GLASS Panel 2019 Annual Meeting

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The 2019 Global Land/Atmosphere System Study (GLASS) Panel Meeting was held over three days in early August at the National Center for Atmospheric Research (NCAR)'s Foothills Lab in Boulder, Colorado. About twenty-five people participated in the event. A recurring theme was the need for coordinated observations to improve understanding of the land-atmosphere system in different climatic regimes and confront and improve Earth system models. The meeting covered a range of topics including project updates, exploration of mutual interests between GLASS and other GEWEX Panels, and presentations from new GLASS members. We heard about numerous observationally-driven initiatives, including the Land-Atmosphere Feedback Experiment (LAFE) field campaign at the Southern Great Plains site in Oklahoma and Kansas, and the associated Land-Atmosphere Feedback Observatory (LAFO) at Hohenheim University; the upcoming Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) experiment in Spain; and the Bedrock to Boundary Layer meeting as a National Oceanic and Atmospheric Administration (NOAA)-centered initiative to address these issues. The Local Land-Atmosphere Coupling (LoCo) project update included mention of a handful of other important field campaigns and/or new monitoring stations [the Great Plains Irrigation Experiment (GRAINEX), Nebraska, USA; the Ruisdael Observatory, The Netherlands; the Finse Eco-Hydrological Laboratory, Norway]. On the final day, we discussed a proposal presented by Volker Wulfmeyer for GLASS Land-Atmosphere Feedback Observatories (GLAFOs), building on the success of LAFE and LAFO. All of these field efforts stem from the recognition that the evolution of clouds and precipitation is dependent on the evolution of the boundary layer (BL), which has long been difficult to adequately observe and monitor. Recent advances in instrumentation are now making better BL observations a reality.

The GLAFO vision includes defining a standard set of measurement devices that would allow for full and continuous characterization of the boundary layer, surface layer, soil profile and vegetation, and installing these suites of devices at various sites in different climatic regimes. We intend to follow-up with this meeting discussion by first determining where existing field sites can be augmented to include the full suite of GLAFO instruments, and then by writing a paper outlining the justification and benefits of a consistent and compatible measurement platform at different field locations. We are hopeful that international and national funding agencies will hear this unified voice from the land-atmosphere scientific community as an opportunity to advance land-atmosphere interaction science rapidly.

In addition to these themes, we heard research presentations from two new Panel members, Nate Chaney and Samiro Khodayar Pardo. We also heard brief reports on various GLASS-relevant activities including efforts at National Aeronautics and Space Administration (NASA)-Goddard to model irrigation (Patricia Lawston), single-column modeling work at NCAR (Grant Firl), precipitation downscaling efforts at the University of Kansas (Joshua Roundy), research from the Geophysical Fluid Dynamics Laboratory (GFDL) on the changing continental hydrologic cycle (Kirsten Findell), efforts at NCAR related to the North American Coordinated Regional Climate Downscaling Experiment (CORDEX) project (Rachel McCrary) and research on water security projections from NCAR (Flavio Lehner).

The GLASS Panel meeting was an excellent forum for sharing advances in observing and modeling the land and land-atmosphere system. We look forward to building on the progress and momentum of the meeting in the months ahead.

LoCo Project

The LoCo project and working group update was presented by Joseph Santanello. LoCo consists of 18 international scientists across academia and government, with a LoCo review article recently published in the *Bulletin of the American Meteorological Society* (Santanello et al., 2018) summarizing the last decade of research. LoCo has identified three near-term objectives that it has made significant progress on: 1) promoting the importance and development of improved observations of the land-atmosphere (L-A) system, namely planetary boundary layer (PBL) profiles, as well as improved utilization of soil moisture and surface flux measurements in models; 2) pursuing adoption of LoCo metrics by operational numerical weather prediction (NWP) and climate centers; and 3) expanding the scope and reach of LoCo in terms of processes and scale beyond that of warm season thermodynamics and beyond that of 1-D column assumptions. Progress on those goals is evident in the recent NASA Decadal Survey prioritization of PBL measurements and spaceborne mission concepts, and in the new NOAA/U.S. Department of Energy (DOE) Climate Process Team (including six GLASS panel members) tackling the difficult issue of communicating subgrid-scale heterogeneity between the land and the atmosphere. Numerous proposals are being submitted to other funding agencies to address remaining goals and continue this momentum of LoCo outreach to the scientific, modeling and observational communities.

