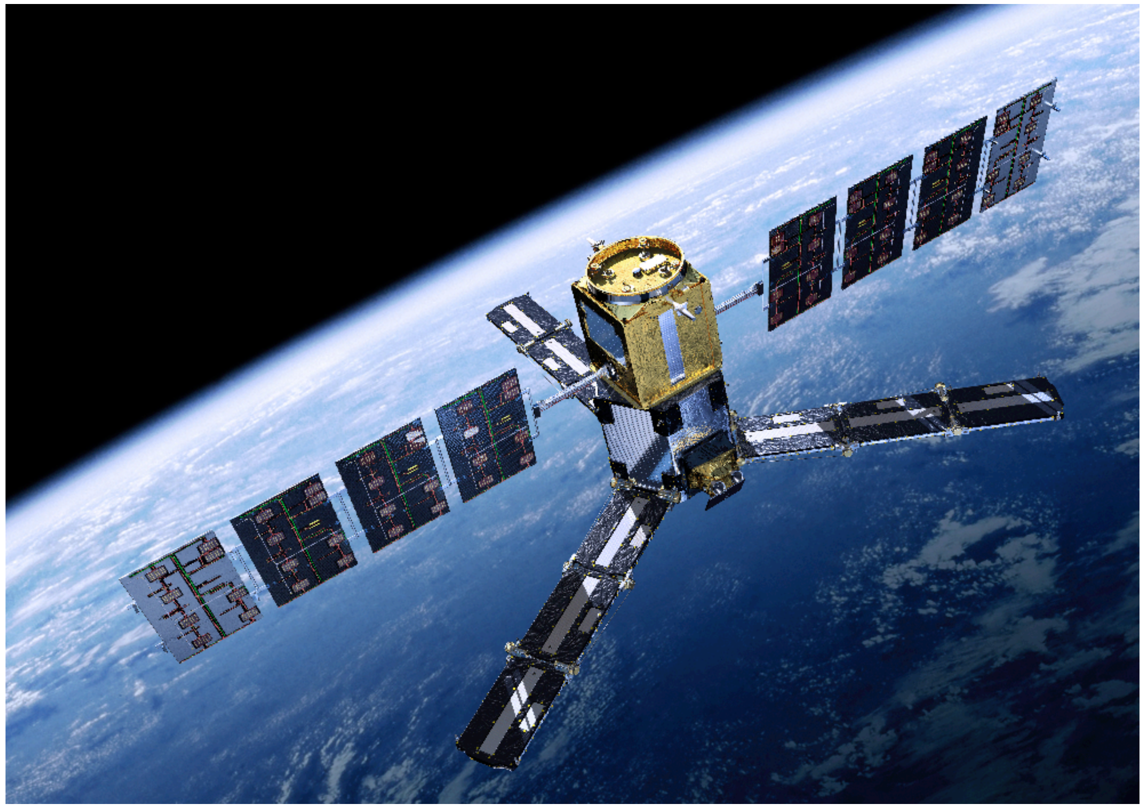
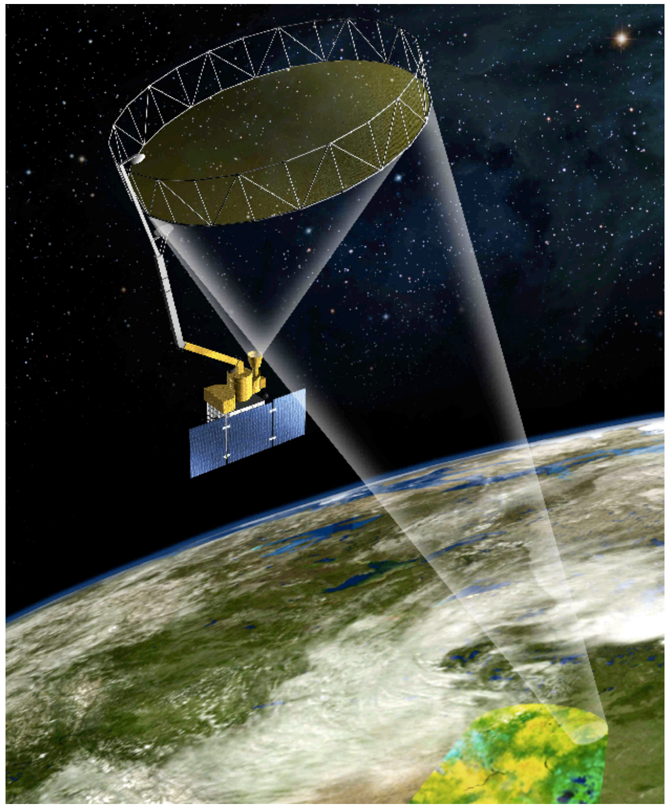
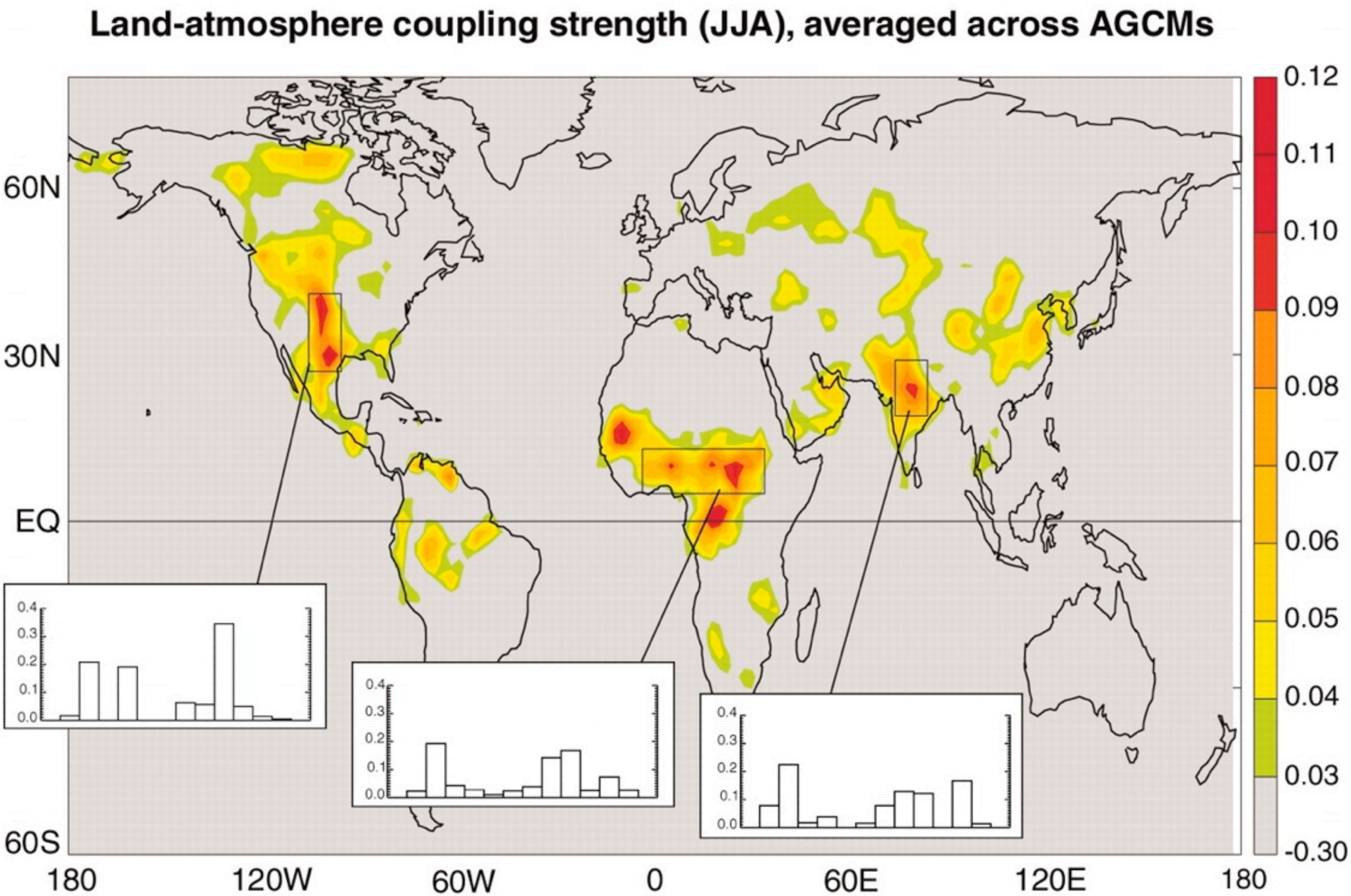
 

Soil moisture (and vegetation?) remote sensing products in Oklahoma

Jason Patton
Plant and Soil Sciences, Oklahoma State University

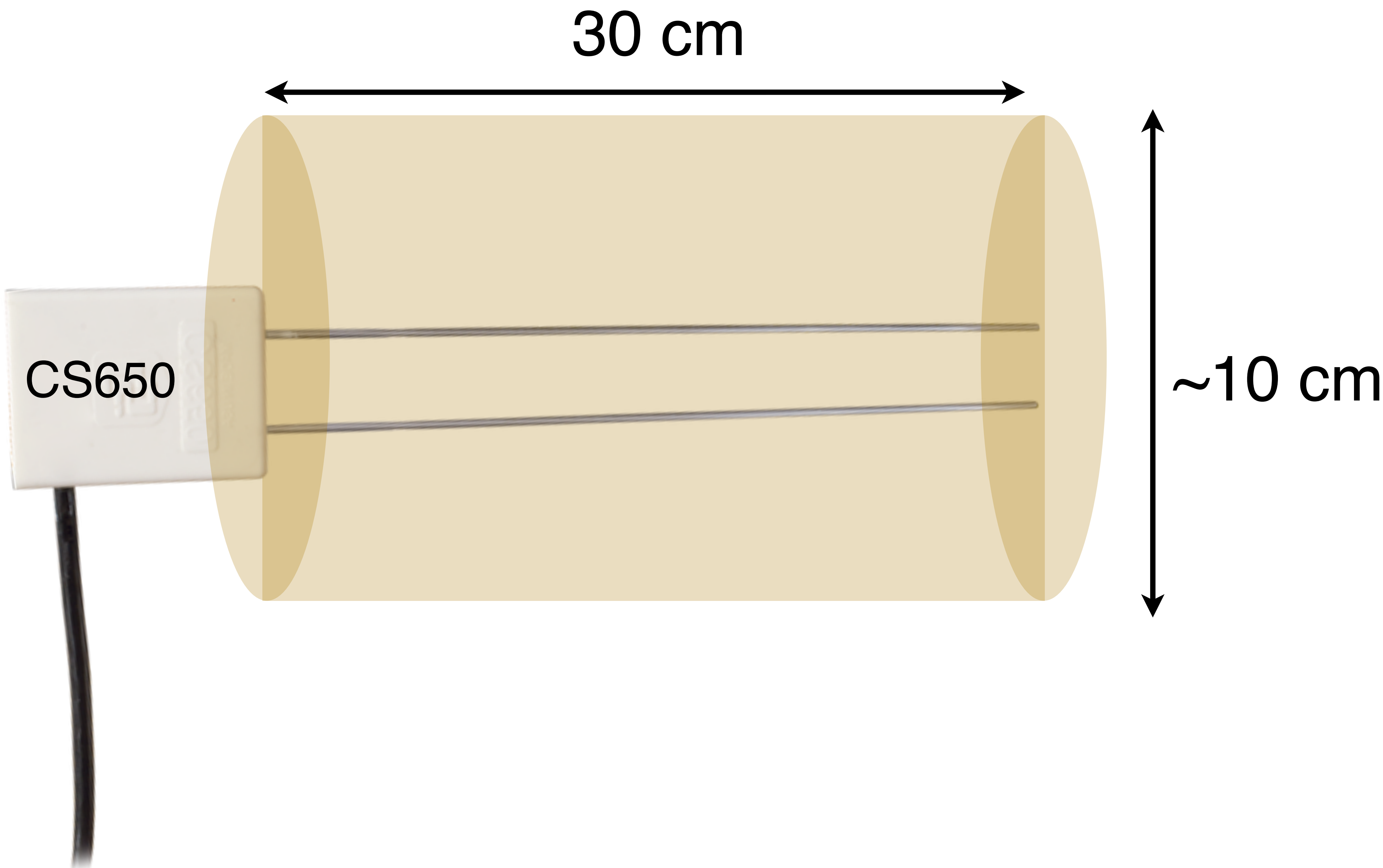
Wednesday, November 12, 2014
Oklahoma Workshop on Remote Sensing Technology and Applications

The coupling between weather/climate and soil moisture is apparent in models.



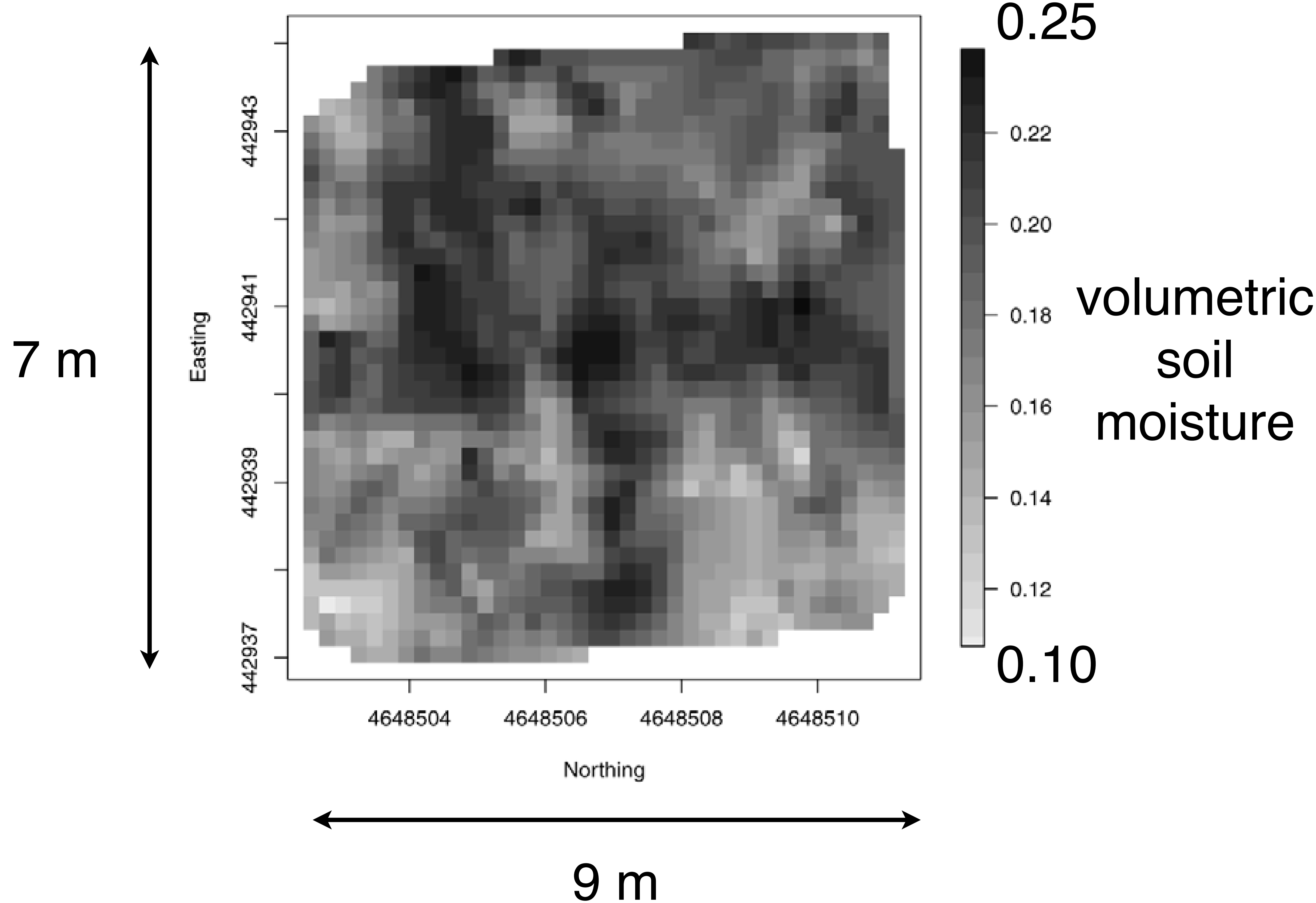
(Koster et al. 2004)

Current regular soil moisture measurements are made at single points.



(Campbell Scientific)

Point measurements may not represent larger scale averages of soil moisture.



(Bramer et al. 2013)

Weather and climate models need soil moisture data for initialization and validation at large spatial scales (>1 km), while in-situ measurements are available at point (~10 cm) scales.

Satellite remote sensing of soil moisture can provide global measurements of soil moisture at large spatial scales.

