

**PROJECT TITLE:** Facilitating adaptive management under conditions of rapid drought onset using the GOES-based Evaporative Stress Index

**INVESTIGATORS:**

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**PROJECT YEARS:** 2 year project (2013-2015)

**TIME PERIOD ADDRESSED BY REPORT:** September 1, 2013 – May 31, 2014

**I. PRELIMINARY MATERIALS**

**A. Research project objective**

This project will seek to develop and evaluate an innovative drought early warning toolkit based on satellite-derived maps of evapotranspiration (ET) that will be used to support decision-making and risk characterization for the agricultural and natural resources communities. Recent examples of rapid drought intensification across the U.S. have clearly demonstrated the need for a reliable drought early warning system (DEWS) that would be capable of providing stakeholders additional time to prepare for worsening drought conditions. The study will use the Evaporative Stress Index (ESI) dataset generated with the Atmosphere-Land Exchange Inverse (ALEXI) surface energy balance model using GOES thermal infrared imagery. Focus group studies will be convened in two National Integrated Drought Information System (NIDIS) pilot regions to examine how real-time access to the ESI-based drought toolkit could have assisted stakeholders during recent drought events. The end goal is to provide useful remote sensing tools that can be implemented globally to help mitigate crop losses and other drought-related damages – promoting resilience in a changing climate.

**B. Stakeholder and decision maker involvement**

- Individual farmers and ranchers
- Farm organization representatives
- Federal and state agency representatives
- County and university extension agents
- Natural resources experts and representatives

## **C. Approach**

In this work, statistical and case study analyses will be used to quantitatively assess the ability of the Evaporative Stress Index (ESI) to accurately identify drought onset and development. The ESI is generated using evapotranspiration (ET) estimates from the Atmosphere-Land Exchange Inverse (ALEXI) surface energy balance model using GOES thermal infrared imagery. The ESI represents standardized anomalies in the ratio of the actual-to-potential ET, and has been shown to agree well with standard precipitation-based drought indices and with classifications in the U.S. Drought Monitor (USDM) archive. Because ALEXI computes ET using remotely sensed land surface temperature, which responds quickly to changes in soil moisture content, the ESI is often able to detect increasing water stress earlier than other drought metrics, sometimes by several weeks, thereby making it a potentially useful drought early warning tool.

A Rapid Change Index (RCI) product derived from rapid temporal changes in the ESI that is designed to identify areas experiencing rapid stress emergence will be refined through comparisons with various drought monitoring and observational datasets. Focus group studies will be convened to examine how real-time access to ESI and RCI products could have assisted stakeholders during recent drought events by facilitating adaptation to changing climate conditions. User feedback will promote improvements in the analysis and visualization tools developed during this project. The project will focus on the NIDIS Southern Plains and Missouri River Basin pilot regions; however, the analysis and visualization tools will be available for the entire contiguous U.S. and will be applicable to multiple end users. The end goal is to develop an innovative suite of drought early warning tools designed to inform the public about rapidly changing drought conditions over regional scales with high spatial resolution.

## **D. Matching funds**

None.

## **E. Partners**

The project team will work with the National Drought Mitigation Center and the USDM authors to examine the potential for integrating the ESI drought early warning toolkit into the operational USDM mapping process. Additional partners in academia, the private sector, federal agencies, and non-governmental organizations will provide input on the drought early warning toolkit through involvement in the focus group meetings.

# **II. ACCOMPLISHMENTS**

## **A. Summary of accomplishments and findings**

During the first nine months of the project, two studies were conducted to improve our understanding of flash drought events through an analysis of in situ observations and to examine the ability of rapid changes in the ESI to provide useful drought early warning

signals. Materials are also being prepared for the two focus group meetings that will be held in August 2014. These accomplishments are described in greater detail below.

