ARM CLIMATE RESEARCH FACILITY

THE NEW SOIL TEMPERATURE AND MOISTURE PROFILE (STAMP) SYSTEM

David Cook
Jenni Kyrouac
Environmental Science Division
Argonne National Laboratory

Abstract: The STAMP (Soil Temperature And Moisture Profile) system is replacing the SWATS system for the measurement of soil temperature and moisture profiles at all SGP (Southern Great Plains) Extended Facilities, including new Extended Facilities E39, E40, and E41. The STAMP system employs new data logger and multiplexer equipment, and Stevens Water Monitoring System Inc. Hydra Probe probes. As much of the old SWATS infrastructure as possible is being re-used. The SWATS at the SGP Central Facility will be maintained for a year to enable possible comparison between the SWATS and STAMP measurements. The STAMP makes measurements at 5, 10, 20, 50, and 100 cm depth, replicated in three profiles, and includes a heated rain gauge for precipitation measurements. All of the STAMP systems have been installed.

STAMP MEASUREMENTS

The STAMP measures soil properties at five depths (5, 10, 20, 50, and 100 cm) in three profiles (west, south, and east), plus precipitation, at every SGP Extended Facility, including EF21 Okmulgee Forest. There are two exceptions to the depths at which the soil measurements are made, because of shallow soil. Bedrock is found at 80 cm for two of the EF13 Lamont, OK profiles (deepest measured depth at two profiles of 75 cm, 100 cm at one profile) and at 25 cm at EF21 Okmulgee Forest (5, 10, and 20 cm depths are measured at EF21). SWAT measurements were not made at EF21 Okmulgee Forest or at the three newest SGP EFs (EF39 Morrison, OK; EF40 Pawnee, OK; EF41 Peckham, OK). The STAMP system produces two output tables of data, a 1 minute table of precipitation and a 30 minute table of soil measurements:

- Precipitation in mm
- Soil-Specific Soil Water Content in % by volume
- Plant Water Availability (also commonly called Available Water Capacity) in mm:
- Total Plant Water Availability per profile (west, south, east) in mm
- Soil Temperature in deg C
- Loam Soil Water Content in % by volume
- Soil Conductivity in Siemens/m
- Real Dielectric Permittivity (unitless)
- Data logger battery voltage

MEASUREMENTS METHODOLOGY

The STAMP system employs the Stevens Water Monitoring Systems, Inc. Hydra Probe for the soil measurements, the Texas Instruments TR-525M Metric Heated tipping bucket rain gauge for precipitation measurements, and a Campbell Scientific, Inc. CR800 data logger and peripheral equipment for data acquisition and processing. Precipitation is measured and reported every minute; all other measurements are made once per half hour and reported every half hour. The Hydra Probe fully characterizes the soil dielectric spectrum using a radio frequency of 50 MHz. Complex mathematical computations are performed by an onboard microprocessor to process the reflected signal measurements and accurately determine the real dielectric permittivity (RDP), soil conductivity, and loam-based soil water content. Low inner-sensor variability means that there is no need for sensor-specific calibrations. This is a great advantage when replacing probes; no changes need to be made to the CR800 datalogger program. The mentors performed calculations of soil-specific soil water content (SWC)[1] in % and plant water availability (PWA)[2] in mm, based on soil texture. SWC can be significantly different from the default loam-based soil water content measurement of the Hydra Probe.

Soil texture can vary widely between sites and between depths at some sites. The soil textures and bulk densities of the soil have been determined for each of the Extended Facilities for the depths of measurement. Differences in the measurements between profiles at an individual site are quite common and reflect a lack of horizontal homogeneity of soil texture and moisture content. Eleven soil textures are used to determine coefficients (A, B, C, D, E) and the crop lower limit water capacity (CCL) for calculating SWC and PWA. PWA reflects the water held by the soil between the drained upper limit, or field capacity, and CCL on the basis of the measured RDP.

For sandy/silty soils:

$$SWC = 100(A \times RDP^{1/2} + B)$$

$$PWA = 0.1(SWC-CCL)/S$$

For loamy soils:

$$SWC = A + B \times RDP + C \times RDP^2 + D \times RDP^3$$

$$PWA = 0.1(SWC-CCL)/S$$

where S is the slice of soil in cm

CCL represents the soil water content for which roots cannot extract water from the soil, and is sometimes called the wilting point. For the first few days after a heavy rain or irrigation, water drains from the soil profile until its water content approaches a relatively stable value. When plants have extracted all of the water available to them, the root zone water content approaches the CCL.

