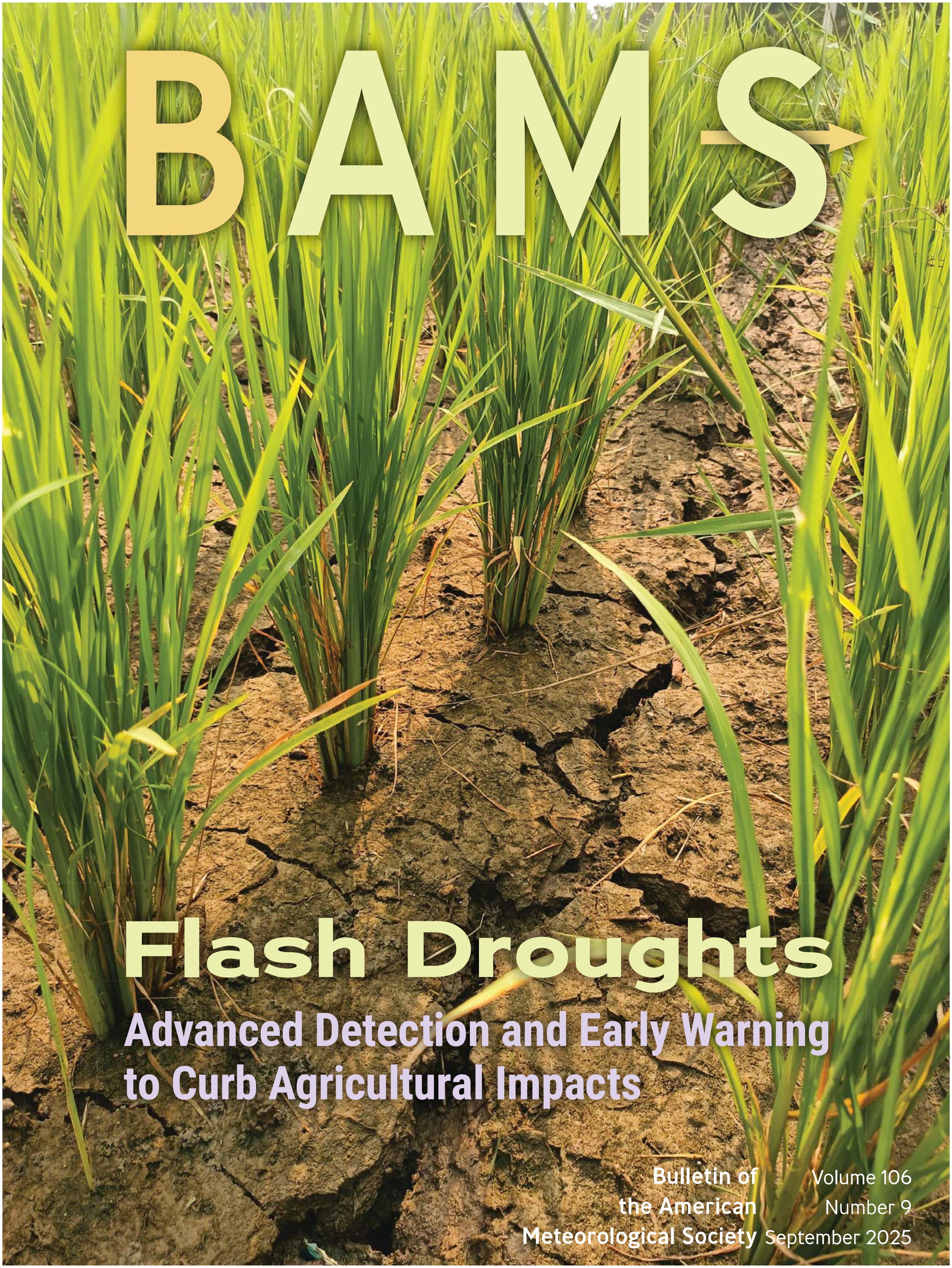

BAMS

Flash Droughts

Advanced Detection and Early Warning to Curb Agricultural Impacts

Bulletin of the American Meteorological Society

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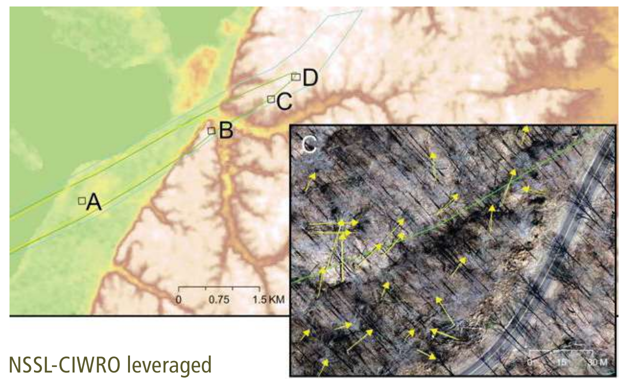
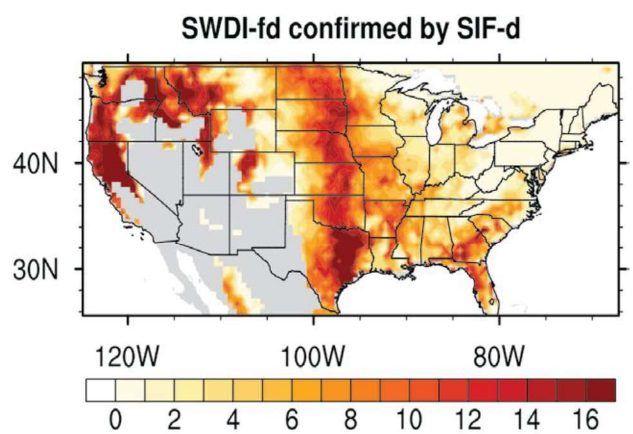
FEATURES



633 NSSL-CIWRO leveraged uncrewed aerial systems (UAS) technologies and high-resolution satellite imagery to better document wind damage and provide new insights into severe storm dynamics and behavior.

WAGNER ET AL.



637 A new approach to safeguard global food security detects agriculturally impactful flash droughts based on soil water deficit, and its efficacy is confirmed by a remotely sensed proxy of plant photosynthesis.

MOHAMMADI AND WANG

Guiling Wang hiking the Fimmvörðuháls Trail in Iceland.

"I grew up in a mountainous village with rain-fed agriculture in northern China, and got my bachelor's degree in water resources and master's degree in river dynamics and sediment transport from Tsinghua University. When I was searching for a Ph.D. dissertation topic as a student in Director Elfatih Eltahir's group at MIT, I had zero background in atmospheric science, but the idea that