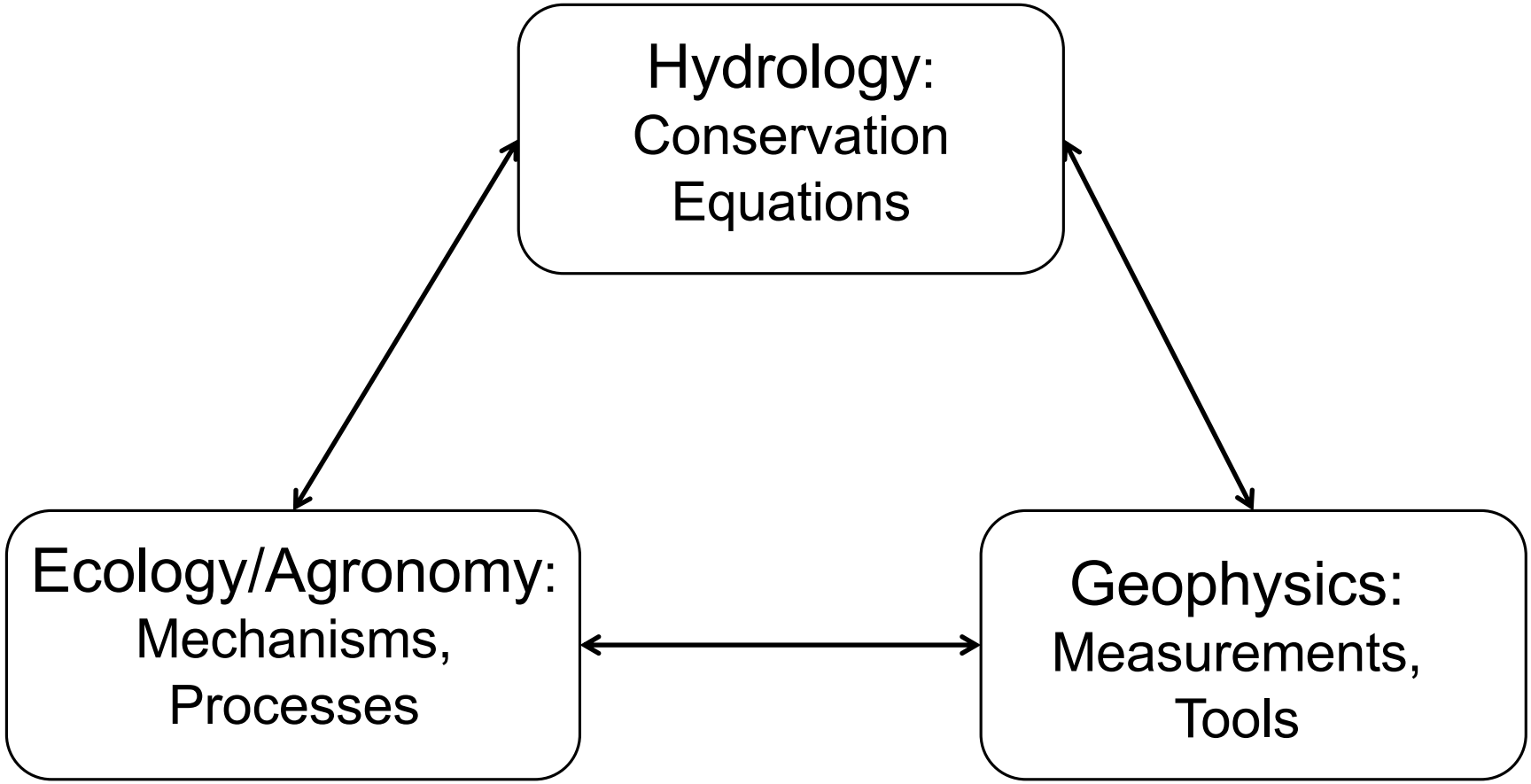
Overview and applications of cosmic-ray neutron sensor

Trenton Franz and Ammar Wahbi

Assoc. Professor of Hydrogeophysics
School of Natural Resources
University of Nebraska-Lincoln

August 18 2019

What do I study?



Prof. Trenton Franz

Grow up in Colorado, USA

2004-BS in Civil Engineering, University of Wyoming

2005-MS in Civil Engineering, University of Wyoming

2007-MS in Civil and Environmental Engineering, Princeton University

2011-PhD in Civil and Environmental Engineering, Princeton University

2011-2013-Postdoctoral researcher in Hydrology and Water Resources, University of Arizona

Sept. 2013- Asst. Professor University of Nebraska-Lincoln, Faculty Fellow of Daugherty Water for Food Global Institute

July 2018- Assoc. Professor UNL

Installed and worked with 60+ CRNS systems in the USA, South Africa, Australia, UK, Austria, Germany, Kenya, Spain …

Authored 25+ peer reviewed publications on CRNS

Authored 2 TEC-DOCs and 1 Springer Book on CRNS

Completed 1 week Expert Mission to Austria July 2017, Kuwait 2018

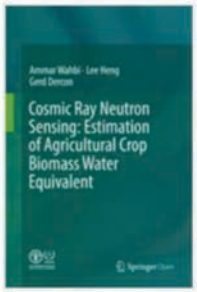
IAEA-TECDOC-1809

Cosmic Ray Neutron Sensing: Use, Calibration and Validation for Soil Moisture Estimation

IAEA-TECDOC-1845

Soil Moisture Mapping with a Portable Cosmic Ray Neutron Sensor

Joint FAO/IAEA Programme



Cosmic Ray Neutron Sensing: Estimation of Agricultural Crop Biomass Water Equivalent

Authors (view affiliations)

Ammar Wahbi, Lee Heng, Gerd Dercon

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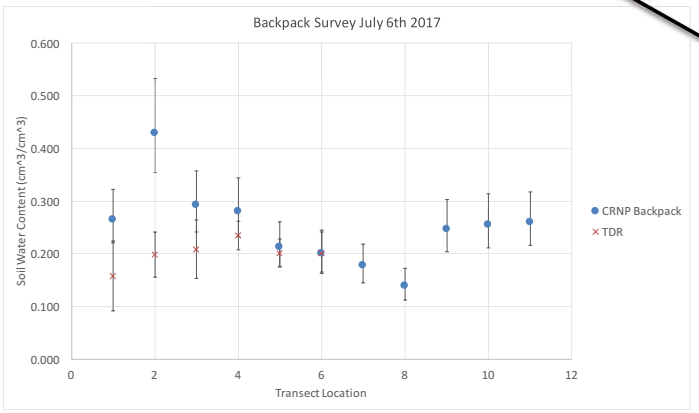

Goals and Objectives for this Training Mission

Main Purpose

National Training activity on "Use of Advanced Nuclear and Related Tools for Agricultural Water Management and use of nuclear techniques to partitioning the Evapotranspiration”

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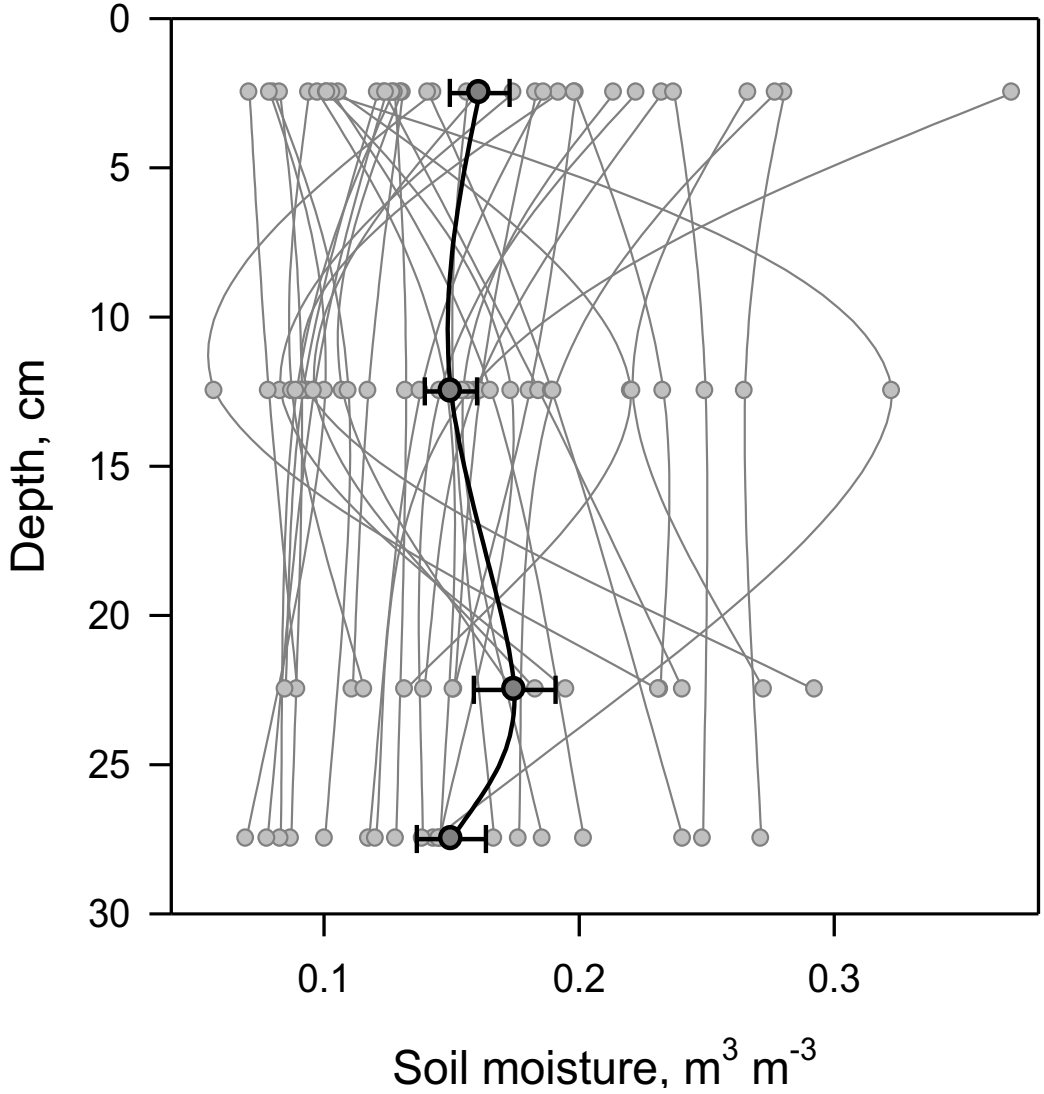
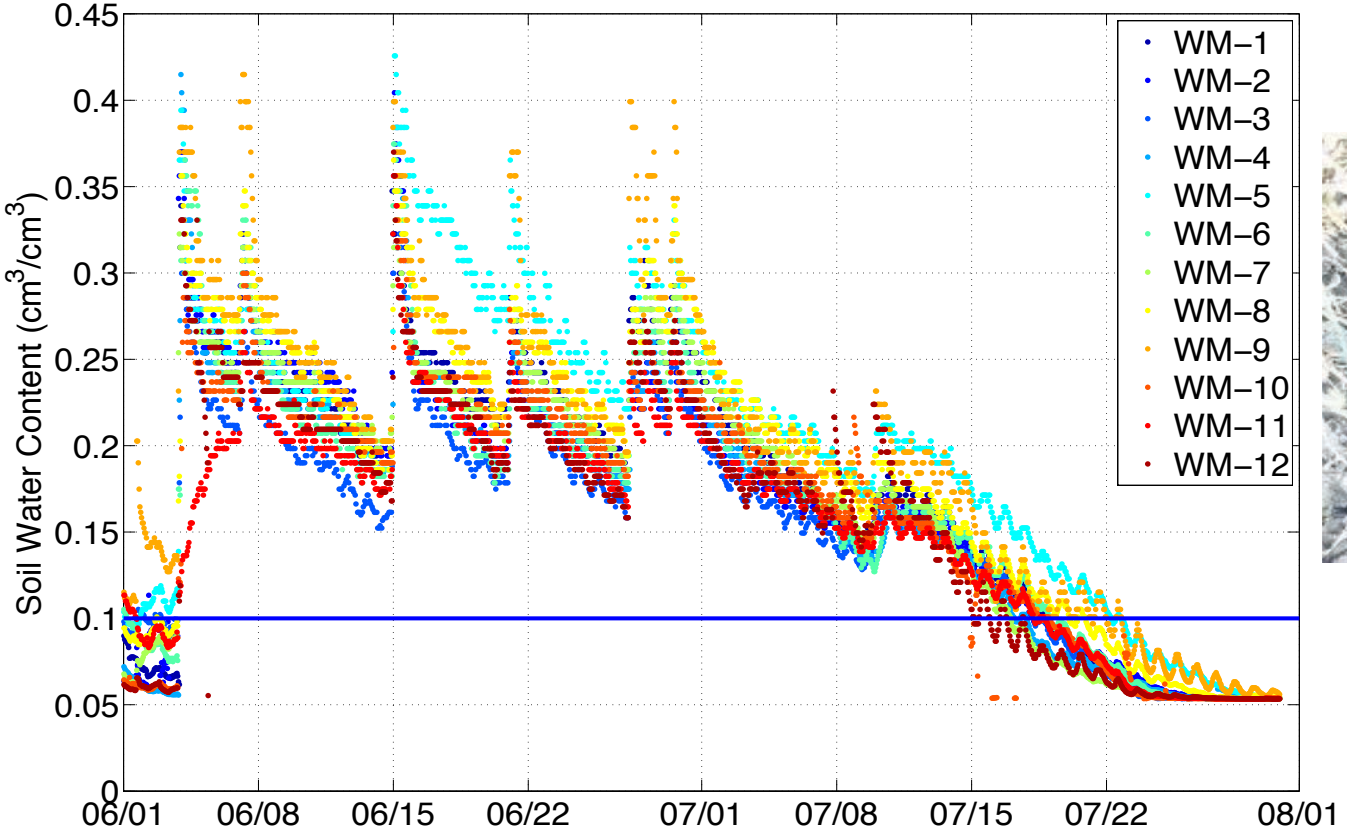
4. A full demonstration of data processing of the CRNS output

