Global Land Atmosphere System Study (GLASS)

Reporting Period: 27 August 2010 – 31 August 2011
URL: http://www.gewex.org/glass.html
Chair(s) and Term Dates: Martin Best (2009 – 2012); Joseph Santanello (2011 – 2014)

Objective:
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

Status:

PILPS-URBAN
The Project for the Intercomparison of Land-Surface Parameterizaton Schemes (PILPS) Urban Surface Energy Balance Land-Surface Comparison Project (URBAN) model comparison experiment has been successfully completed. There were results from 33 models with a wide range in complexity. Some models were essentially the same model but run by different groups, which will enable a future analysis of initial conditions and user assumptions. The initial results from the comparison have now been published and show that for the considered application, there is little benefit from additional complexity, as the simple models on the whole performed at least as well as the more complex models.

GLACE2
Published results from the second Global Land Atmosphere Coupling Experiment (GLACE2) show that skill in temperature and precipitation increases mainly in areas where the precipitation forcing quality is high (high station density gives better initial soil moisture data), when soil moisture is relatively extreme, and where potential predictability is high. Ongoing GLACE2 experiments from KNMI, ECMWF and ETH are being performed for the period 2000-2010 in order to check possible signals emerging from known strong droughts in this period. Also yet to be carried out are possible studies involving hydrological forecast models fed by the GLACE2 GCMs.

LoCo
The Land Information System (LIS) now contains a number of land surface models including HTESSEL, JULES, and CABLE, a Data Assimilation feature and a standardized verification system (LVT). The coupling of LIS-WRF has therefore been able to provide an initial testbed for the Local coupled land-atmospheric Modelling Project (LoCo) diagnostics by offering land (LSM) and atmosphere (PBL) scheme flexibility. A LoCo working group has been established and expanded with bi-monthly telecons and coordination of LoCo research. This group has been bringing together and testing a wide range of land-atmosphere coupling diagnostics (the traditional mixing diagrams, LCL-deficit, Findell-Eltahir diagnostics of triggering of convection, revised relative humidity tendency variables, McNaughton coupling coefficient). There have been many LoCo papers published this year that define these diagnostics and apply them to a range of models (from local to global) and reanalysis products. In addition, this working group has organized a 'LoCo Poster Cluster' at the WCRP Open Science Conference planned for October 2011. They have identified a 1st-order LoCo experiment based on the LIS-WRF framework, but also plan a wider GLASS panel discussion on if/when/how a proper LoCo Project should be organized and sponsored under GLASS, or if the working group approach should remain the thrust of the effort for the near-term.

GSWP3
A follow-up project to the Global Soil Wetness Project 2 (GSWP2) is currently being planned. The new components being considered for this project are:

- Provide a comprehensive set of land surface states for the period including entire 20th Century and recent years (~1901 to present) that can serve as a long-term land surface reanalysis suite.
- Include carbon models, to explore/attribute a possible carbon-related effect or changes in Hydro-Energy-Eco functioning. This could make a bridge to the terrestrial carbon cycle modelling community.
- Explore uncertainties of input data sets and their propagation through different model schemes under super-ensemble (multi-input and multi-model) experiments.
- Build a robust simulation benchmarking framework through component-wise verification using a broad set of independent observational products (e.g. routing scheme for a validation of discharge (flux); GRACE for a validation of terrestrial water storage variation (storage)).
- Include simulations using CMIP5 models, both present day and future conditions.

Results from a pilot error propagation analysis have shown that differences in precipitation lead to non-linear

differences in evaporation and runoff whose size and sign depends on the climate and vegetation regime. However, the spread between different land models was generally larger than the spread in the precipitation forcings and showed different spatial pattern, pointing at a model dependent sensitivity of evaporation and runoff. A white paper (experimental protocol) has been produced and discussed at a GLASS sub-meeting in March 2011, after which further iterations have taken place. This included engagement of the carbon community and inclusion of a suite of LSMs in varying hydrological and carbon treatments. A revised version will be circulated for discussion at the October panel meeting, with expected kick-off date of the experiments to be ~3 months following.