vegetation dynamics may have played a role in the development and persistence of the multidecadal Sahelian drought really clicked with me. I tackled this topic with a numerical modeling approach. To support this research pursuit, I loaded myself with hydrology courses from the Department of Civil and Environmental Engineering, meteorology courses from the Department of Earth, Atmospheric, and Planetary Sciences, and an ecology course from Harvard University. As a faculty member at the University of Connecticut, in collaboration with my students and postdocs, my research has grown significantly in both depth and breadth, but interactions between vegetation and the terrestrial water cycle remain a major focus."

— Guiling Wang, University of Connecticut

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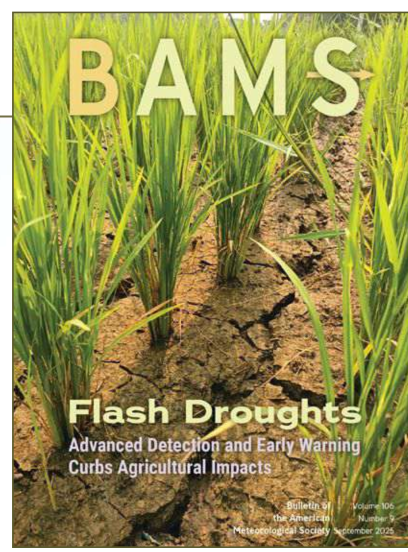

ON THE COVER: Flash droughts often devastate agriculture and ecosystems, and until now their impacts eluded detection and monitoring. A new impact-based approach connects the soil water stress that crops exhibit when plant-available water is rapidly lost to flash droughts to a photosynthesis proxy for their early detection, enabling farmers to more quickly respond.

