

Tallying up the California drought

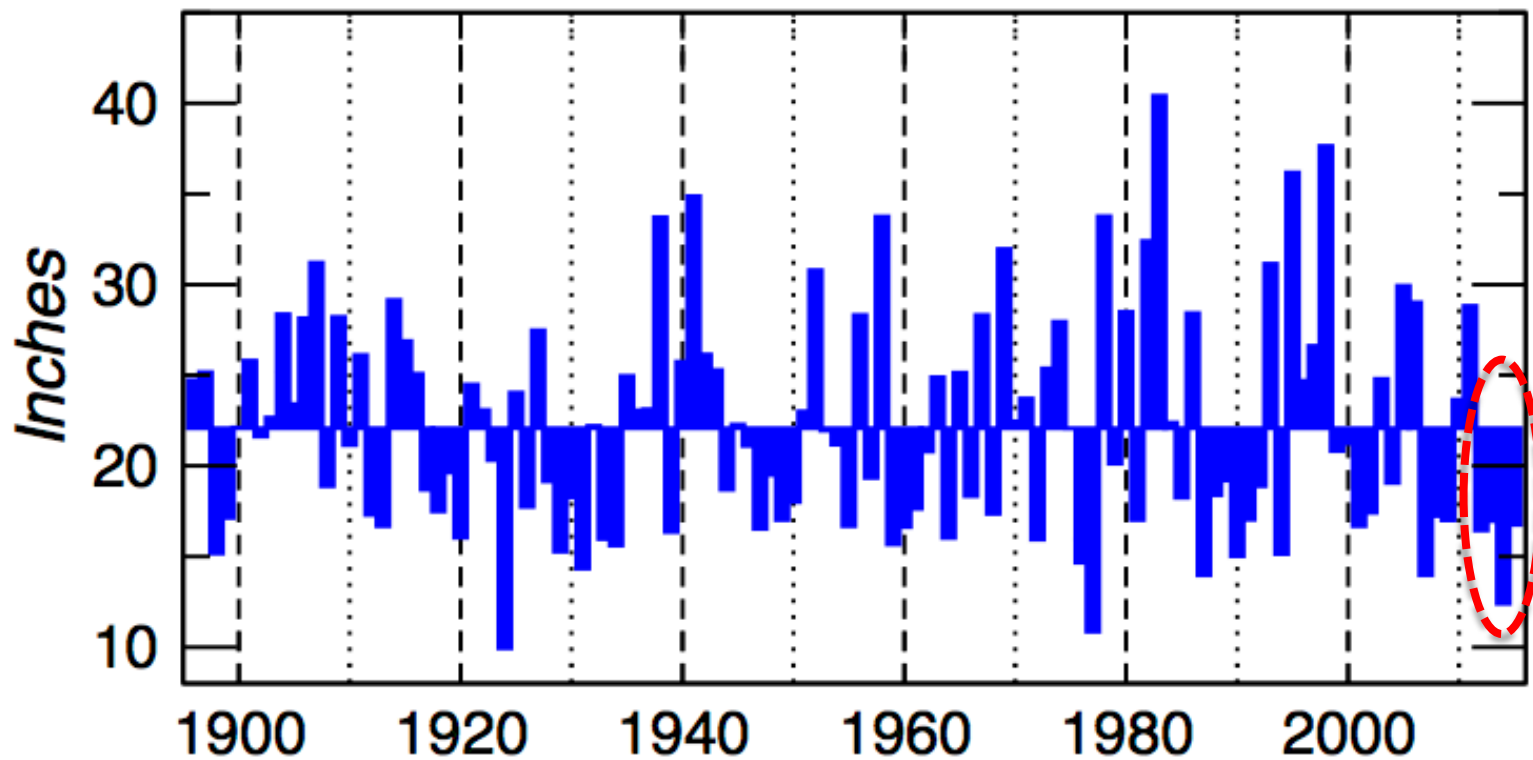
Mike Dettinger, USGS & Dan McEvoy, DRI

- ***The blue-water & green-water droughts, 2012-15 & 2016***
- ***How much of this drought has been precipitation deficit? Snowpack drought? Streamflow drought?***

How much is extra evaporative demand?

In passing: How much less vapor has come to us from over the Pacific?

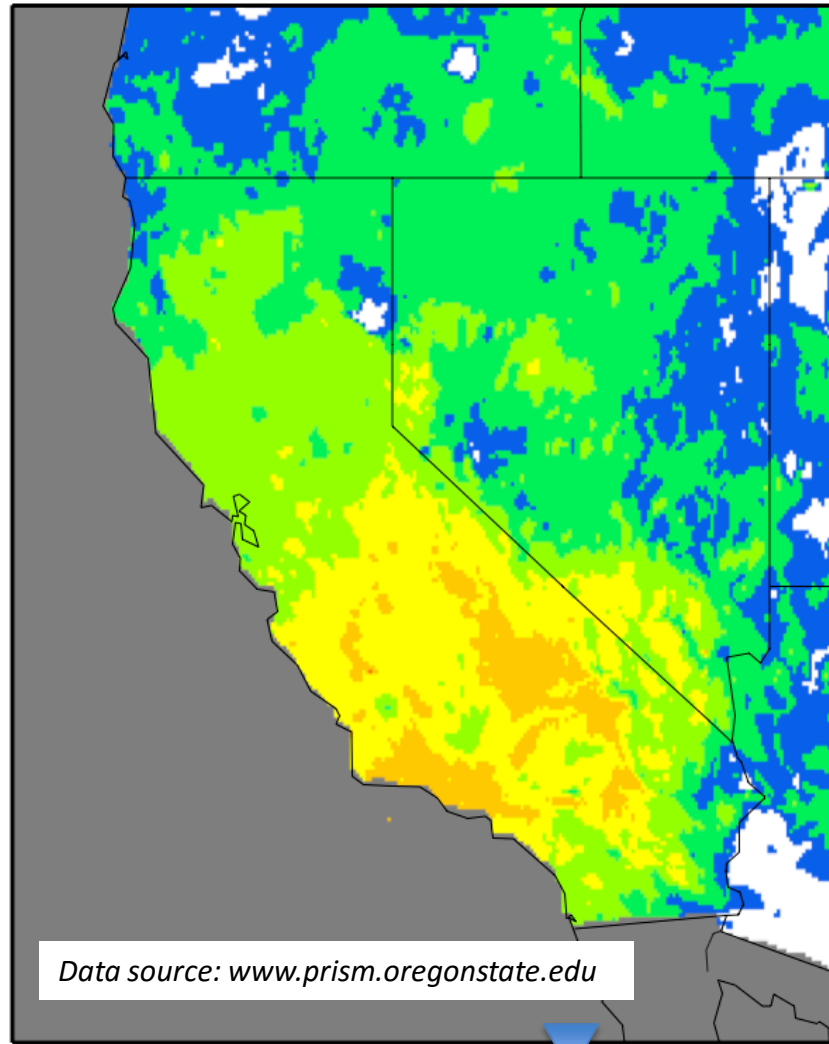
California Statewide Water-Year Precipitation



Data source: NOAA/NCEI

NET PRECIPITATION DEFICITS WY2012-2015

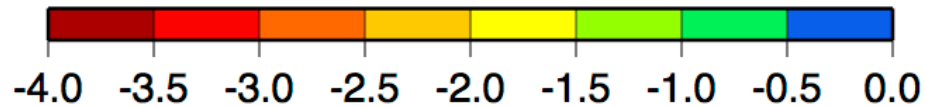
[in terms of PRISM 1981-2010 WY normals]



$\langle \delta \text{Precip} \rangle_{\text{state}} = -273 \text{ MAF}$

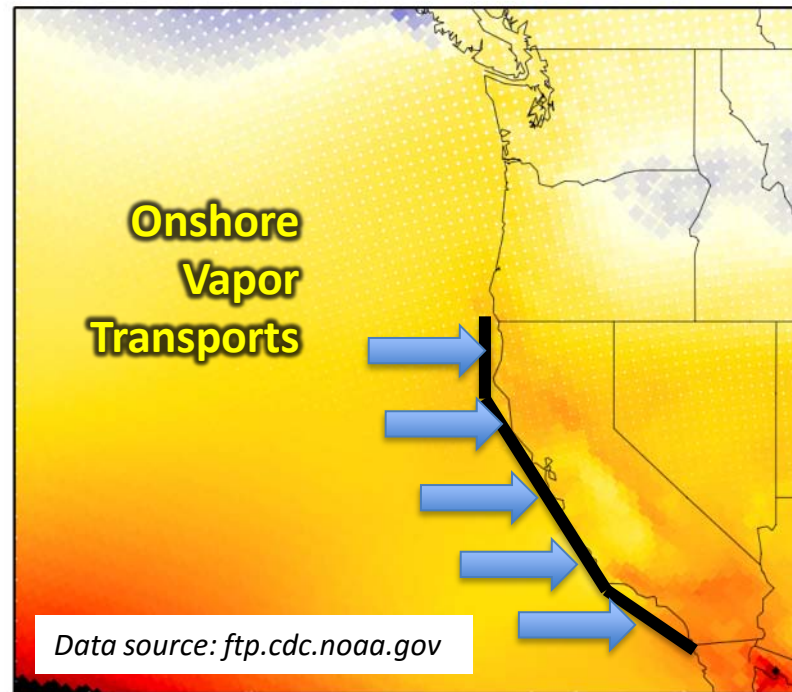
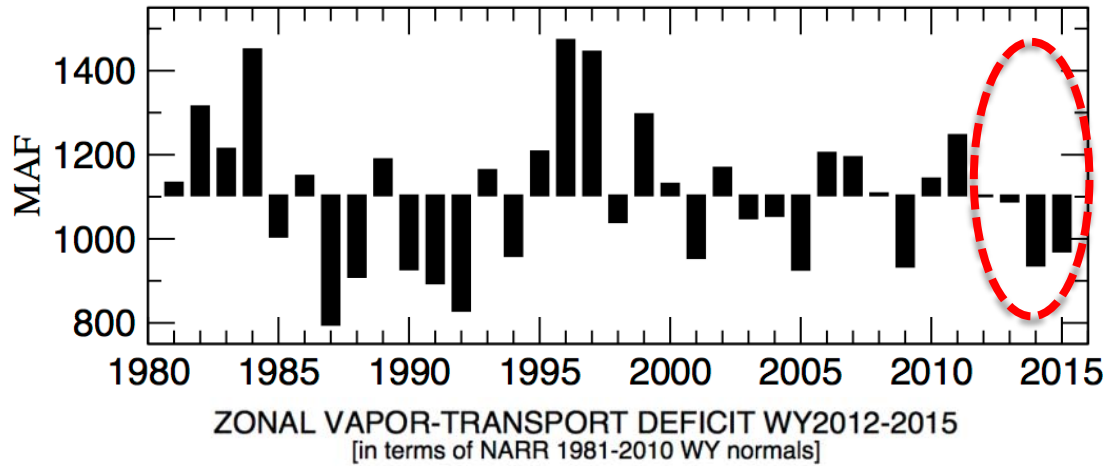
Data source: www.prism.oregonstate.edu

Missing normal-years of precipitation



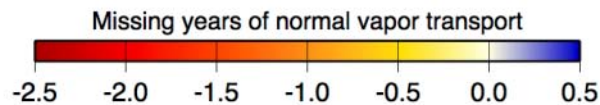
Water-Year Net Onshore IVT, Delta Catchment

[North American Regional Reanalysis, NCEP]



