RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Using in situ soil moisture observations to evaluate SMOS soil moisture retrievals

Alan Robock and Thomas W. Collow

Department of Environmental Sciences
Rutgers University, New Brunswick, New Jersey

robock@envsci.rutgers.edu

http://envsci.rutgers.edu/~robock

Reviews of Geophysics

http://www.agu.org/journals/rg/

Reviews of Geophysics distills and places in perspective previous scientific work in currently active subject areas of geophysics. Contributions evaluate overall progress in the field and cover all disciplines embraced by AGU.

Authorship is by invitation, but suggestions from readers and potential authors are welcome. If you are interested in writing an article please talk with me, or write to reviewsgeophysics@agu.org, with an abstract, outline, and explanation of how the paper fits the goals of the journal.

Reviews of Geophysics has an impact factor of 8.021 in the 2009 Journal Citation Reports, highest in the geosciences.

Alan Robock
Department of Environmental Sciences

Thanks to the following for providing data:

Yann Kerr and colleagues, SMOS

Michael Palecki, Climate Reference Network

Jeff Basara and Brad Illston, Oklahoma Mesonet

How well can SMOS soil moisture retrievals measure soil moisture?

We compared SMOS retrievals to in situ soil moisture observations at 5 cm depth from the following networks:

Soil Climate Analysis Network (SCAN)

Atmospheric Radiation Measurement (ARM)

United States Climate Reference Network (USCRN)

Oklahoma Mesonet

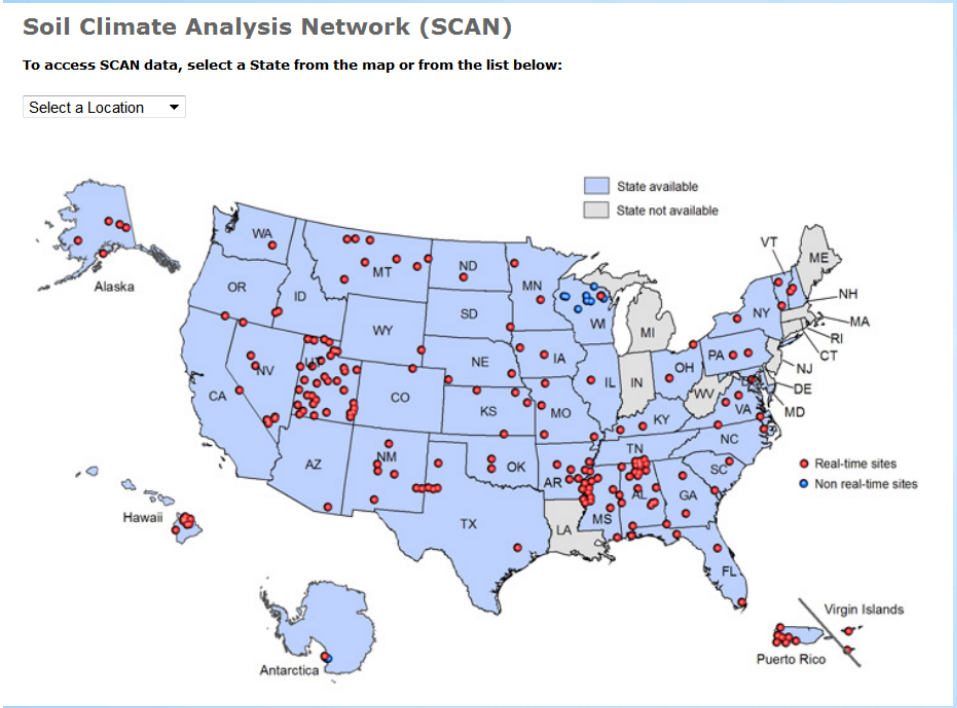
Alan Robock
Department of Environmental Sciences

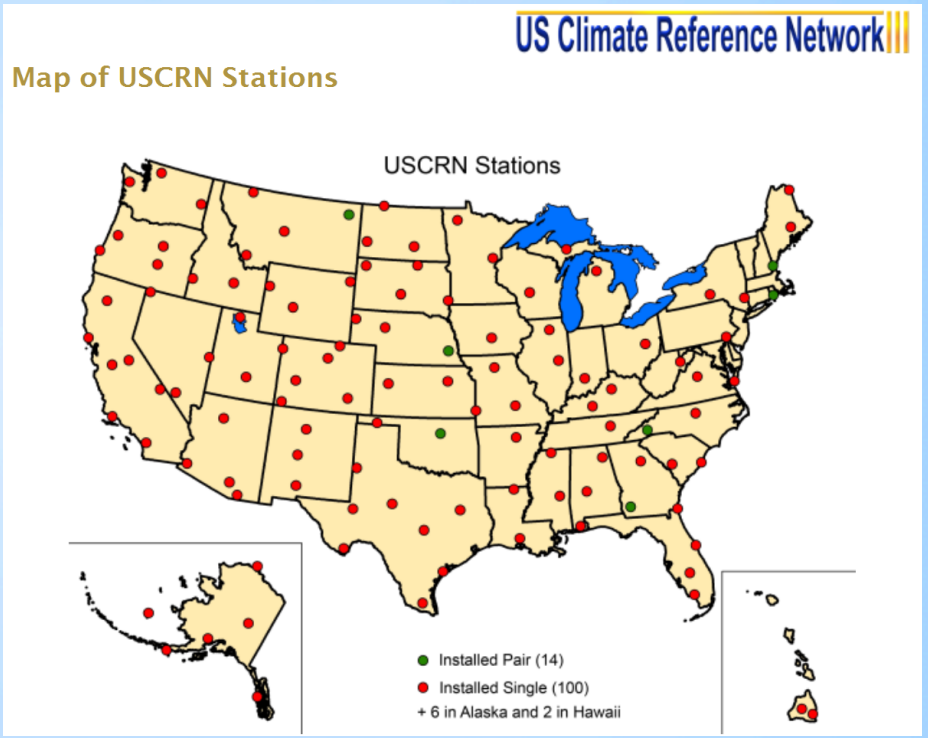
The Soil Moisture Ocean Salinity (**SMOS**) satellite was launched in November 2009 on a modified Russian SS-19 ICBM. The satellite retrieves surface (top few cm) soil moisture using a passive L-band (1.4 GHz) interferometer with a 40 km footprint, and we evaluated the level 2 (L2) data stream.

Surface in situ soil moisture observations from:

Soil Climate Analysis Network (SCAN)
http://www.wcc.nrcs.usda.gov/scan/

U.S. Climate Reference Network (USCRN)
http://www.ncdc.noaa.gov/crn/





Alan Robock
Department of Environmental Sciences

OK Stillwater 2 W, Oklahoma State Univ. (Ag. Research Farm Site)

36.1°N 97.1°W 910'

March 15, 2002

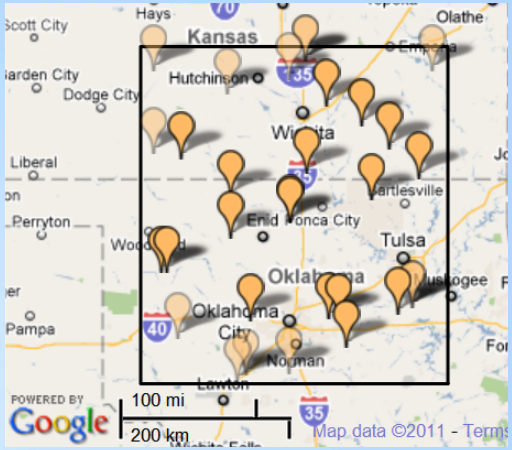
OK Stillwater 5 WNW, Oklahoma State University (Efaw Farm Site)

36.1°N 97.1°W 909'

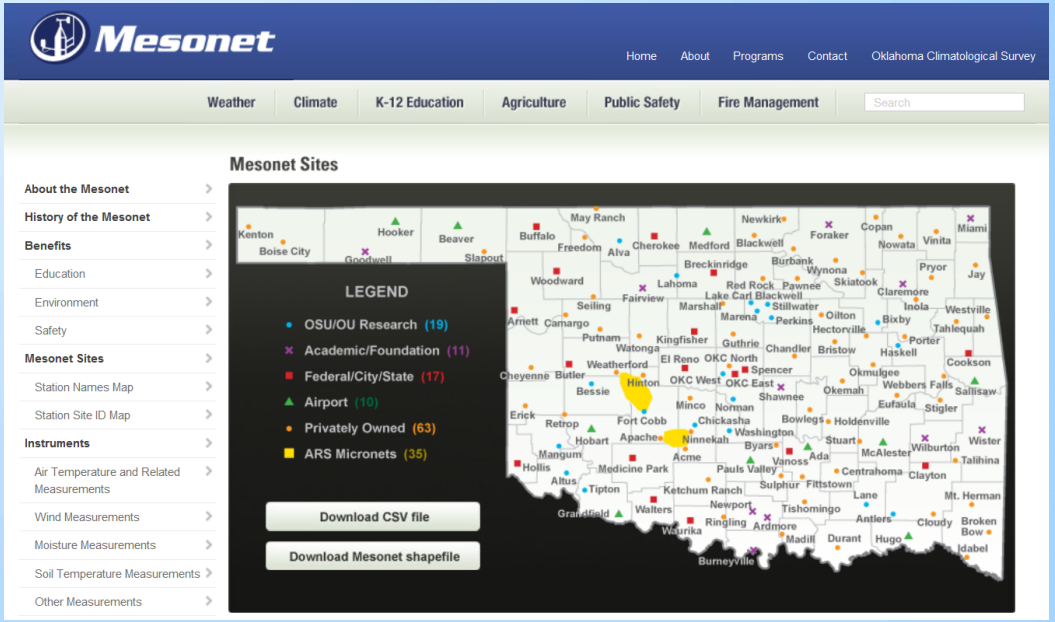
March 15, 2002

Surface in situ soil moisture observations from:

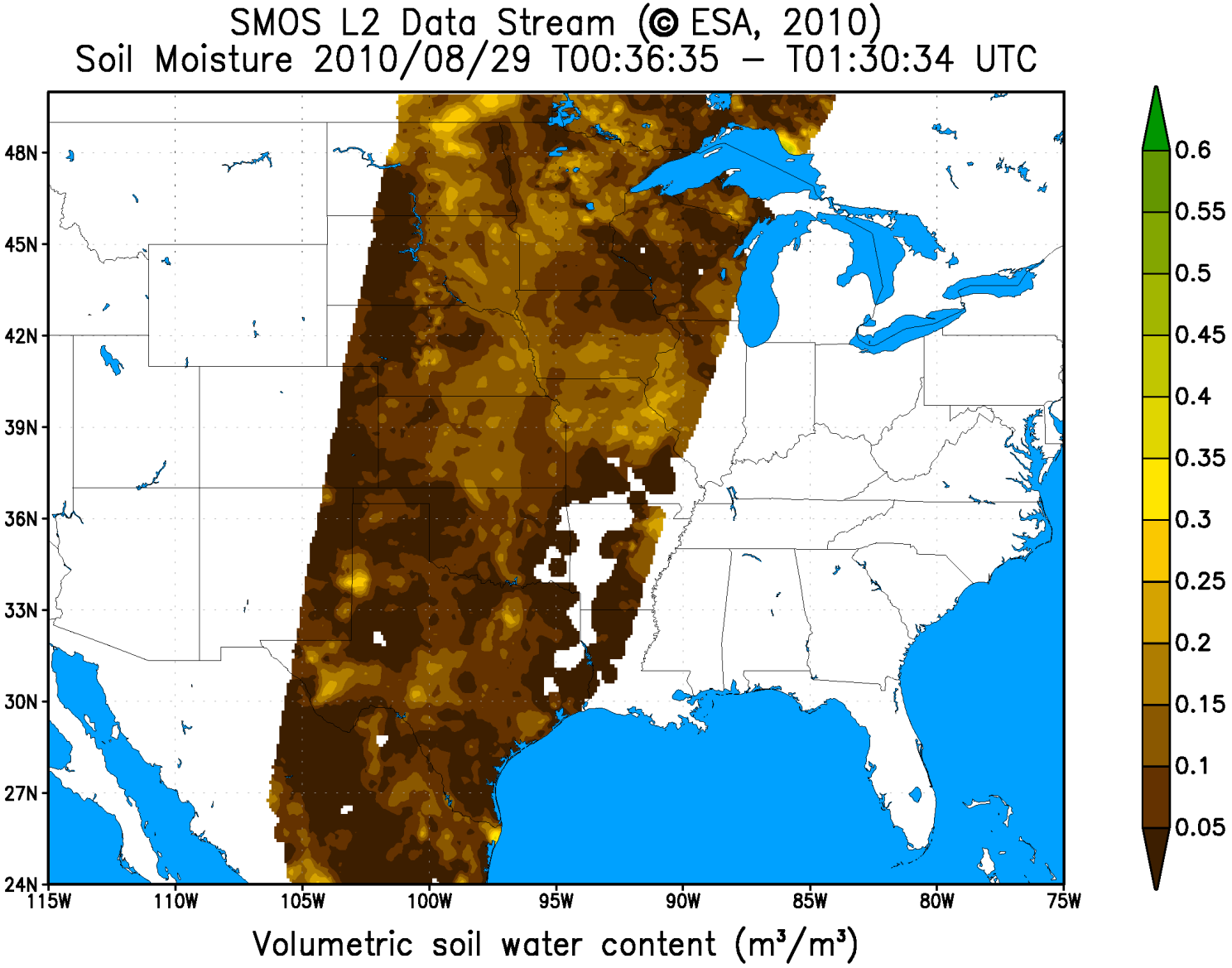
ARM Climate Research Facility
http://www.arm.gov/measurements/soilmoist

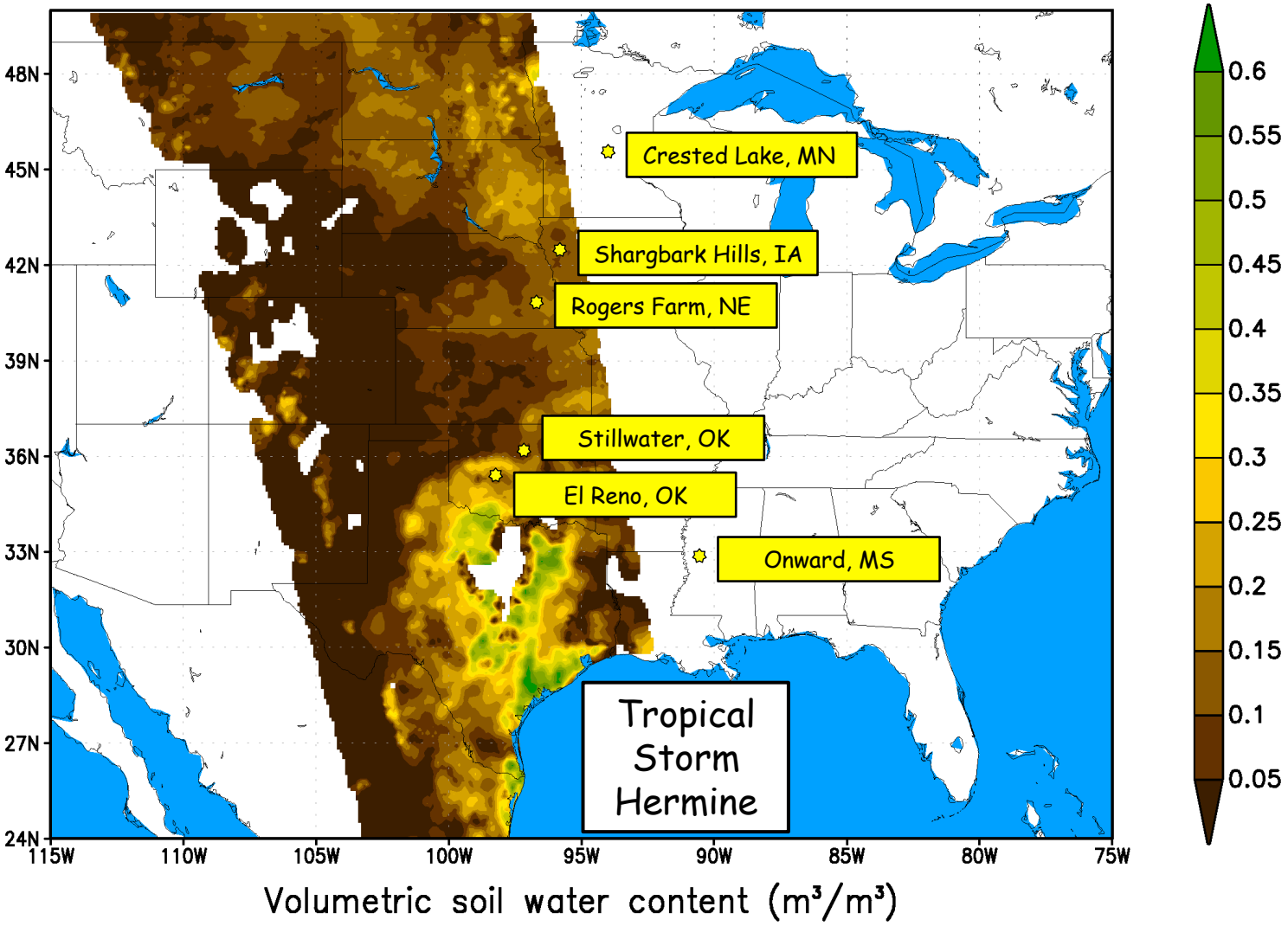


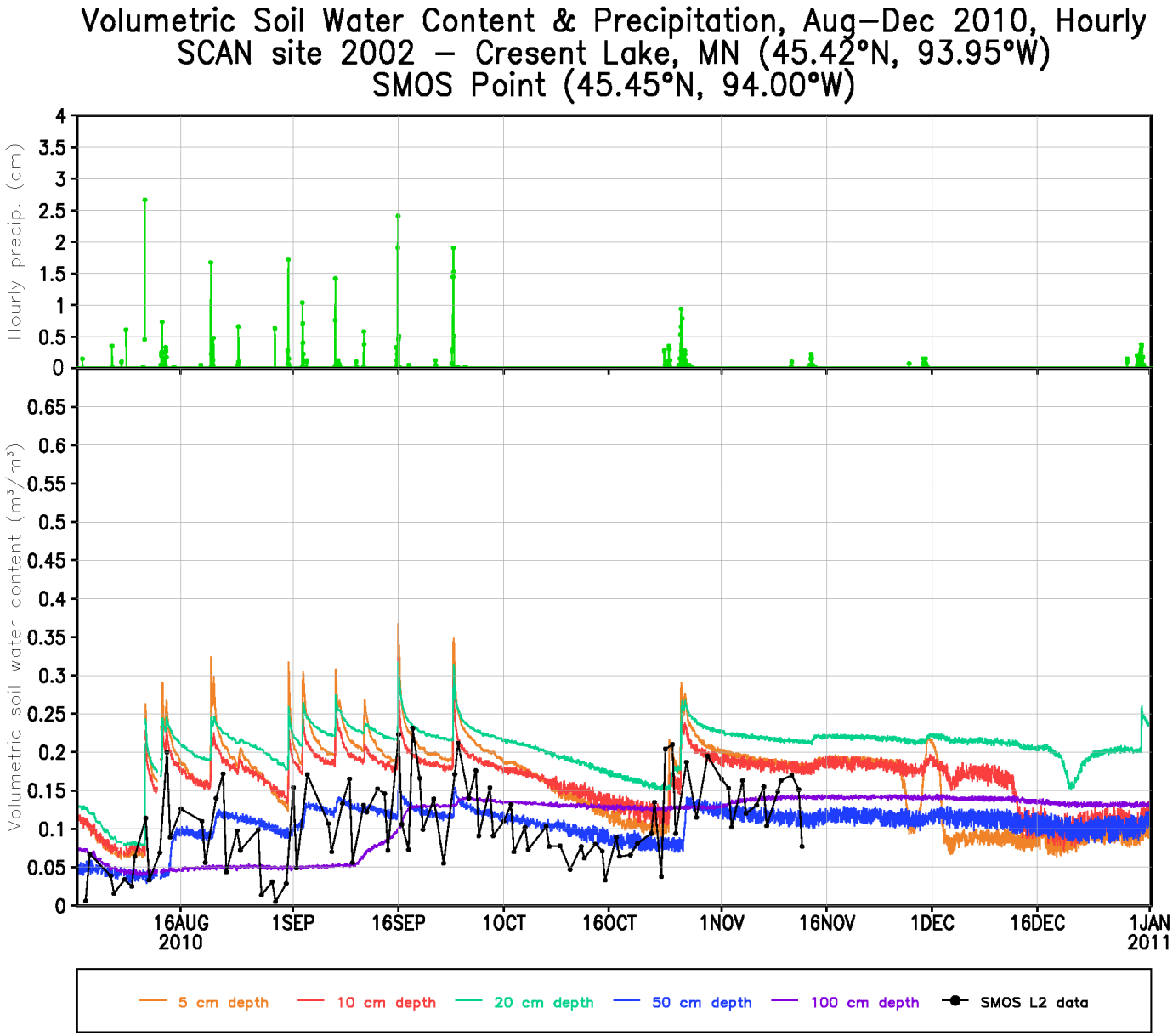
Oklahoma Mesonet
http://www.mesonet.org/index.php/weather/category/soil_moisture

