CW3E Event Summary: 9 - 12 June 2022

An Unseasonably Strong Atmospheric River Produced Heavy Rainfall and Flooding in the Pacific Northwest, Northwest Wyoming, and Southern Montana

- An atmospheric river (AR) impacted the Pacific Northwest and Northern California between 9 and 12 June
- An AR 5 (based on the Ralph et al. 2019 AR Scale) was observed in coastal Oregon, where AR conditions persisted for more than 60 consecutive hours with maximum IVT values exceeding 1100 kg m^{-1} s^{-1}
- AR 4 conditions extended inland across eastern Oregon and northern California
- Maximum total precipitation up to 7 inches fell in parts of the Oregon Cascades with more than 2 inches elsewhere throughout Oregon and Washington
- Thunderstorms produced intense rainfall over portions of the Dixie Fire burn scar that triggered multiple post-wildfire debris flows that impacted SR70 in the Feather River Canyon
- A favorable atmospheric environment for severe weather over Yellowstone National Park, including diurnally driven instability and low-level shear, was enhanced by the presence of moisture associated with the AR. This resulted in intense rainfall and heavy snowmelt in Northwest Wyoming and Southern Montana forcing evacuations of parts of Yellowstone National Park
- Stream gauges along rivers within Yellowstone National Park experienced flows well above previous records

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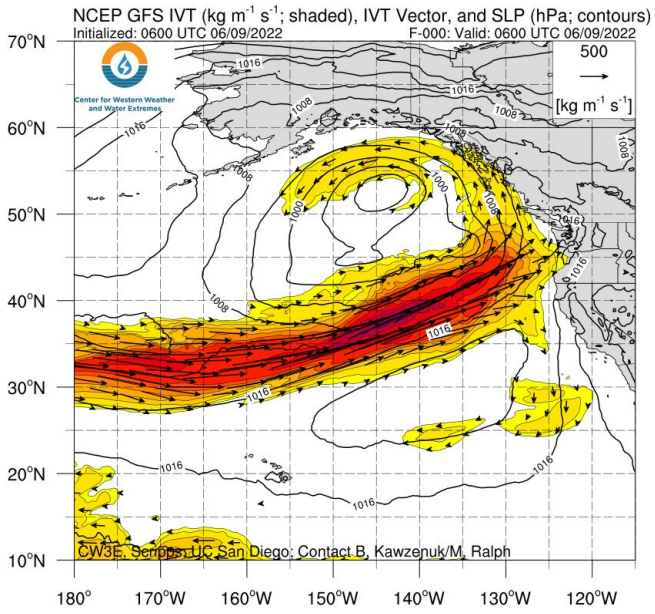
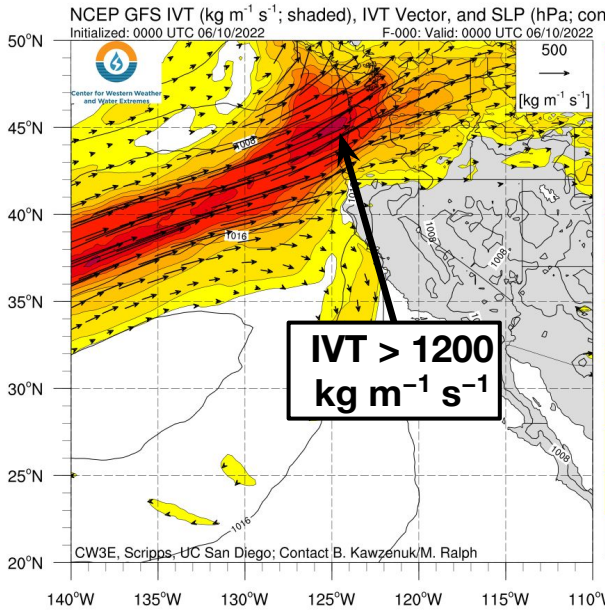
GFS IVT/SLP Analyses