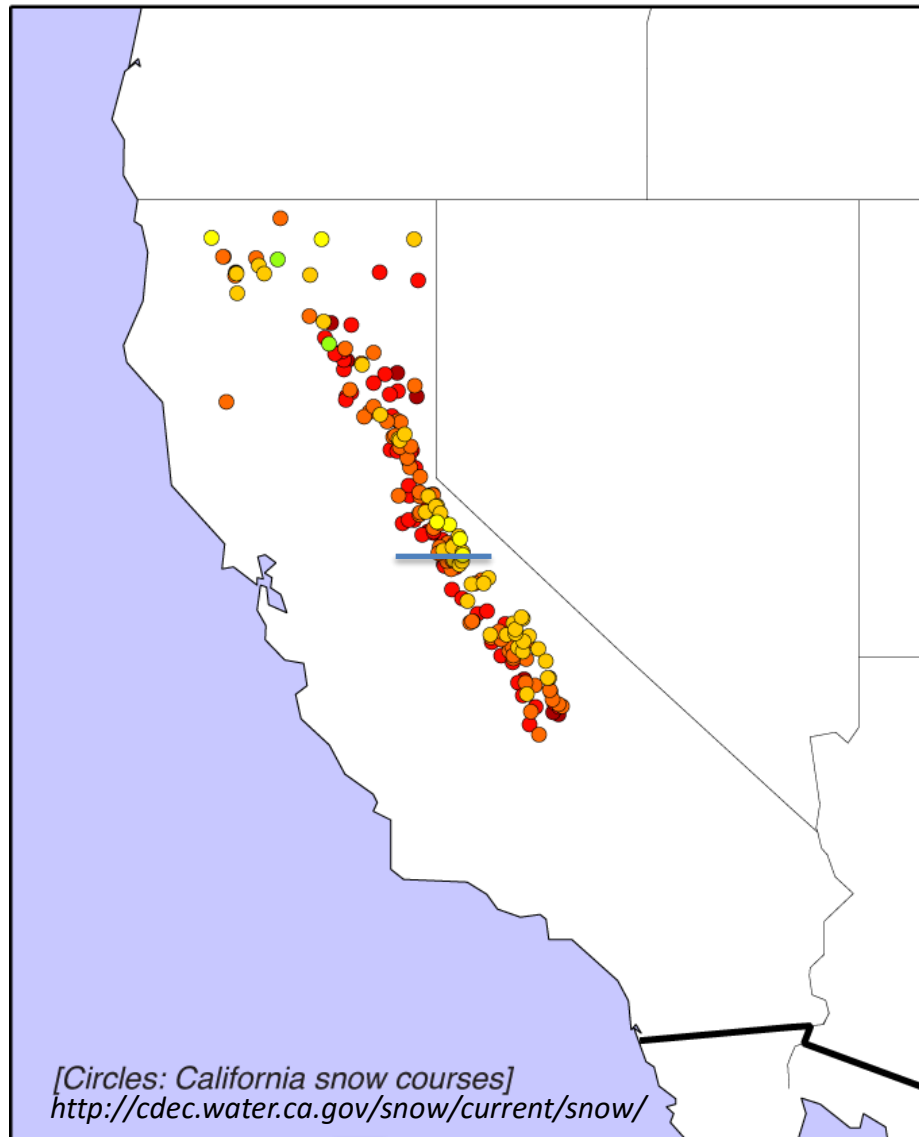
$$\langle dVapor \rangle_{\text{Delta}} = -1.18 \text{ yr} \\ = -1310 \text{ MAF}$$

$$\langle \delta \text{Precip} \rangle_{\text{Delta}} = -1.27 \text{ yr} \\ = -313 \text{ MAF}$$

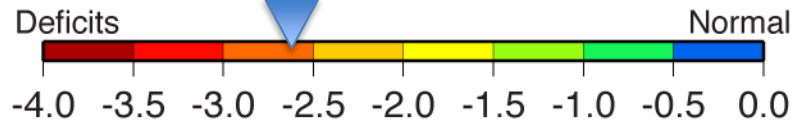


NET APR1 SWE DEFICITS WY2012-2015 [in terms of 1951-2000 WY normals]

Using
California DWR
Snow Courses

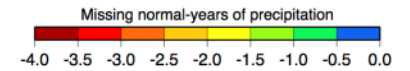
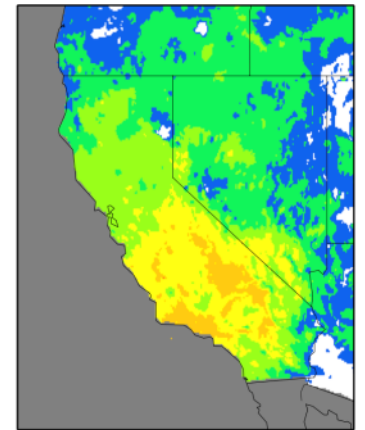


[Circles: California snow courses]
<http://cdec.water.ca.gov/snow/current/snow/>



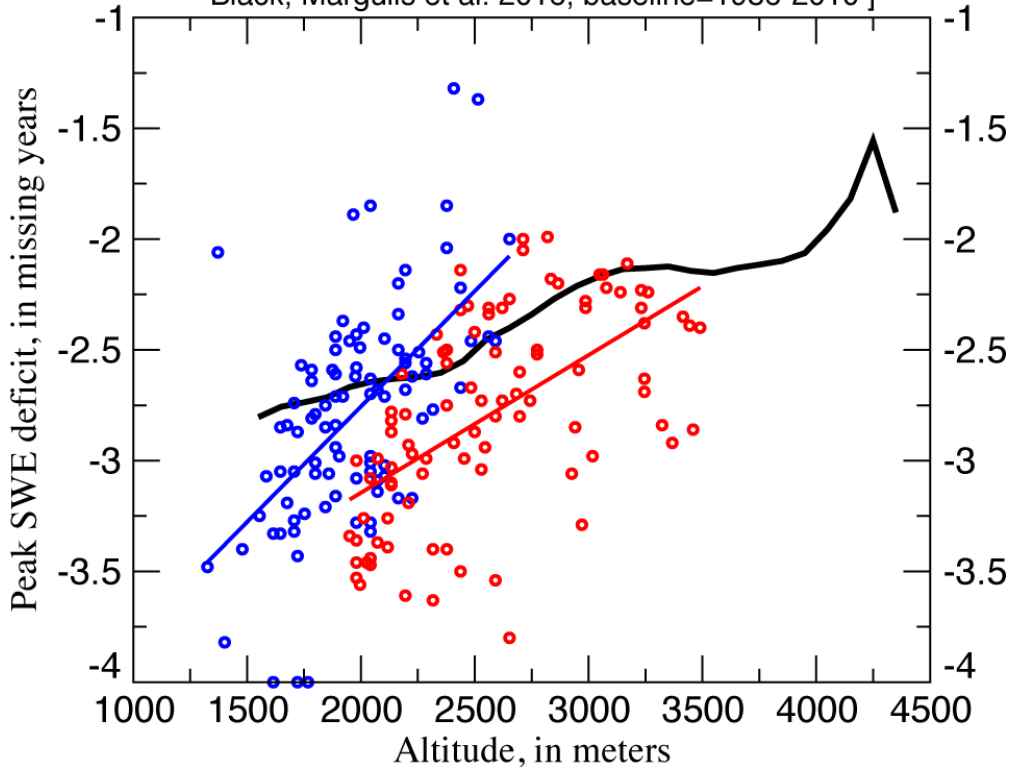
Missing normal-years of flow

NET PRECIPITATION DEFICITS WY2012-2015 [in terms of PRISM 1981-2010 WY normals]



Snowpack Deficits, 2012-2015

[Red & blue, snowcourses, baseline = 1951-2000;
Black, Margulis et al. 2016, baseline=1986-2010]



- Margulis Sierra-wide Peak-SWE deficits
- DWR Apr 1 SWE deficits, Mokulmne R & north
- DWR Apr 1 SWE deficits, Stanislaus R & south

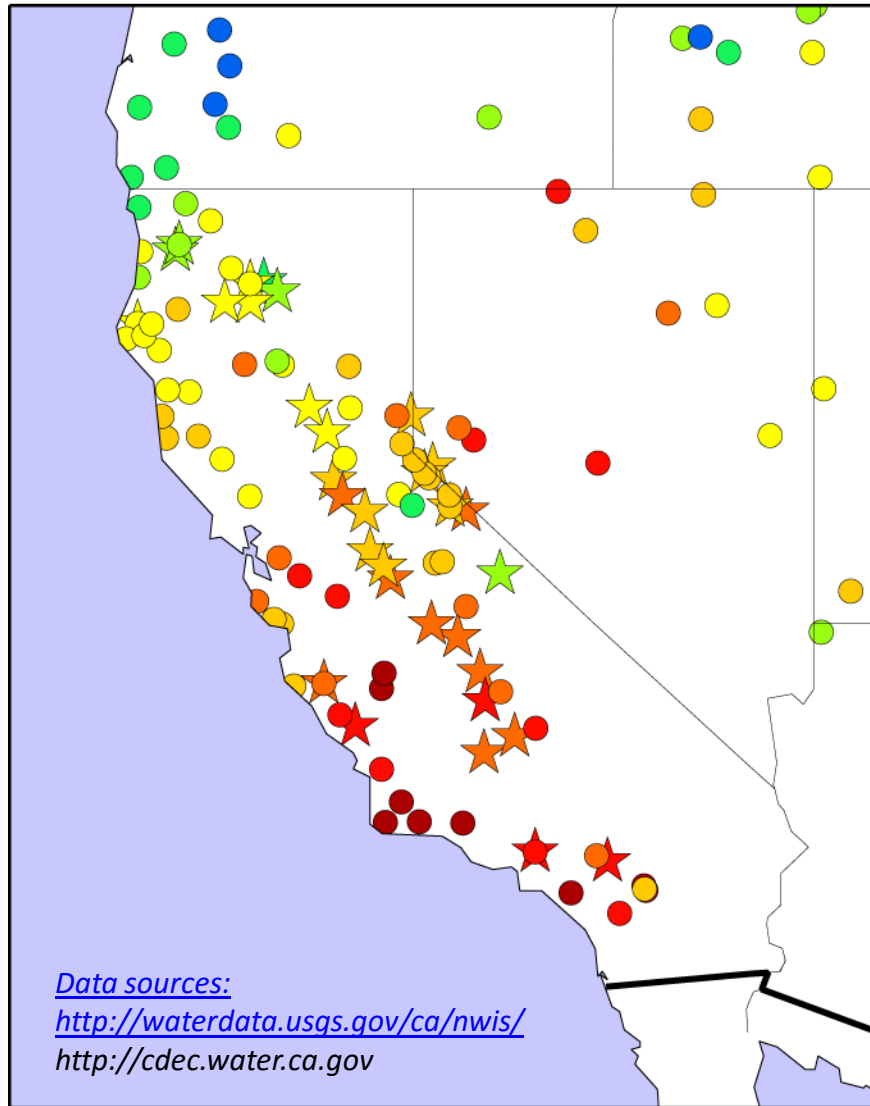
Margulis: $\langle dSWE_{peak} \rangle = -2.6 \text{ yr}$
Snow courses: $\langle dSWE_{Apr1} \rangle = -2.8 \text{ yr}$

Margulis: $\langle dSWE_{peak} \rangle = -43 \text{ MAF}$
Snow courses: $\langle dSWE_{Apr1} \rangle = -47 \text{ MAF}$

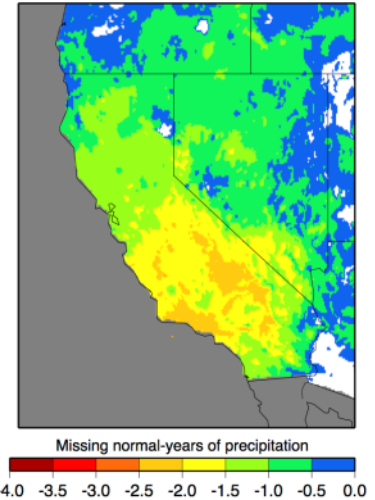
$\langle dPrecip \rangle_{state} = -273 \text{ MAF}$



NET STREAMFLOW DEFICITS WY2012-2015
[in terms of 1961-2010 WY normals]

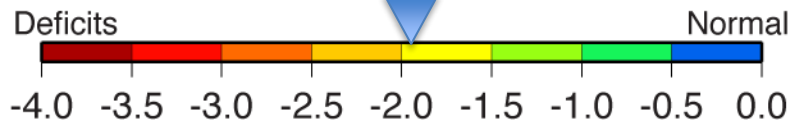


NET PRECIPITATION DEFICITS WY2012-2015
[in terms of PRISM 1961-2010 WY normals]



$\langle dPrecip \rangle_{state} = -273 \text{ MAF}$

$\langle dSFlow \rangle_{state} = -134 \text{ MAF}$

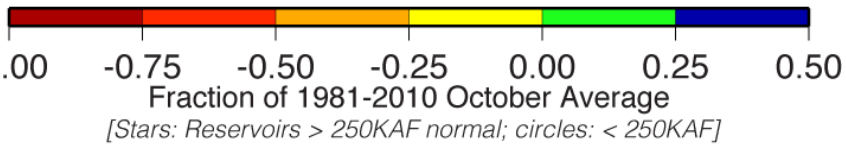
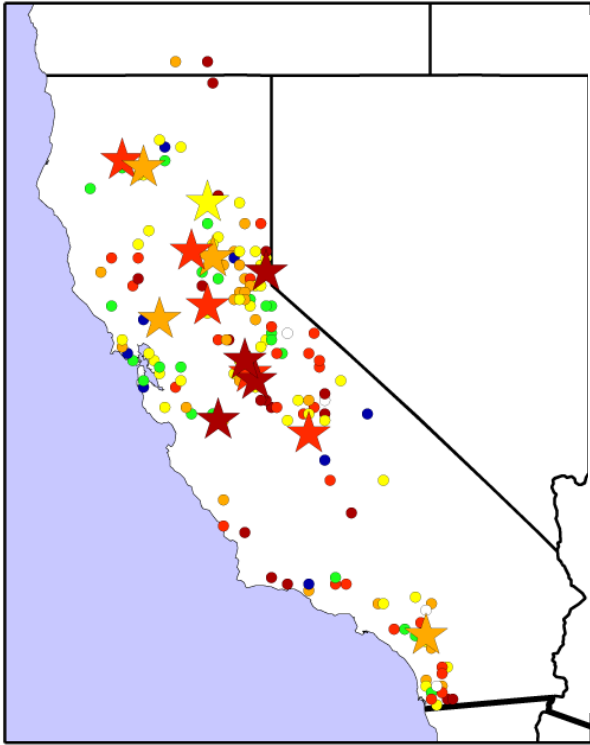


