Did climate change cause the 2013-2014 California drought?

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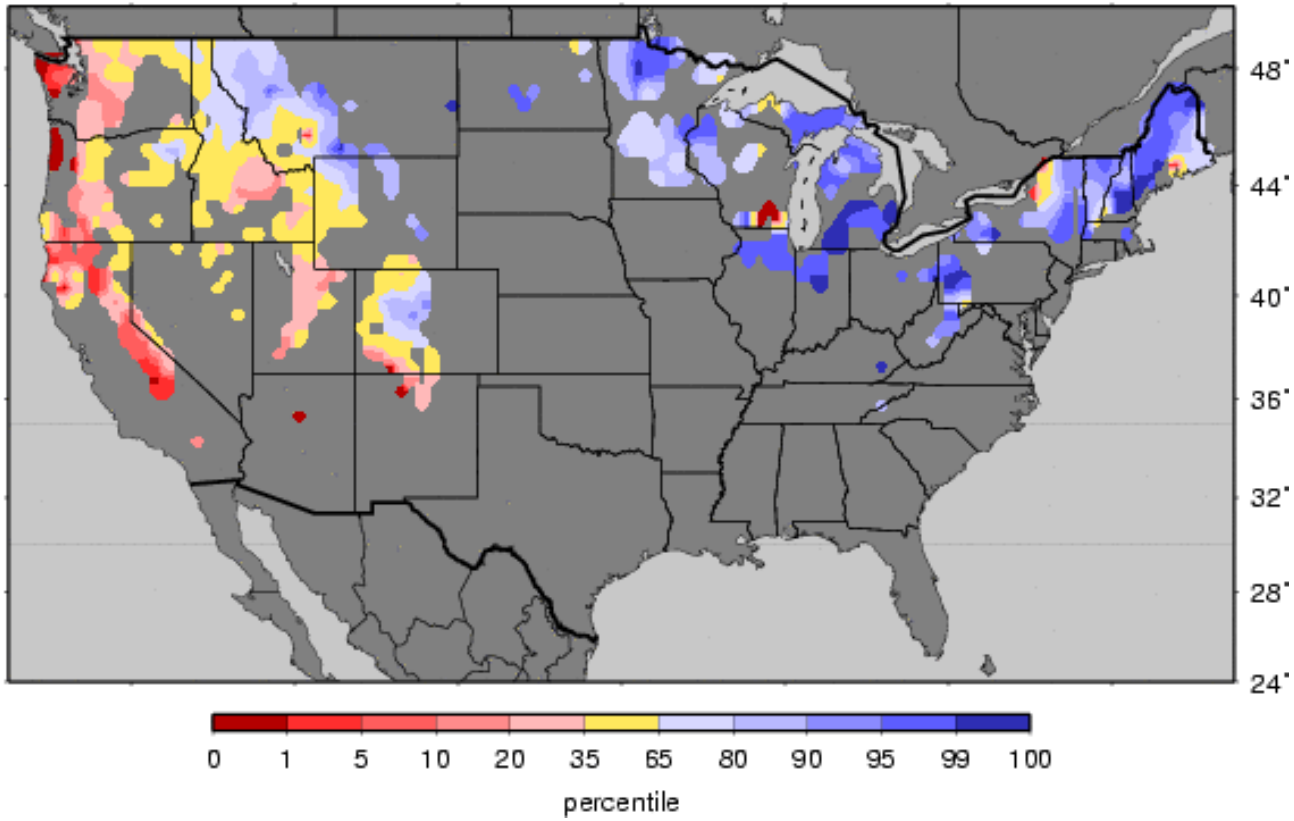
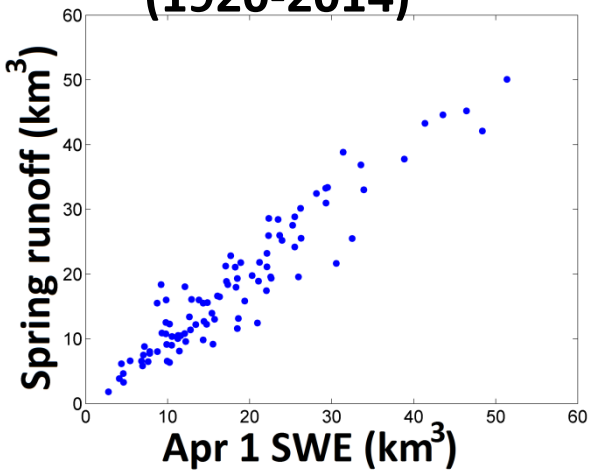
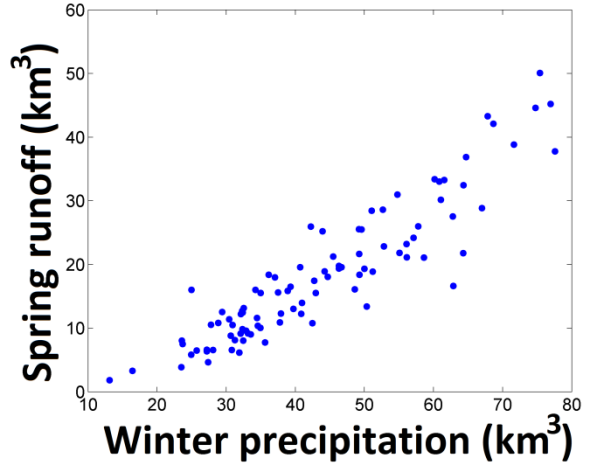
Introduction

VIC Snow Water Equivalent Percentiles (wrt/ 1916-2004), 20140401



Historical data in the Sierra Nevada (1920-2014)





University of Washington Surface Water Monitor for the Continental U.S.
http://www.hydro.washington.edu/forecast/monitor

California drought in 2013-2014

U.S.

The New York Times

Severe Drought Has U.S. West Fearing Worst

By ADAM NAGOURNEY and IAN LOVETT FEB. 1, 2014

CNN U.S.

West's drought leads to rising prices, shrinking lakes

By **Paul Vercammen**, CNN
updated 10:17 AM EDT, Fri August 1, 2014

San Jose Mercury News

California's drought linked to greenhouse gases, climate change in Stanford study

POSTED: 09/29/2014 10:51:27 AM PDT

California drought in 2013-2014

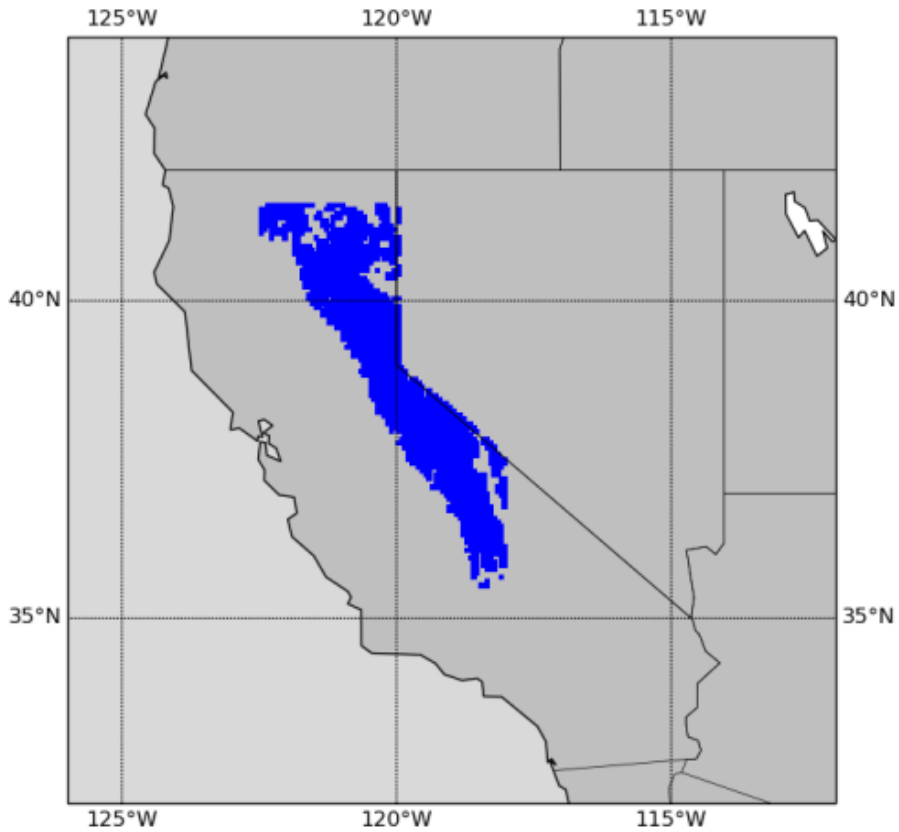
- Did climate change cause this extreme drought event?

VS.

- Was it simply a result of natural variability?

Methodology

Methodology - Study area and period



- **Sierra Nevada mountain range**

  - Long-term Apr 1 SWE > 10 mm

- **1920-2014**

Methodology - Data

- Daily precipitation (P)
- Daily temperature (T)

UW Drought Monitor
1/16 degree station-based dataset

- Snow water equivalent (SWE)
- Runoff

Methodology - Data

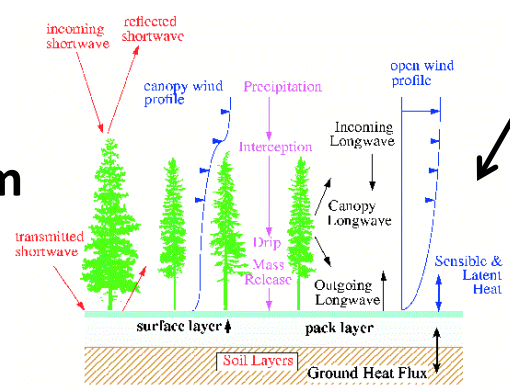
- Daily precipitation (P)
- Daily temperature (T)

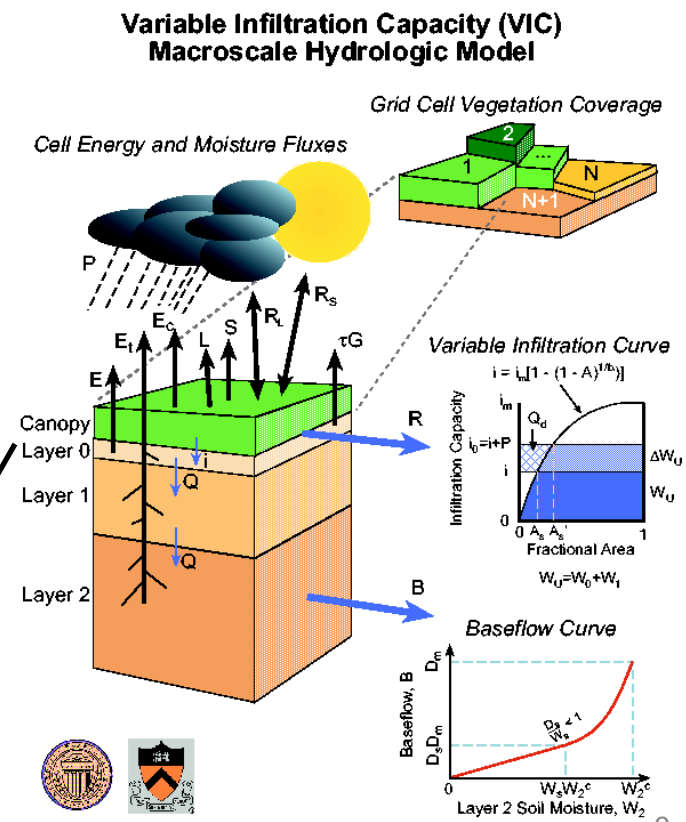
UW Drought Monitor
1/16 degree station-based dataset