Outline

I. Soil Moisture and Ocean Salinity mission

II. Soil Moisture Active Passive mission

III. Cosmic-ray Soil Moisture Observing System

SMOS is the **S**oil **M**oisture **O**cean **S**alinity satellite mission.

European Space Agency

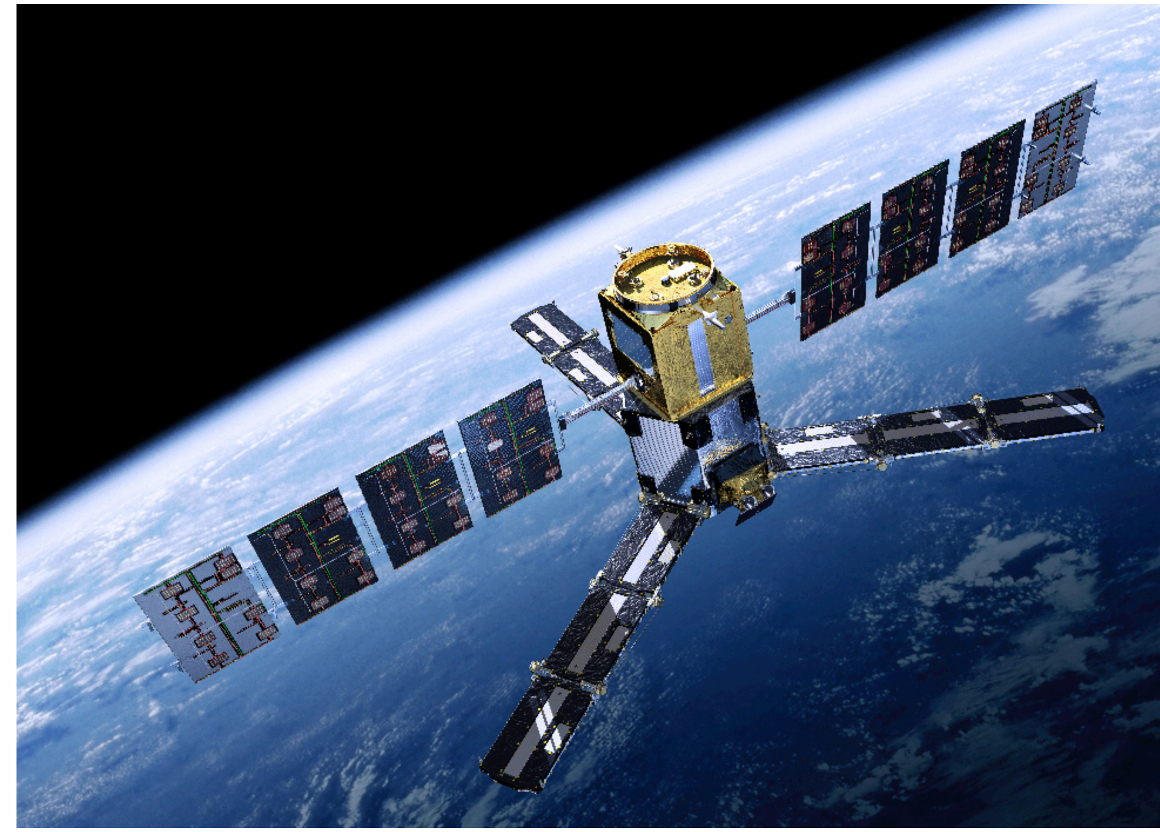
Launched November 2009

Passive L-band (1.4 GHz, 21 cm)

43 km average resolution

Sensitive to top 3-5 cm of soil

Polar orbiting:
- Measurements every 3 days at equator
- More often at higher latitudes



(ESA)

The “tau-omega” model describes the natural emission of microwave radiation from Earth’s surface.

$$
\begin{aligned}
T_B = T_{soil}\,(1 - R_{soil})\,e^{-\tau/\mu} \quad &\textbf{(1)} \\
+ \left(1 - e^{-\tau/\mu}\right)(1-\omega)T_{veg} \quad &\textbf{(2)} \\
+ \left(1 - e^{-\tau/\mu}\right)(1-\omega)T_{veg}\,R_{soil}\,e^{-\tau/\mu} \quad &\textbf{(3)}
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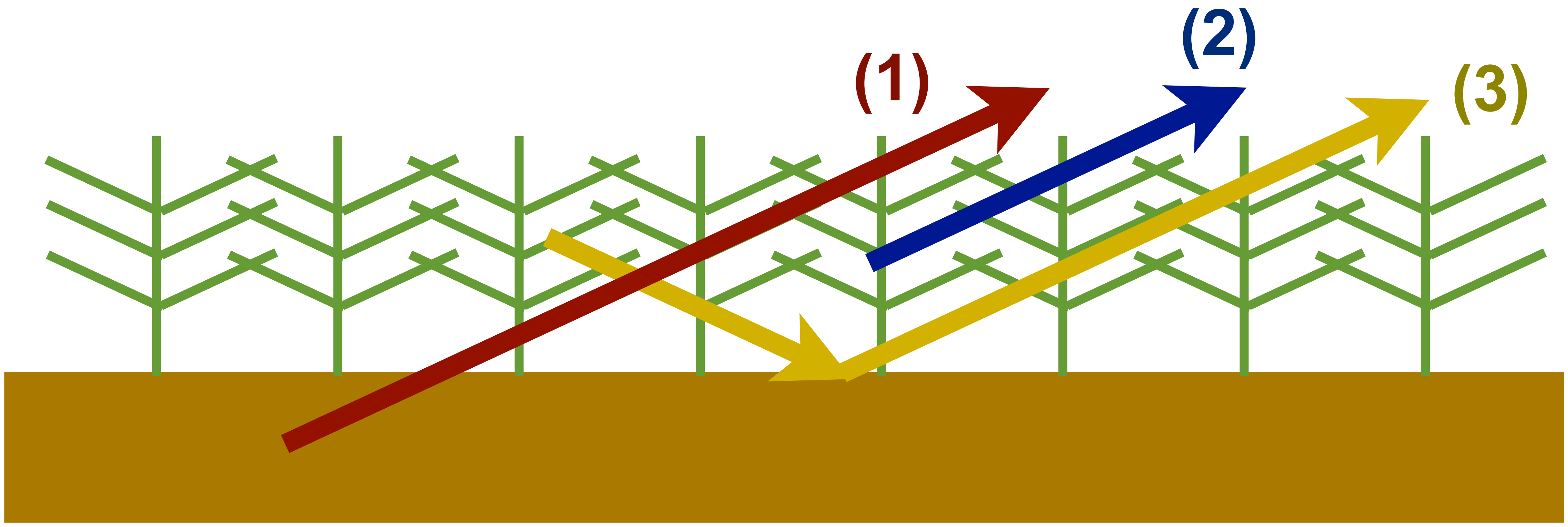

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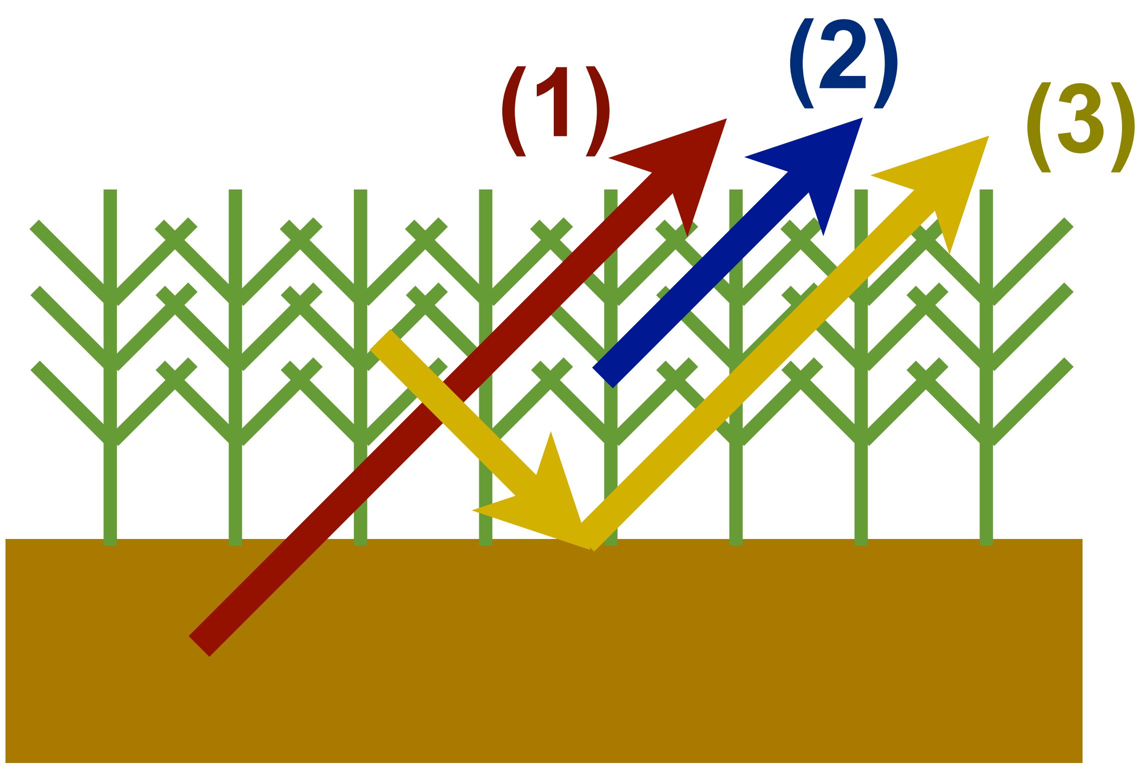

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$R_{soil} = f$(soil moisture, roughness)

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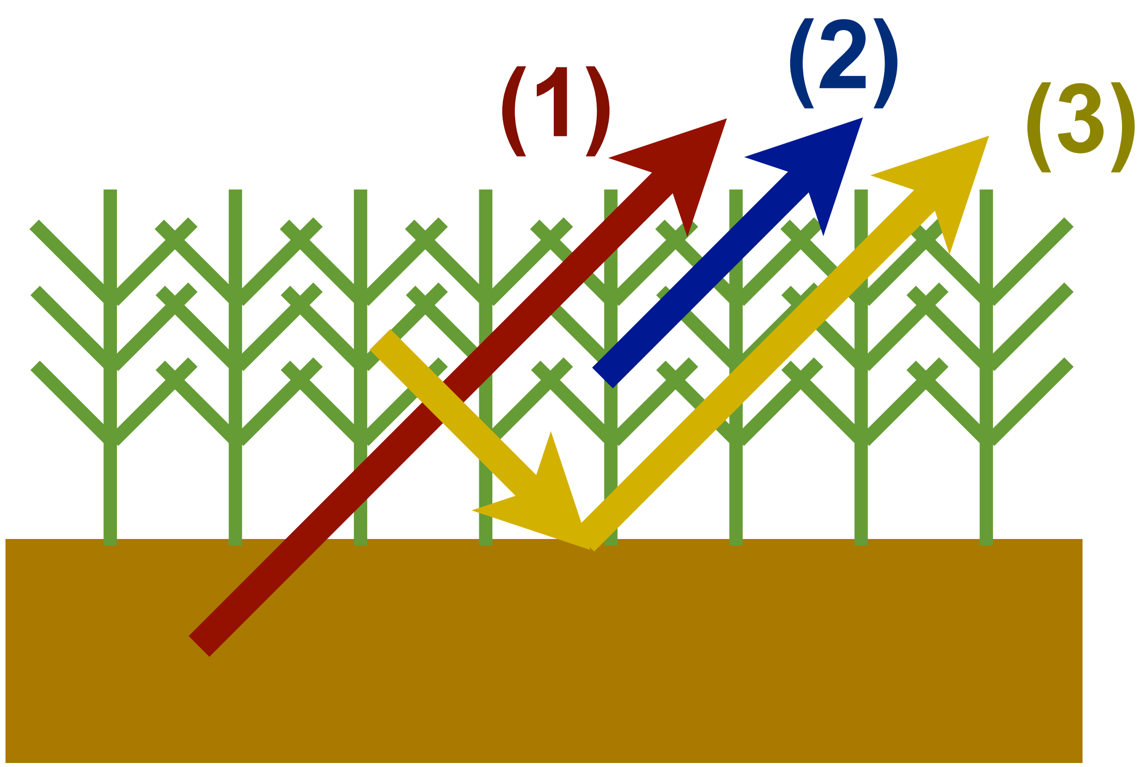

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= *b* × veg water content (VWC)

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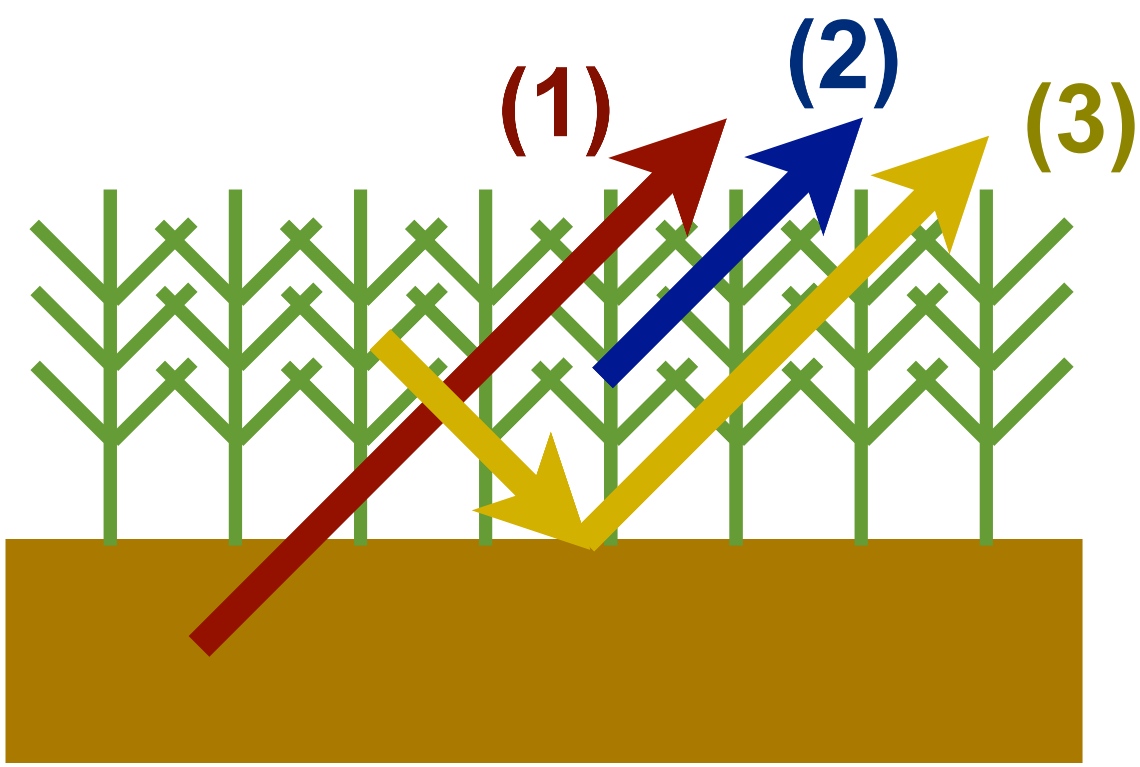

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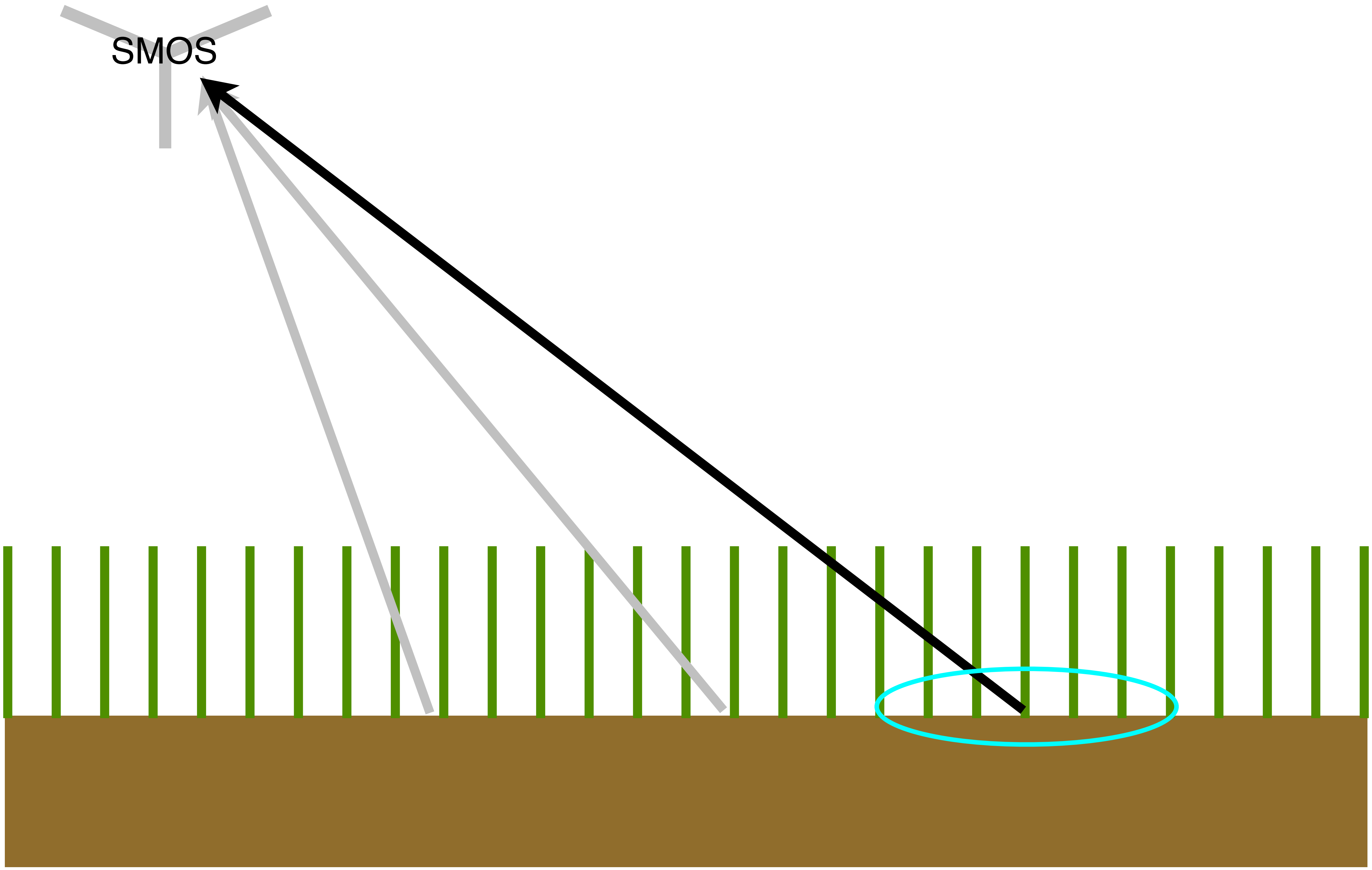
SMOS uses a multi-angular approach to simultaneously estimate soil moisture and optical thickness.



