

CW3E Winter Storm and Atmospheric River Outlook: 2 March 2023

Winter Storms Bury California in Heavy Snow

- A series of upper-level shortwaves brought widespread precipitation to the western US during 26 Feb – 1 Mar
- More than 4 feet of snow fell across the Sierra Nevada, with nearly 8 feet reported near Lake Tahoe
- Significant snowfall also occurred in the Klamath Mountains and the higher terrain of the Colorado Basin

Cold Storm to Bring More Snow to California this Weekend

- Another upper-level trough is forecast to impact Washington, Oregon, and California beginning on Friday
- More than 3 feet of snow are forecast over the Sierra Nevada, and 1–3 feet of snow are forecast in the Klamath Mountains and southern Cascades
- Low freezing levels will once again allow for significant snowfall accumulations below 3,000 feet
- Major winter storm impacts are expected over the Northern California Coast Ranges and Northern/Central Sierra Nevada Saturday into Sunday

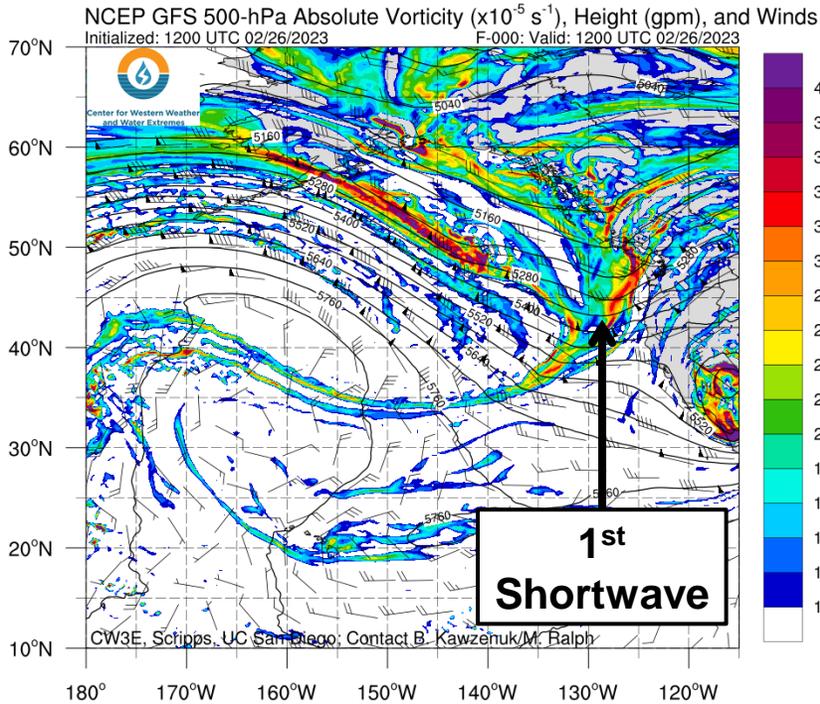
Potential for Atmospheric River Activity in California Late Next Week

- NCEP GEFS and ECMWF EPS are both showing the possibility of landfalling AR activity over California during 9–12 March, but there is a considerable amount of forecast uncertainty given the long lead time
- Overall, GEFS is showing a higher likelihood of landfalling atmospheric river (AR) activity than EPS
- More than 30% of all GEFS + EPS ensemble members are forecasting maximum IVT $> 500 \text{ kg m}^{-1} \text{ s}^{-1}$ over the next 10 days near Bodega Bay, CA
- Forecast uncertainty in storm track and AR activity is evident in the large spread of ensemble precipitation forecasts in Northern California

