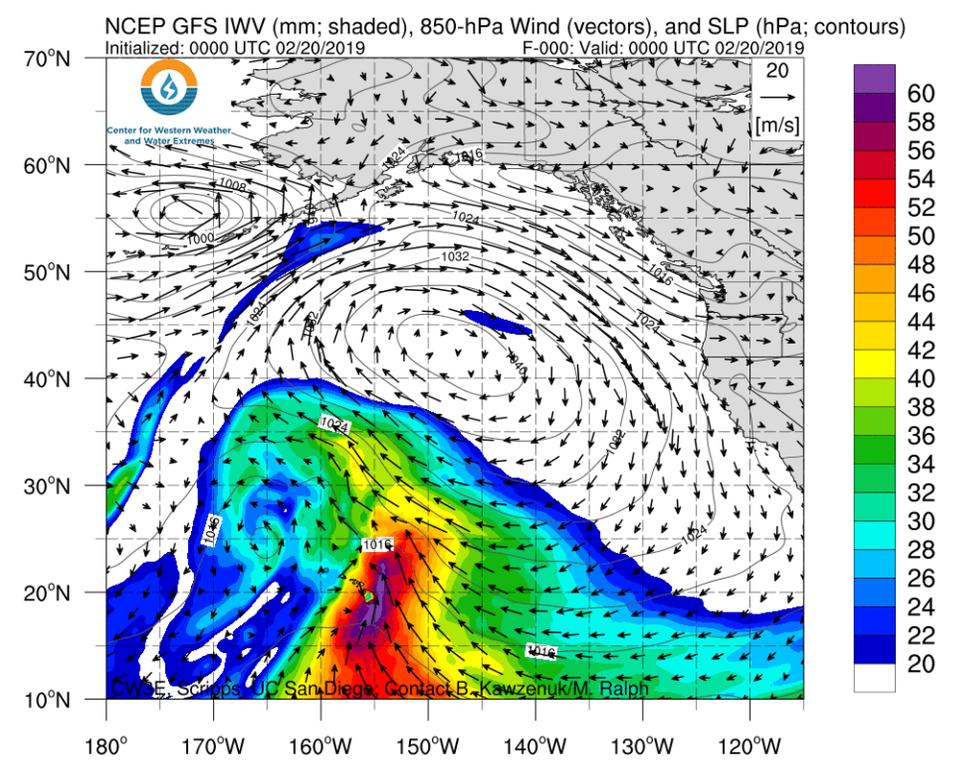
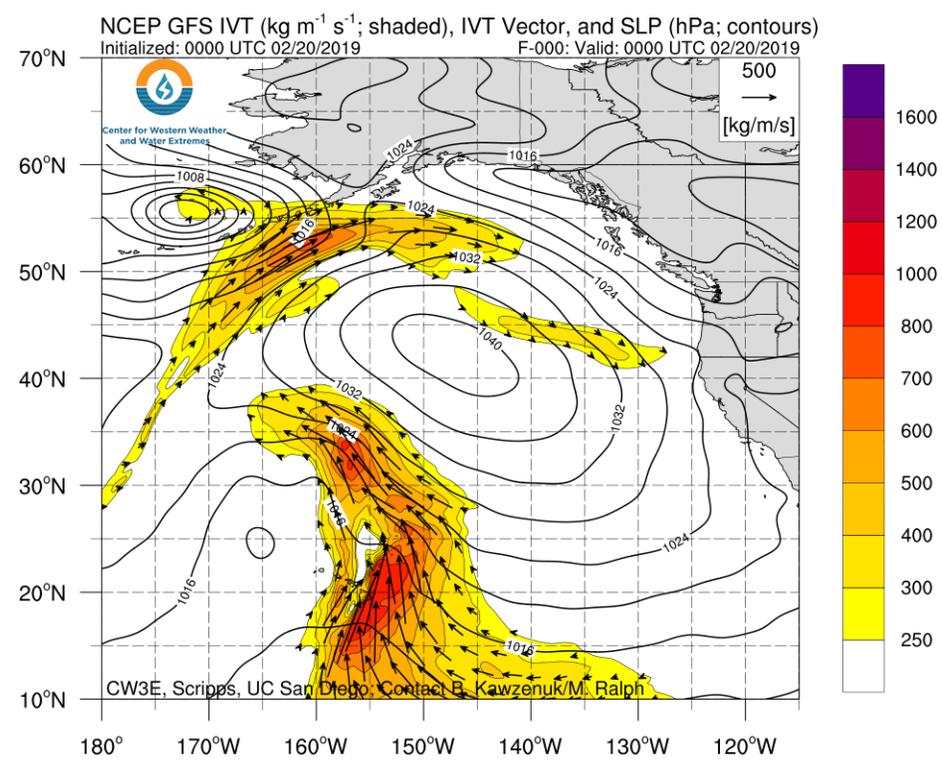


CW3E Post Event Summary: 25–27 Feb. AR



Landfalling Atmospheric River brings Record Breaking precipitation and flooding to Northern California

- A long duration AR impacted Northern California between 25 and 27 February 2019
- A cut off low interacted with the AR as it was making landfall, intensifying IVT and prolonging AR conditions over the coast
- This event was classified as an AR Category 3 event over a large portion of North-Coastal California by GFS Analysis
- Numerous locations across Northern CA experienced >5 inches of rain with Venado, CA receiving the most at 21.36 inches
- Several rivers and streams throughout the region experienced flooding, such as the Russian River in Guerneville, which rose to 45.4 feet (13.4 feet above flood stage)



