between 8000 and 2000 cal yr BP, and Indochina and Australia between 12,000 and 4000 cal yr BP, do the records show less fire than today.

Although charcoal records show the patterns of climate-driven environmental changes, it is difficult to identify the explicit causes of an observed change because climate affects fire regimes both directly and indirectly through changes in vegetation and in fuel load and the changes in fire incidence are extremely heterogeneous. Earth system models, however, can be used to examine the impact of specific changes in external forcing, such as changes in incoming solar radiation (insolation) resulting from changes in the Earth’s orbit, on climate [e.g. 11], vegetation [12] and fire [13]: when simulated conditions are in agreement with observations, the model experiment provides a coherent explanation for the observed changes.

In this mode, the Palaeofires Working Group has used a dynamic global vegetation-fire model, LPJ-SPITFIRE, (the Lund-Potsdam-Jena dynamic global vegetation model coupled to the

Spread and Intensity of FIRE model) to simulate the changes in fire regimes at the LGM and during the mid-Holocene (ca 6,000 calendar years BP). These simulations were driven by climate output from coupled ocean-atmosphere general circulation models, run by the Palaeoclimate Modelling Intercomparison Project, PMIP2 [14]. Comparisons of the simulated changes in fire regimes (Fig. 4) show a surprisingly good match to the charcoal-based reconstructions of changes in fire regime at a regional scale. During the mid-Holocene the spatially-complex response of fire regimes to insolation-driven changes in the African and South American monsoons shown in the simulations mirror the changes shown by the charcoal records. Similarly, at the LGM, the simulations show a substantial increase in fire as a result of the expansion of C4 grasses in the tropics and subtropics – an increase borne out by observations.

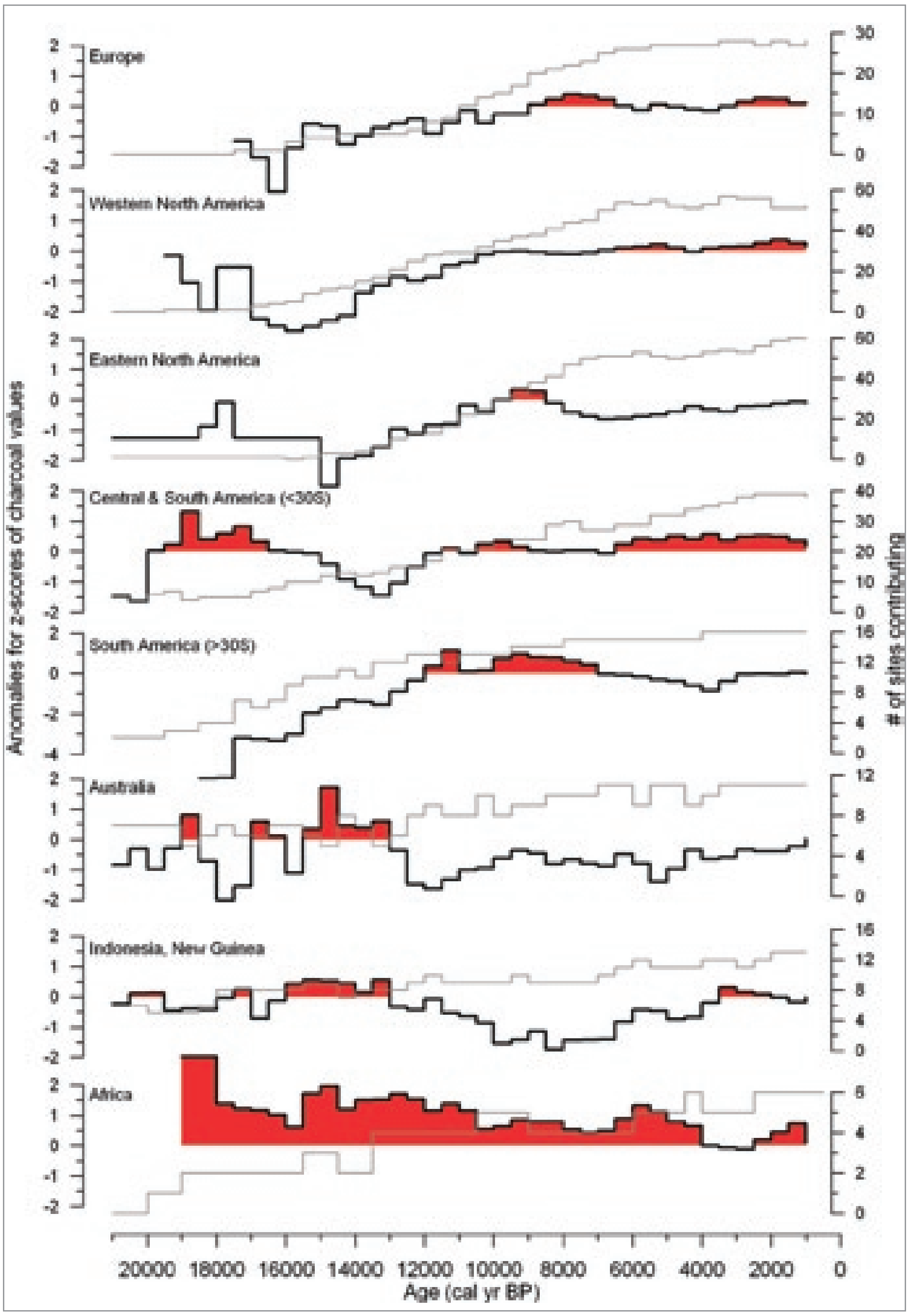


Figure 3. Palaeofire reconstructions for the last 21,000 years from eight regions of the world; individual charcoal records have been combined to create regional indices of biomass burned. The black lines illustrate Z-score anomalies of charcoal values averaged over a 1000-year window across all palaeofire sites within each region. Z-score anomalies of charcoal values can be interpreted as differences from present (present = 1000 to 100 cal yr BP) and red coloring highlights periods of greater-than-present biomass burning since the Last Glacial Maximum, ca 21,000 years ago. The number of records contributing to each regional time series is represented by the light gray line and generally increases toward present. Palaeofire reconstructions from regions with few records (e.g. Africa) are less reliable and additional sites are required to confirm the regional signal.

These results are preliminary in nature, but demonstrate the power of global-scale syntheses of charcoal data to document past changes in fires and the use of carefully-designed model experiments to explain these changes. There is still much work to do. The Palaeofire Working Group database represents an order-of-magnitude increase in site coverage compared to existing archives or synthetic data sets, but is still incomplete. Russia, Africa, Southeast Asia and India are poorly covered, although sites exist in these regions. Much more also remains to be done on the modelling side, both in developing the vegetation-fire model itself and in exercising this model to explore the causes of past changes in fire regime. With the advent of fast Earth system models, it is possible to contemplate simulating the full glacial-interglacial cycle in transient mode. There is also interest in simulating earlier geological periods, specifically to examine how fire may have shaped the modern vegetation [e.g. 15]. The IGBP Fast Track Initiative on Fire has framed a research agenda for the next several years; the Palaeofires Working Group, with the help of the wider community, now needs to carry this through.

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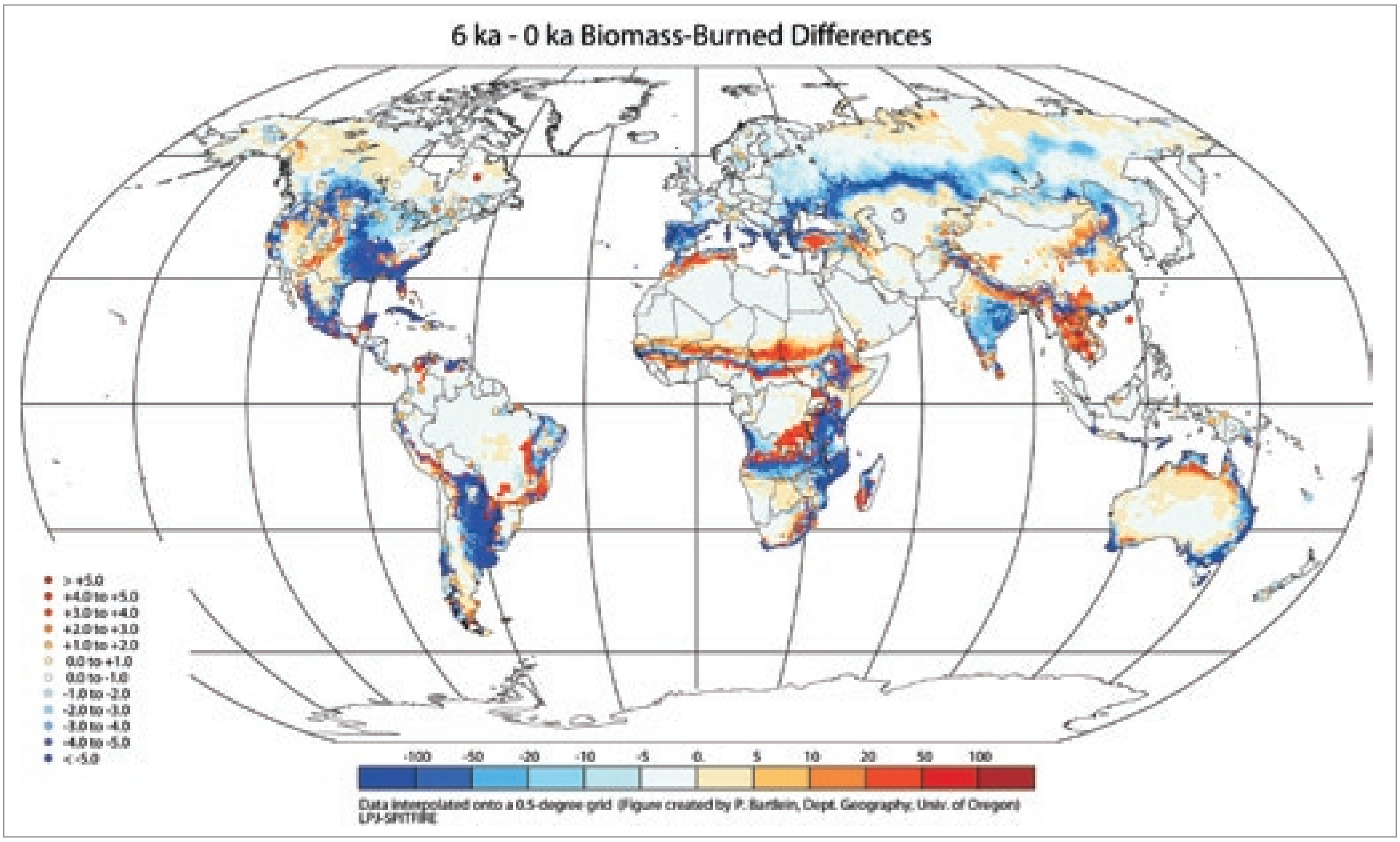

Figure 4. Changes in the fire regime during the mid-Holocene (MH, 6000 years ago, 6000 cal yr B.P.) compared to today, where blue colours show reduced fire in the MH and red colours show increased fires in the MH compared to today, as shown by charcoal data (dots) superimposed on the model-simulated changes. The simulated change is an ensemble of multiple simulations with LPJ-SPITFIRE driven by climate-model output from the Palaeoclimate Modelling Intercomparison Project. The observations are presented as anomalies of the MH and modern Z-scores. Both the observations and the simulations indicate considerable spatial heterogeneity in fire regimes. There are regions where the observations and simulations are in good agreement, and this presents the possibility of using the model results to explain observed changes in fire regimes. However, there are regions where the model and the data disagree; the challenge now is to determine whether these mismatches are due to problems with the climate-model inputs, with the fire-vegetation model or with our interpretation of the data.

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Biomass burning as a driver for atmospheric composition and ecosystem changes

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The composition of the atmosphere is controlled by several natural and anthropogenic processes, and emission from biomass burning is one of the strongest. For example, agricultural residues have been burnt for millennia, and the reduction in forest area in North America and Europe over the last centuries has evidently contributed to the changes in atmospheric composition. More recently, during the last 4–5 decades, the rapid and intensive land use change in the tropics has significantly enhanced attention to the issue.

It is important to emphasize that biomass burning is a major atmospheric driver not restricted only to the tropical areas. Two recent examples show the impacts of biomass burning emissions on ozone and $PM_{2.5}$ particles (particulate matter with an aerodynamic diameter of less than 2.5 µm) far from tropical areas. Even in megacities, with large emission of pollutants from industrial sources and vehicles, biomass burning contributes a significant proportion of the urban air pollution burden. Results from the MILAGRO (Megacity Initiative: Local and Global Research Observations) experiment, a detailed study of urban pollution in Mexico City, indicate that even in downtown Mexico City, biomass burning emissions are responsible for 20–50% of the $PM_{2.5}$ levels. In megacities around the world, inhabitants burn wood for a variety of reasons. Burning of fuelwood in large urban conglomerates leads to smoke that significantly contributes to urban air pollution levels. In Beijing, black carbon and potassium measurements indicate a high atmospheric impact of wood combustion. Similar emissions from biomass burning are expected in medium and large sized cities in Asia and Africa. In the western United States, forest fires during the past 10 years have been claimed as responsible for up to a 6 ppb increase in the regional ozone concentrations – a large proportion of the atmospheric concentration of the oxidant. The latest IPCC report [1] shows that the positive global radiative forcing of ozone is increasing rapidly and today is as high as 0.35 Watt per m². In regions downwind of biomass burning emissions, high ozone concentrations have been reported, particularly over the remote South Atlantic Ocean. In Amazonia, ozone con-

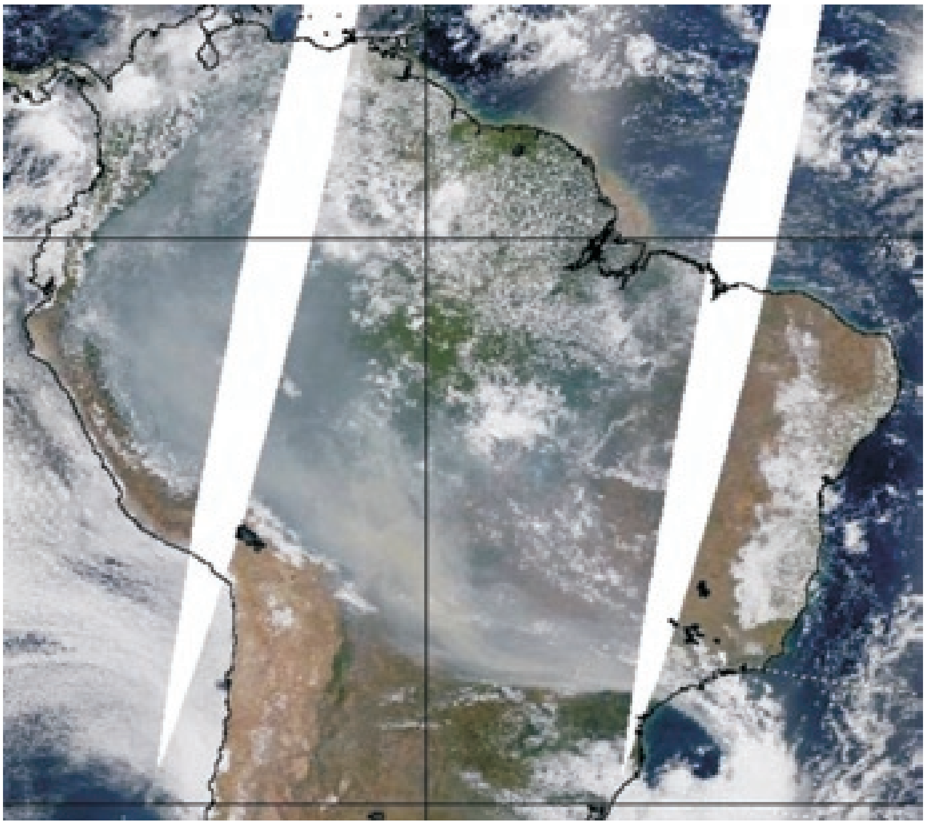

Figure 1. MODIS image of an aerosol plume from biomass burning, reaching continental scales and affecting a large area of South America.

Every year about 20.000 km^2 of primary tropical forests are cleared in Amazonia, with significant atmospheric emissions of aerosols and trace gases.

centrations as high as 100 ppb have been measured downwind of biomass burning plumes. These high ozone levels are harmful for vegetation over thousands of kilometers away from the sources of emission. In the southern hemisphere, biomass burning is one of the major factor affecting ozone concentrations. Fig.1 shows a MODIS image of aerosol plume from vegetation fires, reaching continental scales, and hence affecting a large area of South America.

Aerosol particles emitted from vegetation fires have profound impacts on the regional and global radiative forcing and on cloud properties. During seven years (1995–2002) of LBA (The Large Scale Biosphere-Atmosphere Experiment in Amazonia) measurements in Alta Floresta, the surface radiative forcing is calculated to be on average -37 Watt m^{-2}, significantly cooling the surface. Based on surface measurements in several locations impacted by biomass burning plumes, the radiative forcing is very significant regionally and has important impacts on several aspects of ecosystem functioning. Aerosols from vegetation fires contain high amounts of black carbon particles and thus the atmospheric absorption of heat is very significant, heating the top of the boundary layer by about 2–3 degrees and cooling the surface. This effect stabilizes the atmosphere and reduces the convection that pumps up water vapor to higher altitudes where it is available for cloud formation and development.

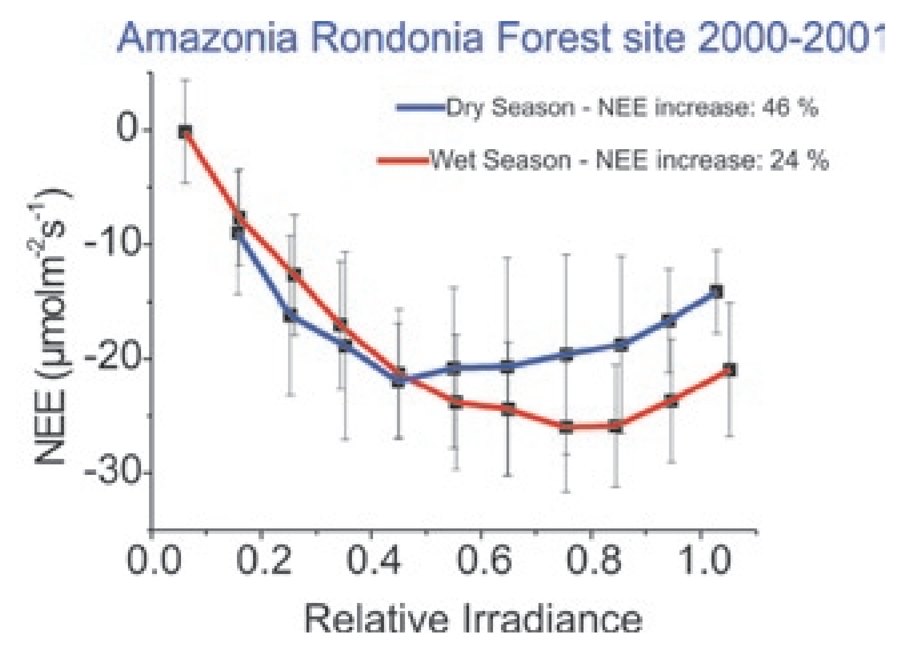

Figure 2. Net ecosystem exchange (carbon flux in µmol m^{-2} s^{-1}) as a function of aerosol loading in the atmosphere expressed as the relative irradiance index. Note that negative values of NEE correspond to net ecosystem uptake, and that relative irradiance index decreases with increasing AOT. For details, please refer to Oliveira et al. [6].

The large increase of aerosol loading in the Amazonian atmosphere due to biomass burning emissions has a strong effect on the photosynthetic rate over large areas. Fig. 2 shows the impact of the increase in aerosol loading in the atmosphere as a function of measured carbon fluxes in the Amazonian topical rain forest. A small increase in aerosol loading actually increases the fraction of diffuse versus direct radiation, and therefore the vegetation increases the efficiency of the use of solar radiation, increasing net primary productivity (NPP) (defined as the net flux of carbon from the atmosphere into green plants per unit time), up to a certain point. From clean conditions (aerosol optical thickness, AOT, around 0.1 at 500 nm) to an AOT of 1.2, NPP increases by 46% in the dry season and 24% in the wet season in Rondonia [6]. As soon as the aerosol optical thickness becomes larger than 1.2 at 500 nm, the reduction in the total flux starts to reduce carbon assimilation, and at an AOT of about 3-4, the vegetation basically stops assimilating carbon efficiently due to the low radiation flux. As the areas of the biomass burning plumes in South America, Africa and Southeast Asia are very large, the effect of aerosols from biomass burning on the carbon exchange is most important in the Southern Hemisphere.

The suppression of low cloud formation is another important climatic effect of aerosols from biomass burning. Results from the LBA Smoke, Aerosols, Clouds, Rainfall and Climate (LBA-SMOCC) experiment both from in-situ measurements and remote sensing show that the high number of cloud condensation nuclei suppress cloud formation and alter cloud microphysics affecting the hydrological cycle over large areas in the Southern Hemisphere [2, 3]. The high concentration of particles makes smaller cloud

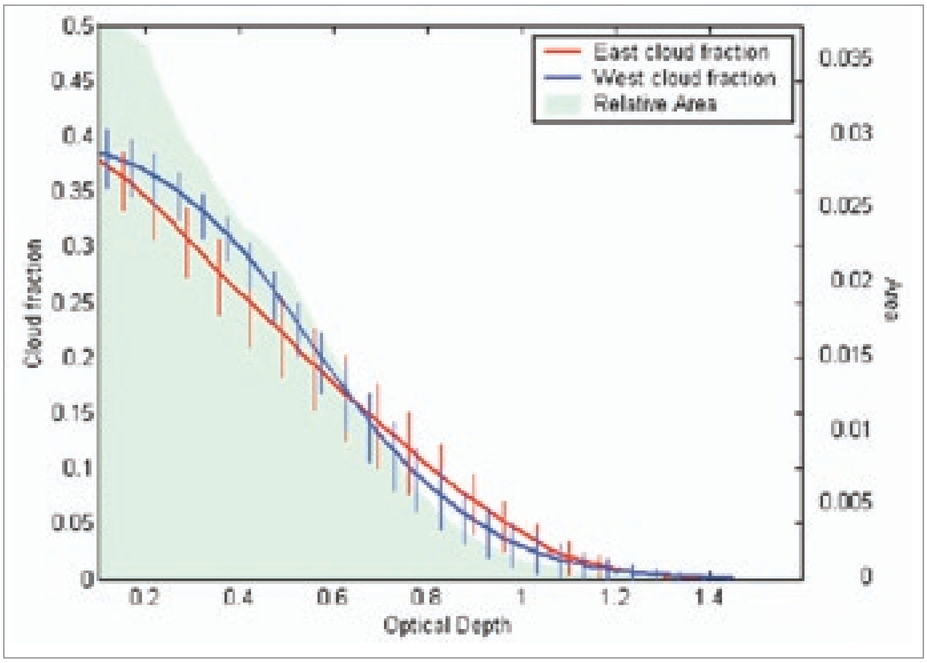

Figure 3. Reduction in low cloud fraction as a function of biomass burning aerosol loading in Amazonia. From Koren et al. [3].

droplets and inhibits droplet growth, reducing precipitation on the ground and increase cloud lifetime. This aerosol indirect effect has global climatic influences on the radiative forcing. Fig. 3 shows the cloud cover fraction for low clouds as a function of aerosol loading in the atmosphere. When aerosol optical thickness exceeds 1.0, cloud cover is strongly suppressed [3]. This mechanism was observed in Amazonia, but similar cloud suppression mechanisms that affect the hydrological cycle could be found in other tropical regions where biomass burning emissions are significant.

