Applied Sciences Program
NASA Earth Science

Development of a Global Evaporative Stress Index Based on Thermal and Microwave Land Surface Temperature towards Improving Monitoring of Agricultural Drought

Providing Early Warning for the Onset of Vegetation Stress

Background

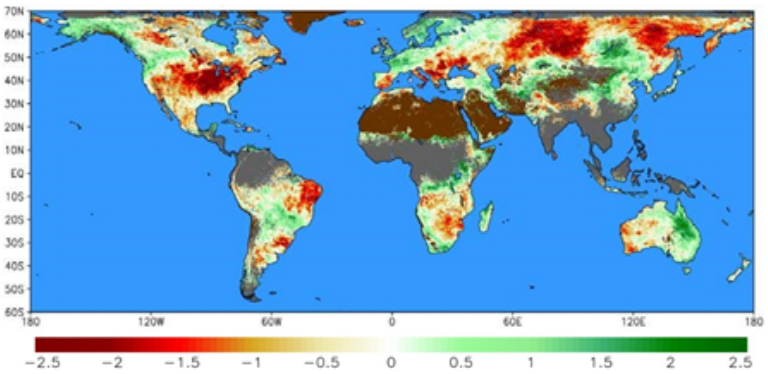
As atmospheric and land surface processes controlling drought evolution are becoming more variable and are shifting in intensity, frequency and duration. The unusually rapid increase in water and/or vegetation stress during several recent rapid onset drought ("flash drought") events has not been well predicted by standard drought indicators Agricultural droughts can result in significant yield loss, with impacts on both local and global markets through reduced economic output and higher grain and food prices, and on food supply in regions dependent on subsistence farming. Current global agricultural monitoring systems are primarily based on remotely sensed vegetation indices (e.g., NDVI), reflecting anomalies in crop canopy "greenness" or light-harvesting capacity. However, vegetation indices typically show a signal only after significant damage to the crop has occurred, at a time where mitigation opportunities are limited. Lack of early warning of impending drought development may delay actions by stakeholders in mitigating crop and economic losses, or mobilizing famine relief efforts. There is a clear need for global operational agricultural drought monitoring systems that provide direct information about developing vegetation stress and early warning of potential crop failure to provide actionable information regarding potential agricultural losses.

Project highlights:

- *Uses NASA satellite data to monitor anomalies in evapotranspiration and provides early warning of drought-induced vegetation stress*
- *ESI provides early warning of drought through thermal signatures of the underlying vegetation.*
- *Near-real-time global ESI products are being generated and have been integrated into the decision-making process of project partners.*

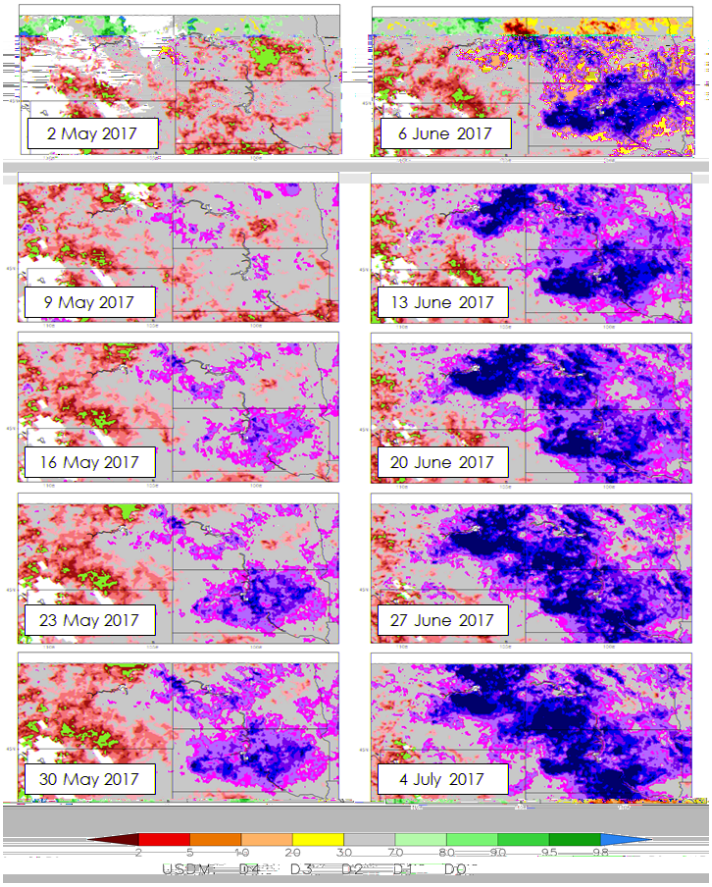
The Evaporative Stress Index: Providing Early Warning of Drought

This tool is based on remotely sensed estimates of evapotranspiration (ET), retrieved via energy balance approach using observations of land surface temperature (LST). The Evaporative Stress Index (ESI) represents anomalies in the ratio of actual-to-potential ET generated with the thermal remote sensing based Atmosphere-Land Exchange Inverse (ALEXI) model. The LST inputs to ESI have been shown to provide early warning information about the development of with stress-elevated canopy temperatures observed well before a decrease in "greenness" is detected in remotely sensed vegetation indices. *Whereas many drought indicators based on precipitation or atmospheric conditions capture meteorological drought, the ESI is one of few indicators of agricultural drought that reveals actual vegetation stress conditions realized on the ground.* This distinction is



4-week Global ESI composite product for 1 August 2012. Grey shading denotes regions where significant cloud cover leads to inadequate clear-sky retrievals. Brown shading denotes desert regions where ET is negligible.

particularly important for the agricultural sector where human activity can alter how the drought is actually affecting crop health (e.g., through irrigation, use of drought-resistant crop varietals, etc.). Not all meteorological droughts develop into an agricultural drought, and having indicators specifically related to crop vegetation stress is imperative for improved decision-making by agricultural stakeholders. As a diagnostic indicator of actual ET, the ESI requires no information regarding antecedent precipitation or soil moisture storage capacity - the current available moisture to vegetation is deduced directly from the remotely sensed LST signal. This signal also inherently accounts for both precipitation and non-precipitation related inputs/sinks to the plant-available soil moisture pool which can modify crop response to rainfall anomalies. Independence from precipitation data is a benefit for global agricultural monitoring applications due to sparseness in existing ground-based precipitation networks, and time delays in public reporting. Even as satellite precipitation monitoring has closed some of the observational gaps, these data are usually provided at coarse resolution with accuracy dependent extensive calibration with ground-based precipitation estimates. Additionally, the ESI also provides an important distinction from drought indicators that focus on atmospheric demand (e.g., the Evaporative Demand Drought Index; EDDI) which signal the potential for stress but provide no direct physical link to the onset of actual vegetation stress. In each of these respects, the ESI will give stakeholders a unique perspective for assessing impacts of agricultural drought on crop and rangeland productivity at the global scale.



Evolution of the North Central United States Flash Drought of 2017. Normal conditions at the beginning of the growing season were replaced with severe to extreme drought with had significant agricultural impacts.

Applications: Flash Drought

Flash droughts are rapid onset events typically driven by:

1) precipitation deficits,
2) high temperature anomalies;
3) strong winds;
4) Anomalous incoming solar radiation.

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. While providing information about actual vegetation stress and not just the potential for vegetation stress. ESI provided early warning of the significant flash drought which affected the north central US during the 2017 growing season.

Data Availability:

Near-real-time ESI data is available at:

https://gis1.servirglobal.net/data/esi/