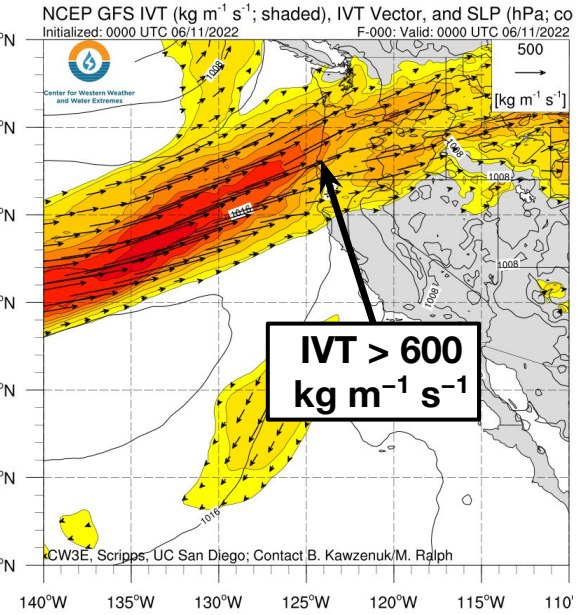
A) Valid: 10 PM PT 08 June



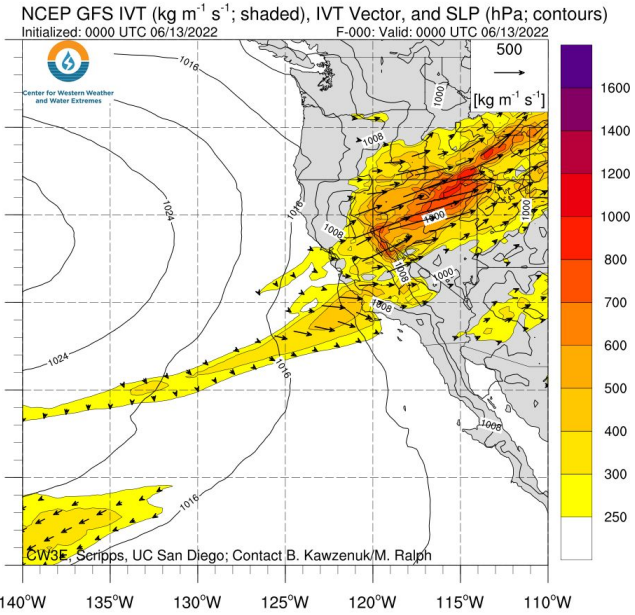
B) Valid: 4 PM PT 9 June



C) Valid: 4 PM PT 10 June



D) Valid: 4 PM PT 12 June



- An AR developed over the Pacific Ocean and made landfall in the Pacific Northwest on 8 June (Figure A)
- Extreme AR conditions (IVT > 1000 kg m^{-1} s^{-1}) were experienced along coastal Oregon and Washington (Figure B)
- IVT values above 250 kg m^{-1} s^{-1} continued for 60+ hours along portions of coastal Oregon (Figure C)
- The AR then moved down the US West Coast before dissipating over northern California and exiting the region (Figure D)

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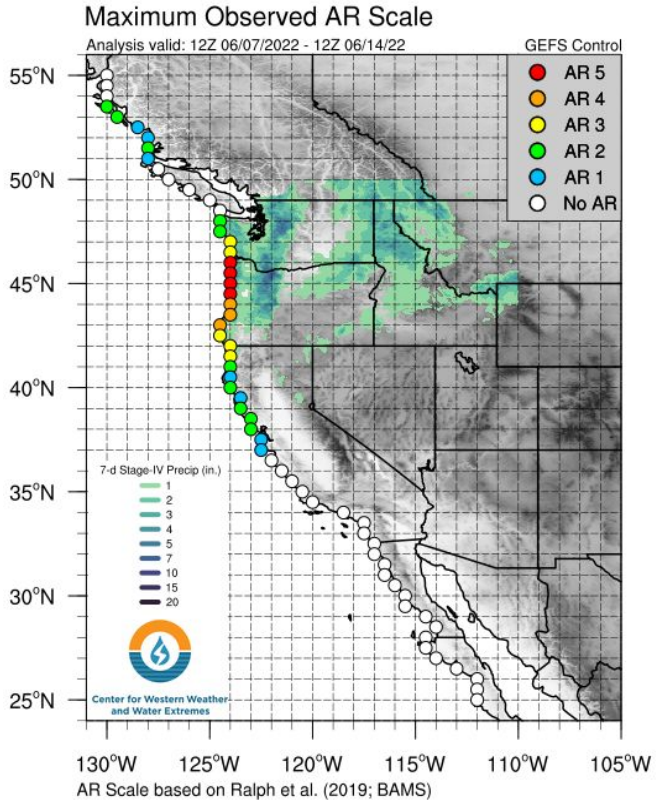
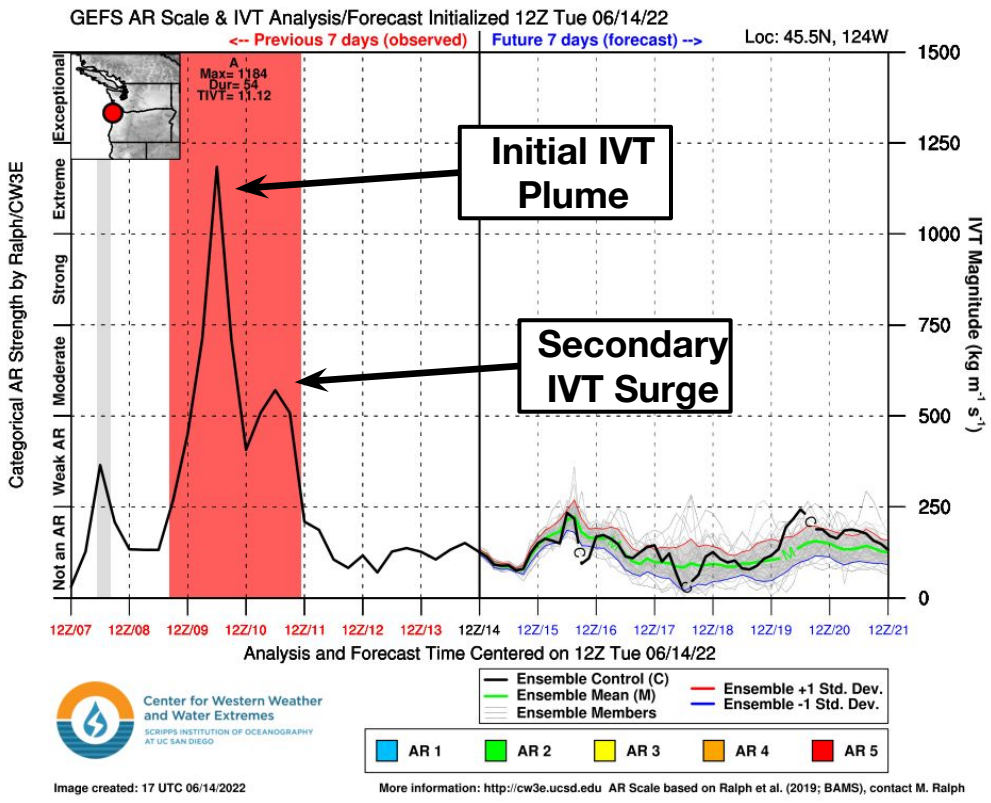
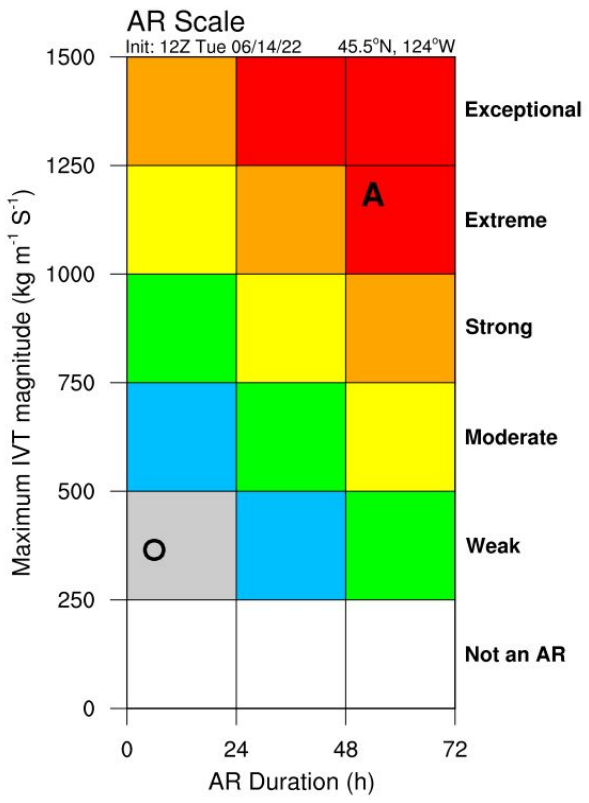
GEFS Coastal AR Scale & IVT Analyses







