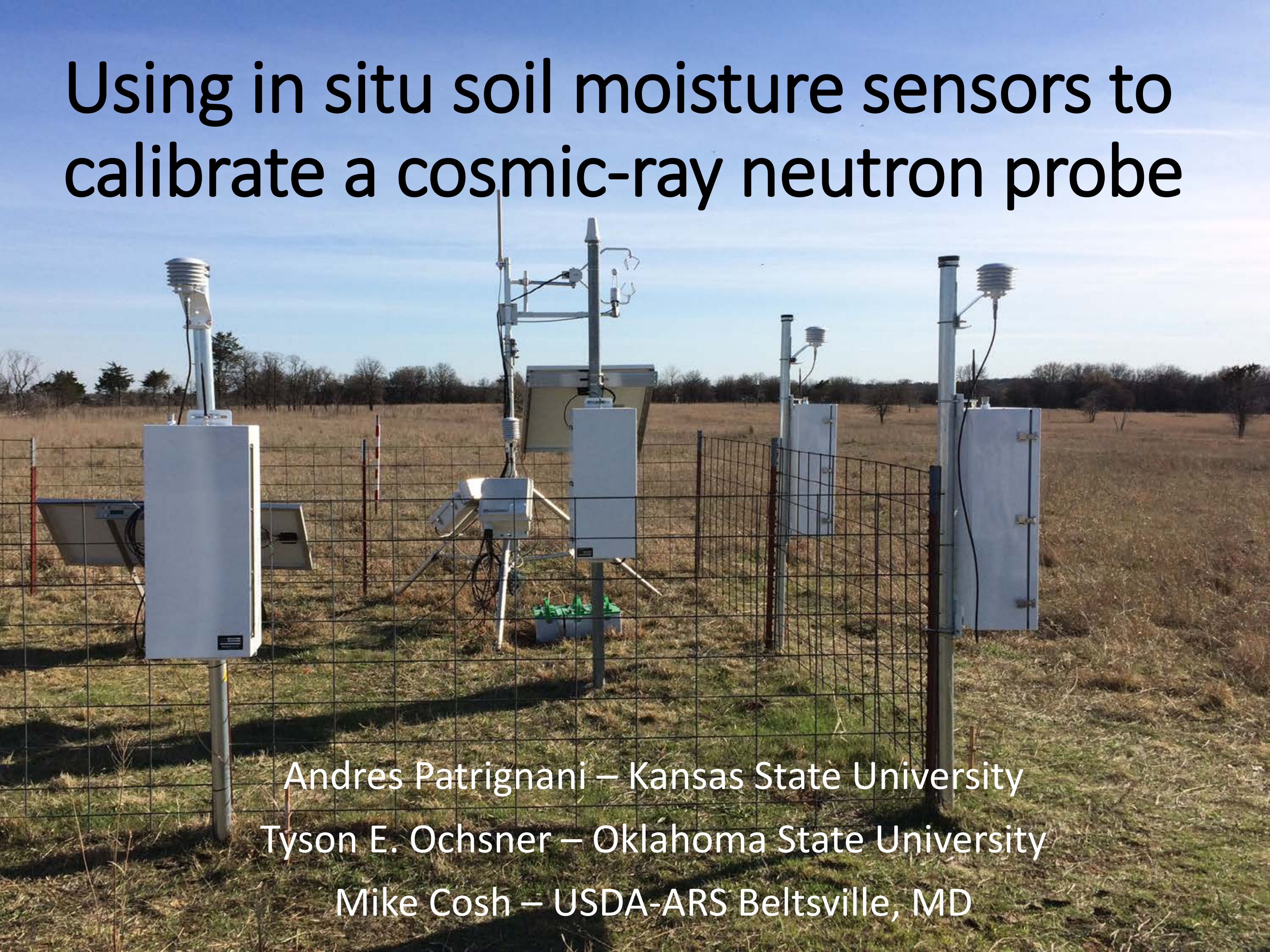

Using in situ soil moisture sensors to calibrate a cosmic-ray neutron probe

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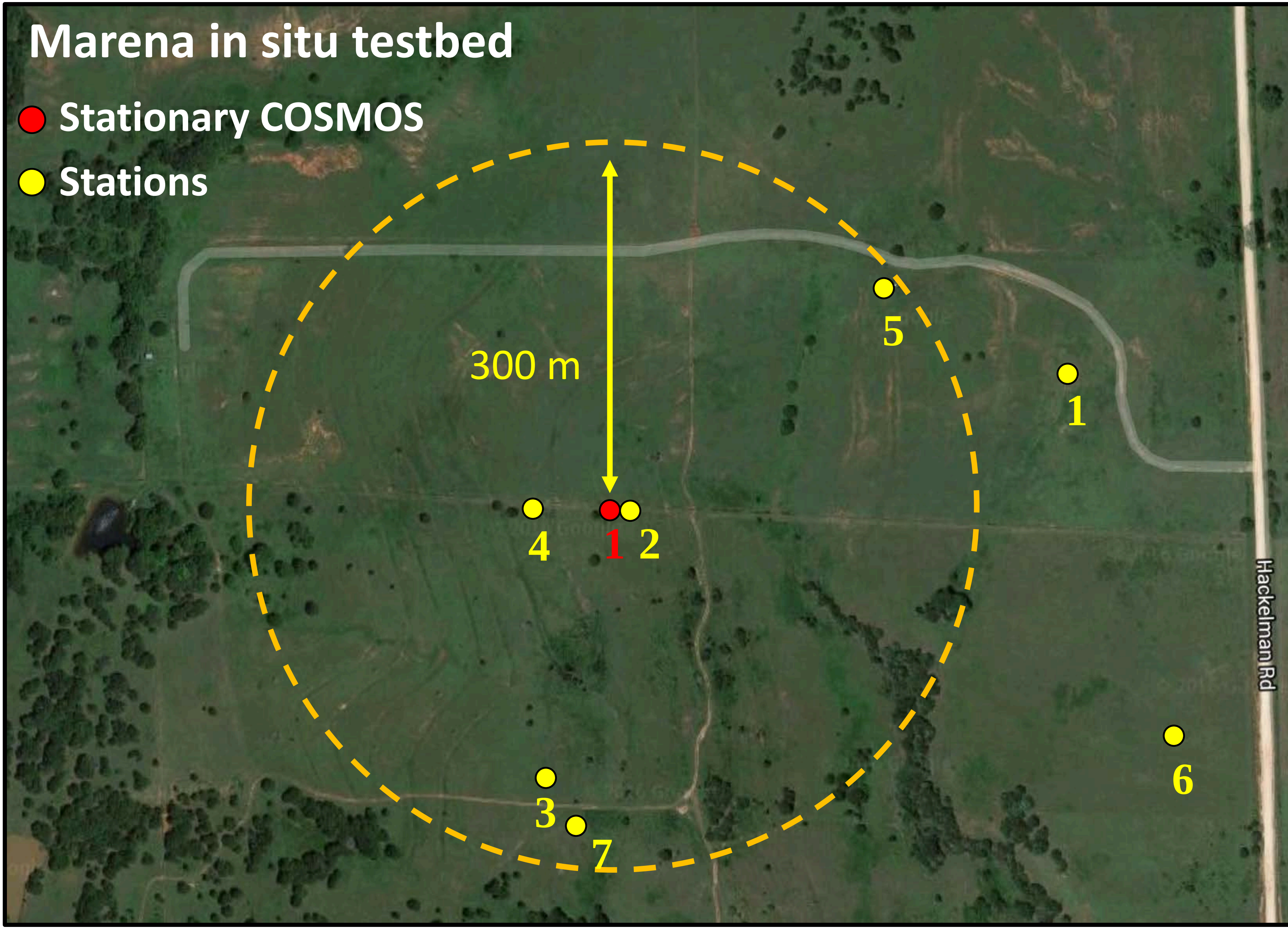


