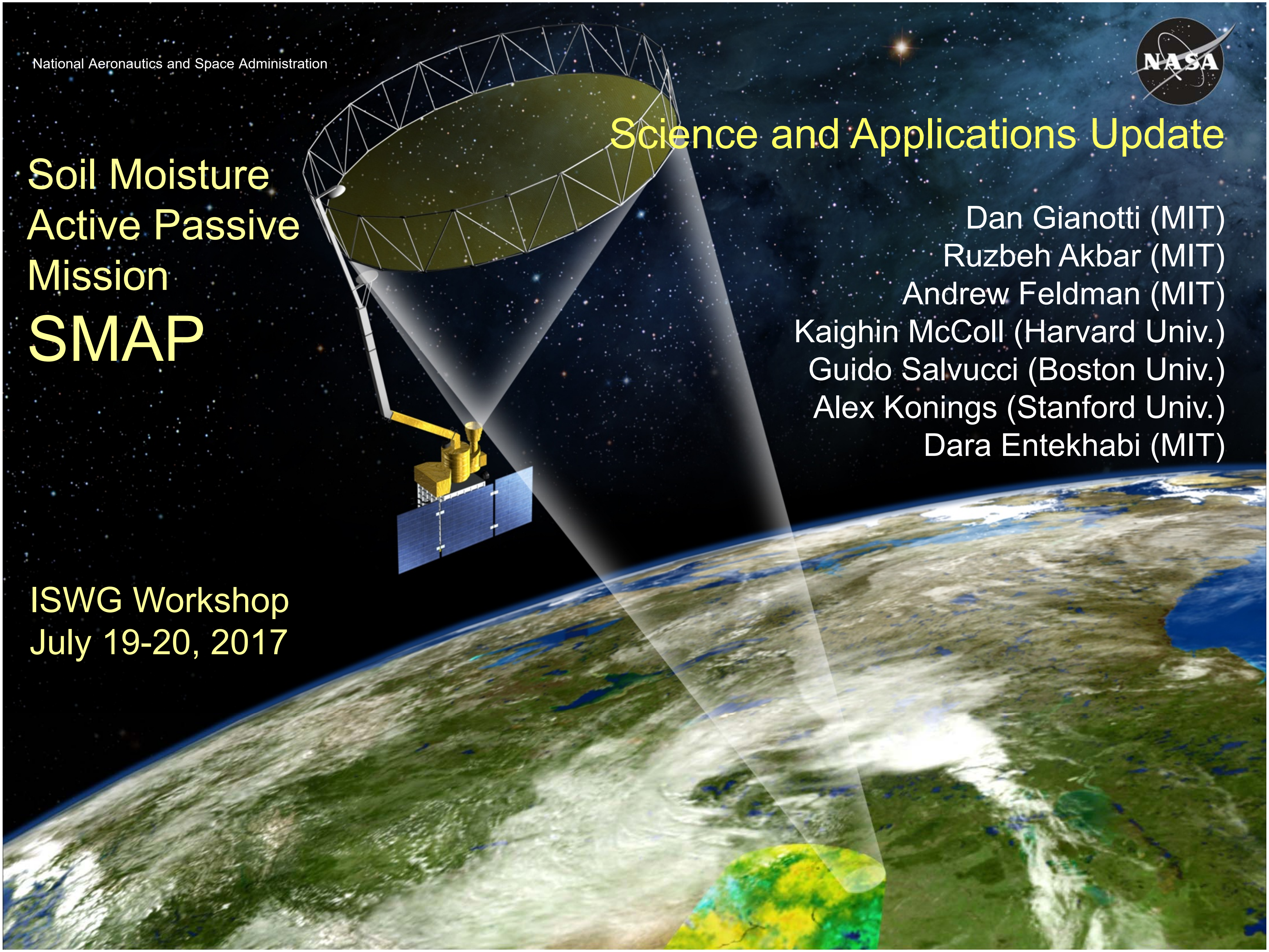


National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP

Science and Applications Update

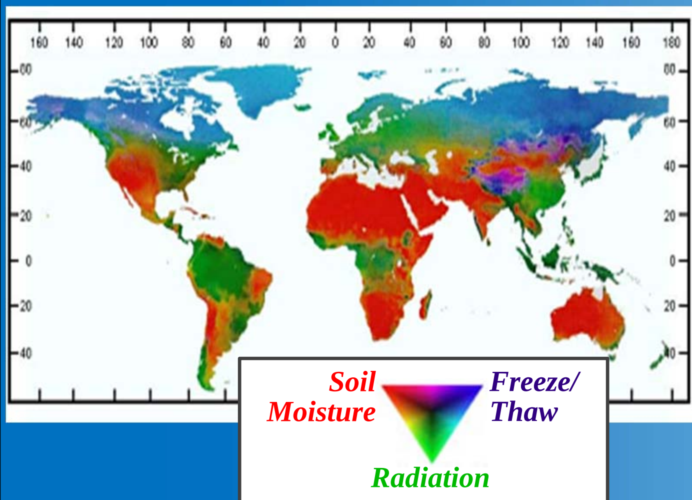
Dan Gianotti (MIT)
Ruzbeh Akbar (MIT)
Andrew Feldman (MIT)
Kaighin McColl (Harvard Univ.)
Guido Salvucci (Boston Univ.)
Alex Konings (Stanford Univ.)
Dara Entekhabi (MIT)

ISWG Workshop
July 19-20, 2017

SMAP Science and Application Returns

Science Returns

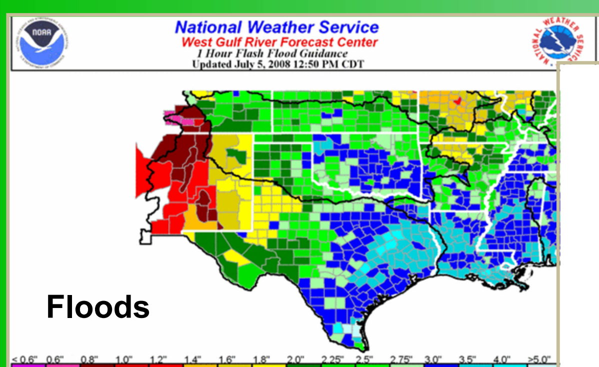
Soil Moisture *Links* the Global Land Water, Energy, and Carbon Cycles

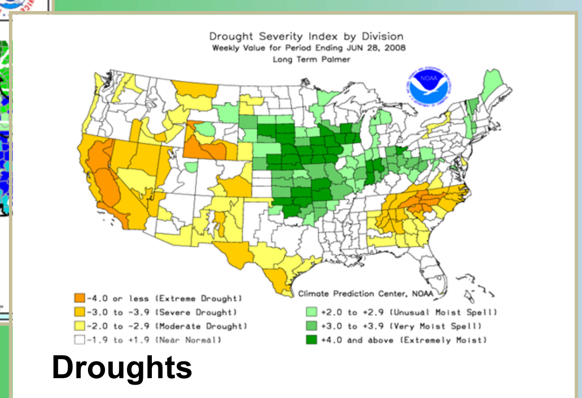


1. Estimating global surface water and energy fluxes
2. Quantifying net carbon flux in boreal landscapes
3. Reducing uncertainty of climate model projections

L-band (~21 cm; All-Weather; Canopy Penetration; Sensing Depth)

Applications Returns



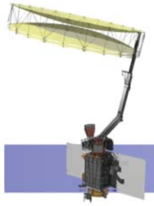


4. Enhancing weather forecasts
5. Improving flood prediction and drought monitoring

6m conically scanning (14 rpm) antenna for 1000 km swath

Global coverage every 2-3 days


CALIFORNIA
RODEO
SALINAS
JULY 20 - 23, 2017



Core Science Objective

EARTH SYSTEM SCIENCE PATHFINDER (ESSP) MISSIONS — HYDROS STEP 2, SECTION F

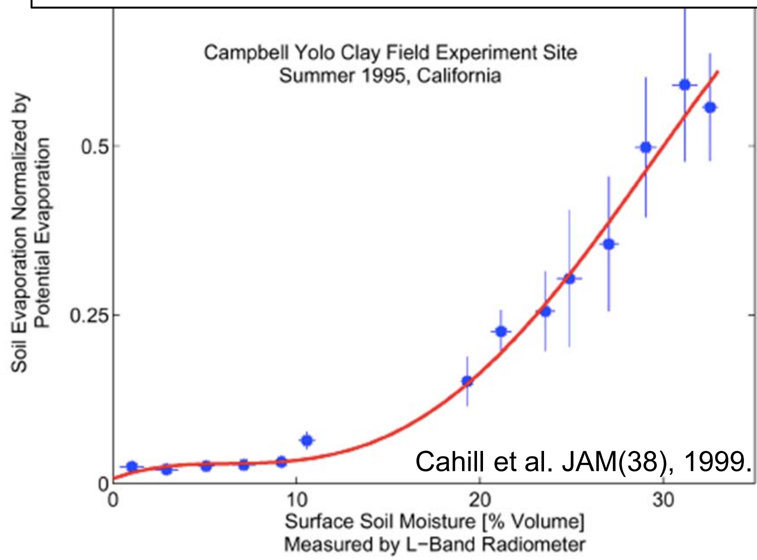


Figure F.1-2. A ground-based L-band radiometer is used to make the soil moisture field measurements to estimate the surface control on evaporation (fitted red line). Global HYDROS soil moisture measurements, together with meteorological and hydrological data, will allow for the first time a quantification of influential processes such as this across diverse climatic and seasonal regimes.