- A strong AR brought AR 5 conditions (based on the Ralph et al. 2019 AR Scale) to multiple points along the coast of Oregon.
- AR conditions were present at 45.5N, 124.0W, near Tillamook, OR for 54 hours, with maximum observed IVT of 1,184 kg m^{-1} s^{-1}
- The primary column of IVT was followed by a secondary peak in IVT, associated with a mesoscale frontal wave, extending AR conditions during the late stages of the event.

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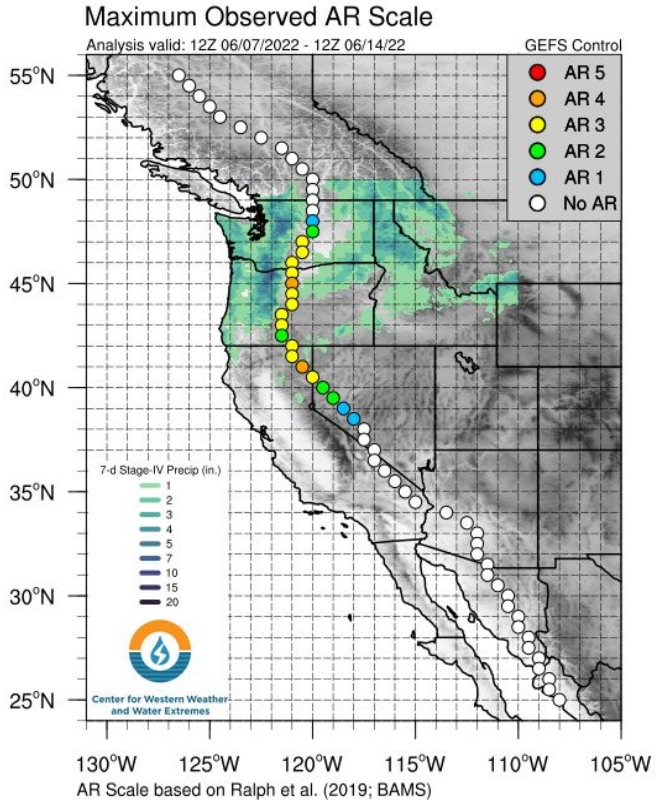
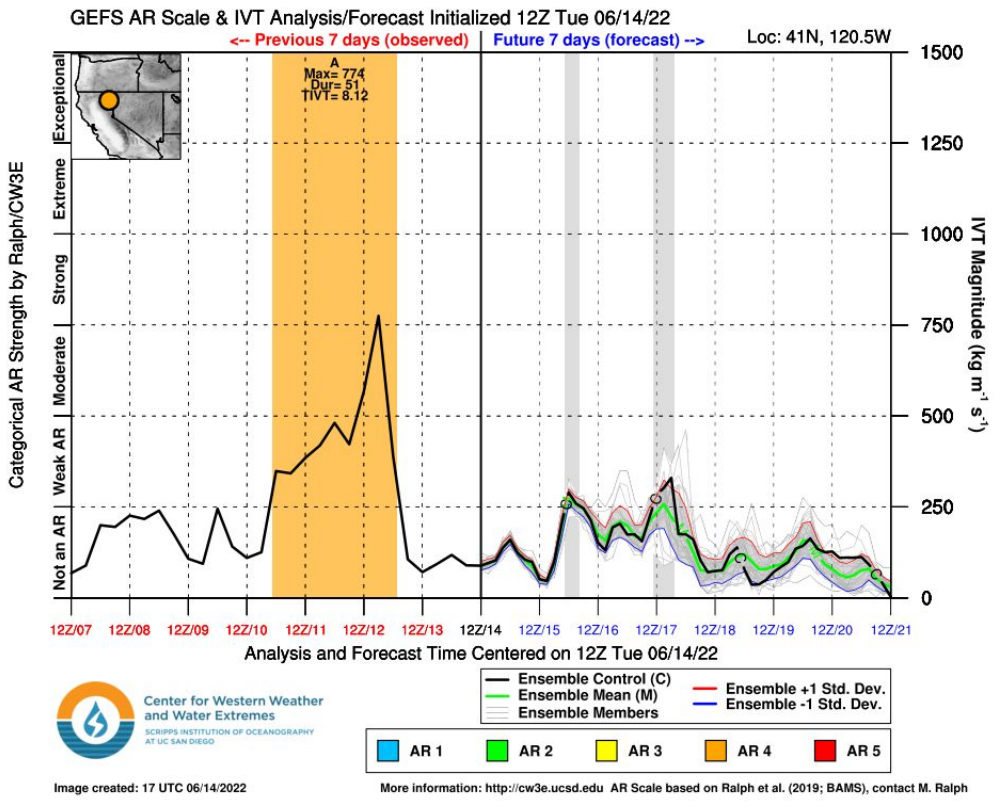
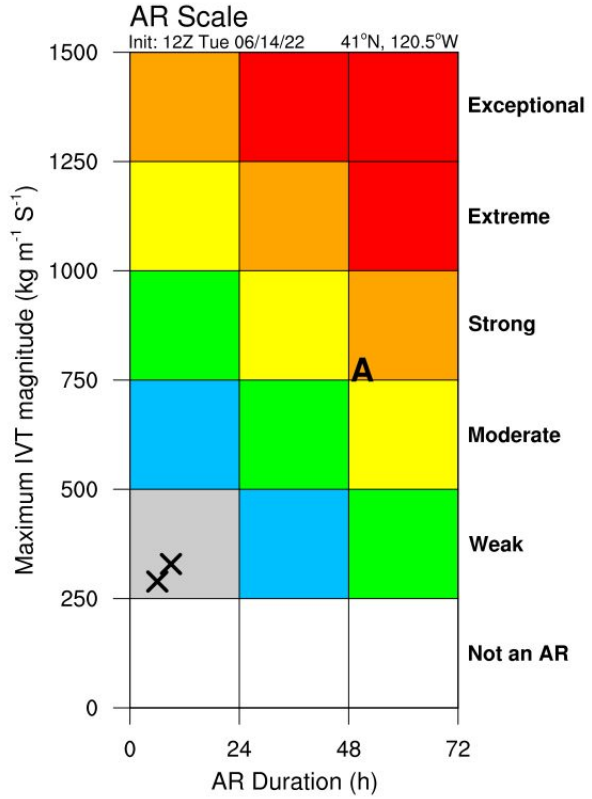
GEFS Inland AR Scale & IVT Analyses