### *1) Drought early warning capabilities of the Rapid Change Index*

We conducted a study that examined the potential utility of using rapid temporal changes in three drought indices that are sensitive to ET, precipitation, and soil moisture (e.g., the ESI, Standardized Precipitation Index, and soil moisture from the North American Land Data Assimilation System, respectively) to provide early warning of an elevated risk for drought development over sub-seasonal time scales. RCI datasets were computed for each drought index, and then a simple statistical method was used to convert the RCI values into drought intensification probabilities depicting the likelihood that drought severity would worsen in subsequent weeks. Local and regional case study analyses revealed that elevated drought intensification probabilities often occur several weeks prior to changes in the USDM and in topsoil moisture and crop condition datasets compiled by the National Agricultural Statistics Service (NASS). The results indicate that tools used to identify areas experiencing rapid changes in drought indices may be useful components of future drought early warning systems.

Figure 1 shows the evolution of the drought intensification probabilities, drought indices, and meteorological conditions during a flash drought event across east central Oklahoma in 2011. Flash drought rapidly developed across the region during June, with the USDM drought analysis degrading by one category for three consecutive weeks before stabilizing at extreme drought severity only six weeks after the area was drought-free. The NASS topsoil moisture assessment also transitioned from normal conditions to a severe moisture deficit during this time period. Each of the RCI variables became negative by the second week of June, with elevated drought intensification probabilities occurring thereafter. For this event, rapid changes in the ESI provided the earliest sustained warning of an enhanced risk for drought development.

### *2) High resolution analysis of flash drought development at the Marena Oklahoma In Situ Sensor Testbed (MOISST) during 2012*

To provide increased insight into how the physical relationships within the soil-vegetation-atmosphere continuum impact the development and intensity of flash drought development, in situ observations from the Marena Oklahoma In Situ Sensor Testbed (MOISST) were examined during the flash drought of 2012. The results demonstrated that below normal precipitation during May 2012 yielded rapid drying of the soil column as vegetation in the region extracted water from the soil to maintain overall health. Increased rain during June 2012 led to moistening of the topsoil, but observations from the in situ soil moisture sensors demonstrated that the soil column at deeper depths (e.g., 60 cm via the Marena Oklahoma Mesonet station) was not replenished. As such, when precipitation ceased in July and atmospheric demand increased, the soil rapidly dried due to increased evaporation and water extraction by the vegetation. As a result, once the moisture from the topsoil was removed (1) the entire column dried very rapidly, (2) the vegetation quickly reached the wilting point, and (3) the overall ecosystem collapsed by

mid-August, which further accentuated the flash drought development. The results demonstrate that the soil and ecosystem played a critical role in flash drought development at the site. Current analyses are examining ESI values at the MOISST site and the in situ soil and vegetation observations to verify the performance of ESI in forecasting flash drought development.

### 3) Preparation for focus group meetings

In recent months, several telecons were held with members of the research group to discuss plans for the focus group meetings that are a key component of this project. These meetings will be held in Norman, Oklahoma and Lincoln, Nebraska during the second week of August and will be used to better understand how stakeholders could use the ESI and other drought products to mitigate their drought exposure and to prepare for an increased risk for drought development. Presentation slides and hands-on material are currently being prepared for each of these meetings.

