Monthly Technical Report

(Due to AQRP Project Manager on the 8th day of the month following the last day of the reporting period.)

PROJECT TITLE	Soil Moisture Characterization for Biogenic Emissions Modeling in Texas	**PROJECT #**	14-008
PROJECT PARTICIPANTS **(Enter all institutions with Task Orders for this Project)**	The University of Texas at Austin	**DATE SUBMITTED**	12/8/14
REPORTING PERIOD	**From:** 11/1/2014 **To:** 11/30/2014	**REPORT #**	6

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

Detailed Accomplishments by Task *(Include all Task actions conducted during the reporting month.)*

A comparison has been performed to evaluate the NLDAS-2 Mosaic and Noah soil moisture datasets with available observations. An initial summary of results is provided below:

BEGIN PRELIMINARY RESULTS: Comparison of in-situ soil moisture observations with results from NLDAS-2 land surface models

Dataset description

In-situ measurements of soil moisture from two networks [Soil Climate Analysis Network (SCAN) and the U.S. Climate Reference Network (USCRN)] were used to evaluate the simulation of soil moisture by the NLDAS-2 land surface models Mosaic and Noah. **An evaluation of two additional NLDAS-2 land surface models is on-going: (1) Noah with Multi-Parameterization (Noah MP) and (2) Variable Infiltration Capacity (VIC).** The evaluations were performed within the 12km grid domain that covers Texas and surrounding states for years 2006-2013. The observed soil moisture datasets provide measurements along vertical soil columns between the surface and one meter in depth typically at 5, 10, 20, 50, and 100cm.

Initially, all available in-situ measurements for Texas, Oklahoma, New Mexico, Louisiana, Arkansas, Mississippi and eastern Tennessee were retrieved; in total, 84 individual monitoring locations collected data for at least a portion of 2006-2013 but the data completeness varied substantially between locations. For example, USCRN was not commissioned until 2009; therefore, data measurements are often unavailable until late 2009 or early 2010 at USCRN locations. SCAN has a longer history; however, data completeness still had substantial variability between sites and years. Sites are sometimes retired, new locations added, or measurements at one or more depths became unavailable. For the preliminary analysis presented here, sites were selected that had at least one year of measurements at 100cm during 2006-2013; this criteria identified 36 SCAN sites and 18 USCRN sites (ref. Figure 1).

The NLDAS-2 Mosaic and Noah land surface models simulate soil moisture between the surface and 200cm. To compare the NLDAS-2 modeled soil moisture contents with the in-situ measurements, the modeled values were extracted at the NLDAS-2 grid cell node nearest to the individual SCAN and USCRN site locations. The NLDAS-2 grid cells are 1/8th degree; this horizontal spatial resolution is sufficient to represent the soil moisture at the point measurement location.

Data resampling, interpolation, and handling for missing values

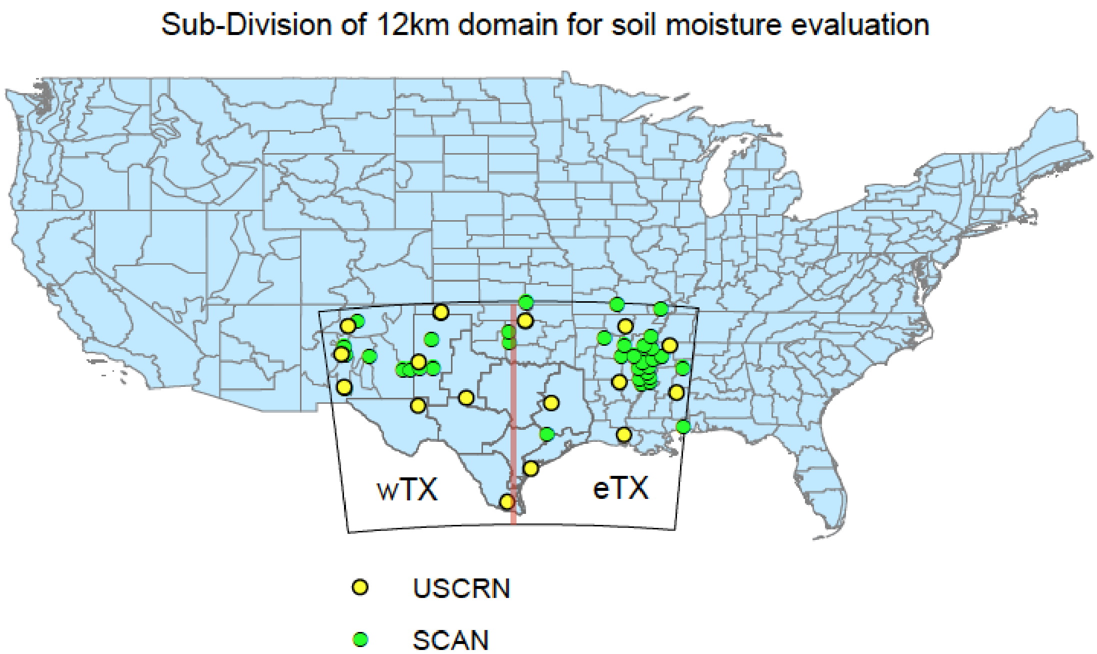
The original dataset for SCAN, USCRN, and NLDAS-2 are available at hourly resolution. To reduce the size of datasets as well as CPU processing time, the hourly data were resampled at a daily time resolution by utilizing 00 UTC values. Because the diurnal variation of soil moisture is minimal, once-per-day sampling is sufficient to capture seasonal and inter-annual variation for comparison between the modeled and in-situ measurements. At each monitoring locations, the NLDAS-2 values were only processed when a valid (paired) observation was available to ensure consistency of sampling between the measured and modeled datasets.