- AR conditions extended inland with AR 4 conditions observed over central Oregon and northern California
- The maximum AR conditions observed over inland locations occurred at 41.0 N, 120.5W with an IVT maxima of 774 kg m–1 s–1 over a period of 51 hours.

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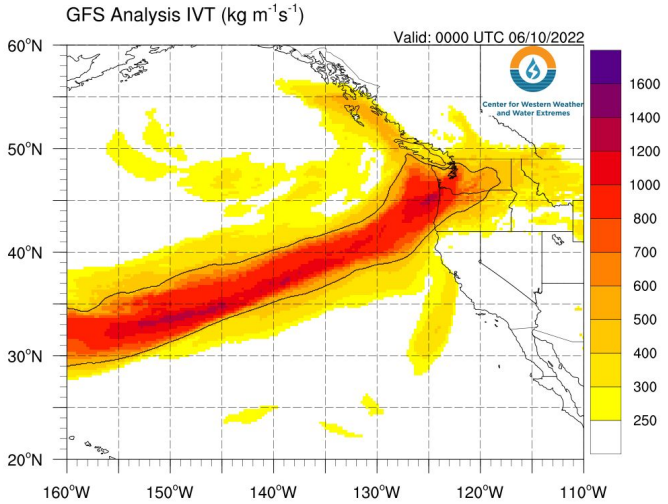
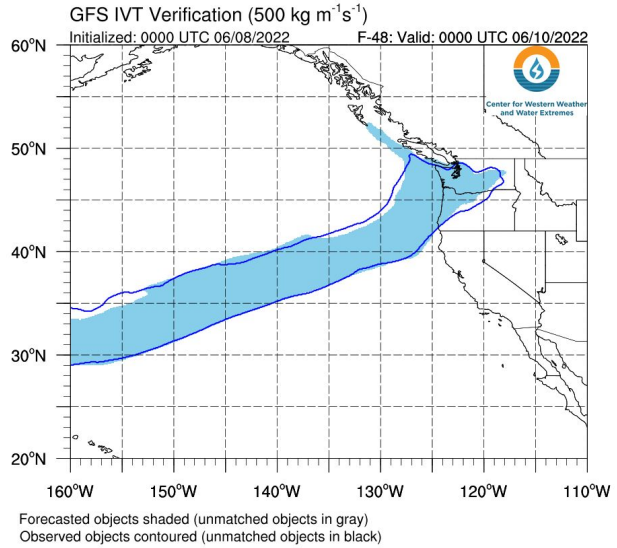
GFS AR/IVT Forecast Verification: Valid 00Z 10 June

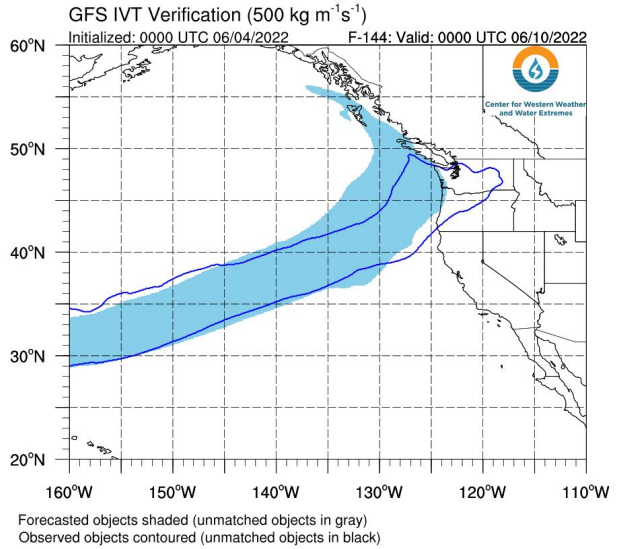
Model Analysis



48-h Forecast



144-h Forecast



Forecast objects shaded (unmatched objects in gray)
Observed objects contoured (unmatched objects in black)
Objects defined based on IVT > 500 kg m^{-1} s^{-1}