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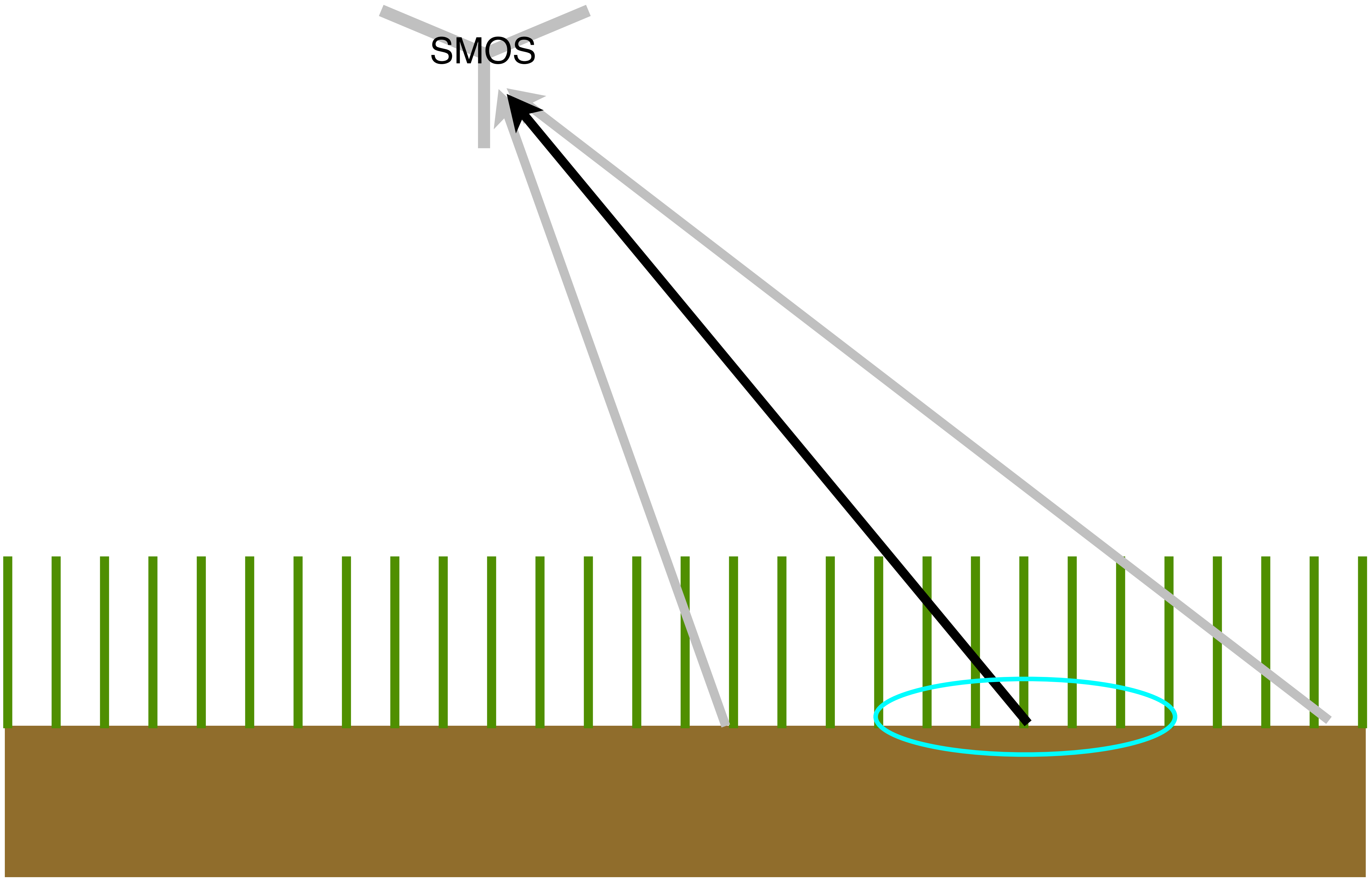

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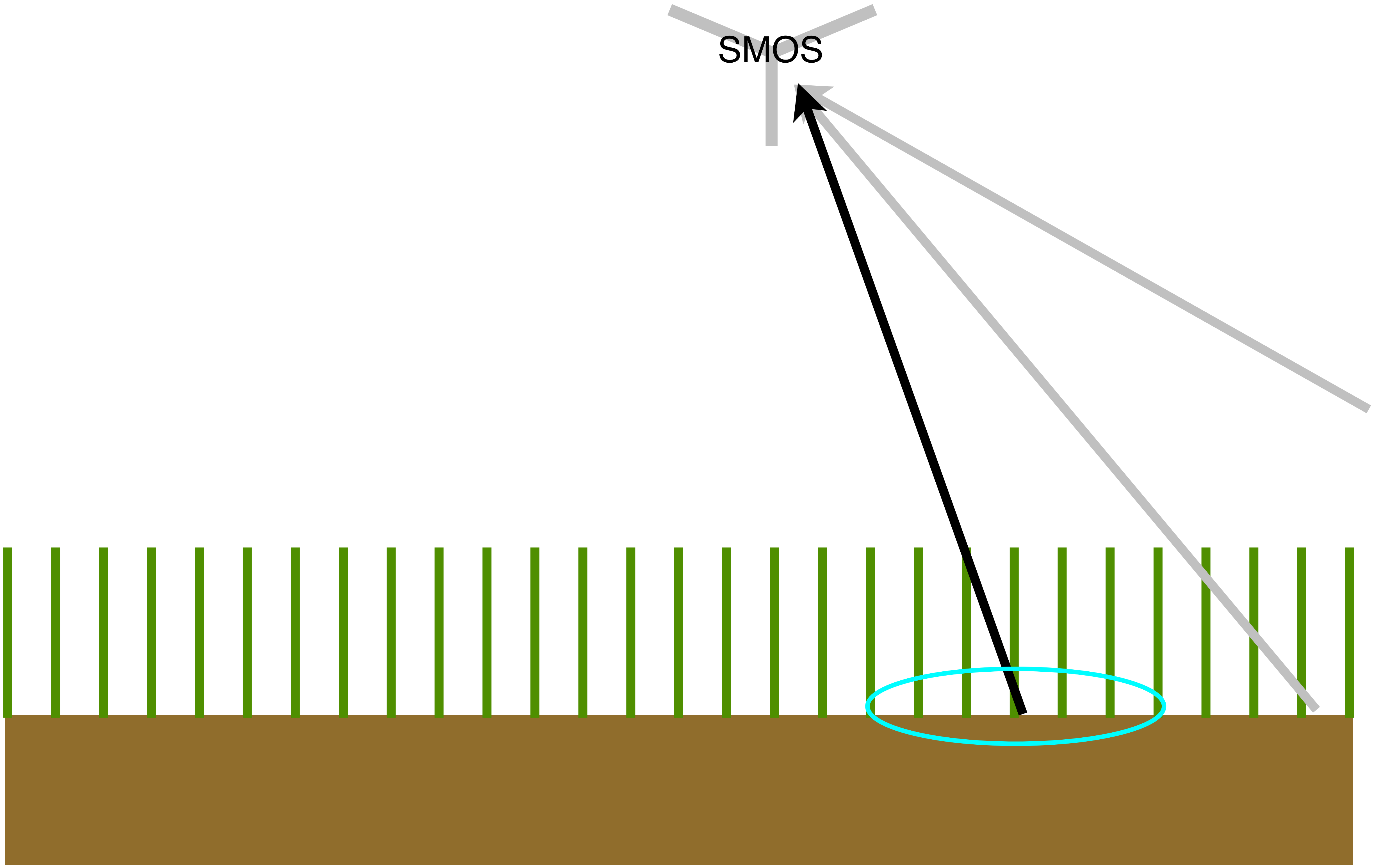

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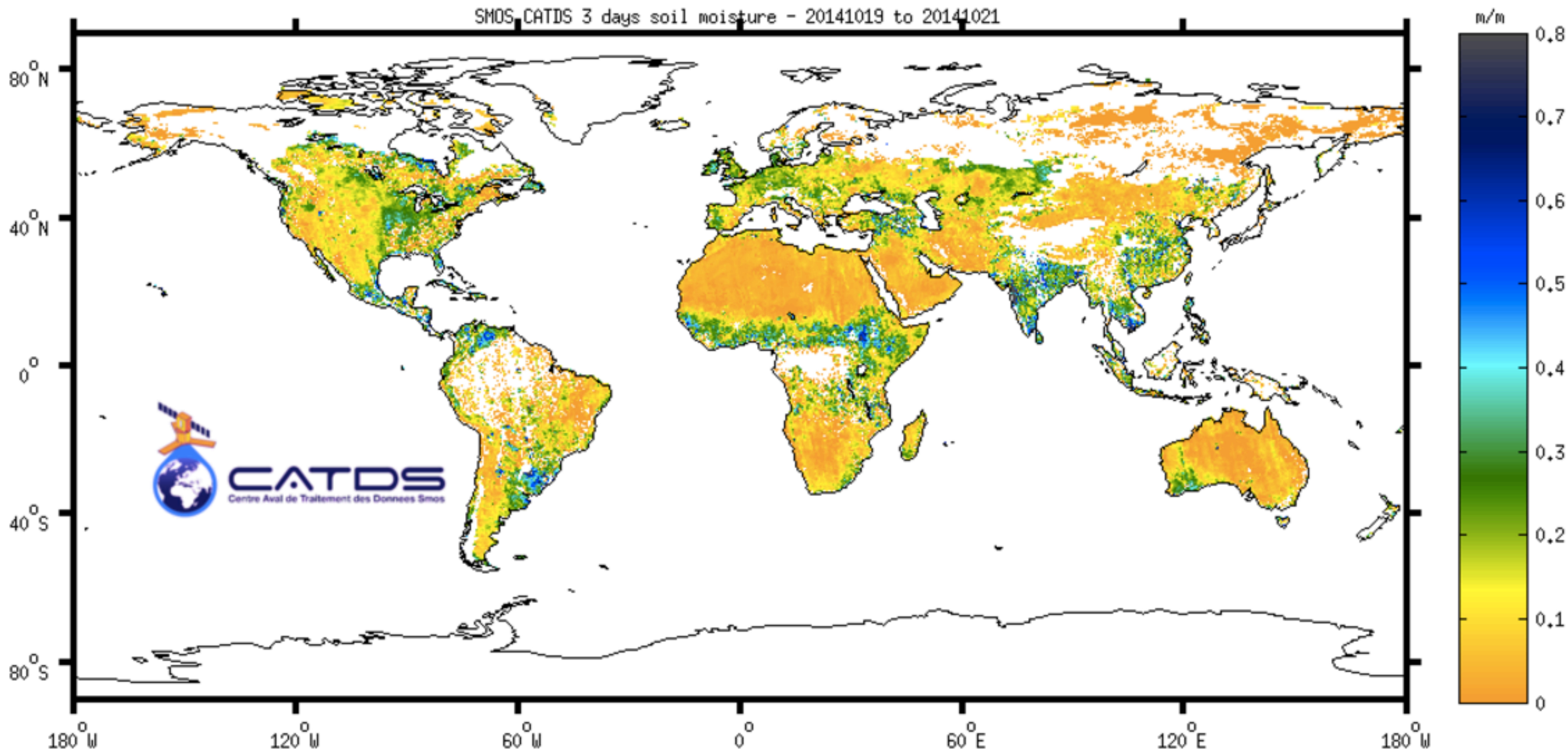
$$
\begin{aligned}
T_{B1} &= T_{soil}(1 - R_{soil})e^{-\tau/\mu_1} + \cdots \\
T_{B2} &= T_{soil}(1 - R_{soil})e^{-\tau/\mu_2} + \cdots \\
&\vdots \\
T_{Bn} &= T_{soil}(1 - R_{soil})e^{-\tau/\mu_n} + \cdots
\end{aligned}
$$

$$\text{where } \mu = cos(\theta)$$

SMOS also assumes $\omega = 0$.

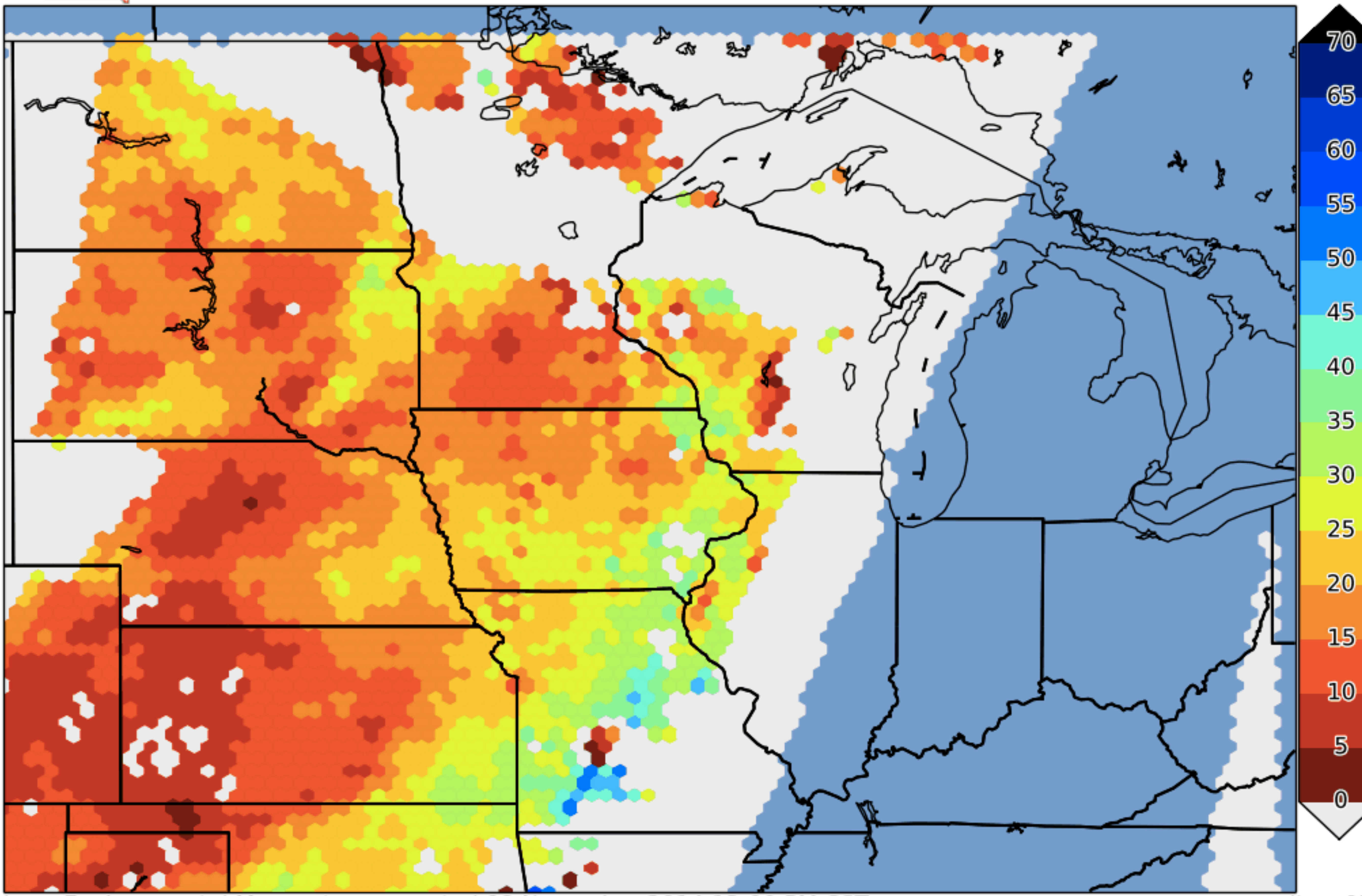
Validation of SMOS has, so far, shown a slight dry bias in most cases, but it does capture dynamics well.