VIC model

- Snow water equivalent (SWE)
- Runoff

VIC Snow Algorithm

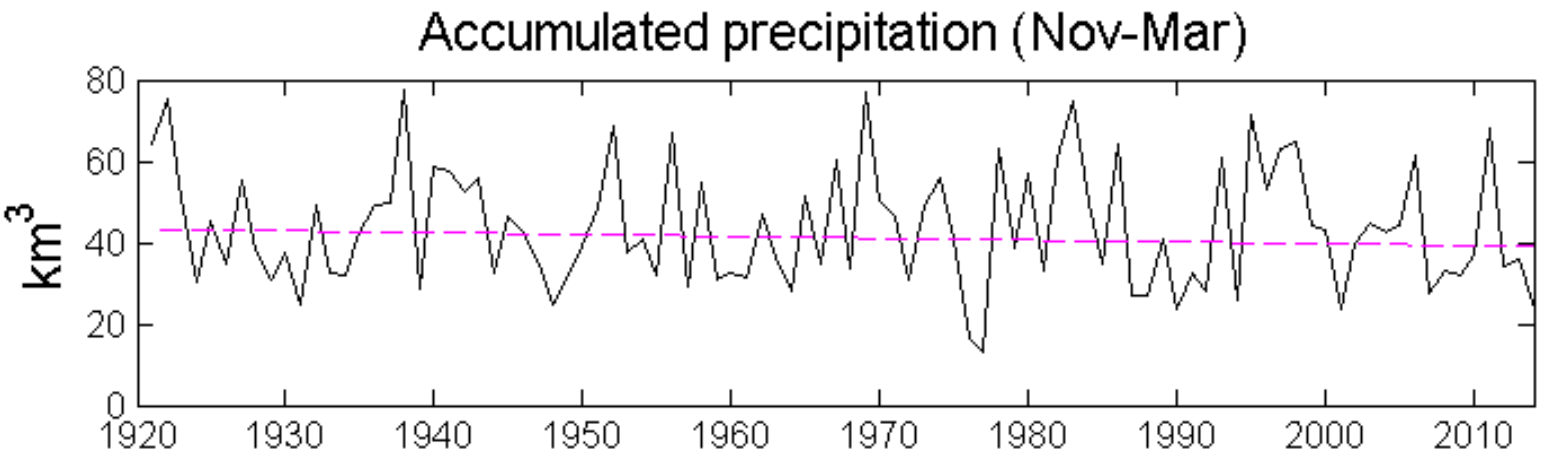




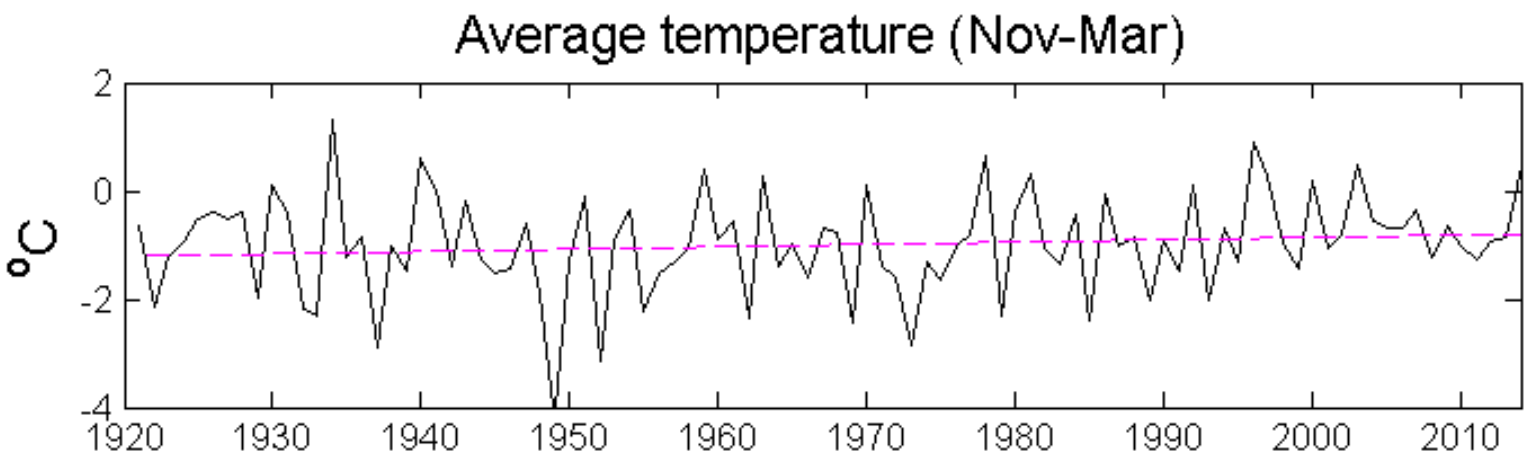
Analysis and results

1. How has the climate changed in California? (Trend analysis)

1. How has the climate changed in California?



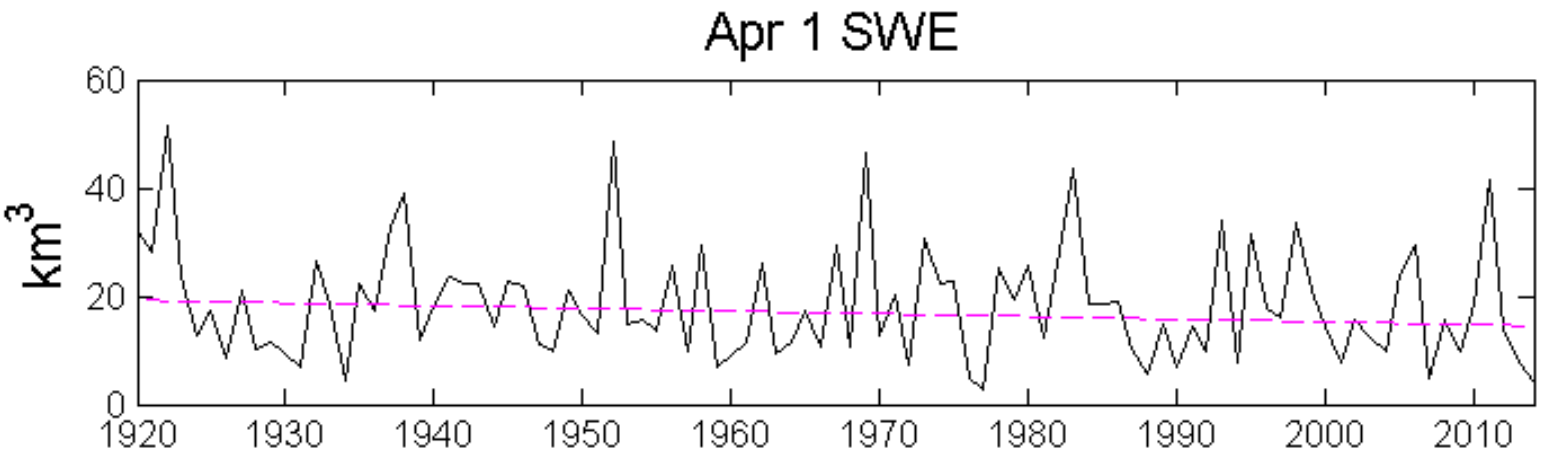
No trend



Increasing trend

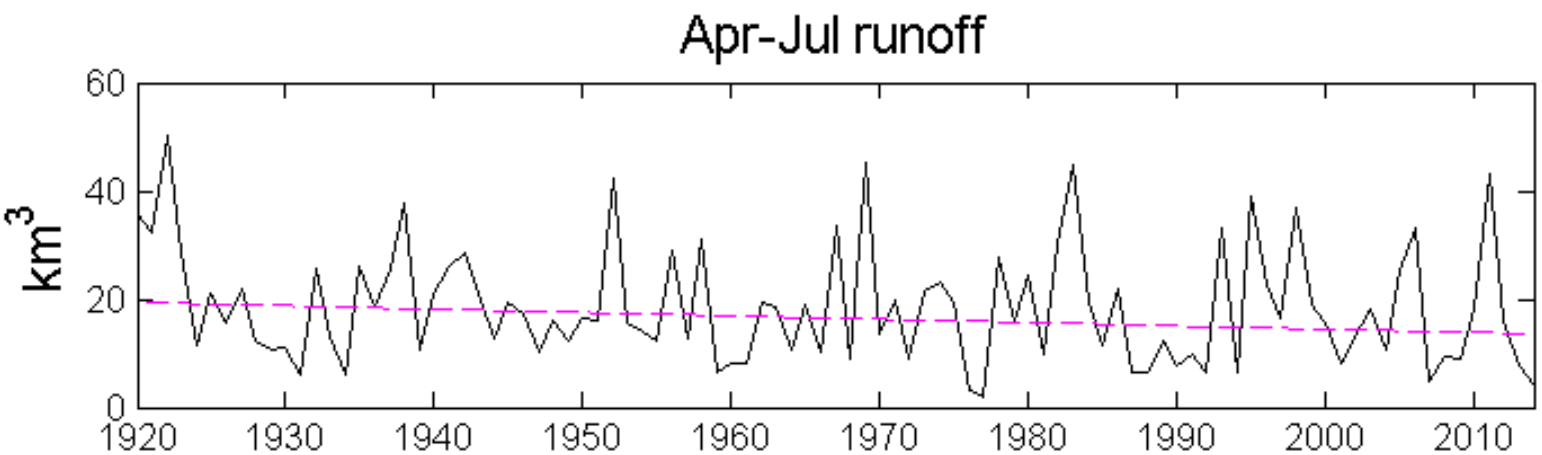
+0.4 °C/95 years
p-value=0.10

