

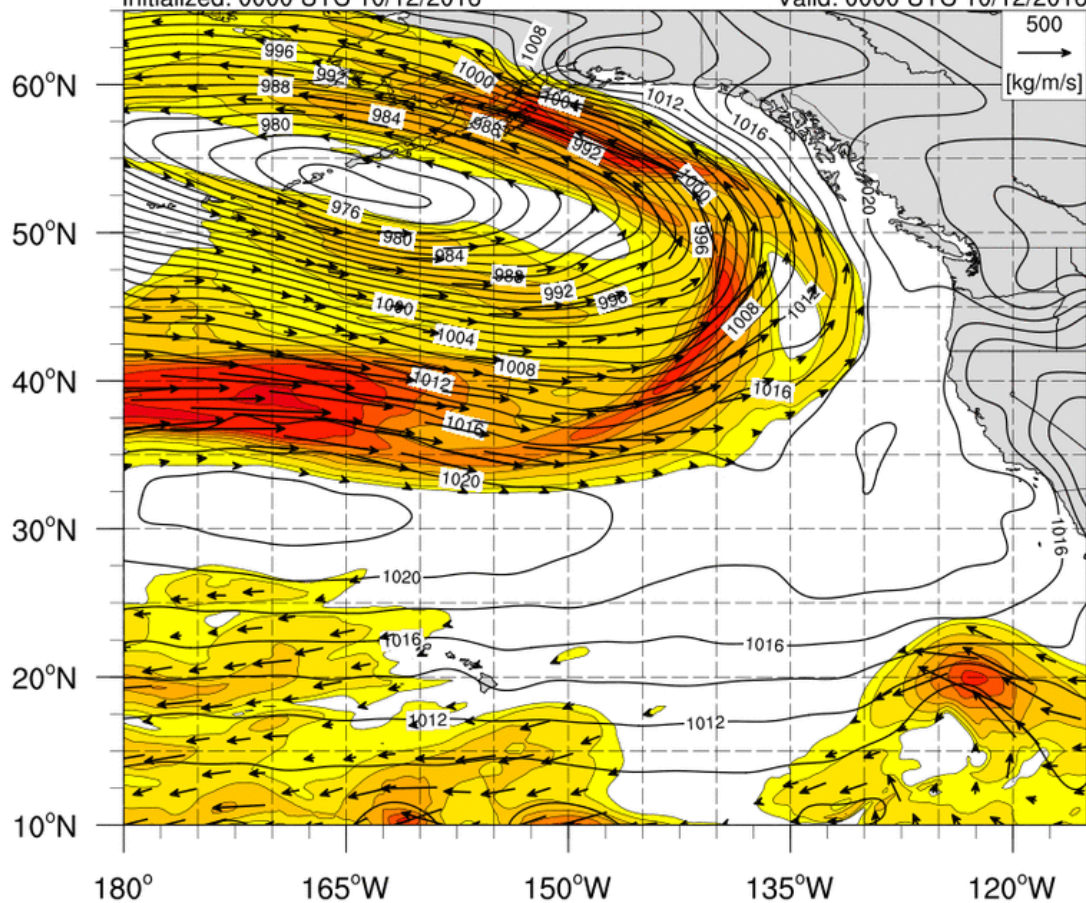
# CW3E Atmosphere River Update - Summary



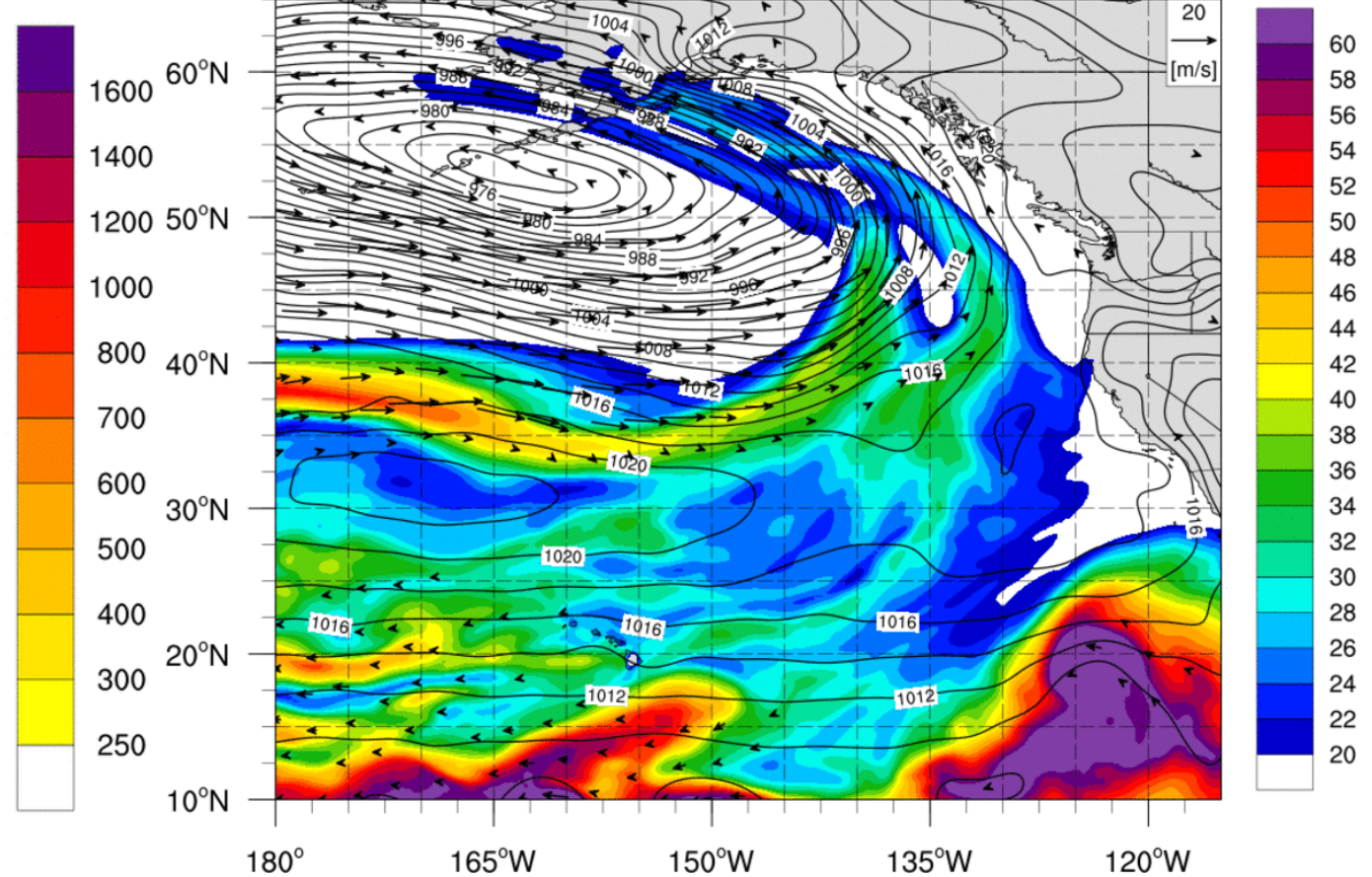
Center for Western Weather and Water Extremes

