Observing and Detecting ARs in California – Water Management Opportunities

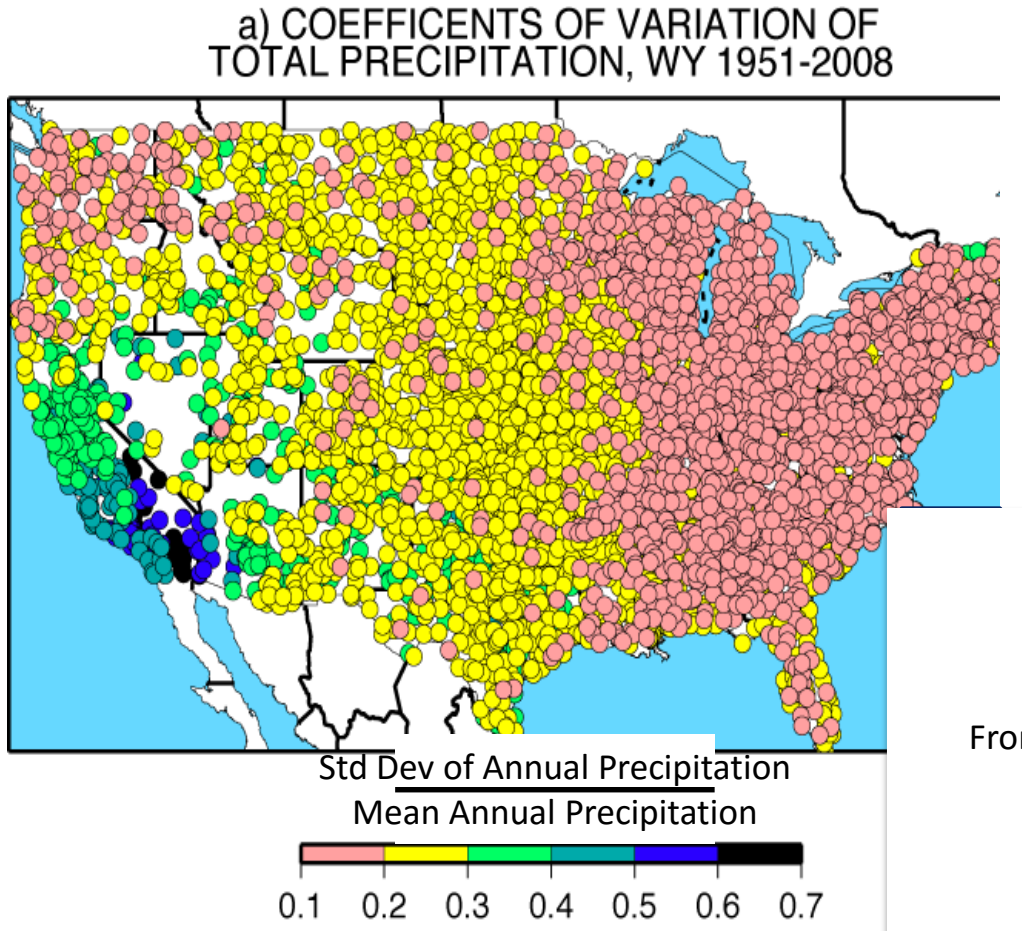
Overview

- A Brief History
- Observations, and Current Capabilities
- Opportunities in Integrated Water Management
- Next Steps

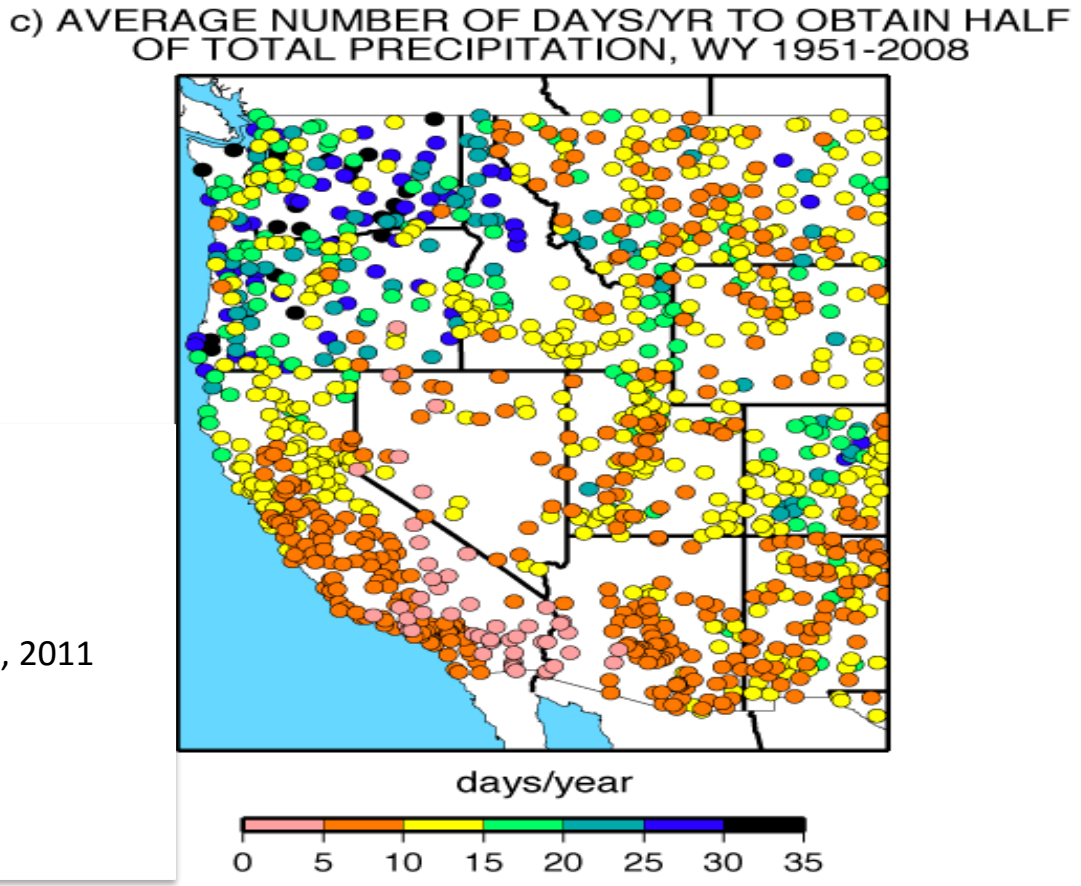
History

- Sustained engagement with federal research partners: CalJet, HMT West, Calwater I and II…
- Post HMT-West investment in AR Observing Network for California to improve Flood Emergency Response and Preparedness
- Expanded engagement with academic research community on atmospheric rivers and water management applications

California's precipitation is uniquely variable

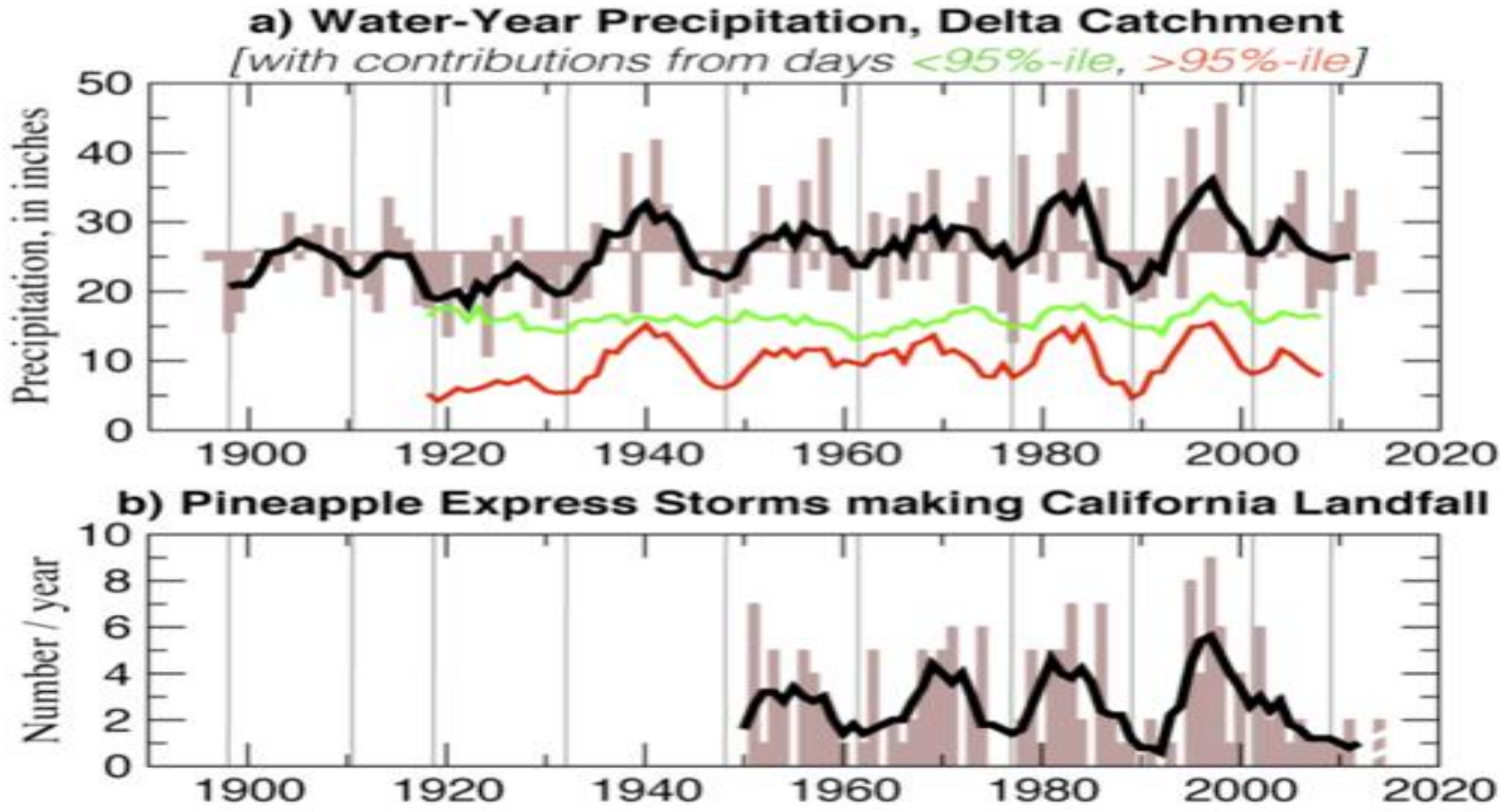


From Dettinger et al, 2011



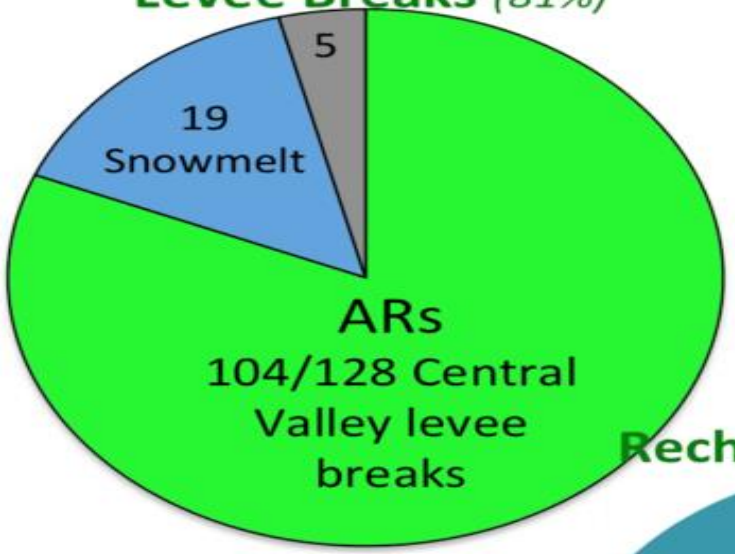
Decadal scale precipitation variability tied to Atmospheric River landfall variability

