Analysis of Soil Moisture Metrics to Assess Societal Risks to Hydrological Extremes

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Introduction

Soil moisture is a fundamental component of the hydrological cycle with broad implications across agricultural, health, and economic sectors (Seneviratne et al. 2010). This is particularly true during hydrological extreme events where overly dry or abundantly wet soil conditions (droughts and floods) elevate societal risks and environmental degradation. Unfortunately, available stations monitoring soil moisture conditions are challenging to interpret due to differences in sensing technology, reporting depths, and station placement (i.e., soil type, topography, etc; Fig. 1). However, standardizing soil moisture observations can alleviate these biases and enrich decision makers' interpretation of current soil conditions to lessen societal vulnerability to hydrological extremes.

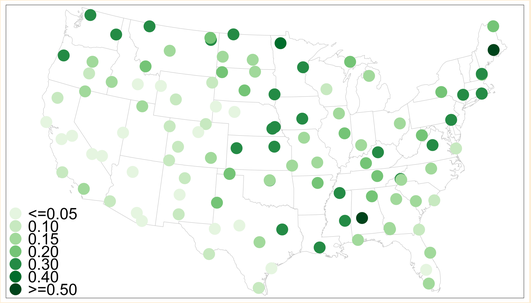

Figure 1. U.S. Climate Reference Network (USCRN) seven averaged 5cm volumetric soil moisture ending on June 19th 2012, during one the most intense droughts in U.S. history

Methodology

Soil moisture observations from the U.S. Climate Reference Network (USCRN) were used in this study to analyze two hydrologically extreme events affecting the Southeast and the Carolinas (Diamond et al. 2013, Bell et al. 2013). These events include the 2011-2012 drought, 2013 floods in the Southeast, and Hurricane Joaquin. Evaluations of extremes will focus on how standardized observations of soil moisture conditions and associated metrics improve the assessments of soil moisture conditions.

Soil moisture observations were standardized by subtracting a seasonally adjusted period of record mean and dividing through by the standard deviation over the same period. This analysis was applied to hourly observations from each station independently. Hourly standardized anomalies were then averaged over weekly timescales corresponding to drought monitor releases for comparison purposes.

