Global Energy and Water Cycle Exchanges Project

Global Land-Atmosphere System Studies (GLASS) Panel

Kirsten Findell and Anne Verhoef, GLASS co-chairs
With materials from the GLASS Panel Project Leaders

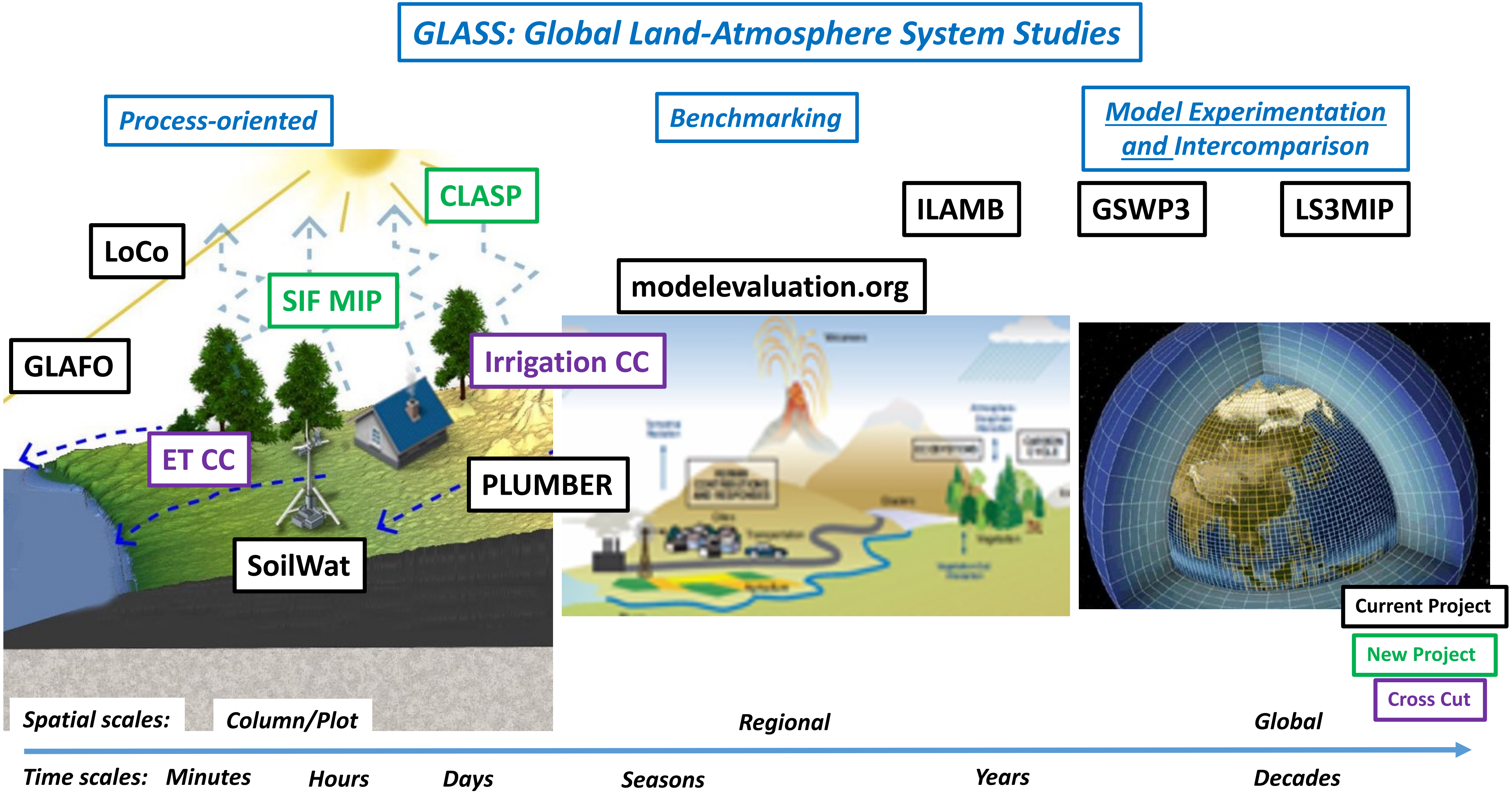
The 34th Meeting of the GEWEX Scientific Steering Group
Tuesday 26 July, 2022, Monterey USA

Global / Land - Atmosphere System Studies

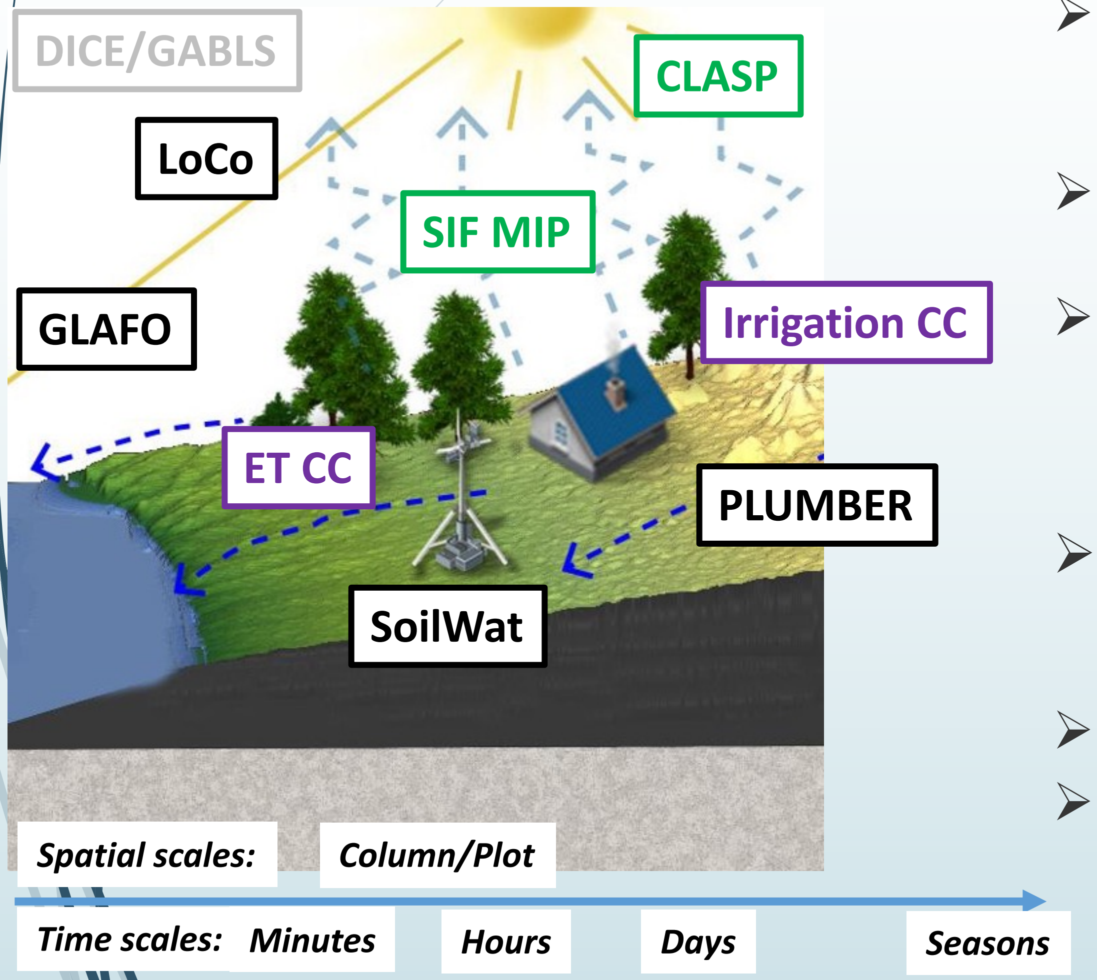
GLASS Science Objectives and Activities

- **Scientific Objectives of GLASS**:
  - To improve understanding of **energy and water cycling on land** and in the coupled land-atmosphere system
  - to improve representation of these processes in **Earth System models**.
- **Activities of GLASS**:
  - To facilitate and support international projects that use **observations, process studies, and numerical model experiments** to develop and improve the representation of the land and land-atmosphere system in climate models.
- At present, GLASS has **10 projects**, and is involved in **2 cross-cutting** activities.

GLASS Panel Projects (v. July 2022):



Process-oriented projects



- **LoCo**: Local Coupling Working Group
  - Land-atmosphere interactions at local to regional (to global) scales
- **GLAFO**: GEWEX/GLASS Land-Atmosphere Feedback Observatories
- **PLUMBER2**: The Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2
  - Offline single-column land model experiments
- **SoilWat**: Soils and Subsurface processes
  - Understanding and improving representation of soil physics and groundwater transport in earth system models
- **SIFMIP**: Solar-Induced Fluorescence MIP
- **CLASP:** Coupling of Atmospheric Land and Sub-grid Parameterizations

Global Land - Atmosphere System Studies

LoCo: The Local Coupling Working Group

LoCo WG Objective:

- To understand, quantify, model, and predict ***the role of local land-atmosphere coupling*** in the evolution of land-atmosphere fluxes and state variables and the respective water and energy cycles, including clouds.

Goals:

- Promote the importance and development of ***improved observations*** of the L-A system, namely in the PBL, as well as improved utilization of soil moisture and surface fluxes measurements in models
- Pursue ***adoption of LoCo metrics*** by operational NWP and Climate Centers.
- ***Expand the scope and reach of LoCo*** in terms of processes and scales beyond that of warm season thermodynamics and beyond that of 1-D column assumptions.

Composition: ~20 affiliated researchers contributing, Project Lead: Joe Santanello

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LoCo Achievements & horizon

- Enhanced adoption of LoCo paradigm at operational centers, use of **LoCo metrics** and diagnostics for integrative analysis
  - E.g., NOAA's CLASP Climate Process Team and UFS development both stress LoCo process understanding;
  - Funding of LoCo-driven initiatives through NOAA COM, SMAP and MAP, THP Scoping Study
- The NASA **PBL Study Team Report**: supportive of LoCo-inspired PBL incubation activities, and vision of monitoring PBL from space
- **Field campaigns** (past and future) include LoCo-driven activities
  - GRAINEX (2018), LAFE (2017), LIAISE (2021), FESSTVal (2021)
  - AmeriFlux workshop and paper on supplementing FLUXNET sites with PBL profilers
- Enthusiasm for LoCo science seen in successful **AGU and AMS sessions** convened by LoCo WG members
- *Gaps in L-A scientific scope not captured by existing metrics* -> **expand scope**: Cold climates? Carbon? Ecosystem scale?

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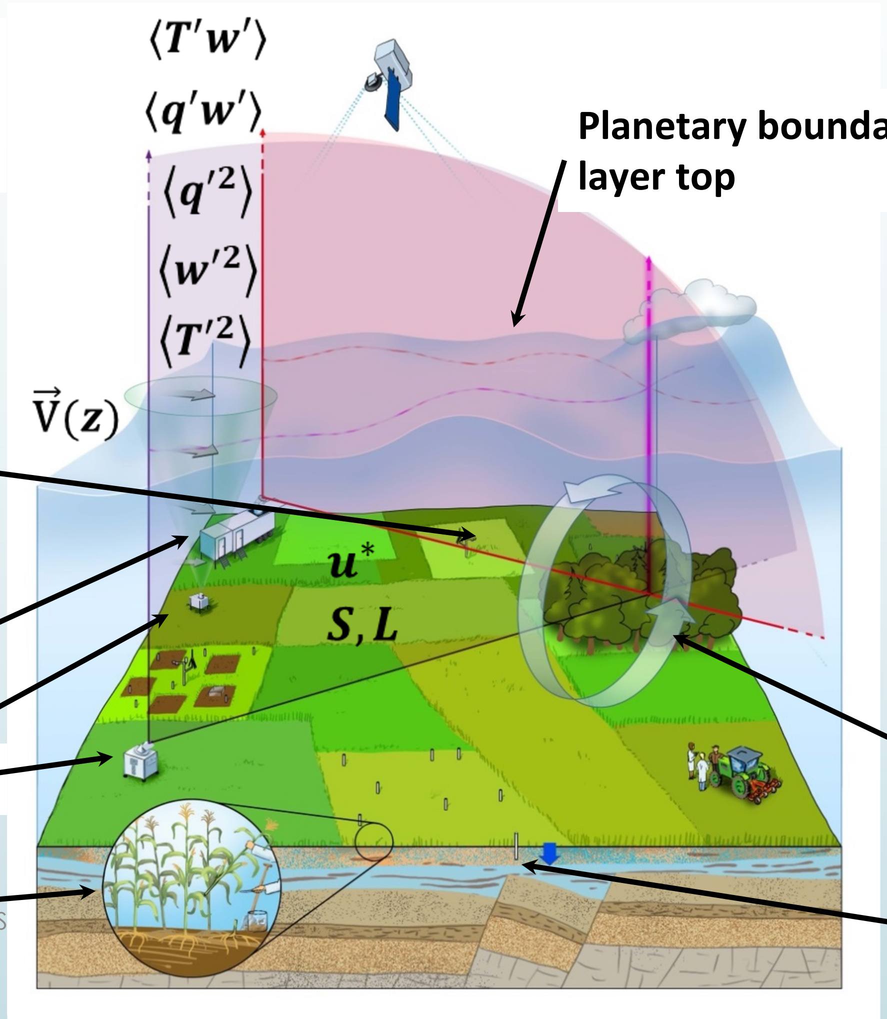
GLAFO: GEWEX/GLASS Land-Atmosphere Feedback Observatories