Source: Dettinger and Cayan (2014)



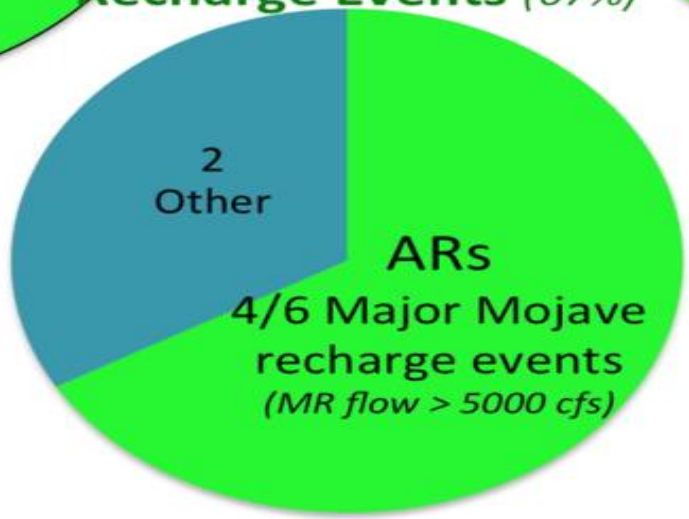
Some California extremes since 1950

Levee Breaks *(81%)*

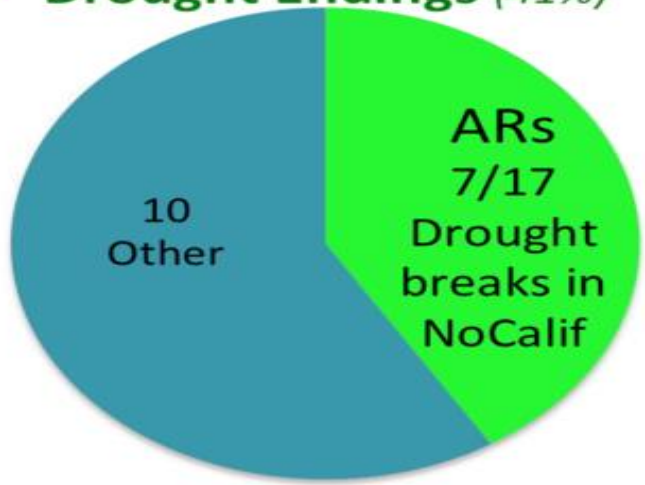


Floodplain Inundations *(78%)*

Recharge Events *(67%)*



Drought Endings *(41%)*



All Calendar Days *(4%)*

Florsheim & Dettinger, book chapter, 2014; Dettinger, JHM, 2013

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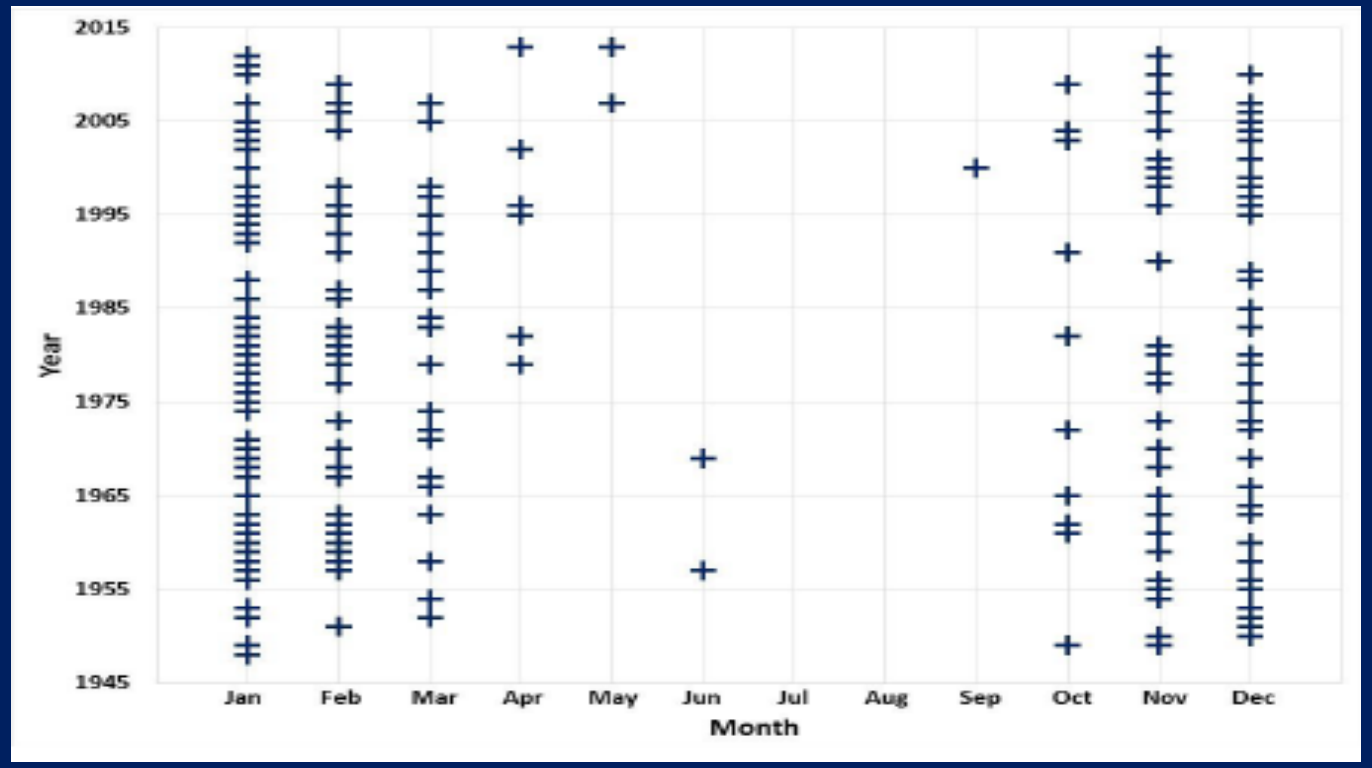
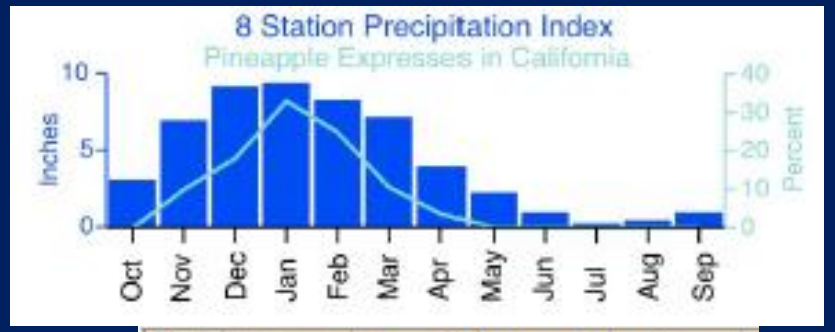
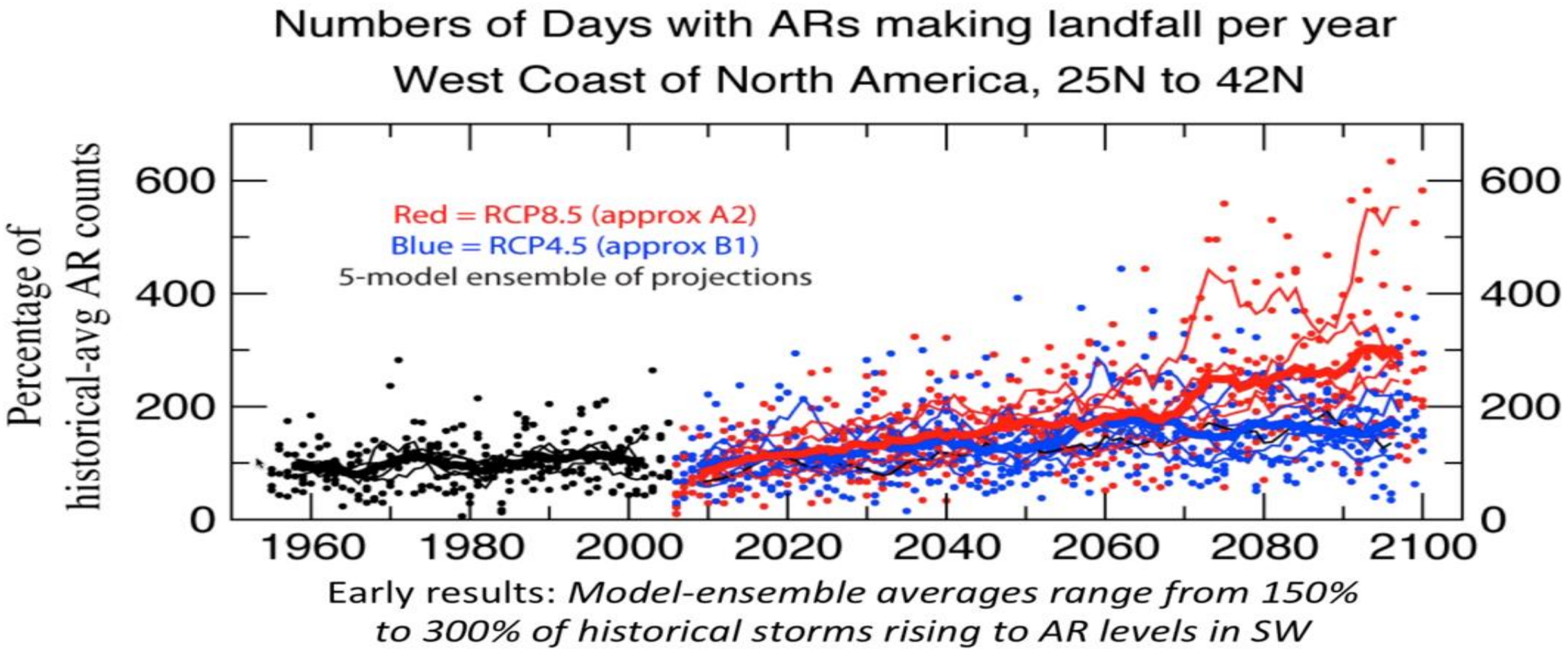
Atmospheric River Timing



Pineapple Express (AR subset) catalog from Mike Dettinger



CMIP5 (2013-vintage) projections of atmospheric rivers



Early results: *Model-ensemble averages range from 150% to 300% of historical storms rising to AR levels in SW*

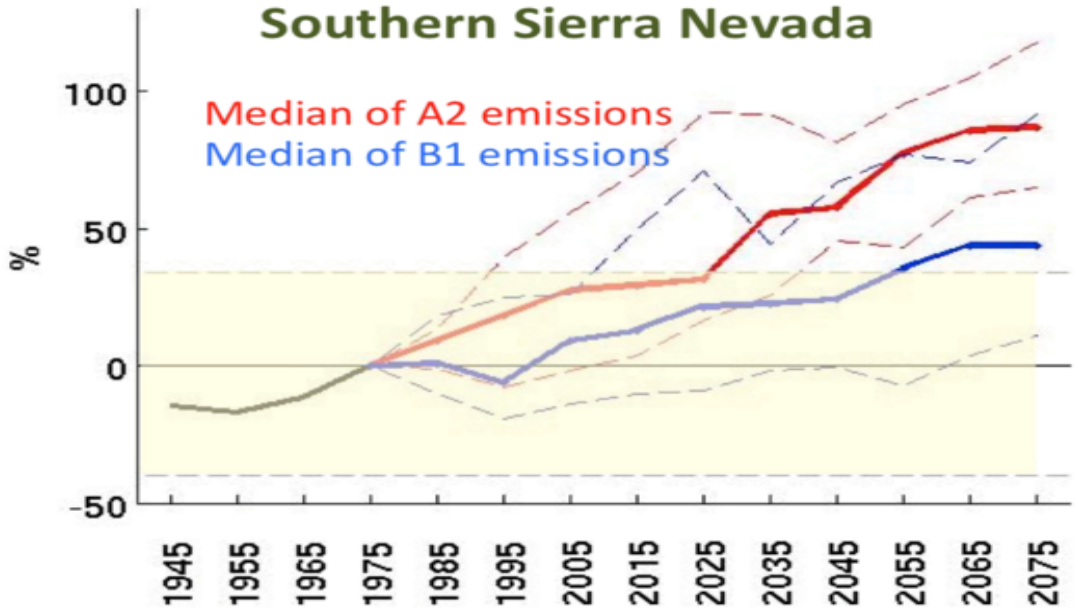
NB: Lavers et al., ERL, 2013, find an approximate doubling of ARs reaching the UK in similar projections.

