Evaluation of In-Situ Soil Moisture Metrics to Monitor Hydrological Conditions

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Introduction

Interpretation of soil moisture observations can be challenging due to local variability. Observations of soil moisture conditions during one of the most wide-spread droughts in U.S. history does not convey information about ongoing drought conditions (Fig. 1a). However, if soil moisture data were presented in a relative context to typical soil moisture conditions soil observations may be more meaningful. Provided a long enough time series, an inter-annual mean can provide context to current observations (i.e. how dry or wet is the soil?). Quiring et al. (2015), notes that 3-5 years of data can explain 85% of the soil moisture distribution. The U.S. Climate Reference Network (USCRN), with 6 to 7+ years of data (Bell et al. 2012), were standardized using an inter-annual approach. Apart from improved spatial interpretation (Fig. 1b), how well do these observations compare to the U.S. Drought Monitor (USDM) and other hydrological indices?

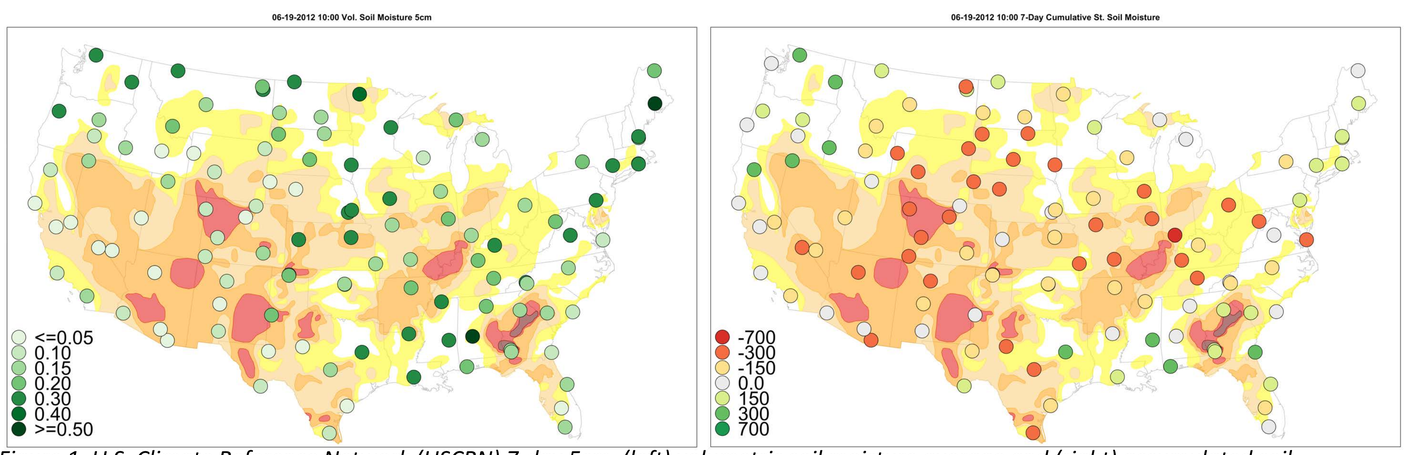

Figure 1. U.S. Climate Reference Network (USCRN) 7-day 5cm (left) volumetric soil moisture average and (right) accumulated soil moisture anomaly overlaid U.S. Drought Monitor categories for June, 19th 2012*