- Two Atmospheric Rivers (ARs) made landfall over the Pacific Northwest over the previous four days
- These events combined to produce >400 mm of precipitation in southern OR and northwest WA (R-Cat 3)
- Dry soil conditions resulted in absorption of high amounts of rain and large increases in soil moisture

NCEP GFS IVT ( $\text{kg m}^{-1} \text{s}^{-1}$ ; shaded), IVT Vector, and SLP (hPa; contours)  
Initialized: 0000 UTC 10/12/2016 Valid: 0000 UTC 10/12/2016



NCEP GFS IWV (mm; shaded), 850-hPa Winds, and SLP (hPa; contours)  
Initialized: 0000 UTC 10/12/2016 Valid: 0000 UTC 10/12/2016



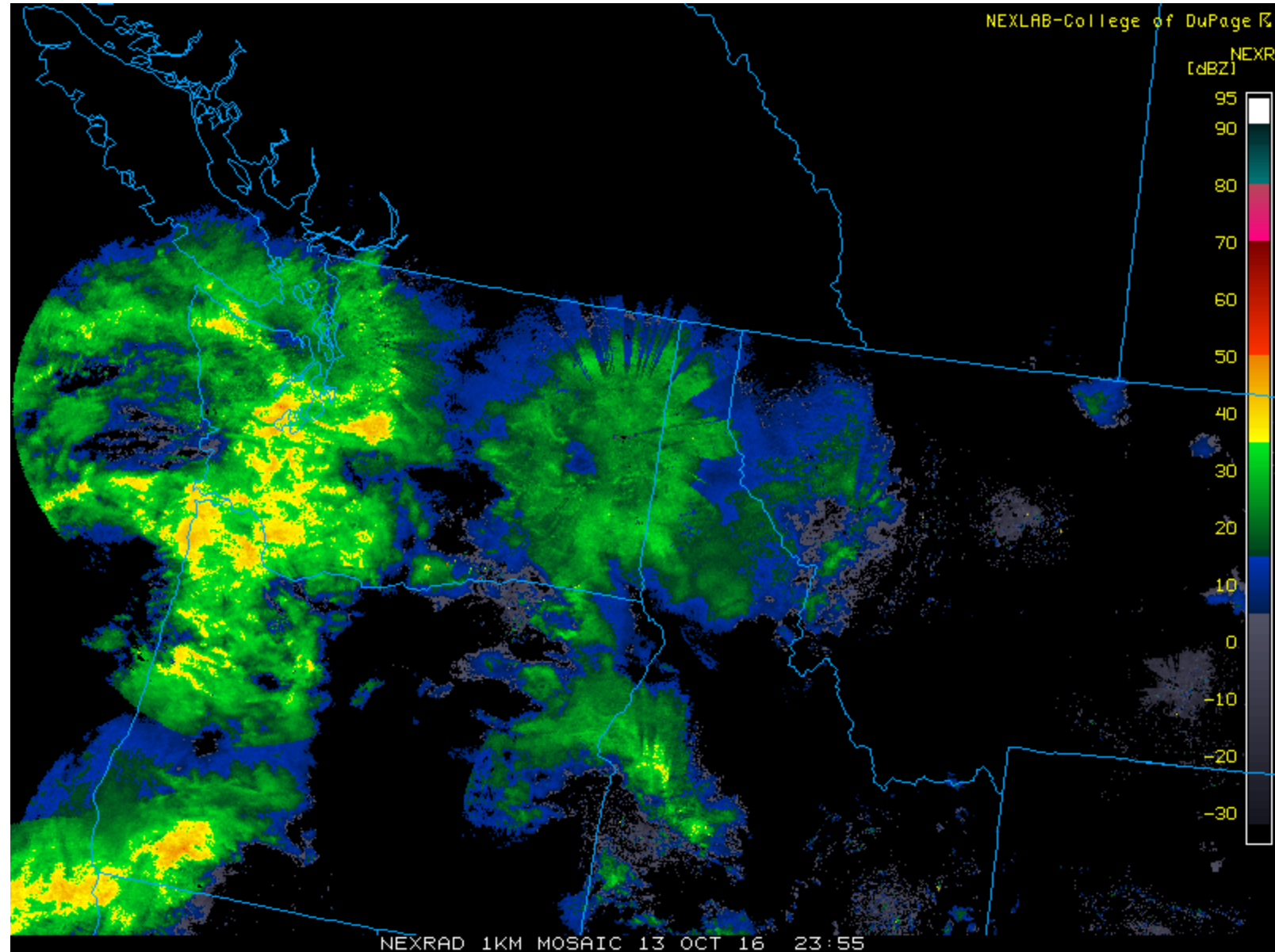
NCEP GFS Analysis – Valid: 0000 UTC 12 Oct 2016 – 0600 UTC 17 Oct 2016