We add PWA for the slices of soil represented by the five depths of soil measurements in a soil profile to provide total plant water availability in a soil column (PWAw, PWAs, PWAe for the west, south, and east profiles respectively).

INSTALLATIONS

Figures 10 through *12* show how the STAMP systems were installed. Six holes were dug with an auger, three for the deepest probes and three for the more shallow probes (*Figure 10*). The shallow probes were installed horizontally in the wall of a hole (*Figure 11*), whereas the deep probe was installed vertically in the bottom of its hole (*Figure 12*). Separate holes were used for the deep probe and the shallow probes so that a deep probe can be replaced without disturbing the shallow probes. The horizontal spacing between each pair of profiles is approximately one meter. The deep probe was installed with the use of a PVC conduit tool designed and fabricated by Larry Swords, SGP engineer. The probe cables were run through buried conduit to the data logger enclosure to reduce the likelihood of the cables being chewed by animals.

Figure 10

Figure 11

Figure 12

REFERENCES

[1]Keith Bellingham, "The Stevens Hydra Probe Inorganic Soil Calibrations", Stevens Water Monitoring Systems Inc., available at http://www.soilsensor.com/articles/The%20Stevens%20Hydra%20Probe%20Inorganic%20Soil%20Calibrations.pdf

[2]"BCG Soil Tests Interpretation Workshop Notes", prepared by Brooke White, Cropfacts Pty Ltd., available at www.bcg.org.au/resources/Workshop_notes_2009.pdf

DATA EXAMPLES

Figures 1 and *2* show an example of the soil profile of soil water content and soil temperature at EF13.

Figures 4, 5, and *6* show the difference between the three profiles of soil water content, soil temperature, and plant water availability at 10 cm at EF13. Even though the soil depth is greater for the south profile, the south soil column contains the least total plant available water (see *Figure 3*). Horizontal inhomogeneity is observed at most of the STAMP locations and is normal.

Furthermore, large half hour to half hour variations in soil water content occur for some depths at some sites, as at the 20 and 50 cm depths at SGP EF36 in *Figure 7*. Large variability usually results from the probe having been installed in a more sandy/silty soil, where the measurement technique suffers from the medium being non-continuous (lots of pore space filled with air instead of water). Therefore, we are experimenting with a data logger program modification at EF36 to determine if averaging several measurements during a half hour may reduce the variability in comparison to the single half hour measurement used in the original STAMP program.

A stark difference in soil water available to plants can be seen across the SGP from northwest to southeast. *Figures 8* and *9* show this contrast dramatically, for EF31 Anthony, KS (northwest) and EF40 Pawnee, OK (southeast), reflecting a significant difference in climate between the northwest and southeast corners of SGP.

