Precipitation, Irrigation and Crop Growth Signals in COSMOS Data

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Abstract

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- Soil water sensors are used to characterize water content in the root zone and below for water management and environmental monitoring, but only a few are capable of sensing soil volumes larger than a few hundred liters. Scientists with the USDA-ARS Conservation & Production Research Laboratory, Bushland, Texas, compared three soil water sensing systems against each other and against precipitation and irrigation amounts measured using a large weighing lysimeter. The three sensor systems were: 1) the Cosmic Ray Soil Moisture Observing System (COSMOS), which responds to surface soil water content changes in a circular area of radius up to several hundred meters; 2) electromagnetic (EM) soil water sensors (model CS655, Campbell Scientific, Inc., Logan, Utah) that each sense only a few hundred cubic centimeters, and that were used in a wireless sensor network to interrogate larger volumes of soil; and 3) the neutron probe (NP), used in a network of eight access tubes to take readings from 0.10 to 2.30 m in depth increments of 0.20 m. The large precision weighing lysimeter measured soil water storage changes to within 0.04 mm (<0.01 inch) accuracy. COSMOS was well correlated (r^2=0.87) with 0-0.30 m (1 ft) water content and storage as measured by the field-calibrated CS655 sensors. COSMOS was more sensitive to increases in soil water from rainfall compared with those from subsurface drip irrigation at 0.30-m depth. COSMOS water content data were biased upward by green, living vegetation. The COSMOS "effective depth" algorithm did not work well in this study. However, assuming that the effective depth was constant at 0.30 m depth resulted in good correlation with CS655 measured soil water storage. The wireless CS655 sensor system worked very well, providing timely information that correlated well with weighing lysimeter soil water storage data. This wireless sensor system would be very useful for irrigation scheduling since the tall corn crop did not result in signal and data loss and the data accurately represented soil water content as it changed over time due to irrigation and precipitation. Data from the COSMOS system were not accurate enough for irrigation scheduling. Data from the neutron probe were accurate but labor intensive, and the neutron probe lacked both automation and wireless data transfer.

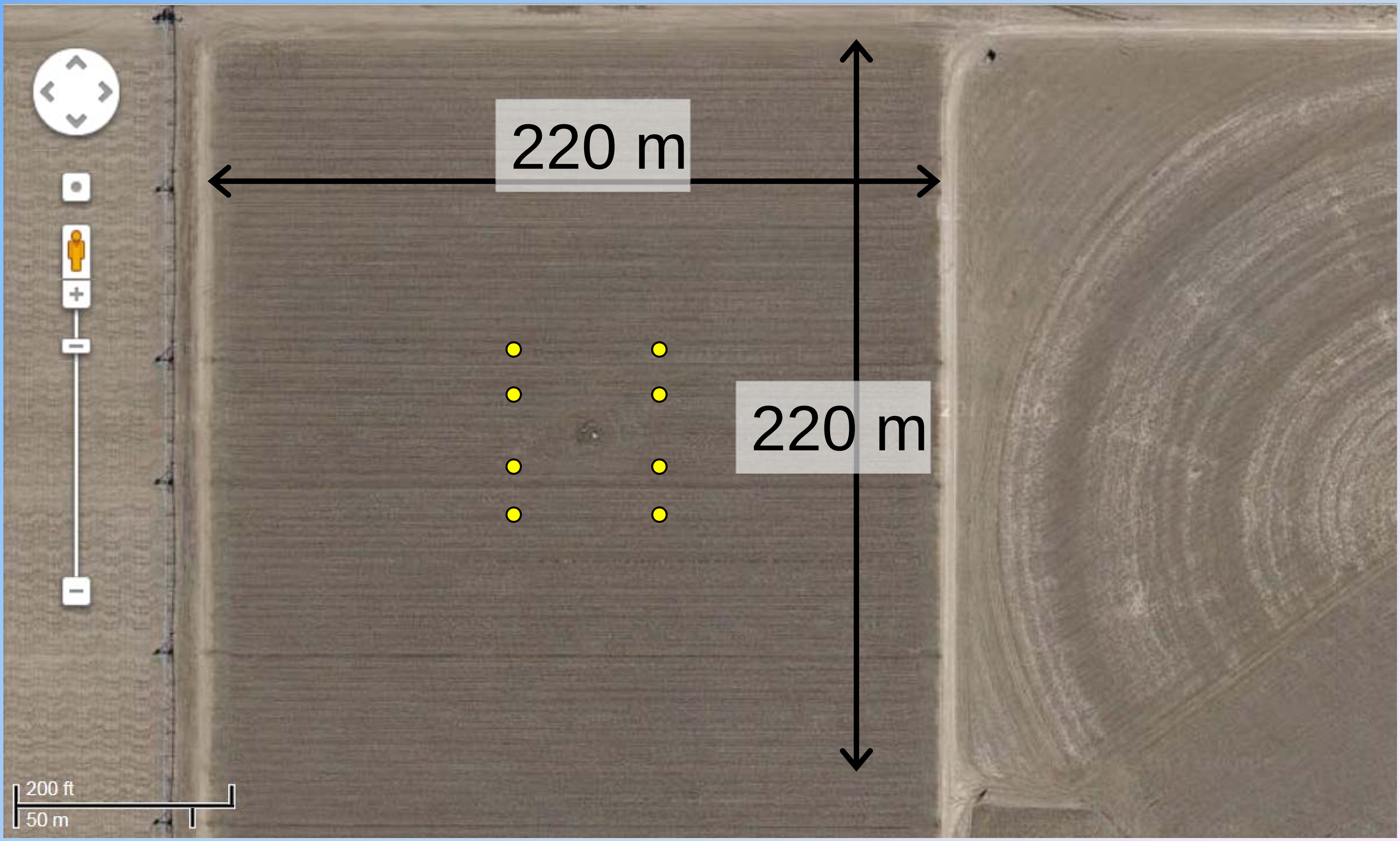
COSMOS Study – Methods

- Study Cosmic Ray Soil Moisture Observing System (COSMOS) system in a square, 5-ha field
- Pullman silty clay loam soil
- Subsurface drip irrigation (tape at 30- to 35-cm depth and 1.5-m spacing)
- 3 m x 3 m x 2.4-m deep precision weighing lysimeter at field center (RMSE = 0.04 mm).
- Weekly reading of 8 neutron probe access tubes to 2.3-m depth in 0.2-m vertical increments.
- Wireless sensor network, 5 CS655 sensors at each access tube, placed normal to and below the crop row.
- Sensors at depths of 5, 10, 15, 20 and 25 cm.