Missing normal-years of flow

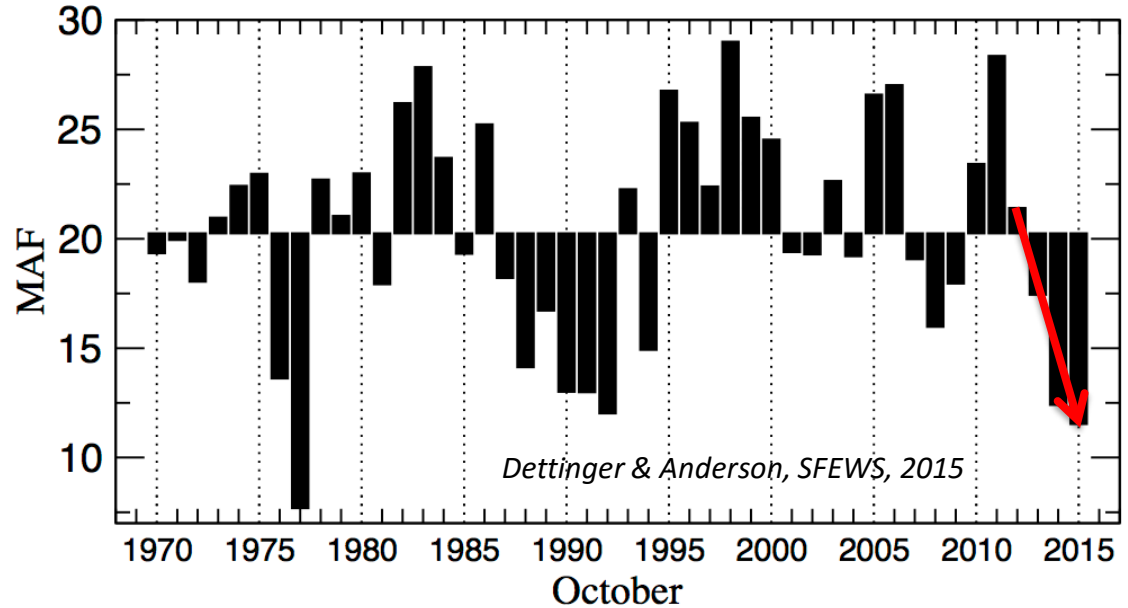
[Circles: HCDN gages; stars: reconstructed flows]

End of water year Reservoir Storage

October 2015 Reservoir Storage Anomaly
[as a fraction of 1981-2010 October normals]

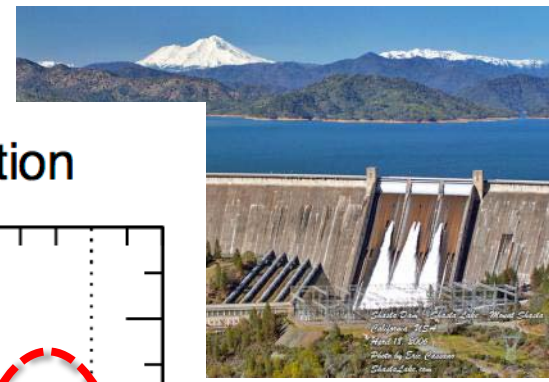


WY-End Reservoir Storage, California

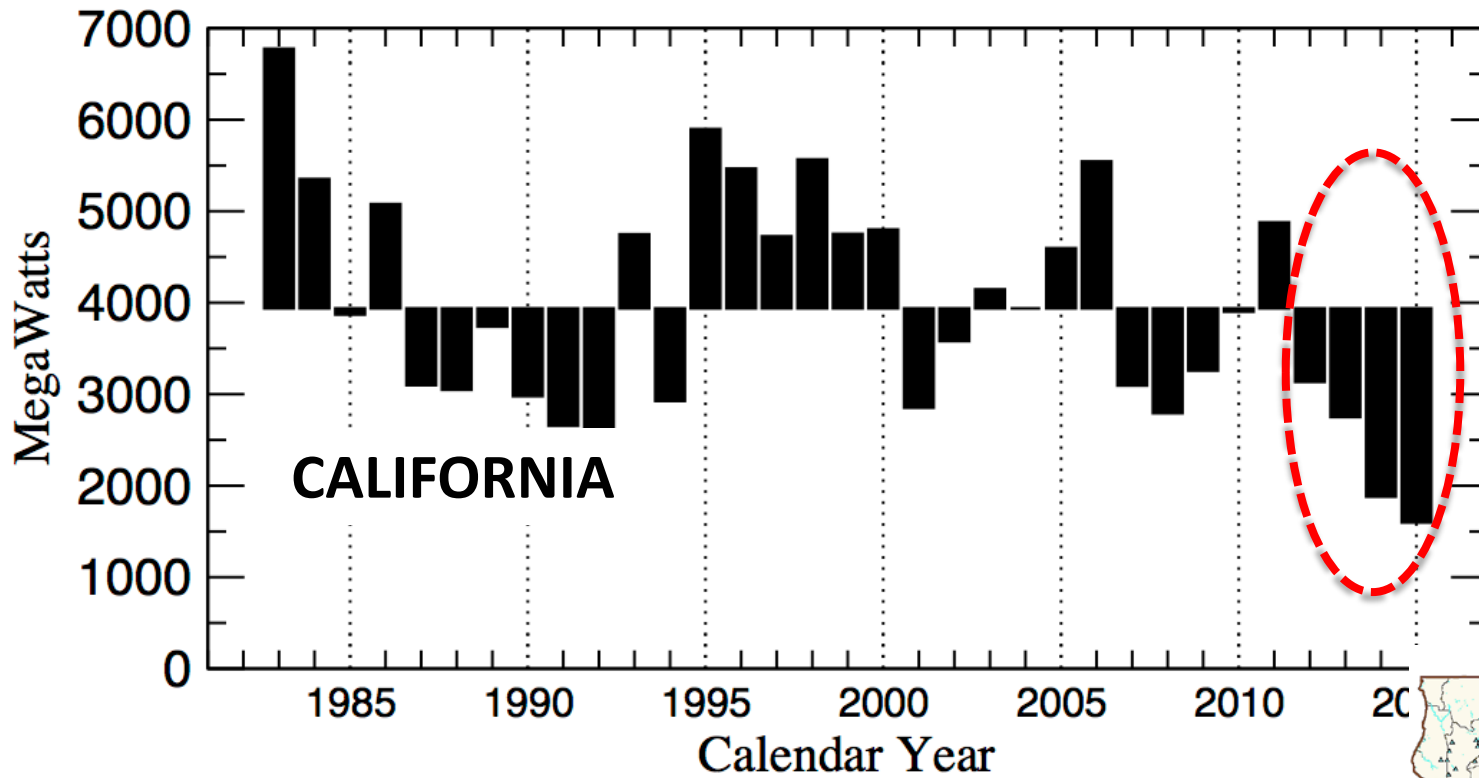


$$\langle d\text{Precip} \rangle_{\text{state}} = -273 \text{ MAF}$$

$$\langle d\text{Resvr} \rangle_{\text{state}} = -21 \text{ MAF}$$



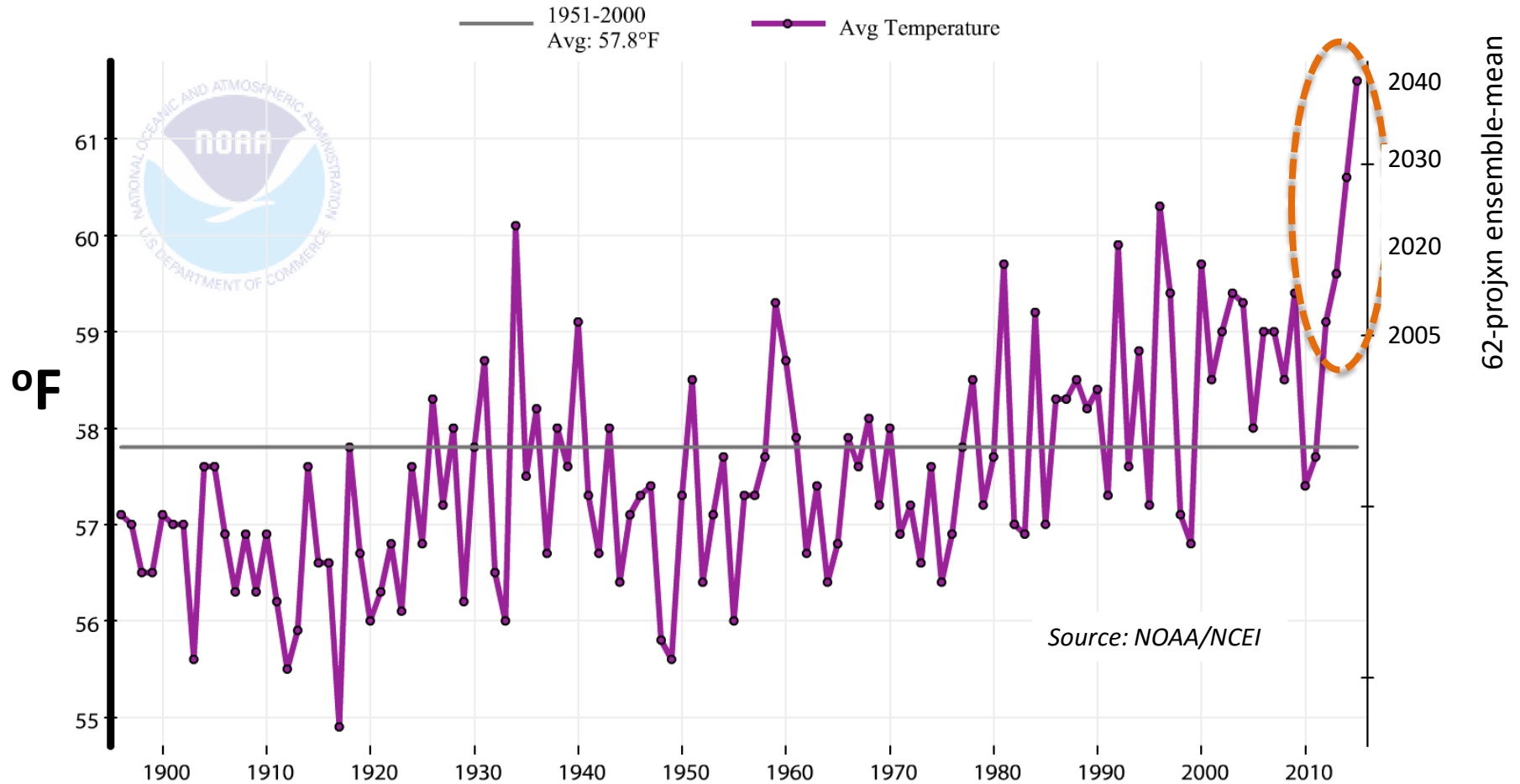
Average Rate of InState Hydropower Generation



$$\langle d\text{Hydropower} \rangle_{\text{state}} = -1.50 \text{ yrs}$$



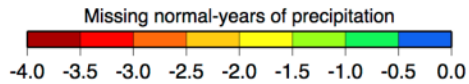
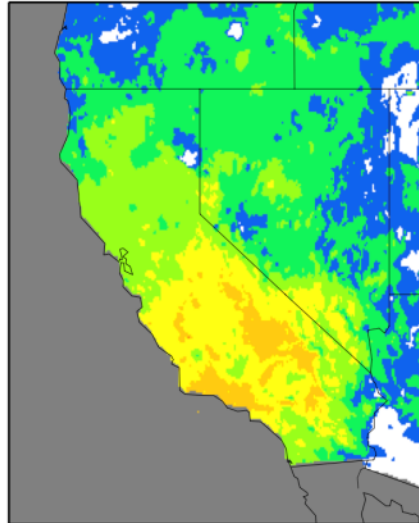
Water-year Temperatures Statewide-avg California



NET ET_o SURPLUSES WY2012-2015 [in terms of 1981-2010 WY normals]

NET PRECIPITATION DEFICITS WY2012-2015
[in terms of PRISM 1981-2010 WY normals]

