

Otkin et al. 2018

- NCEI for source on drought costs.
- Examples in Introduction have a 3 - 5 category increase in 2 months (United States Drought Monitor (USDM) category).
- Flash drought requires more than a precipitation deficit. Main features is evaporative stress to quickly deplete soils via ET.
  - Can be done with high temperatures and winds, sunny skies, and low relative humidity.
- The term “flash drought” was coined by Svoboda et al. 2002 in the introduction to the USDM.
- Otkin et al. (2014, 2015a) for development of the rapid change index (RCI), which encases the accumulated magnitude of moisture stress changes over multiple weeks.
  - $RCI < 0$  indicates drought is likely. The probability increases as the RCI becomes more negative.
- Also consider the soil moisture index (SMI)
- Soil moisture deficits starts at the surface and works down.
  - This can be used to check models.
- Precipitation ( $P$ ) – potential evapotranspiration ( $PET$ ) is a better predictor for flash drought than precipitation and temperature.
  - $P - PET$  indicates the balance between supply and demand for surface moisture.
- Rapidly declining soil moisture could be a precursor for flash drought.
- See page 4, paragraph 3.
  - Description on heat wave flash drought and precipitation flash drought from Mo and Lettenmaier (2015 and 2016).

- For a flash drought definition, the rate of intensification is emphasized, as well as the dry conditions.
- First requirement: Drought indices used to monitor it should be computed over short time scales ( $< 1$  month) to monitor rapid changes and be sensitive to soil moisture, ET, evaporative demand, or vegetation health.
- Second requirement: Indices must fall into drought during rapid intensification (below the 20<sup>th</sup> percentile).
- Suggests a suite of different magnitude and temperature change thresholds to classify flash drought.
  - E.g., change in 2 USDM categories over 5 weeks could be moderate flash drought.
  - These should capture change in time and actually be sufficiently dry conditions.
- Flash droughts are more likely to occur when evaporative demand is above normal for several weeks.
- Consider the evaporative demand drought index (EDDI; Hobbins et al. 2016; McEvoy et al. 2016).
- Standardized precipitation evapotranspiration index (SPEI) should be used.
- Evaporative stress ratio ( $ET/PET$ ) can provide a clearer signal than PET.
- EDDI and ESI compliment each other.
  - EDDI identifies drought earlier, but has a higher false alarm rate.
- Flash drought can also be monitored with vegetation indices, NDVI, EVI, LSWI, etc. (i.e., monitoring the health of the vegetation).
- New forecast methods that leverage the long-term memory of soil moisture should be explored (see Lorenz et al. 2017a, b).

- Land-atmosphere interactions and their role in flash droughts should also be further studied.
- Easy to use and deliver drought forecasting tools are what are desired by effected groups (e.g., stakeholders).

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- The evaporative stress ratio (ESR) incorporates temperature, wind speed, vapor pressure deficit, latent heat flux, sensible heat flux, soil moisture, precipitation, and short wave radiation.
  - Unlikely these are all satellite derived.
- The standardized ESR (SESR) are more easily compared between regions.
- Mean and standard deviations for ESR and SESR are over all available years.
- See p. 2, equations 1 – 3, and Figure 1 for method on SESR calculations.
- There are four criteria for identifying flash drought:
  - 1) Minimum length of 5 SESR changes (i.e., 6 pentads for 30 days).
    - \* Eliminates dry spells.
  - 2) Final SESR values should be below the 20<sup>th</sup> percentile of SESR values.
    - \* Drought condition from Otkin et al. 2018.
  - 3a) Change in SESR must be below the 40<sup>th</sup> percentile between individual pentads.
  - 3b) No more than 1 change in SESR is allowed to be above the 40<sup>th</sup> percentile, following that a change in SESR meets criteria 3a.
    - \* Requires drying conditions while allowing some moderation that may occur.
    - \* Also helps prevent traditional droughts from being classified as flash droughts.

- 4) Mean change in SESR during the entire length of the flash drought (i.e.  $SESR_{FD,end} - SESR_{FD,start}$ ) must be less than the 25<sup>th</sup> percentile of the climatological change in SESR for that grid point and time of year.
  - \* Ensures rapid rate of development, and that the drought is not significantly slowed by temporary moderation.
- Figure 2 for an example of this analysis method.
- Figure 3 for how to apply this method.
- Evaporative stress is limited in winter due to dormant vegetation (ET) and cold temperatures (PET).
- SESR calculated from NARR performed okay when tested against ESI.
  - Figure 4 for comparison.
  - Page 6 for discussion.
- SESR calculated from NARR performed well when tested against the USDM.
  - Figure 6 for comparison.
  - Pages 6 – 8 for discussion.
- Figure 7 is interesting.
- Table 1 for an index on flash drought intensity.
- Figure 8 is also interesting.
  - Same as Figure 7 but with intensity categories from Table 1.
- Found 24% of flash droughts had a monotonic decrease in SESR and 76% included a significant, but temporary moderation.
- Great Plains, western Great Lakes, Corn Belt, and Atlantic Coast (to a lesser degree) identified as hotspots.
  - One reason may be land-atmosphere interactions & positive feedbacks.
  - Another could be due to agriculture.

- A hypothesis supported: regions with crops act as an accelerant for changes in evaporative stress and thus lead to more intense flash drought.
- Agricultural regions tend to contain a higher frequency of flash droughts.
  - Only regions like the Corn Belt and Great Plains are highlighted. Potentially in areas like Central Valley, Scab Lowlands, Salt Trough, etc.?
- SESR method could depend on the land surface model (LSM) used for the dataset.
  - LSM has to capture ET and PET variability.
- SESR method places a cap on too many flash droughts identified (false alarm) error.
- Too few flash droughts identified error (some flash droughts missed) can have subjectivity to it though.