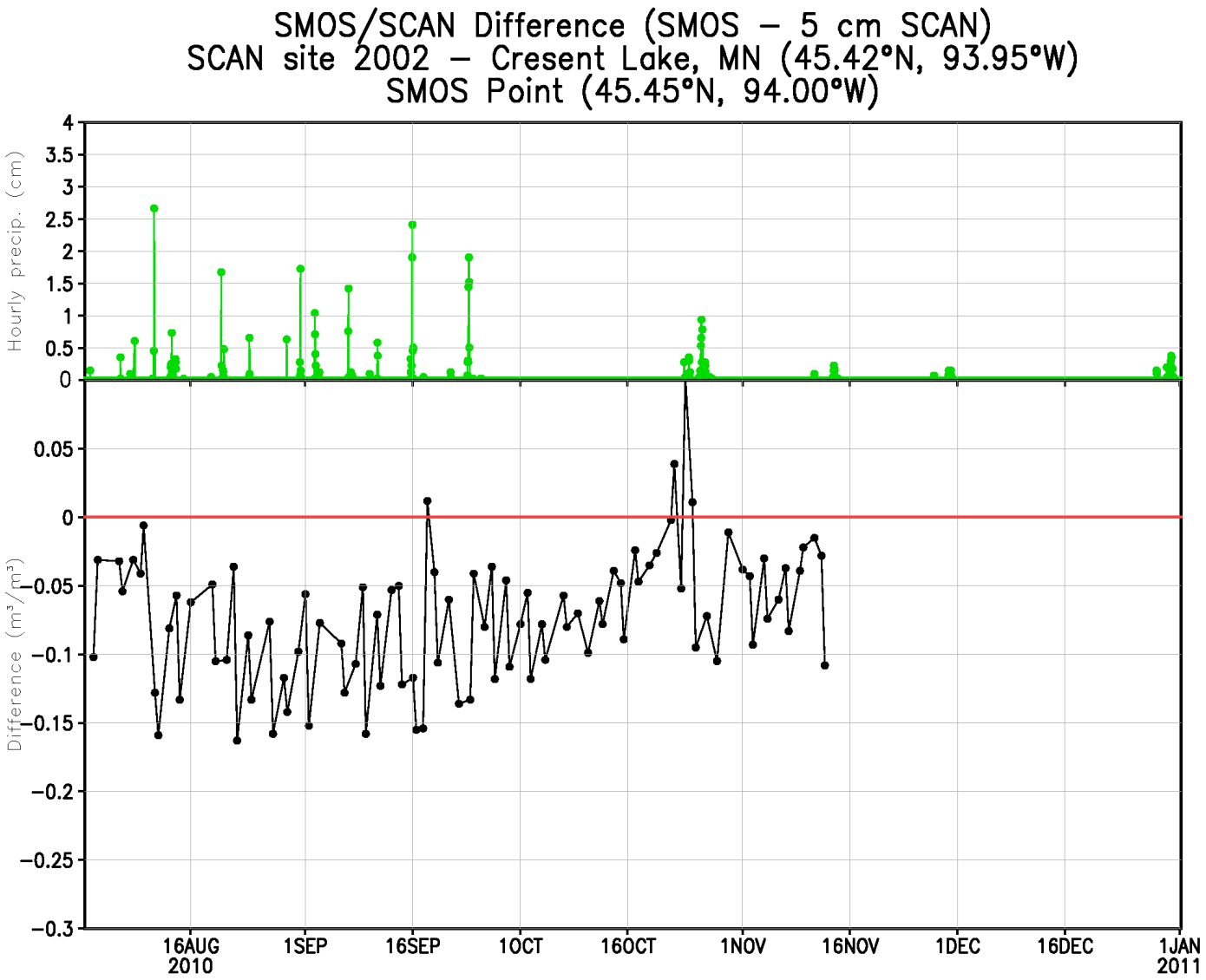


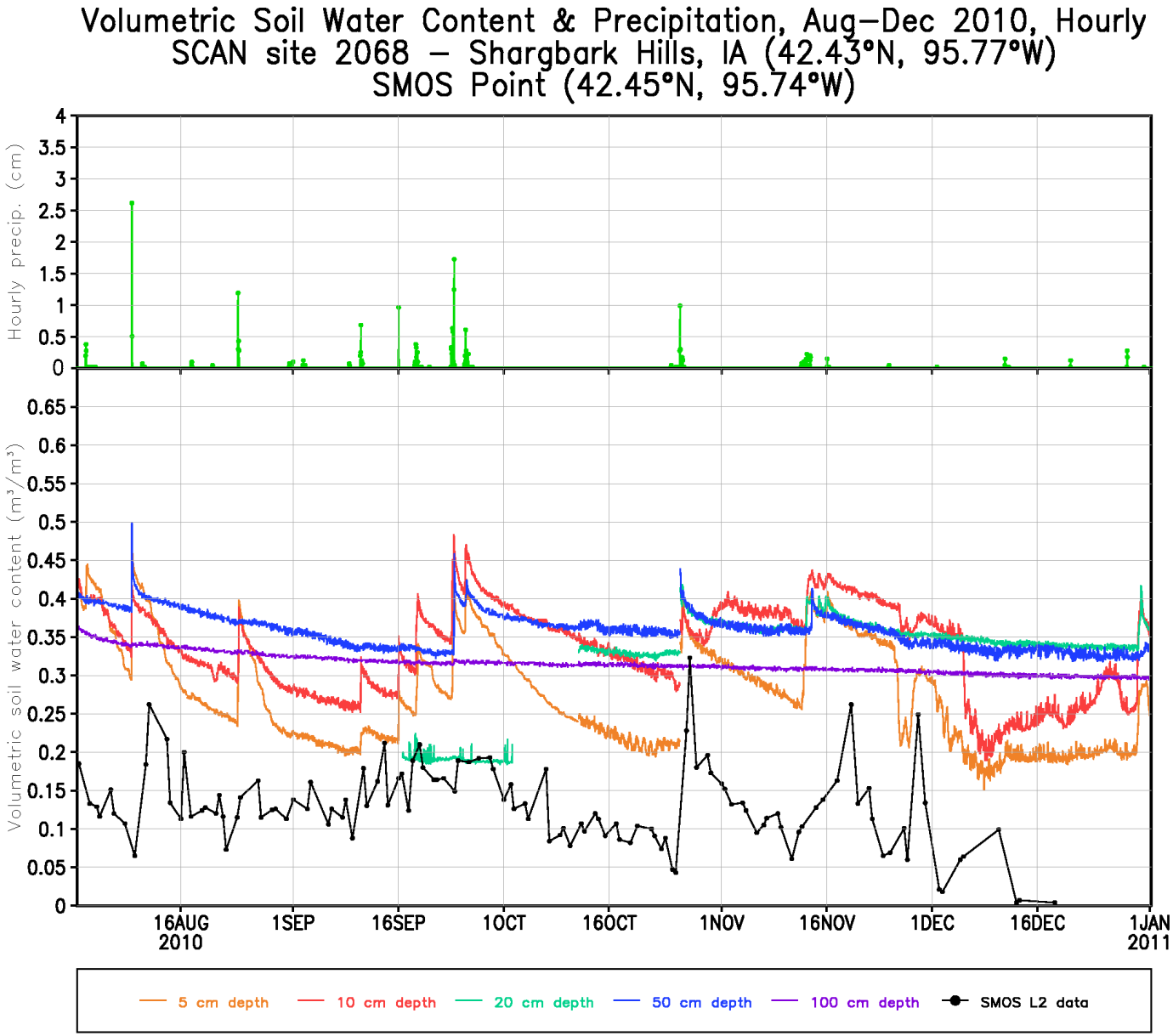
RUTGERS
Alan Robock
Department of Environmental Sciences

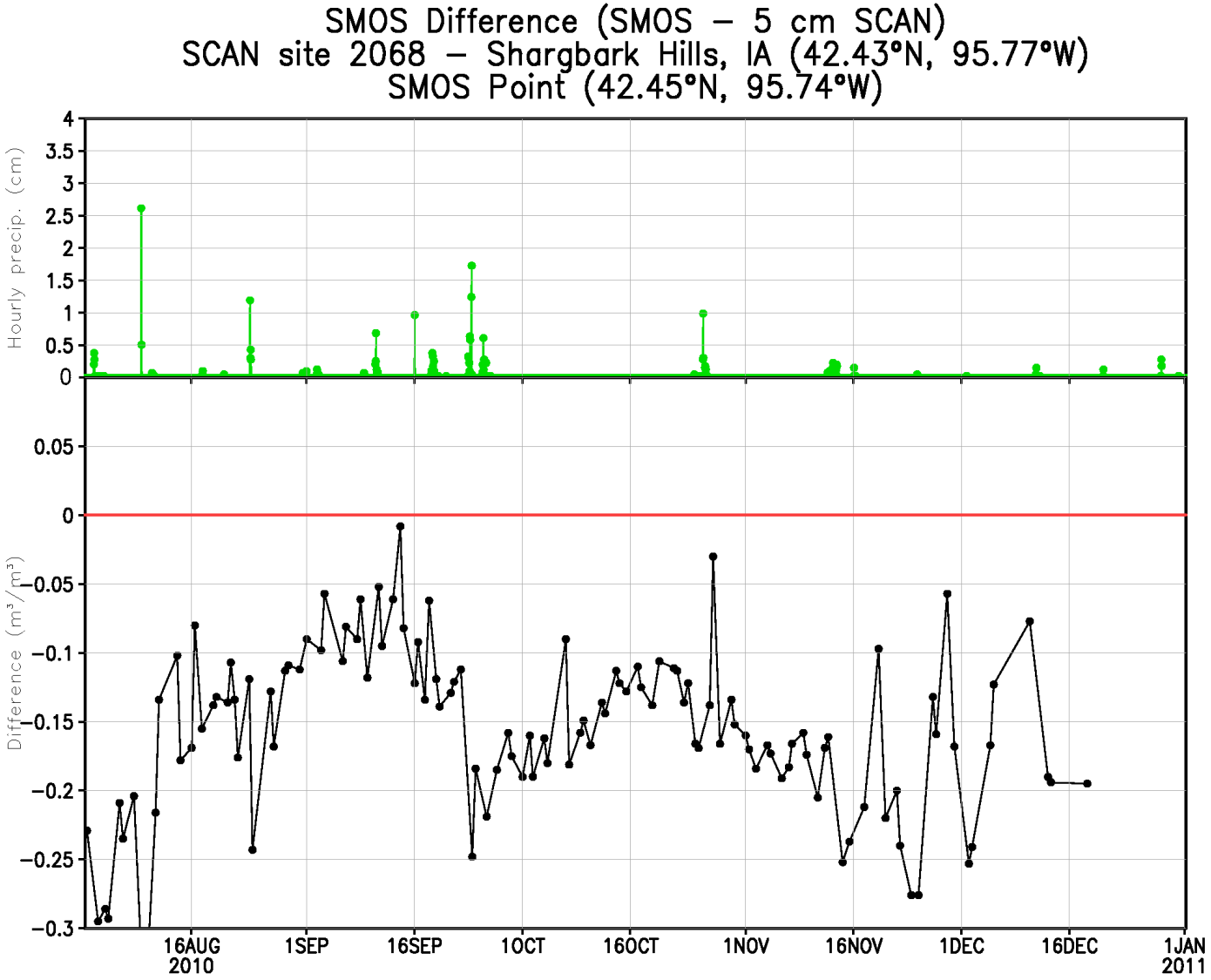

SMOS L2 Data Stream (© ESA, 2010)
Soil Moisture 2010/08/29 T00:36:35 – T01:30:34 UTC
48N
45N
42N
39N
36N
33N
30N
27N
24N
115W
110W
105W
100W
95W
90W
85W
80W
75W
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Volumetric soil water content (m³/m³)