A recent review article by Fuzzi et al. [4] illustrates the complexities of aerosol particles emitted through biomass burning in tropical areas. Due to the complex organic composition and size distribution, modelling of transport processes of the aerosol particles to cloud droplets is quite difficult. We are also far from understanding the possible effects of aerosol particles on precipitation rate. Kaufman and Koren [5] showed that aerosol can either increase or decrease cloud cover, depending on the amount of absorbing particles. It appears that the absorbing properties and black carbon amount are among the key issues in aerosol-cloud-climate interactions. The balance between the effect on clouds from the dynamics of the atmosphere versus the aerosol effects on clouds is not yet solved.

The recent IPCC reports stated that it is urgent to significantly reduce tropical deforestation and biomass burning emissions and that the reduction has global and regional climate implications. Several modelling studies indicate that climate change will affect very intensively the extent of tropical forest area. Lower precipitation rates and higher temperatures in Amazonia could reduce the forest area up to 35% during this century. These climate effects will feed back to the carbon cycle injecting large amounts of carbon stored in the Amazonian forest into the atmosphere, since Amazonian rain forest has 200–350 tons of carbon per hectare. This possible reduction in forest area also will reduce tropical evapotranspiration, with important consequences for the global hydrological cycle.

Through research in the framework of LBA we found out that the Amazonian forest is much less robust than had been thought previously. The strong drought in 2005 in Amazonia showed that the equilibrium of the climatic system that sustains the Amazonian forest is actually quite fragile. If the current deforestation figures continue at the level we have been observing these last years, about 40% of the Amazon forests could disappear by 2050, and as a consequence, there could be an emission of 32 Pg of carbon to the atmosphere [7]. These possible emissions will increase CO_2 concentrations, aggravating the greenhouse effect. At the same time, water vapor fluxes from Amazonia will be reduced significantly. It is an important task to reduce tropical deforestation rapidly, and to implement conservation policies in Amazonia as well as tropical Africa and Southeast Asia.

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4th IGBP CONGRESS
‘SUSTAINABLE LIVELIHOODS IN A CHANGING EARTH SYSTEM’
(by invitation only)

Venue and Date

Cape Town, South Africa, 5–9 May 2008

Congress participants and target groups

- IGBP Scientific Committee
- IGBP Core Projects Scientific Steering Committees
- International Project Office (IPO) staff
- IGBP/Global Change National Committees (NCs)
- Adhering Bodies (DIVERSITAS, IHDP, WCRP, SCOR, ESSP Joint Projects, IAI, APN, ICSU Unions)
- Local science community and end users

Congress website

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Meetings in connection with the congress

IGBP Scientific Committee meeting, 10–11 May 2008
IGBP core projects Scientific Steering Committee meetings, 5–6 May 2008

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Impacts of wildland fire on water quality

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Water quality refers to the physical, chemical, and biological characteristics of water in reference to a particular use. Among the physical characteristics of interest to hydrologists and watershed managers are sediment concentrations, turbidity, and water temperature. Dissolved chemical constituents of importance include nitrogen, phosphorus, calcium, magnesium, and potassium. Some of these nutrients are adsorbed on organic and inorganic sediment particles. Bacteriological quality is also important if water is used for human consumption or recreation. The processes in the hydrologic cycle directly or indirectly affect the magnitude of soil erosion and, as a consequence, the transport and deposition of sediment in water. They also affect the physical, chemical, and biological quality characteristics that collectively determine the quality of water.

Increases in streamflow discharges following a fire can result in little to substantial effects on the physical, chemical, and biological quality of the water in streams, rivers, and lakes [1]. The magnitude of these effects is largely dependent on the size, intensity, and severity of the fire, and on the condition of the watershed at the time of burning. Higher postfire streamflow discharges can result in an additional transport of solid and dissolved materials into stream channels or other water bodies, adversely affecting the quality of water for human, agricultural, or industrial purposes. The most obvious effects are produced by suspended and bedload sediments. These components of water quality are important for municipal water supplies because of the costs of treating sediment loaded water and long-term reservoir capacity loss due to sedimentation.

Figure 1. Ash slurry flow in an ephemeral drainage after the Rodeo-Chediski Fire, Apache-Sitgreaves National Forest, Arizona, USA in 2002.

Increased soil erosion, or sediment, is often the most viable effect of a fire other than the loss of vegetation by burning. Maintaining a vegetative cover or a cover of litter and other organic material on the soil surface of a watershed is the best means of preventing excessive soil erosion rates. However, fire can cause the loss of these protective covers and in turn cause excessive soil erosion and soil lost from the burned site [1, 2, 3].

Wildfires generally produce more sediment than prescribed burning. The large inputs of sediment into a stream following a wildfire can tax the transport capacity of the stream and lead to channel deposition (aggradation). However, prescribed burns by their design do not normally consume extensive layers of litter or accumulations of other organic materials. Hence, generally resulting in less sedimentation than a wildfire.

Suspended sediments and turbidity are often the most dramatic of water quality responses to fire. Turbidity is an expression of the optical property of water that scatters light [3]. It reduces the depth to which sunlight can penetrate into water and, therefore, influences the rate of photosynthesis. In-

Figure 2. Dropping of fire retardant, San Bernadino National Forest, California, USA.

creased suspended sediment concentrations that produce turbidity after a fire can result from erosion and overland flow, channel scouring (due to the increased streamflow discharge), landslide accumulations in stream channels, or combinations of all three actions. [1]. Less is known about the effect of fire on turbidity than on the sedimentation processes. It has been observed that postfire turbidity levels in stream water are affected by the steepness of the burned watershed. Turbidity increases after fires are generally a result of the postfire suspension of ash and silt-to-clay sized soil particles in water as well as coarse, burned woody debris (Fig. 1).

Water temperature is a critical water quality characteristic of many streams and aquatic habitats. Temperature controls the survival of certain flora and fauna in the water that are sensitive to water temperature. The removal of streambank vegetation by burning can cause water temperature to rise, leading to thermal pollution, which in turn can increase biological activity in a stream [2,3]. Increased biological activity places a greater demand on the dissolved oxygen (O_2) content of the water, one of the more important water quality characteristics from a biological perspective. Severe wildfires can function like streamside timber clearcuts in raising the temperature of streams due to direct heating of the water surface. Increases up to 16.7°C have been measured in streamflows following fire, and following timber harvesting and fire in combination. Another important aspect of the temperature is the increase in fish mortality posed by stream temperature increases. The main concerns relative to aquatic biota are the reduction in the concentrations of O_2 that occurs with rising temperatures, fish pathogen activity, and elevated metabolic activity. All of these can impair the survivability and sustainability of aquatic populations and communities. Dissolved O_2 contents are affected by temperature, altitude, water turbulence, aquatic organism respiration, aquatic plant photosynthesis, inorganic reactions, and tributary inflow. Dissolved O_2 concentrations less than 10 ppm (less than 10 mg L^{-1}) are lethal to salmonid fishes. Temperature increases of 1-5 °C by fire may not be problematic for salmonid fish at sea level but may become relevant for salmonids at high altitude where waterbodies have lower O_2 saturation values than lowland waters. Fishes adapted to warm water can tolerate warmer stream temperatures and O_2 contents below 10 ppm (10 mg L^{-1}), and are not as easily impacted by O_2 concentration declines.

Dissolved chemicals come from a variety of sources in watersheds such as geologic weathering, decomposition of photosynthetic products into inorganic substances, and large storm events. Vegetative communities accumulate and cycle large quantities of nutrients in their biological role of linking soil, water, and atmosphere into a biological continuum [2,3,]. Nutrients are cycled in a largely orderly (tight) and often predictable manner until a disturbance alters their distribution. One such disturbance is fire. The effects of fire on the nutrient capital (status) of a watershed ecosystem are largely manifested by a rapid mineralization and dispersion of plant nutrients. Nitrogen as NO_3-N, NH_4-N, and organic-N are most commonly studied and most important as indicators of fire disturbance [1]. Most of the attention of hydrologists and watershed managers relative to water quality responses to fire focuses on NO_3-N because it is highly mobile. The potential for increased NO_3-N concentratations in streamflow after burning is attributed mainly to accelerated mineralization and nitrification [2] and reduced plant demand. These postfire effects are short lived, usually lasting only a year or so. The changes in NO_3-N concentrations in response to burning vary. Some investigators have found no significant change in the postfire NO_3-N concentrations in streamflows, while others report increases in NO_3-N concentrations in either the soil solution or streamflow [2]. Regardless of the burning treatment or treatment combinations on watersheds, NO_3-N concentrations in the streamflow are usually well below maximum allowable concentrations for water quality standards.

Fire retardants are frequently used in the suppression of wildfires. Although their effects on the soil-water environment are not a direct effect of fire, their use in the control of wildfires can produce adverse environmental impacts. The main environmental concerns with fire retardant use are: 1) effects on water quality and aquatic organisms, 2) toxicity to vegetation, and 3) human health effects. Ammonium-based fire retardants (diammonium phosphate, monoammonium phosphate, ammonium sulfate, or ammonium polyphosphate) play an important role in protecting watershed resources from destructive wildfires (Fig. 2). However, their use can affect water quality in some instances, and they can also be toxic to aquatic organisms. Nitrogen-containing fire retardants have the potential to affect the quality of drinking water, although the research on the applications of these retardants to streams has largely focused on their impacts on aquatic environments. A number of studies have noted that the amount of fire retardant used and its placement on the landscape are the two main factors determining the degree of environmental impact. Thus, planning of placement and operational control of aircraft releasing fire retardant are critical for minimizing impacts on streams and lakes and their biota

Summary: When a wildland fire occurs, the principal concerns for change in water quality are: 1) introduction of sediment, 2) potentially increasing nitrates, especially if the foliage being burned is in an area chronic atmospheric deposition, 3) possible introduction of heavy metals from soils and geologic sources within the burned area, and 4) introduction of fire retardant chemicals into streams that can reach levels toxic to aquatic organisms. The magnitude of the effects of fire on water quality is primarily driven by fire severity, and not necessarily by fire intensity. Fire severity is a qualitative term describing the amount of fuel consumed, while fire intensity is a quantitative measure of the rate of heat release. The more severe the fire, the greater the amount of fuel consumed and nutrients released, and the more susceptible the site is to erosion of soil and nutrients into the stream where they could potentially affect water quality. Wildfires usually are more severe than prescribed fires. As a result, they are more likely to produce significant effects on water quality. Use of prescribed fires gives the opportunity to control the severity of the fire and to avoid creating large areas burned at high severity. The degree of fire severity is also related to the vegetation type. For example, in grasslands the differences between prescribed fire and wildfire are small and effects to the water quality are then minor. Because of the larger amount of fuel consumed in a wildfire in forested environments, the impacts of fire on water quality are much higher than after a prescribed fire. Canopy-consuming wildfires are of the greatest concern due to the increase in soil erosion after the loss of vegetation. These canopy-consuming wildfires present the worst-case scenario in terms of water quality. The differences between wild and prescribed fire in shrublands are probably intermediate between those seen in grasslands and forest environments.

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Figure 1. Daniel Neary
Figure 2. U.S. Forest Service

Forthcoming paleo-fire activities

The paleo-record provides ideal opportunities for evaluating components of Earth system models. Charcoal records from sedimentary contexts provide a way of documenting and exploring past changes in fire regimes. Global syntheses of charcoal data can be used to derive benchmarks for the evaluation of state-of-art coupled vegetation-fire models.

Paleo-FIRE activities will be carried forward through a series of workshops. These workshops will be designed to allow specific tasks to be carried out (e.g. data collection and analysis, evaluation of model output, writing). Earlier experience in FIRE FTI shows that it is possible to achieve concrete products in workshop mode. The workshops will be complemented by using more conventional opportunities to present/discuss fire-related research at conferences, and by organizing symposia or sessions of paleofire at major international conferences (e.g. EGU, AGU, INQUA).

The first workshop will be held in Dartington Hall, Totnes, UK, 22–27 October 2007

Workshop theme: Kick-off meeting for the new phase of paleoworking group activities. This workshop will assess the status of the data synthesis and develop concrete plans for ongoing data collection; it will explore and prioritise new analyses of the data; it will also focus on evaluation of new paleofire simulations using the charcoal data.

Please contact Mitchell Power (Mitch.Power@ed.ac.uk) or Sandy Harrison (sandy.harrison@bristol.ac.uk) for more detailed workshop information.

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Vegetation fires and the Earth system: trends and needs for action

Johann G. Goldammer

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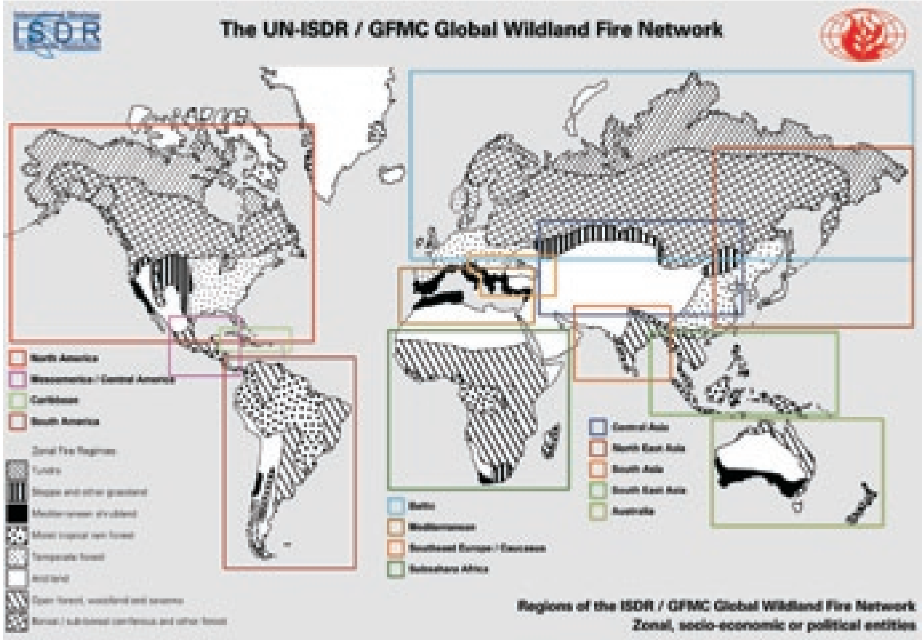

Figure 1. This map shows the demarcations of the 13 Regional Wildland Fire Networks established under the auspices of the UN International Strategy for Disaster Reduction (UNISDR) Global Wildland Fire Network. Specific regional projects are underway to facilitate science and knowledge transfer into national and regional fire management policies. Global projects such as fire monitoring and fire early warning are facilitated by the Global Observation of Forest Cover/Global Observation of Land Cover Dynamics (GOFC/GOLD) Programme. Source GFMC.

Over the past two decades, many regions of the world are experiencing a growing trend of excessive fire application in the forestry-agriculture interface, land-use systems and land-use change, and an increasing occurrence of extremely severe wildfires (megafires). Several global issues or trends are impacting the occurrence and consequences of fire on the environment and societies, such as 1) demographic changes resulting in alterations of sustainable fire regimes, e.g. the consequences of rural exodus or – viceversa – exurban migrations, coupled with a loss of traditional, sustainable land-use systems, 2) widespread poverty associated with unemployment, exurban migrations and land tenure conflicts and resulting in increasing human-caused fires, 3) land-use change involving increasing fire use for conversion of vegetation, notably in the tropics, and expansion of land use to fire-sensitive lands, e.g., peatlands, drained or otherwise desiccating wetlands, and other fire-sensitive vegetation, 4) expansion of the wildland-urban interface in some countries and increasing vulnerabilities and greater exposure of rural settlements to increasing occurrence of severely damaging fires, 5) consequences of climate change, resulting in increasing occurrence of extreme droughts in many regions, desiccation of wetlands, thawing of permafrost sites, and a general trend of increasing area burned, fire intensity, and fire severity, and longer fire seasons, 6) human health and security threatened by increasing wildfire activity and land-use fires, causing release of a greater amount of pollutants and resulting in greater public exposure to hazardous emissions, including transboundary transport of fire smoke pollution at regional to global levels, and 7) human security and peace threatened by fires burning on radioactively contaminated lands, by fires on areas with unresolved conflicts, and on territories with post-war hazards such as landmines and unexploded ordnance.

Some of the fire effects are transboundary, for example smoke and water pollution and its impacts on lives, human health and safety, loss of biodiversity or site degradation at landscape level leading to desertification or flooding. The depletion of terrestrial carbon by fires burning under extreme conditions in some vegetation types, including organic terrain in peatland biomes, is one of the driving agents of disturbance of global biogeochemical cycles, notably the global carbon cycle. Observed and modelled consequences of regional climate change suggest an alteration of fire regimes with consequences on ecosystem degradation and depletion of terrestrial carbon.

Ecosystems that are experiencing changes of fire regimes include fire-dependent vegetation affected by fire exclusion, or fire-sensitive ecosystems that are undergoing degradation due to

Figure 2. Knowledge transfer and capacity building in fire management involving local communities (Community-Based Fire Management) ensure the transfer of state-of-the-art science to local application, e.g. for sustaibale land-use planning and carbon management. The photograph shows a meeting of a local community in Mozambique preparing a fire management plan for the community, sponsored by the UNEP/GEF project "Integrating Vulnerability and Adaptation to Climate Change into Sustainable Development Policy Planning and Implementation in Southern and Eastern Africa".

recurrent fires, or due to fire occurring at the wrong time. The coupled impacts of climate extremes, environmental pollution, ecosystem manipulation, and fire effects are drivers of vegetation degradation throughout the world. An increase of vulnerability of human populations to fire and to secondary effects of fire is also obvious. Although this trend is revealed by a wealth of scientific knowledge, the gaps in fire management capabilities from local to global levels are evident. Thus, the current situation and the expected trends are challenging the international community to address the problem collectively and collaboratively.

With the increase of fire application in land-use change in the 1990s it was recognized that a facility for the documentation, information and monitoring of vegetation fires was needed to support action and development of policies to reduce the negative impacts of fire and fire exclusion on the global environment. In 1998 the Global Fire Monitoring Center (GFMC) was established at the Max Planck Institute for Chemistry to provide a mechanism of science and technology transfer to application. The GFMC was set up under the auspice of UN International Strategy for Disaster Reduction (UNISDR) and is focussing on three main arenas: 1) development and dialogue with international and national policies, non-legally binding agreements and conventions binding under international law, addressing the role fire management for mitigating environmental degradation and impacts of climate change, 2) support of the development of national programmes for sustainable land-use involving integrated fire management approaches, and 3) capacity building of national to local actors in fire management, notably at community level.

Since the late 1990s the outreach work of the GFMC has focussed on Africa – a continent where the ecology of fire and the fire-atmosphere relationships have been well explored by interdisciplinary research, e.g., the STARE/TRACE-A/SAFARI-1992 and SAFARI-2000 research campaigns. Subsequently the GFMC has supported or backstopped the development of national fire management strategies and policies (Namibia, Ethiopia, South Africa) and conducted a number of advanced wildland fire management training courses and courses for instructors in community-based fire management. The main objective of capacity building is to enable local to national actors to implement fire management on the basis of state-of-the-art science, concerning ecology, sustainability of land-use systems and carbon management.

Although there is a rich expertise in wildland fire ecology, fire-emissions related atmospheric chemistry and biogeochemistry research, the science community is challenged to contribute to further improvement of information for policy makers and fire management decision makers, e.g. through improvement of spaceborne tools for monitoring and assessment of changing fire regimes, user-friendly smoke transport and impact models, development of global to people-centred early warning systems, and modelling of changes, e.g. the pyrogenic net flux of terrestrial carbon to the atmosphere.

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Figure 2. GFMC

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Characterization of particle emissions from laboratory combustion of wildland fuels

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Aerosol particles in the atmosphere influence the Earth's radiation balance and climate, atmospheric chemistry, visibility, and the human health on scales ranging from local to global. On a global scale, direct radiative effects from particles of directly anthropogenic origin (as opposed to dust entrainment caused by desertification) are dominated by sulfate and carbonaceous particles. While sulfate particles have a very high albedo and predominantly scatter light in the visible part of the spectrum, carbonaceous particles contain components that both scatter and absorb visible light resulting in a wide range of albedos. Black carbon (BC) is the strongly light absorbing component, while organic carbon (OC) is mostly light scattering. BC and OC can coexist in internally mixed particles that may consist of a BC core coated with OC. In addition to the direct radiative effects of carbonaceous particles, they can also serve as cloud condensation nuclei (contributing to the indirect climate effect) and assist in the evaporation of clouds due to light absorption and heating by BC (semi-direct effect). Transport, deposition, chemistry, radiative effects, and health effects of particles depend largely on their composition, size distribution, and morphology.

Wildland fires of both anthropogenic and natural origin are a major source of carbonaceous particles in the global atmosphere. The properties of aerosol particles emitted by wildland fires vary strongly and are largely determined by fuel properties and combustion conditions. Unfortunately, very little is known about the characteristics of particles emitted from the combustion of wildland fuels as function of fuels and combustion conditions.

To improve our understanding of the influence of wildland fires on the environment, we are conducting a series of experiments studying the characteristics of aerosol particles freshly emitted from the combustion of individual wildland fuels under controlled laboratory conditions. This study, called FLAME (Fire Lab at Missoula Experiment), is a cooperative effort between the National Park Service, the Forest Service's Missoula Fire Sciences Laboratory (FSL), the Desert Research Institute (DRI), and Colorado State University, with participation from a number of outside investigators. Experiments are taking place in the FSL Combustion Laboratory with two different modes of operation: 1) stack burns vent all fire emissions through a 17 meter high stack (see Fig. 1) with sampling of the emissions occurring near the top of the stack with instruments and filter/canister samplers located on the sampling platform at 15 meters height, 2) chamber burns with fire emissions filling the whole chamber with smoke.

Stack burns allow for the characterization of the time evolution of fire emissions as the combustion process evolves from flaming to smoldering combustion. Instruments with high temporal evolution (typically 1 to 5 seconds) enable characterization of particle mass, optical properties (e.g., absorption, scattering, and extinction), and gaseous emissions (e.g., CO_2, CO, NO_2, and NO) as a function of time.

Chamber burns store the emissions from the burn in a large room where

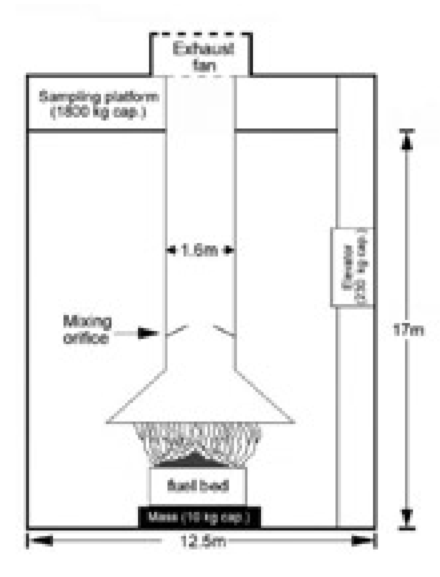

Figure 1. Schematic diagram of the Forest Service's Fire Sciences Laboratory (FSL) combustion facility in Missoula, Montana, USA.