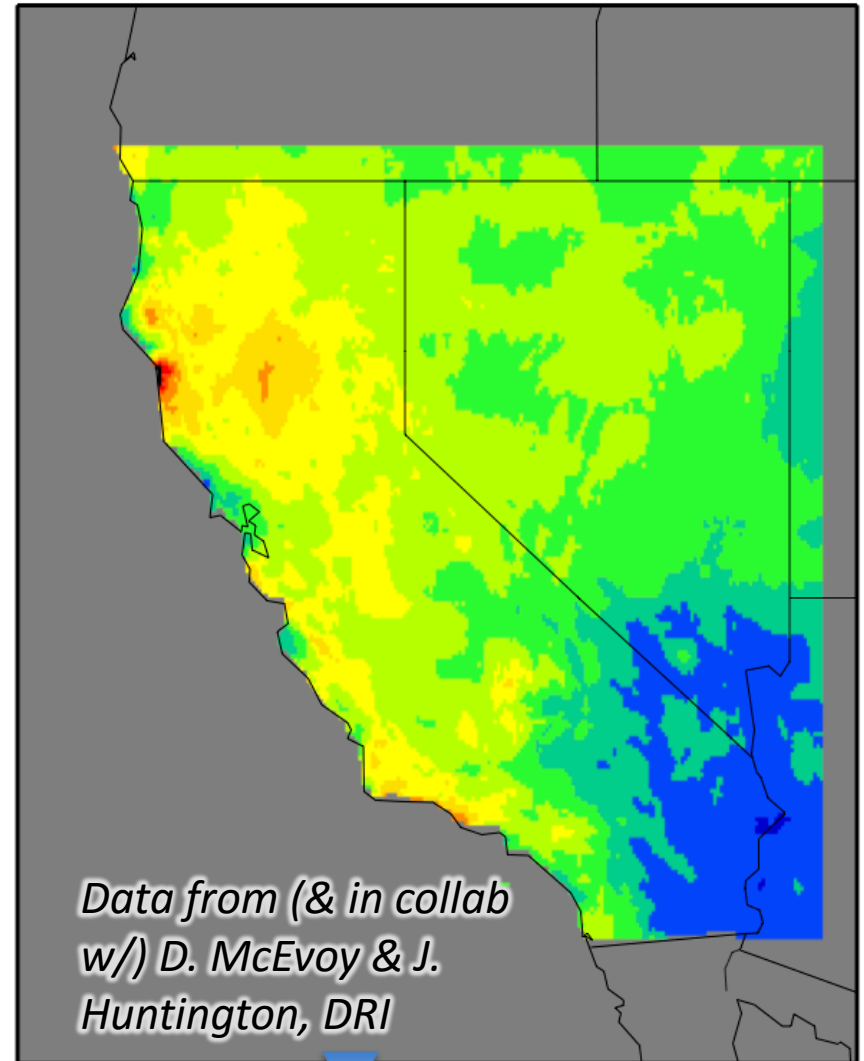
$$ET_o = \frac{0.4}{\dots}$$



$$\langle dPrecip \rangle_{state} = -273 \text{ MAF}$$

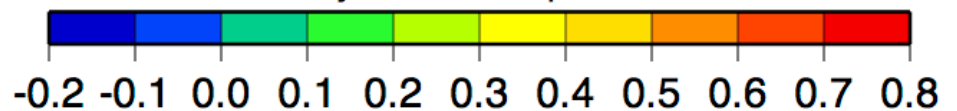
$$\langle dET_o \rangle_{state} = +106 \text{ MAF}$$

$$\frac{e_a}{\dots}$$



*Data from (& in collab
w/) D. McEvoy & J.
Huntington, DRI*

Extra normal-years of evaporative demands



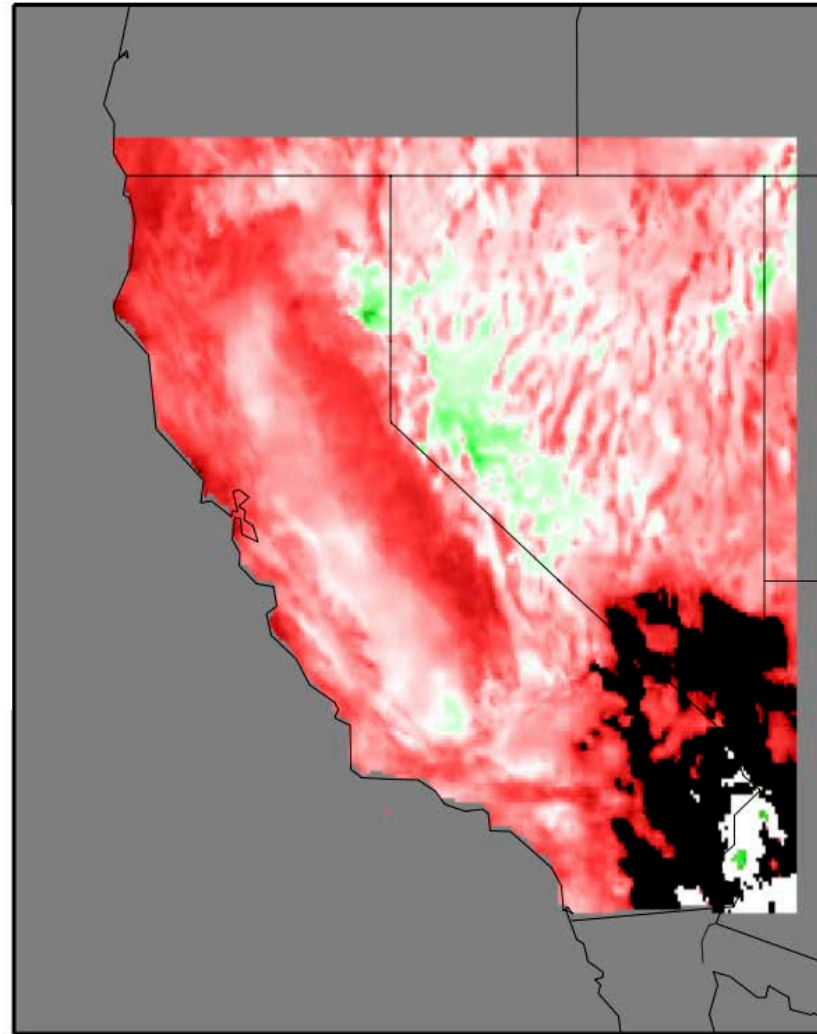
NET PRECIPITATION CONTRIBUTION TO DROUGHT WY2012-2015

$$\Delta P = \sum P - 4 * \langle P \rangle$$

$$\Delta ET_o = \sum ET - 4 * \langle ET \rangle$$

Mapped here:

$$- \Delta P / (\Delta ET_o - \Delta P)$$

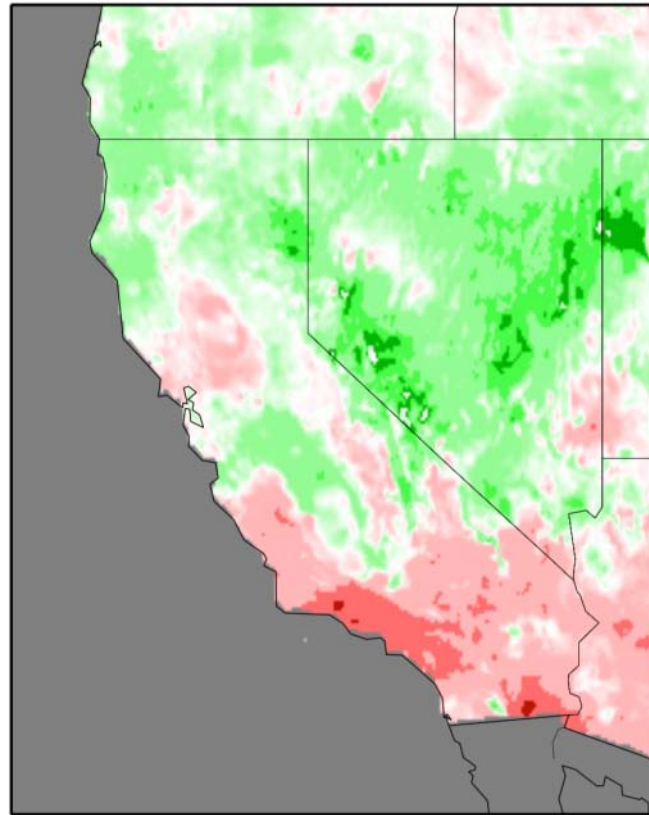


Precipitation as fraction of precipitation-plus-ETo contribs



Turning to WY 2016...

PRECIPITATION ANOMALIES OCT2015-JUNE2016
[in terms of PRISM 1981-2010 ONDJFMAMJ normals]



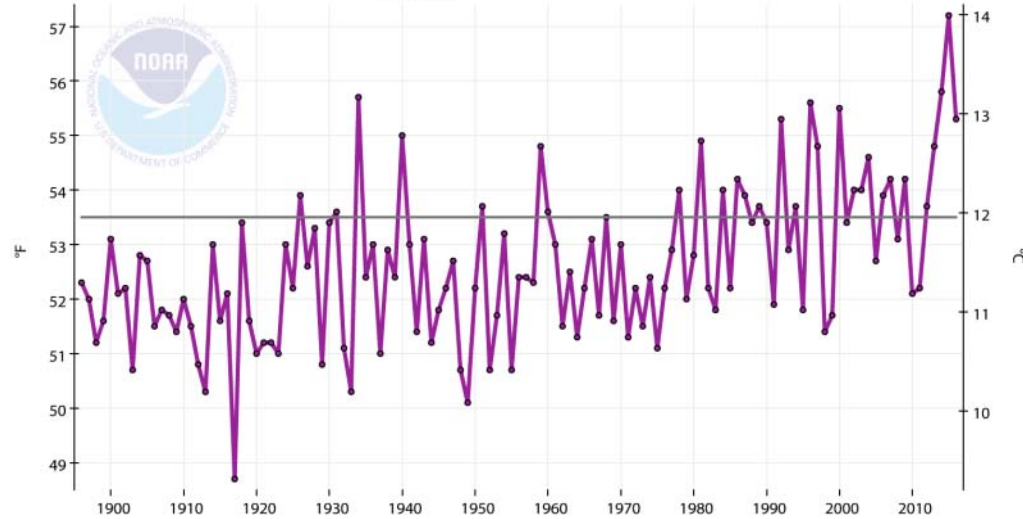
Deviation as fraction of a normal ONDJFMAMJ



STATE-AVG TEMPERATURES, OCT-JUNE

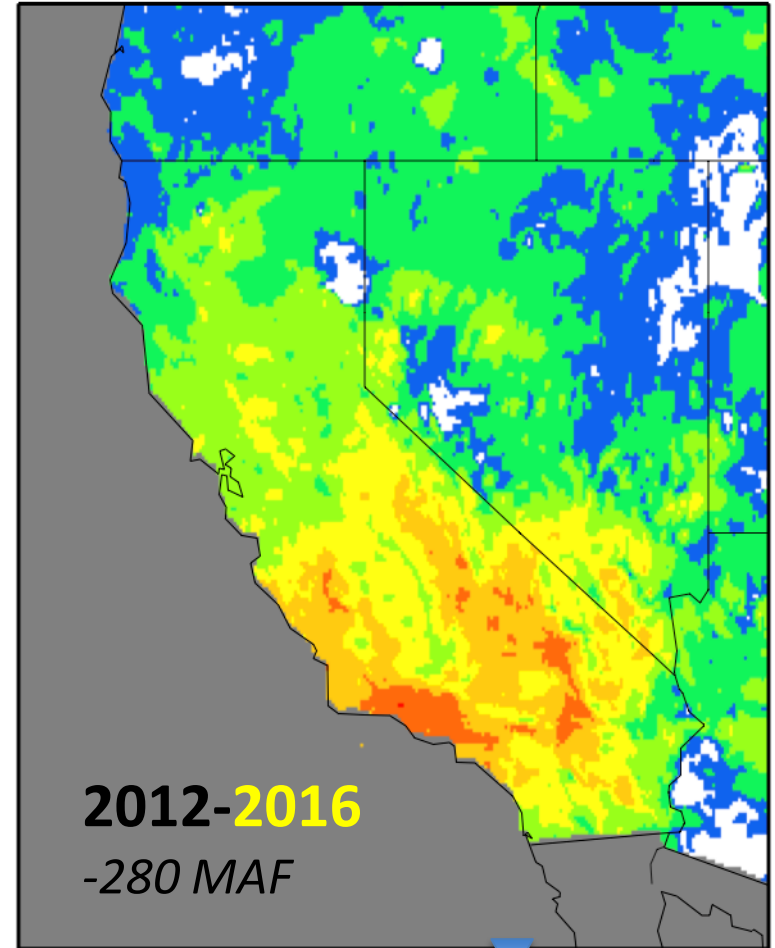
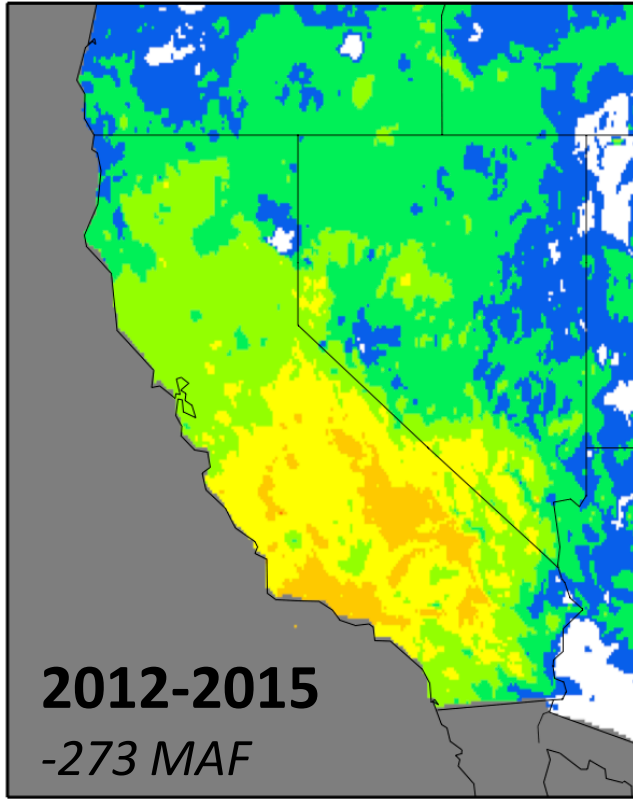
California, Average Temperature, October-June

