Flash Drought over the United States

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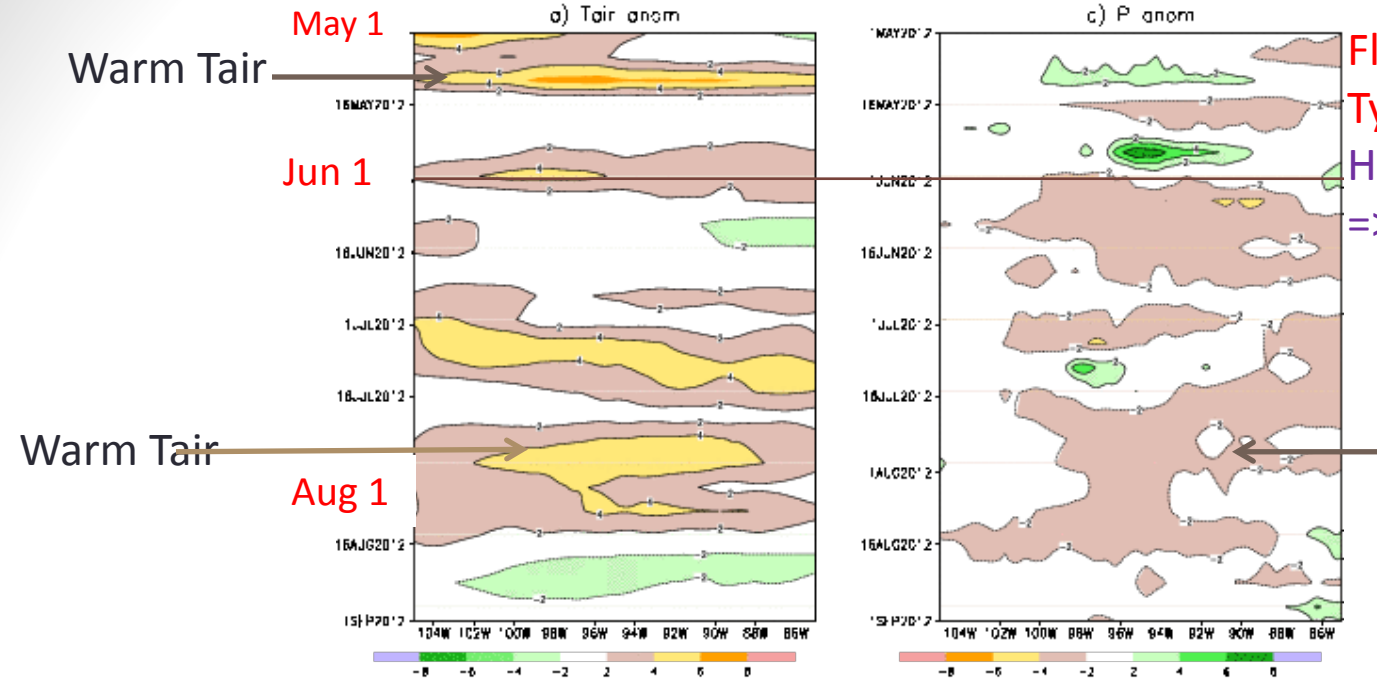
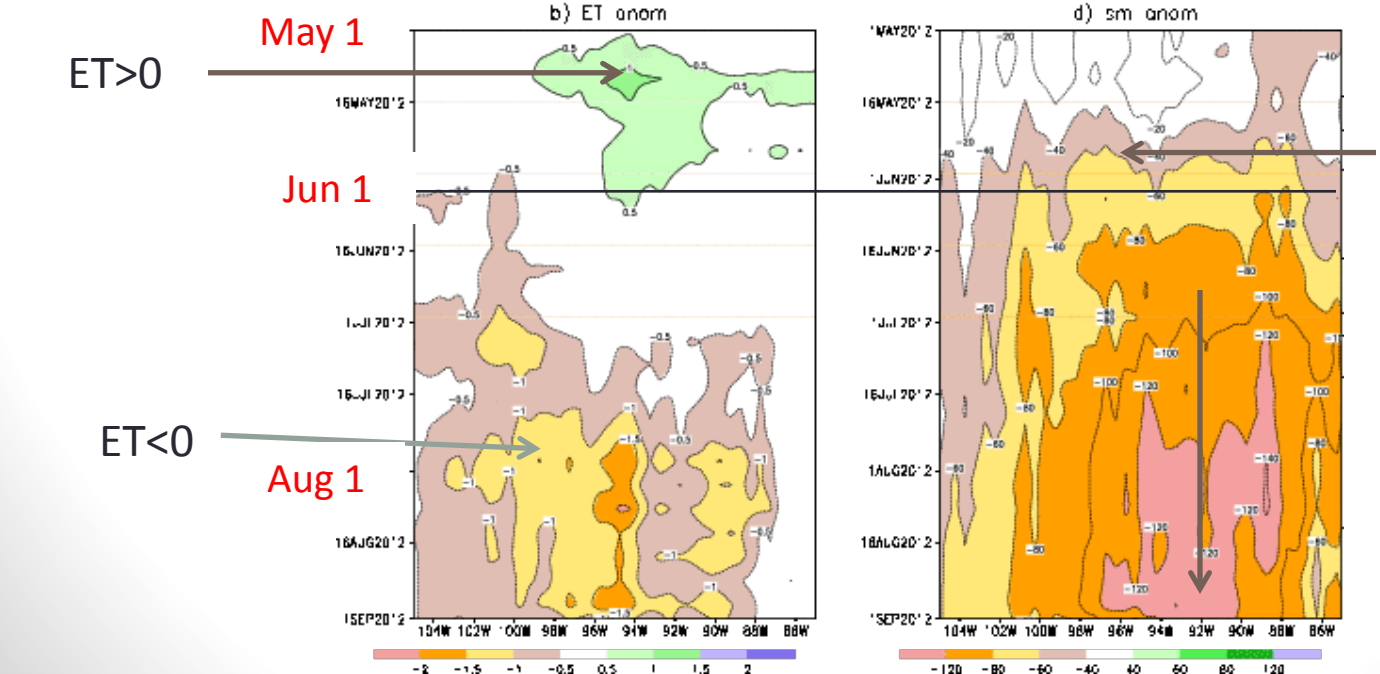
What is flash drought?