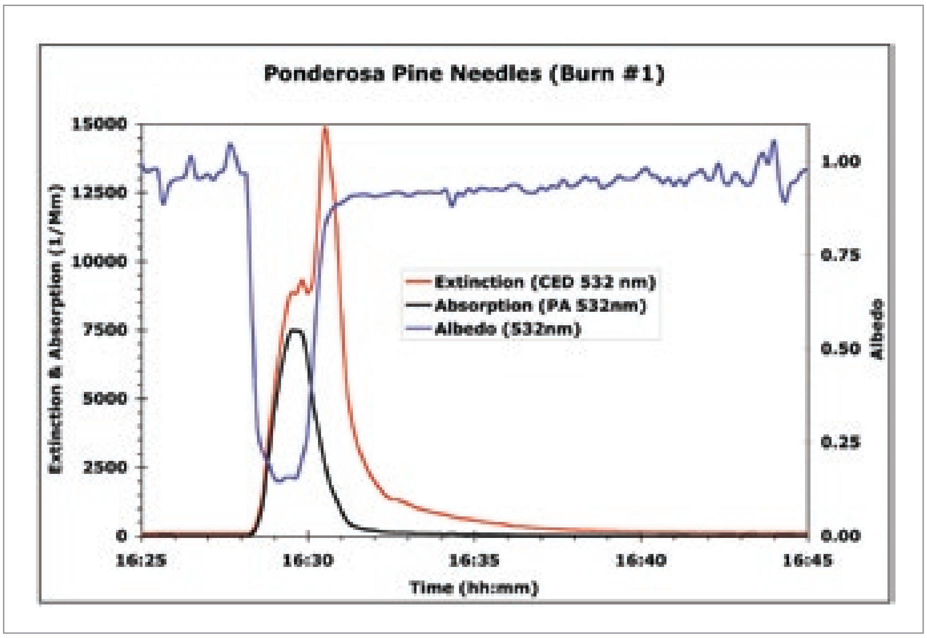

Figure 2. Change in particle optical properties during combustion of Ponderosa Pine needles from flaming to smoldering phase.

conditions only slowly change. Therefore it is possible to use more time consuming measurements relying on near-constant smoke properties such as determining the particle size distribution with a scanning mobility particle sizer.

Specific FLAME objectives include: a) determination of fuel-based aerosol particle emission factors, b) characterization of physical and optical properties of particles and their change as function of relative humidity conditioning, and c) development of improved chemical smoke tracer profiles and measurement methods.

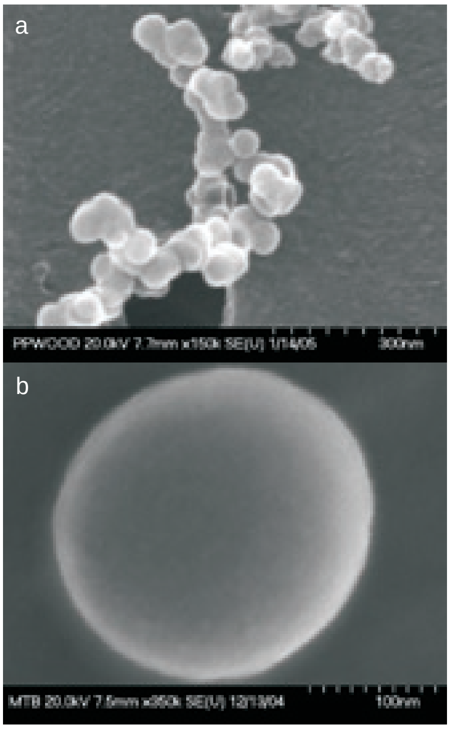

Figure 3. (a) Fractal-like chain aggregates from the flaming combustion of Ponderosa Pine wood; (b) Tar ball from the smoldering combustion of “Montana grass”.

Initial results include the determination of emission factors for particles and gaseous species emitted during the flaming and smoldering combustion of several wildland fuels [1], the characterization of particle optical properties [2] and morphology [3], the change of particle light scattering as a function of relative humidity [4], the characterization of organic emissions used as smoke tracers [5], the development and application of an improved detection technique for levoglucosan, a commonly used smoke tracer [6], and an improved understanding of partitioning biomass combustion mercury between particle-phase and gaseous elemental mercury [7].

One example of our results shows the evolution of particle optical properties (Fig. 2), namely absorption, extinction, and single scattering albedo (indicating the whiteness). During the initial flaming combustion phase, nearly all extinction is due to absorption indicating the emission of very black particles (albedo = 0.15), followed by a transition to smoldering combustion, emitting very white particles (albedo > 0.95) [2]. The black smoke emitted during flaming combustion consists largely of fractal-like chain aggregates of strongly light absorbing BC monomers coated with OC (Fig. 3a; [3]). Smoldering combustion emits rather white smoke consisting of larger round particles (tar balls) containing mostly OC (Fig. 3b; [3]). Due to the extremely different physical, chemical, and optical properties of particles emitted from flaming and smoldering combustion, and the large variability between fuel consumption by flaming and smoldering, it is very important to separately characterize their emissions and emission factors.

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Pyrocumulonimbus and climate change

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In northern summer 1998, the U.S. Naval Research Lab's Polar Ozone and Aerosol Measurement (POAM) III satellite instrument started detecting mysterious clouds in the stratosphere [1]. Experience suggested that this was an obviously unusual phenomenon. We now know that these mysterious aerosol-cloud layers were smoke, originating from forest fires that erupted like a volcano into the atmosphere. The phenomenon is called pyrocumulonimbus [2] (pyroCb for short). This discovery has been followed by much more research and discoveries - e.g. stratospheric smoke has been observed during at least six boreal summers since 1998, and even in the southern hemisphere. In this article we touch on illustrative aspects of pyroCb in action and its global importance.

Until the discovery of pyroCb the common belief was that there was only one natural terrestrial phenomenon that could inject material through the tropopause into the lower stratosphere - the volcanic eruption. Volcanic eruptions are well characterized and their impact on climate can be significant. Material transported to the lower stratosphere can easily have a global impact because it spreads fast with strong winds and encounters essentially no external forces to transport it back into the troposphere. Where there is smoke…there are also many other important biomass burning emissions. Hence the observed stratospheric smoke plumes are a strong indicator that a host of other chemically and radiatively important, non-native gases have also entered this sensitive atmospheric realm. The tropopause, historically considered to be an effective lid on rapid upward transport except for the strong volcano, is undergoing reassessment in light of the pyroCb discovery.

The PyroCb, Up Close and Personal. On 17 August 2003 a large fire near Conibear Lake (~60ºN, 114ºW) in Alberta, Canada erupted into deep pyroconvection. On that day the Conibear Lake pyroCb created a large, thick, deep plume in the lowermost stratosphere. In Fig. 1. imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) shows the Conibear Lake pyroCb in its maturity. A true-color rendering is overlain with a red near-infrared (NIR) radiance contour showing the flaming fires. Thermal infrared (THIR) brightness

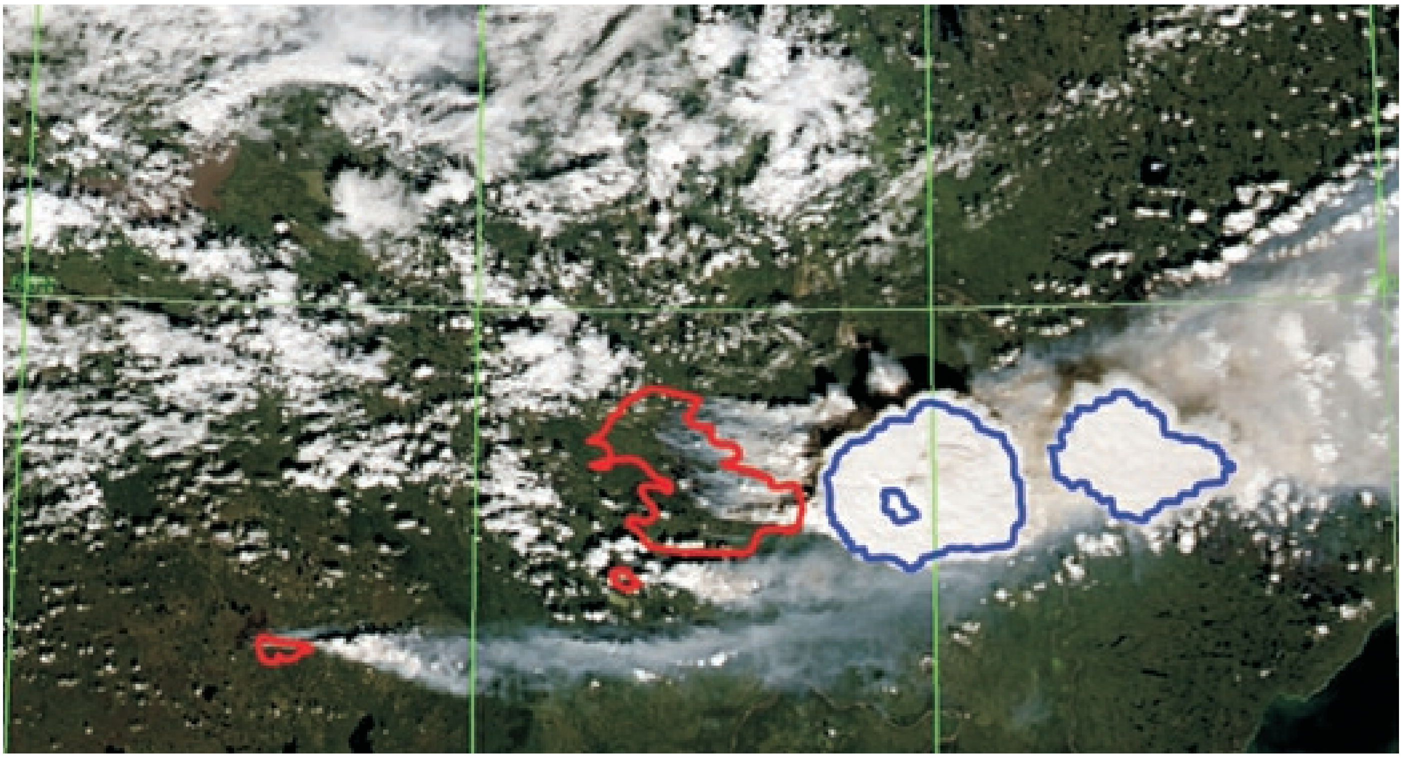

Figure 1. Pyrocumulonimbus, pyroCb on 17 August, 2003 in Conibear Lake, Alberta, Canada. North is up; east is right. True color image with fires (red) and -45° C infrared temperature contour (blue).

temperature (good for cloud-top height determination) is displayed as the blue contour, enclosing the cloud surface colder than -45°C.

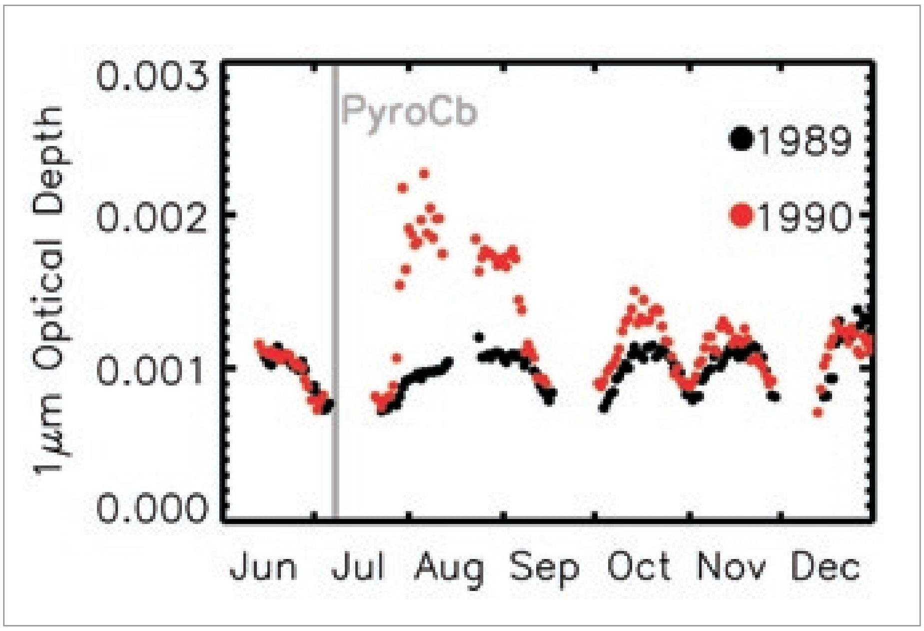

Figure 2. Northern Hemisphere zonal median stratospheric aerosol optical depth in 1989 and 1990. Data from NASA's Stratospheric Aerosol and Gas Experiment II (SAGE II). Vertical gray bar indicates the date of Alaskan pyrocumulonimbus.

Notice two dominant flaming spots in the scene. The Conibear Lake fire is upstream of the convective cloud complex, and another fire to the west is emitting a long smoke plume (in Fig. 1. to the right). The pyroCb consists of two cumulonimbus anvils, indicative of multiple eruptive pulses. The western anvil has a bumpy texture manifested by shadows near its center. This cloud is still being fed by the forest fire heat. The cloud-top texture is indicative of strong tropopause-penetrating updrafts. The eastern anvil, at this time well downwind of the fire, has a smoother texture because the turbulence of the convection is subsiding. Perhaps the most remarkable feature, on both anvils, is the smoky coloration in comparison to nearby pristine airmass convection. Obviously this pyroCb has injected enough smoke to the cloud top to visibly pollute it.

The THIR component to this image shows that both anvils are dense and penetrate to the tropopause. The blue -45°C contour encloses an area wherein the cloud-top particles are exclusively ice—it is several degrees colder than the homogeneous freezing threshold. Another feature of the THIR contour is a second appearance near the very center of the western anvil. Inside this contour the cloud top temperature actually increases. This "warm core" is a well known (albeit poorly understood) "enhanced V" signature of extreme convection. Taken together, the THIR and true-color analyses reveal that this is a vigorous convective cloud with a unique smoke/ice mixture.

MODIS made observations of the Conibear Lake fire on two successive orbits. We were able to tell from changes in the NIR hot spot that the onset of pyroconvection was accompanied by a firefront in which spread rate was of ~9 km hr^{-1} – an enormous speed, implying an extreme instantaneous energy release that no doubt translated into the deep pyroCb development.

Climate Implications of PyroCb. A fundamental question is whether pyroCb have an important impact on weather or climate. It is already known that stratospheric volcanic plumes can strongly perturb climate. Our research into pyroCb has revealed that on three consecutive years - 1989 to 1991 - there were newly discovered pyroCbs that explained mystery layers originally ascribed to volcanoes. For instance, Yue et al. [3] observed a hemispheric, season-long increase of stratospheric aerosol optical depth (Fig. 2) by NASA's Stratospheric Aerosol and Gas Experiment (SAGE) II in the boreal summer/fall of 1990. This was attributed to an unreported volcanic eruption as no reported eruption with stratospheric potential was observed. Fig. 2 shows how strong and enduring the 1990 SAGE observations were, in comparison to 1989. With techniques and data that have proved invaluable to pyroCb detection we found a major blow up in Alaska on 6 July 1990; it appears that smoke and not volcanogenic aerosols were responsible for this strong perturbation.

Climate-model simulations of global warming estimate the largest temperature increases at high latitudes with subsequent impacts on the boreal zone. Forest fire experts project that forest fire size and frequency will increase due to this forcing. Obviously this provides great motivation to explore the pyroCb phenomenon more fully.

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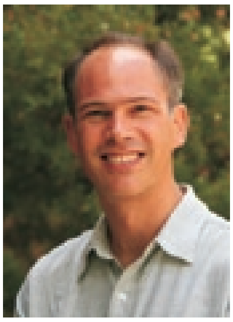

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Classifying and comparing spatial models of fire dynamics

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Wildland fire is a significant disturbance in many ecosystems worldwide [1] and the interaction of fire with climate and vegetation over long time spans has major effects on vegetation dynamics, ecosystem carbon budgets, and patterns of biodiversity. Landscape-Fire-Succession Models (LFSMs) that simulate the linked processes of fire and vegetation development in a spatial domain are one of the few tools that can be used to explore the interaction of fire, weather and vegetation over century-long time scales [2]. There is a diverse set of approaches to predicting fire regimes and vegetation dynamics over long time scales, due in large part to the variety of landscapes, fuels and climatic patterns that foster frequent forest fires, and variation in modeller's approaches to representing them.

Over recent years, an international group of scientists working under the auspices of Global Change and Terrestrial Ecosystems (GCTE) and funded by the US National Centre for Ecological Analysis and Synthesis classified an extensive set of spatial models of fire and vegetation dynamics and compared the behaviour of a subset of the models to determine the relative sensitivity of simulated area burned to variation in terrain, fuel pattern, climate and weather. A set of recommendations for the incorporation of fire dynamics into global dynamic vegetation models was also developed.

Keane et al. [3] identified and classified 44 published spatial models of fire and vegetation dynamics. The models were evaluated according to four components (succession, fire ignition, fire spread, and fire effects) by the three evaluation gradients (stochasticity, complexity, and mechanism) using a scale from 0 to 10 (zero meant that it was not modelled or applicable and 10 represented the highest level of stochasticity, mechanism, or complexity). Rankings were assigned by model developers and Keane et al.'s [3] own review of publications of the models.

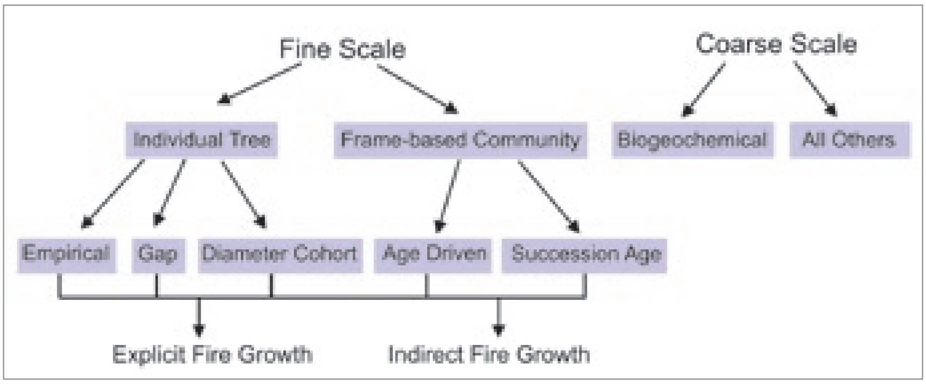

Figure 1. Final set of categories for landscape fire succession models classified using the degree of stochasticity, complexity, and mechanism in the design of the model components of succession, fire ignition, fire spread and fire effects.

A general classification of spatial fire models was developed by combining results from a principal components analysis and a TWINSPAN (Two-way Indicator Species Analysis) clustering analyses of the evaluation element data. Given the high variance in evaluation elements across models, explanatory categories such as approach, strategy, scale and other descriptive elements were assigned to models. The frequency of keywords for each category across all LFSMs was then analysed to qualitatively identify similar characteristics and natural clusters.

The classification (Fig. 1) had 12 hierarchically nested classes that are distinguished by their scale of application (coarse vs fine), representation of vegetation (individual plant cohorts vs framed-based community), simulation of succession (empirical, gap diameter, age, or successional pathway) and the explicit or implicit simulation of fire spread. A full description of the classification results are presented in Keane et al. [3].

Direct comparison among models can be difficult [4]. Cary et al. [5] developed an approach to compare the sensitivity of modelled area burned to a range of factors in a standardised design across a subset of the spatial models of fire dynamics (EMBYR, FIRESCAPE, LAMOS(DS), LANDSUM and SEM-LAND). Ideally, the comparison would have selected models from all categories of the classification, however, model selection was also constrained by the availability of modellers with sufficient resources to implement the design. The five models represented a spectrum of complexity in model formulation and represented three out of the twelve classification categories presented by Keane et al. [3].

SOURCE OF MODEL VARIATION	EMBYR	FIRESCAPE	LAMOS	LANDSUM	SEM-LAND
Terrain		●			
Fuel	●				
Terrain x Fuel					
Climate		●	●	●	●
Terrain x Climate					
Fuel x Climate					
Terrain x Fuel x Climate					
Weather	●	●		●	●
Terrain x Weather		●			
Fuel x Weather	●				
Terrain x Fuel x Weather					
Climate x Weather	●			●	●
Terrain x Climate x Weather		●			
Fuel x Climate x Weather					
Terrain x Fuel x Climate x Weather					

Table 1. Important sources of variation (●) in area burned in five spatial models of fire and vegetation dynamics. Variation in terrain (Terrain), fuel pattern (Fuel), climate (Climate) and weather (Weather) factors, and their interactions, was considered important if they explained more than 0.05 and 0.025 of total variation within a model respectively.

Variation in terrain was introduced by varying the minimum and maximum elevation of the simulation landscape so that flat, undulating, and mountainous landscapes had relief of 0, 1250 and 2500 m respectively. Fuel pattern was varied to represent finely clumped (25 ha patches) and coarsely clumped (625 ha patches) patterns of varying fuel age. Weather and climate can be different at fine temporal scales and were treated as orthogonal. Variation in weather was introduced by selecting ten representative years of daily weather records for the landscape where the model has undergone most rigorous validation. Three types of climate were included in the design, including observed, warmer/wetter (+3.6ºC, +20% precipitation), and warmer/drier (+3.6ºC, -20% precipitation) climate. In this experiment, simulations were limited to one year and vegetation dynamics were not invoked.

Modelled area burned was most sensitive to climate and variation in weather, with four models sensitive to each of these factors and three models sensitive to their interaction (Table 1), giving similar results to the findings of Bessie and Johnson [6]. Models generally exhibited a trend of increasing area burned from observed, through warmer and wetter, to warmer and drier climates. Area burned was sensitive to fuel pattern for EMBYR and terrain for FIRESCAPE which was the only model that incorporated the effect of elevation on site weather by invoking lapse rates in temperature, humidity and precipitation.

These findings have particular significance for the inclusion of fire in Dynamic Global Vegetation Models (DGVMs). The lack of sensitivity of area burned to fine scale fuel pattern indicates that coarse scale DGVMs may not need to incorporate pattern of vegetation within simulation cells, although this depends on the importance of vegetation succession on area burned which was not tested in this experiment. Also, the general finding of the importance of inter-annual variability in weather (compared with climate) has important implications for the inclusion of fire into DGVMs, because an increase in the year-to-year variation in weather may translate into large effects on area burned as long-term changes in mean temperature and precipitation brought about by climate change. On the other hand, landscape scale pattern in terrain was demonstrated to be important by the one landscape-fire-succession model that incorporates the effect of terrain on weather.

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Southeast Asian forest and land fires: how can vulnerable ecosystems and peoples adapt to changing climate and fire regimes?

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Forest and land fires – both natural and human-lit – are not new to the landscapes of Southeast Asia. Today's fire regimes are a consequence of past interactions between humans, climate and ecosystems. In many places fire is a tool for converting forests to agricultural lands and in subsequent land management [1]. But fire is also described as a problem, or even, disaster. Carefully distinguishing among types of fires, the ecosystems in which they occur, and their relationship to spatial and temporal scales of historical fire regimes is important but does not eliminate politics. Differences in interests and perspectives affect land and forest policies in ways which can have important consequences for ecosystems and human well-being at several levels [2].

