

# Weather on Steroids: Extreme Weather Events in our Changing Climate

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# Weather Extremes in a Varying and Changing Climate

**WECLIMA**

Weather Extremes and Climate Impacts Analytics  
[weclima.ucsd.edu](http://weclima.ucsd.edu)

**Precipitation Regimes and Extremes**

**Heat Waves** and Cold Spells

Marine Layer Clouds

**Santa Ana Winds**

**Wildfires**

Snowpack

**Atmospheric Rivers**

**Droughts and Floods**

**IMPACTS ON SOCIETY**

CLIMATE CHANGE PROJECTION

SUBSEASONAL–SEASONAL (S2S) PREDICTION



# Heat Waves in a Varying and Changing Climate

HEAT WAVES [SEP]

THEIR HEALTH IMPACTS [SEP]

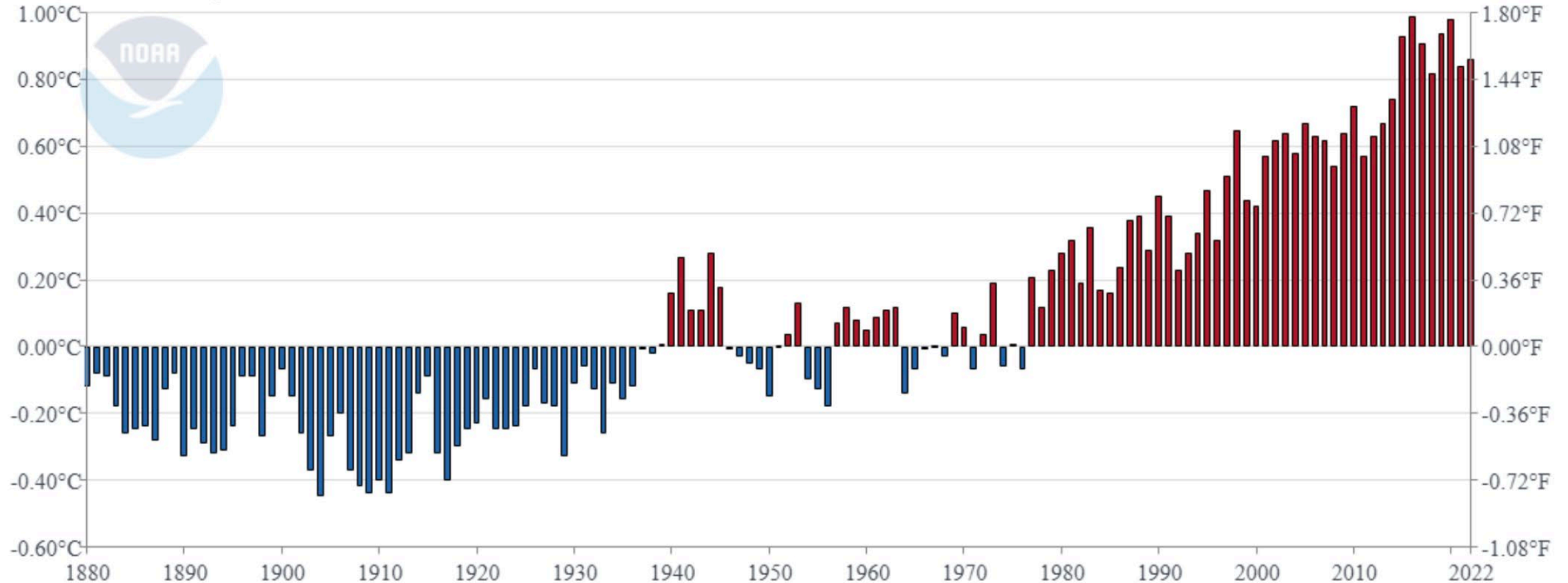
HOW ARE THEY CHANGING [SEP]

# Temperature trend over the Globe

global-land-ocean-anomalies-202201-202212.png

## Global Land and Ocean

January-December Temperature Anomalies

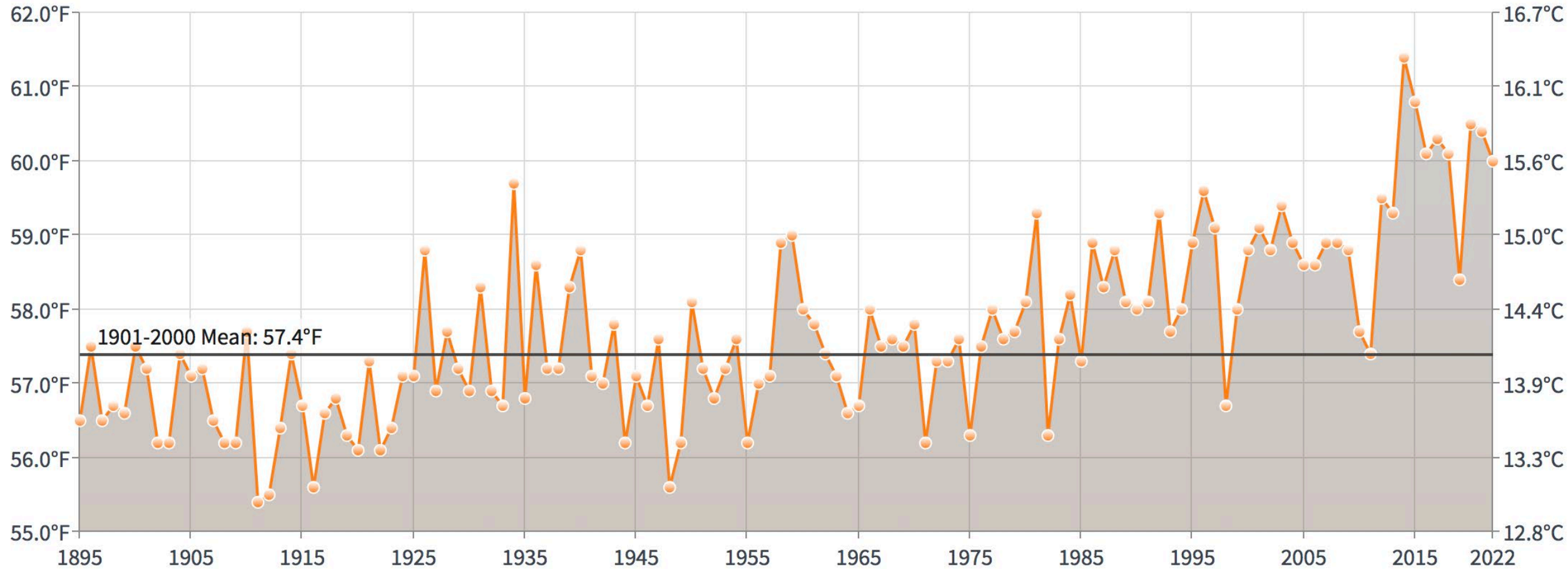




# Temperature trend over California

## California Average Temperature

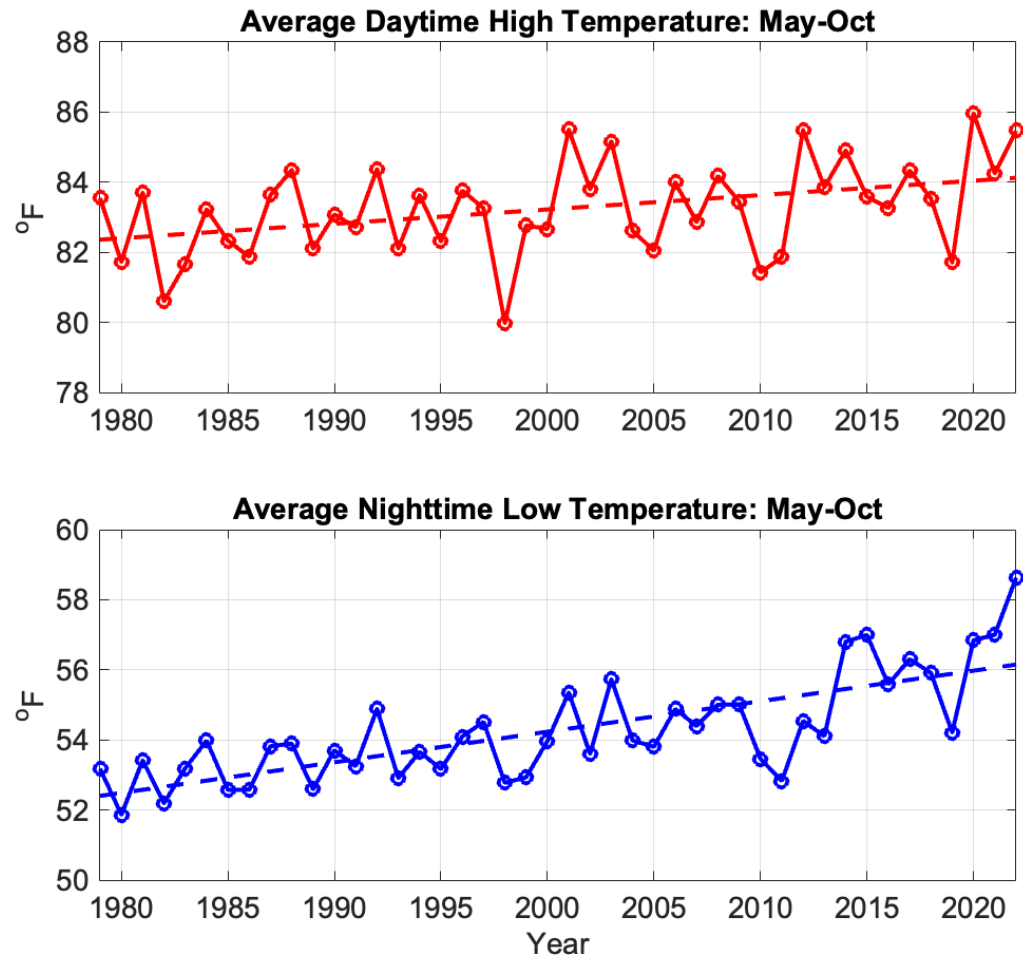
January-December



# Temperature trends and heat waves over California

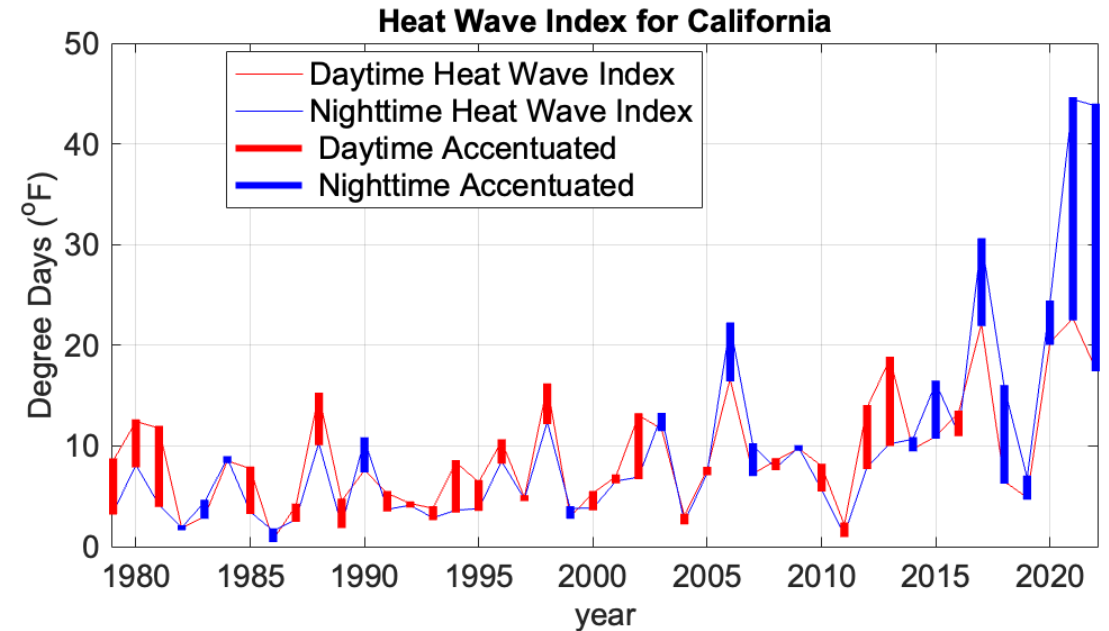
## California Statewide Temperature Trends