- 1. Relatively short but severe periods of warm air temperature Heat waves
- 2. Anomalously low and rapid decreasing soil moisture (SM).
- It is agricultural drought

2012 drought evolution (36-42N)





Flash drought
Type1 1 (may-June)
High Tair=> ET>0
=> SM drops

Flash drought
Type 2 (aug)
Lack of P=>
decreases of
SM=> ET<0
=> High Tair

Two types of flash drought

Flash drought: Both Types show

1. High temperature (Tair> 1 std)
2. SM below 30% (agricultural drought)

1. Type 1 : ET anom >0

High Temp => increases of ET anom(Evapotranspiration) => decreases of SM .

2. Type 2 : ET anom <0

Imbedded in meteorological drought

ref :Yang 2013, Myoung and Nielsen-Gammon 2012

ref: Otkins et al 2012, Anderson et al 2012, Hunt et al. (2008)

Data –

Pentad data:

- Observations: surface temperature (Tair) , Precipitation (UW)
- (They derived from index stations so consistent through the study period)
- Surface variables: total soil moisture, (SM) and ET from the UW VIC , SAC, Catchment and Noah pentad outputs from 1916-2013
- Data period: April to September (Total 36 pentads/yr and 98 years, total 3528 pentads)
- Atmospheric conditions_ 200 hPa streamfunction anomalies from 1958-2013 (CDAS)

Frequency of occurrence

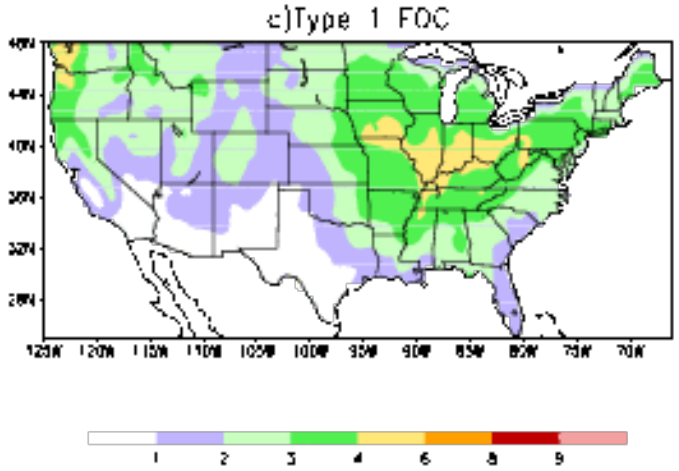
Select events

For each pentad and each grid point, we select drought events using criteria

- For both types:
- Tair> 1 std dev -- high temp
- SM<30% D0 or higher--Drought
- type 1 ET anom> 0 ; type 2 ET<0.
- Frequency of occurrence = total pentads under drought/ record

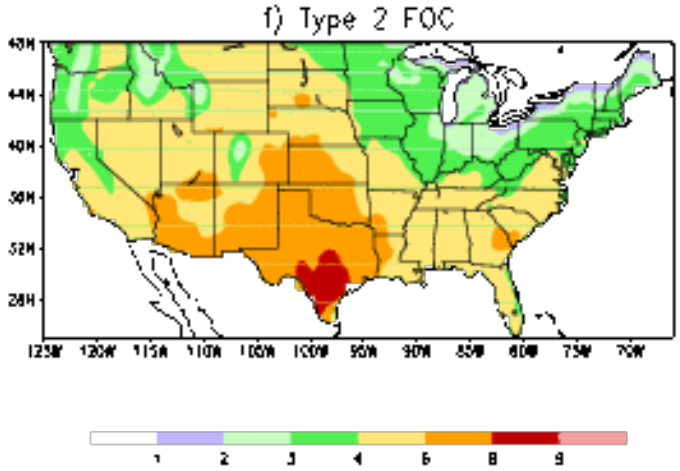
Frequency of occurrence

TYPE 1



1. Less common: Only about 4-5% of total record
2. Occur over the vegetation dense areas
3. Max: North Central and Ohio basin and the Pacific Northwest

