

# Flash Drought Identification

Jordan I. Christian<sup>1</sup>, Jeffrey B. Basara<sup>1,2</sup>, Jason A. Otkin<sup>3</sup>, Eric D. Hunt<sup>4</sup>, Paul Flanagan<sup>1</sup>, and Xiangming Xiao<sup>5</sup>

<sup>1</sup>School of Meteorology, University of Oklahoma, Norman, OK

<sup>2</sup>Oklahoma Climatological Survey, University of Oklahoma, Norman, OK

<sup>3</sup>Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, Madison, WI

<sup>4</sup>Atmospheric and Environmental Research, Inc., Lexington, MA

<sup>5</sup>Department of Microbiology and Plant Biology, Center of Spatial Analysis, University of Oklahoma, Norman, OK



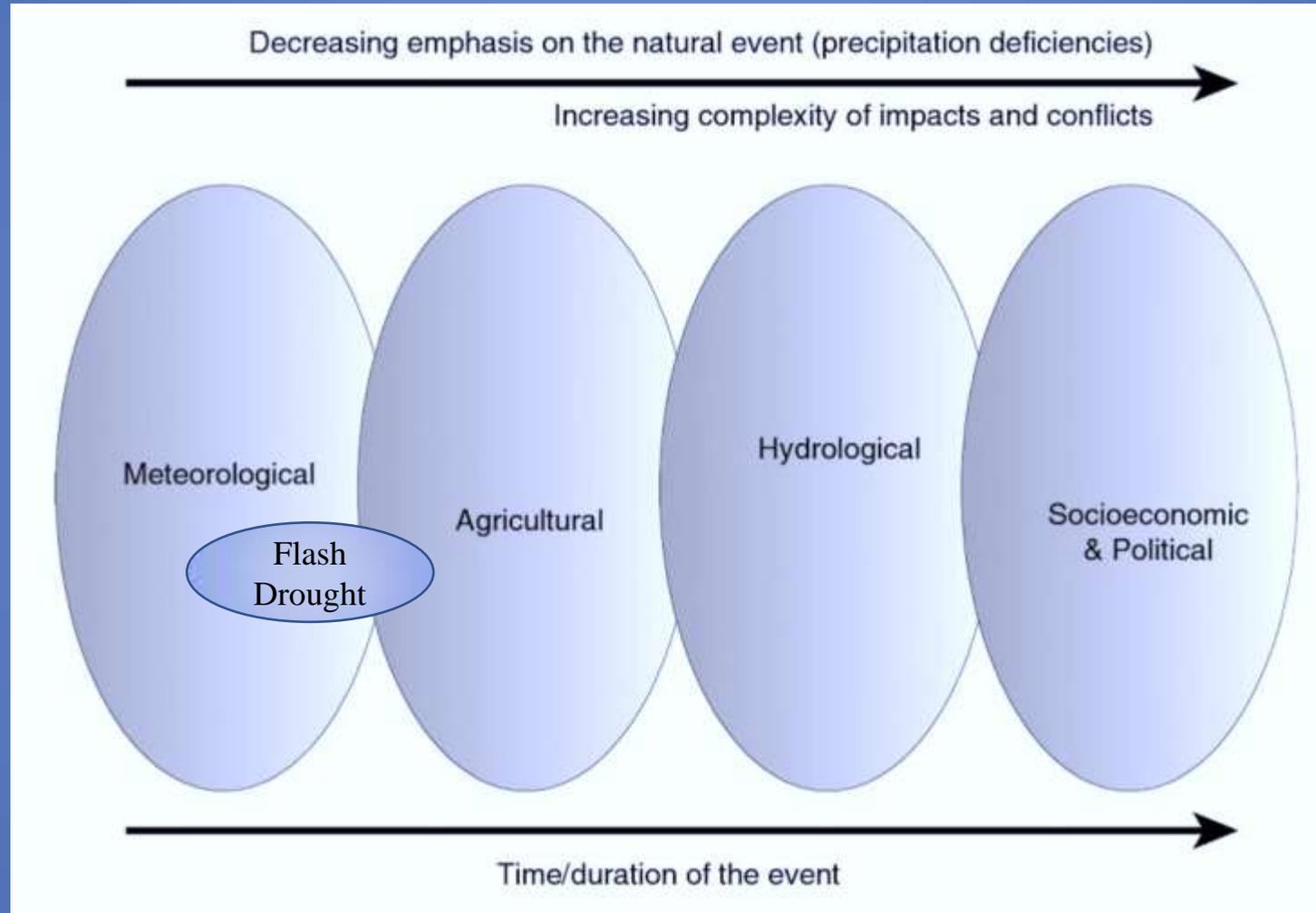
# Acknowledgements

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# Types of Drought



# Impact of Flash Drought

- Flash droughts are characterized by the rapid onset and development of drought conditions
- Can adversely affect vegetation health by quickly depleting root zone soil moisture and increasing moisture stress
- Significant yield loss can occur in agricultural regions if flash drought develops during sensitive stages in the growing season

## Marena Site (North Central Oklahoma)

1 July  
2012



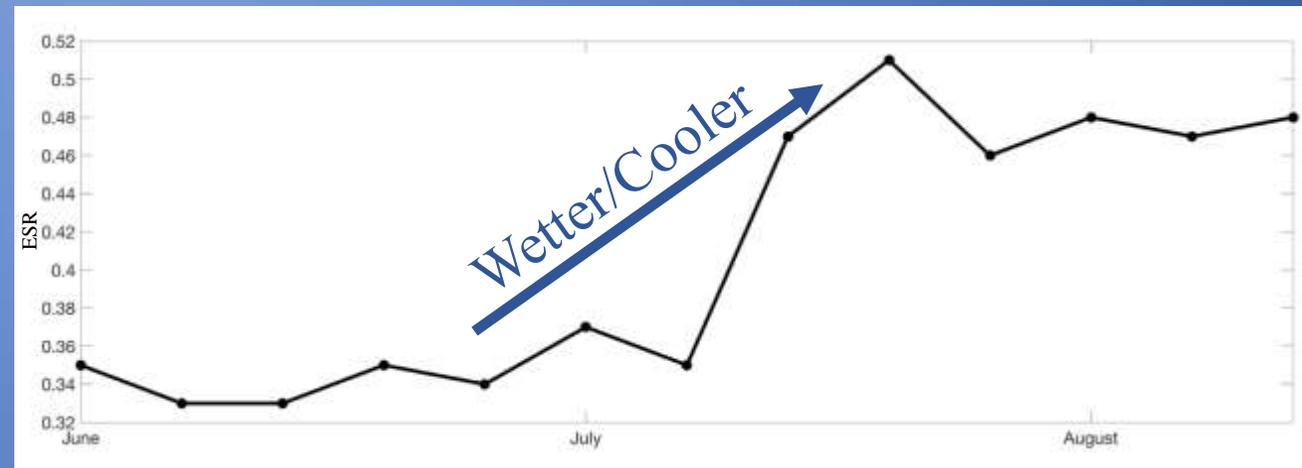
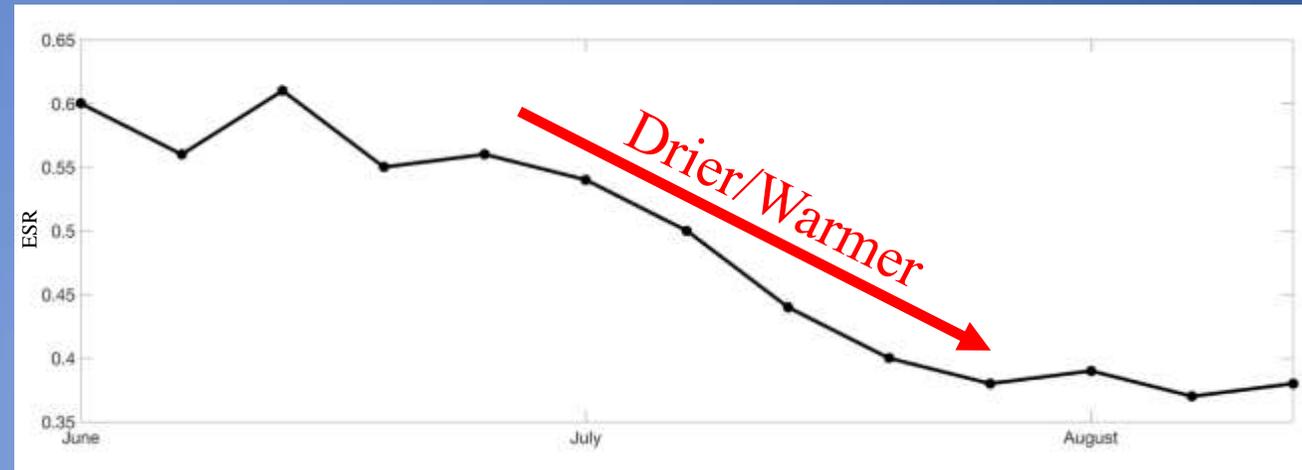
31 July  
2012



# Standardized Evaporative Stress Ratio

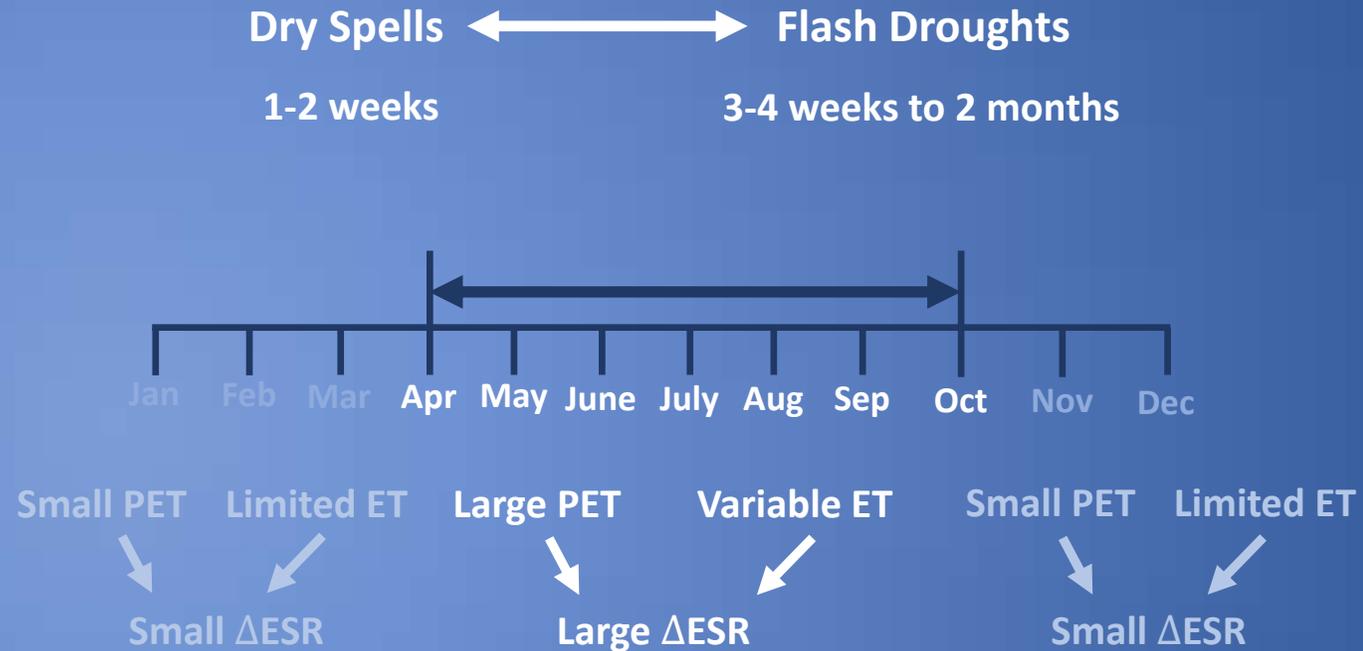
- The Standardized Evaporative Stress Ratio (SESR) was used to identify flash droughts
- Mathematically:  $ESR = \frac{ET}{PET}$  (Evaporative Stress Ratio)
- ET – evapotranspiration
- PET - potential evapotranspiration
- Physically:
  - ESR approaching 1 indicates that atmospheric demand of evapotranspiration is met
  - ESR approaching 0 indicates that nearly none of the atmospheric demand of evapotranspiration is met
  - As ESR decreases, the evaporative stress increases
  - As ESR increases, the evaporative stress decreases

