Surface Soil Moisture and Plant Water Uptake at L-band

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Background

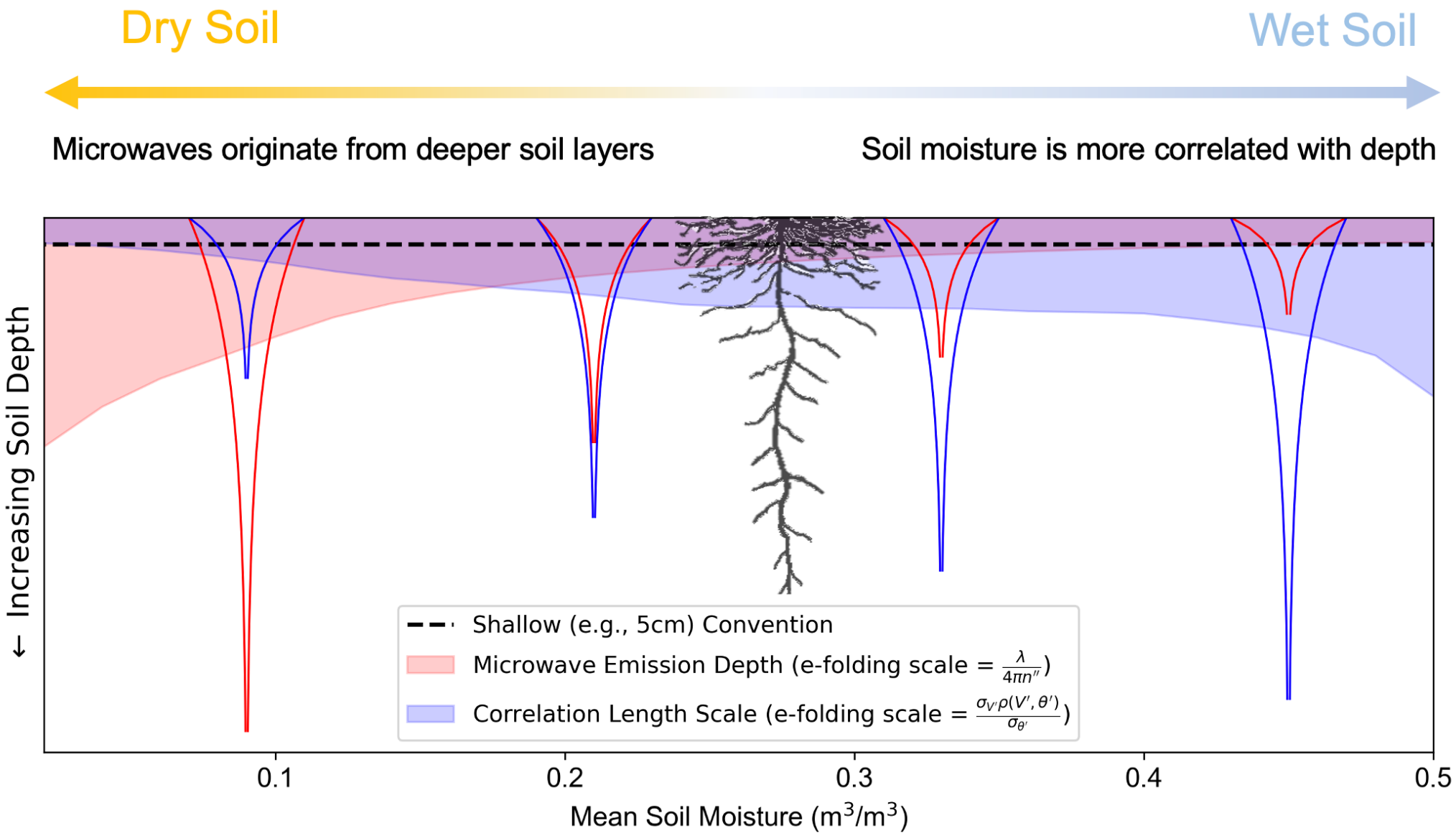
- Several often-repeated statements:

1. "*L-band radiometry-based soil moisture products represent the soil moisture only in the top 5 cm.*"
2. "*Plant roots uptake water from deeper in the soil*
   Maximum rooting depth is meter and more."

Do L-band microwave remote sensing products only represent soil moisture in the top 0–5 cm?
Can L-band satellite soil moisture retrievals be useful for studying plant water use and, if so, under what conditions?