Nighttime temperatures are rising faster than daytime temperatures



Trend towards more humid heat waves in California

Nighttime accentuated

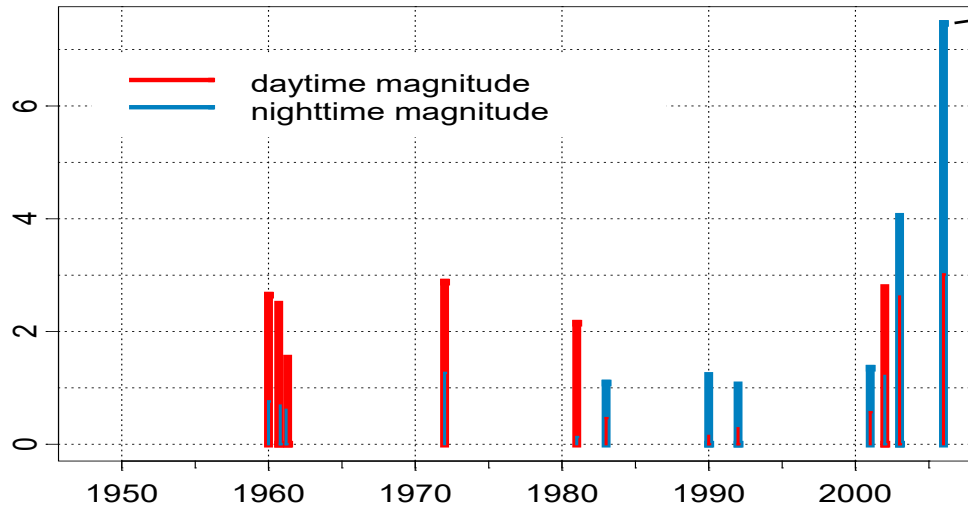




# California's Heat Waves are Changing

End of July 2006

## INDIVIDUAL HEAT WAVES



The heat wave of July 2006 was an unprecedented deadly event.

99% of cases lived in zip codes where > 50% of residents live below Poverty Guide Line

## TOTAL HEAT WAVE ACTIVITY

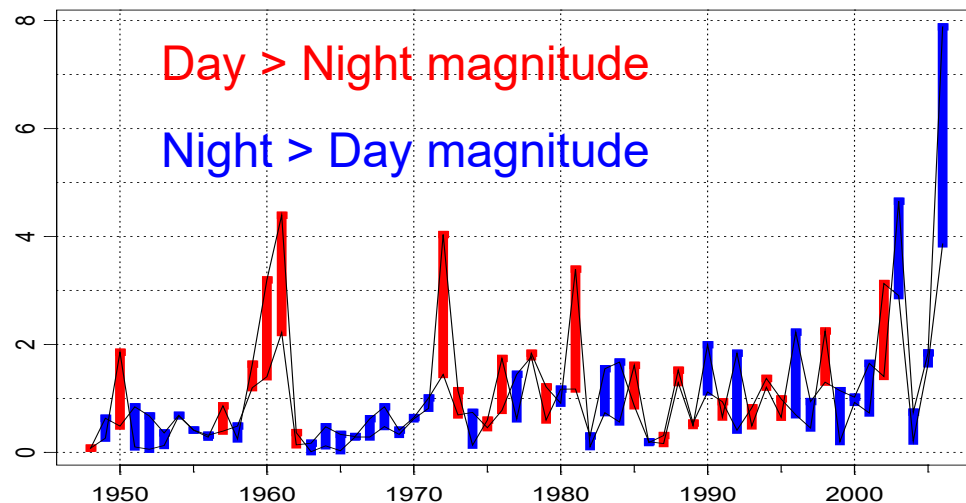
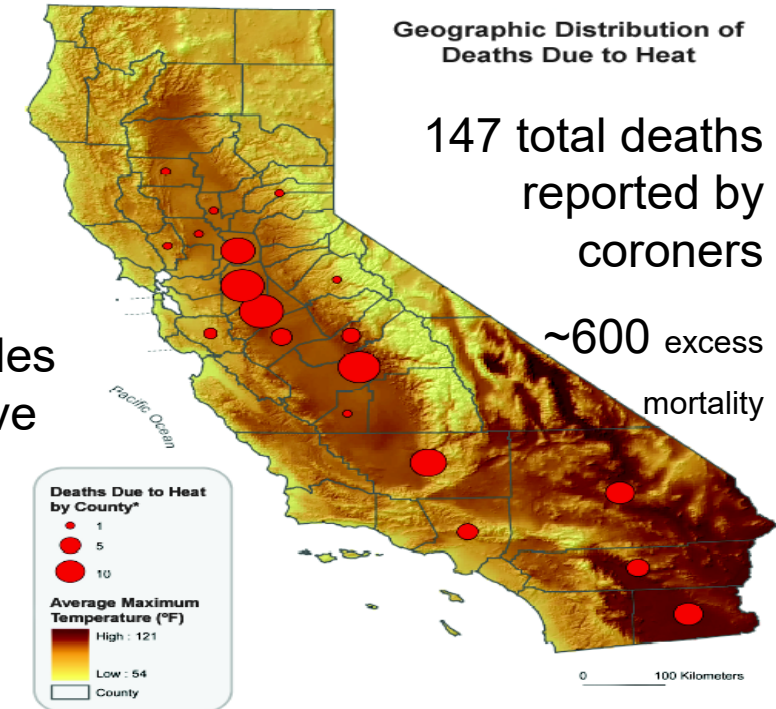


Figure 6:



\*Note: Proportional circles representing the number of deaths per county have been placed at the counties' geographic center.

Source: California Department of Public Health

Climate Change Public Health Impacts Assessment and Response Collaborative  
California Department of Public Health and the Public Health Institute

California heat wave activity is increasing

Specifically, humid, **nighttime-accentuated** heat waves are on the rise

Gershunov, A., D. Cayan and S. Iacobellis, 2009: The great 2006 heat wave over California and Nevada: Signal of an increasing trend. *Journal of Climate*, 22, 6181–6203.

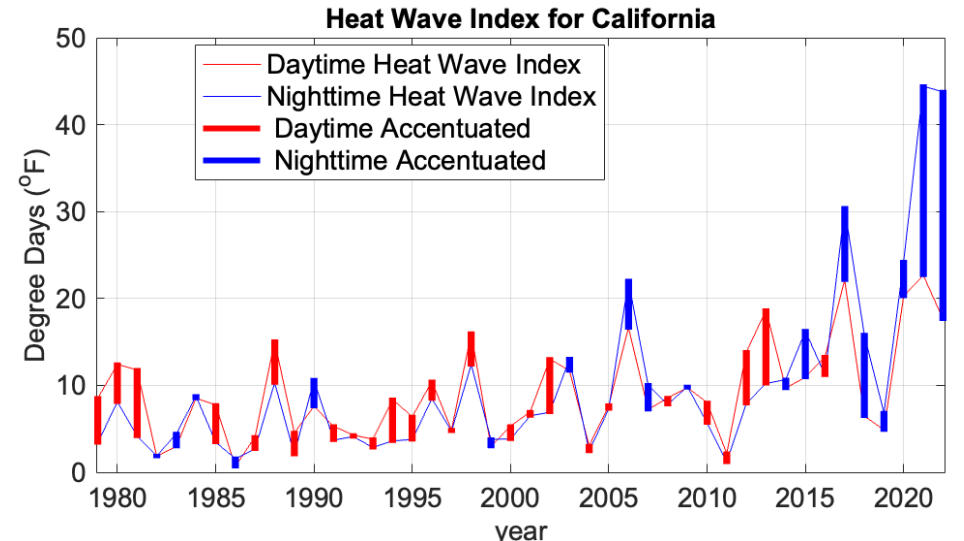




# Heat Waves

and LUNA Rossel  
*Dust*

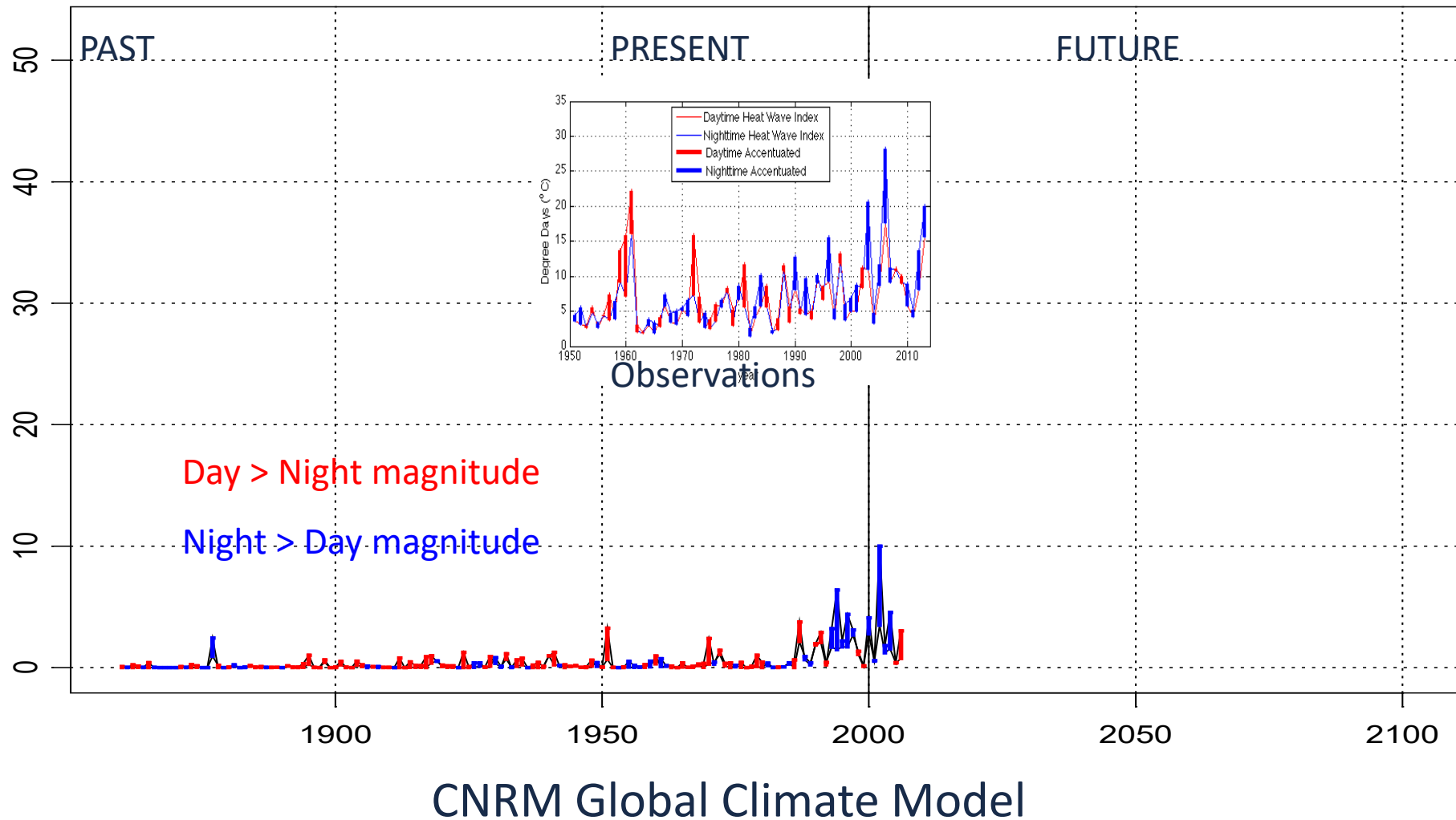
## Observed Heat wave index for California