## ESR Time Series Schematic



# Characteristics of Flash Drought

- Rapid development of drought conditions (flash droughts) take place on the order of 3-4 weeks to a couple of months
- Flash droughts are primarily limited to the growing season
- **Flash droughts are defined by their *rate of intensification*, not their short duration or final level of drought conditions**
- Flash droughts are associated with extreme atmospheric anomalies that persist for several weeks



- **Warmer temperatures**
  - **Lack of precipitation**
  - Less cloud coverage
  - **Higher wind speeds**
- 
- ET decreases
  - PET increases
  - $\Delta$ ESR large

# A Methodology for Flash Drought Identification

## Initial Flash Drought Criteria

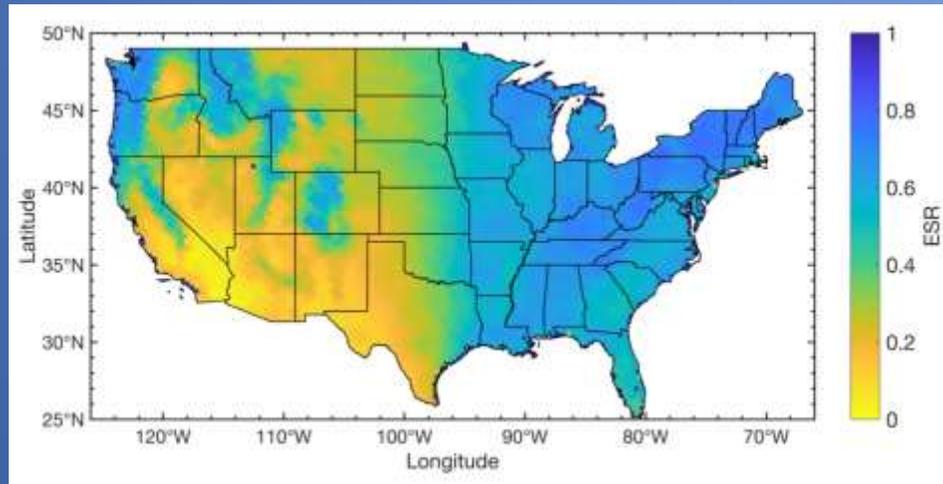
- 1) The length of the flash drought must be *at least 5 total pentads long (25 days)* →
  - Longevity and impact on the ecosystem
  - Separates flash droughts from dry spells
- 2) The final SESR value at the end of the flash drought must be below the 20<sup>th</sup> percentile (Otkin et al. 2018) → Satisfies the “drought” component of flash drought, with respect to evaporative stress

The “flash” component of flash drought is evaluated with the change in standardized ESR (SESR).

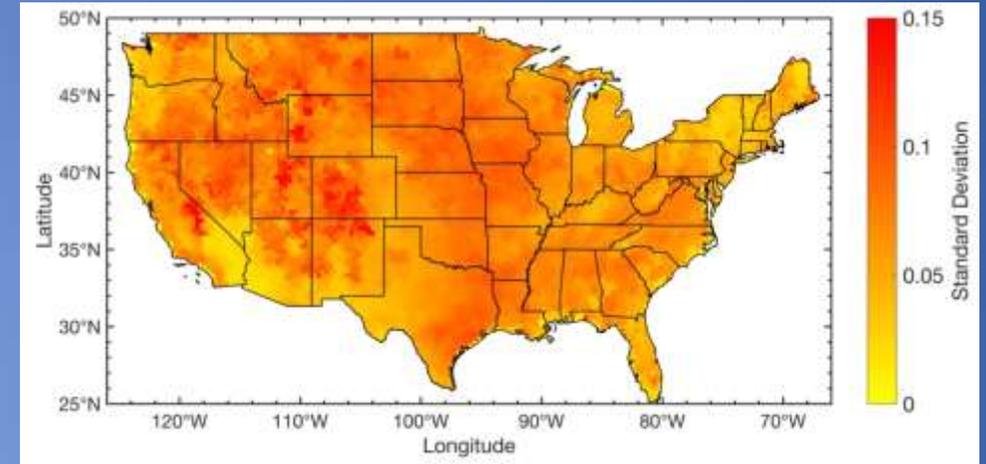
# Standardized Evaporative Stress Ratio

- ESR values were standardized at each grid point for each day of the year
- This conversion allows inter-region, inter-annual, and intra-seasonal comparison of ESR and flash droughts

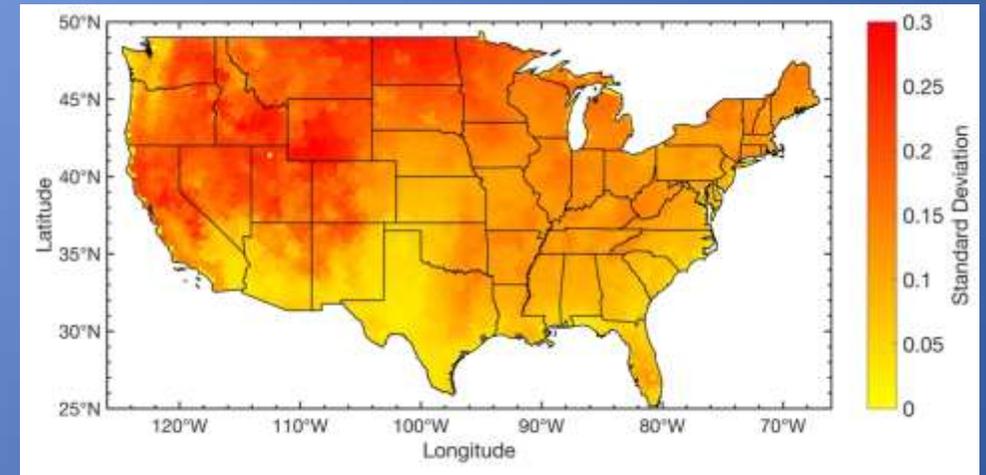
## Mean ESR



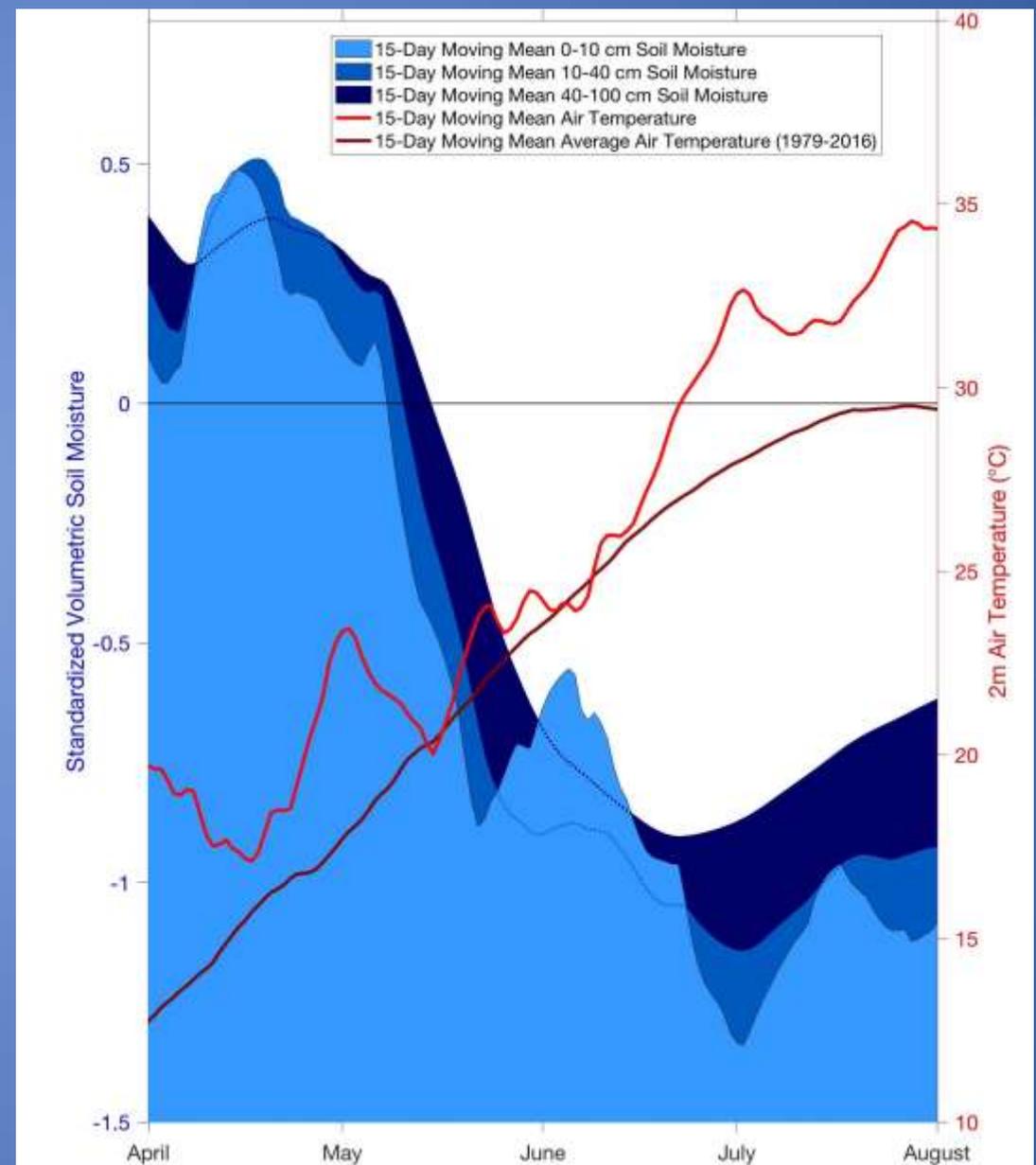
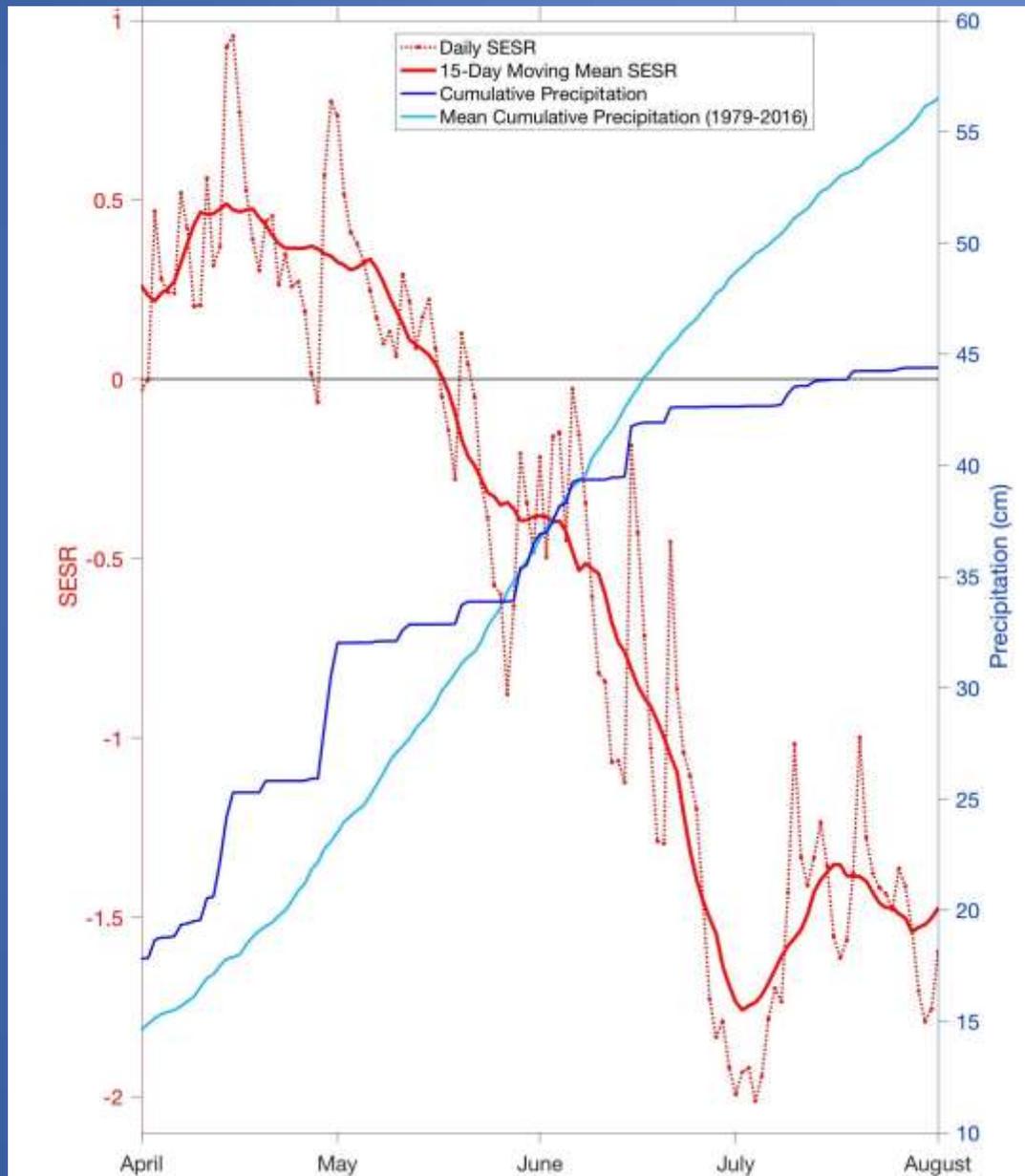
## Inter-annual (year-to-year) variability of ESR



