

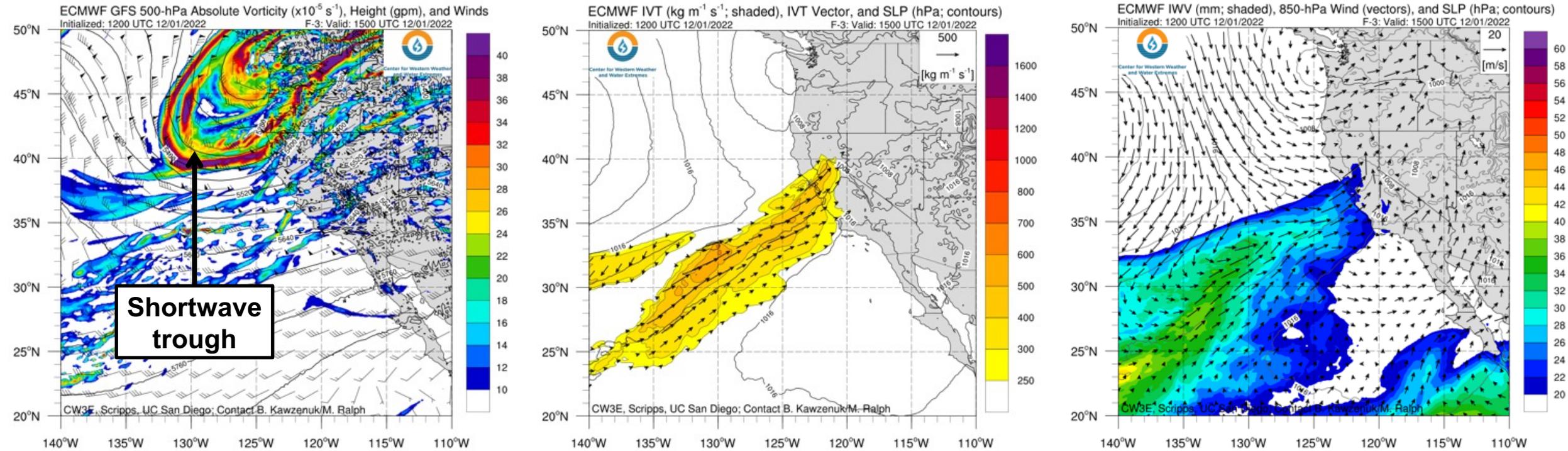
CW3E Event Summary: 29 Nov – 5 Dec 2022

Active Weather Pattern Brings Heavy Rain and Snow to Western US

- A low-pressure system associated with an upper-level shortwave trough and a weak atmospheric river (AR) impacted the western US during 30 Nov – 2 Dec
- A second low-pressure system and shortwave trough/cutoff low primarily impacted California on 2–5 Dec
- A moderate-strength atmospheric river (AR) developed over California on 3 Dec as the second shortwave trough became cut off from the main midlatitude flow and interacted with a region of subtropical moisture
- AR 2 conditions (based on the Ralph et al. 2019 AR Scale) were observed over the Central California coast
- A separate AR associated with a tropical moisture export (TME) brought AR 2 conditions to southern Arizona on 3–4 Dec
- The first storm produced 2–4 feet of snow in the Washington Cascades and Rocky Mountains in Idaho, Montana, and Wyoming, as well as 1–2 feet of snow in the Sierra Nevada
- The second storm and AR produced more than 5 inches of rain over the Big Sur coast and 1–3 feet of snow in the higher terrain of the Sierra Nevada
- Heavy rain on 3 Dec caused a rockslide on Highway 1 south of Big Sur, CA
- The third AR produced 2–4 inches of rain across portions of Arizona, resulting in flooding in Pinal County

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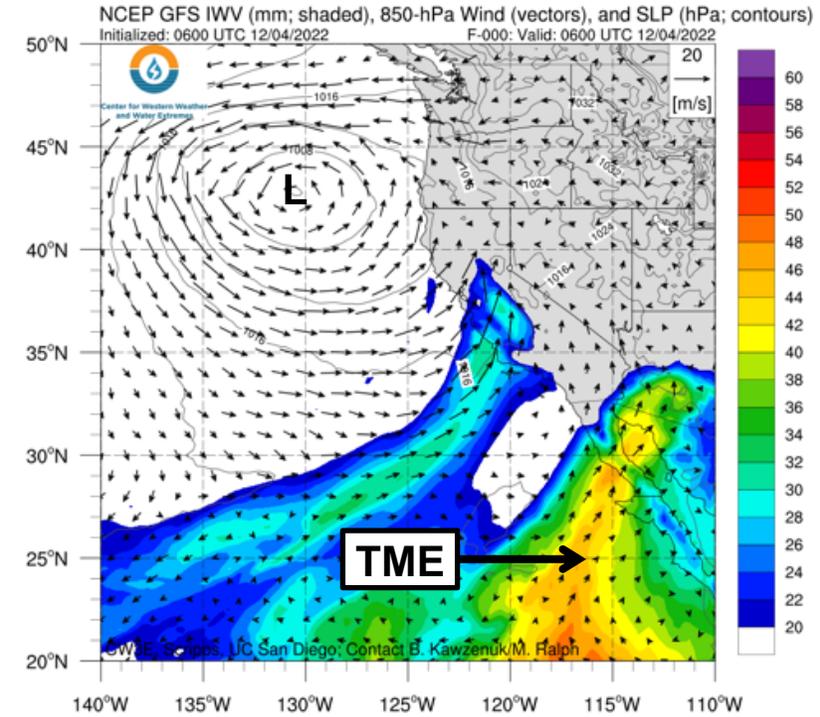
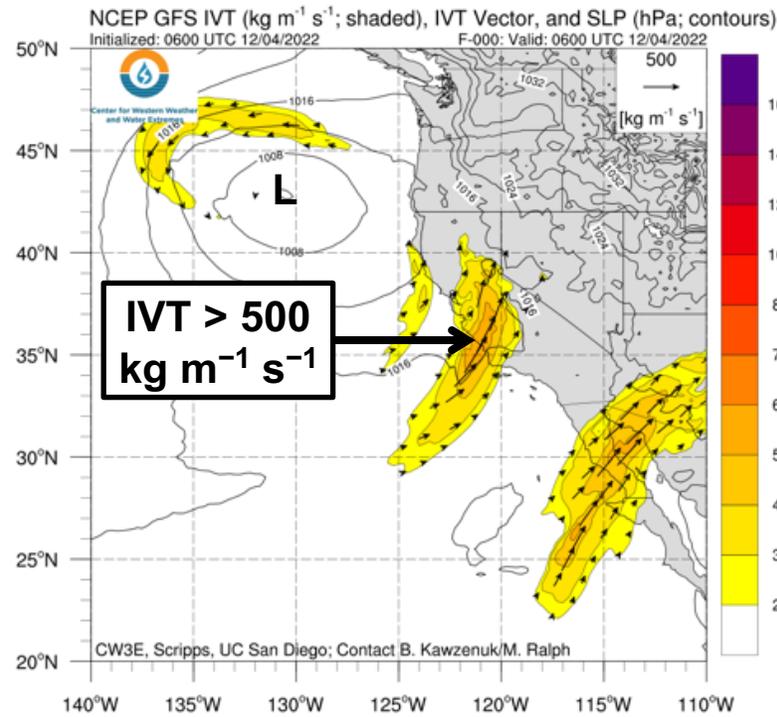
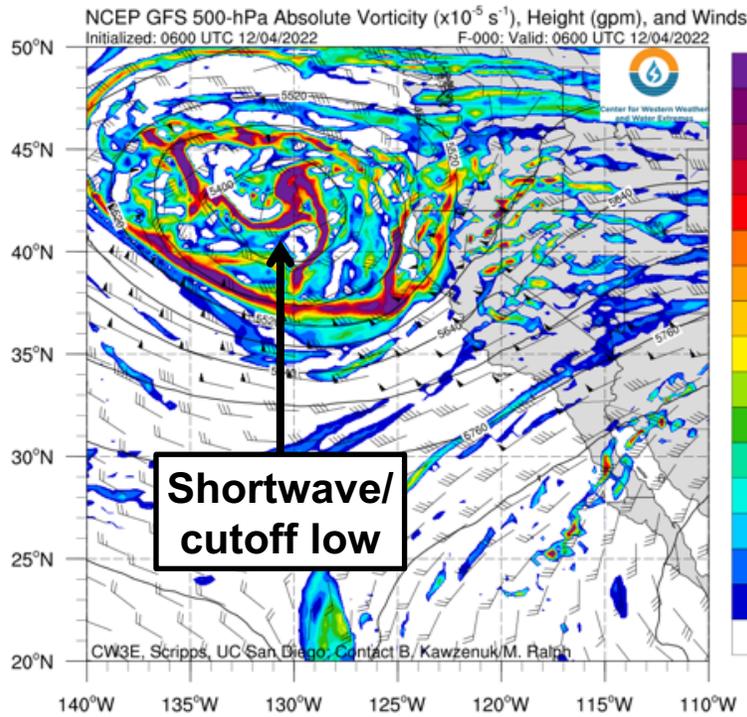
ECMWF 500-hPa, IVT, and IWV Analysis: Valid 7 AM PT 1 Dec