Soil Moisture Varies Across Space

San Pedro, 5 March 2010



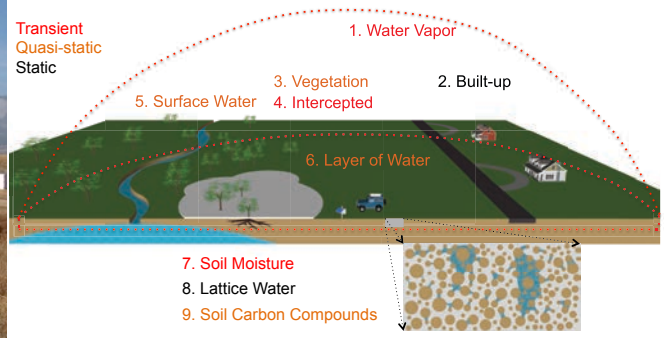
And Time

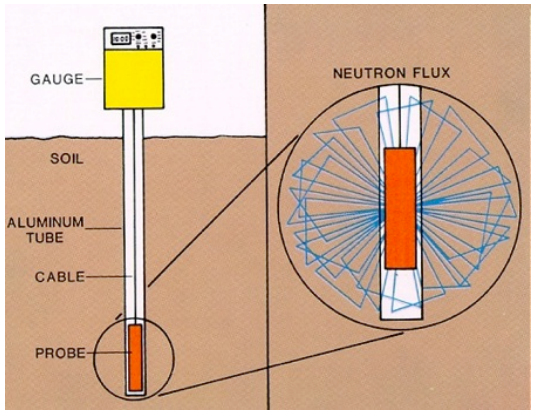

Soil Water Content (cm3/cm3)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
06/01
06/08
06/15
06/22
07/01
07/08
07/15
07/22
08/01
WM–1
WM–2
WM–3
WM–4
WM–5
WM–6
WM–7
WM–8
WM–9
WM–10
WM–11
WM–12

Current Methods

- Labor intensive
- Time intensive
- Unreliable
- Not representative of areas where water management decisions are made

One Solution

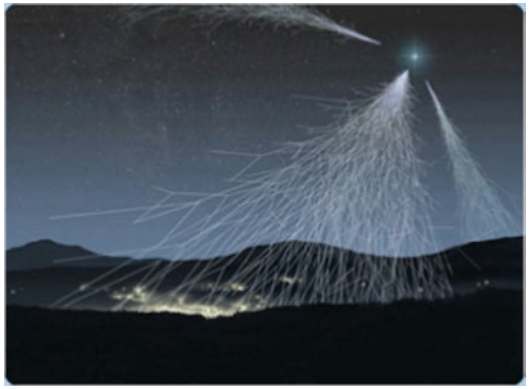
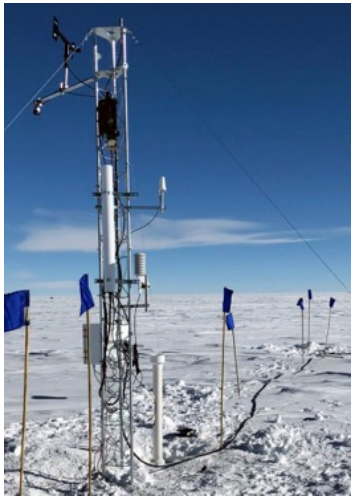




- Essentially same detector but with updated electronics and high voltage NPMs
- Same basic physics as in-situ neutron probe
- Passive sensor, uses cosmic-ray neutrons as source
- Relates fast neutrons to water content instead of slow or thermal neutrons
- Footprint is ~1000x larger (density of soil vs. air)
- Probe sees about top 30 cm
- In-situ probe considered gold standard in agronomy and soil physics

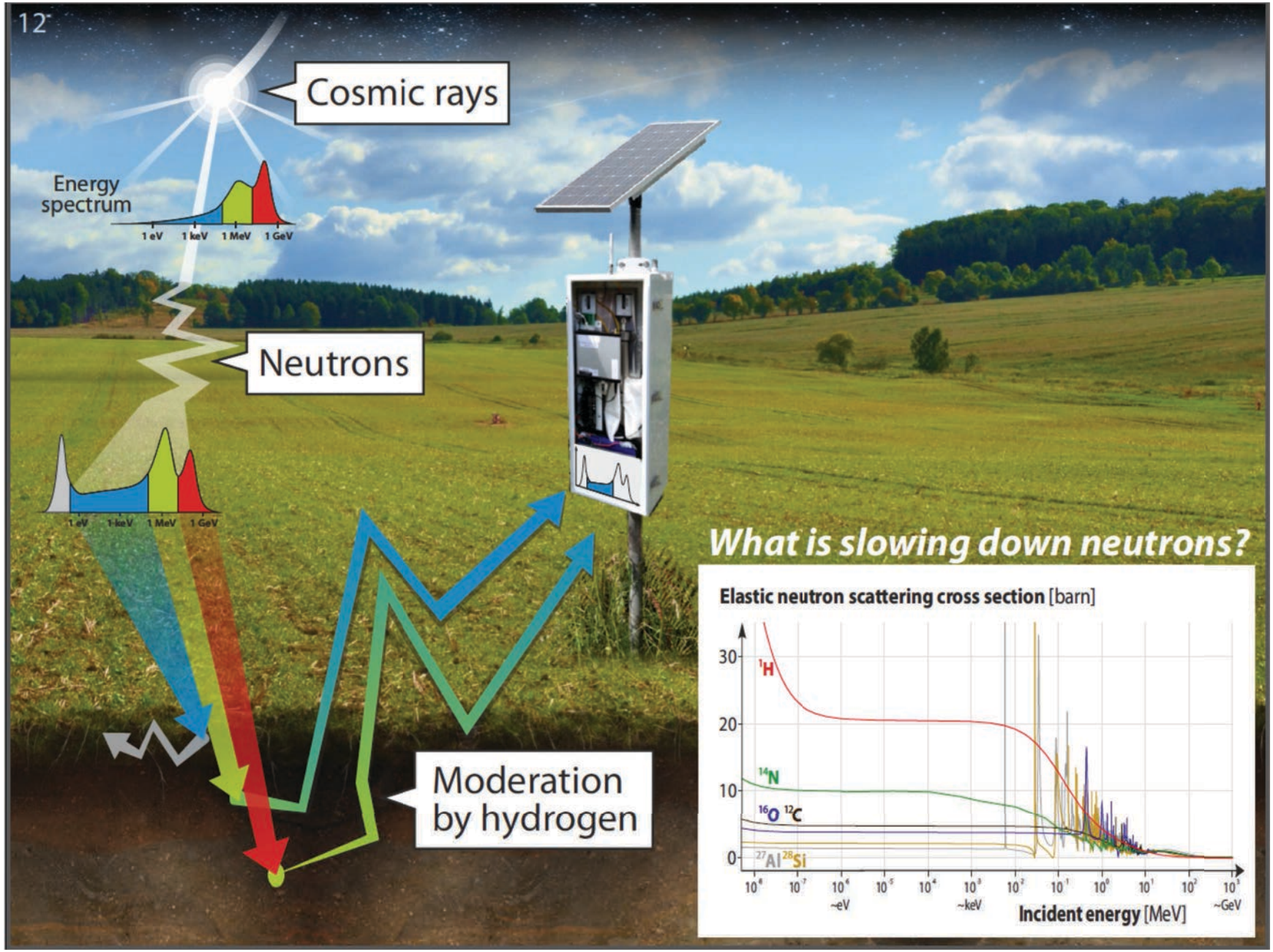
http://sanangelo.tamu.edu/agronomy/sorghum/neutron.htm

