Global Energy and Water Cycle Exchanges Project

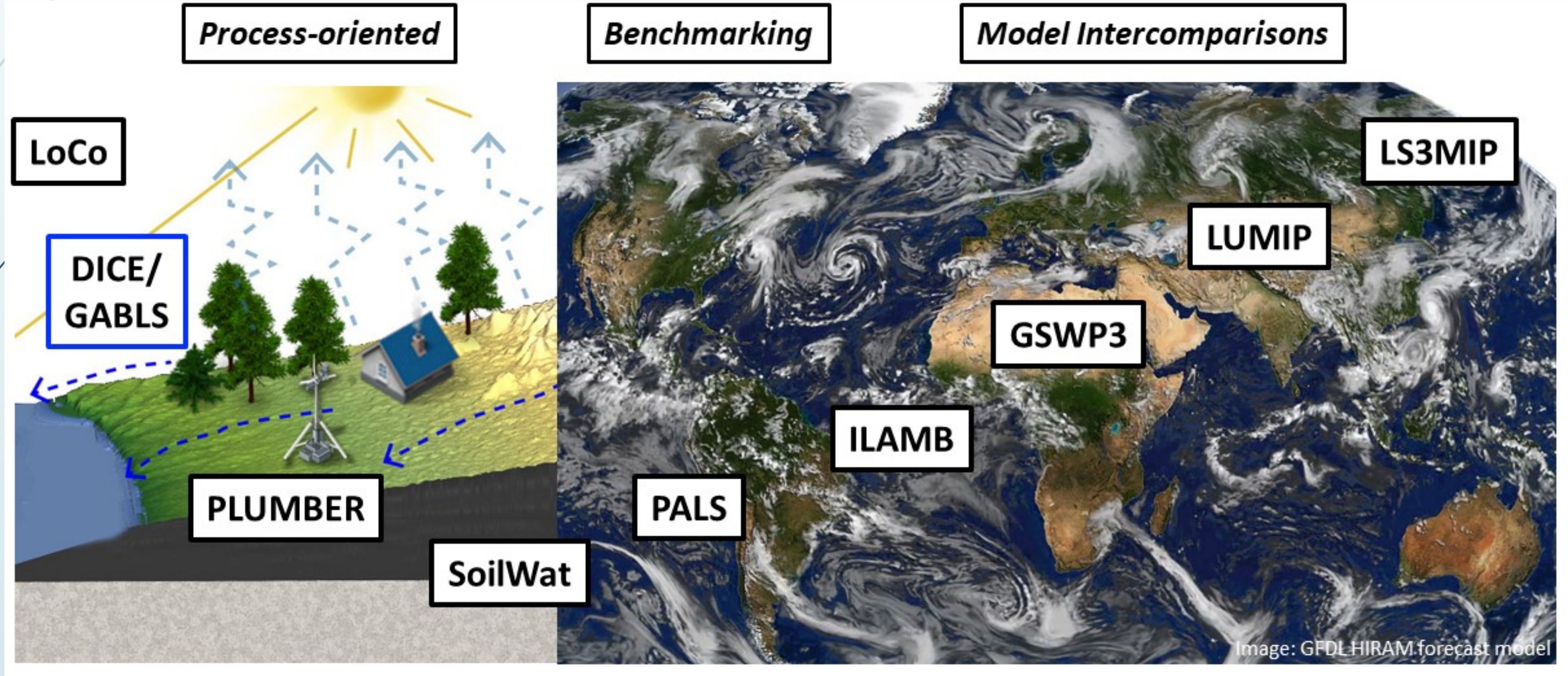
Global Land-Atmosphere System Studies (GLASS) Panel Update

Mike Ek and Kirsten Findell, GLASS co-chairs
GLASS Panel Project Leaders

The 32nd Meeting of the GEWEX Scientific Steering Group
January 27-31, 2020
Pasadena, California

Global Land - Atmosphere System Studies

GLASS Panel Projects: From process to global scale



SoilWat Goals and Participants

- 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
- Leaders and key participants: *Dani Or, Matthias Cuntz, Anne Verhoef*, Harry Vereecken, Lutz Weihermuller, Lukas Gudmundsson, Peter Lehmann, Stefan Kollet, Simone Fatichi, Mehdi Rahmati plus many others

ISMC
International Soil Modeling Consortium

GEWEX

The GEWEX-SoilWat initiative:
first planning workshop for scope and interactions

Advancing Integration of Soil and Subsurface Processes in Climate Models

Leipzig June 28-30, 2016

Organizing committee

Gerrit Rooij – UFZ
Dani Or - ETH
Sonia Seneviratne - ETH
Peter van Oevelen - GEWEX
Aaron Boone – CNRM
Harry Vereecken – Julich FZ

GLOBAL LAND ATMOSPHERE SYSTEM STUDY
GLASS

GLASS
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SoilWat Activities

- Various **review papers**, e.g. on “PTFs” (Van Looy et al., 2017) on "Infiltration for land surface modelling” (Vereecken et al., 2019); **Discussion paper** on groundwater in global hydrological/climate models, led by Stefan Kollet (in progress);
- Compilation of **soil-related databases**, e.g. global soil hydraulic properties (Montzka et al., 2017); infiltration (Rahmati et al., 2018); Saturated conductivity (ETHZ 2019)
- **Surveying hydraulic pedotransfer** functions used in land surface models (Weihermuller et al.);
- Conducting a **global soil parameter MIP** (Cuntz and Gudmundsson - ongoing);
- Assessing **effects of soil structure on land surface fluxes** (Fatichi et al. 2019, Bonetti)
- Using SoilGrids to revise global surface **evaporation** (Lehmann and Or, 2019)
- Comparison of **thermal properties** between LSMs (led by Verhoef)

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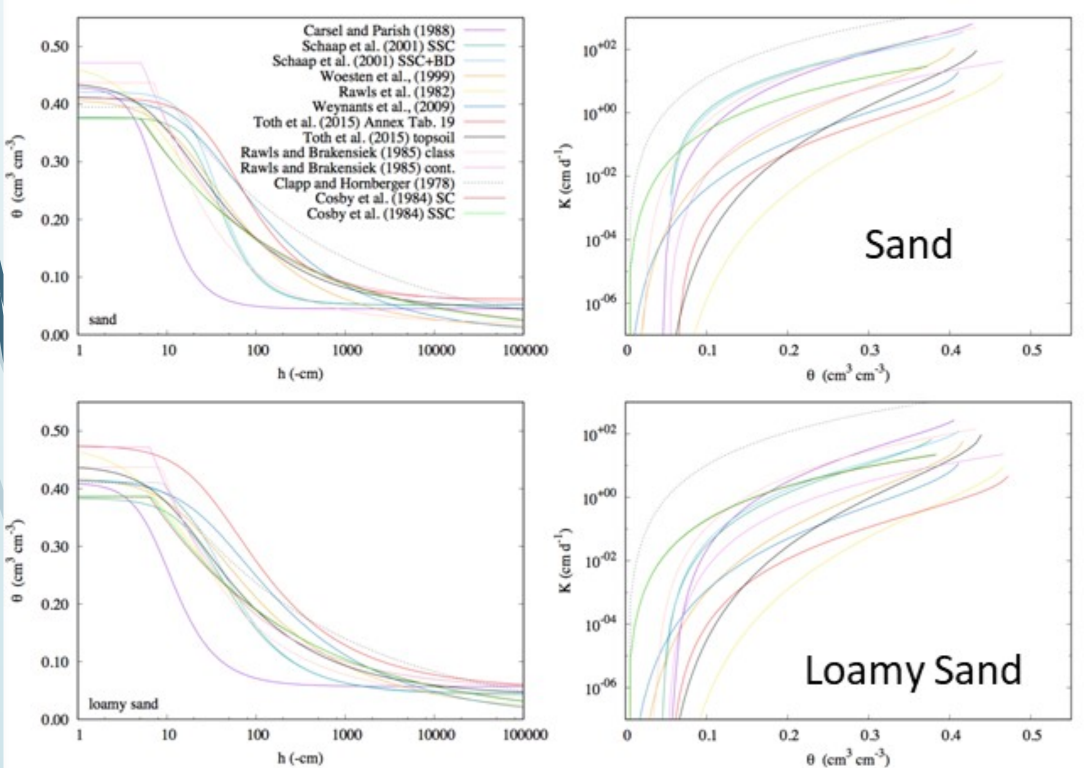
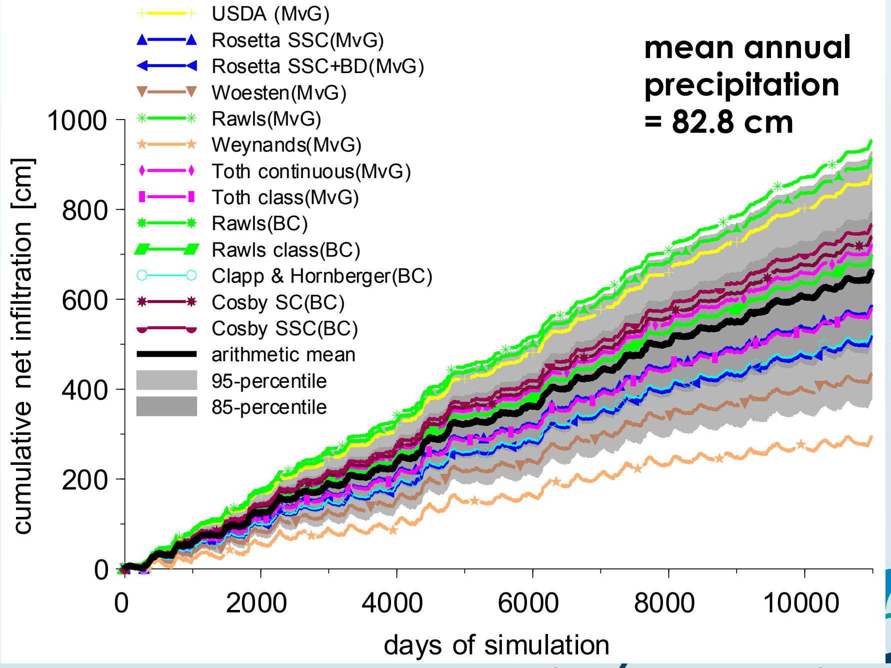
Functional Sensitivity Study of Pedotransfer Functions used in Land Surface Models

- L. Weihermüller[1], N. Moosafi[1], M. Herbst[1], C. Montzka[1], A, Verhoef[2], D. Or[3], and H. Vereecken[1]

- The “*hydraulic zoo*” - different PTF predict different hydraulic functions for the same soil

That has implications for infiltration, runoff, recharge….





Soil Structure: an important absence in Land Models

- Led by Simone Fatichi, Dani Or and and Bob Walko
- Completed **30 years of OLAM** global climate model simulations
- Examined the influence of **soil structure on climate variables**
- Revising a paper for Nature Communications

Effect of soil structure on saturated hydraulic conductivity

- Does introducing soil-structure modify the hydrological and land-surface fluxes?
- Could soil structure affect large-scale climate?

Conclusion: Small-scale soil structural features may have large-scale implications in water and carbon cycles and ultimately on climate.

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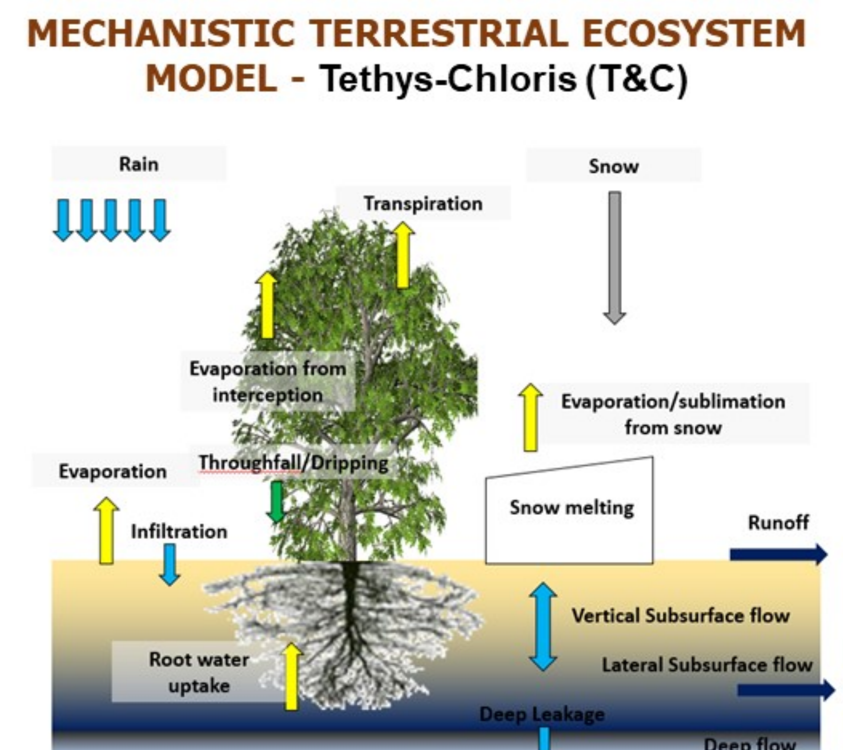
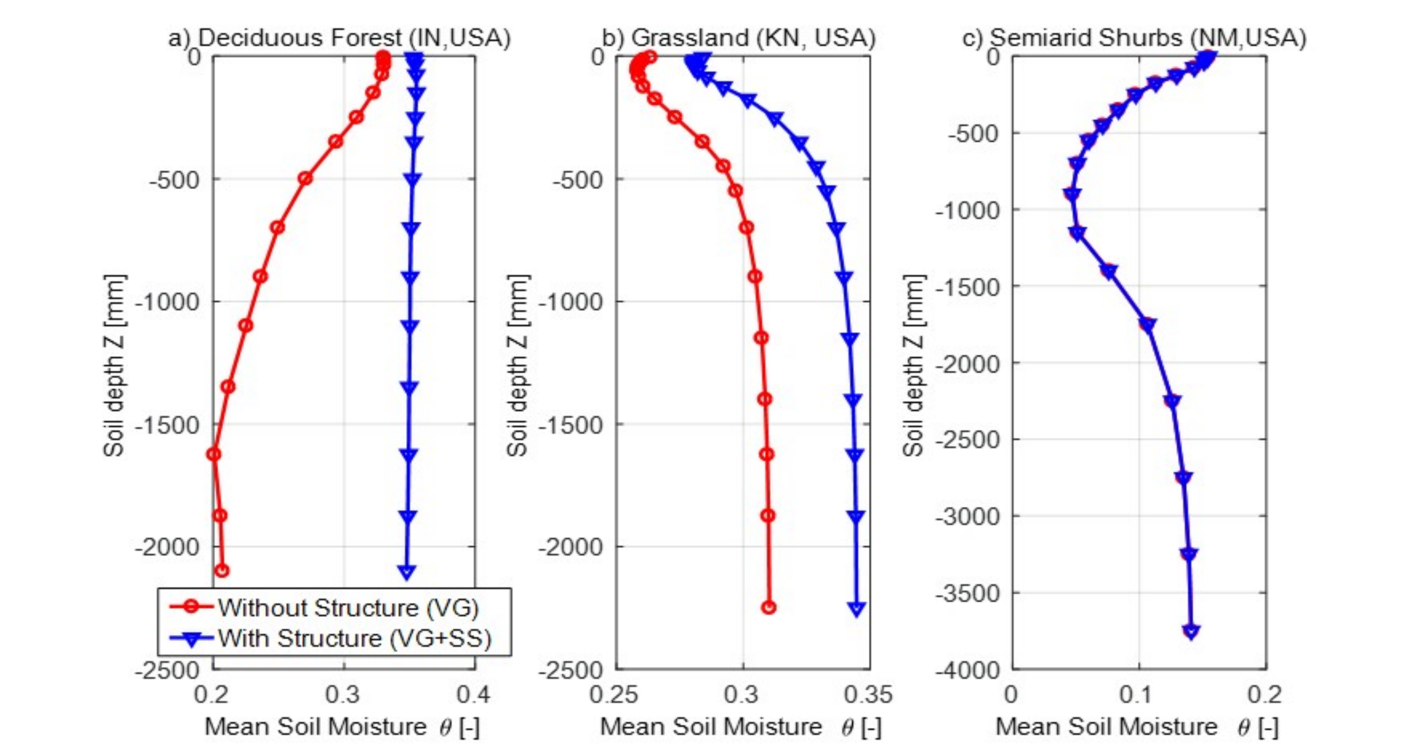
Soil structure impacts at site-level: Changes in soil water content profile

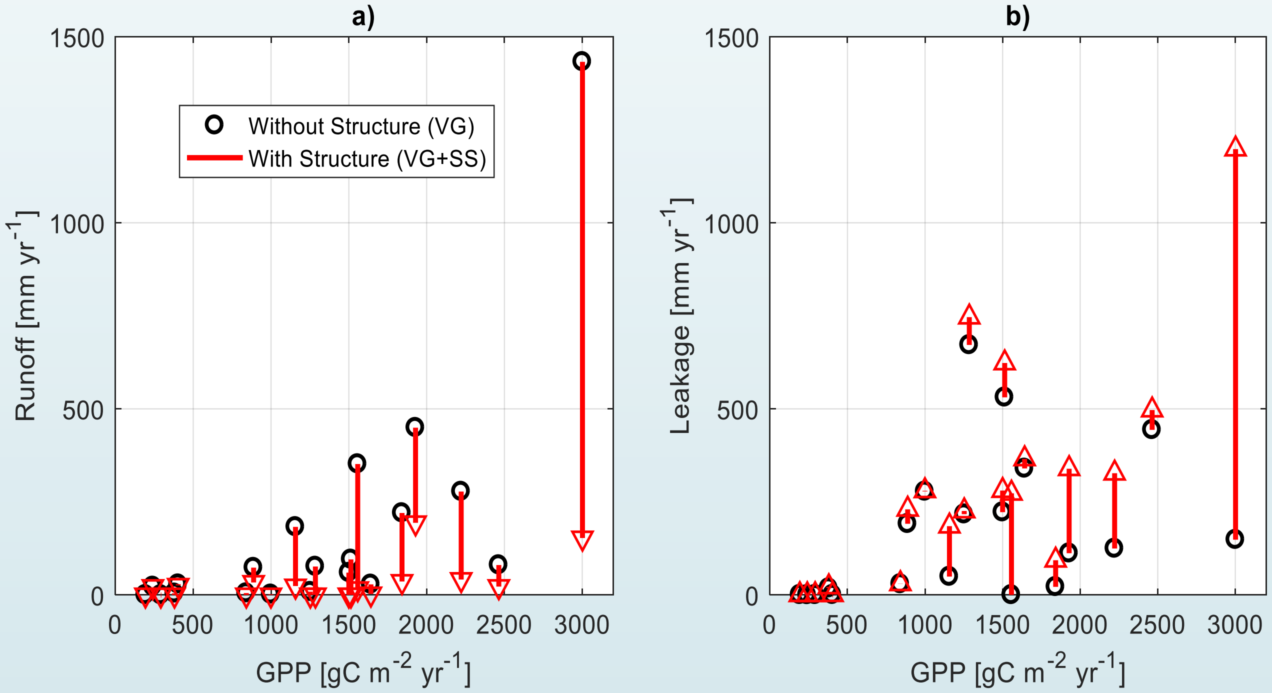


Fatichi et al., 2012a,b



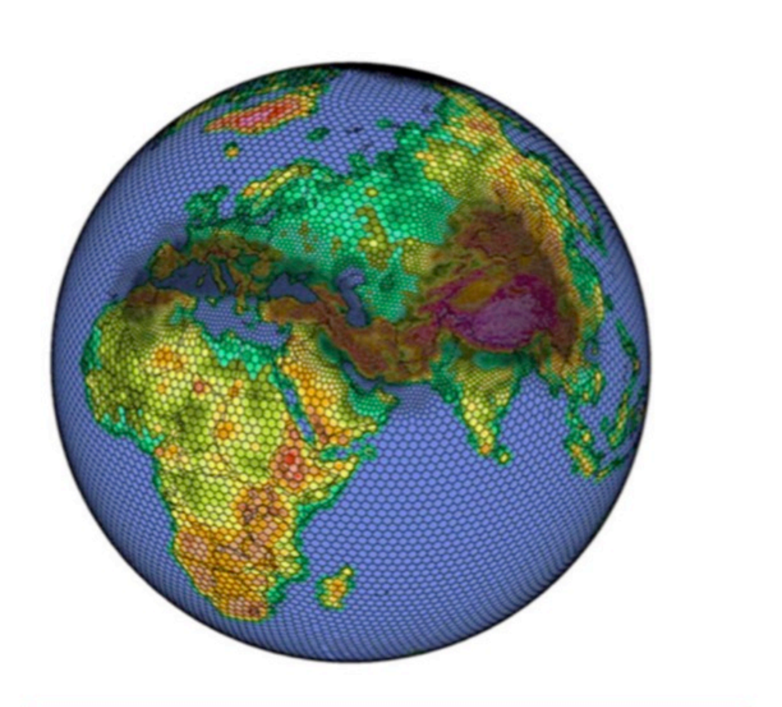
Soil structure impacts at site-level: Changes in partitioning between runoff and recharge

20 locations with different biomes and climates



Soil structure impacts at global level: Impacts are present, but statistically muted by internal variability

GLOBAL OCEAN-LAND-ATMOSPHERE MODEL - OLAM

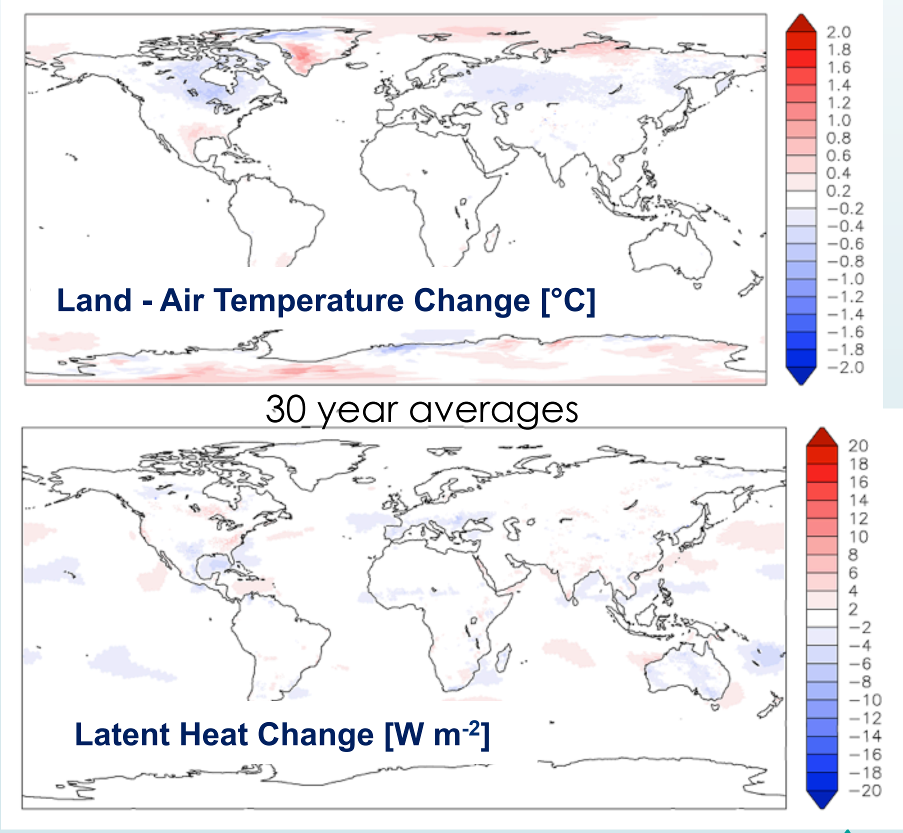


Walko and Avissar 2008a,b 2011; *Month. Weath. Rev.*

Simulations:

1) Soil texture, no soil structure.
2) Soil texture with parameterized soil-structural effects.

