Verifying Coupled Land-Hydro: NWP to S2S, and longer timescales

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with material from:
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Ahmed Tawfik (formerly NCAR),
Craig Ferguson (SUNY-Albany),
and the GEWEX GLASS LoCo WG,
i.e. Kirsten Findell (GFDL) et al,
Grant Firl (NCAR/RAL/JNT) & the DTC

Developmental Testbed Center Metrics Workshop
30 July – 01 August 2018

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Tara's questions:

Users: What is(are) the target audience(s) for your temporal application or specialty? What products do they typically use and how? What level of skill is considered to signify "success"?

Traditionally 2-m T & RH, 10-m wind for NWP, Hydro & S2S forecasting, plus all the usual NWP metrics, e.g. ***500mb AC****,* ***profiles****, etc. But now water resources & drought, e.g. veg. cover/density (veg stress), snowpack, streamflow, flooding/standing water, etc.*

Current Status: What are the legacy verification methods used for this particular application? How does EMC currently verify this aspect of models currently and is this sufficient? What are the diagnostics/metrics needed for evaluating performance? How are they similar to other applications? How are they different? What observation data sets are available to conduct a comprehensive evaluation?

Traditionally 2-m T & RH, 10-m wind, etc, per above.

Obs data sets: Surface fluxes/radiation, comprehensive energy, water & biogeochemical evaluation & other process-level metrics for plants, soils, snow, hydrology/groundwater, plus PBL information (e.g. height, profiles & mean properties).

What's Missing: What aspects should be verified but are currently not?

Per above, re-cast into ***Land-Atmosphere Interaction (L-AI) Coupling metrics****. (See subsequent slides.)*

Other Ques. re: Land

How does land surface influence forecasts at different time scales? How much of the errors are coming from poor atmospheric predictions vs. LSM prediction? Also relevant: What are the differences between verifying S2S forecasts and Global NWP forecasts?

Land has a big impact, from the first diurnal cycle to S2S and longer. NWP vs S2S: Still need to get the right land-hydro states, fluxes, ***diurnal cycle****, &* ***land-atmos. coupling****.*

Hierarchical Testing: Which diagnostics can be used to evaluate results from simplified versions of the model (e.g., single column model, low-res global etc.), so 1) we cut down on non-linear interactions among components, and 2) we can do some tests without using too much computer power (helpful for the research community to participate).

Land-hydrology states, fluxes, and ***L-AI coupling*** *evaluated at all steps along the way.*

Land-Atmosphere Interactions: Important!

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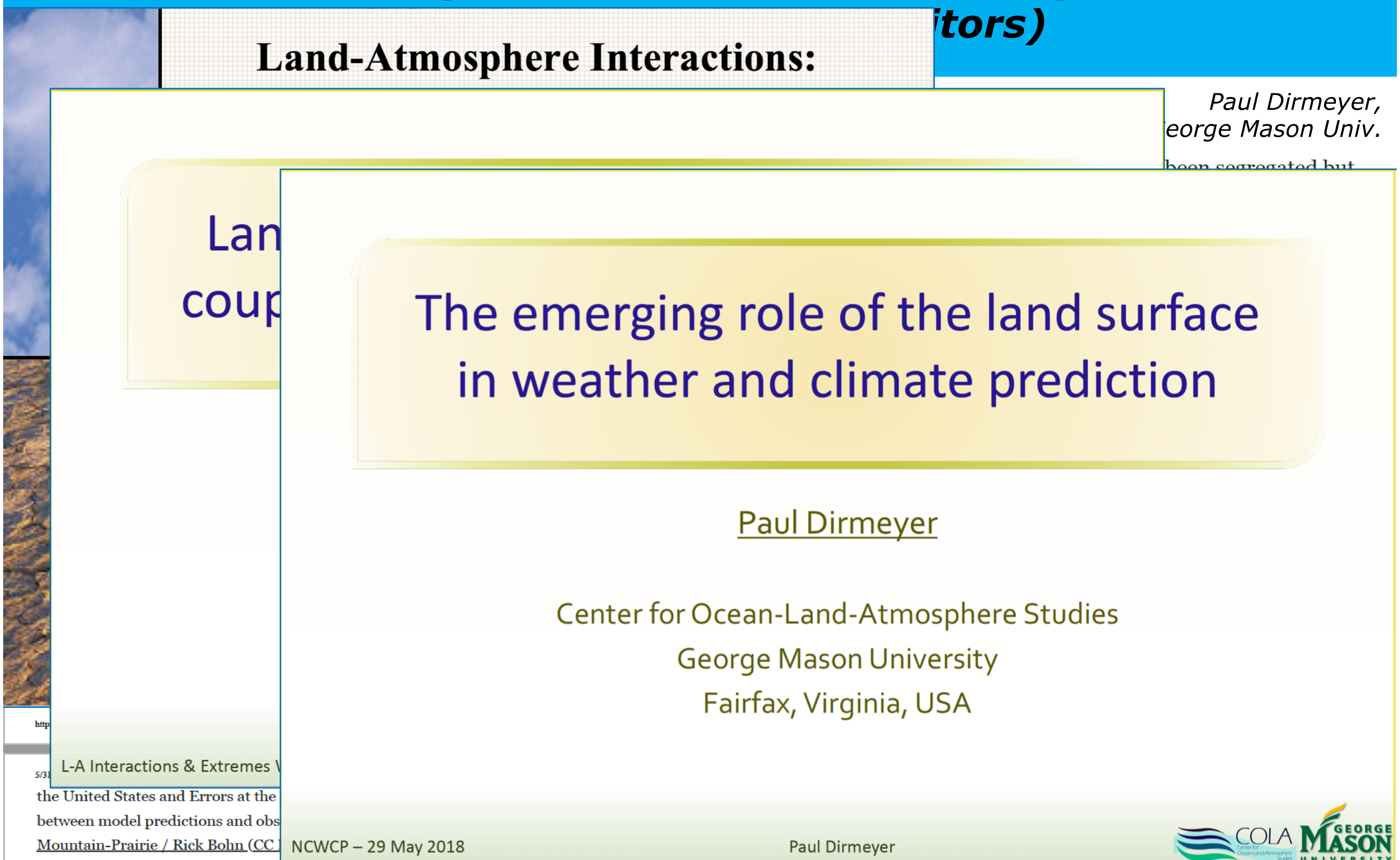

Land-Atmosphere Interactions: Important!