Provided by B. Kawzenuk

# Observed Precipitation

NEXRAD Radar: 0000 UTC 14 Oct 2016 – 0000 17 UTC Oct 2016

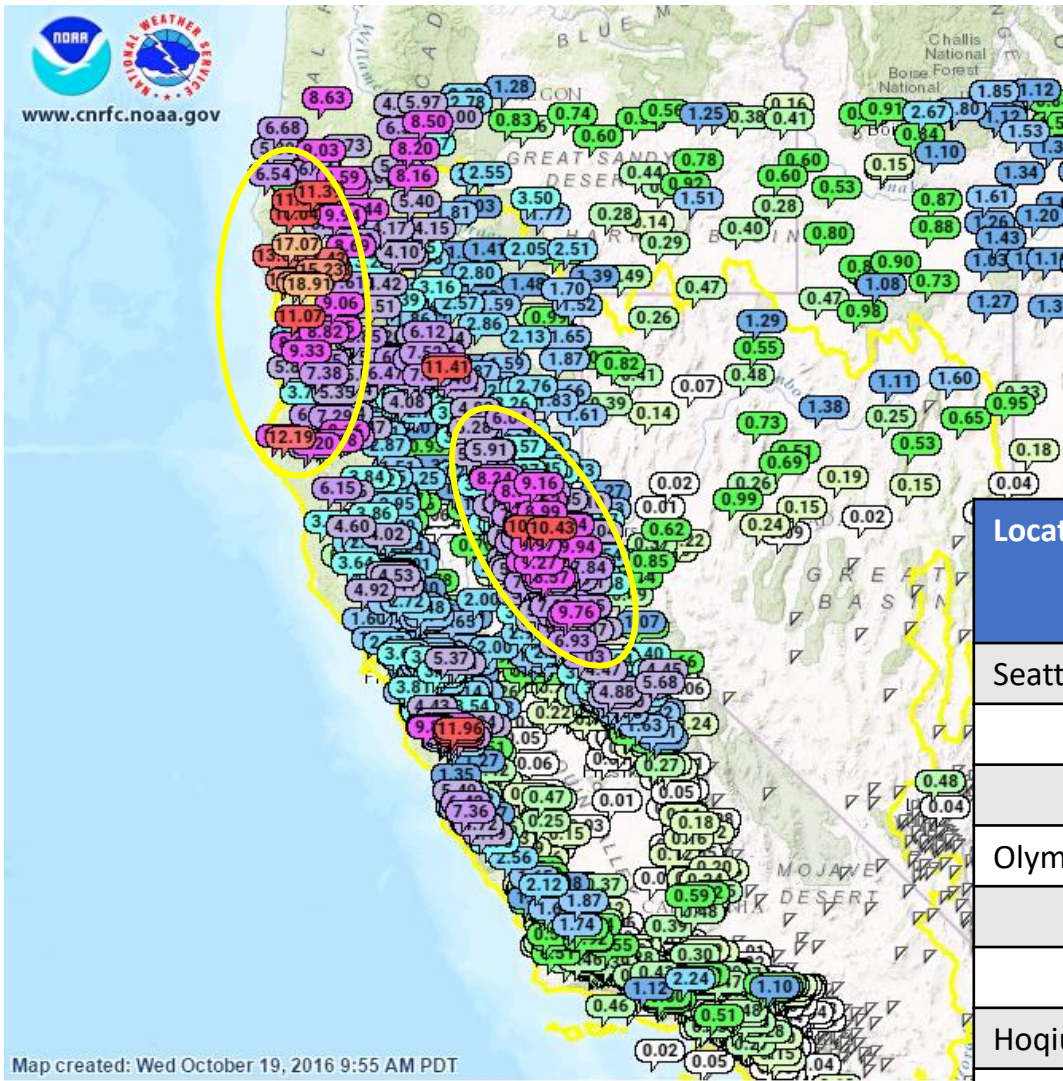
- Radar imagery shows widespread precipitation over the Pacific Northwest on 14–17 Oct 2016
- Severe convection on 14 Oct produced multiple tornadoes in OR and high winds across the region
- Throughout the period the PNW was impacted by several alternating periods of stratiform and convective precipitation



Provided by B. Kawzenuk

# Observed Precipitation

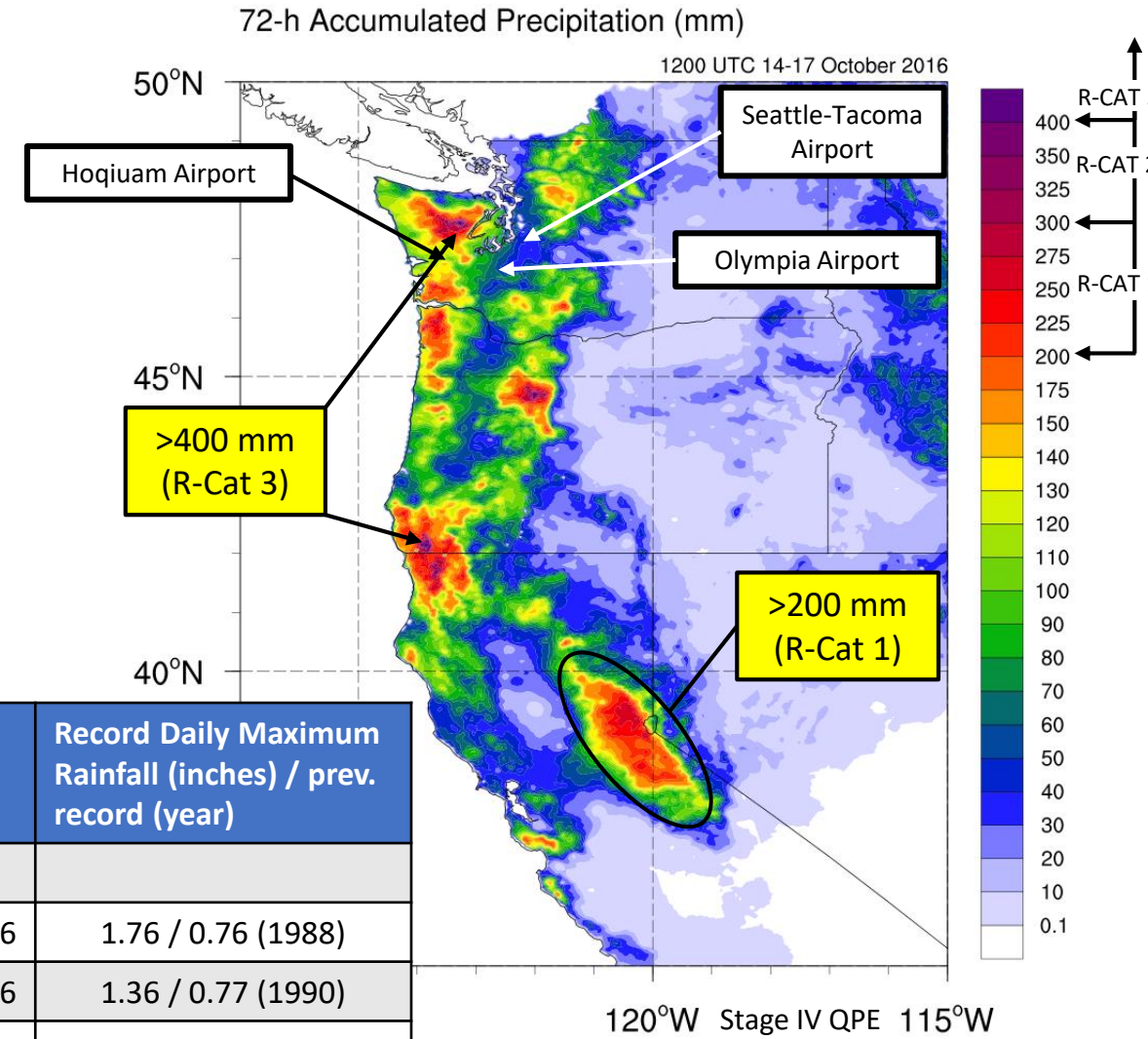
Observed Precipitation 8:00 AM PDT 14 – 19 Oct 2016



