Global Land/Atmosphere System Study (GLASS)
Brief Overview

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GLASS Co-chairs
GLASS panel members and other GEWEX collaborators

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Global Land/Atmosphere System Study (GLASS)





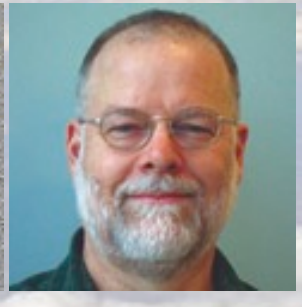
Paul Dirmeyer *Andy Pitman* *Ann Henderson-Sellers*

Jan Polcher *Taikan Oki*

"Founding" Chairs **PILPS Era**








Bart van den Hurk *Joe Santanello* *Mike Ek*

Martin Best *Aaron Boone* *Gab Abramowitz*

Former/Current Co-Chairs

Complexity of Land–Atmosphere Interactions

GEWEX Imperatives

GEWEX Plans for 2013 and Beyond:

Diagnostics of stand-alone model components are more straight-forward, but it is important to establish metrics for coupled systems (i.e., land-atmosphere) to quantify strength of the interactions.

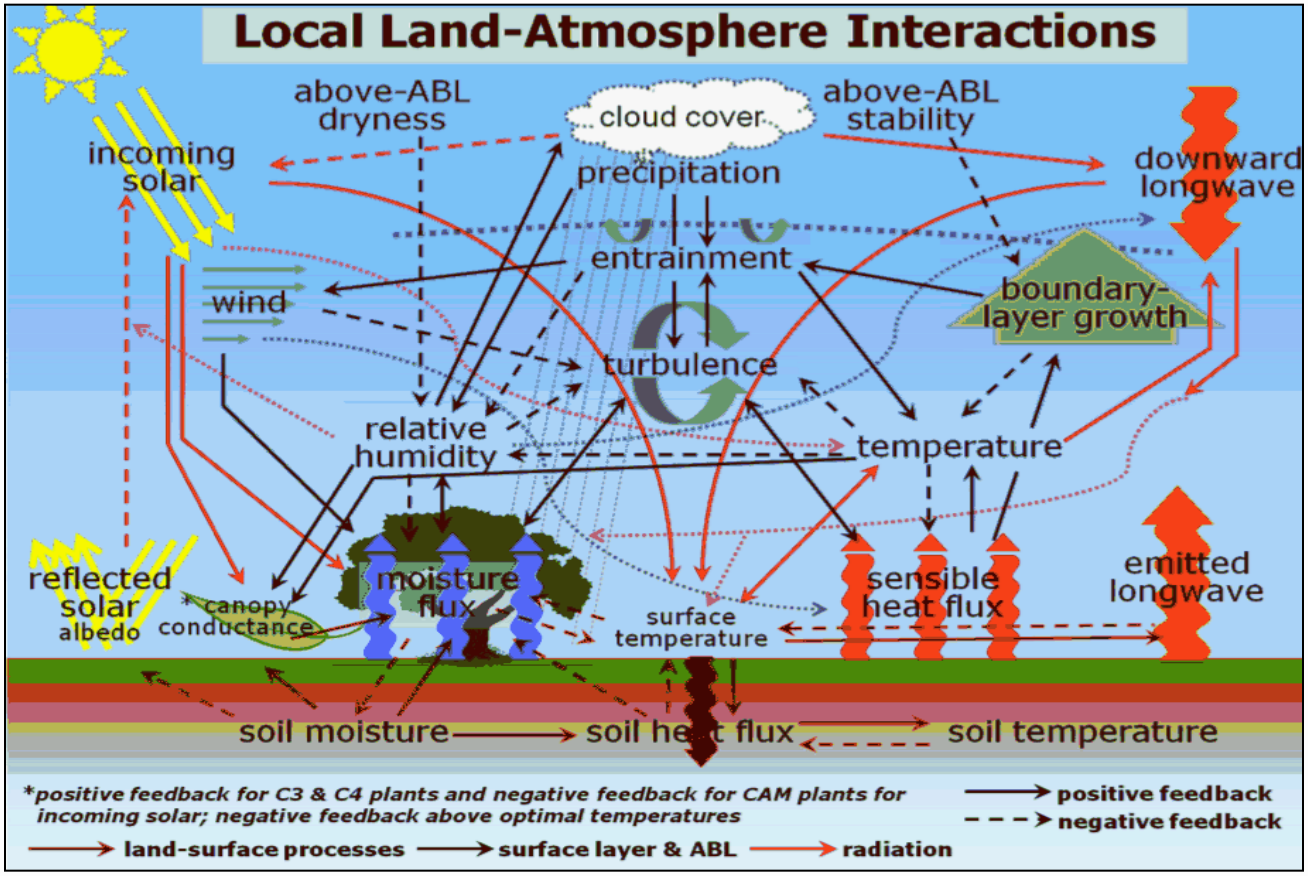
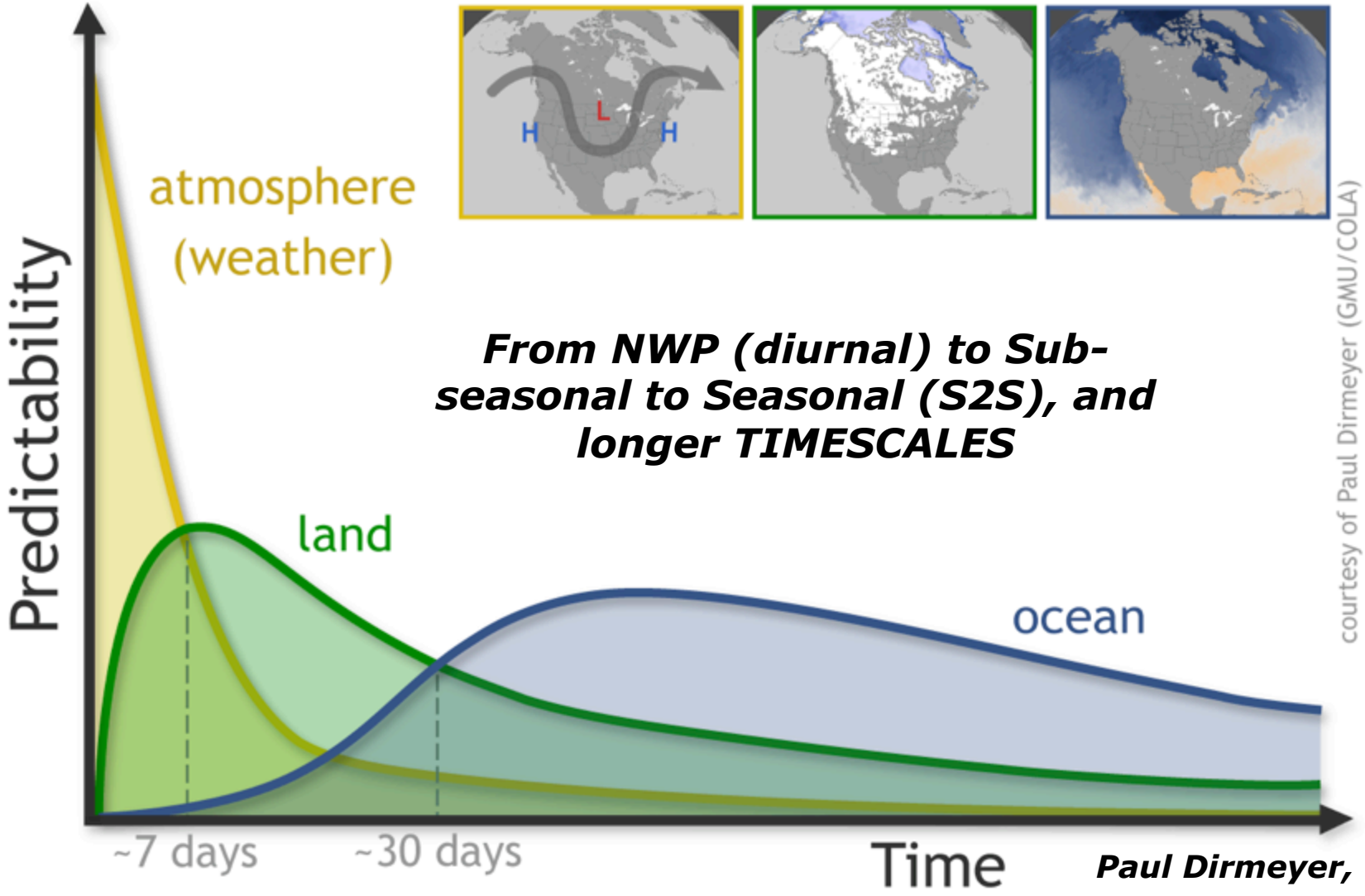


