Integrated Land Ecosystem - Atmosphere Processes Study

iLEAPS

Newsletter

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International Geosphere-Biosphere Programme
GLOBAL IGBP CHANGE

iLEAPS Melbourne Science Conference 2009 – selected highlights

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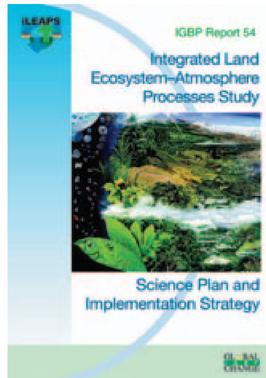

iLEAPS Science Plan and Implementation Strategy is available in English and in Chinese.

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iLEAPS IPO GUEST SCIENTISTS

iLEAPS welcomes collaboration and interaction between the International Project Office (IPO) and the many researchers from a multitude of disciplines involved in iLEAPS activities. We welcome guests from professors and senior researchers to postdocs and PhD students.

A guest scientist can host a workshop, edit a book or journal special issue related to iLEAPS activities, guest–edit the iLEAPS Newsletter, develop new initiatives, plan and enhance national iLEAPS activities, construct a website, for example.

This is an opportunity for close collaboration with an international research program with a view of the activities all over the world, also an opportunity to develop new interactions and lines of research, obtain new contacts, and spend a shorter or longer time period in new surroundings.

Although budget constraints usually limit our ability to fund visitors, we provide for the office and computational needs of visitors who come with independent salary support.

If you are interested in spending a sabbatical, a shorter of longer period at iLEAPS IPO, please contact: *ipo@ileaps.org*

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 site.

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.

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.

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 or other short news.

Text and graphs should be provided in separate files. Please do not send graphs, figures, logos, photos or other graphical material inserted into Word documents.

Text should be in Word doc or plain text.

Graphs and figures should be in its original format or else as high resolution .eps vector images. If you do not have the possibility to save the graph as an EPS file, save it as a very large pixel graph, minimum 300 dpi (TIF, TIFF or JPEG).

Photographs should be in TIF format, minimum 300 dpi. When you take photos, save them using the best possible resolution and quality available in your camera settings, with as little compression as possible. Generally digital cameras (and photo scanners) save photos in RGB format. Send the photos in the format saved by the camera, do not make any transformations. If you use Photoshop or some other program to edit the photo, then save the file in EPS format with resolution 300 dpi, no compression. If the program forces you to compress the file, select the best possible quality. Even .tif and very little compressed JPEG formats are applicable. In addition to EPS format, a good format for sending all kinds of photos is PDF, with resolution at minimum 300 dpi (in the size it will be printed in) and as little compression as possible.

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.

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Editorial

Pavel Kabat,
Co–Chair of the iLEAPS Scientific Steering Committee

Where should iLEAPS be going?

iLEAPS is the land–atmosphere core project of the International Geosphere–Biosphere Programme (IGBP). The scientific goal of iLEAPS is to provide understanding how interacting physical, chemical and biological processes transport and transform energy and matter through the land–atmosphere interface. iLEAPS encourages international and interdisciplinary collaboration, particularly involving scientists from the developing countries.

iLEAPS started as a new IGBP project in 2004, as a result of the first IGBP Synthesis process. iLEAPS was initiated—up to some extent—as a follow up of successful IGBP projects Biospheric Aspect of the Hydrological Cycle (BAHC), and in parts, of the International Global Atmospheric Chemistry, IGAC–I project.

From the very beginning the scope of iLEAPS has been much more multi- and interdisciplinary and more integrative than both of its predecessors. The core of the iLEAPS science community, also reflected in the composition of its Scientific Steering Committee, consists of ecologists, hydrologists, atmospheric chemists and biogeochemists, atmospheric physicists, biologists, meteorologists and climate modelers.

The wide range of expertise, together with an "open" and proactive attitude towards collaborations with adjacent programs and projects, and enjoying a sustained and effective support of the International Project Office in Helsinki, made iLEAPS in my view a successful and very visible international program. iLEAPS should continue to contribute to advancing of Earth System Science also during the coming years.

To take stock in progress of iLEAPS related Earth System Science and research activities, iLEAPS has organized so far two major International Science Conferences, attended by several hundreds of scientists from all over the world.

This iLEAPS Newsletter issue reports on some of the scientific highlights from the last iLEAPS Science Conference, which was jointly organized with the Global Energy and Water Experiment (GEWEX), a core project of World Climate Research Programme (WCRP), in August 2009 in Melbourne, Australia. The selected articles are representative of some of the main topics that iLEAPS addressed at the conference.

A special feature of this iLEAPS Science Conference was the so called Early Career Scientist Workshop, where young PhD students and post docs were offered an opportunity to present and discuss their work among each other, and with specially invited senior scientists. In Melbourne, over 50 early career scientists met at a three–day workshop prior to the main conference to discuss their approaches and results in land–atmosphere interaction research.

So far looking back. Let me now briefly elaborate on a selected number of scientific and societal issues which I believe iLEAPS should be contributing to in the future. I will focus on some items which were discussed during the last iLEAPS Scientific Steering Committee (SSC) meeting in February in Stockholm, and I will also give here some additional "personal" flavor to those issues to challenge the readers of iLEAPS Newsletter to contribute to our debate.

1. LULCC and Climate and IGBP synthesis

Land Use and Land Cover Change (LULCC) interacts with the climate system through physical, biological, and biogeochemical exchange processes. Numerous research activities, both experimental and modeling, and at variety of scales, have been focusing on this fundamental feature of the Earth system. However, a comprehensive synthesis which at the same time would suggest a strategy about how to proceed in addressing many of still outstanding issues is missing.

As a part of a broader IGBP Synthesis effort, iLEAPS, in collaboration with other relevant programmes, should initiate and lead an international synthesis and inter-comparison effort in this field. The first results (publications) should be available already in 2012, in order to provide background for IPCC AR5 assessment process and to be presented also at the IGBP Open Science Conference, May 2012 in London.

2. Towards true integration of surface measurements

iLEAPS and its predecessors were instrumental and supporting in developing of a "network of regional networks," a global network of surface stations currently known as FLUXNET. At present more than 400 stations are part of the network, distributed around the world and clustered in regional tower networks covering all continents. The flux network has provided a basis for an unprecedented amount of scientific studies and publications in carbon ecology, surface meteorology, soil–vegation–atmosphrere exchanges and other related fields.

Many of these stations record—in many cases continuously and year–round—a full set of meteorological variables, including all four components of the radiation balance, soil heat and moisture profiles and fluxes, momentum fluxes, surface layer and boundary layer profiles and many more. Despite of this extensive amount of data, the use of this network in weather and climate studies has been so far limited to lucky incidents.

A better coordination with other measurements networks, operated under the auspices of World Meteorological Organization (WMO), is also badly needed. There are examples of flux stations measuring a full four-component radiation next to the Surface Radiation Balance (SRB) stations, without any mechanism in place to share the data or to serve a common database. iLEAPS, in collaboration with GEWEX, should intensify its efforts to overcome this gap.

In addition, iLEAPS should further develop and implement a concept of so called "anchor stations," or flagship stations where a comprehensive set of surface data from all relevant disciplines can be continuously collected.

3. Missing link in Earth System- and climate models: planetary boundary layer

Most of the Earth System and climate models "suffer" from severe under–representation of the processes which take place in the planetary boundary layer (PBL). PBL has its distinct dynamics which up to a large extent depend on the exchanges with land surface and with the overlaying atmosphere.

The nocturnal and stable boundary layers, and the role of advection, present a major problem when it comes to transport processes. Biochemical sink and sources, and species which react within the boundary layer before leaving it to the above atmosphere, do require highly complex models, which are too complex to be directly applied at the global scale.

There seems to be a "gap" between the research community addressing all different facets of PBL on one hand, and the large scale atmospheric modeling community. This results in "underuse" of experimental data and modeling experience across both communities, and a lack of progress in dealing with PBL in large scale models. iLEAPS should orchestrate a major effort in coming years to help overcome this gap.

4. New generation of integrated regional approaches: contribution to the Belmont Challenge

There is a rich evolution and history to so called large scale land–atmosphere experiments, which aim to address—both through measurements and by modeling—exchanges between land and atmosphere at

multiple, nested scales. These experiments started during late eighties of the last century (Hapex Mobilhy in France and FIFE in USA), and developed to more and more integrated global change regional studies like the Large–scale Biosphere–Atmosphere Experiment in Amazonia (LBA) and the Monsoon Asia Integrated Regional Study (MAIRS) in China and South East Asia.

Currently, a momentum for this type of integrated regional experiments is seemingly loosing ground, especially with funding agencies. iLEAPS should make a serious effort to revitalize the interest in such type of comprehensive, integrated regional studies, both with funders and within the science community.

A new concept—an Earth System Regional Laboratory—could be introduced to funding agencies and to the society at large, as a mean to obtain better understanding of complex Earth System interactions at regional scale, being at the same time connected to pressing global change issues at the scale tangible to the societal stakeholders. Doing this, iLEAPS will be making a direct contribution to a so called Belmont Challenge—a call of major funders around the world to accelerate research in the global change challenge at regional scale.

5. Modeling of impacts, vulnerability and adaptation: towards seamless, multi–model approaches

Currently, the "climate system modeling community" and the "climate impact modeling community" are often only linked through climate scenarios which are produced by climate modelers and used as input by impact modelers. This often leads to a number of inconsistencies across climate impact modeling results.

Climate models, however, are becoming more and more comprehensive in representation of land surface processes, including anthropogenic drivers. For example, many of the climate models will soon incorporate all major anthropogenic components of the water cycle, like dams/reservoirs and irrigation schemes. iLEAPS, in collaboration with GEWEX and other partners, should initiate an effort to investigate impact indicators in a seamless approach towards impact studies, by employing advanced climate models in a coupled mode also to the impact and vulnerability studies.

The above list of issues suggested as future focus of iLEAPS is far from complete, and it will be a task of the iLEAPS SSC, supported by all scientists contributing to iLEAPS program, to arrive over the next year at a consolidated, well–focused science agenda which will guide iLEAPS activities over the years to come. The 3rd iLEAPS International Science Conference, which will be held on 18–23 September 2011 at Garmisch–Partenkirchen, Germany, should already fully reflect the future course of iLEAPS.

It needs to be emphasized that updated science agenda will not be replacing the *iLEAPS Science Plan and Implementation Strategy*, as published in 2005. On the contrary—it will be well rooted in our original science plan, analyzing the extent to which the science questions originally asked have been successfully answered, and elaborating on a strategy about how to progress on those issues where additional, and more consolidated effort is still needed—some of these I mentioned above.

Many of these science issues can only be addressed effectively if iLEAPS can substantially enhance its collaborative links with its sister core projects within the IGBP family, most notably with IGAC, Analysis, Integration, and Modeling of the Earth System (AIMES), Surface Ocean Lower Atmosphere Study (SOLAS) and Global Land Project (GLP). And develop new ones, for example with Past Global Changes (PAGES), where we need to look jointly into retrospective analysis of the interactions between land and (palaeo)-climate.

Following on a decade of very successful collaboration, which culminated in parallel and joint science conferences last August in Melbourne, iLEAPS intends also in the future to share many of its programmatic, experimental and modeling activities with WCRP core project GEWEX. We are calling on our GEWEX colleagues to keep investing in this very important collaboration which has been historically pioneering the links across IGBP and WCRP programmes. ■

Pavel.Kabat@wur.nl

ESA–iLEAPS–EGU Topical Conference

Earth Observation for Land–Atmosphere Interaction Science

ESA–ESRIN, Frascati (Rome), Italy
3–5 November 2010

The event aims at bringing together the Earth–observation (EO) and Earth–system communities, as well as scientific institutions and space agencies involved in the observation, characterisation, and forecasting of land–atmosphere interactions and their impacts.

In particular, the conference represents a unique opportunity to facilitate the communication and scientific exchange among these different communities in order to enhance the coordination of specific scientific efforts and advocate for a common view of major scientific needs and priority areas for the future.

Contributions are invited for oral and poster presentations on novel research activities and developments exploiting EO data in support of land–atmosphere interaction studies.

Conference themes:

- ❑ Current observational gaps and potentialities of novel EO missions in support of land–atmosphere studies
- ❑ Impact of land–atmosphere interactions on the climate system
- ❑ Characterisation of vegetation–atmosphere dynamics
- ❑ Characterisation of biomass–burning emissions into the atmosphere
- ❑ Aerosols and non–CO_2 greenhouse/reactive gas fluxes

Abstract submission deadline 31 May 2010

Registration deadline 1 September 2010

For detailed information about organisation, abstract submission, and registration, please visit the conference website:

www.eo4landatmosphere.info

Organising Committee:

Diego Fernández–Prieto (ESA)
Mattia Marconcini (ESA)
Anni Reissell (iLEAPS International Project Office)
Michael Ellis (EGU – BGS, UK)

Piers Sellers is currently an astronaut at the NASA Johnson Space Center. He was born and educated in the United Kingdom: Cranbrook School in Kent, Edinburgh University for a degree in Ecology, and Leeds University for a PhD in Biometeorology. He moved to the USA in 1982 to carry out climate research at NASA Goddard Space Flight Center in Maryland. From 1982 to 1996, he worked there on global climate problems, particularly those involving interactions between the biosphere and the atmosphere, and was involved in constructing computer models of the global climate system, satellite data interpretation and conducting large-scale field experiments in the USA, Canada, Africa and Brazil. He joined the US astronaut corps in 1996 and flew to the International Space Station (ISS) in 2002 and 2006, carrying out six spacewalks. He is scheduled to fly to the ISS again in May 2010. He is married, with two children, one dog and no cats.

Piers J. Sellers
Johnson Space Center, National Aeronautics and Space Administration (NASA), Houston, Texas, USA

Challenges to understanding the climate system

When I was a practicing scientist, I often used to think about how the global system would look if I could see it from orbit with my own eyes.

Like all of you, I am familiar with looking at satellite images, global analyses, animations and the like, but none of that prepared me for the view I enjoyed as a satellite in my own right. It is truly amazing to see the world in all its beautiful glory—oceans, mountains, clouds, rivers, cities—gliding by between your feet, once around every 100 minutes. I wish I could have taken you all with me. I know that you would have found the experience to be as joyous and fascinating as I did, and I hope that some of you will get to see it in your lifetimes too.

To business: government and public have come to a fork in the road with respect to climate science. The choices are (i) to support the climate science community at more or less the current level, or (ii) to ramp up the science to support a global program which could be two or three times as large and much more capable than the current effort.

The potential dividends from a more capable program are obvious: better climate observations and modelling should give us all, particularly policy-makers, a more precise idea about the consequences of future energy–use strategies and environmental policies in general.

It is therefore quite likely that given the high stakes in this climate-energy policy business, we may be asked to expand our scope of work within a very short time. The next few years should be interesting at the very least, and demanding, exciting and very rewarding if things work out as they should. A huge amount of work needs to be done and currently there are not many qualified hands available.

Still, if you Earth scientists had wanted a quiet life, you would probably have found something else to do. So if you find the ææprospect of hard work, stress and overstretch daunting, this might be a good time to switch over to landscape gardening.

Why is this moment in time different from previous history? I think its different because our community is confronted with some serious challenges that have to be addressed right now.

The first concerns our ability to observe the Earth system. We in the US are in the fortunate position of having a fully functional satellite–based Earth Observing System (EOS) which has provided us with some real breakthroughs in understanding how our planet works.

This system has connected beautifully with the global operational meteorological

satellite system over the last decade with the result that we have started to lay down a truly useful global satellite record—a very worthy achievement.

In fact, the ten-year celebrations for Terra, the first EOS platform, took place at the American Geophysical Union meeting in San Francisco this winter—this is worth remarking on as the design life of Terra was about five years at launch. Terra and her sister platforms—Aqua, Aura, CloudSat, Calipso (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation), GRACE (Gravity Recovery And Climate Experiment), and others—have been remarkably successful in both supporting basic research programs and in adding to the climate record.

However, the design life of these first EOS platforms is coming to an end and it is not clear how well the mix of upcoming environmental satellite systems will be able to continue the work. The planned foundation US weather and climate monitoring program is a multiagency initiative—the National Polar Orbiting Environmental Satellite System (NPOESS)—that has experienced a number of schedule, funding and technical problems. As a result, it is very likely that the US science agencies and their international counterparts will have to reassess their long–term plans for satellite-based climate studies—this will require continuing accurate input from the scientific community.

In addition, the global network of *in situ* measurements, provided by the operational meteorological and ocean–observing networks and some research projects (*e.g.* atmospheric CO_2 monitoring) needs continuous review and support to prevent spatial and temporal gaps from appearing in the record. Fortunately, there are some very effective international bodies that keep an eye on this business.

Our second challenge lies in the area of climate modelling. In this field, we are on the verge of a new revolution: computer hardware may make it possible to run climate simulations at spatial resolutions of a few kilometres in the very near future, and also to run very large ensembles of runs.

Increased resolution, by itself, should greatly enhance the representation of moist processes and tropical meteorology, leading to improved climate predictions and may also provide us with significantly more insight into regional climate effects. To implement this capability will require a huge commitment by government and science, in effect a doubling of the current investment, but the potential yield in scientific understanding and societal benefit could be enormous.

These two areas need the support of a vigorous process study community. Scientists have added great value to satellite measurements through field studies and other validation techniques, and the climate modelling community has also benefited immensely from a better understanding of physical processes gained from direct observation and experiment.

We can expect that these efforts will be expanded in the future as we strive to get more information from our satellites and better performance from our models. The trick will be to ensure that the process study and modelling communities work closely together—a clear understanding of each other's needs and limitations will be essential to prevent us from wasting time and resources.

Given the amount of work that needs to be done, it is obvious that we need more people, and we need them soon. In many of the US agencies and elsewhere around the world there have been several years of reduced hiring of scientists and technicians. In NASA (National Aeronautics and Space Administration) for example, an entire generation of highly skilled people is approaching retirement age while only a relatively small successor cohort is in place to acquire their skills and continue with the work.

On the bright side, there are many people in science and government who are keenly aware of the urgent need to improve our climate monitoring and prediction capability, and are also aware of the existing institutional and funding problems. There is little doubt that we can improve the situation if we are given adequate resources—the rest will depend on our own hard work and good will. I am sure that we will all step up to the mark when the time comes.

Brace yourselves—we could all be very busy in the years ahead. ■

Adrian Simmons received his PhD at the University of Cambridge, UK, on dynamical meteorology of the stratosphere. As a post-doctoral researcher at the University of Reading, UK, he combined research and development in atmospheric modelling with further research in atmospheric dynamics, the life cycles of mid–latitude cyclones in particular.

He joined the European Centre for Medium–Range Weather Forecasts (ECMWF) in 1978, where he first participated in building and refining ECMWF's atmospheric forecast model. From 1995 to 2007, he led development of the assimilation of *in situ* and satellite data for both numerical weather prediction and climate reanalysis.

He currently coordinates a project developing and operating pilot atmospheric environmental services for Europe's GMES (Global Monitoring for Environment and Security) initiative. He is Chair of the Steering Committee for the Global Climate Observing System and a Visiting Professor at the University of Reading.

Adrian Simmons
European Centre for Medium–Range Weather Forecasts, Reading, UK

Integrated observation and modelling of atmospheric dynamics, thermodynamics, and composition

Integration of observation and modelling is fundamental to predicting weather and air quality, to monitoring and analysing the climate system, and to validating and improving the models used for climate projection.

The principal integrating approach is through data assimilation, which is a step-wise process in which a prior, or "background", model-based estimate of the atmospheric state from a short–range forecast is updated with information from recent observations, to provide an optimal estimate of current conditions, known as an "analysis". The latest analysis serves as the starting point for the next short–range background forecast in the sequence.

The background forecast not only carries forward in time information assimilated from earlier observations, but also spreads information from regions that are well–observed into regions where observational coverage is poorer. In each analysis step the background model forecast is adjusted to improve its fit to the observed values using estimates of the errors of the observations and background.

The analyses of one variable may be improved by assimilating observations of another. This can be either through interactions within the model during the forecast step or because correlations are specified between the errors of the background forecasts of different variables. For example, assimilating prior observations of precursor species for ozone should lead to better background forecasts of ozone itself, and temperature measurements influence the analysis of wind as well as temperature when background errors for these variables are specified to be related through geostrophic balance.

In addition, iterative methods enable assimilation of observations that are related indirectly to one or more of the model variables. For example, temperature and humidity analyses can benefit from assimilating satellite measurements of the radiance emitted by the atmosphere and of the atmosphere's refraction of GPS signals emitted by other satellites. The integrating assimilation process can thus make simultaneous use of a wide variety of *in situ* and remotely–sensed measurements.

Historical records built up from long sequences of analyses have found widespread application when produced by applying a modern data assimilation system to the observations taken and archived over many decades, a process named reanalysis. In particular, such records are used for determining how well the models used to make projections of future climate can reproduce the climate of the recent past.

The reanalysis process also provides metadata on the quality of observations and the time–varying differences between observations and the background forecasts. This can aid understanding of variations and

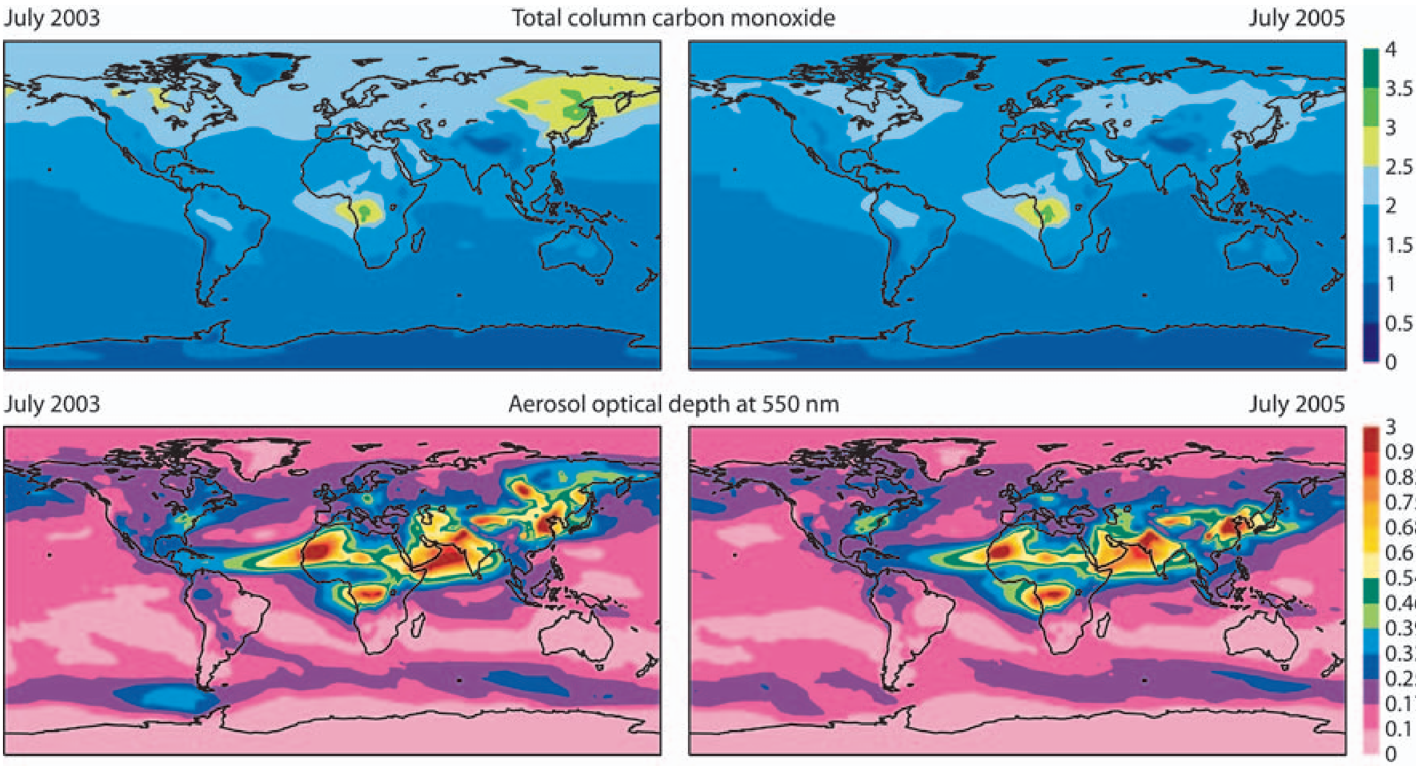


Figure 1. Monthly–mean analyses of total column carbon monoxide (10^{18} molecules cm^{-2}) and aerosol optical depth for July 2003 and July 2005.

trends in temperature and other key climate variables [1].

A more integrated approach is also emerging through coupling components of the Earth system that in the past were treated largely separately, with minimal one–way driving: atmosphere and ocean, or meteorology and atmospheric chemistry, for instance.

Europe's GMES (Global Monitoring for Environment and Security) initiative is developing services covering atmosphere, land and ocean that include space–based and *in–situ* observation and provision of monitoring and forecast information based *inter alia* on data assimilation. Its primary atmospheric environmental services are being developed and provided in pilot form by ECMWF (European Centre for Medium–Range Weather Forecasts) and 44 partner organisations in a project called MACC (Monitoring Atmospheric Composition and Climate) funded by the European Community under its 7th Framework Programme.

MACC [2] utilises modelling and data assimilation components for greenhouse gases, reactive gases and aerosols that were integrated within the ECMWF global weather forecasting system by the earlier GEMS project [3]. The integrated system was used in GEMS to produce a reanalysis for the period 2003–2007 and daily forecasts of aerosols and reactive gases for several days ahead.

Fig. 1 presents maps of total aerosol and carbon monoxide (CO) distributions for July 2003 and 2005 from the reanalysis. Large values over north–eastern Asia for both variables in 2003 are consistent with large emissions of CO and smoke from an unusually high level of fire activity over Siberia in this year.

Information on the anomalies comes directly from the assimilated observations of aerosol from the MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on NASA's (National Aeronautics and Space Administration) Terra and Aqua satellites [4] and of carbon monoxide from the MOPITT (Measurements Of Pollution In The Troposphere) instrument on Terra [5]. It also comes indirectly from background model values, which are influenced by specified emissions based on the Global Fire Emissions Database GFEDv2 [6].