Cosmic-ray Neutron Probes

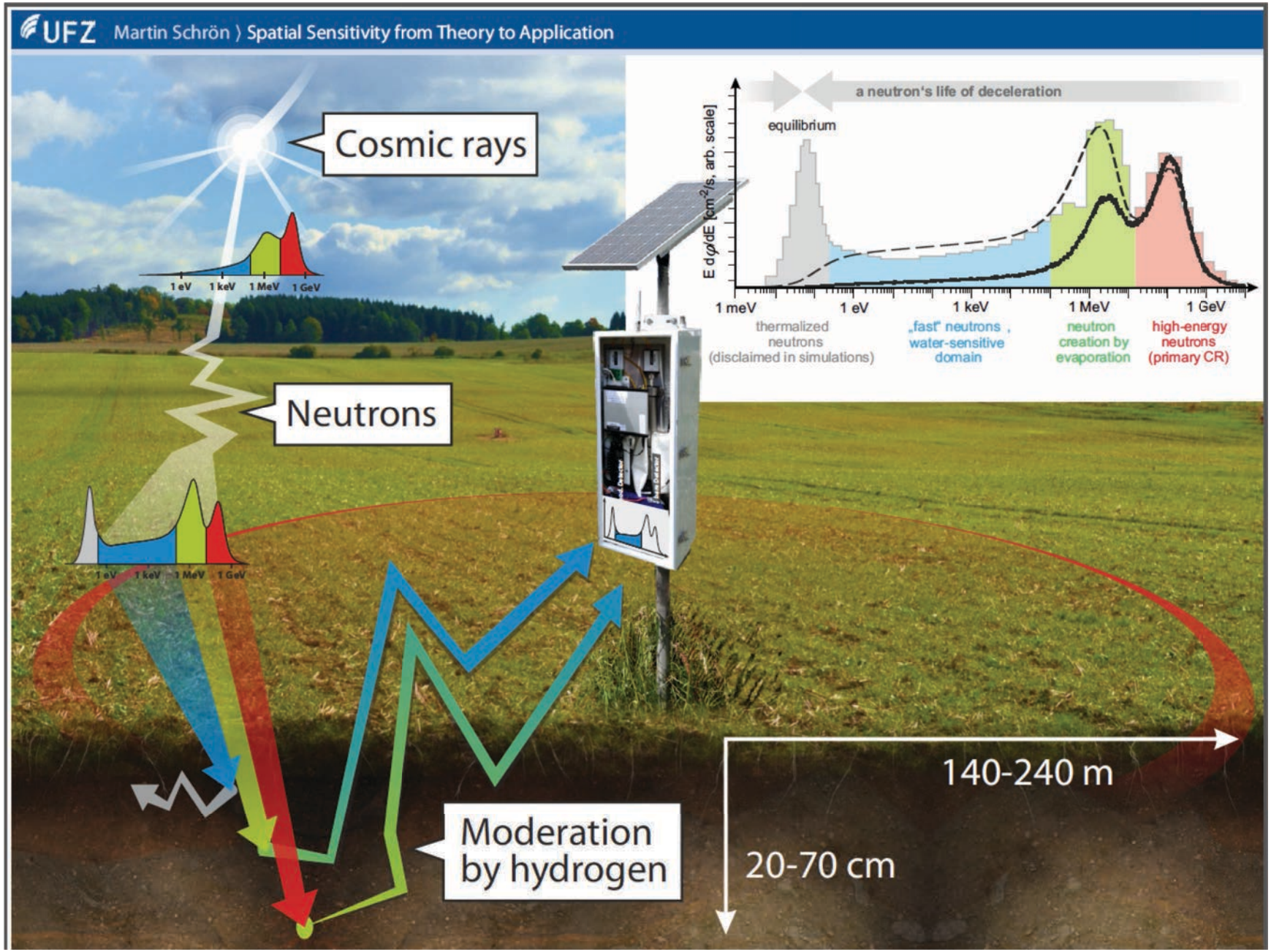









Slide courtesy of M. Schron



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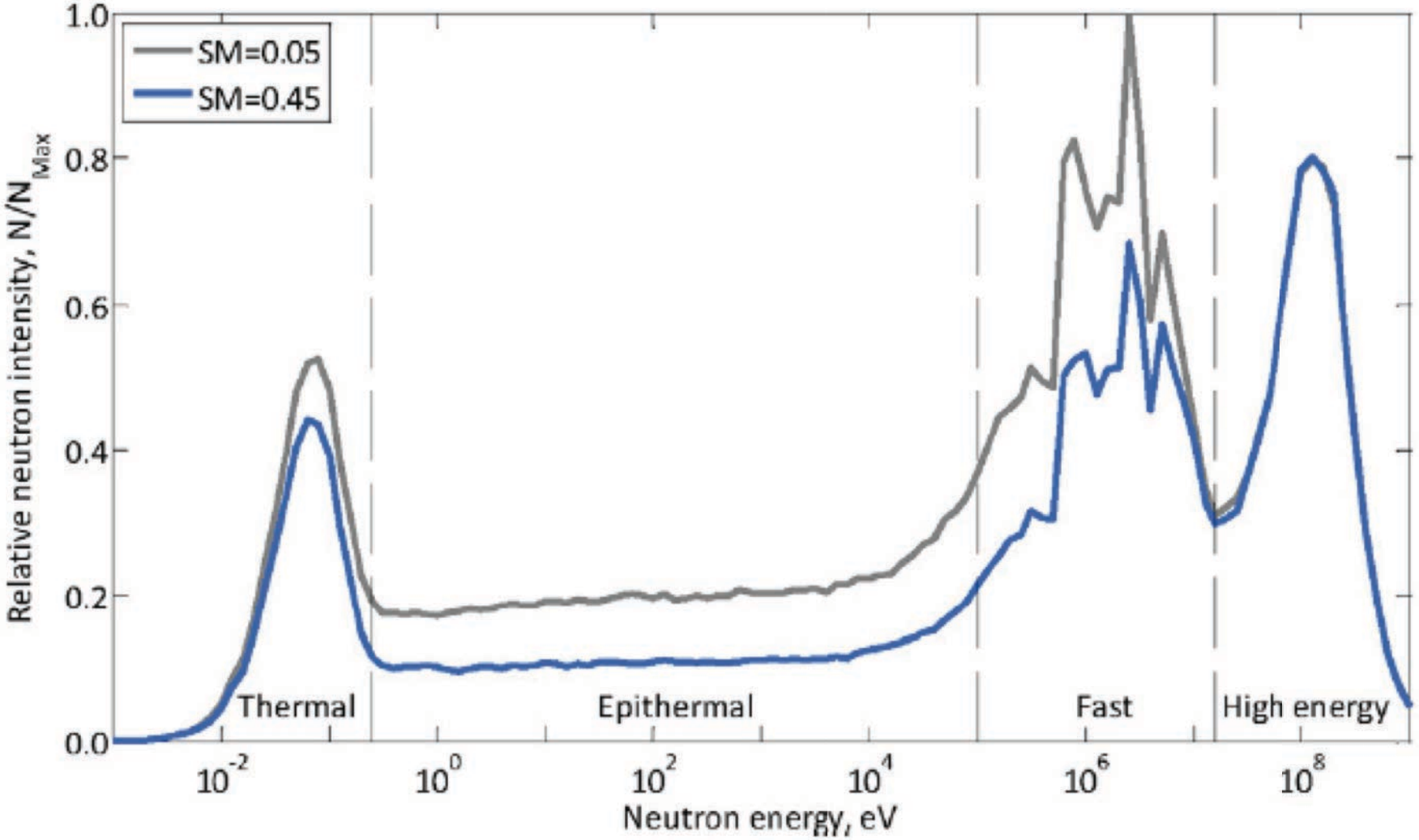
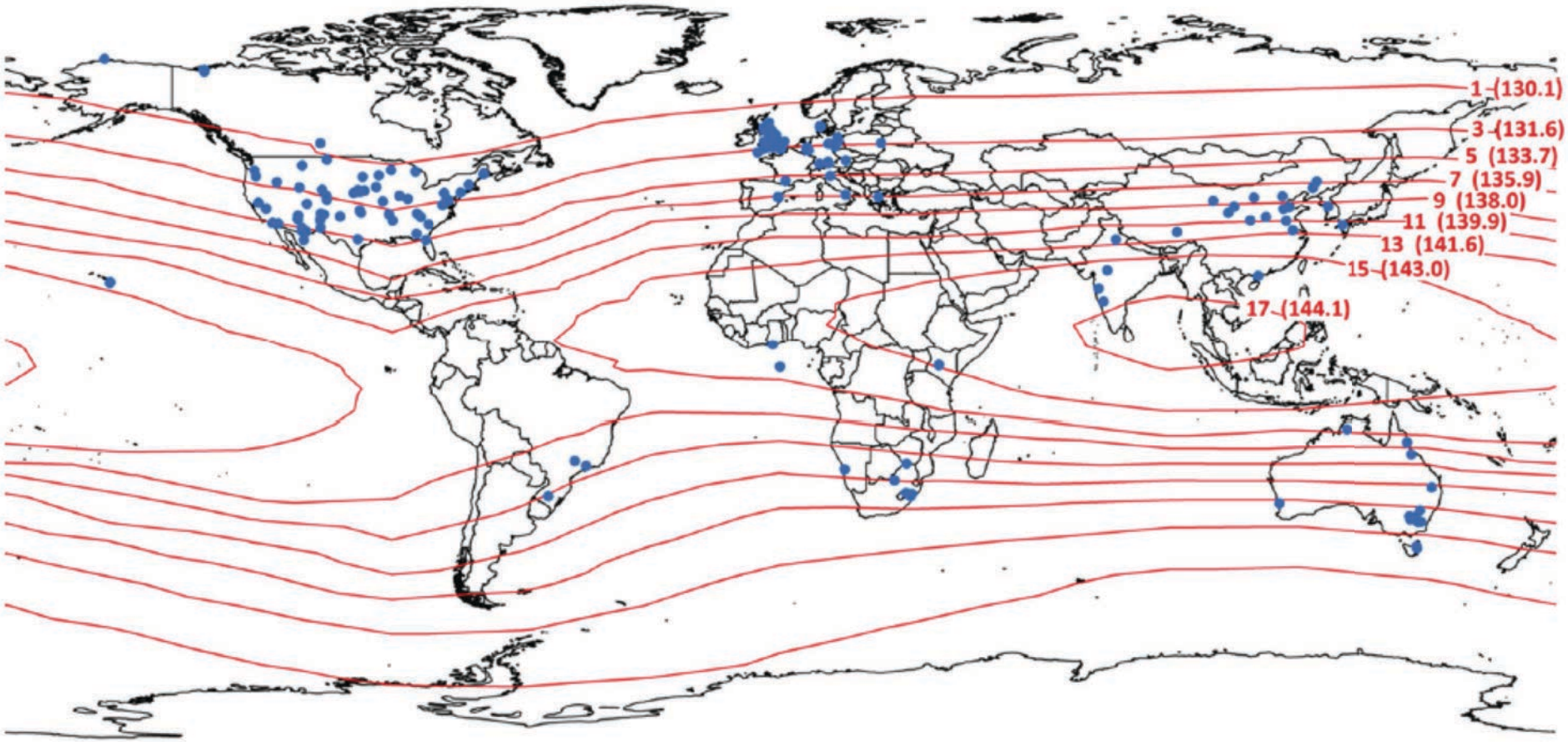


Andreasen, 2017 VZJ

COSMOS Project

- COSMOS data freely available at (http://cosmos.hwr.arizona.edu/) with some quality control, usually co-located with eddy covariance towers, over 90% reliability

- Probes: 70 COSMOS (10 UNL), 200 Independent networks around globe (CosmOz, TERENO, UK, South Africa), with more to come online (Saudi Arabia, Brazil, China?)

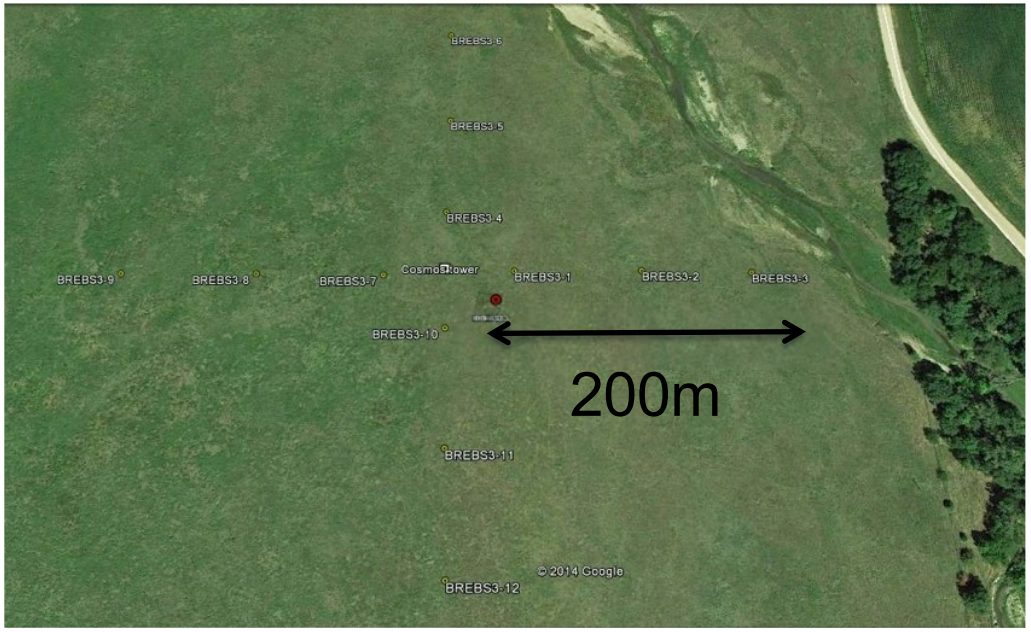


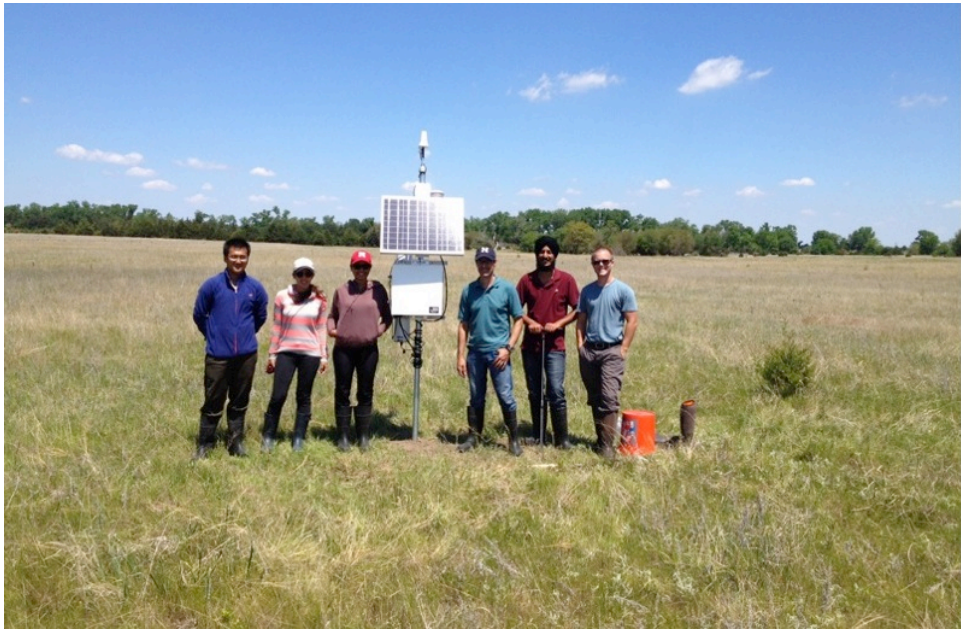
Great, but do they work?

Example

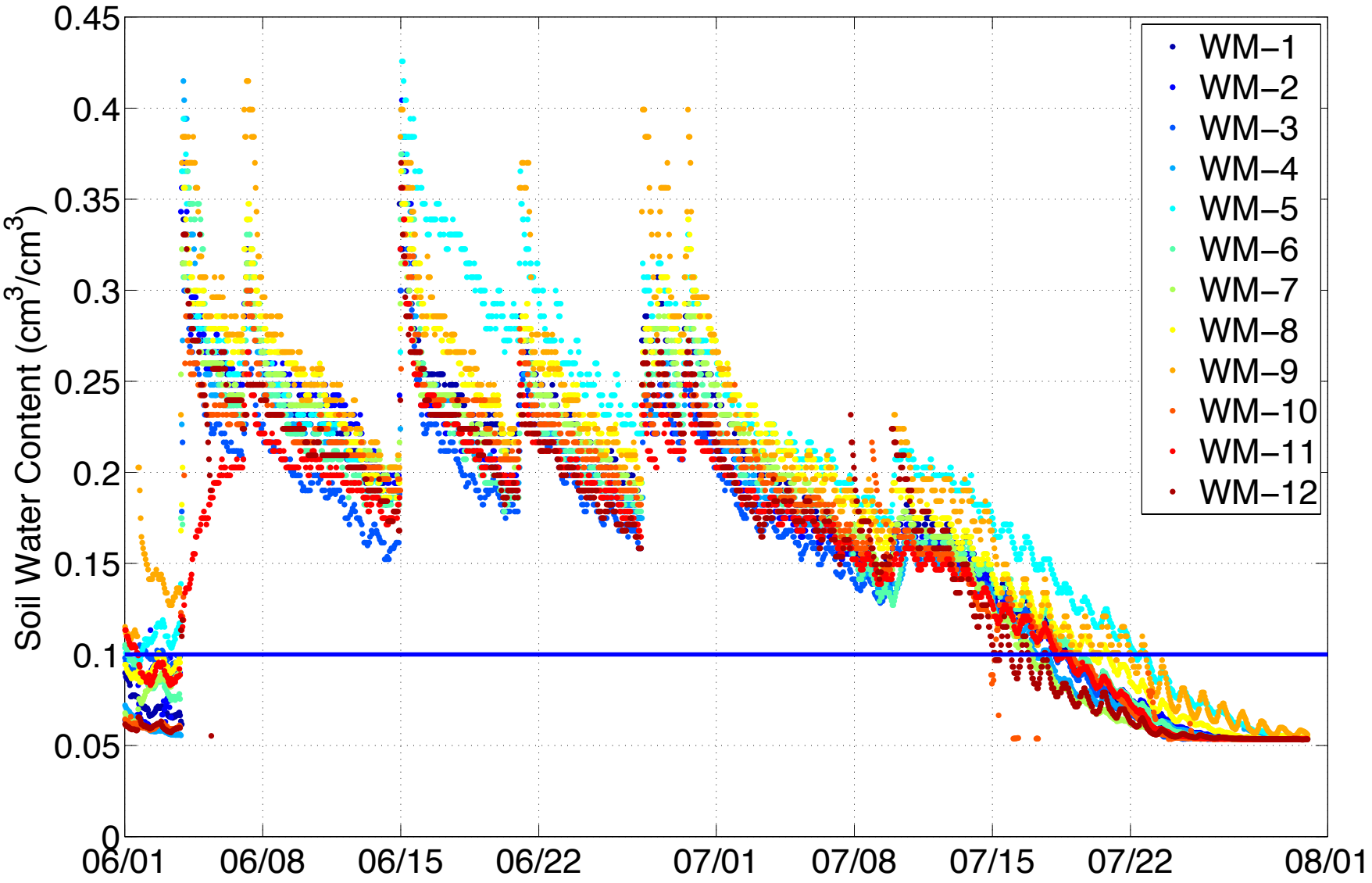
Flat, homogeneous vegetation, sandy loam soil texture,

ideal setting for homogeneity?





