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Newsletter

Integrated Land Ecosystem - Atmosphere Process Study

Issue No. 13- April 2013

GEWEX and iLEAPS land-surface modelling – *Bridging the gaps*

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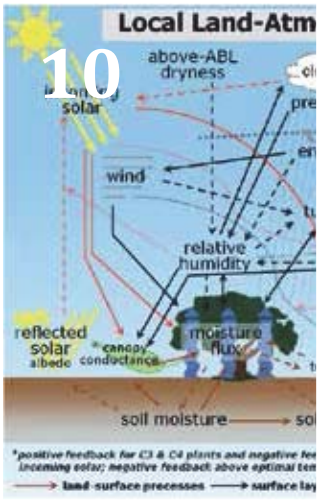

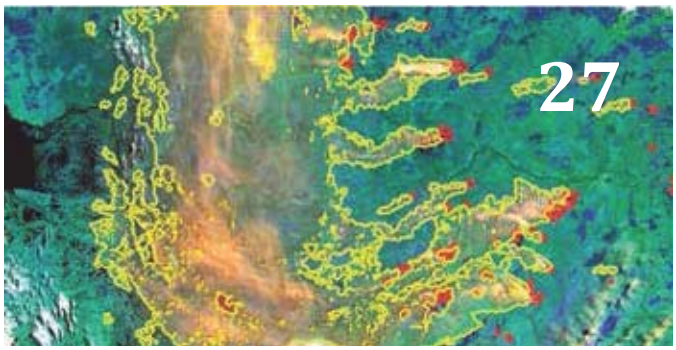

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Phase 1 of iLEAPS (2004-2014) is coming to an end, but land-atmosphere research is expanding and iLEAPS is getting ready for its 2nd phase (2014-2024) by starting up several new activities. One of the main actions is the restructuring or launch of iLEAPS regional nodes, where local scientists come together to plan and coordinate research based on the specific needs of a country or a region.

iLEAPS-China

The iLEAPS-China group represents a comprehensive view on land-atmosphere interactions with expertise ranging from measurements and modelling of trace gases, aerosols, and hydrology to emissions, land-use and land-cover changes, urbanisation, and remote sensing. The official launch of iLEAPS-China will take place in April 2013. For more information, please contact Dr. Aijun Ding (dingaj@nju.edu.cn) from Institute for Climate and Global Change Research at the Nanjing University.

iLEAPS-Japan

iLEAPS-Japan, a sub-committee of the Science Council of Japan, was restructured in 2012. Some of the main foci of iLEAPS-Japan are the expansion of ASIAFLUX in Japan and nearby regions, large-scale manipulation experiments in managed ecosystems such as the Free-Air CO_2 Enrichment Experiment (FACE), also with nitrogen (FACE-N), and land-atmosphere-society interactions in East Siberia. For more information, please see: http://ileaps-japan.org/.

iLEAPS-Eurasia

iLEAPS-Eurasia starts its activities in 2013. iLEAPS-Eurasia focuses on the boreal and Arctic regions in Eurasia and coordinates the multidisciplinary research programme Pan-Eurasian Experiment (PEEX). For more information on iLEAPS-Eurasia, please contact: Dr. Hanna Lappalainen (hanna.k.lappalainen@helsinki.fi) from the Division of Atmospheric Sciences at the University of Helsinki. More information about the PEEX initiative can be found in the Meetings section of this issue.

iLEAPS has identified other regions with crucial importance and characteristic needs and is planning regional activities also in South-East Asia, Mediterranean, Africa and Latin America.

Seed funding

iLEAPS not only facilitates scientific collaboration and acts as a hub for information exchange, but aims to directly support actual research as well. In 2013, iLEAPS offers seed funding to help start new LEAP research, typically 5-7k € per activity. You are welcome to submit your free-form applications for relevant research activities to iLEAPS Executive Officer Tanja Suni (tanja.suni@helsinki.fi).

Call for new SSC members

The overall direction and development of the iLEAPS is guided by its Scientific Steering Committee, which is composed of 16 experts selected from the international environmental research community. iLEAPS is currently looking for new SSC members for the period 2014-2016. In order to promote regional and gender equality, we particularly encourage applications from females from various land-atmosphere research fields outside EU and US. Please contact Executive Officer Tanja Suni (tanja.suni@helsinki.fi) if you are interested.

iLEAPS observation community assesses the influence of vegetation on precipitation patterns

In a new Nature publication, Spracklen *et al.* (2012) used satellite remote-sensing data of tropical precipitation and vegetation combined with simulated atmospheric transport patterns to assess whether forests actually have an influence on tropical rainfall. They found that for more than 60% of the tropical land surface, air that had passed over extensive vegetation in the preceding few days produced at least twice as much rain as air that has passed over little vegetation. The authors demonstrated that this empirical correlation was consistent with evapotranspiration from the forested areas and estimated that deforestation in the Amazon will lead to reductions of 12 and 21% in wet-season and dry-season precipitation, respectively, by 2050. See: http://www.nature.com/nature/journal/v489/n7415/full/nature11390.html.

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Bridging the gap between the iLEAPS and GEWEX land-surface modelling communities

Models of Earth's weather and climate require fluxes of momentum, energy, and moisture across the land-atmosphere interface to solve the equations of atmospheric physics and dynamics. Just as atmospheric models can, and do, differ between weather and climate applications, mostly related to issues of scale, resolved or parameterised physics, and computational requirements, so too can the land models that provide the required surface fluxes differ between weather and climate models. Here, however, the issue is less one of scale-dependent parameterisations. Computational demands can influence other minor land model differences, especially with respect to initialisation, data assimilation, and forecast skill. However, the distinction among land models (and their development and application) is largely driven by the different science and research needs of the weather and climate communities.

Our understanding of Earth's climate has progressed to the point that no credible modelling centre would develop a model without representation of the terrestrial biosphere, the interacting physical, chemical, and biological components of the Earth system, and human perturbations to the biosphere. A particular focus is the carbon cycle and its feedback with climate, but other biogeochemical cycles related to reactive gases and atmospheric chemistry are also important. In addition, changes in ecosystem state and biogeography in response to climate change or human activities drive changes in climate by altering energy, water, and biogeochemical cycles. Inclusion of these biotic and human processes is part of the evolution of models of Earth's physical climate to Earth system models (ESM).

In contrast, numerical weather prediction (NWP) relies more heavily on accurate representation of the terrestrial hydrosphere, including the initialisation of soil moisture and snow, their time evolution, and their influence on and feedbacks with boundary layer processes. The carbon cycle and long-term biological processes are not necessary on these short time scales, and, as a result, the development and scope of land models for NWP has diverged over time from that of the climate community.

This distinction in the scientific scope of the land-atmosphere interface is embodied in two entities within the international scientific governing bodies. The Global Land Atmosphere System Study (GLASS) is a scientific panel of the Global Energy and Water EXchanges (GEWEX), a core project within the World Climate Research Programme (WCRP). Its focus has historically been diurnal to seasonal to annual hydrometeorological coupling between land and atmosphere. The Integrated Land Ecosystem – Atmosphere Processes Study (iLEAPS) is the land-atmosphere core project of the International Geosphere-Biosphere Programme (IGBP). The focus of iLEAPS has historically been biogeochemical processes that affect atmospheric chemistry and climate. As a result, GLASS and iLEAPS activities and associated land model intercomparison projects have typically proceeded in parallel as a function of their particular capabilities and applications.

Given the current and continued dissolution of traditional discipline boundaries driven by global environmental change research, it is now timely to survey the two communities to better understand their recent past, present, and future evolution in order to develop improved prediction models across scales. To this end, this special iLEAPS-GEWEX joint Newsletter contains five contributions that illustrate common land-atmosphere research across these two diverse land modelling communities: a perspective on modelling the land-atmosphere interface across scales (G. Bonan and J. Santanello); the parameterisation of land surface processes in numerical weather prediction models (M. Ek); similar model development in an Earth system model (D. Lawrence and R. Fisher); modelling across weather and climate scales (M. Best and C. Jones); and approaches towards land model benchmarking (E. Blyth and D. Lawrence). ■

GEWEX News

This 13th iLEAPS Newsletter issue has been prepared in cooperation with the Global Energy and Water Exchanges (GEWEX) project. The mission of GEWEX is to observe, understand and model the hydrological cycle and energy fluxes in the Earth's atmosphere and at the surface.

Save the Date!

7th International Scientific Conference on the Global Energy and Water Cycle, The Netherlands, 2-5 June 2014

The 7th GEWEX Conference is being hosted by Wageningen University, in the Netherlands. The Conference theme will be focused on the WCRP Grand Challenges related to water resources, extremes and climate sensitivity. For updates on the Conference, see: http://www.gewex.org.

Two GEWEX Assessment Reports are now available

Assessment of Radiation Flux

The assessment evaluated the overall quality of available global, long-term radiative flux data products at the top-of-atmosphere and surface. Special emphasis was placed on evaluating the overall fidelity with which the GEWEX Surface Radiation Budget (SRB) Project data set captures seasonal to interannual variability, as well as longer-term trends. The objectives of this assessment were twofold: 1) to characterise the uncertainties in SRB and similar products from both a quantitative as well as qualitative perspective; and 2) to develop a better understanding of the strengths, weaknesses and assumption that define the SRB product and its uncertainties.

Assessment of Global Cloud Data Sets

The Cloud Assessment Working Group has completed its evaluation of the overall quality of available global, long-term cloud data products. The Working Group went beyond simple product comparisons at fixed space and time resolutions to provide expert insight into whether or not a specific cloud product is accurate enough to meet a specific application. While all the assessed products were covered, special emphasis was placed on the International Satellite Cloud Climatology Project (ISCCP) product that is the GEWEX standard product for clouds.

Summaries of both the Radiation Flux and Global Cloud Data assessments are being submitted for publication in the Bulletin of the American Meteorological Society.

The complete reports are available at: http://www.wcrp-climate.org/reports.shtml.

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Modelling the land-atmosphere interface across scales: from atmospheric science to Earth system science

Gordon Bonan is a senior scientist at the National Center for Atmospheric Research. He specialises in the development of terrestrial biosphere models for climate simulation and is a member of the iLEAPS Scientific Steering Committee.

Joe Santanello is a scientist at the NASA Goddard Space Flight Center. His expertise is in land-atmosphere coupling of water and energy cycles, and he co-chairs the Global Land/Atmosphere System Study (GLASS) panel of GEWEX (Global Energy and Water Exchanges).

The parameterisation of Earth's land surface for numerical models of weather and climate has evolved greatly over the past three decades. The initial focus was geophysical control of energy and water fluxes and hydrometeorological coupling between land and atmosphere. Terrestrial vegetation regulates these fluxes, for example, through the absorption of radiation, the partitioning of radiation into sensible and latent heat fluxes, and the partitioning of precipitation into evapotranspiration, runoff, and soil water storage. The current generation of operational land models explicitly recognises many aspects of canopy micrometeorology, though the details can vary greatly among models.

The representation of plant canopies, and more generally recognition that the biogeophysical processes that regulate momentum, energy, and water fluxes are closely tied to plant physiological and biogeochemical processes, led to a broad expansion of the scientific scope of land models. A key part of this growth is simulation of trace gas fluxes in addition to energy and water fluxes, so that the models are critical components in the simulation of weather, climate, and the chemical composition of the atmosphere. The current generation of models can now simulate leaf phenology, the carbon cycle, community composition, and vegetation dynamics in response to prevailing meteorological conditions and climate [1, 2].

However, model frontiers exist and they include: linkages among biogeochemical cycles (such as carbon, nitrogen and phosphorus); reactive gases and atmospheric chemistry (such as biogenic volatile organic compounds, nitrogen emissions, methane, ozone, and secondary organic aerosols); improved representation of wetlands, river flow, groundwater, and cryospheric processes; managed ecosystems, including cropland and pastureland; and urban areas.

The expanding interdisciplinary scientific breadth

of the models is part of the growth of the atmospheric sciences towards Earth system science. Indeed, the ability to simulate biotic and biogeochemical feedbacks is one of the defining aspects of the evolution of climate models to Earth system models.

The development and use of land models consequently spans a wide spectrum of research communities. The models provide a framework to integrate theories of physiological, ecological, biogeochemical, hydrological, and meteorological functioning; global models test the generality of these theories in a diverse array of ecosystems and environments across the planet. Some researchers apply the models to discover and understand feedbacks among soil moisture, surface energy fluxes, boundary layer development, and precipitation to improve weather prediction and climate simulation. Others are interested in longer term processes (such as carbon cycle) that influence past and future climates.

"Land models provide a framework to integrate theories of physiological, ecological, biogeochemical, hydrological, and meteorological functioning."

While the land models are designed for coupling with atmospheric models and specifically simulate terrestrial feedbacks with the atmosphere, an emerging frontier is to apply land models for climate change impacts, adaptation, and mitigation research. For example, the models can be used to study the impacts of extreme weather events or climate change on water resources, biotic resources, and urban climate; societal adaptations to climate change; and land management policies to mitigate climate change over the twenty-first century. The models provide an integrated framework to assess physical, chemical, and biological responses to the multitude of anthropogenic perturbations in the Earth system, including climate change, CO_2, nitrogen deposition, ozone, aerosols, and land use and land cover change. Underlying all this research is the recognition that Earth's ecosystems and watersheds, and their coupling with the atmosphere, are critical elements of global planetary change and planetary habitability.

Two entities within the international scientific governing bodies have addressed various aspects of the land-atmosphere interface. The Global Land Atmosphere System Study (GLASS) is a scientific panel of the Global Energy and Water EXchanges (GEWEX), a core project within the World Climate Research Programme (WCRP). The principal goal of GLASS is to coordinate the evaluation and intercomparison of land models and their applications to scientific queries of broad interest. The Integrated Land Ecosystem – Atmosphere Processes Study (iLEAPS) is the land-atmosphere core project of the International Geosphere-Biosphere Programme (IGBP). The scientific goal of iLEAPS is to provide understanding of the interacting physical, chemical, and biological processes in the land-atmosphere interface, human modification of these processes, and their effects on climate and other Earth system processes. The science of GLASS and iLEAPS is as diverse as that of the land modelling community as a whole. However, some common research needs are evident.

Much of our understanding of land-atmosphere interactions is gained from models, and scientific advancement is only as robust as the models themselves. Model development and evaluation by the hydrometeorological community focuses on short-term (diurnal to seasonal to annual) energy and water fluxes. GLASS has advanced methodologies to critically evaluate the models, both at the local flux tower scale with the Project for the Intercomparison of Land-Surface Parameterisation Schemes (PILPS) and at the global scale with the Global Soil Wetness Project (GSWP) [3]. PILPS- and GSWP-style uncoupled flux tower and global simulations forced with observed meteorology are routinely used to evaluate energy, water, and carbon fluxes in the land components of Earth system models [4, 5].

These evaluations focus on fluxes at diurnal to annual timescales, and there is a need to include biogeochemical processes and ecosystem states in a systematic evaluation of models across multiple spatial and temporal scales [6, 7]. Models of the terrestrial carbon cycle must be additionally tested for long timescale (decadal to centennial) demographic processes (such as mortality), biogeochemical processes (such as litter decomposition and soil organic matter formation), and whole-plant physiological processes (such as carbon allocation). Matching flux tower data over the course of a day or year does not mean that the model performs appropriately for the transient response to climate change, CO_2 fertilisation, or nitrogen deposition. Consequently, the terrestrial carbon cycle and its feedback with climate are routinely assessed in transient simulations over the twentieth century forced with reconstructed meteorology [8, 9] or in coupled carbon cycle-climate simulations [10]. These carbon cycle evalua-

"An emerging frontier is to apply land models for climate change impacts, adaptation, and mitigation research."

tions must be integrated with the PILPS and GSWP hydrometeorological evaluations.

The distinction between land-atmosphere coupling for numerical weather prediction models and climate, or Earth system, models is not straightforward. Many of the processes that affect the land-atmosphere interface for weather prediction or simulation of seasonal-to-interannual variability are similarly relevant for climate simulation. Many of the land-atmosphere feedbacks found in climate simulations are a manifestation of local-scale feedbacks between land and atmosphere, mediated through the boundary layer, and must be understood in that context. Common processes across weather and climate scales include: snow and vegetation masking of snow albedo; soil moisture-evapotranspiration-precipitation coupling; leaf area and its effect on evapotranspiration; and land cover change.

"Climate parameterisations need to be robust across changing environmental and biological conditions, whereas simpler, empirical parameterisations in combination with data assimilation may be better in the context of weather prediction."