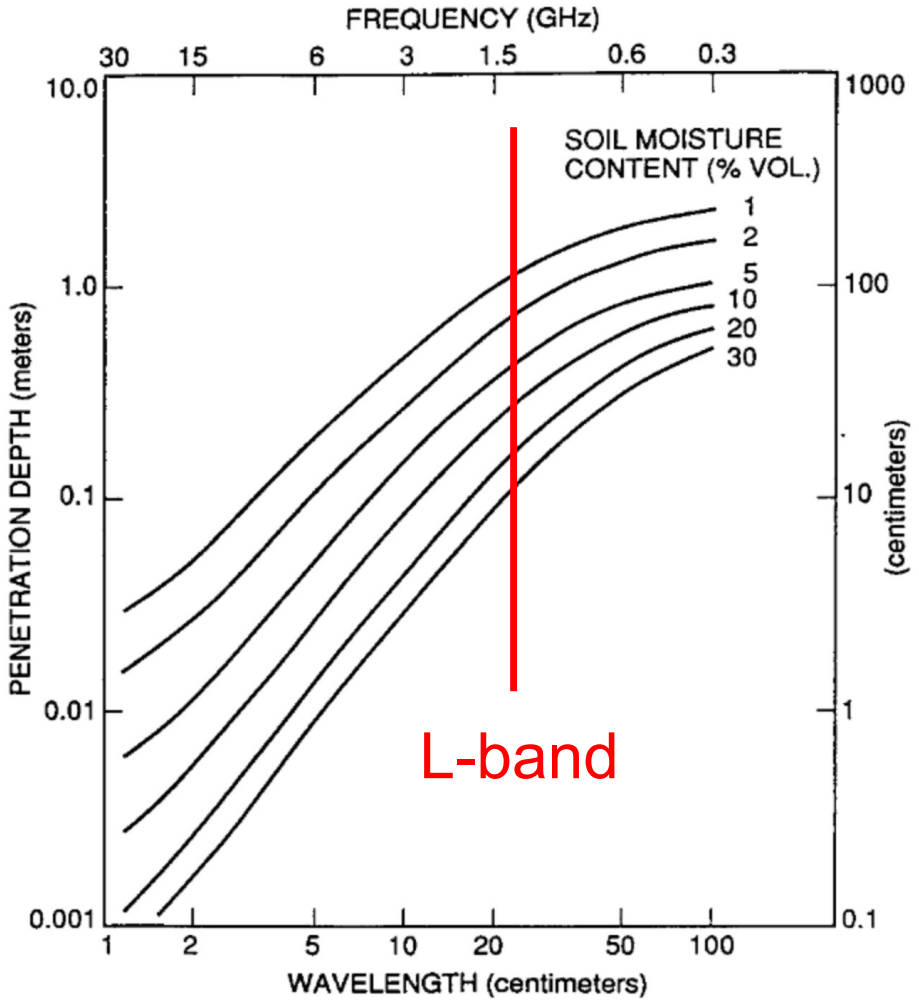
Andrew F. Feldman, Daniel J. Short Gianotti, Jianzhi Dong, Ruzbeh Akbar, Wade T. Crow, Kaighin A. McColl, Alexandra G. Konings, Jesse B. Nippert, Shersingh Joseph Tumber-Dávila, Noel M. Holbrook, Fulton E. Rockwell, Russell L. Scott, Rolf H. Reichle, Abhishek Chatterjee, Joanna Joiner, Benjamin Poulter, Dara Entekhabi, 2023. Remotely sensed soil moisture can capture dynamics relevant to plant water uptake, *Water Resources Research*, 59, https://doi.org/10.1029/2022WR033814

Satellite soil moisture effective sensing depth (3-5? times) deeper than 5 cm



Feldman et al. 2023 (WRR)

Drier Conditions: Deeper L-band emission



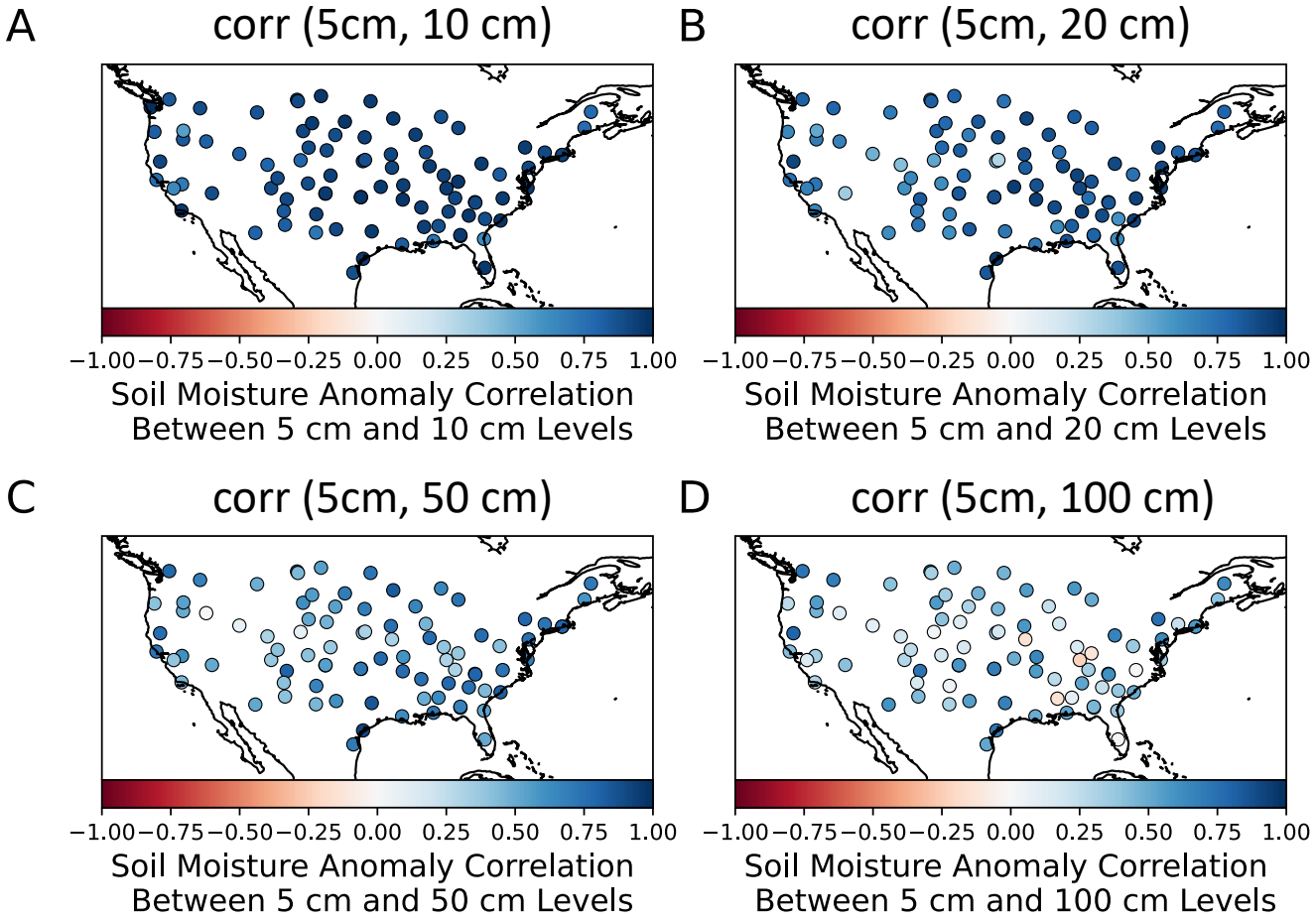
Njoku and Kong (1977)

