Global Land/Atmosphere System Study (GLASS) Brief Overview

Michael Ek (NCAR)
Gab Abramowitz (UNSW Sydney; outgoing)
Kirsten Findell (NOAA/GFDL; incoming)
GLASS Co-chairs
GLASS panel members and other GEWEX collaborators

WGNE-33
JMA, Tokyo, JAPAN, 09-12 October 2018

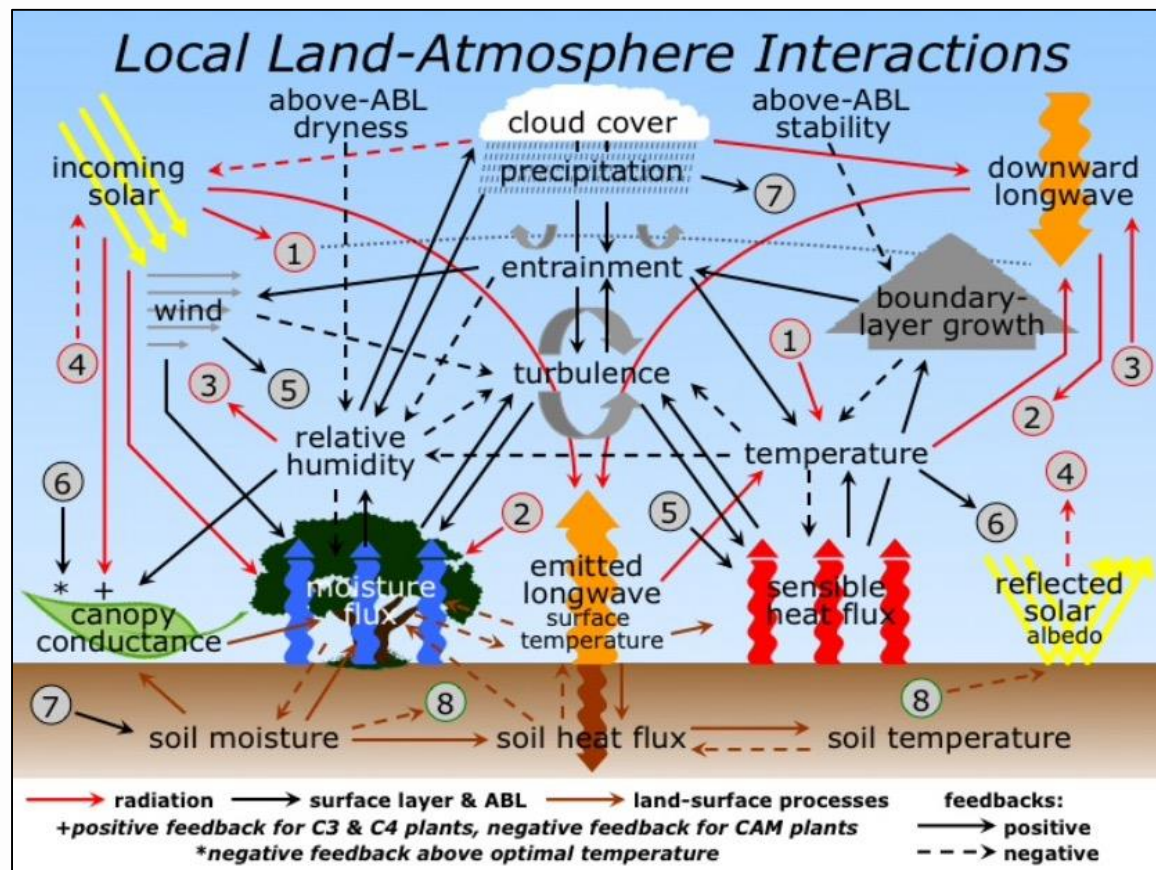# Complexity of Land-Atmosphere Interactions

GEWEX Imperatives
Plans for 2013 & 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.