- The initial low-pressure system and associated shortwave trough impacted much of the western US during 30 Nov – 2 Dec
- As the shortwave trough moved south, it interacted with a region of subtropical moisture in the eastern Pacific, bringing a brief period of weak AR conditions to much of California on 1 Dec
- Although moisture was limited, strong low-level southwesterly flow likely contributed to orographic enhancement of precipitation over the California Coast Ranges and Sierra Nevada

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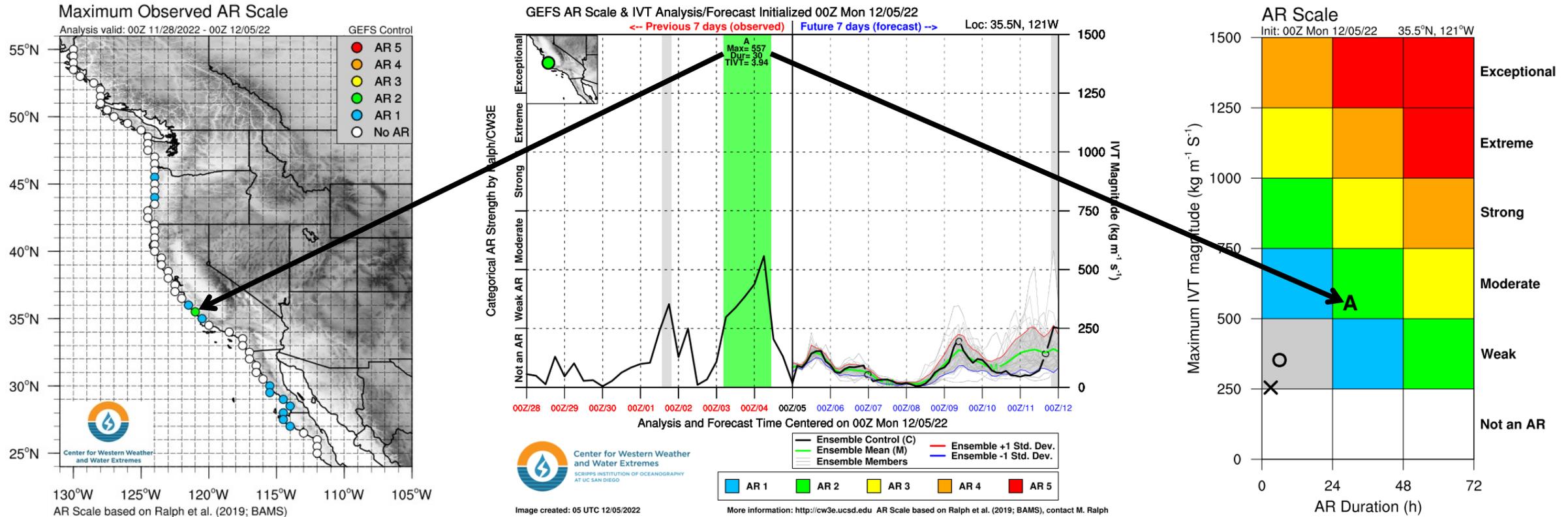
GFS 500-hPa, IVT, and IWV Analysis: Valid 10 PM PT 3 Dec



- A second shortwave trough approached the US West Coast and became cut off from the main midlatitude flow on 3 Dec
- The cutoff low remained nearly stationary off the coast of Northern California through 5 Dec
- An AR developed over Central California on 3 Dec as the shortwave/cutoff low interacted with a region of subtropical moisture, bringing IVT values $> 500 \text{ kg m}^{-1} \text{ s}^{-1}$ and IWV values near 30 mm to the Big Sur coast
- Strong low-level southwesterly flow supported strong upslope moisture flux and orographic enhancement of precipitation over the Central California Coast Ranges
- A separate AR associated with a tropical moisture export (TME) brought a period of AR conditions to southern Arizona on 3–4 Dec