The importance of different perspectives and scale for understanding fires is illustrated sharply in situations where vulnerable ecosystems and peoples coexist with important stocks of carbon susceptible to fire. In the context of Indonesia this means managing risks of low frequency, but high impact, fires in peatlands.

Peatlands are important for the hydrology of a region as they buffer flooding as well as for conservation of biodiversity, fishing and hunting, and carbon storage. Peatlands cover more than 10% of Indonesia's land area including many agricultural locations critical to sustaining livelihoods of vulnerable peoples. When peatlands are drained upper layers dry-out and become prone to fire. Fire policies need to give high priority to the management of vulnerable peatlands.

The large fires of 1997/1998 in Indonesia resulted from a combination of fires lit to clear and prepare land by smallholders and larger firms as well as accidental fires in forest and peat swamps. Dry weather generated by El Niño Southern Oscillation (ENSO) made conditions ideal for fire. Impacts on timber and estate crops were relatively modest; valuable investments and assets were protected. Other forest types, like logged-over forests suitable for conversion to oil palm plantations, on the other hand, were extremely "vulnerable" to being burnt.

Peat fires in Kalimantan and Sumatra made a huge contribution to trans-boundary smoke haze. Heil et al. [3] modelled dispersion of fire pollutants. They found that if peat fires are excluded then ambient air quality standards would only be exceeded close to the main fires, whereas if peat fires are included air quality standards are exceeded far away from the source as was observed. For Asia, burning of forest comprises 45% and burning of crop residues in the fields comprises 34% of vegetation burnt openly, that is, outside stoves [4].

Goldammer's [5] study of recovery of forests after major fire is important to policy in several ways. First it underlines the need, from a biodiversity conservation perspective, to go beyond peat lands and look carefully at vulnerable dipterocarp forest ecosystems. Excessive use of fire in dipterocarp forest ecosystems is altering tree family-level composition. Second, it draws attention to the very different fire-vegetation relations in seasonally dry tropical forests and pine forests. Here outright fire suppression policies would be misplaced and likely to be detrimental to the ecosystems. Fire suppression policies may also increase the vulnerability of swidden farmers dependent on using fire to clear forests for cultivation. Fire management policies need to be adjusted to local ecological and social contexts.

Fire mitigation has largely been conducted in conjunction with building capacity in fire fighting. Prior to the large forest fires in Borneo 1982 fire fighting strategies and infrastructure were not well developed in many parts of Southeast Asia. During the past 20 years 40 international fire projects and missions costing well over US$ 30 million have been implemented, primarily in Indonesia [6]. National governments have also invested significantly in fire management and capacity building at local levels.

Science has made an important contribution to the understanding of the causes and impacts of fires, and in turn, has informed operations. Early warning systems such as the Fire Danger Rating System (FDRS) for Indonesia and Malaysia, for example, were developed jointly by scientists and government agencies [7]. Research has also highlighted alternative ways to manage land to reduce episodes of high fire-related emissions to the atmosphere [8]. These involve delays in time of burning as well as use of zero-burning methods for disposing of waste vegetation. Incentives and regulations are justified because of immediate benefits to human health at local and regional levels. In addition, where total long-term emissions of greenhouse gases could also be reduced through such efforts then this provides additional reasons to encourage such practices.

A focus on building adaptive capacity in fire management could be an effective way to adapt to climate change. Changes in fire regimes, as a result of recurrent droughts and human interventions, mimic some of the key features of the anticipated impacts of climate change on forest and plantation ecosystems. Chokkalingham et al. [9] in particular emphasise the importance of stimulating alternative livelihood options during drought years. They also suggest that, properly guided, the private sector could play an important role through estate tree or palm crops and agroforestry systems rather than current emphasis on annual crops. Industry expertise could be a helpful ally in estimating costs of adaptation to climate change in the commercial forestry sector.

Ultimately adaptation to fire regime changes resulting from climate change would benefit from an explicitly multilevel approach that recognizes some capacities are more appropriately developed at particular levels (e.g. Adger et al. [10]). Better coordination of smoke-haze monitoring and risk management at the regional level would be useful. The vulnerable carbon-rich peatland areas would benefit from improved fire management at district or national levels

Fire has very different meanings and policy implications when viewed as a tool for clearing, as a producer of damaging smoke, or as a source of greenhouse gas emissions. The biophysical and social implications of fires vary greatly from place to place. More attention needs to be paid to the relationships between fire regimes and vulnerable ecosystems and peoples, both under current and future climate. With improved understanding of these interactions and differences the possibility arises of moving tropical forest fire management from *suppression everywhere* to a more reasoned *guided use.*

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Capacity to control fire is important. But how can such capacity be built at community level?

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Airborne and ground-based measurements of fire and biogenic emissions during the 2004 Amazonian dry season

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Volatile organic compounds (VOC) are key species in atmospheric chemistry because of their reactivity and roles as pollutants, precursors to ozone (O_3, an air toxic and greenhouse gas), and as greenhouse gases themselves. Fine carbonaceous particles also have important atmospheric impacts such as effects on radiative transfer (through light scattering and absorption) and cloud formation (by acting as condensation nuclei). The two largest sources of VOC and fine carbonaceous particles in the global atmosphere are biomass burning and vegetation [1]. Fires due to tropical deforestation account for much of the total global vegetation burning [2] and moreover, tropical forests produce a large part of the global biogenic emissions [3]. A substantial portion of the global deforestation is occurring in the Amazon basin driven by conversion to pastures, shifting cultivation, and intensive agriculture (e.g. plantations). Conversion is associated with both long-lasting changes in the vegetative emissions and large "pulses" of fire emissions. Intensive agriculture requires removal of all onsite woody material in relatively intense fires, while use for pasture and shifting cultivation can tolerate large amounts of residual woody debris (RWD). Therefore these latter uses are usually associated with a long-term series of smaller fires. The RWD subsequently contributes to emissions both through decomposition and by providing large amounts of fuel in post-conversion, site maintenance fires.

The Tropical Forest and Fire Emissions Experiment (TROFFEE) was affiliated with the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), an international co-operative research program led by Brazil, focused on producing new scientific knowledge on the functioning of Amazon ecosystems. TROFFEE was funded by the US National Science Foundation, and led by the Universities of Montana and São Paulo, the Brazilian National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais, INPE), and the (US) National Center for Atmospheric Research (NCAR). The measurements in the Brazilian Amazon were made during the 2004 dry season (August-September). The field work was preceded by comprehensive laboratory measurements of the emissions from burning tropical fuels. During this phase we compared multispecies chemical analysis results from two instruments recently developed to minimize the common problem of chemical interference: an open-path Fourier transform infrared spectrometer (FT-IR) and gas chromatography (GC) coupled with a proton-transfer reaction mass spectrometer (PTR-MS). The results allowed us to determine "generic" branching ratios for compounds in smoke with the same mass-to-charge ratio. This means that the signal for various mass channels measured by the PTR-MS during the field campaign could be divided into the contributions from the individual VOC. One of the most important atmospheric VOC is formaldehyde (HCHO) and the PTR-MS response to HCHO is humidity dependent. The laboratory FTIR data for water and HCHO was compared to the PTR-MS HCHO and a humidity-dependent correction factor for the PTR-MS field HCHO data was determined. Finally, the lab work allowed us to probe some additional tropical fuels we did not sample in the field, for example sugar cane [4].

The TROFFEE smoke sampling [5]

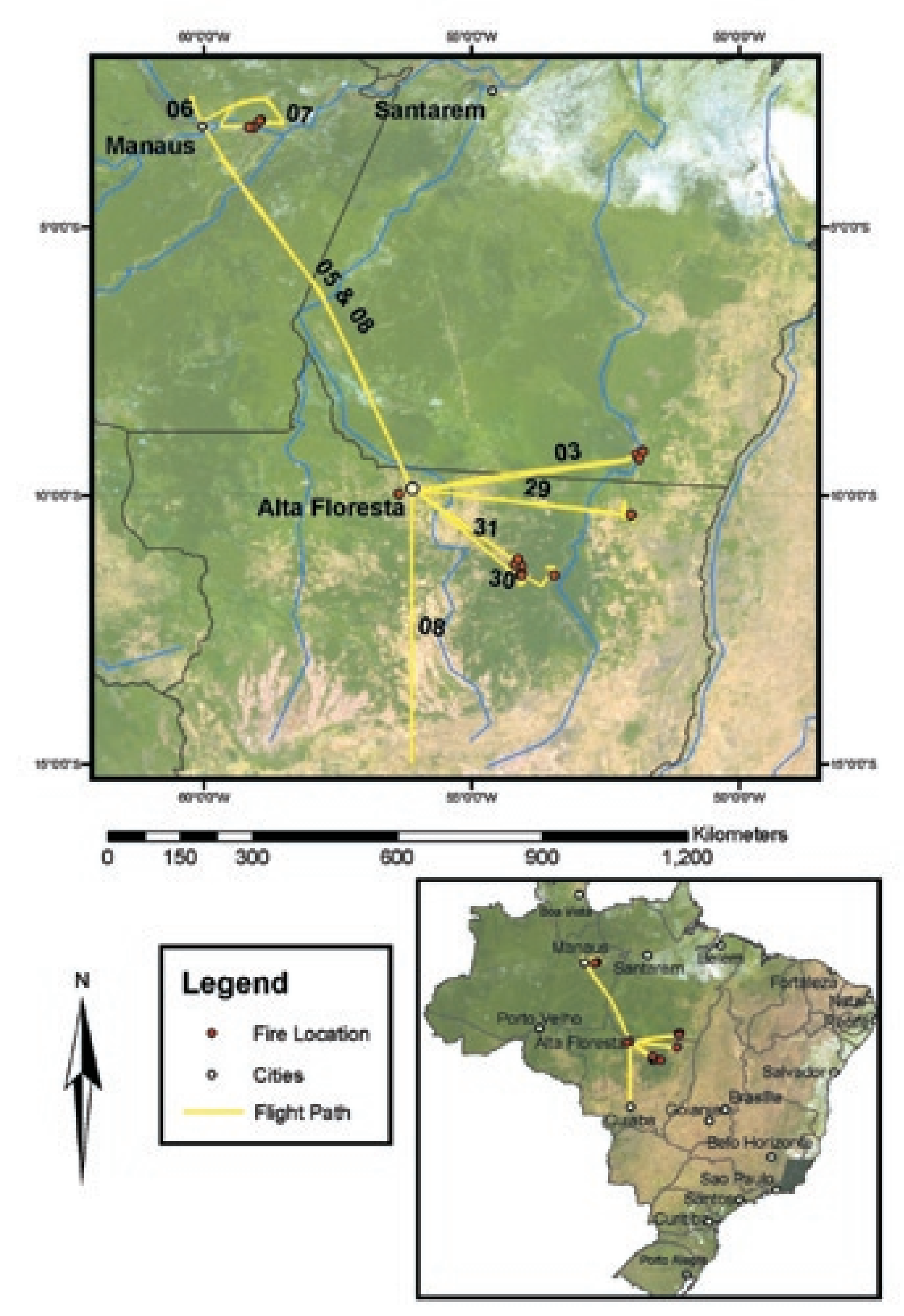

Figure 1. The Tropical Forest and Fire Emissions Experiment (TROFFEE): the flight tracks and the locations of the fires sampled in the Brazilian Amazon during the dry season of 2004 (August-September).

included the first-ever field measurements of the emissions of oxygenated VOC (OVOC) from tropical deforestation fires. The previously known VOC were hydrocarbons that react mainly with atmospheric oxidants such as the hydroxyl radical (OH). The OVOC are of great interest because they also photolyze (react with sunlight), can be precursors for OH, and are now known to be much more abundant in the atmosphere than previously believed. Our TROFFEE data showed that about 80% of the VOC emissions from tropical deforestation fires are OVOC, a much higher contribution than previously assumed for modeling purposes. Our particle (PM_{10}, particulate matter with an aerodynamic diameter of less than 10 µm) emission factor (average emission rate of given pollutant for a given souce) was 17.7 g kg^{-1}, which is about 25% higher than implied by previous reports for tropical forest fires and probably reflects both a trend towards, and the sampling of, larger fires than in previous studies. Comparison of fresh and aged smoke showed evidence of secondary gas phase production of O_3, organic acids, and acetone, but not of acetaldehyde and methanol. A significant fraction of the total burning in 2004 occurred within about 10 ideal lower humidity days and generated a mega-plume, greater than 500 km in width. We sampled one hour to one day old smoke in the mega-plume on its peak day (September 8). The mega-plume contained 10-50 ppbv of numerous reactive species such as O_3, ammonia, nitrogen dioxide, methanol, and organic acids and high PM_{10}. This is an intense, poorly understood, but globally important, chemical processing environment. The mega-plume was transported over São Paulo, Brazil (~1800 km from the source region) during September 14-19 and more than tripled the city's aerosol optical thickness on September 17.

Ground-based smoke measurements [6] with a new cart-based FTIR system showed that residual smoldering combustion of RWD (which produces initially unlofted emissions) can cause the estimated regional fire emissions of several reactive VOC to increase by 20–50% compared to estimations based only on airborne measurements in lofted plumes. Spot measurements of charcoal kiln emissions showed an increasing VOC/CO ratio in the emissions when the carbonization period was extended. We observed high emission ratios from burning dung for acetic acid to CO (~7%) and ammonia to CO (~9%). This has implications for secondary aerosol formation in regions such as South Asia where dung is an important biofuel. The INPE/UW team investigated the dynamics of fuel consumption and site recovery as well as fire effects on ground water and other ecosystem components.

In a relatively fire-free part of the Amazon basin, airborne and ground-based concentration measurements and flux measurements by eddy covariance and two different (mean and variance) mixed layer gradient techniques were used to assess the impact of isoprene and monoterpene emissions on atmospheric chemistry in the Amazon basin [7]. Average noon isoprene (7.3±2.3 mg m^{-2} h^{-1}) and monoterpenes fluxes (1.2±0.5 mg m^{-2} h^{-1}) from pristine forest compared well between ground and airborne measurements. The biogenic emission model MEGAN (Model of Emissions of Gases and Aerosols from Nature) predicts similar isoprene fluxes within the model uncertainty, but tended to underpredict the isoprene emissions from some plantations (e.g. soybean) that were sampled from the air. Isoprene

Figure 2. Instrumentation used in TROFFEE on the INPE Bandeirante aircraft: on the right PTR-MS (NCAR) and on the left Airborne FTIR and whole air sampling (University of Montana and University of California Irvine). In front O_3, PM_{10}, 3-wavelength nephelometry, GPS (University of São Paulo).

and monoterpenes accounted for ~75% of the total OH reactivity in this region suggesting that these species control the oxidative capacity of the tropical, and much of the global, atmosphere. The rate of photochemical oxidation of isoprene increased significantly within a ubiquitous, broken layer of fair weather cumulus. This may help explain why some global models tend to incorporate estimates of vegetative emission rates that are near the low end of measured values, yet still predict ambient concentrations of these species that are higher than many observations.

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Figure 2. Thomas Karl

The second ACCENT Symposium will be hosted once again by the charming Urbino – Italy. The Symposium will be focussed on the relevance of atmospheric composition change on key societal issues as climate change, air quality, human health and ecosystems. It will also deal with outreach themes, such as training the next generation of atmospheric scientists and synthesis of scientific results for policy makers and the general public.

The Symposium will consist of plenary oral presentations, poster sessions and special sessions for outreach activities and is based on five thematic sessions and two outreach sessions:

1. Atmospheric Composition Change and Climate (CL)	Conveners: Claire Granier and Ivar Isaksen
2. Atmospheric Composition Change and Ecosystems (ES)	Conveners: David Fowler and Colin O'Dowd
3. Atmospheric Composition Change and Air Quality (AQ)	Conveners: Tony Cox and Paul Monks
4. Atmospheric Composition Change and Health (H)	Conveners: Markus Amann and Alfred Wiedensholer
5. Measuring atmospheric composition changes (M)	Conveners: John P. Burrows, Paolo Laj
6. Special Session: "Training the Next Generation of Scientists"	Convener: Eva Schuepbach
7. Special Session: "Science and the the Public"	Convener: Frank Raes

More information from ACCENT (www.accent-network.org) and to the Symposium website (http://www.accent-network.org/2nd-symposium/).

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Wildfires and land use fires in western Russia and Siberia frequently contaminates the lower troposphere in northern Eurasia

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Wildfires are mostly initiated by small-scale agricultural activities, such as burning of vegetation for land clearing. In some cases these small fires can develop into widespread and uncontrolled fires [e.g. 1]. This can be demonstrated by comparing satellite observations of fires (http://maps.geog.umd.edu/firms/maps.asp) with corresponding locations of human activities in populated areas as indicated by roads, railroads and cities. It is known that the frequencies of wildfires generally follow a clear seasonal cycle. The frequency and intensity of fires is also dependent on meteorological and climatic conditions, such as seasonal precipitation or large-scale climatic phenomena, e.g., El Niño.

Wildfires emit gases and aerosol particles into the atmosphere. Fire-related gases can be either long (as CO_2) or short lived (as many organic compounds). Primary aerosol particles from fires have a relatively short residence time in the lower troposphere (a few days). It is not conclusively known what are the large-scale climatic and health consequences of wildfires. For example, the carbon emitted as CO_2 is not necessarily later used completely in new biomass formation. In fact, some recent studies have shown that wildfires may affect global CO_2 and CH_4 cycles, e.g., due to permanent deforestration [2,3]. In addition to the role of wildfires in climate change, wildfires have several other environmental effects, for example due to mercury emissions [4], but are also of great concern in terms of human health [5].

The wildfires in the western and southern Russia and Siberia are of special interest because these fires have usually not been controlled up to date by man. It has also been predicted that the frequency and intensity of these fires will increase in the future due to changes in temperature and precipitation with climate change. In addition, these boreal wildfires have several climatic and environmental impacts over large areas in the Northern Hemisphere, including the Arctic region [e.g. 6]. In this paper, we summarise recent results on studies of aerosol emissions from Siberian forest fires and wildfires in western Russia.

The TROICA-9 (Trans-Siberian Observations Into the Chemistry of the Atmosphere) expedition was carried out at the Trans-Siberian railway between Moscow and Vladivostok in October 2005. This offered an unprecedented opportunity to investigate the Siberian forest fires at close range. The online aerosol chemistry measurements at an observatory carriage connected to a fast-moving passenger train were challenging but enabled us to localize the fire plumes with a spatial resolution of 20 km. Using black carbon, potassium and oxalate as tracers of fires, we were able to characterize, for example, if the smoke was coming from flaming or smouldering fires. This information was completed with offline chemical analysis (including levoglucosan), which confirmed that Siberian forest fires significantly contributed to the fine particulate matter mass concentrations over several hundreds of kilometers around the source area, Lake Baikal. During the expedition, the highest mass concentration of fine particles, 34.8 µg m^{-3} (24 h average) was observed in Siberia, while generally the mass concentration level was similar to concentrations measured at urban background stations in European cities. The fraction of

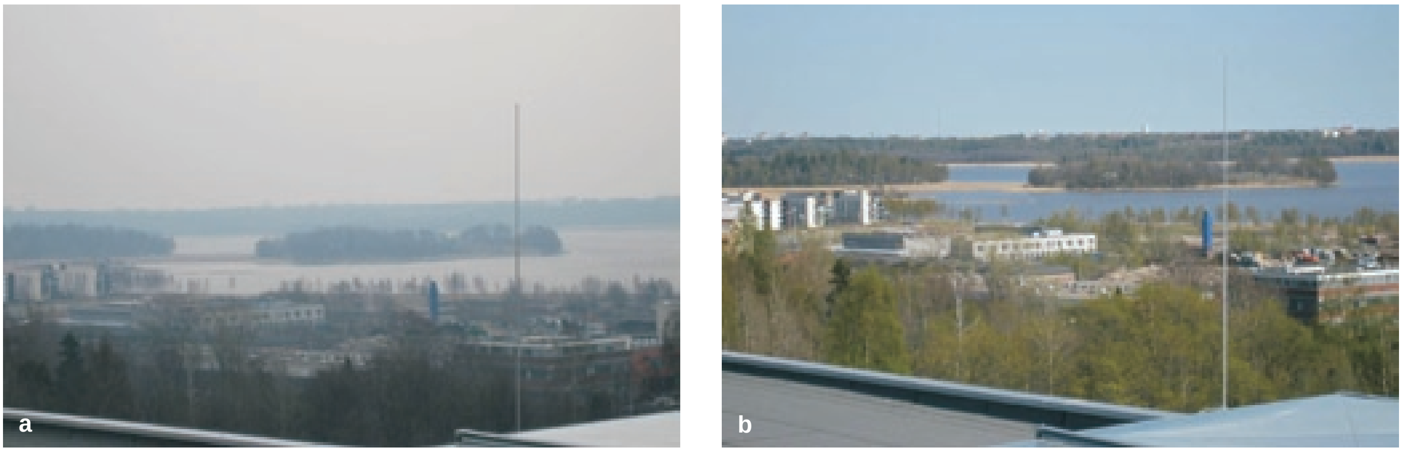

Figure 1. Visibility degradation in Helsinki due to western Russia land use fires and wildfires, a) during the smoke episode in spring 2006 visibility was around 10 km, b) after the smoke episode visibility returned to normal background levels (50 km).