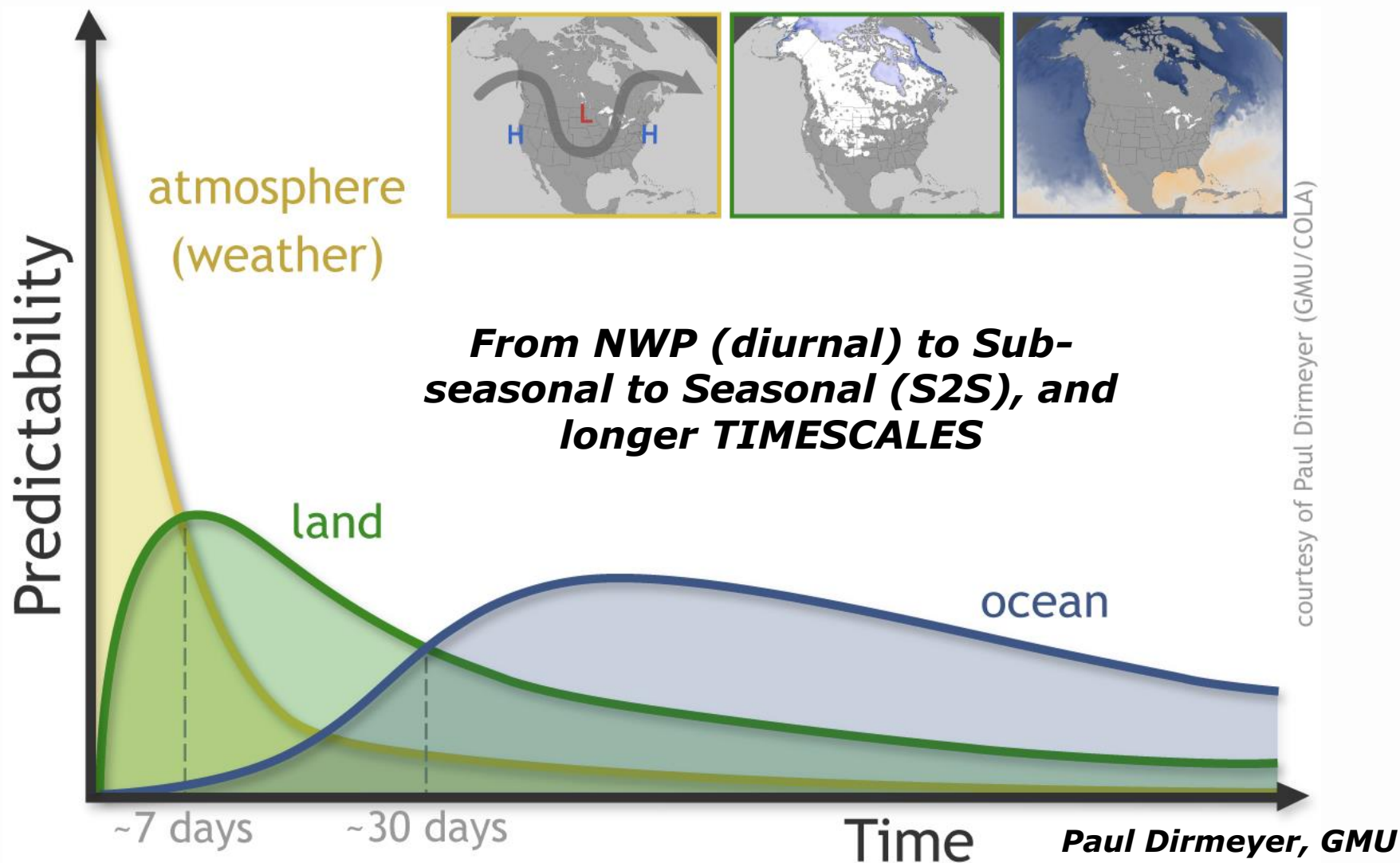**GEWEX and GLASS relevance to WGNE:**
Process-level improvements to weather and climate models, i.e. **land-hydrology and land-atmosphere interaction** on NWP to S2S and longer time scales, i.e. "Coupled from the Start" (Paul Dirmeyer, GLASS member, previous chair).

Schematic showing the complex interactions between the land surface, atmos-pheric boundary layer (ABL), and radiation via many variables (temperature, relative humidity, wind and associated turbulence, cloud cover, etc).

Adapted from Ek and Holtslag (2004, J. Hydromet.)

