Integrated Land Ecosystem - Atmosphere Processes Study

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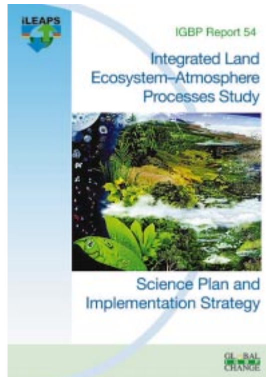

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A guest scientist can host a workshop, edit a book or journal special issue related to iLEAPS activities, guest-edit the iLEAPS Newsletter, develop new initiatives, plan and enhance national iLEAPS activities, construct a website.

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 page.

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, job vacancies or 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, the 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 a 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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CONTENTS

Editorial

Guest Editor Nathalie de Noblet-Ducoudré

In recent years, the role land surfaces play in the climate system has received increasing attention.

The scientific articles in this issue of the iLEAPS Newsletter focusing on land-climate interactions are based on the presentations and working group discussions at the Marie Curie-iLEAPS Conference *Feedbacks-Land-Climate Dynamics – Key Gaps: Current understanding of how integrated land ecosystem atmosphere processes influence climate dynamics*.

The conference was organised 16–20 November 2008 in Hyères, France. The event was the last one in a series of four Marie Curie-iLEAPS events taking place in 2007–2008 (www.ileaps.org/marie-curie-ileaps).

The objective of this Marie Curie – iLEAPS conference was three-fold:

a) to illustrate our present knowledge on how land surfaces influence climate variability and changes through their interactions with the atmosphere, at both regional and global scales;

b) to illustrate our present knowledge on the important feedbacks between the climate system and the land-surfaces;

c) to list the missing processes/components that may be involved in important land-atmosphere feedbacks and that need to be explored in the near future.

The workshop was organised in four successive sessions (combining oral and poster presentations) to try and address all the complex aspects of the land-atmosphere interactions:

- energy and water cycle
- biogeochemical cycles
- interactions with atmospheric chemistry and aerosols
- evaluation of models describing the above.

Model evaluation still remains one of the big challenges. The introductory talk by Colin Prentice mainly summarised the current unknowns in quantifying the influence of land in the main biogeochemical cycles (carbon and nitrogen). In addition, three specific parallel discussion sessions chaired and re-

Smoke trapped in the nocturnal boundary layer in Rondonia, Brazil. Photo: Andi Andreae.

ported by early-career scientists allowed for more interaction among the participants. The discussion sessions were:

- land use in land-atmosphere interactions
- missing feedbacks that need to be quantified
- evaluation of not only our vegetation models but also of their interactions with the atmosphere.

The two main points raised in the Land-use group discussion (see page 63) were land-use transitions and cropland representation in dynamic global vegetation models (DGVM).

Land-use transitions determine whether forest within a grid box is primary (old-growth) or secondary (recovering from previous human land-use activities). Carbon budgets and physical feedbacks between the land and the atmosphere are very different in these two forest types, and the group concluded that land-use transitions should be included in all DGVM contributing to the IPCC 5th assessment report.

Several modelling groups throughout the world are currently developing global cropland parameterisations. However, compared to the development of DGVMs, progress is slow, and the group suggested that although representing crops adequately would be most useful, it may be appropriate to use the existing parameterisations of natural vegetation as much as possible.

Finally, the Land-use group presented a wish list of datasets for representing land use in climate models. It included details on crop management, irrigation, and fire suppression.

The Feedbacks discussion group (see page 62) came up with a number of candidates for important processes hitherto omitted in climate modelling.

The role of micro-organisms in atmospheric chemistry such as aerosol formation and photochemical processes and the role of volatile organic compounds emitted by vegetation were identified as phenomena not sufficiently understood at the moment. Acid deposition and the human influence in it were mentioned as well as the influence of global warming on wetlands.

Soil-plant interactions and the human influence on the linked carbon-nitrogen-phosphorus cycles in plants and soil were also considered very important for better description of carbon, nitrogen, and phosphorus cycling.

The Model evaluation group formulated a list of elements important for organised and methodical model-data comparisons (see page 64). The group recommended writing a review paper on the current state of best available data sets for model evaluation and encouraging the development and sharing of "best" data sets by the community.

The Model evaluation group also stressed the importance of documenting model processes better to improve understanding of evaluation results. Closer collaboration among modelling groups and between the measurement and modelling communities was also considered important.

In conclusion, the group reiterated the importance of confronting models with observations and that this should be done early and often. Models must be tested and evaluated in offline, partially coupled, and fully coupled modes over short and long time scales and over small and large spatial scales. Experiments should include historical, present-day, and future time periods.

One of the main objectives of the workshop was to bring together early-career scientists all working on land-atmosphere interactions but from different viewpoints: physics, chemistry, biogeochemistry, and biology. The successful discussions we had proved that we achieved this objective, and many participants returned home with contact details of potential collaborators.

There were quite fewer candidates than we originally expected: we had planned on about 90 participants and selected only 55. Our interpretation is that the conference was meant to bring together specialists of the land-atmosphere interactions at the continental to global scale and *there are not enough of them working in this field nowadays*. This is really worrying since the purposes of developing such dynamic global vegetation models, apart from using them as diagnostic and impact tools, is to include more feedbacks in the modelled climate system!

Moreover, although the original goal of the conference was really to address *coupled* land-atmosphere studies to better understand their interactions, more than half of the talks and posters did not report on such interactions but mainly on influence of either land on atmosphere or the reverse in what we refer to as a 'forced' mode. This may be the result of the rather recent inclusion of biogeochemical cycles, aerosol production, emissions of biogenic compounds in those models.

This special issue gives an overview of the studies that were illustrated and discussed throughout those four days with its interdisciplinary diversity ranging from hydrology to biology.

The iLEAPS and GEWEX Parallel Science Conferences with joint sessions to be organised 24–28 August 2009 in Melbourne, Australia also stress the importance of research on land-climate interactions. This is illustrated by the iLEAPS Science Conference sessions and by selected joint sessions, for example: *Surface exchange processes from leaf level to Earth System scale* (iLEAPS Session 1); *Progress in land-atmosphere interactions and climate change* (iLEAPS Session 2); *The role of atmospheric boundary layer processes in modulating surface exchanges* (iLEAPS Session 3); *Aerosols from the land surface and their interactions with the climate system* (iLEAPS Session 4); *Land in the climate system* (Joint Session A). ■

George Hurtt is Associate Professor in the Department of Natural Resources and the Environment and the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. He has published on a wide range of topics including the role of dispersal in the dynamics and structure of plant communities, latitudinal and elevational gradients in biodiversity, and ocean and terrestrial ecosystem models for use in studies of the global carbon cycle and global climate change. His current research focuses on the development and application of mathematical models to address issues such as the sustainability of land-use practices, the effects of disturbances on ecosystem structure and function, and interactions between the biosphere, hydrosphere, and atmosphere.

Harmonisation of global land-use scenarios for the period 1500–2100 for IPCC-AR5

*Authors 4–20 in alphabetical order

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The evidence is now overwhelming that human activity has significantly altered basic element cycles (*e.g.* of carbon and nitrogen), the water cycle, and the land surface (*e.g.* vegetation cover, albedo) at regional, continental, and planetary scales, and that these alterations are influencing the regional and global environment, including the Earth's climate system.

During the last 300 years, 42–68% of the land surface has changed because of land-use activities (crop, pasture, and wood harvest), some of it multiple times [1]. Agricultural land now covers more than a third of the land surface [1,2], and globally there are 10–44 · 10^6 km^2 of land that is recovering from previous human land-use activities ("secondary" land) [1].

These land-use changes are estimated to have added carbon to the atmosphere, altered the surface albedo, surface aerodynamic roughness, and rooting depth of

This work was coordinated by a joint venture between the Analysis, Integration and Modelling of the Earth System (AIMES) core project of the International Geosphere-Biosphere Programme (IGBP) and the Integrated Assessment Modelling Consortium (IAMC) in preparation for IPCC-AR5. George C. Hurtt, Louise Parsons Chini, and Steve Frolking gratefully acknowledge the support of a National Aeronautics and Space Administration research grant (NNX07AH32G). Data products described in this study are available at: http://luh.unh.edu.

vegetation, with resulting changes in regional and global water, carbon, and climate. Looking ahead, population and the demand for energy, food, fibre, and water are expected to increase further, placing even greater pressure on the Earth system.

In preparation for the fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the international community is developing new advanced Earth System Models (ESM) to address the combined effects of human activities (*e.g.* land use and fossil fuel emissions) on the carbon-climate system.

In addition, four Representative Concentration Pathways (RCP) scenarios of the future (2005–2100) are being provided by four Integrated Assessment Model (IAM) teams to be used as input to the ESMs for future climate projections). The RCPs represent three mitigation pathways (two stabilisation and one overshoot and decline) and one no-policy pathway that continues to increase radiative forcing beyond 2100.

The diversity of requirements and approaches among ESMs and IAMs for tracking land-use changes (past, present, and future) is significant. Moreover, IAM future projections must smoothly transition from the end of historical reconstructions. For these reasons treating land use comprehensively and consistently among these communities in the IPCC exercise (Fig. 1) is an important challenge.

As part of an international working group, we have been working to meet these challenges by developing a "harmonised" set of land-use change scenarios. Each harmonised scenario smoothly connects spatially gridded historical reconstructions of land use with future projections in a format required by the ESMs.

Previously, we created the Global Land-use Model (GLM) that produced estimates of 1° x 1° fractional land-use patterns (*e.g.* crop, pasture, secondary) and underlying land-use transitions annually 1700–2000 [1].

Land-use transitions describe the annual changes in land use and are important because changes such as harvesting trees and establishing or abandoning agricultural land often directly alter land-surface characteristics that, in turn, affect energy, water, and carbon exchanges between the land surface and the atmosphere. Resulting land-use data have been successfully used as input to a new global dynamic land model (LM3V) able to track the consequences of these changes for both the carbon cycle and climate [3].

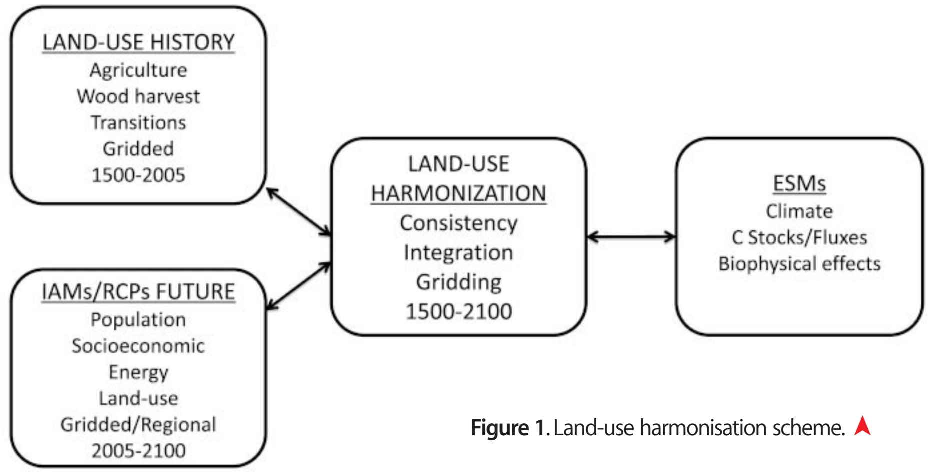
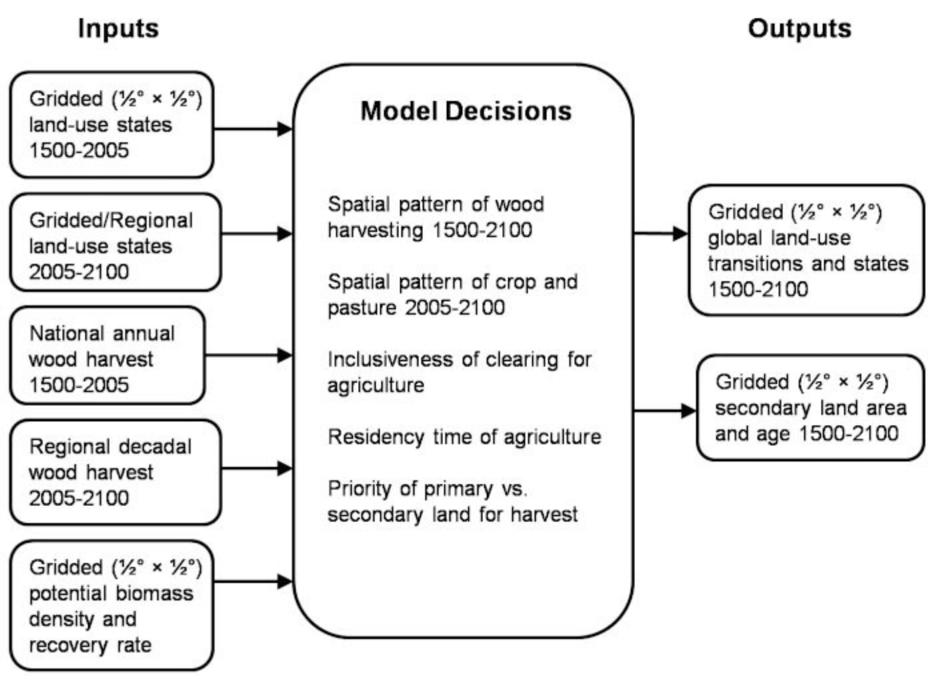


Figure 1. Land-use harmonisation scheme.

Figure 2. Flow diagram of inputs, outputs, and model decisions for the global land-use model (GLM) used in harmonisation.



Our new land-use harmonisation strategy builds upon the GLM framework by computing enhanced estimates of land-use patterns and underlying land-use transitions annually for the time period 1500–2100 at 0.5° x 0.5° resolution (Fig. 2). Inputs include new gridded historical maps of crop and pasture data from HYDE 3.0 1500–2005 [2], updated estimates of historical national wood harvest and of shifting cultivation, and future information on crop, pasture, and wood harvest from the IAMs implementations of the RCPs for the period 2005–2100.

Our computational method integrates these multiple data sources while minimising differences at the transition between the historical reconstruction ending conditions and IAM initial conditions, and working to preserve the future changes depicted by the IAMs at the grid level.

Fig. 3 illustrates preliminary harmonisation time series results based on one of the IAMs, the IMAGE model, aggregated globally for the period 1900–2100.

The four solid lines in Fig. 3 represent global time series (1900–2100) for cropland, pasture, primary land (natural vegetation with no prior land-use history) and secondary land. The dashed lines represent global cropland and pasture time-series (2005–2100) from the IMAGE model. The figure shows that the transition from past to fu-

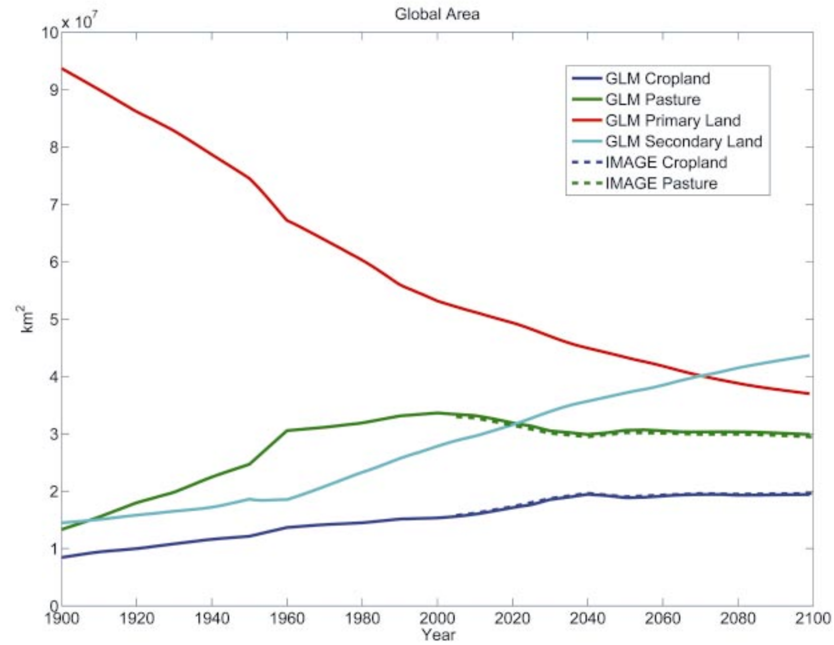


Figure 3. Time series of global area of cropland, pasture, primary land, and secondary land from the output of global land-use models (GLM) compared with IMAGE model (one of the IAMs) inputs. A major goal of our harmonisation was to re-grid the IAM crop and pasture inputs by applying IAM decadal changes to the historical reconstructions to ensure a smooth transition from past to future in 2005. This figure shows that the global harmonised land-use data (output from GLM) does indeed transition smoothly from past to future in 2005 and faithfully preserves global land-use changes in the IAM land-use data (IMAGE cropland and pasture data). Primary and secondary land were computed as part of the GLM. The algorithms used there are one of the key contributions of our work.

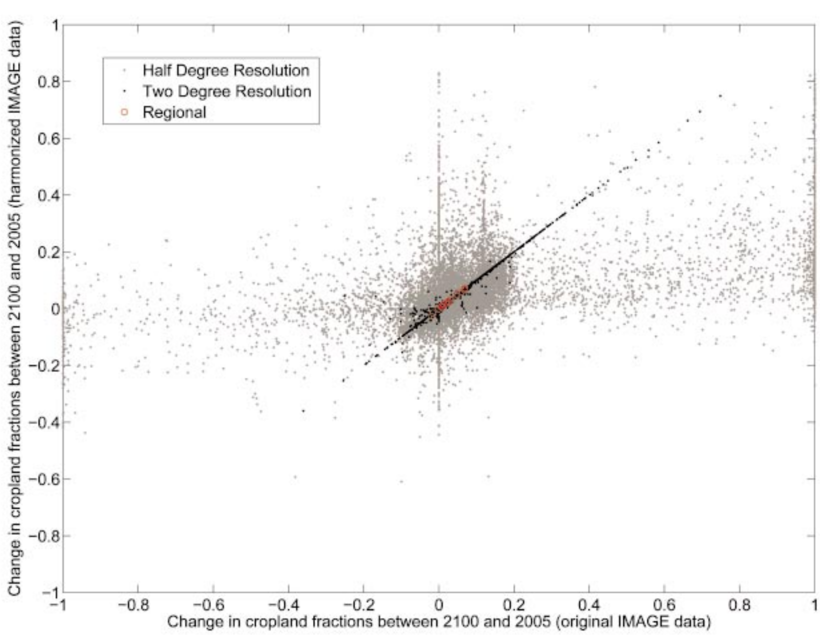


Figure 4. Scatter plot of gridded cropland changes in IMAGE (one of the IAMs) data compared with cropland changes in the harmonised dataset (2005 to 2100), at 0.5-degree (grey, $n \sim 70{,}000$), 2-degree (black, $n \sim 5000$), and regional (red, $n = 24$) resolution. Our harmonisation scheme attempts to preserve spatial patterns of IAM decadal crop and pasture changes while ensuring a smooth transition from past to future in 2005—this figure shows that although at 0.5-degree spatial resolution the land-use changes computed from the harmonisation strategy do not preserve those provided by the IAMs, at 2-degree and regional spatial resolutions the land-use changes are preserved well.

ture is smooth for all land-use categories (cropland, pasture, primary, and secondary) and close to the aggregated results from the IMAGE model (for cropland and pasture). It also shows that the harmonised land-use projections faithfully preserve future crop and pasture land-use changes computed by the IAMs.

Fig. 4 summarises corresponding gridded results, and indicates that the harmonisation strategy does a reasonable job of also preserving IMAGE gridded changes, particularly when aggregated to 2° x 2° resolution, and at regional scales.

Understanding the effects of human activities on the Earth system requires that the best technical expertise and data on land use be incorporated into the best climate models. Our approach of harmonising the treatment of land use between ESMs and IAMs represents a major advance that will facilitate fuller and more consistent treatments of how both land use and land-use change influence the Earth system, including the effects of CO_2 emissions, and corresponding gridded land-surface changes that potentially have biogeophysical effects.

Preliminary products from this activity are currently available; final products will include urban lands, and be finalised using data from all four IAMs later in 2009. Future efforts are necessary to fully implement these products and to integrate ESM and IAM modelling communities even more tightly for future studies of the coupled human-climate system. ■

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surface ocean solas lower atmosphere study

Sam Levis is a Project Scientist in the Community Land Model (CLM) development and support team and the team's "scientific liaison" at NCAR. Sam specialises on vegetation and crop modelling, and his published work focuses on climate-vegetation interactions using coupled models. He has also studied aspects of land-atmosphere interactions relating to snow, volatile organic compounds, and hydrology.

At the moment, Sam directs his attention to land use, land management, and biogeochemistry in Earth System Models. Other than at scientific meetings, Sam talks about his work to high school students, the Colorado Public Utilities Commission, science panels visiting NCAR, and university departments.

He earned a BA in Physics from Cornell University, and an MSc and PhD in atmospheric and oceanic sciences (minor ecology) from the University of Wisconsin-Madison. While in graduate school, Sam worked on a three-month project in Germany at the Potsdam Institute for Climate Impact Research (PIK) with the LPJ (Lund-Potsdam-Jena)-Dynamic Global Vegetation Model group.

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Modelling land use and land management with the Community Land Model

Global climate models have included progressively more complex representations of the land surface to improve the simulated biogeophysics (for instance, transport of water and energy among the atmosphere, land, and ocean) and biogeochemistry (carbon and nitrogen cycles, dust and biogenic emissions). Such coupled systems of increasing complexity are referred to as Earth System Models (ESMs).

Groups developing ESMs cannot neglect the human footprint on the landscape in simulations of historical and future climates. Traditionally we have represented this footprint with a vegetation category mimicking the behaviour of crops, sometimes using grassland or savannah as a proxy for managed ecosystems.

Most efforts have yet to incorporate more explicit representations of land management such as crop type, planting, harvesting, tillage, fertilisation, and irrigation, particularly because global-scale datasets of these factors have lagged behind vegetation mapping.

This is beginning to change. Today, we are increasingly developing models that will predict the biogeophysical and biogeochemical effects not only of natural but also of human-managed land cover [1, 2].

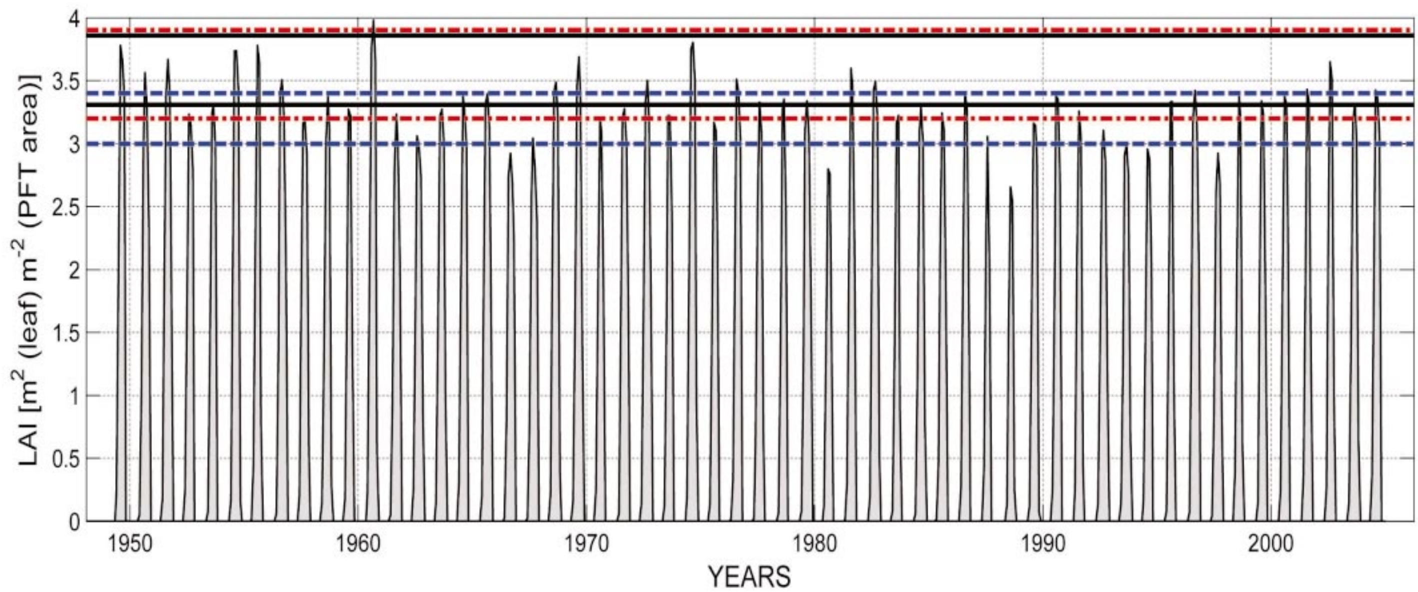

Figure 1. Corn leaf area index (LAI) in Arlington, Wisconsin, USA, from a >50-year CN-crop point simulation driven with observed weather (filled curves) [11]. Black horizontal lines indicate the range of maximum simulated values by AgroIBIS [4]. Red (dash-dot) and blue (dashed) lines indicate the range of maximum observed values quoted in the same study for fertilised and unfertilised corn, respectively.

AgroIBIS is a state-of-the-art land-surface model with options to simulate dynamic vegetation [3] and crop life-cycles [4].

We have coupled the crop parameterisations from AgroIBIS directly to the carbon and nitrogen cycle algorithms (CLM-CN [5]) of the Community Land Model version 3.5 (CLM3.5) [6]). We refer to this coupling as CN-crop.

In summary, simulated carbon allocation in the plants – in the presence of limited nitrogen – determines simulated crop growth, leaf area index (sum of leaf area per unit area of ground, LAI), plant height, and grain harvest. Temperature drives crop life-cycle transitions, which affect the plants' simulated carbon allocation and phenology.

For example, carbon allocation to the crop's leaf, live stem, fine root, and reproductive pools begins upon leaf emergence and ends with harvest, but allocation to the reproductive pool, in particular, happens only during the last phase of development (from the beginning of grain fill to physiological maturity and harvest).

CLM's list of plant functional types (PFTs; simple plant categories following general morphological and phenological characteristics) includes a generic crop that is modelled like a grass and distributed spatially according to satellite data [6].

CN-crop's new PFTs (corn, soy, and wheat) get grid cell coverage from the 1992 crop dataset of Ramankutty and Foley [7]. With guidance from AgroIBIS, we changed a variety of parameters to distinguish the simulations of corn, wheat, and soy from CLM's generic crop. We expect to expand CN-crop to include other crops of global significance, such as rice.

To allow crops to coexist with natural vegetation in a model grid cell, yet be simulated separately by a crop and a dynamic vegetation model, respectively [8], we separated the vegetated land unit into two: naturally vegetated and human managed. PFTs in the former share one soil column and compete for water, while crops in the latter do not share soil columns to permit for differences in management. Methods of implementing realistic [9] and prognostic irrigation (not published), as well as fertilisation, have not yet been attempted with CN-crop.

The agreement of preliminary results with observations is encouraging. For example, the simulated LAI of corn in Arlington, Wisconsin, begins to increase every year upon leaf emergence and reaches maximum values of a range similar to the maximum values observed at this site. The range of maximum LAIs simulated by CN-crop is also similar to that simulated for this site by the AgroIBIS model (Fig. 1).

The average annual cycle of the simulated LAI looks completely different for corn, wheat, and soy relative to that of the grass and the generic crop PFTs (Fig. 2).

The grass and generic crop grow in the natural portion of the model grid cell and are not subject to human management, such as harvest in late summer. Harvest removes the vegetation from the landscape at a time that agrees qualitatively with observations for this site. The model also overestimates the grass and generic crop LAIs throughout the growing season, while simulating quite reasonable LAIs for unfertilised and rain-fed corn, wheat, and soy.

With a more accurate representation of agricultural landscapes we hope to improve the simulated biogeophysics and biogeochemistry in the CLM. These advances may improve fully coupled simulations with the Community Climate System Model (CCSM), while helping human societies answer questions about changing food, energy, and water resources in response to changes in

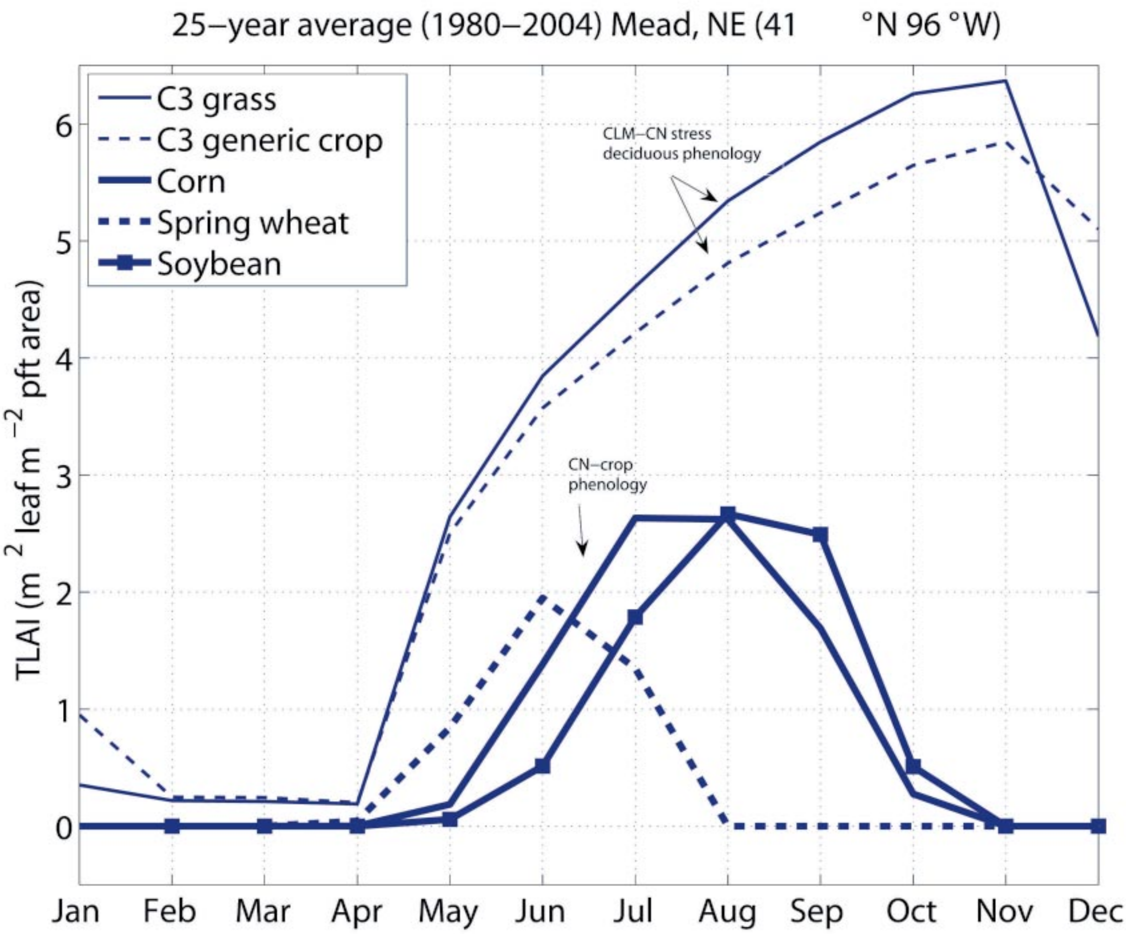

Figure 2. 25-year average monthly leaf area index (LAI) in Mead, Nebraska, USA, from a CN-crop point simulation driven with observed weather [11]. The grass, crop, corn, wheat, and soy plant functional types occupy different parts of the single model grid cell in this simulation. The grass and generic crop phenologies (*i.e.* their periods of greenness and dormancy) are simulated by CLM-CN, while the phenologies of corn, wheat, and soy are simulated by CN-crop.

climate, the environment, and land use/management [4, 10]. Land management practices available in updated versions of CN-crop may include crop rotation, irrigation, fertilisation, and tillage. ■

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Africa Palaeofire Workshop
26–30 October 2009
Nairobi, Kenya

Late-Quaternary sedimentary charcoal records are used to explore the linkages among climate, vegetation and humans and to evaluate components of Earth System Models (ESM). The Global Palaeofire Working Group (GPWG) has created the first Global Charcoal Database (GCD) now being used for regional syntheses and for testing hypotheses. The African Palaeofire Workshop will train participants in the use and applications of the GCD. Specifically, the goal of this workshop is to promote the exchange of information among the fire science community within Africa.

The workshop will explore state-of-the-art analytical techniques used in fire history reconstructions, and introduce workshop participants to palaeofire model simulations.

This workshop will expand the existing data coverage of late Quaternary charcoal records from Africa and produce a multi-authored paper synthesizing late Quaternary palaeofire activity in Africa.