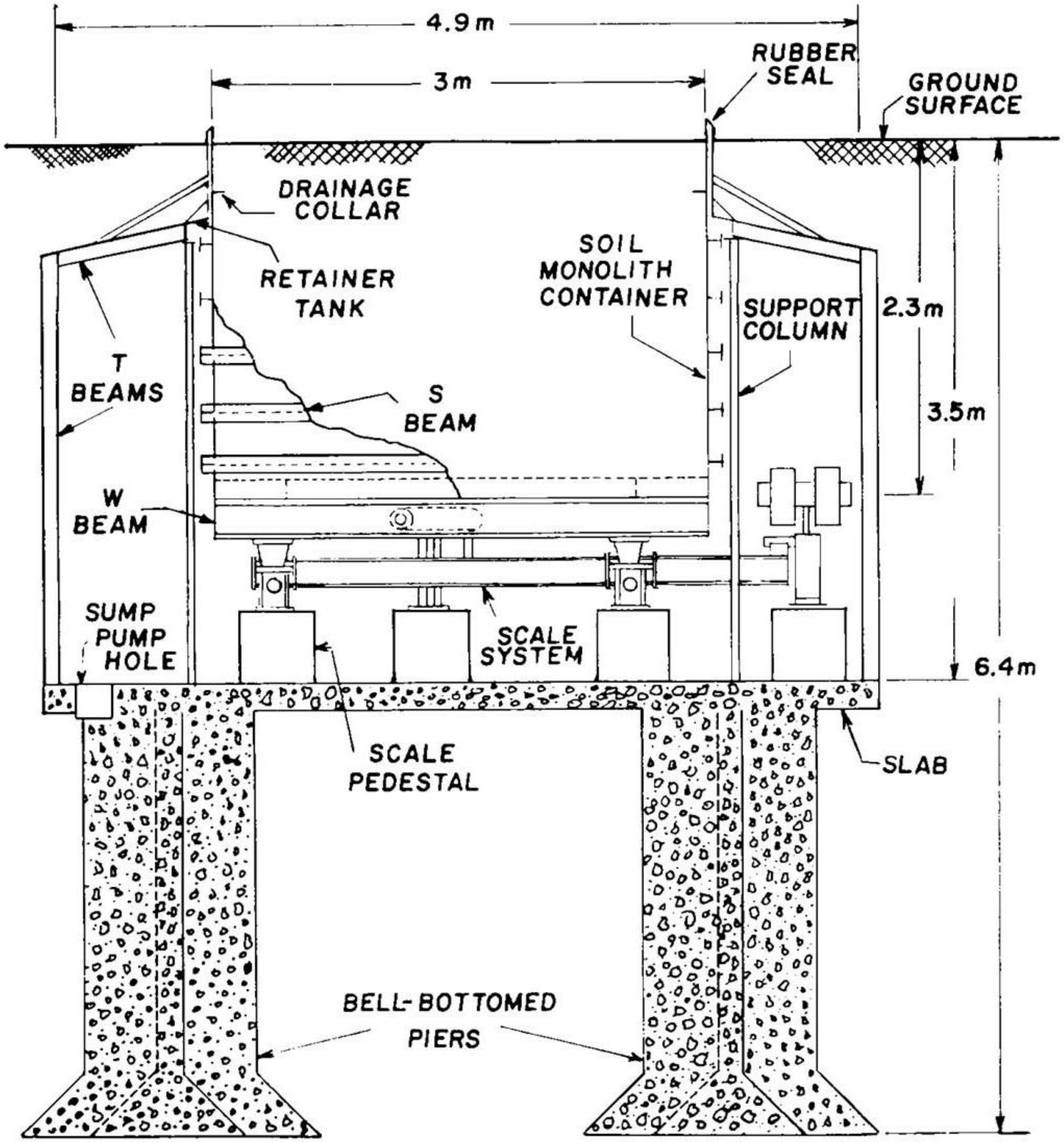
Methods

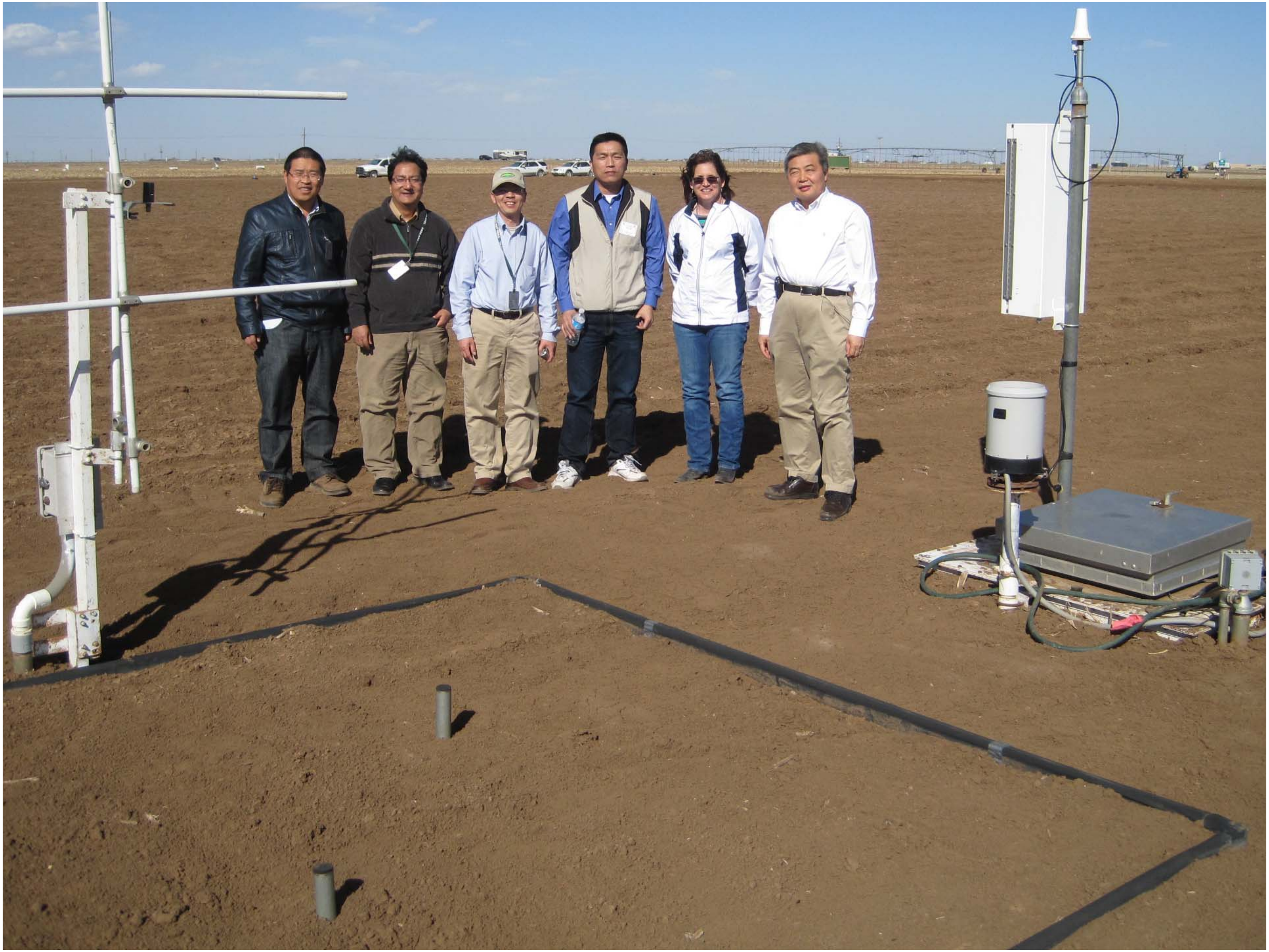
- COSMOS system installed at weighing lysimeter – April 2012, fallowed field
- Corn 2013, cotton 2014, corn 2015, cotton 2016.
  - Plant height, LAI & above-ground biomass measured biweekly.
  - Assess the interference with the COSMOS system of green biomass accumulation over time.
  - Assess COSMOS sensitivity to irrigation at 30 cm depth and to precipitation.