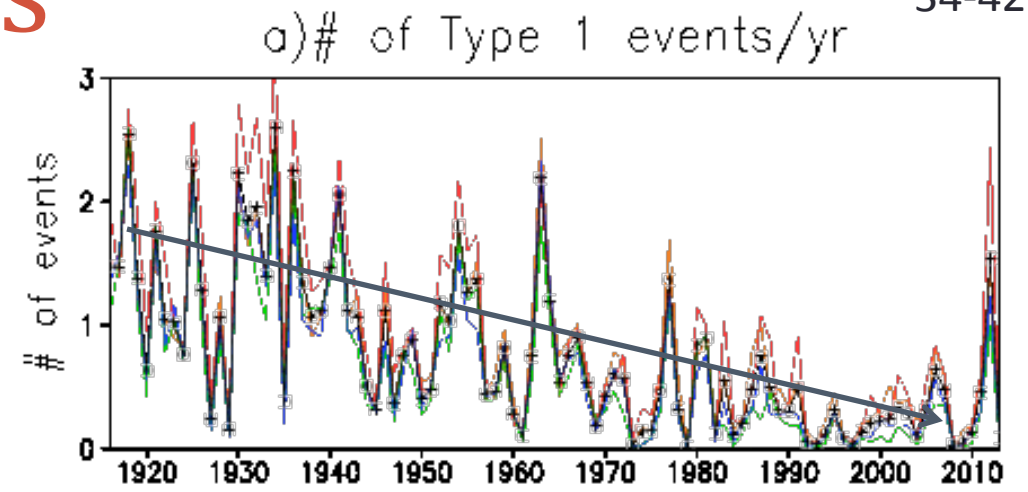
TYPE 2



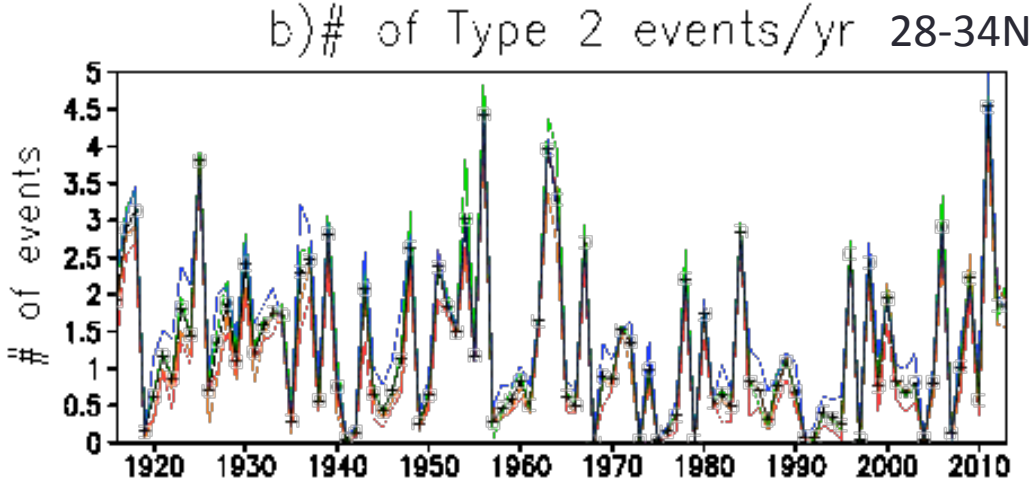
1. More common about 6-12% of total record
2. With maxima over the Southern Plains and the Gulf states
3. Less events over the Type1 frequent areas

Trends

34-42N,85-100W



Decreasing trends



28-34N,95-100W

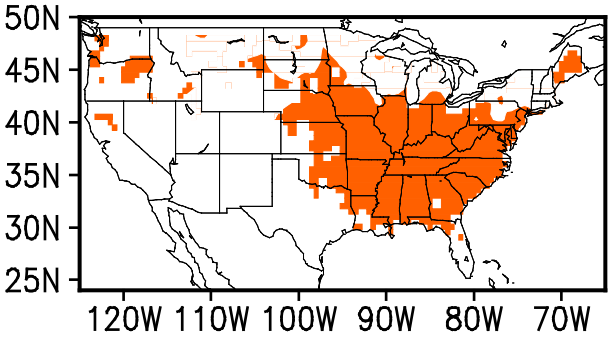
Interannual variability

Different color lines indicate different models For type 1 flash drought, there are trends . There were more events in the 1920-1050s then the current period 1979-2010

