- Survey the pedotransfer functions that are used in global climate models.
- Carry out a sensitivity analysis.
- Set up a soil parameter MIP.
- Seek or develop a modeling case study in which several soil models are run to model fluxes (of mass and energy) that are relevant for climate models. This could be developed into a MIP, or become part of a MIP that is already running. Joining existing MIPs has the strategic advantage of connecting with the climate science community.
- Establish a global database for historical and current groundwater levels.

Summary

The workshop was successful in galvanizing interaction between the communities and highlighted the commitment and interest in finding ways to cooperate for improving soil and subsurface processes in climate models and informing the soil communities of climate model capabilities and opportunities. A perspective paper will be written to clarify the needs, objectives and future directions of the GEWEX SoilWat Initiative. A second GEWEX-SoilWat planning workshop is planned in 2017 to report on progress and discuss items not addressed at this workshop, such as soil and plant processes and human interactions.

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Resources

Soil maps at various resolutions (90 m to 1 km) on global and continental scales are available at the International Soil Reference and Information Centre (ISRIC, *http://www.isric.org/*).

Five quantitative SSPs were developed by ICONICS (*https://www2.cgd.ucar.edu/research/iconics*; *https://www2.cgd.ucar.edu/research/iconics/background*). These SSPs are available at: *https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about*. The International Institute for Applied Systems Analysis (IIASA) and the National Center for Atmospheric Research (NCAR) developed population and urbanization scenarios for each of the SSPs. For GDP, three alternative interpretations of the SSPs by the teams from the Organization for Economic Cooperation and Development (OECD), IIASA and the Potsdam Institute for Climate Impact Research (PIK) have been developed.

ERA-Interim is a global atmospheric reanalysis from 1979 that is continuously updated in real time. It is available from the European Centre for Medium-Range Weather Forecasts (ECMWF; *http://www.ecmwf.int/en/research/climate-reanalysis/era-interim*). The system includes a 4-dimensional variational analysis with a 12-hour analysis window. The spatial resolution of the data set is approximately 80 km on 60 vertical levels from the surface up to 0.1 hPa.

GLASS Science Panel Meeting

3–5 October 2016
Gif-sur-Yvette, France

Michael Ek[1], Gab Abramowitz[2] and Aaron Boone[3]
[1]NCEP Environmental Modeling Center, College Park, MD, USA; [2]Climate Change Research Centre, University of New South Wales, Sydney, Australia; [3]CNRM, Météo France, Toulouse, France

The Global Land/Atmosphere System Study (GLASS) Science Panel Meeting was held at the Université Paris-Saclay Centre/National de la Recherche Scientifique (CNRS) with 17 Panel members and guests attending. Community activities under the three GLASS Panel elements were reviewed, including: (i) land model benchmarking to improve understanding and representation of land-surface processes; (ii) understanding of land-atmosphere interaction and feedbacks; (iii) data model fusion; and (iv) crosscutting activities.

Local Land-Atmosphere Coupling (LoCo) Project

LoCo, which is led by Joseph Santanello, has reached its 10-year anniversary. The LoCo Working Group (WG) has 15 members and many of them are early career scientists. Its focus is on accurately representing the relationship between soil moisture, precipitation and coupling strength in models (e.g., Dirmeyer and Halder, 2016). To have the proper understanding and related model improvements, it is necessary to carefully examine and quantify the full series of interactions (i.e., links in the chain) at the process level, including boundary layer feedbacks. The WG is tackling the development of quantitative process-based metrics and diagnostics of land-atmosphere (L-A) coupling (see figure on the cover) that can be applied to observations as well as to models across scales, where many studies and publications from the WG in recent years have concentrated on various metrics, models and applications.

Field campaigns have been a point of emphasis, including the enhanced sonde at the Department of Energy (DOE) Southern Great Plains (SGP) site (Craig Ferguson, Joseph Santanello, Pierre Gentine) in summer 2015, improved soil moisture and co-located L-A measurements from the DOE Atmospheric Radiation Measurement Program (ARM; Joseph Santanello), New York State Mesonet (Craig Ferguson) and the Land-Atmosphere Feedback Experiment [LAFE; Volker Wulfmeyer, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA)] at SGP in summer 2017. The LoCo WG is suggesting that the Coupled Model Intercomparison Project-6 (CMIP6), via Global Soil Wetness Project Phase 3, and the Land Surface, Snow and Soil Moisture Model Intercomparison project (LS3MIP) include an increased set of L-A variables in the standard output of participants. LoCo has the closest links with the GEWEX Atmospheric Boundary Layer Study (GABLS) and the GLASS-GABLS Diurnal Coupling Experiment (DICE), due to the inherent importance of the boundary layer and model development in each. In the future, LoCo

will continue to follow and broaden the science of LoCo and WG participation, synthesize what we have now in terms of metrics and message, and engage and entrain the operational and model development communities. See the LoCo website (*http://www.gewex.org/loco*). Paul Dirmeyer also provides a synthesis of the project at *http://cola.gmu.edu/dirmeyer/Coupling_metrics.html* and the LoCo coupling metrics toolkit by Ahmed Tawfik is available at *http://www.coupling-metrics.com*.