Fig. 3.1. Schematic of the complex interactions between the land surface, atmospheric boundary layer (ABL), and radiation via many variables (temperature, relative humidity, wind and associated turbulence, cloud cover, etc).

Courtesy Mike Ek and Kevin Trenberth, adapted from Ek and Holtslag (2004, J. Hydromet.)

Role of Land in Predictability



From NWP (diurnal) to Sub-seasonal to Seasonal (S2S), and longer TIMESCALES

Paul Dirmeyer, GMU

GLASS Vision and Mission

The GEWEX Vision

Water and energy are fundamental for life on Earth. Fresh water is a major pressure point for society owing to increasing demand and vagaries of climate. Extremes of droughts, heat waves and wild fires, as well as floods, heavy rains, and intense storms increasingly threaten to cause havoc as the climate changes. Other challenges exist on how clouds and aerosols affect energy and climate. Better observations and analysis of these phenomena, and improving our ability to model and predict them, will contribute to increasing information needed by society and decision makers for future planning.

GLASS role: Better representation of the Earth System by understanding the role of land.

The GEWEX Mission

To measure and predict global and regional energy and water variations, trends, and extremes, such as heat waves, floods, and droughts, through improved observations and modeling of land, atmosphere, and their interaction, thereby providing the scientific underpinnings of climate services.