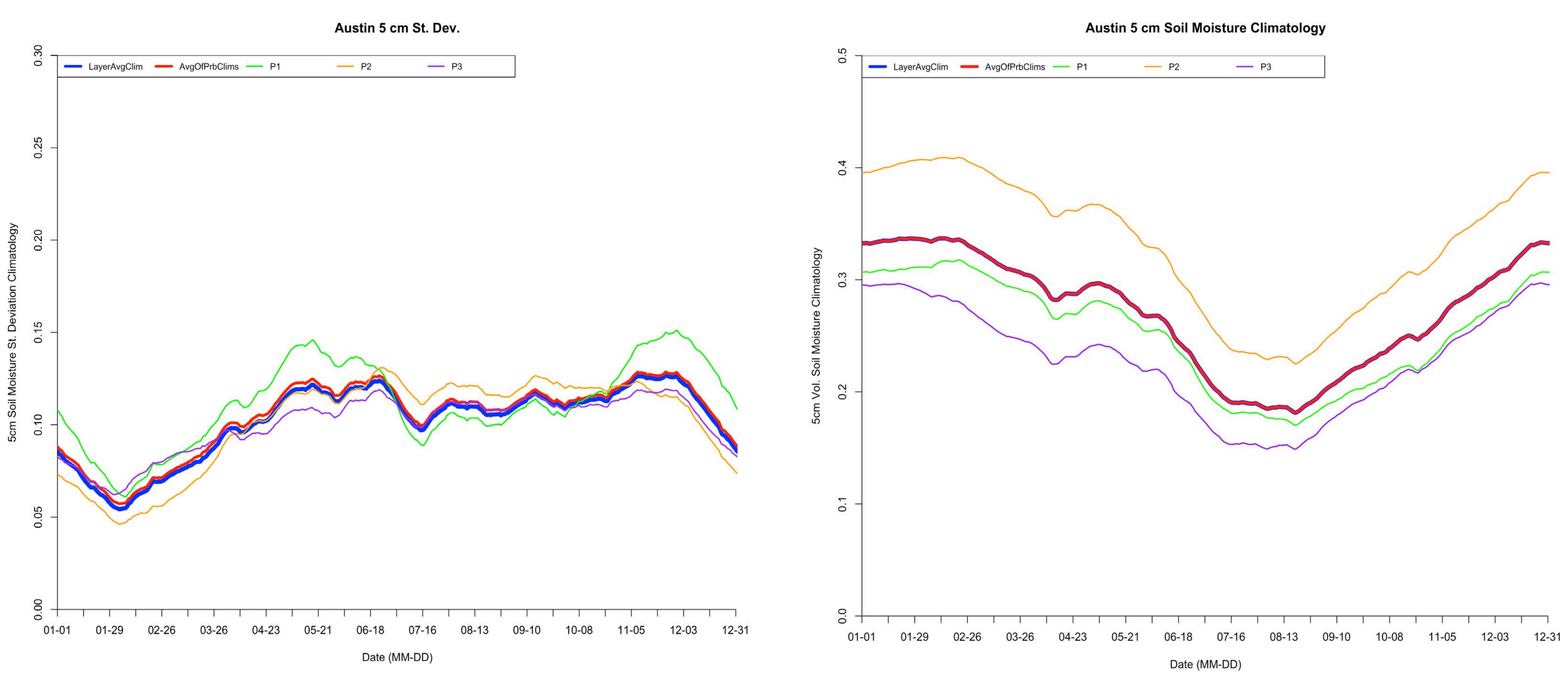

Figure 2. USCRN station in Austin, TX 5 cm inter-annual (left) standard deviation and (right) mean soil moisture for each of the five probes and layer average

Methodology

At each station, an internal annual mean and standard deviation was evaluated over the period of record (Fig. 2). The inter-annual variables are then smoothed over a 60-day moving window to lessen precipitation spikes. A minimum of 3 years was required to evaluate inter-annual mean and standard deviation, which often excludes northern stations over the winter season when soils are frozen.

Soil moisture anomalies were evaluated with respect to the inter-annual mean, and standardized by dividing through by the inter-annual standard deviation. Standardized anomalies were accumulated or averaged to provide information about soil moisture conditions over short (days to weeks) or long (months to seasons) durations. These metrics were compared against the USDM and precipitation indices: the standardized precipitation index (SPI) and the standardized precipitation and evapotranspiration index (SPEI).

Results

Comparisons with the USDM revealed that short cumulative durations can be provide context when monitoring meteorological drought conditions or drought trends (i.e. drought moderation or further degradation). Longer durations (annual) may be more suitable for drought severity or hydrological drought conditions (Fig. 3). For instance, longer term cumulative anomalies are better aligned with moderate to severe drought regions. However, the shorter 7-day cumulative period is more similar to drought change classifications such as those stations in NM (improvements) and the Southeast (degradation). Drought indices based on precipitation (SPI and SPEI) are more variable from month to month (Fig. 4) than mean standardized soil moisture anomalies, which is likely a reflection of soil moisture persistence (i.e. temporal autocorrelation). In addition, the timing of precipitation within the month (toward the end) may result in timing offsets between SPEI/SPI and standardized soil moisture. Overall, trends in SPEI, SPI and soil moisture anomalies were similar over time, despite the much shorter soil moisture period of record.