AR Summary: 25-27 Feb 2019

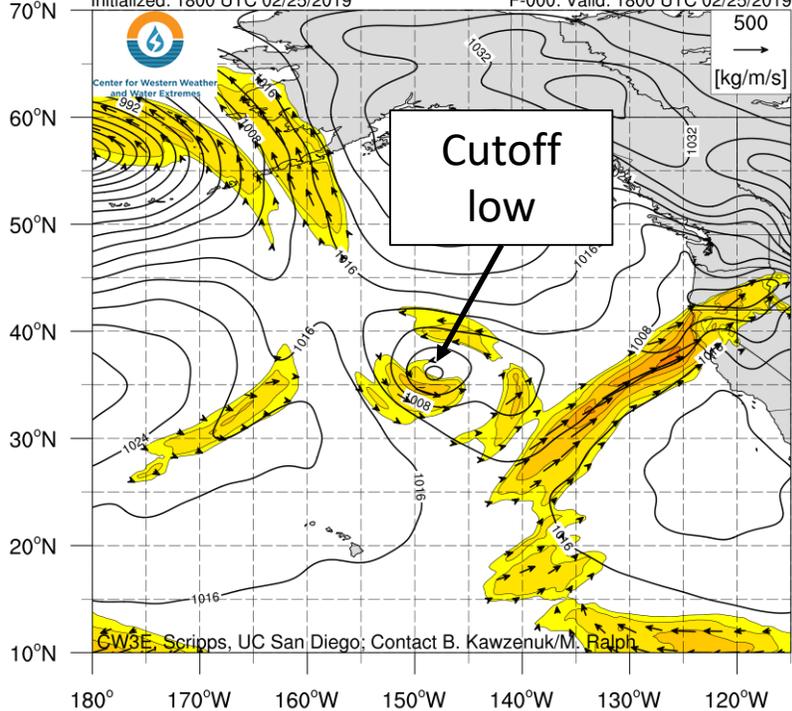
For California DWR's AR Program



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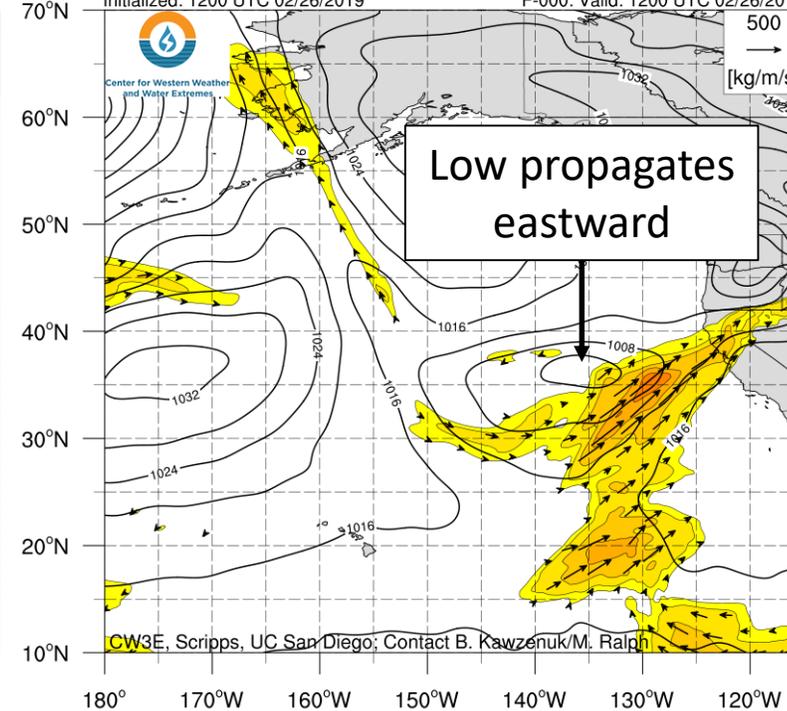
18 UTC 25 February

NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 1800 UTC 02/25/2019 F-000: Valid: 1800 UTC 02/25/2019



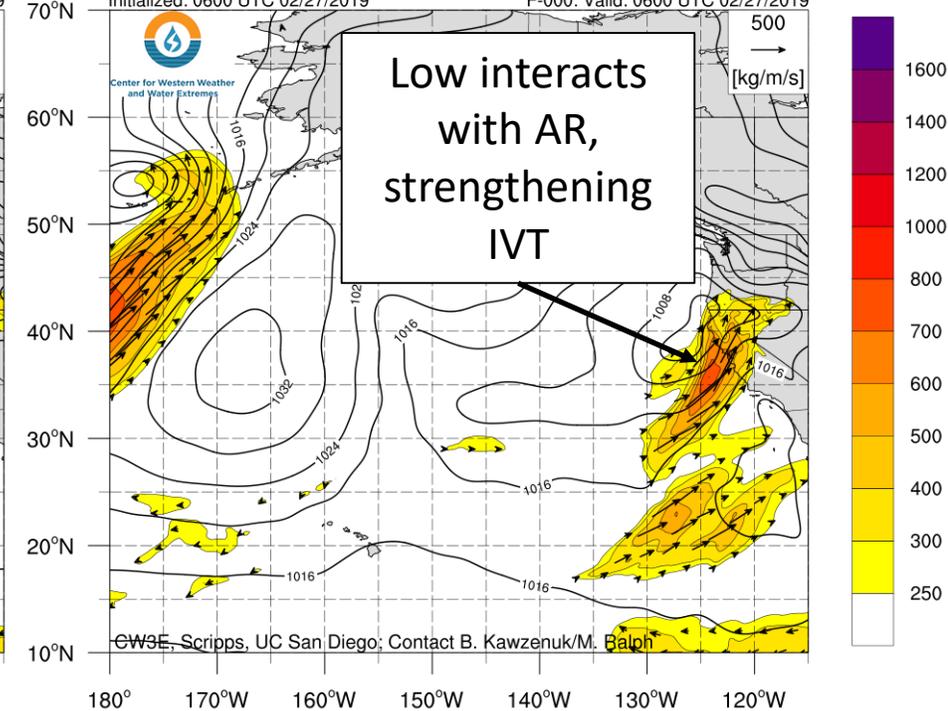
12 UTC 26 February

NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 1200 UTC 02/26/2019 F-000: Valid: 1200 UTC 02/26/2019



06 UTC 27 February

NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 0600 UTC 02/27/2019 F-000: Valid: 0600 UTC 02/27/2019



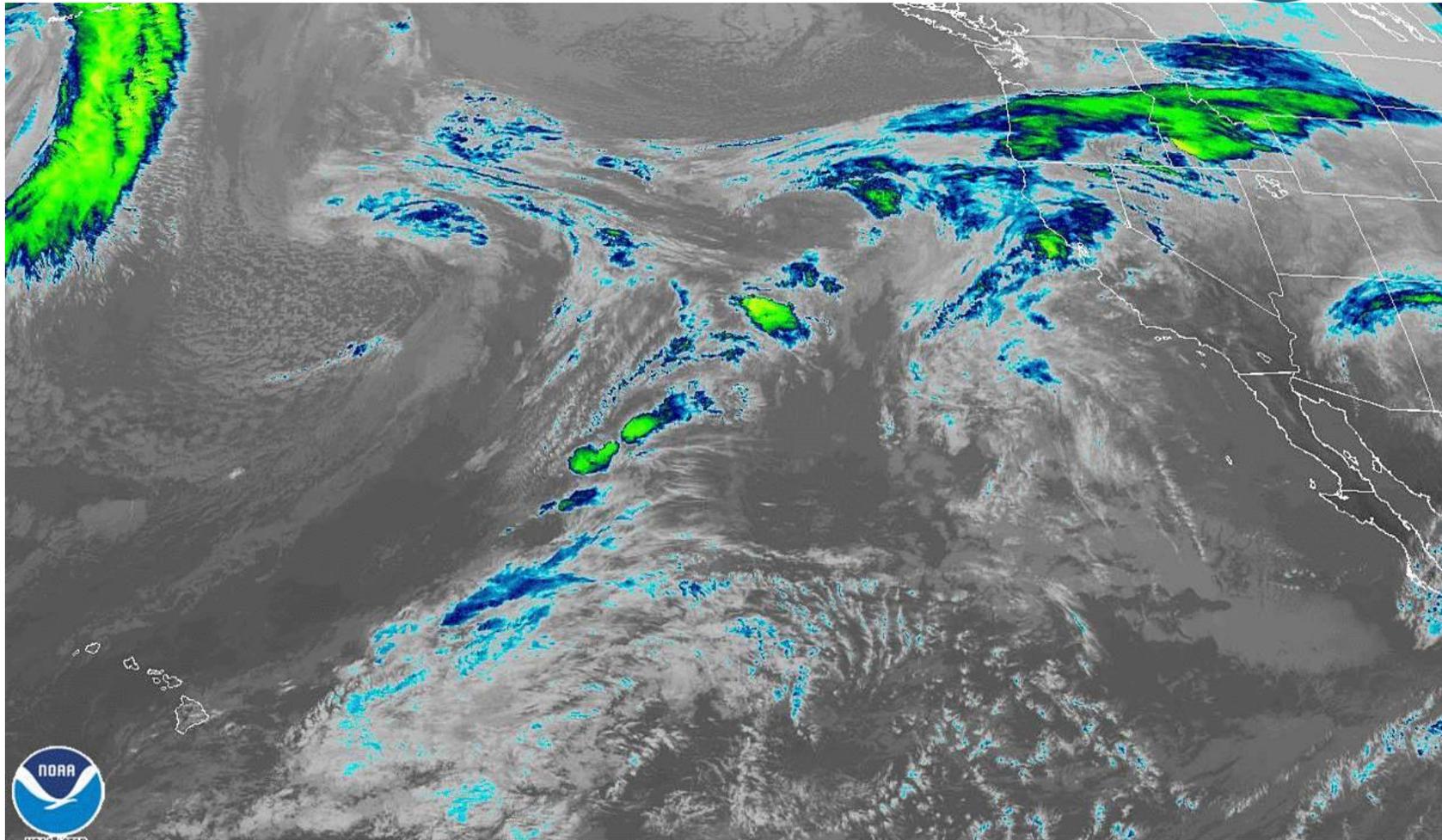
- A cutoff low in the central East Pacific began to propagate eastward beginning on 25 February 2019
- As the low propagated eastward, it began to interact with the AR that was impacting Northern California
- The interaction between the eastward propagating low and the landfalling AR resulted in an intensification of IVT within the AR, a cyclonic rotation of the IVT orientation, and ultimately resulted in the AR stalling over Northern California
- The cyclonic rotation of the AR to a more south/southwesterly orientation may have led to a more favorable IVT orientation to topography for upslope more flux, enhancing precipitation over the coast

