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Evolution of 2016 drought in the Southeastern United States from a Land surface modeling perspective

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ABSTRACT

The Southeastern United States (SEUS) climate region experienced a marked transition from excessively wet conditions early in 2016 to an exceptional drought during the Autumn. The unusually warm and dry conditions led to numerous wildfires, including the devastating Gatlinburg, Tennessee (TN) firestorm on 28–29 November. The evolution of soil wetness anomalies are highlighted through soil moisture percentiles derived from an instance of NASA's Land Information System (LIS). A 33-year soil moisture climatology simulation combined with daily, real-time county-based distributions illustrate how soil moisture began above the 96th percentile early in 2016, and declined to below the 2nd percentile in many locales by late November.

Introduction

A combination of three-month mean temperatures of 3–4 °C above normal coupled with very little rainfall led to a rapid intensification of drought over the SEUS from September to November 2016. The drought culminated in numerous wildfires during November, including the tragic firestorm in Gatlinburg, TN on 28–29 November, resulting in $500 M + in property damage and the deaths of 14 persons. This micro article documents the rapid intensification of the SEUS Autumn drought by presenting regional and local soil moisture percentiles, which are derived from a high-spatial-resolution, real-time instantiation of the NASA LIS [1], as configured and managed by the NASA Short-term Prediction Research and Transition (SPoRT) Center (hereafter "SPoRT-LIS"; [2,3]). The objective is to illustrate the evolution of modeled soil moisture leading up to a rapid drought onset and significant wildfire event. By applying a relatively long-term/high-resolution modeled soil moisture database with real-time output, we aim to demonstrate the potential utility of such a tool for enhanced drought and wildfire situational awareness, and form the basis for future wildfire decision support.

Method and datasets

The SPoRT-LIS is an observations-driven, real-time simulation of the Unified Noah land surface model [4] over a full Contiguous U.S. (CONUS) domain, providing soil moisture estimates at ~3-km grid resolution over a 2-meter deep soil column. The basis of the SPoRT-LIS is a 33-year soil moisture climatology simulation spanning 1981–2013 and extended to the present time, forced by atmospheric analyses from the operational North American Land Data Assimilation System-Phase 2 [5]. The 33-year climatology comprises daily histograms of 0–2 m relative soil moisture (RSM; ratio of volumetric soil moisture between wilting and saturation points for a given soil texture) for every county in the CONUS, resulting in $\sim 10^6$ unique soil moisture distributions. Real-time percentile maps are generated using current soil moisture values at a given model point in relation to the daily county distributions from 1981–2013. Proxy U.S. Drought Monitor (and analog wetness) categories are represented by threshold percentiles used within the drought community (Fig. 1 caption and color bar; described further in [6]).

Results and discussion

Year 2016 began quite wet in the SEUS due to heavy rainfall and flooding from December 2015. The 0–2 m RSM exceeded the 95th percentile across many parts of the SEUS on 1 January 2016, but substantially dried throughout the Spring to below the 20th

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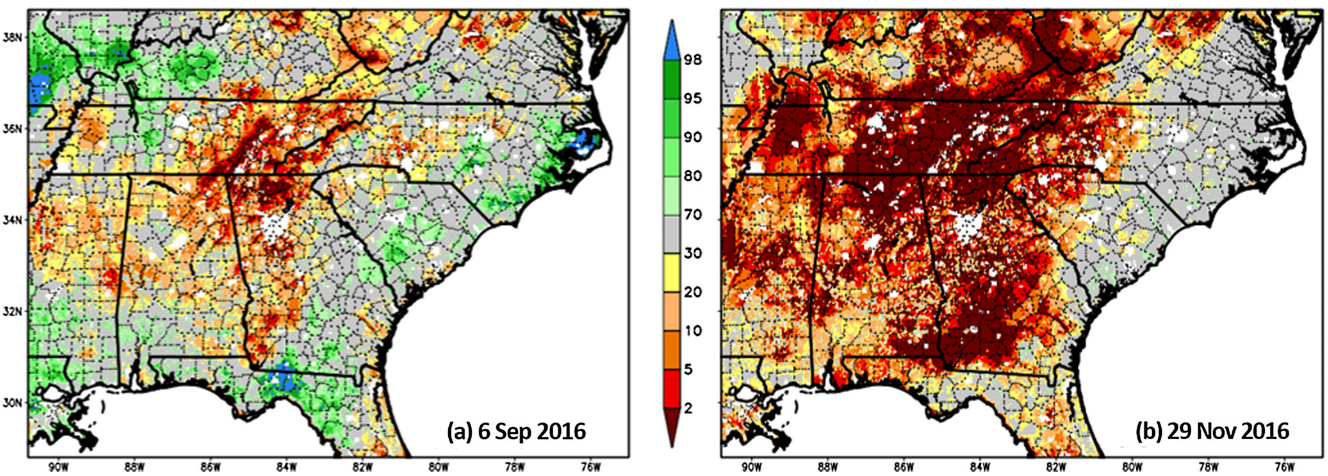

