Flash Droughts Across the Southern Great Plains

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Types of Drought

Wilhite 2005
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
Characteristics of Flash Drought

- Rapid development of drought conditions (flash droughts) take place on the order of 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

- Higher temperatures
- Lack of precipitation
- Less cloud coverage
- **Higher wind speeds**
Research Motivation

• Provides a consistent definition of flash droughts
• Emphasis on the identification of flash drought via rate of intensification instead of duration
• Longevity and impact are fundamental characteristics of drought, and hence flash drought

The research presented here is complementary to Otkin et al. (2018) by providing a quantitative methodology for identifying flash drought events.
Evaporative Stress Ratio

• Mathematically: \( \text{ESR} = \frac{ET}{PET} \) (Evaporative Stress Ratio)

• ET - evapotranspiration

• PET - potential evapotranspiration

Potential evapotranspiration represents the “Atmospheric Demand” and can be estimated via the Penman-Monteith equation.

PET is impacted by:
• Net Radiation
• Vapor Pressure Deficit
• Wind Speed
• Temperature
Evaporative Stress Ratio

- \( ESR = \frac{ET}{PET} \) (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
Standardized Evaporative Stress Ratio

\[ SESR = \frac{ESR - \bar{ESR}}{\sigma_{ESR}} \]

- 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
A Methodology for Flash Drought Identification

Initial Flash Drought Criteria

1) The length of the flash drought must be at least 6 total pentads long (30 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 20th 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).
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) What are the temporal characteristics of flash droughts?
Flash Drought Occurrence

A map of the United States showing the percentage of years with a flash drought. The colors range from yellow (low percentage) to red (high percentage).
Flash Drought Intensity

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

<table>
<thead>
<tr>
<th>Flash Drought Intensity Index</th>
<th>Flash Drought Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD1</td>
<td>Moderate Flash Drought</td>
</tr>
<tr>
<td>FD2</td>
<td>Severe Flash Drought</td>
</tr>
<tr>
<td>FD3</td>
<td>Extreme Flash Drought</td>
</tr>
<tr>
<td>FD4</td>
<td>Exceptional Flash Drought &lt; 10th Percentile</td>
</tr>
</tbody>
</table>
Flash droughts were partitioned by month.

Flash drought likelihood increases until the middle of the warm season and decreases after June.

June had the highest frequency of flash drought events in the South climate region.
Monthly Flash Drought Intensity

• Flash drought intensity was averaged for each month

• Flash drought intensity increases until May, then decreases throughout the remainder of the warm season

• May had the highest average intensity of flash drought events in the South climate region
Evaporative stress (SESR) was averaged 2-months prior to each flash drought event.

- 59% of flash drought events had 2-month preceding SESR less than 0 (below normal).
- 41% of flash drought events had 2-month preceding SESR greater than 0 (above normal).
Conclusion

1) A “hot spot” of flash droughts exists across the Great Plains and Midwest, with Oklahoma experiencing flash droughts in approximately 2 out of 5 years.

2) Along with the Central Plains and Midwest, Oklahoma can experience some of the most *rapidly intensifying* flash drought events.

3) Across the Southern Great Plains:
   - Flash droughts can occur regardless of preceding moisture conditions.
   - The peak timing for flash droughts is June.
   - Flash drought events are most intense in May on average, and their average intensity decreases through the warm season.
Questions?

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