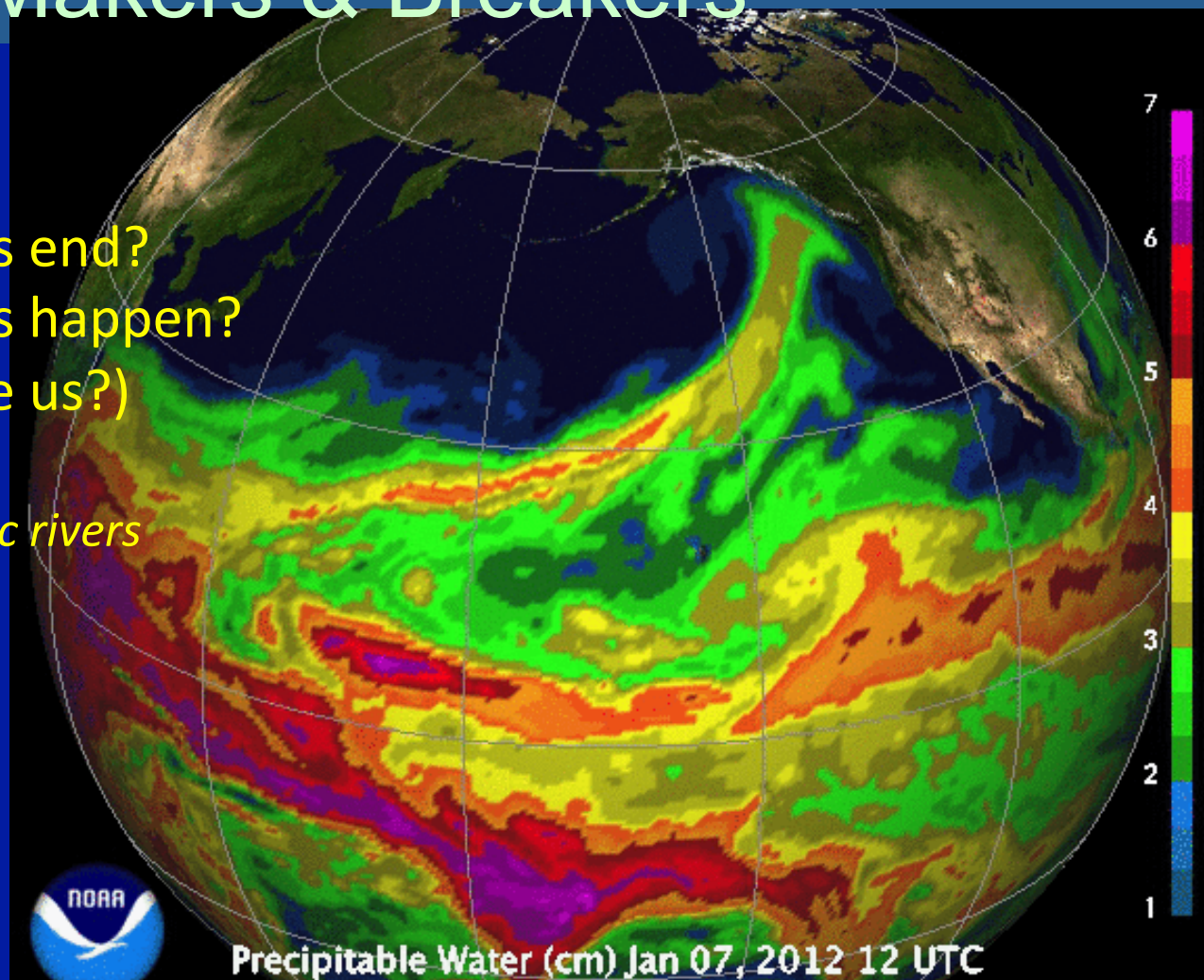


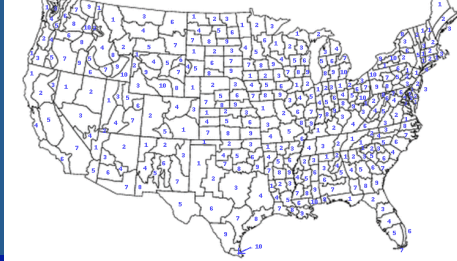
# Atmospheric rivers as Drought Makers & Breakers

- How do droughts end?
- How do droughts happen?
- (Will El Nino save us?)

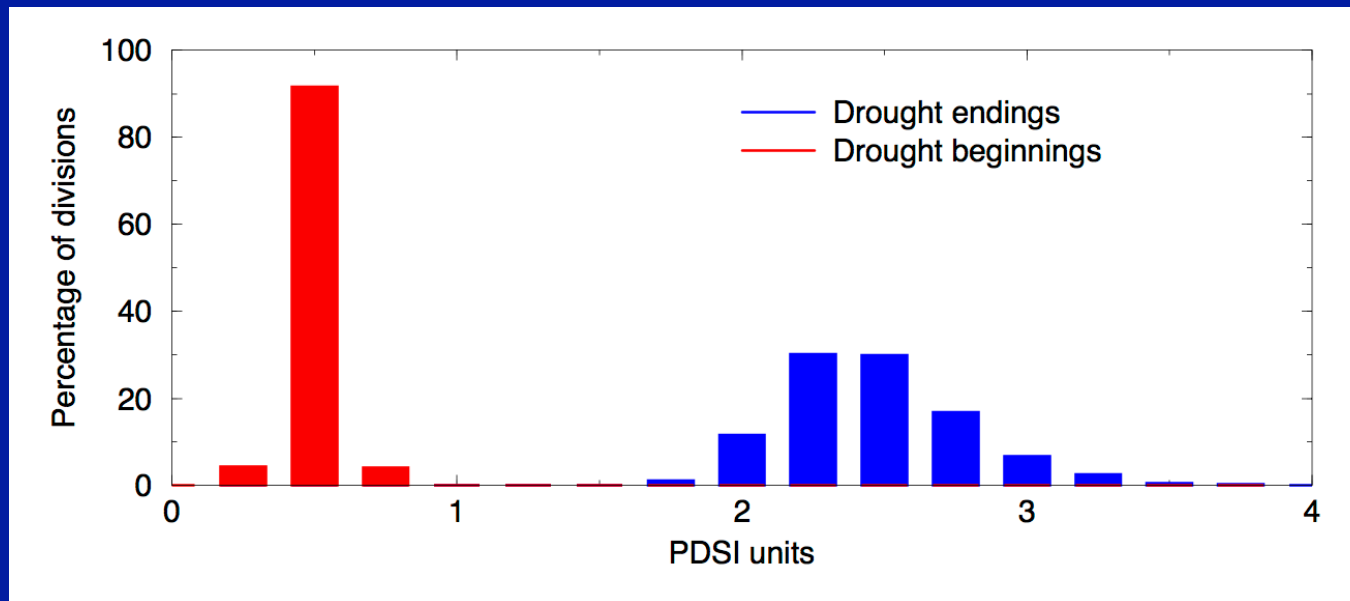
*...and what atmospheric rivers  
have to do with all this.*