Protocol for Analysis of Land Surface Models (PALS)

Gab Abramowitz reviewed the PALS Project, a web application designed for automated evaluation and benchmarking of land-surface models (LSMs). PALS hosts experiments that include: (i) data sets required to force or constrain a model for a particular experiment; (ii) model outputs uploaded by users (who run their models locally), including ancillary files; and (iii) automated analyses of model outputs, compared with evaluation data products, other models and empirical benchmarks. The first-generation PALS site had around 250 users from more than 60 institutions, and was used for the LSM Model Intercomparison Project (MIP) "PLUMBER," described below. The second-generation PALS system is in testing and development and will be more flexible, with user-defined benchmarks. Structured to allow the original PALS analysis suite, it will also integrate other existing packages, such as International Land Model Benchmarking Project (ILAMB, in Python) or the NASA Land Validation Toolkit (LVT, in Fortran), with use of a relatively simple wrapper. With all source code public on GitHub and coding structures built for team development, the future aim for PALS is to get the second-generation system functioning and adopted by the community as its own project.

PALS LSM Benchmarking Evaluation (PLUMBER) Project

Gab Abramowitz also summarized the PLUMBER project, an LSM MIP using the PALS system, designed to highlight the importance of benchmarking over traditional evaluation; that is, defining performance expectations a priori. In defining benchmarks before model simulations are performed, we can help answer the question of whether a group of models is performing well or not, as opposed to simply identifying which models perform better or worse than others. To achieve this, PLUMBER used two first-generation LSMs and three empirically based models (testing out-of-sample) as a way to set performance expectations. Results for sensible and latent heat flux were compared at 20 flux tower sites across nine International Geosphere-Biosphere Programme (IGBP) vegetation types, using eight different performance metrics. The key result from the original PLUMBER paper (Best et al., 2015) was that despite clearly performing better than older LSMs, current generation LSMs as a whole were not utilizing the information available in their input data about latent and sensible heat fluxes. The second paper by PLUMBER participants (Haughton et al., 2016) investigated whether or not this result was because of methodological flaws in the original PLUMBER experiment (i.e., whether lack of energy conservation in flux tower data, time scale of analysis, diurnal biases, poor LSM initialization, metric value aggregation or site choices might have been responsible for the original result). The paper concluded that the most plausible explanation for the result was a shared weakness among LSMs, noting that the mean of all participating LSMs did not show a radical improvement in performance (suggesting that LSM error correlation is high). Follow-on LSM benchmarking studies are continuing.

International Land Model Benchmarking (ILAMB) Project

David Lawrence provided an update on the ILAMB Project and its goals to develop internationally accepted LSM evaluation experiments; promote the use of these benchmark experiments; support the design and development of open source benchmarking tools; and strengthen links among experimental, remote sensing and climate modeling communities in the design of new model tests and new measurement programs. ILAMB is mainly led and funded through the U.S. DOE Regional Climate Modeling Program. It is integrated with all the land MIPs in CMIP6 (LUMIP, LS3MIP, C4MIP) and will serve as one of the land analysis packages for CMIP6 and related MIPs. In the future, ILAMB will continue to be augmented with new metrics introduced by international collaborators, and will be utilized in CMIP6 assessments, including assessments of LS3MIP land-only simulations. Collaboration with PALS is under discussion.

Global Soil Wetness Project Phase 3 (GSWP3)

Hyungjun Kim outlined the status of GSWP3, a global offline LSM MIP with meteorological forcing at 0.5 degree developed specifically for this project. It will also be used for the Land Surface, Snow and Soil moisture Model Intercomparison Project (LS3MIP) and SoilWat (both described below). The "fast-track" phase of initial simulations using a preliminary version of the forcing data is complete, as is analysis with the ILAMB package. The goal was to test the forcing within a subset of the LSMs in order to identify any issues (which, in turn, could result in changes or updates to the input forcings), a critical step as the model simulations should have the best possible forcing data as inputs. Significant effort has been expended on refining the forcing data (due to be frozen in May 2017). GSWP3 is also tied in with LS3MIP under its offline component, LMIP (which is endorsed as part of CMIP6). While GSWP3 simulations will run off the 0.5-degree forcing grid, LS3MIP model output is intended to match coupled simulations as closely as possible and so will run on each coupled model's grid. In order to remain consistent with CMIP6, a long-term retrospective GSWP3 experiment (EXP1) starts in 1850, with prescribed land-use and land-cover changes derived from the Land Use Harmonization (LUH) data set. Results submissions are due mid-2017, and GSWP3 land reanalysis fields are expected to be released in late 2017.

