GLASS Project Report for the GEWEX 30th SSG Meeting
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URL: https://www.gewex.org/panels/global-landatmosphere-system-study-panel/
Chair(s) and term dates: Michael Ek, 2015-2018; Gab Abramowitz, 2017-2020

GLASS overview
GLASS focuses on land surface model development and evaluation, concentrating on improving the representation of land states, fluxes and interaction with the overlying atmosphere. Ultimately, it aims to understand the predictability of land surface variables and their role in the predictability of weather and climate. While GLASS has recently been organized into three 'themes' (Land-Model Benchmarking, Land-Atmosphere Coupling and Model Data Fusion), panel activity is of course community-driven by volunteer based - activity this year has primarily focused on the first of these two themes.

Suggested GEWEX reporting items:

1. **2-3 major panel accomplishments or significant contributions for the reporting period**

- Local Land-Atmosphere Coupling (LoCo). The LoCo working group is going strong after being established over a decade ago to focus on the goal of accurately understanding and modeling coupled land-atmosphere processes. A BAMS review article led by the LoCo WG was accepted Dec 2017 that covers the first decade of LoCo with an eye towards future work, and is already getting attention via early online release (Pielke email).
- Additional research and analyses spinning off from the PLUMBER experiment (published by GLASS co-authors in 2015) has multiplied, and several external parties have enquired about driving and taking part in a second phase of the experiment. The first paper is past 60 citations in 2 years. Details on planning and a timeline for the follow-up.

2. **Panel activities**

GLASS panel projects are listed below, divided into the three panel themes identified in the overview above. Most entries have a percentage next to their title, intended to indicate the degree that GLASS has been involved in the project (so that 100% implies entirely a GLASS initiative, and 0% implies the project would have precisely the same form if GLASS did not exist). Most projects are also broken into two sections: ***What is it?*** explains the motivation and structure of the project, and may include material duplicated from previous GLASS SSG reports; ***Update:*** is exactly that, news about this project over the last year.

Projects broadly under the theme of ***Land model benchmarking and evaluation***:

PALS (Gab Abramowitz) 50%

What is it? The Protocol for analysis of Land Surface models (PALS) is a web application designed for automated evaluation and benchmarking of LSMs. PALS hosts experiments, which each include: the data sets required to force or constrain a model for a particular experiment; model outputs uploaded by users (who run their models locally), including ancillary files; and 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 60+ institutions, and was used both for MIPs (e.g. PLUMBER, SavannaMIP) and model development. The system is currently offline, with the second generation system in testing and development. The PALS system had very strong initial uptake, with users at: UKMO, NASA, NOAA, NCAR, ECMWF, ORNL, CSIRO, BureauMet, USGS, COLA, Yale, Imperial, UExter, Ureading, BostonU, UColorado, UWashington, ColumbiaU, UArizona, UMaryland, Stony Brook, UOklahoma, ANU, MonashU, UNSW, and 40+ others, from 20+ countries.

Development on the second generation system, however, has been slow, largely due to limited resources and a lack of external collaborators. The second generation PALS system ('modelevaluation.org') is not specific to LSMs, and is much more flexible, partly to attract new funding possibilities from other institutions engaged in natural system modelling. Key features of the second generation system include analysis not being specific to any particular computing language or analysis package. It is structured to allow the original PALS analysis suite, as well as integrate other existing packages, such as ILAMB (Python) or NASA LVT (Fortran), with use of a relatively simple wrapper.

The new system also allows flexible user-defined benchmarks. When submitting a model output to an experiment, users can nominate any other model outputs already submitted as benchmarks, so that the analysis engine can utilise this information when generating plots.

A workflow system dedicated to benchmarking and evaluation allows increasingly strict enforcement of provenance and ancillary data collection. This ultimately aids reproducibility, the ability to tie a model's performance history to changes in structure, and the potential to data mine simulation meta-data as part of automated analyses. With all source code public on GitHub, and coding structures built for team development, the future aim for PALS is simply get the second generation system functioning and adopted by the community as a community owned project.

Update: After a visit to ORNL in December 2016 (where ILAMB developers Nate Collier and Forrest Hoffman are based) Gab Abramowitz, Nate Collier and others have been working to integrate ILAMB into PALS as an analysis engine. While this is not yet fully functional, some successful test cases are complete and it should be fully realised throughout 2018. UNSW Sydney infrastructure funding has been secured for a ⅔ appointment to develop PALS for 2018, which will ensure development continues throughout 2018. A paper that collated and further developed the Fluxnet data processing routines from the first incarnation of PALS was also published this year (Ukkola et al, 2017). Additionally, the NOAA-funded Global Model Testbed (GMTB) will include a component of their work under PALS.

PLUMBER (Martin Best, Gab Abramowitz) 100%

What is it? The PALS Land sUrface Model Benchmarking Evaluation pRoject (PLUMBER) is a LSM MIP using the PALS system, designed to highlight the importance of benchmarking over traditional evaluation. That is, defining performance expectations *a priori*. Defining benchmarks before model simulations are performed, if done well, can help answer the question of whether a group 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 9 IGBP vegetation types, using 8 different performance metrics. While LSMs performed markedly better than 1st generation LSMs, they performed poorly against empirical models, especially for sensible heat flux.

Fifteen different LSM variants participated, including those from the UKMO, ECMWF, CNRM, LSCE, NOAA, NASA, COLA, CSIRO. Two papers were published by PLUMBER participants in the *Journal of Hydrometeorology* (2015, 2016, each with 20+ co-authors), lead by Martin Best (UKMO) and Ned Haughton (UNSW). The first currently has 37 citations on Google Scholar – it is clearly having an impact on the broader community. Other bodies of work using PLUMBER data are continuing (e.g. Ukkola et al, 2016, ERL; Clark et al, in prep).

The key result from the original PLUMBER paper was that despite clearly performing better than older LSMs, current generation LSMs as a whole were not utilising the information available in their input data about latent and sensible heat fluxes. That is, simple empirical models, tested out of sample (i.e. training site data was not used to test the empirical models), clearly outperformed LSMs for common metrics (such as correlation, normalised mean error, standard deviation and mean).

The second paper by PLUMBER participants (published mid 2016, led by Ned Haughton, UNSW) investigated whether this result was because of methodological flaws in the original PLUMBER experiment, and was essentially a collection of negative results. It investigated whether lack of energy conservation in flux tower data, time scale of analysis, diurnal biases, poor LSM initialisation, metric value aggregation, or site choices might have been responsible for the original result. It concluded that the most plausible explanation for the result was a shared weakness amongst LSMs, noting that the mean of all participating LSMs did not show a radical improvement in performance (suggesting that LSM error correlation is high).

Recent work by Ukkola et al (2016, ERL) used the PLUMBER data to show that in dry-down periods LSMs tended to systematically under-estimate evapotranspiration, and commonly over-estimated evapotranspiration early in the growing season.