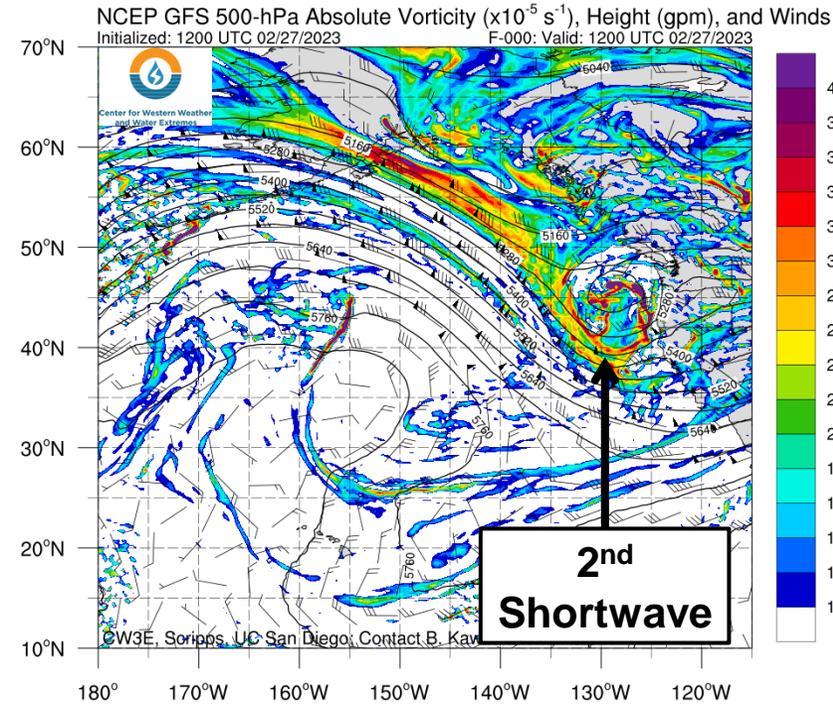
Event Summary: 26 Feb – 1 Mar 2023

GFS 500-hPa Vorticity, Height, and Wind Analyses

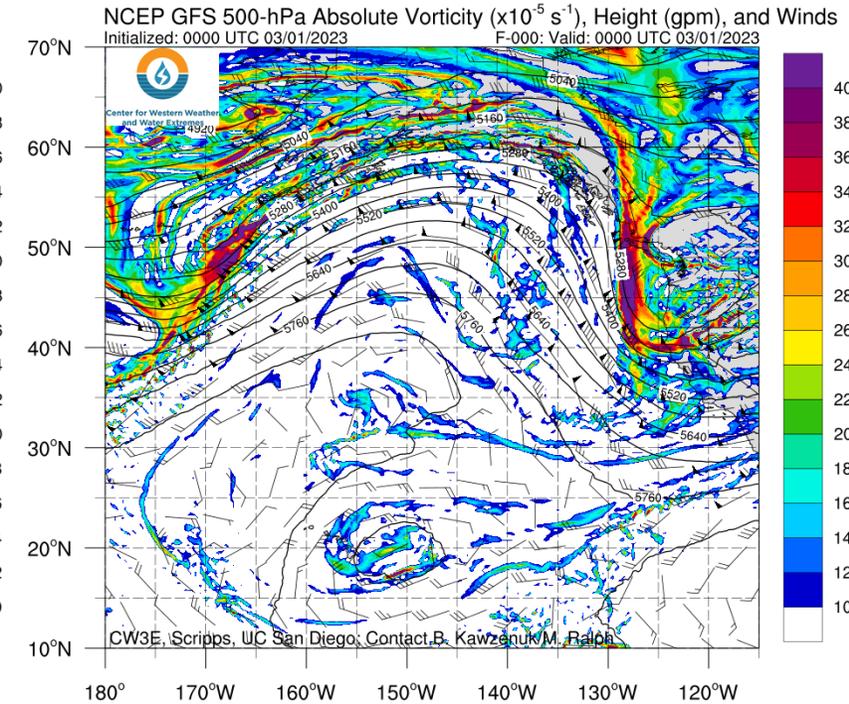
A) Valid: 4 AM PT 26 Feb



B) Valid: 4 AM PT 27 Feb



C) Valid: 4 PM PT 28 Feb



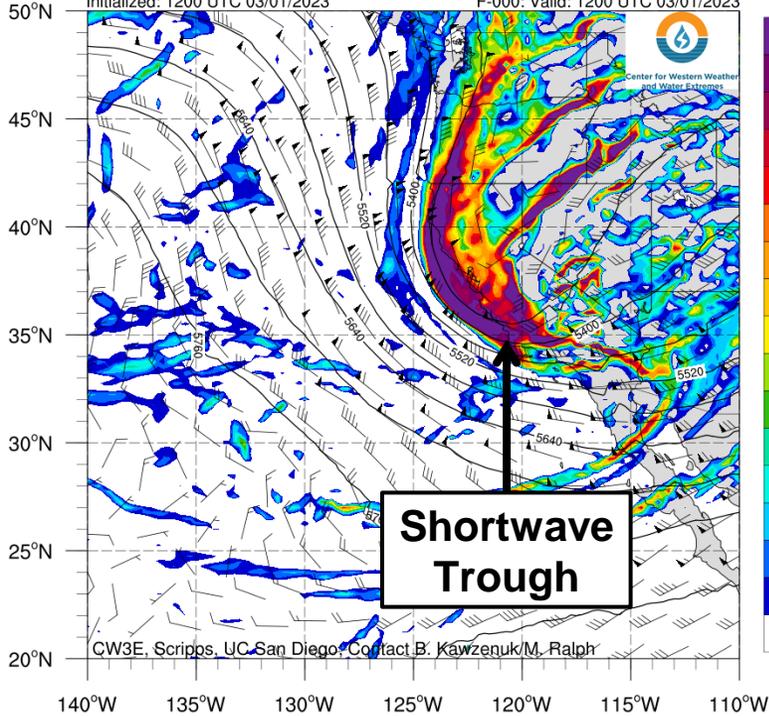
- A series of upper-level shortwaves brought unsettled weather to the western US during 26 Feb – 2 Mar
- The first shortwave moved onshore on 26 Feb, bringing light-to-moderate precipitation to Washington, Oregon, and Northern California (Figure A)
- A second, stronger shortwave approached the US West Coast on 27 Feb, bringing heavier precipitation to the California Coast Ranges and the Sierra Nevada (Figure B)
- As the large-scale flow became more amplified, the trough deepened over the US West Coast on 1 March, bringing a period of moderate precipitation to Southern California and Arizona (Figure C)

Event Summary: 26 Feb – 1 Mar 2023

GFS Model Analyses: Valid 4 AM PT 1 Mar

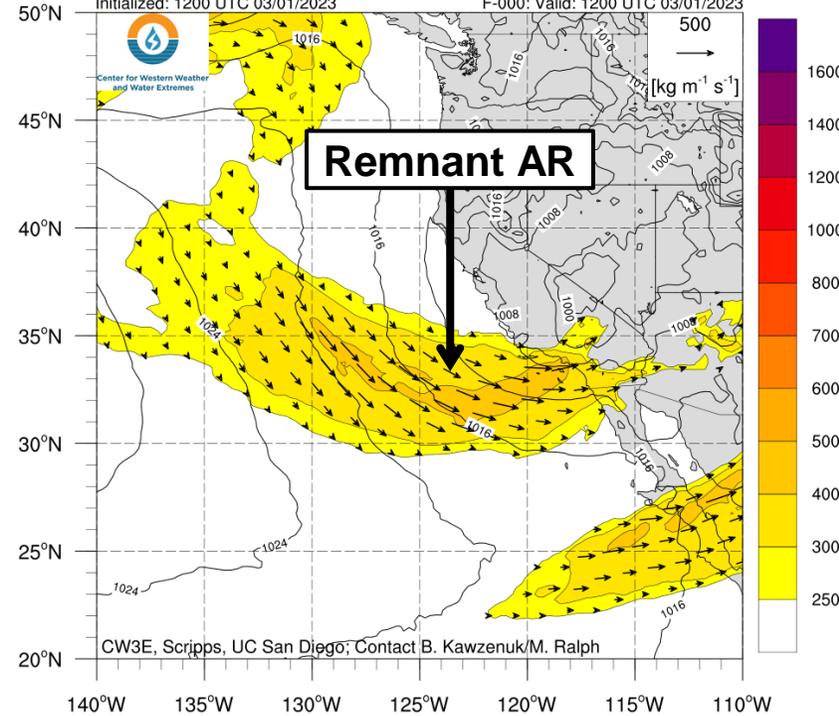
500-hPa Vorticity, Height, and Wind

NCEP GFS 500-hPa Absolute Vorticity ($\times 10^{-5} \text{ s}^{-1}$), Height (gpm), and Winds
Initialized: 1200 UTC 03/01/2023 F-000: Valid: 1200 UTC 03/01/2023



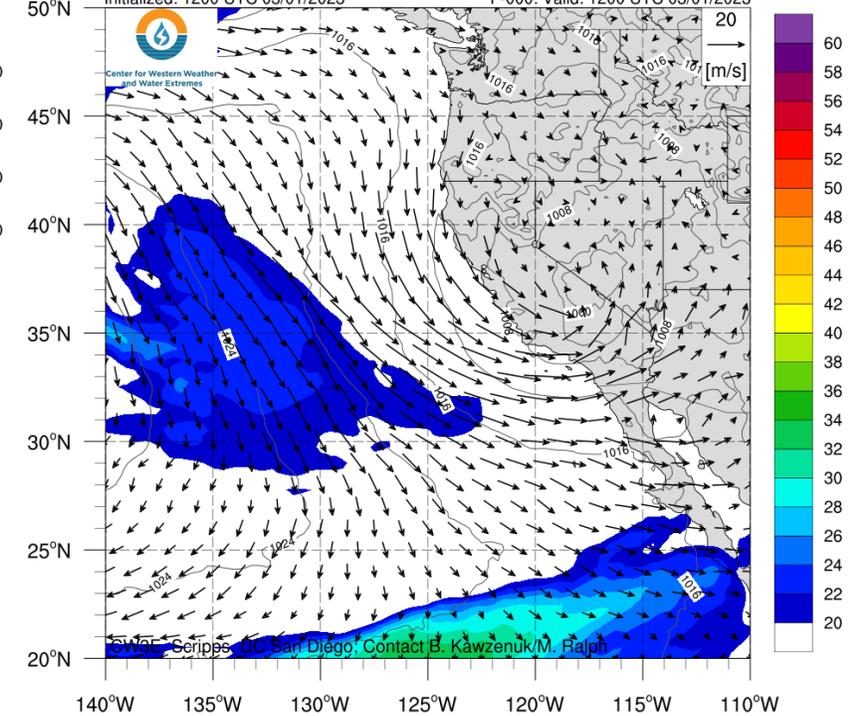
IVT and SLP

NCEP GFS IVT ($\text{kg m}^{-1} \text{ s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 1200 UTC 03/01/2023 F-000: Valid: 1200 UTC 03/01/2023