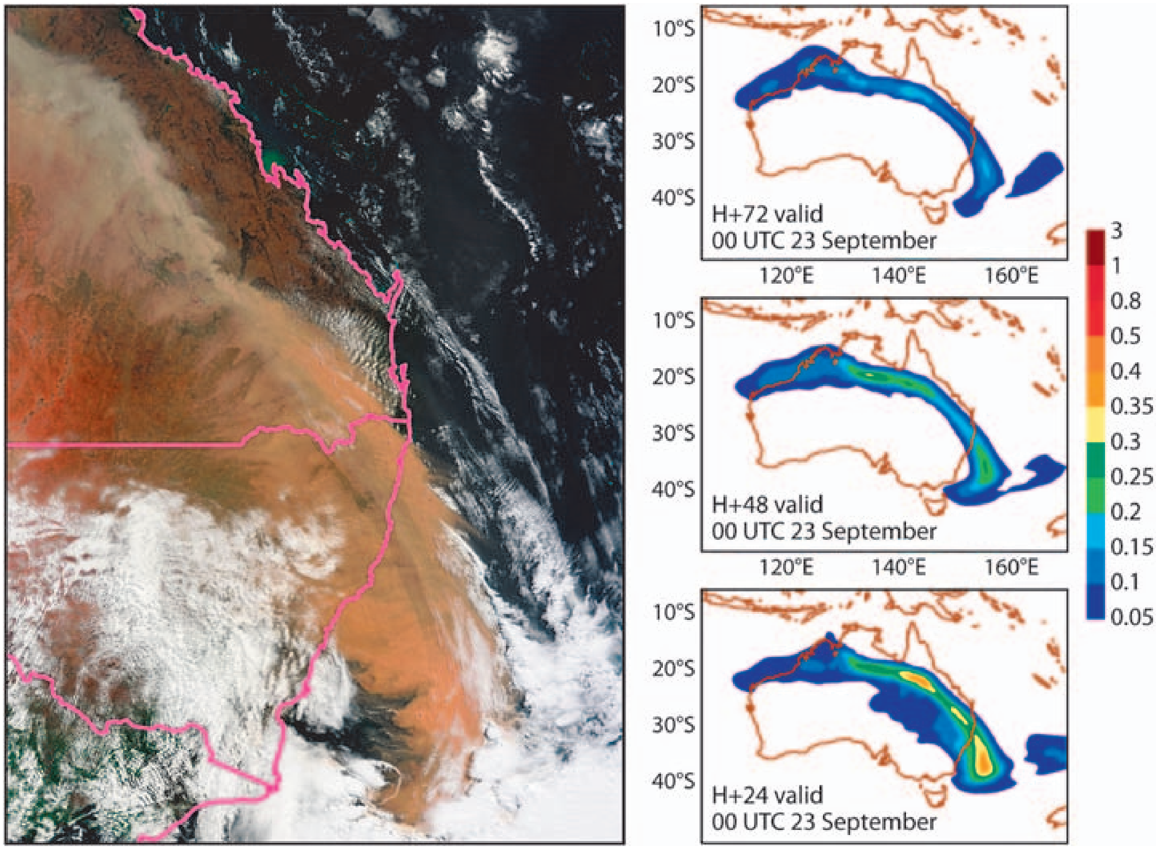
Fig. 1 also shows stronger transport of Saharan dust aerosol westward to the Caribbean in 2003. Information on the inter–annual differences in this case comes both directly from the assimilated aerosol optical depth data from MODIS and indirectly from the assimilated meteorological observations, through the influence of meteorological conditions on the sources, transport and sinks of dust in the background model.

The daily forecasting started by GEMS is now run by MACC. Fig. 2 illustrates the system's treatment of the extreme dust storm that affected Sydney and other parts of Australia in September 2009. It shows three-, two- and one–day dust forecasts valid at midnight UTC (Coordinated Universal Time) 23 September, and a satellite image taken close to this time.

There is clearly small-scale detail in the image that cannot be depicted by the ~125–km resolution of the assimilating model, but the position of the dust band is captured well in each of the forecasts, indicating that the controlling meteorology is predicted accurately out to at least three days ahead.

The predicted dust band becomes more intense as the forecast range shortens. As the differences between the three–, two– and one–day forecasts come only from the observations assimilated in the period between one and three days ahead, assimilating these observations must have compensated for an underestimation of dust in the background model forecast.

Lack of dust may not be entirely due to a deficient model however, as the forecast



could have underestimated dust because the soil moisture analysis underestimated the dryness of the land surface.

MACC builds also on the GMES Service Element project PROMOTE (PROtocol MOniToring for the GMES) [7]. In addition to the basic global constituent monitoring and forecasting, it provides or is developing:

- estimates of emissions, including those from fires that are identified day–by–day from satellite measurements;
- inferred corrections to the net surface fluxes of carbon dioxide, methane and aerosols, from inversion techniques;
- higher–resolution regional air–quality forecasts and reanalyses from a set of nationally developed regional models run cooperatively over a common European domain, taking boundary conditions from the global system;
- support for providers of specialized services in areas such as health and solar energy;
- estimates of long–range pollutant transport and source attribution;
- tools for evaluating pollution control strategies.

Although focussed on providing and developing services, MACC and its follow–on will be reliant upon the results of projects such as iLEAPS for guiding the improvement and expansion of its modelling and analysis systems. In turn, one application of the data provided by MACC is the support of research–oriented measurement campaigns and process studies. ■

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Figure 2. Optical depth of dust aerosol over Australia in three–, two– and one–day forecasts for 00 UTC 23 September 2009, and a corresponding image from the MODIS instrument on NASA's Terra satellite (Credit: Jeff Schmaltz, MODIS Land Rapid Response Team, NASA GFC).

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iLEAPS–organized/co–sponsored/related sessions

European Geosciences Union General Assembly 2–7 May 2010, Vienna, Austria

meetings.copernicus.org/egu2010
www.egu.eu

iLEAPS is organising and co–sponsoring several sessions at EGU2010. Six belong to a series of sessions called Biosphere–Atmosphere Interactions (BAI).
http://meetingorganizer.copernicus.org/EGU2010/sessionprogramme

Monday, 03 May 2010

CL1.22 *BAI session:* Feedbacks in the global Earth system in the past, present, and future
M. Claussen, V. Brovkin
Oral session 08:30–10:00, Room 18;
Poster session 08:00–19:30, Halls X/Y

CL2.4 Shifting Seasons: Phenological evidence from observations, reconstructions, measurements and models (co–sponsored by PAGES & ILEAPS)
T. Rutishauser, A. Menzel, J. Weltzin
Oral Session 08:30–10:00, Room 17;
Poster Session 08:00–19:30, Halls X/Y

CL2.7/HS5.6 Land–climate interactions from models and observations: Implications from past to future climate
B. van den Hurk, S. Seneviratne, P. Ciais
Oral Session 13:30–17:00, Room 18;
Poster Session 08:00–19:30, Halls X/Y

Tuesday, 04 May 2010

BG2.9/AS4.20 *BAI session:* Carbon and water cycles at multiple spatial and temporal scales
M. Reichstein, A.D. Richardson, C. Beer, D. Papale
Oral Session 13:30–17:00, Room 24;
Poster Session 08:00–19:30, Poster Area BG

Wednesday, 05 May 2010

BG2.1 Biotic interactions and biogeochemical processes
M. Bahn, R. Bardgett, M. Reichstein
Oral Session 08:30–12:00, Room 24;
Poster Session 08:00–19:30, Poster Area BG

BG2.3/AS4.17 *BAI session:* Trends and temporal variability in biogeochemical surface fluxes
P. Stoy, S. Luyssaert, A.D. Richardson
Oral Session 13:30–17:00, Room 24;
Poster Session 08:00–19:30, Poster Area BG

HS6.9 *BAI session:* Production, transport, and emission of trace gases from the vadose zone to the atmosphere
L. Weihermueller, M. Lamers
Oral Session 15:30–17:00, Room 39;
Poster Session 08:00–19:30, Hall A

AS3.14 From gas to particles, new perspectives on organic compounds in the atmosphere
B. Noziere, M. Kulmala
Oral Session 15:30–17:00, Room 12;
Poster Session 08:00–19:30, Halls X/Y

Thursday, 06 May 2010

BG2.5/AS4.18 *BAI session:*
Improving measurements and models of soil respiration and its components
J. Subke, M. Khomik, M. Carbone, P. Stoy
Oral Session 08:30–12:00, Room 24;
Poster Session 08:00–19:30, Poster Area BG

AS2.1 Air–Land Interactions
A. Ibrom, T. Foken
Oral Session 08:30–12:00, Room 11;
Poster Session 08:00–19:30, Halls X/Y

BG2.2/AS4.16 *BAI session:*
From biogenic primary exchange to atmospheric fluxes of reactive trace gases
J. Kesselmeier, J. Rinne, J. P. Schnitzler
Oral Session 13:30–15:00, Room 24;
Poster Session 08:00–19:30, Poster Area BG

European Geosciences Union General Assembly 2–7 May 2010, Vienna, Austria

We warmly welcome you to attend these sessions!

Paul Dirmeyer is an Associate Research Scientist at the Center for Ocean-Land-Atmosphere Studies in Calverton, Maryland, USA. Dr. Dirmeyer conducts research on the role of the land surface in the climate system. This includes the development and application of land-surface models, simulation of soil moisture and its feedbacks on surface fluxes, studies of the influence of land surface variability on the predictability of climate using global models, exploration of the interactions between the terrestrial and atmospheric branches of the hydrologic cycle, and the influence of land-use change on regional and global climate.

Paul Dirmeyer, Zhichang Guo and Jiangfeng Wei
Center for Ocean-Land–Atmosphere Studies, Calverton, Maryland, USA

Building the case for (or against) land–driven climate predictability

A large body of numerical climate modelling studies has grown over the last 30 years that suggest the state of the land surface, particularly the amount of water in the top few meters of soil, can have a striking influence on the atmosphere on time scales of weeks to months.

The pioneering study by Shukla and Mintz [1] showed that an atmospheric general circulation model (AGCM) is sensitive to whether the land surface is wet or dry, and that the response, reflected in temperature and precipitation, is not uniform in space. There have been hundreds of papers published since then that examine variations on this idea—how land–surface boundary conditions or the initial state of soil moisture affect weather and climate forecasts.

The influence of the land surface on weather and climate is secondary to that of the oceans on a global scale, both because the oceans cover twice as much surface area as land, and because they are a much larger reservoir of exchangeable energy through latent and sensible heat fluxes.

The proportionate effects of land and ocean have been quantified [2], and they vary spatially and with season [3, 4]. These studies suggest that there might be places and seasons where the land surface state can be an important or predominant predictor of seasonal-scale climate. This provided the motivation for the GEWEX (Global Energy and Water Cycle Experiment) Global Land–Atmosphere Coupling Experiment (GLACE) [5].

GLACE was a numerical modelling study with the goal of determining the places across the globe where the land surface exerts significant control on the atmosphere. A dozen global weather and climate models participated, each conducting identical ensemble experiments for boreal summer.

The aggregate model results showed "hot spots" in several areas of the globe where the state of soil moisture constrains the range of surface heat fluxes, atmospheric temperature and precipitation [6, 7]. Fig. 1a shows the hot spots for the North American region. However, there was significant variation among models, which is attributable to the different parameterisations of processes in both the atmosphere and land.

In order to have land surface conditions feed back on precipitation, there must be a pathway from land to atmosphere. Specifically, it is clear that precipitation directly affects soil moisture, but soil moisture must then affect surface fluxes, which then must influence precipitation.

The hot spots for land–atmosphere coupling tend to occur over continents in transition regions of the mid–latitudes and subtropics between arid and humid zones during the warm or monsoon season. GLACE results suggest that the Sahel region of Africa, the wheat belt of Eastern Europe, northern India, and eastern China are also hot spots, while related studies also pinpoint regions of South America, Australia and South Africa during other seasons. Note that there are some variations regarding the exact location of these hot spots between studies (see also Seneviratne *et al.*, page 18 in this issue). A number of factors appear to contribute to the sensitivity of these regions.

As shown in Fig. 1b, regions where daily variations of evaporation are highly correlated to anomalies in soil moisture are predominant over arid western North America.

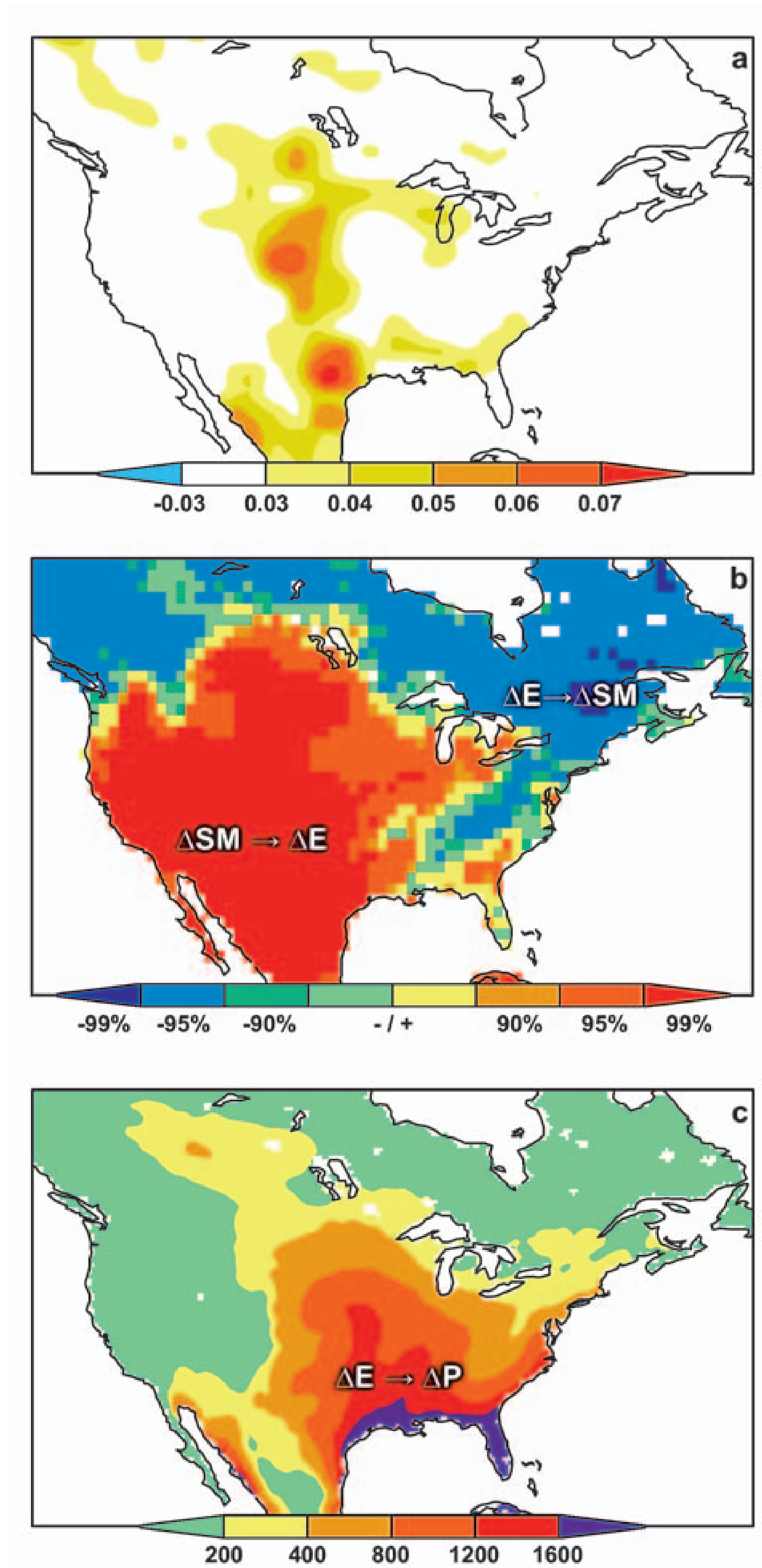

Figure 1. (a) The average boreal summer land–atmosphere coupling strength [dimensionless] across all GLACE models; (b) The temporal correlation between daily soil moisture and evapotranspiration during summer from the GSWP multi–model analysis [units are confidence thresholds]; (c) Average convective available potential energy CAPE [J/kg] during July and August from the North American Regional Reanalysis. Regions of overlapping high values in (b) and (c) correspond to shaded regions in (a), showing how both land surface and atmospheric conditions must be present for land–surface states to influence the atmospheric water cycle.

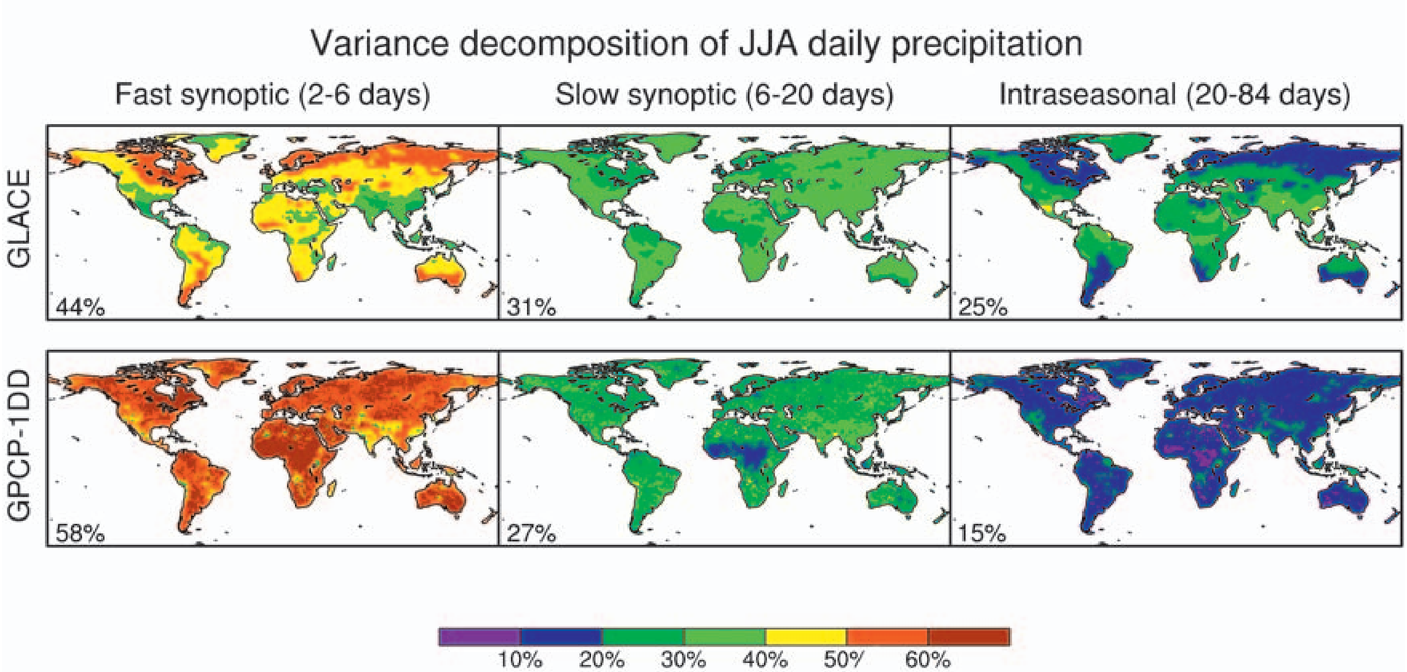

Figure 2. The average variance of JJA daily precipitation in three time scales: fast synoptic (left column), slow synoptic (middle column), and intraseasonal (right column) expressed as a percentage of the total variance. The top row is an average from 12 models that participated in GLACE. The bottom row is from observations. Numbers in the lower left corner give the global average over land in each time band—each row adds to 100%.

These results are from the Second Global Soil Wetness Project (GSWP–2) multi–model analysis [8].

In the northern and eastern parts of the continent, the correlations are significant but negative. Negative correlations occur where moisture is plentiful but sunlight to evaporate it is not. In these areas, evaporation determines soil wetness by the rate at which it depletes water from the soil.

Positive correlations occur where soil moisture determines evaporation—energy to evaporate water is ample (warm and sunny). These are the areas where land surface has the potential to affect the atmosphere most.

Dependence of evaporation on the state of soil moisture is a necessary but not sufficient condition for strong land-atmosphere coupling. The atmosphere must be prepared to translate a surface flux anomaly into an atmospheric anomaly.

For precipitation, this is determined by the moist stability of the atmosphere—how readily can rain showers be triggered by a little extra heat or moisture from the surface. Fig. 1c shows the average summer convective available potential energy (CAPE) in the atmosphere from the North American Regional Reanalysis (NARR [9]). This quantity is largest over the south-eastern quarter of North America.

For soil moisture anomalies to feed back on precipitation, the signal must pass through both the terrestrial and atmospheric legs of the upward branch of the hydrologic cycle. This occurs where we see large positive values in both Fig 1b and 1c, namely over the Great Plains.

It is important to realise that these results come from numerical models, not from direct observations. All models have errors, and the GLACE models exhibit large systematic errors in their ability to represent observed relationships between land and atmosphere [10].

For instance, over the Great Plains, most models have too much solar radiation reaching the land surface, and thus simulate a climate too warm and dry for this region. Also, the relationship between soil moisture, surface heat fluxes and growth of the atmospheric boundary layer only crudely resemble the observed in most cases.

There is also considerable variation among models. Comparisons among IPCC (Intergovernmental Panel on Climate Change) 4th Assessment climate models show a wide range of mean precipitation and evapotranspiration values among climate models.

Furthermore, it has been found that the GLACE models regularly under-represent the precipitation variance at synoptic (weather) time scales and place too much variance at intraseasonal scales except at high latitudes [11].

Fig. 2 compares the decomposition of boreal summer precipitation variance between the GLACE models and the Global Precipitation Climatology Project (GPCP) 1DD observed daily data set. We have found [11] that the intraseasonal timescales of variance in model precipitation actually contribute most of the coupling strength found in GLACE. Thus, it may be that coupling strength is over–estimated by the models.

One unsatisfying aspect of the GLACE research is that the land–atmosphere coupling strength as defined in that study is based on ensemble modelling statistics, and thus has no observed analogue. Nevertheless, observationally-based estimates of land-atmosphere coupling strength appear to confirm the distribution of hot spots [12], although these estimates have been synthesised largely from atmospheric reanalyses that blend observations and models using data assimilation.

There are very few locations with long-term monitoring of all quantities necessary for assessing land–atmosphere coupling strength in the real world; precipitation, soil moisture, surface heat fluxes, and near–surface thermodynamic quantities like air temperature and humidity.

However, the growing record of data from fully instrumented research networks like FLUXNET [13] have brought us to the point where a global assessment of actual land–atmosphere interaction is becoming possible (Seneviratne *et al*., page 18 in this issue).

The hope is that water and energy feedback processes between land and atmosphere can lead to improved forecasts of weather and climate on time scales of several days to a season.

A follow–on experiment called GLACE–2 is addressing this question in a predictive framework, assessing the influence of initial soil moisture states on two-month retrospective forecasts (test forecasts made for previous years) across many global models [14]. Early results suggest a small but significant increase in forecast skill, when realistic soil moisture anomalies are used to initialise forecasts.

These gains in skill increase markedly with the size of the initialisation soil moisture anomalies, and the hot spots found in GLACE appear to be the most sensitive regions for predictability as well. In this way, the influence of land surface states is similar to that of ocean states, and the hot spots are much like the El Niño region of the tropical Pacific—regions where knowledge of large anomalies can enhance forecast skill.

In conclusion, it appears that the regions of the globe that modelling studies have shown to produce significant feedback of soil moisture on the subseasonal time scale are likely genuine and may be exploited for improved forecasts. However, there remains pathological behaviour in global weather and climate models that may give us a somewhat flawed impression of land–atmosphere coupling.

Observational networks for research such as FLUXNET are now providing the surface state and flux data necessary to identify and correct these errors in the models. However, development of a real–time operational network of soil moisture monitoring focussing on the areas in and around the hot spots is necessary to exploit this source of predictability. Because these regions generally correspond to major agricultural zones, the potential economic consequences are large. ■

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Prof. Seneviratne has been involved in several national and international research projects such as the National Centre of Competence in Research NCCR-Climate, and projects of the European Union's Sixth and Seventh Framework Programme (such as EU-FP6 CECILIA: work package leader, EU–FP7: Carbo–EXTREME: executive board).

She is also a member of the Global Energy and Water Cycle Experiment (GEWEX) radiation panel (GRP) and of the panel of the Global Land/Atmosphere System Study (GLASS), as well as coordinating lead author of the new IPCC SREX report (2009–2011). Her main area of interest relates to the role of soil moisture and vegetation for the energy and water cycles, and their implications for climate variability and climate change.