AR Summary: 25-27 Feb 2019

For California DWR's AR Program



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25 Feb 2019 00:02Z NOAA/NESDIS/STAR GOES-West Band 14

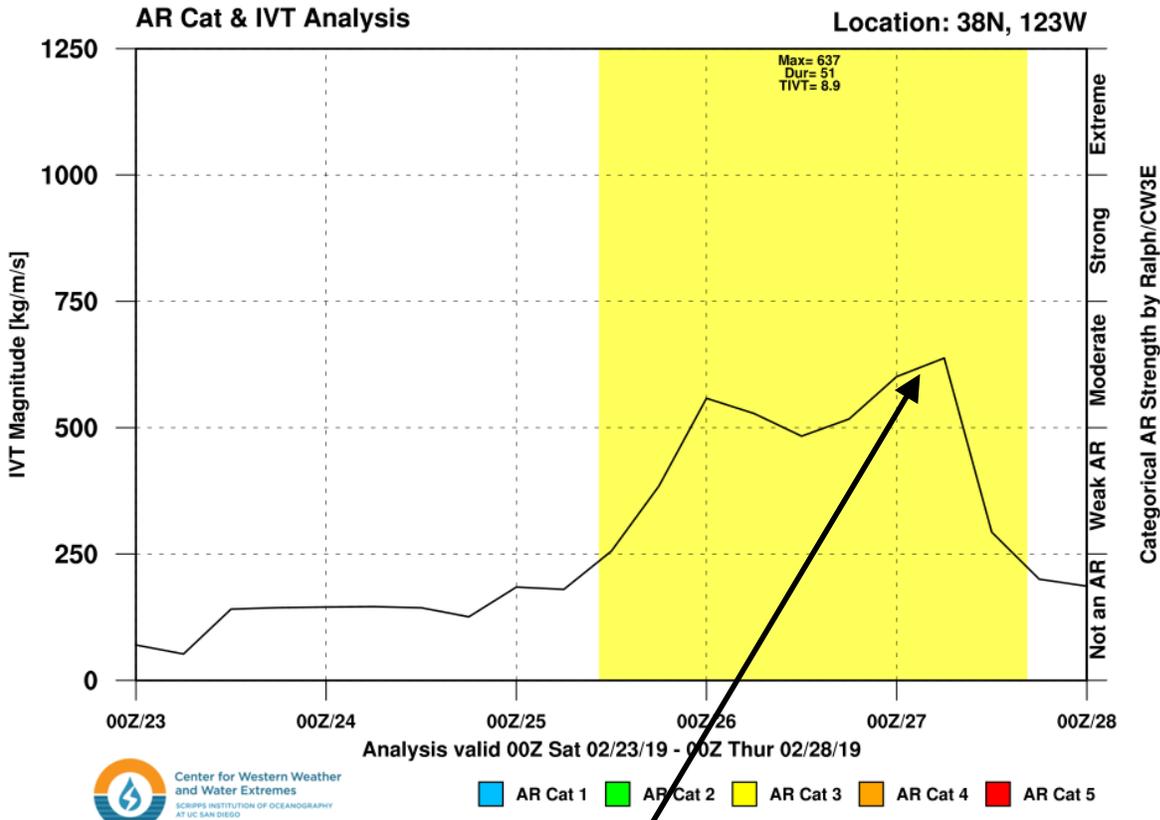
GOES West infrared satellite imagery suggests that as the East Pacific low began to interact with the landfalling AR and associated frontal boundary, convection was initiated just offshore of the Northern CA coast (based on colder cloud top temperatures), potentially leading to higher precipitation rates onshore.

AR Summary: 25-27 Feb 2019

For California DWR's AR Program

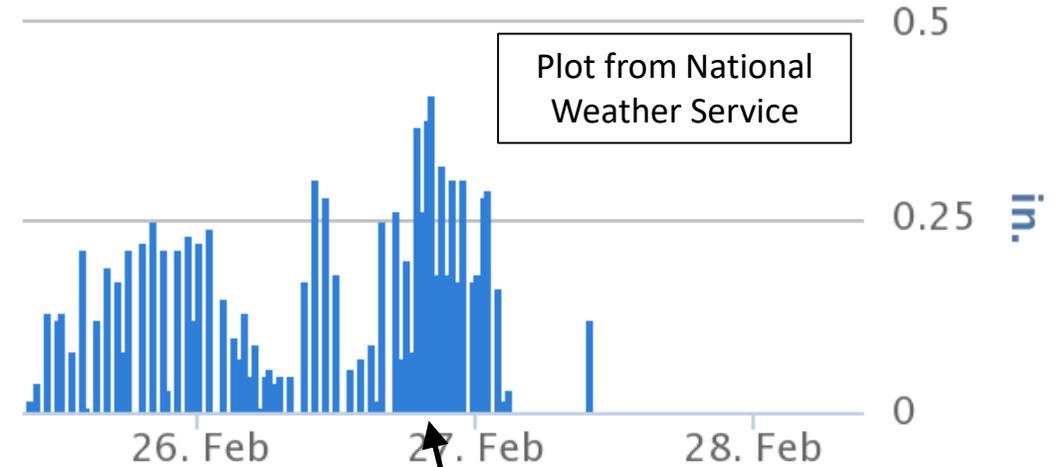


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1 Hour Precipitation

72-hour total: 7.83



(Click to hide)

1 Hour Precip

The interaction between the low and the landfalling AR resulted in enhancement of the IVT and longer duration of AR conditions along the Sonoma County Coast

A max IVT of 637 kg/m/s and duration of AR conditions of 51 hours results in AR-Category 3 conditions based on the recently published AR Category (Ralph et al. 2019)

Santa Rosa, which received its highest 24-hour precipitation accumulation on record (5.56 in.), experienced the heaviest precipitation rates (.32/hr ending 9 PM 26 Feb.) as the highest IVT and enhanced convection moved on shore