Update to Dettinger, JAWRA, 2011, to reflect new CMIP5 projections

Southwest Climate Science Center

Future floods: California

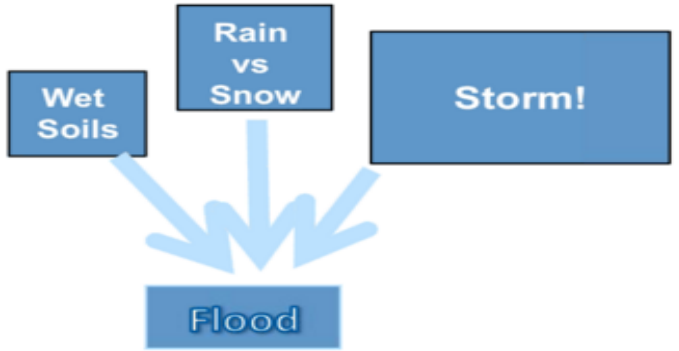
Distributions of projected "50-yr flood" changes,
from ensemble of 16 GCMs (Das et al., 2013)



NB: *Raff et al., 2009, ensemble-simulated increases in 100-yr floods of +48% for San Joaquin R and +8% for Gunnison R.*

These changes are due to combinations of:

- Increases in heavy-storm precipitation amounts
- Increases in storm frequencies
- More rain vs snow (i.e., higher snow lines)
- Increased winter soil moisture



Das et al., Clim. Chg., 2011; Das et al., J. Hydrol., 2013; Raff et al., HESS, 2009

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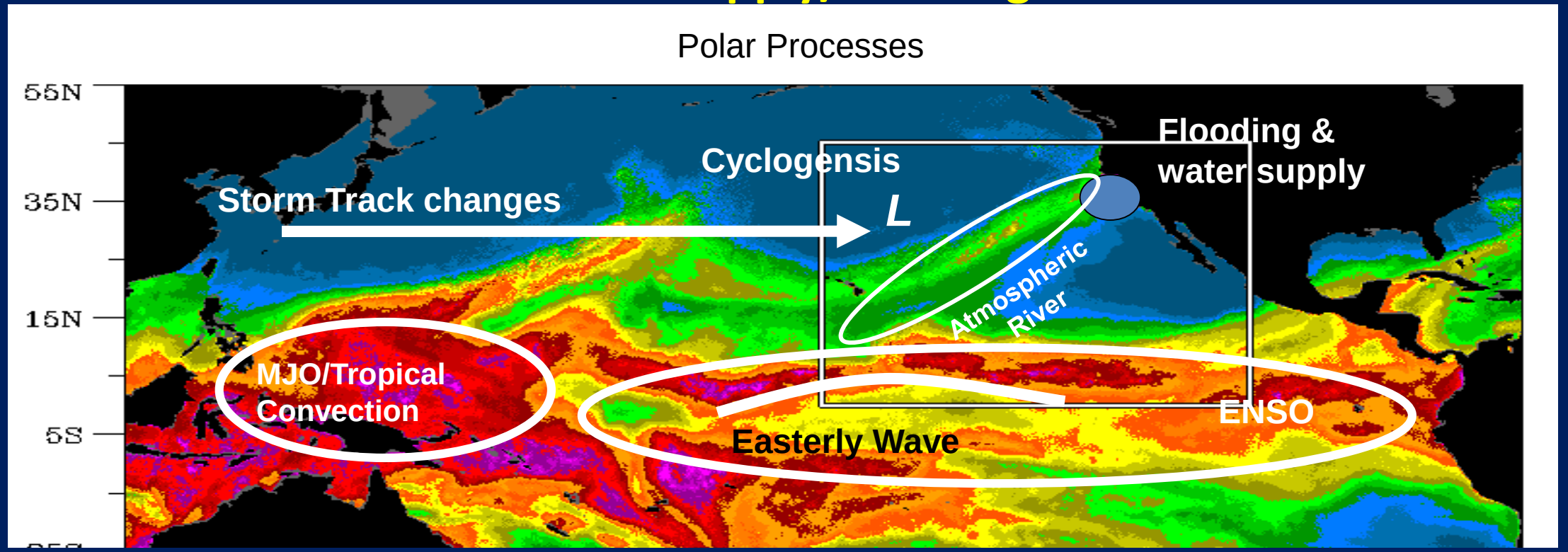
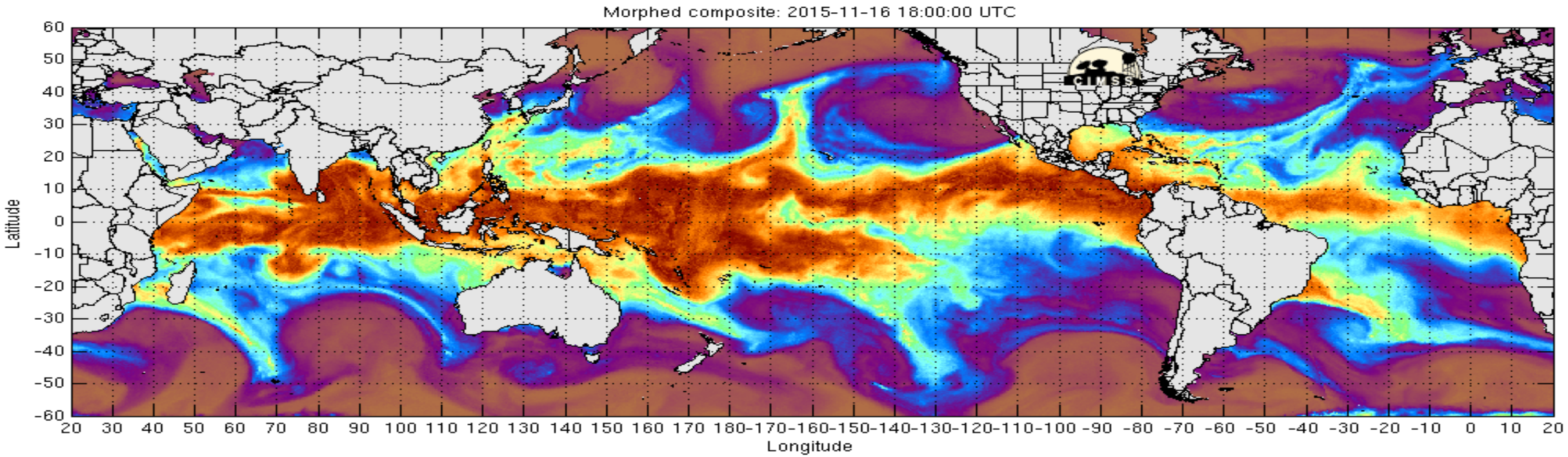
Key Phenomena Affecting California Water Supply/Flooding:



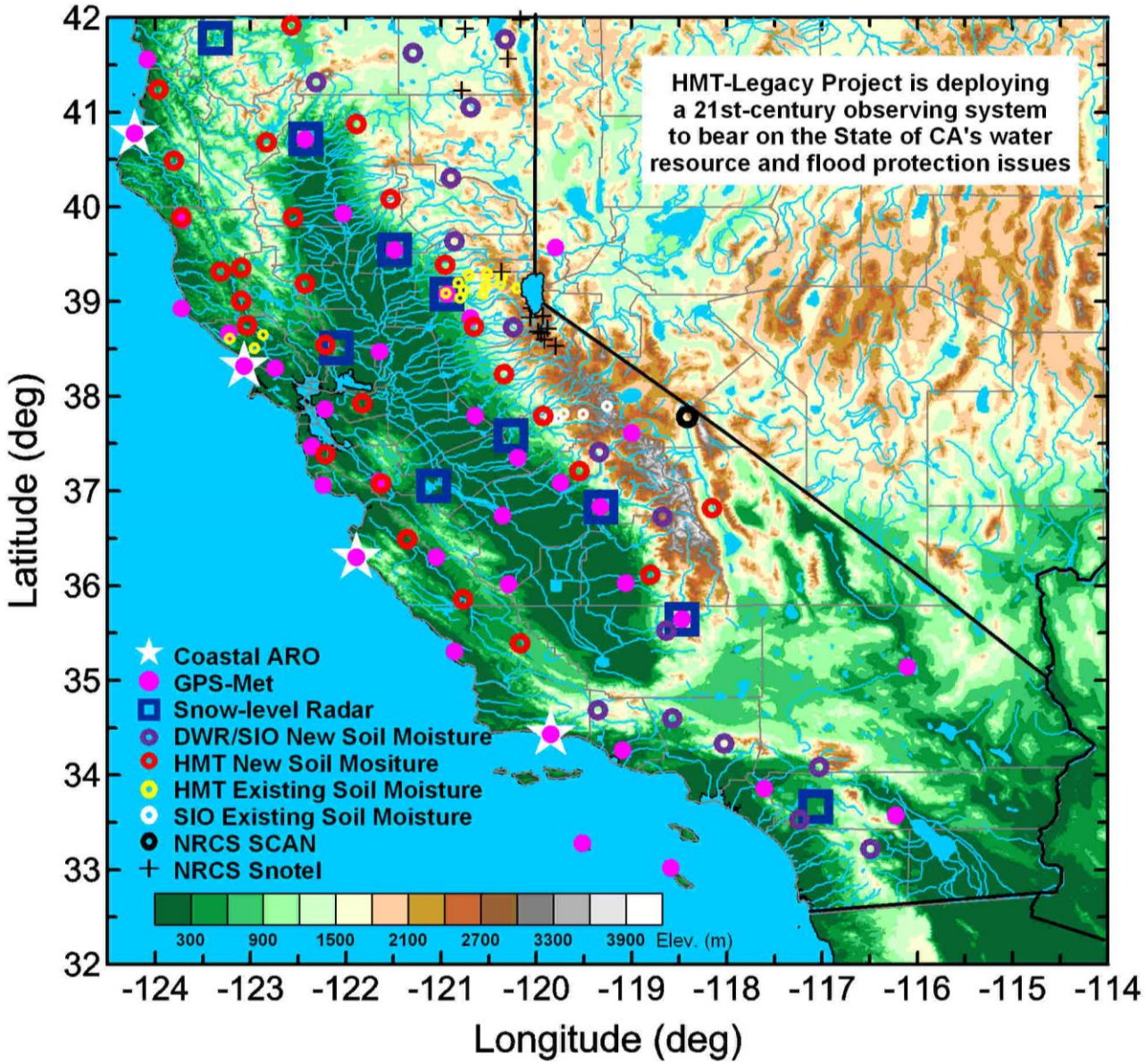
The size, number, and characteristics of atmospheric river events (ARs) result from the alignment of key processes operating on different space/time scales

