Whiteface Mtn. Field Station, 1500m ASL

Intercomparison between LIS-Noah and LIS-HTESSEL surface flux partitioning

ASRC, Albany, NY

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In this talk...

- Research Context
- Impetus for OpenIFS and Workflow
- Future Plans

Research Foci:

1. Assessing variability, long-term trends, and change in the Earth's coupled water, energy and carbon cycles.

2. Understanding the role of land-atmospheric coupling in climate variability, climate extremes and the predictability of regional climate.

3. Developing and applying process-oriented diagnostics that help identify and attribute model errors.

GEWEX GLASS GHP

Research Data and Models:

Observational data:

- satellite retrievals (MODIS, AIRS, AMSR, SMAP)
- routine in-situ (met, raobs, EC, BL profilers, tall towers, soil moisture) data, field campaigns incl. 2015 Enhanced Soundings for Local Coupling Studies (Ferguson, Santanello, and Gentine, 2016; https://www.arm.gov/campaigns/sgp2015eslcs)

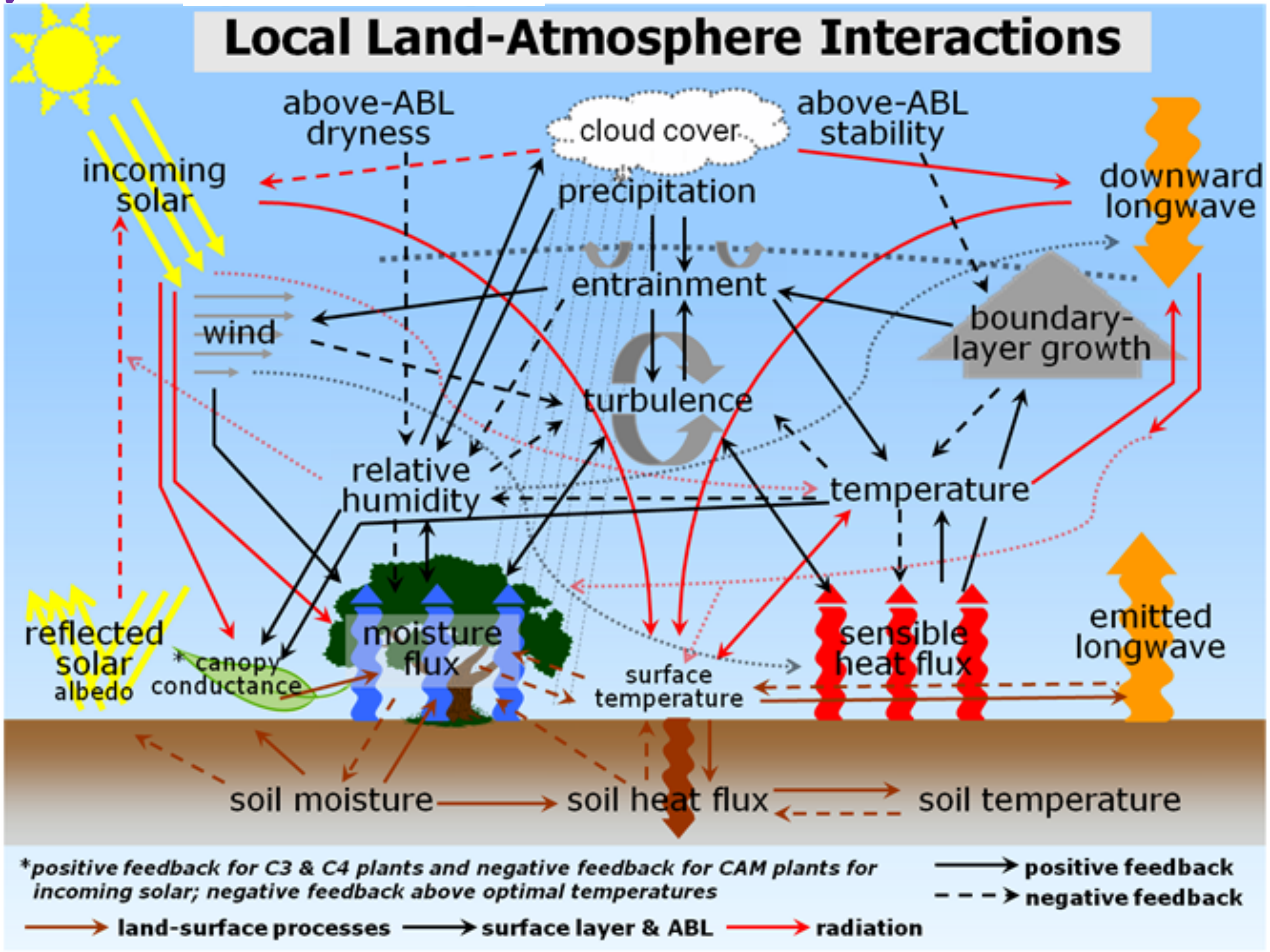
Models:

- in-house: land-only (offline), coupled Weather Research and Forecasting (WRF), coupled WRF w/DA;

- other: North American Land Data Assimilation System (NLDAS), CMIP5/6, global atmospheric reanalyses

Fully-coupled system!

