CLM Update

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with input from members of LMWG and BGCWG

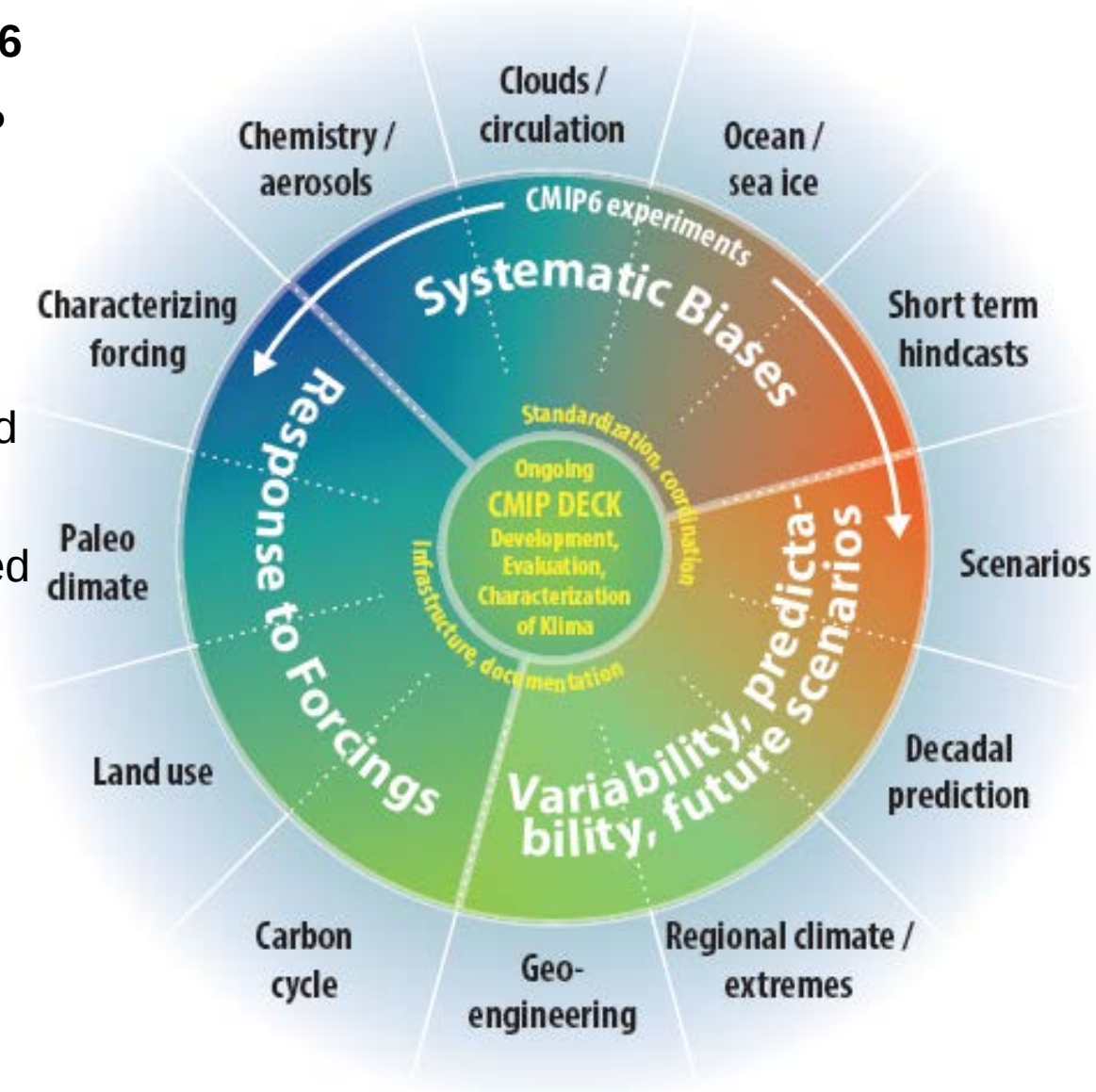
First CLM Tutorial, Feb. 18-21
www2.cesm.ucar.edu/events/tutorials/clm/2014

40 students, 15 lectures (incl. 5 by TSS postdocs), 5 practical sessions
all materials available online

CMIP6 planning

Terrestrial processes in CMIP6

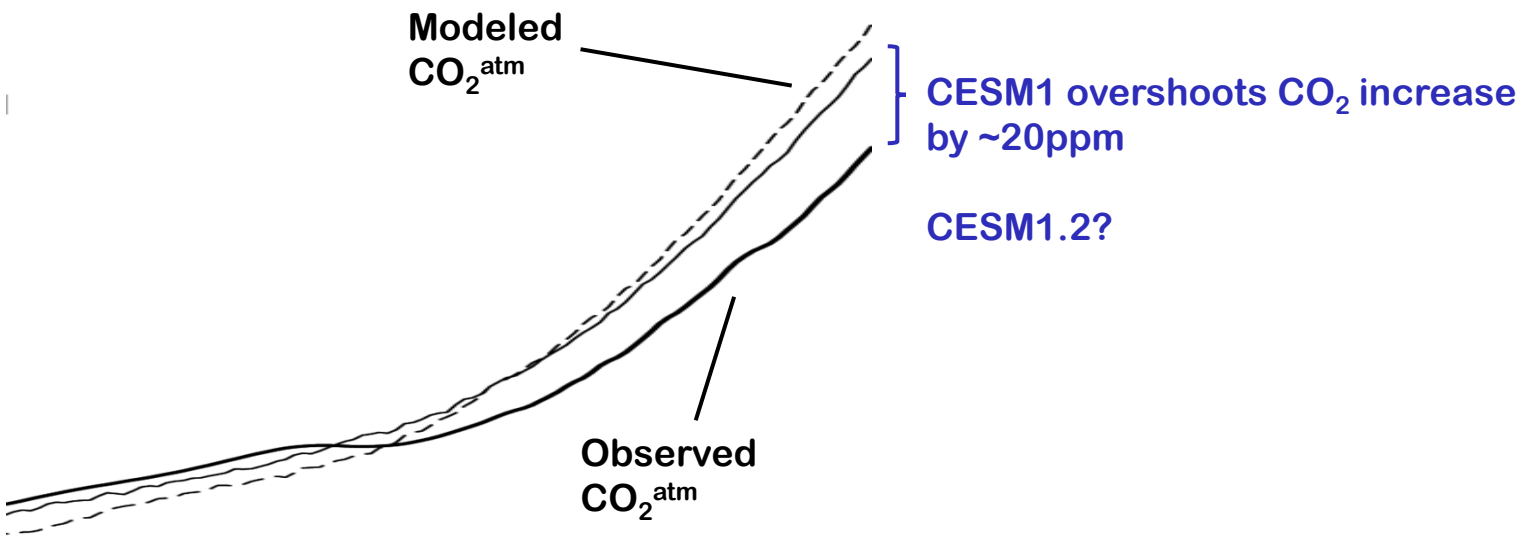
- LUMIP, C4MIP, ScenarioMIP likely to contain aspects that address land role in and response to climate change
- Pushing for land-only simulations; with/without land use change
- Are there critical land-focused science questions that were not dealt with in CMIP5 and could fall through cracks again?