# California Heat Waves and Climate Change

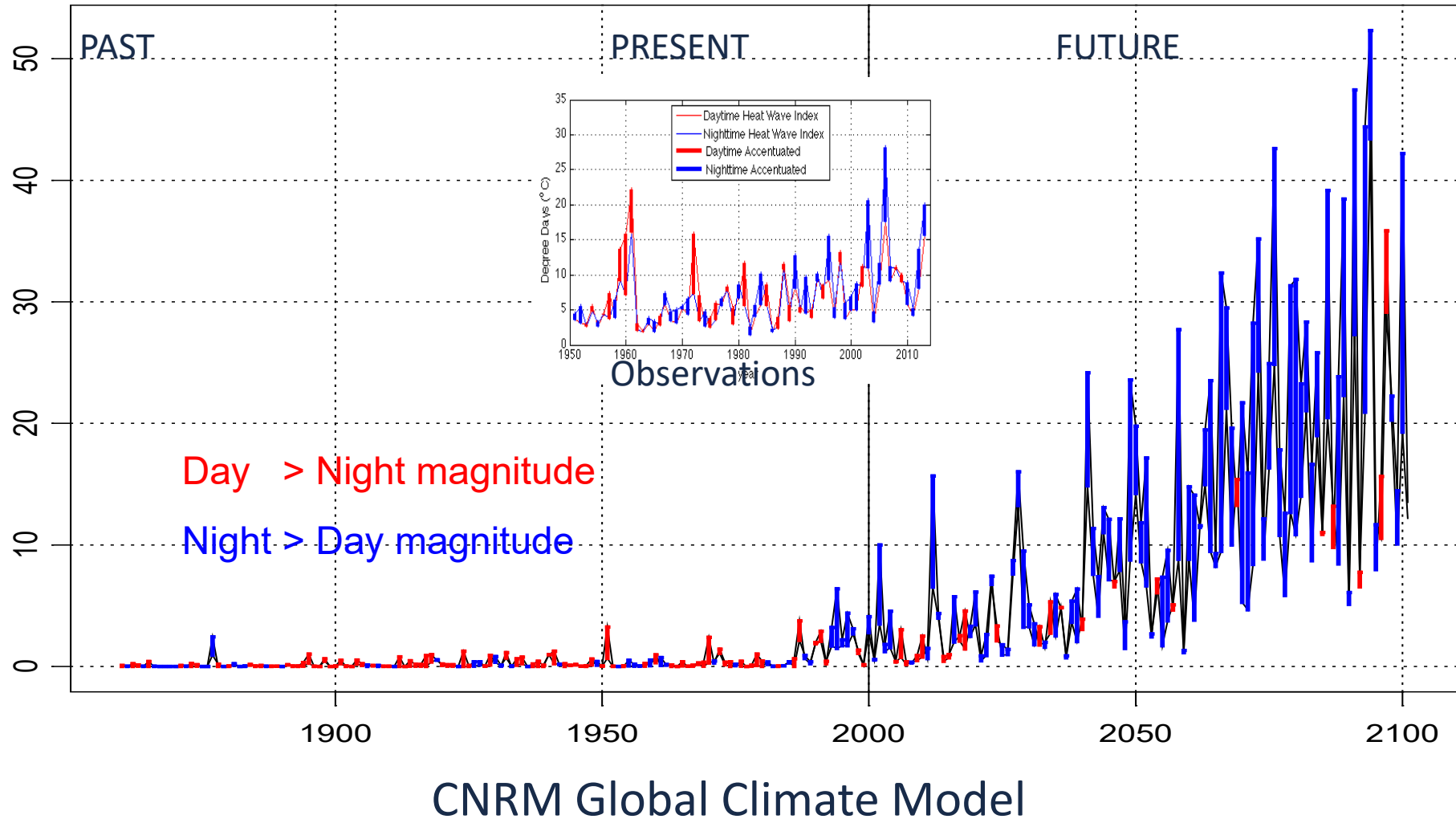
A vetted **climate model** under a **mild emissions scenario**



# California Heat Waves and Climate Change

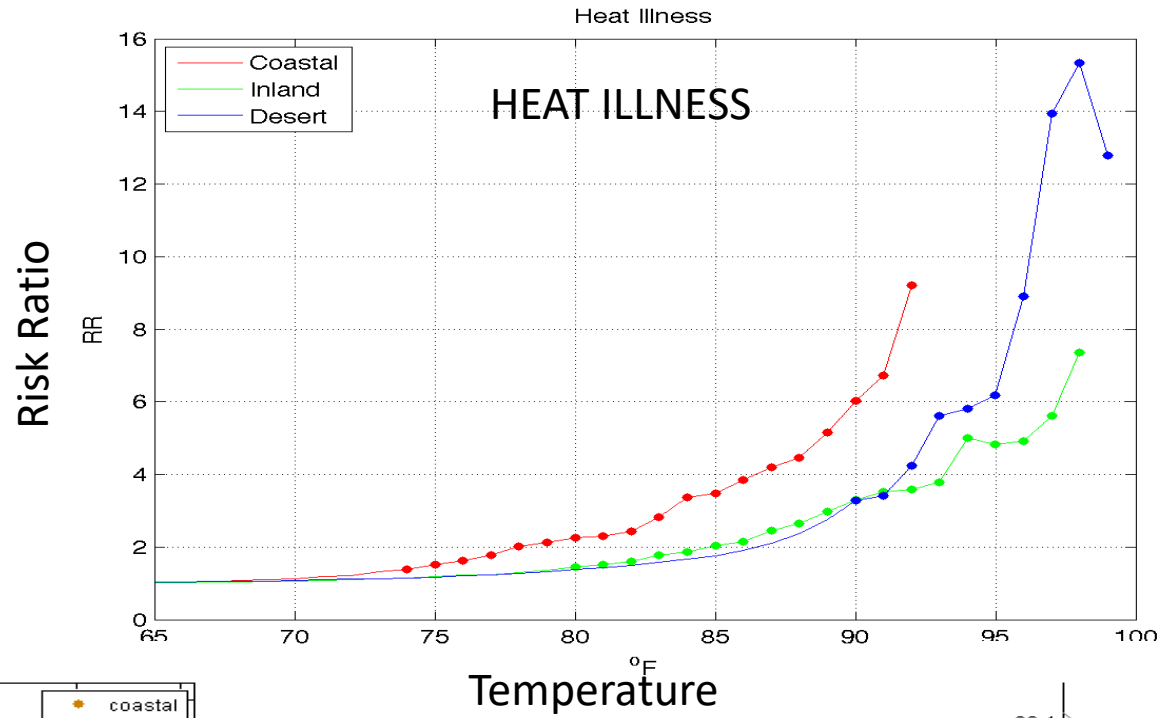
A vetted **climate model** under a **mild emissions scenario** suggests that the observed change is a tip of the iceberg.

HEAT WAVES  
ON STEROIDS



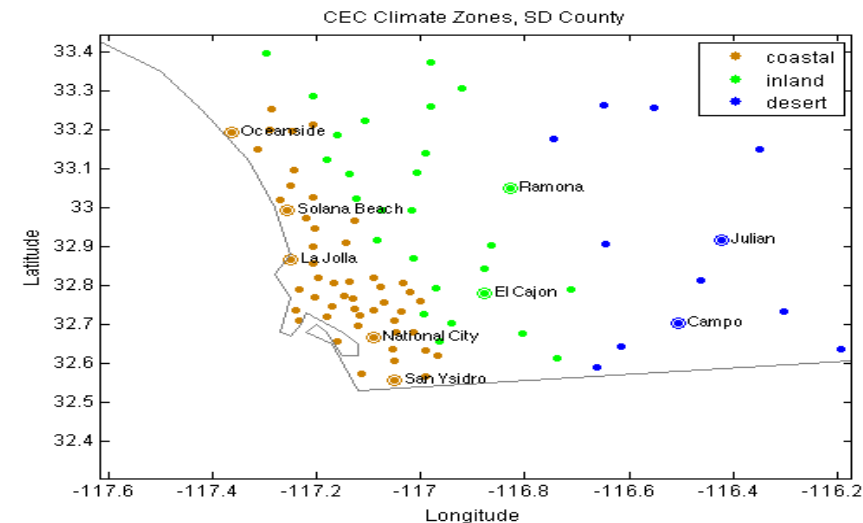


# San Diego County Heat Waves and Health Impacts



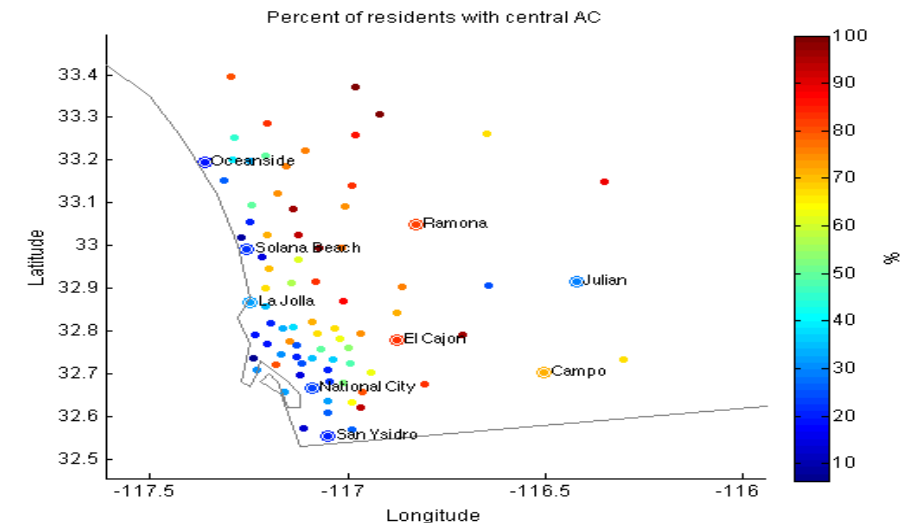
**PHYSIOLOGICAL  
AND  
TECHNOLOGICAL  
ACCLIMATIZATION**

## CLIMATE ZONES



Guirguis et al. 2018: Heat, disparities, and health outcomes in San Diego County's diverse climate zones. *GeoHealth*.

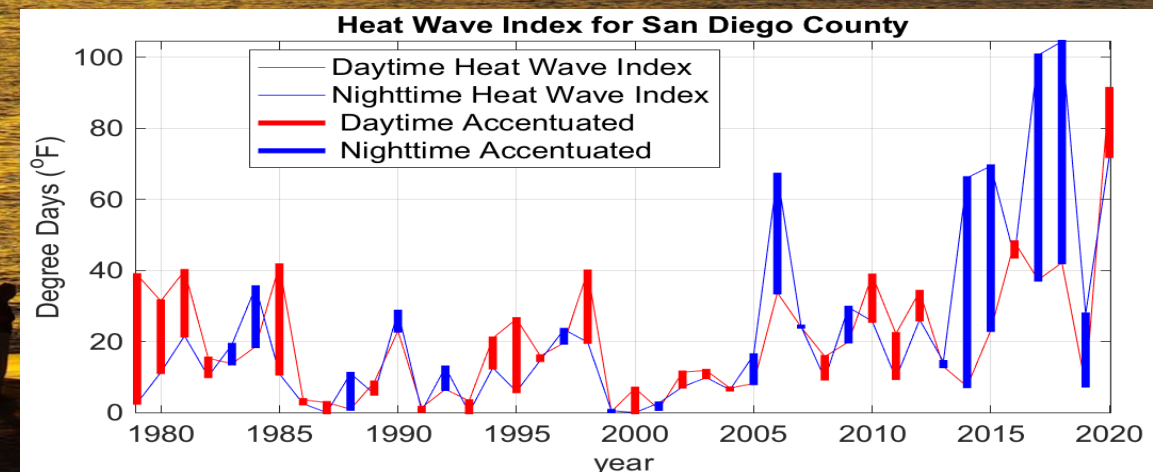
## AC PENETRATION



# Heat Waves

- are on the rise in terms of their
  - frequency
  - intensity
  - duration
- differ in their impacts regionally
- are becoming more humid and hotter at night
- will continue to intensify, become more frequent and longer-lasting