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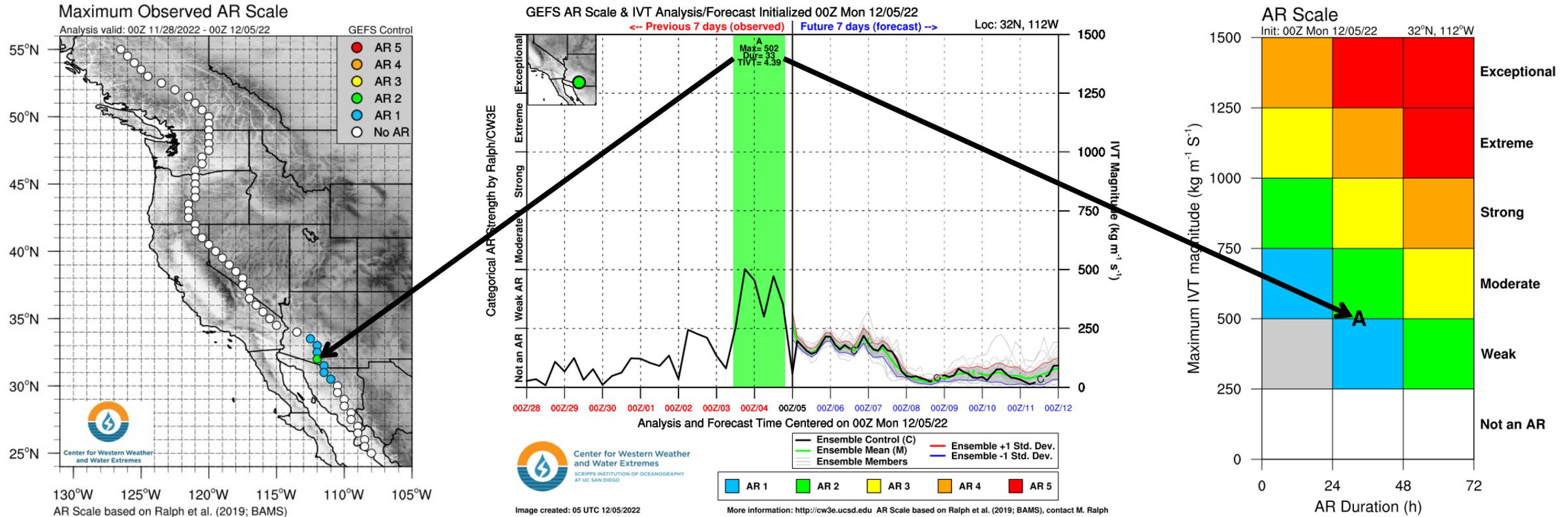
GEFS Control AR Scale (Coastal)



- The first AR only brought a brief period of weak AR conditions to coastal California on 1 Dec
- The second AR produced AR 1/AR 2 conditions (based on the Ralph et al. 2019 AR Scale) over Monterey and San Luis Obispo Counties
- A maximum IVT value of $557 \text{ kg m}^{-1} \text{ s}^{-1}$ and an AR duration of 30 hours were observed at 35.5°N , 121°W (near Cambria, CA)

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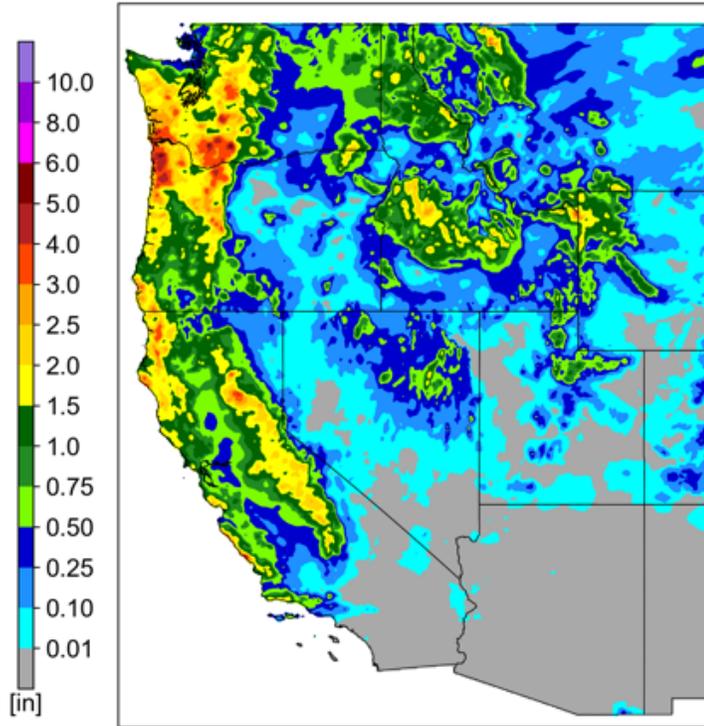
GEFS Control AR Scale (Inland)



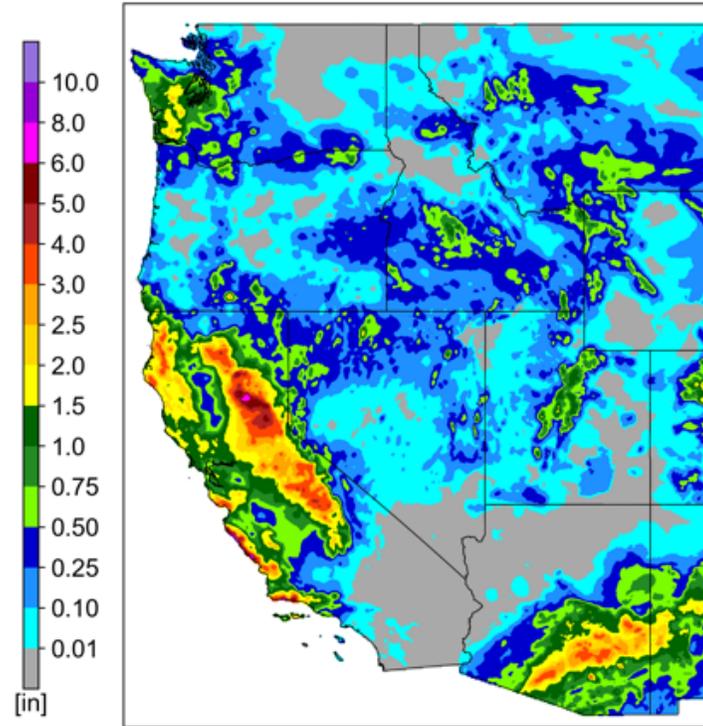
- Another AR crossing the Baja Peninsula produced AR 1/AR 2 conditions in southern Arizona on 3–4 Dec
- A maximum IVT value of $502 \text{ kg m}^{-1} \text{ s}^{-1}$ and an AR duration of 33 hours were observed at 32°N , 112°W (Pima County, AZ)

Observed Precipitation

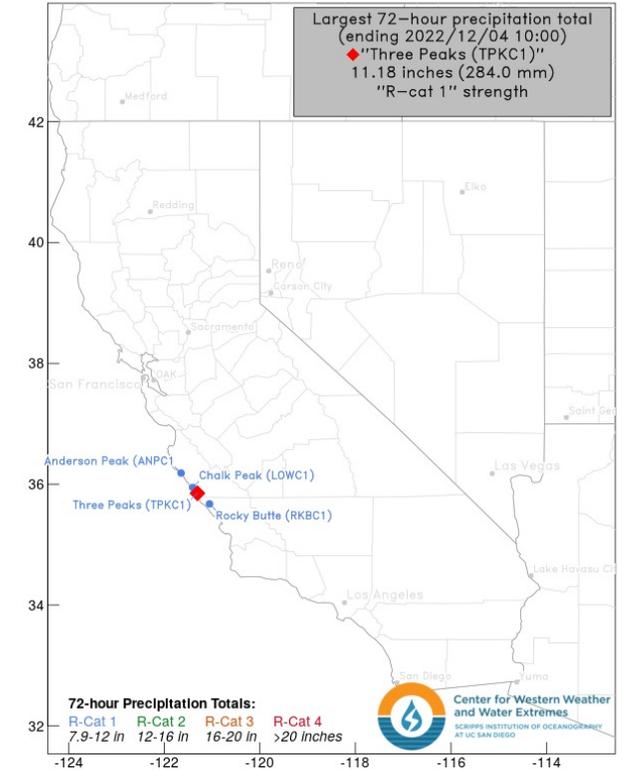
NCEP Stage IV 72-h QPE
Valid: 4 AM PT 2 Dec