AR Summary: 25-27 Feb 2019

For California DWR's AR Program



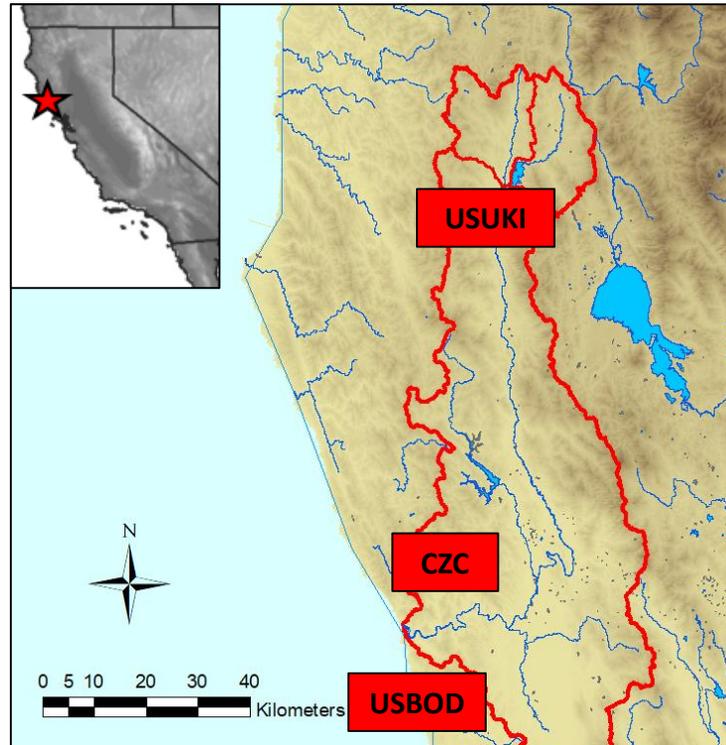
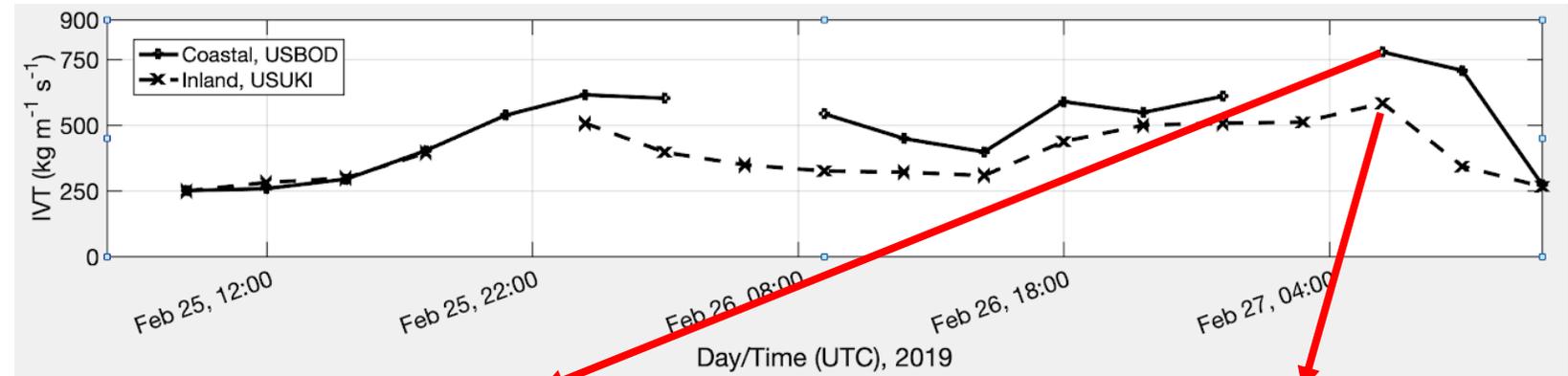
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CW3E Radiosonde Observations

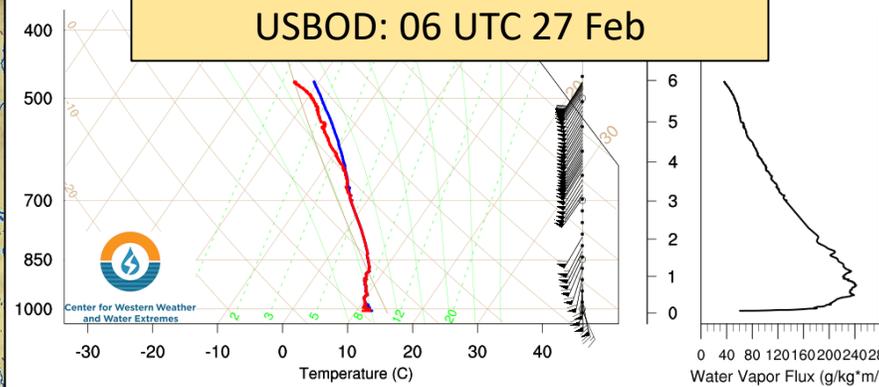
During this AR, CW3E team members were in the field and launched weather balloons every three hours from two locations (USBOD and USUKI)

	Duration (hr)	Max IWV (mm)	Max IVT ($\text{kg m}^{-1} \text{s}^{-1}$)	BBY Precip (mm)	CZC Precip (mm)	Orographic Ratio	Number of Sondes
USBOD (USUKI)	51 (48)	28.1 (25.4)	777 (583)	180	459*	2.5	20 (19)

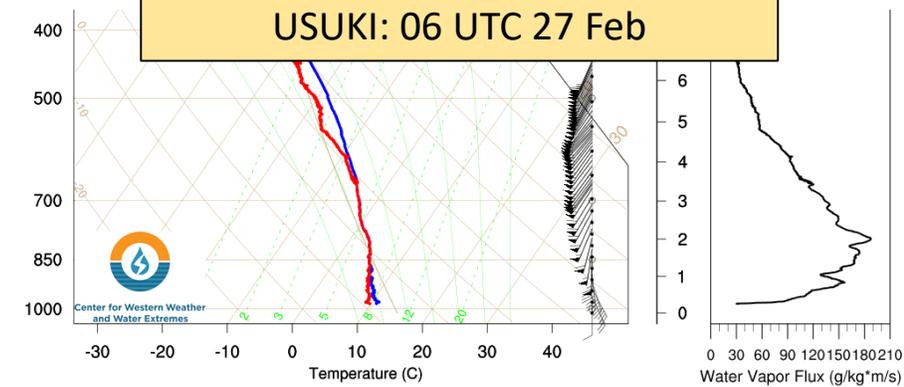
*preliminary data, station went off line at 05 UTC 27 Feb



USBOD: 06 UTC 27 Feb



USUKI: 06 UTC 27 Feb



During the strongest part of the storm, both locations lost signal around 500 mb. While most of the moisture is focused in the lower atmosphere, these values are still likely an underestimate of the total IVT.