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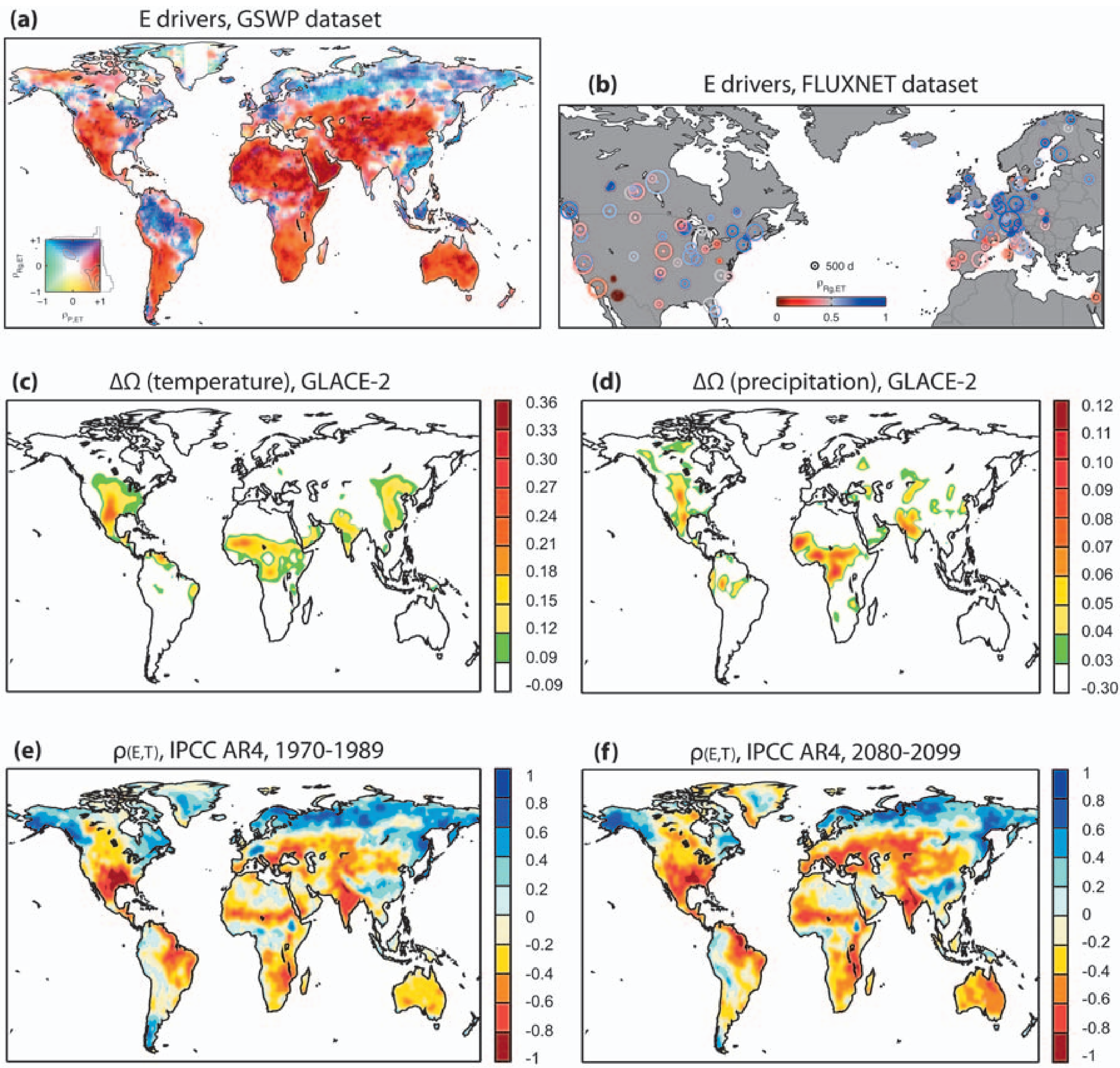
Climate change and soil moisture–climate interactions: Using new diagnostics to identify hot spots of land–atmosphere coupling

Soil moisture is a key variable of the climate system because of its influence on the surface energy and water balances [1]. This has consequences for near-surface climate (temperature, humidity), for the development of the planetary boundary layer (the layer directly influenced by the ground surface: typically below ~1 km from surface in daytime), and potentially also for precipitation formation and large–scale atmospheric circulation patterns.

As a storage element for water and hence indirectly also for energy (given its control on evapotranspiration, the sum of evaporation from surfaces and transpiration by plants), soil moisture moreover represents an important memory component for the regional climate system, with high potential for subseasonal and seasonal forecasting.

However, many results in this research field are so far based on modelling experiments. We highlight here how new diagnostics can be used to assess the role of soil moisture and vegetation for the climate system and applied as constraints to evaluate the accuracy of current climate models with regard to the associated processes.

Fig. 1 displays different analyses based on modelling results and/or observational data. The top two figures present analyses of evapotranspiration regimes based on data from the 2nd phase of the Global Soil Wetness Project (GSWP–2, [3]) and the



FLUXNET network ([4], www.fluxdata.org). Fig. 1a displays *yearly* correlations of measured evapotranspiration with global radiation and precipitation, whereas Fig. 1b displays *daily* correlations of the same at FLUXNET sites for the months May to September.

Blue shadings indicate large correlations between measured or simulated evapotranspiration and radiation, that is, energy-limited evapotranspiration regimes, while red shadings indicate low correlations with radiation (and in the GSWP–2 analysis also large correlations with precipitation), that is,

Figure 1. Land-atmosphere coupling diagnostics based on model and observational data [1].

Top row: Estimation of the drivers of evapotranspiration (moisture and radiation [2]) based on a) simulations from the GSWP–2 project (yearly correlations with radiation and precipitation for the period 1986–1995, redrawn for whole globe) and b) FLUXNET observations (daily correlations with radiation for May–September over the record length of each station). Blue shadings indicate large correlations between measured or simulated evapotranspiration and radiation (energy–limited evapo–transpiration regimes), whereas red shadings indicate low correlations with radiation (moisture–limited evapotranspiration regimes). In the GSWP-2 analysis, red also indicates large correlations with precipitation.

Middle row: Estimations of c) soil moisture–temperature and d) soil moisture-precipitation (right) coupling in 12 GCMs from the GLACE project [5, 6] in simulations driven with 1994 SSTs. Increasing values indicate stronger coupling.

Bottom row: Estimations of soil moisture-temperature coupling for e) 1970–1989 and f) 2080–2099 climates, based on 3 IPCC GCMs and diagnosed with the correlation between evapotranspiration and temperature [7]. Negative values (*red shadings*) indicate strong coupling, positive values (*blue shadings*) indicate low coupling.

moisture–limited evapotranspiration regimes.

Note that the GSWP–2 data cover the 1986–1995 time period, while the FLUXNET observations are mostly available in recent years. Despite the different temporal and spatial resolutions, reference time periods, and data basis for these two analyses, it is striking that similar geographical patterns can be identified in the Northern mid–latitudes.

Both datasets suggest that in Central and Northern Europe (for current climate), evapotranspiration is limited by radiation, whereas in the Mediterranean region, the limiting factor is soil moisture. In North America, both datasets suggest that the limiting factor is soil moisture in the Great Plains and in the western part of the continent, and radiation in the eastern part of the continent and in Canada.

These results are interesting, since they bring some perspectives on recent modelling analyses of land-atmosphere coupling. The Global Land-Atmosphere Coupling Experi-ment (GLACE [5, 6]) provided an analysis of the strength of soil moisture–precipitation and soil moisture–temperature coupling in state–of–the–art Atmospheric Global Circulation Models (AGCMs), based on three-month (June–July–August, JJA) experiments driven with 1994 sea surface temperature conditions.

Based on this analysis, "hot spots" of land–atmosphere coupling, *i.e.* regions where soil moisture is expected to have a major impact on the atmospheric conditions, could be identified. These were found to be located in transitional zones between dry and wet climates. In GLACE the identified regions included the Great Plains of North America, the Sahel region, equatorial Africa and India (Figs. 1 c, d).

More recently, an analysis was made [7] of land–atmosphere coupling in IPCC (Intergovernmental Panel on Climate Change) AR4 GCM simulations. In this analysis (Figs. 1e,f), the interannual correlation between summer (JJA) evapotranspiration and temperature was used as diagnostic. Negative values of this diagnostic indicate a strong influence of soil moisture on surface fluxes, *i.e.* moisture-limited evapotranspiration regimes (when soil moisture is low evapotranspiration is low, sensible heat flux is high, and thus air temperature is high, with opposite behaviour for wet soils), whereas positive values indicate energy–limited evapotranspiration regimes (higher evapotranspiration when air temperature is higher). More details on this diagnostic are also provided in [1].

Figs. 1e and 1f display the results of this analysis for two time periods in late 20th *vs.* late 21st century climate (1970–1989, respectively 2080–2099) for the mean of three AGCMs found to have the best representation of north–hemispheric circulation patterns, HadGEM1, GFDL, and ECHAM5. They highlight similar regions of strong land–atmosphere coupling (red shadings) as the GLACE study for present climate (*i.e.* transitional zones between dry and wet climate), but an important distinction is the identification of the Mediterranean region as additional hot spot of land-atmosphere coupling (also located in a transitional climate region).

The analysis of evapotranspiration regimes based on GSWP–2 and FLUXNET data (Figs. 1a,b) suggests that the hot spot of land-atmosphere coupling in the Mediterranean region identified in the IPCC simulations (but not in the GLACE experiment) is indeed a realistic feature. Note that the time scale of the analysis, subseasonal for GLACE *vs.* interannual for the IPCC analysis, as well as the fact that the GLACE results are based on 1994 simulations, may play a role for these results, as discussed in [7]. This will be investigated in more detail in the 2nd phase of the GLACE project [8].

This comparison highlights the high potential of using observations and observation–based data to investigate such relationships, and the need to develop corresponding new diagnostics of land–atmosphere coupling that can be applied both to observations and model data. This is particularly relevant given the large uncertainties existing in current climate models regarding the representation of land-atmosphere interactions [5, 9; see also Dirmeyer *et al.*, page 14 in this issue]. The comparison provided in Fig. 1 is in this respect still preliminary.

Europe is not only found to entail a hot spot of land-atmosphere coupling in the Mediterranean region in present climate (Fig. 1e), but this region of strong land–atmosphere coupling is also projected to expand northward with climate change, with significant implications for *e.g.* extreme events, and in particular heat waves [7]. Note that even in present climate, soil moisture is identified as playing an important role for the occurrence of heat waves in (individual) extreme European summers [10, 11].

Although Europe is a region with overall good observational coverage, it does not include long-term soil moisture measurement networks so far [1]. Because of the projected enhancement of soil moisture–climate coupling in this region, which implies an increasingly important role of soil moisture for the occurrence of precipitation and extreme temperatures, the development of such measurement networks should be strongly encouraged. This would also be of high relevance for weather and subseasonal to seasonal forecasting.

First initiatives to extensively measure soil moisture are starting to take place, among others in Spain [12], France [13], Germany (www.tereno.net) and Switzerland (www.iac.ethz.ch/url/research/SwissSMEX). These newly collected data will be invaluable for the validation and improvement of current models regarding land-atmosphere interactions and associated processes, in particular using new diagnostics of land–atmosphere coupling. ■

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Joe Santanello is a Physical Scientist in the Hydrological Sciences Branch at NASA's Goddard Space Flight Center. Joe has been with NASA since 2005 where he specializes in land–atmosphere interaction research and the quantifying the role of the planetary boundary layer in modulating the energy and water cycle. He has published on a range of topics that combine mesoscale, boundary layer, and land surface modelling with satellite and ground–based remote sensing observations. Having been formally trained (BS and MSc) in meteorology, his PhD research in the Dept. Geography at Boston University provided the interdisciplinary expertise necessary to become a liaison between hydrologic and atmospheric research groups working towards a fuller understanding of Earth System Science. His current research focuses on developing diagnostics to quantify the strength and accuracy of the land–atmosphere coupling in prediction models, and evaluating the ability of satellite remote sensing to capture such interactions at global and daily time scales.

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Diagnosing the local land–atmosphere coupling in models and observations

Numerical models used to simulate and predict the state of the land surface and atmosphere are typically developed, tested, and evaluated separately and by different scientific communities. This has resulted in deficiencies in models where the land and atmosphere are coupled, with little understanding of the strengths and the interactions between the two. Therefore, this study aims to develop a robust methodology to quantify and evaluate the land–atmosphere (L–A) components of coupled models.

The degree to which the land influences the atmosphere (and vice-versa) is difficult to quantify given the varying resolutions and complexities of the governing processes and lack of comprehensive observations [1, 2, 3]. However, the growth of the daytime planetary boundary layer (PBL) in the lowest few kilometres above the surface serves as a short-term memory of land surface processes. The PBL acts to integrate the fluxes of heat and moisture from the land surface into the atmosphere each day on regional scales (10–100 km). The evolution and properties of the PBL are therefore diagnostic of the L–A interaction [4, 5, 6, 7].

Furthermore, the balance established between fluxes from the land surface and the response of the growing PBL is a function of the strength of coupling and the influence of feedbacks within the L–A system [8]. As a result, knowledge of temperature and moisture evolution in the PBL is instrumental in estimating the heat and moisture exchange with the land surface and in turn quantifying and improving L–A representations in coupled models.

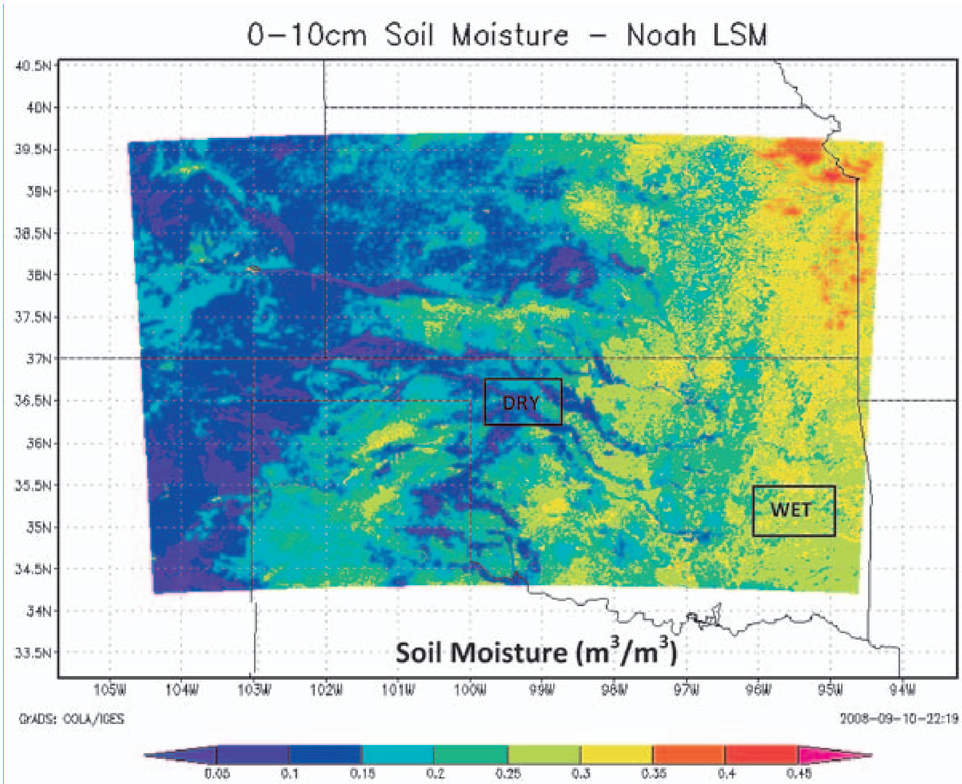

Figure 1. Near-surface (0–10 cm) soil moisture (m^3m^{-3}) valid at 7am on 12 June 2002 as simulated from a 2.5 year spinup of the Noah land surface model (using LIS) over a 1-km horizontal resolution domain in the SGP.

Recently, identifying hotspots of large–scale and seasonal L–A coupling with models has progressed [9]. However, comprehensive understanding of *local land–atmosphere coupling* (hereafter referred to as 'LoCo') at the process level has to be developed. For example, the broader impact of soil moisture on precipitation is comprised of multiple L–A relationships such as those of soil moisture–evaporation, and evaporation–PBL turbulence. The strength and nature of these relationships ('coupling strength') is therefore a critical component of prediction models and influences the simulation of sensible weather (such as temperature, humidity, wind), turbulence, cloud development, and precipitation across a range of scales.

A methodology to quantify LoCo and its inherent relationships must be robust and useful to the community. It must, therefore, be comprehensive and incorporate the full set of L–A processes and feedbacks. At the same time, it should be implemented by using easily observed and understood properties of the system (such as air temperature, humidity, PBL depth) such that it can be applied to any model and evaluated against observations.

A relatively straightforward but untested approach that satisfies these requirements is the concept of representing LoCo processes in the form of 'mixing diagrams', as introduced by Betts [10]. This is done by using the integrative nature of the PBL and commonly measured variables such as air temperature and humidity to derive more complex land-atmosphere processes that control the L–A exchange of water and energy.

Specifically, the mixing diagram approach relates the daytime evolution of air temperature (T) and humidity (q) to the L–A exchange of heat and moisture and the growth of the PBL. As a result, the variability of T and q is sensitive to and integrative of the dominant processes involved in LoCo, the calculation of which requires only variables which are routinely measured and output from coupled models.

To serve as an experimental testbed for this approach, the community–based Weather Research and Forecasting (WRF) atmospheric model has been coupled to the Land Information System (LIS) developed by the National Aeronautics and Space Administration (NASA) [11]. The LIS–WRF coupled system thus combines a suite of atmospheric turbulence (PBL) models with multiple land surface model (LSM) options. This provides a flexible modelling interface that can be used to evaluate the behaviour of different LSM–PBL scheme interactions (L–A coupling) using readily available observations.

Fig. 1 shows the near-surface soil moisture conditions during a June 2002 campaign in the US Southern Great Plains (SGP) as simulated by the Noah land surface model in LIS at 1–km spatial grid spacing. The soil temperature and moisture states generated by this simulation are then used as input to the coupled LIS–WRF simulation over the same region. The high-resolution of the land (soils and vegetation) data in LIS produces a much improved representation of the spatial variability of surface heat and moisture conditions in the SGP region versus what the WRF model provides on its own.

36-hour simulations are then run using the fully coupled LIS–WRF system, each with a different LSM–PBL scheme combination. This allows for the PBL and land surface states (*e.g.* T, q) to evolve in response to the L–A interactions generated by each LSM–PBL combination.

An example of applying the mixing diagram approach to these results is shown in Fig. 2 [12]. Here, the daytime evolution of T and q as simulated by LIS–WRF during 12 June 2002 is shown for the dry and wet soil moisture sites seen in Fig. 1. Each line colour (red, green, blue) represents a different LSM–PBL scheme combination in relation to what was observed (black) at each site.

Overall, the results show that soil moisture anomalies (dry *vs.* wet) lead to different patterns of T and q evolution throughout the day. Significant warming and drying occurs at the dry site as a result of strong surface heating that leads to large PBL growth (and warm, dry air mixing in at the PBL top, known as 'entrainment'). The converse is evident at the wet site, with a signature of moistening and very little warming as a result of strong surface evaporation and limited PBL growth and entrainment.

More importantly from a LoCo perspective, the evolution of T and q can be broken down to components that represent the contribution of heat and moisture from the land surface versus that from the top of the PBL (via entrainment). Therefore, mixing diagrams such as these provide a snapshot of the full nature of the L–A interaction, including quantification of the governing processes (*i.e.* fluxes of heat and moisture). Further, the model range depicts the spread due to different LSM–PBL combinations in LIS-WRF, and when these are evaluated against the observations can be used to pinpoint the weaknesses in either the land and/or atmospheric component of the model.

Overall, this approach provides a pathway to study the individual and collective factors determining the strength and nature of LoCo. This work, funded by the NASA Energy and Water Cycle Study (NEWS), also serves as the backbone for an international effort supported by the GEWEX Global Land/Atmosphere System Study (GLASS) to evaluate LoCo in models and observations across the globe.

Lastly, these studies combine models with observations to evaluate the significance and accuracy of these interactions and can be applied to any model and location of interest. Therefore, a simple yet robust technique such as this highlights the potential utility of routine observations of land surface and PBL properties (such as T and q) from current and future NASA satellite platforms to evaluate and improve prediction models. ■

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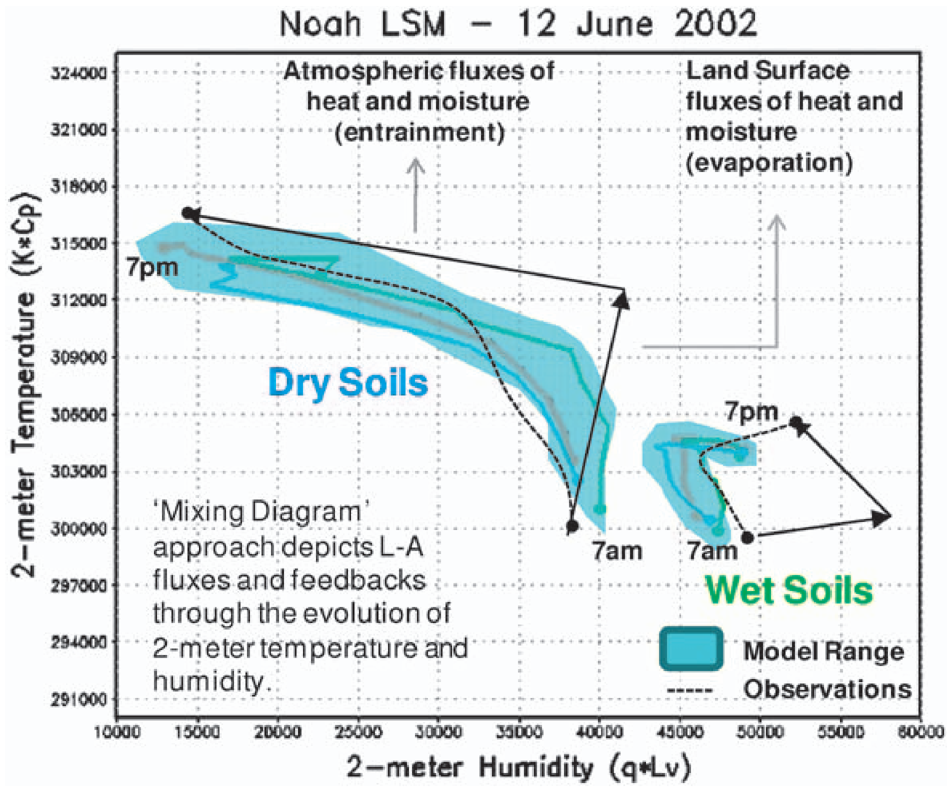

Figure 2. Diurnal co–evolution of 2m–specific humidity and 2m-potential temperature as simulated by LIS–WRF for the dry and wet soil moisture locations in Fig. 1 using the Noah LSM coupled to the three different PBL schemes. The shaded regions for each indicate the model range for each of the LSM–PBL couplings (*red, green, and blue lines*). Also shown are the vectors (black arrows) that represent the fluxes of heat and moisture from the land surface versus those from the atmosphere due to entrainment.

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6. Managing land systems to cope with global change and to develop sustain-able pathways for the future

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- Direct and indirect interactions of urban areas and land use changes
- Competition for land
- Urban areas and climate impacts
- Impact of urbanisation on large scale (beyond urban areas) biogeochemical cycles and ecosystem functions and sustainable cities in arid areas
- Sustainable cities in arid areas

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The ecological theory of climate models

The world's terrestrial ecosystems influence climate through physical, chemical, and biological processes that affect planetary energetics, the hydrologic cycle, and atmospheric composition [1].

The development of numerical models that represent these land–surface processes in global models of the Earth's climate is a compelling example of scientific advancement through multi–disciplinary research. The same applies to the evolution of these land–surface models from their hydrometeorological origin to include the carbon cycle, vegetation dynamics, and land use. The interdisciplinary science used there seeks to identify and understand ecosystem feedbacks in the Earth system and the potential of ecosystems to mitigate climate change.

The first representation of the Earth's land surface in global climate models excluded vegetation. Instead, it represented the hydrologic cycle as a simple water balance in which precipitation fills the soil to a specified water–holding capacity beyond which precipitation runs off [2].

Model development in the mid–1980s expanded this geophysical representation of the land surface to a biogeophysical paradigm by addressing the full hydrologic cycle and plant canopies, especially the physical and biological controls of evapotranspiration (evaporation from surfaces and transpiration by plants) [3, 4]. Model experiments demonstrated that vegetation indeed regulated climate by biogeophysical processes such as albedo, turbulent fluxes, and the hydrologic cycle (*e.g.* tropical deforestation [5]).

In the mid–1990s, new theoretical developments advanced the representation of the biological control of evapotranspiration: it was now possible to link the biochemistry of photosynthesis with the biophysics of stomatal conductance (a measure of how open stomata are; stomata, small pores on leaf surfaces, conduct water and carbon dioxide) and to scale leaf processes to the plant canopy using concepts of sunlit and shaded leaves and the optimal allocation of photosynthetic enzymes [6, 7].

Including stomatal processes in the models identified an important physiological feedback for climate simulations: the decline in stomatal conductance and transpiration with increasing atmospheric carbon dioxide (CO_2) [8]. Model simulations also revealed the role of the biosphere in influencing the annual cycle and inter-hemispheric gradient of atmospheric CO_2 [9, 10].

Formalisation of global models of vegetation dynamics in the late–1990s [11, 12] and their coupling to land–surface models incorporated theoretical advances in ecology to form a model of the coupled biosphere-atmosphere system. In these models, climate influences the biosphere, and in turn, the type of plants (*e.g.* tree, grass, shrub) and the amount of biomass regulate energy, water, and carbon fluxes that affect climate.

Model experiments demonstrated biogeophysical feedbacks from coupled climate–vegetation dynamics. For example, expansion of forest into tundra in the Arctic [13] and forest into desert in North Africa [14] decreases surface albedo and alters climate. Other model experiments identified the role of the carbon cycle to accentuate anthropogenic greenhouse gas warming [15, 16].

Development of the current generation of land–surface models for climate simulations continues to incorporate theoretical advances in ecology. For example, many models do not represent individual plants and exclude key ecological principles of plant allometry (relative size of organs or parts of organisms; tree allometry estimates *e.g.* tree volume from an easily–measured attribute such as diameter) and size–structure that are important determinants of vegetation dynamics.

A new class of models integrates the biogeophysics and biogeochemistry of surface energy, water, and carbon fluxes with long–term demographic and ecosystem processes [17]. Such developments mark the evolution of land–surface models to ecosystem models.

Adding new ecological processes to the models has helped researchers identify novel feedbacks. High surface ozone concentration reduces stomatal conductance [18]. Increased diffuse radiation from aerosols enhances photosynthetic CO_2 uptake [19]. Methane emissions from peatlands may exacerbate global warming [20]. However, two long–standing ecological mechanisms of climate change—the carbon cycle and land cover change—remain at the forefront of model development.