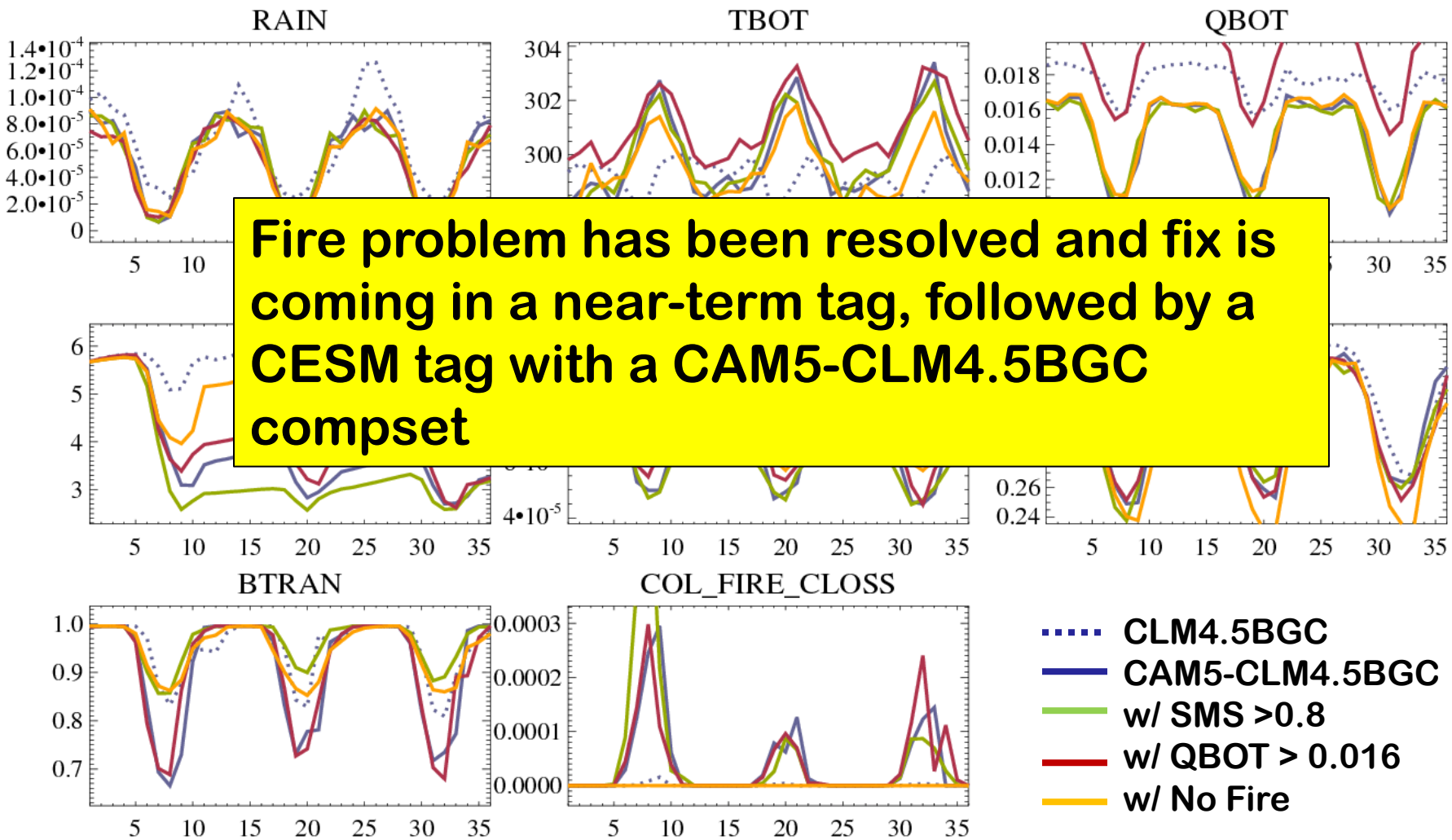
Meehl et al., EOS, 2014

CAM5-CLM4.5BGC coupling

First stage of goal to complete a CESM1.2 carbon cycle simulation



Unhealthy Amazon in CESM1.2

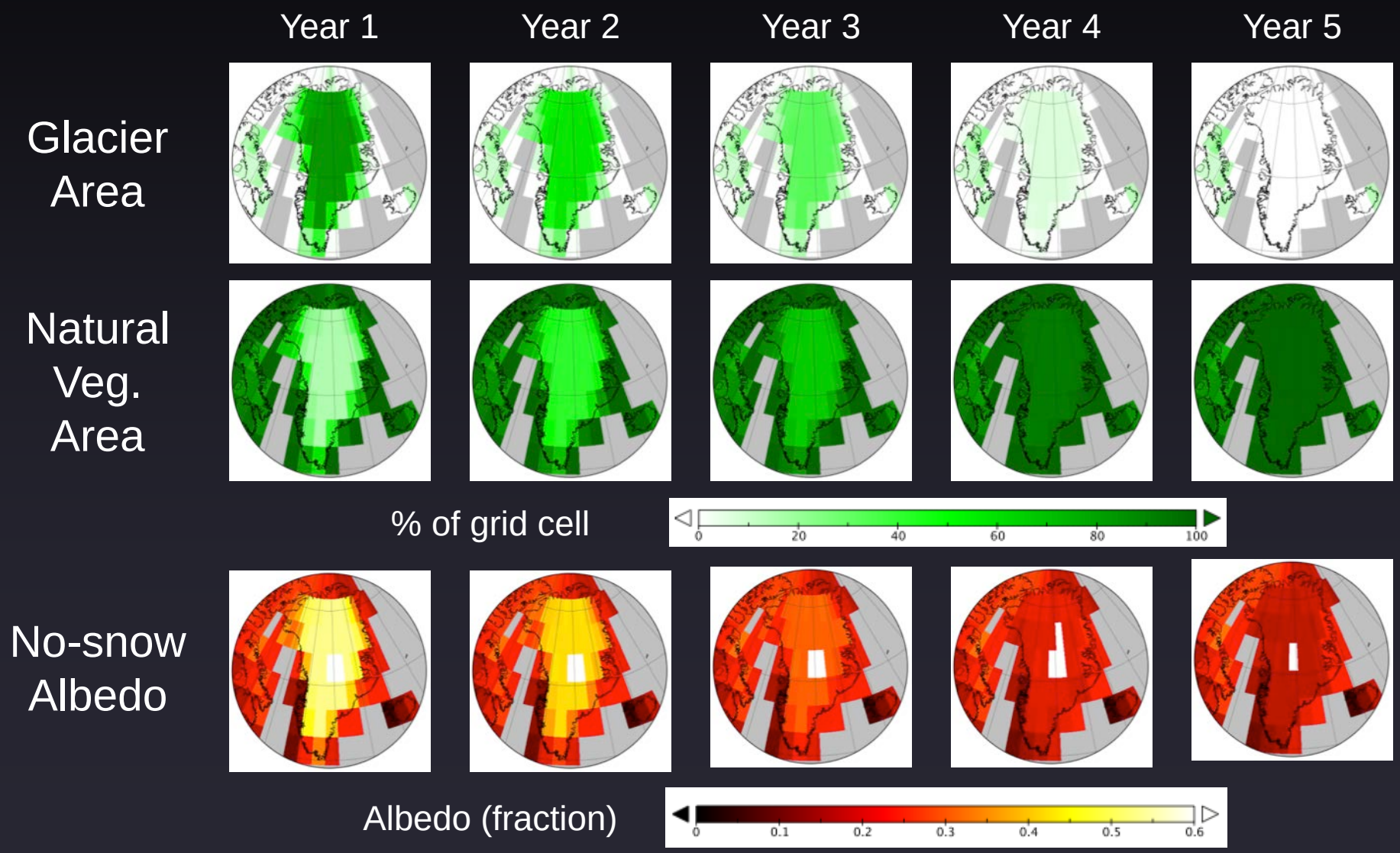


Fire problem has been resolved and fix is coming in a near-term tag, followed by a CESM tag with a CAM5-CLM4.5BGC compset

* New fire model depends on SM in root zone and atm RH to determine fire spread
* Fire suppression dependent on pop density/GDP, low in Amazon
* Low rainfall and low humidity are amplifying the problem

Dynamic Landunits: Glacier and crop transitions working!

Fast deglaciation experiment: 100% to 0% in 5 years



CESM Planning

CESM2 Targets

For "scientifically supported" versions -

- Configurations:
  - Physical Climate w/CAM5.5
  - Physical Climate w/CAM6,
  - Physical Climate w/WACCM,
  - Carbon Cycle/BGC with enhanced atm chem coupling,
  - Coupled Ice Sheet integrations (level of coupling TBD – particularly for ocean)

- Plan to use CAM5.5 atmosphere for WACCM, Carbon Cycle, CISM Model Versions

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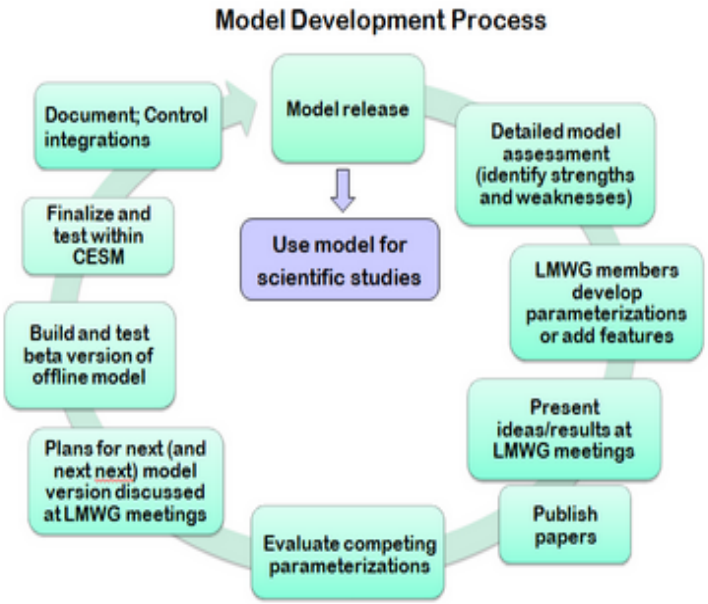
CLM Development Plans

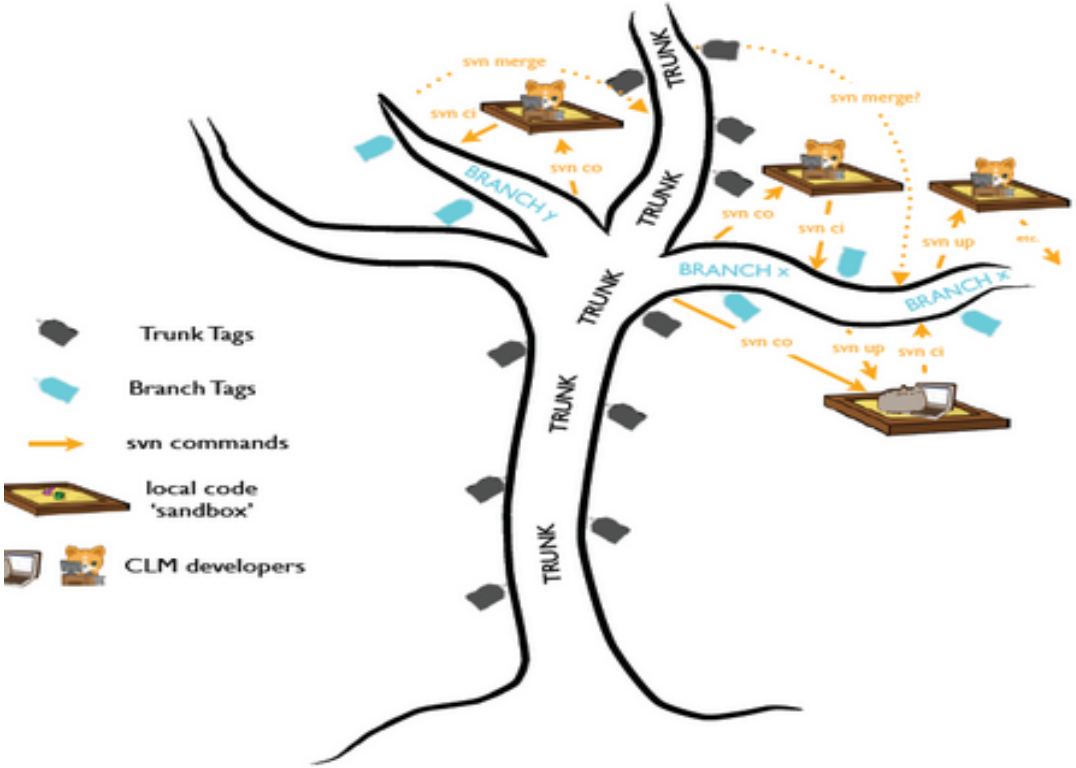
Model Developers' Guide (thanks to CLM software team)

http://www2.cesm.ucar.edu/working-groups/lmwg/developer-guidelines

Software development guidelines

- Software developer's guide: read this for general information on the steps in t development process including information on coding standards, maintaining a testing, and working with the CLM Code Management Team
  - Coding practices
  - Using SVN to work with development branches
  - CLM testing
  - Upcoming CLM branch and trunk tags
  - Recent CLM code refactoring





