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^{th} 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$^{\text{th}}$ percentile of SESR values.
     * Drought condition from Otkin et al. 2018.

  3*a*) Change in SESR must be below the 40$^{\text{th}}$ percentile between individual pentads.

  3*b*) No more than 1 change in SESR is allowed to be above the 40$^{\text{th}}$ percentile, following that a change in SESR meets criteria 3*a*.
     * 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$^{\text{th}}$ 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.