Marena in situ testbed
Stationary COSMOS
Stations
300 m
5
1
4
1
2
3
7
6
Hackelman Rd

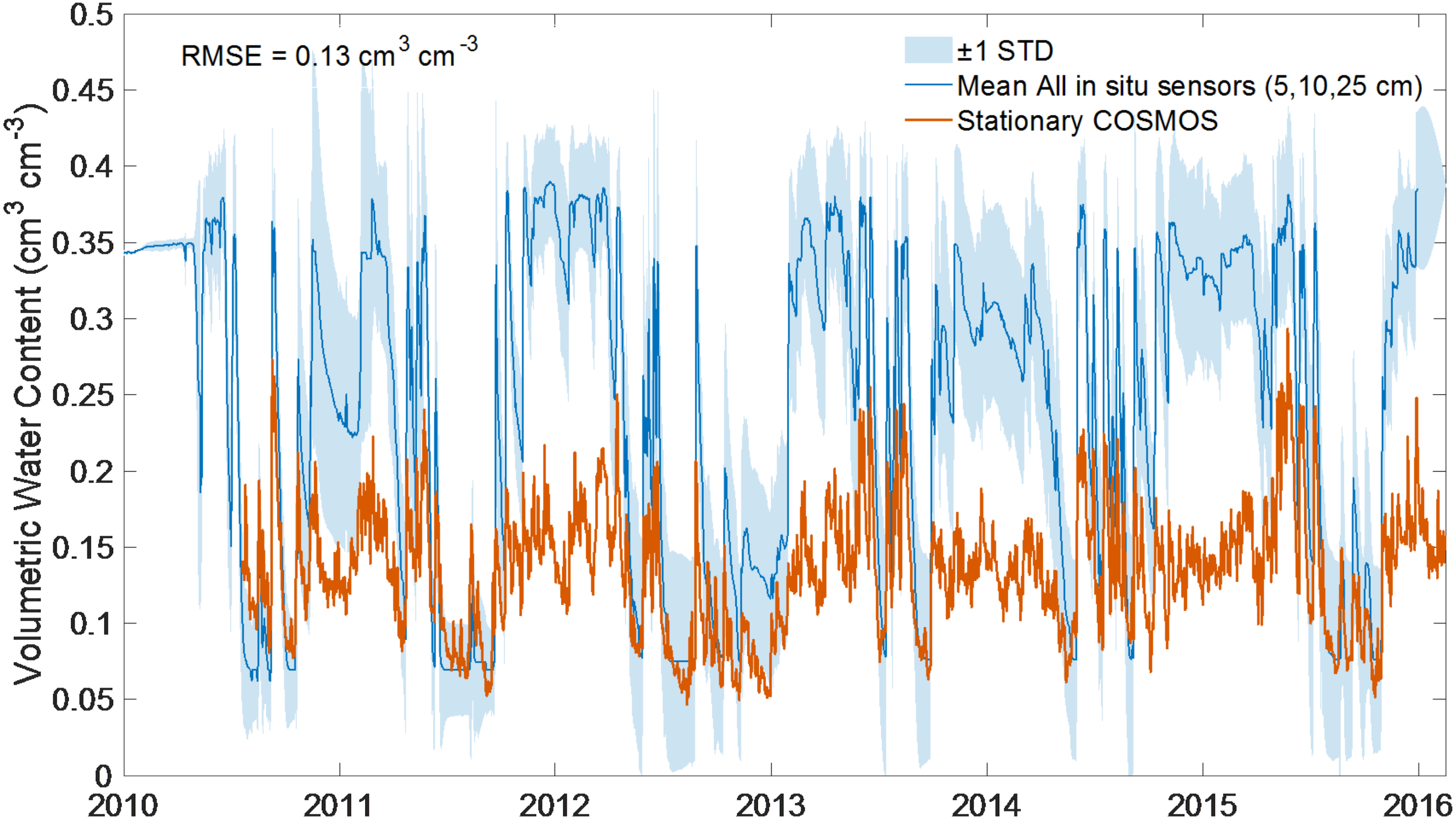
#	Station	Distance (m)	Depths (cm)	Start record	Sensor
1	COSMOS	0	Variable (0-50)	21-Jul-2010	^{3}He
2	MOISST A	7	5, 10, 20, 50, 90	11-May-2010	CS229-L
3	MOISST B	203	5, 10, 20, 50, 90	11-May-2010	CS229-L
4	MOISST C	70	5, 10, 20, 50, 90	11-May-2010	CS229-L
5	MOISST D	256	5, 10, 20, 50, 90	11-May-2010	CS229-L
6	JFSP 4	490	5, 10, 20, 50	13-Apr-2012	CS655
7	JFSP 5	230	5, 10, 20, 50	20-Apr-2012	CS655
8	Oklahoma Mesonet	396	5, 25, 60	10-May-1996	CS229-L