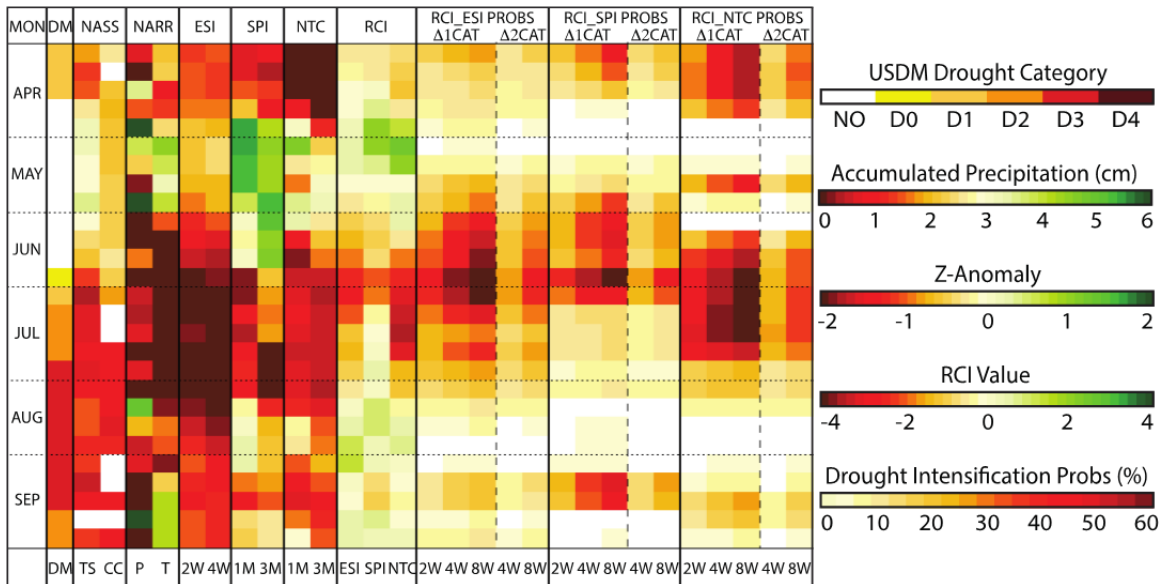


Fig 1. Drought evolution across east-central Oklahoma during 2011. The USDM drought category is shown in column 1, NASS topsoil and crop condition anomalies in columns 2 and 3, and 1-week rainfall (cm) and 2-week temperature anomalies (K) in columns 4 and 5. ESI anomalies for 2- and 4 week composite periods are shown in columns 6-7, with 4- and 8-week SPI and 2- and 4-week NTC anomalies shown in columns 8-9 and 10-11, respectively. RCI\_ESI, RCI\_SPI, and RCI\_NTC values are shown in columns 12-14. 1-category USDM drought intensification probabilities for 2, 4, and 8-week periods, and 2-category probabilities for 4 and 8-week periods computed using RCI\_ESI, RCI\_SPI, and RCI\_NTC data are shown in columns 15-19, 20-24, and 25-29, respectively.

## B. Application of your findings to inform decision-making

Results from the first year of the project were shown in two presentations at the 2014 Annual Meeting of the American Meteorological Society (listed below). Additional information and results will be shared with decision makers during the second year of the

project through involvement in the focus group meetings and through dissemination of the meeting results.

Otkin, J. A., M. C. Anderson, C. Hain, and M. Svoboda, 2014: Examining the relationship between drought development and rapid changes in the thermal-based Evaporative Stress Index. *28th Conference on Hydrology*, Atlanta, GA.

Spade, D. M., W. R. Denito, J. B. Basara, and J. A. Otkin, 2014: New insight into the development of flash drought: A case study at the Marena Oklahoma In Situ Sensor Testbed. *28th Conference on Hydrology*, Atlanta, GA.

### **C. Planned methods to transfer information and lessons learned from this project**

Information concerning the drought early warning capabilities of the ESI will be shared with members of the agricultural community via the focus group meetings and through a continued dialogue with the participants after the meetings. In addition, the ESI will be generated and delivered weekly to the USDM authors in a form enabling overlay of the USDM, facilitating real-time assessment and evaluation. The ESI will be exposed to the larger USDM list server group of ~350+ experts for their feedback concerning the accuracy and responsiveness of the indicator. Finally, we will work with the USDM authors to investigate the potential for the ESI to be part of a new suite of gridded objective blend products, particularly the short-term blend, as a means of helping the USDM detect and depict rapid onset drought events.

### **D. Significant deviations from proposed work plan**

None.

### **E. Completed publications, white papers, or reports**

Otkin, J. A., M. C. Anderson, C. Hain, and M. Svoboda, 2014: Examining the relationship between drought development and rapid changes in the Evaporative Stress Index. *J. Hydrometeor.*, **15**, 938-956.

## **III. WEBSITE ADDRESS FOR FURTHER INFORMATION**

<http://hrsl.arsusda.gov/drought/>