First results of the Land-Atmosphere Feedback Experiment (LAFE)

Volker Wulfmeyer[1], David D. Turner[2], B. Baker[3], R. Banta[2], A. Behrendt[1], T. Bonin[4], W.A. Brewer[2], M. Buban[3,5], A. Choukulkar[4], E. Dumas[3,5], R.M. Hardesty[4], T. Heus[6], J. Ingwersen[7], D. Lange[1], T.R. Lee[3,5], S. Metzendorf[1], S.K. Muppa[1], T. Meyers[3], R. Newsom[8], E. Olson[9], M. Osman[5,10], J. Santanello[11], C. Senff[4], F. Späth[1], T. Wagner[9], T. Weckwerth[12]

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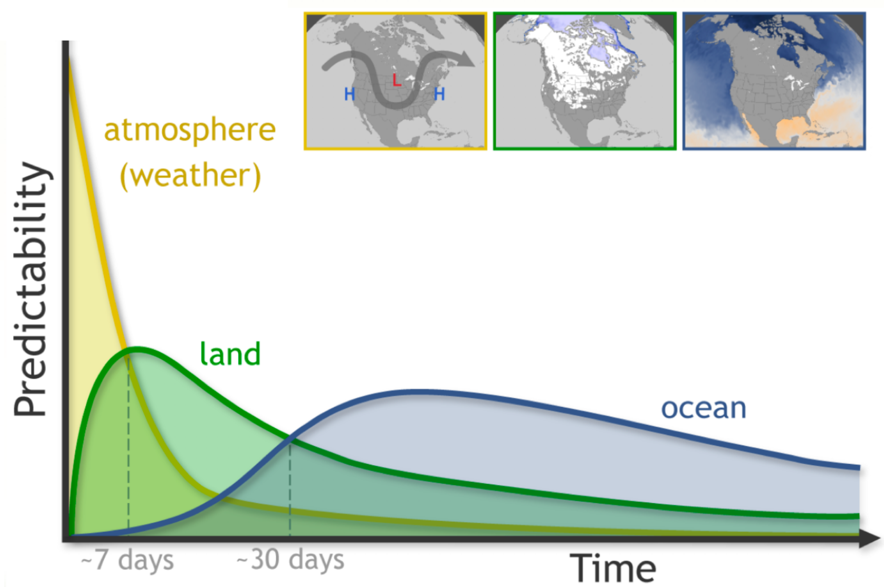
8: Pacific Northwest National Laboratory (PNNL), Richland, USA
9: Space Science and Engineering Center (SSEC), University of Wisconsin-Madison, USA
10: The University of Oklahoma and NOAA/National Severe Storms Laboratory, Norman, USA
11: NASA Goddard Space Flight Center, Greenbelt, USA
12: National Center for Atmospheric Research (NCAR), Earth Observation Laboratory, Boulder, USA

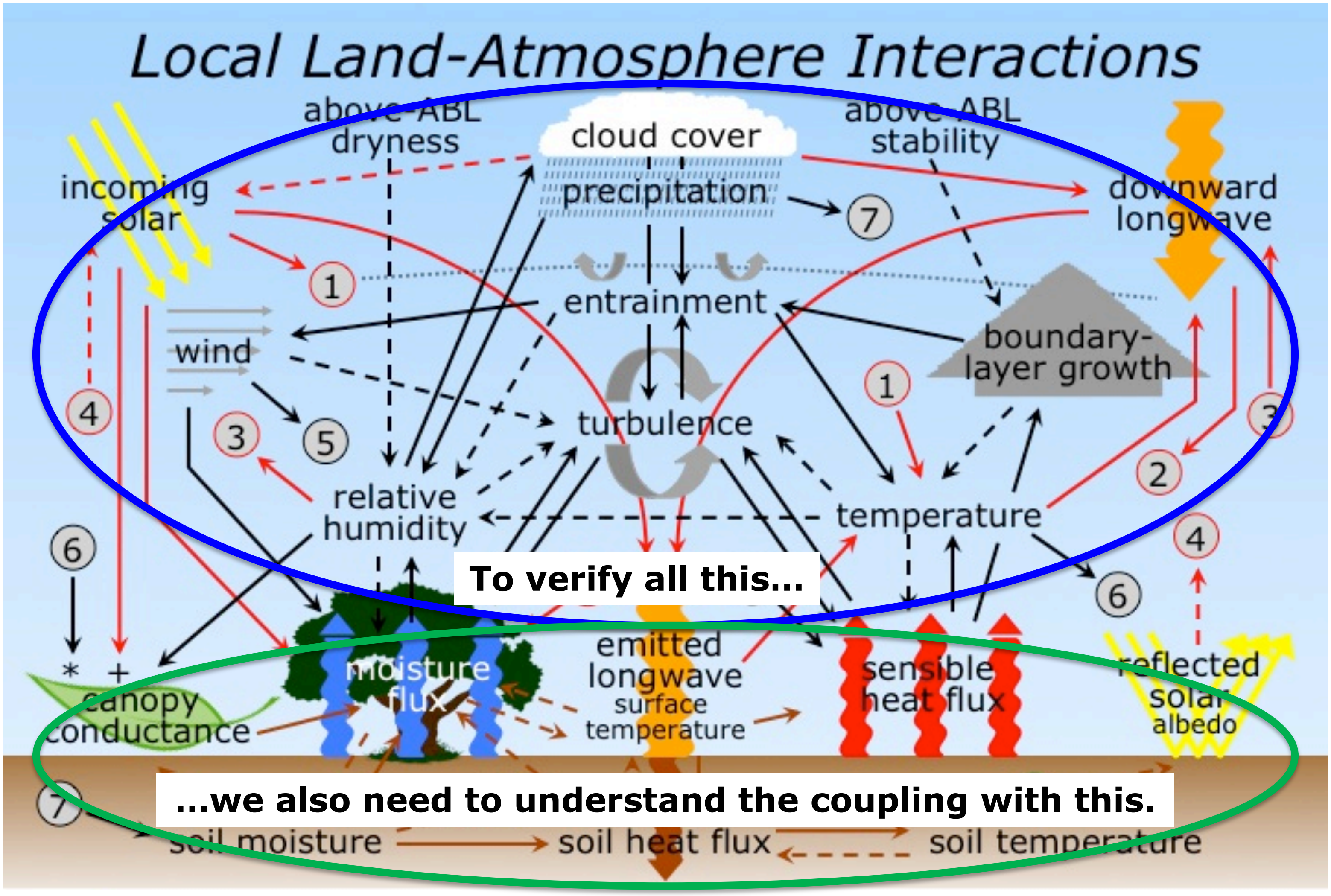
Why Land?