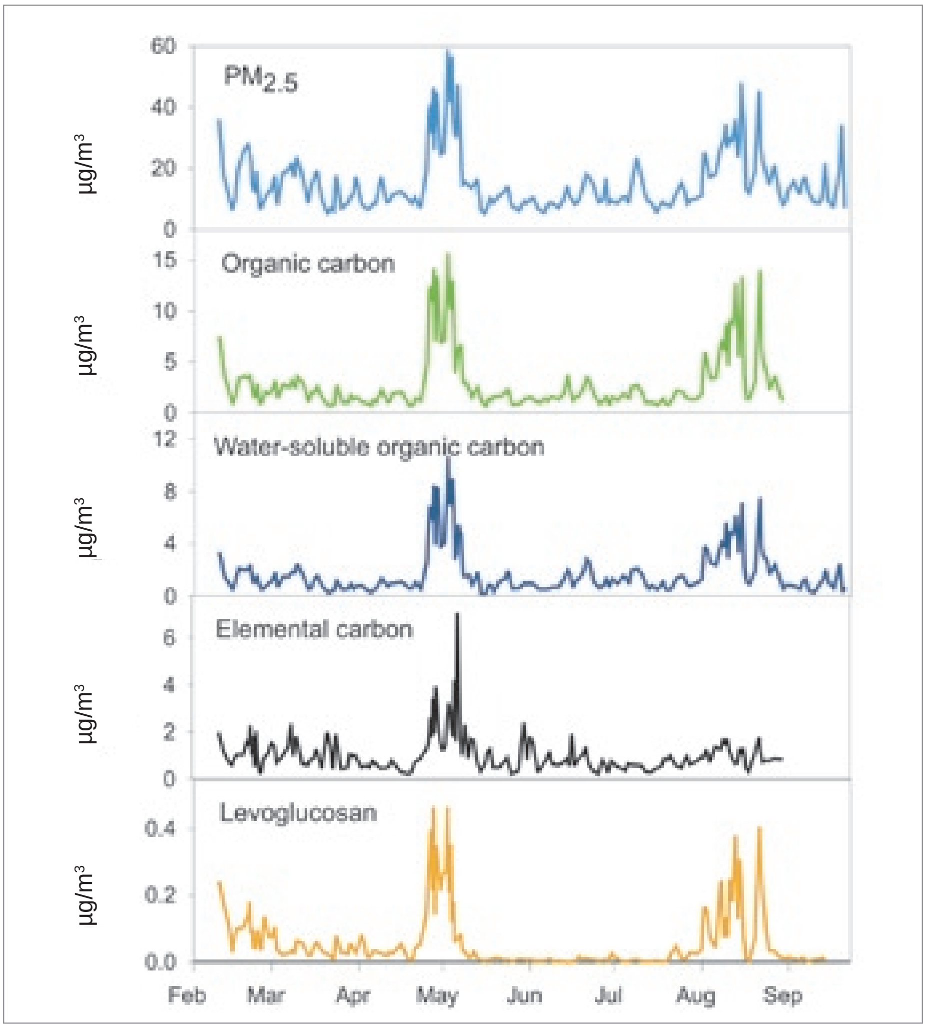

Figure 2. The two smoke episodes (spring and autumn) observed in Helsinki 2006 differed from each other by their burning material and fire conditions. The spring fires had higher burning temperature with significantly higher soot (elemental carbon) formation. High levoglucosan concentrations before spring episode are due to local and regional wood combustion in small-scale residential heating. The source areas of the autumn fire plumes were in Russia 150-200 km from Helsinki. The maximum hourly mass concentration of fine particles was 180 $\mu g\ m^{-3}$, but the plume was over Helsinki only a few hours per day, and the daily means shown here remained below 50 $\mu g\ m^{-3}$.

monosaccharide anhydrides (mainly levoglucosan) was usually in the range of 0.4–1.6%, but in one sample (6 000–7 000 km from Moscow) it was elevated up to 4%. Therefore it is obvious that emissions from the Siberian forest fires have a significant effect on the concentration levels and chemical composition of particles over large areas, and certainly have implications on the lower troposphere radiation balance.

We have also studied pollution episodes caused by the fires in western-Russia. Observations were made at an urban background station in Helsinki, Finland during the spring and summer in 2006. Similar instrumentation was used for online aerosol chemistry as during the TROICA-9 expedition, and complementary offline chemical analysis was also performed. Two major smoke episodes originating from western Russia were observed in Helsinki.

Fig. 1 shows the degradation of visibility in Helsinki during the first smoke episode in April 2006. The visibility decreased from 50 km to less than 10 km due to light scattering of organic material in aerosol particles. Fig. 2 summarizes the chemical composition of fire-related particulate matter in year 2006. The fire-related tracer concentrations were measured, and elevated levels were observed during both smoke episodes. Briefly, levoglugosan in submicrometer aerosols is one of the best tracers of vegetation burning as it has no other sources. The levoglugosan concentrations were significantly elevated between 24 April and 5 May, and again between July 19 and August 30. Based on elemental carbon concentrations aerosols were from the flaming phase of the fire during the spring smoke episode. The autumn episode had lower elemental carbon concentration, indicating a different source area and fire mechamism. In fact, the source areas were substantially different between these two smoke episodes. The spring episode was related to intentional land use fires in relatively dry climate conditions, while in the autumn episode burning material was fresh trees in a boreal forest, and emissions were dominated by organic aerosols from smouldering fires.

In the next stage the observed chemical data will be compared with dispersion modelling and satellite observations. The satellite observations provide unique information on the radiative energy of the fire, burning area and the composition of burning material (i.e., based on the information of land use). This information will improve fire model simulations. The ultimate goal is to use experimental data, satellite observations and modelling to establish an integrated data system that improves our possibilities to quantitatively predict and forecast the atmospheric aerosol concentrations and the composition of plumes originated from wildfires and land use fires.

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Towards the improved understanding of land-surface processes and coupling with the atmosphere over West Africa

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Land-atmosphere feedbacks in the West African Monsoon (WAM) region are of critical importance for numerical weather prediction in Africa. The pioneering work of Charney [1] was among the first studies to show the impact of land surface vegetation and surface soil conditions on regional scale atmospheric circulations, and more recently Koster et al. [2] showed that an ensemble of global climate models (GCMs) predict significant land-atmosphere coupling over this region. The dominant feature of land-atmosphere interactions over West Africa is the large range of characteristic coupled processes at different spatial and temporal scales. At the small scale, these interactions have an impact on convective cells within mesoscale storm systems, while at the regional scale they influence the position of the Intertropical Convergence Zone and the African Easterly Jet through a significant meridional surface flux gradient [3]. A better understanding and prediction of land-atmosphere coupling processes are key scientific foci of the African Monsoon Multidisciplinary Analysis (AMMA) Project.

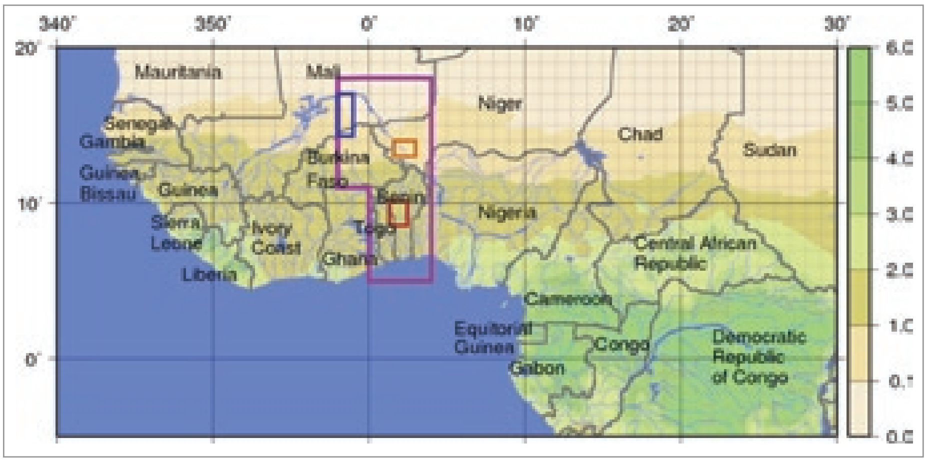

Figure 1. The AMMA regional scale land surface modelling domain. The regional-scale computational grid cells are shown in grey. The CATCH transect or sub-domain (outlined in violet) contains three meso-scale sites: Oueme (red), Niamey (orange) and Gourma (blue). There are 22 local scale soil moisture measurement sites within the transect. Contours correspond to the annually-averaged Leaf Area Index (LAI m^2 m^{-2}).

The land surface modelling strategy of AMMA relies on the following structure: 1) coordinated development and use of various Land Surface Models (LSMs), each focusing on different processes and working at different temporal and spatial scales. These include hydrological models, soil-vegetation-atmosphere transfer schemes, and crop models. 2) Creation of a multiscale low-level atmospheric forcing database over land. These data are essential for a coherent multi-disciplinary modeling approach at various spatio-temporal scales. 3) Development of an African Land Data Assimilation System. The goal is to improve the representation of initial conditions corresponding to the land surface vegetation and surface soil conditions in operational numerical weather prediction (NWP) models, especially in terms of soil moisture which can influence the initiation and development/decay of convective systems fundamental to the monsoon hydrological cycle. The development and improvement of model parameterizations, coupling, and calibration, as well as assimilation methods, are the basis for the modelling studies conducted in AMMA.

Land Surface Models require forcing variables consisting of near-surface atmospheric state variables, downwelling radiative fluxes and rainfall as well as land parameters (land cover, vegetation metrics, soil texture) as input. Precipitation is the most crucial forcing input, and it must be well resolved in terms of intensity, frequency, duration of events, and spatial distribution. At the regional scale, the use of Meteosat Second Generation (MSG) remote sensing products gives a consistent set of atmospheric forcing variables. The precipitation is from the EPSAT (Estimation of Precipitation by SATellite) product available within AMMA-SAT (the AMMA-PRECIPitation sub-group), and the downwelling radiative fluxes are from the Satellite Application Facility projects (LAND-SAF and Oceans and Ice SAF). Model evaluation and/or calibration depend upon observations of surface turbulent fluxes (latent and sensible heat, carbon, net radiation) and model prognostic and diagnostic variables (soil moisture, stream flow, vegetation dynamics, etc.). These requirements are addressed by the comprehensive AMMA field campaign. Instruments have been deployed during the course of AMMA for the Long (LOP: 2002–2010), Extended (EOP: 2005–2007), and Special (SOP: 2006) Observation Periods. In particular, SOP measurements provide ancillary information needed to perform specific case studies, for example aircraft based measurements of thermal infrared temperature of the surface and atmospheric humidity along a latitudinal transect where significant spatial heterogeneities of soil moisture are observed [4]. The overall AMMA study domain, the location of the meridional transect, and the three main mesoscale observation sites are shown in Fig. 1.

Coordination of the land surface modelling activities in AMMA is supported by the AMMA LSM Intercomparison Project (ALMIP). It is an international effort conducted along the same lines as previous LSM intercomparison studies, such as the Rhône AGGregation Land Surface Scheme Intercomparison Project (Rhône-AGG [5]), but it focuses on West African land processes. ALMIP has the following main objectives: 1) intercompare results from an ensemble of state-of-the-art models, 2) determine which processes are missing or not adequately modeled by the current generation of LSMs over this region, 3) examine the LSM response to changing spatial scales, 4) develop a multi-model climatology of "realistic" high resolution (multiscale) soil moisture, surface fluxes, as well as water and energy budget diagnostics at the surface that can then be used by other projects within AMMA, 5) evaluate how relatively simple LSMs simulate vegetation response to atmospheric forcing on seasonal and interannual timescales, and 6) examine the impact of satellite-based forcing data compared to data

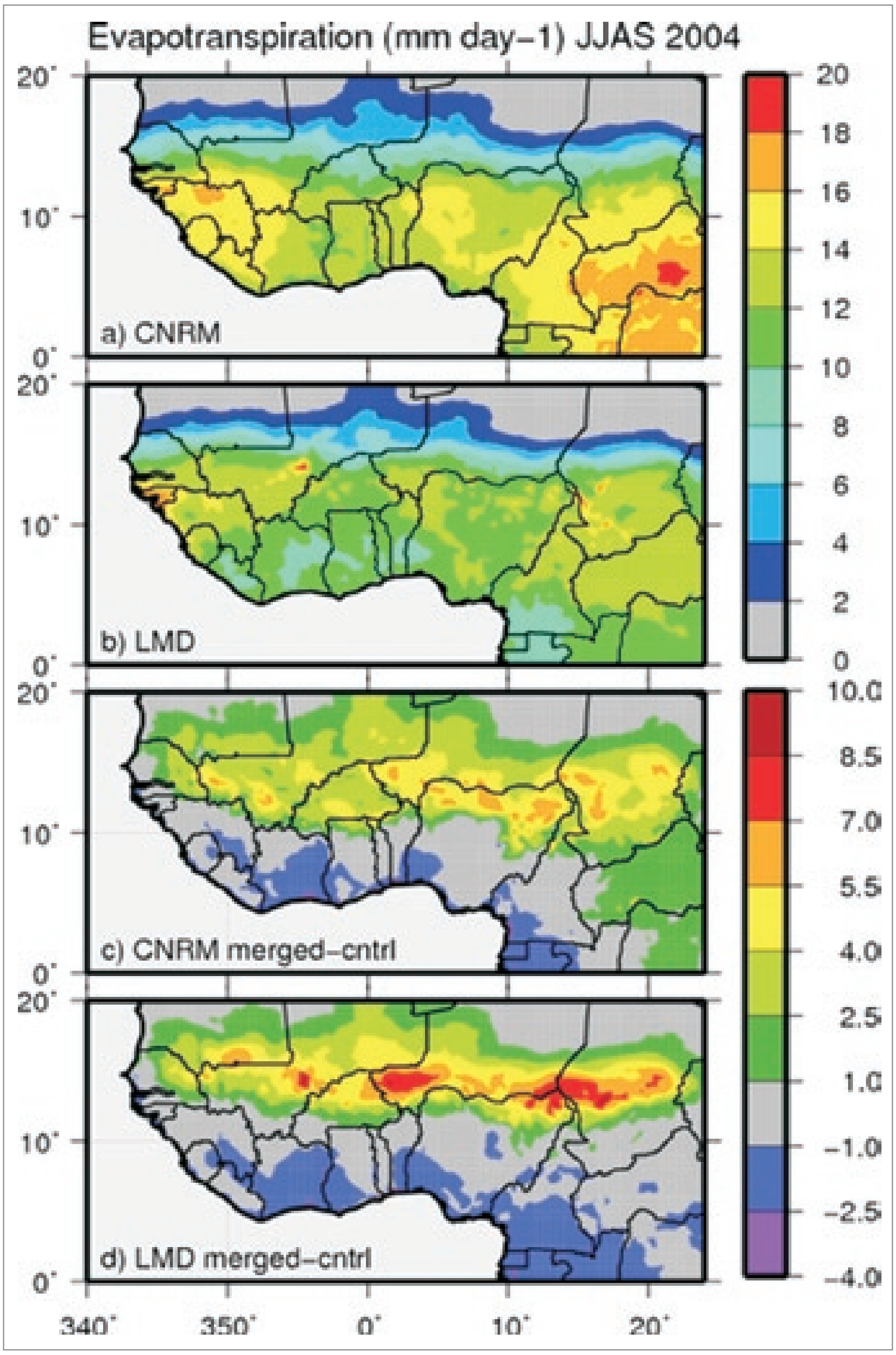

Figure 2. The evapotranspiration (Evap) simulated by two Land Surface Models from the Centre National de Recherches Météorologiques (CNRM) and the Laboratoire de Météorologie Dynamique (LMD) averaged over the monsoon season (June-Sept.) in 2004, using the merged/inferred (satellite-based product combined with numerical weather prediction, NWP data) atmospheric forcings (panels a and b). The Evap simulated using the merged forcing less Evap produced using the control or pure NWP forcings are shown in panels c-d. The increased Evap in the northern part of the domain is associated with errors in the NWP data (a monsoon displaced too far south compared to satellite-based data).

from NWP models. The average evapotranspiration (*Evap*) simulated by two LSMs averaged over the monsoon season (June - Sept.) in 2004, are shown in Fig. 2a-b. Despite the same input forcings, the *Evap* (the critical link between atmosphere coupling and hydrology) is significantly different. The impact of replacing satellite-inferred precipitation and radiative fluxes with NWP (control) data is shown in Fig. 2c-d. Both LSMs show the displacement of the active precipitation zone to the north when using the inferred data, but the magnitude and spatial distribution of the *Evap* difference is quite different. The high atmospheric *Evap* demand combined with the water-limited precipitation regime should act to enhance LSM differences over the semi-arid portion of the AMMA domain.

In summary, there is a need to better understand land-atmosphere and hydrological processes over western Africa due to their potential feedbacks with the regional monsoon circulation. This is being addressed through a multi-scale modelling approach using an ensemble of LSMs which rely on dedicated satellite-based forcing and land surface parameter products, and data from the AMMA observational field campaigns. The far reaching goal of this effort is to obtain better understanding and prediction of the WAM which then can be used to improve water management and agricultural practices over this region.

Based on a French initiative, AMMA has been established by an international group and is currently funded by a large number of agencies, especially from France, the UK, the US and Africa. It has been the beneficiary of a major financial contribution from the European Community's Sixth Framework Research Programme. Detailed information on scientific coordination and funding is available on the AMMA international web site (https://www.amma-eu.org/).

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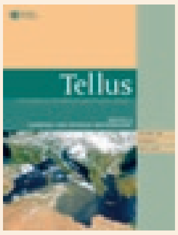
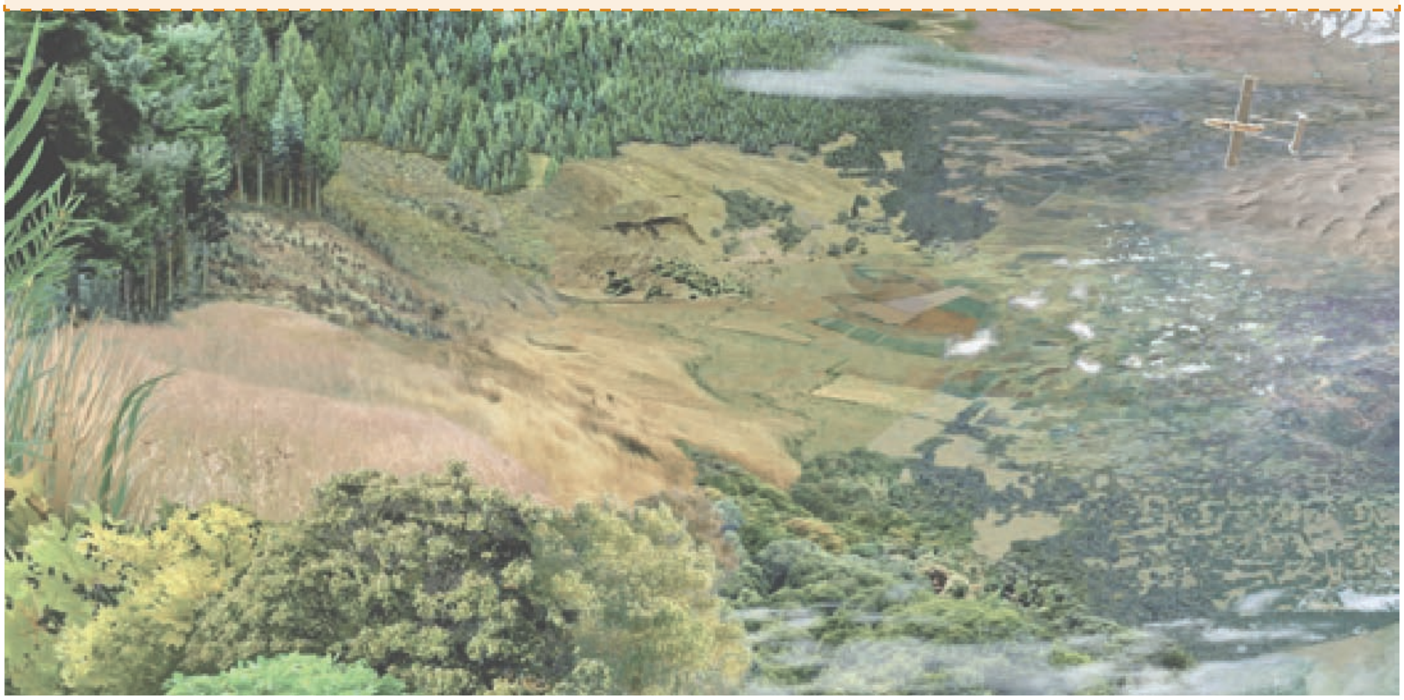


iLEAPS Special Issue in Tellus B

Tellus B Journal Special Issue from iLEAPS Science Conference held in Boulder, Colorado, USA, 21-26 January 2006 is now available at http://www.blackwell-synergy.com/toc/teb/59/3. Special issue contains a preface and 29 science papers.



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Theodore Bohn is currently a PhD student in the Department of Civil and Environmental Engineering at the University of Washington, Seattle, USA. His PhD dissertation focuses on estimating the large-scale effects of changes in climate and hydrology on carbon storage and methane emissions from lakes and wetlands across northern Eurasia. His research interests include large-scale modeling of hydrological and biogeochemical processes, hydrology and carbon cycling of lakes and wetlands, investigations of how processes behave at different scales, and statistical methods of stream flow forecasting.

Large-scale modeling of wetland methane emissions

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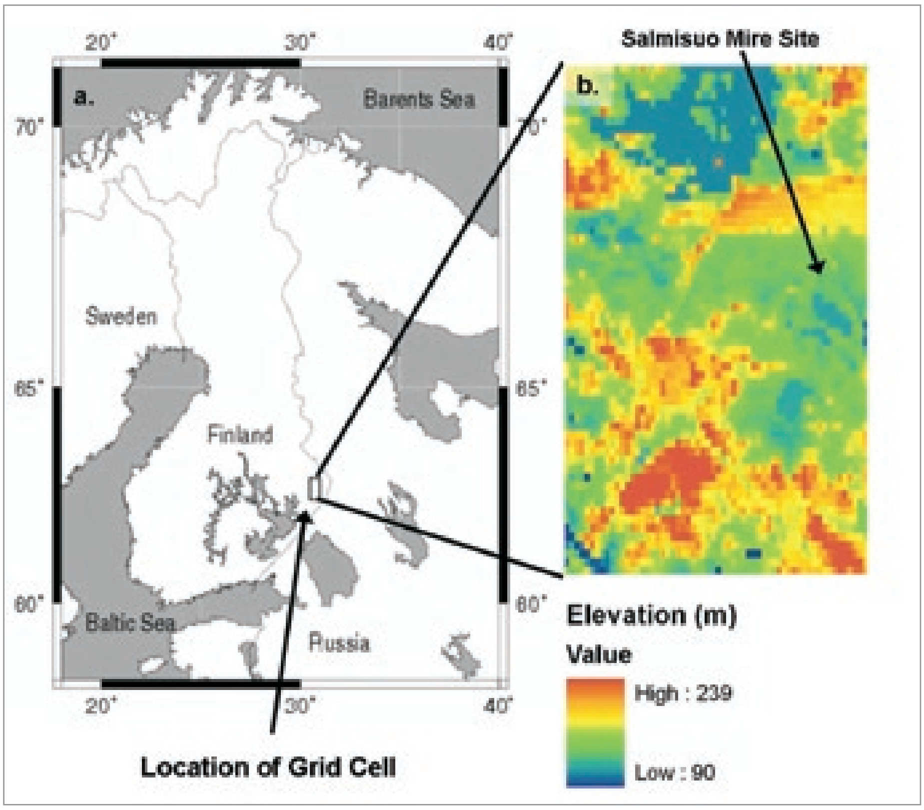

Figure 1. Location of test grid cell and Salmisuo Mire field site. Panel a) shows the location of the 0.5-degree grid cell (62.5°-63° N, 30.5°-31° E) used in the simulation. Panel b) shows the SRTM 30-arc-second DEM [6] for the grid cell, along with the location of the Salmisuo Mire site (62° 47' N, 30° 56' E) within the grid cell.

Wetlands play an important dual role in the global carbon cycle as both the largest natural methane source (115 TgCH$_4$ y^{-1} [1]) and a large net carbon sink (76 TgC y^{-1} for high-latitude peatlands alone [2]). Both the extent of wetlands and the balance between their methane emissions and carbon sequestration depend on climatological and hydrological factors, leading to potentially significant feedbacks to the global climate system. This is especially true in northern Eurasia, where roughly 30 percent of global wetlands are located [1, 2], and where ongoing and projected climate change is most pronounced. Despite the importance of these systems to the global carbon cycle, large uncertainties remain in the estimates of their extents, carbon fluxes, and responses to climate change. This is largely due to the sparseness of *in situ* observations in northern Eurasia.