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

courtesy of Paul Dirmeyer (GMU/COLA)

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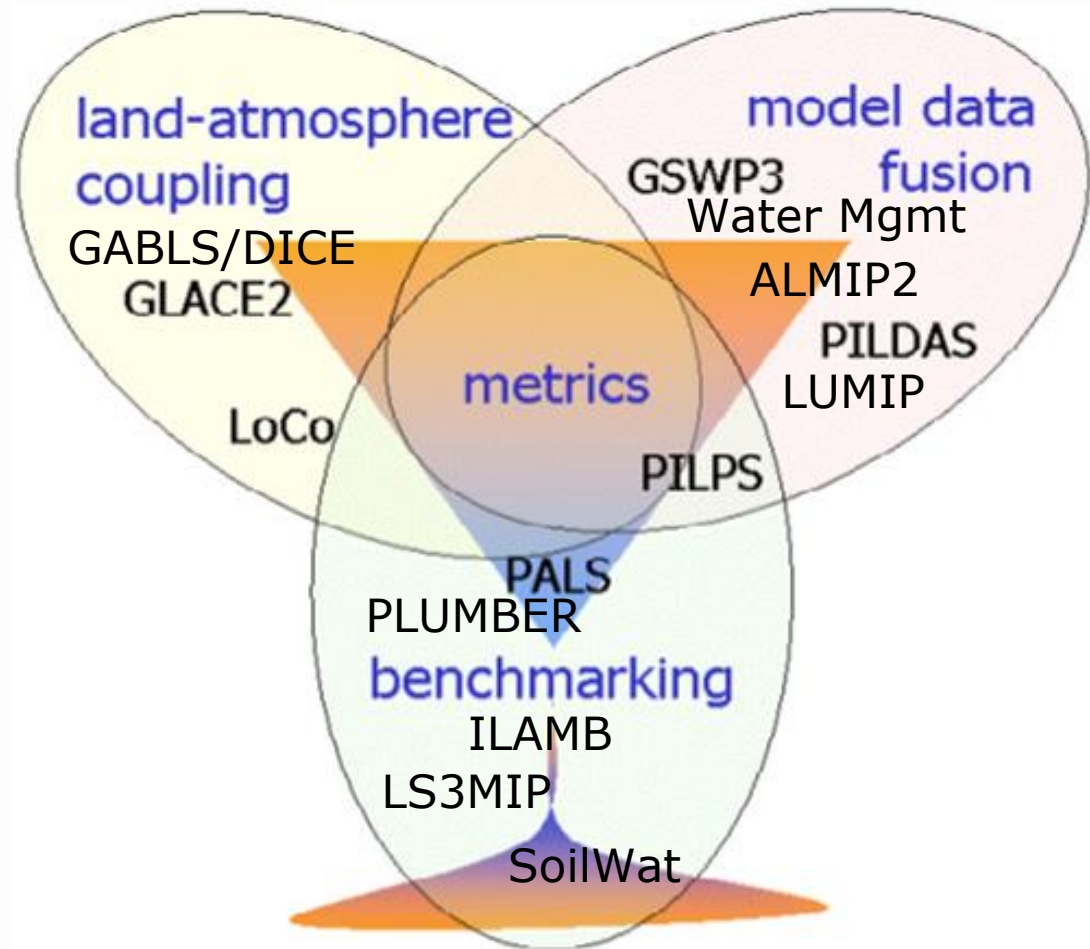
GLASS role: Identify and improve modeling of land-surface processes and land-atmosphere interactions to support the GEWEX Mission.

GEWEX
www.gewex.org

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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:

land-atmosphere coupling
GABLS/DICE
GLACE2
LoCo

model data fusion
GSWP3
Water Mgmt
ALMIP2
PILDAS
LUMIP

metrics

PILPS

PALS
PLUMBER
benchmarking
ILAMB
LS3MIP
SoilWat

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 – Southern Great Plains 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 GEWEX Global Atmospheric System Studies (GASS).

Recently launched or to be launched:

SoilWat - datasets, improved soil process representation, parameter sensitivity understanding - potential links with GEWEX GDAP,GHP panels.
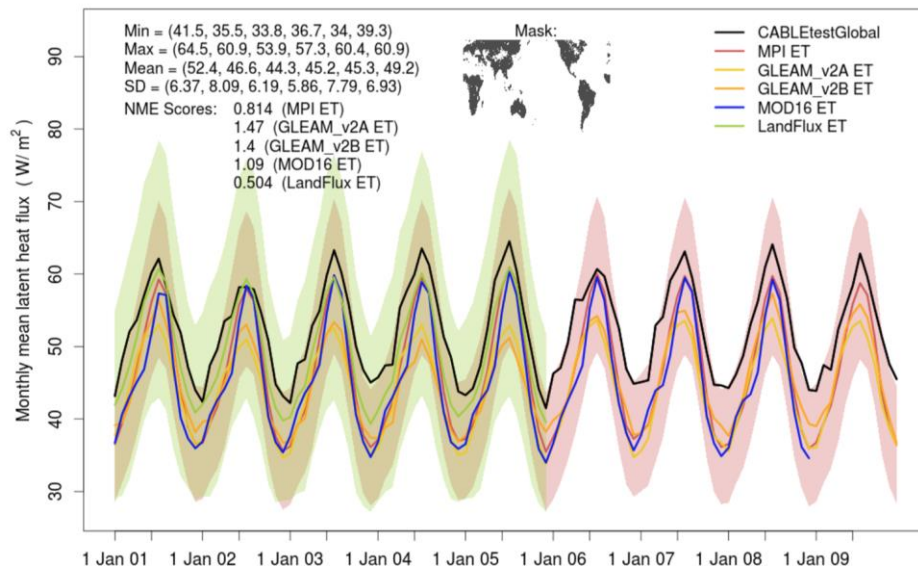
PLUMBER2 – as for PLUMBER above, additional sites/metrics.

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.
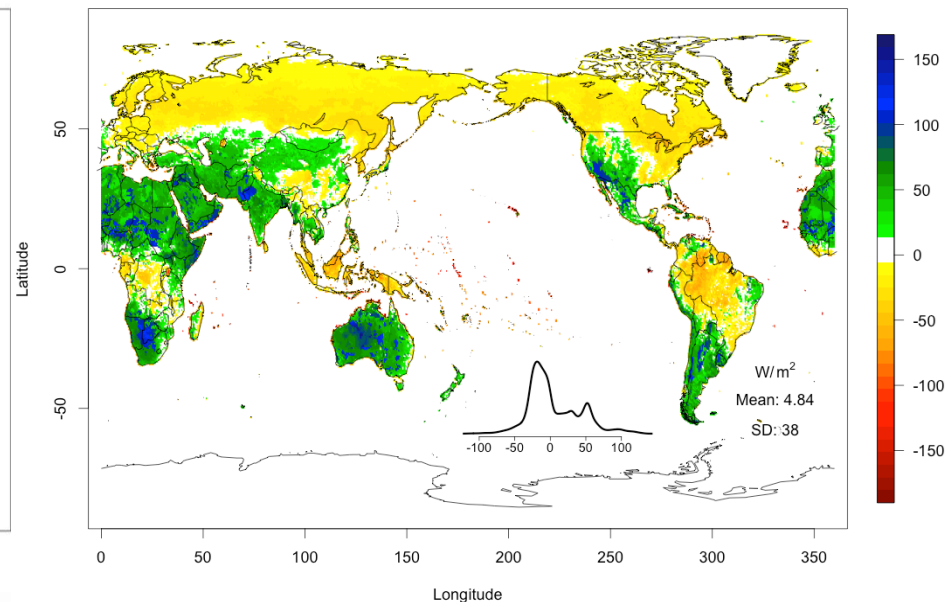
The PALS Land sUrface Model Benchmarking Evaluation pRoject (PLUMBER)
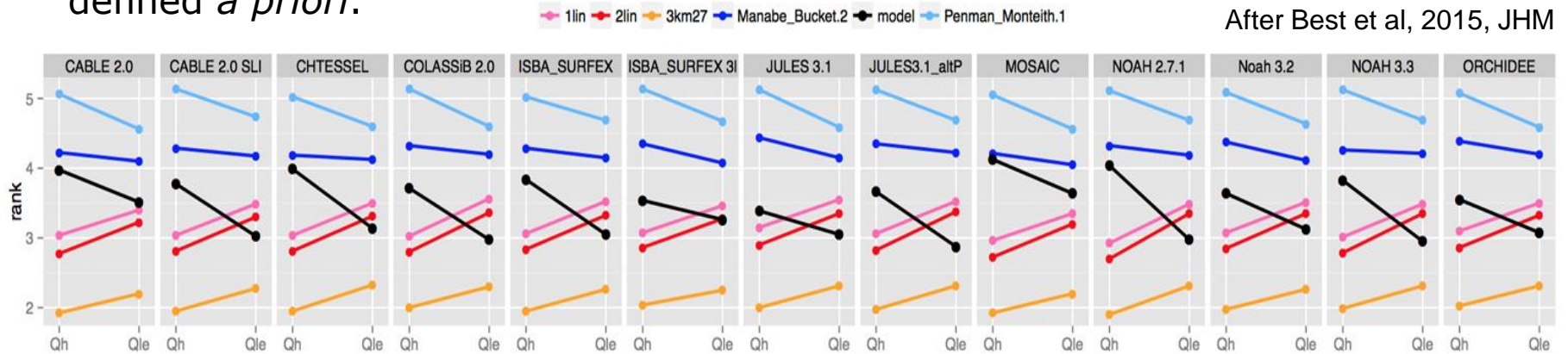
- Compares land surface models to benchmarks with performance expectations defined *a priori*.