Ek complexity

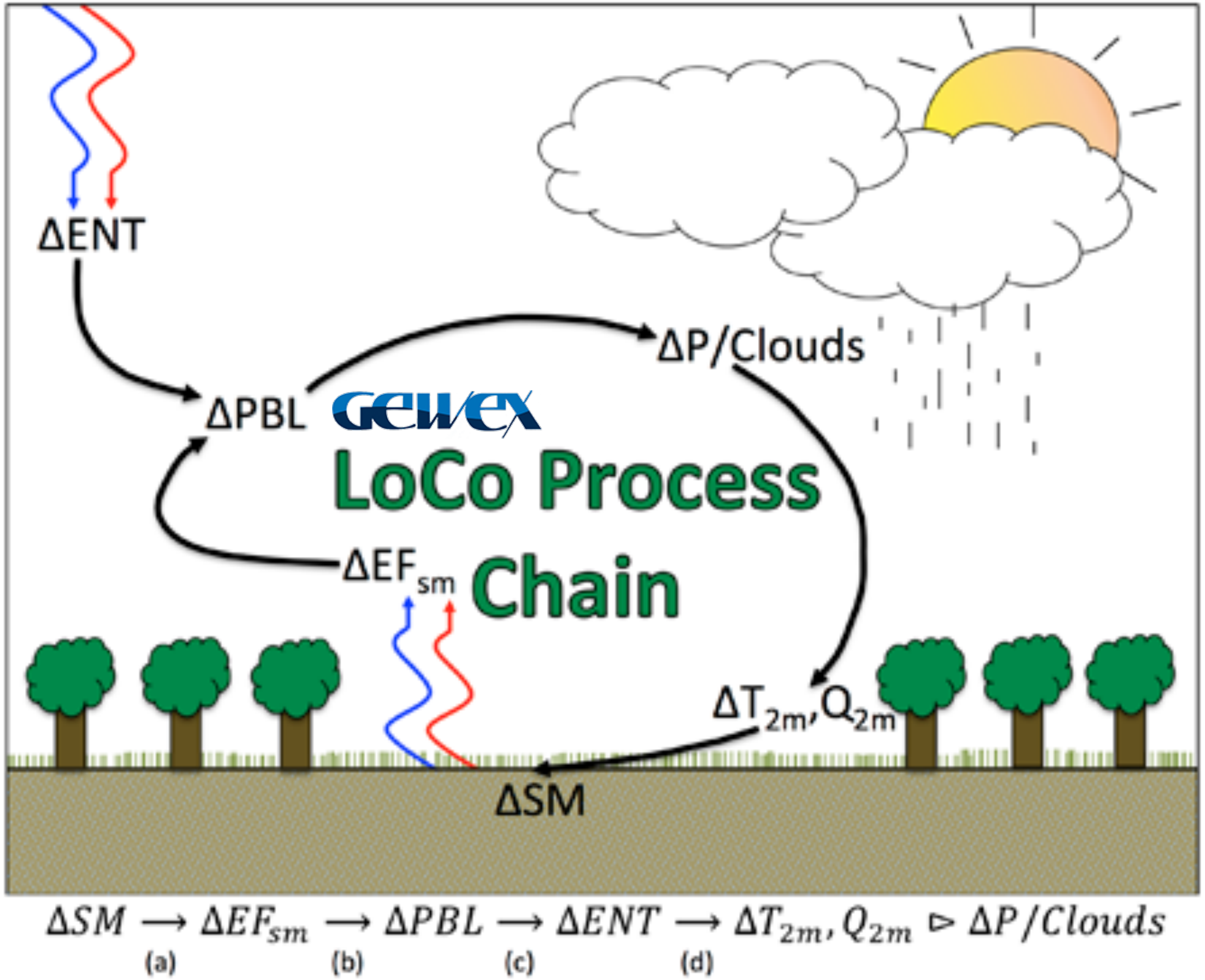


Ek, M. B., and A. A. M. Holtslag, 2004: Influence of Soil Moisture on Boundary Layer Cloud Development. J Hydrometeorol., 5, 86-99.

Fully-coupled system!

simplified LoCo form…

ΔSM→ΔEF→ΔLCL→Δclouds/P→ΔSM



All coupling starts **locally**. The land signal is a necessary but not sufficient pre-requisite for land-atmosphere coupling.

Ferguson, C.R., E.F. Wood, and R.K. Vinukollu, 2012: A Global Intercomparison of Modeled and Observed Land–Atmosphere Coupling. J. Hydrometeor., 13, 749–784.