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Additional information can be found on the GPWG website:
www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeofire_WG

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Since 2005, she has been working within the UK-Japan Climate Collaboration, a joint project between NCAS Climate, the UK Met Office and Earth Simulator Center (Japan). The group is developing a high-resolution climate model.
(www.earthsimulator.org.uk)

Marie-Estelle's principal scientific interest is the hydrological cycle, focusing on precipitation distribution in atmospheric models of different resolution. This work contributes to her PhD project, which addresses the role of land surface - atmosphere interactions in global climate models. The project focuses on understanding the processes controlling the water cycle over land, especially the role of soil moisture and its variability in time and space, which is mainly determined by the precipitation distribution.

Marie-Estelle Demory and Pier Luigi Vidale
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Does overestimated canopy interception weaken the UK land surface model response to precipitation events?

Interactions between the land surface and the atmosphere occur at all spatial and temporal scales. These interactions are mainly regulated by the amount of radiation received at the Earth's surface and by the hydrological cycle. The atmosphere precipitates water, which modulates soil wetness, and in return transmits water to the atmosphere by soil evaporation and plant transpiration (hereafter ET) (Fig. 1).

These local interactions strongly depend on the location, intensity and frequency of precipitation. Precipitation, however, is not simulated properly in climate models [1], and models disagree on the land surface - atmosphere coupling strength, the degree to which these two components influence each other [2].

An example is the UK - Met Office general circulation model (GCM), the Unified Model (UM). The UM is a fully coupled ocean - atmosphere - land surface model in which the land surface - atmosphere feedback is weak compared to that simulated by other models [2]. This deficiency has been explained by the insensitivity of the boundary layer evolution to soil moisture in the UM, together with an overly high frequency of drizzle rainfall (0–1 mm day^{-1}) [3]. Drizzle leads to relatively constant soil moisture and, consequently, to small variability in evaporation, which diminishes the impact of land surface processes on the atmosphere [3].

This study is an attempt to understand the mechanisms involved in the land surface response to different temporal distributions of precipitation. Because of the difficulty in analysing mechanisms in a coupled land-atmosphere model, a land surface-only model (JULES) driven (forced) by meteorological data is used in this study.

The scientific questions addressed in our study are:

- Is the land surface model used in the UM sensitive to precipitation frequency and intensity?
- What are the mechanisms involved in the land surface response to drizzle precipitation events?
- What are the implications for the land surface state (e.g. soil moisture, photosynthetic activity)?

In order to remove the feedback processes between the land surface and the atmosphere in the UM, we isolated the land surface model, JULES [4], used in the UM. We forced it, as described below, with observed (CONTROL experiment) and synthetic atmospheric data that re-shape the observed distribution of precipitation events by, for instance, over-weighting high frequency (drizzle) precipitation, so as to mimic the drizzle precipitation simulated by the UM (SMOOTH experiment).

We show here two of the simulations performed over the Alpine region for one year after reaching equilibrium (via a ~25-year spinup).

1. CONTROL: JULES is forced with the 3-hourly meteorological data used in the Global Soil Wetness Project GSWP2 [5]. The forcing data are the observed air temperature and humidity, wind, radiation, surface

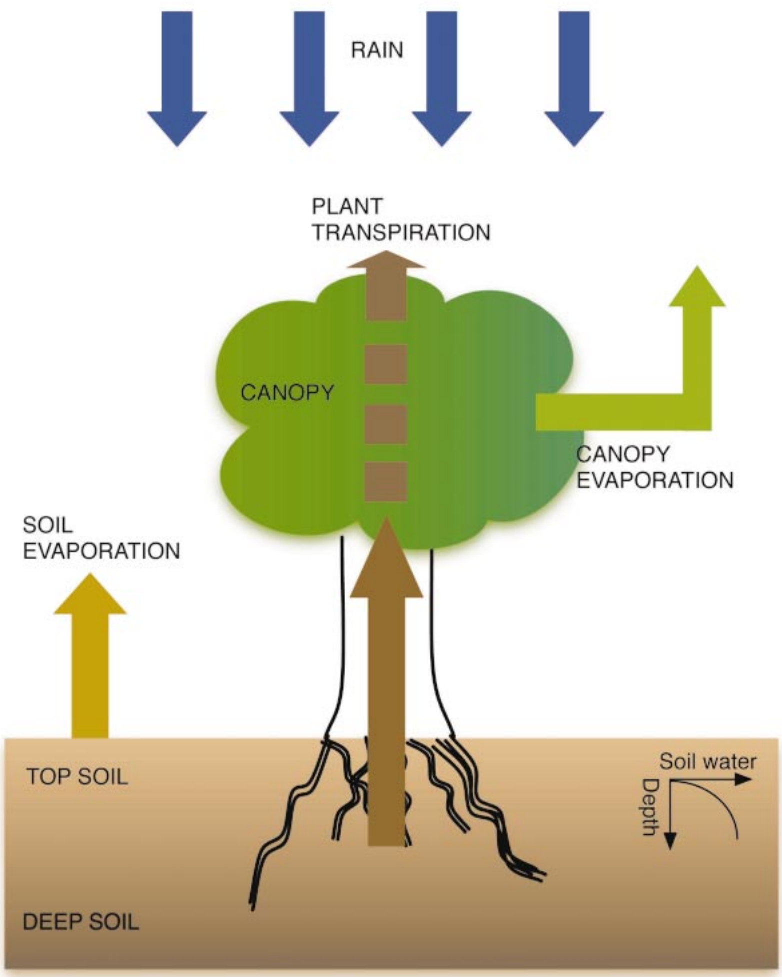

Figure 1. A schematic diagram of the different sources of evaporation over a vegetated surface: soil evaporation, plant transpiration and evaporation from canopy interception (also called canopy evaporation).

pressure, rainfall and snowfall rates for the chosen year of 1983.

2. SMOOTH: To mimic drizzle precipitation events as simulated in the UM, each GSWP2 forcing field listed above is averaged monthly, based on 3-hourly data to conserve the diurnal cycle. Within a month, the model therefore receives the same amount of rain, radiation, wind, etc., each day. The seasonal cycle is also conserved.

Each grid point (112 over the domain) is considered independent, as if there were 112 meteorological stations. In this summary, the results are presented for the entire domain, by taking an average of all grid points.

Total evapotranspiration (ET plus evaporation from canopy interception) is generally larger in the SMOOTH experiment than in the CONTROL experiment (Fig. 2), especially in early summer. This result is consistent with UM (coupled) past simulations, which produced too much evapotranspiration over land [3].

However, in July the total evapotranspiration in SMOOTH is less than in CONTROL. This is because the consistently exaggerated evapotranspiration, together with the drizzle precipitation, has not allowed sufficient springtime recharge of deep soil moisture, causing a peak-summer soil water deficit, and preventing plants from transpiring (Fig. 3).

The principal component of total evapotranspiration in the SMOOTH experiment is the evaporation from canopy interception (about 55%), while the CONTROL experiment has a dominant ET (about 70%). Although CONTROL is more realistic, the results still differ considerably from the multi-model ensemble GSWP2 data, where ET contributes to 82% of total evapotranspiration and evaporation from canopy interception to 16% over the same alpine domain.

The evaporation from canopy interception is controlled by interception of precipitation by leaves, a function of the canopy capacity (mm), which is the maximum amount of water necessary to saturate the canopy before the water falls over.

In JULES, the canopy capacity is parameterised as 0.5+0.05 · LAI (Leaf Area Index; the total leaf area per unit surface area), which is much larger than in most other land surface models (0.1 · LAI for SiB [6] and NCAR-LSM [7], 0.2 · LAI for CLASS [8]). This implies that JULES exaggerates the average interception of rainfall by leaves, especially if precipitation is in the form of drizzle.

Changing this expression to 0.1 · LAI in the new CONTROL (called CONTROL_CAN) and SMOOTH (called SMOOTH_CAN) experiments (Fig. 2) has a beneficial effect on the partitioning of total evapotranspiration.

ET contributes to 78% of the total evapotranspiration in CONTROL_CAN (55% in SMOOTH_CAN) and evaporation from canopy interception to 17% in CONTROL-_CAN (39% in SMOOTH_CAN), although the mean total evapotranspiration does not change. In SMOOTH_CAN the plants are also more active than in SMOOTH, due to deep soil moisture recharge in spring (Fig. 3).

The new canopy capacity also has an impact on the amplitude of the seasonal cycle of soil moisture. In the CONTROL experiment, the amplitude is 139 mm. In the SMOOTH experiment, the amplitude is lower (126 mm); reducing the canopy capacity amplifies it by 15% in SMOOTH_CAN (145 mm), and by 3% in CONTROL_CAN (143 mm). For reference, the multi-model ensemble GSWP2 data predict a soil moisture seasonal cycle amplitude of about 190 mm. These results show that the combination of an overly large canopy interception capacity and the overestimation of drizzle precipitation strongly affects the land surface state.

Our study provides additional insight into the causes for the poor land surface-atmosphere coupling in the Unified Model [2]. Evaporation of canopy interception is the fastest process involved in the water exchanges between the land surface and the atmosphere, as it has an immediate response that does not depend on the state of soil, nor on the state of vegetation.

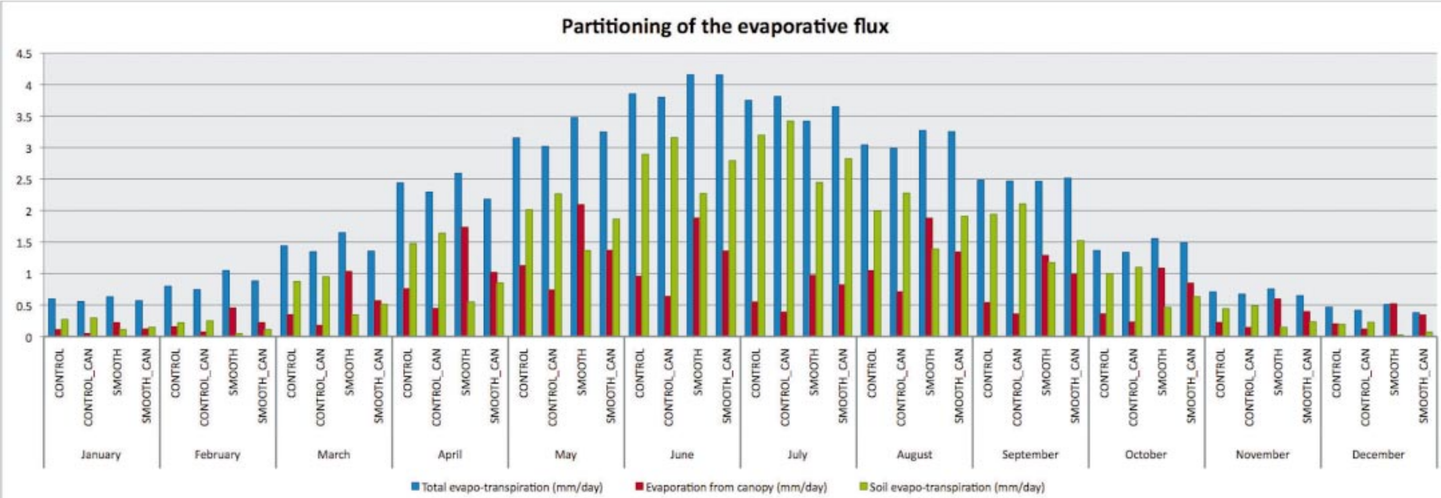

Figure 2. Annual cycle of total evapotranspiration (*blue*), in mm day^{-1}, partitioned into evaporation from canopy interception (*red*) and soil evaporation plus transpiration (ET) (*green*) for the CONTROL, CONTROL_CAN (CONTROL with a new canopy capacity), SMOOTH and SMOOTH_CAN (SMOOTH with a new canopy capacity) experiments. The fields are averaged over the Alps (2-17.5E/42.5-49N).

If the response in evaporation is dominated by evaporation of rain from canopy interception, as is the case in JULES, the state of soil and vegetation has very little influence on the atmosphere. By decreasing the role of this process in JULES, we showed that soil moisture increased and its seasonal cycle was amplified, giving more weight to the soil evaporation and transpiration response.

Plant activity in our results indicated that deep soil moisture, involving longer-term processes, also plays an increasing role in the land-atmosphere interactions. As this is especially true for drizzle precipitation, decreasing the role of canopy interception is very likely to strengthen the land surface -atmosphere coupling strength in the UM, which simulates too much drizzle precipitation [3]. After further investigation, we plan to integrate these modifications into the UM to investigate the feedback processes and possible impacts on precipitation. ■

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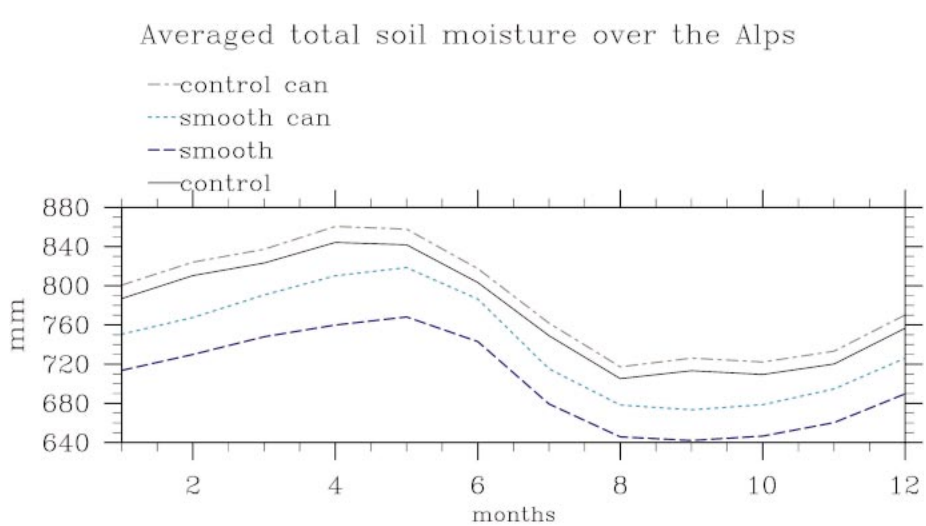

Figure 3. 1-year time series of monthly total soil moisture (mm day^{-1}) averaged over the Alps (2-17.5E/42.5-49N) for the CONTROL (*black*), SMOOTH (*blue*), CONTROL_CAN (*grey*) and SMOOTH_CAN (*light blue*) experiments.

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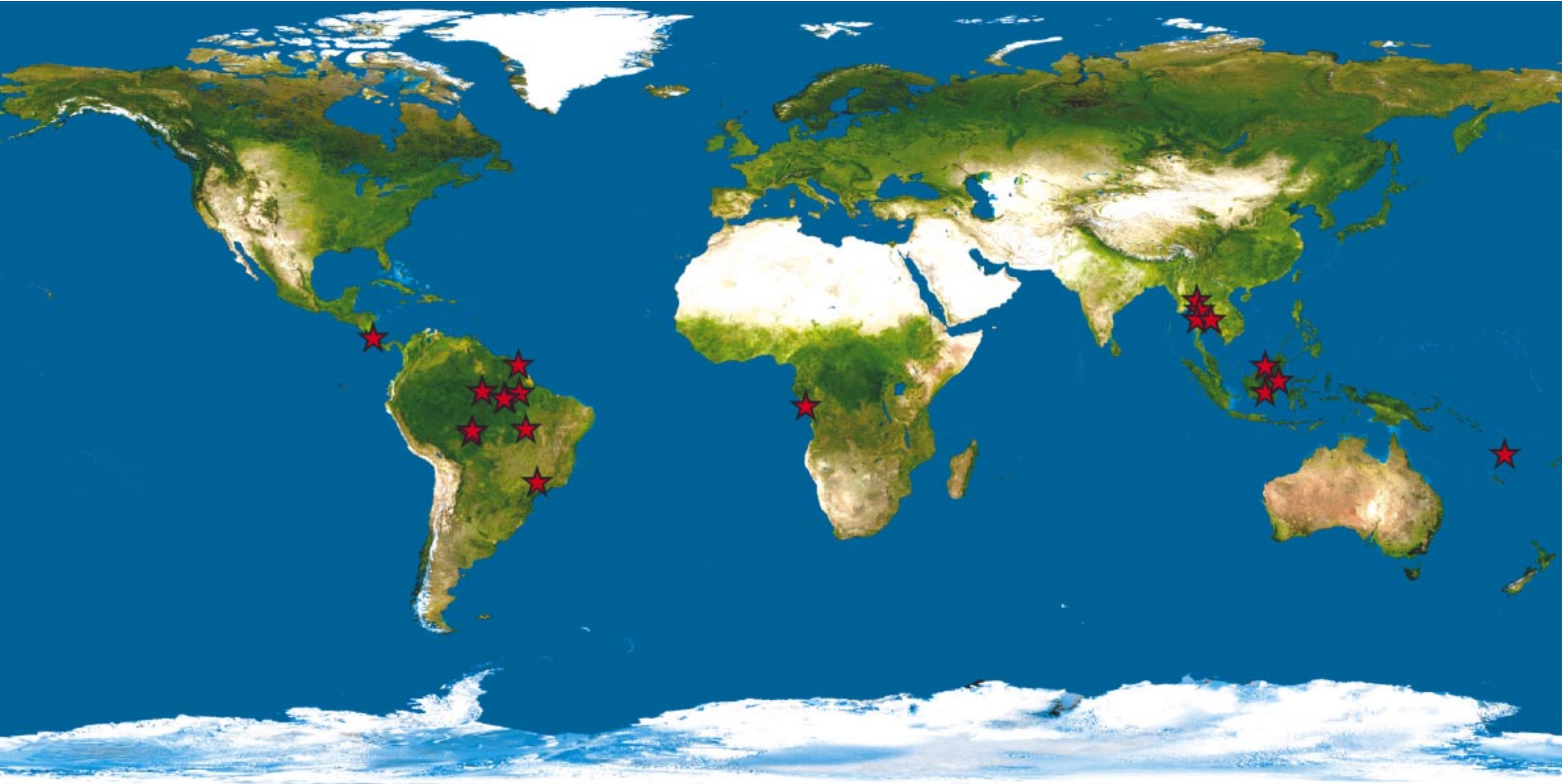

Figure 1. The 21 tropical eddy-covariance measuring sites.

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Evapotranspiration from tropical vegetation

Tropical vegetation is a major source of global land-surface evapotranspiration, and can thus play an important role in global hydrological cycles and global atmospheric circulation [1, 2, 3]. Accurate prediction of tropical evapotranspiration (evaporation from surfaces and transpiration by plants) is critical to our understanding of these processes under the changing climate.

We examined the controls on evapotranspiration in tropical vegetation at 21 pan-tropical eddy-covariance sites (Fig. 1), conducted a comprehensive and systematic evaluation of 13 evapotranspiration models (based on radiation, temperature, or atmospheric transfer/resistance) at these sites, and assessed the ability to scale up model estimates of evapotranspiration for the test region of Amazonia.

Net radiation turned out to be the strongest determinant of evapotranspiration (average evaporative fraction, the ratio of evapotranspiration to net radiation, 0.72) and explained 87% of the variance in monthly evapotranspiration across the sites. Vapour-pressure deficit was the strongest predictor (14%) of the residual variation that net radiation could not predict, followed by the Normalised Difference Vegetation Index (NDVI, 9%), precipitation (6%), and wind speed (4%).

Overall, the radiation-based evapotranspiration models performed best for three reasons:

1) evapotranspiration was largely unaffected by atmospheric turbulent transfer, especially at the wetter sites;

2) the difficulty of characterising canopy and stomatal resistance (water vapour transfer in canopy and at leaf surface) consistently in the highly diverse vegetation hindered the resistance-based models;

3) the temperature-based models captured the variability in tropical evapotranspiration inadequately.

Finally, we evaluated the potential to predict regional evapotranspiration for one test region: Amazonia. We estimated the evapotranspiration for the whole Amazonia to be 1370 mm yr^{-1}. ■

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The influence of a dry winter on the development of the South-American monsoon

In this sensitivity study, we used the Rossby Centre regional atmosphere model RCA3 [1] modified by including the surface database Ecoclimap and by adjusting the atmospheric physics to improve the performance of the model for tropical and subtropical climates (RCA3-E). The continental model domain had a horizontal resolution of 0.5º and 24 levels in the vertical.

In the tropical and subtropical South America, a warm-season precipitation maximum associated with the South American Monsoon System (SAMS) dominates the seasonal precipitation cycle. The ongoing deforestation in South America can decrease soil moisture in the region which, in turn, can potentially modify the monsoon rainfall.

Previous studies of the effect of modified soil moisture on SAMS have led to quite opposite results [2, 3]. On the one hand, a dryer soil can lead to higher air column temperatures because evapotranspiration (latent heat flux; evaporation from surfaces and transpiration by plants) decreases and, therefore, a larger portion of outgoing energy will be in the form of warm air rising (sensible heat flux). This increases the thermal gradient between the continent and the ocean which can produce stronger inflow of the Atlantic trade winds over the continent, bringing moisture to the monsoon region and producing an early onset of the monsoon. On the other hand, some studies [*e.g.* 2] have shown that destabilisation of the atmosphere through latent heat flux influences the large-scale circulation triggering the inflow of trade winds. A dry disturbance resulting in weaker latent heat fluxes may, therefore, lead to a later onset of the monsoon.

We explored the influence of anomalous soil moisture in late austral winter on the development of SAMS through two ensembles of simulations. The first ensemble was initialised with extremely dry and the other one with extremely wet soil moisture conditions over the whole continent. Members of each ensemble differed only in initialisation dates.

Our study covered the monsoon of only one summer, from August 1992 to March 1993. However, the surface and dynamical processes of SAMS act independently of the large-scale conditions [3, 4] and could therefore be similar in other summers. Our results showed that soil moisture anomalies induce both large-scale and local precipitation responses.

The difference between the wet and dry ensemble in the partitioning of surface fluxes (the relationship of latent heat flux to sensible heat flux) induced a large difference between the ensembles in air column temperature over the central part of Amazonia.

In the dry ensemble, the continental air temperature was higher and brought in stronger Atlantic trade winds over the northern part of the continent that were blocked and turned anti-clockwise to the south by the Andes mountains. Moisture convergence for dry initial conditions was therefore larger than for wet conditions east of the northern Andes and in southern Amazonia, producing more rainfall over these regions during spring (Sep-Oct).

In summer (Dec-Jan), precipitation was stronger in the wet ensemble than in the dry one in central Amazonia. Because no difference was observed in moisture convergence (a large-scale phenomenon) in this region among the two ensembles, an explanation could be local precipitation recycling: the region remained wetter since springtime precipitation was similar in both wet and dry ensembles although the soil moisture conditions differed.

Our results are only preliminary. A more thorough analysis on different time scales is in progress. ■

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Streamflows simulated by ORCHIDEE over the Mississippi river basin: sensitivity to the forcing resolution and parameters

The variability and uncertainties of regional water resources can be studied using land surface models (LSM). In order for the models to give reasonable results, we need a good understanding of the simulated processes. River discharge is a crucial variable to LSMs because it integrates all the large-scale hydrological processes on land surface. Therefore, it is very useful for model validation against many available observations.

In this study, we tested the ability of LSM ORCHIDEE (ORganising Carbon and Hydrology In Dynamic EcosystEm) to simulate streamflows (the amount of water flowing in a river; the main mechanism by which water moves from the land to the oceans) with two atmospheric input datasets (forcings) differing in resolution.

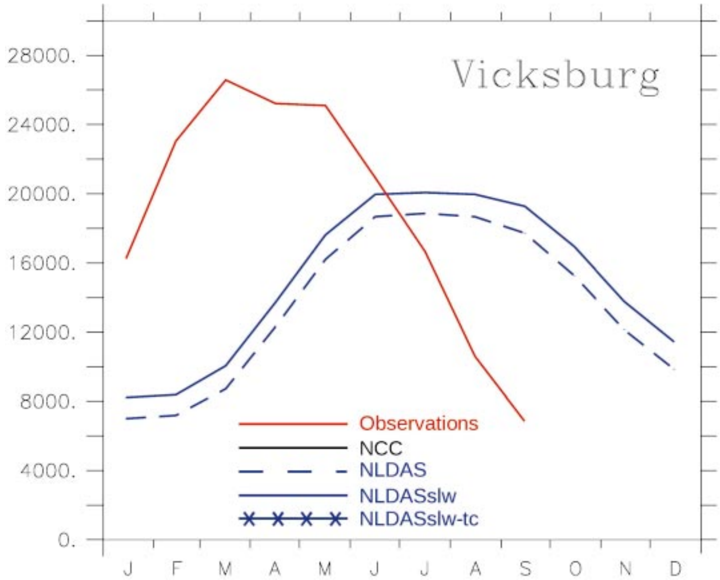
ORCHIDEE is composed of three components but only SECHIBA (Schématisation des EChanges Hydriques à l'Interface Biosphère-Atmosphère) [1] is used in this study; it computes the hydrological exchanges between the soil, the vegetation and the atmosphere. The routing module that routes all the water simulated by the model from the land surface scheme to the outlet of the rivers was activated in the model.

The routing module of ORCHIDEE has been described in [2] and is based on a parameterisation of the lateral waterflow on a global scale [3]. Given the global map of the main watersheds [4, 5] which delineates the boundaries of sub-basins (one of several basins that form a watershed) and gives the directions of water flow, the total runoff simulated by ORCHIDEE is routed to the ocean (without anthropogenic uptakes such as irrigation). The resolution of the basin map is 0.5° x 0.5° and we can have more than one basin in ORCHIDEE grid cell (sub-basins) and the water can flow either to the next sub-basin within the same grid cell or to the neighbouring cell.

In each sub-basin, the water is routed through three reservoirs which do not interact with the atmosphere:

1) the slow and deep reservoir where the drainage (water moving downward from surface water to groundwater) is an input,
2) the fast reservoir where the runoff (portion of incoming water (such as precipitation and irrigation) not infiltrating in the soil but discharged from the area) is an input, and
3) the stream reservoir.

All these three reservoirs then flow into the stream reservoir of the next sub-basin downstream. The reservoirs are characterised by their time constants which have been calibrated over the Senegal river basin only [2], at a resolution of 1°. The time constant determines how quickly the water is routed through each reservoir.



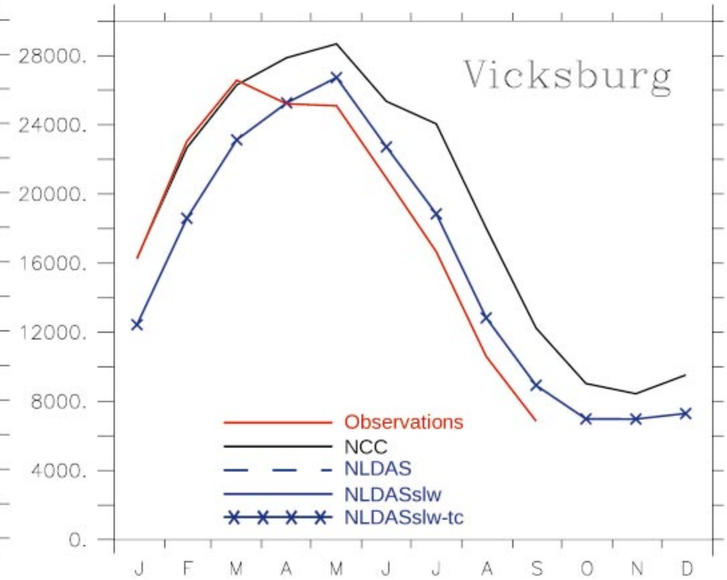


Figure 1. Monthly mean streamflows (m^3 s^{-1}) at Vicksburg station for the period 1997–1999 from observations and from different simulations. *Left:* comparison between observations, NLDAS, and NLDASslw simulations. *Right:* comparison between observations, NCC, and NLDASslw-tc.

The "slow reservoir" has the highest time constant (25 days) in order to simulate the groundwater. The time constant of the "fast reservoir" is lower (3.0 days) because it retains the water of runoff which flows faster. The "stream reservoir", which represents all the water of the stream, has the lowest value (0.24 days). Those figures are the same for all the basins of the world.

Our study focused on the Mississippi river basin in USA. We compared our streamflow simulations results with data obtained from databases of the University Corporation for Atmospheric Research (UCAR) (http://dss.ucar.edu/datasets/ds552.1/) and the United States Geological Survey (USGS) (http://waterdata.usgs.gov/nwis/sw) during the period 1997–1999. The results were analysed for Vicksburg which is usually used as a reference station for the Mississippi river basin because it is near the outlet of the river.

The two atmospheric data sets used as input to ORCHIDEE were NCC [NCEP (National Centers for Environmental Prediction) / NCAR (National Center for Atmospheric Research) Corrected by CRU (Climatic Research Unit)] [6] and NLDAS (North American Land Data Assimilation System) [7]. They include numerical model outputs and observations of meteorological variables such as precipitation, incident radiation, wind, and humidity.

NLDAS has a higher longitude-latitude resolution (0.125°) than NCC (1°). The precipitation forcing of the two data is very similar over the basin and close to GPCP (Global Precipitation Climatology Project [8,9]) observed precipitation (average annual difference < 5%). However, we noticed large variation in radiation between the NCC and NLDAS datasets: the average annual difference was about 21% for short-wave and 8% for long-wave radiation.

We compared NCC and NLDAS data to observations by FLUXNET, a global network of biosphere-atmosphere flux measurements [10], over seven stations across USA during 1997 to 1999. We found a good agreement between NCC short-wave radiation and FLUXNET observations whereas

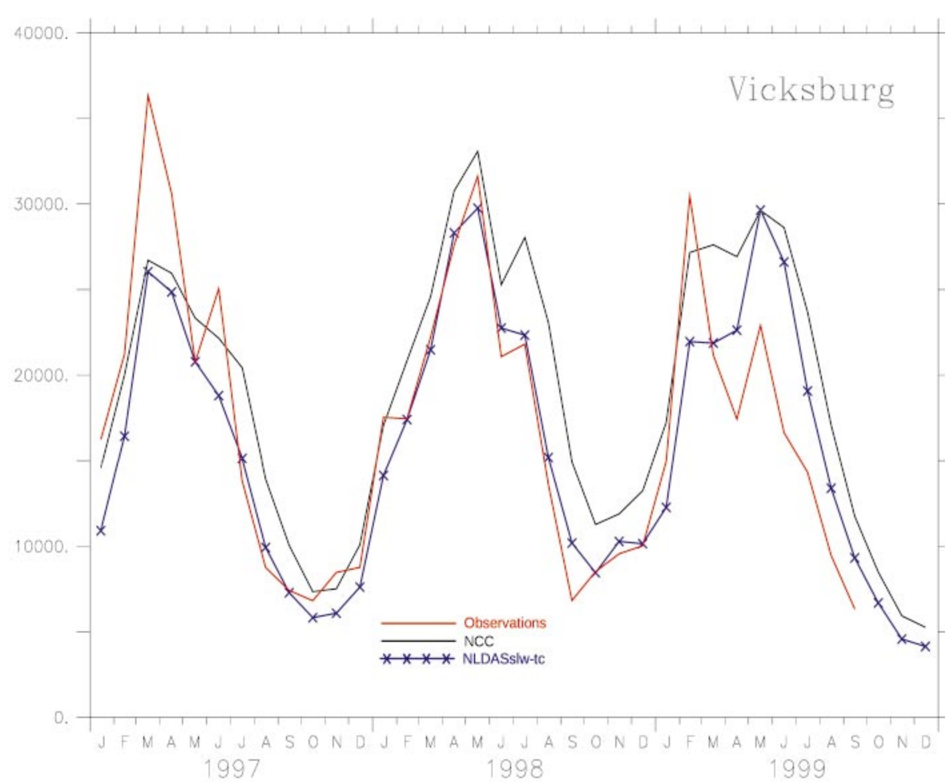


Figure 2. Time series of monthly mean streamflows (m^3 s^{-1}) at Vicksburg station, for the period 1997–1999, from observations, NCC, and NLDASslw-tc.

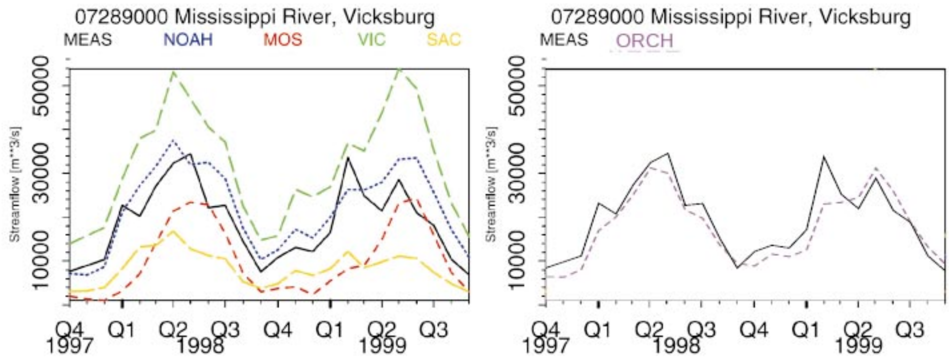


Figure 3. Time series of monthly mean streamflows ($m^3\ s^{-1}$) at Vicksburg station for the period October 1997 – September 1999, from observations (*black*), four LSMs (*colours, left*) [11], and ORCHIDEE (*dashed pink, right*).