NCEP Stage IV 96-h QPE
Valid: 4 AM PT 6 Dec



R-Cat report produced 2022/12/04 10:14:12



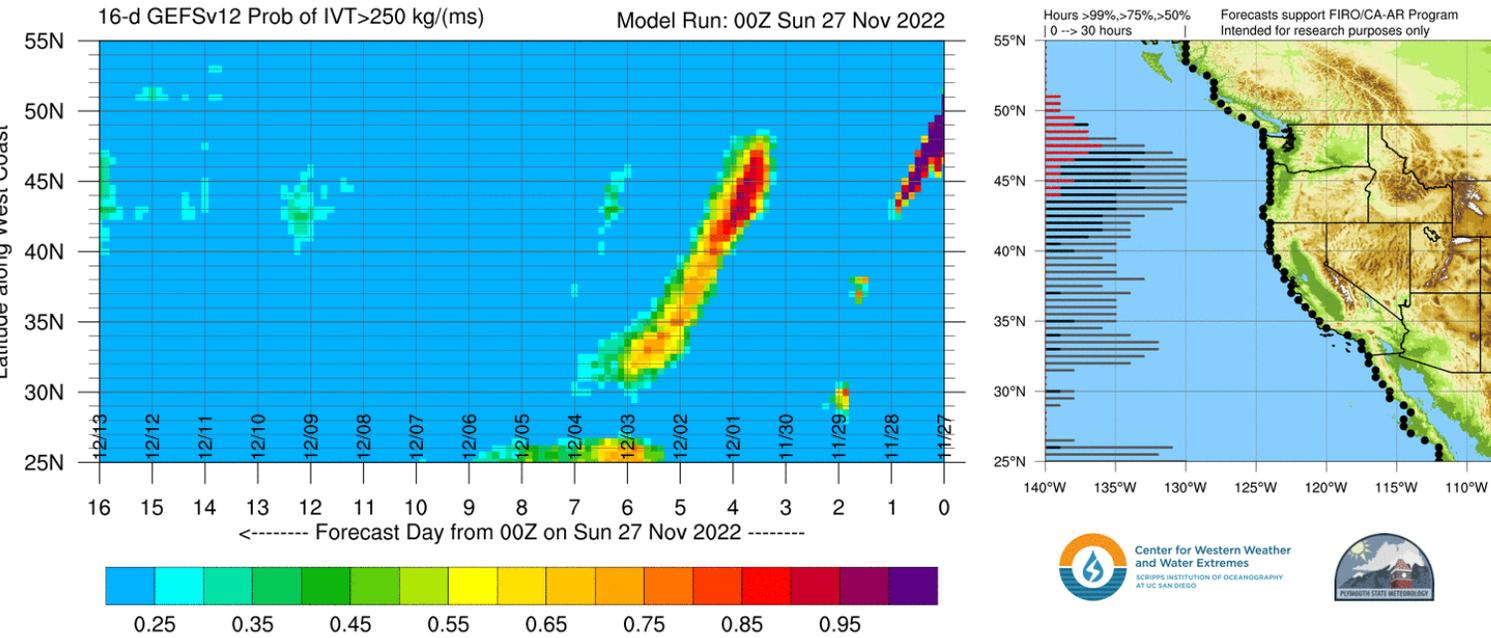
- The first storm produced widespread precipitation over much of the western US, with the highest amounts (3–6 inches) in the Coast Ranges and Cascades near the Oregon/Washington border
- The second storm and AR primarily impacted California, producing more than 5 inches of precipitation over portions of the Northern Sierra Nevada, the Big Sur coast, and the western Transverse Ranges
- A separate AR crossing the Baja Peninsula produced 2–4 inches of rain across portions of Arizona on 3–4 Dec
- Four stations in Central California experienced an R-Cat 1 storm, with the highest 72-hour precipitation recorded at Three Peaks (11.18 inches)

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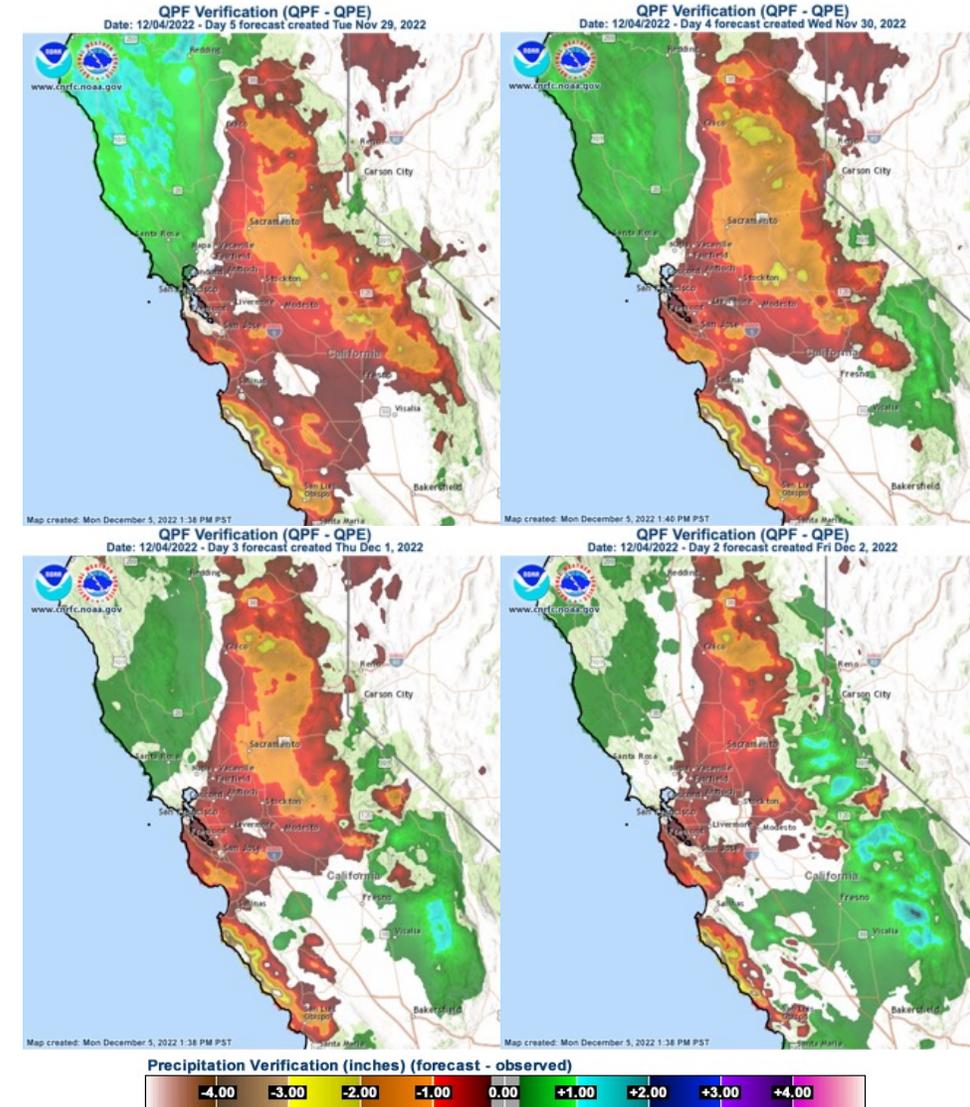