1. How has the climate changed in California?



Decreasing trend

-25%/95 years
p-value=0.07



Decreasing trend

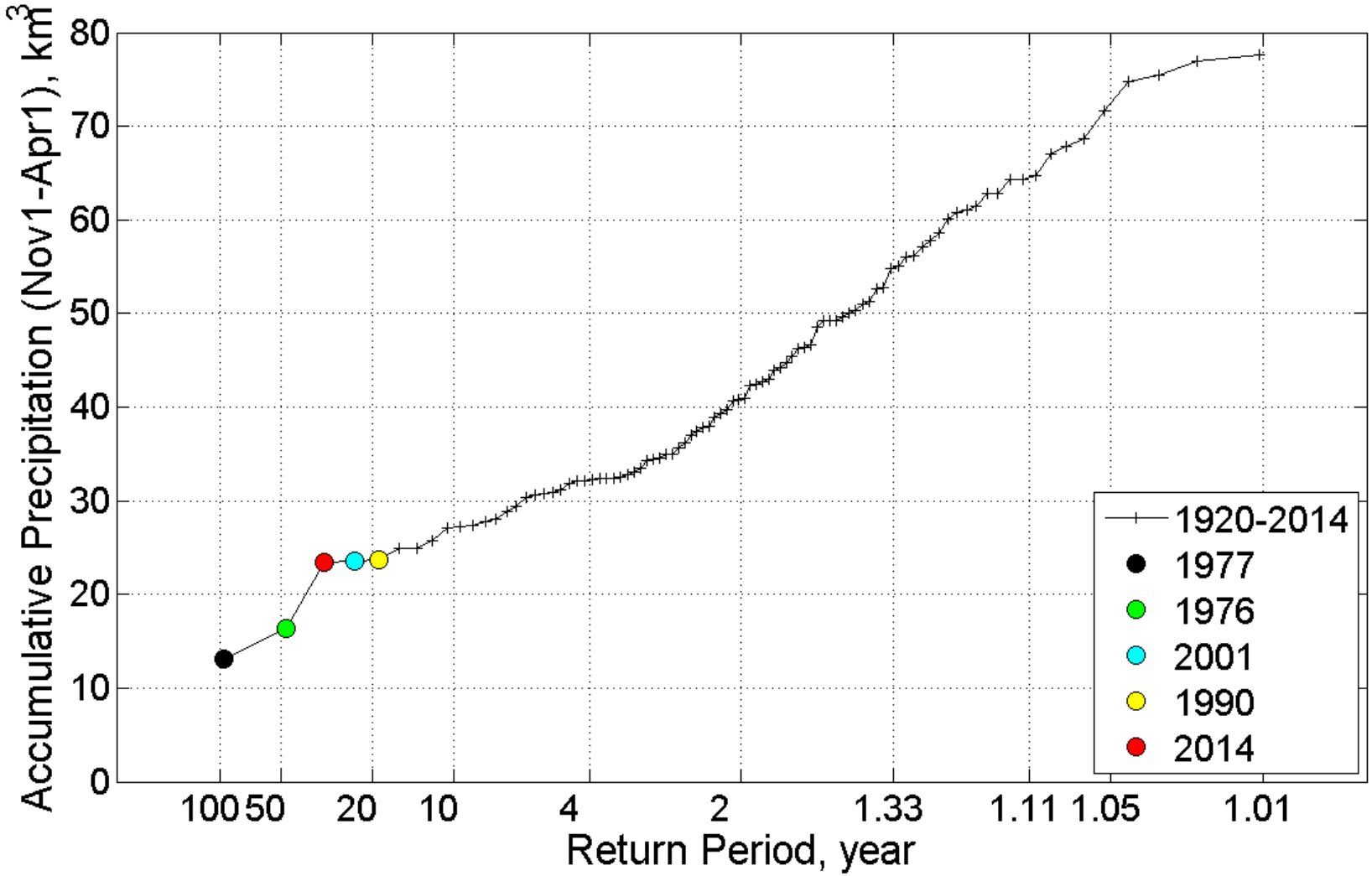
-30%/95 years
p-value=0.03

Analysis and results

2. How dry was California in 2013-2014? (Return period analysis)

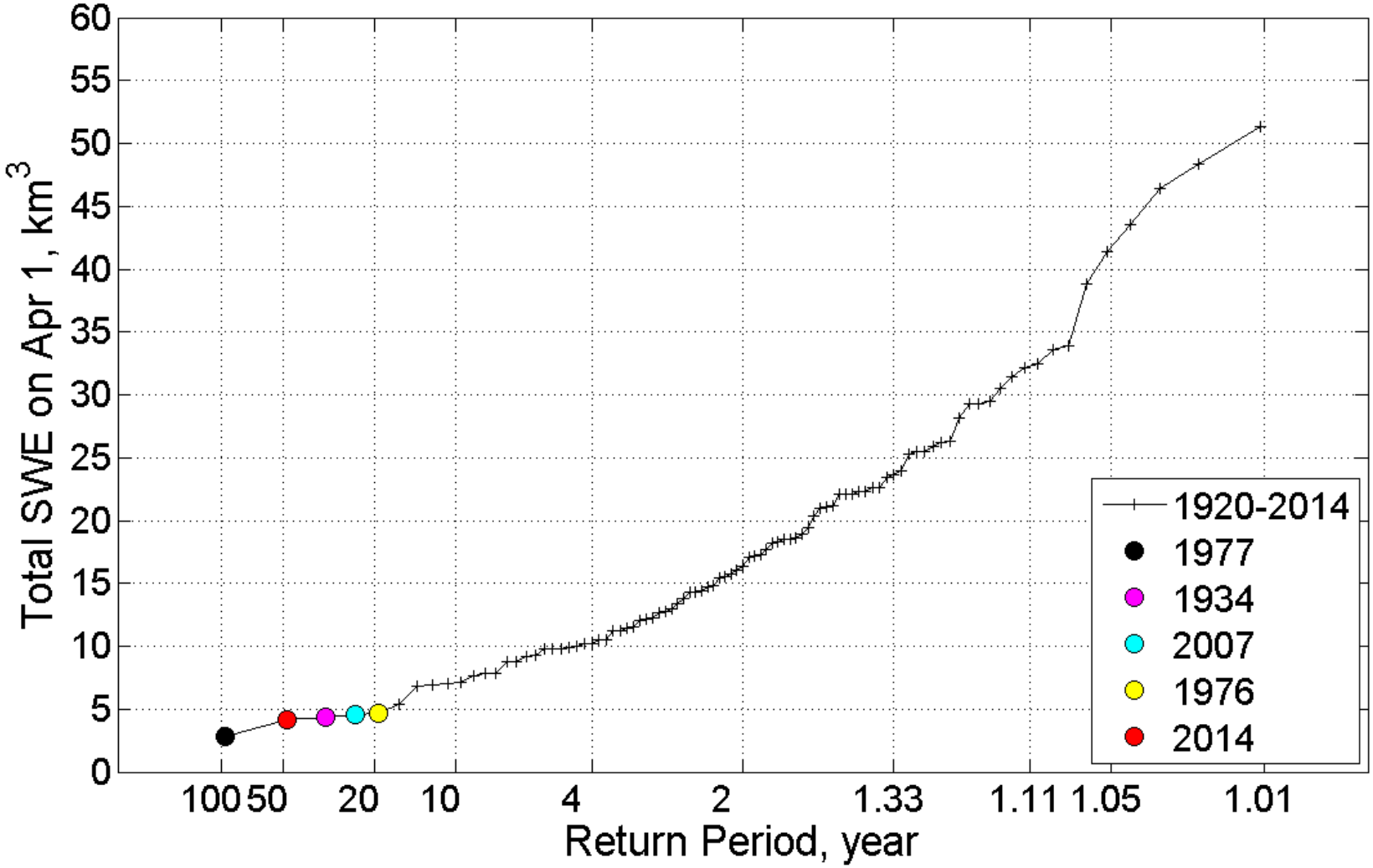
2. How dry was California in 2013-2014?

Winter precipitation



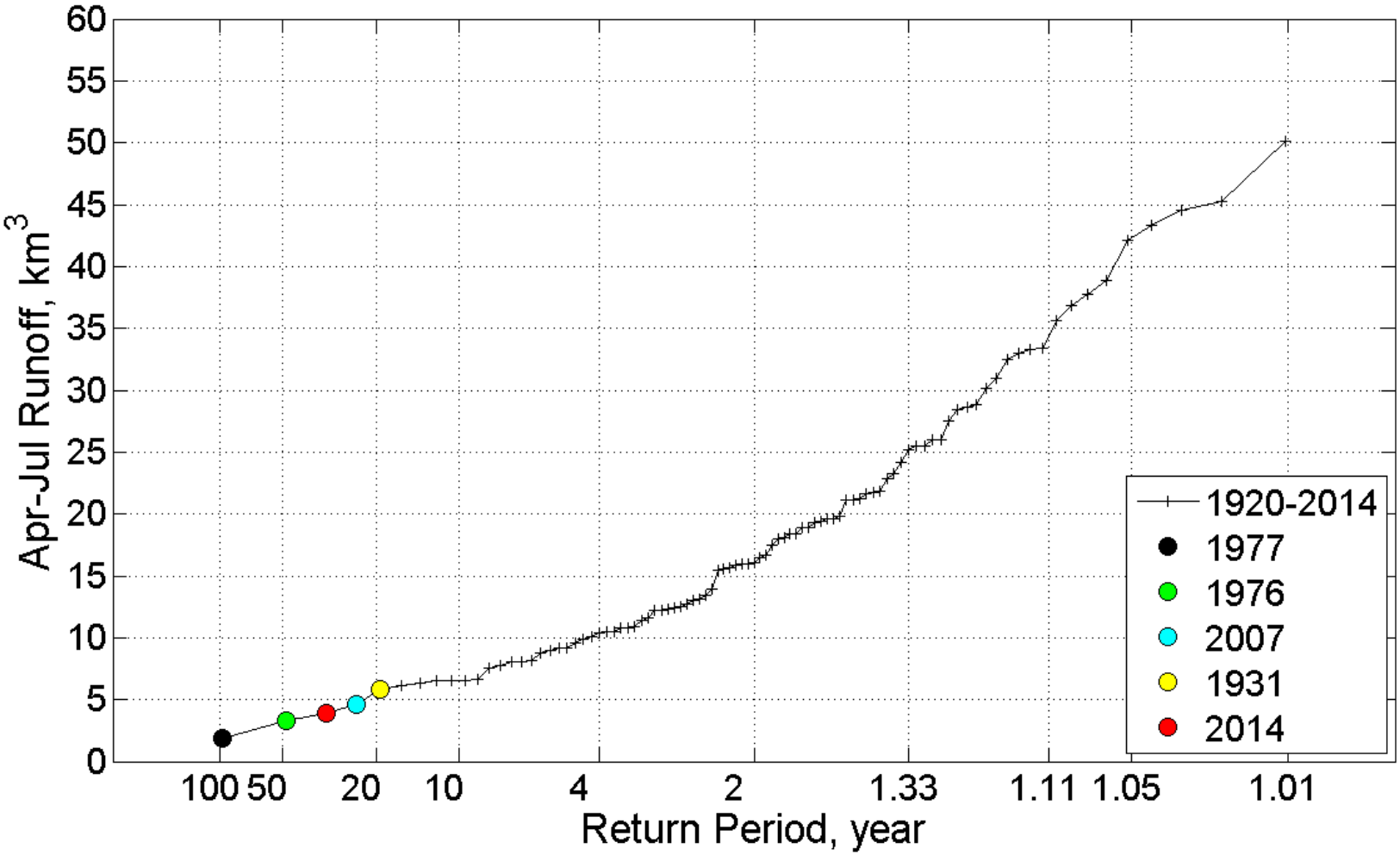
2. How dry was California in 2013-2014?