NCC long-wave radiation was systematically underestimated compared to FLUXNET data. Moreover, we found that the NLDAS short-wave data was systematically overestimated and the long-wave radiation even more underestimated than that of NCC. In order to have the same amount of energy in both datasets, we corrected the radiation of NLDAS.

The streamflow simulated with NLDAS forcing without the radiation correction ("NLDAS" simulation) pointed out discrepancies with observations at Vicksburg over the mean period 1997–1999. There was a pronounced time shift in seasonality: ORCHIDEE simulated maxima of streamflow during summer (June/July) whereas the observations showed a maximum in March (Fig.1 left). The streamflow simulated with NCC forcing ("NCC" simulation) was much more realistic with a peak flow occurring in May (Fig. 1 right).

Correcting the radiation in the NLDAS dataset ("NLDASslw" experiment) led to a decrease in evapotranspiration and, consequently, to a better mean annual discharge, but the time shift in seasonality did not improve (Fig. 1 left). Therefore, we chose to evaluate the influence of the reservoir time constants on streamflow seasonality.

The time constants used in ORCHIDEE were originally calibrated during experiments with a resolution of 1° [2].

In our NLDAS experiment, we applied the same time constants in the model to a much higher resolution (0.125°). As a result, the stream reservoir stored much more water in the NLDAS experiment than in the NCC one. In order to correct this, we implemented two changes: the time constant of the stream reservoir and the time step of the routing scheme of ORCHIDEE were both divided by a factor 10 ("NLDASslw-tc" experiment).

The results of NLDAslw-tc were remarkably better than those of NLDASslw: the maximal amount of water stored in the stream reservoir during summer in NLDASslw was largely reduced and shifted to the spring season. This shift also moved the maximum peak of streamflow to May instead of June/July, closer to the observed one (March) (Fig. 1 right).

This remaining time lag of two months can be explained by the variability of the results during the three years (Fig. 2). In fact, the pronounced underestimation of the peak flow simulated by ORCHIDEE in March 1997 together with the large overestimation in May 1999 (Fig. 2) explains the result obtained for the mean period 1997–1999. We conclude that re-calibrating the time constants is necessary when using a forcing resolution higher than 1° x 1° with the routing scheme of ORCHIDEE.

Finally, we compared our results with streamflow simulations performed by four other LSMs at Vicksburg (Fig. 3) [11]. The studied period was the same as ours (October 1997 – September 1999) and all the models were forced by NLDAS with no radiation correction. Therefore, we left the radiation correction out from our simulation as well and kept only the calibration of the time constant of the stream reservoir and the routing time step of ORCHIDEE. The four LSMs exhibited large variations (Fig. 3); the streamflow simulated by ORCHIDEE was in good agreement with observations. Leaving out the radiation correction actually improved ORCHIDEE results. This was most likely because of compensating errors. ■

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Earth System Science Partnership

DIVERSITAS IGBP IHDP WCRP

The Earth System Science Partnership (ESSP) consists of four international global environmental change research programmes: DIVERSITAS, IGBP, IHDP, and WCRP. The aim of ESSP is to strengthen the cooperation amongst these programs to allow greater integration across disciplines, environment and development issues and the natural and social sciences. See for more information: www.essp.org

A new ESSP Joint Project on Global Environmental Change and Human Health (GECHH)

Human activities increasingly affect the structure and functioning of ecosystems. In turn, these changes can influence the entire chain of factors involved in the infectious disease cycle: pathogens, vectors, reservoir species, and human populations. Seemingly unrelated human activities can thus have serious consequences for human diseases, both infectious and non-infectious. The scientific community recognises the growing need to better understand the multi-faceted and complex linkages between global environmental†change (including climate change, land and sea use change, global biodiversity loss and change, global socio-economic change) and human health. However, as yet, little systematic research has been undertaken on the many important aspects of this topic. Nor has there been any sustained attempt to establish an international research community.

ESSP's response

With its wide network of scientists involved in Global Environmental Change (GEC) research, ESSP is well positioned to take up this challenge. This Joint Project is being developed in partnership with the World Health Organisation (WHO).

The Project's main research goals are to:

1. Identify and quantify health risks posed by GEC, now and in the reasonably foreseeable (scenario) future
   - Develop methods of modelling/understanding tradeoffs between economic development, environmental change and human health
   - Take account of the roles of culture, social institutions and technology choices in modulating health risks, affecting vulnerability and influencing policy response
2. Describe spatial (geographic, intra/inter-population) and temporal differences in health risks, to better understand vulnerabilities and priorities for interventions
3. Develop adaptation strategies for reducing health risks, assess their cost-effectiveness, and communicate results (especially to decision-makers)
4. Foster research training programs, to boost networked international research capacity in GEC and human health

Co-Chairs, Global Environmental Change and Human Health:

- Prof. Ulisses Confalonieri, National School of Public Health, Brazil
- Prof. Mark Rosenberg, Queens University, Canada

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DIVERSITAS an international programme of biodiversity science

GLOBAL IGBP CHANGE

IHDP International Human Dimensions Programme on Global Environmental Change

WCRP World Climate Research Programme

Rice field in northern Thailand. Photo: Tanja Suni.

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Data assimilation: effect of agricultural land-use modifications on surface fluxes and microclimate

Evapotranspiration (evaporation from surfaces and transpiration by plants) and microclimate depend on feedback effects between the land surface and the atmosphere and on the spatial and temporal variability of surface characteristics. Therefore, land-use modifications such as crop rotation and reduction or increase of irrigation may have a significant effect on regional climate and water resources.

In order to determine such dependencies and to predict microclimate and land-surface fluxes, we developed a coupled planetary boundary layer – land-surface model (named PBLs [1]) which takes into account landscape heterogeneity. The developed model combines a "Big Leaf" formulation of the surface fluxes (the whole vegetation is approximated as one big "leaf") and a simplified representation of the atmospheric boundary layer [2]. It can predict the evolution of microclimate and land-surface fluxes such as evapotranspiration throughout the day.

The PBLs model considers the heterogeneity of the land surface by dividing the area in patches ("tiled approach"), each with particular characteristics of main vegetation. Some of these, such as the leaf area index (LAI) and albedo, can be estimated from remote sensing images in the solar domain [3]. On the other hand, some important characteristics such as the soil moisture in the root zone and the aerodynamic roughness are impossible to determine directly. To solve this problem, we implemented a meteorological method of variational data assimilation (VDA) [4] into PBLs.

In the VDA method, we defined a cost function "J" that included observed surface temperatures T_s (from thermal infrared images), a priori information (deduced from climatology or expert knowledge) of the desired parameters (aerodynamic roughness and soil moisture), and information of measurement errors. The VDA method minimised J and obtained values for aerodynamic roughness and soil moisture by adjusting them until the observed T_s and the T_s estimated by PBLs were consistent. These values were then included in the patch characteristics in PBLs.

An intensive experiment was conducted in 2006 over the Crau-Camargue region in south-eastern France with numerous ground and airborne measurements [1].

Among the various satellite data recorded during this period, 32 FORMOSAT-2 images were acquired from March to October with a time step of 3 days at a spatial resolution of 8 m, which allowed us 1) to derive accurate information of the vegetation structure such as LAI and f_{cover} (the fraction of green vegetation covering a unit area of horizontal soil) for the patches [5] and 2) to detect the main agricultural practices such as the cut dates of irrigated meadows [1].

In order to estimate evapotranspiration in the region, we mapped the spatial variability of LAI and agricultural practices and used them as input data into two model types: a) the PBLs model with and without VDA and b) a crop model STICS [6] which takes into account the spatial variability of agricultural practices and predicts some future scenarios in case they are modified (used as input to PBLs if no measurements are available). Finally, we compared the evapotranspiration estimates from PBLs and from PBLs+VDA to measurements and found that PBLs+VDA gave better estimates (Fig. 1).

The simulated surface fluxes by PBLs+VDA showed great spatial variation because of differences in soil moisture and surface roughness - both highly dependant on the agricultural practices performed in the region. We concluded that 1) even at a small scale, different crop types and agricultural practices induce significant variations both on temperature and surface fluxes; 2) in order to accurately assess their influence on climate and agricultural production, detailed information of the agricultural practices is necessary.

At the moment, coupling between our two models is passive (output of crop model STICS is used as input for PBLs). However, development of a more integrated approach is in progress. ■

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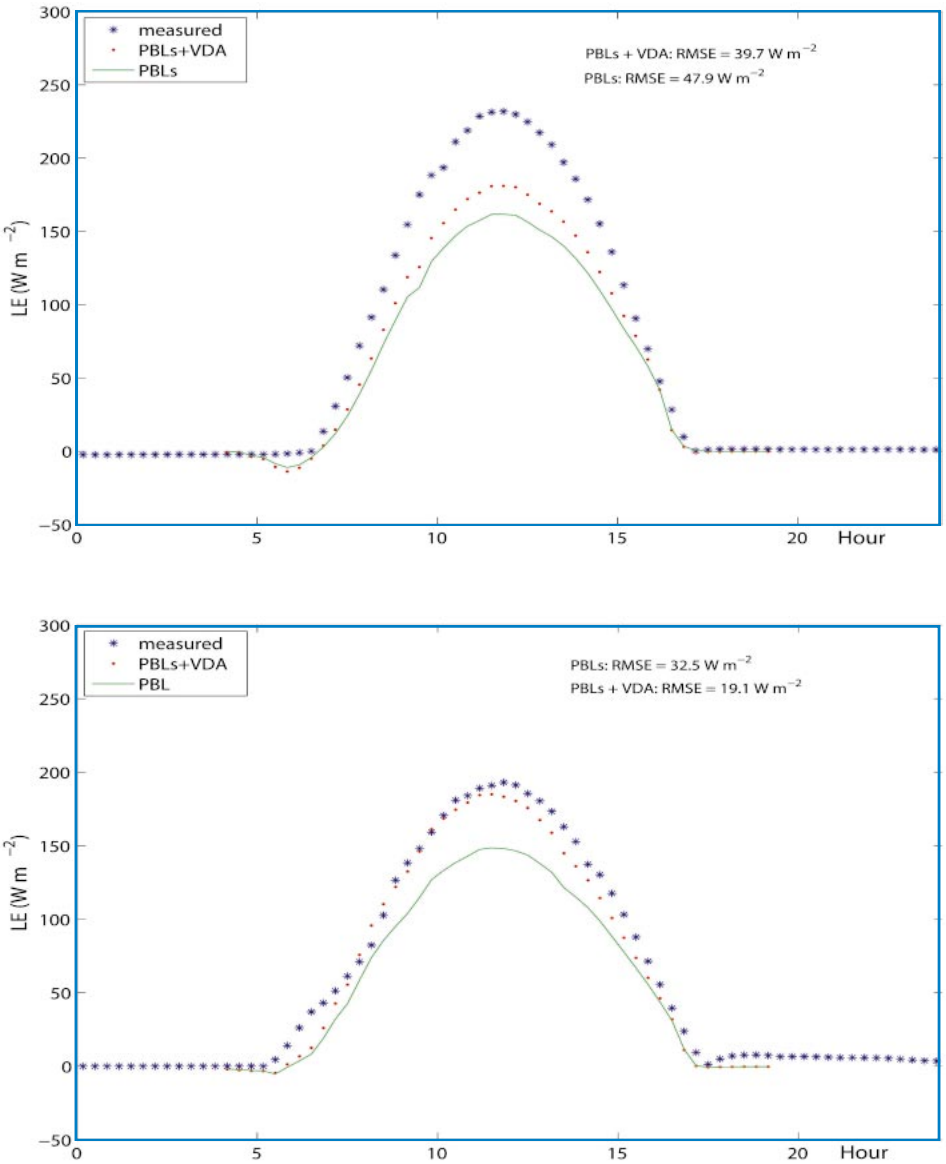

Figure 1. Model estimates of evapotranspiration (latent heat flux LE) compared to measurements over wheat crops in Alpilles – ReSeDA region. (*top*) 26 Mar 1997 (*bottom*) 18 Apr 1997. Root mean square error (RMSE) is given for PBLs only and for PBLs+VDA.

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Anna Wramneby obtained her MSc in physical geography from Lund University, Sweden in 2000. After a break of a few years, she returned to Lund and the Department of Physical Geography and Ecosystems Analysis, within the Geobiosphere Science Centre, to continue her scientific career. Anna started her current PhD work in 2004 under the supervision of Dr. Benjamin Smith, Dr. Patrick Samuelsson, and Prof. Martin T. Sykes. Her project involves the coupling of regional climate modelling and dynamic ecosystem modelling to investigate potential feedback mechanisms between the atmosphere and the terrestrial biosphere within the scope of regional climate change. She has now reached the fourth and final year of her PhD research.

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Hotspots of vegetation-climate feedbacks under future greenhouse forcing in Europe

Coupled processes and mechanisms linking atmospheric and terrestrial ecosystem dynamics play an important role in climate change, since interacting feedbacks have the potential both to amplify and dampen the magnitude of a change. Studies using Earth System Models (ESM), in which a global circulation model (GCM) is coupled to a model of terrestrial biogeochemistry and land surface dynamics applied at the global scale have demonstrated that changes in climate can lead to vegetation and carbon cycle changes that may, in turn, significantly modify the climate.

Climate scenarios for the coming century point towards a northward expansion of boreal forests into tundra [1] and a possible partial deforestation in parts of the tropics [2]. Both of these phenomena are likely to play an important role in global climate change because of the resulting reduction in albedo (ratio of solar radiation reflected by a surface (clouds, snow, forest, ocean) to incoming solar radiation) at high latitudes and the reduction in hydrological cycling in the

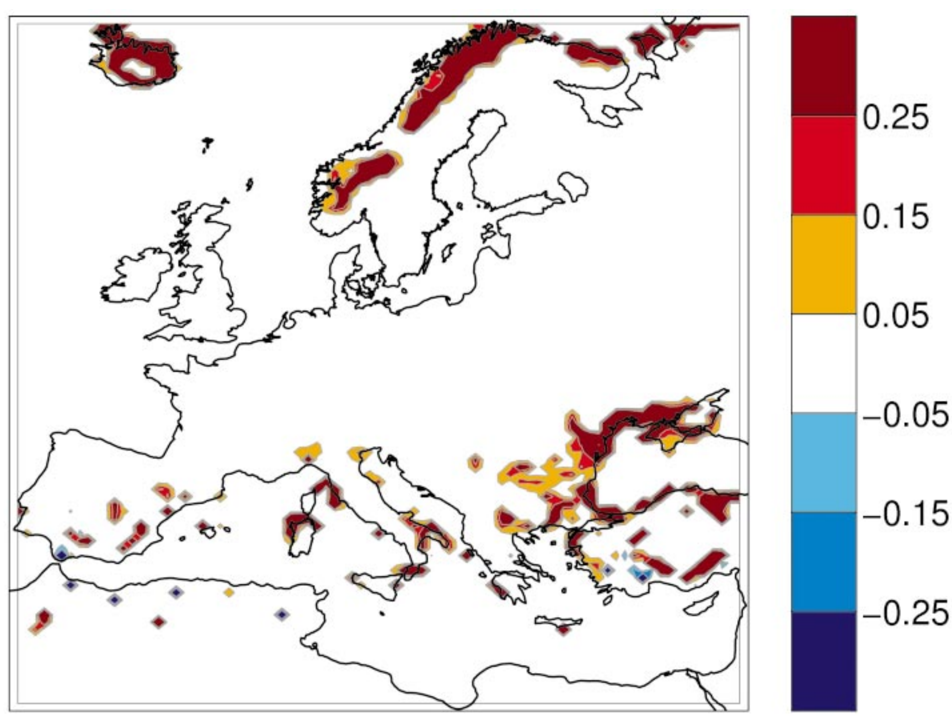

Figure 1. Differences in forest cover between the scenario period (2071–2100) and the control period (1961–1990) in RCA-GUESS, indicating a future increase in forest fraction.

tropics. Although these feedbacks have been described at continental to global scales using global models, the underlying processes are local to regional in character and are also likely to play an important role in regional climate change.

Here we describe a regional "Earth System" model, RCA3-GUESS; the product of coupling a regional climate model, RCA3 [3], with a process-based model of vegetation dynamics and ecosystem biogeochemistry, LPJ-GUESS [4]. The coupled model is applied under an emission scenario for the coming century to investigate feedbacks of vegetation changes on the climate of Europe.

LPJ-GUESS continuously updates RCA3 with daily values of leaf area index (leaf area per unit ground area, LAI) and the distribution of different types of vegetated surfaces influencing the albedo, hydrological cycling, and energy partitioning at the land surface. The advantage of this type of a coupled model approach is that the combined effect of the models is regional and dynamic, which in this particular study has enabled the identification of four potential regions/hotspots of vegetation-climate feedbacks in Europe.

The two northerly hotspots in the Fennoscandian Mountains and in north-western Russia are dominated by the effect of the reduced albedo; feedbacks at the southerly ones are related to decreasing evapotranspiration (the southerly sites are to be investigated further).

Although the future carbon dioxide (CO_2) forcing overall leads to a warmer climate, the albedo reduction has a sharply contrasting influence on temperature in the two northern hotspots via its effect on vegetation dynamics. Below, we explain how.

RCA-GUESS simulates a treeline advance in the Fennoscandian Mountains (Fig. 1). This result is in agreement with many other studies of future warming, in which boreal forests expand northwards into tundra [1]. The simulated successional order of the plant functional types (PFT) involved agrees well with documented life history strategies of pioneer versus successional tree species from real plants and ecosystems [5].

Additional warming in boreal and temperate regions is likely to be attributed to the feedback between decreasing albedo and the combined effect of expansion of forests and reduction in snow-covered areas. This is also why the albedo decrease in our simulations is accentuated in winter – forests mask snow (Fig. 2).

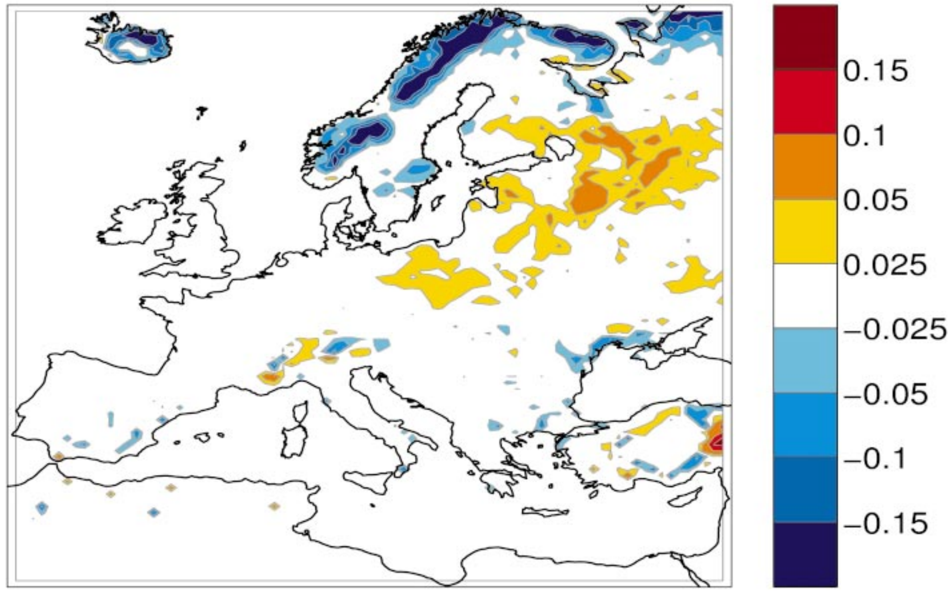

Figure 2. Winter albedo feedback showing the differences in the albedo anomalies of the scenario period (2071–2100) and the control period (1961–1990) between RCA-GUESS (vegetation dynamics included) and standard RCA (only climate, no vegetation dynamics). Positive values indicate a smaller albedo decrease (north-western Russia - deciduous tree fraction increases) and negative values an accentuated albedo decrease (Fennoscandian Mountains – tree line advance).

In contrast to the albedo-related warming in the Fennoscandian mountain range, north-western Russia is characterised by a strong negative temperature feedback. In response to the initial CO_2 forcing and warming effect, the broadleaved, deciduous trees become relatively more abundant in the forest at the expense of conifers. The implication of this is that the forest loses its dense structure which, in turn, increases the albedo all year round. The net effect in this area is still an albedo reduction but a smaller one than in the Fennoscandian Mountains. This weakening of the albedo reduction is most notable in winter since there is less masking of snow beneath a broadleaved deciduous canopy (Fig. 2).

Our results suggest that an albedo-related positive warming feedback in parts of northern Europe is rather modest compared to the global greenhouse forcing. This is in apparent disagreement with studies suggesting that albedo shifts related to afforestation (planting forest to areas originally without forest) and greening could significantly offset gains through enhanced carbon sinks [6].

The two contrasting albedo responses of the Fennoscandian Mountains and north-western Russia also emphasise that feedbacks may be highly regional in character. Our next step will be to take land management into account – a feature that is most likely to affect the strength of the investigated feedbacks. We believe that our findings will be of general interest since vegetation-climate feedbacks have been recognised to play an active role in climate change. ■

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Eva Kowalczyk is a mathematical modeller at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Melbourne, Australia. She has been working in the area of land surface - atmosphere interactions for more than 20 years. In collaboration with her CSIRO colleagues, she has worked on the development of several generations of land surface schemes in the CSIRO global circulation models.

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Nutrient constraints on carbon-climate feedback in an Earth System model

Predictions by climate models with a fully coupled carbon cycle consistently show a positive feedback between the global carbon cycle and climate. That is, an increase in atmospheric carbon dioxide (CO_2) concentration will result in a warmer climate, and a warmer climate will reduce the net carbon uptake by the land biosphere and thus accelerate the growth rate of atmospheric CO_2 concentration and global warming. However, there is considerable scientific uncertainty about the magnitude of this positive feedback at time scales from decades to centuries [1].

Carbon (C) uptake by the terrestrial biosphere is co-limited by available soil nutrients, particularly nitrogen (N) and phosphorus (P), along with limitations by water and light. Models used in the Coupled Carbon Cycle Climate Model Intercomparison Project (C4MIP) Phase II experiments [1] did not include nutrient limitation, and therefore they may have overestimated the carbon uptake by the terrestrial biosphere and underestimated the magnitude of positive carbon climate feedback. This has been recently demonstrated by results from a climate model with fully coupled carbon and nitrogen cycles [2].

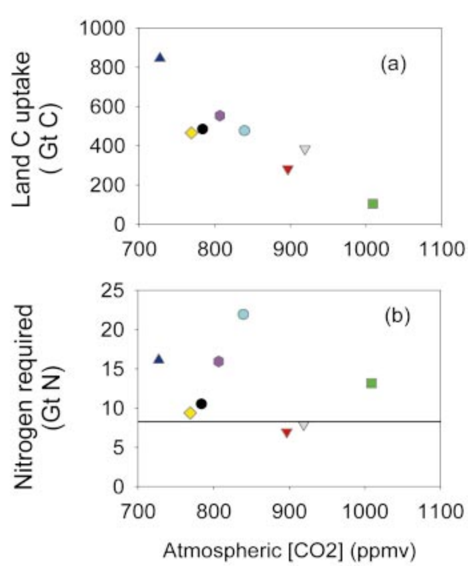

Figure 1. The amount of carbon accumulated in the land biosphere from 1860 to 2100 as predicted by eight models in the C4MIP Phase II experiment and the estimated amount of nitrogen required for storing the carbon for each model. We estimated that the maximal N available from 1860 to 2100 was 8.3 Gt (N) (solid line) by assuming that the carbon was stored in wood at a C:N ratio of 500:1 and in soil at a ratio of 25:1 on mass basis. This analysis is preliminary.

Fig. 1 shows a simple analysis of the amount of nitrogen required for storing the amount of accumulated carbon as estimated by eight of the eleven models in the C4MIP Phase II experiment [1]. Previously, Hungate *et al.* [3] assessed the plausibility of the estimated carbon uptake by different terrestrial models as reported in the third IPCC assessment report. We assumed that the carbon was stored in wood at a C:N ratio of 500:1 (g(C)/g(N)) and in soil at a C:N ratio of 25:1. This ratio provided a lower limit for the N required to store the carbon. This N limit, in turn, gave the maximal C uptake possible by terrestrial biosphere by 2100.

We estimated that the maximal amount of N available for plant and soil from 1860 to 2100 was 8.3 Gt, less than the amount of N required for the carbon uptake estimated by six of the eight models. Therefore, it is likely that those models underestimated the global carbon-climate feedback. This result is preliminary; a detailed analysis is necessary

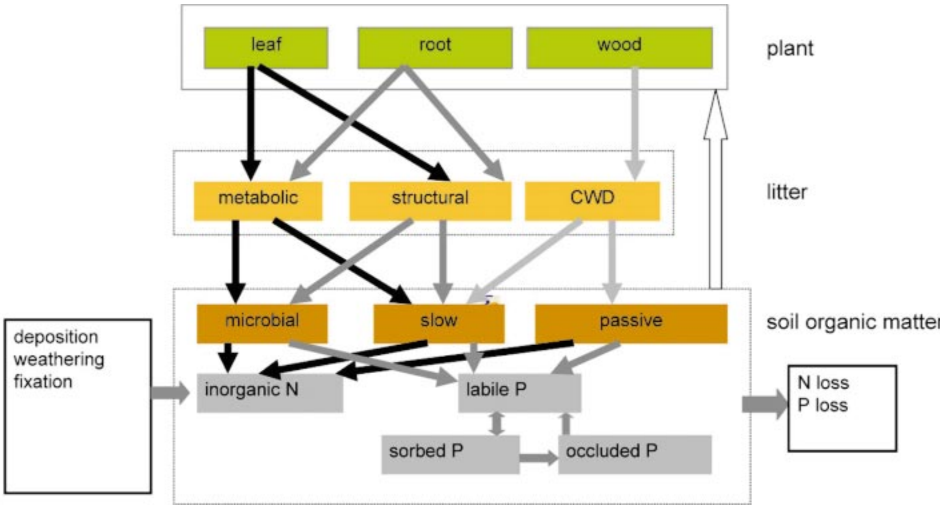

Figure 2. A schematic diagram of the CASA-NP model. The plant has three pools: leaf, root, and wood; litter has three pools: metabolic, structural litter and coarse woody debris (CWD); and soil organic matter has three pools: microbial biomass, slow, and passive pools. Each organic pool has three state variables, carbon (C), nitrogen (N) and phosphorus (P). The model has one soil inorganic nitrogen pool and three inorganic soil phosphorus pools (labile, sorbed P, and occluded P). The inputs of N to soil include deposition and fixation, and the input of P to soil includes deposition and weathering rate.

to account for the complex interactions between carbon and nitrogen in different ecosystems under the present and future conditions.

To take into account the nutrient limitation on carbon uptake by the land biosphere, we need to implement nitrogen and phosphorus cycles in Earth System models. Nitrogen fixation is the most significant source of nitrogen for most unmanaged land systems but it has not been represented in most global biogeochemical models for the terrestrial biosphere.

Recently, a new model of N_2 fixation based on resource optimisation principles was developed by [4]. Their modelling framework has been used to explain the geographic variation of N_2 fixation globally, see [5].

Based on previous work [6], we added nitrogen and phosphorus cycles into a carbon cycle model CASA. The modified model was named CASA-NP (Fig. 2).

The model consists of 9 carbon pools, 10 nitrogen pools, and 12 phosphorus pools. Nitrogen fixation and biochemical soil phosphorus mineralization are represented explicitly.

We coupled CASA-NP with a land surface model CABLE [7], and this coupled model is being implemented into a global climate model for studying carbon-climate interactions for the past, present, and future. We have calibrated the stand-alone version of CASA-NP using independent estimates of plant and soil pools. Figure 3 compares the estimates of plant biomass carbon with the observation-based estimates as described in [8]. CASA-NP can reproduce the latitudinal variation of plant biomass under the present climate conditions quite well.

The next steps are to calibrate the CASA-NP model using independent estimates of soil carbon, nitrogen, and phosphorus pools and measurements of surface atmospheric CO_2 concentrations. We will then conduct the uncoupled and coupled simulations for studying carbon-climate feedbacks and constraints of nutrient limitation on the magnitude of this positive feedback between carbon cycle and climate at time scales from decades to centuries. ■

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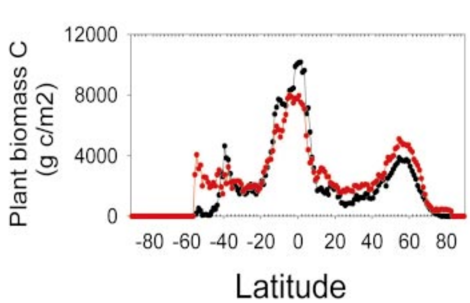

Figure 3. Comparison of the modelled plant biomass carbon variation with latitude using CASA-NP (black circles) with observation-based estimates [7] (red circles).

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Sami Ullah recently joined the Lancaster Environment Centre at Lancaster University as a Senior Researcher investigating the influence of hydrologic fluxes on nitrogen (N) transport and transformations in the hyporheic (an interface of surface-groundwater mixing zone in river beds) zones of groundwater-fed rivers in UK.

He started off his research as a student at Louisiana State University (LSU), USA, under the Fulbright Scholarship program in 1999. In 2001, Dr. Ullah enrolled in the PhD program at LSU and completed his research on denitrification and greenhouse gas emission from alluvial soils (river floodplain) in the Lower Mississippi valley.

In 2005, Dr. Ullah studied the influence of chronic N loading on N_2O emissions from riparian (wetlands bordering rivers) wetlands at Rutgers University, USA. For 2006-2008, he worked at McGill University as a Postdoctoral Fellow on greenhouse gas fluxes from forest soils in eastern Canada along a transect running from southern Ontario to northern Quebec under the supervision of Dr. Tim Moore.

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Topographic controls of CH_4 and N_2O fluxes from temperate and boreal forest soils in eastern Canada

Globally, forest soils are net sources of atmospheric nitrous oxide (N_2O) ranging from 2.4 to 5.7 Tg (N_2O-N) yr^{-1} and net sinks for atmospheric methane (CH_4) ranging from 1.8 to 11.8 Tg (CH_4-C) yr^{-1} [1].

The large range in N_2O emissions and CH_4 uptake in forest soils mainly arises from uncertainties associated with limited measurements elucidating the influence of topographic heterogeneity and seasonality on CH_4 and N_2O fluxes.

Canada contains about 400 million ha of forested land, about 10% and 33% of the total global and boreal forest cover, respectively. This vast forest cover in Canada can have a significant influence on the exchange of greenhouse gases with the atmosphere. Forested landscapes in Canada are not homogeneous, but rather consist of a mosaic of well and poorly drained soils determined by topography.

In topographically heterogeneous forests, well drained soils are sinks of atmospheric CH_4 whereas poorly drained soils with larger soil moisture contents are sources of CH_4 [2]. The net CH_4 flux from soils is a balance between CH_4 consumption through methanotrophy (aerobic process where bacteria metabolise methane to energy and cell material) and CH_4 production through methanogenesis (anaerobic process, formation of methane by microbes).

Similarly, poorly drained forest soils can emit more N_2O than well drained soils because of their higher denitrifier activity [2].

N_2O is produced in soils through nitrification (aerobic process, oxidation of ammonia into nitrite and further to nitrates by microorganisms) and denitrification (anaerobic microbial process of converting nitrate to nitrogen gas).

Even though the aerial extent of poorly drained and wetland soils in forested landscapes may be small, the net exchange of CH_4 and N_2O from these soils can be large. Therefore, in addition to carbon dioxide (CO_2) emissions, fluxes of CH_4 and N_2O need to be included when modelling net greenhouse gas fluxes from forest soils.

In this study, we investigated fluxes of CH_4, N_2O, and CO_2 from two temperate deciduous and two boreal forest sites in 20 plots including both well drained and poorly drained soils in eastern Canada.

The two deciduous forest catenas (groups of closely associated soils with similar parent material) were located near Montreal (~45°N); the two boreal forest sites were located near Chibougamau in central Quebec (~49°N) and Eastmain in northern Quebec (~52°N), respectively.

Four static flux measurement collars were installed at 4 locations within each plot (total 80 collars) and fluxes were measured bi-weekly from May 2006 to May 2008 at the two deciduous forest sites and during the snow-free period in 2007 at the two boreal forest sites.

In these forests, soil drainage class and forest type significantly influenced fluxes of CH_4 and N_2O (Table 1). Well drained soils were net sinks of atmospheric CH_4 whereas poorly drained soils were net sources of CH_4 in both deciduous and boreal forest soils, and both emission and consumption of atmospheric CH_4 were much stronger in deciduous than boreal forests (Table 1).