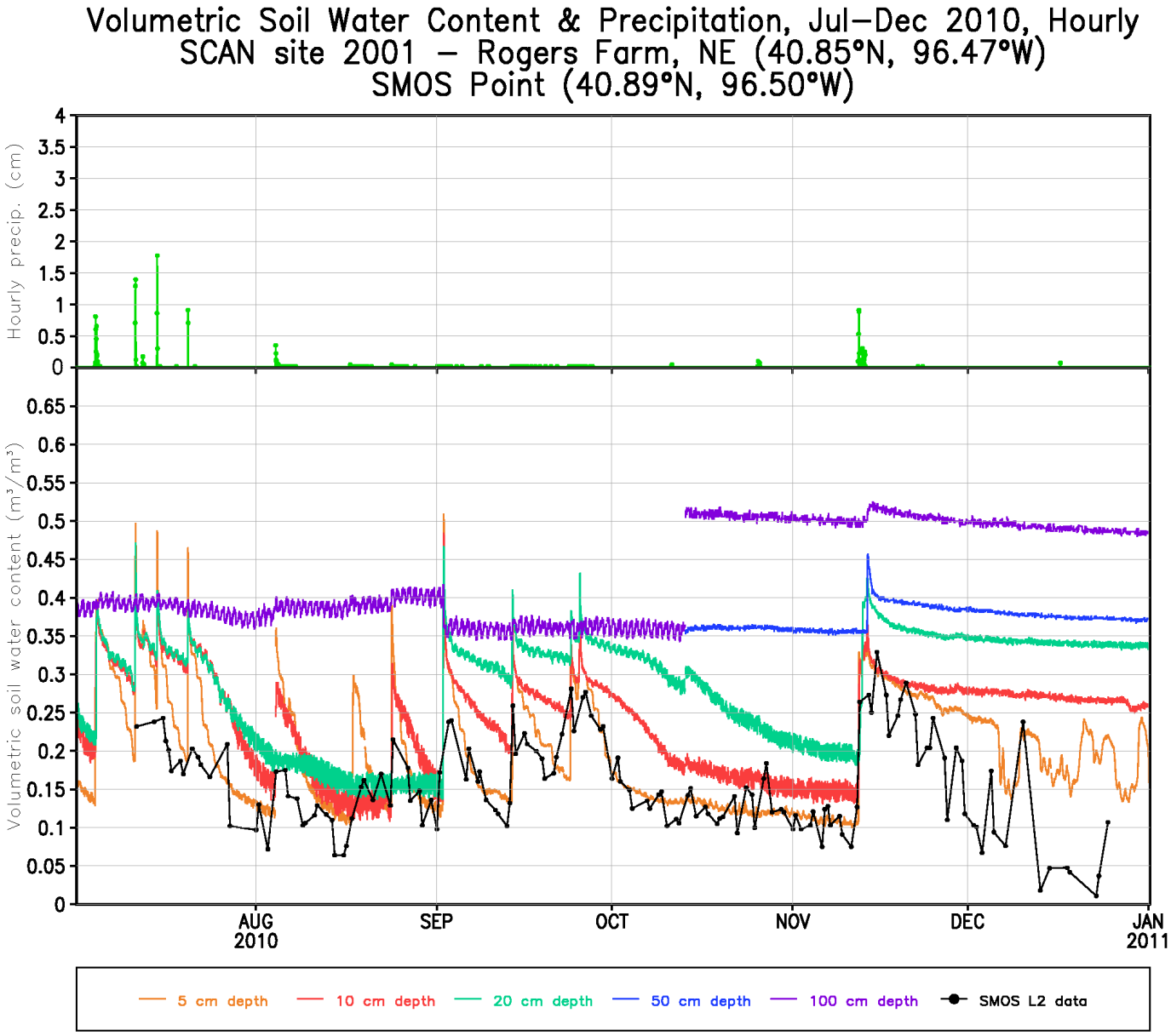

SMOS L2 Data Stream (© ESA, 2010)
Soil Moisture 2010/09/08 T11:37:45 – T12:31:44 UTC
Crested Lake, MN
Shargbark Hills, IA
Rogers Farm, NE
Stillwater, OK
El Reno, OK
Onward, MS
Tropical Storm Hermine
48N
45N
42N
39N
36N
33N
30N
27N
24N
115W
110W
105W
100W
95W
90W
85W
80W
75W
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Volumetric soil water content (m³/m³)

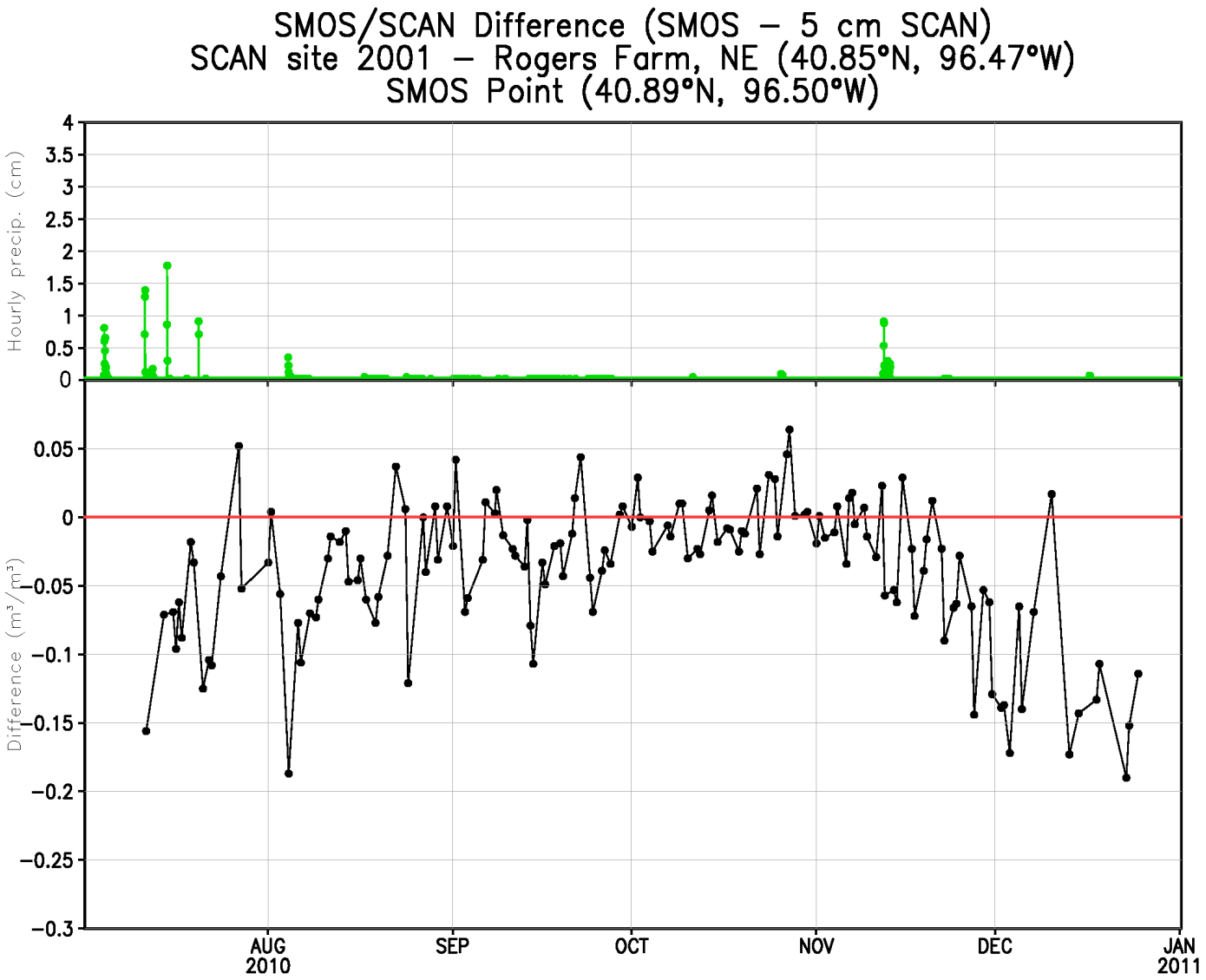

Volumetric Soil Water Content & Precipitation, Aug–Dec 2010, Hourly
SCAN site 2002 – Cresent Lake, MN (45.42°N, 93.95°W)
SMOS Point (45.45°N, 94.00°W)
Hourly precip. (cm)
Volumetric soil water content (m³/m³)
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011
5 cm depth
10 cm depth
20 cm depth
50 cm depth
100 cm depth
SMOS L2 data