Forecast Verification

GEFS Probability of AR Conditions Along Coast: dProg/dt

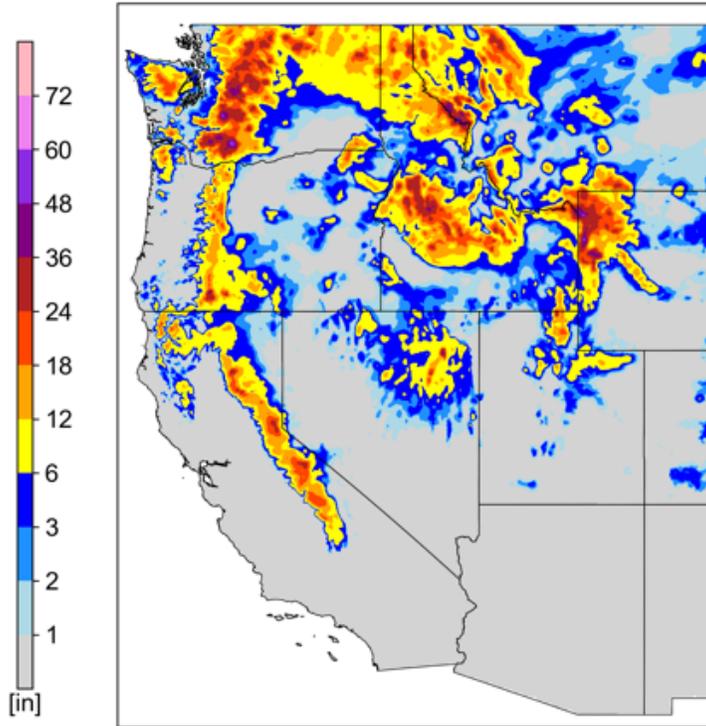


- Models struggled to accurately forecast the second AR that made landfall over Central California on 3 Dec
- GEFS only showed low-to-moderate probabilities (20–60%) of AR conditions in Monterey and San Luis Obispo Counties until ~72 hours prior to AR landfall
- As a result, precipitation forecasts significantly underestimated the observed precipitation over the Big Sur coast

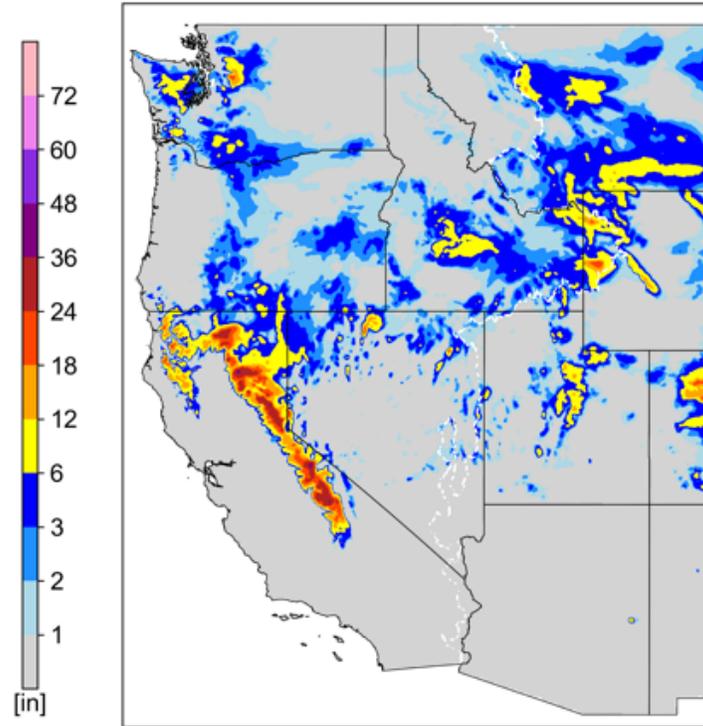


Observed Snowfall

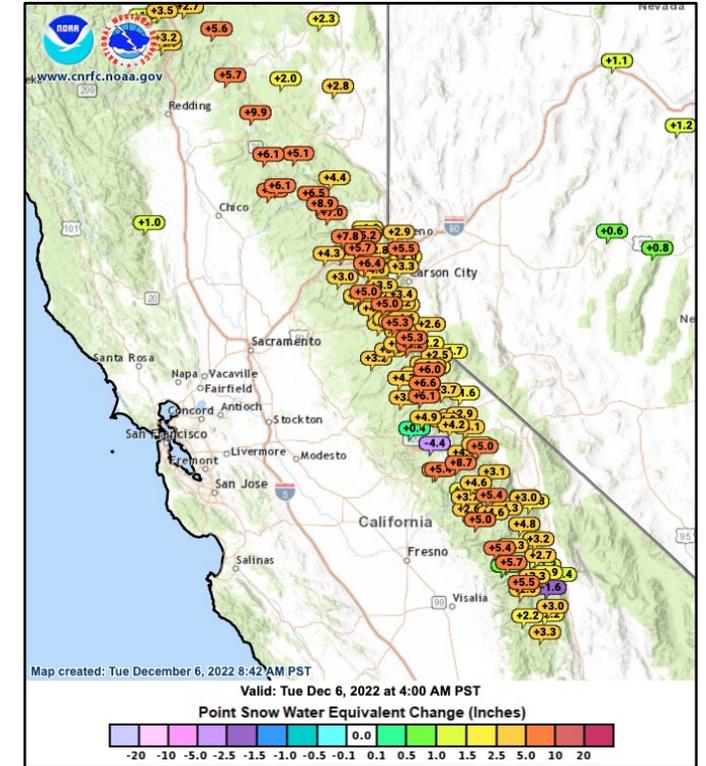
NOHRSC 72-h Snowfall Analysis
Valid: 4 AM PT 2 Dec



