GEWEX-iLEAPS LandFlux Workshop
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The GEWEX Radiation Panels (GRP) LandFlux initiative is focused on developing an operational approach for routine production of a multi-decadal global land based surface flux data set: in recognition of a current lack of such data in the Earth science community. As part of this effort, a one-day workshop was organized to coincide with the joint GEWEX-iLEAPS "Water in a Changing Climate" conference held in Melbourne, Australia this past August. The workshop, attended by over thirty people from around the world, brought together researchers with expertise and interest in the estimation of land surface turbulent fluxes of heat and water to discuss the current state of the art in global flux estimation techniques.

The workshop focused on three broad topics, encompassing a range of flux estimation and evaluation efforts currently being developed within the research and operations community. These included a review of:

- Remote sensing based data sets and approaches
- Model based estimation techniques
- Validation data sets and intercomparison efforts.

Specific objectives of the meeting were to: 1) review the current state of the art in global flux estimation techniques; 2) compile an inventory of available global surface heat flux products, spanning observationally-based (in situ and satellite), model-based, and mixed observation-model approaches; 3) develop a program for systematic intercomparison of these different approaches; and 4) identify options for an operational approach and the needed protocols in producing such data sets. Chris Kummerow and Peter Van Oevelen opened the meeting by identifying the motivation, objectives and desired outcomes for the day's proceedings.

The first session on remote sensing based approaches heard from Bill Rossow, Eric Wood, Carlos Jimenez, Ray Leuning and Joshua Fisher on a variety of satellite based estimation techniques. These efforts encompassed empirical and statistical approaches, as well as more physically based energy balance techniques. A number of these talks presented results from global flux data sets that have recently been produced for selected periods, across a range of spatial and temporal resolutions, illustrating that the development of a multi-decadal product is progressing well.

The second session on model based estimation techniques included talks by Mike Bosilovich, Christa Peters-Lidard, Paul Dirmeyer, Matt Rodell and Sonia Seneviratne (on behalf of Gianpaolo Balsamo), that all reviewed on-going efforts by groups within NASA and meteorological operational centres to produce and assess information on global water and energy cycles. Multi-model analyses and ensemble approaches, global land data assimilation schemes and systems, and new re-analysis products were reviewed. The synergy between remote sensing and other model based approaches was highlighted, particularly with regards to the capacity of both approaches to inform and improve each other.

The final session focused on validation data and also on product intercomparison efforts. Presentations by Dennis Baldocchi and Markus Reichstein highlighted some of the recent developments with FLUXNET data and presented a new data set derived from the upscaling of FLUXNET measurements. Eleanor Blythe presented a summary of the recent Evaporation

Symposium, held at the Centre for Ecology and Hydrology (CEH) at Wallingford, UK in July. At the end of the session, Sonia Seneviratne presented initial results of the intercomparison exercise of global data sets that had been submitted by a number of participants prior to the workshop, and outlined plans for the new LandFlux-EVAL activity.

Discussion during each of the sessions was active, with participants offering perspectives from research areas spanning in-situ measurement, land surface model output and remote sensing estimation approaches. There was clear recognition that a global land surface product would fill a critical gap in advancing our knowledge of the global water and energy cycle behaviour. In identifying a path forward to achieving this, it was apparent from the initial intercomparison exercise that a comprehensive evaluation and intercomparison of presently available products is a priority. This will be undertaken as part of the new LandFlux-EVAL activity.

The preliminary intercomparison of the submitted global products, based on analyses of the Observatoire de Paris (1993-1994) and ETH Zurich (1989-1995/2006), proved to be an extremely interesting and valuable exercise, particularly in identifying consistencies and disparities between remote sensing and other model based estimation approaches. While there seemed to be generally good agreement between spatial patterns among the various approaches, there was also a large range in values across many regions of the world (Fig. 1). Identifying the causes and mechanisms producing these differences, model dependencies and sensitivities and the complicated issue of how to actually evaluate global products remains a major challenge. The LandFlux-EVAL intercomparison effort will shed more light on addressing these important issues.