SoilWat

Anne Verhoef reported on the GEWEX Soil and Water (SoilWat) Initiative GLASS working group, which has as its main objective to improve the representation of water-related soil and subsurface processes in land models (LMs) and climate models, and to identify the most pressing challenges and topics related to this effort. This activity has already produced review papers on pedotransfer functions (PTFs) and on infiltration, as well as related datasets (Van Looy et al., 2017; Vereecken et al., 2019). During the meeting, Anne gave an overview of a selected number of SoilWat activities relating to

the assessment and improvement of PTFs used in land models, and the incorporation and assessment of the effects of soil structure on land surface fluxes on the plot and global scale.

LUMIP and ILAMB

David Lawrence presented updates for both the Land Use Model Intercomparison Project (LUMIP) and the International LAnd Model Benchmarking Project (ILAMB). LUMIP simulations are ongoing at the modeling centers, and data is starting to appear at the Coupled Model Intercomparison Project Phase 6 (CMIP6) data distribution site. Analysis plans are in place, and these efforts were discussed at a workshop in September 2019 at the Aspen Global Change Institute. A paper documenting the ILAMB package has been published (Collier et al., 2018). ILAMB is being used by several modeling centers and model intercomparison projects. Analysis of CMIP6 (versus CMIP5) models using ILAMB is underway.

The Panel discussed the possibility of providing input to the Climate Data Guide (*https://climatedataguide.ucar.edu/*) on datasets of high relevance to the GLASS community. The Climate Data Guide is a data portal that combines data discovery, metadata, figures and world-class expertise on the strengths, limitations and applications of climate data. The Panel agreed that providing data pages for key GLASS-related datasets would be valuable, though a lead to push this idea through has not yet been identified.

Group photo of participants of the annual 2019 GLASS Workshop

PLUMBER2 and Modelevaluation.org

Gab Abramowitz presented progress on the Protocol for the Analysis of Land Surface models (PALS, now at *modelevaluation.org*) and the PALS Land Surface Model Benchmarking Evaluation Project Phase 2 (PLUMBER2) land model intercomparison experiment. Gab showed an example of PALS aiding development of the Community Atmosphere–Biosphere Land Exchange (CABLE) land model through benchmarking multiple model configurations, following the original PLUMBER framework. The full functionality of the ILAMB suite is also available through PALS as one of the analysis engines. PALS is hosting PLUMBER2 and Urban-PLUMBER.

A proposed global-scale land surface budget-based experiment was also shown, using the Derived Optimal Linear Combination Evapotranspiration (DOLCE) and Conserving Land-Atmosphere Synthesis Suite (CLASS) products (Hobeichi et al, 2018, 2019), focusing observationally constrained uncertainty estimates for surface energy and water budget terms. It was argued that understanding the circumstances in which land models were outside observational uncertainty ranges was likely more informative than simply quantifying model-observational discrepancy for different products using traditional metrics.

Finally, progress with PLUMBER2 was discussed. Sample Network Common Data Form (NetCDF) driving data has been distributed to participants, and the facility to assess model output formats on PALS is ready. Some of the tower data processing issues were outlined, noting that this had slowed progress somewhat. It is anticipated that all data for the experiment should be released within a month or two, with a total of 200-300 sites anticipated in the final product. Initial analyses were outlined to include an improved empirical model hierarchy (following Haughton et al, 2018), quantile-based (rather than rank-based) metric averaging and a Budyko-style analysis following recent work by Martyn Clark.

Discussion around the synthetic experiment part of PLUMBER2 suggested that the nature of the synthetic forcing datasets still required some iteration with the GLASS community, but there was agreement that this would likely be a valuable addition. Details of relatively flexible data assimilation-based submissions to PLUMBER2 (using whichever sources participants chose) were presented with slides provided by Sujay Kumar.

