

Statistical Analysis of Hydrology in California under Climate Variability

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Michael Anderson
Michael.L.Anderson@water.ca.gov

Kwabena O. Asante
kasante@geiconsultants.com

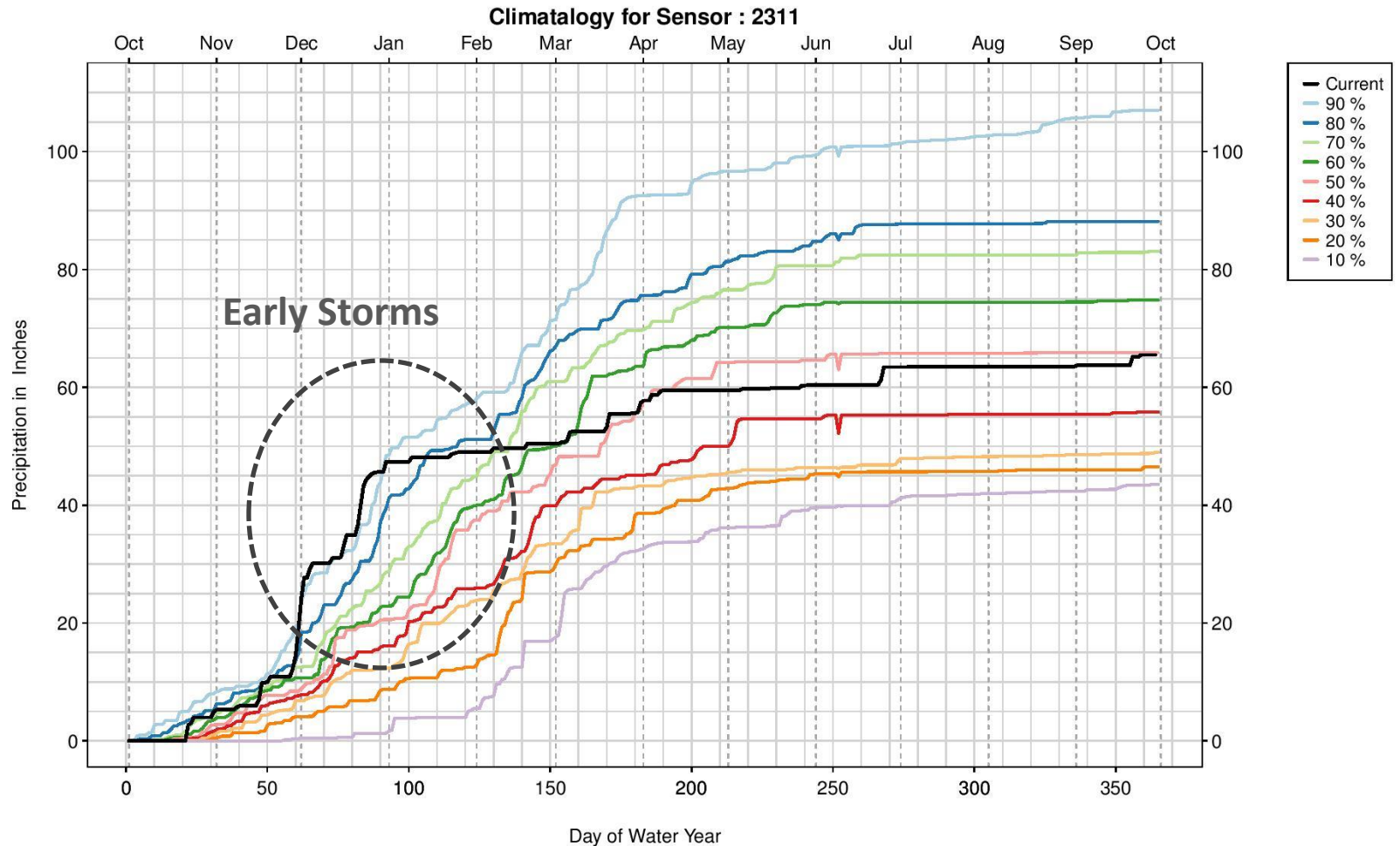


Outline

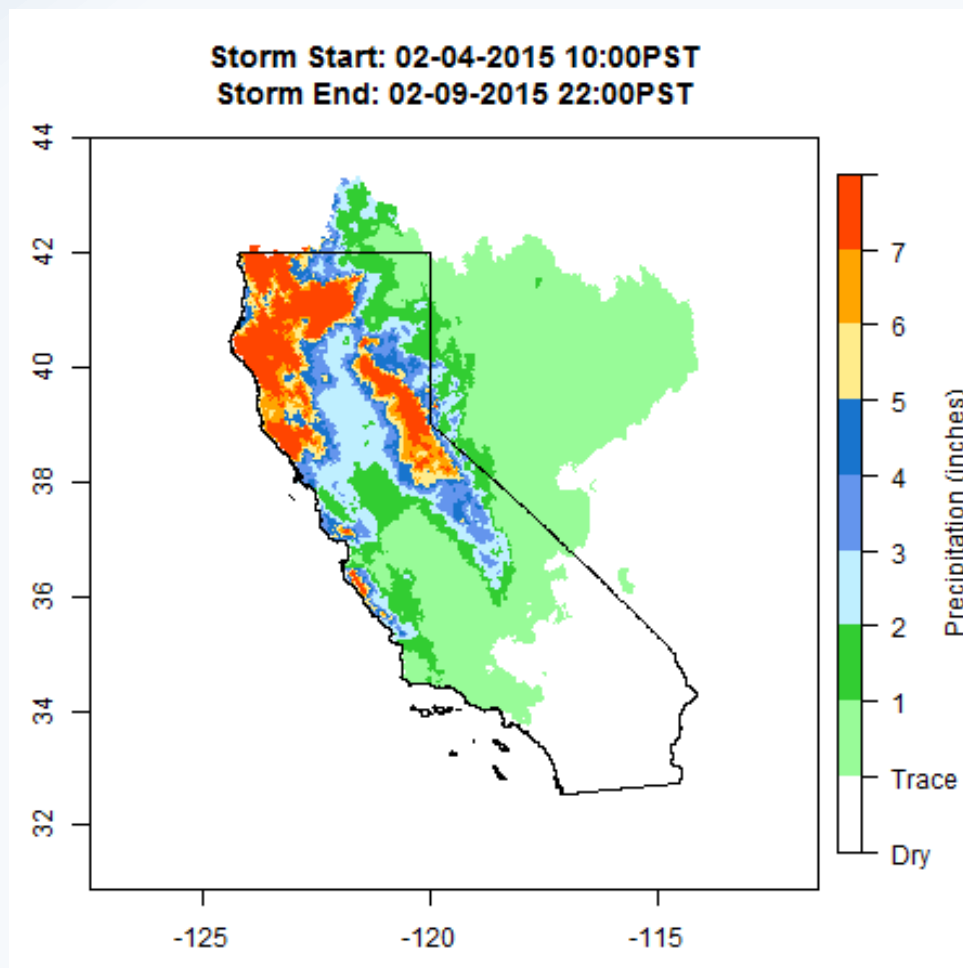
- Motivation: Forecasting Challenges
- California Storm Characteristics Database
- Analysis of Storms and Climate Variability
- Integration with CHRS Storm Database
- Other Statistical Climatology Applications