Land-atmosphere coupling recap

DEF: The degree to which anomalies in the land surface state (i.e., soil wetness, soil texture, surface roughness, temperature, and overlying vegetation composition and structure) can affect (through complex controls on the partitioning of surface turbulent fluxes) the planetary boundary layer (PBL), mesoscale circulations, and in extreme cases-- rainfall generation.

"the single most fundamental criterion for evaluating hydrologic and atmospheric model performance" (Betts 2004, 2009)

Cases when realistic coupling especially matters:

Diurnal cycle (T2, q2, clouds and rainfall; e.g. Song, Ferguson and Roundy, 2016)
Drought evolution and recovery; e.g. Roundy, Ferguson and Wood, 2013)
Heatwave severity; e.g. Fischer et al., 2007)

When large-scale synoptic forcing is weak and spatial gradients in surface fluxes are sufficient enough to drive mesoscale circulations (e.g. Taylor and Ellis, 2006)

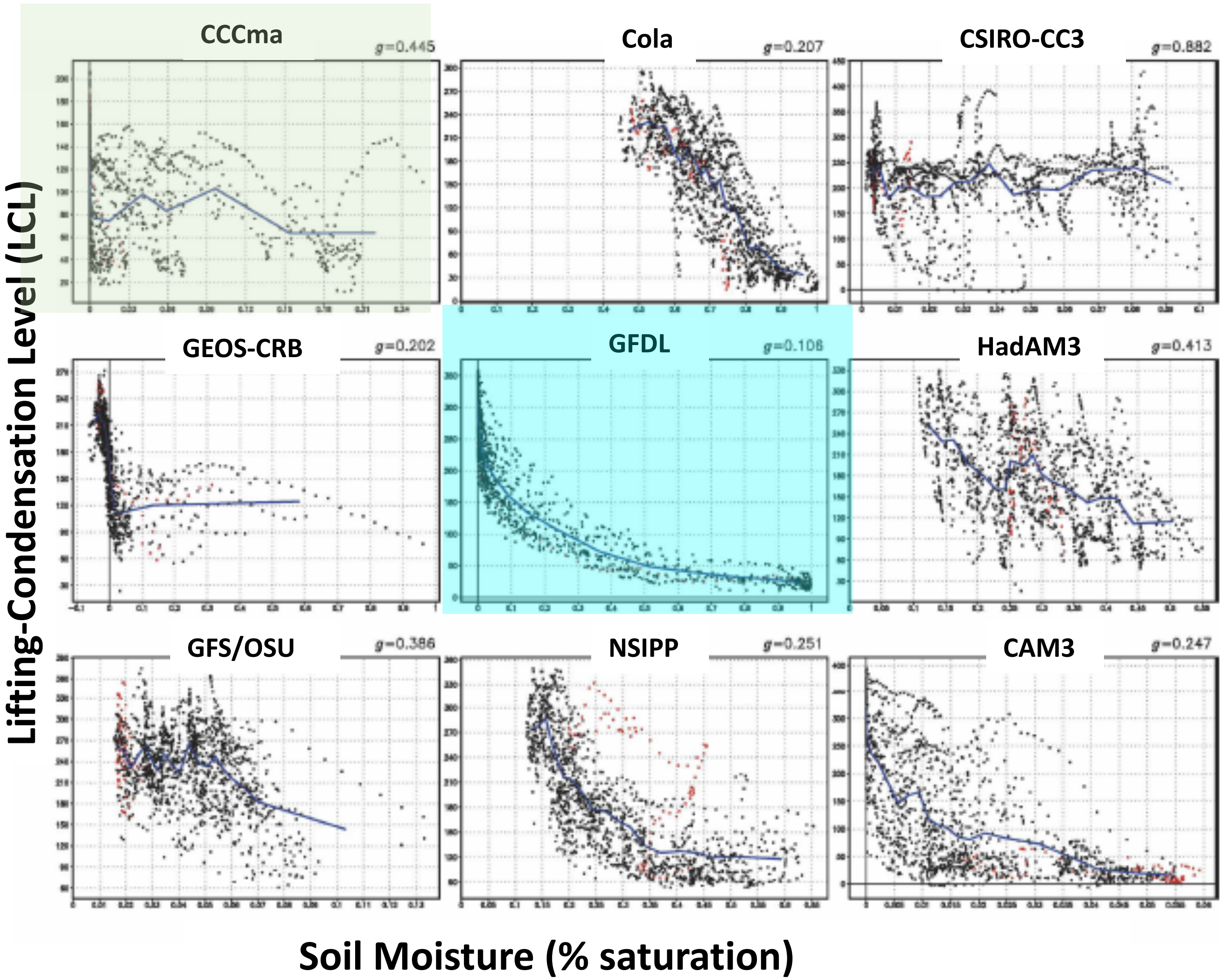
Sensitivity ∩ Variability ∩ Memory (Dirmeyer and Halder, 2017)
(L-A covariability and large anomalies that persist)

