Panel and Project Reports for the GEWEX SSG Meeting

Global Land/Atmosphere System Study (GLASS)

Reporting period: 16 October 2013– 31 December 2014

URL: http://www.gewex.org/glass.html

Chair(s) and term dates:
Joseph Santanello 2011-2014 (ended 31 Dec.)
Aaron Boone 2013 – 2016
Michael Ek 2015 – 2018 (began 1 Jan)

GLASS Overview and Summary:
"Support improved estimate and representation of (land) states and fluxes in models, the interaction with the overlying atmosphere, and maximize the utilized fraction of inherent predictability."

The aim of GLASS is to promote community activities that improve our best estimates and the model representation of state variables (e.g., soil moisture) and fluxes (e.g., evaporation), or to improve our understanding of land/atmosphere feedbacks and the role of land surface in predictability. To achieve these aims, GLASS is organized into three 'themes': Benchmarking, Model Data Fusion (MDF) and Land-Atmosphere Coupling (LAC). The concept of model benchmarking (rather than validation) enables the modeling community to identify the current strengths and weaknesses of our models in relation to their required applications. This is a big shift of focus for the modeling community and considerable work and discusstions have been engagded on the definitions of the a priori metrics that a model needs to achieve. The GLASS PLUMBER project directly addresses this theme with the goals of demonstrating this approach to benchmarking for the community. As of the writing of this report, a paper is under review on the results of this project. This paper will serve as a community-wide reference on the subject and an example which is applicable to land surface models. Many of the GLASS panel members participated and have co-authored this international effort.

The second theme of MDF brings data assimilation and parameter estimation techniques to both the initial value problem and to constrain the bounds of unknown parameters by using historical datasets. In the past, land data assimilation has been limited due to restrictions in observational data of the land components (e.g. soil moisture), but new satellite data enables an opportunity to explore more advanced data assimilation techniques. The PILDAS project will directly address this theme of GLASS, and connections look to be made between GHP/GDAP and GLASS with regards to the GSWP3 and ALMIP2 projects, and a new potential GHP-GLASS-iLeaps project.

The final theme of LAC aims at understanding the physical interactions between the land and the atmosphere and how feedbacks can change the subsequent evolution. Whilst the GLACE1 and GLACE2 projects demonstrated regions of the globe and situations where the land can have a significant impact on atmospheric evolution, they also highlighted large differences between modeling systems. The goal of the LS3MIP experiment is to provide a comprehensive assessment of land surface-, snow-, and soil moisture-climate feedbacks, and diagnosing systematic biases in the land modules of current ESMs using constrained land-module only experiments. The solid and liquid water stored at the land surface has a large influence on the regional climate, its variability and its predictability, including effects on the energy and carbon cycles. Hence GLASS will help to facilitate two aspects of land/atmosphere coupling, the first being to understand the physical processes whilst the second will strive to understand how both land and atmospheric parameterizations interact. The focus is at both the process/local level (LoCo) and the global behavior of the coupling (GLACE). This understanding will help to maximize the inherent predictability of the coupled land/atmosphere system.

In summary, GLASS currently has a good mix of established and new projects getting off the ground and in the planning stages, each of which maps well to the themes (MDF, Benchmarking, LAC). GLASS has reached out to GHP on a number of projects, is launching projects with GABLS (e.g. DICE), CliC (ESMsnowMIP as a part of LS3MIP) and continues to engage WGNE on benchmarking and data assimilation activities.

1. Panel activities and 4. Science Highlights

GSWP3 (Hyungjun Kim)
The pilot stage of the Global Soil Wetness Project Phase 3 was initiated in autumn 2014 and is ongoing, and the results of 'fast-track' simulations were reported at a GLASS side-meeting of AGU Fall Meeting, San Francisco in December 2014. Since it has been proposed to be a part of LS3MIP (Land Surface, Snow, Soil moisture Model Intercomparison Project) under LMIP (which is endorsed as part of CMIP6), there are new or updated components being considered for this project:

- In order to keep the consistency with CMIP6, a long-term retrospective experiment (EXP1) extends the proposed simulation back to 1850 (as opposed to the original proposaition of 1870), and future simulations (EXP2) span the period 2015-2100 using multiple projected future climate from CMIP6 ScenarioMIP. This includes some interesting global trends in hydrology, but is also long enough for carbon processes considering land use/cover changes (LULCC).