Predictability and Prediction

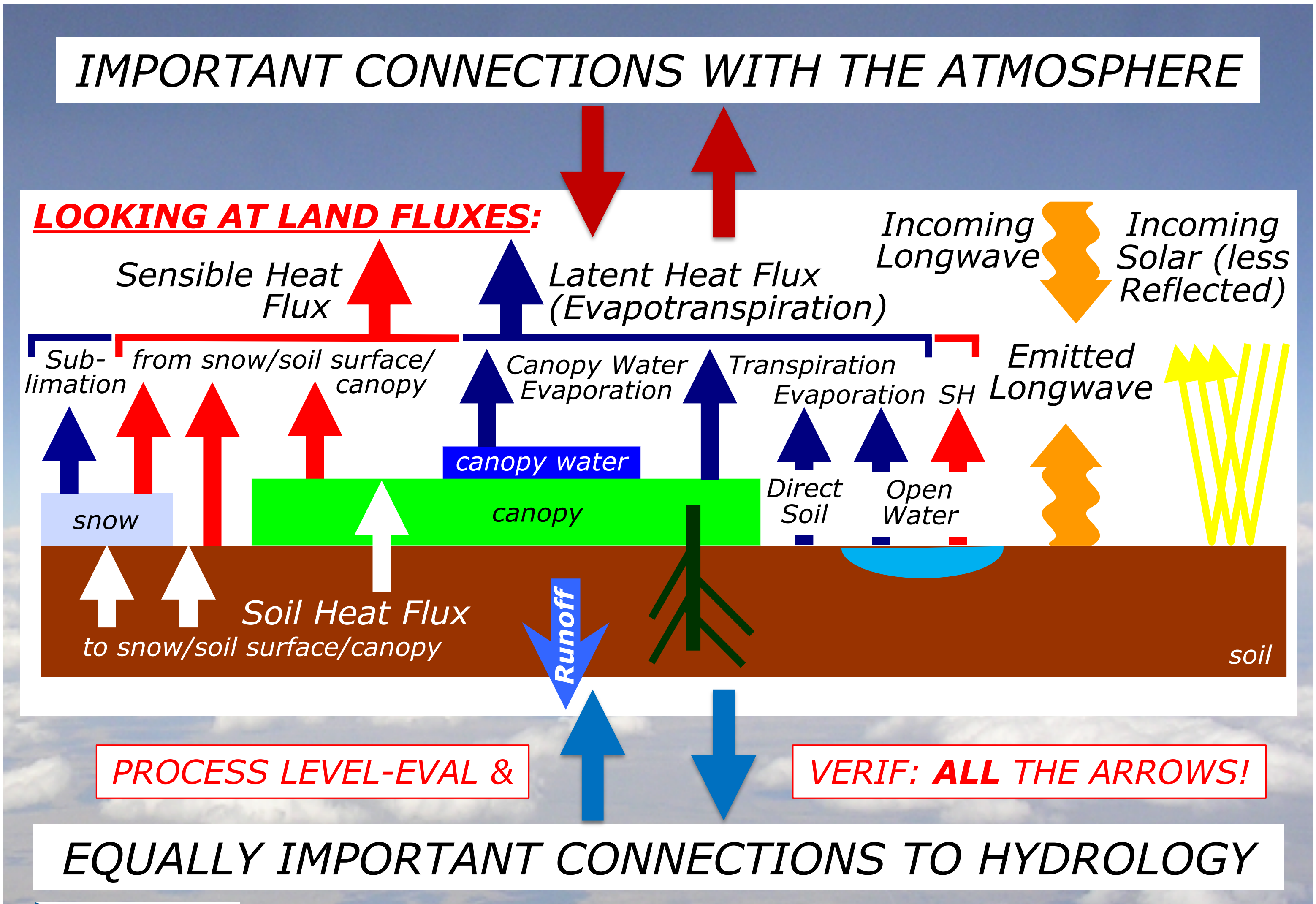


Paul Dirmeyer

COLA Center for Ocean-Land-Atmosphere Studies
GEORGE MASON UNIVERSITY

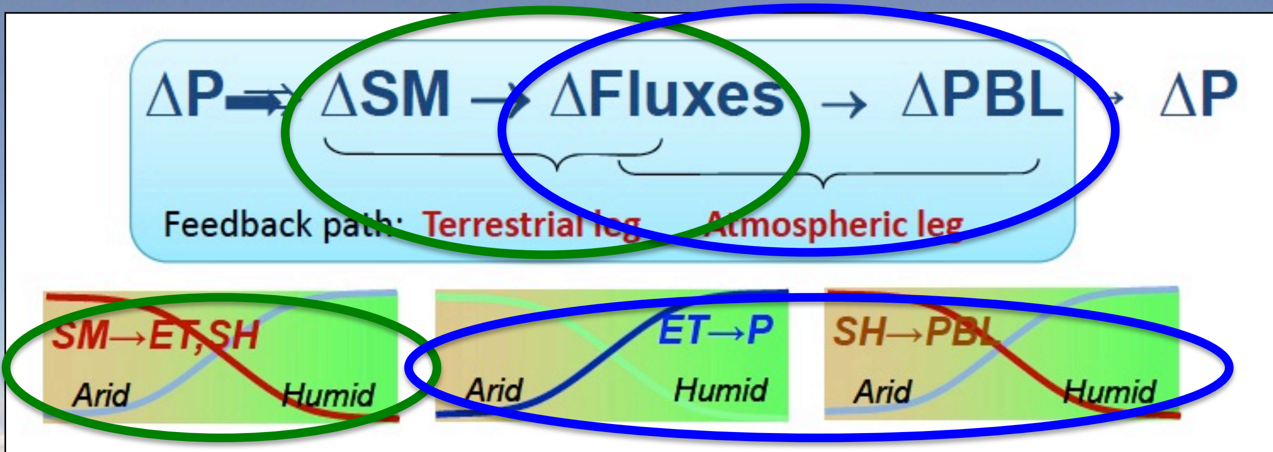


- **Many land & atmospheric processes and land-atmos feedbacks, some competing.** ***How to verify all these processes in models? What Metrics?***


IMPORTANT CONNECTIONS WITH THE ATMOSPHERE
LOOKING AT LAND FLUXES:
Sensible Heat Flux
Latent Heat Flux (Evapotranspiration)
Incoming Longwave
Incoming Solar (less Reflected)
Sub-limation
from snow/soil surface/ canopy
Canopy Water Evaporation
Transpiration
Evaporation
SH
Emitted Longwave
canopy water
Direct Soil
Open Water
snow
canopy
Soil Heat Flux
to snow/soil surface/canopy
Runoff
soil
PROCESS LEVEL-EVAL &
VERIF: ALL THE ARROWS!
EQUALLY IMPORTANT CONNECTIONS TO HYDROLOGY