Satellite Data of Water Vapor

http://woodland.ucsd.edu/images/ssmi/download/images/Global/GlobalAnim.gif



The California AR Observing Network

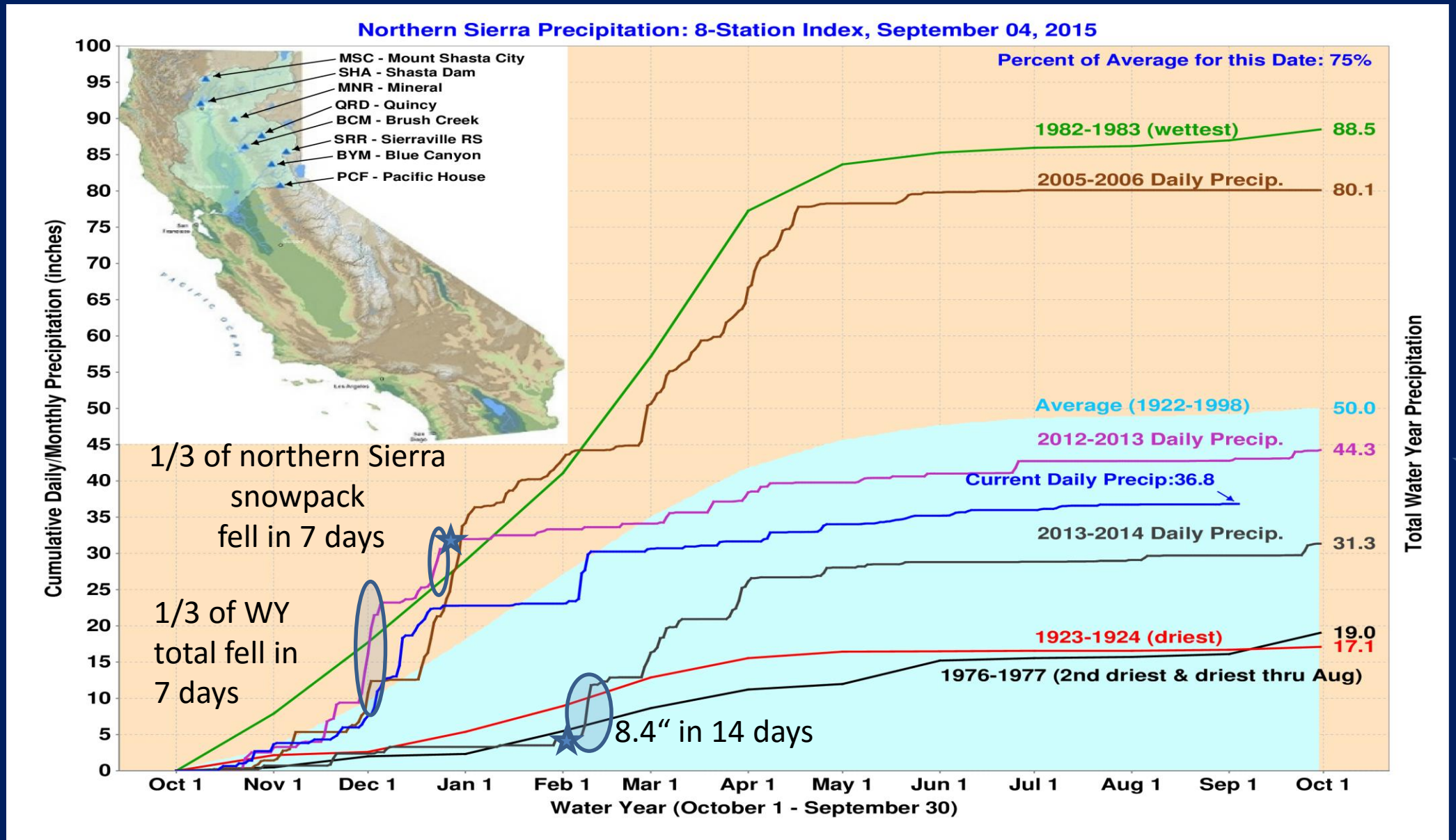


Shasta Dam SLR

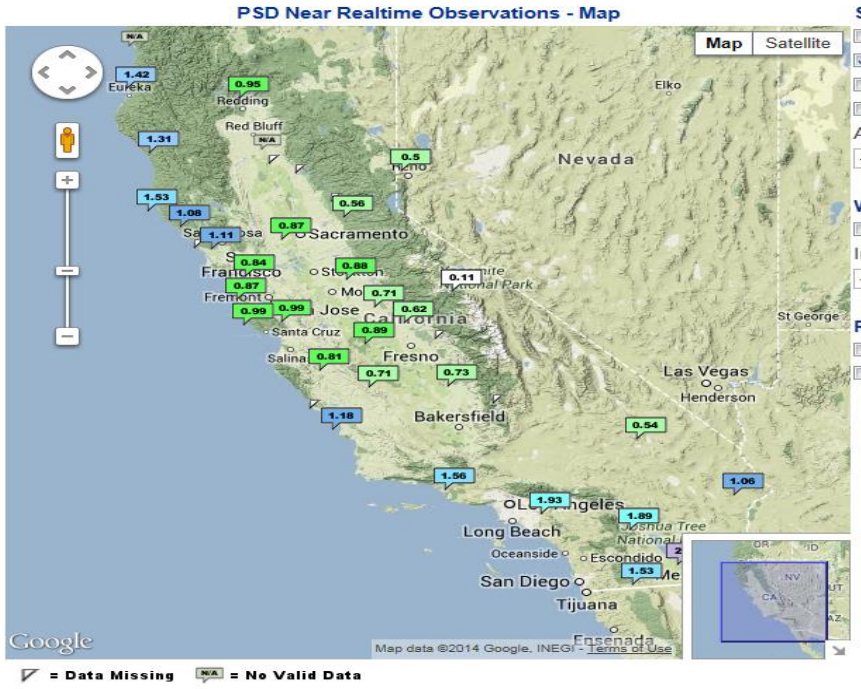
Bodega Bay ARO

Potterville GPS-Met

Atmospheric Rivers and Precipitation Accumulation



16.8”
404 Days



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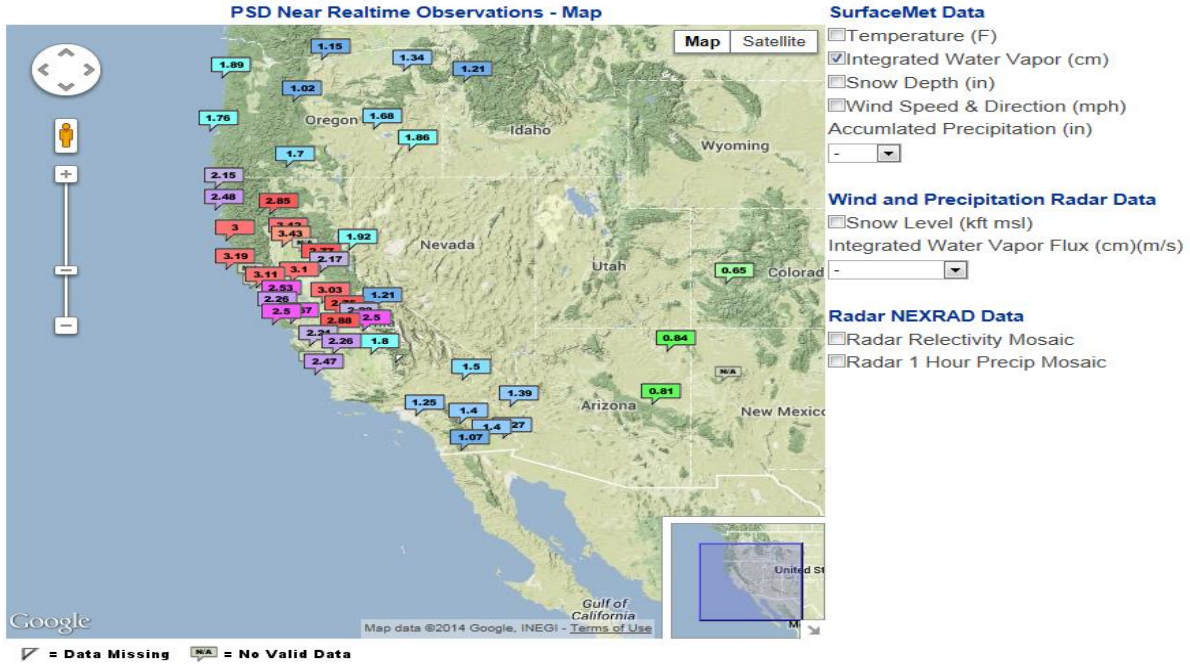

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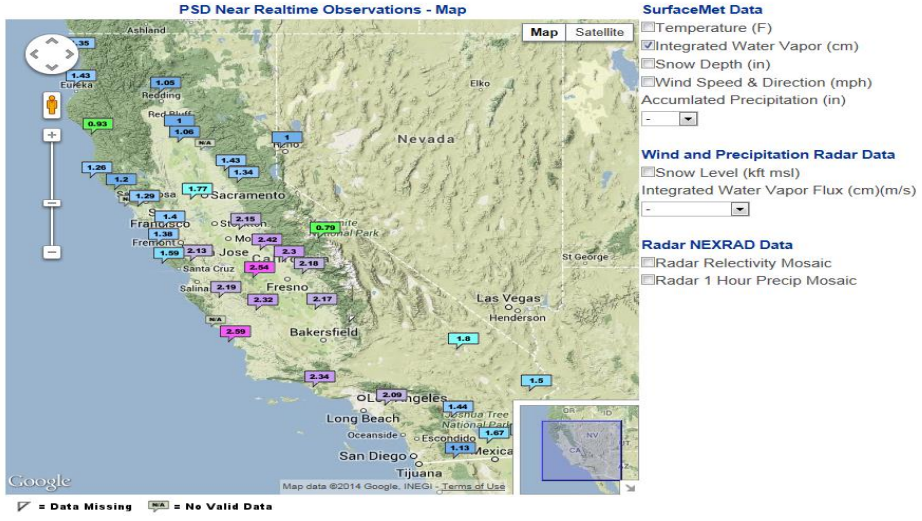

