

Flash Droughts over the United States

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Data sets from UCLA

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

What is flash drought?

Heat waves

meet

Dryness

Damages to crops are in the \$Billions

Two kinds of flash droughts:

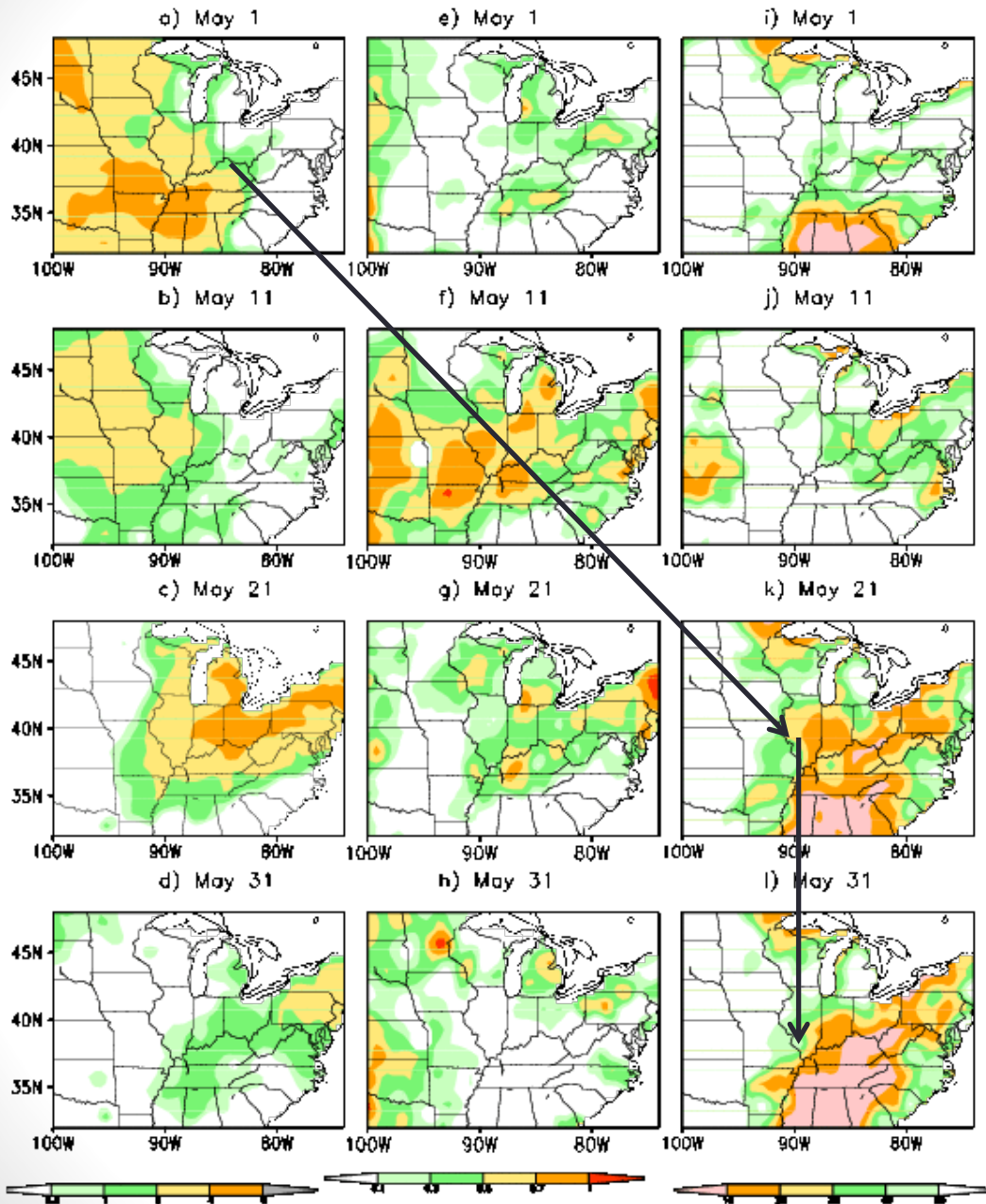
- Heat wave flash drought
- Precipitation Deficit flash drought