Among environmental variables, CH_4 fluxes at plot scales at daily time steps were mainly regulated by % volumetric soil water content (VWC) and temperature (Table 2) both in well and poorly drained soils [3].

Both well drained and poorly drained soils in deciduous and boreal forests were net sources of atmospheric N_2O; however, N_2O emission rates in deciduous forests were larger than those from boreal forests (Table 1). In well drained soils, the driving force behind N_2O emissions in both deciduous and boreal forests appears to have been the large nitrification rate [4,5]. In contrast, denitrification was the major source of N_2O emissions from poorly drained soil in deciduous forests (unpublished data).

Hourly N_2O fluxes at the scale of individual flux chamber measurements in these forests did not show a strong correlation with substrate and environmental variables (Table 2) [6].

However, averaged annual N_2O fluxes from well and poorly drained soils showed a significant exponential relationship with the soil carbon/nitrogen (C:N) ratio (Figure 1). This is in agreement with the findings of [7] in Europe.

Soil C:N from these forests [5] and the White mountains forests in New Hampshire [8] also exhibited a significant relationship with nitrification rates, showing that the C:N ratio exerts a strong control on internal N cycling and N_2O emissions because of its direct control on the rate of nitrification and indirect effect on nitrate (NO_3) supply in soils for denitrifier activity.

In general, when microbes decompose organic carbon, they respire about 60% of it as CO_2 and assimilate about 40% in their biomass. Soils with a C:N ratio of around 25 would provide just enough N through decomposition by bacteria to maintain the C:N ratio of microbial biomass at 10:1, assuming an assimilation fraction of 40%.

Soils with C:N ratios >25 are N-limited and thus whatever N is released is immobilised by the microbes rather than released and made available for nitrification and denitrification processes [9].

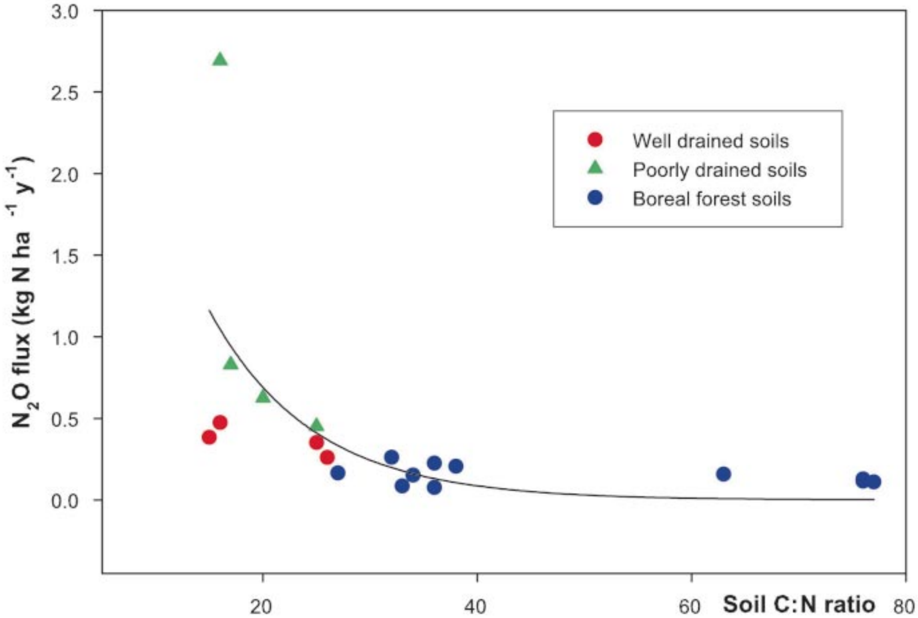

Figure 1. Relationship of annual N_2O fluxes and soil C:N ratio in well and poorly drained and boreal forest soils. Boreal forest soils data are taken from [3].

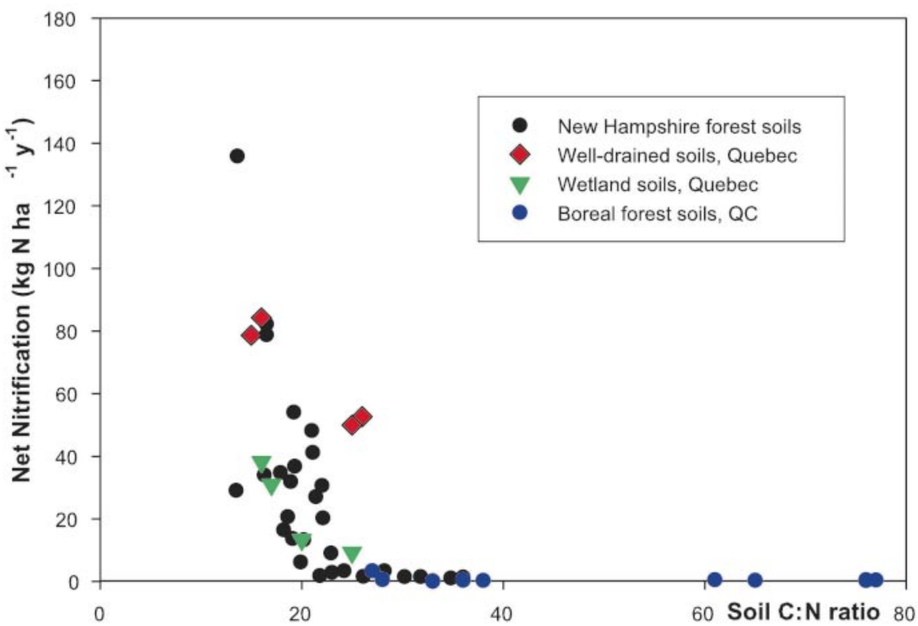

Figure 2. Relationship of soil C:N ratios and nitrification rates in deciduous and boreal forest soils. Data for the New Hampshire forests is taken from [8] and for boreal forest soils in Quebec from [3] and [5].

CO_2 emissions were generally larger from well drained than from poorly drained soils in the deciduous forest soils and soil temperature and VWC explained 48 and 46% variability in CO_2 emissions from well and poorly drained soils (Tables 1 & 2).

Moreover, deciduous forests emitted more CO_2 than the boreal forest soils (Table 1 and [4]). In boreal forests, soil temperature explained 11% of the variability in CO_2 emissions (Table 2).

In summary, forest type and the differences in soil drainage caused by topographic heterogeneity significantly influenced greenhouse gas fluxes in eastern Canada. Integrating these factors into modelling greenhouse fluxes from forest soils is crucial, as was concluded in the discussions held at the iLEAPS workshop in Hyères, France in November 2009.

Soil temperature and moisture are variables that are easily available and/or monitored

Forest type	Soil drainage and/or management type	CH_4 flux *(kg (C) ha^{-1} yr^{-1})**	N_2O flux *(kg (N) ha^{-1} yr^{-1})*	CO_2 flux *(kg (C) ha^{-1} yr^{-1})*
Deciduous forest soils	Well drained	-4.1 ± 0.1	0.58 ± 0.05	6377 ± 203
	Poorly drained	28 ± 7	1.8 ± 0.3	4965 ± 192
Boreal forest soils	Well drained	-0.29 ± 0.30	0.05 ± 0.03	1306 ± 113
	Poorly drained	0.50 ± 0.18	0.04 ± 0.04	1816 ± 208
	Poorly drained cut-over wetland	71 ± 28	0.09 ± 0.005	1430 ± 433
	Well drained burned forests	-0.36 ± 0.32	0.05 ± 0.03	1006 ± 102

**Average fluxes from boreal forest soils represent snow-free period only (May to October).*

Table 1. Annual fluxes of CH_4, N_2O, and CO_2 from well and poorly drained soils in temperate and boreal forests soils (mean ± SE). CH_4 consumption in well drained soils was 14 times stronger in deciduous than in boreal forests, and CH_4 emissions from poorly drained soils were 56 times larger in deciduous than in boreal forests. CH_4 emissions in boreal cut-over (clear-cut silviculture) forested wetland were 142 times larger than in mature boreal forested wetlands [3]. Well drained soils in deciduous forests produced 3 times smaller N_2O than those from poorly drained soils. N_2O emissions in boreal cut-over forested wetland were 2.3 times larger than in mature forested wetlands [3].

Gas flux	Deciduous forests	
	Well drained soils	Poorly drained soils
CH_4 flux *[ln(CH_4 m^{-2} d^{-1}]*	$\ln(CH_4\ \text{flux}) = 2.1 + 0.003VWC - 0.006T_s$; $R^2 = 0.27$; $n = 123$; $p < 0.0001$	$\ln(CH_4\ \text{flux}) = 0.77 + 0.008VWC - 0.42(CO_2\ \text{flux}) + 0.12T_s$; $R^2 = 0.30$; $n = 116$; $p < 0.0001$
N_2O flux *[ln(µg (N) m^{-2} h^{-1})]*	$\ln(N_2O\ \text{flux}) = 3.5 - 0.02T_s - 0.02(\text{C:N ratio})$; $R^2 = 0.10$; $n = 88$; $p < 0.01$	$\ln(N_2O\ \text{flux}) = 3.04 + 0.003\,[NO_3]$; $R^2 = 0.06$, $n = 84$; $p < 0.0001$
CO_2 flux *(g (C) m^{-2} d^{-1})*	$CO_2\ \text{flux} = -0.54 + 0.01VWC + 0.20T_s$; $R^2 = 0.48$; $n = 479$; $p < 0.0001$	$CO_2\ \text{flux} = 2.7 - 0.03VWC + 0.09T_s$; $R^2 = 0.46$; $n = 486$; $p < 0.0001$
	Boreal forest soils (well and poorly drained)	
CH_4 flux *[ln(CH_4 m^{-2} d^{-1})]*	$[CH_4] = 0.69 + 0.1VWC + 0.04T_s$; $R^2 = 0.32$; $n = 227$; $p < 0.0001$	
N_2O flux *[ln(µg (N) m^{-2} h^{-1})]*	Non-significant with any variable	
CO_2 flux *(g (C) m^{-2} d^{-1})*	$[CO_2] = 0.11 + 0.07T_s$; $R^2 = 0.23$; $n = 235$; $p < 0.0001$	

Table 2. Stepwise regression equations of CH_4, N_2O, and CO_2 fluxes with environmental variables. Volumetric soil water content (VWC) in %; Soil temperature (T_s) in °C; CO_2 emissions in g (C) m^{-2} d^{-1}. Data on CH_4 and CO_2 fluxes from boreal forest soils are taken from [4].

and could be used for estimating the range of CH_4 and CO_2 fluxes from forest soils.

Furthermore, N_2O fluxes are highly variable but dependent on ecosystem scale variables such as soil C:N ratio, which can be used to estimate annual N_2O fluxes.

Finally, logging of boreal forested wetlands results in larger emissions of CH_4 and N_2O compared to mature forests. This is a critical factor to consider in studies of greenhouse gas exchange between land surface and the atmosphere. ■

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Mike Tosca is a graduate student researcher at the University of California, Irvine, working with Dr. James Randerson and Dr. Charles Zender. Mike is studying the climate effects of biomass burning aerosols in south-eastern equatorial Asia. He uses a combination of remote sensing data and global climate models (GCM). Before coming to Irvine, Mike earned his BSc at the University of Connecticut in Storrs, Connecticut, in mathematics-statistics.

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El Niño and fire in equatorial Asia

There now exists enough satellite evidence to link fire and drought induced by El Niño (a global coupled ocean-atmosphere phenomenon causing important climate anomalies worldwide) in equatorial Asia (EAS) [1]. Reduced precipitation in EAS is well accepted as a consequence of the eastward relocation of convection during El Niño [2]. However, the potential role of drought-induced fire in enhancing and modulating El Niño dynamics has not been systematically investigated.

The four most recent El Niños (1997–1998, 2002–2003, 2004–2005 and 2006–2007) were all characterised by heightened levels of EAS fire aerosol emissions. Increased fire activity and subsequently high aerosol emissions in the fall of 1997 coincided with one of the strongest El Niño events on record. This was due in part to the positive relation between El Niño strength and the spatial extent of EAS drought [3]. Because of increased human presence in the region and poor land use management, El Niño-induced drought leads to fires more frequently now than two decades ago [4, 5, 6].

We assessed the influence of fire aerosols on climate in equatorial Asia using the Community Atmosphere Model, version 3.1 (CAM3) [7], to which we coupled the SNow ICe And Radiation (SNICAR) model [8]. CAM3 was run using a slab ocean model ("simplified ocean," SOM) with varying surface layer depths. Prognostic transport and deposition of hydrophobic (water-repellent) and hydrophilic (affinity to water) black carbon (BC) and organic carbon (OC) aerosols was the same as in [9].

We forced (used as input) CAM3 with monthly biomass burning emissions of BC and OC from the Global Fire Emissions Database, version 2 (GFEDv2) [10]. Total carbon emissions were calculated from satellite-derived estimates of burned area and from fuel loads and combustion completeness factors obtained from a biogeochemical model.

In one set of simulations with CAM3, we prescribed GFEDv2 fire emissions from 1997 to represent a high-fire (El Niño) year. In another set of simulations, we prescribed fire emissions from 2000 to represent a low-fire (control) year. Total carbon emissions in EAS were 821 Tg (C) yr^{-1} in 1997 and 47 Tg (C) yr^{-1} in 2000. During 1997, the sum of OC and BC were 9.5 Tg (C) yr^{-1} and 1.2 Tg (C) yr^{-1}, respectively.

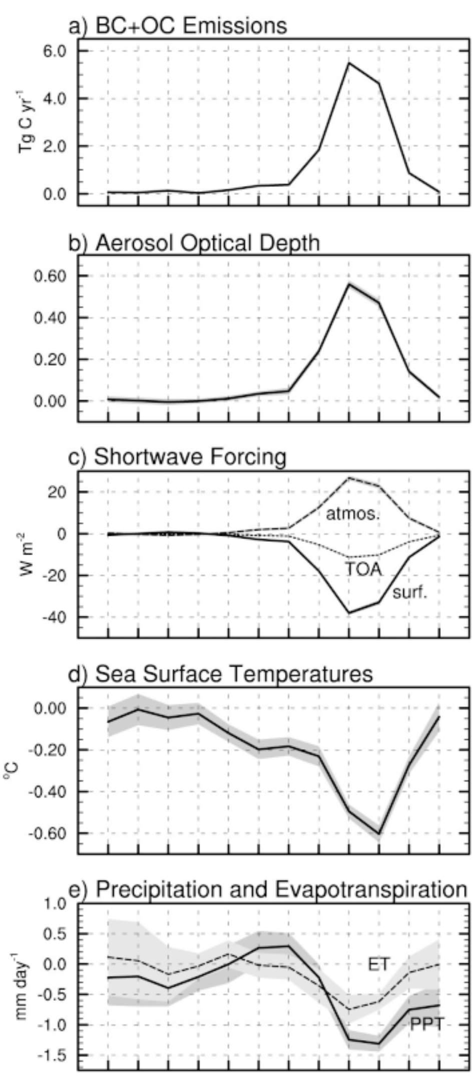

Figure 1. Observed climate forcing and simulated (CAM3) response to fire emissions in south-eastern Equatorial Asia (90°E-120°E, 5°S-5°N). a) observed fire emissions from the Global Fire Emissions Database (GFED), b) simulated aerosol optical depth, c) simulated net clear-sky shortwave radiation at the surface and through the troposphere (surface – 200 mbar) (W m^{-2}), d) simulated sea surface temperatures (°C), and e) simulated evapotranspiration (ET, light line) and precipitation (*PPT, dark line*) (mm d^{-1}).

We performed two forty-year simulations with the above-described GFEDv2 fluxes for 1997 and 2000, repeating them for each of the 40 years. Monthly emissions were interpolated to match the time-step resolution of the model [7, 11]. We then injected the emissions into the surface layer because many of the fires in this region are in low-temperature smoldering peatlands [12]. The relative wetness of peatlands prevents fires from being too hot, thus confining their plumes close to the surface.

We determined the climate response to the aerosol forcing by constructing a mean annual cycle from the last thirty years of each simulation. The first ten years were excluded to allow for SOM spin-up. We calculated anomalies by subtracting the low-fire (control) simulation from the high-fire (El Niño) simulation. For analysis of climate effects, our focus domain was a sub-region of EAS bound by 90°E-120°E and 5°S-5°N that included most of Sumatra and Borneo.

Fig. 1 shows simulation results for several climate parameters. Elevated fire aerosol concentrations coincided with a reduction in convection and precipitation (0.9 mm d^{-1}) for the region of analysis in EAS [13]. This is because fire aerosols reduced surface insolation during August–October by 20 W m^{-2} (10%) in the same region. The reduced insolation cooled sea surface temperatures (SSTs) and 2-m air temperatures by 0.5 and 0.3°C, respectively, during these months.

Previous studies have linked sea surface cooling with increased surface pressure and decreased surface convergence (the confluence of air at the surface which causes uplift and convection) [14]: cooler SSTs and the resulting decreased surface wind speeds can combine to limit surface convergence as in [15]. Lower surface wind speeds over the western Pacific have been observationally linked to reduced convection [16], and this is consistent with our study. The established relationship between convection and convergence explains why elevated fire aerosol concentrations led to decreased precipitation in the modelled study region [14, 17].

Tropospheric heating from BC absorption averaged 26 W m^{-2} (31%) and was balanced by a simultaneous decrease in latent heating (reduction in water vapour condensation throughout the column). BC is dark and absorbs solar radiation, which in turn warms the atmosphere. A warmer atmosphere is less able to support condensation. The combination of heating from absorption and cooling from decreased condensation combined with the SST cooling to aid in reducing precipitation by 10 mm $month^{-1}$. Because the decrease in precipitation coincided with a decrease of evapotranspiration (Fig. 1), favourable conditions for fire were enhanced. Thus, accidental anthropogenic burning in the region may intensify drought during El Niños, in a positive feedback loop.

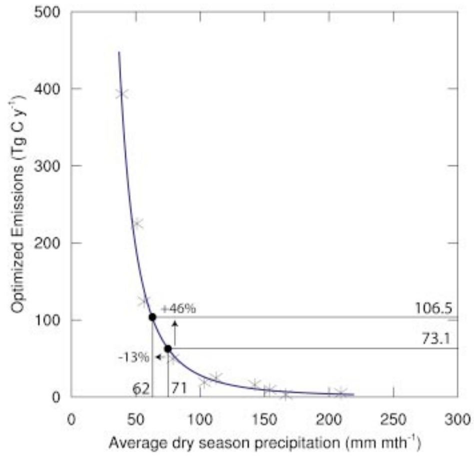

Figure 2. Relation between GFED (Global Fire Emissions Database)-predicted emissions and average precipitation rates during the three consecutive months of lowest rainfall for southern Borneo. The arrow pointing left indicates a fire-induced 13% decrease in El Niño precipitation, from 71 mm d^{-1} to 62 mm d^{-1}. This corresponds to a 46% increase in optimised emissions (upward pointing arrow) from 73.1 mm d^{-1} to 106.5 mm d^{-1}.

Data from [1] show a near-exponential relationship between dry-season precipitation and fire emissions in southern Borneo. Using data from the Tropical Rainfall Measuring Mission (TRMM) we estimated that the southern Borneo precipitation during a moderate El Niño (2002, 2004, 2006) was 62 mm $month^{-1}$. Assuming that our simulations accurately model the response of climate to smoke, a 13% August-October rainfall reduction in southern Borneo would indicate that biomass burning aerosols had decreased the moderate El Niño precipitation by 9 mm $month^{-1}$ (71 to 62 mm $month^{-1}$;13%). According to Figure 5 in [1], this reduction would increase regional fire emissions by 46% (Fig. 2). ■

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Exchange of organic compounds between the biosphere and the atmosphere

Emissions of volatile organic compounds (VOC) from the terrestrial biosphere to the atmosphere are significant, with estimates on the order of 1200 Tg (C) yr^{-1} [1].

Compared to total global VOC emissions from anthropogenic sources, biogenic sources dominate the inventory (Fig. 1), particularly in non-urban areas. These often highly reactive compounds have long been known to play a key role in the oxidation chemistry of the troposphere, giving rise to reaction products such as formaldehyde and carbon monoxide, in part controlling the atmospheric lifetime of methane, and contributing significantly to ozone formation.

In many regions, biogenic VOCs (BVOC) are a key component of the chemical mix that controls air quality (*e.g.* [2]).

More recently, BVOC and their less volatile reaction products have been recognised to play a potentially large role in formation and growth of secondary organic aerosol (formed in the atmosphere by gas-to-particle conversion), with implications for cloud processes and climate.

This biogenic secondary organic aerosol (BSOA), combined with primary emissions of particles from the biosphere, contributes

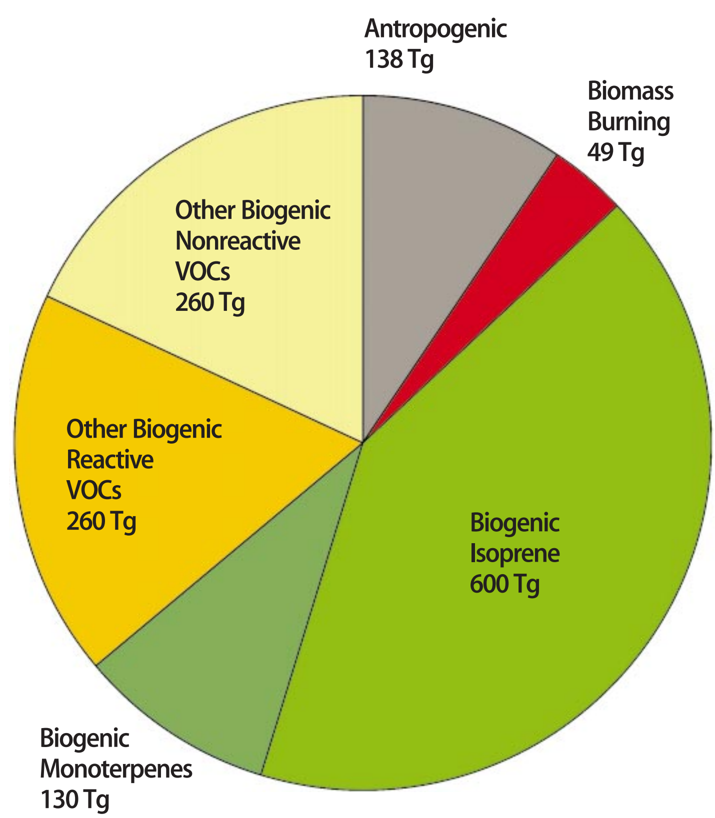

Figure 1. Global estimates of non-methane VOC from different sources [1, 5, 16].

substantially to the atmospheric burden of organic aerosol [3].

These atmospheric aerosols can affect air quality and visibility and alter climate directly (by scattering incoming radiation) and indirectly (by influencing cloud characteristics). The indirect effect has potential feedbacks to terrestrial ecosystems via changes in radiation and precipitation [4].

Our current understanding of biogenic emissions and atmospheric chemistry has reached the point where we can begin to use BVOC emission models in conjunction with atmospheric chemistry and transport models to address scientifically interesting and societally relevant issues such as the influence of large-scale deforestation due to bark beetle infestation on BVOC emissions and regional chemistry or the possible interactions among BVOC emissions, aerosol loading and properties, clouds, and climate.

The Model of Emissions of Gases and Aerosols from Nature (MEGAN; [5]) estimates emissions of over 100 compounds from the terrestrial biosphere at a horizontal resolution of 1 km^2, applicable for input to both regional and global models.

The MEGAN framework, based on measurements made from the leaf level to the canopy scale, consists of maps of species-specific emission fluxes that are scaled to environmental controlling variables: current and past temperature, current and past light, leaf area index (LAI, sum of leaf surface area per unit ground area), leaf age, and soil moisture. Using emission estimates from MEGAN, we can model the influence of biogenic emissions on atmospheric chemical processes; furthermore, we can begin to assess the effect of global change on these processes. For example, incorporating biogenic sesquiterpene emissions within the MEGAN framework revealed that BSOA from these compounds contribute significantly to organic aerosol in the continental USA [6].

The magnitude and chemical speciation of BVOC emissions, their pathways and fate in the atmosphere, and the possible indirect feedbacks on the terrestrial biosphere are critical components of the Earth System and need to be well constrained.

Although elements of these components have been extensively studied and our understanding has come a long way, there remain many key issues to be addressed. Since BVOC emissions are controlled by the type and density of the vegetation as well as by climatic variables such as temperature, radiation, and water availability, they are expected to change dramatically in the future, particularly for those regions susceptible to rapid changes in temperature or precipitation.

Climate change will clearly alter BVOC emissions, but land-use changes can also have a dramatic influence on predicted BVOC emissions with concomitant changes in important trace gases such as tropospheric ozone [7,8].

Our ability to project future changes in BVOC emissions is limited, however, by our inadequate understanding of how atmospheric variations, such as changes in concentrations of carbon dioxide and ozone and in nitrogen deposition, affect productivity and species composition of global landscapes.

That stresses and other disturbances can result in large changes in BVOC emissions is also becoming more evident. Considering

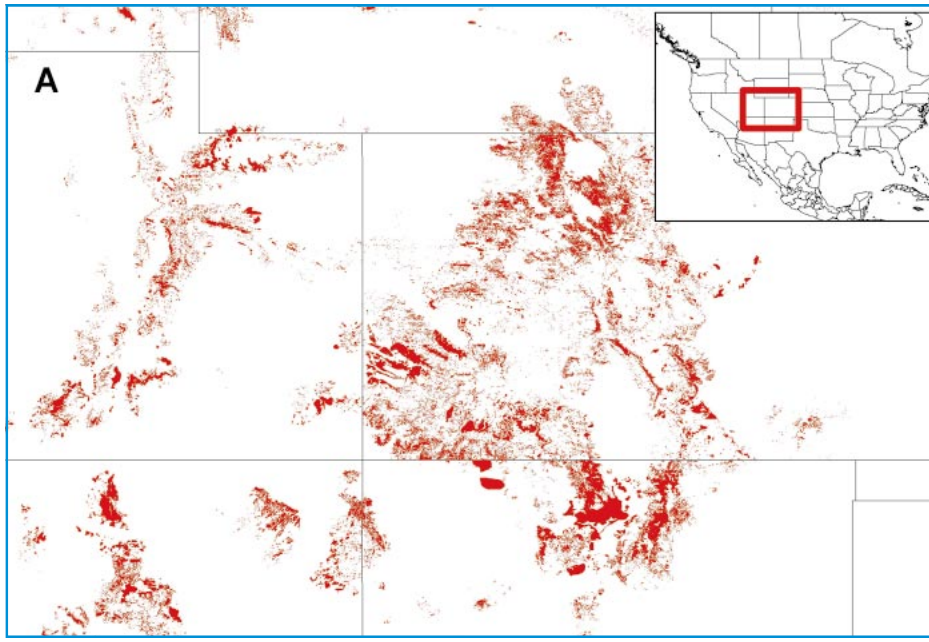

Figure 2A. Areas infested by mountain pine beetles in the central Rocky Mountain region of the western US (red). The infestations are resulting in large diebacks of forests; this may result in large changes in BVOC emission estimates.

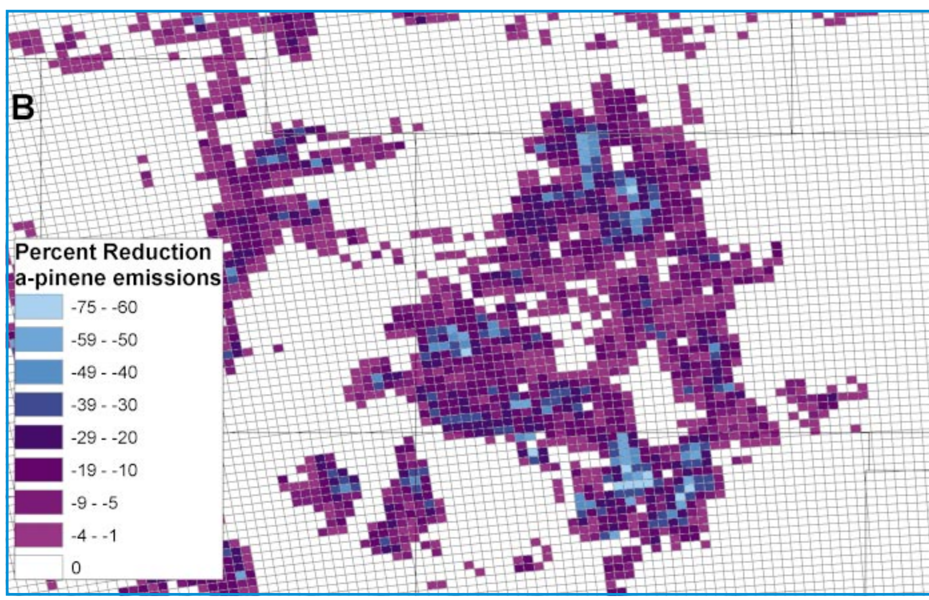

Figure 2B. The percent reduction in predicted biogenic α-pinene emissions caused by a dieback of trees because of the insect infestation, assuming a short-term cessation of emissions.

disturbances such as fire and insect epidemics in land-atmosphere and climate models is necessary in order to accurately simulate energy, water, and carbon transfer [9]. This is also true for BVOC emissions.

It is suspected that large disturbances, such as the current bark beetle epidemic in North America [10], will alter BVOC emissions in several ways:

1) emission of VOC in direct response to the infestation may occur;
2) as forests die as a result of insect infestation, emissions will decrease, or cease altogether (Fig. 2); and
3) as forests regrow and the distribution of plant species and density changes, biogenic emissions will change, too.

For instance, if aspen replaces lodgepole pine in currently devastated regions of the Rocky Mountains, the current regime dominated by methyl butenol and monoterpenes will be replaced by isoprene-dominated BVOC emissions. Despite the recognition that emissions can be altered both in quantity as well as in the particular chemical species, current emissions models do not yet include these effects.

Improved land-use classification and emission factor estimates are necessary to better constrain regional and global BVOC emissions. Additional compounds are continuously being discovered either in emission measurements or in the ambient air. For example, methyl salicylate was recently identified in the atmosphere above a walnut plantation [11]; how much of this compound, associated with plant stress, is released in different landscapes and what factors control its emission is unclear.

We also need to characterise the effects of vegetation stress on emissions. Herbivory [12], ozone deposition [13], and water stress [14] can lead to enhanced emissions of BVOC from plants. However, the compounds emitted, the controlling variables, and the magnitude of these emissions must be determined. Moreover, our current lack of understanding prevents any quantitative prediction of emissions controlled by stress factors.

Further requirements for the estimation of BVOC emissions and the prediction of their chemical and physical paths in the atmosphere include more constrained chemical oxidation pathways and a better understanding of the heterogeneous reactions for key BVOC species, such as isoprene [15].

The influence of land-use change is of critical importance to the rate and magnitude of BVOC emissions. With the implementation of new plantation species and extensive development of biofuels, these altered landscapes will directly impact the amount of BVOCs emitted.

This is one of the topics highlighted in the NERC OP3 project where measurements above an oil palm plantation in Borneo highlight the atmospheric importance of these huge monocultures from local to regional scale (www.es.lancs.ac.uk/op3/index.html).

The significance of BVOC emissions to the Earth System is clear; in conjunction with the incorporation of BVOC emissions into Earth System Models, there is a concurrent need for further research to better constrain the emissions, to elucidate biological and physical controls over the emissions, and to better understand the oxidation pathways and fate of BVOCs in the atmosphere. ■

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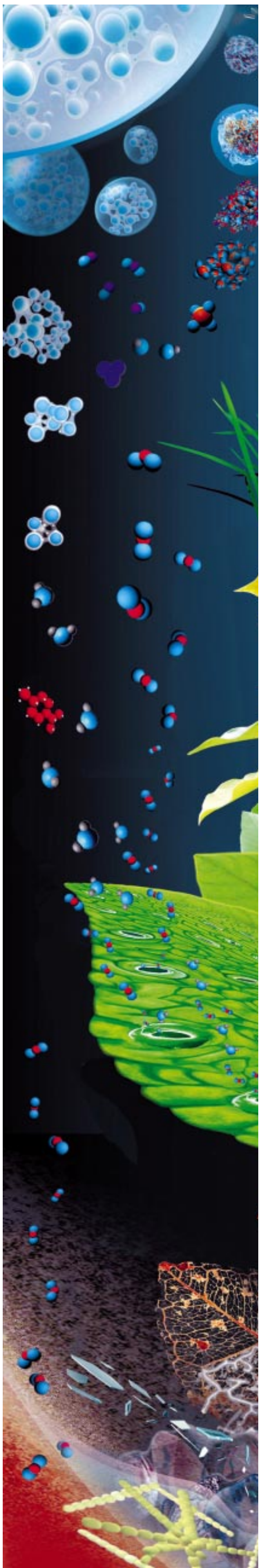

A new starting COST ESSEM Action ES0804:

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

This COST Action creates a platform for analysis, harmonisation, and synthesis, assessment of future needs and further development of a European integrated monitoring program for comprehensive trace gas and aerosol flux observations.