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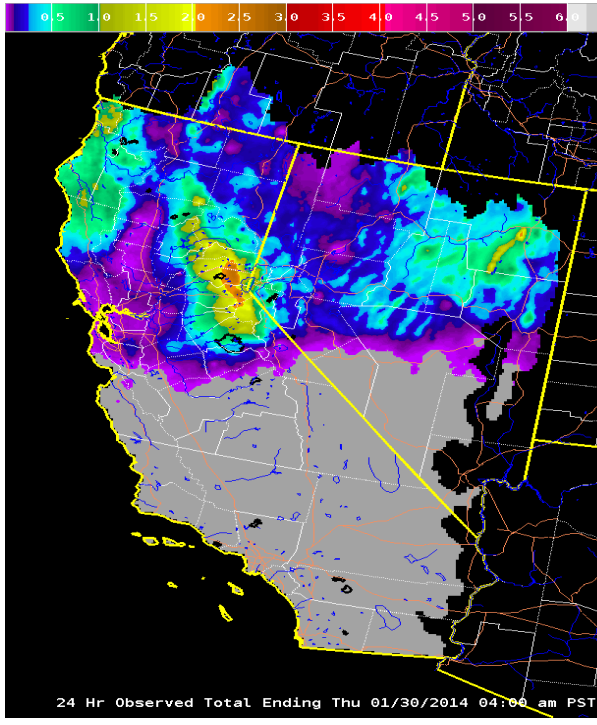
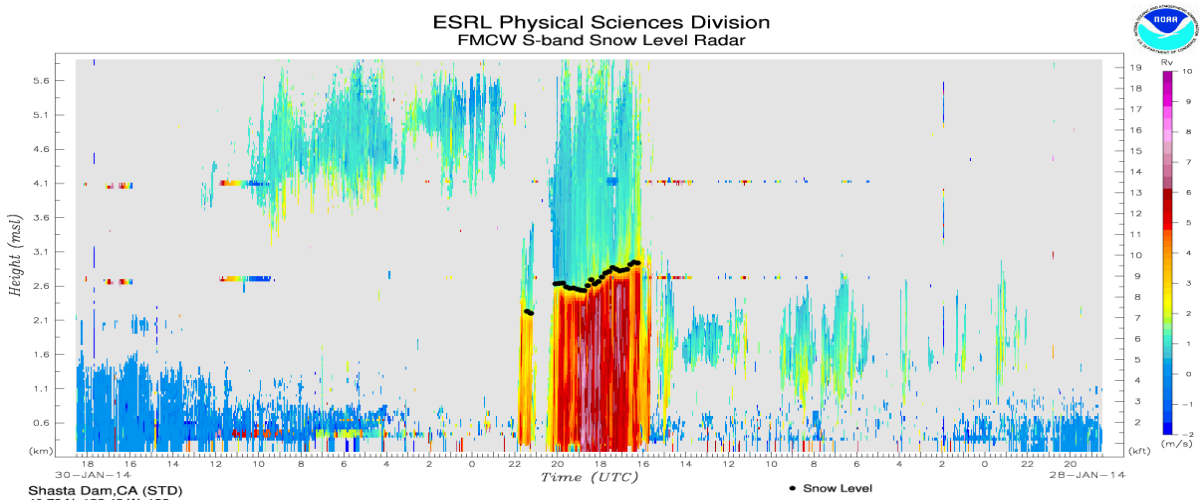


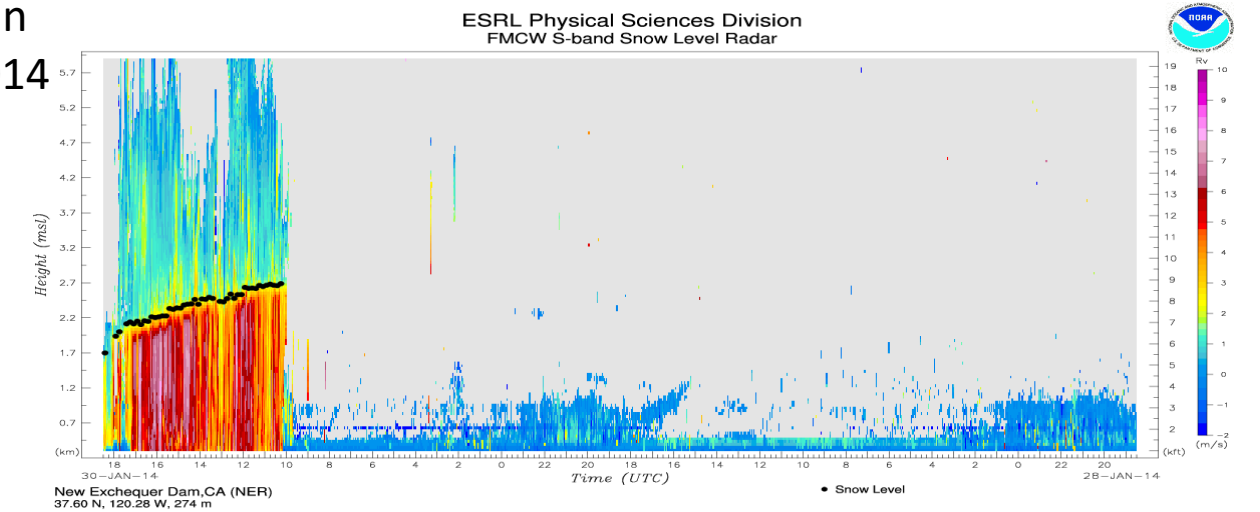
Jan 2014



Shasta Dam,CA (STD)
40.72 N, 122.43 W, 183 m

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	2215	2635	2560
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	7266	8644	8396
Sfc Temp (C)	10.11	8.78	7.33	7.34	7.99	8.07	8.27	8.45	8.88	9.23	9.29	9.12	8.97	8.88	9.24	9.60	10.22	10.96	11.25	11.27	11.12	10.76	10.40	10.04

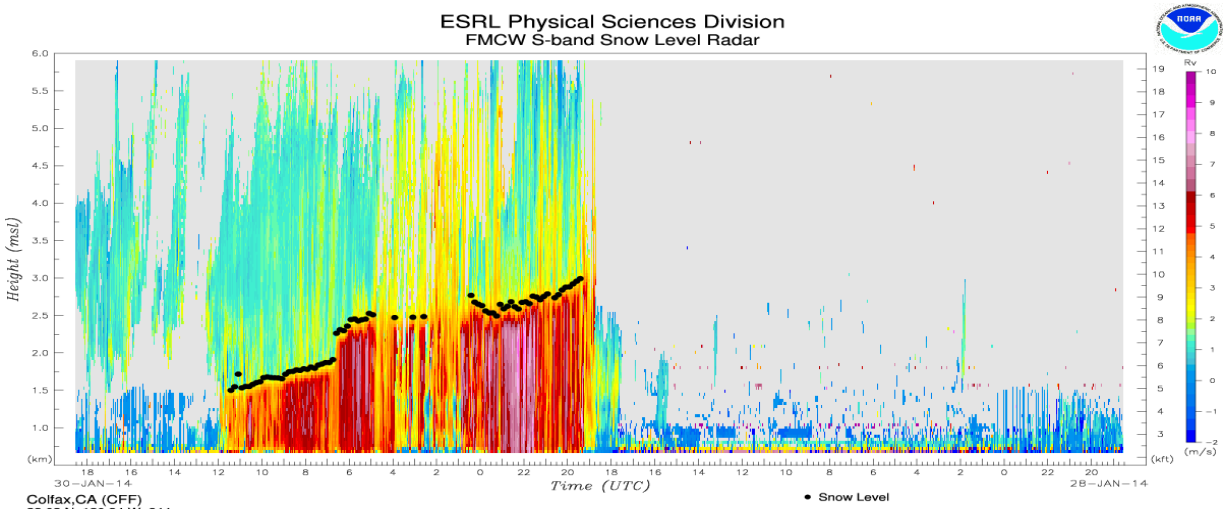
Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	2711	2845	2943	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	8893	9331	9653	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)	9.95	10.28	11.23	11.42	11.59	11.67	11.98	12.42	12.67	12.99	13.05	13.16	13.29	13.73	14.15	14.69	15.90	17.36	17.93	17.32	17.31	16.45	15.72	14.64



New Exchequer Dam,CA (NER)
37.60 N, 120.28 W, 274 m

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	1938	2127	2214	2339	2463	2474	2576	2664	2674	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	6356	6978	7261	7673	8078	8114	8450	8737	8770	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)																								

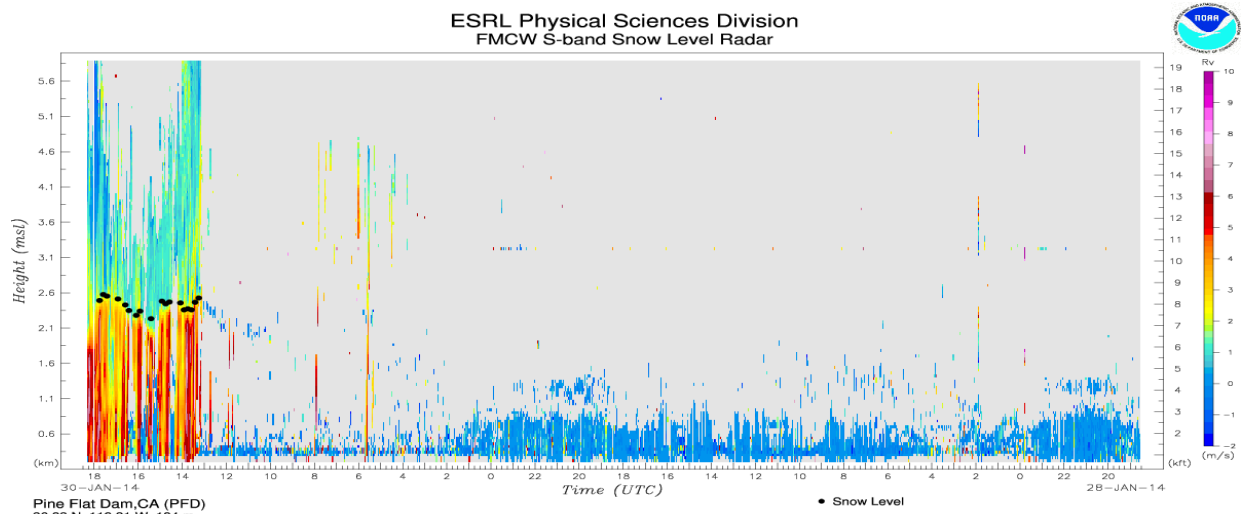
Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)																								



Colfax,CA (CFF)
39.08 N, 120.94 W, 644 m

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	none	none	none	none	none	none	none	1549	1642	1692	1785	1871	2392	2480	2472	2480	none	none	2640	2606	2666	2745	2880	2992
Snow Level (ft)	none	none	none	none	none	none	none	5082	5385	5549	5854	6136	7845	8136	8108	8136	none	none	8660	8547	8744	9003	9446	9813
Sfc Temp (C)																								

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)																								

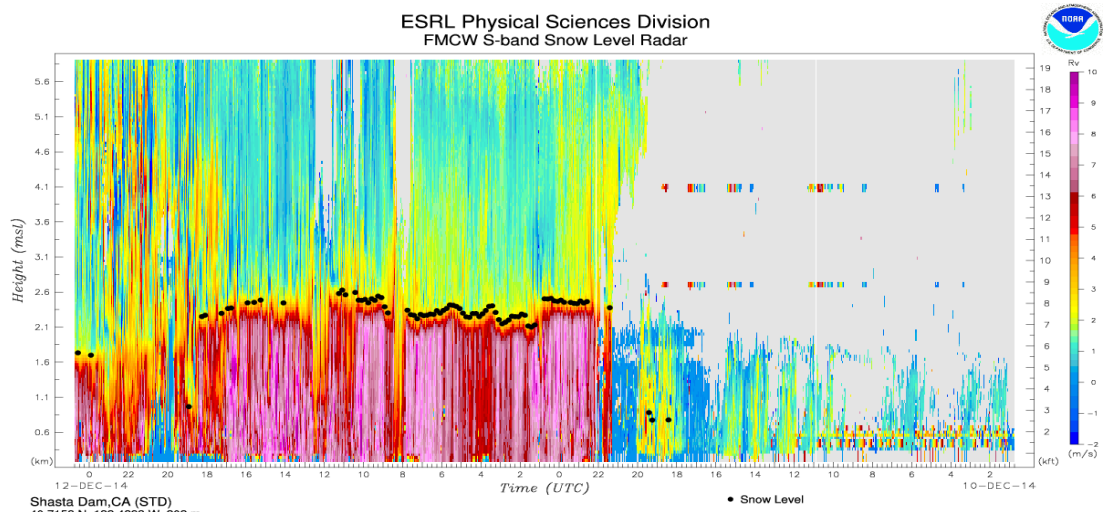


Pine Flat Dam,CA (PFD)
36.83 N, 119.31 W, 184 m

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	2533	2513	2340	2456	2365	2496	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	8309	8242	7675	8057	7758	8186	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)	11.17	12.76	13.72	13.93	12.44	12.69	12.91	13.14	12.89	13.11	13.63	14.04	14.69	14.53	14.39	14.63	15.15	17.97	20.41	21.04	20.32	19.67	19.03	15.24