Emission profile where some information is coming from deeper layers

5 cm is not a cut-off

“Skin-depth” e-folding depth scale is larger for dry soils and smaller for moist soils

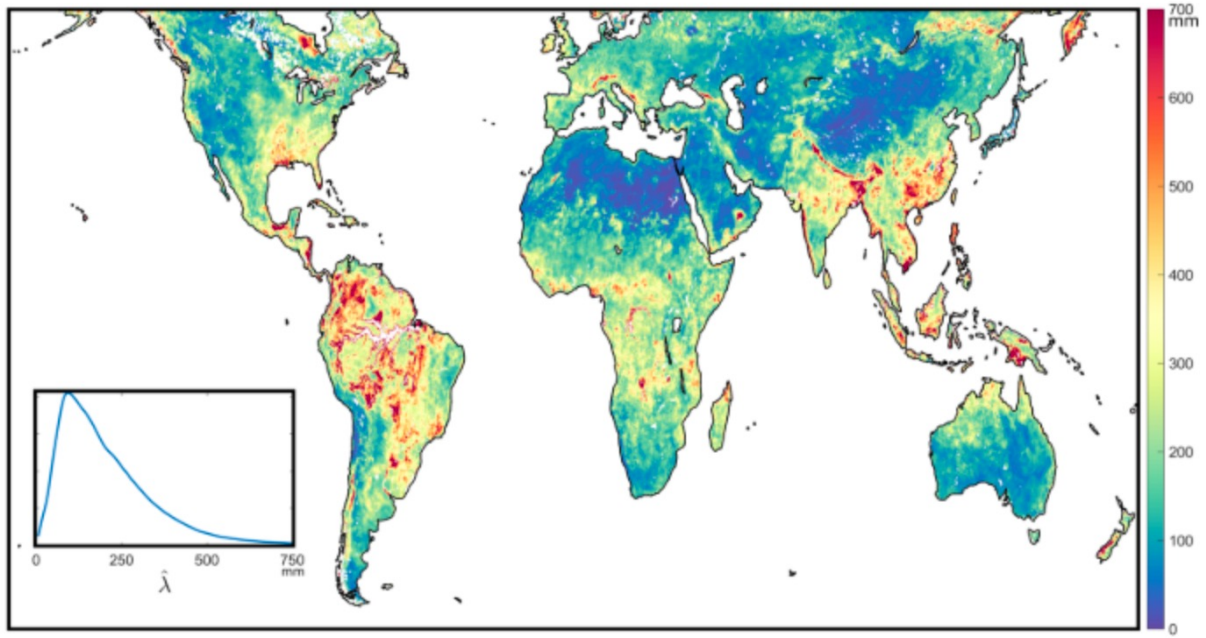
Wetter Conditions: Soil Moisture Vertical Correlation



USCRN correlation between 5cm soil sensor and other sensors with depth (Akbar et al. 2018; Feldman et al. 2023)

- Soil moisture highly correlated with depth
- Perturbations at the surface appear in deeper layers