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
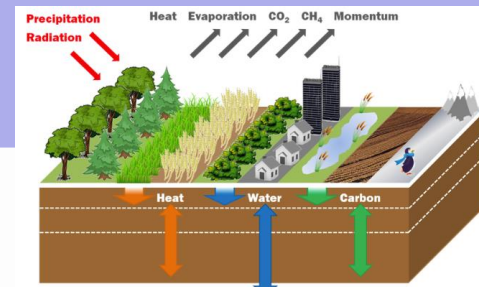
Land surface model

➢ <u>Joint ISMC and GEWEX communities</u>: Initiatives to improve soil and subsurface processes in current climate and hydrological models: SoilWat-PTF & SP-MIP.

➢ Evaluation of <u>pedotransfer functions</u> & related <u>functional descriptions</u> for calculation of <u>hydraulic & thermal soil properties</u> in global climate models.

➢ Possibly include some SoilWat component in PLUMBER-2.
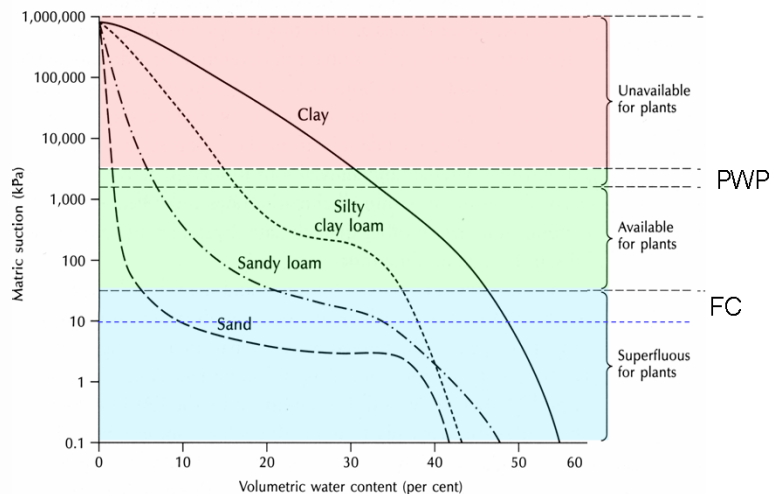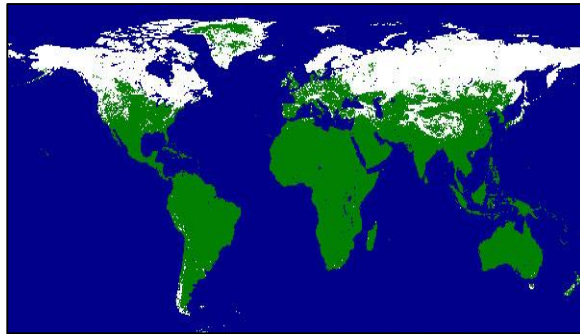

Moisture retention curve (MRC)
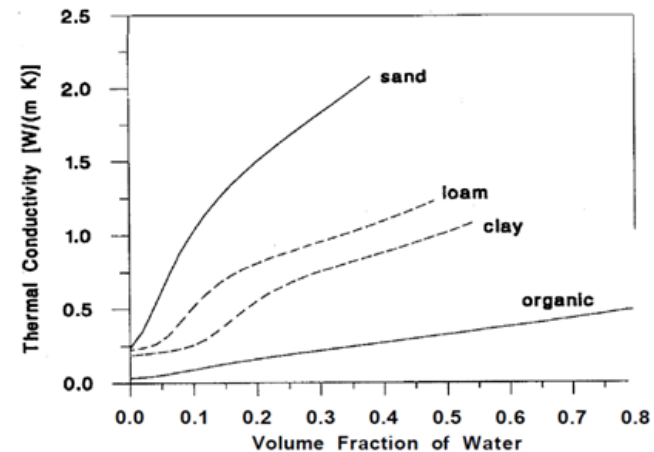
Thermal conductivity curve

