P2.12

COMPARISON OF AGRMET MODEL RESULTS WITH IN SITU SOIL MOISTURE DATA

Cynthia L. Combs*
CIRA/Colorado State University

Dustin Rapp
Colorado State University

Andrew S. Jones
CIRA/Colorado State University

George Mason
Engineer Research and Development Center
Army Corp of Engineers

1. INTRODUCTION

The U.S. Army has operational requirements for soil moisture profiling capabilities using advanced satellite data assimilations techniques. Colorado State University is using a four dimensional variational (4DVAR) data assimilation system that requires quantitative knowledge of the first guess background covariance fields. To evaluate the accuracy of the first guess soil moisture, a statistical analysis of the USAF AGRMET land surface model output was performed.

2. DATA

For the study, the time period of September 1-30, 2003 was chosen. A strong front with associated precipitation crossed the Midwest during the month, allowing a view of soil moisture both before and after a heavy rain event, plus periods of drying. Many locations had two significant rain events during the period.

2.1 *AGRMET Model*

The Air Force Weather Agency's (AFWA) Agricultural Meteorology model (AGRMET) was used in this study(AWFA, 2003). It is a near real-time global land surface analysis model with 47 km resolution. One of its distinguishing features is that it produces a 3 hourly SSM/I rain estimate amounts as one of several sources of estimated precipitation. One of the output products is soil moisture at four soil layer depths: 0-10 cm, 10-40 cm, 40-100 cm and 100-200 cm. In order to compare the model output with the in situ data, a 110 km by 63km grid box was centered over each site and averaged.

2.2 *In situ*

In situ measurement of soil moisture is done by a variety of groups, with different instruments for different purposes. Since it wasn't collected with satellite calibration in mind, we must understand the strengths and limitations of each data set in order to compare properly with our satellite-based results. Thus, at this point we are more concerned with signal response than with absolute calibration or 'truth'.

2.2.1 *Mud Lake*

Mud Lake near Mound, LA, is a site run by the Army Corp of Engineer's Engineer Research and Development Center (ERDC) to measure various soil parameters along with other weather parameters(Mason et al., 2003). This information is used to study their affects on various military equipment, such as tanks and ground sensors. Since our work pertains to their interests, it most closely matches our requirements.

The instrument used at Mud Lake was a Campbell scientific moisture probe #615. It measures the deviation of the return of a transmitted signal which corresponds to soil moisture for a given soil type. The probes were places at depths of 2.5 cm, 15.25 cm and 30 cm. Unfortunately, the 30cm probe not working during period. Soil temperatures were also take at the same depth by a different instrument.

* *Corresponding author address*: Cynthia Combs, CIRA/Colorado State University, W. Laporte Avenue, Foothills Campus, Fort Collins, CO 80523-1375; e-mail: combs@cira.colostate.edu

2.2.2 *Little Washita*

Our second data set is from USDA Agricultural Research Service (ARS) Micronet in the Little Washita creek watershed in southwestern Oklahoma. Measurements of the hydrologic conditions in the watershed have been ongoing since 1961. Surface soil moisture probes were installed during the Summer of 2002 at several of the sites. The instruments used are Vitel Type A Hydra Probes. They determine soil moisture and salinity by making a high frequency (50MHz) complex dielectric constant measurement, which resolves the capacitive and conductive parts of a soil's electrical response. Output is four voltages that can be converted into soil moisture (VWC) and salinity.

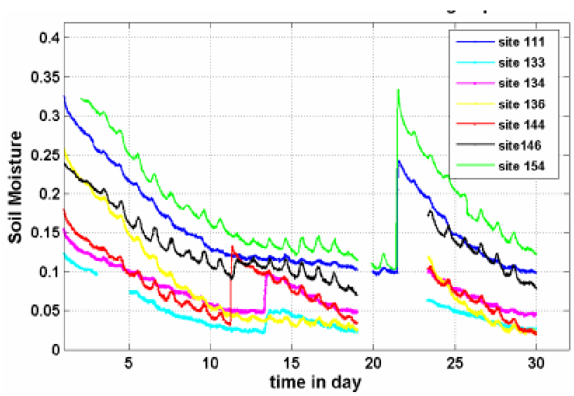

Figure 1: Soil Moisture during September 2003 for Little Washita sties.

Only one depth (5 cm) is measured. Figure 1 shows the soil moisture for seven of the sites. One obvious problem is that there are at least one data gap for each site, the largest one starting on day 19 and for some stations lasting until day 23. Unfortunately, there is a significant rain event with corresponding responses is soil moisture on day 21, which is captured by only two of the sites. It is these two sites (sites 111 and 154) that we will examine more closely.