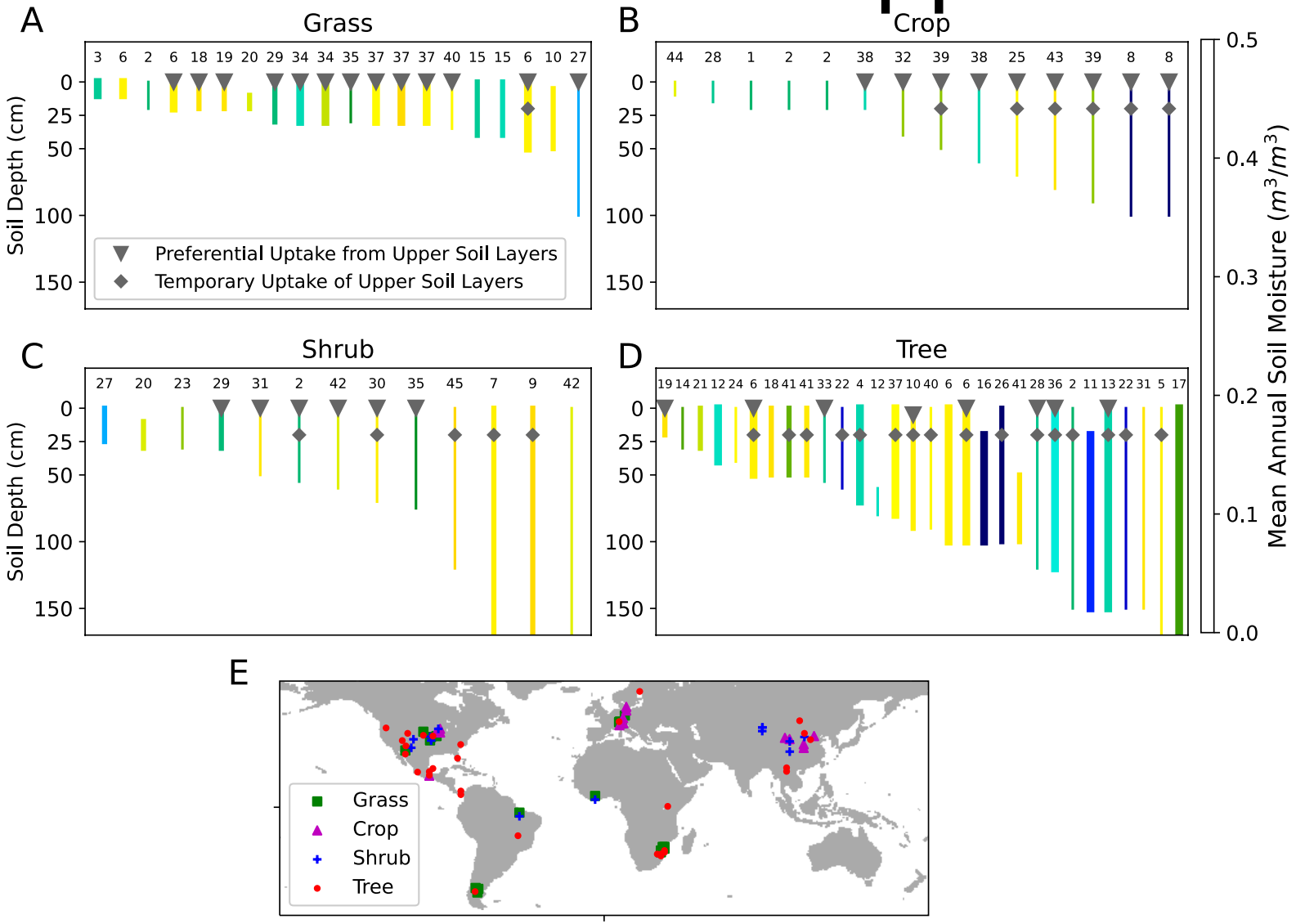
Wetter Conditions: Soil Moisture Vertical Correlation



SMAP estimated vertical correlation length scale (Short Gianotti et al. 2019)

- Estimates of effective sensing depth range between 5 cm and 50 cm
- Spatiotemporal changes in depth are likely

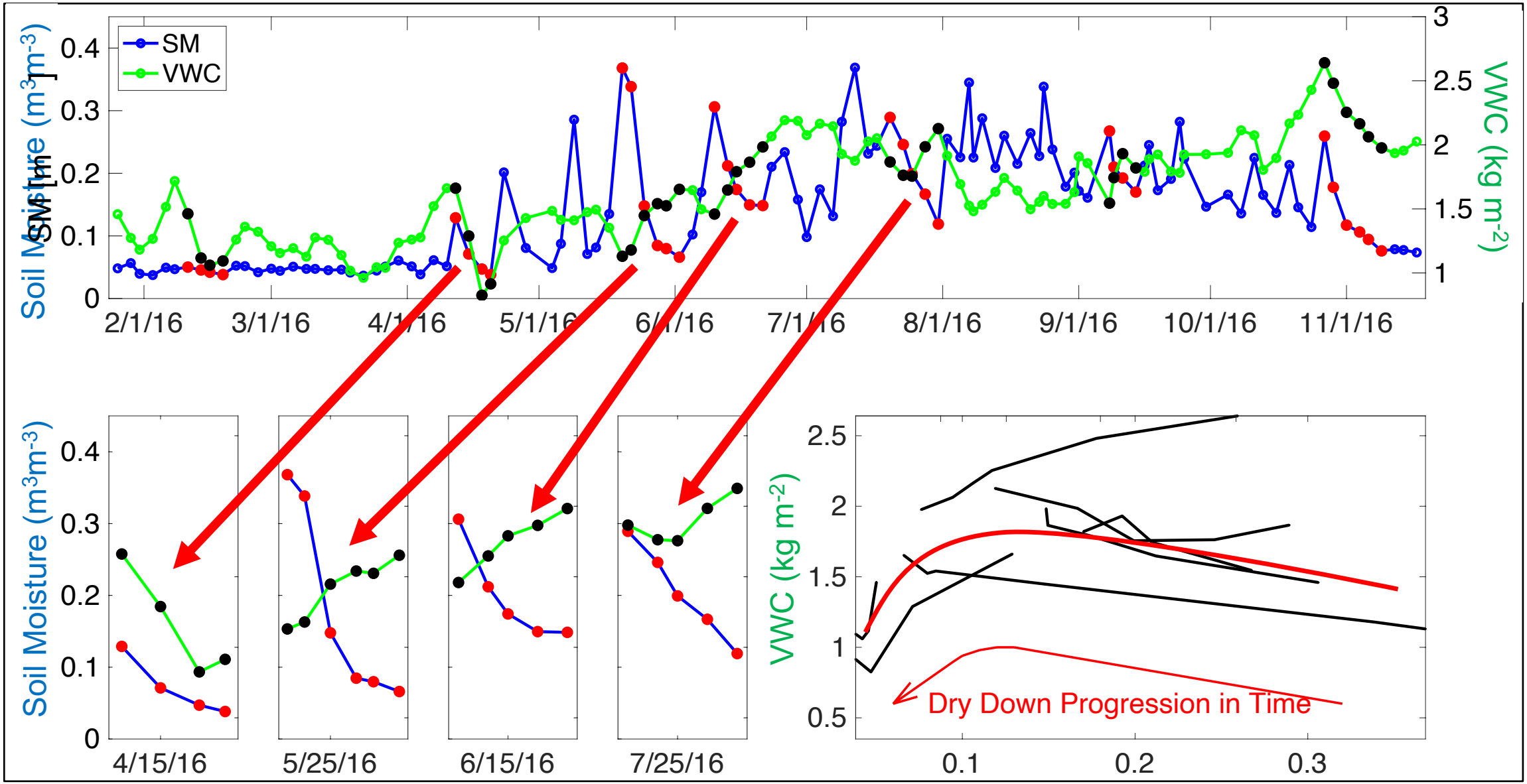
Isotopic tracers reveal many plants draw from upper soil layers