An integrated representation of the physics, chemistry, and biology of the land-atmosphere interface must inform model development and evaluation across weather and climate scales. The UK Met Office has a unified land model (the Joint UK Land Environment Simulator, JULES) for weather prediction and climate simulation (Best and Jones, this Newsletter). In contrast, weather prediction models in the US use a land model (the Noah model; Ek, this Newsletter) for operational forecasting and research; the Community Earth System Model uses a different model (the Community Land Model, Lawrence and Fisher, this Newsletter) for climate simulation.

There are also ongoing community projects that clearly demonstrate the connection between the iLEAPS and GLASS domains. For example, the Land-Use and Climate, IDentification of robust impacts (LUCID) study [11] and the Global Land-Atmosphere Coupling Experiment (GLACE) [12] both address land surface effects on climate change through hydrological and biospheric interactions. Benchmarking has become a priority in both groups as well, with the approaches adopted by each clearly connected to their particular model capabilities and development foci (Blyth and Lawrence, this Newsletter).

In addition, each of the common processes described above is already or will soon be monitored routinely and at high-resolution from satellite. Snow (such as snow water equivalent and snow cover), soil moisture, land cover, and leaf area are all examples of Earth monitoring and conditions that are required as influential components (parameters, data assimilation, evaluation) of land models in both communities.

However, a unified science of land-atmosphere interactions across multiple scales, codified into a model, may prove to be unwieldy. Climate parameterisations need to be robust across changing environmental and biological conditions. Such parameterisations may not necessarily improve weather prediction; more simple, empirical parameterisations in combination with data assimilation may be "better" in the context of weather prediction. Indeed, use of satellite and ground-based observations in a land data assimilation system to estimate land states and fluxes (such as soil moisture, snow) is necessary to provide initial conditions for numerical weather prediction models.

How to develop the necessary science across multiple disciplines is not clear. What is clear, however, is that the various disciplinary aspects of global environmental change research have morphed into a broader context of: the Earth system and its interconnected physical, chemical, biological, and human components; the planetary stresses arising from our collective activities; and Earth system stewardship to maintain a sustainable future. The land that we inhabit – the ecosystems and watersheds from which we obtain resources necessary for habitability – and its response to planetary pressures is critical to that future. ■

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References

1. Bonan GB 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science 320, 1444-1449.
2. Levis S 2010. Modelling vegetation and land use in models of the Earth System. Wiley Interdisciplinary Reviews: Climate Change 6, 840–856.
3. van den Hurk B *et al*. 2011. Acceleration of land surface model development over a decade of GLASS. Bulletin of the American Meteorological Society 92, 1593-1600.
4. Lawrence DM *et al.* 2011. Parameterisation improvements and functional and structural advances in version 4 of the Community Land Model. Journal of Advances in Modeling Earth Systems 3, M03001.
5. Blyth E, Clark DB, Ellis R *et al*. 2011. A comprehensive set of benchmark tests for a land surface model of simultaneous fluxes of water and carbon at both the global and seasonal scale. Geoscientific Model Development 4, 255-269.
6. Randerson JT *et al*. 2009. Systematic assessment of terrestrial biogeochemistry in coupled climate-carbon models. Global Change Biology 15, 2462-2484.
7. Luo YQ *et al.* 2012. A framework for benchmarking land models. Biogeosciences 9, 3857-3874.
8. Sitch S *et al*. 2008. Evaluation of the terrestrial carbon cycle, future plant geography and climate-carbon cycle feedbacks using five Dynamic Global Vegetation Models (DGVMs). Global Change Biology 14, 2015-2039.
9. Le Quéré C *et al.* 2009. Trends in the sources and sinks of carbon dioxide. Nature Geoscience 2, 831-836.
10. Friedlingstein P *et al*. 2006. Climate-carbon cycle feedback analysis: results from the C4MIP model intercomparison. Journal of Climate 19, 3337-3353.
11. Pitman AJ *et al*. 2009. Uncertainties in climate responses to past land cover change: first results from the LUCID intercomparison study. Geophysical Research Letters 36, L14814, doi:10.1029/2009GL039076.
12. Koster RD *et al*. 2004. Regions of strong coupling between soil moisture and precipitation. Science 306, 1138-1140.

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Land modelling from the perspective of numerical weather prediction

Dr. Michael Ek leads the Land-Hydrology Team at the National Centers for Environmental Prediction/ Environmental Modeling Center (NCEP/EMC) for the National Oceanic and Atmospheric Administration/ National Weather Service (NOAA/NWS). The Land-Hydrology Team is responsible for all aspects of land-hydrology in NCEP operational regional and global weather and seasonal climate models, and includes applications to drought and connections with the hydrology and water resources communities. Prior to joining the NCEP/EMC in 1999, he spent ten years at Oregon State University where he worked on land-atmosphere interaction, and land and atmospheric boundary-layer model developments. His other activities include involvement with the Global Energy and Water Cycle Exchanges (GEWEX; gewex.org) program, including projects on land-surface (GLASS), atmospheric boundary layer (GABLS) and Hydroclimatology (GHP), and the American Meteorological Society Hydrology committee. He is particularly interested in the role of local land-atmosphere coupling in the evolution of land-surface fluxes and boundary-layer development, including clouds, a project under GEWEX/GLASS (called "LoCo").

Numerical weather prediction (NWP) models typically forecast weather for a few days (short-range) out to a few weeks (medium-range). NWP consists of a land-surface model (LSM) coupled with a "parent" atmospheric model; the LSM provides proper lower boundary conditions to the atmospheric model. Specifically, the LSM accounts for the exchange of heat, moisture, and momentum between the surface and lower atmosphere, which involves many interactive land-atmosphere processes (Fig. 1).

To provide proper boundary conditions for the relevant temporal and spatial scales of a NWP model, a LSM must have appropriate physics to represent land-surface processes (such as evaporation), corresponding land data sets and associated parameters (such as vegetation and soil types), and proper initial land states (such as soil moisture). These initial land states are analogous to initial atmospheric conditions, though land states may carry more "memory" (especially in the deeper soil), similar to the inertia in sea-surface temperatures because of the large heat capacity of the ocean.

With input from a radiation scheme in the parent model, the LSM partitions the incoming radiation (long-wave and short-wave) into a surface energy balance accounting for short-wave radiation reflected by the surface, long-wave radiation emitted (upward) by the surface, turbulent sensible and latent heat fluxes, and soil heat flux (heat going into or coming out of the ground). All these energy balance components depend on various surface properties (Table 1) and, therefore, a proper specification of the land state is necessary.

> *"Not all improvements in land surface models are relevant for weather predictions."*

In conjunction with radiation and surface-layer models, in the cold season the LSM must also account for the effects of snow and frozen soils such as changes in surface roughness, reduced plant activity, and heat associated with snow-melt. The LSM must also properly account for the surface water budget as part of the larger hydrological cycle, with inputs to the land from precipitation (and dew/frost), and outputs from evapotranspiration (ET, evaporation from surfaces and transpiration by plants), surface runoff (overland flow for water that cannot infiltrate into wet soil), and sub-surface runoff (or baseflow, leaving the LSM bottom), as well as changes in the land states: soil moisture (including frozen), snow depth and density, and canopy water. Note that ET is part of both surface energy and water budgets.

In the history of NWP, the effect of land (and thus the inclusion of land models) was largely ignored by NWP models, for example those used at the

US National Weather Service. But by the late 1980s the "Nested Grid Model" (NGM) included a simple single-layer soil slab model, and in the early 1990s, the OSU (Oregon State University) LSM was introduced into the NCEP global forecast model, and had two soil layers with soil heat diffusion equations and soil hydraulic properties [1], an explicit annual cycle of vegetation, plant stomatal control [2], and simple snow physics. This was followed by an upgraded version of the OSU model (now "Noah" LSM) in the NCEP mesoscale model. Most notably, the Noah has four soil layers, new infiltration and runoff formulations, improved soil thermal conductivity, and addition of frozen soil physics and patchy snow cover [3], which was later implemented in the NCEP global model. Progress at other NWP centres around the world has evolved somewhat similarly.

LSM testing and validation is often done in a coupled mode: that is, with a NWP model with interactive land and atmosphere components, where LSM "validation" may use near-surface meteorological variables (such as 2-meter air temperature), though errors may be attributable to a number of non-land processes (Fig. 1). An alternative is uncoupled testing. This includes driving the LSM by observed (or model, or synthetic) atmospheric forcing where there is no land-atmosphere interaction, allowing the LSM to be isolated from other NWP model components to more properly address systematic LSM errors, which allows more direct land model validation.

Uncoupled tests are computationally inexpensive, allow for multi-year LSM runs, and thus provide a method to quickly test upgrades prior to coupled testing. Uncoupled LSM validation can make use of specialised measurements (surface sensible and latent heat fluxes, for example). Under the GEWEX programme, the Global Land/Atmosphere System Study (GLASS) leads an ongoing effort in uncoupled LSM evaluation, coordinated with a number of weather and climate centres, to study LSM performance for different seasons at various locations worldwide [4]. NWP centres have been involved and benefited through this cooperative project in learning about their LSM performance. For example, OSU LSM runoff was simply discarded (and unbalanced) in its early phase and participation in this effort, therefore, led to improvement in the OSU model surface water balance.

A parallel activity under GEWEX that extends into the coupled realm is the GLASS local land-atmospheric modelling ("LoCo") project that seeks to understand, model, and predict the role of local land-atmosphere coupling in

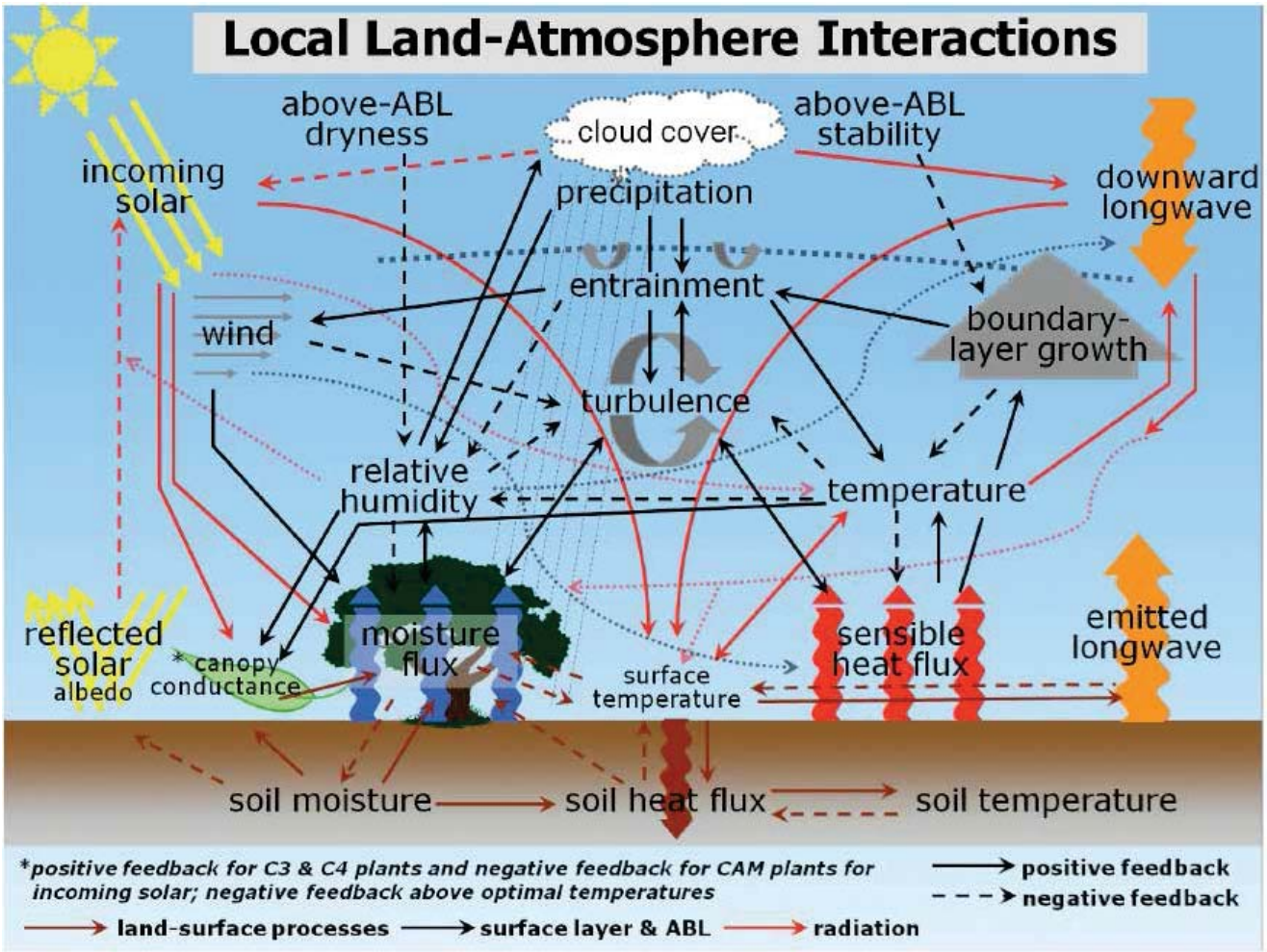

Figure 1. Schematic showing the many interactive processes in the land surface and atmospheric boundary layer (ABL). Adapted from [8], courtesy of Mike Ek and Kevin Trenberth (their Figure 3.1 from www.gewex.org "Draft GEWEX Imperatives").

Energy budget component	Land surface property the component depends on
Reflective properties: • Sun's short-wave radiation reflected back upwards from surface • Emission of long-wave radiation (heat) from land surface (surface emissivity)	• Soil moisture • Vegetation cover and density • Vegetation and soil types
Turbulent fluxes: • Surface momentum flux • Sensible heat flux (warm air rising) • Latent heat flux (water vapour flux resulting from evapotranspiration)	• Soil moisture • Vegetation cover and density • Vegetation and soil types • Surface roughness • Atmospheric stability
Soil heat flux	• Soil moisture and soil type • Overlying vegetation

Table 1. Relationships between energy budget components and land surface properties.

the evolution of land-atmosphere fluxes and state variables, including clouds [5]; the extent of coupling is limited which allows for a more isolated examination of coupled land-atmosphere processes, again, before regional and global coupled testing.

Improved weather forecasts depend on NWP models having proper model physics and good initial conditions, the latter typically generated by long-term "offline" ('spin-up') simulations of the uncoupled LSM. Therefore, from the LSM perspective, upgrades to land physics and better initial land states will help NWP model performance, as long as the LSM improvements are relevant for NWP. For example, a LSM component that predicts the changes in ecosystems (evolving vegetation types) is not relevant, while an improved ET calculation may be because it directly influences the surface energy budget calculation. An example of the latter is the introduction of CO_2-based photosynthesis [6] to replace the empirically based Jarvis [2] formulation that is still widely applied in LSMs used in NWP models. However, the CO_2-based formulation is a better representation of plant stomatal control and thus of ET.

Better initial land conditions may be achieved using remotely sensed observations. For instance, a vegetation "greenness" climatology accounting for seasonal vegetation phenology was an improvement at one time for NWP, but with near real-time observations available, land models may now use actual vegetation greenness. So during springtime "green-up", which may be ahead of or behind the greenness climatology, remote sensing allows a LSM to more appropriately partition available energy at the surface between heat and moisture flux. This way the LSM can provide the atmospheric model with better boundary conditions. This has a subsequent positive effect on, for instance, clouds and convective rainfall.

A land-data assimilation system (LDAS) that combines satellite and ground-based observations may yield optimal estimates of the current land states and surface fluxes. For instance, the NASA Land Information System (LIS) data assimilation techniques [7] may help to assimilate soil moisture, snow, and other land data sets. Additionally, the use of an uncoupled LDAS (run under LIS, for instance) as a cycled (uncoupled) land model system, may then provide better initial land states to the parent atmospheric model for NWP.

As the connection between weather and climate becomes more "seamless", that is, for the case where NWP models are used for extended-range (several weeks) to seasonal climate forecasts, land models must consider their impact out to these time scales. For example, from the NWP perspective, while vegetation types (ecosystems) remain static, vegetation coverage and density will vary seasonally depending on precipitation patterns and other variables important for plant growth and senescence. So although modelling "dynamic" vegetation is not necessary for NWP on time scales from days to weeks, it becomes important for extended-range (many weeks) and out to seasonal climate forecasts.

