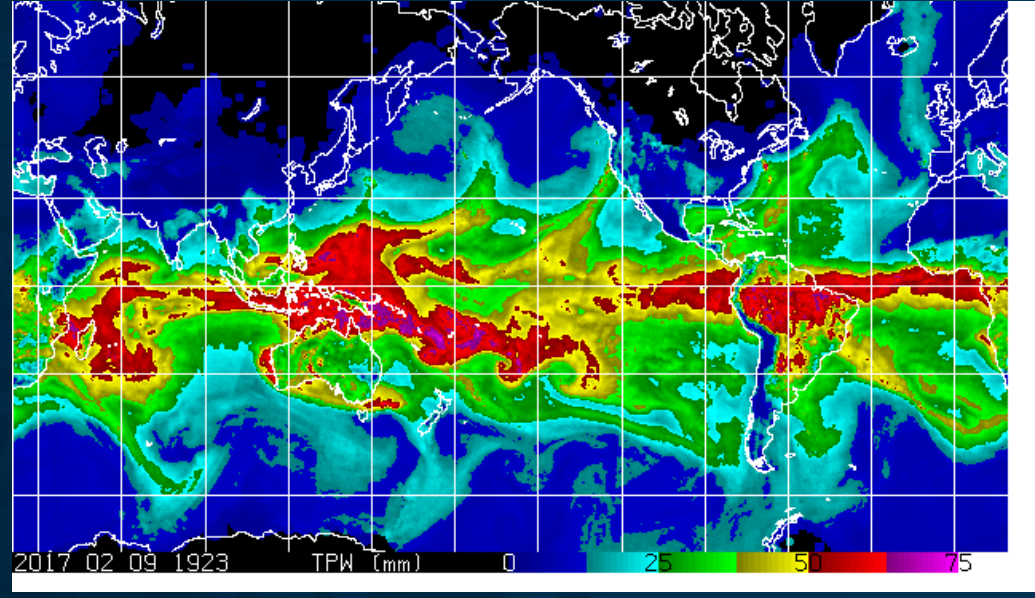


Drought, ARs and a Warming World

Dr. Michael Anderson, State Climatologist

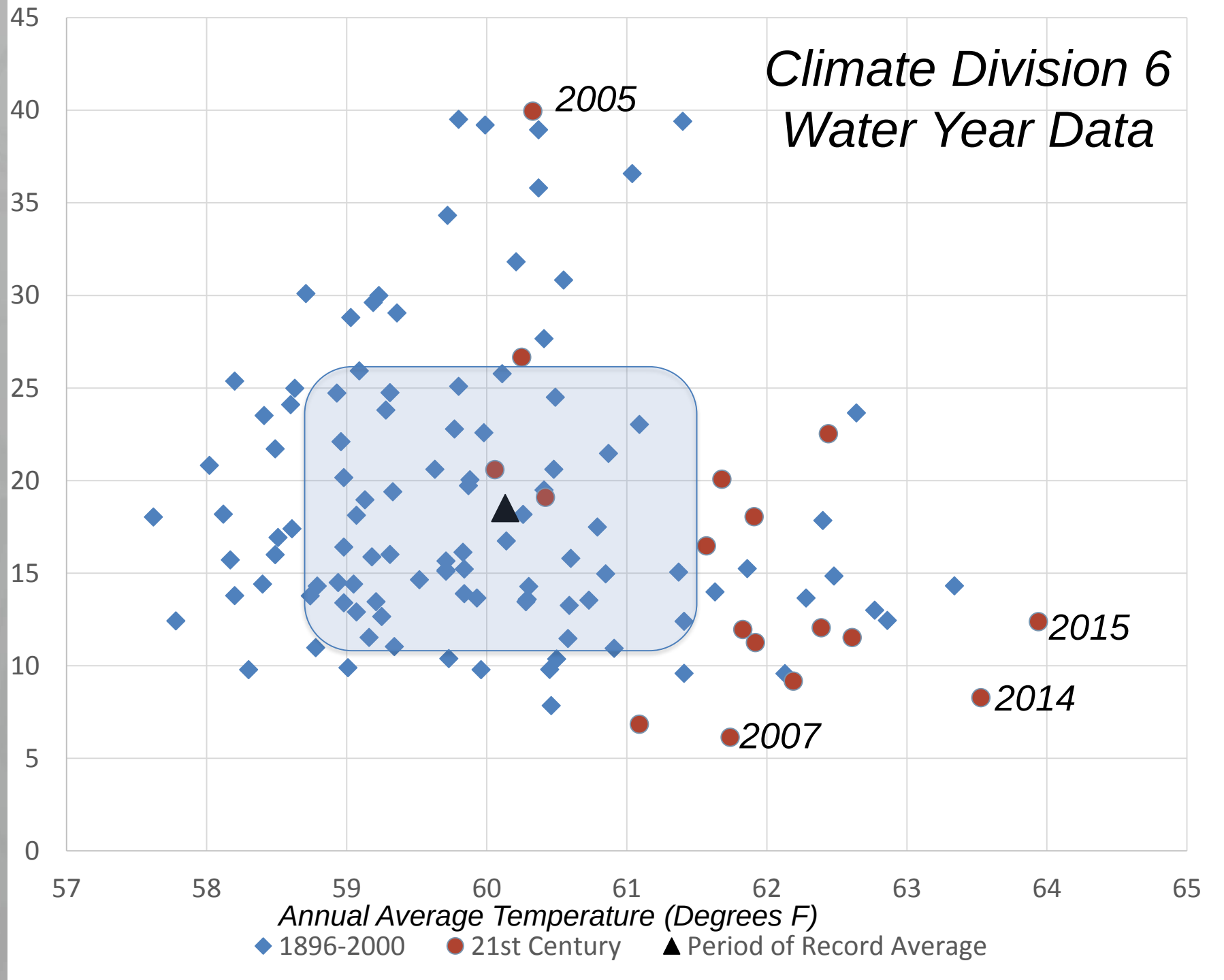
Paleo Drought Workshop, San Pedro

April 19, 2018

Talk Overview

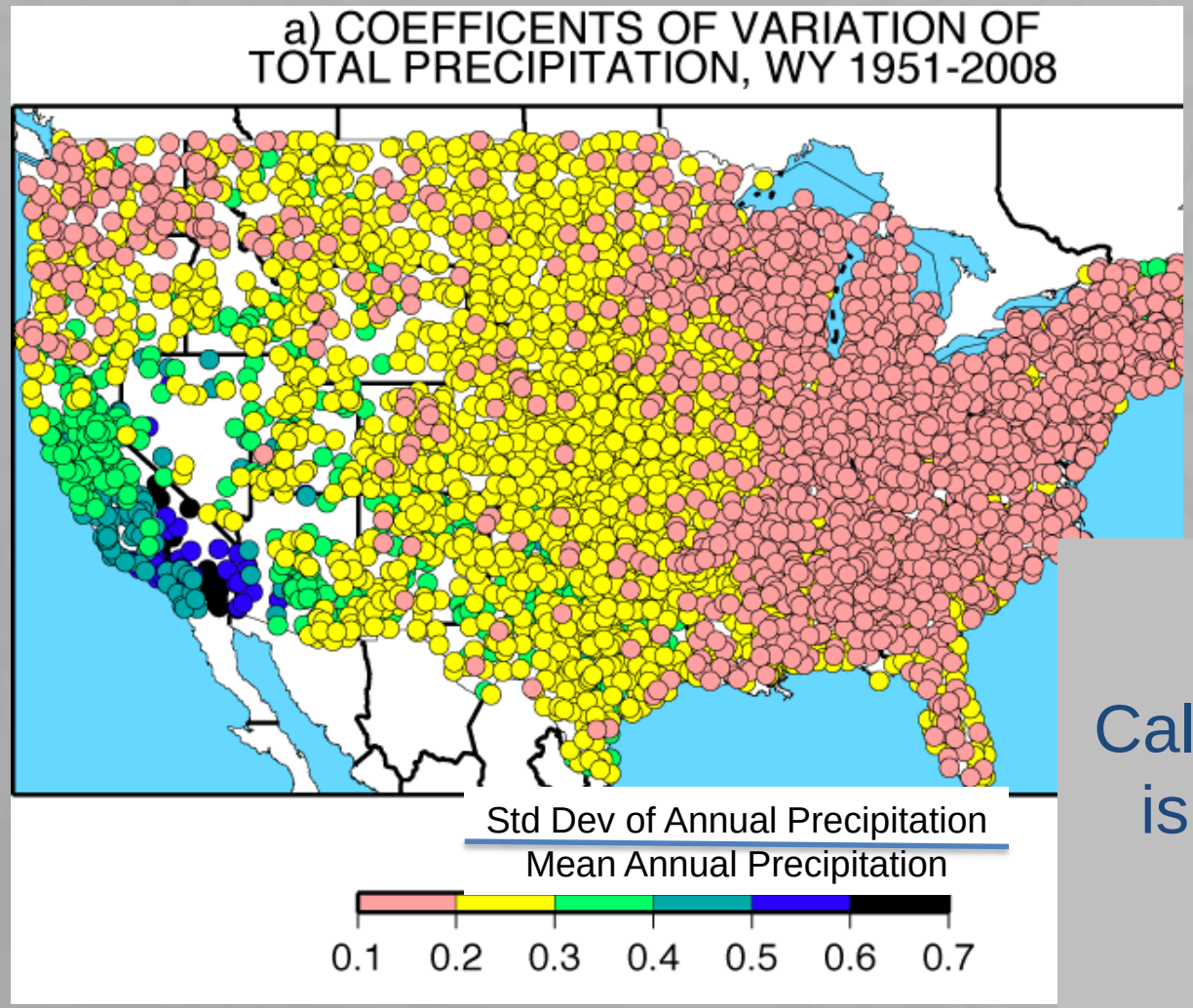
- A Warming World – Observations and Expectations
- Atmospheric Rivers in warming world
- Intel for Integrated Water Management in a Changing Climate