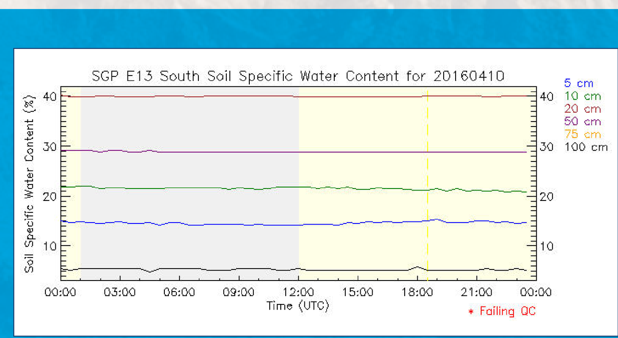

Figure 1

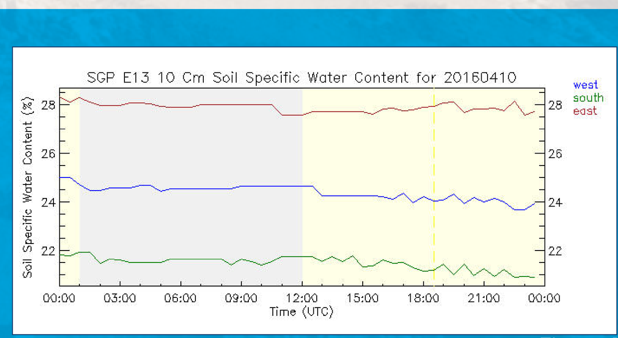

Figure 4

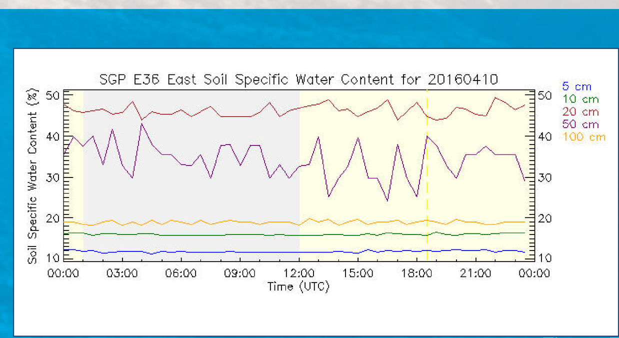

Figure 7

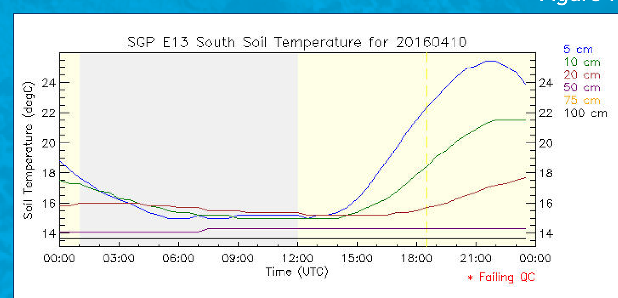

Figure 2

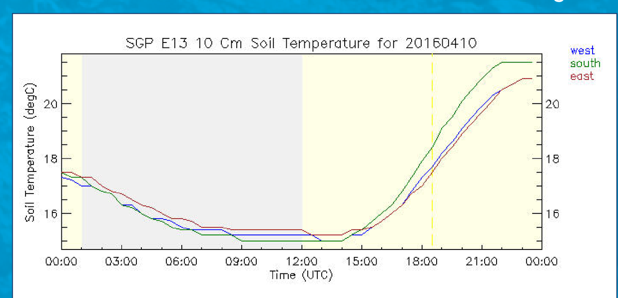

Figure 5

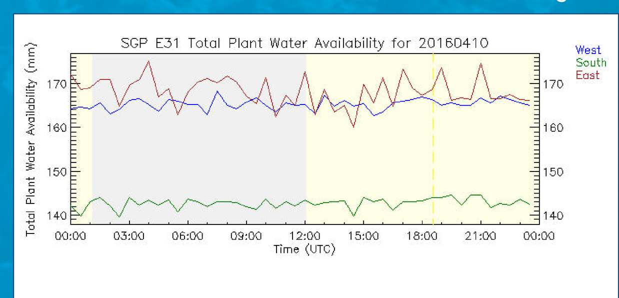

Figure 8

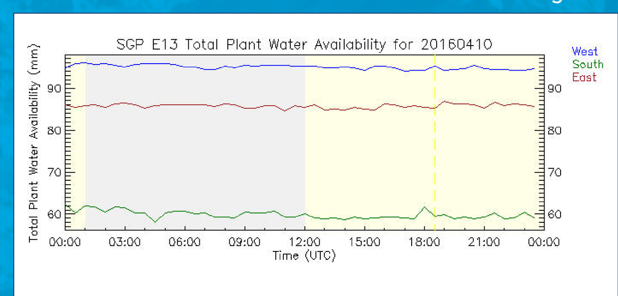

Figure 3

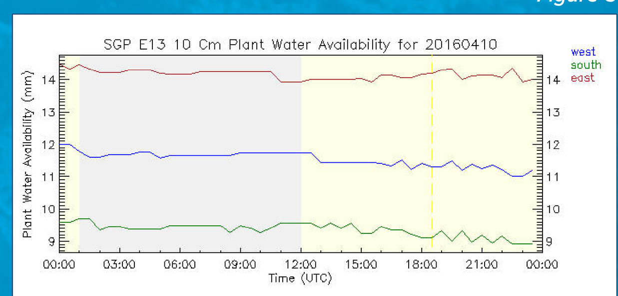

Figure 6

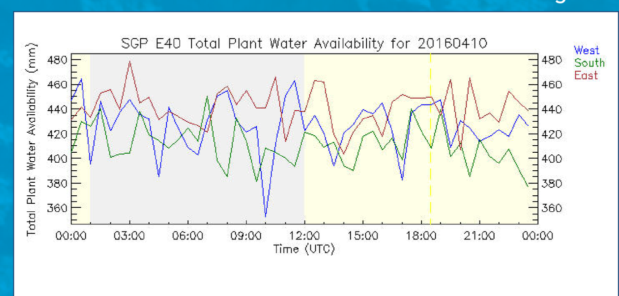

Figure 9

ACKNOWLEDGEMENTS

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