# How droughts end...



## Distributions of average PDSI steps across PDSI=-2 at 344 climate divisions, 1895-2010



### PDSI Categories of Drought to Wet

Extreme  
Drought  
-4

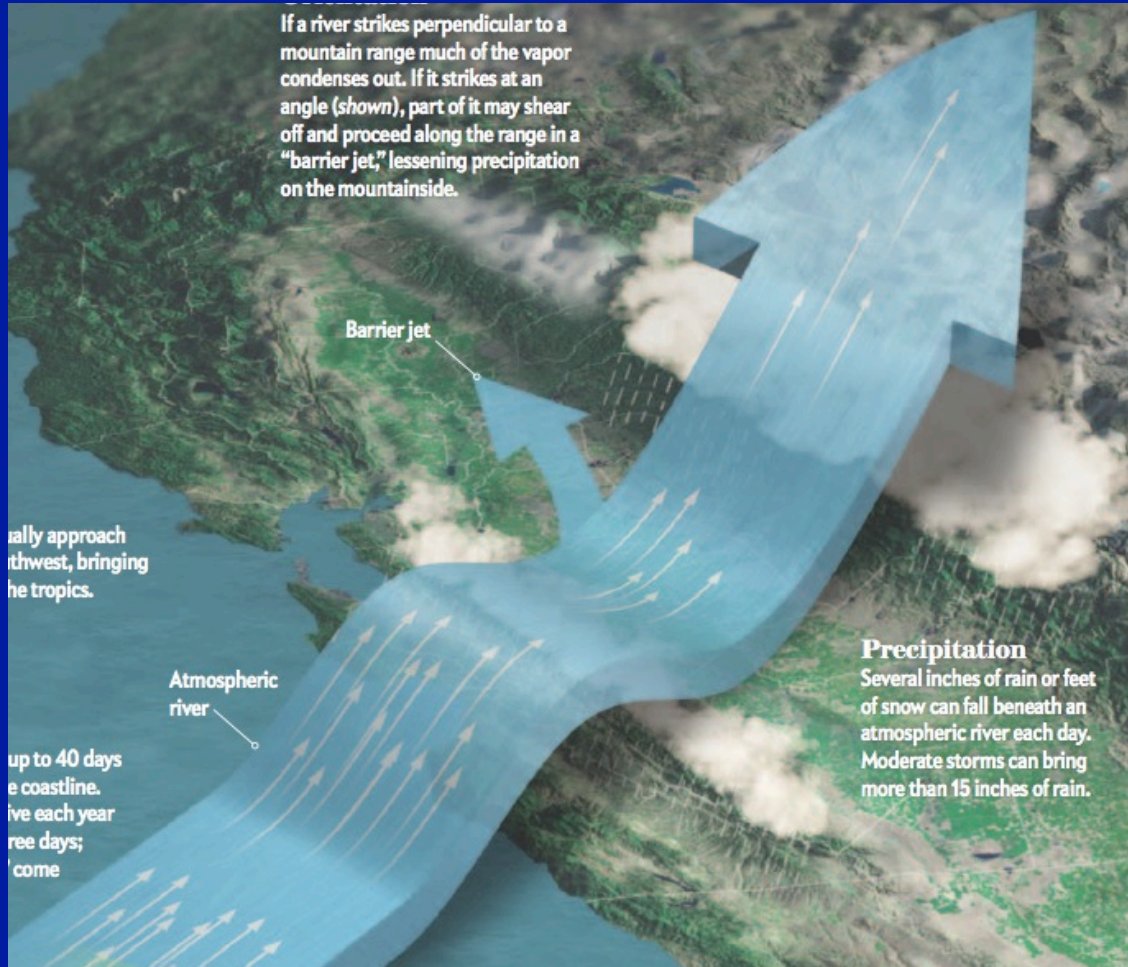
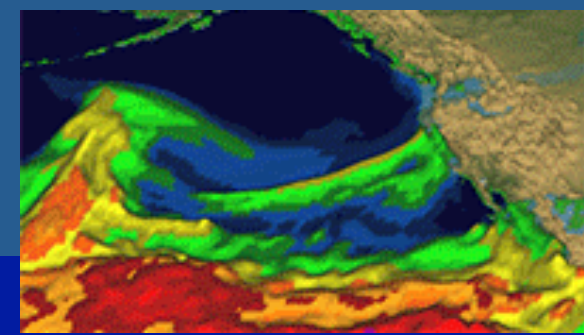
Severe  
Drought  
-3