Finally, as NWP models move towards being more fully Earth System (ES) models, there is a need for an increasingly improved representation of the land surface, with connections to other ES components such as groundwater hydrology, river-routing (completing the water cycle with freshwater flow to the ocean), ecosystems, biogeochemical cycles, plus the required higher spatial resolution. This will lead to fewer degrees of freedom and, therefore, a greater need to properly represent land surface processes at a range of temporal and spatial scales beyond those of NWP. ■

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References

1. Clapp RB and Hornberger GM 1978. Empirical equations for some soil hydraulic properties. Water Resources Research 14, 601-604.
2. Jarvis PG 1976. The interpretation of the variations in leaf water potential and stomatal conductance found in canopies in the field. Philosophical Transactions of the Royal Society of London 273, 593-610.
3. Ek MB *et al.* 2003. Implementation of the Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model. Journal of Geophysical Research 108, doi:10.1029/2002JD003296.
4. van den Hurk B *et al.* 2011. Acceleration of land surface model development over a decade of GLASS. Bulletin of the American Meteorological Society 92, 1593–1600.
5. Santanello JA 2011. Results from Local Land-Atmosphere Coupling (LoCo) Project. GEWEX Newsletter, 21(4), 7-9.
6. Niu G.-Y *et al.* 2011. The community Noah land surface model with multiparameterization options (Noah-MP): 1. Model description and evaluation with local-scale measurements. Journal of Geophysical Research 116, D12109.
7. Kumar SV *et al.* 2008. An integrated hydrologic modeling and data assimilation framework enabled by the Land Information System (LIS). IEEE Computer 41(12), 52-59.
8. Ek M and Holtslag AAM 2004. Influence of soil moisture on boundary-layer cloud development. Journal of Hydrometeorology 5, 86-99.

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Interconnectivity of processes and timescales in land surface modelling: a UK perspective from the JULES model

Martin Best has worked in the Met Office on land surface science for over 20 years and currently leads the research and model development in this area, which includes managing the JULES community land surface model. He has been a member of the Global Land/Atmosphere System Study (GLASS) panel of GEWEX (Global Energy and Water EXchanges) for almost a decade and has co-chaired the panel for the last four years. He has worked on the land surface science on all spatial and temporal scales, gaining an understanding of requirements from all perspectives. He was the first person to implement an urban scheme within both weather forecast and climate models, designed and co-ordinated the first international urban model comparison project and has served two terms on the American Meteorological Society Board on the Urban Environment (BUE).

Chris Jones studied Physics at Cambridge University and joined the Met Office in 1993, working in numerical weather prediction (NWP) research on data assimilation of radar rainfall data with a focus on its influence on soil moisture. In 1997, he joined the Met Office Hadley Centre to work on the first coupled climate-carbon cycle global circulation model (GCM) with Peter Cox. Since then he has pursued research into climate-carbon cycle interactions and framing research results in ways of relevance to policy makers, such as the influence of climate feedbacks on the compatible fossil fuel emissions to achieve different levels of climate targets. In 2005, Chris became manager of the terrestrial carbon cycle group in the Hadley Centre and since 2011 is now Head of the Earth System and Mitigation Science team. Chris is currently a Lead Author on the IPCC AR5 Carbon Cycle chapter.

Inter-connected processes. Inter-connected timescales.

Understanding our environment and being able to predict changes in it are of crucial importance for both weather and climate research. In order to do so, we must be able to understand and simulate natural processes in the environment as well as our interactions with them and our vulnerability to natural hazards across all space and time scales. Carbon and water cycles are crucially important processes for our ability to predict future weather and climate and their influence on society through, for example, food and water availability.

For the purposes of this article we define NWP (numerical weather prediction) timescales as from hours to days with emphasis on quantitative prediction of specific events ("there will be a heavy shower in London at 3 pm on Friday"). Climate projections are concerned with changes in the long-term average of weather conditions ("Europe is likely to experience hotter summers and wetter winters by 2050"). At intermediate timescales (from months to several years) it is becoming possible to try to predict specific deviations from long-term climate (such as a warmer than average UK summer) although not specific weather on a given day.

Land-atmosphere interactions are key processes determining the behaviour of our environment and are at the heart of both iLEAPS and GEWEX scientific goals. Understanding these interactions at a process level and faithfully representing them in numerical models form the foundation on which weather and climate predictions can be built. Process-based land-surface models (LSMs), such as JULES ("Joint UK Land Environment Simulator", http://www.jchmr.org/jules/; the UK community land surface model), coupled to atmospheric general circulation models attempt to represent these key interactions seamlessly to a level

Surface states		Surface fluxes: Momentum	Surface fluxes: Moisture	Surface fluxes: Heat	Surface fluxes: Carbon
	Surface temperature		Surface to atmosphere humidity gradients Surface to atmosphere humidity gradients Surface to atmosphere humidity gradients	Surface to atmosphere temperature gradients Surface to atmosphere temperature gradients Surface to atmosphere temperature gradients	LAI seasonality Influences land cover changes, LAI seasonality, vegetation growth and decomposition
	Soil moisture		Water availability for evaporation Water availability for evaporation Water availability for evaporation	Indirectly influenced by water availability for evaporation, through the surface energy balance Indirectly influenced by water availability for evaporation, through the surface energy balance Indirectly influenced by water availability for evaporation, through the surface energy balance	LAI seasonality Influences land cover changes, LAI seasonality, vegetation growth and decomposition
	Vegetation and soil carbon stores	Specified or assimilated LAI and vegetation height Specified seasonally varying LAI and vegetation height Modelled seasonal variations in the vegetation LAI and the land cover variations on decadal timescales	Specified or assimilated LAI and vegetation height Specified seasonally varying LAI and vegetation height Modelled seasonal variations in the vegetation LAI and the land cover variations on decadal timescales	Indirectly influenced by specified or assimilated LAI and vegetation height, through the surface energy balance Indirectly influenced by specified seasonally varying LAI and vegetation height, through the surface energy balance Indirectly influenced by modelled seasonal variations in the vegetation LAI and the land cover variations on decadal timescales, through the surface energy balance	Turbulent exchanges of CO_2 (uptake and respiration) from available vegetation and soil carbon stores

Table1. Influence of surface states on surface fluxes at various timescales: Hours to days (NWP), Seasonal, Climate. LAI = leaf area index (area of leaf surface per unit ground surface).

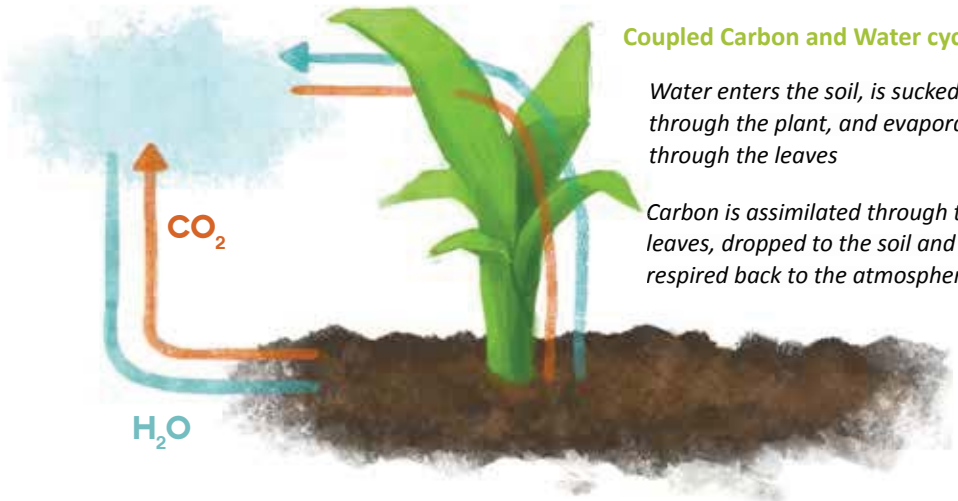

Figure 1. Simplified schematic of synergies between the water and carbon cycles through vegetation and soil and how they interact.

of accuracy that allows skilful predictions.

Although iLEAPS has more focus on biogeochemical processes whilst GEWEX focuses on the large-scale hydrological cycle, these are not two separate areas. Carbon, water and energy cycles are closely intertwined – in reality and in LSMs. Figure 1 shows, in a very simplified way, synergies between water and carbon cycles as they move in opposite directions but around a similar pathway across the land-atmosphere interface.

Although this does not capture the full carbon or hydrological cycle, it forms a simple example of key processes. Whereas rainwater enters through the soil, is sucked up by the plant and subsequently evaporates from the leaves, carbon is taken up through the leaves, is allocated to the plant, deposited to the soil and eventually decomposed back into CO_2. At each stage the presence or cycling of water and carbon affects the presence and cycling of the other – for example soil moisture affects plant growth and carbon uptake, whereas CO_2 affects stomatal opening and evapotranspiration (evaporation from surfaces and transpiration by plants). Both also strongly affect, and are affected by, energy partitioning and transformation.

More generally, the land surface stores of energy, water and carbon interact with each other and are key controllers of land-atmosphere exchange of energy, water and carbon as well as momentum. The physical system does not distinguish between time or spatial scales, so physical controls such as the carbon cycle play a role at all scales for each surface flux. However, such parameterisations are made more difficult by the availability of data on which to base the model.

The modelled influence of the land surface states of energy (as observed, for instance, through temperature), water, and carbon on the surface fluxes have traditionally involved a different emphasis for the various spatial and temporal scales as listed below and depicted in the top part of Fig. 2. However, some developments required for the longer climate timescales are now being adopted by the shorter forecasting timescales as well. These interactions are summarised in Table 1.

The requirement for modelling all of these time and spatial scales for a model such as JULES delivers benefits at the forecasting timescales through a more detailed understanding of the longer-timescale processes important for climate. As such, climate modelling developments are gradually being adopted into forecasting applications. For example, the crucial role of the carbon cycle in climate projections has been shown [1,2] and is becoming common in climate modelling, but it is not yet common to include carbon cycle processes at shorter timescales. However, prognostic leaf area could, for example, improve weather predictions in seasons that have had unusually early or late leaf onset. Similarly, remote sensing of vegetation greenness could be used by data assimilation schemes to help initialise soil moisture in places where direct observations of moisture content are not available.

Other trace gases and aerosols both affect, and are affected by, the land-sur-

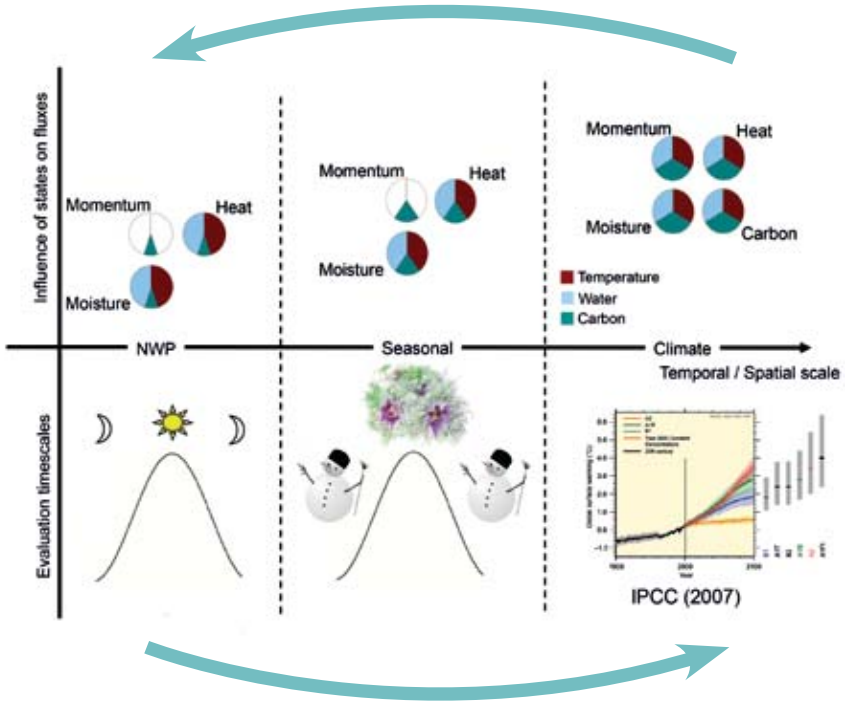

Figure 2. Flow of benefits in the development cycle of a seamless surface modelling system for all spatial and temporal scales. Pie charts represent schematic of proportional influence of land surface states on fluxes. Evaluations can be applied on diurnal, seasonal and decadal to centennial timescales, but with decreasing data availability.

face and vegetation state. Biogenic VOC (volatile organic compounds) emissions and aerosol formation, ozone deposition and subsequent damage to plant cells and vegetation response to diffuse light caused by aerosols are all important land-atmosphere interactions [3-5]. These are beginning to be included in climate models but also have applications at seasonal and NWP timescales especially related to air quality forecasting.

"Carbon and water cycles are crucially important processes for our ability to predict future weather and climate and their influence on society through, for example, food and water availability."

On the other hand, there are more opportunities to evaluate the land surface scheme on the forecasting timescales than for the climate timescales. Routine evaluation of the diurnal to seasonal cycles that are undertaken in the forecasting community deliver insight into the physical processes that can not be determined by studying timescales longer than the diurnal cycle. Observations of short-term variability are increasingly being used to relate observable quantities to long-term projections with the ultimate goal of constraining uncertainty [6,7]. As such, climate modelling processes are improved using information from the evaluation of the forecasting performance (bottom part of Fig. 2).

The JULES perspective

JULES is the UK community land-surface model that is used across all scales from operational NWP to climate modelling at the Met Office and is a key research tool throughout the UK research community [8,9]. It includes the main interactions among the carbon, water and energy cycles described above and has a wide user base across space and timescales. It is commonly used offline (driven by prescribed input conditions) and coupled to an atmosphere model. The future JULES developments have to pass a series of benchmarking tests [10], cover short and long timescales, local and regional spatial scales and processes controlling all of energy, water and carbon.

In short, the land-atmosphere system is a complex coupled system of inter-connected processes and inter-connected timescales. Both the models we use, and the data we use to evaluate them must reflect these interactions. Through this approach, applications across all space and timescales can learn and benefit from each other and bring robustness to our understanding of and prediction of weather and climate. ■

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References

1. Cox PM *et al*. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature 408, 184–187.
2. Friedlingstein P Cox PM, Betts RA, *et al.* 2006. Climate–carbon cycle feedback analysis, results from the C4 MIP model intercomparison. Journal of Climate 19, 3337–3353.
3. Mercado LM *et al.* 2009. Impact of changes in diffuse radiation on the global land carbon sink. Nature 458, 1014–1018.
4. Pacifico F, Harrison SP, Jones CD *et al.* 2011. Evaluation of a photosynthesis-based biogenic isoprene emission scheme in JULES and simulation of isoprene emissions under present-day climate conditions. Atmospheric Chemistry and Physics 11, 4371–4389.
5. Sitch S *et al.* 2007. Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. Nature 448, 791–794.
6. Cox PM *et al*. 2013. Sensitivity of tropical carbon to climate change constrained by carbon dioxide variability. Nature, doi:10.1038/nature11882.
7. Hall A and Qu X 2006. Using the current seasonal cycle to constrain snow albedo feedback in future climate change. Geophysical Research Letters 33, L03502.
8. Best MJ, Pryor M, Clark DB *et al.* 2011. The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes. Geoscientific Model Development 4, 677-699.
9. Clark DB, Mercado LM, Sitch S *et al*. 2011. The Joint UK Land Environment Simulator (JULES), model description – Part 2: Carbon fluxes and vegetation dynamics. Geoscientific Model Development 4, 701-722.
10. Blyth E *et al*. 2011. A comprehensive set of benchmark tests for a land surface model of simultaneous fluxes of water and carbon at both the global and seasonal scale. Geoscientific Model Development 4, 255–269.

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The Community Land Model Philosophy: model development and science applications

David Lawrence is a scientist in the Terrestrial Sciences Section of NCAR's Climate and Global Dynamics Division. He is a co-chair of the Community Earth System Model (CESM) Land Model Working Group (LMWG) and is also a member of the CESM Scientific Steering Committee. As LMWG co-chair he directs the development and application of the Community Land Model, which is improved and utilised by a diverse array of scientists from NCAR, the Department of Energy (DOE) national laboratories, and US and international universities. His research interests centre around land processes and Earth system modelling, with an emphasis on Arctic terrestrial climate system feedbacks.

Rosie Fisher is a project scientist in the Terrestrial Sciences Section at the National Center for Atmospheric Research (NCAR) in Boulder, CO. She is interested in integrating ecological processes, plant optimality theory, and emerging trait databases into land surface models. Her graduate studies at Edinburgh University focused on measuring the response of tropical rainforests to low rainfall, and using those data to test process-based models. Since then she has worked in Sheffield, Los Alamos and NCAR on developing new methodologies for predicting and testing vegetation responses to climate change.

The Community Land Model (CLM) is the dynamic land model component of the Community Earth System Model (CESM). As with many land models, it was originally developed primarily as a lower boundary condition for the atmosphere, principally the Community Atmosphere Model within the CESM (though CLM is also used in several regional climate models and the Norwegian Earth System Model). The focus, therefore, of early versions of CLM was on the simulation of water and energy budgets over land.