SMAP L1 Science Requirements and Mission Success Criteria

2.0 SCIENCE DEFINITION

2.1 BASELINE SCIENCE OBJECTIVES

The SMAP Project will implement a spaceborne earth observation mission designed to collect measurements of surface soil moisture and freeze/thaw state, together termed the hydrosphere state. SMAP hydrosphere state measurements will yield a critical data set that will enable science and applications users to:

- Understand processes that link the terrestrial water, energy and carbon cycles;
- Estimate global water and energy fluxes at the land surface;

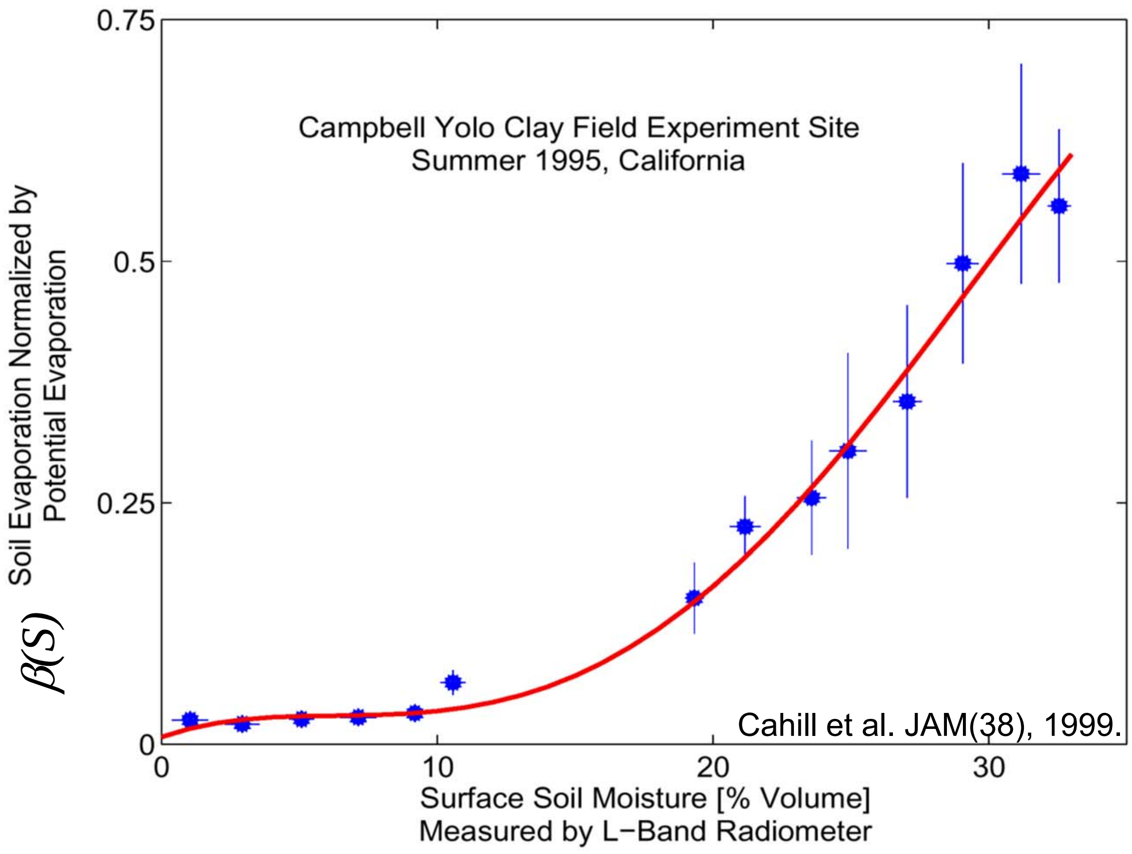
Multiple approaches being pursued and coordinated (R. Koster, G. Salvucci, J. Kimball, D. Entekhabi and others).

Estimate with least reliance on models and parameterizations (i.e., be observations-driven).

Relate function to vegetation type, seasonal climate and soil texture.

How well have we measured/estimated?

Only measured at a few flux tower sites. But valid for the footprint of flux tower (does not scale to a global model grid area) and only known for a few landscape types.



To estimate this closure function, **independent** observations of

soil moisture state

and

evaporation flux

are required. Globally.

Evaporation

Emergent relation between surface vapor conductance and relative humidity profiles yields evaporation rates from weather data

PNAS

Guido D. Salvucci[a,1] and Pierre Gentine[b]

[a]Department of Earth and Environment, Boston University, Boston, MA 02215; and [b]Department of Earth and Environmental Engineering, Columbia University, New York, NY 10027

Water Resources Research

RESEARCH ARTICLE

10.1002/2014WR016072

Evapotranspiration based on equilibrated relative humidity (ETRHEQ): Evaluation over the continental U.S.

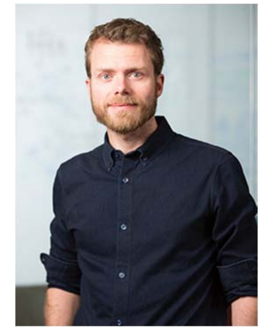
Angela J. Rigden[1] and Guido D. Salvucci[1]

[1]Department of Earth and Environment, Boston University, Boston, Massachusetts, USA

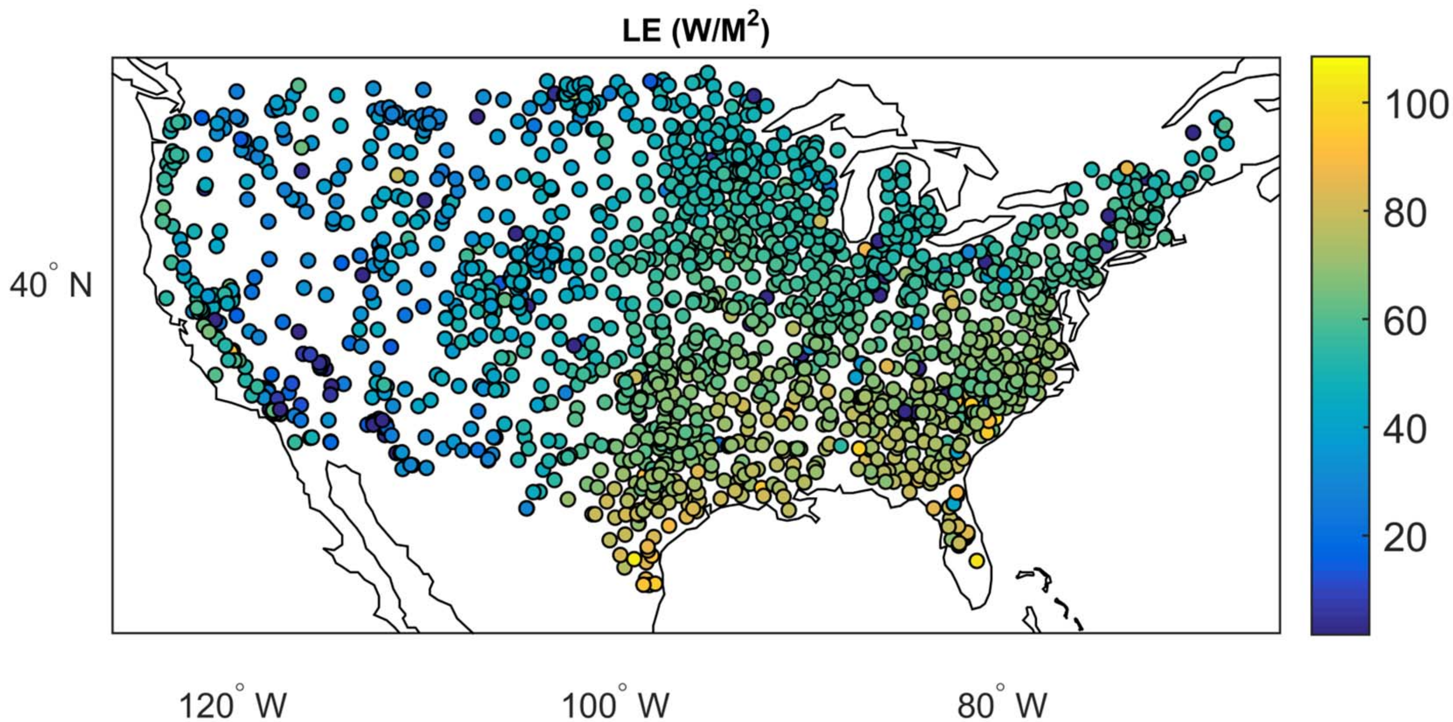
Key Points:

- Surface conductance is estimated without detailed knowledge of surface state

Guido Salvucci
(Boston Univ.)

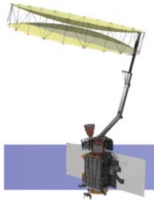


Pierre Gentine
(Columbia Univ.)