A direct comparison of soil moisture between observations and predictions is not possible because the measurements are made at depths that differ from the NLDAS-2 configurations. The NLDAS-2 models simulate the average water availability within vertical layers of soil, i.e., 0-10, 0-40, 0-100, 0-200, 10-40, and 40-200cm for Mosaic and 0-10, 0-100, 0-200, 10-40, 40-100, and 100-200 for Noah. In order to compare volumetric soil moisture values between observations and predictions, the NLDAS-2 values were linearly interpolated to convert to measurement depths. The depth at the middle of each NLDAS-2 layer was used in support of the interpolation, i.e. 5, 25, 70, and 150cm for 0-10, 10-40, 40-100, and 100-200cm layers, respectively. The NLDAS-2 values were then linearly interpolated to the 5, 10, 20, 50, and 100cm measurement depths.

Calculation of soil moisture anomaly

Because of the sometimes large biases between model simulations and in-situ measurements as demonstrated in previous monthly technical reports, a soil moisture anomaly was calculated to better compare the interannual variability in soil water contents. This was achieved by subtracting a reference value that represents the background (i.e., long-term average) soil moisture. The reference value was calculated as the mean across all years (2006-2013) for the same calendar day from day 1 to day 365 (and to day 366 if a leap year). The soil moisture anomaly for each day was calculated as the departure of its absolute magnitude from the corresponding reference value. A positive anomaly then indicates above-average water availability, while a negative anomaly is a potential signal of drought. This processing methodology can remove the large bias arising from the background moisture content and its underlying seasonal cycle, both of which are primarily controlled by precipitation and land cover type, allowing for a more targeted focus on interannual variability.

Figure 1. Soil Climate Analysis Network (SCAN, green circles) and U.S. Climate Reference Network (USCRN, yellow circles) site locations utilized for the NLDAS-2 evaluation. For the purposes of analysis, the 12km grid domain (in black) was divided into eastern and western sections along -98° longitude.



Spatial subdivision

To obtain some quantification of the east/west spatial gradient of soil moisture, the 12km grid domain was divided into two sub-regions along -98° longitude (ref. Figure 1). This longitude roughly splits the region into two contrasting precipitation regimes: annual average precipitation in the eastern region is typically > 30 inches compared to 0-30 inches in the west. The eastern region has a generally denser vegetation cover (forest, woodland, and cropland) while semi-desert (shrubland/grassland) dominates the west. Within each region, the comparison of measurements and predictions was performed by first calculating results at each measurement location followed by an averaging of results across all site locations within the region.

Results

<u>Seasonal variability</u>: Overall, NLDAS-2 captures the directional seasonal variability of observed soil moisture (ref. Figure 2). For the eastern region, both measurements and simulations show relatively large moisture contents in winter and spring (to a lesser degree) and lowest water availability in summer. This seasonal pattern holds at all soil depths, but the near-surface layers exhibit a larger seasonal variation (ref. Figure 3). In the west, the soil moisture contents are <50%, on average, compared to those in the east. Moreover, water availability is more evenly distributed among different seasons (ref. Figure 2) especially at the deeper soil layers (ref. Figure 4). The Mosaic model has better agreement with observations at all layers for all seasons across

both regions, while Noah tends to underestimate soil moisture in the east but overestimates in the west especially in the top soil layers.