PIs: Volker Wulfmeyer, University of Hohenheim
Dave Turner, NOAA ESRL

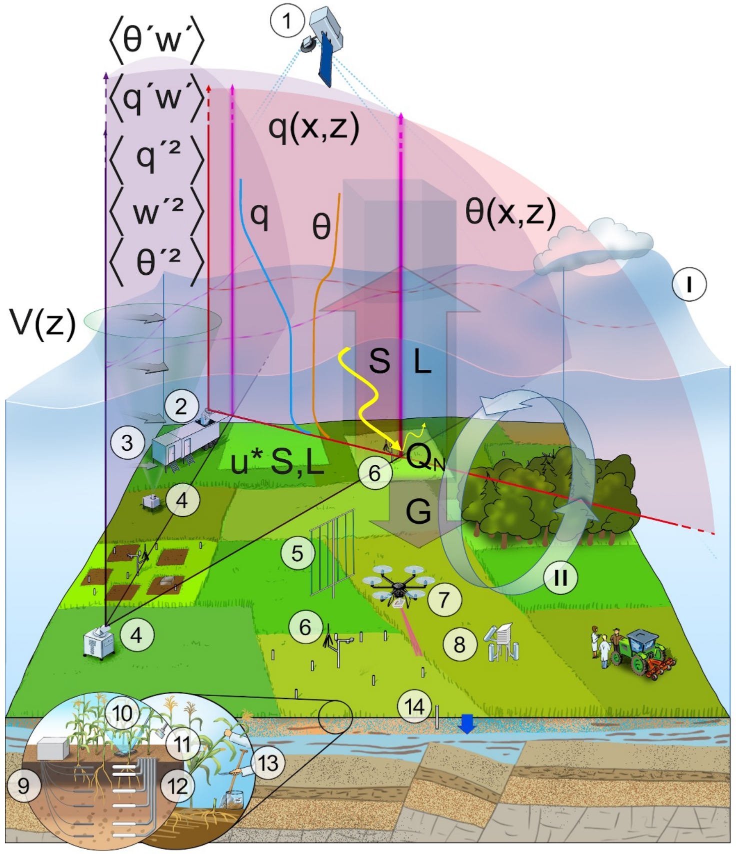


- Modeled on the success of the **LAFE campaign** (SGP, August 2017)
- Measurement of **L-A feedback** possible in heterogeneous terrain. Basis of new generation of international experiments and observatories (*Wulfmeyer et al. BAMS 2018, GEWEX Newsletter 2020*).

GLAFO Design and Objectives

The **objectives** of GLAFO are to:

- Understand and characterize **L-A feedback** with advanced metrics
- **Develop and operate GLAFOs** from groundwater to soil to land cover to the lower troposphere
- Study **transport** and **exchange** processes at **the interfaces** between the compartments
- Identify the **role of vegetation** with respect to L-A feedback
- Assess the processes and scales at which **L-A feedback is sensitive to terrestrial hydrology and heterogeneity**



Wulfmeyer et al. GEWEX Newsletter 2020

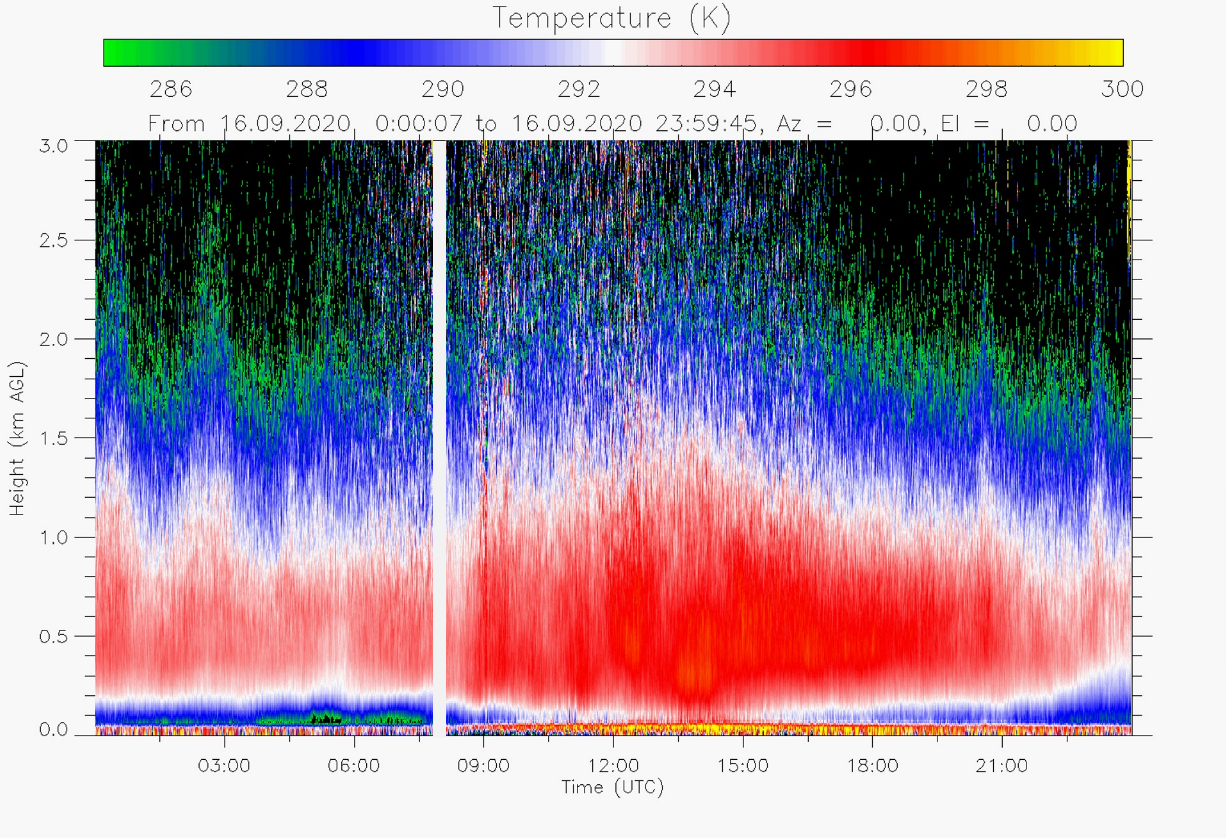
Proposed sensor synergy for the GLAFOs.
I: PBL top, II: mesoscale vortex
1: Satellite remote sensing
2: vertically staring Doppler, water vapor, temperature, and CO_2 lidar systems, atmospheric emitted radiance interferometer (AERI), microwave radiometer (MWR), cloud radar
3: scanning Doppler, water vapor, temperature, and CO_2 lidar systems
4: scanning Doppler lidar systems
5: via fiber-based distributed sensors
6: energy balance and eddy covariance stations
7: unmanned aerial vehicle (UAV)
8: water vapor and CO_2 isotope sensor
9: time-domain reflectometers (TDRs)
10: leaf area index (LAI) measurement
11: gas exchange system for photosynthesis and transpiration rate measurements
12: tensiometers
13: in-situ canopy measurements such as biomass and canopy height
14: soil moisture and temperature network

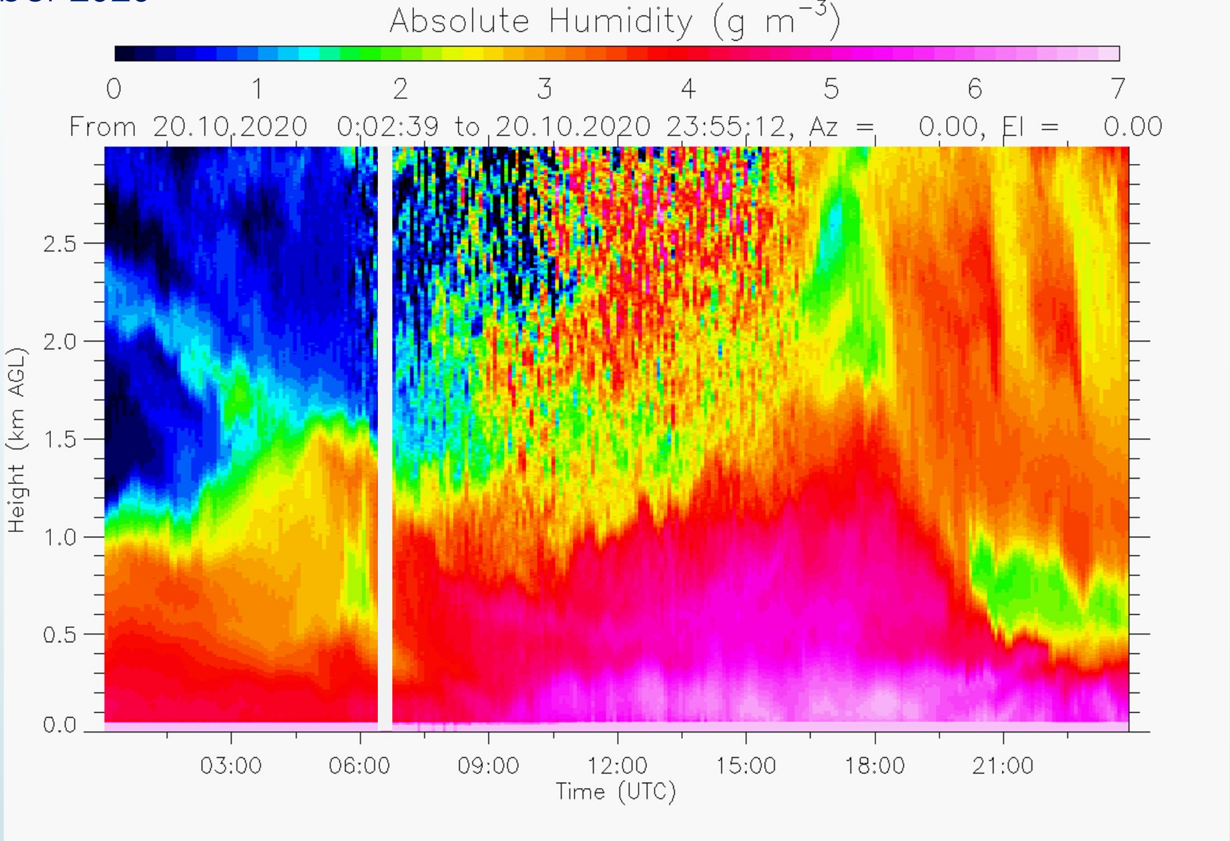
GLAFO Hierarchical Design Matrix

Level, costs	Soil		Land cover		Atmosphere	
	State	Variables	State	Variables	Variables	Instrument
L1a, $	Soil state	T, Θ	Type	Albedo, LST, surface energy balance, snow	zi, WV, T, mixing diagram, $CTP\text{-}HI_{low}$	Thermodynamic profiler
L1b, $	Soil state	T, Θ	Type	Albedo, LST, surface energy balance, snow	zi, WV, T, V(z), TKE, momentum flux, TKE diss.	L1a plus scanning Doppler lidar (DL)
L2, $$$	Soil state	Ground-water level, T, Θ	Type	Albedo, LST, surface energy balance, snow	zi, V(z), w'(z), T(z), m(z), latent and sensible heat flux, turbulent moments	L1 + vertical DL, Raman lidar (RL) or DIAL
L3, $$$	Soil state	Ground-water level, T, Θ	Canopy height	Canopy T, m, rad, albedo, LST, surface energy balance, snow	zi, V(z), T(z), m(z) also in the atmospheric SL	L2 + scanning DL, RL, and/or DIAL
L4, $$$	Same as L3 + a triangle of V(z), T(t) and m(z) profiles					L3 + scanning DL and vertical TD lidar or FTIR

ARTHUS: Atmospheric Raman Temperature and Humidity Sounder

20 October 2020





SoilWat (lead; Yijian Zeng)

Goals: To improve the representation of soil and subsurface processes in climate models and to identify the most pressing challenges and topics related to this effort, in terms of understanding the role of: i) **soil properties** and parameters; ii) **soil physical processes** (e.g., infiltration, surface evaporation, water and heat flow); iii) **Soil-root** hydraulics; iv) **Soil-groundwater** dynamics, and ***their interactions with the vegetation and biogeochemical cycles***, deploying Earth observations (in situ and remote sensing), modeling, and data assimilation.