Land Data Assimilation

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

Snow

e.g. Snow Cover from Moderate Res. Imaging Spectroradiometer (MODIS)
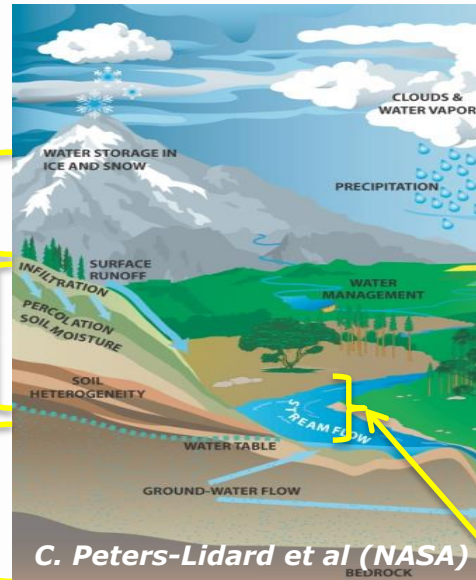
C. Peters-Lidard et al (NASA)

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)

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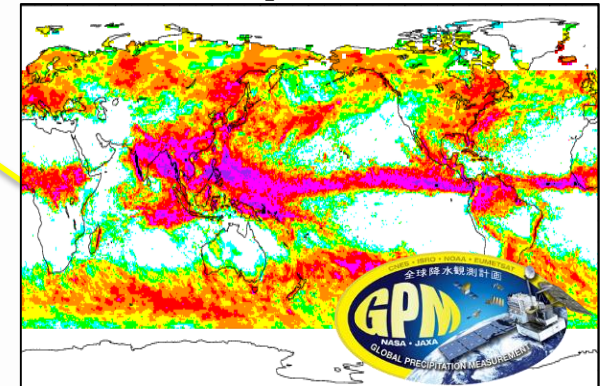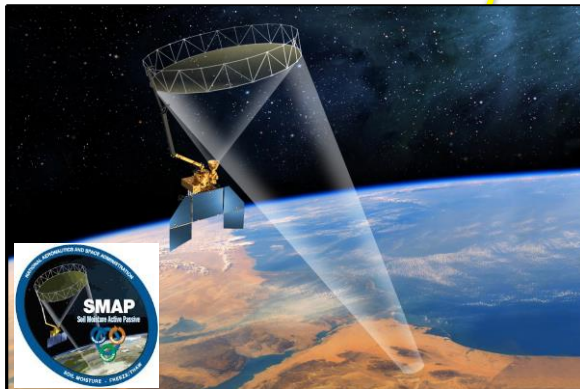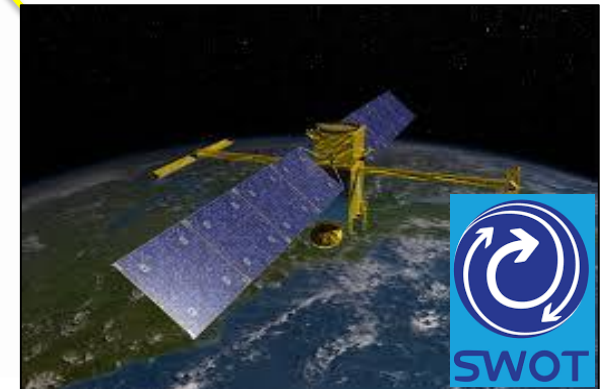
LoCo: GEWEX-GLASS core theme to understand, model, and predict the role of local land-atmosphere coupling in the evolution of land-atmosphere fluxes and state variables, including clouds.

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) <u>at the process-level</u>, 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

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www.gewex.org

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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.*

Leads: Adrian Lock & Martin Best (UKMO)

DICE-1: CASES-99 Experiment Southern Great Plains, USA

GABLS4 ("DICE-Over-Ice") Dome C – Antarctica

Leads: Eric Bazile, Fleur Couvreux, Patrick Le Moigne (Météo-France, CNRM/GAME)

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.

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

GLASS Projects	WCRP GC							GEWEX GSQ			
	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 Predictions 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 both weather and climate, e.g. Seasonal/Drought Prediction, & 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, from individual parameterizations and earth system components, building to a fully-coupled system, with 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 and validation data sets. This HMD paradigm is also being employed at NCAR and elsewhere in weather and climate model testing and development.

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