Map created: Wed October 19, 2016 9:55 AM PDT



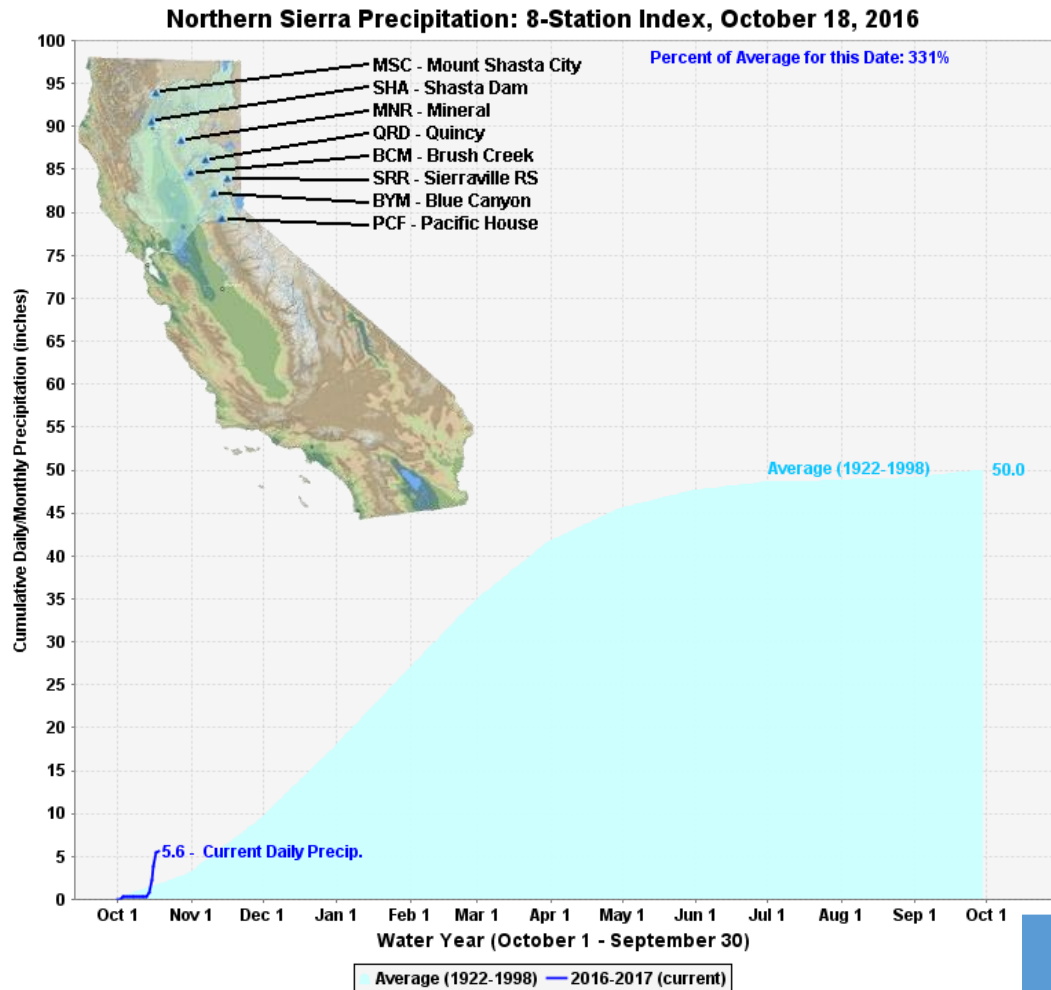
Location/Date	Record Daily Maximum Rainfall (inches) / prev. record (year)
Seattle-Tacoma Airport	
Thursday, 10/13/16	1.76 / 0.76 (1988)
Friday, 10/14/16	1.36 / 0.77 (1990)
Olympia Airport	
Thursday, 10/13/16	1.61 / (0.56 2014)
Friday, 10/14/16	2.01 / 0.99 (1956)
Hoquiam Airport	
Thursday, 10/13/16	2.5 / 1.18 (2014)
Saturday, 10/15/16	2.11 / (1.12 year)