Time (UTC)	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	00 0	2300	2200	2100	2000	1900
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)	12.18	9.88	8.77	8.36	7.71	8.54	9.70	8.59	9.04	9.76	11.17	11.88	11.77	11.62	11.38	12.64	14.62	16.94	19.32	20.14	19.64	19.85	18.99	15.84

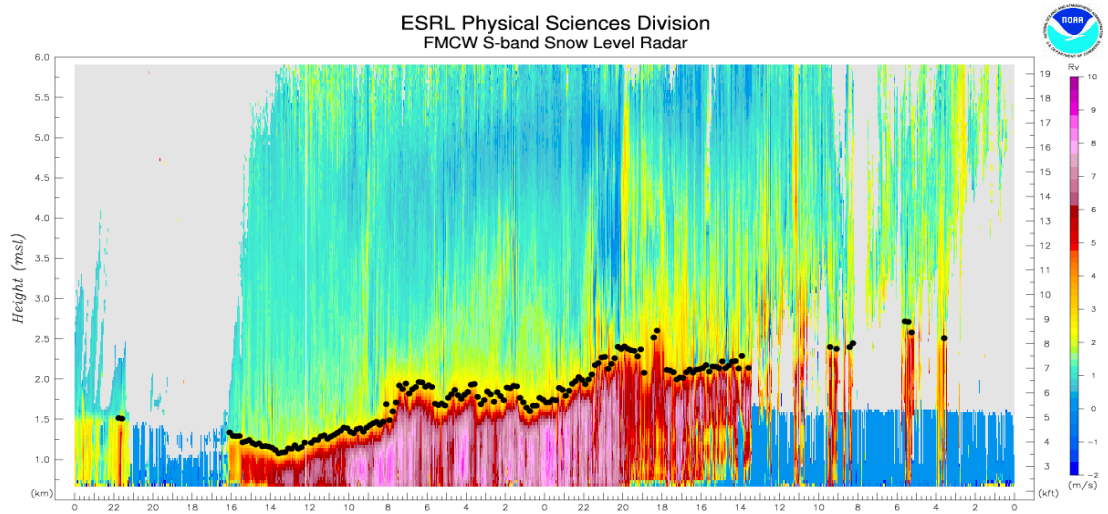
Dec 2014



Shasta Dam,CA (STD)
40.7158 N, 122.4293 W, 202 m

Time (UTC)	0015	2315	2215	2115	2015	1915	1815	1715	1615	1515	1415	1315	1215	1115	1015	0915	0815	0715	0615	0515	0415	0315	0215	0115
Snow Level (m)	1716	none	none	none	none	965	2260	2365	2446	2469	2445	none	none	2579	2485	2492	2341	2269	2316	2379	2291	2257	2252	2123
Snow Level (ft)	5628	none	none	none	none	3165	7412	7757	8022	8098	8019	none	none	8459	8150	8175	7678	7442	7596	7804	7514	7404	7388	6965
Sfc Temp (C)																								

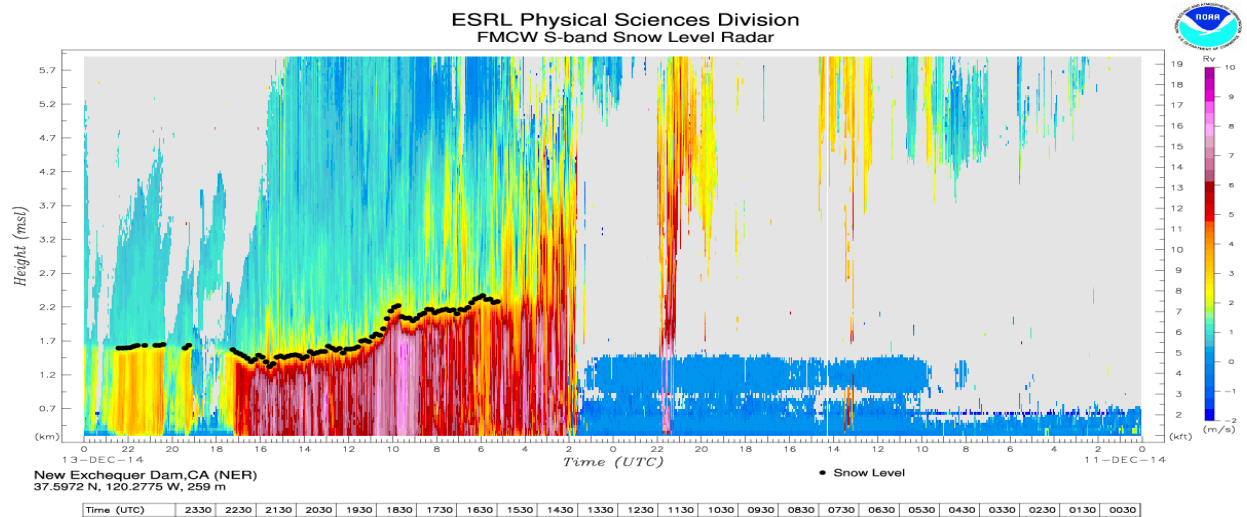
Time (UTC)	0015	2315	2215	2115	2015	1915	1815	1715	1615	1515	1415	1315	1215	1115	1015	0915	0815	0715	0615	0515	0415	0315	0215	0115
Snow Level (m)	2478	2444	2463	2376	none	827	777	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	8129	8016	8078	7793	none	2714	2548	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)																								*****



Colfax,CA (CFF)
39.0800 N, 120.9400 W, 644 m

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	none	none	1512	none	none	none	none	1337	1266	1177	1105	1153	1250	1345	1361	1460	1792	1902	1694	1803	1809	1799	1889	1669
Snow Level (ft)	none	none	4959	none	none	none	none	4385	4154	3860	3624	3781	4100	4411	4465	4790	5879	6240	5557	5915	5935	5902	6197	5474
Sfc Temp (C)																								

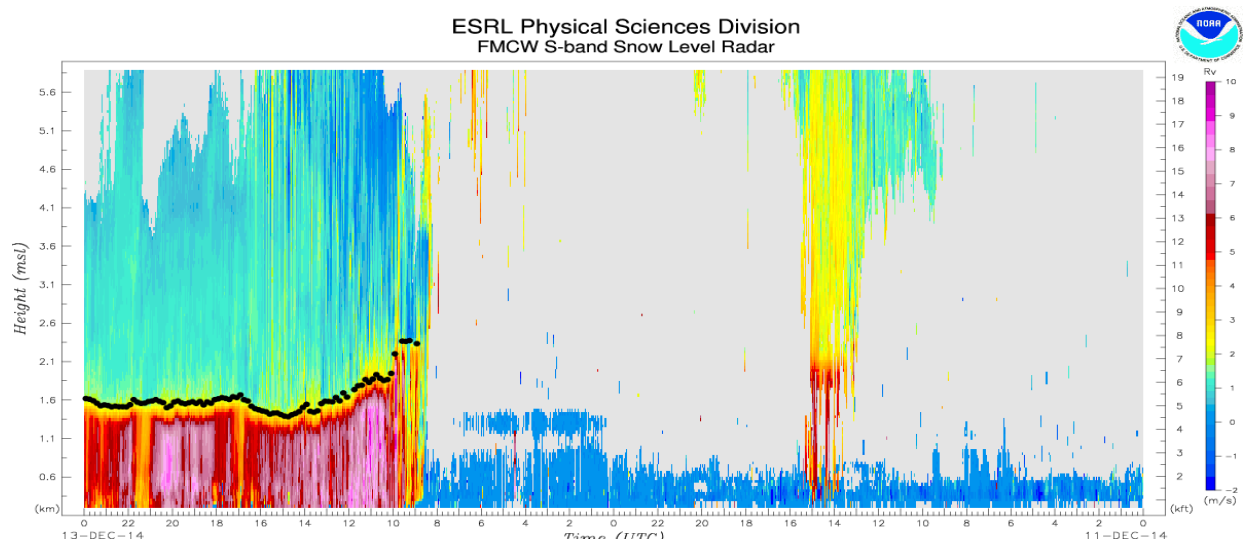
Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	1740	1957	2115	2267	2364	2516	2085	2100	2145	2193	2213	none	none	none	2387	2421	none	none	2710	none	2508	none	none	none
Snow Level (ft)	5707	6420	6937	7437	7753	8252	6838	6889	7035	7194	7258	none	none	none	7829	7940	none	none	8888	none	8226	none	none	none
Sfc Temp (C)																								



New Exchequer Dam,CA (NER)
37.5972 N, 120.2775 W, 259 m

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	none	1594	1626	1634	1615	none	1550	1460	1425	1478	1534	1584	1650	1841	2049	2111	2152	2229	2311	none	none	none	none	none
Snow Level (ft)	none	5228	5334	5359	5298	none	5084	4790	4674	4847	5033	5195	5413	6038	6722	6925	7058	7311	7580	none	none	none	none	none
Sfc Temp (C)																								

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)																								

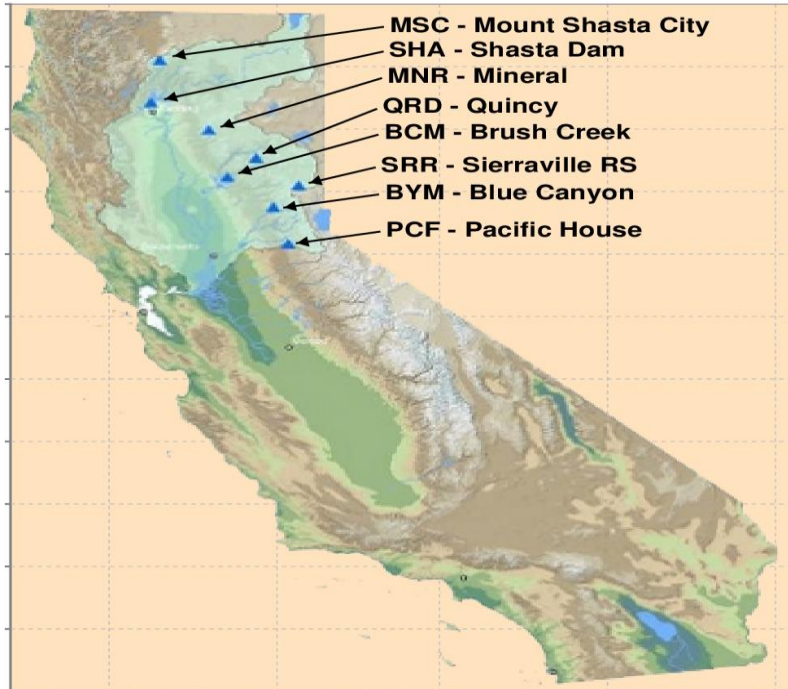


Pine Flat Dam,CA (PFD)
36.8301 N, 119.3324 W, 184 m

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	1574	1513	1566	1575	1569	1567	1626	1554	1432	1417	1502	1611	1793	1878	2364	2333	none	none	none	none	none	none	none	none
Snow Level (ft)	5164	4962	5136	5166	5147	5139	5333	5097	4696	4649	4928	5285	5881	6159	7755	7652	none	none	none	none	none	none	none	none
Sfc Temp (C)	9.18	9.27	9.53	9.32	9.00	8.93	9.11	8.77	8.92	9.21	9.52	10.35	11.05	11.13	11.77	15.09	16.55	18.26	18.73	17.91	19.05	18.47	14.52	14.22

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)	14.30	14.21	13.89	13.42	12.27	13.38	13.34	13.42	13.35	12.88	12.28	12.80	12.85	12.59	12.03	12.06	13.81	12.72	10.96	10.86	10.82	10.80	11.72	14.00

North Sierra Precipitation: 8-Station Index, May 25, 2016



Percent of Average for this Date: 120%

1982-1983 (wettest) 88.5

1997-1998 82.4

3/3/16-3/15/16 3ARs
24.7% of water year precip
1MAF gain Shasta
818taf gain Oroville
20% northern region SWE (6")

Current Daily Precip: 56.7

Average (1922-1998) 50.0

2014-2015 Daily Precip 37.2

1976-1977(2nd driest & driest thru Aug) 19.0

12/2/14 – 12/18/14
34% of WY Precip
481 taf gain Shasta
273 taf gain Oroville
60% of northern region SWE (3")
Flood Stages Obs.