Since that time, CLM has evolved considerably. Its principal (but not exclusive) purpose continues to be as the terrestrial component within an Earth System Model (ESM) and as a tool to promote understanding of the complex land surface contributions and responses to climate variability and change. To this end, two central themes drive CLM development and use: 1) terrestrial ecosystems, through their cycling of energy, water, chemical elements, and trace gases, are important determinants of weather and climate, and 2) the land surface is a critical interface through which climate change influences humans and ecosystems and through which humans and ecosystems can affect global environmental change.

When viewed in this light, the utility of CLM is and can be vastly expanded beyond its original purpose and in fact there are multitudinous actual and possible applications of CLM. Importantly, it is increasingly used as a tool for assessing climate change impacts on ecosystems and ecosystem services, hydrological systems (including drought and flooding), agriculture, and urban environments.

Development philosophy and science priorities

The overarching development strategy for CLM rests on the notion that the land system is highly coupled and that improvements, for example in the represen-

tation of biogeochemical cycles, contribute to improved hydrologic and energy cycle simulation, and vice versa. The model thus benefits from a holistic perspective of the terrestrial system on a wide variety of time and spatial scales. Core biogeophysical and biogeochemical parameterisation development is complemented by efforts to expand model functionality. Priorities are broadly set to improve and enable the capacity of the model to be applied to address pressing terrestrial climate science questions. Examples of scientific topics that are driving current CLM model development include the following:

• To improve understanding of carbon and nitrogen cycle interactions and their influence on long-term trajectory of the terrestrial carbon sink;
• To assess the response and vulnerability of ecosystems to climate change and disturbances (human and natural) and the possibility for ecosystem management to mitigate climate change;
• To quantify the role of terrestrial processes in diurnal to interannual weather and climate variability including influence on droughts, floods, and extremes;
• To establish the vulnerability of water resources under climate change;
• To quantify land feedbacks to climate change: for instance, permafrost-carbon feedback, snow- and vegetation-albedo feedback;
• To prognose anthropogenic and natural land cover/land use change and trace gas emissions and their influence on climate;
• To examine the impact of urbanisation on local climate and the unique impact of climate change in urban areas;
• To assess how land surface heterogeneity affects land-atmosphere interactions and carbon cycling, including scale issues;
• To enable model – data fusion and increase exploitation of experimental ecosystem data;
• To quantify parameter uncertainty and investigate parameter optimisation techniques

"The Community Land Model is increasingly used as a tool for assessing climate change impacts on ecosystems and ecosystem services, hydrological systems, agriculture, and urban environments. "

Current capabilities, use, and evaluation

The most recently released version of the model, CLM4 [1,2], represents a significant improvement in terms of model performance and functionality. In addition to its core functions of carbon, water and energy cycling, CLM4

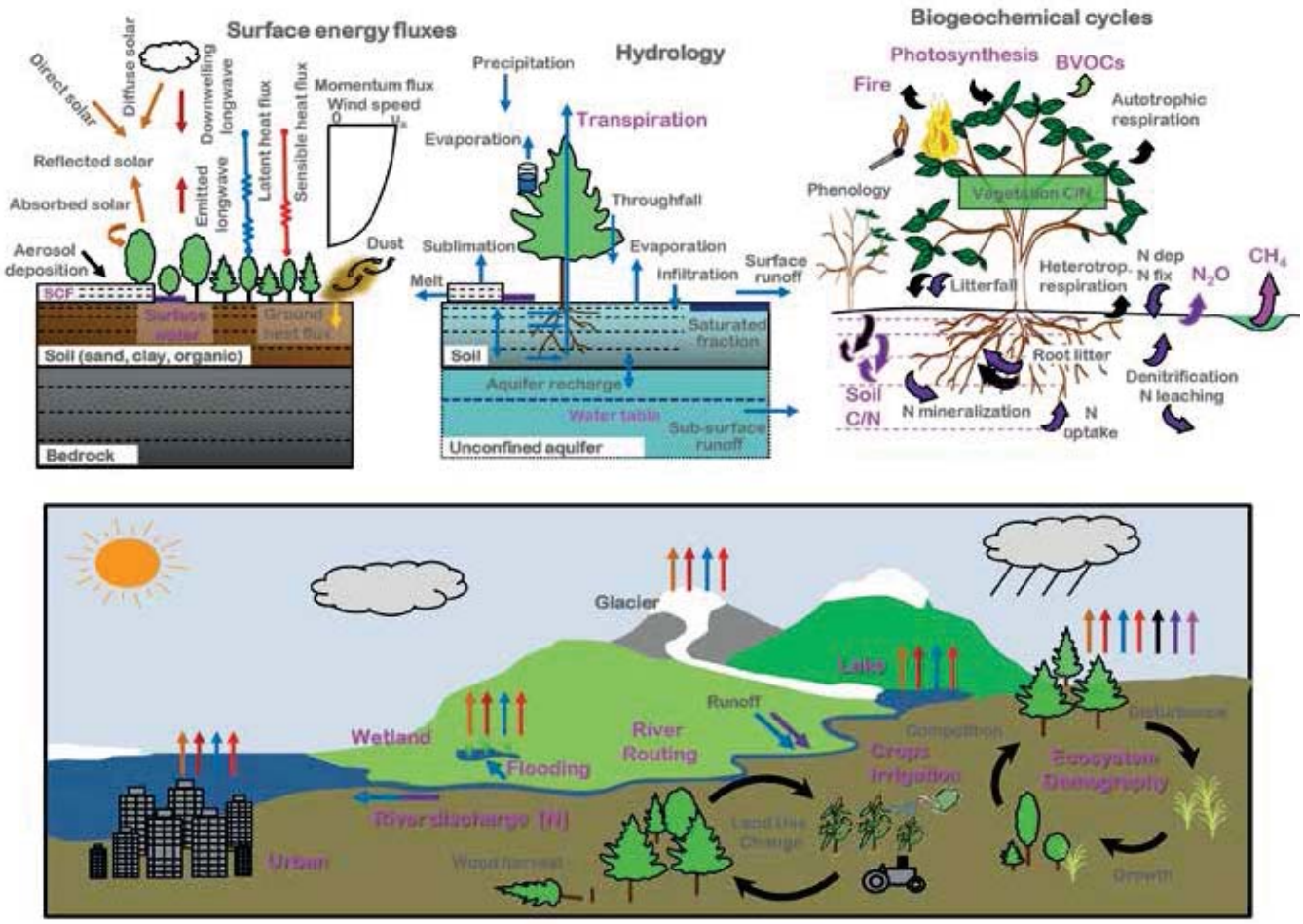

Figure 1. Schematic diagram depicting processes represented in CLM. Items highlighted in pink are new or modified for CLM4.5. Note that not all processes are depicted.

also simulates a suite of more complex terrestrial processes. Such processes include dynamic vegetation changes that allow plant types to adapt to changing climate conditions, interactive nitrogen cycling that restricts the ability of the biosphere to sequester carbon beyond the limits of nutrient supply, crop behaviour, land-use change (including wood harvest) impacts on both carbon cycling and biogeophysics, urban environments, as well as permafrost dynamics, dust production, aerosol deposition onto snow, and, last but not least, biogenic volatile organic compound emissions.

With increased model complexity comes the need for new, better, and more comprehensive tools to evaluate the behaviour of the coupled land system. Though many of the fundamental questions that drive CLM development focus on longer timescales, long-term validation data is sparse. Consequently, model behaviour is routinely evaluated at diurnal, seasonal, and interannual time-scales, which is reasonable as these are the temporal resolutions at which the majority of simulated processes operate. Ideally, new developments to model structure should be evaluated systematically against a suite of validation data at multiple temporal and spatial scales. A comprehensive benchmarking system is not in place and therefore CLM validation remains overly subjective and case specific.

Improved model validation is the goal of the International Land Model Benchmarking project (ILAMB) and CLM researchers strongly support and maintain an active role in this project. There is also recognition that ILAMB will only be part of the model evaluation picture. We are increasingly exploiting experimental data from manipulation studies and process observations as powerful constraints on model behaviour and structure. Recent examples include model/experimental-data comparisons on the influence of nitrogen fertilisation on tree growth [3], litter-bag decomposition [4], ozone poisoning of vegetation [5], and snow-shrub-permafrost interactions [6].

CLM also benefits from and contributes to many model intercomparison projects. CLM is employed as part of CCSM (Community Climate System Model) /CESM in the CMIP3 and CMIP5 coupled climate model intercomparison projects and a prior version of the model was used in the C4MIP carbon cycle feedback analysis. CLM simulations have also been submitted to the ongoing, biogeochemically focused TRENDY and Permafrost Carbon projects and several GEWEX-supported projects such as LUCID, the series of Global Land-Atmosphere Coupling Experiments (GLACE), which investigate the influence of soil moisture variability and trends on weekly to seasonal weather and climate, and the historic and forthcoming Global Soil Wetness Projects (GSWP). Feedback from participation in these projects informs CLM developers of deficiencies in the model that can be addressed in future versions of the model. For example, TRENDY analysis revealed that CLM underestimates the 20th century land carbon uptake (excluding carbon losses due to land cover change) and has led to an intensive effort to improve CLM carbon and nitrogen cycling.

"One major challenge facing CLM is an appropriate balance across the processes represented: the overall model will suffer if excessive attention is paid to one set of processes at the expense of others."

Future Directions

Knowledge of model limitations and strengths, determined in part through model intercomparisons and the increasingly numerous applications and science priorities of CLM and CESM, has spurred increasingly diverse and comprehensive model development activities. These development activities are within the scope and have benefited from the expertise of both the GEWEX and iLEAPS communities. Consequently, CLM researchers maintain a presence in both communities.

During the ongoing development cycle, the transformation of CLM4 to CLM4.5 (scheduled for release in 2013) has seen model improvement and expansion across many fronts (Fig. 1). Improved parameterisations are being incorporated throughout the model including for canopy physiology and photosynthesis [7], permafrost hydrology [8], snow, lake dynamics [9], river flow, runoff generation [10], and fire dynamics including anthropogenic triggers and suppression [11]. New features slated for inclusion in CLM4.5 include methane emissions [12], flooding and prognostic wetland distribution, ecosystem demography [13], vertically resolved soil biogeochemistry [14], multi-layer canopy radiation, crop fertilisation [15] and irrigation [16], and riverine transport of nutrients. The comprehensive development approach helps maintain scientific balance and is consistent with past CLM development experience that indicates that improvements in one facet of model behaviour often benefit other coupled processes.

On the longer term, developments that are being pursued for future model releases include data assimilation within the CESM Data Assimilation Research Testbed, enhanced two-way interactions with the socio-economic processes represented by Integrated Assessment Models, feedbacks between vegetation and canopy airspace properties, the influence of ozone on vegetation, and the capacity to simulate sub-grid soil moisture/snow distributions and lateral groundwater flow along with further parameterisation improvements to existing biogeochemical and biogeophysical processes.

Challenges

As is clear from the above discussion, CLM is being developed with the overarching goal of steady improvement in the process-oriented depiction of the global terrestrial system in an Earth System Model. Clearly, there are myriad directions in which the model can be developed with ever-increasing complexity and process fidelity. One major scientific and management challenge facing CLM is the maintenance of appropriate scientific balance across

the processes represented: the overall model will suffer if excessive attention is paid to one set of processes at the expense of others. Ideally, process resolution should advance in parallel across the range of the model components in the context of emerging science priorities, which has roughly been the case (at least partly by design) for CLM4.5 development (model improvements spread across model, Fig. 1).

The existing CLM structure reflects a compromise between demands for increased process resolution both from ecological and hydrological perspectives. One way of ensuring a diversity of input is to engage with as wide a community of scientific developers, testers, and users of the model as possible, so that inappropriate model structures and parameterisations come to light quickly. Maintenance of such a complex and dynamic modelling environment requires broad trans-disciplinary participation, open-source coding practices, and sustained support for software development and maintenance as well as documentation.

Despite these challenges, the future of CLM and land modelling is bright. The number of problems to which these models can now be applied is impressive. CLM has advanced to the point that it is probably more appropriate to think of CLM (and comparable land models) as terrestrial systems models which are a result of synthesis and integration of existing knowledge manifest in land surface models but also drawing from hydrologic, ecosystem, and human dimensions models. Continued progression of these terrestrial systems models will require a sustained and cooperative effort involving the iLEAPS and GEWEX research communities and beyond. ■

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References

1. Lawrence DM, Oleson KW, Flanner MG *et al.* 2011. Parameterization improvements and functional and structural advances in version 4 of the Community Land Model. Journal of Advances in Modeling Earth Systems 3, M03001.
2. Oleson KW, Lawrence DM, Bonan GB *et al.* 2010. Technical description of version 4.0 of the Community Land Model (CLM). NCAR Technical Note NCAR/TN-478+STR, National Center for Atmospheric Research, Boulder, CO, 257 pp.
3. Thomas RQ *et al*. 2012. Global patterns of nitrogen limitation: confronting two global biogeochemical models with observations. Global Change Biology *(submitted).*
4. Bonan GB *et al*. 2012. Evaluating litter decomposition in earth system models with long-term litterbag experiments: An example using the Community Land Model version 4 (CLM4). Global Change Biology 19, 957-974.
5. Lombardozzi DL *et al*. 2012. Predicting photosynthesis and transpiration responses to ozone: Decoupling modeled photosynthesis and stomatal conductance. Biogeosciences 9, 3113-3130.
6. Lawrence DM *et al*. 2011. Permafrost response to increasing Arctic shrub abundance depends on relative influence of shrubs on local soil cooling versus large-scale climate warming. Environmental Research Letters 6, 10.1088/1748-9326/6/4/045504.
7. Bonan GB, Lawrence PJ, Oleson KW *et al.* 2011. Improving canopy processes in the Community Land Model (CLM4) using global flux fields empirically inferred from FLUXNET data. Journal of Geophysical Research 116, G02014.
8. Swenson SC *et al*. 2012. Improved simulation of the terrestrial hydrological cycle in permafrost regions by the Community Land Model. Journal of Advances in Modeling Earth Systems *(in press).*
9. Subin ZM *et al.* 2012. An improved lake model for climate simulations: Model structure, evaluation, and sensitivity analyses in CESM1, Journal of Advances in Modeling Earth Systems 4, M02001.
10. Li H, Huang M, Wigmosta MS *et al.* 2011. Evaluating runoff simulations from the Community Land Model 4.0 using observations from flux towers and a mountainous watershed. Journal of Geophysical Research 116, D24120.
11. Li F *et al.* 2012. A process-based fire parameterization of intermediate complexity in a Dynamic Global Vegetation Model. Biogeosciences 9, 2761-2780.
12. Riley WJ, Subin ZM, Lawrence DM *et al.* 2011. Barriers to predicting changes in global terrestrial methane fluxes: analyses using a methane biogeochemistry model integrated in CESM. Biogeosciences 8, 1925-1953.
13. Fisher R, McDowell N, Purves D *et al*. 2010. Assessing uncertainties in a second-generation dynamic vegetation model caused by ecological scale limitations. New Phytologist 187, 666–681.
14. Koven CD, Riley WJ, Torn MS *et al.* 2012. The effect of vertically-resolved soil biogeochemistry on C and N dynamics in a land surface model. Biogeosciences *(submitted).*
15. Drewniak B *et al.* 2012. Modeling agriculture in the Community Land Model. Geoscientific Model Development *(submitted).*
16. Sacks WJ *et al*. 2009. Effects of global irrigation on the near-surface climate. Climate Dynamics 33, 159–175.

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iLEAPS and GEWEX activities on benchmarking of land models

Eleanor Blyth has worked for NERC (Natural Environment Research Council) for over 20 years and has extensive experience in land surface modelling. Her expertise is in developing land surface models to include hydrological and soil hydraulic processes. Recently she has concentrated on developing methods to evaluate models at the global scale, pioneering the idea of benchmarking the UK community land surface model: JULES. She is a member of several international committees which foster land surface modelling and evaluation of the models: the SSG of GEWEX and the SSC of iLEAPS. Her work has been published in peer-reviewed scientific journals.

David Lawrence is a scientist in the Terrestrial Sciences Section of NCAR's Climate and Global Dynamics Division. He is a co-chair of the Community Earth System Model (CESM) Land Model Working Group (LMWG) and is also a member of the CESM Scientific Steering Committee. As LMWG co-chair he directs the development and application of the Community Land Model, which is improved and utilised by a diverse array of scientists from NCAR, the Department of Energy (DOE) national laboratories, and US and international universities. His research interests centre around land processes and Earth system modelling, with an emphasis on Arctic terrestrial climate system feedbacks.