Ongoing WGs:	**New initiatives:**
Pedotransfer Functions and Land Surface Parameterization	The 'Math' of Soil Processes (current state of soil modeling with a focus on water, carbon, nutrient and energy cycles)
Soil Thermal Properties	Soil Properties on L-A Interactions ("Soil-Cloud cascades")
Soil Carbon Potential	
SP-MIP (Soil Parameter Model Intercomparison Project)	

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SP-MIP methodology

(Leads: Matthias Cuntz, Lukas Gudmundsson)

SP-MIP Models

model	reference
ORCHIDEE	Krinner et al., 2005
JSBACH	Kaminski et al., 2013
Noah-MP	Niu et al., 2011
JULES	Best et al., 2011
MATSIRO	Takata et al., 2003
MATSIRO-GW	Takata et al., 2003
ISBA	Noilhan et al., 1989
CLM	Lawrence et al., 2018

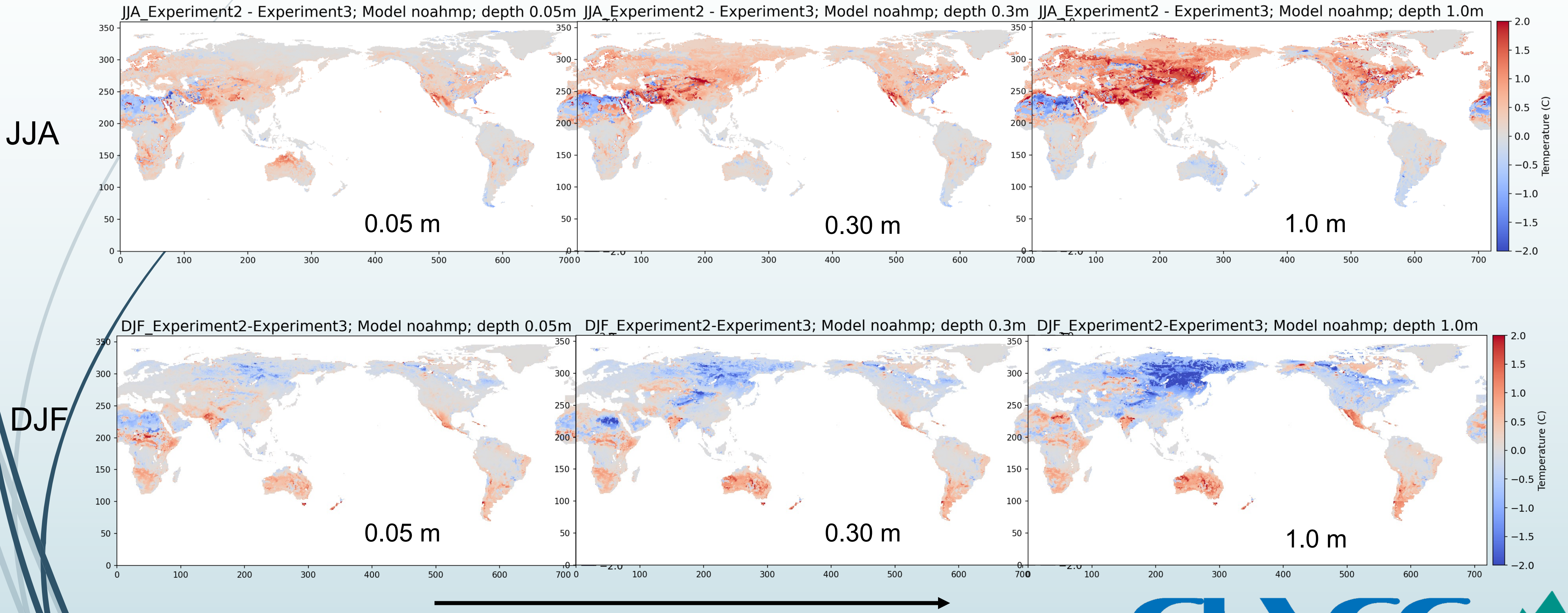
- Following LS3MIP protocol (van den Hurk et al. 2016)
- 30 years (1980-2010) of atmospheric forcing: GSWP3 (Kim et al. 202X, in prep.)
- Coverage: 0.5-degree spatial, 3 h temporal resolution
- Soil data:
  - SP-MIP: **SoilGrids.org**
  - **Model-specific** soil maps

Pedo-transfer function (PTF): basic soil properties → soil hydraulic (and thermal) parameters

Role of <u>different soil maps</u> on soil temperatures

(Leads: Yijian Zeng & Anne Verhoef)

<u>Noah-MP</u> 30-year daily average temperature *difference*



Increasing depth

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Preliminary conclusions on soil thermal regime

- Changes in **soil maps** have a larger effect than changes in **hydraulic & thermal PTFs**, but there is variation between models
- Implications for energy, water and **carbon** balance (e.g., permafrost)

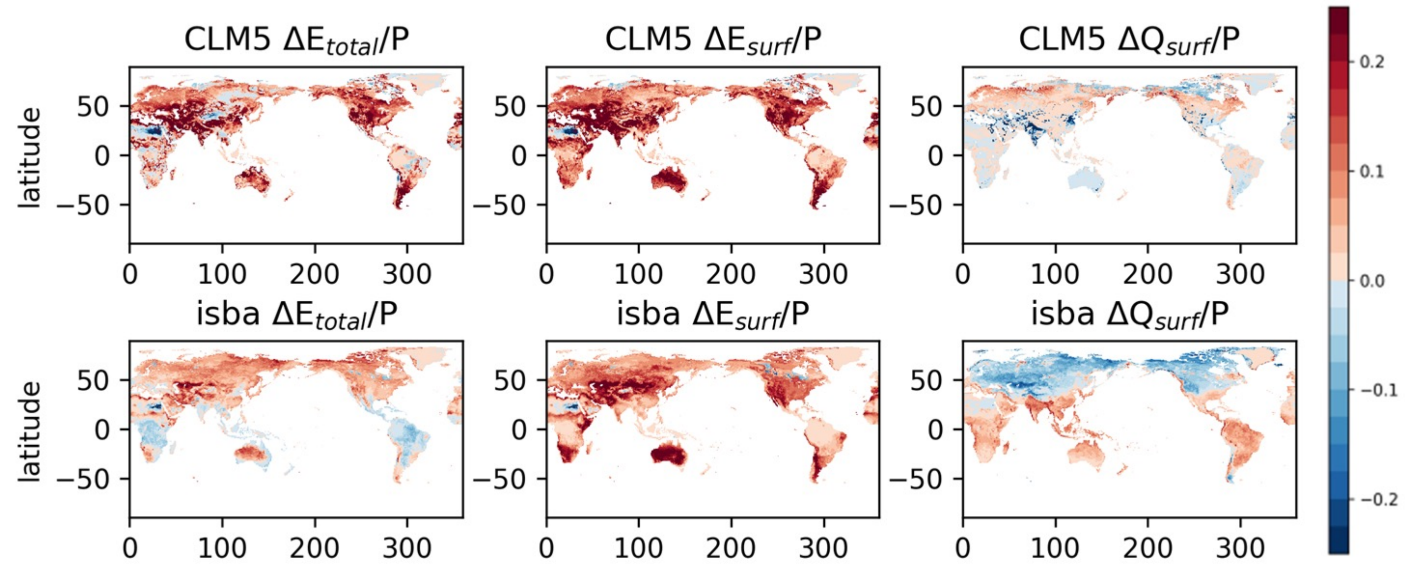
Causes:

- Difference in **thermal properties** approaches (thermal conductivity and heat capacity); thermal functions & PTFs
- Difference in **freeze-thaw** approaches
- Differences in **soil profile depth** and **bottom** boundary condition

Exp. 4: Spatially uniform soil parameters

- Four model runs with spatially uniform soil parameters
- Considered soil types: loamy sand, loam, clay, and silt

Impact of changing soil types from **sand to silt** (SP-MIP) (Leads: Matthias Cuntz, Stephan Thober)



- Example plots for **CLM5** and **ISBA**; change from sand to silt, globally, in terms of $E_{total\_silt} - E_{total_{sand}}$ and so on.
- All models show **increasing surface evaporation** E_{surf} (middle column) for most regions with few exceptions.
- Some models show **increasing total evapotranspiration** E_{total} (left column) in dry regions while others show **decreasing E_{total}** in those regions (not shown).
- The models show **very different responses for surface runoff Q_{surf}** (right column) due to competing effects: 1) sand has higher saturated conductivity than silt, but 2) sand also dries quicker and thus has lower soil moisture, which in turn decreases the actual hydraulic conductivity. → large differences between CLM5 and ISBA.

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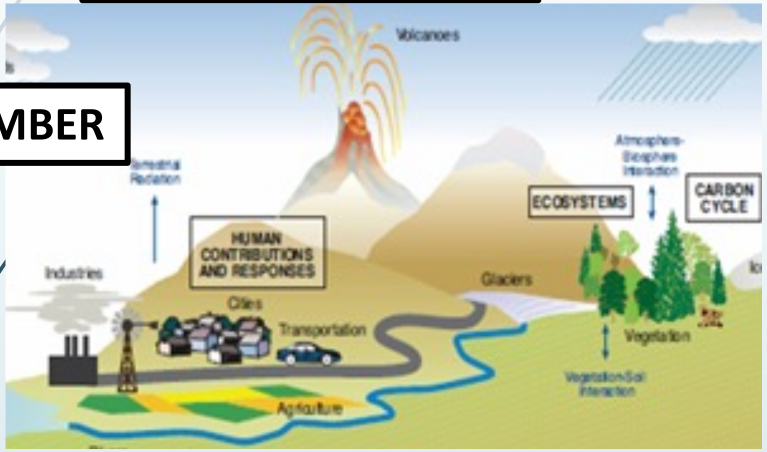
Benchmarking Projects

ILAMB

modelevaluation.org

PLUMBER



Spatial scales: *Regional*

Time scales: *Days* *Seasons* *Years*

- **PLUMBER2**: The Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2
  - Offline single-column land model experiments
- **modelevaluation.org**: Broader implementation of PLUMBER, web-based platform for benchmarking models against observations
  - Hosts experiments: forcing data is on web platform, users run experiments locally then upload simulations, me.org runs analysis routines to compare simulations to benchmarks and other models
- **ILAMB**: International LAnd Model Benchmarking
  - Global benchmarking toolkit for climate model variables (seasonal to annual)

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PLUMBER2: The Protocol for the Analysis of Land Surface Models (PALS) LSM Benchmarking Evaluation Project, phase 2

PLUMBER2 WG Objective:

- ***PLUMBER2*** is a model intercomparison project for land surface models. The project is conducted within the ***Protocol for the Analysis of Land Surface Models (PALS) benchmarking*** system. PALS is now Modelevaluation.org (ILAMB is now also running inside ME.org!)