NE Weighing Lysimeter Field

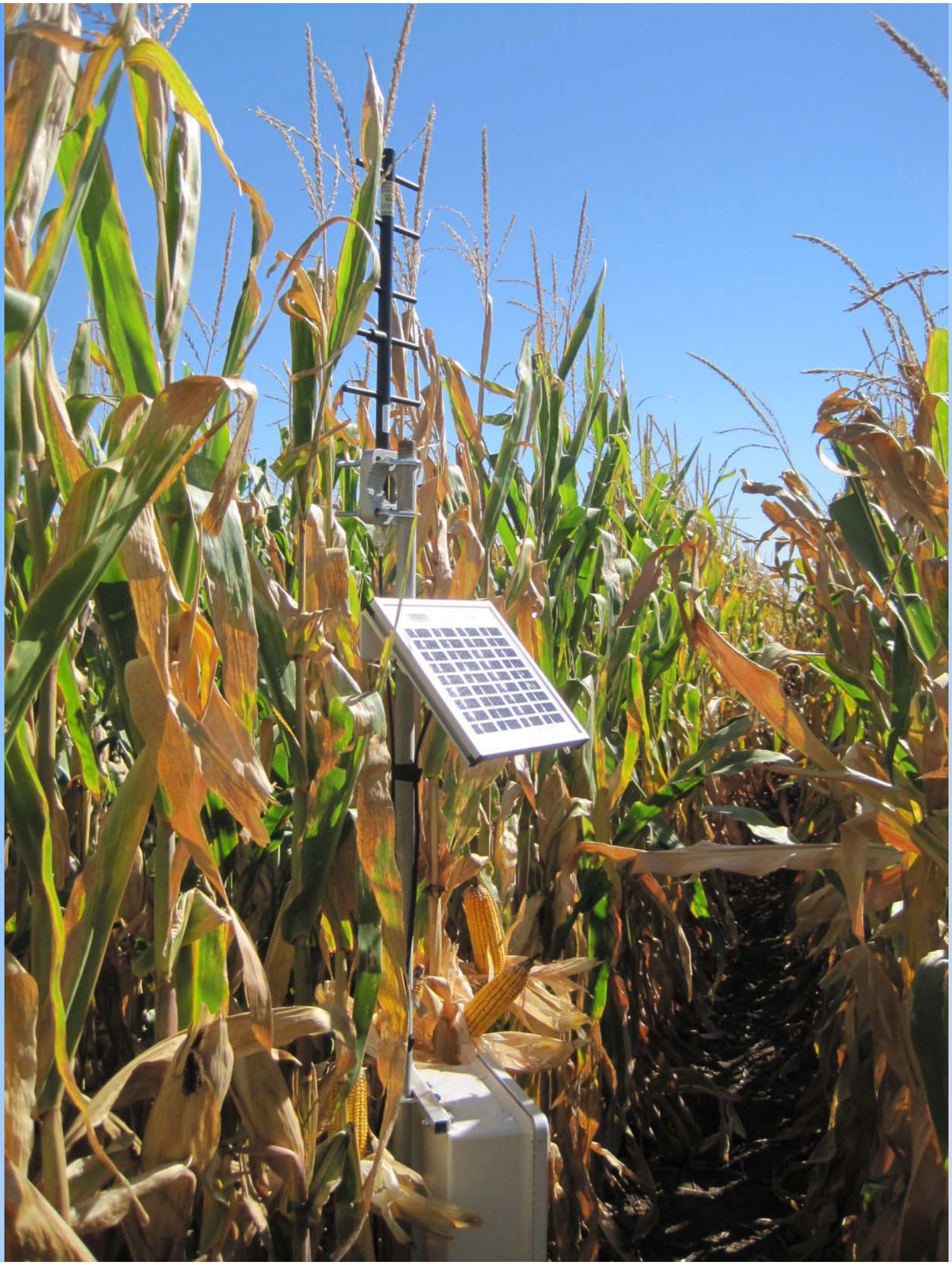


Large weighing lysimeter, Bushland. ~42 Mg mass, accurate to 0.05 mm H_2O. Counter-balanced multiple beam balance.






Q-DL-2100
Hydroinnova
SunSaver-6



Sept. 2013

- CS655 network
- Wireless
- 4 CR206X dataloggers
- 10 CS655 sensors per logger
- 15-m wires

Relative Permittivity Calibration

Table 2. Linear regressions comparing Acclima ACC-TDT, Hydra Probe, 5TE and CS655 apparent permittivity, ε_a, and Hydra Probe real permittivity, ε_r, to that from the TDR system, which was calibrated by mass balance.

Sensor	Intercept (-)	slope	RMSE (-)	r^2
ACC-TDT	2.00	1.088	0.40	0.988
Hydra Probe	0.88	1.328	0.85	0.965
5TE	4.76	0.815	1.00	0.877
CS655	0.03	1.334	0.54	0.985

Bulk EC Calibration

Table 3. Linear regression relationships comparing Acclima ACC-TDT, Hydra Probe, 5TE and CS655 bulk electrical conductivity, σ_a, to that from the TDR system.

Sensor	Intercept (S/m)	slope	RMSE (S/m)	r^2
ACC-TDT	-0.014	2.347	0.009	0.950
Hydra Probe	0.000	0.850	0.004	0.924
Hydra Probe (temperature corrected)	0.013	0.706	0.010	0.584
5TE	0.005	0.650	0.009	0.588
CS655	-0.008	1.007	0.001	0.993

Water Content Calibration

Table 5. Linear regression relationships comparing estimated water contents from the Acclima ACC-TDT, Hydra Probe, 5TE and CS655 to data from the TDR system, which was calibrated by mass balance.

Sensor	Intercept (m^3 m^{-3})	Slope	RMSE (m^3 m^{-3})	r^2
ACC-TDT	0.05	0.932	0.004	0.994
Hydra Probe	0.02	1.027	0.015	0.938
5TE	0.10	0.687	0.018	0.820
CS655	0.04	1.037	0.010	0.973

Bushland

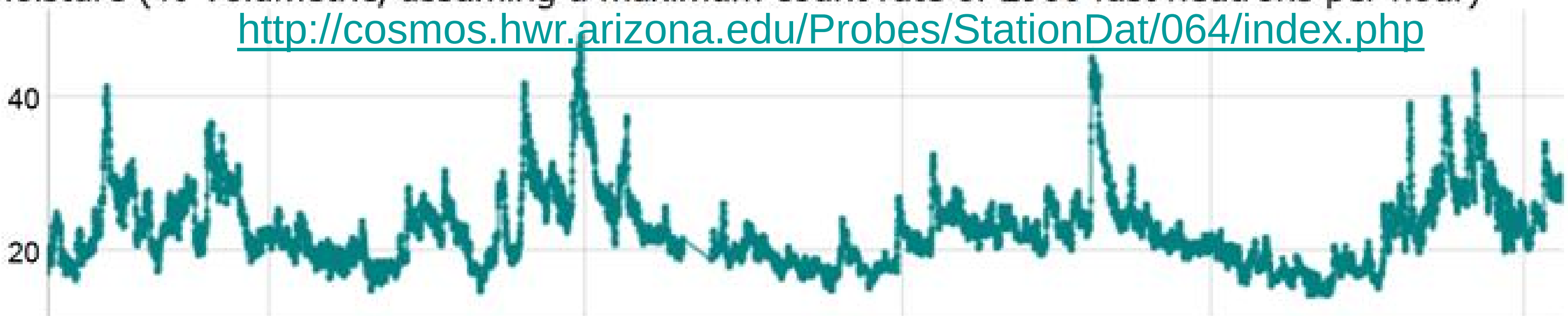
Flat agricultural field with center pivot irrigation. Site is collocated with a suite of USDA meteorological measurements and lysimeter.

Installation Date:	2012-04-27
Location (lat,lon):	35.1882,-102.0955
Elevation (m asl):	1172
Timezone (UTC):	-6

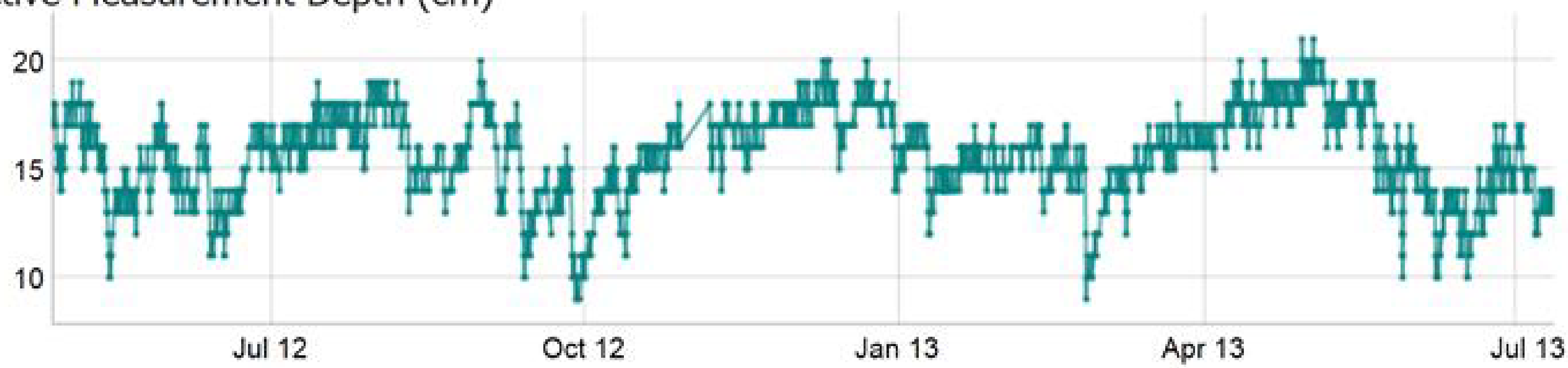
Cutoff Rigidity (GV):	3.64
Mean Pressure (mb):	880
Lattice Water (%):	4.00
Soil Organic Carbon (%):	0.02
Max Count Rate (/hr):	2900

Soil Moisture (% Volumetric, assuming a maximum count rate of 2900 fast neutrons per hour)