Intercomparison of climate simulations with carbon cycle feedbacks reveals large variation in the simulated carbon cycle –

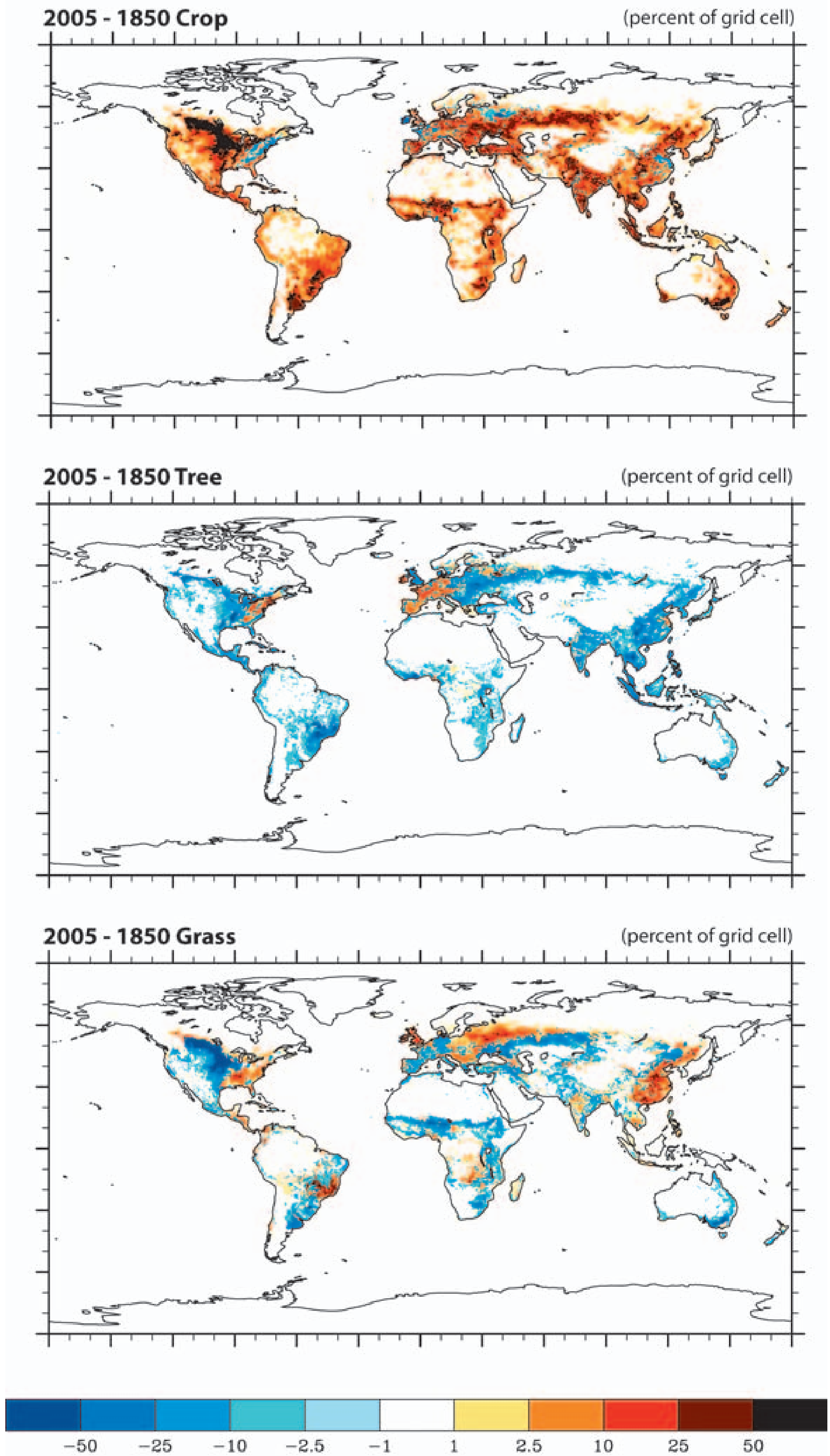

Figure 1. Land cover change as represented in the NCAR Community Land Model version 4 (CLM4). Shown is the difference in crop, tree, and grass cover (percent of model grid cell) in 2005 compared with 1850. Crop and pasture extents are based on the University of New Hampshire Land–Use History version 1 (LUHa.v1) historical dataset (*http://luh.unh.edu*).

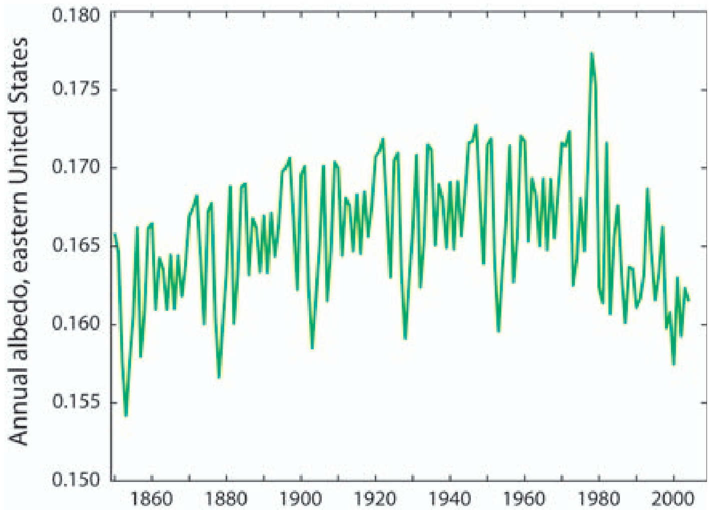

Figure 2. Annual albedo for eastern United States simulated by CLM4 (uncoupled from a climate model) for the period 1850–2005. The time period through 1972 uses a 25–year repeating meteorology. The period 1973–2005 uses observed meteorology.

climate coupling [16]. The prevailing paradigm of these models is that CO_2 fertilisation increases terrestrial carbon sinks but warming weakens the sinks because of higher respiration losses.

However, plant productivity depends not only on available CO_2 but also on available nitrogen. Models of the terrestrial carbon cycle that also include a nitrogen cycle highlight a critical carbon–nitrogen interaction: limited nitrogen availability decreases the CO_2 fertilisation response, but greater nitrogen mineralisation in a warmer climate may stimulate plant productivity [21, 22, 23, 24]. The relative importance of these processes is still unclear.

Few models currently account for the effect of land use change on CO_2 flux directly [25], although much of the natural vegetation of the world has been cleared for agriculture and pastureland (Fig. 1). Most models suggest that land cover change in mid–latitudes during the industrial era has influenced climate, but the magnitude and even the sign of this simulated climate change varies according to the different parameterisations of albedo, evapotranspiration, and crop phenology (seasonal development) in the models [26].

For albedo, satellite observations can guide model development (*e.g.* differences between forest and crop), but the effects of land cover change on evapotranspiration are less well known [1].

Many models utilise a paradigm in which deep–rooted trees have greater rates of evapotranspiration than shallow–rooted crops and grasses, but the validity of this is not certain. Some models include parameterisations of crop growth and management [27, 28], which can affect the resulting simulated climate change signal [26].

An understanding of the combined biogeophysical and biogeochemical climate forcing through land use and land cover change remains an elusive goal.

Historical land cover datasets have been incorporated into the current generation of models and provide input data for transient land cover change as part of climate change simulations (Fig. 1). This includes deforestation, reforestation, timber harvest, cultivation of cropland, and pastureland and has competing biogeophysical and biogeochemical effects on climate.

For example, according to the National Center for Atmospheric Research (NCAR) Community Land Model version 4 (CLM4) loss of forest increased surface albedo in eastern United States through the mid–twentieth century until warming reduced snow cover and decreased the albedo in the late–twentieth century (Fig. 2). Globally, land use and land cover change have provided a net release of carbon to the atmosphere during this period (Fig. 3).

Future land use and land cover change driven by socioeconomic needs, societal responses to climate change, and policy implementation will also affect climate [29, 30]. As climate models evolve into Earth system models with representation of terrestrial ecosystems, they can provide valuable information necessary for better land management practices that can serve to mitigate climate change.

Reforestation, afforestation, and avoided deforestation are such potential practices, but the interplay among albedo, evapotranspiration, and the carbon cycle is not well understood [1]. These, and other, climate effects of ecosystems need to be better understood to craft strong climate change mitigation science.

The progression of climate models into Earth system models requires much ecological theory about terrestrial ecosystem feedback processes. However, extrapolation of process-level understanding of ecosystem functioning gained from laboratory experiments or field studies to large–scale Earth system models remains a challenge. Improved observational constraints across a variety of scales including eddy covariance flux towers, ecosystem manipulation and long–term monitoring, satellite sensors, and atmospheric monitoring of CO_2 as well as model–data fusion techniques are necessary to better understand ecological forcing and feedbacks in the Earth system. ■

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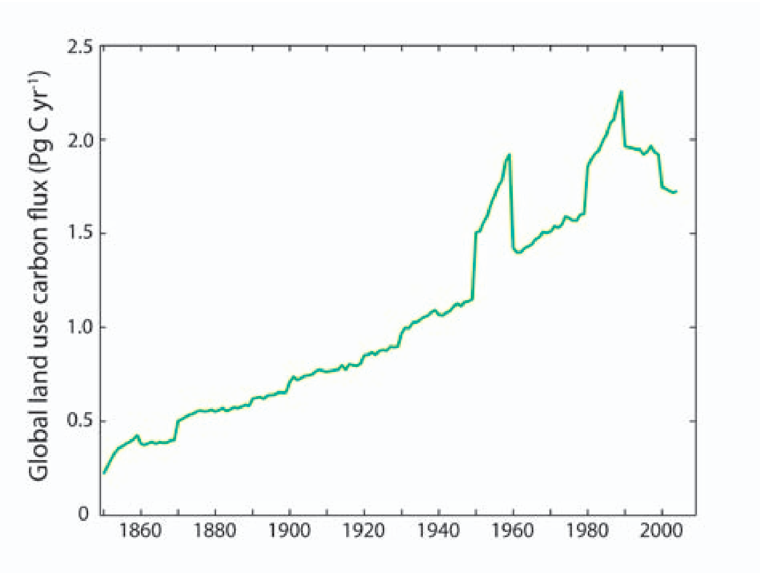

Figure 3. As in Fig. 2, but for annual global land use carbon flux simulated by CLM4 for the period 1850–2005.

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Using observations to help constrain coupled climate–carbon cycle models

Climate–carbon cycle science

Elevated atmospheric CO_2 concentration will be the principal driver of climate change in the 21st century. Global models of the coupled climate–carbon system have shown that climate change induces a reduction in the capacity of both terrestrial and ocean to absorb atmospheric CO_2 [1–10].

Consequently, these reduced sinks lead to further build–up of atmospheric CO_2 concentrations. The Coupled Climate–Carbon Cycle Model Inter–comparison Project (C4MIP) [11] estimated that this increase is 20–220 ppm by 2100. This corresponds to an additional climate warming of up to 0.9 °C [12]. This has major policy implications for climate change mitigation and reduces the amount of "permissible" emissions that have been designed to stabilise the atmospheric CO_2 concentration [13].

Most C4MIP models attribute their overall carbon-climate change response to the combined effect of

1. reductions in land carbon uptake in the tropics, and a widespread, climate–driven, loss of soil carbon
2. increases in vegetation biomass in the temperate and boreal zone, and
3. to a decrease of CO_2 uptake by the oceans, caused both by ocean warming and by a shrinking volume of the surface mixed layer.

The broad range of the carbon cycle response to climate warming among these models reflects the differences in how the models represent basic carbon cycle processes and their interactions [14–16].

However, despite future uncertainties, all C4MIP models are able to simulate a 20th century CO_2 increase broadly consistent with the historical record, with an atmospheric CO_2 concentration of 380 ±14 ppm in 2005. The observed concentration in 2005 was 379 ppm [17]. Simulating the cumulated change in atmospheric CO_2 during the 20th century is thus *a necessary but not sufficient* condition to validate a coupled climate–carbon cycle model. In other words, the capability of a model to reproduce atmospheric CO_2 concentration over the 20th century does not guarantee that it perfectly represents biogeochemical processes.

Model evaluation

It is important both to identify sufficient observational constraints that will reduce the uncertainty in the range of future model projections and to improve the understanding of carbon cycle mechanisms.

Typically, each carbon cycle model component has been evaluated against a subset of the data derived from measurement, field experiment, and Earth Observation data. Data used in model evaluation of the terrestrial carbon cycle include:

- atmospheric CO_2 concentration as measured by the global network of monitoring stations which are influenced by air masses originating from both oceanic and terrestrial regions [18–20]
- eddy-covariance flux towers (measure local net land–atmosphere fluxes on a hourly basis from individual terrestrial ecosystems [21, 22])
- forest inventory and surveys [23, 24]
- satellite-derived maps of vegetation activity, also called greenness (measures seasonal plant phenology [25, 26]).

The systematic benchmarking (evaluation of simulated variables against observations) of models are emerging themes in the modelling community. Yet there is a need to develop a consensus on the datasets to use as well as on the evaluation methods exploiting these datasets.

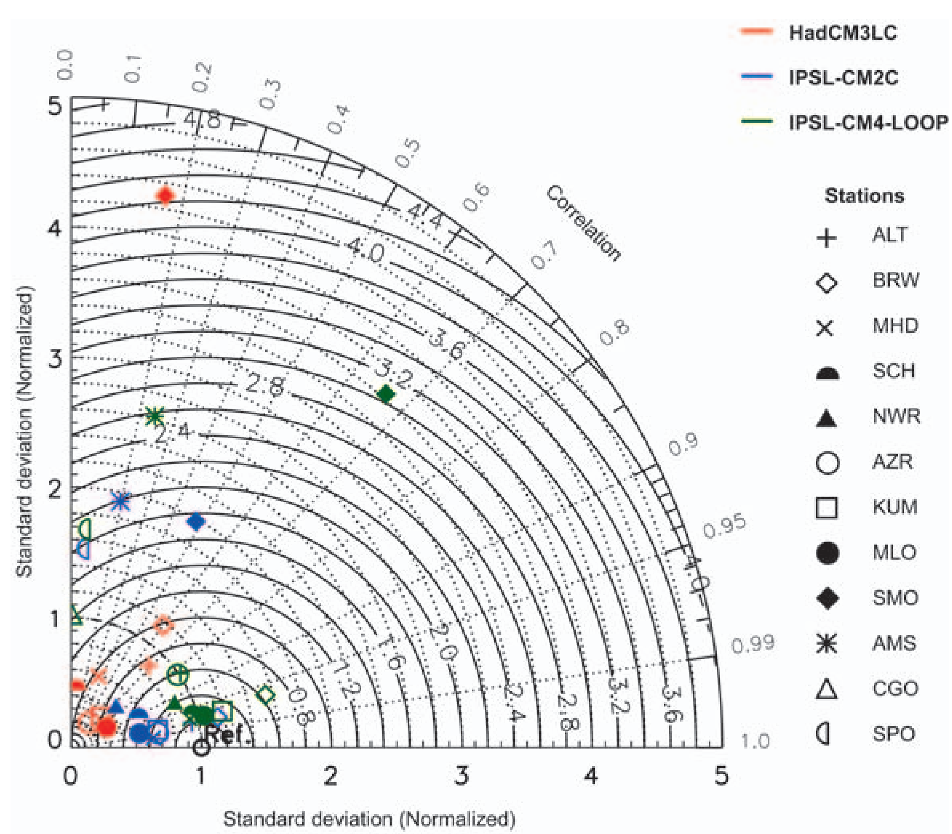

Figure 1. Taylor diagram of the mean seasonal cycle at the 12 stations, for the 3 models (HadCM3LC, IPSL–CM2–LC, and IPSL–CM4–LOOP) over 1979–2003.

Several national and international projects (such as Carbon Land Model Intercomparison Project [C–LAMP], International Land–Atmosphere Model Benchmarking [I–LAMB], CARBONES, GreenCycle2) are today contributing to that objective. The evaluation methods, based on statistical analysis, aim at directly or indirectly evaluating the capability of models to simulate biogeochemical processes.

In that context, Taylor diagrams (graphically conveying information about the similarity between a pattern (or a set of patterns) and observations) enable us to summarise the relative performance of a set of models [27]. However, Taylor diagrams make multi–criteria evaluation amongst several models very difficult (Fig. 1).

From evaluation to benchmarking coupled carbon–climate models

There is thus a need for a scalable set of performance metrics to quantify the ability of coupled climate–carbon models to reproduce key processes of climate–carbon projections [12, 28].

Cadule *et al.* [29] designed new metrics based on various characteristics of atmospheric CO_2 at three different time scales (Fig. 2):

- TR: the long–term term trend of atmospheric CO_2. TR demonstrates the model's capability to simulate realistic terrestrial and ocean carbon sinks over the historical period
- SC: the modelled atmospheric CO_2 seasonal cycle. Particularly at northern–hemisphere atmospheric CO_2 stations, SC constrains the model's simulation of the terrestrial fluxes seasonal activity: vegetation growth in spring and summer, and vegetation decay in autumn
- IAV: the inter-annual variability of the atmospheric CO_2. IAV is a constraint on the model capability to simulate realistic El Niño–Southern Oscillation (ENSO) climate patterns and effects on terrestrial and ocean carbon fluxes.

We first evaluated the model capability

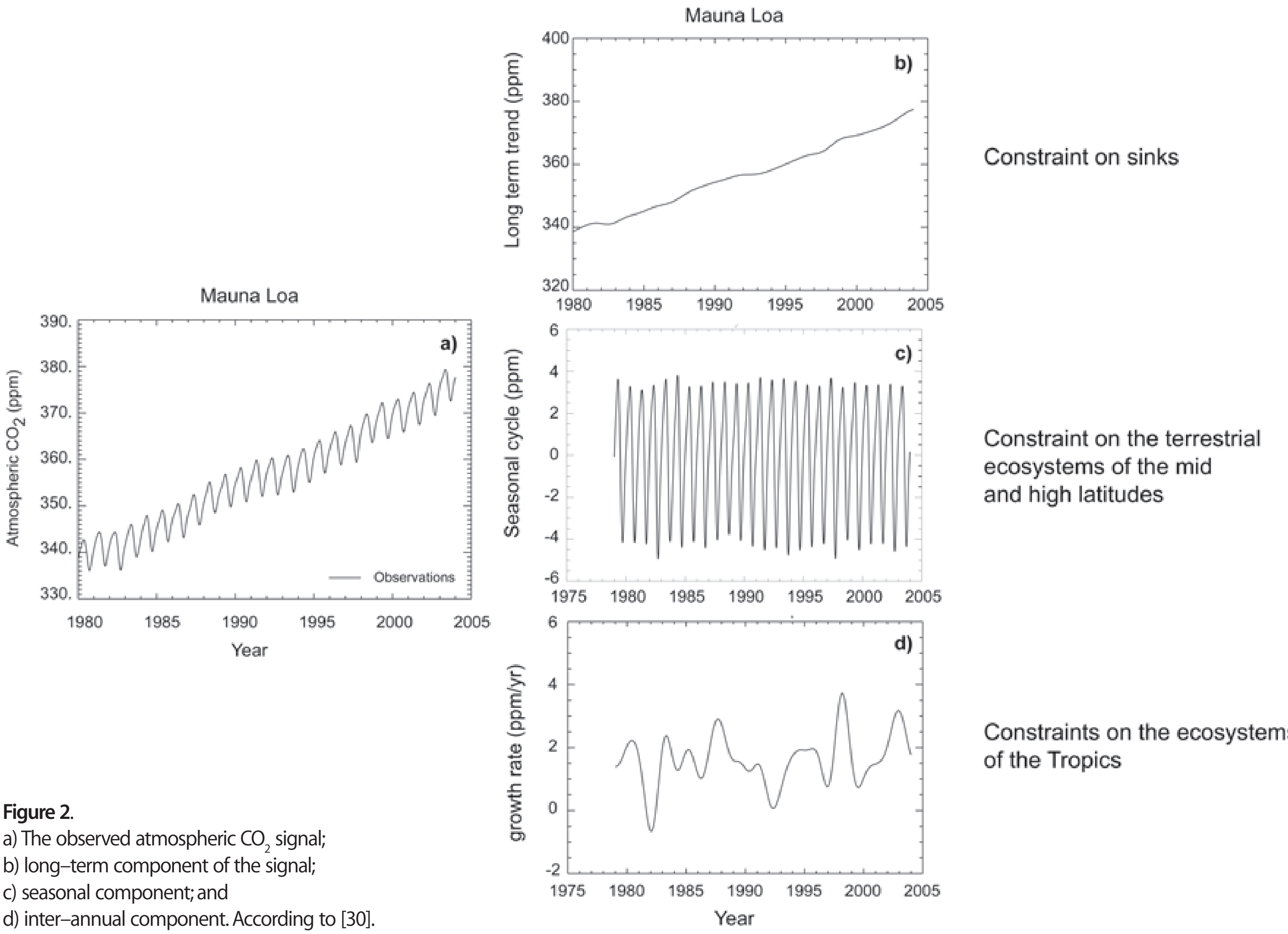

Figure 2.
a) The observed atmospheric CO_2 signal;
b) long–term component of the signal;
c) seasonal component; and
d) inter–annual component. According to [30].

to represent the CO_2 signal and then the sensitivity of the atmospheric CO_2 to climatic fluctuations at seasonal and inter-annual time scales [12].

These new metrics were applied to three C[4]MIP models, HadCM3LC [1], IPSL–CM2–C [3], and IPSL–CM4–LOOP [10]. Our results confirmed that multiple time scales are necessary to evaluate models: the best model on seasonal time scale did not out–perform others on the inter–annual time scale.

A further advantage of defining single metrics is that it allows for testing future structural improvements of models and inclusion of new processes in the same rigorously defined framework. Indeed, the new generation IPSL model (IPSL–CM4-LOOP) out-performs the older IPSL–CM2–C on all metrics [1].

However, it is important to appropriately interpret the absolute and relative performance of the models. The models do not integrate all forcings consistently with the C[4]MIP project simulations) and neither do they represent the full complexity of the Earth system. Therefore, an agreement with the observations is not a guaranty that the simulated process is perfect. Conversely, when using models with an equivalent level of complexity it becomes possible to compare the models' results and thus highlight their differences.

In the future, efforts should be continued to design metrics than can condense in few indicators a lot of information such as satellite observation, flux tower data (now more than 500 sites; *www.fluxnet.ornl.gov/fluxnet/viewstatus*), and continuous (as opposed to discrete flask sampling) atmospheric CO_2 observations. Particular attention should be devoted to metrics and data that are related to important characteristics of future projections rather than simply verify that models broadly perform, and can thus help improve their parameterisations and also constrain predictions. ■

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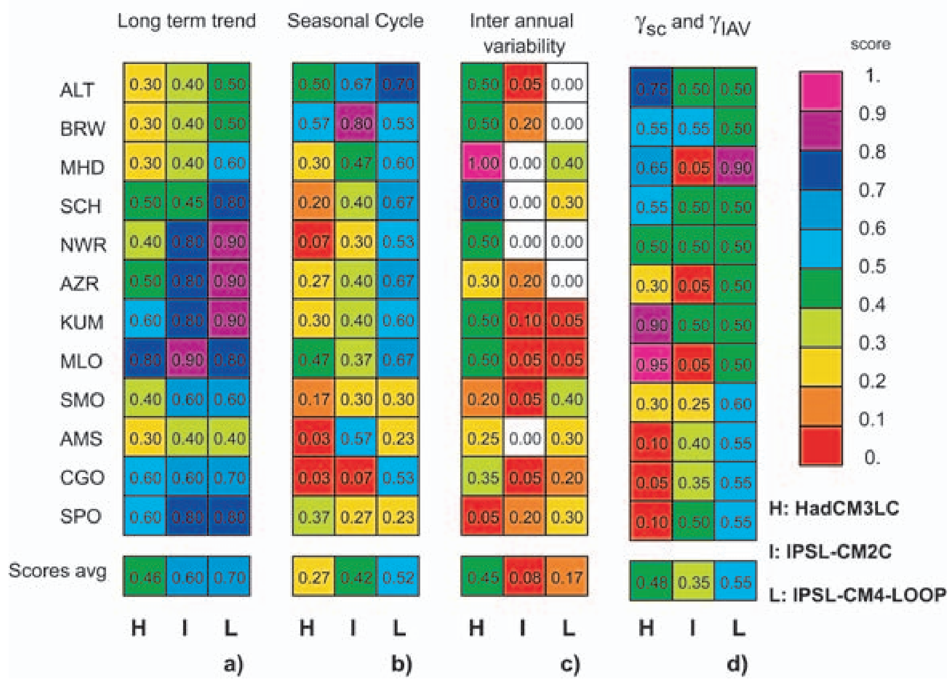
Figure 3. Matrix displaying the three models (H: HadCM3LC, I: IPSL–CM2–LC, and L: IPSL–CM4–LOOP) scores (see colour bar) at all stations. Long-term trend (TR) score is the average of 2 traits: the trend in growth rate and the trend in inter–hemispheric gradient. Seasonal cycle (SC) score is the average of 3 traits: climatic average traits (phase and amplitude), and the trend in the peak to peak amplitude. Inter–annual variability score (IAV) is the average of 2 traits: the El Niño and La Niña CO_2 variability. "SC and IAV" is the average of 2 traits: (seasonal and inter–annual) CO_2-temperature sensitivity. According to [29].



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Lina Mercado works on vegetation modelling with emphasis on the representation of plant physiology within land surface models. Her recent work includes improvement of model description of radiation interception and photosynthesis within the JULES land surface scheme of the UK Hadley centre model. These improvements have specifically led to better representation of photosynthetic rates within JULES globally. Additional research interests include the Amazon forest and biogeochemical cycling. She did her PhD studies at the Max Planck Institute for Biogeochemistry in Jena, Germany, and in the Free University of Amsterdam in Amsterdam, the Netherlands.

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The impact of diffuse radiation changes on the land carbon sink

Radiation levels are crucial for plant photosynthesis: both the quantity and quality of the radiation are important. Atmospheric aerosols and clouds influence both of these characteristics, tending to reduce the amount of sunlight reaching the surface but also enhancing the fraction of sunlight that is diffuse.

Volcanic eruptions and the increase of anthropogenic aerosol emissions have led to significant changes in radiation reaching the land surface at global and regional levels. Such changes have mainly occurred after the 1950's with a decrease in total surface radiation in many regions of the world between 1950 and 1980, known as "global dimming" [1, 2], and a subsequent increase over 1980–2000 in some regions which has been coined "global brightening" [2].

Plants respond differently to direct and diffuse sky light conditions. At the high light levels received when the sky is clear, leaf photosynthesis tends to saturate (reach maximum and not increase further), whereas at low radiation levels typical of cloudy conditions, leaf photosynthesis increases with increasing radiation (Fig.1).

However, there are two counteracting effects of radiation on plant photosynthesis. When the number of clouds and scattering aerosol particles increases, total radiation decreases which tends to decrease photosynthesis. On the other hand, the diffuse fraction of radiation increases, which tends to enhance photosynthesis. Field-based [3–6] and modelling studies have shown that plants are overall more efficient under diffuse radiation conditions. This has long been recognised by the agriculture and meteorological community [7–10].

We modified the land surface scheme used in the Hadley Centre climate models (JULES) to quantify the effects of changes in surface radiation over the 20th century on photosynthesis and the global land carbon sink. The modifications accounted for the effects of direct and diffuse radiation on canopy photosynthesis, and the new version of JULES was successfully tested against observations from sites where diffuse radiation measurements were available [11].