IWV, SLP, and 850-hPa Wind

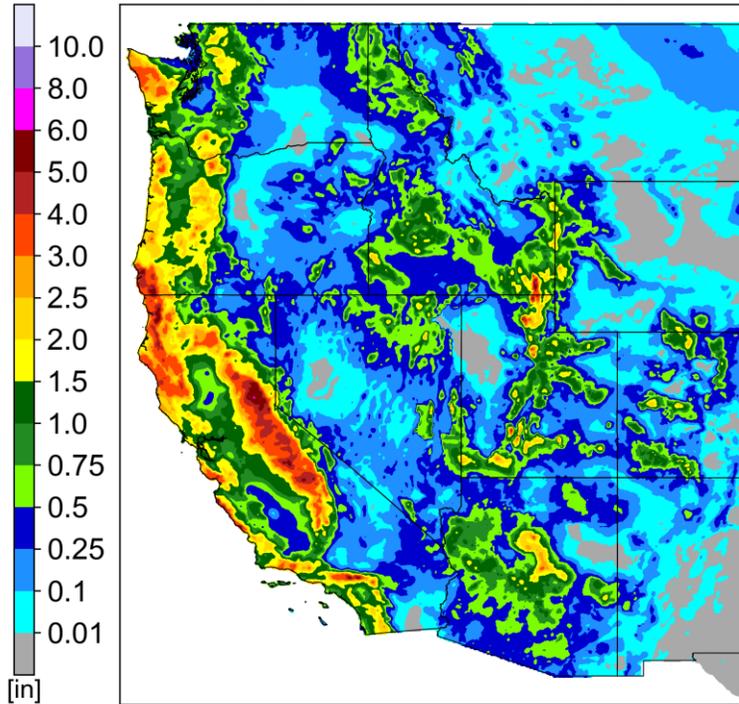
NCEP GFS IWV (mm; shaded), 850-hPa Wind (vectors), and SLP (hPa; contours)
Initialized: 1200 UTC 03/01/2023 F-000: Valid: 1200 UTC 03/01/2023



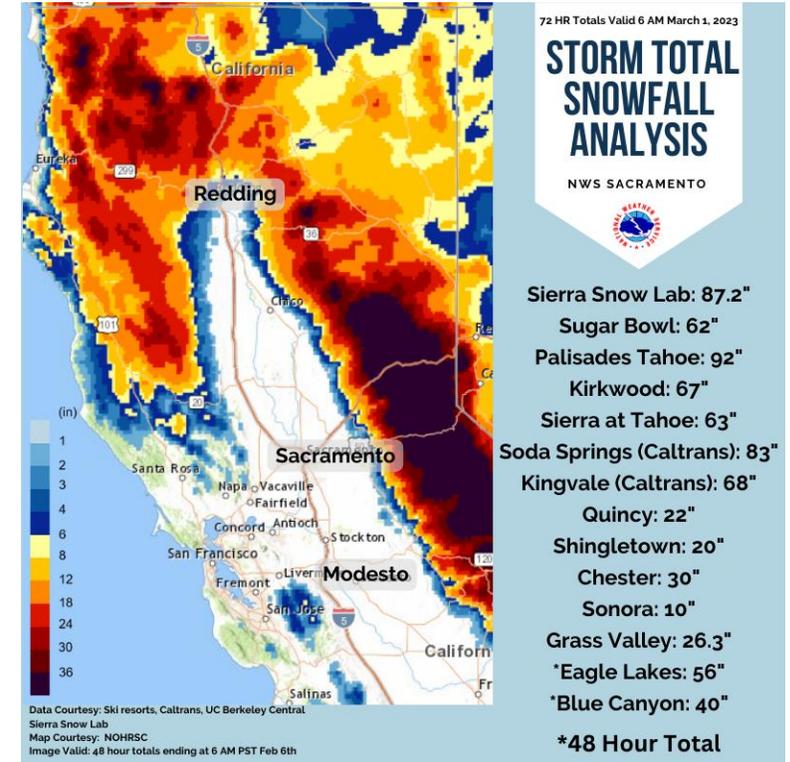
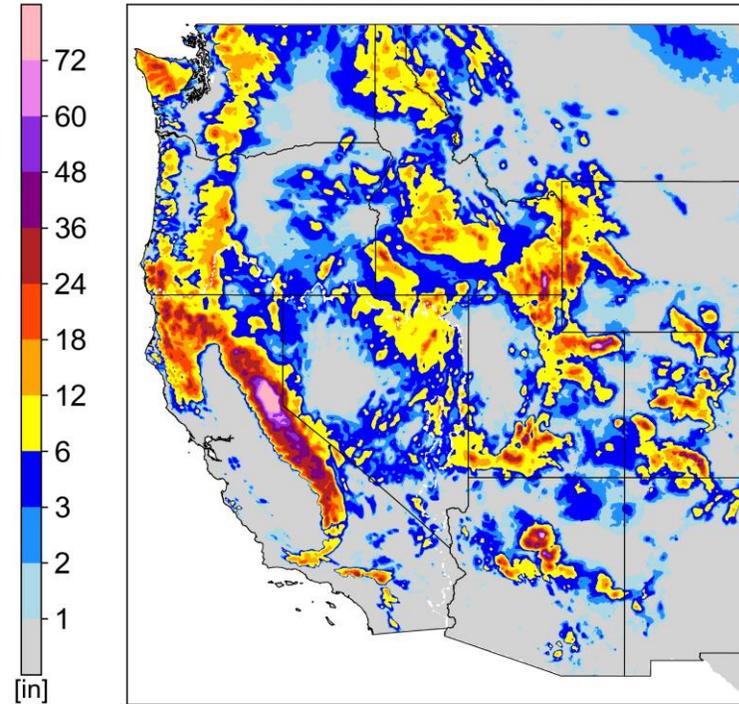
- As the shortwave trough moved southward along the coast, strengthening low-to-midlevel westerly flow in the vicinity of a remnant AR brought weak AR conditions ($\text{IVT} < 500 \text{ kg m}^{-1} \text{ s}^{-1}$) to Southern California and Arizona
- Despite the lack of tropical moisture, strong low-level westerly-to-southwesterly flow supported upslope moisture flux over the Peninsular Ranges and the higher terrain in north-central Arizona

Precipitation and Snowfall Analysis

NWS Stage IV 96-h QPE
Valid: 4 AM PT 2 Mar 2023



NWS 96-h Snowfall Analysis
Valid: 4 AM PT 2 Mar 2023



Source: NWS Sacramento

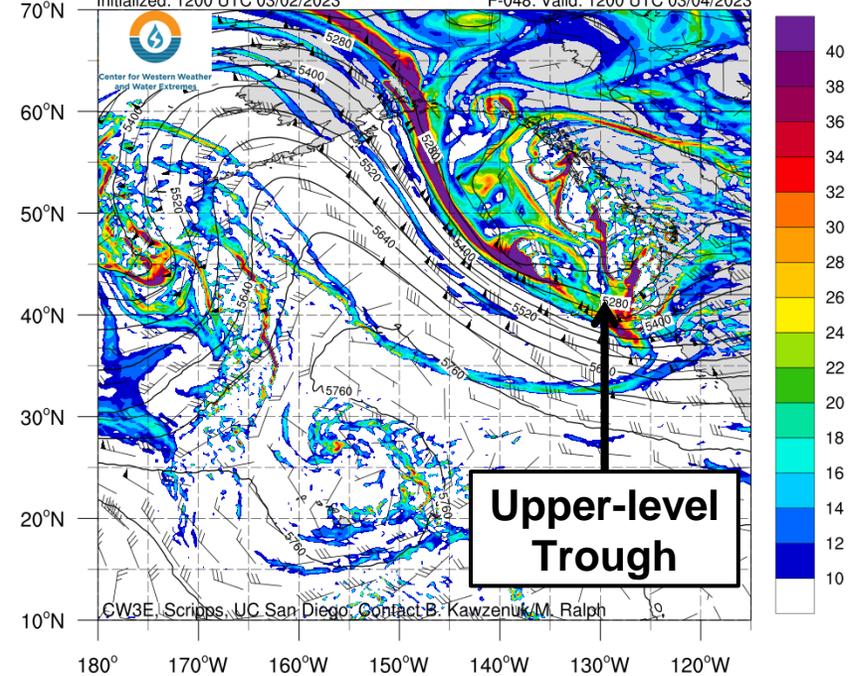
- These shortwaves combined to produce at least 1–3 inches of precipitation over much of the US West Coast and the higher terrain in the Intermountain West
- The heaviest precipitation (3–6 inches) occurred in the Pacific Coast Ranges, Sierra Nevada, and Transverse Ranges
- At least 12 inches of snow fell in the higher terrain throughout the western US, including the Upper and Lower Colorado Basins
- The highest snowfall totals (> 48 inches) were observed in the Sierra Nevada, especially near Lake Tahoe
- Low freezing levels allowed for significant snowfall accumulations below 3,000 feet