Observed Heat wave index for SD County





# Atmospheric Rivers in California's Changing Hydroclimate



Center for Western Weather  
and Water Extremes

Alexander (Sasha) Gershunov

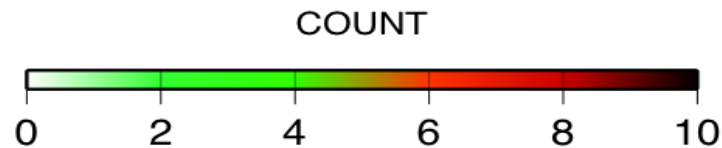
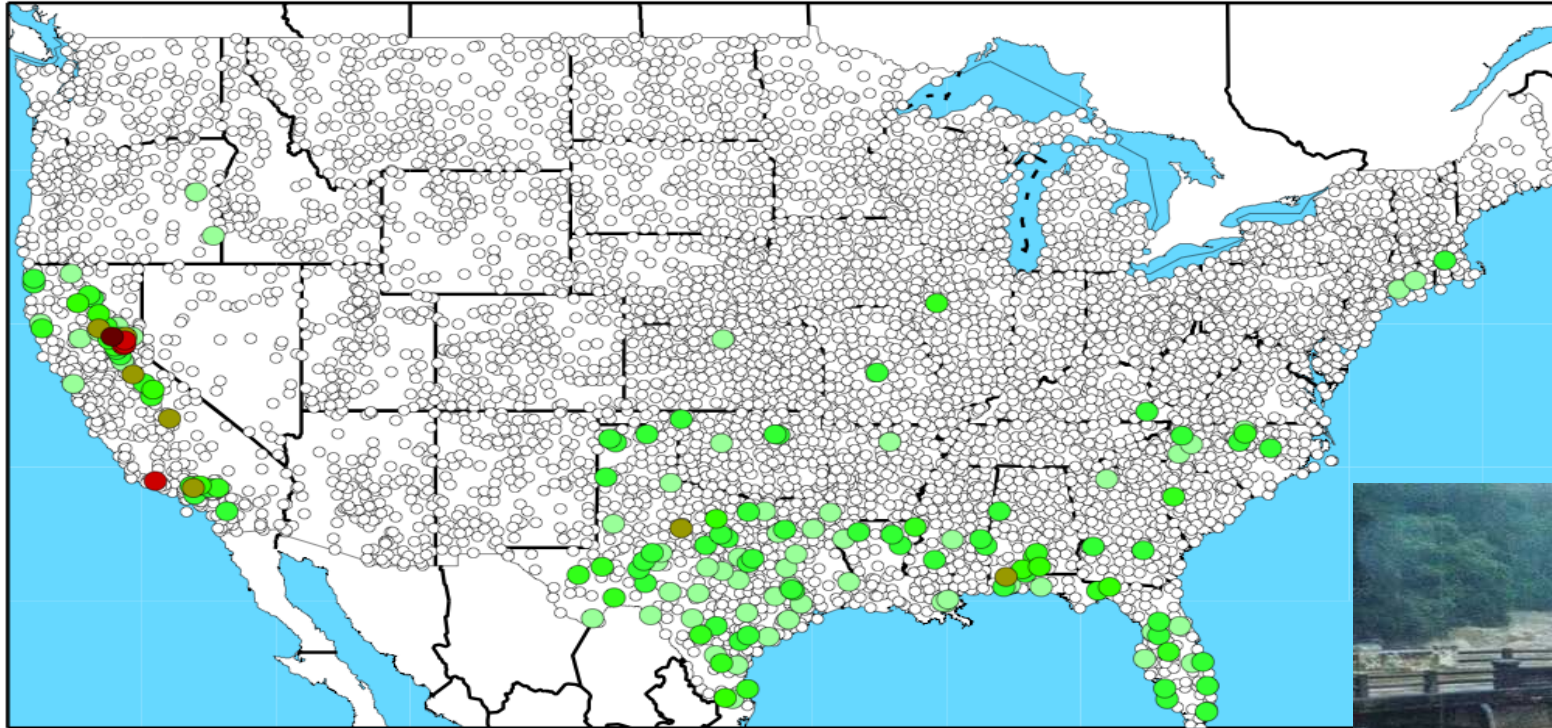
Climate, Atmospheric Science and Physical Oceanography

Scripps Institution of Oceanography

La Jolla, California

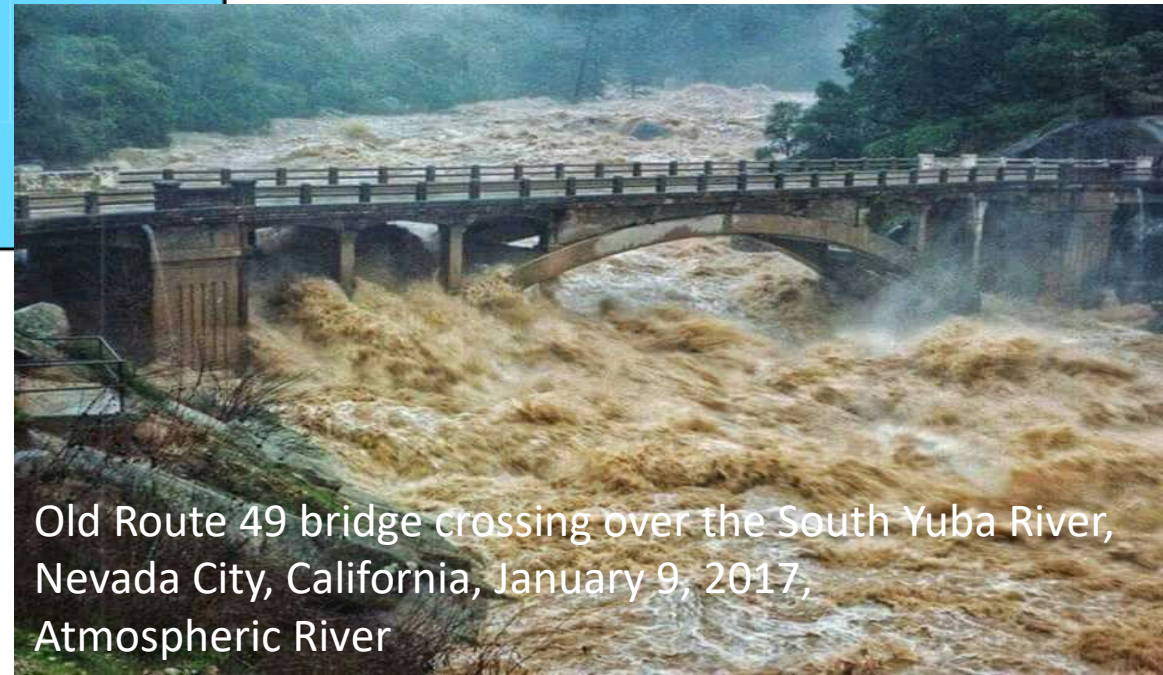
# California's Wild Precipitation

Three-day episodes with  $> 40$  cm (15 in) precipitation since 1950



*Dettinger et al, Water, 2011*

California's BIG  
storms are as big as  
any in the country!



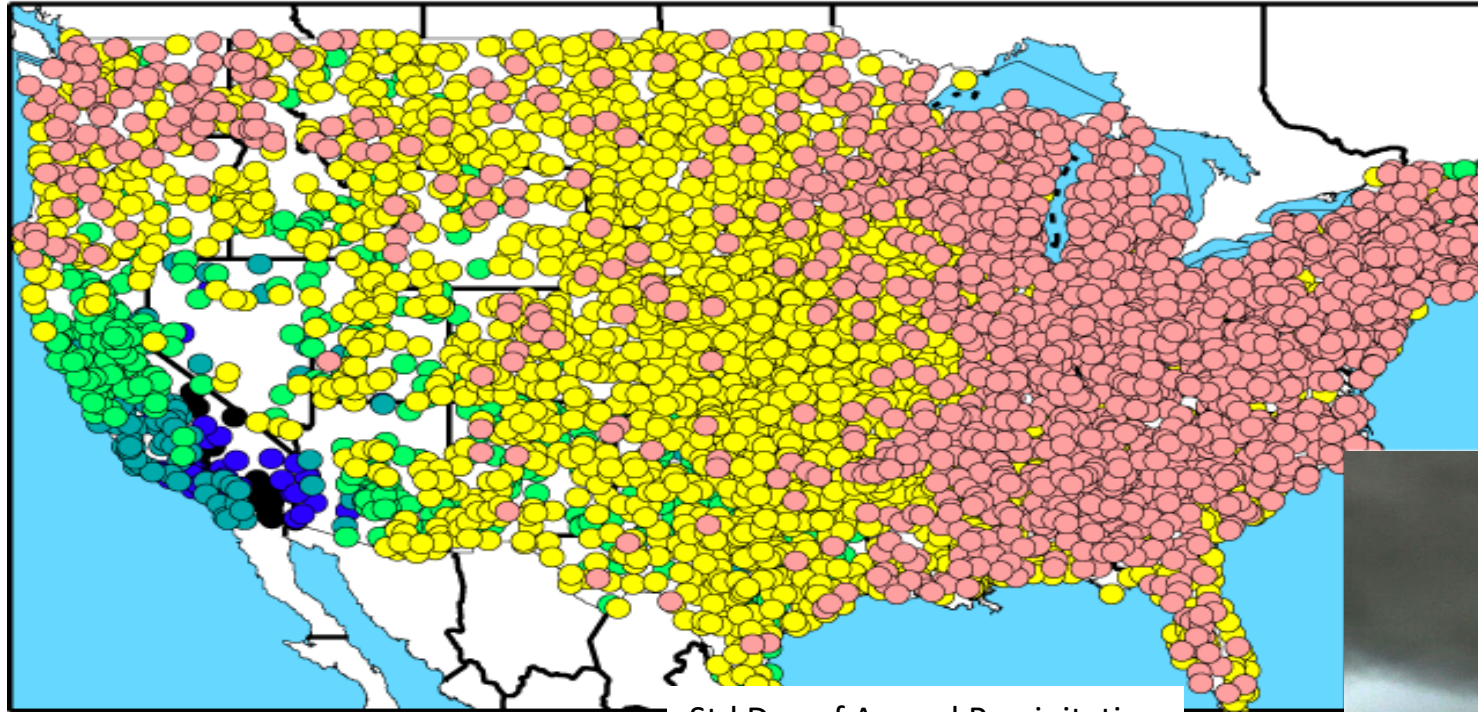
Old Route 49 bridge crossing over the South Yuba River,  
Nevada City, California, January 9, 2017,  
Atmospheric River



# How variable is California's hydroclimate?

Year-to-year variability relative to the climatological total annual precipitation at each station