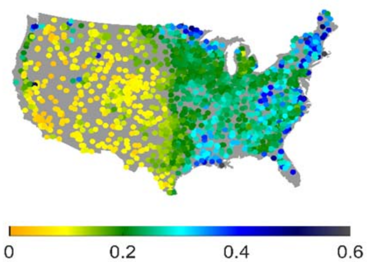


April 1, 2015 to
March 30, 2016

Coupling of Terrestrial Water, Energy and Carbon Cycles

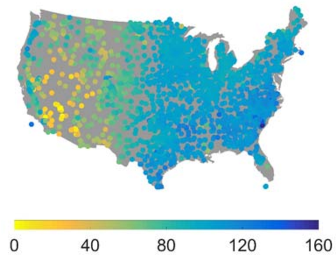


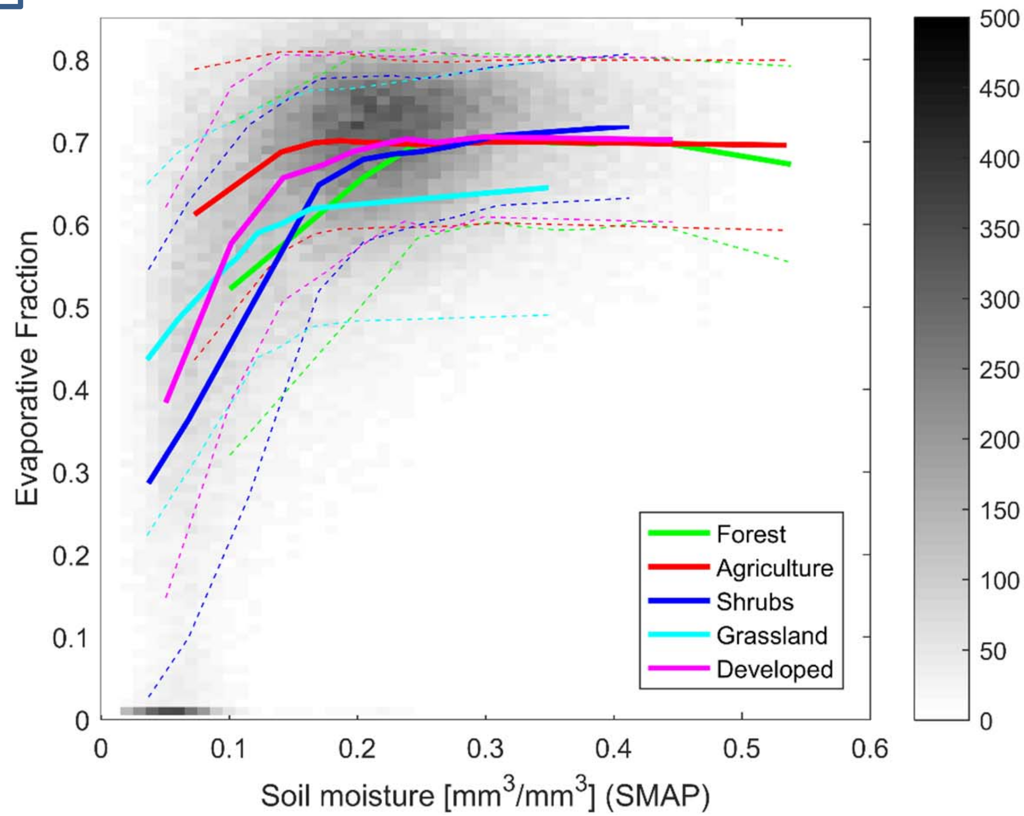
SMAP L2



+

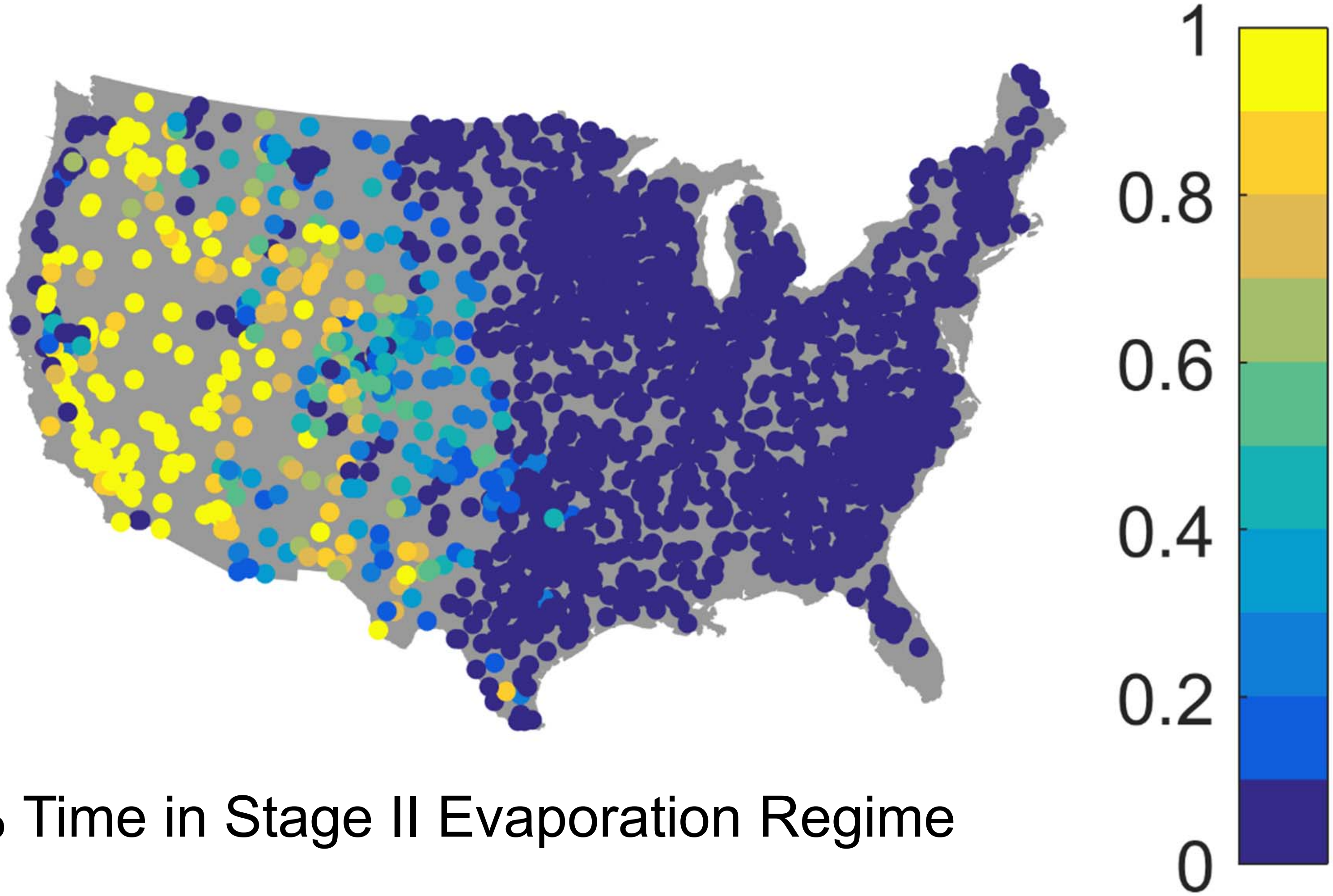
ETRHEQ (Evaporation Rate)





Gianotti, Rigden, Salvucci and Entekhabi (2017)

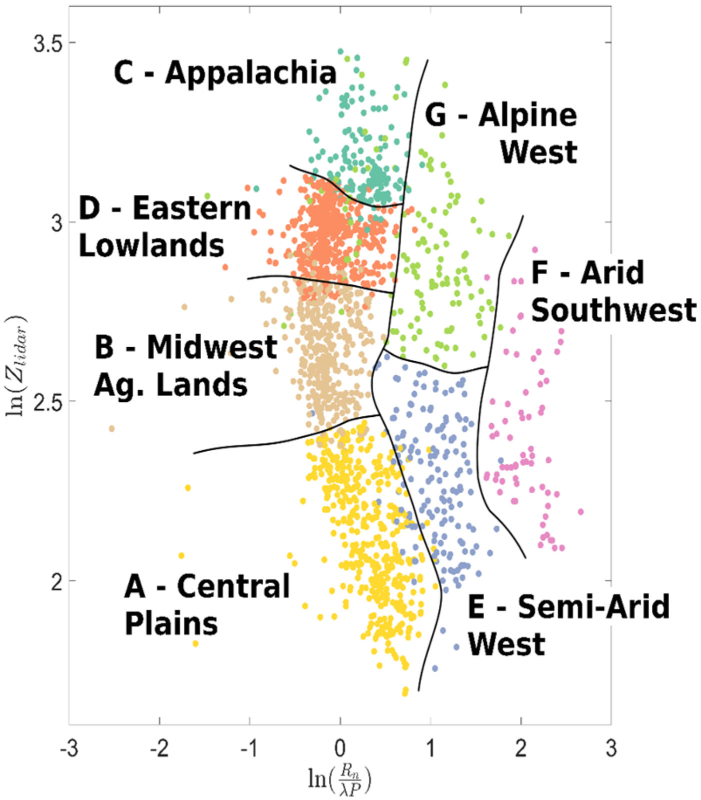
Coupling of Terrestrial Water, Energy and Carbon Cycles