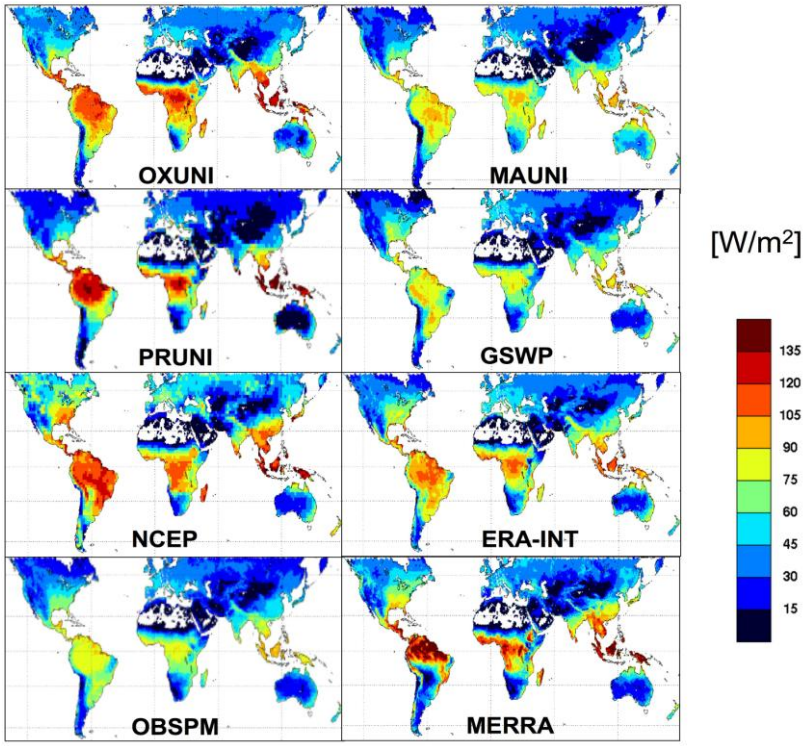

Figure 1. Yearly averaged latent heat fluxes for 1993 from a suite of different products. The following products are displayed: (a) four remote sensing products from Oxford University (OXUNI, provided by Joshua Fisher), the University of Maryland (MAUNI, provided by Kaikun Wang), Paris Observatory (OBSPM, by Carlos Jimenez), and Princeton University (PRUNI, by Justin Sheffield and Eric Wood);(b) Land surface model estimate from the GSWP-2 multi-model ensemble; (c) three reanalysis estimates (MERRA, NCEP-DOE and ERA-INTERIM). ***Note that these data represent a subset of products considered as part of LandFlux-EVAL*****.**

A key outcome of the workshop was the recognition that there are already a number of groups independently pursuing global scale estimation of flux components. These products vary in terms of

the forcing data used, the governing equations employed, and the spatial and temporal scales of their application. The GEWEX LandFlux activity will provide a framework for undertaking coordinated evaluation and assessment of these various products, ultimately identifying and delivering a robust procedure for operational production of a global land surface flux data set to improve climate scale water and energy cycle characterisation. A plan for product development and the identification of specific activities and tasks required to achieve this, was discussed in the final session of the workshop. Key action items included:

- Initiate Working Groups to focus on: 1) remote sensing based approaches; 2) land surface model estimates; and 3) forcing and evaluation data-sets (including radiation, meteorology, vegetation, and landscape characteristics). These working groups will assist in identifying appropriate approaches for product development, examine uncertainty in forcing data and and establish protocols for dealing with multi-model output.

- Expand the workshop based intercomparison exercise into a focused activity (LandFlux-EVAL), that will include multi-scale (spatial and temporal) data sets, assessment over longer time-periods, and identification of specific regions for focused analysis. ETH Zurich and the Observatoire de Paris are the contact institutions for this activity (see http://www.iac.ethz.ch/url/LandFlux-EVAL).

- Identify regional scale test-beds over which detailed assessment can be undertaken. The collection and compilation of data to evaluate and assess model output is a major task. The CEOP Regional Hydroclimate Projects (RHPs) provide an obvious focus for evaluation efforts. Acquiring the needed forcing and validation data over these RHPs will be critical in advancing the LandFlux product. Contact with CEOP and RHP coordinators will be made to access these data-sets.

The amount of activity in this area encourages the belief that well-evaluated global products of land surface turbulent fluxes of heat and water can be produced soon. It is anticipated that these activities will culminate in the development of a GEWEX LandFlux data set, completing the suite of GRP water and energy cycle products and provided a new source of information with which to better understand climate scale interactions within the Earth system.