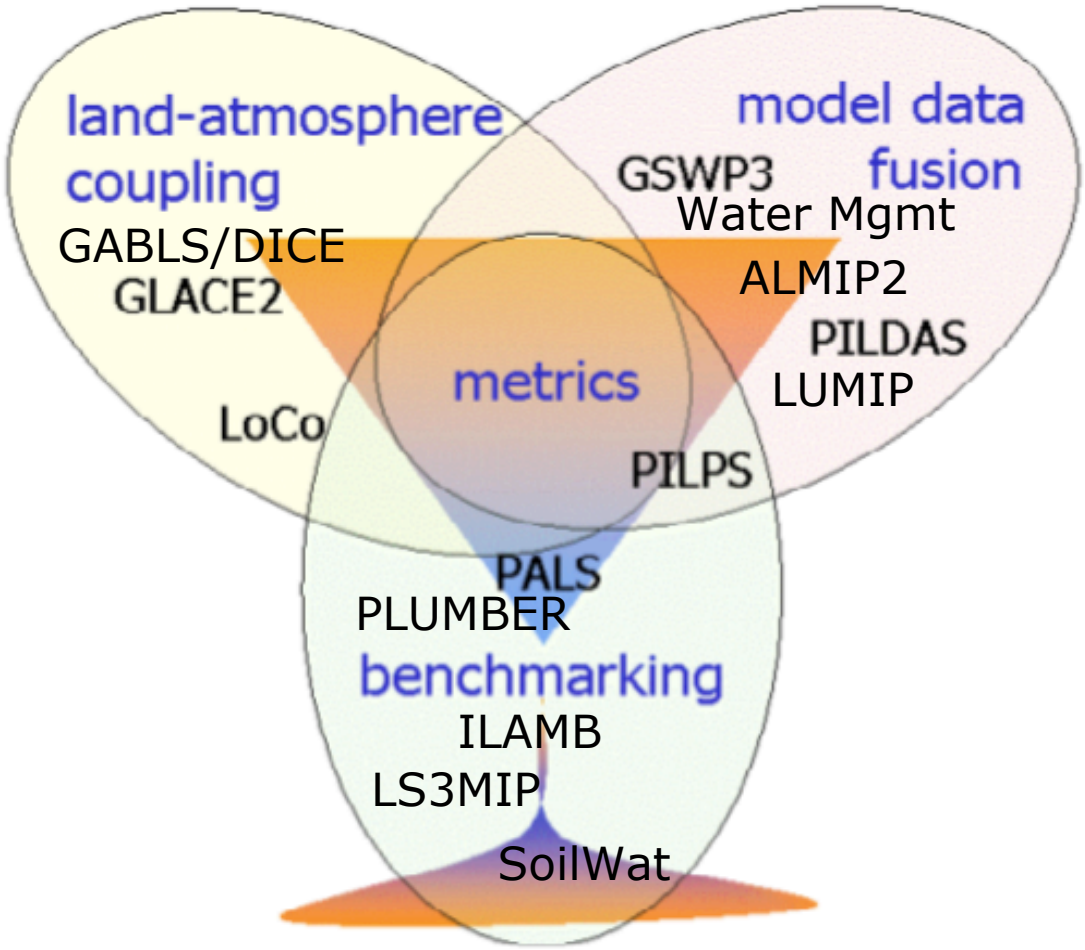
GLASS role: Identify and improve modeling of land-surface processes and land-atmosphere interactions to support the GEWEX Mission.

GLASS Structure

The aim of GLASS is to promote community activities that improve:

- **Our best estimates and the model representation of state variables.**
- **Our understanding of land/ atmosphere feedbacks.**
- **Our understanding of the role of land surface in predictability**

To best achieve these aims, GLASS has been structured into three elements:



GLASS Projects

BENCHMARKING:

PLUMBER	PALS Land sUrface Model Benchmarking Evaluation pRoject
PALS	Protocol for the Analysis of Land Surface models
ILAMB	International Land Atmosphere Model Benchmarking activity
GSWP3	Global Soil Wetness Project phase 3 (offline)
SoilWat	GEWEX Soils and Water initiative

LAND-ATMOSPHERE INTERACTION:

LoCo	Local (land-atmosphere) Coupling
GABLS/DICE	DIurnal land/atmosphere Coupling Experiment, including GEWEX Atmospheric Boundary Layer Study GABLS4/DICE-over-ICE (Dome C, Antarctica)
LS3MIP	Land surface, snow, and soil moisture MIP (CMIP6)
LUMIP	Land Use Model Intercomparison Project

GLASS Projects: Cross-cuts

Cross-Cutting projects/actions:

PALS, PLUMBER – LSM benchmarking, links to GSWP3 / LMIP / **ILAMB**

GSWP3 – Links to carbon community (Integrated Land Ecosystem-Atmosphere Processes Study, iLEAPS), LMIP (CMIP6)

LS3MIP – Land surface, soil moisture and snow model intercomparison project; CMIP6 endorsed

LUMIP – Land use/change, links to iLeaps, heritage of LUCID, CMIP6 endorsed

LoCo – SGP testbed, assessment of land-atmosphere coupling diagnostics.

DICE – Land-atmosphere interaction, links to GABLS, including GABLS4 "*DICE-over-ICE*" – land-atmosphere interaction (stable BL-Antarctica), links to GASS

Recently launched or to be launched:

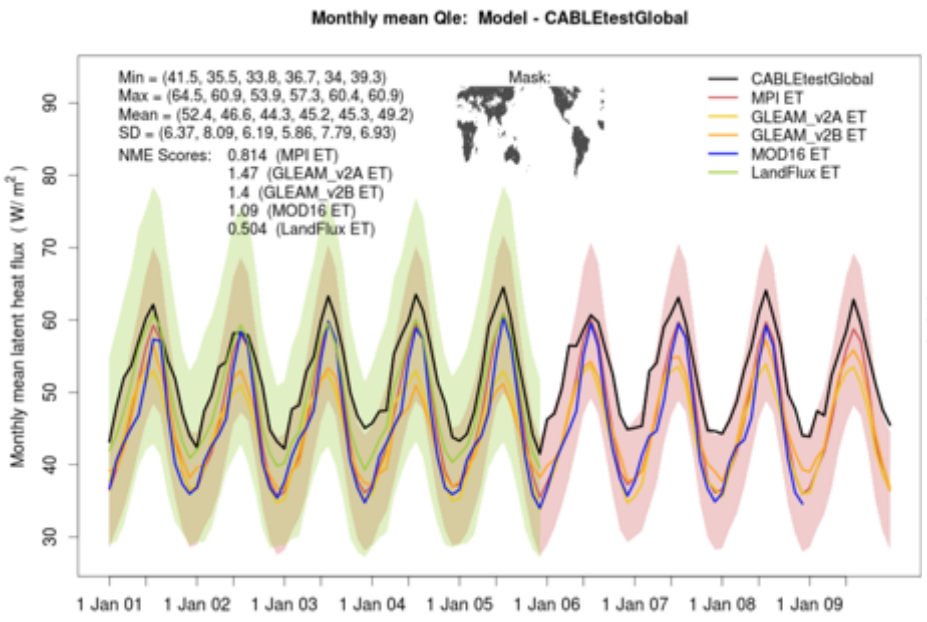
SoilWat - datasets, improved soil process representation, parameter sensitivity understanding - potential links with GDAP, GHP