Modeled coupling

GLACE-1 results

ΔSM→ΔEF→ΔLCL→Δclouds/P→ΔSM

GLACE-1 revealed exceptional model spread in SM-LCL covariance

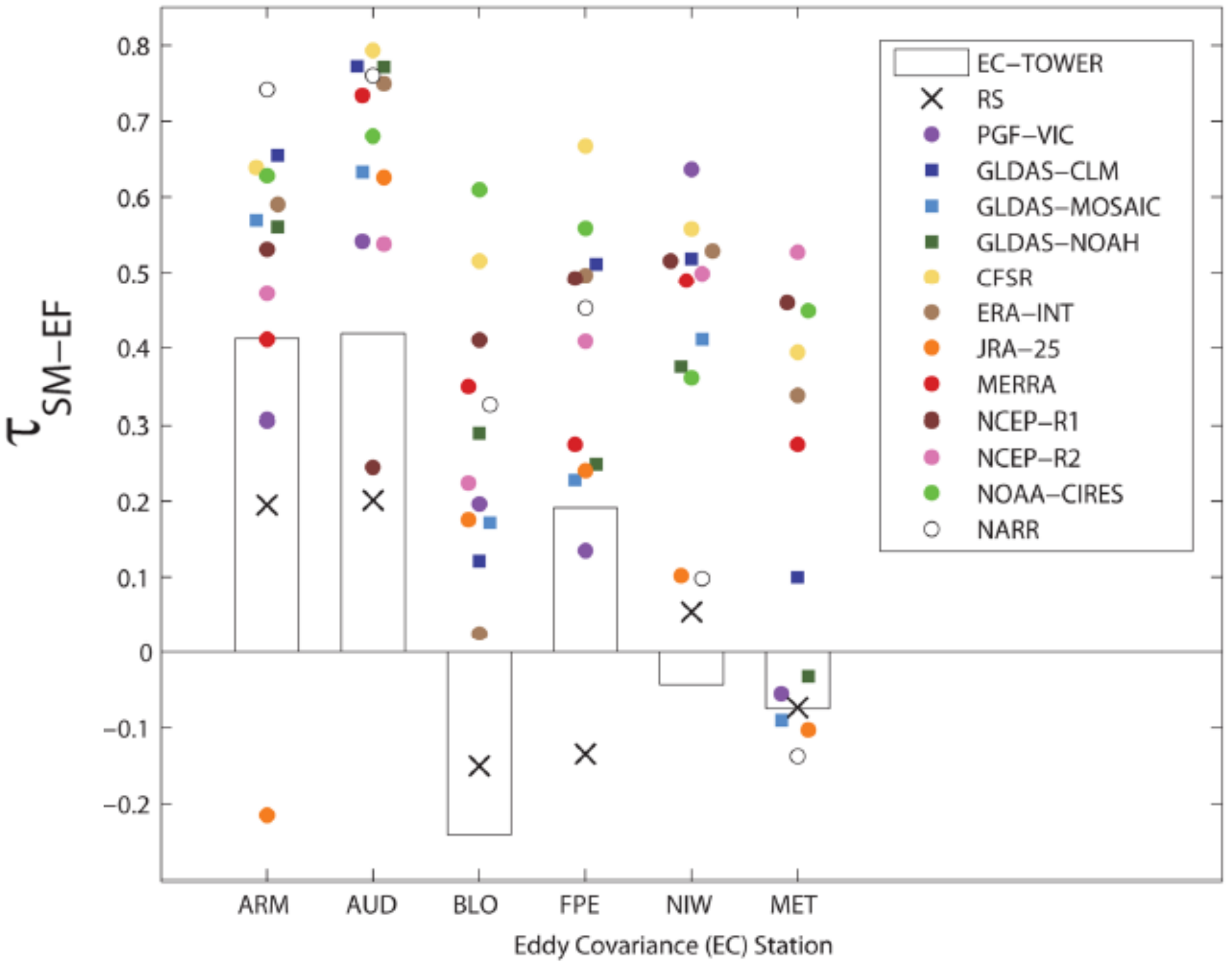


Dirmeyer, P. A., R. D. Koster, and Z. C. Guo, 2006: Do global models properly represent the feedback between land and atmosphere? Journal of Hydrometeorology, 7, 1177-1198.