Winter Storm Outlook

GFS 500-hPa Vorticity, Height, and Wind Forecasts; WPC Precipitation Forecasts

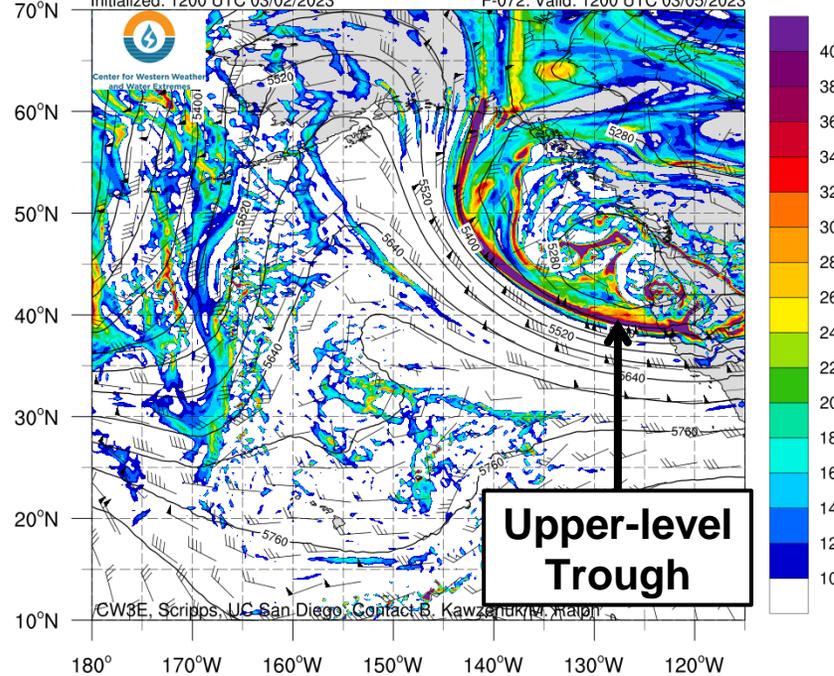
Valid: 4 AM PT 4 Mar (F-48)

NCEP GFS 500-hPa Absolute Vorticity ($\times 10^{-5} \text{ s}^{-1}$), Height (gpm), and Winds
 Initialized: 1200 UTC 03/02/2023 F-048: Valid: 1200 UTC 03/04/2023

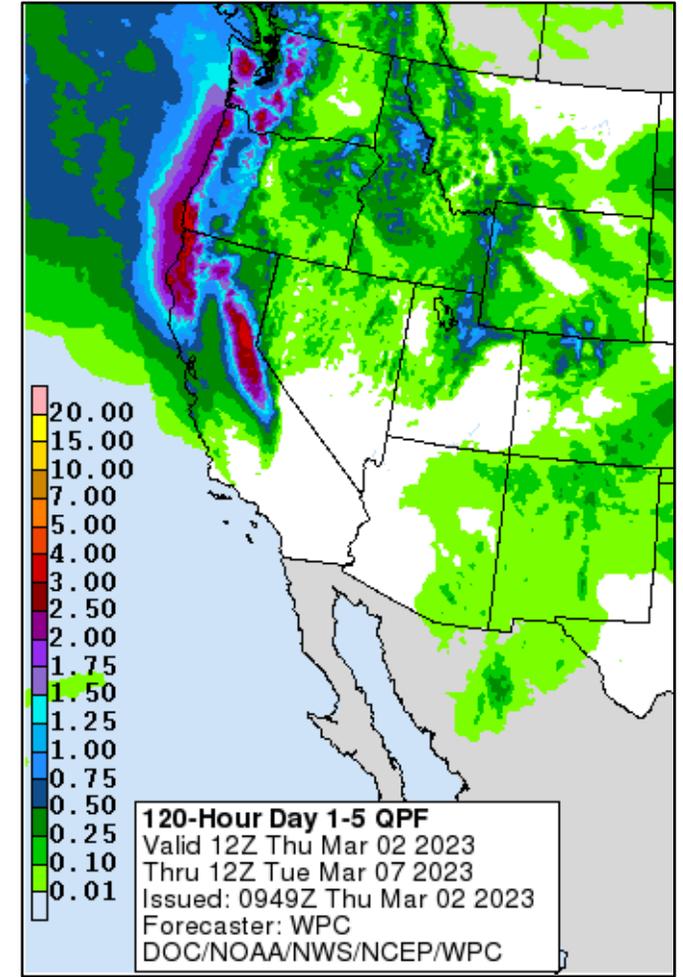


Valid: 4 AM PT 5 Mar (F-72)

NCEP GFS 500-hPa Absolute Vorticity ($\times 10^{-5} \text{ s}^{-1}$), Height (gpm), and Winds
 Initialized: 1200 UTC 03/02/2023 F-072: Valid: 1200 UTC 03/05/2023