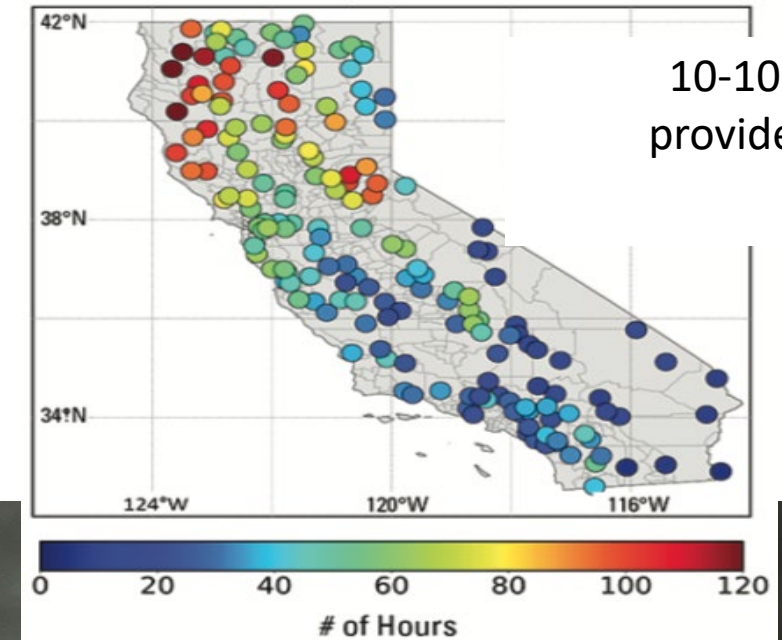
a) COEFFICIENTS OF VARIATION OF  
TOTAL PRECIPITATION, WY 1951-2008



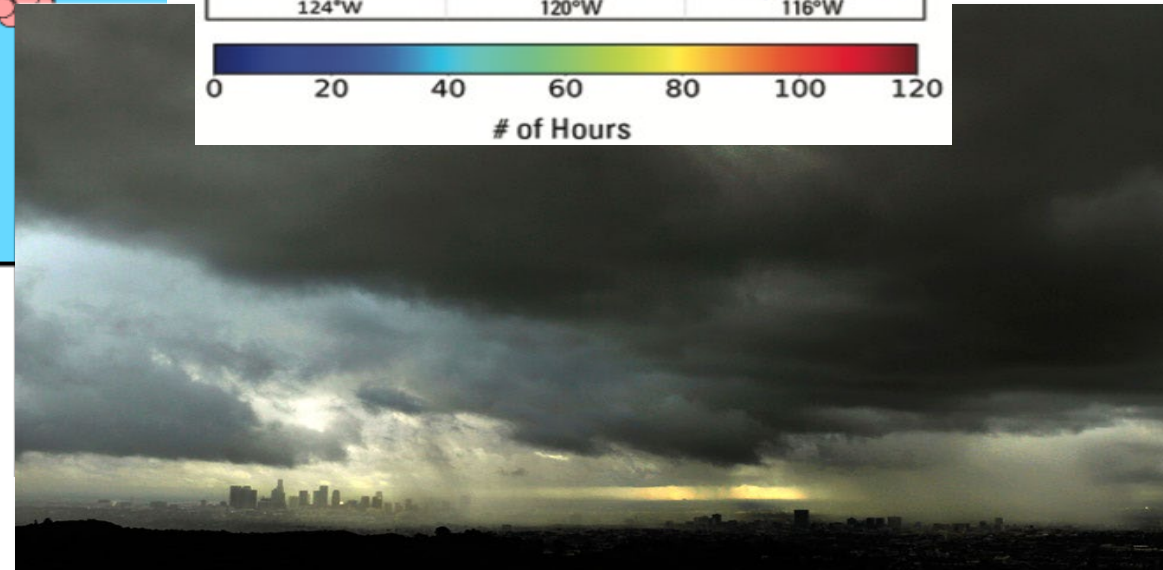
Std Dev of Annual Precipitation  
Mean Annual Precipitation



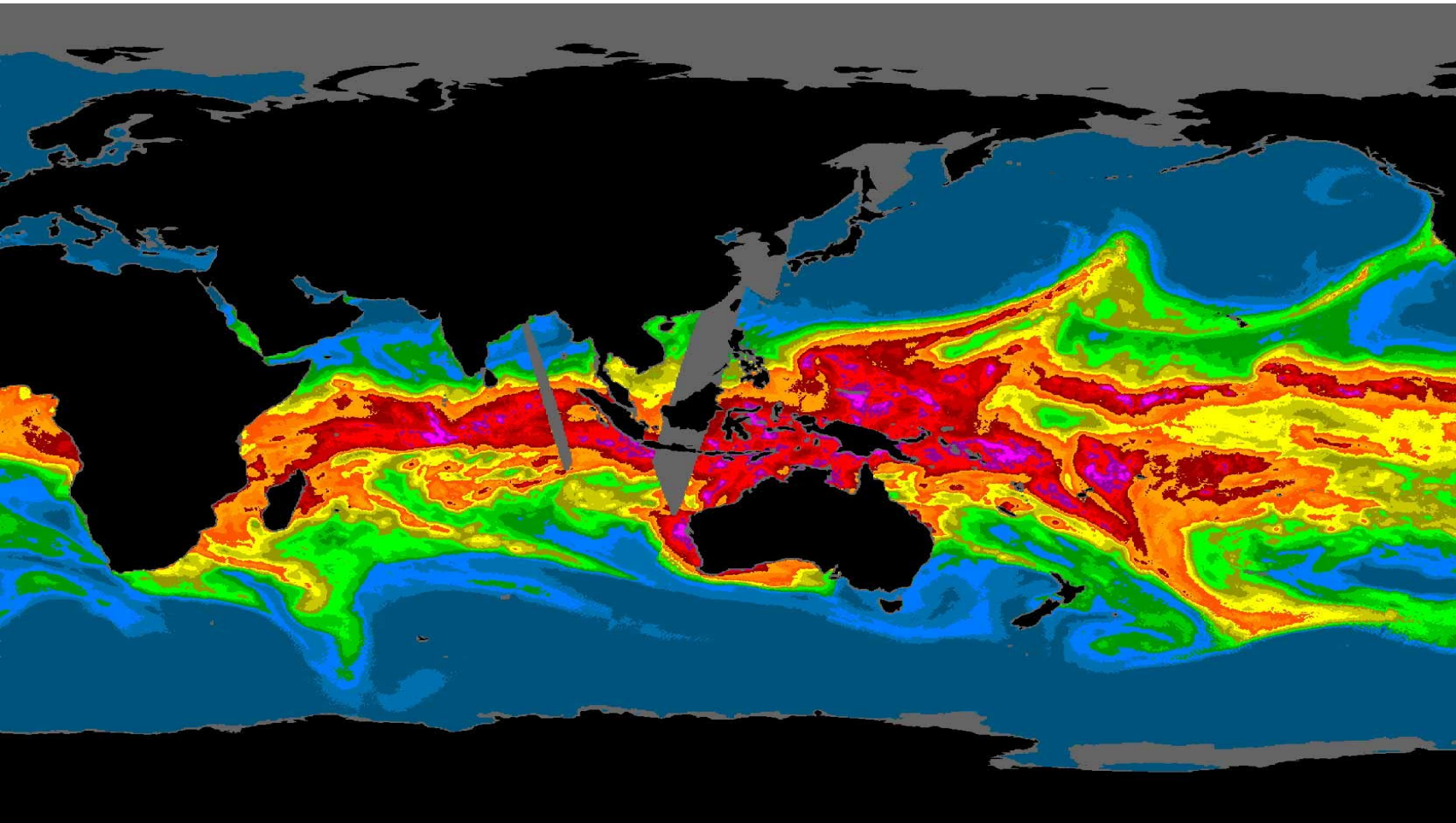
Number of Hours / Year Generating 50%  
of Total Precipitation, 1995-2016



10-100 hrs/yr  
provide half of  
precip

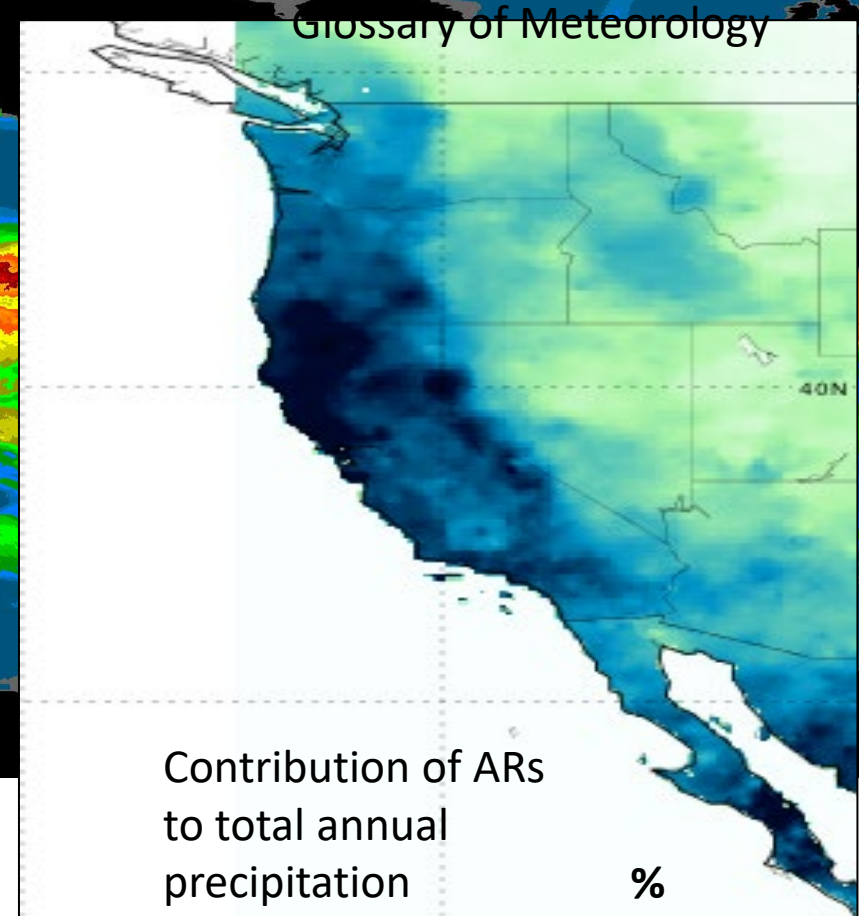


# Atmospheric Rivers



ATMOSPHERIC  
WATER VAPOR

Gershunov A., T.M. Shulgina, F.M. Ralph, D. Lavers and J.J. Rutz, 2017: Assessing climate-scale variability of Atmospheric Rivers affecting western North America. *Geophysical Research Letters*, 44, doi:10.1002/2017GL074175.



Glossary of Meteorology

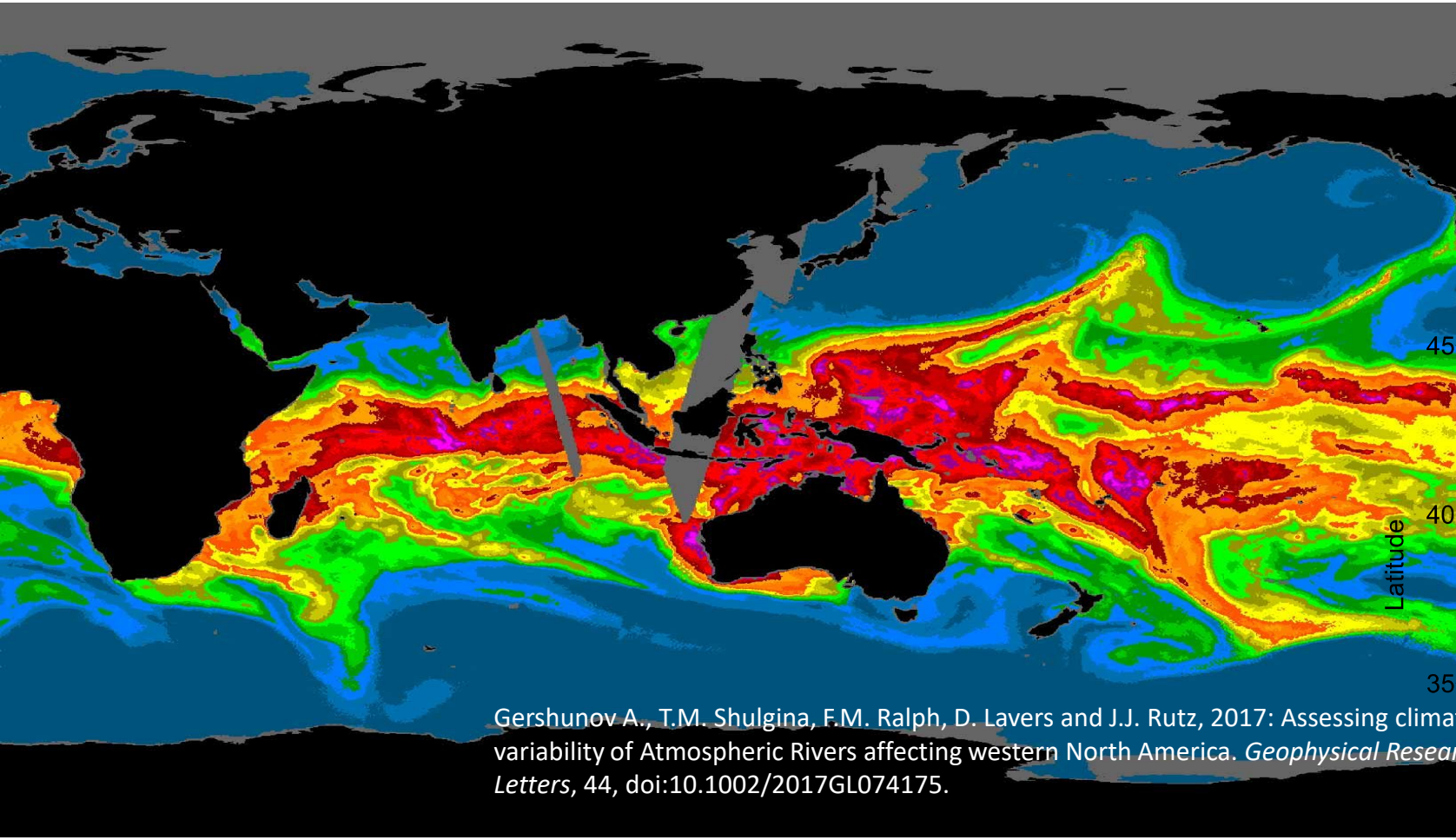
Contribution of ARs  
to total annual  
precipitation