## Intra-annual (within season) variability of ESR



# 2012 - North Central Oklahoma: Example of SESR



# Validation Case Study

## 2000 - Eastern Oklahoma/Western Arkansas

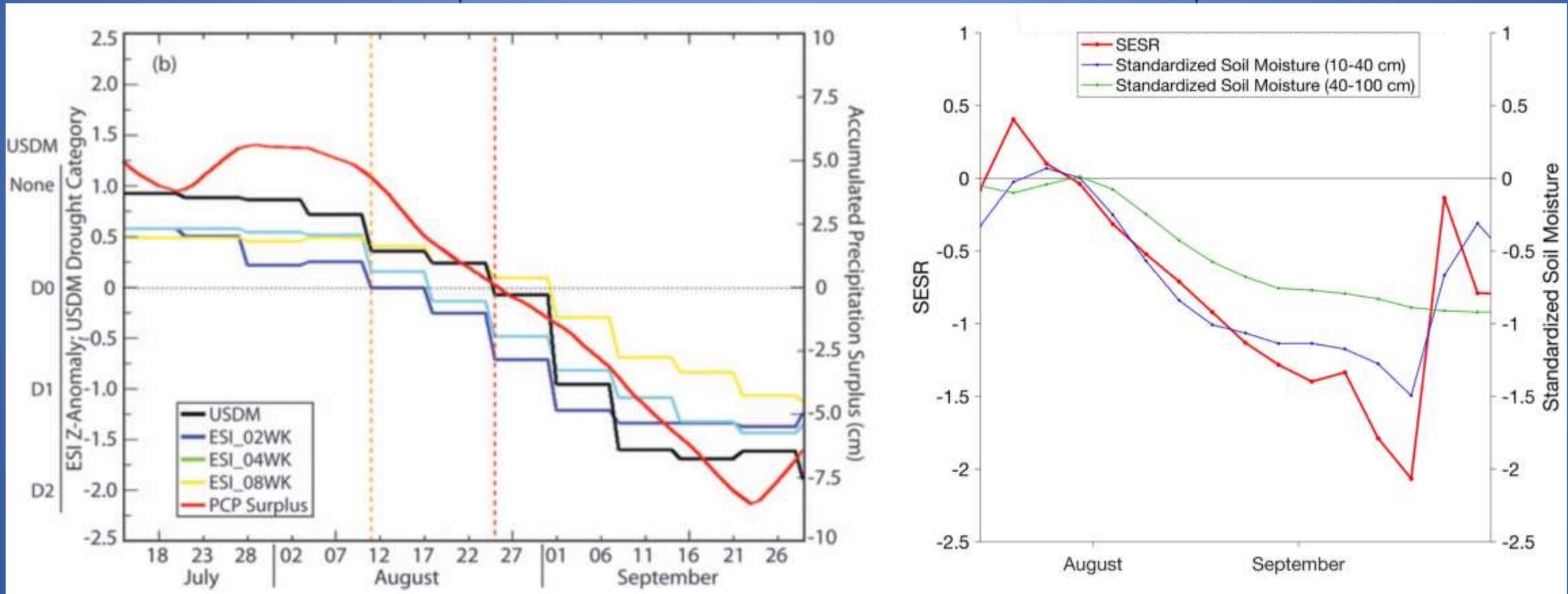
Otkin et al. 2013

Satellite-based ESI composite analysis



NARR

SESR pentad analysis



# Application of Methodology

Dataset: North American Regional Reanalysis

Domain: CONUS

Study period: The growing season (April through October) between 1979-2016

Analysis: Flash droughts identified via pentads using the Standardized Evaporative Stress Ratio (SESR)



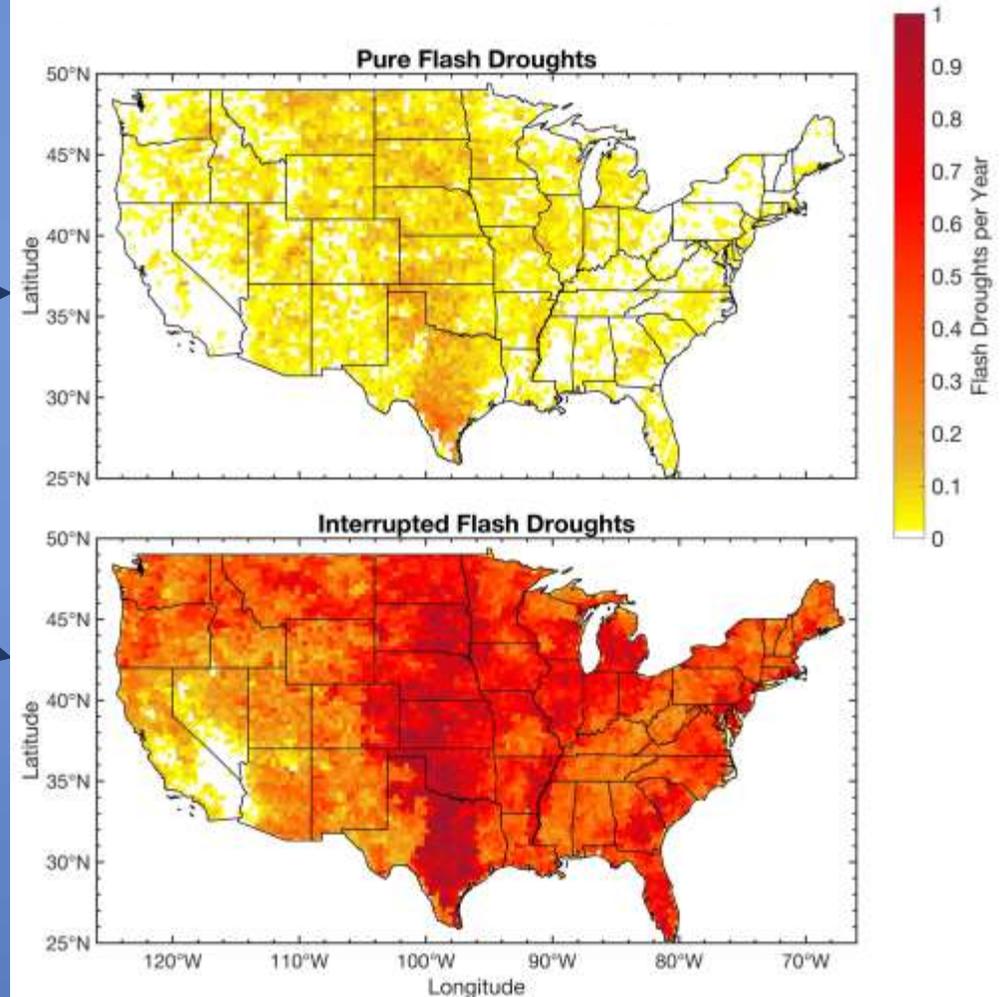
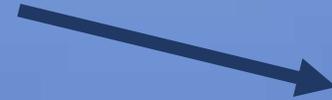
# Climatological Characteristics of Flash Droughts