Apr 1 SWE



2. How dry was California in 2013-2014?

Spring runoff

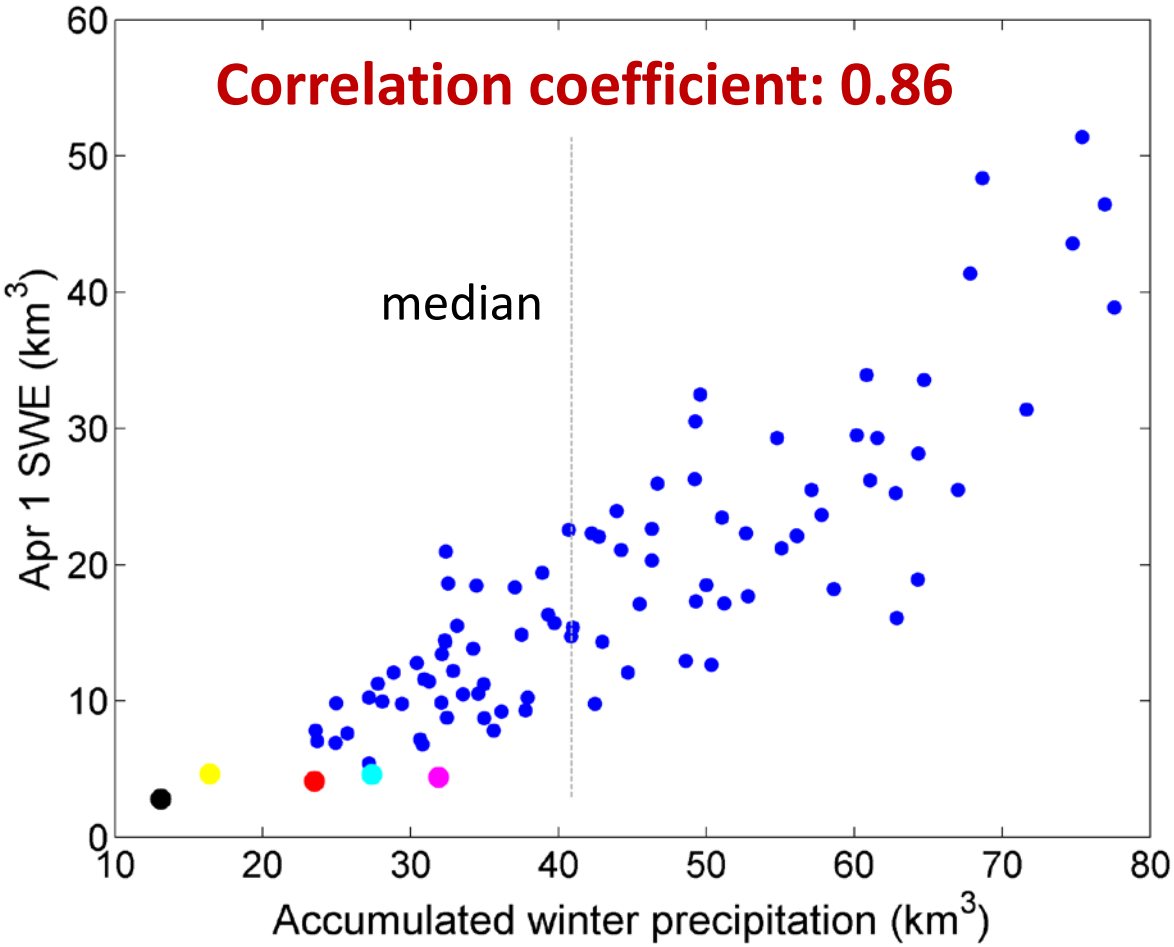


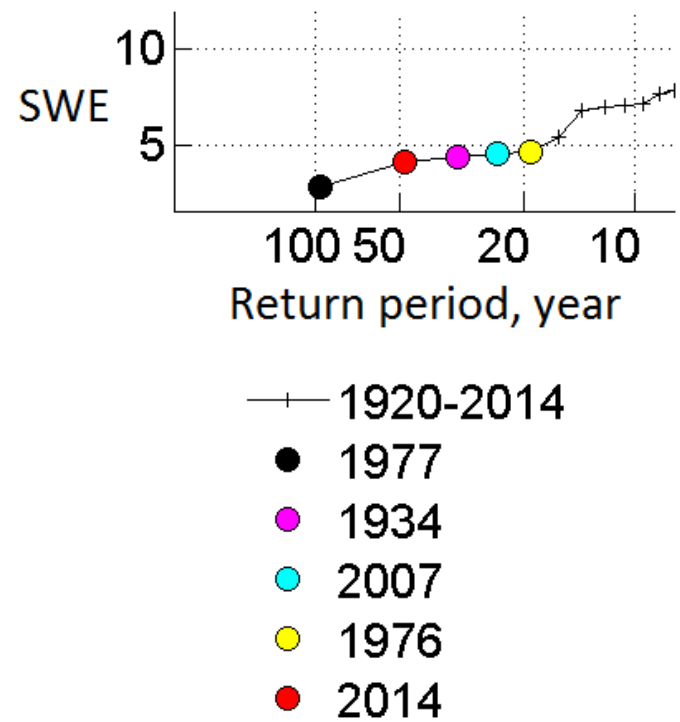
Analysis and results

3. Is there a link between climate change and drought events in California? (correlation analysis & hydrologic simulation)