- Include carbon models in order to explore/attribute a possible carbon-related effect or changes in eco-system functioning on these trends. This could provide a bridge to the terrestrial carbon cycle modeling community. GLASS will recruit member(s) of iLeaps to be actively involved in both the planning and analysis of the carbon component of GLASS.

- Explore uncertainties in model physics, forcings, and parameters by assessing the large set of ensemble combinations, and propose an optimal set as a land reanalysis. Extensive sets of observations including both in-situ (e.g., discharge and soil moisture) and satellite remote sensing products (i.e., terrestrial water storage) will be aggressively exploited.

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 3hourly 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. A "white paper" (experimental protocol) and the list of variables is being updated with a inter-community contribution component. It will be distributed to the participating modeling groups before launching the actual phase (planed in February 2015). The second phase of ISI-MIP (Inter-Sectoral Impact Model Intercomparison Project) adopted GSWP3 EXP1 forcing data as one of standard model input data sets, and it will be circulated among key contacts within the carbon community to get their buy-in before the project begins. This will enable both carbon and water and energy cycle land surface models to be included, and simultaneously evaluated in them (e.g. the hydrology of carbon models and vice-versa).

GLASS/GABLS DICE Experiment (Martin Best, John Edwards)
The GLASS/GABLS DIurnal Coupling Experiment (DICE) experiment began in 2013. The first DICE workshop was held during Oct 14-16 at the UKMO in Exeter and a second workshop was held at the GEWEX science conference from 14-18 July 2014 at The Hague. This project involves the GABLS and GLASS members running fully coupled SCMs at the CASES 99 experiment (which was the GABLS2 project) and controlling for surface fluxes vs. atmospheric forcing in each component to isolate the impact of land-atmosphere coupling in the models over the full diurnal cycle (stable and unstable PBLs). Stages 1 (offline land surface), 2 (fully coupled) and 3 (column models forced by surface fluxes) are complete and analyses are currently being undertaken with a view to having 3 draft scientific papers ready for a further workshop in Toulouse during 20-22 May 2015. In addition, the hope is that a number of studies will be undertaken with these data by other DICE participants on the various coupling diagnostics that have been developed, with the subsequent scientific papers forming a special collection of a journal. These further studies will also be discussed during the workshop in Toulouse.

LoCo and the SGP Testbed (Joe Santanello)
The LoCo Working Group has continued to grow over the last year and is actively continuing work on diagnostics of L-A interactions and coupling across an array of scales and models. Over 25 recent papers have been produced by members of the WG focusing on aspects of LoCo such as diagnostic development, soil moisture-precipitation coupling, cold process coupling, mesoscale processes, and

GCM/RA/CMIP applications. A wide net has been cast in developing coupling metrics and producing maps, but it is recognized that now is the time to reel in these efforts, and synthesize them to get at more science-driven questions of coupling. To this end, the LoCo WG has been collaborating with the U.S. Department of Energy's ARM-SGP campaign and has produced an ARM-supported dataset for coupling studies over the U. S. SGP. In addition, a radiosonde campaign led by the LoCo WG will commence in Summer 2015 to augment the current ARM-SGP sonde launches for application to LoCo studies. These new dataset will allow the array of LoCo diagnostics to be applied consistently to the same location in order to understand their hierarchy and to develop a classification system based on the metrics.

PALS and Benchmarking (Gab Abramowitz)
The Protocol for the Analysis of Land Surface models (http://pals.unsw.edu.au) has progressed to a more advanced version that includes gap filling, empirical benchmarks, and automated metrics along with a large suite of Fluxnet data. PALS been designed to analyze in a standard way uploaded single site model simulations with site observations. Extensions to other data sets and the development of benchmarking tests are under development. For example, implementation of the Manabe bucket model and the Priestly-Taylor approach to flux estimation has been performed in order to use as standard benchmarks of the 'goodness' of current LSMs. The joint GHP-GLASS project PLUMBER has been conceived to demonstrate benchmarking through PALS and a review paper is currently udner review (see next item). Discussions are now under way for including two-dimensional (ideally for specific well-instrumented and documented basins which implies developing links with GHP and GDAP) case studies within PALS potentially under the auspices of a future follow-on intercomparison project.