When using the COSMOS…

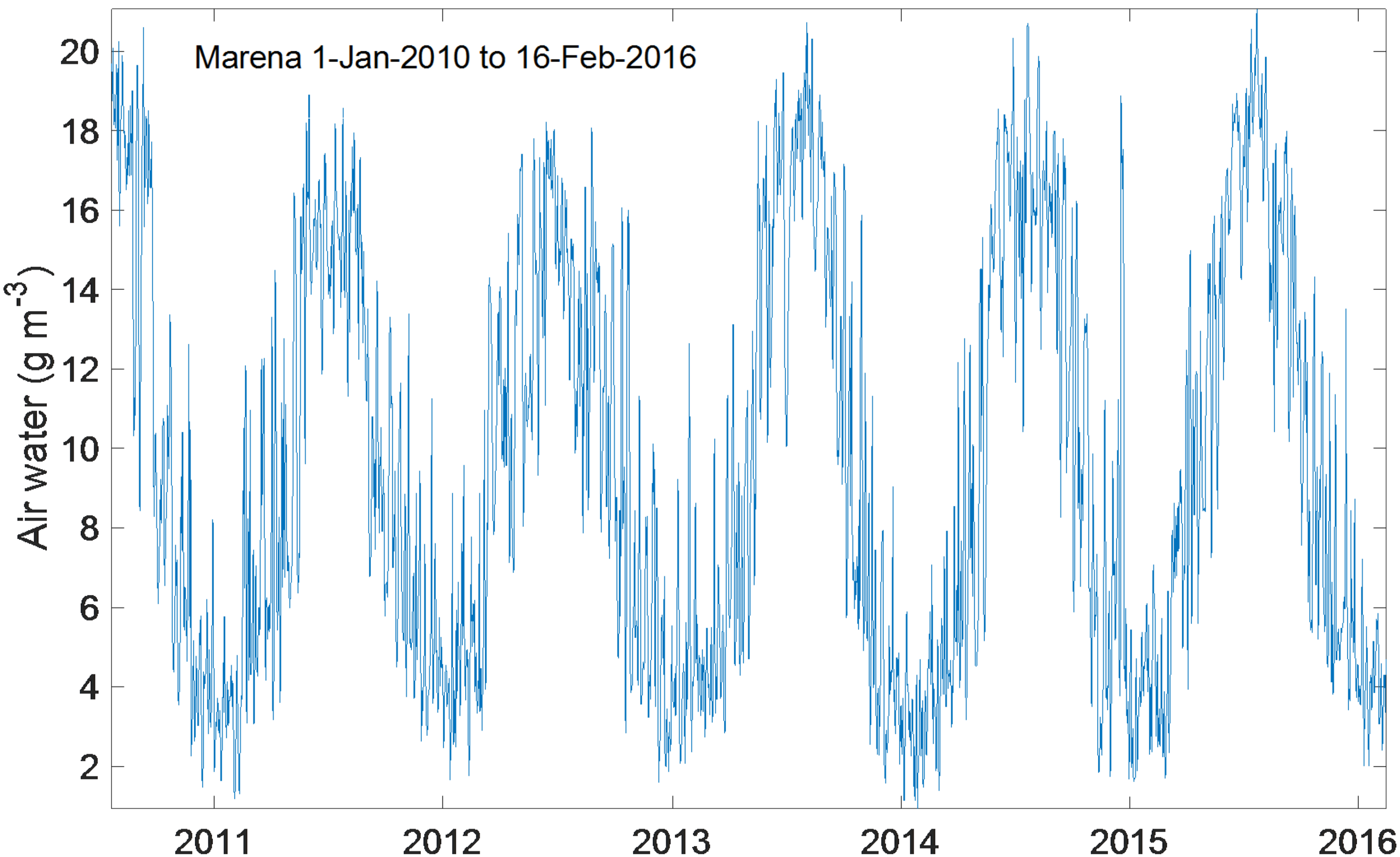
➔ Straight forward: Retrieve the volumetric water contents from the COSMOS website (Level 3 data).

Custom calibration: Retrieve the volumetric water contents from the COSMOS website (Level 2 corrected fast neutrons).

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



RMSE = 0.13 cm3 cm-3
±1 STD
Mean All in situ sensors (5,10,25 cm)
Stationary COSMOS
Volumetric Water Content (cm3 cm-3)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2011
2012
2013
2014
2015
2016



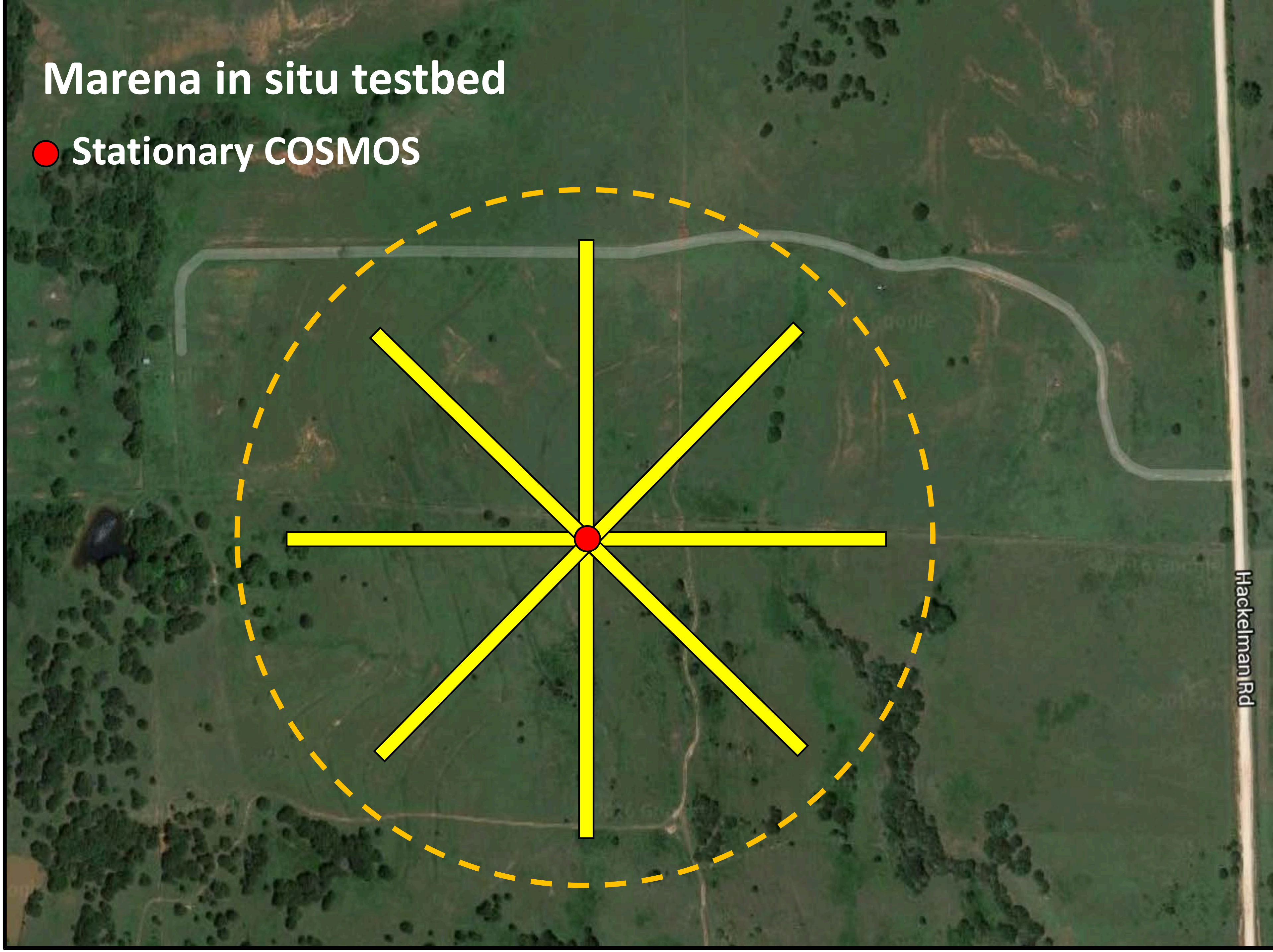
Marena 1-Jan-2010 to 16-Feb-2016
Air water (g m-3)
20
18
16
14
12
10
8
6
4
2
2011
2012
2013
2014
2015
2016

When using the COSMOS…

Straight forward: Retrieve the volumetric water contents from the COSMOS website (Level 3 data).