California's topography affects our weather and climate



New Extremes
More Variability

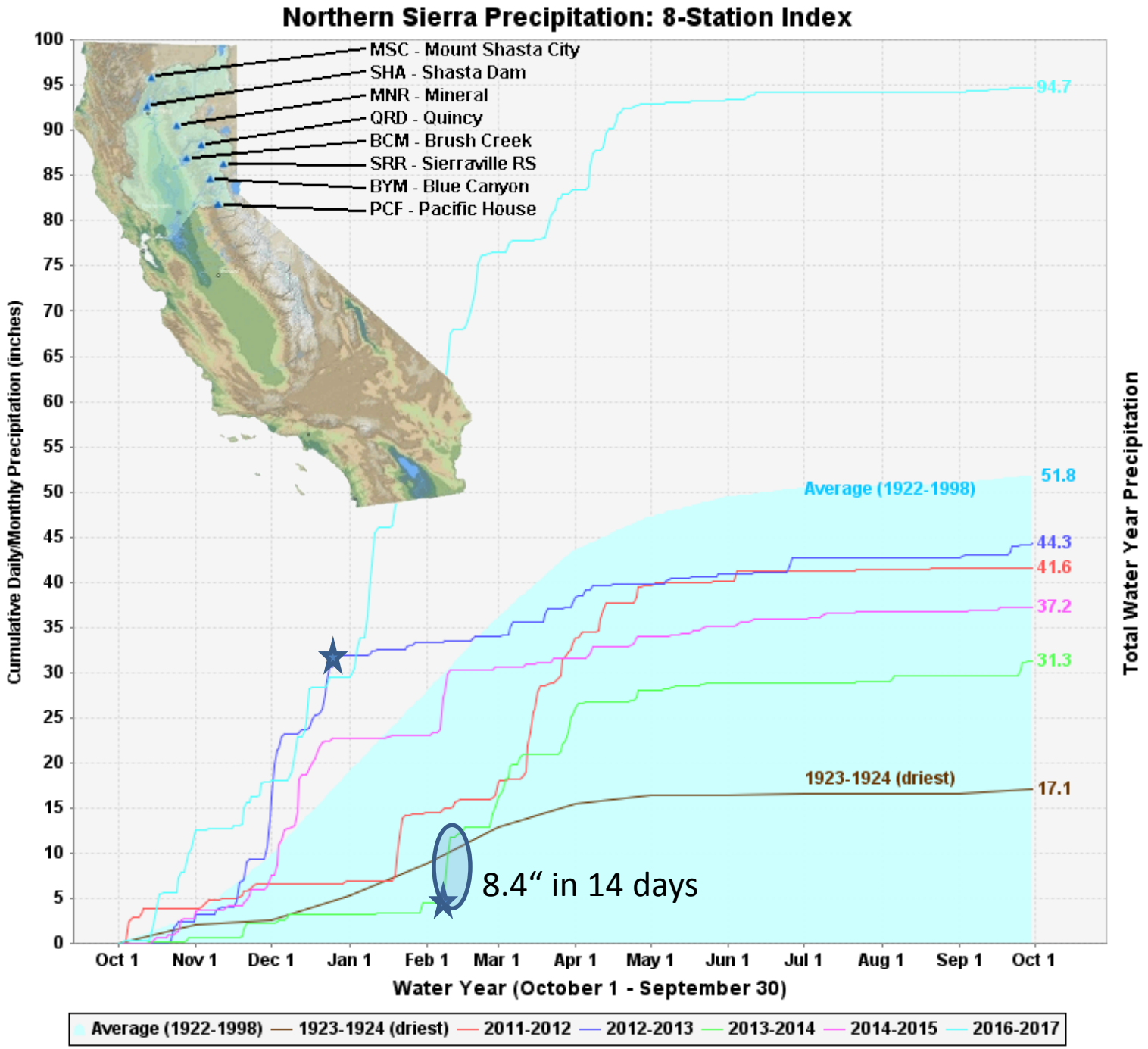
Year to Year Precipitation Variability



California precipitation is uniquely variable

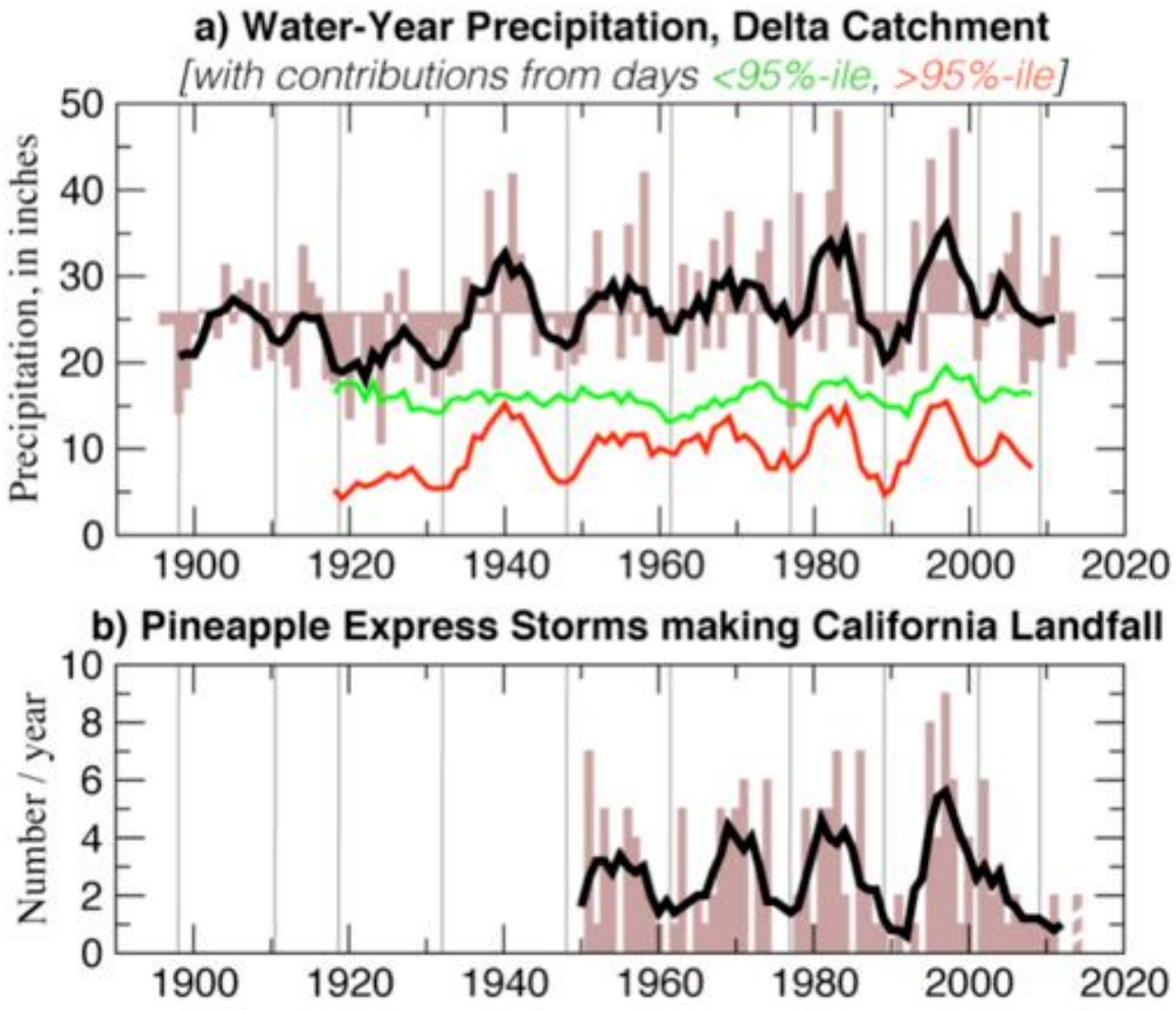
Higher values are higher variability

Dettinger et al, 2011