Moderate  
Drought  
-2

Normal  
Conditions  
-1 to 1

Wet  
Categories  
> 1

# Atmospheric Rivers

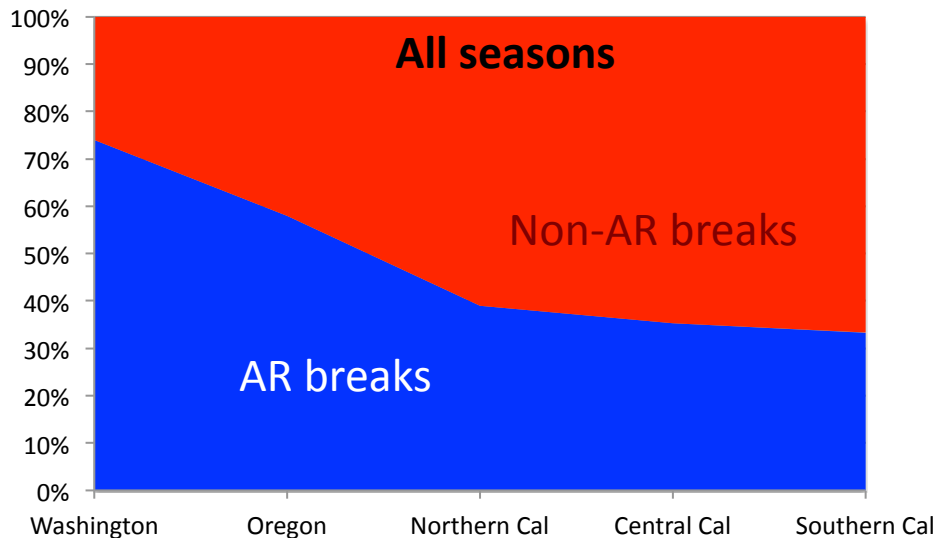


-Map-view structure (~400 km width & 2000 km long)--from satellite data

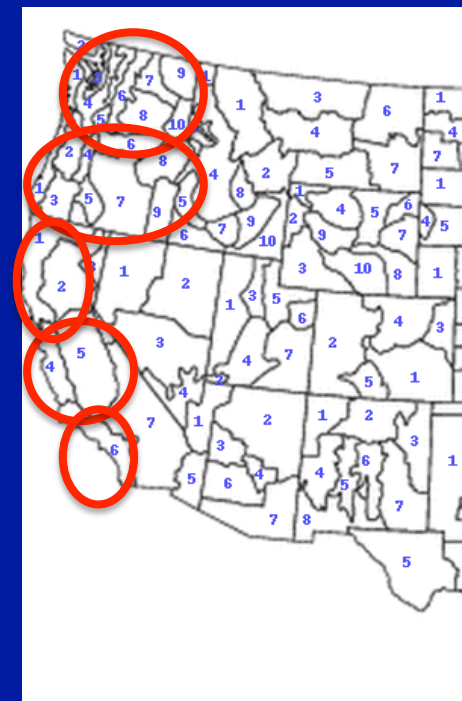
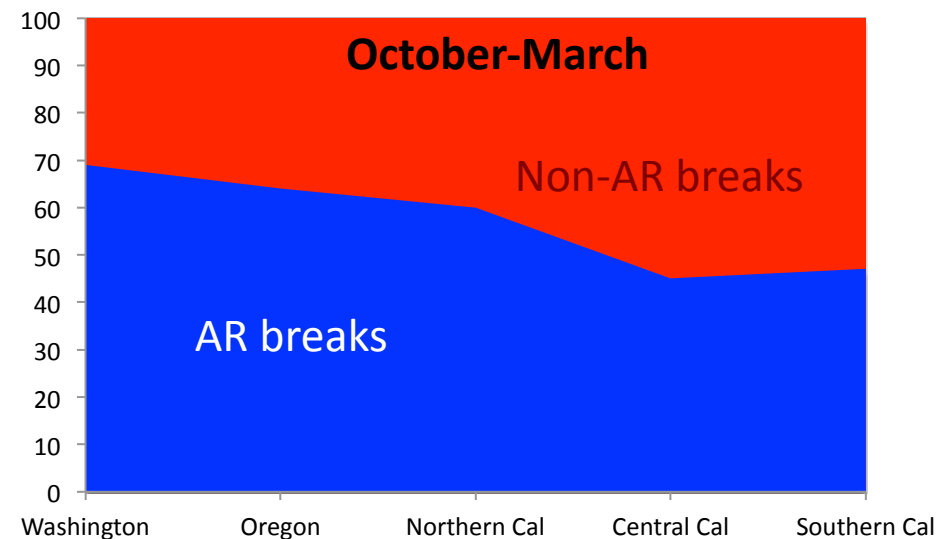
-Vertical structure (intense jet of vapor between 1 – 2 km above sea level; 10-20 Mississippi; easily uplifted)--from airplanes & AROs