When observations are sparse, large-scale modeling gives an opportunity to study and understand these interactions listed above .As part of the Northern Eurasia Earth Science Partnership Initiative (NEESPI), the University of Washington is collaborating with researchers at Jet Propulsion Laboratory, NASA, Purdue University, the Max Planck Institute for Meteorology and the Max Planck Institute for Biogeochemistry to couple a large-scale hydrological model (VIC, [3]) to a large-scale terrestrial ecosystem model (BETHY, [4]) and the wetlands methane emissions model of Walter and Heimann [5].

Previous attempts to model wetland methane emissions over large areas have been limited by the coarse spatial resolution (normally 0.5 – 3 degree grid resolution) of the models applied Wetland methane emissions are highly sensitive (and non-linearly related) to the depth of the water table, which can exhibit large variations within a typical model grid cell (0.5 degrees latitude-longitude in this study). As a result, a model grid cell containing potentially methane-emitting wetlands, for instance, may have an average water table that is too deep to support methane emissions. Emissions from such a grid cell would be missed by a model that simulates only the grid-cell average water table. To avoid the computational requirements of higher spatial resolutions, we have extended the Variable Infiltration Capacity (VIC) model [3] to parameterize the sub-grid variability of the water table,

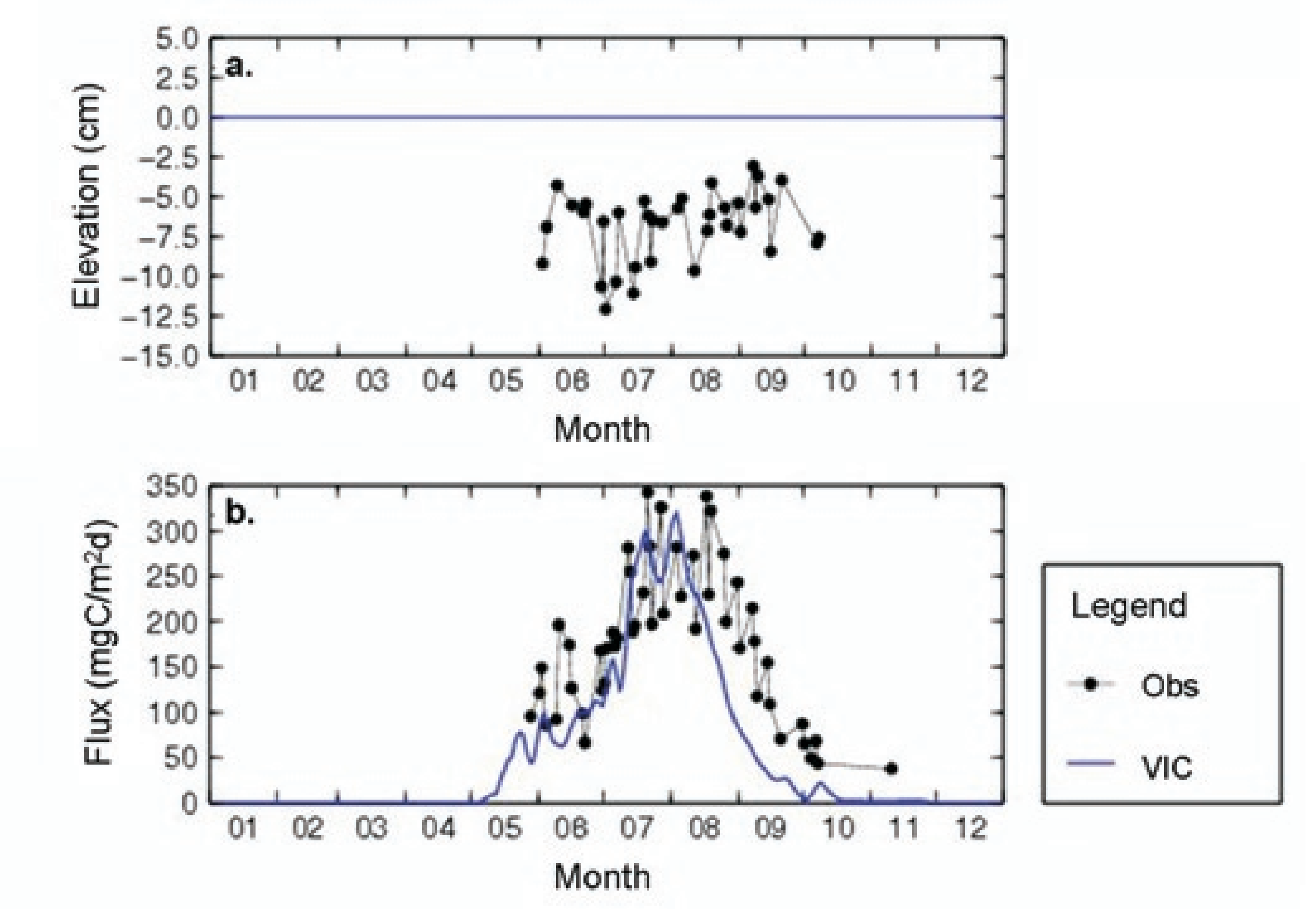

Figure 2. Comparison of observed and simulated (VIC) water table depth (panel a) and methane emissions (panel b) at Salmisuo Mire site [7] for 1993. Note that the simulated water table depth for the pixel containing the site is zero (soil is completely saturated) for the entire period.

based on grid cell topography (supplied by the 30-arc-second Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) [6] in this study), yielding a time-varying (spatial) probability distribution of water table levels within the grid cell. This probability distribution of water table levels is then used in conjunction with the methane model to derive a time-dependent probability distribution of methane emissions for the grid cell. The methane emissions reported for that grid cell represent the expected value of the subgrid probability distribution of emissions.

To test the model's capabilities, we simulated the hydrology and carbon fluxes at the Salmisuo Mire complex in Finland (see Fig. 1), where Saarnio et al. [7] observed water table depth, soil temperature, and methane fluxes in summer 1993. The site consists of flat areas called *lawns*, where the water table is typically very near the surface, interspersed with small rises, or *hummocks*, where the water table can be more than 20 cm below the surface. Lawns and hummocks occupy 86% and 14% of the site, respectively.

Because the site is too small to be simulated by large-scale models, we ran simulations for the 0.5-degree grid cell containing the site (62.5°– 63° N, 30.5°–31° E; see Fig.1a). As a consequence, we were unable to compare the model results of the entire grid cell to the observations from the site. Instead, we compared the observations to the model results for the 30-arc-second (roughly 500m×1250m) SRTM [6] pixel containing the site (Fig. 1b), which corresponds to the 90th percentile of the model's probability distributions of water table depths and methane emissions.

Results of the observed and simulated water table depths for the year 1993 are shown in Fig. 2. Fig. 2a shows the area-weighted average of the water table depths across the site (via piezometers at 11 lawn microsites and 9 hummock microsites, along a 100-m transect), compared with the water table depth predicted by the model for the pixel containing the site. Unlike observations, the simulated water table depth for this pixel remains at the surface for the entire year (this is not necessarily the case for other pixels within the grid cell). Fig. 2b compares the area-weighted average of the site's observed methane emissions to the simulated emissions for this pixel. Simulated methane emissions have roughly the same magnitude as observed, except for the beginning and end of the growing season when simulations are lower than observed. This may be due to underprediction of available labile soil carbon during these periods.

Saarnio et al. [7] estimated total annual methane emissions for the Salmisuo Mire site to be approximately 20.4 gC $m^{-2} y^{-1}$. Summing simulated emissions for the (30 arc-second) pixel containing the site over the year 1993 gives a total of 18.3 gC $m^{-2} y^{-1}$. While this value is slightly lower than observed, it falls well within the range of typical bog emissions [1, 2]. We can also integrate over the probability distribution to estimate the total emissions for the 0.5-degree grid cell, which yields 1.2 gC m^{-2} y^{-1} over the land surface of the grid cell (excluding open water), or 17.6 gC m^{-2} y^{-1} over the methane-producing areas in the grid cell, whose areal extent ranged from 0 to 360 km^2 over the course of the year.

It is important to note that the average simulated water table level for this grid cell is much deeper (ranging from 100 to 200 cm) than the observations at the Salmisuo Mire site. Using this average depth with the methane emissions model would have yielded zero methane emissions for this grid cell. Hence, representation of the sub-grid probability distribution of water table depths is critical to estimation of realistic grid cell methane emissions.

Eventually, we intend to apply this modeling framework to all of northern Eurasia and to investigate the interactions of a changing climate with wetland methane emissions over the region.

Acknowledgements

Observations of water table depth and methane emissions at Salmisuo Mire, used in Fig. 2, were graciously provided by Dr. Sanna Saarnio, in the Department of Biology at the University of Joensuu, Joensuu, Finland.

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Forthcoming iLEAPS events

IGBP-WCRP Aerosols, Clouds, Precipitation and Climate Initiative (ACPC)

iLEAPS-IGAC-GEWEX Specialist Workshop
8-10 October 2007
NCAR, Boulder, Colorado, USA

Interactions and feedbacks among aerosols, cloud processes, precipitation, and the climate system are still poorly known although they have profound impacts on the thermodynamic and radiative energy budgets of the Earth. In order to develop the ACPC research agenda, a science workshop will be held on 8-10 October at NCAR in Boulder, Colorado. The goals of this workshop will be an assessment of ongoing activities, a review of existing datasets and modeling strategies, and the development of the ACPC research strategy. The ultimate goal of the ACPC is to establish an IGBP-WCRP level project. For more information, please contact the project offices.

Science questions of the workshop:
Question 1: What are the relative roles of aerosols and dynamics on precipitation and what feedbacks exist?
Question 2: Can the slowing of auto-conversion result in increasing precipitation?
Question 3: How do aerosol-precipitation interactions affect the energetics of climate system?
Question 4: What are the aerosol-precipitation effects at larger scales?

Invited presentations by V. Ramanathan, Bill Cotton, Graham Stevens, Bjorn Stevens, Sandro Fuzzi, Maria Assunção da Silva-Dias, Danny Rosenfeld, Brian Soden, Cynthia Twohy, Bill Lau and Ulrike Lohmann.

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Prof. Christiane Schmullius is head of the Department for Earth Observation within the Institute of Geography at the Friedrich-Schiller University, Jena (Germany). For more than a decade she has been active in utilizing Earth observations to answer environmental science questions in Siberia.

The Siberian Earth System Science Cluster (SIB-ESS-C) - a spatial data infrastructure to facilitate Earth system science in Siberia

Christiane Schmullius, Roman Gerlach and Sören Hese

Institute of Geography, Friedrich-Schiller University, Jena, Germany

The Siberian Earth System Science Cluster (SIB-ESS-C) is the follow-on activity to the EU funded SIBERIA-II project (EVG2-2001-00008, 2002-2005), which was a joint Russian-European remote sensing project focusing on a 300 Million ha area in the central Siberian region (Fig 1). The overall objective of the SIBERIA-II project was to demonstrate the viability of full carbon accounting including greenhouse gases (GHG) on a regional basis using state-of-the-art environmental methods and advanced remote sensing technologies. The tools and systems which have been employed include a selected yet spectrally and temporally diverse set of 15 Earth observation instruments on 8 satellites, detailed GIS databases and Dynamic Global Vegetation Models to account for fluxes between land and atmosphere.

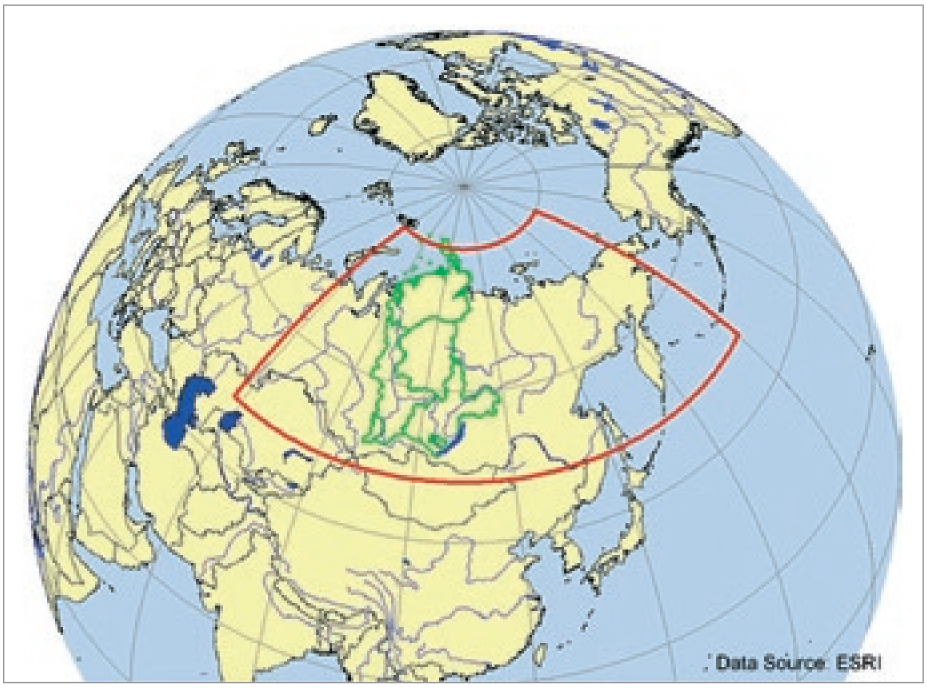

Figure 1. The study area of the Siberian Earth System Science Cluster (red line) and the SIBERIA-II project (green line).

SIB-ESS-C has been initiated by the Department for Earth Observation at the University of Jena to facilitate and carry out interdisciplinary research on the role of the Siberian environment within the global Earth system. It has been widely recognized that Siberia is a key region in global change research, showing a pronounced increase in temperature over the past decades. Moreover, future projections indicate significant changes to occur in terrestrial ecosystems, especially in the biogeochemistry, energy and water cycles. Process knowledge of this part of the Earth's system, including the human interaction, is still incomplete. Given the geographic extent of Siberia and the limited availability of in-situ measurements, the SIB-ESS-C team will focus on the creation and validation of information products derived from satellite observations.

Besides the scientific objectives, which are in line with those proposed by the Northern Eurasia Earth System Partnership Initiative (NEESPI), there are recent advancements in information technology, especially in the field of spatial data infrastructures that provide new opportunities for the earth science community to efficiently share data, results and also applications over the World Wide Web. Standards published by the Open Geospatial Consortium (OGC™), the International Organization for Standardization (ISO) or the World Wide Web Consortium (W3C®) are the basis for interoperable information systems. Based on these standards the Siberian Earth System Science Cluster will be developed as a spatial data infrastructure for remote sensing product generation, data dissemination and scientific data analysis.

In the initial phase of the SIB-ESS-C project, data sets and value-added products created within the SIBERIA-II project will form the basic set of products to be disseminated. These products include regional maps of land cover, fire induced disturbances, phenology, snow depth, snow melt date, onset and duration of freeze and thaw, fraction of photosynthetically active radiation, leaf area index and others. Most of these products are available

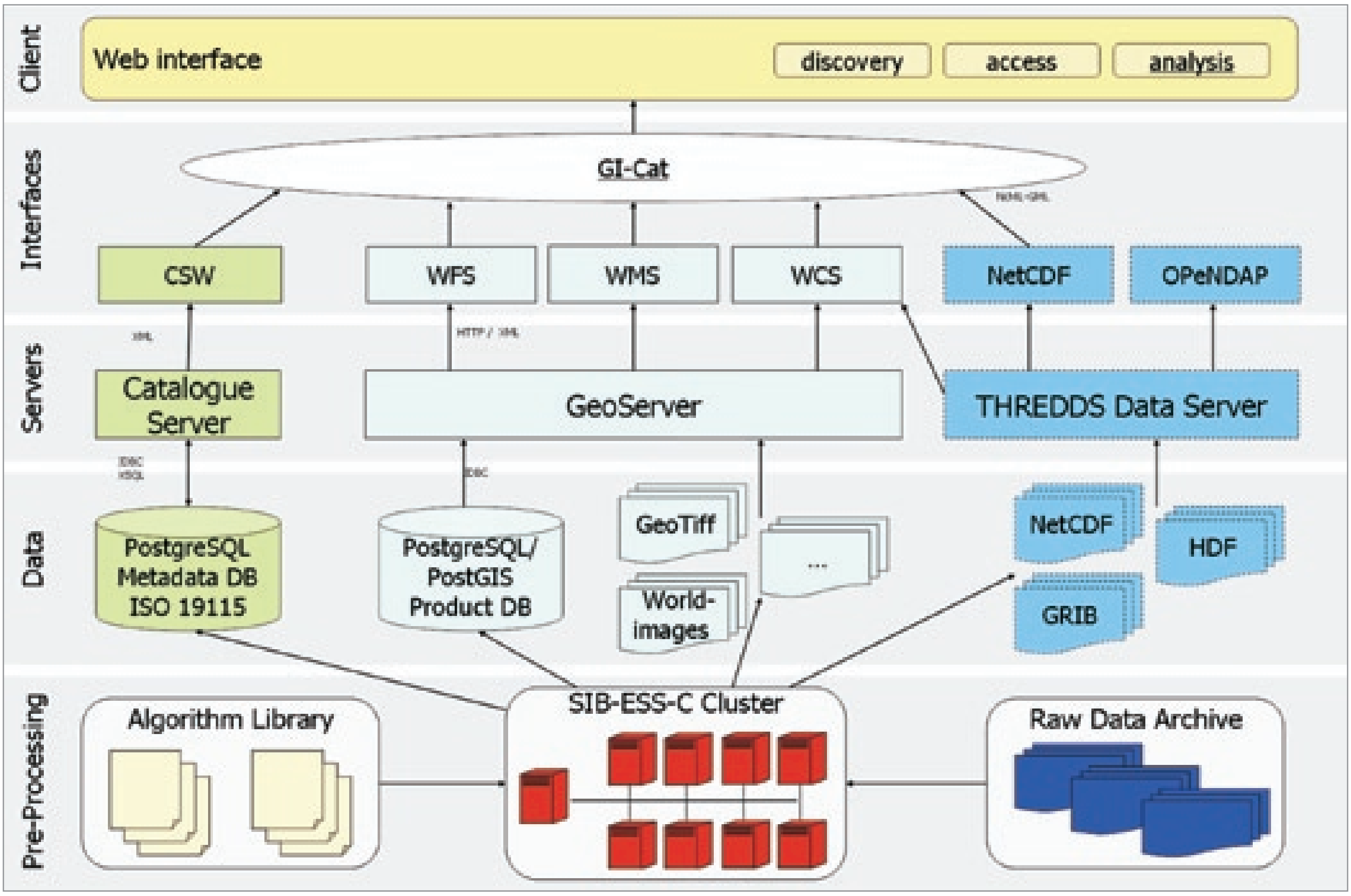

Figure 2. Planned architecture of the SIB-ESS-C infrastructure.

for several years and cover the entire SIBERIA-II region. A major goal of SIB-ESS-C is to continue product generation in order to build up time series for environmental monitoring and as input parameters for earth science models. Additional information products will be incorporated as they become available. In order to provide a comprehensive spectrum of data sets relevant for Earth system research collaboration with other data providers and research organisations to share data sets is highly desired. A first step in attaining more researches to get involved with SIB-ESS-C has been September 2006 made by an inaugural symposium of the SIB-ESS-C project team, hosted by the University of Leicester.

The technical development and implementation of the Siberian Earth System Science Cluster is being supported by the Friedrich-Schiller University Jena (Germany) for the period commencing January 2006 until December 2010. The technical components of SIB-ESS-C comprise: i) an online data repository enabling users to search, (pre-) view and download existing datasets, ii) a computing cluster for operational data processing to ensure continued product generation and iii) comprehensive online analysis tools allowing users to exploit the information content of the data sets provided. Following the principle of interoperability SIB-ESS-C is planned to become part of a distributed network of similar systems where not only data is being distributed and shared, but also applications (e.g. analysis functionalities, processing modules) are being offered and used throughout the network.

Access to data products is available through the SIB-ESS-C website (http://www.sibessc.uni-jena.de). All data products are provided free of charge following a simple registration procedure.

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New projects

LUCID – Land-Use and Climate, IDentification of robust impacts

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LUCID

Over the last decade there has been a tremendous increase in the literature regarding the impact of land cover change on climate at the regional and global scale. However, the results of the impact of large scale land cover change on the Earth's climate varies from "significant and large", "only local to the perturbation", or "small enough to be ignored" in the literature. This variability is mainly due to the fact that modelling groups have used different models, different land parameterizations, different land-cover maps, different model configurations and different experimental protocols. Inspite of controversial results, the land cover change community has clearly demonstrated the importance of the land cover change on climate. In discussions within GEWEX-GLASS and IGBP-iLEAPS, a sense that the land cover change community had proven *to itself* that land cover change was important, but not proven to the major modelling groups *how important* it is led to a decision to launch a major experiment to evaluate the impact of land-use induced land-cover changes on climate.

Under the auspicies of IGBP-iLEAPS and GEWEX-GLASS, a project called LUCID (Land-Use and Climate, IDentification of robust impacts) has therefore been launched. LUCID is self describing: we are not trying to identify model-specific sensitivities to land cover change, rather we seek to explore, using methodologies that the major climate modelling groups recognise, those impacts of land cover change that are *robust* – that is, above the noise generated by model variability.

Our objective is therefore to *identify* and *quantify* the impacts of land-used induced land-cover changes on the evolution of climate between the pre-industrial epoch and present-day. We will use a) multi-model and b) ensemble simulations to *assess the robustness of the identified changes*. Assessments of the impacts of land cover change *will explore the mean climate*, *climate variability* and *climate extremes*. Assessment will also be made on the potential impact land-use induced land-cover change can have on the sea-surface temperatures and on ocean circulation. Among the final objectives is to build the case, if the case can be proven, to ensure land-cover changes are included in any future assessments by the IPCC.

Three sets of simulations have been designed to be run by different climate models. Our intent is to identify robust changes via simulations that first use prescribed sea-surface temperatures and sea-ice extent, but then move rapidly to coupled model simulations since these are the tools now used for climate projection. Our strategy was to perform fixed SST experiments first, to (we hope) establish the value of the subsequent more expensive simulations.

1) The first set includes snap-shot simulations with prescribed sea-surface temperatures and sea-ice extent of the present-day climate (1992-2002) and of pre-industrial times (1870-1900). Simulations will differ by the land cover distribution that will reflect the observed changes in both crops and pasture between both time periods. To assess the robustness of the results we will conduct ensemble simulations.

2) The second set includes transient simulations over the past 150 years (1870 to 2002), with prescribed SSTs and sea-ice. They will be run following the protocol designed within the C20C project.

3) Then finally, within the European project ENSEMBLES, IPCC simulation will be re-run with coupled atmosphere-ocean general circulation models, from 1850 till 2100 following the A1b economical scenario.

The simulations in steps 2 to 3 will be run with and without land-use induced land-cover changes.

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This email address is used to reach all scientists who have declared interest in the project and who will participate either by running some or all experiments or by carrying out some diagnoses.