Tair

ET

SM

2007 case



May 1: high Tair

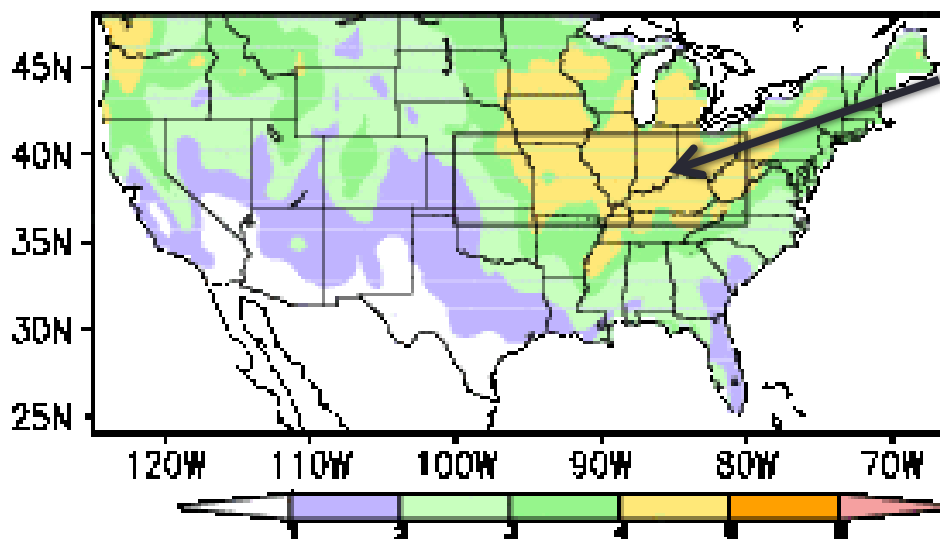
May 11: ET increased

May 21: SM decreased

May 31: Temp cooled down, only SM was positive

Heat wave flash drought

Frequency of occurrence

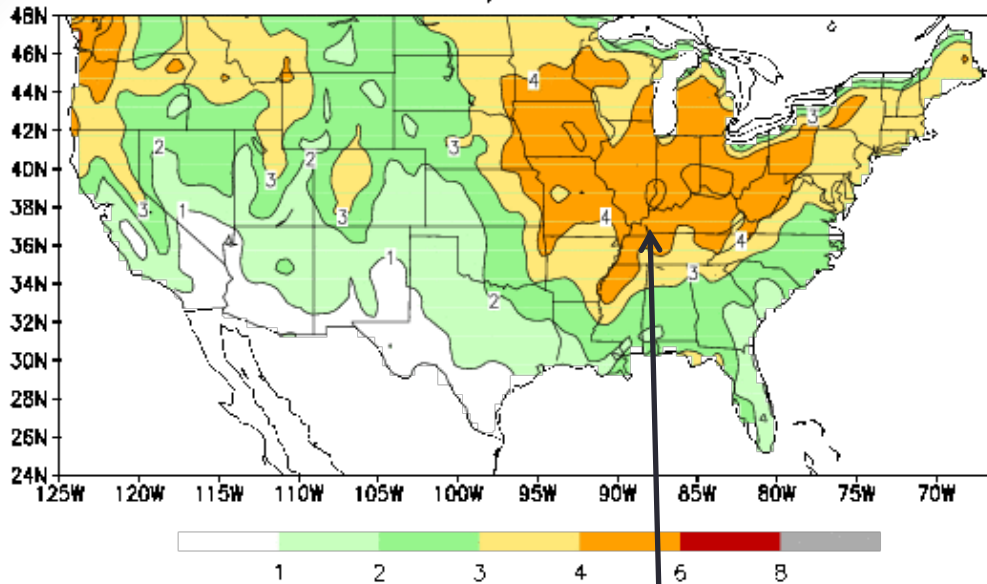


4-5% max

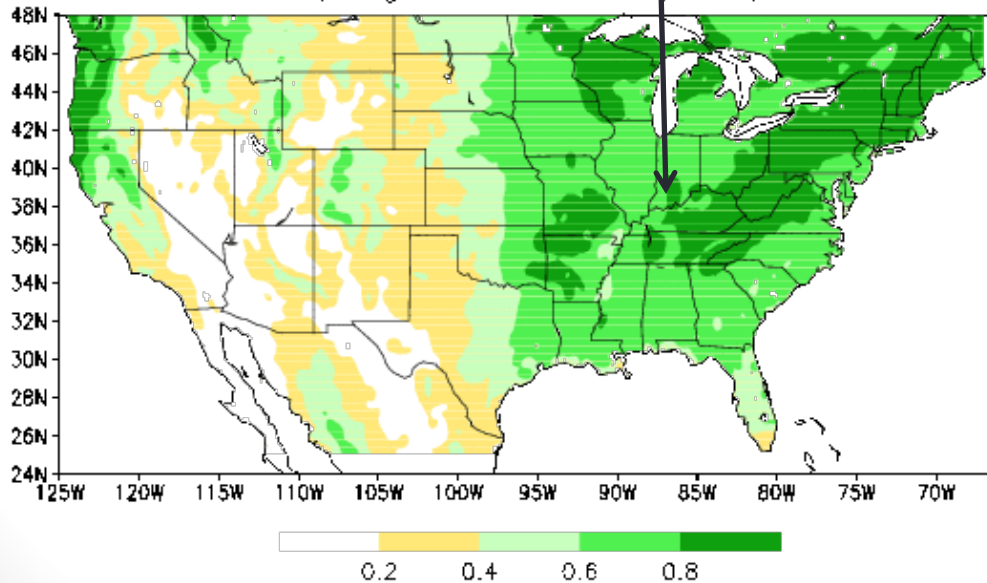
Definition

High temperature == $T_{air} > 1$ standard dev
ET increases (anomaly > 0 .)
SM decreases— to 40% or lower

a) FOC



b)vegetation flux (clim)



Heat wave flash drought

High temperature=>
Increase of ET
That needs
vegetation

heat wave flash
drought occurs in the
vegetation dense
areas

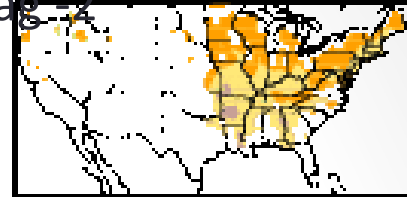
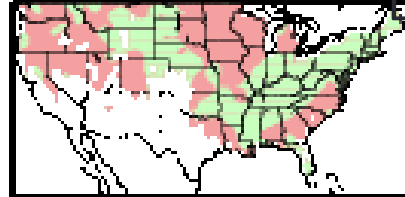
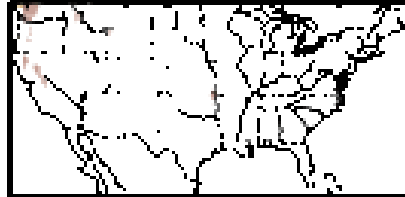
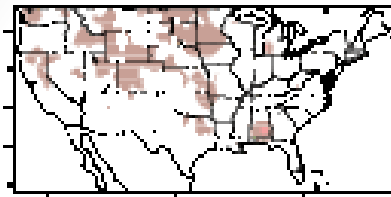
Tair

ET

SM

P

P deficits appear and SM anom is negative at **Lag -2 pentads**



120W 100W 80W

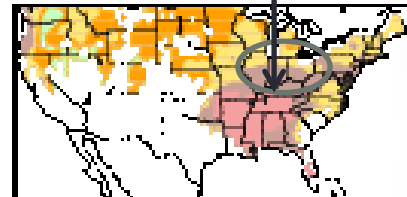
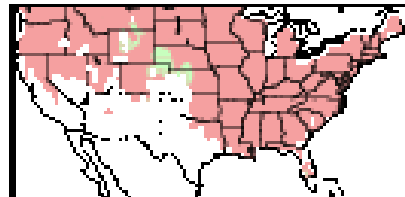
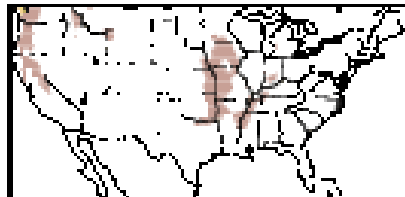
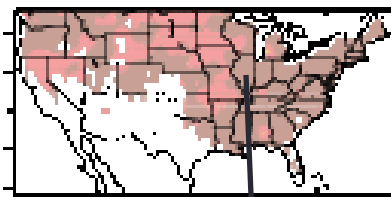
120W 100W 80W