The existing national and European flux monitoring communities work separately; therefore, networking by means of this COST Action creates added value and is crucial for advancing the continuity, scope, and quality of flux monitoring.

This Action advances the applicability of produced data in climate and Earth system modelling research and in more operational short- to medium-term forecasting of weather and air quality.

Current methodologies, operationality, dissemination, and coordination will also be addressed in this COST Action. Development of common methodologies, data management systems, and protocols will increase the reliability, value and cost-efficiency of European flux observations.

The Action has seventeen European member countries and two more pending. The Action consists of four Working Groups (WG) and a Management Committee with maximum two representatives of each member country. The co-chairs and Working Group leaders were selected in the Kick-Off Meeting in Brussels, 17–18 February 2009.

Co-Chairs: Timo Vesala and Almut Arneth
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WG1 Analysis and synthesis of the current state of the flux monitoring sites, measurement techniques, data handling methods and storage of data in Europe.

Leader: Dario Papale
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WG2 Work towards comprehensive multi-species flux monitoring sites.

Leader: Klaus Butterbach-Bahl
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WG3 Assessing regional representativeness of the flux sites in different ecosystems.

Leader: Laurens Ganzeveld
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WG4 Training and capacity building.

Leader: Janusz Olejnik
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The Action organises scientific workshops that are open to the public. Next workshop in February 2010 will be announced on the Action's web page:
www.ileaps.org/cost0804

COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally funded research on a European level. COST does not fund research itself but provides a platform for European scientists to cooperate on a particular project and exchange expertise.

For information on the Action, please see the COST website:

www.cost.esf.org

The latest events of the Action can be found on:

www.ileaps.org/cost0804

Benjamin Cook is a Global Change Postdoctoral Scholar at the National Oceanic and Atmospheric Administration (NOAA), based at Lamont-Doherty Earth Observatory and the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies. His research focuses on the interactions among climate, the land surface, and terrestrial ecosystems. Dr. Cook's current projects include analysis of historical phenology records in the USA, modelling of feedbacks between land surface and drought, and drought forcing of ecosystem processes.

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Amplification of the North American 'Dust Bowl' drought through human-induced land degradation

Recurrent periods of drought are a common feature of the mid-latitudes, modulated on interannual and decadal timescales primarily by the El Niño Southern Oscillation [1–6].

Over North America, drier-than-normal conditions occur in the south-western and south-eastern United States when sea surface temperatures (SST) in the eastern tropical Pacific are lower than normal ('La Niña' conditions). La Niña conditions, with additional forcing from warm Atlantic SST, have been implicated as the initial causes of the 1930s drought known as the 'Dust Bowl' [1, 2, 4].

The Dust Bowl was a significant disaster for the United States, resulting in large economic and agricultural losses, farm abandonment, and massive human migration. The Dust Bowl, however, differed in important ways from the canonical La Niña drought pattern (Fig. 1, left panels): The Dust Bowl was warmer and drier than would have been expected given the modest size of the La Niña SST anomaly observed during the 1930s.

Another difference was that the Dust Bowl drought centre moved from the southwest and Mexico into the Central Great Plains. Models forced with observed SSTs during the 1930s produce a drought [1, 2, 4] that is centred too far south, and fail to replicate the near-continental-scale warm anomaly of the Dust Bowl centred in the northern United States (Fig. 1, middle panels). This implies either some deficiencies in the models or, alternatively, some missing physical processes.

One hypothesis regarding the atypical Dust Bowl drought pattern invokes large-scale changes to the land surface during this time period. During the 1920s, agriculture in the United States expanded into the central Great Plains. Much of the original, drought-resistant prairie grass was replaced with drought-sensitive wheat. With no drought plan and few erosion control measures in place, this led to large-scale crop failures at the initiation of the drought, leaving fields devegetated and barren, exposing easily eroded soil to the winds.

This was the source of the major dust storms and atmospheric dust loading of the period, on a level unprecedented in the historical record. We hypothesise that the dust storms and the loss of vegetation amplified the La Niña -forced drought and caused the anomalous pattern of temperature and precipitation. The importance of land-surface feedbacks during the Dust Bowl has been suggested previously [1, 5], but few studies to date have quantitatively tested the impact of dust aerosols and vegetation loss during this period.

We used the atmospheric General Circulation Model (GCM) of the Goddard Institute for Space Studies (GISS ModelE) to test our hypothesis that land degradation during the period could explain the anomalous features of the drought. We conducted four suites of 5-member ensemble simulations using observed SST from 1932–1939, with each ensemble member starting from different initial conditions.

In SST-ONLY, observed global SST (1932–1939) are used as input (forcing) to the

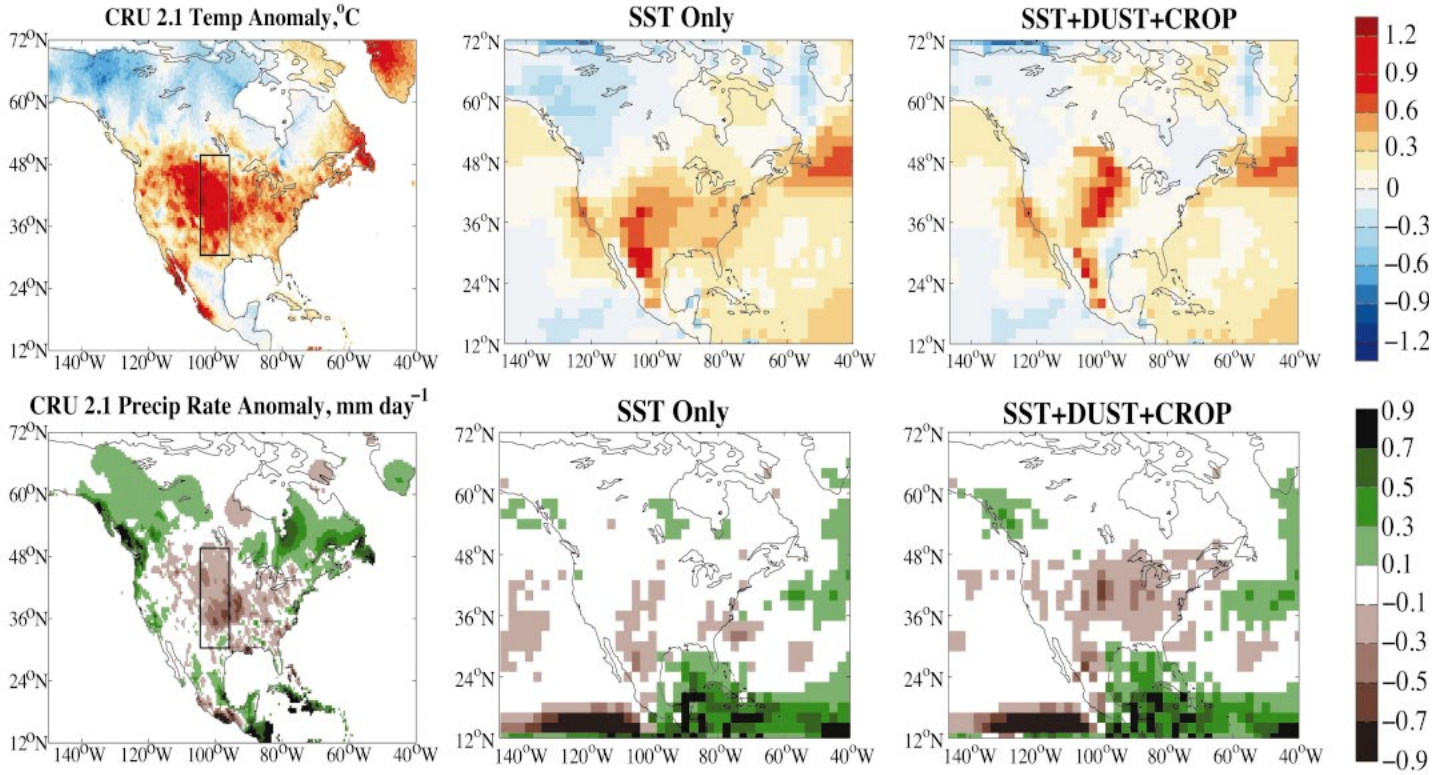

Figure 1. Temperature (°C) and precipitation (mm day^{-1}) anomalies for the 'Dust Bowl' drought from the Climate Research Unit (CRU) version 2.1 data set and two of our model experiments: SST-ONLY (our control) and SST+DUST+CROP (full land degradation in the form of a Great Plains dust aerosol source and crop removal). Anomalies are for the period 1932–39, relative to the 1920–1929 observed average (for CRU data) or an ensemble average from a 5-member ensemble run using observed SSTs for 1920–1929 (for the model plots).

model, with no modifications to the land surface. In SST+DUST, we added a dust aerosol source over the Plains over the approximate region of wind erosion during the period (Fig. 2, top and middle panels). Ensemble average net dust emission (emission minus deposition) from our Great Plains dust source in this simulation was ~369 million metric tons per year, a magnitude consistent with the limited available estimates of soil loss.

In SST+CROP, we simulated vegetation losses associated with the crop failure by converting the crop areas over the Great Plains to bare soil (Fig. 2, bottom panel). This led to fractional vegetation reductions of almost 50% in some grid cells. Finally, in our SST+DUST+CROP experiment, the model was forced with observed SST, along with a full representation of crop failure via inclusion of both a dust source over the Plains and vegetation reductions.

SST-ONLY produces only a modest drying and warming over the Great Plains region (Fig. 1, middle panels). When both land-surface forcings are included (SST+DUST+CROP), the temperature and precipitation anomalies are amplified to the observed level, and the drought is now correctly centred over the central and northern Great Plains (Fig. 1, right panels).

Different mechanisms explain the temperature and precipitation anomalies. Removal of vegetation reduces total evapotranspiration from the land surface by severely limiting transpiration, the flux of water from the soil to the atmosphere through plants during photosynthesis. Decreased summertime evaporation, mostly compensated by increased sensible heating, raises the Bowen ratio (ratio of sensible heat flux [heat transport in the form of rising warm air] to latent heat flux [evapotranspiration in energy units]) from 0.52 to 0.59. This leads to increased soil and near-surface air temperatures. Warming during the summer is carried over into the fall and winter seasons by positive soil temperature anomalies, when these warmer soils release this heat to the atmosphere.

The addition of a dust source and the subsequent increase in dust aerosol loading reduces net radiation at the top of the atmosphere and at the surface largely by shortwave reflection. This radiative heat loss must be balanced to maintain thermal equilibrium. Within the model, this is accomplished by enhanced sinking (subsidence) of air over the Great Plains, which warms as it sinks. The sinking air, in turn, increases the stability of the atmosphere, suppressing convection and cloud formation, and reducing precipitation.

The end result is a reduction in precipitation and a shift of the drought centre northward over the central Great Plains, near the centre of the dust aerosol cloud. When the effects of dust and crop removal are combined, feedbacks from the separate experiments act in concert to augment the impact of SST forcing, simultaneously warming the surface and reducing precipitation (Fig. 1, right panels).

Our improved simulation of temperature and precipitation anomalies, when more realistic land-surface boundary conditions are included, suggests that land-surface feedbacks from the human-induced land degradation are necessary to explain the Dust Bowl drought.

The Dust Bowl drought provides a good example of the complexity in atmosphere-ocean-land interactions that can lead to severe droughts. It also illustrates the way SST-forced droughts can be amplified through land-surface feedbacks. Understanding the relative importance of these feedbacks for drought in the future will require integrated model studies, similar to the study presented here. ■

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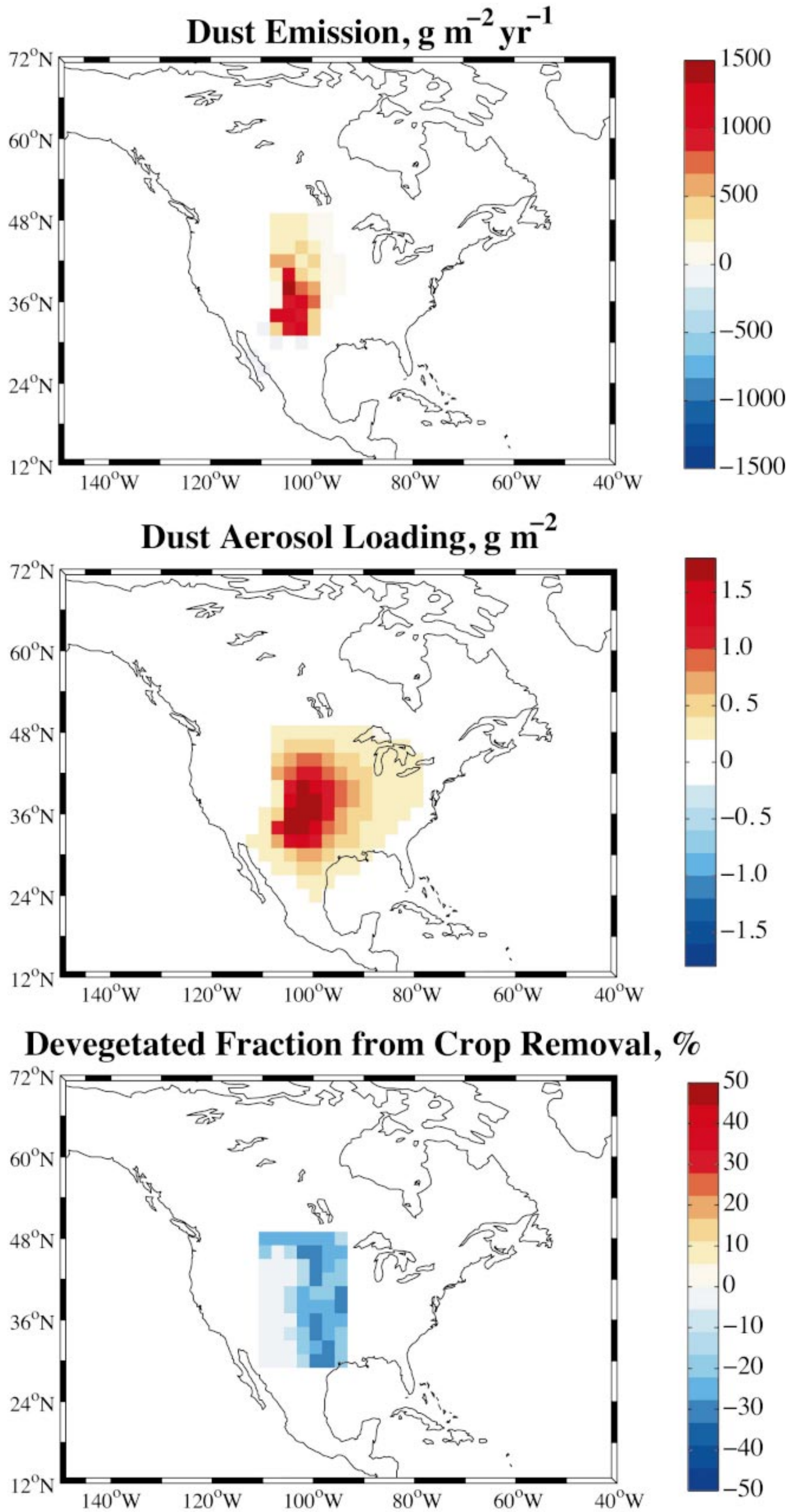

Figure 2. Dust emission (top, g m^{-2} yr^{-1}) and dust aerosol loading (middle, g m^{-2}) from the SST+DUST experiment and devegetated fraction (bottom, %) from the SST+CROP experiment, relative to SST-ONLY for 1932–1939. The devegetated fraction is identical in the SST+DUST+CROP experiment, and the dust emissions and loading are similar.

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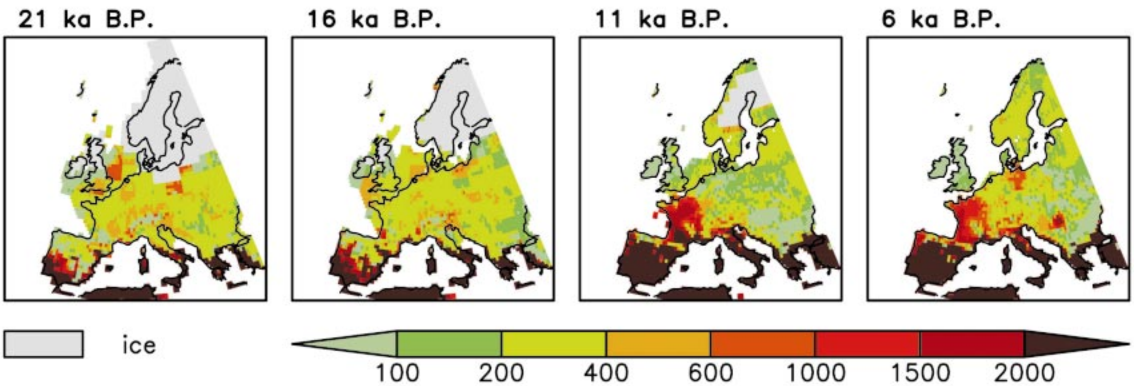

Figure 1. Annual monoterpene emissions (mg (C) m^{-2} yr^{-1}) for five time slices between the Last Glacial Maximum (21000 yrs B.P.) and present-potential (0 yrs B.P.).

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Tree species composition and emissions of volatile organic compounds in Europe during the Holocene

Biogenic volatile organic compounds (BVOC) such as isoprene and monoterpenes (part of the terpenoid family) are reactive compounds emitted from vegetation into the atmosphere. They affect the concentrations of the main atmospheric oxidants ozone (O_3) and the hydroxyl radical (OH) and act as precursors for biogenic aerosol particles.

On the European scale, current emission estimates are often based on tree species inventories representing a present-day distribution of species. In this study, we applied a dynamic vegetation model which enabled us to assess the changes in emissions in response to changes in species composition and vegetation productivity since the Last Glacial Maximum (LGM, 21000 years B.P.).

We performed simulations for Europe with the dynamic vegetation model framework LPJ-GUESS [1, 2] in which we incorporated process-based algorithms for isoprene and monoterpene production and emission [3,4]. The model was driven with climate anomalies from general circulation model (GCM) simulations and with ice core-derived CO_2 concentrations. Twenty important European tree species and generic functional types were distinguished.

In the simulations, total European emissions of isoprene and monoterpenes increased after the LGM. This was primarily caused by a change in climate, with higher temperatures as the most important driver for plant physiology and terpenoid production. However, isoprene emissions have also been observed to be stimulated by low (glacial) CO_2 concentrations [5]. This enhancement was incorporated in our model [3], but it could not offset the lower emission rates at the LGM caused by the climate.

The gradual increase in emissions since the LGM particularly in northern, western, and southern Europe (Fig. 1) was a response to higher temperatures and a more abundant vegetation. However, in eastern Europe monoterpene emissions declined (Fig. 1) because of a change from monoterpene-emitting coniferous forests to predominantly isoprene-emitting temperate broadleaf forests.

The simulations presented here that applied species rather than plant functional types represent an important step forward in the realistic simulation of BVOC emissions. Because species grouped within one plant functional type can differ considerably in their BVOC emission characteristics, local changes in emissions can only be represented with accurate species information. Given the high reactivity of these compounds, these local effects are particularly important for atmospheric chemistry. ■

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Microbiological Meteorology: investigating atmospheric processes at the cross-roads of biological and physical sciences

The abundance of micro-organisms in the atmosphere has been known since the insightful experiments of Spallanzani in the 18th century and Pasteur in the 19th century. These first observations of atmospheric microflora were crucial for refuting the theory of spontaneous generation and in establishing microbiology as a veritable scientific discipline. Today, studies of the microbiology of the atmosphere are on the verge of contributing to another paradigm shift: that airborne micro-organisms contribute to processes influencing atmospheric chemistry, planetary albedo, and precipitation in similar and even more varied ways as aerosol particles.

These potential roles of micro-organisms have been inferred from properties of their cells that can take part in radiative forcing, in the formation of cloud droplets and ice crystals, or in metabolism of chemical components of aerosols. During the past few years, we have been working to bring together different fields of scientific expertise—microbiology, atmospheric physics and chemistry, environmental modelling, and agronomy—to create a field that we have christened "Microbiological Meteorology" [1].

The research contributing to this paradigm shift has four main branches, analogous to research on atmospheric aerosols:

1) identification of potential atmospheric influence of micro-organisms based on their behaviour in laboratory studies;
2) quantification of the abundance of these micro-organisms in air, clouds, and precipitation;
3) estimation of the influence of airborne micro-organisms on atmospheric processes based on laboratory and field observations coupled to modelling and
4) characterisation of the sources of microbial aerosols and elucidation of processes involved in their formation; and transport in the atmosphere.

The goals of these studies are particularly pertinent to contemporary changes in the environment of our planet. One of these goals is to understand the effects of anthropogenic sources of airborne micro-organisms on atmospheric processes and to determine how they could buffer or mitigate climate change.

Classical microbiology is at the heart of the idea that micro-organisms could have an influence on the atmosphere. A century of studies on microbial behaviour has revealed properties that can be crucial in atmospheric processes. The most striking example is that certain bacteria and fungi can catalyse freezing of super-cooled water at temperatures near 0°C.

For bacteria, this property is conferred by an unusual, highly folded protein produced on the cell surface. This property was discovered in the search for the cause of plant frost damage and of ice crystal formation leading to snow [2].

Lively speculation still takes place about the ability of these biological ice nucleators to influence precipitation [3, 4].

The continuing discussion on this subject can be followed at: http://bio-ice.forumotion.com/forum.htm.

Bacterial cells also seem capable of acting as cloud condensation nuclei (particles around which cloud droplets form by condensation of atmospheric water vapour) [5, 6], most probably because of the hygroscopic (moisture-absorbing) polysaccharides on their cell surface. Some bacteria also produce strong surfactants (wetting agents that lower the surface tension of a liquid allowing easier spreading) (bio-surfactants). This can be an advantage on waxy hydrophobic (water-repellent) plant surfaces where they help these bacteria to degrade plant tissue (and hence to access food resources) [7].

Furthermore, by enhancing the condensation of atmospheric water across a large number of airborne particles that might otherwise be hydrophobic, bio-surfactants of airborne bacteria could favour the persistence of fog. In other words, surfactants would enhance the formation of numerous very small water drops that could remain suspended in air (fog) rather than formation of large droplets apt to precipitate [8].

Studies of microbial metabolism for diverse purposes such as industrial processes, bioremediation (detoxifying pollutants by micro-organisms), and deciphering plant-microbe interactions have revealed the capacity of micro-organisms to metabolise (break down organic material to obtain energy and form cell material), for example, dicarboxylic acids, methane, isoprene, and longer chained alkanes and phenols that constitute the bulk of dissolved organic carbon or major pollutants in atmospheric aerosols. The significance of these capacities for atmospheric chemistry is being explored actively [9].

In addition to the direct roles that micro-organisms could play in atmospheric processes, there are exciting questions to consider about feedbacks. Micro-organisms are metabolically active with dynamic biological properties, many of which are likely maintained also in the atmosphere.

Hence, the microbial traits that lead to their potential effects on the atmosphere are due to capacities that vary with metabolism, gene expression, the distribution of charges across the cell wall, and with other cellular characteristics. These capacities wax and wane as a function of the local environment and as cells mature and senesce.

The study of aerobiology, with regard to micro-organisms, has overwhelmingly been the realm of plant pathologists attempting to follow the flight of drying, UV-stressed propagules (bacterial cells or parts of fungi or yeasts) of plant pathogens such as fungal spores, single cells of bacteria, or yeasts on their way to distant cropped fields. The decisive work of Stackman [10] and of Gregory [11] on aerial dissemination of spores that spread rusts and other plant diseases set the stage for decades of similar pursuit. This research has nourished the literature with data on the occurrence and abundance of fungi, bacteria, yeasts, and viruses in the air.

In the early 1900's, microbiologists accompanied Charles Lindberg on flights to assess the abundance of micro-organisms in the upper atmosphere [11].

In the late 1970's scientists in the Soviet Union used meteorological rockets to assess the presence of micro-organisms at farther reaches of Earth's atmosphere to define the limits of the biosphere [12].

But only recently has there been an attempt to characterise the microflora of clouds *per se*, where they are set to play important roles. Micro-organisms that can be cultured are present at about 10^3–10^5 propagules ml^{-1} of cloud water [13–16] and include dozens of species of bacteria and fungi and several yeasts among which are strains capable of metabolising atmospheric organic compounds under laboratory conditions [14].

Overall, data on names and numbers of micro-organisms is accumulating. That oceanic sources – as well as plants – also contribute to the microflora of clouds is also becoming clear [17].

However, there is a great need for assessing the *in situ* state of these micro-organisms to better evaluate whether they are indeed in a physiological condition necessary for influencing atmospheric processes. A significant step in this direction is the recently developed technique to quantify biological ice nucleators directly from environmental samples without culturing the microbial components of the sample [18, 19].

This has revealed that up to 69–100% of the ice nuclei in fresh snowfall can be of biological origin. In over 45% of these samples, biological ice nuclei were sensitive to lysozyme (an enzyme that specifically degrades components of bacterial cell walls) suggesting that they were associated with bacteria [18].

Evidence that micro-organisms indeed have effects on atmospheric processes is currently circumstantial or indirect. The coming decades will see great progress in obtaining more solid evidence. Biological ice nucleators have been found in clouds [14,20], and, compared to other substrates, freshly fallen snow has been observed to contain an enriched concentration of ice-nucleation-active strains of certain bacteria [21]. Under simulated cloud conditions, these bacteria can induce ice crystal formation [22,23] and, under certain conditions in simulated numerical models, they can have an effect on precipitation [3,24].

Likewise, the roles of micro-organisms in atmospheric chemistry have been studied mostly in laboratory reactors [13,14] to estimate potential kinetics for subsequent use in atmospheric models. Attempts have been made to evaluate the overall metabolic activity of the whole complex of micro-organisms in cloud water directly in fresh samples via incorporation of radioactive isotopes under super-cooled conditions [16] or by assessing growth without nutrient supplementation [25].

Similarly, by determining the concentration of adenosine triphosphate (ATP) in cloud samples, we have revealed that the vast majority of micro-organisms in these samples has maintained metabolic activity [26].

The major gap in knowledge about the interaction of micro-organisms and atmospheric processes concerns microbial emissions. The few published measurements of microbial flux into the atmosphere were reported 15 to 20 years ago [27–30]. Plants are considered to be one of the major sources of micro-organisms in the atmosphere. Many of the micro-organisms cited as potential actors in atmospheric processes are typical inhabitants of plant surfaces and some of these are *bona fide* plant pathogens. As a source, leaf surfaces represent over 10^9 km^2 of microbial habitat and likely harbour 10^{24}–10^{26} total bacteria [31] and so far unestimated numbers of fungi and yeasts.

At present, we do not know what fraction of these micro-organisms take off into the atmosphere and in what state – single cells and spores, or clumps of micro-organisms and debris. Factors determining the source strength of plant canopies are likely to be complicated by the plant species involved – different species and cultivars harbour widely different quantities of micro-organisms that potentially can influence the atmosphere [32, 33] – and by the local land scape through its influence on micro-climate.

Renewed efforts to install field platforms for assessment of microbial flux into the atmosphere [34] are necessary to achieve the long term goals of Microbiological Meteorology. If in fact microbes are involved in atmospheric processes, there are exciting questions to address about the leverage of agronomy and land use practices – via, for example, grazing, crop varietal selection, rotations, and intercropping – on these processes. ■

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- Susannah Eliott (*AUSSMC, Australia*)
- Lindsay Hutley (*CDU, Australia*)

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- Satellite sensors and remotely sensed products
- Local-to-regional and regional-to-global interfaces (upscaling/downscaling issues)
- Interaction of biogeochemical, water, and energy cycles
- Land-ocean interface - the coastal zone
- Data-model assimilation
- Science-to-applications interface

Training and discussion sessions:

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- Data fusion in remote sensing applications
- Data-model assimilation
- Q & A session with experts
- Communication and presentation skills – preparing a 2-minute oral summary of posters
- Communicating science to media and policy makers

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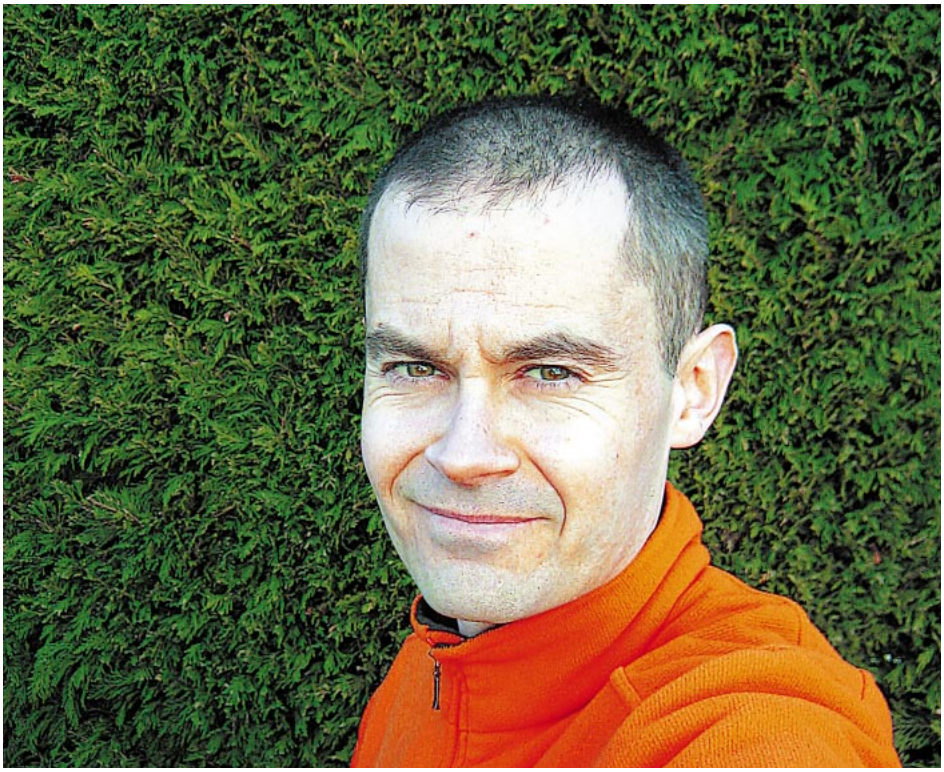

Carlos Jimenez graduated in engineering at the Telecommunication Engineering School (ETSIT), Technical University of Madrid, Spain, and got his MSc in environmental measurement techniques and his PhD in environmental science at Chalmers University, Gothenburg, Sweden. He is currently a researcher at the Laboratory for the Study of Radiation and Matter in Astrophysics (LERMA), Paris Observatory, working on the characterisation of the land surface from multi-wavelength satellite observations. His group has a long experience in exploiting global satellite datasets to characterise continental surfaces, including the production of a continental atlas of microwave emissivities directly estimated from satellite observations, and the first global estimations of inundated (flood-covered) areas over several years.

Carlos Jimenez[1], Catherine Prigent[1] and Filipe Aires[2]

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Combining multi-satellite observations and land surface models to estimate land-surface heat fluxes

Land-surface heat fluxes are essential components of the water and energy cycles and govern the interactions between the Earth surface and the atmosphere [1]. Over land, energy balance and flux partitioning (division of outgoing energy into fluxes of latent heat (evapotranspiration) and sensible heat (rising of warm air)) are complex mechanisms that vary strongly in both space and time and across climates and ecosystems depending on the physical properties of the surface.

Land-surface heat fluxes are measured during field experiments and by some flux tower networks. However, in order to obtain global, consistent estimates of the surface heat fluxes, a transition to satellite remote sensing is necessary.

The challenge is that fluxes cannot be remotely detected. Therefore, the fluxes have to be indirectly estimated from satellite observations containing information about the surface and atmospheric properties that control the fluxes (for instance, surface and air temperature and humidity).

How to merge the information coming from the satellite observations to derive the fluxes is not straightforward. Acknowledging these difficulties, the Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel (GRP) launched the LANDFLUX activity to develop the necessary capabilities to produce a complete, physically consistent, global, multi-decadal land-surface heat flux data product.

Different schemes to produce the fluxes already exist. They range from simple physical formulations (having as inputs the surface and atmospheric properties derived from the satellite observations) to complex land surface models (where the satellite observations are directly incorporated into the model). The problem is that the current flux estimates at a global scale from different schemes can still differ considerably.

Contributing towards the goal of producing global land-surface heat fluxes, we have evaluated the potential of a suite of satellite observations to estimate the latent and sensible heat fluxes over snow-free continents. We used a methodology based on calibrating a statistical method that links the satellite observations to the fluxes [2]. The statistical model (SM, based on neural networks) learns the global relationship between satellite data and fluxes, and is then used to map the satellite observations into heat fluxes.