WPC 5-day QPF: Valid 4 AM PT 7 Mar

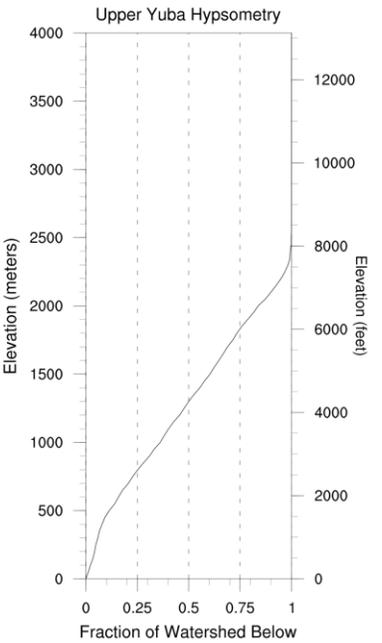
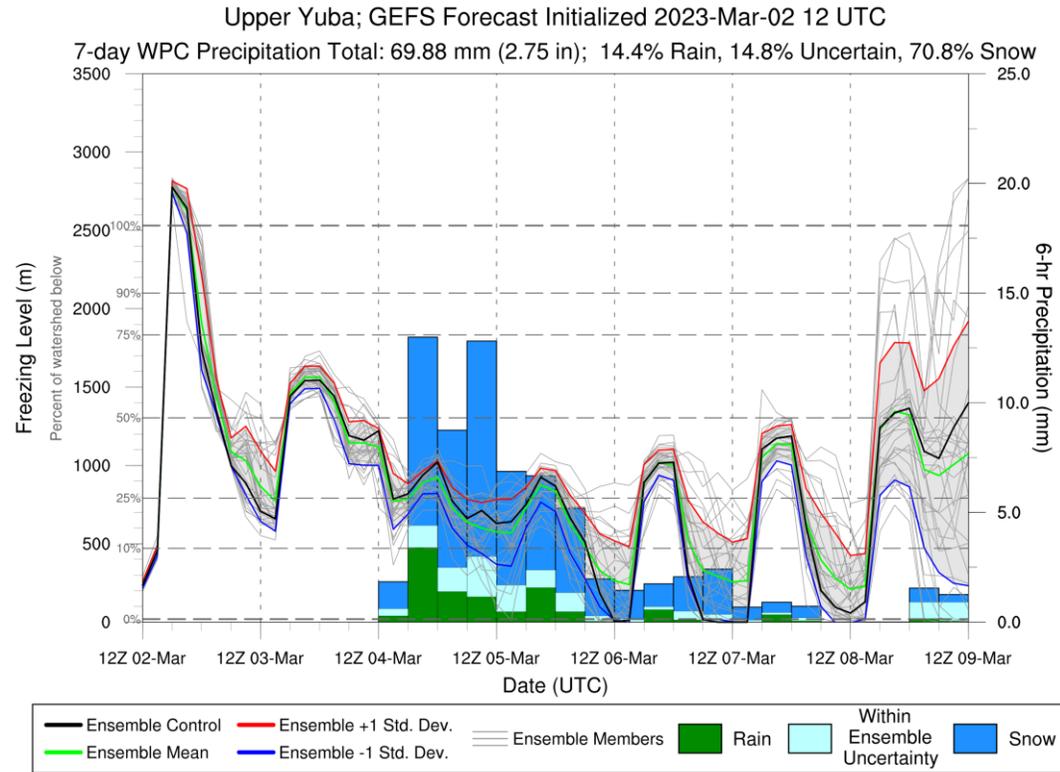
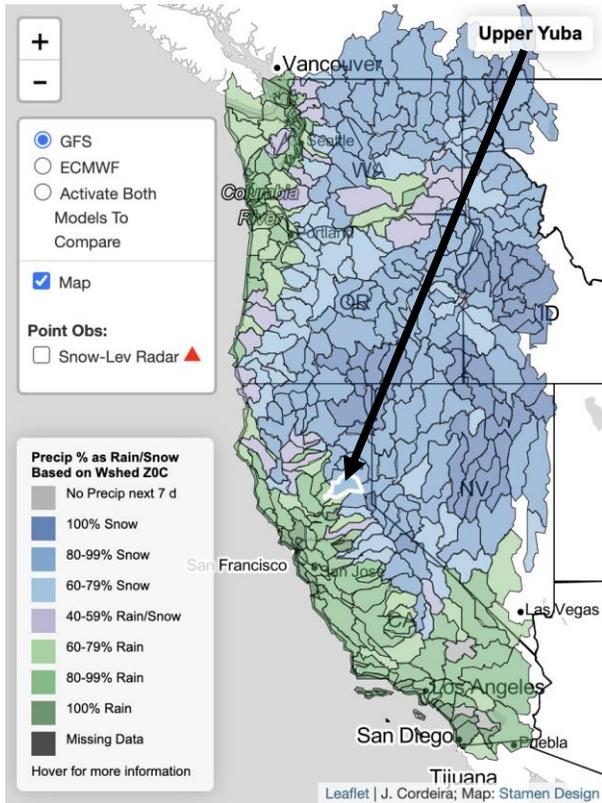


Source: NOAA/NWS Weather Prediction Center

- Another upper-level trough is forecast to impact the US West Coast this weekend, bringing more precipitation to portions of Washington, Oregon, and California
- The NWS Weather Prediction Center is forecasting at least 1–3 inches of precipitation in the Pacific Coast Ranges of Washington, Oregon, and Northern California, the Cascades, and the Sierra Nevada during the next 5 days
- Higher amounts are possible in the Northern Sierra Nevada west of Lake Tahoe

Winter Storm Outlook

Watershed Freezing Level Forecasts: Upper Yuba Watershed

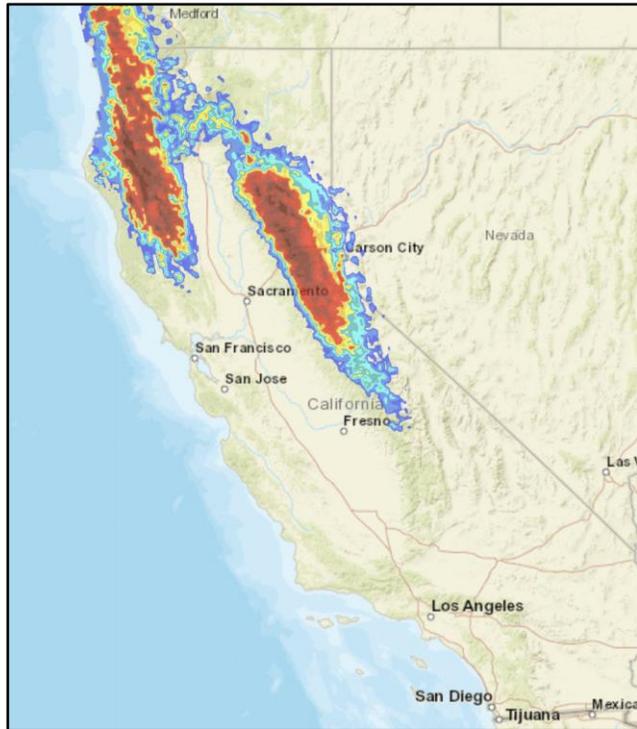


- Due to low freezing levels, a majority of the precipitation is forecast to fall in the form of snow over the Klamath Mountains, southern Cascades, and Sierra Nevada
- Freezing levels in the Upper Yuba watershed are forecast to remain below 3,000 feet throughout the period of heaviest precipitation on Sunday and Saturday
- The CW3E watershed freezing level tool is forecasting 71% of the total precipitation over the next 7 days to fall in the form of snow in the Upper Yuba watershed

Winter Storm Outlook

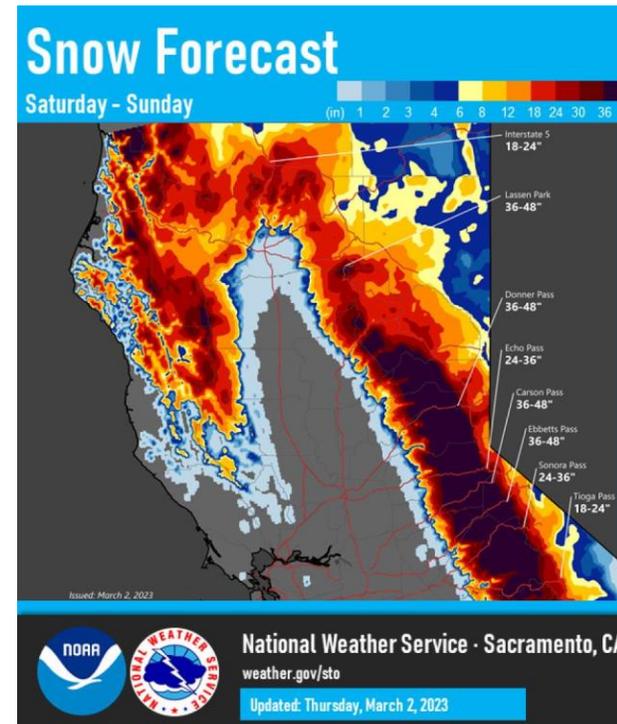
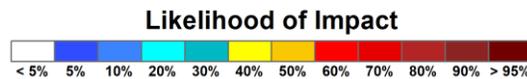
Winter Weather Hazards

Experimental Probabilistic Winter Storm Severity Index: Major Impacts
Valid: 4 AM PT 5 Mar



Source: NOAA/NWS Weather Prediction Center

Potential Winter Storm Impacts	
Minor Impacts	<p>Expect a few inconveniences to daily life.</p> <ul style="list-style-type: none"> Winter driving conditions. Use caution while driving.
Moderate Impacts	<p>Expect disruptions to daily life.</p> <ul style="list-style-type: none"> Hazardous driving conditions. Use extra caution while driving. Closures and disruptions to infrastructure may occur.
Major Impacts	<p>Expect considerable disruptions to daily life.</p> <ul style="list-style-type: none"> Dangerous or impossible driving conditions. Avoid travel if possible. Widespread closures and disruptions to infrastructure may occur.
Extreme Impacts	<p>Expect substantial disruptions to daily life.</p> <ul style="list-style-type: none"> Extremely dangerous or impossible driving conditions. Travel is not advised. Extensive and widespread closures and disruptions to infrastructure may occur. Life-saving actions may be needed.