Sensor View of Seasonal Precipitation

WY 2013: Very high early season precipitation, only minor events after Jan 1st



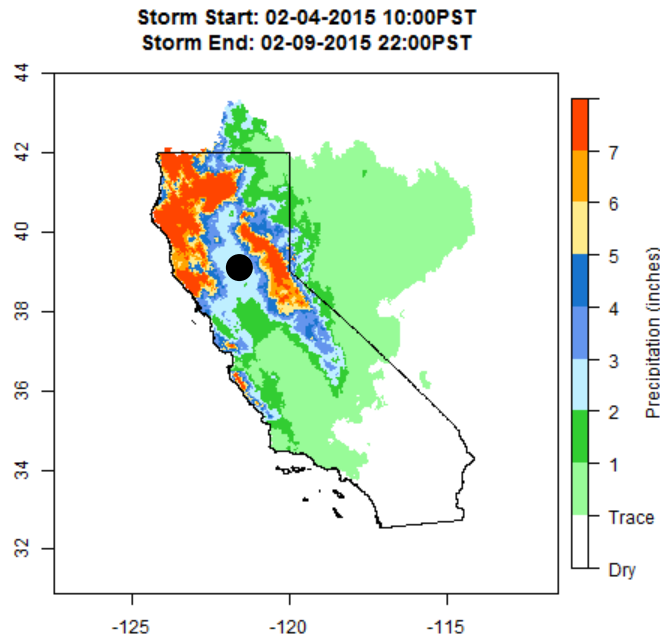
Migrating to a Storm View of Precipitation



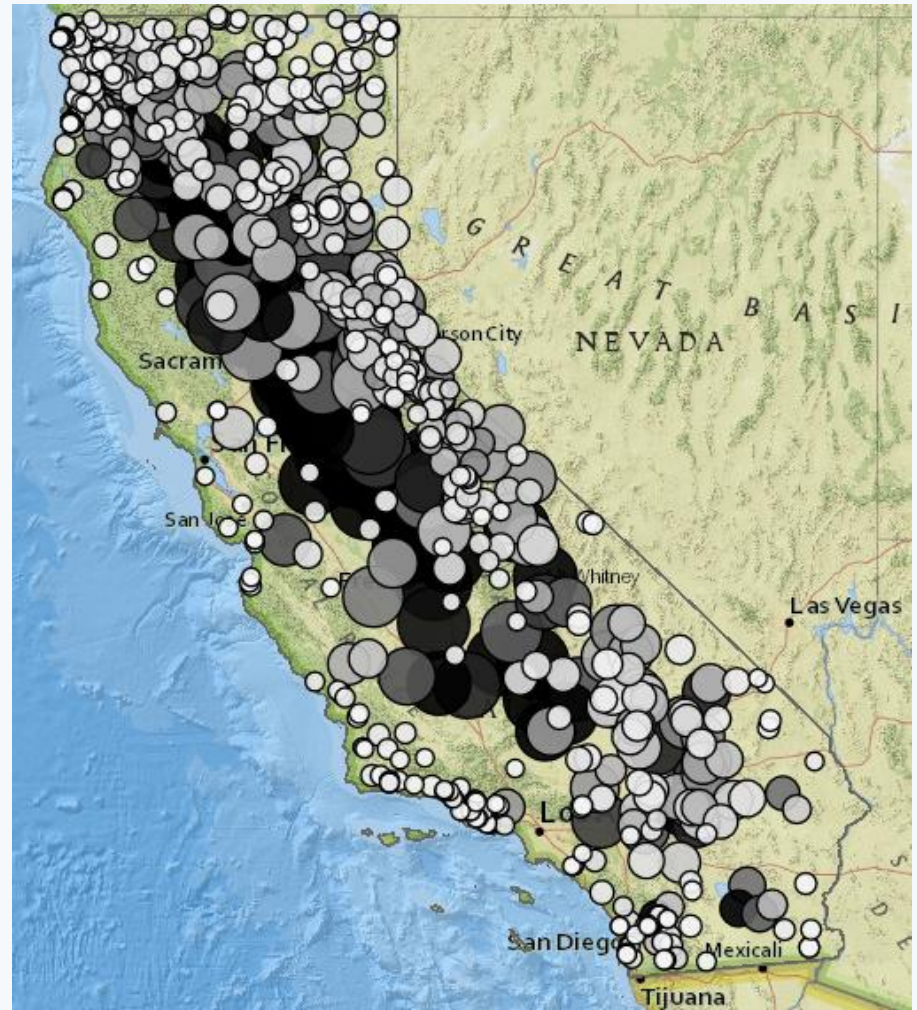
Storm Detail

Storm ID	Start Date
2015020410	2015-02-04
Average Depth	Max Depth
3.16 inches	19.29 inches
Long Mass Center	Lat Mass Center
-121.886	39.507
Length Wet Coast	Max Storm Elevation
685 miles	473.0 meters
Madden Julian Oscillation	El Nino Southern Oscillation
Weakly Suppressed	El Nino
Area	Volume
73,076,100 acres	19,260,081 acre-feet
Long Max Depth	Lat Max Depth
-124.150	40.225
Long Area Center	Lat Area Center
-120.784	38.282
Time Between Storms	Storm Duration
222 hours	132 hours
Pacific Decadal Oscillation	Oceanic Nino Index
Positive	Neutral

Assembling the Storms Characteristics Database



- Over 700 storms from 2004 to present
- Derived from 6-hourly NOAA CNRFC QPE grids



Climate Phases from ONI, PDO and MJO Indices

	Definition	Time in Phase (%)
ONI Cold	ONI < -0.5 for at least 5 months	21%
ONI Neutral	Neither Warm nor Cold phase	62%
ONI Warm	ONI > 0.5 for at least 5 months	17%
Negative PDO	5-year moving average PDO < 0	78%
Positive PDO	5-year moving average of PDO > 0	22%
Strongly Suppressed MJO	MJO at 120°W between -3 to -1.5	4%
Weakly Suppressed MJO	MJO at 120°W between -1.5 to 0	41%
Weakly Enhanced MJO	MJO at 120°W between 0 to 1.5	46%
Strongly Enhanced MJO	MJO at 120°W between 1.5 to 3	9%

ONI=Oceanic Nino Index

PDO=Pacific Decadal Oscillation

MJO=Madden Julian Oscillation

Statewide Storm Characteristics by ONI Phase

	Cold	Neutral	Warm
Annualized Storm Count	77	92	73
Storm Area (million acres)	6.7	3.8	9.7
Precipitation Volume (thousand acre-feet)	27	14	48
Average Precipitation Depth (in)	0.05	0.04	0.06
Peak Precipitation Depth (in)	0.40	0.28	0.36
Mean Storm Event Date	Jan	Apr	Dec
Calendar Month with Most Storms	Nov	May	Oct
Time Between Storms (hr)	24	24	24
Mean Storm Event Duration (hr)	18	12	18

Statewide Storm Characteristics by PDO Phase

	Negative	Positive
Annualized Storm Count	90	73
Storm Area (million acres)	4.5	4.5
Precipitation Volume (thousand acre-feet)	18	16
Average Precipitation Depth (in)	0.05	0.05
Peak Precipitation Depth (in)	0.31	0.34
Mean Storm Event Date	Mar	Feb
Calendar Month with Most Storms	Oct	Oct
Time Between Storms (hr)	24	24
Mean Storm Event Duration (hr)	12	12