Fig. 1. SPoRT-LIS 0–2 m RSM percentiles during 2016 valid (a) 6 Sep, and (b) 29 Nov. Following [6], drought categories (see Fig. 2) are given by: D4 (≤2%); D3 (≤5%); D2 (≤10%); D1 (≤20%); D0 (≤30%).

percentile across northern Alabama (AL), Georgia, and central/eastern TN (not shown). Soil moisture rapidly declined over a large portion of the SEUS during the Autumn (Fig. 1) when a combination of above-average temperatures and little rainfall led to soil moisture falling below the 2nd percentile of the 1981–2013 climatology by late November (Fig. 1b). The expanse and intensity of the weekly U.S. Drought Monitor product categories markedly increased from early September (Fig. 2a) to late November (Fig. 2b), showing a strong correspondence to the patterns of SPoRT-LIS soil moisture percentiles in Fig. 1.

Using Madison County, AL [Huntsville] and Sevier County, TN [Gatlinburg] as representative localities, county-averaged soil moisture began the year above the 96th percentile in both counties on 1 January. The soil moisture then rapidly declined relative to historical values during two periods in the Spring (Mar-Apr) and Autumn months (Sep-Nov; Fig. 3). Dry soil moisture anomalies were most severe in late November immediately preceding the Gatlinburg firestorm on 28–29 November. The county-averaged SPoRT-LIS soil moisture percentiles across Sevier County, TN reached a minimum of less than 3% on 28 November and an aston-

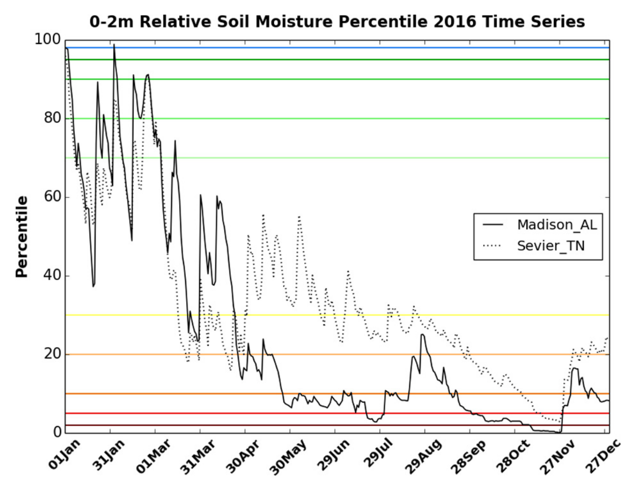

Fig. 3. Time series during 2016 of daily 0–2 m RSM percentiles for Madison County, AL (solid) and Sevier County, TN (dotted). Horizontal reference percentile lines are plotted at 2, 5, 10, 20, 30, 70, 80, 90, 95, and 98 values using the color scale of Fig. 1.