%





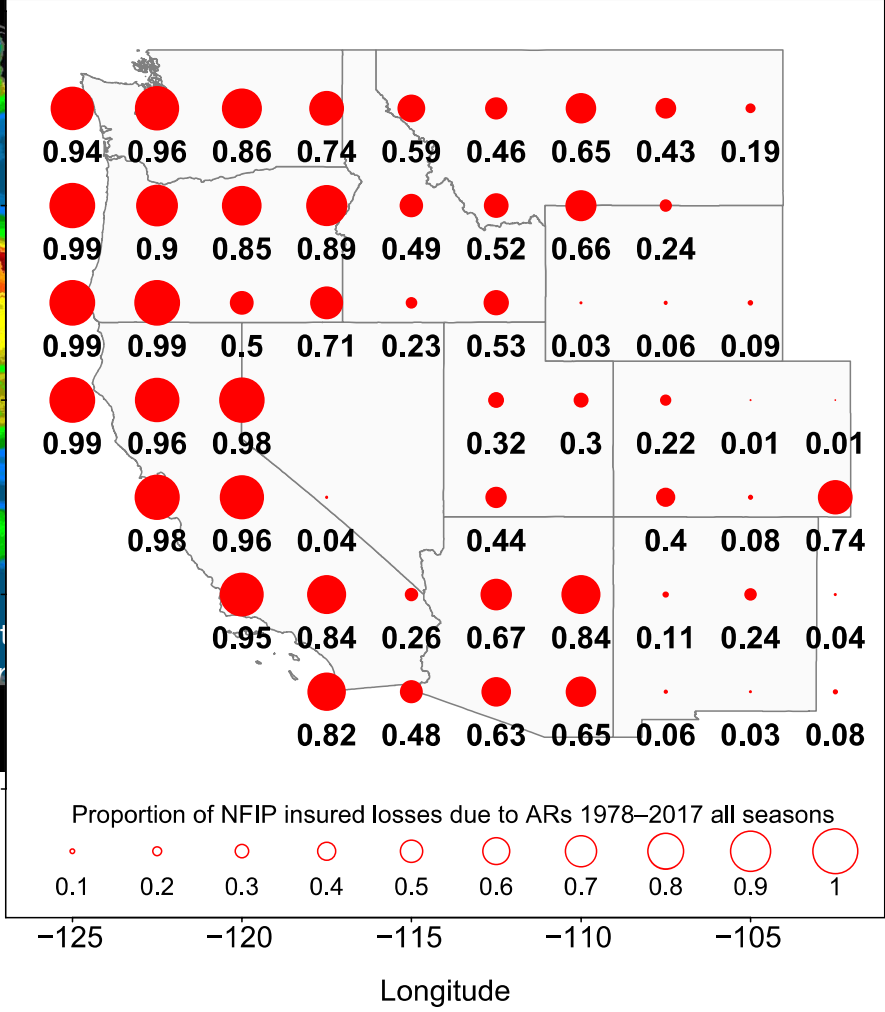
# Atmospheric Rivers



Gershunov A., T.M. Shulgina, F.M. Ralph, D. Lavers and J.J. Rutz, 2017: Assessing climate variability of Atmospheric Rivers affecting western North America. *Geophysical Research Letters*, 44, doi:10.1002/2017GL074175.

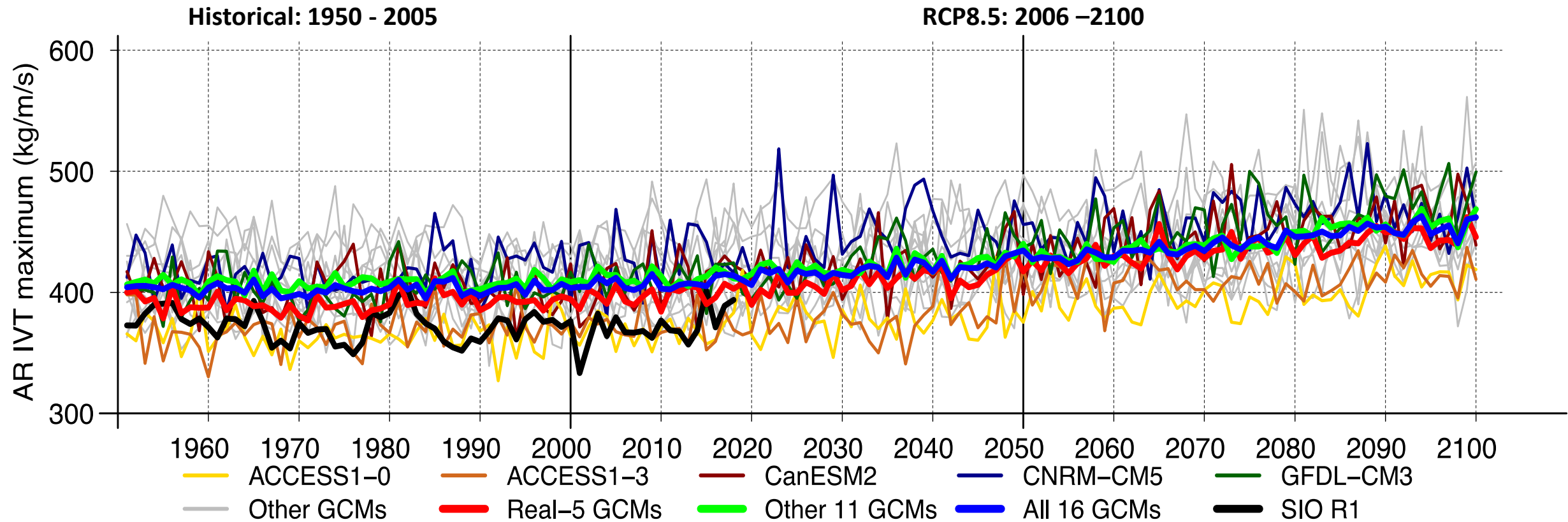
ATMOSPHERIC WATER VAPOR

Corringham et al., *Science Advances* 2019





# Intensity of ARs land-falling upon the West Coast (20-60° N)

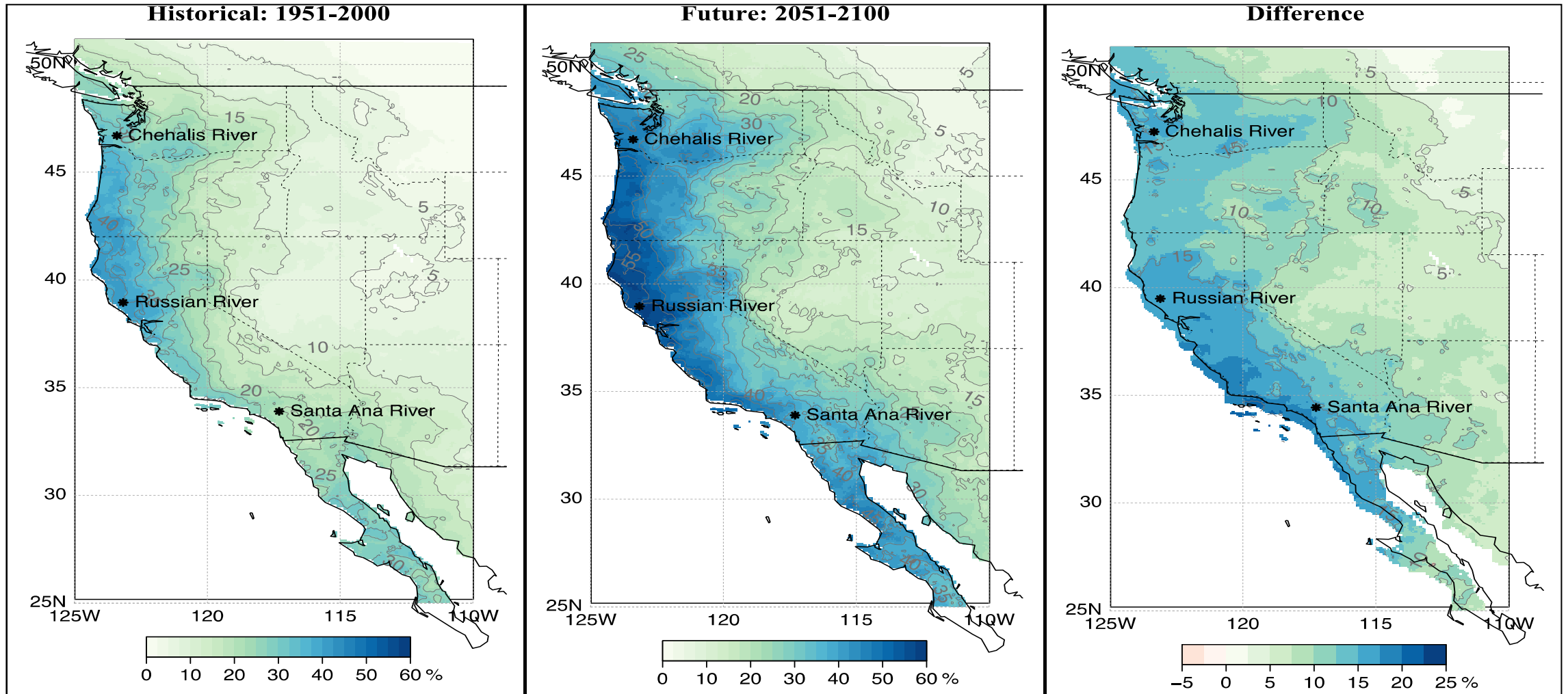


Annual average maximum IVT (kg/m/s) for AR events land-falling upon the West Coast [20-60°N]  
in historical and projected epochs.

Gershunov, A., T.M. Shulgina, R.E.S. Clemesha, K. Guirguis, D.W. Pierce, M.D. Dettinger, D.A. Lavers, D.R. Cayan, S.D. Polade, J. Kalansky and F.M. Ralph, 2019: **Precipitation regime change in Western North America: The role of Atmospheric Rivers**. *Nature Scientific Reports*, 9:9944, DOI: 10.1038/s41598-019-46169-w.