Statewide Storm Characteristics by MJO Phase

	Strongly Suppressed	Weakly Suppressed	Weakly Enhanced	Strongly Enhanced
Annualized Storm Count	89	91	82	90
Storm Area (million acres)	22.0	2.9	4.9	5.0
Precipitation Volume (1000 acre-ft)	250	11	24	15
Average Precipitation Depth (in)	0.14	0.04	0.05	0.04
Peak Precipitation Depth (in)	1.17	0.27	0.34	0.28
Mean Storm Event Date	Mar	Mar	Mar	Jan
Calendar Month with Most Storms	Apr	Feb	Dec	Oct
Time Between Storms (hr)	24	24	24	30
Mean Storm Event Duration (hr)	30	12	12	12

Analyzing Characteristics by Drainage Region

Drainage Region	Storms (%)
Central Coast (CC)	40%
Colorado River (CR)	34%
North Coast (NC)	74%
North Lahontan (NL)	55%
Sacramento River (SR)	58%
San Francisco Bay (SF)	32%
San Joaquin River (SJ)	46%
South Coast (SC)	44%
South Lahontan (SL)	46%
Tulare Lake (TL)	39%




Drainage Region Patterns: Peak Storm Frequency

	CC	CR	NC	NL	SR	SF	SJ	SC	SL	TL	All
ONI Cold (La Niña)	Dec	Feb	Nov	Apr	Apr	Nov	Oct	Nov	Nov	Nov	Nov
ONI Neutral	Mar	Aug	May	May	May	Mar	May	Apr	May	May	May
ONI Warm (El Niño)	Nov	Dec	Oct	Oct	Oct	Nov	Nov	Dec	Nov	Jan	Oct
Negative PDO	Apr	Aug	Oct	May	May	Mar	May	Apr	Mar	May	Oct
Positive PDO	Feb	Feb	Nov	Jan	Jan	Jan	Jan	Feb	Jan	Jan	Oct
Strongly Suppressed MJO	Feb	Apr	Apr	Apr	Apr	Feb	Apr	Apr	Apr	Apr	Apr
Weakly Suppressed MJO	Apr	Aug	Oct	May	May	Feb	Mar	Feb	Aug	Aug	Oct
Weakly Enhanced MJO	Dec	Dec	Nov	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec
Strongly Enhanced MJO	Feb	Dec	Oct	Feb	Feb	Nov	Oct	Oct	Oct	Oct	Oct

 *Peaks Earlier Than Statewide*

 *Peaks Later Than Statewide*

Storm Characteristics Database on FERIX



Department of Water Resources
FLOOD EMERGENCY RESPONSE INFORMATION EXCHANGE (FERIX) - Storm Characteristics

DWR Sites | Help

Search

DWR

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STATIONS MAP

Search for SEARCH

STORM CHARACTERISTICS

☒ Date:

to

☒ Max Depth (inches):

to

☒ Average Depth (inches):

to

☒ Storm Area (acres):

to

☒ Storm Volume (acre-ft):

to

☒ Storm Duration (hours):

to

☒ Hydrological Region:

SHOW

CLEAR

Click on a row to view storm on map.



Current Tool: Identify Active Layer: Lat/Long: 32.642439, -119.676

Storm Characteristics by Drainage Region

Storm Climatology Summary

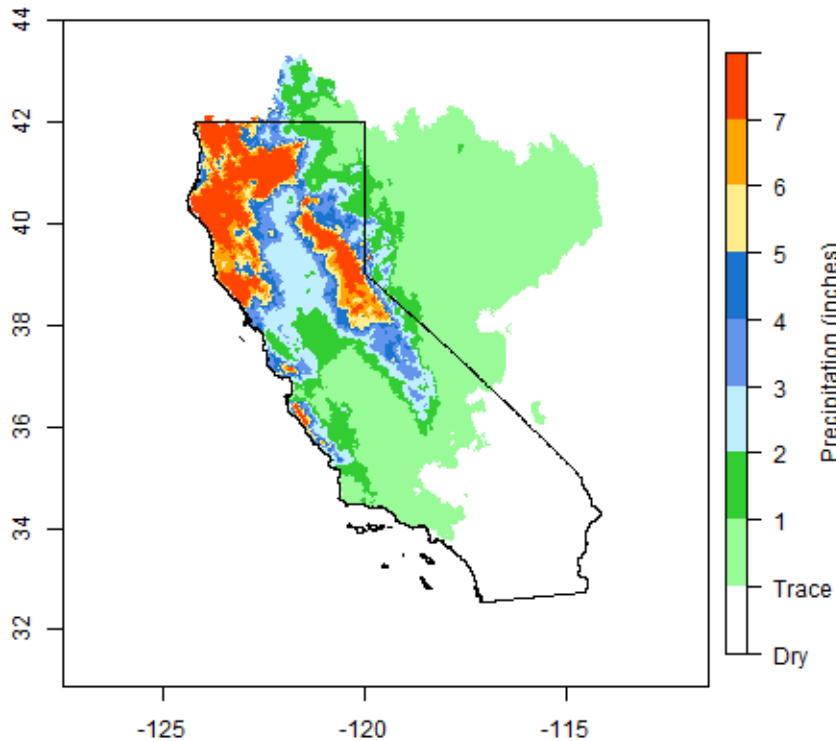
Climate State ▼	Number of Storms	Annualized Storm Count	Percent Time in Climate State (%)	Median Area (acres)	Median Volume (acre-feet)	Median Avg Depth (inches)	Median Max Depth (inches)	Median Long Max Depth
ONI Cold	174	77.3	20	6,065,900	24,294	0.01	0.40	-123.699
ONI Neutral	673	93.9	64	2,988,500	10,189	0.00	0.30	-121.534
ONI Warm	133	72.7	16	6,289,600	23,863	0.01	0.36	-123.609

Individual Storms

Storm ID	Start Date ▲	Drainage Region	Area (acres)	Volume (acre-feet)	Average Depth (inches)	Max Depth (inches)	Long Max Depth	Lat Max Depth	Long Mass Center
2015022022	2015-02-20	North Coast	104,100	0	0	0.03	-122.932	38.303	-122.923
2015020410	2015-02-04	North Coast	12,144,100	7,165,000	7.08	19.29	-124.150	40.225	-123.289
2015020116	2015-02-01	North Coast	10,311,100	1,196,000	1.39	6.28	-123.880	41.578	-123.334