Update: Ned Haughton recently (late 2017) led a paper accepted that built a broader hierarchy of empirical models, extending those used in PLUMBER. Another 3 tiers of more capable empirical models are again tested out-of-sample, as per original PLUMBER work. This provides a lower bound estimate of how much information about latent /sensible heat fluxes is available in met forcing data (i.e. the predictability of sensible, latent heat flux). This has furthered the goals of PLUMBER in highlighting the importance of this definition of benchmarking, so that LSM performance can then be assessed by utilisation of information. We are aware of several other papers in review that also extend the PLUMBER work.

There is also no question that momentum exists for a second PLUMBER experiment, and that it will again be led by GLASS. The original PLUMBER paper attracted significant interest (60+ citations so far) and several parties have informally proposed additional experiments they are keen to lead as part of a second phase. These range from statistically-based information theory based analyses through to process evaluation studies. Running these through the

revamped PALS application would ensure all analyses and data are publicly available where participants agree. More detail on this is below in *New projects and activities being planned.*

SoilWat (Aaron Boone, Dani Or) 40%

What is it? Following discussions between GEWEX and the soil and critical zone communities regarding how to improve interactions and integration of soil and subsurface processes in present climate models and other activities of *GEWEX*, the *GEWEX-SoilWat* first planning workshop in 2016 attracted 25-30 participants. The key issues discussed revolved around how soil processes (infiltration, evaporation, soil properties, etc.) are represented in land-surface models; issues related to the role of plants in climate models; how to bridge scales between traditional soil models and representation relevant to climate modeling; effective incorporation of groundwater models; and how to best move forward with integration of the communities. Three subprojects came of this process that are now all active:

1. A survey of how basic soil processes are represented in climate models with emphasis on revisiting the pedotrasnfer functions used to convert soil information to parameters for modeling, led by Harry Vereecken and Anne Verhoef
2. Soil Parameter MIP, or SP-MIP aims to assess the utility of more resolved soil maps and conduct a sensitivity analysis to evaluate several climate models using old and new soil maps and parameters. Led by Lukas Gudmundsson and Matthias Cuntz
3. A survey of the groundwater database and investigation of strategies for incorporating groundwater in climate models, led by Stefan Kollet and Anne van Loon.

Update: The "Pedotransfer functions in Earth system sciences; challenges and perspectives" workshop was held at the Fall AGU meeting (December 2017) to discuss the status of these three subprojects, where the scope of application of PedoTransfer Functions (PTFs) has been expanded from estimating soil hydraulic properties to other soil characteristics such as thermal properties, solute transport and root water uptake, soil carbon pools and nitrogen mineralization. Six major actions were decided upon as outcomes from the workshop: (1) Role of the structure of soil, (2) Infiltration processes, thermal processes, from point to gridscale and upscaling, (3) "Ksat" in models, but what values of saturation do exist; questions for measures and values, (4) Biotic, biogeochemical processes PTFs, etc, (5) Thermal data information; thermal conductivity, (6) Soil freezing; how to enter soil freezing in LSM. It is anticipated that this effort will be included in some aspects of GLASS land model benchmarking efforts.

GSWP3 (Hyungjun Kim) 50%

What is it? The Global Soil Wetness Project Phase 3 is a global offline LSM MIP. Meteorological forcing at 0.5 degree has been developed specifically for this MIP, and is additionally being used for LS3MIP and SoilWat (both described in this report). The "Fast-track" phase of initial simulations using preliminary a version of the forcing data is complete, with submissions from seven institutes (NCAR, ETH, U-Tokyo, Meteo-France, ECMWF, KNMI, and JMA). Analysis with the ILAMB package is complete, and manuscript preparation from the first round analysis and validation is under way. The goal was to test the forcing within a subset of the land surface models in order to identify any issues (which in turn, could result in changes/updates to the input forcings). This is 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 (frozen at the end of 2016) and global simulations in some instances (with CLM), have been shown to better using the GSWP3 forcing as opposed to CRU-NCEP or WFDEI forcing.

GSWP3 is also tied in with LS3MIP (Land Surface, Snow, Soil moisture Model Intercomparison Project) under its offline component, LMIP (which is endorsed as part of CMIP6). While GSWP3 simulations are run on a 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. To keep the consistency with CMIP6, a long-term retrospective GSWP3 experiment (EXP1) starts in 1850, with prescribed land-use/land-cover changes derived from the Land Use Harmonization (LUH) data set

Update: The standard forcing data of EXP1 is generated combining spectral nudging dynamic downscaling and bias correction techniques. 20Th Century Reanalysis is spatio-temporally disaggregated to 3-hourly T248 resolution using a global spectral model. Multiple in-situ measured surface variables (i.e., precipitation, short-/long-wave downward radiation, and air temperature) are used to reduce intrinsic biases of the downscaled reanalysis fields. This bespoke forcing data was frozen and formally released in early July 2017. After the LS3MIP kick-off telecon in September 2017, several technical issues on GSWP3 forcing V1 were raised including negative amount of snowfall and missing value over coastline due to land-sea mask mismatch. To address those, GSWP3 V1.1 is being developed to be released in early 2018. The update will include an extended period up to 2014 as well (Hyungjun Kim); Princeton forcing V2 is available online which runs from 1948 until 2016, and V3 will become available later in 2017 which will have assimilated station

data (Justine Sheffield). Therefore, recommended versions will possibly change as time proceeds. See also the **LS3MIP update**, which is described in detail below in the land-atmosphere coupling section.

LS3MIP (Bart van den Hurk, Sonia Seneviratne, Hyungjun Kim et al) 40%

Note that LS3MIP, which is described in detail below in the land-atmosphere coupling section, also has a strong benchmarking focus.

International Land Model Benchmarking (ILAMB) project (Dave Lawrence) 10%

What is it? Building upon past model evaluation studies, the goals of the International Land Model Benchmarking (ILAMB) project are to:

• Develop internationally accepted land model evaluation experiments by drawing upon international expertise and collaboration
• Promote the use of these benchmark experiments by the international community for model intercomparison
• Strengthen linkages among experimental, remote sensing, and climate modeling communities in the design of new model tests and new measurement programs
• Support the design and development of open source benchmarking tools.

ILAMB is mainly lead/funded through US DOE Regional Climate Modeling Program. Project leadership team includes Forrest Hoffman (ORNL), Jim Randerson (UCI), Bill Riley (LBNL), David Lawrence (NCAR), and Gretchen Keppel-Aleks (U. Michigan). 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. ILAMB is being utilized by the international land modeling research community, and hosted a workshop in May, 2016 at DOE with approximately 50 participants from around the world. The workshop report, which was released in spring 2017, provides a roadmap for land model benchmarking/assessment activities going forward.

Update: ILAMB continues to be augmented with new metrics introduced by our international collaborators, and will be utilized in CMIP6 assessments, including assessments of LS3MIP land-only simulations. Collaboration with PALS is underway and early results look promising.