CESM CLM and RTM Development cseg.cgd.ucar.edu Public

CLM/RTM Trello page

Software Engineering (new functionality, refactoring, etc)

- Put in capability into data models to have a new flexible way of introducing user-defined streams (1) SPM
- move anomaly forcing wholly inside of datm and add ability to bring in mods by user_nl_datm or DATM_BLDNML_OPTS
- implement dynamic landunit functionality for glacier and crop (1) Jan 31 WJS
- Create tool that parses input/output arguments and corrects current comments in the associate statements
- Work on PTCLM. So can create many datasets and tool to setup cases for a bunch as well.
- white space refactor (1) SPM
- Compiler Warning and deadcode refactor SPM

Science development (LMWG)

- create a high resolution surface dataset (2) (1/4)
- Purge some of the history fields being output by default.
- ED Tag 2 (Science) (1) SPM
- Bring urban development branch to the trunk

Testing

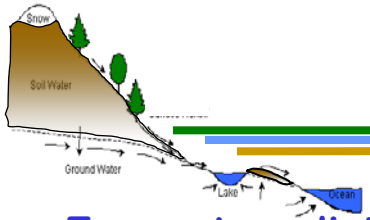
- Add unit tests to build-namelist
- Get CLM aux tests on edison (3)
- Implement unit testing with CLM physics (3)
- Testing for PTCLMmkdata and create_newcase from it's datasets. (3/5)
- Rework some CLM aux tests

Upcoming tags

- clm4_5_63 refactor initerpinic (3) (2/14) Feb 10 WJS
- clm4_5_64 Activate virtual vegetated columns in some circumstances (simple change, but changes answers for 1-d hist files) Feb 14 WJS
- clm4_5_65 ED Tag 1(Science) (1) Feb 21 SPM
- clm4_5_66 Glacier area dynamics!!! Feb 28 WJS
- clm4_5_67 Add the stub ability for clm5_0 physics to CLM build system.

Completed trunk tags

- clm4_5_62 US-UMB fix in scripts and datm update. fix so build-namelist will abort if there is an inconsistency with crop in CLM_BLDNML_OPTS and user_nl_clm. Add CO2 streams. (6/8) Feb 6
- clm4_5_61 Snow diagnostic fields from Jeremy Fyke; change harvest logic when passing the end of the pftdyn dataset (bfb except for 3 tests that trigger the new harvest logic) (1) Feb 4 WJS
- clm4_5_60 build-namelist refactor so modular and unit-testable (18/18) Jan 30
- clm4_5_59 [in test] Change weight calculation to use new routine in clm_time_manager (roundoff-level changes) Jan 22 WJS
- clm4_5_58 [in test] Refactor transient land cover code - add high-level driver and some low-level routines (bfb) Jan 22 WJS
- clm4_5_57 Change CNDV water conservation to use



Development targets for CLM5+

Ecosystem disturbance

- Ecosystem Demography model; add soil BGC, land use change, +++
- Fire model updates including trace gas and aerosol emissions

Landscape dynamics

- Dynamic landunits
- iESM infrastructure

Evapotranspiration, partitioning of ET

- Soil evap, canopy turb, canopy evap
- Rooting depth
- Water isotopes

Hydrology

- MOSART routing model
- Revised solution to Richard's eqn, variably saturated flow
- Progress on lateral flow processes

Nutrient dynamics

- Plant N uptake / competition
- N-gas emissions
- Leaching and riverine transport
- Phosphorous dynamics

Carbon allocation

- Replace dynamic allocation with fixed allocation params based on field observations