3. Is there a link between climate change and drought events in California?

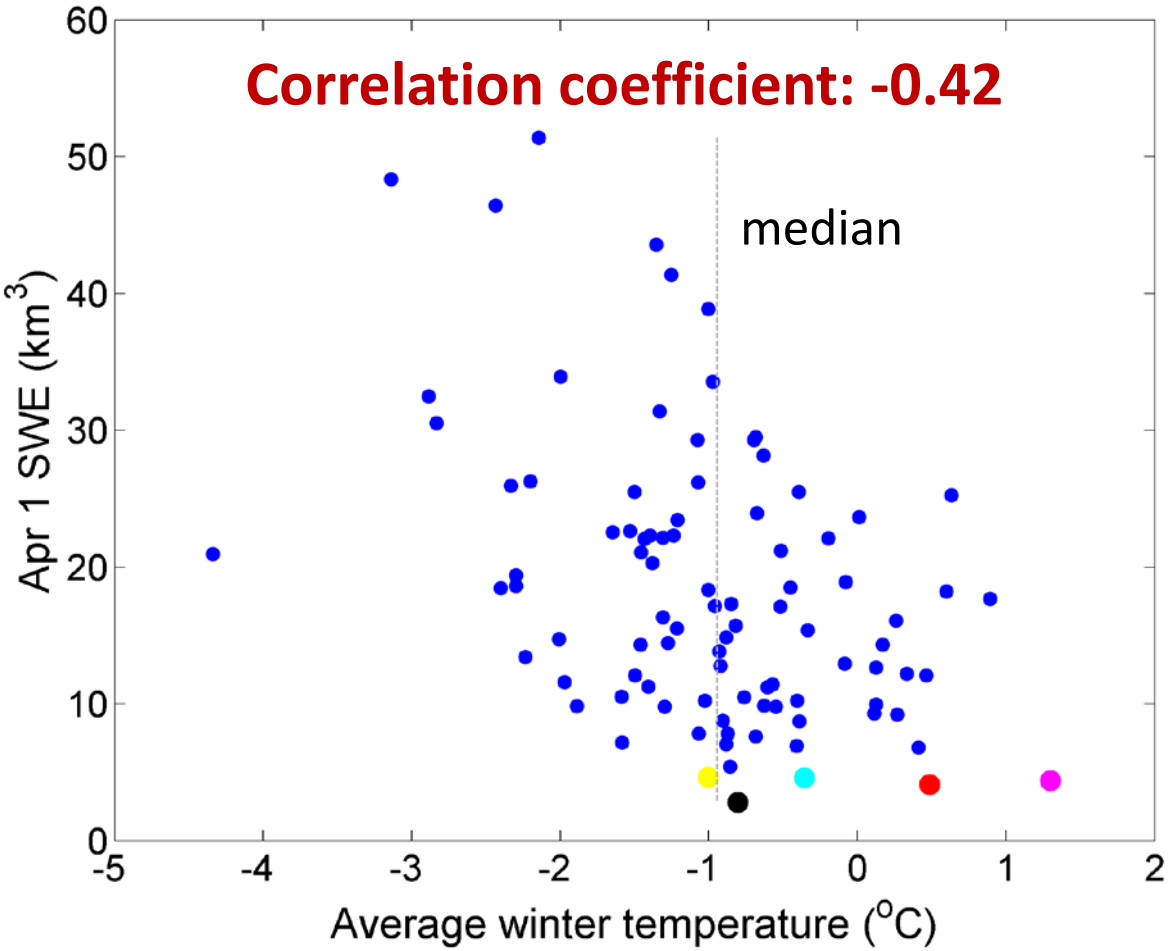
- Method 1 - Correlation analysis

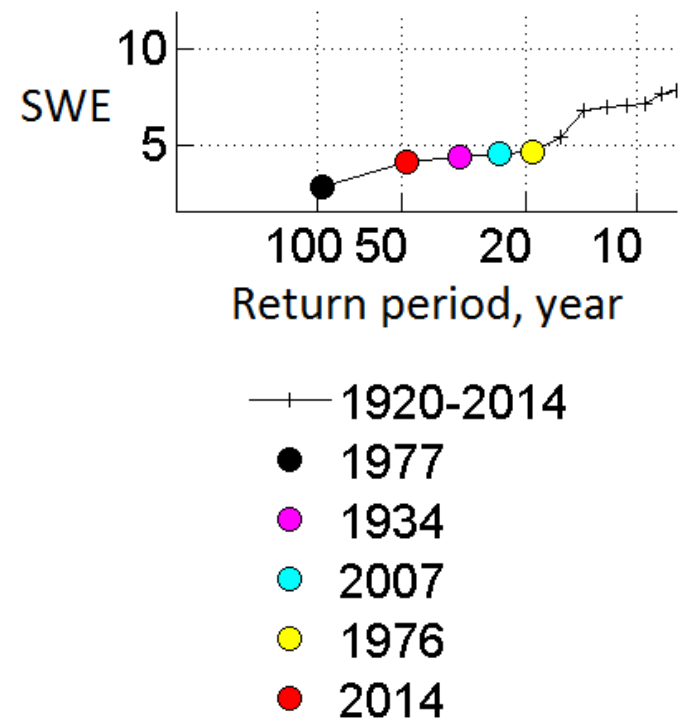




3. Is there a link between climate change and drought events in California?

- Method 1 - Correlation analysis





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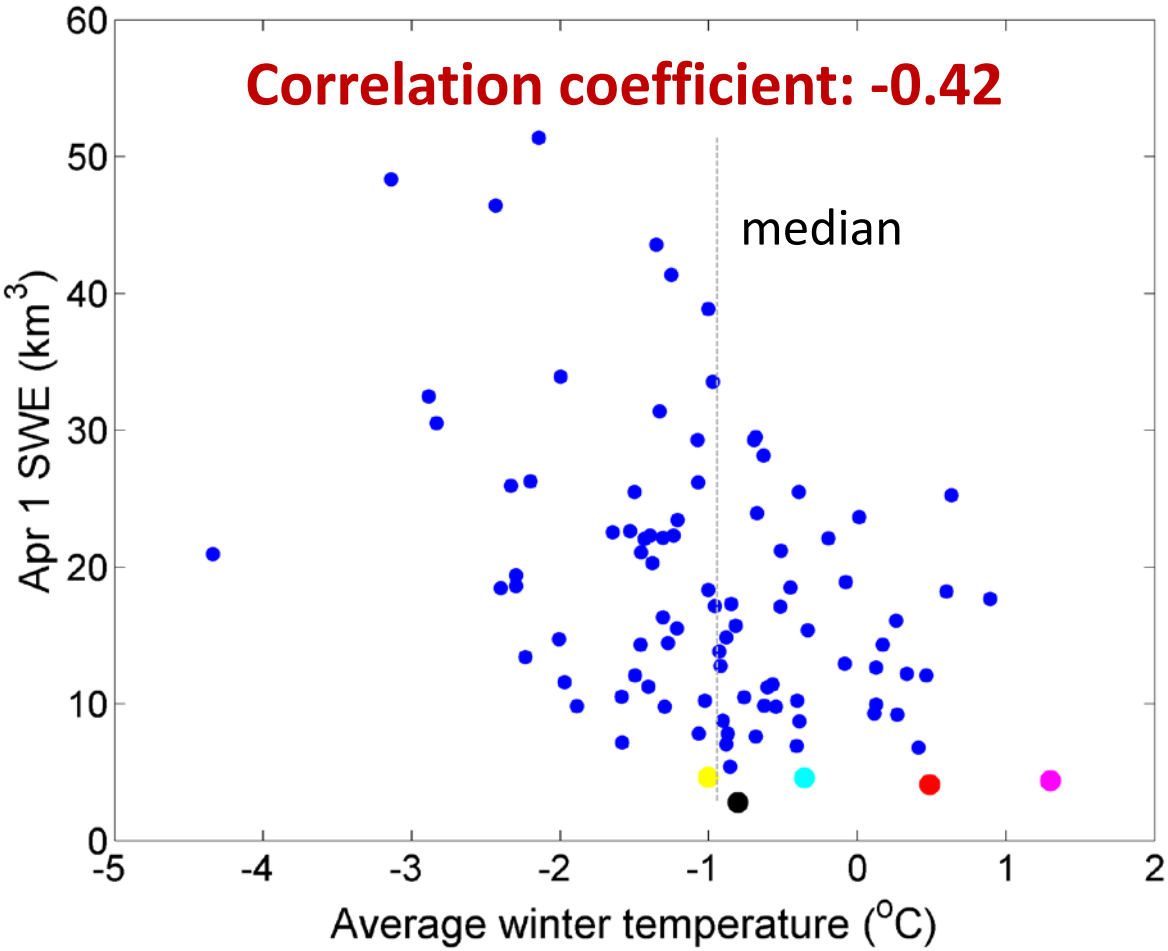
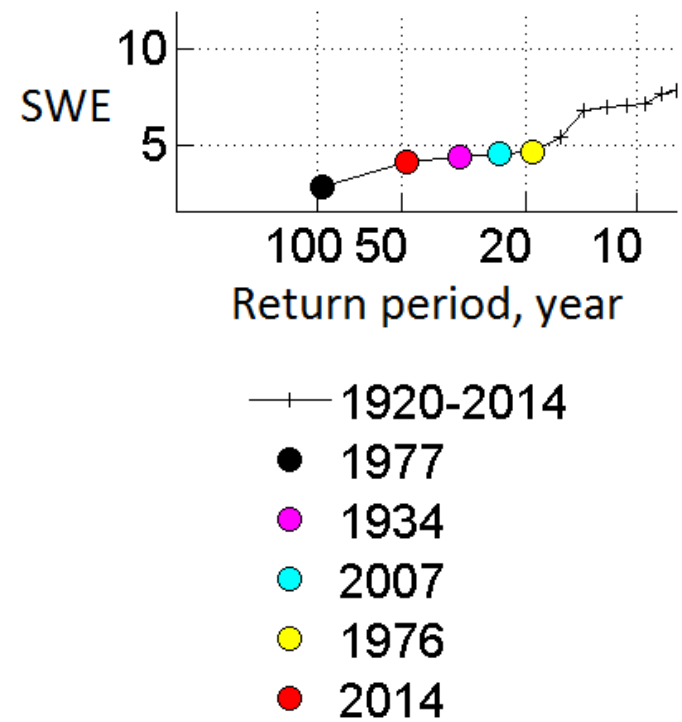
- Method 1 - Correlation analysis

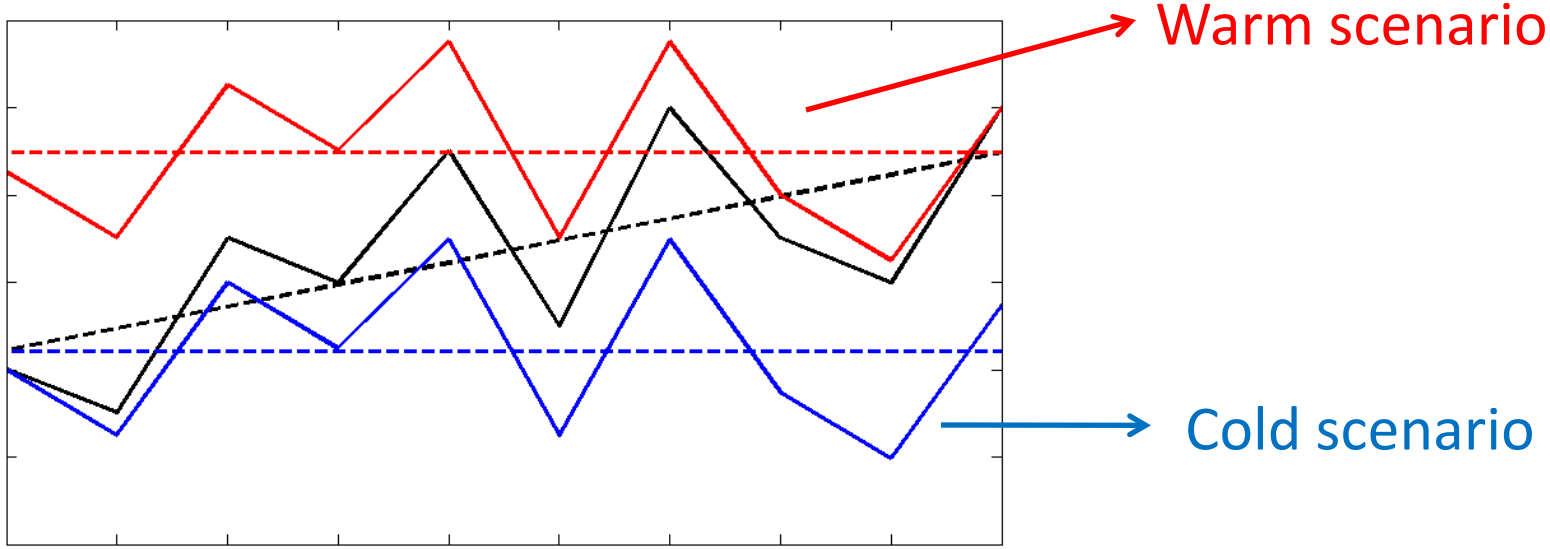




Apr 1 SWE has much stronger correlation with winter P than with winter T

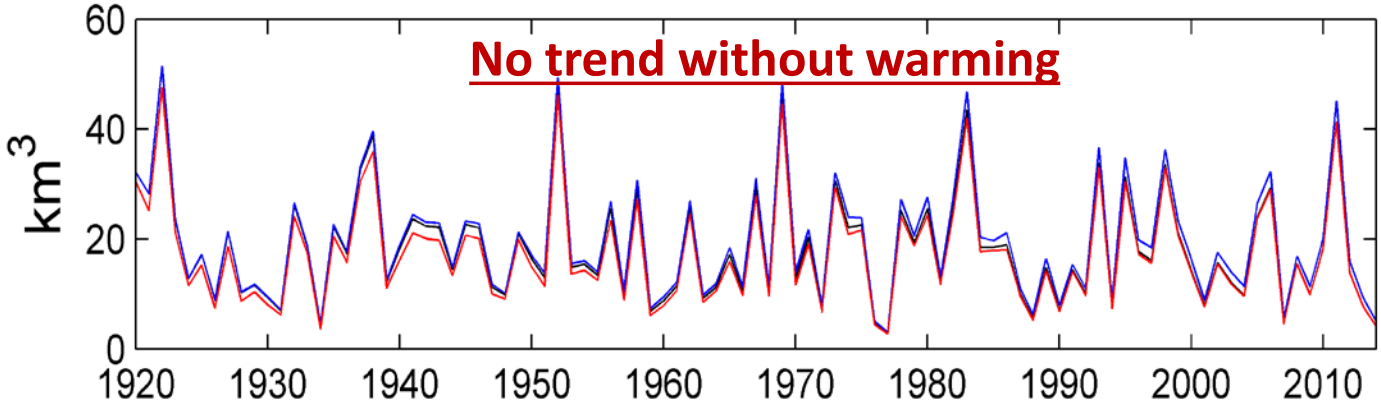
3. Is there a link between climate change and drought events in California?

- Method 2 – Detrended-T scenarios
  - In addition to the reconstructed time series (the ‘base scenario’), we removed the warming trend and simulate hydrological conditions using the VIC model (‘Detrended-T scenarios’ without climate change)
  - Removing long-term Tmin trend for each grid cell (Tmax does not have significant trend); preserving daily variation
  - Two detrended-T scenarios:



Apr 1 SWE

Base scenario
Cold scenario
Warm scenario



Apr 1 SWE

Base scenario
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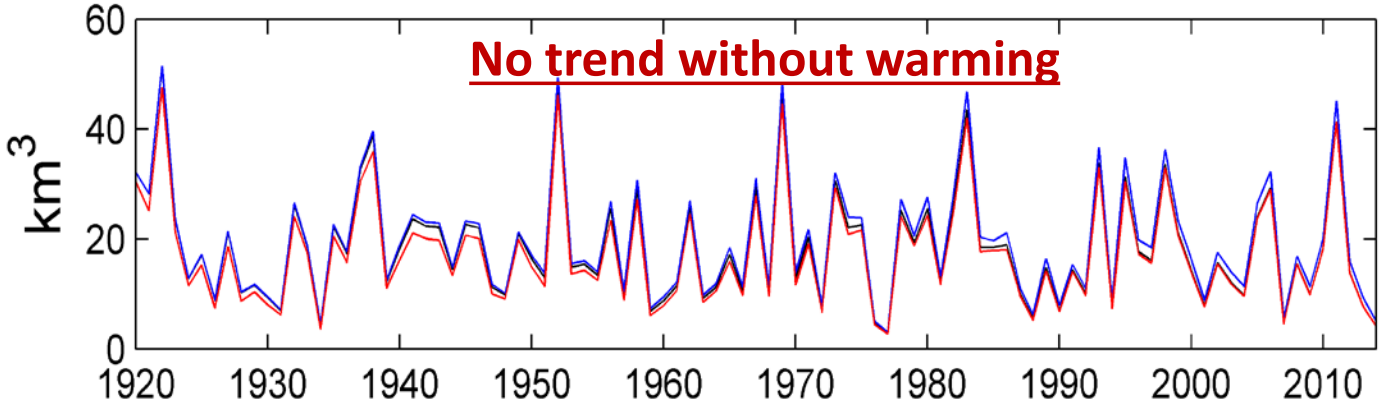
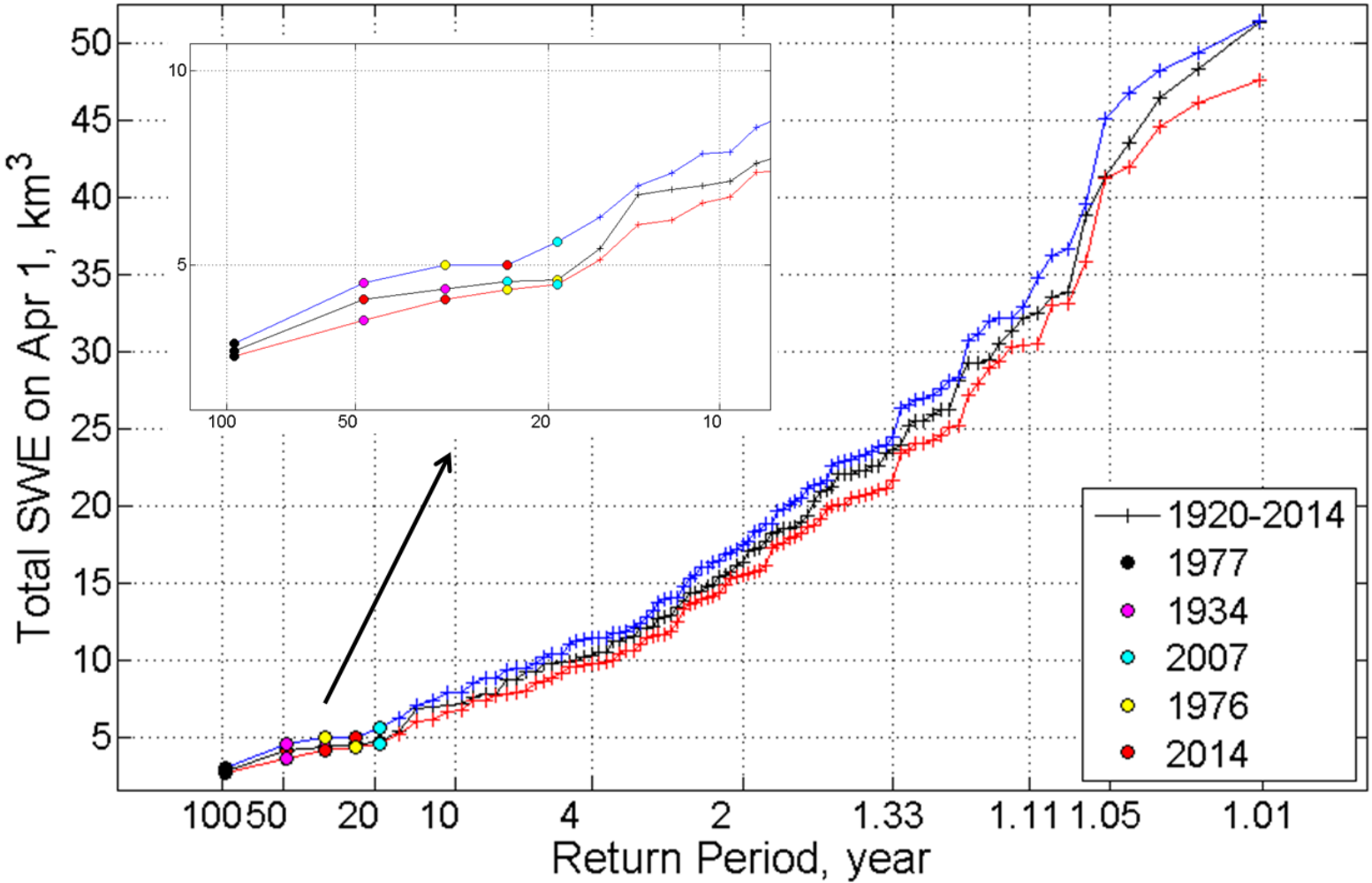
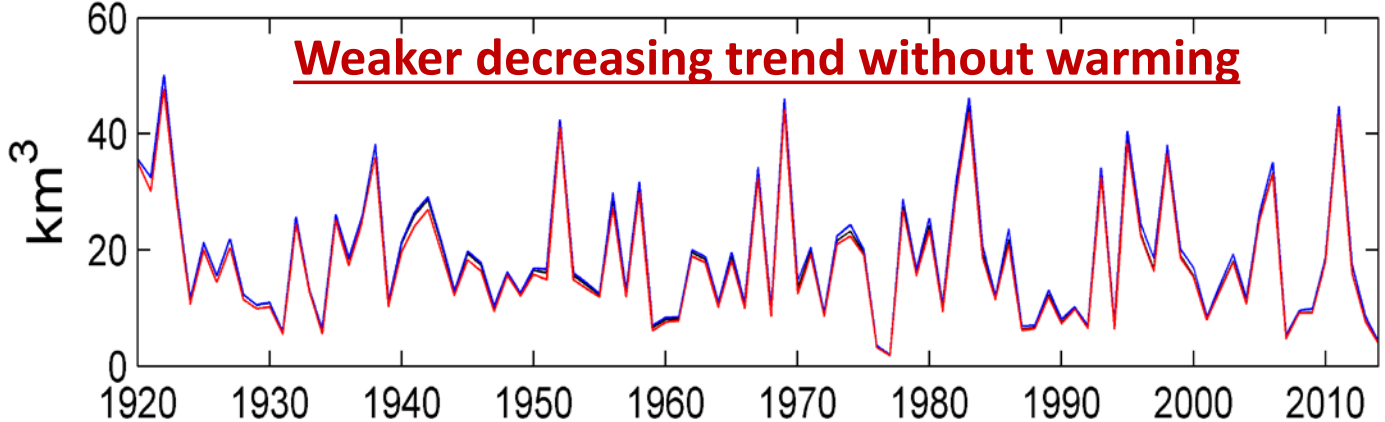
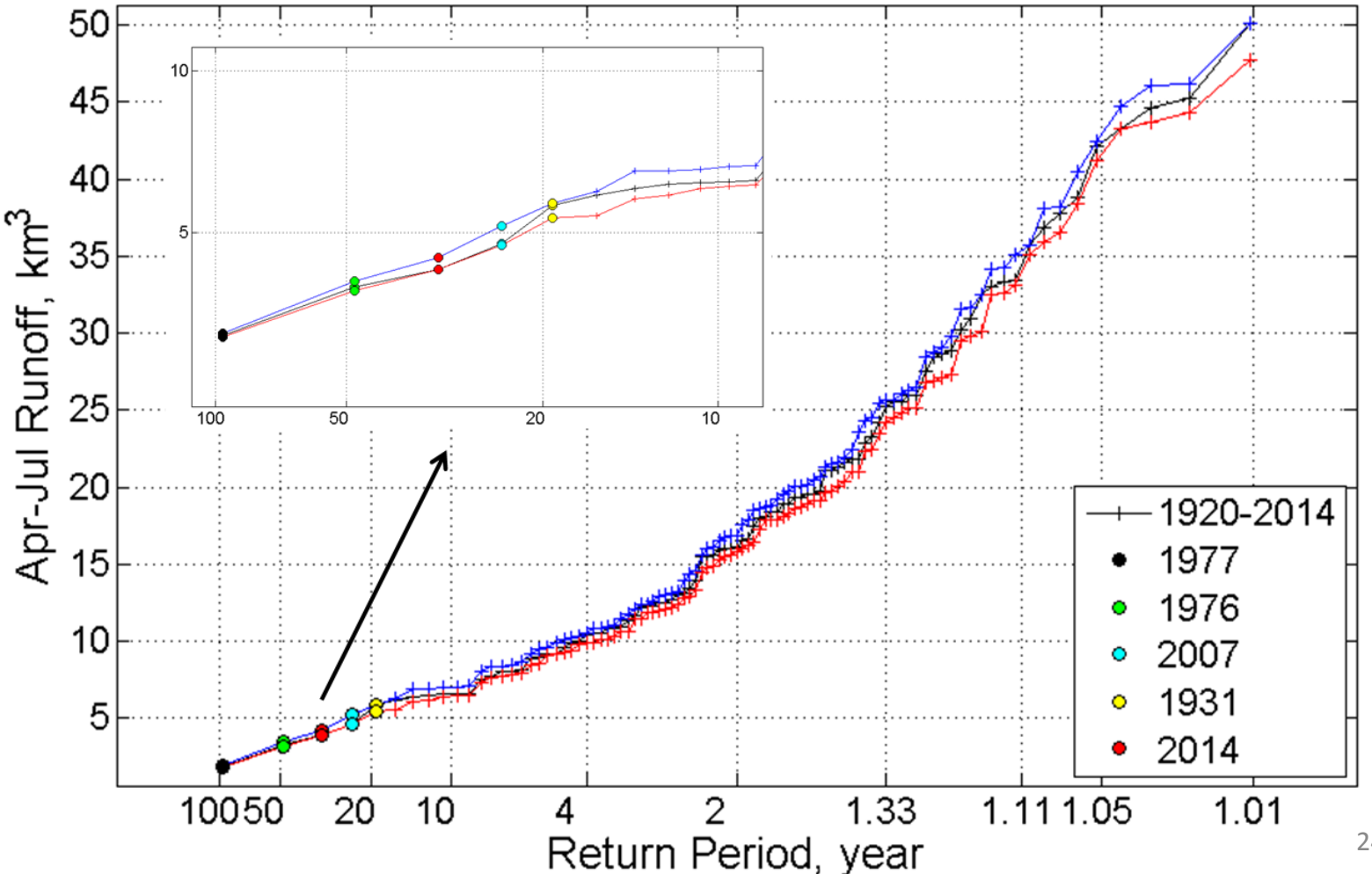