For two groundwater table initializations.



SoilWat: Other results and on-going work

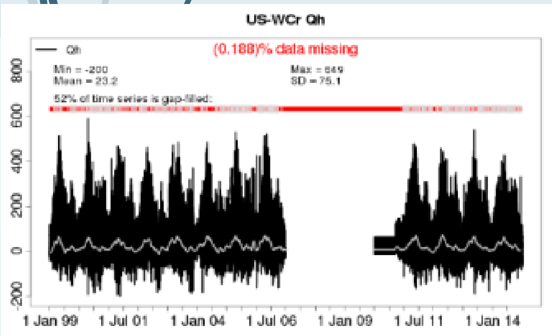
- Sara Bonetti (ETH-Zurich): injecting soil structural effects onto pixel-scale, vegetation-mediated hydraulic properties to get high-res hydrologic response
- Lehmann et al. (2019): introduced physical constraints to improve PTF-based soil hydraulic parameterization (reduce unphysical combinations of parameters based on fitting of SMC only)
- Zhang and Schaap (2019): New global saturated conductivity (ksat) map: based on extensive legacy data, incorporates remote sensing covariates, is compared with a map that uses soil info from US and Europe
- Soil Parameter MIP (SP-MIP): examine impact of soil texture and hydraulic properties on model performance: For runoff, mean not different but **model spread is reduced by using identical texture and parameters**, esp. low-flows
- SOPHIE: SOil Program on Hydro-physics, via International Engagement
  - ***Mission:*** *To provide acceptable harmonization and standardization of Soil Hydro-Physics (SHP) property determination in field and laboratory, and make SHP data based on these standardized procedures available to support policies*

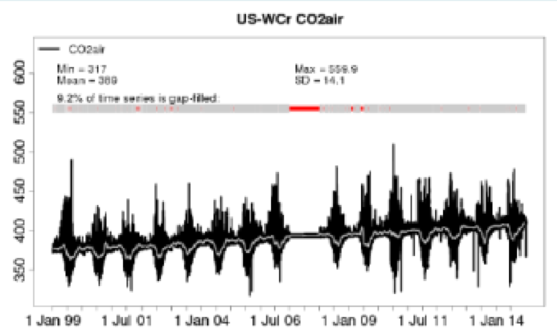
GLASS Global / Land - Atmosphere System Studies

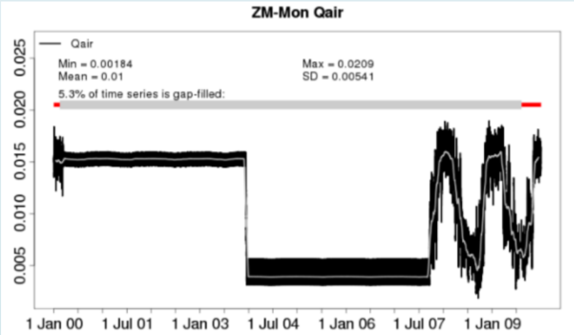
PLUMBER2: The Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2

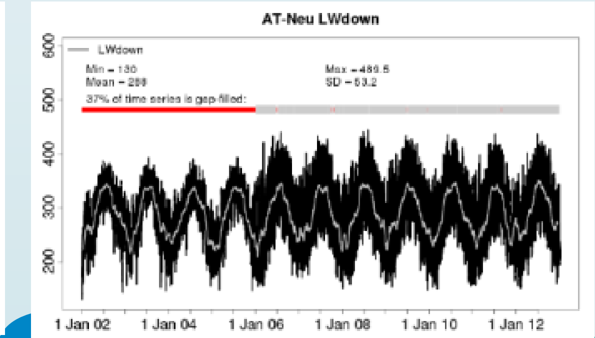
Gab Abramowitz et al.

- A land model comparison experiment that uses out-of-sample empirical models as benchmarks.
- Increases flux tower site locations from 20 to 200+.
- Data preparation and QA/QC for such a large volume of sites is cumbersome and time-consuming.
- Whole years of data only; Need energy balance correction; Fill data gaps in CO2air, LWdown, Rnet, Qle, Qh, Qg
  - How much gap-filled Swdown, Tair, P, Q, Wind is acceptable?









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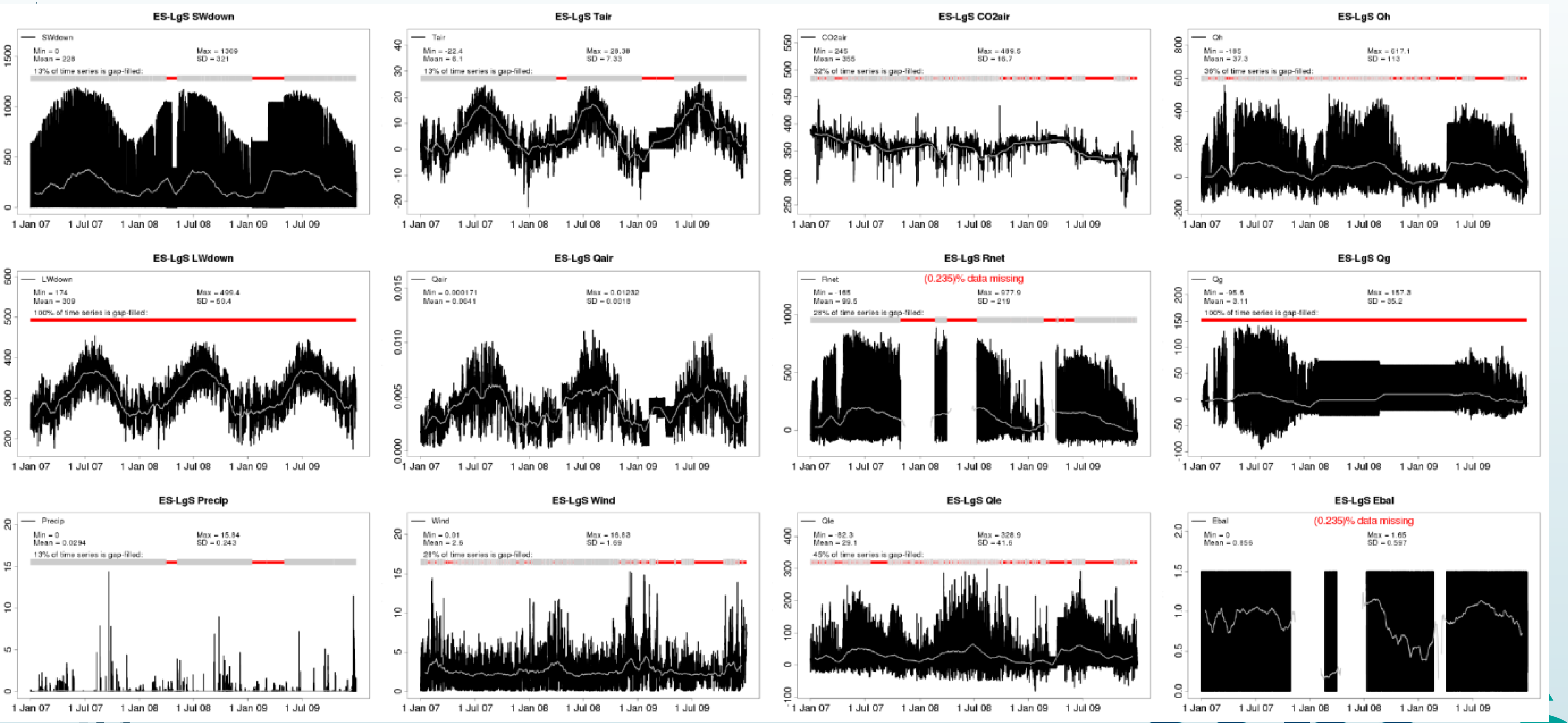
PLUMBER2: data processing



PLUMBER2: Improved empirical models

- Model calculations of fluxes and more (e.g., Net Ecosystem Exchange)
- Benchmarks: S_lin (linear regression against SW_{dn}), ST_lin (add temp), STH_km27 (add humidity and k-means clustering) as in PLUMBER
- Adds meteorologically-based empirical models to the suite, inc. winds, precip, short and long-term lagged averages as inputs
- Comparisons through quantiles rather than discrete ranks

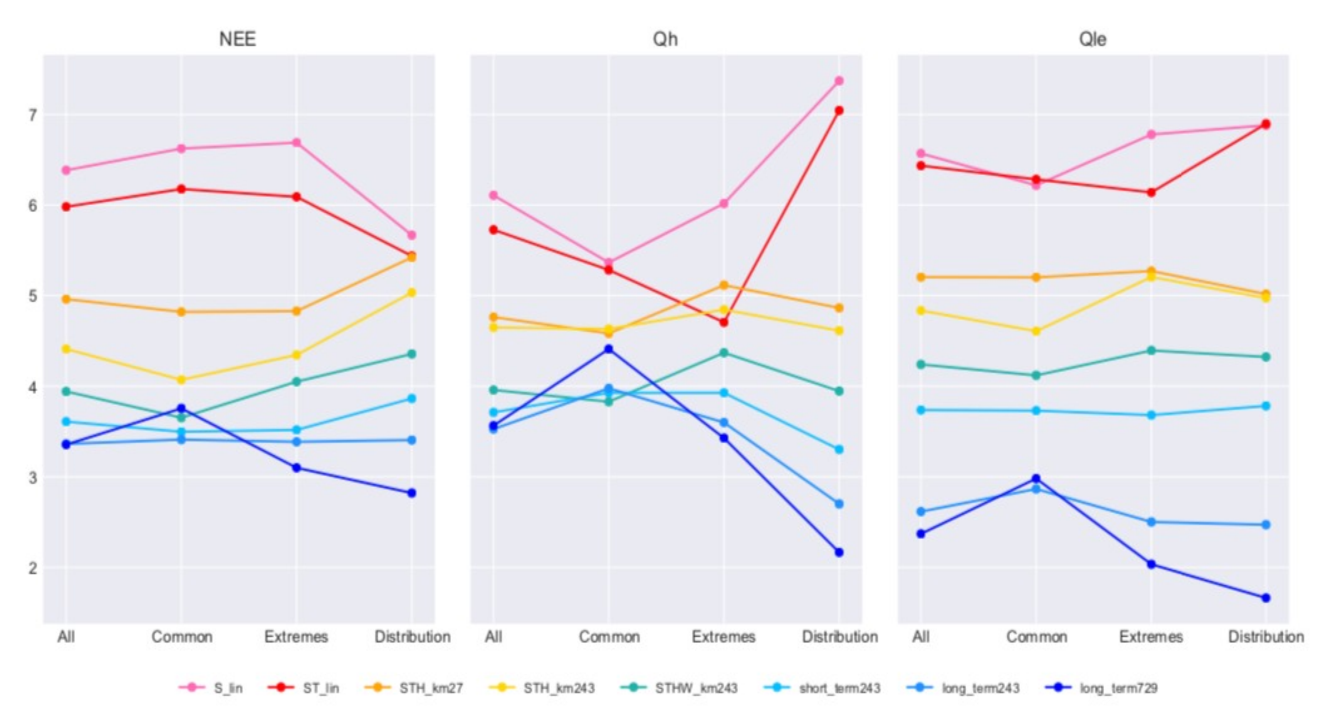


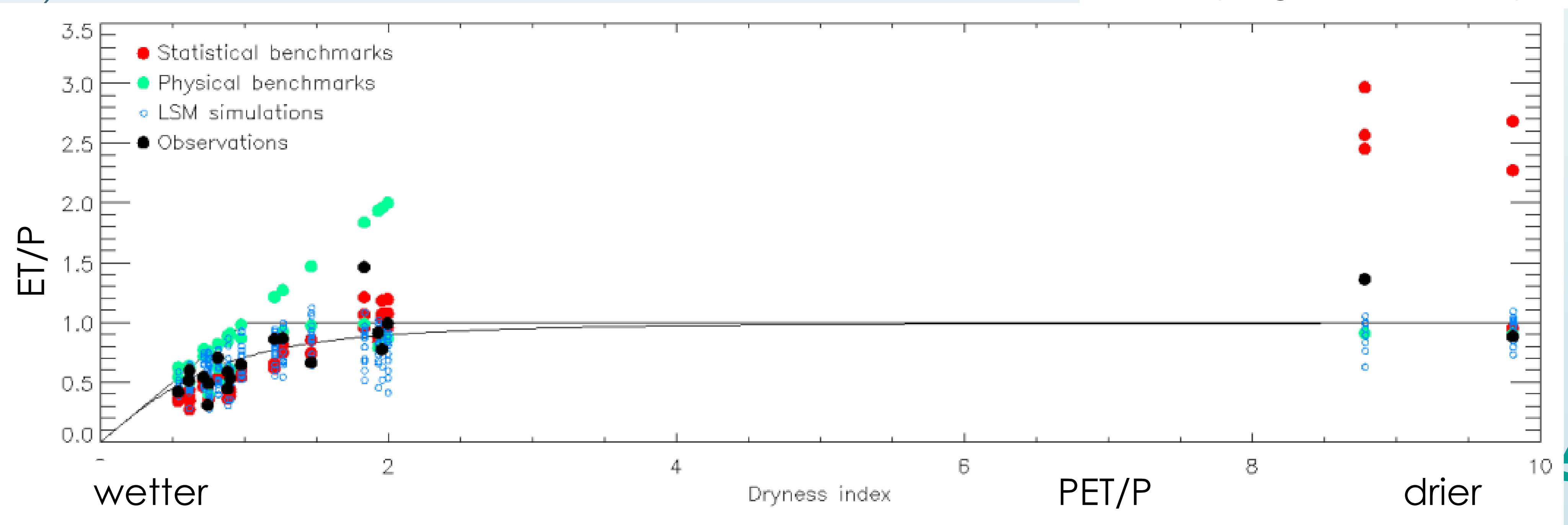
Figure 6. Rank-average plot of the eight models in the final ensemble.

Haughton, Abramowitz and Pitman, GMD 2018

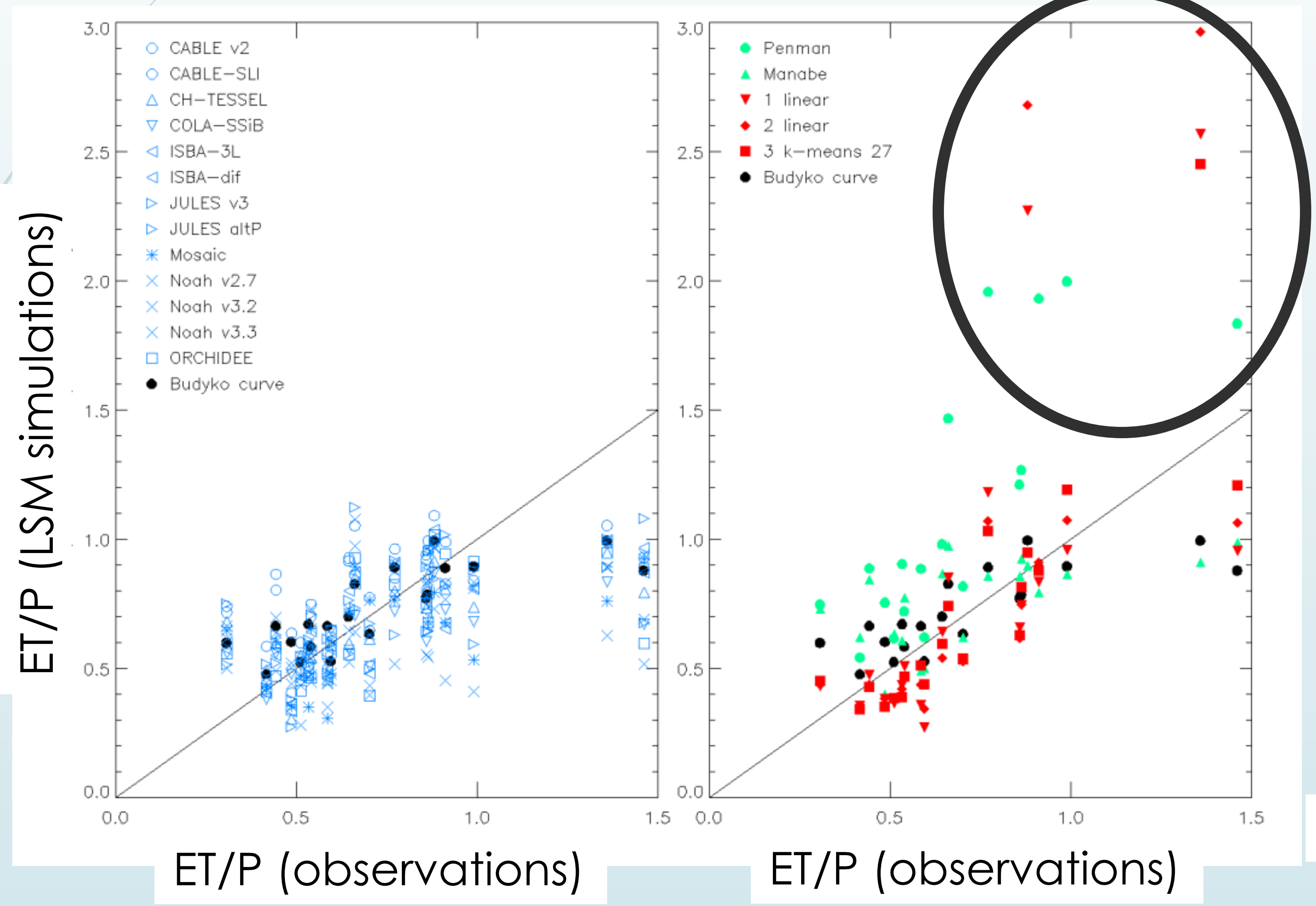
PLUMBER2: Budyko-style analysis

- The Budyko framework examines the relationship between an aridity index (PET/P) and the ratio of ET to P.
- The statistical models tend to be lower than the Budyko curve for the wetter sites and higher than the Buyko curves for the drier sites.
- At drier sites the statistical models can have ET greater than P.