Agriculture

- Extend crops to global
- Additional crop management processes as options

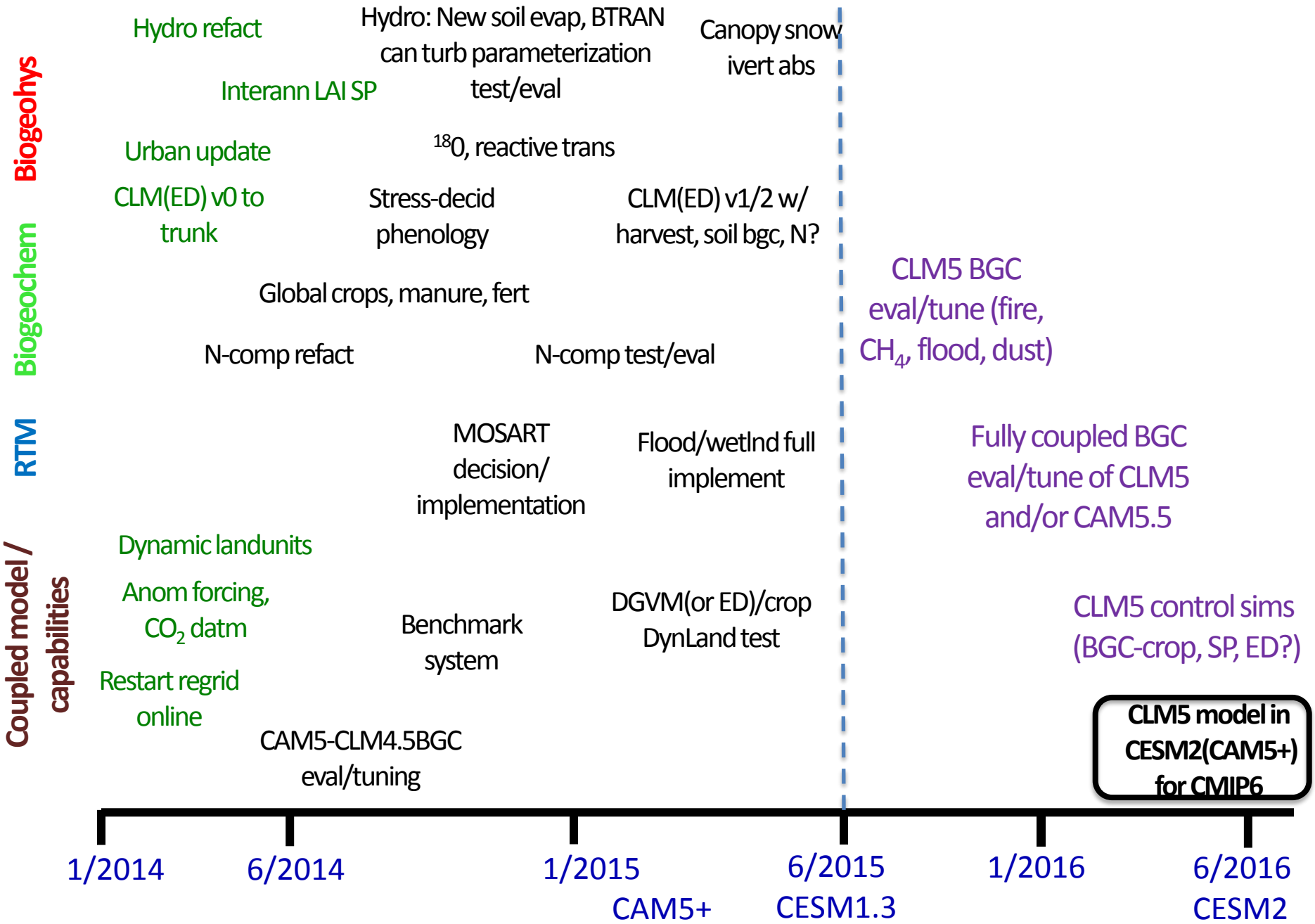
Urban

- New building energy model
- New urban surface dataset

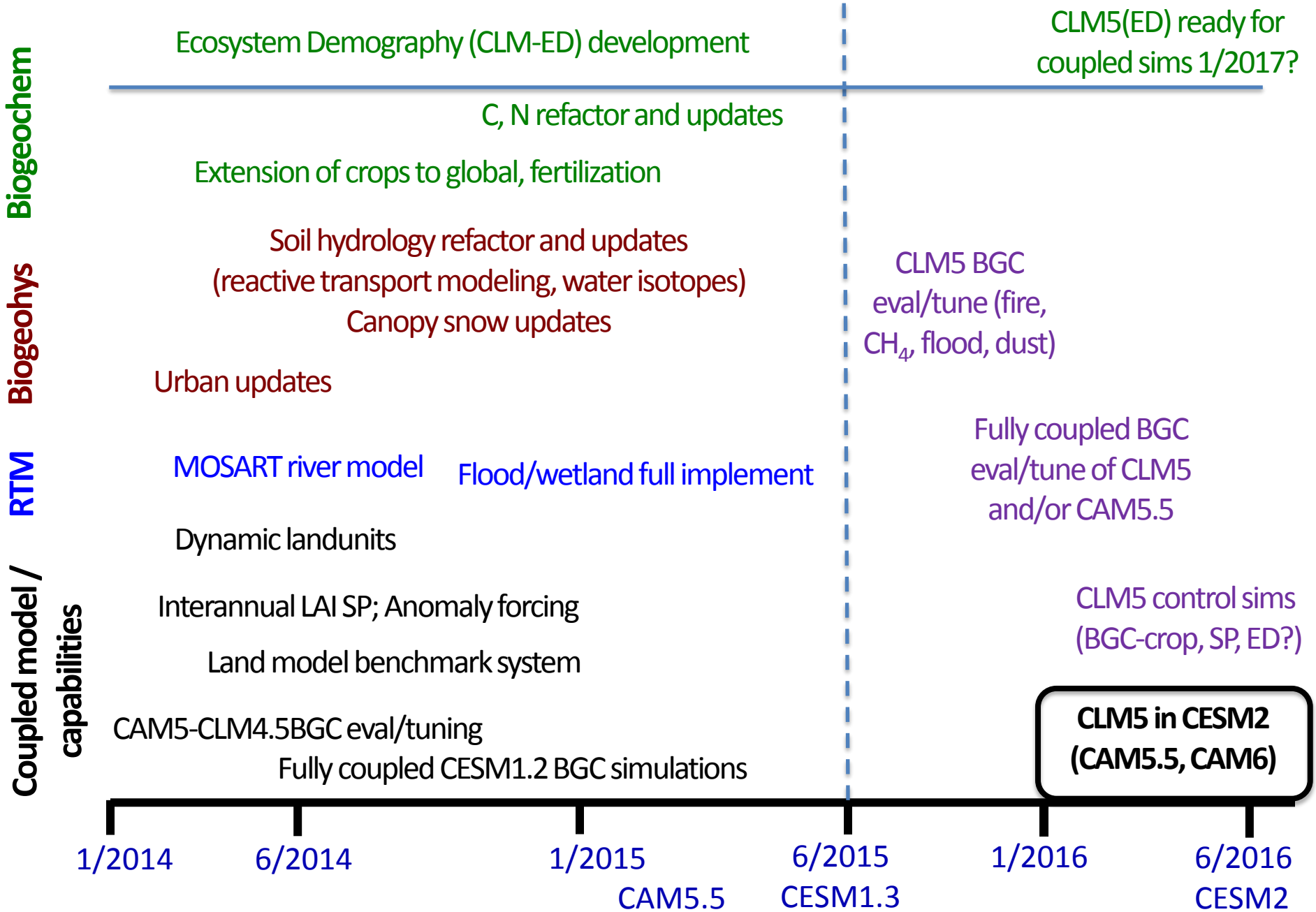
Canopy processes

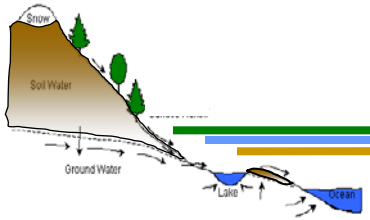
- Canopy snow radiation, unloading

CLM Development Timelines: *The path towards CLM5/CESM2*



CLM Development Timelines: *The path towards CLM5/CESM2*





Offline vs Coupled Model Tuning of CLM

- **CLM5 will include several features that are non-linearly dependent on the climate simulation (especially precip)**
  - **Fire, CH_4 emissions, river flooding, dust emissions**
  -

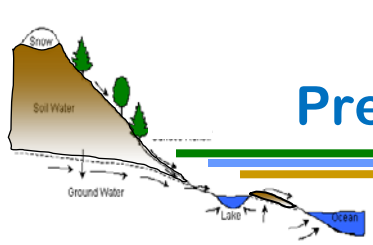
	CLM4.5	CAM5-CLM4.5
Fire area:	~370 Mha/yr	~700 Mha yr^{-1}
River discharge:	~28,000 km^3/yr	~44,000 km^3/yr

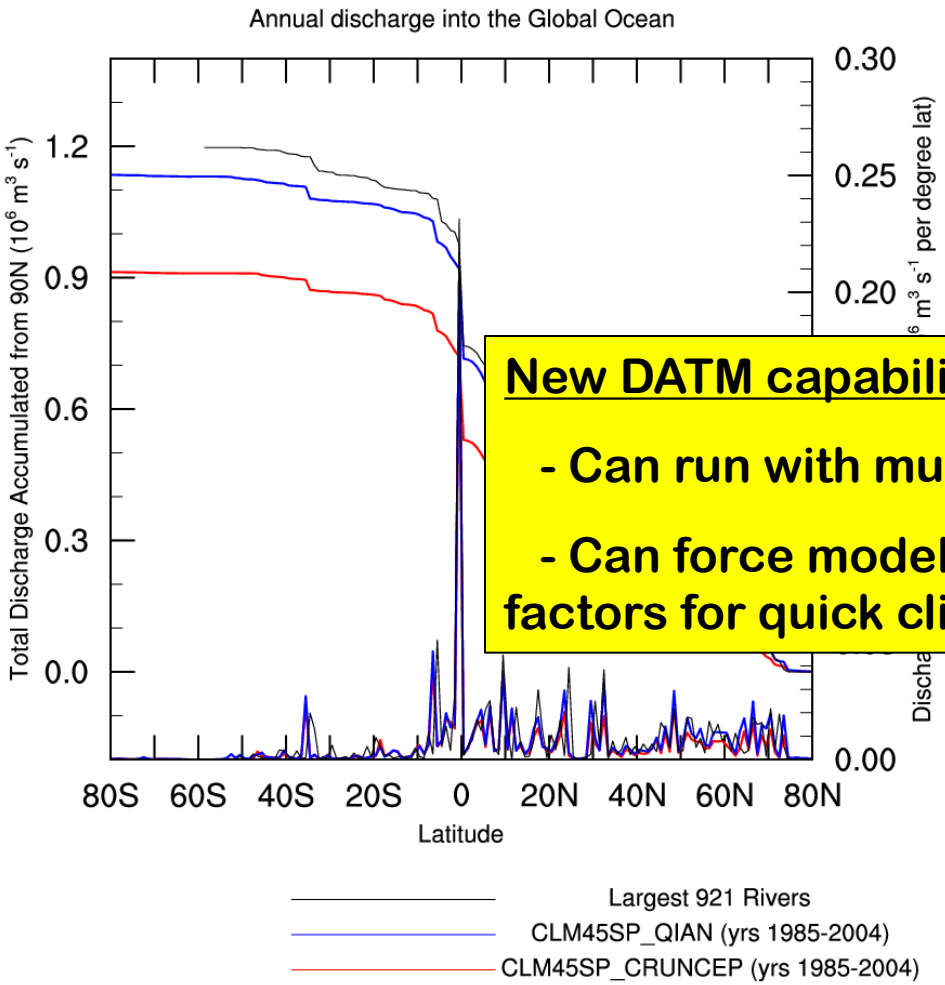
- **In past, we have tuned CLM offline only and used these parameters in all coupled simulations**
- **For CESM2, the LWMG tentatively propose that there could/should be a separate set of parameters for offline and coupled simulations**

Potential metrics for inclusion in a comprehensive land benchmarking system

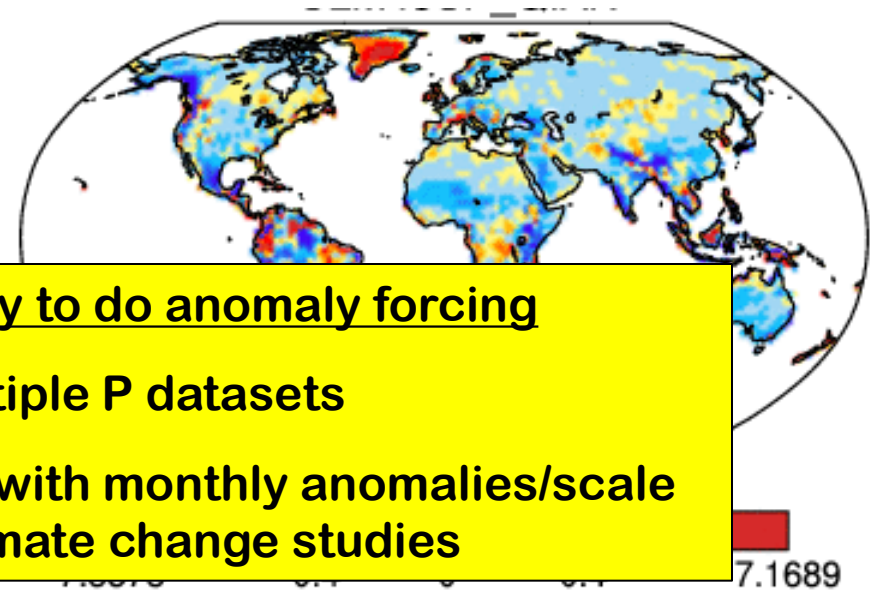
- **Large-scale state and flux estimates**
  - LH, SH, total water storage, albedo, river discharge, SCF, LAI, soil and veg C stocks, GPP, NEE, ER, burnt area, permafrost distribution, T_{2m}, P, …
  - RMSE, annual cycle phase, spatial pattern corr, interannual variability
- **Functional relationships and emergent properties**
  - soil moisture – ET, soil moisture – runoff, stomatal response to VPD transient carbon storage trajectory, runoff ratio, land cover change
- **Experimental manipulation (testing model functional responses)**
  - N additions, FACE, artificial warming, rainfall exclusion

Forcing uncertainty:
Precipitation and annual discharge to the global oceans





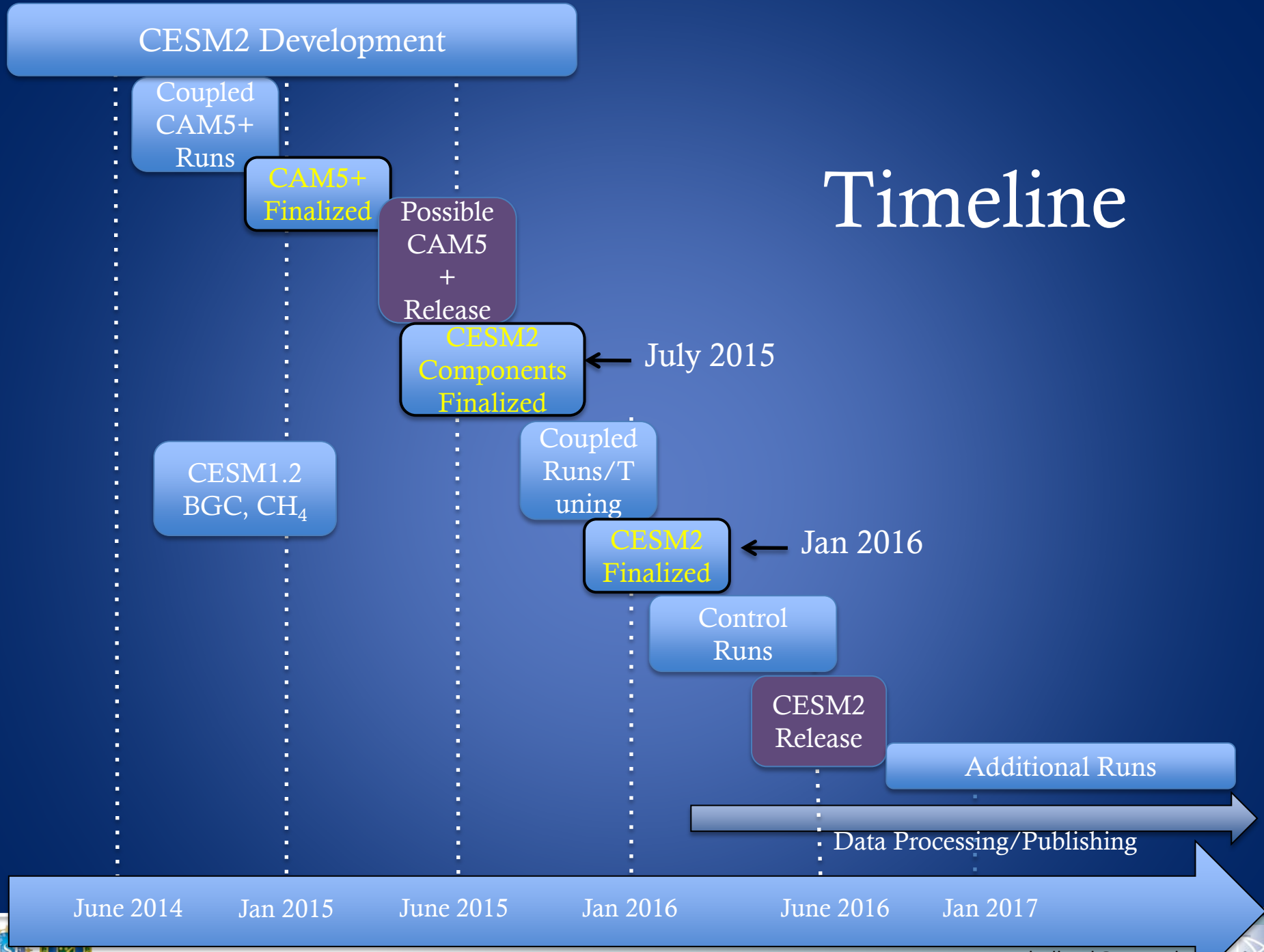
Precipitation
CRUNCEP(CRU) – QIAN(GPCP)