Land-Atmosphere Interactions

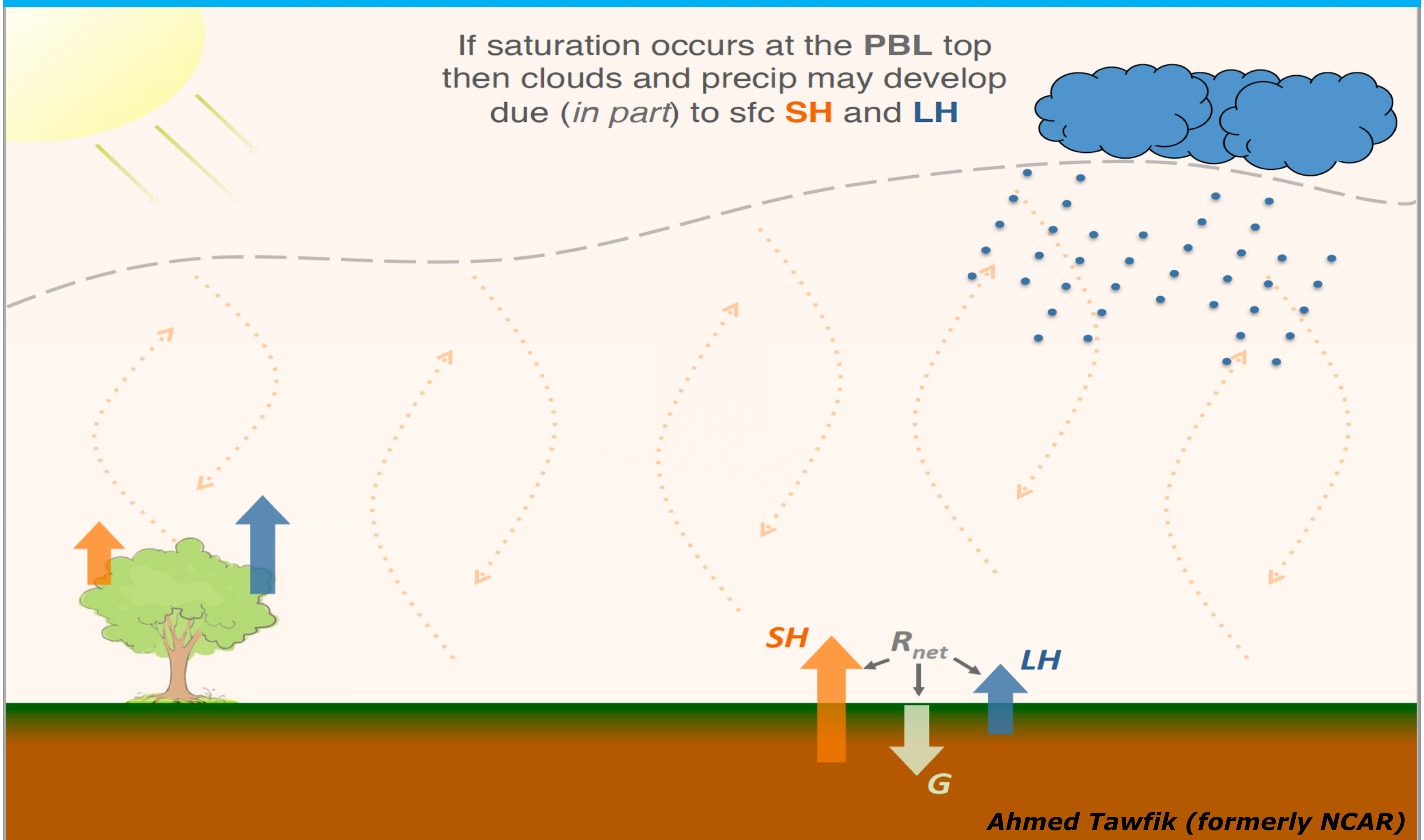
Land-Atmosphere Feedbacks "Stand on 2 legs"



Paul Dirmeyer, George Mason Univ., Joe Santanello, NASA/GSFC.

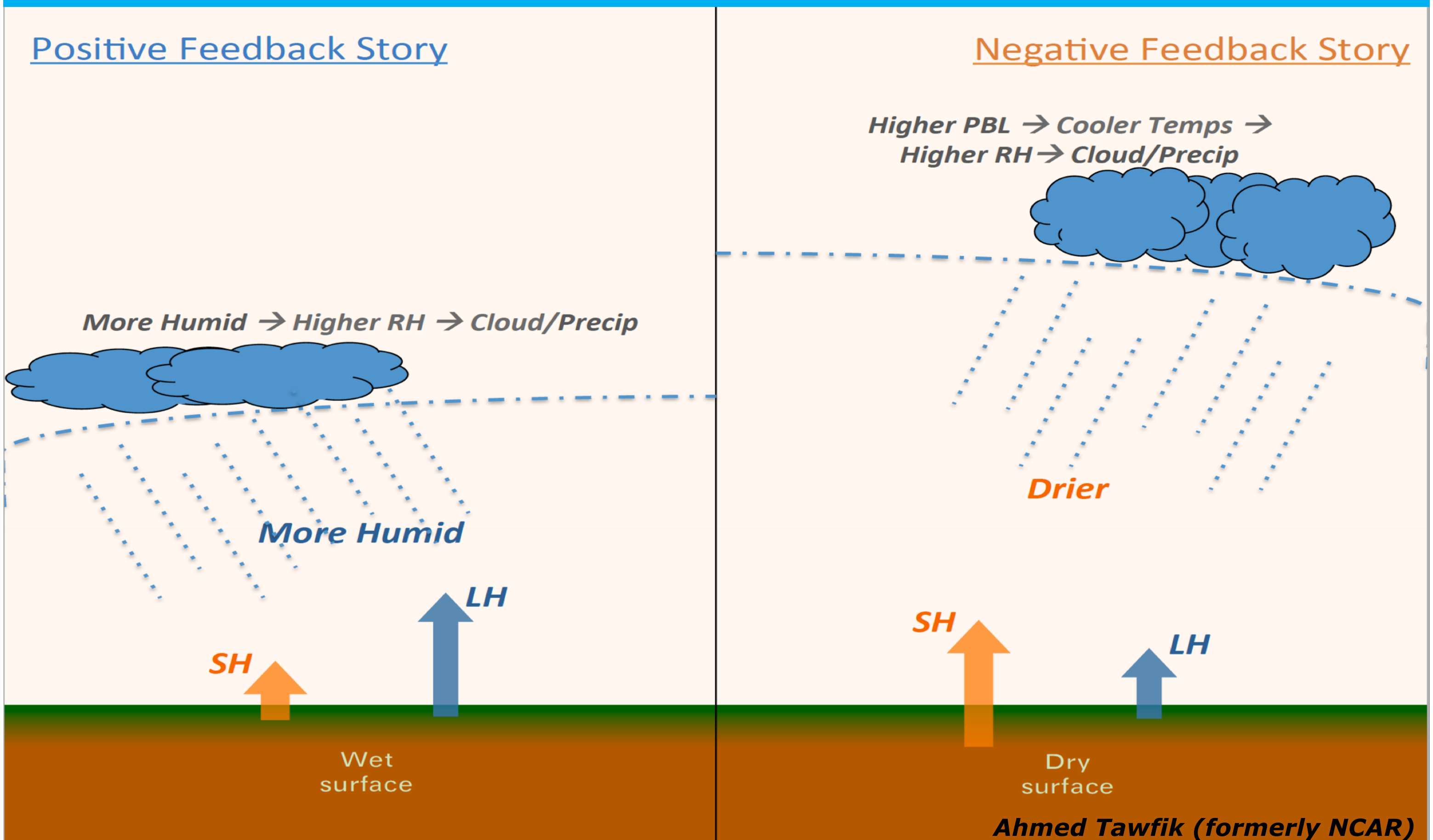
- **Terrestrial – *Soil moisture-surface fluxes relationship*.** When/where/how does soil moisture, vegetation and snow (via plant, soil, snow physics and surface-layer physics) control the partitioning of net radiation into sensible, latent & soil heat flux?
- **Atmosphere – *Surface fluxes-PBL relationship*.** When/where/how do surface fluxes affect boundary-layer evolution, clouds (& microphysical processes) and precipitation?