Improvements in land surface models (LSM) are seen in both the GEWEX and the iLEAPS communities as key to further progress towards understanding and predicting the interactions of terrestrial ecosystems with weather, climate variability, and climate change. Broad agreement exists that we need improved mechanisms to assess the quality and suitability of current and future generation land models for a wide array of studies and uses. These include seasonal forecasting, the vulnerability of water systems and ecosystems to climate change, and carbon cycle feedbacks; the approach is similar to earlier treatment of coupled climate models (Fig. 1).

Several international projects under the general banner of 'benchmarking' have recently been initiated to try to improve the situation. Luo *et al.* [1] have defined the term carefully. Fundamentally, the goal of a land model benchmarking process is a more substantive, detailed, and systematic evaluation of land models and land model processes which will enable modellers to track progress, intercompare models, and identify avenues for improvement. Benchmarking should provide a measure of model 'goodness' against some predefined metrics or thresholds. This is in contrast to the more common approach to date of 'model evaluation', whereby a single or set of observed variables of interest are simply measured against model output. Benchmarking will provide information about model strengths and weaknesses to scientists that utilise land models in their research.

Over the past few years, the interest in land model benchmarking has grown. This is evident in the several meetings and papers focused on scoping out the problem, proposing community projects, and designing prototype benchmarking systems. Early on, the C-LAMP project outlined a set of tests that the Community Land Model (CLM) modelling group put to-

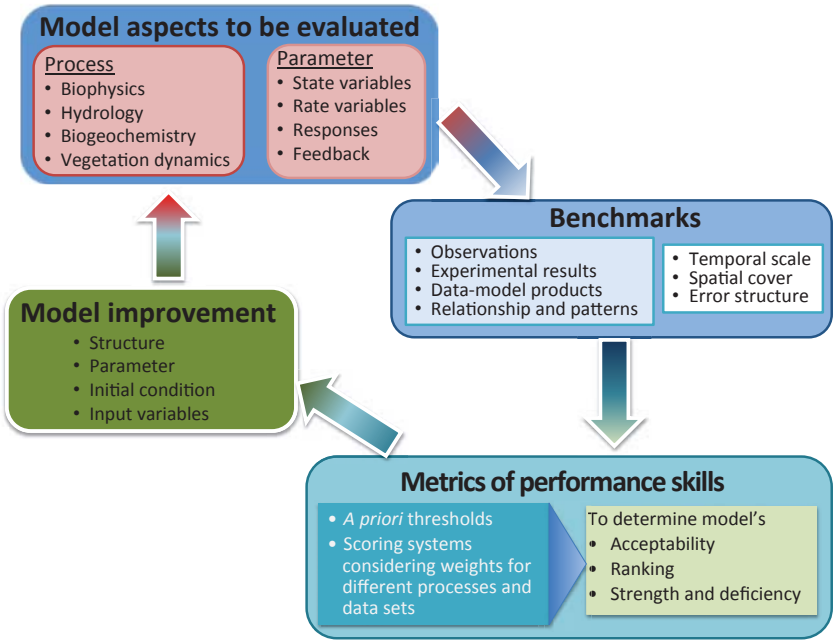

Figure 1. Schematic diagram of the benchmarking framework for evaluating land models. The framework includes four major components: (1) defining model aspects to be evaluated, (2) selecting benchmarks as standardised references to test models, (3) developing a scoring system to measure model performance skills, and (4) stimulating model improvement. Adopted from [1].

gether to help choose between competing carbon cycle model versions [2]. Subsequently, a proposal was made by Cadule et al [3] of how to test coupled climate-carbon models with observations. Last but not least, the JULES modelling group [4] proposed that the water and the carbon cycle should be tested together and presented a simple suite of data to do that. This cross-over between the carbon and water cycles is key to the links between the iLEAPS and the GEWEX benchmarking activities.

A new group was formed to bring the community together: iLAMB (International Land-Atmosphere Model Benchmarking) (www.ilamb.org). The discussions and decisions made by that group have been reported in a publication that sought to clarify definitions and outline a framework for benchmarking [1]. Figure 2 summarises the findings.

Targets for benchmarking

Benchmarking can be simplified by identifying which processes in the models are relevant for the different timescales: the energy balance is important (and should be benchmarked) at the hourly timescale, the water balance at the monthly timescale, and the carbon balance at the annual timescale.

However, this simplification of the required performance of the model can be deceiving. In practice, it is not possible to get the hourly energy balances right without ensuring that also the hourly evaporation (water flux) is simulated correctly; neither is it possible to get the annual carbon balance right without ensuring that the daily carbon response to sunlight and soil moisture stress are correct. So although the final requirement that only the relevant processes work in each timescale looks reasonably straightforward, the processes that deliver it are not only complex but interrelated.

"Scientists across a surprising number of countries and disciplines have expressed the need for a robust and extensible land model benchmarking system."

The interrelations of land surface processes mean that comparing the model against a single observation is almost meaningless. Instead of testing the model against surface states and fluxes, we need to test it against the underlying functions of the model, such as the control of soil moisture on evaporation and runoff. Recently, Koster et al. [5] showed that a simple water balance model in combination with multi-decadal observations can be utilised to evaluate more complex land surface models and to guide their further development. The assumption is that the soil moisture–evapotranspiration (evaporation from surfaces and transpiration by plants) and soil moisture–runoff relationships are, to first order, universal and that the simple model can provide estimates for the underlying relationships that operate in nature, which can then be evaluated against models. A similar proposal is made by [1] for the carbon cycle function of the land surface.

Observations for benchmarking

Luo *et al.* [1] give a comprehensive list of possible sources of data for benchmarking the models, ranging from tower flux data, river flows, satellite products and experiments. Choosing between these data is a task in itself as each has some inherent errors, may not be presented in a suitable time scale or requires some intermediate model to translate between model output and observation. But one thing is certain: despite the improved availability of data, the human cost of gathering and manipulating the data for analysis against model output remains high and is one of the principal reasons that benchmarking systems are desirable.

The increase in relevant data availability is a boon to land modellers and needs to be better exploited. But risks do exist. Since the number and length of datasets are limited, the same dataset that is used to develop a parameterisation or to calibrate a model is often used again in the model evaluation process [6]. In some cases, a dataset can even be used a third time to weight or eliminate models within a multi-model database based on their skill at replicating some aspect of the climate system prior, for example, to using the models to examine climate projections.

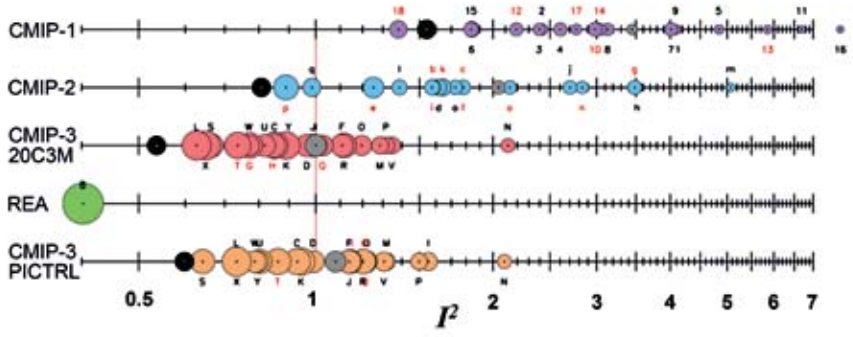

Figure 2. Performance index I2 for individual models (circles) and model generations (rows). Best performing models have low I2 values and are located toward the left. Circle sizes indicate the length of the 95% confidence intervals. Letters and numbers identify individual models (see supplemental online material at doi: 10.1175/BAMS-89-3-Reichler); flux-corrected models are labeled in red. Grey circles show the average I2 of all models within one model group. Black circles indicate the I2 of the multimodel mean taken over one model group. The green circle (REA) corresponds to the I2 of the NCEP/NCAR reanalyses. Last row (PICTRL) shows I2 for the preindustrial control experiment of the CMIP-3 project. Adopted from [10].

Using the same data multiple times during the model development and evaluation process is clearly a problem, but because available data is so sparse, this is often unavoidable.

Metrics for evaluation

The benchmarking framework requires a set of metrics that quantify the performance across the full range of model processes. There are many potential metrics, but establishing ones that test the performance of the model rather than the quality of the driving data can be challenging. For example, how should one design metrics for river discharge in the face of uncertain estimates of basin-scale precipitation?

In other situations, the outcomes of the model are entirely influenced by the meteorology: for instance, completely dry deserts and very wet regions do not require a complex carbon-water-energy model with sophisticated mathematical components solving partial differential equations of the flow of water through an unsaturated soil in order to calculate the evaporation. Evaporation is difficult to determine or model only when the land is limited neither by water nor by energy. But how can the metrics take into account that the model performance may not depend on the model itself but be driven by the driving data as in these previous examples?

"Despite the improved availability of data, the human cost of gathering and manipulating the data for analysis against model output remains high and is one of the principal reasons that benchmarking systems are desirable."

One proposed way to distinguish the role of the model in capturing true response of the land surface to the weather or climate is to provide an alternative, statistical 'model', that is simpler than the LSM and based on the driving data only. Abramowitz [7] not only shows how this can be done, but also have delivered a freely available web-based system: PALS (Protocol for Analysis of Land Surface models) that will do the tests and load up the models (www.PALS.unsw.edu.au). The GLASS panel of GEWEX is proposing this as the international standard and is incorporating a suite of flux-tower data to be used by everyone.

A NASA design, the Land Surface Verification Toolkit (LVT) [8] has been built which can contain several model as well as all the data that is used for model testing and hosts a suite of tests related to the energy and water balance. This type of tool kit may become increasingly useful for modellers.

As noted above, it is often challenging to design metrics that test a specific land model process. Often, real insight into these models is gained through comparison of the model against experimental data or case studies of particular extreme climatic events. As an example, Bonan *et al.* [9] utilised a set of litter-bag decomposition studies to evaluate simulated vs. observed carbon loss over time through a controlled set of model experiments. They concluded that "long-term litter decomposition experiments provide a real-world process-oriented benchmark to discriminate ecological fact from model fantasy."

Useful information about model behaviour can be gleaned through analysis of models against available and future manipulation experiments including for example, rainfall exclusion, FACE (Free-Air CO_2 Enrichment), nitrogen fertilisation, and snow-fence experiments.

Community response

Scientists across a surprising number of countries and disciplines have expressed the need for a robust and extensible land model benchmarking system. The linkage between iLEAPS (where the focus is on ecosystems and carbon exchanges of the land surface to the atmosphere) and GEWEX (where the focus is on energy and water exchanges between the land and the atmosphere) is clear; the two communities have contrasting expertise in carbon, energy and water balance studies. This article chronicles thinking that has gone on in this area by the international community of land surface modellers, and the story is typical of many cross-discipline, cross-country (and therefore cross-funders) projects in that it does not always flow evenly, smoothly or always in the same direction, but is always steered by people with good will, good humour and good intentions! ■

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References

1. Luo YQ *et al.* 2012. A framework for benchmarking land models. Biogeosciences 9, 3857-3874.
2. Randerson JT *et al*. 2009. Systematic assessment of terrestrial biogeochemistry in coupled climate–carbon models. Global Change Biology 15, 2462-2484.
3. Cadule P, Friedlingstein P, Bopp L *et al.* 2010. Benchmarking coupled climate-carbon models against long-term atmospheric CO2 measurements. Global Biogeochemical Cycles 24, 1-24.
4. Blyth E, Clark DB, Ellis R *et al*. 2011. A comprehensive set of benchmark tests for a land surface model of simultaneous fluxes of water and carbon at both the global and seasonal scale, Geoscientific Model Development 4, 255–269.
5. Koster Randal D *et al.* 2012. Land Surface Controls on Hydroclimatic Means and Variability. Journal of Hydrometeorolgy 13, 1604–1620.
6. Knutti R 2008. Should we believe model predictions of future climate change? Philosophical Transactions of the Royal Society A 366, 4647-4664.
7. Abramowitz G 2012. Towards a public, standardized, diagnostic benchmarking system for land surface models. Geoscientific Model Development 5, 819-827.
8. Kumar SJ *et al.* 2012. Land surface Verification toolkit (LVT) – a generalised framework for land surface model evaluation. Geoscientific Model Development 5, 869-886.
9. Bonan GB *et al.* 2012. Evaluating litter decomposition in earth system models with long-term litterbag experiments: an example using the Community Land Model version 4 (CLM4). Global Change Biology 3, 957-974.
10. Reichler T *et al*. 2008. How well do coupled models simulate today's climate. Bulletin of the American Meteorological Society 3, 303-311.

"Using the same data multiple times during the model development and evaluation process is clearly a problem, but because available data is so sparse, this is often unavoidable."

Physical and Physiological Forest Ecology

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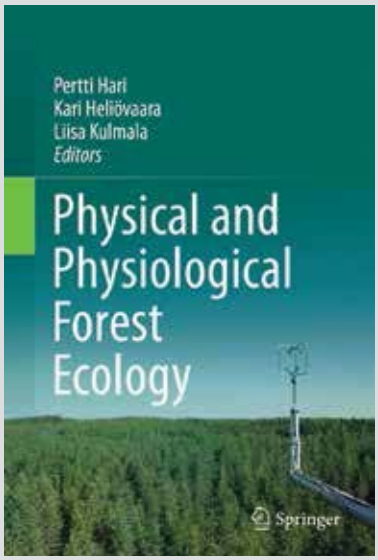

Features robust predictions and explanations of the effects of climate change on forests and feedbacks from forests to climate change.

Synthesizes a wealth of information from cells in trees and microbes to the ecosystem.

Features a wealth of illustrations to clarify ecological phenomena and concepts in the text.

This important contribution is the result of decades of theoretical thinking and high-value data collection by the University of Helsinki examining forest ecosystems in great detail. The ecology is dominated by a qualitative approach, such as species and vegetation zones, but in contrast quantitative thinking is characteristic in the exact sciences of physics and physiology. The editors have bridged the gap between ecology and the exact sciences with an interdisciplinary and quantitative approach. This book recognises this discrepancy as a hindrance to fruitful knowledge flow between the disciplines, and that physical and physiological knowledge has been omitted from forest ecology to a great extent. Starting with the importance of mass and energy flows in the interactions between forest ecosystems and their environment, the editors and authors offer a strong contribution to the pioneer H. T. Odum and his work from over 50 years ago.

This book introduces a holistic synthesis of carbon and nitrogen fluxes in forest ecosystems from cell to stand level during the lifetime of trees. Establishing that metabolism and physical phenomena give rise to concentration, pressure and temperature differences that generate the material and energy fluxes between living organisms and their environment. The editors and authors utilize physiological, physical and anatomical background information to formulate theoretical ideas dealing with the effects of the environment and the state of enzymes, membrane pumps and pigments on metabolism. The emergent properties play an important role in the transitions from detailed to more aggregate levels in the ecosystem. Conservation of mass and energy allow the construction of dynamic models of carbon and nitrogen fluxes and pools at various levels in the hierarchy of forest ecosystems.

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Multi-scale modelling approaches for land-atmosphere interaction and feedback studies

Community land surface models (LSMs) are similar in many respects, since each must serve as a physically reasonable lower boundary responding to and constraining atmospheric fluxes of energy, moisture, and, in many cases, carbon. In particular, some representation of the physical and biophysical properties of the vegetation canopy is a common feature used in LSMs.

One the major shortcomings of current coupled land-atmospheric models is the inability to generate the proper canopy turbulence near the surface because of the low heat capacity and complex canopies of plants which complicate surface exchange and isolate the surface and canopy layers from the overlaying atmosphere. By including a photosynthesis component to the LSM, it is possible to achieve better understanding of soil-vegetation-land-atmosphere feedbacks and interactions (including biophysical, hydrological, and biogeochemical interactions) between the land-surface and the atmosphere at micro- and meso-scales [1,2].

Adopting biophysical approaches in climate models is not new, but simple vs. complex approaches to representing biophysical processes can produce different feedbacks from changes in CO_2 levels. Thus, present modelling efforts are oriented towards adapting the biophysical approaches within a weather or climate model. The physiological processes within LSMs are primarily represented through a stomatal conductance formulation, which describes the rate of passage of carbon dioxide (CO_2) entering or water vapour exiting through the stomata of a leaf, where plant transpiration of water vapour reaches a maximum rate when canopy resistance is at lowest value (that is, high stomatal conductance).

We have investigated two canopy resistance methods, the well-known Jarvis approach and a more complex Gas-Exchange Evapotranspiration Model (GEM) approach based on the Ball-Berry approach. In brief, the Jarvis approach is function of meteorological parameters such as air temperature, ambient vapour pressure, radiation, and soil moisture availability, whereas Ball-Berry employs more rigorous plant gas-exchange responses such as carbon assimilation rate and respiration [3,4].