<u>New DATM capability to do anomaly forcing</u>

- **Can run with multiple P datasets**
- **Can force model with monthly anomalies/scale factors for quick climate change studies**

Timeline



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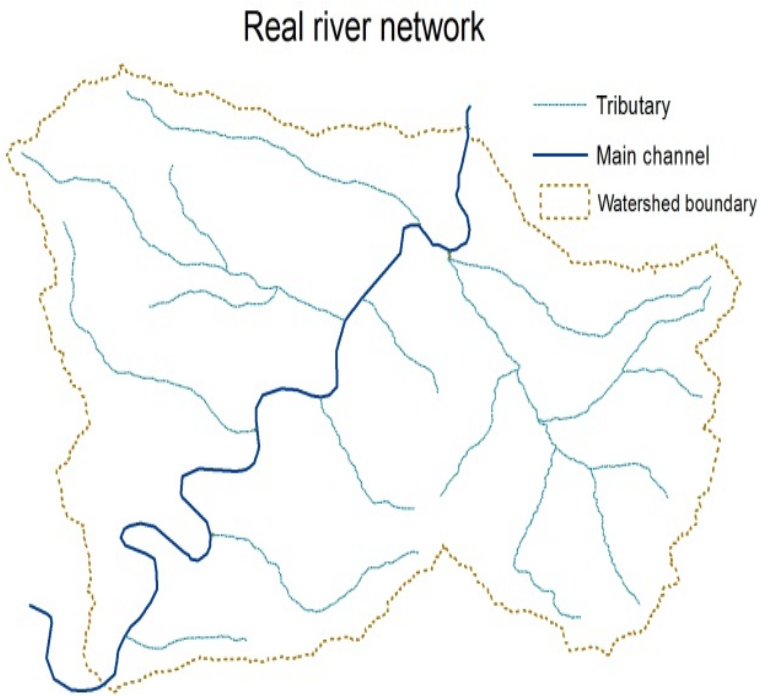
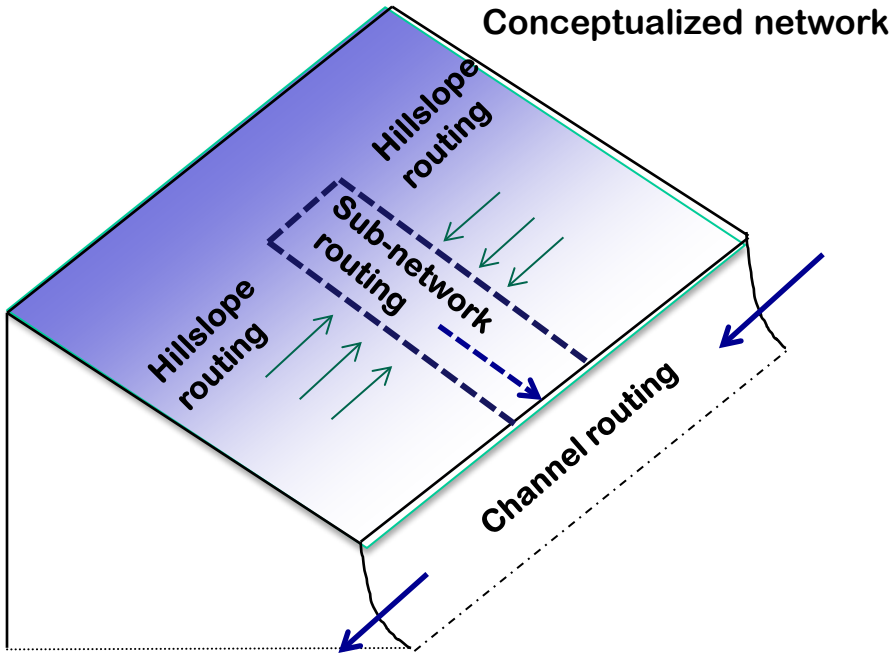
Land Model Benchmarking / Metrics

Summary Table

Class	Variable	Obs dataset	W (1-5)	CCSM4	CLM4 CN	CLM4.5 BGC
Global or regional	LH	FLUXNET-MTE	4	0.68	0.63	0.71
	SCF	AVHRR	3	0.68	0.75	0.74
	Albedo	MODIS	4	0.62	0.65	0.66
	Biomass	NBCD (US), Tropical Biomass	3	0.65	0.59	0.63
	Burnt Area	GFED3	3	0.39	0.38	0.43
	P	CMAP	2	0.48	0.93	0.93
	T_{air}	CRU	2	0.91	0.93	0.93
Site level	NEE	FLUXNET	3	0.19	0.23	0.25
	GPP	FLUXNET	3	0.66	0.76	0.80
	SH	FLUXNET	4	0.73	0.80	0.79
Functional relationship	R / P	riv disc, CMAP	5	0.63	0.57	0.59
Total				21.76	22.98	23.86

Model for Scale Adaptive River Transport (MOSART)





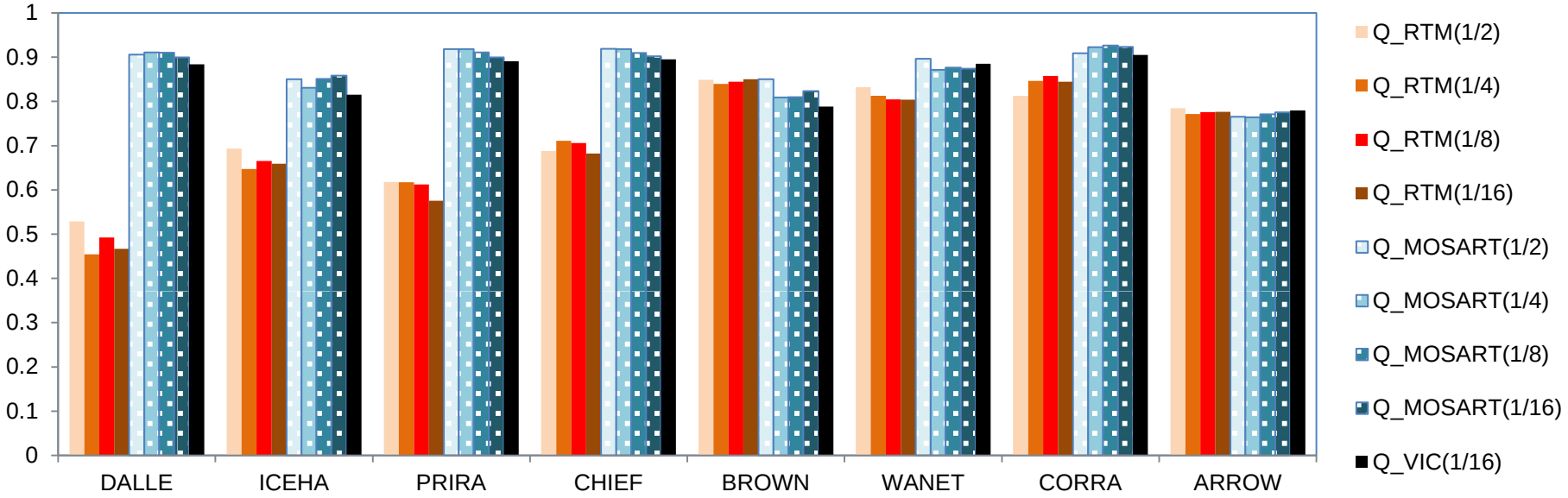
- Hillslope routing to account for event dynamics and impacts of overland flow on soil erosion, nutrient loading etc.;
- Sub-network routing: scale adaptive across different resolutions to reduce scale dependence;
- Main channel routing: explicit estimation of in-stream status (velocity, water depth etc).