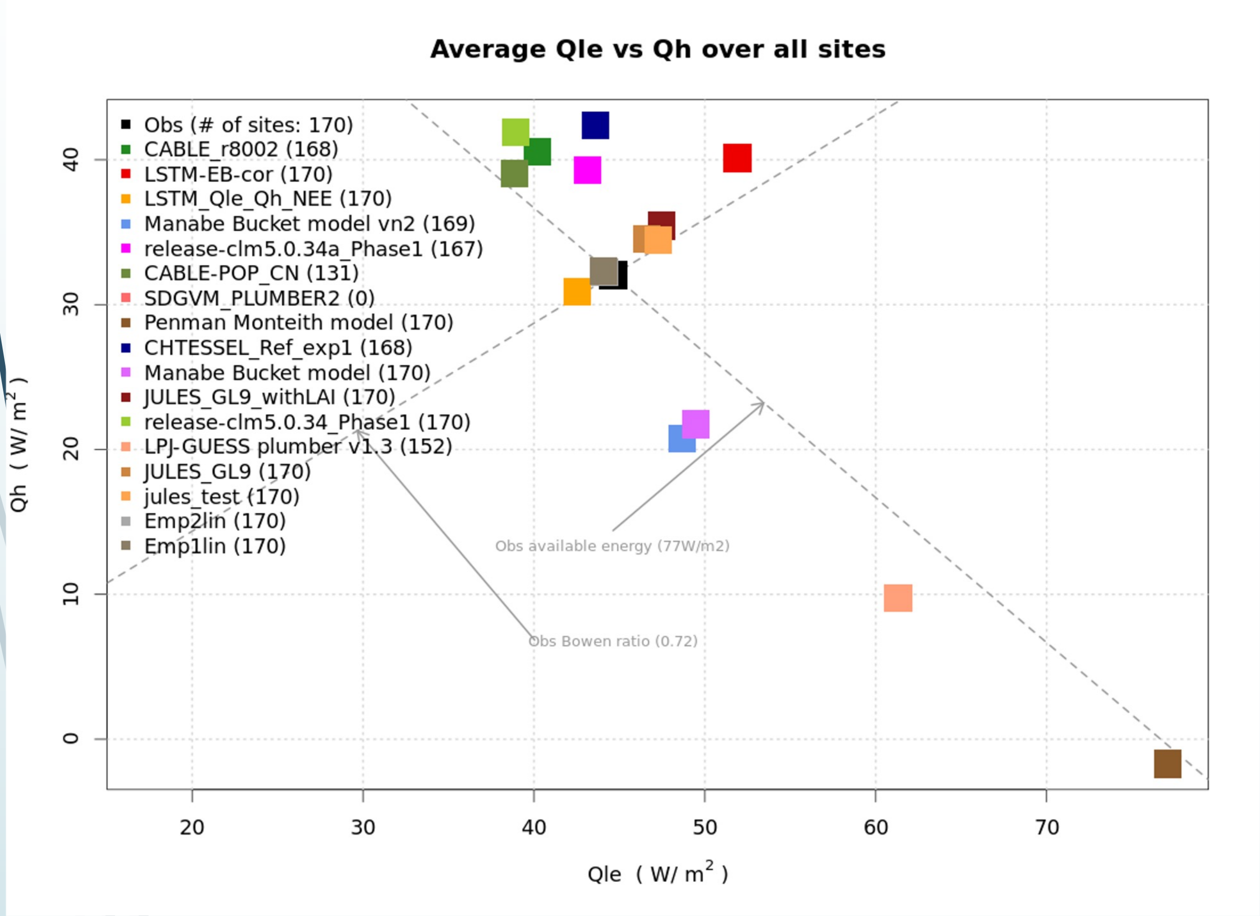
Goals:

- ***Evaluation*** of multiple leading ***land surface and ecosystem models*** for water and carbon fluxes.
- PLUMBER2 provides ***forcing and evaluation datasets*** for a model intercomparison project for land surface models.
- The dataset is a collection of ***170 flux tower sites (Published: Ukkola et al., ESSD 2022)***, spanning multiple biomes and climate zones globally. It provides meteorological variables to force models and flux variables for evaluation. The original data were derived from the FLUXNET2015, La Thuile and OzFlux collections

Composition: PIs Gab Abramowitz, Anna Ukkola, Martin De Kauwe, UNSW, ARC Centre of Excellence for Climate Extremes, Sydney, Australia, and and many others affiliated researchers contributing with their models

PLUMBER2:

Example Output



Planned analyses

- ***Diurnal*** hysteresis / phase lag (Maik Renner, Gab)
- Benchmarking ***momentum flux*** as well as heat fluxes (Martin Best, Ian Harman)
- '***Conditional analysis***' (Gab, Martin DeKauwe, Anna Ukkola):
  - E.g. WUE and EF during dry-down events, heatwaves
  - Domain clustering (forcing only, forcing+model states) to identify conditions of poor simulation
- Focus on ***empirical models*** defining good/bad performance; removes flux magnitude & site complexity as confounding variables

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PLUMBER2 status; participation growing

Model	Who	Institution	Test simulations	170 site simulations
ISBA	Aaron Boone	CNRM, France		
ORCHIDEE variants	Nicolas Vuichard / Philippe Peylin / Daniel Goll / Vladislav Bastrikov / Philippe Ciais	LSCE/IPSL	X	X
JULES x 2 config	Martin Best, Heather Rumbold	Met Office, UK	✔	✔
Manabe bucket	Martin Best	Met Office, UK	✔	✔
Penman Monteith	Martin Best	Met Office, UK	✔	✔
CLM	Dave Lawrence	NCAR, USA	✔	✔
CABLE x 4 config	Martin De Kauwe, Anna Ukkola	UNSW, Australia	✔	✔
CABLE-POP	Juergen Knauer, Vanessa Haverd	CSIRO, Australia	✔	✔
SUMMA	Wouter Knoben, Martyn Clark	U Saskatchewan, Canada	X	
GFDL	Sergey Malyshev	GFDL, USA	✔	X
NOAH	Sujay Kumar	NASA, USA	X	X
MATSIRO	Tomoko Nitta, Hyungjun Kim	U Tokyo, Japan	X	
HTESSEL	Souhail Bousetta, Gianpaolo Balsamo, Gabriele Arduini	ECMWF, UK	✔	✔
ELM	Xitian Cai	Lawrence Berkeley National Lab, USA		
TECO	Yiqi Luo	Northern Arizona U, USA		
STEMMUS-SCOPE	Yijian Zeng, Bob Su	U Twente, Netherlands / Northwest Agriculture and Forestry U, China		

CLASS-CTEM / MESH-CTEM	Altaf Arain	McMaster U, Canada	X	X
NASA Ent	Yeonjoo Kim	Yonsei U, Korea	✔	X
PCR-GLOBWB2	Niko Wanders	Utrecht U	X	X
SDGVM	Anthony Walker	ORNL, USA	✔	✔
ACASA	Kyaw Tha Paw U, Kuangyu Chang	UC Davis, USA	✔	X
LPJ-GUESS	Peter Anthoni / Almut Arneth	KIT, Germany	✔	✔
Ecosys	Zelalem Mekonnen	LBL, USA		
BEPS	Xiangzhong (Remi) Luo	LBL, USA	X	X
MuSICA	Matthias Cuntz, Jérôme Ogée	INRAE, France	✔	X
QUINCY	Silvia Caldararu, Sönke Zaehle	MPI BGC	✔	X
EC-Earth LSM	Etienne Tourigny	BSC/ECMWF/KIT, Spain		
NOAH-MP ?	Fei Chen, Mike Barlage ?	NCAR/NCEP, USA		
ELMv1-CTC-CNP	Jiafu Mao, Dan Ricciuto	ORNL, USA	X	
DA contributions				
Mosaic/Catchment +DA	Sujay Kumar	NASA, USA		
Noah-MP + DA	Sujay Kumar	NASA, USA		
HTESSEL + DA	Patricia de Rosnay, David Fairbairn and Pete Weston	ECMWF, UK	✔	✔
ISBA / LDAS-Monde	Clément Albergel	CNRS, France		
WEB-SVAT	Dongryeol Ryu, Wade Crow, Shirui Hao	U Melbourne, Australia, USDA-ARS, HRSL, USA	✔	
USDA FAS Palmer	Iva Mladenova	USDA		
Empirical models				
LSTM	Grey Nearing	U Alabama	✔	✔
Cluster+regression	Gab Abramowitz	UNSW, Australia		

PLUMBER2 protocol document: https://docs.google.com/document/d/1T3s6rgT-OAVNOf2RAUTDgyiMOHnaPReDWDDTs09heHU

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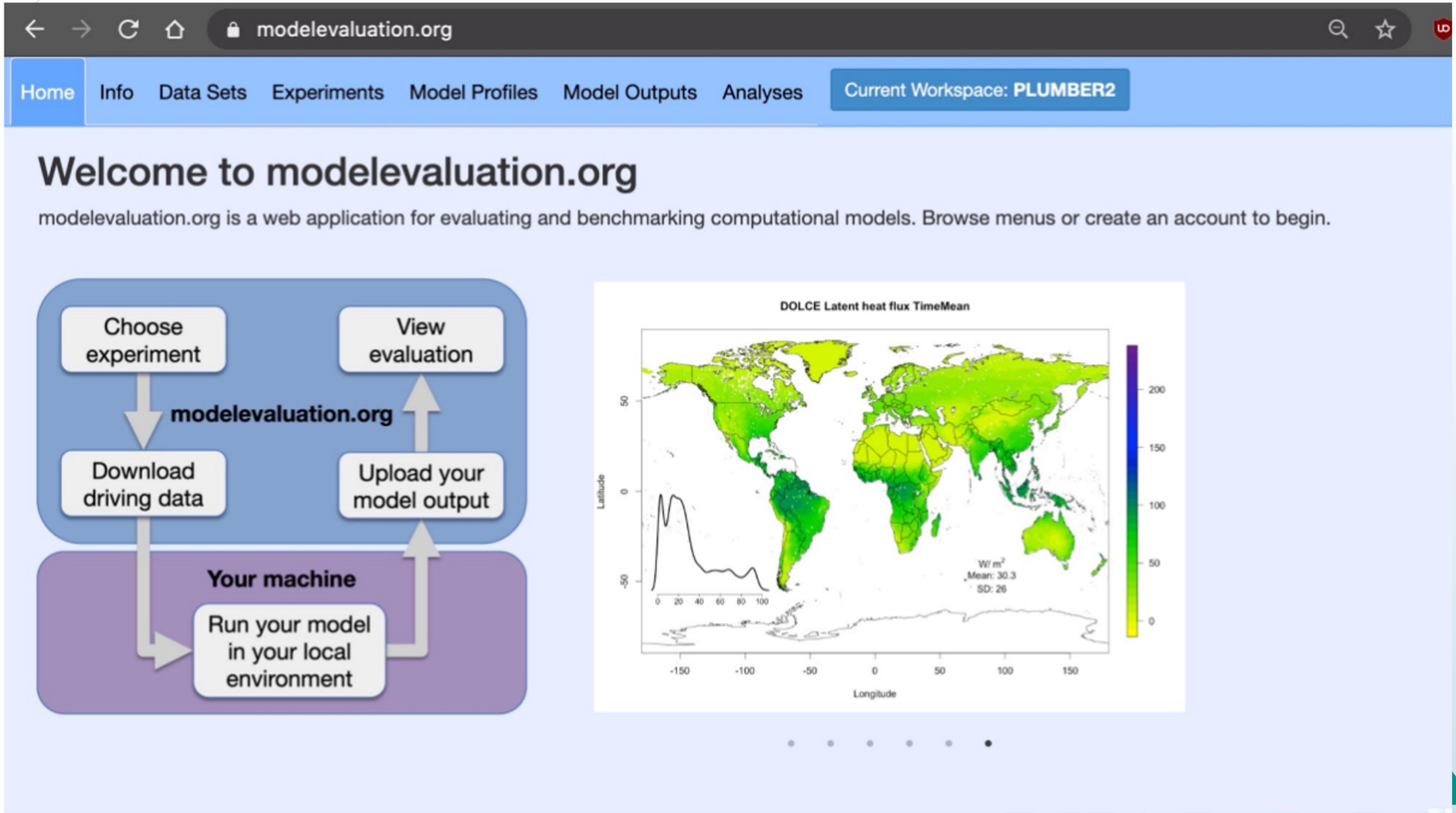
modelevaluation.org: Broader implementation of PLUMBER, web-based platform for benchmarking models against observations



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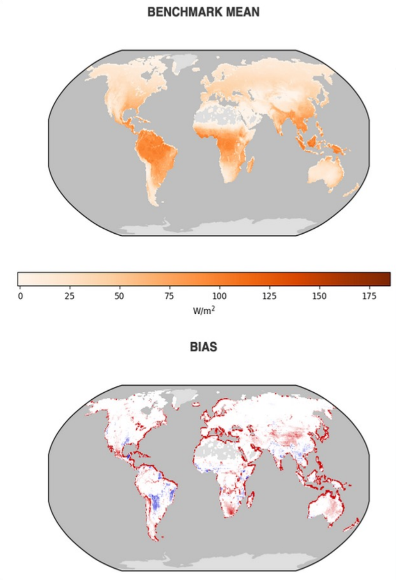
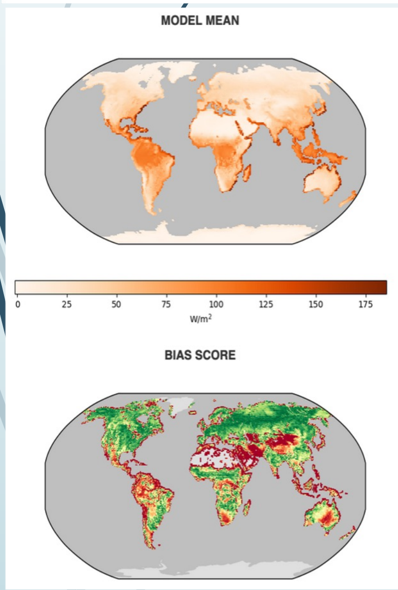
ILAMB: International LAnd Model Benchmarking