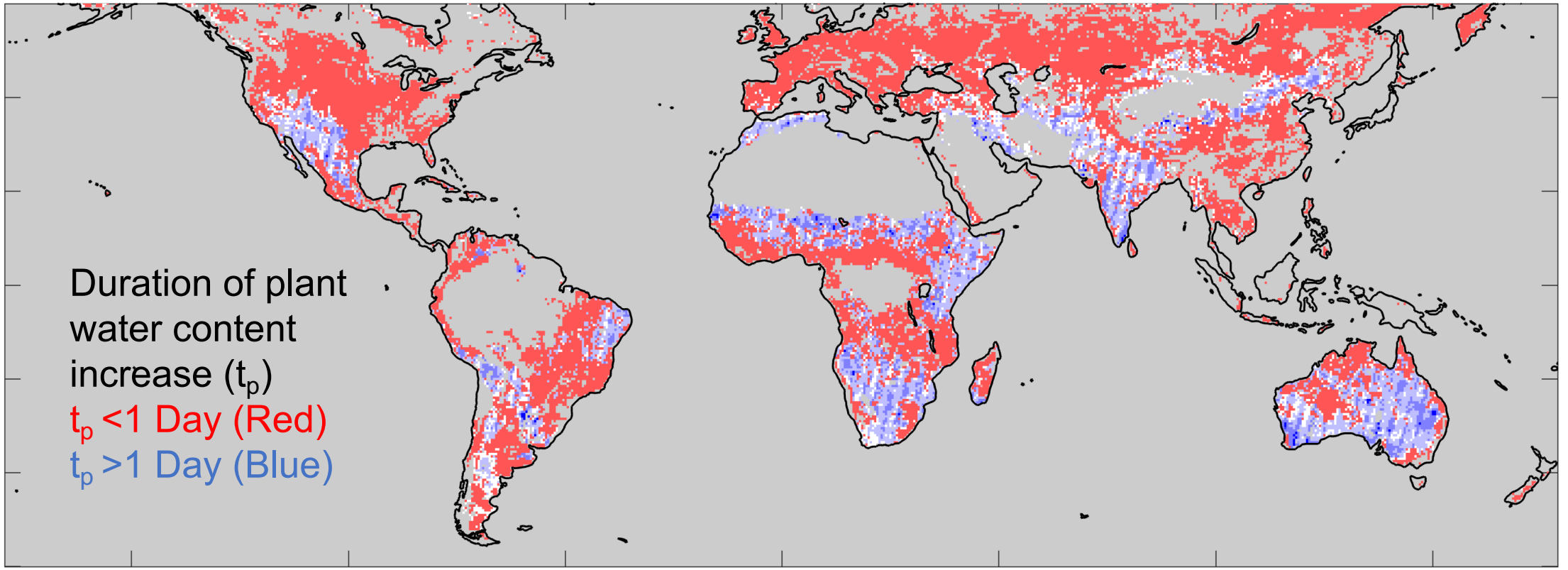
- Most grasses and crops draw from 0-25 cm
- Preference for upper layer soil water uptake in cases that uptake extends deeper than 50 cm

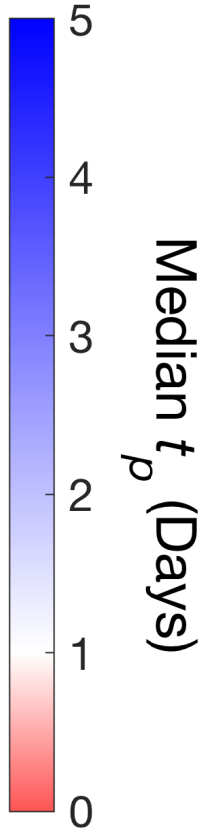
Feldman et al. 2023 (WRR)