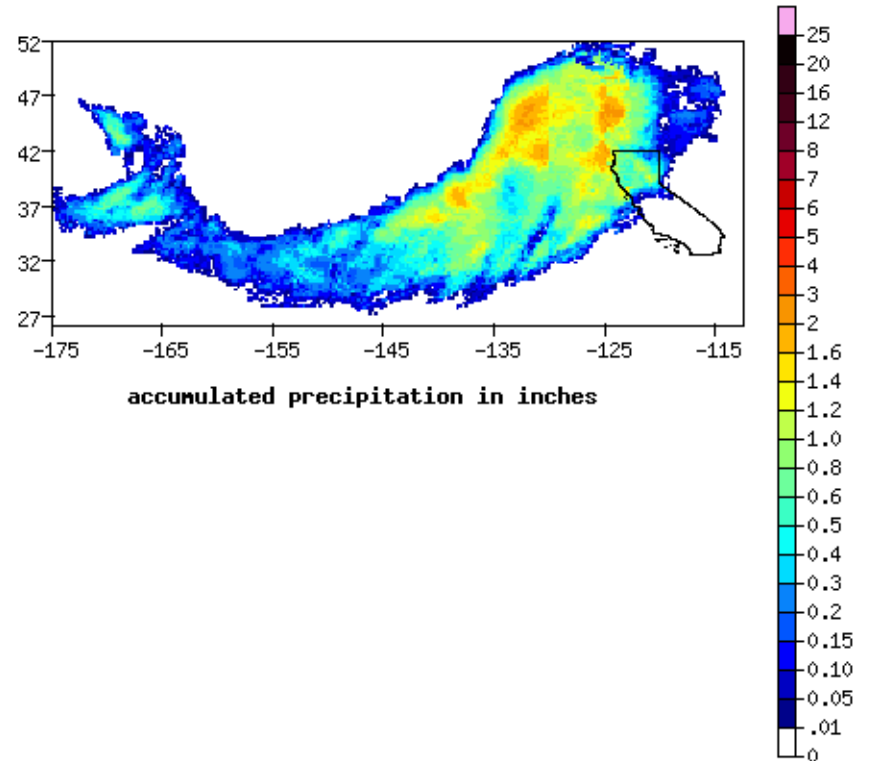
Expanded View of The Storm Event

Storm Start: 02-04-2015 10:00PST
Storm End: 02-09-2015 22:00PST



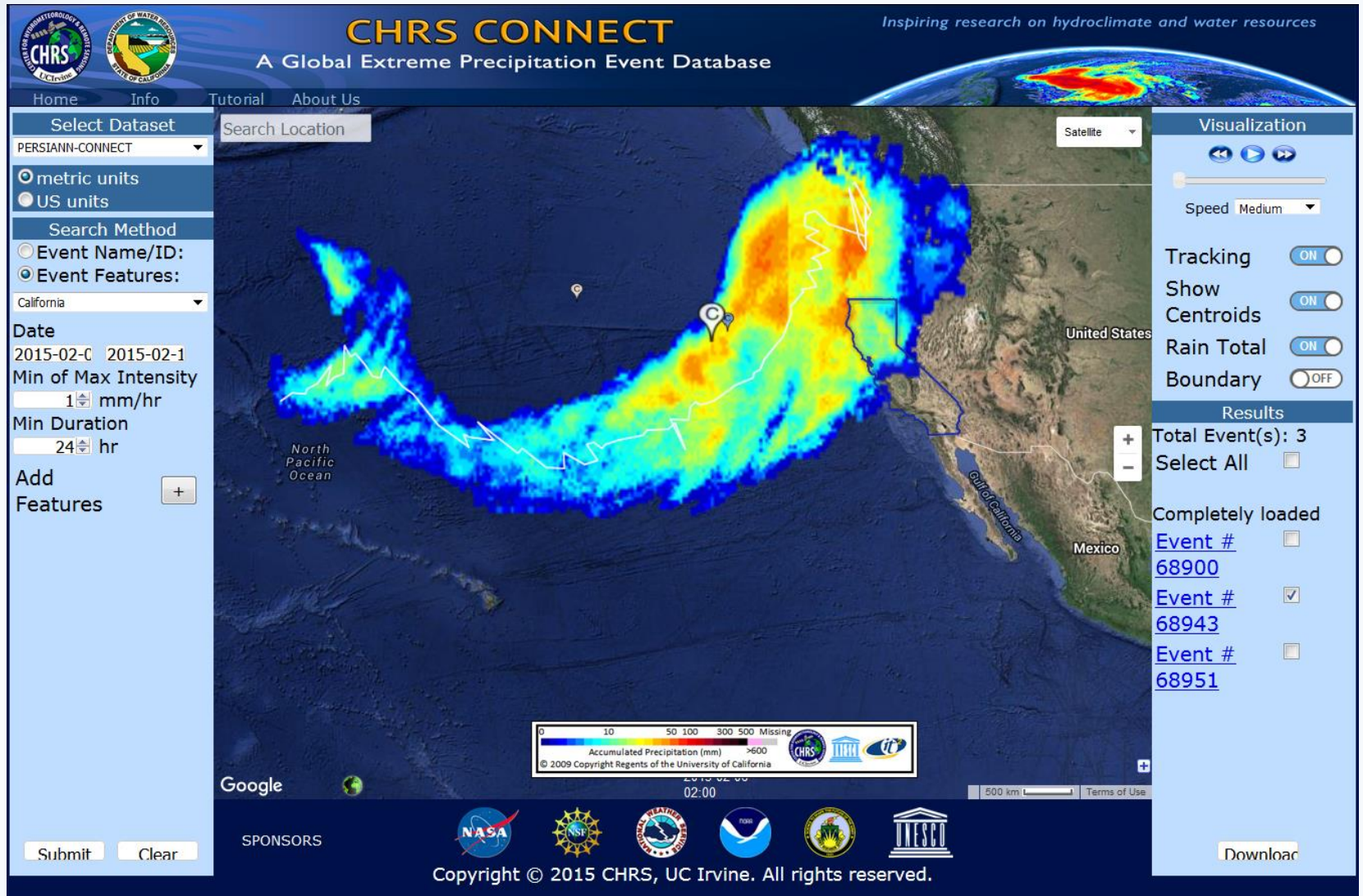
Gauge-Derived

event ID#:68943 storm begin time: 2015-02-05 18:00 PST
ending: 2015-02-09 08:00 PST



Satellite-Derived


UC-Irvine CHRS Connect Storm Database



UC-Irvine CHRS Connect Storm Database

- **Source:** Extracted from PERSIANN, a satellite-derived precipitation dataset
- **Spatial Coverage:** global
- **Temporal Coverage:** 2000 to 2015; periodically updated
- **Attributes:** 55 fields including 15 storm characteristics and 40 weather/climate indices
- Dataset of 673 storms impacting California has been extracted and transferred to DWR

CHRS Connect Storm Database on DWR FERIX



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FLOOD EMERGENCY RESPONSE INFORMATION EXCHANGE (FERIX) - CHRS

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STATIONS MAP

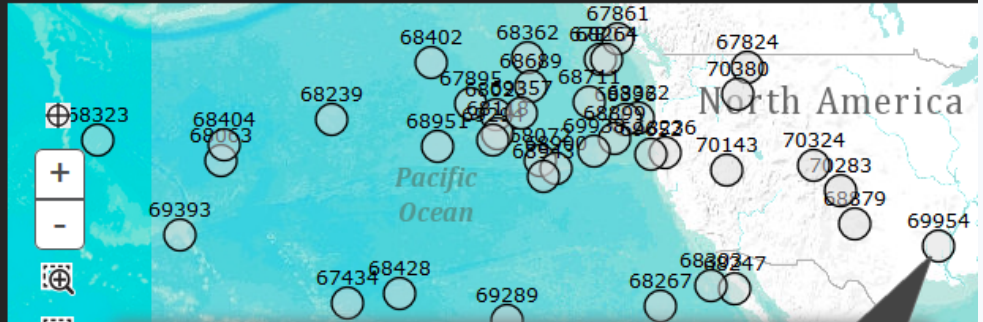
CHRS

SEARCH STORMS

☒ Start Date: 10/01/2014 to 09/30/2015
 ☒ Storm Volume (km3): to
 ☒ Storm Duration (hours): to
 ☒ Max Intensity (mm/hr): to
 ☒ IDs (comma separated):

Click on a row to view storm on map.