Variability at multiple scales

16.8”
404 Days



Source: Dettinger and Cayan (2014)

Decadal scale precipitation variability tied to Atmospheric River landfall variability

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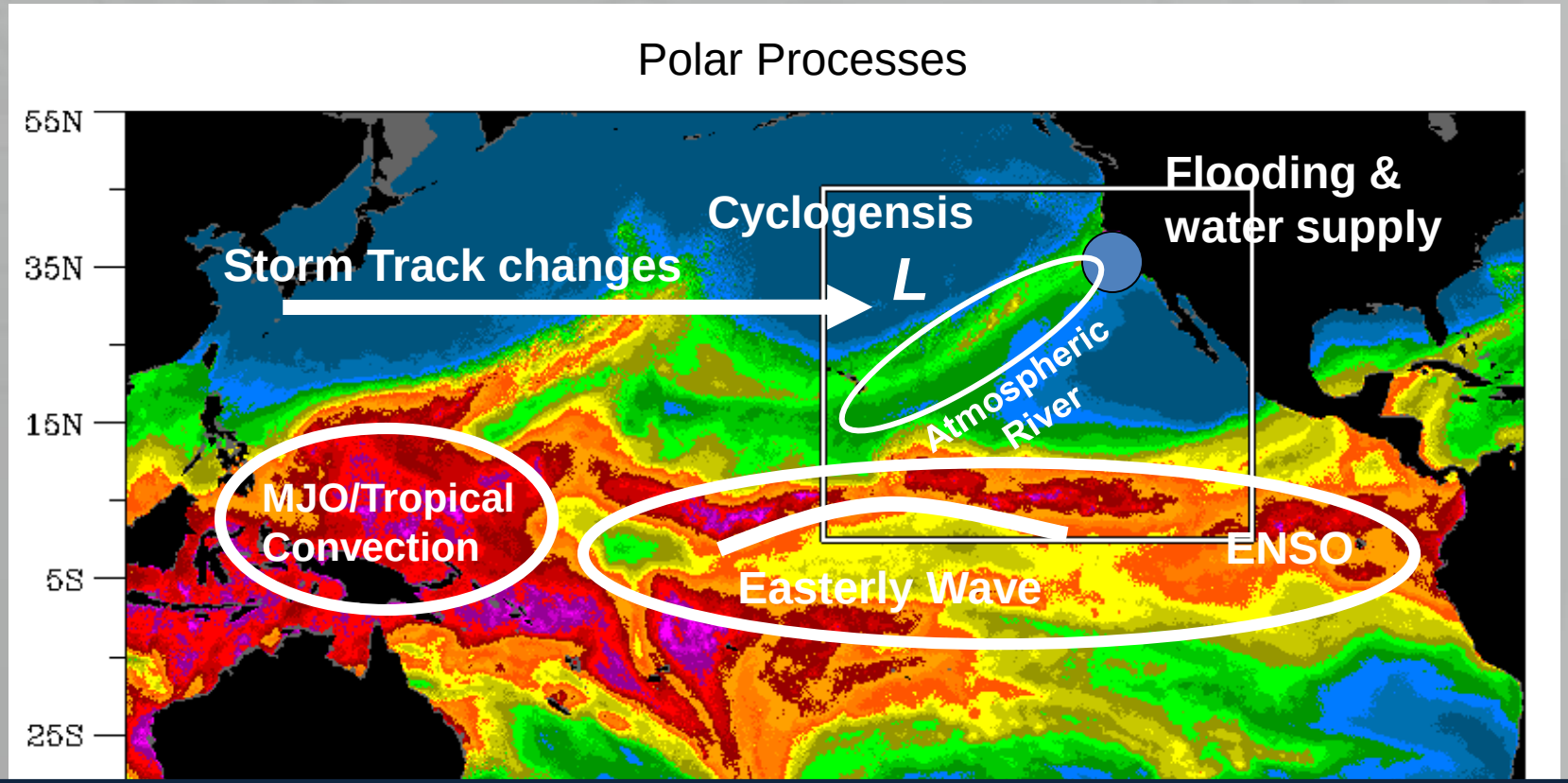
Key Phenomena Affecting California Water Supply/Flooding:



The size, number, and strength of atmospheric river events (ARs) result from the alignment of key physical processes operating on different space and time scales that will change with climate change

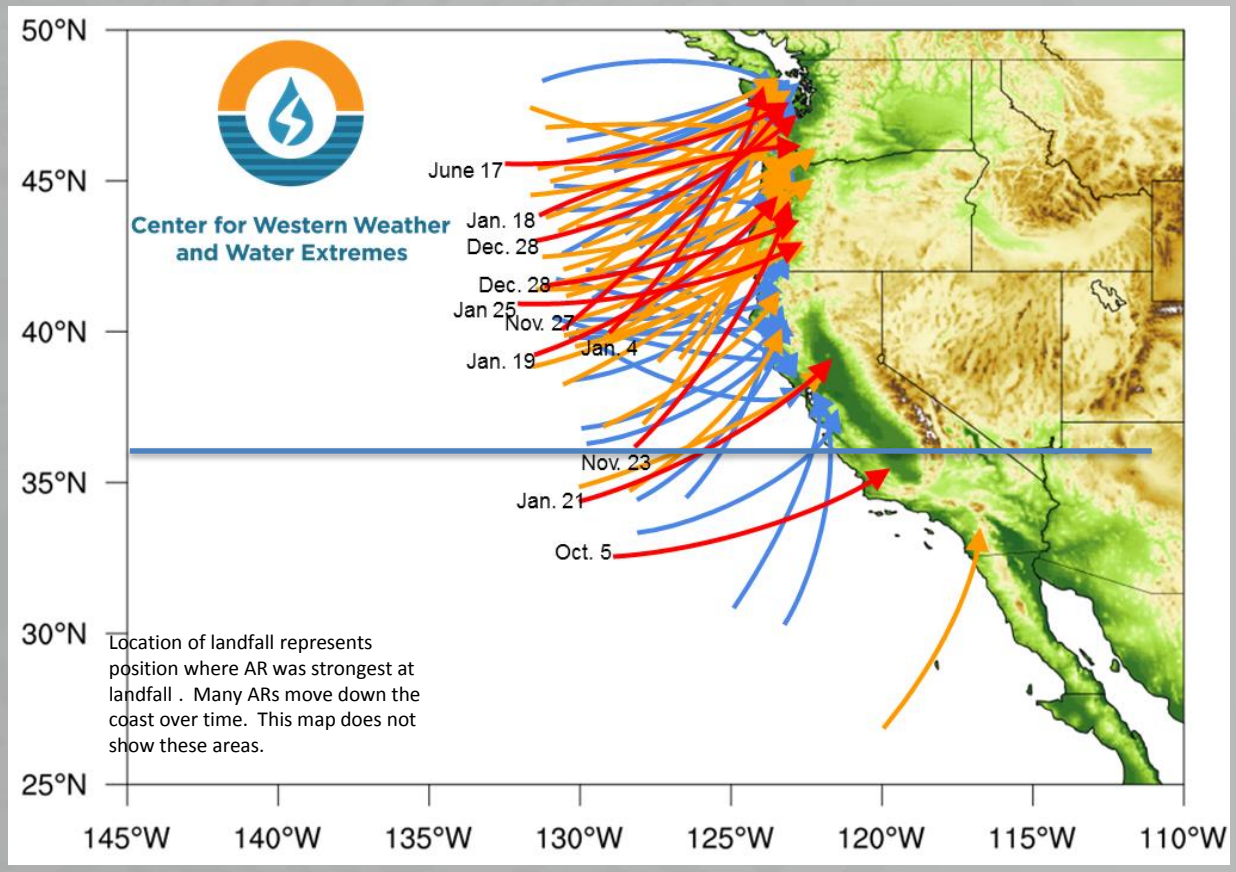
Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast During Water Year 2012

- **72** Atmospheric Rivers made landfall on the US West Coast during the 2012 water year

AR Strength	AR Count
Weak	31
Moderate	30
Strong	11
Extreme	0
Exceptional	0

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
- Extreme: IVT=1000–1250 kg m^{-1} s^{-1}
- Exceptional: IVT>1250 kg m^{-1} s^{-1}