Custom calibration: Retrieve the volumetric water contents from the COSMOS website (Level 2 corrected fast neutrons).

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


Marena in situ testbed
Stationary COSMOS
Hackelman Rd

Current stationary COSMOS calibration method

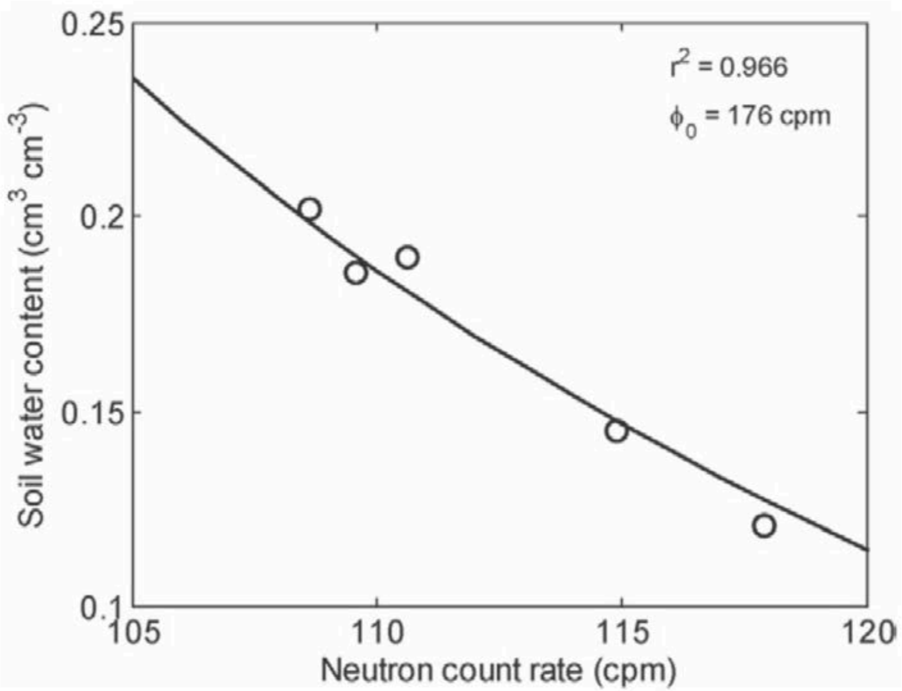


Fig. 4 from Dong et al., 2013. Calibrated shape-defining function for the first MOISST survey (3 June).

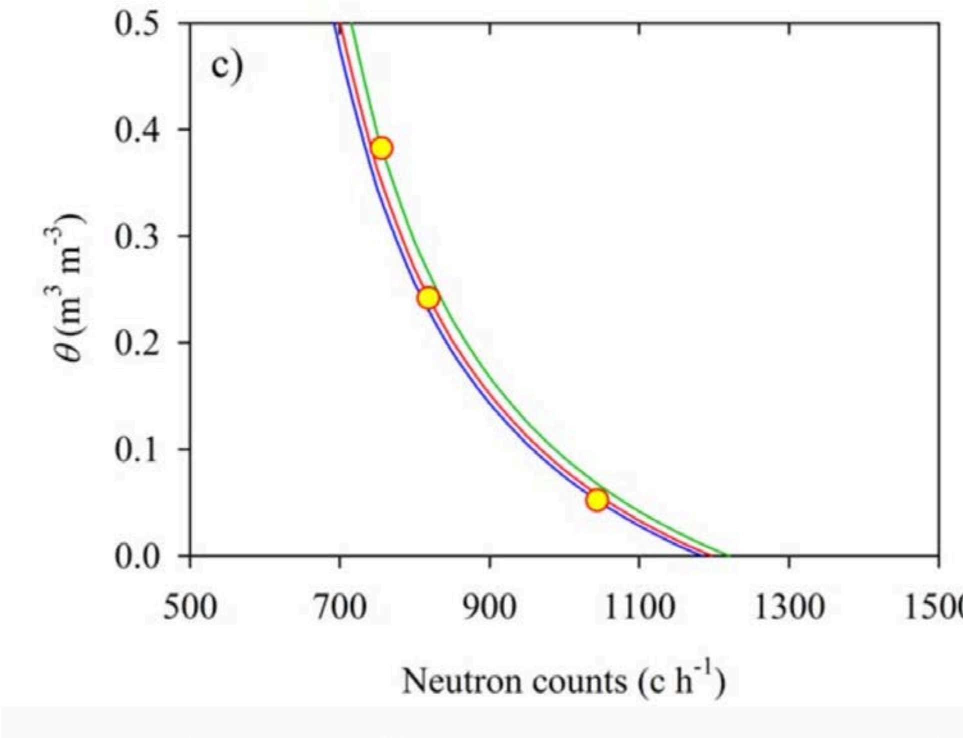
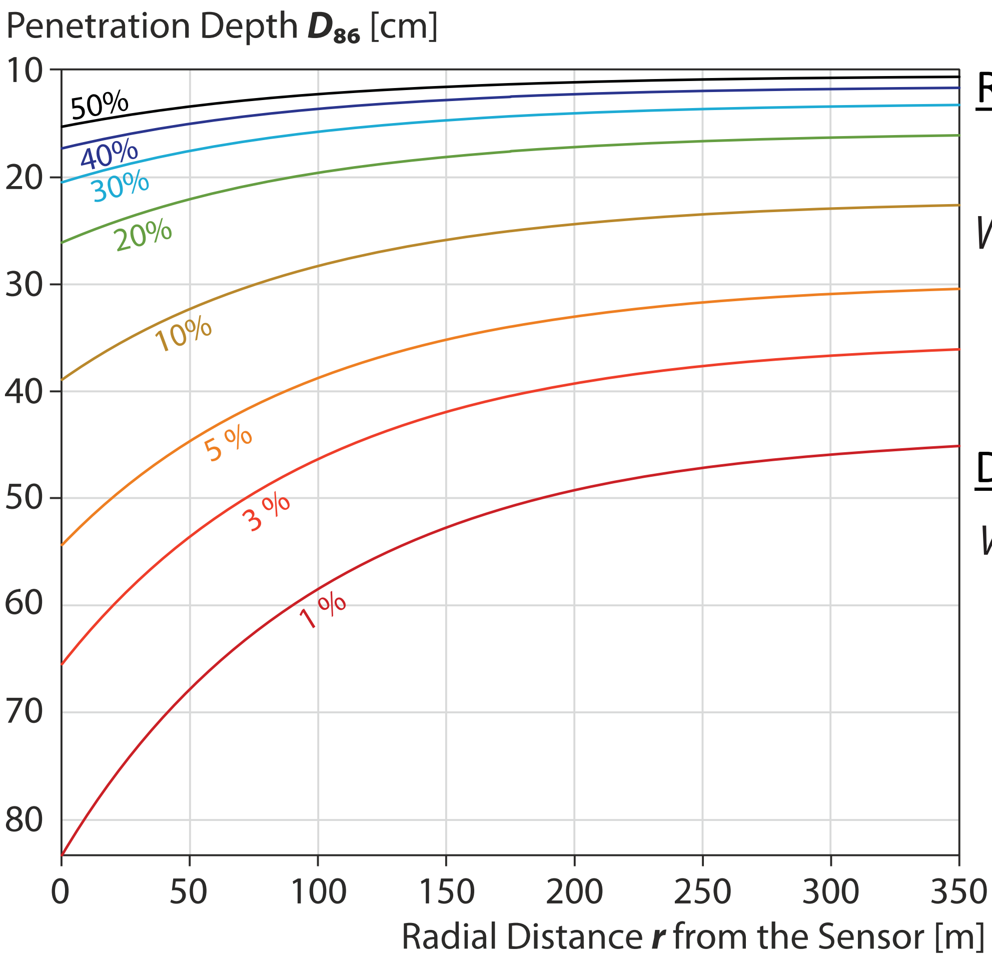