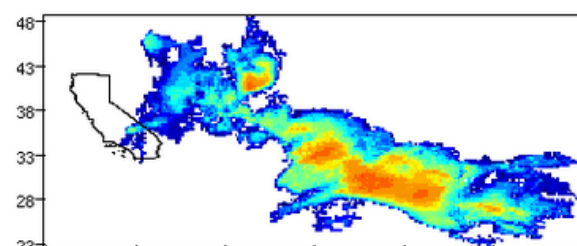
Storm ID	Start Date	End Date ▲	Latitude	Longitude	Start Lat	Start Long
70651	2015-06-19 03:00	2015-07-01 14:00	-8.858	-149.955	3.625	-192.3
70380	2015-05-25 18:00	2015-05-27 07:00	45.961	-114.563	42.125	-116.8
70324	2015-05-21 14:00	2015-05-23 15:00	40.232	-106.155	33.042	-110.7
70283	2015-05-18 15:00	2015-05-20 17:00	38.058	-103.203	39.75	-113.6
70143	2015-05-07 17:00	2015-05-09 05:00	39.799	-115.921	38.253	-120.1
69954	2015-04-25 11:00	2015-04-29 04:00	32.974	-92.317	35.708	-117.4
69938	2015-04-24 11:00	2015-04-25 13:00	41.308	-130.597	44.42	-145.2
69652	2015-04-06 14:00	2015-04-07 15:00	41.099	-124.209	40.061	-127.3
69393	2015-03-18 19:00	2015-03-24 13:00	33.958	-176.609	25.208	-203.3
69357	2015-03-15 19:00	2015-03-21 11:00	44.445	-138.631	30.44	-170.1
69289	2015-03-09 21:00	2015-03-18 11:00	25.818	-140.263	7.394	-144.5



Storm Detail

NP Pattern	Average Intensity	Duration	Max Intensity	Median Intensity	Speed	STDDEV Intensity
1,015.87	3.215 mm/hr	90 hours	23.092 mm/hr	2.289 mm/hr	46.919 km/hr	2.627 mm/hr
Time of Year	Volume	ONI	PAC Warm	PDO	PNA	QBO
4	76.065 km3	0.68	0	1.44	-0.39	-24.38
SOI	Solar Flux	SW Monsoon	TNA	TNI	TSA	WHWP
-0.1	1,290	0	-0.24	-1.434	0.36	2.3
WP						
1.23						

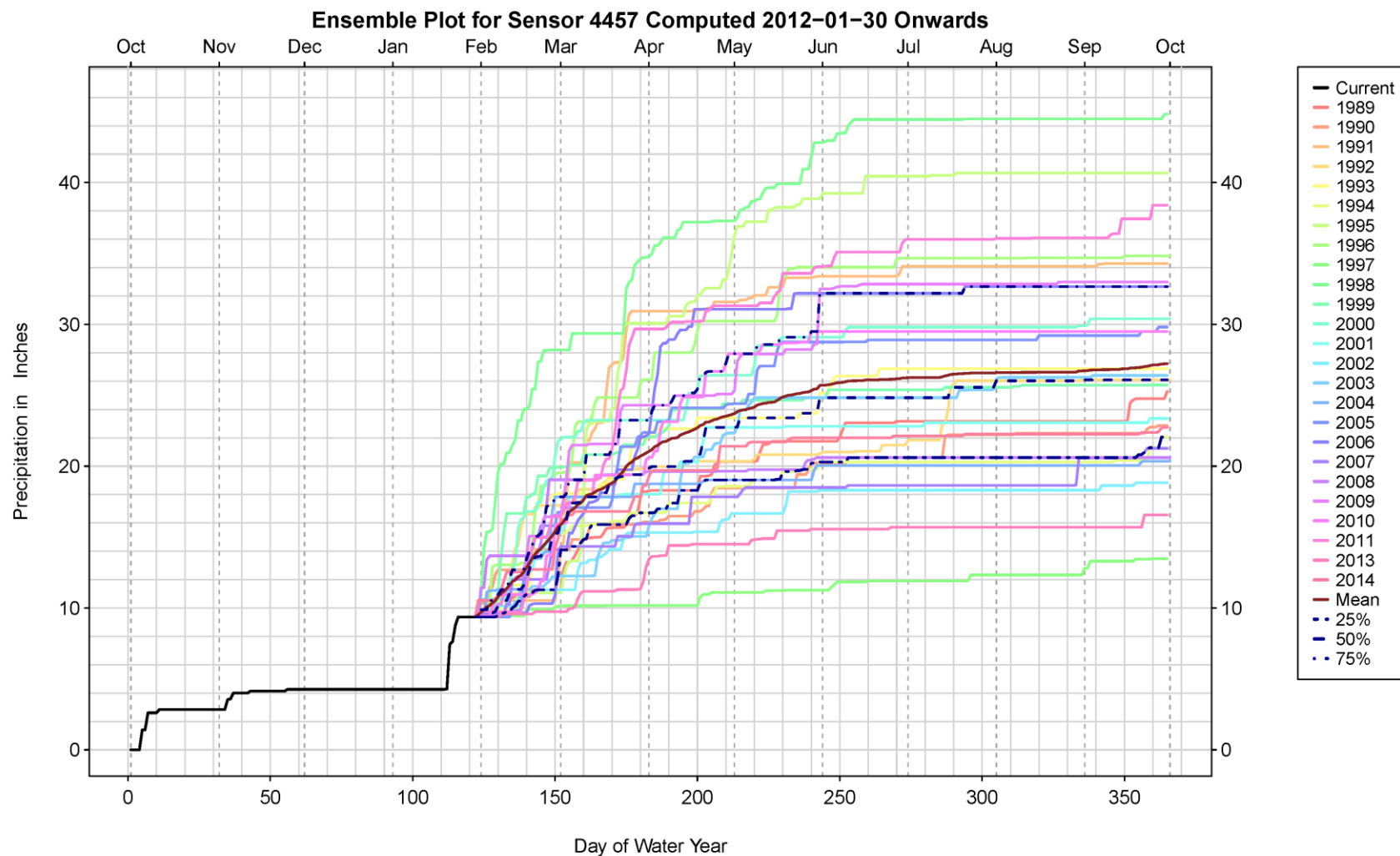
event ID#:69954 storm begin time: 2015-04-25 03:00 PST
ending: 2015-04-28 20:00 PST