Hyungjun Kim and Sonia Seneviratne provided additional updates on LS3MIP, part of the CMIP6 experiment suite to assess land-surface, snow and soil moisture feedbacks on climate variability and climate change. It focuses primarily on the physical system with two phases: LMIP (offline) and LFMIP (coupled, with feedbacks), including coordinated SnowMIP model intercomparisons, while carbon cycle and vegetation dynamics are covered in more depth by CMIP complements

C4MIP and LUMIP respectively (more on LUMIP below). A detailed description of the protocol was published by van den Hurk et al. (2016).

New GLASS Projects

New projects include the Land Use Model Intercomparison Project (LUMIP) led by David Lawrence in collaboration with the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS), where LUMIP is one of the CMIP6 satellite MIPs and therefore is integrated with all CMIP6 activities (Lawrence et al., 2016). LUMIP aims to further advance understanding of the impacts of land-use and land-cover change (LULCC) on climate, and is a follow-up to the previous GLASS project called Land Use and Climate–Identification of robust impacts (LUCID). LUMIP includes a two-phase experimental design where phase one features idealized coupled and land-only model simulations designed to advance process-level understanding of LULCC impacts on climate, as well as to quantify model sensitivity to potential land-cover and land-use change. Phase two LUMIP experiments focus on quantification of the historic impact of land use and the potential for future land management decisions to aid in mitigation of climate change.

Also new is the GEWEX Soils Initiative (SoilWat), presented by Dani Or. The goal of SoilWat is to examine how soil processes are represented in land-surface models and how to bridge scales between traditional soil models and representation relevant to climate modeling, including the effective incorporation of groundwater models. Following the first GEWEX-SoilWat planning workshop from 28-30 June 2016 in Leipzig (see workshop report on page 7), the LSM community is being surveyed about existing treatment of soils, soil maps, groundwater databases and handling in models.

Other GLASS Projects Reviewed

Additional programs reviewed included the Project for the Intercomparison of Land Data Assimilation Systems (PILDAS), presented by Sujay Kumar. The PILDAS initiative is being reinvigorated and is expected to help in the development of best practices in land data assimilation systems for the optimal exploitation of the information content of remote sensing data.

Aaron Boone summarized the status of the African Monsoon Multidisciplinary Analysis (AMMA) Land Surface Intercomparison Project-Phase 2 (ALMIP2). The project is nearing completion, having sought to improve understanding and modeling of key surface vegetation and hydrological processes over West Africa (e.g., large rooting depths, near-surface aquifers, soil crusting, lateral transfer processes and strong runoff variability). A number of ALMIP2 papers were submitted in 2016 for the ALMIP2 special collection. Possible future work for ALMIP2 includes expanding LoCo studies to the AMMA region. Pere Quintana Seguí provided links with the GEWEX Hydroclimatology Panel (GHP) such as land-atmosphere data sets that will help in process-level studies in the Hydrological Cycle in the Mediterranean Experiment (HyMeX).

The new Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) Project was presented by Martin Best. LIAISE could involve GHP, GLASS, and GABLS, as well as iLEAPS. There is a relevant session to LIAISE at the European Geophysical Union Meeting in April on the changing Mediterranean environment.

As GLASS liaison, Paul Dirmeyer provided updates on the joint GEWEX-Climate and Ocean: Variability, Predictability and Change (CLIVAR) Sub-seasonal to Seasonal (S2S) Project where there is a potential contribution of the land to predictability on S2S timescales, and on the WCRP-World Weather Research Programme (WWRP) Monsoon Panel where land-atmosphere interactions are important within monsoons. Joseph Santanello, GLASS representative to the WCRP Modeling Advisory Council (WMAC), noted the GLASS contributions in promoting model development and coordination across WCRP. Similarly, Mike Ek, GLASS representative to the Working Group on Numerical Experimentation (WGNE), also brought up the importance of GLASS activities for data assimilation and process-level improvement to model physical parameterizations.

Finally, possible future process-level studies on snow (SnowMIP, as presented by Gerhard Krinner) and permafrost (presented by David Lawrence) could involve GLASS collaborations with iLEAPS, the Climate and Cryosphere (CliC) Project, and with other GEWEX Panels as partners.

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