- **Many land & atmospheric processes and land-atmos feedbacks, some competing.** ***Example: Formation of boundary-layer clouds.***



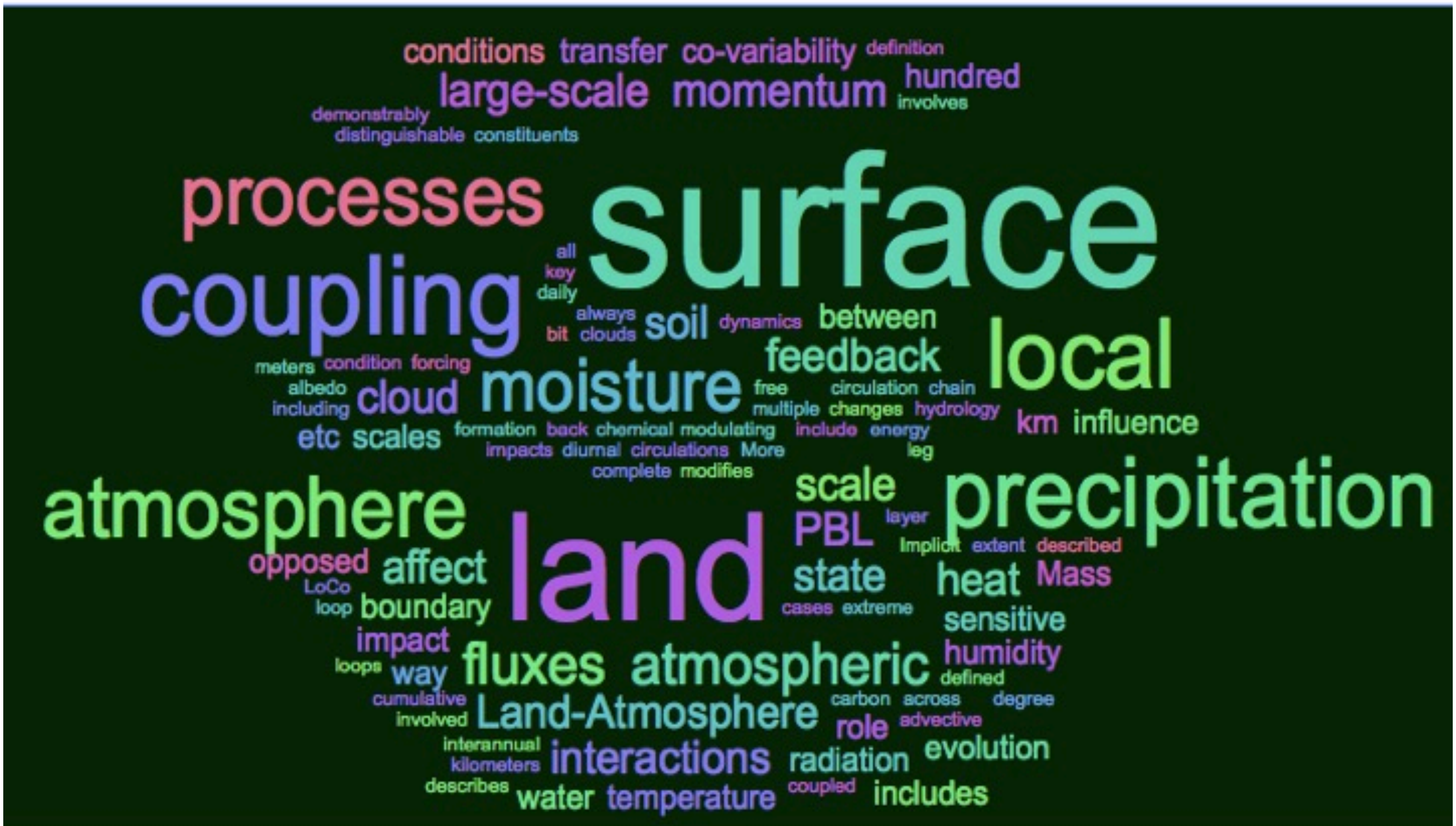
Ahmed Tawfik (formerly NCAR)

• **Many land & atmospheric processes and land-atmos feedbacks, some competing.** ***Clouds via Positive or Negative Feedbacks. How exactly?***



HOW TO EXAMINE? Local Land-Atmosphere Coupling (LoCo) Project
What is LoCo?

Joe Santanello (NASA/GSFC)



HOW TO EXAMINE? Local Land-Atmosphere Coupling (LoCo) Project
What is LoCo?

Motivation:

- ***Land-Atmosphere Interactions (L-AI)*** play a critical role in supporting and modulating extreme dry and wet regimes, and must therefore be quantified and simulated correctly in coupled models.

Objectives:

- Address deficiencies in NWP and climate models by developing diagnostics to quantify the strength and accuracy of the Local L-A Coupling ('LoCo') at the process-level.

Deliverables:

- Diagnostics that can be applied to any model, scale, or observation (in-situ or satellite).
- Assessment of coupled model components and their integration through the land-PBL 'process-chain' linking the soil to precipitation.
- Provide a diagnostic and observational testbed for GEWEX-GLASS directed studies of LoCo and model intercomparisons.