Vertical variation: There is a gradual increase of observed soil moisture with increasing depth in the east (ref. Figures 2 and 3); however, the NLDAS-2 moisture contents show lower variability leading to a large underestimation of soil moisture values at the 50 and 100cm depths. The seasonal variations with respect to depth are also different, seasonal differences in observed soil moisture decay with increasing depth while modeled soil moisture maintains a similar seasonal variation across all depths (for example, ref. Figure 3, left panel, 100cm) especially for Noah. In the west, measurements show that soil moisture values increase with respect to depth though the magnitude is less than that shown for the east (ref. Figure 4, left panel). There is strong fluctuation in the near-surface measurements (e.g., 5 and 10cm) similar to the eastern region; soil moisture for the deeper layers shows relatively low variability except during significant rain events. The Mosaic model simulates a similar magnitude of soil moisture to observations for the near-surface layers while Noah overestimates by about a factor of two. At deep soil layers, NLDAS-2 soil moisture remains stable and is less affected by precipitation events.

Spatial gradient: The western soil moisture contents are about half those in the east (ref. Figure 2). This is likely related to both higher precipitation in the east as well as the associated dense vegetation (e.g., primarily forests) that can hold more water within the soil. Mosaic generally captures the spatial gradient as observed, but Noah fails to simulate the east/west contrast, especially in the top soil layers (<=20cm). At deeper soil layers, neither Mosaic nor Noah fully simulates the east/west spatial variation.

The performance of year 2011: Across the 12km grid domain and all soil depths, soil moisture values during 2006-2013 were generally minimal during 2011 except for the near-surface layers during winter (ref. Figure 2). This may be related to late fall and winter rains that can quickly moisten upper soil layers, while it takes substantial and repeated rainfall to replenish soil moisture at deeper layers.

Interannual variability: The overall bias in soil moisture values simulated by NLDAS-2, especially for Noah, makes it difficult to assess interannual variability. Results for the soil moisture anomaly (ref. Figures 3 and 4, right panels) show that the models generally reproduce the interannual variability of observed soil moisture, with the exception of deep layer soil moisture in the west. In the east, both observations and predictions show a large moisture deficit beginning in late 2010 and persisting through 2011. Near-surface soil moisture values slowly recover and deep soil moisture is not restored to average levels until late 2013 (ref. Figure 3). In the west, large water deficits in both observations and NLDAS-2 values began during summer 2011 within the near-surface layers (>=20cm, ref. Figure 4); however, observed soil moisture shows greater fluctuations compared to the NLDAS-2 patterns for the deeper soil layers. The deep soil moisture anomalies remain negative throughout 2013 suggesting that water contents have not yet returned to normal.

Figure 2. Seasonal comparison of in-situ measurements (OBS) and NLDAS-2 predictions (Mosaic and Noah) for the east and west portions of the 12km domain (ref. Figure 1). Seasons are defined as January-February-March (JFM), April-May-June (AMJ), July-August-September (JAS), and October-November-December (OND). To account for missing measurements (i.e., data gaps), the average values use all daily soil moisture contents during 2006-2013 only when an observation is available. Error bars show the maximum and minimum values during 2006-2013; the values for 2011 are labeled using a white circle.