120W 100W 80W

120W 100W 80W

Tair starts to increase at **Lag -1**

P deficits



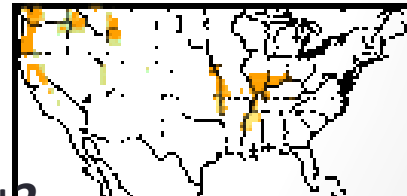
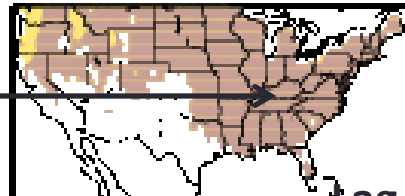
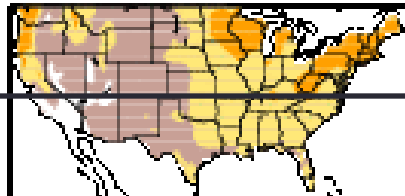
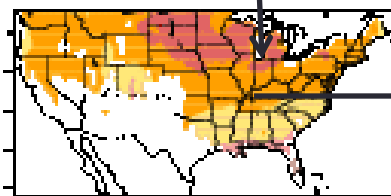
120W 100W 80W

120W 100W 80W

120W 100W 80W

120W 100W 80W

ET responds and increases and SM drops at **onset**



120W 100W 80W

120W 100W 80W

120W 100W 80W

120W 100W 80W

P is negative before the onset of droughts



Evolution of heat wave flash droughts

Heat wave flash droughts

- Occur over the North Central and the Pacific Northwest over the vegetation dense areas
- Start from High temperature=> **increase of ET anomalies**=> decreases of SM
- **P deficits start before the occurrence of heat wave flash drought to drive down SM to create favorable conditions for drought to occur**
- P plays an indirect but important role