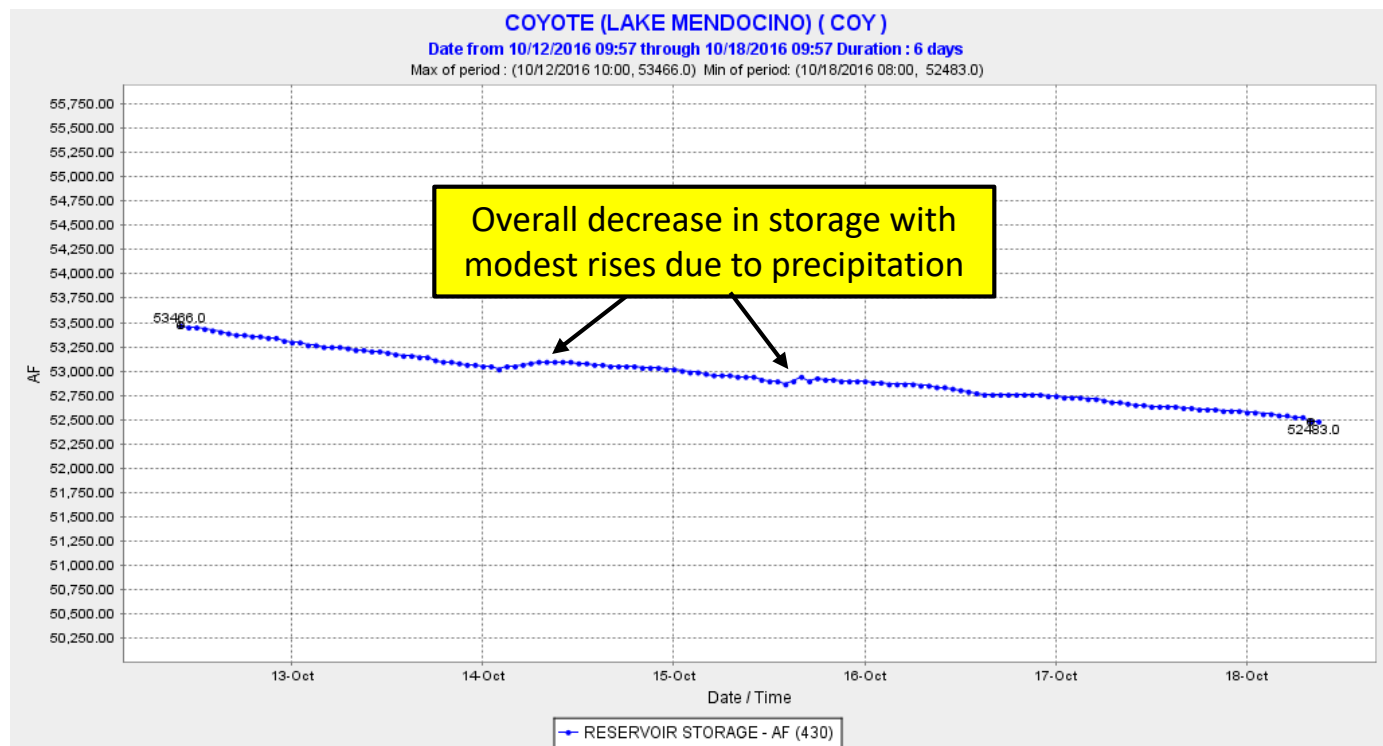
120°W Stage IV QPE 115°W

Provided by B. Kawzenuk and R. Weihs

# Observed Conditions

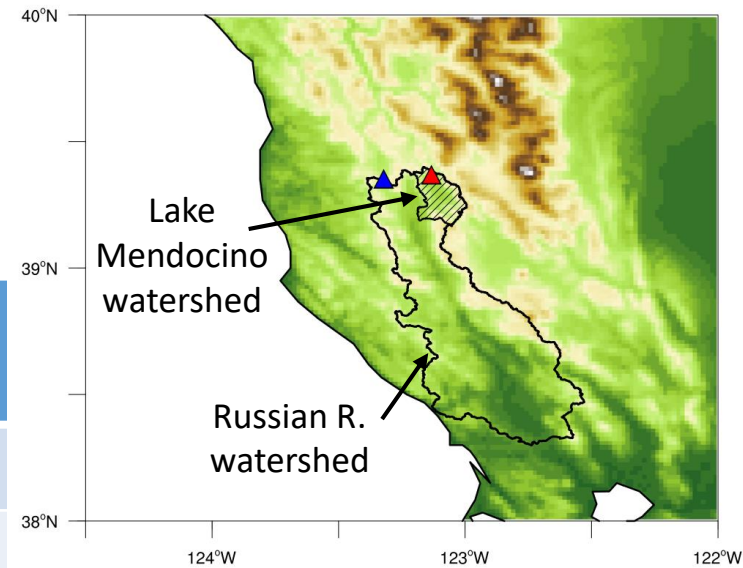


The Northern Sierra 8-Station Index received >5 inches of precipitation, equivalent to ~10% of the normal water year precipitation



Significant precipitation occurred in the Lake Mendocino Watershed, but it did not lead to an increase in reservoir level

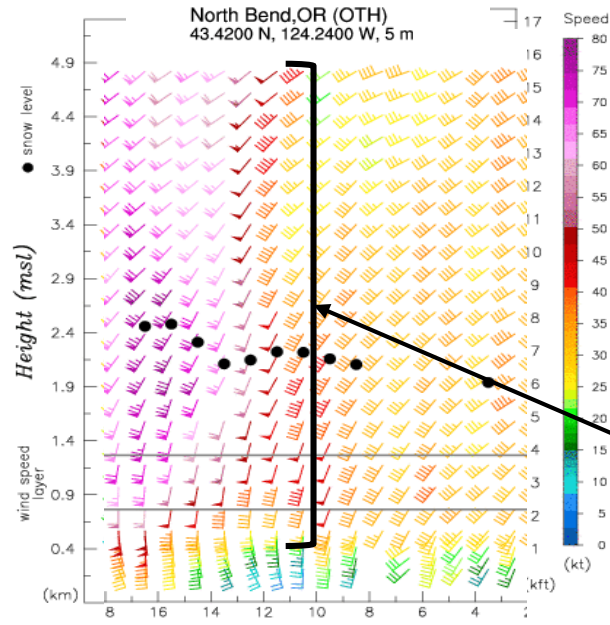
Rain Gauge	72-hr Precip (in.) 14-17 Oct
Willits Howard ▲	4.08
Potter Valley ▲	2.71



