

CW3E Event Summary: 19–23 Nov 2024

Heavy Precipitation Event Driven by Atmospheric River and Bomb Cyclone

- An atmospheric river (AR) and bomb cyclone impacted the US West Coast from 19–23 Nov, as heavy precipitation, snowfall and high winds brought impacts across the coast.

The AR:

- A strong AR developed in the Northeast Pacific in association with a tropical moisture export (TME) west of Hawaii.
- As the AR propagated toward the US West Coast on 18–19 Nov, its presence helped fuel a bomb cyclogenesis event, with the developing cyclone's minimum pressure dropping more than 50 mb in less than 24 hours.
- A secondary low-pressure system developed south of the primary low as the AR stalled over Northern California, driving a second wave of moisture transport into Southern Oregon and Northern California and extending AR conditions in the region.

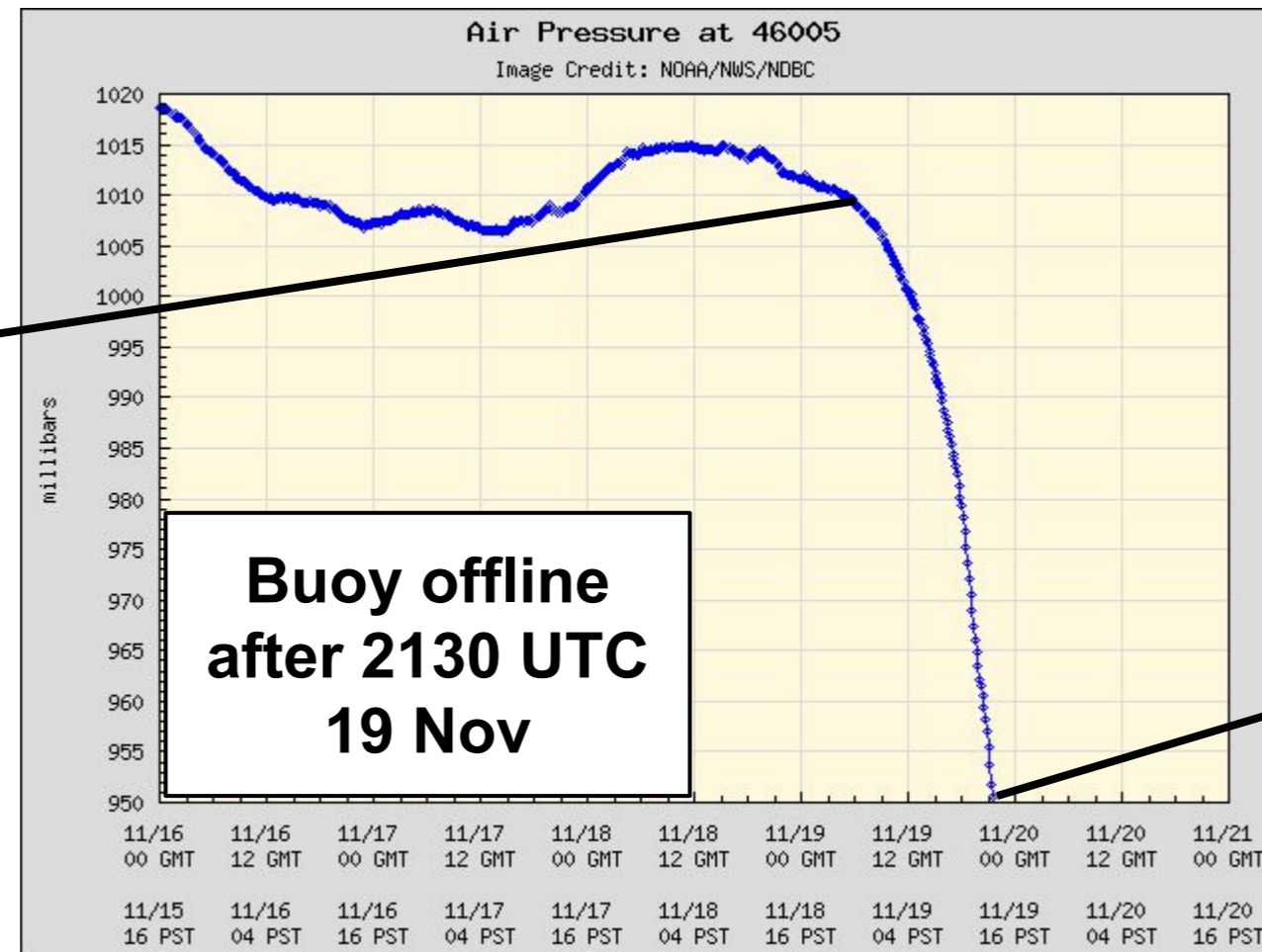
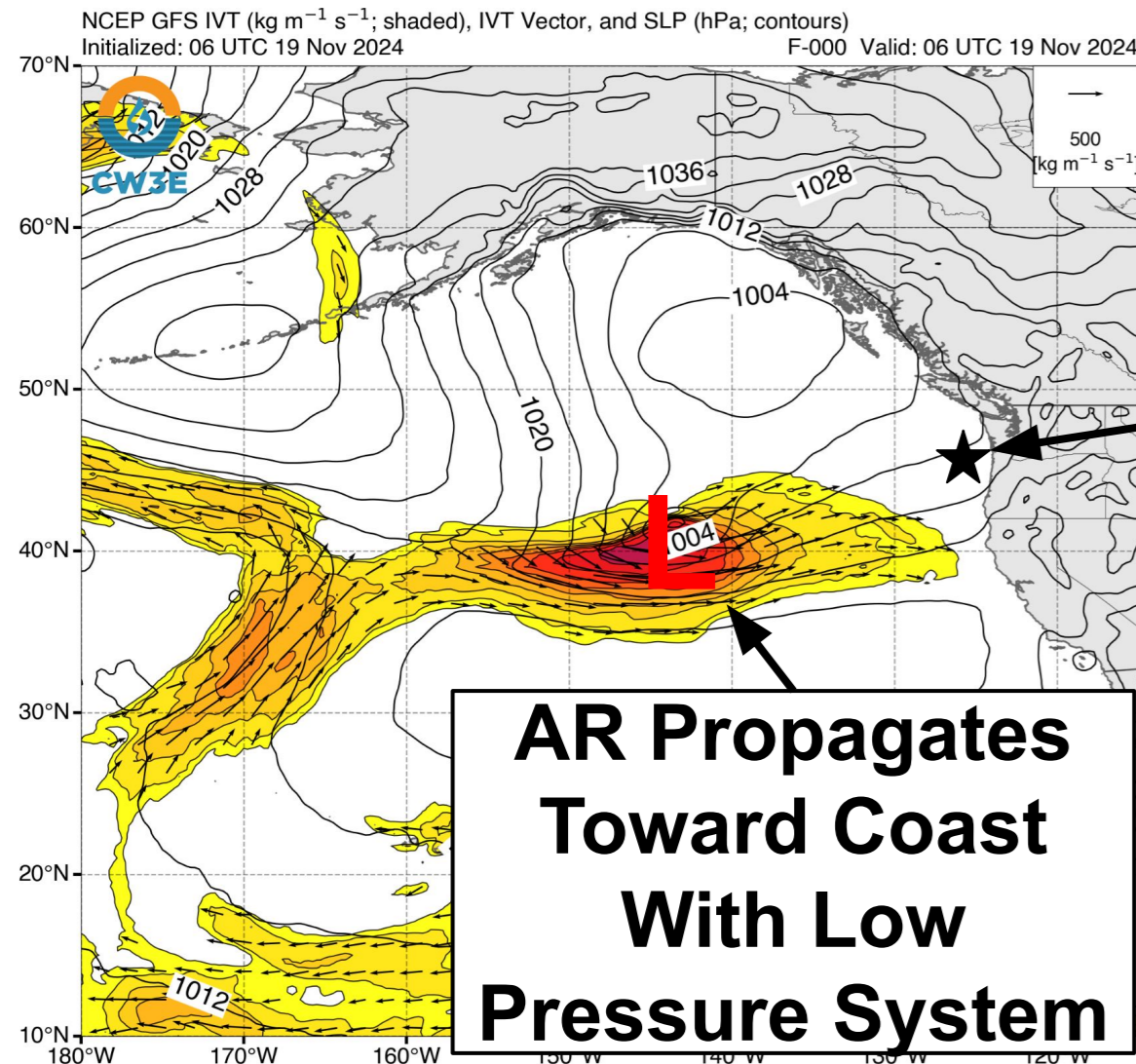
Impacts:

- This storm produced > 10 inches of precipitation over much of Northern California and an estimated 2–5 feet of snow in the higher terrain of the Klamath Mountains, Southern Cascades, and Northern Sierra Nevada.
- Portions of Northern California received > 25% of the normal annual precipitation from this storm.
- High winds and heavy rain caused significant impacts in the Pacific Northwest and Northern California, with numerous reports of fallen trees, power outages, flooding, and landslides/debris flows/rockfalls. Two fatalities due to falling trees and two fatalities due to flood waters were reported during this AR.

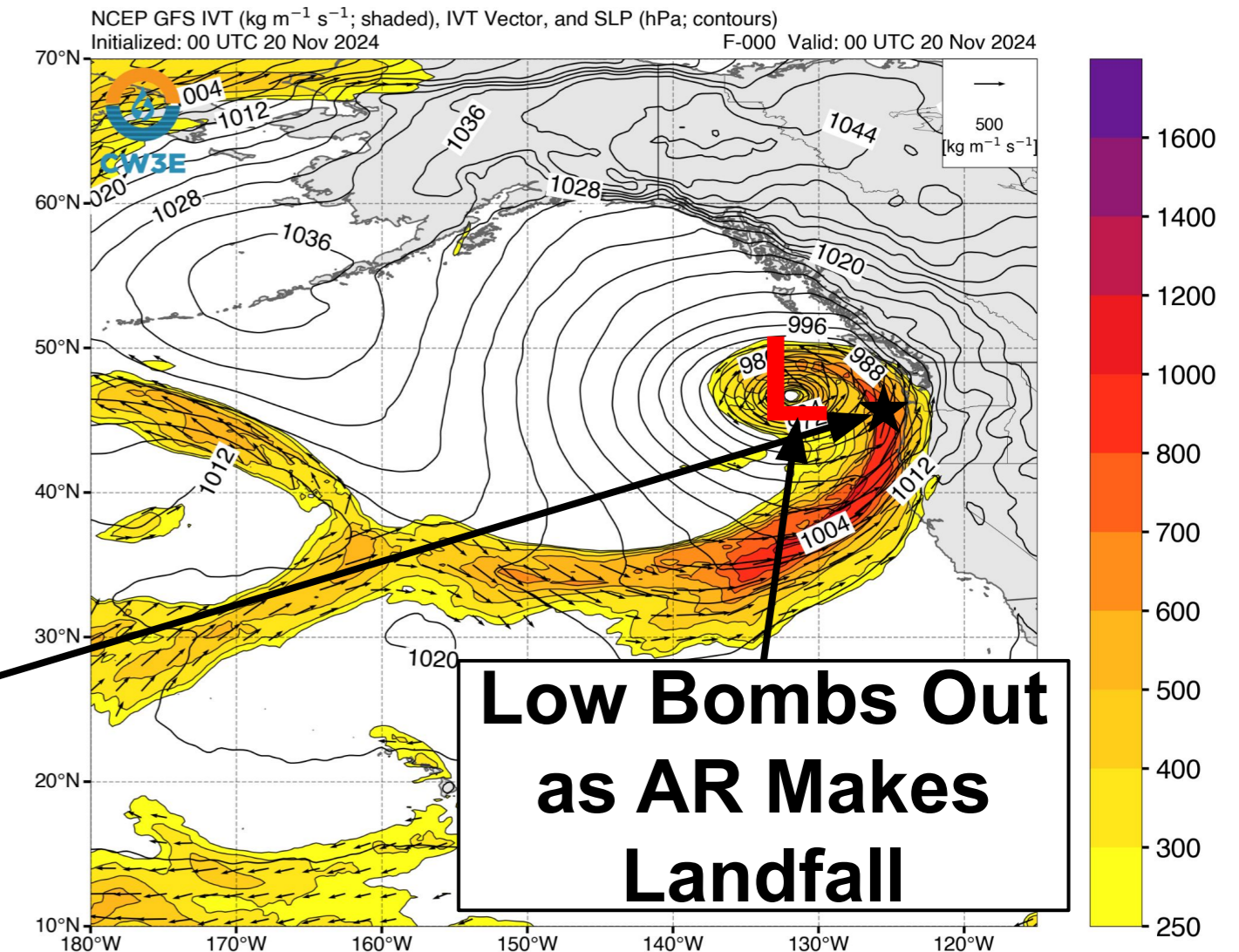
CW3E Event Summary: 19–23 Nov 2024

Cyclone Bombs Out

GFS IVT: Valid 10 PM PST 18 Nov



GFS IVT: Valid 4 PM PST 19 Nov

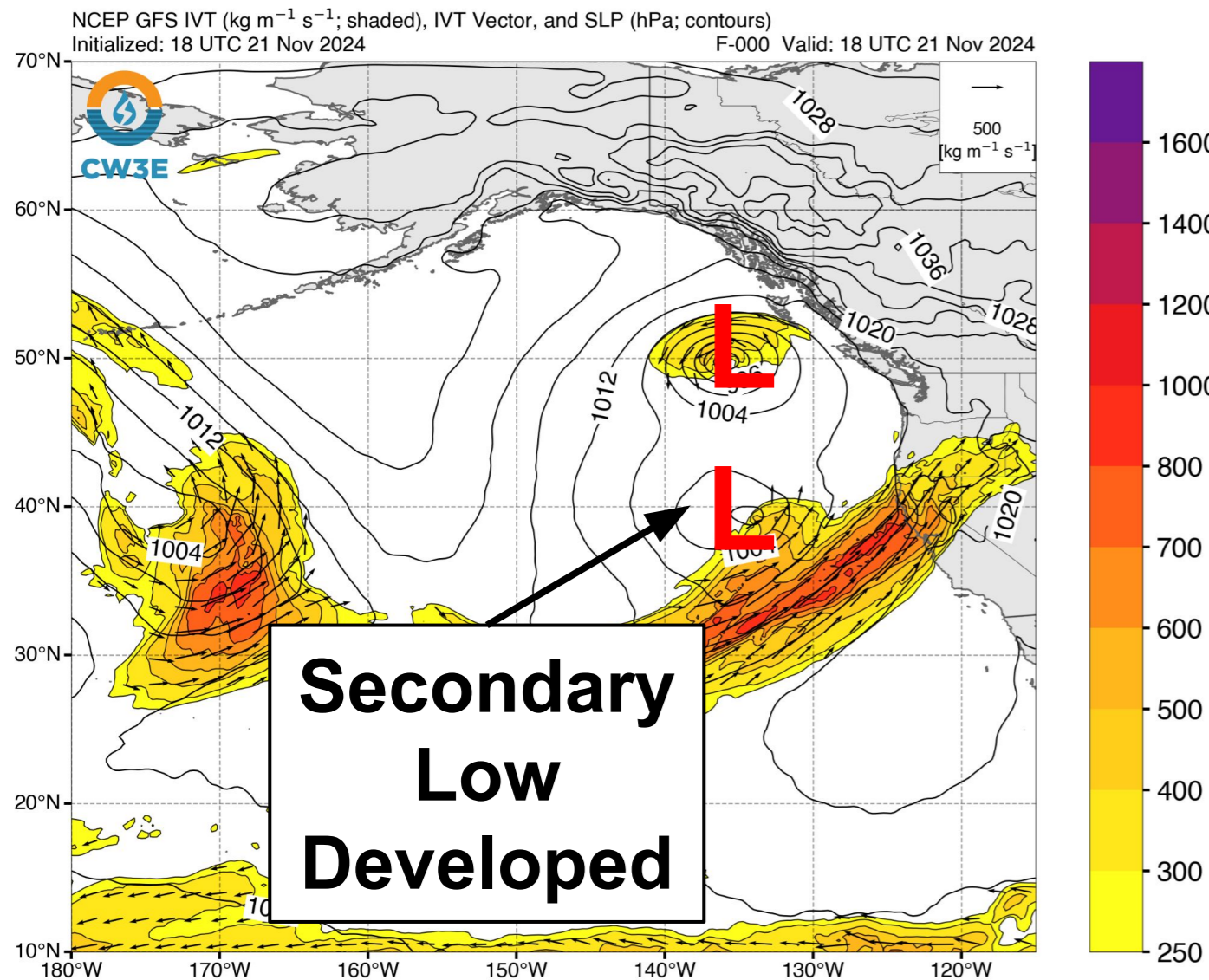


- The AR formed over the Northeast Pacific in association with a tropical moisture export (TME) originating west of Hawaii.
- As the AR propagated toward the US West Coast on 18–19 Nov, a low-pressure system formed near the core of the AR and underwent rapid intensification, with the minimum pressure dropping more than 50 mb in less than 24 hours.
- Previous research by [Zhang and Ralph \(2021\)](#) suggests that the antecedent extreme AR ($\text{max IVT} > 1000 \text{ kg m}^{-1} \text{ s}^{-1}$) triggered the bomb cyclogenesis by providing extra water vapor inflow to the cyclogenesis, which substantially intensified the diabatic process.
- A buoy near the Oregon coast observed a pressure drop from 1010 mb at 06Z 19 Nov to 950 mb at 2130 UTC 19 Nov before dropping offline.