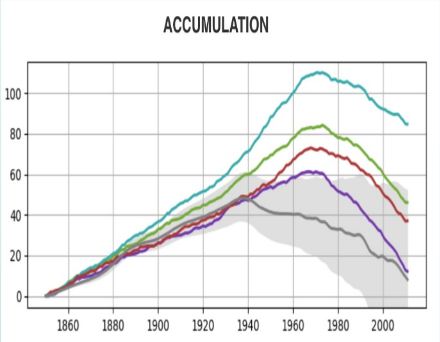
ILAMB WG Objective:

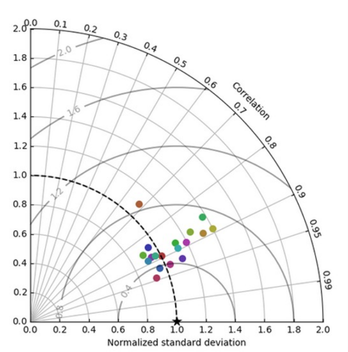
- ILAMB's main aim is to conduct a systematic analysis of simulation of land variables and surface climate

Goals:

- ***Integrates analysis*** of 30+ variables with 70+ global, regional, and site-level datasets
- Focus on ***4 categories***: ecosystem and carbon, hydrologic cycle, radiation and energy cycle, and forcings
- ***Graphics and scoring system***
  - annual mean, bias, relative bias, RMSE, seasonal cycle phase, spatial distribution, interannual variability, variable-to-variable

Composition: Pis Forrest Hoffman, Nate Collier, Dave Lawrence, Jim Randerson, Charlie Koven, Bill Riley, Gretchen Keppel-Aleks





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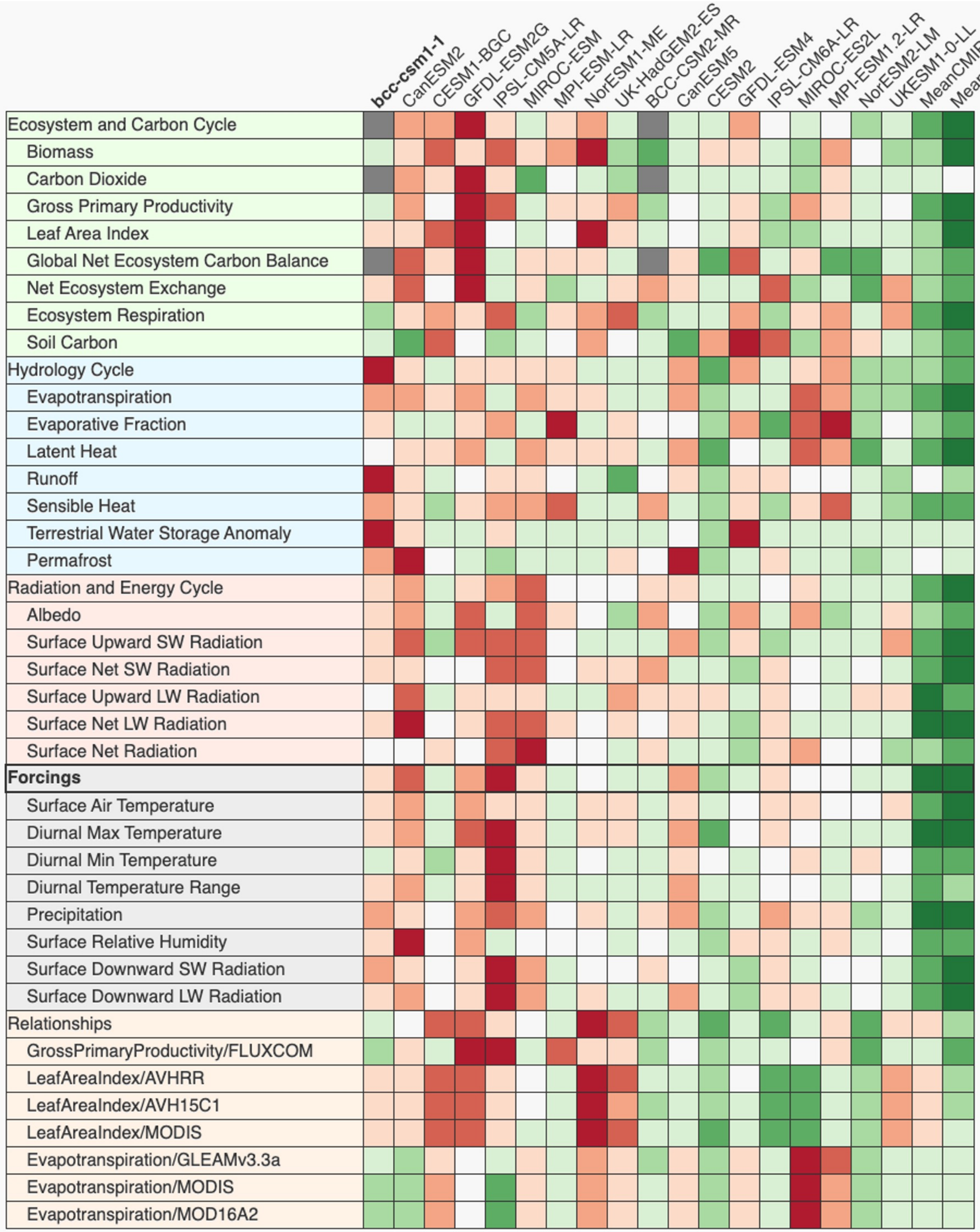
ILAMB: Outputs

- 9 models
- Mean CMIP6 generally better than mean CMIP5

CMIP5 vs CMIP6
left right

- ➢ **Land States/Fluxes**: 216 improve, 74 degrade, 202 same
- ➢ **Surface climate**: 46 improve, 6 degrade, 119 same
- ➢ **Relationships**: 40 improve, 17 degrade, 6 same

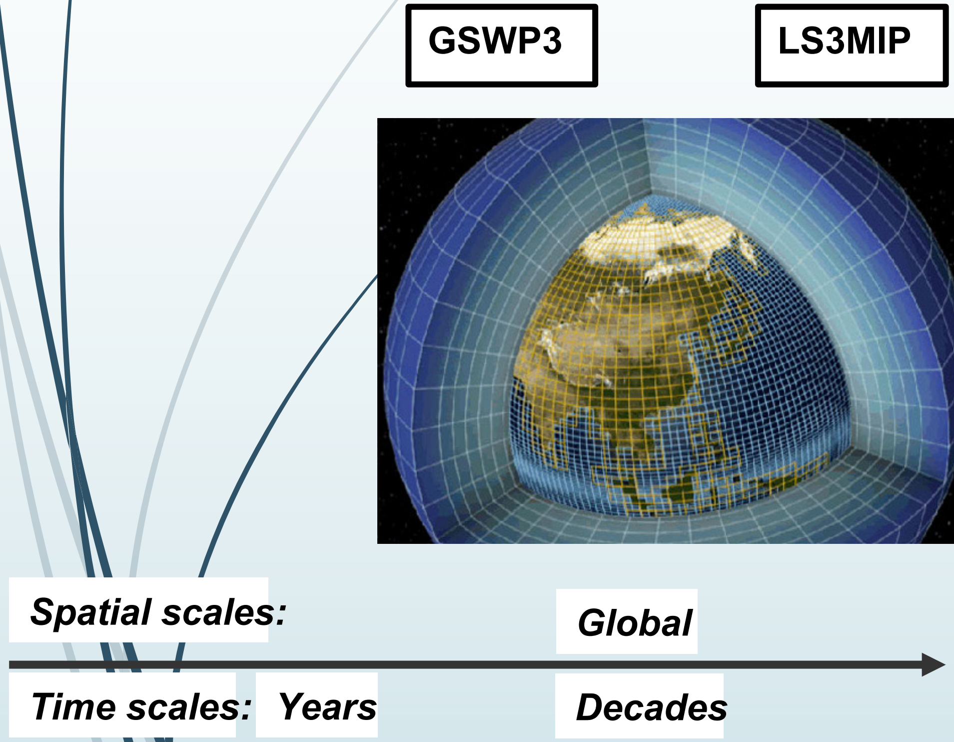


ILAMB: Next steps

Future development of ILAMB to enhance utility in model development

- ***Diurnal cycle*** metrics (prototype has been developed)
- Add ***metrics from literature*** (runoff sensitivity, seasonal albedo transition, snow insulation)
- Land-atmosphere ***coupling metrics*** (CPT)
- Experimental ***manipulations*** (N-addition, rainfall exclusion, etc)
- ***Land use change*** metrics

Model Intercomparison Projects



- **GSWP3**: Global Soil Wetness Project, phase 3
  - terrestrial modeling activity, produces a long-term land reanalysis and investigates changes of the energy-water-carbon cycles
- **LS3MIP**: Land Surface, Snow and Soil Moisture MIP
  - assess the performance of current land surface modules of earth system models and quantify land surface feedbacks in a changing climate
- Timeline tied to CMIP6; First results were in at the time of our panel meeting; Three papers in prep:
  - The CMIP6 land-historical simulations:
    - 1. Overview
    - 2. Land water and carbon balances
    - 3. Simulations of cold processes

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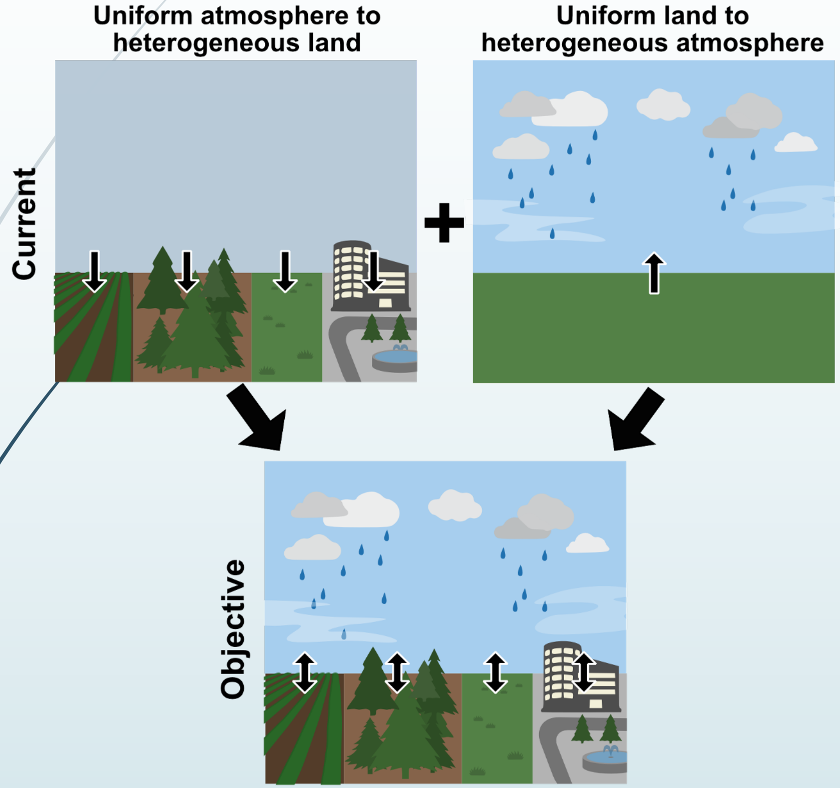
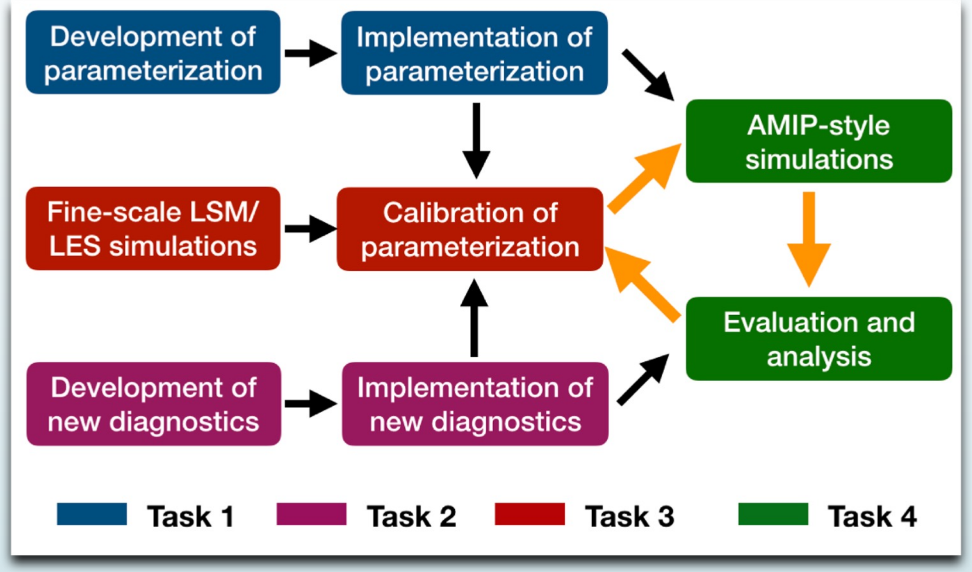
New Projects and Proposed Initiatives