PLUMBER (Martin Best, Gab Abramowitz)
PLUMBER is a benchmarking project using the PALS system. Data was acquired in conjunction with GHP for 20 FLUXNET sites was used to evaluate an array of land surface models and comparing metrics vs. that of simple formulations (bucket model, P-M, and simple regressions). Many GLASS member groups participated in this initial stage of PLUMBER, and results have been presented at conferances (e.g. AMS, January 2014) and a overview paper (co-authored by many GLASS panel members) is currently under review for the Journal of Hydrometeorology.

LUCID (Andy Pitman& Nathalie de Noblet-Ducoudré)
Seven papers have been published during 2012-2014 summarizing the LUCID and LUCID-CMIP5 results. This includes evaluation the impact of land cover change in 7 GCMs using the LUH dataset. The Effects of land cover change on temperature and rainfall extremes in multi-model ensemble simulations have been studied, along with the effect of anthropogenic land-use and land-cover changes on climate and land Carbon storage. Some of the main findings are that LULCC matters at the regional scale even though it may not be visible at the global scale, the differences in the land surface model parameterizations explain 1/2 to 2/3 of the inter-model dispersion, and that differential amounts of forests removed explain approximately 1/3 of the inter-model dispersion.

Thus:

- a key result supports the need to engage LSM and LCC dataset providers both, to see how to intelligently implement LCC in models. This is what will be achieved within the framework of a new EU project (http://luc4c.eu/) that has begun in November 2013. N. De Noblet-Ducoudré (LUCID) is contributing to the development of a new methodology to include LUC within DGVMs, and coordinating the Work Package entitled 'Net climate effects of past and future LULCC' of this project.

- LUCID would also like to gauge interest of C20C / D&A community as regional impacts of LUC may be as strong as changes GHG-induced climate changes, and may also be of opposite sign of the LCC community in CO2C/CMIP5, but it has been tough to get their attention. More may be needed to ensure that the impact of LUC on 20C climate is properly discussed in future papers.

In terms of future actions:

- some plans linking LUCID and GLACE are emerging building on Lorenz et al. (2014). The issue of how land coupling affects climate sensitivity to land cover change will require coordinated experiments in AMIP-style and could be combined with C20C simulations.

- LUCID would like to gauge interest of the CORDEX community as downscaling of future scenarios of global climate change need to be combined with scenarios of regional LUC, specially if those regional climates are meant to be used for impact studies. Some CORDEX leaders have been approached but more needs to be done.

- There may be linkages between GSWP3 and the landcover treatment in the 20c simulations and LUCID efforts that will be investigated.

GLACE-CMIP5 (Sonia Seneviratne and Bart vd Hurk)
Experiments1-A and 1-B of GLACE-CMIP5 have been completed. This involved AR5 reruns of climate change projections using a 1971-2000 soil moisture climatology versus using a seasonal transient cycle of soil moisture and evaluated during the 2070-2100 period. Six groups are participating in the simulations (GFDL, IPSL, ECHAM, CESM and EC Earth, as well as ACCESS since 2014). The analysis and the experimental design are coordinated by ETH and KNMI. An overview article has been published (Seneviratne et al. 2013). Additional papers have also been submitted. Future phases of experiments are considered, including some investigating the joint effects of changes in soil moisture verses changes in CO2 concentration for plant transpiration. Highlights show a large impact of projected soil moisture changes on changes in daily mean and max temperature, including hot extremes. Effects on precipitation changes are less clear, and additional analyses will be conducted to investigate the underlying feedbacks and associated effects on the water balance (E-P). These analyses are expected to be completed over the next 18 months. The currently planned CMIP6 experiment LS3MIP ("Land Surface, Snow and Soil Moisture MIP") builds in part on the GLACE-CMIP5 framework (e.g. Seneviratne et al. 2014).

PILDAS (Rolf Reichle)
The launch of PILDAS has been delayed to 2015. The experimental design is essentially complete, and a pilot study by the project lead to use 2 LSMs with 1 DA algorithm in NASA's LIS has been developed, however, this portion of the project was delayed by new modifications to the ALMA convention made by the GLASS panel (requiring a considerable effort to update software). Phase-1 is focused on operational centers (rather than niche research projects), synthetic obs, and different DA algorithms w/different LSMs for a 1/8 degree domain over the SGP. Later phases will focus on coupled DA systems and actual satellite observations from SMOS and SMAP. GLASS will take the experimental plan and pilot results to WGNE to put pressure on centers that are not currently listed.