Supporting Evidence



In collaboration with S. Irmak, A. Kilic, and A. Diotto

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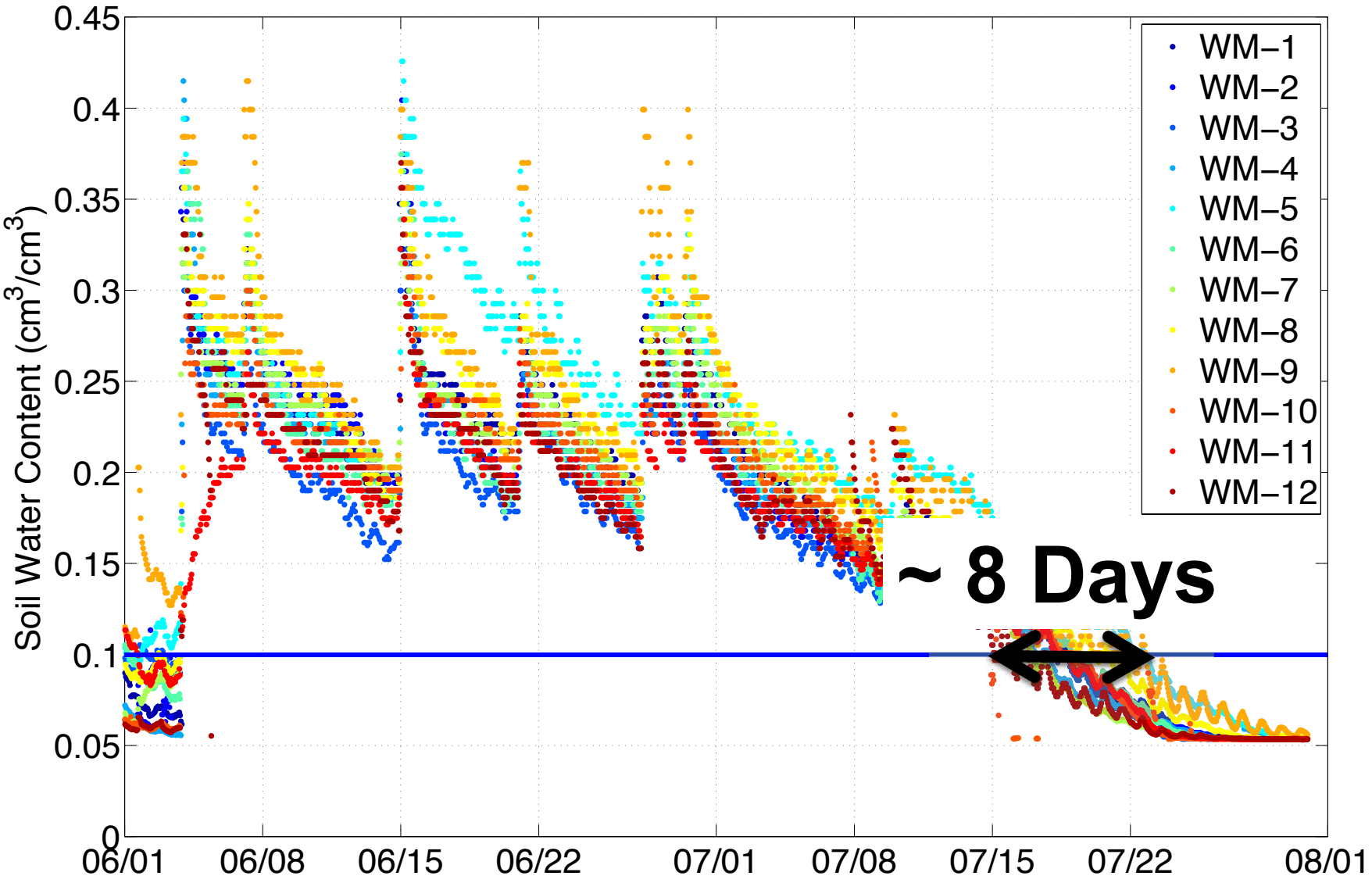

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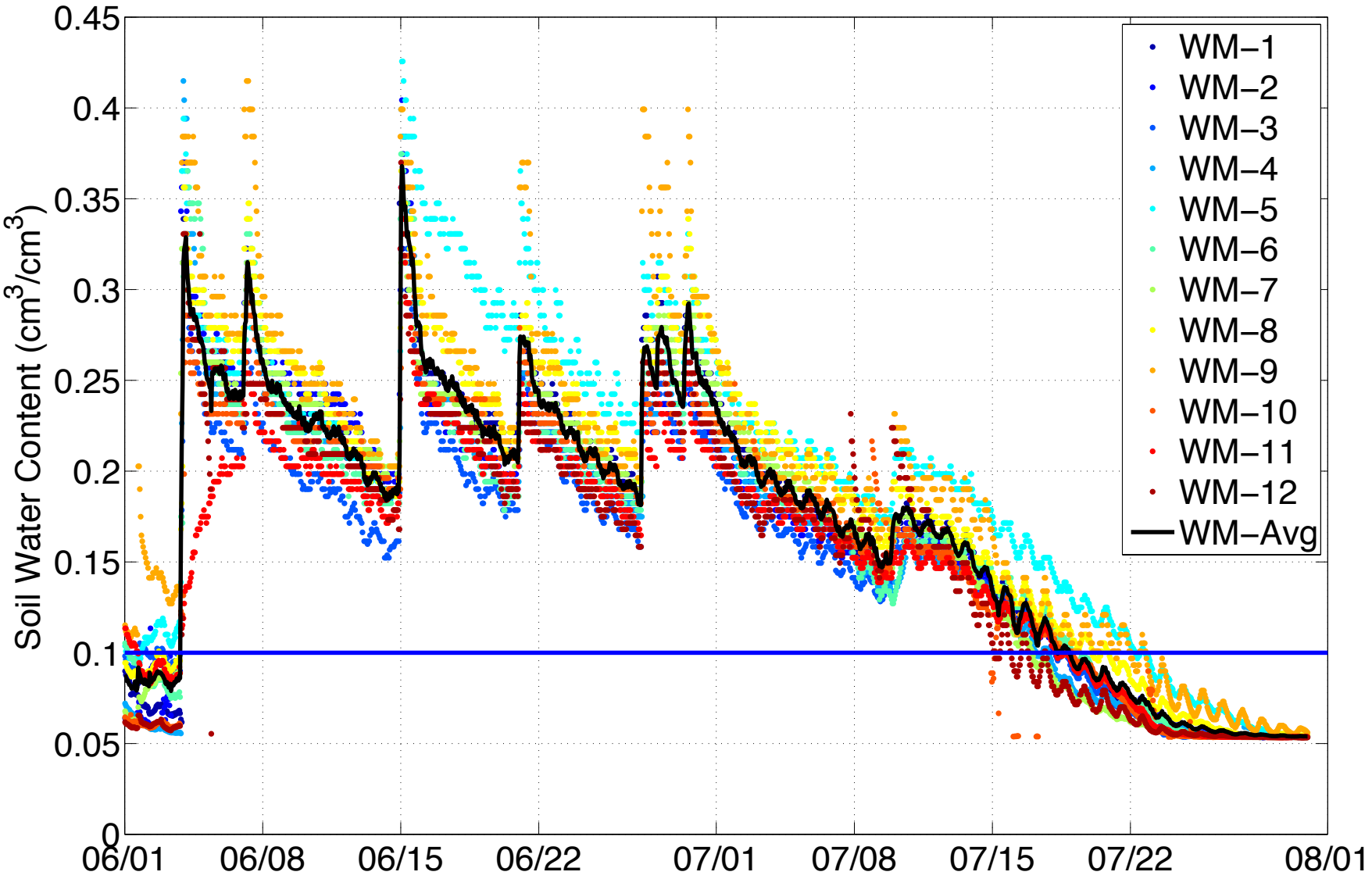

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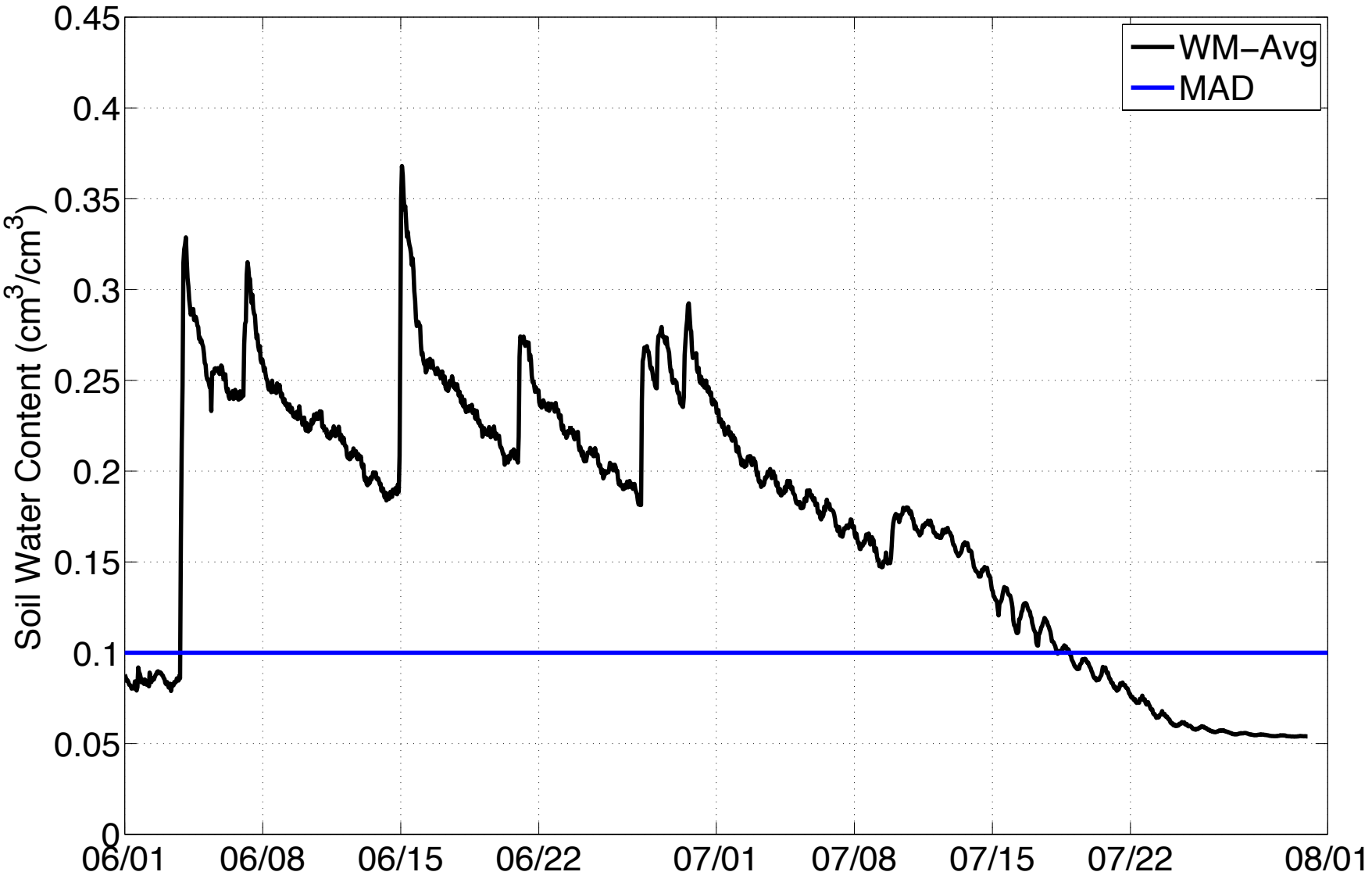

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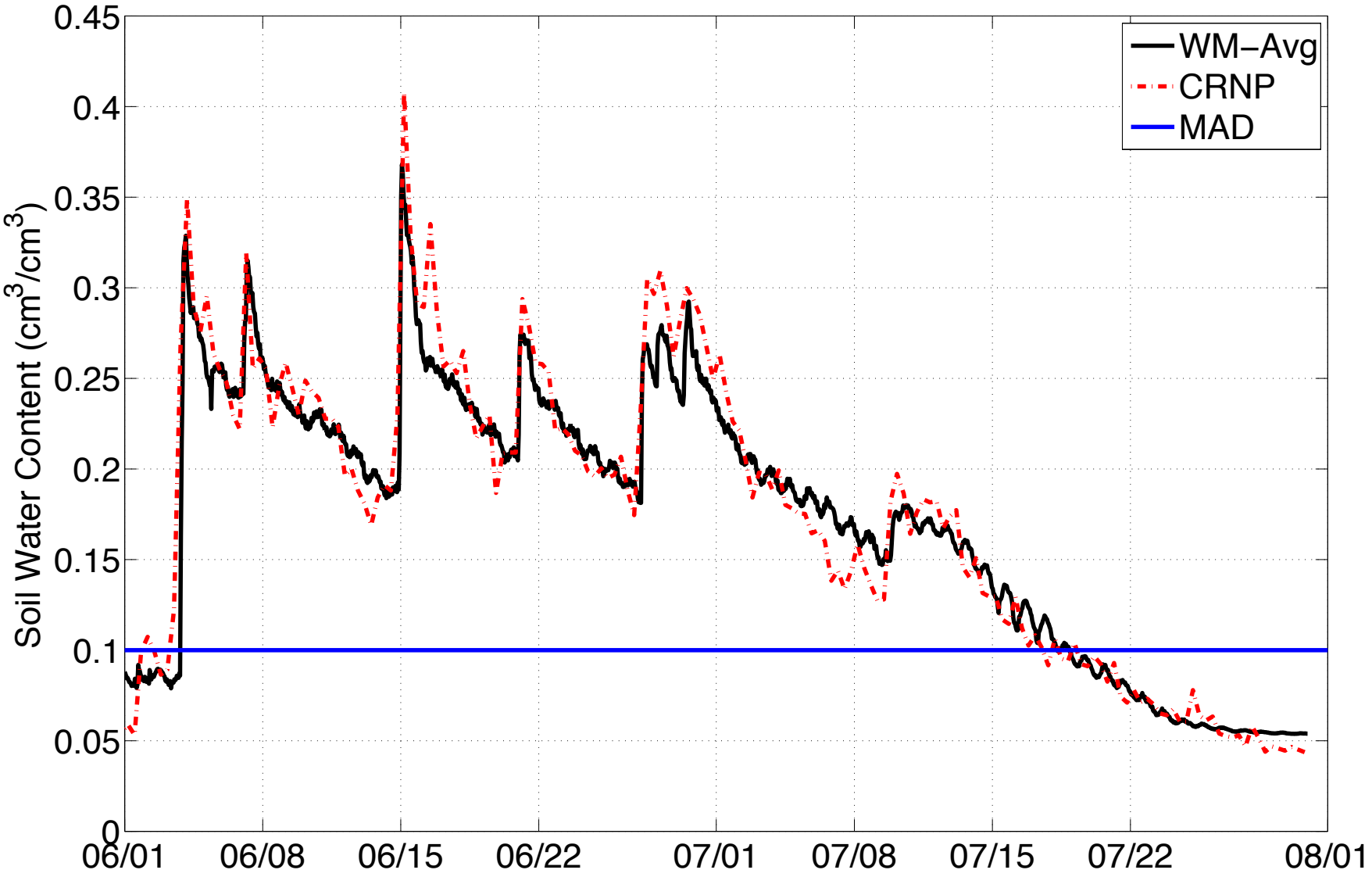