<https://rdcu.be/bJPK0>

# Modeled AR contribution to total annual precipitation (Real-5 GCM ensemble average)



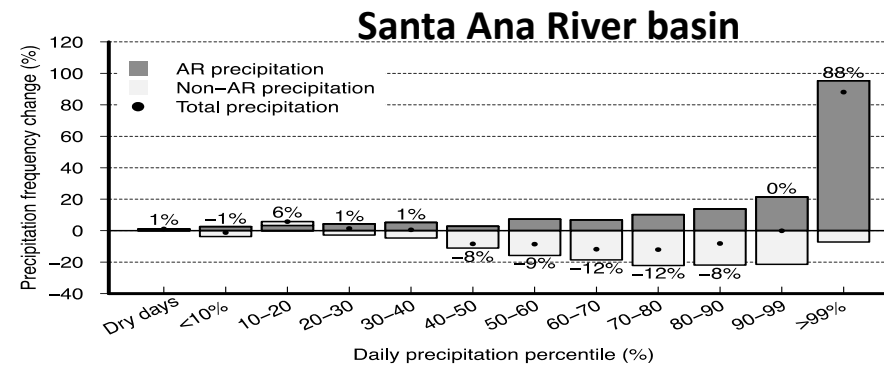
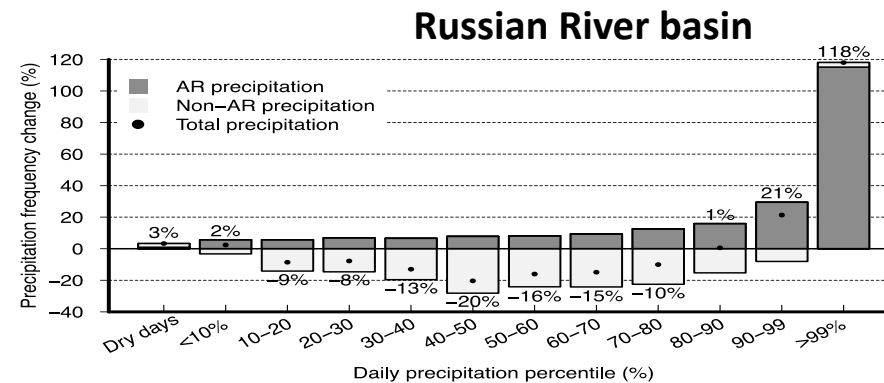
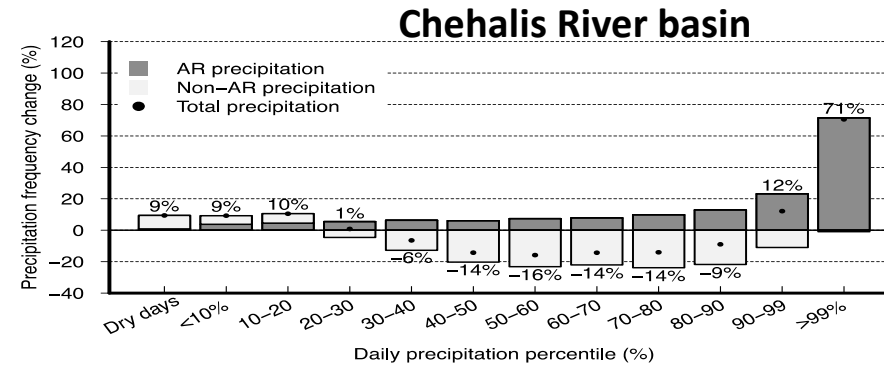
LOCA-downscaled precipitation (Pierce et al. 2015)

Gershunov, A., T.M. Shulgina, R.E.S. Clemesha, K. Guirguis, D.W. Pierce, M.D. Dettinger, D.A. Lavers, D.R. Cayan, S.D. Polade, J. Kalansky and F.M. Ralph, 2019: **Precipitation regime change in Western North America: The role of Atmospheric Rivers**. *Nature Scientific Reports*, 9:9944, DOI: 10.1038/s41598-019-46169-w.

<https://rdcu.be/bjPKO>

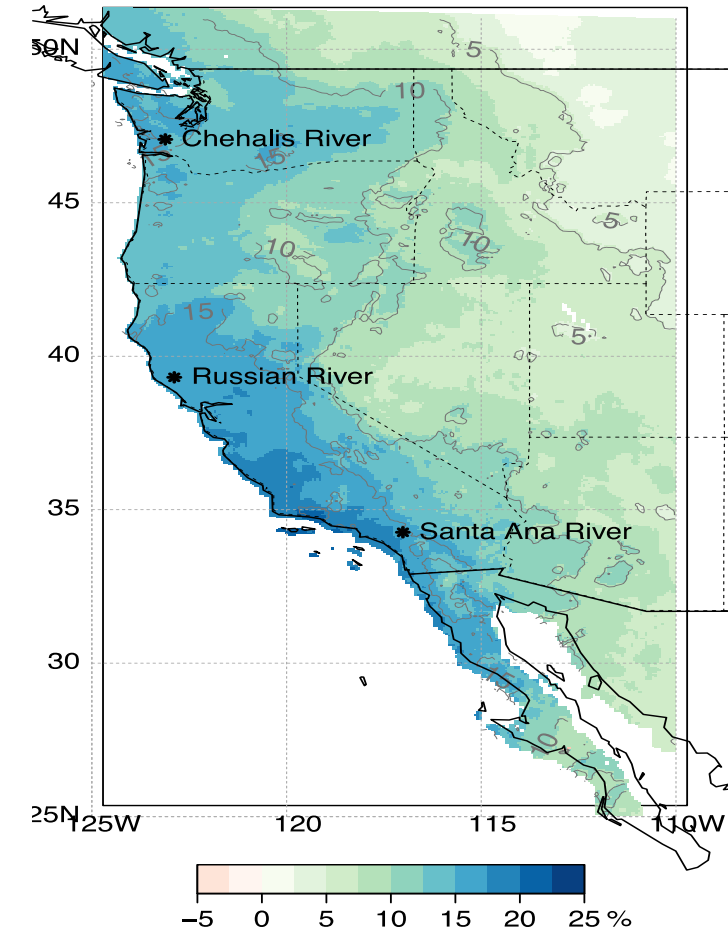


## Change (%) in precipitation frequency by intensity bins (LOCA, 5 GCM average):



Historical intensity bins

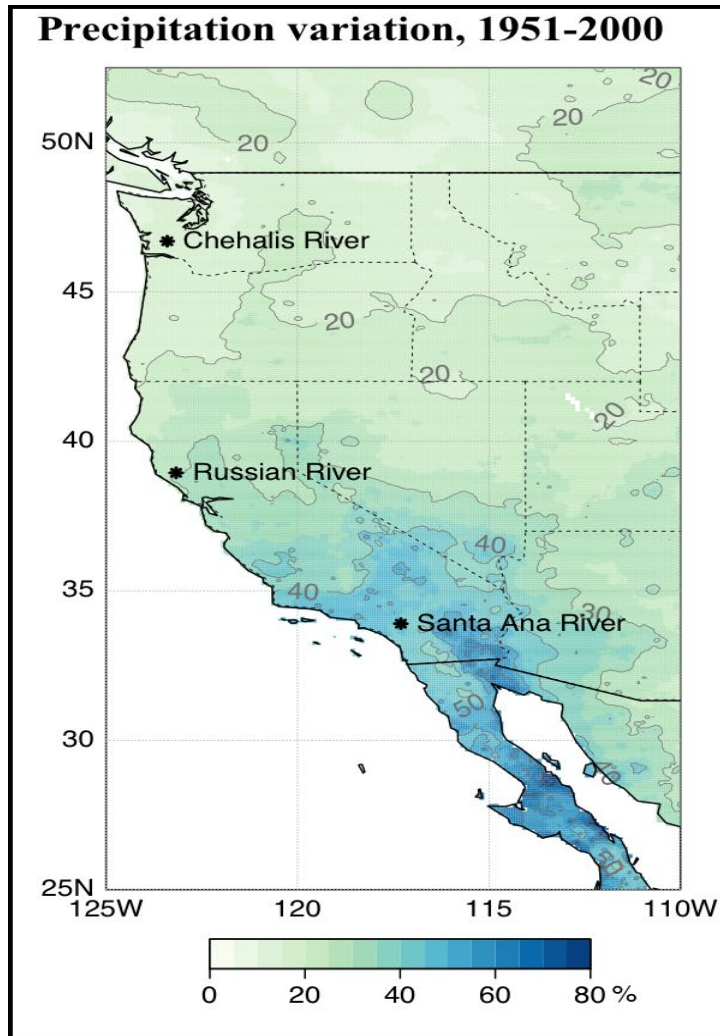
## Change (%) in AR contribution to total annual precipitation:



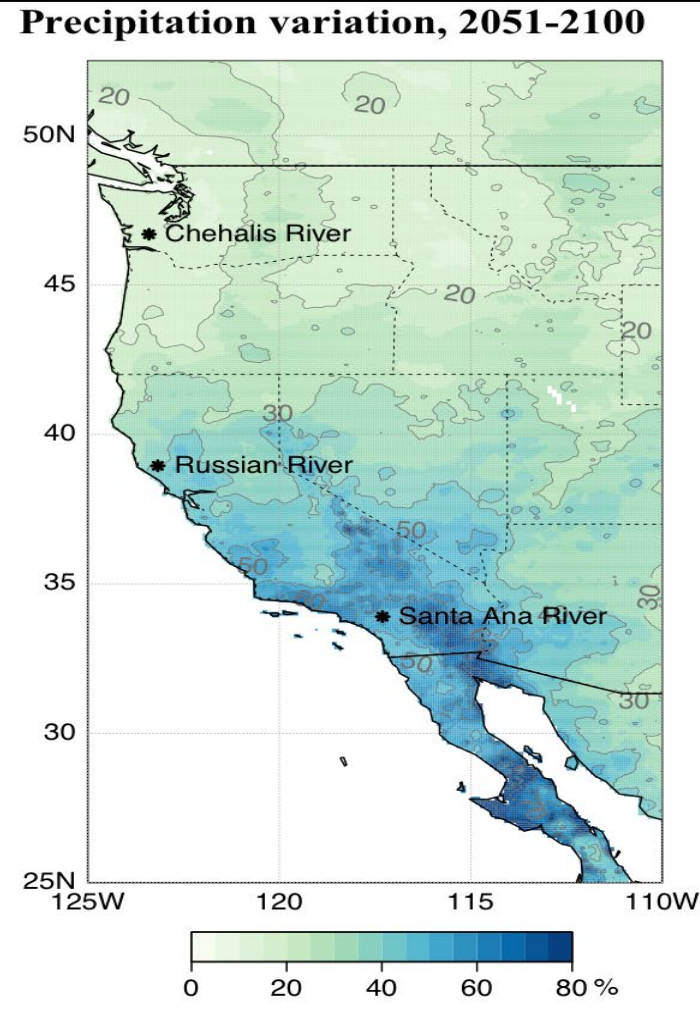
**EXTREME PRECIP INCREASING DUE TO ARs**  
(PRECIP DISTRIBUTION SHIFTING TO MORE EXTREME VALUES DUE TO ARs)

# California's hydroclimate is becoming more variable

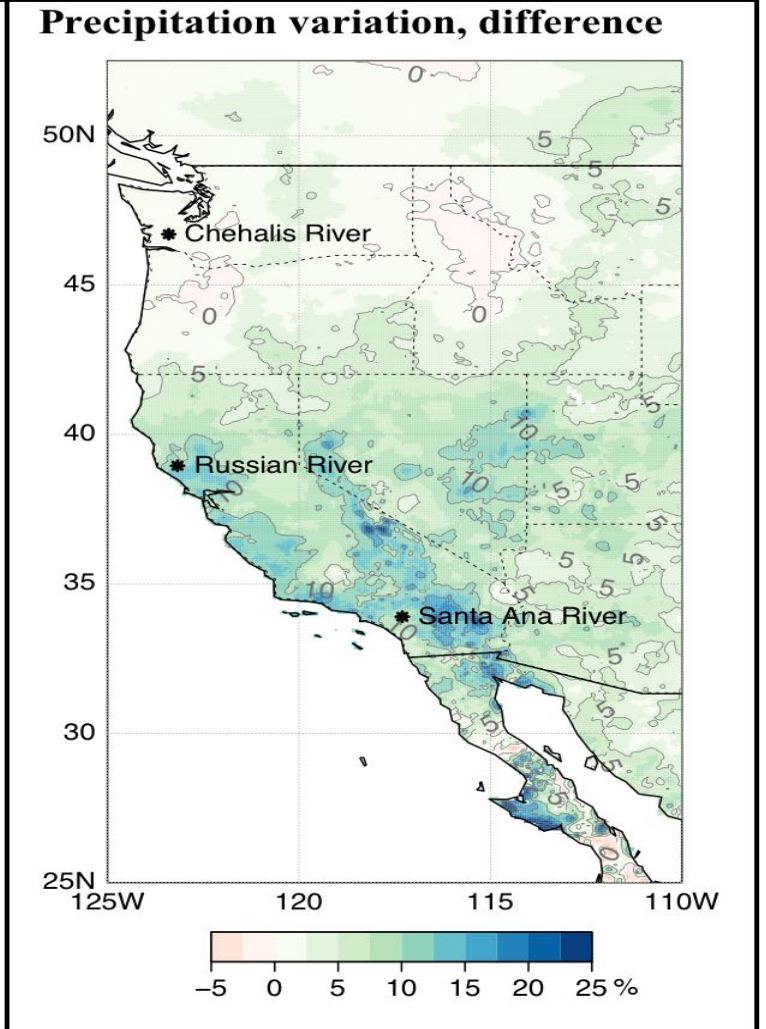
Natural variability of total annual precipitation  
Historical



Future



relative to the historical annual average  
Change (%)



Gershunov, A., T.M. Shulgina, R.E.S. Clemesha, K. Guirguis, D.W. Pierce, M.D. Dettinger, D.A. Lavers, D.R. Cayan, S.D. Polade, J. Kalansky and F.M. Ralph, 2019: **Precipitation regime change in Western North America: The role of Atmospheric Rivers**. *Nature Scientific Reports*, 9:9944, DOI: 10.1038/s41598-019-46169-w.