Transitioning Storms to Other Applications

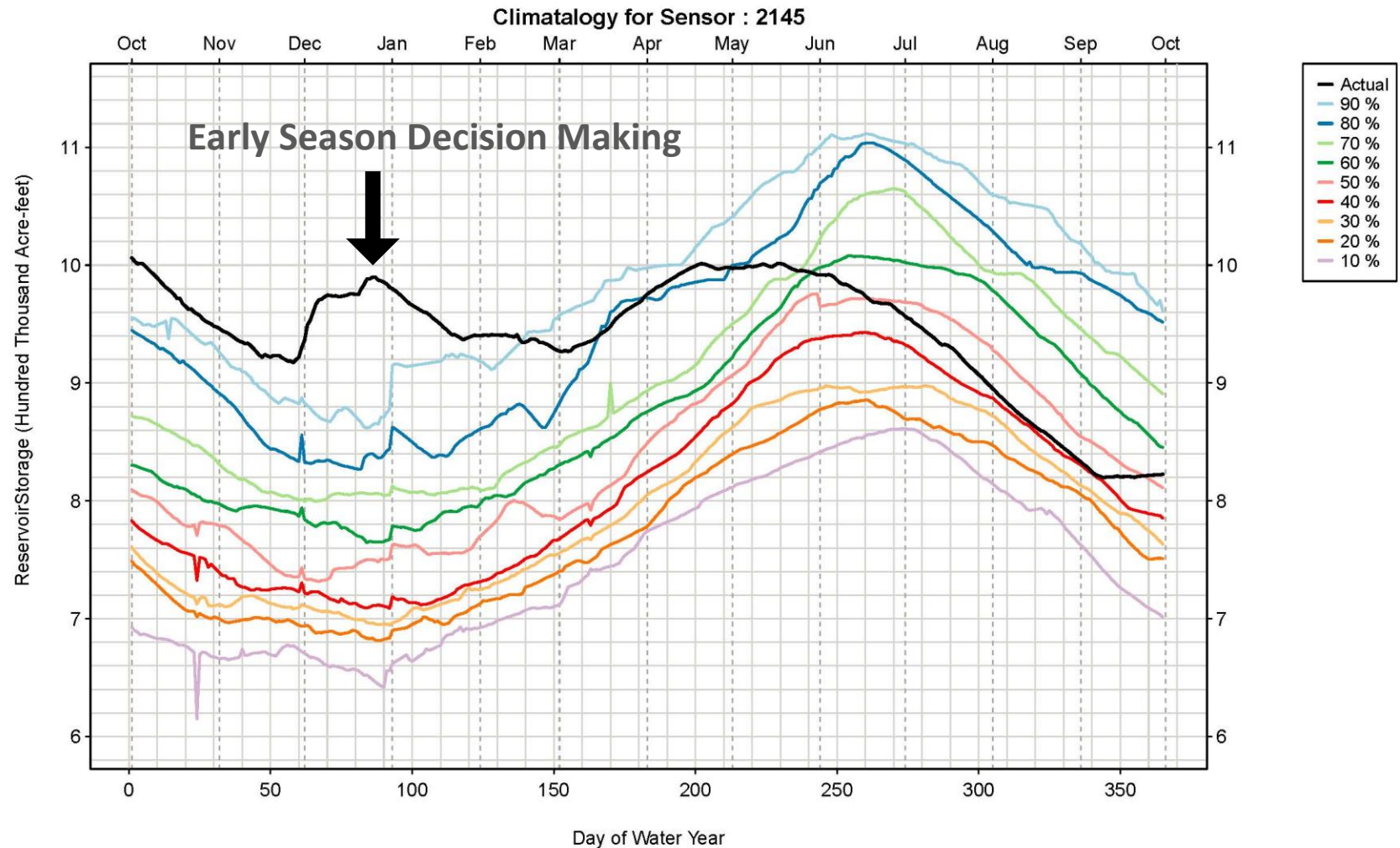
- Can predictable storm characteristics be used to improve precipitation and/or water supply forecasts?
- What else can we use predictable storm characteristics for?

Historical Ensemble Predictions



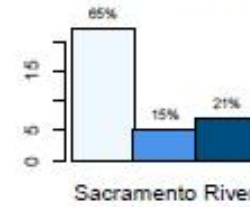
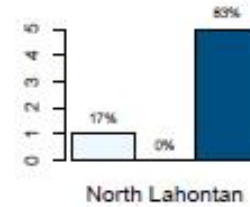
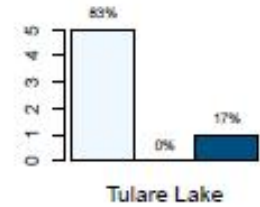
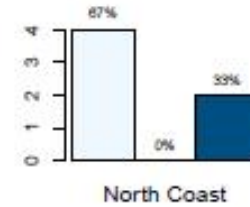
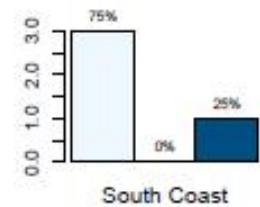
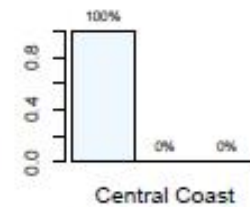
Can S2S forecasts inform subsetting of hydrologic ensembles?

Reservoir Storage Management



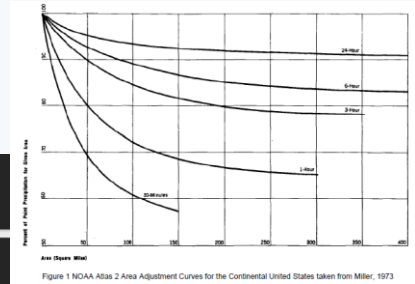
Can S2S forecasts tell us how long a given anomalous condition is likely to persist?

Reservoir Storage Forecast Maps



Could storm-based forecasts yield improved forecast storage probability maps?