# ARs as West Coast drought busters

Percentage of Persistent Drought Breaks Overall, 1950-2010

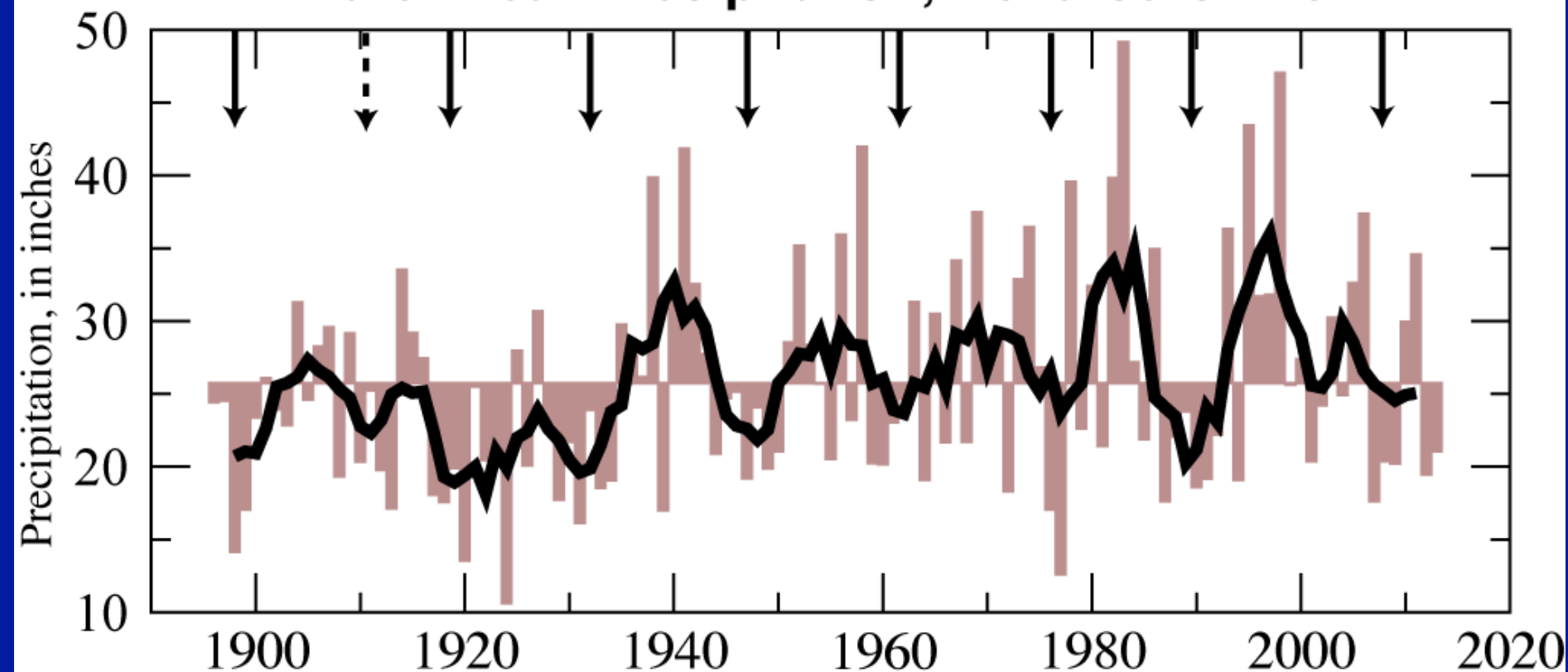


Percentage of Persistent Drought Breaks in Wet (AR) Seasons, 1950-2010

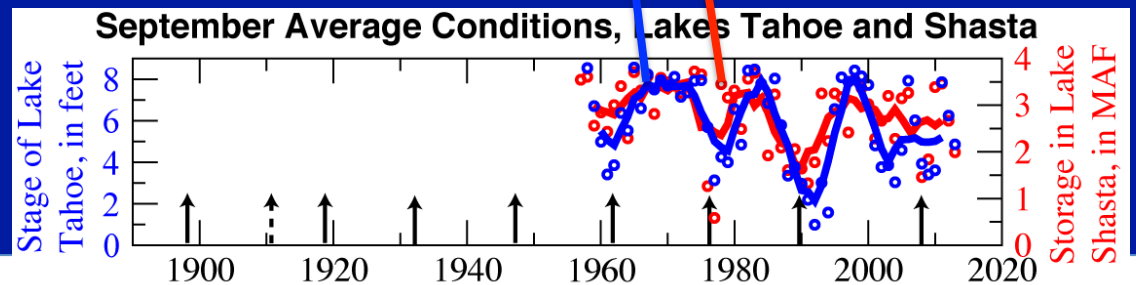
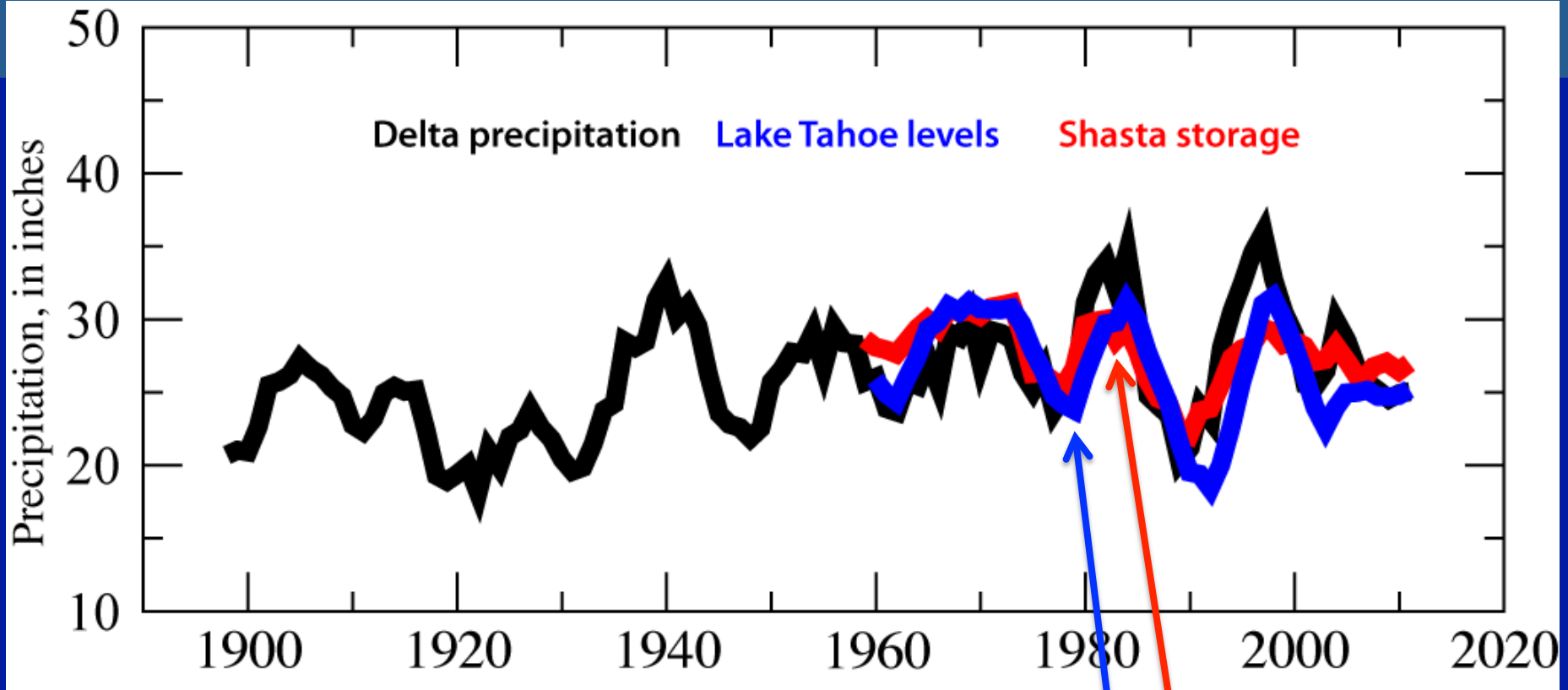


# Drought and plenty in California...

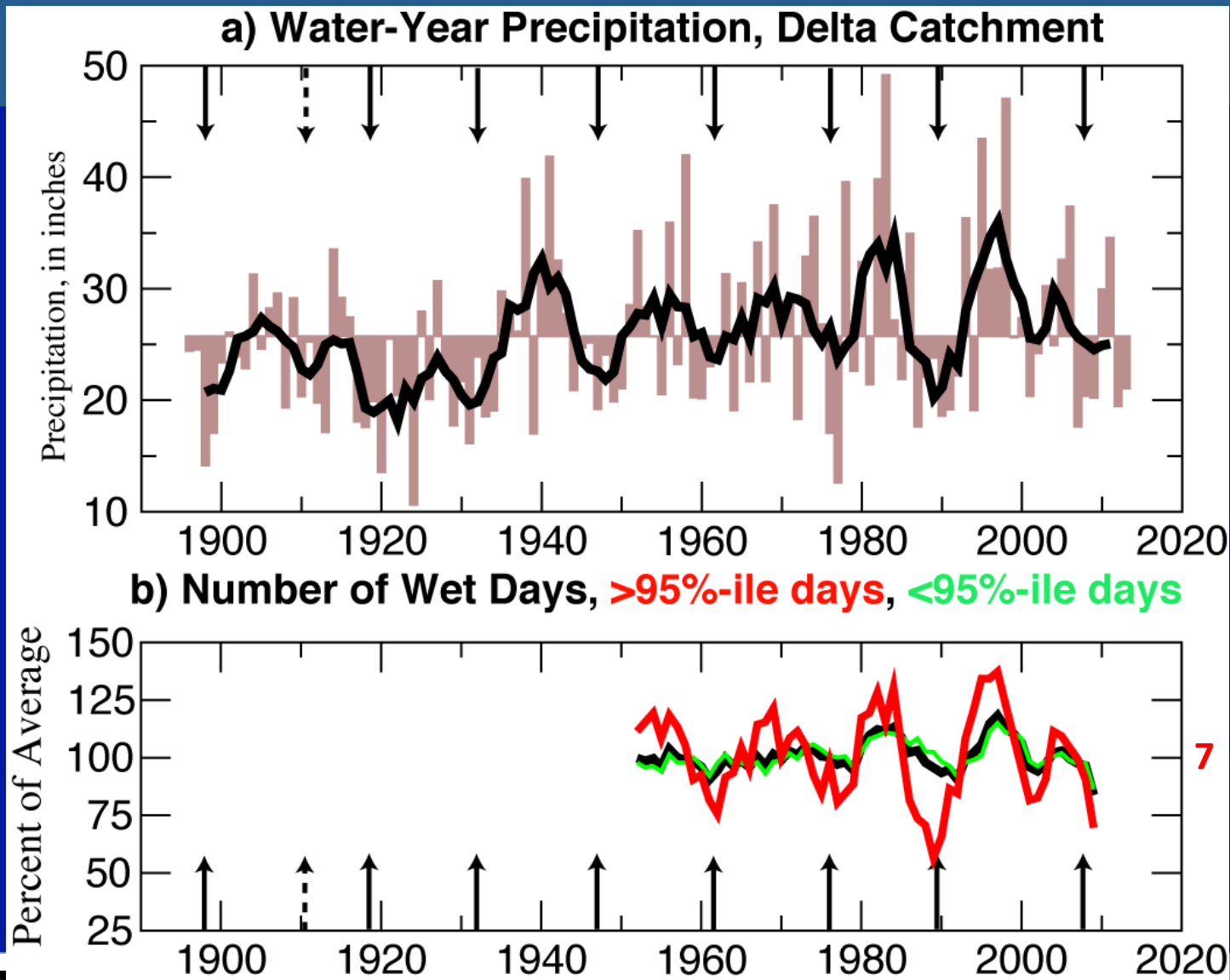
## Water-Year Precipitation, Delta Catchment