AR Summary: 25-27 Feb 2019

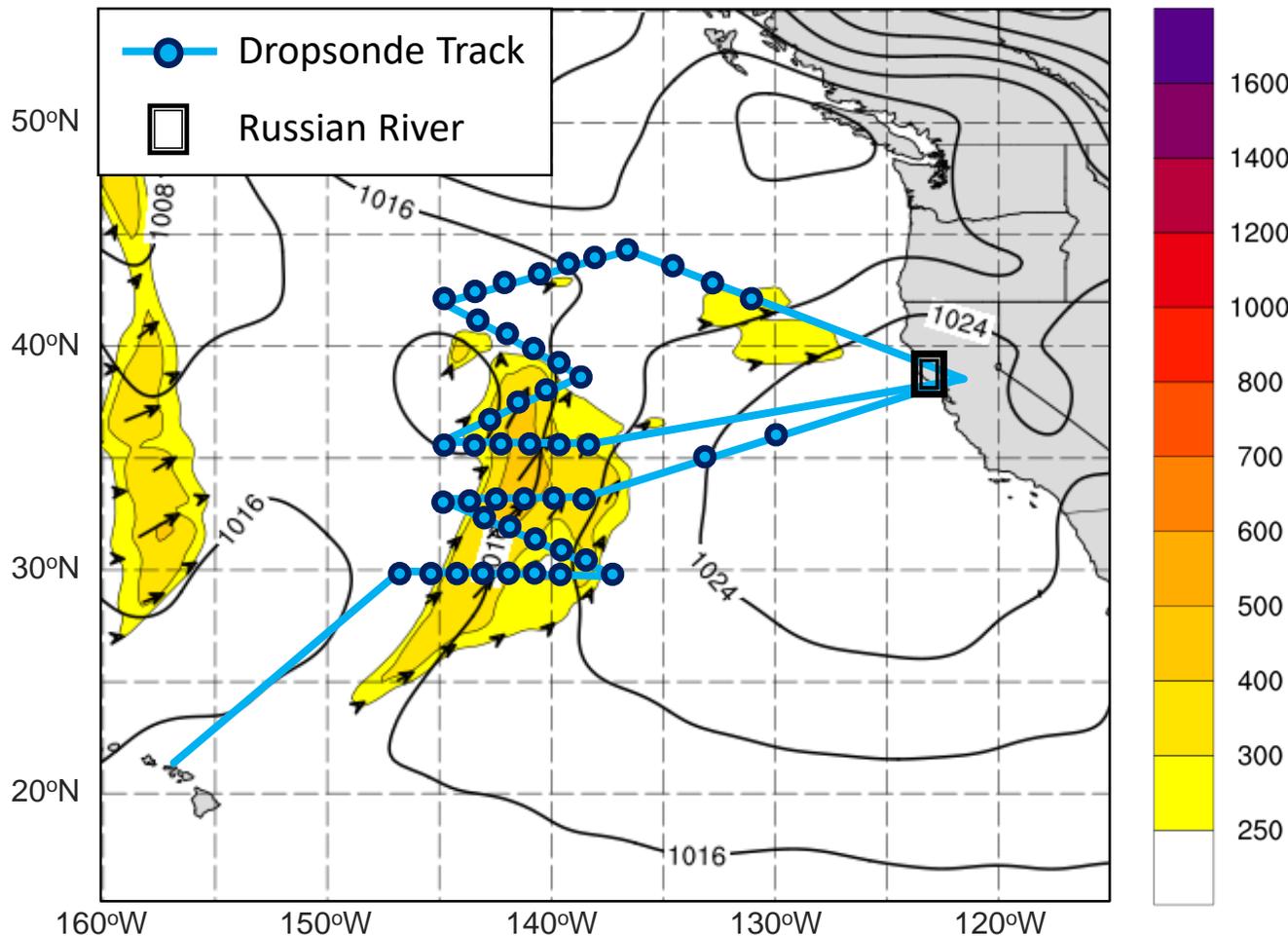
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AR Recon 2019 – Mission #4 24 Feb. 2019

NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 0000 UTC 02/26/2019 F-000: Valid: 0000 UTC 02/26/2019



Atmospheric River Reconnaissance 2019

PI: F. Martin Ralph, CW3E-Scipps

Two missions were flown with U.S. Air Force aircraft departing from California

Both aircraft sampled the development of the AR that impacted the Russian River 72 hours later

The observations of full profiles of atmospheric temperature, winds and humidity are assimilated by global forecast centers in near real-time

For the two missions combined:
44 drops assimilated into ECMWF (42 in 00Z and 2 in 18Z runs)
45 drops assimilated into Navy COAMPS and the GFS 00Z run

For more details on AR Recon visit cw3e.ucsd.edu/arrecon_data/

AR Summary: 25-27 Feb 2019

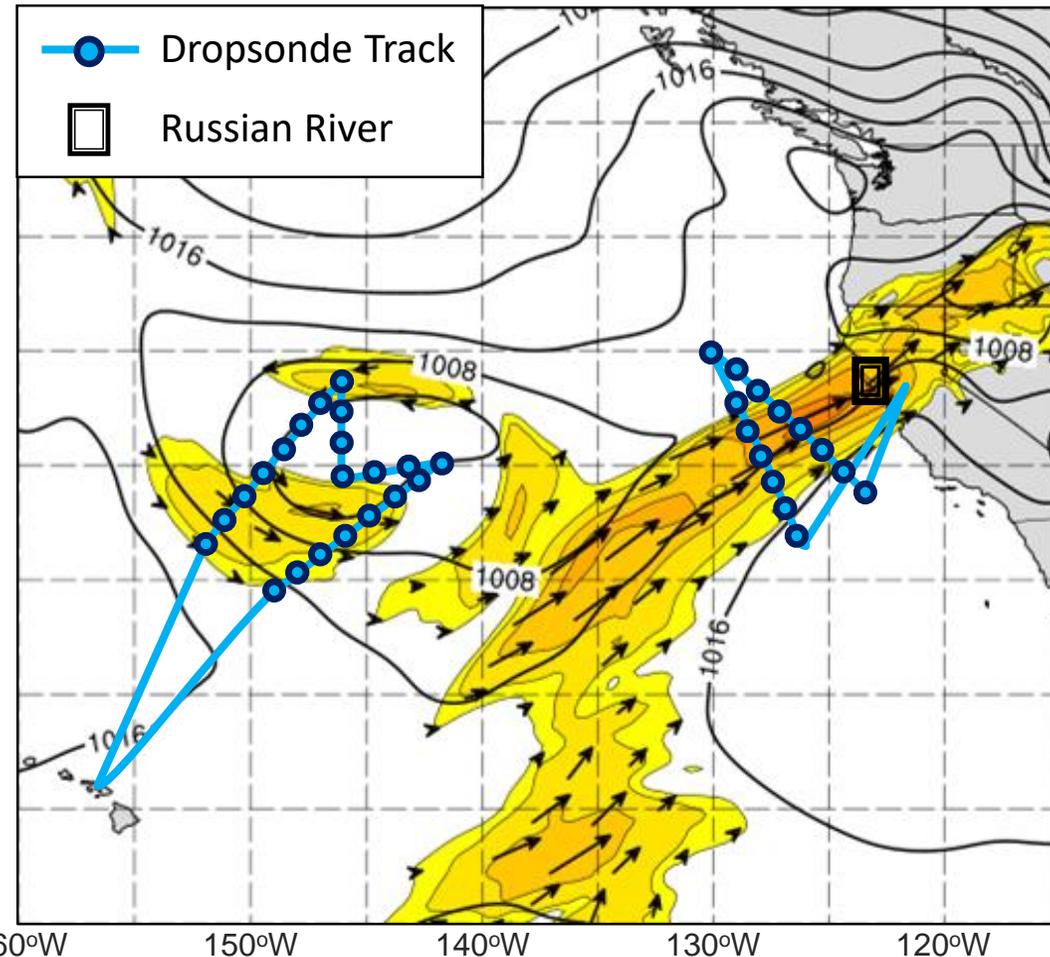
For California DWR's AR Program



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AR Recon 2019 – Mission #5 25 Feb. 2019

NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 0000 UTC 02/26/2019 F-000: Valid: 0000 UTC 02/26/2019



Atmospheric River Reconnaissance 2019

PI: F. Martin Ralph, CW3E-Scripps

Two missions were flown with U.S. Air Force aircraft departing from California and Hawaii

The California aircraft (left) sampled the AR as it made landfall, 24 hours before maximum precipitation

14 dropsondes from this mission were assimilated into global forecasting models in near-real time