See: Al Bitar et al. 2012; Gherboudj et al. 2012; **Collow et al. 2012;** Magagi et al. 2013



SMOS Satellite: Soil Moisture (0-5cm)

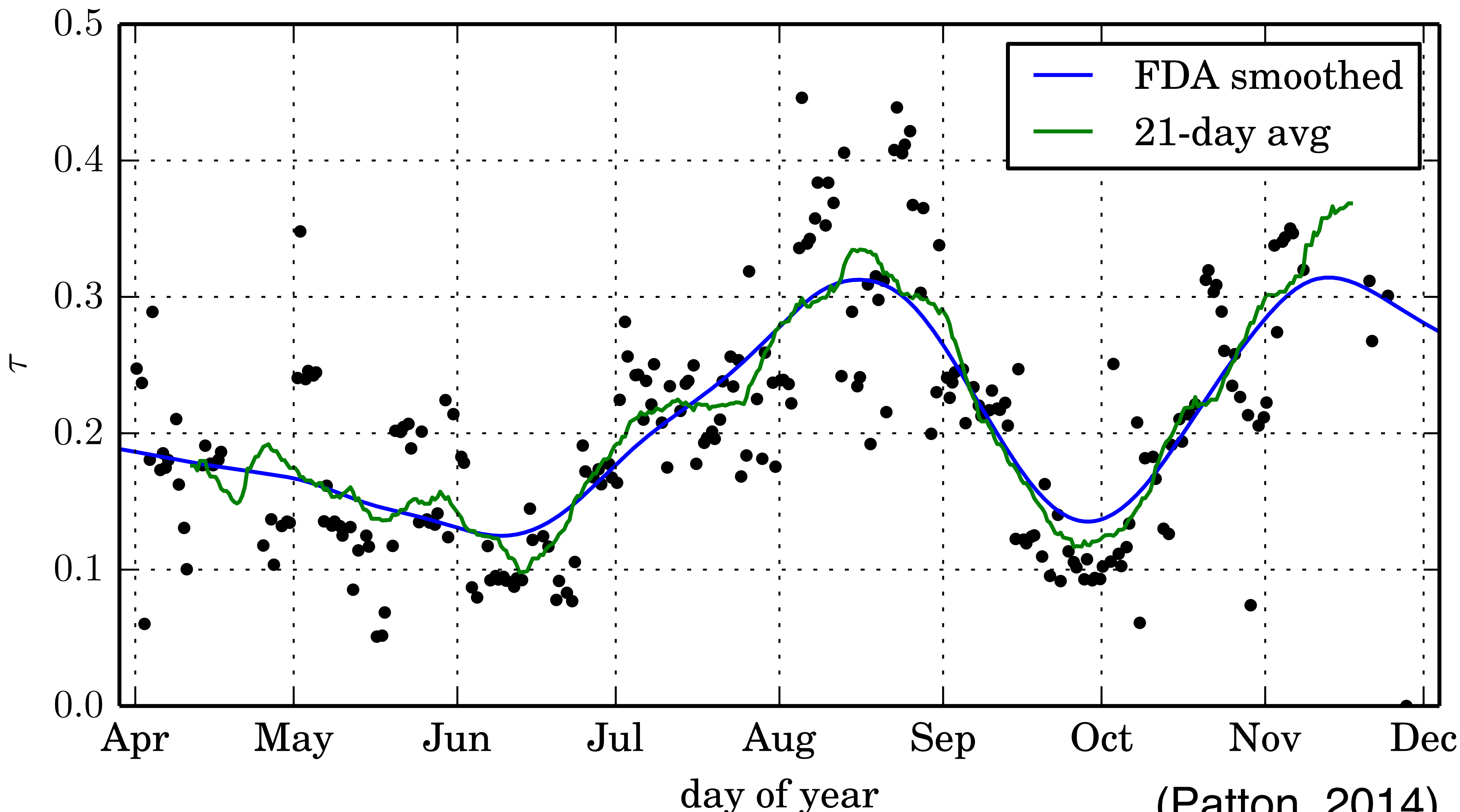
Satelite passes around 07 November 2014 00 UTC



Iowa Environmental Mesonet :: generated 08 November 2014 12:00 PM CST

map units :: %

Vegetation optical thickness from SMOS is very noisy, but still may contain some information about vegetation.



(Patton, 2014)

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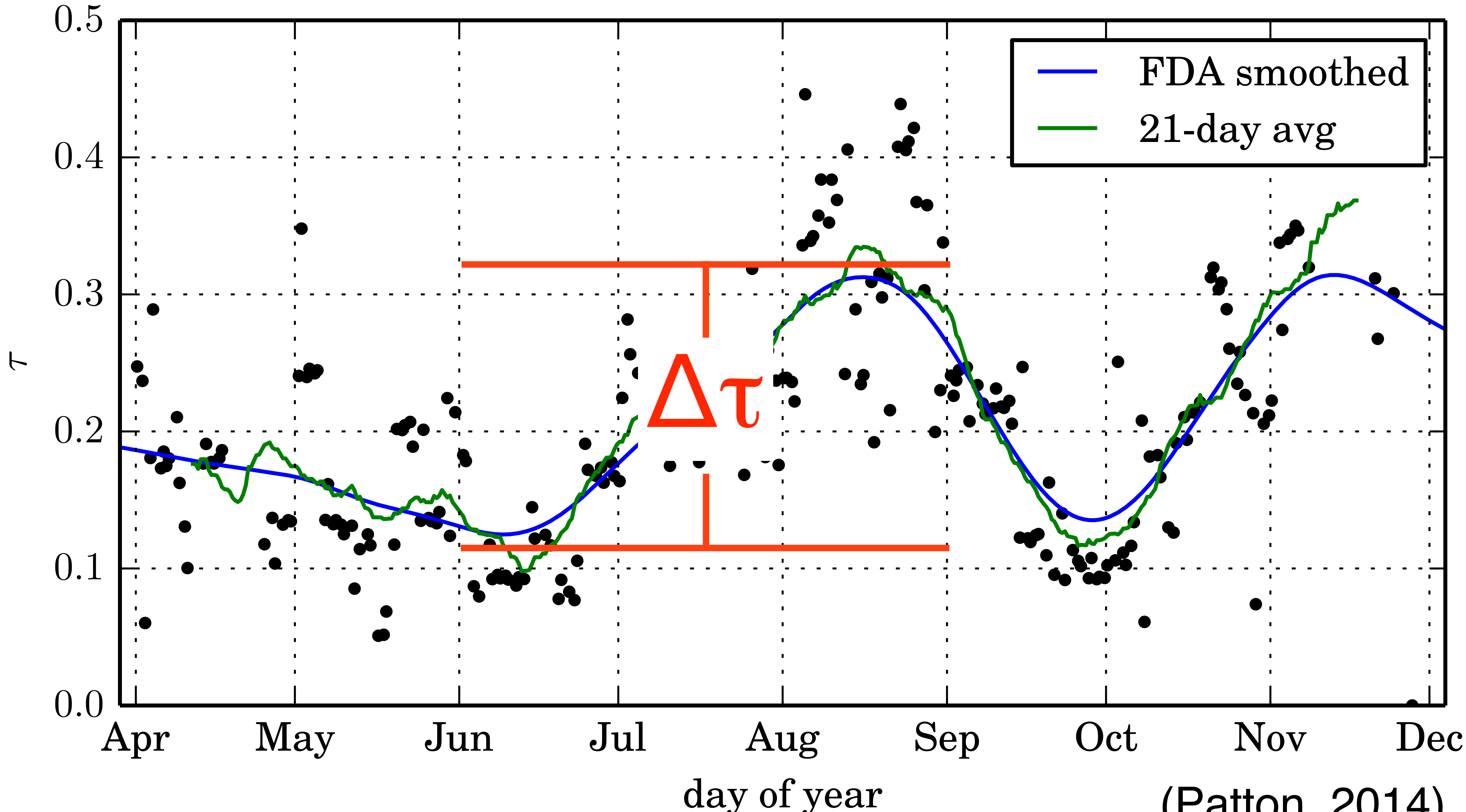
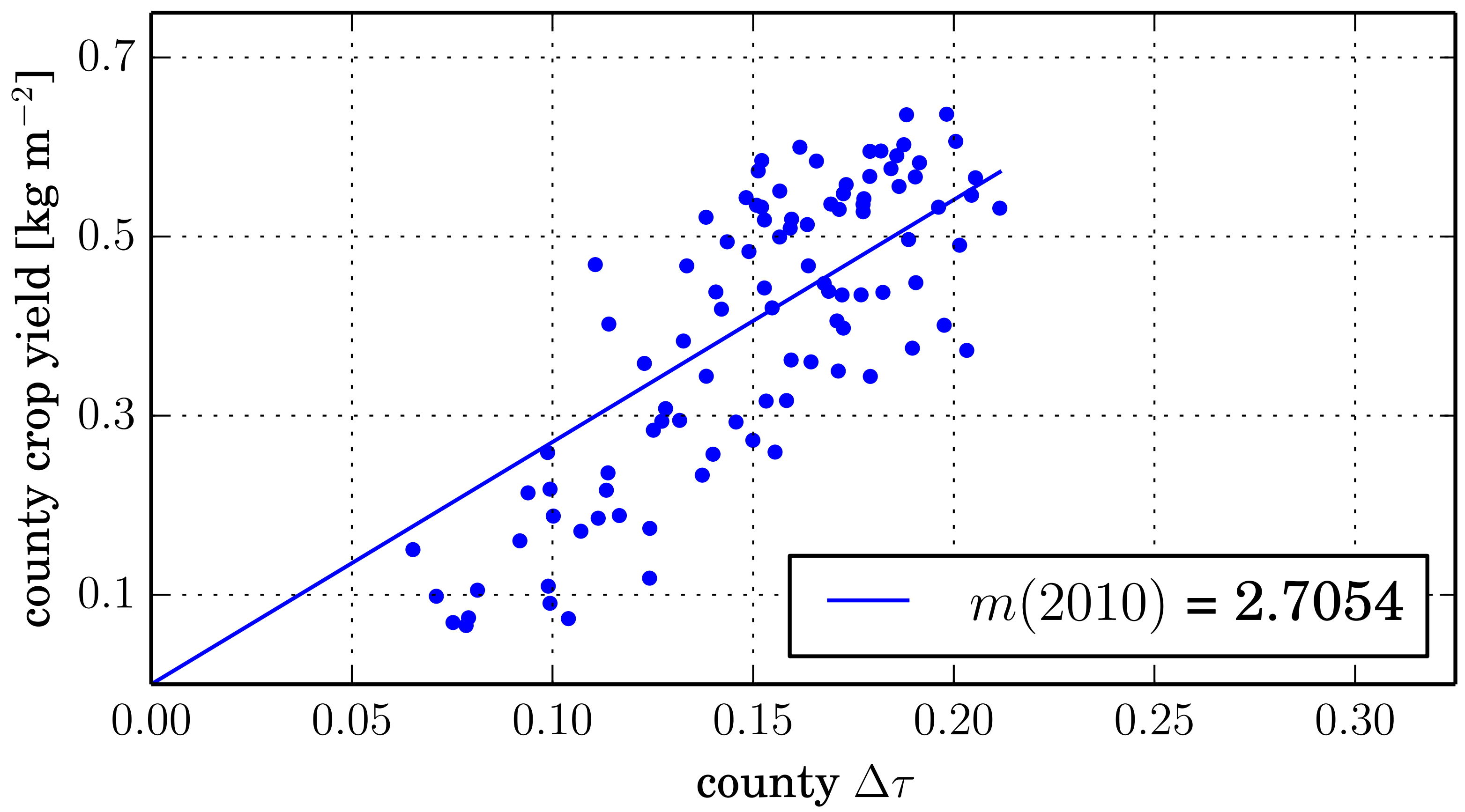


(Patton, 2014)

The change in τ over the growing season can be related to county crop yield estimates (in Iowa).



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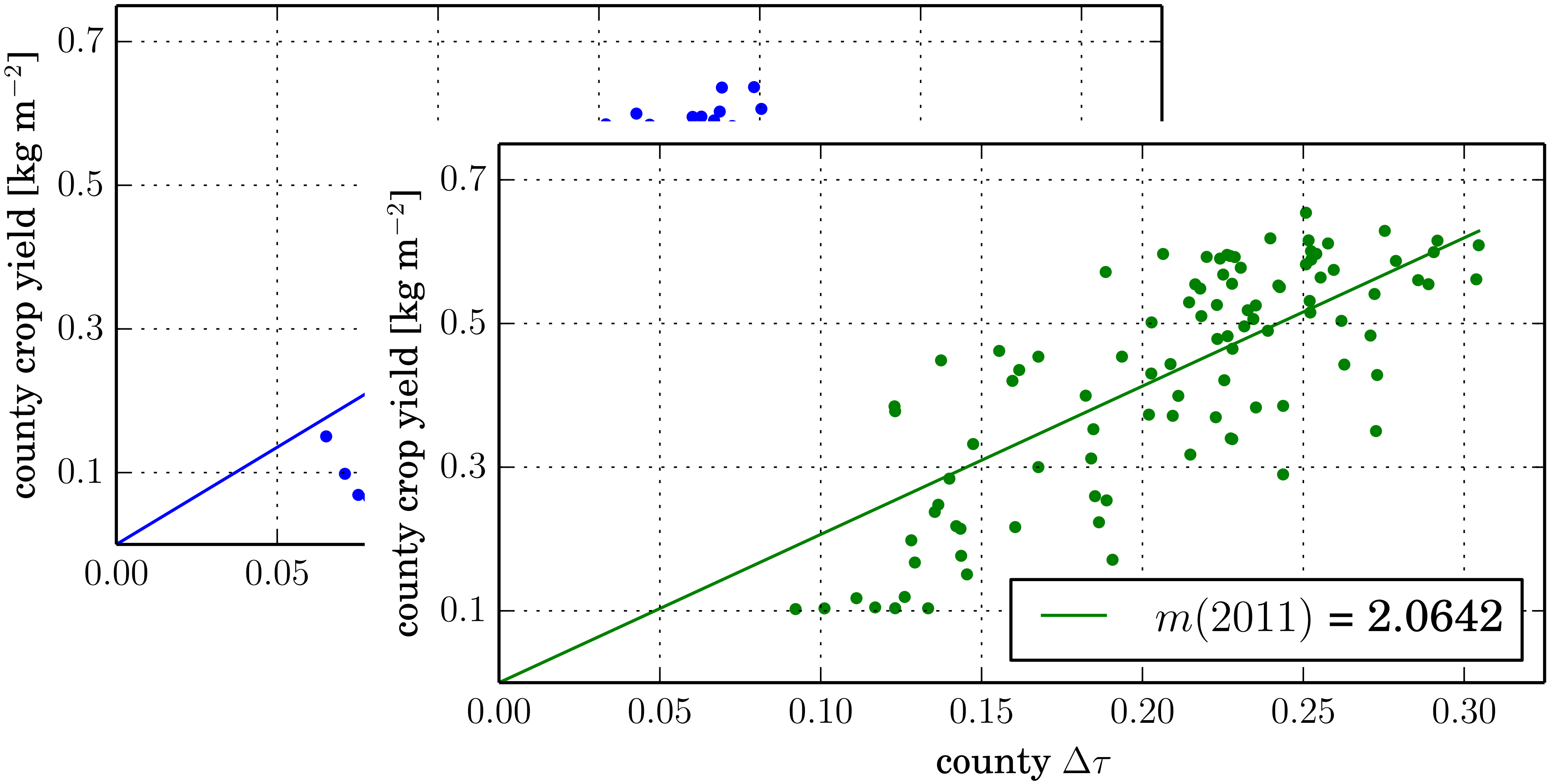