LUMIP (Dave Lawrence) 10%

What is it? The Land Use Model Intercomparison Project (LUMIP) aims to further advance understanding of the impacts of land-use and land-cover change (LULCC) on climate, specifically addressing the questions: (1) What are the effects of LULCC on climate and biogeochemical cycling (past-future)? (2) What are the impacts of land management on surface fluxes of carbon, water, and energy and are there regional land-management strategies with promise to help mitigate against climate change? In addressing these questions, LUMIP will also address a range of more detailed science questions to get at process-level attribution, uncertainty, data requirements, and other related issues in more depth and sophistication than possible in a multi-model context to date. There will be particular focus on the separation and quantification of the effects on climate from LULCC relative to all forcings, separation of biogeochemical from biogeophysical effects of land-use, the unique impacts of land-cover change versus land management change, modulation of land-use impact on climate by land-atmosphere coupling strength, and the extent that impacts of enhanced CO2 concentrations on plant photosynthesis are modulated by past and future land use.

LUMIP involves three major sets of science activities: (1) development of an updated and expanded historical and future land-use dataset, (2) an experimental protocol for specific LUMIP experiments for CMIP6, and (3) definition of metrics and diagnostic protocols that quantify model performance, and related sensitivities, with respect to LULCC. In this manuscript, we describe the LUMIP activity (2), i.e., the LUMIP simulations that will formally be part of CMIP6. These experiments are explicitly designed to be complementary to simulations requested in the CMIP6 DECK and historical simulations and other CMIP6 MIPs including ScenarioMIP, C4MIP, LS3MIP, and DAMIP. LUMIP includes a two-phase experimental design. 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 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. This paper documents these simulations in detail, explains their rationale, outlines plans for analysis, and describes a new subgrid land-use tile data request for selected variables (reporting model output data separately for primary and secondary land, crops, pasture, and urban land-use types). It is essential that modeling groups participating in LUMIP adhere to the experimental design as closely as possible and clearly report how the model experiments were executed.

Update: LUMIP kicked off in 2017 so there are no science highlights at this point. It has been presented at many meetings, including AGU, CESM Workshop, ILAMB, and CRESCENDO meetings. LUH2 (land use datasets) have been made available, with Historic 850-2014 5+ SSP-RCP 2015-2100 datasets released. CMIP6 and LUMIP model experiments will be conducted in 2018, and LUMIP hosts quarterly webinars. One or more meetings are being planned for 2018.

What is it? **ALMIP2** (Aaron Boone)
AMMA (African Monsoon Multidisciplinary Analysis) Land Surface Intercomparison Project Phase 2 (ALMIP2) focused on the local to meso-scale, where the main goal was to improve understanding and modeling of key surface, vegetation and hydrological processes over West Africa, e.g. the subtle hydrology and vegetation processes in the region (large rooting depths, near-surface aquifers, soil crusting, lateral transfer processes, strong runoff variability). This project is spinning down with a number of papers submitted in 2016. As follow on, in addition to GHP links to AMMA, it was suggested that sensitivity to surface forcing could be further investigated by expanding LoCo or DICE for the AMMA region.

Update: The ALMIP2 project is spinning down, with a few publications in the works that will be part of a special collection in J. Hydrometeorol. (see the publications section below). A future DICE-like (SCM land-atmosphere interaction) study may be of interest for this region, with details to be determined.

Projects broadly under the theme of ***land-atmosphere coupling***:

LoCo (Joe Santanello and LoCo working group) 80%

What is it? The motivation for Local Land-Atmosphere Coupling (LoCo) has been clear for some time, in that the results of offline projects such as the Project for the Intercomparison on Land-surface Parameterization Schemes (PILPS) and the Global Soil Wetness Project (GSWP) are limited by the lack of atmospheric feedback. Although the results of Global Land-Atmosphere Coupling Experiment (GLACE) provide an assessment of global circulation model (GCM) coupling coherence, they cannot isolate and evaluate the processes implied in the coupling that lead to model development. In terms of accurately representing the relationship between soil moisture (SM) and precipitation (P) and coupling strength in models, and to have the proper understanding and related improvement, it is necessary to carefully examine and quantify the full series of interactions and feedbacks (i.e., links in the chain) at the process-level, including the planetary boundary layer (PBL) feedback. To this end, the LoCo working group (WG) was established nearly a decade ago to focus on development of quantitative process-based metrics/diagnostics of land-atmosphere (L-A) coupling that could be applied equally to observations and models across scales.

The LoCo WG is comprised of ~15 GLASS panel and non-panel members. It is not meant to be exclusive, and has a high proportion of young scientists who have been motivated by L-A interactions studies. Outside GLASS, LoCo has closest links with GEWEX GASS/GABLS (Global Atmosphere System Studies/GEWEX Atmospheric Boundary Layer Study) and Diurnal Coupling Experiment (DICE), due to the inherent importance of the Planetary Boundary Layer (PBL) and model development in each. LoCo attempted a CMIP6 request (via GSWP and Land Surface, Snow and Soil Moisture Model Intercomparison Project, LS3MIP) for an increased set of L-A variables to be included in the standard output of participants. This failed due to timing (too late) and time constraints of those involved in GSWP3 and CMIP6.

Update: With the LoCo effort reaching the 10-year mark last year, the WG felt it timely to pursue an overview paper to the general community (as there had been no such paper to date). BAMS was chosen as the suitable forum, where the motivation and foundation for LoCo, the WG, LoCo metrics and resources, and LoCo's future could all be summarized together and provide a foundation going forward. More importantly, it will serve as an introduction to those in the atmospheric and other communities who have not been familiarized with LoCo (or GEWEX-GLASS), or who have been confused by the many groups, acronyms and terminology. This BAMS paper was accepted in December 2017. There are also many studies and publications from the WG in recent years focused on various metrics, models, and applications. See the GEWEX-LoCo website: www.gewex.org/loco/, for an updated list of WG members and publications, and also a nice synthesis by Paul Dirmeyer: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html, and LoCo coupling metrics toolkit from Ahmed Tawfik: www.coupling-metrics.com.

Observations of L-A processes and the need for assessment/improvement continue to be a recent point of emphasis of the LoCo WG, including the importance of co-located PBL, soil moisture and surface flux measurements. As a result, field campaigns have been a point of emphasis such as the enhanced sonde at the DOE Southern Great Plains site (SGP) (Craig, Joe, Pierre) in Summer 2015, improved soil moisture and co-located L-A measurements from DOE-ARM (Joe), NY State Mesonet (Craig), and the recently conducted Land-Atmosphere Feedback Experiment (LAFE : Volker Wulfmeyer, NASA, NOAA) @ SGP site in Summer 2017 and the The North American Monsoon GPS Hydrometerological Network, held 20 June - 30 September 2017 over the SW US focused on L-A interactions during the NA Monsoon (B. Lintner). In addition, Joe Santanello has received a second year of funding for his NASA Science Task Group focused on PBL retrieval from space. NSF has also funded 'GRAINEX' (PI: Rezaul Mahmood, Co-I: Joe Santanello), which will be held in Summer 2018 over SE Nebraska, focused on observing L-A interactions over irrigated vs. non-irrigated areas.