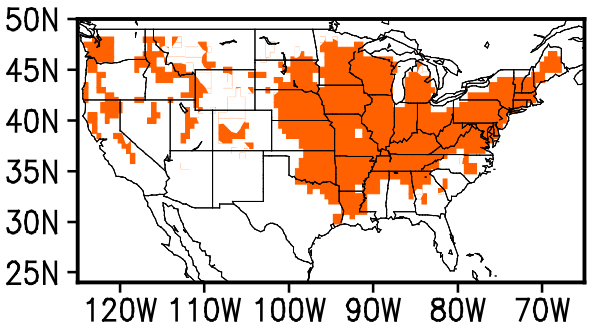
Type 1 events/yr -- decreasing trends

Mann Kendall test of Type 1 events/yr for each grid

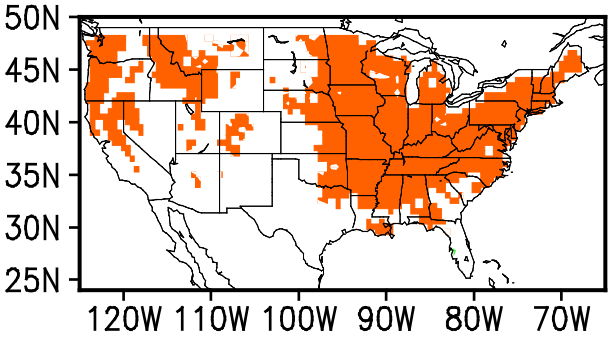
c) Noah



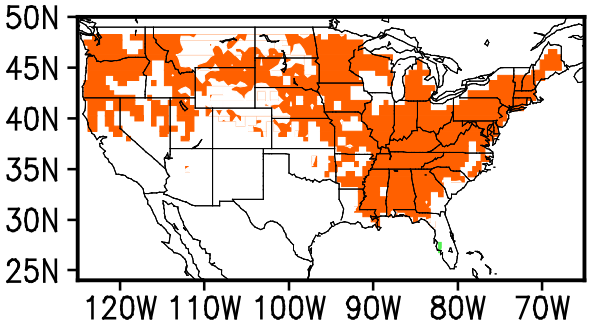
a) VIC



d) Catchm



b) SAC



Red- decreasing trends

Green – increasing trends

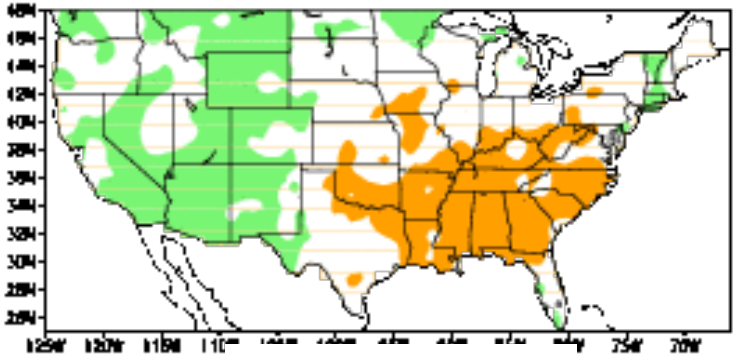
Ref: Hirsh and Slack 1984, Hirsh et al 1982

Trends are statistically significant

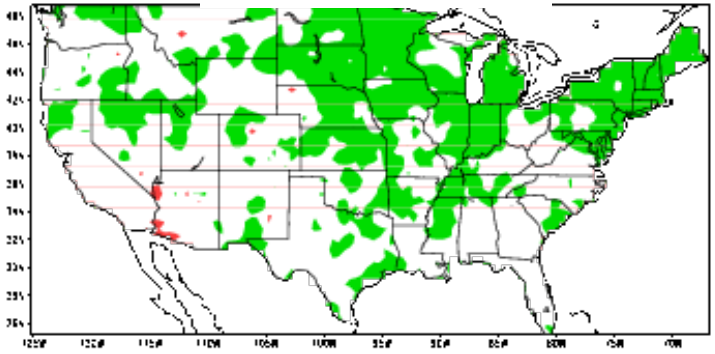
type 1 occurrence trends

Trends of increasing P=> trends of increasing SM=> decreasing of type 1 flash drought