In addition, we used observed climatological variables [12] and simulated fields of direct and diffuse radiation from a general circulation model (GCM).

On a global scale, our model simulations suggest that changes in the diffuse fraction of solar radiation contributed almost 25% to the global land carbon (C) sink over the period 1960–2000. This effect was counteracted by a 15% reduction of the land C sink caused by the decrease in total radiation over this period. In sum, the simulated net effect of radiation changes on the land carbon sink was therefore an enhancement of about 10%.

At the regional level, the simulations over the global dimming period, showed contributions to the land C sink from increasing diffuse fraction in Europe, the Eastern United States, East Asia and some tropical regions of Africa. (Figs. 2 a & b, *next page*).

Over the global brightening period, our simulations showed a weaker contribution to the carbon sink from changes in diffuse fraction (Figs. 2 c & d). This was because of reductions in diffuse fraction over this period in places such as Europe, Eastern United States, Western Australia, and some regions of Russia and China.

However, across regions of rapid growth and industrialisation such as India and South East China, and some regions of Russia, where diffuse fraction continued to increase, our simulations showed a continued positive contribution of changes in diffuse radiation to the land carbon sink.

We also conducted a simulation to the future using an environmentally friendly scenario where emissions of sulphur dioxide (SO_2) were reduced to the levels of the 1970's and carbon dioxide (CO_2) emissions reach 420 parts per million by volume by the end of year 2100, whereas climate variables were kept constant at 1999 values. Under this scenario, the contribution to the

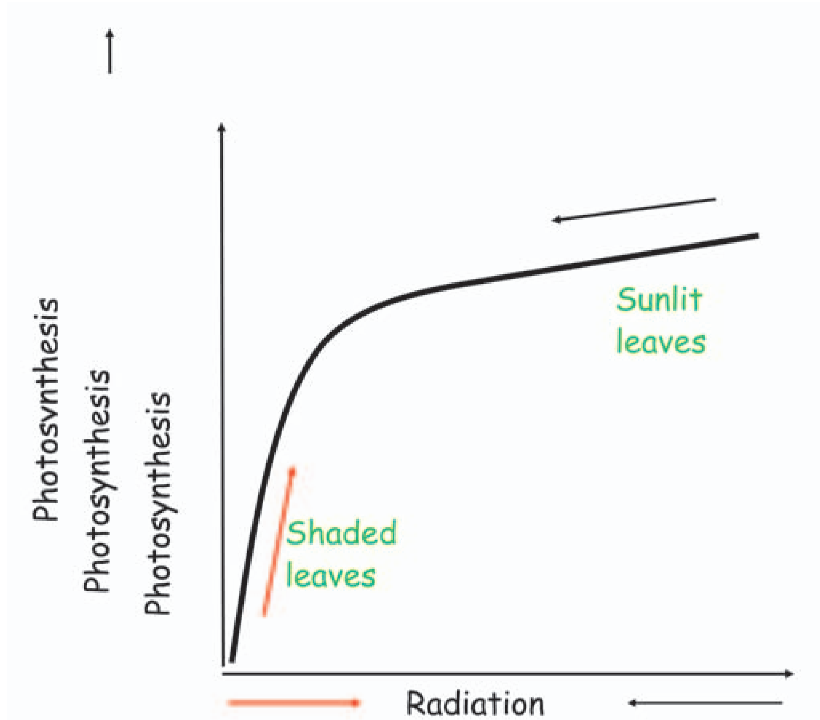

Figure 1. The response of photosynthesis to light. At low radiation levels, photosynthesis increases steeply with light. At high radiation levels, it saturates to near maximum.

land C sink from changes of diffuse radiation disappears. This is because the reduction in aerosols also reduces the diffuse fraction.

If we continue cleaning up the air, which we must do for human health reasons, a loss of this C sink from diffuse radiation changes; in other words, a 'diffuse–radiation fertilisation effect', is inevitable. This implies that the challenge of avoiding dangerous climate change through reductions in CO_2 and other GHG emissions will be even harder.

This is the first global study that quantifies the effect of diffuse radiation on the land carbon sink, and it raises many questions that are worthy of further study, such as:

- What is the limit of aerosol loading up to which photosynthesis increases with increasing diffuse fraction?
- What is the global and regional effect of diffuse radiation changes on the hydrological cycle?
- What are the consequences of climate engineering based on increasing the aerosol load?
- How much does diffuse radiation produced by biogenic aerosols enhance plant photosynthesis?

Photosynthesis increases under diffuse radiation most likely because diffuse sunlight is distributed more evenly than direct sunlight across leaves within the canopy. However, recent research has suggested that the increase in blue/red light in forest canopies under cloudy skies could also lead to larger opening of leaf stomata (pores through which plants transport water and CO_2 between cells and atmosphere) [13] .

More experimental and modelling studies, over a wider range of ecosystems, should allow us to understand these different mechanisms, and to represent important 'diffuse–radiation fertilisation' effects more accurately in climate and carbon cycle models. ■ ➤➤➤

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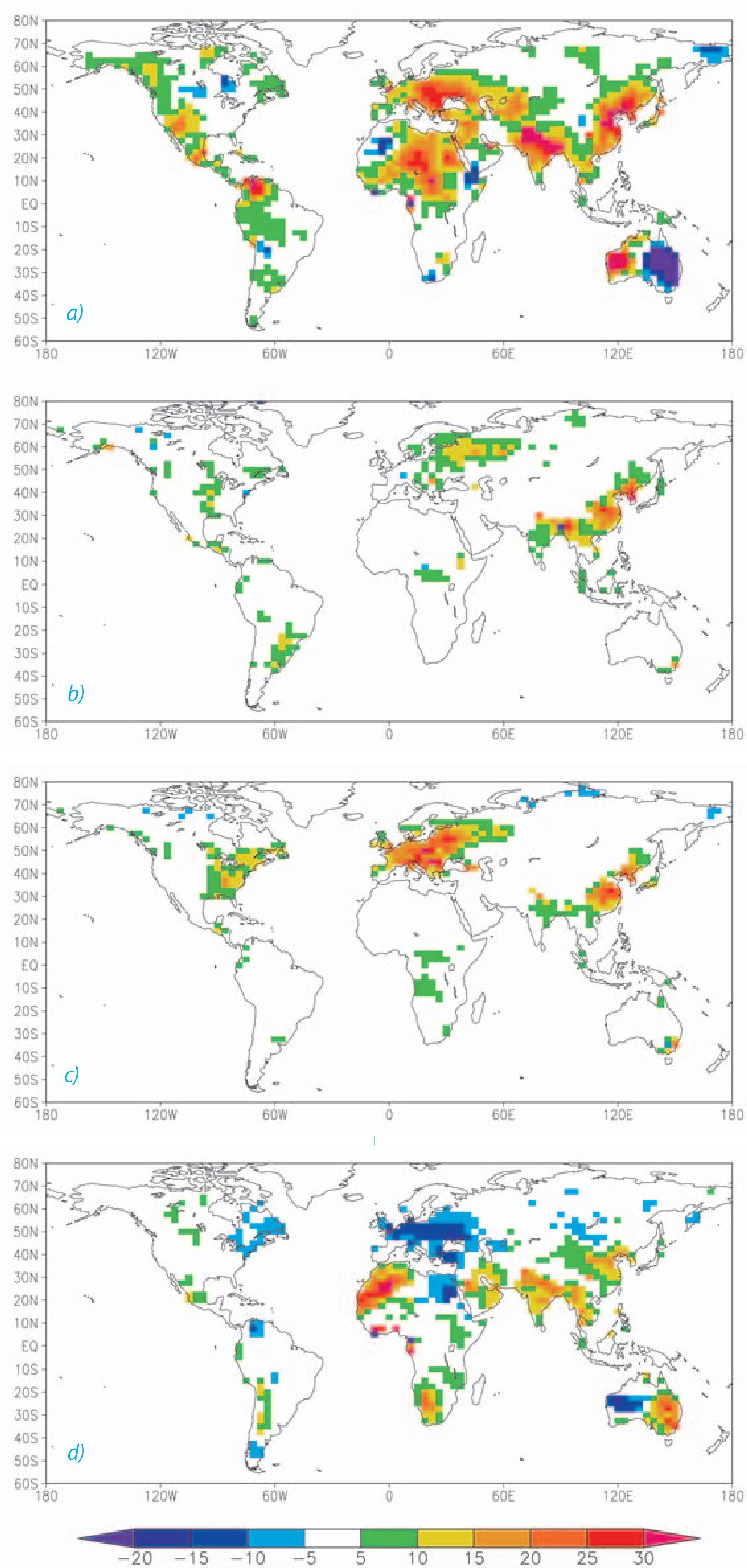

Figure 2.

a) Simulated percentage change in diffuse fraction from 1950 to 1980 and
b) from 1980 to 1999.
c) Simulated change in diffuse fraction contribution to land carbon accumulation from 1950–1980 and
d) from 1980 to 1999 in [g (C) m^{-2} yr^{-1}].

Figure adopted from [11].

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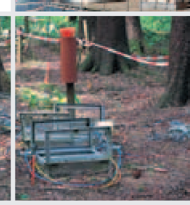

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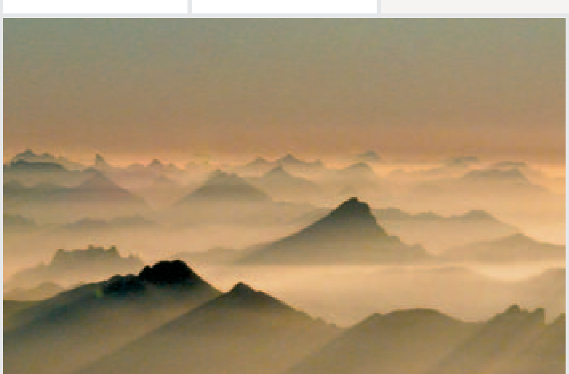

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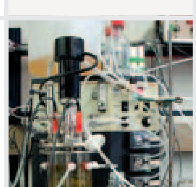

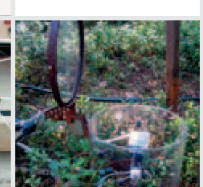

Best poster presentation award at iLEAPS Science Conference, 24–28 August, 2009, Melbourne, Australia

Carol Hensley is currently undertaking a PhD in Environmental Science at Monash University, Australia under the supervision of Associate Professor Jason Beringer and Dr. Peter Isaac. She studies remote sensing of the hydrological cycle, particularly of evapotranspiration and soil moisture. Carol has a background in geology, geophysics, and remote sensing and was introduced to the hydrological field by Dr. Marc Leblanc from James Cook University, Australia in the early stages of her PhD research.

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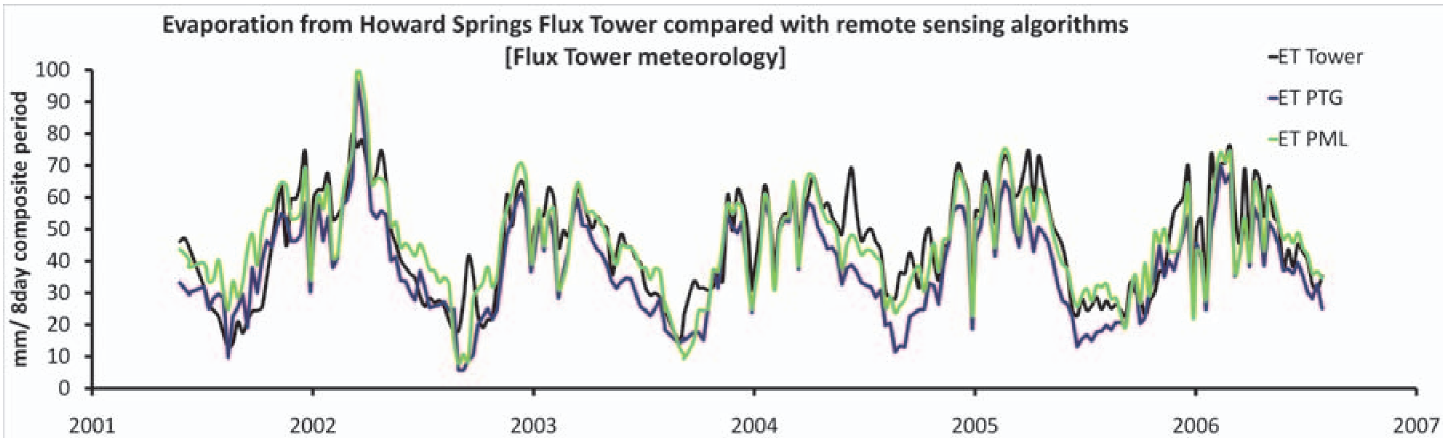
Comparison of remote sensing evapotranspiration models in the Australian savanna

Evapotranspiration (ET) is the combined product of evaporation from free water, the soil surface and from water resting on vegetation surfaces after recent rainfall (interception evaporation), and transpiration where water is pumped via the vegetation vascular system from the roots through the plant until it exits as water vapour through the stomata on the surface of leaves.

Over 80% of global terrestrial ET occurs as transpiration through plants [1] but measurement and analysis of ET using remote sensing techniques is still in development and as yet there are few global ET products available to resource managers. However, recent innovations to estimate ET with remote sensing look extremely promising. In the near future an ET product is expected to be added to the MODerate resolution Imaging Spectroradiometer (MODIS) suite of data products at spatial scales of 500 m – 1 km and daily to monthly frequency. This will provide a critical dataset for a wide range of uses including sustainable water management and climate modelling.

Validation of ET models and products within different biomes is critically important to define the models' capacities and limitations and provides the primary motivation for this work.

We assessed the performance of two recently published models in the wet–dry savanna of northern Australia. Savannas cover one sixth of the Earth's land surface [2] and approximately 25% of Australia. They are particularly difficult to model because of the uneven distribution of trees and grassy vegetation at ground level and how much they vary in green leaf cover between the



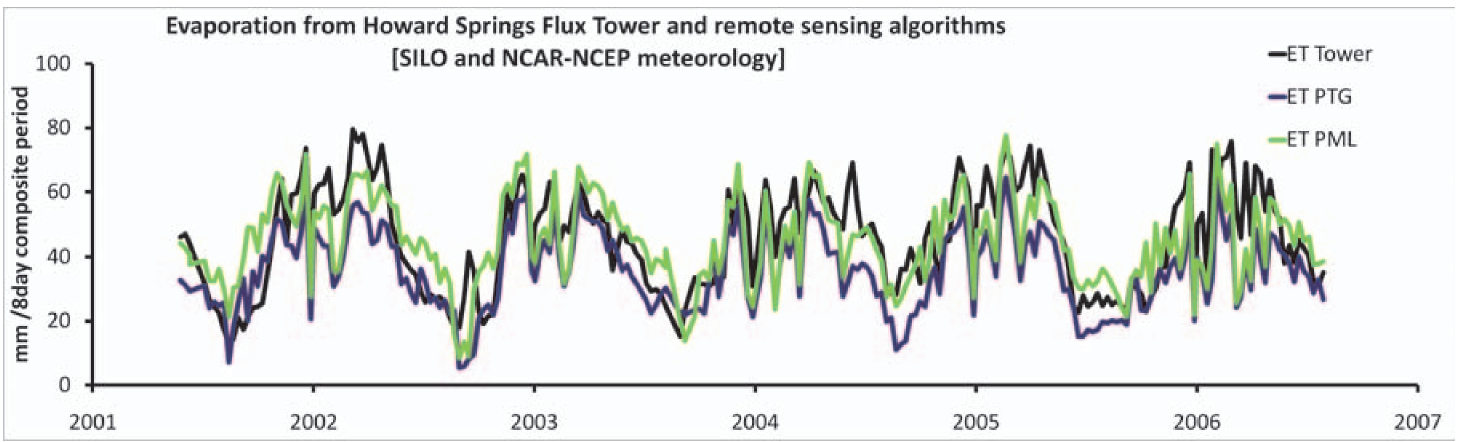


Figure 1. Evapotranspiration (ET) modelled at the Howard Springs flux tower site using locally observed meteorology.

Figure 2. Evapotranspiration (ET) modelled at the Howard Springs site using regional gridded meteorology and showing no significant deterioration in results for either model.

Table 1. PTG and PML model results.

Howard Springs	Regression coefficients	r^2	Daly uncleared	Regression coefficients	r^2
PML 8 days	y = 0.94 x + 4.84	$r^2 = 0.78$	PML 8 days	y = 1.02 x + 3.26	$r^2 = 0.92$
PTG 8 days	y = 0.90 x – 1.23	$r^2 = 0.80$	PTG 8 days	y = 0.73 x + 1.61	$r^2 = 0.75$
PML 1 day	y = 0.82 x + 1.02	$r^2 = 0.66$	PML 1 day	y = 1.02 x + 0.43	$r^2 = 0.88$
PTG 1 day	y = 0.83 x + 0.07	$r^2 = 0.66$	PTG 1 day	y = 0.73 x + 0.16	$r^2 = 0.77$

wet and dry seasons.

The savanna typically receives >90% of annual rainfall in a ~4 month wet season (Dec-Mar). During this time, the grassy understorey grows 1–3 metres high (in areas where grazing and fire are minimised), a sparse partially deciduous shrubby mid–storey comes into full leaf and total leaf area index (LAI, sum of leaf surface area per unit ground area) of under+mid+overstorey increases from as little as 0.7 at the end of the dry season to ~2.4 toward the end of the wet season [3].

In this study we have used MODIS v5 datasets that measure different spectral properties of the Earth's surface that can be used to estimate LAI, indices of vegetation greenness and surface moisture at 500–m spatial scale and 8–day composite intervals. To minimise effects from clouds, NASA (North American Space Agency) provides many of its products as a composite of the best cloud-free pixels over an 8 day period. Our study also uses meteorological data derived from 30–minute flux tower observations and spatially interpolated average daily meteorology.

The first model, PTG (Priestley–Taylor–Guerschman) [4] is based on a modified Priestley-Taylor approach whereby the potential amount of evaporation from a well watered vegetated surface is modelled. The main driver of evaporation is the available energy: the balance of incoming and outgoing short and longwave radiation minus the amount of energy absorbed by the soil. Actual ET is calculated by scaling the Priestley–Taylor potential evapotranspiration term by a crop factor function (k_c) and adding an interception evaporation term (k_{Ei}). The crop factor function is based on the MODIS-derived EVI (Enhanced Vegetation Index) and RMI (Rescaled Moisture Index).

The PTG model has previously been calibrated empirically using observed ET from seven eddy covariance flux tower sites spread across Australia. Model details and parameterisations are published in [4].

The second model, PML (Penman–Monteith–Leuning) is based on the Penman–Monteith equation that describes the evaporation from a vegetated surface that actively participates in restricting evaporation via selective closure of leaf pores (stomata) under non–ideal conditions. This model incorporates terms for both aerodynamic conductance (wind-driven evaporation) and stomatal conductance (transpiration through the leaves) [5]. For regional applications, stomatal conductance can be scaled to canopy conductance using a MODIS–derived leaf area index.

The PML model apportions the available energy between the canopy and bare soil surface according to a fractional vegetation cover function of the MODIS-derived leaf area index. The energy available to the vegetation fraction drives transpiration according to the Penman–Monteith equation whereas the energy available to the bare soil fraction is modelled by the equilibrium evaporation function (similar to the Priestley–Taylor equation but assumes a non–vegetated surface) and is decreased under drier conditions by a soil moisture parameter, *f*, that varies from 1 in wet conditions to 0 in dry conditions.

Typical parameterisations are published in [5] and note that because of a lack of spatial and temporal soil moisture information, *f* has previously been set a fixed value calibrated by flux tower data. This was found to cause relatively large errors at our savanna sites where soil moisture varies so remarkably over the course of a year.

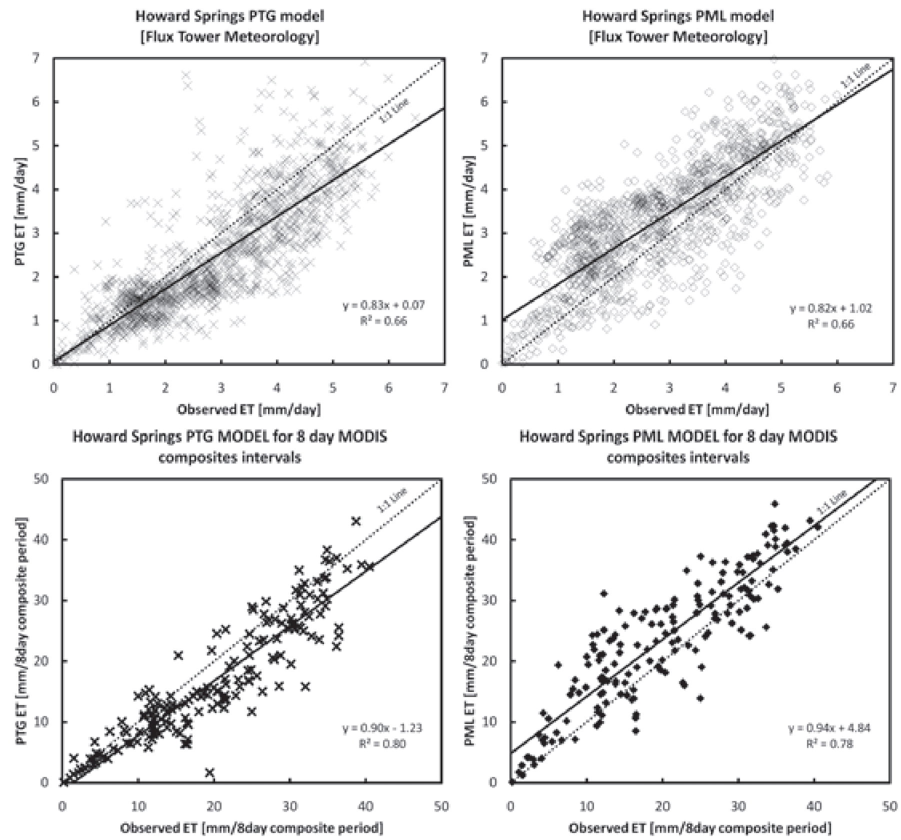


Figure 3. PTG and PML model results *vs.* observed ET at Howard Springs. Results are shown calculated in mm day^{-1} as well as mm per 8–day-period and show that the longer period gives consistently better accuracy and precision. Both models perform equally well.

We therefore extended the original PML model by parameterising *f* based on the Global Vegetation Moisture Index [6], thereby capturing the important seasonal wet–dry dynamic more effectively than a constant site-value of *f*.

The models were driven with site–specific meteorology (30–minute observations) from two savanna flux tower sites (Howard Springs [7] and Daly Uncleared Savanna). For comparison, we also used daily regional gridded meteorology from the Australian SILO [8], McVicar wind speed [9] and AWAP (Australian Water Availability Project) [10] datasets at 0.05-degree resolution in conjunction with NCAR–NCEP (National Center for Atmospheric Research, National Centers for Environmental Prediction) wind speed data at 0.25–degree resolution [11]. Model results degraded only slightly when using regional gridded meteorology (Figs. 1 and 2).

The PTG model tended to underestimate ET at the savanna sites in both the wet and the dry seasons which suggests that the PTG model parameters could be tuned more effectively for savanna environments. Overall, however, the PTG model gave reasonable correlation coefficients (Figs. 3 and 4, Table 1).

The PML model performed particularly well at the Daly Uncleared Savanna site (r^2 = 0.92 for 8-day composite analyses) and acceptably well at the Howard Springs site (r^2 = 0.78). Performance of the PML model was approximately equal in both the wet and the dry seasons. (Figs. 3 and 4, Table 1).

The PML model requires wind field data to calculate aerodynamic conductance. However, the relative contribution of aerodynamic conductance to total ET is small, and if wind data is absent, the aerodynamic conductance may be estimated based on vegetation type as described in [5].

For detailed studies, where wind speed

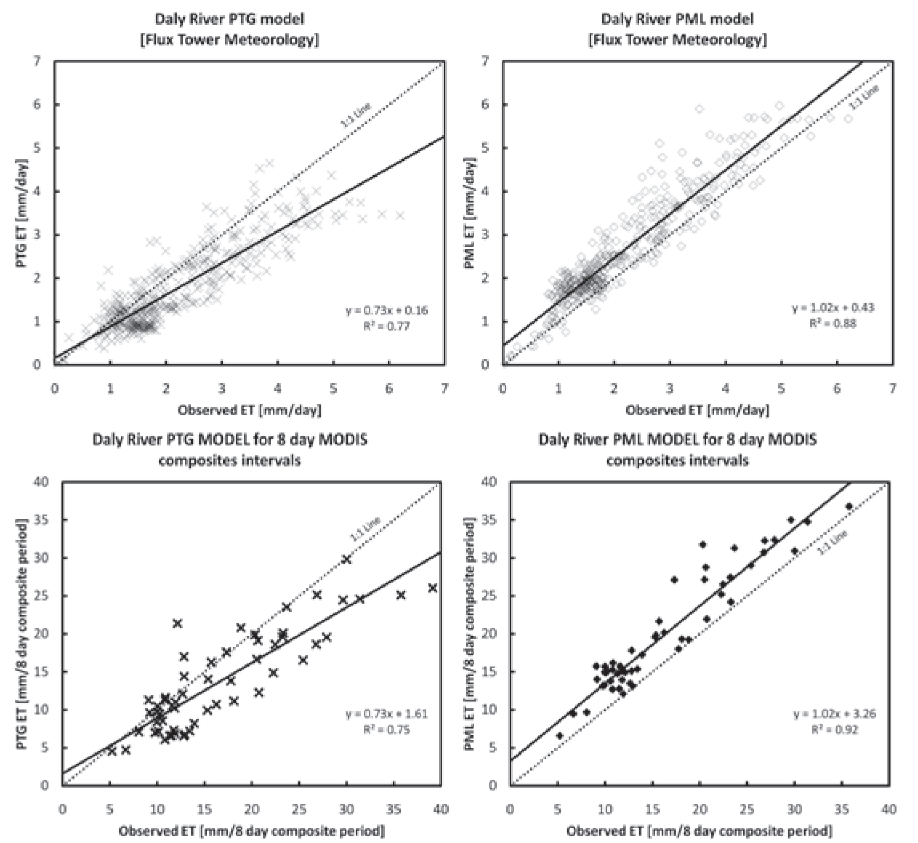


Figure 4. PTG and PML model results vs observed ET at Daly River uncleared savanna flux tower site. In this case, the PML model performs better than the PTG model.

data of reasonable quality and a spatially distributed vegetation height dataset (or aerodynamic parameters dataset) are available, the PML model is relatively straightforward to tune and may therefore offer greater accuracy than the PTG model at the catchment scale.