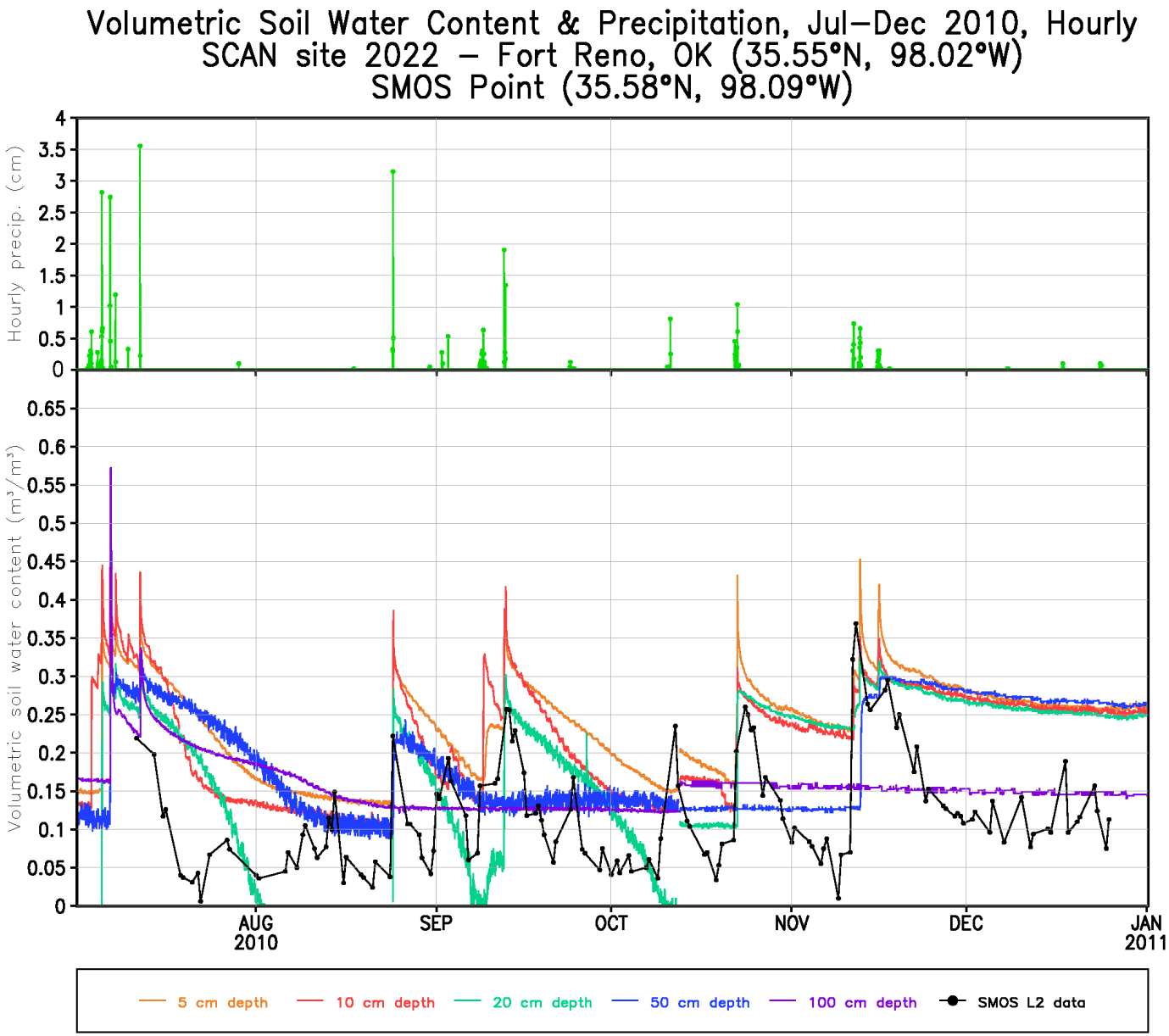

SMOS/SCAN Difference (SMOS – 5 cm SCAN)
SCAN site 2002 – Cresent Lake, MN (45.42°N, 93.95°W)
SMOS Point (45.45°N, 94.00°W)
Hourly precip. (cm)
Difference (m³/m³)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011

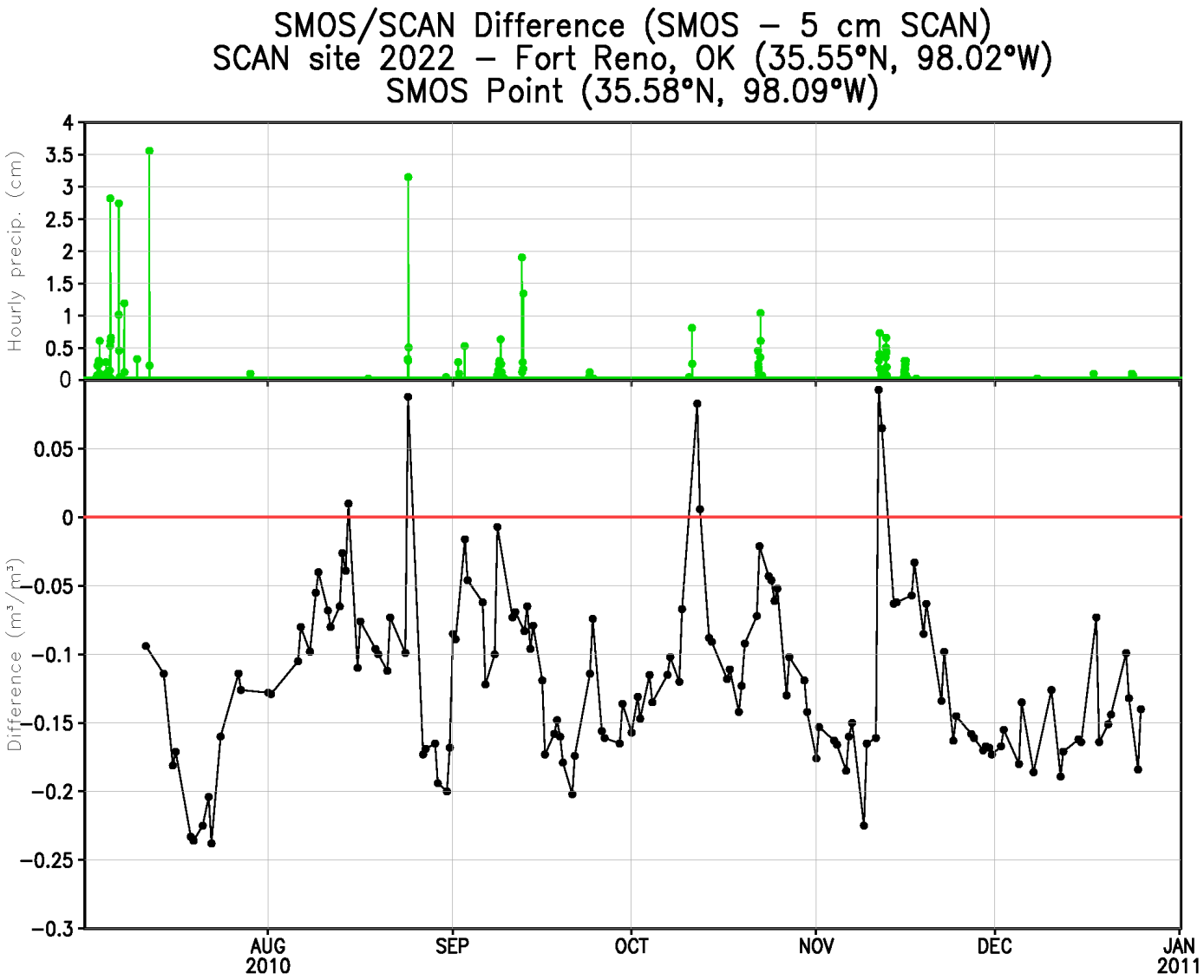

Volumetric Soil Water Content & Precipitation, Aug–Dec 2010, Hourly
SCAN site 2068 – Shargbark Hills, IA (42.43°N, 95.77°W)
SMOS Point (42.45°N, 95.74°W)
Hourly precip. (cm)
Volumetric soil water content (m³/m³)
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011
5 cm depth
10 cm depth
20 cm depth
50 cm depth
100 cm depth
SMOS L2 data

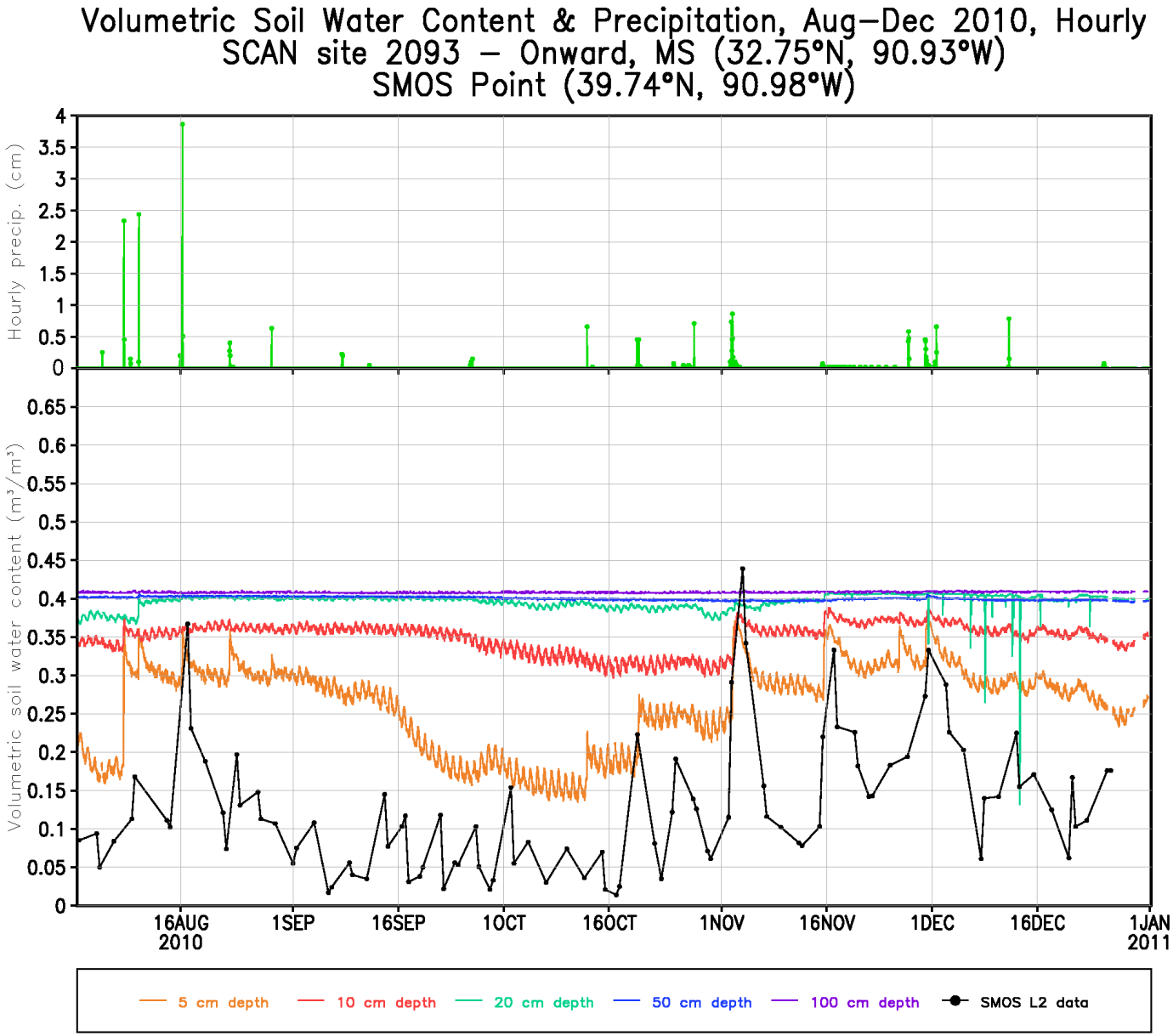

SMOS Difference (SMOS – 5 cm SCAN)
SCAN site 2068 – Shargbark Hills, IA (42.43°N, 95.77°W)
SMOS Point (42.45°N, 95.74°W)
Hourly precip. (cm)
Difference (m³/m³)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011