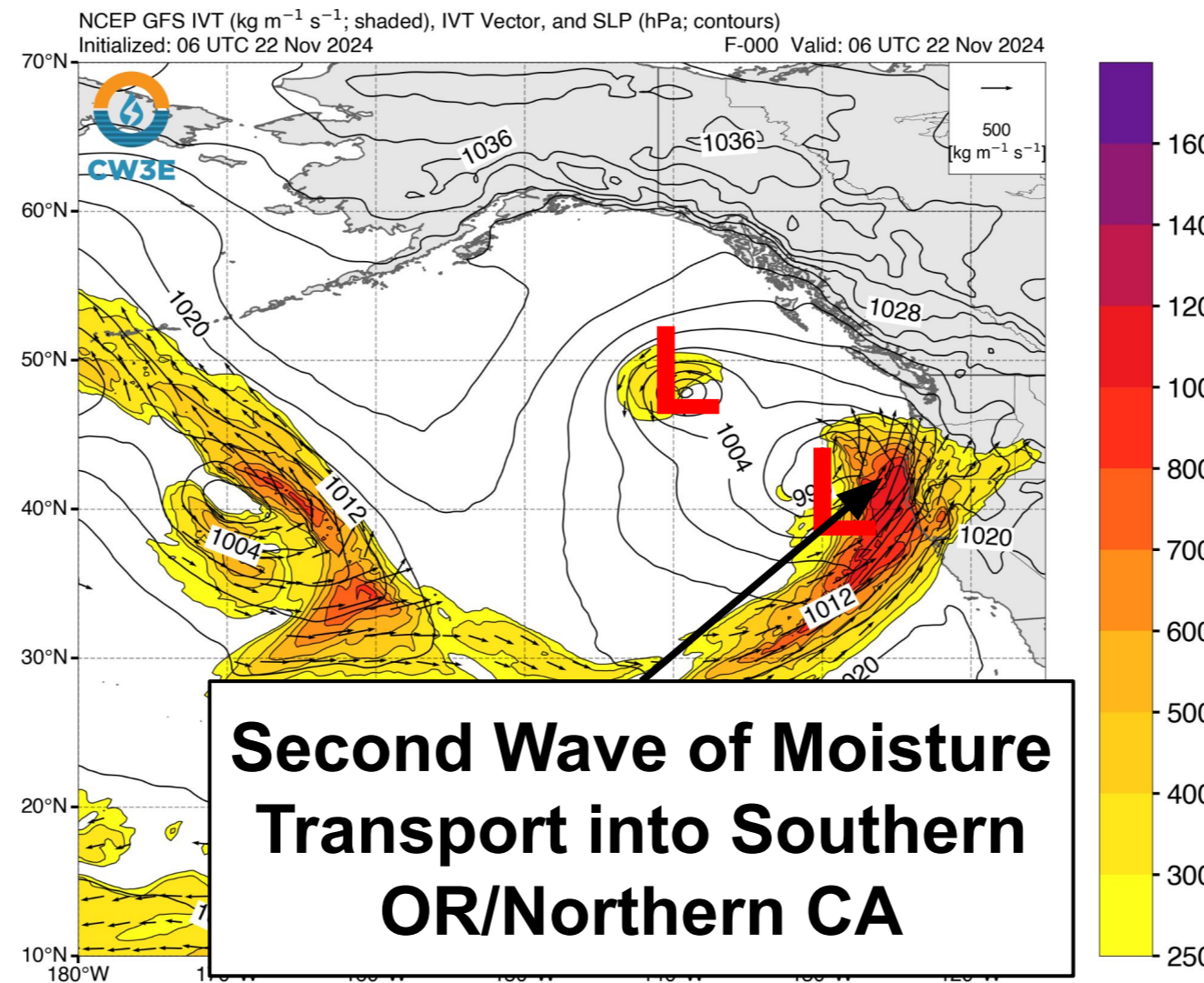
CW3E Event Summary: 19–23 Nov 2024

Secondary Low Develops

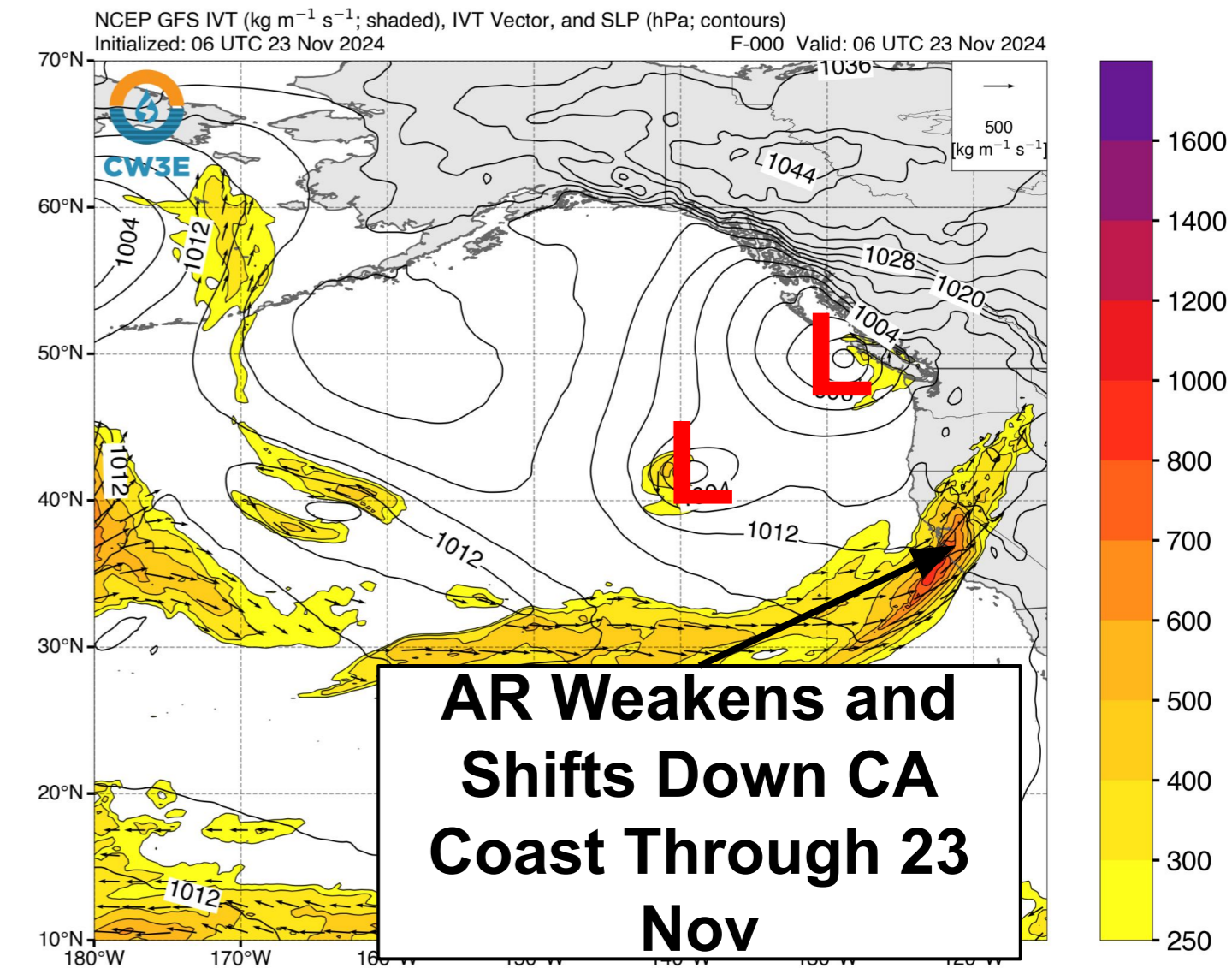
GFS IVT: Valid 10 AM PST 21 Nov



GFS IVT: Valid 10 PM PST 21 Nov



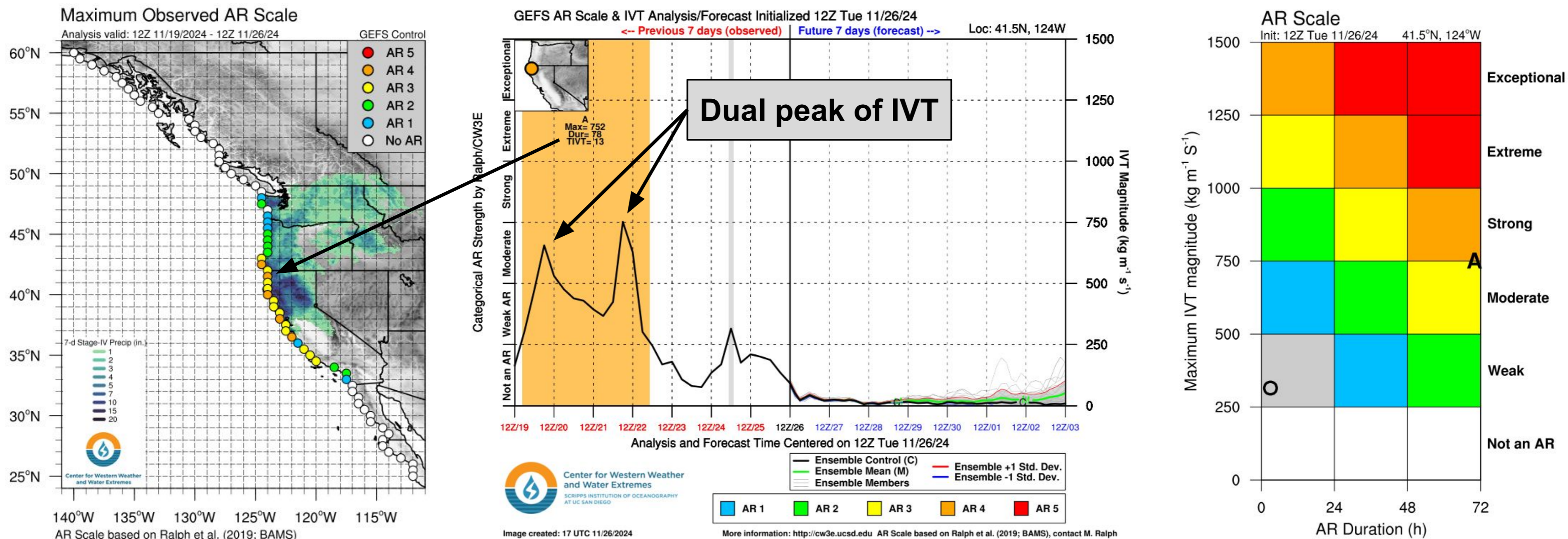
GFS IVT: Valid 10 PM PST 22 Nov



- As the low-pressure system shifted north, the AR stalled over Northern California through 21 Nov into 22 Nov.
- A secondary low developed to the south of the primary low, bringing a second wave of moisture transport to southern Oregon and Northern California, extending the AR conditions in the region.

CW3E Event Summary: 19–23 Nov 2024

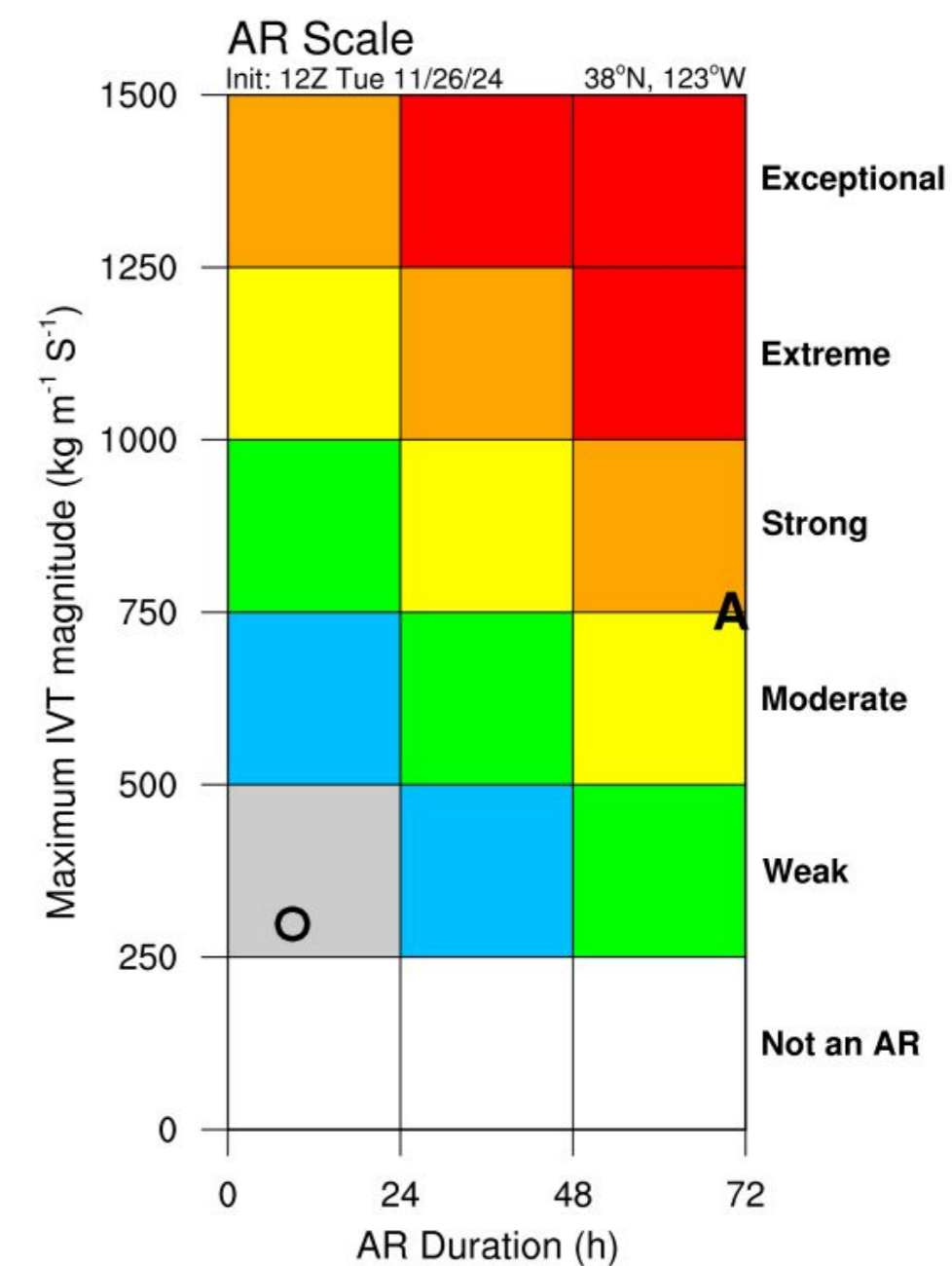
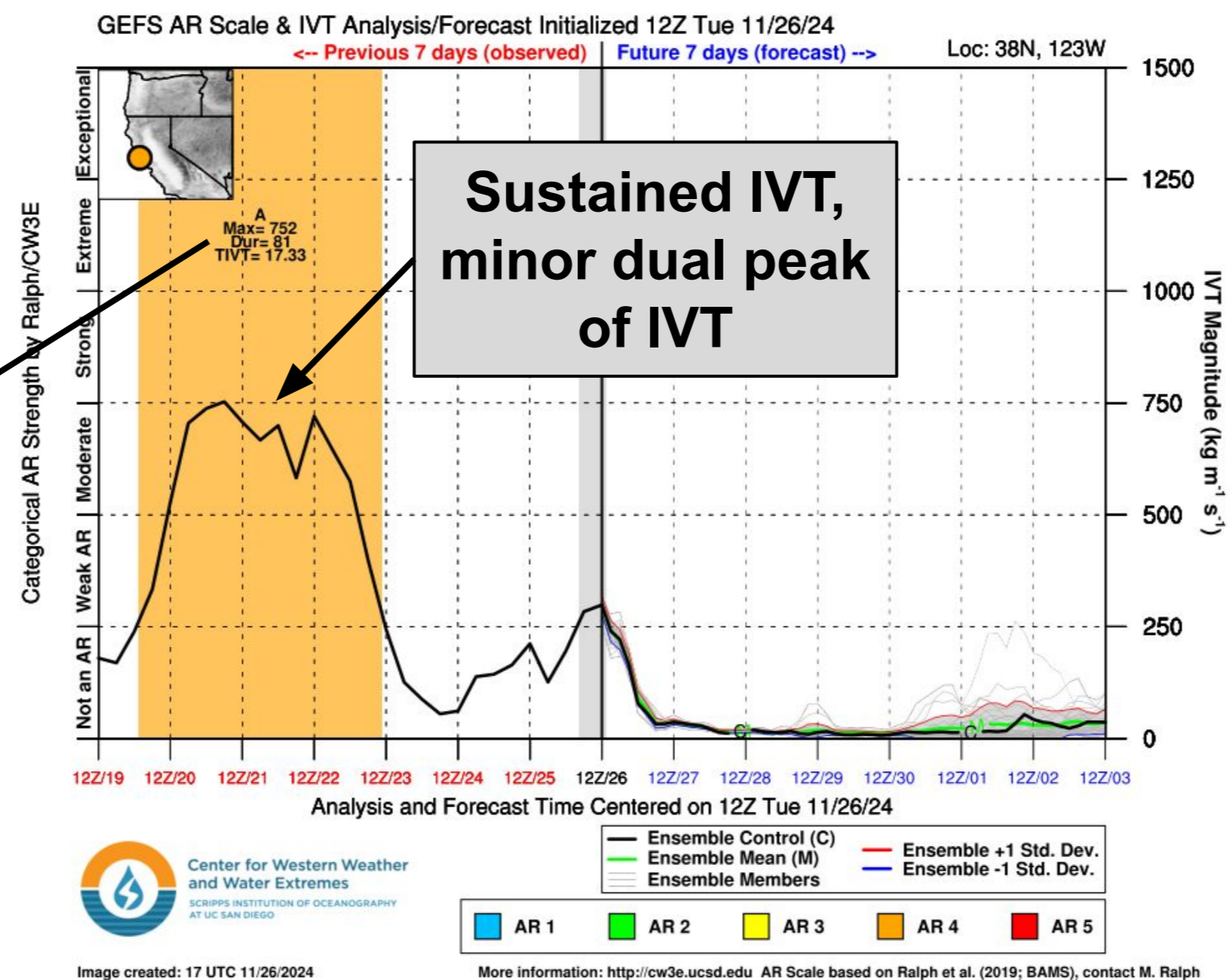
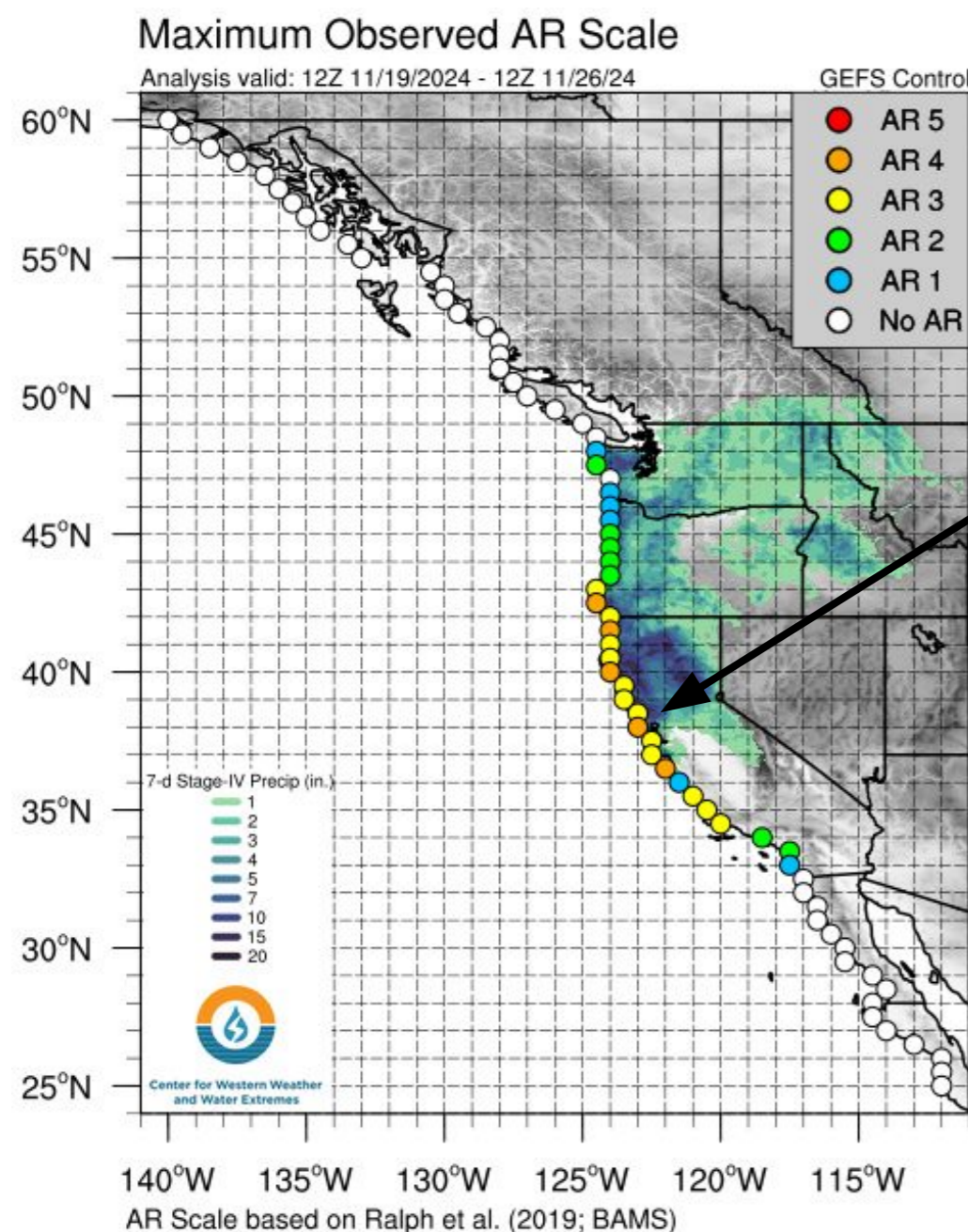
Observed AR Scale - GEFS Control: 41.5 N, 124.0 W



- Based on the GEFS control, coastal points in Northern California observed AR3-4 conditions and had a dual peak in IVT during the secondary cyclogenesis and restrengthening of the AR.
- An AR duration of 78 hours and maximum IVT of $752 \text{ kg m}^{-1} \text{ s}^{-1}$ (**AR4**) was analyzed in coastal Del Norte County.

CW3E Event Summary: 19–23 Nov 2024

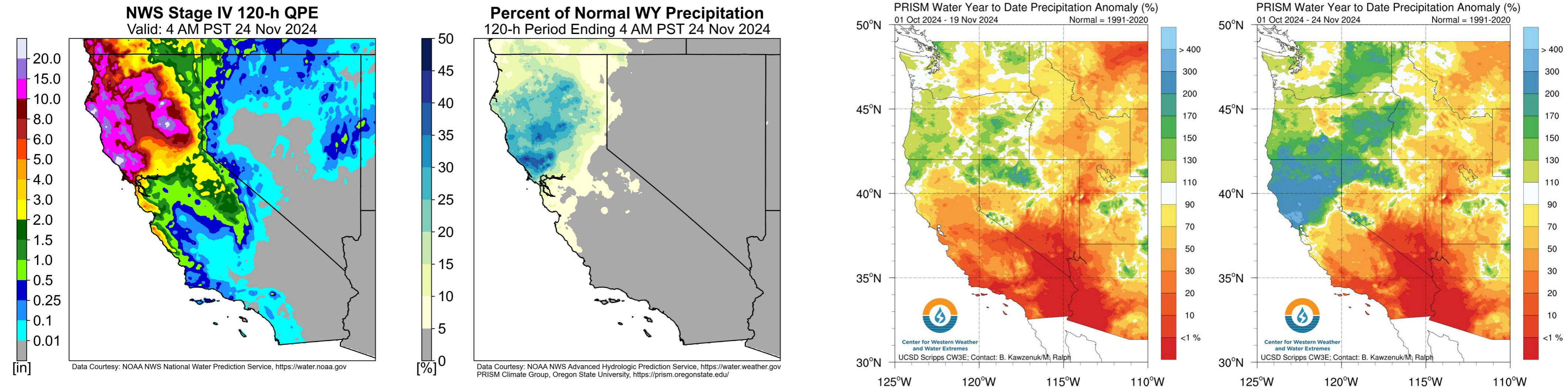
Observed AR Scale - GEFS Control: 38.0 N, 123.0 W



- Based on the GEFS control, points further south near the Bay Area also observed AR3-4 conditions and experienced sustained AR conditions, with a minor dual peak in IVT observed.
- An AR duration of 81 hours and maximum IVT of $752 \text{ kg m}^{-1} \text{ s}^{-1}$ (**AR4**) was analyzed in coastal Marin County.

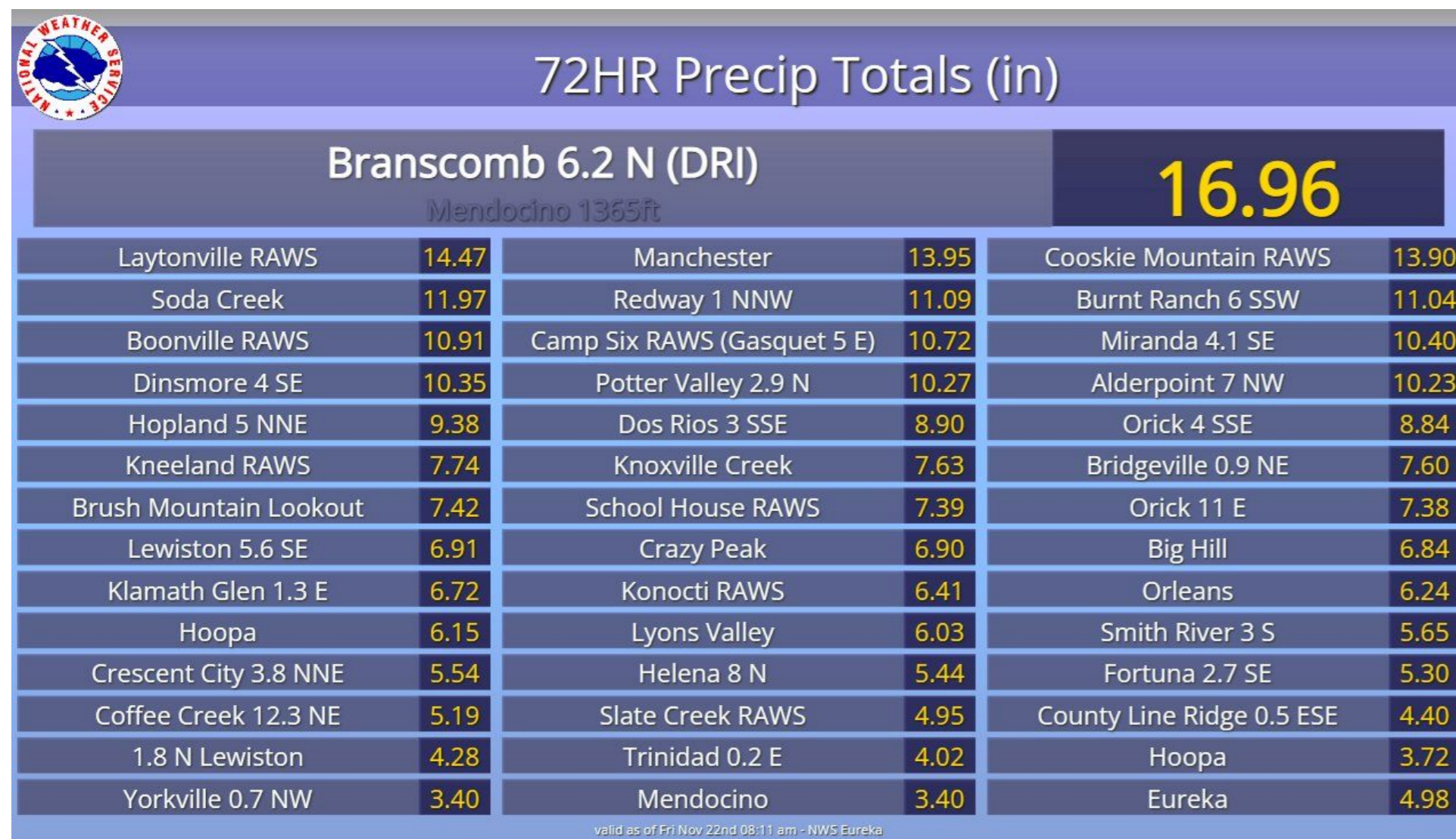
CW3E Event Summary: 19–23 Nov 2024

Observed Precipitation



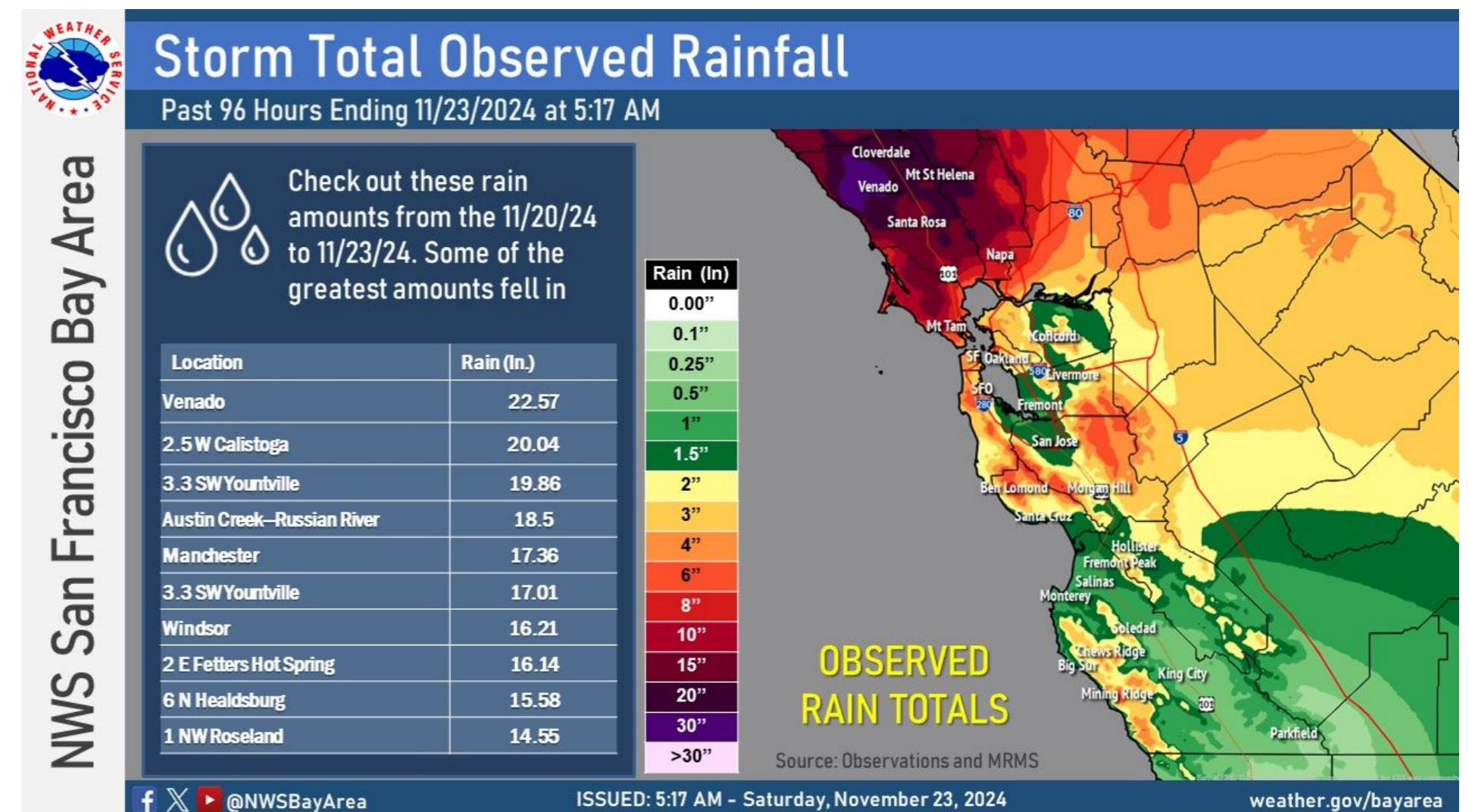
- More than 10 inches of precipitation fell over the Northern California Coast Ranges, Southern Cascades, and Northern Sierra Nevada, with some of the highest amounts in the Russian and Feather River Basins.
- Storm-total precipitation exceeded 25% of the normal annual precipitation in portions of Northern California. The Russian watershed received 31% of its normal annual precipitation from this storm.
- Water-year-to-date precipitation over much of Northern California increased from < 70% of normal on 19 Nov to > 200% of normal on 24 Nov.