Multiple NASA ROSES projects (SU-SMAP) are currently underway, many of which utilize new SMAP products in studies of L-A interactions and NWP. There was a working group meeting in July (ISWG and SMAP Wx Focus Area) in California, where the connection of soil moisture to NWP was discussed at length as well as the role of data assimilation. It is likely that there will be a close connection between any new GLASS-supported 'land DA' initiative and the LoCo WG as a result of this interaction.

The future of LoCo and a three-pronged approach was developed, which continues this year:

- a) Continue to follow and broaden the science of LoCo and WG participation. Suggestions: snow, geology, carbon, LULCC, momentum, radiation, fluorescence, monsoon – each are evolving naturally via independent research. This also includes a push for new/improved L-A observations: PBL, soil moisture, surface fluxes.
- b) Synthesize what we have now in terms of metrics and message. Leverage off existing MIPs: LoCo-Plumber, LoCo-DICE, LoCo-CMIP.
- c) Engage and entrain the operational/model development community. CMIP6 variable request (unsuccessful), and new coupled testbed idea (Mike).

LS3MIP (Bart van den Hurk, Sonia Seneviratne, Hyungjun Kim et al) 40%

What is it? The Land surface, soil moisture and snow model intercomparison project (LS3MIP), part of the CMIP6 experiment suite, aims to assess land surface, snow and soil moisture feedbacks on climate variability and climate change, including:

- land-atmosphere coupling and its impacts (for climate trends, water resources, predictability);
- linking patterns and trends of ECVs to land model properties and biases;
- mapping (uncertainty of) water resources over the 20th century (and beyond);
- explore model-dependent land-atmospheric coupling;
- investigate the ability of climate models to capture observed rates of spring snow cover
- understand the linkage between snow-albedo feedback and 21st century warming

LS3MIP therefore focuses primarily on the physical system, with carbon cycle and vegetation dynamics covered in more depth by CMIP complements C4MIP and LUMIP respectively (more on LUMIP above). It is divided into two phases: LMIP (offline) and LFMIP (online, with Feedbacks), and aims both to compare CMIP6 historical and DECK simulations with observations, as well as examine changes to energy and water cycles through the historical period through to projected futures. These also include coordinated SnowMIP model intercomparisons.

The LFMIP experiments include land-atmosphere as well as land-atmosphere-ocean coupled simulations, with different combinations of prescribed land conditions, sea surface temperatures and smoothed boundary conditions used to assess the roles of land-climate and land-climate-ocean feedbacks on ECVs and seasonal predictability.

A detailed description of the protocol was published last year in GMD by van den Hurk et al (2016).

The LS3MIP timetable is essentially determined by the CMIP6 timetable. Participants include: ACCESS, BCC-CSM2-MR, CanESM, CESM, CMCC, CNRM-CM, EC-Earth, FGOALS, GFDL, GISS, IPSL-CM6, MIROC6-CGCM, MPI-ESM, MRI-ESM1.x, NorESM, UKESM.

Update: The Kick-off teleconference of LS3MIP was held in September 2017 with 25 participants representing 15 groups. General concept and overall status (Bart van den Hurk), status of forcing (Hyungjun Kim) and analysis plans (Sonia Seneviratne and Gerhard Krinner) were presented by coordination team, and reflections from individual groups were shared. For the "first results" delivery, a meeting will be scheduled in September or October 2018. To archive and maintain related information, a wiki (https://wiki.c2sm.ethz.ch/bin/viewauth/LS3MIP) has been set up as LS3MIP information repository. Currently, the historical LMIP (i.e., land-history) has been tested by six modeling group (CCSM, MeteoFrance, IPSL, MPI, HadCM and MIROC), and IPSL and EC-Earth have done experimentation with various flavors of the soil nudging. Requests on "housekeeping" of Data Request and experimental set-up were raised. Duplicated requested variables and several errors in the naming convention will be resolved (Hyungjun Kim), and variables related with frozen ground will be reprioritized (Gerhard Krinner and Hyungjun Kim). It has been agreed to perform LMIP simulation and submit output in 0.5 degree grids instead model native grids. As a mutual piece between LS3MIP and LUMIP, a template for generation future LMIP (i.e., land-future) forcing data was proposed by Dave Lawrence, but further careful consideration is still needed.

GABLS/GLASS/DICE Experiments (Adrian Lock and GASS panel members, Martin Best, & some LoCo WG participation)

What is it? Understanding the processes in and modeling the atmospheric boundary layer (ABL), with focus on the role of land processes and land-atmosphere interaction in the evolving surface fluxes, land states, and atmospheric profiles. The original Dirunal Cycle Coupling Experiment (DICE-1) was motivated by an earlier Global Atmospheric Boundary Layer Study (GABLS) project that identified the importance of land processes and land-atmosphere interaction. The DICE-1 paper is still under preparation (M. Best and A. Lock). The subsequent GABLS4 (or "DICE-over-ice") project had similar goals as DICE-1, except this time with focus on ice/snow-surface-atmosphere interaction in the extremely stable environment of Antarctica, and is being led by Eric Bazile, Fleur Couvreux, Patrick Le Moigne (Météo-France).

Update: new DICE efforts are being proposed to study other geographical regions leveraging the large amount data from many land-atmosphere field programs over the year. (Mike Ek is currently promoting the initial development of ideas for this effort.)

Projects broadly under the theme of ***Model-data fusion***:

While there are currently no community-led projects under this sub-theme within GLASS, after we removed Project for the Intercomparison of Land Data Assimilation Systems (PILDAS) for lack of activity, we note there is still enthusiasm to pursue a scaled-down version of PILDAS - more detail in ***New projects and activities being planned*** below.

3. New projects in place

SoilWat (Aaron Boone, Dani Or, SoilWat team) 40%

In the last year all three SoilWat projects have started in earnest. More details are given above in the active GLASS projects list.

PALS-ILAMB coupling (Gab Abramowitz and ILAMB team) 80%

For the last couple of months of 2017, work has begun coupling ILAMB into the PALS environment, and initial results are encouraging. Both the PALS and ILAMB codes have been evolving to accommodate this effort. Whether or not the combined product will be ready in time to be useful for GSWP3 and LS3MIP is not clear, but it will at least be useful for similar efforts of this nature, as well as internal model development programs across many institutions.

4. New projects and activities being planned, including timeline

PLUMBER2 (Gab Abramowitz, Martyn Clark, Sujay Kumar) 100%

As noted above, there is plenty of momentum for a second phase of PLUMBER. So much so that the biggest obstacle is likely to be understanding how we might accommodate all of the additional analyses, variables and process investigations that have been directly requested, offered to be led by others, or partially already investigated in PLUMBER spin off work. Containing and managing such a large suite of investigations will likely be made easier, and indeed be more easily expanded in future, if we run this through the PALS system (but this will have its own learning curve and investment time of course). Examples of extensions to the existing PLUMBER framework likely to be included are:

- significant increase in the number and variety of tower sites included with recent release of gap-filled, energy-balance corrected Fluxnet dataset, and quality control flux tower data processing package specifically for LSMs (Ukkola et al, 2017),
- Application of information theory based metrics for benchmarking (recent work by Grey Nearing, Martyn Clark)
- latent factor analysis exploring the similarity of LSMs (Sujay Kumar),
- Application of an improved hierarchy of empirical benchmark models for benchmarking (Gab Abramowitz, as outlined in Haughton et al, 2017, below).