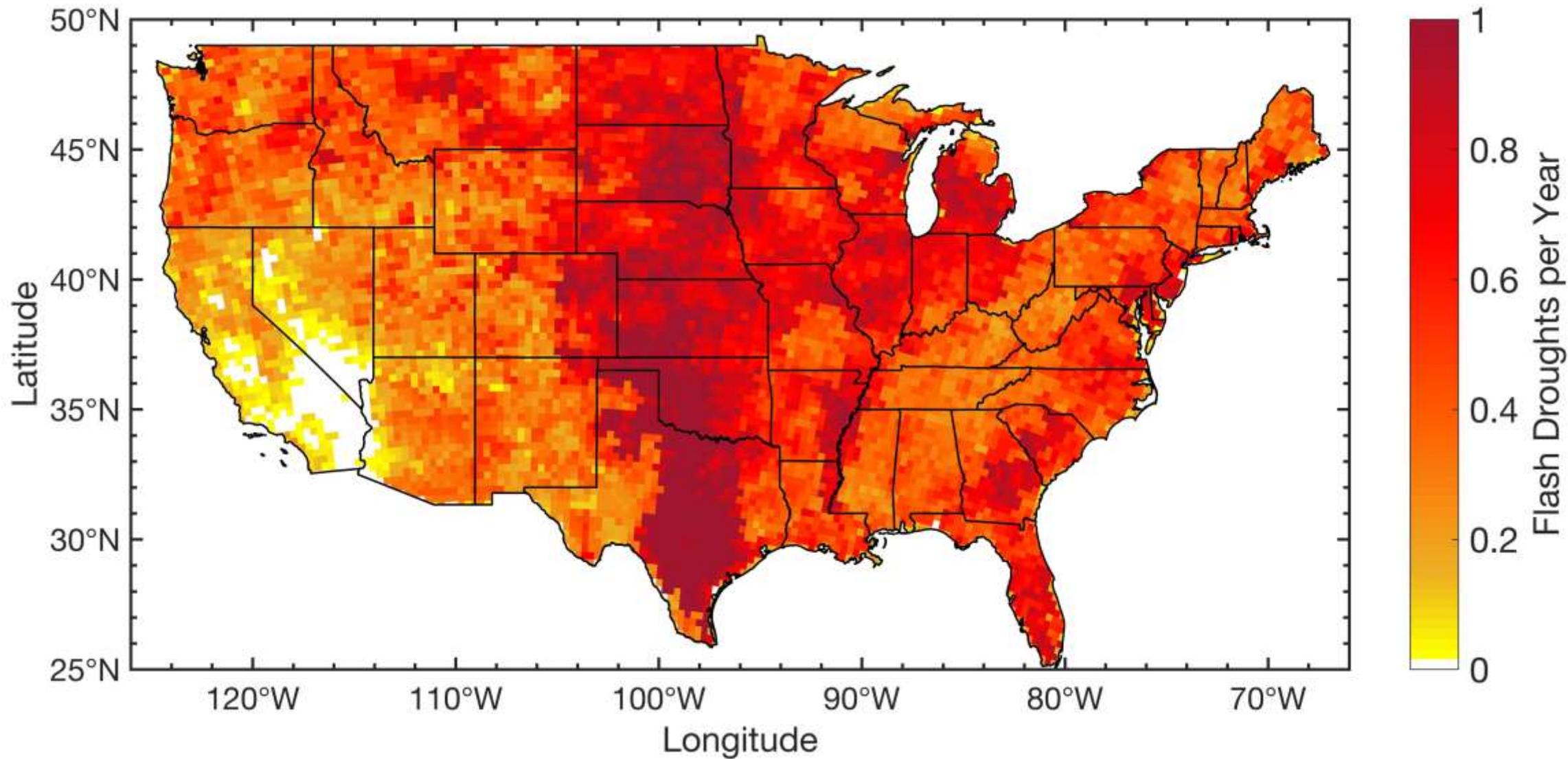
- 1) Where do flash droughts occur most often within the United States?
- 2) Are flash droughts more intense than others?
- 3) Can flash droughts occur more than once per growing season?
- 4) Can flash droughts be preceded by below-normal evaporative stress conditions? (abundant soil moisture, cooler temperatures, etc.)

# Flash Drought Occurrence

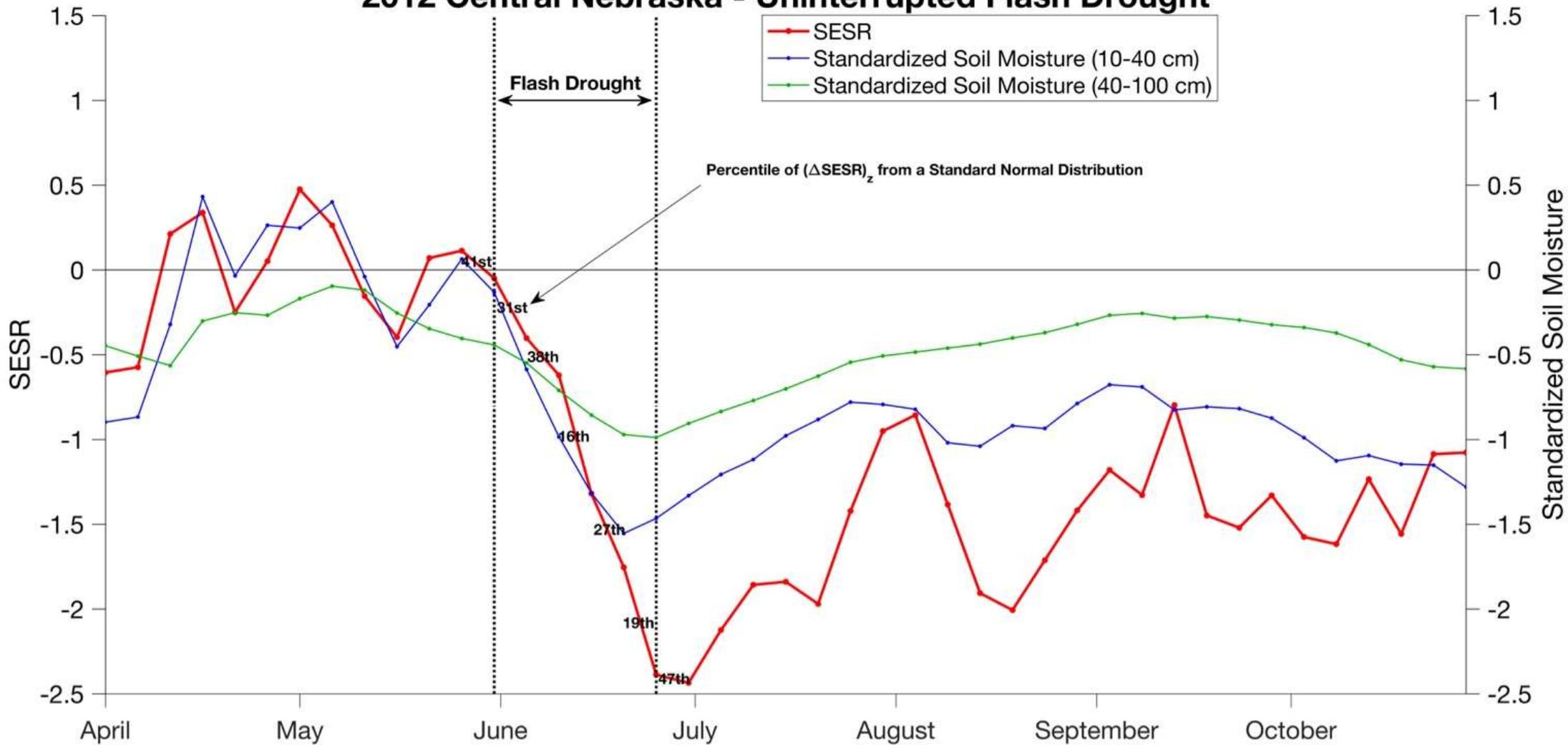
Flash droughts can be partitioned into two types:

1. Uninterrupted (pure) flash droughts: rapid monotonic increase of evaporative stress
2. Interrupted flash droughts: rapid increase of evaporative stress with brief moderation