In comparing both approaches, we found that GEM does a better job in capturing both diurnal and long-term variability in canopy resistance over different vegetation types. GEM also reproduces better surface heat fluxes and reasonable soil moisture variability relative to that of the Jarvis approach [4]. The parameterisation of stomatal resistance over vegetation has a profound impact on the energy partition-

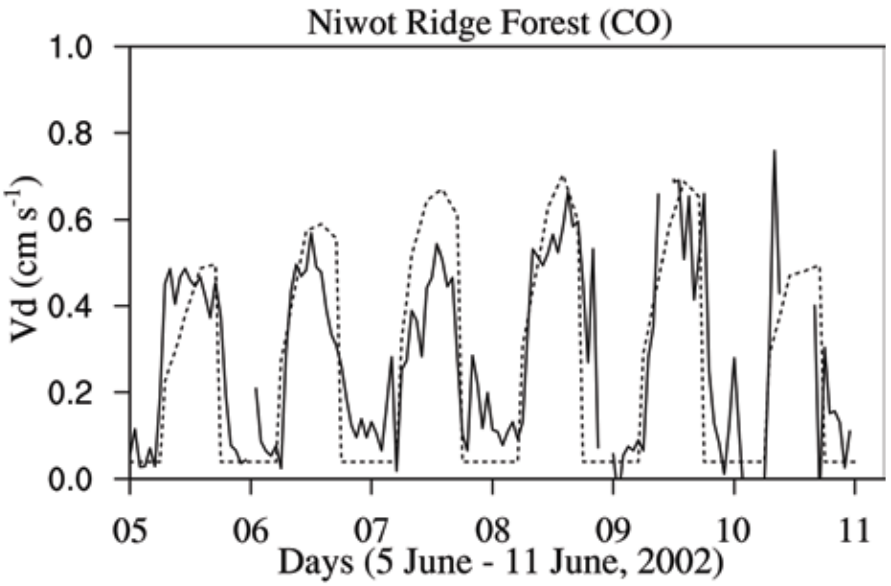

Figure 1. Modelled dry deposition veloocity (V_d) estimates by coupling GEM in the Noah LSM. Observed V_d (solid line) and modelled V_d (dashed line).

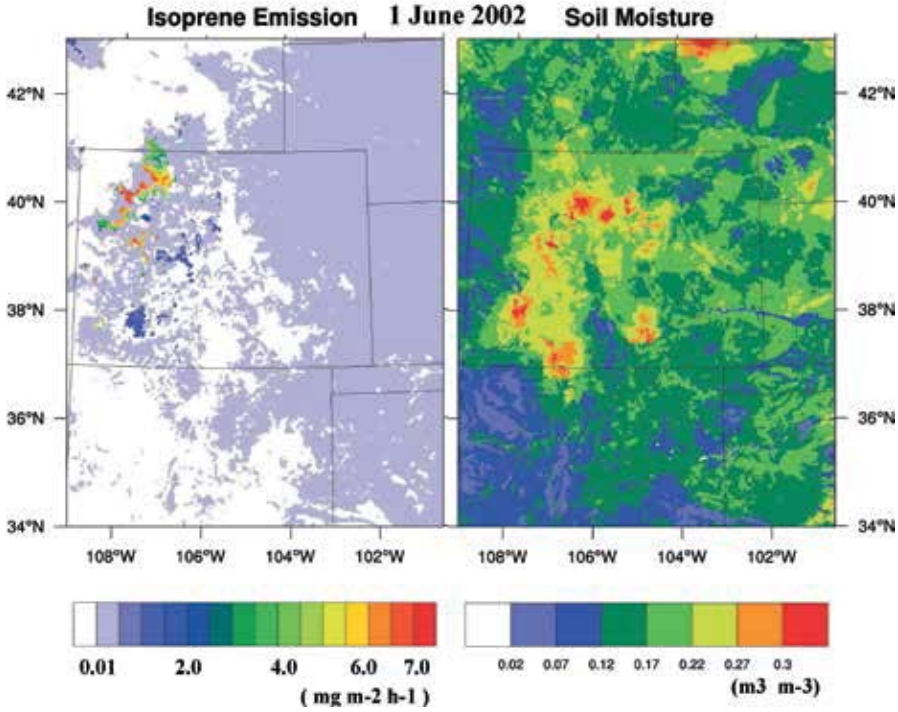

Figure 2. Model-resolved isoprene emission rate (left) in response to soil moisture (right).

ing and the prediction of boundary layer fluxes and surface parameters such as temperature and humidity through the transpiration regulation. Furthermore, by coupling a multi-layer canopy-soil model to GEM we have tested the influence of plant biophysics and soil properties on atmospheric turbulence exchange from the leaf level scale to planetary boundary layer scale. Such efforts can therefore be integrated into weather and climate models, which typically cannot resolve the canopy, as a means to account within-canopy processes on the total flux [5].

The land surface is also important as a sink for atmospheric pollutants through deposition pathways, which GEM is also capable of resolving via the air-pollutant deposition velocity. By implementing GEM within the NOAH LSM (the operational LSM component used by the National Centers for Environmental Prediction (NCEP) in the United States, we are able to capture day-to-day variation of dry deposition velocity over different vegetation types (Fig. 1). Furthermore, dry deposition velocity is sensitive to leaf area index (leaf area per unit land area) and to maximum stomatal resistance prescription in the model [6], and suggests that GEM can be effectively applied to estimate deposition velocity values for air quality/biogeochemical studies.

The Model of Emissions of Gases and Aerosol from Nature (MEGAN) is widely used for estimating biogenic volatile organic compounds (BVOCs) in global and regional models. The emission estimate of isoprene (a hydrocarbon volatile compound emitted in high quantities by many woody plant species, with significant impact on atmospheric chemistry) is important, especially in climate model simulations, because the increasing atmospheric CO_2 concentration will decrease isoprene emission, increase CCN concentration, and lead to a cooling of the planet. The clouds formed at higher CCN concentration have more and smaller drops, and so reflect more sunlight and are longer-lived and enhance planetary cooling [7]. Nevertheless, MEGAN lacks correct representation of canopy resistance and must include physiological approaches such as Ball-Berry canopy resistance and prognostic soil moisture processes.

Preliminarily analyses conclude that the coupled system (consisting of MEGAN and NOAH LSM with the Ball-Berry scheme) is capable of estimating the isoprene emission and its day-to-day variability in response to soil moisture variability (Fig. 2) [8]. Likewise, current mesoscale (for instance, the Weather Research and Forecasting (WRF) model), emission and air quality models lack correct representation of vegetation and canopy characteristics in the LSM, but such deficiencies can be addressed by bridging the gaps that can effectively capture physical processes from leaf scale to planetary boundary scale (~1 km). This can be achieved by coupling multi-layer vegetation canopy models with photosynthesis-based models (such as GEM) within a large-scale modelling system (meso, regional and climate scales).

From an energy and water cycle perspective, land-atmosphere interactions play a very crucial role in extreme weather events that can lead to drought or flash flood situation. To this end, the National Aeronautics and Space Administration (NASA) Unified WRF model coupled to Land Information System (LIS) (NU-WRF; https://modelingguru.nasa.gov/community/atmospheric/nuwrf) modelling system at NASA's Goddard Space Flight Center (GSFC) has been developed with the goal to integrate satellite- and ground-based observational data products and advanced land surface modelling techniques to produce optimal fields of land surface states and fluxes. NU-WRF also integrates the hydrology (LSM), biology (for instance MEGAN), aerosol, radiation, cloud, and chemistry components of the coupled system. The atmospheric and hydrologic components of NU-WRF have shown that excessive run-off leading to flood and landslides was favoured by the occurrence of unusual heavy rainfall over Leh city in India [9]. NU-WRF has also shown that the impact of the LSM on local land-atmosphere interactions and coupling (known as 'LoCo') is maximized during dry conditions, while planetary boundary layer (PBL) schemes becomes more important during wet regimes [10].

As these studies have shown, further LSM development is necessary for better understanding of physical processes from leaf-level to the planetary boundary layer (PBL) scale.

Results continue to demonstrate that LSM components and coupling are very important in all aspects of weather and climate modelling systems, and are critical to explaining the role of carbon and biogenic emission on weather and climate. This suggests that only with more sophisticated coupled Earth system model (such as atmospheric, hydrological, and biological) components will we be able to predict extreme events and to provide detailed assessments of hydrological aspects of the system that have greatest impacts on society (such as precipitation amount and surface runoff/flooding). ■

References

1. Van den Hurk B *et al.* 2011. Acceleration of land surface model development over a decade of glass. Bulletin of the American Meteorological Society 92, 1593–1600.
2. Levis S, 2010. Modeling vegetation and land use in models of the earth system. Wiley Interdisciplinary Reviews: Climate Change 6, 840-856.
3. Niyogi D *et al.* 2009. Development and Evaluation of a Coupled Photosynthesis-Based Gas Exchange Evapotranspiration Model (GEM) for Mesoscale Weather Forecasting Applications. Journal of Applied Meteorology and Climatology 48, 349-368.
4. Kumar A *et al.* 2011. Evaluation of a photosynthesis-based canopy resistance formulation in the Noah land surface model, Boundary-Layer Meteorology 138, 263 – 284.
5. Patton GE *et al.* 2008. A coupled canopy-soil model for the simulation of atmospheric turbulent modified by tall vegetation, 18th Symposium on Boundary Layers and Turbulence, Stockholm, Sweden.
6. Charusombat U, Niyogi D, Kumar A *et al.* 2010. Evaluating a new Deposition Velocity Module in the Noah land surface model, Boundary-Layer Meteorology 2, 271-290.
7. Kiendler-Scharr A, Wildt J, Dal Maso M *et al.* 2009. New particle formation in forests inhibited by isoprene emissions. Nature 461, 381-384.
8. Kumar A *et al.* 2009. Coupling vegetation, hydrological, and biogenic emission processes to improve modeling of isoprene emission, Joint Special Symposium on Biogeochemical Cycling of Trace Gases and Aerosols, AMS Annual Meeting, 11-15 January 2009, Phoenix, Arizona.
9. Kumar A *et al.* 2012. Simulation of a Flash Flooding Storm at the Steep Edge of the Himalayas. Journal of Hydrometeorology *(in revision).*
10. Santanello JA Jr *et al.* 2012. Diagnosing the Nature of Land-Atmosphere Coupling During the 2006-7 Dry/Wet Extremes in the U.S. Southern Great Plains. Journal of Hydrometeorology, e-View doi: http://dx.doi.org/10.1175/JHM-D-12-023.

New iLEAPS Research initiative

Interactions among Managed Ecosystems, Climate, and Societies (IMECS)

Jointly organised by iLEAPS, GLP, and AIMES

In order to understand the relative strengths and weaknesses of various land use classification systems and models for use in climate and water assessments, an organised comparison is necessary. In 2013, the research communities focussing on land processes (Global Land Project, GLP), land-atmosphere interactions (iLEAPS), and integrated Earth System modelling (Analysis, Integration, and Modelling of the Earth System, AIMES) are jointly launching a new research programme to address the knowledge gaps and make progress in advancing research in the field of managed ecosystems and their interactions with the atmosphere and societies.

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ALANIS project results: a joint ESA-iLEAPS Atmosphere-Land Interaction Study over Boreal Eurasia

Determining the role of the Eurasian boreal region in the global Earth system is of critical importance. However, the size and remoteness of boreal Eurasia pose a challenge to quantification of both terrestrial ecosystem processes and their feedbacks to regional and global climate. In the last few years, Earth Observation (EO) data have demonstrated the potential to become a major tool for estimating key variables and for characterising main processes governing the land-atmosphere interface.

In order to utilise this potential, the European Space Agency (ESA), as part of the Support To Science Element (STSE), has launched, in collaboration with iLEAPS, the ALANIS (Atmosphere LANd Interaction Study) project to advance towards the development and validation of novel EO-based multi-mission products and their integration into suitable land-atmosphere coupled models that may respond to some of the key challenges of land-atmosphere interactions science in boreal Eurasia.

The three thematic areas addressed: smoke plumes, methane, and aerosols, and their results are summarised in the following sections.

ALANIS - Smoke Plumes

Boreal forests play a vital role in curbing global warming by storing billions of tons of carbon in forest and peat ecosystems. However, forest fires can significantly perturb this important carbon sink, especially as global warming may increase the number and extent of fires, as well as the length of the fire periods.

The ALANIS Smoke Plumes project utilised multi-mission Earth Observation (EO) data for improving current large-scale dispersion forecasts of compounds emitted from biomass burning events occurring in boreal Eurasia. Different EO products have been integrated into the global chemistry Transport Model, version 5 (TM5) [1], explicitly simulating the main processes characterising fire-plume dispersion and providing optimised surface CO emissions. In particular, the following satellite

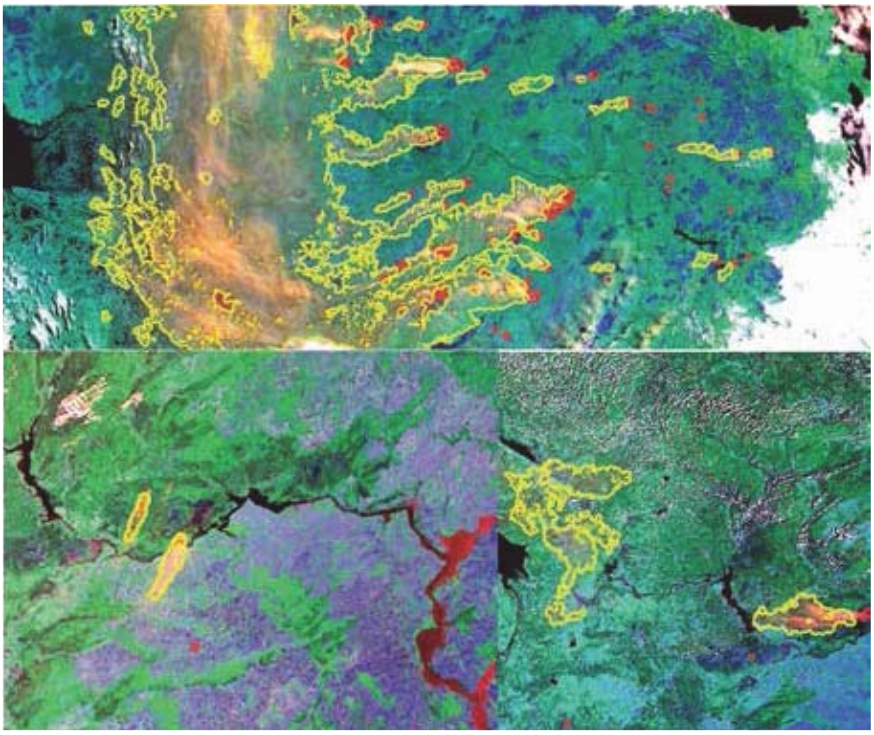
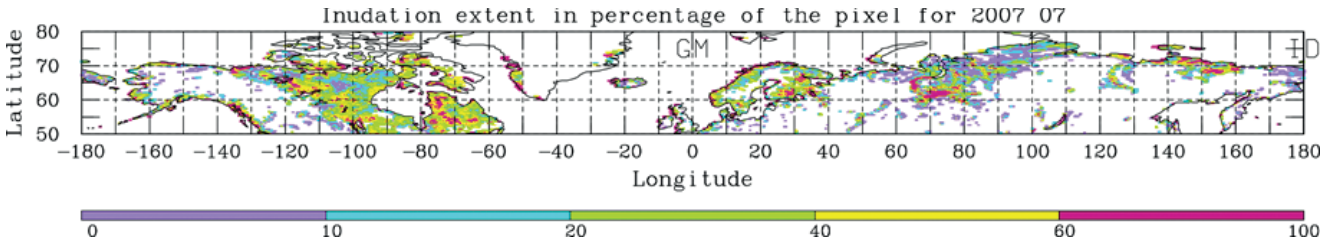


Figure 1. A selection of scenes showing the capabilities of the algorithm developed in ALANIS for smoke detection. The red points on the scene are fire hot spots (FRP) detected by the MODIS instrument. The yellow/green bounded regions represent where smoke plumes/clouds have been detected. The upper most scene was taken on the 30th July 2010, the bottom left image is from the 14th July 2010 and the bottom right from the 7th July 2010.



derived geo-information have been used: 1) burned areas and emissions derived from the MEdium Resolution Imaging Spectrometer (MERIS) and the Moderate Resolution Imaging Spectroradiometer (MODIS); 2) data smoke-plume extent (Fig. 1) and injection height products using stereo retrievals from the Advanced Along-Track Scanning Radiometer (AATSR) instruments on board ESA ENVISAT satellite [2] and 3) CO columns derived from near-real-time Infrared Atmospheric Sounding Interferometer (IASI) satellite data retrievals. Using these data sets, we were able to calculate the 3D carbon monoxide (CO) distributions over boreal Eurasia.