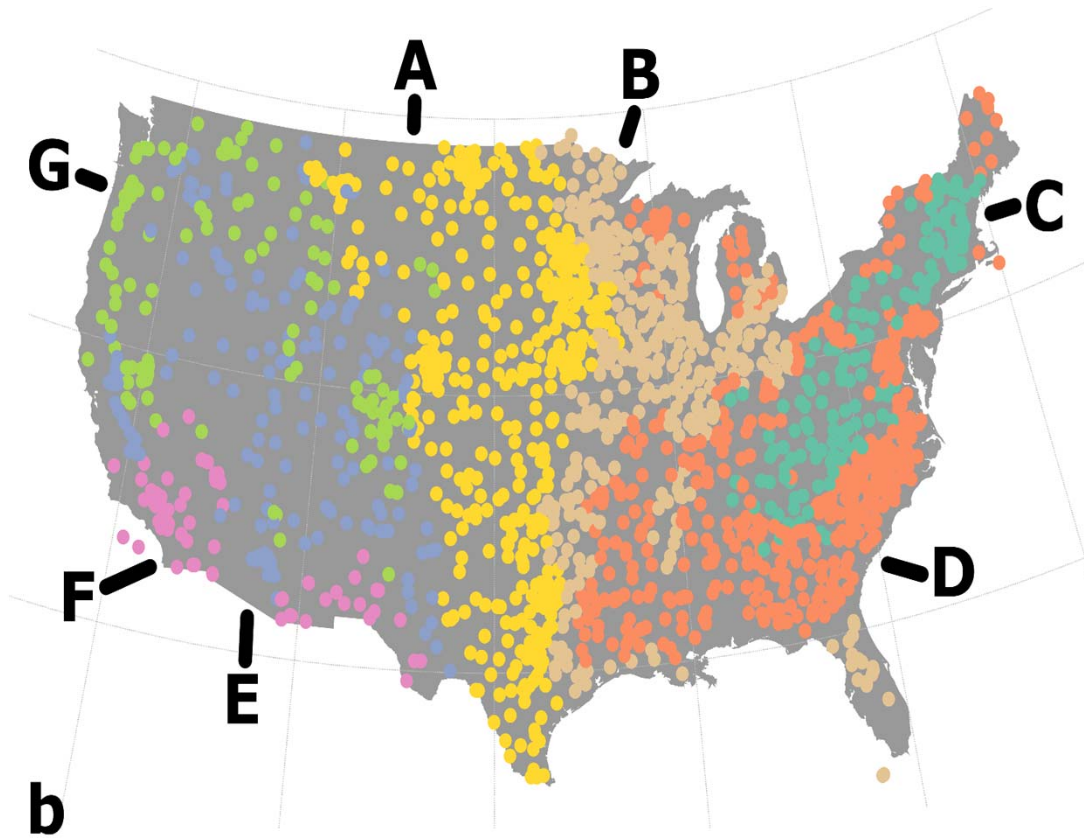


% Time in Stage II Evaporation Regime

Gianotti, Rigden, Salvucci and Entekhabi (2017)

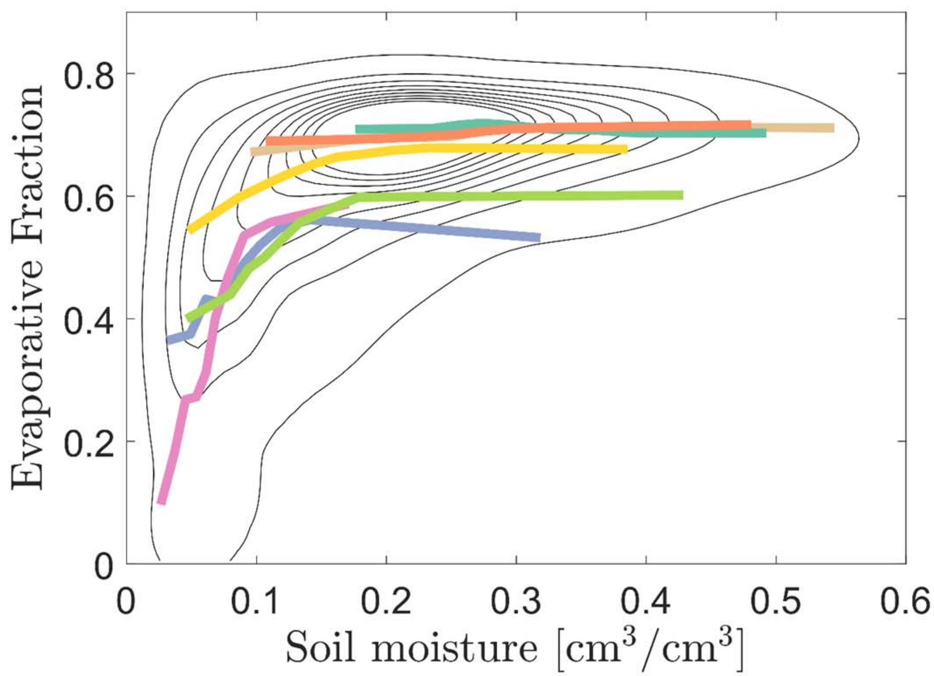
Ecohydrological Regions



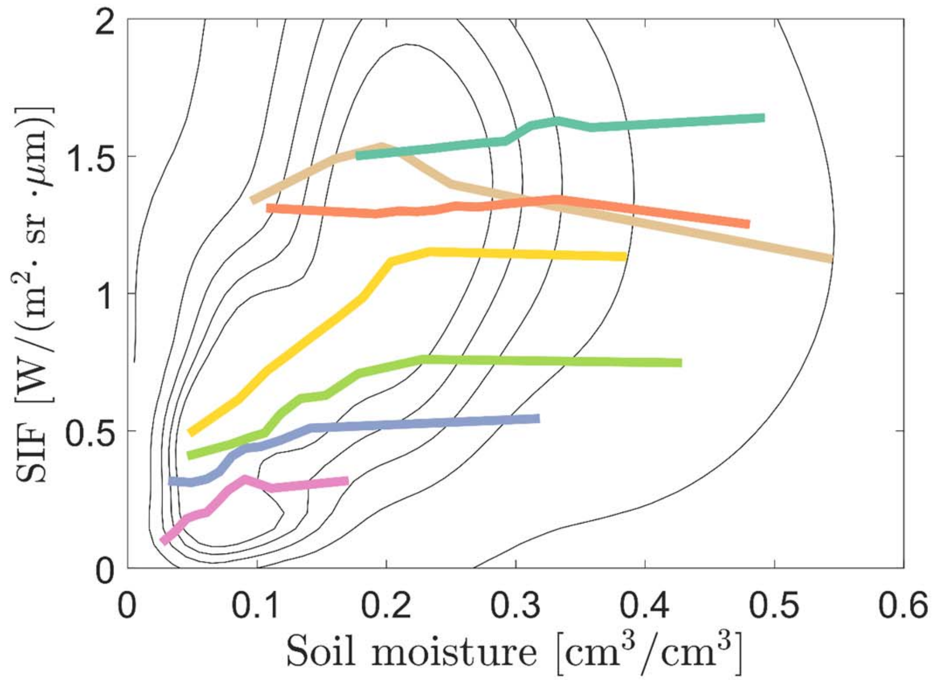


Soil Moisture Controls on Water and Carbon Cycles

SMAP-Evaporation



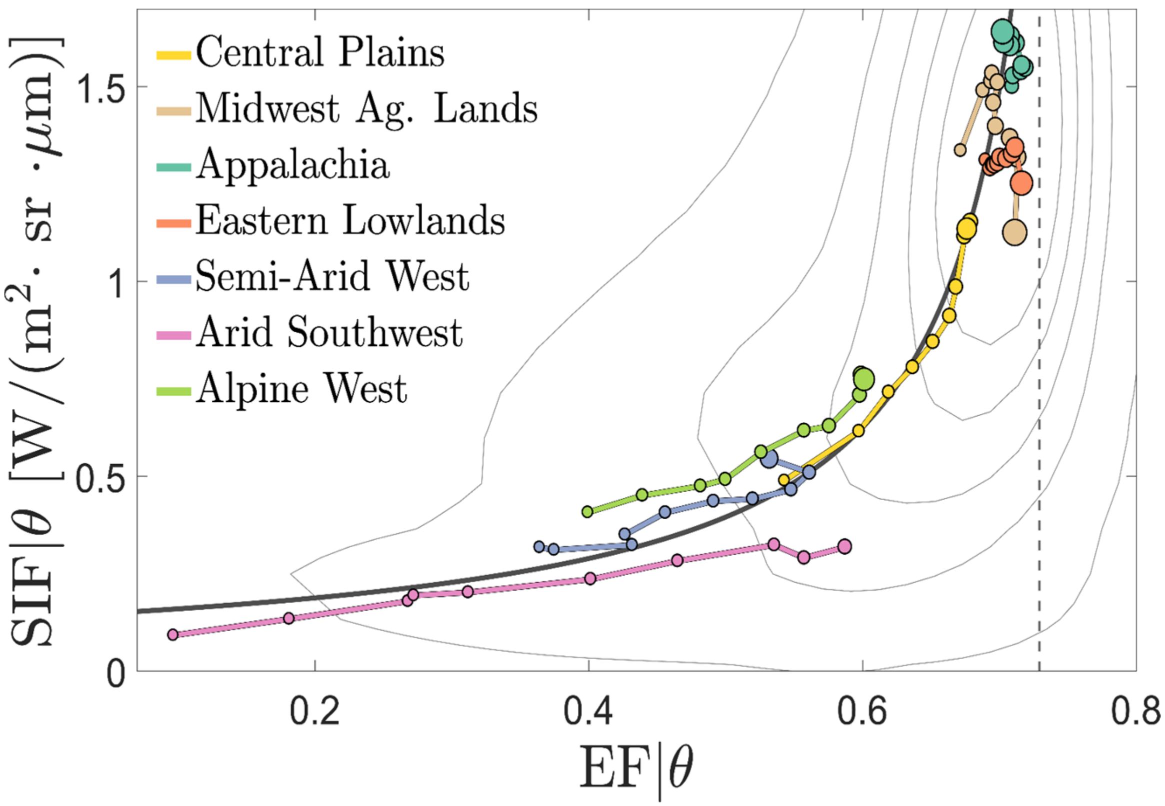
SMAP-OCO2/GOME



A – Central Plains
B – Midwest Agricultural Lands
C – Appalachia
D – Eastern Lowland Forests
E – Semi-arid West
F – Arid Southwest
G – Alpine West