- Using the Method for Object-Based Diagnostic Evaluation (MODE) with a 500 kg m^{-1} s^{-1} IVT threshold, the position and structure of the AR were very well forecasted by the GFS model at a 48-hour lead time
- The area of the forecasted AR object was slightly smaller than observed and extended north along the coast
- Examination of the 144-hour GFS forecast shows that the forecasted AR object was much farther north and west, and much slower than observed
- In addition, the orientation of the AR in the 144-hour is more northerly with the AR barely making landfall

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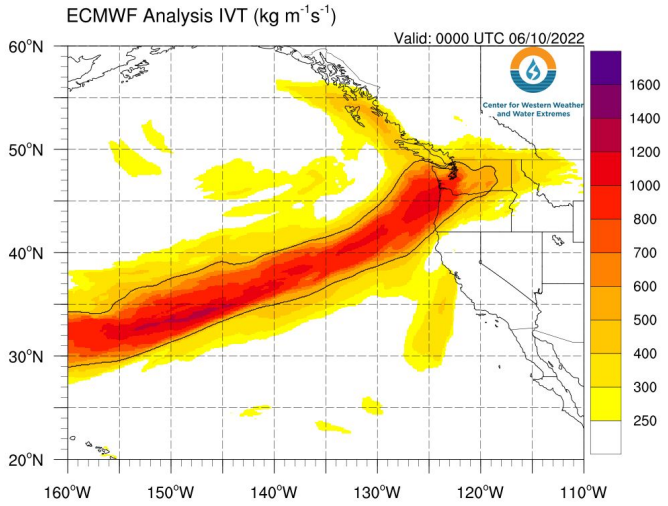
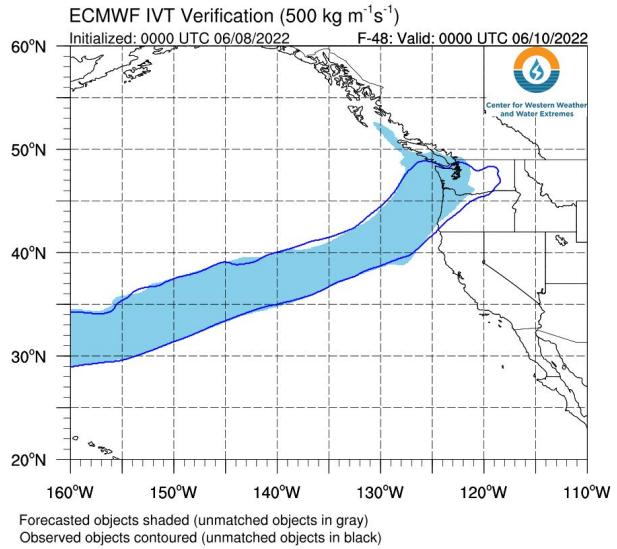
ECMWF AR/IVT Forecast Verification: Valid 00Z 10 June

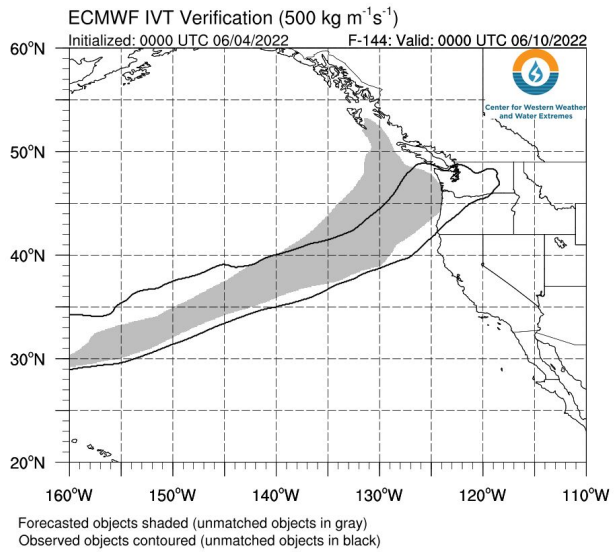
Model Analysis



48-h Forecast



144-h Forecast



Forecast objects shaded (unmatched objects in gray)
Observed objects contoured (unmatched objects in black)
Objects defined based on IVT > 500 kg m^{-1} s^{-1}

- Using the Method for Object-Based Diagnostic Evaluation (MODE) with a 500 kg m^{-1} s^{-1} IVT threshold, the position and structure of the AR were well forecasted by the ECMWF model at a 48-hour lead time but the AR did not extend quite as far inland
- Examination of the 144-hour ECMWF forecast is similar to that of the GFS. The forecasted AR remained just offshore and is slightly further north than observed. However, the gray shading indicates that the forecast object did not match the observed