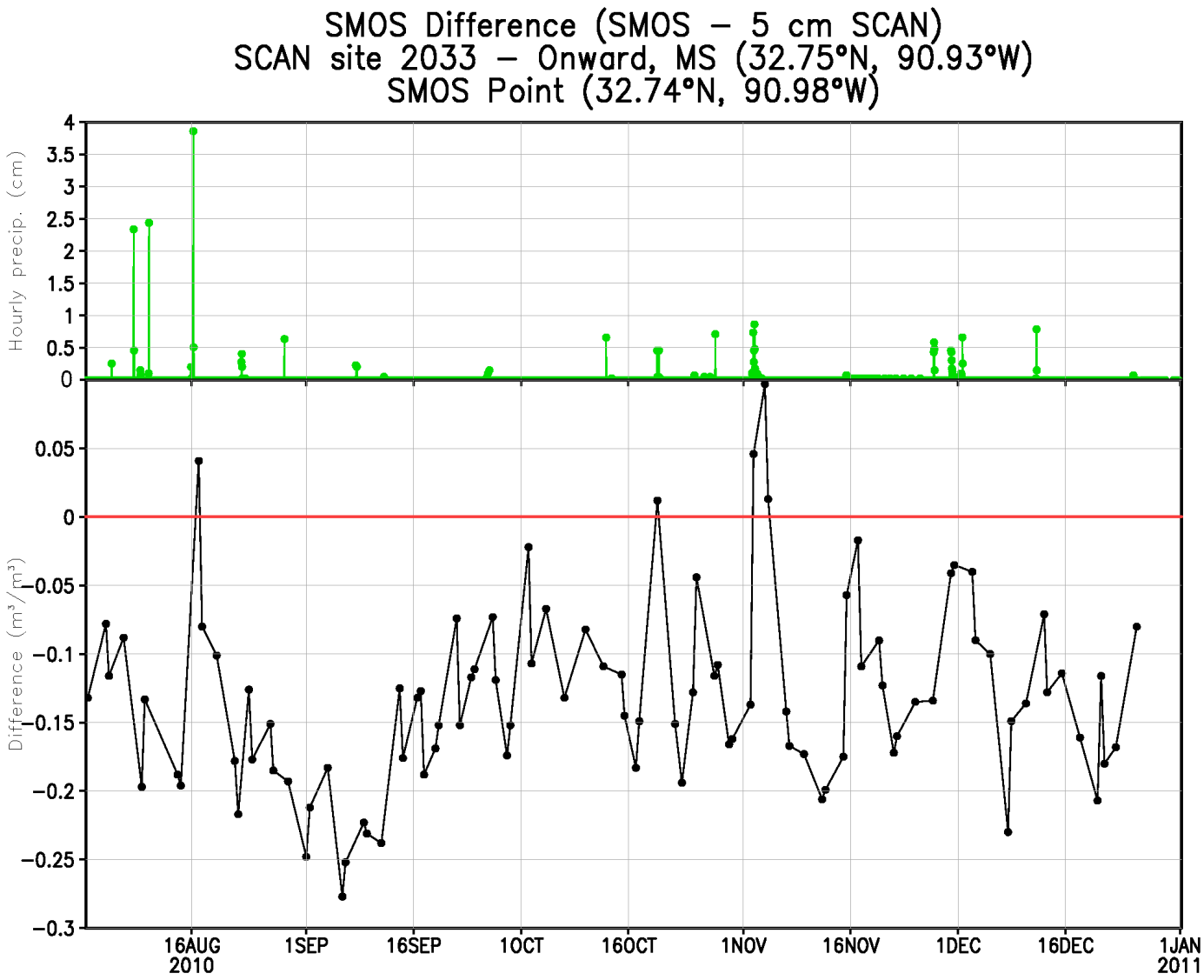

Volumetric Soil Water Content & Precipitation, Jul–Dec 2010, Hourly
SCAN site 2001 – Rogers Farm, NE (40.85°N, 96.47°W)
SMOS Point (40.89°N, 96.50°W)
Hourly precip. (cm)
Volumetric soil water content (m³/m³)
AUG 2010
SEP
OCT
NOV
DEC
JAN 2011
5 cm depth
10 cm depth
20 cm depth
50 cm depth
100 cm depth
SMOS L2 data


SMOS/SCAN Difference (SMOS – 5 cm SCAN)
SCAN site 2001 – Rogers Farm, NE (40.85°N, 96.47°W)
SMOS Point (40.89°N, 96.50°W)
Hourly precip. (cm)
Difference (m³/m³)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
AUG
2010
SEP
OCT
NOV
DEC
JAN
2011

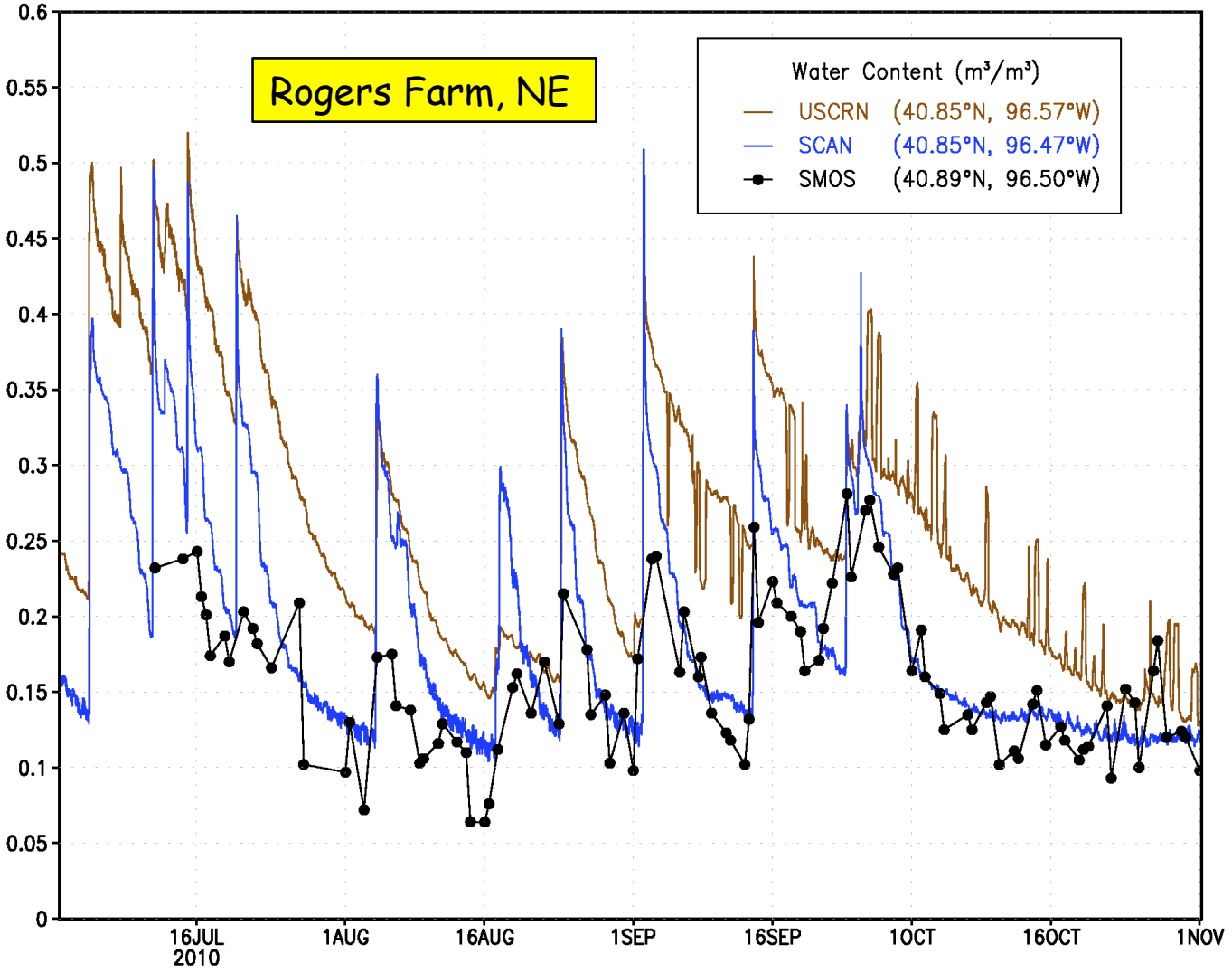

Volumetric Soil Water Content & Precipitation, Jul–Dec 2010, Hourly
SCAN site 2022 – Fort Reno, OK (35.55°N, 98.02°W)
SMOS Point (35.58°N, 98.09°W)
Hourly precip. (cm)
Volumetric soil water content (m³/m³)
AUG 2010
SEP
OCT
NOV
DEC
JAN 2011
5 cm depth
10 cm depth
20 cm depth
50 cm depth
100 cm depth
SMOS L2 data


SMOS/SCAN Difference (SMOS – 5 cm SCAN)
SCAN site 2022 – Fort Reno, OK (35.55°N, 98.02°W)
SMOS Point (35.58°N, 98.09°W)
Hourly precip. (cm)
Difference (m³/m³)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
AUG
2010
SEP
OCT
NOV
DEC
JAN
2011


Volumetric Soil Water Content & Precipitation, Aug–Dec 2010, Hourly
SCAN site 2093 – Onward, MS (32.75°N, 90.93°W)
SMOS Point (39.74°N, 90.98°W)
Hourly precip. (cm)
Volumetric soil water content (m³/m³)
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011
5 cm depth
10 cm depth
20 cm depth
50 cm depth
100 cm depth
SMOS L2 data