Work in progress from Martyn Clark



PLUMBER2: Budyko-style analysis



Large errors in some of the benchmarks, especially when ET/P > 1.0

Work in progress from Martyn Clark

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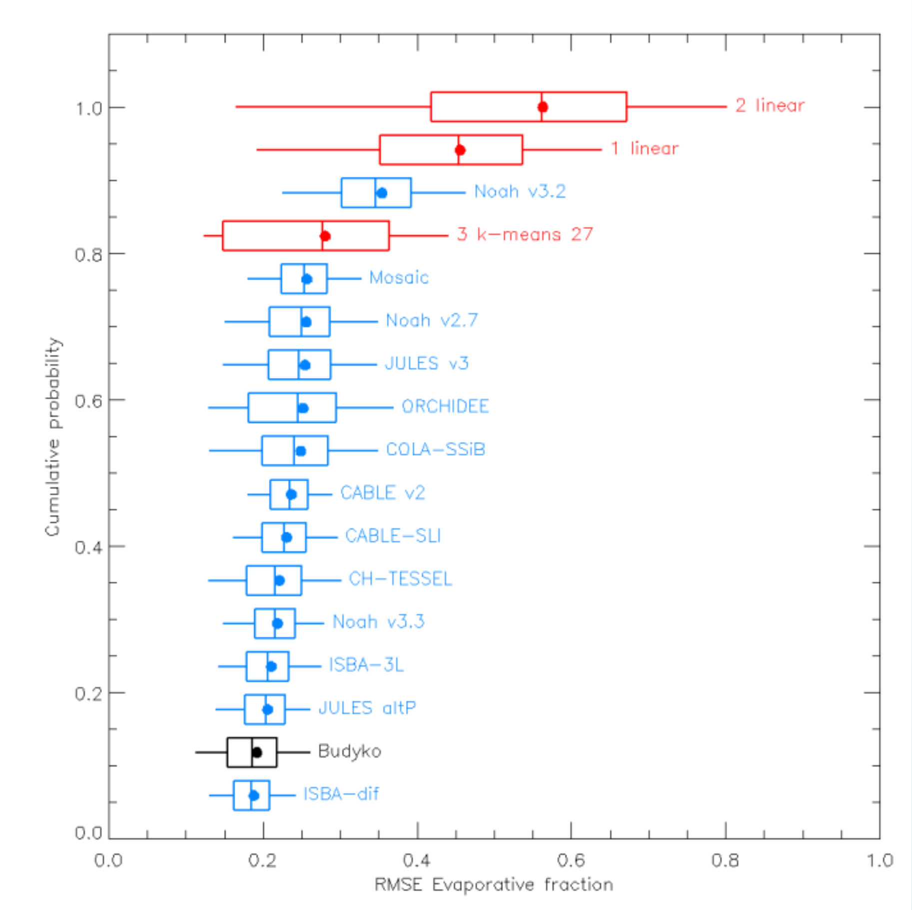
PLUMBER2: Budyko-style analysis

- Approach: RMSE across the 20 FLUXNET sites
  - Impact of the small sample size is characterized by resampling the sites (with replacement) 1000 times
- Results:
  - Most of the land models actually outperform the statistical models.
  - The Budyko curve provides better predictions than most of the land models, suggesting that **the land models are incapable of predicting departures from the Budyko curve**.
- The conclusions of PLUMBER still hold, with a simple model (Budyko) outperforming most land models.



Work in progress from Martyn Clark

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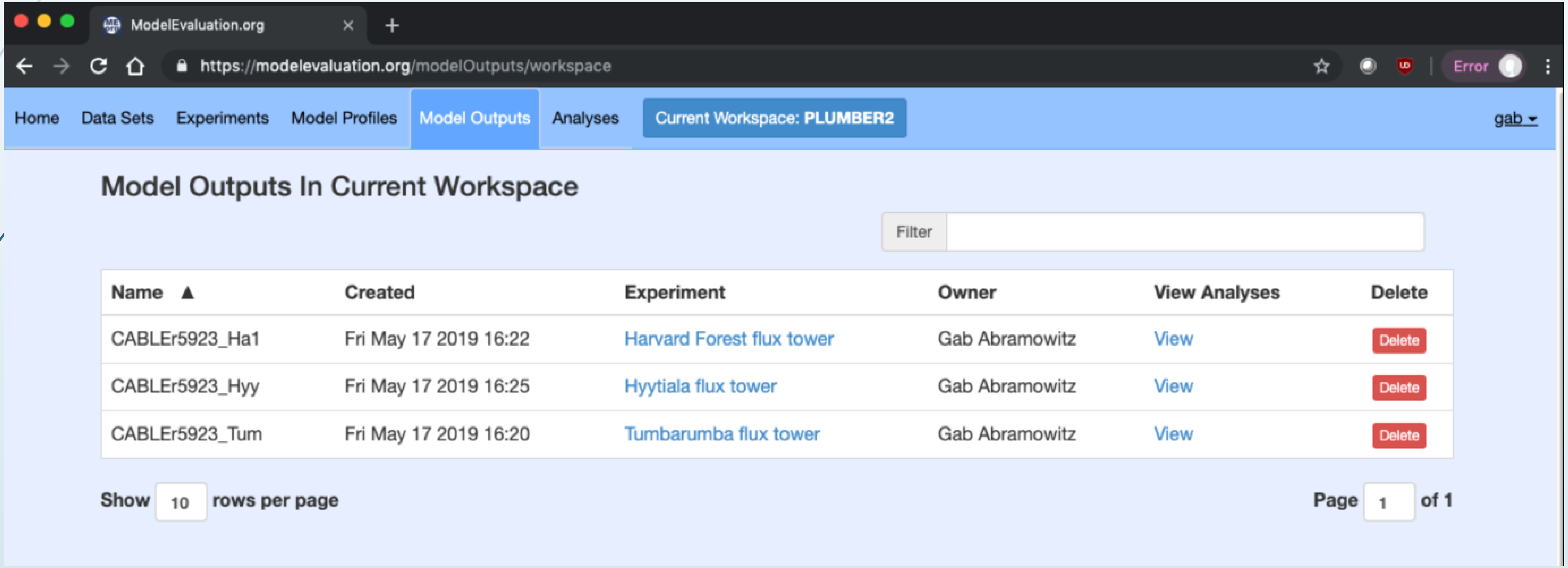
PLUMBER2: Possibilities to add data assimilation or synthetic data experiments

- PLUMBER-Urban using data from 20 urban flux tower stations
  - Objective: To demonstrate if urban schemes offer any performance advantage over default land models
- PLUMBER-DA (Data Assimilation): Sujay Kumar leading the effort
  - Objective: To quantify the utility of data assimilation towards beating the benchmarks.
  - Experiments planned, nine participants committed
- Synthetic experiments planned, fitting them into the schedule is difficult

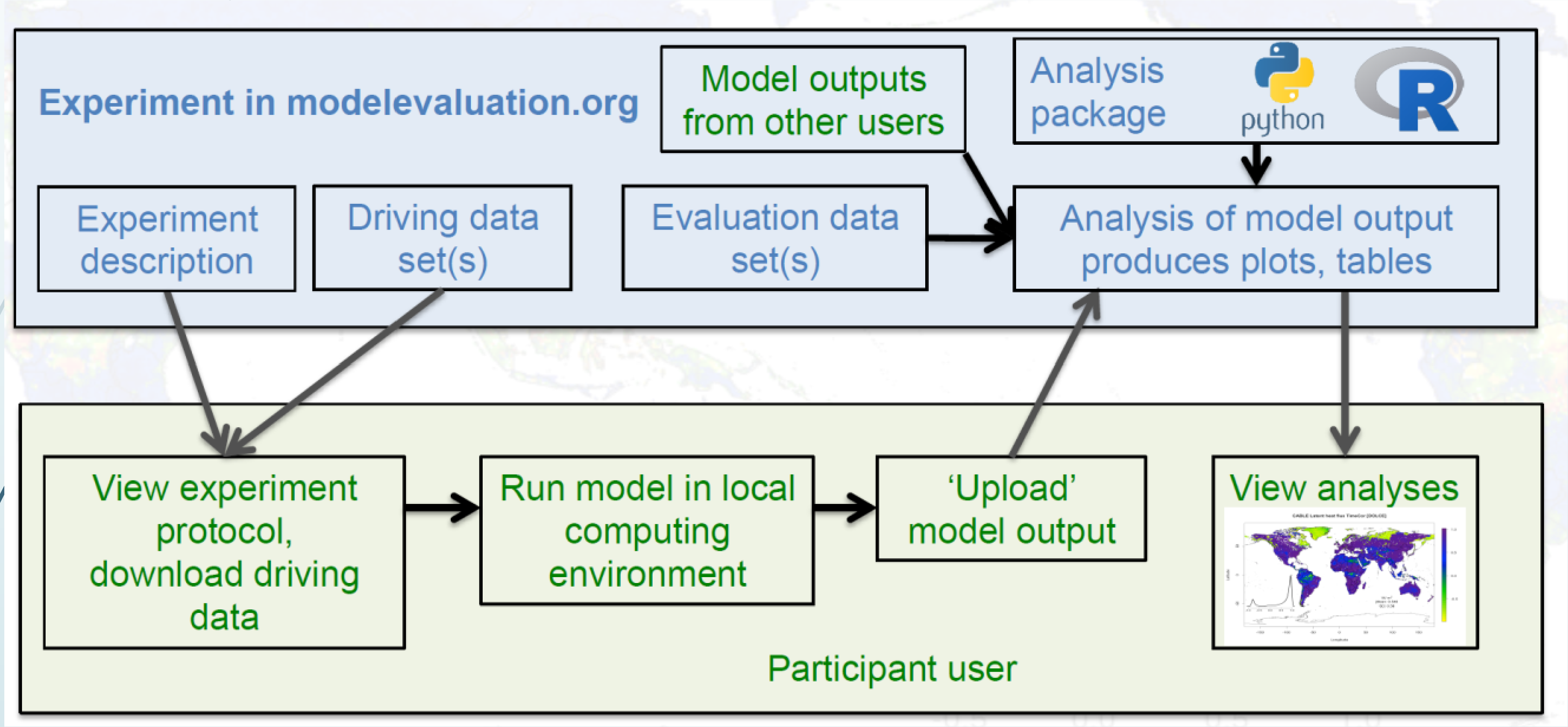
PALS: Now modelevaluation.org

- A web-based platform for evaluating and benchmarking computational models.

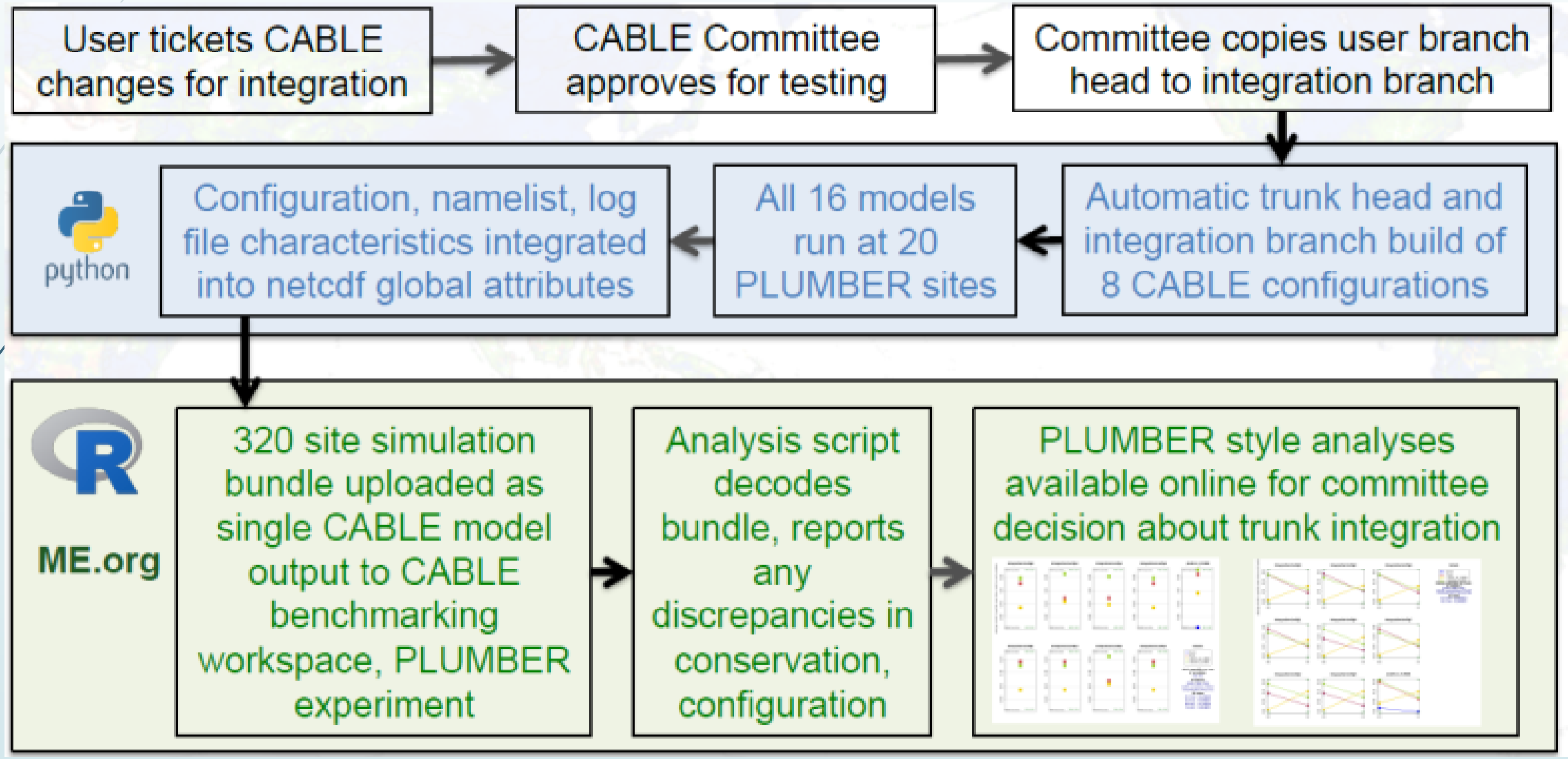


Name ▲	Created	Experiment	Owner	View Analyses	Delete
CABLEr5923_Ha1	Fri May 17 2019 16:22	Harvard Forest flux tower	Gab Abramowitz	View	Delete
CABLEr5923_Hyy	Fri May 17 2019 16:25	Hyytiala flux tower	Gab Abramowitz	View	Delete
CABLEr5923_Tum	Fri May 17 2019 16:20	Tumbarumba flux tower	Gab Abramowitz	View	Delete

Participating in an experiment



Modelevaluation.org for model development: CABLE benchmarking example



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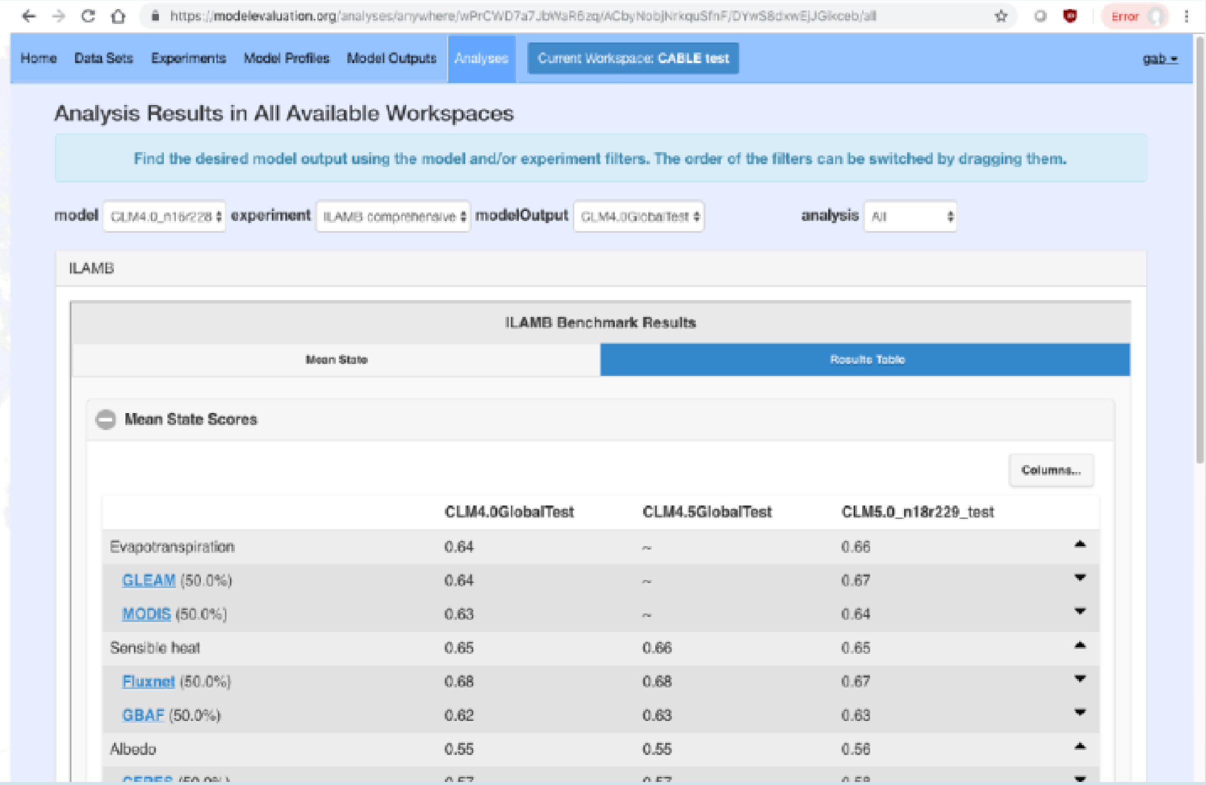
Modelevaluation.org existing experiment types

- Single site analyses (as per original PALS)
- Multiple site PLUMBER-style analyses
- Multi-configuration CABLE benchmarking PLUMBER-style analyses
- Simple global RMSE/correlation/std. dev./mean single variable global or regional plots
- ILAMB suite
- Easy MIP participation in the Model Intercomparison Environment

ILAMB running inside ME.org



ILAMB: The International LAnd Model Benchmarking Project

David Lawrence et al.

- A model-data intercomparison and integration project designed to improve the performance of land models and, in parallel, improve the design of new measurement campaigns to reduce uncertainties associated with key land surface processes.
- Goals:
  - develop internationally accepted benchmarks for land model performance,
  - promote the use of these benchmarks by the international community for model intercomparison,
  - strengthen linkages between experimental, remote sensing, and climate modeling communities in the design of new model tests and new measurement programs, and
  - support the design and development of a new, open source, benchmarking software system for use by the international community.

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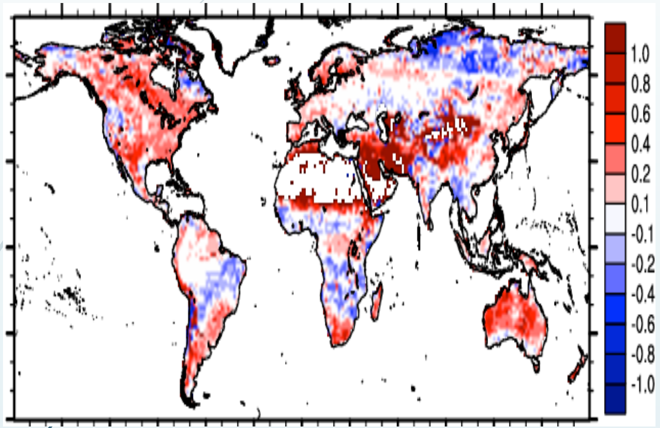
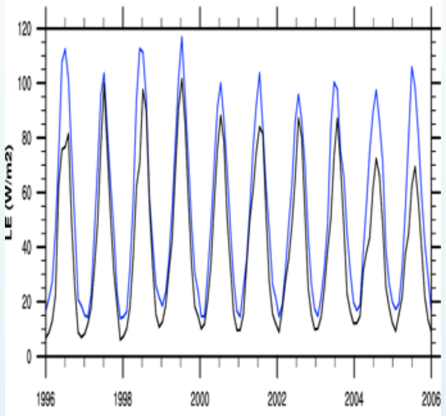
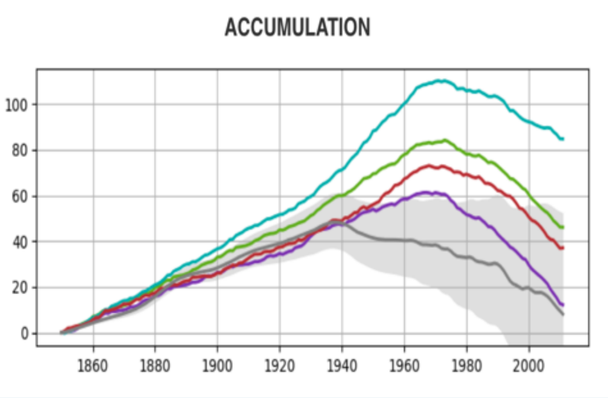
Examples of ILAMB metrics / plots