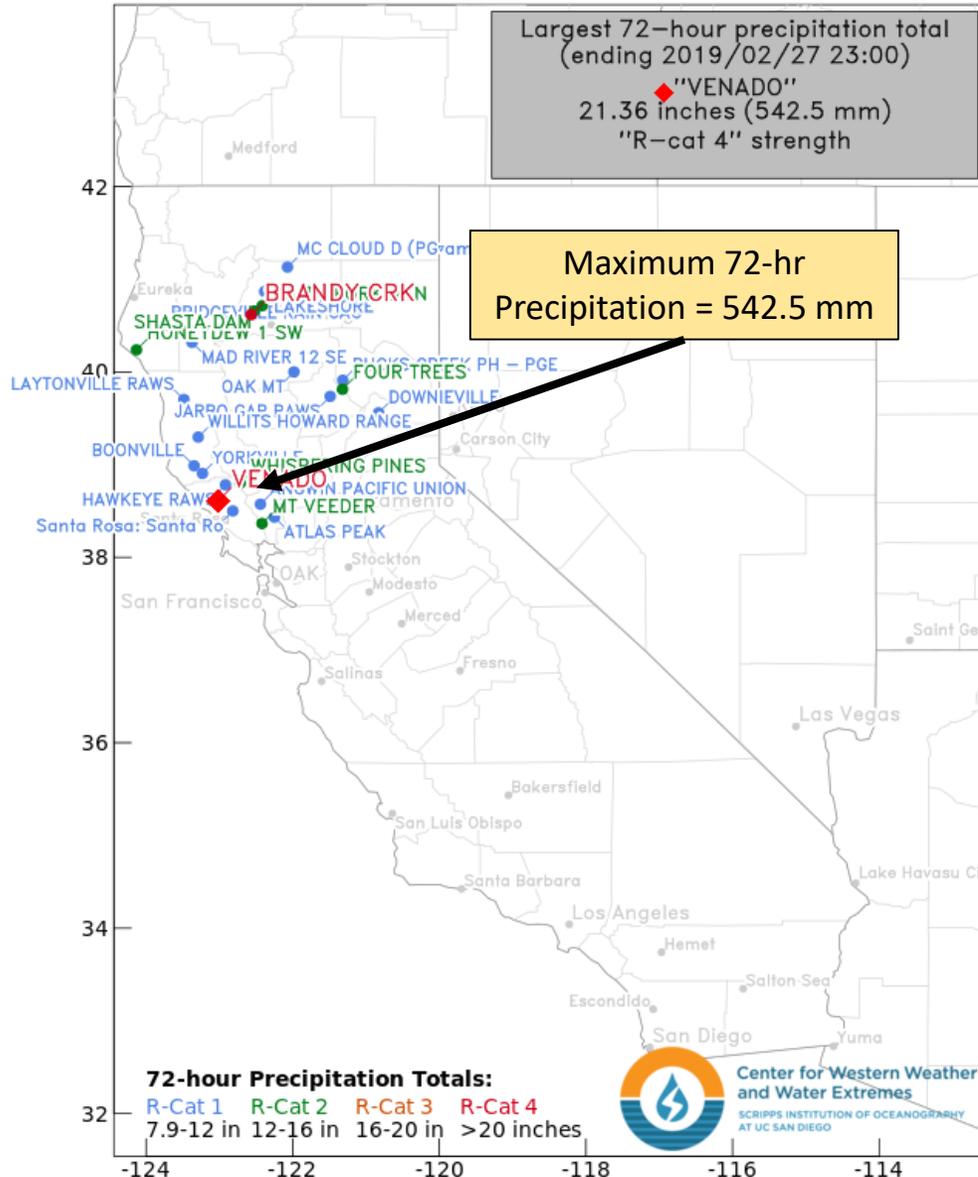
A second aircraft from Hawaii sampled the upstream circulation and moisture transport

**For the two missions combined:
35 drops assimilated into ECMWF (33 in 00Z and 2 in 18Z runs)
35 drops assimilated into Navy COAMPS and the GFS 00Z run**

For more details on AR Recon visit cw3e.ucsd.edu/arrecon_data/

AR Summary: 25-27 Feb 2019

R-Cat report produced 2019/02/28 07:43



For California DWR's AR Program



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Twenty four rain gauges in northern CA experienced at least a R-Cat 1 event over the past 72 hours.

Two locations (Venado, CA and Brandy Creek, CA) observed R-Cat 4 events (>500 mm), six locations observed R-Cat 2 (300-400), and 16 locations observed R-Cat 1 events (200-300 mm) over the past 72 hours.

The highest 72-hour accumulated precipitation, observed at Venado, CA near the Russian River, was 542.5 mm (21.36 inches). Daily accumulations over the past three days at this locations were 181.9 mm (25 Feb), 311.9 mm (26 Feb) and 48.8 mm (27 Feb).

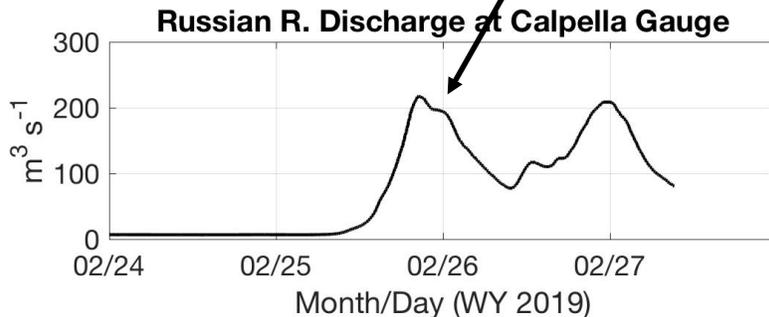
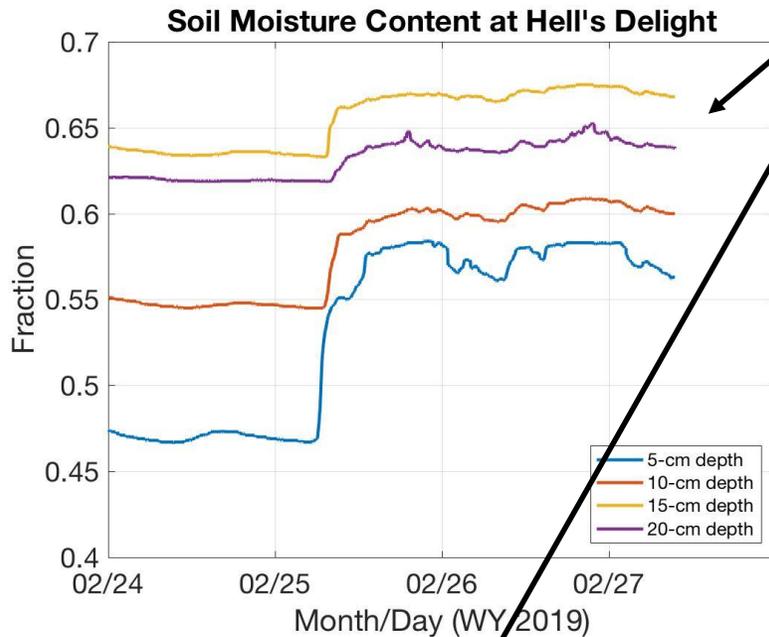
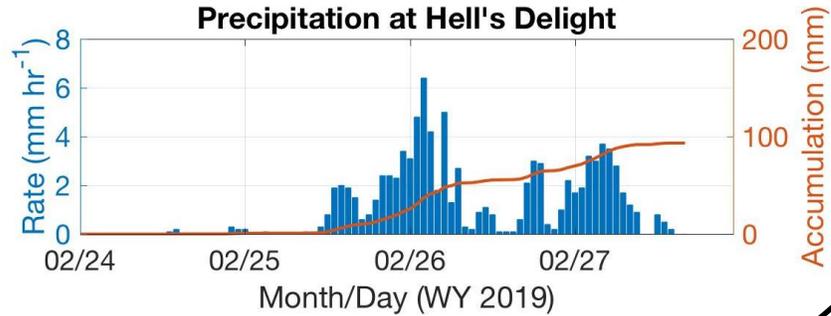
To subscribe to this automated CW3E R-Cat Extreme Precipitation Alert via email: just email a message with subject "subscribe" to rcatalert@cirrus.ucsd.edu.