GSWP3 and LS3MIP

Hyungjun Kim shared progress on the Global Soil Wetness Project Phase 3 (GSWP3) and on the Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP). GSWP3's goal is to produce a century-long comprehensive set of quantities for hydro-energy-eco systems in order to investigate the long-term changes of energy-water-carbon cycle components and their interactions. Hyungjun showed the progress to-date by comparing preliminary output from three participating models of snow cover, evapotranspiration (ET), runoff and terrestrial water storage anomalies with observational equivalents. Additional pilot studies tackle questions of long-term variability and trends of runoff at global and continental scales. The LS3MIP experiment is designed to provide a comprehensive assessment of land surface, snow and soil moisture-climate feedbacks and to diagnose systematic biases in the land modules of current Earth system models using constrained land-module-only experiments. These experiments are being conducted as part of the CMIP6 initiative; significant progress is expected in the coming months as CMIP6 deadlines approach.

Crosscuts and Projects with Other GEWEX Panels

Craig Ferguson provided an overview of the current portfolio of the GEWEX Hydroclimatology Panel (GHP) Regional

Hydroclimate Projects (RHPs), crosscuts, and data centers. Of direct relevance to GLASS's current activities are the HYdrological cycle in the Mediterranean Experiment (HyMeX) RHP's 2020 field campaign, Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE), and the crosscutting initiatives related to evapotranspiration and water management in models. Martin Best provided a presentation about many of the details of the LIAISE experiment. Large-scale irrigation, vegetation heat and water stress response and the land-atmospheric processes that determine land anomaly impacts on regional climate variability at the heart of these GHP activities are also central to multiple GLASS projects [e.g., phase 2 of the Diurnal Land/Atmosphere Coupling Experiment (DICE-2), LoCo, PLUMBER2]. GLASS was well represented at the evapotranspiration crosscut workshop in October 2019. Over the coming months, GLASS will work together with GHP and the GEWEX Data and Analysis Panel (GDAP) to define and team-build for the water management crosscut.

John Edwards shared information on some of the Global Atmospheric System Studies (GASS) Panel efforts that are relevant to the GLASS community. Papers on the large-eddy and single column model intercomparisons in the fourth phase of the GEWEX Atmospheric Boundary Layer Study (GABLS4) are in an advanced stage of drafting and submission is expected in the near future. Following the Pan-GASS workshop in Melbourne last year, a number of new projects on drag, fog modeling and convective processes have been launched. The analysis of results from some of these is beginning.

Paul Dirmeyer provided an update on the beginnings of the second phase of the International Subseasonal to Seasonal (S2S) Prediction effort. The parallel Subseasonal Experiment (SubX) project, centered on North American models, is undergoing review to determine whether and how it will continue. There are currently several other multi-model projects with bearing on the role of various aspects of the land surface on S2S timescales: the "Changing Arctic Cryosphere: Snow and Sea-Ice Impact on Prediction and Climate over Europe and Asia" (SNOWGLACE, on snow initial states), the Global Land-Atmosphere Coupling Experiment–Earth System Model (GLACE-ESM, on vegetation states), the Impact of Initialized Land Temperature and Snowpack on Sub-seasonal to Seasonal Prediction project (LS4P, on initial soil temperature in elevated terrain) and the Land Feedback Model Intercomparison Project with a pseudo-observed boundary condition (LFMIP-Pobs, including all land states, especially soil moisture). All of these efforts produce large global sets of model forecast output on daily or finer time scales that can be mined to examine the impact of the land on subseasonal predictions in a range of frameworks from operational forecasting to predictability in a changing climate. A summer school at NCAR on the S2S topic will occur in July 2020, providing an opportunity to expose and educate 80-100 students and young scientists on the role of the land in subseasonal prediction.