# Drought and plenty in California...



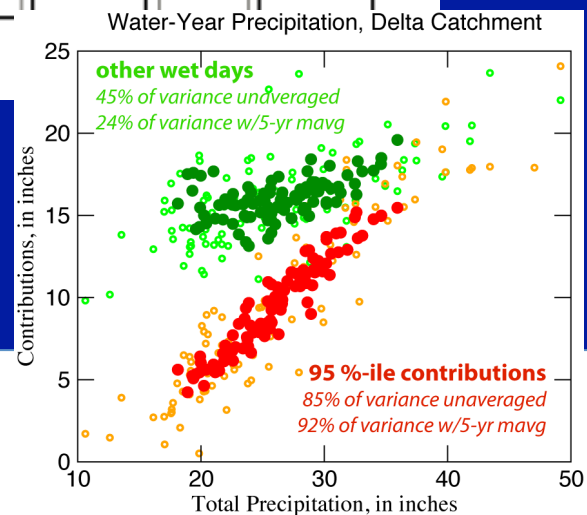
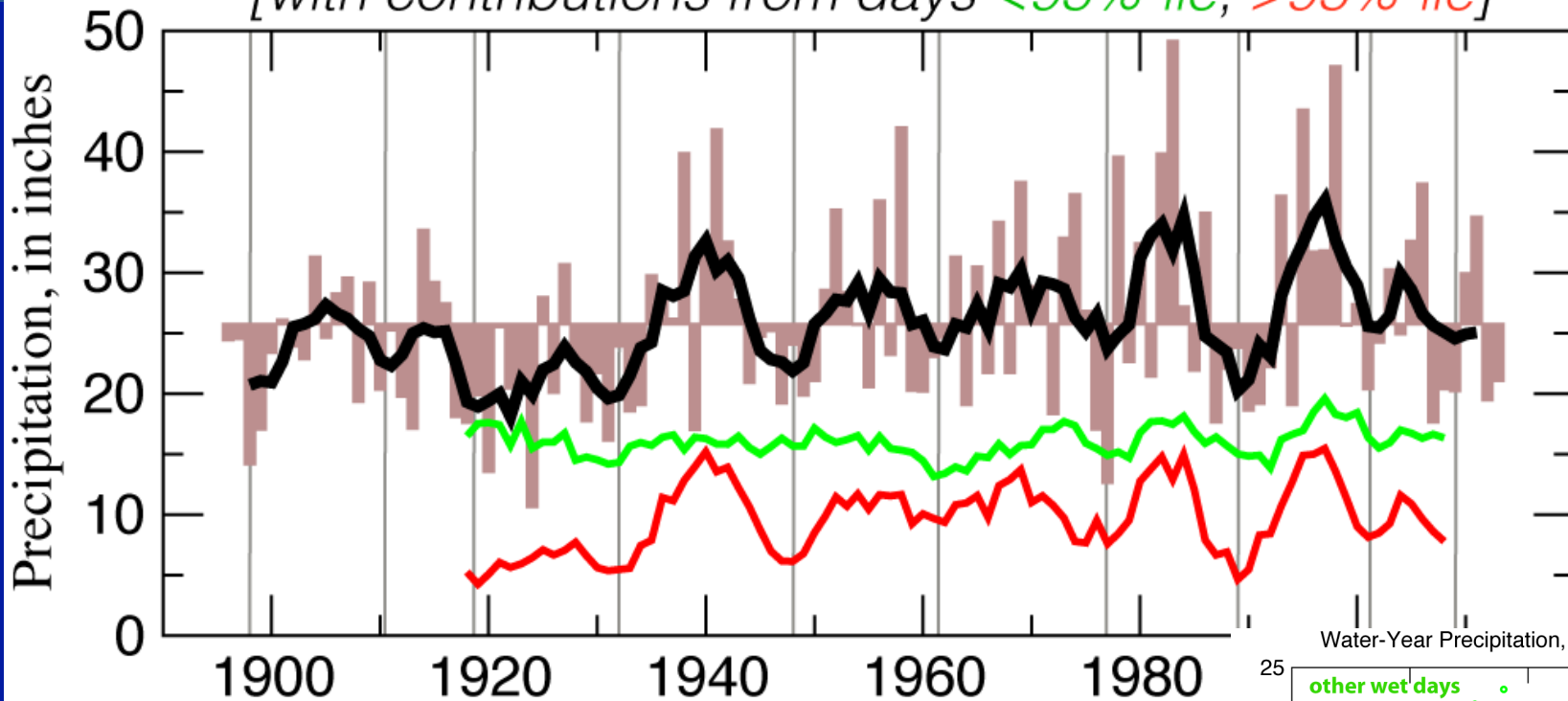
# How are droughts made?



# How are droughts made?

## a) Water-Year Precipitation, Delta Catchment

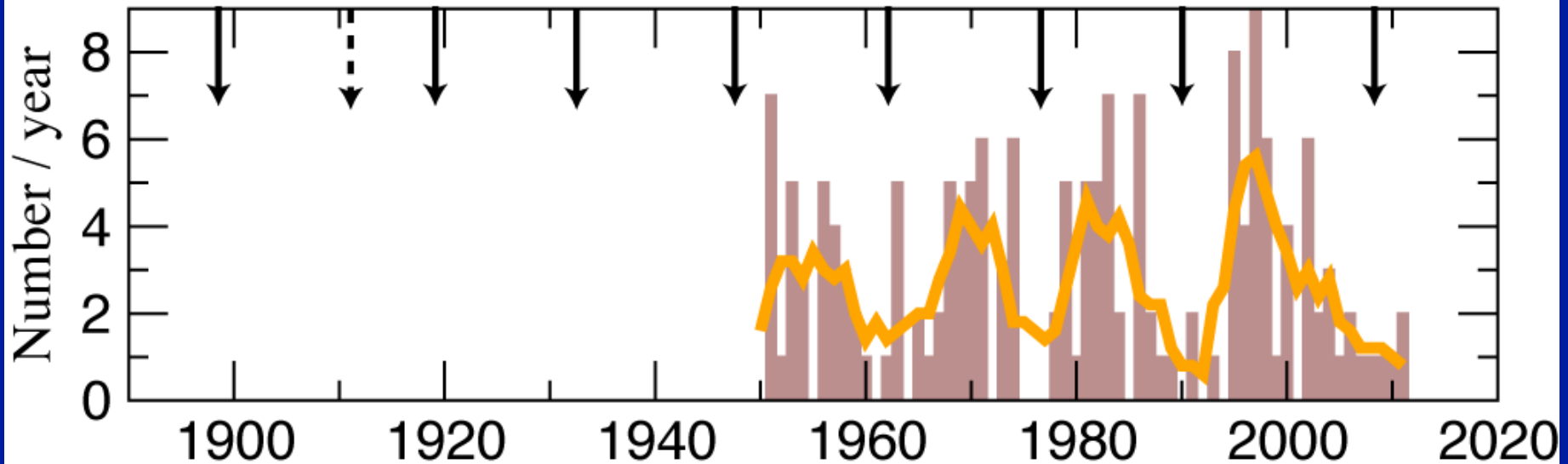
[with contributions from days <95%-ile, >95%-ile]