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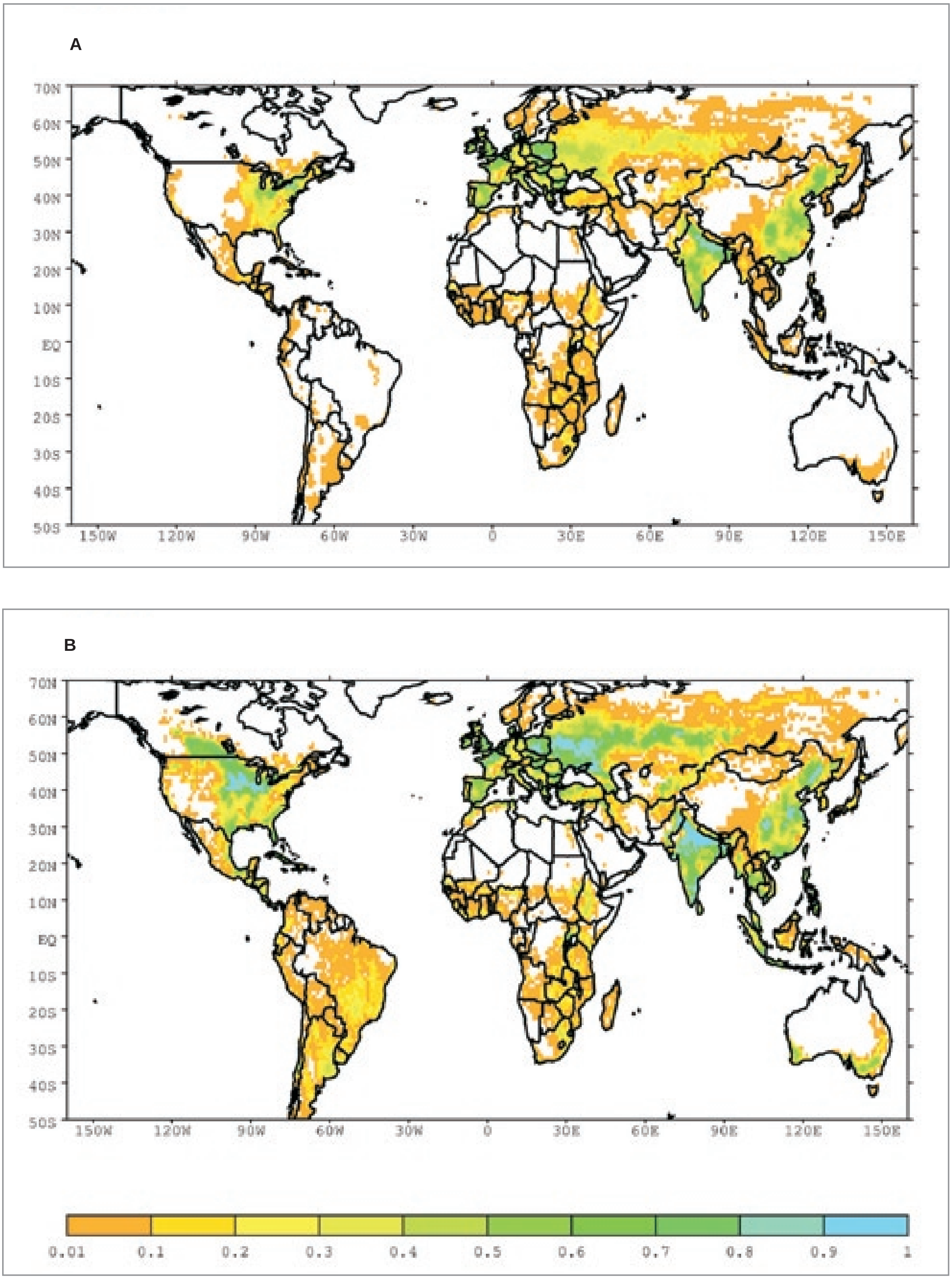

Extent of crop areas for a) pre-industrial times and b) present-day. The extent is expressed as the fractional area occupied by crops within each 0.5°x0.5° grid cell. This extent results from a combination of two datasets, the one derived from Ramankutty and Foley [1], and the one provided within the HYDE database [2].

EUCAARI – European Integrated project on Aerosol Cloud Climate and Air Quality Interactions

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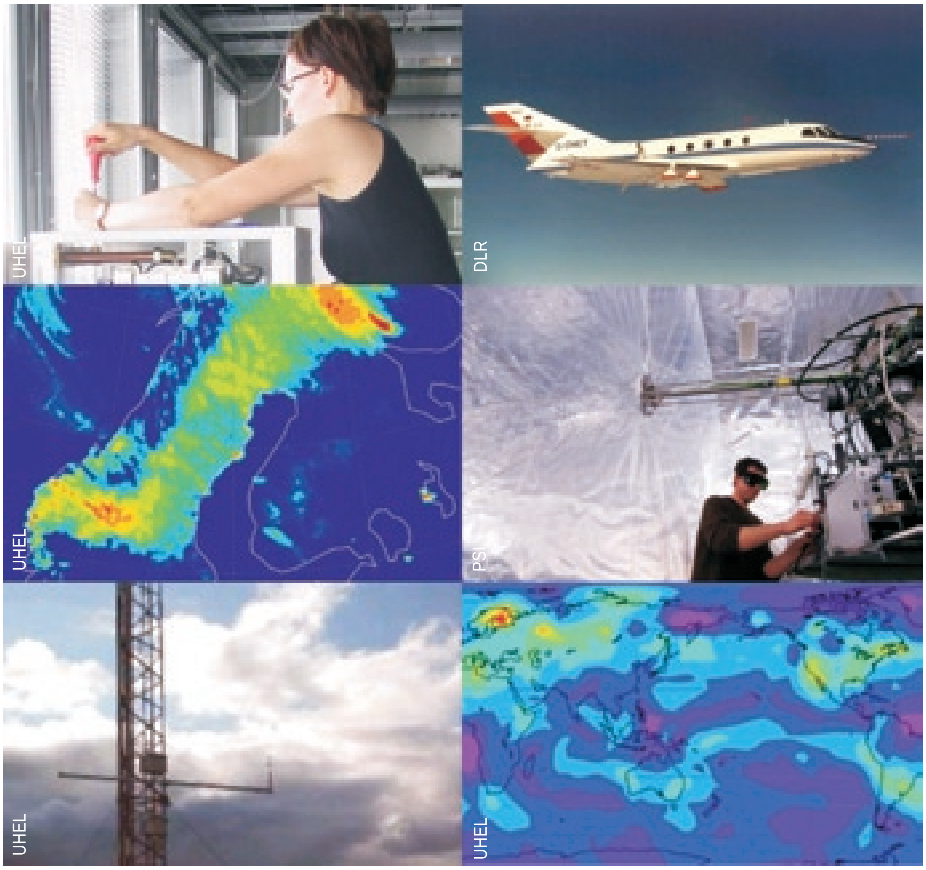

Figure 1. EUCAARI employs a wide variety of reseach methods: from instrumental developments, laboratory and field measurements to air quality and climate models.

Climate change and air quality issues are strongly linked at a variety of levels. Sources of greenhouse gases are often responsible for deterioration of air quality and changes in weather patterns can result in significant air quality changes. The system is highly nonlinear and contains all atmospheric components from emissions via transport, transformation and deposition to effects and impacts. Considerable effort is required to understand just how strong emission control policies can or should be, given the existence of such inherent feedbacks. Current versions of integrated assessment models used in policy making are unsuitable for such research efforts as they do not capture the full complexity of the system.

The reduction of aerosol particles due to emission controls could result in reduced scattering of sunlight back to space. However, the role of natural and anthropogenic aerosols in climate processes are uncertain. Some of the key uncertainties involve the formation of new particles, their growth from clusters of a few molecules to cloud condensation nuclei size (>100 nm) and the formation of cloud droplets. Once formed, clouds have an extensive influence on the Earth's radiation budget through their albedo and greenhouse effects. Future cloud properties are likely to change due to the warmer and moister conditions, and possibly due to changed aerosol particle emissions from both primary and secondary aerosols.

Clouds are rather crudely represented in global and regional climate models. Processes, such as nucleation, droplet activation during condensation, diffusive growth, droplet evaporation, droplet coalescence and conversion to raindrops, are not taken into account with achievable accuracy in present-day atmospheric large-scale models. In addition to the climatic aspect, the effects of ultra-fine particles on urban air quality and human health have been receiving increased attention during last few years. In urban areas, atmospheric aerosol particles cause also a loss of visibility. Heavily industrialized areas suffer from pollution fogs (smogs) that are often related to coal burning and nowadays also to traffic.

EUCAARI - The European Integrated project on Aerosol Cloud Climate and Air Quality Interactions – is a project within the Sixth Framework programme of European Commission. EUCAARI brings together the leading European research groups, state-of-the-art infrastructure and key players from third countries to investigate the

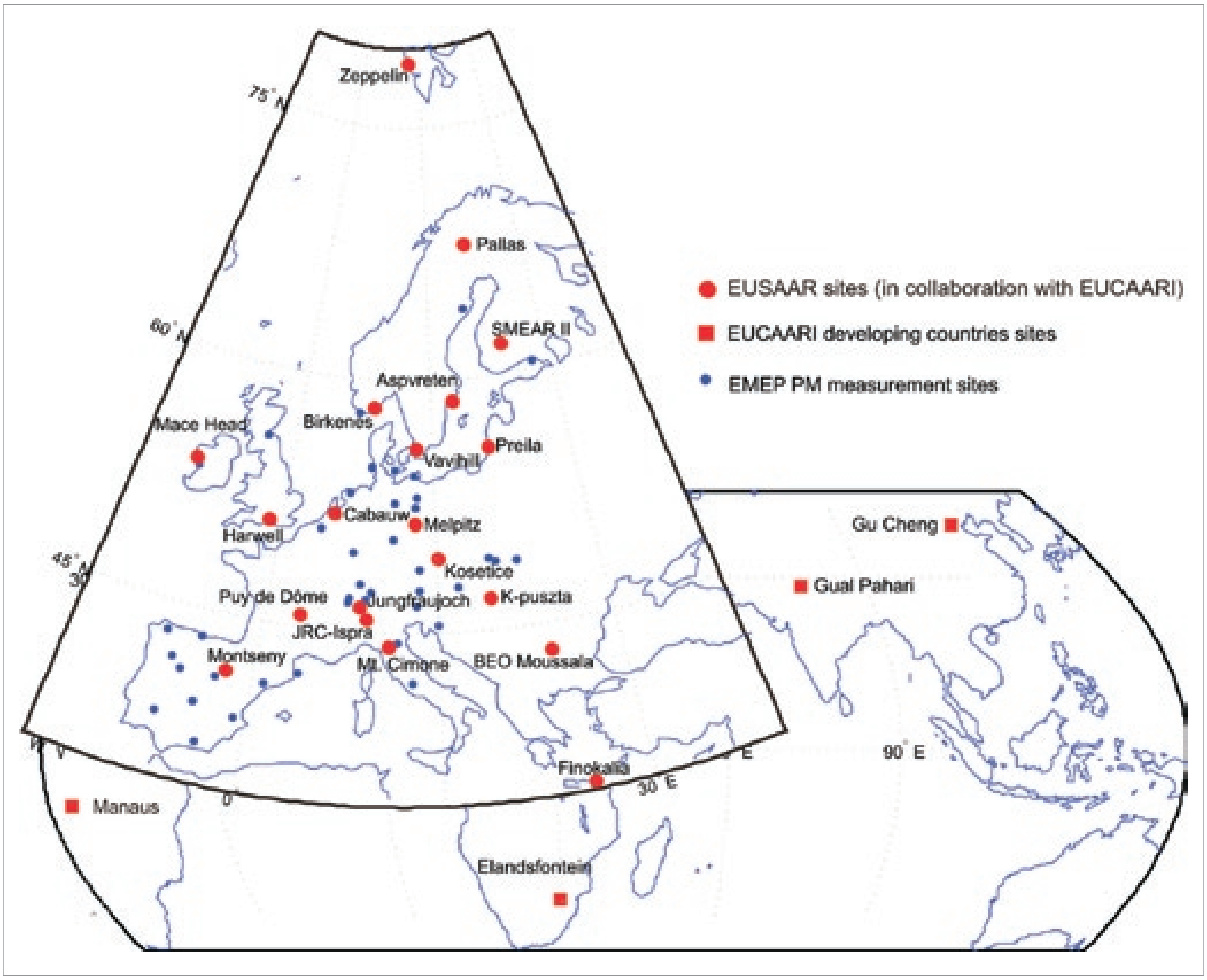

Figure 2. The network of EUCAARI, EUSAAR and EMEP aerosol measurement sites.

role of aerosol on climate and air quality. The project is active from 2007 to 2010 and it is coordinated by prof. Markku Kulmala, University of Helsinki, Finland.

The objectives of EUCAARI are 1) reduction of the current uncertainty of the impact of aerosol particles on climate by 50% and quantification of the relationship between anthropogenic aerosol particles and regional air quality, and 2) quantification of the side effects of European air quality directives on global and regional climate, and 3) provision of tools for future quantifications for different stakeholders. EUCAARI will also contribute to technological developments in aerosol measurements, enhancing future experiments and air-quality monitoring networks (Fig. 1).

The project is organized into four scientific elements designed to maximize the integration of methodologies, scales and ultimately our understanding of air quality and climate. New ground-based, aircraft and satellite measurements will be integrated with existing data to produce a global consistent dataset with the highest possible accuracy. A European measurement campaign will be designed around simultaneous multi-station observations (Fig. 2), Lagrangian aircraft measurements and carefully selected “supersites”. A hierarchy of models will be developed based on the results from laboratory and theoretical investigations. The models will be used to interpret the measurements and will be integrated in regional air quality and global climate models. The result will be measurable improvements in the project’s climate and air quality models.

The outcomes of the project (scenarios, recommendations, models, harmonized datasets and new knowledge) will be disseminated to authorities, policy makers, the research community, industry, instrument designers, and the EU-ESA Global Monitoring for Environment and Security (GMES) Program.

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Water and Global Change – the WATCH programme

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Globally, the supply of freshwater far exceeds human requirements. However, it has been estimated that by the end of the 21st century these requirements begin to approach the total available water. Regionally, however, the water demand for agriculture, and domestic and industrial use is approaching, or already exceeds, the supply, particularly in Southwestern USA, North Africa and Southeastern Asia [1]. In many of these regions ground water storages are used in unsustainable ways in order to support the current water demand. This will certainly get worse with increasing population and societies' changing water demands, a situation exacerbated by the need to maintain river flows for ecological and human services. In addition, recent international reports [2, 3] have highlighted the potentially dramatic influence of climate change on the hydrological cycle. In fact, there is already evidence from the last 40 years that changes are taking place.

The global water cycle is an integral part of the Earth system and plays a central role in global atmospheric circulations. It controls the global energy cycle (through latent heat) as well as the carbon, nutrient and sediment cycles. Increasing CO_2 levels and temperature are intensifying the global hydrological cycle, with an overall net increase in rainfall, runoff and evapotranspiration – and more rapid increase projected. Regionally, the predictions of future rainfall are fairly uncertain. There is, however, some agreement between the climate models over which areas are likely to see an increase and which a decrease. The indications are that the many regions which are already semi-arid, such as the Mediterranean, southern Africa, and Southwest USA will become even drier. In contrast, the high latitudes, and some equatorial regions, such as India, will see increased rainfall. The seasonality may also change,

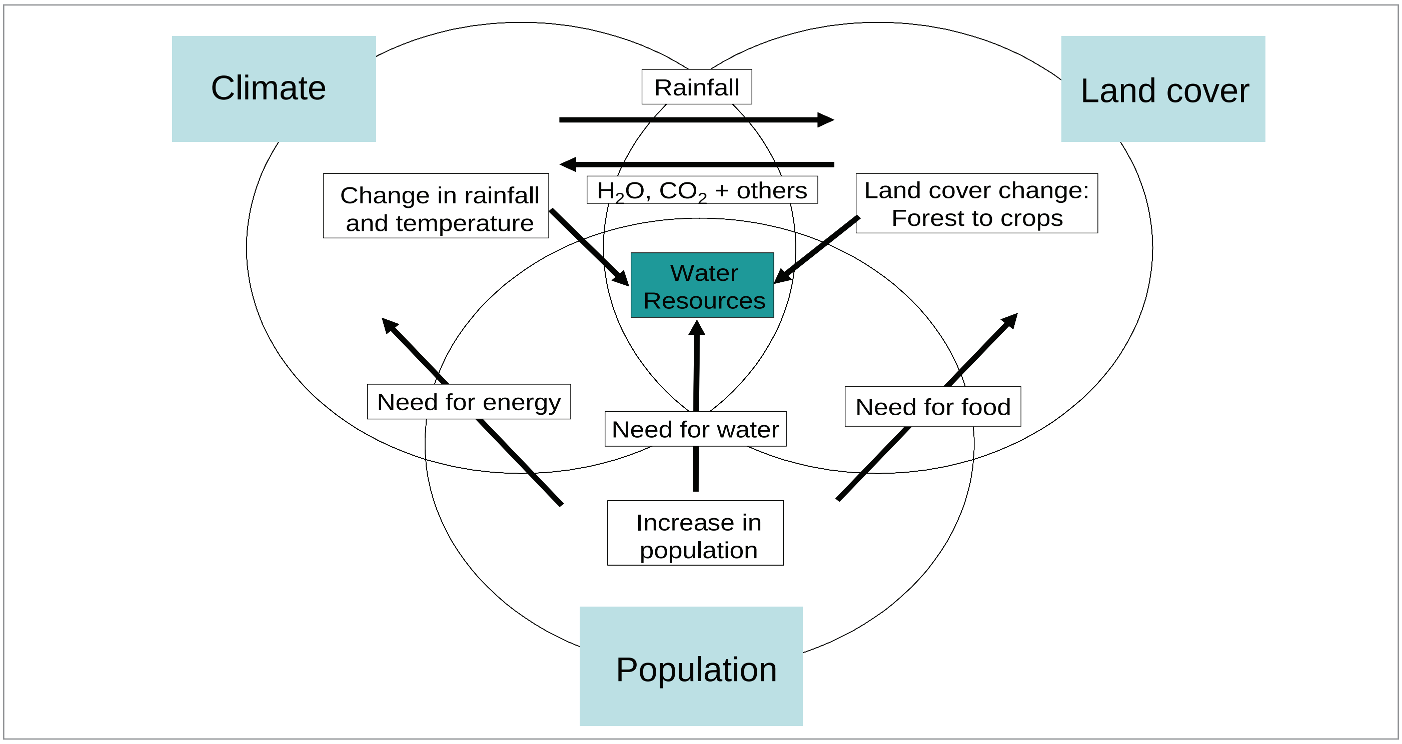

Figure 1. Drivers of global change and feedbacks to the global water cycle.

Drought conditions in the Rio Araguaia, Brazil.

causing new, and sometimes unexpected, vulnerabilities. The intensification of the hydrological cycle is likely to lead to an increase in extremes in rainfall – with the possibility of increased flooding and droughts. There are suggestions that inter-annual variability will also increase – with an intensification of the El Ninõ and NAO cycles – again leading to more droughts and large-scale flooding events. These cycles are global phenomena which will impact different regions simultaneously, although often in different ways.

A variety of feedbacks between the climate and hydrology will take place [4]. The snow-climate feedback is well known but feedbacks between CO_2 increase, vegetation, soil moisture and climate are less well understood and are not properly described in most climate and hydrological models. There are thus many uncertainties in our understanding of the current water cycle and how it will develop in the future. All these drivers and feedbacks to the global water cycle are interlinked. For example increasing population will intensify land use bringing about changes not only in evaporation and runoff but also (probably increasing) changes in greenhouse gas emissions, see Fig. 1.

Our understanding of the current (20th century) global water cycle is incomplete. There are many sources of information – notably measurements of rainfall, runoff, synoptic weather observations and satellite retrievals. The spatial and temporal scales of these observations and analyses vary greatly and also come from different scientific communities. To this day, no systematic collection and analysis of the observations have been established globally.

These urgent issues require a concerted effort by climate and hydrological scientists to combine the most recent climate model simulations with hydrological models and global and regional observations. A historical, disciplinary "disconnect" exists between communities developing integrated water cycle and water resources assessment models on one hand, and the communities developing climate modelling frameworks on the other. This has resulted in many conceptual and data-related inconsistencies in the studies and in projections of the state of the future water cycle – both globally and regionally. The different approaches are, however, gradually converging [5]. Process representation in the models is becoming more comprehensive, the grid size of climate models is approaching that needed to resolve large basins and methods to use statistical information from climate models are being developed.

The Integrated Project Water and Global Change (WATCH), funded under the Sixth Framework programme of European Commission, will bring together the hydrological, water resources and climate communities in Europe and establish links to respective communities in America and Asia. The programme will analyse, quantify and predict the components of the current and future global water cycles and related water resources states, evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors.

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IGBP-WCRP Aerosols, Clouds, Precipitation and Climate Initiative (ACPC)

iLEAPS-IGAC-GEWEX Joint White Paper and Workshop Announcement

Background

There is mounting evidence that atmospheric aerosols have profound impacts on the thermodynamic and radiative energy budgets of the Earth. With the advent of the industrial revolution, humans started generating large quantities of aerosols and aerosol precursors that are characteristically different from those emitted naturally. Recognition of the potential climate impacts of anthropogenic aerosols has led to a great deal of research to assess their role on the Earth's radiative balance. Much less is known about the effects of aerosols on precipitation, and the consequences for the climate system. Existing knowledge and research needs have been summarized in the soon-to-be released report of the WMO/IUGG International Aerosol Precipitation Science Assessment Group (IAPSAG). The initiative proposed here, Aerosols, Clouds, Precipitation and Climate (ACPC), is intended to develop an integrated research program to investigate the interactions and feedbacks among aerosols, cloud processes, precipitation, and the climate system.

A subset of the atmospheric aerosol population has the potential to become cloud droplets (cloud condensation nuclei, CCN) or ice crystals (ice nuclei, IN). The changes in cloud microphysics resulting from these CCN and IN may lead to substantial changes in precipitation development, impacting hydrological cycles at local and regional scales. Large concentrations of sub-micron aerosols act as small cloud condensation nuclei that produce large concentrations of small cloud drops, which are slow to coalesce into raindrops. The reduction of cloud drop size also delays the formation of ice in the cloud to lower temperatures. This can lead to suppression of precipitation in shallow and short-lived clouds, such as form during winter over topographical barriers, and so decreases water resources in semi-arid regions. Furthermore, small scale convection may be suppressed by atmospheric warming due to strongly absorbing aerosols, leading to reduced cloudiness and precipitation.

In deep convective clouds with warm bases, such as prevail in the tropics and during summer in the mid-latitudes, the delayed precipitation due to more and smaller droplets may cause the condensates to ascend to the supercooled levels instead of raining out earlier by processes that do not involve the ice phase. By not raining early, the condensate would then form ice hydrometeors that release the latent heat of freezing aloft and reabsorbing heat at lower levels where they melt. The result would be more upward heat transport for the same amount of surface precipitation. The consumption of more static energy for the same precipitation amount would then be converted to equally greater amount of released kinetic energy that could invigorate the convection and lead to a greater convective overturning, more precipitation and deeper depletion of the static instability. Furthermore atmospheric moisture that is not rained out due to suppression by aerosol, may be advected and accumulated in regions downstream of prevailing wind, where rainfall may be increased at a later time. The enhanced and delayed aerosol-induced release of latent heat may lead to regional scale enhancement and re-distribution of convection, low level moisture convergence and precipitation.