The satellite observations were selected for their known sensitivity to the surface

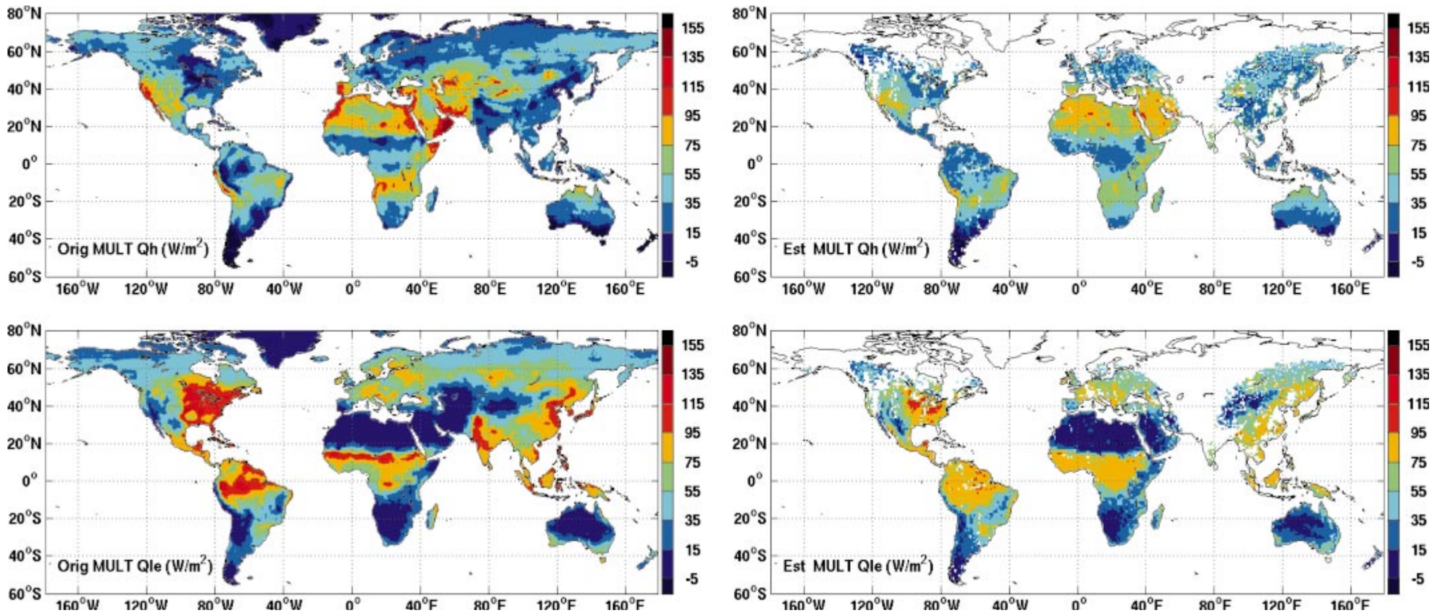

Figure 1. Example of the original LSM GSWP multi-model and corresponding estimated satellite-derived SM monthly mean fluxes for August 1995. The fluxes were not estimated over central Asia for this specific period as one of the satellite inputs was not available. *Top left*: the original LSM GSWP sensible heat flux; *top right*: the estimated SM sensible heat flux; *bottom left*: the original LSM GSWP latent heat flux; *bottom right*: the estimated SM latent heat flux.

properties that affect the fluxes (soil moisture, surface temperature and its diurnal cycle, vegetation) as well as for their global coverage and their availability over many years. They covered a broad range of wavelengths from the visible to the microwaves, including visible and near-infrared reflectances (Advanced Very High Resolution Radiometer, AVHRR), radiative fluxes and thermal infrared surface skin temperature and its diurnal cycle (International Satellite Cloud Climatology Project, ISCCP), active microwave backscatter (European Remote Sensing satellite system, ERS scatterometer), and passive microwave emissivities (Special Sensor Microwave Imager, SSM/I).

Because *in situ* flux measurements are very scarce in space and time, we calibrated the SMs with fluxes calculated from land surface models (LSM) which we regarded as the most reliable estimates of land-surface heat fluxes at the global scale. Three Global Soil Wetness Project (GSWP) version 2 [3] estimates of the fluxes were selected (the fluxes estimated by the multi-model analysis, and the two participating LSMs ISBA and ORCHIDEE), along with the National Centers for Environmental Prediction (NCEP) / the National Center for Atmospheric Research (NCAR) reanalysis NCEP/NCAR (a retroactive record of more than 50 years of global atmospheric analyses produced by a frozen global data assimilation).

The LSM fluxes and satellite data were gridded with a spatial resolution of 0.25˚x 0.25˚ and used as monthly averages for the 1993–1995 period. Independent SMs for each combination of satellite observations and specific LSM were set and calibrated with 4 months of fluxes and observations in 1993.

Once calibrated, the SMs were used to map the satellite observations into fluxes for the remaining months in 1993–1995. For this period, the SMs reproduced the LSM fluxes on a global scale with theoretical root mean square (RMS) errors < 25 W m^{-2}, proving that the satellite data contained relevant information for flux estimation.

In general, the spatial and temporal patterns of the LSM fluxes were well captured in the satellite-derived fluxes produced by the SM (see an example with the GSWP multi-model fluxes in Fig. 1).

These SMs were calibrated with all the satellite observations as inputs, but SMs calibrated only with individual satellite observations (for instance, only with AVHRR and ISCCP data) were also tested, and they could not yield such results.

The synergetic use of various wavelengths with complementary sensitivity clearly improved the ability to reproduce the fluxes for all types of environments. The use of multiple satellite information also made the scheme more robust to the lack of one specific observation.

We evaluated the quality of the original LSM fluxes and the SM estimates. Compared to one another, the three LSMs and the NCEP/NCAR reanalysis considered here produced sometimes quite different fluxes in some regions both in terms of magnitude and spatial structures. This was true especially for the sensible heat fluxes, even when the three LSMs shared the same forcing (meteorological inputs), as did the multi-model, ISBA, and ORCHIDEE. Obviously, having been trained with the LSMs, the SMs cannot remove existing biases like these at the global scale but for specific regions where there is a departure from global relationship, they can potentially produce local fluxes that are more consistent with the learned global relationships.

For instance, the comparison between the original LSM fluxes and the SM-estimated fluxes at the end of 1995 revealed an anomaly in the LSM heat fluxes related to an anomaly in the radiative fluxes used to force the model. Fig. 2 shows these anomalous heat fluxes around the Tapajos National Forest station in Brazil. This scheme can thus help diagnose specific problems with the LSMs, though any discrepancies between original and estimated fluxes have to be evaluated also in the context of possible observation artefacts or errors introduced by

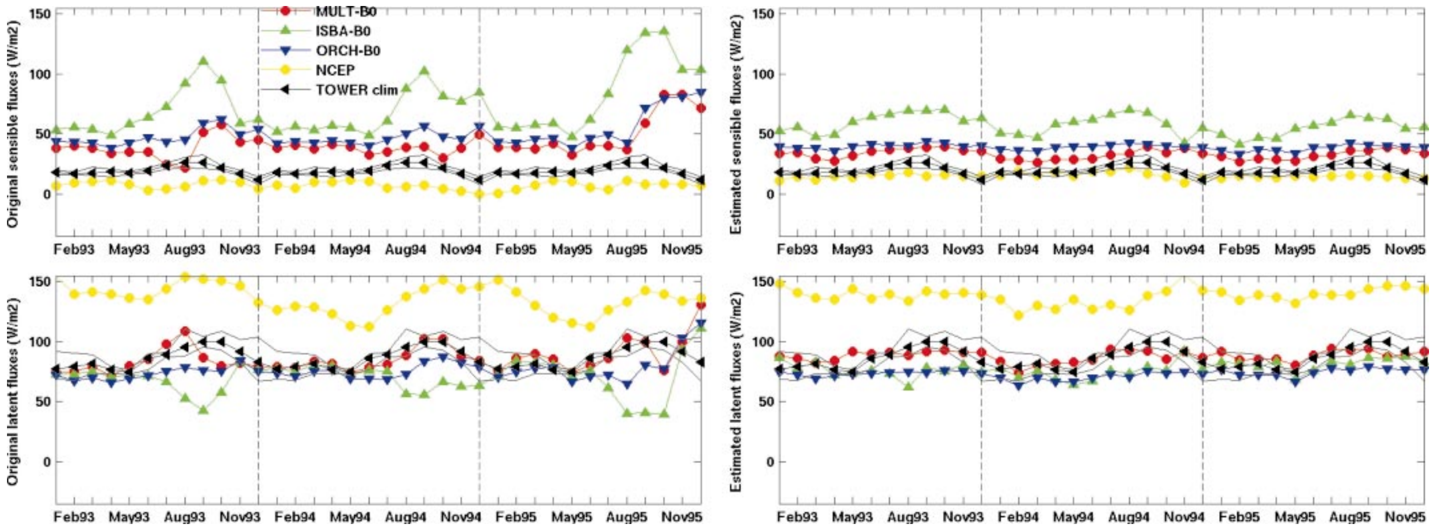

Figure 2. Averaged fluxes in a 2°x2° box around the Tapajos National Forest station near Santarém in Brazil (3°S 55°W). *Top left*: the original LSM sensible heat flux; *top right*: the SM sensible heat flux; *bottom left*: the original LSM latent heat flux; and *bottom right*: the SM latent heat flux. Fluxes displayed correspond to the three LSMs: multi-model analysis (red), ISBA (green), ORCHIDEE (blue), the NCEP/NCAR reanalysis (yellow), and an annual climatology built by averaging the tower fluxes at the station over the 2002–2006 period (black, with thin solid lines plotting the tower monthly maximum and minimum fluxes for that period).

the SM itself. The scheme is general and can be applied to other LSM variables (for instance, to modelled soil moisture [4]).

A quantitative assessment of the accuracy of both original and estimated fluxes is very difficult because of the lack of validation data. We did collect flux-tower measurements and compared them with the original LSM and the SM-estimated fluxes but the comparison was rather limited because:

1) the geographical coverage of the tower data was largely limited to mid-latitude environments, which are not the regions where the largest differences among the LSM fluxes are observed;

2) flux point measurements (towers) were compared with fluxes averaged over large areas (LSMs); and

3) there were hardly any tower data for the years considered during the GSWP exercise, so the comparison had to be based on a climatology of the tower flux measurements derived from the later 2000–2006 period.

Although some examples tended to show that the SM fluxes were closer to the flux tower climatologies when the differences between the LSM and tower fluxes were large (see for instance Fig. 2), a systematic comparison with all the available stations (mostly at mid-latitudes with the AmeriFlux network) did not statistically prove it. The extension of the exercise to other regions remains very challenging in the absence of validation data, and the arguable better accuracy of the satellite-derived SM fluxes in those regions remains to be demonstrated.

Data assimilation is the incorporation of observations into a numerical model with the purpose of providing the model with the best estimate of the current state of a system. In that sense, the proposed methodology can be considered similar in nature to an assimilation scheme as the LSM fluxes are merged with the satellite observations with the objective of providing a better estimate of the fluxes.

This also means that the satellite-derived SM fluxes will always be related to a specific LSM flux, and the method cannot then derive independent land-surface heat fluxes from satellite observations. Nevertheless, the fact that independent satellite observations can be related to LSM fluxes with a sufficient level of accuracy is already a positive sign for relating these observations to the real-world fluxes, and the proposed methodology can be considered as a pragmatic step forward in the search of reliable methodologies for flux estimation at a global scale. ■

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4. Aerosols from the land surface and their interactions with the climate system

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Paulo Artaxo (*University of São Paulo, Brazil*)
Roger R. Pielke, Jr. (*Center for Science and Techhnology Policy Research, USA*)

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Siikaneva wetland in southern Finland. Photo: Lauri Laakso.

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Wetland extent under climate change and its potential role on future methane emissions

The feedbacks between wetland emissions and the climate change have been previously hypothesised [1] but their existence and strength remain uncertain [2]. Climate variability influences methane (CH_4) sources from wetlands via changes in methane flux and via changes in wetland areas in response to surface hydrological processes. Previous studies [3] have shown that wetland area variations must be taken into account in order to understand the variability in current CH_4 emissions from wetlands.

The first aim of this study was to simulate, in a very simple way, wetland extent for present-day conditions and to validate it using data from multiple satellite observations [4]. The second aim was to estimate wetland extent under future climate conditions and to quantify the potential role of this wetland area modification on methane emissions.

To compute wetland extent, we integrated a TOPMODEL [5] approach in the global vegetation model ORCHIDEE [6]. Using sub-grid topography and soil water content, TOPMODEL calculated the water-saturated fraction of each pixel [7, 8]. Wetland extent was then calculated based on the saturated fraction and compared to the remotely-sensed wetland area observations during the period 1993–2000 [5]. Relative wetland extent, seasonality, and interannual variability were reproduced with good agreement in several regions.

Next, to calculate future changes in potential wetland extent, we used outputs of one climate system model (IPSL-CM4) obtained under the economic scenario (description of possible future levels of emissions and environmental variables) A2 published by the Intergovernmental Panel on Climate Change (IPCC) in 2000. The A2 scenario describes a very heterogeneous world

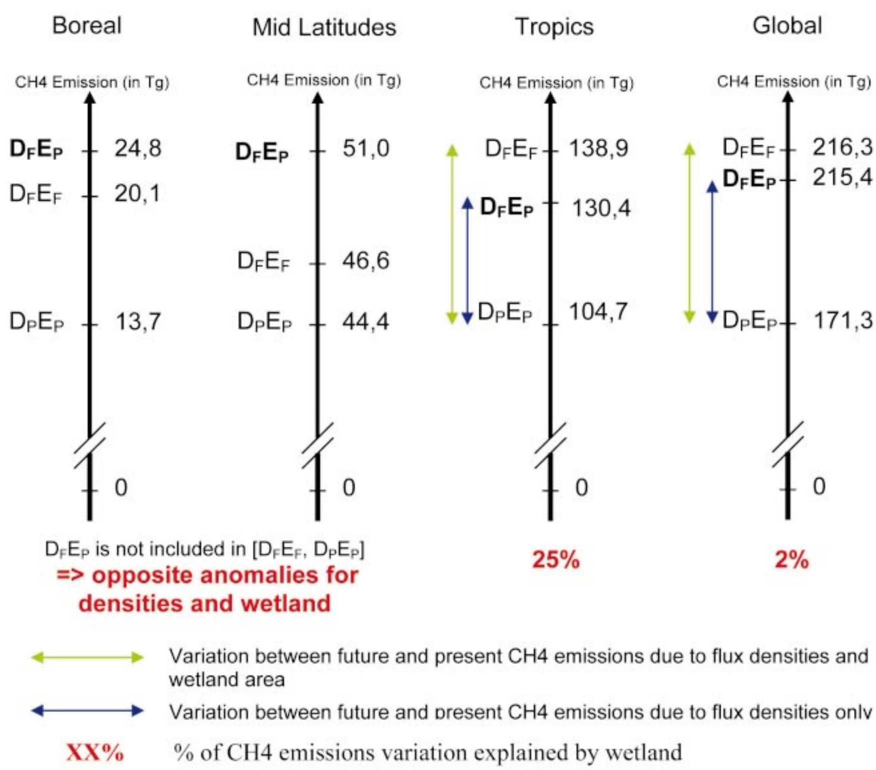

Figure 1. Annual methane emissions for each latitude band using different combinations of flux densities (D)/wetland extent (E). The subscripts P and F refer to Present and Future. For example, D_FE_P means that CH_4 emissions were computed using future flux densities and current wetland extent. The relative position among D_PE_P, D_FE_F and D_FE_P for each latitude band indicates the influence of wetland extent changes on CH_4 emissions.

with continuously increasing global population and comparatively slow economic growth (http://sedac.ciesin.columbia.edu/ddc/sres). In order to remove systematic biases of the IPSL model, we also used current observed climatological fields of the University of East Anglia's Climate Research Unit [9].

According to our results, the changes in annual wetland extent were minor in each latitude band except in boreal regions where the annual wetland area increased by about 20%. We also calculated CH_4 flux densities under the current and future climates; our results predicted that CH_4 emissions would increase in the future in each latitude band, with large variations from one latitude band to another.

Finally, using different combinations of wetlands extent/CH_4 flux to compute CH_4 emissions (Fig. 1), we analysed the role the surface plays in future CH_4 emissions.

Our results showed that in the boreal regions the seasonality of wetland extent changes: because of hotter summers and milder winters, the maximum summer extent of wetlands will decrease although the maximum extent lasts longer. This leads to a slower increase in CH_4 emissions than predicted previously even though the total annual wetland extent increases. On the contrary, the increased wetland extent in the tropics can explain 25% of the predicted increase in CH_4 emissions in this region.

To conclude, predicting the variations in wetland extent is necessary for reliable simulations of changing methane emissions under the changing climate. ■

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Process-based crop growth within the land-surface model JULES

It is estimated that approximately 18% of the land surface is used for crop production [1]. The increasing demand for food and forest products, in conjunction with the climate change, is expected to significantly alter the terrestrial ecosystem and, by consequence, the energy, water, and carbon fluxes between land and the atmosphere [2].

In addition, the availability of resources such as water further constrains agricultural production in many regions. In order to evaluate the sustainability issues that we will face in the near future, we need to understand the relationships between crop production, land-surface characteristics, and energy and water cycles.

In this study, these relationships are analysed using the Joint UK Land Environment Simulator (JULES) [3]. JULES was originally designed to represent the land surface in meteorological and climate models developed in the UK. Its scheme includes the full hydrological cycle and vegetation effects on energy, water, and carbon fluxes. However, JULES simulates land surface processes only in natural ecosystems.

To represent crop growth, development, and harvest, we added crop modules to JULES. Since most of the crop modules were derived from the crop model SUCROS [4], the resulting model was denoted JULES-SUCROS. JULES-SUCROS incorporates crops and natural vegetation within the same biogeochemically consistent numerical framework.

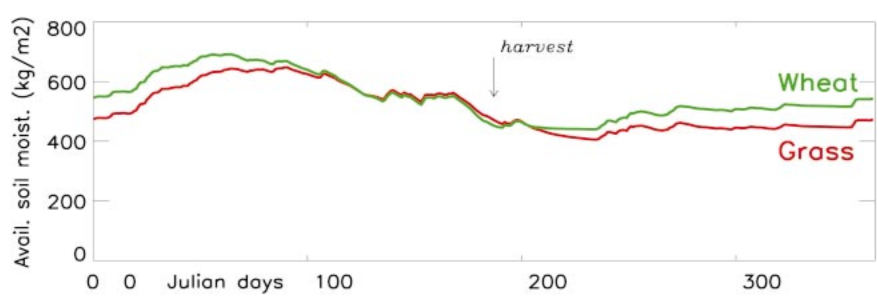

Figure 1. The available soil moisture within the depth of 3 m on a grassland (green) and a wheat field (red) simulated with JULES over a single grid cell in France (47°51'N, 2°41'E) for the year 1995.

Prior to any model adaptation, however, we investigated the sensitivity of JULES to morphological and physiological differences between natural vegetation and crops by reparameterising a natural grass into a crop.

To this end, we forced (used as input) JULES with observed time series of the crop's LAI (leaf area index, the area of leaf surface per unit ground area), height, and rooting depth. To better understand the physics behind the surface exchange processes, we ran the model over a single grid in France (47°51'N, 2°41'E) for the growing season of 1995. So far the study has been restricted to wheat, the most abundant crop type worldwide. Wheat is also cultivated extensively throughout Europe.

The conversion from natural grassland to cropland in JULES resulted in a distinct overall increase in annual soil moisture content (Fig. 1).

In the simulation, the soil retained more water after harvest because the transpiration by plants ceased on the bare crop field; this difference in soil moisture (~70 kg m^{-2} in autumn) was significant when compared to the seasonal variability (~200 kg m^{-2}).

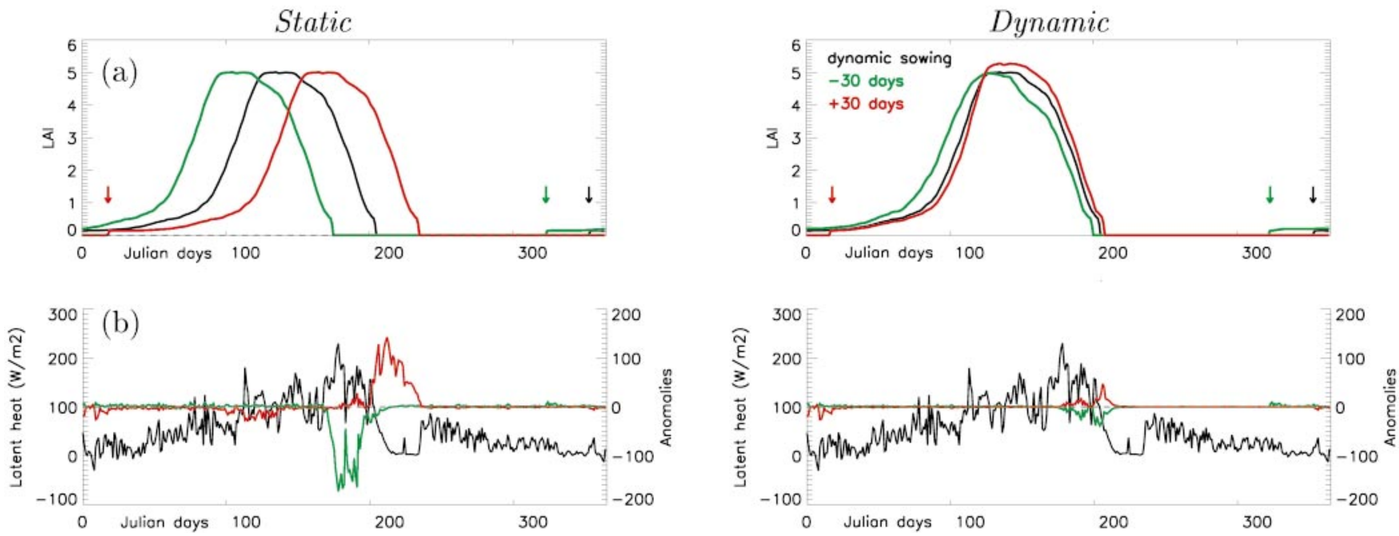

Figure 2. a) Leaf area index (LAI) and b) latent heat (energy needed for a change of phase *e.g.* energy released during evapotranspiration) on a cropland simulated with JULES ('static') and a more dynamic cropland simulated with JULES-SUCROS ('dynamic'), and their anomalies (departures from the control (black)) with crop emergence at +30 days (red), and –30 days (green) compared to control (black). The arrows represent the emergence days.

The soil moisture increase remained through the autumn. The higher water content of the soil limited the infiltration capacity of the soil during the winter (more run-off). As already indicated by Twine in his study on the Mississippi Basin [5], the changes in the energy and water balance after the grass-to-crop conversion were mainly due to the changes in the growing season length and timing, and in particular the evaporative seasons, not to the physiological differences between the vegetation types.

Having shown that JULES was indeed sensitive to grass-to-crop conversion, we further converted the static cropland into the more dynamic cropland of JULES-SUCROS. The timing of the dynamic crop emergence depends on the prevailing meteorology and crop requirements. The development rate of the dynamic crop is determined by temperature, and the growth rate of each organ (root, stem, leaf, and storage organs) is a function of phenological stage, partitioning of assimilates to organs, and environmental conditions. The biophysical parameters LAI, crop height, and rooting depth, which link the vegetation and the land surface, are dynamic and consistent with the growth and development of the crop organs.

Next, we compared the effect of different crop emergence times (control, +30 days, and –30 days) on the crop growth and development, and surface fluxes for the static and the dynamic crops (Fig. 2).

Since its phenological cycle is prescribed, the static crop developed at an equal rate regardless of the timing of crop emergence. Therefore, the emergence time had a strong effect on the evapotranspiration (evaporation from surfaces and transpiration by plants), and by consequence on the hydrological cycle. On the other hand, because the dynamic crop adapted its growth and development to new environmental conditions, it matured always at roughly the same time of the year regardless of emergence time. Hence, the influence of dynamic-crop emergence on the land surface and fluxes was less significant (Fig. 2).

The ability of the dynamic crop to adapt to a changing environment was noted also under climate change conditions. At the level of the individual organs, the influence of changed environmental conditions varied. For example, under changed climate the dynamic crop produced less total biomass (~-20%) because of the shorter development time (result of faster development rate under higher temperatures) and the lower water availability. Grain production, however, did not suffer from the new conditions simply because the faster development rate moved the grain filling period earlier in the year when the water stress was smaller.

JULES-SUCROS is still under development but we can already conclude that the influence of crop growth and development on energy and water fluxes is important because of the strong interactions between crops, land surface, and the atmosphere.

A change in the length and timing of the growing season has an important effect on the hydrological cycle. This, in turn, might influence weather and climate and feed back to the crop's life cycle. Therefore, simulations without a dynamic crop-growth structure might strongly bias the effects of changes in atmospheric conditions on the land surface.

In the near future, we will couple JULES-SUCROS back to the UK climate model and study the feedbacks between crop growth and the climate system.

However, we first need to test JULES-SUCROS on other sites for several consecutive years to evaluate its sensitivity to changes in environmental conditions, crop type, and inter-annual variability. To achieve this, the data collected in the framework of FLUXNET and CarboEurope projects will be very useful. ■

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Including tropical croplands in a terrestrial biosphere model: application to West Africa

Studying the large-scale relationships between climate and agriculture raises two coupled questions: the influence of climate on crops, and the potential feedbacks to climate from croplands through biophysical and biogeochemical processes.

A consistent framework to address this twofold issue in an integrated way is to extend existing Dynamic Global Vegetation Models (DGVM), which simulate vegetation on a global scale and can be coupled to climate models, explicitly to croplands. So far, most of the DGVM only approximate croplands by grasslands.

Following this approach for tropical croplands, we included in the IPSL (Institut Pierre-Simon Laplace) land-surface model ORCHIDEE [1] processes and parameterisations taken from an existing crop model, SARRAH [2], which is routinely used by agronomists for millet in West Africa. The resulting version of ORCHIDEE, called ORCH-mil [3], realistically simulates millet growth and yield when tested at an experimental station in Senegal (Fig. 1). We then applied the model over West Africa, forced by the NCC dataset (NCEP [National Centers for Environmental Prediction] reanalysis Corrected by CRU [Climatic Research Unit] monthly data) over 1965–2000.

First, we compared the simulated yield at national scale with data from the Food and Agricultural Organisation of the United Nations (FAO) database. Because the model simulates a highly productive variety sowed at high density, which corresponds to experimental conditions but not to local on-farm situations, it largely overestimates average yields. This problem should be corrected in further model developments.

However, in terms of interannual variability, the model already captures the relationship between crop yields and rainfall (which, in the context of tropical rainfed agriculture, is the main climatic forcing) correctly. The positive correlation (R) of the model results with FAO data was significant for some countries (R=0.51 for Niger, 0.48 for Burkina Faso).

As the next step, we analysed how the simulated land surface fluxes were influenced by the explicit accounting for croplands. We compared the 36-year simulation by ORCH-mil with one by ORCHIDEE which represents croplands as grasslands.

Significant differences appeared, mainly at the end of the rainy season: contrary to grasslands, croplands are then harvested and replaced by bare soil. Thus, on average, latent heat fluxes (evapotranspiration) in ORCH-mil were smaller (by up to 25% annually) whereas sensible heat fluxes (warm air rising) and albedo were higher.

These differences in land surface fluxes between grasslands and croplands may be reflected also in the monsoon system, mainly during the retreat of monsoon rains. Coupling ORCH-mil to an atmospheric model should enable us to investigate such a question. ■

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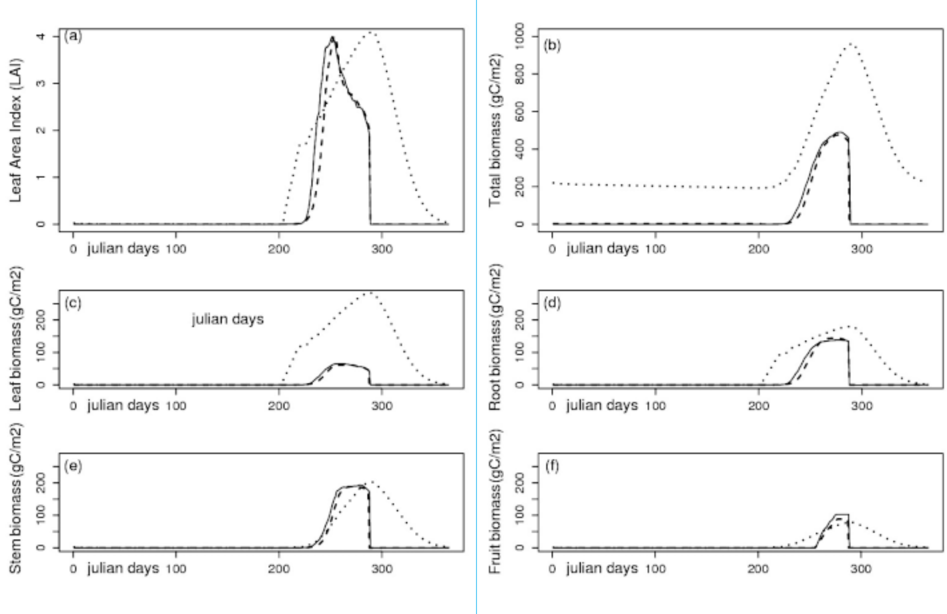

Figure 1. Comparison between standard version of ORCHIDEE (dotted line), the crop model SARRAH (full line), and ORCH-mil (dashed lines) for simulations of (a) leaf area index (LAI, sum of leaf area on unit ground area), (b) total biomass, (c) leaf biomass, (d) root biomass, (e) stem biomass, and (f) fruit biomass, for year 1997 in Bambey, Senegal (biomasses are in g (C) m^{-2}).

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Effects of agricultural production on regional CO_2 fluxes and concentrations

To investigate regional carbon fluxes and the mechanisms driving them, the North American Carbon Program (NACP) launched a Mid-Continent Intensive (MCI) Campaign in 2007 centred over the Midwestern United States [1]. As part of the MCI campaign, high-precision atmospheric carbon dioxide (CO_2) concentrations were sampled at five communications towers throughout the region [2].

In this study, we analysed CO_2 fluxes and concentrations from June through August 2007 using the coupled ecosystem-atmosphere model SiB3-RAMS [3,4].

To improve the simulation of CO_2 fluxes over the mid-continent region, we coupled SiB3-RAMS to a crop phenology model that calculated the leaf area index (LAI), the fraction of photosynthetically active radiation (FPAR), and the net ecosystem exchange (NEE) of CO_2 for both corn and soybean [5]. As a result, we obtained more realistic fluxes at local scale for these two crops compared with observations.

This coupling approach also dramatically altered the simulated regional fluxes over the central mid-continent, increasing the average summertime uptake from ~ 1–2 μmol m^{-2} s^{-1} to more than 6 μmol m^{-2} s^{-1}. Because of this increased uptake of carbon, the average total column CO_2 concentration decreased by more than 1 ppm over the region; concentrations near the surface decreased by more than 20 ppm.

During summer 2007, the south-eastern US experienced both a heat wave and a drought. These climatic conditions stressed the plants and significantly reduced the photosynthesis while increasing the respiration. As a result, the south-eastern region of the United States became a large source of CO_2 for the summer. The mid-continental region was a sink of CO_2, and the northern half of the continent was also a moderate summertime sink.

The average distribution of CO_2 concentration matched the carbon fluxes, with high concentrations in the South East and low concentrations in the North. This large-scale concentration gradient over the mid-continent was strong, with differences of over 4 ppm in the total column and over 40 ppm near the surface between North and South. Average wind flow shifted this large-scale gradient from time to time and the effect was evident in the CO_2 concentrations observed at the MCI measuring sites in the mid-continent.

During southerly winds, the high southern concentrations created differences of over 30 ppm among the measuring towers ~300 km apart; however, during northerly winds, the large-scale gradient shifted to the southwest and smaller differences were observable.

Comparing the modelled CO_2 concentrations with the tower data collected during the MCI campaign revealed that the simulated CO_2 concentrations over the MCI region improved dramatically when the crop model was included, reducing the squared differences between the observations and the model by nearly half.

Including the crop phenology model also improved the simulated synoptic variability in CO_2 concentrations, as well as the simulated North-South concentration gradient that could be compared with the observed concentrations at the towers. Concentrations lower than 340 ppm were observed during July and August in both the model results and in the observations.

This study showed that corn and soybean are highly productive crops that significantly influence both regional CO_2 fluxes and concentrations. ■

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A previously neglected methane source from the Andean *páramo*?

Anaerobic production in wetlands has traditionally been considered the primary natural source of methane (CH_4) in the world. However, recently a new source of methane emission was discovered: the photochemical production of methane from plants under aerobic conditions and UV light [1, 2]. In their first publication, Keppler *et al.* [1] suggested that plants may emit 62–236 Tg yr^{-1} of CH_4, i.e., 24–163% of global natural CH_4 emissions as given by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [3]. Even though the upper limit of methane emissions from plants was later scaled down to 85 Tg yr^{-1} [4], it is still uncertain if and how much the photochemical production contributes to the global CH_4 budget. This example shows that natural methane sources are still poorly quantified.