Timeline: A PLUMBER2 planning meeting is scheduled immediately after the GLASS panel meeting in Canmore, May 2018.
Timeline likely dictated by availability of PALS-ILAMB coupling

PILDAS (Sujay Kumar) 100%

As noted above, a revival of a more conservative, and so achievable PILDAS is being discussed. Sujay Kumar is still the likely protagonist, and seems to have the enthusiasm, but identifying at least one other key participant is key. A revised PILDAS is still in the inception of ideas stage. We need to have a focused discussion on how the experiment should be structured, to be relevant to the community and in making a useful contribution. From the earlier PILDAS effort, we

learned that there are very few (2-3) groups that actually have the infrastructure to carry out offline DA integrations. One result that should come out of PILDAS is for us to quantify if the community needs to spend efforts on DA algorithms versus retrievals versus models themselves, so such efforts could be closely related to efforts such as PLUMBER. A simpler PILDAS experiment would be to align it with benchmarking projects. For example, how does a retrieval-based benchmark compare to ground-based benchmark? In other words, is there any utility to assimilating these retrievals (which is less about DA, but the relevant question is whether the community effort needs to be on improving retrievals or DA algorithms). Another idea is to stand up a statistical benchmark (based on observations) to see if DA systems can beat that. It can then be less about conforming to all the experiment details (which was another problem with the original PILDAS design). Clearly we need a land DA effort under GLASS, and was endorsed after feedback from WGNE panel and others at the Pan-WCRP meeting in Exeter in October 2017).

Timeline: Something that we'll no doubt discuss at the is year's panel meeting in Canmore, with no timeline apparent yet.

LIAISE (Martin Best, Aaron Boone, et al) 20%

*Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE***;** Martin Best et al). Semi-arid environments are sensitive regions for land-atmosphere coupling with stressed vegetation at times, and often a high degree of heterogeneity. There is a need to better evaluate the simulation of the surface energy budget in order to improve models and properly represent the seasonal dry-down period in these regions. Data sets to be used for comparisons with models will include a comprehensive collection of surface/near-surface measurements over the diurnal cycle for a full annual cycle, augmented by atmospheric profile and aircraft measurements. The ground site is not yet definitively chosen, but the current likely timing for the measurement program is May 2019 to May 2020, with linkage between GLASS, GHP (e.g. HyMEX) and other projects. An associated French effort, HILIAISE: Human imprint on Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment, is being proposed with the overall objective of HILIAISE to better understand and model the human imprint on the semi-arid energy and water cycles over a region which has significant anthropization.

Timeline: While inclusion of **anthropogenic water management in LSMs** was the subject of a GHP-GLASS workshop in October 2016, there has been no significant coordinated activity in this area as far as we are aware. As with all volunteer-led community based projects, an enthusiastic protagonist with dedicated time is required, and no one appears to have emerged to fill that role at this time.

5. **Science highlights (described with 2. Panel activities)**

6. **Science issues (described with 2. Panel activities)**

7. **Contributions to developing GEWEX science; fit into GEWEX imperatives**

GLASS contributes *most directly* to the following GEWEX Imperatives:

<u>Process</u>: Develop approaches to improve process-level understanding of energy and water cycles in support of improved land and atmosphere models.

- Identify feedbacks and the interactions among different processes, and build confidence in their replication in models (LoCo).
- Develop metrics to aid benchmarking activities for both un-coupled and coupled modeling activities (PALS/PLUMBER, ILAMB, LS3MIP, GSWP3, DICE)
- With the current and expected increasing complexity of land models in terms of various hydrologic and vegetation treatments, model optimization (i.e., parameter estimation approaches) will continue to be relevant to GLASS efforts (through Model Data Fusion).
- Investigate alternative representations of sub-grid processes in land surface schemes (SoilWat).
- Develop improved understanding of climate variability and change on land surface properties, including soils, vegetation and hydrological processes, and an associated modeling capability (GSWP3, LUMIP, LS3MIP, SoilWat).
- Investigate the scope for development of next generation land surface models with improved representation of subsurface hydrology, including groundwater processes; identify suitable areas for their evaluation.
- Improved representation of cold season land surface, Carbon and hydrological processes (potential CCRN project)

<u>Modeling</u>: Improve global and regional simulations and predictions of precipitation, clouds, and land hydrology, and thus the entire climate system, through accelerated development of models of the land and atmosphere.

- Coordinate the construction of a global land reanalysis system, building on ongoing and preparatory activities in Landflux, GSWP3, GLDAS and operational weather centers.

- Develop a framework and infrastructure for evaluation of land-atmosphere feedbacks. This should include the development of more quantitative estimates of uncertainty in the land condition and how this uncertainty propagates through to the atmosphere (e.g., PBL, convection, water and energy, carbon). This objective will be advanced in conjunction with the Processes Imperative in developing diagnostics.
- Organize coordinated intercomparison experiments for a range of model components in state-of-the-art land models, especially with regard to: treatment of soils, groundwater hydrology; surface water treatment (snow, river routing, lakes, irrigation, and dynamic wetlands); vegetation phonology and links between carbon and water; treatment of soils (GEWEX Soils Initiative); and Land Data Assimilation systems (follow-up to the PILDAS initiative).
- Evaluation of these land model components will also have to be considered in their interactive (coupled) context with the PBL, while taking into account and developing more quantitative measures of uncertainty in the land parameters and states will enable more robust evaluation of data assimilation systems.

Additionally, GLASS contributes to: **Technology Transfer** (develop new observations, models, diagnostic tools and methods, data management, and other research products for multiple uses and transition to operational applications in partnership with climate and hydrometeorological service providers), and **Capacity Building** (Promote and foster capacity building through training of scientists and outreach to the user community).

8. List contributions to the GEWEX Science Questions and plans to include these.

Observations and Predictions of Precipitation: How can we better understand and predict precipitation variability and changes?

The GLASS activities below address the linkages of precipitation (and its accuracy) to land surface processes and LSM predictability. Related current GLASS activities:

- LS3MIP to begin within CMIP6 framework.
- LoCo – Regional/Local Process-Level Quantification of land-PBL interactions and impact of land surface on precipitation (POC: Joe)
- ALMIP2 – Specific precipitation event studies and heterogeneity issues in soil moisture-precipitation feedbacks (POC: Aaron, project ending)
- GSWP3 – Precipitation as a key forcing for 20th Century simulations – this effort should quantify the error bounds on the 'land reanalysis' generated due to precipitation uncertainty (POC: Hyungjun)
- Land Model Benchmarking – How does Precip uncertainty impact offline and coupled model evaluation – spread of LSM physics vs. spread due to precipitation errors (POC: Martin, Gab)
    - *Future activities:*
- Incorporation of new satellite products (GPM, SMOS, SMAP) into these efforts more explicitly.
- PILDAS (re-initiated in some manner) – Land DA of soil moisture; multi-variate coupled DA (precip and soil moisture) in a future phase (POC: Sujay)

Global Water Resource Systems: How do changes in land surface and hydrology influence past and future changes in water availability and security?