AR Summary: 25-27 Feb 2019

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Given the wet antecedent soil moisture conditions throughout Northern CA, precipitation from this event saturated soils quickly, resulting in high runoff rates and a rapid response in streamflow.

Site	Soil Moisture Content Correlation with Hell's Delight*			
	5-cm Depth	10-cm Depth	15-cm Depth	20-cm Depth
Boyes Creek Canyon	0.95	0.93	0.93	0.93
Deerwood	0.93	0.96	0.95	0.96
North Cow Mountain	0.75	0.69	0.64	0.54
Potter Valley North	0.97	0.98	0.98	0.94
Windy Gap	0.96	0.89	0.96	0.92

*Between 02/24/2019 and 2/27/2019

High soil moisture cross-correlations across soil depths indicate uniform soil moisture response to the AR event across the Upper Russian River watershed.

More information on the CW3E's surface stations can be found at cw3e.ucsd.edu/cw3e-surface-meteorology-observations/

AR Summary: 25-27 Feb 2019

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Flooding on Laguna de Santa Rosa inundated downtown Sebastopol. Fire department helping residents evacuate flooded areas. Photo: N. Oakley

Flooding in the Barlow shopping area in downtown Sebastopol. Photo: N. Oakley



Sonoma County placed evacuation orders on 24 areas
(<http://nixle.us/ASDYN>).

AR Summary: 25-27 Feb 2019

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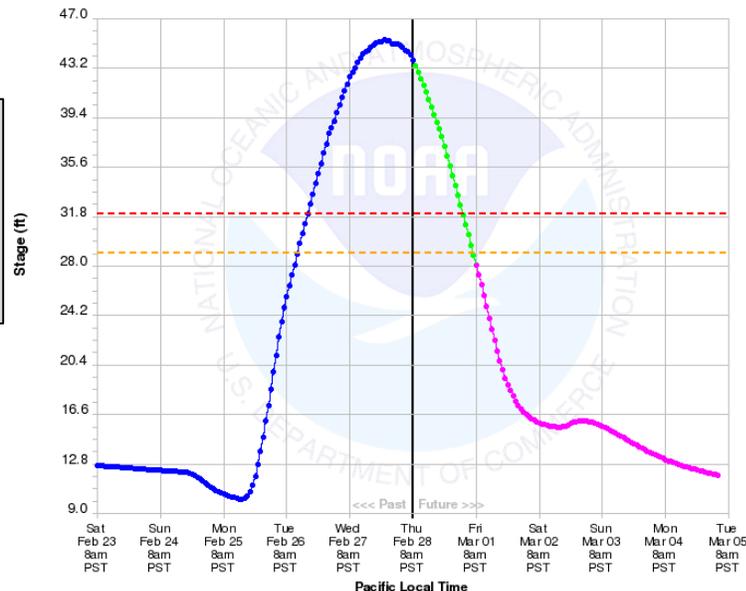
Guerneville along River Road
(Sonoma Sherriff via Twitter)



Residents use a raft to cross flooded Highway 116 between Santa Nella and Guerneville (Feb 27). Photo: N. Oakley



Guerneville gauge peaking over 45 feet
For more information please visit cnrfc.noaa.gov



Observed ● Forecast ● Guidance ● Monitor ● Flood ●
Created: 02/28/2019 at 8:49 AM PST (GUEC1 Forecast Run Time = 1641Z)
California Department of Water Resources
NOAA / NWS / California Nevada River Forecast Center

Governor Newsom declared State of Emergency for five northern CA counties due to storm impacts: Amador, Glenn, Lake, Mendocino and Sonoma

AR Summary: 25-27 Feb 2019

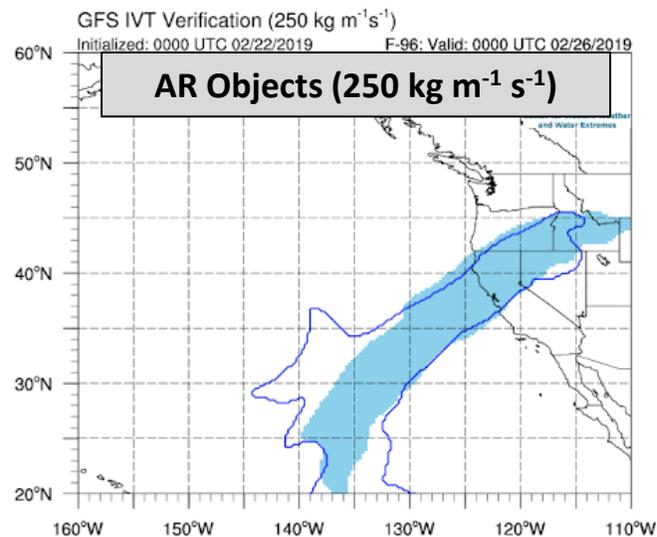
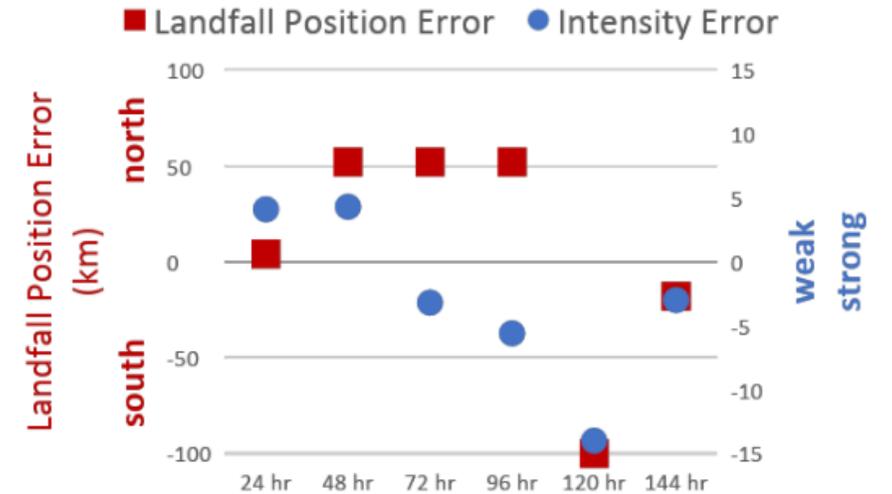
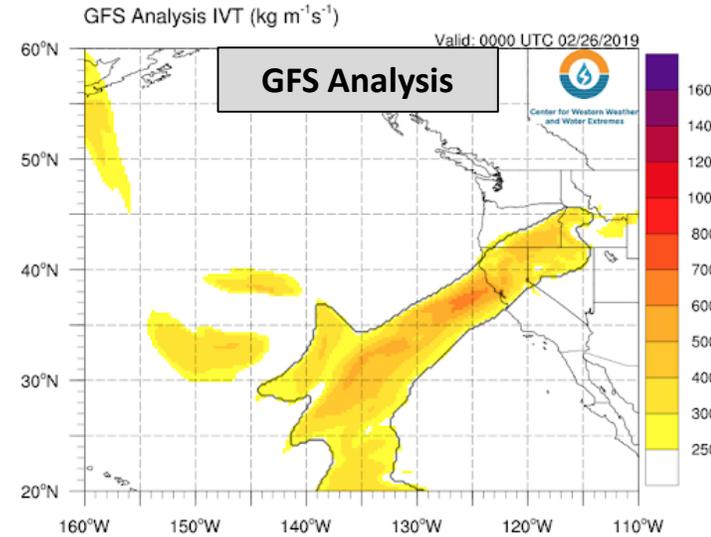
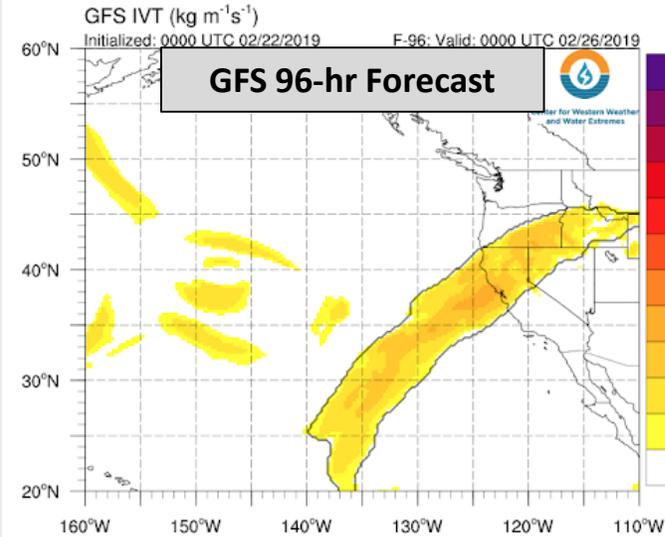
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AR Forecast Verification using NCAR MODE