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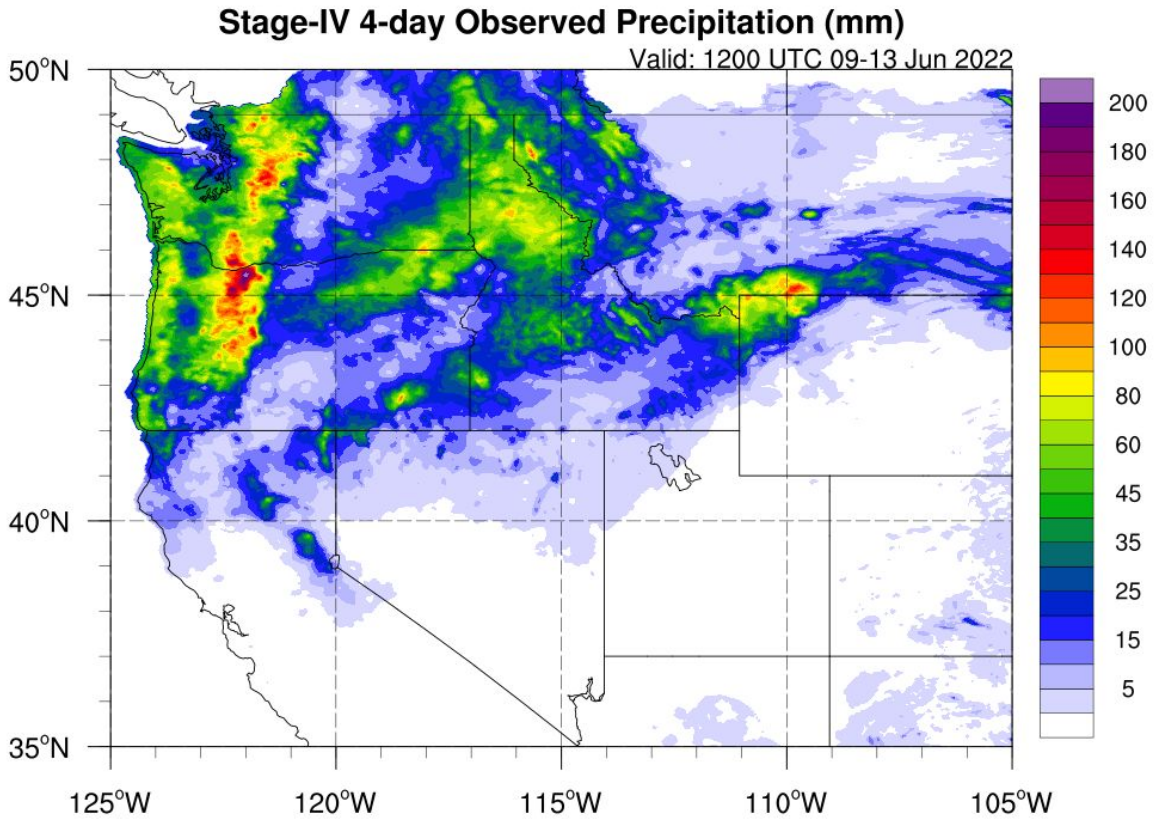
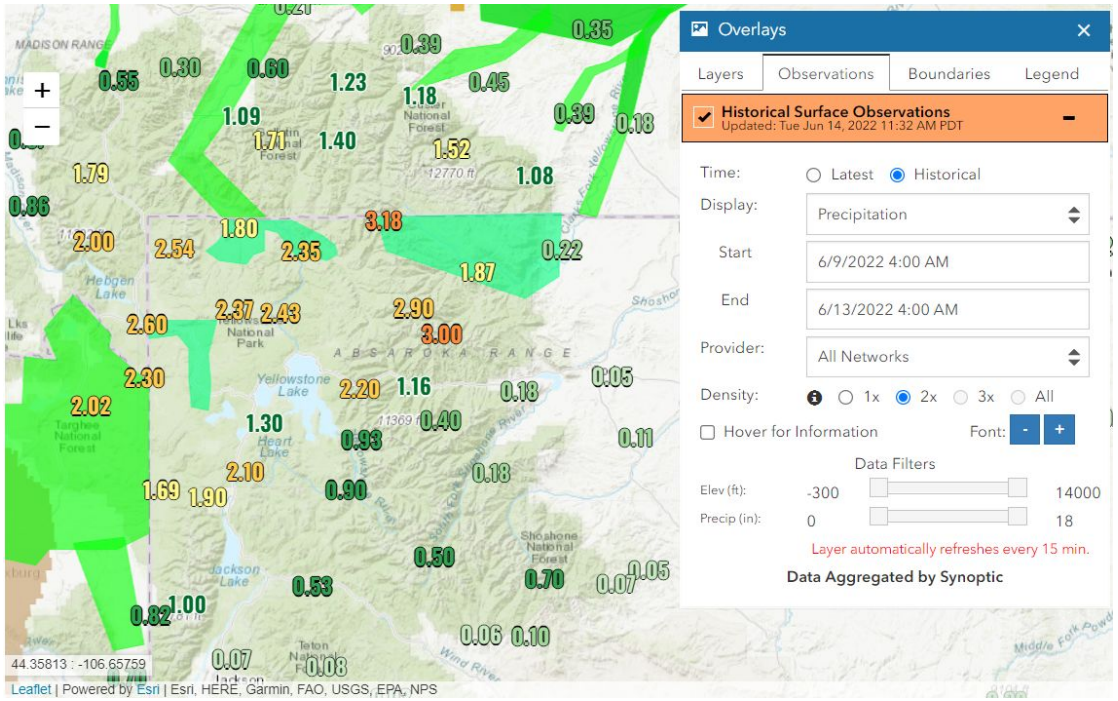


Observed Precipitation around Yellowstone:
Valid 4 AM PT 9 June – 4 AM PT 13 June



Source: NWS Western Region Headquarters

- The AR produced heavy precipitation in the Pacific Northwest, particularly in the Olympic Mountains, the Northern Oregon Coast Ranges, and the Oregon Cascades, where more than 7 inches fell during a 4-day period
- All six climate sites around Seattle, Washington set precipitation records for 9 June which increased runoff produced by this storm and exacerbated hydrologic impacts
- Inland penetration of AR conditions led to unusually heavy precipitation in Northwest Wyoming and Southern Montana
- Precipitation combined with snowmelt caused severe flooding in Yellowstone National Park and forced evacuations of the park