Precipitation Area Adjustment Factors



Drainage Regions

00-20%

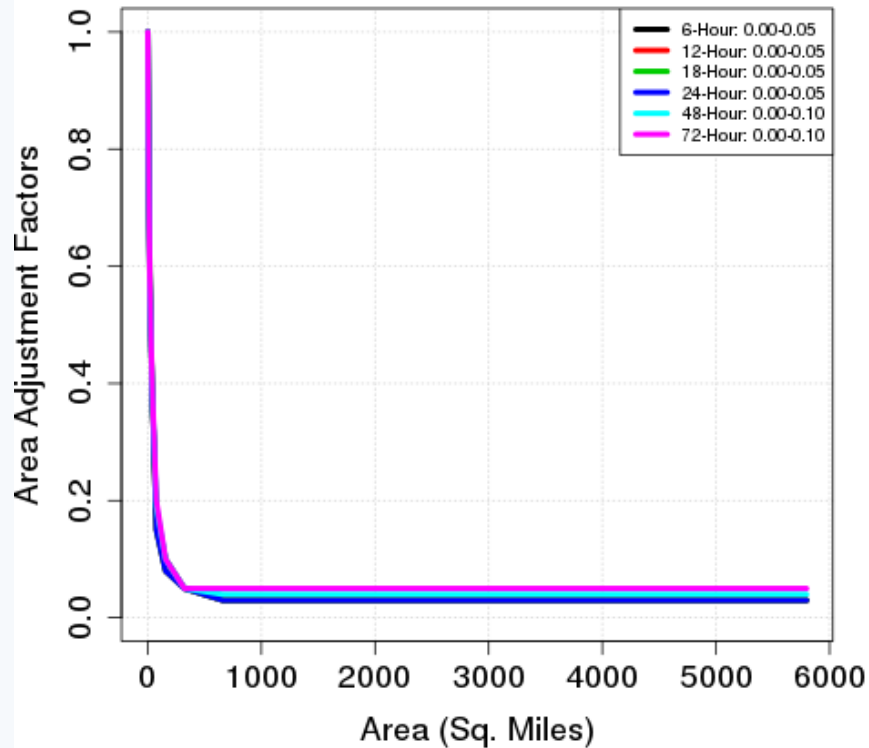
20-40%

40-60%

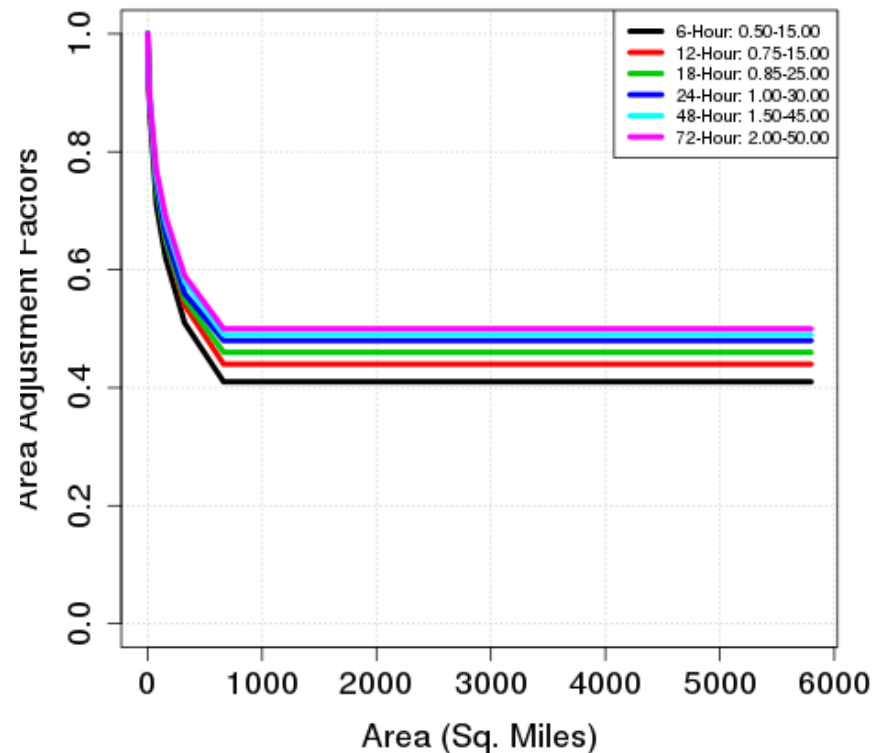
60-80%

80-100%

**Area Adjustment Factors for Region A60
and Rainfall Intensity Percentiles: 0%-20%**



**Area Adjustment Factors for Region A60
and Rainfall Intensity Percentiles: 80%-100%**



Could storm-derived factors be used to interpret storm forecasts?

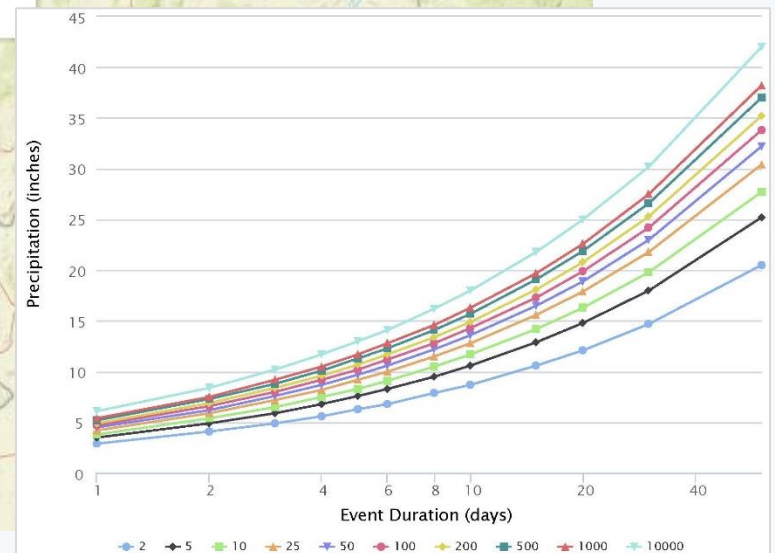
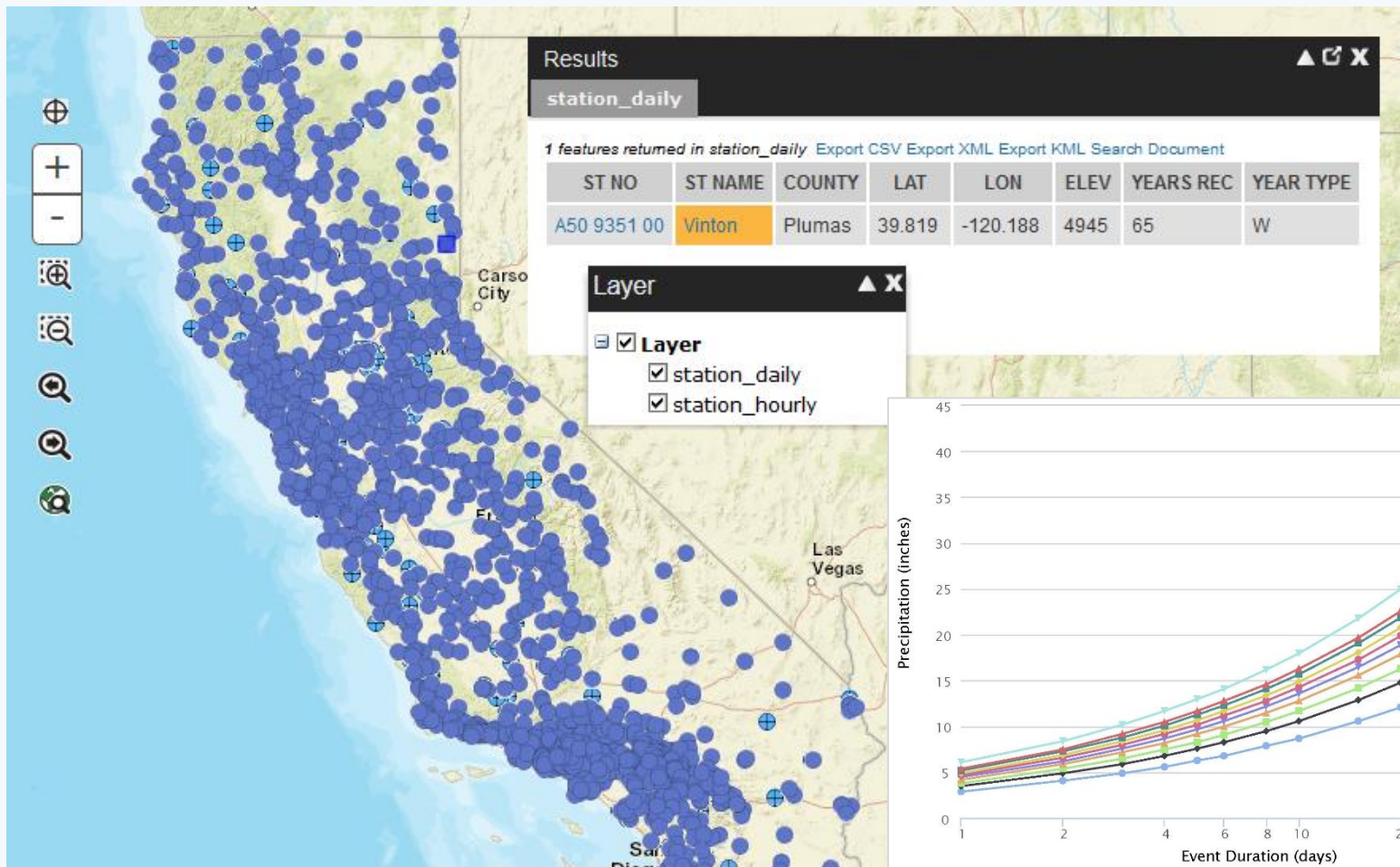
Bulletin 195: Precipitation Frequency Analysis