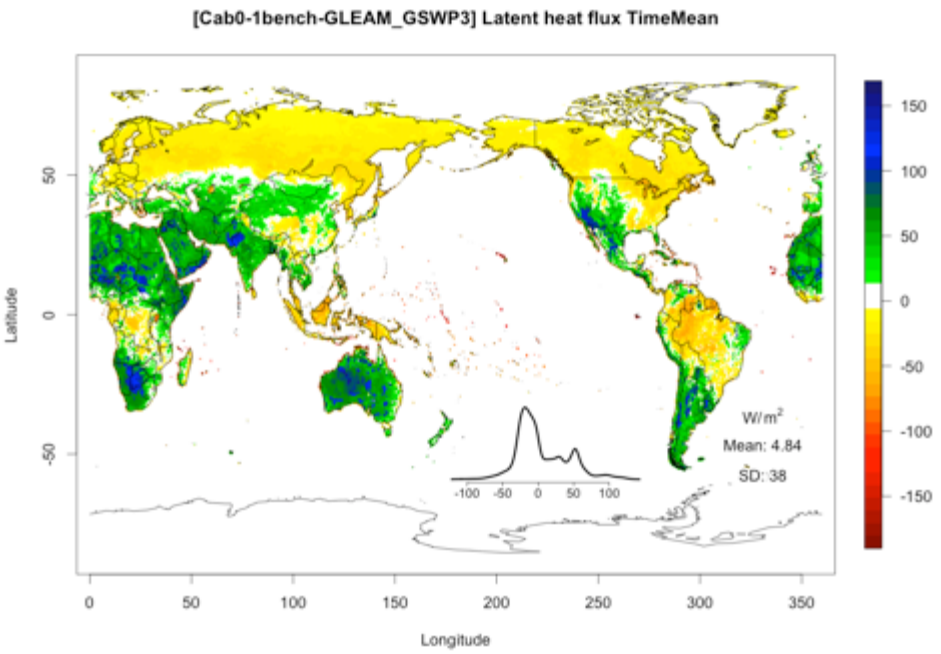
PLUMBER2 – as for PLUMBER above, additional sites/metrics.

Land Data Assimilation (legacy "PILDAS") – to be folded into a future phase of PLUMBER.

Protocol for analysis of Land Surface models (PALS)

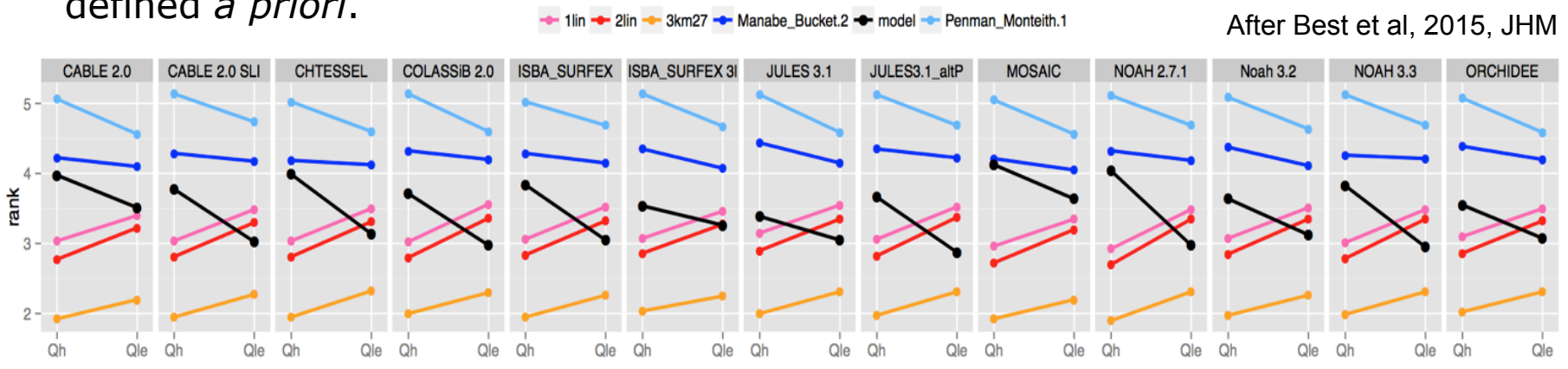
- A web application for automated evaluation and benchmarking of land surface models (LSMs), hosting data sets required to drive/force and evaluate a LSM for an experiment. ”PALS2” to be used for PLUMBER-2. See: *modelevaluation.org*
- Analysis not specific to particular package / language (e.g. R, Python, NCL, Matlab, Fortran etc all possible) – ILAMB, LVT, PALS.
- Future: Integration of ILAMB into PALS is well advanced; Developing distributed architecture that will allow analysis to be co-located with big model outputs; Increasingly strict about enforcement of provenance and ancillary data collection.





The PALS Land sUrface Model Benchmarking Evaluation pRoject (PLUMBER)

- Compares land surface models to benchmarks with performance expectations defined *a priori*.

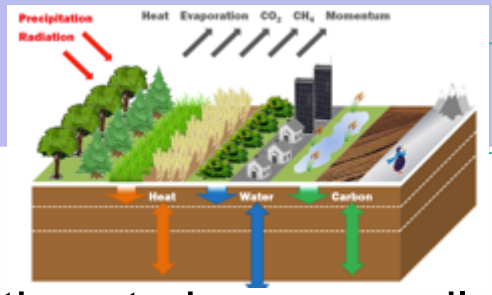


After Best et al, 2015, JHM

Headline result: Vertical axis: rank of each land surface model (LSM; black) against the 5 benchmarks, averaged over 20 Flux tower sites, 4 metrics: bias, correlation, SD, normalized mean error.