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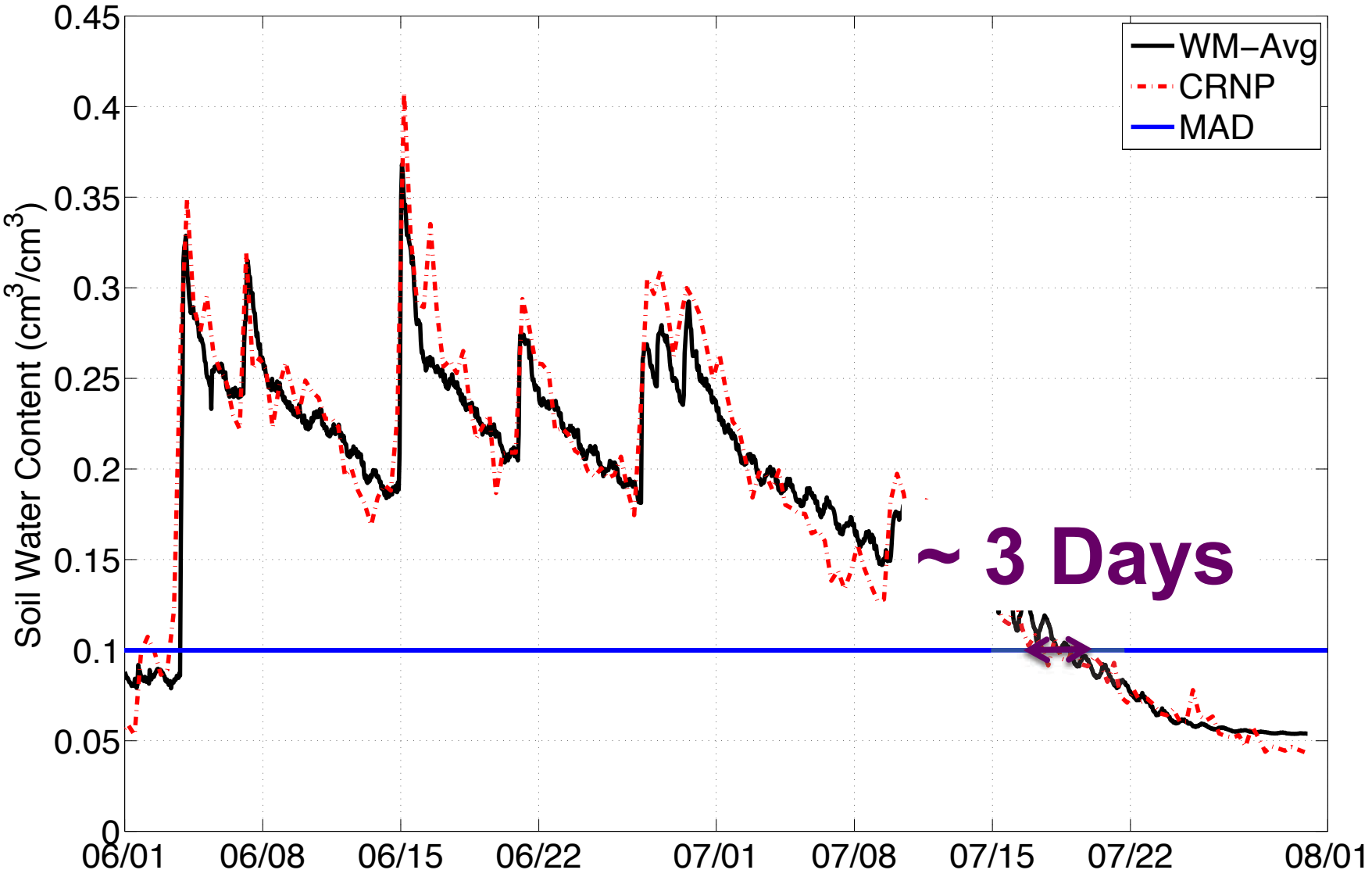

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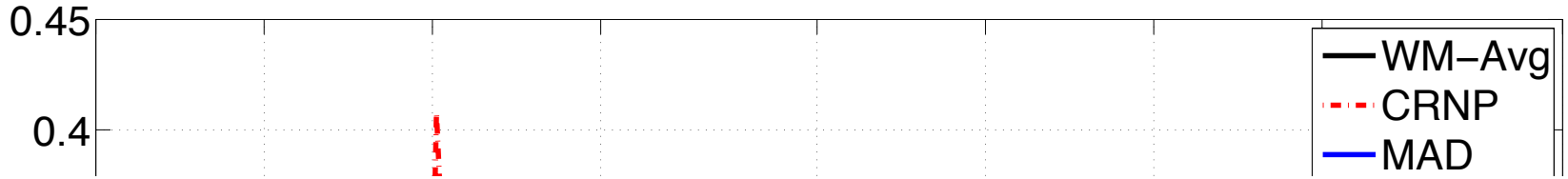
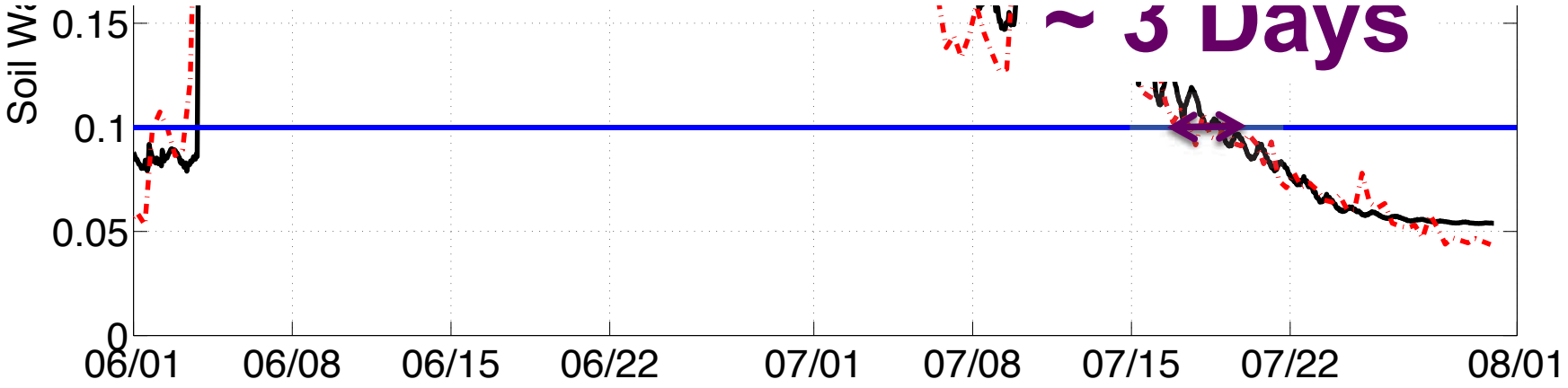


What are savings in:
water use, energy use, nutrient loss, crop yield loss? $$$$$$$



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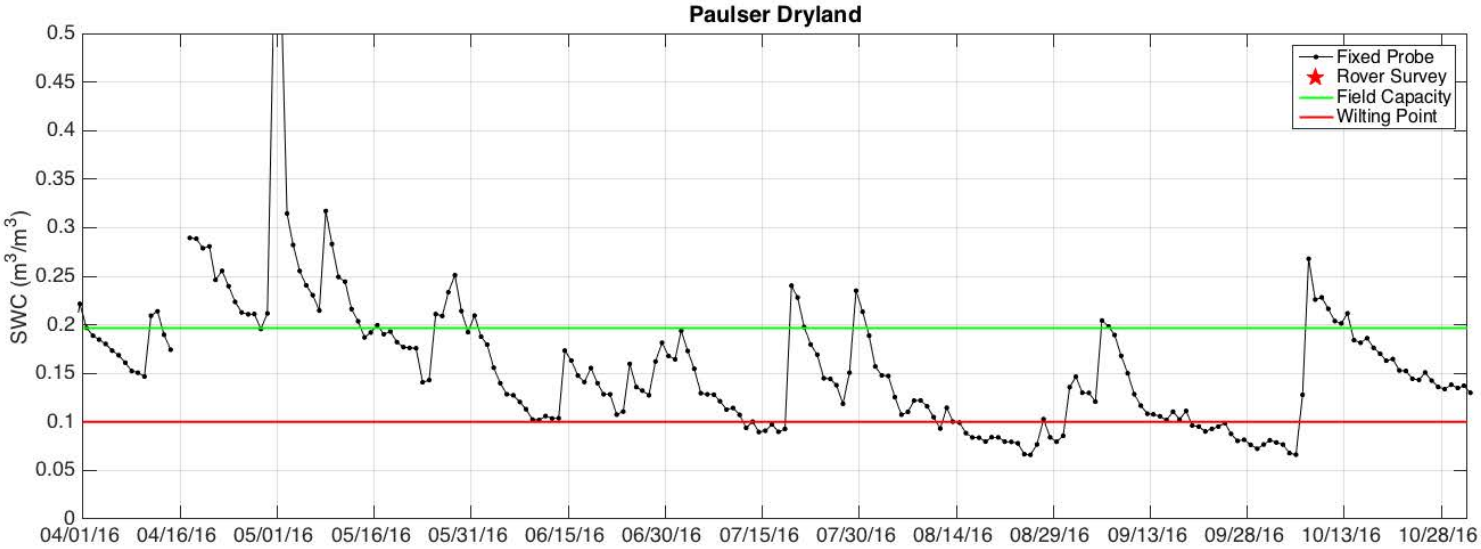
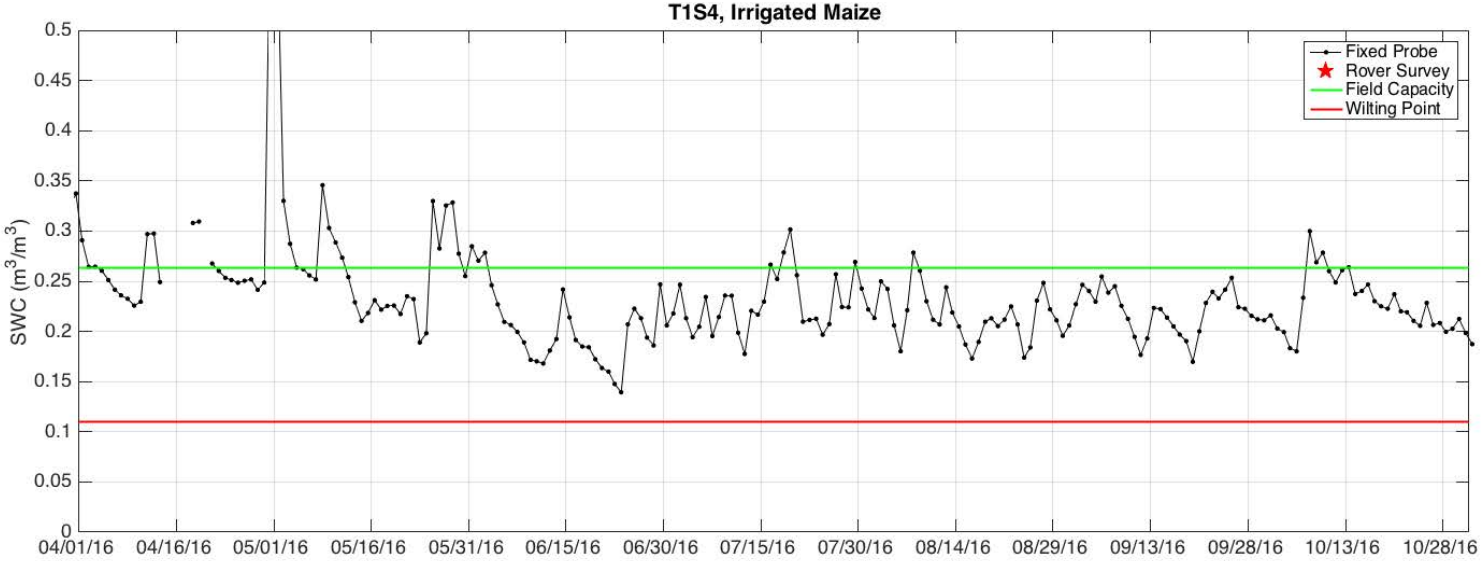
Applications: Irrigation Scheduling of Entire Field