SIF|θ vs EF| θ

Gianotti, Rigden, Salvucci and Entekhabi (2017)

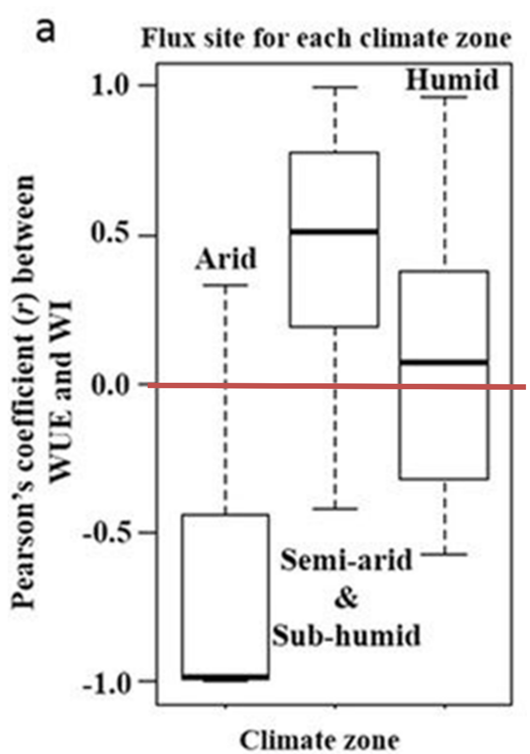


- Connects EF vs θ and SIF vs θ curves
- AIC\prefer a single relationship over independent relationships by region
- Convex shape implies landscape-level Water Use Efficiency increases with EF (opposite of physiological WUE)

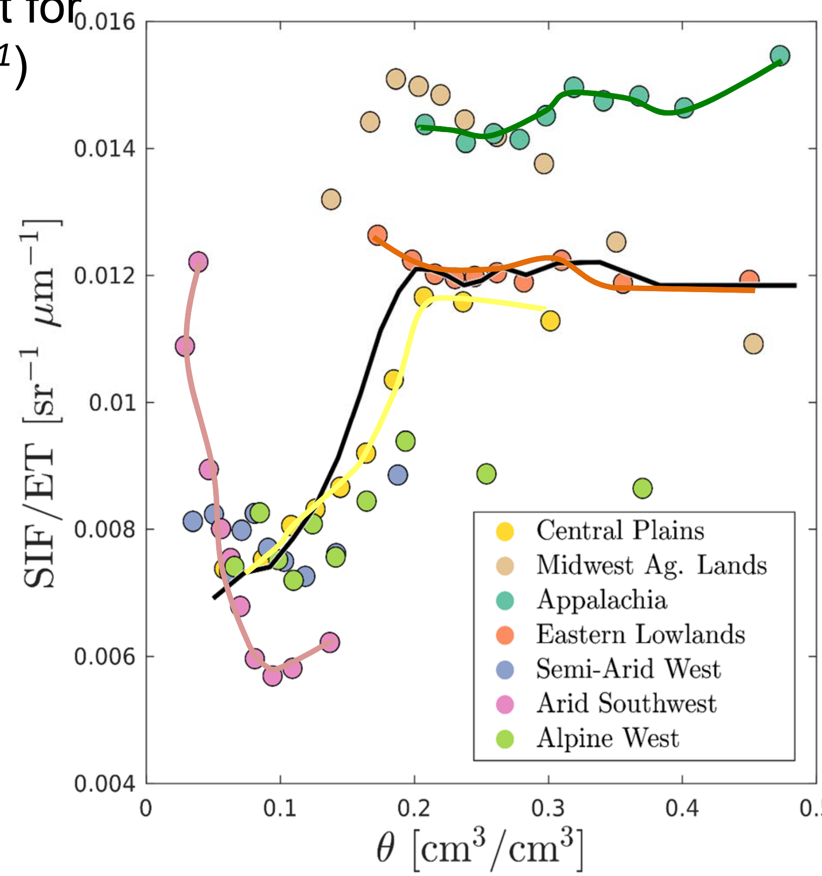
Landscape-Level "Water Use Efficiency (WUE)"

SIF/ET is WUE at the landscape scale

Decreases with θ for the arid regions, then increases with θ for semi-arid regions and flat for humid regions (in agreement with Yang *et al.*[1])

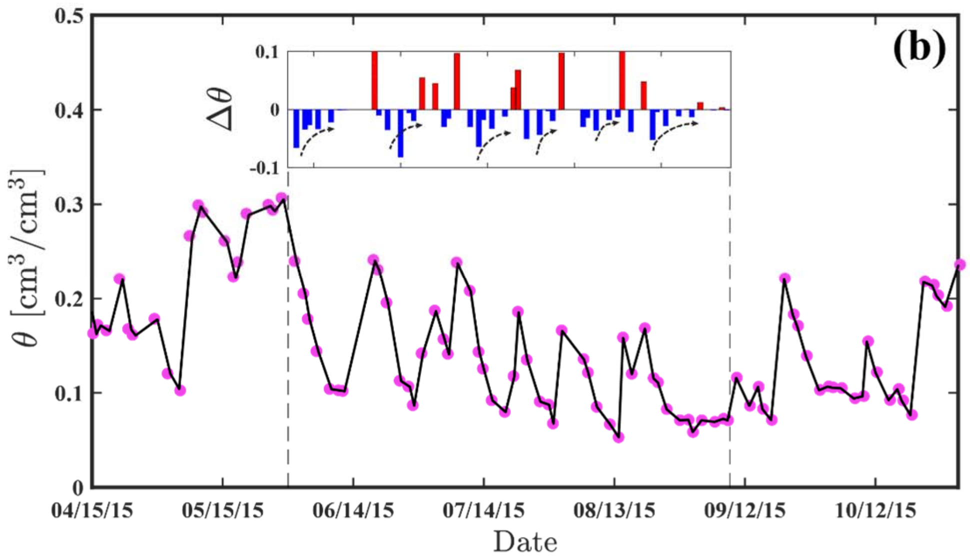


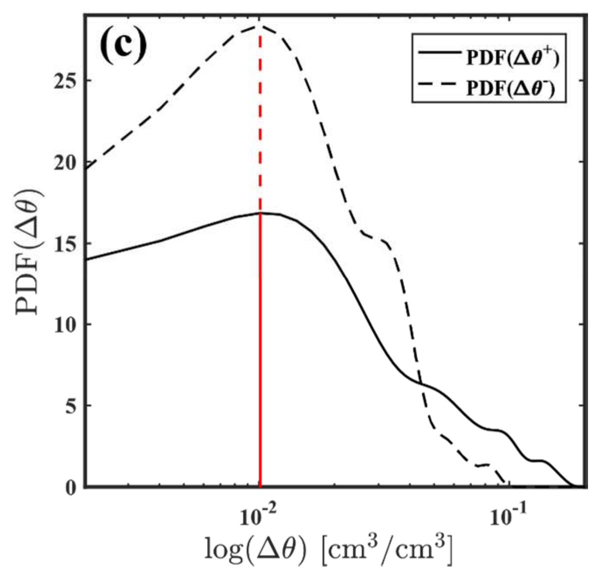
Gianotti, Rigden, Salvucci and Entekhabi (2017)



[1] Yang, Y. *et al.* Contrasting responses of water use efficiency to drought across global terrestrial ecosystems. *Nature,* **6,** 23284 (2016). [WI=Wetness Index]_

Landscape Water Loss Function: Observation-Driven Estimates





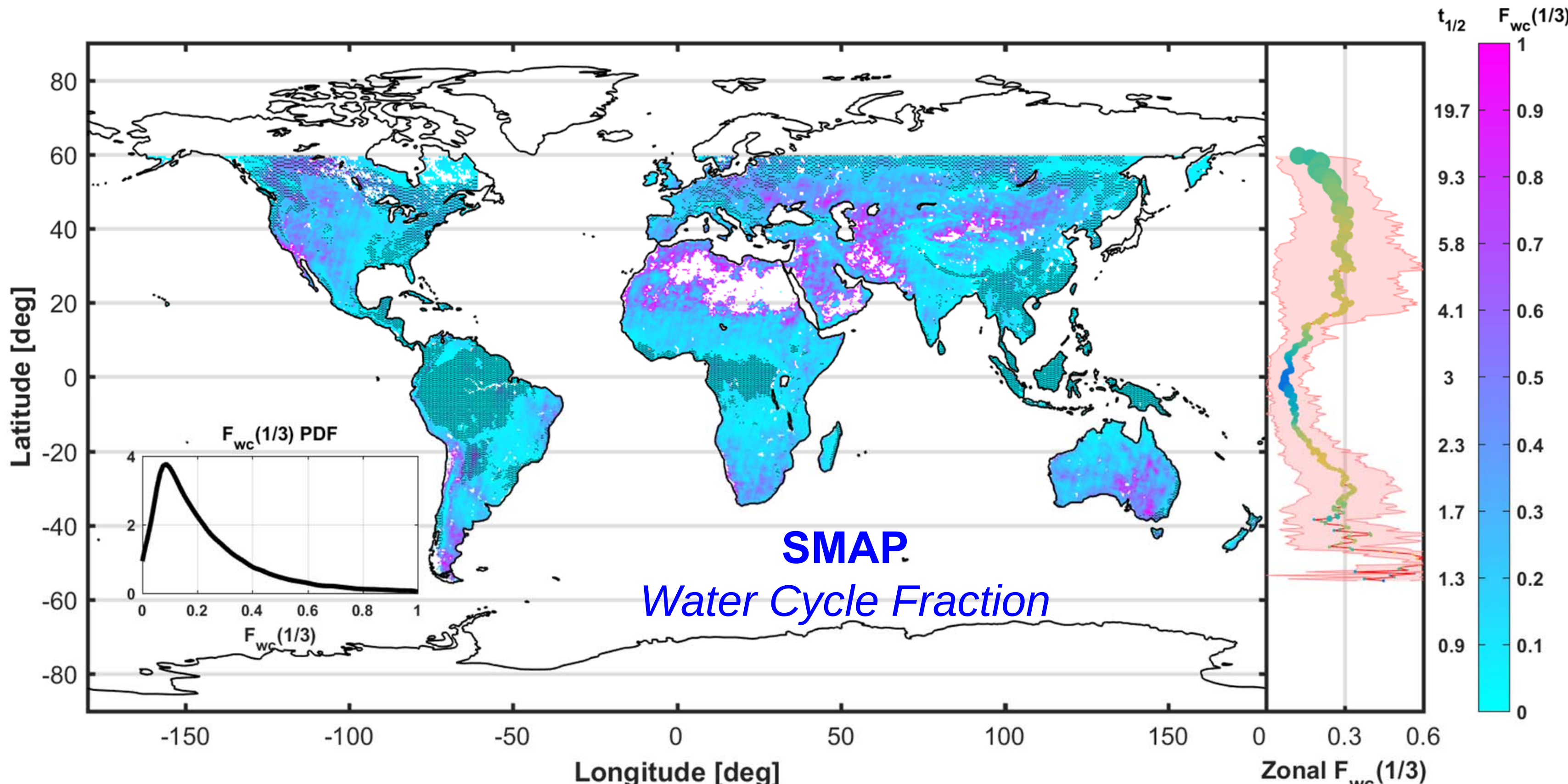
$$\Delta\theta_{i_+} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i > 0 \\ 0, \text{ otherwise} \end{cases}$$