Source: NWS Sacramento

Impact

None Minor Moderate **Major** Extreme

- Dangerous travel
- Chain controls and road closures likely
- Whiteout conditions at times & downed trees & local power outages due to gusty winds

Snow Levels

- 1500 ft to 2500 ft, locally down to the valley floor across the northern Sacramento Valley

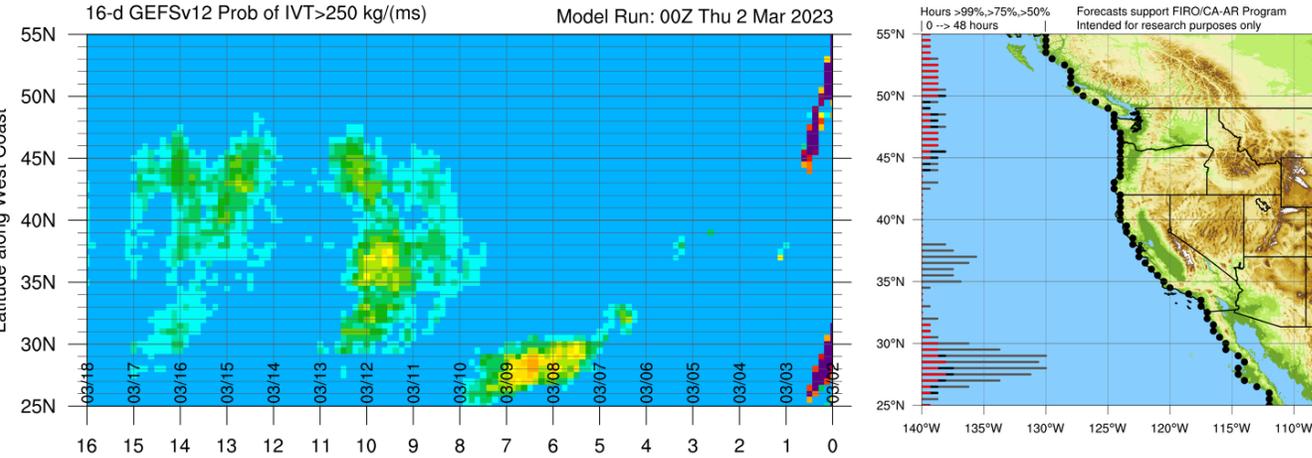
Timing

- Saturday - Sunday. Heaviest Saturday afternoon - Sunday morning.

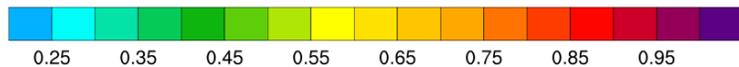
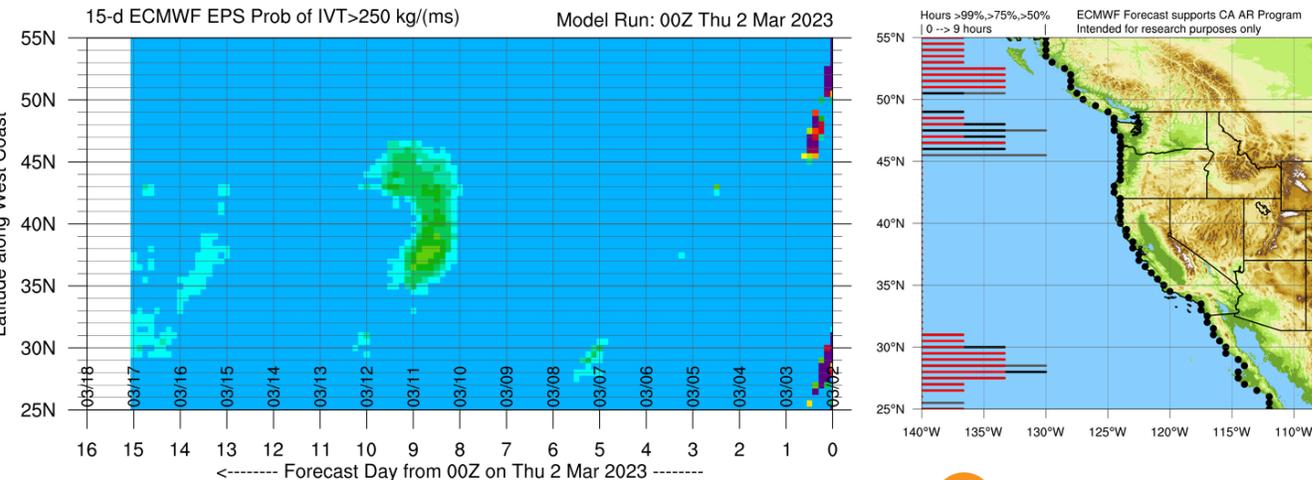
- The NWS WPC is forecasting a greater than 80% probability of **major** winter storm impacts (i.e., dangerous travel conditions, widespread disruptions to infrastructure) in the Northern California Coast Ranges and Northern/Central Sierra Nevada
- More than 3 feet of snow are forecast in the Sierra Nevada through Sunday, with 1–3 feet of snow forecast in the Northern California Coast Ranges and southern Cascades, and accumulating snow possible below 1,500 feet

Atmospheric River Outlook

GEFS Probability of AR Conditions Along Coast



EPS Probability of AR Conditions Along Coast



- GEFS is showing low-to-moderate probabilities (30–70%) of AR conditions ($IVT > 250 \text{ kg m}^{-1} \text{ s}^{-1}$) in far Southern California and Baja California in association with a weak tropical moisture export (TME) on 6–8 Mar
- EPS is showing a much lower probability of landfalling AR activity during 6–8 Mar
- Both GEFS and EPS are showing the possibility of landfalling AR activity over California and Oregon during 9–12 Mar
- However, the models disagree on the timing (EPS is earlier) and the likelihood (GEFS is showing higher probabilities) of AR activity over California
- Beyond 12 March, there is a weak signal ($< 50\%$ probability) of landfalling AR activity in GEFS

*GEFS = NCEP Global Ensemble Forecast System (United States)