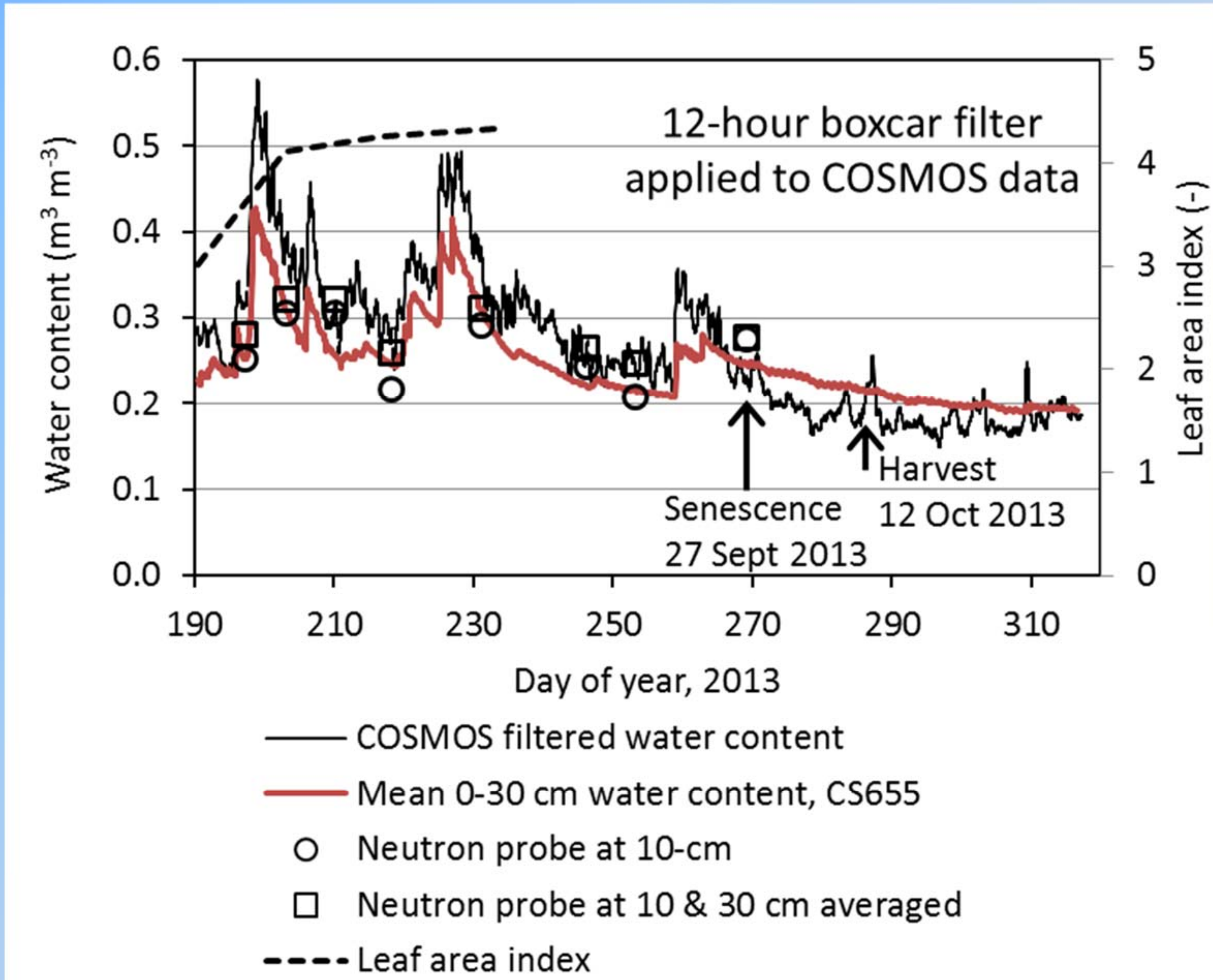
http://cosmos.hwr.arizona.edu/Probes/StationDat/064/index.php

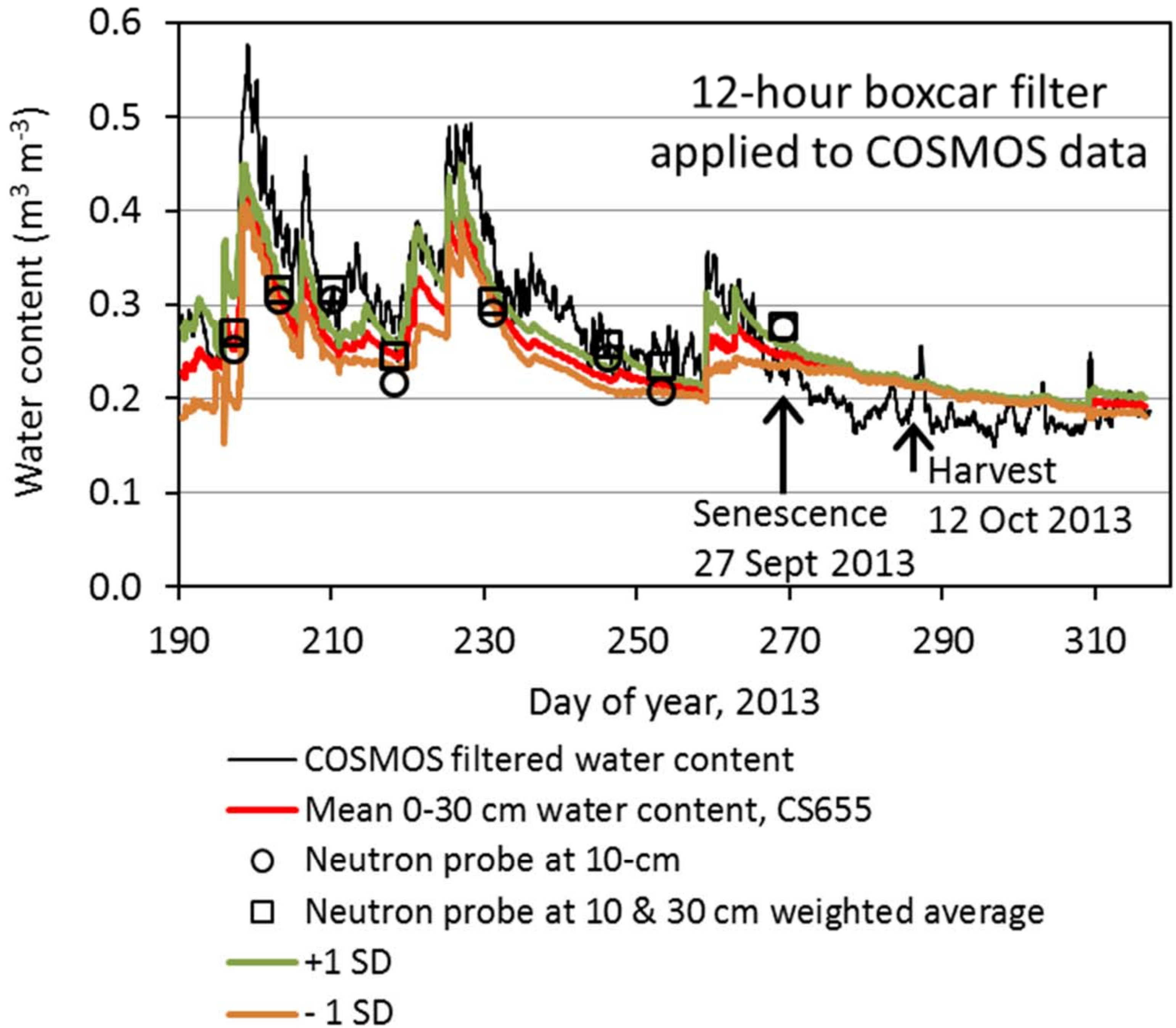


Effective Measurement Depth (cm)