$$\Delta\theta_{i_-} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i < 0 \\ 0, \text{ otherwise} \end{cases}$$

Soil Moisture and the Terrestrial Water Cycle: Positive Increments

McColl, Alemohammad, Akbar, Konings, Yueh and Entekhabi, 2017: The global distribution and dynamics of surface soil moisture, *Nature-Geoscience*, 10(2).

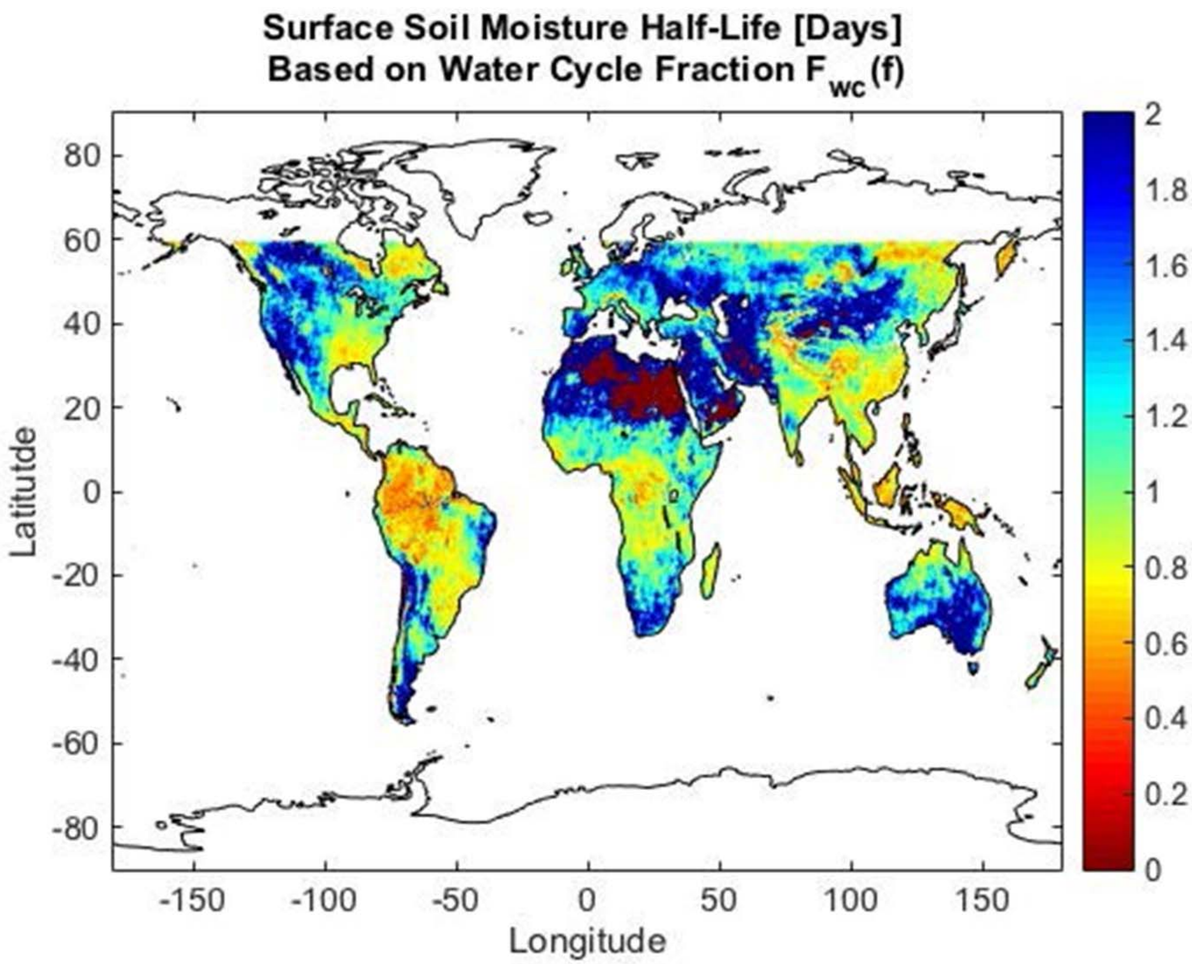
$$\Delta\theta_{i_+} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i > 0 \\ 0, \text{ otherwise} \end{cases}$$



Even Though Soil Moisture is 0.001% of the Global ***Water Budget***, it Captures About 20% of the ***Water Cycle***

Soil Moisture Memory: From Wetting to Field Capacity

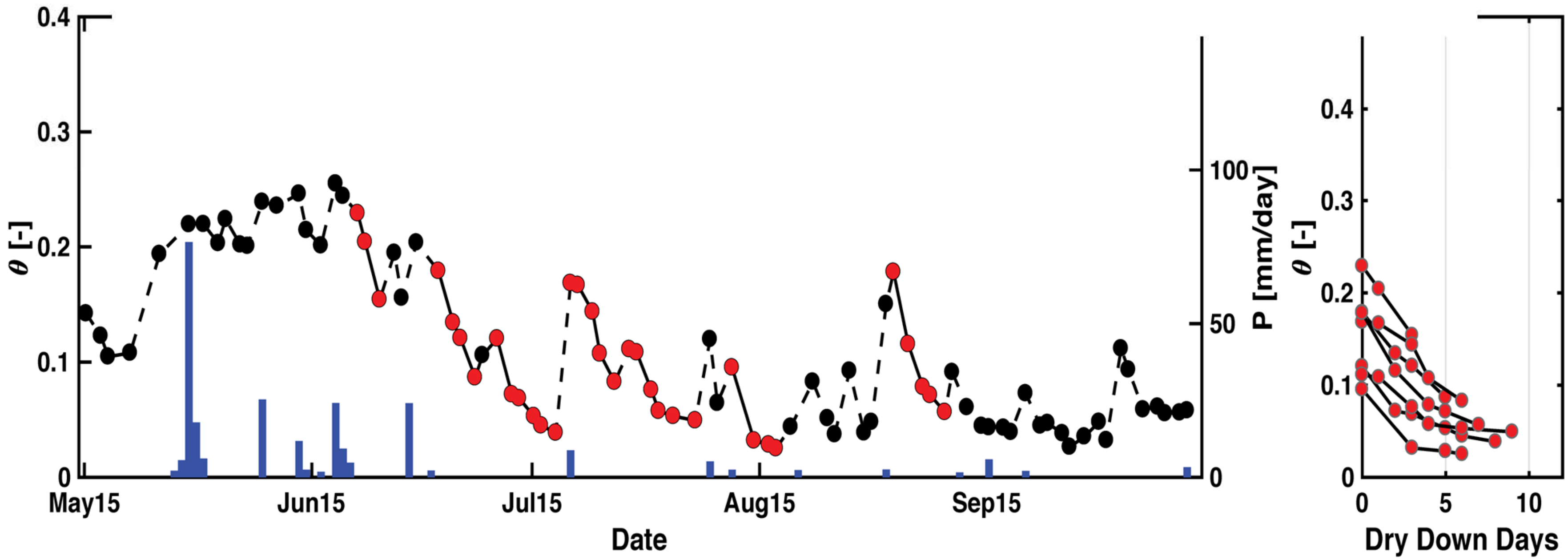
$$t_{1/2} = -\frac{f^{-1}}{log_2(F_{wc}(f))}$$



Negative Increments (Dry-Downs): From Field Capacity to Driest

$$\Delta\theta_{i_+} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i > 0 \\ 0, \text{ otherwise} \end{cases}$$