— 1981-2010 Avg: 53.5°F —●— Avg Temperature

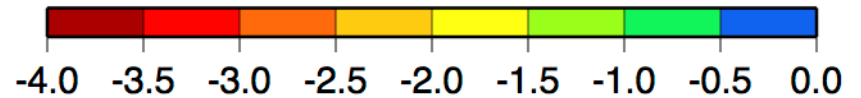


NET PRECIPITATION DEFICITS WY2012-2016 [in terms of PRISM 1981-2010 WY normals]

NET PRECIPITATION DEFICITS WY2012-2015 [in terms of PRISM 1981-2010 WY normals]

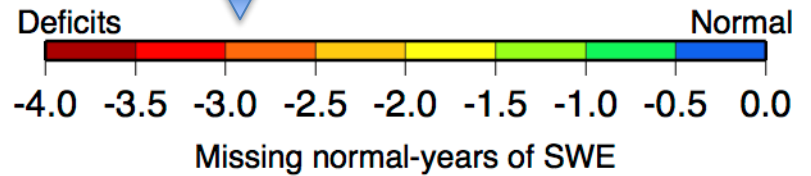
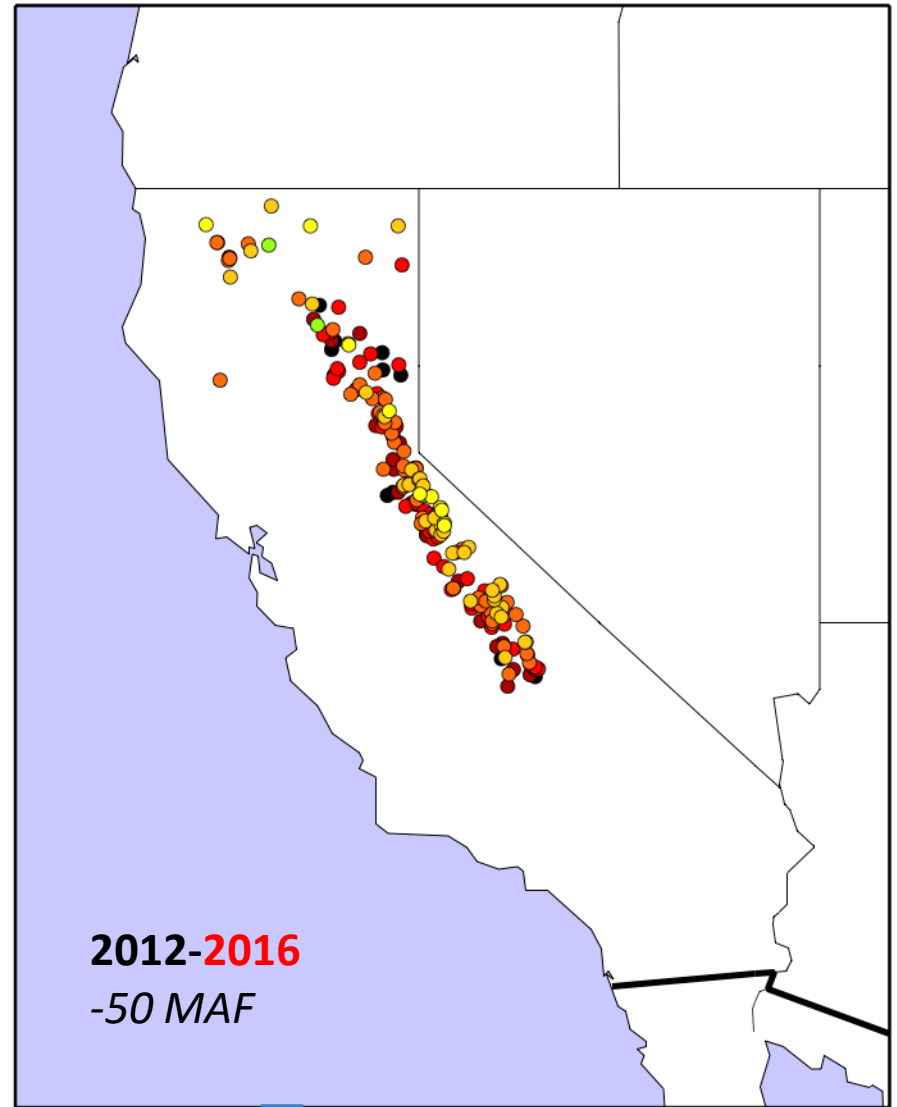
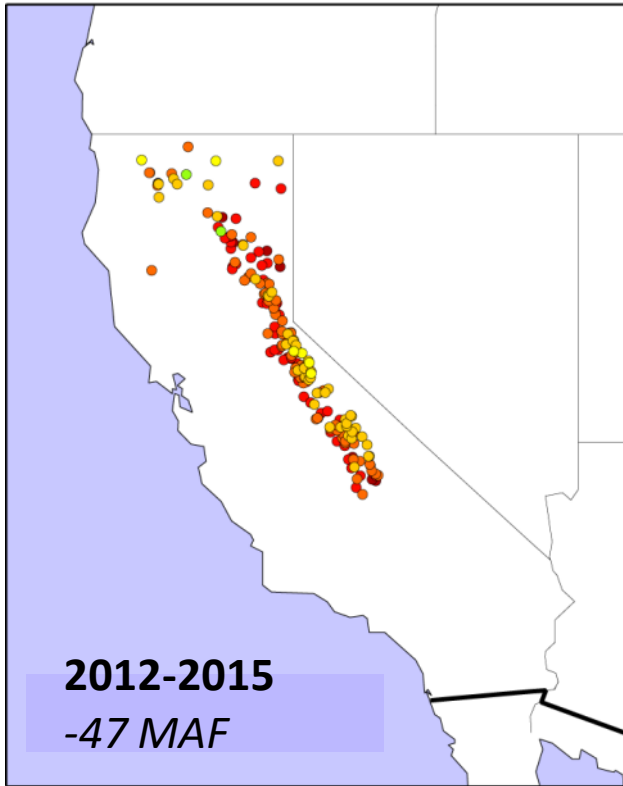


Missing normal-years of precipitation



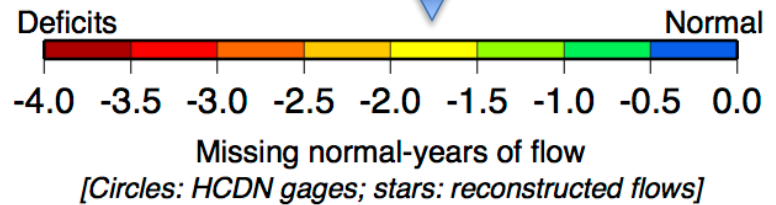
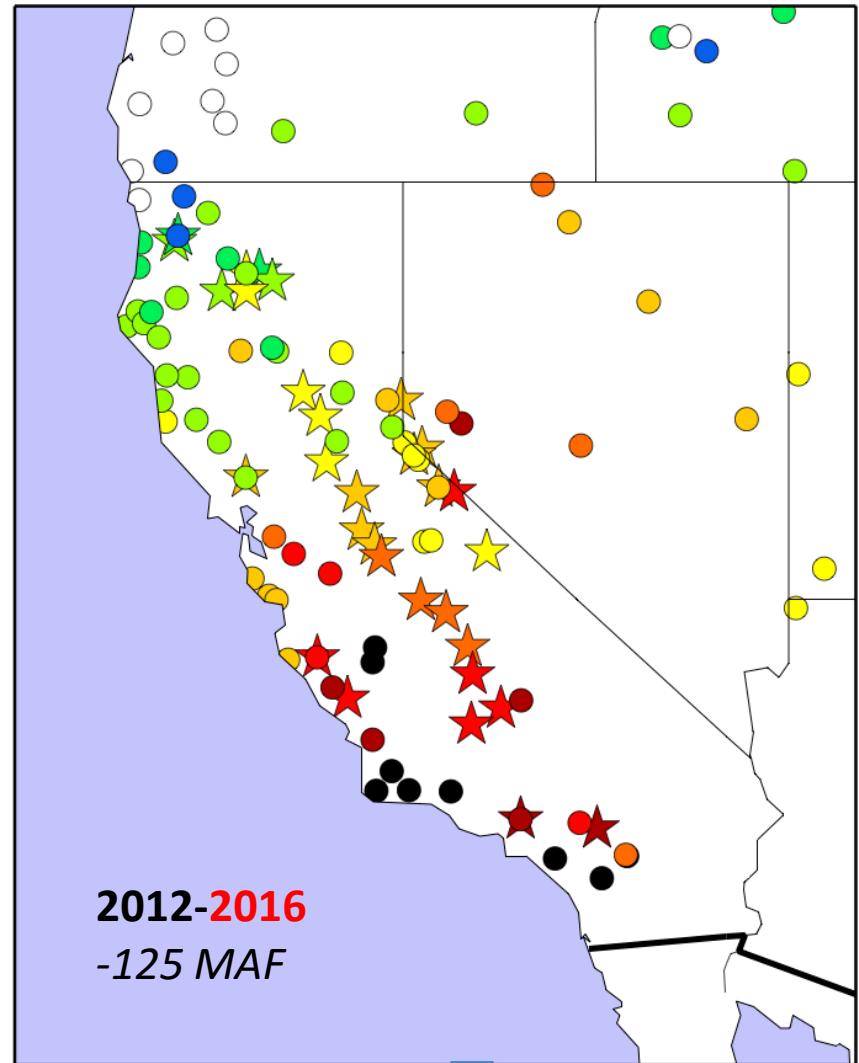
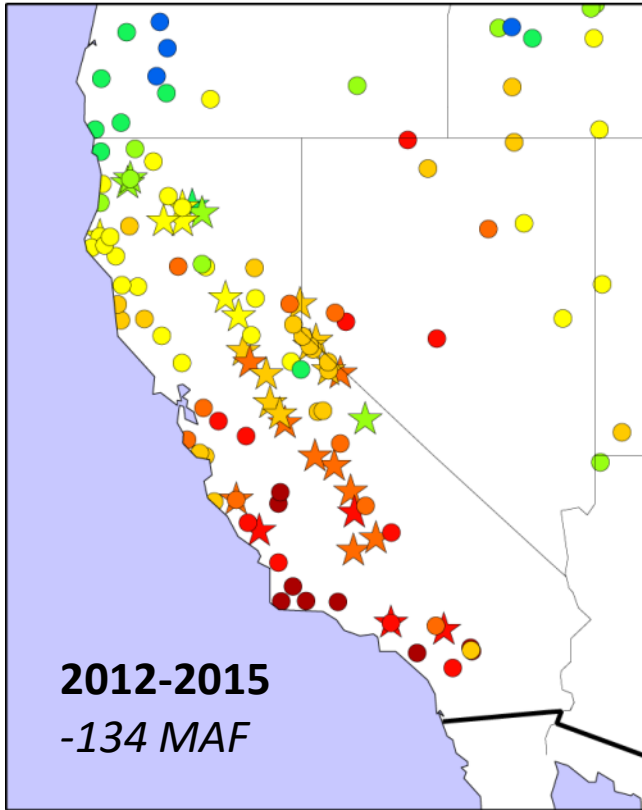
NET APR1 SWE DEFICITS WY2012-2016
[in terms of 1951-2000 WY normals]

NET APR1 SWE DEFICITS WY2012-2015
[in terms of 1951-2000 WY normals]