Tair annual trends



P annual trends

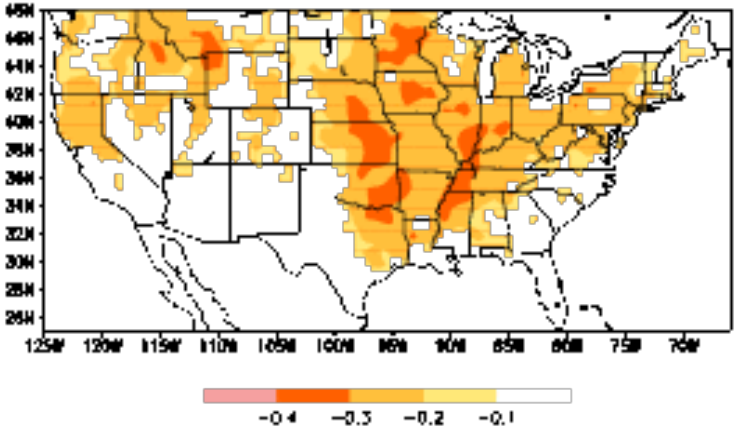


Green –increasing trends

Red– decreasing trends

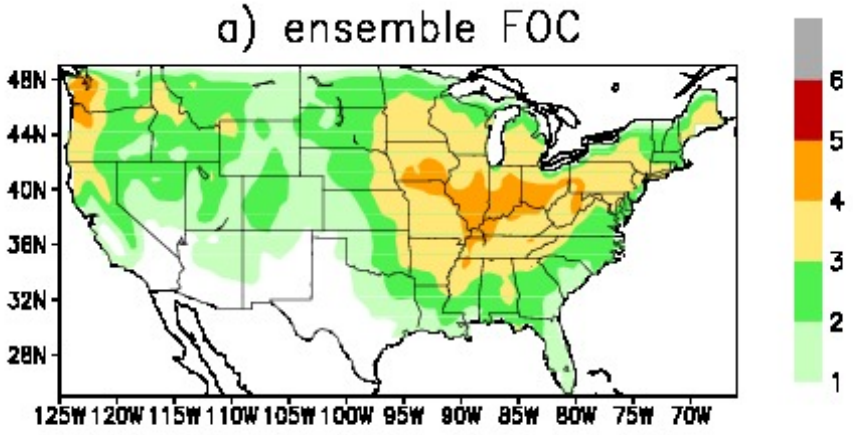
Kendall's tau

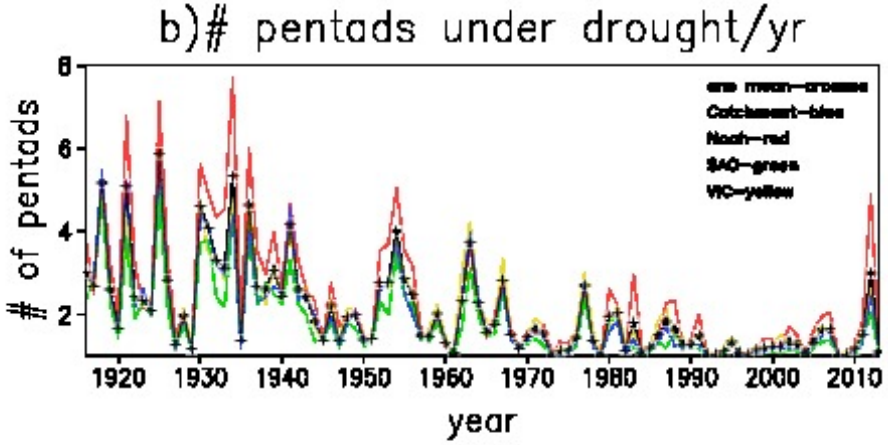
Type 1 occurrence, P

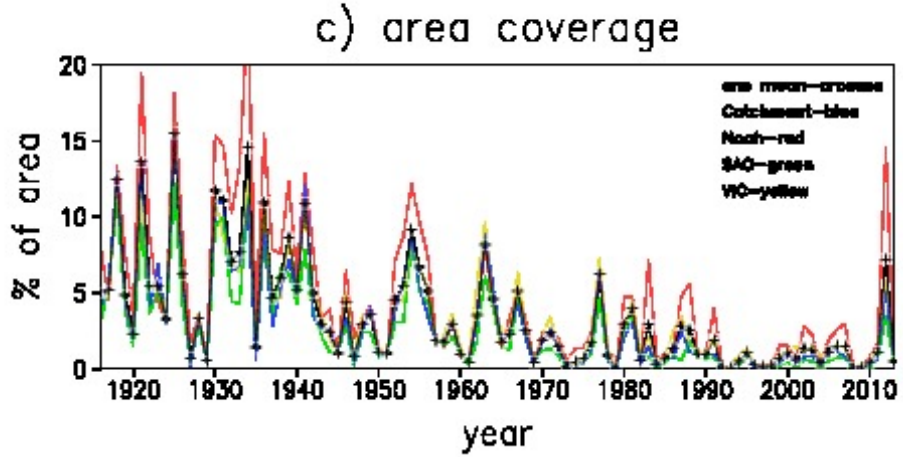


P has positive trends
In the North Central
And they are correlated well with the type 1 occurrence trends

Ref: Lettenmaier et al. (1994), Groisman et al. (2004)
Andreadis and Lettenmaier 2006







Type 1 flash drought

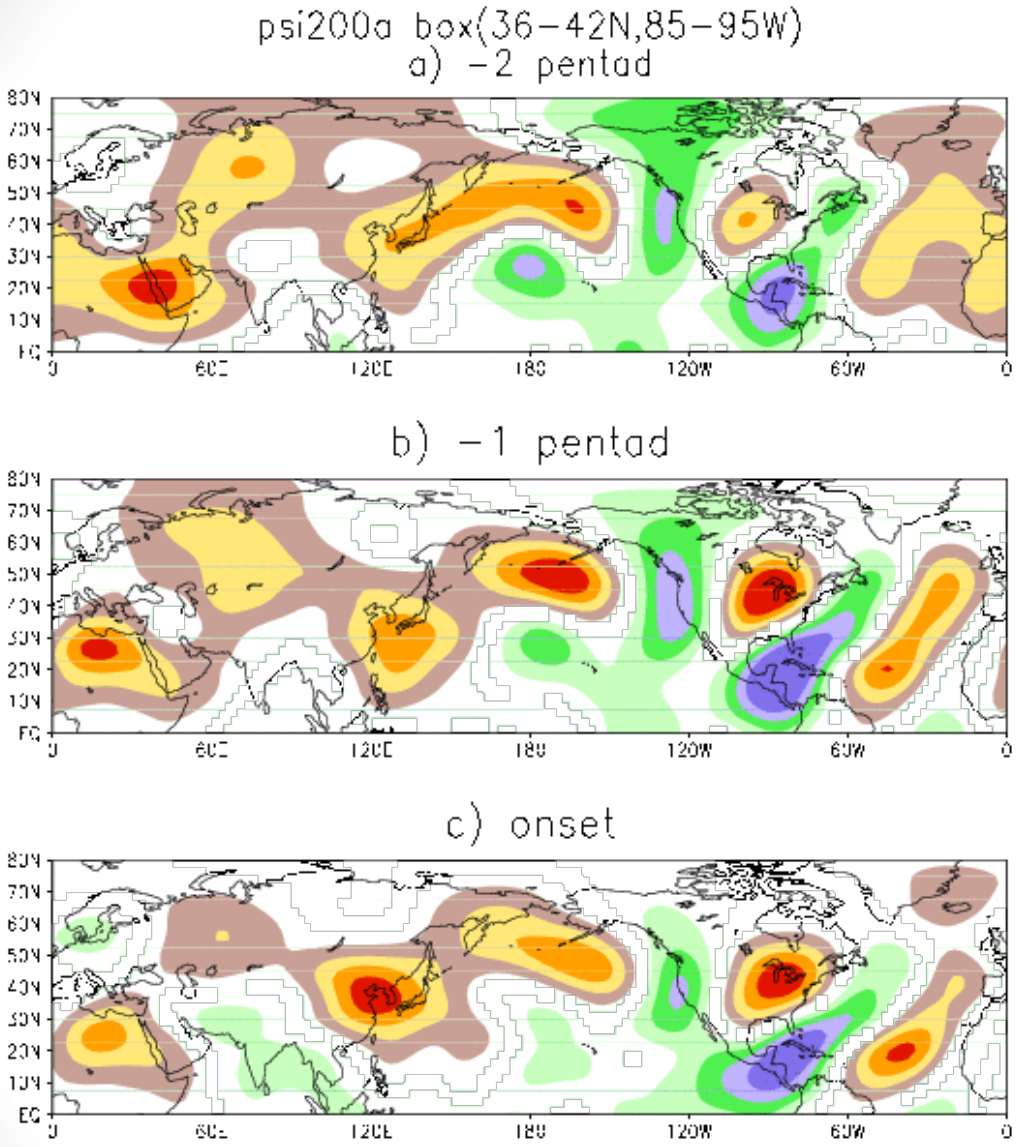
trends:

It occurs

1. Less often
2. Less area coverage
3. Shorter duration
4. Less intense
5. Similar to the trends of conventional drought

Ref: Andreadis and Lettenmaier 2006

Composites of 200 hPa streamfunction

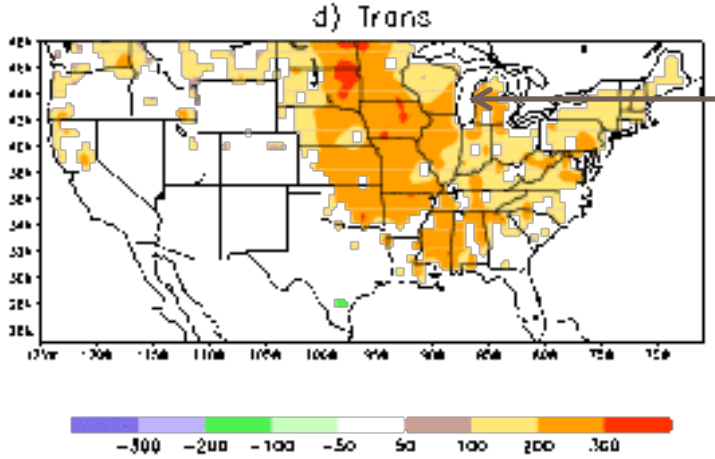


Wave trains start to appear -2 pentad before the onset
At -1Pentad, positive anomalies move into the central U.S.
Onset: intensify

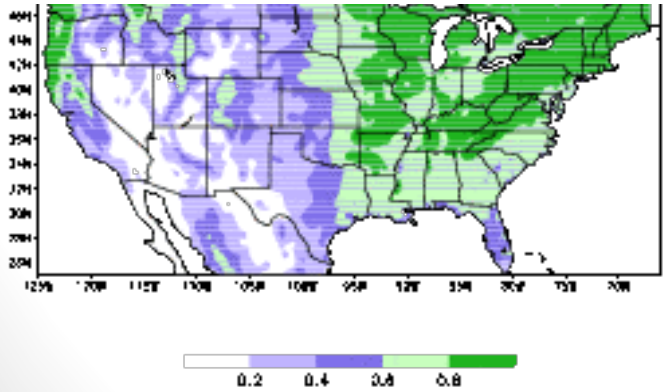
Positive anomalies are Consistent with high Tair and also are unfavorable for rainfall

Type 1

Composite of transpiration



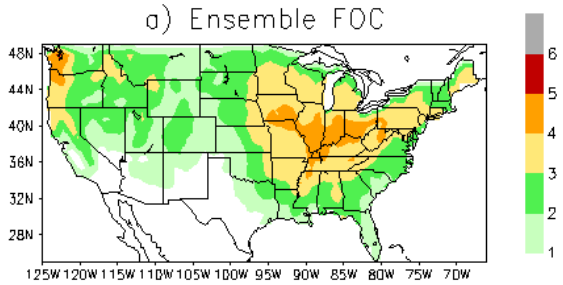
Vegetation fraction JJA



Type 1 is temperature driven, so what roles do P and SM play?

- The type 1 flash drought is a temperature driven event.
- High temperatures lead to the increases of ET and the decreases of SM;
- The increases of ET come from transpiration, so type 1 flash drought occurs in the vegetation dense areas.
- *Without P forcing, this process can still occur , but SM may not be low enough to be classified as drought*

FOC type 1



Land conditions for Type 1 drought to occur

Tair> 3 C (1.5-2 std)