Modeled coupling
FLUXNET comparison

ΔSM→ΔEF→ΔLCL→Δclouds/P→ΔSM

Models are too strongly coupled in SM-EF 'leg'

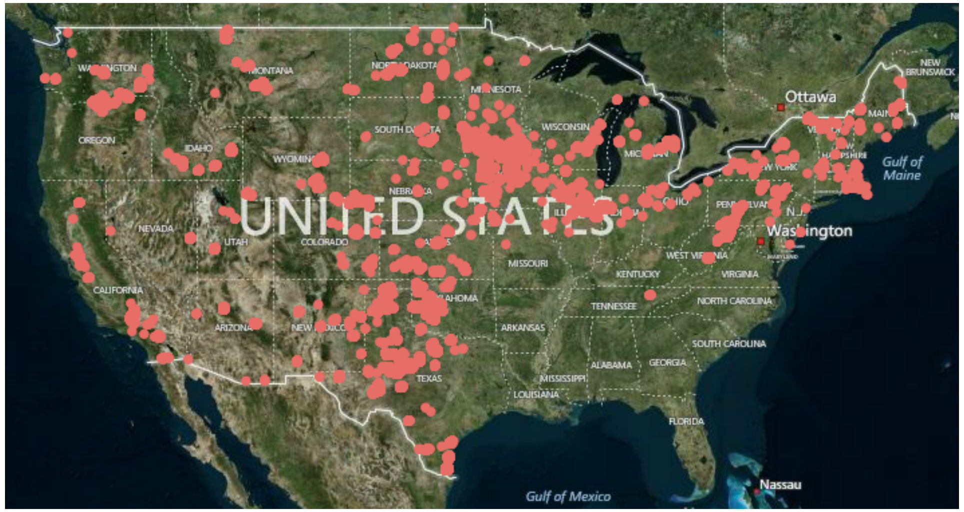


Ferguson, C.R., E.F. Wood, and R.K. Vinukollu (2012), A global inter-comparison of modeled and observed land-atmosphere coupling, J. Hydrometeor., JHM-D-11-0119, 13(3), 749-784, doi:10.1175/JHM-D-11-0119.1.

Impetus for OpenIFS: "The role of soil moisture in weather predictability over the U.S. Great Plains" (NASA SMAP, 2016-2019)

Science Question: How will assimilation of high-resolution NASA Soil Moisture Active/Passive (SMAP) data refine modeled land-atmosphere coupling and lead to improvements in short-term (6-30hr) weather and wind energy forecasts?

Approach: Undertake a series of idealized experiments, designed in a manner that will provide a clean distinction between the roles of model physics, local-remote soil moisture affects, SMAP data assimilation (DA), and synoptic weather on forecast skill.



Active wind farms (2016)

Impetus for OpenIFS:

1. Hypothesis: the best DA results will derive from the most realistically coupled model.

2. Noah and HTESSEL LSMs benefit from 20+ and 30+ year operational development histories, respectively. There should be more direct inter-comparisons.

3. U.S. operations are transitioning from Noah3.6 to Noah-MP LSM; Noah-MP already implemented in National Water Model (WRF-Hydro) and soon to be implemented in NCEP operations (NLDAS, GLDAS, GFS, and CFS)

Suggestion: An opportune time for inter-comparison as part of needed Noah-MP critical evaluations.

OpenIFS @ UAlbany:

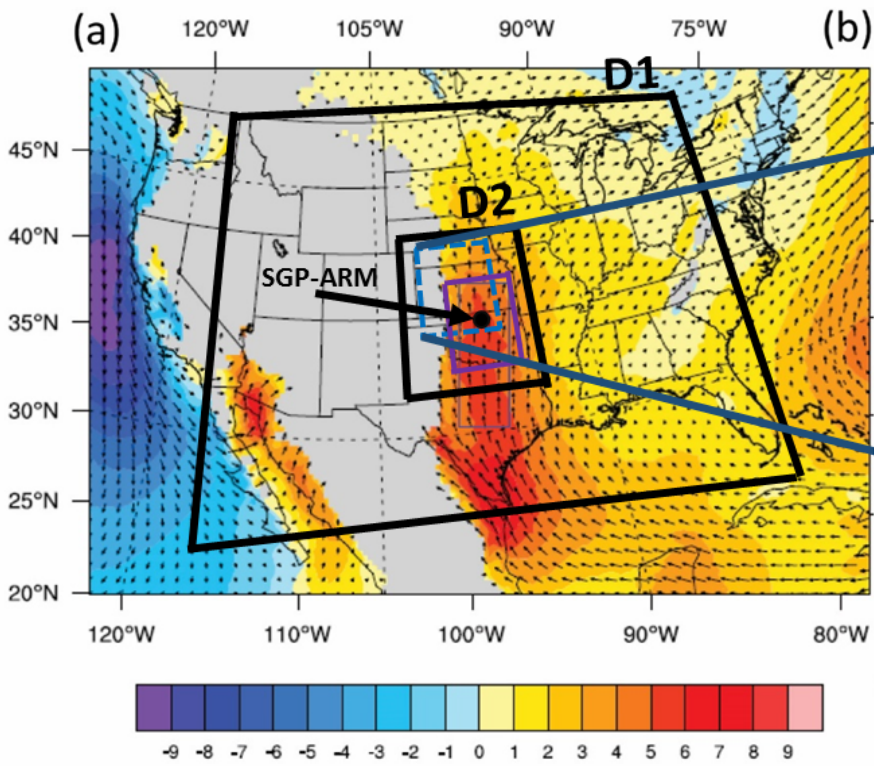
1. Implement common (or consistent) surface parameters at 1km resolution. Incl.: soil properties, landcover, topography, LAI, greenness fraction, rooting depth, and albedo. For LAI, greenness and albedo: realtime daily or 4-day. Also, implement common soil layering geometry and common meteorological forcing (NLDAS-3) at 3km, 1-hourly.