ALMIP2 (Aaron Boone)
The 2nd AMMA phase 2 Land MIP was launched in Spring 2012. In all, 22 LSMs, 5 hydrological models, and 1 ET model are all included in this phase. In this experiment, the focus is on a much higher spatial resolution (mesoscale: 5km) than in ALMIP1 (regional scale: 0.5 deg), to focus on the subtle hydrology and vegetation processes that dominate there (occasionally very large rooting depths which access water in near surface aquifers, soil crusting, lateral transfer processes, strong variability in surface runoff), and to enable use of high resolution satellite data. The period covers 4 years, where the forcing is coming from a blend of in-situ and NWP/radar/Landsat/other satellite data. ALMIP2 takes advantage of observational data along a meridional transect from the AMMA-CATCH network which cuts across a zone with a large gradient in surface characteristics and rainfall. The project will give recommendations on the parameterization of runoff scaling and potentially missing or poorly parameterized processes which are key to the functioning of the west African land surface. This project is now in publication phase: a proposal for a special collection of papers has been accepted by the Journal of Hydrometeorology: 8 to 10 papers will be submitted during a time window (yet to be defined by JHM) during 2015. Some parts of this project will likely be folded in the proposed LOCO-AMMA project.

2. Projects being launched

1) PILDAS was delayed to this year, but should finally be able to get started. The PI of this project has been very busy as he plays a major role in the SMAP science team. Launch of the satellite is slated for January 2015, thus it is anticipated that the PI will likely have time to re-initiate this effort during 2015. In the meantime, there is a pilot experiment underway internally at NASA-GSFC with the PI and Sujay Kumar that should lead to the larger community experiments. There is a very big interest in this project (especially from WGNE), thus the panel has continued to strongly encourage the PI to luanch this project, despite the delays.

2) The LoCo-SGP Testbed project (Ferguson, Santanello, Gentine, Findell, and Shaocheng Xie) was proposed to the DOE Atmospheric Research Program. Three GLASS panel mmebers (Ferguson, Santanello, and Gentine) were successful in securing radiosondes from DOE for an IOP for summer, 2015.The ARM Climate Research Facility will support a LoCo working group-led enhanced frequency radiosonde campaign this summer at the ARM Southern Great Plains Central Facility (CF). For twelve days the operational launch schedule at the CF will be augmented by daytime hourly radiosondes with 3-hourly trailer (10-minute lagged) radiosondes—a total of (14) additional radiosondes/day. The data will be useful for: forcing single column model experiments such as DICE; evaluation and refinement of the PBL daytime transition in models; and directing the instrument reconfiguration at ARM-SGP to better support high-resolution modeling.

3) CMIP6-Endorsed MIPs: Land Surface, Snow and Soil Moisture (LS3MIP). The goal of the LS3MIP experiment is to provide a comprehensive assessment of land surface, snow, and soil moisture-climate feedbacks, and diagnosing systematic biases in the land modules of current ESMs using constrained land-module only experiments. Snow cover is an essential component of the Earth System that interacts with the atmosphere and the surfaces it covers (land, ice, sea ice). It is also an important source of (positive) feedbacks within the climate system. A WCRP/CliC Initiative was proposed in 2013 for an ESM-SnowMIP intercomparison programme as a contribution to the WCRP Grand Challenge Cryosphere in a Changing Climate. The experimental design of the GLACE-CMIP5 study, carried out with a limited CMIP5 ensemble with prescribed SSTs (AGCMs) and vegetation, is used as blueprint for the second set of proposed LS3MIP experiments. The new LS3MIP experiments will allow a full quantification of soil moisture-climate feedbacks in the CMIP6 models and provide reference diagnostics for the evaluation of the CMIP6 ESMs, which will be of key relevance for the application of constraints to reduce uncertainties in projections.

4) GSWP3: The official launch for the Global Soil Wetness Project phase 3 is planned for early 2015.See **GSWP3** in the section **1. Panel activities and 4. Science Highlights** for further details.

3. New Projects and Activities Planned

1) Proposals related to the LoCo/SGP Testbed Project have been submitted by LoCo PI's (Ferguson, Santanello, Gentine) to implement new ARMBE-Land project to establish a benchmark of L-A coupling based on LoCo-derived diagnostics compiled by the working group. This includes a proposal for an extended field campaign to better monitor the PBL through augmented radiosonde launches, an integrative proposal to bring together the LoCo metrics and the ARMBE data, and investigation of additional site suitability for LoCo studies (e.g. India (monsoon), AMMA, and Cabauw) as suggested by the GEWEX SSG (2012).