GFS AR Statistics for Forecasts Valid 00 UT 26 Feb



- The GFS 96-hour IVT forecast shown here SHOWS similar skill as forecasts of shorter lead times and other models.
- The AR objects identified had a maximum landfall error of 50 km (to the north) and IVT intensity error below 6% for GFS forecasts with lead times up to 4-days.
- The skill of the 5 day forecast is significantly less than the skill at shorter lead times.
- For more information and more products visit the CW3E AR landfall verification website: <http://cw3e.ucsd.edu/cw3e-atmospheric-river-landfall-met-mode-verification-tool/>

Forecasted objects shaded (unmatched objects in gray)
Observed objects contoured (unmatched objects in black)

AR Summary: 25-27 Feb 2019

For California DWR's AR Program



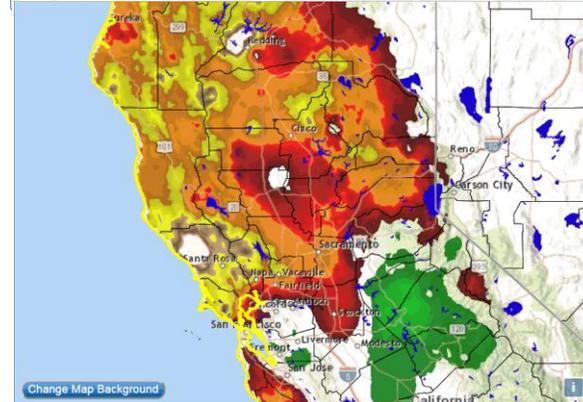
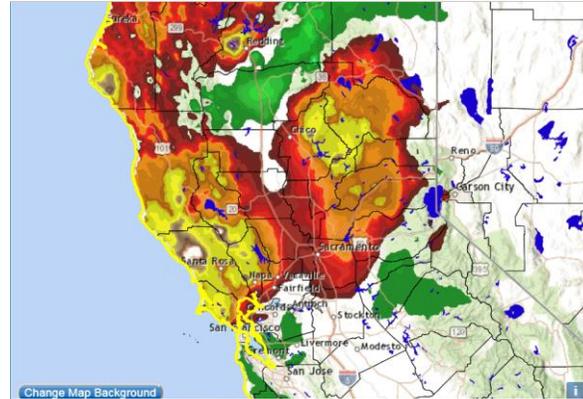
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48-hr Rainfall Observed
4am Sunday 25 Feb to 4am
Tuesday 27 Feb 2019

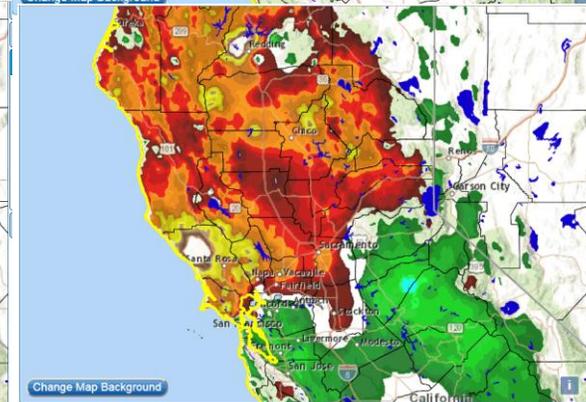
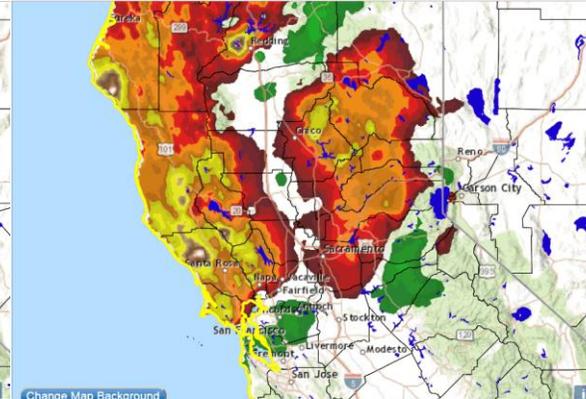


Forecast Verification products
from cnrfc.noaa.gov

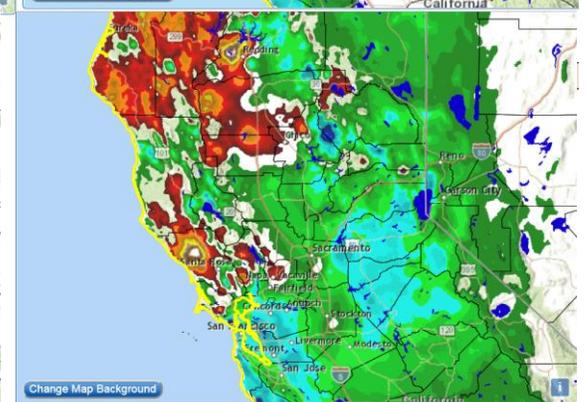
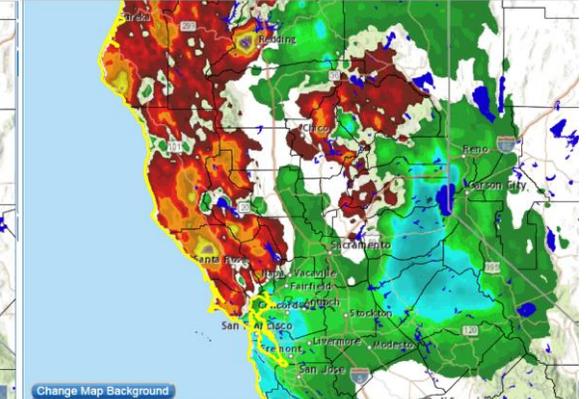
Day 5



Day 3



Day 1



24-hr QPF Errors
Valid 26 Feb
2019

24-hr QPF Errors
Valid 27 Feb
2019

- Models predicted a land-falling Atmospheric River but varied on the duration of the AR over Northern CA likely due to uncertainties in how the eastward propagating Pacific Low was going to interact with the landfalling AR (discussed above)
- Global models such as the GFS moved the rainfall too far south with shorter lead times
- Given the large variation in NWP forecasts the CNRFC QPFs that were issued tended to underpredict the magnitude of the heaviest rainfall