Uncalibrated COSMOS vs. CS655 & NP





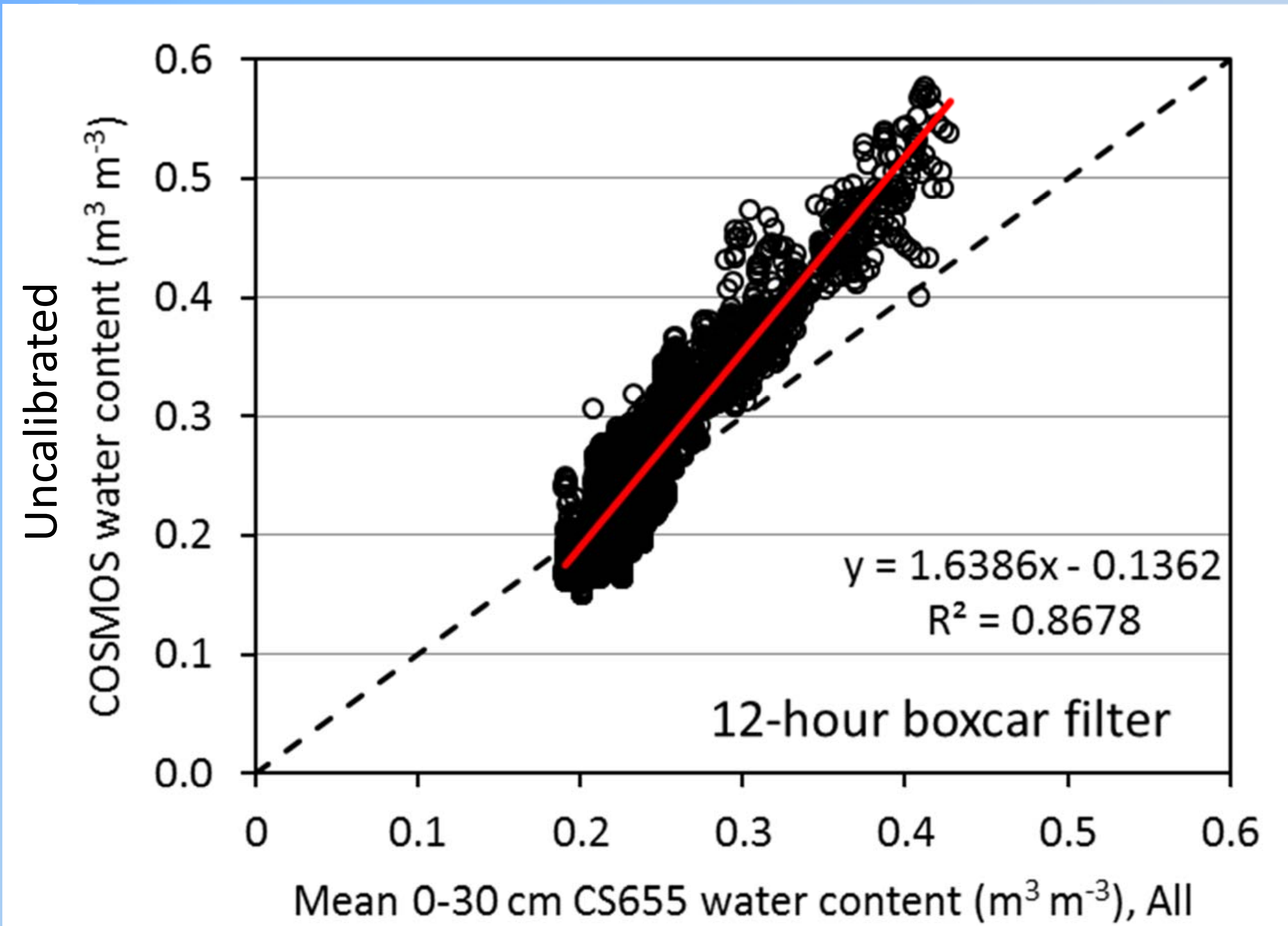
12-hour boxcar filter
applied to COSMOS data
Water content (m³ m⁻³)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
190
210
230
250
270
290
310
Day of year, 2013
Senescence
27 Sept 2013
Harvest
12 Oct 2013
COSMOS filtered water content
Mean 0-30 cm water content, CS655
Neutron probe at 10-cm
Neutron probe at 10 & 30 cm weighted average
+1 SD
- 1 SD

Neutron probe water contents (m^3 m^{-3}) and standard deviations (SD) in 2013.

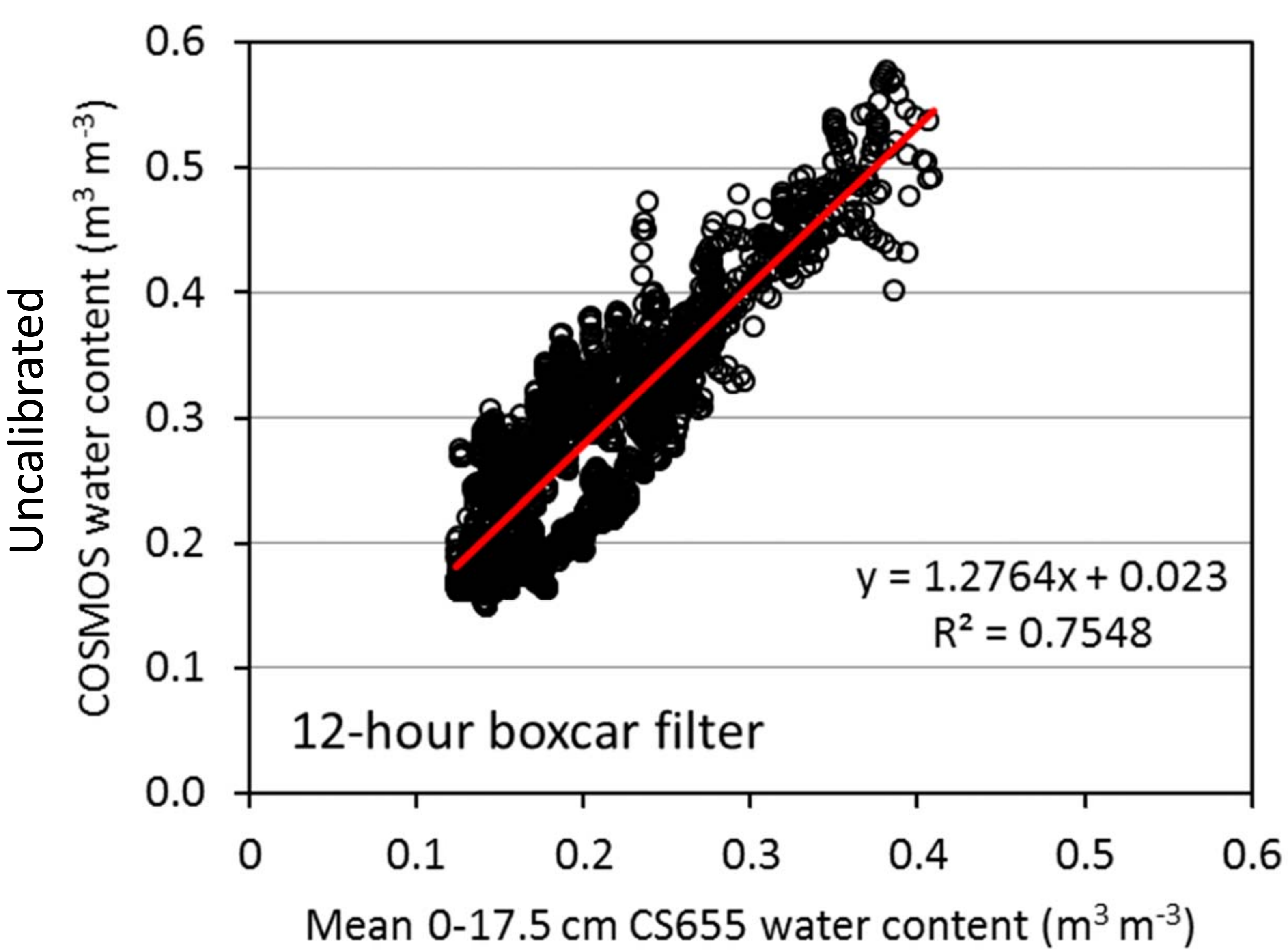
DOY	10 & 30-cm weighted mean	SD	10-cm	SD
171	0.306	0.018	0.286	0.025
176	0.266	0.016	0.230	0.022
183	0.244	0.015	0.209	0.016
189	0.288	0.017	0.278	0.020
197	0.272	0.023	0.252	0.024
203	0.317	0.010	0.306	0.015
210	0.317	0.011	0.306	0.015
218	0.246	0.012	0.218	0.015
231	0.304	0.013	0.291	0.019
246	0.258	0.013	0.243	0.015
253	0.234	0.013	0.209	0.013
269	0.277	0.012	0.276	0.014
	Means:	0.014		0.018

Mean SD for CS655 arrays was 0.015.