Joe Santanello (NASA/GSFC)

LoCo and Indices

LAND–ATMOSPHERE INTERACTIONS

The LoCo Perspective

Joe Santanello (NASA/GSFC)

Joseph A. Santanello Jr., Paul A. Dirmeyer, Craig R. Ferguson,
Kirsten L. Findell, Ahmed B. Tawfik, Alexis Berg, Michael Ek, Pierre Gentine,
Benoit P. Guillod, Chiel van Heerwaarden, Joshua Roundy, and Volker Wulfmeyer

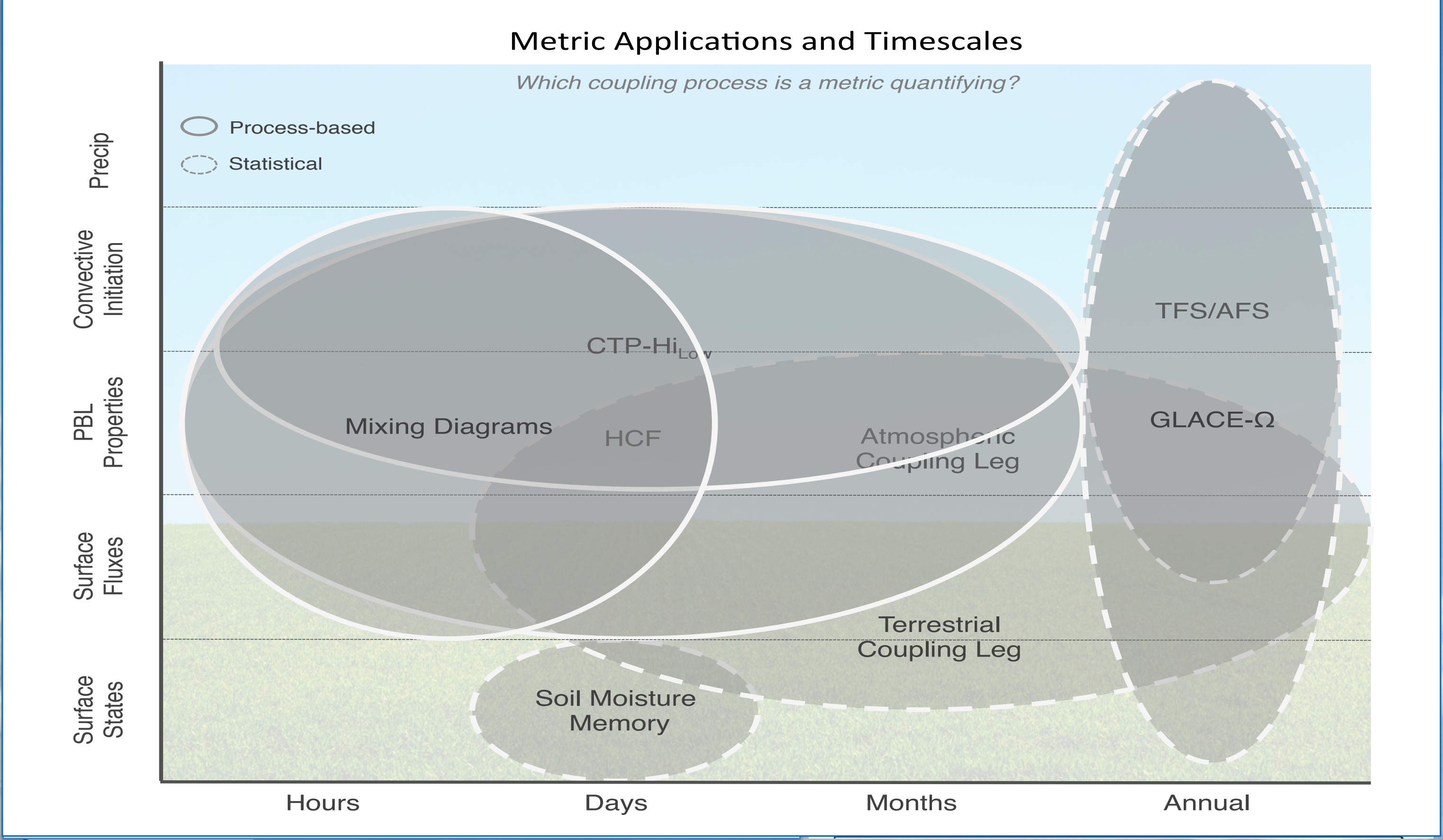
Metrics derived by the LoCo working group have matured and begun to enter the mainstream, signaling the success of the GEWEX approach to foster grassroots participation.

BAMS, June 2018 (EOR available)

Ahmed Tawfik (formerly NCAR) →

Paul Dirmeyer

LoCo Diagnostics
“Shopping List” of Different L-AI Coupling Metrics



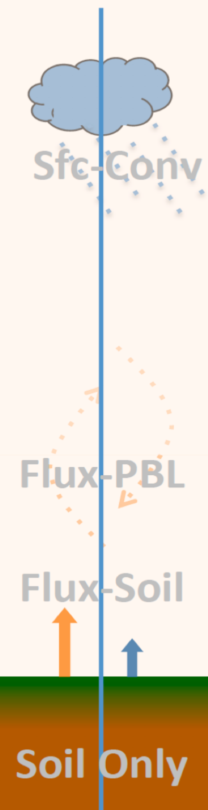
Common Metrics for L–A Coupling and Feedbacks

Statistical

Soil moisture memory

- How long a soil moisture anomaly is retained
- Statistically – using the lagged autocorrelation of soil moisture and identify when the correlation falls below some "information thershold"

Good references:
Dirmeyer 2016 – models versus observations
Seneviratne 2012 – decent review and comprehensive process framework



Process-Based

- **Why we care?** Because persistence of an anomaly is potential for predictability!
- Process – using water balance equation to estimate the water storage