Water Use, Resources, and Sustainability issues are at the heart of this challenge. How can GEWEX be positioned to meet this challenge given the current structure and makeup, currently focused on modeling groups and model intercomparisons with loose ties only (at best) with water resource and planning communities? Current activities are trying to answer various aspects of the science issues here (e.g. soil moisture and drought in a changing climate), but not yet at the stage of integrating the entire terrestrial water budget. GRACE is the only current tool we have in this regard (perhaps SWOT in the future), but is very limited in space and time scales such that regional and diurnal studies and models cannot be improved or assessed using this dataset. Carbon, ecosystem, cryosphere, groundwater, and distributed hydrology models are not traditionally GEWEX activities – but fully integrated Earth System and Land models are the future so we need to be forward thinking. It seems this challenge is really the overarching challenge of all land hydrology for climate studies.

- As a result, this challenge also intersects directly with other entities (ILEAPS, iLAMB, CLiC, DMIP, LULCC/LUMIP). This challenge might boil down to coordinating model development from previously disparate disciplines and applications, and based on CMIP5 results in terms of the limitations and sensitivities to the land hydrology (e.g. previously reported LUCID results).
- Related concluded GLASS activities:
- LUCID1 and 2 (POC: Andy)
- ALMIP1 and 2 (POC: Aaron)
- PILDAS/SMAP (DA of surface and root zone soil moisture will be critical to link with GRACE, SWOT)

Changes in Extremes: How does a warming world affect climate extremes, esp. droughts, floods, and heat waves, and how do land area processes, in particular, contribute?

This continues to be a 'hot topic', e.g. how will the frequency and location of extremes change due to 'x' amount of warming in the future? The NASA Energy and Water Cycle Study (NEWS) chose 'Extremes' as one of it's core integration projects, and could be looked at as a model both of what and what not do, and what can be learned by a limited subset of the community (material available online). Model evaluation and benchmarking becomes critical here as well. Most models are tested offline and only for average conditions, and once into extreme realms of forcing or states tend to behave much differently. Recent LSM calibration/parameter estimation studies suggest that a vastly different set of parameters (lookup tables) is required for extremes vs. average conditions. As observational data improves (e.g. challenge #1), this is no guarantee the models will behave better as a result. DA and Calibration studies should be a focus here. Calibration is a weak component of GLASS currently and should be expanded under 'Model Data Fusion'. You can learn a lot about model behavior and limitations that way, especially in concert with DA. Related current GLASS efforts:

- LoCo - quantification during extremes to get at model behavior and how LSMs impact the persistence of droughts/floods/feedbacks. Seasonal drought prediction needs much improvement with the emphasis on the land impact (http://www.climatecentral.org/news/lack-of-warning-on-2012-us-drought-reflects-flaws-in-forecasting-14823/)
- ALMIP2 - inherently encompasses dry extremes/feedbacks over AMMA with monsoon precipitation.
- LS3MIP is examining impact of soil moisture on extremes in CMIP5 (IPCC report just out on the subject).
- Benchmarking - should look at model performance stratified by regime (e.g. PLUMBER)
    - *Future activities:*
- CORDEX-GLASS collaboration possibly needs to a) exist and b) accelerate to answer these questions in the context of climate model predictions.
- PILDAS (as re-initiated) - DA w/ Calibration for improved soil moisture representation during extreme conditions.

Water and Energy Cycles and Processes: How can understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

This seems to be the most traditional GEWEX-type challenge in that it promotes a lot of activities in the current panels and relies on the strengths of the current makeup. What this challenge also shows is how much more work needs to be done in quantifying and improving water and energy cycle prediction in models of all scales and types. Results and improvements as a result are felt throughout the remaining three challenges, WCRP, and other communities as well. In order to close the land surface energy balance, we need to address all the issues and model evaluation and development listed in this challenge, and it will require SMOS/SMAP, GPM, GRACE, etc. to get right.

- Related current GLASS efforts:
- GSWP3 – Land reanalysis and sensitivity of surface fluxes to forcing uncertainties including radiation.
- LoCo – Determining Processes; How are land and PBL fluxes quantified and interact with each other.
- PILDAS (as re-initiated) – Constraining LSMs with observations for improved land surface energy balance.
- Benchmarking – Asses land surface energy balance in models vs. empirical models, and evaluating the 'goodness' of a model prediction.
    - *Future activities:*
- GLASS-GDAP – Improve connection between SRB, Landflux and GLASS modeling and prediction and consistency between data products and models.
- Anthropogenic Influences on the Global Water Cycle initiative: better characterize and prediction the impact of the human imprint on the water cycle

9. Other key science questions that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project (1-3 suggestions)

- identify causes for PLUMBER results - that is, source of shared LSM bias. PLUMBER will likely help address this to some degree, but it is definitely a long term goal.

10. Briefly list any specific areas of your panel's activities that you think would contribute to the WCRP Grand Challenges as identified by the JSC (not covered under 9).

a. Provision of skillful future climate information on regional scales (includes decadal and polar predictability)
b. Regional Sea-Level Rise
c. Cryosphere response to climate change (including ice sheets, water resources, permafrost and carbon)
d. Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity
e. Past and future changes in water availability (with connections to water security and hydrological cycle)
f. Science underpinning the prediction and attribution of extreme events

- identify the role of land processes and land-atmosphere interaction with other components of the earth system (e.g. atmosphere), in the prediction of extreme events, as well as the evolving high-latitude climate. Partnering with other GEWEX panels, i.e. GHP (regional hydromet/climate projects and associated data sets), GDAP

(remote sensing data sets), and GASS (atmosphere-related efforts) is necessary to be successful, and with WWRP, WCRP, Future Earth/iLEAPS and others.

11. **Cooperation with other WCRP projects (CLIVAR, CliC, SPARC), outside bodies (e.g. IGBP) and links to applications**

Subseaonal-to-Seasonal (S2S) Project (Paul Dirmeyer is GEWEX/GLASS Liaison)

• S2S hindcast and real-time forecast data set documentation from 11 operational centers was originally lacking information on land surface model characteristics and initialization. GLASS drafted a questionnaire on recommendation of F. Vitart that was circulated to modeling centers. The information has been incorporated into the models' documentation on the S2S Project web site: https://software.ecmwf.int/wiki/display/S2S/Models

• Many S2S models still do not report soil moisture ("required" variable). Once confronted, centers promise to include it with updated versions of their models / S2S data sets. Only about half of the S2S models are thus useful for assessing soil moisture / atmosphere interactions.