Cumulative Daily/Monthly Precipitation (inches)

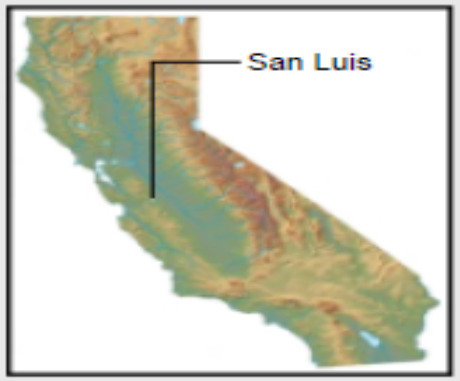
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

Oct 1 Nov 1 Dec 1 Jan 1 Feb 1 Mar 1 Apr 1 May 1 Jun 1 Jul 1 Aug 1 Sep 1 Oct 1

Water Year (October 1 - September 30)

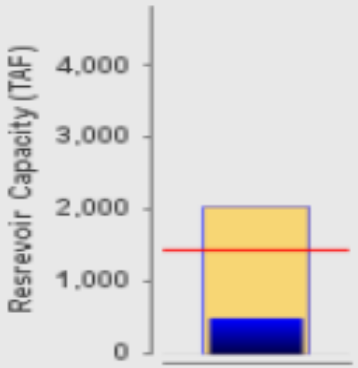
Total Water Year Precipitation

Reservoir Conditions - San Luis



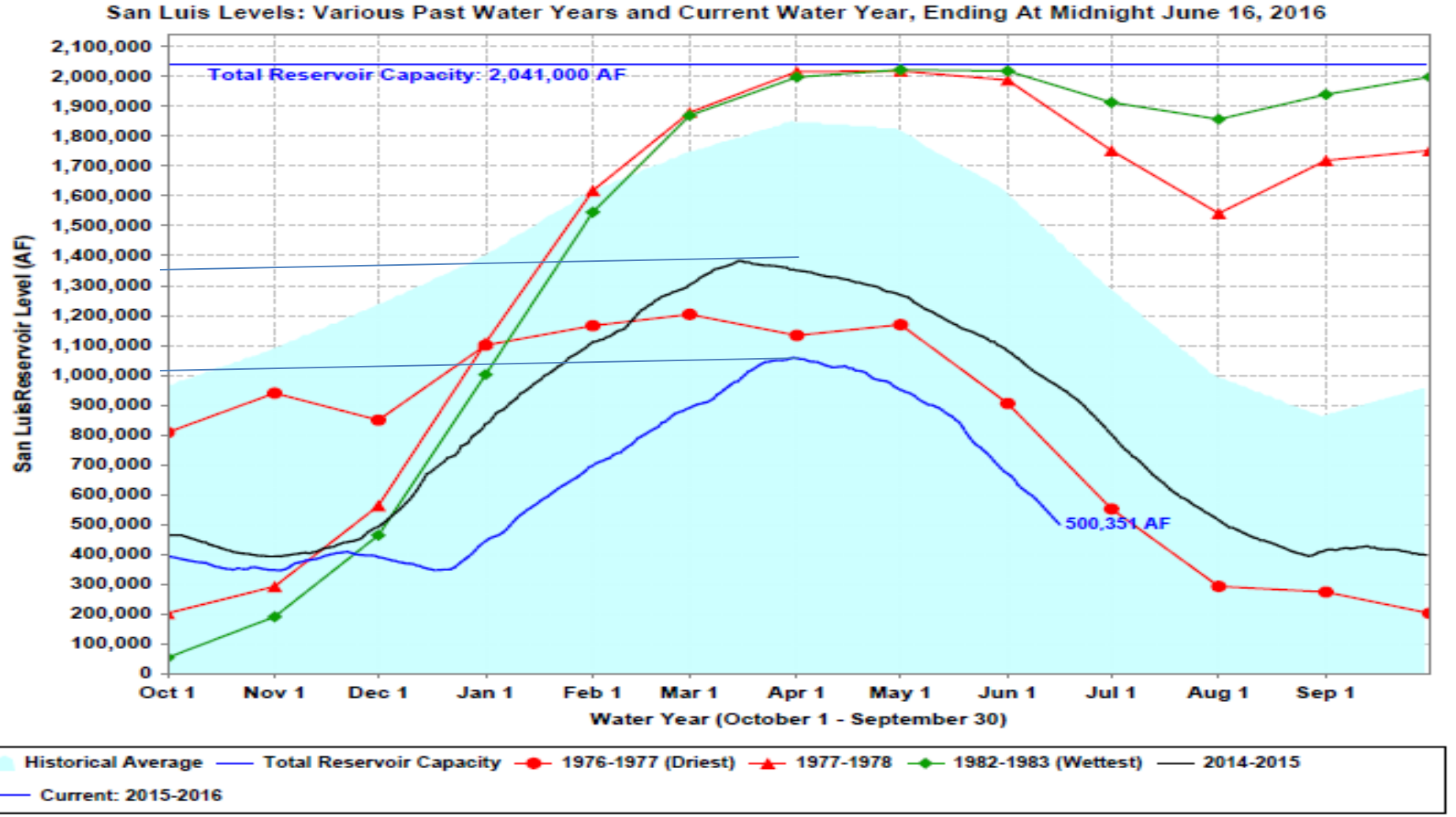
San Luis Conditions

(as of Midnight - June 16, 2016)



Current Level: 500,351 AF

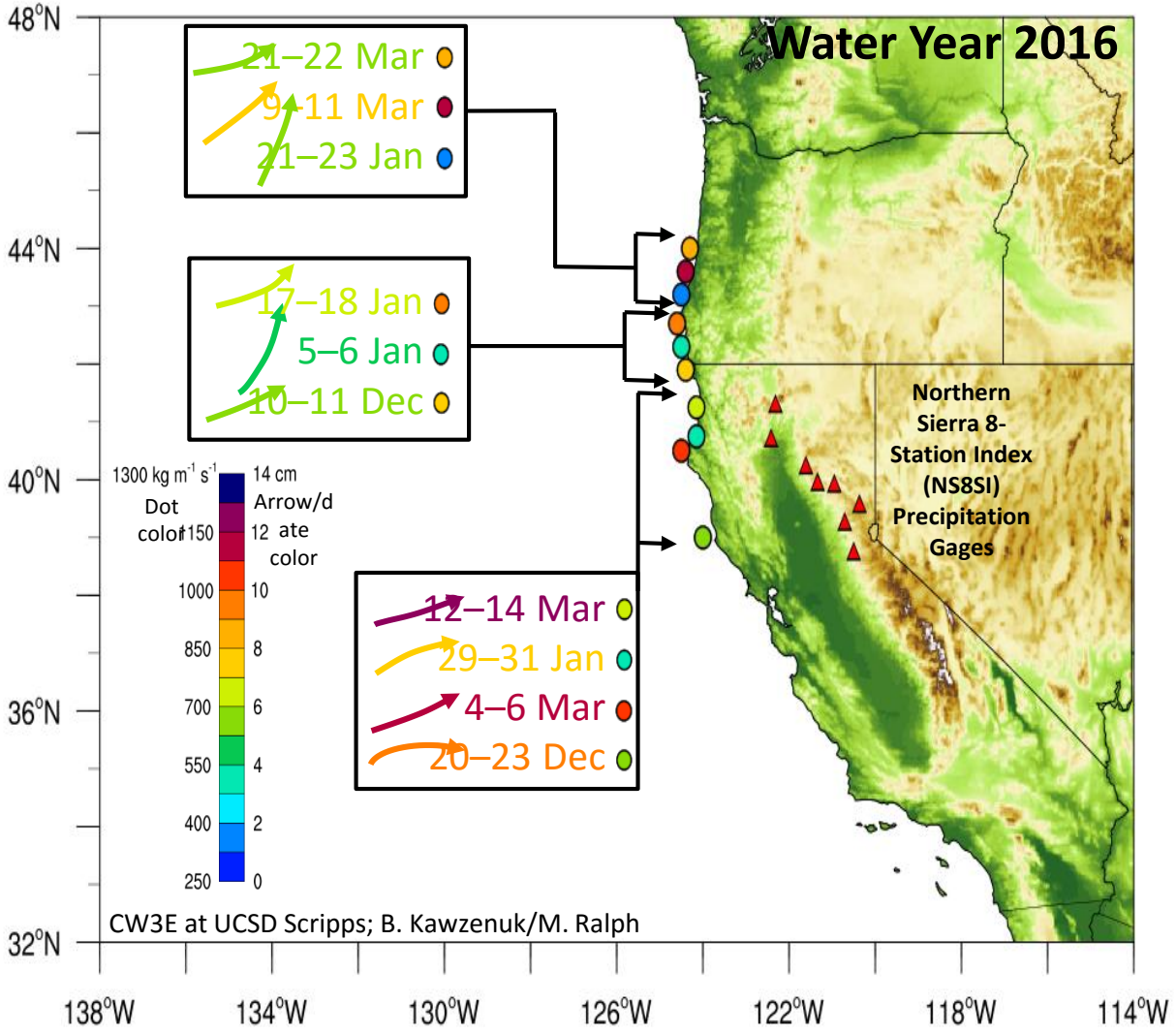
25% (Total Capacity) | 35% (Historical Avg.)