2) GABLS Stable Boundary Layer project. Eric Bazile presented a proposal for a GABLS project for the Dome-C site in Antarctica. A science plan is fourthcoming. GLASS will be involved in terms of assessing the thermal coupling and momentum flux in a polar climate (to date has been lacking in terms of GLASS activities and focus). Since GLASS does not currently have members with experience cold region processes in an antarctic climate, it has been proposed that a link to CLiC needs to be established. An approach to CLiC will be made to find someone who could join the GLASS panel and form a link between GLASS, GABLS and CLiC for this project. It was also agreed at the Pan-GASS GABLS breakout session that the first step of a joint project should have both communities concentrating of their components of the system to fully understand these. A second step could then investigate the impact of land/atmosphere coupling in this environment.

3) Discussions have been initiated with Howard Wheater (University of Saskatchewan) on a potential GHP-iLeaps-GLASS-CliC Cold Season Processes Project. This project would use observational data from the Changing Cold Regions Network (CCRN) (http://www.ccrnetwork.ca/). CCRN will integrate existing and new experimental data with modelling and remote sensing products to understand, diagnose and predict changing land, water and climate, and their interactions and feedbacks, for this important region. CCRN will use a network of world class observatories to study the detailed connections among changing climate, ecosystems and water in the permafrost regions of the Sub-arctic, the Boreal Forest, the Western Cordillera, and the Prairies. CCRN will integrate these and other data to understand the changing regional climate and its effects on large-scale Earth system change and the region's major rivers - the Saskatchewan, Mackenzie and Peace-Athabasca. So, this project could potentially help improve land surface, Carbon and hydrological processes in a region which is very sensitive to climate change. Discussions on preparing a white paper for a potential multi-model project have begun.

5. Science Issues

1. The LS3MIP science details are being finalized: A document was circulated among a number of the GLASS panel members in December, 2014. The objectives of LS3MIP respond to each of the three CMIP6 overarching questions: what are regional feedbacks and responses to climate change, what are the systematic biases in the current climate models, and what are the perspectives concerning the generation of predictions and scenarios.
2. The definition of 'local' vs. 'non-local' coupling and representation of each by the array of LoCo diagnostics is a non-trivial issue. This will be addressed directly by the SGP Testbed dataset and diagnostic intercomparison, and will include the effect on coupling metrics of spatial and temporal scales.
3. Forcing height used to force the PILDAS experiments needs to be resolved (either 2/10m or lowest model level). There is not an optimal best solution here at the moment, as some models have only one or the other available.

6. Contributions to GEWEX Science and Fit to Imperatives

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

1) Develop diagnostic 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 (GLACE, LoCo).
- Spin-up activities in *advanced diagnostics* through a joint pan-GEWEX effort/workshop (GRP, GLASS, GHP, and others).
- Develop metrics to aid benchmarking activities for both un-coupled and coupled modeling activities (PLUMBER)
- 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 (heterogeneity).
- Develop improved understanding of climate variability and change on land surface properties, including soils, vegetation and hydrological processes, and an associated modeling capability (GSWP3, ALMIP2).
- 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)

2) 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). 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: groundwater hydrology; surface water treatment (snow, river routing, lakes, irrigation, and dynamic wetlands); vegetation phonology and links between carbon and water; and Land Data Assimilation systems (follow-up 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.

7. Contributions to the GEWEX Grand Science Questions

#1: 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:
GLACE – Land/SM impact on precipitation and predictability (POC: Sonia/Bart; 1 and 2 complete; CMIP in progress), 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, nearly complete)

PILDAS – Land DA of soil moisture; multi-variate coupled DA (precip and SM) in a future phase (POC: Rolf)

GSWP3 – Precip 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)

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.

#2: How do changes in the 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, 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, ground water, 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). 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. LUCID recent results).

Related current GLASS activities:
LUCID1/2 (POC: Andy)
ALMIP1/2 (POC: Aaron)
PILDAS/SMAP (DA of surface>root zone will be critical to link with GRACE)

#3: How does a warming world affect climate extremes, and especially droughts, floods and heat waves, and how do land area processes, in particular, contribute?

*This seems to be the 'hot topic of the year', 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:
PILDAS - DA w/ Calibration for improved soil moisture representation during extreme conditions.

LoCo - quantification during extremes to get at model behavior & how LSMs impact the persistence of droughts/floods and feedbacks. Seasonal drought prediction needs a lot of 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.

GLACE2-CMIP is examining impact of SM 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.