P

SM

ET

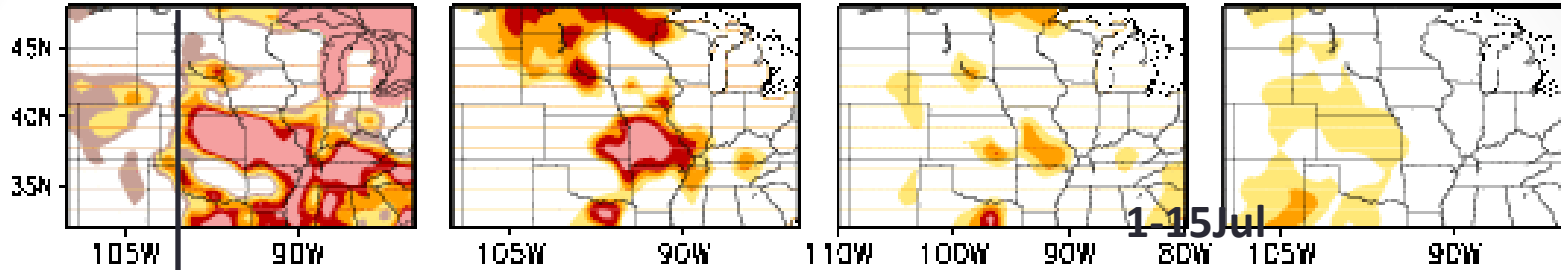
Tair

P anom
a) 1-15Jun

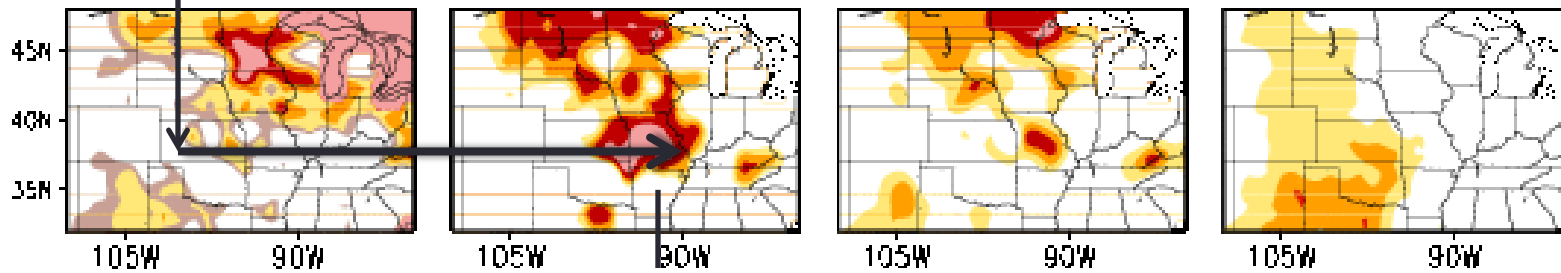
SM anom
f) 1-15Jun

ET anom
k) 1-15Jun

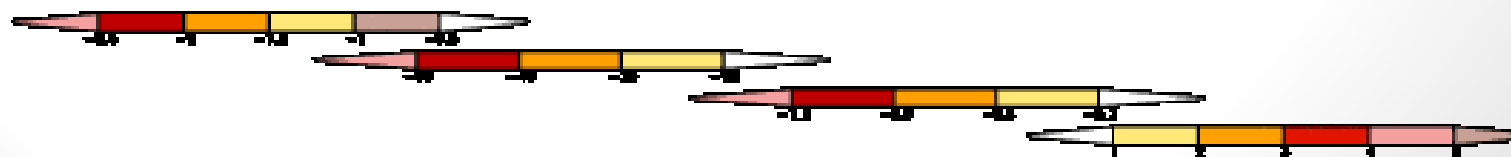
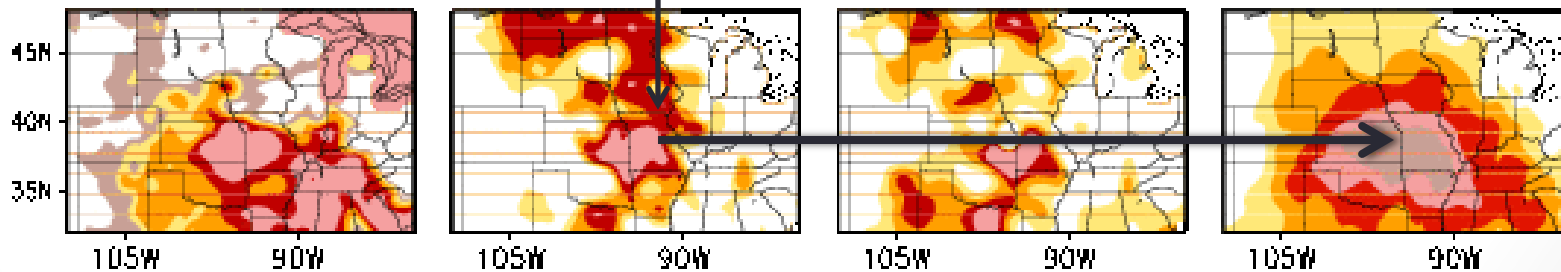
Tair anom
p) 1-15Jun



b) 15-30 Jun **P deficits=> drop of SM**



c) 1-15 Jul **SM deficits=> ET decreases=> high temperature**



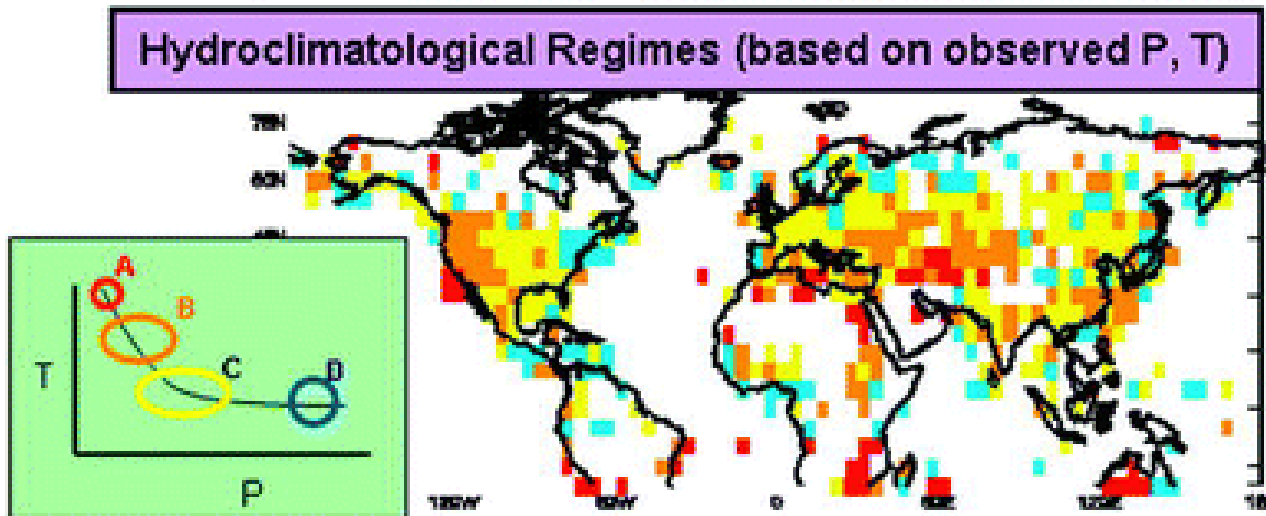
P deficit flash droughts

Different from the heat wave flash droughts

- It starts from the lack of precipitation (P)
- P deficits = > *decreases of SM*
- => *decreases of ET*
- => balanced by increases of sensible heat
- => increases of Temperature

- This kind of flash drought also has High temperature and lack of SM anomalies
- It is initialized by the P deficit
- We call it
- **P deficit flash drought**