ALMIP2
The 2nd African Monsoon Multidisciplinary Analysis (AMMA) Land Model Intercomparison Project (MIP) is currently under development. In this experiment, the focus is on a much higher spatial resolution (5 km) than in the Atmospheric Model Inter-comparison Project (ALMIP1), to focus on the subtle hydrology and vegetation processes that dominate there (occasionally very large rooting depths, land use change, sloping bedrocks removing water from the catchment, strong variability in runoff), and to enable use of high resolution satellite data. The period will cover 4 years, where the forcing is coming from a blend of in situ and radar/Landsat/other satellite data. The project can give recommendations on the parameterization of runoff scaling. As this project has regional hydrological aspects, it is also considered to be in ideal candidate for a collaborative project between GLASS and GHP to foster close working relationships. Once completed, the "white paper" will be circulated to GHP representatives for input on experimental design changes required for the GHP community, and is expected to occur this fall.

PALS and Benchmarking
The Beta-version of the Protocol for the Analysis of Land Surface (PALS) models (http://pals.unsw.edu.au) has been designed to analyse in a standard way uploaded single site model simulations with Fluxnet observations. Extensions to other datasets and the development of benchmarking tests are under development. Synchronization with components of the Land Information System (e.g. the verification package, LVT) is being considered. The aim has been for the Fluxnet community to up load appropriate data to PALS, but to date there has been almost no uptake from the flux data community. Hence a semi-automated script has been written to process data directly from the Fluxnet.org website. However, there are issues with data duplication, gap filling and quality control. Currently 15 sites have been successfully processed. The benchmarking activities are a second opportunity to link to the terrestrial carbon cycle modelling community who are also currently working towards a benchmarking system (iLAMB).

A related activity is that of a joint GEWEX Hydroclimatology Panel (GHP)-GLASS project to demonstrate benchmarking approaches using PALS that ultimately will be published in GEWEX News. This includes GHP providing CEOP-level data sets for use in PALS, and establishing empirical benchmarks in PALS from which to evaluate a suite a models.

Lastly, a Benchmarking Working Group has been established with GLASS panel members and related activities that convenes via bi-monthly telecons. Activities include PALS, ALMIP-2, GHP-integration project (see below), LIS LVT, and outreach towards the International Land Model Benchmarking (ILAMB) Project and the Carbon- Land Model Intercomparison Project (C-LAMP). In addition, a dedicated session on benchmarking will be hosted by GLASS panel members at the American Meteorological Society's Annual Meeting in January 2012.

PILDAS
The Project for Intercomparison of Land Data Assimilation Schemes (PILDAS) is aimed at defining a land data assimilation framework that has known and desirable properties with respect to the information gain, possibility to tune and apply the system, flexibility of data and models etc. The experimental design is aimed at eventually assimilating satellite soil moisture data [Soil Moisture Observing System (SMOS) and Soil Moisture Active Passive (SMAP] mission, but will use model generated synthetic data in the first phase. The experiment will address a multi-year period for a limited domain. It will be soil moisture instead of brightness temperature that is assimilated, to avoid too much focus on the retrieval algorithm. Currently a test phase of PILDAS is underway with NASA and MeteoFrance as partners. After successful testing, more groups will be invited. A poster will be presented at the WCRP Open Science Conference in Denver in October 2011.

New Directions
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 has been re-structured into three elements: Benchmarking, model data fusion and land-atmosphere coupling. The concept of benchmarking (rather than validation) will enable the modelling

community to identify the current strengths and weaknesses of our models in relation to their required applications. This is a complete shift of focus for the modelling community and will require careful definitions of the a priori metrics that a model needs to achieve.

The second strand of model data fusion will bring data assimilation 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 final strand of GLASS aims at understanding the physical interactions between the land and the atmosphere and how feedbacks can change the subsequent evolution. While the GLACE1 and GLACE2 projects have demonstrated regions of the globe and situations where the land can have a significant impact on atmospheric evolution, they also highlighted large differences between modelling systems. 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 parameterisations interact. The focus is at both the process/local level (LoCo) and the global behavior of the coupling (GLACE). This understanding will help to maximise the inherent predictability of the coupled land/atmosphere system.