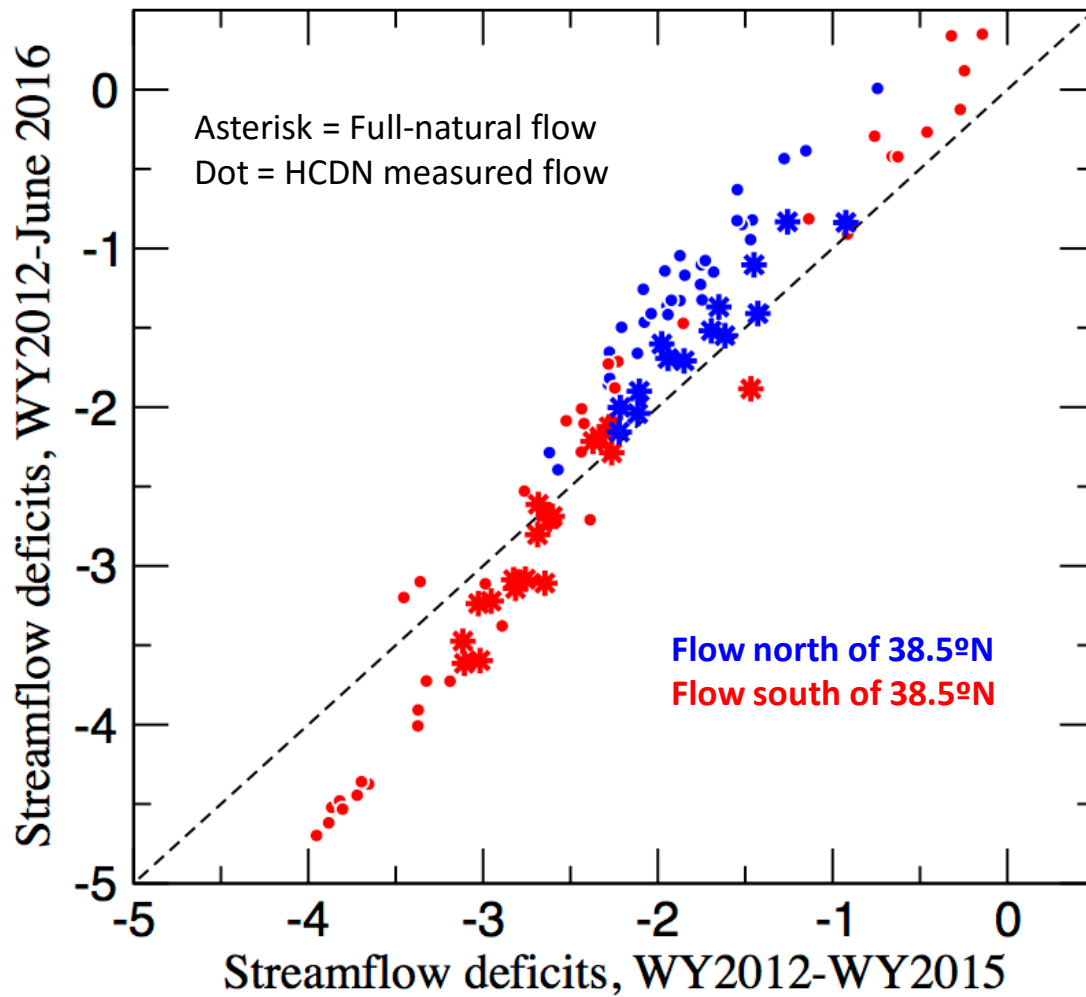


NET STREAMFLOW DEFICITS WY2012-June 2016
[in terms of 1961-2010 WY normals]

NET STREAMFLOW DEFICITS WY2012-2015
[in terms of 1961-2010 WY normals]



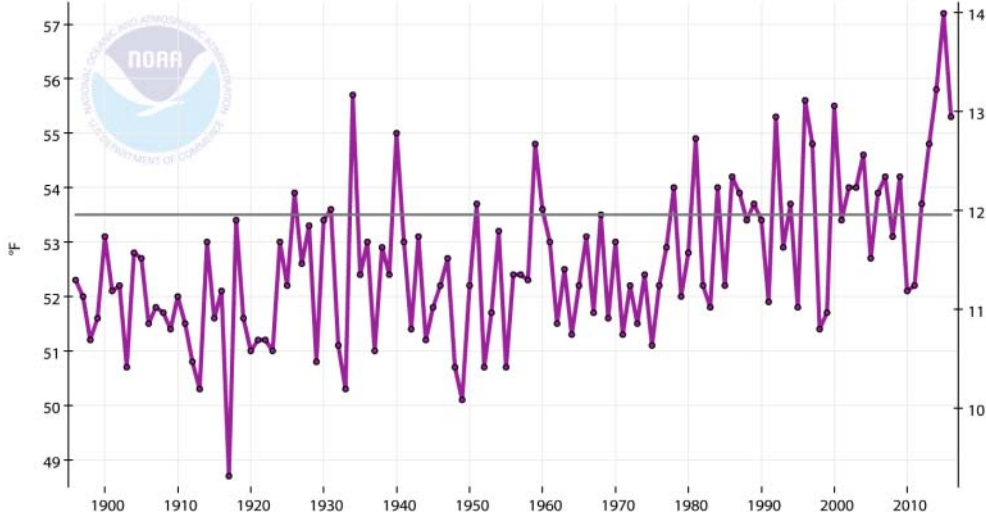
Streamflow Deficits, in Years of Normal Flow



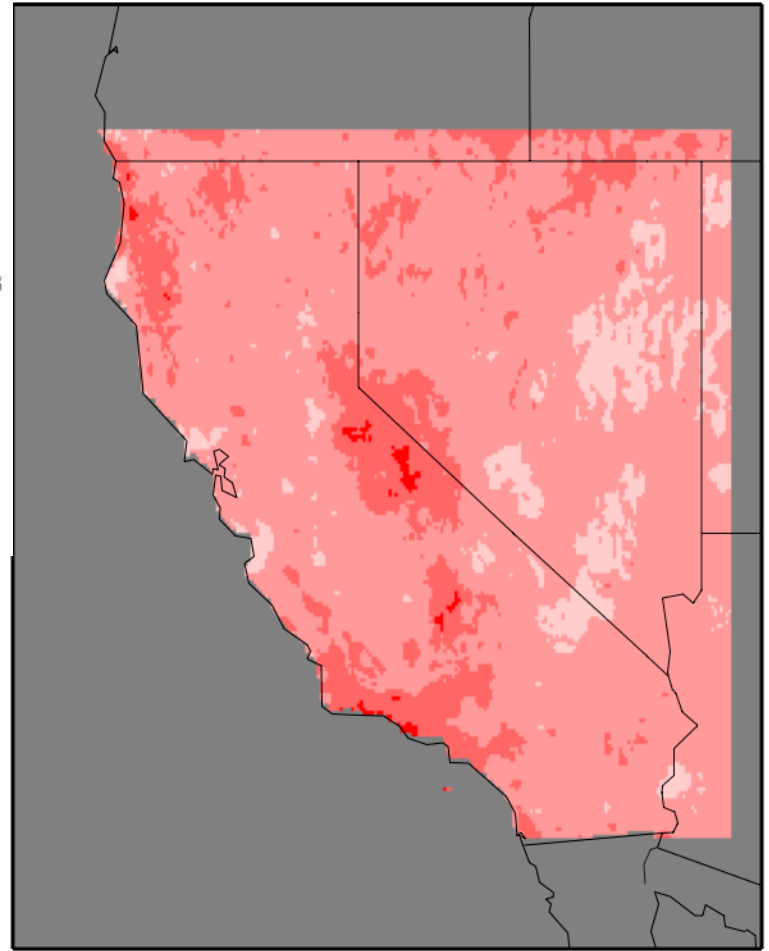
Remember re: WY 2016...

California, Average Temperature, October-June

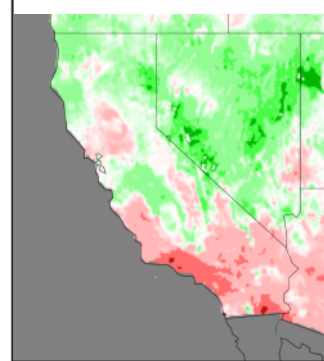
— 1981-2010 Avg: 53.5°F —●— Avg Temperature



ANOMALOUS ETo, Oct2015-July2016 [in terms of 1981-2010 Oct-Jul normals]

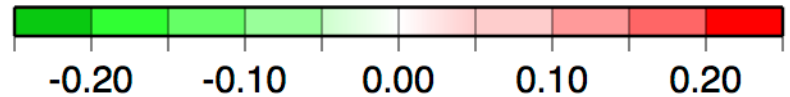


2016 precip (wyr thru June)



Deviation as fraction of a normal ONDJFMAMJ
-0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8

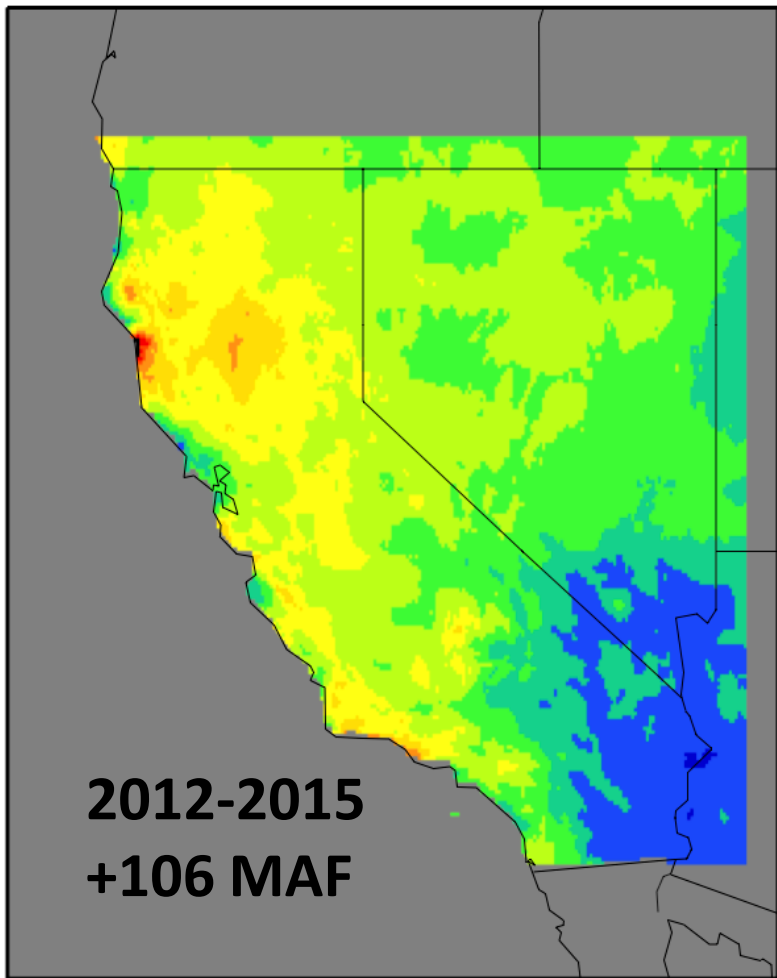
Anomalous ETo as fraction of Oct-Jul normal



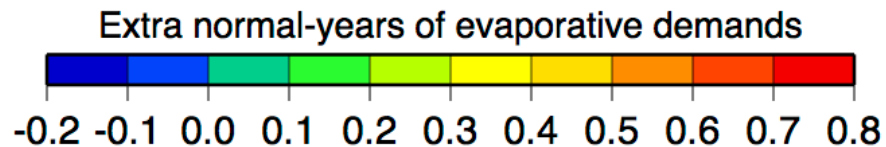
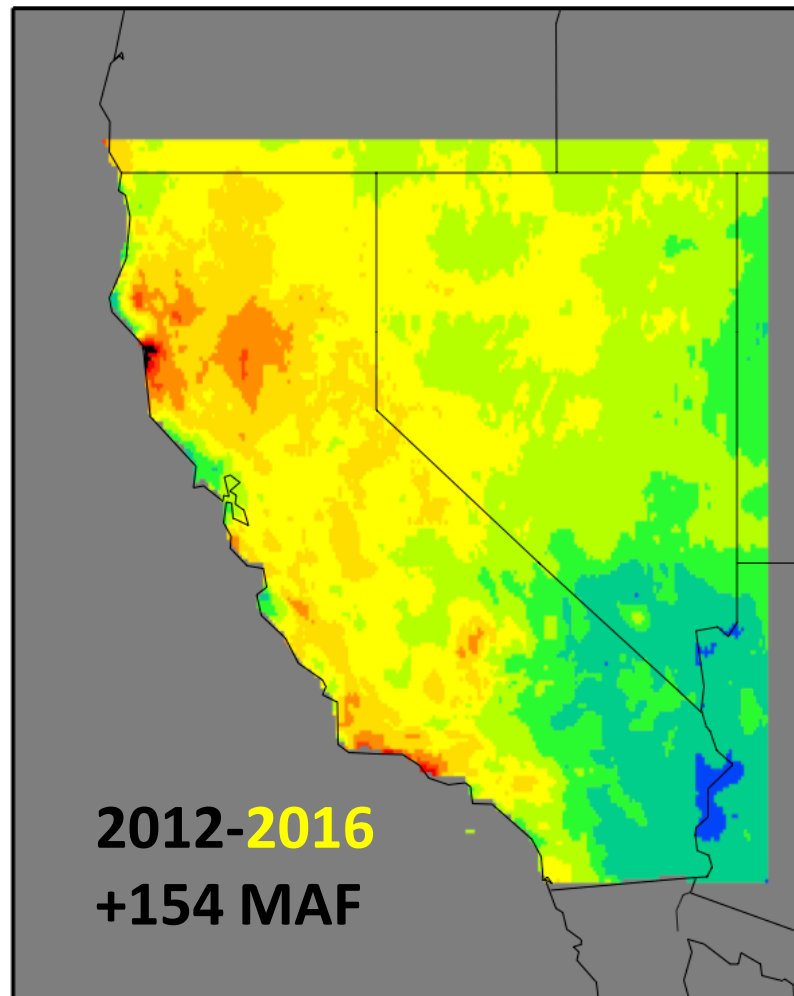
6