By F.M. Ralph, C. Hecht, J. Kalansky

Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast During Water Year 2013

- **59** Atmospheric Rivers made landfall on the USWC during the 2013 water year

AR Strength	AR Count
Weak	19
Moderate	27
Strong	10
Extreme	3
Exceptional	0

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
- Extreme: IVT=1000–1250 kg m^{-1} s^{-1}
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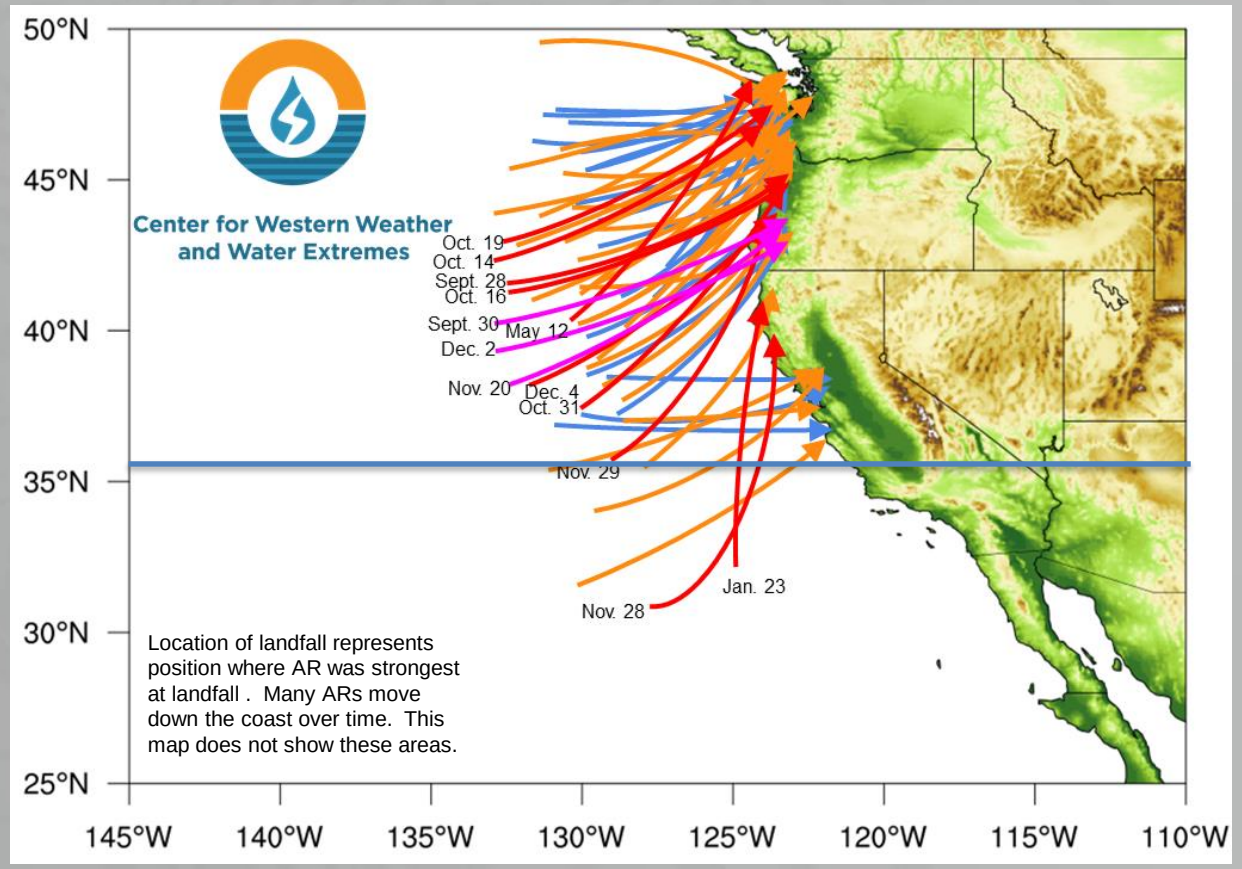

By F.M. Ralph, C. Hecht, J. Kalansky

Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast During Water Year 2014

- **54** Atmospheric Rivers made landfall on the USWC during the 2014 water year

AR Strength	AR Count
Weak	24
Moderate	23
Strong	6
Extreme	1
Exceptional	0

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
- Extreme: IVT=1000–1250 kg m^{-1} s^{-1}
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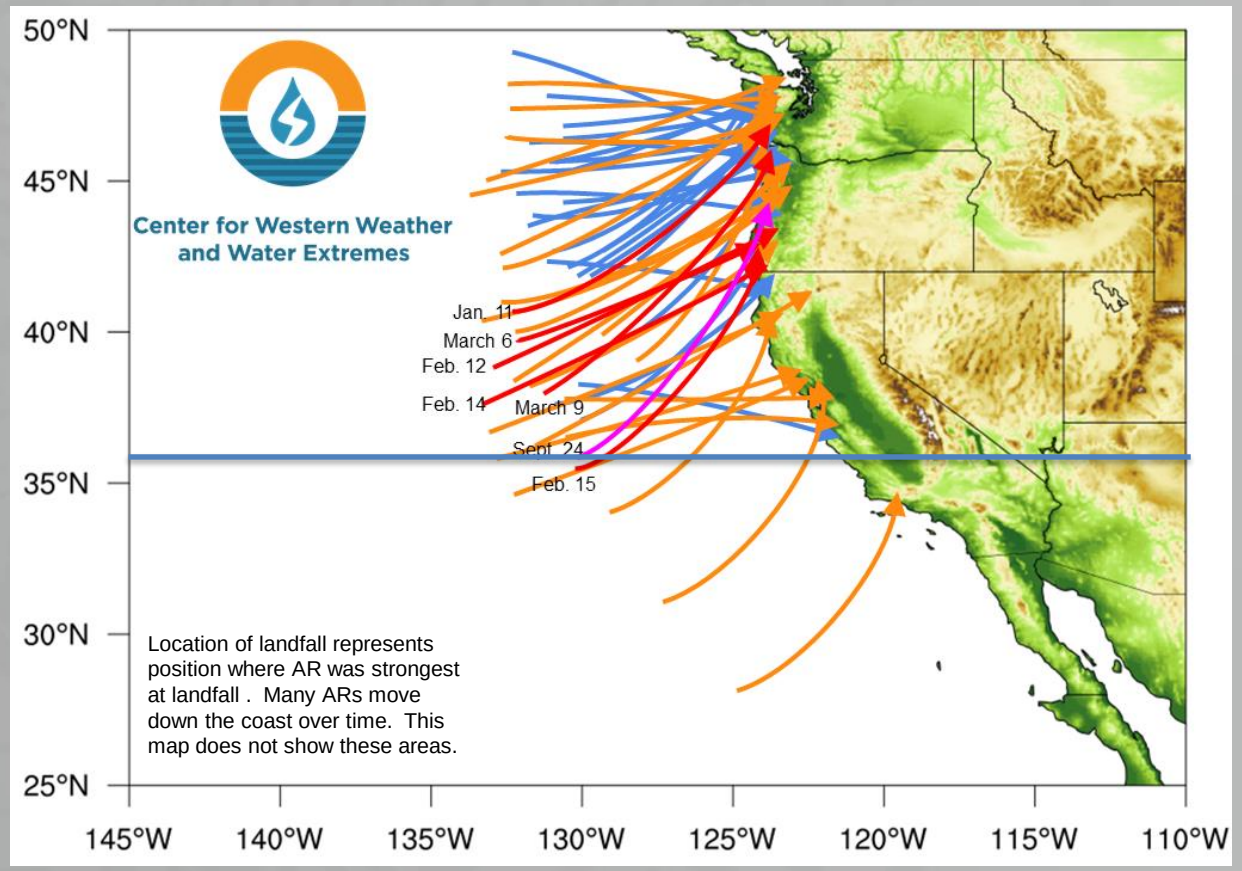