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An Impact-Centric Approach to Flash Drought Detection

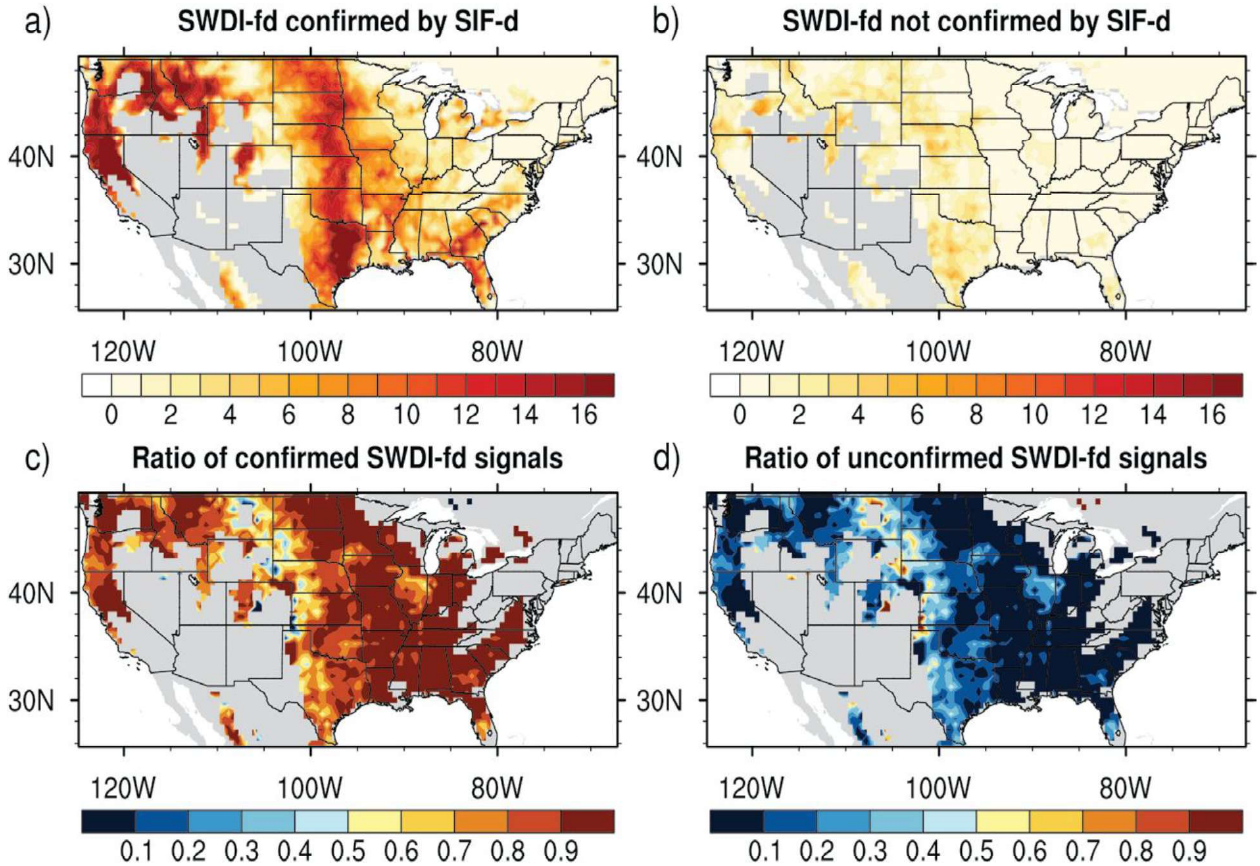
Key messages from "Impact Matters: Detection and Early Warning of Agriculturally Impactful Flash Droughts," by **Koushan Mohammadi** (University of Connecticut) and **Guiling Wang**. Published online in *BAMS*, April 2025. For the full, citable article, see https://doi.org/10.1175/BAMS-D-24-0143.1.