Results

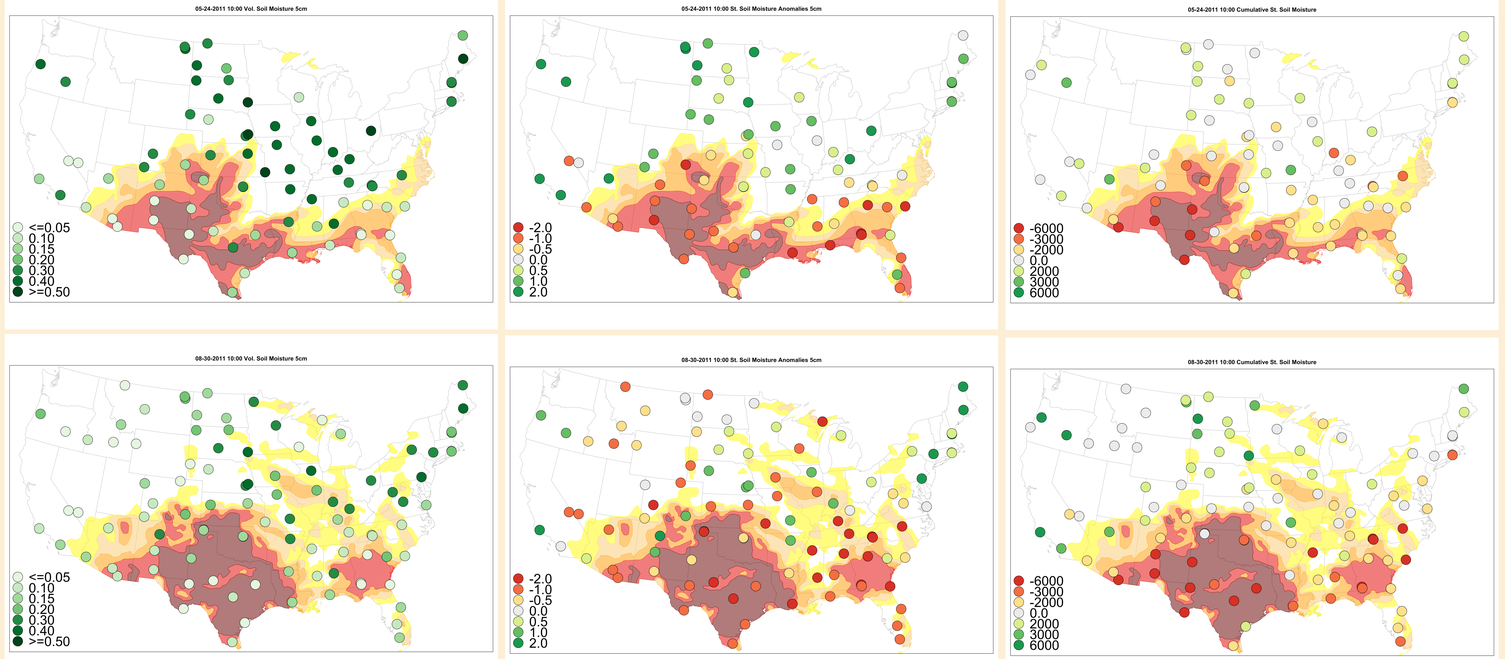

Figure 2. USCRN seven day averaged 5cm (left) unstandardized volumetric soil moisture, (middle) standardized soil moisture, and (right) annual cumulative standardized soil moisture for the week ending (top) May, 24th 2011 and (bottom) Aug. 30th 2011 representing established and peak drought conditions during the 2011 Southern U.S. drought. Station observations are overlaid on U.S. Drought Monitor regions experiencing

Comparisons of USCRN station soil moisture conditions indicate that standardized volumetric soil moisture observations are better aligned with the U.S. drought monitor than unstandardized measurements (Fig. 2). This was more true for the onset of drought (top left and middle) than at peak of drought (bottom-right and middle). For instance, anomalously wet conditions in NM over the Jun. 30th 2011 week were not enough to alleviate the severe drought conditions. Annual accumulations of weekly mean standardized soil moisture conditions can provide a longer term perspective of soil conditions (figure2 right most panels) that better aligns with drought timescales, which in this case confirms the three NM stations are still fairly dry over for the year.

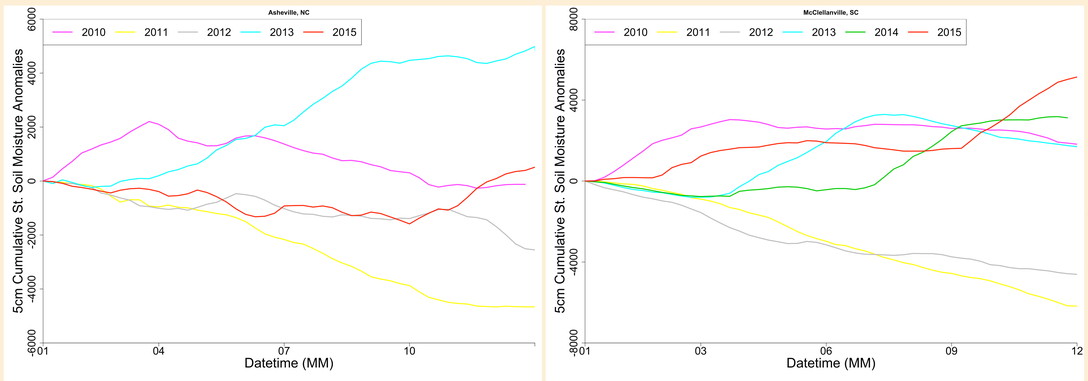

Figure 3. Annual accumulation of standardized soil moisture for years with at least 51 reporting weeks for (left) Asheville, NC and (right) McClellanville, SC stations.

Time series of accumulated standardized soil moisture reveal instances stations were impacted by hydrological extremes (Fig. 3). The Southeast 2011 through 2012 drought are prominently the driest years on record for both NC and SC stations. However, it seems the McClellanville, SC station was impacted by more severe drought conditions over a longer period of time (2011 and 2012) than the NC station. The wettest years on record for both stations coincide with flooding events. The Southeast floods of 2013, which impacted both stations, and Hurricane Joaquin that setup an atmospheric river over the SC coast in early Oct. help setup 2013 and 2015 as the wettest years on record for the NC and SC stations respectively.

Preliminary Conclusions

- Standardizing soil moisture observations improve the interpretation of soil moistures conditions; how wet or dry is the soil?
- Standardized soil moisture observations were better aligned with US Drought Monitor assessments of the 2011 drought.
- Standardized metrics enhanced spatial assessments of soil moisture conditions, which would be useful when considering the extent of extreme hydrological events (wet or dry).
- Averages of standardized soil moisture observations provide a measure of soil moisture trends over a specified period of time.
- Accumulations of standardized soil moisture observations offer an aggregate sense of soil conditions are over a period of time, which may prove useful when assessing drought recovery or flood vulnerability.

Future Work

- Explore approaches that integrate soil moisture observations from multiple depths over the soil column.
- Fit empirical cumulative distribution functions to the standardized soil moisture observations for assessments of soil moisture percentiles.
- Examine the sensitivity of standardized soil moisture metrics to station record length.
- Compare standardized soil moisture observations and associated metrics with other metrics commonly used to monitor hydrological extremes such as the Palmer Drought Severity Index (PSDI).

References
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