Global bias, relative bias, RMSE

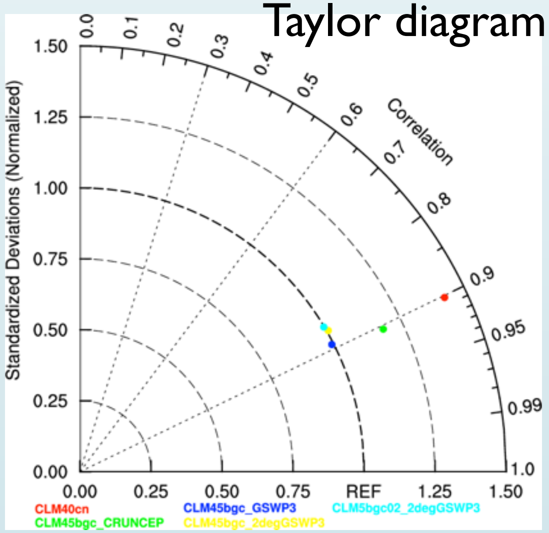


Tower Site

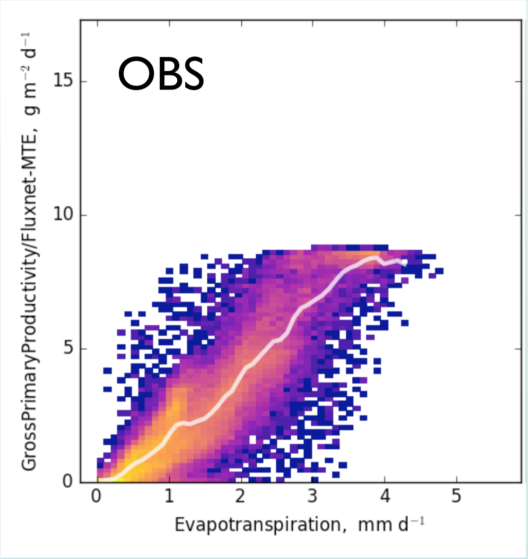


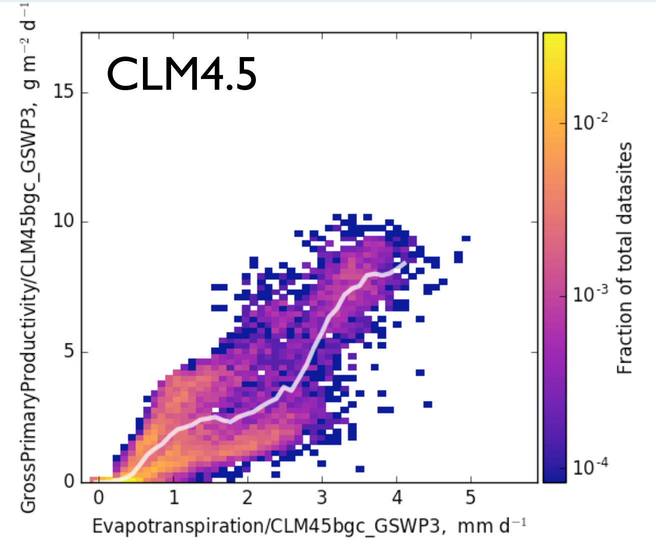


Taylor diagram



2-d histograms



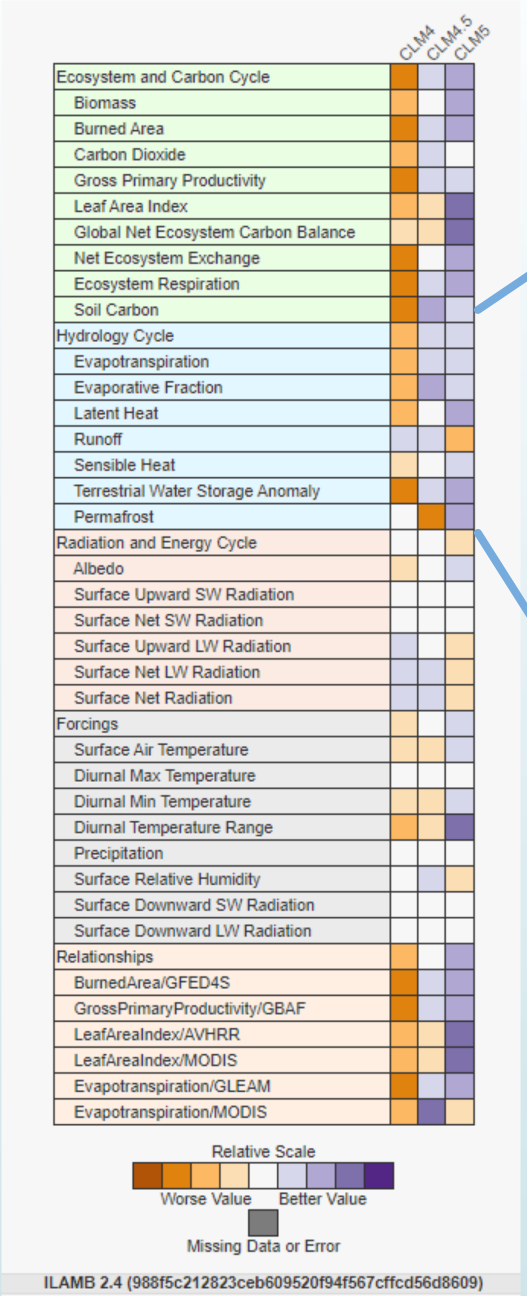


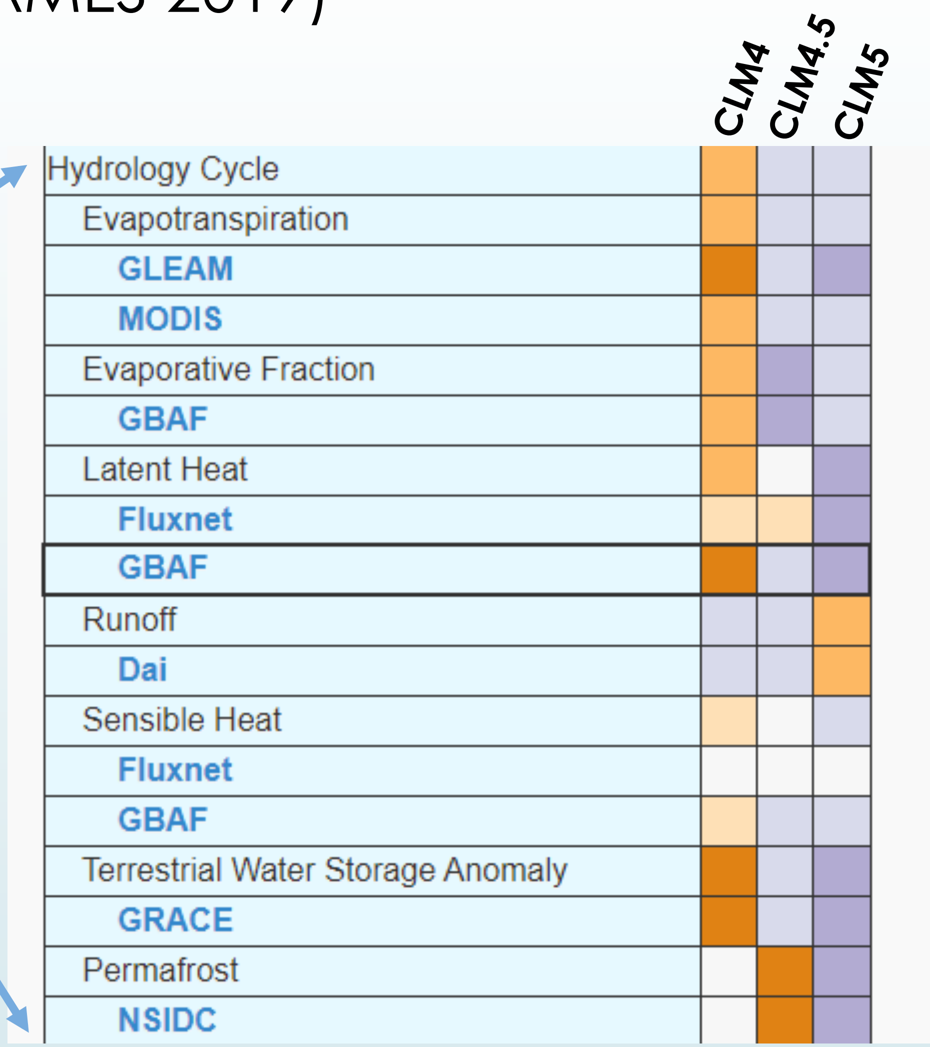
Example: CLM5 paper (Lawrence et al., JAMES 2019)

ILAMB Benchmarking

Overall Score

Globe





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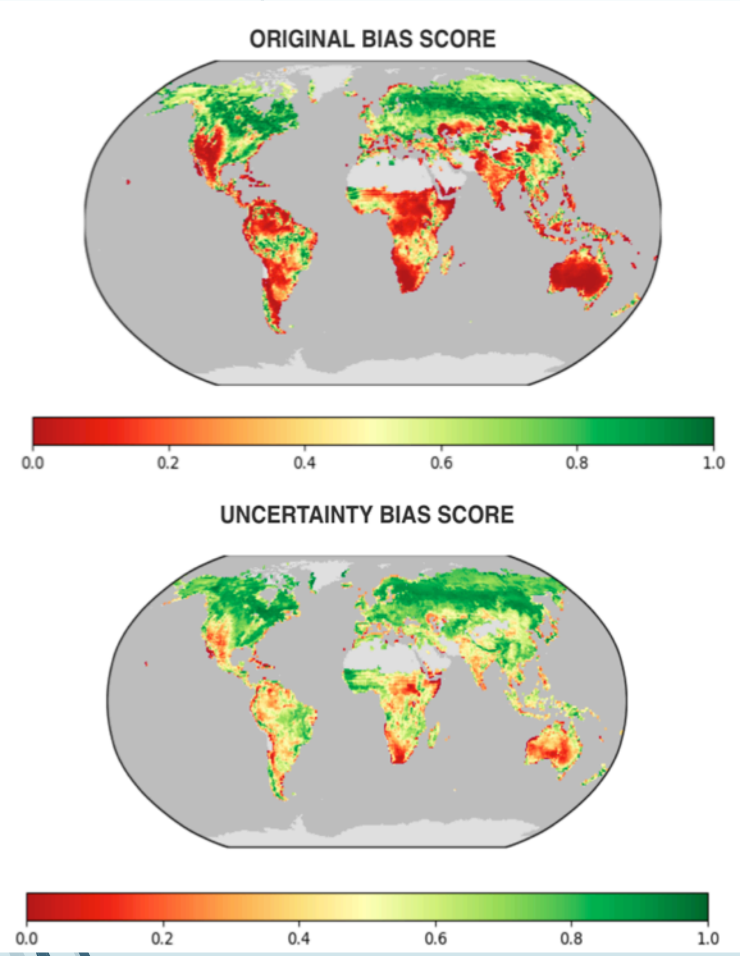
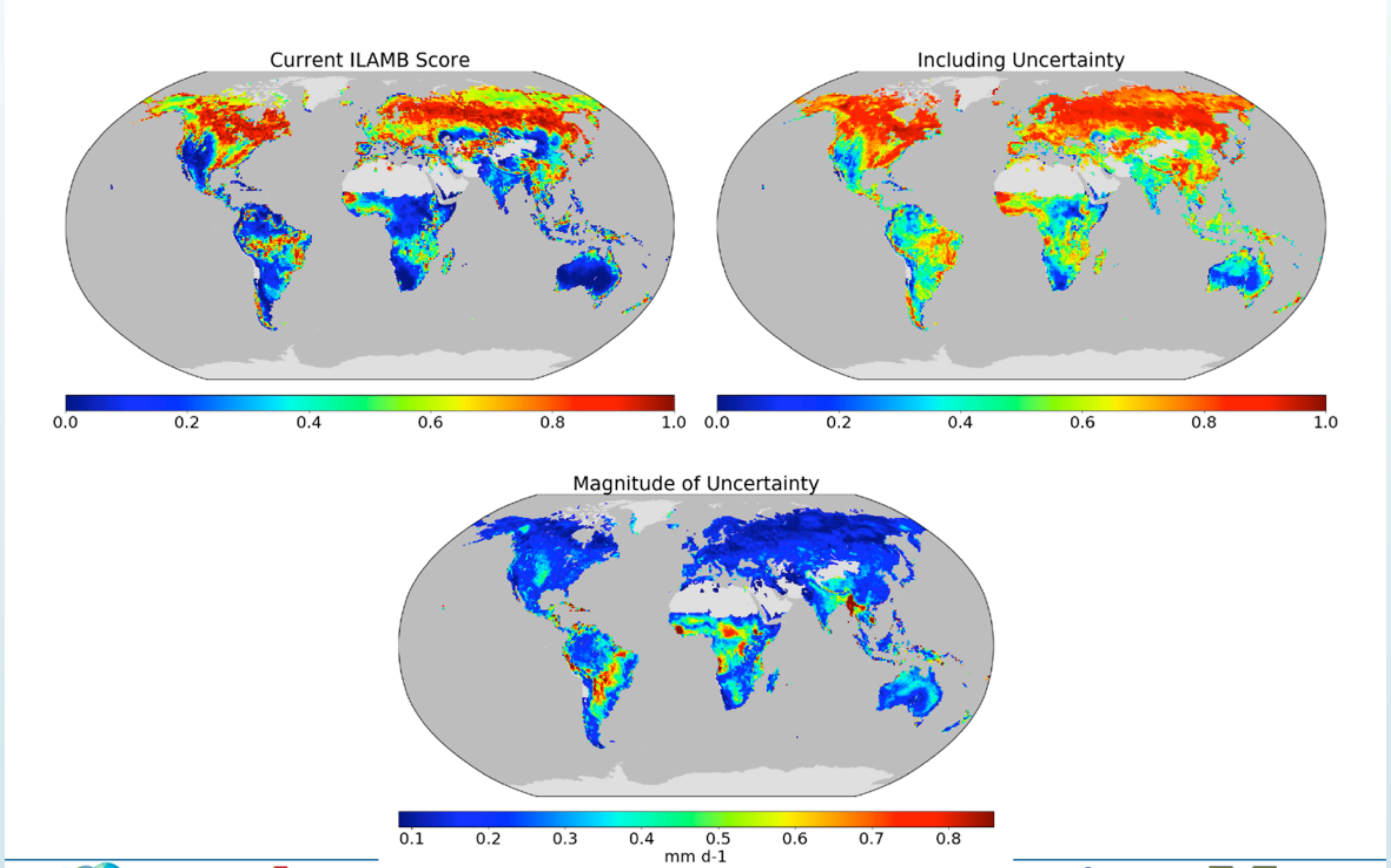
Accounting for uncertainty
Example: Using multiple datasets (GLEAM, MODIS) as measure of uncertainty for ET

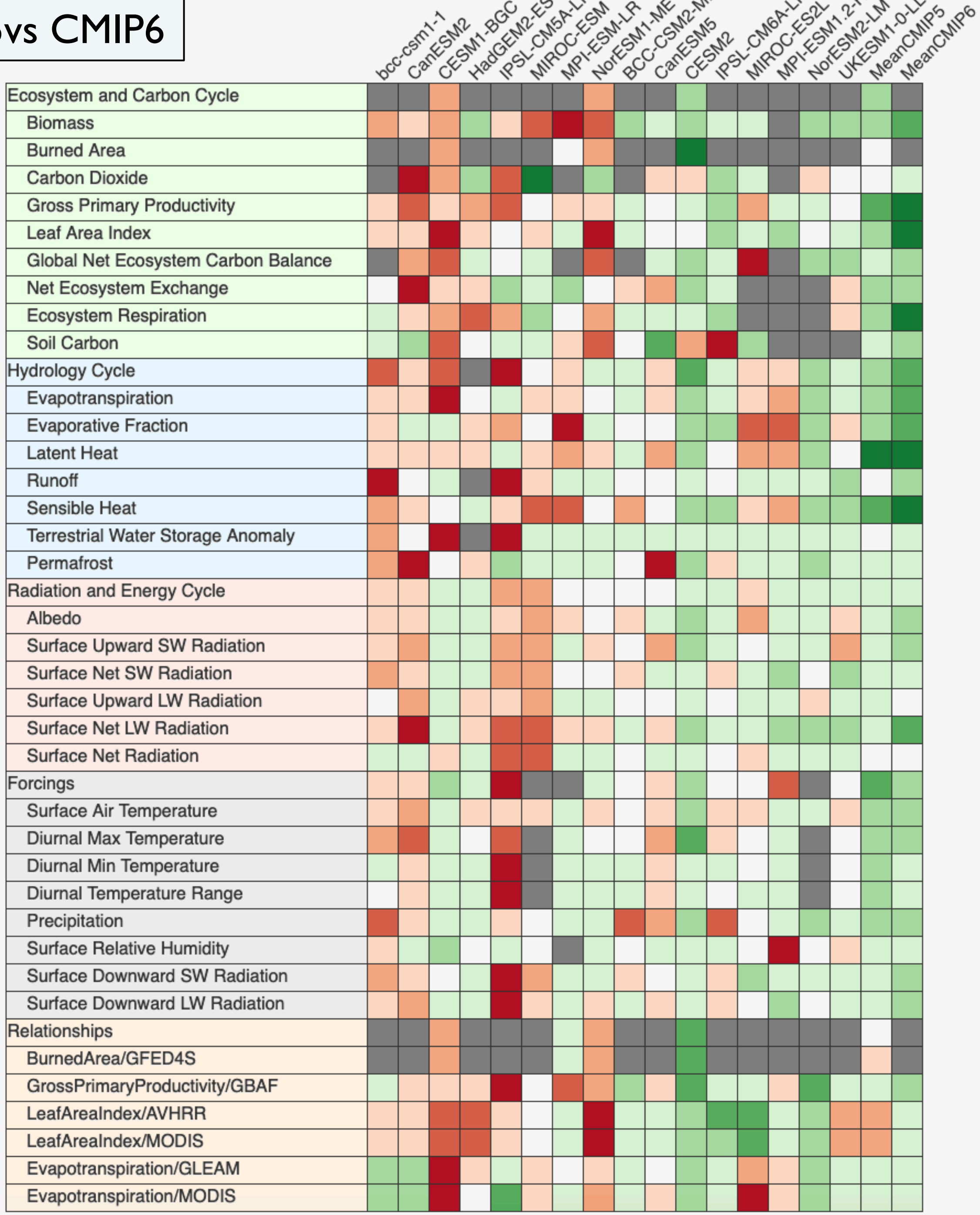




ILAMB: Next steps

- CMIP6 versus CMIP5 analysis
- Future development of ILAMB to enhance utility in model development
  - Incorporate and release uncertainty option and assess impact
  - Add new datasets (DOLCE, LORA, WECANN)
  - Update existing datasets and enhance provenance tracking
  - Diurnal cycle metrics (prototype has been developed)
  - Add metrics from literature (soil carbon turnover time, seasonal albedo transition, snow insulation)
  - Land-atmosphere coupling metrics (CPT)
  - Experimental manipulations (N-addition, rainfall exclusion, etc)
  - Land use change metrics

CMIP5vs CMIP6



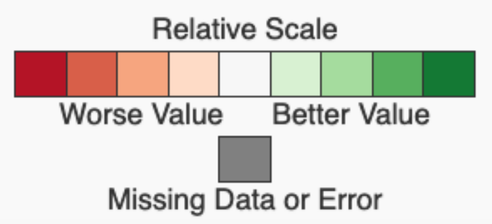
Preliminary Results

Analysis of strengths and weaknesses of CMIP6 models

ILAMB – CMIP6

Improvement since CMIP5?

ILAMB – CMIP5 vs CMIP6



RUBISCO

GLASS Global Land - Atmosphere System Studies

Advancing our understanding of the impacts of historic and projected land use in the Earth System

LUMIP
Land Use Change

The Land Use Model Intercomparison Project (LUMIP)

Chairs: David Lawrence (NCAR) and George Hurtt (University of Maryland)

SSG: Almut Arneth, Victor Brovkin, Kate Calvin, Andrew Jones, Chris Jones, **Peter Lawrence**, Julia Pongratz, Sonia Seneviratne, Elena Shevliakova

with input from many from Earth System Modeling, Integrated Assessment Modeling, and historical land use communities

https://cmip.ucar.edu/lumip

LUMIP Goals

What are the effects of land use and land-use change on climate and biogeochemical cycling (past-future)?

What are the impacts of land management on surface fluxes of carbon, water, and energy and are there regional land-management strategies with promise to help mitigate against climate change?

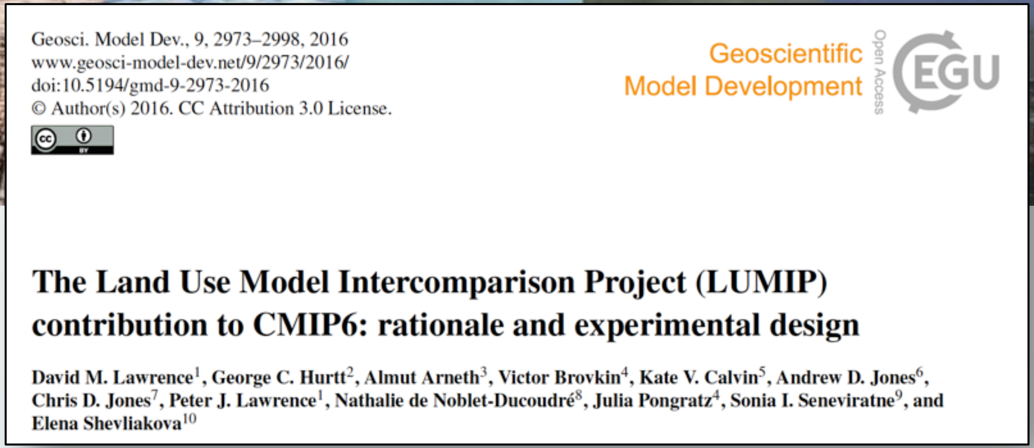
- Fossil fuel vs. land use change
- Biogeochemical vs. biogeophysical impact of land use
- Impacts from land-cover change vs land management
- Modulation of land use impact on climate by land-atmosphere coupling strength (LS3MIP)
- Modulation of global CO_2 fertilization by LULCC
- Direct vs indirect carbon consequences of LULCC
- *Total radiative forcing from LULCC*
- *Scale issues*
- *Fragmentation of forests*

CMIP6 Questions: How does Earth System respond to forcing?

