Land Surface Modeling and Evaporative Stress Products for Increased Situational Awareness

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Introduction

- The NASA SPoRT Center maintains a suite of land surface modeling and remote sensing products designed to facilitate enhanced situational awareness in the areas of drought, flood, and wildfire monitoring.
- These products are created and disseminated in real time to national and international operational and research stakeholders such as NOAA/NWS, USGS, FEMA, NASA SERVIR, etc.
- This poster provides a high-level description of these land surface products, along with impactful examples shown below.

SPoRT-LIS and ESI Background

- SPoRT-Land Information System (SPoRT-LIS)
  - ~3-km resolution Land Information System (LIS) simulation of the Noah land surface model over CONUS that includes a 33-year climatology simulation (1981-2013) and real-time output of soil moisture, select temporal changes in soil moisture and green vegetation fraction (GVF), and percentiles relative to climatology.
  - Incorporates NOAA/NESDIS real-time, global VIIRS GVF and near-term MRMS QPE.
  - Additional domains over Caribbean and Eastern Africa incorporating GPM/IMERG QPE.
  - Disseminated in multiple formats (e.g., GRIB2, geotiff) via LDM/ftp. Select web graphics available at https://weather.msfc.nasa.gov/sport/case_studies/lis_CONUS.html.
- Evaporative Stress Index (ESI)
  - CONUS domain at 4-km resolution using GOES-Land Surface Temperature (LST) with a temporal coverage of 2000 to present.
  - Global domain at 5-km resolution using MODIS/VIIRS-LST with a temporal coverage of 2000 to present.

Tools and Methodologies

- SPoRT-LIS
  - Noah land surface model run apart from NWP model (2-m soil column with 4 layers: 0-10, 10-40, 40-100, and 100-200 cm).
  - Long-term spin-up of satellite-era hourly analyses from NLDAS-2.
  - Climatology run consists of daily output fields, with total column relative soil moisture aggregated into county climatologies for each day of the year (~10^6 unique soil moisture distributions).
- ESI
  - Based on temporal anomalies of evapotranspiration as estimated by the Atmosphere Land Exchange Inverse (ALEXI) model.
  - Main inputs include mid-morning change in LST, leaf area index, and surface meteorological fields.

Summary and Future Efforts

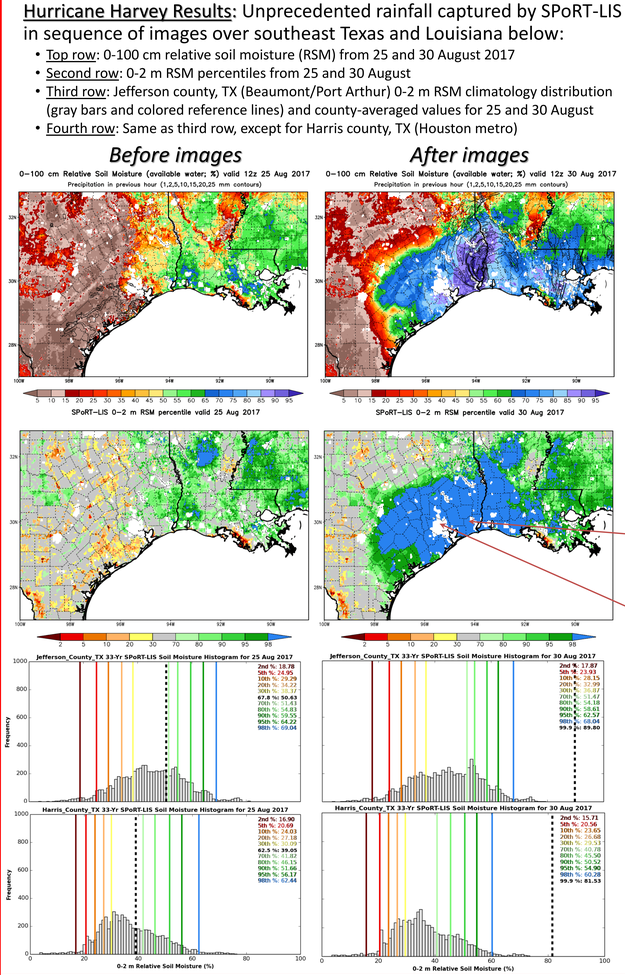
- SPoRT-LIS summary
  - Offline Noah LSM on full CONUS domain at 0.03-deg resolution provides climatological context of soil moisture for situational awareness applications.
  - Real-time demonstrations and dissemination have paved the way for future operational products such as NLDAS-3 and the National Water Model.
- ESI summary
  - Global and CONUS ESI maps are being produced in near-real-time at NASA SPoRT
- Future Direction
  - Implemented parallel SPoRT-LIS simulation assimilating SMAP soil moisture retrievals; validation against in situ sensors and NWP model impacts underway.
  - Global ESI dataset based on microwave (all-sky) LST is under development and will be available in Spring of 2018.