CW3E Event Summary: 19–23 Nov 2024




<https://x.com/NWSEureka/status/1860018769864851931>

- The highest rainfall totals from this storm occurred in the Coast Ranges of Northern California, with a maximum of 22.57 inches at Venado in Sonoma County.
- NWS Bay Area analysis shows the 12.47 inches of rain during a 3-day period in Downtown Santa Rosa qualifies as a 1 in 1,000 year event based on NOAA Atlas 14.
- According to analysis by the NWS California-Nevada RFC, the total 13.91 inches of rain at the Santa Rosa Airport was 41% of normal yearly rainfall. Storm-total rainfall also exceeded 20% of normal yearly rainfall at Ukiah (8.51 inches), Redding (7.18 inches), and Red Bluff (5.47 inches).



<https://x.com/NWSBayArea/status/1860319334335414466>

CW3E Event Summary: 19–23 Nov 2024




12HR Peak Winds (mph)

Mattole Road		94	
Humboldt 1075ft			
Bell Springs	75	Scotia 4.3 SW (PGE)	75
Blocksburg 6.1 NW (PGE)	67	Ft Seward 3.3 W (PGE)	66
Cooskie Mountain RAWS	64	Miranda 1.8 SW (PGE)	61
Horse Ridge Lookout	60	Honeydew 2.7 NE (PGE)	59
Miranda 2.8 SW (PGE)	57	Snow Camp Lake	56
Sabertooth Road	56	Honeydew	56
Barry Ridge	55	School House RAWS	54
Crazy Peak	53	Cobb Mountain RAWS	52
Camp Six RAWS (Gasquet 5 E)	51	Bridgeville 1.8 N	50
Albion Ridge Road	50	Bridgeville 4.7 N (PGE)	49
Comptche 4.9 W (PGE)	48	Crescent Harbor	48
Hobergs (PGE)	47	Fort Seward West	46
Bridgeville 6.3 N (PGE)	45	Whispering Pines 0.8 NE	45
Elk Rock	45	Kneeland 2.2 S (PGE)	44
Konocti RAWS	44	Piercy	43
Lyons Valley	43	Iron Peak 1.6 WNW	42
Ridgewood 1.6 NW	42	County Line Ridge 0.5 ESE	41
Redway 1 NNW	41	Dos Rios 3 SSE	40
Elk Valley Rd	40	Smith River	40
Arcata/Eureka Airport	40	Smith River 3 S	40


valid as of Fri Nov 22nd 08:05 am - NWS Eureka

<https://x.com/NWSEureka/status/1860018769864851931>



EUREKA, CA

NOAA NATIONAL WEATHER SERVICE
Issued November 22, 2024 10:34 AM



Record Precipitation!

November 20th Record Precipitation at Ukiah

3.27"

This beats the previous record
of:

2.79"

Set in 1937

Climate records at Ukiah cover the period 1903-2024
| Photo credit: Ken Burton

November 21st Record Precipitation at Ukiah




3.66"


This beats the previous record
of:

3.16"

Set in 1977

Climate records at Ukiah cover the period 1903-2024
| Photo credit: Ken Burton




@NWSEureka



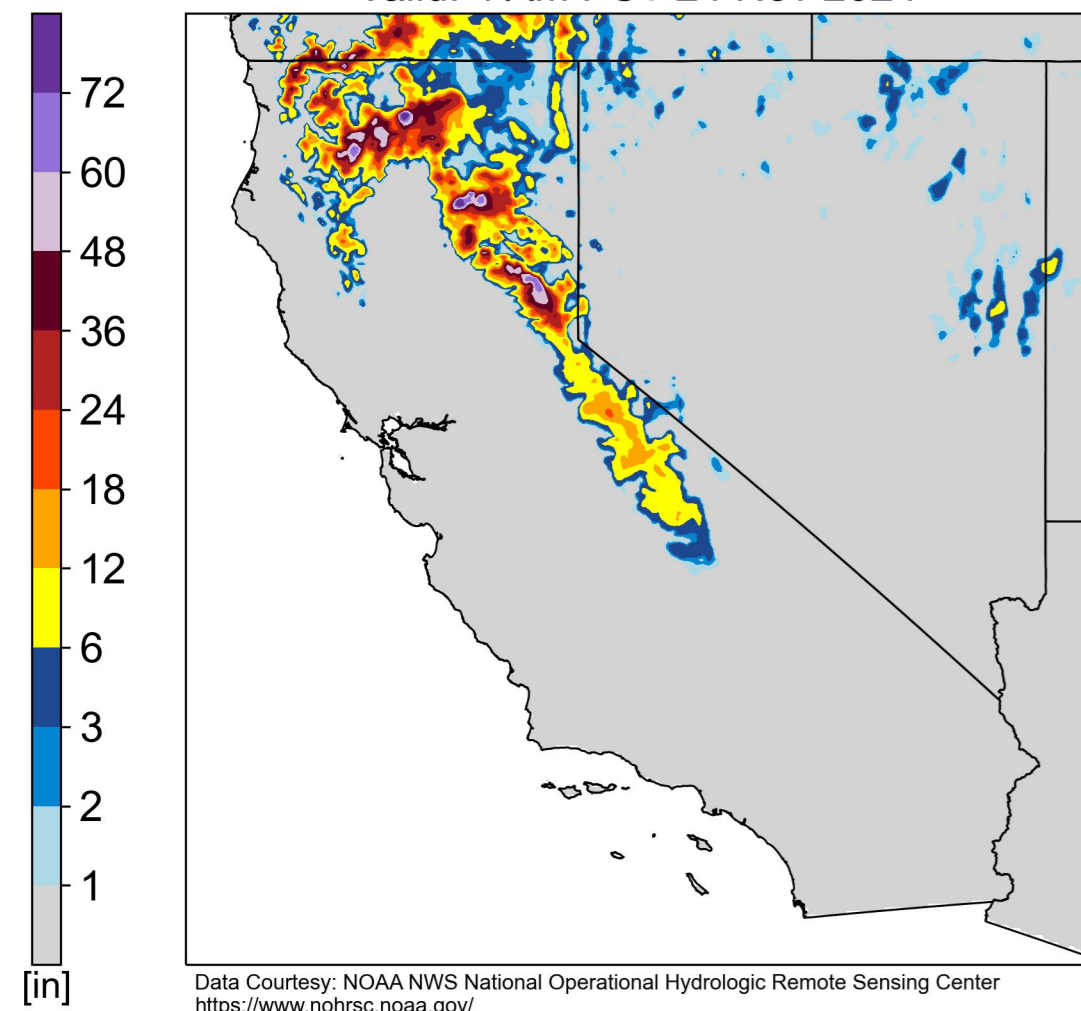
<https://x.com/NWSEureka/status/1860029545740734635>

- Extremely strong winds were also observed at many locations in coastal Northern California.
- Daily rainfall totals were broken in Ukiah, CA, on both 20 Nov and 21 Nov, with the observed rainfall breaking prior records by approximately 0.5 inches each day. The period of record dates back to 1903 at this location.

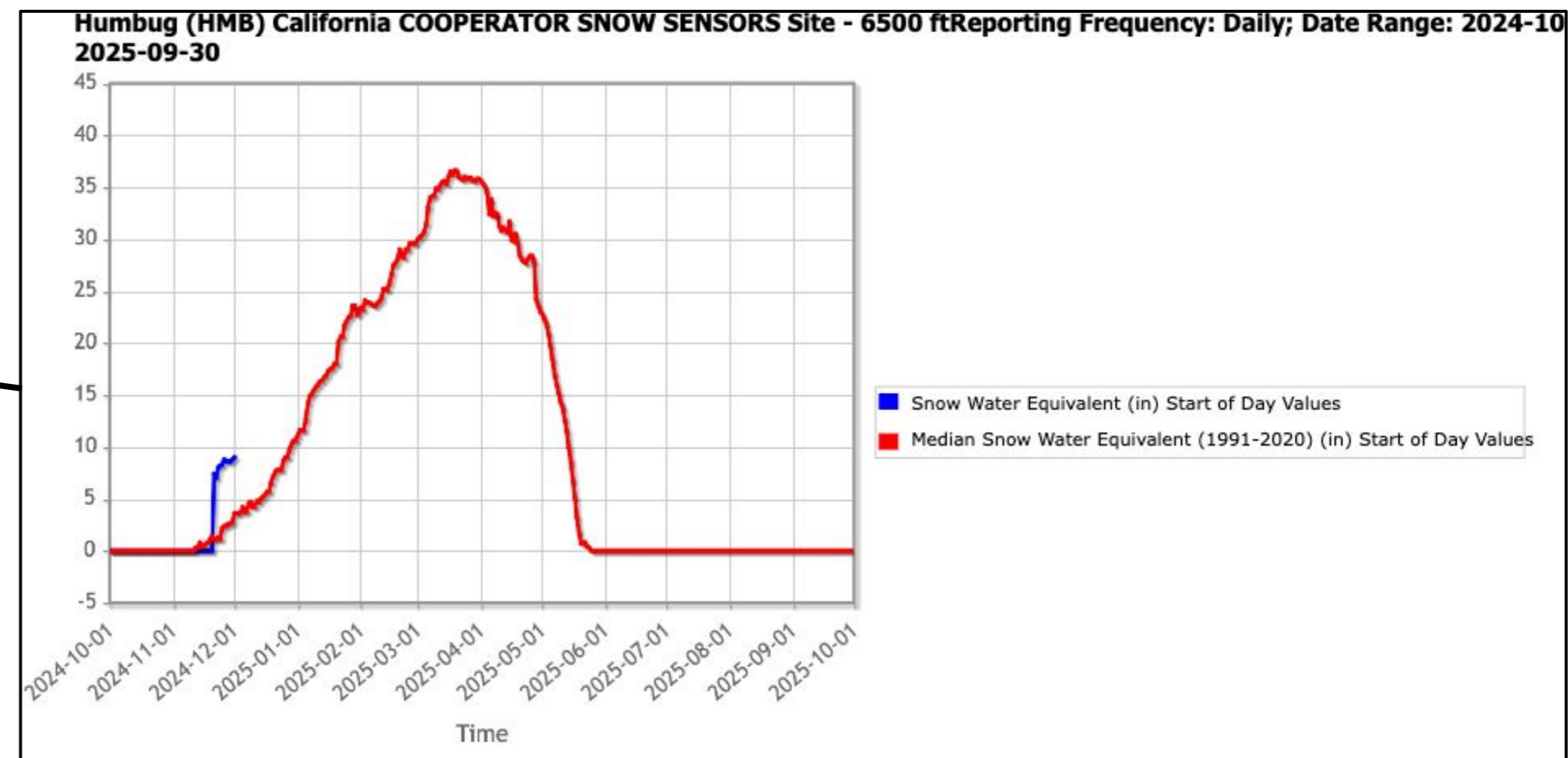
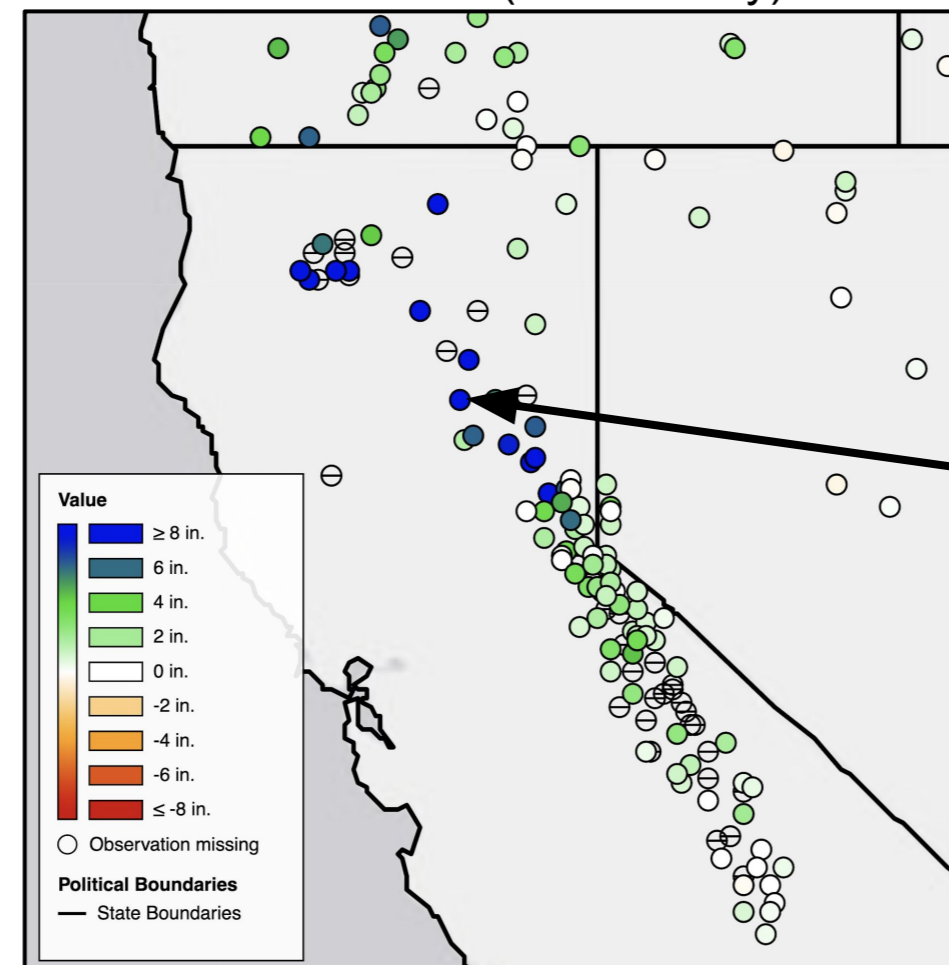
CW3E Event Summary: 19–23 Nov 2024

Snowfall

NWS 120-h Snowfall Analysis
Valid: 4 AM PST 24 Nov 2024



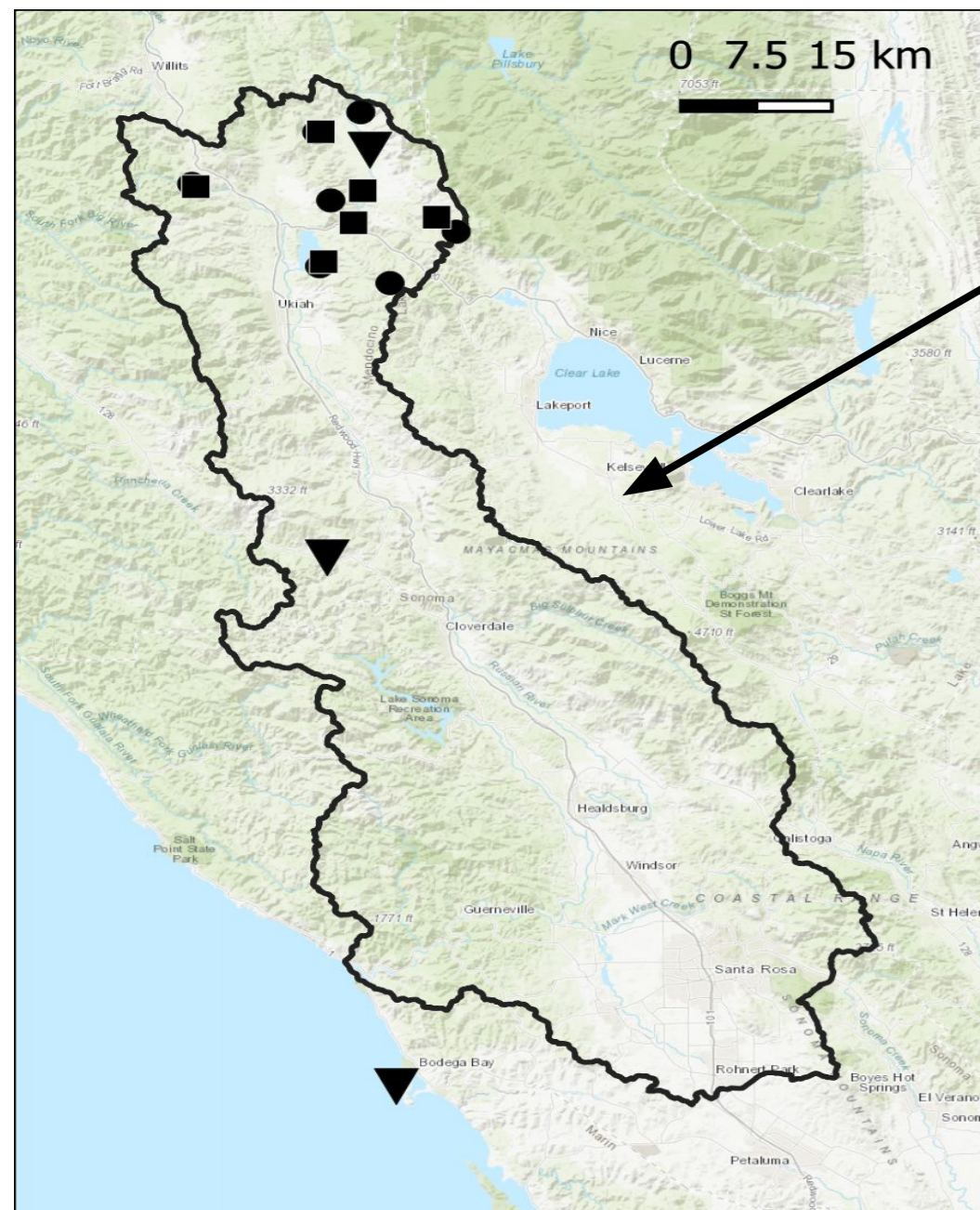
5-day SWE Change
Valid: 24 Nov (Start of Day)



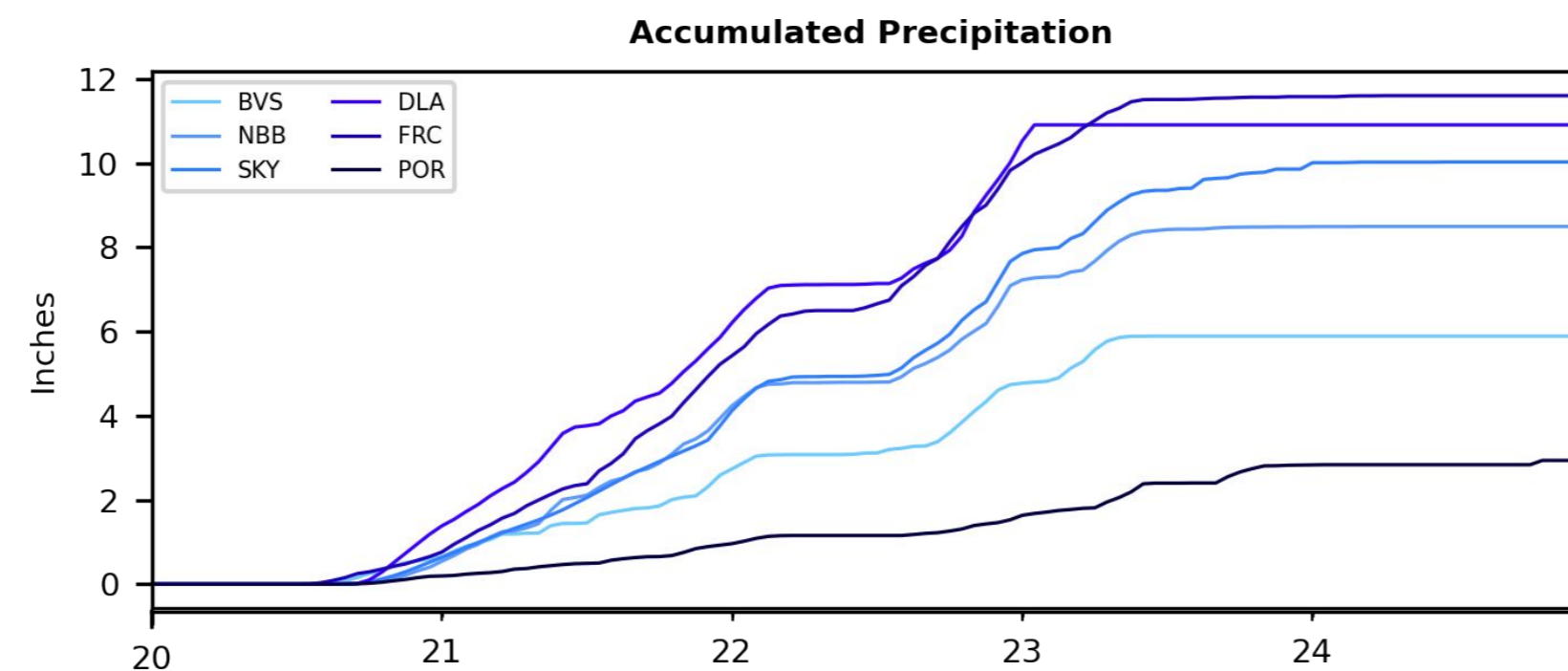
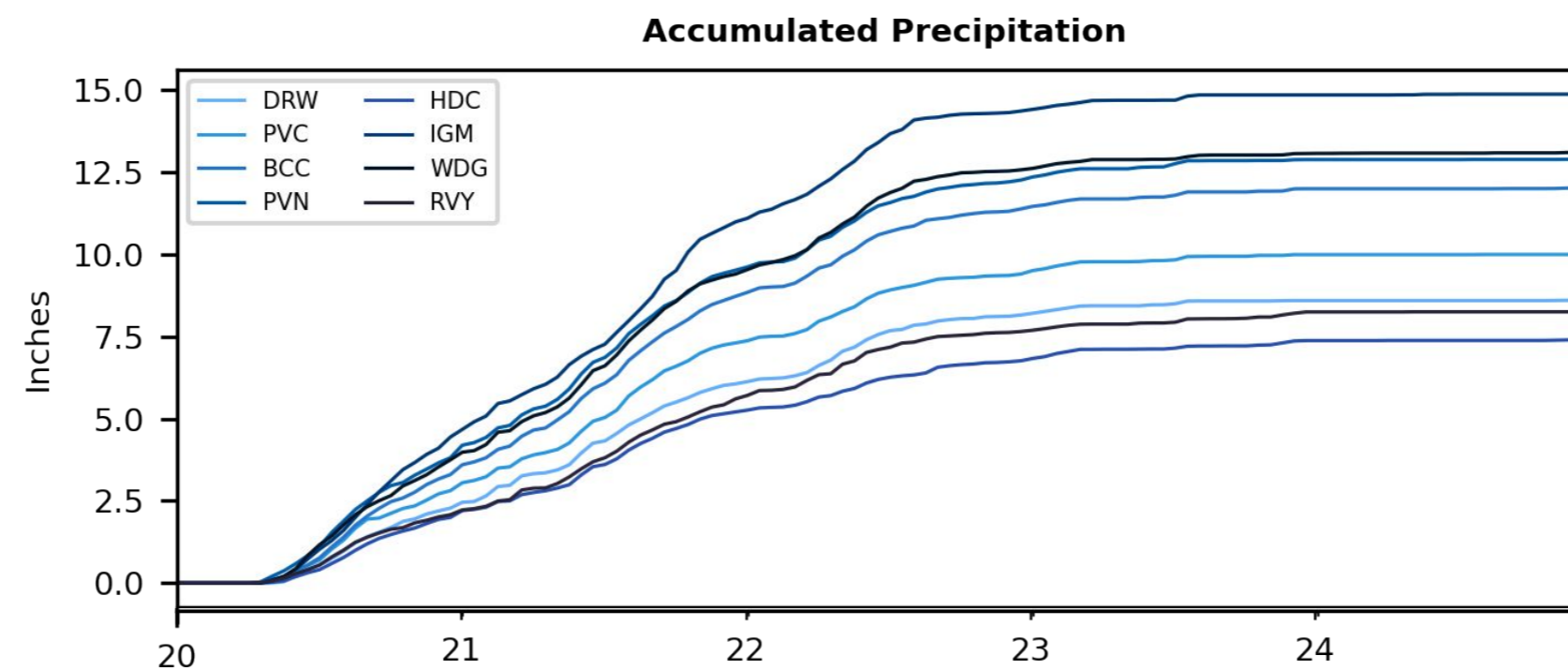
- This storm produced an estimated 2-5 feet of total snowfall in the higher terrain of the Klamath Mountains, Southern Cascades, and Northern Sierra Nevada.
- Several stations above 6,000 feet recorded snow water equivalent (SWE) increases larger than 8 inches.
- The 5-day increase in snowpack at Humbug (8.2 inches), located at 6,500 feet in the North Fork Feather watershed, represents 23% of the 1991-2010 median peak SWE (36.3 inches).