CLASP

Coupling of Land and Atmospheric Subgrid Parameterizations

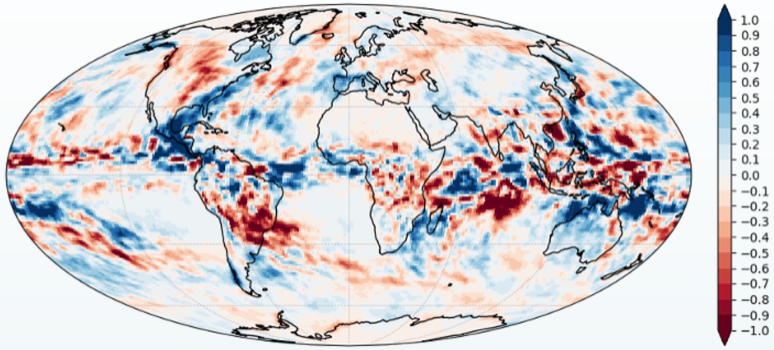


Objective: Parameterize the heterogeneous sub-grid exchange between the land and atmosphere and characterize its implications for surface climate, variability, and extremes.



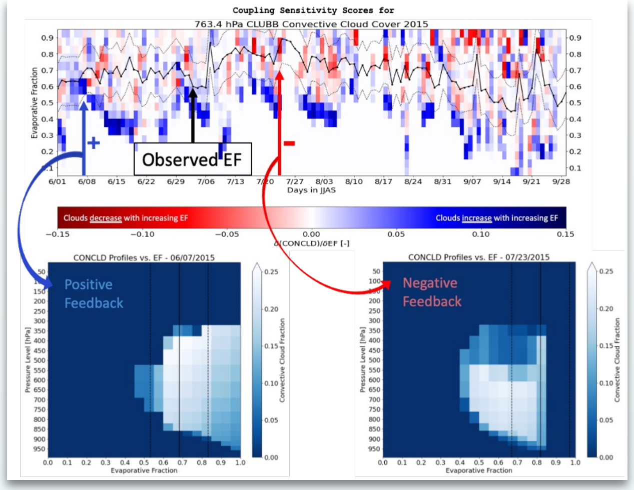
Overview of CLASP efforts

Difference in annual precipitation (mm/day) using CLASP parameterization in GFDL AM4



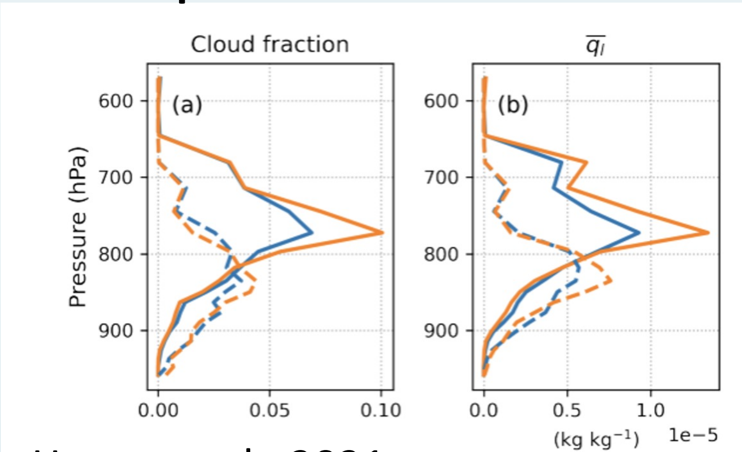
Ghannam et al., In preparation

Boundary layer coupling sensitivity to evaporative fraction



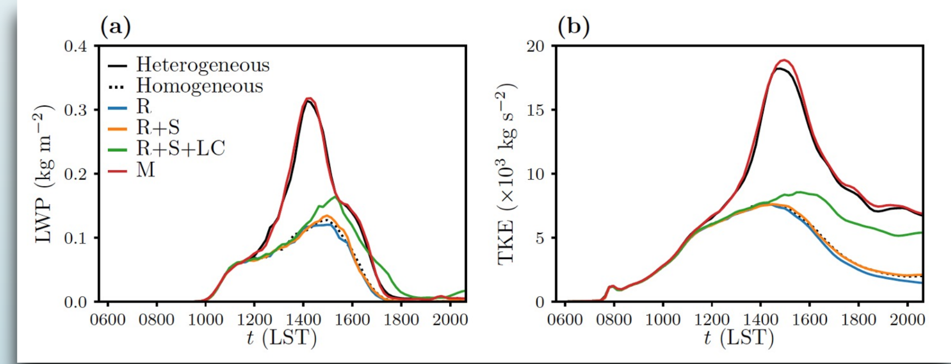
Hay-Chapman et al., In preparation

Changes in cloud development using CLASP parameterization in E3SM



Huang et al., 2021

LES experiments at ARM-SGP show a key role of sub-grid heterogeneity on cloud development

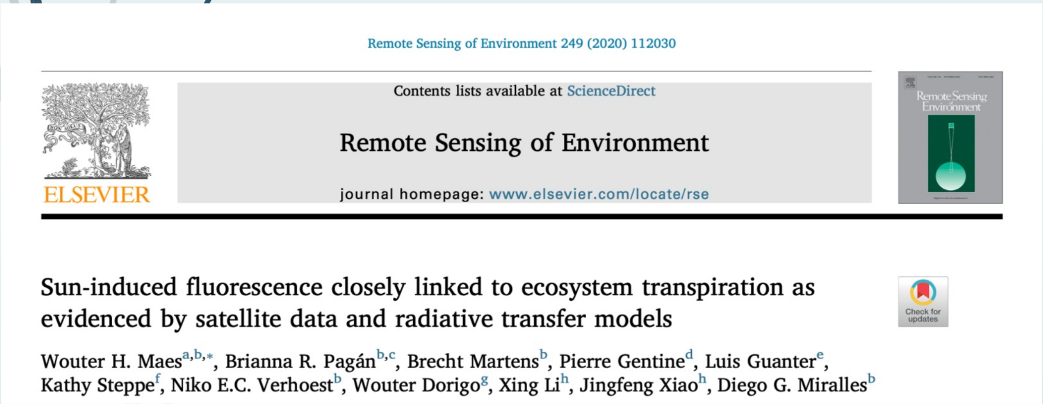


Simon et al., 2021

SIFMIP (solar-induced chlorophyll fluorescence -MIP)

Rationale

- GLASS keen to also represent the **coupling** between the **water and carbon cycles** in our activities
- Passive remote sensing of **far-red SIF** has spurred the development and integration of **canopy-level fluorescence models** in global terrestrial biosphere models (TBMs) for climate and carbon cycle research.
- Provides opportunities to **diagnose and constrain model simulations** of *photosynthesis* and related processes
- Direct comparison to and assimilation of **tower**, **airborne**, and **satellite** data.


Remote Sensing of Environment 249 (2020) 112030

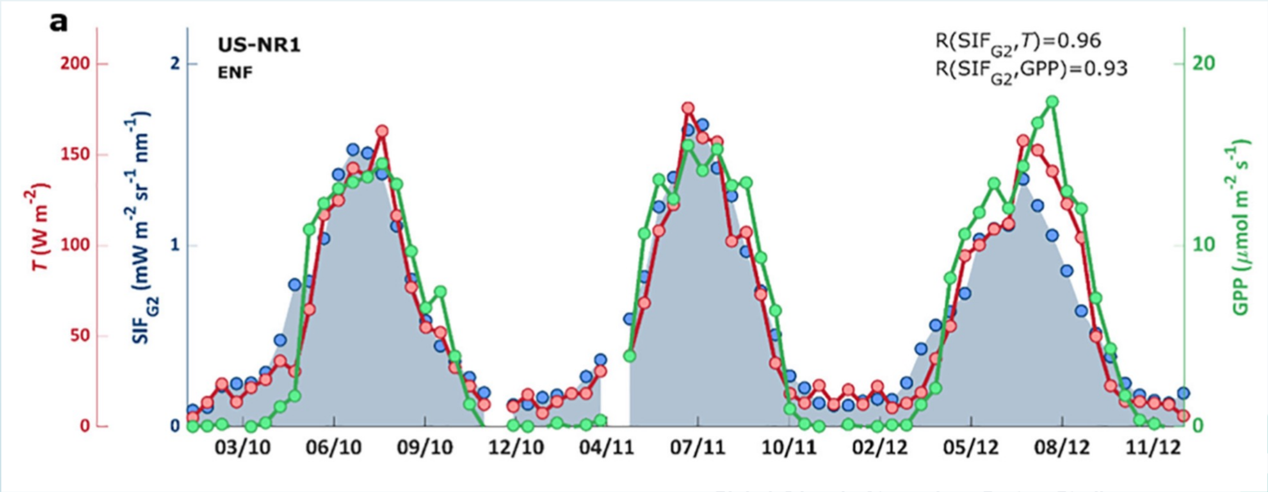
Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Sun-induced fluorescence closely linked to ecosystem transpiration as evidenced by satellite data and radiative transfer models

Wouter H. Maes[a,b,*], Brianna R. Pagán[b,c], Brecht Martens[b], Pierre Gentine[d], Luis Guanter[e], Kathy Steppe[f], Niko E.C. Verhoest[b], Wouter Dorigo[g], Xing Li[h], Jingfeng Xiao[h], Diego G. Miralles[b]



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SIFMIP (solar-induced chlorophyll fluorescence -MIP)

- **Activity leads**: Nick Parazoo (JPL), Alexander Norton (JPL), Troy Magney (UC-DAvis)
- **SIF-MIP** focuses on targeted assessments of simulations from an **ensemble of process-based TBM-SIF models**, forced with local meteorology and analyzed against tower based continuous far-red SIF, NEP, GPP and energy exchanges
- Basic protocol follows the **Phase 1 SIF-MIP** study (diurnal variability at Niwot Ridge, Colorado (Parazoo et al., 2020)
- **Phase 2 of SIF-MIP** will expand the time and spatial scale of analysis, focusing on **diurnal, synoptic, and seasonal variability** at evergreen needleleaf (Old Black Spruce, Niwot Ridge, Delta Junction) and crop (Iowa corn and soybean) sites in North America.

SIF Benchmarking product

- **Activity lead**: Nick Parazoo (JPL)

- Production of a **carbon-water cycle reanalysis product**, to be submitted to the **NASA program "Making Earth System Data Records for Use in Research Environments"**

- "Data Record" is a **global gridded daily time series** of coupled carbon-water surface fluxes (**NEE, ET and component fluxes**) derived from a model-data fusion system (CARDAMOM)

- Uses include
  - (1) LSM benchmark,
  - (2) observational constraint for data assimilation system
  - (3) diagnostic of global carbon/water budgets and trends.

- Links to **ILAMB** and **GDAP Integrated Product**

Action & discussion points taken forward from meeting with Rapporteurs (June 2022)

- Seamless GEWEX-GLASS links to **Space Missions**
  - Models process representation for data assimilation and with a focus on **observables**: SIF (SIF-MIP), VOD, optical spectra, brightness temperature.
  - Modelling that caters for OSEs and OSSEs
- Importance of **Carbon Cycle**:
  - link to water cycle (SIF-MIP), uncertainty in ET, don't decouple from carbon cycle. GPP gives much better indication of accuracy of water balance
  - carbon monitoring in context of Paris agreement
- Approach model improvements/bench-marking with **stakeholders in mind** (model products, metrics)
- **Cryosphere**:
  - permafrost/snow processes, glaciers (LS3MIP, GEWEX Central Asia initiative; GHP (Canada); WCRP (CliC))
  - Snow-MIP: led by Rasmussen NCAR?