Fig. 9 from Hawdon et al., 2014. Calibration functions for the Tullochgorum site

Can we use more than five years of data from in situ stations to to calibrate the COSMOS?



Radial distance weights (Kohli et al., 2015)

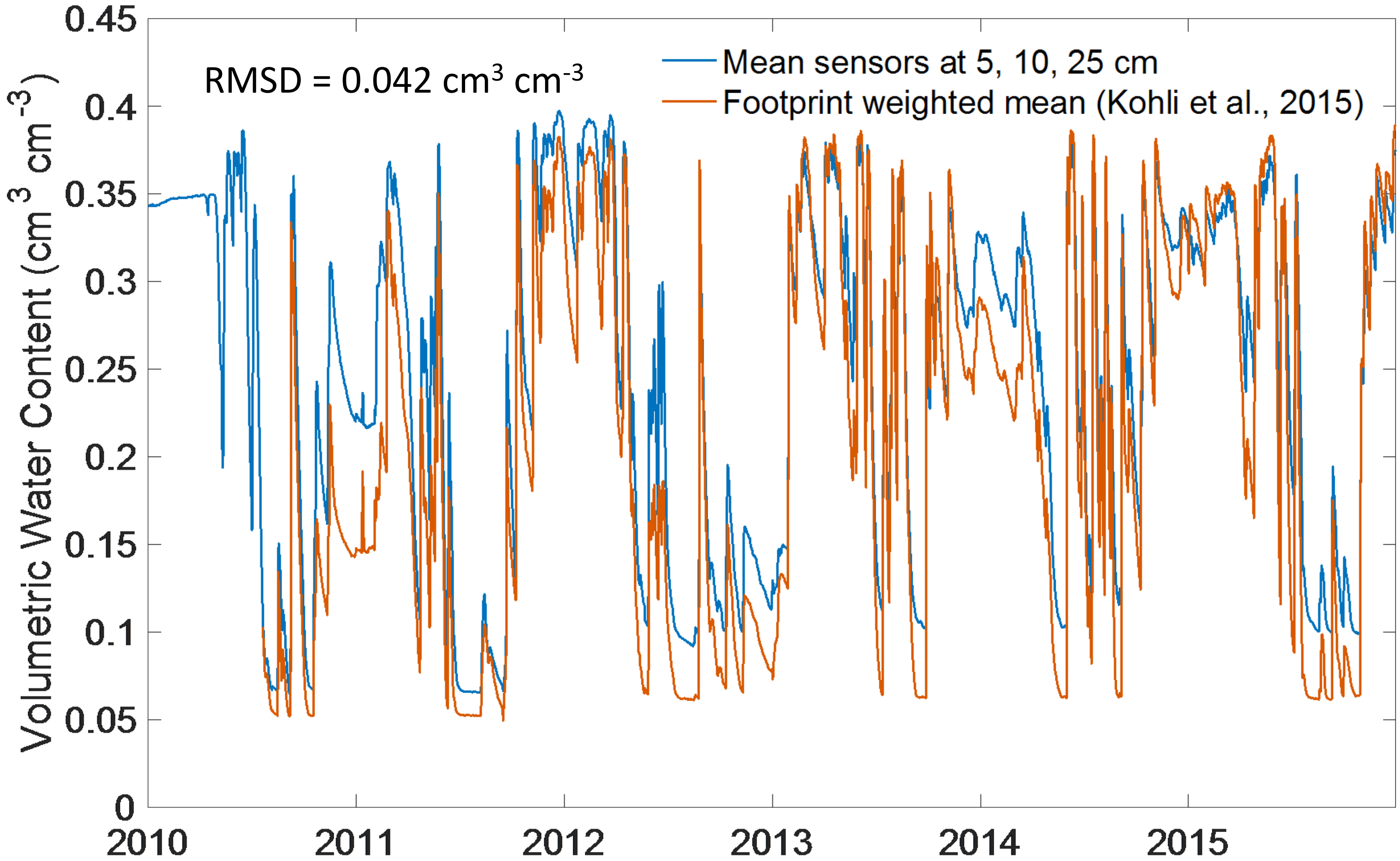
$$W_r(h,\theta) \approx \begin{cases} F_1\, e^{-F_2 r} + F_3\, e^{-F_4 r}, & 0.5\,\mathrm{m} < r \leq 50\,\mathrm{m} \\ F_5\, e^{-F_6 r} + F_7\, e^{-F_8 r}, & 50\,\mathrm{m} < r < 600\,\mathrm{m} \end{cases}$$

Depth weights (Kohli et al., 2015)

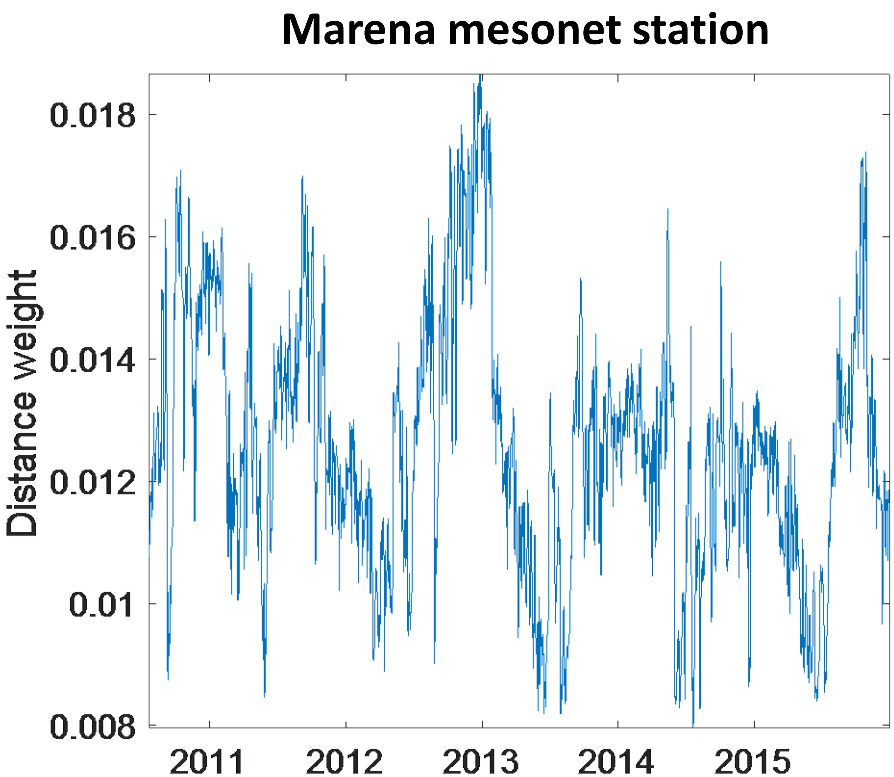
$$W_d(r,\theta) \propto e^{-2d/D_{86}(r,\theta)}$$

