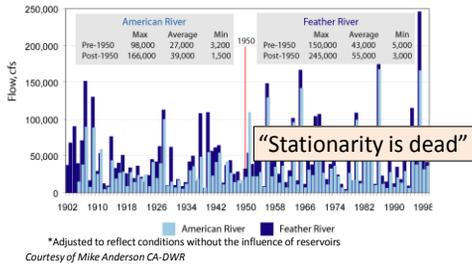


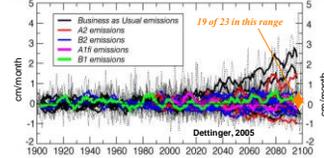


20<sup>th</sup> Century Annual Peak 3-day Flows\*



A Key Challenge: Changing Climate

PROJECTED CHANGES IN ANNUAL PRECIPITATION, NORTHERN CALIFORNIA



Annual precipitation projections vary mostly due to how extreme precipitation events are handled (in CA this means ARs).

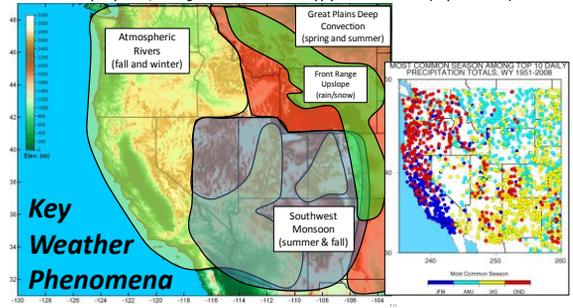
Pierce et al 2013 (J. Clim.). Model disagreements in the projected change in occurrence of the heaviest precipitation days (>60 mm day<sup>-1</sup>) account for the majority of disagreement in the projected change in annual precipitation, and occur preferentially over the Sierra Nevada and Northern California.

CalWater-2015

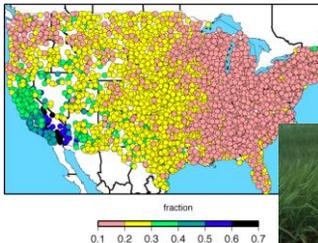


DOE G-1 aircraft: measuring cloud, rain and snow particles, as well as aerosols such as dust and smoke from sources near and far  
 NOAA G-IV aircraft: measuring atmospheric river strength and structure offshore using dropsondes and precipitation radar  
 NOAA P-3 aircraft: measuring ocean and atmosphere with radars for precipitation, cloud & ocean waves, and air & ocean sondes  
 NOAA Ron Brown Ship: measuring aerosols, clouds, atmospheric rivers, ocean surface and subsurface conditions  
 DOE AMF2: many sensors mounted on the NOAA ship; measuring aerosols, precipitation, clouds & winds aloft and at the surface  
 CA Dept. of Water Resources extreme precipitation network: measuring atmospheric rivers, snow level and soil across California  
 NSF - sponsored aerosol and rain measurements at the coast  
 NASA ER-2 aircraft: measuring aerosols, clouds and water vapor with radar, lidar and radiometer

Schematic illustration of regional variations in the primary weather phenomena that lead to extreme precipitation, flooding and contribute to water supply in the Western U.S. (Ralph et al. 2014)



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



SOUTHWEST U.S. PRECIPITATION IS UNIQUELY VARIABLE



Dettinger et al. 2011, Water

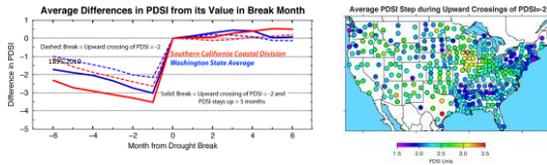


Thank you!

[mralfph@ucsd.edu](mailto:mralfph@ucsd.edu)  
[cw3e.ucsd.edu](http://cw3e.ucsd.edu)

Droughts, on average, end with a bang (and begin with a whimper) all over the U.S.  
 • **Atmospheric rivers provide the bang** in a large fraction of the west coast drought breaks, especially in winters

Dettinger, Michael D., 2013: Atmospheric Rivers as Drought Busters on the U.S. West Coast. *J. Hydrometeor.* **14**, 1721–1732.