NOHRSC 96-h Snowfall Analysis
Valid: 4 AM PT 6 Dec



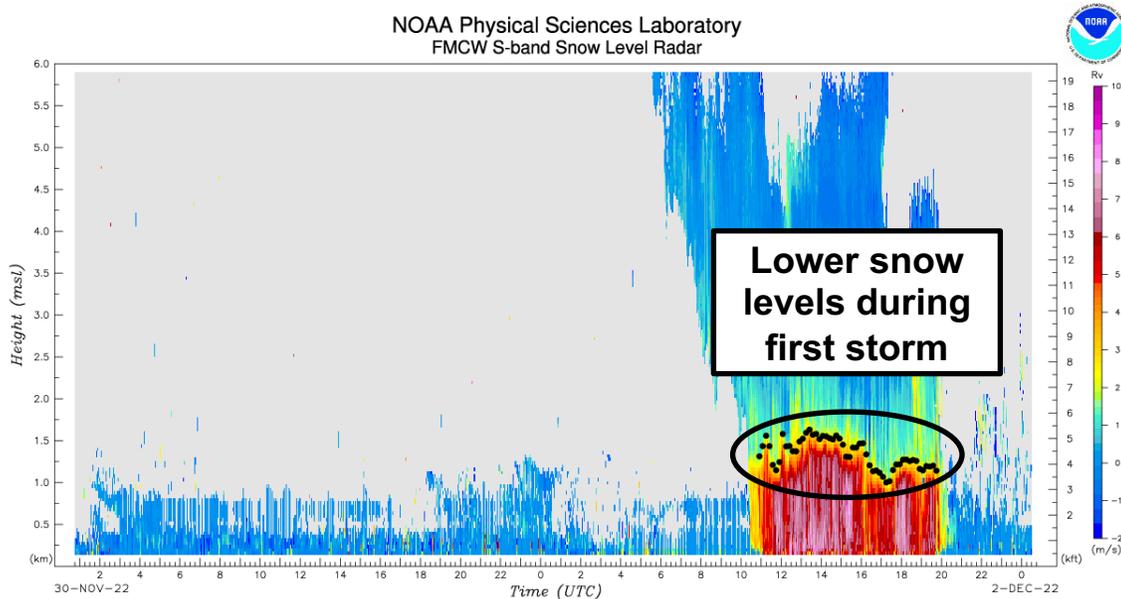
7-day Change in SWE: Valid 6 Dec



- The first storm produced at least 2–4 feet of snow over the Washington Cascades, the Sawtooth Range, the Bitterroots, and northwestern Wyoming, as well as 1–2 feet of snow in the Olympic Mountains, Oregon Cascades, and Sierra Nevada
- The second storm produced an additional 1–3 feet of snow over the higher terrain in the southern Cascades and Sierra Nevada
- These two storms significantly boosted snowpack in the Sierra Nevada, with many stations recording SWE increases of 4–8 inches between 29 Nov and 6 Dec
- Lower Lassen Peak recorded a 7-day SWE increase of 9.9 inches

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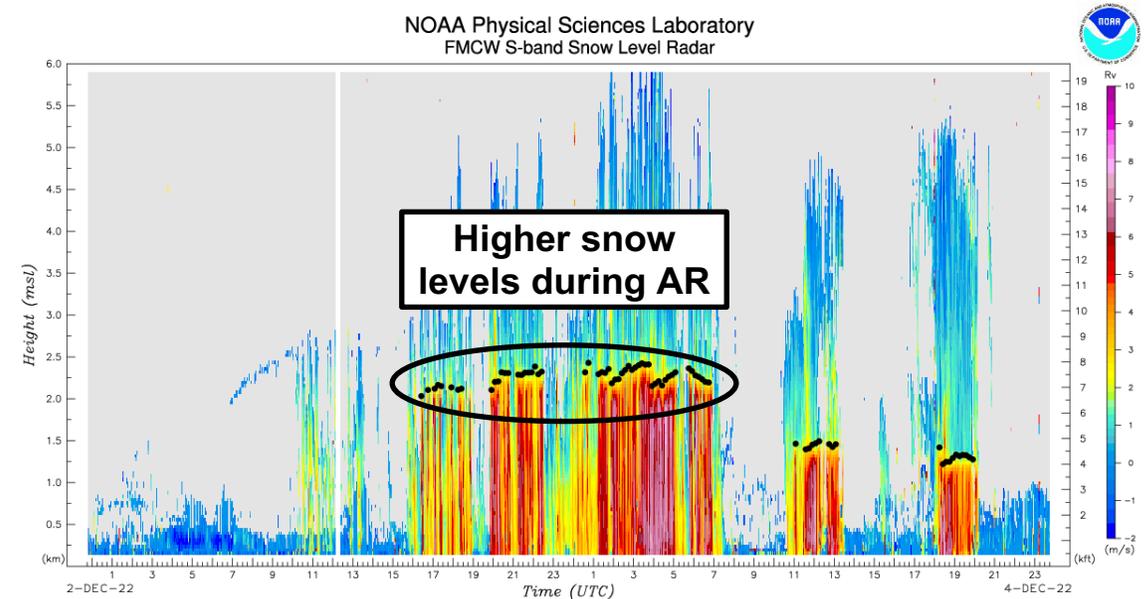
Snow Level Observations (Oroville, CA)



Oroville,CA (OVL)
39.5318 N, 121.4876 W, 114 m

Time (UTC)	0115	0215	0315	0415	0515	0615	0715	0815	0915	1015	1115	1215	1315	1415	1515	1615	1715	1815	1915	2015	2115	2215	2315	0015	
Snow Level (m)	none	none	none	none	none	none	none	none																	
Snow Level (ft)	none	none	none	none	none	none	none	none																	
Sfc Temp (C)	7.39	5.85	7.78	6.90	6.15	5.94	6.55	6.30	5.34	5.35	5.43	4.66	4.37	4.80	5.06	6.39	7.94	10.41	11.60	12.87	13.71	13.73	13.45	12.25	

Time (UTC)	0115	0215	0315	0415	0515	0615	0715	0815	0915	1015	1115	1215	1315	1415	1515	1615	1715	1815	1915	2015	2115	2215	2315	0015	
Snow Level (m)	none	none	none	none	1433	1401	1545	1539	1433	1375	1090	1281	1191	1140	none	none	none	none	none						
Snow Level (ft)	none	none	none	none	4700	4596	5069	5047	4701	4511	3576	4136	3908	3739	none	none	none	none	none						
Sfc Temp (C)	10.12	10.56	10.58	10.82	10.83	10.47	10.15	9.90	9.99	10.26	9.44	7.85	7.89	7.85	7.64	7.37	7.12	7.11	7.59	7.98	8.27	8.24	8.44	8.60	



Oroville,CA (OVL)
39.5318 N, 121.4876 W, 114 m

Time (UTC)	0015	0115	0215	0315	0415	0515	0615	0715	0815	0915	1015	1115	1215	1315	1415	1515	1615	1715	1815	1915	2015	2115	2215	2315
Snow Level (m)	none	2031	2134	2119	none	2206	2295	2315	none															
Snow Level (ft)	none	6661	6999	6950	none	7235	7529	7593	none															
Sfc Temp (C)	7.79	5.38	4.24	3.10	2.85	3.70	3.28	4.99	3.51	3.81	4.31	4.82	5.01	7.60	7.57	7.06	6.64	6.35	6.40	6.67	6.66	6.38	6.61	6.73

Time (UTC)	0015	0115	0215	0315	0415	0515	0615	0715	0815	0915	1015	1115	1215	1315	1415	1515	1615	1715	1815	1915	2015	2115	2215	2315
Snow Level (m)	2315	2312	2268	2395	2194	2284	2269	2193	none	none	none	1428	1459	1456	none	none	none	none	1246	1319	1287	none	none	none
Snow Level (ft)	7593	7585	7439	7855	7196	7491	7442	7193	none	none	none	4685	4787	4775	none	none	none	none	4086	4327	4221	none	none	none
Sfc Temp (C)	6.75	6.63	6.23	6.08	6.22	6.26	6.19	5.98	5.98	5.81	5.60	6.41	7.69	7.54	7.49	8.03	8.77	9.54	8.46	7.79	8.85	11.57	12.94	12.94