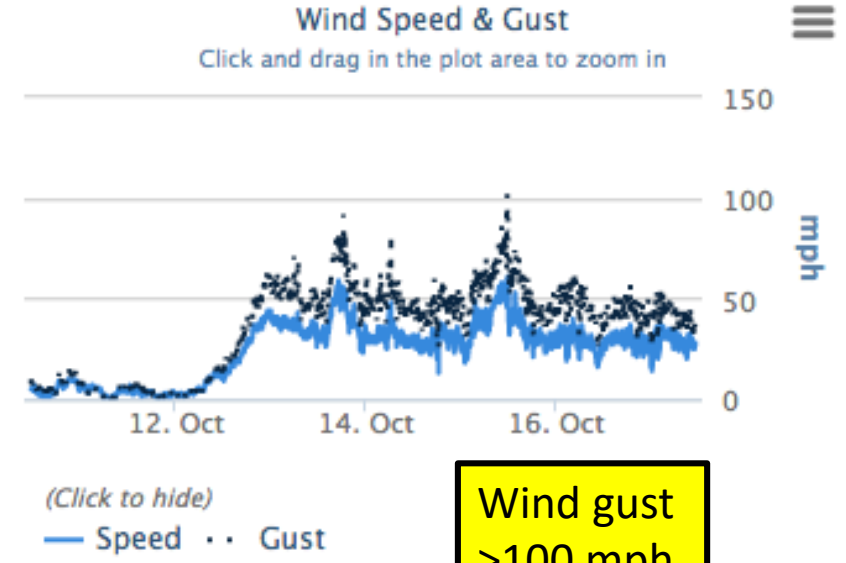
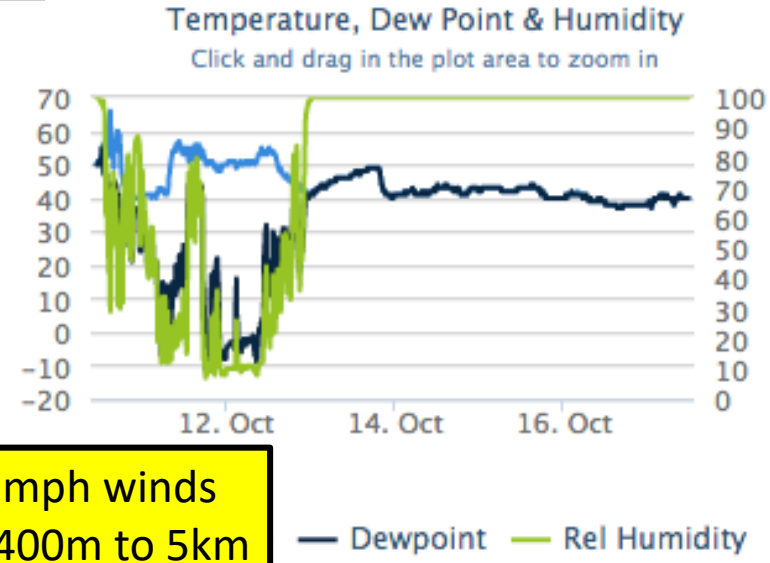
Provided by B. Kawzenuk

# Observed Conditions

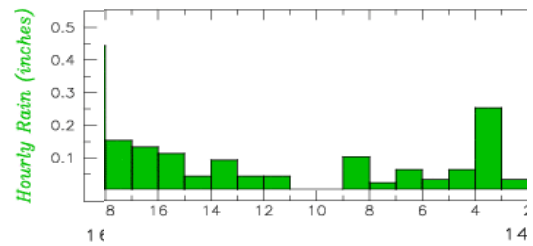
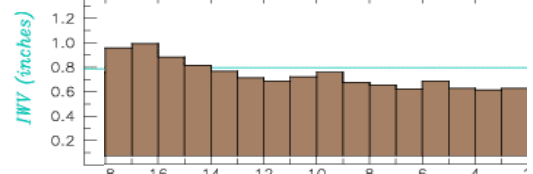
## Weather conditions at Mary's Peak, OR



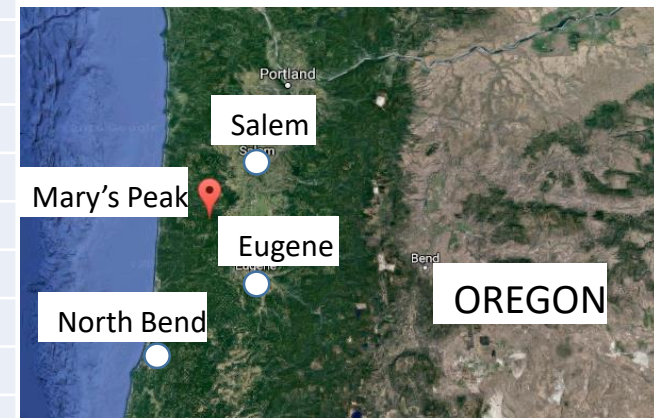
>60 mph winds from 400m to 5km



Wind gust >100 mph



Location	Max Wind Gust (mph)	Time/Date	Lat/Lon/Elev. (ft)
Bellingham Airport	52	1139 PM 10/13	48.79N/122.54W/158
1 NNW Blanchard	61	0111 AM 10/14	48.61N/122.43W/1066
6 W Crystal Mountain	99	0600 PM 10/13	46.92N/121.64W/6900
3 SSW Crystal Mountain	87	1200 AM 10/14	46.88N/121.52W/6240
Crystal Mountain	85	1100 PM 10/13	46.94N/121.50W/6830
Crystal Mountain Nwac	85	1100 PM 10/13	46.93N/121.47W/4570
Sunrise Mt. Rainier Np	76	0900 PM 10/13	46.91N/121.64W/6420
2E Oceanside	103	0716 PM 10/13	45.47N/123.92W/1420
1 WNW Snoqualmie Pass	65	0200 AM 10/14	47.44N/121.44W/5470
Alpentalski Area Nwac	65	0200 AM 10/14	47.44N/121.43W/3100
Snoqualmie Pass	65	0200 AM 10/14	47.42N/121.43W/3760
Mount Baker	87	0300 AM 10/14	48.85N/121.68W/5020
Mt. Baker Base Nwac	87	0300 AM 10/14	48.86N/121.68W/4210