CW3E Event Summary: 19–23 Nov 2024

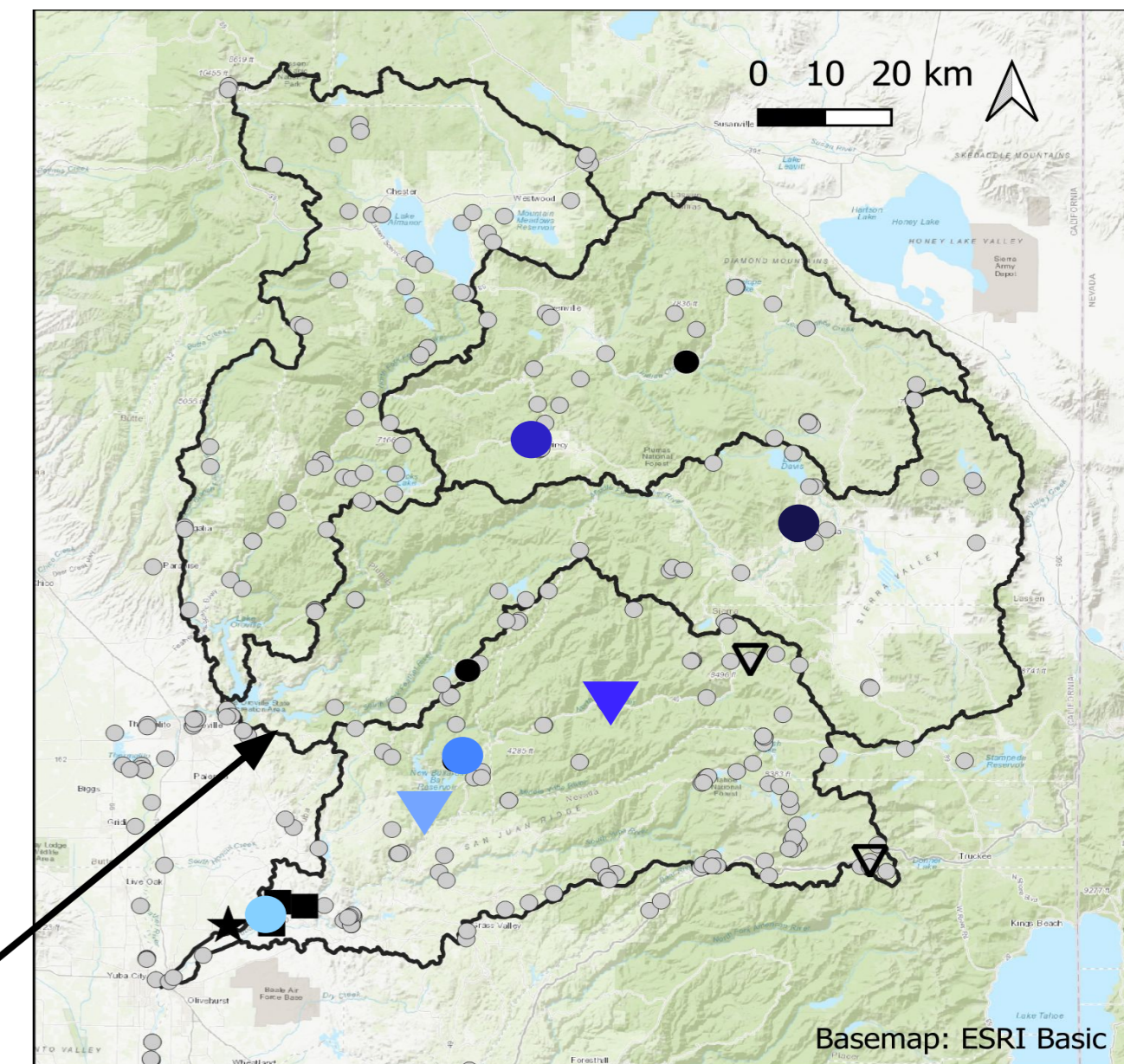
CW3E Observations Russian River Watershed



- CW3E stream gage
- ▼ CW3E Rad Met
- CW3E SMOIL



Yuba-Feather Watersheds

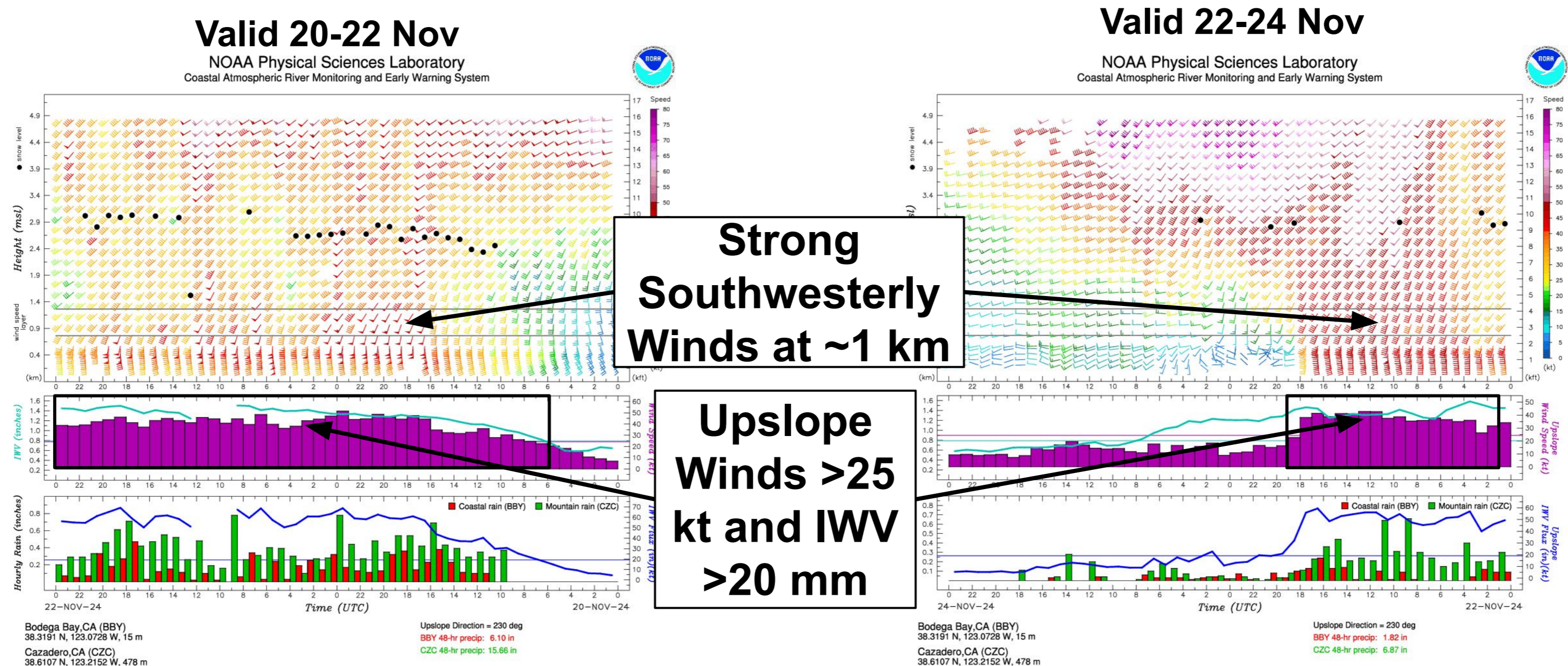


- ★ USYUB radiosonde
- CW3E stream gage
- CW3E SMOIL
- ▽ CW3E Disdro Met
- ▼ CW3E Rad Met
- Other station on CDEC

- CW3E stations in the Russian River watershed observed between 7-15 in. of precipitation (14.9 in. maximum)
- All but one CW3E station in the Yuba-Feather watersheds observed 6-12 in. (11.6 in. maximum)

CW3E Event Summary: 19–23 Nov 2024

Wind Profiler and GPS-Derived IWV: Bodega Bay (BBY)

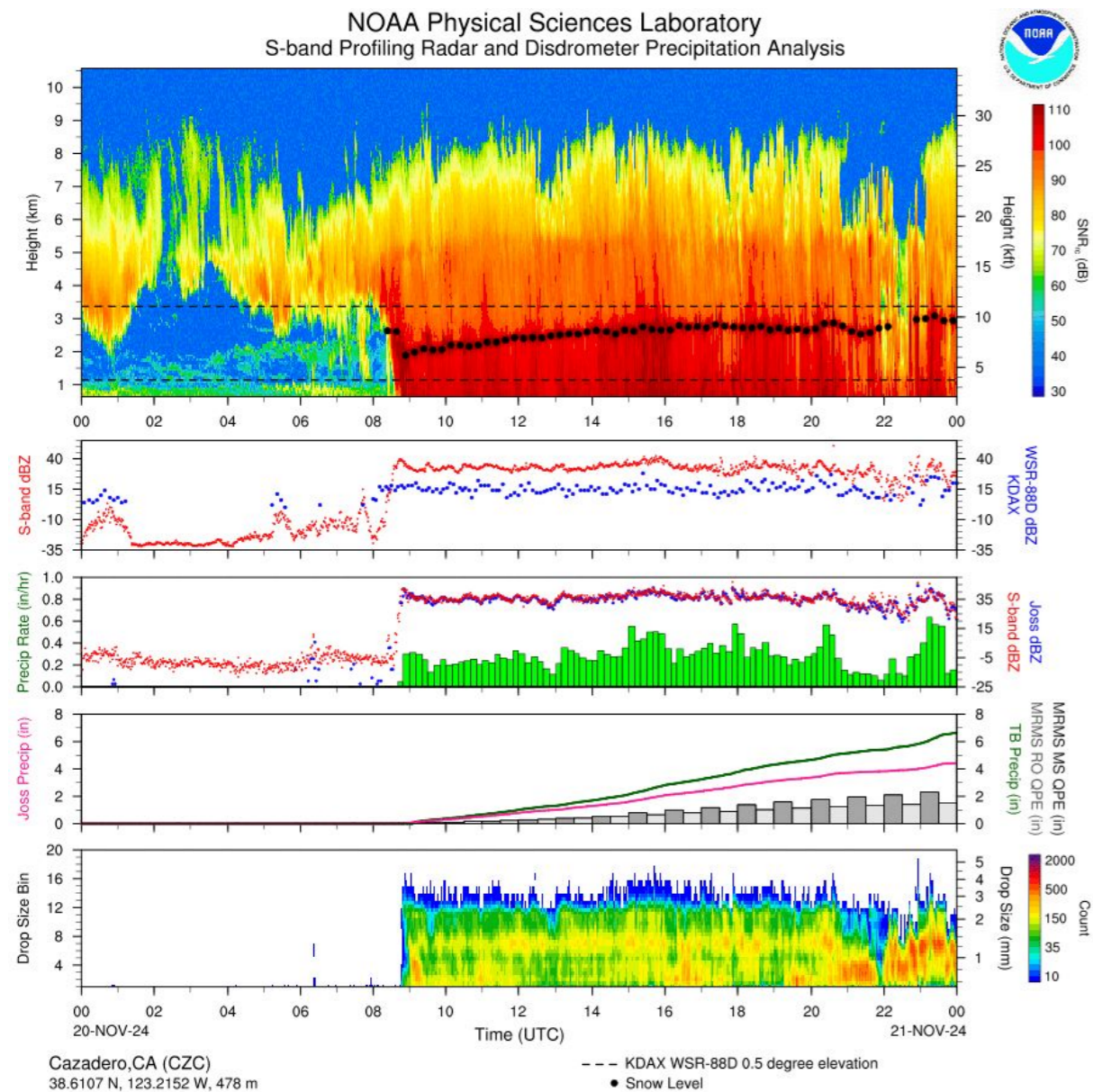


- Stations in Bodega Bay (BBY) and Cazadero (CZC) were able to perfectly capture the conditions that helped drive the extreme precipitation amounts in the Coast Ranges over the full duration of the event.
- The wind profiler in Bodega Bay observed persistently strong upslope moisture flux, a result of sustained southwesterly upslope winds in excess of 25 knots and IWV above 20 mm from 06Z 20 Nov through 18Z 22 Nov.

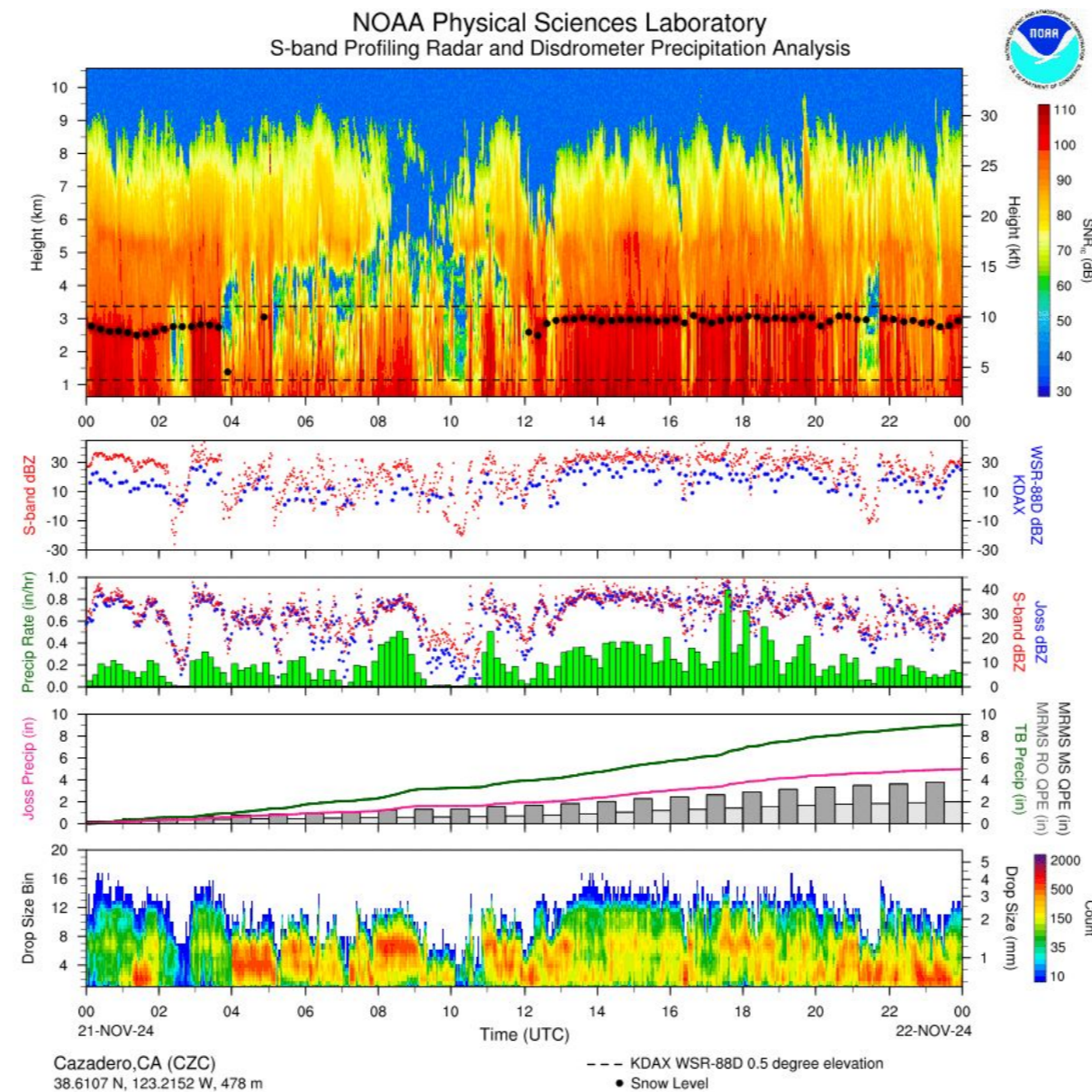
CW3E Event Summary: 19–23 Nov 2024

S-Band Profiling Radar and Disdrometer: Cazadero (CZC)

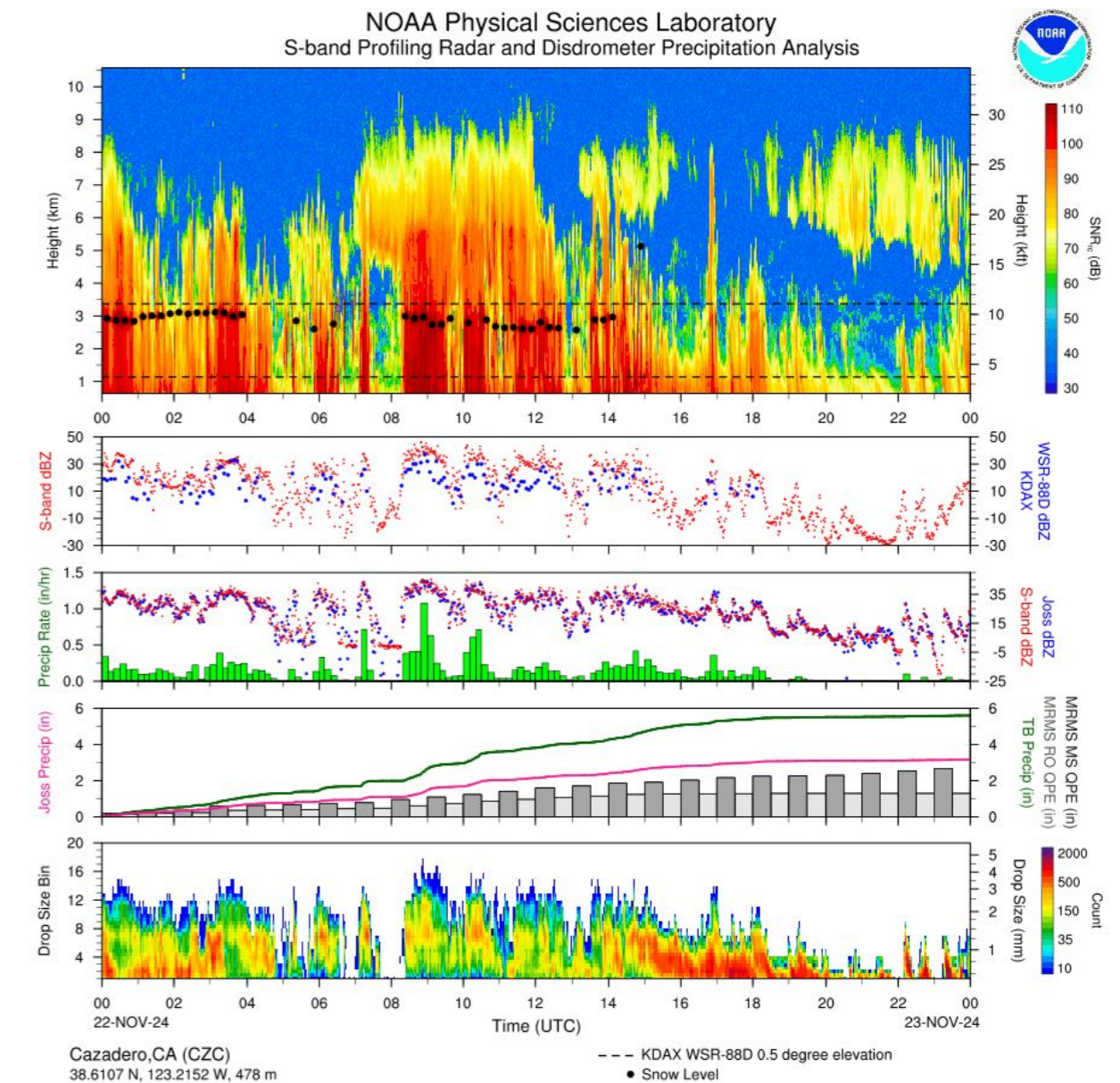
Valid 20-21 Nov



Valid 21-22 Nov



Valid 22-23 Nov

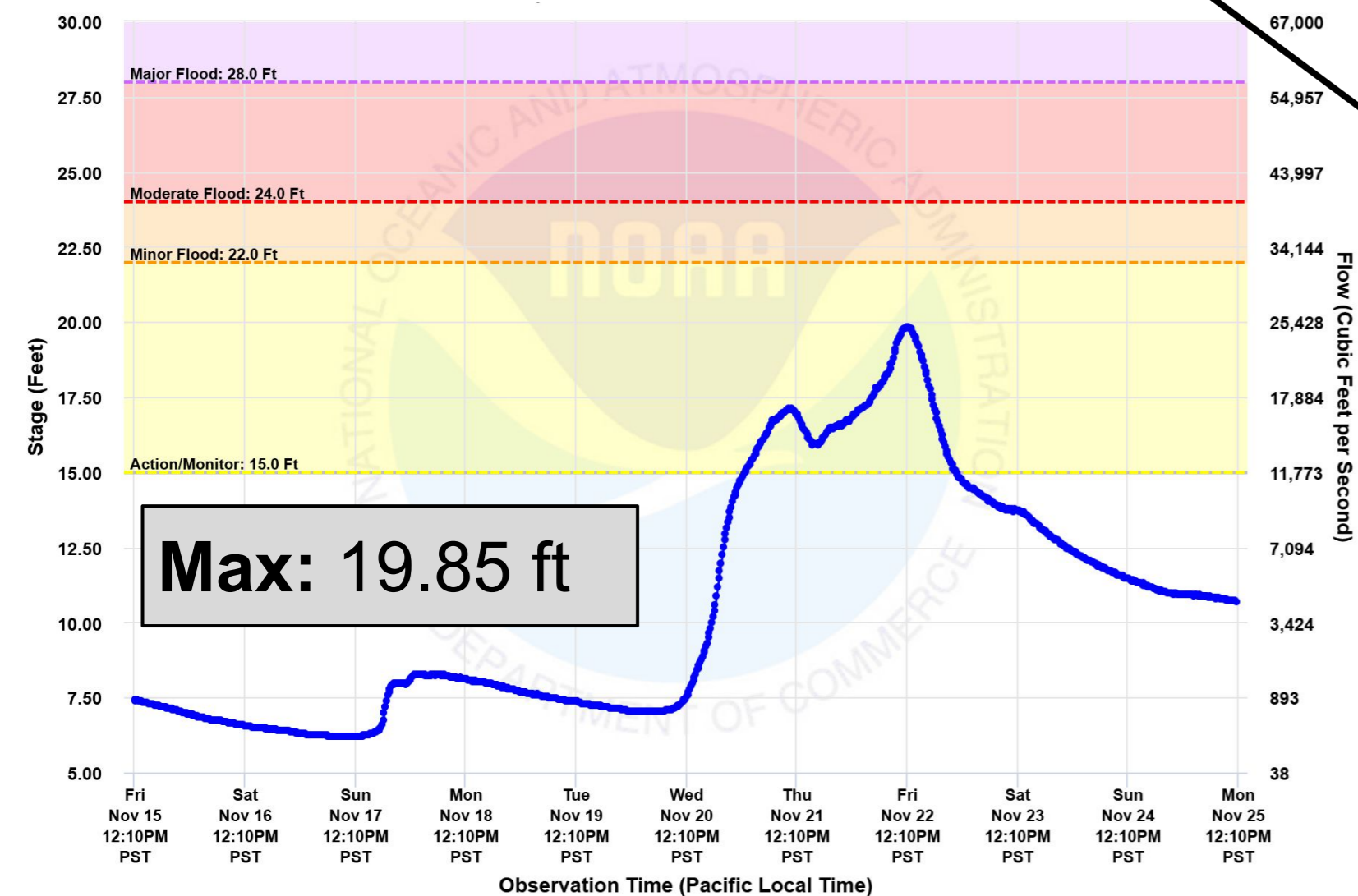


- The profiling radar in Cazadero captured the persistent non-bright band rain (a signature of orographic precipitation) and moderate-to-heavy precipitation rates that resulted in 20+ inches of total precipitation as measured by the CZC rain gauge.