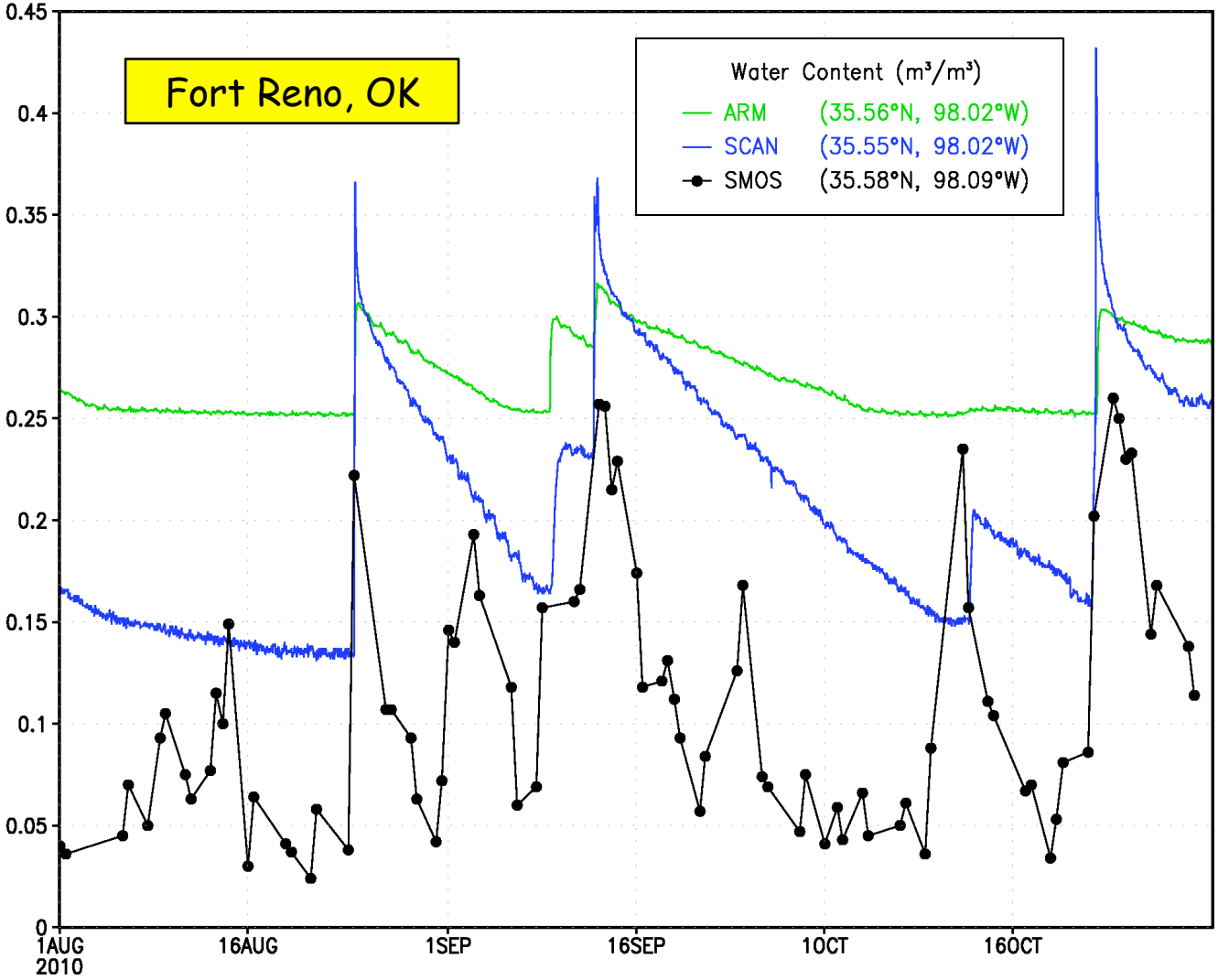

SMOS Difference (SMOS – 5 cm SCAN)
SCAN site 2033 – Onward, MS (32.75°N, 90.93°W)
SMOS Point (32.74°N, 90.98°W)
Hourly precip. (cm)
Difference (m³/m³)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
16AUG 2010
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV
1DEC
16DEC
1JAN 2011

Comparision between SCAN & USCRN 5 cm soil moisture Data
SCAN site 2001 & USCRN site 94995



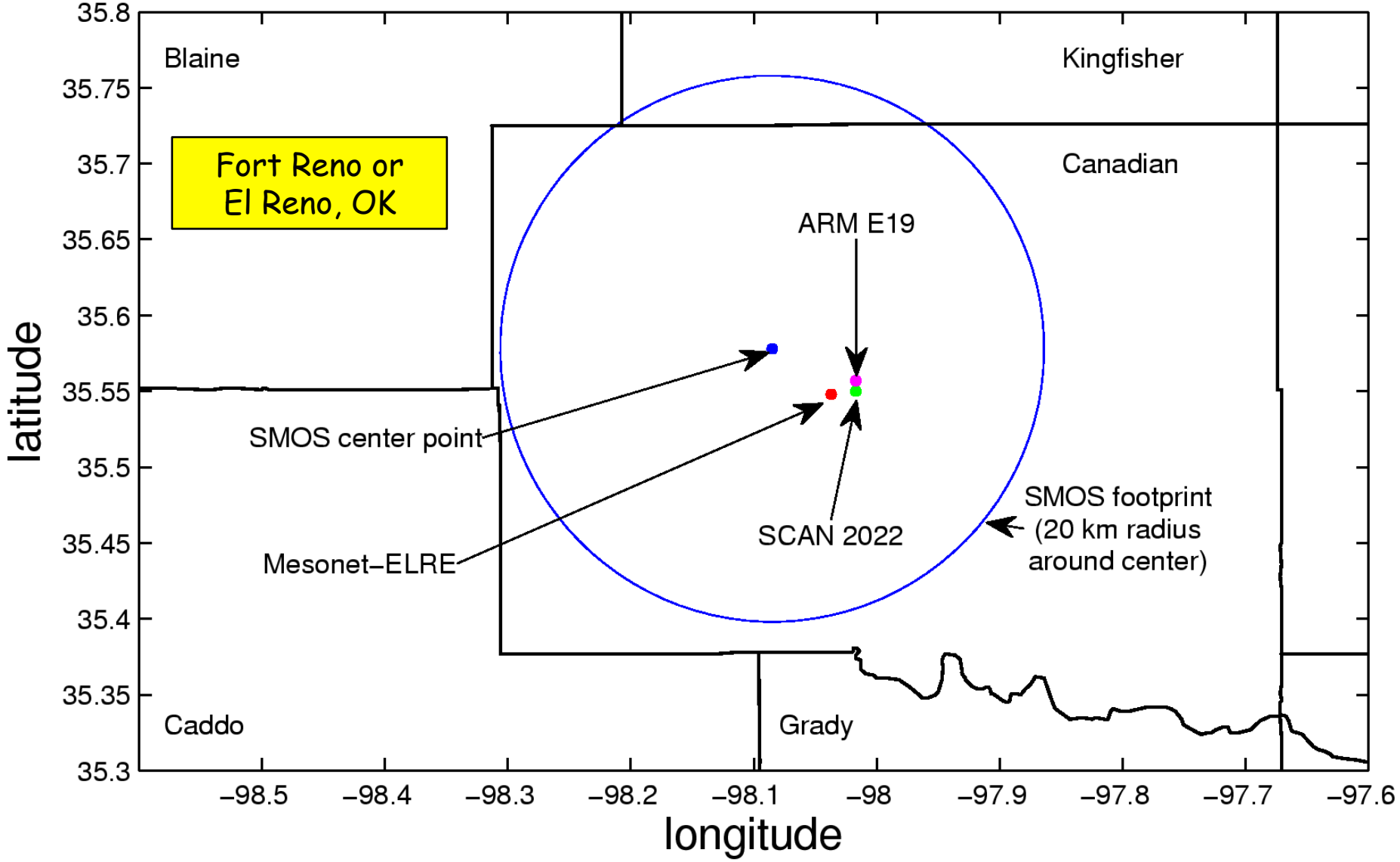
Alan Robock
Department of Environmental Sciences

Comparision between SCAN & ARM 5 cm soil moisture Data
SCAN site 2022 & ARM site E19