2.2.3 *Oklahoma Mesonet*

Our third data set is from the Oklahoma Mesonet. This state-wide monitoring network was set up due to the need of OSU agricultural scientists to expand the use of weather data in agricultural applications and the need of OU scientists to plan and implement a flood warning system in Tulsa. Currently, the network has at least one site in each county, measuring a variety of weather parameters.

The instrument used is a Campbell Scientific 229-L sensor. It measures the temperature difference of the sensor before and after a heat pulse is introduced. Equations and coefficients are then provided to convert the temperature difference into soil matric potential, Fractional Water Index (FWI) and Volumetric Water Content (VWC). For physically-based land surface models the more quantitative VWC measure is preferable due to mass transport of water within the soil column. However, there are several more coefficients in the VWC equation, potentially leading to more sources of error. We will keep this in mind as we compare this data with our other data sets.

Soil moisture is measured at each site at depths of 5 cm, 25 cm, 60 cm and 70 cm. The documentation mentions data quality issues at the two lower depths, so we will concentrate on the first two. For this paper, we chose three OK Mesonet sites, BUFF, PAUL and SHAW. They were chosen for their response to the presence of rain and for their potential as satellite retrieval validation sites.

3. COMPARISON AND ANALYSIS

3.1 *AGRMET vs. Mud Lake*

For the single Mud Lake station, we have two measurements depths of 2.5 cm and 15.25 cm, which we will compare to the AGRMET layers of 0-10cm and 10-40cm. Keep in mind that the comparisons are between point measurements and layered, gridded measurements.

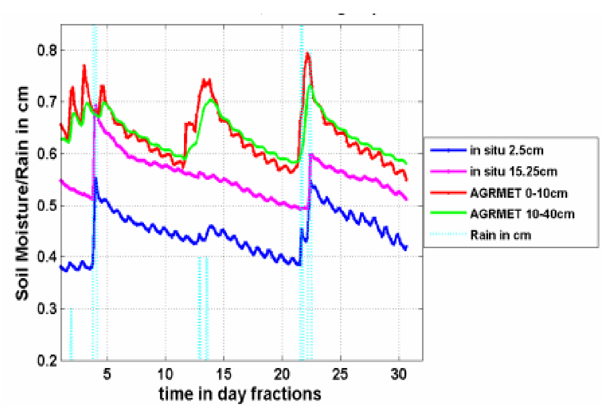

Figure 2: Soil Moisture at Mud Lake, LA during September 2003

Figure 2 is the time series comparison of the Mud Lake soil moisture measurements at two depths(blue and pink) and the corresponding layers of AGRMET(red and green). The cyan dotted line is to show where rain was measured at the site and an indication of how much. There are three significant rain events for the month at this site, on September 3rd (1.6cm), 12-13th (.5 and .5 cm), and 21-22nd (1.1 and 1.8 cm). For all three events, both AGRMET time series show strong responses. The Mud Lake series show strong responses for the first and third event. However, for the second event, the 2.5 cm series shows only a small response, with almost no response at 15.25 cm. This seems more reasonable, since the amount of precipitation is less than half the other two events. It is the AGRMET response that seems overdone.

One reason for this may be due to a difference between the amount of rain measured at Mud lake and how much AGRMET estimated.

3.2 *AGRMET vs. Little Washita*

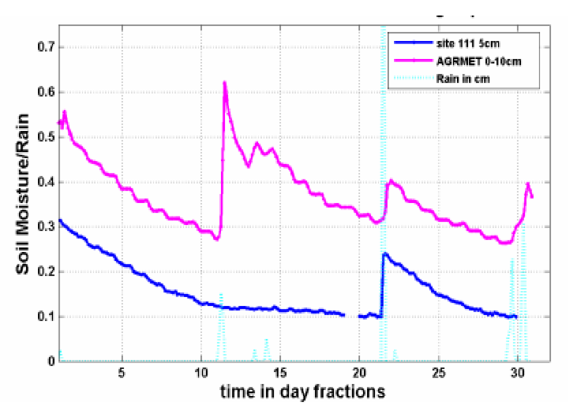

Figure 3: Soil Moisture for Little Washita site 111 during September 2003.

Figure 3 is the soil moisture comparison between Little Washita site 111 at the 5 cm depth (blue) and AGRMET 0-10cm layer (green), and the dotted cyan line is rain. There was two significant rain events during the month that were covered by site 111 data, on September 11th (.3 cm) and 21st (1.52 cm). The first event was much smaller than the second, and site 111 series reflects it. There is no response at 5 cm for the first event, and a large response for the second. However, AGRMET shows a large response for the first event (and additional jumps for even smaller event on the 14th), and small response for the second. The reason for the discrepancy is clear when the rain amounts between site 111 and the AGRMET model is compared (Figure 4). AGRMET sees a much larger rain event on the 11th than was measured at the site, and less rain on the 21st. It is reasonable that this caused the difference in soil moisture between in situ and model. A similar discrepancy is seen at site 154 (not shown).