Two 65 ha commercial agriculture fields in Nebraska located 20 km apart

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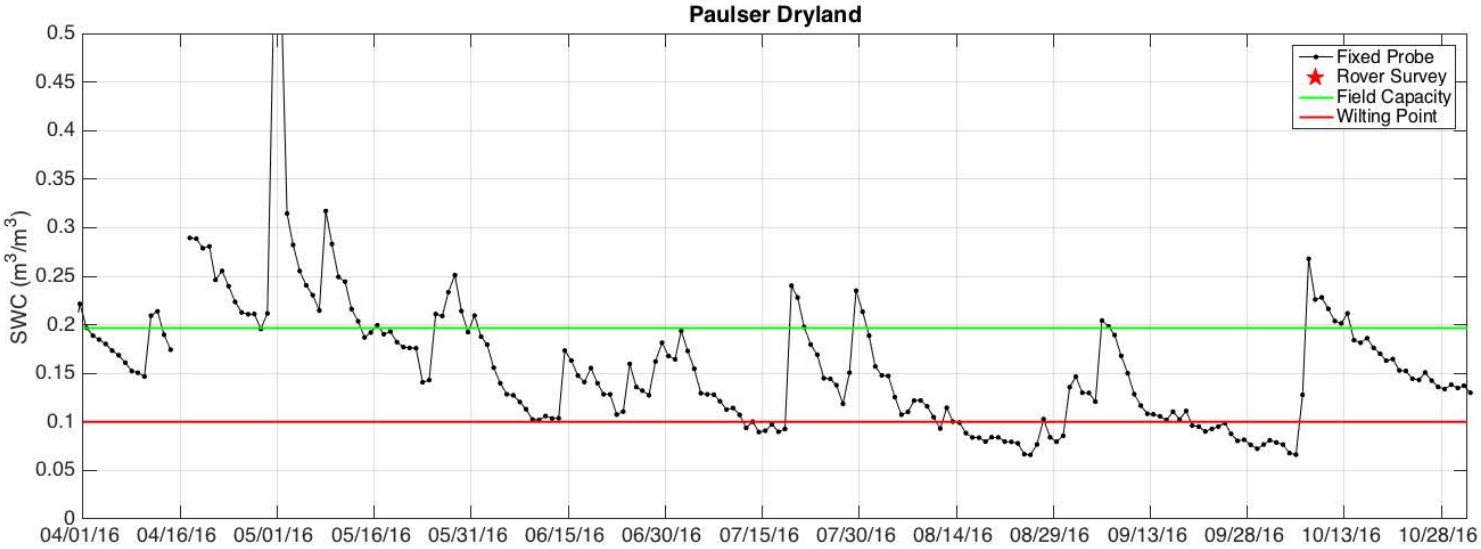
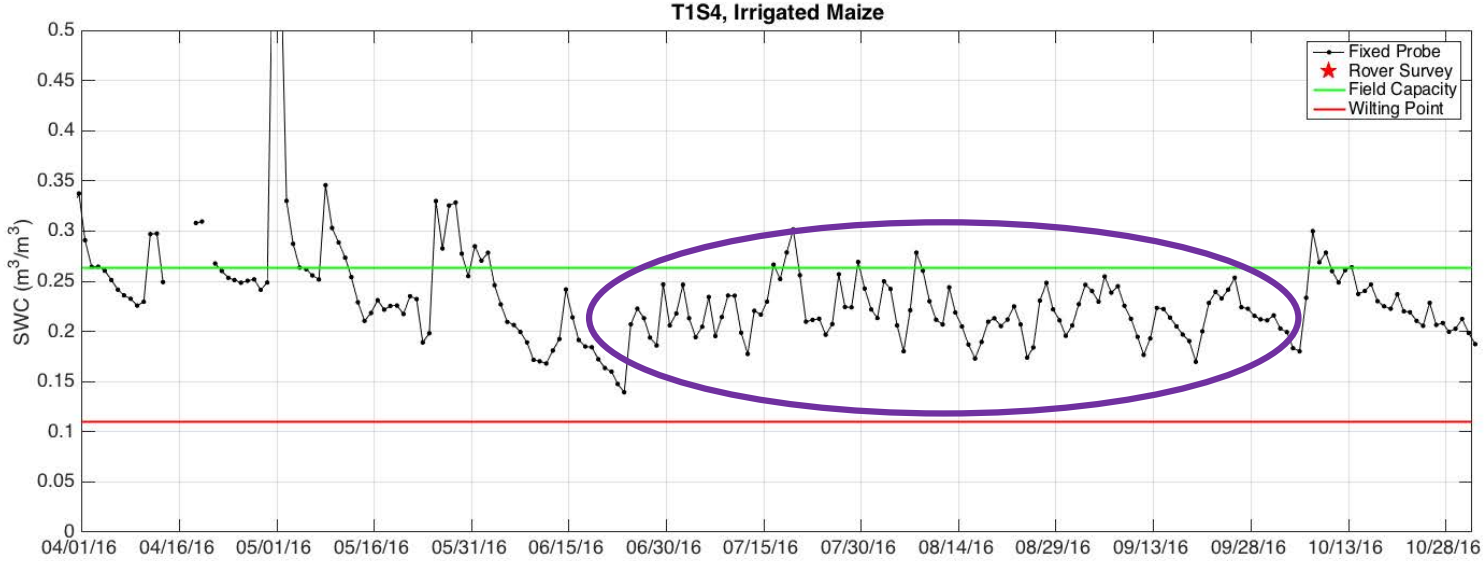


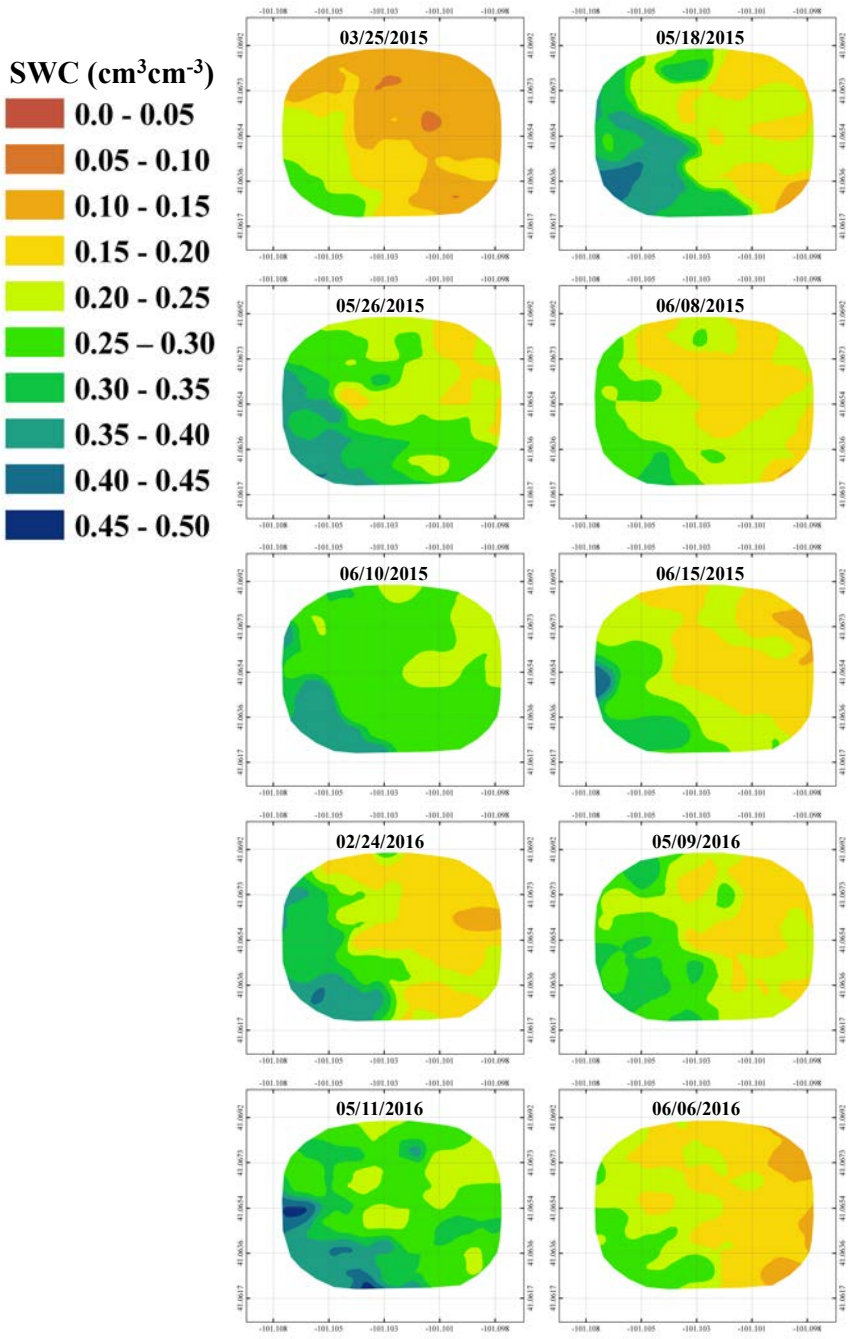


Two 62 ha commercial agriculture fields in Nebraska located 20 km apart

Current agricultural water management

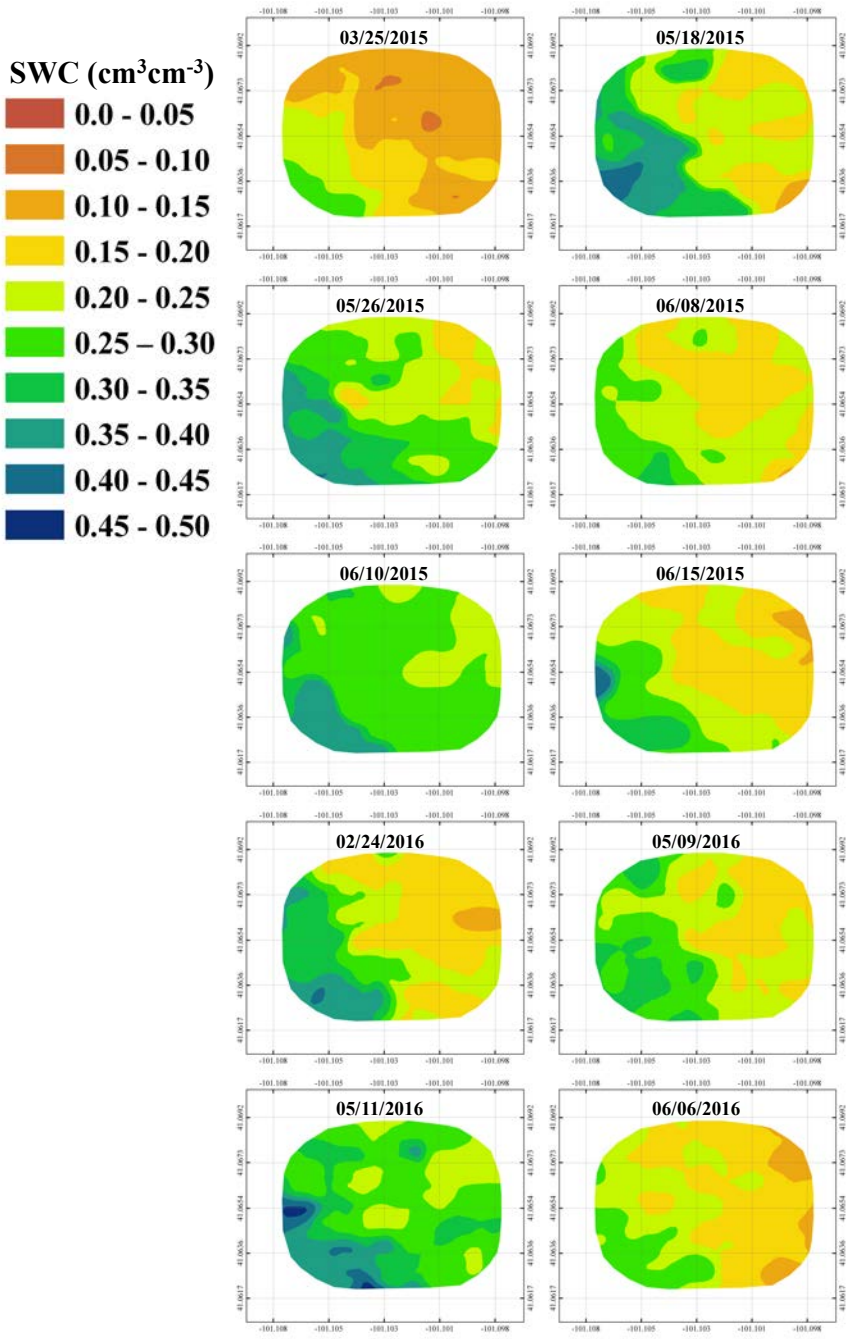
Have mechanical technology but do we have spatial information?