• S2S Prediction project http://s2sprediction.net/ is entering the final year of its 5-year lifetime. A proposal for a second 5-year phase has been drafted, and I have contributed to ensure better representation of GEWEX goals, particularly those regarding surface-atmosphere interactions. This should make S2S model forecasts/hindcasts/data sets more useful and relevant to the
GEWEX community.

• S2S includes 6 subprojects with different research foci – all are open to additional membership by interested parties http://s2sprediction.net/static/subproject:

- Extreme weather (F. Vitart)
- Monsoons (A. Marshall, H. Hendon)
- MJO (S. Woolnough and D. Waliser)
- Africa (R. Graham, A. Robertson)
- Teleconnections (H. Lin, C. Stan)
- Verification (C. Coelho, Y. Takaya)

New US effort supported by NOAA/CPO called "SubX" is also a sub-seasonal forecast/hindcast experiment http://cola.gmu.edu/subx/, and differs from S2S in the following ways:

- Evolved from seasonal prediction predecessor: NMME (North American Multi-Model Ensemble) – focus remains on multi–model ensemble techniques
- Only North American models involved, includes research models (NCEP/CFSv2, NCEP/GEFS, NASA/GMAO, NCAR-CCSM4, ECCC, USNavy)
- All models synchronize IC dates, output data grid, land/sea mask, period of hindcasts
- No time embargo on real-time forecasts

Also more GEWEX-relevant output variables than S2S – another resource for GLASS studies. Hindcasts from all models are scheduled to be completed by end of 2017, with operationalstyle real-time forecasts beginning January 2018.

• NOAA/CPO/MAPP also support a research effort on S2S predictability and prediction:
http://cpo.noaa.gov/ClimatePrograms/ModelingAnalysisPredictionsandProjections/MAPPTaskForces/S2SPredictionTaskForce.aspx. The task force (made of funded PIs) leadership includes Dirmeyer.

Joint GEWEX/CLIVAR Monsoon Panel (MP; Françoise Guichard co-chair)

Regional working groups have been constituted – these are the primary bodies through which research and outreach occur, and including Working Groups from Asia-Australia, Africa, and the Americas. MP membership updates put before the GEWEX SSG, include Françoise Guichard replacing Paul Dirmeyer this year as co-chair from GEWEX, Francina Dominguez as second member from the Americas working group. The CMIP6 Global Monsoons Modeling Inter-comparison Project (GMMIP) constituting an SSC, ToR, soliciting input from regional monsoon WGs for performing analyses as well as global analyses from the MP. There is interest in promoting a workshop on the role of the land surface and land-atmosphere feedbacks in monsoons, possibly as an ICTP workshop / targeted training activity, and/or as a theme/topic for the next GEWEX Open Science Conference. ICMPO-Pune functionality issues are an ongoing problem; qualified project office personnel and leadership are still lacking.

WCRP Modelling Advisory Council (WMAC; Michael Ek, GEWEX representative)

The Mission of WMAC is to coordinate high-level aspects of modelling across WCRP, ensuring cooperation with main WCRP partners such as World Weather Research Programme (WWRP), and acting as a single entry point for all WCRP modelling activities. Mike Ek is now representing GEWEX and GLASS interests on land modeling and related efforts.

Working Group on Numerical Experimentation (WGNE; Michael Ek, GEWEX/GLASS representative)
The Working Group on Numerical Experimentation (WGNE), jointly established by the WCRP Joint Scientific Committee (JSC) and the WMO Commission for Atmospheric Sciences (CAS), which is responsible for WWRP and GAW, has the responsibility of fostering the development of atmospheric circulation models for use in weather, climate, water and environmental prediction on all time scales and diagnosing and resolving shortcomings. Mike Ek is has been representing GEWEX and GLASS interests on land modeling and related efforts, where WGNE spans both weather and climate time scales.

HyMeX (Hydrological Cycle in the Mediterranean Experiment (Pere/Philippe)
The aim of the HyMeX Water Resources and Drought Science team is to improve the knowledge on Mediterranean Drought and Water Resources, understand the relevant processes and feedbacks, including the human component, improve current models and improve our capacity to predict drought at different time scales. Of particular note, remote sensing is crucial for the HyMEX science team where new methods are being developed to estimate surface soil moisture (SSC) using Sentinel-1 and MODIS NDVI data. Additionally, dam level data has been obtained using altimetry data from Sentinel-3. The capacity of land models to reproduce drought and its propagation has been studied in Spain within the FP7 eartH2Observe project showing large differences between the tested models both in terms of drought status and drought propagation; uncertainty must be reduced in LSMs if they are to be used to study drought, with soil moisture and underground water processes being highly uncertain. HyMEX links with GEWEX GLASS and GHP, and other groups. Several national projects also support HyMEX activities, and proposals are being written that would support the future LIAISE campaign.

ILEAPS collaborations (Eleanor Blyth)
While GEWEX/GLASS focuses on observations and modeling of the land-atmosphere exchanges of heat and water, ILEAPS has as its focus biogeochemical cycles and the interaction of land with atmospheric chemistry and role of humans. The potential for joint GLASS-ILEAPS activities includes land model benchmarking, observations for process-level understanding, freezing and arctic processes, and extremes. With regards to freezing and arctic processes, a group or key individual is required to move a project on this forward, perhaps in association with participants in the Year of Polar Prediction (YOPP) under the leadership of the WWRP Polar Prediction Project (PPP).

12. Workshops/meetings held
- GLASS panel meeting, May 2018, Tokyo
- HESS-S4 workshop, May 2017, Tokyo

13. Workshops / meetings planned. Include travel support needs anticipated (for WCRP). Include tentative meetings planned up to 2 years (for IGPO planning purposes)
- PLUMBER2 planning meeting in Canmore, AB in May (any travel support will likely be covered by OSC requests)
- GLASS panel meeting in Canmore, AB in May (any travel support will likely be covered by OSC requests)
- GEWEX OSC in Canmore, AB in May
- PLUMBER2 implementation meeting likely concurrent with GLASS panel meeting in 2019
- GLASS panel meeting around May 2019 (location TBA)

14. Other meetings that were attended on behalf of GEWEX or your Panel
- Mike attended the Pan-WCRP modeling working groups meeting in October 2017 (in Exeter, UK), which included WGNE and WMAC (Mike is members of both as the GEWEX rep.), and reported on GEWEX/GLASS activities of interest to these groups.
- Mike will attend the GEWEX-SSG-30 meeting in Washington, DC, 29 Jan - 01 Feb 2018.
- Gab will attend pan-GASS meeting in February 2018 (Lorne, Australia)

15. Issues for the SSG

None at this time.

16. List of key publications (*where appropriate*)

Dirmeyer, P. A., J. Wu, H. E. Norton, W. A. Dorigo, S. M. Quiring, T. W. Ford, J. A. Santanello Jr., M. G. Bosilovich, M. B. Ek, R. D. Koster, G. Balsamo, and D. M. Lawrence, 2016: Confronting weather and climate models with observational data from soil moisture networks over the United States. J. Hydrometeor., 17, 1049-1067, doi: 10.1175/JHM-D-15-0196.1.