Around the same time as the new methane source was discovered [1], Frankenberg *et al.* [5] published the first satellite-derived information on atmospheric methane mixing ratios. The SCIAMACHY satellite instrument on board of European Space Agency (ESA)-operated ENVISAT observed very high concentrations of atmospheric methane over the north-western part of South America (Fig. 1). Wetland maps used for another study could not explain the high atmospheric methane concentrations above Colombia and Venezuela, especially from October to December [6]. Bergamaschi *et al.* [6] pointed towards a potential aerobic contribution of methane emissions from plants in that area as suggested by [1].

We postulated that high-altitude wetlands in the tropical Andes had been neglected in the wetland maps used in [6] and that they could be (in part) responsible for the high atmospheric concentrations of methane over the north-western part of South America. Those wetlands, part of a tropical alpine ecosystem locally known as *páramo*, occur in the Andes of Venezuela, Colombia, Ecuador, and Peru (8°N to 11°S), at altitudes between 3200 and 5000 m above sea level.

The *páramo* extends over an area of around 35000 to 77000 km² [7]. *Páramo* vegetation is characterised by wet grasslands, with patches of peat bogs, forests and shrublands; in other words, an ideal habitat for methane production. The climate is wet

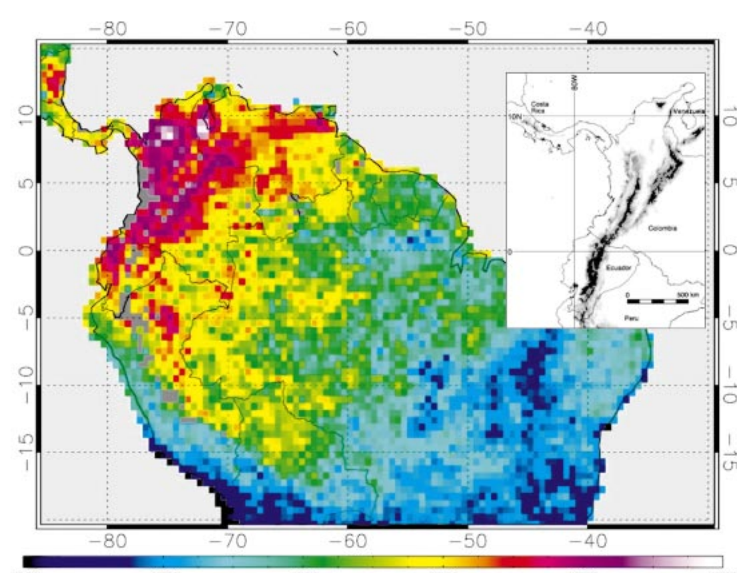

Figure 1. Atmospheric methane concentrations (mean column mixing ratio, ppb) averaged from January 2003 to December 2004 as observed by SCIAMACHY on board of the ENVISAT satellite [5]. The inset shows the *páramo* distribution in South America [7].

(annual precipitation from 600 to more than 3000 mm) and relatively cold with mean annual temperatures around 8°C.

We were not aware of any measurements of methane emissions conducted in the Andean *páramo*. Therefore, we used a modelling approach to estimate anaerobic methane emissions from the *páramo* region. In order to first determine the potential area of the *páramo* ecosystem, we used the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center's (NGDC) ETOPO2v2 2' gridded topography dataset (www.ngdc.noaa.gov).

We used elevation (as a proxy for temperature) and precipitation to identify tropical alpine wetland areas: all grid cells between 3000 and 4500 m above sea level with annual precipitation >600 mm were considered potential *páramo* area. The resulting map shown as insert in Fig. 1 was used as a mask to run LPJ-WHyMe (described further below).

However, when using only altitude and precipitation as boundary conditions for the occurrence of the *páramo*, the resulting area was at least four times too large compared to best estimates. We therefore applied a further mask based on the topographic index (a measure of landscape steepness) to limit the *páramo* ecosystem to the less steep parts of the area, which we assumed to be the wetter ones and therefore the more important ones in terms of methane emissions. Based on field observations in Ecuador and Colombia, we classified areas with a topographic index of 9 or 10 as wetlands. This way, we obtained a *páramo* area of 56750 and 32320 km^2, respectively, close to current estimates.

LPJ-WHyMe is a dynamic global vegetation model that simulates wetland hydrology, peatland plant functional types and methane emissions [8]. To run LPJ-WHyMe, we used air temperature and precipitation climatology data (1950–2000) at 2' resolution that were derived from the WorldClim (www.worldclim.org) project. Cloud data were taken from the CRU CL1.0 (Climate Research Unit Climatology data, University of East Anglia) data set and interpolated to 2' resolution.

LPJ-WHyMe showed a clear north-south gradient in methane emissions (Fig. 2), with higher annual emission rates in the northern areas of Colombia and Ecuador and lower emission rates in Peru. This pattern was the result of either wetter conditions and/or higher net primary production in the north. Both of these conditions enhance anaerobic

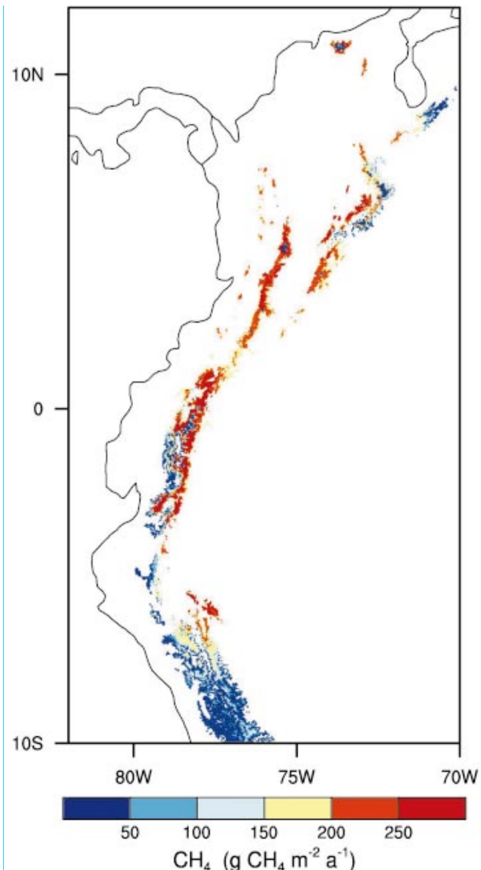

Figure 2. Methane emissions from the *páramo*.

methane production: wet conditions provide ideal conditions for methane production, and high net primary production provides organic substrate that can be utilised by the methane-producing microbes.

Soil temperature did not exhibit a clear north-south gradient. Annual methane emission rates exceeded 250 g (CH_4) m^{-2} yr^{-1} in the *páramo,* about 50% higher than in the northern high-latitude peatlands [8]. The reason was the constant temperature throughout the year.

We estimated that total annual methane emissions from the Andean *páramo* lie between 1.4 and 2.4 Tg, depending on the topographic index used to limit the *páramo* area. Previously, methane emissions from the whole of South America were estimated to be between 29.3 Tg yr^{-1} [9] and 38 – 44.2 Tg yr^{-1} [6]. Both studies excluded areas above 500 m above sea level in their methane emission estimates.

According to [6], matching model results to SCIAMACHY observations in the northwestern part of South America was difficult, especially from October to December. This is exactly the region where large areas of wet *páramo* occur. Our first estimates of methane emissions from the *páramo* indicated significant anaerobic methane emission rates, higher than from peatlands in the northern hemisphere [8], although the total emissions are relatively small because of the areal constraint of the *páramo*.

Clearly, more work on methane emissions from this part of the world is necessary. However, our main aim was to show that methane sources other than aerobic methane emissions from plants may exist and that they may help to explain the high methane concentrations observed in the SCIAMACHY data. Our results warn us against making hasty conclusions based on incomplete knowledge of ecosystems. ■

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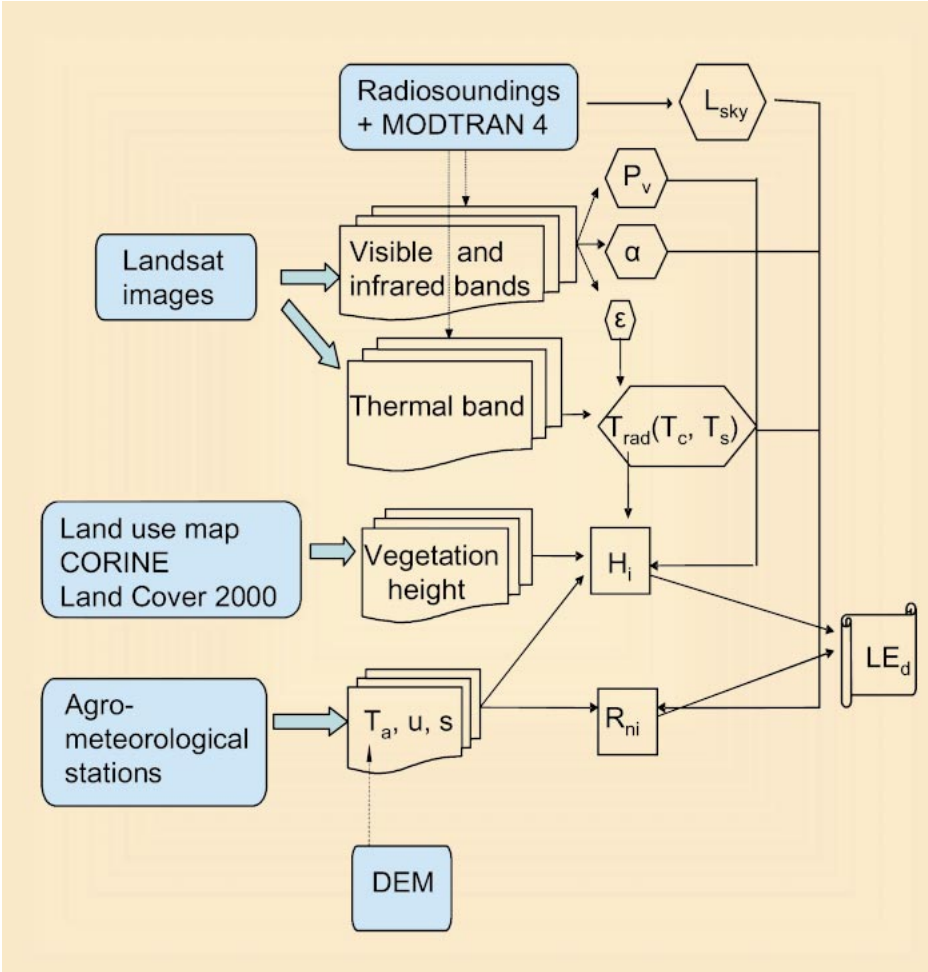

Figure 1. Scheme of the methodology proposed to retrieve actual daily evapotranspiration (latent heat flux LE) at a regional scale, integrating remote sensing data and ground meteorological information. Description of all the variables and parameters can be found in [4].

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Monitoring the surface energy balance using remote sensing

Anomalies in the global energy balance play an important role in the global climate change. A good knowledge of the surface-atmosphere interactions, and particularly of the water and energy cycles, is essential to help the scientific community in this regard. Also, the different terms of the surface energy balance may be used to evaluate land-surface models embedded within climate models.

The latent heat flux (LE), or evapotranspiration (evaporation from surfaces and transpiration by plants), is the least understood process of both the water and energy cycles. However, its determination is crucial for meteorological, climatological, and hydrological studies. Traditional local models to estimate LE cannot be applied at regional nor global scales as required in climate assessment.

Remote sensing techniques allow us to obtain information on surface variables with a global coverage. This includes regions of special interest such as, for example, boreal forests which occupy about 11% of the total terrestrial surface, representing an important contribution to global energy balance [1].

In this study, we developed a physical model for estimating local surface energy fluxes that can be operationally used together with satellite images at a regional scale. Because of its particular significance in the water cycle, we focussed on the retrieval of daily LE.

The model is based on a two-source patch representation of the soil-canopy-atmosphere system [2]. The feasibility of the model at a local scale has been explored using data collected over different ecosystems. In this work we focus on two of them: a maize (corn) crop in Maryland, USA, and a boreal forest in Finland.

In the corn crop, the energy balance (net radiation ≈ soil heat flux + LE + sensible heat flux) was governed by LE [2] whereas in the boreal forest LE was less significant [3].

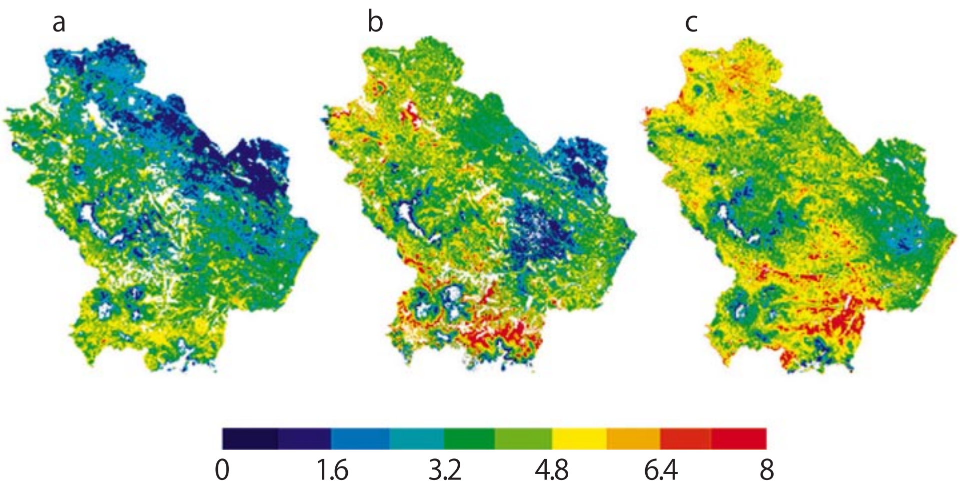

Figure 2. Actual daily evapotranspiration *i.e.* daily latent heat flux, LE_d (mm day^{-1}) over maps of the Basilicata region (100x100 km^2 approximately) in southern Italy for three Landsat scenes corresponding to different dates: (a) 26 Sep 1999, (b) 14 Jun 2002, (c) 25 May 2004. Coniferous and broad-leaf forests, together with fruit trees and agriculture areas, generally produced the highest LE_d. On the other hand, the lowest LE_d values were usually found in sparsely vegetated areas, arable lands, and pastures. Because of the phenological stage of the vegetation, overall the highest LE_d was observed in May 2004 and the lowest one in September 1999. Figure reproduced from [4].

Comparison of the results with ground measurements indicated errors between ±15 and ±60 W m^{-2} for the retrieval of net radiation, soil heat flux, and sensible and latent heat fluxes at both sites [2,3]. According to a sensitivity analysis of typical uncertainties in the required input parameters at a regional scale, the model was most sensitive to surface and air temperatures.

For regional scale, we developed a detailed methodology to apply the model to Landsat satellite imagery in [4]. The different surface cropland features were characterised according to the CORINE Land Cover [5] maps, and the required meteorological variables were obtained by interpolating the data of a network of agro-meteorological stations distributed within the region of interest (Fig. 1).

We applied the methodology to three different Landsat scenes corresponding to different dates covering the whole Basilicata region (southern Italy). As a result, we obtained maps of the different surface fluxes including daily LE (Fig. 2). Comparison of the results with ground measurements revealed that the accuracy of the model was close to ±30 W m^{-2}.

It should be noted that the spatial resolution of some satellite sensors, especially those with a daily overpass frequency, may be too coarse to discriminate between different land uses, depending on the field pattern size. In order to improve the applicability of the surface energy model in these cases, some procedures can be applied to estimate subpixel energy fluxes [6]. ■

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Working group chairs: Juliette Lathière, Dominick Spracklen

Working Group report on **Land-atmosphere feedbacks**

The aim of this working group was to find answers to the following two questions:

- What are the important potential feedbacks between land and atmosphere that have not already been studied?
- What type of experiments need to be designed to illustrate and quantify them?

The discussion in the group was lively and produced multiple candidates for feedbacks that have so far not been addressed in climate modelling.

Here, we summarise some of the main points.

The role of micro-organisms in atmospheric chemistry such as aerosol formation and photochemical processes came up early on in the conversation. *Bioprecipitation* is related to bacteria that participate to supercold cloud formation. Evidence of bioprecipitation has been obtained at several locations in the USA and also in Brazil.

However, although the group felt this phenomenon is important for understanding cloud formation, the number of micro-organisms with the necessary properties is small. Most of these micro-organisms are active only in cool temperatures and will probably become less active in the warming climate.

Interactions between biogenic trace gas emissions and atmospheric chemistry have an influence on aerosol dynamics and on ozone formation. Volatile organic compounds (VOC) such as isoprene and monoterpenes are emitted from vegetation and oxidised in the atmosphere by ozone (O_3), the hydroxyl radical (OH^-) and the nitrate radical (NO_3). The oxidised products are less volatile and can condense on small aerosol particles and grow them to climatically relevant sizes (> 80–100 nm in diameter) where the particles can act as cloud condensation nuclei (CCN) and, eventually, form clouds. Aerosol particles cool the climate also by scattering incoming sunlight back to space.

New VOC are constantly being discovered, and more information on their role in the formation of climate-cooling aerosol particles is necessary for better modelling of the Earth's radiative balance. Experiments should be conducted both in the laboratory and in the field to achieve a better understanding of the oxidation processes. The hydrological cycle also has an important effect on aerosol dynamics via cloud formation, precipitation, and indirectly through plant productivity and, therefore, VOC emissions.

By scattering, aerosols can reduce the amount of photosynthetically active radiation reaching the Earth's surface and change the relationship of direct and diffuse light. This effect is not considered in current climate models and it could dramatically change the simulated biogenic emissions, both directly, by modifying the radiation available for the synthesis of biogenic VOCs, and indirectly, by its effect on plant productivity.

The importance of the chemical composition of the atmosphere and soil in the development of ecosystems was pointed out in the conversation. There are already studies about ozone but we need a better understanding about the influence of acid deposition (wet and dry) and other pollutants and particles on ecosystems and the carbon cycle. A good example is China with its industrial development. Important substances in this regard are, for example, sulphuric acid, dissolved organic carbon (DOC), and total dissolved nitrogen (TDN) which are currently missing in climate studies. The human influence on these compounds can be great. Remote sensing can be used for monitoring sulphur dioxide (SO_2).

The influence of global warming on wetlands is an important consideration. The melting of permafrost can become a new source of wetlands in the future. One important feedback is the coupling of methanotrophy (methane consumption) and methanogenesis (methane emission) in wetland ecosystems and forests in response to increasing loads of reactive nitrogen (all atmospheric nitrogen except N2) species from the atmosphere. For example, more research is necessary on gaseous losses and uptake of N such as nitrous oxide (N_20) consumption in ecosystems and on N_20 export from rivers.

We need more information about the human influence on the linked carbon-nitrogen-phosphorus cycles in plants and soil. For example, determining the magnitude of nitrogen (N) fixation in different ecosystems and the variety and functional groups of organisms participating in the N fixation is crucial for understanding carbon-nitrogen interactions. Plant roots influence the physical, chemical, and biological conditions of the soil. The biogeochemical reactions induced by micro-organisms affect the availability of nutrients to plants and microbes.

However, because of insufficient understanding of soil-plant interactions, models are still incapable of fully describing the carbon, nitrogen, and phosphorus cycling in the soil. Reactive nitrogen has a key role in the atmosphere and soil because it controls nitrogen availability and hence, for instance, carbon sequestration of forest ecosystems. The use and development of remote sensing for both wet and dry nitrogen deposition studies is of great importance in order to understand larger-scale interactions of nitrogen and ecosystem functioning.

Land-use change is a crucial factor that has many potential effects in terms of trace gas emissions, albedo, evapotranspiration, energy, and atmospheric chemistry. Yet another aspect are the feedbacks among dust, ice nuclei, and surface meteorology. So far, these processes have only been taken into account on large scale.

However, they also influence ecosystems on a local level (fertilisation effect, change in the availability of nutrients for plants). This could be studied mainly in the laboratory: aerosols in different solutions can be used to study how much is soluble (solubility of iron for example) at different pH. Extending experiments like these to the field would be difficult.

Finally, the group mentioned that wildfires are not very well detailed in models so far (height of injection). We need better understanding of the influence of wildfires on aerosol formation, clouds, the radiative/energy budget, and convection. Satellite observations are a good way to detect wildfires. ■

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Deforested landscape in Rondonia, Brazil.
Photo: Andi Andreae.

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Working Group report on **Land use**

We were tasked with two objectives: firstly, to assess how we can properly account for land use in climate models; and secondly, to determine what datasets are required for this that do not currently exist. Several land-use processes are currently missing from the land surface/vegetation component of climate models that should be included. The two main points of discussion were

- including land-use transitions;
- representing croplands.

Land-use transitions are an important consideration as they determine whether forest within a grid box is primary (old-growth) or secondary (recovering from previous human land-use activities). Forests in these two land types have different growth rates that lead to large differences in simulated carbon budgets and in physical feedbacks between the land and the atmosphere.

It was noted that all dynamic vegetation models contributing to the 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC) would need to include land-use transitions in the simulations. Therefore, discussion and debate arose also on the issue of how current Dynamic Global Vegetation Models (DGVM) would represent transitions.

The second major point of discussion concerned representing croplands in DGVMs. It was noted that several modelling groups throughout the world are currently developing global cropland parameterisations. However, compared to the development of DGVMs, progress is slow, and the group discussion focussed on the possible reasons.

One possible explanation is an overall lack of a common objective. Crop parameterisations have been included in some land-surface models to improve the simulation of seasonal carbon fluxes, in others to better represent biophysical feedbacks to the atmosphere, and in others to provide estimates of crop yield. So far, these various objectives have been met using different approaches.

Related to the objectives, another point raised was that crop parameterisations were perhaps too complex for inclusion in DGVMs given the small proportional area of croplands and the extent to which current crop growth parameterisations differ from existing DGVM growth models. Additionally, the large number of dynamic crop models, many of which are crop-specific, was speculated to have hindered progress towards a single generic parameterisation for all crops globally.

These factors, combined with the computing costs of DGVMs, suggest that it may be appropriate to use the existing parameterisations of natural vegetation as much as possible.

An alternative view was that progress was slower because more validation was being conducted for croplands than was done during the development of natural vegetation models, possibly because of the availability of datasets on crop yield. This led to the question: is it appropriate to validate crop yield simulations when we are more interested in simulating carbon and physical fluxes correctly? This question is even more valid considering that many non-climatic factors can influence crop yield, such as variability in inputs (*e.g.* fertilisers) and choice of crop variety. However, it was also noted that these factors affect the growth of the crop and therefore influence the biogeophysical feedbacks we are interested in.

A wish list of datasets for representing land use in climate models included details on crop management (sowing dates, fertiliser inputs, tillage practices), irrigation (not just area, but volume applied, efficiencies, sources), and fire suppression. It was noted that integrated assessment models (IAM, used to produce future world scenarios for IPCC) should provide details on crop area, fertiliser use and irrigation volume; however, it was thought unlikely that this information would be crop-specific. ■

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Working Group report on

Terrestrial biosphere model evaluation

About 15 of the iLEAPS-Marie Curie workshop attendees from Africa, Europe, and the United States participated in a lively discussion focussed on the evaluation of terrestrial models typically run within general circulation models (GCMs). The task was to recommend the best methods for thoroughly evaluating scientific model performance. Initially, group members identified a variety of difficulties that impede such evaluations, including

1) the mismatch between the spatial and temporal scales of measurements and models,
2) limits of model assumptions, and
3) the dangers of tuning models for specific geographic regions / forcing (input) data / execution modes (offline or coupled).

The group formulated a list of elements important for organised and methodical model-data comparisons. These elements are

- an experimental protocol designed to elucidate model performance under past, present, and future climates across all relevant space and time scales;
- metadata standards to simplify manipulation and analysis of model results, including standardising biome and carbon pool types;
- evaluation metrics based on comparison of model results with best available satellite- and ground-based observational data sets;
- standardised diagnostics supporting all metric comparisons;
- a scoring methodology based on a community-developed weighting of model performance on metrics, taking into account importance and data uncertainty; and
- open distribution of model results, supporting related research by the wider community.

The group thought it important that models should be evaluated based, as much as possible, on our understanding of individual processes. Therefore, performance metrics should be based on comparison against measurements of processes such as photosynthesis and phenology instead of, for instance, global CO_2 fluxes with multiple error sources.

Moreover, because there are many ways to get "the right answer for the wrong reason," a comprehensive evaluation of model processes must include comparisons of a wide array of model variables. Also discussed was the importance of combining many data sets of similar observations for comparison with model results and of processing data sets in a consistent manner.

The group constructed lists of forcing and evaluation data sets, and group members described many of the strengths and weaknesses of these data. Commonly used meteorological forcing data sets include NCEP/NCAR reanalysis (National Center for Environmental Prediction/National Center for Atmospheric Research, 1948–2004), CRU (Climate Research Unit of the University of East Anglia, 1850–present), NCC (NCEP Corrected with CRU, 1949–2000), and ERA-interim (European Centre for Medium-Range Weather Forecasts reanalysis, 1989–2007).

Sources of observational data identified were the FLUXNET and AmeriFlux sites for surface energy and carbon flux measurements, Free-Air Carbon Dioxide Enrichment (FACE) sites for vegetation response to increases in CO_2, river gauge and GRACE (Gravity Recovery and Climate Experiment) satellite observations for hydrological measurements, NOAA (National Oceanic and Atmospheric Administration) flasks for records of the CO_2 seasonal cycle, National Aeronautics and Space Administration (NASA) MODIS (Moderate Resolution Imaging Spectroradiometer) and other satellite products for phenology and carbon fluxes, and tree rings and other proxies for climate and disturbance.

In addition, an effort was made to characterise the spatial (small to large) and temporal (short to long) scales of a variety of individual processes and variables/characteristics. The group felt it was important to develop metrics that would consider model performance across all relevant scales.

Recommendations from the group discussion were to

- write a review paper on the current state of best available data sets for model evaluation;
- encourage the development and sharing of "best" data sets by the community;
- better document model processes to improve understanding of evaluation results;
- encourage closer collaboration between modelling groups;
- encourage closer collaboration between measurement and modelling communities; and
- establish a mailing list to continue the model evaluation discussion and invite others in the research community to participate. Interested researchers can subscribe to this mailing list at: www.climatemodeling.org/mailman/listinfo/land-eval

In conclusion, the group reiterated the importance of confronting models with observations and that this should be done early and often. Models must be tested and evaluated in offline, partially coupled, and fully coupled modes over short and long time scales and over small and large spatial scales. Experiments should include historical, present-day, and future time periods.

Finally, everyone agreed that these are challenging and time-consuming tasks, but that we should work together to take advantage of one another's efforts and expertise. An international model evaluation effort focusing on models to be used in the upcoming IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report could be the first step in building such a wide collaboration. ■

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Aerosol Clouds Precipitation Climate

Atmospheric aerosols have profound impacts on the thermodynmic and radiative energy budgets of the Earth. Recognition of the potential climate impacts of anthropogenic aerosols has led to a great deal of research to assess their role on the Earth's radiative balance. Much less is known about the effects of aerosols on precipitation, and the consequences for the climate system. The Aerosols, Clouds, Precipitation and Climate (ACPC) initiative is intended to develop an integrated research program to investigate the interactions and feedbacks among aerosols, cloud processes, precipitation, and the climate system.

Join ACPC emailing list.

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To strengthen the communication among researchers from a variety of disciplines and to encourage collaborations on the ACPC-related research worldwide. The ACPC mailing list not exclusively serves for the following needs from the ACPC community:

- discussions
- research exchange
- events logbook
- consultation
- conference calls
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GLOBAL CHANGE IGBP

WCRP World Climate Research Programme

ACPC-Initiative

Yellow River in tropical Darwin. Photo: Tanja Suni.

Marjut Nyman
iLEAPS International Project Office, University of Helsinki, Helsinki, Finland

Workshop report: 12–17 January 2009, Khon Kaen, Thailand

NASA-LCLUC meeting on land-cover and land-use change in Monsoon Asia

More than a hundred participants gathered in Khon Kaen, Thailand, for a workshop to transfer knowledge, to strengthen cooperation, and to find regional priorities in land-cover and land-use change (LCLUC) research in the South-East Asia region.

This NASA-LCLUC (National Aeronautics and Space Administration - Land-Cover and Land-Use Change) Science Team Joint Meeting was hosted by Mekong Institute and included

- MAIRS (Monsoon Asia Integrated Regional Study, www.mairs-essp.org),
- GOFC/GOLD (Global Observation of Forest and Land Cover Dynamics, www.gofc-gold.uni-jena.de), and
- SEA START (South-East Asia SysTem for Analysis, Research and Training, www.start.or.th) programmes.

Most of the participants came from Thailand, USA, and China. Other countries represented were Cambodia, Indonesia, Vietnam, Laos, Malaysia, Myanmar, the Philippines, South Korea, Switzerland, Canada, India, Japan, and Finland.

Khon Kaen is Thailand's fourth largest city with 200 000 inhabitants; it is located in the North-East province of Isaan which has the spiciest food in the country. The close connection between land-use practices and the atmosphere was clearly demonstrated by the yellow haze above the area. The haze is caused by the smog rising from biomass burning in the surrounding sugar cane fields.

The meeting was divided into keynote lectures, thematic presentations, programmatic presentations, working group discussions, and poster sessions. We had a possibility to visit the Khoen Kaen University and the Mekong Institute.

A one-day field trip was organised to the village of Kham Muang in the Khao Suan Kwan district. There we had an opportunity to explore how the traditional land-use system is coping under economic development pressures and climate change. The field trip was led by Dr. Patma Vityakon from Khon Kaen University.

Additionally, a one-day practical training session about LCLUC and climate change took place and offered a review on geo-spatial technologies, methods, and applications.

The theme of the meeting is highly important for the South-East Asia (SEA) region which is going through many socio-economic changes. The economy of China has grown significantly during the last thirty years. Economic growth, urbanisation, diet structure changes, and population growth affect land-use practices in several ways. Population growth causes urban expansion and deforestation.

More than two-thirds of the world's megacities are located in developing countries. In the next 20 years, the most intensive growth rate and mega-urban development processes are predicted to take place in East Asia, South Asia, and Africa. Indeed, megacities and their effects on the environment are among the most important research questions for SEA.

Other questions are, for example, the increase in the cultivation of commodity crops, such as rubber and palm, at the expense of food crop production. Deforestation is a serious issue that is linked to carbon budgets as well. The extensive changes in land use and land cover affect the atmosphere and can have an effect on the regional climate. The need to involve socio-economic components in climate modelling was stressed in the meeting outcome.

The meeting also encouraged the regional actors to share information and to

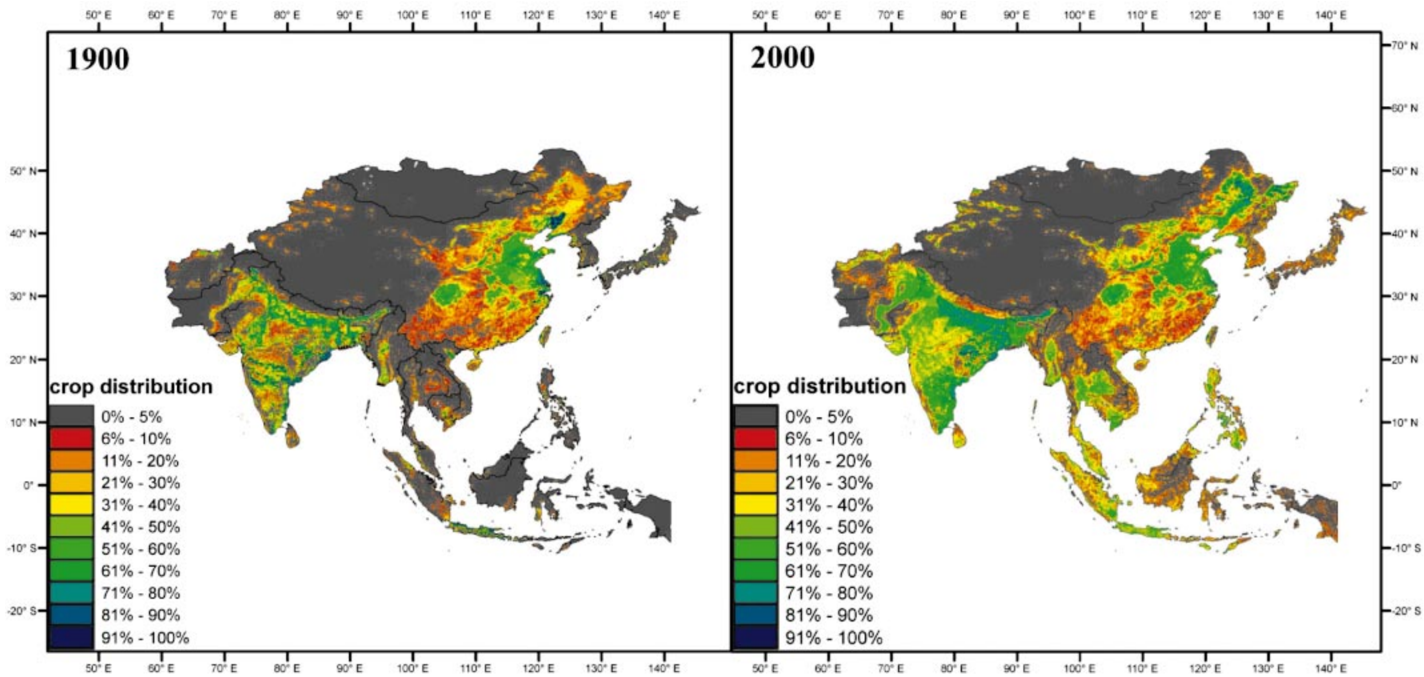

Figure 1. Cropland distribution in monsoon Asia in 1900 and 2000 represented as percentage within grid cell. These data sets were generated from HYDE 3 [2] and China's reconstructed historical land-use data based on fine-scale remotely sensed data and historical archives [3]. From 1900 to 2000, croplands increased considerably in the north-eastern region of East Asia, in South-East Asia, and in most of South Asia. Maps published by courtesy of Dr. Hanqin Tian and the Ecosystem Dynamics and Global Ecology Laboratory at Auburn University.

actively network to find synergies and share resources in the LCLUC and climate change research which will eventually lead to problem solving.