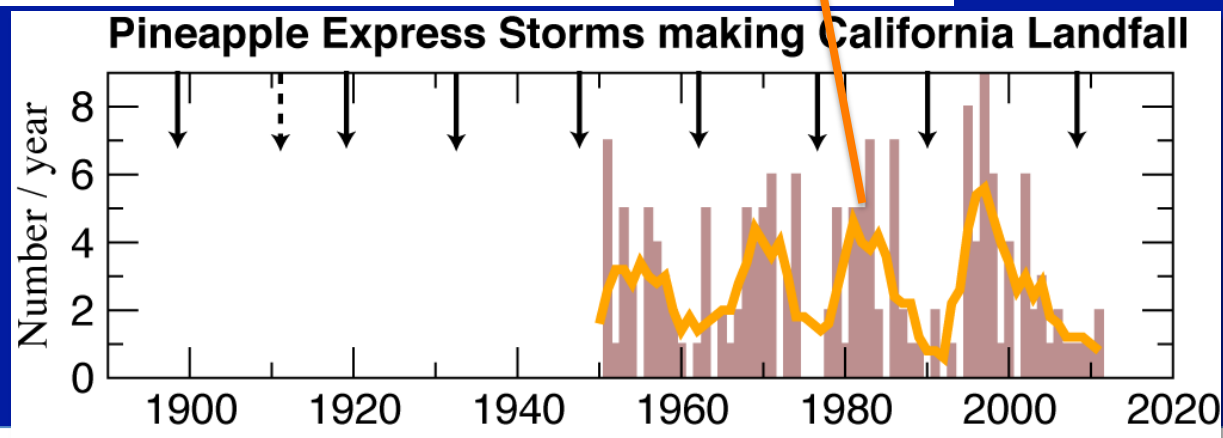
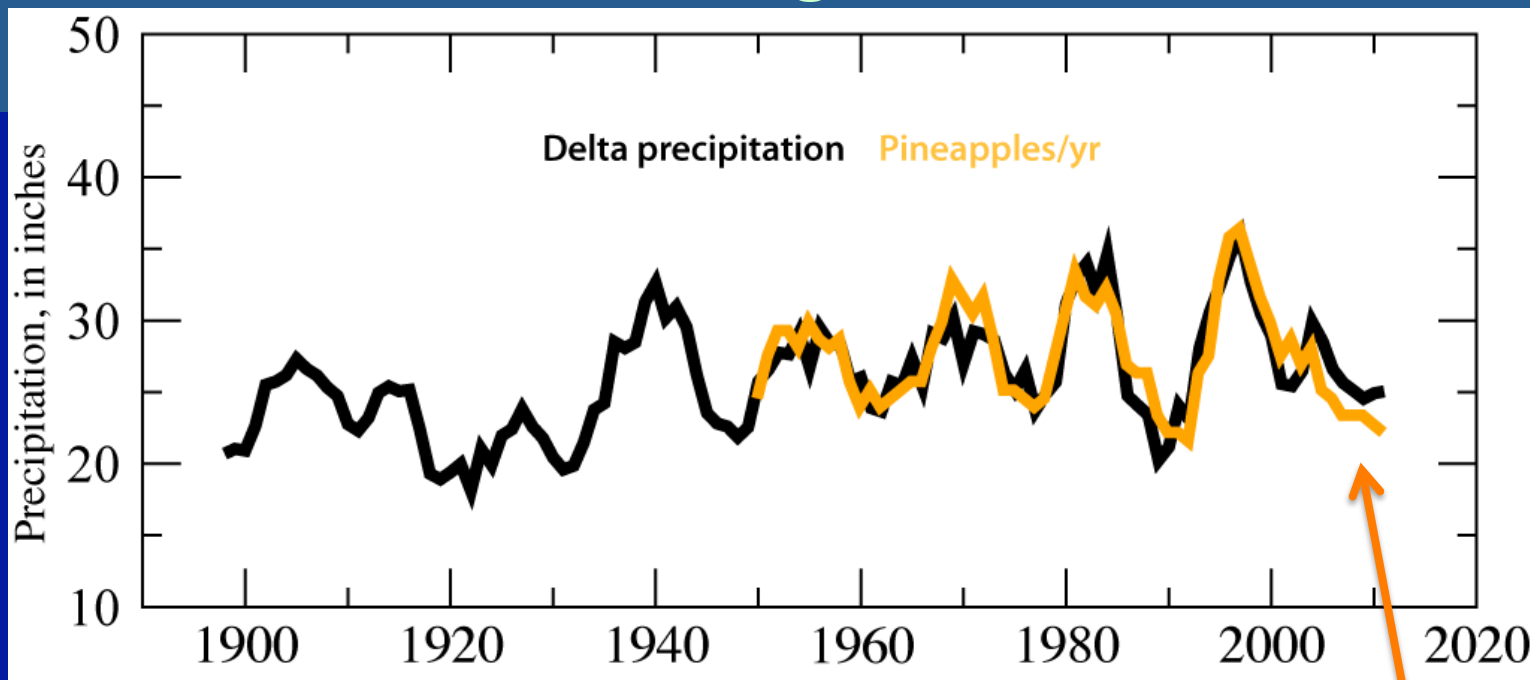