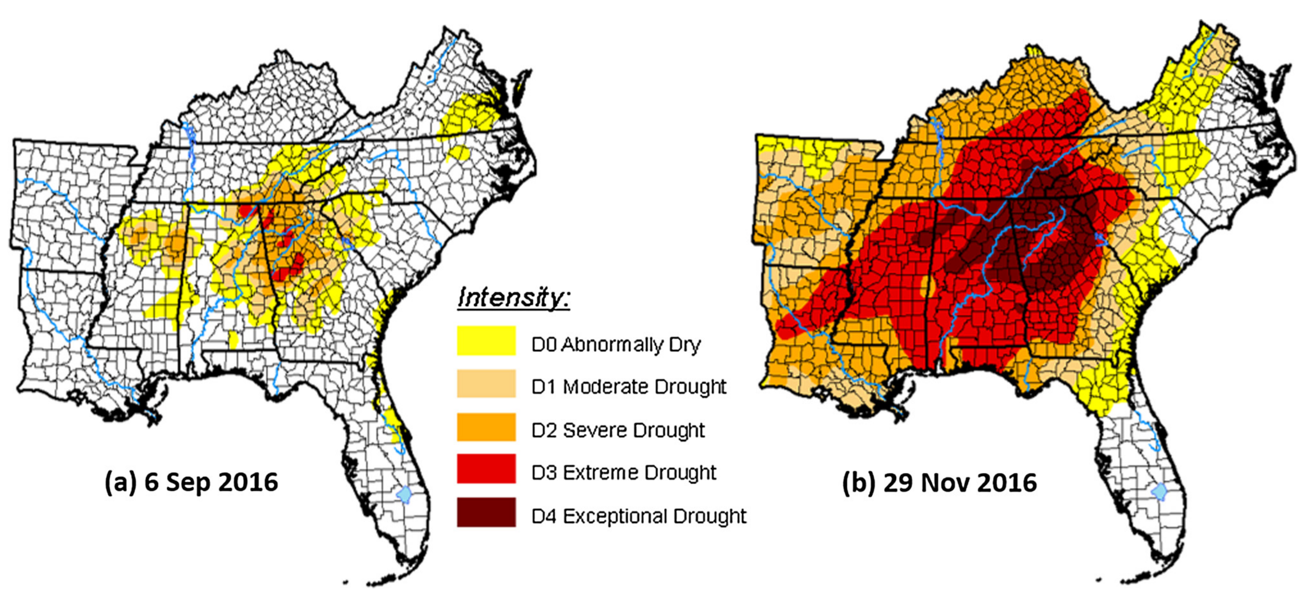

Fig. 2. U.S. Drought Monitor product valid (a) 6 Sep, and (b) 29 Nov 2016.

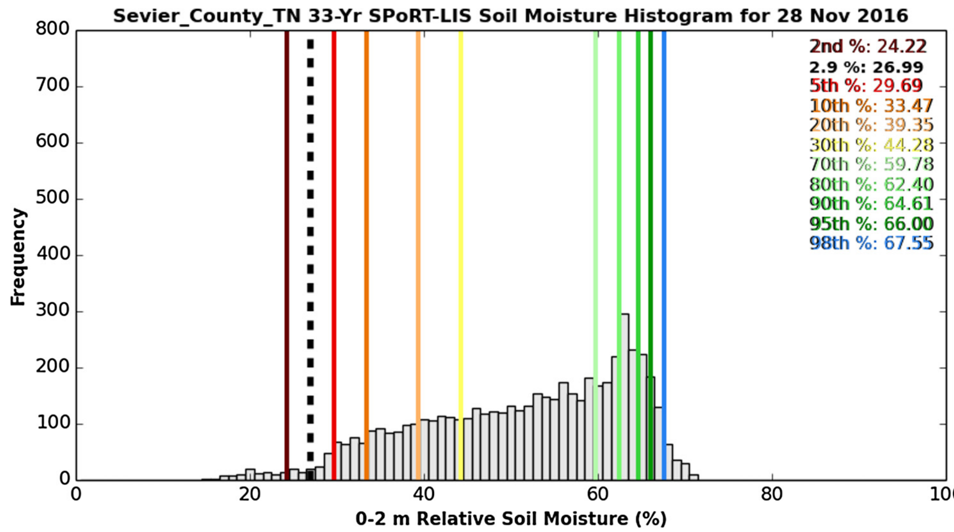

Fig. 4. Historical 0–2 m RSM histogram on 28 Nov for Sevier County, TN. Gray bars represent the 33 yr frequency of RSM values for all SPoRT-LIS grid points within Sevier County; vertical colored lines and corresponding legend text are reference percentiles for proxy drought categories (defined in Fig. 1) and mirror wet analogs; vertical dashed line is the 28 Nov 2016 county-wide mean (black font value in legend).

ishing 0.1% in Madison County, AL on the same day (Fig. 3). The historically low soil moisture brought on by the unusually prolonged period of above-average temperatures and lack of rainfall established the environmental conditions favoring wildfires across the SEUS during October and November 2016. Similar to a study of wildfires in the Iberian Peninsula of Southwestern Europe [7], work is underway to relate soil moisture anomalies and trends, vegetation stress [8], and lightning activity to wildfire risk [9]). In support of these efforts, daily soil moisture histograms were developed to quantify current soil moisture values against the climatological distribution, as depicted for Sevier County, TN on 28 November (Fig. 4). These graphs can help end-users to relate the present-day, county-averaged soil moisture (dashed line) to the historical frequency distribution (gray bars) and reference percentiles used by the drought community (colored vertical lines).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rinp.2017.12.029.

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