(Li et al., JHM, 2013)

Model for Scale Adaptive River Transport (MOSART)

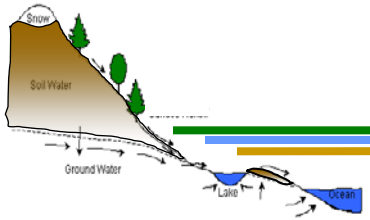
MOSART is more skillful in simulating streamflow compared to RTM

NS coeff. for monthly mean streamflow – grid based representation

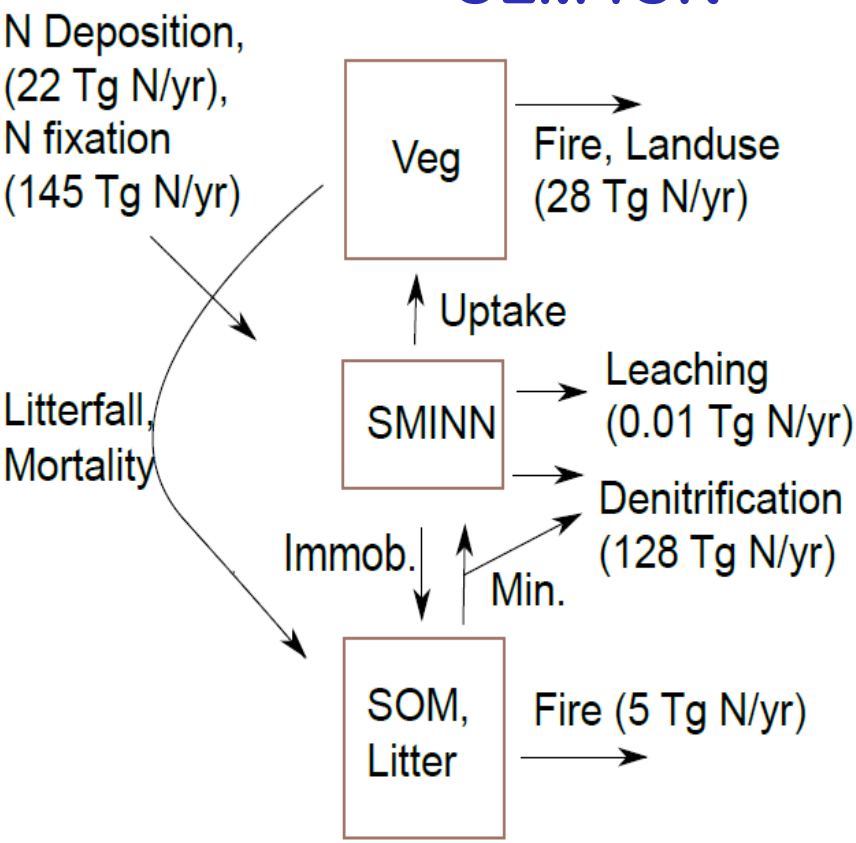


Large drainage area → **Small drainage area**

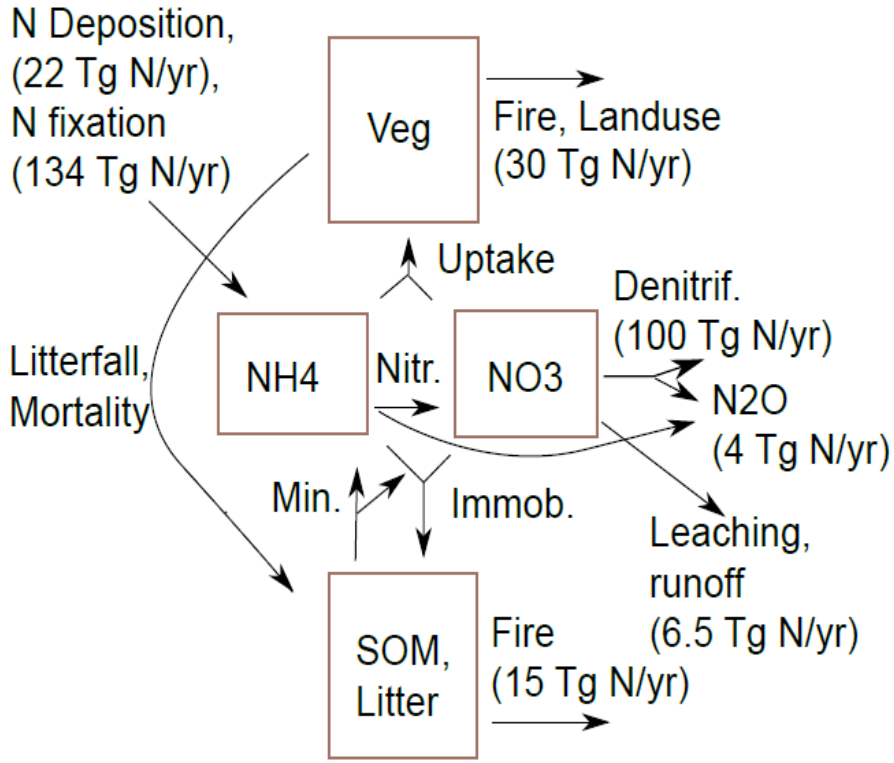
Nitrogen-cycle



CLM4CN

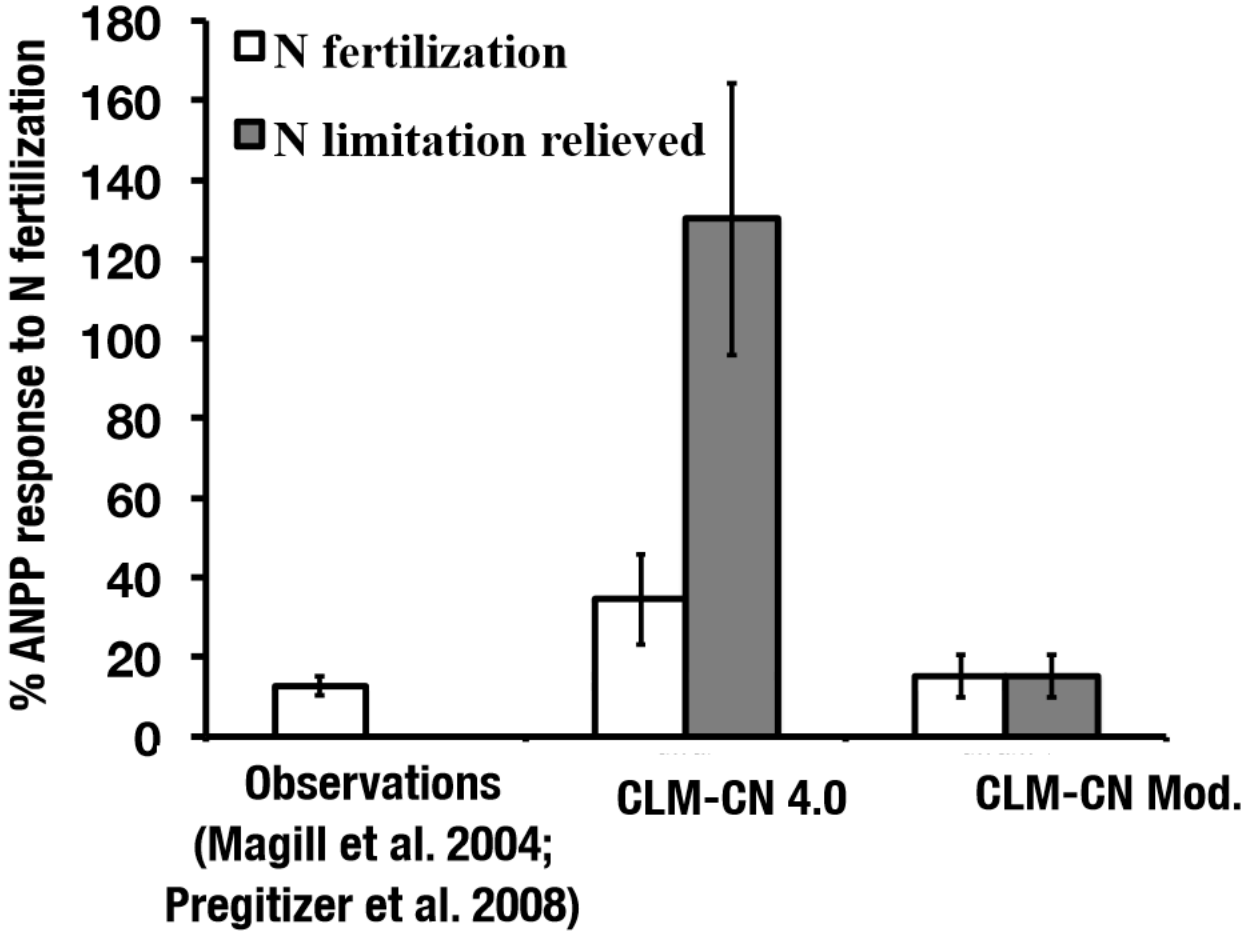


CLM4.5BGC



Obs (preindustrial, Galloway et al. 2004)
Deposition 17; BNF 120; Denitrification 98; Export to Rivers 70; N_2O 6