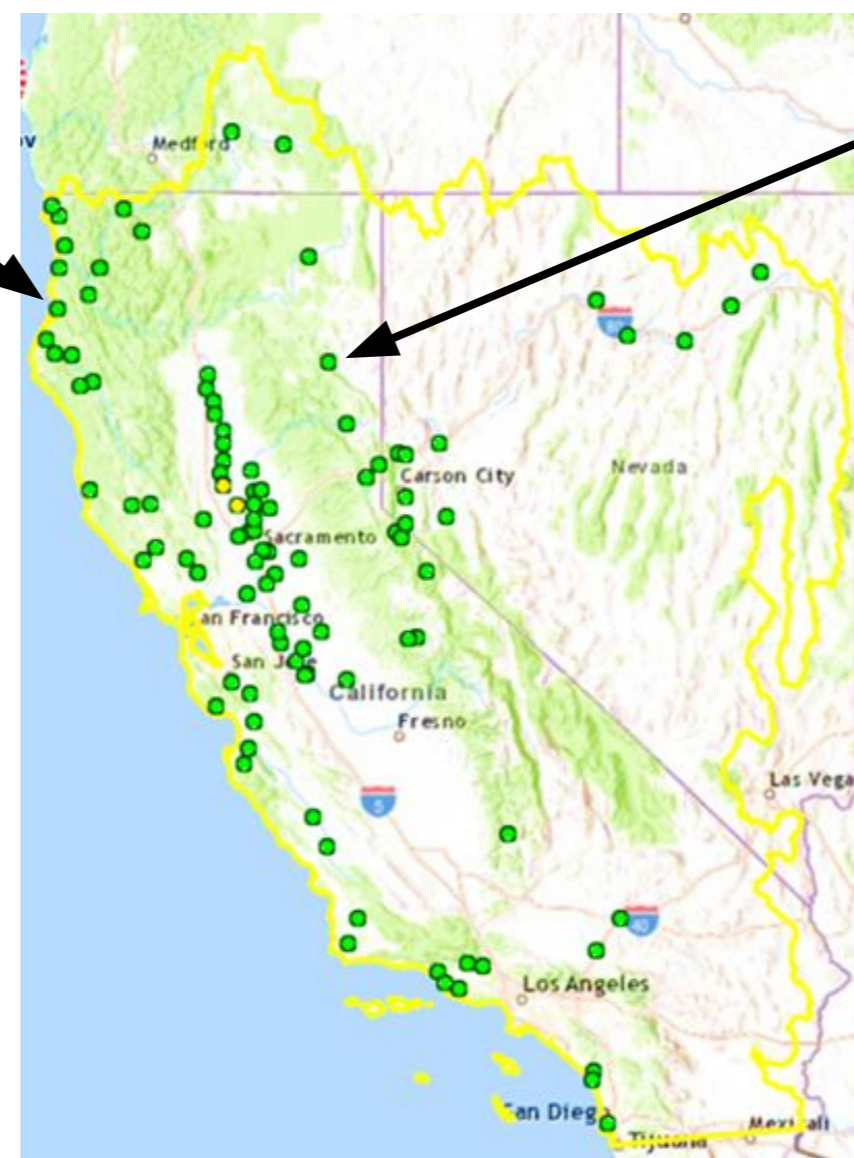
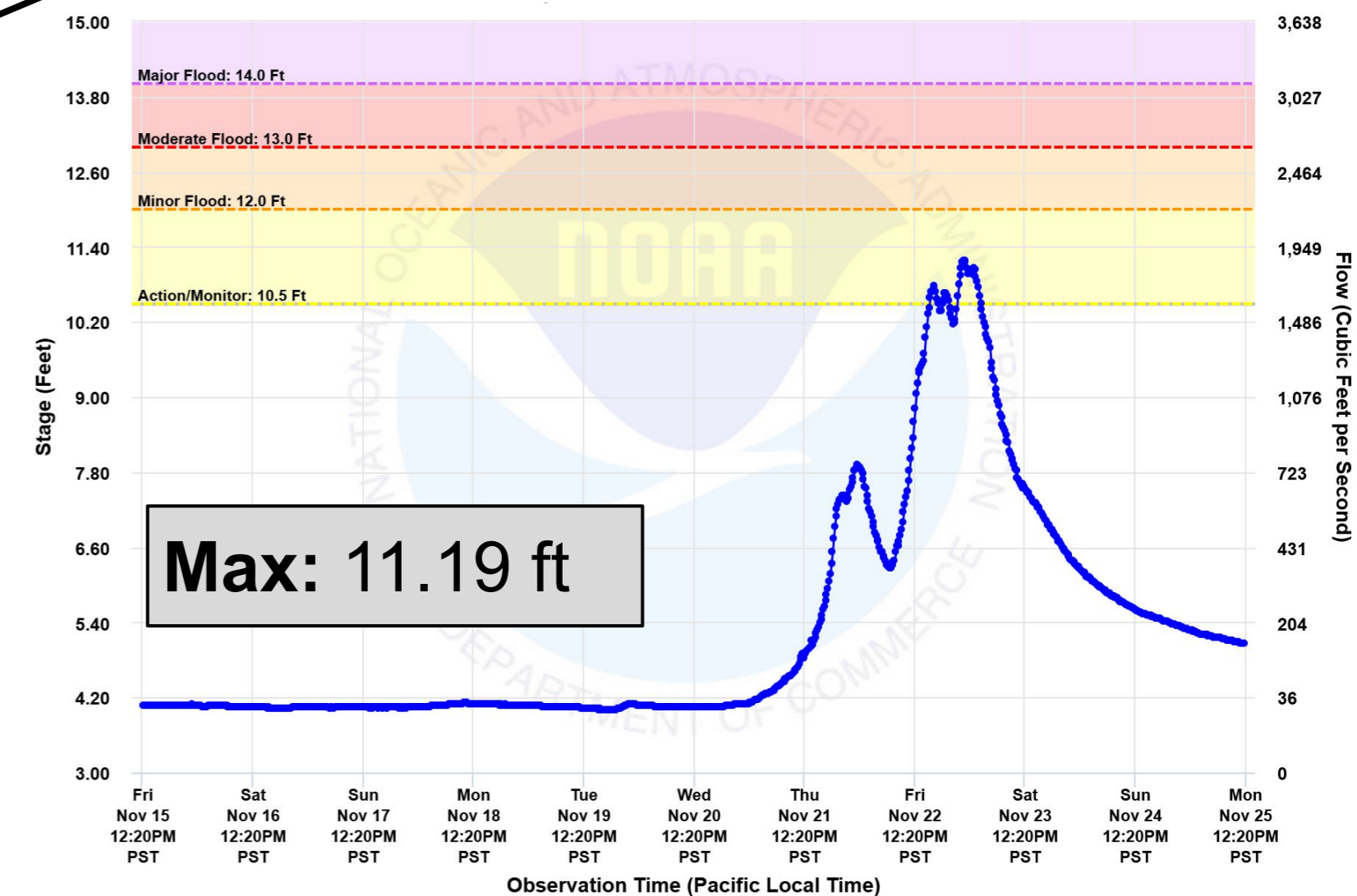
CW3E Event Summary: 19–23 Nov 2024

Hydrographs - Northern California & Sierra Nevada

Mad River - Arcata (ARCC1)



Susan River - Susanville (SUSC1)

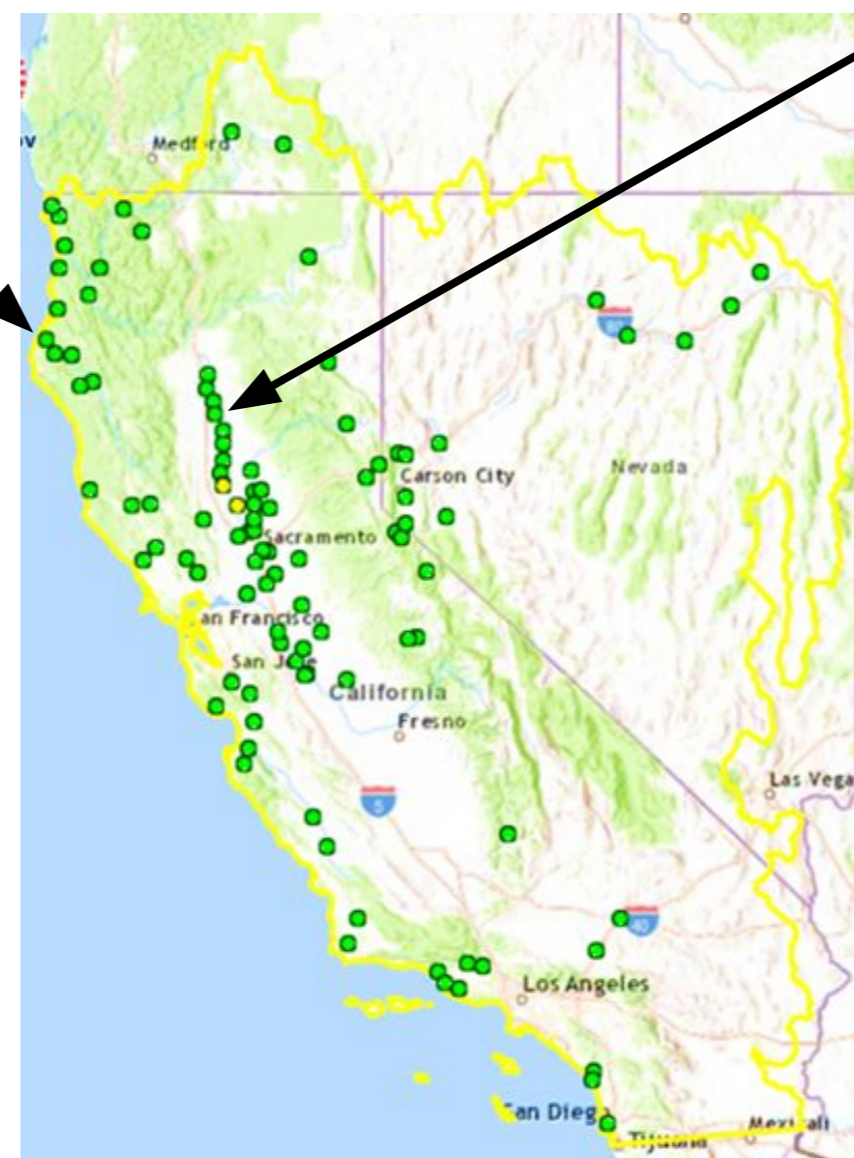


- The Mad River at Arcata rose approximately 13 feet, exceeding **Action/Monitor** stage.
- The Susan River at Susanville rose approximately 7 feet, exceeding **Action/Monitor** stage.

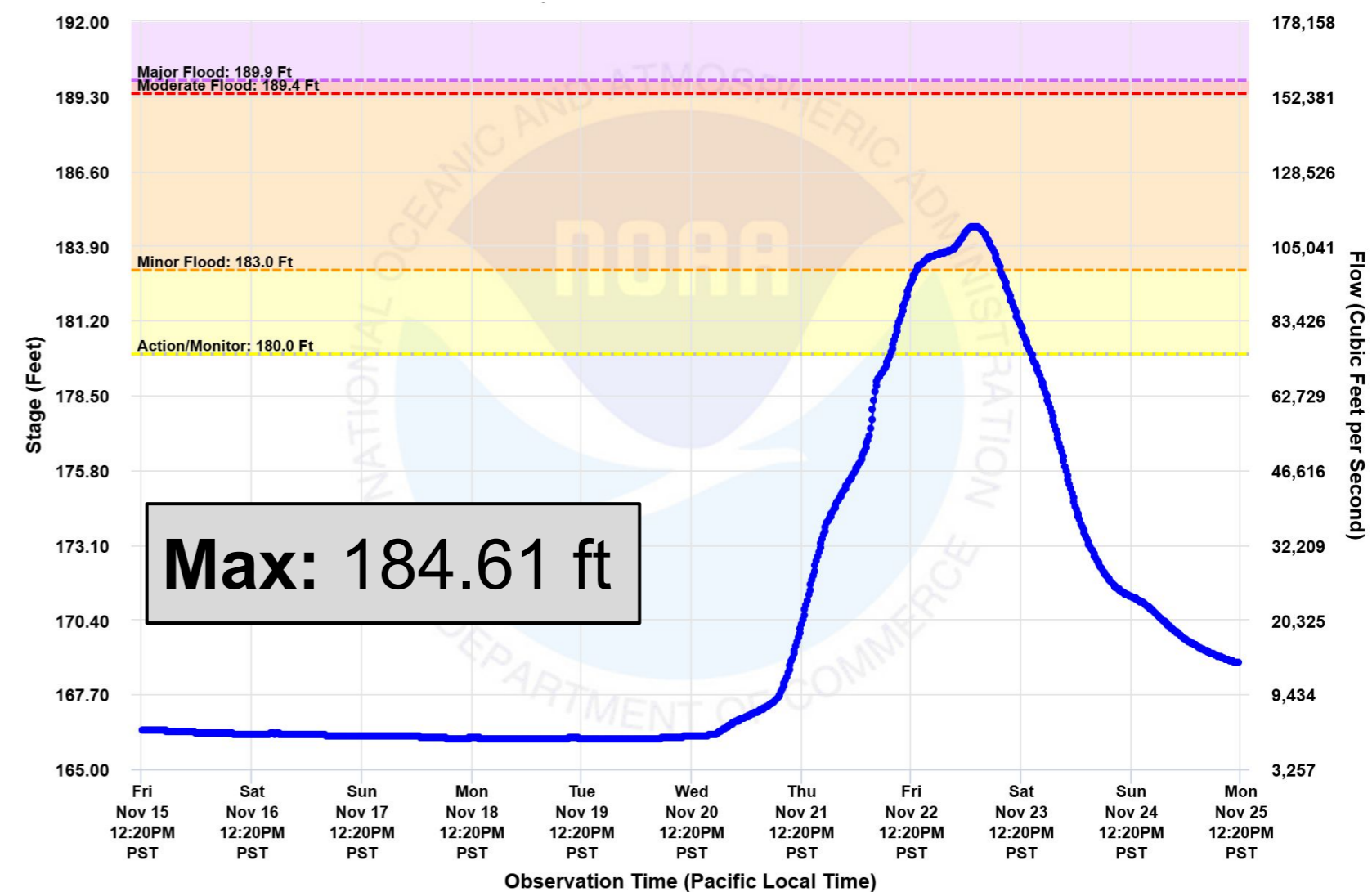
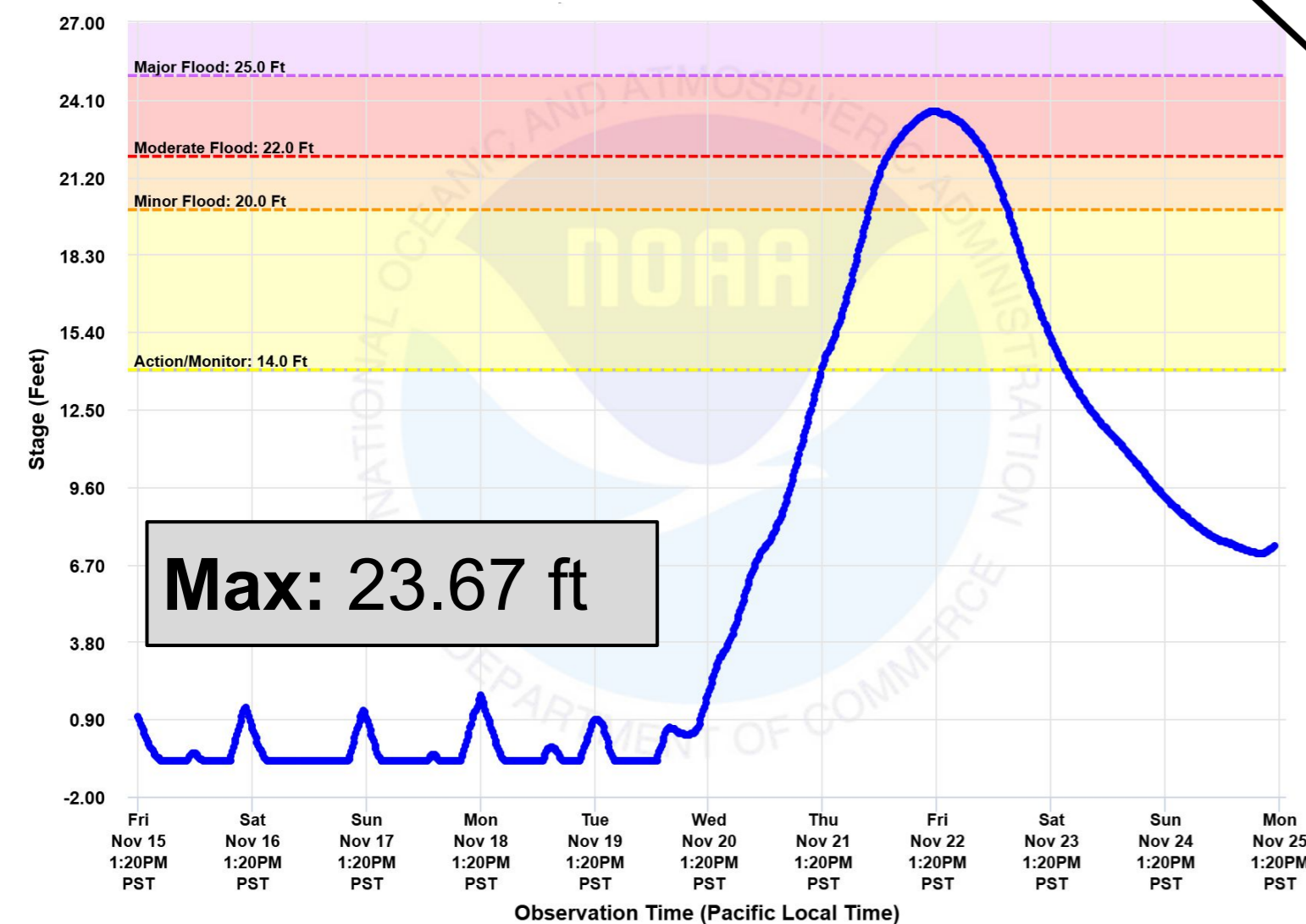
CW3E Event Summary: 19–23 Nov 2024

Hydrographs - Northern California & Sacramento River Valley

Eel River - Fernbridge (FRNC1)



Sacramento River - Woodson Bridge (VWBC1)