# Are ARs part of all this?

## Pineapple Express Storms making California Landfall

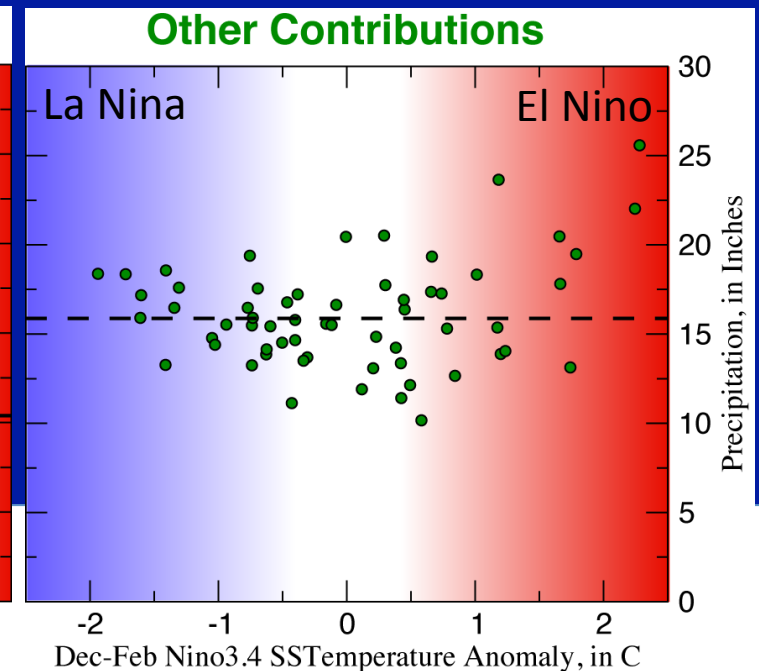
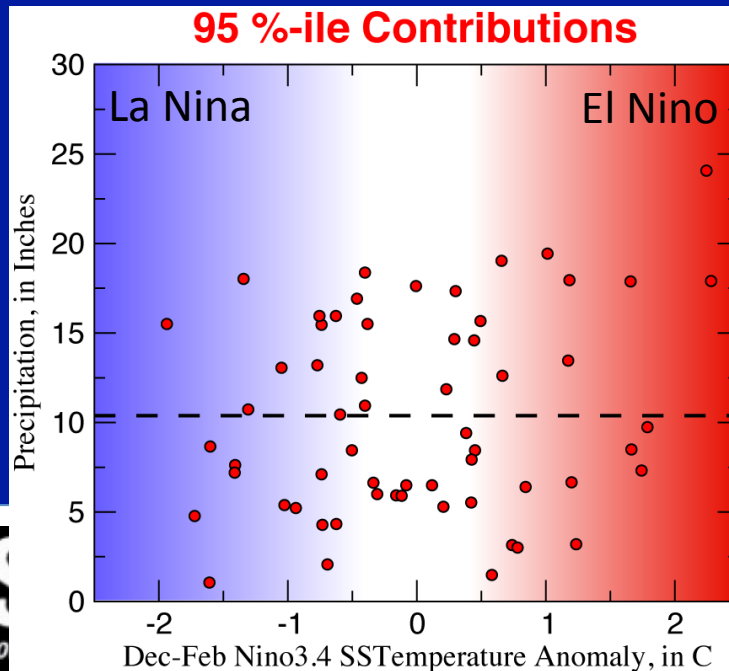
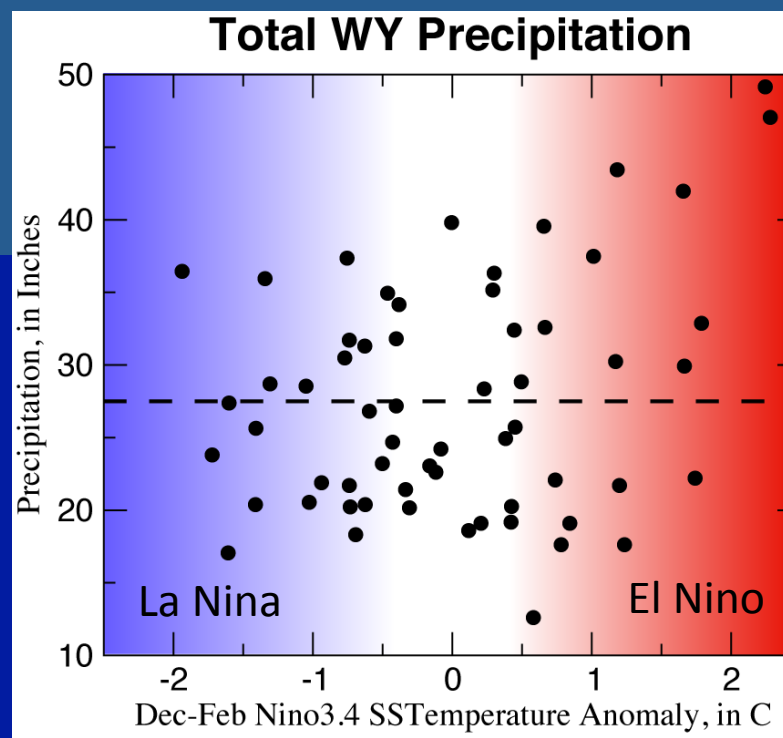


# ARs as West Coast drought makers



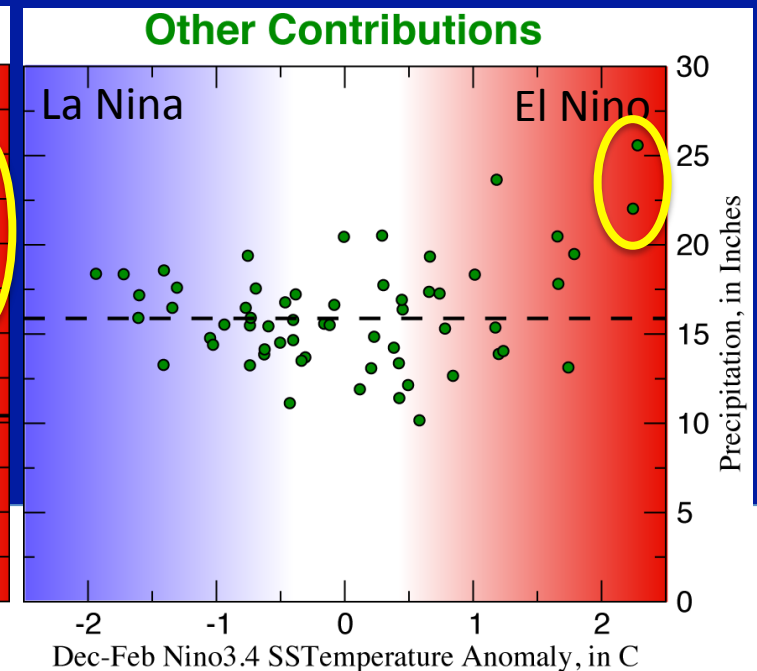
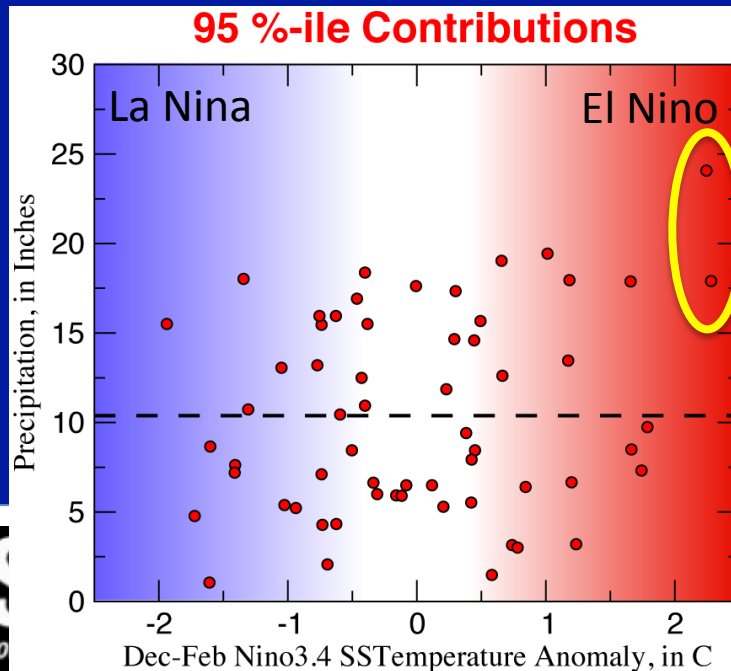
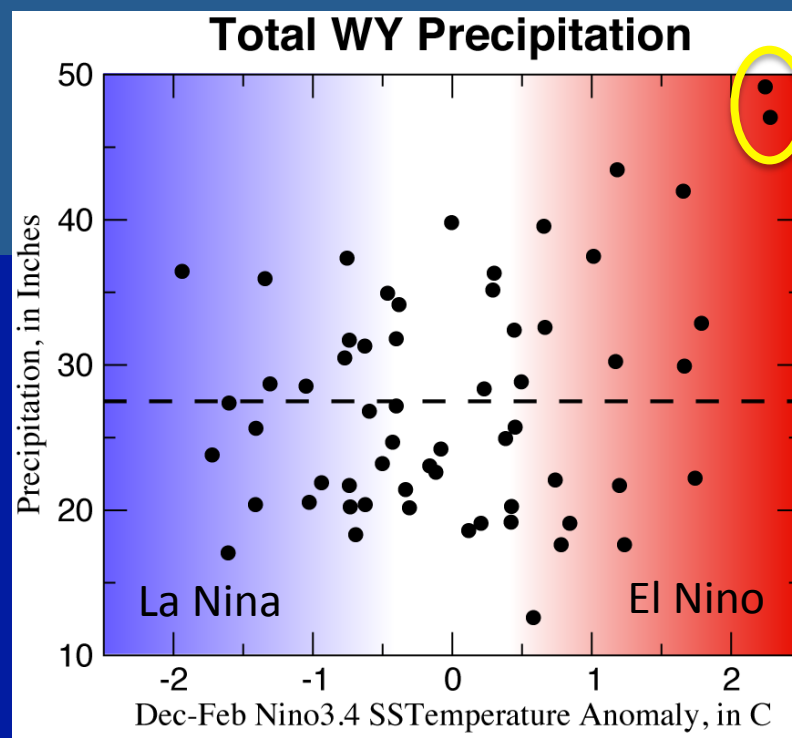
# El Nino as savior?