Flash droughts wreak havoc on agricultural land worldwide. Useful and usable detection and monitoring of flash drought must be grounded on its impact on vegetation, especially on crops. However, existing drought monitoring and detection metrics are either percentile-based or standardized; due to the dependence on long-term statistics, they lack direct linkage to agricultural impact at the event level, which limits their usability for farmers and other stakeholders.

For a given soil type, the difference between field capacity and wilting point determines the potential water availability for plants, while the difference between soil moisture and wilting point reflects the actual water availability. The Soil Water Deficit Index (SWDI) is an instantaneous measure of the "deficit," or the loss of water availability; when soil moisture drops below the field capacity, SWDI becomes negative, with −3 representing a 30% loss of plant water availability and −5 representing a 50% loss. Most crops start to experience water stress when SWDI drops below −5, lower for drought resistant crops (e.g., −6.5 for cotton) and higher for many vegetables (e.g., −3 for lettuce). We propose to define agriculturally impactful flash drought as an event that causes SWDI to decrease by 2 in less than 30 days, from −3 (or lower) to −5 (or lower), and to stay below −5 for at least another 15 days. In local on-the-farm applications, the SWDI threshold of −5 should be adjusted according to the specific agricultural commodity of interest. Our proposed event definition eliminates the need for long-term statistics and enables drought monitoring and detection based on new or short-duration data such as SMAP (i.e., soil moisture active passive satellite measurements).

To pave the way toward global application, our analysis focuses on a data-rich region, the contiguous United States (US), to facilitate a comparison of the SWDI-detected flash droughts with other inventories. Our new approach identifies the Central US as a hot spot of agriculturally impactful flash droughts based on the SWDI averages among three soil moisture products; relative to flash droughts derived from the United States Drought Monitor (USDM) based on similar criteria of "flashness" and duration, the new approach picks up about three times as many events as the USDM-based detection in the western US and labels many USDM-detected events in the eastern US as not impactful.

How do we know whether the SWDI-detected events are indeed agriculturally impactful? To answer this question, we seek



The SWDI-detected flash droughts during 2001–19 that (a,c) are or (b,d) are not followed by substantial negative anomalies of plant photosynthesis, in (a,b) absolute count and (c,d) in fraction.

evidence from an independent product, the spaceborne measurement of solar induced chlorophyll fluorescence (SIF), which is a remotely sensed proxy of plant photosynthesis. Over most regions of the US, more than 90% of the SWDI-detected events are accompanied or followed by negative SIF anomalies that exceed the magnitude of one standard deviation or 15% of its long-term mean (whichever is larger), indicating a strong impact on crop productivity.

A major challenge for stakeholders to prepare for flash drought impact is the lack of early warning due to its rapid onset. Here we examine the role of the SIF Rapid Change Index (SIF-RCI) as a potential early warning signal for agriculturally impactful events. A negative SIF-RCI indicates a slower-than-usual increase or faster-than-usual decrease of SIF. Over most of the regions, more than 80%–90% of the flash drought events are associated with a negative SIF-RCI during a sustained period (of at least 24 days across three consecutive 8-day periods) that commenced prior to the flash drought onset. Note that SIF-RCI becomes negative when the SIF downturn starts, long before the SIF anomalies become negative. Since multiple meteorological factors contribute to flash drought development, plant photosynthesis may slow down in response to excessively high evaporative demand and/or temperature in addition to (and often prior to) the decrease of SWDI. These "catch-all" effects lend SIF-RCI the predictive power as a flash drought early warning signal for crops and may enable longer lead time than some early warning indicators based on individual hydrometeorological factors; land surface feedback is another mechanism contributing to the vegetation-mediated predictability of flash drought. The "catch-all" effects of SIF-RCI also cause false alarms for flash droughts, as other impactful events such as heatwave, conventional drought, wildfire, storm damage, or pests can also cause crop photosynthesis to slow down. Combining SIF-RCI with hydrometeorological indicators may reduce false alarms for flash drought early warning and enable detection of other societally impactful events. This will be studied in future research.