The material and the presentations for this meeting can be found at: www.lcluc.hq.nasa.gov

An extended description of the meeting can be found in [1]. ■

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In the next issue

on Permafrost and the Arctic—for example:

Anja Engel, Eva-Maria Nöthig

Future carbon cycling in the Arctic Ocean

John E. Walsh

Recent and future Arctic regional climate variations

Vladimir Kattsov, Kathy Hibbard, Annette Rinke,
Vladimir Romanovsky, and Diana Verseghy

Terrestrial permafrost carbon in the changing climate

Guest Editor:
Professor Torben R. Christensen
GeoBiosphere Science Centre, Lund University, Sweden

Figure 1. Two moderately sized cumulus clouds in the western Amazon separated by 100 km providing a striking example of aerosol effects on precipitation. *Left*: raining cloud in pristine air; *right*: visible smoke entering cloud and suppressing rainfall..

Anni Reissell

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Workshop report: 6–8 April 2009, International Space Science Institute, Bern, Switzerland

ACPC Steering Committee/ ISSI Team meeting

The interactions between aerosols, clouds and precipitation in the climate system are the largest uncertainties in the estimation of anthropogenic climate forcing and climate sensitivity.

Recent developments in process understanding, modelling, and observational capabilities make it now possible to address long-standing and fundamental questions in this field. The Aerosols, Clouds, Precipitation, Climate (ACPC) program has been established to facilitate and enable international and interdisciplinary research in this field.

ACPC was jointly initiated by the IGBP (International Geosphere-Biosphere Programme) core projects iLEAPS, IGAC (International Global Atmospheric Chemistry project), and the WCRP (World Climate Research Programme) core project GEWEX (Global Energy and Water Cycle Experiment). The goal of the ACPC research program is to obtain a quantitative understanding of the interactions between the aerosol, clouds and precipitation, and their role in the climate system.

The ACPC Steering Committee (SC) is also an International Space Science Institute (ISSI) Team (www.issibern.ch). The SC comprises representatives from the three international research organisations iLEAPS (3), IGAC (3), and GEWEX (4). The members are Meinrat O. Andreae (co-chair), Bjorn Stevens (co-chair), Graham Feingold, Sandro Fuzzi, Markku Kulmala, William K. Lau, Ulrike Lohmann, Daniel Rosenfeld, and Pier Siebesma.

Three ISSI Team/ACPC Steering Committee meetings took place in Bern: 28–30 January 2008, 7–9 October 2008, and 6–8 April 2009. The aim of the meetings was to:

- finalise and publish the workshop report from the Boulder iLEAPS-IGAC-GEWEX ACPC Specialist Workshop, 8–10 October 2007 [1];
- write a peer-reviewed science article [2];
- outline the program's scientific aims, implementation strategy, timeline, and organisation as the ACPC Science Plan and Implementation Strategy (SP&IS) [3];
- initiate and plan focussed, coordinated observational and modelling campaigns to study the aerosol-cloud-precipitation interactions.

In the third and last ISSI Team meeting, the ACPC SC finalised the SP&IS for external review, to be published before the iLEAPS and GEWEX Parallel Science Conferences in Melbourne, Australia, 24–28 August 2009.

The SP&IS outlines ACPC's scientific approach which is based on the selection of a number of precipitating cloud regimes. These regimes represent key environments for cloud formation and precipitation with strong indication of aerosol-cloud-precipitation interactions. The regimes include some of the major convective and precipitating environments such as the monsoon systems, organised deep convective systems over land, tropical cyclones, and shallow and deep marine cumulus convection. Other regimes have been selected because they are suitable for investigation of key processes, *e.g.* orographic clouds, diurnally variable convection over land, and mixed-phase clouds, including those that produce lightning and hail.

The coordinated interdisciplinary ACPC program strategy includes the following elements:

1. a focus on regimes with strong indication of aerosol-cloud-precipitation interactions;
2. an emphasis on statistical characterisation of aerosol-cloud-precipitation interactions;
3. the development of approaches that leverage past and ongoing activities;
4. thorough integration of modelling and observational activities;
5. a hierarchical approach to both modelling and data collection/analysis;
6. continued development of measurement techniques.

The first ACPC field experiments will start in Barbados and India in 2010. The program essentially also includes capacity building, knowledge transfer and training, and so, for example, a winter school in the Alps is planned for 2011. ■

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Issue 6 errata

The iLEAPS Newsletter production team apologises for the mistakes!

The correct author list for the Workshop report *On the relevance of surface and boundary layer processes for the exchanges of reactive and greenhouse gases, 9-12 October 2007, Wageningen, the Netherlands* (p. 34–35) is as follows:

Laurens Ganzeveld, Department of Environmental Sciences, Earth System Science, Wageningen University and Research Centre (WUR), Netherlands & Max Planck Institute for Chemistry, Germany, Jordi Vilà-Guerau de Arellano, Department of Environmental Sciences, Meteorology and Air Quality, WUR, Wageningen, Netherlands, and Cor Jacobs, Department of Environmental Sciences, WUR, Wageningen, Netherlands.

The correct author list for the Workshop report *Biogenic secondary organic aerosols: Observations to global modelling, 1-4 July 2007, Hyytiälä, Finland* (p. 41-42), is as follows:

Tatu Anttila, Finnish Meteorological Institute, Finland; Jaana Bäck, University of Helsinki, Finland; Kelley Barsanti, University Center for Atmospheric Research, USA; Merete Bilde, University of Copenhagen, Denmark; Michael Boy, University of Helsinki, Finland; Ann Marie Carlton, Environmental Protection Agency, USA; Annica Ekman, Stockholm University, Sweden; Juliane Fry, Reed College, USA; Marianne Glasius, University of Aarhus, Denmark; Gannet Hallar, Storm Peak Laboratory, USA; Colette Heald, Colorado State University, USA; Christopher Hoyle, University of Oslo, Norway; Kara Huff Hartz, Southern Illinois University, Carbondale, USA; Hannele Korhonen, University of Kuopio, Finland; Tuukka Petäjä, National Center for Atmospheric Research, USA; Markus Petters, Colorado State University, USA; Janne Rinne, University of Helsinki, Finland; Thomas Rosenoern, Harvard University, USA; Guy Schurgers, Lund University, Sweden; Allison Steiner, University of Michigan, USA; Amy Sullivan, Colorado State University, USA; Birgitta Svenningsson, Lund University, Sweden; Timothy Van Reken, Washington State University, USA; Christine Wiedinmyer, National Center for Atmospheric Research, USA; David Worton, University of California at Berkeley, USA; Alessandro Zardini, University of Copenhagen, Denmark.

AMMA - African Monsoon Multidisciplinary Analyses

Adaptation to climate change in West Africa. The AMMA WP 3.2 perspective

AMMA aims to improve our ability to forecast weather and climate in the West African region as well as our understanding of the effects and adaptive responses of people and the environment. While the complexity and unpredictability of the West African monsoon system provide an intriguing challenge for science, they are potentially devastating for the many West African people affected by it.

The objective of the AMMA Work Package 3.2 (Human processes, adaptation and evironmental interactions) is to understand and map adaptation strategies and to attempt to determine the importance of climate factors for local land-use and livelihood strategies, decision-making and social relations. Researchers from Senegal, Mali, Burkina Faso, Niger, Nigeria, and Denmark developed a common questionnaire and interview guide that was implemented at 16 field sites in 5 countries (1350 questionnaires). The sites were selected to represent the region and were located along north-south and east-west transects, and included both agricultural and pastoral areas. Moreover, in-depth studies took place in several sites.

The results of the WP 3.2 showed that farmers in the Sahel have always been subject to climatic variability at intra-, inter-annual, and decadal time scales. While coping and adaptation strategies have traditionally included crop diversification, mobility, livelihood diversification, and migration, attributing the changes directly to climate is challenging. Local people are aware of climate variability and identify wind and occasional excess rainfall as the most destructive climate factors. They attribute poor health of livestock, reduced crop yields, and a range of other effects to climate factors, especially to wind. However, when the questions about changing land use and problematic livelihood are posed in other than a climate context, the locals assign economic, political, and social rather than climatic factors as the main drivers.

Hombori village in Mali. Photo: Françoise Guichard and Laurent Kergoat–AMMA. CNRS copyright.

We conclude, therefore, that the communities studied have a high awareness of climate issues but that climatic narratives are likely to influence the responses when questions refer to climate. Change in land-use and livelihood strategies is driven by adaptation to a range of factors of which climate does not appear to be the most important.

In the near future, WP 3.2 plans to publish a special issue in a peer-reviewed journal on adaptation to climate change in West Africa. Several papers are foreseen on various topics from perception of climate change to pastoralist livelihoods, forest resources, gender and social livelihoods, migration, agriculture, national adaptive policies, and conceptual modelling of the future of adaptation in this region. The field data are already organised in a database, and WP 3.2 will try to find funding to keep and develop it to enable better tracking of adaptive options through the years. ■

www.amma-international.org

www.ileaps.org
Science and Projects / Current Projects / AMMA

GPWG/FIRE - The Global Palaeofire Working Group on the IGBP Cross-Project Initiative on Fire

The influence of human activity and abrupt climate changes on fire frequency

Sedimentary charcoal records are a valuable resource for documenting past changes in fire regimes. The Global Palaeofire Working Group has created a database of nearly 800 individual charcoal records worldwide. Continental- to global-scale analyses of these records are providing challenges to our current understanding of fire behaviour and the controls on fire regimes, as well as stimulating a critical evaluation of methods to predict future changes in fire regimes.

A GPWG analysis of over 400 records worldwide spanning the last two millennia [1] revealed a clear link between human activity and decreasing fire frequency. The first finding was that global fire activity declined in parallel with the global cooling trend between 1 AD and ca 1750 AD (Fig. 1), despite the rise in human population during this interval. The fire records showed centennial-scale variability similar to that shown by climate. A marked increase in fire occurred after 1750 AD but, surprisingly, the charcoal records showed a downturn in fire activity from the late 19th century through the 20th century [1].

This downturn, which was opposite to the simultaneous changes in climate, probably reflected landscape fragmentation and the global expansion of intensive grazing and agriculture. Both of these processes decrease the frequency of fire because they reduce fuel load and connectivity and thus limit the ability of fires to spread across the landscape. This inadvertent suppression of fire has occurred on most continents and reflects the only unequivocal evidence of human influence on global fire regimes during the past two millennia.

A second GPWG study (Fig. 2) [2] addressed the response of fire regimes to abrupt climate changes in North America, focussing particularly on the Younger Dryas interval (12900 to 11700 yrs BP). According to [2], the abrupt cooling associated with the onset of the Younger Dryas led to large fires in some regions, but a more widespread increase in fire activity occurred during the rapid warming that marked the end of this cold interval.

The rapid response of fire regimes to abrupt climate changes seems to be related to climate-driven fuel availability: transitions from warm to cold climates increase fuel loads because of vegetation dieback, whereas transitions from cold to warm climate increase fuel loads because of increases in productivity [2]. Despite some increase in fire activity at the onset of the Younger Dryas, no evidence was found for continent-wide wildfires at that time or indeed at any time during the deglaciation [2]. This finding casts doubt on the hypothesis that a comet impact triggered massive catastrophic wildfires and caused the Younger Dryas. ■

1. Marlon J, Bartlein PJ, Carcaillet C, Gavin DG, Harrison SP, Higuera PE, Joos F, Power M, and Prentice IC 2008. Climate and human influence on global biomass burning over the past two millenia. Nature Geosciences, DOI: 10.1038/ngeo313.
2. Marlon JR, Bartlein PJ, Walsh MK, Harrison SP, Brown KJ, Edwards ME, Higuera PE, Power MJ, Anderson RS, Briles C, Brunelle A, Carcaillet C, Daniels M, Hu FS, Lavoie M, Long C, Minckley T, Richard PJH, Scott AC, Shafer DS, Tinner W, Umbanhower CE Jr, and Whitlock C 2009. Wildfire responses to abrupt climate change in North America. Proceedings of the National Academy of Sciences (PNAS) 106, DOI/10.1073/pnas.0808212106.

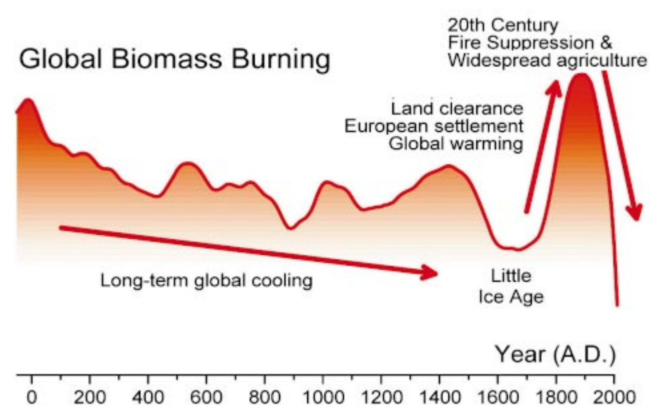

Figure 1. ➤ Global fire activity during the last two millennia.

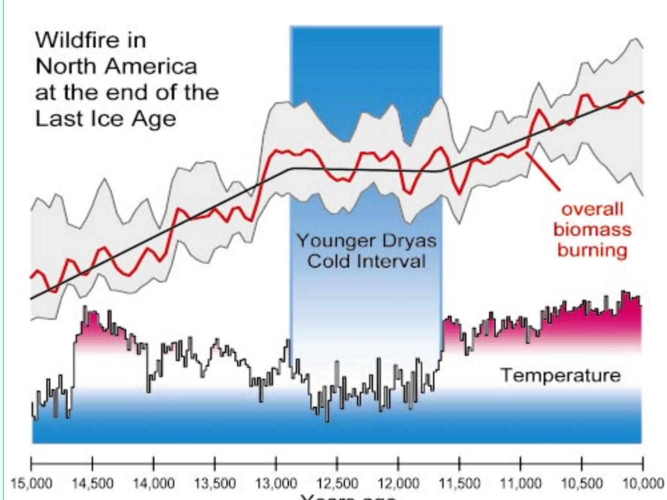

Figure 2. ➤ Fire activity and temperature in North America around the Younger Dryas interval (12900 to 11700 yrs BP).

www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeofire_WG

★Project ★Highlights

POLARCAT - POLar study using Aircraft, Remote sensing, surface measurements and models of Climate, chemistry, Aerosols, and Transport

Intensive campaigns during the International Polar Year 2007–2008

At least thirty institutes from over ten nations contributed to the major airborne and ship-based POLARCAT campaigns during the International Polar Year (IPY) in March 2007 – March 2009. It is too early for a balanced report on the scientific results but a few publications on the first results have already appeared. A data analysis and integration workshop will be held in Durham, New Hampshire, USA, on 2–5 June 2009.

ASTAR 2007

ASTAR 2007 (Arctic Study of Tropospheric Aerosols, Clouds, and Radiation) was the first POLARCAT campaign conducted already in spring 2007. An ASTAR journal special issue was recently opened for submission of papers in Atmospheric Chemistry and Physics. One of the highlights of the campaign were layers with high concentrations of sulphur dioxide and aerosols but with little oxidised nitrogen or carbon monoxide found around Svalbard. These findings are evidence of important local sources of pollution (probably industrial plumes from northern Russia) in the Arctic.

NASA ARCTAS

ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites) was conducted as two 1-month aircraft deployments, in March-April and June-July 2008. It involved the NASA (National Aeronautics and Space Administration) DC-8 aircraft as its primary platform, with the P3-B and B-200 aircrafts as specialised secondary platforms. The spring deployment targeted arctic haze, anthropogenic pollution in general, stratosphere-troposphere exchange, and sunrise photochemistry. The summer deployment was focused more on boreal forest fires, stratosphere-troposphere exchange, and summertime photochemistry.

NOAA ICEALOT

As part of POLARCAT, NOAA (National Oceanic and Atmospheric Administration) conducted a 6-week ICEALOT (International Chemistry Experiment in the Arctic LOwer Troposphere) research cruise in an ice-free region of the Arctic during March and April of 2008. The study area included the Greenland Sea, the Norwegian Sea, and the Barents Sea. Scientific issues addressed included springtime sources and transport of pollutants to the Arctic, evolution of aerosols and gases into and within the Arctic, and climate impacts of haze and ozone in the Arctic.

NOAA ARCPAC

In March–April 2008, NOAA conducted the airborne field measurement ARCPAC (Aerosol, Radiation, and Cloud Processes affecting Arctic Climate) campaigns in Fairbanks, Alaska along with the NASA campaign ARCTAS. The aim was to improve understanding of Arctic climate processes driven by short-lived forcing agents such as aerosols. The measurements took place in the Alaskan Arctic and were closely coordinated with remote sensing and in situ observations at ground sites in the vicinity of Barrow, Alaska. The first peer-reviewed publication resulting from this campaign has just appeared [1] and describes how fires burning in agricultural areas in Asia and in the boreal forest can have an extensive influence on the measurements taken over and close to Alaska.

POLARCAT FRANCE

The French ATR aircraft was based in Kiruna, Sweden, during spring 2008 and, together with the German Falcon, in Kangerlussuaq (Greenland) during summer 2008.

POLARCAT-GRACE

The main objective of POLARCAT-GRACE (Greenland Aerosol and Chemistry Experiment) was to investigate the influence of emissions from boreal forest fires and anthropogenic sources on the chemical composition and particles in the troposphere of the European sector of the Arctic. The Falcon performed 18 local flights from Kangerlussuaq, Greenland, covering the latitudes 58°–82°N. More than 40 pronounced pollution plumes could be measured at altitudes from 4–10 km originating mainly from boreal forest fires and fossil fuel combustion sources in Canada, Siberia, and eastern Asia. ■

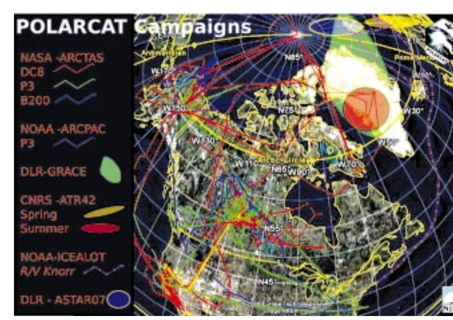

Figure 1. Flight and cruise tracks of the various POLARCAT campaigns during the International Polar Year 2007–2008.

1. Warneke C, Bahreini R, Brioude J, Brock CA, de Gouw JA, Fahey DW, Froyd KD, Holloway JS, Middlebrook A, Miller L, Montzka S, Murphy DM, Peischl J, Ryerson TB, Schwarz JP, Spackman JR, and Veres P 2009. Biomass burning in Siberia and Kazakhstan as an important source for haze over the Alaskan Arctic in April 2008. Geophysical Research Letters 36, L02813.

For more details of the campaigns, please see the POLARCAT webpage:

www.polarcat.no

VOCBAS – Volatile Organic Compounds in the Biosphere-Atmosphere System

Drought breaks down the temperature dependence of isoprene emission

Isoprene, one of the most abundant biogenic volatile organic compounds in the atmosphere, is mainly emitted by deciduous trees in the world's forests. Isoprene is an important precursor of ozone (O_3) and also reacts with OH to produce aerosol particles. The dependence of isoprene emission on temperature has been reported in many published studies. It is the cornerstone of all algorithms modelling the emission of this important volatile compound from vegetation to the atmosphere. However, a VOCBAS study by Fortunati et al. [1] revealed for the first time that a very common stressor, drought, may break this dependency and lead to unexpectedly high isoprene emissions.

Drought is a recoverable stress to which most plants are transiently but recurrently exposed, and this work considered the effects of such a globally important phenomenon to the emission of isoprene. According to [1], the temperature dependency vanishes because sources of carbon alternative to photosynthesis are activated when drought stress is severe. These alternative sources disappear rapidly when the stress is relieved, but they may transiently increase isoprene emission to levels higher than those observed before stress in leaves that recover from drought.

The temperature independence of isoprene emission lasts at least two weeks after the drought ends (Fig. 1). This is possibly because isoprene synthase activity (the biochemical factor driving isoprene temperature dependency) is maximal after the plant has recovered from stress and cannot be further stimulated by temperature.

The discovery of transient yet widespread decoupling of isoprene emission from temperature should lead to further refining of current algorithms and models of isoprene emission, especially when applied to areas that are prone to recurrent drought events. As a result, the expected patterns of isoprene emission in the atmosphere in response to climate change may change considerably. ■

1. Fortunati A, Barta C, Brilli F, Centritto M, Zimmer I, Schnitzler J-P, and Loreto F 2008. Isoprene emission is not temperature-dependent during and after severe drought-stress: a physiological and biochemical analysis. The Plant Journal 55, 687–697, doi: 10.1111/j.1365-313X.2008.03538.x.

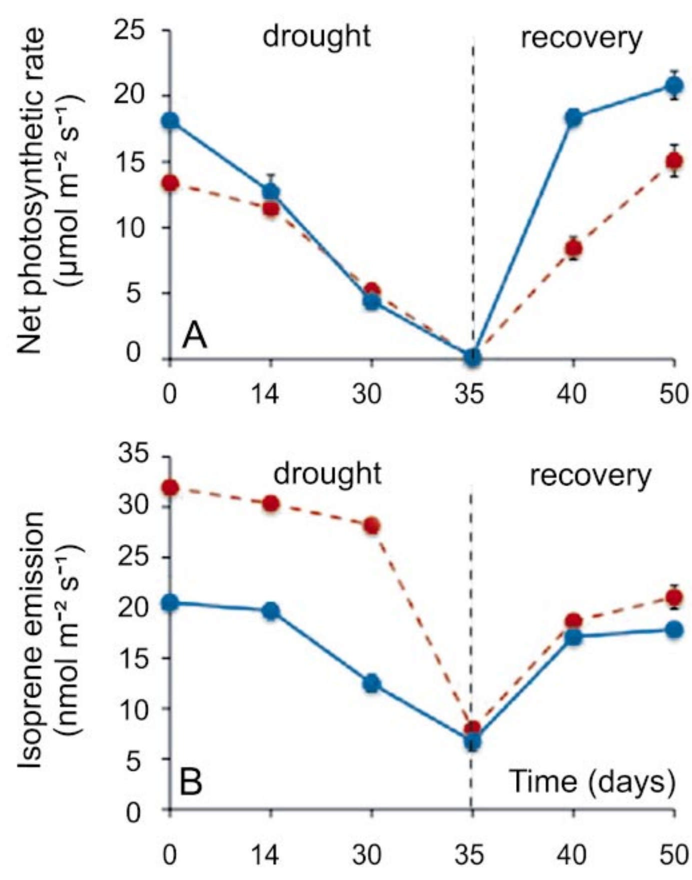

Figure 1. Exposure to severe drought stress breaks the ubiquitous dependence of isoprene emission on temperature. This effect lasts 15 days after recovery from the stress. Photosynthesis (A) and isoprene emission (B) in leaves maintained at 25 (blue lines) and 35°C (red lines).

www.esf.org/activities

www.ileaps.org
Science and Projects/Current Projects/VOCBAS

Project Highlights

Meetings

Open seminar by Prof. Bjorn Stevens (ACPC), University of Helsinki, Helsinki, Finland, 27 January 2009

The iLEAPS International Project Office and the Division of Atmospheric Sciences and Geophysics, Department of Physics, at the University of Helsinki hosted a seminar by Prof. Bjorn Stevens on *"Towards a macroscopic theory of precipitation"*.

Bjorn Stevens is new Director at the Max Planck Institute for Meteorology in Hamburg, Germany. Prof. Stevens came to Hamburg from the University of California in Los Angeles (UCLA), USA, where he was Professor for Atmospheric Sciences. He has published ground-breaking research papers dealing with the theory, modelling and observation of "low" clouds, which is one of the most important problems in meteorology and climate research.

Bjorn Stevens is co-chair in the Steering Committee of ACPC (Aerosol, Cloud, Precipitation, Climate), an international research program initiated by iLEAPS in collaboration with international research organisations IGAC and GEWEX (WCRP).

COST Action ES0804 Kick-Off Meeting, COST Office, Brussels, Belgium, 17–18 February 2009

A new COST ESSEM (Earth System Science and Environmental Management)

Action ES0804: *Advancing the integrated monitoring of trace gas exchange between biosphere and atmosphere* started in this Kick-Off Meeting by the election of Chair, Co-Chair, and Working group leaders:

- Co-Chairs: Prof Timo Vesala, Finland, Prof Almut Arneth, Sweden
- WG1: Analysis and synthesis of the current state of the flux monitoring sites, measurement techniques, data handling methods and storage of data in Europe. Leader: Dario Papale, Italy
- WG2: Work towards comprehensive multi-species flux monitoring sites. Leaders: Klaus Butterbach-Bahl, Germany, and Nina Buchmann, Switzerland
- WG3: Assessment of regional representativeness of the flux sites in different ecosystems. Leaders: Laurens Ganzeveld, the Netherlands, and Markus Reichstein, Germany
- WG4: Training and capacity building. Leader: Janusz Olejnik, Poland.

COST is an intergovernmental framework for European Cooperation in Science and Technology.

It attempts to reduce the fragmentation in European research investments and to open the European Research Area to cooperation worldwide.

For information on the Action, please see the COST website:
www.cost.esf.org/
and the Action website:
www.ileaps.org/cost0804

Third ACPC Steering Committee/ISSI Team meeting, International Space Science Institute, Bern, Switzerland, 6–8 April 2009

ACPC Steering Committee meeting at ISSI in Bern, from left: Bill Lau, Danny Rosenfeld, Andi Andreae, Graham Feingold, Sandro Fuzzi, Bjorn Stevens, Ulrike Lohmann. (Markku Kulmala absent from photo). Photo: Anni Reissell.

The Aerosols, Clouds, Precipitation, Climate (ACPC) Program Steering Committee (SC) is also an International Space Science Institute (ISSI) Team (www.issibern.ch). In Bern, the ACPC SC finalised the ACPC Science Plan and Implementation Strategy (SP&IS) for external review.

The SP&IS outlines ACPC's scientific approach which is based on the selection of a number of precipitating cloud regimes. These regimes represent key environments for cloud formation and precipitation with strong indication of aerosol-cloud-precipitation interactions. See a more detailed description of the ACPC SC / ISSI Team meetings on pages 58–59 of this issue.

The first ACPC field experiments will start in Barbados and India in 2010.

ACPC web page:
www.ileaps.org/acpc/

ACPC mailing list:
acpc@ileaps.org

European Geosciences Union General Assembly 2009, Vienna, Austria, 19–24 April 2009

iLEAPS-sponsored/co-sponsored/related sessions:

- AS1.5 Aerosols-clouds-precipitation-climate. Conveners: M.O. Andreae, U. Lohmann, D. Rosenfeld
- CL20 Land-climate interactions from models and observations: Implications from past to future climate. Conveners: S. Seneviratne, P. Ciais, B. van den Hurk
- BG2.2 Land-Atmosphere-Cryosphere Interactions in Northern Eurasia. Conveners: P. Groisman, A. Reissell, I. Sokolik
- CL44 Shifting Seasons: Phenological evidence from observations, reconstructions, measurements and models. Conveners: T. Rutishauser, A. Menzel, J. Weltzin
- AS1.14 African Monsoon Multidisciplinary Analysis (AMMA). Conveners: C. Taylor, S. Janicot, H. Kunstmann
- BG2.3 Synthesis Efforts From the Global Network of Ecosystem-Atmosphere CO_2, Water and Energy Exchange (FLUXNET). Conveners: M. Reichstein, D. Baldocchi, D. Papale
- BG2.6 From biogenic primary exchange to atmospheric fluxes of reactive trace gases. Conveners: J. Rinne, J. Kesselmeier, JP Schnitzler
- CL6 Physical and biogeochemical feedbacks in the climate system. Conveners: C.D. Jones, V. Alexeev
- CL21 Biospheric feedbacks in the climate system in the past, present, and future. Conveners: M. Claussen, V. Brovkin, N. Zeng
- BG1.8 Interactions between the carbon and hydrological cycle and the climate system. Conveners: C. Beer, M. Reichstein
- AS3.12 Atmospheric VOC: measurements and interpretation. Conveners: Pollmann, M. Boy, V. Sinha

http://meetings.copernicus.org/egu2009

ESA-iLEAPS Scientific Consultation Workshop, Austrian Academy of Sciences, Vienna, Austria, 20 April 2009

The European Space Agency (ESA) and the iLEAPS International Project Office organised a consultation workshop for planning a new collaborative tender, the Atmosphere-LANd Integrated Study (ALANIS).

ALANIS aims at:

- advancing the development and validation of novel advanced Earth Observation -based multi-mission products, improved data sets, and enhanced applications;
- to use these to respond directly to the specific scientific requirements of the iLEAPS community with a special attention to the Northern Eurasian Earth Science Partnership Initiative (NEESPI) area;
- improving the observation, understanding and prediction of land-atmosphere processes in boreal ecosystems at different spatial and time scales;
- setting up a solid scientific basis for further ESA activities in support of the iLEAPS community.

The project will be funded by ESA's Support to Science Element (STSE) and awarded to a consortium of private and public institutions following an open competitive tender. The corresponding invitation to tender is planned for the second quarter of 2009.

Visit for more information on the workshop and the speakers:
http://dup.esrin.esa.int/STSE/news/news160.asp
and
www.ileaps.org/alanis
for ALANIS.

Advanced Aerosol Training Course, Hyytiälä Forestry Station, Finland, 9–15 May 2009

The course focussed on measurements of atmospheric aerosols: aerosol physics, sampling and measurement techniques. 28 students from Finland, Italy, China, Greece, Austria, Pakistan, Brazil, Lithuania, Sweden, Slovenia, the Netherlands, Switzerland, France, Germany, Russia, Austria, and Denmark took part in the course that required an advanced knowledge of atmospheric aerosols.

The target group included PhD students, early-career scientists, and personnel from aerosol measuring stations involved in EUSAAR (European Supersites for Atmospheric Research), EUCAARI (European Integrated Project on Aerosol Cloud Climate and Air Quality Interactions), ACCENT (Atmospheric Composition Change – the European Network of Excellence), GAW (Global Atmosphere Watch), and EMEP (European Monitoring and Evaluation Program). The course was taught in English.

Lecturers were Prof. Dr. Kaarle Hämeri, University of Helsinki, Finland, Dr. Jean-Philippe Putaud, Joint Research Centre, Italy, and Prof. Dr. Alfred Wiedensohler, Leibniz Institute for Tropospheric Research, Germany.

The course was organised within the frame of the EU-projects EUSAAR, EUCAARI and ACCENT as well as the Nordic Graduate School "Biosphere-Carbon-Aerosol-Cloud-Climate Interactions" (CBACCI) and Nordic Master's Degree Program "Atmosphere-Biosphere-Studies" (ABS) in cooperation with NorFA (Nordisk forskarutbildnigsakademi) Network on Atmospheric Aerosol Dynamics (NAD), iLEAPS and EMEP.

www.eusaar.net/files/events/NA6_aerosolcourse2009.cfm iLEAPS

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http://www.ileaps.org

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Almut Arneth, Dept. Physical Geography and Ecosystems Analysis, Lund University, Lund, Sweden

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iLEAPS RECOGNIZED PROJECTS

ACPC · AMMA · EUCAARI · FLUXNET · IGBP X-PROJECT FIRE ACTIVITY · IANABIS · iLEAPS-GEIA · isotope PILPS · LUCID · NEESPI · POLARCAT · VOCBAS · WATCH