#4: 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 W&E 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 – 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.

8. 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)

1. The impact of the land surface, soil moisture and vegetation (interactive phenology), and L-A coupling on Seasonal/Drought Prediction.
2. A common modular interface for LSMs (new ALMA), such that different models and components can be more easily transferred to other's platforms, intercompared, and swapped. This would also include a common land-atmosphere coupling modularity such that different atmospheric and land models can be intercompared in order to evaluate the impact of each on the coupling results.
3. Pressing Model developments/improvements: Improved cold season processes (interactions between permafrost and greenhouse gas emissions), ground water interactions, anthropogenic processes (irrigation, aquifer uptake, crop harvest, improved LULCC), and the LSM "grey zone" (in anticipation of ever-higher resolution research and NWP applications: lateral fluxes of mass, energy...)

9. 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

Provision of skillful future climate information on regional scales (includes decadal and polar predictability)

- **o** GSWP3, ALMIP2
- o Benchmarking (defining skillful), MDF (improved prediction and skill), and LAC (process-level improvement in L-A coupling)

Regional Sea-Level Rise

- **o** None

Cryosphere response to climate change (including ice sheets, water resources, permafrost and carbon)

- **o** Possible links to GABLS4 experiment and stable PBL coupling.
- **o** ESMsnowMIP component of LS3MIP will address coupling between the atmosphere and the cryosphere (namely snow covered areas)
- **o** Possible new project based on CCRN interactions

Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity

- **o** None direct, but L-A Coupling theme addressing the soil moisture-precipitation feedbacks.

Past and future changes in water availability (with connections to water security and hydrological cycle)

- **o** GSWP3, GLACE(CMIP), and GPM/GRACE/SMOS/SMAP synergy
- **o** LAC (process-level improvement in water and energy cycle feedbacks)
- **o** improved understanding of land-surface and hydrological processes in semi-arid zones where water resources are already limited (ALMIP2)

Science underpinning the prediction and attribution of extreme events

- **o** See above wrt GEWEX Challenge #3 (strongest contribution from GLASS is here?)
- o Benchmarking (model goodness during extreme conditions), MDF (data assimilation and model calibration during extremes), and LAC (improvements in coupling leading to improved predictability of extreme events from local to global scales)

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

1) A connection to CliC has been proposed through the GABLS Stable PBL Project over the arctic region. In addition, ESMSnowMIP (of LS3MIP) is a collaborative effort between CliC and GLASS. A suitable GLASS representative for both cold processes and stable PBLs has yet to be identified, however.

2) Better integration between GEWEX and iLEAPS is tentatively underway through collaboration on the GSWP3 project. There is a potential for further interactions within a new project based on the CCRN (as mentioned, still in the planning phase). Discussions on experiment design, protocols (such as variables of interest to study/report, appropriate units, etc.), and input data sets (time length covered) are underway.

3) LS3MIP is addressing core research questions of the WCRP and is relevant for a large fraction of the WCRP activities. It is initiated by two out of four WCRP core projects (CliC and GEWEX) and directly related to three WCRP Grand Challenges (Cryosphere in a changing climate, Changes in Water Availability, and Climate Extremes).

11. Workshops/Meetings Held

- GSWP3 Kick-off meeting: Tokyo, Feb. 2014
- WGNE Annual Meeting (GLASS presentation)
- AMS Annual Meeting (Benchmarking session hosted by GLASS): Atlanta, February 2014
- 2014 GLASS Panel Meeting, Pan-GEWEX 2014, Hague, NL

12. Workshops/Meetings Planned

- Joint GLASS/GABLS - DICE Workshop, 20-22 May, 2015, at Météo-France, Toulouse, France
- 2015 GLASS Panel Meeting, 18-19 May, 2015, at Météo-France, Toulouse, France (Same venue and week as the GLASS/GABLS and DICE Workshops).
- LandMIPMeeting (LS3MIP/GSWP3/GLACE and LUMIP/LUCID), Oct., 2015, Zurich, Switzerland
- Pan-GLASS Conference is proposed for Fall 2016 to be combined with the next Pan-GASS meeting. Likely to be held/hosted in Europe.

13. Other meetings that were attended on behalf of GEWEX or your Panel

14. Issues for the SSG (*need to update these issues or raise new ones)

The LUCID and LUMIP (now evolving into LSMIP) projects both deal with Land Use Land Cover Change (LULCC) in fully coupled models. There have been some communication issues, but now we are trying to actively distinguish/differentiate the two projects (goals, etc.) and foster communication.