Whether it is flash drought or conventional drought, accurate early detection of agriculturally impactful events and effective communication of knowledge to stakeholders are critical. Adopting the impact-centric framework in operational drought monitoring and prediction systems is expected to increase information uptake and enhance societal relevance of our scientific research.

METADATA

BAMS: What would you like readers to learn from this article?

Guiling Wang (University of Connecticut): *One event, different outcomes for different stakeholders. When a flash drought strikes, its impact on agriculture depends on the soil and crop type, as opposed to long-term climate statistics. Our new approach identifies agriculturally impactful events based on the soil water deficit index (SWDI), an instantaneous metric of plant water availability, relative to an established threshold that triggers water stress onset. The value of the SWDI threshold depends on the crop type and should be adjusted in operational applications according to the specific commodity of interest. This new approach aims to make flash drought detection and prediction more useful and usable for local stakeholders.*

Koushan Mohammadi (University of Connecticut): *By identifying water stress based on crop-specific thresholds, this framework is more targeted in detecting impactful drought events and improving preparedness.*

BAMS: How did you become interested in the topic of this article?

GW: *A major focus of my research has been on vegetation–climate interactions, including, for example, how vegetation responds to drought and how this (through surface fluxes and feedback to the atmosphere) may further influence drought development and severity. I just cannot think about drought without thinking about vegetation. The term "flash drought" was first coined by Mark Svoboda et al. in a 2002* BAMS *article to describe a drought with a rapid onset and rapid crop deterioration. The literature on flash drought has grown exponentially in the last decade, especially after a U.S. event in 2012. A plethora of metrics and definitions have been proposed based on hydrometeorological variables relative to their long-term statistics. A common challenge I see among the previous studies is the lack of a clear linkage between the flash drought definition and drought impact on agriculture, the sector influenced by flash droughts the most. That's where our study comes in, viewing flash drought through the lens of impacted crops.*

As an enthusiastic gardener, I grow flowers, vegetables, and a few rows of corn stalks (to deter the deer) in my backyard. Summer is short in New England, so timing is of the essence. I enjoy observing how my plants fare under various weather conditions and how they respond to different watering strategies. In most years I get to harvest some delicious food; in some years I learn lessons instead. This experience plays a role in shaping my perspective about the societal relevance of our research.

BAMS: What surprised you the most about the work you document in this article?

GW: *It is the remarkable similarity between the temporal variations of SWDI and solar-induced fluorescence. They were derived from very different datasets. Although I sort of expected it based on our process understanding, seeing it for the first time gave me goosebumps.*

KM: *What surprised me most was how consistently the detected flash drought events were followed by clear signs of plant stress. While I also expected some alignment, it was striking to see that nearly all detected events led to physiological impacts across diverse ecosystems.*

BAMS: What was the biggest challenge you encountered while doing this work?

GW: *This study involves a large number of datasets that differ in spatial and temporal resolutions. Meticulous consideration went into each of the analyses to make sure that the signal did not get lost or otherwise altered due to the spatial and temporal resampling or aggregation.*

KM: *Both the flash drought definition/detection and the early warning metric involve threshold parameters. Determining the suitable values for these thresholds was challenging. We chose those threshold values based on existing literature and treated each as a source of uncertainty. A long list of sensitivity tests was conducted to comprehensively assess such uncertainties.*