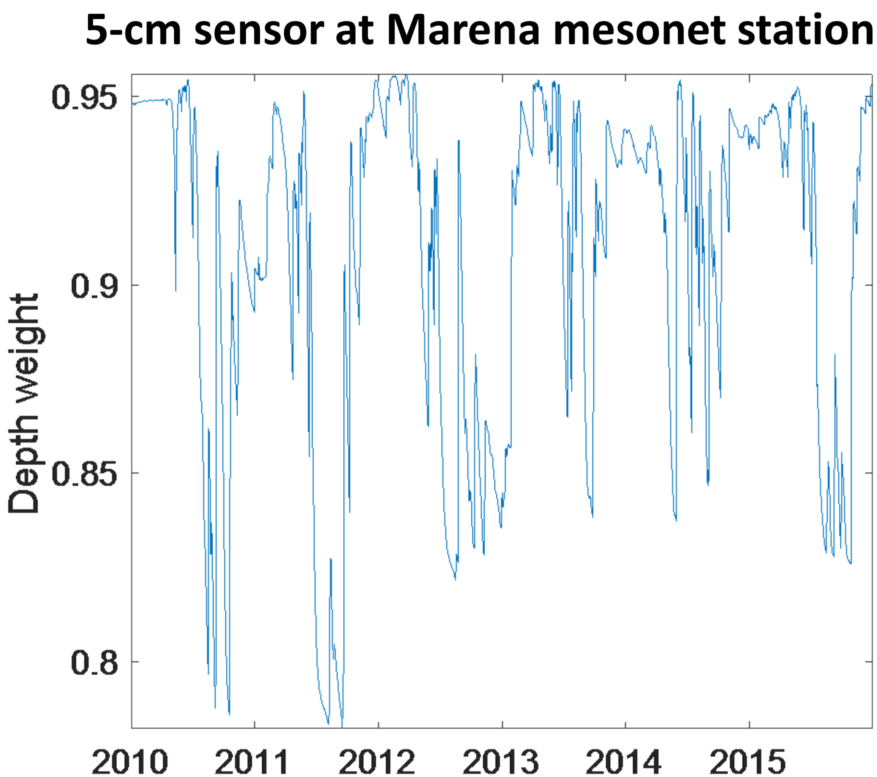
Create distance- and depth-specific weights for every time step (daily)

Ko€hli, M., M. Schro€n, M. Zreda, U. Schmidt, P. Dietrich, and S. Zacharias (2015), Footprint characteristics revised for field-scale soil moisture monitoring with cosmic- ray neutrons, Water Resour. Res., 51, 5772–5790, doi:10.1002/ 2015WR017169.

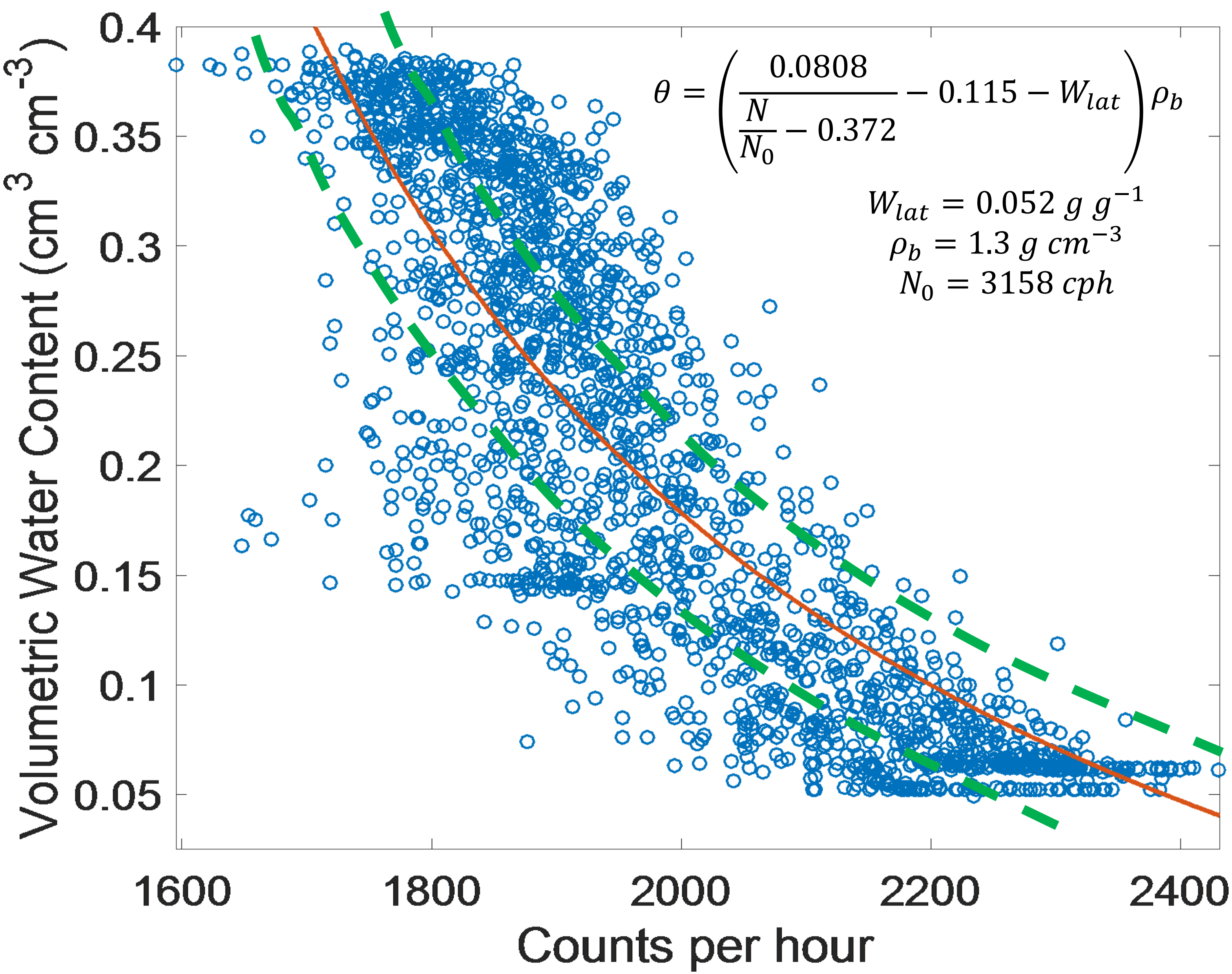


RMSD = 0.042 cm3 cm-3
Mean sensors at 5, 10, 25 cm
Footprint weighted mean (Kohli et al., 2015)
Volumetric Water Content (cm 3 cm -3)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2011
2012
2013
2014
2015