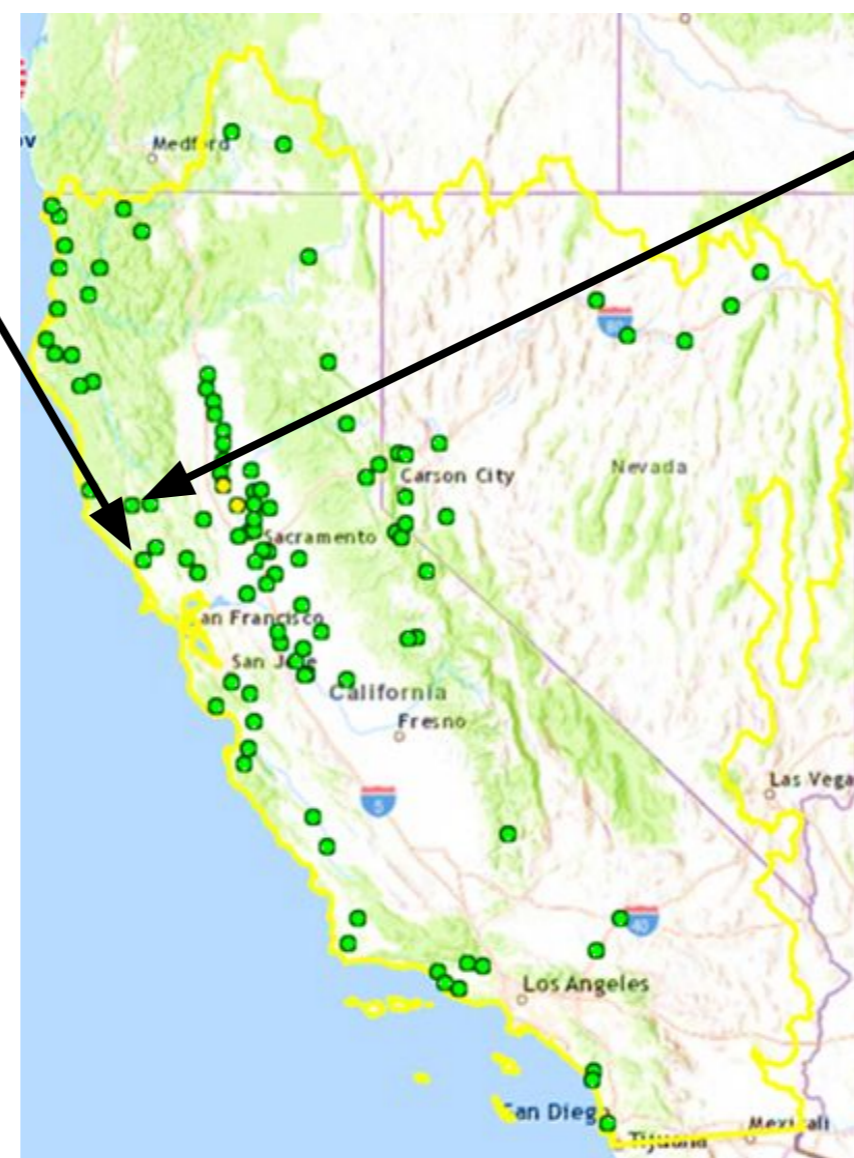
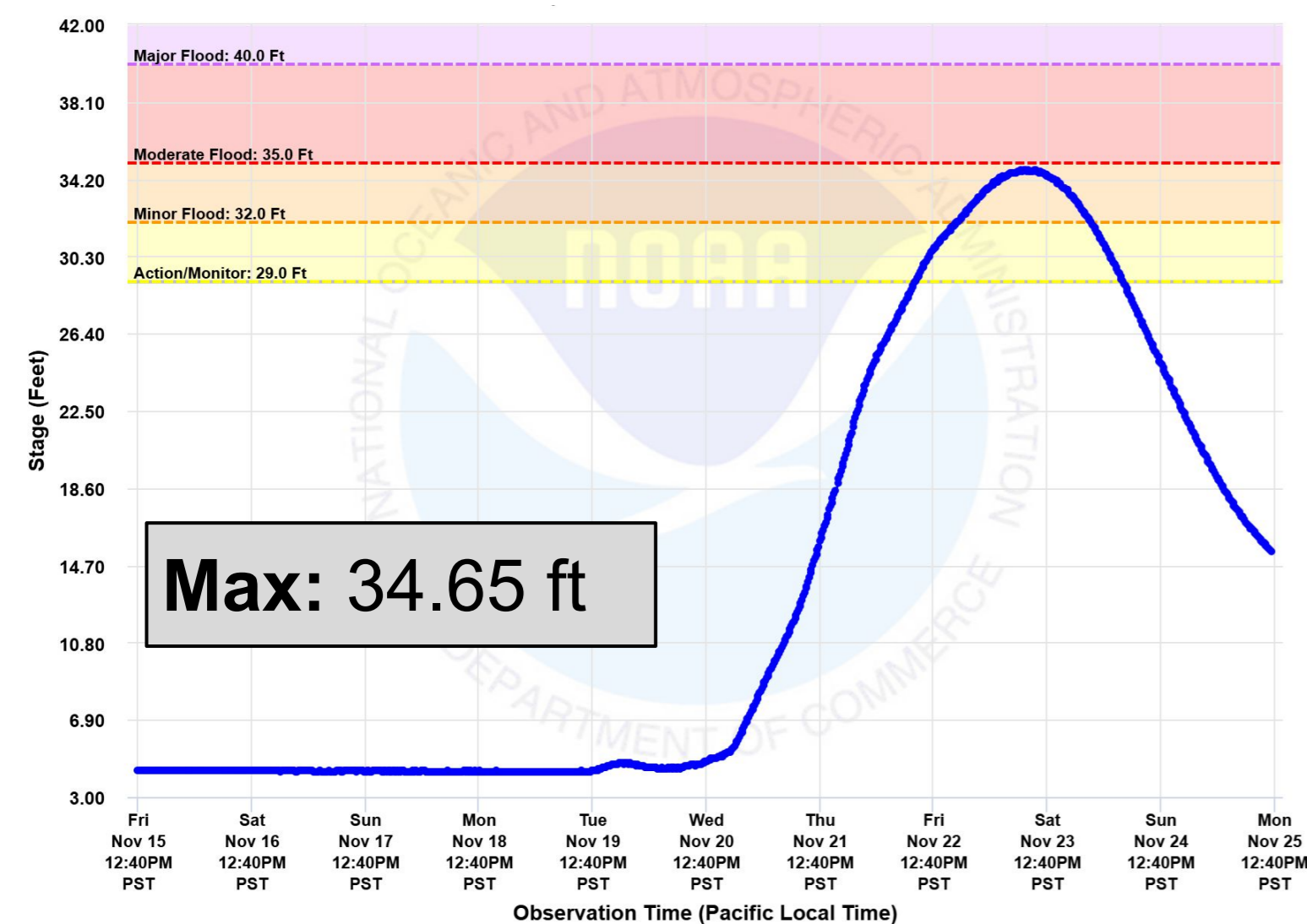


- The Eel River at Fernbridge rose approximately 22 feet, exceeding **Moderate Flood** stage.
- The Sacramento River at Woodson Bridge rose approximately 18 feet, exceeding **Minor Flood** stage.

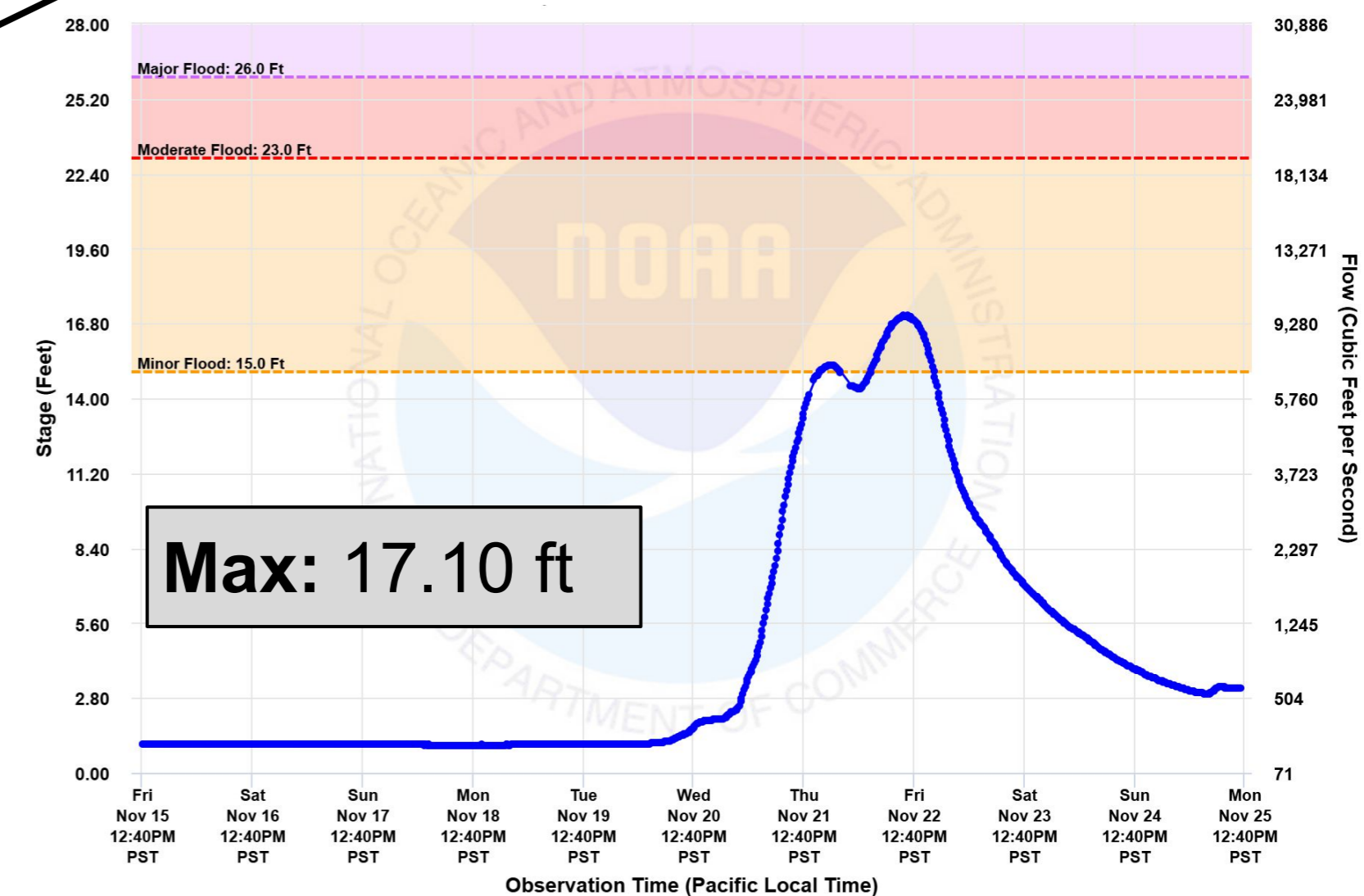
CW3E Event Summary: 19–23 Nov 2024

Hydrographs - Russian River Watershed

Russian River - Guerneville (GUEC1)



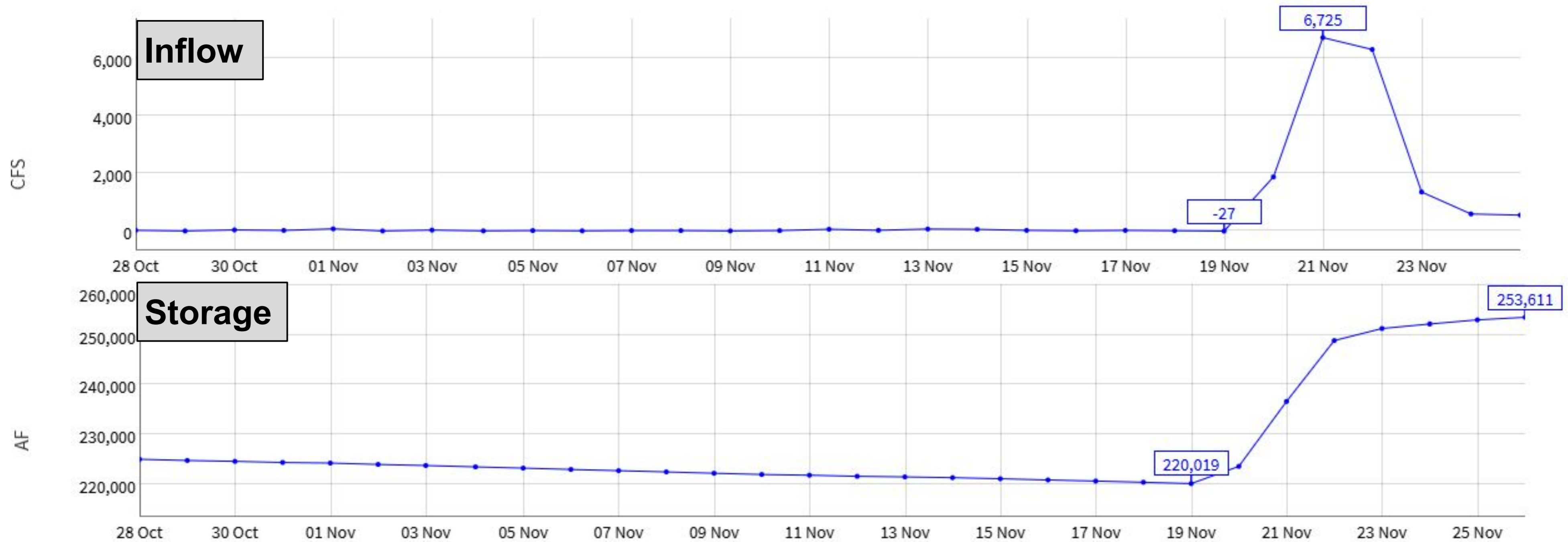
Russian River - Hopland (HOPC1)



- The Russian River at Guerneville rose approximately 30 feet, nearly exceeding **Moderate Flood** stage.
- The Russian River at Hopland rose approximately 15 feet, exceeding **Minor Flood** stage.

CW3E Event Summary: 19–23 Nov 2024

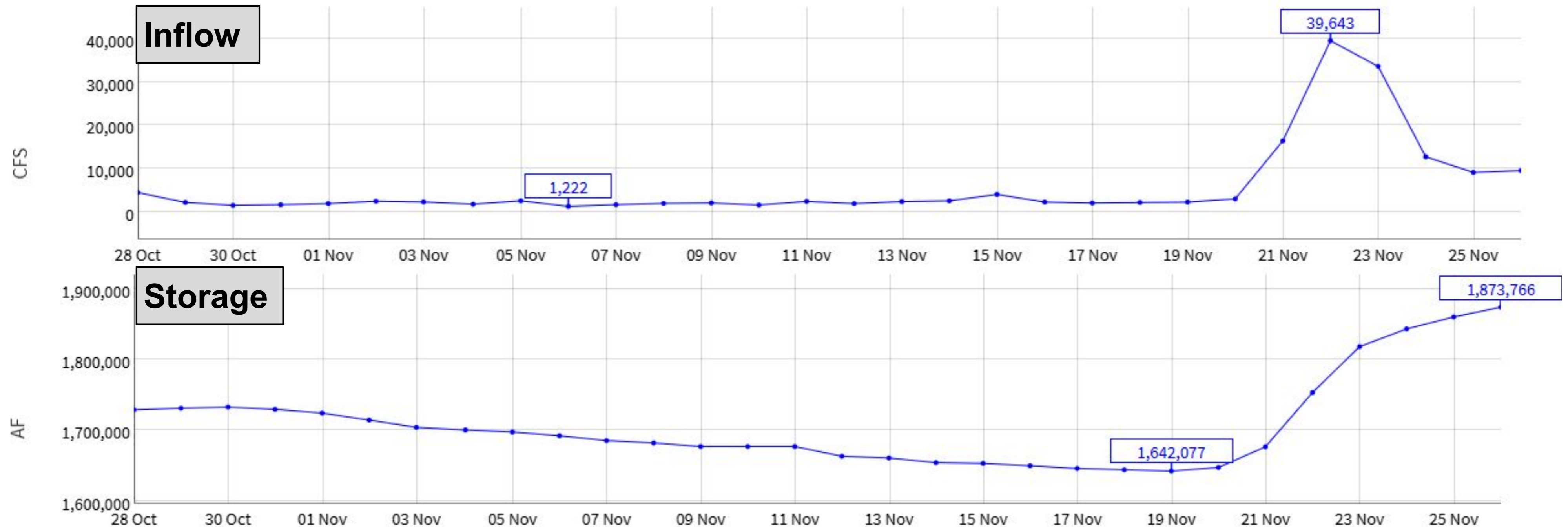
Reservoir Levels: Lake Sonoma



- Daily reservoir inflow at Lake Sonoma exceeded 500 cfs for 20–25 Nov, peaking at 6,725 cfs on 21 Nov, greatly exceeding the -2.25 cfs average inflow from the previous month.
- Higher inflows have allowed the reservoir storage to increase 33,592 acre feet from 19 Nov to 26 Nov.

CW3E Event Summary: 19–23 Nov 2024

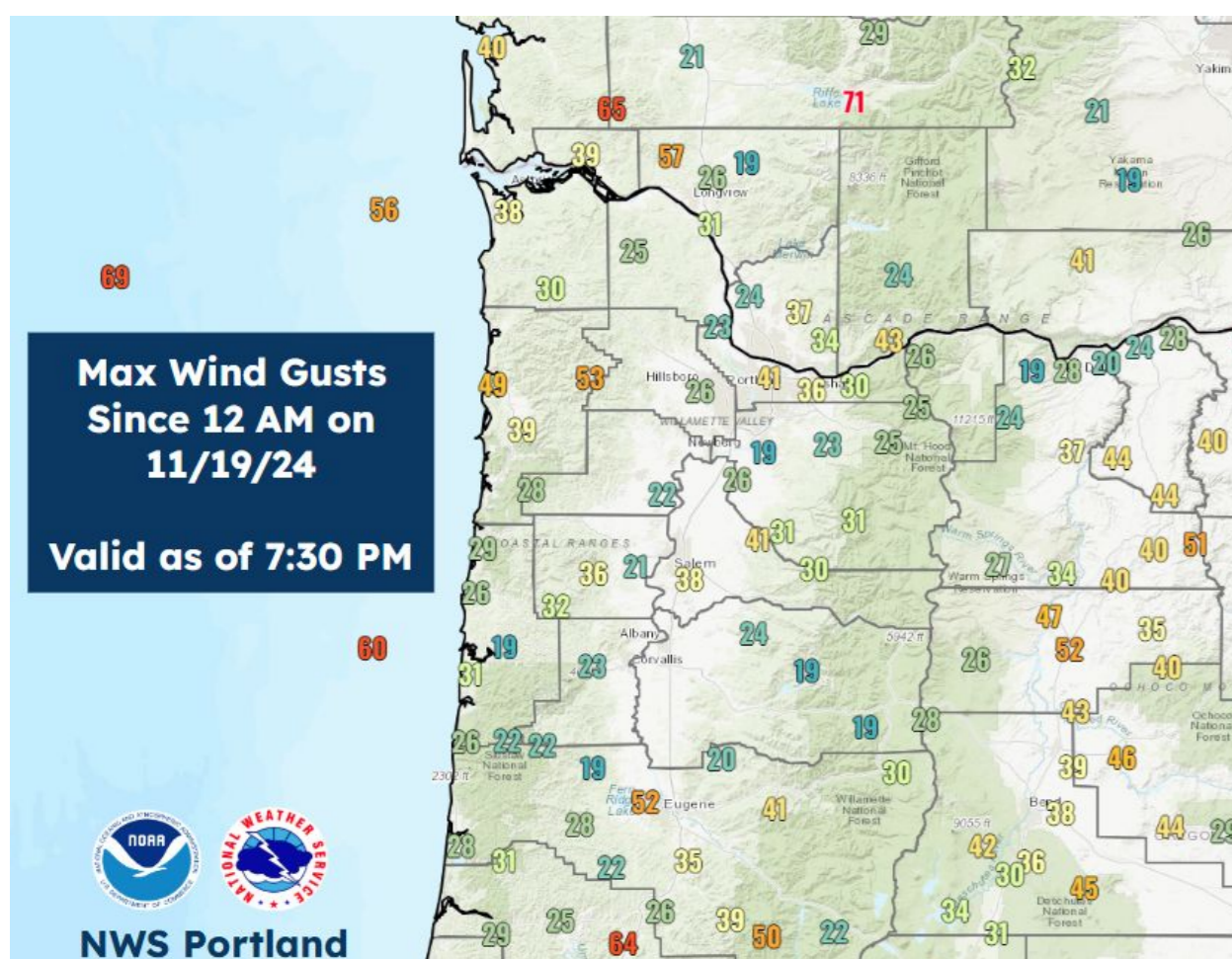
Reservoir Levels: Lake Oroville



- Daily reservoir inflow at Lake Oroville exceeded 9000 cfs for 21–25 Nov, peaking at 39,643 cfs on 22 Nov, far above the previous month’s average inflow of 2,131 cfs.
- Higher inflows have allowed the reservoir storage to increase 231,689 acre feet from 19 Nov to 26 Nov.

CW3E Event Summary: 19–23 Nov 2024

Impacts: Pacific Northwest



<https://x.com/NWSPortland/status/1859084389784973509>

<https://x.com/NWSSeattle/status/1860072500375486526>

<https://x.com/BvueFD/status/1859265258474676378>

<https://x.com/SnoqualmiePass/status/1859320821539537413>

- The bomb cyclone offshore resulted in extremely high winds over the Pacific Northwest, with gusts between 20–40 mph in Washington & Oregon, 40–60 mph offshore, and gusts of 60–80 mph along the peaks of the highest terrain.
- Strong winds and rains resulted in many fallen trees which blocked roadways and hit structures. Two fatalities in the region were attributed to large trees falling on houses.
- Hundreds of thousands of customers were reported to be without power during this storm due to high winds.
- Strong winds combined with heavy snow created blizzard conditions, resulting in dangerous travel conditions.

CW3E Event Summary: 19–23 Nov 2024



<https://x.com/CaltransD2/status/1860348239414985101>



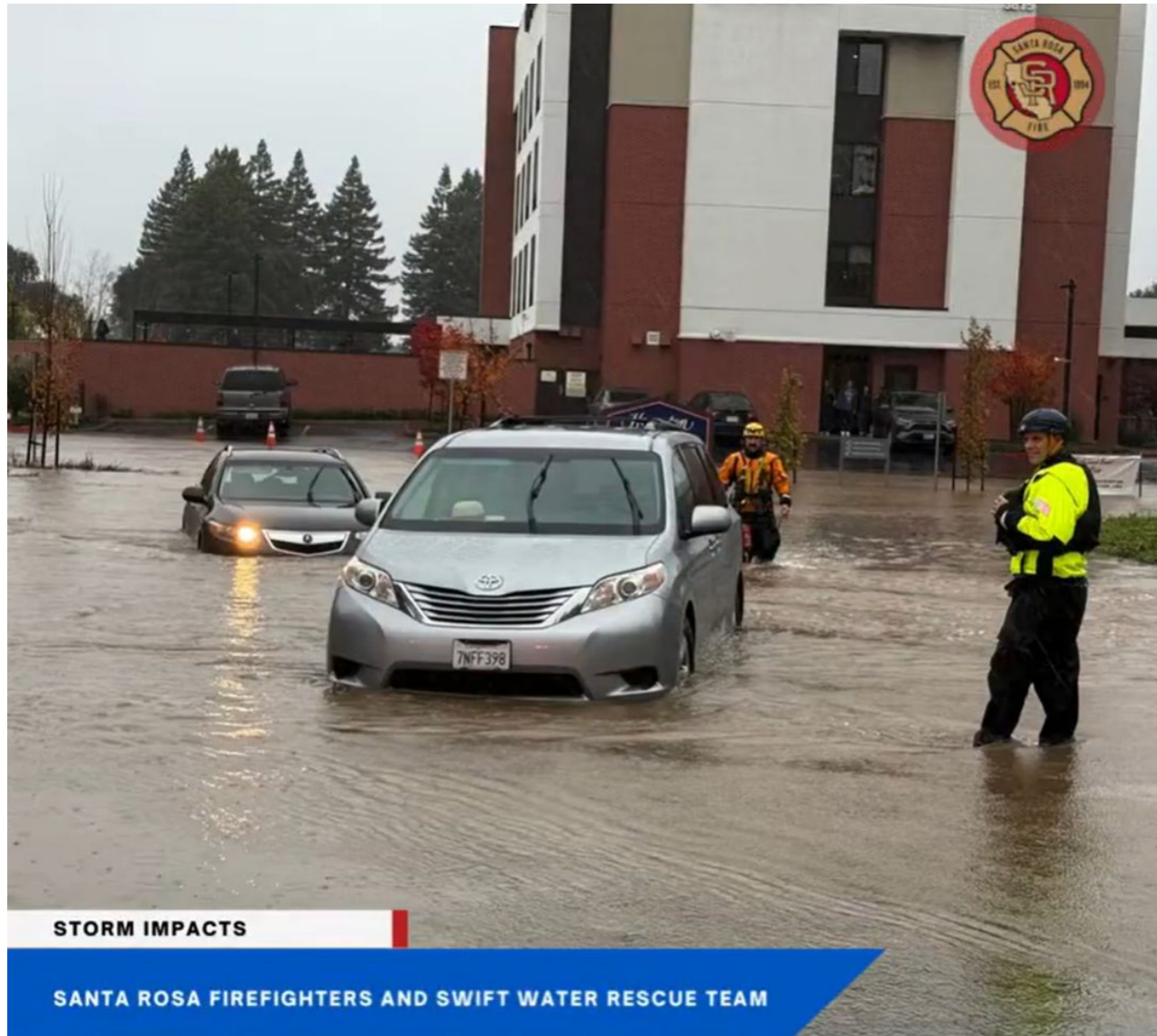
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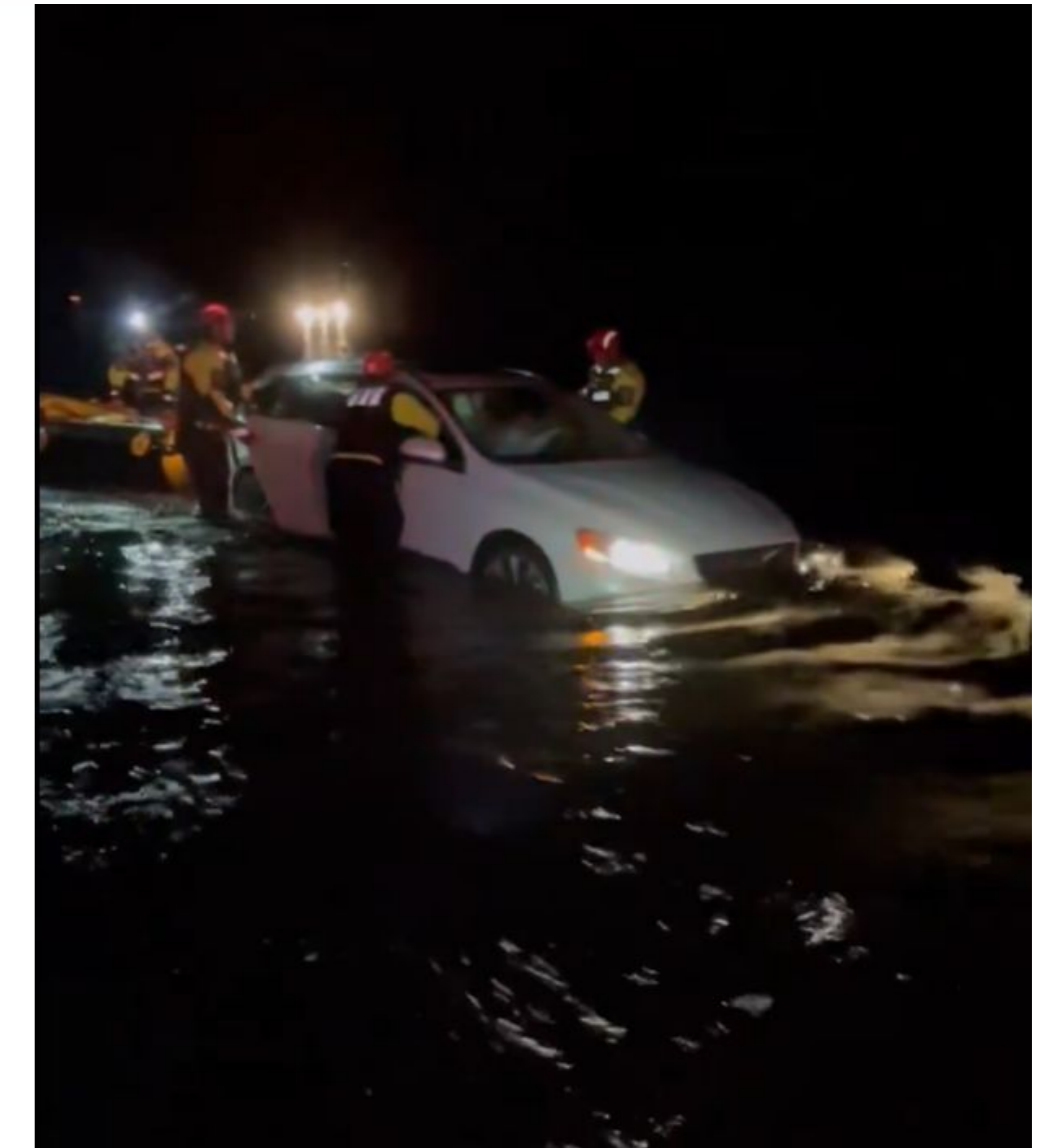
<https://x.com/CaltransDist3/status/1860465764119249077>

- A rock fall along SR70 in Belden, CA caused a road closure on 23 Nov, was one of more than 70 landslides, debris flows, and rock falls reported in California according to NWS Local Storm Reports.
- In Sonoma County, a debris flow associated with rushing waters blocked a roadway and flood waters along the Russian River inundated a mobile home park, requiring fire department assistance during evacuations.
- Flooding was reported across the Sacramento Valley, including along the Sacramento River in Butte City, CA.