Dirmeyer, P. A., L. Chen, J. Wu, C.-S. Shin, B. Huang, B. Cash, M. Bosilovich, S. Mahanama, R. D. Koster, J. A. Santanello Jr., M. B. Ek, G. Balsamo, and D. M. Lawrence, 2017: Verification of land-atmosphere coupling in forecast models, reanalyses and land surface models using flux site observations. J. Hydrometeor., (in revision).

Getirana, A., A. Boone, C. Peugeot, and the ALMIP-2 Working Group, 2017: Streamflows over a West African basin from the ALMIP-2 model ensemble. J. Hydrometeor., 18, 1831-1845. doi:10.1175/JHM-D-16-0233.1

Grippa, M., L. Kergoat, A. Boone, C. Peugeot, J. Demarty, B. Cappelaere, L. Gal, P. Hiernaux, E. Mougin, M. Anderson, C. Hain, and the ALMIP2 Working Group, 2017: Modelling surface runoff and water fluxes over contrasted soils in pastoral Sahel: evaluation of the ALMIP2 land surface models over the Gourma region in Mali. J. Hydrometeor., 18, 1847-1866. doi:10.1175/JHM-D-16-0170.1

Haughton, N., Abramowitz, G., and Pitman, A. J.: On the Predictability of Land Surface Fluxes from Meteorological Variables, *Geosci. Model Dev.*, https://doi.org/10.5194/gmd-2017-153, accepted Dec 2017.

Hoffman, F. M., C. D. Koven, G. Keppel-Aleks, D. M. Lawrence, W. J. Riley, J. T. Randerson, A. Ahlström, G. Abramowitz, D. D. Baldocchi, M. J. Best, B. Bond-Lamberty, M. G. De Kauwe, A. S. Denning, A. Desai, V. Eyring, J. B. Fisher, R. A. Fisher, P. J. Gleckler, M. Huang, G. Hugelius, A. K. Jain, N. Y. Kiang, H. Kim, R. D. Koster, S. V. Kumar, H. Li, Y. Luo, J. Mao, N. G. McDowell, U. Mishra, P. R. Moorcroft, G. S. H. Pau, D. M. Ricciuto, K. Schaefer, C. R. Schwalm, S. P. Serbin, E. Shevliakova, A. G. Slater, J. Tang, M. Williams, J. Xia, C. Xu, R. Joseph, and D. Koch (2017), International Land Model Benchmarking (ILAMB) 2016 Workshop Report, DOE/SC-0186, U.S. Department of Energy, Office of Science, Germantown, Maryland, USA, doi:10.2172/1330803.

Santanello, J., P. Dirmeyer, C. Ferguson, K. Findell, A. Tawfik, A. Berg, M. Ek, P. Gentine, B. Guillod, C. van Heerwaarden, J. Roundy, and V. Wulfmeyer, 2017: Land-Atmosphere Interactions: The LoCo Perspective. *Bull. Amer. Meteor. Soc.* doi:10.1175/BAMS-D-17-0001.1, in press.

Ukkola, A. M., Haughton, N., De Kauwe, M. G., Abramowitz, G., and Pitman, A. J.: FluxnetLSM R package (v1.0): a community tool for processing FLUXNET data for use in land surface modelling, *Geosci. Model Dev.*, 10, 3379-3390, https://doi.org/10.5194/gmd-10-3379-2017, 2017.

17. List of members and their term dates (including changes) where appropriate

GLASS membership continues to require management. The three new members shown below with green highlighted rows were invited in 2017 just prior to GLASS beginning to institute a more rigorous policy of making membership about either (a) active project involvement and leadership, or (b) mentoring of active projects by senior members. In reality this policy is likely to be implemented simply via a smaller annual GLASS panel invitation list. Four inactive members formally left the panel after discussions with co-chairs (bottom of the table below).

We will also need to choose a new co-chair in 2018, as Mike Ek's term will end in 2018.

Name	Affiliation	Membership	Term	Active projects	External reps
Gab Abramowitz	UNSW Sydney	Co-chair	2017-2020	PALS, PLUMBER, ILAMB	
Michael Ek	NCEP	Co-chair	2015-2018	PALS, PLUMBER, DICE	WGNE, WMAC
Eleanor Blyth	CEH	iLeaps representative			iLeaps
Aaron Boone	CNRM-Météo France	Senior member		ALMIP2, SoilWat	SoilWat
Nathan Brunsell	U. Kansas	Member			
Martyn Clark	NCAR	Member	2017 -	[PLUMBER2]	
Paul Dirmeyer	COLA / George Mason Univ.	Senior member			S2S, Monsoon panel
John Edwards	UK Met Office	Member			GASS
Craig Ferguson	SUNY	Member/GHP rep			GHP
Pierre Gentine	Columbia U	Member			
Chiel van Heerwaarden	Wageningen U	Young scientist member			

Hyungjun Kim	U Tokyo	Member		GSWP3, LS3MIP (LMIP)	
Sujay Kumar	NASA	Member		PILDAS	
David Lawrence	NCAR	Member		ILAMB, LUMIP	
Aude Lemonsu	CNRM - Météo France	Member	2017 -		
Lifeng Luo	Michigan State Univ.	Member	2015 -		
Pere Quintana Seguí	Ebro Observatory	HyMex rep			HyMex
Joshua Roundy	Univ. Kansas	Young scientist member		LoCo	
Joseph Santanello	NASA	Senior member		LoCo	
Ahmed Tawfik	NCAR	Young scientist member		LoCo	
Tomo Yamada	Hokkaido Univ.	Young scientist member			
Kun Yang	ITP/CAS	Member	2017 -		
Emeritus (i.e. copy on emails, but participation not necessarily expected)					
Gianpaolo Balsamo	ECMWF	Emeritus	in perpetuity		
Martin Best	UK Met Office	Emeritus	in perpetuity	LIAISE, DICE	LIAISE
Taikan Oki	U Tokyo	Emeritus	in perpetuity		
Christa Peters-Lidard	NASA	Emeritus	in perpetuity		
Andrew Pitman	UNSW Sydney	Emeritus	in perpetuity		
Sonia Seneviratne	ETH	Emeritus	in perpetuity		
Bart van den Hurk	KNMI	Emeritus	in perpetuity		
Matt Rodell	NASA	Emeritus	in perpetuity	GLDAS, terrestrial water	
LoCo working group					
Benjamin Lintner	Rutgers Univ.	LoCo working group			
Patricia Lawston	NASA	LoCo working group			
Benoit Guillod	ETH	LoCo working group			
Obbe Tuinenburg	Univ. Utrecht	LoCo working group			
Potential new					

members?					
Martin de Kauwe	Macquarie Univ.				
Mike Barlage?	NCAR/RAL				
When Zhou?	City University of Hong Kong				
Past members:					
Patricia de Rosnay	ECMWF	Member		PILDAS	
Wade Crow	USDA	Member		PILDAS	
Rolf Reichle	NASA	Member		PILDAS	
Fei Chen	NCAR	Member		LSM benchmarking	