Eleanor Blyth presented an overview of the Integrated Land Ecosystem Atmosphere Processes Study (iLEAPS) program. The five core themes in their science strategy are the urban environment, managed land, forests, arctic and mountain regions, and arid and semi-arid regions. In each of these themes, iLEAPS coordinates science that relates to the ecosystem-atmosphere interactions of water, carbon and other biogeochemicals. Two meetings of interest include the joint iLEAPS-GEWEX workshop for land model developers in September 2020 in Oxford, UK, and the 6th Open Science conference in collaboration with OzFlux in February 2021 in Auckland, New Zealand.

The Land Atmosphere Feedback Experiment (LAFE)

Volker Wulfmeyer gave an overview of the Land Atmosphere Feedback Experiment (LAFE) from the Southern Great Plains in 2017 (*www.arm.gov/research/campaigns/sgp2017lafe*). This experiment included simultaneous measurements of sensible and latent heat flux profiles and the comparison of variance profiles with similarity relationships, where surface layer observations strongly question the applicability of Monin-Obukhov similarity theory. The use of a bulk Richardson number relationship showed much better agreement with observations. Also, the current state of turbulence-permitting modeling and the use of these simulations and the LAFE observations for comparisons with turbulence parameterizations was outlined. The new operational Atmospheric Raman Temperature and Humidity Sounder (ARTHUS), which typically has resolutions of 10 s and 100 m during daytime and nighttime in the lower troposphere, will contribute significantly to process understanding, parameterization development and data assimilation efforts if operated 24/7 at various sites such as the new Land Atmosphere Feedback Observatory (LAFO, *https://lafo.uni-hohenheim.de/en*).

Volker also presented the new integrated Land System Model developed within the German Research Foundation Collaborative Research Unit 1695 at the University of Hohenheim (*https://klimawandel.uni-hohenheim.de*). This model system is capable of simulating crop growth and yield, as well as the feedback to farming activities and management by coupling with a multi-agent system. He showed that the implementation of crop growth had a significant positive impact on the simulation of surface temperatures and two-legged feedback metrics between soil moisture, latent heat flux, and convective available potential energy. The CORDEX Flagship Pilot Study (FPS) Land Use and Climate Across Scales (LUCAS) was also presented (*www.hzg.de/ms/cordex_fps_lucas*). Land use modifications from the current land use to forest or grassland has significant influence on L-A coupling strengths, particularly over south central and eastern Europe.

Presentations from New GLASS Panel Members

Samiro Khodayar Pardo is a senior scientist at the Mediterranean Center of Environmental Studies (CEAM) in Valencia, Spain, and leader of the junior research group "Extreme Weather in a Changing Climate" at the Institute of Meteorology and Climate research, Karlsruhe Institute of Technology (KIT, Germany). Her scientific work focuses on the improved

understanding and modeling of extreme weather and climate phenomena, with particular interest on the role of land-atmosphere interactions. For these investigations, she applies process-based evaluations across space/time scales using the synergy of state-of-the-art observations and high-resolution modeling. She is also an International Scientific Steering Committee member for the HyMeX program, where she coordinates the scientific team on heavy precipitation.

Nate Chaney is an Assistant Professor at Duke University in North Carolina, USA. Nate spoke about the availability of petabytes of data from satellite remote sensing providing us with a unique opportunity to make large improvements in the representation of land surface heterogeneity in Earth system models. The synthesis of these data through clustering at the sub-grid level enables an effective and efficient use of these data for their representation within large-scale models. These advances in the representation of sub-grid heterogeneity can then be used to understand how a more robust representation of sub-grid land surface heterogeneity impacts the coupled land and atmosphere. Building on this work, a recently assembled climate process team (led by Nate) will explore how the coupling of the land and atmosphere at sub-grid scales influences the macroscale response of the coupled land-atmosphere. This project, dubbed the Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP), will provide a more formal coupling between sub-grid parameterizations of heterogeneity between the land and atmosphere in a suite of U.S. climate models.

References

Collier, N., et al., 2018. The International Land Model Benchmarking (ILAMB) System: Design, Theory, and Implementation. *J. Adv. Model Earth Sy.*, https://doi.org/10.1029/2018MS001354.