<https://rdcu.be/bJPK0>



# Atmospheric Rivers are poised to play a bigger role in a warmer future

- Providing heavier precipitation in drier times “Flood during drought”
- Thermodynamics boost ARs (ARs on steroids)
- Hazardous/beneficial AR ratio may be expected to change?
- **More variability of water resources from year to year**
- Bigger challenges for
  - Water resource management
  - Weather and climate forecasting
  - Snowpack accumulation and retention
  - Water quality
  - Wildfire management and related impacts
  - Etc.
- **Skillful prediction of ARs (all timescales and lead-times) becomes even more important**



# Part II: Atmospheric Rivers are already getting a boost from global warming

Michaelis, A., A. Gershunov, A. Weyant, M. Fish, T. Shulgina and F. M. Ralph, 2022: **Atmospheric river precipitation enhanced by climate change: A case study of the storm that contributed to California's Oroville Dam crisis.** *Earth's Future*, 10, e2021EF002537.  
<https://doi.org/10.1029/2021EF002537>

Oroville AR February 2017

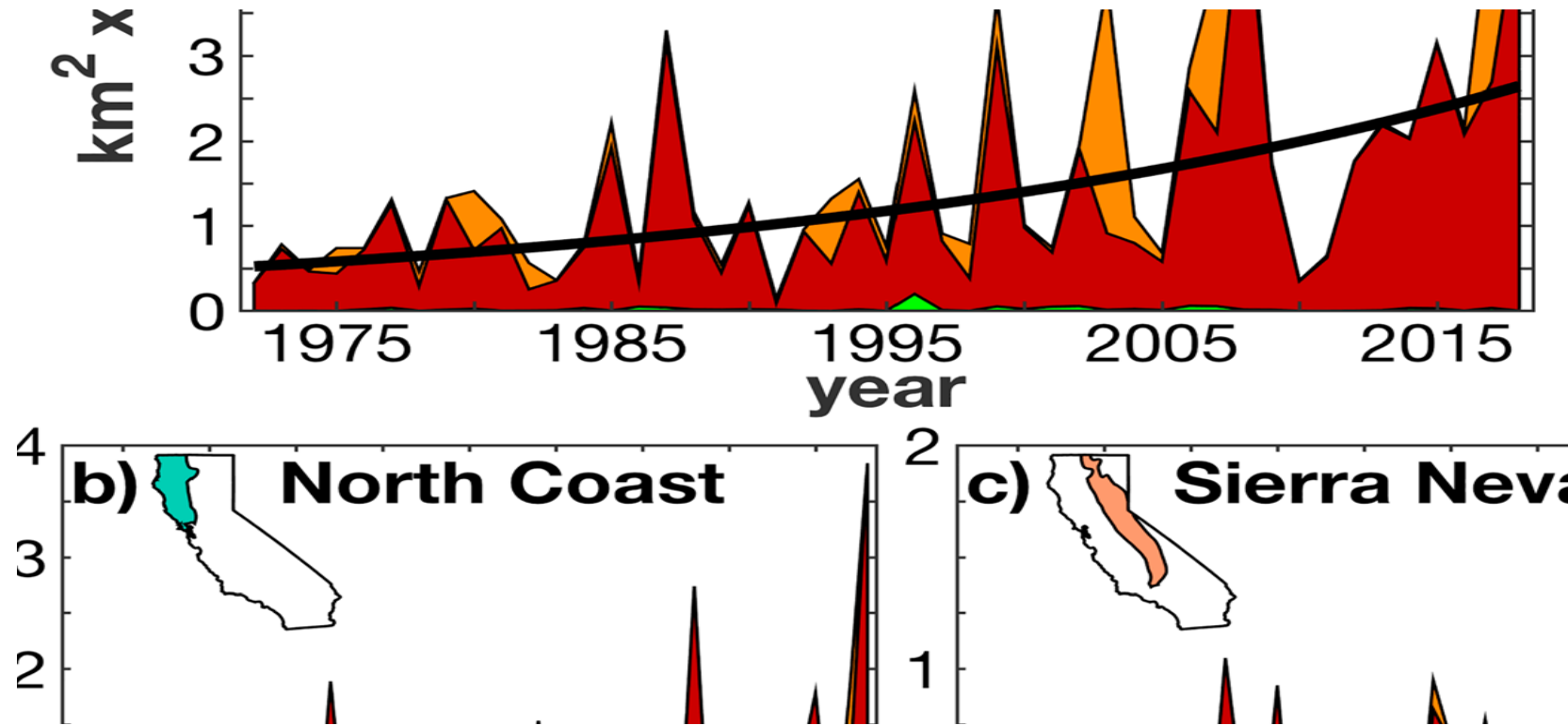




Adding heat, wind, wildfire and smoke to the mix...



# Wildfire Trends in California

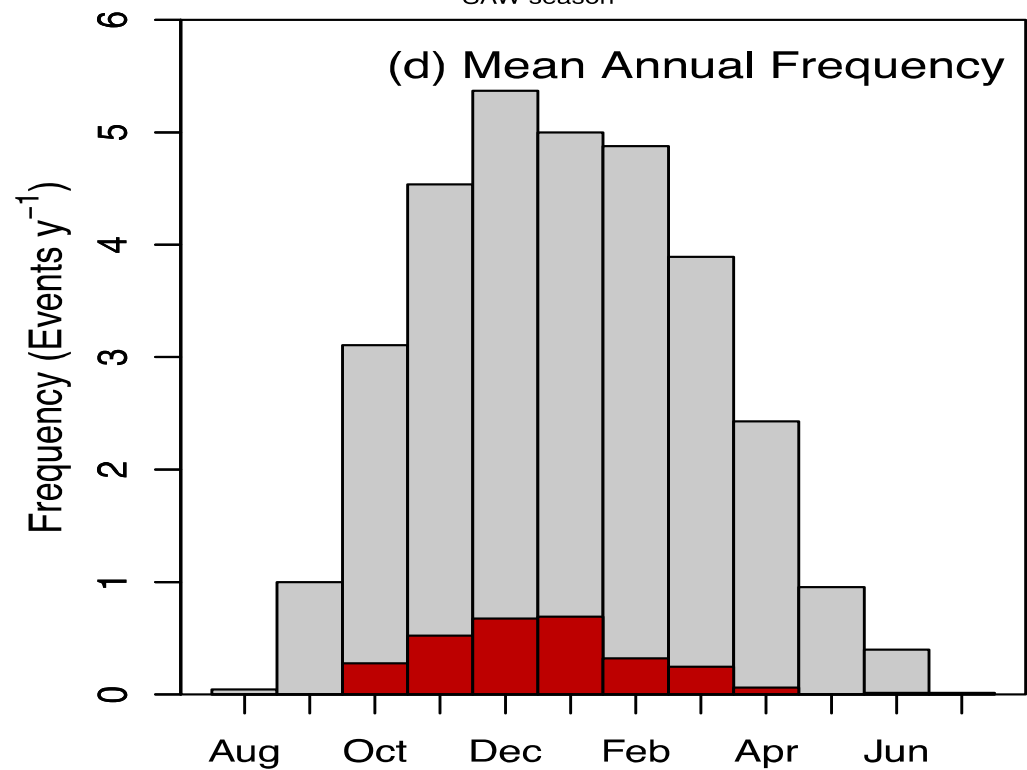
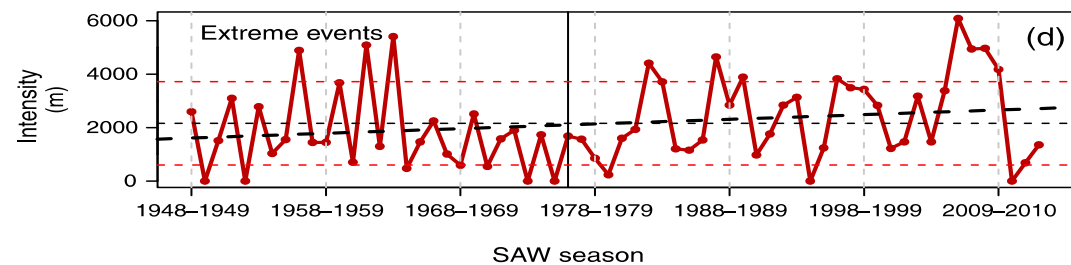


trends are shown as bold black curves.

umber (orange). Significant ( $p < 0.05$ )



# Santa Ana Winds



Guzman Morales, J., A. Gershunov, J. Theiss, H. Li and D. Cayan, 2016: Santa Ana Winds of southern California: their climatology, extremes and behavior since 1948. *Geophysical Research Letters*, 43, doi:[10.1002/2016GL067887](https://doi.org/10.1002/2016GL067887).



# Smoke From Wildfires



- Leibel S., M. Nguyen, W. Brick, J. Parker, S. Ilango, R. Aguilera, A. Gershunov, T. Benmarhnia, 2019: Increase in Pediatric Respiratory Visits Associated With Santa Ana Wind-driven Wildfire and PM 2.5 levels in San Diego County. *Annals of the American Thoracic Society*, in press.
- Aguilera, R., A. Gershunov, S.D. Ilango, J. Guzman Morales and T. Benmarhnia, 2020: Santa Ana winds of Southern California impact PM2.5 with and without smoke from wildfires. *GeoHealth*, 4, e2019GH000225. <https://doi.org/10.1029/2019GH000225>.
- Aguilera, R., K. Hansen, A. Gershunov, S. Ilango, P. Sheridan, and T. Benmarhnia, 2020: Respiratory Hospitalizations and Wildfire Smoke: A spatio-temporal analysis of an extreme firestorm in San Diego County, California. *Environmental Epidemiology*, 4, doi: 10.1097/EE9.0000000000000114.
- Aguilera, R., T. Corringham, A. Gershunov and T. Benmarhnia, 2021: Wildfire smoke impacts respiratory health much more than fine particles from other sources: observational evidence from Southern California. *Nature Communications*. 12:1493, <https://doi.org/10.1038/s41467-021-21708>.
- Aguilera, R., T. Corringham, A. Gershunov, S. Leibel and T. Benmarhnia, 2021: Fine Particles in Wildfire Smoke and Pediatric Respiratory Health in California. *Pediatrics*. 147(4):e2020027128.

David McNew / Getty Images



# STEAM & Smoke...

- Interdisciplinary science and impacts
- Climate and public health
- Co-benefits of solutions
- Art and education
- Engagement



Luna Rossel  
*Ablaze*



# Scripps Science-Inspired Art Collection



Lilleane Peebles  
*Tipping Point*



Luna Rossel  
*Dust*



Luna Rossel  
*Dissolution*

**DOWNSCALING GLOBAL CLIMATE CHANGE TO PERSONAL SCALES**

<https://scripps.ucsd.edu/about/our-campus/scripps-art-collection>



## RESILIENCE DEFINITION

CAPACITY TO ANTICIPATE, PREPARE FOR, SURVIVE (and even thrive),  
AND RECOVER FROM EXTREME EVENTS AND THEIR IMPACTS

(CONSTRUCTIVELY DEALING WITH POTENTIAL DISASTERS)