Net Primary Productivity response to N fertilization

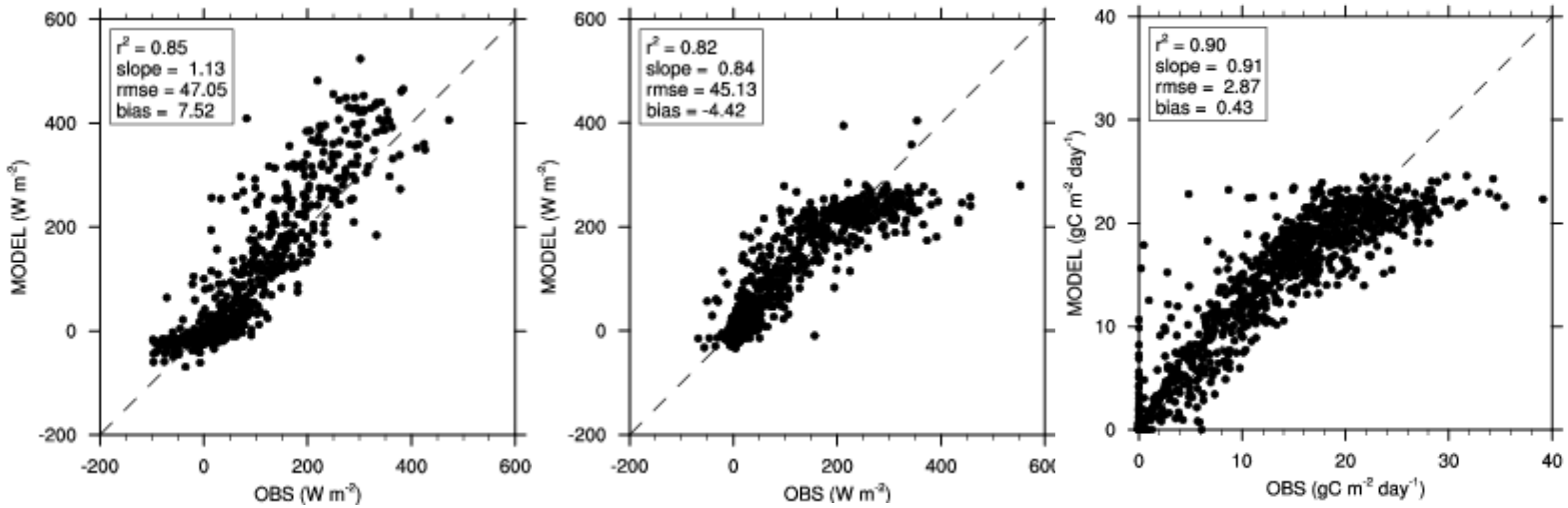


Thomas et al. 2012

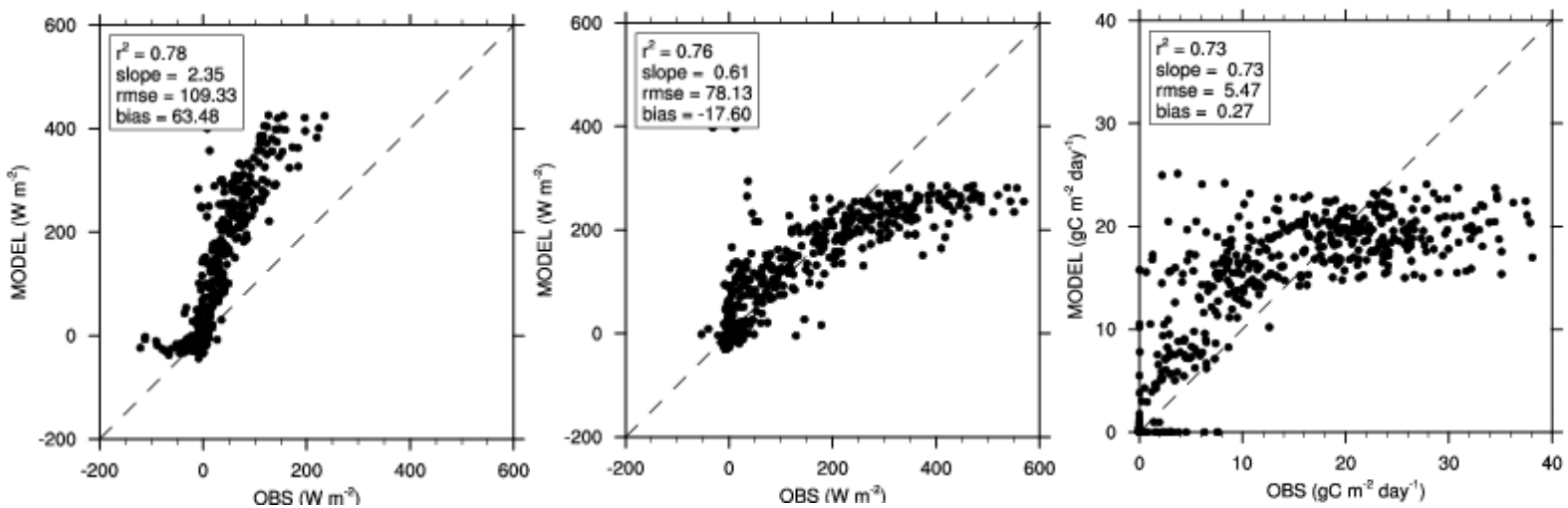
CLM4.5 Performance at Tower Sites

Sensible Heat | Latent Heat | GPP

Howland Forest Main July, 1996 NET-T



Morgan Monroe July, 2001 BDT-T

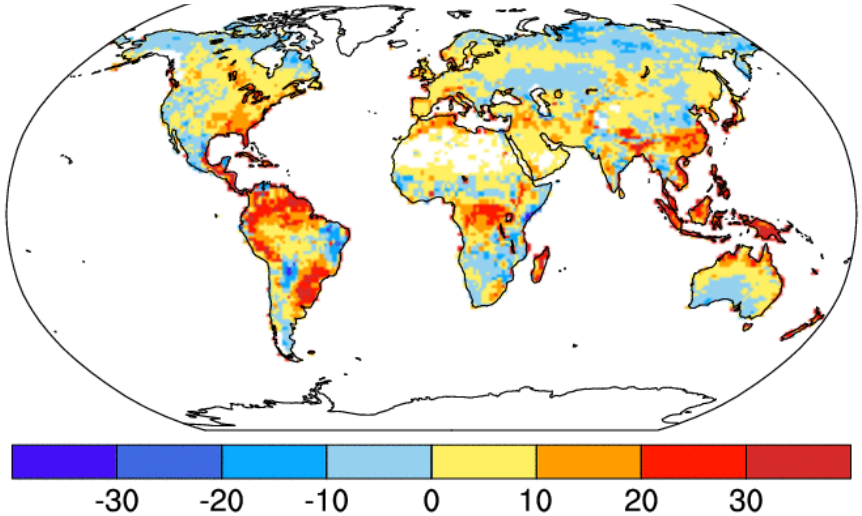


Thanks to D.M. Ricciuto, D. Wang, P.E.Thornton, W.M. Post, R.Q. Thomas, E. Kluzek for PTCLM!

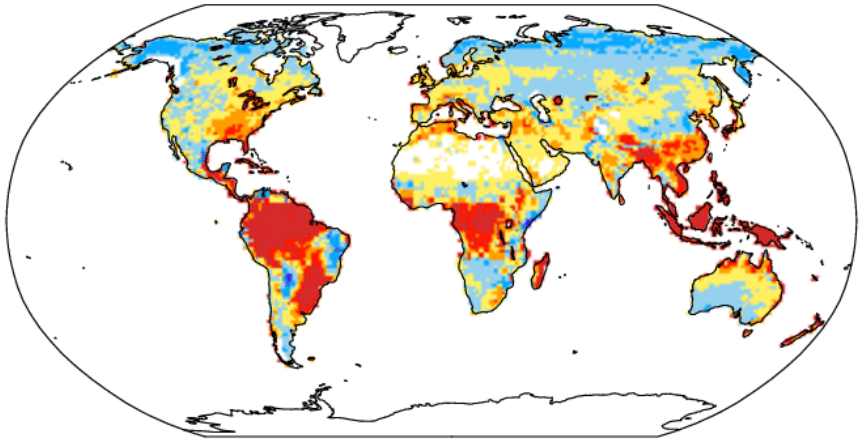
Reduced biases in CLM4.5

ANN Latent Heat bias (obs: FLUXNET MTE)

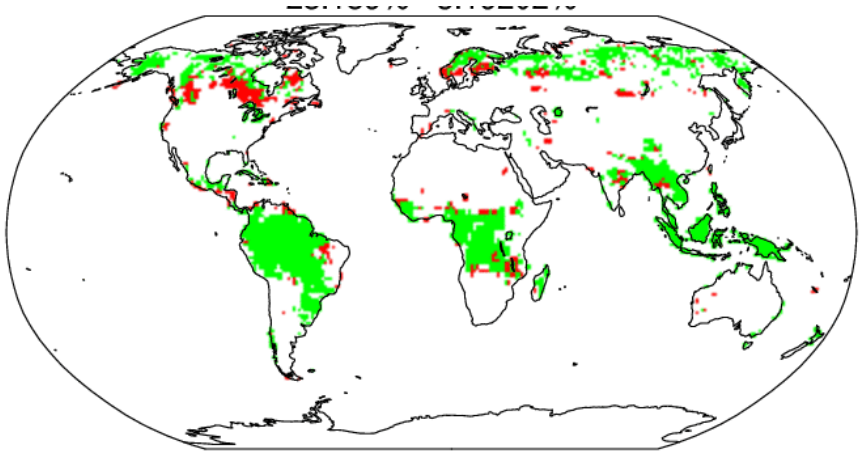
CLM4.5BGC



CLM4CN

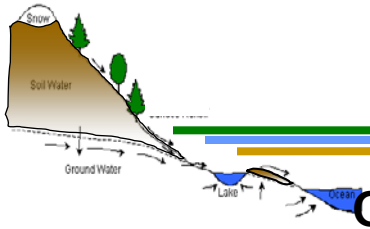


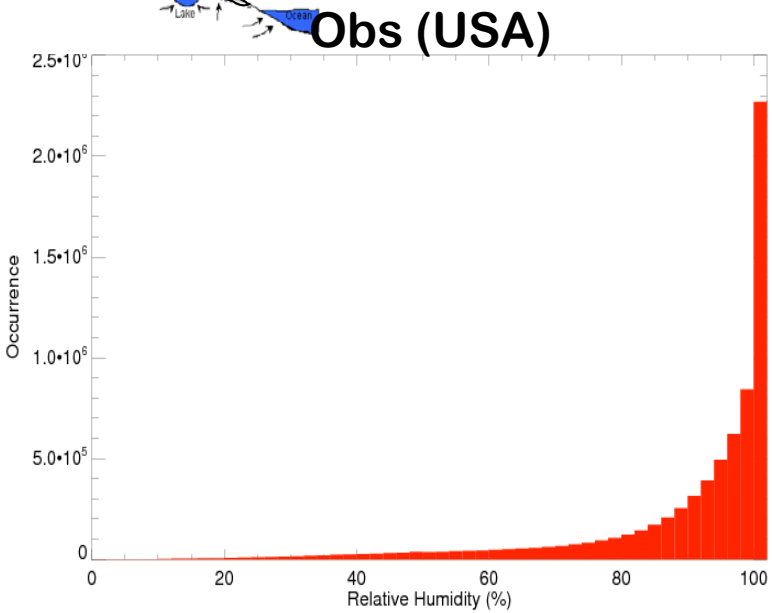
Green: Improved in CLM4.5
Red: Degraded in CLM4.5