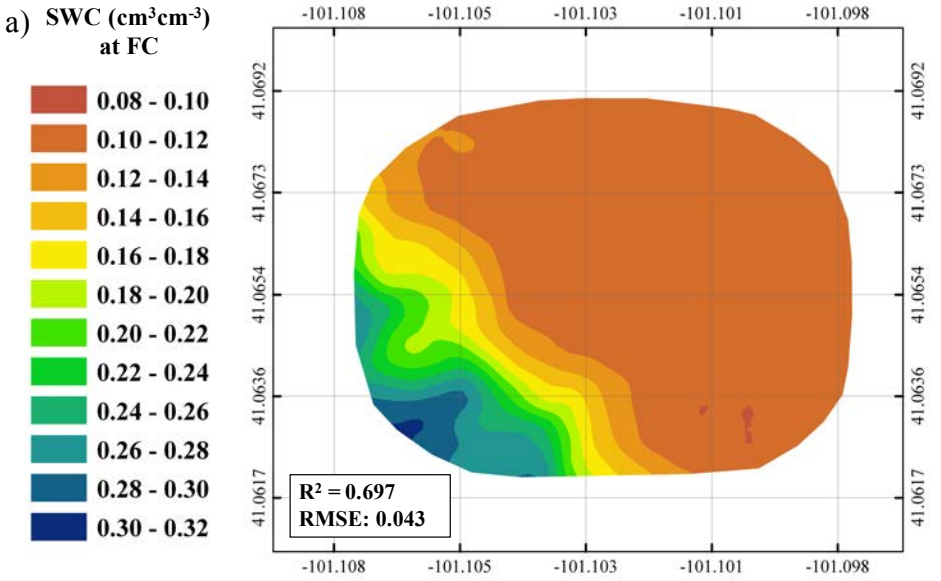
Spatial Mapping of Soil Properties

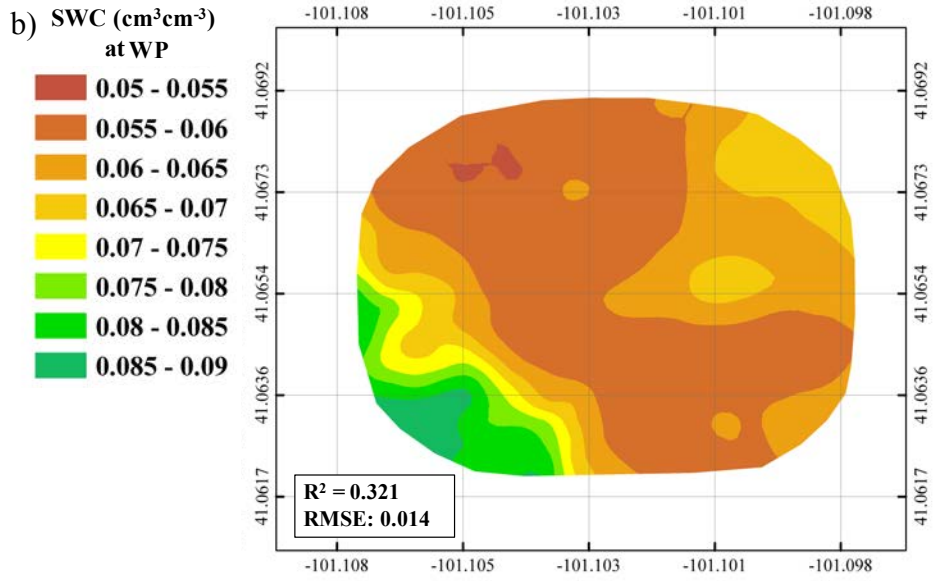


Covers ~60 ha in 1 hour with 25 m resolution

Spatial Mapping of Soil Properties







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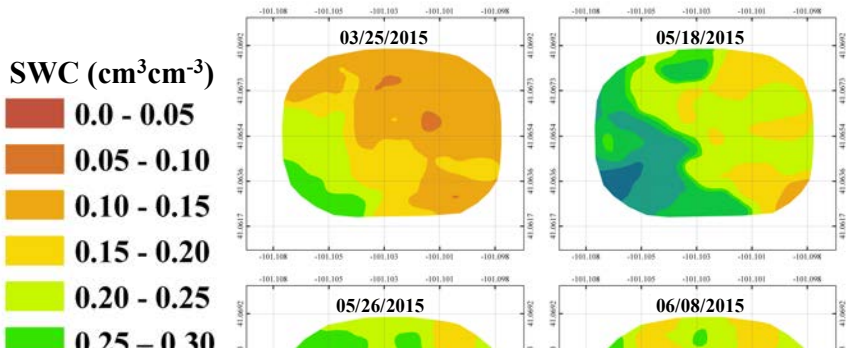
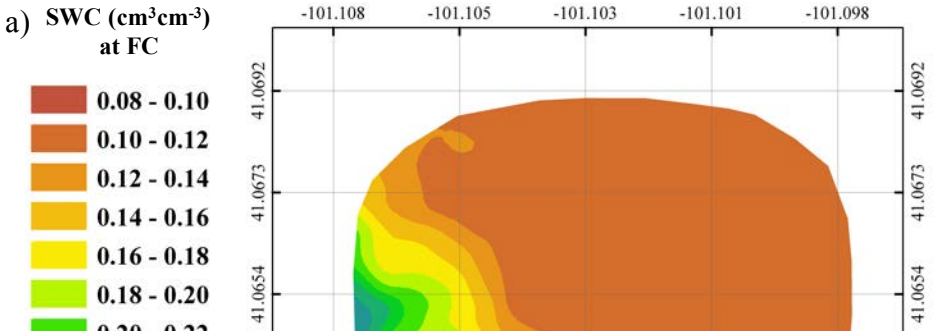
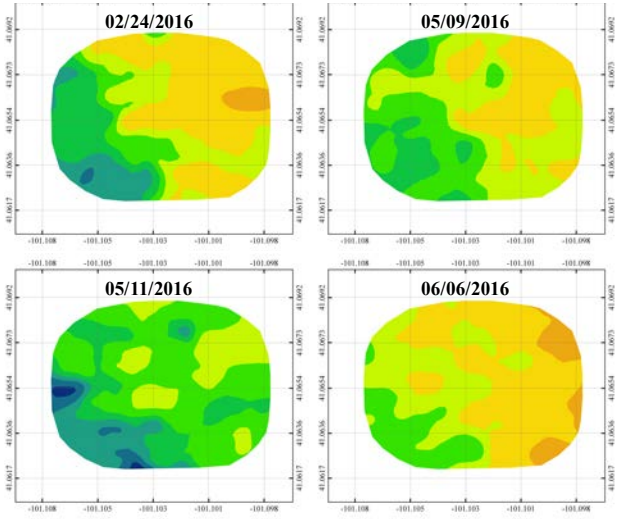




Useful spatial products for management of water and nutrients



Precision Agric
https://doi.org/10.1007/s11119-018-9582-5

CrossMark

Integration of hydrogeophysical datasets and empirical orthogonal functions for improved irrigation water management

Catherine E. Finkenbiner[1,3] · Trenton E. Franz[1] · Justin Gibson[1] · Derek M. Heeren[2] · Joe Luck[2]

What about Rainfall, ET, kc?

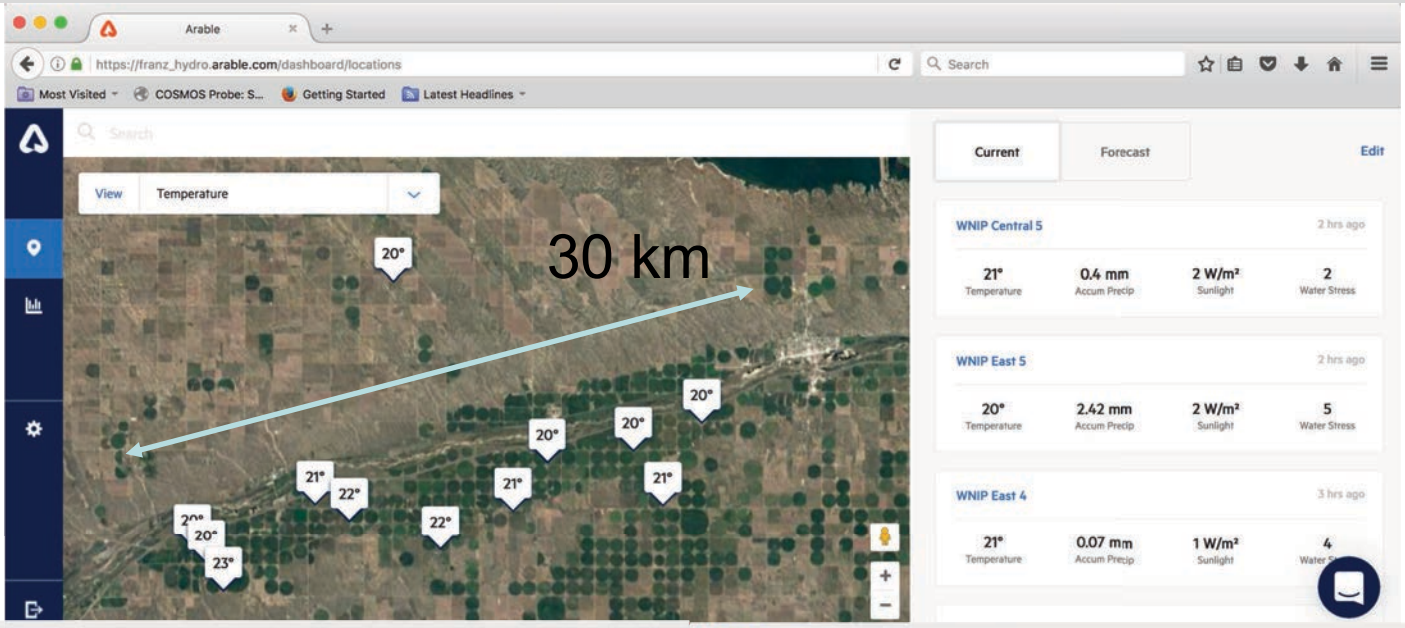
Next generation of low cost met. and crop water demand sensors

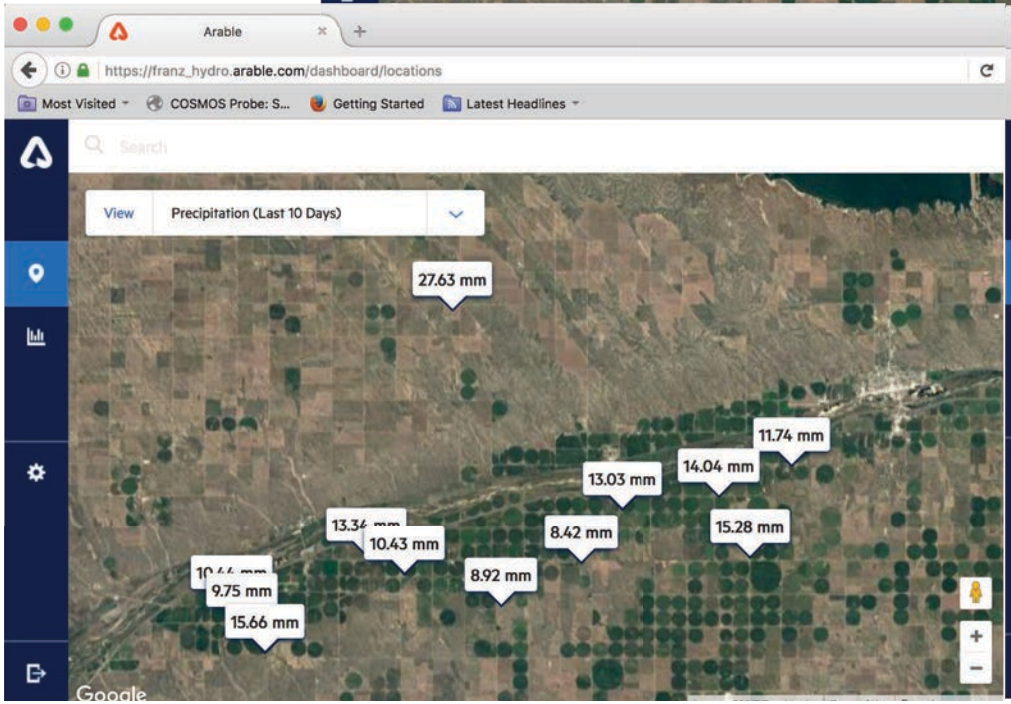
Observations (5 min):

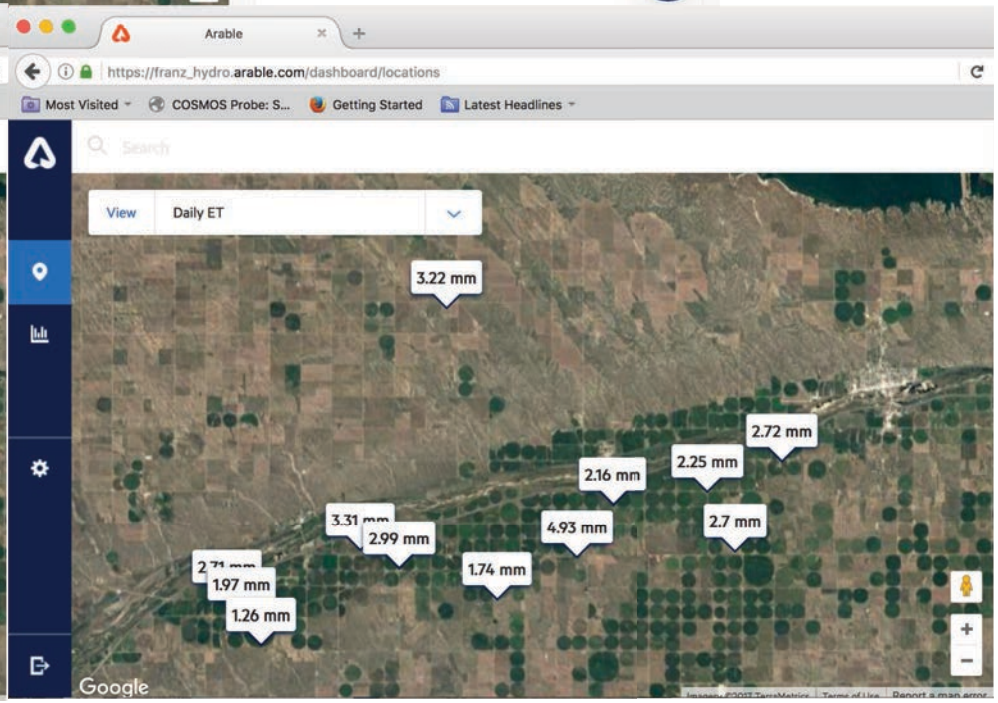
- rain gauge (disdrometer)
- leaf wetness
- shortwave and longwave up and down
- 6-band spectrometer
- air temp
- humidity
- pressure
- GPS
- digital level and compass
- plug for peripherals, i.e. camera, soil moisture, pressure
- Telemetry, Cell, Wifi, or Bluetooth
- Solar powered