**Key Science Gaps**

**Major goal:** Measure influx of moisture to California from landfalling atmospheric rivers and study the influence of transported (cross Pacific) or local (Central Valley) aerosols on precipitation from the coast to Sierra.

- **Evolution and structure of ARs**, including quantifying terms in the water vapor transport budget (air-sea flux, rainout, frontal convergence, entrainment from tropics)
- **Prediction of aerosol burdens and properties** during intercontinental transport from remote source regions to the U.S. West Coast, including dust, biological and ice nuclei
- **Effects of climate variability and change on these phenomena**

**CalWater 2**  
 Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment

F. Martin Ralph, K. Prather, D. Cayan (Co-Leads)  
 UC San Diego/Scipps Institution of Oceanography

Key Agencies  
 NOAA, DOE, NSF, CA DWR, NASA, ONR

**An Observing Network Design for Extreme Precipitation, Flooding and Climate**

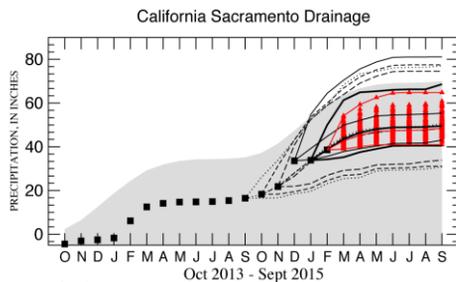
The Western States Water Council passed a Resolution that "supports development of an improved observing system for Western extreme precipitation events, to aid in monitoring, prediction, and climate trend analysis associated with extreme weather events"

Over the last decade, several programs have improved understanding of how extreme events occur, have identified gaps and prototyped solutions. The WSWC requested development of this Western Observing Systems Vision, which was presented at a WSWC workshop and in Ralph et al. 2014.

**26 experts contributed, from more than 20 organizations.**

Major strategies:

- Land-based atmospheric and snow-pack monitoring
- Coastal and offshore storm monitoring (especially ARs)
- Better weather modeling, forecasts, and support for decision makers

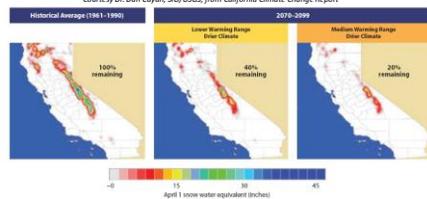


Courtesy of Mike Dettinger

**Decreasing California Snowpack**

Snow pack acts as a natural reservoir for summer and fall water supply. Its capacity is projected to decrease significantly in a warmer climate.

Courtesy Dr. Dan Cayan, SIO/USGS, from California Climate Change Report



- Under an ensemble of climate scenarios, there is marked reduction in spring snow pack:
- by 2100 the chance of achieving historical median SWE falls to about 10%
  - by 2100 the chance of SWE at or below 10 percentile historical rises to about 40%.

NSF-supported aerosol and precipitation measurements at **Bodega Bay: UCSD, Colorado State University, North Carolina University**

PIs: Kim Prather (UCSD/Scripps), Sonia Kreidenweis (CSU), Marcus Petters (NCSU)  
 Also Paul Demott (CSU) and Andrew Martin (UCSD/Scripps)

- Precipitation collections for residue chemical, biological and ice nucleation
- Aerosols
  - Single particle aerosol mass spectrometry
  - IMPROVE chemically-specified PM2.5 and PM10
  - WBS-4A bioaerosols and fluorescence microscopy collections
  - Continuous aerosol size distribution
- Cloud-active aerosols
  - Ice nucleation filter samples (integrated periods for offline analysis)
  - Selected periods of single particle ice nuclei mass spectral composition
  - Real-time ice nucleation measurements 4-8 hours daily
  - Continuous scanning CCN

Metecology (NOAA and CA DWR)



UCSD lab



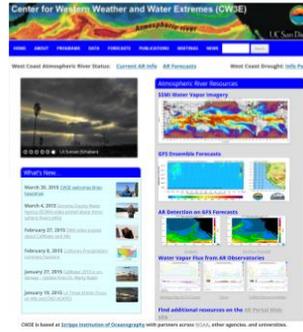
CA DWR and NOAA HMT wind profiler



Bodega Bay Lab and CalWater field site



CSU mobile lab



The CW3E website has up-to-date information on atmospheric rivers.

CW3E.UCSD.EDU