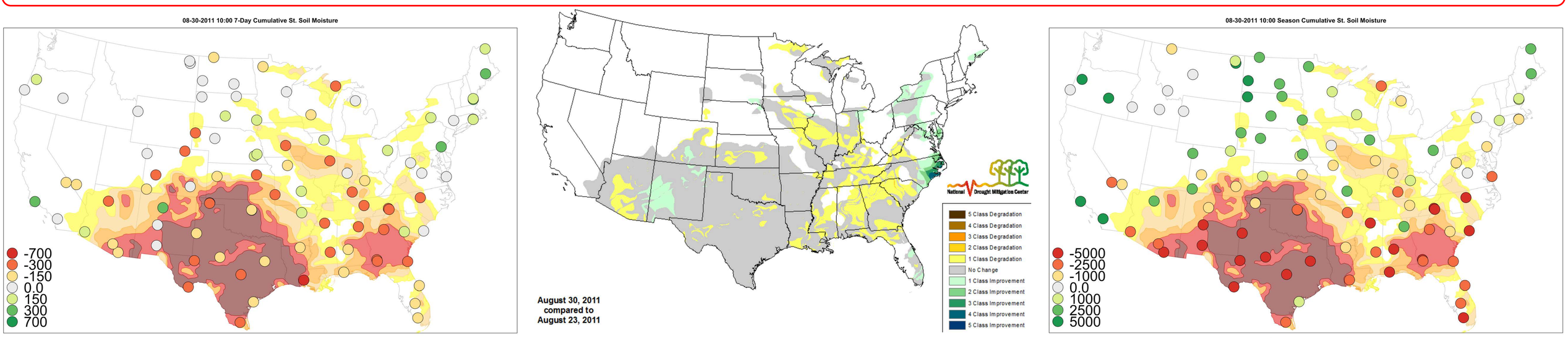

Figure 3. USCRN 5 cm 7-day (left) and seasonal (right) cumulative standardized soil moisture anomaly over laid on USDM regions for August 30th 2011. Drought classification changes between August 23rd and the 30th 2011 (center) illustrate drought moderation in NM and degradation in the Southeast.*

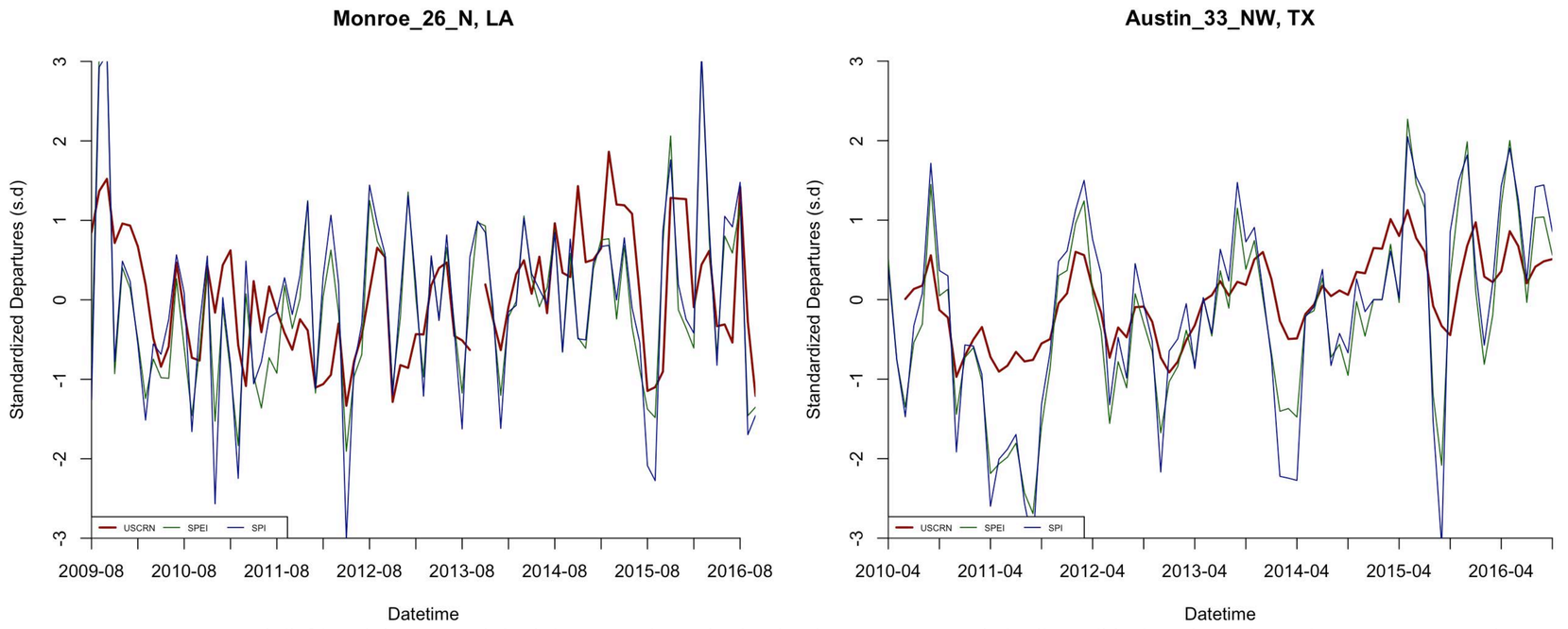

Figure 4. USCRN one-month (left) and three-month (right) averaged standardized soil moisture anomaly (red), SPI (blue), and SPEI (green) at Monroe, LA and Austin, TX respectively.

Conclusions

- Standardizing soil moisture observations improved the interpretation of drought extent across the U.S. using soil moisture data
- Short term cumulative anomalies paired well with changes in drought monitor classification where as longer periods aligned with the drought monitor status.
- Precipitation drought indices (SPI and SPEI) were more variable from month to month than soil moisture anomalies.
- Trends in the 6-7 year based standardized soil moisture anomalies were similar to 30 year based SPEI and SPI indices

References

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**The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.*

Acknowledgements

Leeper and Bell were supported by NOAA through the Cooperative Institute for Climate and Satellites - North Carolina under Cooperative Agreement NA14NES432003.