WCRP Grand Challenge: Biospheric forcings and feedbacks, Water Availability, Climate Extremes

The LUMIP Experimental Design

Clarifications/corrections at https://cmip.ucar.edu/lumip


Geosci. Model Dev., 9, 2973–2998, 2016
www.geosci-model-dev.net/9/2973/2016/
doi:10.5194/gmd-9-2973-2016
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Geoscientific Model Development
Open Access
EGU

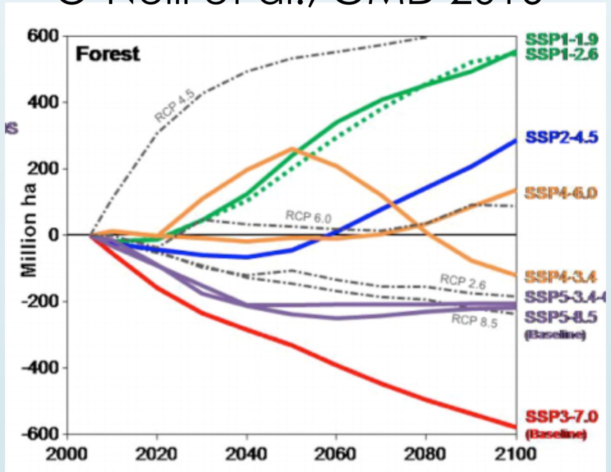
The Land Use Model Intercomparison Project (LUMIP) contribution to CMIP6: rationale and experimental design

David M. Lawrence[1], George C. Hurtt[2], Almut Arneth[3], Victor Brovkin[4], Kate V. Calvin[5], Andrew D. Jones[6], Chris D. Jones[7], Peter J. Lawrence[1], Nathalie de Noblet-Ducoudré[8], Julia Pongratz[4], Sonia I. Seneviratne[9], and Elena Shevliakova[10]

Tier 1

- Idealized deforestation (10 million km2 removal of forest over 50 years)
- Historical no land use change (coupled and land-only)
- Alternative land use scenarios for projection periods (concentration and emissions-driven) – e.g., use SSP1-2.6 land use in SSP3-7 simulation

O'Neill et al., GMD 2016



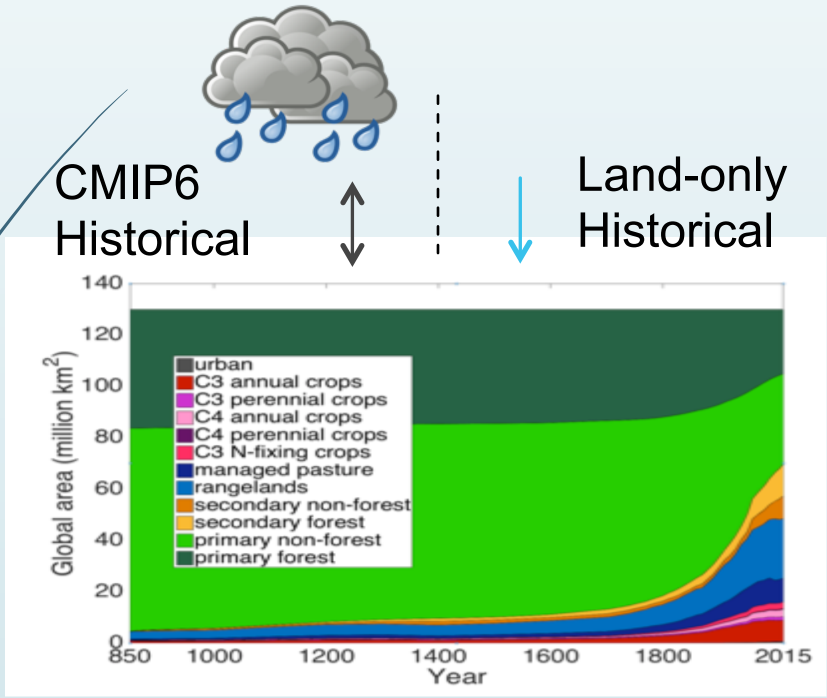
Tier 2

- Additional ensemble members (historical, idealized deforest, SSPs)
- Land management factorial (land-only)

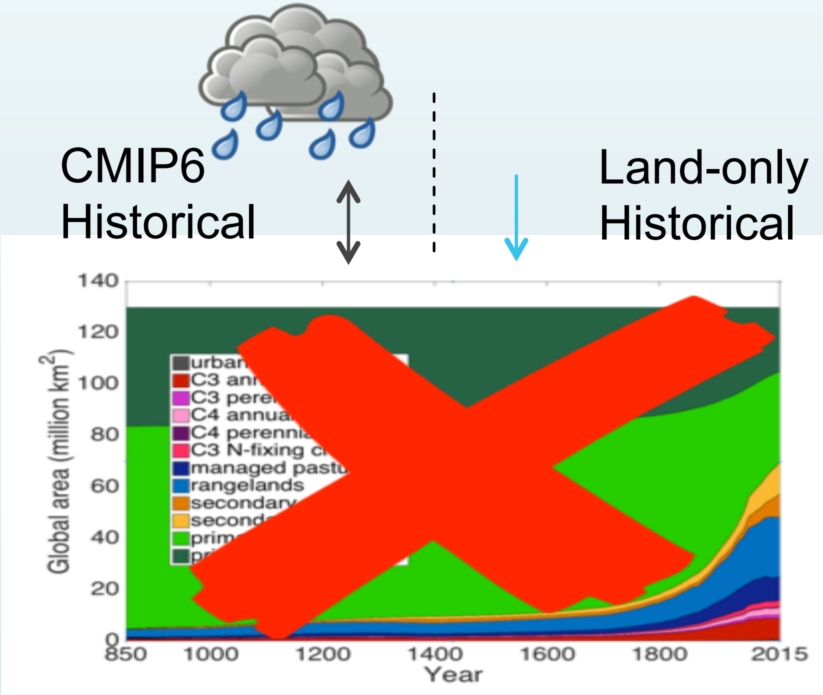
No LULCC experiments: Historic period 1850-2014
Coupled and land-only

For first time, can evaluate land use change impacts on fluxes and climate in BOTH coupled and land-only models (same land model versions and resolutions in both sets of experiments)

All Forcings



No Land-Use Change



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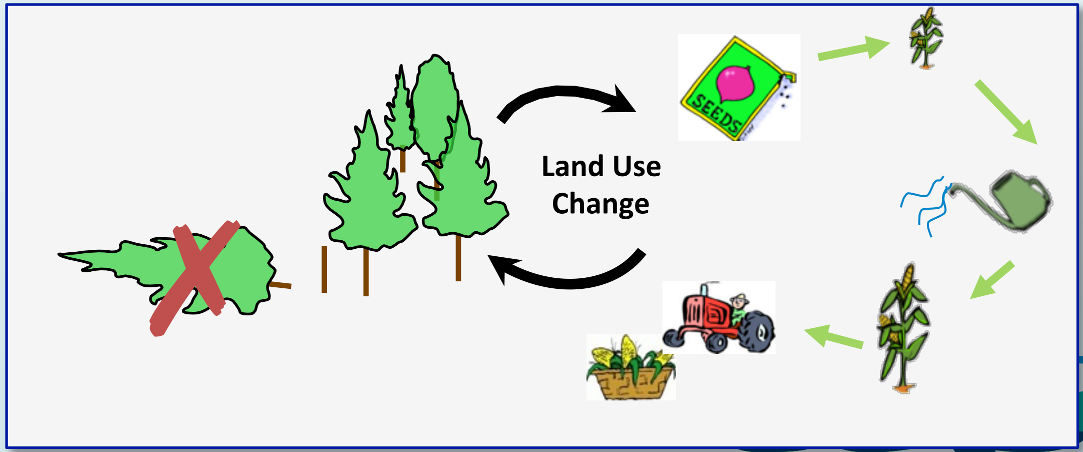
Land-only land management experiments

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

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



Lawrence et al., 2016

Global Land - Atmosphere System Studies

LUMIP Simulations available on ESGF
(as of Friday, December 6)

https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/LUMIP/index.html

model	# of experiments	deforest-globe	esm-ssp585-ssp126Lu	hist-noLu	land-cCO2	land-cClim	land-crop-noFert	land-hist	land-hist-altStartYear	land-noFire	land-noLu	ssp126-ssp370Lu	ssp370-ssp126Lu
# of models	54	5	4	6	3	2	1	7	3	1	6	8	8
BCC-CSM2-MR	7	155	156	156				41			41	150	154
CESM2	11	1230	180	1301	172	172	172		24	172	161	1301	1307
CMCC-ESM2-SR5	2							139			139		
CNRM-CM6-1	1							153					
CNRM-ESM2-1	9	334		334	151	151		229	152		151	333	332
CanESM5	4	342	342									343	343
GFDL-ESM4	7		61	80				29	31		31	65	64
GISS-E2-1-G	1							795					
IPSL-CM6A-LR	7	1366		1884	163			208			208	458	458
MIROC-ES2L	2											255	255
UKESM1-0-LL	3			716								178	178

LUMIP workshop – Aspen Global Change Institute

Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes and Inter-Sectoral Dynamics, September 16-20, 2019

Sessions on:

- State of knowledge of historic LULCC, impacts on climate and biogeochemical cycles
- Progress reports and planning on LUMIP analyses
- Connections with multi-sector dynamics and societal impacts including implications of land use/ land management on water and food security

LUMIP Analysis Plans

Access from LUMIP webpage (cmip.ucar.edu/lumip)

LUMIP simulations will be available to anyone who registers for access to CMIP6 data. Below is a list of planned analysis projects. Please add your proposed analysis following the format provided. We recommend that you try to work with other research groups with similar analysis interests to develop projects that are complementary and that minimize overlap. The LUMIP leads are happy to help organize.

Resources

Full list of CMIP6 experiments:

http://rawgit.com/WCRP-CMIP/CMIP6_CVs/master/src/CMIP6_experiment_id.html
(search for LUMIP to get list of specific LUMIP experiments)

LUMIP experimental description paper:

http://www.geosci-model-dev.net/9/2973/2016/

Project Title: Climate response to idealized deforestation

Project participants: Victor Brovkin (victor.brovkin@mpimet.mpg.de), David Lawrence, et al.

LUMIP / CMIP6 simulations used: deforest-globe, piControl

Brief Project Description: Assess global and regional temperature and precipitation response across models to idealized deforestation. Data from piControl will be used to establish internal variability.

25+ analysis plans (papers) have been registered

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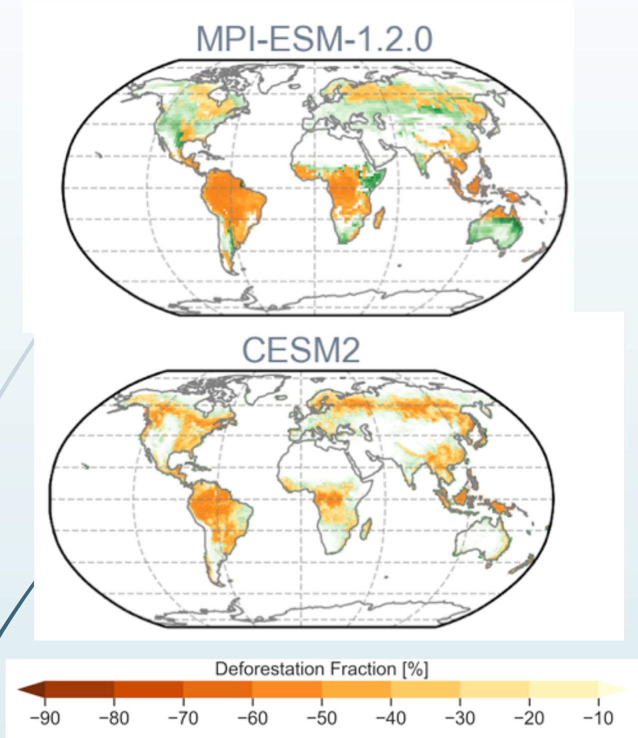
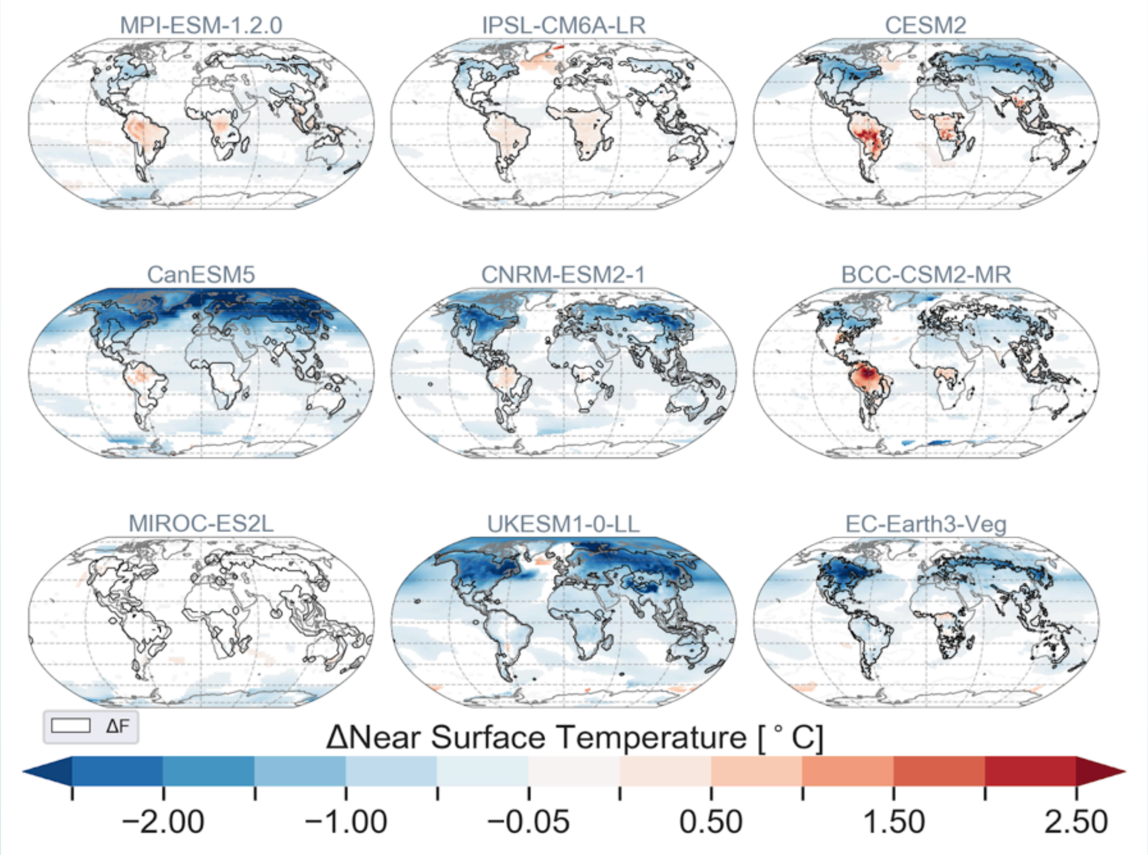
Climate response to Idealized Deforestation (deforest-globe)
Preliminary results



Reasonably similar deforestation patterns across models



- Broad agreement of cooling across boreal forests
- Most (but not all) models show warming in the Tropics

Boysen et al., in prep

Do IAMs and ESMs agree on carbon consequences of alternative future LULCC trajectories?

C Impact of SSP1-2.6Lu vs SSP3-7Lu

<u>IAM projections of accumulated land C</u>

IMAGE SSP1-2.6 : +27 Pg C

AIM SSP3-7: -98 Pg C

+125 Pg C

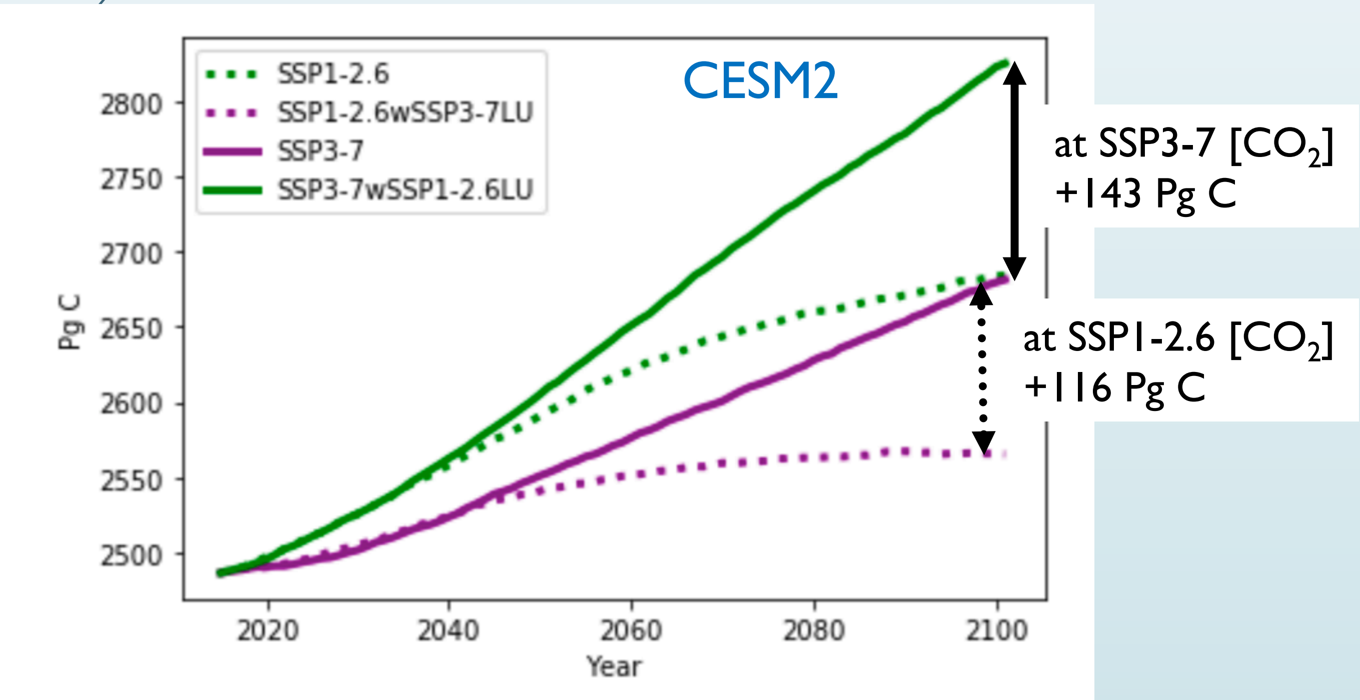
<u>Impact of SSP1-2.6Lu vs SSP3-7Lu</u>

IAMs +125 Pg C

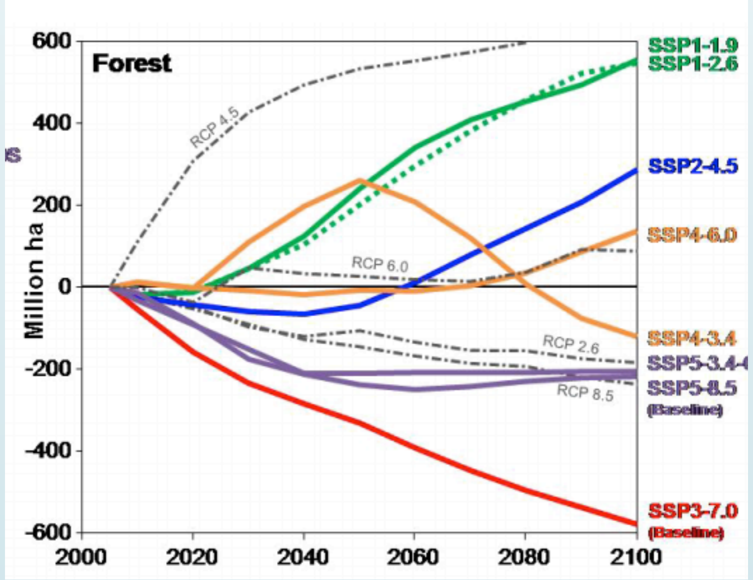
CESM2 +143 Pg C at SSP3-7 [CO_2]

+116 Pg C at SSP1-2.6 [CO_2]

Good news: Model is broadly consistent with IAM expectations, other models?



O'Neill et al., GMD 2016



Lawrence et al., in prep

GSWP3 and LS3MIP

Hyungjun Kim et al.