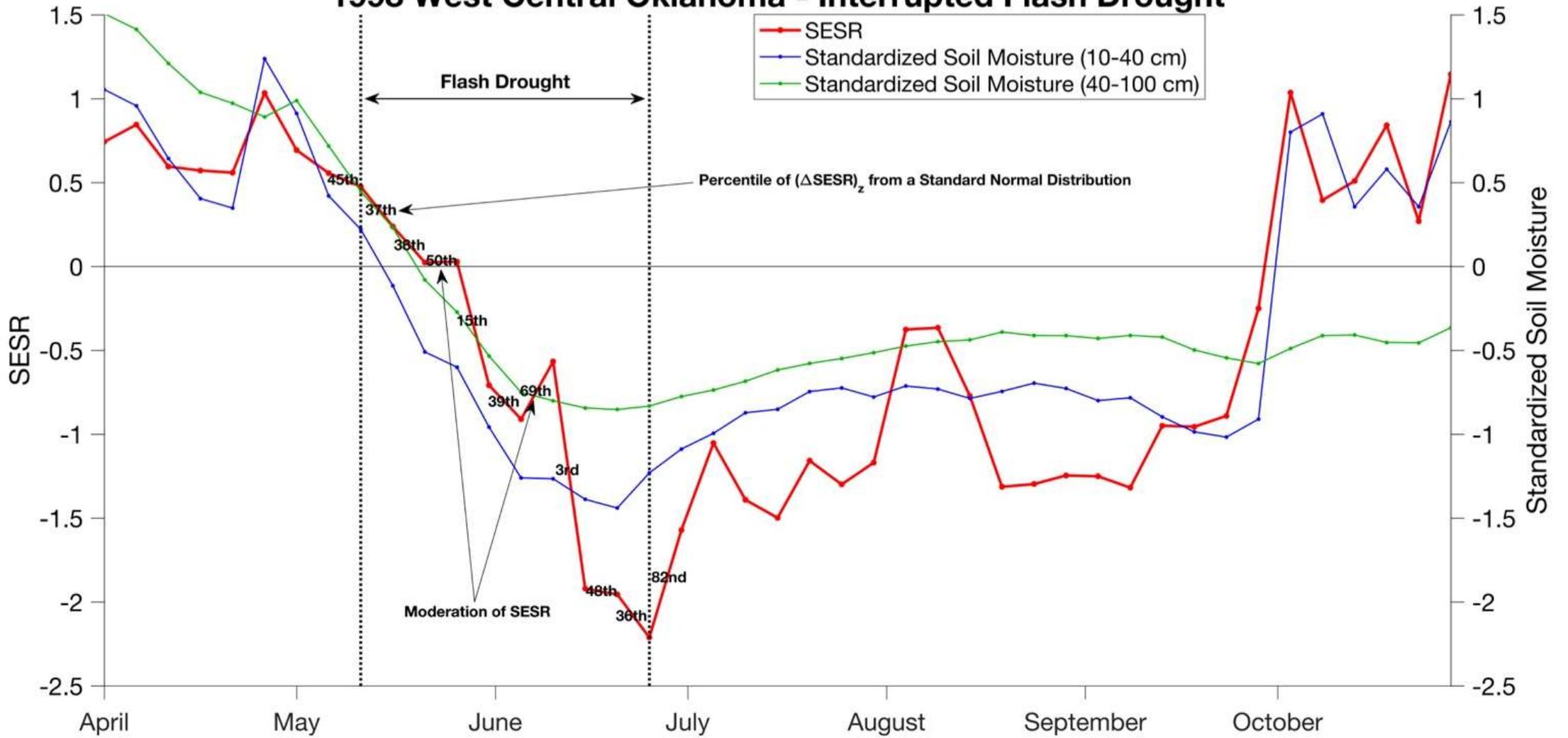




# 2012 Central Nebraska - Uninterrupted Flash Drought



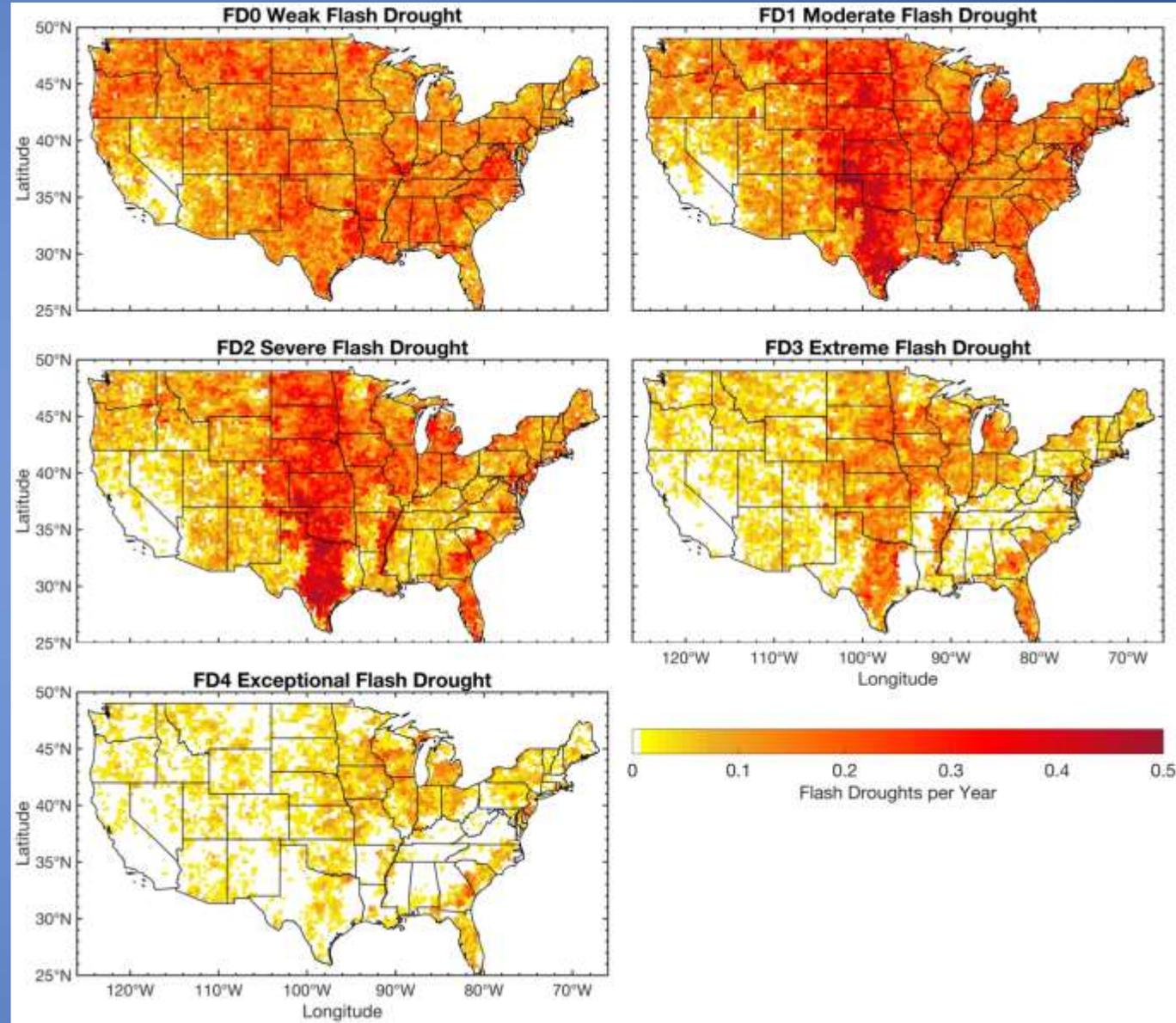
# 1998 West Central Oklahoma - Interrupted Flash Drought



# Flash Drought Intensity

Flash droughts were categorized by intensity using the mean SESR change during the flash drought.

Flash Drought Intensity Index	Flash Drought Intensity	Mean $(\Delta SESR)_z$
FD0	Weak Flash Drought	< 40 <sup>th</sup> Percentile
FD1	Moderate Flash Drought	< 35 <sup>th</sup> Percentile
FD2	Severe Flash Drought	< 30 <sup>th</sup> Percentile
FD3	Extreme Flash Drought	< 25 <sup>th</sup> Percentile
FD4	Exceptional Flash Drought	< 20 <sup>th</sup> Percentile



# Flash Drought “Aftershocks”

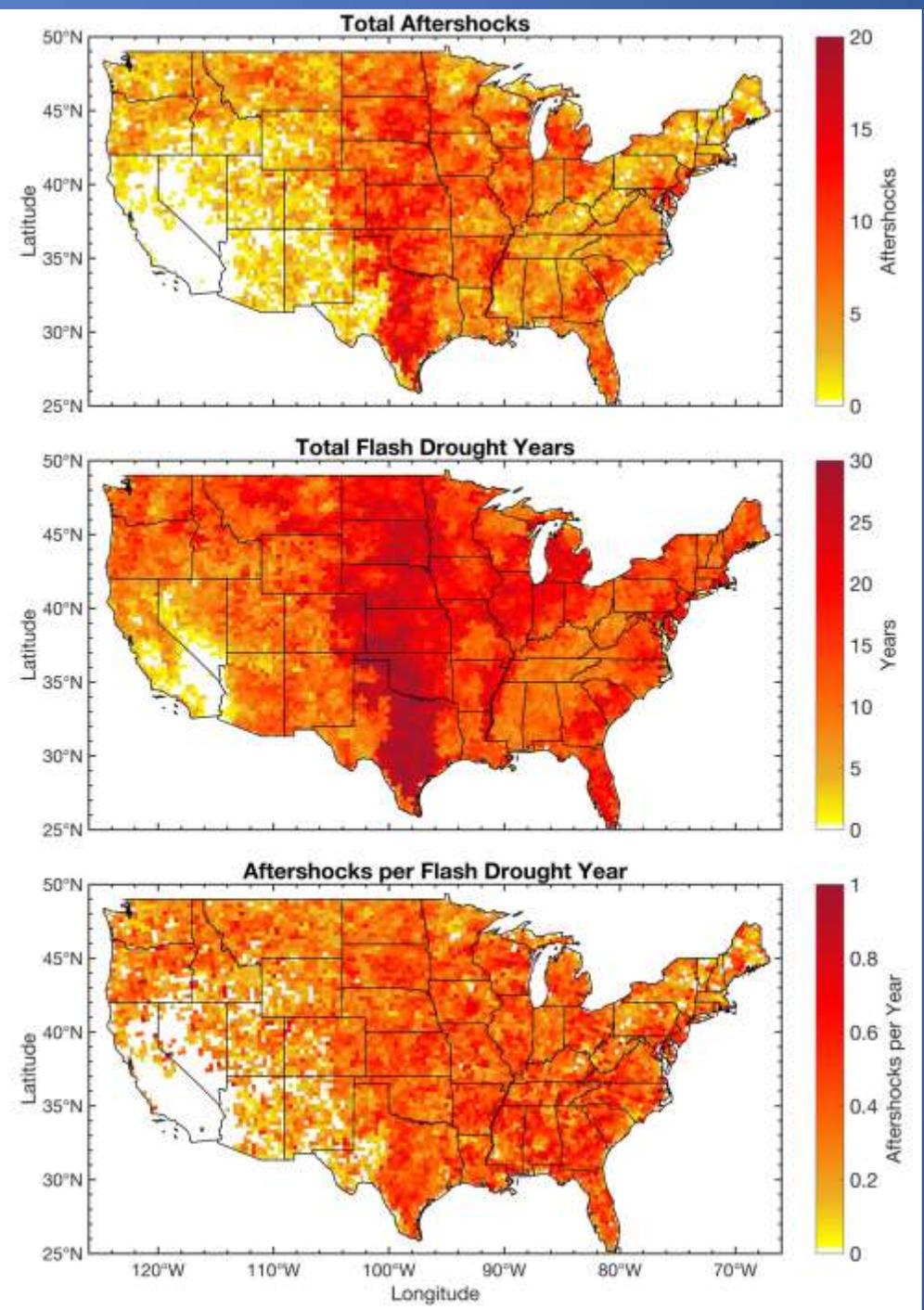
After an initial flash drought in a given year, it is possible for one or more flash droughts to occur following the initial flash drought.

Initial flash  
drought

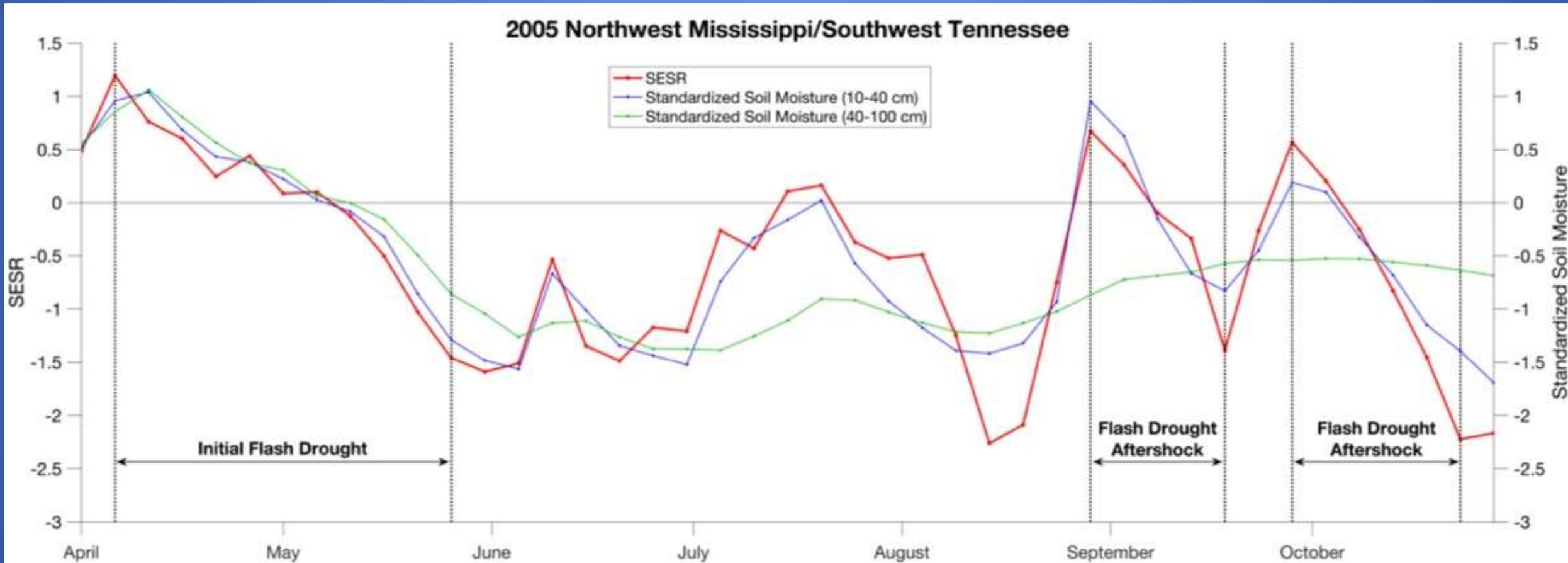
Moderation of SESR (due to precipitation, in combination with cooler temperatures, slower surface winds, etc.)