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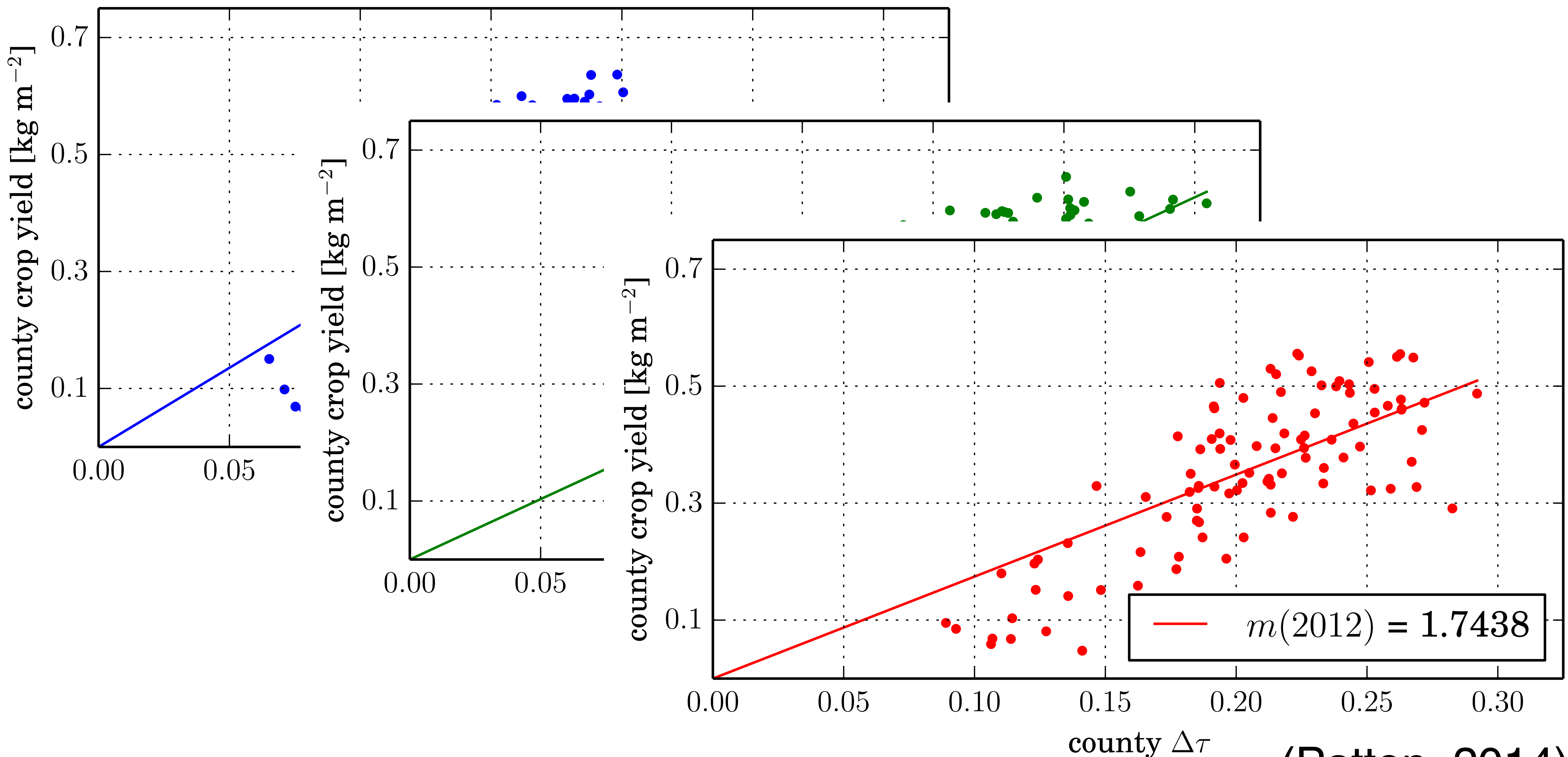
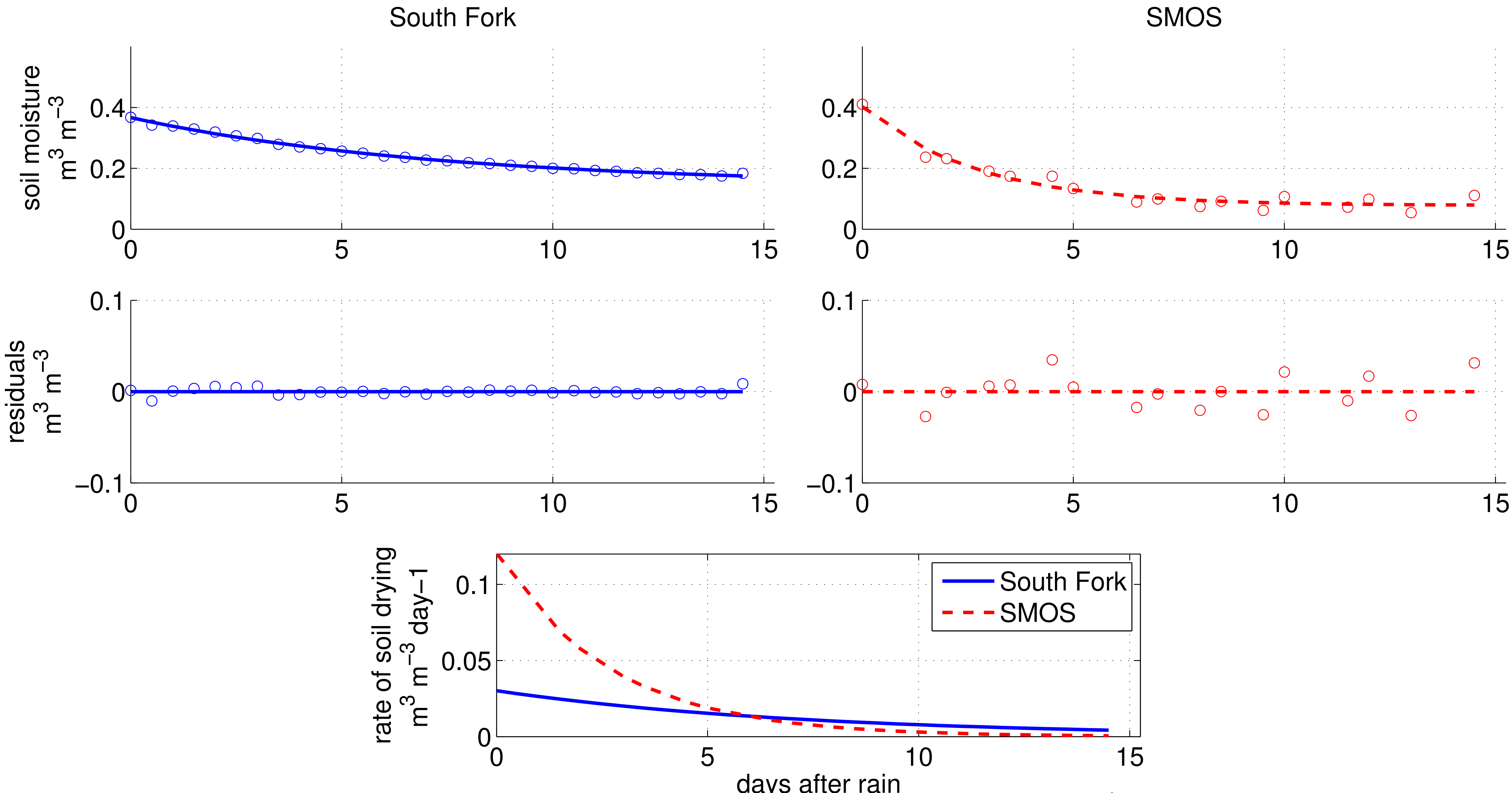


(Patton, 2014)

When using SMOS data, be considerate of the sensing depth, noise, radio frequency interference, and the grid spacing.



(Rondinelli et al, in review)

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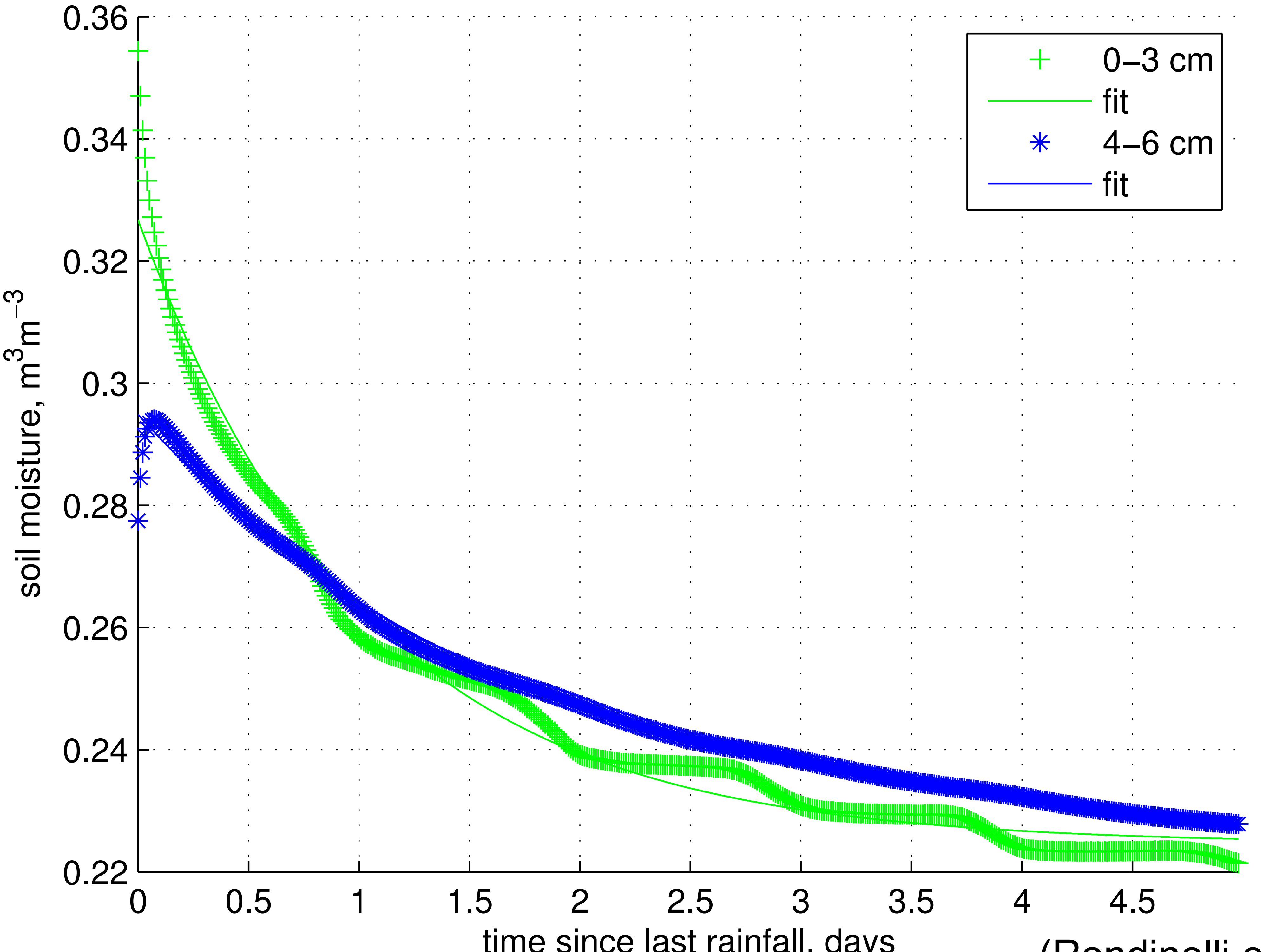

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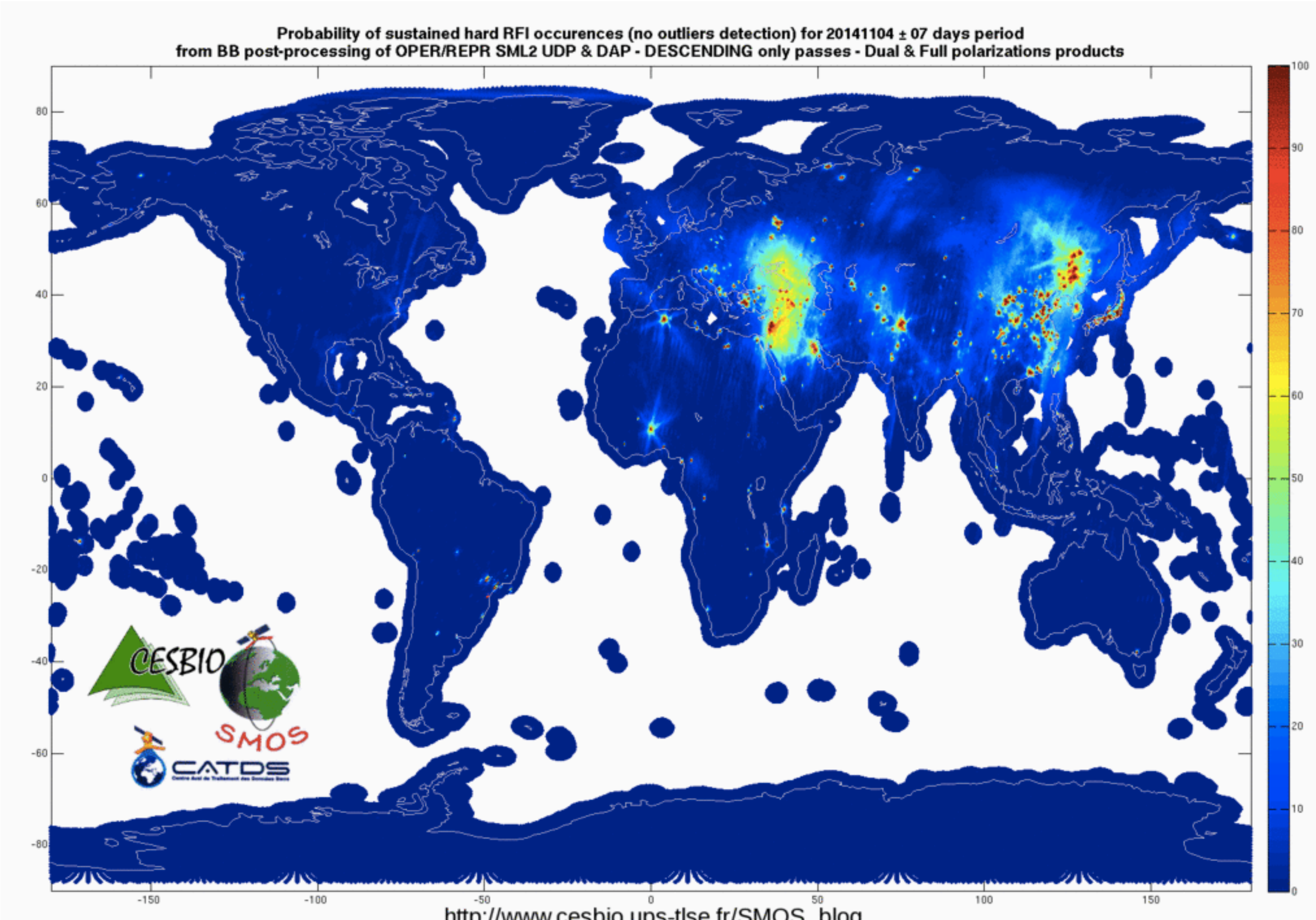