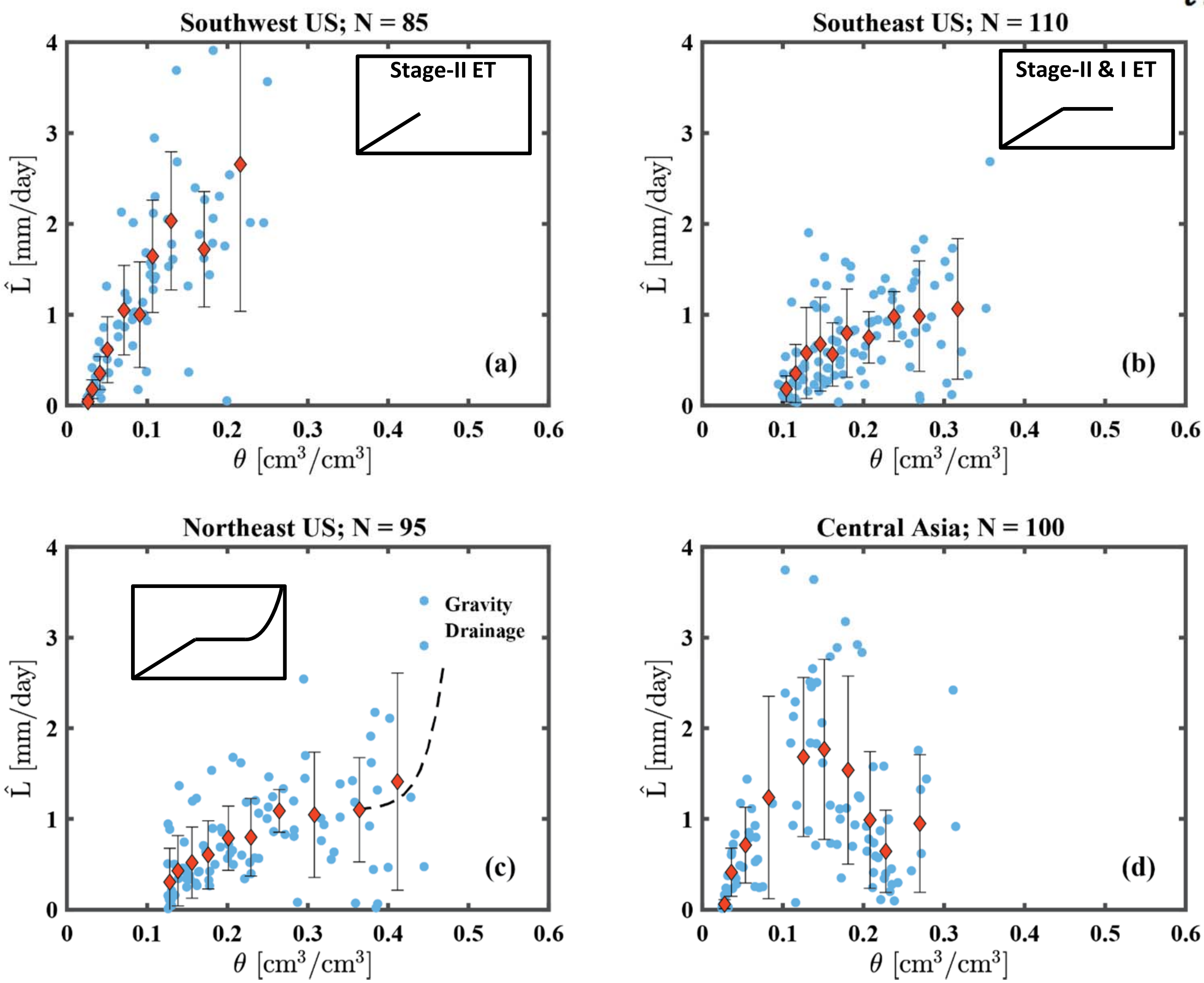
$$\Delta\theta_{i_-} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i < 0 \\ 0, \text{ otherwise} \end{cases}$$



Akbar, Gianotti, Haghighi and Entekhabi (2017)

Observation-Driven Estimates of Landscape Water Loss: Negative Increments

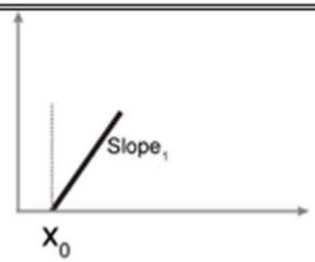
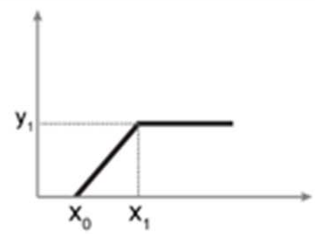
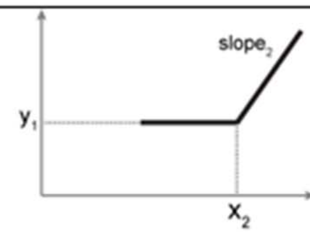
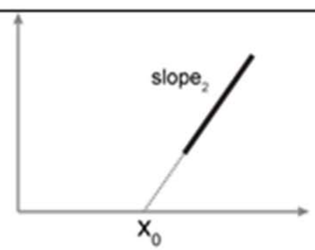
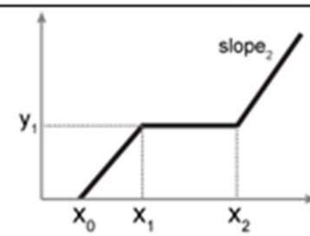
$$\Delta\theta_{i\_} = \begin{cases} \Delta\theta_i, \text{ if } \Delta\theta_i < 0 \\ 0, \text{ otherwise} \end{cases}$$



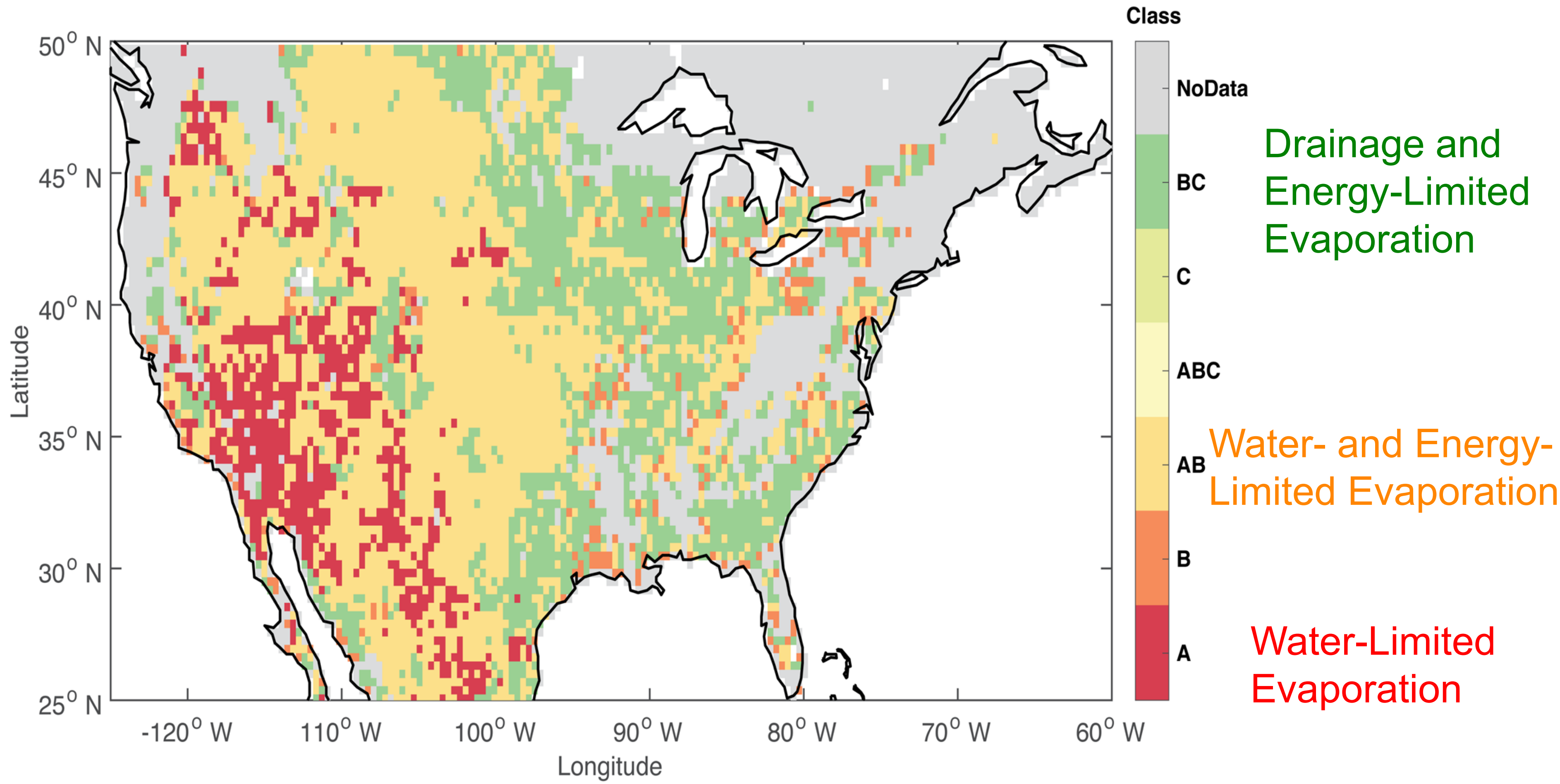
Akbar, McColl, Gianotti, Haghighi and Entekhabi (2017)