CW3E Event Summary: 19–23 Nov 2024



<https://x.com/SantaRosaFire/status/1859769164602409332>

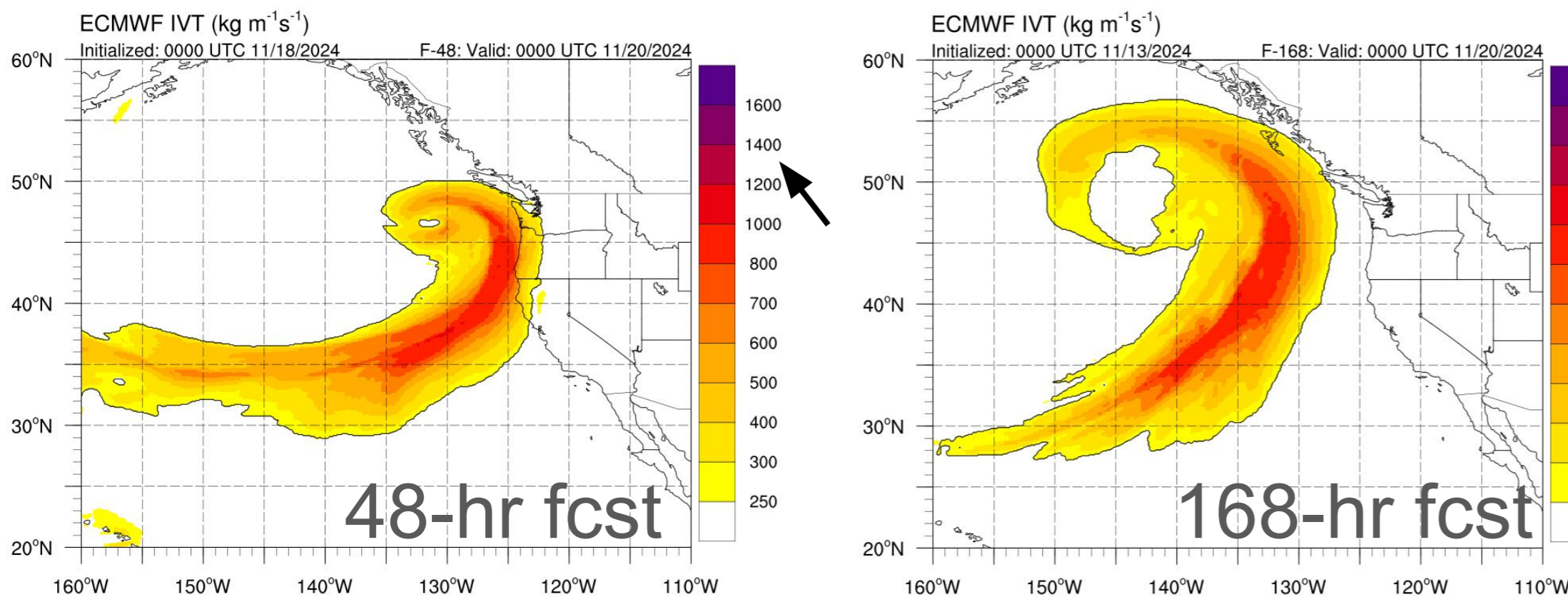


https://x.com/CALFIRE_ButteCo/status/1859989482721759632

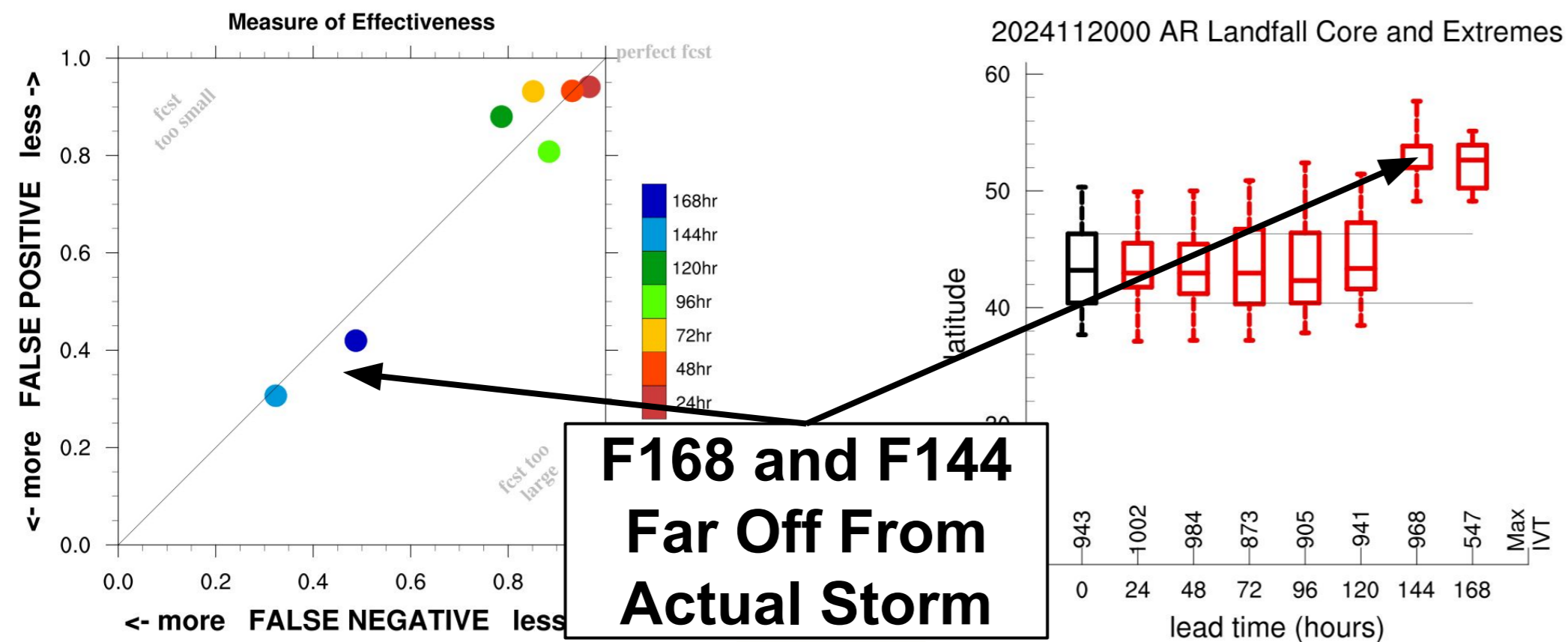
- Heavy rain in Santa Rosa, CA caused a healthcare clinic and hotel to be cut off as roads flooded and a sinkhole developed. Drivers who attempted to drive through floodwaters required rescue from their vehicles.
- CalFire's Swiftwater Rescue Team performed 6 swiftwater rescues in Butte County, assisting 10 people and 1 dog trapped by floodwaters. Additionally, the team evacuated 15 people and 2 goats threatened by floodwaters.

CW3E Event Summary: 19–23 Nov 2024

AR Landfall Forecast Verification: November 20th

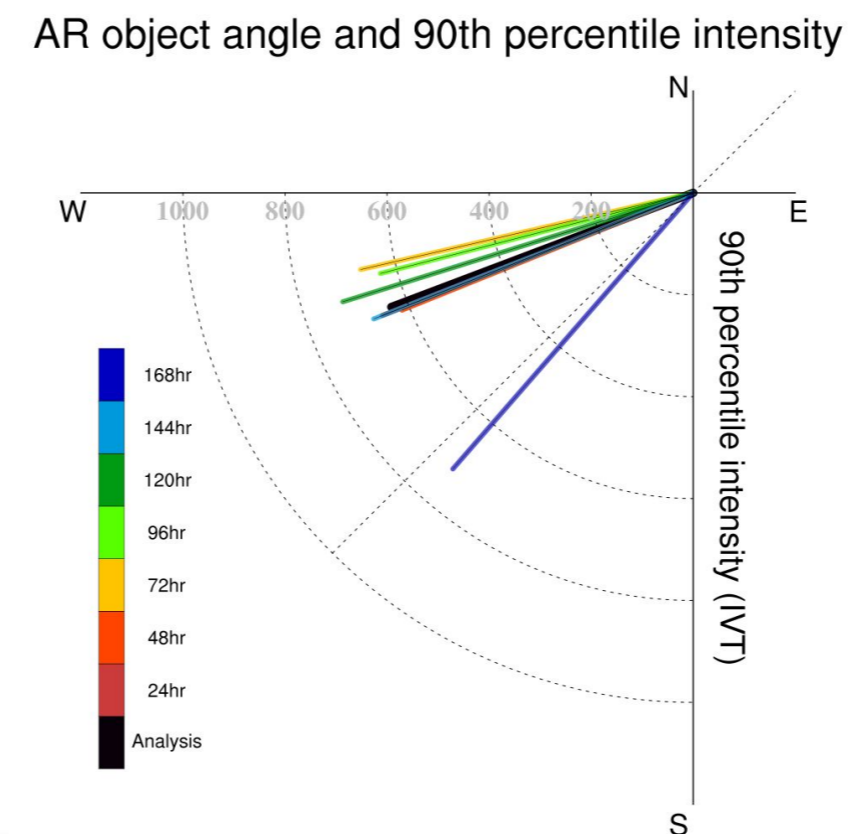
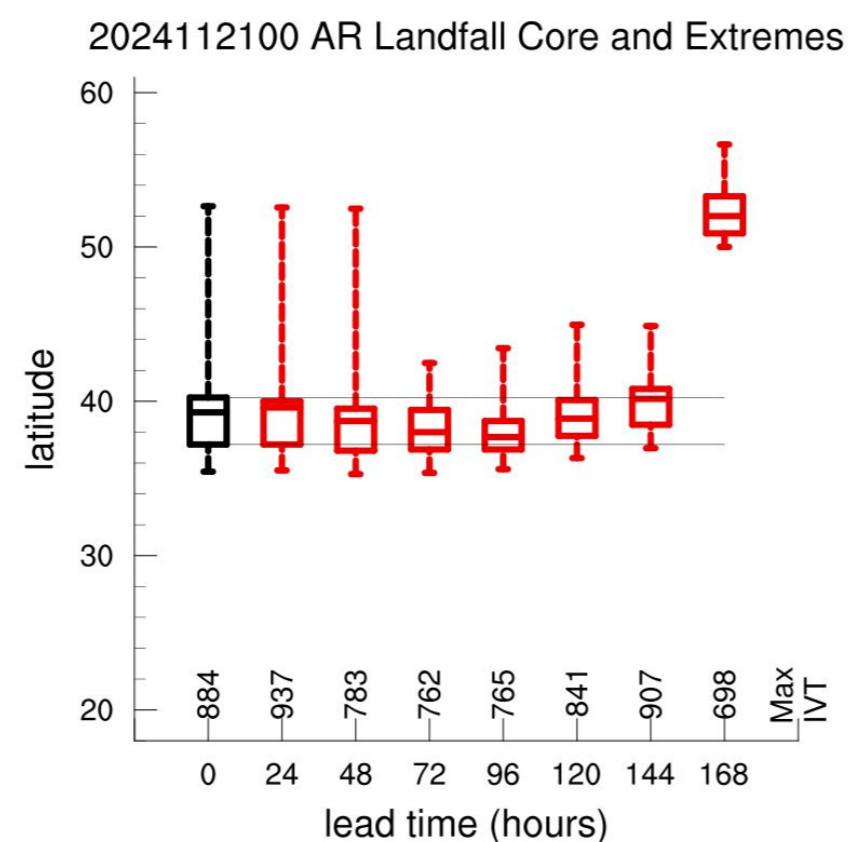
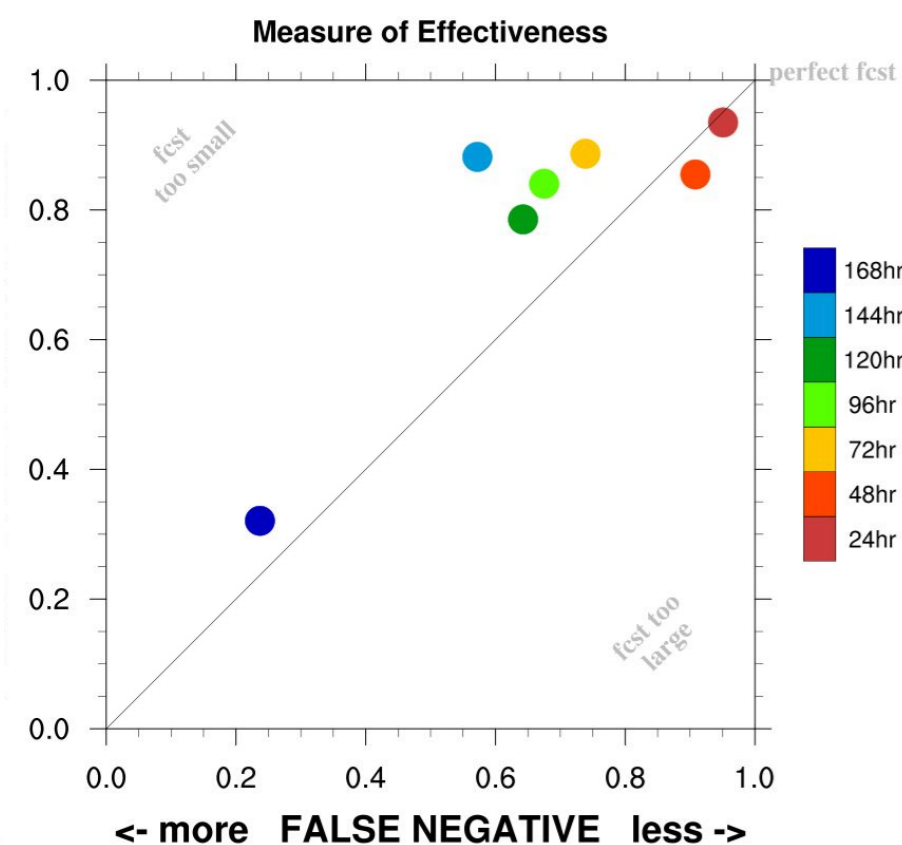
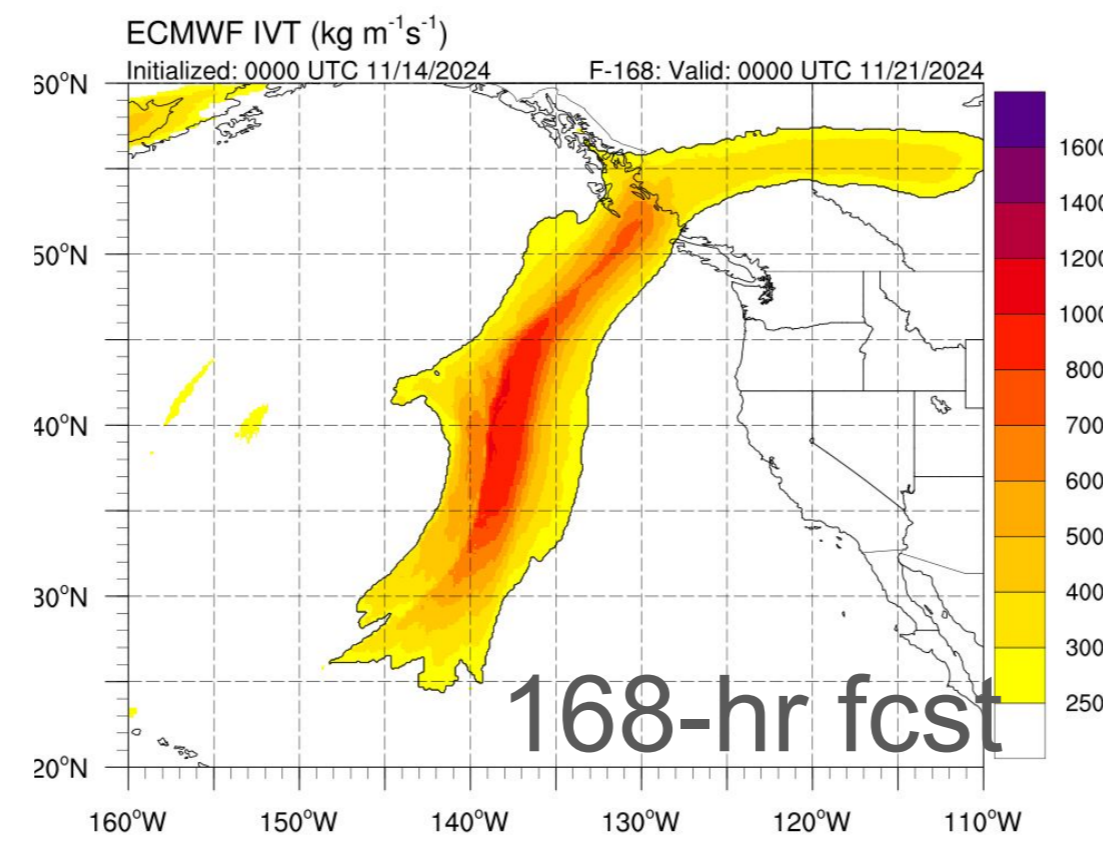
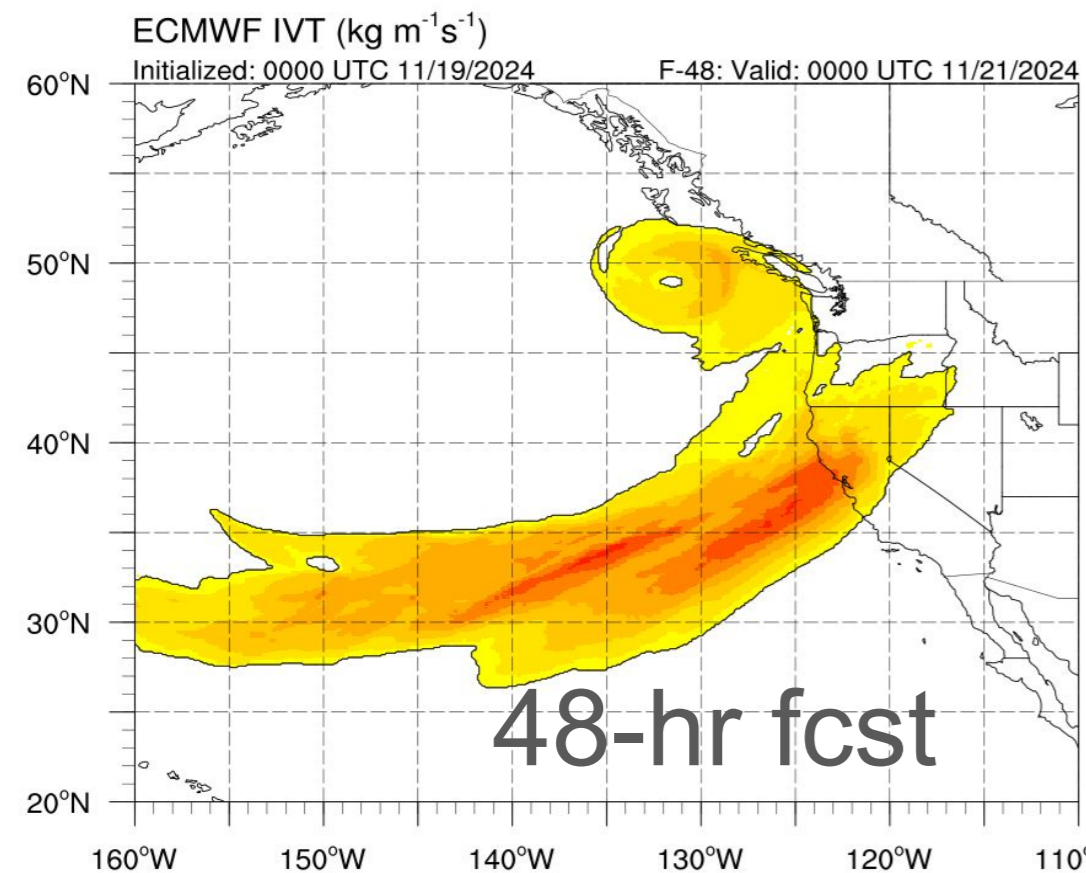


- Each forecast made 24 to 120 hours in advance correctly locked into the strength and landfall latitude of the landfalling AR on 00Z 20 November.
- The storm prediction at 168 hours in advance was much further offshore (onshore IVT was weak) in association with the extratropical cyclone displaced to the north, and the orientation was much more north-south.
- The forecast at 144 shifted toward the proper strength but remained too far north.