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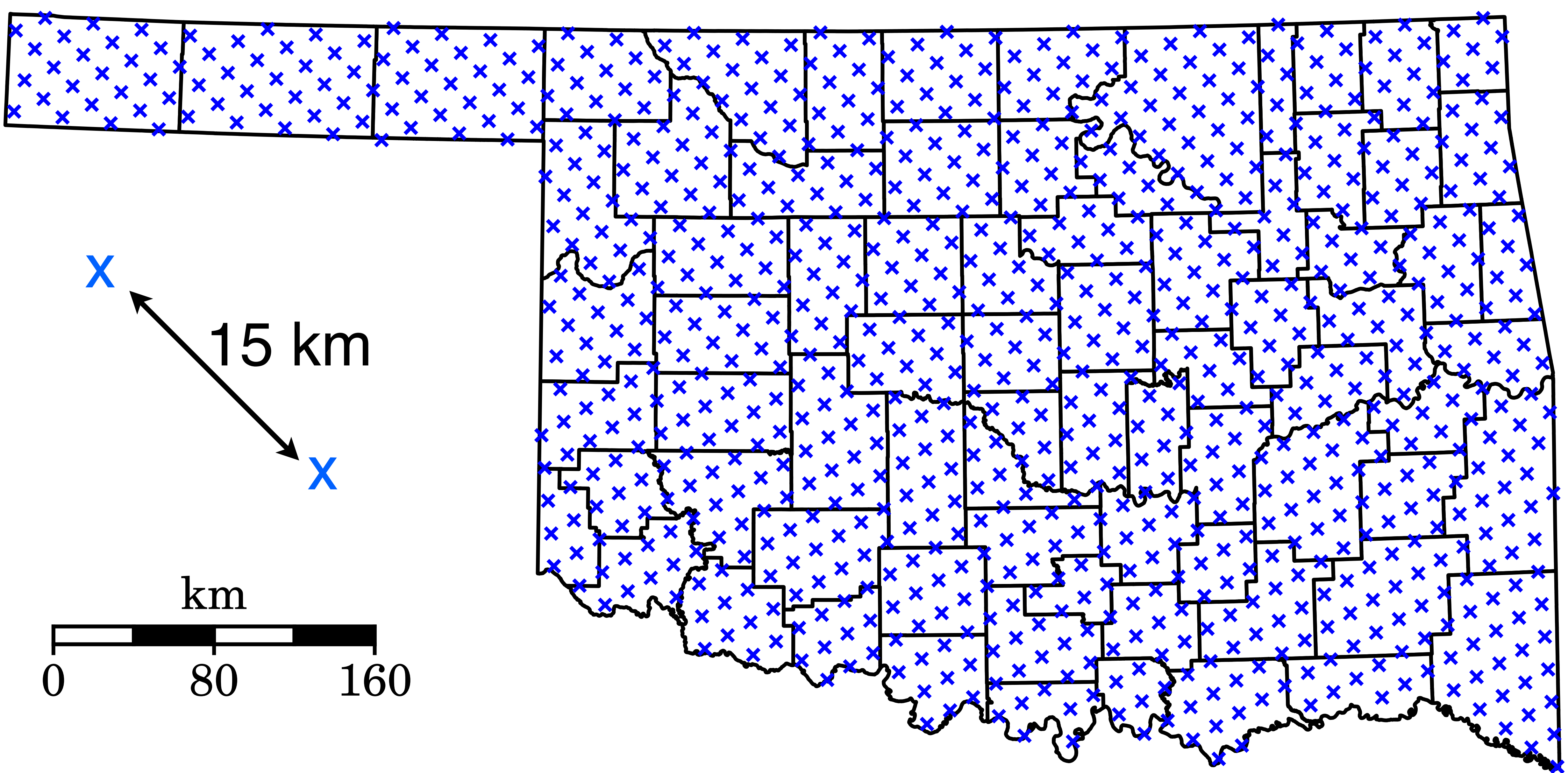
SMOS pixels in Oklahoma



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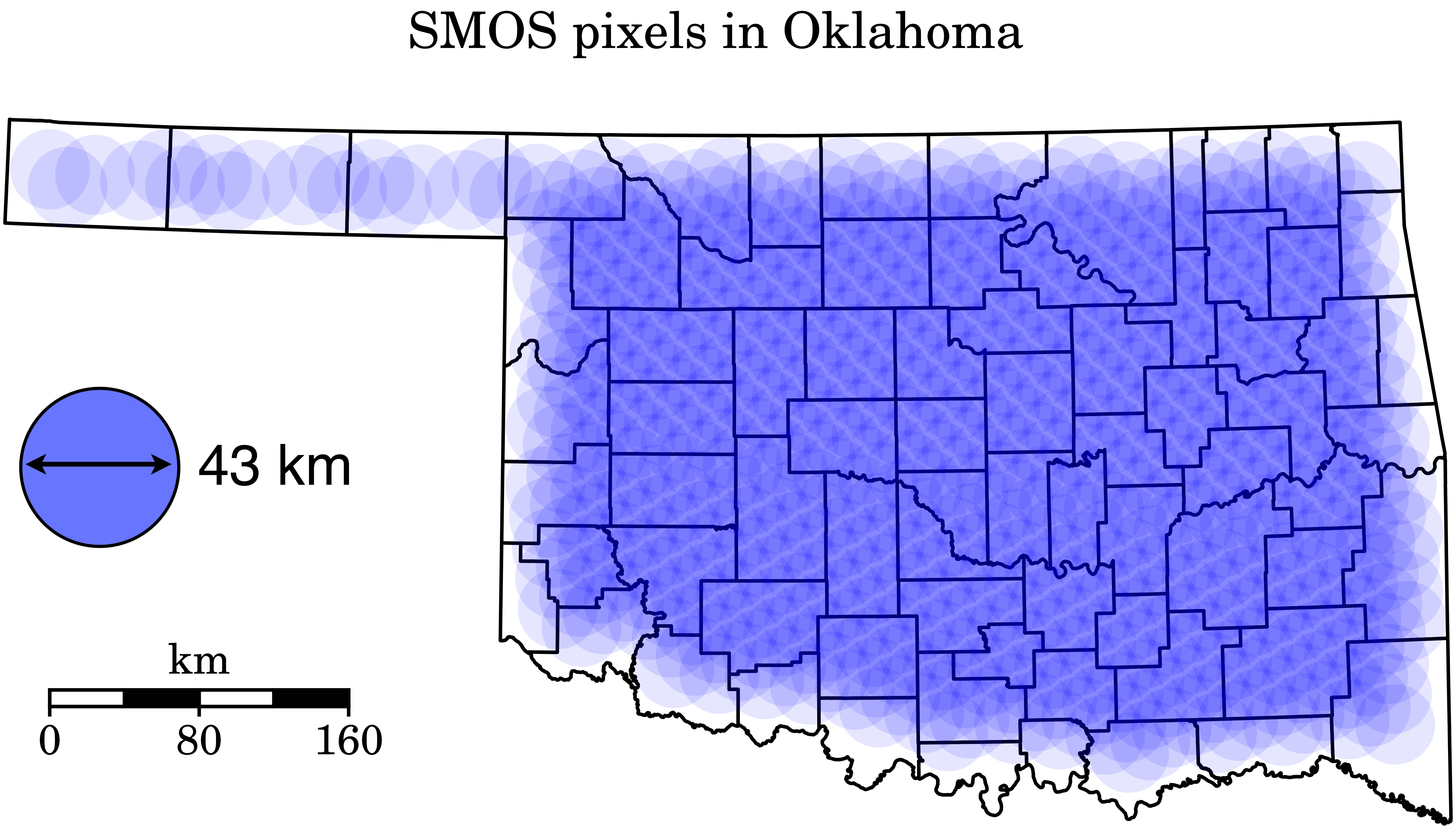

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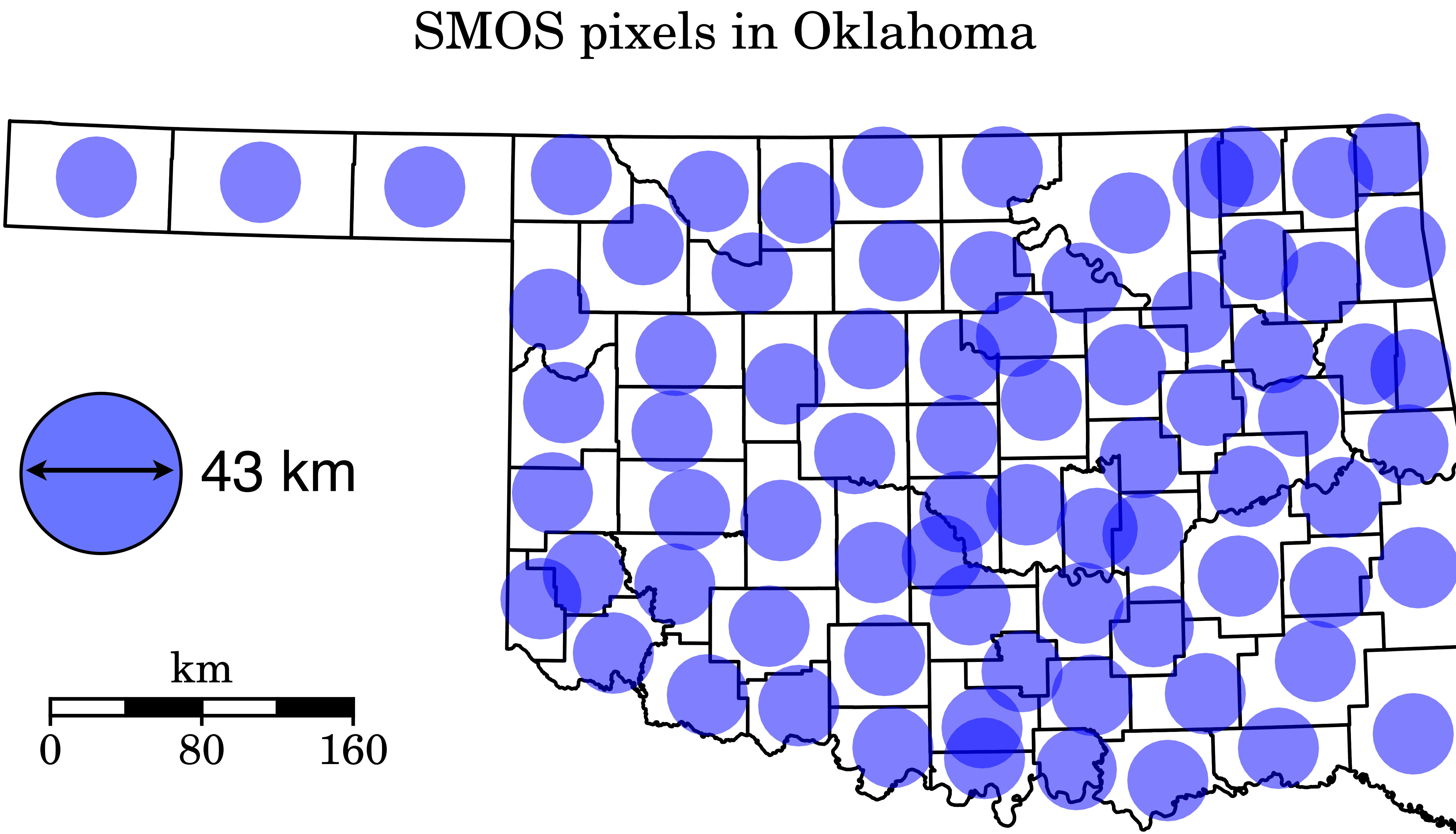


SMOS data

L1 (brightness temps) and L2 (soil moisture, tau) available from ESA:
https://earth.esa.int/web/guest/-/how-to-obtain-data-7329

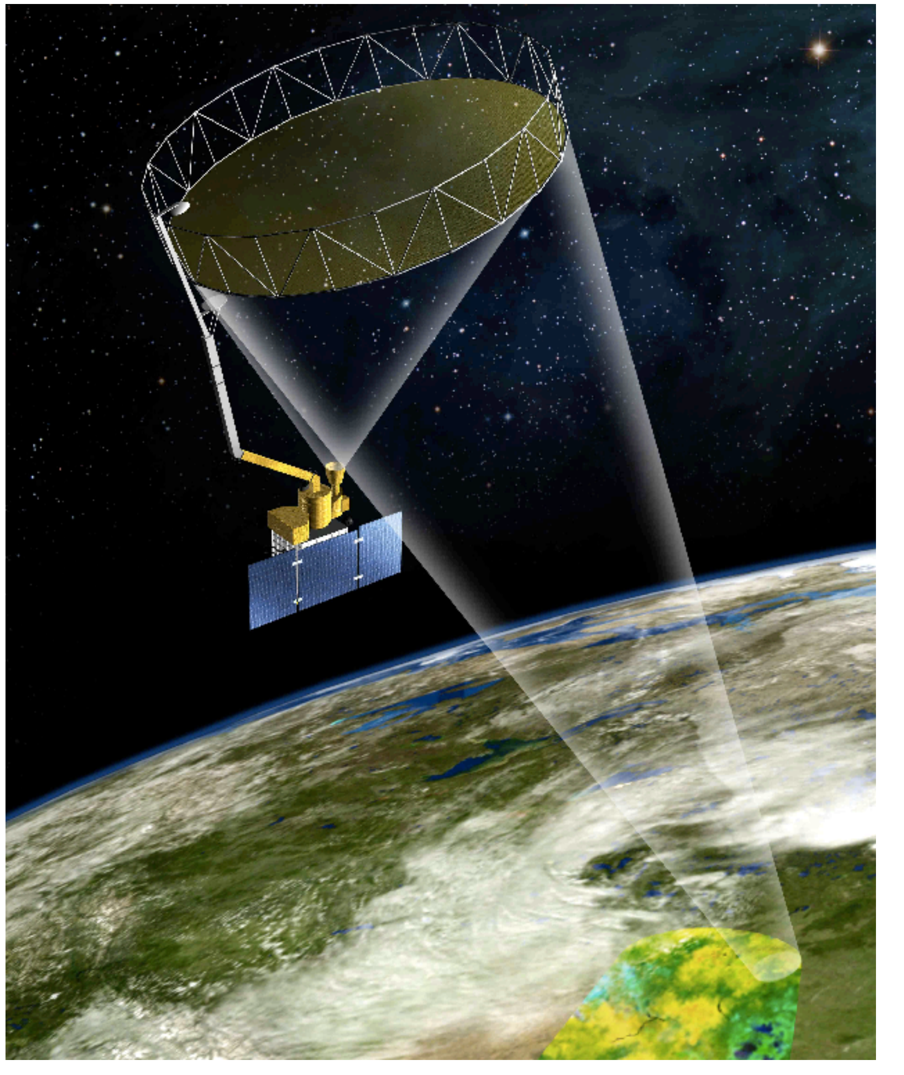
Proprietary format, use BEAM or Matlab API (req. 64-bit Linux) to view or convert to more friendly formats:

BEAM: http://www.brockmann-consult.de/cms/web/beam
Matlab Read API: http://smos.array.ca/web/smos/matlab-tool

L3 (3-day/monthly soil moisture) available from CATDS in NetCDF:
http://www.catds.fr/

Some L2 (soil moisture & tau *only*) available from the Iowa Environmental Mesonet: http://mesonet.agron.iastate.edu/smos

SMAP is the **S**oil **M**oisture **A**ctive **P**assive satellite mission.



(NASA)

NASA

Launching January 2015

Active and Passive L-band

3 km and 36 km resolutions
10 km combined active/passive

Sensitive to top 3-5 cm of soil

Polar orbiting:
- Measurements every 3 days at equator
- More often at higher latitudes

The “tau-omega” model describes the natural emission of microwave radiation from Earth’s surface.

