Flash Droughts over the United States

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outline

• Define flash droughts
• Physical mechanisms for flash droughts
• Flash drought prediction from the CFSv2 seasonal forecasts
Data sets from UCLA

• Data period: 1916-2013
• Interval: Pentads (5-day means)
• Four variables ($T_{air}$, P, ET and SM):
  ➢ $T_{air}$, P (gridded from observed stations 0.5 degrees),
  ➢ ET and total SM (reconstructed from land models: Noah, Catchment, SAC and VIC).

We process each model separately, then took the ensemble mean
flash droughts

Flash droughts == Heat wave meets low soil moisture
High temperature
Low soil moisture
Lack of precipitation

There are two types of flash droughts

- One starts with heat waves--- Heat wave flash drought
- One starts with P deficits----P deficit flash drought
Heat wave flash drought

**Definition**

High temperature $\Rightarrow T_{air} > 1$ standard dev

ET increases (anomaly $> 0$)

SM decreases – to 30% or lower

Frequency of occurrence $\Rightarrow$ number of events/record length

4-5% max
Heat wave flash drought

a) FOC

FOC = Number of events/record length

1. It occurs in the vegetation dense areas
2. Physical mechanisms

High temperature
⇒ Increase of the transpiration and (ET)
⇒ Decrease SM

heat wave flash drought occurs in the vegetation dense areas
P deficit flash drought

Definition
T > 1SD
ET anom < 0
P < 40%

Physical mechanisms
• It starts from the lack of precipitation (P)
• P deficits = \( \Rightarrow \) decreases of SM
• \( IF \Rightarrow \) decreases of ET
• \( \Rightarrow \) balanced by increases of sensible heat
• \( \Rightarrow \) increases of Temperature

The critical element \( \Rightarrow \) relationship btw SM and ET
Physical mechanisms for P deficit flash drought

a) $\text{corr}(\text{sm}, \text{Tair})$

In the areas where the lack of SM $\Rightarrow$ increase of Tair

Pathway through ET

b) $\text{corr}(\text{ET}, \text{SM})$

Only occurs in the areas where ET and SM have a near linear relationship

Too dry

Lack of variability

Koster et al 2009

Monthly mean correlation (apr-sep)
Frequency of occurrence

Heat wave flash drought

P deficit flash drought
Can CFSv2 seasonal forecasts predict flash droughts?

- CFSv2 seasonal (first 90-day) forecasts from April to July
- A) whether forecasts can predict the preferred regions for flash droughts to occur?
- B) whether the CFSV2 can predict each event?
- C) if B is too much to ask, then whether the CFSV2 can predict the occurrence of flash droughts in 3 categories: below, normal and above?
Data from CFSV2 hindcasts

Data:
For each month
• 12 ensemble members
• 18 pentads (90day)
• 29 years (1982-2010) so we have total 12 x 18 * 29 members

4 variables (T,P,ET,SM)
• Correct systematic error of T and P
• Drive a VIC model to get ET and SM
• Bias correct ET and SM
• Get (T (std), ET (anom), P and SM(percentiles))

Verification
• VIC(SIM) – observed T and P to drive a VIC model to get ET and SM
• Same criteria for flash droughts
FOC predicted by the CFSv2 seasonal fcst

Analysis
Heat wave

FCST
Heat wave

P deficit

P deficit
ETS score of flash drought events /yr

- ETS = hit/(hit+miss+false alarm)

- Hit --- both obs and fcst indicate there are flash drought events in the following season
- Miss - obs indicates events, but not forecasts
- False alarm - fcst indicates events, but not obs
- We also correct the random occurrence of flash droughts
ETS scores
Heidke skill of forecasts of the yearly total flash droughts events over the United States in 3-category forecasts

1. There are negative scores
2. It is not influenced by ENSO
Can CFSv2 seasonal forecasts predict flash droughts?

• A) whether forecasts can predict the preferred regions for flash droughts to occur? **YES**

• B) whether the CFSV2 can predict each event? **NO**

• C) if B is too much to ask, then whether the CFSV2 can predict whether there are flash drought events in the coming season?

  Skill is similar to the 5-10 day forecasts of temperature and precipitation
Operational monitoring started from 1 May 2017 to the present

1. We display ET anomaly, T2m stand. Anom and SM and P percentiles
2. Update daily
3. Every 5 days from 10 days ago to the present pentad
Seasonal flash drought fcsts
Summary

There are two types of flash droughts

1. Heat wave flash drought
   • Occurs in the North Central and the Pacific Northwest
   • Max frequency of occurrence is 4-5%
   • Temperature driven
   • High temp => increasing ET => decreasing SM

2. P deficit flash drought
   • Occur over the Great Plains and southern states with a maximum over Texas
   • Max frequency of occurrence is 8-10%
   • Precipitation driven
   • P deficits => Decreasing SM => decreasing ET => Temp increases

3. CFSv2 seasonal forecasts
   • It is able to capture the frequency of occurrence and the
   • Heidke skill for 3-category forecasts is overall positive