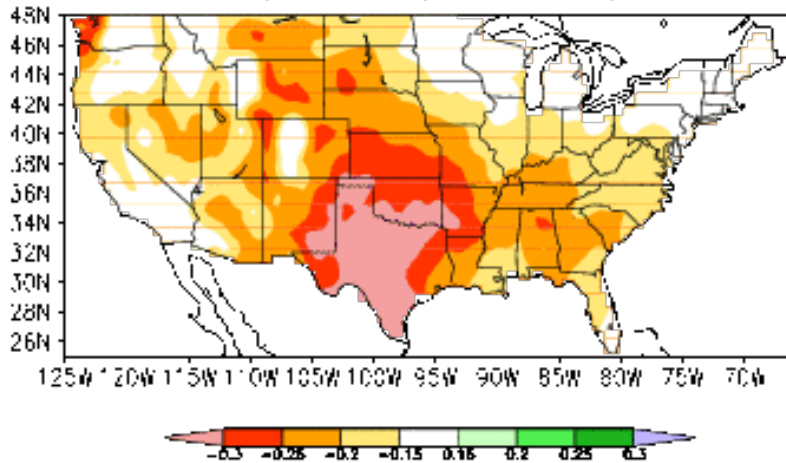
Areas where ET and SM interact



Koster et al. 2009

Physical mechanisms for P deficit flash drought

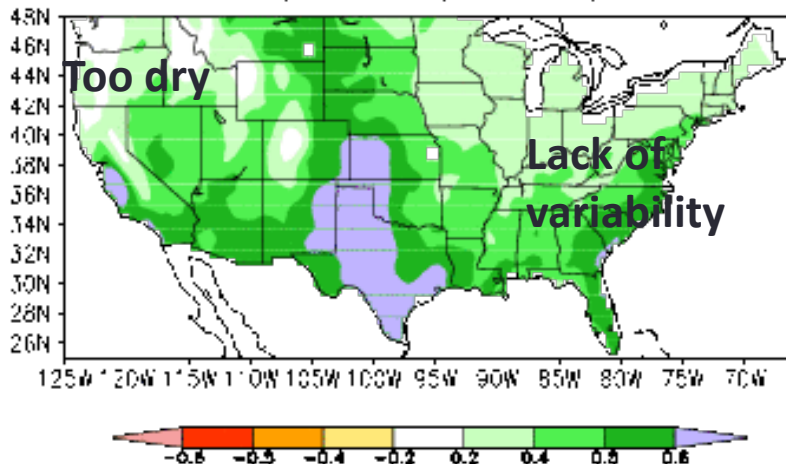
a) $\text{corr}(sm, T_{air})$



In the areas where the lack of SM => increase of T_{air}

Pathway through ET

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

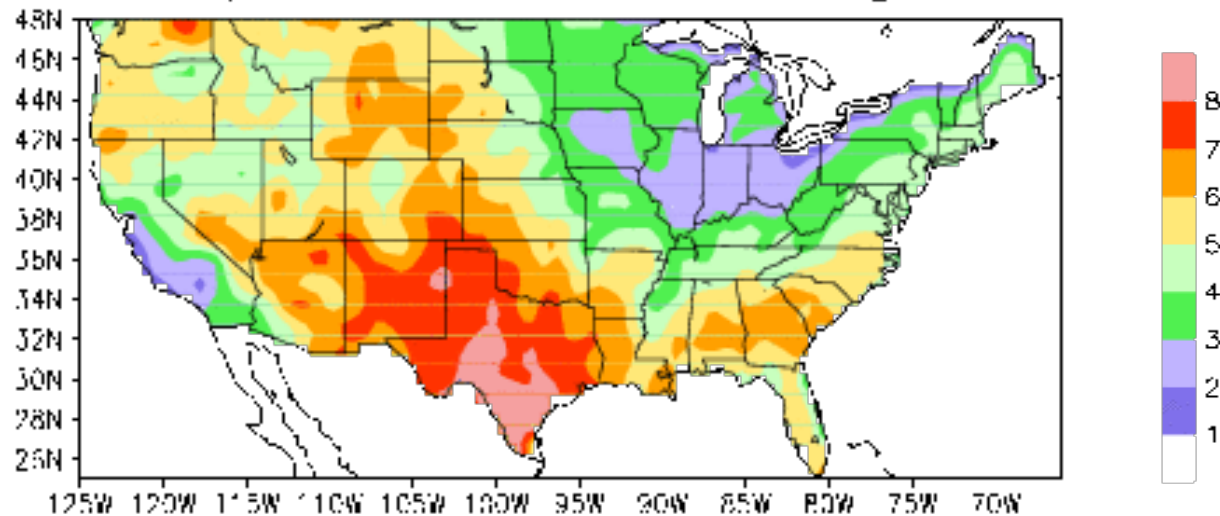


Only occurs in the areas where ET and SM have a near linear relationship

Monthly mean correlation (apr-sep)

P deficit flash drought

a) P deficit flash drought



Definition

P deficits < 40%

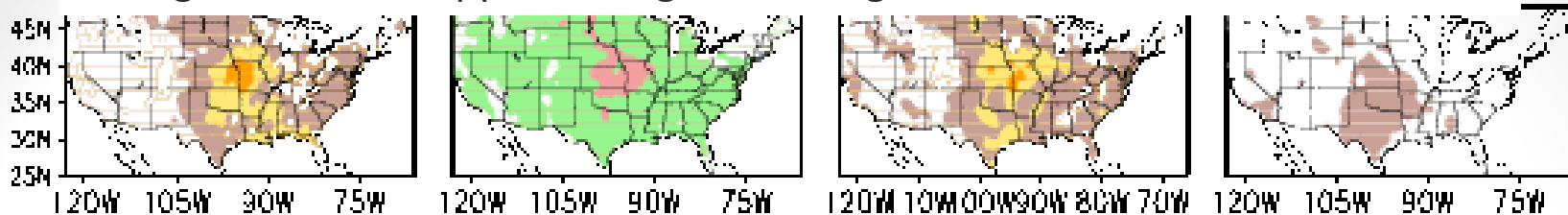
Tair > 1std

ET anom < 0

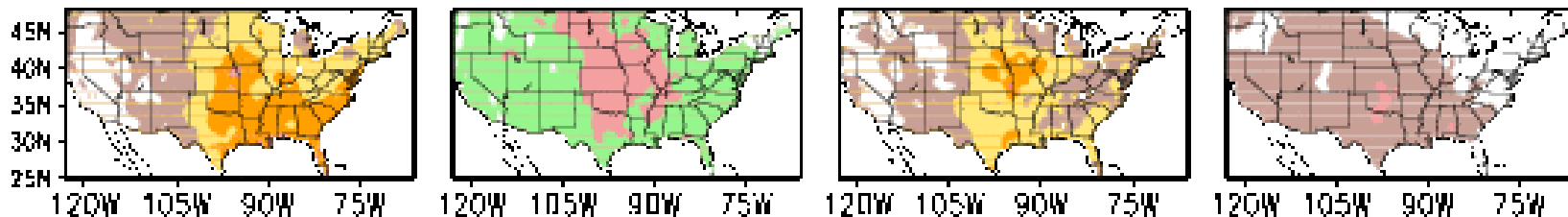
1. Max 8-10% in the Great Plains and southern states.
2. Min at locations that have large heat wave flash drought events.
3. Max in the areas where atmosphere-land interaction is strong

P**SM****ET****Tair**

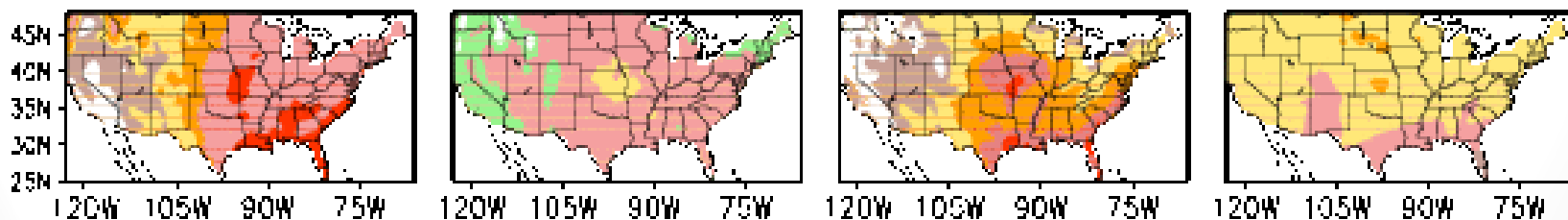
At lag -2 P deficits appear at lag -2, SM negative and ET starts to decrease