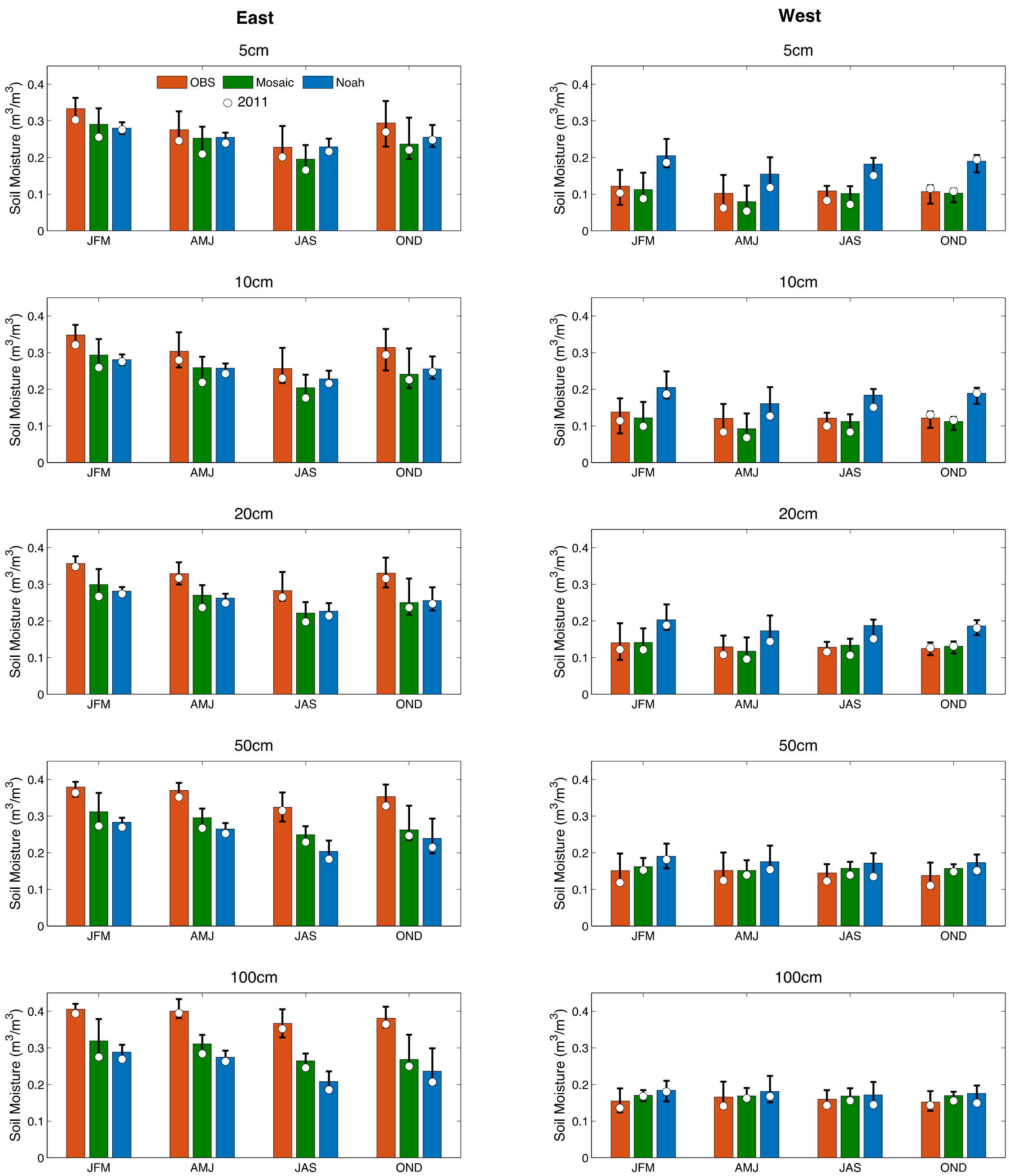
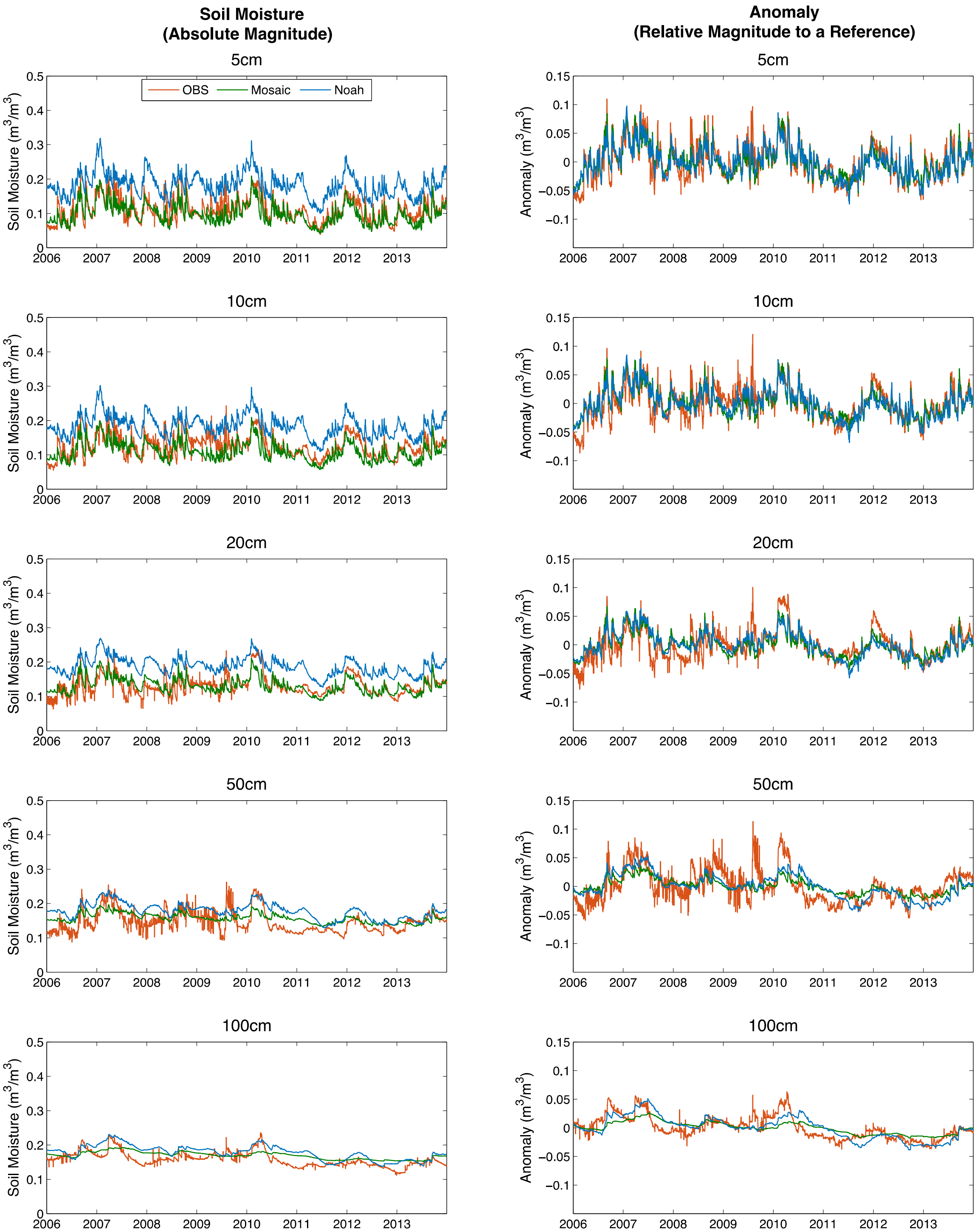