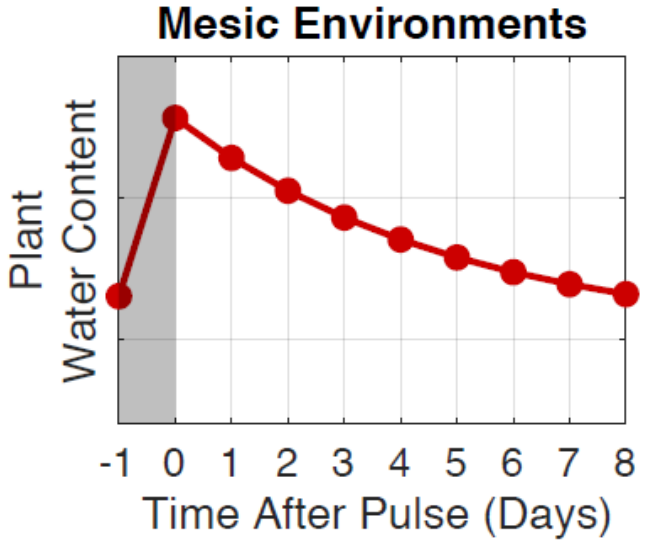
Soil and plant water content during interstorms

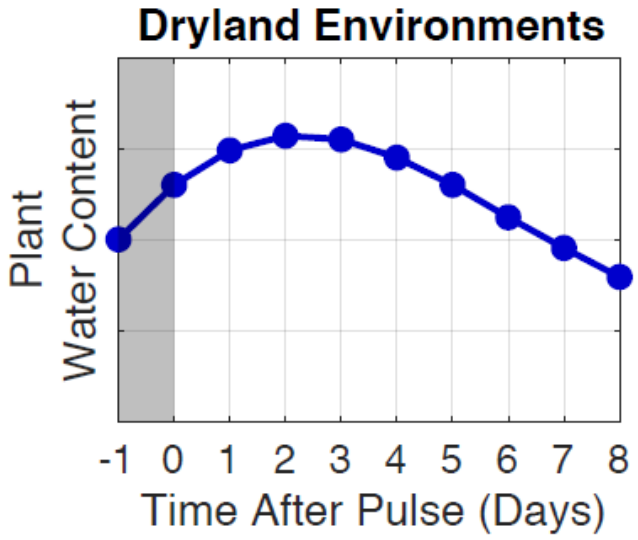


Feldman et al. (2018) *Nature Plants*









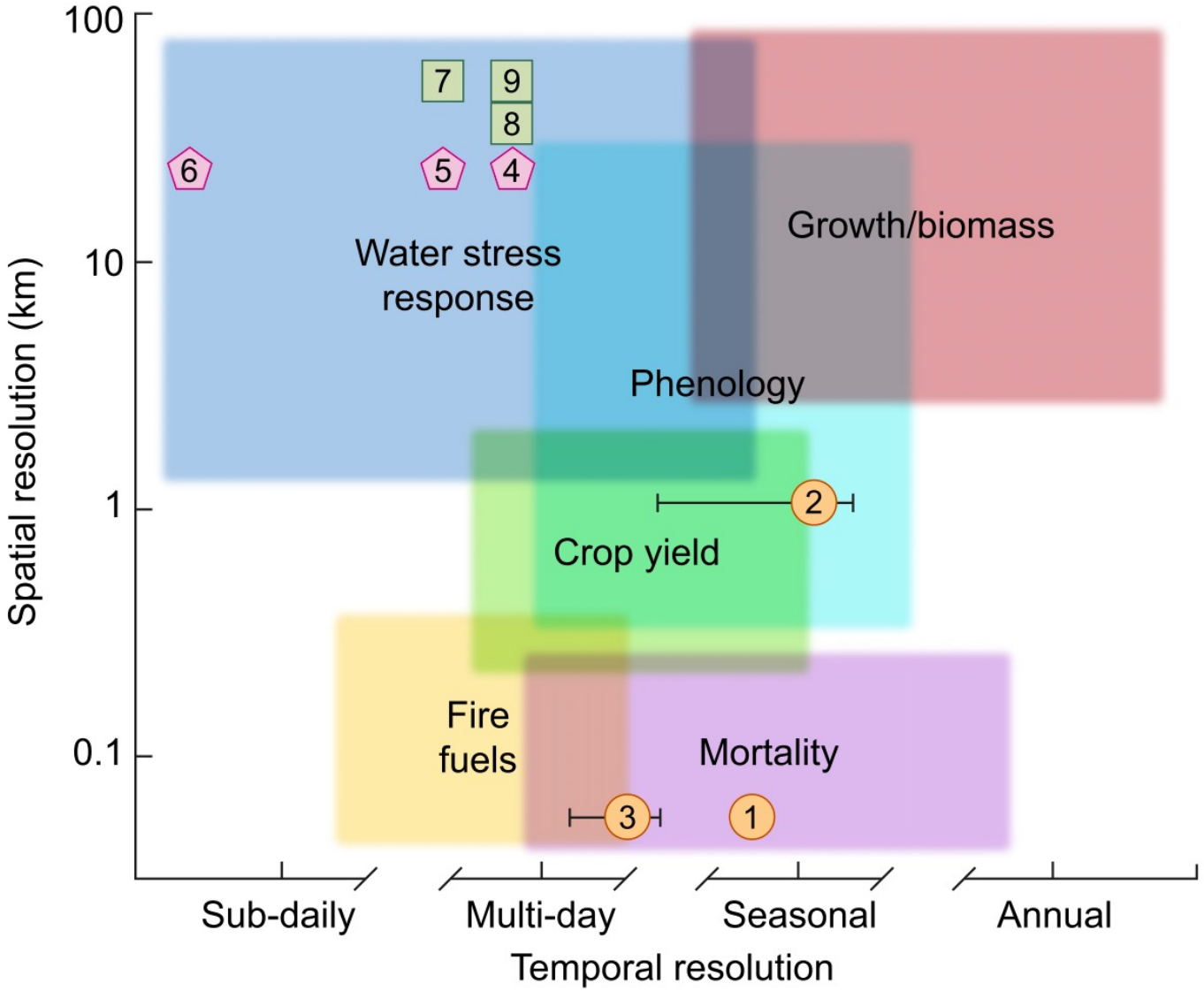
- After storms, plant water content increases
- Does so more frequently and for longer in drylands