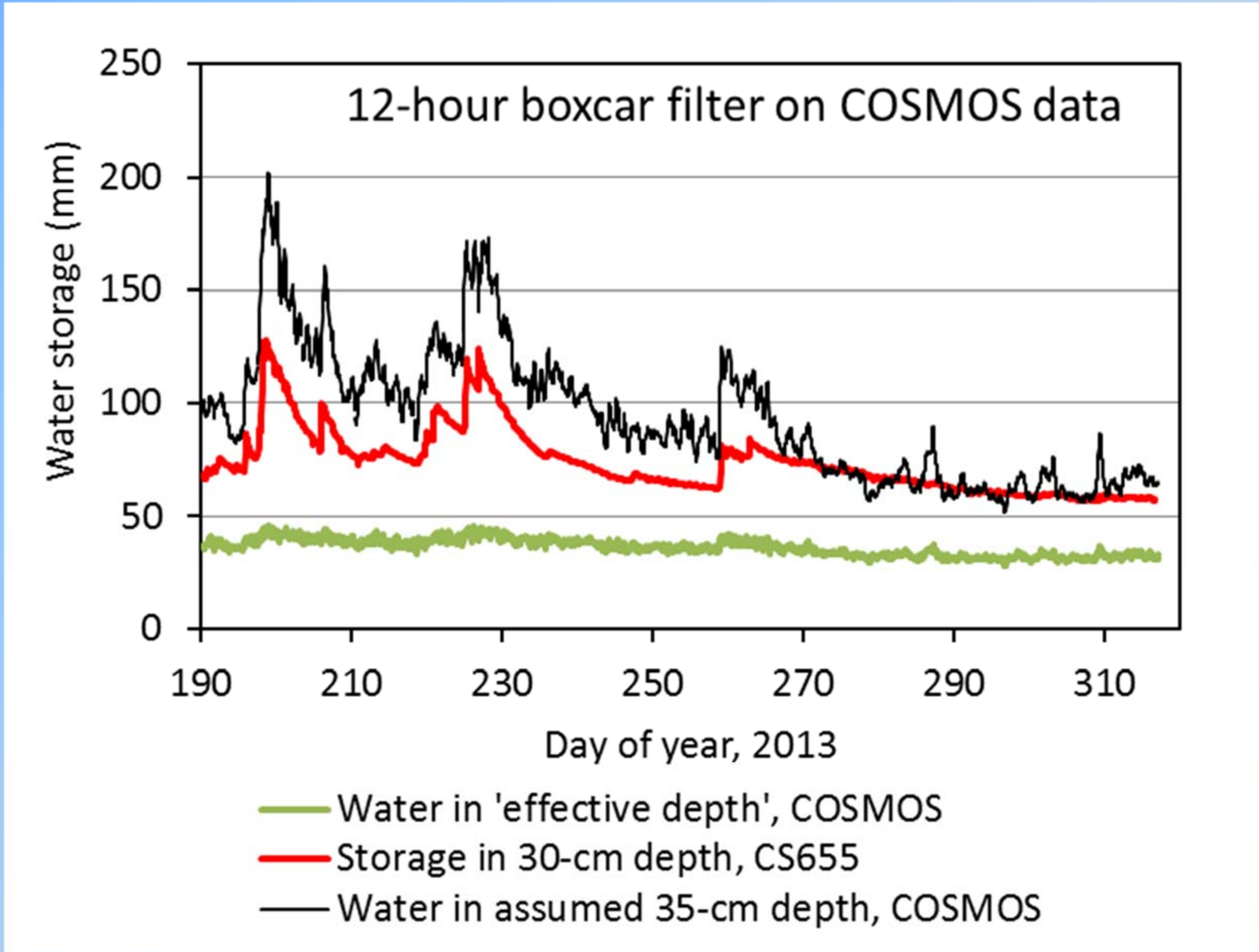
Water Content Correlation



Correlated less well with shallow CS655



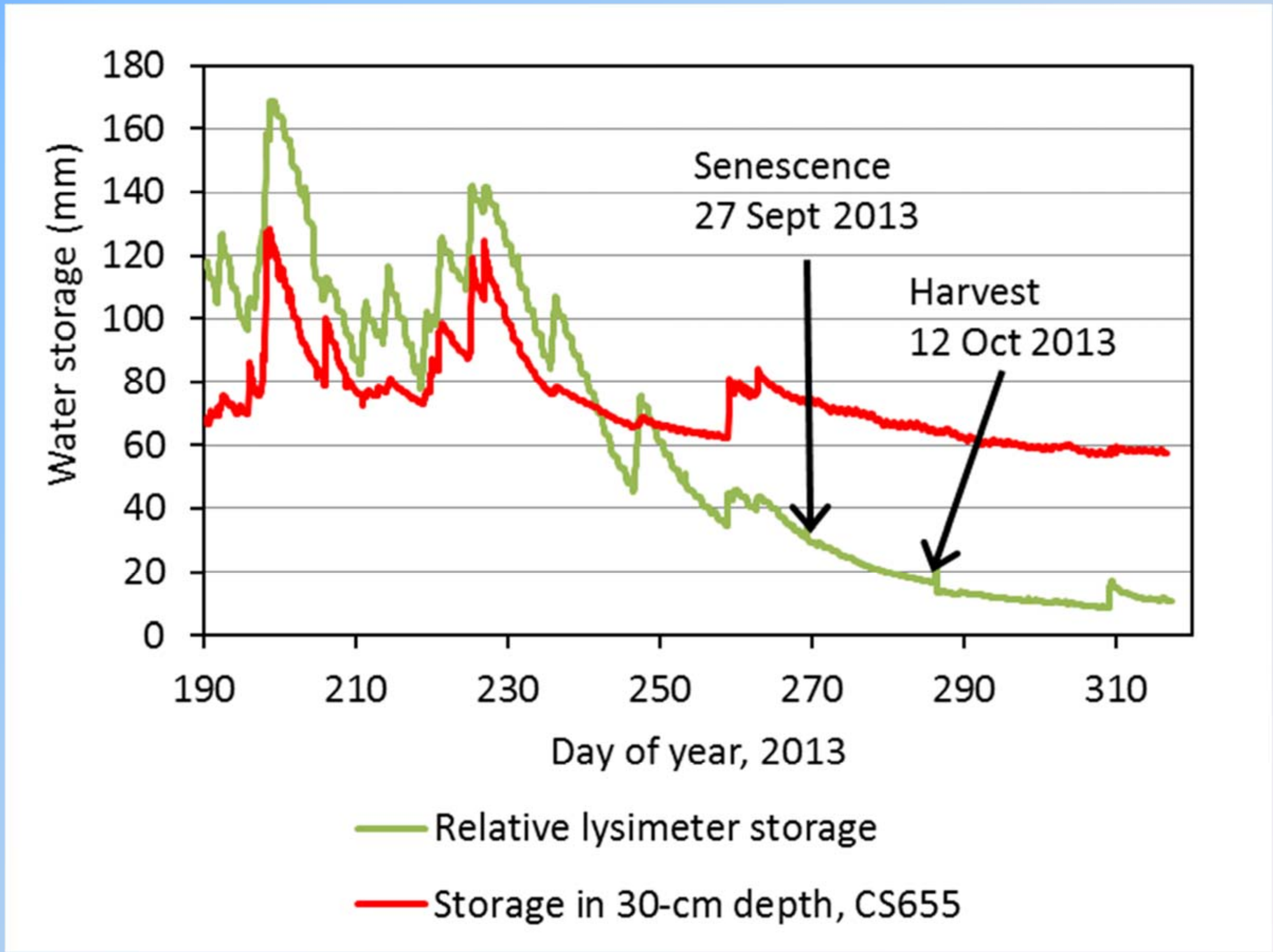
Storage - COSMOS vs. CS655



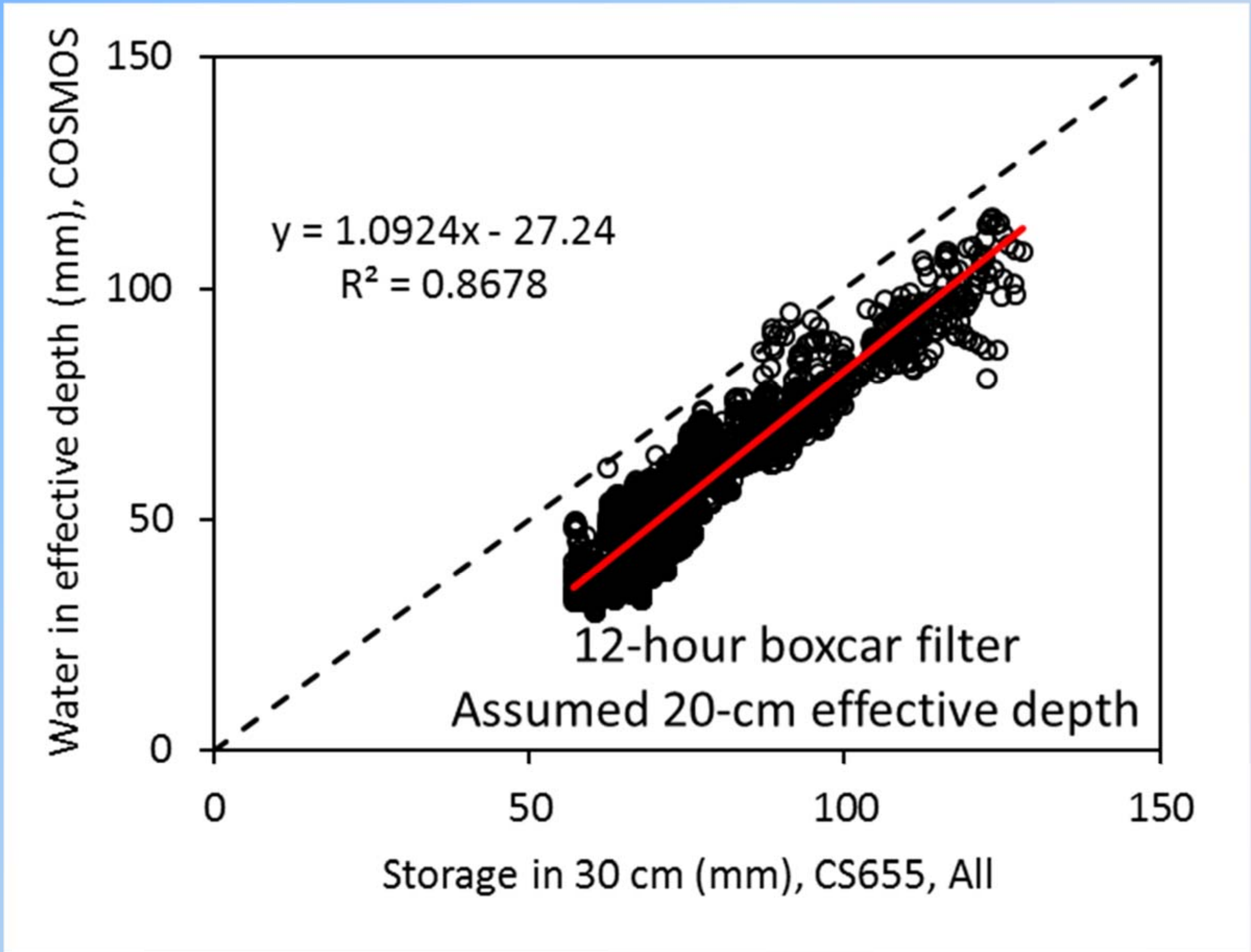
Biomass influence

- LAI > 3
- Clear influence on COSMOS water contents
- LAI $\rightarrow$ 0
- Reduced separation between COSMOS and CS655 arrays