Environment susceptible to rapid increase in evaporative stress (depleted root zone soil moisture)

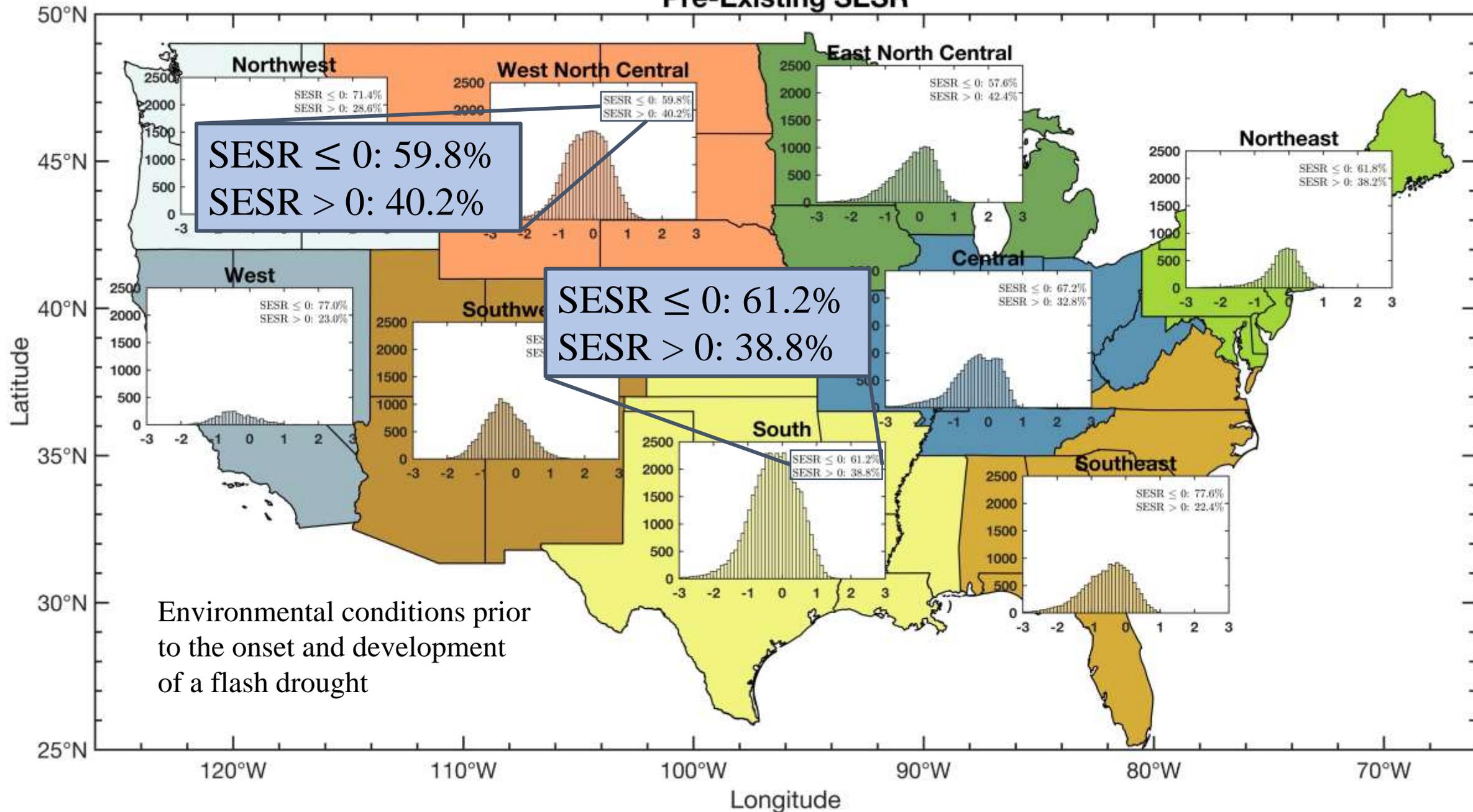
Flash drought  
“aftershock”



# Example of a Flash Drought Aftershock



# Pre-Existing SESR



Environmental conditions prior to the onset and development of a flash drought

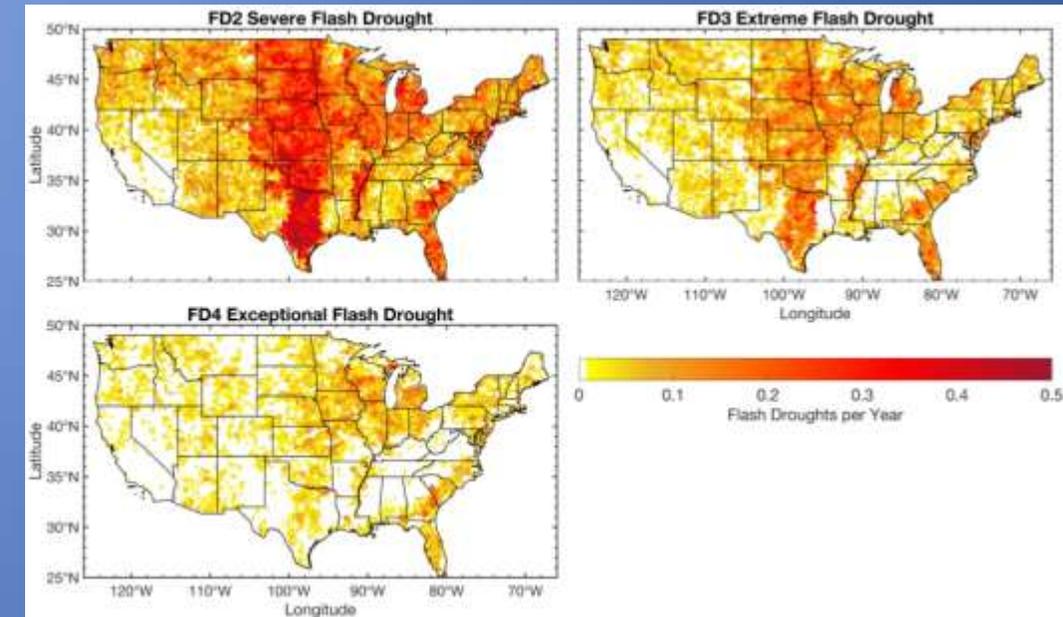
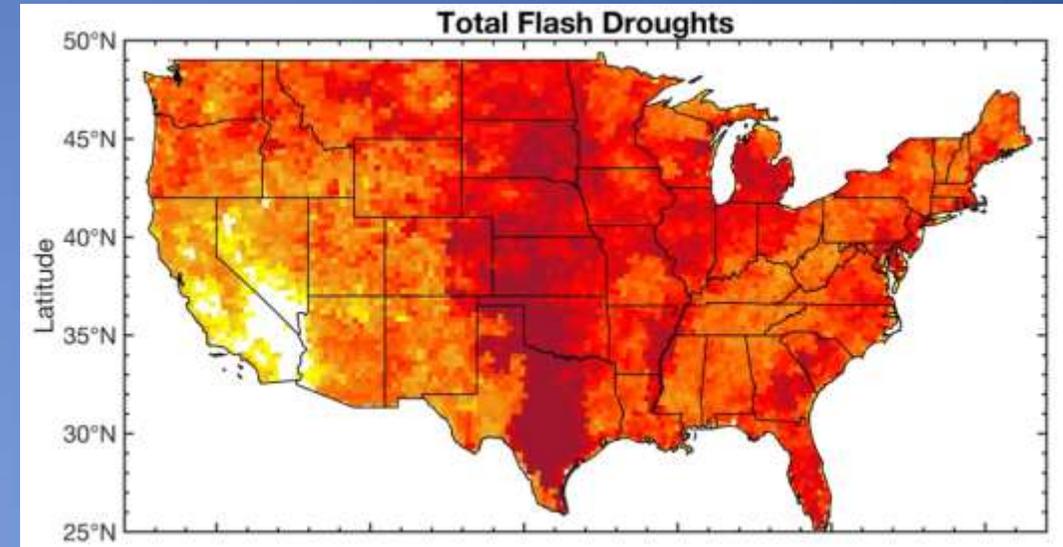
# Methodology Summary

- 1) SESR and the change in SESR are used for flash drought identification
- 2) Identification is defined from a percentile-based methodology on the rate of intensification
- 3) Flash drought methodology can be applied beyond reanalysis datasets

# Results Summary

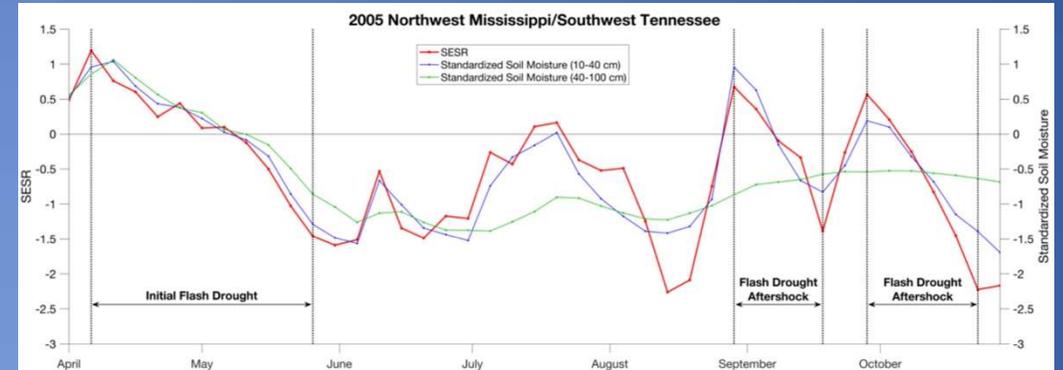
1) A “hot spot” of flash droughts exists across the Great Plains and Midwest

2) Intense flash droughts across the Great Plains, with the most intense flash droughts occurring over the Midwest