GLASS Global / Land - Atmosphere System Studies

New Projects and Activities?

- **Surface water with an emphasis on lakes and reservoirs:** links to ET and irrigation CC, km-scale theme, NASA SWOT satellite launch
- **Groundwater MIP?:** members of SoilWAt team, plus key panel members (Laura Condon)
- **'soil-cloud cascades'**: Yijian Zeng (GLASS), Yunyan Zhang (GDAP) and others. Links to LoCo, CLASP, GLAFO, km-scale & mesoscale organisation of convection themes, GASS and GHP
- **Vegetation (proposed by German Poveda)**
  - **Model improvements** in framework of satellite operational context (observables: VOD, optical spectra, brightness temperature
  - **Amazon VOC, cloud nuclei**. Get person on panel from Amazon scientific community?
- **Urban PLUMBER & Urban PLUMBER-Hydro :** Gert-Jan Steeneveld (Lead Lipson/Jongen): km-scale & mesoscale organisation of convection themes
- **Permafrost/snow** processes activity: Snow-MIP?: Link with CLiC
- **Machine learning** versus **processes?** (Gab Abramowitz, Martin Best, Laura Condon) opinion piece in GEWEX Newsletter in first instance?
- Connect with new **DICE/GABLS:** John Edwards is rekindling this project. A white paper is in progress.

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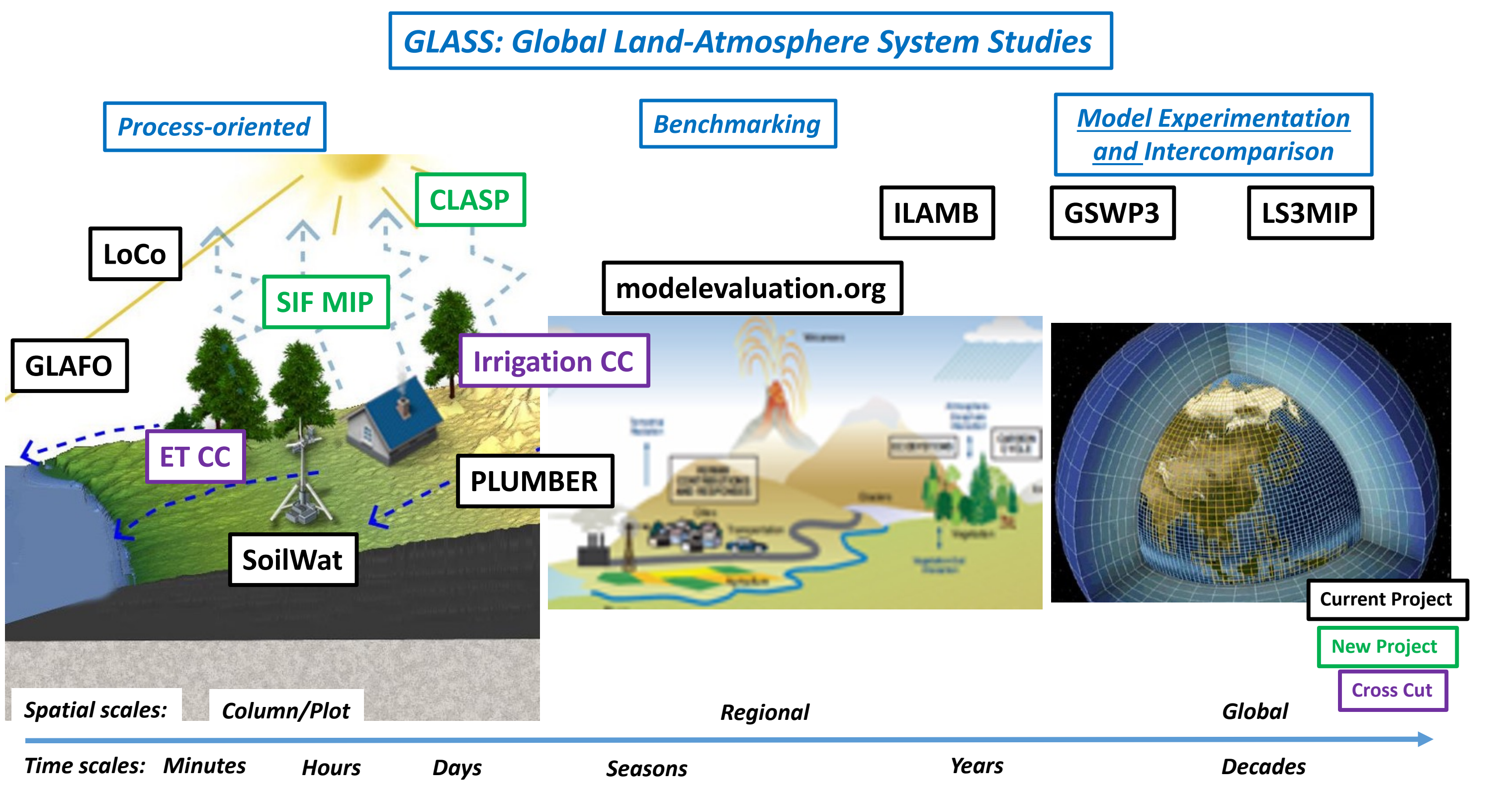
Thank you

Ten GLASS Panel Projects: From column (process) to global scale



- **ILAMB**: International LAnd Model Benchmarking
- **Modelevaluation.org:** web application for evaluating and benchmarking computational models.
- **GSWP3**: Global Soil Wetness Project, phase 3
- **LS3MIP**: Land Surface, Snow and Soil Moisture MIP

- **LoCo**: Local Coupling Working Group
- **GLAFO**: GEWEX/GLASS Land-Atmosphere Feedback Observatories
- **SIFMIP**: Solar-Induced Fluorescence MIP
- **CLASP** (Coupling of Atmospheric Land and Sub-grid Parameterizations)
- **SoilWat**: Soils and Subsurface processes
- **PLUMBER2**: The Protocol for the Analysis of Land Surface Models (**PALS**) Land Surface Model Benchmarking Evaluation Project, phase 2

Global / Land - Atmosphere System Studies

What has LoCo provided? What is on the horizon?

- LoCo has provided **context and a framework** from which to tackle the complex world of L-A coupling that did not previously exist at the time of GLACE.
- LoCo is explicitly (metrics, name recognition) and implicitly (SM-P chain) **supporting the science** contained in the many LoCo studies published each year.
- LoCo's presence can be felt and is requested in **community meetings, workshops, white papers and in funding calls**. Has a place at the table in GCM development now and has a foot in the door with shorter timescales (UFS).
- LoCo motivates the community to consider **new aspects of L-A coupling** (e.g. extending beyond the current LoCo paradigm) and ask new questions.
- *Recognize gaps in L-A scientific scope not captured by existing metrics* means **expanding scope**: Cold climates? Carbon? Ecosystem scale?

Global / Land - Atmosphere System Studies

LAFO site and Instrumentation

(see https://lafo.uni-hohenheim.de/en and https://physik-meteorologie.uni-hohenheim.de/en)

- **EC stations**

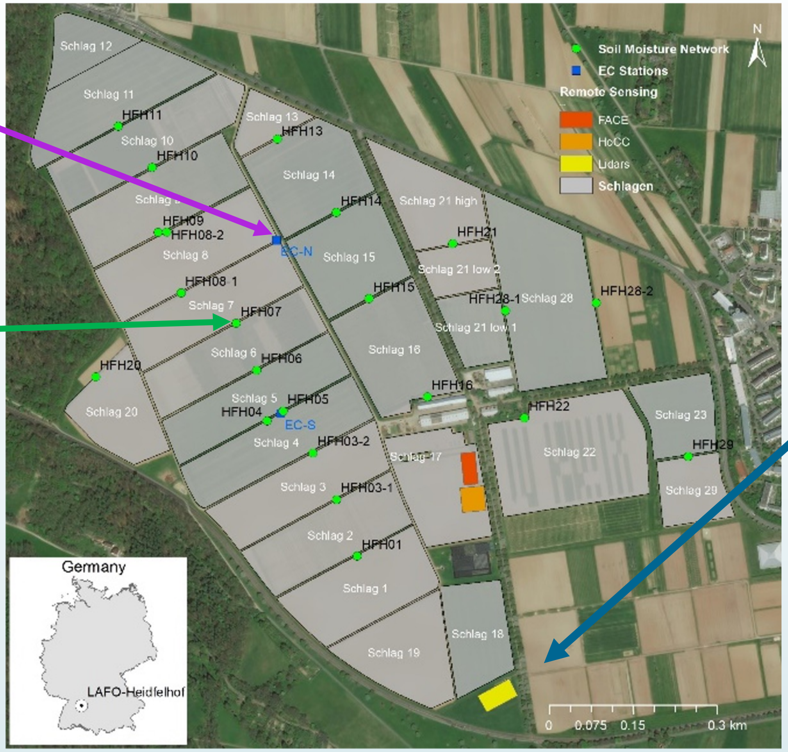
2 stations
operational since
July 2018

- **Soil moisture and temperature network**

22 stations
operational since
July 2018

- **Canopy (T &Rh)**
- 4 heights
- **5 locations**

planned for 2021



- **Field sampling**
- **Field measurements**

Remote Sensing

- **Doppler Wind Lidar**

- **Doppler Cloud Radar**

- **WVDIAL**

- **Raman Lidar**

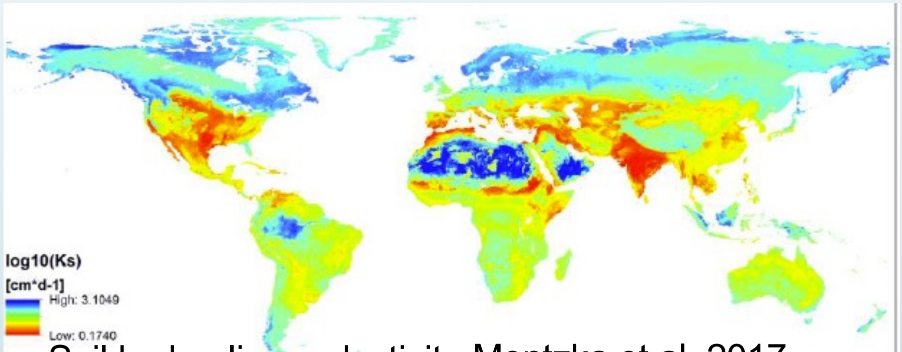
- **Distrometer**
- **Micro Rain Radar**

CLASP-GLASS connections

- The CLASP project falls within GLASS' goals to **improve modeling of land-atmosphere interactions**
  - The role of **sub-grid surface heterogeneity** on atmospheric response remains mostly ignored in practically all Earth system models
- CLASP is composed of **many GLASS members**
  - Kirsten Findell, Nathaniel Chaney, Paul Dirmeyer, Mike Ek, David Lawrence, and Joe Santanello
- Emerging **collaborations** between **CLASP and GLAFO**
  - CLASP helps define GLAFO sites and observation needs
  - GLAFO observes ABL response to surface heterogeneity to inform CLASP efforts
- CLASP is motivating us to think more rigorously about the **validity of Monin-Obukhov similarity theory** for many heterogeneous landscapes
  - Long-term CLASP involvement in GLASS will help provide it with enough momentum to explore these "big-ticket" research questions in land-atmosphere interactions

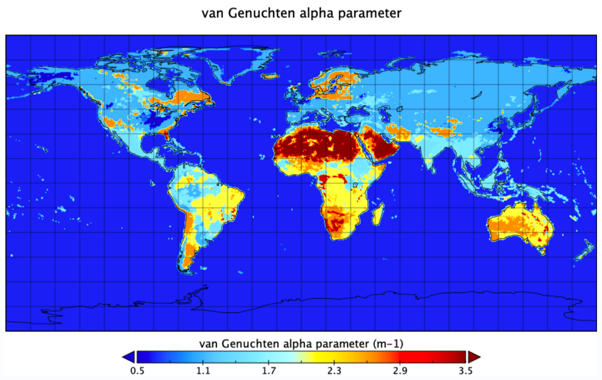
SP-MIP Thermal Regime Analysis
(leads: Anne Verhoef, Yijian Zeng)