By F.M. Ralph, C. Hecht, J. Kalansky

Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast During Water Year 2015

- **57** Atmospheric Rivers made landfall on the USWC during the 2015 water year

AR Strength	AR Count
Weak	22
Moderate	20
Strong	13
Extreme	1
Exceptional	1

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
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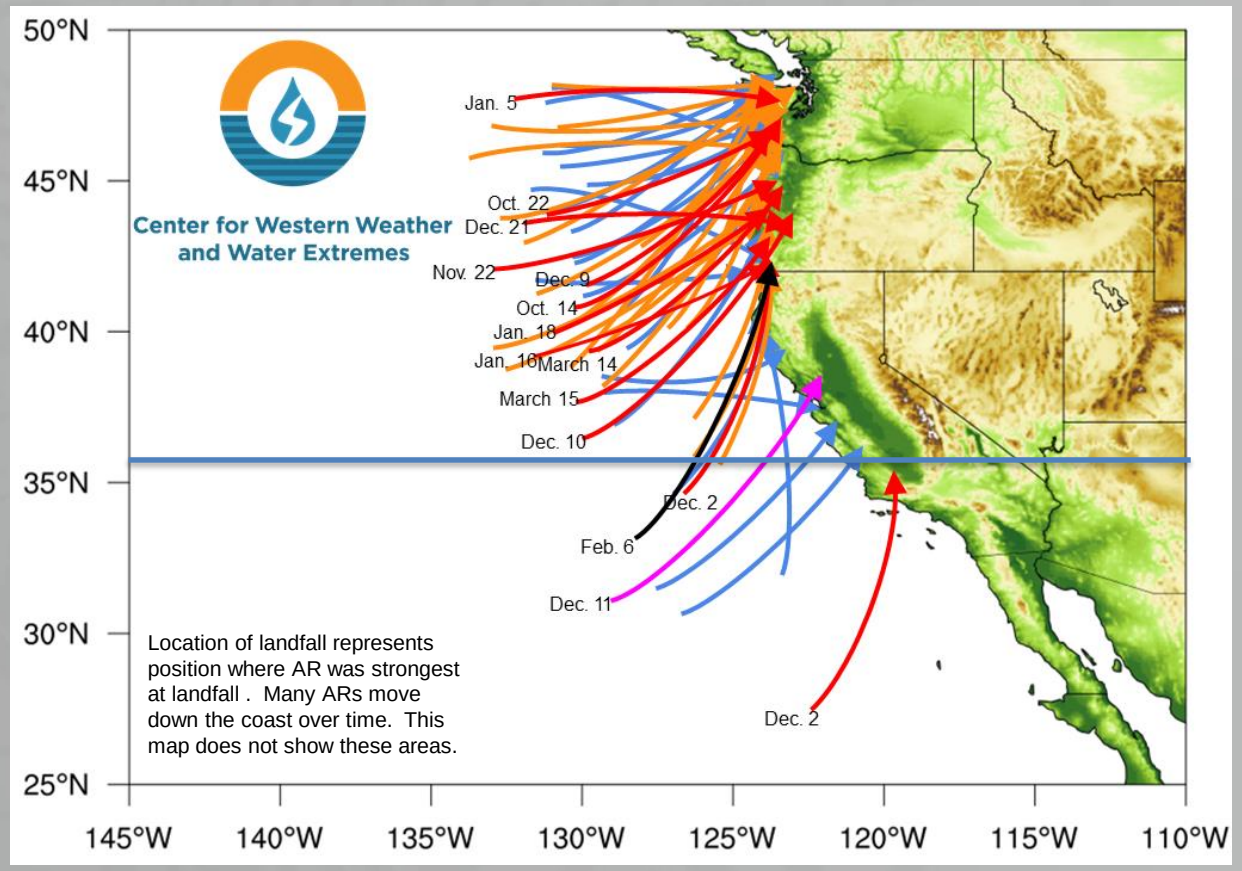

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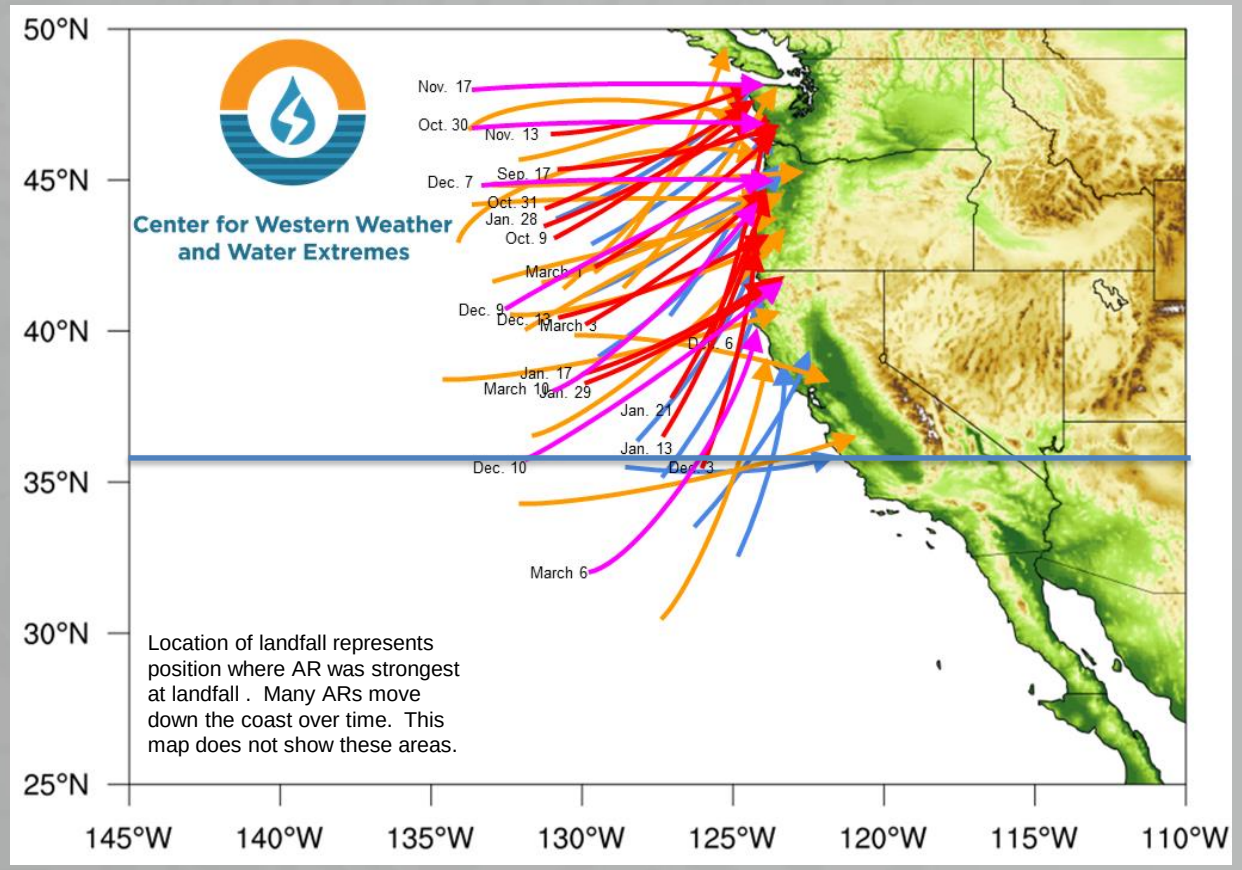
Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast During Water Year 2016