Over large areas up to continental or global scales and in areas of mixed land cover, we prefer the PTG model because of its simplicity. However, the accuracy of the PTG model may be dependent on its adequate calibration for each applicable biome and its performance outside of the calibration set has not yet been thoroughly tested.

Future climate predictions for the north of Australia are uncertain and so is the adaptability of the savanna vegetation to rapidly changing climatic conditions and increasing climate extremes. Although temperatures and evaporative demand are generally predicted to increase, climate change influence on the monsoonal rainfall is less well understood but may affect the date of monsoon onset, its duration and intensity.

We hope that by accurately monitoring the evapotranspiration of the savanna system, early signs of ecosystem failure, benefit or adaptation will become apparent. There is also strong demand for ET products to be used in the management of bushfire, water resources and agriculture, and for improving climate models. ■

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The succulent thicket of South Africa as a climate regulator

The atmosphere and the land surface are linked through biogeochemical and biophysical feedbacks. The patterns of rainfall and temperature experienced by people and other organisms are the net effect of this interaction. As we change the physical landscape, we modify the exchanges between the biosphere and atmosphere, which in turn alters the climate we experience and the 'climate services' on which we have become dependent.

'Ecosystem services' (or 'ecosystem goods and services') refers to the benefits supplied to, or derived by, humans from nature, and which underlie our well–being and continued existence. These services range from direct products (such as food and timber), to benefits obtained from the natural regulation of ecosystem process (such as the decomposition of waste and the purification of water and air), and to non–material benefits (such as the spiritual and recreational use to nature) [1].

'Climate services' refers to the regulation and stabilisation of climate through the exchange of energy, water and chemical elements. The most well–known climate service is the uptake and fixation of carbon by plants.

We are interested in different land–atmosphere processes and how these processes are perturbed by a change in land cover. We want to know whether a reduction in one exchange process balances against an increase in another, how this will affect the regional weather experienced by people, and whether or not these changes are to the benefit of human well–being.

In this study, we focus on carbon exchange and surface albedo (the fraction of sunlight reflected by a surface), and we evaluate the changes in regional radiative forcing that result from restoration efforts in subtropical, semi–arid thickets in South Africa.

The thicket biome is described as a solid tangle of mostly evergreen shrubs, many of which are spiny and succulent, and often impossible to walk through. In places, the thicket is dominated by the evergreen succulent shrub *Portulacaria afra* (locally known as 'spekboom') (Fig. 1). *P. afra* has a facultative Crassulacean Acid Metabolism (CAM). This allows the plant to switch between two photosynthetic pathways, C3 and CAM, depending on the environmental stresses experienced, in theory optimising the CO_2 fixation and plant growth. It has been suggested that this provides the region with a productivity and ecosystem carbon storage potential that is unusually high for a semi-arid environment [2].

Ill–advised goat farming over the last century lead to widespread thicket transformation, and the very edible *P. afra* has in particular been lost from these lands (Fig. 1). Today, 4000000 hectares of the spekboom-dominated thicket extent is considered to be moderately to severely degraded [3].

Spontaneous recovery of the thicket after degradation is slow or absent [4]. The area is a focus for ecosystem restoration projects, which set out to sequester carbon, improve rural livelihoods, restore biodiversity, and improve the security of a range of other ecosystem services. To date, the climate benefits of restoration have been taken as self-evident and solely based on carbon uptake by the restored vegetation.

However, several mechanisms of interaction with the climate system are involved, and it is unclear what the net outcome is. A key factor is the darkening of the surface when bare soil is covered by evergreen foliage which affects the surface albedo.

Monthly estimates of broadband shortwave albedo were estimated [5] for degraded and intact thicket sites using a 9-year time series (2000–2009) of the 1.1 km nadir bidirectional reflectance factor (BRF) parameters retrieved in the red, green, blue and near (NIR) from the Multiangle Imaging SpecroRadiometer (MISR) Land Surface Product (Fig. 2)

Following [5] and [6], the change in the net radiative forcing and the carbon equi-

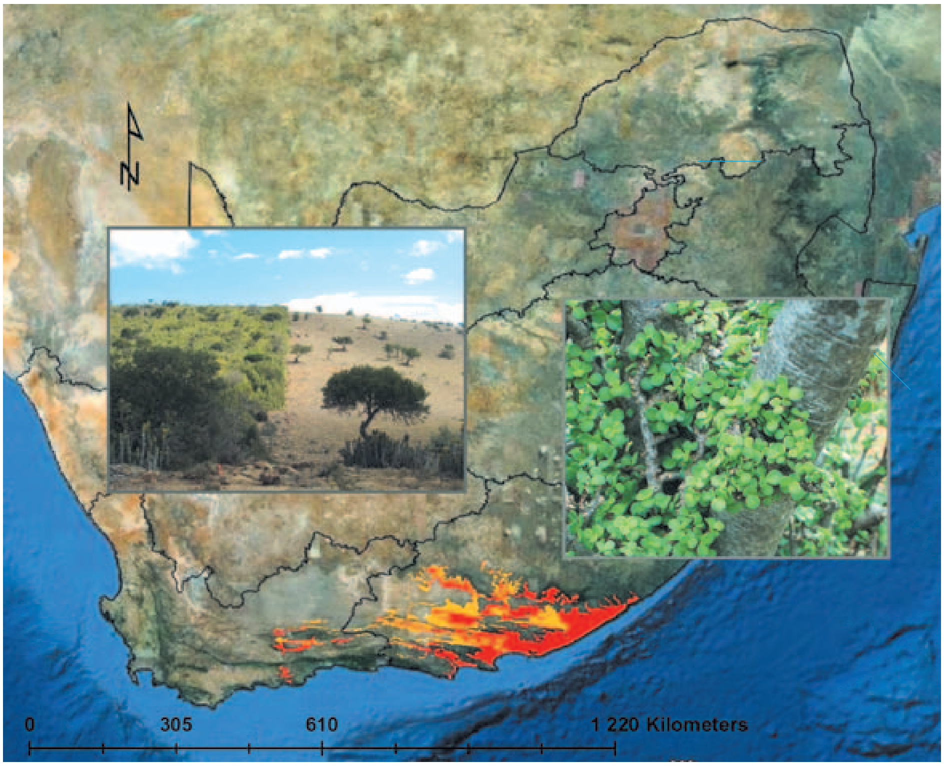

Figure 1. Map of South Africa (black polygon) showing the spatial distribution of the thicket biome (red) and the spekboom–dominated thicket (orange). The top left inset shows a fence line with contrasting land–uses on either side. Goats have been farmed on the right side, but have been excluded on the left of the fence (photo courtesy of R3G, www.r3g.co.za). The bottom right inset shows photograph of *Portulacaria afra*, a key species in the study area (*photos: K Mennell*).

valents (CO_2e, a metric used to compare different perturbations in the climate system based upon their global warming potential using CO_2 as a reference) resulting from the changes in surface albedo following from restoration were calculated for steady–state conditions: The albedo decrease from successful restoration would result in a positive forcing of about 0.00232 pW m^{-2} (a warming effect). In carbon equivalents this is equal to 1.3 to 5 kg CO_2e m^{-2}. Sequestration rates of 1.5 kg CO_2e m^{-2} yr^{-1} have been reported for *P. afra* in the region [8].

On the other hand, the uptake of carbon by the restored thicket results in a negative forcing or cooling effect on the climate, which is of the same order of magnitude as the forcing resulting from the decrease in albedo. These different forcing mechanisms operate over different time horizons, so restoration still results in a net benefit, but the calculation of the magnitude of that benefit needs to take into account the positive radiative forcing through reduced albedo. ■

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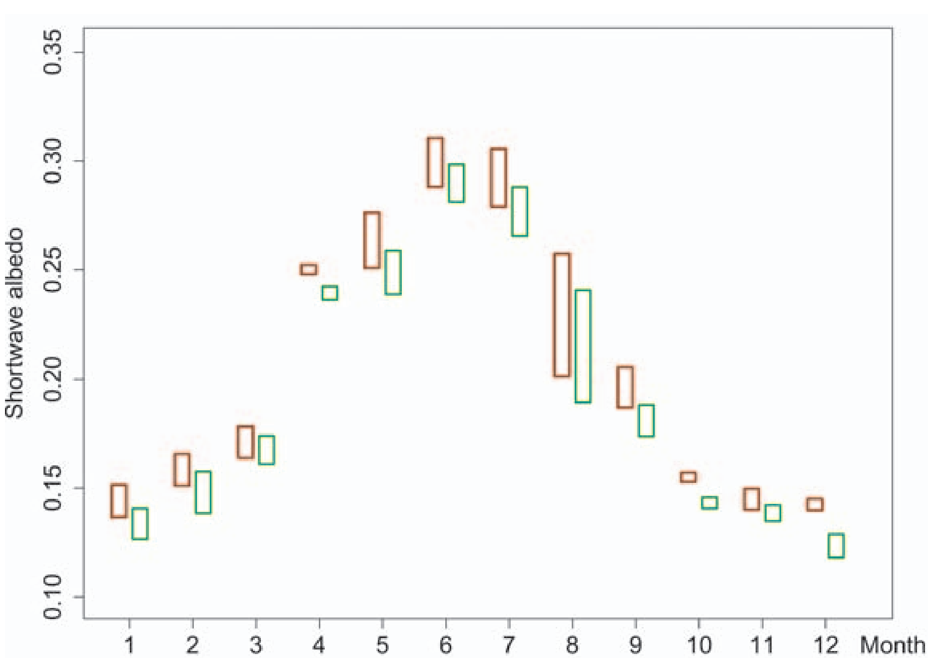

Figure 2. The annual mean, minimum and maximum surface shortwave albedo. Intact vegetation = green, degraded vegetation = brown. The difference is only significant during the April and October, when peak rainfall volumes are received.

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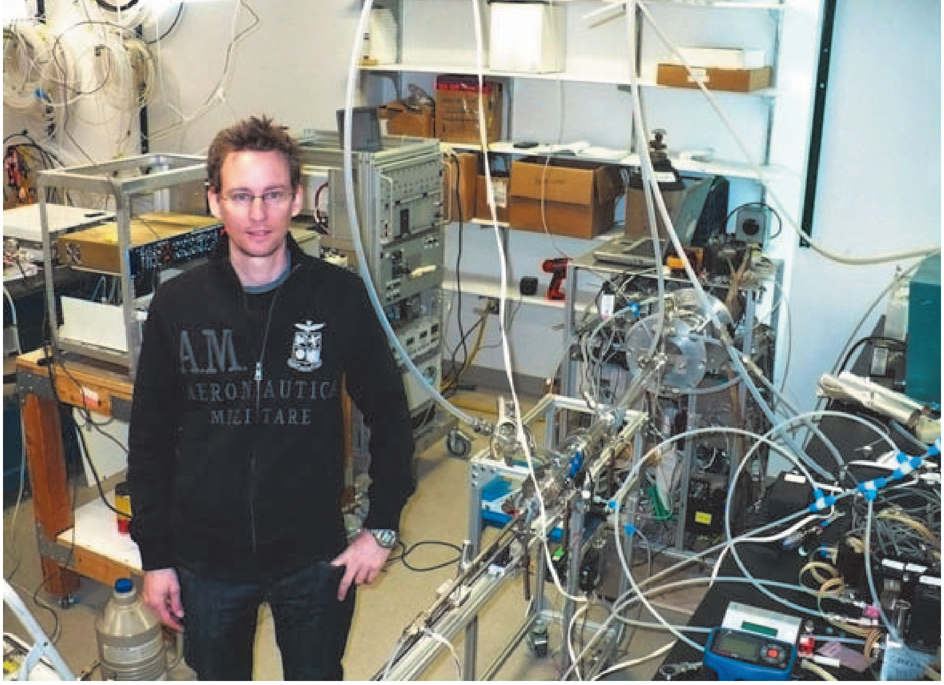

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PTR-MS flux measurements provide observational constraints on biogeochemical cycling of VOCs in tropical ecosystems

Volatile organic compounds (VOC) play an integral part in atmospheric chemistry by modulating the oxidation capacity of the atmosphere [1, 2] and providing condensable material for secondary organic aerosol formation (SOA) [3].

Furthermore, new–generation Earth System Models (ESM) show that the atmospheric composition of reactive gases can have a significant influence on modelled climate forcing [4, 5].

A comparison between an ensemble of detailed global Chemistry and Transport Models (CTM) ([1], Fig. 4.13) shows a large variability of predicted future ozone trends. The reason behind the differences in model sensitivity for tropospheric ozone production is our limited understanding of complex organic gas phase chemistry [6] and sources and sinks of reactive gases.

One example of the effect of poorly understood organic chemistry on model performance is the study by Lelieveld *et al.* [7]. They evaluated their CTM in high VOC – low NO_x (nitrogen oxide) environments in the Amazon, where regional air chemistry is dominated by isoprene (C_5H_8, produced and emitted into the atmosphere by many tree species; acts as a precursor to a large number of compounds).

Lelieveld *et al.* [7] found large inconsistencies between observed and modelled OH (hydroxyl radical) densities and attributed this discrepancy to fast unknown recycling processes of hydrogen oxides (HO_x) linked to the photochemical degradation of isoprene.

Isoprene represents a significant amount (40–60%) of the estimated global VOC flux into the atmosphere (best estimate: 1200 – 1350 Tg (C) yr^{-1}) [8–10]. Based on CTM–simulated distributions of secondary products, the global reactive VOC flux has historically been scaled down from the best estimate. An annual input of 571 Tg (C) yr^{-1} is, for example, recommended by the IPCC [1, 2].

Atmospheric oxidation of VOC can lead to the formation of formaldehyde (HCHO). Satellite observations of HCHO [11] in combination with CTM inversion techniques therefore have the potential to serve as a useful top-down constraint for global VOC emissions estimates.

Another important local–to–regional top–down constraint can be obtained from direct ground-based and airborne VOC flux measurements. Eddy covariance flux observations can quantitatively reduce uncertainties associated with VOC emissions [12].

Since its introduction in the 1990s, Proton–Transfer–Reaction Mass Spectrometry (PTR-MS) [13, 14] has proven to be a valuable tool for VOC eddy covariance measurements [15] and has been used in many field experiments to quantify biogenic and anthropogenic VOC emissions.

Here we present a synthesis of measured isoprene fluxes and concentrations from recent studies conducted in tropical ecosystems (Fig. 1), spanning a wide range of different conditions [16–18].

Fig. 2 (lower panel) shows the relationship between average isoprene fluxes and concentrations in these studies. The data are binned to represent average midday (10–14 local time (LT)) conditions. This relationship (Fig. 2) can serve to shed more light on the atmospheric cycling of isoprene.

In a well mixed planetary boundary layer the concentration (C) of a reactive trace gas can be expressed by the budget equation (1)

$$\frac{F_S - F_e}{C} = \frac{z_i}{\tau} \qquad (1)$$

where F_s represents the surface flux, F_e the entrainment flux, z_i the planetary boundary layer (PBL) height, and t the lifetime; the PBL is the lowest well mi-ed part (*e.g.* 1–3 km) of the atmosphere. The entrainment flux represents the exchange between the PBL and the free troposphere, which extends up to about 8 km.

For isoprene, the lifetime is controlled by the reaction with the hydroxyl (OH) radical and can therefore be simplified to $\tau^{-1} = k_{OH}$ x [OH], where k_{OH} is the reaction rate and [OH] the concentration of OH.

We can therefore modify equation (1) further to:

$$\frac{F_S}{C} \cong k_{OH} \cdot [OH] \cdot z_i + \frac{F_e}{C} \qquad (2)$$

The budget equation (1) can be exploited to deconstruct factors controlling isoprene concentrations in the PBL: the offset (0.7 ppbv) (thin black solid line in Fig. 2) is primarily caused by boundary conditions and dynamics (*e.g.*, advection (horizontal transport) and vertical mixing). The slope (here ~ 1.1 ± 0.3 ppbv mg^{-1} m^2 h) is mostly sensitive to the oxidising capacity of the PBL.

Based on PBL heights between 900 – 1200 m [17, 19], we calculate OH densities over a fairly narrow range between 7 x 10^5 and 11 x 10^5 molecules cm^{-3}.

We also show modelled isoprene concentrations from a photochemical box model [17] based on the MOZART v4 mechanism [20]. A generic recycling scheme was incorporated according to

ISO_2+HO_2 —> n OH, (3)

where ISO_2 represent isoprene peroxy redicals, HO_2 hydroperoxyl radicals, and n a

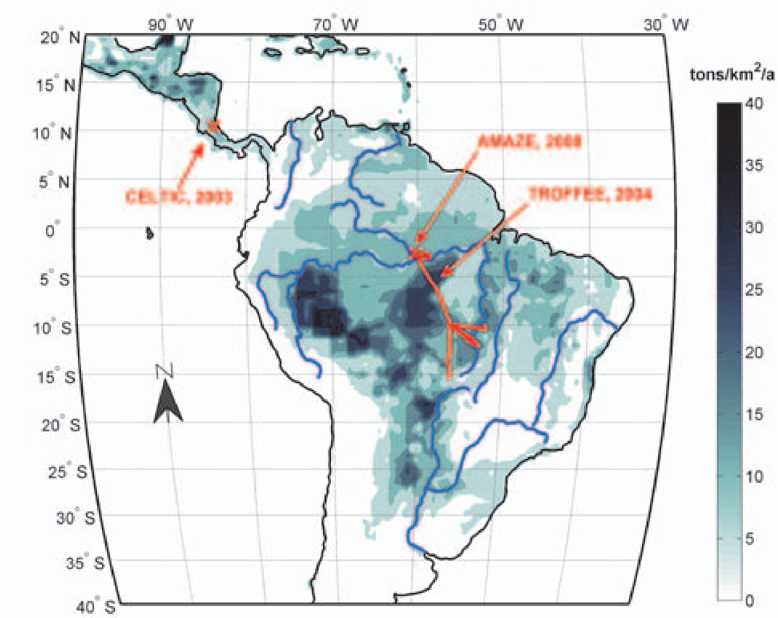

Figure 1. Locations of PTR-MS VOC flux studies plotted on a map showing annual isoprene emissions: CELTIC 2003 [15], TROFFEE 2004 [17], AMAZE 2008 [18].

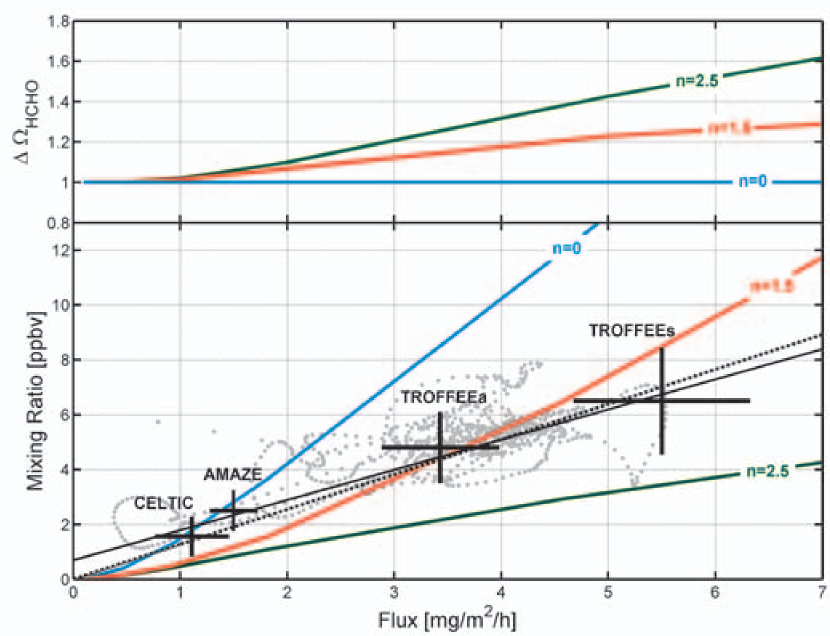

Figure 2. Uncertainties in HO_x recycling can lead to uncertainties in isoprene emission estimates inferred from spaceborne HCHO measurements.

Lower Panel: Average noontime isoprene mixing ratio plotted versus flux for 4 different datasets (CELTIC, surface, dry season, 2003; AMAZE, surface, wet season, 2008; TROFFEEa, mixed layer, dry season, 2004; TROFFEEs, surface, dry season, 2004; thick black lines). Grey points represent individual airborne observations during TROFFEE and have been averaged (TROFFEEa).

The dotted line represents a linear fit forced through zero yielding a slope of 1.3±0.3 ppbv mg^{-1} m^2 h. The thin black line shows a fit yielding a slope of 1.1 ± 0.3 ppbv mg^{-1} m^2 h^{-1} and an offset of 0.7 ppbv. This corresponds to average noontime OH concentrations between 1.1 and 0.7x10^6 molecules cm^{-3}, respectively.

The blue line is obtained from a box model with no additional HO_x production (n=0), representing the base case used in most current atmospheric chemistry models.

The red and green lines represent the same box model runs including additional production mechanisms for HO_x [7].

Upper Panel: Change of PBL HCHO column (Ω) relative to the base case (n=0). Additional HO_x production increases the modelled HCHO column for a given isoprene flux. Relative to the base case this could result in an overestimation of isoprene emissions calculated from CTM inversion techniques using satellite-derived HCHO columns.

yield for the formation of OH. Here we used two different OH yields (n=1.5, 2.5) [7].

Fig. 2 (*upper panel*) depicts the effect of increased HO_x (OH+ HO_2) recycling on the relative change of the HCHO PBL column density (Ω). For high isoprene fluxes typically observed during the dry season (up to 7 mg m^{-2} h^{-1}), the HCHO concentration in the PBL column could increase by 60% if OH was recycled more efficiently (*e.g.* with a yield of n=2.5), which would lead to higher OH concentrations.

Isoprene is oxidised by OH which generates formaldehyde—uncertainties in OH prediction from photochemical models can lead to significant uncertainties for isoprene emissions calculated from observed HCHO columns using inversion techniques.

Uncertainties in HO_x concentrations (OH+HO_2) have therefore consequences for globally derived isoprene and VOC emissions based on HCHO satellite observations which rely on an accurate understanding of photochemical HCHO production in the atmosphere. Direct flux measurements on the ecosystem scale provide an essential constraint for VOC emission models. These measurements can also be used to reveal the lifetime of VOCs in the PBL and can improve understanding of the atmospheric processing of VOCs.

Currently, VOC flux observations are still limited, especially long–term (seasonal to interannual) above–canopy flux measurements and short–term airborne observations that characterise VOC fluxes regionally.

iLEAPS and related international projects should have a role in coordinating and integrating future efforts to extend these observations and make them available to the international community. This will improve the interpretation of satellite–derived column measurements of reactive trace gases (*e.g.* formaldehyde, which is used to constrain global isoprene emissions) and VOC emission estimates used as inputs in CTMs. Combining these strategies will ultimately result in a more accurate global picture of biogeochemical cycling of VOCs in the Earth system. ■

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In photo from left: Erika Zardin, Ella–Maria Kyrö, Joshua B. Fisher, Abigail Swann, Sachin S. Gunthe, Florence Bocquet, Christoph Rüdiger.

In August 2009, iLEAPS (Integrated Land Ecosystem–Atmosphere Processes Study) and GEWEX (Global Energy and Water Cycle Experiment) organised a parallel Science Conference "Water in a changing climate: Progress in land–atmosphere interactions and energy/water cycle research" with several joint sessions. Prior to the conference, iLEAPS and GEWEX hosted a 3–day Early–Career Scientist Workshop attended by that over 50 early–career scientists. Given that these young scientists represent the next generation of leading scientists in land–atmosphere research, we report here on their research foci. Specifically what topics, methods and scales of study form their research? Finally, what does this mean to the future of land–atmosphere exchange science?

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Reporting from the iLEAPS–GEWEX Early–Career Scientist Workshop, Melbourne, Australia, 20–22 August 2009

The New Generation of 'Land–Atmosphere Exchange' Scientists

An overview of the early–career scientists, and how their work will shape the direction of land–atmosphere science

The influence that local– to global–scale interactions between the Earth's surface and the atmosphere exert on climate is widely recognised. Nonetheless, a large fraction of these interactions are still not well understood and may have yet to be discovered. To further progress in this field, iLEAPS provides a major scientific pathway for scientists from a broad range of research areas to interact, communicate and inform one another. It enables scientists to collaborate towards a more thorough understanding of land–atmosphere exchange science.

In line with these objectives, iLEAPS arranged an Early–Career Scientist Workshop (ECSW) on 20–22 August, 2009, prior to the parallel iLEAPS and GEWEX science conferences held in Melbourne, Australia.

Topics of discussion included

- Earth system science
- remote sensing and applications
- land–atmosphere interaction and scaling issues
- climate and global change
- science–media communication
- pathways to careers combining science and politics or science and industry.

Integral to the workshop was interaction with foremost senior scientists: John Finnigan, Mike Raupach, and Ray Leuning (Commonwealth Scientific and Industrial Research Organisation-Marine Atmospheric Research), Einar–Arne Herland (European Space Agency), Lindsay Hutley (Charles Darwin University), and Will Steffen (Australian National University).

The following report is based on 32 surveys (out of 52 attendees) from the participants, including an equal number of male and female. Just over half were current PhD students; the remaining were early–career scientists (<5 years from PhD). Australian institutions were well represented with nearly a third of the respondents, and the rest came from more than 11 different countries.

The majority of the respondents were working on water and energy cycling (27%) as well as on aerosols and volatile organic compounds (VOCs) (24%). A diverse range of other topics were also represented, such as greenhouse gas fluxes and carbon/nitrogen cycling (13%), land–atmosphere coupling (13%), vegetation dynamics (9%), climate (7%), and turbulence and micrometeorology (7%) (Fig.1).

The majority worked with models (34%) and field measurements of vegetation, meteorology, and/or aerosols (30%). Satellite and aerial remote sensing were frequently used (16%) as well as eddy covariance (14%). Finally, a few scientists were working with tracers, isotopes and/or other laboratory studies (6%) (Fig. 2).

Most of the scientists studied processes on the local (39%) and/or regional (37%) scales, whereas the remaining fraction (24%) worked on the global scale (Fig. 3).