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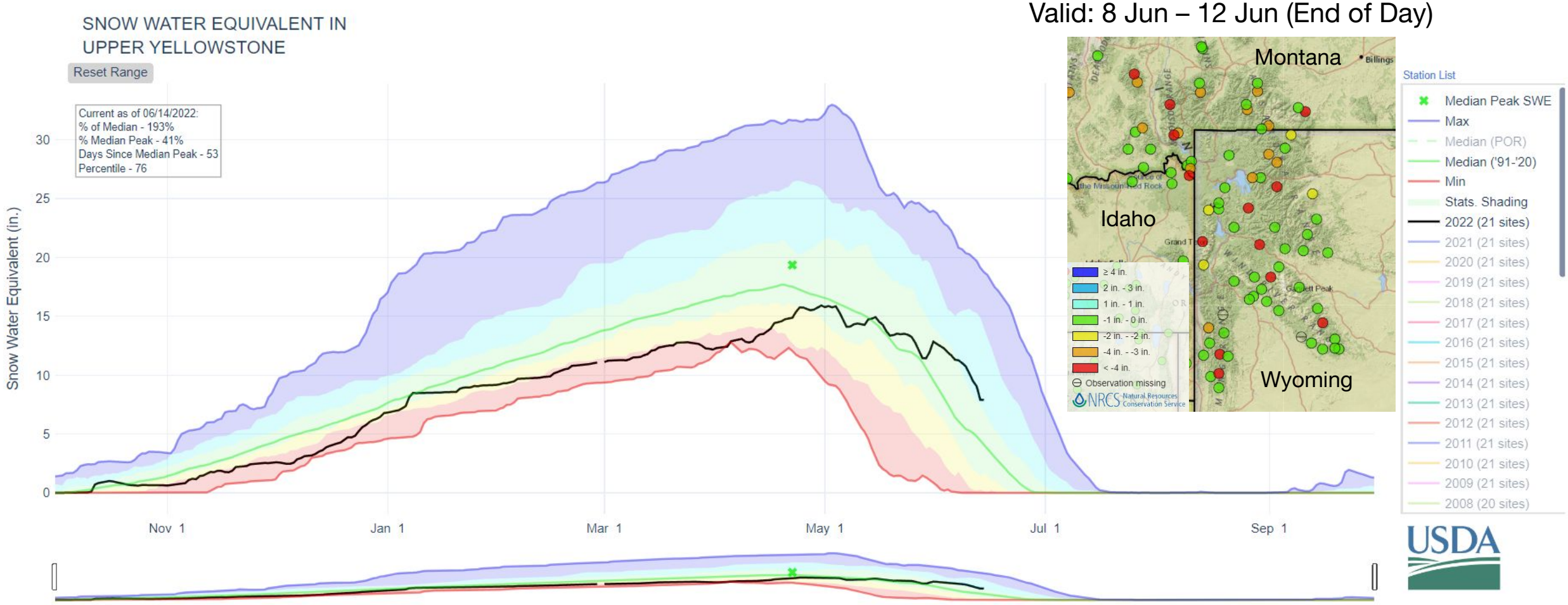

4-day SWE Change

Valid: 8 Jun – 12 Jun (End of Day)

Statistical shading breaks at 10th, 30th, 50th, 70th, and 90th Percentiles
For more information visit: 30-Year Hydroclimatic Normals

Source: NRCS Water and Climate Center

- The Upper Yellowstone basin is currently at 193% of median SWE for the date
- SWE loses over a 4-day period exceeded 3 inches at many stations within the basin