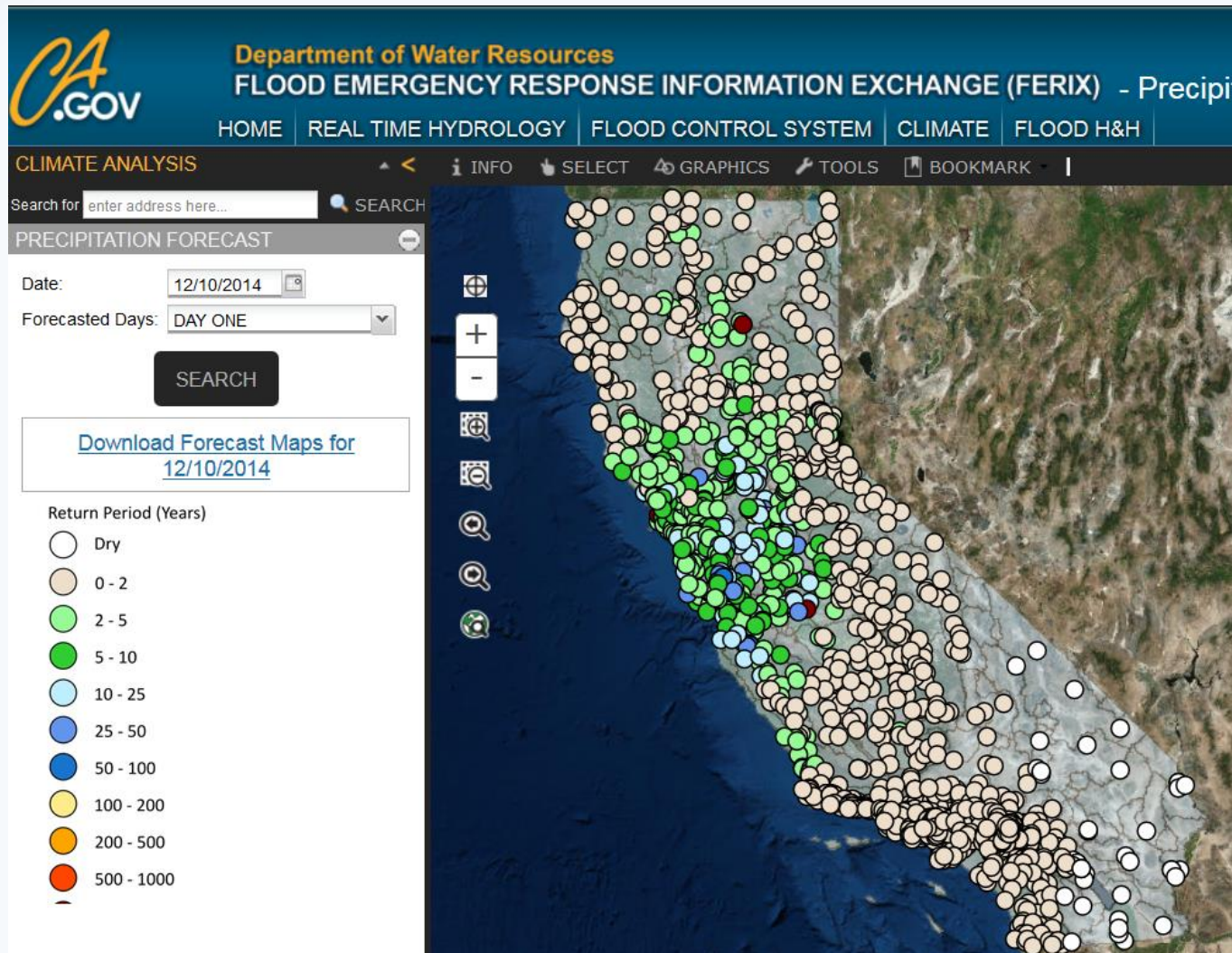
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Severity Maps for 6-Day Precipitation Forecasts



Could storm severity thresholds be predicted at sub-seasonal time scales?

CDAT: Climate Data Analysis Tool

Tool for Performing Interactive Computations and Data Updates



Climate Data Analysis Tool

Log out

Frequency Interpolation

Latitude: Longitude: Add New Point

Station List:

Remove Selected

Ref. Id.	Latitude	Longitude
9023	33.142	-116.849
9010	37.392	-121.552
9041	36.249	-118.871
9097	36.160	-119.871

Interpolated Data

Frequency Plots

Return Period	Days 8	Days 10	Days 15	Days 20	Days 30	Days 60
RP10	3.300	3.600	4.100	4.500	5.200	6.600
RP25	4.000	4.300	5.000	5.500	6.300	8.000
RP50	4.500	4.900	5.600	6.200	7.100	9.000
RP100	5.000	5.400	6.200	6.900	7.900	10.100
RP200	5.500	5.900	6.800	7.500	8.700	11.100
RP500	6.100	6.600	7.600	8.400	9.700	12.400
RP1000	6.600	7.100	8.200	9.100	10.500	13.300
RP10000	8.100	8.800	10.100	11.200	12.900	16.500

Select Map Points

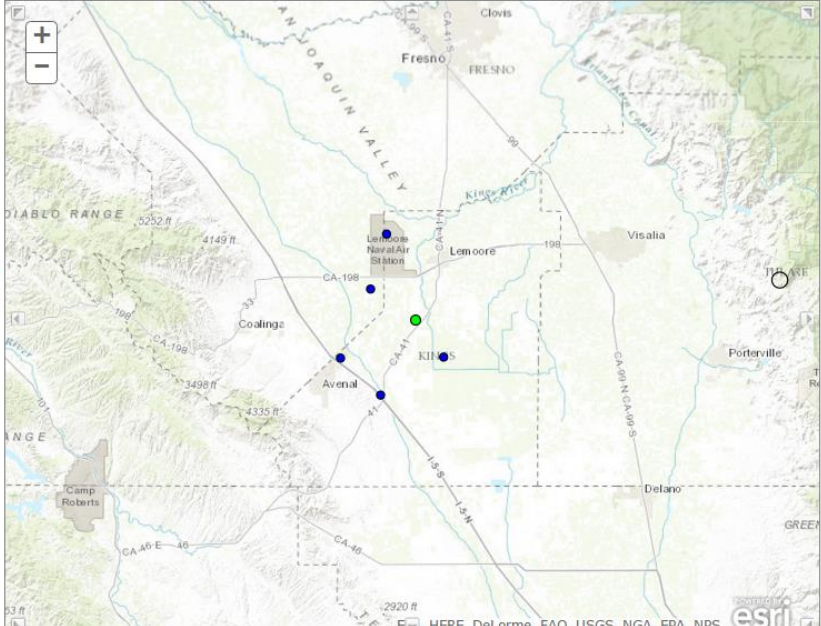
Interpolation Result Table

Interpolation Result Plots

Start Date: End Date:

2010 2010

Interpolate Add New Point



CAMS: Climate Application Management System

System for Executing Repetitive Operational Tasks

CA.GOV Climate Application Management System					
Jobs		History	Processes	Resources	Users
				CREATE NEW PROCESS	REFRESH TABLE
Process Table					
Edit	47	QPE Accumulation	Doing a running accumulation of the 6 hourly QPE data, producing 12, 18, 24, 48 hourly data	QPE and QPF data and R code	
Edit	48	AAF Calculations	Using the AAF Resource file to calculate the areal adjustment factor data	Areal Adjustment Factor Code and Data	
Edit	49	Storm Climatology Process	Storm Climatology Process creates the storm characteristics and higher level table with pngs for the Storm	Storm Climatology Operational Package	

Conclusions

- Select storm characteristics are amplified or suppressed in spatially consistent patterns under the climate phases analyzed.
- The altered storm characteristics could form the basis for generating storm-based forecasts at sub-seasonal to seasonal time scales.
- Statistically-derived storm impact databases and applications being developed can integrate storm forecasts into existing decision processes.