- **49** Atmospheric Rivers made landfall on the USWC during the 2016 water year

AR Strength	AR Count
Weak	11
Moderate	17
Strong	14
Extreme	7
Exceptional	0

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
- Extreme: IVT=1000–1250 kg m^{-1} s^{-1}
- Exceptional: IVT>1250 kg m^{-1} s^{-1}



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Distribution of Landfalling Atmospheric Rivers Over the U.S. West Coast During Water Year 2017

- **68** Atmospheric Rivers made landfall on the USWC during the 2017 water year

AR Strength	AR Count
Weak	21
Moderate	26
Strong	16
Extreme	5
Exceptional	0

Ralph/CW3E AR Strength Scale

- Weak: IVT=250–500 kg m^{-1} s^{-1}
- Moderate: IVT=500–750 kg m^{-1} s^{-1}
- Strong: IVT=750–1000 kg m^{-1} s^{-1}
- Extreme: IVT=1000–1250 kg m^{-1} s^{-1}
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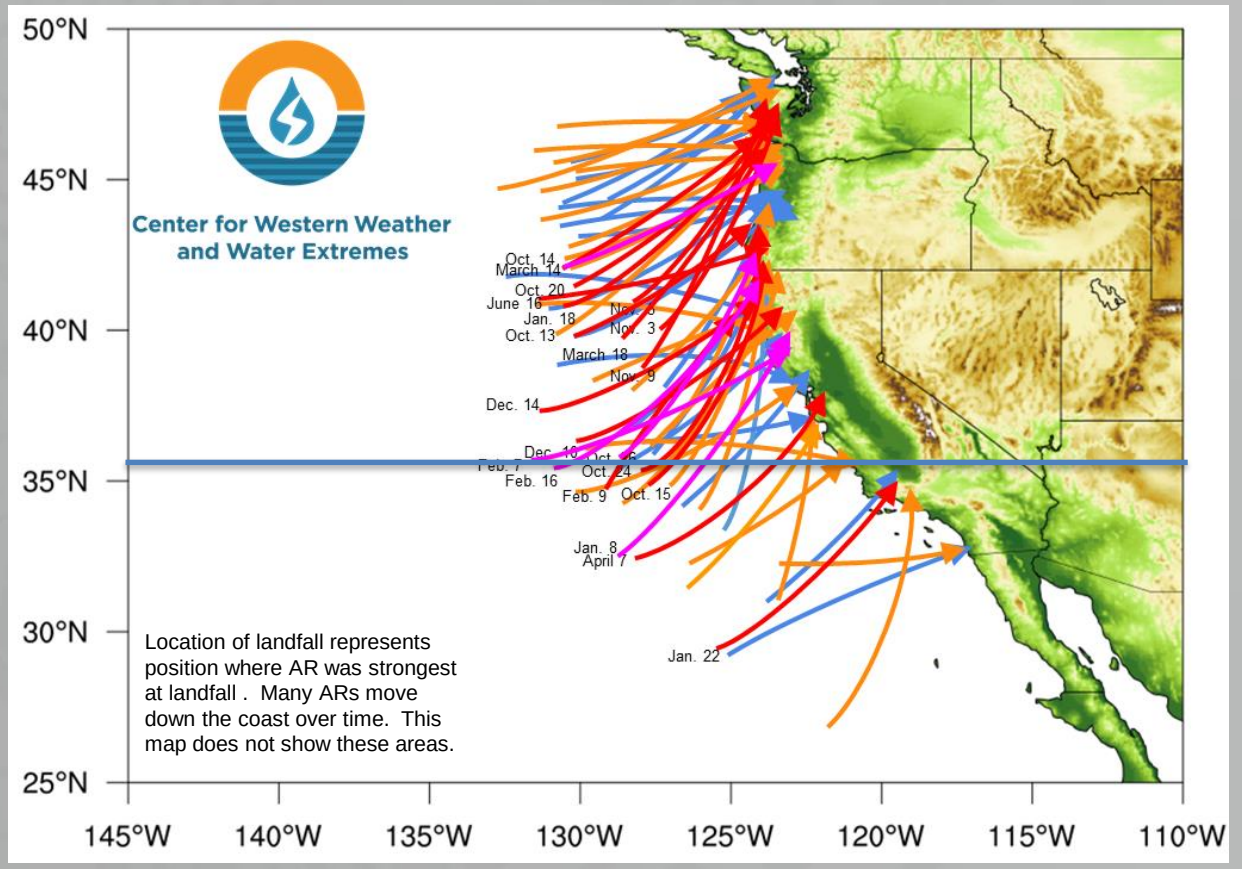