From this simple and admittedly biased survey (represents only the early–career scientists who attended the workshop, not a representative sample globally), it appears that the strengths of the early–career scientists cover the research areas of water and

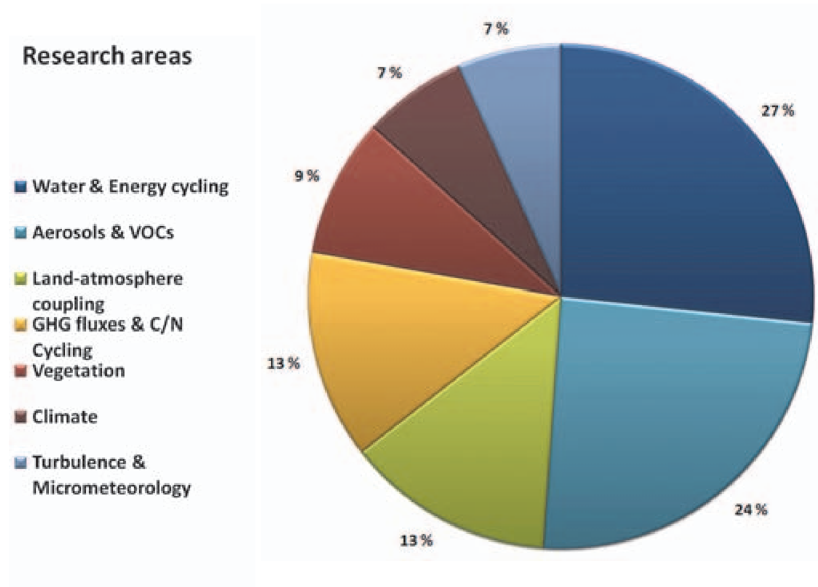

Figure 1. Research areas of the ECSW early–career scientists.

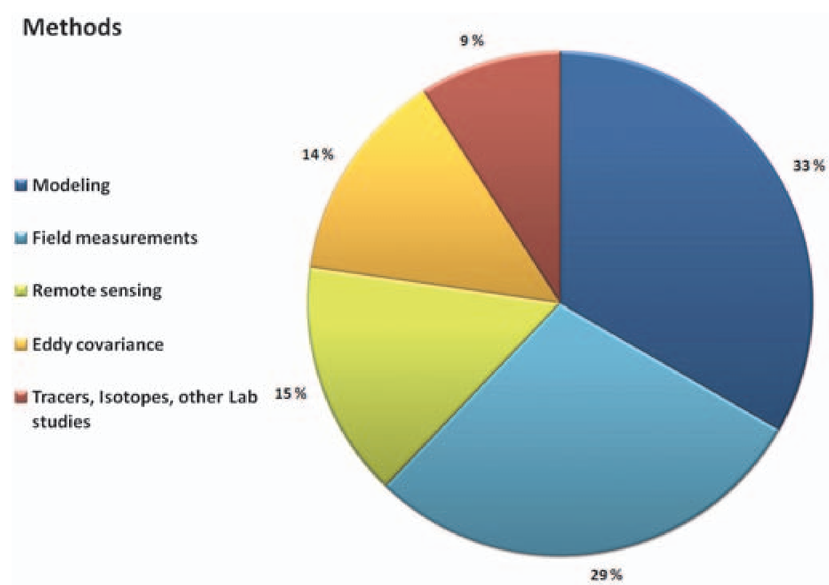

Figure 2. Research methods employed by the ECSW early–career scientists.

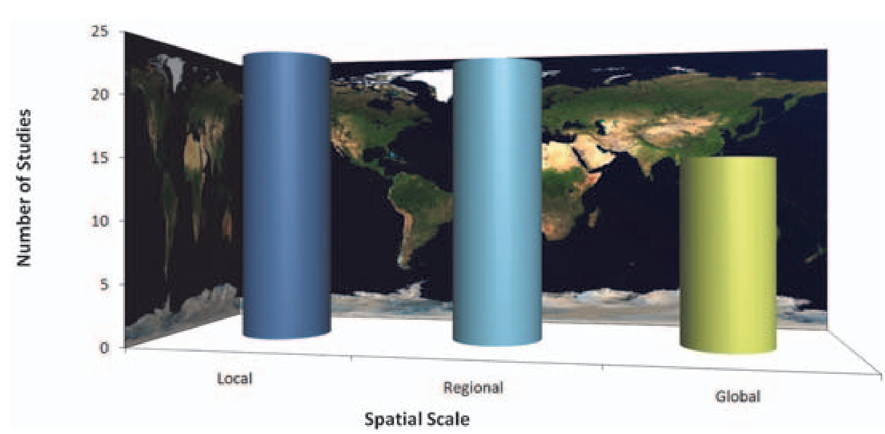

Figure 3. Spatial scales of study addressed by the ECSW early–career scientists.

Melbourne city center in August 2009. Photo by Ella–Maria Kyrö.

energy cycling, aerosols and VOCs, modelling and field measurements. Because of the research foci of the parallel iLEAPS–GEWEX conferences taking place the following week, it was indeed expected that water and energy cycling would be strongly represented. Nonetheless, the highly represented categories of aerosols and VOCs highlight the importance of physical and chemical land–atmosphere processes of these compounds.

Modelling and field measurements were the two main methods used by the respondents. Modelling is crucial in land–atmosphere interactions; yet to advance modelling practices, it is important to collect the data that are being used as well as to understand the physical and chemical processes behind the observations. Clearly, this new generation of land–atmosphere exchange scientists has the tools and training to advance their science.

Finally, the relatively even representation of spatial scales of study is also worth noting. Each scale category is rather well studied which is necessary to establish linkages among the scales and to yield an even broader understanding of scaling–related processes.

Furthermore, the ECSW group expressed their opinions on the current gaps in knowledge in their fields of research. Greater understanding of physical and physicochemical processes such as atmospheric turbulence and the formation of aerosols and cloud condensation nuclei is important to advance the science of land–atmosphere interactions. To this end, substantial field campaigns are necessary.

For example, additional in–depth observations of aerosols and gas processes from a large variety of ecosystems, at multiple spatial and temporal scales, can advance the understanding of the physical, chemical, and biological processes. Additionally, standardisation of analytical methods to link, analyse and parameterise the measurements (*e.g.* eddy covariance and remote sensing data) within models needs improvement.

The iLEAPS–GEWEX ECSW succeeded in bringing together early-career scientists from around the world whose research interests covered a diverse range of scientific topics related to ecosystem–atmosphere interactions. The workshop provided a forum for early–career scientists to express and build their views for linking the processes/issues scanned jointly by iLEAPS and GEWEX. This common platform is perhaps the most important outcome of the workshop.

The goals and interests of this new generation of land–atmosphere exchange scientists are summarised in the following:

- to further the understanding of atmospheric, biogeochemical, physical, biological and ecological processes at local, regional and global scales;
- define the scaling properties of measurements and models, and the effects of scale on ecosystems processes and feedbacks.
- to improve the parameterisation and representation of ecosystems processes and feedbacks in numerical models;
- to carry forward and aim at improving the interdisciplinary connections between the diverse fields of study;
- to coordinate the future research effort among measuring and modelling communities;
- to constructively merge the acquired scientific knowledge with policy–making debates driving our society of today and tomorrow.

The ECSW, in particular, addressed key challenges facing early–career scientists as they begin their careers, while highlighting promising research avenues that will enable them to become leading scientists carrying forward the scientific understanding of 'land–atmosphere exchange'. ■

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ABBA – Advancing the integrated monitoring of trace gas exchange between biosphere and atmosphere

ABBA, a 4–year European Cooperation in Science and Technology (COST) Action, was created in 2008 with a view on the next generation of European comprehensive multi–species flux monitoring sites. ABBA provides a strong and dedicated coordination platform where the planning, analysis and synthesis efforts of current flux monitoring sites can take place. ABBA will create standardised methods and protocols for

- **site location selection**
- **flux measurement techniques**
- **processing and storage of data.**

The aim is to facilitate wider use of flux data by a more diverse community of researchers, operational forecasters, and environmental assessment organisations. ABBA is a pan–European network of land–atmosphere interaction scientists jointly working towards these goals.

ABBA is co–chaired by

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At present, ABBA includes 18 Member Countries and consists of four Working Groups (WG) with individual Action Plans, each divided into two main Activities.

www.ileaps.org/multisites/cost0804

ABBA Working Groups:

WG1: Analysis and synthesis of the current state of the flux monitoring sites, measurement techniques, data handling methods and storage of data in Europe

Co–Leaders:

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Activity 1.1 aims at reviewing the quality and availability of existing exchange flux measurement data. This includes, for instance:

- instrumentation and maintenance
- (inter site) calibration
- data processing
- gap filling algorithms
- quality control procedures
- synthesis of data storage and accessibility
- timeliness of data delivery
- institutional embedding and funding and its consequences for continuity and accessibility.

In order to collect all this information, a questionnaire will be circulated in the different communities. This activity is strongly related to WG2.

Other positive interactions will be with FLUXNET that is working on the collection of the metadata of the different sites at global scale and with other European projects.

Activity 1.2 will evaluate the possibility to have at least one site per country working in the direction of full standardisation of measurements and processing and providing data openly to all the different communities.

The first task is to define which characteristics these sites should have in terms of variables, accuracy, meta–information, delay from measurement to data sharing *etc.* This task requires input from users and will be in coordination with ICOS (Integrated Carbon Observation System). We will then determine which potential sites are able to participate. This will be a crucial point for the activity: with too few sites interested to participate, the activity will cancelled. A similar initiative is ongoing in FLUXNET and will be coordinated with this task.

Next, WG1 will define the methods and data policy for open sharing and select the sites that will share the data on the basis of the free access policy.

WG1 will contact and select potential users for the data and disseminate the results, possibly showing the improvements obtained using the data. The success of this activity depends on finding users willing to work with the data and give us feedback about the improvements and results enabled by the use of the data.

WG2: Work towards comprehensive multi–species flux monitoring sites

Co–Leaders:

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Activity 2.1 includes compilation and review of data needs (parameters, spatial/temporal resolution) of the Earth System Science community (measurements and modelling) to broaden understanding of processes governing land-atmosphere exchange and which can be obtained by (terrestrial) monitoring networks. This activity is strongly linked to Activity 1 of WG1.

In practice, WG2 will develop a questionnaire with key experts from the modelling and measurement community and distribute it to the COST community in close cooperation with WG1.

Finally, WG2 will compile existing databases used by different communities for storage and documentation of measurements from monitoring networks/sites (*e.g.* CarboEurope), analyse stored parameters, data retrieval procedures (structure) and accessibility of the database for external users.

Activity 2.2 aims at reviewing availability of new instrumentation (*e.g.* isotope–specific lasers) for characterising ecosystem and exchange processes. Ranking not only according to feasibility but also with regard to the importance for understanding exchange processes such as N_2 measurements.

WG2 will report (incl. literature review / contact with leading experts) on new developments in measuring devices with regard to the quantification and characterisation of land-atmosphere–exchange processes and ecosystem / landscape internal exchange and turnover processes.

WG2 will also give recommendations on the extension to- or minimum selection of component flux measurements at currently operated or newly established flux monitoring sites. It will distinguish between essential, preferred and ideal set of observations, both primary component fluxes, as well as background/auxiliary measurements accompanying each of these. These recommendations will be based on the outcome of a focussed expert workshop.

WG3: Assessing regional representativeness of flux sites in different ecosystems

Co-Leaders:

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Activity 3.1 aims to assess the major limitations in the available observations of energy, water and carbon fluxes to arrive at reliable continental scale budgets of exchange of these parameters.

Because of the important role of data-assimilation systems that rely on the integration of the observations with empirical or process–based models, it is also important to assess the current state–of–the–art of the numerous applied modelling and data–assimilation systems within the European community and to assess the major challenges in further improving the skills of these systems to arrive at continental scale flux budgets.

Since there is a promising number of available remote-sensing products that can be applied to further constrain the inversions of large–scale exchange inventories, this task should also particularly address limitations and further opportunities using these remote-sensing products.

In practice, WG3 will assess missing or under–sampled European ecosystems in terms of their contribution to the energy, water and carbon exchange budget and review the state–of–the–art of data–assimilation systems, including empirical and more process-based model systems constrained with site observations as well as remote sensing observations, in terms of their limitations and priorities of further development of these data–assimilation systems.

Finally, WG3 will assess the potential and further need of remote sensing products to constrain large-scale budgets of the exchange of water, energy and carbon.

Activity 3.2 will assess the main priorities of future measurement and modelling activities to improve our skills to arrive at continental-scale inventories of the exchange of reactive compounds and aerosols.

There is only a limited number of flux observations of reactive compounds and aerosols. At a range of sites embedded in the European air quality networks generally the concentrations of reactive compounds, *e.g.* ozone, some nitrogen species, and aerosols are measured. However, translating these concentration measurements into the actual exchange fluxes of reactive compounds and aerosols requires the use of models which also require information on local micro– and boundary–layer meteorology, hydrology and biogeochemistry.

A lack of observations of these site characteristics poses another limitation to infer site–scale fluxes of reactive compounds and aerosols.

The most promising methodology to improve continental–scale exchange inventories is the development and application of process–based models. In addition, because of the limited feasibility of establishing an extensive network of observations of fluxes of reactive compounds and aerosols we need to identify the most optimal locations of a limited number of super–sites to reflect the most important (European) ecosystem exchange regimes.

The first task in this activity will be to assess the sites that should get a preference to establish in future super–sites, comparable to the Finnish Hyytiälä site, to observe the exchange of reactive compounds and aerosols over ecosystems that contribute significantly to the continental (European) exchange inventory.

Next, WG3 will assess the state–of–the–art of process–based models to simulate the continental scale distribution of atmosphere-biosphere exchange of reactive compounds and aerosols including limitation as well as the priorities of further model development supported by observations.

WG4: Training and capacity building

Co-Leaders:

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This WG focuses mainly on training, education and dissemination of the results of WG1, WG2 and WG3 efforts. We will take the following steps to reach these goals:

- Organising expert– as well as multi–community workshops to disseminate results from WG1–3;
- Establishing an optimal interaction between the micrometeorological, greenhouse and reactive trace gas and aerosol exchange measurement and modelling communities using STSMs;
- Organising summer/winter schools for early career scientists and field training at the multicomponent measurement sites.

During the First ABBA Workshop held in Helsinki 18–20 May 2009, the initial WG4 plans were formed on the basis of WG 1–3 activities and results as follows:

1. The next MC meeting will be held in Krakow, Poland, 19–21 April, 2010. The 3–day meeting will consist of WG reports, discussion on selected scientific issues and on future activities, and lectures by invited experts.
2. Six Short Term Scientific Missions (STSMs) will be funded during the 2009/10 period.
3. With special permission from COST Office, ABBA supported two early–career scientists to the iLEAPS–GEWEX Early Career Scientist Workshop and iLEAPS and GEWEX parallel Science Conferences in Melbourne in August 2009.
4. 1st Summer School: June 2011, Hyytiälä Forest Station in southern Finland. Approximately 30 students will receive training in comprehensive approach of trace gas and aerosol exchange between biosphere and atmosphere as well as in flux measurement using micro-meteorology methods. The structure of the summer school will consist of lectures, classes, site visits, and social programme. Lectures will be held by ABBA MC members as well as by invited experts.
5. 2nd Summer School: June 2012, Poznan University of Life Sciences Teaching Centre in Zielonka, Poland. Approximately 30 students will receive training in the Earth System model and observation approaches.
6. Additional WG4 plans will be formed in the future on the basis of results of WG1–3 activities. ■

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8th AsiaFlux Workshop, Sapporo, Hokkaido, Japan, 27–29 October 2009

Integrating cross–scale ecosystem knowledge: bridges and barriers

The 'human–in–ecosystem' perspective is a way to think about the relationship between nature and society and about the interfaces between the two. Linking ecological and social systems is a cross-scale issue. In Asia, reaching a serviceable understanding of the dynamics, sustainability, and resilience of these complex social-ecological systems will require a stronger push to advance focused cross-disciplinary research with a clear vision.

AsiaFlux, the Asian arm of FLUXNET, is a science community with a mission to bring Asia's key ecosystems under observation to ensure quality and sustainability of life in Asia. Our vision has not changed but has been refined to serve as a 'science frontier'—the agora for ecosystem science, service, and stewardship through developing and transferring knowledge characterised by cross-disciplinarity, contextualisation, and cultural diversity.

To pursue our vision, we have set two short-term goals: (1) to assess and synthesise the first Asian carbon budget (ACB) report and (2) to establish an infrastructure for the Asian Carbon Tracking System (ACTS).

Our vision is processual, and it is an invitation to re–think global sustainability science. In a beautiful city of Hokkaido in northern Japan on 27–29 October 2009, we

Photos: Prof. Joon Kim

Workshop participants.

held the 8th AsiaFlux Workshop on "Integrating Cross–scale Ecosystem Knowledge: Bridges and Barriers." The workshop was organised around six topics:

1. flux observation and analysis
2. CarboEastAsia
3. bridges between ecosystem observation and remote sensing
4. global biogeochemical cycles
5. barriers in flux measurements, and
6. interfaces between carbon science and society.

The highlights of the new findings and questions addressed in these sessions were:

- AsiaFlux has grown to a multi-national science community with 449 members from 28 countries with 109 tower flux observation sites
- the "CarboEastAsia" A3 Foresight Program is making real progress in bringing robust collaborations among members through data sharing, synthesis, and assessment toward regional carbon budget
- the handshake of multi–years' tower observations, modelling and remote sensing in various plant functional types in AsiaFlux enables better understanding of coupled cycles of carbon and water in monsoon Asia
- heterogeneity and complexity of landscapes, natural (*e.g.*, monsoon, typhoons, drought) and man-made (*e.g.*, land use change, fires) disturbances, and the consequent gap-fillings of the missing data are the challenges facing the AsiaFlux community, and
- resilience thinking is complementary with the vision of AsiaFlux which can provide qualitative monitoring, management, and long time-series of local observation and ecological and social memory for understanding ecosystems change throughout their adaptive cycles.

More than 180 scientists and students took part in the workshop from 16 countries and regions, and we had about 36 oral and 100 poster presentations. The workshop not only brought students, scientists, technologists, entrepreneurs, and policy-makers together, but also helped cross the cultural, disciplinary, geographic and hierarchical boundaries.

Many of the results presented at the workshop are currently being published in several scientific journals, including the 'CarboEastAsia' special issue in Biogeosciences. More details are also available at the AsiaFlux homepage: www.asiaflux.net

Science is currently going through a painful evolutionary process and a new concept of knowledge is emerging based on plurality of perspectives and awareness of complexity, uncertainty, and values.

AsiaFlux will continue to create space to deal with emerging paradigms for re–thinking ecosystem science such as cultural boundaries and authority of climate change science, its co–evolution with risk society, context–sensitive science, and the challenge of nurturing diverse functional groups. We invite you to join our next AsiaFlux agora in China (20–22 October), where we will synthesise and contextualise scientific knowledge by welcoming diversity, tolerating uncertainty, and embracing paradox.

Finally, sincere thanks to the guest speakers and the sponsors – Japan Society for Promotion of Science, National Natural Science Foundation of China, National Research Foundation of Korea, Global COE (Centers of Excellence) Program–MEXT (Ministry of Education, Culture, Sports, Science and Technology – Japan), Japan Aerospace Exploration Agency, National Institute for Environmental Studies, LI–COR Biosciences, Meiwafosis Co. Ltd., Campbell Scientific Inc., and Sapporo International Communication Plaza Foundation, Society of Agricultural Meteorology of Japan, iLEAPS Japan, and Japan Long–Term Ecological Research Network. ■

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Workshop report: Farnham Castle, UK, 14–16 September 2009

Understanding the processes involved in biomass burning

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Smoke from vegetation fires constitutes a major source of trace gases and aerosol particles that greatly influence the composition of the atmosphere as well as human health and security [1].

Recent advances in space–based observation of vegetation fires have enabled innovative ways of quantifying fire emissions and other effects. In particular, the availability of new sensors and retrieval techniques provide the opportunity to derive more accurate information on fire occurrence, behaviour, severity and effects.

At the same time, fire and atmospheric modelling have greatly advanced on scales from very localised chemical reactions to inter–continental transport.

To improve the collaboration between the very diverse disciplines studying biomass burning, the European Science Foundation (ESF) funded the Exploratory Workshop *Improved Quantitative Fire Description with Multi–Species Inversions of Observed Plumes* under its Standing Committee for Life, Earth and Environmental Sciences (LESC).

The workshop in Farnham Castle, UK, brought together 24 scientists from nine European countries, Brazil, and the United States. The discussions explored opportunities for a better quantitative understanding of the processes involved in biomass burning and sought new and innovative ways to exploit the recent developments in remote sensing, modelling and data assimilation. The most pertinent research questions during the discussions are outlined below (Text box).

The discussion emphasised that research on wildfires has become increasingly fragmented since the 1990s because of the diversity of scientifically productive approaches to the problem. All participants agreed that a closer inter–disciplinary collaboration now bears great potential for individual research. Such collaboration would lead to improved quantitative air quality forecasts, assessments of global air pollution transport patterns, climate change observations, climate change predictions, and guidance for managing large–scale fire situations.

Key contributions to these improvements would come from the following:

- quantification of the relationships between emission factors (relating species emission and biomass combustion rates) and physical parameters that are available from remote sensing or provided from operational systems with data assimilation (*e.g*. humidity, accumulated precipitation, wind, spectral characteristics of fire observations, topography and vegetation characteristics);
- derivation of estimates for other fire parameters (fuel consumption, fire spread, fire intensity and change in vegetation on longer time scales) from remote sensing data and numerical weather prediction models;
- better integration of biogeochemical fire science with socioeconomic research and investigation of the role of driving parameters such as population density, gross domestic product, land ownership structures, and the use of wildfires as a landscape management tool.

We need a coordinated and funded research network to establish the necessary inter–disciplinary collaboration in Europe, and increasingly beyond. Such a network could build on the previous achievements of field experiments during the 1990s, most of which were coordinated in the Biomass Burning Experiment (BIBEX) programme, and more recent research in several European, international and national projects.

Coordinated activities should lead to interdisciplinary laboratory measurements and field campaigns that integrate ground–based and airborne observations as well as detailed analyses of satellite data and numerical modelling results. Meteorological analyses play a crucial role in relating fire and subsequent smoke plume observations when they are hundreds or thousands of kilometres apart.

Opportunities exist in Europe and elsewhere to organise field campaigns around prescribed burns as well as to exploit situations with very high likelihood of wildfire. Different fire types (flaming, smouldering) in various environments and ecosystems will need to be sampled with small experiments. Also up–scaling to satellite–based remote sensing and to global scale will require additional large experiments.

The ultimate goal would be to establish a worldwide collaboration with field experiments on several continents. Coordination is also necessary to integrate the results from the laboratory and field studies into numerical systems for forecasting and monitoring atmospheric composition and land surface properties and to further improve the parameterisations for fire emissions applied in these systems.

The final Scientific Report and all presentations are publicly available at:

www.ecmwf.int/newsevents/meetings/workshops/2009/ESF

Workshop proceedings will also be published in the Monitoring Atmospheric Composition and Climate (MACC) project report series.

The workshop has very successfully enhanced the collaboration between scientists working in diverse disciplines, all of whom are interested in fires and their effects. Indeed, following the workshop, the participants and other colleagues have prepared and submitted a joint proposal for an ESF Research Network for the collaborative exploitation of fire experiments and model improvements. The overall outcome of the workshop can be best captured by the statement "If we joined the different approaches and aspects together, we could learn so much more!" ■

(*adapted from ECMWF Newsletter No. 122*)

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Key research issues concerning biomass burning

- A major discrepancy exists between fire emissions estimated by bottom–up models based on simulating the combustion of vegetation and top–down approaches using inversions based on satellite observations of atmospheric components, mainly CO.
- A discrepancy exists between emission factors derived in the laboratory or observed *in situ* (e.g. air–borne) and those inferred from satellite observations for several species (e.g. aerosols). Furthermore, the chemical and microphysical evolution of the smoke on the 15–30 minutes to 1–day scale has not been fully understood yet.
- Disentangling fire emissions from other sources is necessary: for example, the observed seasonal cycle of smoke is additionally shaped by biofuel emissions.
- Combustion efficiency is a key uncertainty in emission estimates.
- Generally, a more systematic approach is necessary to tie fire satellite observations, which generally miss small fires and cannot observe biomass combustion in closed systems, with emission inventory estimates, which often rely on incomplete statistical data and generally neglect fires of natural origin.
- Given that the accuracy of single–species flux inversions are still being assessed, multi–species inversions are currently too challenging. An additional complication in CO_2 inversions is introduced by the large diurnal cycle of CO_2 in the boundary layer.