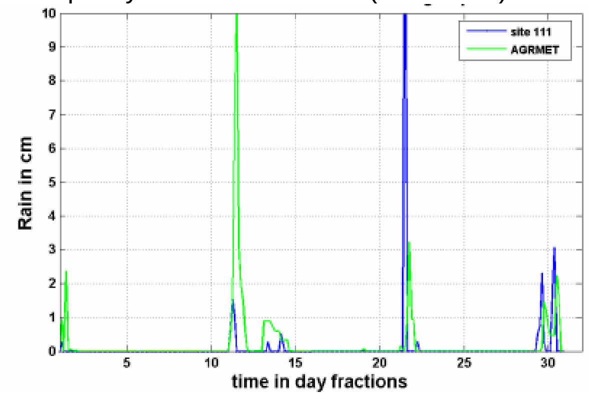

Figure 4: Precipitation amounts for Little Washita site 111 during September 2003.

Alternatively, site 144 picks up a larger rain event for the 11th (Figure 5). Considering the time of year, a convective cell may have passed over the area. Only one site (144) out of seven measured rainfall.

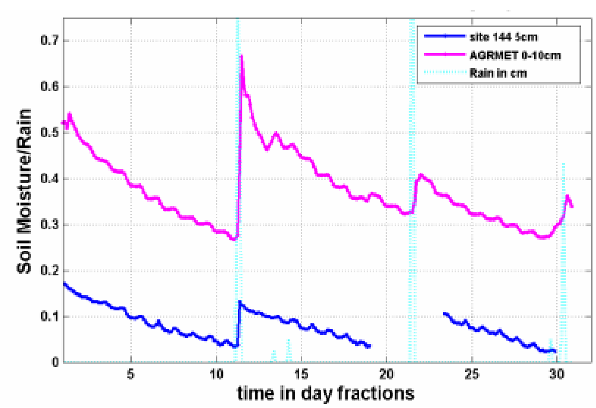

Figure 5: Soil Moisture for Little Washita site 144 during September 2003.

3.3 *AGRMET vs. OK Mesonet*

Figure 6 compares in situ soil moisture at 5 and 25 cm with AGRMET 0-10cm and 10-40 cm for BUFF (near Buffalo, OK). Four main rain events occurred during the month on September 6th (.61cm), 11th (2.44 cm), 21st (1.96 cm) and the 29-30th(1.68 and .99 cm). AGRMET shows good response with all four events, especially the 0-10 cm. The station data response is muted; there is no response for the first event, some response in both 5 and 25 for the other three.

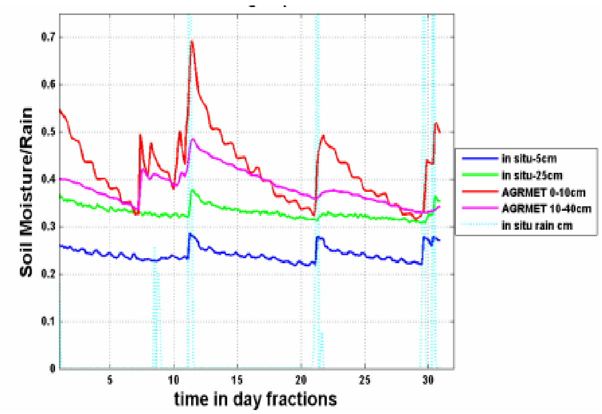

Figure 6: Soil Moisture for station BUFF during September 2003

This is not due to a difference in rain between model and the station. Figure 7 shows the comparison, and the station measured even greater amounts than the model, though slightly off in timing. One factor may be that there was a heavy rain event Aug 31st. The ground probably started off saturated, but that can not account for the lack of drying in between events. This leaves the possibility of unresolved station calibration issues, due to sensor hardware or incorrect calibration coefficients, or possibly equivalent soil texture errors within AGRMET.

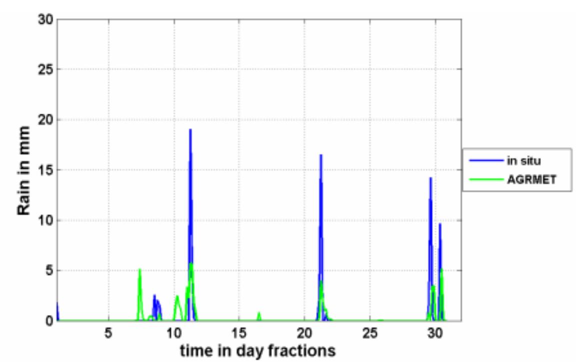

Figure 7: Precipitation over station BUFF during September 2003

Soil moisture for PAUL (Pauls Valley) compares much better to the rain events and AGRMET (Figures 8 and 9). Four significant rain events occurred during the month, on August 31st-September 1 (1.7 and .28cm), the 11th (4.09 cm), 21st (3.68cm), and 30th (.15 cm). There is good response for all of them for both the station and AGRMET.