- A **global multi-model** experiment
- **Overarching question**: to which degree is LSM spread related to uncertainties in soil model parameters (as opposed to model structure)
- **SP-MIP** was set up to look at soil hydraulic parameters and water balance
- However, the soil thermal regime is important too:
- (i) **soil** and surface **temperatures**
- (ii) Soil **heat flux**
- (iii) soil **thermal properties**
- (iv) related metrics (e.g., **damping depth**)



Soil hydraulic conductivity Montzka et al. 2017

SP-MIP experimental design



Effect of different **PTFs**

Effect of different **soil maps**

Exp. 1: Identical soil <u>hydraulic parameter</u> maps

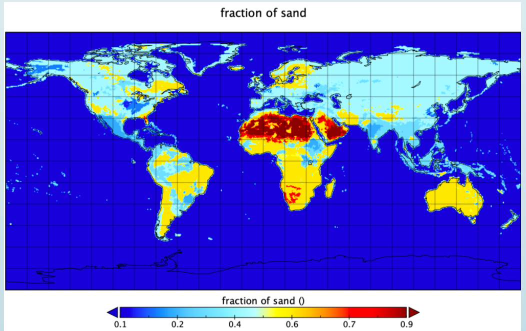
- Global soil hydraulic parameter maps provided by SP-MIP (1 set of hydraulic PTFs was used (BC & VGM))
- (Thermal parameters derived by modelling teams, multiple sets of maps & thermal PTFs)

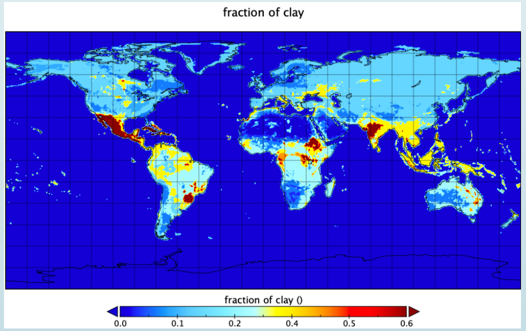
Exp. 2: Identical <u>soil texture</u> maps

- Global soil texture maps provided by SP-MIP
- Hydraulic (and thermal) parameters derived by modelling teams (multiple sets of PTFs)

Exp. 3: Model-specific soil texture maps

- Individual teams use their own global soil texture maps
- Hydraulic (and thermal) parameters derived by modelling teams (multiple sets of PTFs)





ISMC International Soil Modeling Consortium

GLASS Global / Land - Atmosphere System Studies

New initiative/Proposal
Effect of Soil Properties on L-A Interactions

- **Participants**: Yunyan Zhang, Min Huang, Anne Verhoef, Bob Su, Lai-Yung (Ruby) Leung
- This WG is looking at the **cascading effect of different soil maps** (and the PTFs used to translate these maps into soil hydraulic and thermal parameters) —> spatio-temporal distribution (heterogeneity) of soil moisture contents, surface temperatures & evaporative fraction —> **convective cloud-forming processes**
- Could have intra-GLASS (links to LoCo and CLASP) or cross-cut project (with GASS/GHP)

GLASS
Global / Land - Atmosphere System Studies

PLUMBER2: Planned analyses

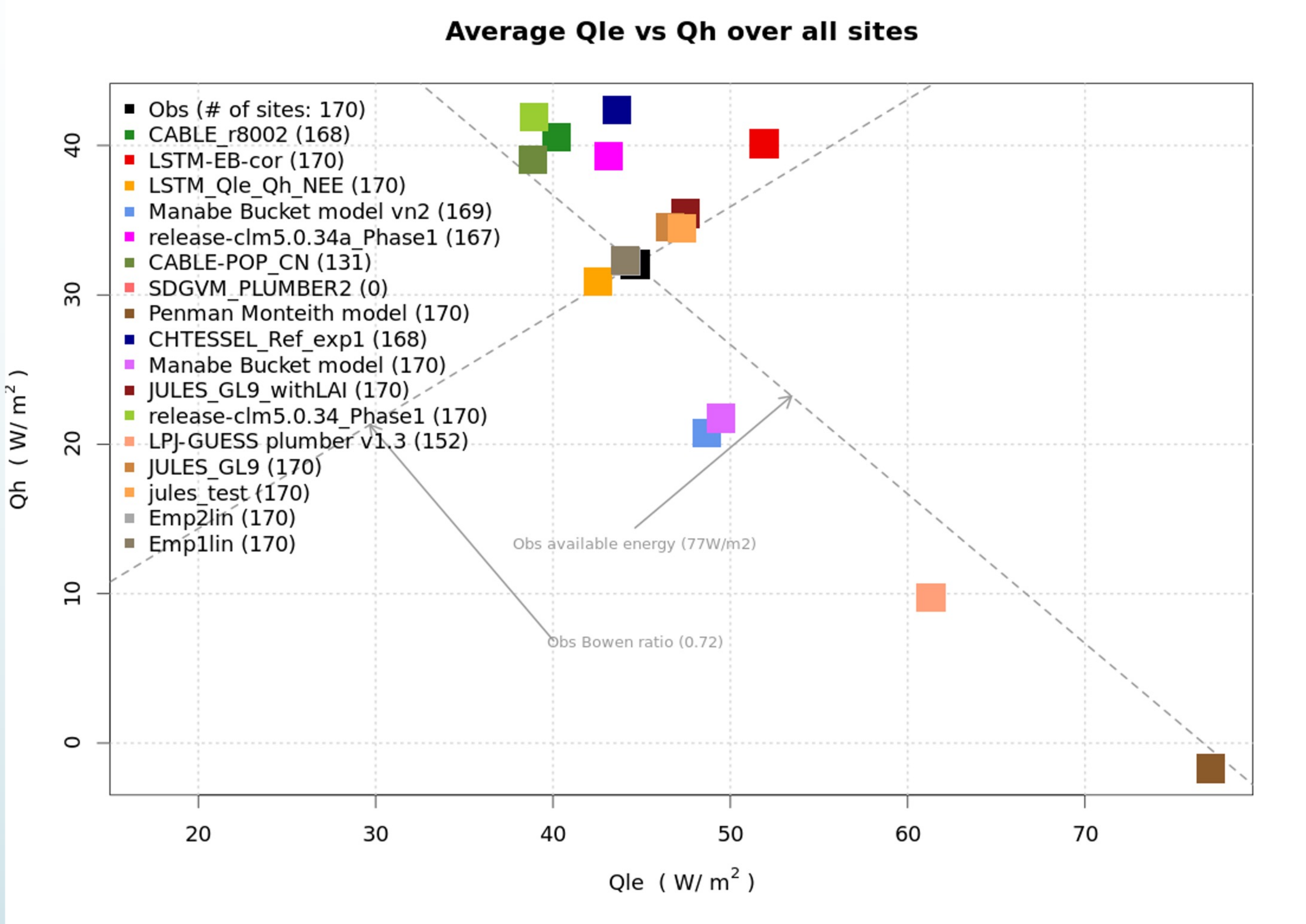
- ***Budyko curve*** departure analysis (Martin Best, Gab, Martyn Clark)
- ***Diurnal*** hysteresis / phase lag (Maik Renner, Gab)
- Benchmarking ***momentum flux*** as well as heat fluxes (Martin Best, Ian Harman)
- '***Conditional analysis***' (Gab, Martin DeKauwe, Anna Ukkola):
  - E.g. WUE and EF during dry-down events, heatwaves
  - Domain clustering (forcing only, forcing+model states) to identify conditions of poor simulation
- Transfer ***entropy networks*** to identify process representation issues (Grey Nearing)
- ***Improved 'PLUMBER plots'*** as high level all / site / variable / metric overview
- Focus on ***empirical models*** defining good/bad performance; removes flux magnitude & site complexity as confounding variables
- ***Paper on QC*** is forthcoming

PLUMBER2: Outputs

Existing automated analyses through

modelevaluation.org

av. latent vs av. sensible scatter (all models)



Global / Land - Atmosphere System Studies

CC-dET (Determinining Evapotranspiration)update

Current leadership: Joan Cuxart, Oscar Hartogensis, Aaron Boone, Anne Verhoef

- Initiative related to methods allowing to determine Evapotranspiration (ET), **experimentally**, through **remote sensing methods** or in **models,** at different spatial and temporal scales
- **History**: arose from the 2018 GEWEX Science conference in Canmore and the two workshops that followed (Sydney October 2019, and Wageningen/online February 2021)
- paper in **GEWEX News** stating **four main challenges** (definition/understanding, in-situ measuring, parameterisation, remote sensing and catchment scale)
- **LIAISE campaign (summer 2022)** on ET and water management in semi-arid conditions (a HyMeX follow-up)
- **third workshop** (joint with LIAISE) is planned for **March 2023;** second workshop discussed the contributions to ET of vegetation, soil and inland open-water, as well as surface heterogeneity, anthropogenic water management and the interaction between scales, from leaf to landscape and catchment.
- To contribute to the **GEWEX Science Goals:** (i) the flux exchanges in the prediction of the Earth's water cycle (Goal 1) (ii) in the ABL representation and Land-Atmospheric Interactions in the quantification of Earth's energy, water and carbon cycles (Goal 2) (iii)to the water variabililty, trends and water management influences (Goal 3).

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CC-dET update

Cross-cut is preliminarily organised in **four main working groups**:

- WG1. **Measuring ET** and its role in the Surface Budgets (energy, water, carbon)
- WG2. **Models and parameterisations** of ET (including their use in numerical models and remote sensing methods), validation and networks
- WG3. ET from the different elements of the surface and **partitioning: soil, vegetation, open-water**
- WG4. **Heterogeneity, irrigation**, varying spatial and temporal scales, extreme events.

It is expected that the working groups will be finally established after revision at the end of the March 2023 workshop.

- With regards to observation networks: two meetings have taken place with **Ameriflux.** One Ameriflux person may also join the board
- **Formal application to GHP** has been submitted May 2022

Cross-cut Irrigation Effort Update

CROSS-CUT GOALS

- To make progress on a narrowly focused and pressing irrigation topic
- Enhance communication among existing groups that may be working independently on related irrigation topics

APPROACH

- Model intercomparison project to better understand where/when our models have predictive capabilities for irrigation
- Series of meetings/workshops to bring the community together

SPECIFIC GOALS

1. Definition of the most pressing challenges that need to be addressed about the understanding of the irrigation's role in the earth system and its modeling
2. Identification of existing or future field campaigns, besides LIAISE and GRAINEX, on other irrigation climates across the globe
3. Utility of available satellite data products for the detection of irrigation impacts
4. Design and execution of a **Model Intercomparison Project** to advance our understanding of the predictive capabilities for irrigation of our models

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CC-dET update

- ET-cross -cut will function as a **Board**. This form of organization makes it more flexible and less dependent of one or two persons. Oscar and Joan are the coordinators.

- Currently the expertise on the Board covers **numerical models**, **experimental work and process understanding**. We aim to enlarge the Board with one or two persons covering **RS & Networks**. We should take into account geographical/gender balances.

- With regards to networks: two meetings have taken place with **Ameriflux.** One Ameriflux person may also join the board

- **Formal application to GHP** has been submitted May 2022

Brief Updates of SoilWat activities

WG – Pedotransfer Functions and Land Surface Parameterization (Leads: Yonggen Zhang & Lutz Weihermueller)

- Established 2020 (with 25 members). WG missions and minutes of WG meetings can be found here.
- A review paper "Hydro-pedotransfer functions: A roadmap for future development" is currently in its final stage (leads: Tobias Weber, Lutz Weihermueller)

WG – Soil Thermal Properties (Leads: Anne Verhoef, Yijian Zeng)

- Established 2021 (with 20 members). WG missions and minutes of WG meetings can be found here.
- Preparing a science roadmap for soil thermal property studies.
- A survey has been sent out for solicitating inputs from all participants. For those who are interested, you are invited to fill in the Google Form here
- SP-MIP results have been explored with thermal analysis

New Projects and Activities?

- **Surface water with an emphasis on lakes and reservoirs:** links to ET and irrigation CC, km-scale theme, NASA SWOT satellite launch
- **Flood Inundation (extent, duration)** activity: with GHP, GDAP?
- **Groundwater MIP?:** members of SoilWAt team, plus key panel members
- **'soil-cloud cascades'**: Yijian Zeng (GLASS), Yunyan Zhang (GDAP) and others. Links to LoCo, CLASP, GLAFO, km-scale & mesoscale organisation of convection themes, GASS and GHP
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