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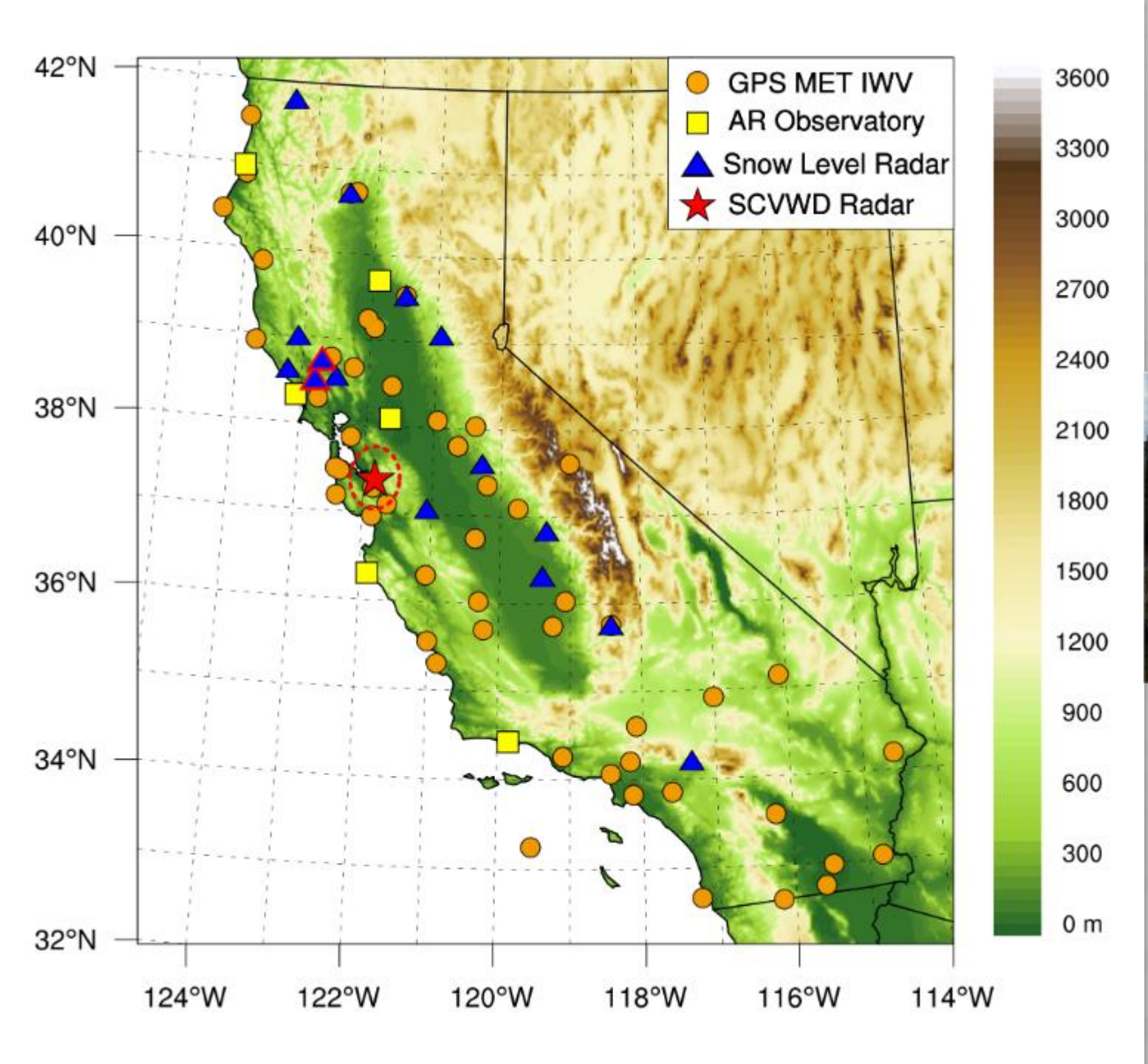
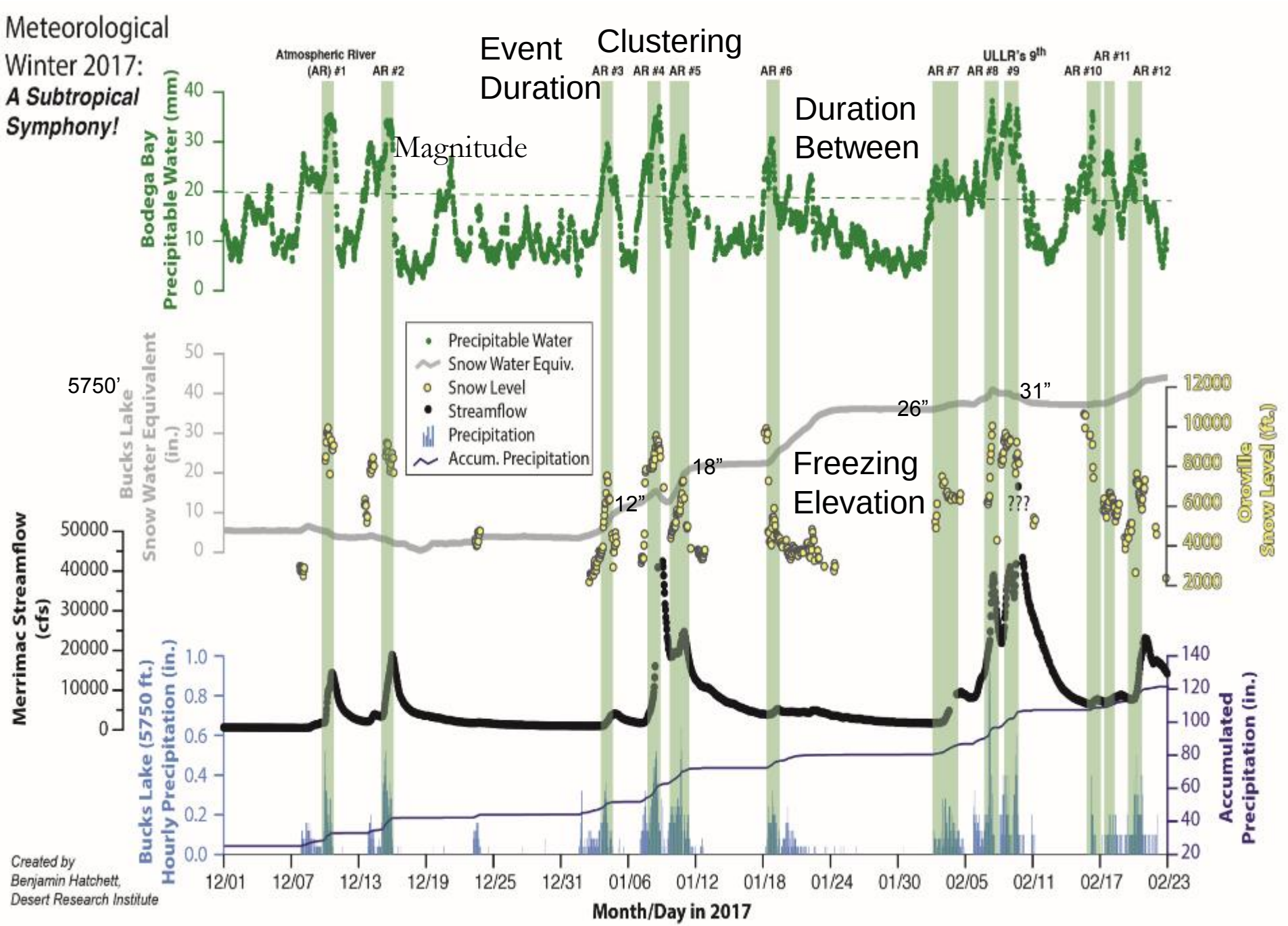
California's Advanced Observing System for Atmospheric Rivers




Meteorological Winter 2017:
A Subtropical Symphony!
Event Duration
Clustering
Magnitude
Duration Between
Freezing Elevation
Atmospheric River (AR) #1
AR #2
AR #3
AR #4
AR #5
AR #6
AR #7
AR #8
ULLR's 9th #9
AR #10
AR #11
AR #12
Bodega Bay Precipitable Water (mm)
Precipitable Water
Snow Water Equiv.
Snow Level
Streamflow
Precipitation
Accum. Precipitation
Bucks Lake Snow Water Equivalent (in.)
5750'
12"
18"
26"
31"
???
Oroville Snow Level (ft.)
Merrimac Streamflow (cfs)
Bucks Lake (5750 ft.) Hourly Precipitation (in.)
Accumulated Precipitation (in.)
12/01
12/07
12/13
12/19
12/25
12/31
01/06
01/12
01/18
01/24
01/30
02/05
02/11
02/17
02/23
Month/Day in 2017
Created by
Benjamin Hatchett,
Desert Research Institute

Summary Thoughts

- Atmospheric Rivers are a key component to California's water supply and flood risk. The character, size, number, and timing of atmospheric rivers play a key role in seasonal hydrologic outcomes for California.
- New advanced observing systems to track and record characteristics of atmospheric rivers will advance our understanding of these key processes and track their changes as the world continues to warm.
- Improved observations and forecasting support improved decision support tools enabling more options for water management in California.

Questions?

Michael.L.Anderson@water.ca.gov