A comparison between prior emissions from MERIS and MODIS and posterior emissions produced by employing the optimised TM5 model that integrates the ALANIS EO-based products showed that the ALANIS optimisation improved some of the estimates significantly.

ALANIS-Smoke plumes project demonstrated the potential offered be

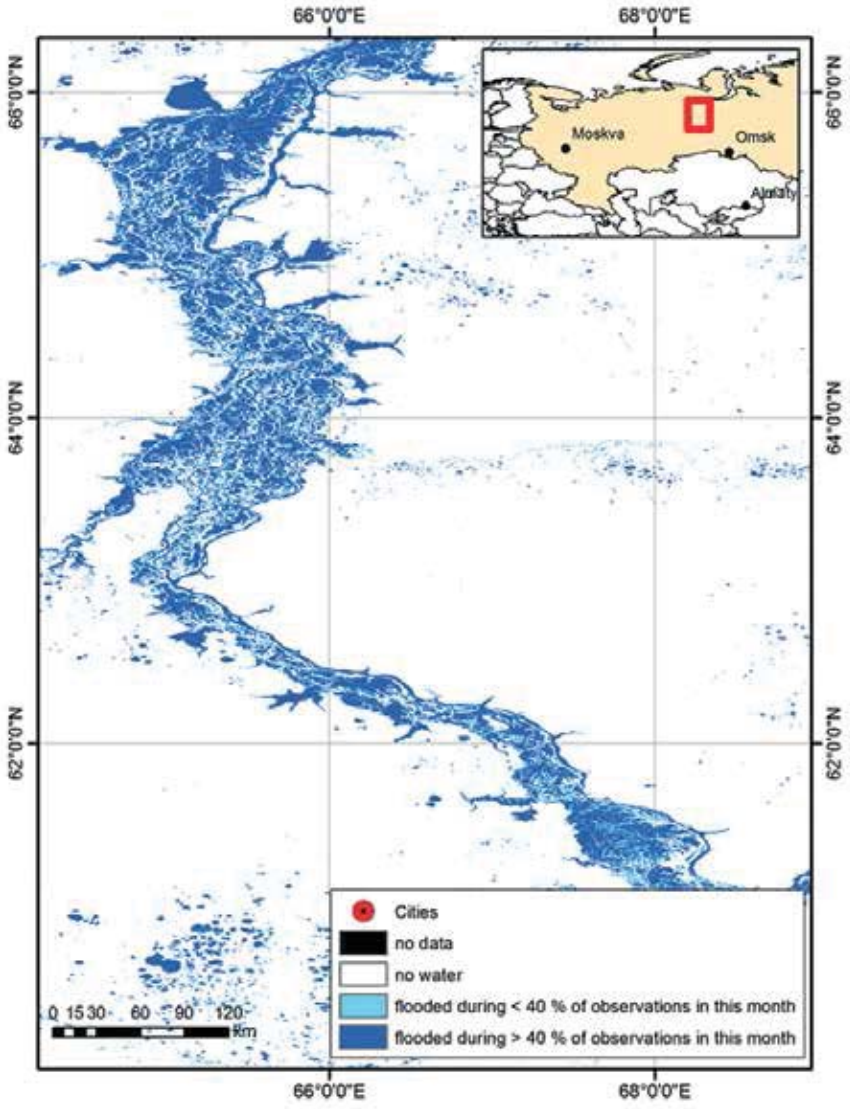


Figure 2: Inundation extent as derived for the boreal domain for July 2007 from the regional inundation product.

the combination of global modelling and satellite observations in a consistent framework to improve dispersion forecasts of compounds emitted from biomass burning events occurring in boreal Eurasia.

ALANIS - Methane

Boreal Eurasian lakes and wetlands play an important role in the carbon cycle as they represent both the largest natural methane (CH_4) source in this region and one of the major carbon sinks. Modelling the natural variability of methane fluxes from boreal Eurasian lakes and wetlands is an important cross-cutting topic, linking climate, hydrology and biogeochemistry. However, the high spatial and temporal variability of CH_4 emissions combined with patchy and incomplete information on their geographical distribution makes it difficult to obtain reliable estimates.

The ALANIS methane project investigated the potential of EO data to reduce current uncertainties in methane emissions from boreal lakes and wetlands through the synergistic use of EO-based products in a coupled land surface-atmosphere model. The project has produced a number of new or extended EO-based products for boreal Eurasia, which are highly relevant to the surface characterisation of wetlands and their emissions of methane (Figs. 2-4): (i) wetland/inundation dynamics for the period July 2007 to June 2008 from a combination of active and

Figure 3: Example of the wetlands extension product derived from ASAR Envisat data over the Ob river watershed.

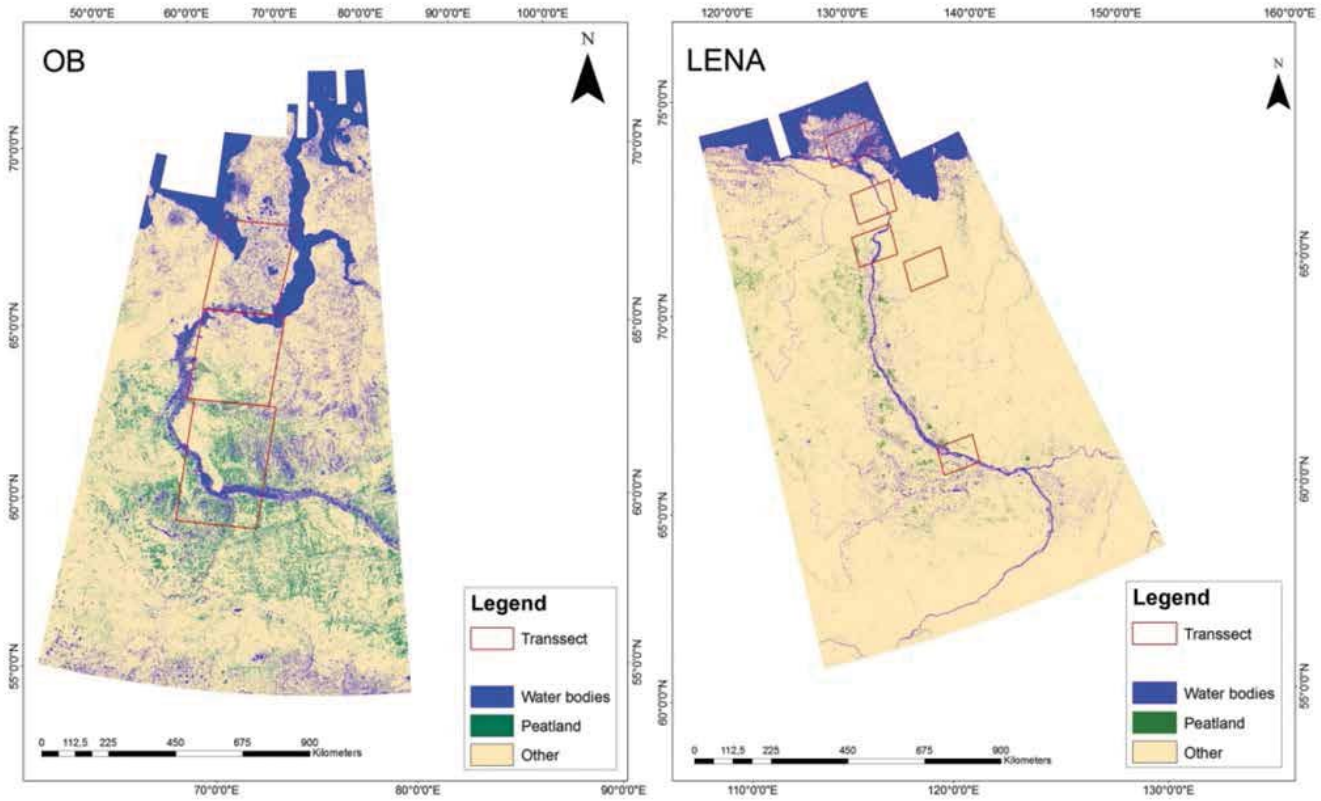


Figure 4. The classification of open water bodies and peatlands from the higher resolution product for the Ob and Lena rivers.

passive microwave measurements, supplemented with vegetation indices derived from infrared data (the earlier global product is described in [3]; (ii) wetland/inundation dynamics at higher spatial resolution using active microwave measurements for the spring/summer months of 2007 and 2008 [4]; (iii) surface state (frozen, unfrozen, melting) for the years 2007-2010 [5], and (iv) atmospheric CH4 columns for the years 2003-2009 [6].

The EO products were then used to evaluate the wetland hydrology and methane production schemes in the JULES land surface model (JULES, the Joint UK Land Environment Simulator, development led by the UK Centre for Ecology and Hydrology). JULES is a state-of-the-art land surface-atmosphere model, which can simulate methane emissions from boreal lakes and wetlands (and wetlands globally). The JULES land surface model was used to derive a number of wetland emission scenarios for use in the HadGEM2 climate-chemistry model (Note: JULES is also the land surface component of HadGEM2).

The wetland emission scheme in JULES had previously been evaluated at specific locations where measurements had been made. This was the first time that the JULES model had been evaluated over a larger spatial domain, and the ALANIS Methane project identified a number of limitations in the JULES land surface and HadGEM2 models. The limitations were related to the treatment of wetland hydrology and biogeochemistry (in JULES) and the atmospheric chemistry and physics of methane (in HadGEM2), thus demonstrating the potential of EO data to test, validate and enhance model performances.

ALANIS – Aerosols

The contribution of atmospheric aerosols is the largest uncertainty in current estimates of the Earth's radiation balance. Both natural and anthropogenic aerosol dynamics are important over boreal Eurasia: firstly, besides emitting biogenic volatile organic compounds (BVOC) important in atmospheric chemistry, boreal Eurasian forest sites regularly produce bursts of new secondary organic aerosol particles. Secondly, anthropogenic aerosol, produced from, such as energy production, industry, road traffic, forest fires in Russia or Central Europe is periodically transported to northern Eurasia.

Detailed aerosol properties can only be measured *in situ* at point locations, but remote sensing with satellite-based instruments can provide aerosol information over large spatial areas, albeit with significant limitations: the information is limited to particles in the optically active size range, larger than about 100 nm in diameter; furthermore, today's satellites are not able to measure the aerosol chemical composition.

To obtain spatial information on the concentrations of smaller particles, especially nucleation-mode particles smaller than about 25–30 nm in diameter, the ALANIS-Aerosols project investigated the possibility of developing proxies (parameterisations) in terms of a combination of satellite-observable quantities to determine. These proxies were developed based on the current understanding of the atmospheric nucleation and growth processes in continental boundary-layers. Regional

nucleation is driven by photochemistry and occurs typically over spatial scales of hundreds of kilometres. Satellite-observable parameters affecting this process are UV radiation, concentrations of trace gases such as NO_2 and SO_2, and aerosol optical depth (the extinction of solar radiation due to scattering and absorption by aerosol particles, integrated over the atmospheric column) which is used as a proxy for the condensation sink: the aerosol surface on which gases can condense [7].

The behaviour of the proxy was investigated in detail at Hyytiälä and Pallas in Finland during nine days in May and July 2006. The analysis used simultaneous data from satellites, ground-based observations at these two sites, and GLOMAP model simulations. The proxies, when calculated based solely on input from model simulations, performed quite satisfactorily in predicting the presence/absence of nucleation-mode particles at the two *in situ* measurement sites. We concluded that supporting the satellite proxies designed for predicting nucleation mode particle number concentrations with model simulation data is very likely to improve the predictive power of such proxies.

As an example of aged long-range transported pollution, we also investigated a biomass-burning episode observed over Finland during 2–6 May 2006 [8]. The main origin of pollution during this period were forest/agricultural fires in Eastern Europe and Russia. The study showed that satellite instruments like ESA's Advanced Along-Track Scanning Radiometer are capable of detecting the presence of long-range transported pollution aerosols over the boreal environment. When aerosol optical depth (AOD) exceeds a value of about 0.1, this is an indication on the presence of pollution aerosols in addition to natural boreal forest aerosol particles.

Acknowledgements

The authors wish to thank all the ALANIS team members for their contribution: CEH (UK), IUP Bremen (DE), Estellus (FR), UK Met Office (UK), NOVELTIS (FR), UCL (UK), Univ. of Wageningen UR (NDL), LATMOS (FR), JRC (EC), Vienna Univ. of Technology (AU), Univ. of Helsinki (FI), Lund University (SE) and FMI (FI).

References

1. Hooghiemstra PB *et al.* 2011. Optimizing global CO emission estimates using a four-dimensional variational data assimilation system and surface network observations, Atmospheric Chemistry and Physics 11, 4705-4723.
2. Fisher DN *et al.* 2013. Automated retrieval of Smoke Plume Injection Heights (SPIH) and Smoke Plume Masks (SPM) from AATSR stereo for mapping aerosol and trace gas injection into the free troposphere. Journal of Applied Earth Observation and Geoinformatics *(submitted).*
3. Prigent C *et al.* 2012. Changes in land surface water dynamics since the 1990s and relation to population pressure. Geophysical Research Letters 39, L08403.
4. Bartsch A *et al.* 2012. Detection of wetland dynamics with ENVISAT ASAR in support of methane modelling at high latitudes. Biogeosciences 9, 703-714.
5. Naeimi V *et al.* 2012. ASCAT Surface State Flag (SSF): Extracting information on surface freeze/thaw conditions from backscatter data using an empirical threshold-analysis algorithm. IEEE Transactions on Geoscience and Remote Sensing 50, 2566-2582.
6. Schneising O *et al.* 2011. Long-term analysis of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY. Atmospheric Chemistry and Physics 11, 2863–2880.
7. Kulmala M *et al.* 2011. The first estimates of global nucleation mode aerosol concentrations based on satellite measurements. Atmospheric Chemistry and Physics 11, 10791-10801.
8. de Leeuw G *et al.* 2011. On the use of satellites to obtain information on the occurrence of natural and anthropogenic aerosols over the boreal Eurasian forest. Biogeosciences Discuss 8, 8451-8483.

ileaps

4th iLEAPS Science Conference

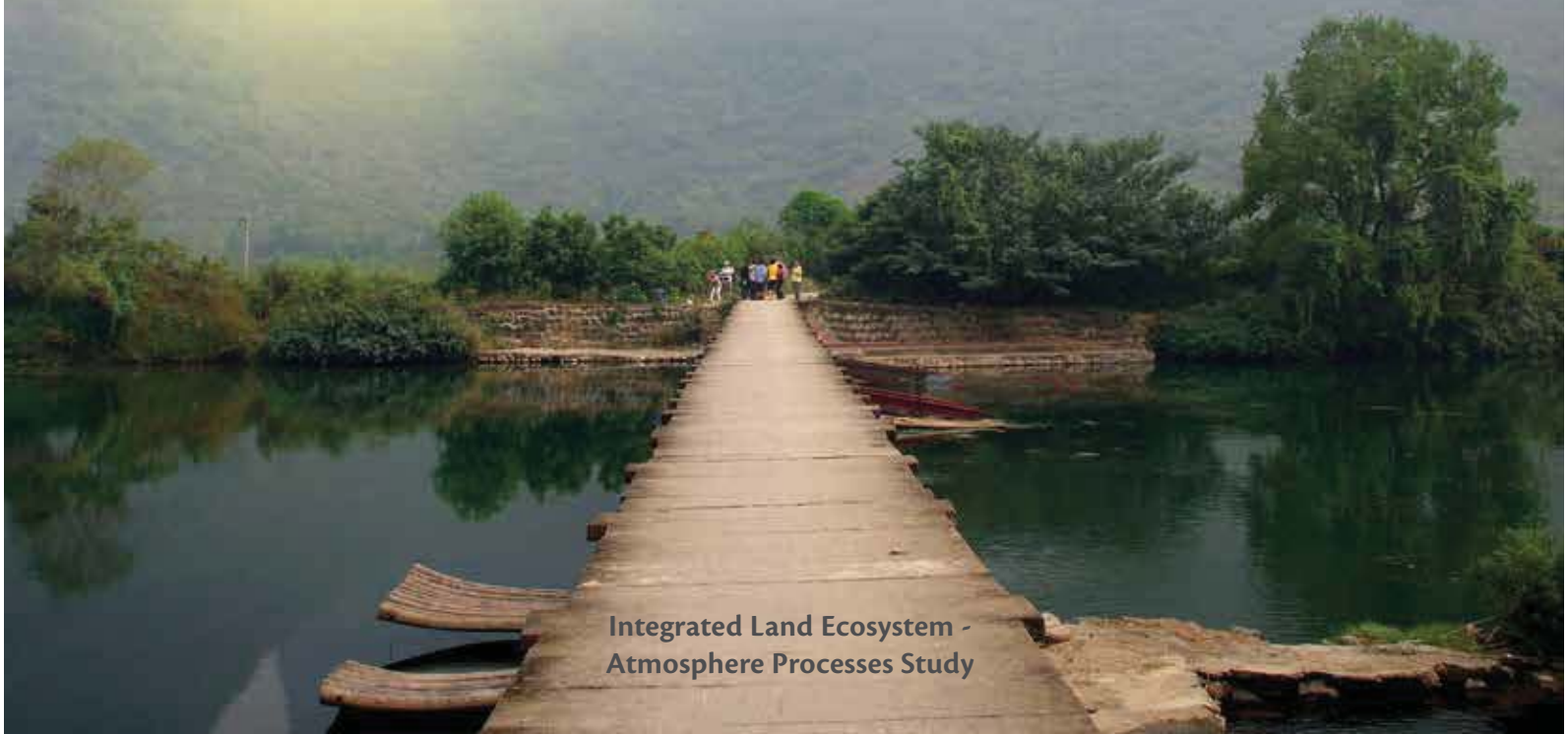
Terrestrial ecosystems, atmosphere, and people in the Earth system