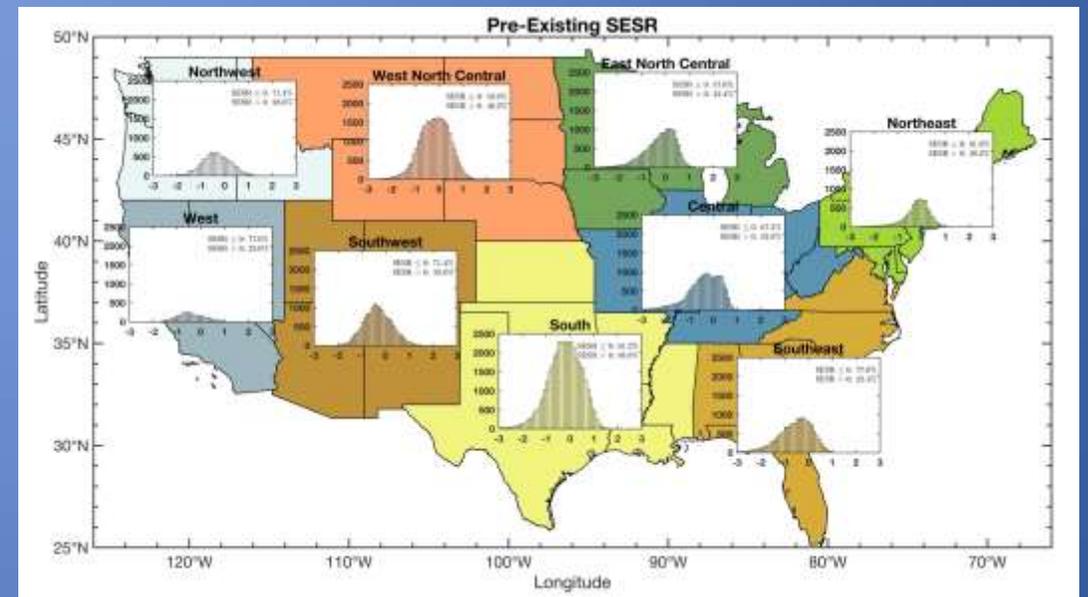


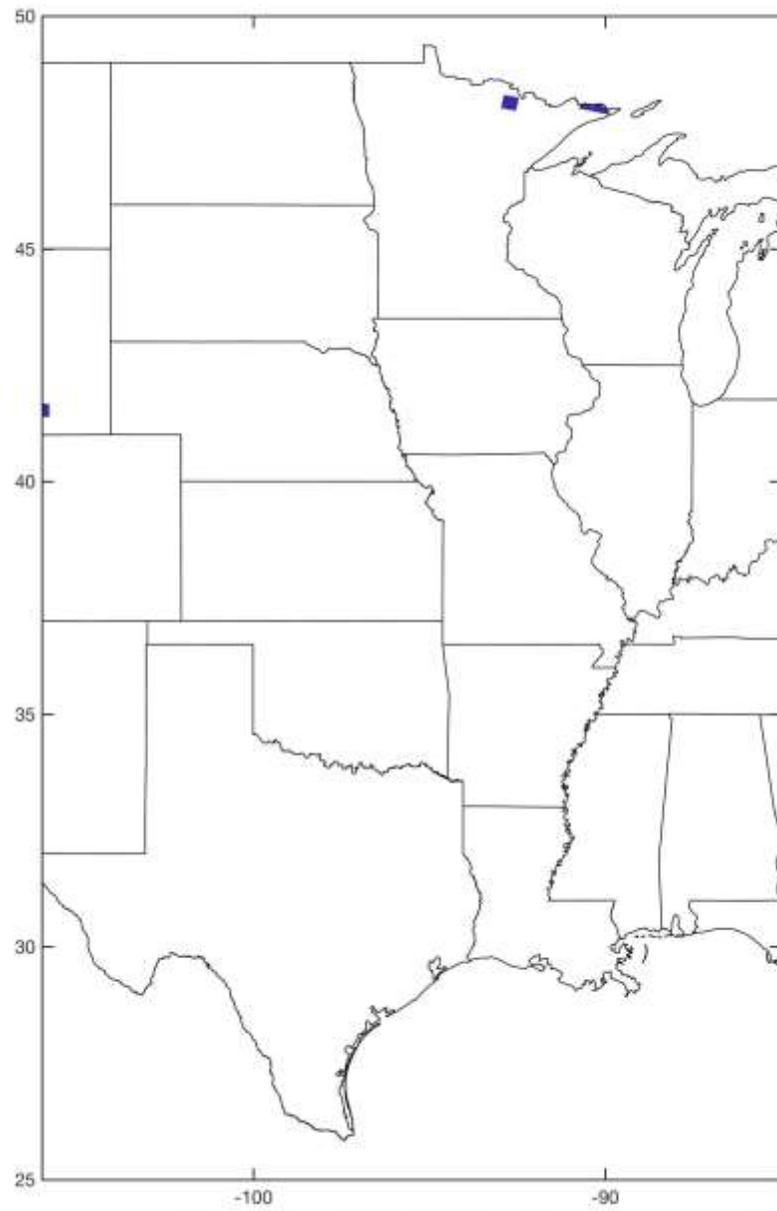
# Results Summary

3) The occurrence of a flash drought at the beginning of the growing season can lead to subsequent flash droughts (“aftershocks”) in the same year



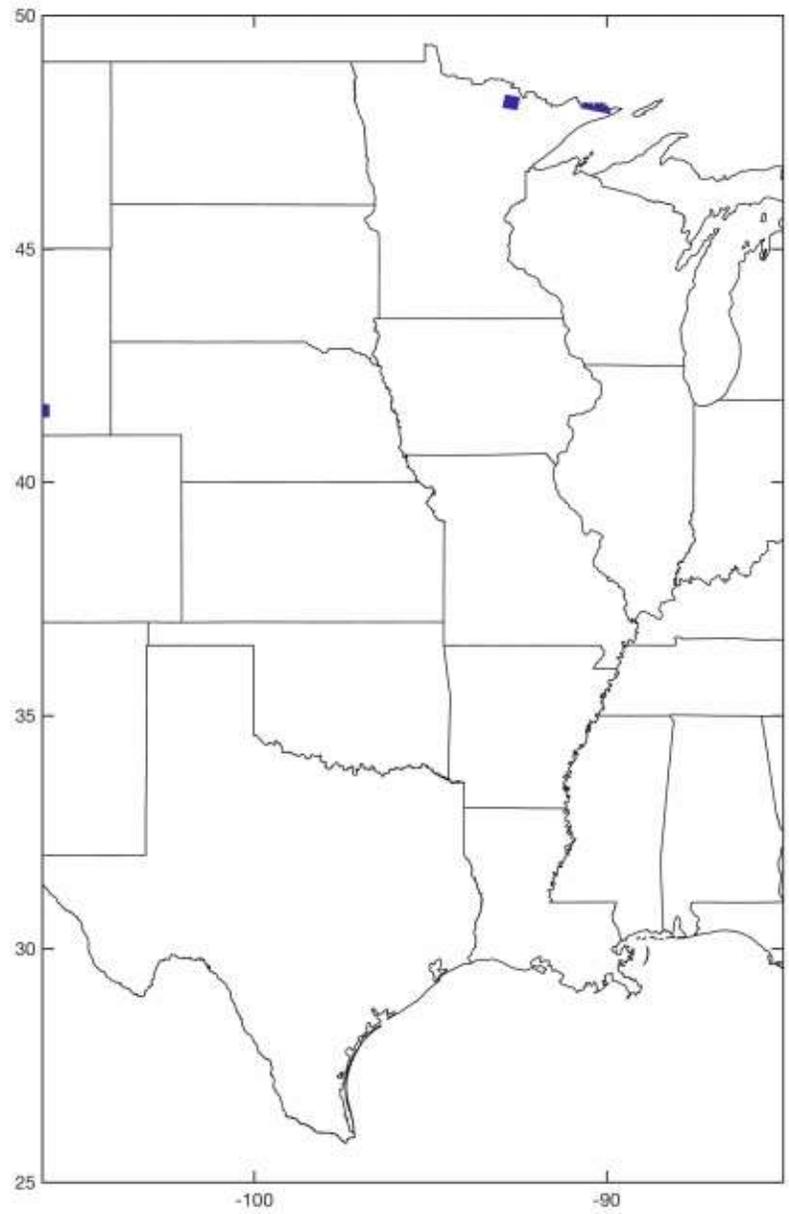
4) A significant amount of flash droughts (greater than 40%) are preceded by below-normal evaporative stress conditions in the Northern Great Plains, Southern Great Plains, and Midwest