Updates, Status and Pilot Analyses for:

Global Soil Wetness Project phase 3 (GSWP3)

Land Surface, Snow, and Soil Moisture MIP (LS3MIP; CMIP6)

GSWP3: **Produce century-long** comprehensive and extensive set of quantities for hydro-energy-eco systems in order to investigate the long-term changes of the components of the energy-water-carbon cycles and their interactions, with appropriate model verifications in ensemble land simulations.

http://hydro.iis.u-tokyo.ac.jp/GSWP3/

LS3MIP: **One of the 23 CMIP6-Endorsed MIPs.** Assess performance of current land surface models in Earth System Models (ESMs) and quantify land surface feedbacks in a changing climate. Goal: provide comprehensive assessment of land surface-, snow-, and soil moisture-climate feedbacks, and diagnose systematic biases in the land schemes in current ESMs using coupled, and constrained land-only experiments.

http://www.gewex.org/ls3mip-land-surface-snow-and-soil-moisture/
http://www.climate-cryosphere.org/activities/targeted/ls3mip

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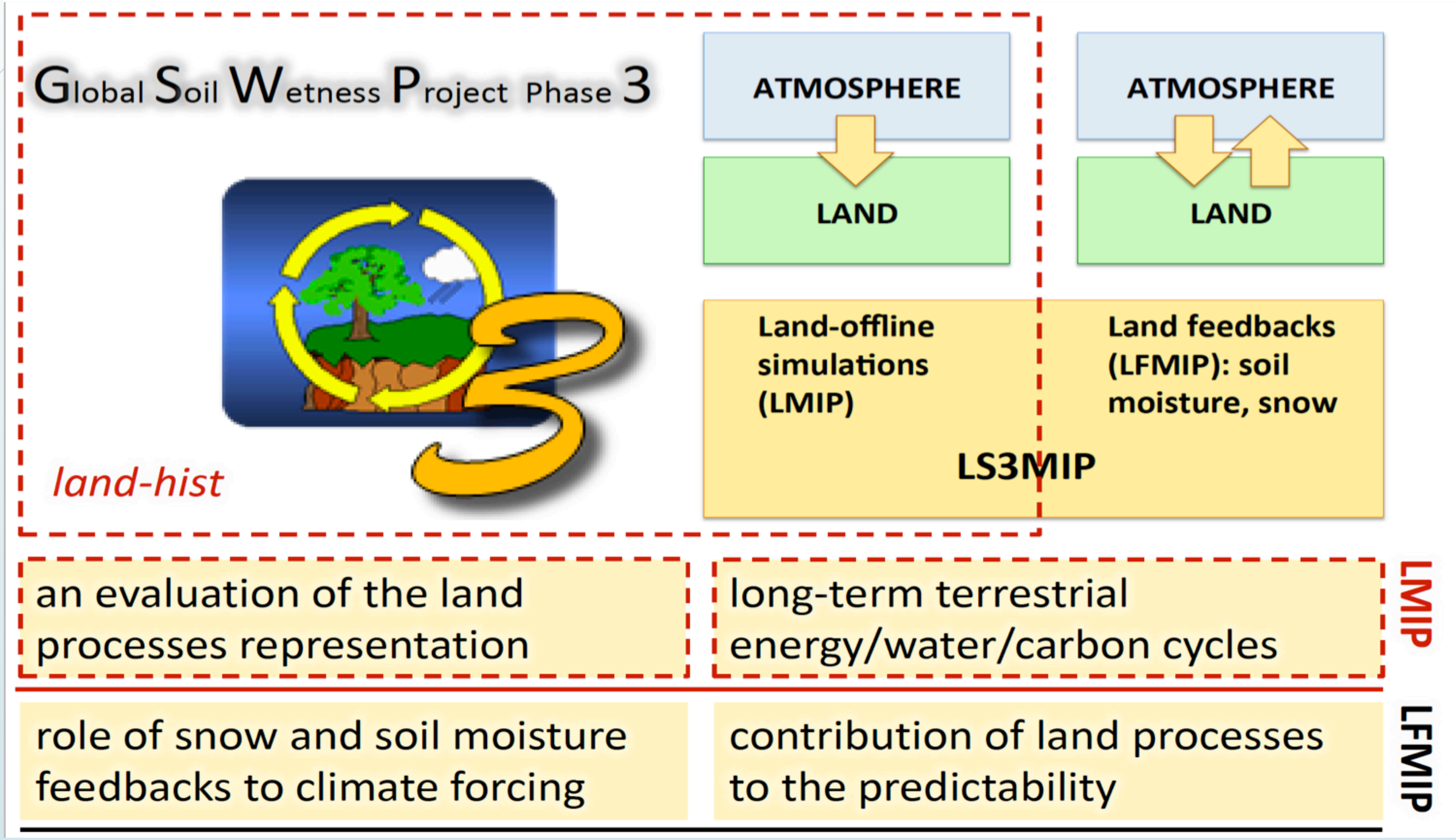
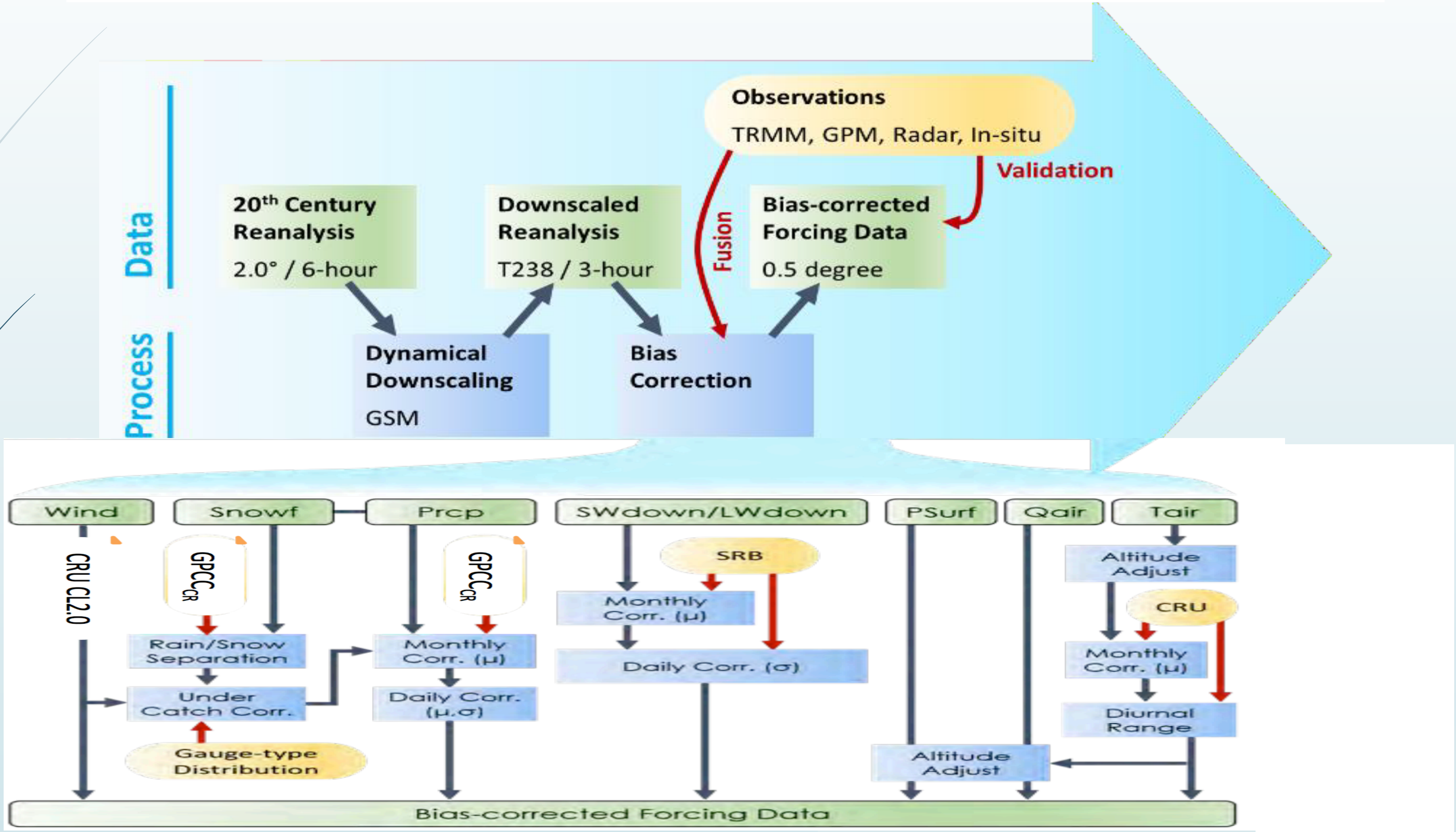
GSWP3 and LS3MIP Experimental Design



Development of GWSP3 Forcing Data



GSWP3 ("land-hist") Experiments of LS3MIP

Institute(s)	Analysis/Topic	Key variables
Sonia & colleagues (ETH)	Soil moisture effects on climate extremes	TBD
Sonia & colleagues (ETH)	Soil moisture effects on land carbon exchanges	TBD
Frederique Chéruy (IPSL)	LFMIP-Pobs	TBD
Hyungjun & colleagues (UTokyo)	Long-term EWC balance / changes (land-hist & land-future)	TBD
Hyungjun & colleagues (UTokyo)	Land model benchmarking (Land-hist)	TBD
Andrea Alessandri, Franco Catalano & colleagues (ENEA/KNMI)	Albedo effects, dynamic vegetation	TBD
G. Krinner (CNRS), C. Derksen (ECCC)	Snow in Land-Hist and Land-Future	snc, snd, snw

~Spring 2019

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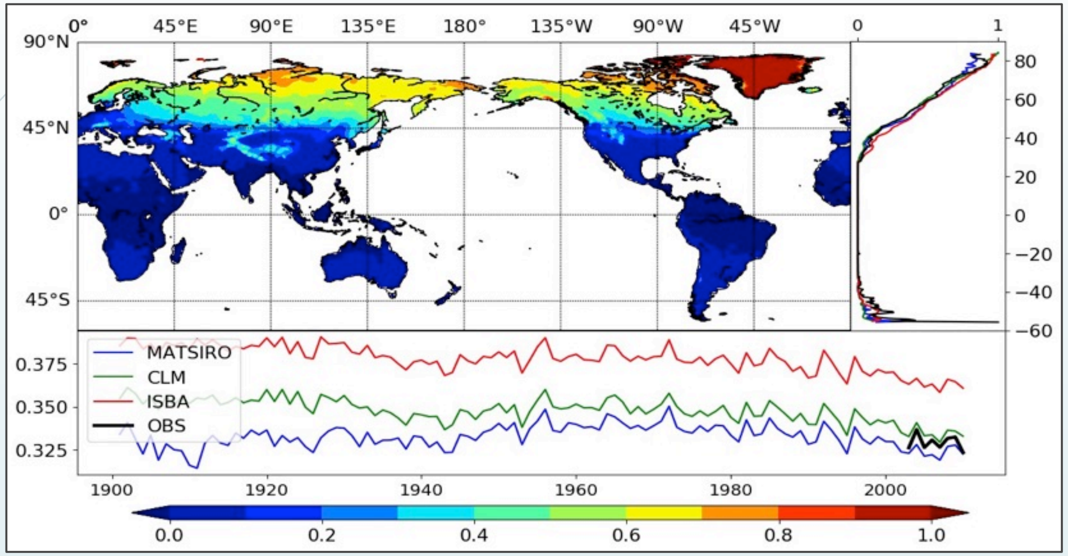
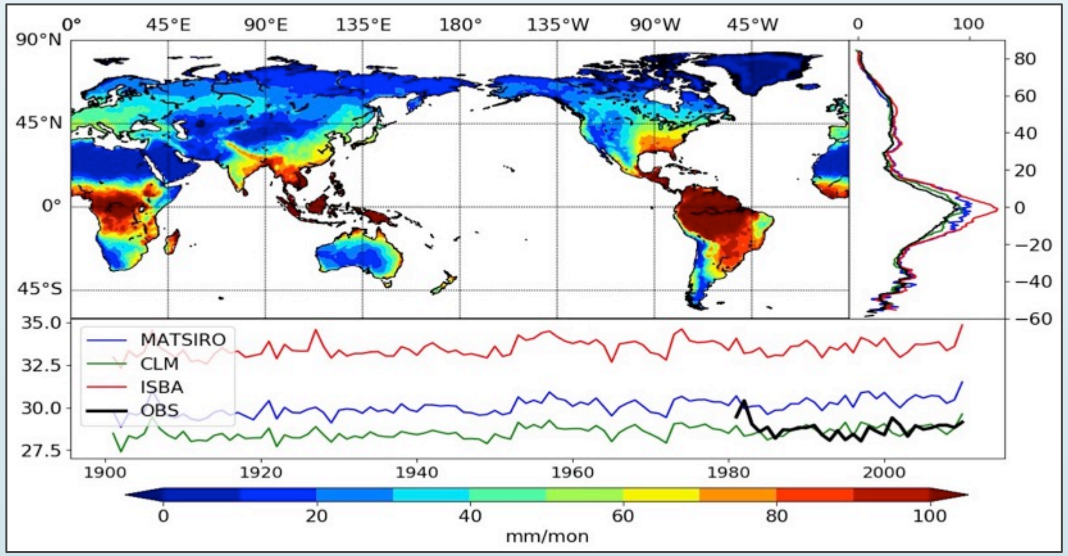
Pilot Analysis for *Land-Hist*: Evaluation of Land Processes



Snow Cover
MODIS (2003-2010)

All models well-capture the decreasing trend of snow cover extent which has been under-estimated in coupled simulations. (e.g., CMIP5)



ET
GLEAM (1980-2010)

Model spread is greater in tropics, probably because of sensitivity to dry bias in forcing data.

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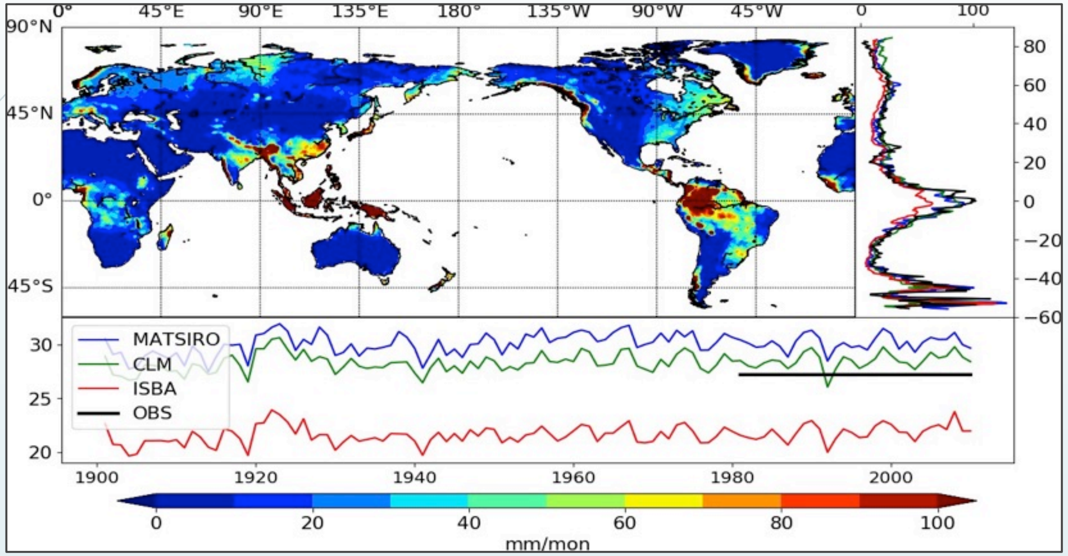
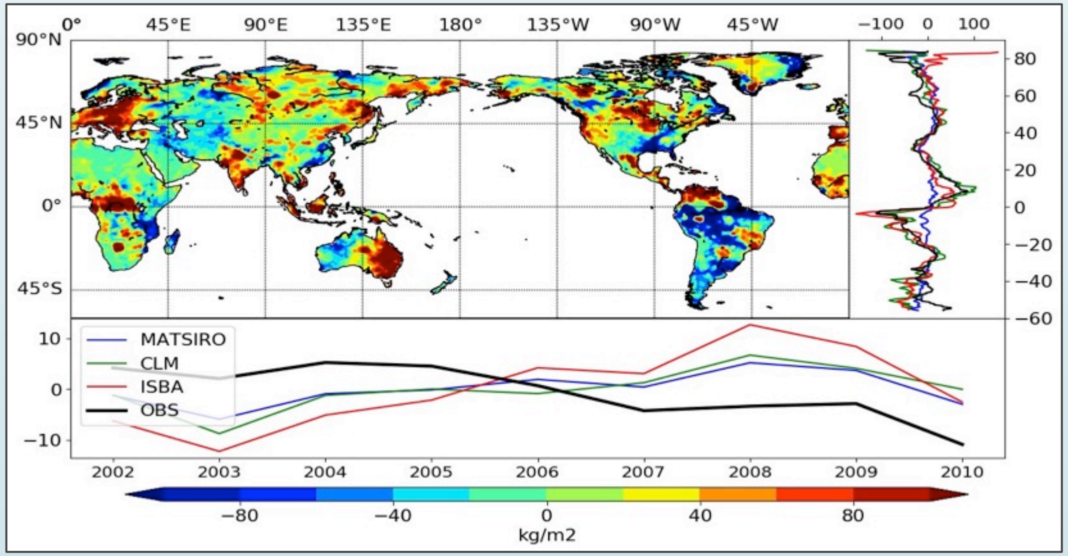
Pilot Analysis for *Land-Hist*: Evaluation of Land Processes



Runoff
GRDC (1980-2010)

Large inter-model disagreement for long-term mean than temporal variability



TWSA
GRACE (2002-2010)

Opposite trends between GRACE TWSA and models.
→ Human impact?

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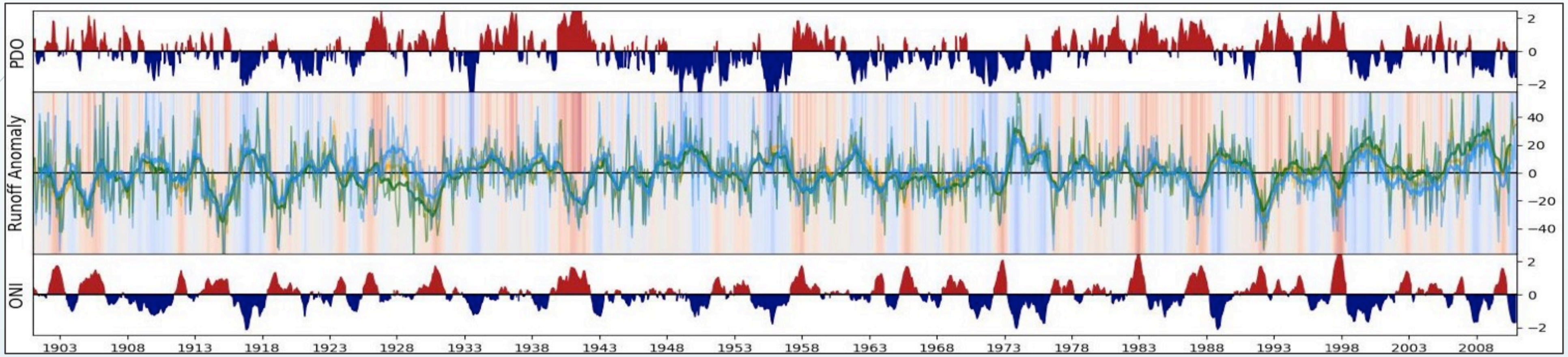
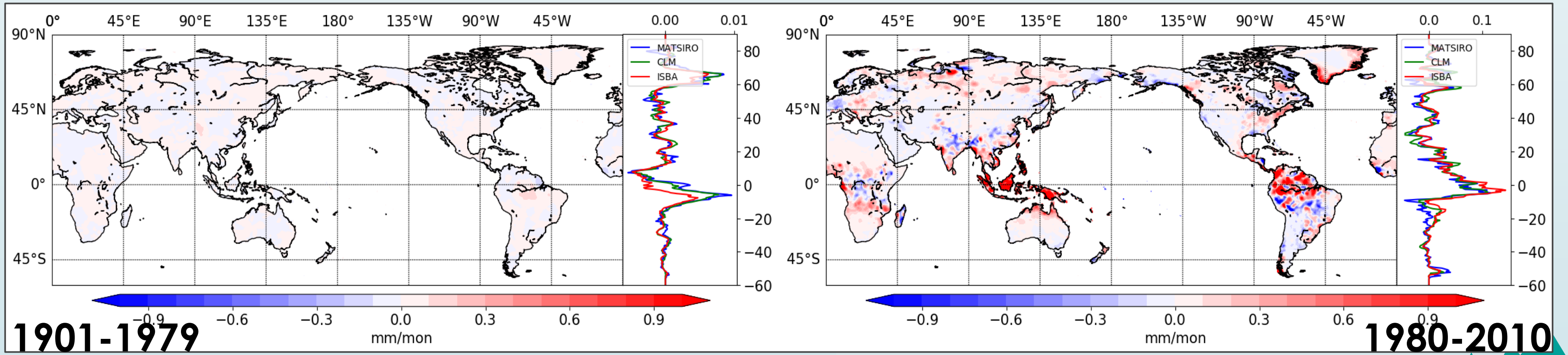
Pilot Analysis for *Land-Hist*: Long-term Variability & Trend



Interannual variability of global runoff is significantly modulated by Pacific SST variability. (combining ONI and PDO reproduces ~50% of total variability)



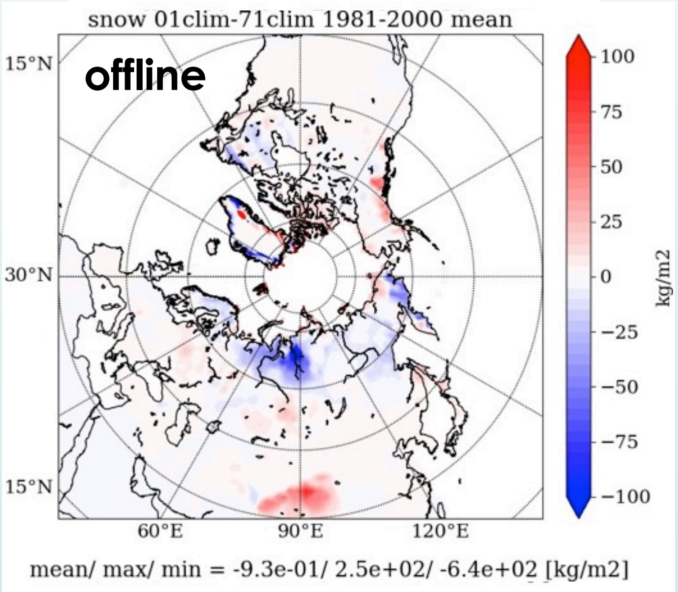
Recent 30-year trend show stronger regional variability

"High" vs "Low" Snow Runs

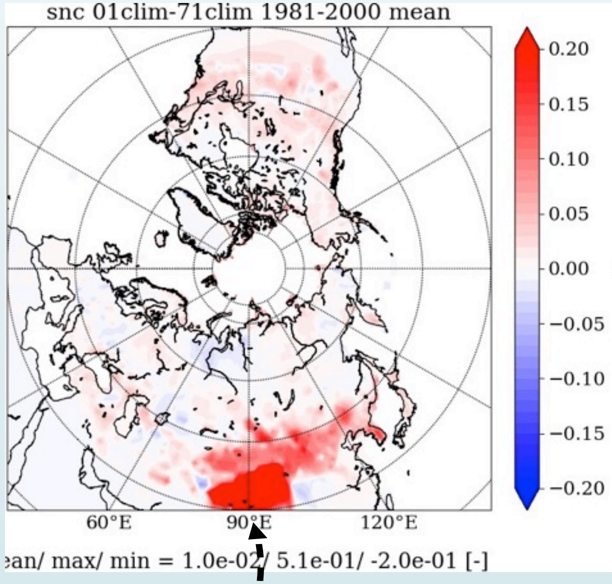
"**High**": nudging climatological snow mass in early 20C (1901-1930).
"**Low**": nudging climatological snow mass in late 20C (1971-2000).

Initial condition: CMIP6 Historical (Jan 1970) / Boundary condition: CMIP6 AMIP
Nudging data: snow mass calculated from land offline exp. w/GSWP3 forcing.