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

GEWEX

Santanello, J. and **A. Boone**, 2014: Global Land/Atmosphere System Study Panel Meeting. *GEWEX News*, November 2013, **23**(4), 13-16.

Seneviratne, S. I., B. van den Hurk, **D. Lawrence**, G. Krinner, G. Hurtt, **H. Kim**, C. Derksen, **T. Oki, A. Boone, M. Ek**, V. Brovkin, **P. Dirmeyer,** H. Douville, P. Friedlingstein, S. Hagemann, R. Koster, N.

de Noblet-Ducoudré and **A. Pitman**, 2014: Land processes, forcings, and feedbacks in climate change simulations: The CMIP6 LandMIPs. *GEWEX News*, **24**(4), Nov., 2014.

LAC

Gentine, P., A. A. M. Holtslag, F. D'Andrea, and **M. Ek,** 2013 : Surface and atmospheric controls on the onset of moist convection over land, J Hydrometeorol, 130211131121003, doi:10.1175/JHM-D-12-0137.1.

Seneviratne, S.I., M. Wilhelm, T. Stanelle, B.J.J.M. van den Hurk, S. Hagemann, A. Berg, F. Cheruy, M.E. Higgins, A. Meier, V. Brovkin, M. Claussen, A. Ducharne, J.-L. Dufresne, K.L. Findell, J. Ghattas, **D.M. Lawrence**, S. Malyshev, M. Rummukainen, and B. Smith, 2013: Impact of soil moisture-climate feedbacks on CMIP5 projections: First results from the GLACE-CMIP5 experiment. Geophys. Res. Lett., 40 (19), 5212-5217

Boysen L R, V Brovkin, V K Arora, P Cadule, N de Noblet-Ducoudré, E Kato, J Pongratz and V Gayler, 2014: Global and regional effects of land-use change on climate in 21st century simulations with interactive carbon cycle. Earth Syst. Dynam., 5, 309–319.

Lorenz, R. and **A. J. Pitman**, 2014: Effect of land-atmosphere coupling strength on impacts from land cover change experiments in Amazonia, Geophysical Research Letters, 41, 5987–5995, doi: 10.1002/2014GL061017.

Benchmarking

Best, M.J., G. Abramowitz, H. Johnson, **A.J. Pitman, A. Boone**, M. Cuntz, B. Decharme, **P.A. Dirmeyer**, J. Dong, **M. Ek**, V. Haverd, B.J.J.M van den Hurk, G.S. Nearing, B. Pak, **C. Peters-Lidard, J.A. Santanello Jr.**, L. Stevens, N. Vuichard, 2014: The plumbing of land surface models. *J. Hydrometeor.*, (under review)

Model Data Fusion (MDF)

Santanello, J. A., S. V. Kumar, **C. D. Peters-Lidard**, K. Harrison, and S. Zhou, 2013: Impact of Land Model Calibration on Coupled Land-Atmosphere Prediction. J. Hydromet., 14, 1373-1400.

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

The GLASS Terms of Reference have been presented at the panel meetings in 2011 and 2012, and were ratified by the GEWEX SSG. These TORs include term limits on chairs of 4 years, staggered in 2-year intervals for continuity of leadership. Two main categories of panel members have been established and without term limits: Experienced Scientists (including project leads) and Young Scientists, as well as a protocol for new members of each category that they attend the next panel meeting and establish their interest and relevance to the panel activities. Template letters signed by GEWEX/Sonia Seveviratne and Graeme Stephens have also been developed to welcome new panel members and to thank departing members for their service.

Joe Santanello (Co-chair through 31 Dec 2014)
Aaron Boone
Michael Ek (Co-chair beginning 1 Jan 2015)
Hyungjun Kim
Rolf Reichle
Martin Best
Paul Dirmeyer
Andy Pitman
Gianpaolo Balsamo
Matt Rodell
Christa Peters-Lidard

Patricia de Rosnay
Sonia Seneviratne
Gab Abramowitz
Craig Ferguson
Nathan Brunsell
Lifeng Luo
Fei Chen
Pierre Gentine
Tomo Yamada
John Edwards
Wade Crow
Taikan Oki
Ahmed Tawfik
Sujay Kumar
Chiel van Heerwaarden
Obbe Tuinenburg
Benoit Guillod
Josh Roundy