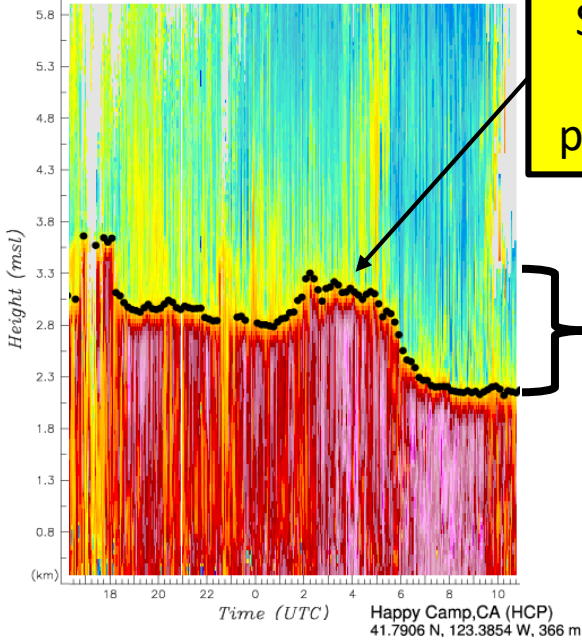


Time (UTC), 15 Oct 2016

# Observed Conditions



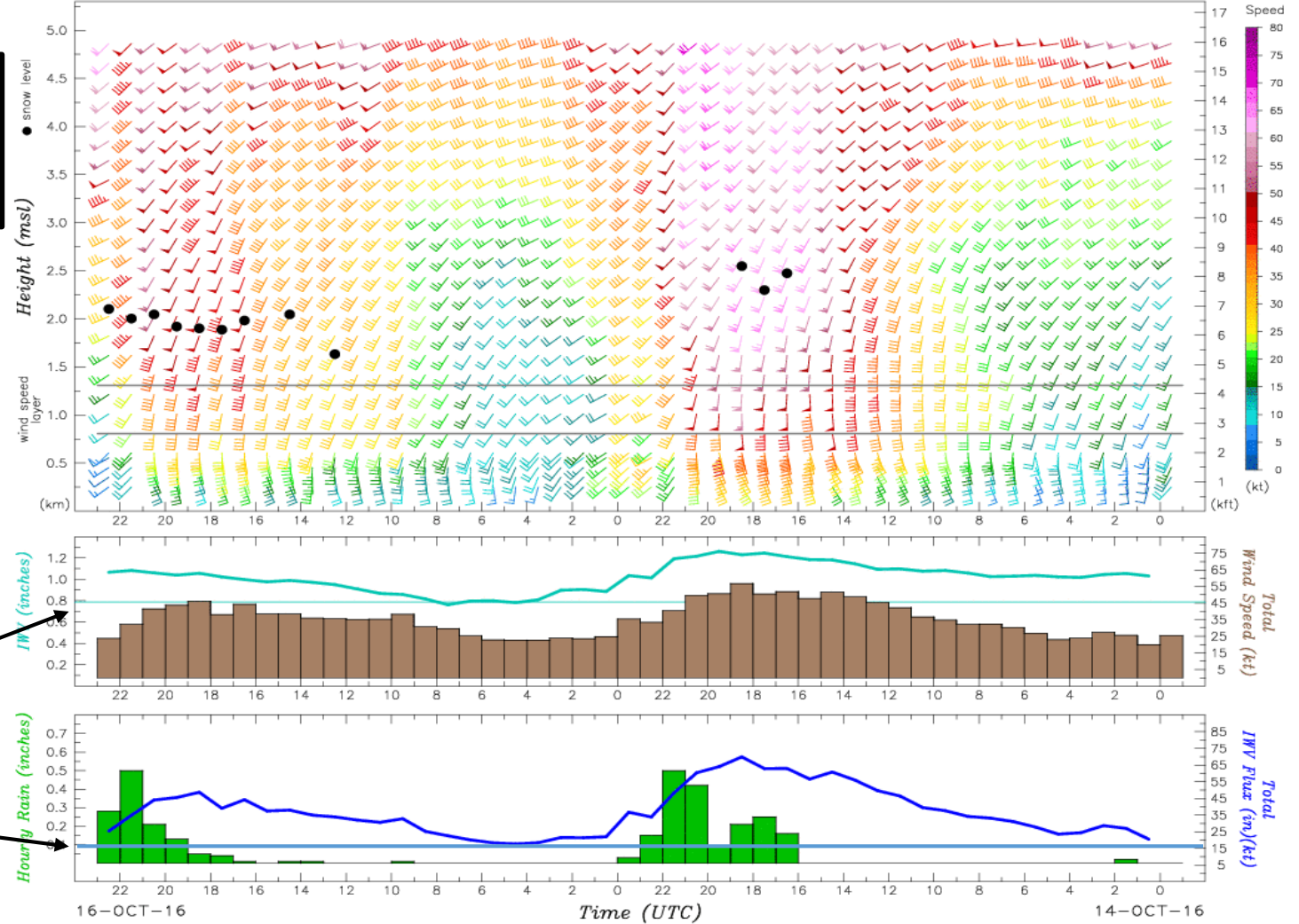
ESRL Physical Sciences Division  
FMCW S-band Snow Level Radar