↓

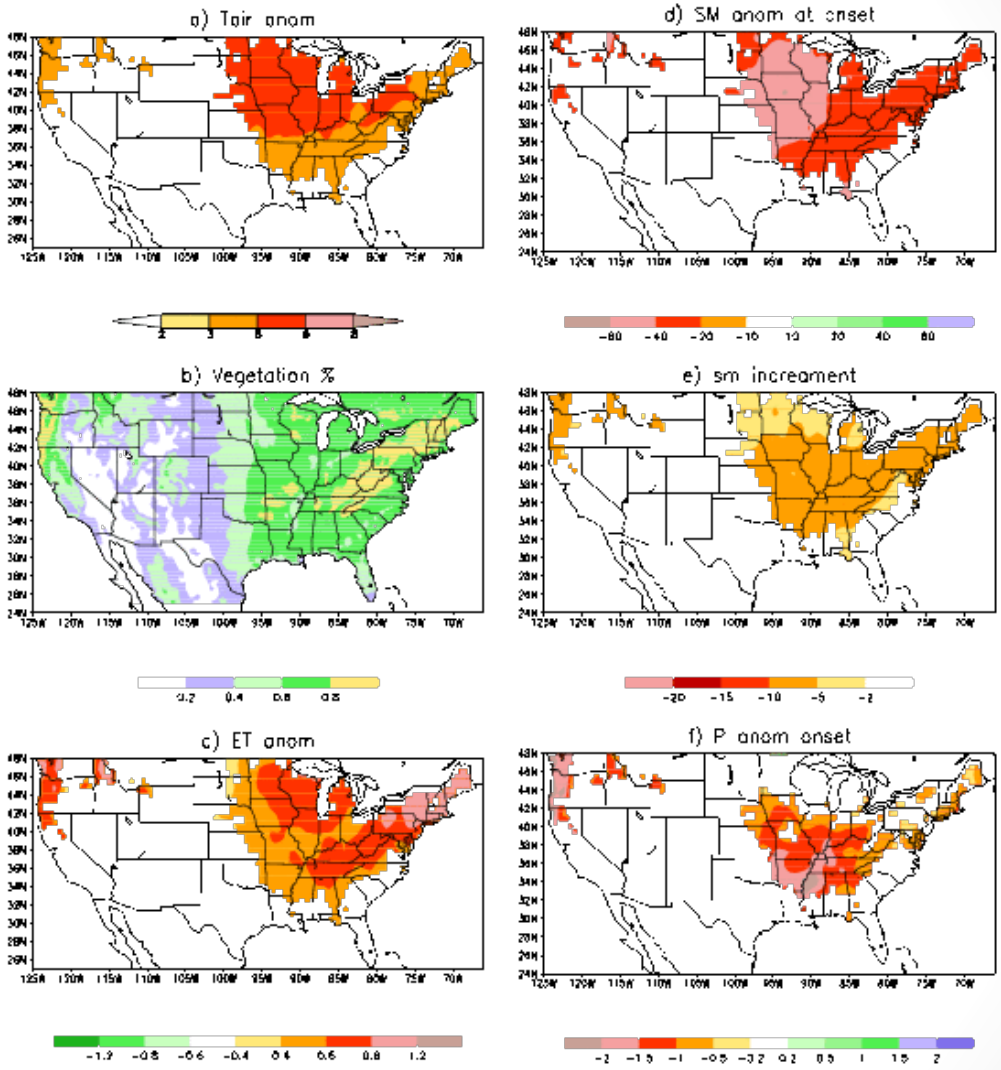
Increases of ET
due to vegetation

↓

SM to drop
(only 10-15mm)