NET ETo SURPLUSES WY2012-2015 [in terms of 1981-2010 WY normals]



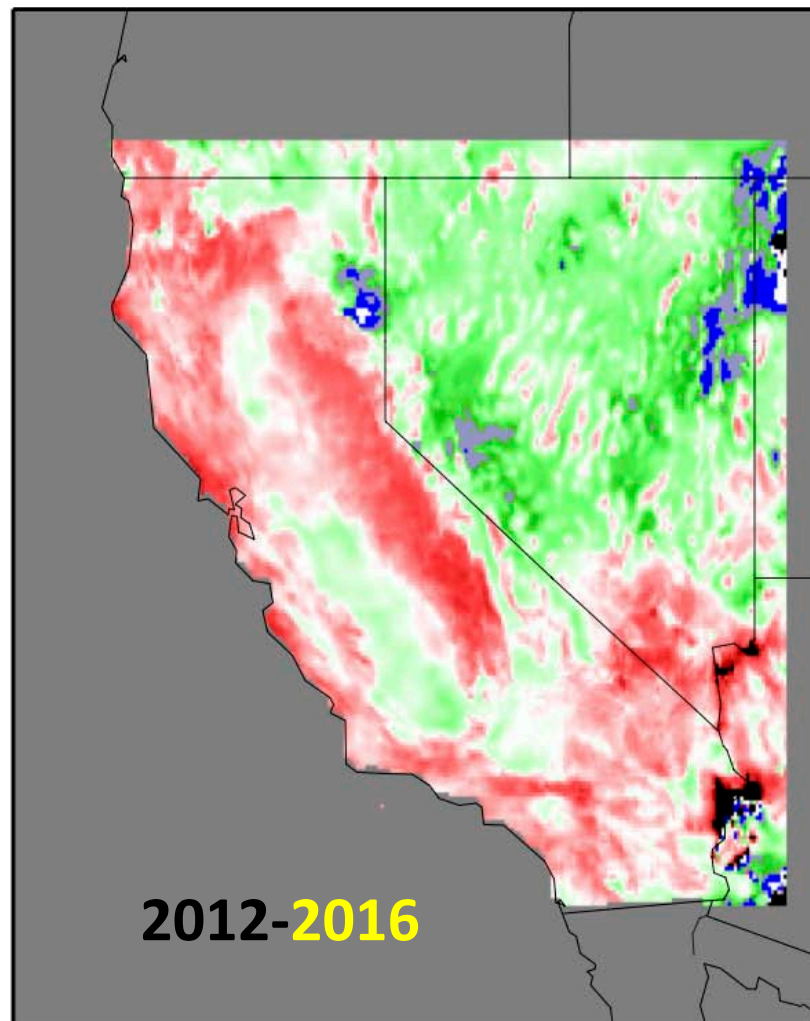
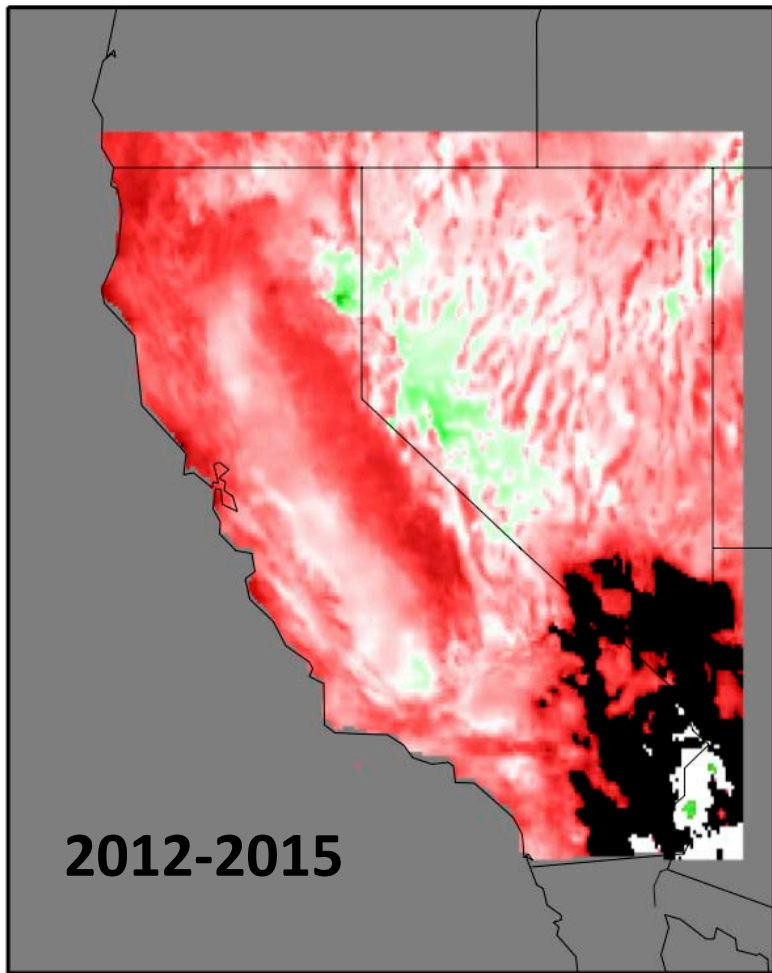
NET ETo SURPLUSES WY2012-July2016 [in terms of 1981-2010 WY normals]



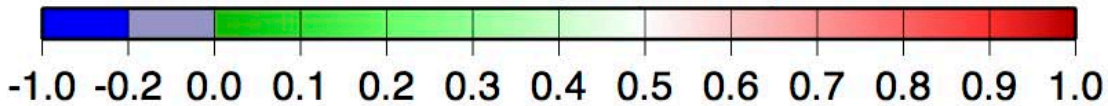
Data from (& in
collab w/) D. McEvoy
& J. Huntington, DRI

NET PRECIPITATION CONTRIBUTION TO DROUGHT WY2012-July2016

NET PRECIPITATION CONTRIBUTION TO DROUGHT WY2012-2015

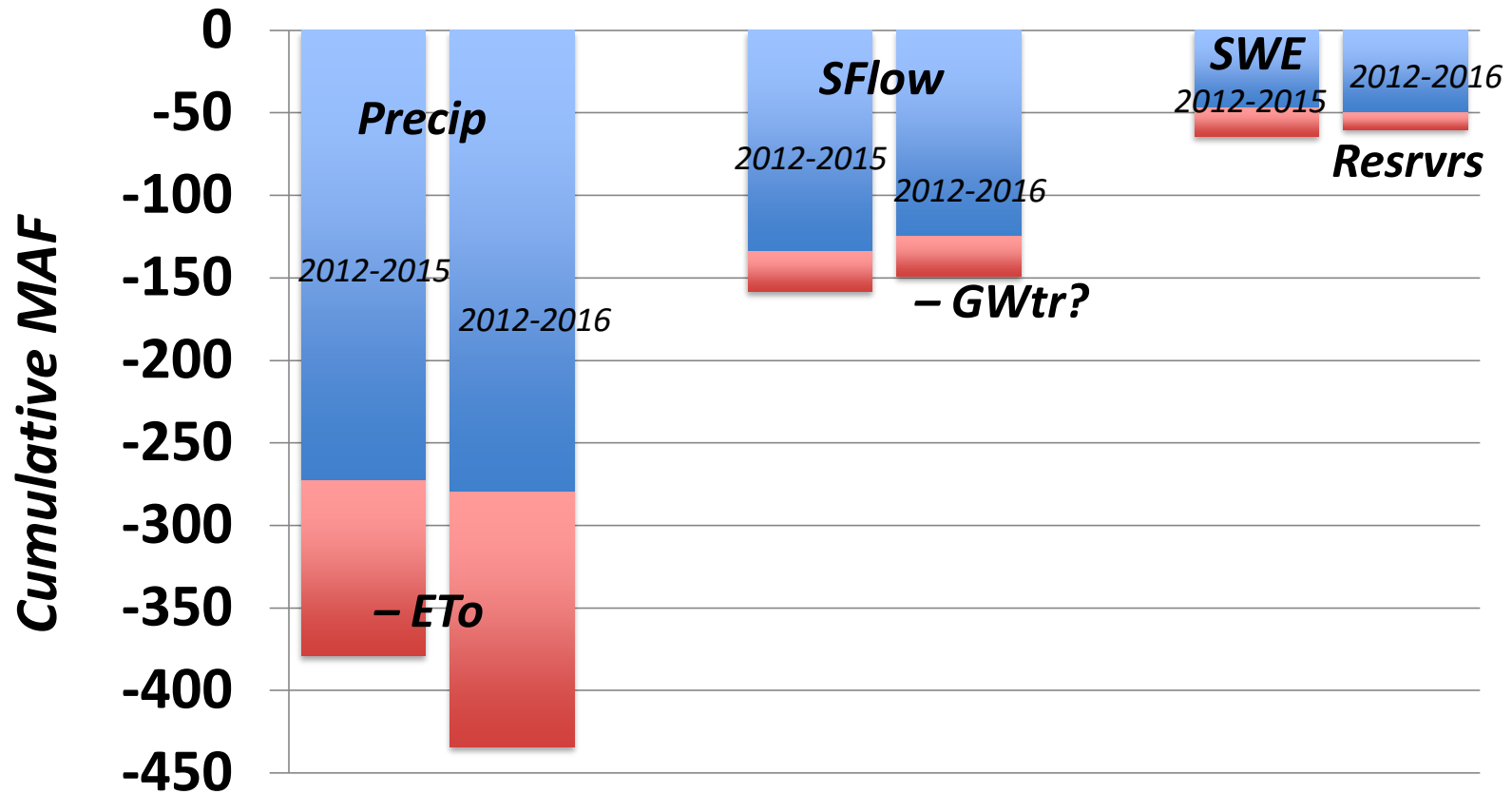


Precipitation as fraction of precipitation-plus-ETo contribs



Eto data from (& in collab w/) D. McEvoy & J. Huntington, DRI

Comparisons of Accumulated Deficits, State-Totals, WY2012-2015 vs WY2012-2016



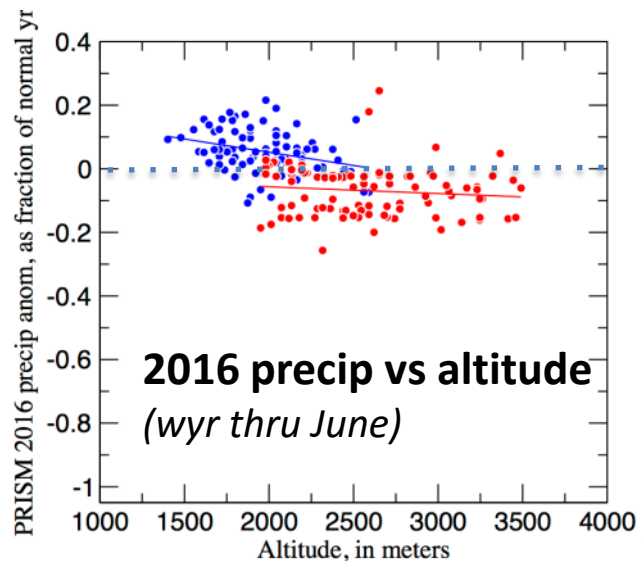
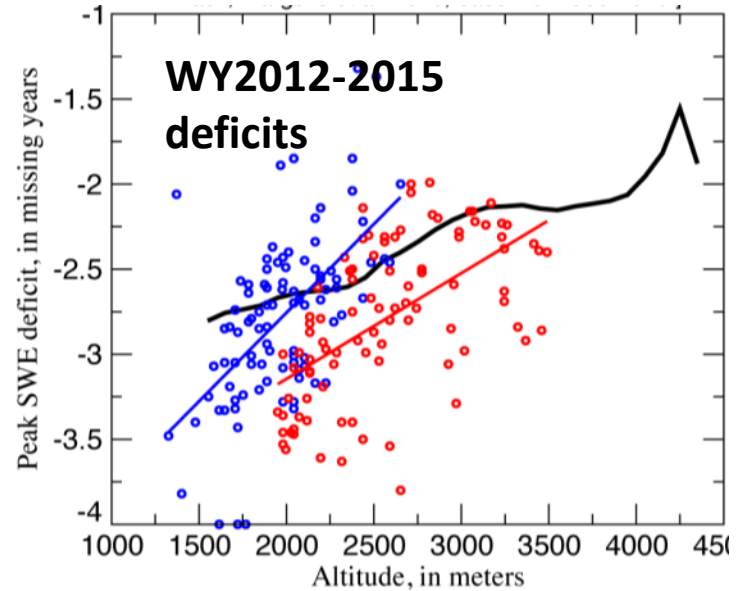
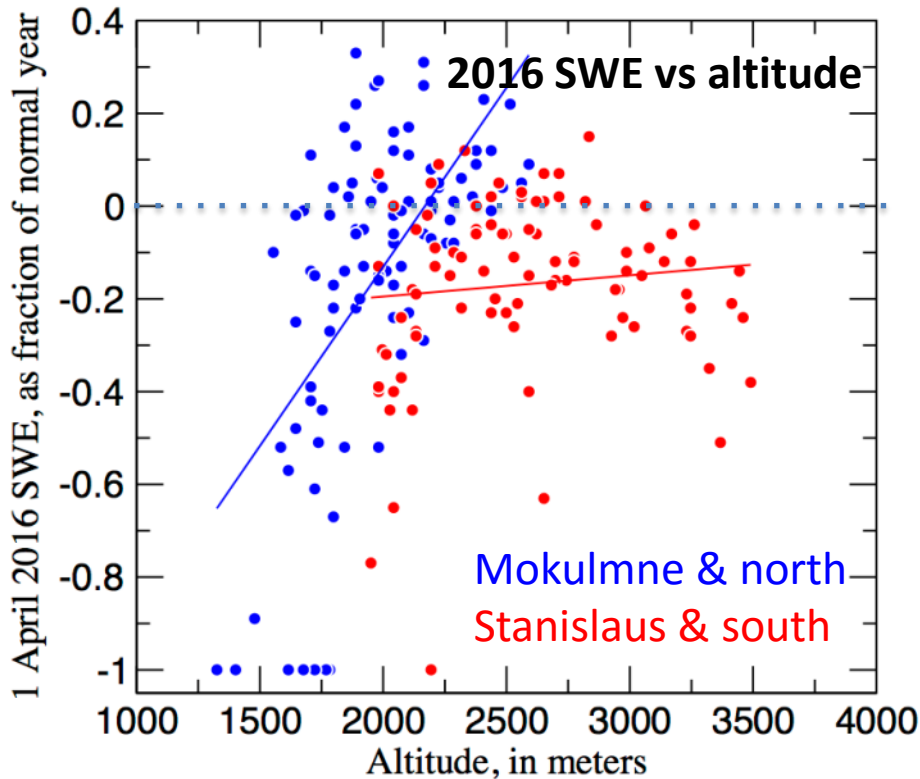
Caveat: Lots of apples & oranges here, but illustrative for comparing relative magnitudes of key deficits/surpluses pairs.