Nothing is guaranteed...



# El Nino as savior?

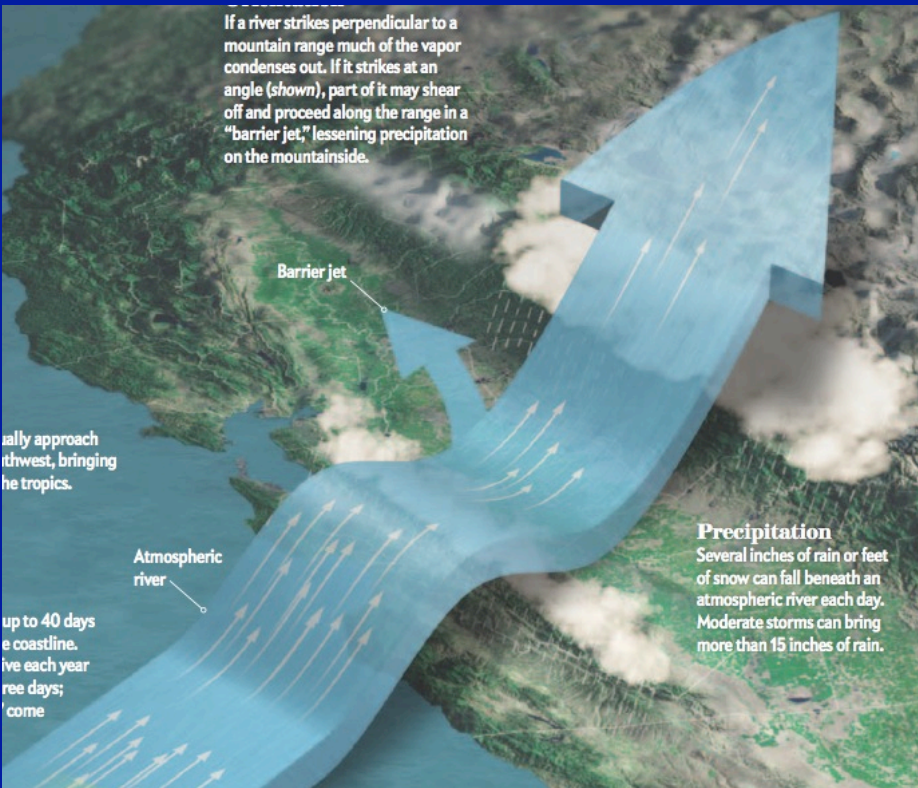
Nothing is guaranteed...  
except maybe in a really  
BIG El Nino



# Conclusions

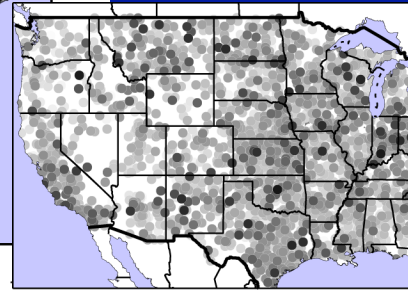
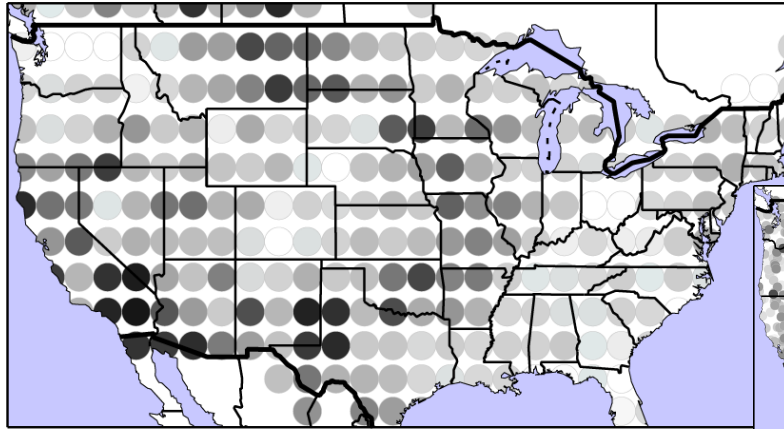
## Nor/Cen California droughts:

- **End abruptly in big storms, with ARs contributing disproportionately to drought busting**
- **Are mostly due to missing “big” storms (95 %-ile wet days), with ARs contributing disproportionately to drought formation**
- **An El Nino does not guarantee a very wet year nor an end to drought, except for unusually warm El Ninos?**



- Dettinger, M.D., Ralph, F.M., Das, T., Neiman, P.J., and Cayan, D., 2011, Atmospheric rivers, floods, and the water resources of California: *Water*, 3, 455-478.
- Dettinger, M.D., 2013, Atmospheric rivers as drought busters on the US west coast: *Journal of Hydrometeorology*, 14, 1721-1732, doi:10.1175/JHM-D-13-02.1.
- Dettinger, M., and Ingram, L., 2013, The coming megafloods: *Scientific American*, 308(1), 64-71.
- Dettinger, M.D., and Cayan, D.R., 2014, Drought and the Delta—A matter of extremes: *San Francisco Estuary and Watershed Science*, 7 p.

CONTRIBUTIONS OF 95th %-ILE DAYS TO 5yr avg TOTAL PRECIP, 1950-99



CONTRIBUTIONS OF REST OF DAYS TO 5yr avg TOTAL PRECIP, 1950-99