Spring runoff

Base scenario
Cold scenario
Warm scenario





3. Is there a link between climate change and drought events in California?

Warming climate

Decreasing trends in SWE and spring runoff

More severe droughts

3. Is there a link between climate change and drought events in California?

Warming climate

Probably

Decreasing trends in SWE and spring runoff

More severe droughts

3. Is there a link between climate change and drought events in California?

Warming climate

Probably → **Decreasing trends in SWE and spring runoff**

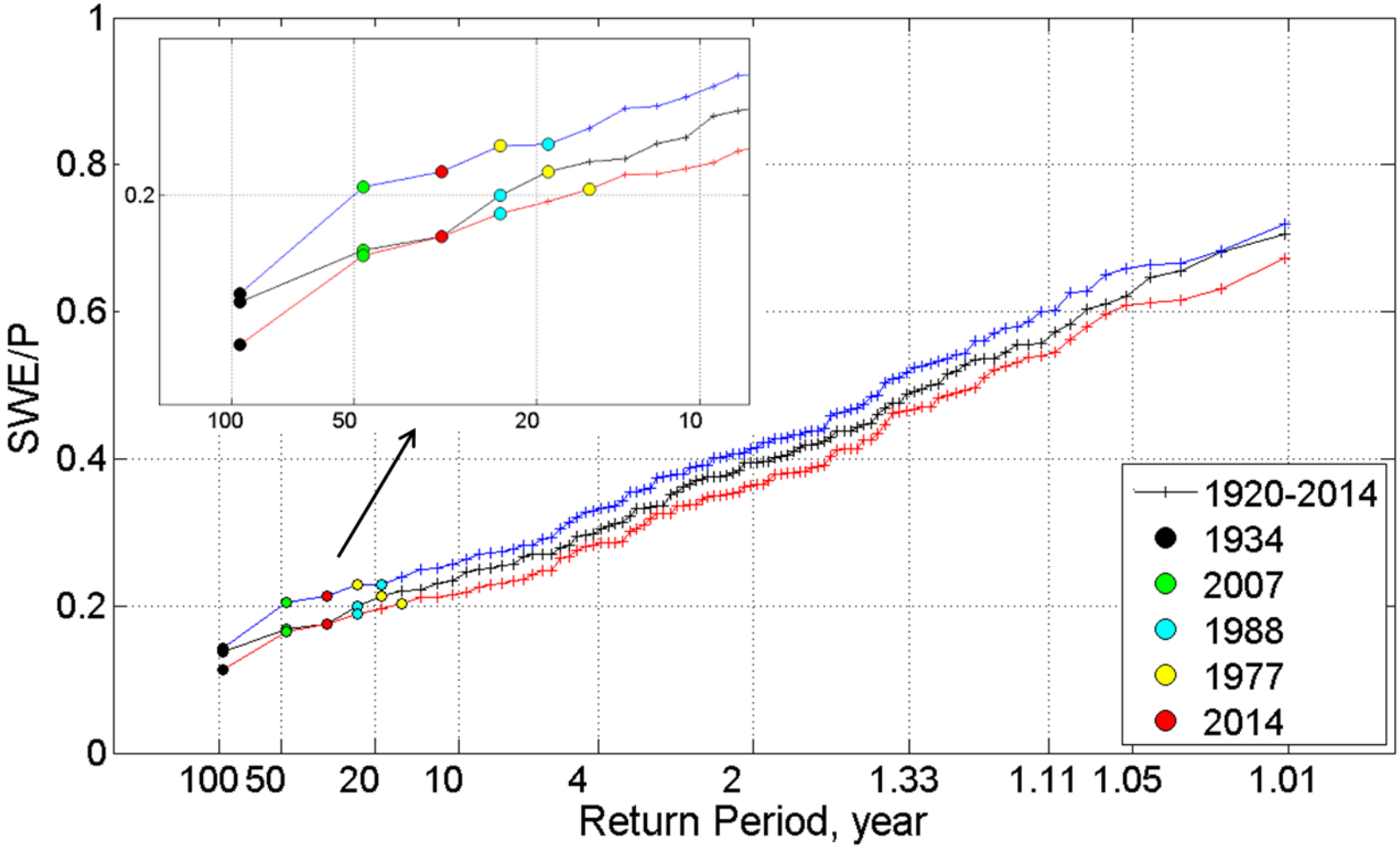
Not so much → **More severe droughts**

Conclusions

Conclusions

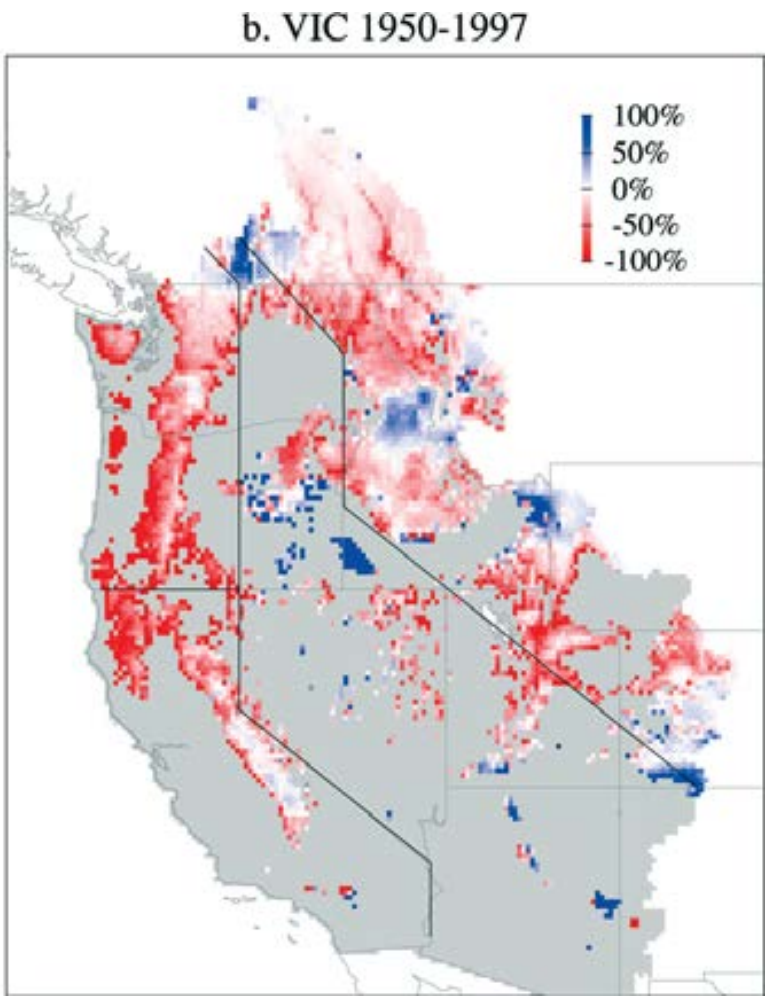
- Lots of natural variability in the record
- SWE primarily correlated with winter precipitation, secondarily with winter temperature
- The warming climate does not affect extreme drought events too much
- Climate change might have slightly exacerbated the 2014 drought (anomalously warm winter)
- But these kinds of extreme drought events in the Sierra Nevada are mainly due to natural variability in precipitation

Thanks!

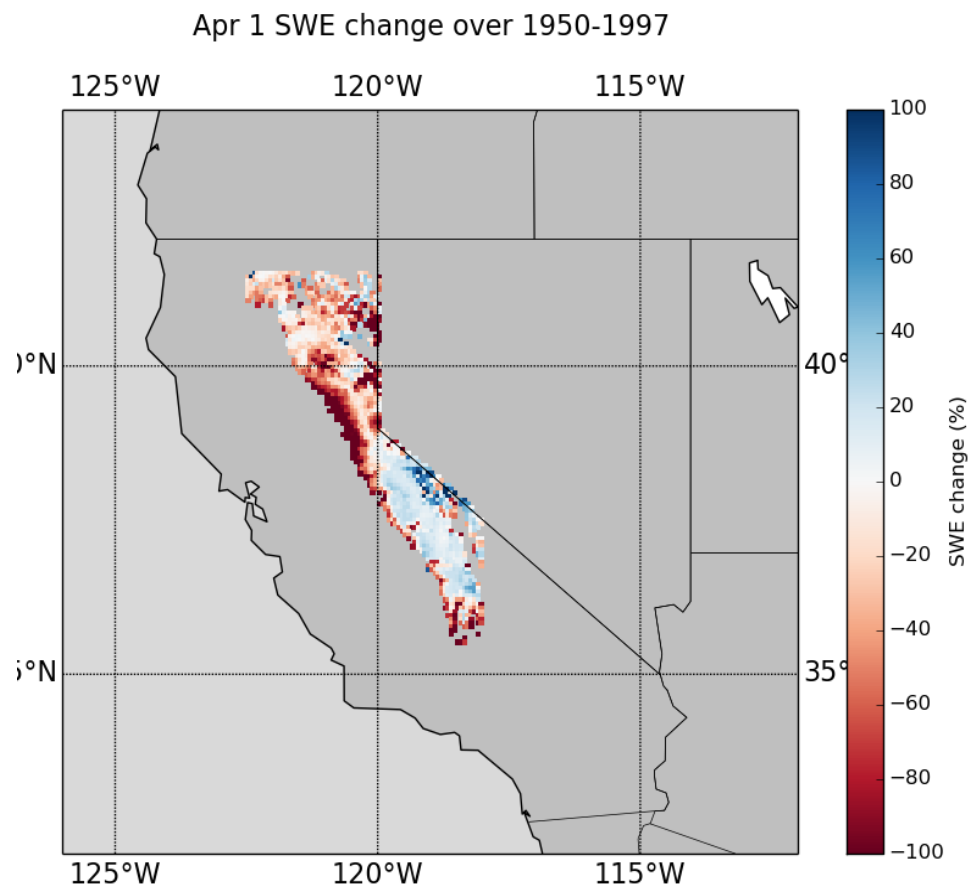

SWE/P
Return Period, year
1
0.8
0.6
0.4
0.2
0
100 50 20 10 4 2 1.33 1.11 1.05 1.01
0.2
100 50 20 10
1920-2014
1934
2007
1988
1977
2014

Trend maps of Apr 1 SWE, 1950-1997

From Mote et al., 2005

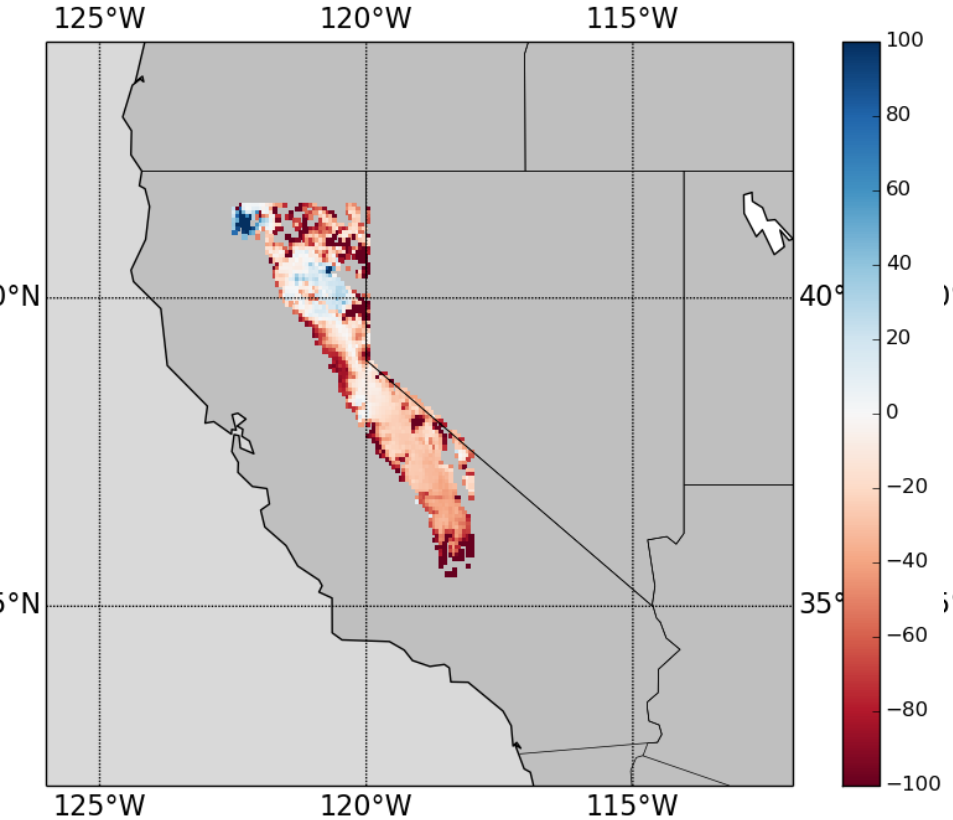


From our simulation

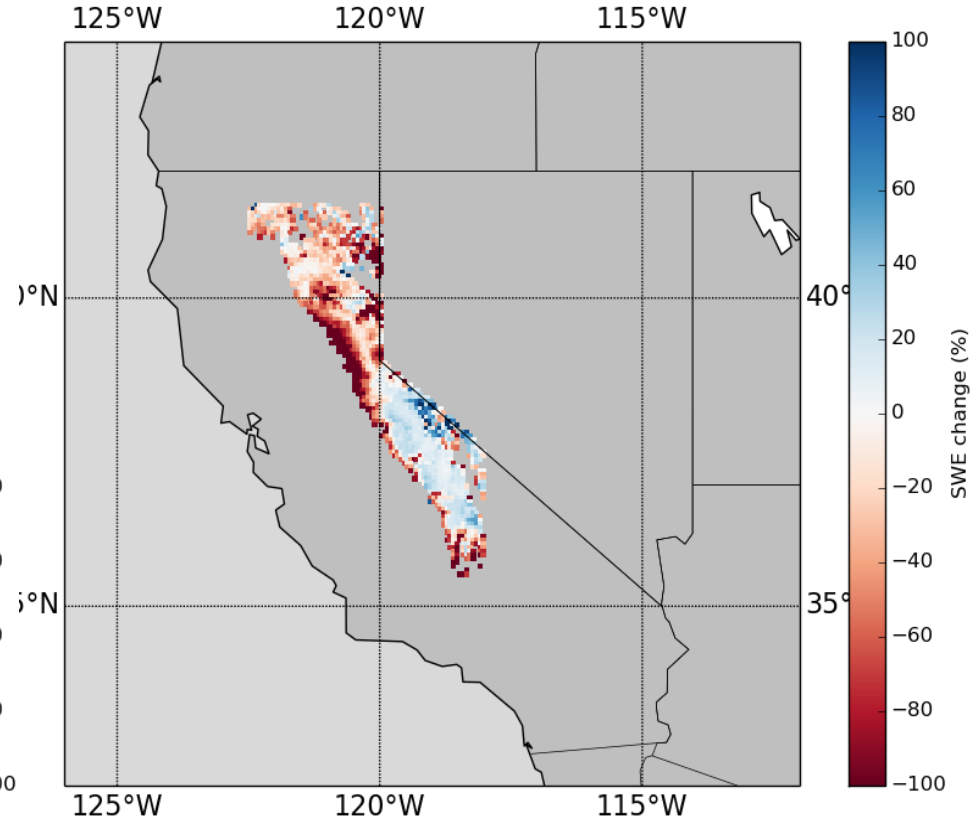


linear trends in Apr 1 SWE relative to the starting value for the linear fit, simulated by the VIC model