CONCLUSIONS

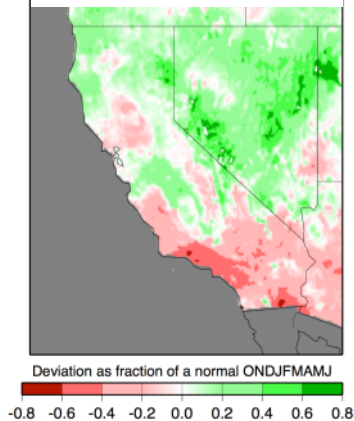
- In this drought, precipitation & temperature (ET) aspects vie with each other to determine drought severity
- The drought deficits amplify as they pass into & thru the water system
- As climate change takes hold, temperature effects will become even more important and will add to more frequent, more ferocious droughts

A painting of a herd of horses in a field under a massive, towering cumulonimbus cloud against a blue sky. The cloud is the central focus, with a dark, stormy base. The horses are in the foreground, grazing or standing in a yellowish field. The sky is a deep blue, and the overall scene is dramatic and atmospheric.

Questions?



2016 precip
(wyr thru June)

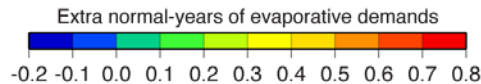
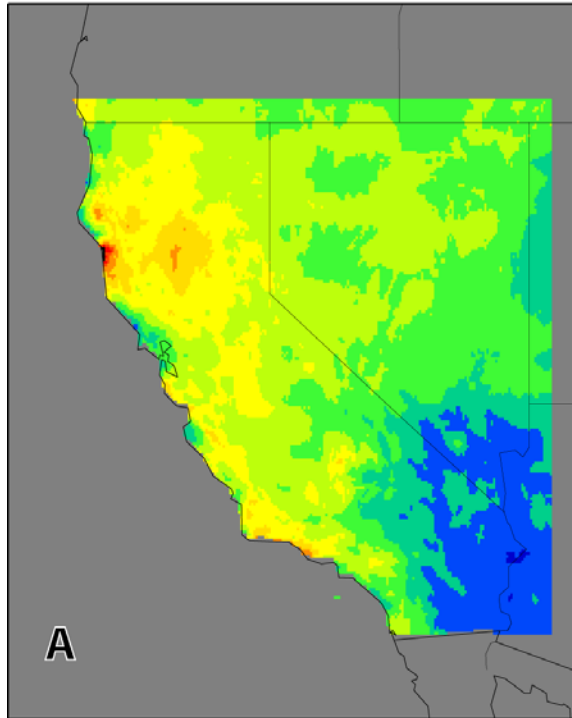


In 2016, northern Sierra show strong elevation (temperature) effect

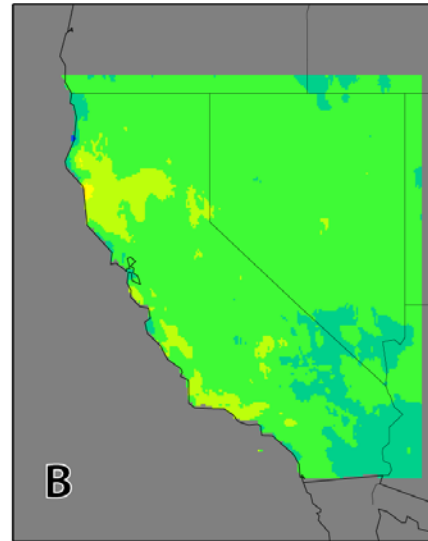
In 2016, southern Sierra show no elevation (temperature) effect, & reflect instead precipitation deficit

Breaking the total dETo surplus into cool- & warm-seasons

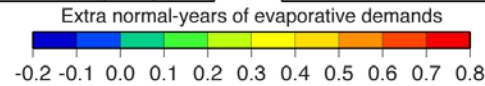
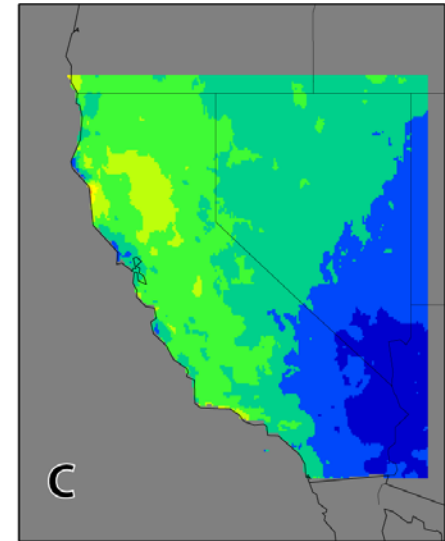
NET ET_o SURPLUSES WY2012-2015
[in terms of 1981-2010 WY normals]



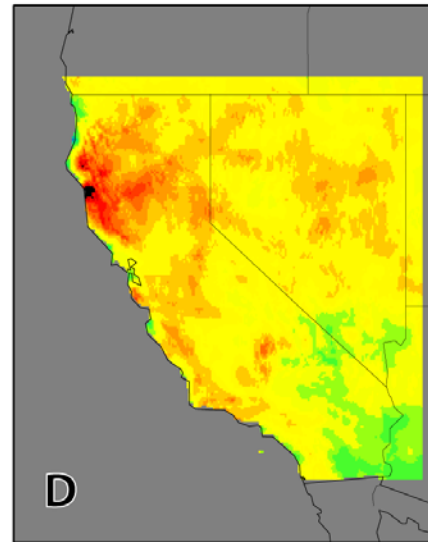
NET ET_o SURPLUSES Nov-Apr 2012-2015
[in terms of 1981-2010 WY normals]



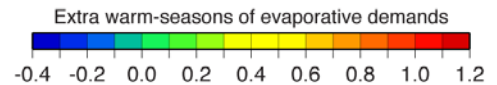
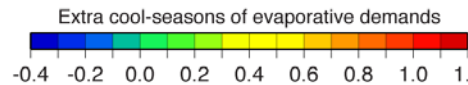
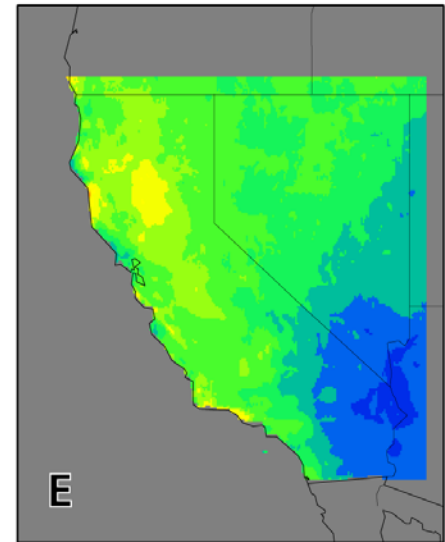
NET ET_o SURPLUSES May-Oct 2012-2015
[in terms of 1981-2010 WY normals]



NET ET_o SURPLUSES Nov-Apr 2012-2015
[in terms of 1981-2010 NDJFMA normals]

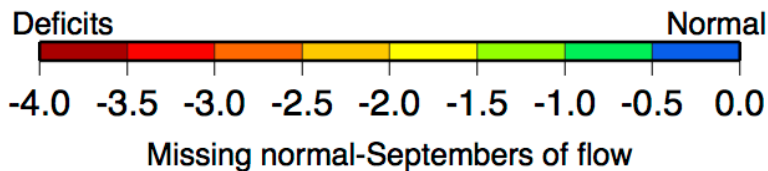
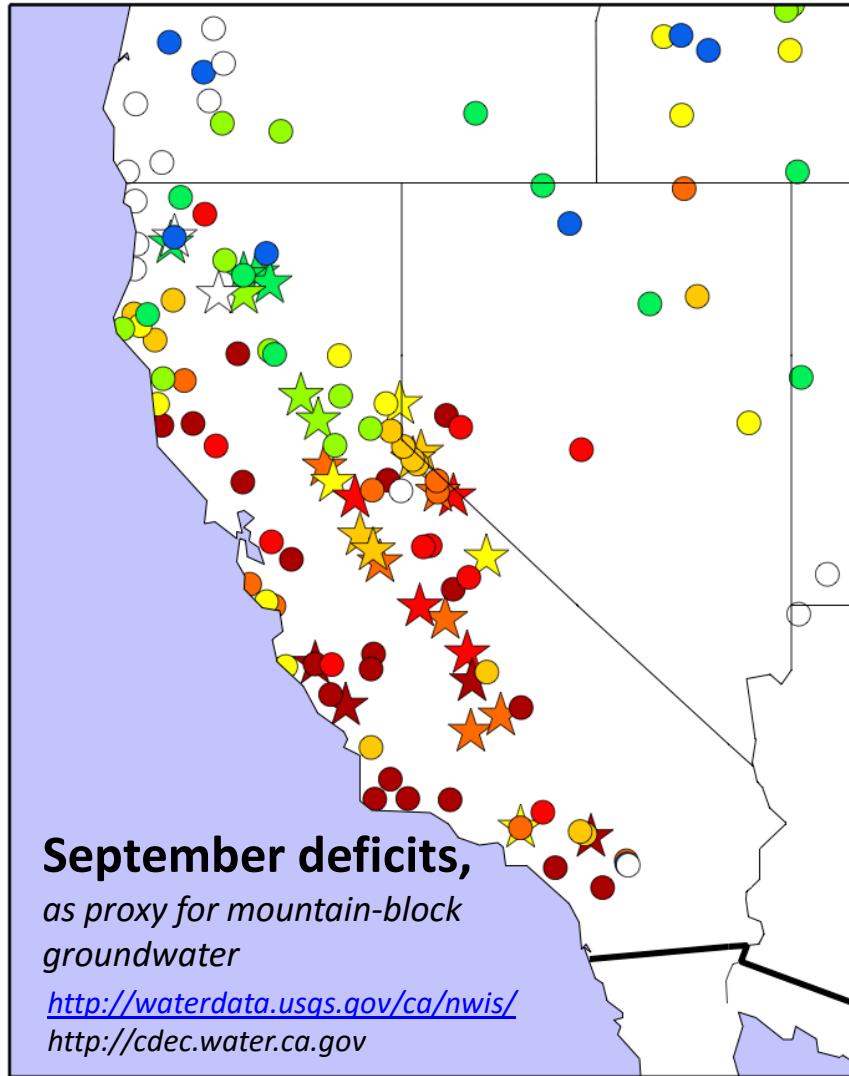


NET ET_o SURPLUSES May-Oct 2012-2015
[in terms of 1981-2010 MJJASO normals]



*Data from (& in collab w/)
D. McEvoy & J. Huntington,
DRI*

NET STREAMFLOW DEFICITS SEPTEMBERS 2012-2015
 [in terms of 1961-2010 September normals]



BASEFLOW DEFICITS DURING THE DROUGHT?