Haughton, N., et al, 2018. The Plumbing of Land Surface Models: Is Poor Performance a Result of Methodology or Data Quality? *J. Hydrometeorol.*, 17(6), DOI: 10.1175/JHM-D-15-0171.1.

Hobeichi, S., G. Abramowitz, J. Evans and A. Ukkola, 2018. Derived Optimal Linear Combination Evapotranspiration (DOLCE): a global gridded synthesis ET estimate. *Hydrol. Earth Syst. Sci.*, 22(2), 1317–1336, 2018, https://doi.org/10.5194/hess-22-1317-2018.

Hobeichi, S., G. Abramowitz, J. Evans and H.E. Beck, 2019. Linear Optimal Runoff Aggregate (LORA): a global gridded synthesis runoff product. *Hydrol. Earth Syst. Sci.*, 23(2), 851–870, *https://doi.org/10.5194/hess-23-851-2019*.

Santanello, J.A., Jr. et al, 2018. Land–Atmosphere Interactions: The LoCo Perspective. *Bull. Amer. Meteor. Soc.*, *https://doi.org/10.1175/BAMS-D-17-0001.1*.

Van Looy, K., et al., 2017. Pedotransfer Functions in Earth System Science: Challenges and Perspectives. *Rev. Geophys.*, *https://doi.org/10.1002/2017RG000581*.

Vereecken et al., 2019 Vereecken, H., et al, 2019. Infiltration from the Pedon to Global Grid Scales: An Overview and Outlook for Land Surface Modeling. *Vadose Zone J.*, doi:10.2136/vzj2018.10.0191.

Alaska Soil Moisture and Wetland Mapping Validation Workshop

Fairbanks, AK, USA
9–13 September 2019

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The Alaska Soil Moisture and Wetland Mapping and Validation Workshop was hosted at the University of Alaska Fairbanks (UAF) from 9–13 September 2019. The workshop was organized by UAF, the U.S. Geological Survey (USGS) and George Mason University, and was sponsored by the World Meteorological Organization. One objective of this workshop was to improve soil moisture and wetland mapping over high latitudes to support a better understanding of the Soil-Ecosystem-Carbon-Climate (SECC) nexus, or the feedbacks between soils and ecosystem carbon cycling and the climate. The workshop included two days of presentations with discussions and three days of visits to long-term study sites in and around Fairbanks. The presentations and discussions focused on (1) assessing the current understanding and state-of-the-art techniques for detection of soil moisture and wetlands in high latitude ecosystems, and (b) identifying current and future research directions and data gaps. Field site visits included the Alaska Peatland Experiment (APEX) fen and bog ecosystems, the U.S. Army Corp of Engineers Cold Regions Research and Engineering Laboratory (CRREL) Permafrost Tunnel and the upland boreal ecosystems at Nome Creek. In collaboration with the National Aeronautics and Space Administration (NASA)'s Arctic Boreal Vulnerability Experiment (ABoVE), a small crew of participants also collected in situ soil moisture data synchronized with the airborne imagery acquisition campaign conducted by NASA's L -band fully polarimetric Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument. These in situ observations will contribute to the calibration and validation effort of soil moisture remote sensing products in the region.

High latitude areas, defined as above 60°N latitude, are warming faster than other regions. Permafrost landscapes contain 38% of the world's surface waters, but the characterization of surface water dynamics across northern high latitudes remains highly uncertain, as does the influence of permafrost on hydrology, leading to major challenges in mapping and characterizing soil moisture and wetlands in the region. Permafrost is actively thawing in high latitudes in response to climate warming, affecting soil moisture and saturation. Changes in soil moisture affect carbon sequestration potential by impacting water availability for plant growth, and by influencing soil decomposition rates and the relative contribution of aerobic and anaerobic processes driving soil carbon emissions (in the form of carbon dioxide and methane). Soil moisture also affects the risks of wildfires that are common in this region and that alter the landscape in many ways, producing massive carbon emissions to the atmosphere, altering permafrost and vegetation compo-