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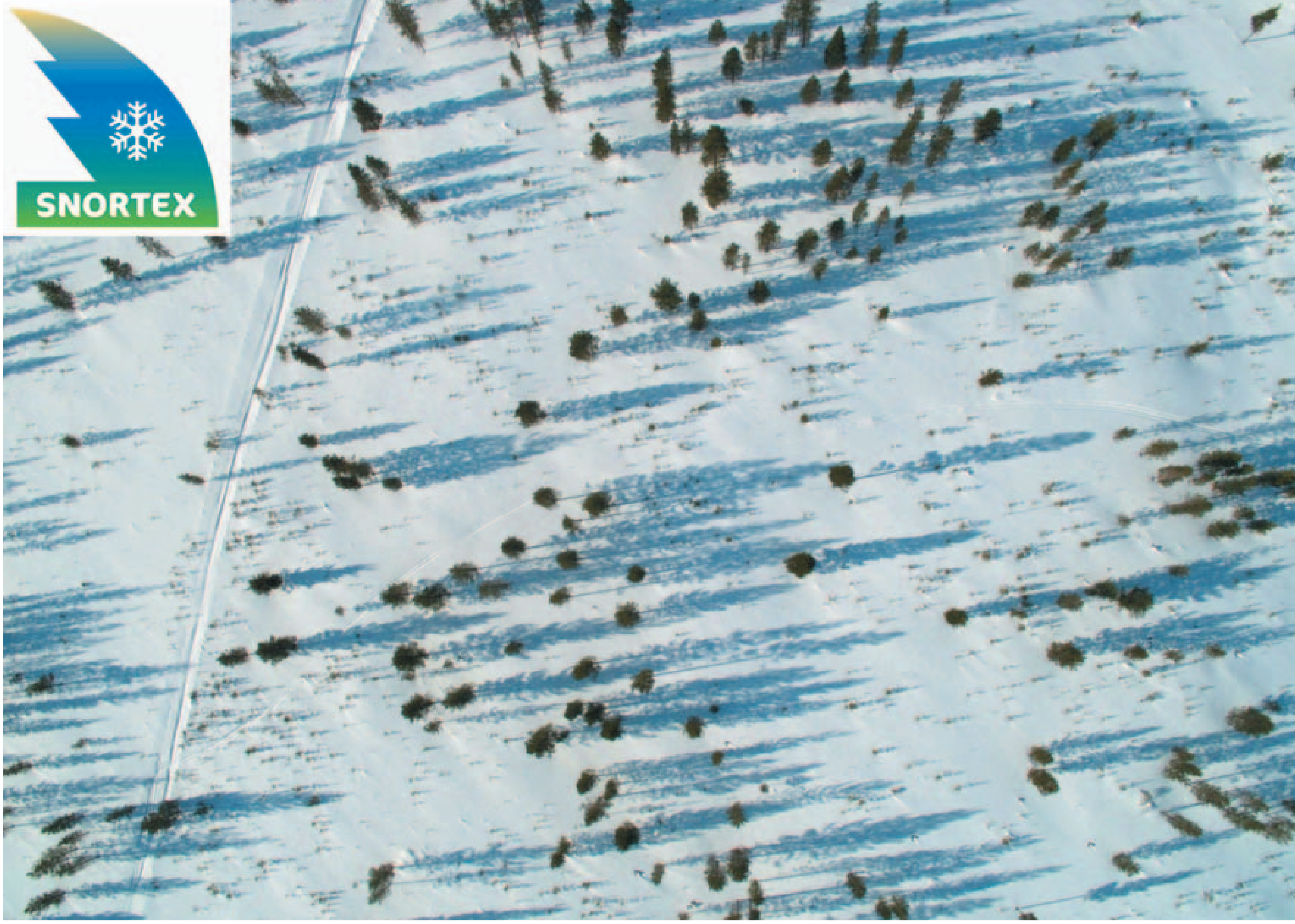

Photo 1. Boreal landscape investigated during SNORTEX, Sodankylä, Finland. Photo: Terhikki Manninen.

Jean–Louis Roujean[1], Terhikki Manninen[2], Timo Sukuvaara[3], Jouni Peltoniemi[4], Sanna Kaasalainen[4], Olivier Hautecoeur[1], Panu Lahtinen[2], Aku Riihelä[2], Niilo Siljamo[2], Milla Lötjönen[2], Tuure Karjalainen[2], Anna Kontu[3], Hanne Suokanerva[3], Osmo Aulamo[3], Juha Lemmetyinen[3], Juha Suomalainen[4], Teemu Hakala[4], Harri Kaartinen[4], Laura Thölix[5], Outi Meinander[5] and Juha Karhu[5]

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SNORTEX: Remote sensing measurement of snowmelt in European boreal forest

Climate change will primarily affect high–latitude regions where one third of the Earth's forest systems are located. How the northern boreal forest will adapt to new environmental factors (temperature, rainfall, humidity) is at the core of current scientific research.

Climate research, meteorology, and hydrology need information of snow coverage, snow depth, snow water equivalent and snow albedo in order to characterise the status of snow and snow melting. The albedo of snow in the boreal biome is one uncertainty in climate modelling because the shadow cast by vegetation is misrepresented [1].

The SNORTEX (Snow Reflectance Transition Experiment) project aims at obtaining quantitative estimates of those snow variables that influence snow albedo (how much solar radiation is reflected back from

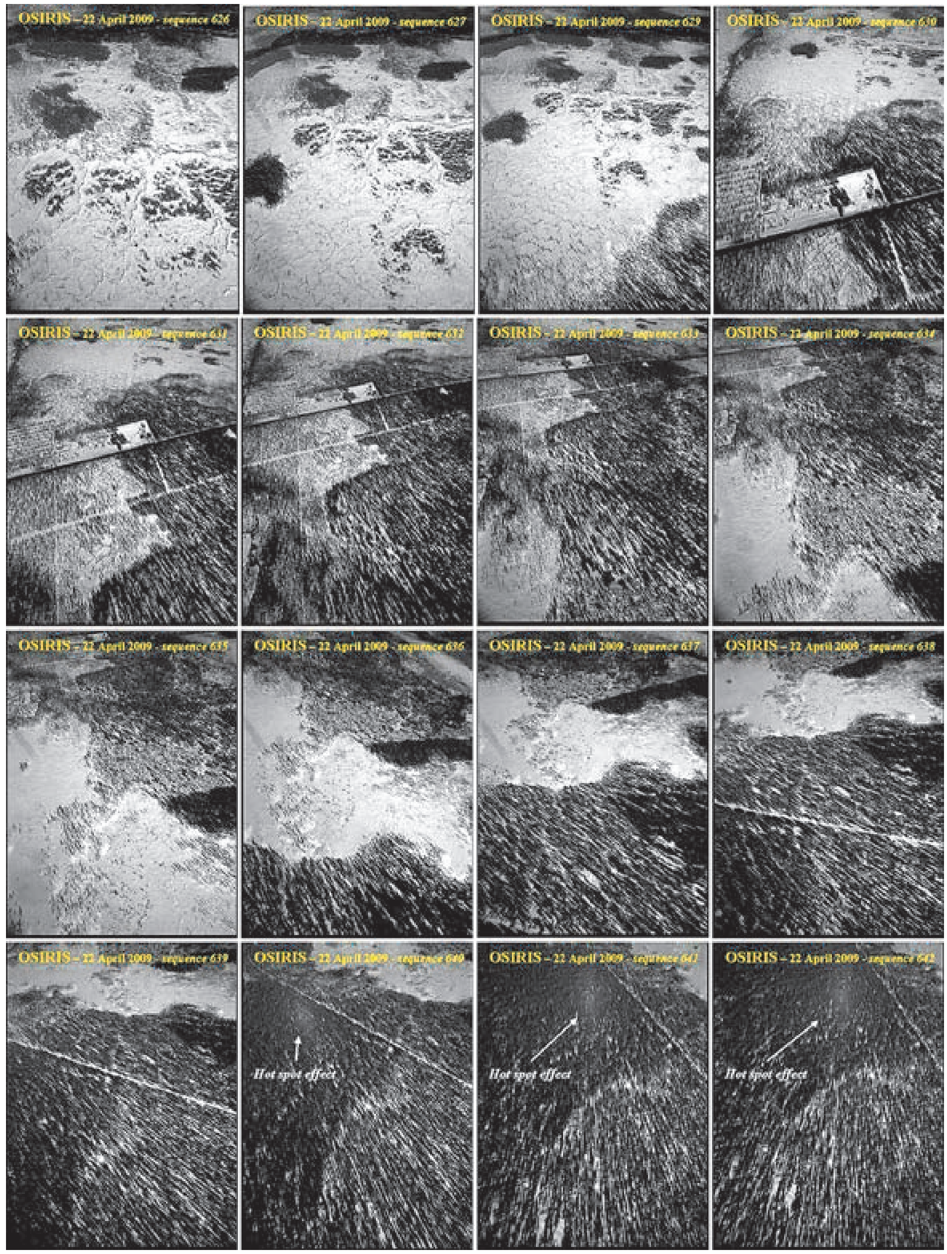

Figure 1. Sequence of red band OSIRIS images on 22 April 2009 showing specular effect from snow underneath forest canopy and and the hot spot phenomenon.

snow surface) and snow water equivalent (SWE), that is the liquid content of solid precipitation that accumulated on the ground. Because albedo and SWE characterise the history of the snow aging and snow pack, we investigated the seasonal variations by a multi-scale strategy in combining various means of observations (ground–based, airborne, satellite) and modelling effort.

SNORTEX took place in an area about 100 km near the city of Sodankylä (67.4ºN, 26.6ºE) located in Finnish Lapland where the landscape is essentially composed by forest and wetlands. We collected data from two springs (2008, 2009). Our objectives were:

- To characterise snow–melting patterns at landscape scale using a multi–scale strategy supported by multi–angular and multi–spectral remote sensing information.
- To quantify how snow reflects differently according to direction of illumination and the relation between albedo and measured key properties for snow from ecosystem level to remote sensing data validation.

Our snow measurements included depth, density, water equivalent, humidity profile, density profile, temperature profile, grain size profile, and surface roughness. The snow temperature, humidity and density profiles were obtained at 76 points at 10–cm intervals.

Snow depth and density are used to estimate snow water equivalent (SWE) but the slope of their relationship curve changes with snow characteristics. This pattern can be used to reveal the onset of melting. For determining grain size, we took a small sample of snow on a snow crystal screen with a 1–mm grid and the reached accuracy was 0.25 mm. We obtained a good correlation between snow density and moisture.

Measurements

We measured the snow surface albedo with a portable Kipp & Zonen albedometer (CM14) and the irradiance and the reflected snow radiation by various landscape units with portable spectrometer Analytical Spectral Devices (ASD) Field Spec 3.

The terrestrial laser scanner (TLS) Leica HDS600 uses a phase modulation technique for range measurement of snow roughness and snow depth, this latter from measurements collected at different times.

The Bidirectional Reflectance Distribution Function (BRDF) determines how light is reflected at an opaque surface while the linear polarization specifies the orientation of the wave's electric field. The two can help distinguishing snow aging. They were analysed for various snow samples using FIGIFIGO (FInnish Geodetic Institute FIeld GOnio–spectro–polari–photometer) [2].

We used an Unmanned Aerial Vehicle (UAV) to characterise snow BRDF with a 1–m spatial resolution. In–flight BRDF component encompassed two pairs of Kipp & Zonen pyranometers attached to the helicopter for measuring global and reflected radiation.

OSIRIS (Observing System Including polaRisation in the solar Infrared Spectrum) is the airborne prototype of POLDER (Polarization and Directionality of Earth Reflect ance) [5]. It measures directional and polarized reflectance in visible and solar infrared bands. OSIRIS was mounted on a pod placed below the helicopter. Flying at low altitude allows getting a high density of directional points, allowing sampling specular and hot spot phenomena (Fig. 1).

Results and conclusion

The snow depth ranged between 20 and 71 cm in March and from no snow to 76 cm in April, the average values being 52 cm and 34 cm, respectively. The TLS estimate for snow depth based on measurements on April 2 and August 27 was 57 cm, which is in line with the ground measurements.

In spring, increasing solar radiation raises the temperature of snow and determines the onset of snowmelt. At night–time, melt–refreeze events are typical and create accumulation of alternative slabs of snow and ice.

In the SNORTEX campaign, for a snow depth of about 10 cm, snow completely dominated the surface albedo. The observed diurnal cycle of snow albedo was essentially monotonic in nature. All snow samples showed a strong forward scattering peak, new snow sharpest, old rough snow weakest. The spectrum depended strongly on grain size and impurities, less on wetness (Fig. 2).

Our project was the first to sample polarization data in high spectral and angular resolutions. Forward polarization data can be used to monitor snow melting, and the presence of impurities can potentially be deduced from spectral BRDF [3]. Besides, the seasonal variations were well captured and the generalisation of the snow properties was confirmed, in favour of a coarse–resolution validation of SWE. We found that the diurnal variations of the snow albedo were closely related.

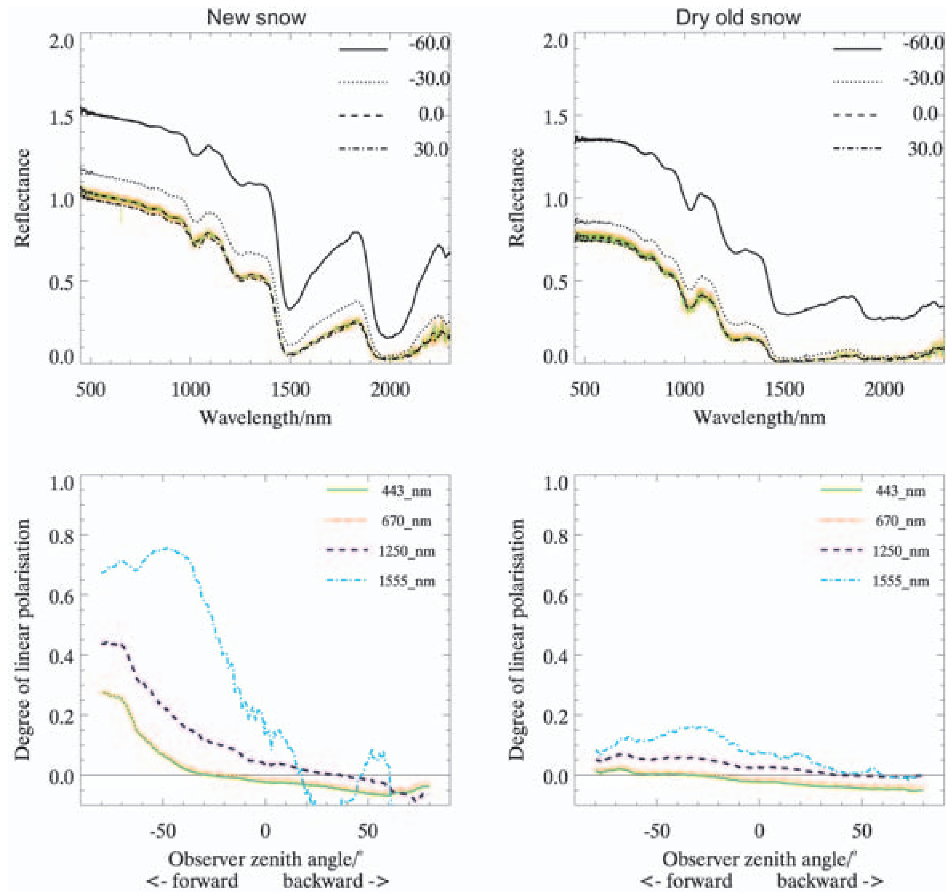

Figure 2. Results of FIGIFIGO measurements. *Top*: reflection spectra at four directions in the principal plane, 30¡ backwards, nadir 30¡ forward, and 60¡ forward. *Bottom*: degree of linear polarization as a function of the zenith angle in the principal plane: wet snow (*left*) and dry snow (*right*).

Our multi–scale strategy worked very well to support our aims. The SNORTEX follow–on for 2010 will encompass in addition airborne hyper–spectral measurement.

Climate modelling aimed at predicting future scenarios in northern Europe. However, useful results can only be obtained with realistic input values for snowmelt conditions. Therefore, even when temporal variations of snow properties at landscape scale are well depicted, ground–level campaigns are crucial. ■

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People

New SSC member

Aijun Ding
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Dr. Ding is Professor of atmospheric environment and atmospheric physics and Assistant Director in the Institute for Climate and Global Change Research (ICGCR), School of Atmospheric Sciences, Nanjing University, China.

Previously, he has worked in The Hong Kong Polytechnic University as Post–Doctoral Fellow and Research Fellow. Dr. Ding is involved in data analysis for several international measurement programs such as TRACE–P (TRAnsport and Chemical Evolution over the Pacific) and MOZAIC (Measurements of OZone, water vapour, carbon monoxide and nitrogen oxides by in–service Airbus airCraft).

Dr. Ding has also coordinated several field experiments (mountain–top/aircraft measurements) for national–level projects on ozone and acid rain in China. His scientific expertise is in the analysis and simulation of chemical and physical processes related to tropospheric ozone in East Asia. Dr. Ding has published over 20 peer–reviewed articles.

People

New SSC member

Francesco Loreto
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Dr. Loreto is Research Director at the National Research Council of Italy (CNR) and is currently the Director of the Institute for Plant Protection (IPP). He studies the interaction between the biosphere and atmosphere with emphasis on biosynthesis and emissions of biogenic volatile organic compounds (BVOC) and on primary and secondary metabolism of plants under environmental constraints.

He is a member of the managing committees of the COST Actions on Plant Proteomics and Climate Change and Forest Mitigation and Adaptation in Polluted Environments. He is also a delegate of the Italian Ministry of Research in the "Bio–economy panel" of the European Commission.

Dr. Loreto has published more than 120 peer-reviewed papers in international journals. He is a member of the editorial boards of the main international journals of plant biology and has coordinated the Marie Curie Research and Training Network "Ecological and physiological functions of biogenic isoprenoids and their impact on the environment (ISONET)", and the European Science Foundation Programme "Volatile Organic Compounds in the Biosphere-Atmosphere System (VOCBAS)".

People

New SSC member

Paul I. Palmer
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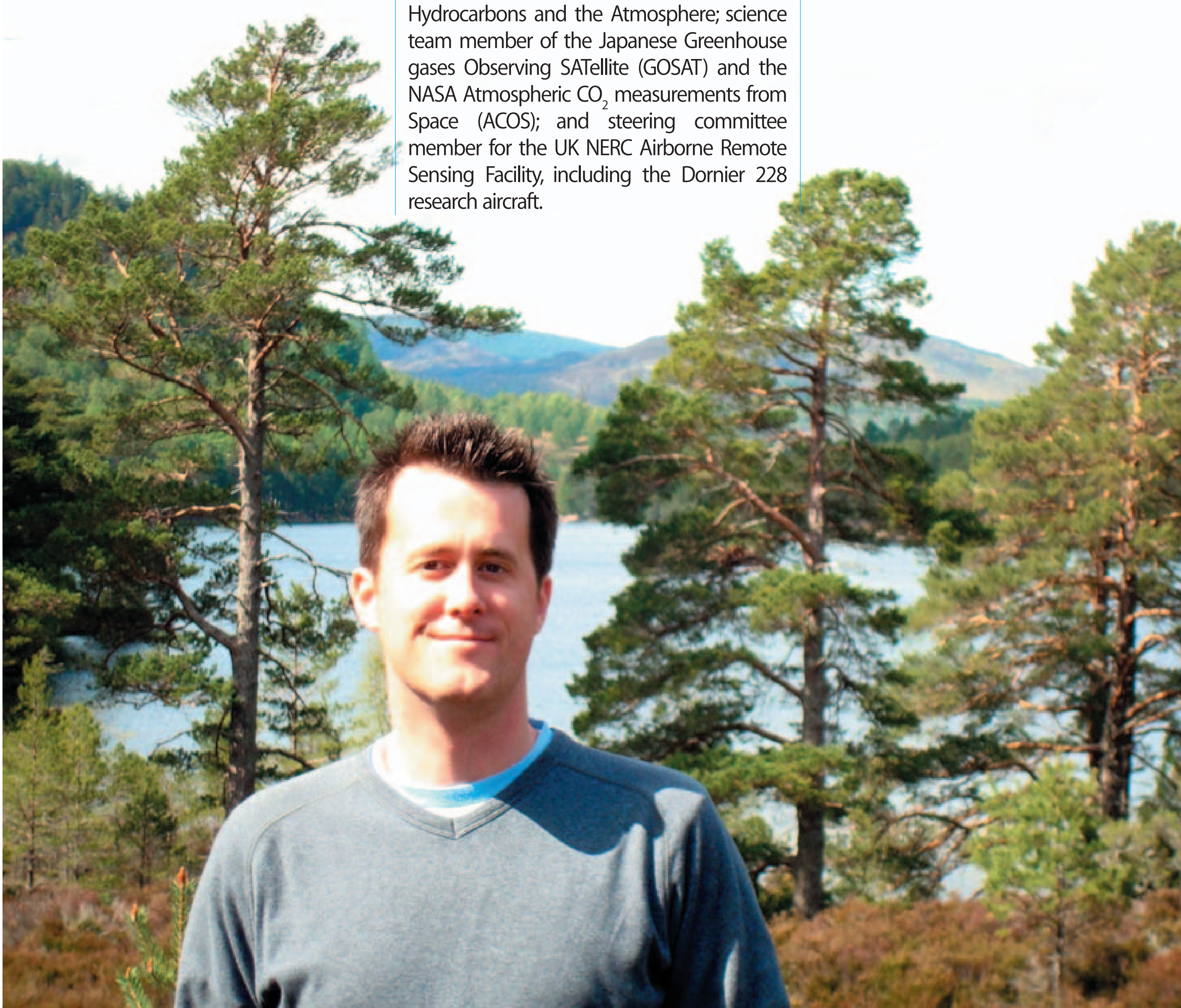
Dr. Palmer is Professor of Quantitative Earth Observation at the School of GeoSciences, University of Edinburgh, Edinburgh, UK. He received a 2008 Philip Leverhulme Prize for "outstanding young scholars who have made a substantial and recognised contribution to their particular field of study."

With a background in physics, Dr. Palmer's scientific expertise is in atmospheric chemistry and physics, biogenic volatile organic compound (BVOC) emissions, satellite remote sensing, and source/sink estimation methods. He has published 60 peer–reviewed articles.

Dr. Palmer is PI in the UK National Centre for Earth Observation; PI and aircraft mission scientist for BORTAS (Quantifying the impact of BOReal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites); vice chair (co–chair in 2012) of the Gordon Research Conference on Biogenic Hydrocarbons and the Atmosphere; science team member of the Japanese Greenhouse gases Observing SATellite (GOSAT) and the NASA Atmospheric CO_2 measurements from Space (ACOS); and steering committee member for the UK NERC Airborne Remote Sensing Facility, including the Dornier 228 research aircraft.



Meetings

Sapporo, Japan. Photos: Prof. Joon Kim.

8th AsiaFlux Workshop, Sapporo, Hokkaido, Japan, 27–29 October 2009

More than 180 scientists and students took part in the 8th AsiaFlux Workshop on "Integrating Cross-scale Ecosystem Knowledge: Bridges and Barriers." They represented 16 countries and regions with about 36 oral and 100 poster presentations. The workshop not only brought students, scientists, technologists, entrepreneurs, and policy-makers together, but also helped cross the cultural, disciplinary, geographic and hierarchical boundaries.

The workshop was organised around six topics:

1. Flux observation and analysis
2. Synthesising flux studies in Asia (CarboEastAsia)
3. Global biogeochemical cycles. This session focused on research on biogeochemical cycles conducted in collaboration with biogeochemical study programs such as iLEAPS.
4. Bridges between ecosystem observation and remote sensing
5. Barriers in flux measurements
6. Interfaces between carbon science and society

For the highlights and new findings addressed in these sessions, please see the full workshop report on pages 52–53 in this issue.

Many of the results presented at the workshop are currently being published in several scientific journals, including the 'CarboEastAsia' special issue in Biogeosciences.

More details are also available at the AsiaFlux homepage: www.asiaflux.net

NitroEurope 5th General Assembly and Open Science Conference, Solothurn, Switzerland, 1–5 February 2010

Organised by the NitroEurope Integrated Project1 and funded under the EC 6th Framework Programme, the conference brought together both the NitroEurope community and scientists outside the project to discuss the state of the art of nitrogen cycle research and its importance for the European greenhouse gas balance.

The aim of the conference was to

- contribute to underpinning N research by bringing together scientists from variousfields and disciplines working on related issues;
- improve the linking between compartments, by including keynotes on aquatic and oceanic ecosystems;
- address issues of scale from plot to landscape to European; and
- provide a platform to discuss and further the development of methodologies for up- and downscaling.

The conference hosted a side event bringing together key authors contributing to the European Nitrogen Assessment Report.

The conference was organised in 6 sessions:

1. Flux measurements of reactive nitrogen, pools and processes
2. Influence of changes in external drivers (global change, N deposition, management, land use change) on fluxes and exchange of nitrogen (N), carbon (C), and greenhouse gases (GHG) in terrestrial ecosystems
3. Plot-scale modelling of processes controlling the biosphere-atmosphere exchange of trace gases to predict effects of changes in climate, land use and land management on gas exchange of C and N compounds
4. Upscaling from plot to regional scales – analysing interactions on different spatial scales
5. Assessment of nitrogen and green house gas fluxes in response to human influence at large regional scales
6. Verification and uncertainty assessment of N and GHG management across disciplines.

More information at:
www.nitroeurope.eu/solothurn_5thAM

1st Terrestrial Biosphere in the Earth System Symposium (TERRABITES), University of Hamburg, Hamburg, Germany, 9–11 February 2010

The First TERRABITES (COST Action ES0805) Symposium was part of a sequence of biennial conferences. It was jointly organised with the sister network ABBA (Advancing the integrated monitoring of trace gas exchange between biosphere and atmosphere, COST Action ES0804) on trace gas exchange between biosphere and atmosphere.

The symposium aimed at

- providing a comprehensive overview on the current research on the terrestrial biosphere in an Earth System context
- identifying knowledge gaps
- showing perspectives for future research
- fostering cross–community exchange and research cooperation in the field.

Presentations and keynote speeches were divided to six sessions:

- Improving ecophysiological processes in vegetation models
- Flux constraints from ecosystem to global scale
- Quantifying community scale processes for vegetation models
- Challenges in understanding biogeochemical processes
- Key land–use processes for global change modelling
- Vegetation from space.

TERRABITES:
www.terrabites.net/1st-Symposium.906.0

ABBA:
www.ileaps.org/multisites/cost0804

7th iLEAPS SSC meeting, Royal Swedish Academy of Sciences, hosted by IGBP Secretariat, Stockholm, Sweden, 22–24 February 2010

The Scientific Steering Committee (SSC) of iLEAPS with 7 new members met in Stockholm to discuss the achievements and future directions of iLEAPS. At the moment, iLEAPS is half–way through its lifetime with 5 years still to go.

Overall, the SSC was happy with the current situation but felt that some adjustments could be made to the prioritising of key questions. Boundary–layer processes, micrometeorology, and cryosphere studies were brought up as potential focus points deserving more attention during the following years. The SSC recognised the success of the ACPC (Aerosols, Clouds, Precipitation, Climate) program and LUCID (Land–Use and Climate, IDentification of robust impacts) project and recommended similar activities for the new focus points.

In addition, for example, the SSC decided to concentrate on writing position papers and reviews of important issues such as comprehensive measuring stations, high–latitude processes, model evaluation, and land cover change. An International Science Committee was formed for iLEAPS International Science Conference 2011. The Science Conference takes place 18–23 September 2011 in Garmisch–Partenkirchen, Germany hosted by Karlsruhe Institute of Technology (KIT).

Information about iLEAPS SSC can be found at: www.ileaps.org / Organisation iLEAPS

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iLEAPS SCIENTIFIC STEERING COMMITTEE 2010

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iLEAPS RECOGNIZED PROJECTS

ACPC
AMMA
EUCAARI
FLUXNET A Global Network
IGBP X-PROJECT FIRE ACTIVITY
iLEAPS-GEIA
LUCID
NEESPI
POLARCAT
VOCBAS
WATCH Water and Global Change