2. Add HTESSEL to NASA Land Information System (LIS; Kumar et al., 2006)

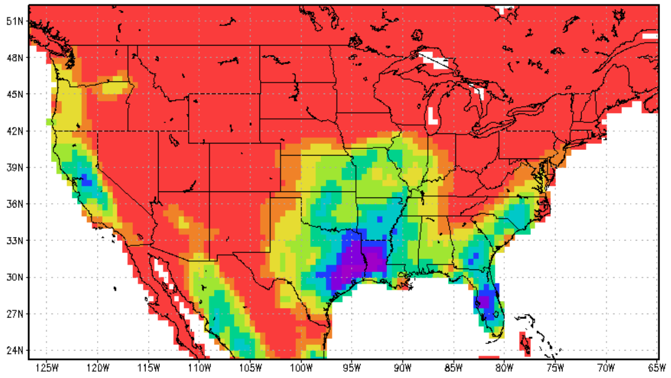
3. Quantify off-line NoahMP and HTESSEL uncertainty using available in-situ data and NASA Land Verification Toolkit (LVT)

4. Couple LIS-HTESSEL to NASA Unified WRF (NU-WRF; Peters-Lidard et al., 2015)

5. Intercompare soil moisture data assimilation (DA) performance in LIS/NU-WRF using NoahMP and HTESSEL

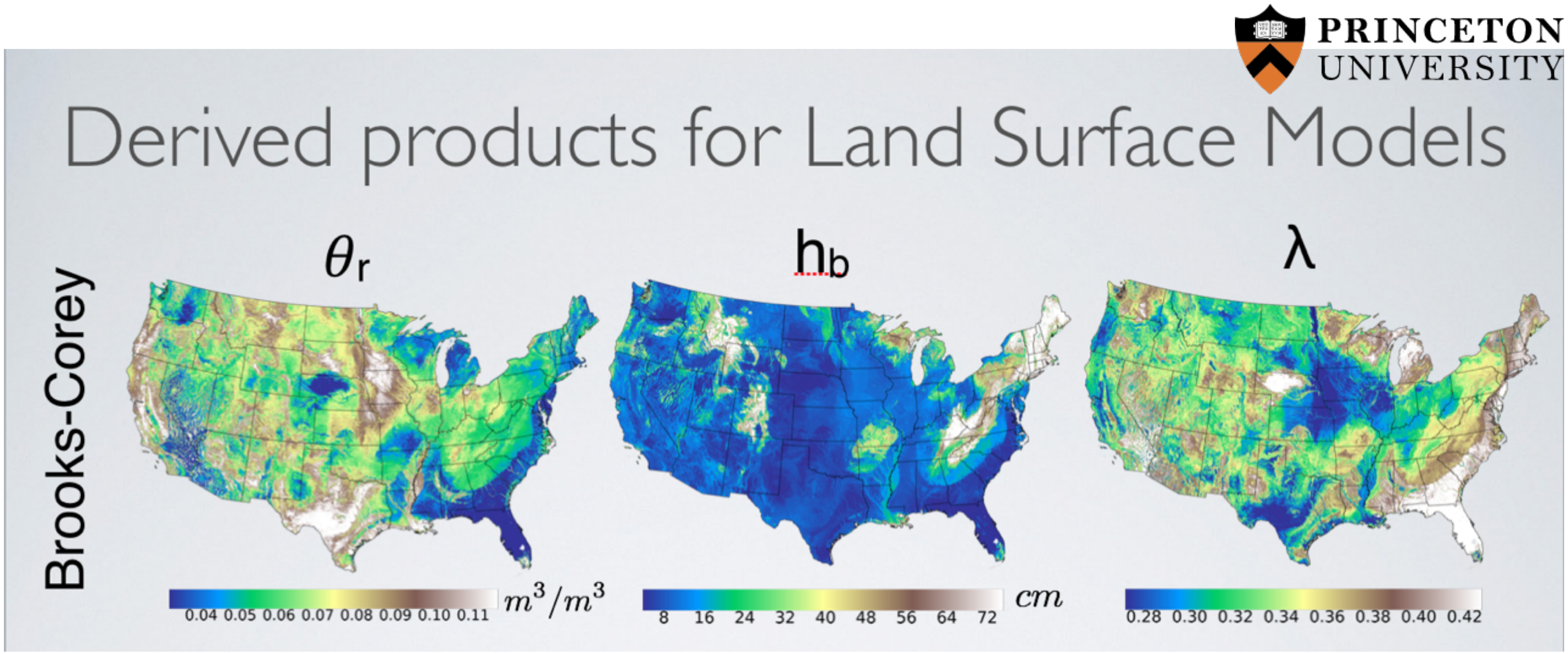


(Above) Averaged 925 hPa wind vectors and the meridional wind speed (shaded; m s-1) from the North American Regional Reanalysis (NARR) during JJA for 1979-2011 (taken from Du and Rotunno 2014; their Fig. 6)