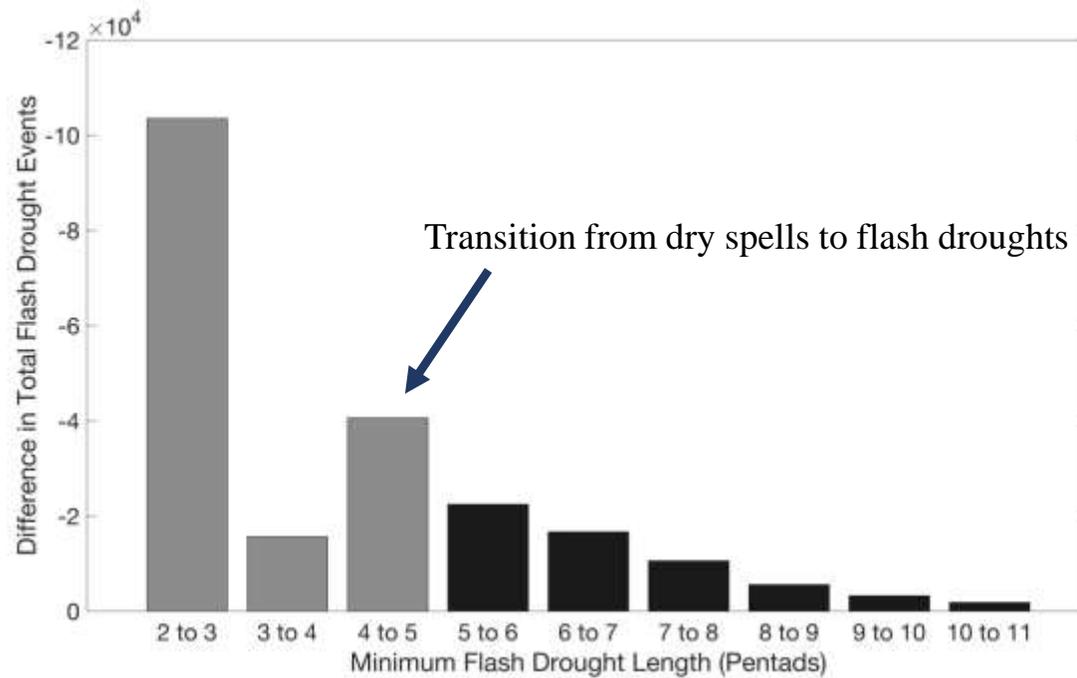
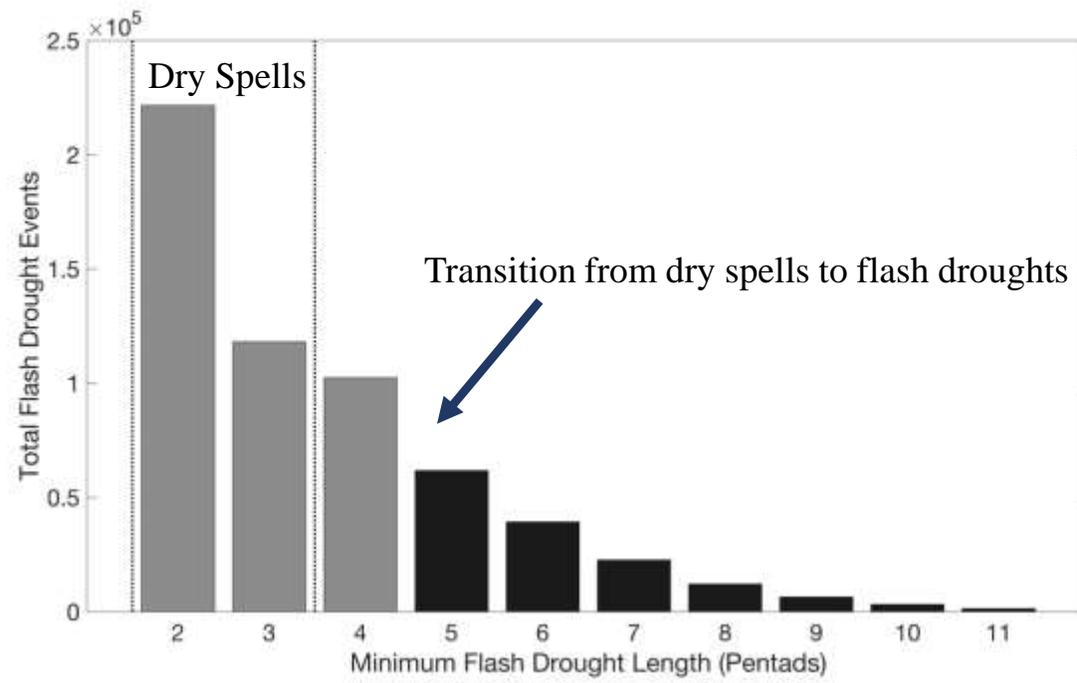
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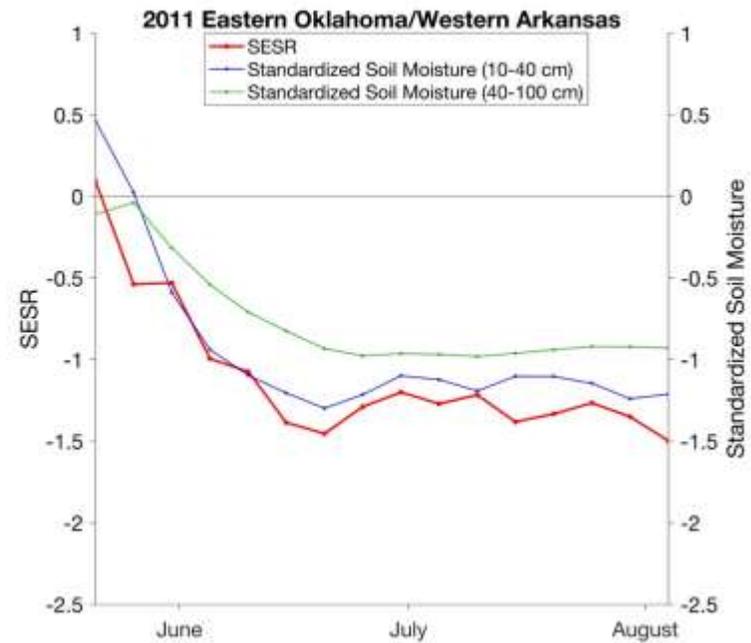
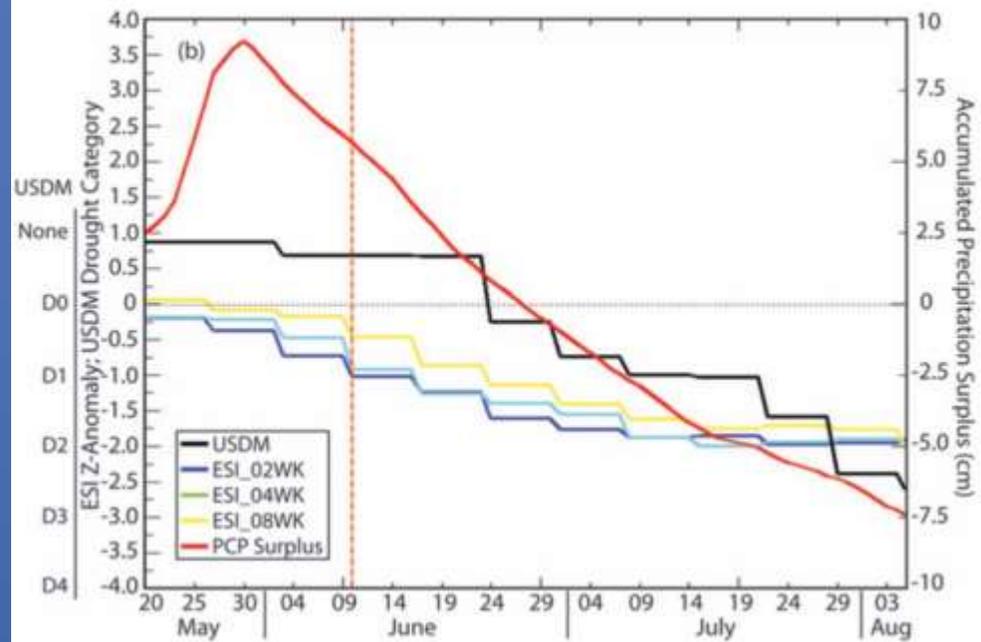
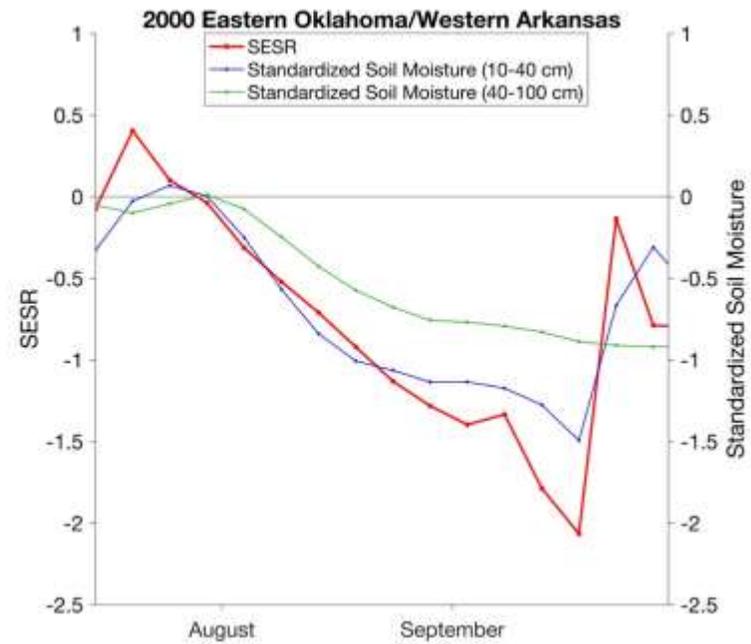
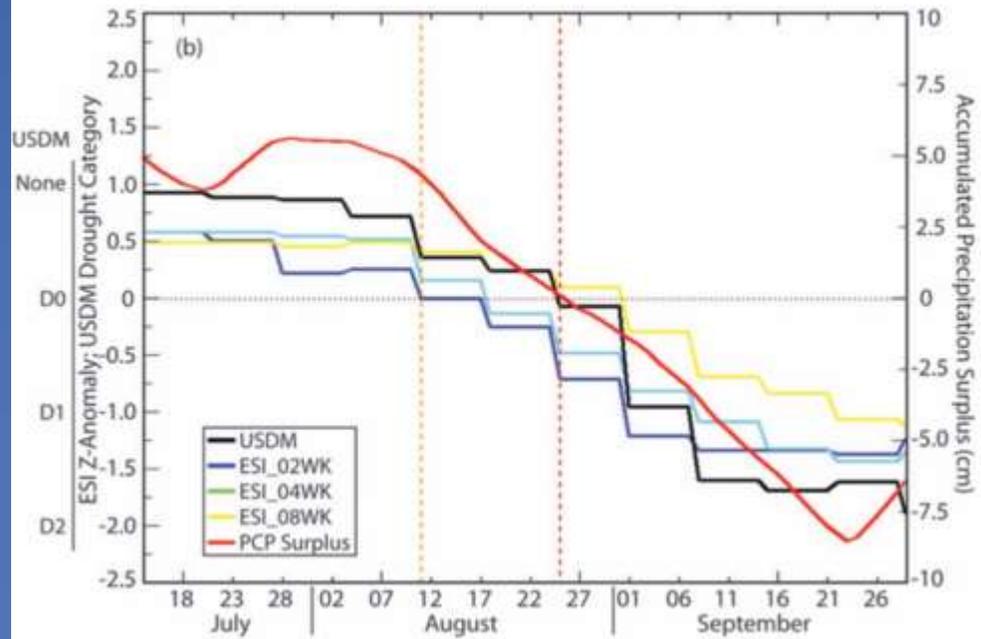
Pentad into Growing Season



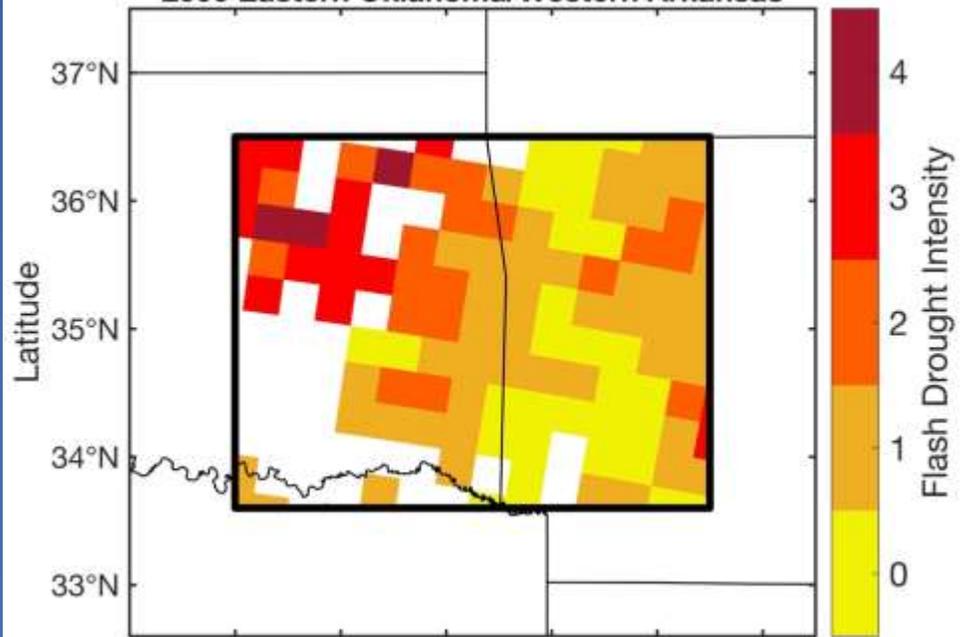
5 10 15 20 25 30 35 40 45  
Pentad into Growing Season

Questions?





2000 Eastern Oklahoma/Western Arkansas



2011 Eastern Oklahoma/Western Arkansas