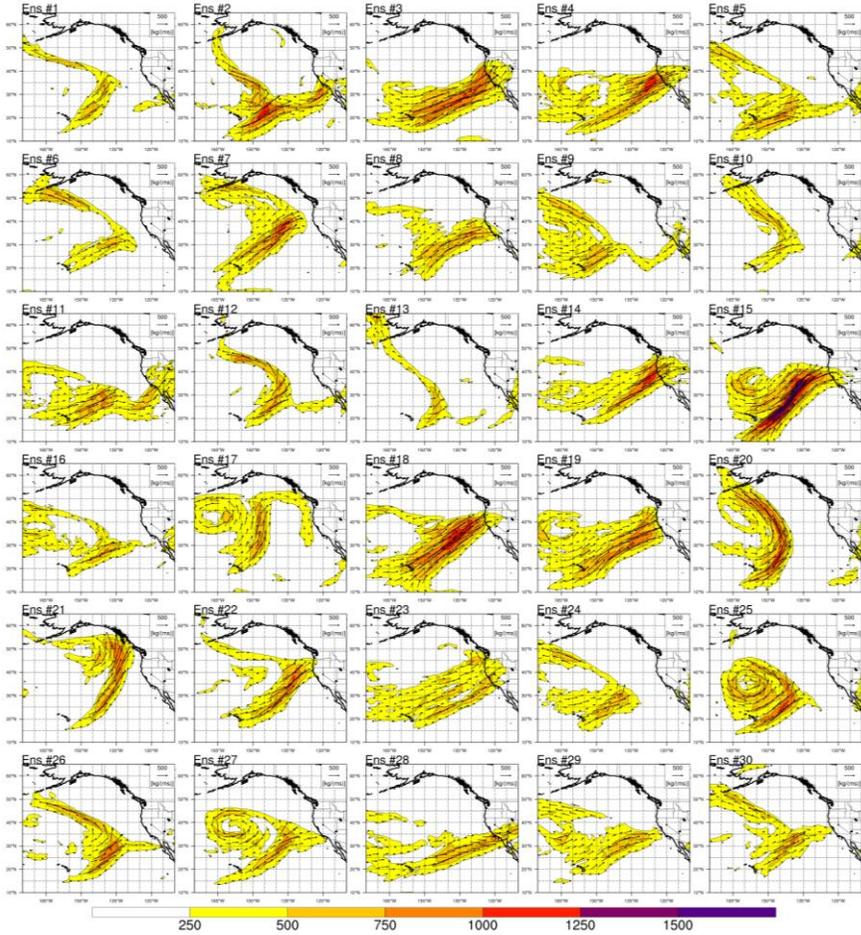
*EPS = ECMWF Ensemble Prediction System (Europe)

Atmospheric River Outlook

Model IVT & SLP Forecasts: Valid 4 PM PT 9 Mar (F-192)

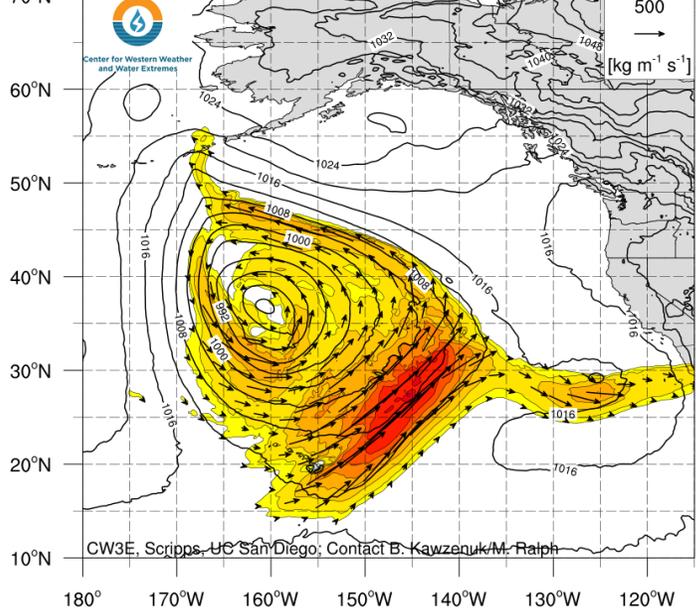
GEFS IVT Thumbnails

GEFS IVT [$\text{kg}/(\text{m}\cdot\text{s})$] valid 0Z Fri 03/10/23 | F+192h



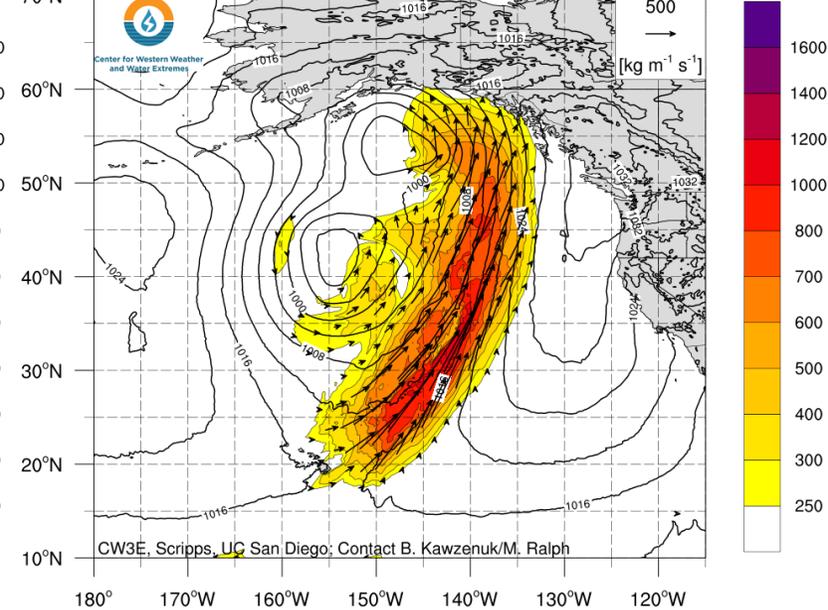
GFS Deterministic

NCEP GFS IVT ($\text{kg}\cdot\text{m}^{-1}\cdot\text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 0000 UTC 03/02/2023 F-192: Valid: 0000 UTC 03/10/2023



ECMWF Deterministic

ECMWF IVT ($\text{kg}\cdot\text{m}^{-1}\cdot\text{s}^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 0000 UTC 03/02/2023 F-192: Valid: 0000 UTC 03/10/2023

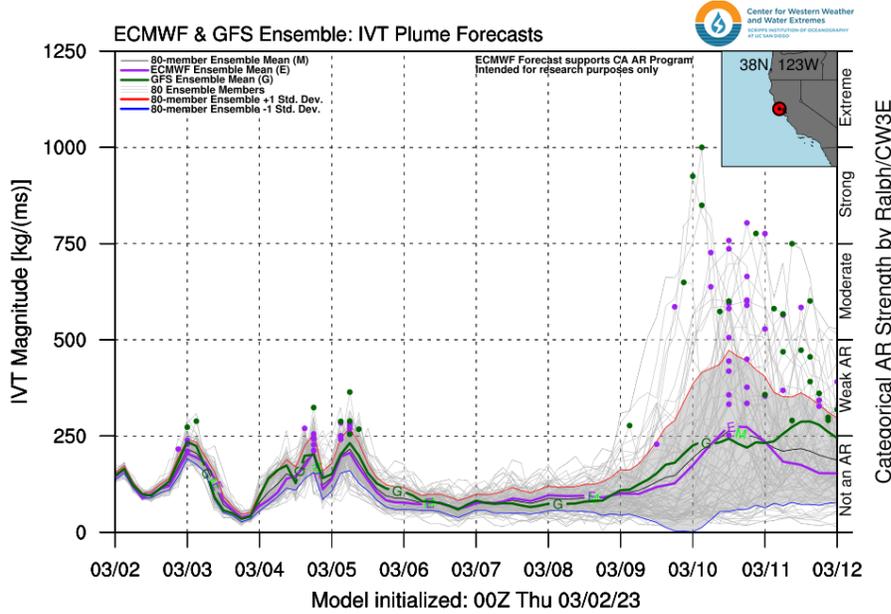


- As shown by the GEFS IVT thumbnails, there is considerable uncertainty regarding the evolution of a low-pressure system and an associated AR in the Northeast Pacific next week
- There are major differences between the 00Z GFS and 00Z ECMWF deterministic models, with the ECMWF bringing an AR northward into Alaska, and the GFS keeping the AR much farther south (and eventually bringing the AR into California)