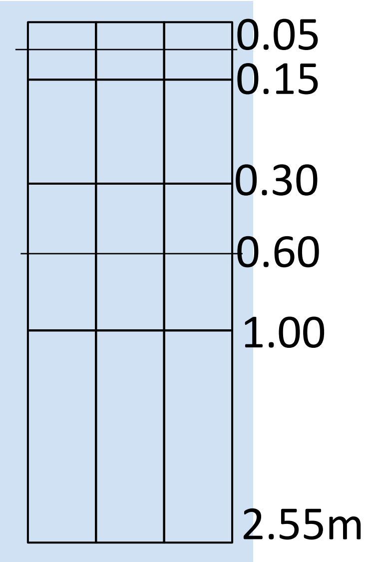
(Left) First HTESSEL testcase: 20120101 transpiration

POLARIS: A 30m probabilistic soil series map of the contiguous U.S.



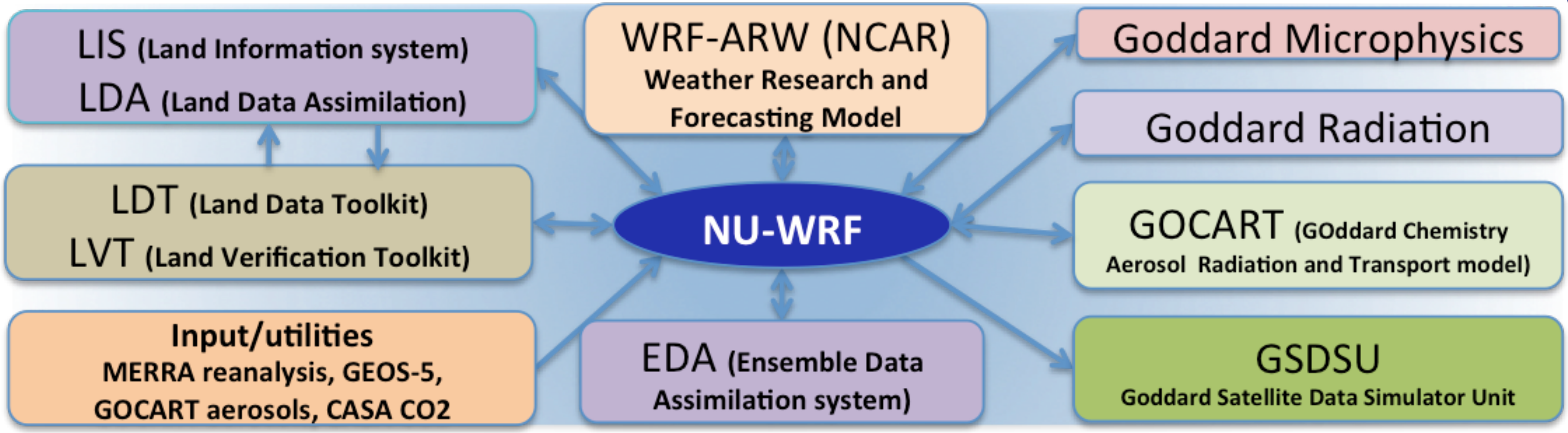
Residual soil moisture ($\boldsymbol{\theta}$r), Sat. soil matric potential (hb), pore size distribution index ($\boldsymbol{\lambda}$)

New layering geometry (after POLARIS)



Nathaniel W. Chaney, Eric F. Wood, Alexander B. McBratney, Jonathan W. Hempel, Travis W. Nauman, Colby W. Brungard, Nathan P. Odgers, POLARIS: A 30-meter probabilistic soil series map of the contiguous United States, Geoderma, Volume 274, 15 July 2016, Pages 54-67, ISSN 0016-7061, https://doi.org/10.1016/j.geoderma.2016.03.025.