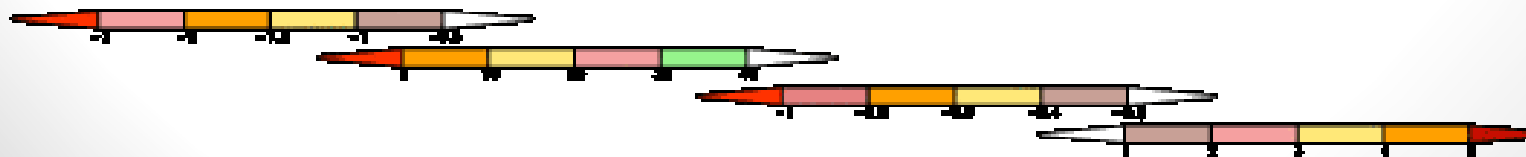
At lag -1, P deficits and SM deficits increase and ET decreases more



At onset, P and SM deficits reach maxima and ET decreases => T increases



Evolution of P deficit drought



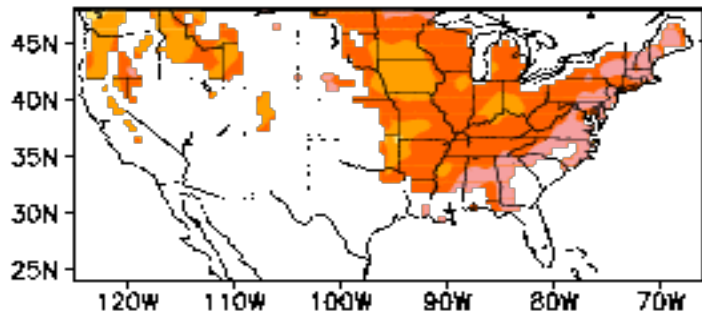
Comparison between heat wave and P deficit flash droughts

Features	Heat wave flash drought	P deficit flash drought
Forcing	Temperature driven	P deficit driven
Conditions		
Temperature	above 1SD	above 1SD
Soil moisture	below 40%	below 40%
Precipitation	below normal before onset	below normal before onset reaches a min during onset
ET anomalies	positive	negative
Locations of Max occurrence	North Central and the Pacific Northwest	Great Plains and southern states
Max FOC	4-5%	8-9%
Persistence	1 pentad	1pentad
Trends	decreasing over the North Central	increasing over the Southwest