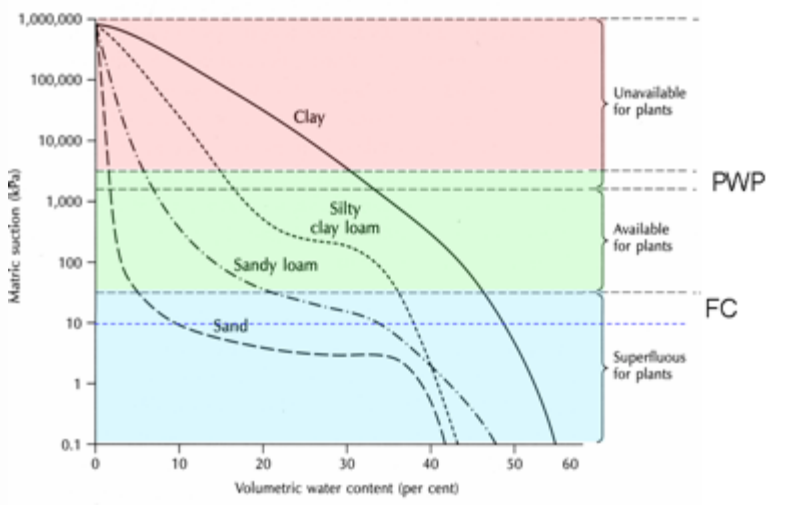
- On average, LSMs outperform Penman-Monteith and Manabe bucket.
- On average, LSMs sensible heat prediction is worse than an out-of-sample linear regression against downward SW radiation.
- For all fluxes, land models are comfortably beaten by out-of-sample regression against SWdown, Tair and RelHum.
- *Need to make better use of the information in the data sets, with "higher bars".*
- *Look "Deeper": surface-layer turbulence, vegetation/soil processes,* ***hydrology****.*

"SoilWat": **GEWEX** and International Soil Modeling Consortium (**ISMC**) project

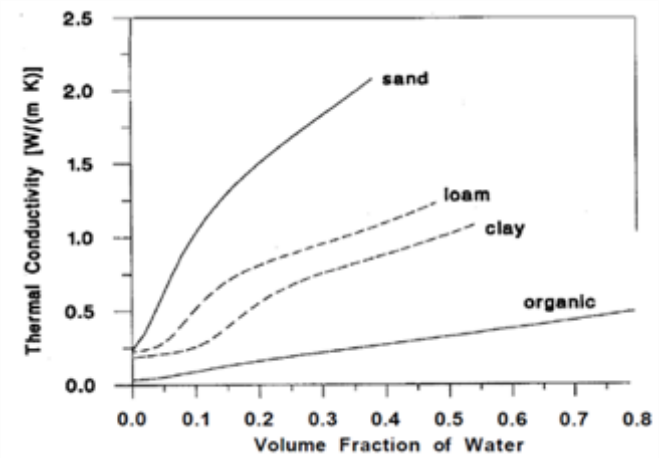


Land surface model

- Joint ISMC and GEWEX communities: Initiatives to improve soil and subsurface processes in current climate and hydrological models: SoilWat-PTF & SP-MIP.
- Evaluation of pedotransfer functions & related functional descriptions for calculation of hydraulic & thermal soil properties in global climate models.
- Possibly include some SoilWat component in PLUMBER-2.



Moisture retention curve (MRC)



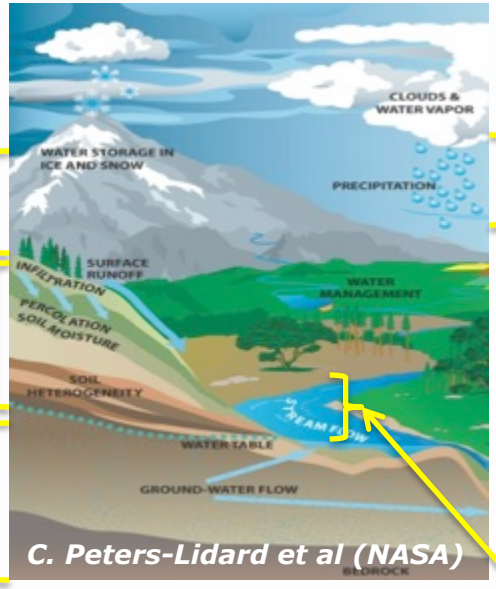
Thermal conductivity curve

Land Data Assimilation

- **Possibly include some land DA component in PLUMBER-2**

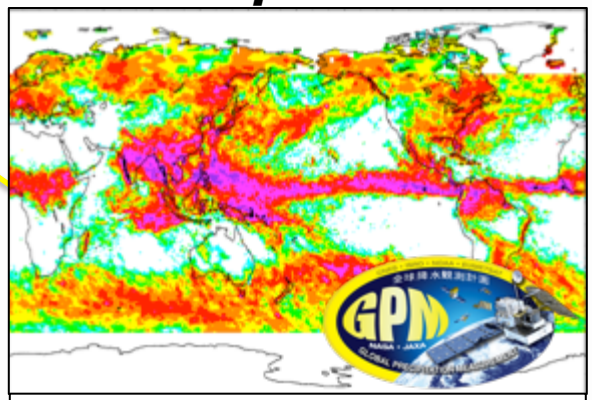
Snow

e.g. Snow Cover from Moderate Res. Imaging Spectroradiometer (MODIS)



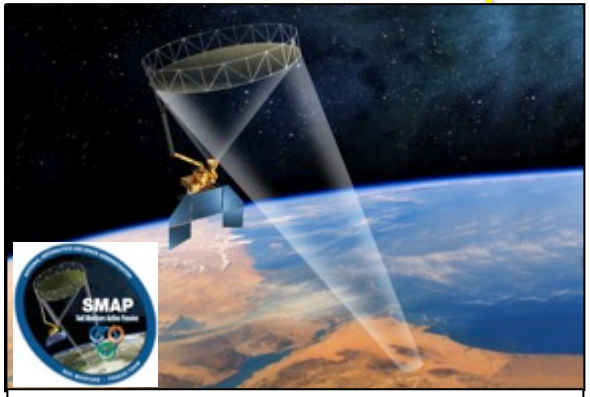
C. Peters-Lidard et al (NASA)