Key Results:

- Launch of the GSWP3 project in collaboration with the terrestrial carbon cycle modelling community
- Launch of the ALMIP2 project in collaboration with GHP
- Demonstration of the PALS benchmarking system in collaboration with GHP and for publication in GEWEX-News
- Refinement of a white paper and completion of experimental design for the PILDAS experiment
- Identification of possible LoCo community experiments
- Design of a possible GLASS/GALBS project to study diurnal cycles, including both the stable boundary layer and land/atmosphere coupling in unstable conditions.

Issues and Recommendations:

- Identification of gaps in current GLASS activities (e.g., cold processes) should be a priority

Issues for attention by the SSG:

There has been little up-take of the PALS system by the Fluxnet community. This has lead to the data being analysed by the modelling community rather than the observational community that collected the data. This is far from ideal and means that the population of the PALS database is leading to data that are not precisely the versions that are on the Fluxnet.org website.

It has been difficult to identify representatives from GHP who would be willing to be involved in helping to design the ALMIP2 project. This has not held the project up, but could do in the near future. The result of such delays may be that the project goes ahead without GHP involvement. Hopefully, the GHP-GLASS-PALS activity and article will provide an impetus for broader collaboration going forward.

Contributions to WCRP Strategic Themes:

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 (GLACE2, 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.
- 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).

- 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.

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.

Summary:

GLASS activities and projects have transitioned well over the last year into the new framework (MDF, Benchmarking, LAC). This includes formation of working groups to organize and support projects that are at the early formation and launch stages (e.g. ALMIP2, GSWP3). Although a core component of LAC is winding down in GLACE2, the LoCo working group has expanded to include studies of local and global coupling, and the formality of a community-wide project will be discussed in the near-term. GLASS has identified integration with GHP as a priority, and the activities described above should further this interaction. GLASS-GABLS and GLASS- Working Group on Numerical Experimentation (WGNE) collaboration will also be addressed in the near term. The adoption of new terms of reference for the panel will improve the expectations of and for panel members, bring young scientists into the fold, and allow the outside community better access to and understanding of the panel operations.

List of Meetings/Workshops:

23 – 27 August 2010: GLASS panel meeting at Pan-GEWEX
2 March 2011: GSWP3 sub-group meeting at WCRP Workshop on Drought Predictability and Prediction in a Changing Climate

Working Group Telecons:

LoCo: September, November, December 2010, January 2011, July 2011
Benchmarking: November, December 2010, January, February, April 2011

Planned Meetings/Workshops:

17 – 21 October 2011: WGNE annual meeting (GLASS presentation)
23 October 2011: GLASS panel meeting at WCRP OSC
7 – 10 November 2011: ECMWF/GABLS workshop (proposal for GLASS-GABLS experiment)
22 – 26 January 2012: AMS Annual Meeting (Benchmarking session hosted by GLASS)

List of Key Publications:

Koster, R.D., S. P. P. Mahanama, T. J. Yamada, Gianpaolo Balsamo, A. A. Berg, M. Boisserie, P. A. Dirmeyer, F. J. Doblas-Reyes, G. Drewitt, C. T. Gordon, Z. Guo, J.-H. Jeong, W.-S. Lee, Z. Li, L. Luo, S. Malyshev, W. J. Merryfield, S. I. Seneviratne, T. Stanelle, B. J. J. M. van den Hurk, F. Vitart, and E. F. Wood (2011): The Second Phase of the Global Land-Atmosphere Coupling Experiment: Soil Moisture Contributions to Subseasonal Forecast Skill; J.Hydrometeorol., in press.

Hurk, B.J.J.M. van den, F. Doblas-Reyes, G. Balsamo, R.D. Koster, S.I. Seneviratne en H. Camargo Jr, Soil moisture effects on seasonal temperature and precipitation forecast scores in Europe; Clim. Dyn., 2010, doi:10.1007/s00382-010-0956-2.