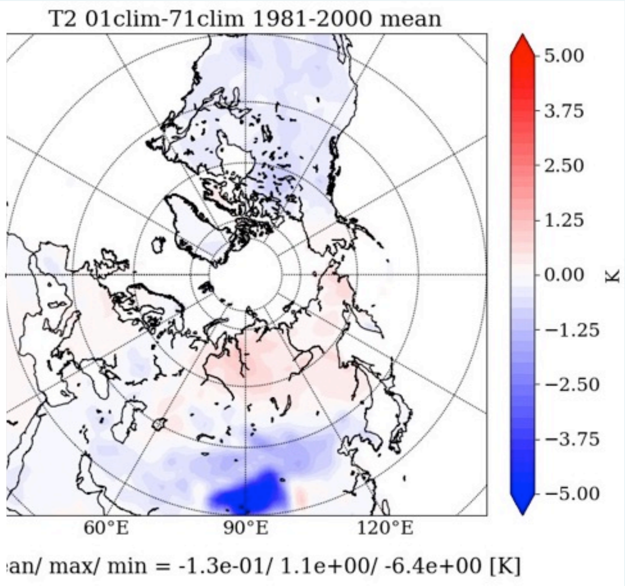
Δ snow cover fraction [-]



Δ snow cover fraction [-]



Δ surface air temperature [K]



Snow cover fractions in early 20th century were greater than that in late 20th century over north hemisphere.

The relationship between snow cover fraction and surface air temperature changing shows negative correlation.

Local Land-Atmosphere Coupling (LoCo)

LoCo Working Group Objective

To understand, 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 (last 1-2 years)

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

Membership:
Joe Santanello (lead)
Alexis Berg
Paul Dirmeyer
Michael Ek
Craig Ferguson
Kirsten Findell
Trent Ford
Pierre Gentine
Tobias Gerkin
Benoit Guillod
Patricia Lawston
Benjamin Lintner
Joshua Roundy
Ahmed Tawfik
Merja Tölle
Chiel van Heerwaarden
Volker Wulfmeyer
Yunyan Zhang
Ian Williams

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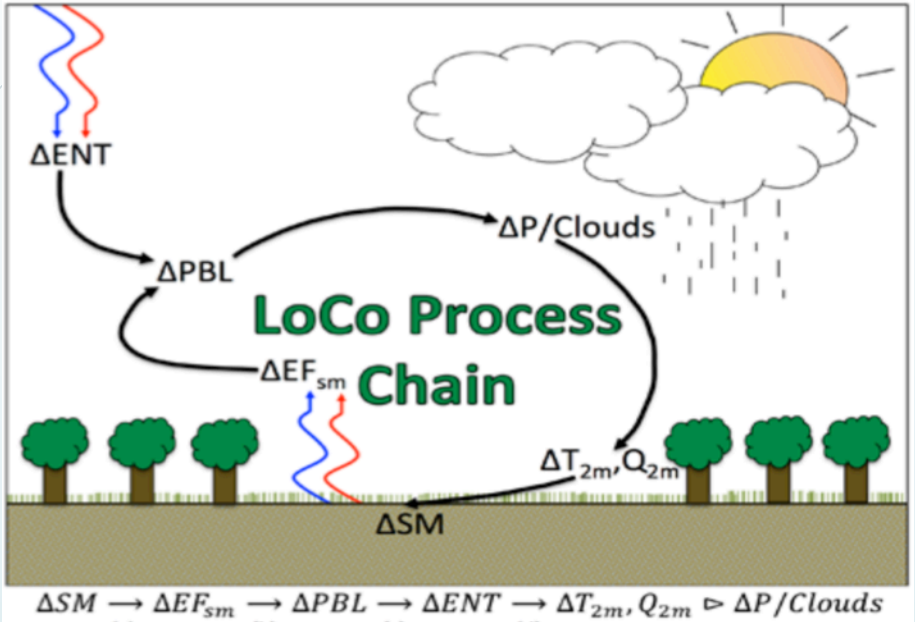
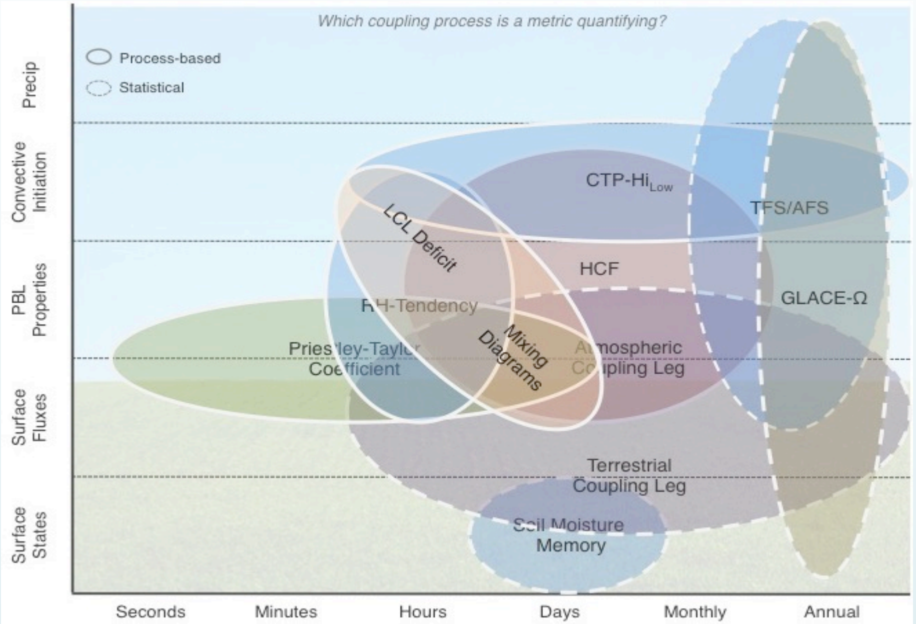
LoCo Metrics



Metric Applications and Timescales



Impact of soil moisture anoma-lies (ΔSM) on cloud development and subsequent precipita-tion (ΔP) depends on sensitivities: (a) surface fluxes (EFsm) to SM; (b) PBL evolution to surface fluxes; (c) entrain-ment fluxes at the PBL-top (ENT) to PBL evolution; and (d) the collective feedback of the atmosphere (through PBL) on ambient weather (2-meter T & q).

http://www.coupling-metrics.com/

LoCo "cheat sheets": http://cola.gmu.edu/dirmeyer/Coupling_metrics.html

http://www.gewex.org/loco/

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LoCo Achievements and Plans

Principal Achievements

- **LoCo overview article** in BAMS (July 2018).
- **PBL observations were cited as a most important measurement in the 2018 NAS Decadal Survey.** The LoCo WG submitted white papers to the DS and galvanized the community as to the importance of PBL measurements, which will result in increased funding opportunities for PBL instrument development and NWP & Climate modeling over the next decade.
- **Outreach and collaborations** to address the goal of entraining the NWP operational centers into the LoCo paradigm and to promote LoCo metrics for integrative analysis. U.S. Climate Modeling Summit (April 2018) led to the NOAA Climate Process Team solicitation, and selection of the land-PBL heterogeneity focused proposal (PI: Chaney, Duke Univ.), as well as the NASA Energy & Water Cycle Study (NEWS) and SMAP proposals (PI: Dirmeyer).

Near-term Plans

- **Continue to coordinate LoCo-based analysis activities** from recent and planned campaigns such as LAFE, GRAINEX, and LIAISE.
- **Engage operational centers via CPT**, as well as NGGPS/DTC Testbed collaborations.
- **Influence PBL mission development** via FY20 NASA PBL Study Team
- **Explore coordinated expansion of LoCo scope** via collaborative proposals, experiments

Projects and Activities: Leveraging LoCo

LIASE (starting summer 2020) (Aaron Boone, Martin Best and many others). Summer 2020 Iberian Peninsula campaign focused on L-A interactions, including surface & PBL observations, aircraft, ground measurements. Contains an anthropocene (irrigation) component. LoCo experiments/coordination. https://www.hymex.org/?page=liaise. ***Pan-GEWEX involvement.***

GRAINEX (2018) *(Tricia Lawston, Joe Santanello, Paul Dirmeyer, Craig Ferguson) field campaign held in Summer 2018 over Nebraska, focused on impact of irrigation on L-A interactions, involving in situ and remotely-sensed surface and PBL measurements. https://data.eol.ucar.edu/master_list/?project=GRAINEX.*

Ruisdael Observatory *- Wageningen (Chiel van Heerwaarden) - 100m resolution network over Netherlands to improve L-A understanding and weather prediction.*

Organization of Tropical East Pacific Convection *(OTREC) field campaign (Ben Lintner): Understand how the Central American landmass modifies tropical waves and associated convection propagating from the Caribbean to the eastern Pacific. Aug-Sept 2019.*

Projects and Activities: Leveraging LoCo (2)

Land-Atmosphere Feedback Observatory *(LAFO; Volker Wulfmeyer) Observatory - April 2019: https://lafo.uni-hohenheim.de/en/1670. See GLAFO slides*

New York State Mesonet (Craig Ferguson): Use of flux tower and profilers for PLUMBER2 initiative; future DICE, LoCo efforts?

DOE ARM observations (Yunyan Zhang): Extend into LES (**LASSO, CASS**) with interactive land surface. **LASSO:** LES ARM Symbiotic Simulation and Observation. **CASS**: A NEW COMPOSITE MODELING CASE FOR CONTINENTAL ACTIVE SURFACE-FORCED SHALLOW CUMULUS.

CWEX: USGCRP, a.k.a. "U.S. GEWEX:" program, includes managers from NASA, NOAA, DOE, NSF, EPA, and others (13 total US.. agencies). Briefings on LoCo, PLUMBER, GLASS, etc to the CWEX group from Joe Santanello, Paul Dirmeyer, Mike Bosilovich, Mike Ek, and others. Better coordination of LoCo, GLASS, GEWEX activities across the U.S. agencies, and in connection with other international programs and institutes.

NOAA MAPP's Model Diagnostics Task Force (Alexis Berg) included a LoCo-type metric (simple SM-ET coupling) in their Diagnostic package. This package is supposed to be used later on by operational modeling centers.

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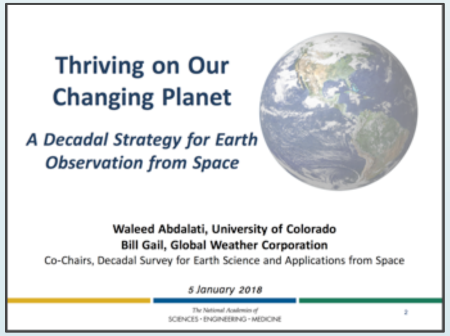
Proposals: Leveraging LoCo

NSF AccelNet program (Craig Ferguson), 3-year $750,000 proposal (2019-2022) titled "Improving Weather and Climate Research by Linking Convection-Permitting Modeling Groups and Regional Observational Networks Worldwide". Expand the CPM community internationally through knowledge and computational resource sharing, capacity building, and greater interdisciplinary involvement from instrumentalists, GEWEX RHPs and Crosscuts, and data scientists. Other Co-PIs include: Peter van Oevelen, Roy Rasmussen, Hugo Berbery, and others.

NOAA-DOE Climate Process Team proposal: See "CLASP" (next slide).

NASA "PBL from Space" mission (2017 NAS Decadal Survey): high priority, incubator measurement program --cuts across nearly all panels (Weather, Climate, Hydrology, Ecosystems, etc). AGU, AMS sessions on PBL from space; AGU townhall including PBL study team; whitepaper on previous workshops with recommendations.
LoCo Relevance: Focus on L-A connections and land-hydrology.


Thriving on Our Changing Planet
A Decadal Strategy for Earth Observation from Space
Waleed Abdalati, University of Colorado
Bill Gail, Global Weather Corporation
Co-Chairs, Decadal Survey for Earth Science and Applications from Space
5 January 2018

Other NOAA, NASA proposal calls: e.g. NOAA Climate Observations and Modeling (COM) Program, NASA 2019 ROSES Solicitation--Terrestrial Hydrology Program (PBL Study Team). **Again, LoCo relevance.**

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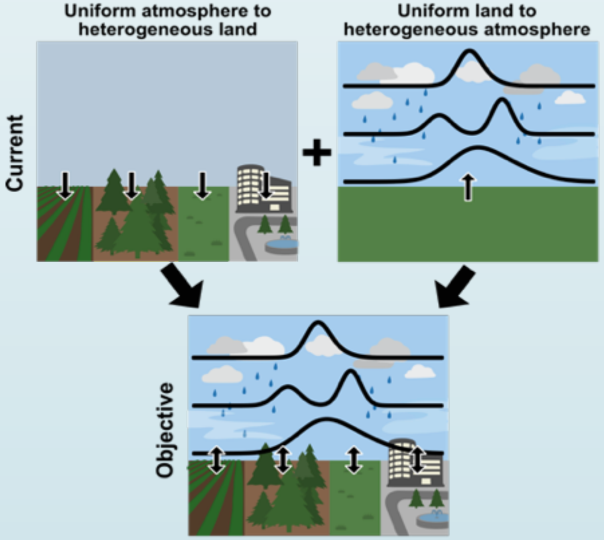
CLASP
Coupling of Land and Atmospheric Subgrid Parameterizations

Parameterizing the effects of sub-grid land heterogeneity on the atmospheric boundary layer and convection (Sep 2019-2022+)

Lead PI/Co-PIs/Co-Is: Nathaniel Chaney (Duke), and others, including GEWEX/GLASS panel members: Kirsten Findell (NOAA/GFDL), Dave Lawrence (NCAR), Joe Santanello (NASA/GSFC), Paul Dirmeyer (GMU), Michael Ek (NCAR).

Motivation: In existing climate models, simulated sub-grid heterogeneous states & fluxes over land are mostly disconnected from sub-grid parameter-izations of the atmosphere. This is a recognized deficiency given the known role of multi-scale land heterogeneity in atmospheric processes including convection, rainfall initiation, & mesoscale circulations.



LoCo called out in the proposal announcement.

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

Project Tasks:

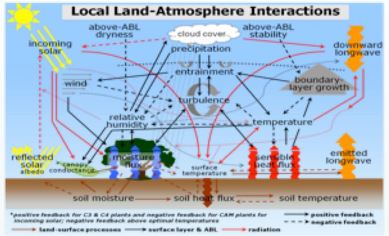
1. Implement a novel interaction scheme between the heterogeneous land and atmosphere in the DOE/E3SM, NOAA/ESM4, NASA/GEOS, and NCAR/CESM2 ESMs.
2. Leverage and enhance coupling metrics to evaluate the modeling of heterogeneous land-atmosphere interactions; include in iLAMB.
3. Evaluate and improve the parameterization using coupled land model/large eddy simulations and observations.
4. Perform simulations to gain understanding of the role of land spatial organization.

LoCo WG Impacts

Question "How much of this would have been done anyway without LoCo"?

- **L-A science in general would have progressed**, but likely more in isolation.
- **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 these studies.*
- **LoCo's presence can be felt at community** meetings in terms of AGU, AMS presentations and discussions, with extremely popular AGU and AMS L-A sessions.
- **LoCo motivates community**: consider new aspects of L-A coupling, ask new questions.
- **LoCo impacts** now extend to agencies and program managers via funding, e.g. NASA, NOAA, DOE measurement and modeling.
- **LoCo is now front and center** in operational Climate development community (CPT), and hopefully NWP will follow suit.
- **LoCo's direct impact has extended** to prioritizing measurements for future NASA missions (PBL/Decadal Survey), as well as field campaigns (GRAINEX, LIAISE).
- ***Summary: A combination of tangible and intangible impacts of the LoCo project over the last decade can be felt throughout scientific, observational, and modeling communities, and achieved without a traditional 'MIP'; as there are more ways to influence model and scientific development than the MIP paradigm. Though sometimes this route may take longer, it may also have greater long-term impact.***

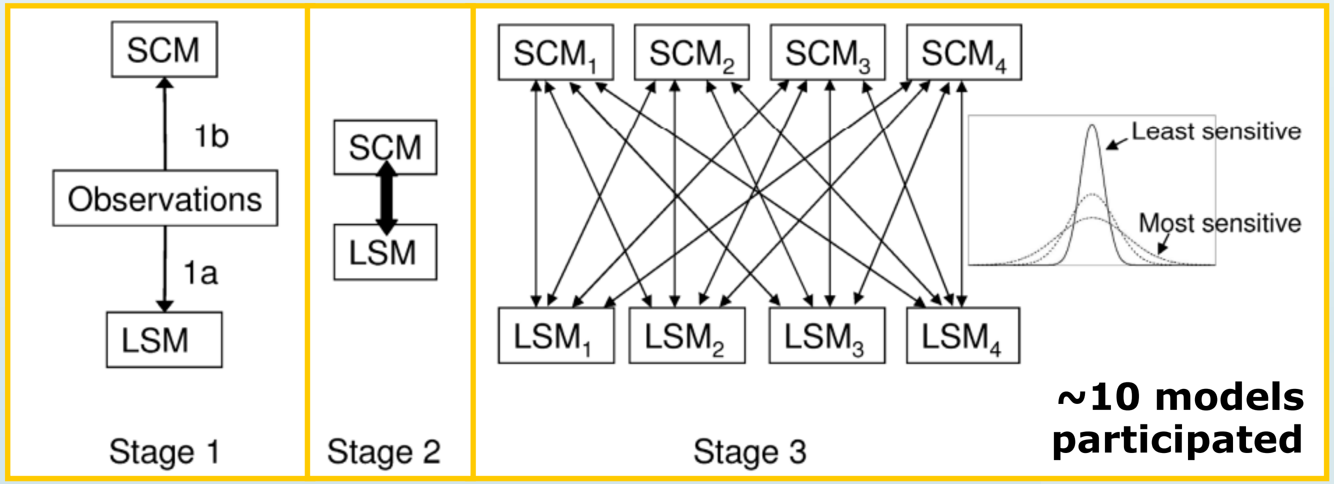
Complexity of Land-Atmosphere Interactions: DICE/GABLS



GEWEX Joint GLASS-GASS Diurnal land/atmosphere Coupling Experiment (DICE)

Objective: Study 1-D interactions between land-surface and atmospheric boundary layer, and assess feedbacks via (1) Stand-alone land model (LM), and Single Column Model (SCM) alone, (2) Coupled LM-SCM runs, (3) Sensitivity of LM and SCM to variations in forcing.

FINDINGS from DICE-1: **Surface fluxes critical** for land-atmosphere where coupling is important to represent properly in our models.
***ACTIONS**: Review/refine land-model surface fluxes.*
FOLLOW-ON: DICE-1 papers (i. setup, ii. results). GABLS4/DICE-Over-Ice" paper progressing. Leverage SCM work at NCAR, elsewhere.



Complexity of Land-Atmosphere Interactions: GLAFO

GLAFO: "GEWEX Land Atmosphere Feedback Observatories"

Background:

Significant biases in surface and atmospheric processes in models. Critical to represent pre-convective environment to simulate clouds/precip.

Significant advances made in observing the atmospheric surface layer (SL) and lower troposphere including PBL. New synergy of observations has successfully been applied during LAFE and led to new insights in processes and parameterizations related to L-A interaction.

Vision:

We propose to design and develop observatories in different climate regions based on the Land-Atmosphere Feedback Experiment (LAFE-2017, U.S. SGP). Make measurements "quasi-operational" for soil, vegetation, SL, PBL.

Volker Wulfmeyer et al

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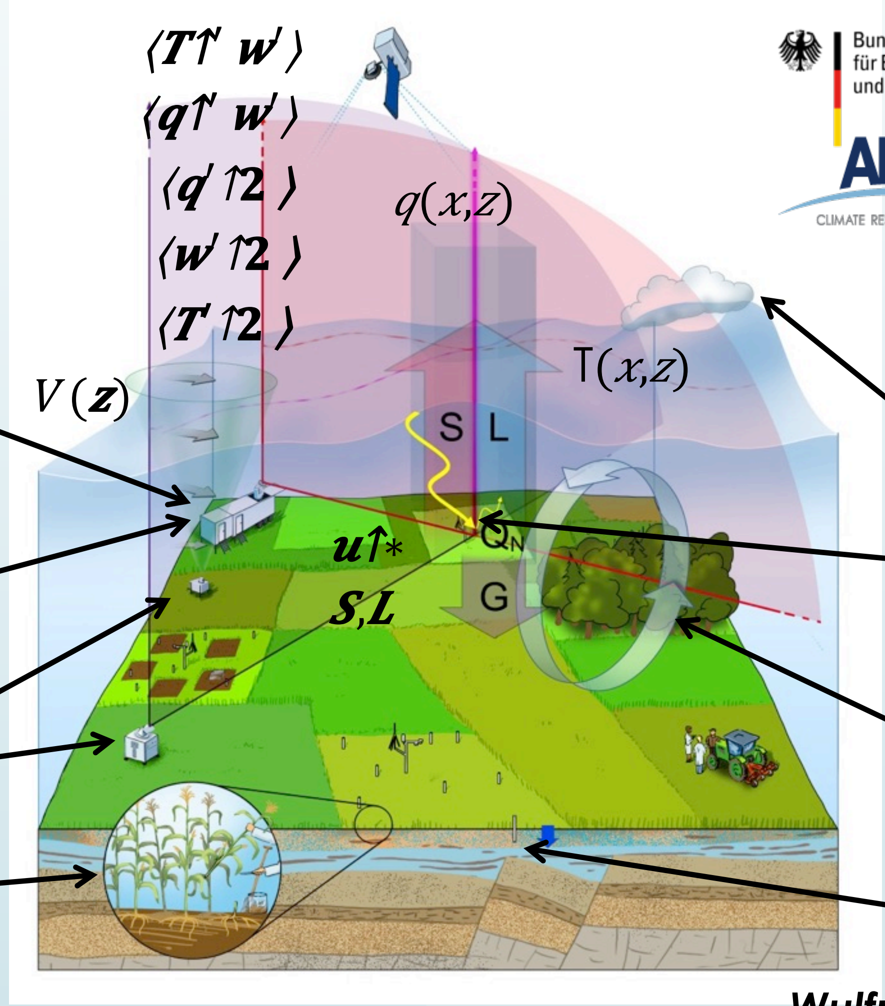
Complexity of Land-Atmosphere Interactions: GLAFO

Vertical pointing instruments to start, then add scanning.