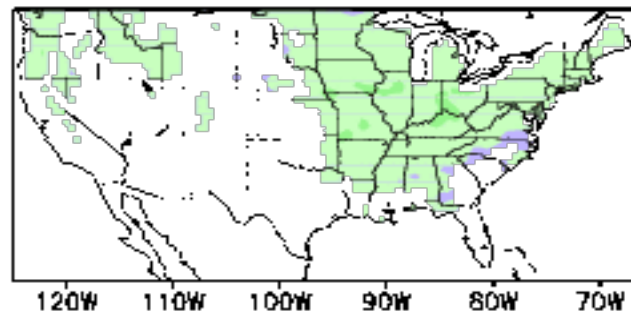
Persistence 1-2 pentads

Heat wave **flash** drought

a) % of events lost 1 ptd

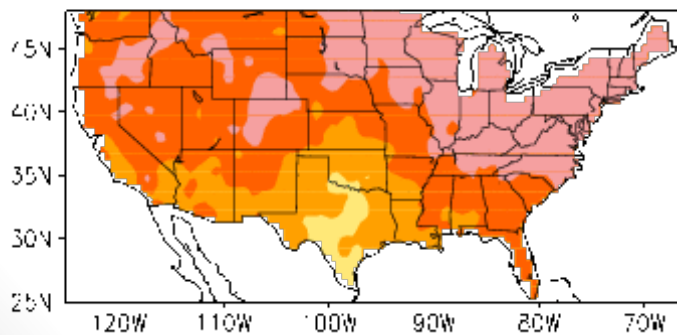


e) % of events lost 2 ptds

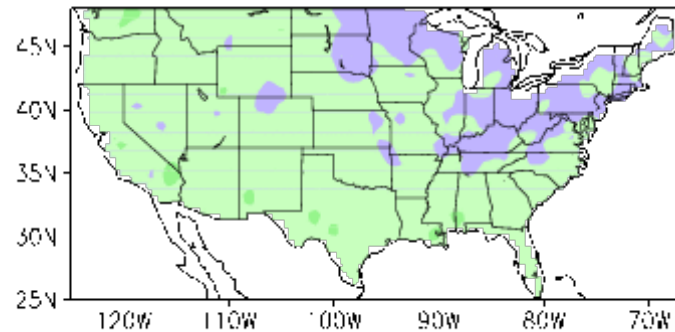


P deficit **flash** drought

a) events per 1 pentad



b) per 2 pentads

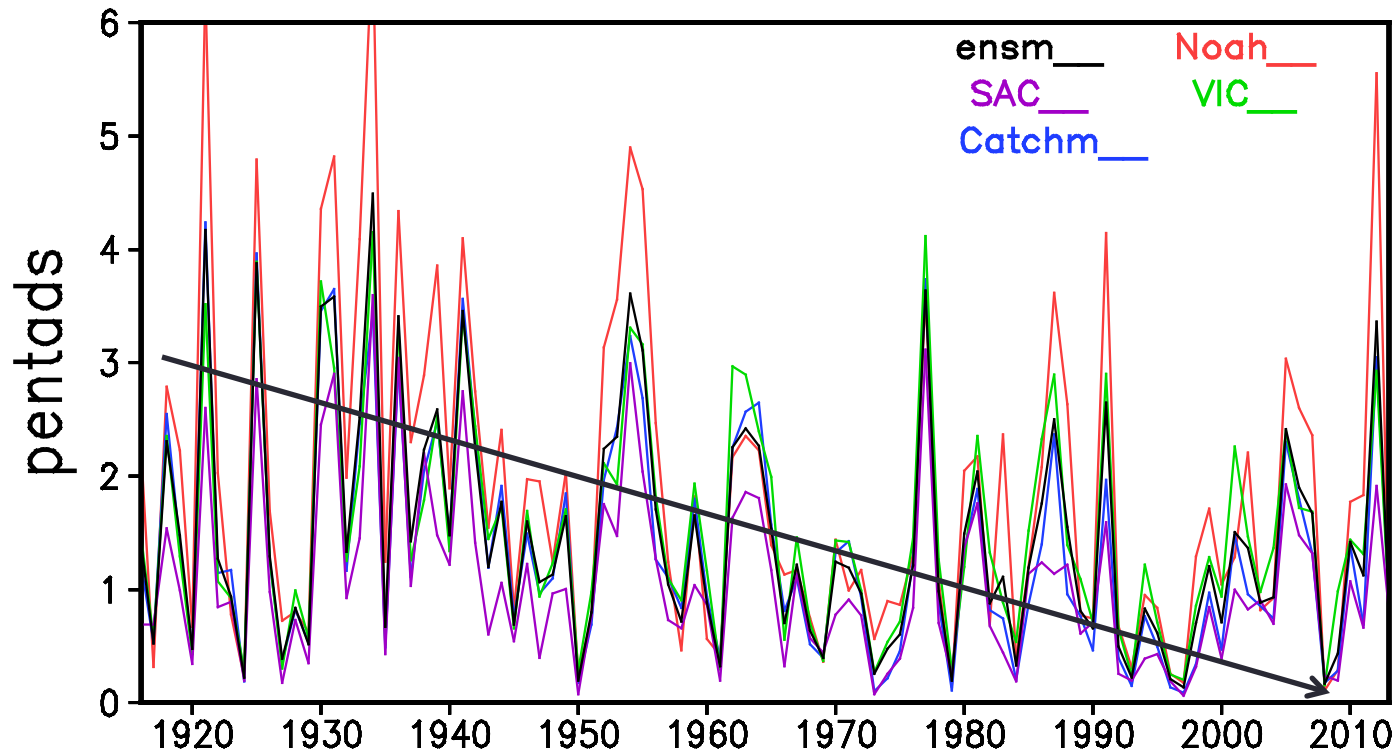


trends

- Do heat wave or P deficit flash droughts have trends?
- If so, do the trends related to trends of forcing such as P or T_{air} ?
- We use the Mann-Kendall test to detect trends and assess the statistical significance.

Example of trends

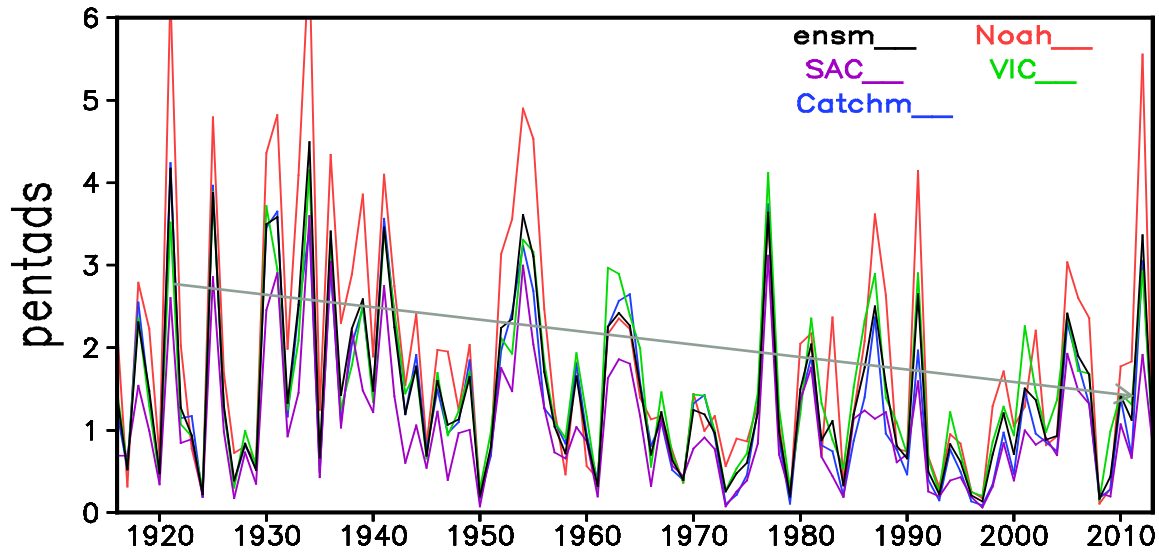
Heat wave flash drought events/yr



of heat wave flash drought events/yr North central
(36-42N, 80-100W)