http://arable.com/

Network of Arable Stations

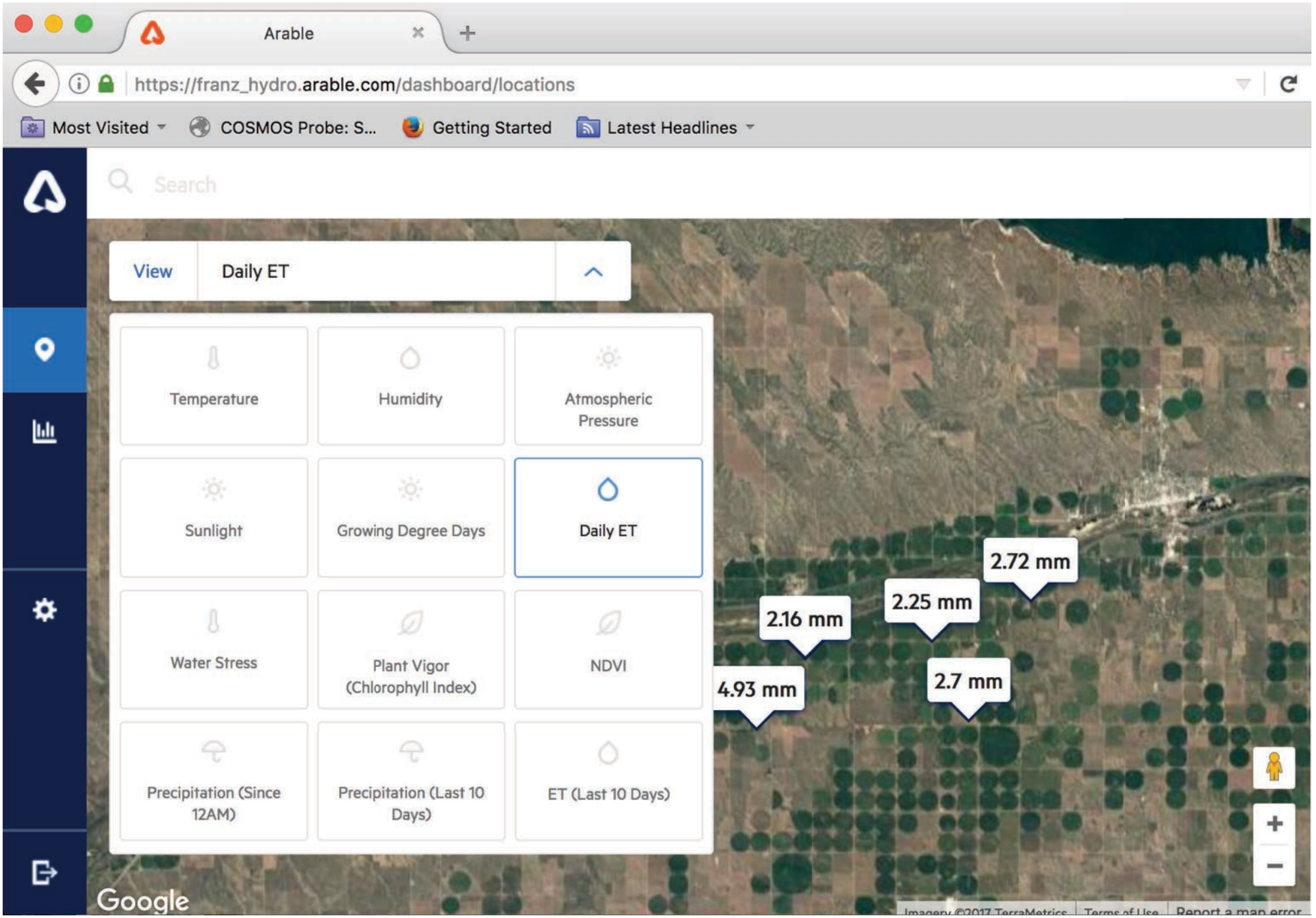






Data view as of July 2, 2017

Network of Stations



The Complete Irrigation Package

Realtime Observations

Soil Water = Fixed CRNP
Soil Properties = Mobile CRNP
Rainfall, ET, NDVI = Arable Mark

The Complete Irrigation Package

Realtime Observations

Soil Water = Fixed CRNP
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+

Realtime Crop Modeling

AquaCrop + Observations

The Complete Irrigation Package

Realtime Observations

Soil Water = Fixed CRNP
Soil Properties = Mobile CRNP
Rainfall, ET, NDVI = Arable Mark

+

Realtime Crop Modeling

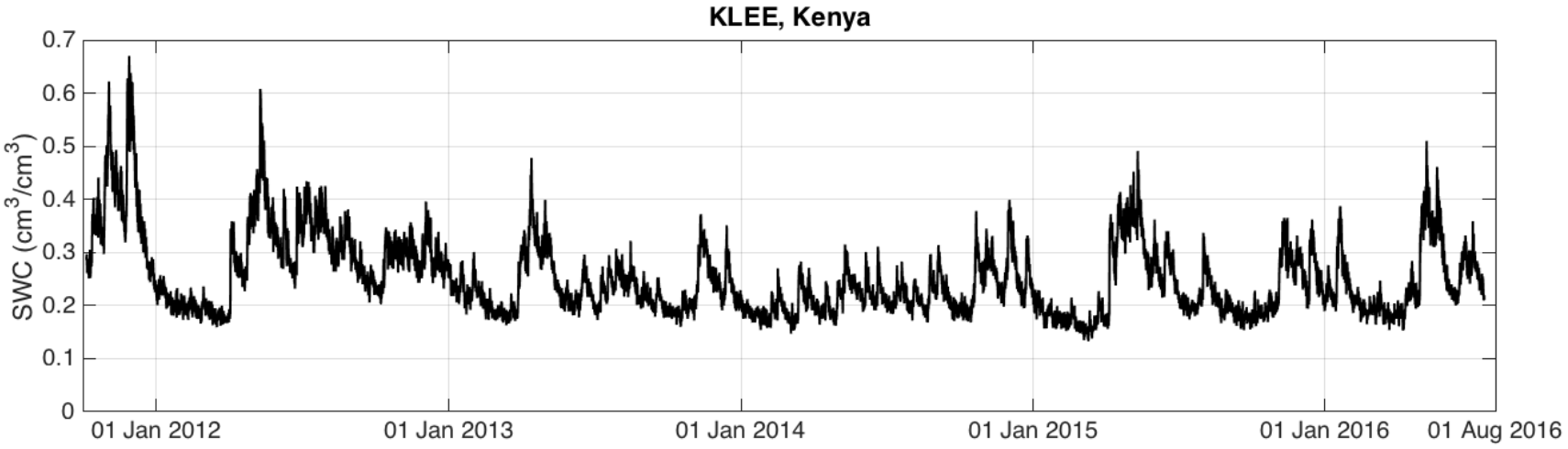
AquaCrop + Observations

=

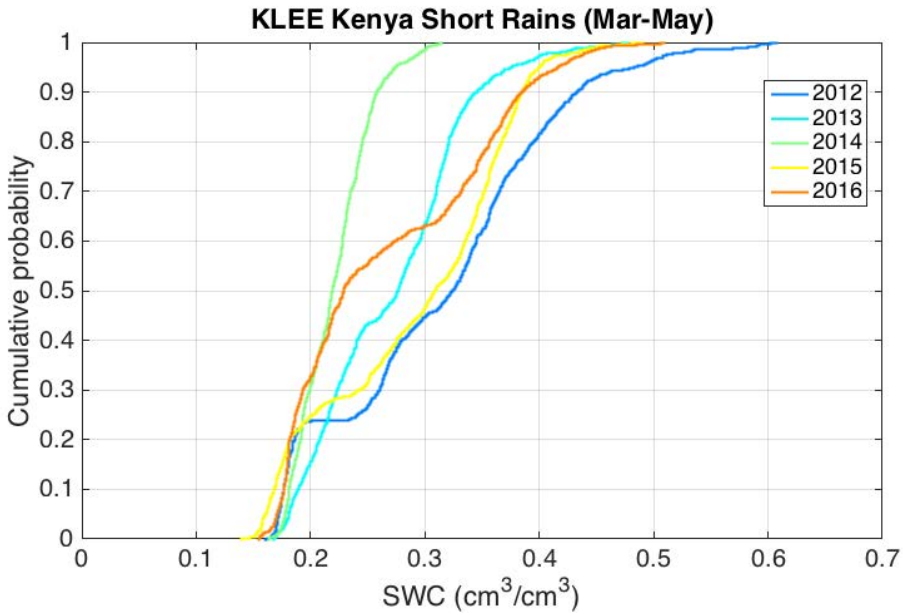
Decision Support Tool

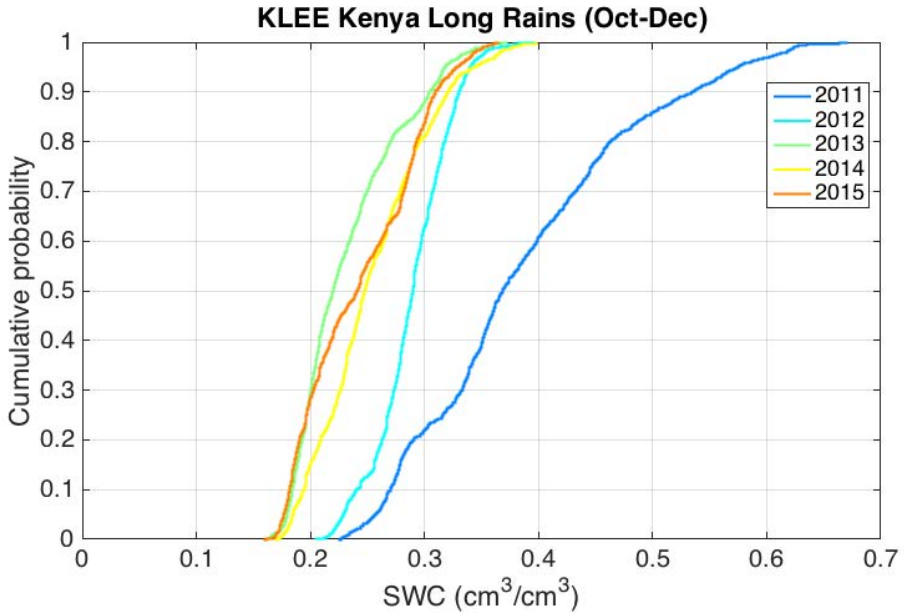
Irrigation, nutrients, planting density, planting variety, crop type, yield forecast

Long-term Ecosystem Monitoring in Drylands



Long-term Ecosystem Monitoring in Drylands





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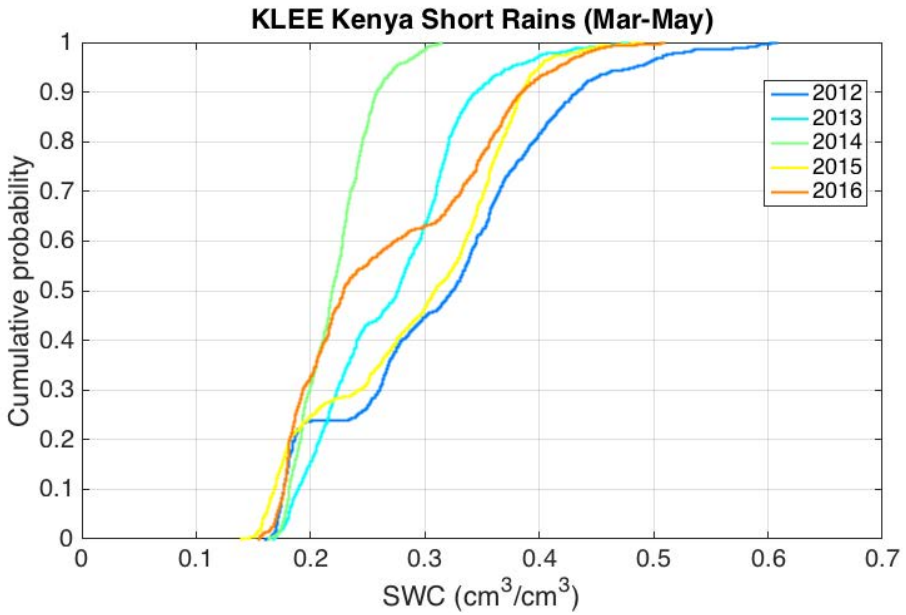

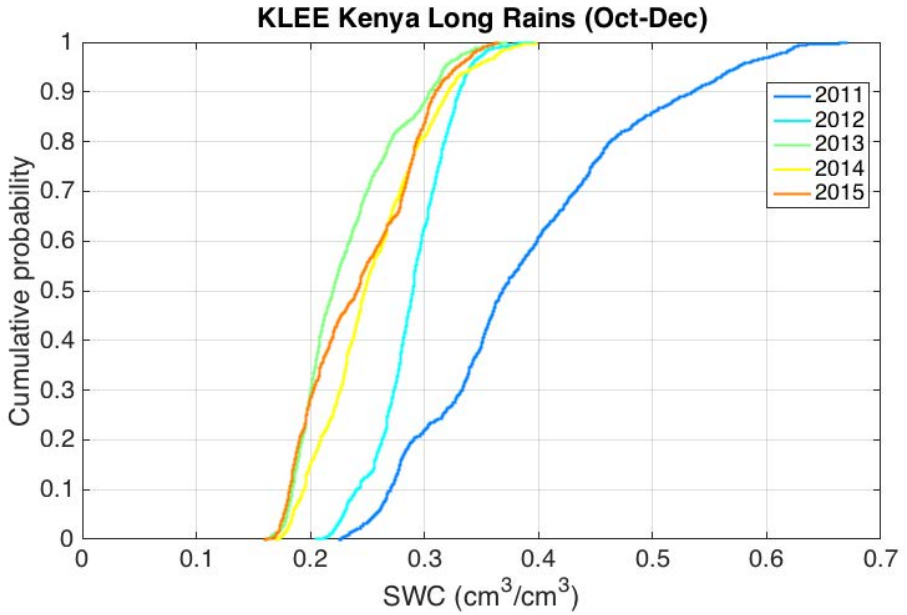

Potential uses for looking at impacts of land use and climate change

- Useful for growing season to growing comparisons (common benchmark)
- Compare quantiles between paired catchments
- Calculation of drought indices (PSI)
- Construct time series models of plant response and fuel loads for fire risk (wet year than dry year)
- Make longer term predictions of drought, fire and erosion potential?

Summary

- Point sensors are inexpensive, but…
  - labor and time intensive, may not represent field conditions
- CRNS is one solution for areal management
  - Real-time irrigation management at field and zone scale
  - Mobile sensors useful in spatial soil property mapping
- Moving Toward Decision Support Tool in Irrigation
  - CRNP + Arable + AquaCrop
- Fixed long-term stations can be useful for monitoring
  - seasonal drought severity, fire risk, landslide risk/early warning