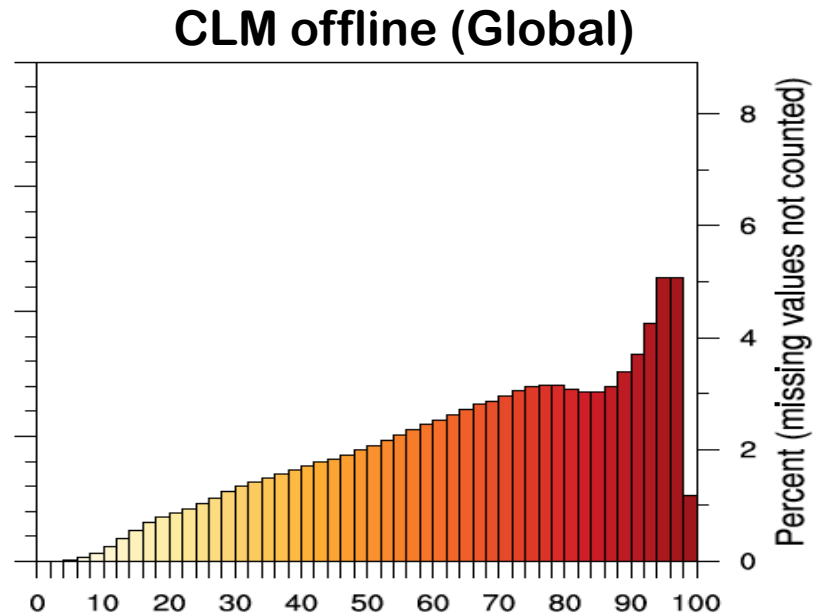


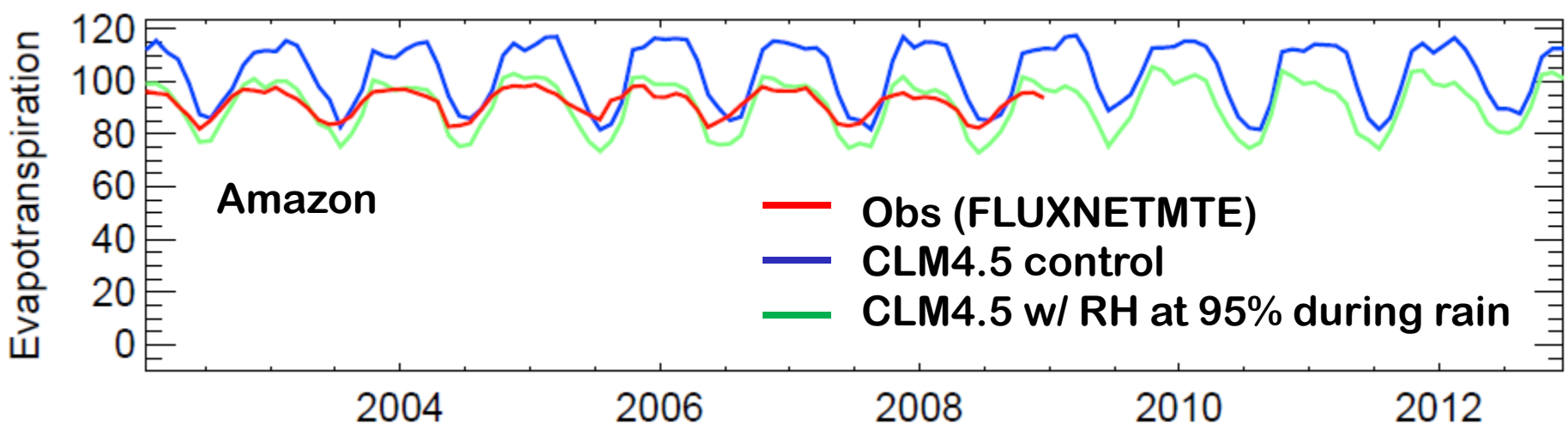
	CLM4	CLM4.5
LH (W m^{-2})	8.9	5.9
GPP (gC m^{-2} d^{-1})	0.41	0.07
Albedo (%)	-0.41	-0.52

Forcing uncertainty: RH during rain events

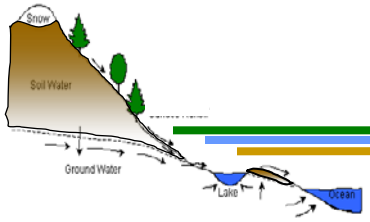






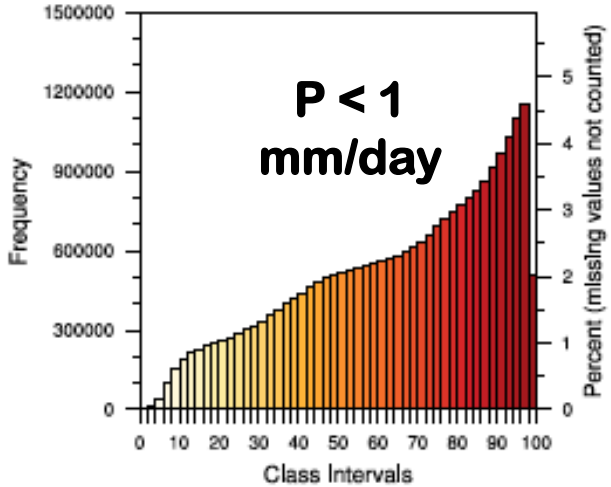


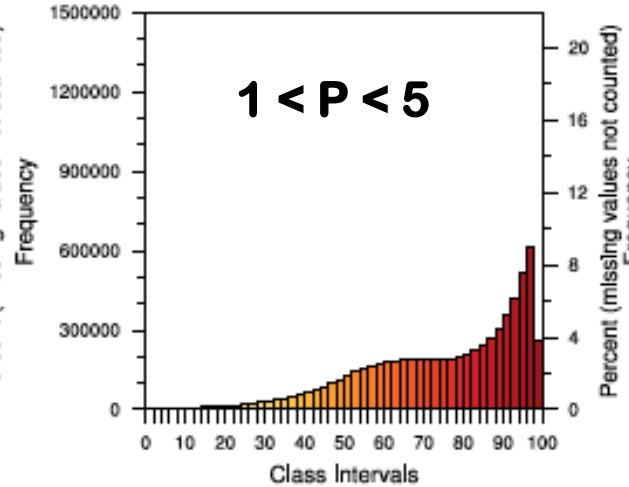
Figs. A. Slater, S. Kumar, S. Swenson

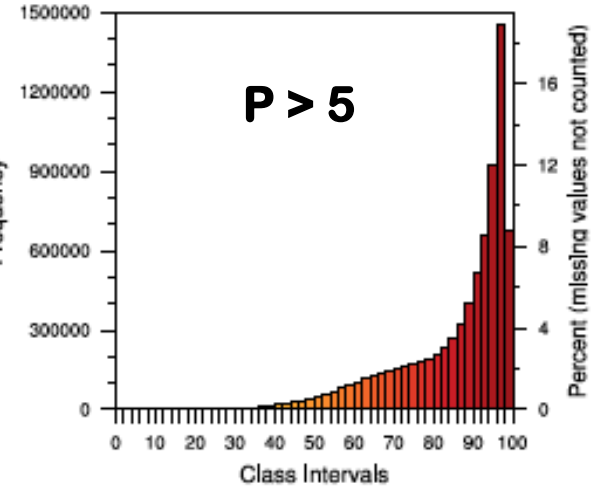
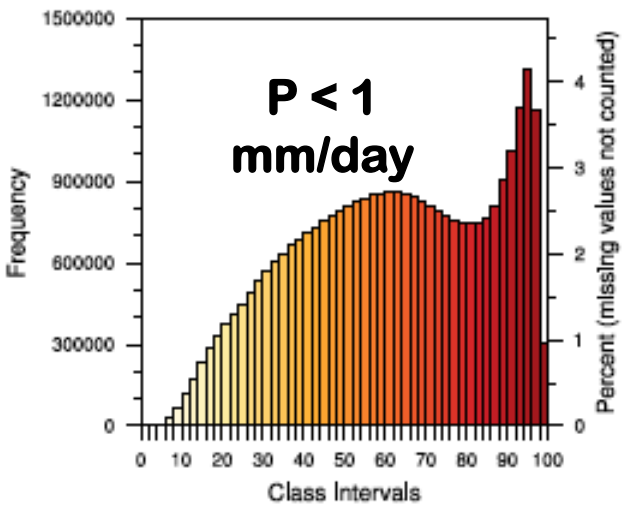
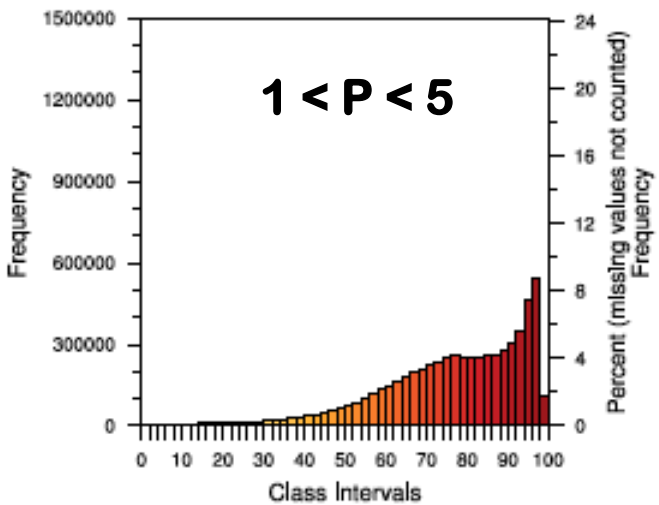
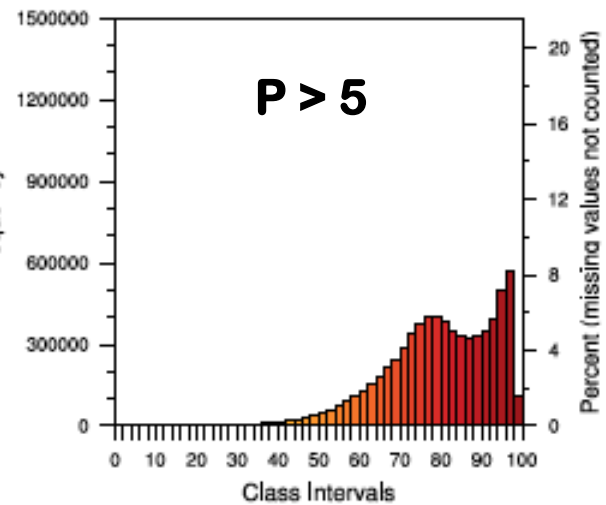


RH Histogram during rainy hours, JJA

Coupled



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