↓

But to be qualified as drought, SM anom < -40 to -60mm

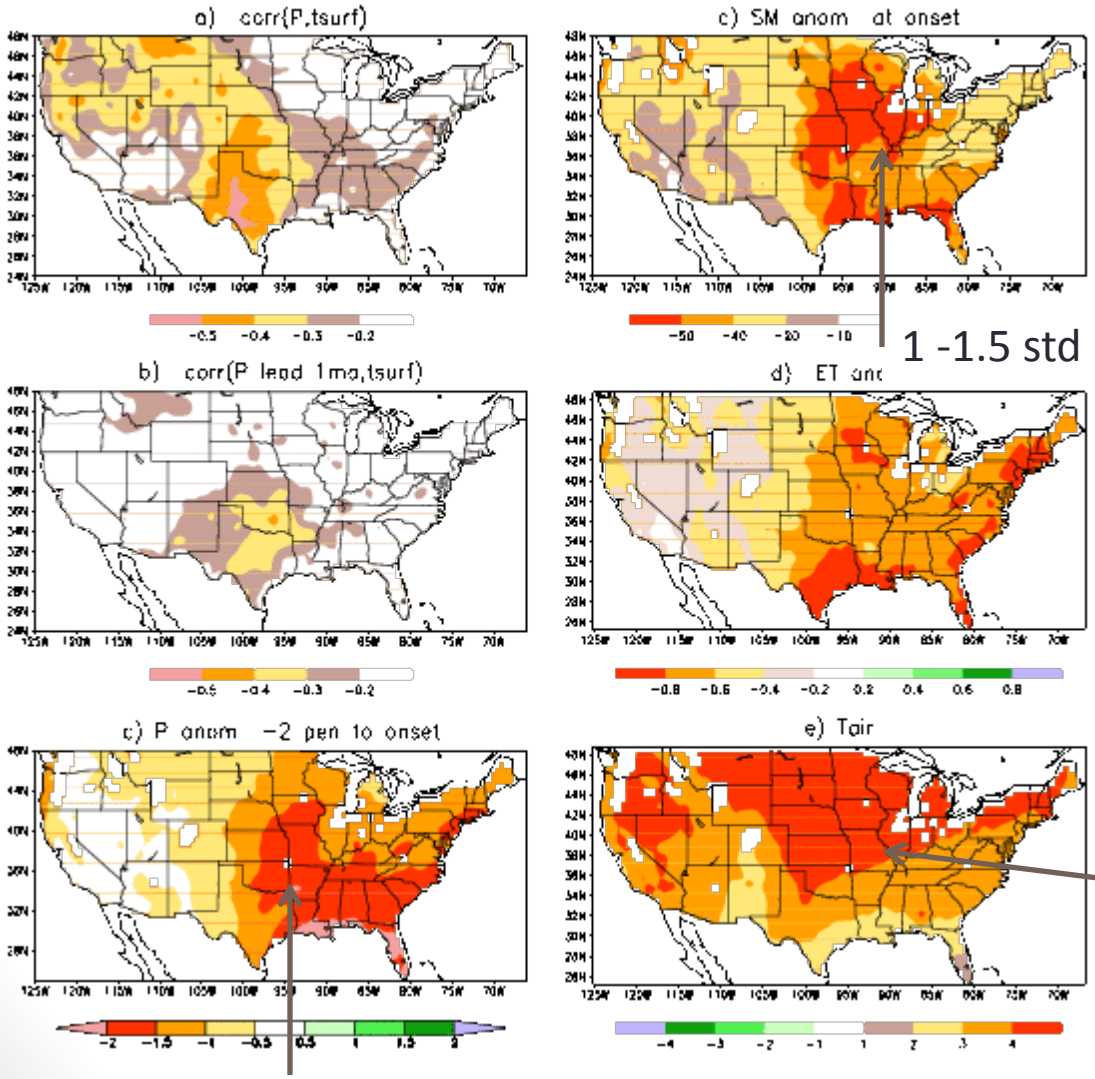


Dry SM is a necessary but not sufficient conditions for Type 1 events

Type 1 flash drought

- Temperature driven
- High Tair=> increases of ET=> drop of SM
- SM increments are not deep enough to be classified as drought unless SM anomalies are already negative before onset
- The negative SM can be viewed as necessary but not sufficient conditions for Type 1 events to occur
- Atmospheric support suggests that anti cyclone is likely to establish 2 pentads before onset so this will help monitoring
- To monitor Type 1 flash drought, ET changes are not enough, we also need to monitor SM anomalies and atmospheric conditions

Type 2 drought



P driven events

Lack of P => less SM
(D2 or higher Drought level)
⇒ decreases of ET
⇒ Increases of sensible heat
⇒ Higher Tair

More than 1std so qualified as heat waves

Ref: trenberth and shea 2005; Madden and Williams 1978

Type 2 drought

- Precipitation driven
- If the SPI or P anom reach D2 or higher , then
- Lack of p=> decreases of SM => decreases of ET
- => increases of Tair

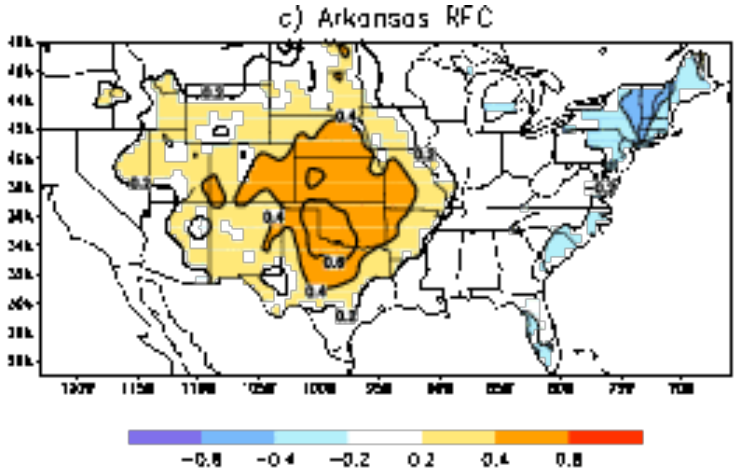
Monitoring flash droughts

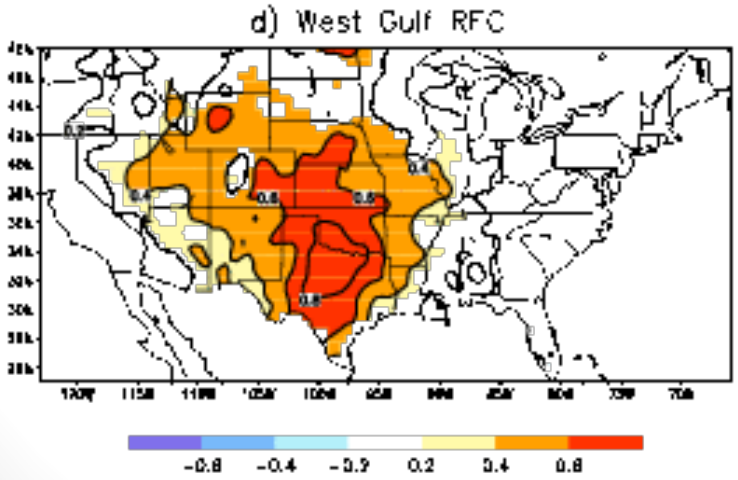
- Type 1
- Wave trains from the North Pacific to downstream the central U.S.
- SM negative (necessary but not sufficient condition)
- ET change
- In the time scales of 5-10 days (one-two pentads)
- Type 2
- Flash drought imbedded in the meteorological drought
- If meteorological drought is D2 or higher then monitor atmospheric conditions and Tair
- Monthly time scales

Conclusions

- There are two types of flash drought
- Type 1:
- A) it occurs in the vegetation dense areas over the North Central and Northeast. Over the western region where the vegetation is sparse, there are few events of this type of drought
- B) Type 1 has a decreasing trends because of the increases of P and SM in the recent years
- Type 2
- It occurs more often in the Southern Plains and the Gulf States where meteorological drought causes heat waves

Does meteorological drought over the type 2 areas lead to heat waves?





1. We picked two RFC areas over the Southern Plains
2. We select drought events when SPI6 is below -0.8 for 6 months or longer
3. Sum up Tsurf anom over drought periods

4. Composites show that heat waves are likely to occur during drought

(The lack of P will increase surface temperature and lead to heat waves)