Feldman et al. (2018) *Nature Plants*

Feldman et al. (2021) *Biogeosciences*

Key Takeaways

- L-band soil moisture a function of soil moisture variations deeper than 5 cm
- Many plant types across the globe draw moisture from these upper soil layers throughout the year
- L-band soil moisture useful for studies of ET and plant response to water stress



- Satellites:
  - low res >30km
  - High res <1km
- Applications between 1-10km haven't been greatly discussed yet

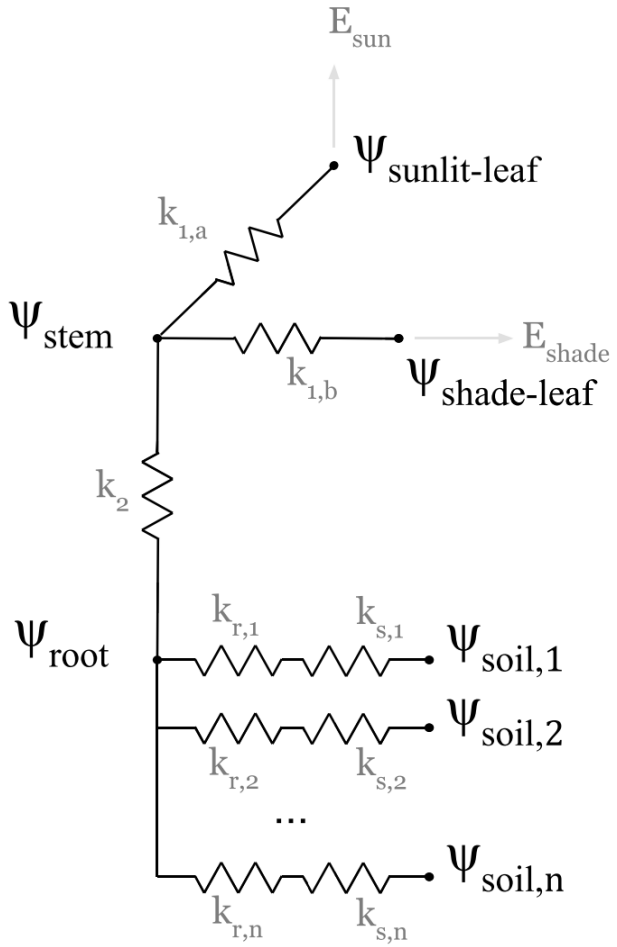
Konings et al. (2019)

10 km soil-plant applications: land surface models

- 10 km soil moisture and microwave vegetation properties useful for assimilating or benchmarking models

- Many models at 10 km scale
  - NLDAS (~10 km)
  - Catchment CN (~20 km)
- Others at ~50 km but with plans to go finer

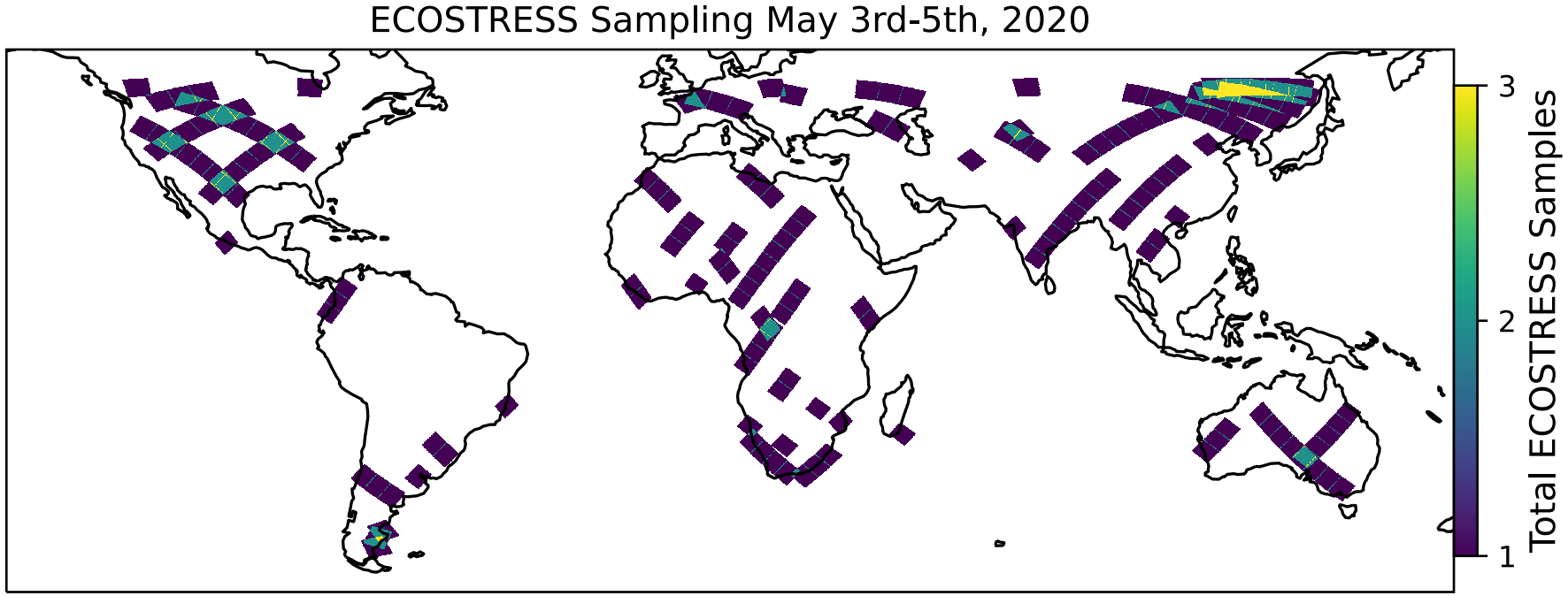
- Push to include plant hydraulics in LSMs which requires L-band measurements