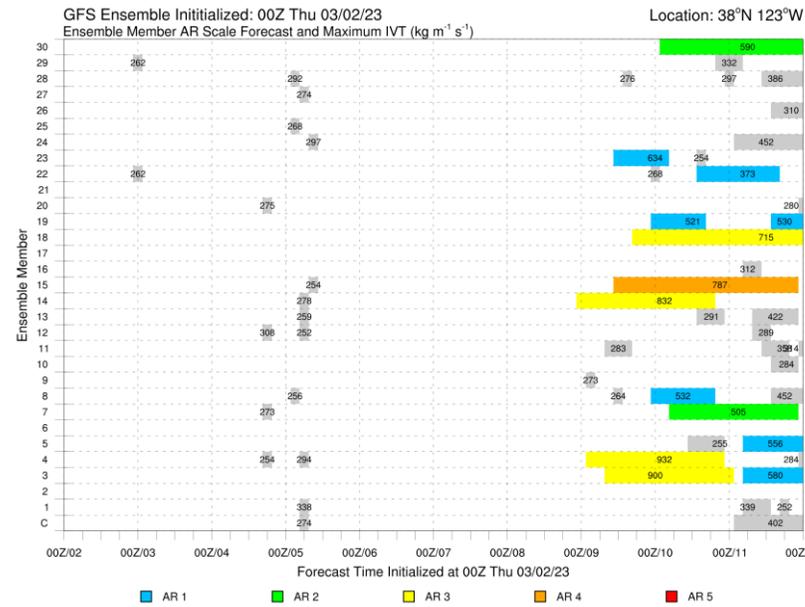
Atmospheric River Outlook

AR Scale and IVT Plume Forecasts

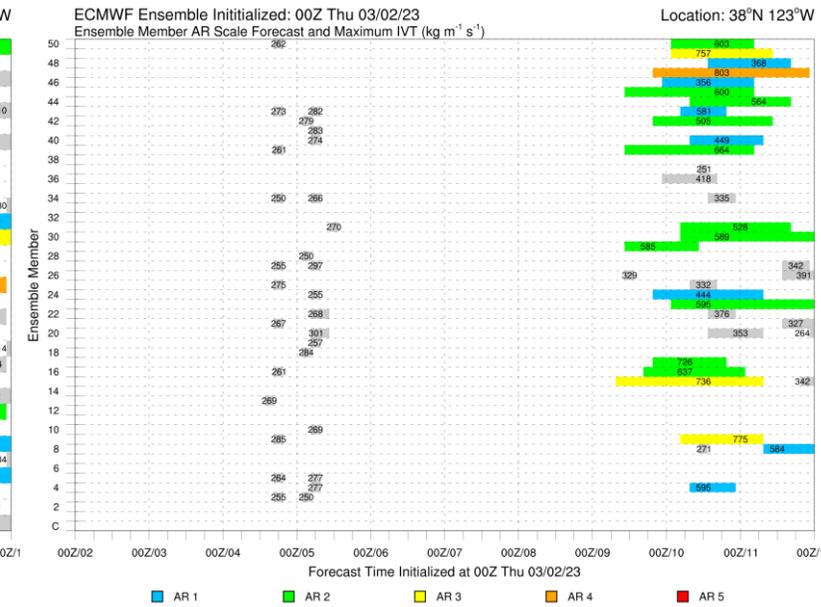
Multi-Model Ensemble IVT Plumes



GEFS 10-day AR Scale



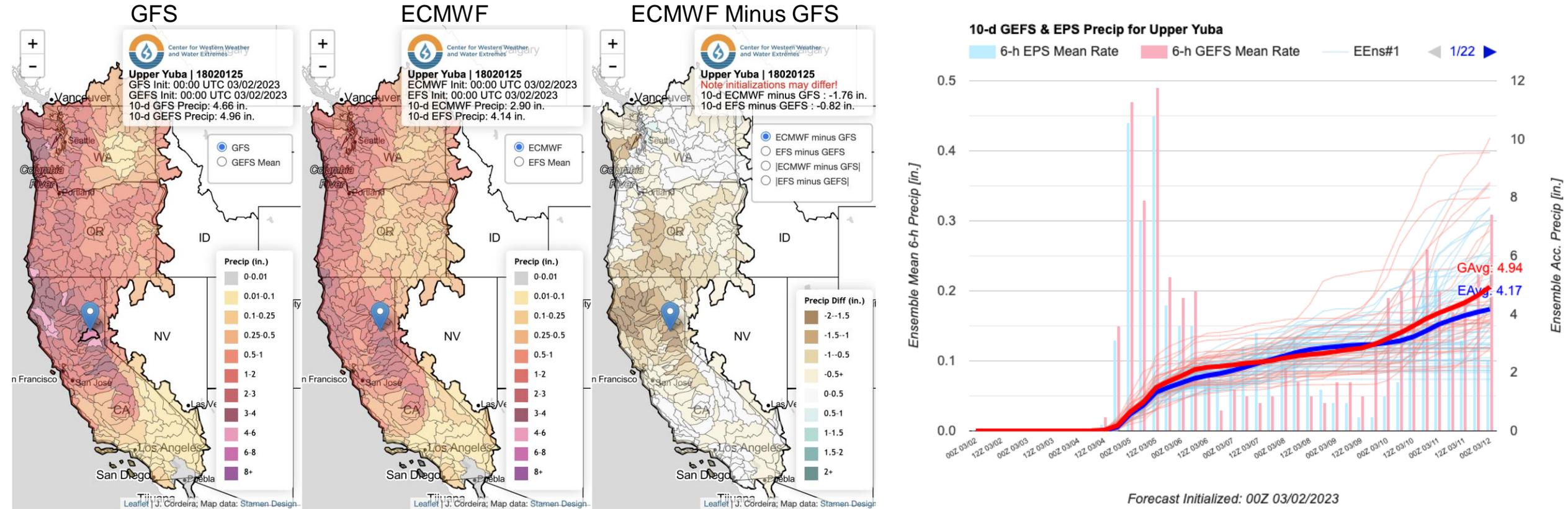
EPS 10-day AR Scale



- Both GEFS and EPS are showing the potential for landfalling AR activity near Bodega Bay, CA, during the 9–12 March period
- There is considerable forecast uncertainty given the long lead time, but 26/80 (33%) ensemble members are forecasting maximum IVT $> 500 \text{ kg m}^{-1} \text{ s}^{-1}$, and several ensemble members are forecasting maximum IVT $> 750 \text{ kg m}^{-1} \text{ s}^{-1}$
- While neither ensemble's control member is predicting AR scale conditions (based on the Ralph et al. 2019 AR Scale) during the next 10 days, 7/30 (23%) GEFS members are forecasting an AR 2 or greater, and 15/50 (30%) EPS members are forecasting an AR 2 or greater

Atmospheric River Outlook

Watershed Precipitation Forecasts: Upper Yuba Watershed



- Model differences in storm track and AR activity are contributing to differences in forecast precipitation over the next 10 days
- Compared to the 00Z ECMWF, the 00Z GFS is forecasting higher precipitation amounts in Oregon and Northern CA
- The 00Z GFS is forecasting 4.66 inches of mean areal precipitation in the Upper Yuba watershed during the next 10 days, whereas the 00Z ECMWF is forecasting only 2.90 inches of mean areal precipitation
- The mean 10-day forecast precipitation is > 4 inches in both the NCEP ensemble (GEFS) and the ECMWF ensemble (EPS)
- Forecast uncertainty is evident in the large spread in both ensembles, with 10-day precipitation ranging from 1.77 inches to 10.04 inches