12-16 May 2014 Nanjing, China

www.ileaps-sc2014.org

Conference themes:

- *Dynamic processes in the land-atmosphere-society continuum*
- *Sustainable management of human-dominated environments*
- *Topical regions: high latitudes and developing countries*
- *Multidisciplinary observations and modelling of land-atmosphere-society interactions*



Integrated Land Ecosystem - Atmosphere Processes Study

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Free-Air CO_2 Enrichment study for paddy rice on nitrogen cycle (FACE-N) at Tsukuba FACE, Japan

The National Institute for Agro-Environmental Sciences, Japan, established a new Free-Air CO_2 Enrichment (FACE) facility for paddy rice in central Japan (Tsukuba FACE) in April 2010. Early FACE studies were originally designed to investigate changes in plant growth, crop yield, and carbon cycle under elevated CO^2 and temperature. In addition to these research agenda, a three-year project at Tsukuba FACE that assesses the changes in nitrogen cycle due to climate manipulation (FACE-N) started in April 2010. The FACE-N project has the following themes: (i) atmosphere-paddy exchange of nitrogen; (ii) nitrogen-related processes in an atmosphere-soil-rice system; and (iii) development of nitrogen cycling model at a plot scale and of regional nitrogen cycling model using remote-sensing technique and geographic information system (GIS) based on the plot-scale model.

Tsukuba FACE (35°58'27"N, 139°59'32"E, 10 m asl) has four bays of paddy fields, each of which has one ambient and one FACE plot (Fig. 1). The FACE plots are exposed under CO_2 levels elevated by averagely 200 ppm to the ambient levels [1]. For the three themes, we have monitored several variables for three years such as wet deposition and air concentrations of nitrogen compounds; NH_3 emission potentials from flag leaves of paddy rice [2]; N_2O fluxes and their isotopic signature at the atmosphere-paddy interface and in the soil [3]; and nitrogen relevant processes such as mineralization and biological nitrogen fixation in combination with long-term investigations on soil organic matter abundance. We have also been developing a multi-layer model for an atmosphere-soil-vegetation system (SOLVEG) [4] to simulate the transfer of water, heat, and gaseous and particulate matters between paddy fields and the atmosphere on an hourly basis, and another mechanistic model to simulate the soil and paddy rice related processes (DNDC-Rice) [5]. Our results show emission tendencies of NH_3 from the paddy field during the cropping season; however, the paddy field was a sink of atmospheric reactive nitrogen with a net deposition flux of approximately 15 kg N ha^{-1} yr^{-1}. Drainage of the paddy fields resulted in occasional N_2O emissions. We tested the SOLVEG using micrometeorological dataset obtained at a nearby paddy field as a registered site of the AsiaFlux, a regional monitoring network for the exchanges of carbon dioxide, water vapour, and energy between terrestrial ecosystems and the atmosphere, and confirmed well reproducibility of the model for the atmosphere-paddy field exchanges of water and energy. ■

This study was supported by the Japan Society for the Promotion of Science. Tsukuba FACE was established and maintained by a project, "Development of mitigation and adaptation techniques to global warming in the sectors of agriculture, forestry, and fisheries", provided by the Ministry of Agriculture, Forestry and Fisheries, Japan.

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References

1. Nakamura and Tokida *et al.* 2012. Journal of Agricultural Meteorology 68:15-23.
2. Hayashi K *et al.* 2011. Agriculture, Ecosystems & Environment 144, 117-123.
3. Yano *et al.* 2012. Abstract of Japan Geoscience Union Meeting 2012, MIS21-P09.
4. Katata *et al.* 2011. Progress in Nuclear Science and Technology 2, 530-537.
5. Katayanagi *et al.* 2012. Soil Science and Plant Nutrition 58, 360-372.

Figure 1: Tsukuba FACE fields.

iLEAPS-Japan meeting at the 3rd International Symposium for Arctic Research (ISAR-3)

15 January 2013
Tokyo, Japan

iLEAPS Executive Officer Tanja Suni and iLEAPS-Eurasia Executive officer Hanna Lappalainen travelled to the 3rd International Symposium of Arctic Research (ISAR-3) in mid-January with the aim to create new collaboration between iLEAPS, iLEAPS-Eurasia, and Japanese and Russian scientists. One of the main points of collaboration was the Pan-Eurasian Experiment (PEEX), a new iLEAPS project coordinated by iLEAPS-Eurasia at the Division of Atmospheric Sciences in the University of Helsinki. The Finnish delegation also included Joni Kujansuu, the Finland-Asia coordinator of the Division working part-time for iLEAPS.

The delegation met five members of the Science Committee of iLEAPS-Japan in a small satellite meeting in the second evening of the conference. All the Japanese researchers present at the meeting are leading scientists in fields very relevant to either the new iLEAPS theme Sustainable Managed Ecosystems or to the Pan-Eurasian Experiment or both; Drs Takeshi Ohta, Tetsuya Hiyama, and Ayumi Kotani have more than 15 years of experience with land-atmosphere-society interactions in Eastern Siberia (http://www.chikyu.ac.jp/rihn_e/project/C-07.html) whereas Dr Kentaro Hayashi is a core member of a large manipulation experiment on Japanese rice paddies in Tsukuba, looking at the influence of CO_2 enrichment on carbon cycles, and, uniquely in Japan, also on nitrogen cycles throughout the year (Free Air CO_2 Enrichment experiment FACE http://www.niaes.affrc.go.jp/outline/face/english/index.html; with nitrogen, FACE-N). The website of iLEAPS-Japan is now available in English as well; this will enable European scientists to keep track of the many land-atmosphere research activities in Japan especially around AsiaFlux, where the leader of iLEAPS-Japan, iLEAPS SSC member Dr Nobuko Saigusa and iLEAPS-Japan coordinator Sawako Tanaka work actively to widen the flux measurement network in Japan, Korea, and other parts of Asia. iLEAPS-Japan and coordinator Joni Kujansuu will also conduct enquiries in the Philippines in order to organise regional land-atmosphere-society activities there; one of the first steps will be an iLEAPS-AsiaFlux early-career scientist workshop in 2014.

iLEAPS IPO and iLEAPS-Eurasia would like to extend a warm thank you for the entire iLEAPS-Japan group for a very pleasant and fruitful meeting!

iLEAPS-Japan

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ILEAPS-Japan committee members can be found at:
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Hans-Christen Hansson
New Co-chair, Executive Committee member
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Hans-Christen Hansson is professor in Air pollution and Head of the Department of Applied Environmental Science (ITM) at Stockholm University, Sweden. His present work focuses on the life cycle of atmospheric particles, and especially on how atmospheric particles influence the radiation budget, both directly through scattering of radiation and indirectly through their influence on the clouds and their effect on the radiation balance. Influence on health is a growing concern, which drives his involvement connecting urban research with the regional focused research. Prof. Hansson was one of the founding partners in the major EU projects EUCAARI and EUSAAR. He is also a scientific leader in several national projects focused on air quality and climate effects and interaction. Prof. Hansson is especially interested in developing regional and global networks of observation stations within the iLEAPS community.

Jason Shogren
New SSC member
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Jason Shogren is the Stroock Professor of Natural Resource Conservation and Management and Chair of the Department of Economics and Finance at the University of Wyoming. He works on the economics of environmental and natural resource policy, focussing on the behavioural underpinnings of choice, the integration of economics and ecology, and the design of incentives for conservation. Prof. Shogren is a Fellow of the American Applied Economics Association and the Beijer Institute for Ecological Economics. He is also a foreign member of the Royal Swedish Academy of Sciences, and has served as professor to the King of Sweden, as a lead author for the Intergovernmental Panel on Climate Change, and as a senior economist on the Council of Economic Advisers in the White House. In iLEAPS, Prof. Sjogren will provide an applied economist's view for global sustainability – related research.

Sirkku Juhola
New SSC member
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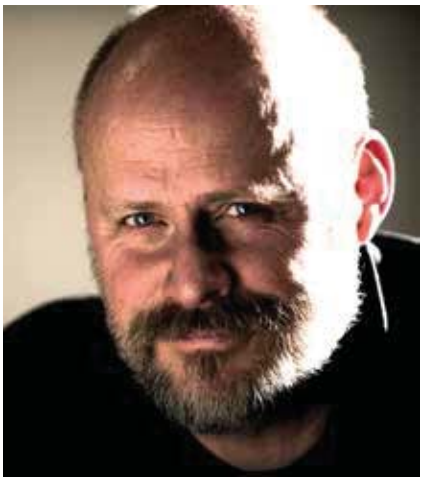
Dr. Juhola is a visiting scholar at the Department of Real Estate, Planning and Geoinformatics at Aalto University, Assistant Professor in urban environmental policy at the Department of Environmental Sciences, University of Helsinki, and Adjunct Professor of social and public policy at the University of Jyväskylä, Finland. She is interested in climate change adaptation in both developed and in developing countries. Dr. Juhola has previously worked for several years in Japan and different parts of Africa. Dr. Juhola's interests include adaptation, agricultural economics, biodiversity, and governance issues related to climate change in both developed and developing countries. In addition to working and leading several international projects, Dr. Juhola is a member of the Finnish Ministry of Environment's Climate Panel. Dr Juhola's aim in iLEAPS is to bring an adaptation and policy view to iLEAPS research on land-atmosphere-society interactions.



Several iLEAPS-relevant meetings and workshops took place in 2012 and in the beginning of 2013.

18th iLEAPS Scientific Steering Committee meeting

30-31 October 2012, Helsinki, Finland

In its 18th meeting, the iLEAPS SSC decided

1. to focus on developing the regional nodes in the key regions identified (see News for additional information);

2. to accept the offer by iLEAPS-China to host the next iLEAPS Scientific Conference in Nanjing University, China, in May 2014;

3. to confirm Dr. Alex Guenther and Professor HC Hansson as iLEAPS co-chairs for 2013-2015. Former co-chair Prof. Markku Kulmala continues as a member of the Executive Committee.

The SSC started planning the iLEAPS Action Plan for the next 3-4 years. Emerging themes in the Plan will be regional issues and land-atmosphere-society interactions. The next SSC meeting will take place on 12-13 April 2014 in Vienna, Austria.

Sat-ACPC final workshop

14-15 February 2013, Bern, Switzerland

Sat-ACPC (Remote Sensing applications in Aerosol-Cloud-Precipitation-Climate Interactions) is one of the key projects of iLEAPS. The main objective of the Sat-ACPC team is to make significant strides in understanding the interplay among the aerosol, clouds and precipitation, and the way these interactions are forcing the climate system.

Eight representatives of the Sat-ACPC community together with iLEAPS Executive Officer Tanja Suni participated in the final workshop of the project. The workshop aimed to edit and advance a large review and recommendation report regarding aerosol-cloud-climate-precipitation interactions and the observation campaigns and next steps required to solve the open scientific questions. The draft report will be circulated within the wider ACPC community and discussed at the upcoming iLEAPS SSC meeting in Vienna together with ACPC, Sat-ACPC, and ESA (European Space Agency) representatives. More information on ACPC and Sat-ACPC: http://www.ileaps.org/multisites/acpc/.

iLEAPS-Japan and iLEAPS IPO meeting

15 January 2013, Tokyo, Japan

Five members of the iLEAPS-Japan Science Committee participated at the meeting together with iLEAPS Executive Officer (EO) Tanja Suni, iLEAPS-Eurasia EO Hanna Lappalainen and Joni Kujansuu, the Finland-Asia coordinator at Division of Atmospheric Sciences, University of Helsinki.

The meeting concentrated on presenting the current activities within iLEAPS-Japan and sharing ideas of possible future directions. The main activities iLEAPS-Japan is concentrating on at the moment are (1) widening the AsiaFlux network in Japan and near regions; (2) land-atmosphere-society interactions research in eastern Siberia; (3) free-air CO_2 enrichment experiments on Japanese rice paddies; (4) creating a network of iLEAPS-related scientists in Japan and also in the Philippines and other near regions; (5) developing outreach activities: expanding the English website and iLEAPS-Japan mailing list and possibly starting a Japanese Newsletter or bulletin.

More information on iLEAPS-Japan can be found in the News section and on the website: http://ileaps-japan.org/.

Third International Symposium on Arctic Research (ISAR-3)

14-18 January 2013, Tokyo, Japan

The theme of ISAR-3 was "Detecting the change in the Arctic System and searching the global influence." The symposium followed on ISAR-1 "Drastic Change under the Global Warming" and ISAR-2 "Arctic System in a Changing Earth". iLEAPS EO Tanja Suni and iLEAPS-Eurasia EO Hanna Lappalainen gave presentations about iLEAPS and the Pan-Eurasian Experiment (PEEX), respectively.

Pan-Eurasian Experiment (PEEX) meetings

2-4 October 2012, Helsinki, Finland
12-14 February 2013, Moscow, Russia

PEEX is a multidisciplinary climate change, air quality, environment and research infrastructure program focused on the Northern Eurasian, particularly Arctic and boreal regions. It is a bottom up initiative by several European, Russian and Chinese research organizations and institutes.

The 1st PEEX workshop was coordinated by the University of Helsinki and Finnish Meteorological Institute (FMI) and was held in Helsinki on 2-4 Oct 2012. Over 80 participants from 42 research institutes from Russia, China and 11 European countries participated in the workshop. The main outcome of the WS was the first outline of PEEX Science Plan.

The 2nd PEEX workshop was held in Moscow on 12-14 Feb 2013. The participants decided to finalise the Science Plan in spring 2013 and to produce a detailed Implementation Plan by the end of 2013.

PEEX is an important project under the iLEAPS umbrella and is coordinated by iLEAPS-Eurasia EO Hanna Lappalainen and Senior Researcher Tuukka Petäjä, both from the Division of Atmospheric Sciences at University of Helsinki. The preparatory Committee of PEEX is represented by Prof. Markku Kulmala (Univ. Helsinki) and Prof. Sergej Zilitinkevich (FMI).

PEEX is open for other institutes to join in. More information on the project can be found here: www.atm.helsinki.fi/peex.

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iLEAPS-ENDORSED PROJECTS AND RESEARCH INITIATIVES

ABBA
Advancing the Integrated Monitoring of Trace Gas Exchange between Biosphere and Atmosphere

ACPC
Aerosols, Clouds, Precipitation and Climate Research Program

Sat-ACPC
Remote Sensing Aerosols, Clouds, Precipitation and Climate Interactions

LULCC
Land Use and Land Cover Change

ALANIS
Atmosphere-LANd Integrated Study in the boreal zone

AMMA
African Monsoon Multidisciplinary Analyses

FLUXNET
International Network Measuring Terrestrial Carbon, Water and Energy Fluxes

FIRE Task

GEIA
Global Emissions InitiAtive

GLACE -CMIP5
Global Land-Atmosphere Coupling Experiment

HENVI Forests and Climate Change

IBBI
Interdisciplinary Biomass Burning Initiative

IMECS
Interactions among Managed Ecosystems, Climate, and Societies

LUCID
Land-Use and Climate, Identification of robust impacts

LULCC
Land Use and Land Cover Change

METHANE LOSS FROM THE ARCTIC

NEESPI
Northern Eurasia Earth Science Partnership Initiative

PEEX
Pan-Eurasian Experiment

TAITA
Multidisciplinary Research Station in Kenya

WELGEGUND
Observation Platform in South Africa