Soil Moisture Memory

Soil Moisture Memory

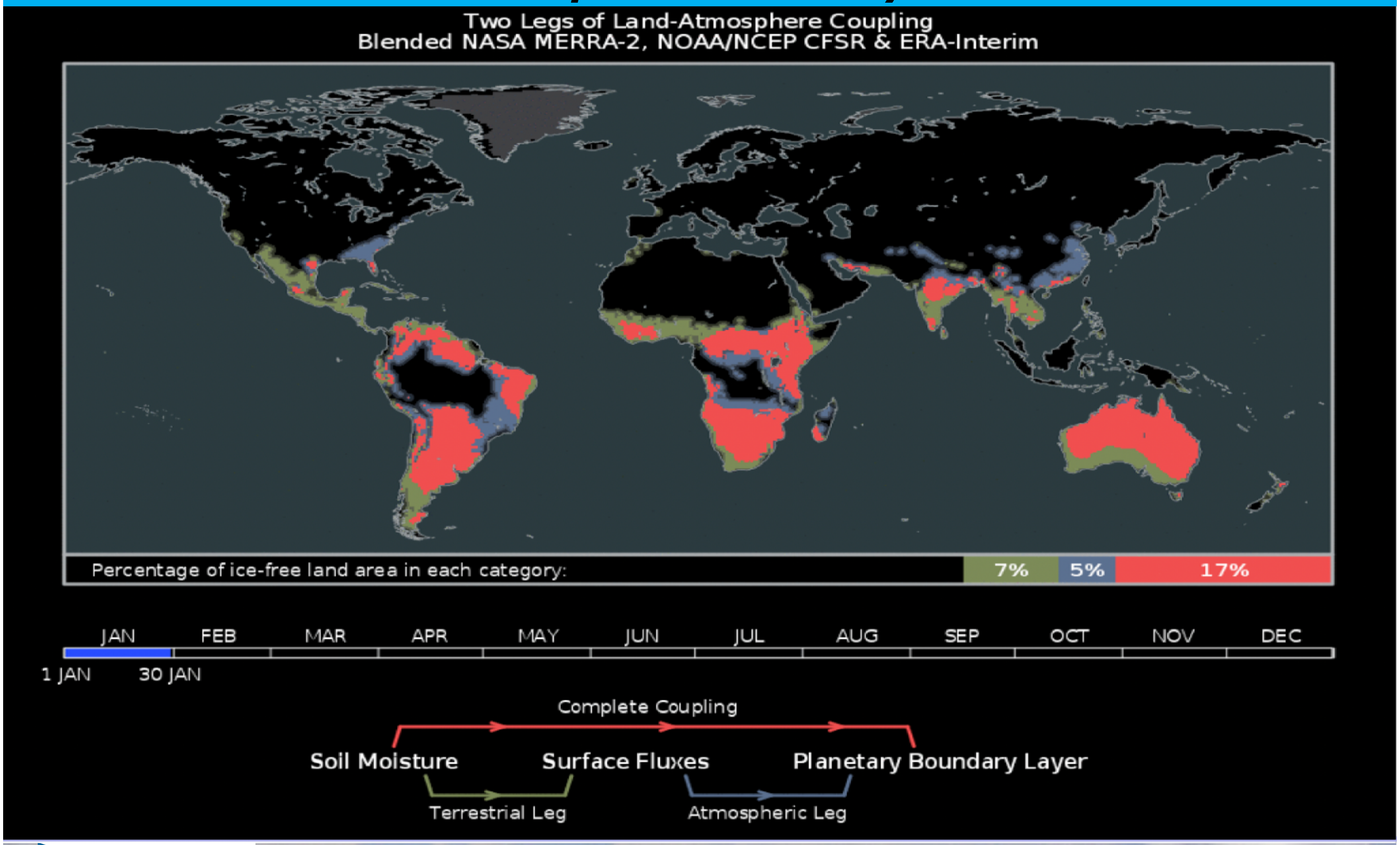
Ahmed Tawfik (formerly NCAR)

Common Metrics for L–A Coupling and Feedbacks

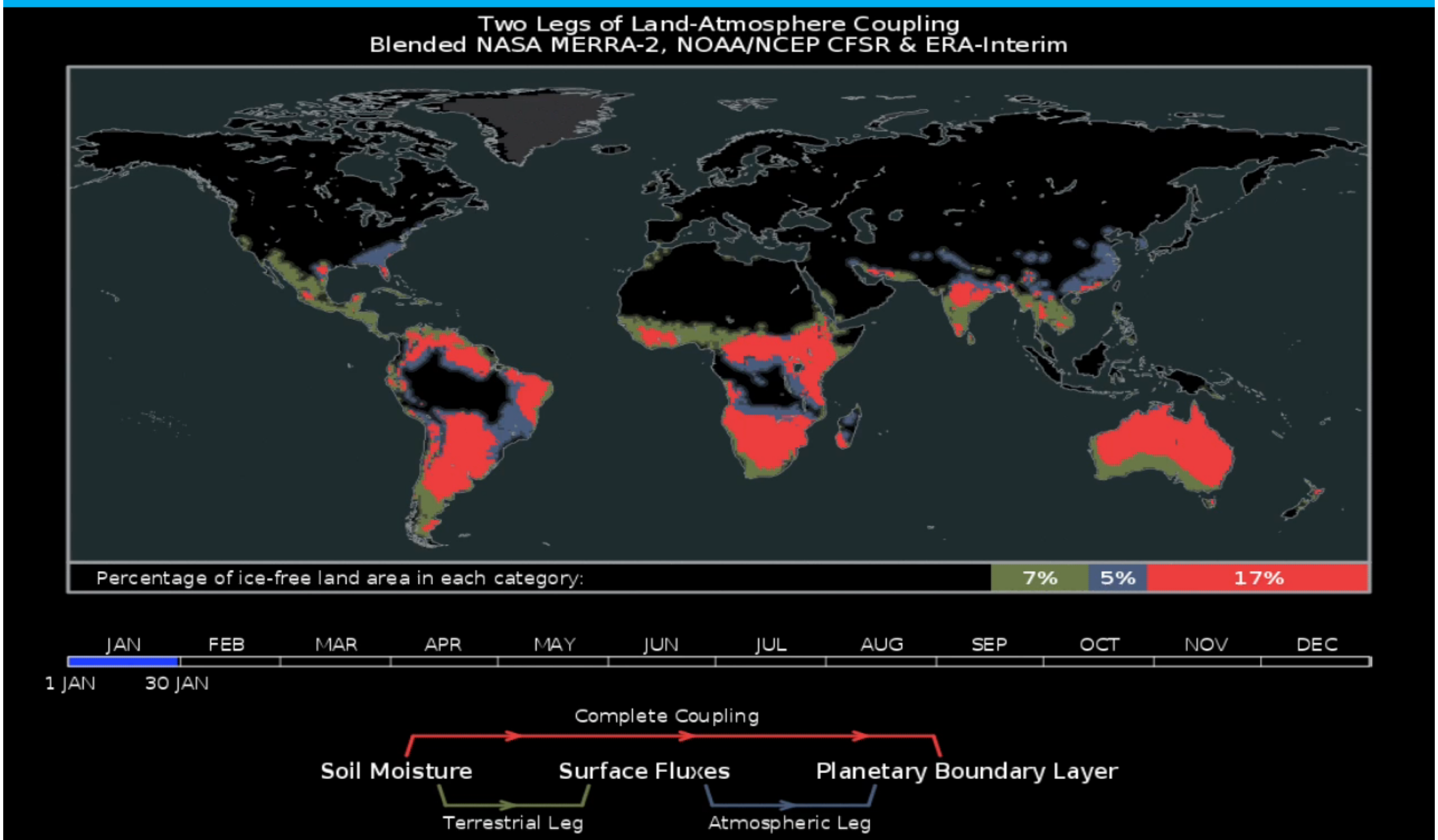
Statistical		Process-Based
	Sfc-Conv	Convective Triggering Potential
		Heated Condensation Framework
Trigger/Amplification Feedback Strength		Relative Humidity Tendency
Two-legged Metric	Flux-PBL	Mixing Diagrams
Terrestrial Coupling Parameter	Flux-Soil	Intrinsic Biophysical Factors
Soil Moisture Memory	Soil Only	Soil Moisture Memory

Ahmed Tawfik (formerly NCAR)