Precipitation



e.g. Global Precipitation Measurement (GPM)

Soil Moisture

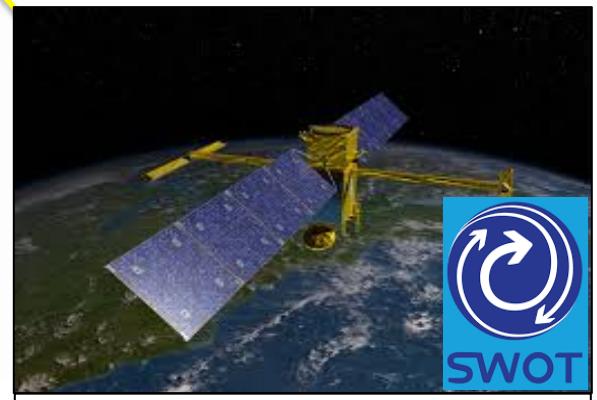


e.g. Soil Moisture Active Passive (SMAP)

Terr. Water Storage

Gravity Recovery and Climate Experiment (GRACE)

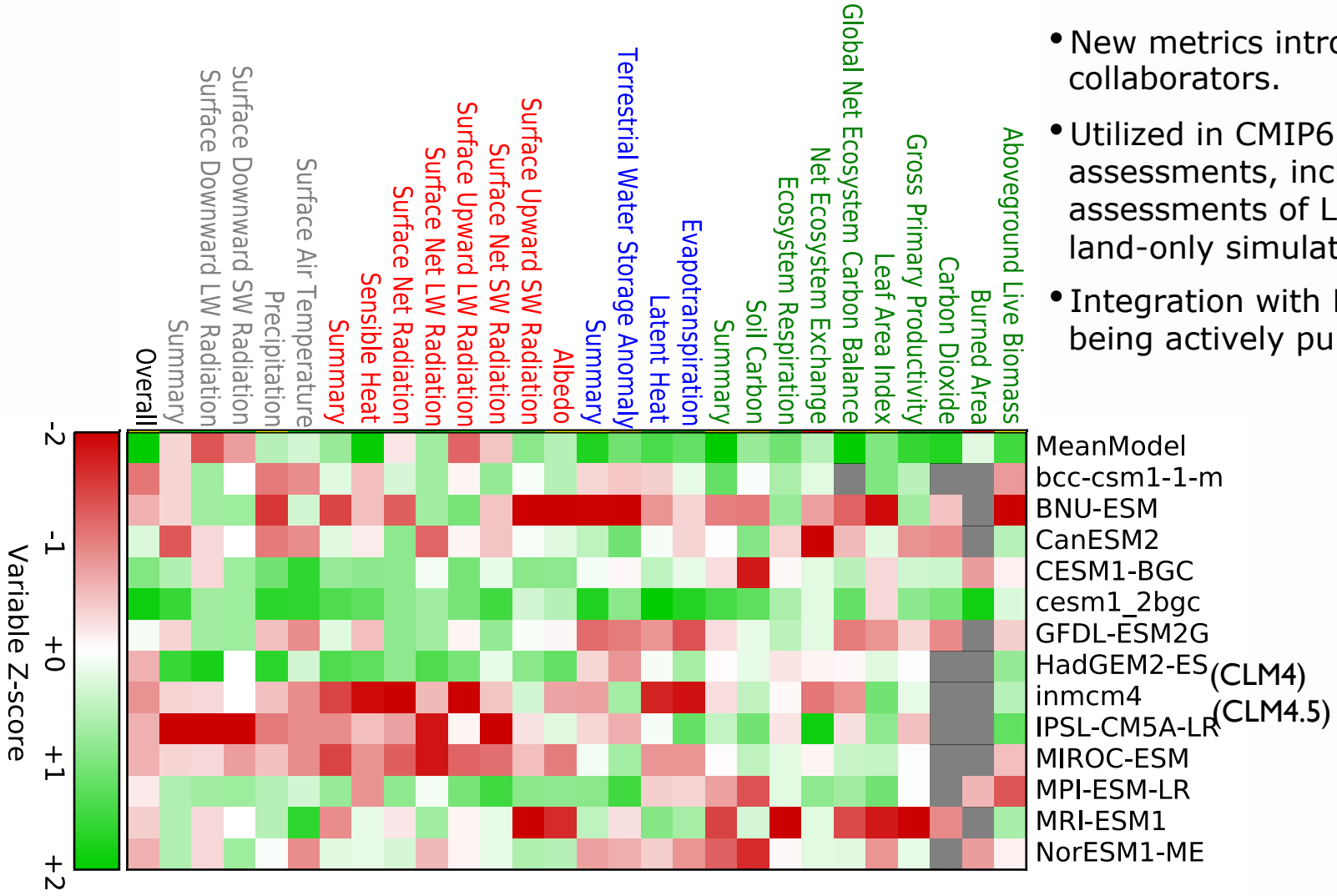
Surface Water



Surface Water & Ocean Topography (SWOT)

International LAnd Model Benchmarking (ILAMB) package

scores for RMSE, interannual variability, pattern correlation, variable-to-variable comparisons, +