SHAW (Shawnee) also compares quite well. (Figures 10 and 11). Even the 60 cm depth, which is considered suspect, compares well.

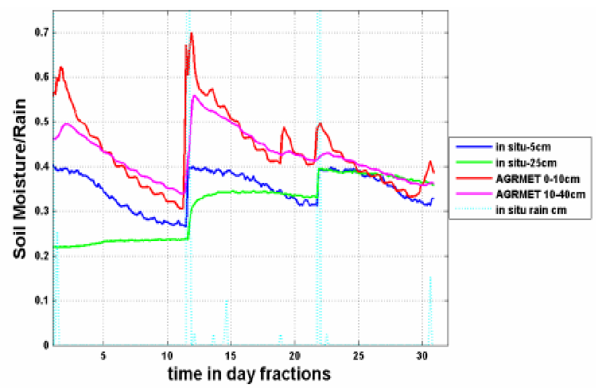

Figure 8: Soil Moisture for station PAUL during September 2003

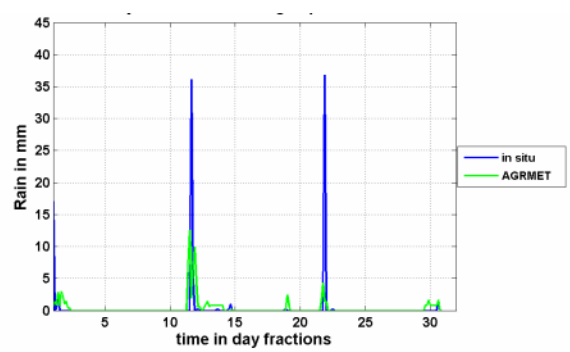

Figure 9: Precipitation over station PAUL during September 2003

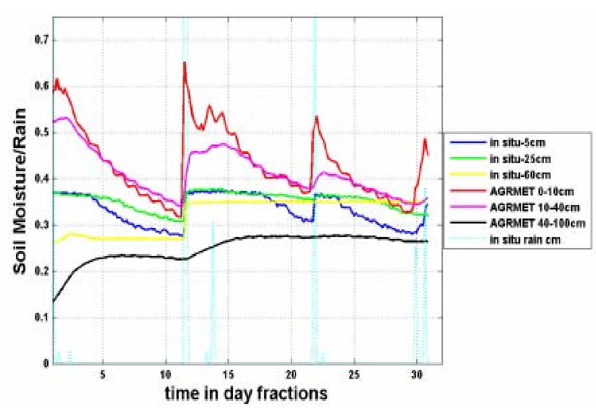

Figure 10: Soil Moisture for station SHAW during September 2003

4. CONCLUSIONS AND FUTURE WORK

We've examined several independent soil moisture in situ systems against the AFWA AGRMET model output. Results indicate a tendency for the AGRMET precipitation estimates to bias the model output. This can result in entire rain events being omitted or added to the AGRMET output. When the AGRMET precipitation estimate is more realistic, the AGRMET soil moisture estimates improve.

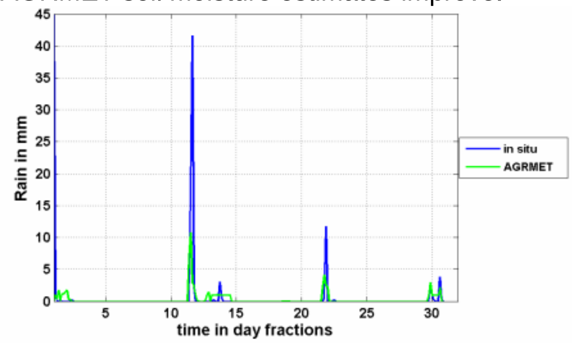

Figure 11: Precipitation over station SHAW during September 2003

Some Oklahoma mesonet sites performed better than others. We suspect that a more detailed calibration effort is needed to reliably use the VWC measurements.

In the future, we intend to perform a more detailed spatial analysis to automate the detection of false signals within a dispersed soil moisture network. This will benefit the efforts to operationalize the spatial calibration needs anticipated for the US Army. In addition, the quantification of covariances will be used to advanced satellite data assimilation experiments (Jones et al. 2007)

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