Unusual warmth and dryness in the Central Sierra Nevada during recent years

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unusual warmth of recent dry years produced inordinately low snowpack mountainous region of California

plot shows 3yr avg seasonal ONDJFM mean T, P and SWE 1915-2015
SWE from VIC model driven by Livneh observed T and P
Jan-Mar 2015 was impressively warm in Yosemite Region. $T_{\text{max}}$ and $T_{\text{min}}$ anomalies from several stations.
Regional Warming during last three decades

Oct-Sept Tmax and Tmin
San Joaquin drainage
California Climate tracker
Increased Warming Rates in next few decades
climate Models predict
~1.5C warming by 2060 approx. 2X observed rates
under RCP4.5 or RCP8.5
average of 10 CMIP5 GCMs
Fourth Calif Climate Change Assessment
Highway 120 Temperature Network

Forty Mile
Dana Meadows
Tuolumne Meadows
Ellery Lake
Poole Power Plant
Daily $T_{\text{max}}$ and $T_{\text{min}}$

Western Sierra

Eastern Sierra

Higher elevation

Note: The black lines are 2006-2015 climatological averages
2015 JFM $T_{\text{min}}$ Anomalies vs. Elevation

anomalies from short (200X-2016) climatology

Higher elevation

Note: $N = \text{Total number of occurrences, normalized by the sample size}$
2015 JFM $T_{max}$ Anomalies
anomalies from short (200X-2016) climatology

Higher elevation

Note: N = Total number of occurrences, normalized by the sample size
Warmth in winter (JFM) 2015 in YOSE

- Both days and nights were warm.
- High occurrence, positive T anomalies nighttime and daytime
- Diminished occurrence of negative temperature anomalies
- Daytime warm anomalies decidedly positive
- Similar pattern in the western and eastern Sierra.
PRECIP

(standardized anomalies)
Mean of years: 2007-9, 2012-15
Projection = normalized dot product of mean dry year pattern and each actual year

(normalized by the dry year pattern dotted onto itself)

So:

A value of 1 means equivalent to the dry year pattern (dry, hot)

A value of 2 means twice as dry/hot

A value of 0 means no projection

A value of -1 means opposite (cool, wet)
2-D histograms of the projection values for all 32 LOCA models

Done in 30-yr periods

RCP 8.5

Precip (X axis) and Tmax (Y axis)
32 RCP 8.5 GCMs
T and P over SW U.S.

• No, under RCP 8.5 model projections it’s unlikely for years to be so “cold”

• Increase in probability of such dry years, by not quite a factor of 2
And the California spring snowpack will decline as CO2 accumulates and temperatures rise.

**Average April 1 Snow**

Franco et al. 2018
to appear in Fourth California Climate Change Assessment
PRECIP

(standardized anomalies)
Tuolumne Meadows

$T_{\text{max}}$ Anomaly at TUM

$T_{\text{min}}$ Anomaly at TUM
32 GCMs

2 to right of box

Many to right of box
Probability of Exceeding projection value of 1.0

- **prec**

- **tmax**
Data sources:

• Livneh 2013 (“L13”) CONUS 1950-2013, daily, 1/16th degree resolution, regridded to 1/8th degree, precip, Tmin, Tmax

• PRISM 1981-2018, daily, regridded to same 1/8th degree grid

• Livneh + PRISM combined 1950-2018, with a simple bias correction matching

• LOCA downscaled Tmin, Tmax, Precip from 32 GCMs, RCP 4.5 & 8.5, regridded to 1/8th degree

• WATER YEAR AVERAGED, STANDARDIZED ANOMALIES (hist: 1950-2005)
Water-year Temperatures
Statewide-avg California

Source: NOAA/NCEI

Record breaking warmth

Water Year 2015

Water Year 2014

Divisional Average Temperature Rank
October 2014 - September 2015
Probing the Unusual Warmth During 2014-2015

Was the average warmth in these recent years attributed to:

- warmer days or warmer nights?
- general increase in positive anomalies (across small- to large-anomaly magnitudes)?
- increased occurrence of high positive anomalies?
- lack of negative anomalies and particularly lack of strong cold outbreaks?
32 GCMs
Highway 120 Temperature Network
Daily Maximum and Minimum Temperature and Anomalies

- The daily maxima (13 LST) and minima (6 LST) are computed from the hourly data.
  - The primary measures used t/o this presentation
Daily $T_{\text{max}}$ and $T_{\text{min}}$

Western Sierra

Eastern Sierra

Lower elevation

Note: The black lines are 2006-2015 climatological averages
Daily $T_{\text{max}}$ and $T_{\text{min}}$ Anomalies

**Western Sierra**

More positive $T_{\text{max}}$ anomalies

**Eastern Sierra**

Lower elevation

Lack of negative $T_{\text{min}}$ anomalies

**Note:** The anomalies are based on 2006-2015 climatological averages
Daily $T_{\text{max}}$ and $T_{\text{min}}$ Anomalies

**Western Sierra**

**Eastern Sierra**

Higher elevation

Note: The anomalies are based on 2006-2015 climatological averages
$T_{\text{max}}$ and $T_{\text{min}}$ Anomalies vs. Elevation (All Seasons)

No obvious $T_{\text{max}}/T_{\text{min}}$ anomalies relationship with elevation
$T_{max}$ and $T_{min}$ Distributions at Forty Mile

Most notable in JFM

Note: N = Total number of occurrences, normalized by the sample size
T_{\text{max}} \text{ Anomalies vs. Elevation (JFM)}

Note: N = Total number of occurrences, normalized by the sample size
$T_{\text{min}}$ Anomalies vs. Elevation (JFM)

Note: $N =$ Total number of occurrences, normalized by the sample size
$T_{\text{max}}$ and $T_{\text{min}}$ Anomalies vs. Longitude (All Seasons)

No obvious $T_{\text{max}}/T_{\text{min}}$ anomalies relationship with longitude