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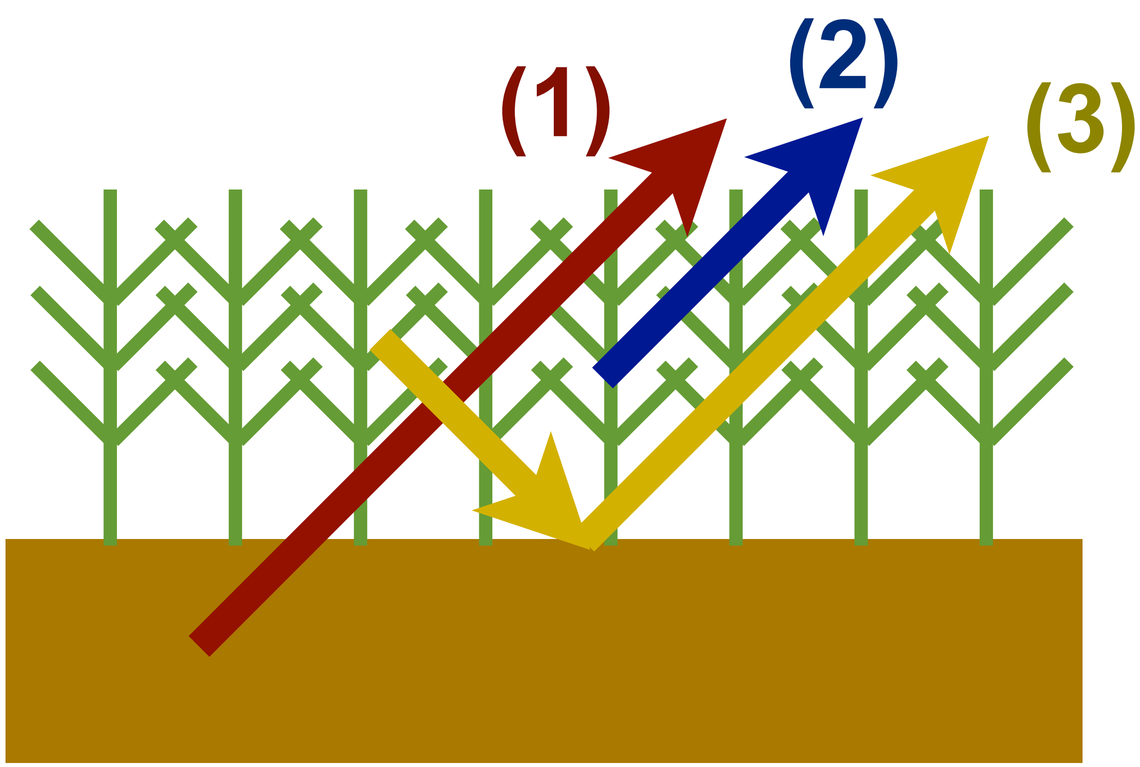

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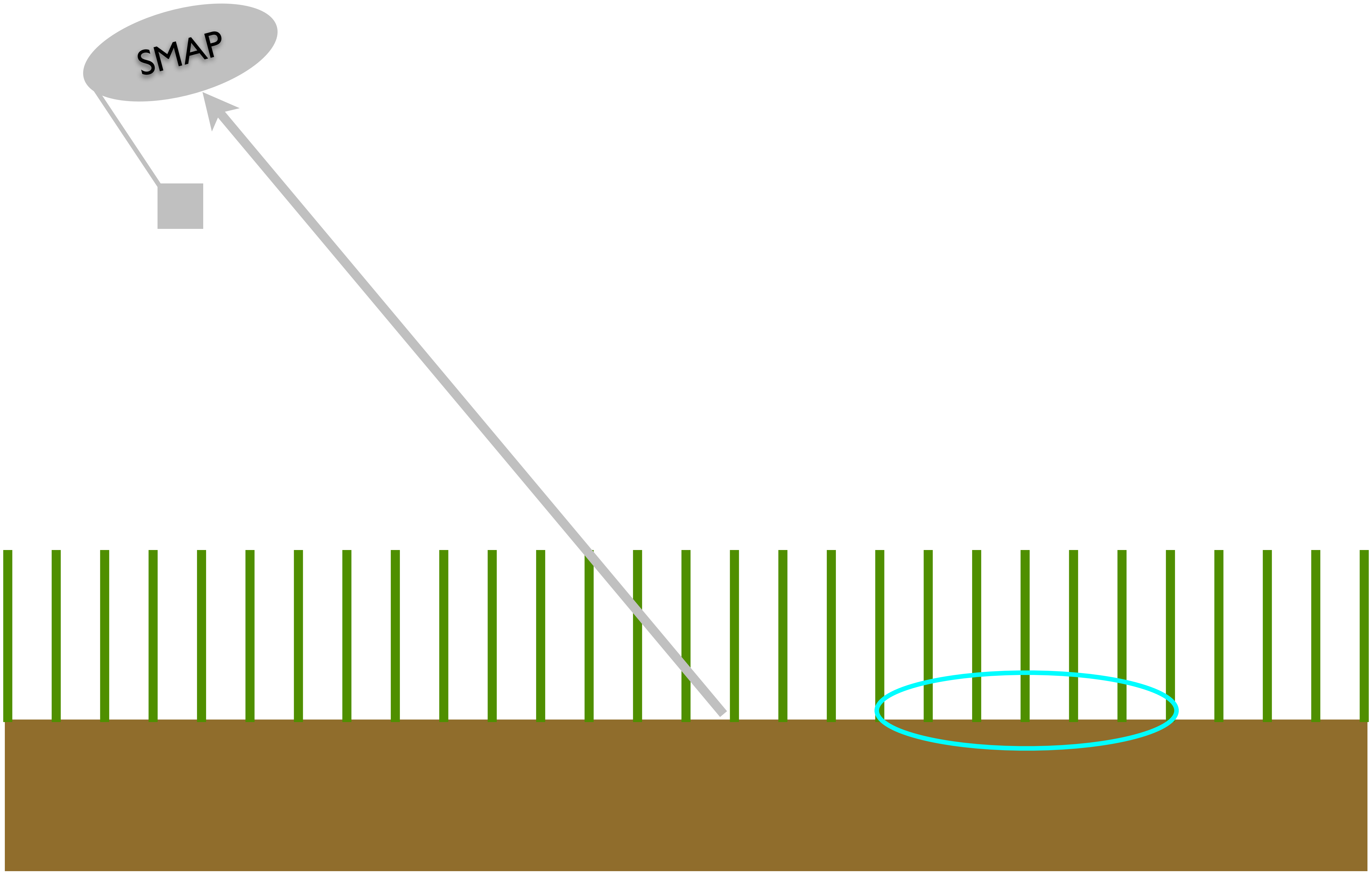
The main difference between SMOS and SMAP passive soil moisture retrieval is multi-angle vs. single angle approach.



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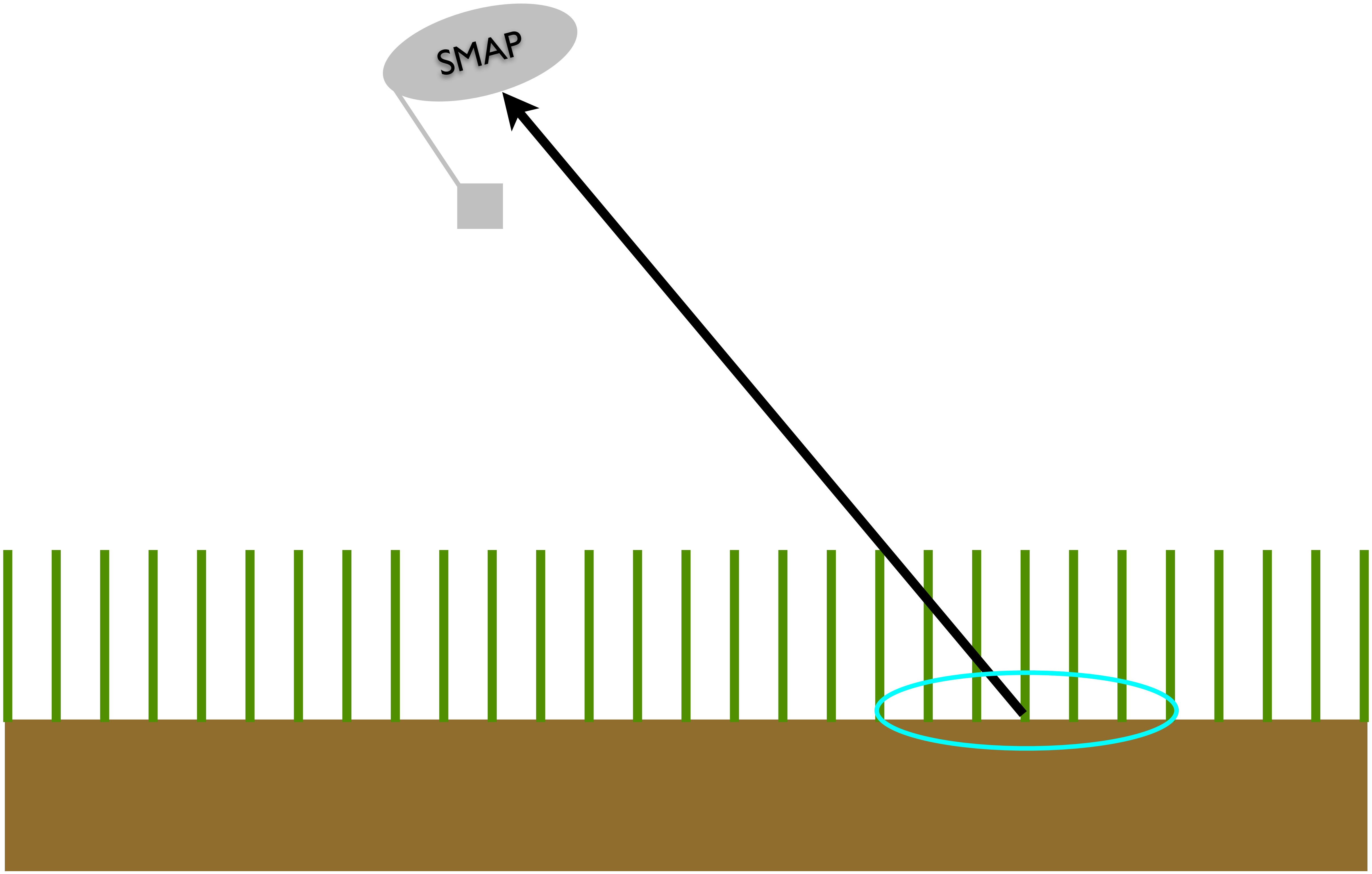

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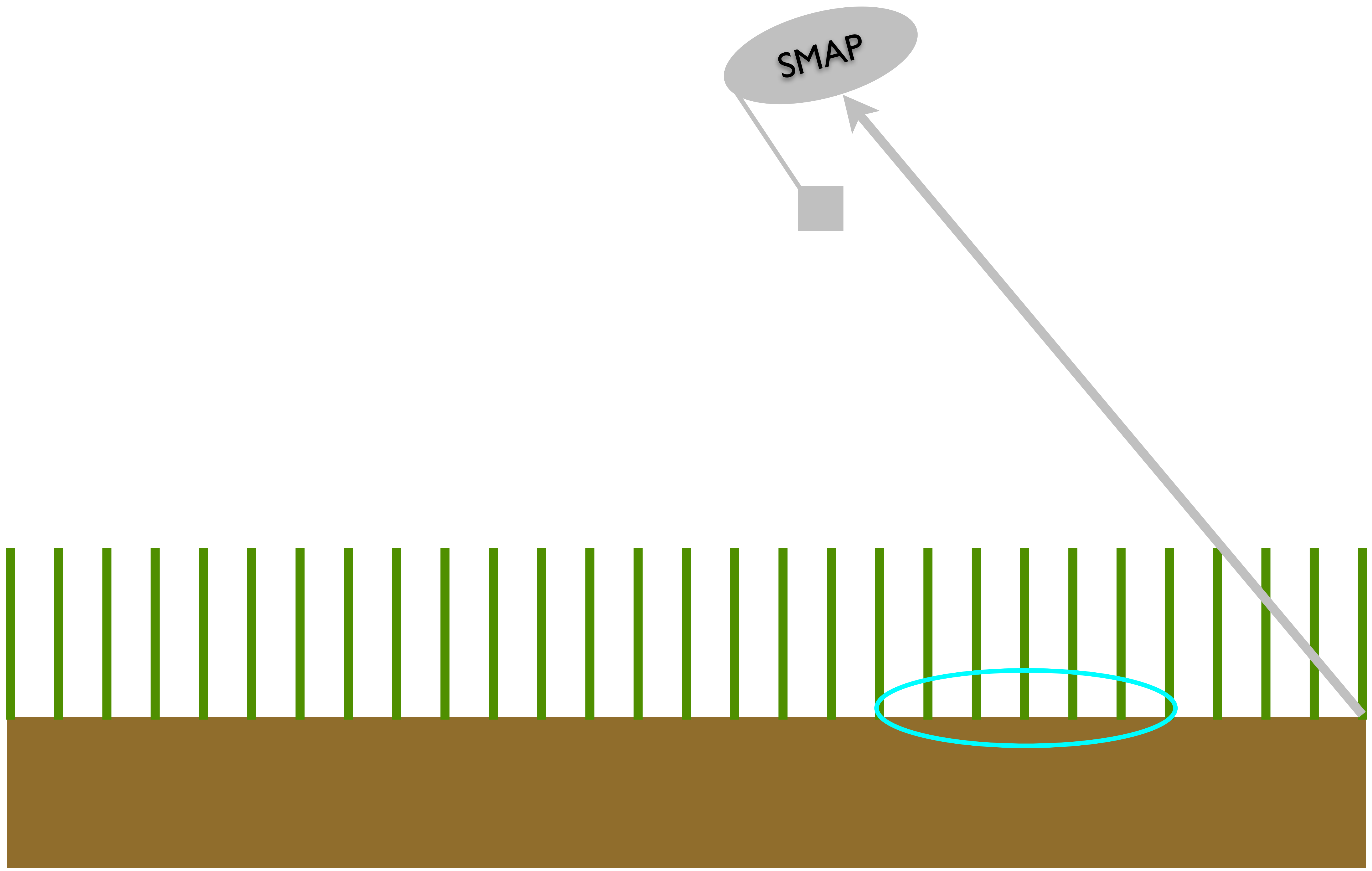


SMOS	SMAP
L-band	L-band
Passive-only (43 km pixels)	Radar dissaggregation of passive pixels (36 km to 10 km)
Multi angle, retrieves τ	Single angle, requires τ
RFI plagued in regions	RFI mitigation built in
15 km ISEA grid (oversampled)	EASE-Grid 2.0 (grid spacing approx. matches resolution)
Already in orbit	Yet to be launched

The baseline SMAP soil moisture retrieval algorithm will require an outside source of vegetation data, will use an NDVI climatology to estimate τ.

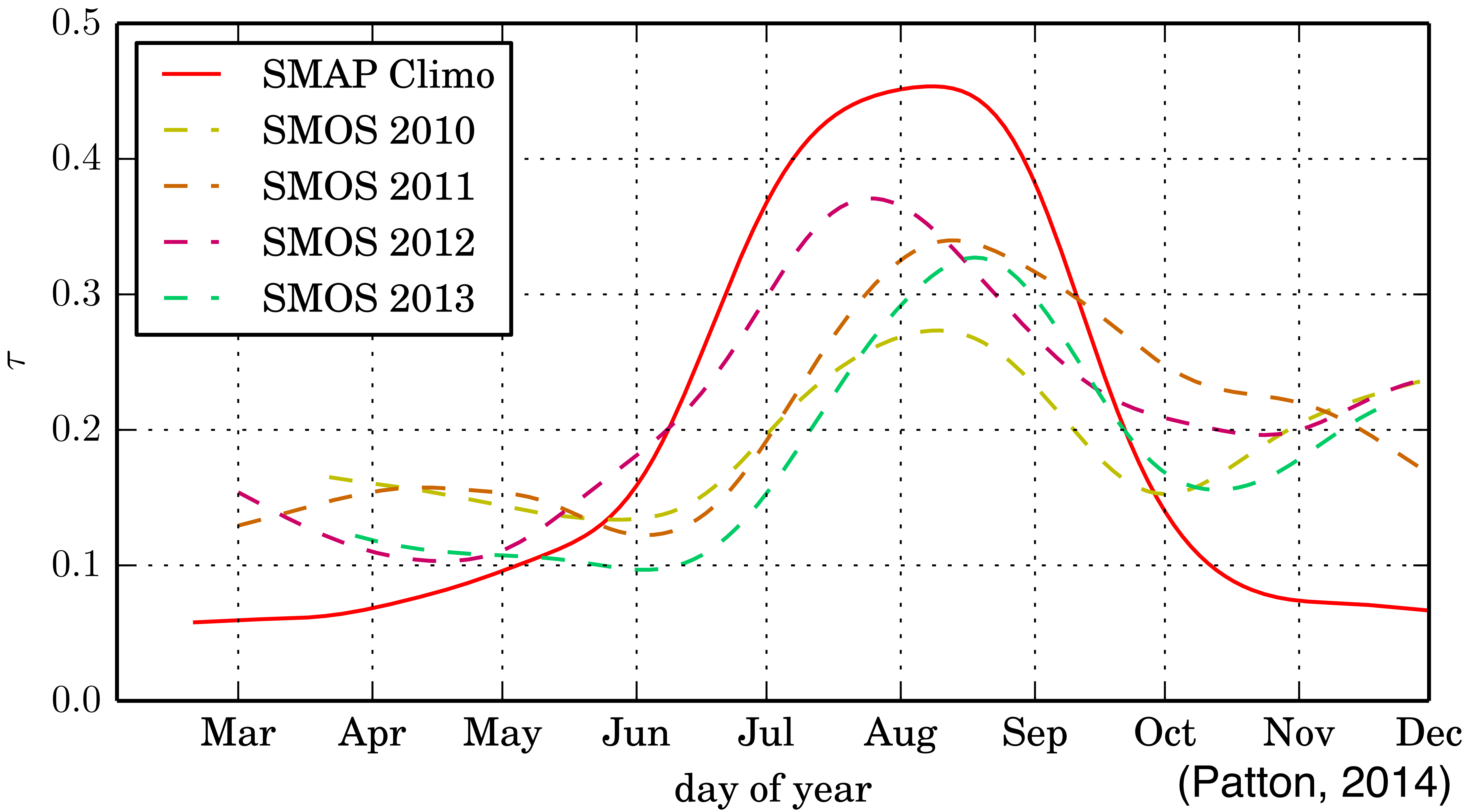
NDVI —> Vegetation Water Content (VWC) —> τ

$$\mathrm{VWC} = \left(1.9134 \times \mathrm{NDVI}^2 - 0.3215 \times \mathrm{NDVI}\right) + stem\ factor \times \frac{\mathrm{NDVI}_{max} - \mathrm{NDVI}_{min}}{1 - \mathrm{NDVI}_{min}}$$

$$\tau = b \times VWC$$

(SMAP L2 Passive ATBD)

Under this baseline approach, SMAP may not be sensitive to interannual variability in vegetation.