Classes of Landscape Water Loss

TABLE 1. CANONICAL FORMS USED FOR CLASSIFICATION OF SOIL MOISTURE LOSS FUNCTIONS

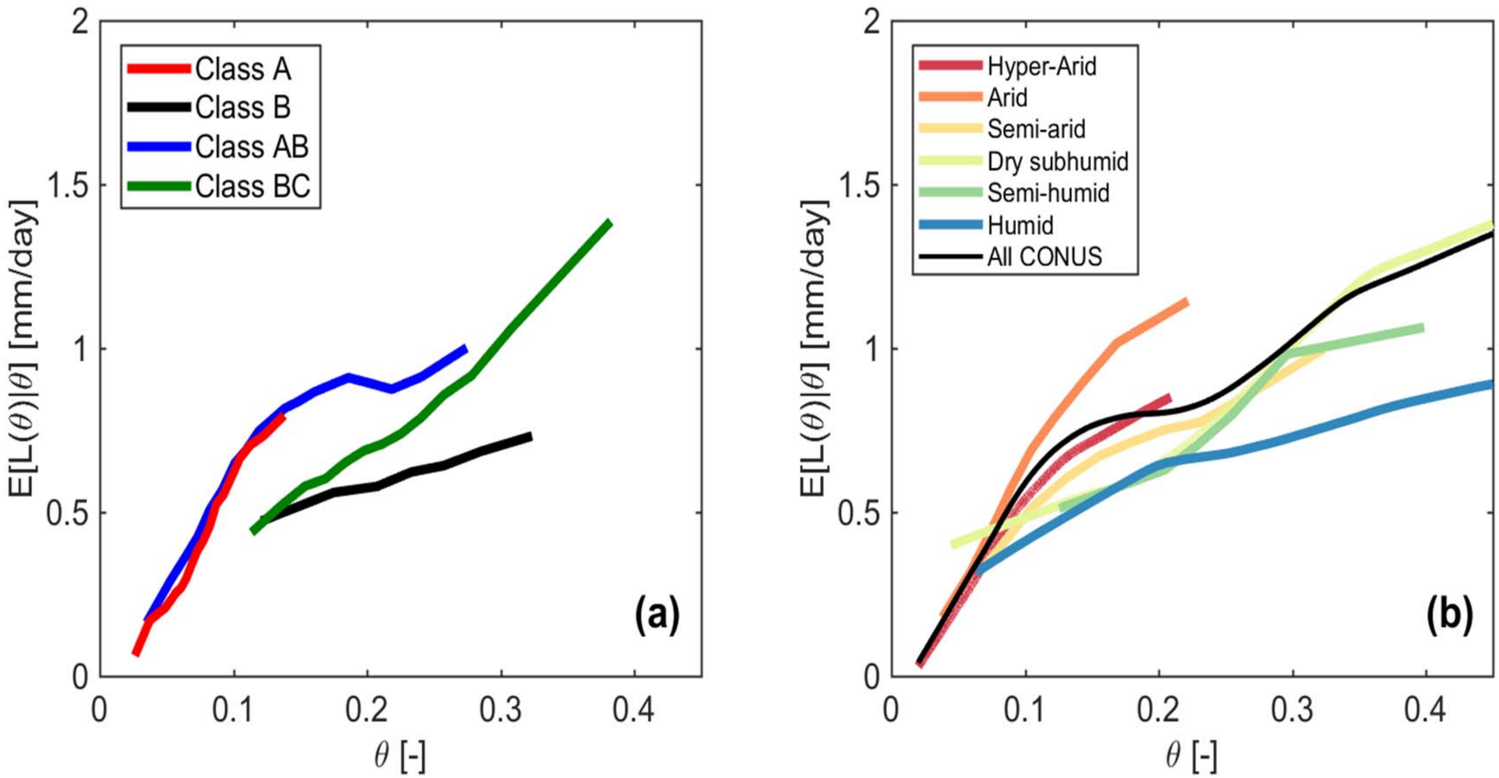
Canonical Model		**Representative Physical Process**	**Canonical Model**		**Representative Physical Process**
Class-A		Stage-I	Class- AB		Stage-II to Stage-I transition
Class-B		Stage-II	Class-BC		Stage-II and drainage-like
Class-C		Drainage-like loss	Class-ABC		Complete Canonical loss function form

Regimes of Hydrological Dynamics



Akbar, Gianotti, Haghighi and Entekhabi, 2017.

Shapes of the Loss Function

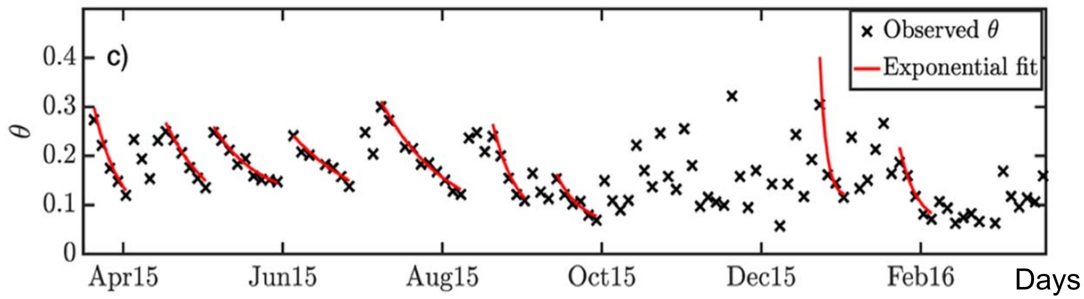


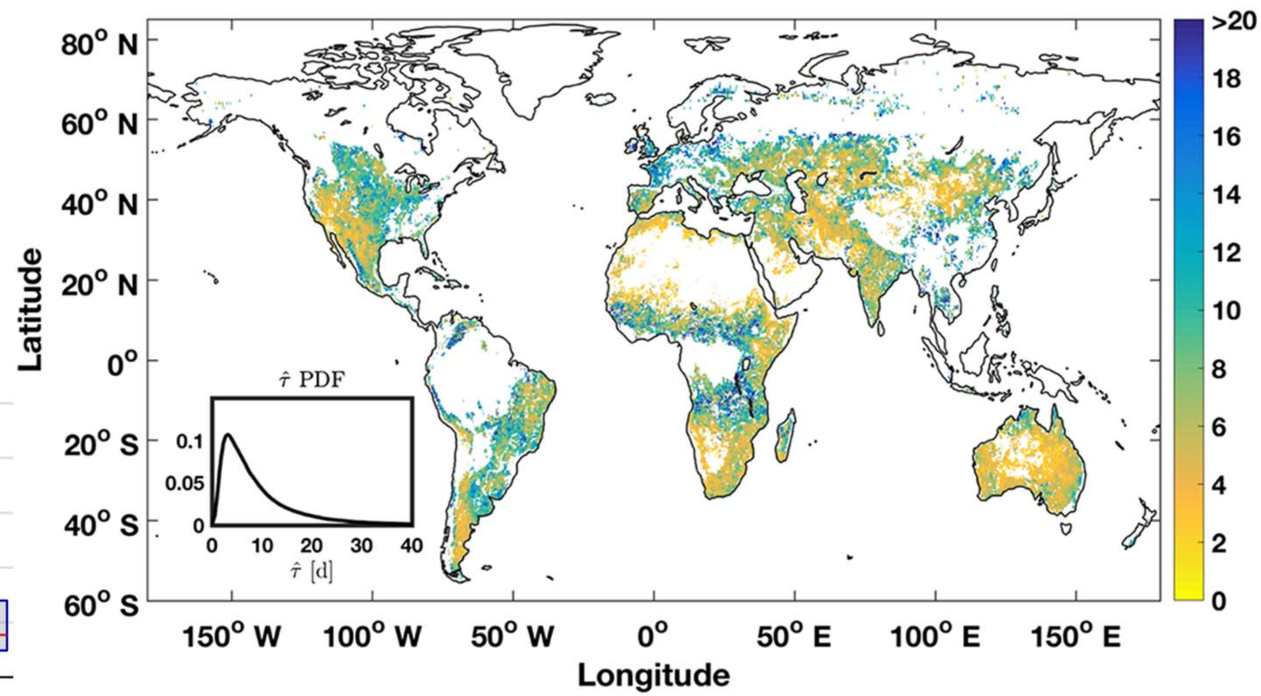
Akbar, Gianotti, Haghighi and Entekhabi (2017)

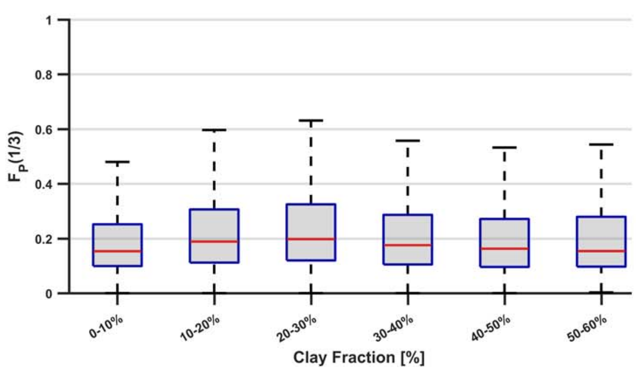
Soil Moisture Memory

Memory of surface soil moisture can extend to days especially where land-atmosphere coupling is significant and forecast skill can be extended.

McColl et al., 2017b: Global characterization of surface soil moisture drydowns, 44, *Geophysical Research Letters*.







Summary

- Exceptional quality global L-band radiometry
- Science uses in characterizing land, terrestrial biosphere and ocean water cycle branches
- Focus on first global characterization of the *link* between the land branches of the water, energy and carbon cycles: Determines how Earth System models respond to and propagate perturbations in one cycle to another
- Learning about soil moisture memory and processes through which soil moisture can influence surface and hydrologic fluxes