Figure 3. Average daily soil moisture by depth during 2006-2013 for the eastern region of the 12km domain. The left panels show the absolute soil moisture values; right panels display the soil moisture anomalies relative to the mean for each calendar day using all values during 2006-2013.

Figure 4. As in Figure 3, but for the western portion of the 12km domain.



Preliminary Analysis (*Include graphs and tables as necessary.)*
A comparison of available in-situ soil moisture observations with Mosaic/Noah predictions has been performed as summarized in the previous section. Efforts to expand this analysis to include Noah MP and VIC are on-going.

Data Collected *(Include raw and refine data.)*
NLDAS-2 Mosaic, Noah, Noah MP, and VIC datasets have been retrieved and processed for years 2006-2013. Work during December 2014 continuing through January 2015 will compare results between these four datasets with an emphasis on interannual and seasonal variability within the 12km MEGAN grid domain. Preliminary results of this comparison for Mosaic and Noah are planned for the January 8, 2015 technical report.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments
None this period.

Goals and Anticipated Issues for the Succeeding Reporting Period
We continue to test MEGAN simulations that utilize NLDAS-2 datasets to predict hourly isoprene emissions for Apr-Oct for years 2006, 2007, and 2011. We selected year 2007 (wet) and 2006/2011 (drought) to contrast the sensitivity of predicted isoprene emissions to interannual variability in meteorology and soil moisture as well as to study the impact caused by differences in the absolute soil moisture values predicted between the NLDAS-2 datasets.

Detailed Analysis of the Progress of the Task Order to Date *(Discuss the Task Order schedule, progress being made toward goals of the Work Plan, explanation for any delays in completing tasks and/or project goals. Provide justification for any milestones completed more than one (1) month later than projected.)*
Ongoing.

Submitted to AQRP by:

Principal Investigator: Elena McDonald-Buller

(Printed or Typed)