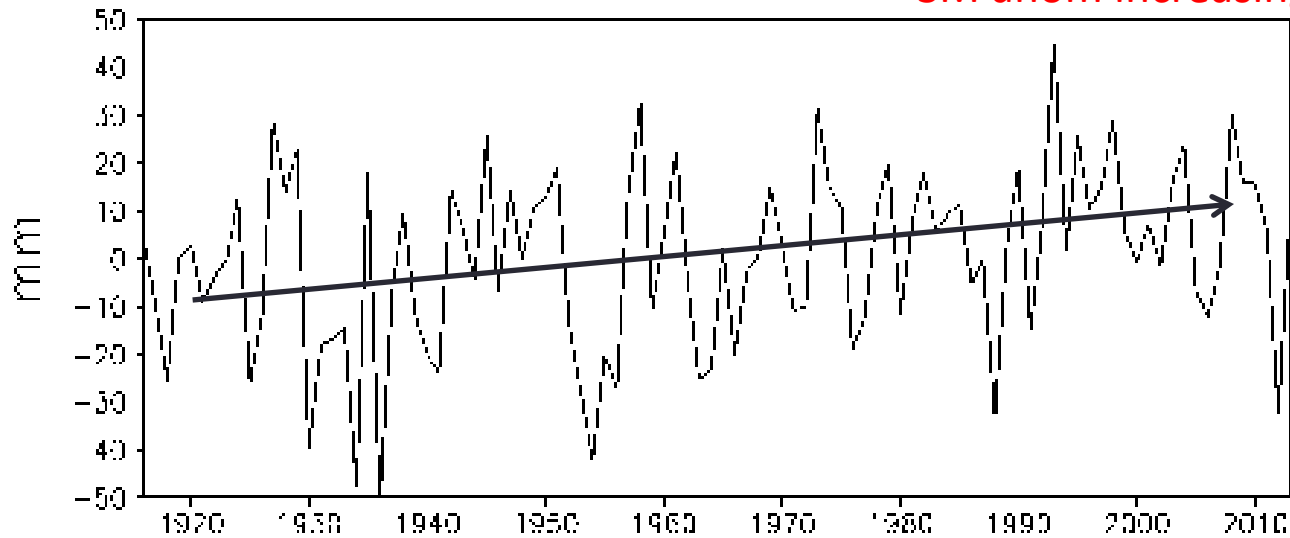
of Heat wavy flash drought events/year

Trends: decreasing



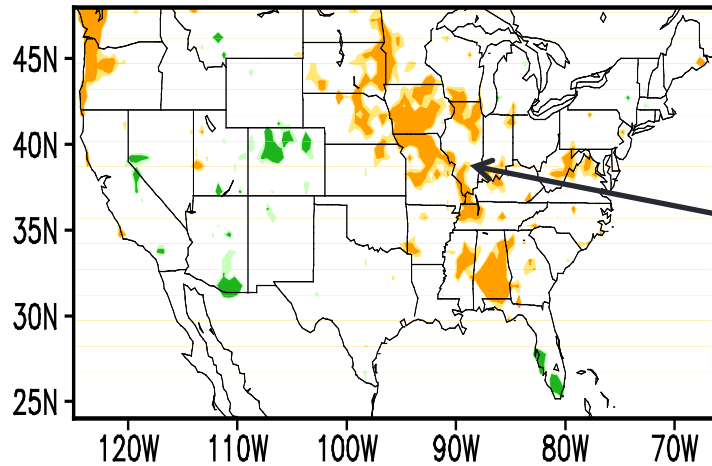
sm anom

SM anom increasing



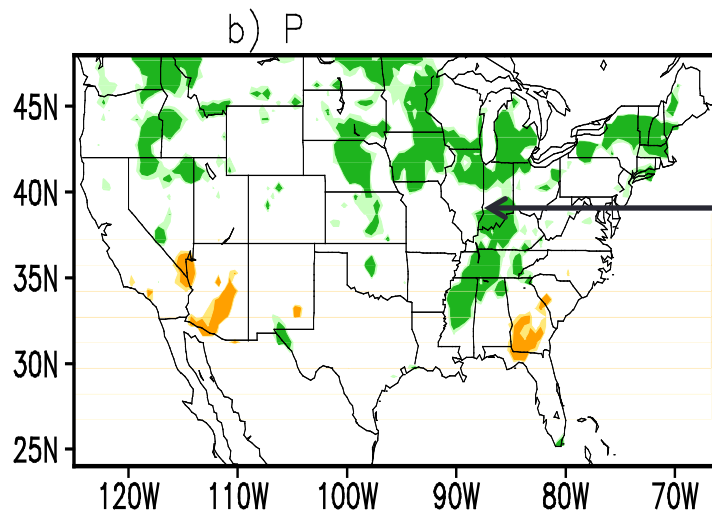
Over the North Central

Heat wave drought Annual events



Mann Kendall tests

decreasing



Increasing wetness

Orange – decreasing trends

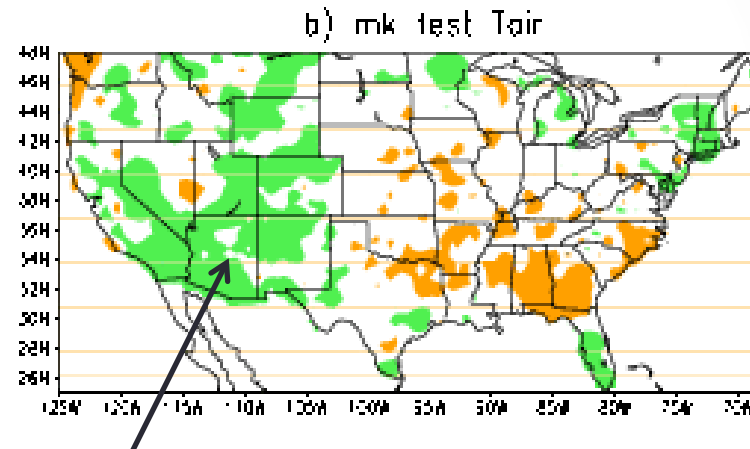
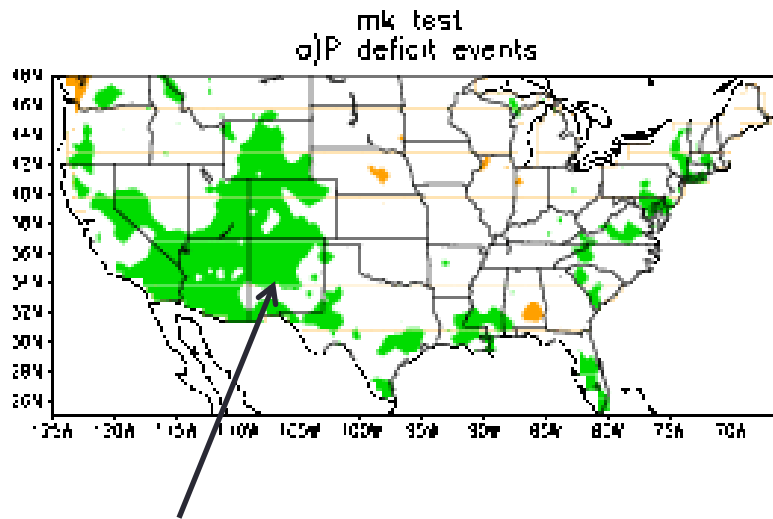
Green – increasing trends

c) Tair

Trends in P deficit flash drought events

MK test events

MK test Tair



warming

Increases of
occurrence

Upward trends in the Southwest related to trends in Tair

conclusions

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 drops