(Patton, 2014)

SMAP data

All products will be available through NSIDC in HDF-5 format about a year after launch.

Data Product Short Name	Short Description	Gridding (Resolution)	Latency*
L1A_Radar	Radar raw data in time order	-	12 hours
L1A_Radiometer	Radiometer raw data in time order	-	12 hours
L1B_S0_LoRes	Low resolution radar σ_o in time order	(5x30 km)	12 hours
L1B_TB	Radiometer T_B in time order	(36x47 km)	12 hours
L1C_S0_HiRes	High resolution radar σ_o (half orbit, gridded)	1 km (1-3 km)**	12 hours
L1C_TB	Radiometer T_B (half orbit, gridded)	36 km	12 hours
L2_SM_A	Soil moisture (radar, half orbit)	3 km	24 hours
L2_SM_P	Soil moisture (radiometer, half orbit)	36 km	24 hours
L2_SM_A/P	Soil moisture (radar/radiometer, half orbit)	9 km	24 hours
L3_F/T_A	Freeze/thaw state (radar, daily composite)	3 km	50hours
L3_SM_A	Soil moisture (radar, daily composite)	3 km	50 hours
L3_SM_P	Soil moisture (radiometer, daily composite)	36 km	50 hours
L3_SM_A/P	Soil moisture (radar/radiometer, daily composite)	9 km	50 hours
L4_SM	Soil moisture (surface & root zone)	9 km	7 days
L4_C	Carbon net ecosystem exchange (NEE)	9 km	14 days

* Mean latency under normal operating conditions (defined as time from data acquisition by the observatory to availability to the public data archive). The SMAP project will make a best effort to reduce these latencies.

** Over outer 70% of the swath.

(NASA)

COSMOS is the **Co**smic-ray **S**oil **M**oisture **O**bserving **S**ystem

NSF project based out of University of Arizona

Passive neutron counting sensor

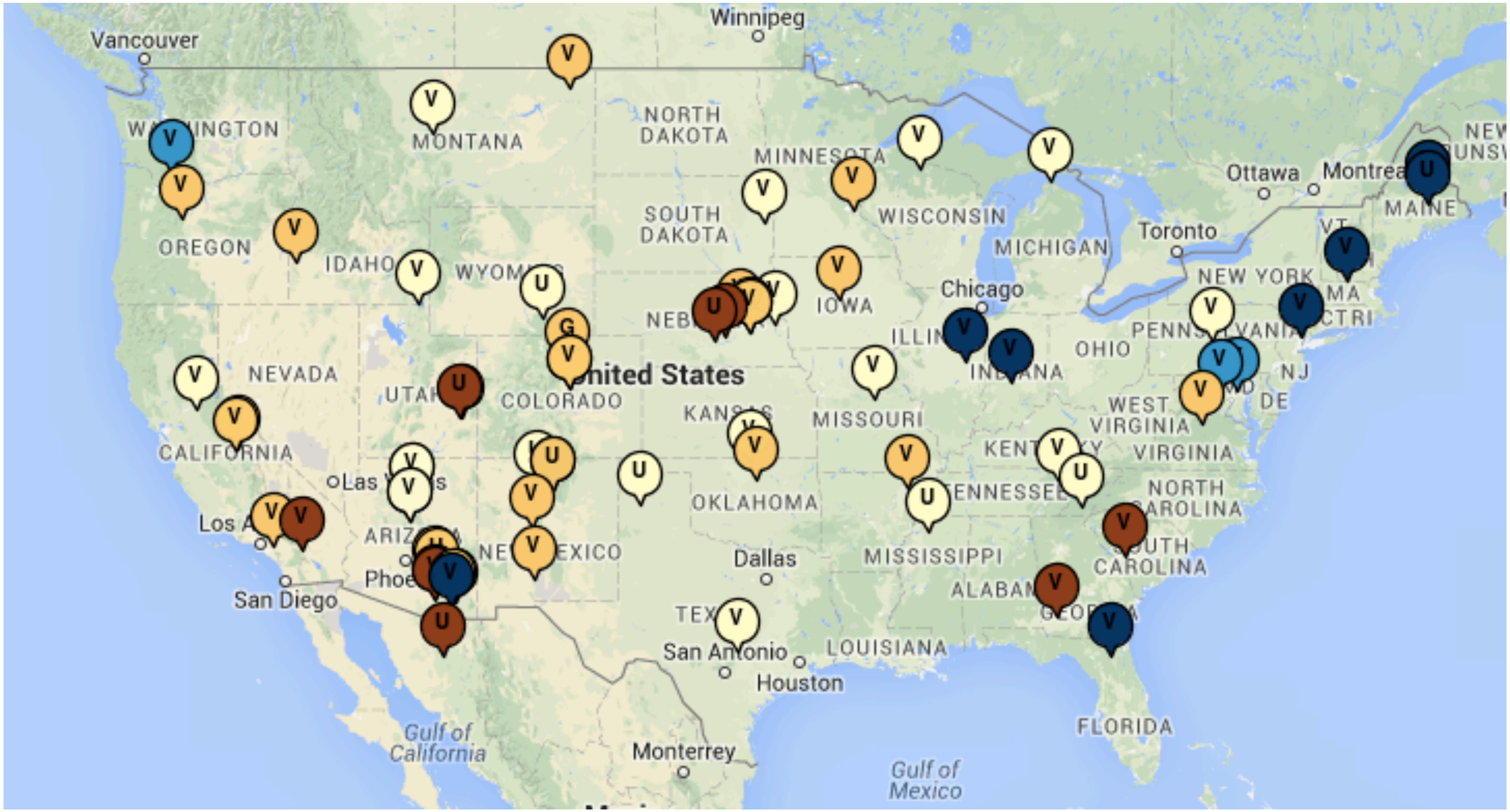
700 m sensing area

Sensitive to top 10-30 cm of soil (dependent on soil moisture)

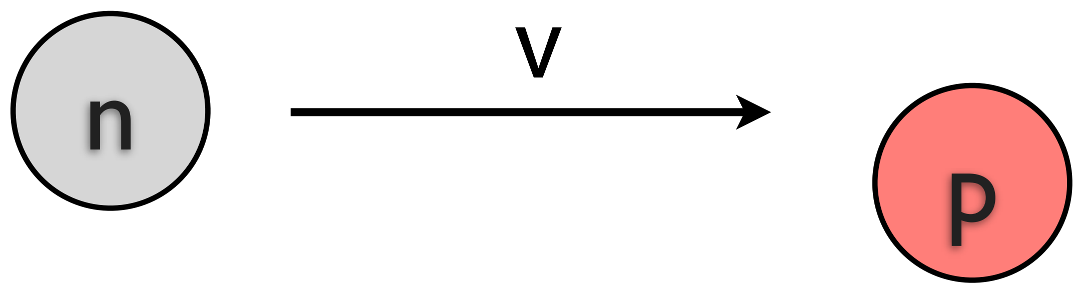
http://cosmos.hwr.arizona.edu/

(COSMOS)

COSMOS is being deployed across the US, already two (project-sanctioned) sensors in Oklahoma.



COSMOS counts “fast” neutrons, which are related to soil moisture because hydrogen slows neutrons.



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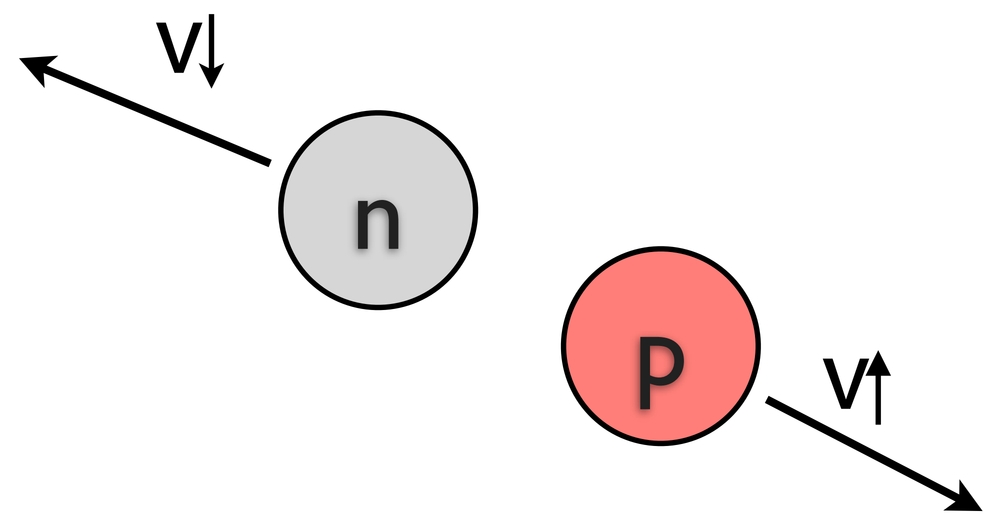

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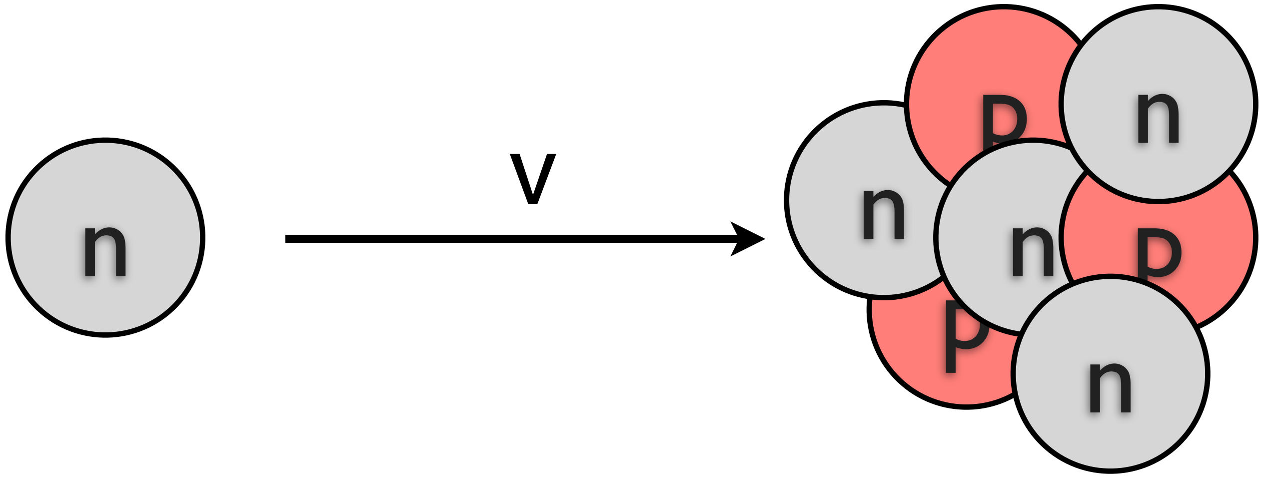

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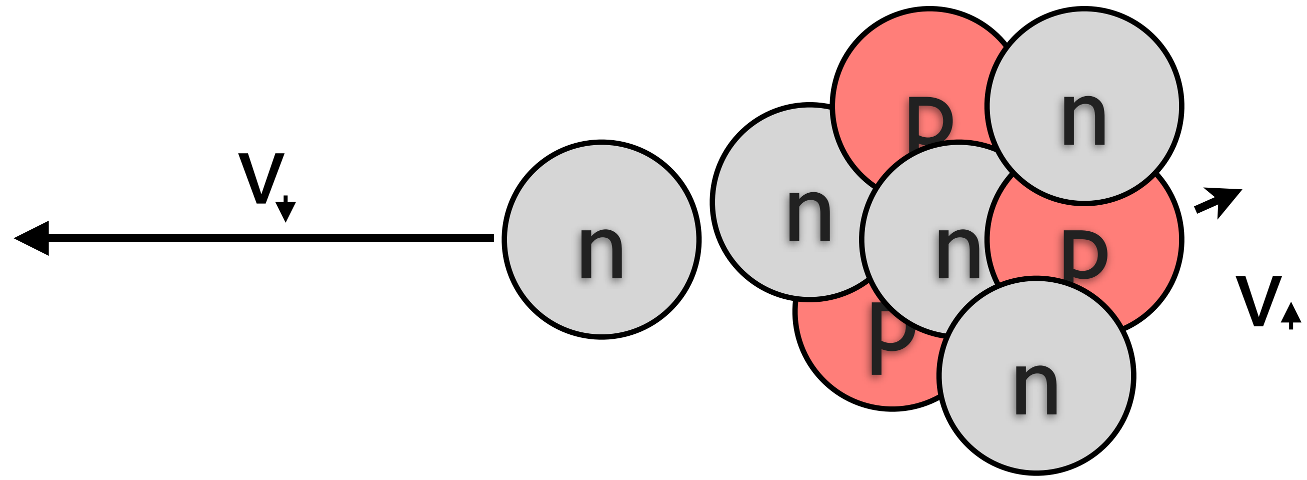
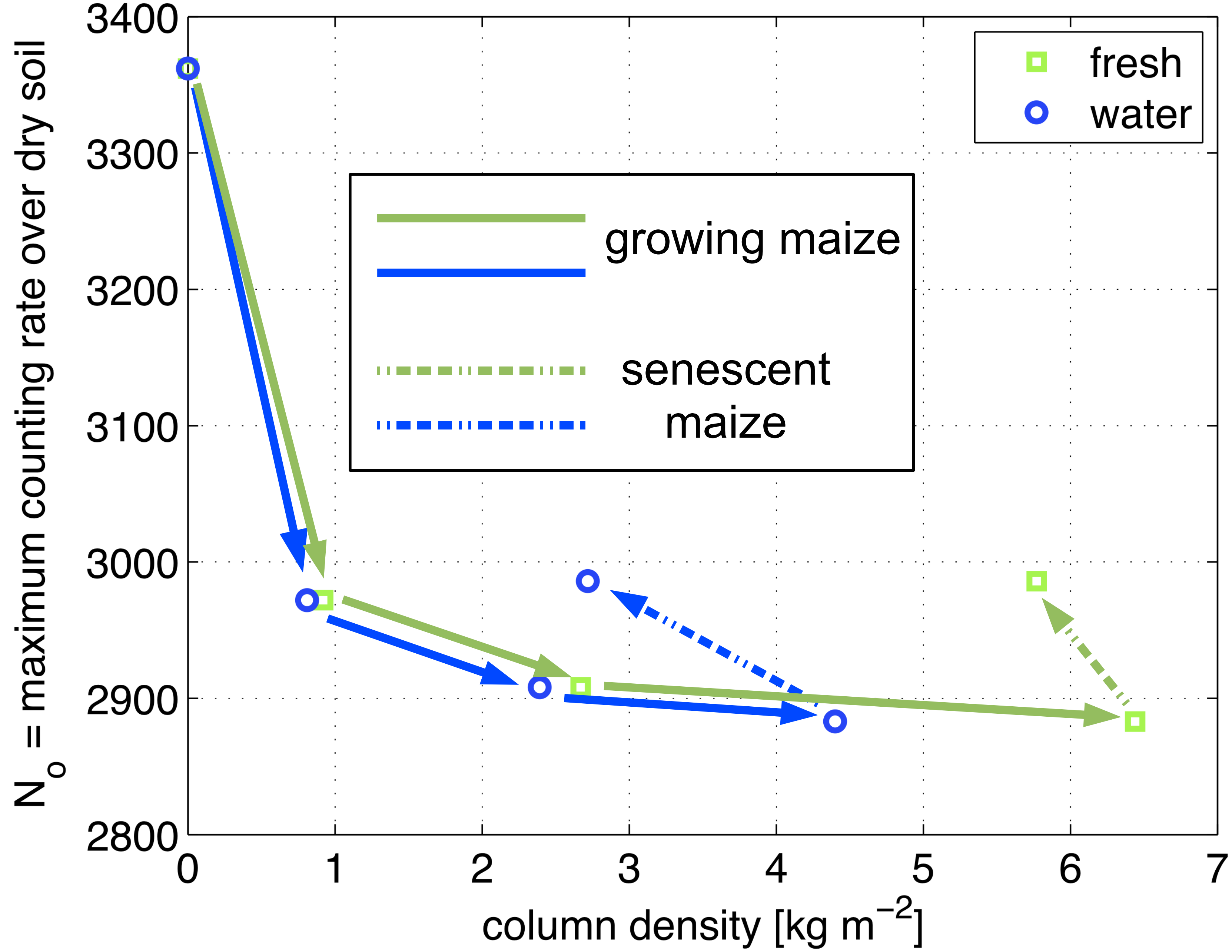


COSMOS requires careful calibration, which can change over time in areas with large changes in vegetation water content.



(Hornbuckle et al 2012)

COSMOS data, publications, etc.

http://cosmos.hwr.arizona.edu/

Thank you

jason.c.patton@okstate.edu