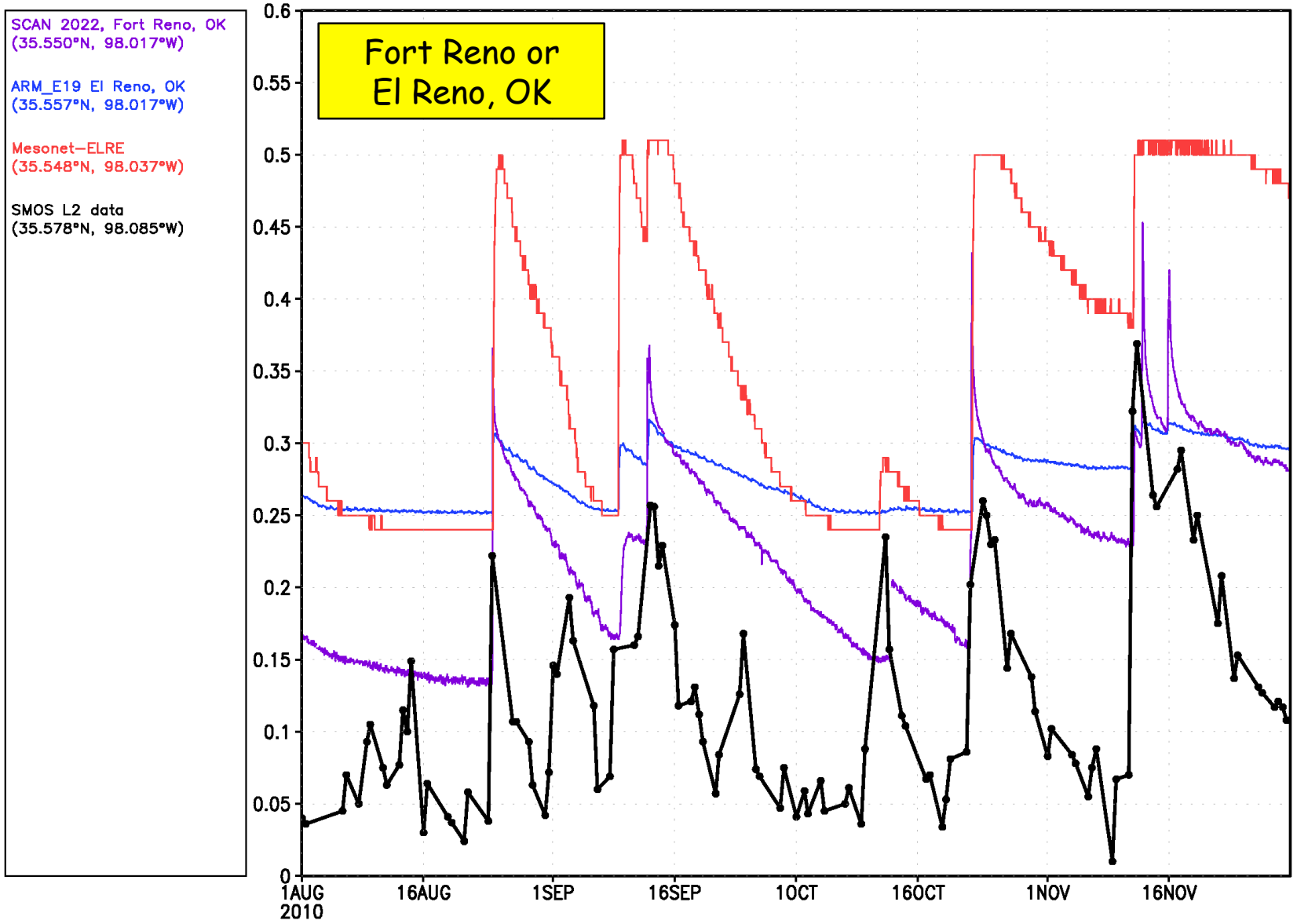


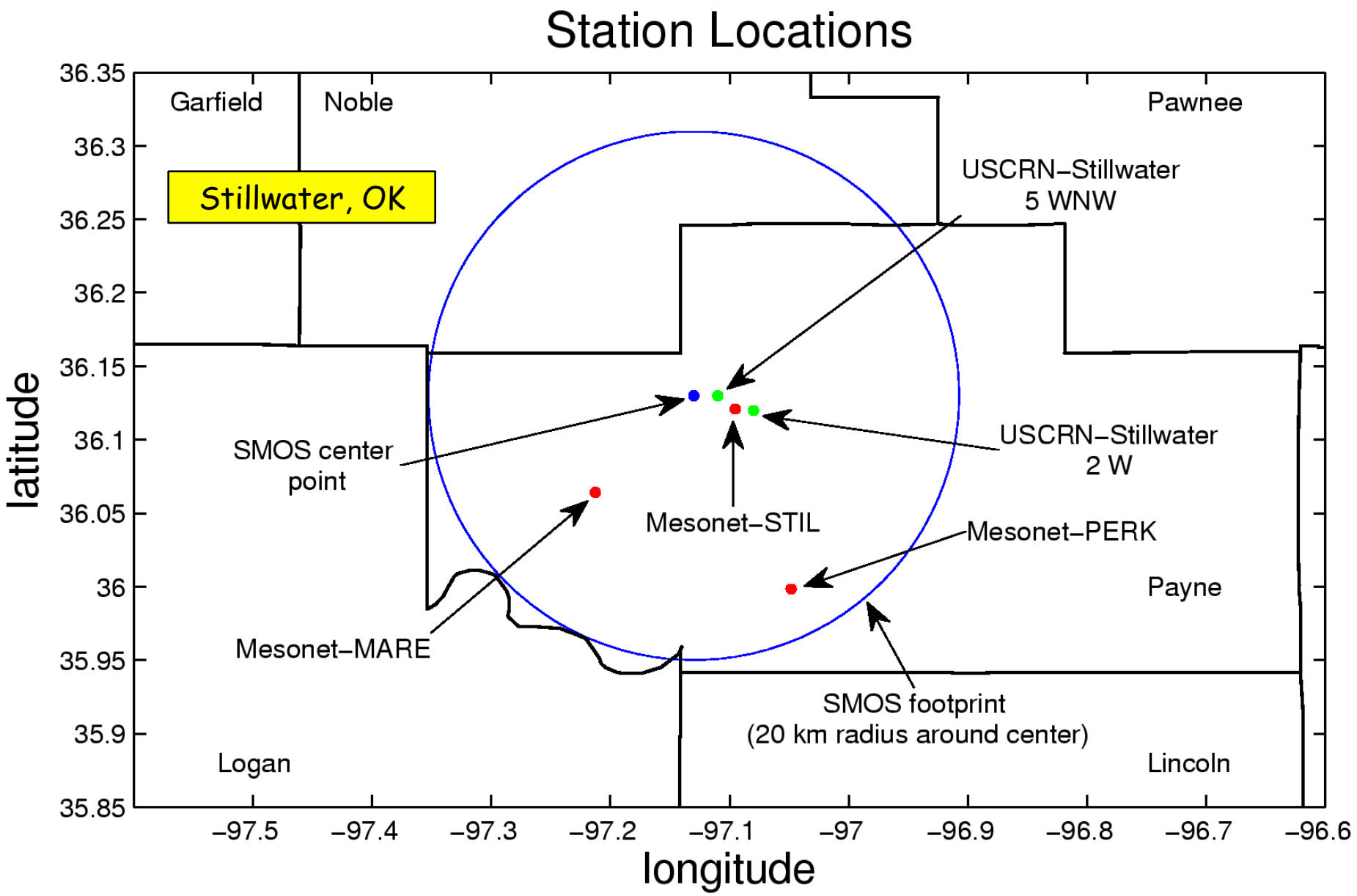
Alan Robock
Department of Environmental Sciences

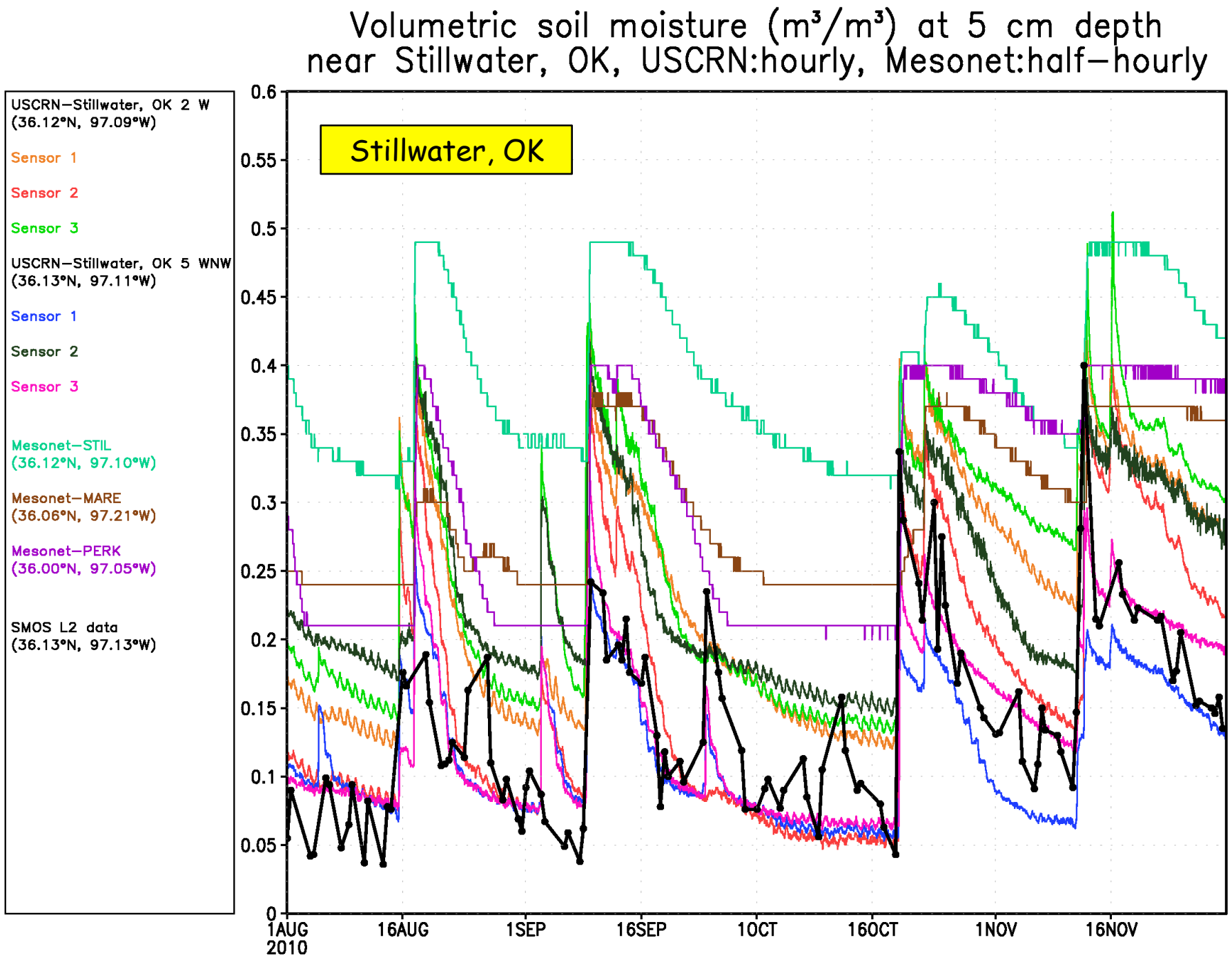
Station Locations



Volumetric soil moisture (m^3/m^3) at 5 cm depth near Fort Reno, OK, SCAN & ARM:hourly, Mesonet:half-hourly




Station Locations
Garfield
Noble
Pawnee
Stillwater, OK
USCRN–Stillwater
5 WNW
SMOS center
point
USCRN–Stillwater
2 W
Mesonet–STIL
Mesonet–PERK
Payne
Mesonet–MARE
SMOS footprint
(20 km radius around center)
Logan
Lincoln
latitude
longitude
36.35
36.3
36.25
36.2
36.15
36.1
36.05
36
35.95
35.9
35.85
–97.5
–97.4
–97.3
–97.2
–97.1
–97
–96.9
–96.8
–96.7
–96.6


Volumetric soil moisture (m³/m³) at 5 cm depth
near Stillwater, OK, USCRN:hourly, Mesonet:half-hourly
Stillwater, OK
USCRN-Stillwater, OK 2 W
(36.12°N, 97.09°W)
Sensor 1
Sensor 2
Sensor 3
USCRN-Stillwater, OK 5 WNW
(36.13°N, 97.11°W)
Sensor 1
Sensor 2
Sensor 3
Mesonet-STIL
(36.12°N, 97.10°W)
Mesonet-MARE
(36.06°N, 97.21°W)
Mesonet-PERK
(36.00°N, 97.05°W)
SMOS L2 data
(36.13°N, 97.13°W)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1AUG
2010
16AUG
1SEP
16SEP
1OCT
16OCT
1NOV
16NOV

Conclusions

1.SMOS (version 1) has a dry bias, as compared to in situ observations.

2. Because in situ data for the same location have differences as large as the differences between SMOS and the in situ observations, and because in situ data are for a point and SMOS retrievals have a footprint with a 40 km diameter, we cannot expect SMOS to exactly reproduce any individual in situ observation. The error characteristics will require further analysis to determine how useful the SMOS retrievals are.

Acknowledgments. This work is supported by NASA grant NNX09AJ99G, and is conducted as part of the SMOS Validation and Retrieval Team activities.

Alan Robock
Department of Environmental Sciences