Data Updated 06/17/2016 11:15 AM

WY 2016 Storm Summary: Top-10 Wettest Events - Northern Sierra 8-Station Index

Dates, Landfall Locations, Storm Orientations – All Were Atmospheric Rivers



Each of the top-10 wettest events of WY 2016 were identified and examined in terms of their strength and nature of the storms that produced them

- The 10 events produced 54% of WY16 precip.
- All 10 were atmospheric river (AR) events*
- All 10 had winds from west or southwest
- All struck NorCal or OR coast and forced water vapor into the northern Sierra/Shasta area

Each dot represents the central landfall location of the associated atmospheric river

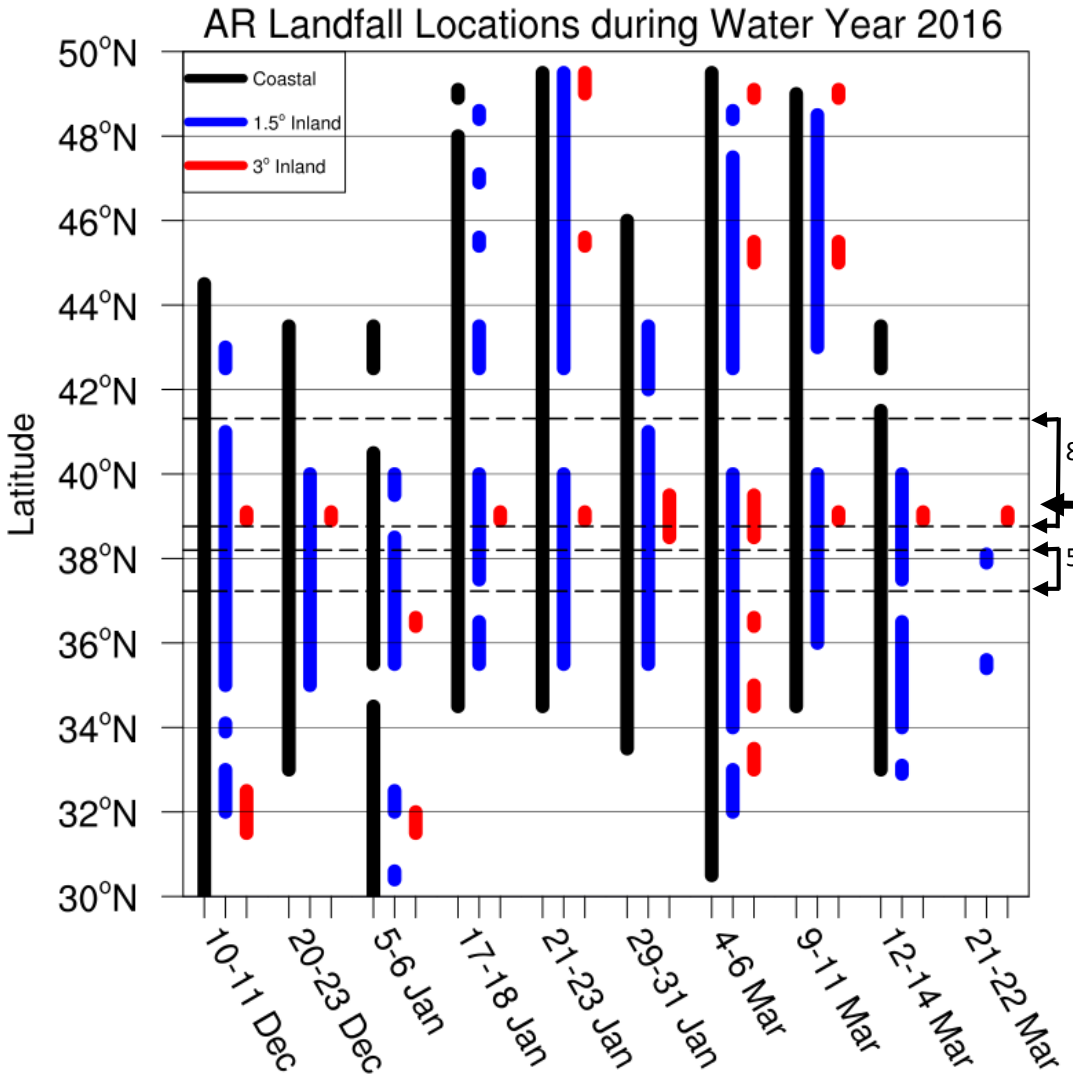
- Dot's color represents the maximum AR strength (i.e., its water vapor transport – IVT)

Dates and AR orientations are shown

- Arrow's color represents total precip. measured by the 8-Station Index in that event (over 48,72, or 96 hours)

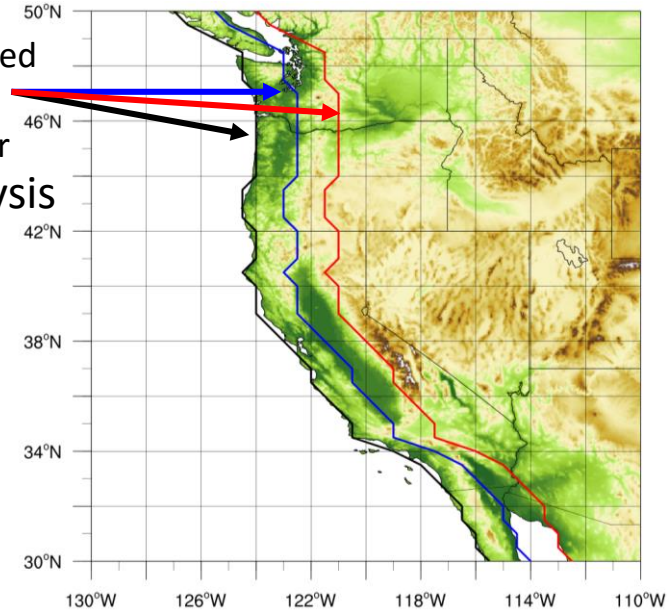
Location of AR Conditions

AR conditions are defined as IWV >20 mm and IVT >250 kg m^{-1} s^{-1}. Data from the GFS 0.5° analysis



- Each line indicates where AR conditions were met during each event
  - Black lines are coastal and red and blue indicate inland penetration of AR conditions

AR conditions indicated along line with corresponding color



- AR conditions made inland penetration near 39°N during nine events
  - ARs most likely made penetration through the Petaluma gap to the northern Central Valley and Sierra Nevada

- The majority of the CA coast experienced AR conditions in nine of the ten cases

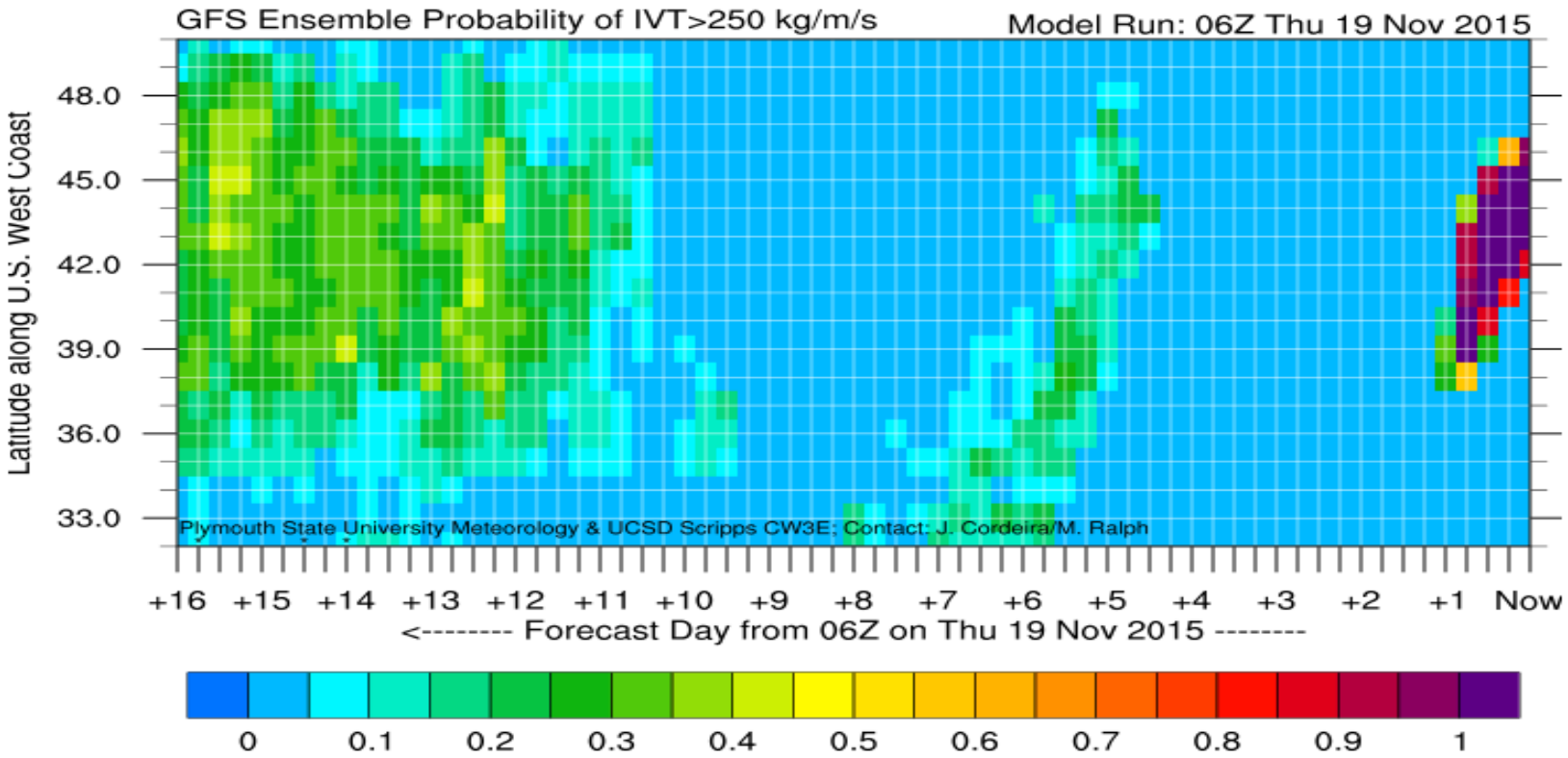
Forecast of AR Landfall Probability using GFS Forecast Data

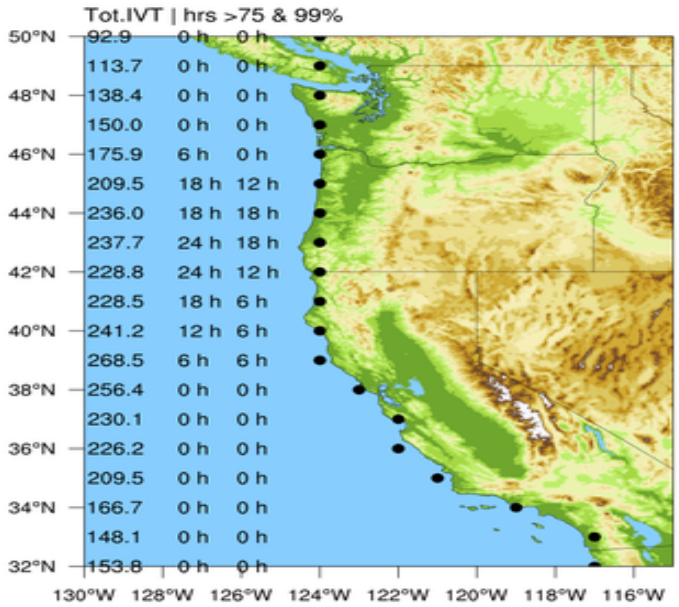
(http://vortex.plymouth.edu/~j_cordeira/ARPortal/Current/Ensemble/LandfallTool/Ensemble_Landfall_IVT250.html)

AR Landfall Tool

Developed in partnership between the Center for Western Weather and Water Extremes at UCSD Scripps and Plymouth State University

There are three images available, all are Latitude versus time:
(1) Ensemble Control IVT, (2) Ensemble Probability of IVT>250 kg/m/s, and (3) Ensemble Probability of IVT>500 kg/m/s





Next Steps

- Continued development of data visualization and archiving capabilities that depict strength and temporal evolution of events including animation of data for past events
- Observational gap analysis and link to water management
- Extreme thresholds and further early warning applications
- Research into seasonal and annual forecasts of AR activity


Questions?
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