SPoRT-LIS for drought, wildfire, & flooding

Hurricane Harvey Results: Unprecedented rainfall captured by SPoRT-LIS in sequence of images over southeast Texas and Louisiana below:

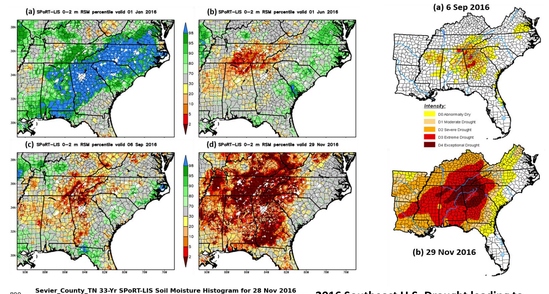
- Top row: 0-100 cm relative soil moisture (RSM) from 25 and 30 August 2017
- Second row: 0-2 m RSM percentiles from 25 and 30 August
- Third row: Jefferson county, TX (Beaumont/Port Arthur) 0-2 m RSM climatology distribution (gray bars and colored reference lines) and county-averaged values for 25 and 30 August
- Fourth row: Same as third row, except for Harris county, TX (Houston metro)

Before images | *After images*



Jefferson county, TX (Beaumont/Port Arthur)

Harris county, TX (Houston metro)

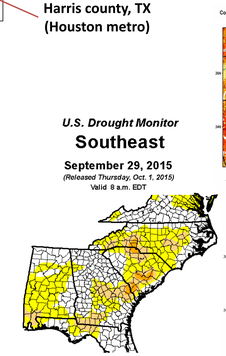


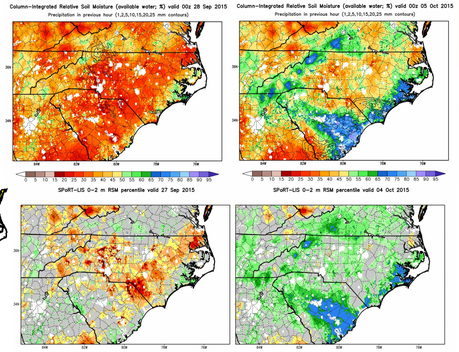
2016 Southeast U.S. Drought leading to numerous wildfires and deadly Gatlinburg firestorm on 29 November (above graphics)

- Upper-left: SPoRT-LIS 0-2 m relative soil moisture percentiles showing rapid degradation in soil moisture during 2016.
- Upper-right: U.S. Drought Monitor maps from 6 Sep and 29 Nov 2016.
- Bottom-left: Soil moisture climatology distribution (gray bars), reference percentiles (colored vertical lines), and 28 Nov 2016 values averaged for Sevier county, TN (Gatlinburg).

South Carolina flooding associated with Hurricane Joaquin (2015; below graphics)

- 20"+ of rainfall completely erased ongoing moderate to severe drought
- Top row: before and after images of total column (0-2 m) relative soil moisture
- Bottom row: before and after total column relative soil moisture percentiles event
- Lower-left: U.S. Drought Monitor classes before the rainfall event.
- Notice rapid transition from excessively dry soils (2nd to 10th percentiles) to anomalously wet soils (> 98th percentile) in a one-week time span!

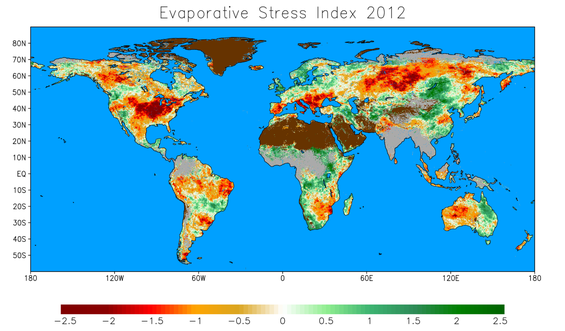




Real-time ESI for monitoring Vegetation Stress

ALEXI ESI represents temporal anomalies in the ratio of actual ET to potential ET.

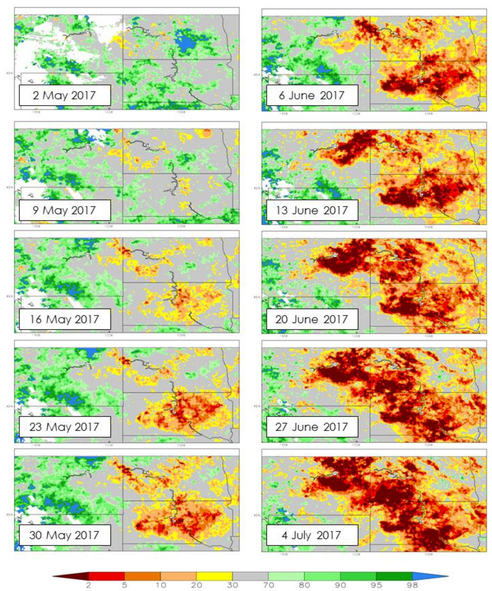
- ESI does not require precipitation data; rather, ***the current surface moisture state is deduced directly from the remotely sensed LST.*** Therefore, it may be more robust in regions with minimal in-situ precipitation monitoring.
- ALEXI ESI inherently includes non-precipitation related moisture signals (such as irrigation; vegetation rooted to groundwater; lateral flows) that need to be modeled a priori in prognostic LSM schemes.
- Signatures of vegetation stress are manifested in the LST signal before any deterioration of vegetation cover occurs (as indicated in NDVI), so thermal infrared-based indices such as ESI can provide an effective early warning signal of impending agricultural drought.



ESI provides an effective early warning of the development of vegetation stress:

Flash drought are rapid onset events driven by precipitation deficits, high temperature anomalies, strong winds, and anomalously high atmospheric demand. ***ESI has the potential to provide an early warning component during such events as water stress is able to be detected in the LST signal before degradation in the vegetation health occurs.***

The recent flash drought of 2017 over the Dakotas and eastern Montana is shown below:



ESI can provide an estimate of crop yield anomaly:

- Examine drought conditions during critical crop stages during the drought of 2012
- Strong relationship between wheat yield and the ESI and VegDRI during critical crop stages
- NLDAS has strong (weak) relationship to corn/soybeans (wheat) yield
- ESI had strongest correlation to the wheat, corn, and soybean yield departures