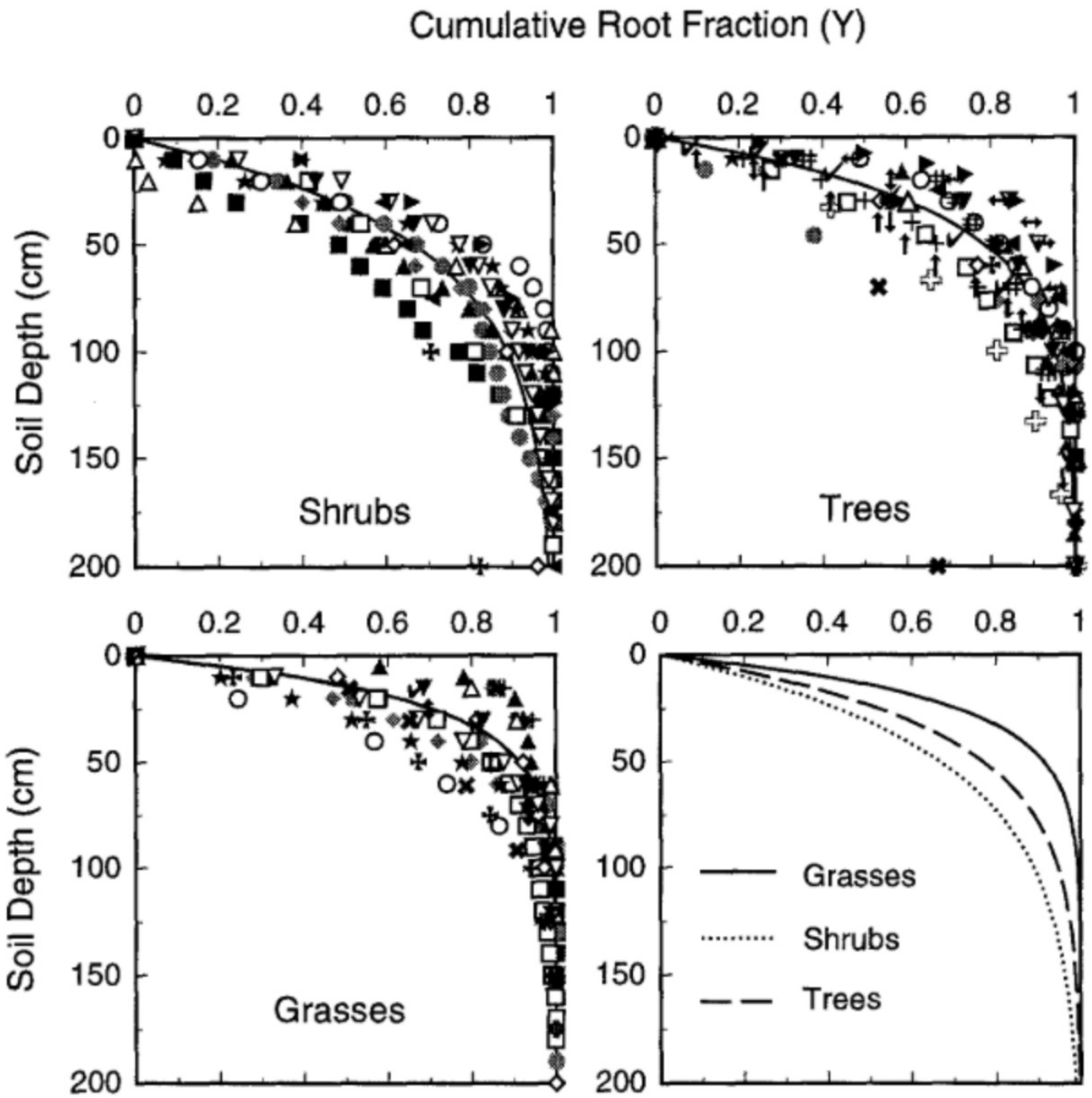
Kennedy et al. 2019 (JAMES)
Implementing plant hydraulics in CLM

10 km soil-plant applications: water cycle coupling

- Better matching of 10km soil moisture with higher res ET and vegetation-observing instruments
  - <1km resolution (ECOSTRESS, GEDI, EMIT, SBG)
- For water-carbon-energy coupling studies
- 10 km with frequent (~1 day) revisits needed to provide coverage to match these products



Back-up



- Rooting depths show similar points
- Most roots are concentrated in upper layers
  - Highest hydraulic conductance
  - Highest nutrient concentration in these layers
- Deepest roots often used under water stress

Jackson et al. 1996