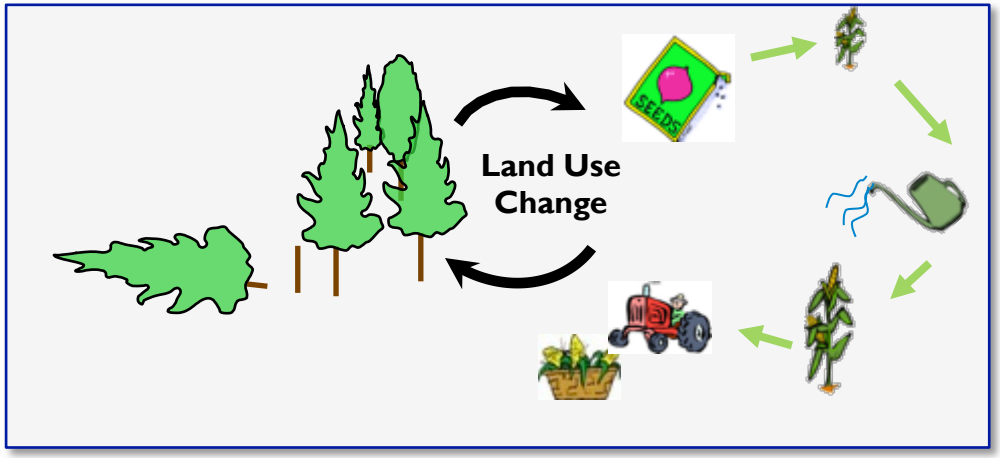


- New metrics introduced by collaborators.
- Utilized in CMIP6 assessments, including assessments of LS3MIP land-only simulations.
- Integration with PALS is being actively pursued.

Land Use Model Intercomparison Project
land-only land management experiments

Set of land-only historic (1850 – 2014) simulations with one-at-a-time modification of particular aspects of land management **850-2014**

1 Land historical all management
2 Year 1700 instead of 1850 start
3 No LULCC change
4 Alternate land use histories
5 No shifting cultivation
6 Crop and pasture as unmanaged grassland
7 Crops with crop model but no irrigation/ fertilization
8 No irrigation
9 No fertilization
10 No wood harvest
11 No grazing on pastureland
12 No human fire ignition/suppression
13 Constant 1850 CO_2
14 Constant 1850 climate



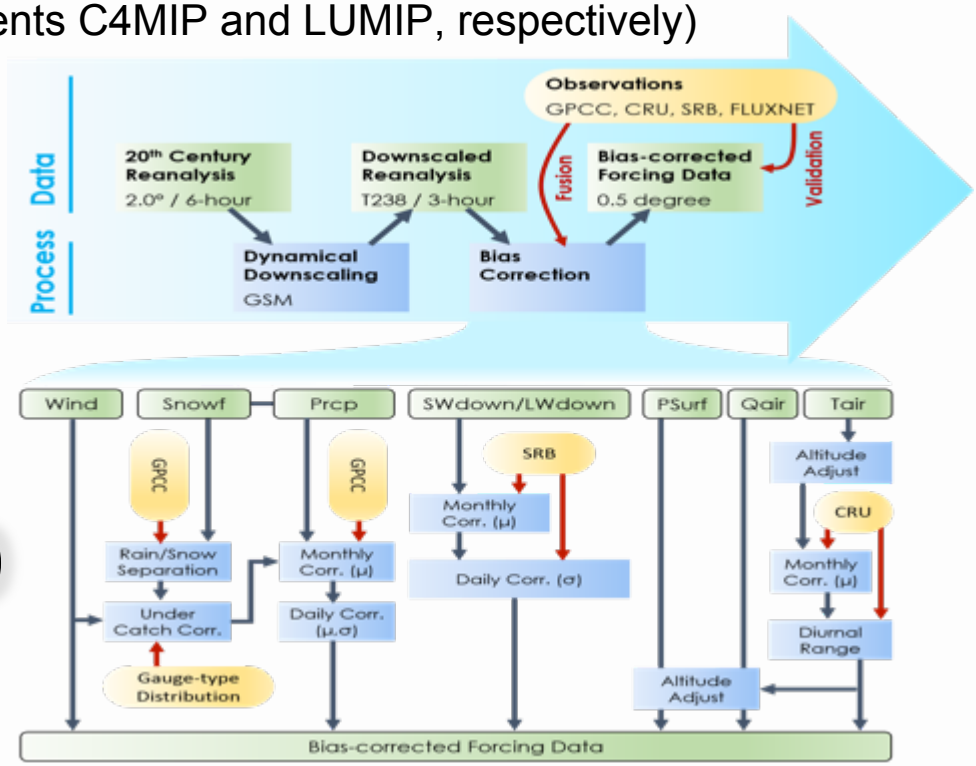
LUMIP is a CMIP6 "satellite" MIP, integrated with all CMIP6 activities. Designed in collaboration with LS3MIP, C4MIP, and DAMIP. LUMIP is cross-cutting across GEWEX and iLEAPS activities

Lawrence et al., 2016

Global Soil Wetness Project v3 (GSWP3) & LS3MIP

- LS3MIP: Land surface, soil moisture and snow model intercomparison project, part of the CMIP6 experiment suite.
- ***Assess land surface, snow, soil moisture feedbacks on climate variability and climate change, with coupled and offline experiments.***
- LS3MIP focuses primarily on the physical system (carbon cycle and vegetation dynamics covered in more depth by CMIP complements C4MIP and LUMIP, respectively)
- Two phases: LMIP/GSWP3 (offline) and LFMIP (coupled, with feedbacks).
- Examine changes to energy and water cycles from the historical period through to projected futures.
- Coordinated with SnowMIP model intercomparisons.

GSWP3 Forcing Data V0



Local Land-Atmospheric Coupling (LoCo) Project

LoCo: GEWEX-GLASS core theme to understand, model, and predict the role of local land-atmosphere coupling in the evolution of land-atmosphere fluxes and state variables, including clouds.

Answer the following questions:

- What role do land-atmosphere interactions (i.e., coupling strength) play in hydrologic extremes and abrupt shifts in regional climate?
- What are the trends in regional coupling strength over the period of record? Where has coupling enhanced (or suppressed) the global warming signal?
- How do we measure & benchmark coupling? *Coupling Metrics Toolkit*

To accurately represent the relationship between soil moisture (SM) and precipitation (P), and coupling strength in models, it is necessary to carefully examine and quantify the full series of interactions & feedbacks (i.e., links in the chain) at the process-level, including the planetary boundary layer (PBL) feedback.