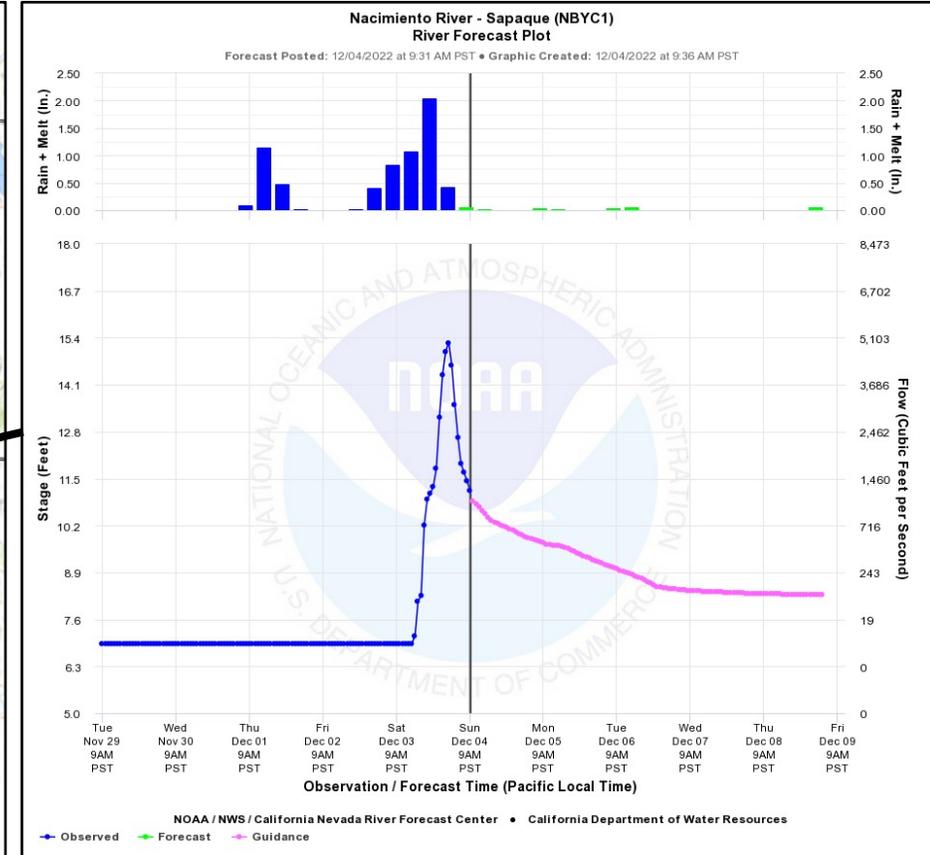
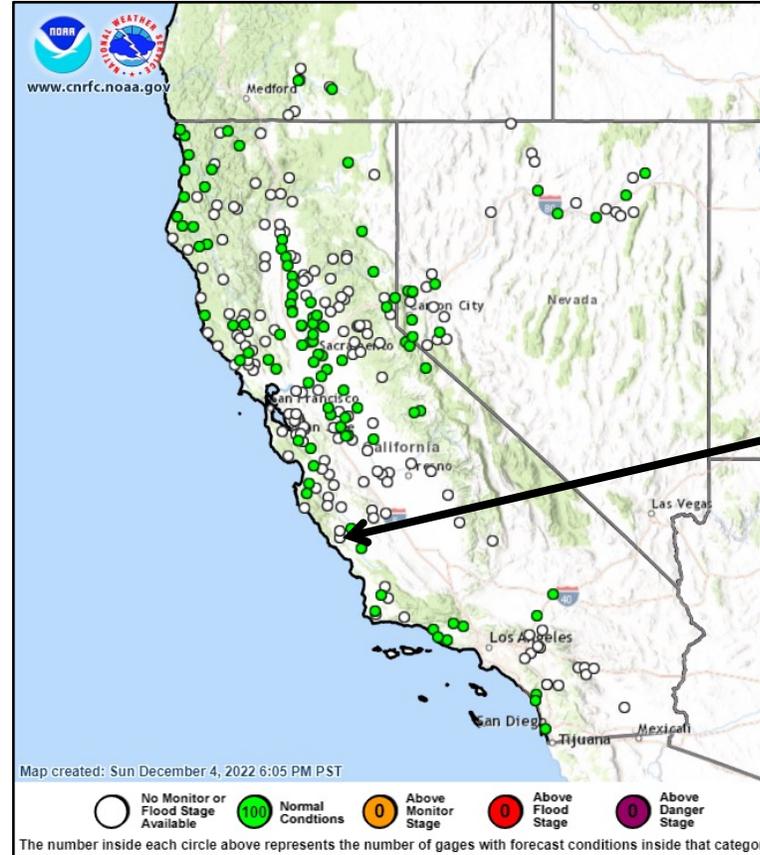
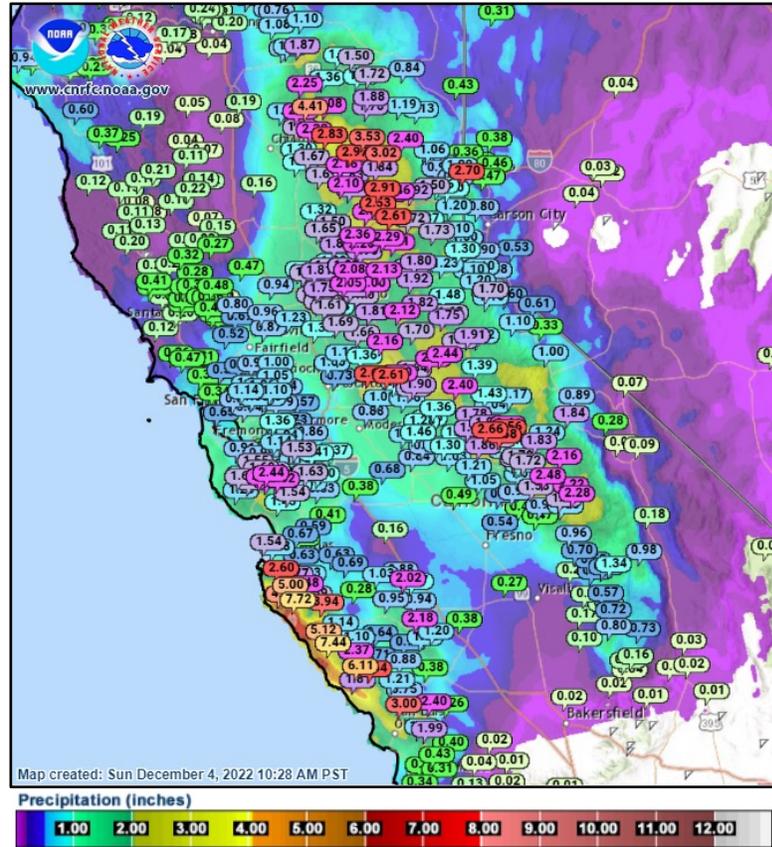
- Low snow levels during the first storm (< 5,000 ft) allowed for accumulating snowfall in the lower elevations of the Northern California Coast Ranges, southern Cascades, and Sierra Nevada
- The AR in the second storm brought much warmer conditions, with snow levels rising above 7,000 ft on 3 Dec
- Snow levels rapidly dropped after the AR dissipated and cold air associated with the second shortwave trough/cutoff low overspread the region