CW3E Event Summary: 19–23 Nov 2024

AR Landfall Forecast Verification: November 21st

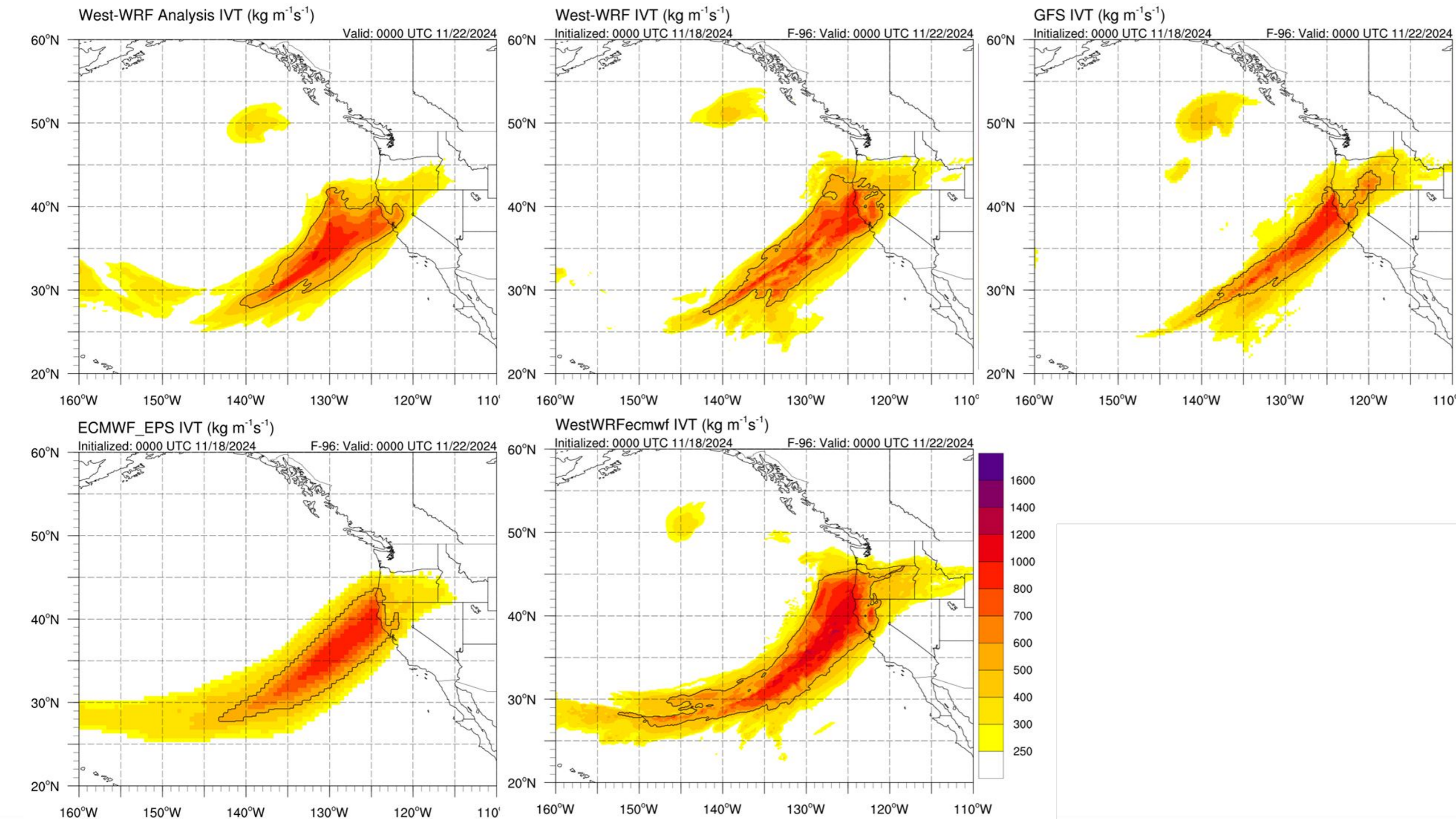


- While the forecast at 168 hours had an AR of approximately the correct strength, the positioning and orientation were far from correct. This can be seen in the Measure of Effectiveness (*Lower Left*), landfall location (*Lower Middle*), and the angle (*Lower Right*).

- Each of the subsequent forecast hours locked in on the correct average landfall location, core, strength, and orientation much better than 168-hour forecast.

CW3E Event Summary: 19–23 Nov 2024

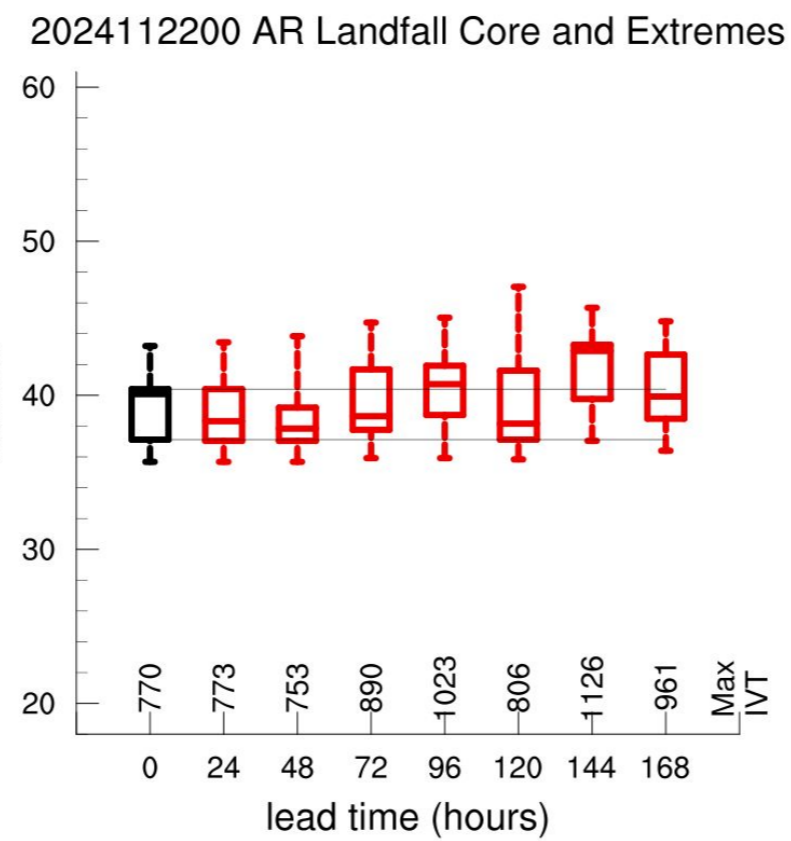
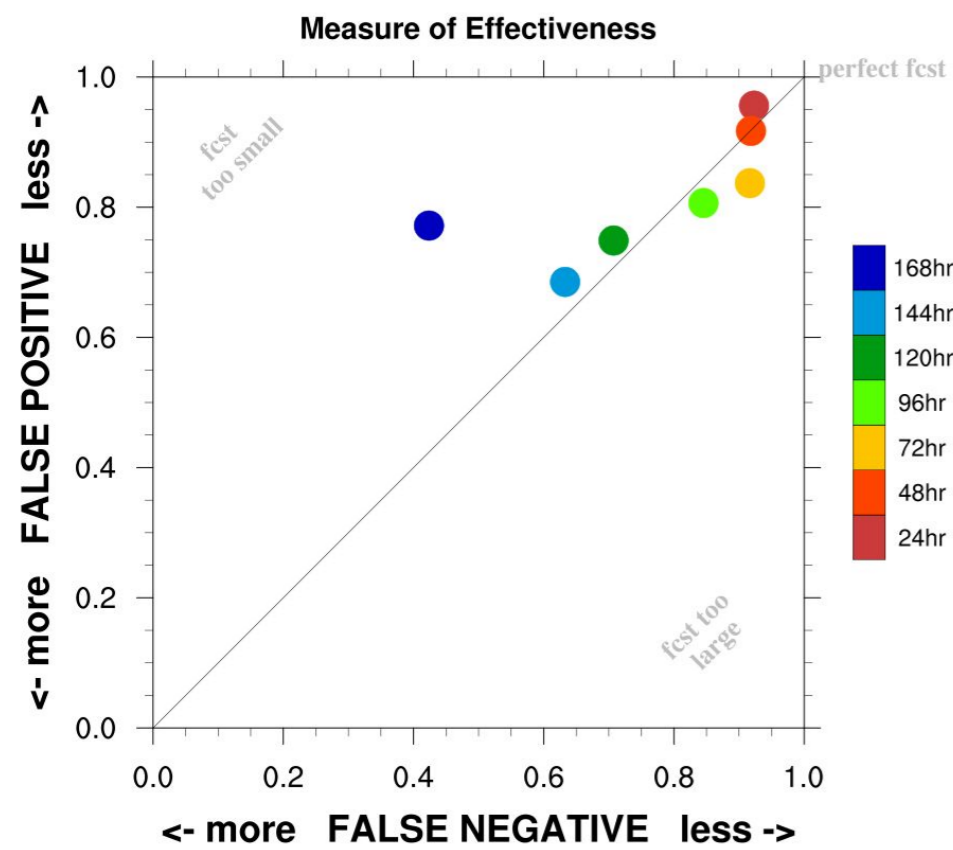
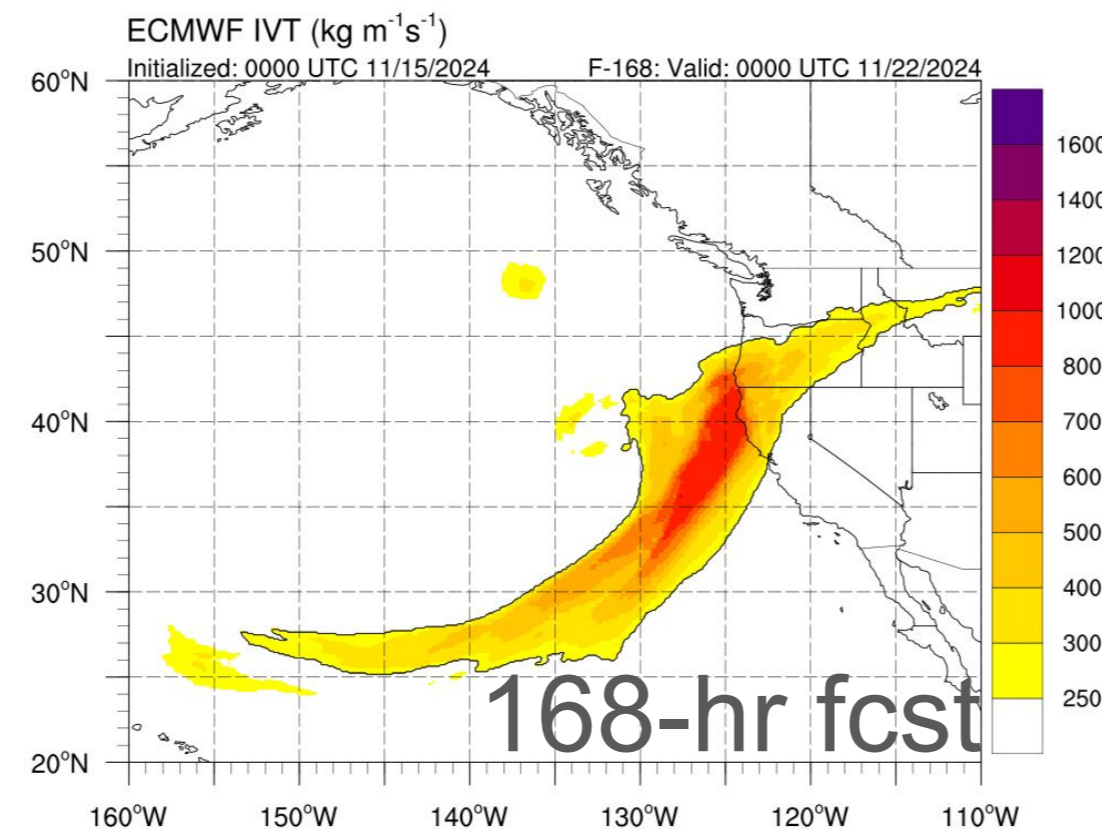
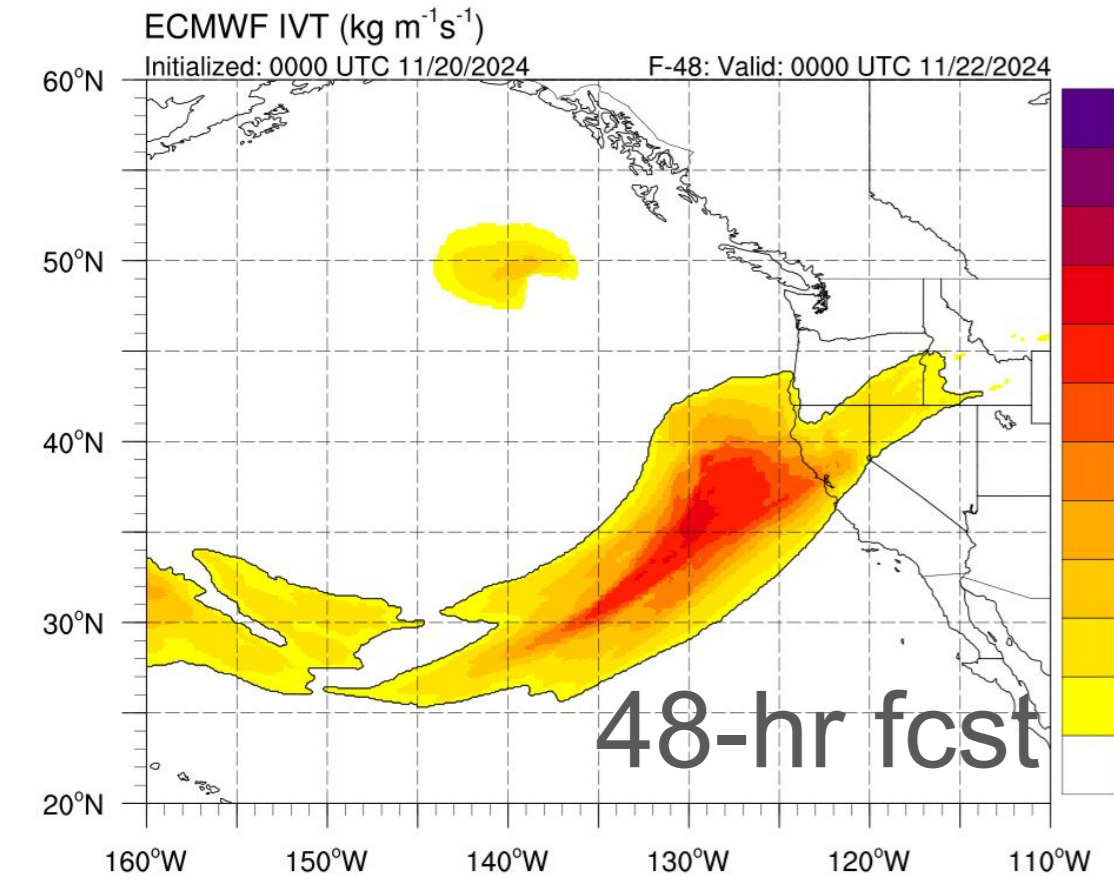
AR Landfall Forecast Verification: November 22nd



- AR duration was prolonged as a secondary area of cyclogenesis developed, which kept AR conditions sustained over Northern California.
- At 96 hours lead time, many of the models were picking up the location of the AR landfall through this sustained period and kept the landfall persistent through this time.

CW3E Event Summary: 19–23 Nov 2024

AR Landfall Forecast Verification: November 22nd

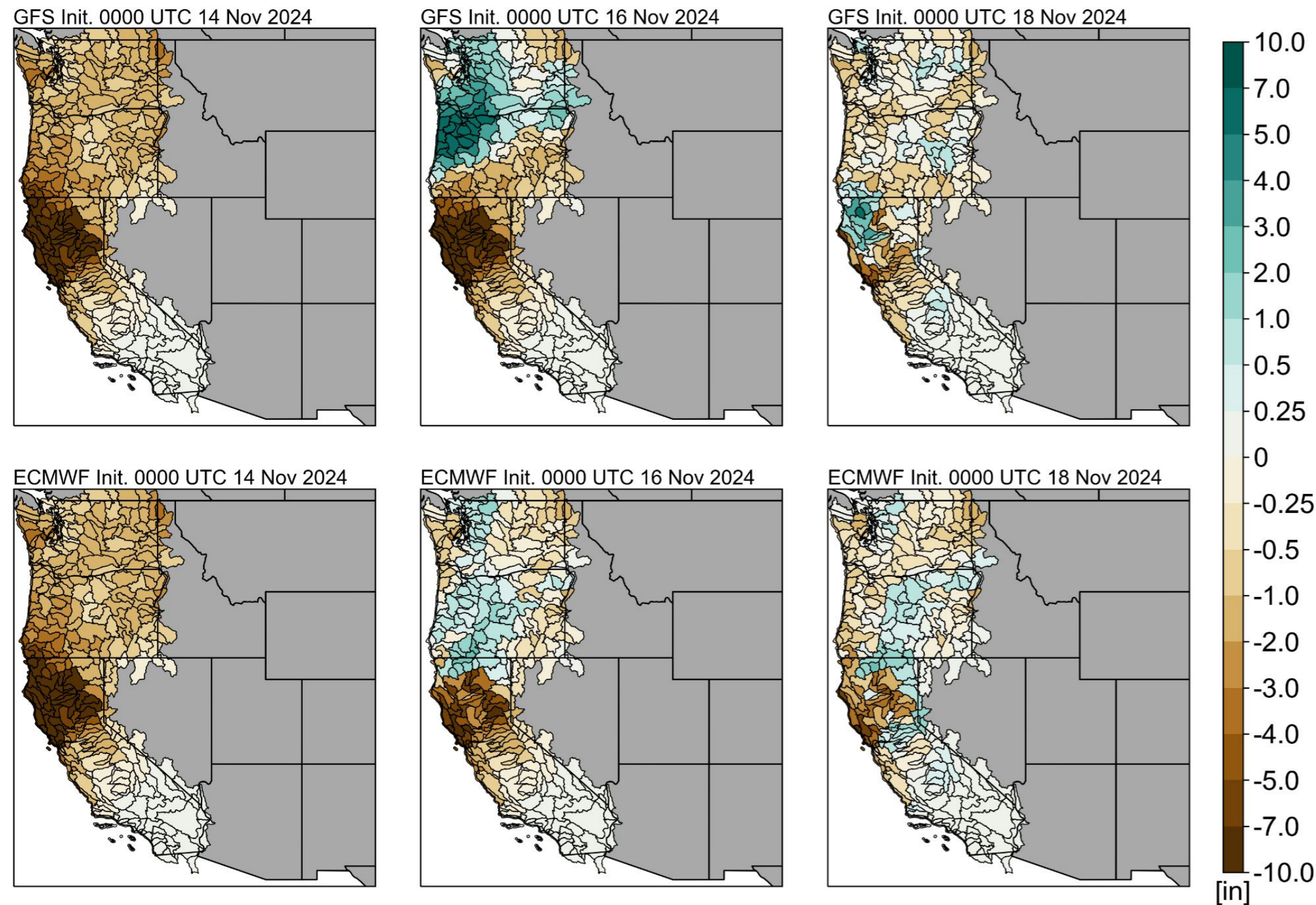


- The forecast at hour 168 was the only one that was too small on the size of the storm and F168–72 were all too strong on the max IVT compared to reality.

CW3E Event Summary: 19–23 Nov 2024

Watershed QPF Verification: GFS vs. ECMWF

72-h Watershed QPF Bias: Valid 1200 UTC 23 Nov 2024

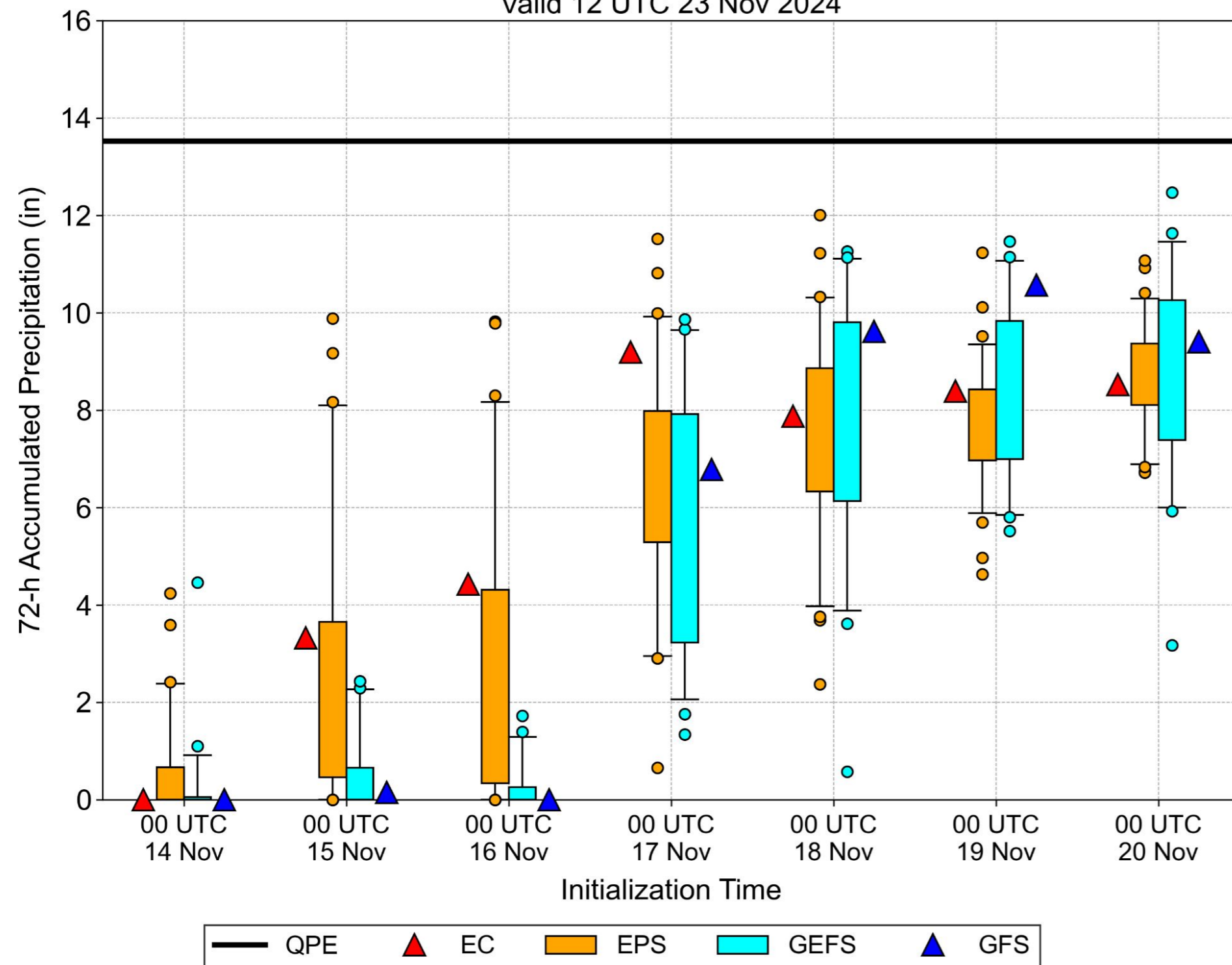


- GFS and ECMWF deterministic forecasts initialized at 00 UTC 14 Nov showed the AR making landfall over southeastern Alaska and British Columbia. As a result, both forecasts significantly underestimated event precipitation over much of the US West Coast, especially in Northern California.
- GFS and ECMWF deterministic forecasts initialized at 00 UTC 16 Nov showed the AR primarily making landfall over Washington and Oregon, with the ECMWF favoring a slightly more southerly landfall. As a result, both forecasts significantly underestimated precipitation over Northern California. The GFS also significantly overestimated precipitation in southwestern Washington and northwestern Oregon.
- By 00 UTC 18 Nov, the GFS and ECMWF were correctly forecasting a long-duration AR over Northern California, but both forecasts still underestimated precipitation in portions of the Coast Ranges, Southern Cascades, and Northern Sierra Nevada.

CW3E Event Summary: 19–23 Nov 2024

Watershed QPF Verification: Russian

72-h Model QPF vs. Stage IV QPE (Russian Watershed)
Valid 12 UTC 23 Nov 2024



- Deterministic and ensemble models initialized at 00 UTC 14 Nov severely underestimated the 72-hour mean areal precipitation in the Russian watershed valid at 12 UTC 23 Nov (~9-day lead time).
- Several EPS members were indicating the potential for 6+ inches of precipitation as early as 00 UTC 15 Nov (~8-day lead time), but GEFS did not catch on until 00 UTC 17 Nov (~6-day lead time).
- While forecast precipitation errors were much lower at shorter lead times, NCEP and ECMWF model guidance still underestimated event precipitation in the Russian watershed at lead times < 6 days.