Koster , R. D., S. Mahanama, T. Yamada, G. Balsamo, A.A. Berg, M. Boisserie, P. Dirmeyer, F. Doblas-Reyes, G. Drewitt, C.T. Gordon, Z. Guo, J.H. Jeong, D.M. Lawrence, W.-S. Lee, Z. Li, L. Luo, S. Maleyshev,

W.J. Merryfield, S.I. Seneviratne, T. Stanelle, B.J.J.M. van den Hurk, F. Vitart and E.F. Wood (2010), Contribution of land surface initialization to subseasonal forecast skill: First results from a multi-model experiment, Geophys. Res. Lett., 37, L02402, doi:10.1029/2009GL041677.

Grimmond C.S.B., Blackett, M., Best, M., Barlow, J., Baik, J.-J., Belcher, S., Bohnenstengel, S.I., Calmet, I., Chen, F., Dandou, A., Fortuniak, K., Gouvea, M.L., Hamdi, R., Hendry, M., Kondo, H., Krayenhoff, S., Lee, S.-H., Loridan, T., Martilli, A., Miao, S., Oleson, K., Pigeon, G., Porson, A., Salamanca, F., Shashua-Bar, L., Steeneveld, G.-J., Tombrou, M., Voogt, J., Zhang, N., 2010. The international urban energy balance models comparison project: First results from phase 1. Journal of *Applied Meteorology and Climatology*, 49, 1268-1292

Grimmond, C.S.B., Blackett, M., Best, M., Baik, J.-J., Belcher, S., Bohnenstengel, S.I., Calmet, I., Chen, F., Dandou, A., Fortuniak, K., Gouvea, M., Hamdi, R., Hendry, M., Kondo, H., Krayenhoff, S., Lee, S.-H., Loridan, T., Martilli, A., Masson, V., Miao, S., Oleson, K., Pigeon, G., Porson, A., Salamanca, F., Steeneveld, G.-J., Tombrou, M., Voogt, J., Zhang, N., 2010: The International Urban Energy Balance Comparison Project: Recent Results and Major Findings. *International Journal of Climatology*, **31,** 244-272

Santanello, J. A., C. Peters-Lidard, S. Kumar, W.-K. Tao, and C. Alonge, 2009**:** A modeling and observational framework for diagnosing local land-atmosphere coupling on diurnal time scales. *J. Hydromet,* **10,** 577-599.

Santanello, J. A. et al., C. Peters-Lidard, and S. Kumar, 2011: Diagnosing the Sensitivity of Local Land-Atmosphere Coupling via the Soil Moisture-Boundary Layer Interaction. *J. Hydromet.,* **in press.**

Ferguson, C. R. and E.F. Wood, 2011: Observed land-atmosphere coupling from satellite remote sensing and re-analysis. J. Hydrometeor., Early Online, doi: 10.1175/2011JHM1380.1.

Findell, K. L., P Gentine, B R Lintner, and Christopher Kerr, June 2011: Probability of afternoon precipitation in eastern United States and Mexico enhanced by high evaporation. *Nature Geoscience*, 4(7), doi:10.1038/ngeo1174.

Dirmeyer, P. A., 2011: The terrestrial segment of soil moisture-climate coupling. *Geophys. Res. Lett.*, (in press), doi:10.1029/2011GL048268.

List of Members and Their Term Dates:
A core agenda item for the full GLASS panel meeting in October is to discuss and set the Terms of Reference for membership. We have distributed a proposed TOR to the panel members and GEWEX. Therefore, term dates (other than chairs) are TBD after that meeting.

Martin Best (Co-chair)
Joe Santanello (Co-chair)
Bart vd Hurk (Co-chair, stepped down 31 Dec 2010)
Christa Peters-Lidard
Eleanor Blyth
Gianpaolo Balsamo
Matt Rodell
Michael Ek
Patricia de Rosney
Sonia Seneviratne
Aaron Boone
Gab Abramowitz
Hyungjun Kim
Rolf Reichle
Andy Pitman
Luis Bastidas
Paul Houser