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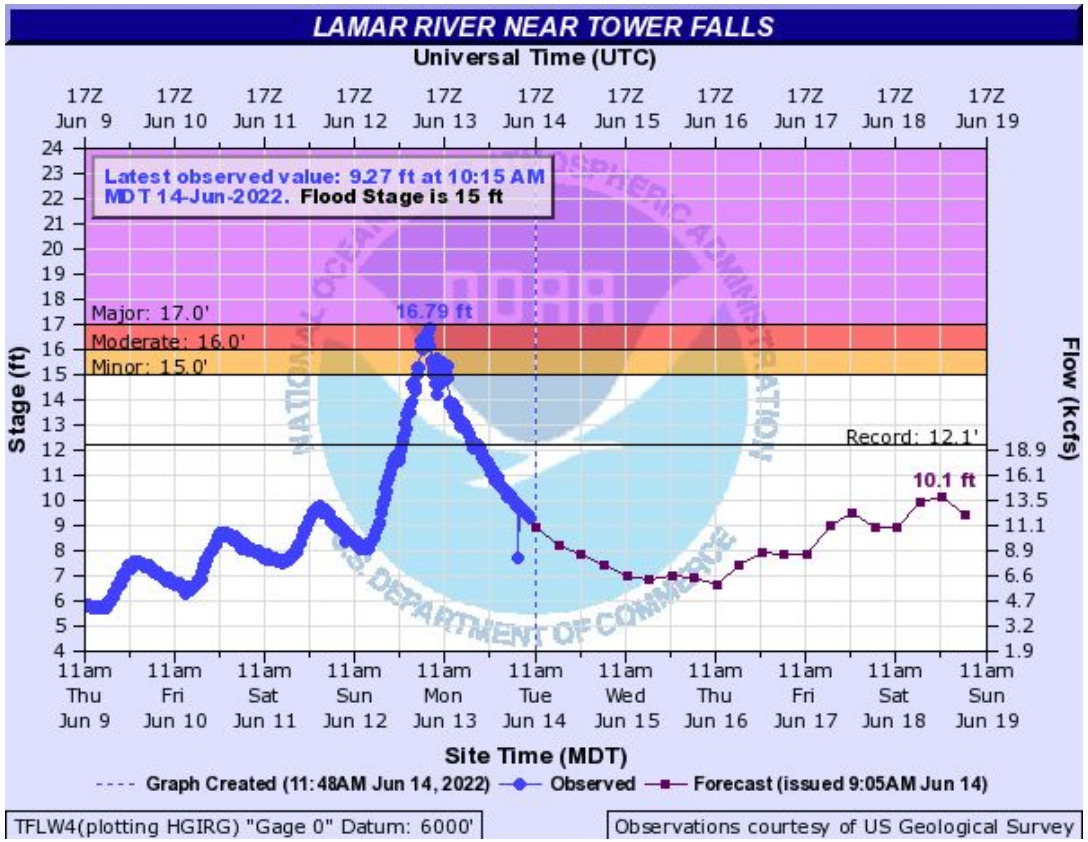
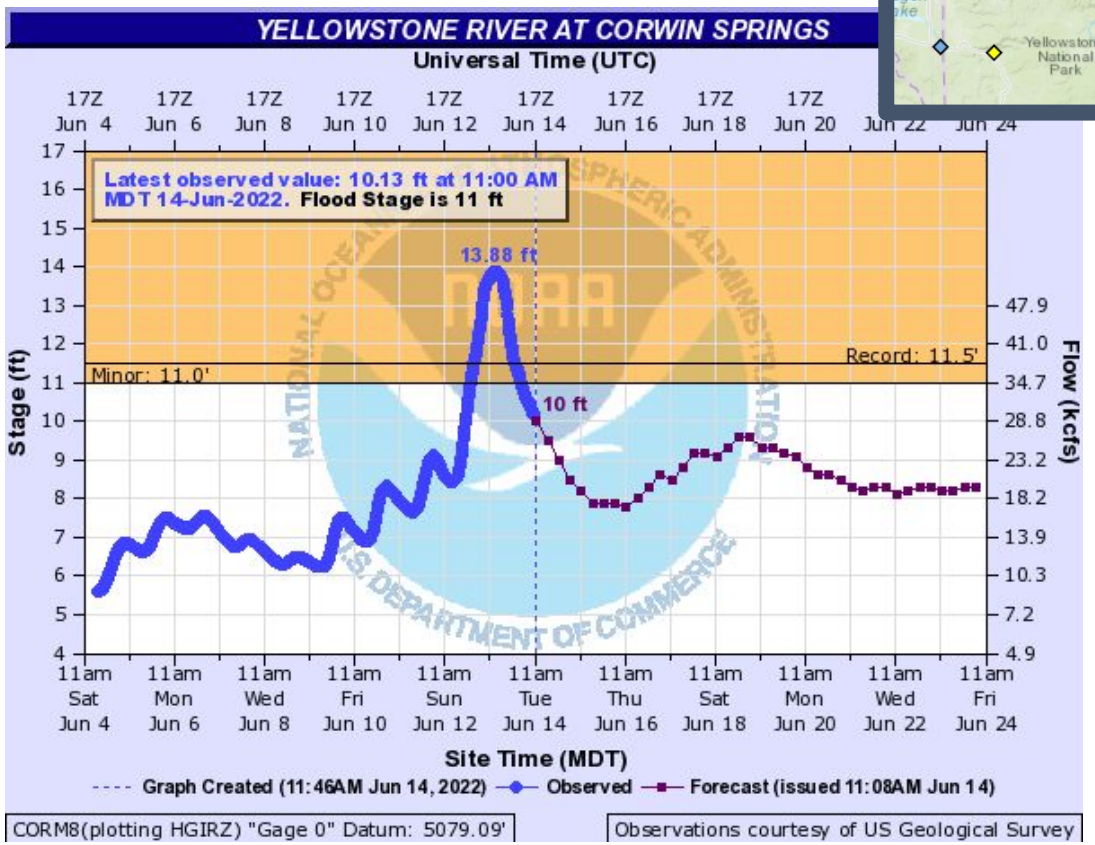
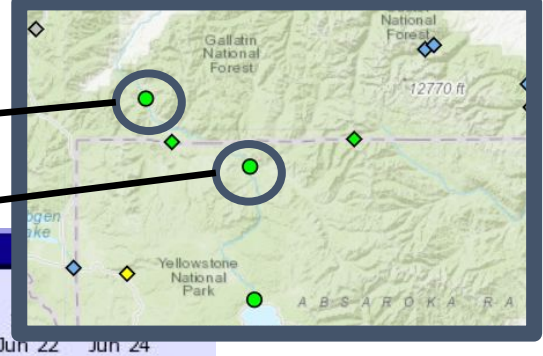
Stream Gauge Observations







- Two stream gauges near Yellowstone National Park illustrate the significant flooding associated with the heavy precipitation.
- The Lamar River (near Tower Falls) rose to 16.79 ft, more than 4.5 ft higher than its previous record and cresting just below major flood stage at 5 AM on 6/13.
- The Yellowstone River (at Corwin Springs) rose to 13.88 ft, more than 2 ft higher than its previous record.

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Structure along the Yellowstone River that was lost from erosion

Source: Sam Glotzbach via AP

Washed out bridge off Highway 89 south of Livingston, MT

Source: Larry Miller/The Billings Gazette via AP

Washington Post article that mentions the AR Scale

https://www.washingtonpost.com/travel/2022/06/13/yellowstone-closes-roads-rainfall-flooding/

- Intense rainfall combined with heavy snowmelt caused flooding and severe erosion along the Yellowstone River
- Multiple structures close to the river have been washed away
- Several roads and bridges were washed out due to flood conditions
- All five entrances to Yellowstone National Park closed for the first time in 34 years. Parts of the park were also evacuated
- Gardiner, Montana, near the confluence of the Yellowstone and Gardiner rivers, was cut off after roads were washed out

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Debris flow along SR70 in the Feather River Canyon

Source: Josh Dixon, Quincy Field Maintenance Superintendent

Debris flow along SR70 in the Feather River Canyon

Source: Josh Dixon, Quincy Field Maintenance Superintendent

Debris flow on Hwy 36, between Mineral, CA and Chester, CA

Source: Susanville CHP

- As the AR drifted into northern California, the combination of moisture, instability in the atmosphere, and an upper-level disturbance led to the development of intense thunderstorms
- Thunderstorms produced intense rainfall over portions of the Dixie Fire burn scar that triggered multiple post-wildfire debris flows that impacted SR70 in the Feather River Canyon. The road remains closed with no estimated opening time.
- Thunderstorms also triggered a debris flow temporarily closing State Route 36