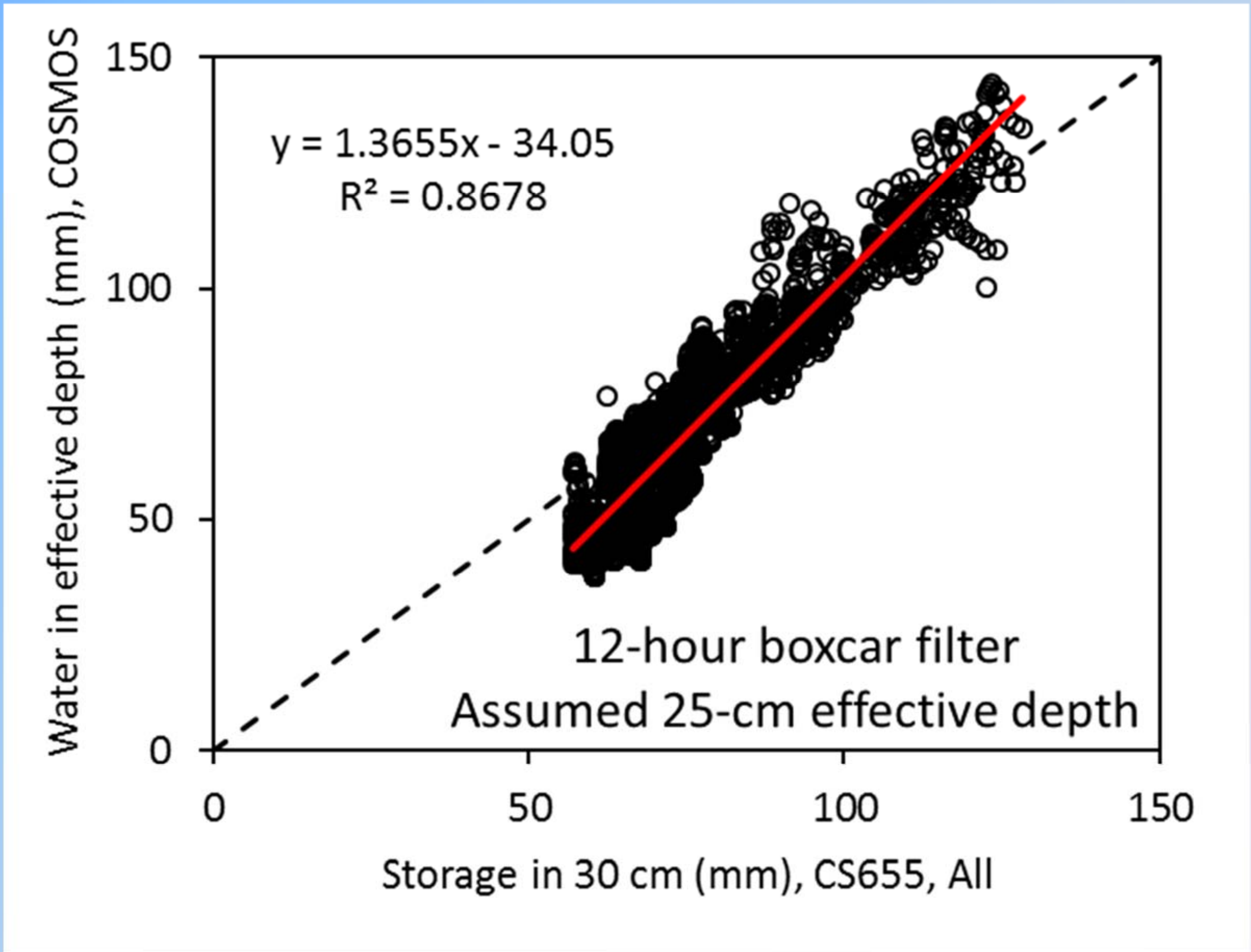
Relative lysimeter storage



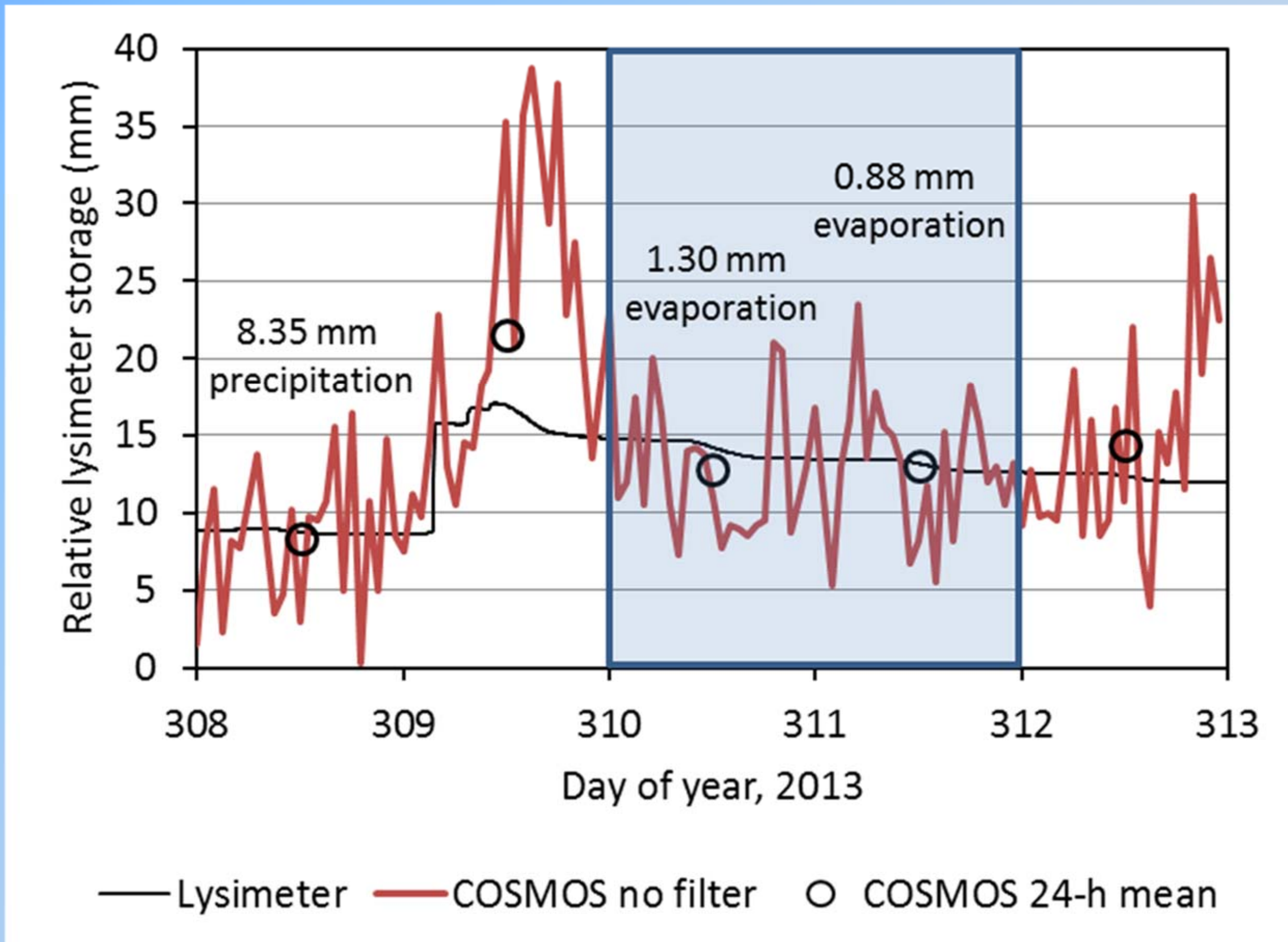
Storage in 20-cm Effective Depth



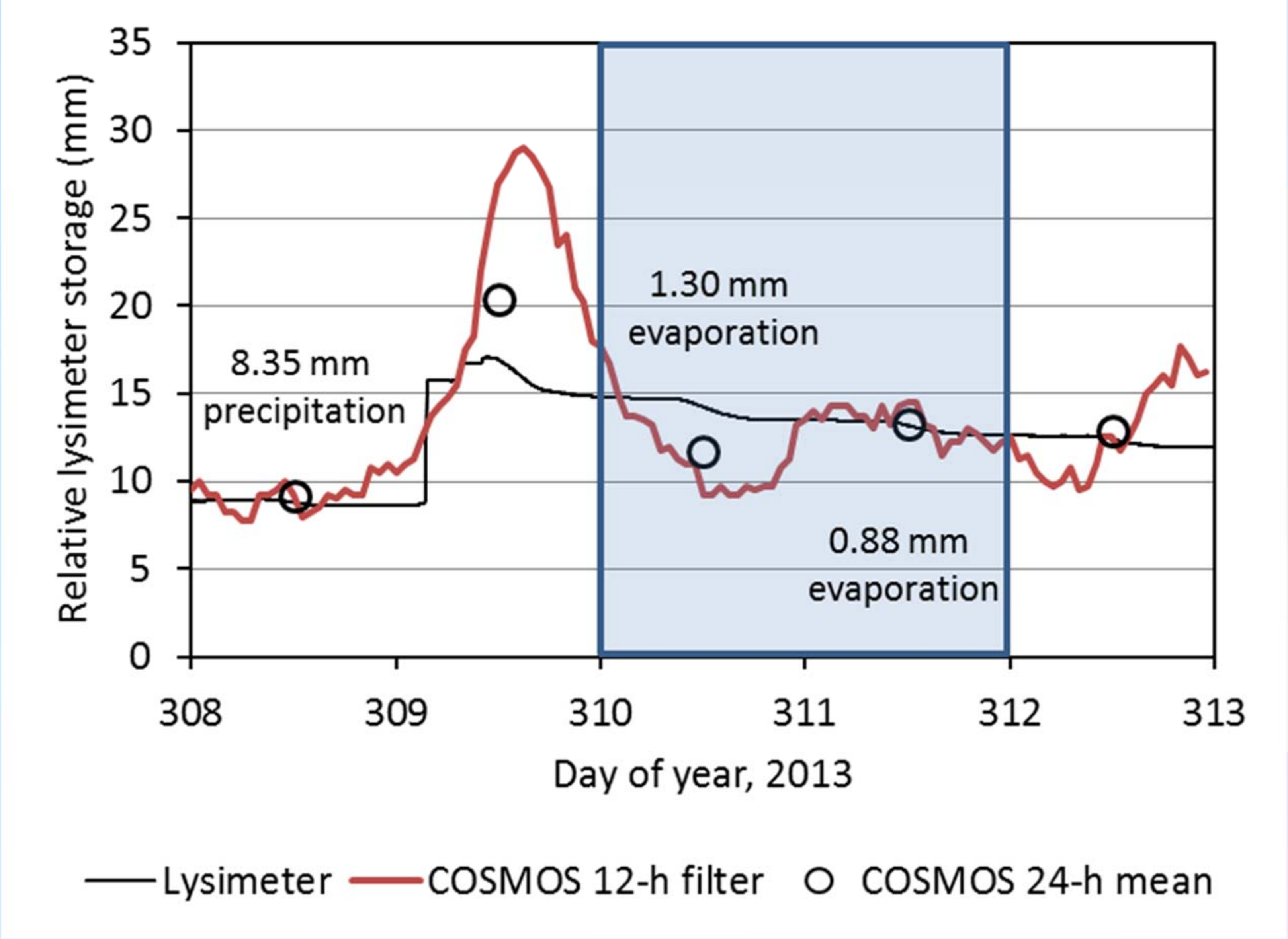
Storage in 25-cm Effective Depth



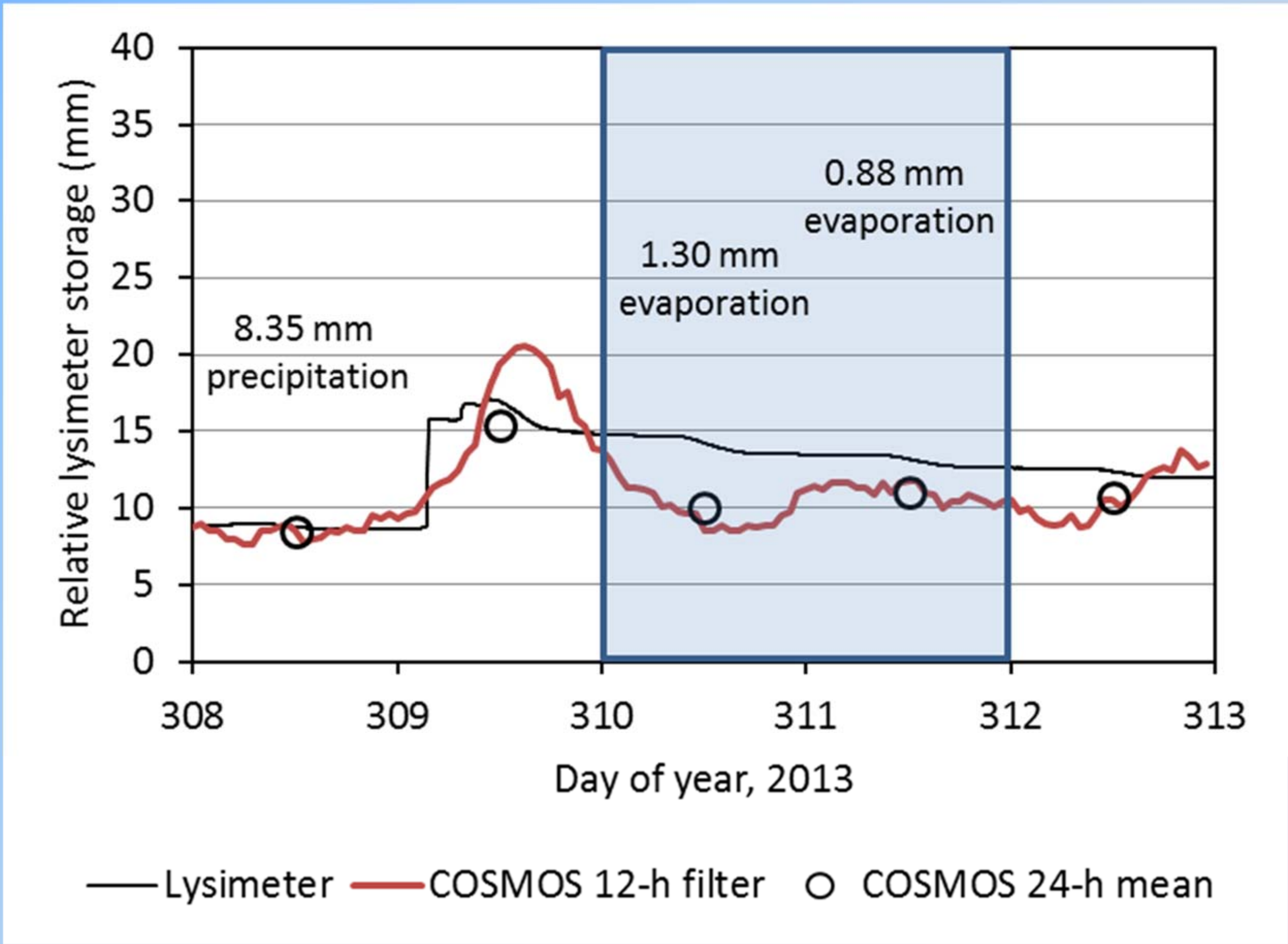
Unfiltered Response to Rain



Filtered Response to Rain



Using Corrected COSMOS VWC



Summary

- COSMOS was well correlated with 0-30 cm water content and storage.
- COSMOS responded to rainfall better than to subsurface drip irrigation at 30-cm depth.
- COSMOS was biased upward by green, living vegetation.
- COSMOS “effective depth” algorithm did not work well in this case.

Thanks

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