Aerosol can also indirectly affect precipitation by changing the vertical thermal stratification of the atmosphere. A thick layer of light-absorbing aerosol will warm the atmosphere while cooling the underlying surface, thus decreasing the thermal gradient and inhibiting the development of precipitating clouds. This effect is strengthened by a positive feedback: more aerosol →less precipitation → longer aerosol lifetime → more aerosol. This mechanism may explain the reduction in precipitation in central China during the last 40 years and its correlation with high aerosol concentrations in the region. However, in a region characterised by a more complex topography and by different patterns of aerosol transport and elevation, like the Indian subcontinent, the net effect of the light-absorbing particles may be to enhance and re-distribute precipitation. Research has shown that the aerosol effects on precipitation can be very complex, and that the net effect of the microphysical processes involving CCN and IN can vary dramatically according to several other factors, like aerosol distribution and temporal variability, atmospheric instability, wind shear, synoptic-scale dynamics, and topography.

Satellite studies indicate large positive relations between cloud cover and aerosol optical depth that is associated with strong negative radiative forcing at top of the atmosphere, which cannot be reconciled without some additional compensating mechanism such as the positive forcing due to enhanced water vapor at the upper troposphere and lower stratosphere due to invigorated convection.

These issues are central to the missions of IGBP and WCRP, and warrant the attention of both programs in a major way, to foster deeper and quantitative understanding, and to develop mitigation strategies. For this reason, the IGBP core projects iLEAPS and IGAC, and the WCRP core project GEWEX are proposing a joint initiative under the title "Aerosols, Clouds, Precipitation and Climate (ACPC)". This initiative is to address the following question: *How do aerosol-precipitation interactions manifest themselves at the full range of temporal and spatial scales in the climate system?*

The question targets phenomena in stratocumulus, convective and precipitating orographic clouds. Cirrus clouds are not considered a topic of ACPC, due to their lack of precipitation potential. Similarly, frontal systems are not a focus due to their minimal susceptibility to aerosol perturbations on precipitation. In preparatory discussions, members of the participating core projects (Andi Andreae, Tom Ackerman, Sandro Fuzzi, Markku Kulmala, Bill Lau, Ulrike Lohmann, Colin O'Dowd, Graciela Raga, Danny Rosenfeld, Pier Siebesma) have defined some guiding questions for ACPC research, which may serve to focus discussions at the planned joint workshop.

Question 1: What are the relative roles of aerosols and dynamics on precipitation and what feedbacks exist?
The focus should include differences between dynamically, thermally, and orographically driven clouds of different vertical extents and the role of aerosols in regulating the relative importance of the liquid and ice phase in precipitation formation. This includes the role of the aerosol physico-chemical properties that determine cloud droplet and ice crystal formation.

Question 2: Can the slowing of autoconversion result in increasing precipitation?
The focus should include convectively and orographically driven clouds at the cloud life-cycle scale; it includes warm clouds, and clouds extending into mixed phase and ice clouds; whether the precipitation enhancement is a local or cloud life-cycle scale phenomenon; the potential of aerosol leading to invigoration of convective storms, and whether this can be predicted by models and detected through observations.

Question 3: How do aerosol-precipitation interactions affect the energetics of climate system?
The focus should include the redistribution of the latent heat vertical profile; the effect on circulation systems of various scales; changes in the radiative budget due to changes in cloud cover; detrainment of ice crystals and water vapor into the UT/LS; and the vertical redistribution of aerosols and trace gases.

Question 4: What are the aerosol-precipitation effects at larger scales?
The focus should include the propagation of aerosol-precipitation effects from the cloud life cycle scale through to the regional, monsoonal and climate scales, and from short time scales to seasonal and decadal scales. It also includes the influence of changing scale on the magnitude and sign of the aerosol-precipitation effect, as well as teleconnection effects in regions far away from the aerosol source through aerosol-induced changes in the general circulation of the coupled atmosphere-ocean-land system. Observational strategies appropriate for underpinning large scale effects should be evaluated and developed.

Investigations of aerosol/precipitation effects at intermediate scales are especially relevant to policy issues. The potential of aerosols to invigorate clouds and precipitation may result in damage through strong rainfall, hail, high winds, and lightning. At larger scales, effects on the hydrological cycle may affect water availability, a great concern in many regions of the world.

Research needs

Answering the ACPC questions will require a coordinated effort using a variety of scientific approaches and tools.

(a) Data sets, data bases, data access
A key component of ACPC is the collection/production and analysis of global, long-term datasets, not only with sufficient detail to diagnose key processes, but also the large-scale scope needed to determine the multi-scale interactions constituting climate variations and feedbacks. As a first step, existing data sets need to be investigated and data needs must be identified.

(b) Models
Model development and model studies must address the relevant processes at all relevant scales, from cloud microphysics to the climate scale. A key issue is the development of improved parameterizations for climate models by improving the understanding of the physical processes for all the relevant cloud types. This can be done by process oriented studies by high resolution numerical models, such as Large Eddy Simulation (LES) models and Cloud resolving Models (CRM's), based on observations from field campaigns. Results of these studies should be used for the design and testing of parameterizations of cloud relevant processes in simplified climate models. As a final step, parameterizations must evaluated in a fully interactive way in the three dimensional version of a climate model.

(c) Process studies, field campaigns, observational strategies
Detailed experimental strategies will have to be developed by the ACPC initiative. They should include process studies that will allow improving the representation of the processes relevant to aerosol-precipitation interactions in the models, as well as measurements that can validate the realism of the simulations of the processes at the experimental domain. It would be of particular interest to explore the possibility of a budget closure experiment that is accurate enough to quantify the influence of aerosols on clouds and the associated precipitation on a scale of 5 by 5 degrees.

(d) Remote Sensing
Remote sensing, especially satellite measurements will play an important role in ACPC. The data from newly available satellite sensors, especially those of the A-Train, must be explored, and the use of large existing data sets, e.g., from MODIS will be a key component of ACPC research. Given the difficulties with in-situ measurements inside precipitating clouds, development of airborne remote sensing tools is to be encouraged.

(e) Tools
As prerequisites of ACPC research, development and validation of instruments to study aerosol, cloud droplet, and hydrometeor properties will be required. Intercomparison workshops are to be encouraged.

ACPC Specialist Workshop

In order to develop the ACPC research agenda, a science workshop will be held on 8–10 October at NCAR in Boulder, Colorado. The goals of this workshop will be an assessment of ongoing activities, a review of existing datasets and modeling strategies, and the development of the ACPC research strategy.

The themes of the workshop will be presented by invited speakers, and then discussed in a series of breakout sessions and plenary meetings. At the end of the workshop, a document should be drafted that can serve as a blueprint for the ACPC Science Plan.

Activities

workshop reports

NCAR workshop on stratified roughness sublayers

26–28 September 2006, Boulder, Colorado, USA

Figure 1. A Wind Tunnel model of a canopy on a hill with stable stratification and LDV measurement. The Wind Tunnel is large boundary layer facility in CSIRO Canberra, Australia.

In September 2006 the National Center for Atmospheric Research hosted a workshop, sponsored by the Geophysical Turbulence Program (GTP). The workshop brought together researchers interested in the roughness sublayer, the layer of flow immediately above (or below) a boundary surface (air-land or air-water interface) containing stationary and moving roughness elements, such as stones, vegetation (trees), buildings, wind turbines, or water waves. The workshop was particularly apposite to Focus 4 of iLEAPS, *Transfer of material and energy in the soil/canopy/boundary-layer system: Measurements and modelling*, as the idea of the Roughness Sublayer (RSL) was first developed in relation to vegetation canopies in the atmosphere and a large part of the discussion centred on this topic.

The workshop was organised around four topics: 1) vegetated canopies, 2) urban canopies, 3) marine RSL (air-water interface), and complex terrain.

The intention was to present and discuss new work in each of these fields but also to see which ideas, concepts, models and experimental approaches were transferable between the different areas. What follows are my own highly condensed and personal impressions of what we learned. First, in general, the presentations on complex terrain were much less focussed than those on the other areas and this is probably an area that deserves a workshop of its own. Second, while fascinating scientific problems were discussed in the context of the marine RSL, particularly on topics like wave-induced modulation of surface fluxes, the parallels between the marine phenomena and the RSL on dry land or in shallow aquatic ecosystems were not strong. From the iLEAPS standpoint, therefore, most interest would be in the discussion of the similarities and differences between vegetation and urban canopies.

Amongst the new findings reported and questions raised in these sessions were:

- Over tall vegetated surfaces, the Monin-Obukhov similarity (Log law) parameters displacement height, d and roughness length, z_0 are strong functions of stability with consequences for both measuring and modelling surface-atmosphere transport.
- New approaches were presented to the modification of Monin Obukhov theory in the RSL that appear to have general applicability and are of direct relevance to FLUXNET type measurements as well as surface exchange models.
- Real progress has been made in extrapolating RSL/surface layer concentration measurements to higher levels in the ABL (the virtual tall tower idea).
- A self consistent mechanism for the generation of turbulence in the RSL over vegetated canopies and the reasons it differs from smooth surfaces was proposed with strong experimental support.
- The corresponding eddy generation mechanism over urban canopies is still unclear with both similarities and differences to natural canopies.
- Contaminant dispersal in a network of urban street canyons follows a consistent inverse power law relationship (x^{-2}).

The outcomes of the workshop will be published in several scientific journals and a paper based on the discussions is in preparation for Bulletin of the American Meteorological Society, BAMS. In the meantime, abstracts of the presentations can be viewed on the website that Dr Jielun Sun has been kindly provided. The URL is http://www.image.ucar.edu/Workshops/GTPSep2006/.

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Joint iLEAPS-GABLS-GLASS scientific symposium “Land - atmosphere interactions in the Earth system”

19 January 2007, Wageningen, Netherlands

An international scientific symposium was organized by the Chair Group Earth System Sciences-Climate Change and the Climate Change and Biosphere Centre of Wageningen University and Reseach Centre (WUR) on 19 January 2007. A main motivation to organize this symposium was to adress some of the specific research foci and the linkages between IGBP’s integrated Land Ecosystem Atmosphere Processes Study (iLEAPS), the WCRP-GEWEX Atmospheric Boundary Layer Study (GABLS) and the Global Land Atmosphere System Study (GLASS) project. In addition, the fact that international and a selection of Dutch scientists, actively involved in the coordination of these international research programs, had gathered in Wageningen for the iLEAPS scientific steering committee meeting (17-18 January), which allowed to put a nice selection of presentations together for the symposium. The symposium has been widely announced among the Dutch universities and research institutes also calling upon the group leaders to also distribute the announcement among the students. This resulted in a good turn-out of a heterogeneous audience of about 50 participants, including ~25 students, from the WUR, Utrecht University, Energy Centre Netherlands and Max Planck Institute for Chemistry, Germany. A young- and senior scientists lunch meeting was organized so that the students could meet in an informal way renowned scientists

The symposium was opened by Pavel Kabat, chair of the ESS-CC group and co-chair of iLEAPS, presenting an overview of the main research foci of iLEAPS. This was followed by a presentation by Ann Henderson-Sellers, director of the WRCP, giving an interesting insight in some of the challenges involved in the communications of the scientific findings on climate and global change to the politicical scene. She made a strong and well appreciated call upon the scientific community to dare to be heared more effectively within the communities which apply the scientific findings to develop global change policies. In a subsequent presentation Paulo Artaxo of the University of São Paulo, Brazil, provided a nice and comprehensive overview of especially tropical atmospheric chemistry and climate issues including the significance of aerosol-cloud interactions. One issue also shortly touched upon, land use and land cover changes, was discussed in more detail by Nathalie de Noblet-Ducoudré, LSCE, France, not only showing the significance of present-day but also historical land use and land cover changes for climate. This presentation provided, besides stressing the role of biosphere in the climate system, a nice link to a presentation by Bart van den Hurk, Royal Dutch Meteorological Institute (KNMI), Netherlands, on ongoing activities with the GLASS project that aims at the improved understanding and representation of the biogeophysical land-atmosphere interactions in climate models. The morning session closed with a presentation by Kendal McCuffie on the Isotopes in Project for Intercomparison of Land-surface Parameterization Schemes (iPILPS) project, which aims at the use of the information on isotopic composition, e.g., $d^{18}O$, to improve the understanding of land surface processes.

The afternoon presentations, following the well appreciated young- and senior scientist lunch meeting, focussed on biogeochemical processes and challenges involved in the representation of surface and boundary layer (BL) processes for meteorology, climate, biogeo- and atmospheric chemistry. Torben Christensen of Lund University, Sweden, discussed the ongoing and anticipated changes in the biogeochemistry in high-latitude regions prone to rapid climate change. This was followed by a presentation by Almut Arneth, also at Lund University, focussing on a more mechanistic modelling of the emissions of reactive carbon related to CO_2 exchange indicating a reduced sensitivity of these emissions to climate change. Gert-Jan Steeneveld of the WUR presented results of ongoing GABLS studies that focus on the representation of the nocturnal BL in climate and meteorological, motivated by large differences between models and the consequences for, e.g., the 2 m temperature. This activity has a follow-up activity focussing on the diurnal development of the BL in these models. Herbert ter Maat, also at the WUR, demonstrated that such improved boundary layer models are also needed for carbon studies by showing the impact of the BL representations on simulated CO_2 concentration profiles and comparison with observations. Finally, the last two presentations by Jordi Vila and Laurens Ganzeveld, both at the WUR, demonstrated the role of surface and boundary processes on atmospheric chemistry where Jordi Vila discussed three key features of turbulence-chemistry interactions including cloud processes, closing the circle with the presentation by Paulo Artaxo of the morning session. The relevance of boundary layer processes in atmospheric chemistry was further supported in a presentation by Laurens Ganzeveld showing various examples of significant changes in the simulated concentrations and fluxes of reactive species based on the assumptions of vertical mixing in large-scale atmospheric chemistry studies.

Overall, the presentations and active discussions were highly appreciated indicating some of the key research themes within the three projects and also the cross-cutting themes where active collaborations between the communities must be pursued.

We would like to express our appreciation to the presenters and participants for having this stimulating and successfull meeting, and also to Ann-Marie Ryan, WUR for all the logistical support. The workshop was supported by the Royal Dutch Academy of Sciences (KNAW).

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FLUXNET – Terrestrial Carbon Observations (TCO) synthesis workshop

18–22 February 2007, LaThuile, Italy

About 60 scientists from eddy covariance networks around the world (CarboEurope, AmeriFlux, Fluxnet-Canada, LBA, AsiaFlux, ChinaFlux, USCCC, OzFlux, CarboAfrica, KoFlux, NECC, TCOS-Siberia and AfriFlux) participated in the FLUXNET-TCO synthesis workshop. The aims of the workshop, organized mainly in parallel sessions, were to discuss the scientific potential of a new global FLUXNET dataset, propose new synthesis activities and to start first data analyses based on the global database.

For the synthesis efforts, a standardized database of carbon, water and energy fluxes was produced. It took over a year to compile the global database but now it consists of *ca*. 620 years of data from 180 eddy covariance sites. This new global database replaces the Marconi FLUXNET database that was produced in 2000 (with 97 years of data from 38 European and North American sites).

Based on discussions during and after the workshop, a common policy for data distribution to the wider scientific community was established. It was agreed that this dataset will be accessible for the first year (until August 2008) only for those scientists and their close collaborators that have contributed data to the database or have helped to build up the database. Currently, we are processing a number of datasets submitted after the workshop and the final dataset will be released in beginning of July 2007.

A call for synthesis papers based on the new database was open until 15 May 2007. First reactions from the FLUXNET community have been very positive with more than 50 papers proposed, covering a large range of traditional as well as new topics and methodologies related to carbon, water and energy balances, ecosystem-atmosphere exchange and biophysical as well as biogeochemical feedbacks therein. The datasets will be used both to improve contemporary landsurface-atmosphere transfer schemes implemented in global circulation models, and to recognize new general patterns in global biogeochemical cycling with data-oriented modelling approaches.

To minimize parallel work and maximise synergies among research groups and to increase the efficiency of the analyses, a “Scientific Moderation Committee” was established. Members of the Scienctific Moderation Committee (Dennis Baldocchi, Jiquan Chen, Bev Law, Hank Margolis, Dario Papale, Markus Reichstein and Celso von Randow) will coordinate the synthesis efforts.

We hope that this is the first step to a new “global flux perspective” where the different eddy covariance networks will harmonize and share data to increase the quality of flux research and the collaboration among scientists. In future this dataset will be regularly updated and data from new sites will be added.

Finally, a sincere thank to the sponsoring institutions - Max Planck Institute for Biogeochemistry, Germany; University of Tuscia, Italy; FAO-GTOS; iLEAPS; US Department of Energy and National Science Foundation, USA - for supporting the Fluxnet-TCO Workshop and allowing broad participation of young and other scientists without their own travel funds to participate in the workshop.

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The Fluxnet - TCO workshop participants surrounded by mountains in LaThuile, Italy.

Marie Curie – iLEAPS Training Course, Measurements

Integrated measurements over land ecosystem - atmosphere boundaries

7–12 May 2007, Hyytiälä Field Station, Finland

For the first training event, the review committee had to make hard choices when selecting only 30 out of the 90 eligible candidates. Candidates were selected on the basis of scientific relevance and resume in addition to motivation to attend the course and eligibility criteria set by the EU commission. The final group was quite diverse in scientific background, years of experience, gender, age, and nationality and as organizers we were very excited to see how the students would be able to work together. The students were divided into six groups and each group was given the enormous task of designing a perfect measurement station for one of the following parameters/variables: aerosols, carbon, nitrogen, energy, trace gases and water. During the course, the students gained from presentations followed by demonstrations and/or exercises by the invited keynote speakers. Nina Buchmann and Andreas Richter filled an afternoon on isotope measurements followed by interactive group work in “isostations”. Eiko Nemitz went in details through surface-atmosphere exchange with focus on flux measurement of reactive gases and aerosols and with the help of Janne Rinne demonstrated continuous flux measurements. Kaarle Hämeri’s presentation went through the basics of aerosol physical properties and principles of measurement instrumentation and then he sent the students out to measure particle concentrations at specified and chosen locations in close proximity to the lecture hall. Pertti Hari raised the students’ awareness on statistics, its precise terms and importance of accurate understanding. Finally, Tiit Nilson presented an introduction to leaf area index. Not all the action took place inside the lecture hall. In addition to evening sauna and sports, the students were given a thorough on-site presentation of the SMEAR II station located at Hyytiälä Forestry Field station and to trace gas measurements (methane) on a close-by peatland, Siikaneva. Having a chance to see instrumentation with online measurements and in the same time have an explanation of what is happening inside the instrument (and the plant!) proved to be invaluable. Unfortunately there was not enough time or available resources to let the students have hands-on experience in experiment design and instrument setup. But still all groups in the end presented a detailed plan for their perfect station with location(s), instrumentation and budget. Presentations from lecturers and groups are available from the Marie Curie - iLEAPS website, www.atm.helsinki.fi/marie-curie-ileaps.

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The aerosol group thinking hard on their ”isostations” assignment; to understand isotope discrimination (Δ) during photosynthesis of C3 plants by making a model stomata and a mesophyll cell with a ballon and plastic tube. Concept developed by Prof. Nina Buchmann.

Activities

meetings

iLEAPS SSC meeting was held in new Atlas building in stormy Wageningen.

iLEAPS SSC meeting, Wageningen, Netherlands, 17–18 January 2007

Annual meeting of the iLEAPS Scientific Steering Committee was hosted by iLEAPS co-chair Pavel Kabat at the Climate Change and Biosphere Centre, Wageningen University last January. In addition to SSC members, several representatives from other research organizations (IGBP, WCRP, IGAC, SOLAS, GLP, GABLS/GEWEX, LoCo/GLASS/GEWEX, GCSS/GMPP/GEWEX, GEWEX IPO, INI, NitroEurope, CarboEurope, iPILPS, WATCH) attended this fruitful meeting.

iLEAPS IPO hosted NEESPI Summit at the University of Helsinki in Finland, 3–4 May 2007

The NEESPI Summit brought together representatives of the Earth System Science Partnership programs and projects, members of the NEESPI Steering and Coordinating Committee, and the Program managers and representatives from contributing organizations that have vested interests in Northern Eurasia climatic and environmental studies. The welcome talk was given by Jukka Paakki, Dean of the Faculty of Science of the University of Helsinki.

NEESPI-iLEAPS Scientific Symposium at the Finnish Meteorological Institute (FMI), Helsinki, Finland, 2 May 2007

Prior to the NEESPI Summit, a joint NEESPI-iLEAPS Scientific Symposium gathered around 70 participants for a full day seminar, welcomed by FMI Director General Pekka Plathan and iLEAPS co-chair Pavel Kabat. The two events were sponsored by iLEAPS IPO, University of Helsinki and Finnish Meteorological Institute. The symposium presentations are available at iLEAPS website (http://www.atm.helsinki.fi/ILEAPS/index.php?page=pres_neespi_symp)

NEESPI Summit attendees and some of the NEESPI-iLEAPS symposium participants having a joint dinner hosted by Finnish Meteorological Institute and iLEAPS IPO at Restaurant Sipuli, Helsinki, Finland, on 3 May 2007.

iLEAPS Science Plan and Implementation Strategy is available in English and in Chinese.

Get your paper copy by contacting ileaps-ipo@helsinki.fi or download the .pdf file from the iLEAPS web page at: http://www.atm.helsinki.fi/ileaps/

INSTRUCTIONS TO CONTRIBUTORS

The iLEAPS Newsletter informs on iLEAPS-related scientific activities. The theme of contributions should be relevant to iLEAPS and integrated land-atmosphere research.
The Newsletter is published twice a year and it is released both in printed and on-line versions. For the paper version the specified word length according to these instructions is enforced. The author may provide additional material to be used on the iLEAPS web page.
EDITORIAL Editorials are around 500 words with or without one accompanying figure. Editorials are by invitation and feature a personal interpretation and evaluation on the theme of the issue.
SCIENTIFIC ARTICLES. Articles are 700-1000 words and cover 1-2 pages with accompanying 2-3 pictures or figures. Articles can contain the following:
RESULTS of scientific research
SUMMARIES presenting synthesis of recent scientific development in land-atmosphere research
POSITION PAPERS stating views and directions in scientific research
REPORTS presenting key scientific outcomes of programmes, workshops, or meetings.
NEWS Other than strictly scientific contents will be max 200 words and can be for
PEOPLE presentation
ACTIVITIES report and commentaries
ANNOUNCEMENTS of coming events, job vacancies or short news.

Text and graphs should be provided in separate files. Text should be in .doc or .txt. Photographs should be in .tiff format, minimum 300dpi. Graphs and figures should be in its original format or else as high resolution .tiff or .eps images. The contributors are kindly requested to handle potential copyright issues of the material. Contributions should be e-mailed to the Executive Editor at the iLEAPS IPO.

LANDSCAPE PHOTO COPYRIGHTS

Cover photo: Slash and burn forest in Lao People's Democratic Republic. Dramatic forest fire photo was taken by Koen Kusters.

Page 2: Plume from smoke originated in a deforestation fire in Mato Grosso state in Amazonia. They form a pyro-cloud that has very different physical properties than natural clouds. Photo taken by Paulo Artaxo.

Page 2: Deforestation fire in the Mato Grosso state in Brazil. Every year about 20.000 km^2 of primary forest is converted to pasture or agricultural land in Amazonia. Photo taken by Paulo Artaxo.

Page 2: Burnt patch of dense Gelam saplings, Mesuji, Lampung. Photo taken by Mamat Rachmat, CIFOR.

Page 19: Peat fire during dry season. Photo taken by Yayat Ruchiyat.

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