LoCo Diagnostic: "Two-Legged Metric" (Dirmeyer et al)
Snapshot: January



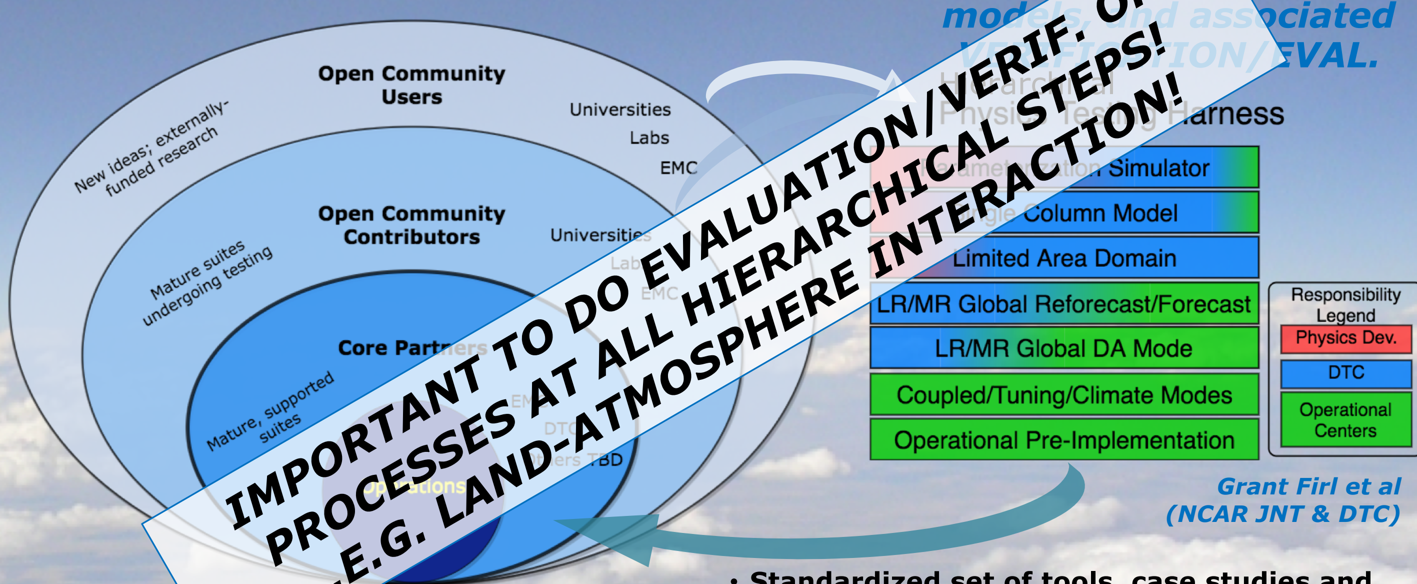
LoCo Diagnostic: "Two-Legged Metric" (Dirmeyer et al)
Soil Moisture -> Surface Fluxes -> PBL



NCAR-NOAA Development Testbed Center (DTC) Global Model Testbed (GMTB) project: Providing a framework & tools for the community to advance atmospheric physics

GMTB Common Community Physics Package (CCPP) Research-to-Operations and Operations-to-Research (R2O2R) "Ecosystem"

R2O2R pathway to move improved physics parameterizations into models, and associated VERIFICATION/EVAL.



Grant Firl et al (NCAR JNT & DTC)

- **Collaborative framework for research and operations to share physics.**
- **Relies on dycore-/physics-agnostic Interoperable Physics Driver (IPD).**

- **Standardized set of tools, case studies and data sets (in situ/field programs, remote sensing) for simpler-to-more-complex hierarchy of physical parameterization tests.**
- **Provides evidence for physics scheme acceptance.**

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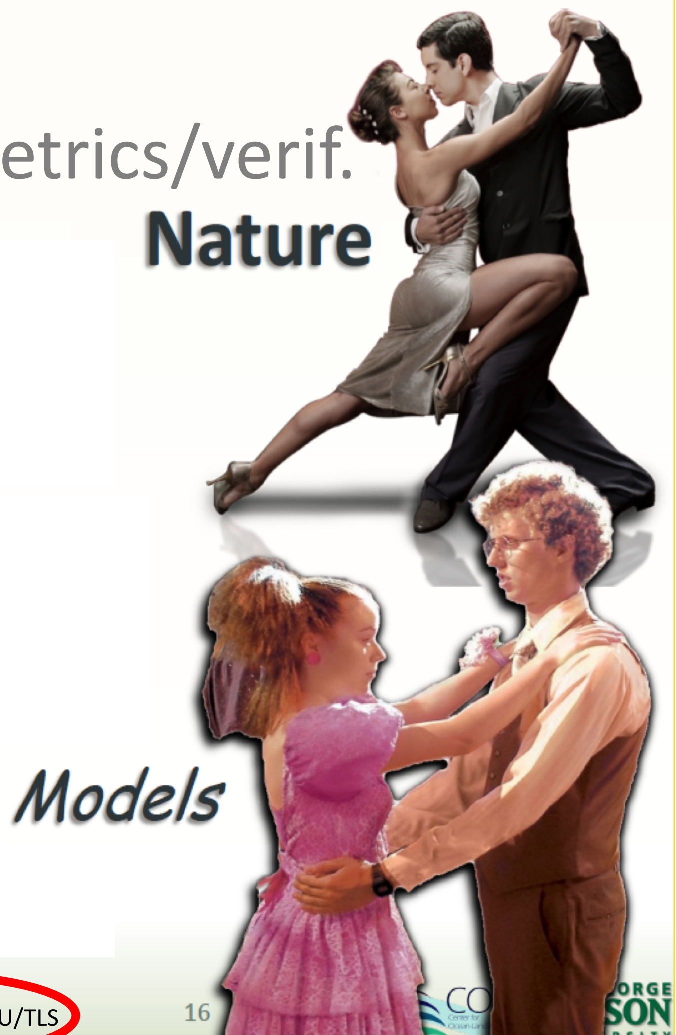
Issues:

A Coupled Land-Atmosphere problem…

1. Surface Energy Balance partition.
2. Evapotranspiration (ET) partition (vegetation control).
3. Momentum fluxes, transport.
4. Surface emissions of dust, aerosols.
5. Sub-surface to surface heat and moisture transport.
6. Soil thermodynamics and hydraulics/hydrology (surface water-groundwater interactions, lateral transport, terrain effects).
7. Cold season: snowpack, frozen soil processes.
8. Dynamic landscapes (i.e. disturbances, e.g. from fire, urbanization, agriculture, etc.).
9. Stable boundary (surface) layer.
10. Surface heterogentity, PBL blending height, complex terrain.
11. Land-atmosphere interaction:
    Soil moisture-surface fluxes (e.g. ET) relationship.
    Surface fluxes-PBL relationship, feedbacks e.g. via clouds/radiation.

Thanks, Fei Chen, Dave Gochis, Lulin Xue (NCAR), Brian Cosgrove (OWP/NWM), & many others.

Summary: Coupled L-A Model Development & metrics/verif.



Paul Dirmeyer, GMU/TLS 16


THANK YOU!
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