- Field Campaign Focus, e.g. LAFE, SGP, etc; link w/SMAP, PBL profiling.
- *LoCo WG continues to grow & support initiatives on L-A coupling, supporting a new generation of L-A coupling leaders–"incubator"!*

SGP site

Diurnal land/atmosphere coupling experiment (DICE)

***Study the interactions between land-surface & atmos. boundary layer*.**

- Joint GLASS (land) - GASS (PBL/atmos.) project; follow on to *GEWEX Atmospheric Boundary Layer Study (GABLS) #2, where land-atmosphere coupling was identified as a important mechanism.*

Objective: Assess impact of land-atmosphere feedbacks.
Stage 1: stand alone land, and single column model (SCM) alone.
Stage 2: Coupled land-SCM.
Stage 3: Sensitivity of LSMs & SCMs to variations in forcing.

Findings so far: *Differences in models' (LSM+SCM) sensitivity to changes in forcing likely important in GCMs; needs better understanding. Examine further: surface momentum flux & profiles; large errors in evaporation dominate signal and impact of coupling; nocturnal fluxes/boundary layers, soil-surface coupling.*

- GABLS4 or "DICE-over-ice": Antarctica, snow/ice and strongly stable conditions.
- *Extend: other sites to cover a broad geographical range, e.g. LIASE (semi-arid).*

GLASS Connections to Other Projects

GHP: land-atmosphere data sets from RHPs for process studies, e.g.:
-> Hydrological Cycle in the Mediterranean Experiment (HyMeX).
-> Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) (Iberian Peninsula), including human effects/influences.
-> Anthropogenic water management: Ebro & Murray-Darling basins? (sufficient obs necessary, including remote sensing), LSM incorporate reservoir, hydrology, groundwater, irrigation, basin transfer. Joint GHP-GLASS workshop in Gif-sur-Yvette, October 2016; project specifics under development.

GDAP: utilize global water & energy products in land model benchmarking projects.

Monsoons (interactions with CLIVAR): joint initiative of GEWEX & CLIVAR
-> Importance of land-atmosphere interactions within monsoons.

Seasonal to Sub-seasonal (S2S): joint initiative of WWRP and WCRP
-> Contribution of land to predictability on the S2S timescales.

ILEAPS: biogeochemical cycles, land-atmosphere chemistry.

Cold Seasons Process: GHP, ILEAPS, CliC, ILEAPS focus on snow, frozen soils/ permafrost, tundra, e.g. Saskatchewan & Mackenzie river basins.

WMAC: Promoting model development and coordination across WCRP.

WGNE: Data assimilation & process-level improvement to model physics (e.g. PALS/PLUMBER, LoCo/DICE, interested in a renewed land DA effort).

WMO: Other working groups, e.g. within WWRP., e.g. Year of Polar Prediction (YOPP) project.

Alignment with WCRP Grand Challenges (GC) and GEWEX Science Questions (SQ)

	WCRP GC							GEWEX GSQ			
GLASS Projects	Melting Ice	Clouds, Circulation and Climate Sensitivity	Carbon Feedbacks	Weather and Climate Extremes	Water for Food	Regional Sea-Level Change and Coastal Impacts	Near-term Climate Prediction	Observations and Predict-ions of Precipitation	Global Water Resource Systems	Changes in Extremes	Water and Energy Cycles and Processes
PALS			✔	✔	✔		✔		✔	✔	✔
PLUMBER				✔	✔		✔		✔	✔	✔
ALMIP2		✔							✔		✔
PILDAS								✔	✔	✔	✔
GSWP3				✔	✔				✔	✔	✔
LS3MIP				✔	✔			✔	✔	✔	✔
Anthro Water		✔			✔				✔		✔
LUMIP			✔	✔	✔				✔	✔	✔
ILAMB			✔	✔	✔		✔		✔	✔	✔
SoilWat			✔	✔	✔		✔		✔	✔	✔
DICE		✔		✔				✔		✔	✔
LoCo		✔		✔	✔			✔		✔	✔

Key science questions in the next 5-10 years

- ***LAND IMPACT*:** Explore the impact of the land processes on Seasonal/Drought Prediction, and other high-impact "Earth System events" on society.

WCRP: "Back to basics"
GLASS efforts to understand processes, and observe and model them:

- ***PLUMBER***: Benchmarking land-surface models (LSMs) in uncoupled mode using many fluxnet data sets to thoroughly assess LSM performance. Include to Urban regions, introduce Land Data Assimilation, and Human Dimension/Water Management/Crops. Bring ILAMB into PALS land model evaluation environment for PLUMBER2. Related: ***Soil-Wat*** (soil processes). Discussed at GLASS panel meeting prior to 2018 GEWEX conference.
- ***LoCo*** (Local Land-Atmosphere Coupling): Continues to galvanize the land-atmosphere observing and modeling community in terms of new observations/field programs, establishing new useful "coupling" metrics. Related: ***DICE*** (Diurnal Land-Atmosphere Coupling Experiment), extend to Urban regions.
- Applied in e.g. ***LUMIP, LS3MIP, GSWP3.***

How to effectively improve our Earth System models?

- ***Hierarchical Model Development (HMD)*:** Component-by-component testing with increased levels of connection, building to a fully-coupled system, *w*ith benchmarks of performance at each HMD stage. GLASS-related HMD activities: **PLUMBER/SoilWat** (land-only), **DICE** (single column), **LoCo** (limited-area/regional coupling), etc. Extensive "data mining" effort required for driving/forcing & validation data sets.

The GEWEX GLASS panel will be soliciting for new members. Look for an announcement on the GEWEX website and in GEWEX News.

THANK YOU!