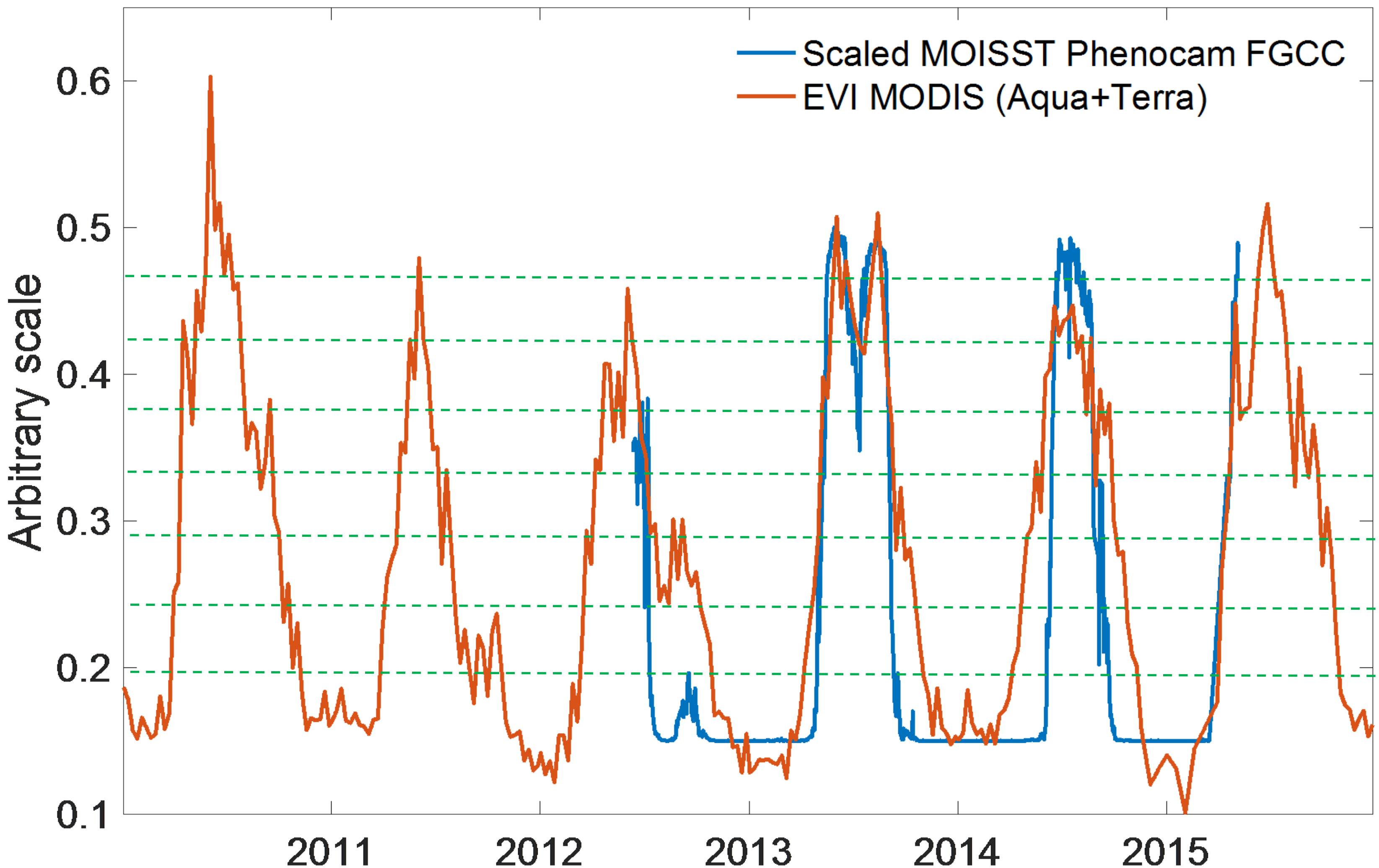


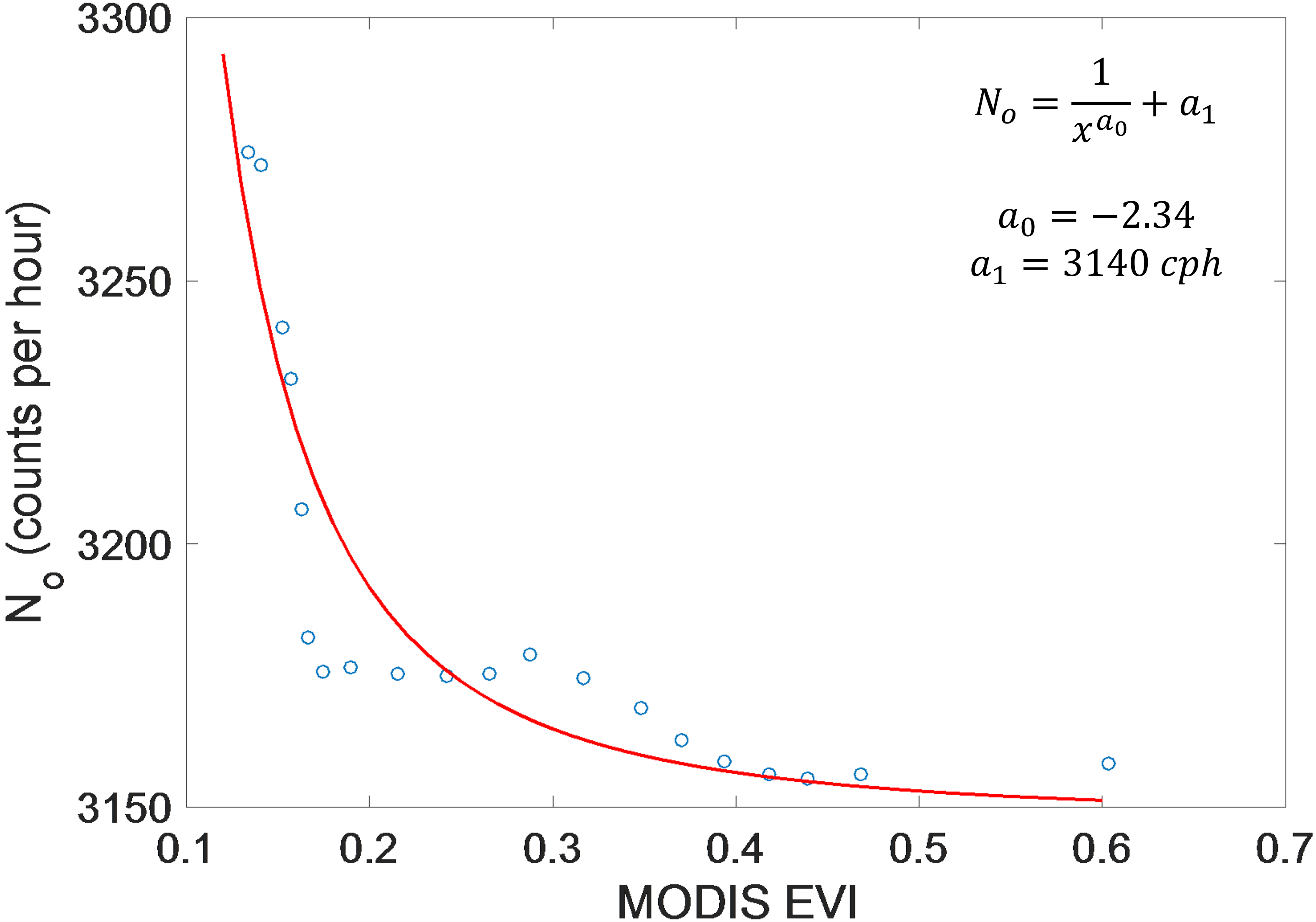


- The Mesonet station has little influence on the footprint average VWC.
- The 5-cm sensor of the Marena Mesonet station predominates the VWC for the station.



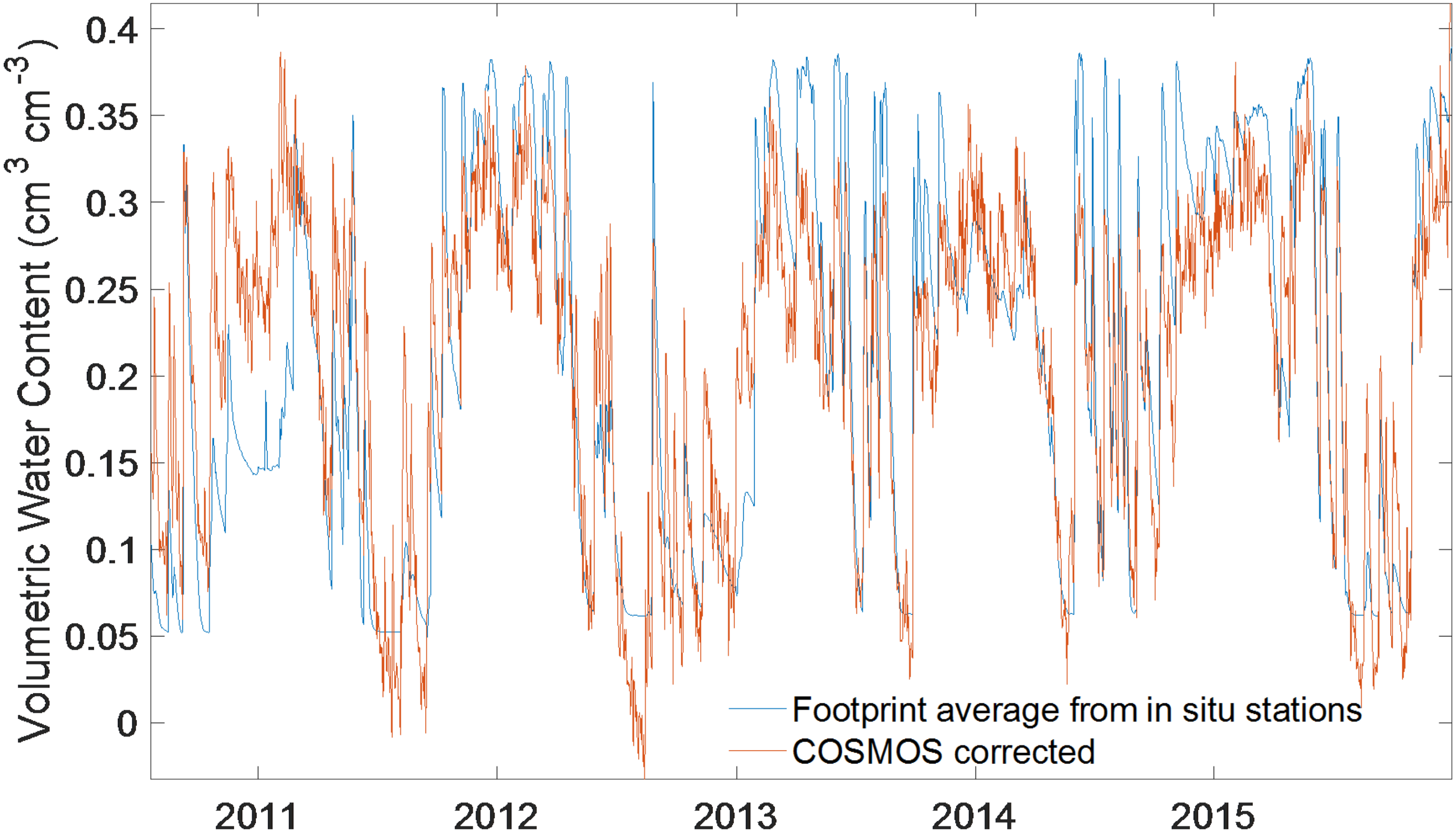
$\theta = \left(\frac{0.0808}{\frac{N}{N_0} - 0.372} - 0.115 - W_{lat} \right) \rho_b$
$W_{lat} = 0.052\ g\ g^{-1}$
$\rho_b = 1.3\ g\ cm^{-3}$
$N_0 = 3158\ cph$
Volumetric Water Content (cm^3 cm^{-3})
Counts per hour
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
1600
1800
2000
2200
2400


Scaled MOISST Phenocam FGCC
EVI MODIS (Aqua+Terra)
Arbitrary scale
0.6
0.5
0.4
0.3
0.2
0.1
2011
2012
2013
2014
2015



$N_o = \frac{1}{x^{a_0}} + a_1$
$a_0 = -2.34$
$a_1 = 3140\ cph$
3300
3250
3200
3150
N_o (counts per hour)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
MODIS EVI

$$\theta = B_0 + B_1 N + B_2\, N_0(EVI)$$



Corrected weighted footprint => **RMSE = 0.052 cm^3 cm^{-3}**

Current VWC => **RMSE = 0.13 cm^3 cm^{-3}**

Corrected VWC from Coopersmith et al., 2014 => 0.02 cm^3 cm^{-3}

Final remarks

- Footprint VWC: pooled average VWC was similar to the weighted average.
- The new footprint average using the framework proposed by Kohli et al., 2015 helps minimizing arbitrary choices and provides a framework to incorporate all sources of information.
- Information from in situ phenocams and vegetation indexes from MODIS may have the potential to correct for vegetation water content.

Solution for vegetation corrections when using the rover?