Wulfmeyer et al. BAMS 2018

Complexity of Land-Atmosphere Interactions: GLAFO

Goals, Impacts and Applications

- **Determine turbulence profiles** to investigate (new) relationships among processes.
- **Improve existing, develop new parameterizations** for PBL, convection, land-atmosphere (L-A) interactions/feedbacks, and-atmosphere heterogeneities.
- **Investigate surface fluxes** using a synergy of in-situ sensors and scanning wind, humidity, and temperature lidar system.
- **Characterize the diurnal cycle, transitions, mesoscale and seasonal variability** of the PBL, land-atmosphere feedbacks, as well as the moisture and energy budgets.
- **Verify large-eddy simulation model runs**, improve turbulence in models.
- **L-A data assimilation, regional-scale reanalyses.**
- **Testbed for observing** system synergies.
- **Calibration of passive sensors** from ground and satellites.
- **Training of future research users** of these data sets.

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Thank you

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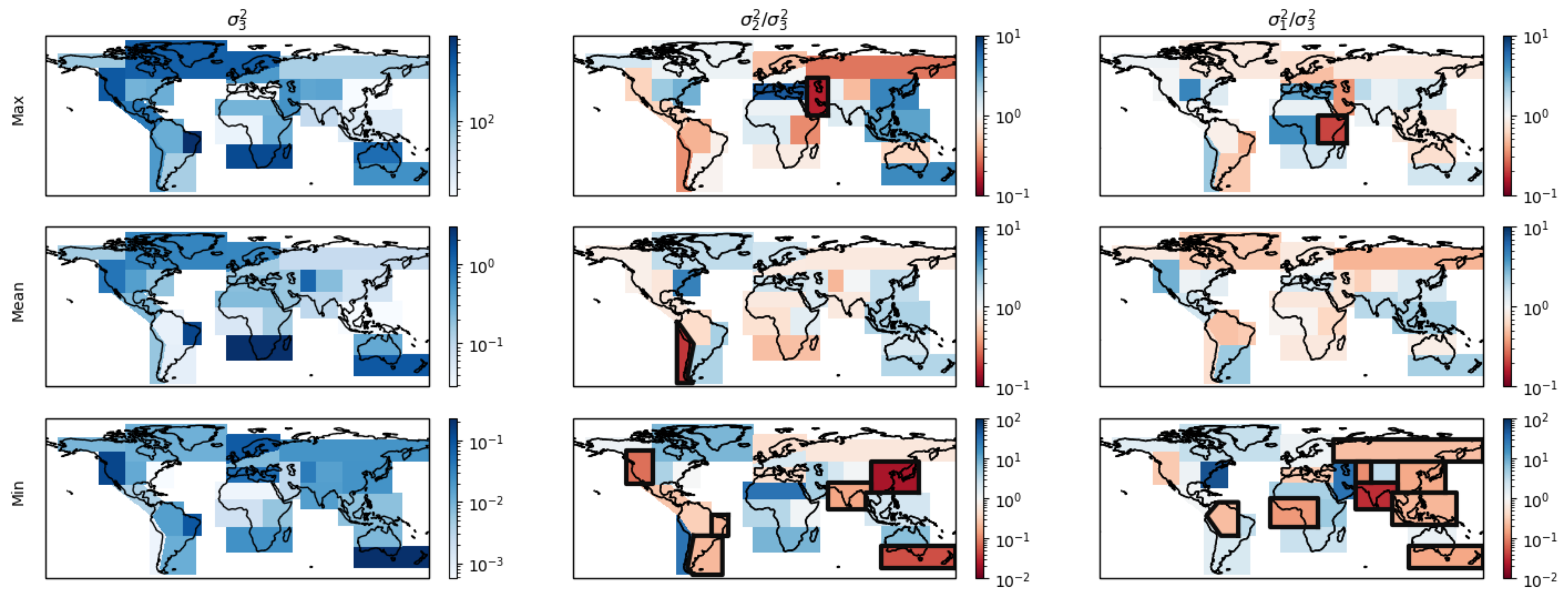
Backup Slides

SoilWat: Soil Parameter MIP (SP-MIP)

- Eight participating models running three sets of experiments:
  - With **default** configuration,
  - the **same** soil **texture** map but their own PTFs,
  - and the **same** soil-hydraulic **parameters**
- Focus on total runoff (surface + sub-surface)
  - The long-term mean is not different between the experiments
  - But the **model spread is reduced by using identical texture and parameters**, with the largest effects seen in low-flows



IDEE	Agnès Duchame	Salma
CH	Philipp de Vrese	Stefan
-MP	Stephan Thober	
;	Rich Ellis	Anne V
RO	Hyungjun Kim	Sujan K
RO-gw	Hyungjun Kim	Sujan K
SURFEXv8	Aaron Boone	
	Dave Lawrence	and oth

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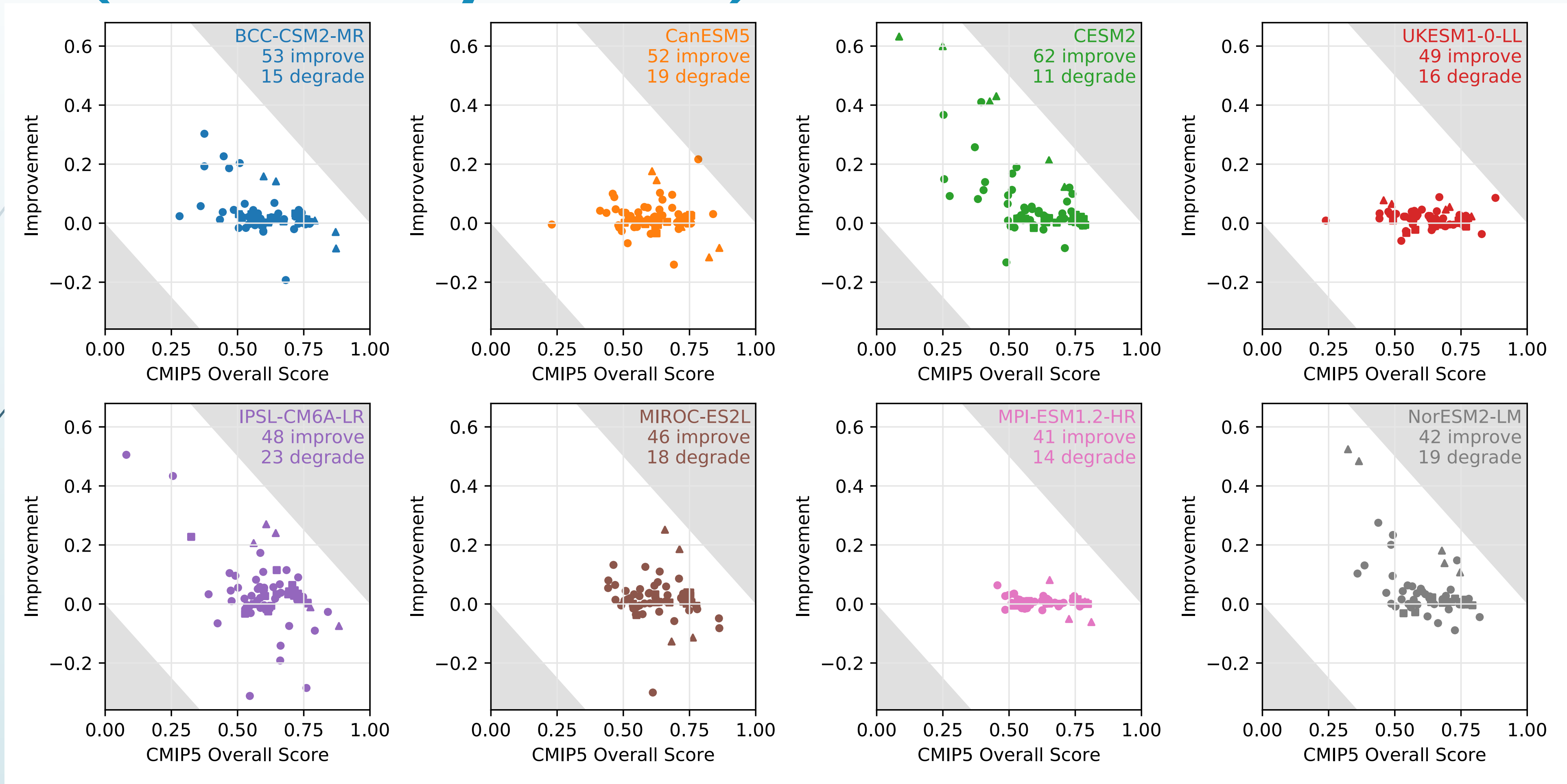
Model improvement for individual models? **(Preliminary results)**



Triangles are for variable-to-variable comparisons
Squares are for land climate forcing variable metrics
Circles are for all other metrics

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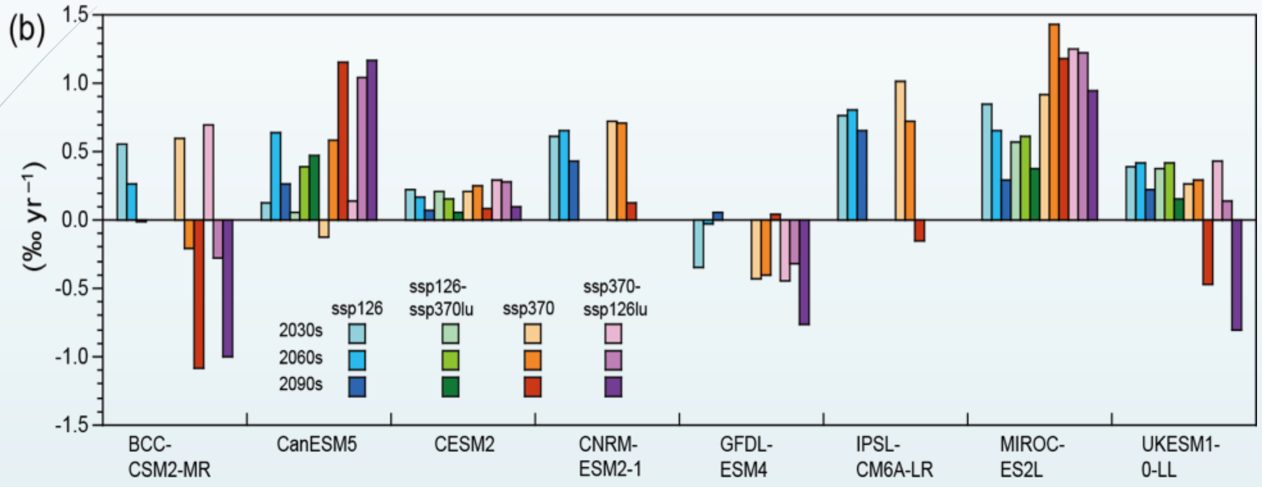
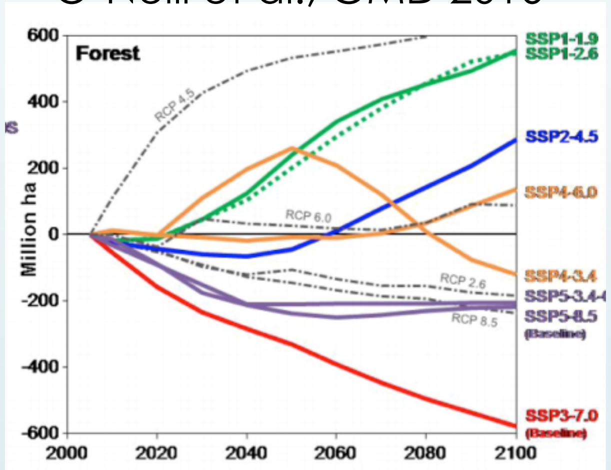
Soil carbon sequestration simulated in the LUMIP models
Implications for the 4 per 1000 initiative (Preliminary results)

% yr^{-1} change in soil carbon stocks



O'Neill et al., GMD 2016



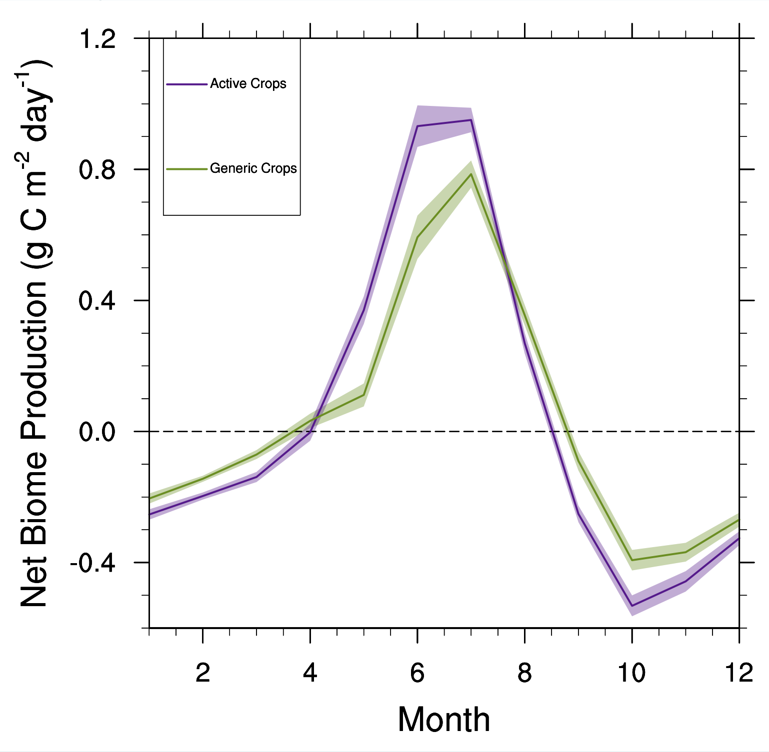
ESM	ssp126-ssp370Lu – ssp126 (Pg C)	ssp370-ssp126Lu – ssp370 (Pg C)
BCC-CSM2-MR		9.1
CanESM5	-17.4	26.3
CESM2	-4.2	9.3
GFDL-ESM4		-4.3
MIROC-ES2L	-7.0	1.2
UKESM1-0-LL	4.6	-14.1

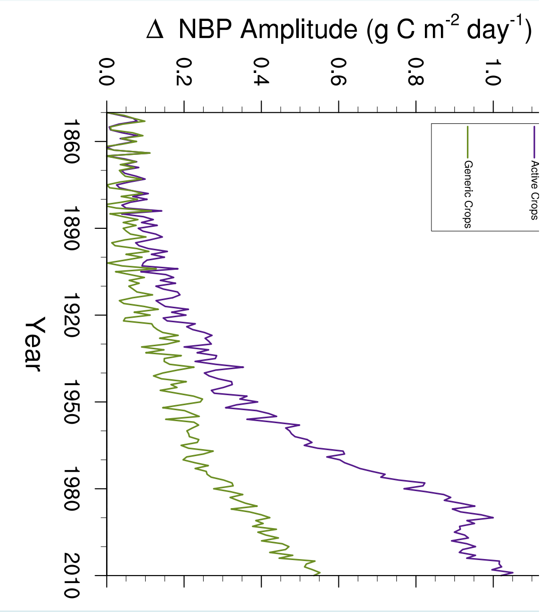
- Lack of agreement across models of implications of alternative LULCC trajectories
- Weak indication from alternative LULCC simulations that afforestation (SSP1-2.6) drives increased soil carbon stocks and deforestation (SSP3-7) results in decreased soil carbon stocks, though not all models agree

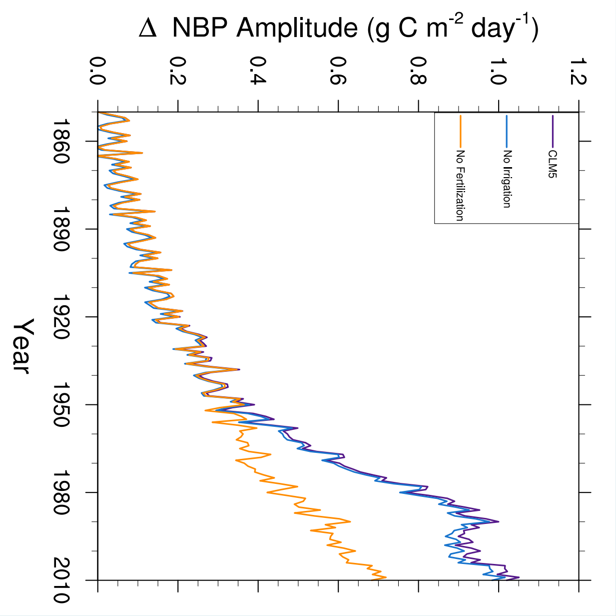
Ito et al., in prep

Crops increase amplitude of Net Biome Production (NBP) annual cycle
Analysis of land management factorial simulations

Community Land Model (CLM5)







- Explicit crop representation results in 20% larger amplitude relative to generic crops
- NBP (which impacts to atm CO_2) annual amplitude increased from 1850 to 2010
- Increasing crop area and introduction of industrial fertilizer are largely responsible for this increase

Lomardozzi et al., in prep

Summary

- LUMIP simulations from a range of ESMs are complete and available through CMIP6 data portals
- Many planned analyses are underway and are beginning to yield new scientific insight
- If interested in participating, please either contact paper leads or register your own interest for a topic that is not yet planned

LUMIP
Land Use Change

Contact Dave Lawrence with questions or comments, dlawren@ucar.edu

GLASS
Global / Land - Atmosphere System Studies

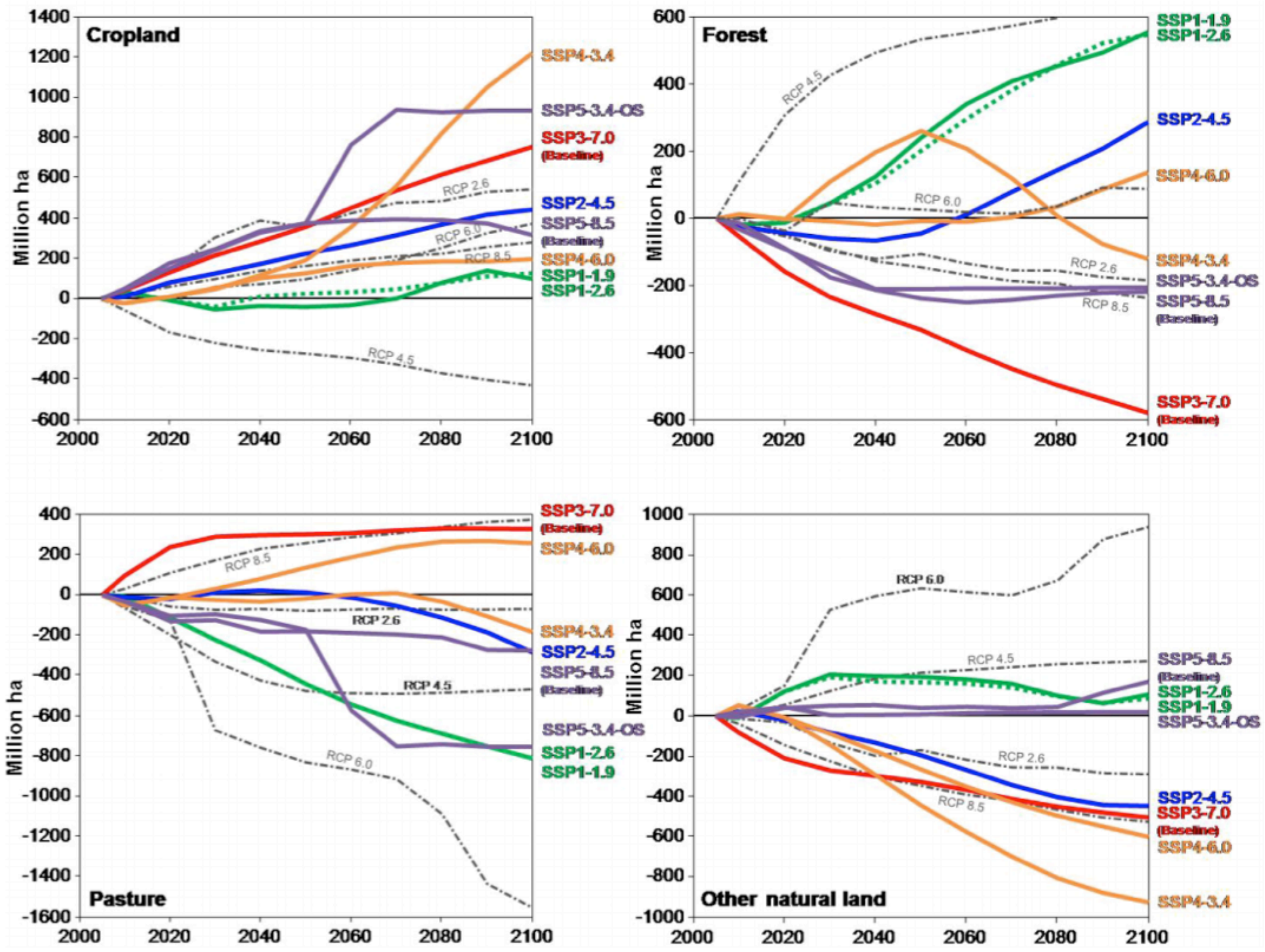


Figure 4. Changes in cropland **(a)**, forest **(b)**, pasture **(c)**, and other natural land **(d)** for the 21st century scenarios in the ScenarioMIP design, from the same IAM runs used to produce Fig. 3. Land use change for the RCPs (van Vuuren et al., 2011b) is shown for comparison.