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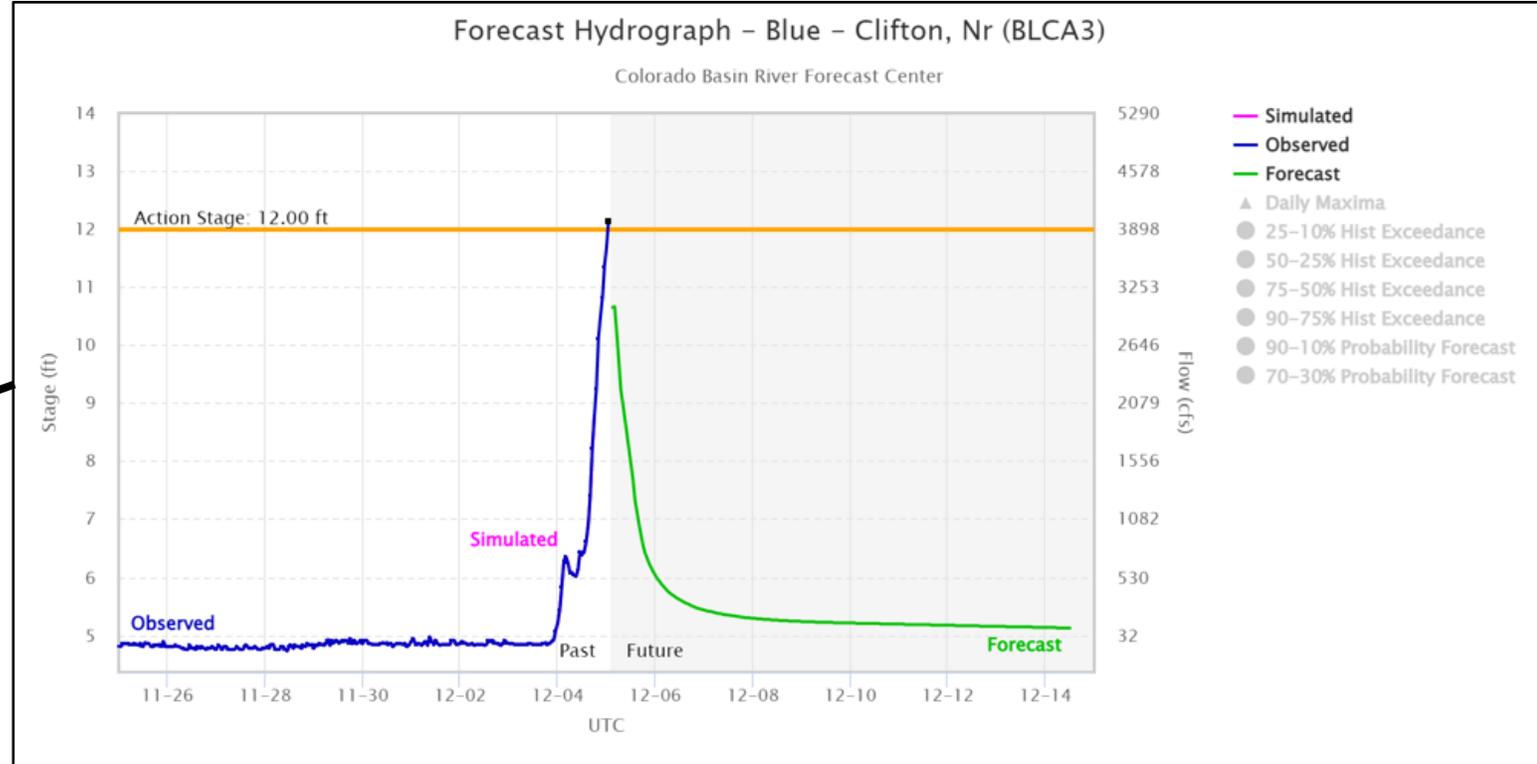
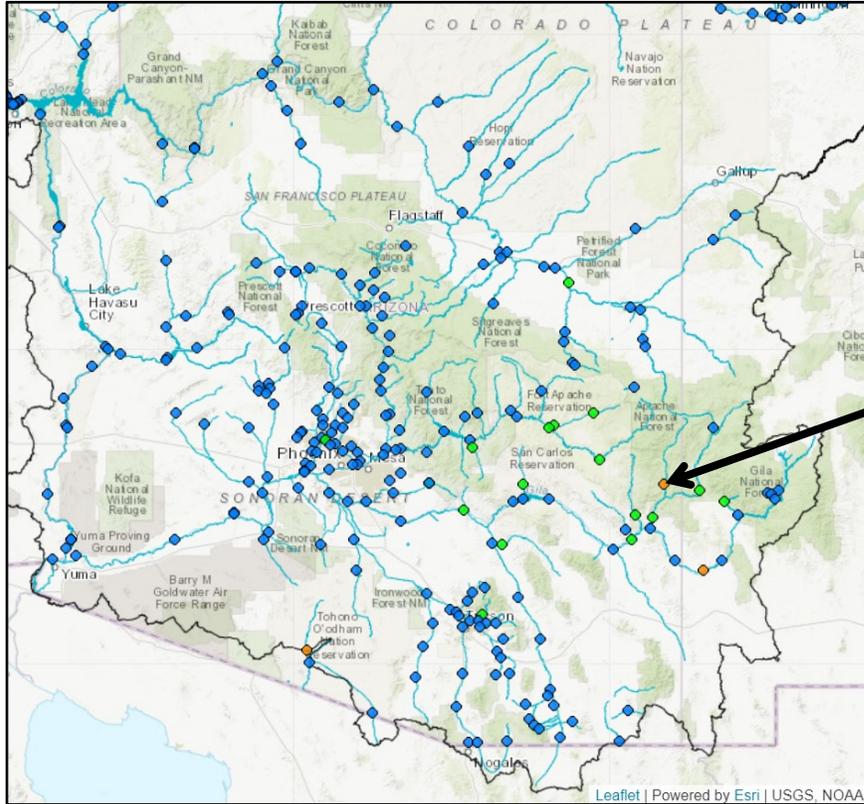
Impacts

CNRFC 24-h QPE: Valid 4 AM PT 4 Dec



- The second AR produced heavy precipitation over the Northern Sierra Nevada and Central California coast on 3 Dec
- Several stations in Monterey and San Luis Obispo Counties recorded more than 5 inches of rainfall in a 24-hour period
- The Nacimientto River (near Sapaque) rose more than 8 feet in a 12-hour period, reaching a peak stage of 15.34 ft

Impacts



Source: Colorado Basin River Forecast Center

- Heavy rain associated with the AR crossing the Baja Peninsula led to rising rivers and creeks throughout southern Arizona
- The Blue River (near Clifton, AZ) rose above action stage (12 ft) on 4 Dec, reaching a peak stage of 12.14 ft

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Impacts



Source: Caltrans District 5



Source: Caltrans District 3



Source: Pinal County Sheriff's Office

- Heavy rain associated with the AR in California on 3 Dec triggered rockslides that closed a portion of Highway 1 south of Big Sur
- Heavy snow in the Sierra Nevada caused dangerous travel conditions and major travel delays on Interstate 80 and Highway 50
- Heavy rain associated with the AR in Arizona on 3–4 Dec resulted in significant roadway flooding in Arizona City