LIS and NU-WRF:



LIS. A multi-LSM modeling environment. LDT is the pre-processor. LIS calls the forcing and parameters from LDT. LVT is the post-processor and intercomparison toolkit. NU-WRF can be run in coupled mode with LIS simultaneously or with LIS output. NASA SPoRT is running LIS/NU-WRF for weather forecasts.

Key utility of LIS is ability to perform a long-term off-line (land-only) spinup (SM) of precise land model configuration that will be used in coupled NU-WRF simulation. Land initial conditions have been key for short term forecasts (surface SM and veg) and seasonal-to-climate scale (veg and root zone SM).

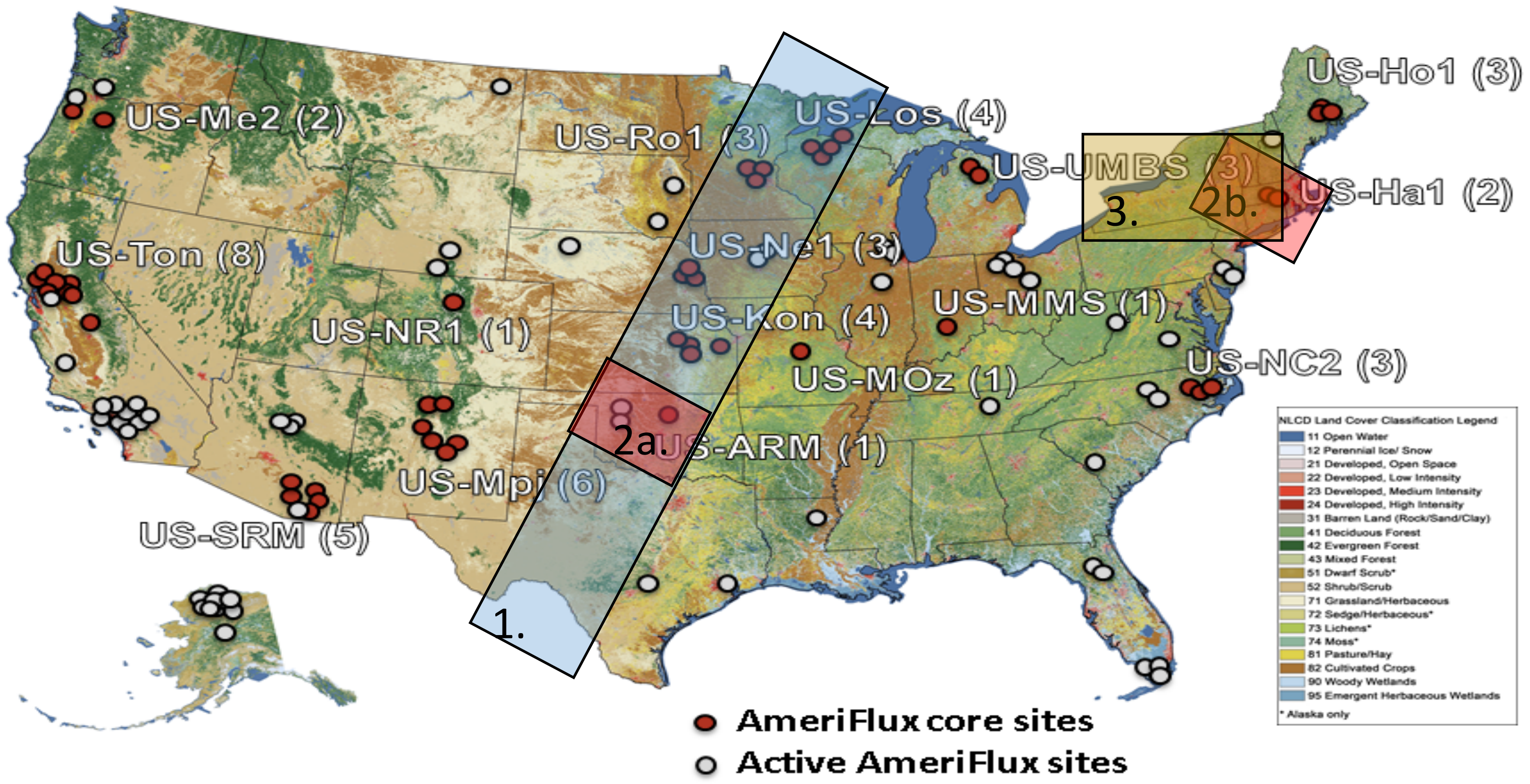
OpenIFS @ UAlbany Summary :

1. So far, we have completed updates to surface parameters and soil layering for NoahMP. HTESSEL is next.

2. Seeking collaborators to help test HTESSEL parameter sensitivity and to compile coupled land-atmosphere observational verification datasets

Potential future observational verification of coupling

Enabling model evaluation and development over regions other than SGP



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Comments?