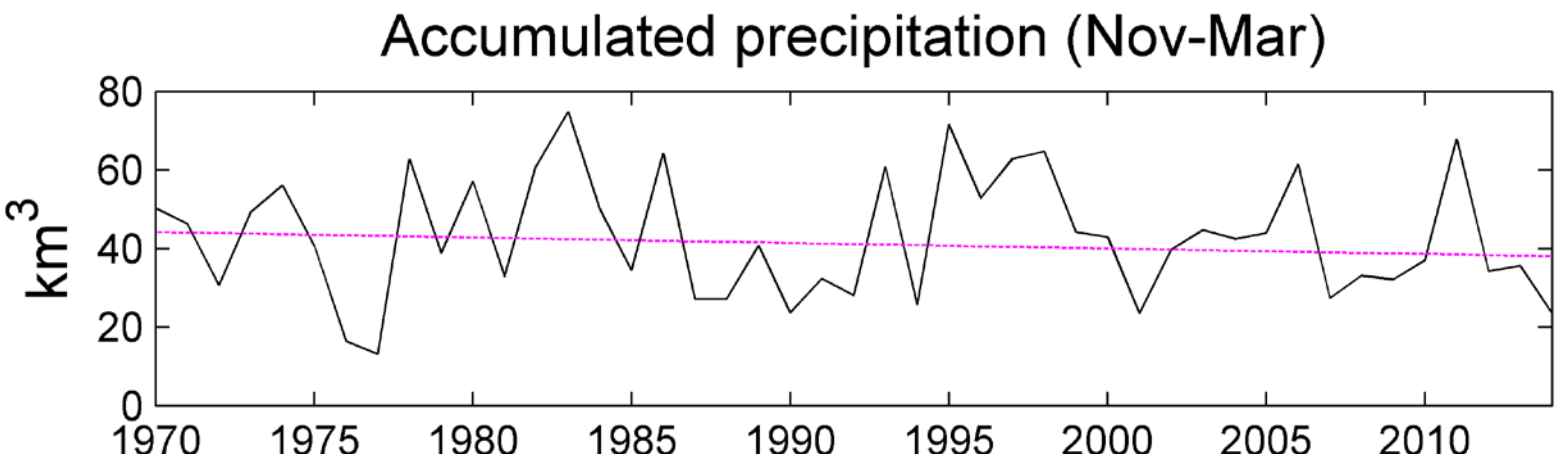
Apr 1 SWE change 1920-2014



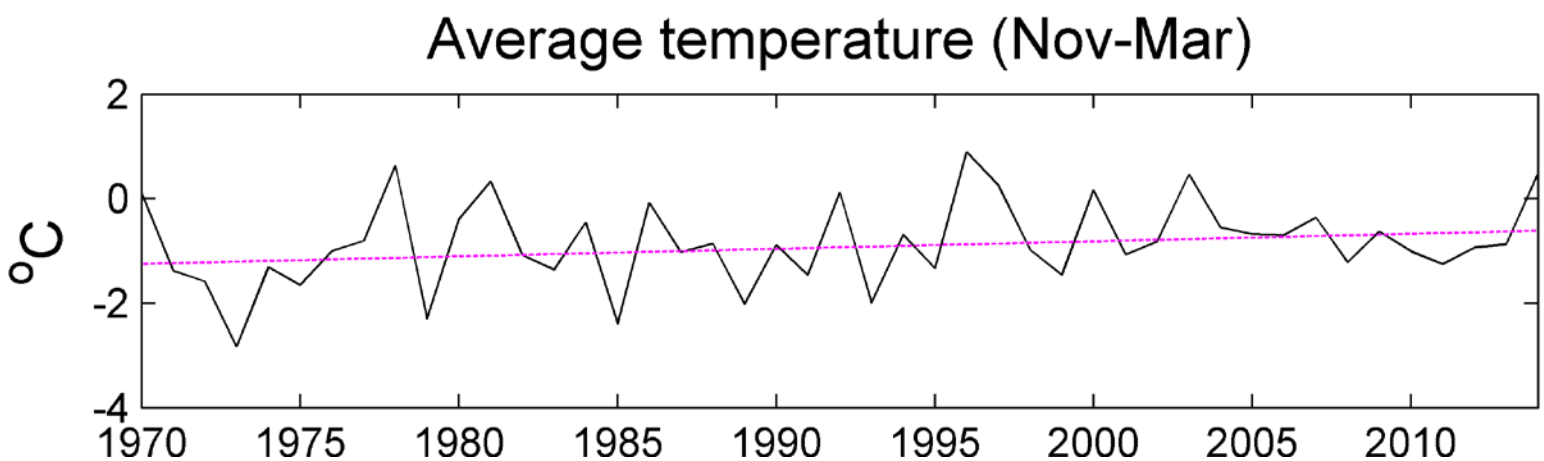
Apr 1 SWE change 1950-1997



Trend analysis for post-1970 period



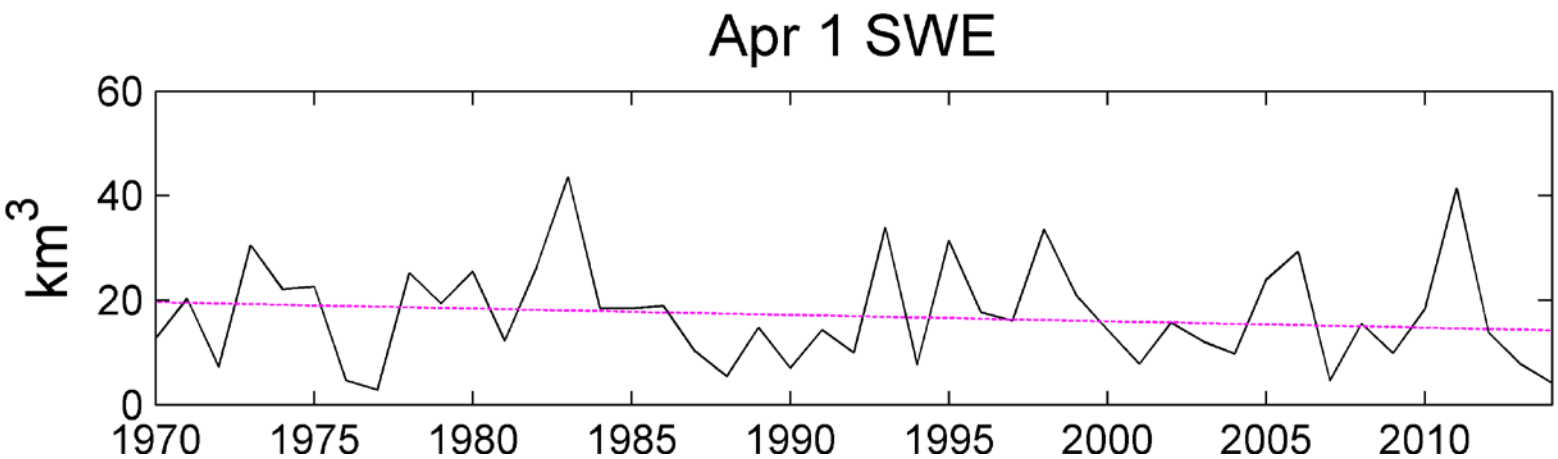
No significant trend



Increasing trend

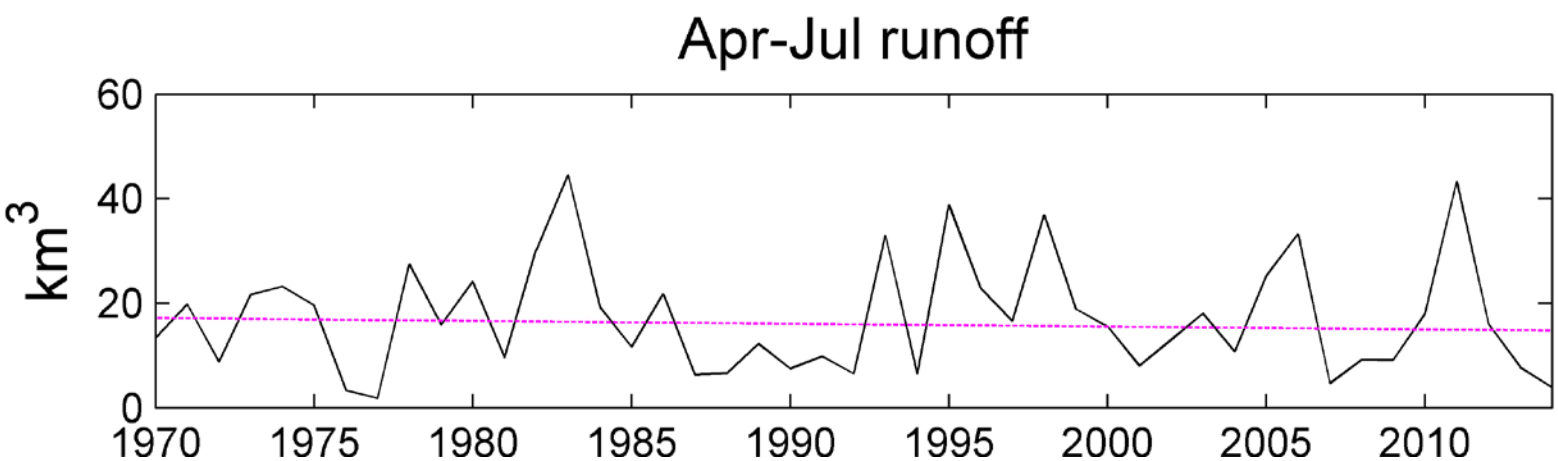
+0.6°C/45 years
p-value=0.04

Trend analysis for post-1970 period



No significant trend

-27%/45 years
p-value=0.13



No significant trend

-14%/45 years
p-value=0.30