Snow level >9000 ft  
for significant  
portions of the storm

500m  
snow level  
change  
14 October  
after  
frontal passage

AR conditions  
sustained at CA  
coast for 24 hours

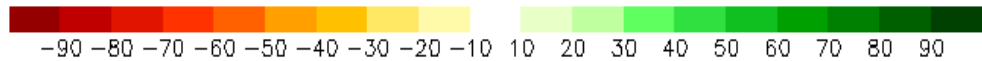
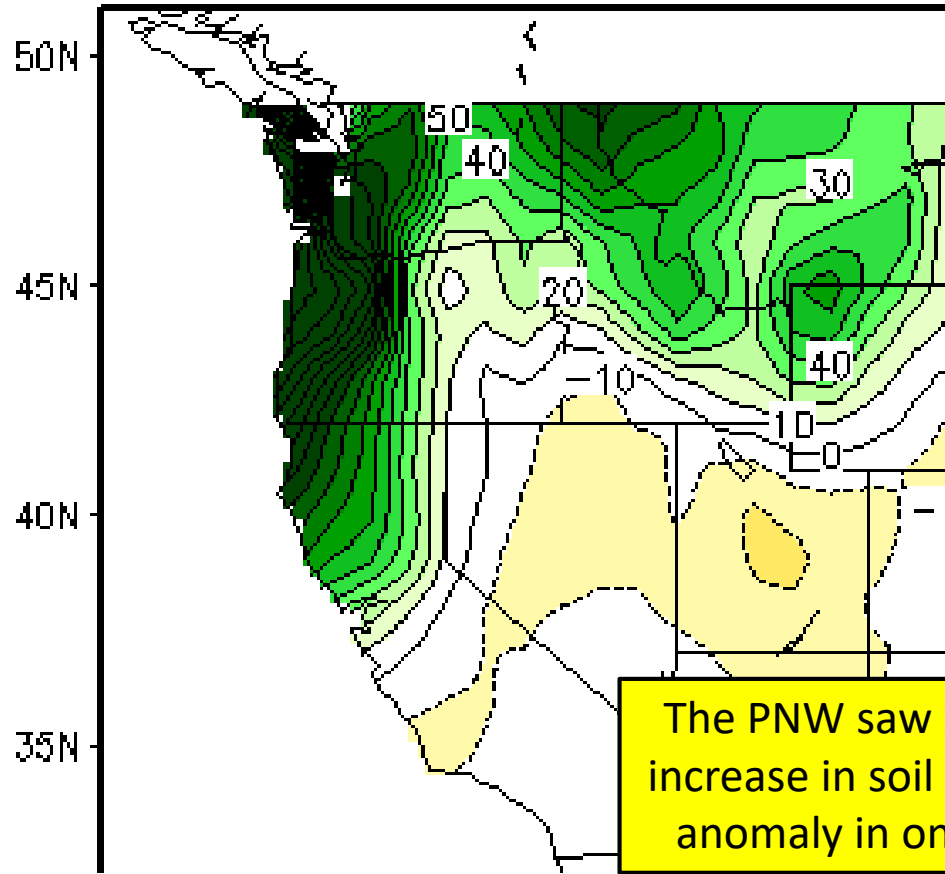


McKinleyville, CA (ACV)  
40.9720 N, 124.110 W, 56 m

48-hr precip: 3.08 in

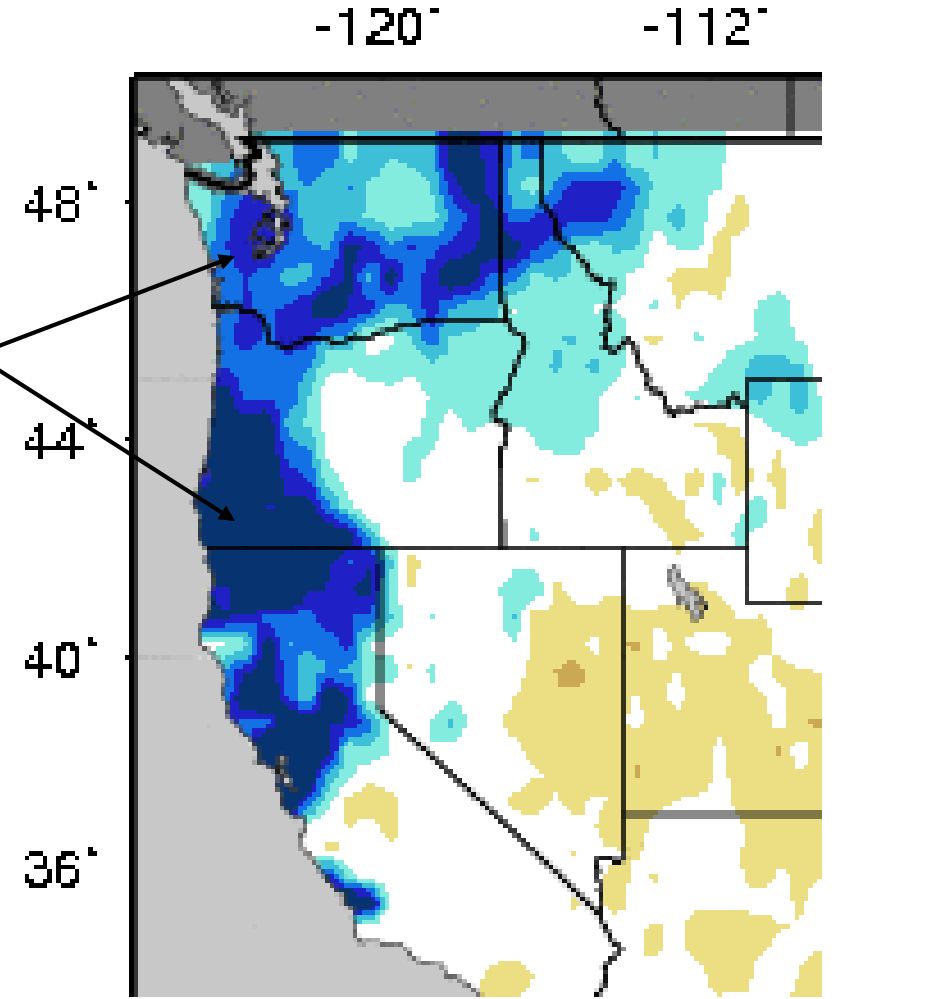
# Impacts on Soil Moisture

Calculated Soil Moisture Anomaly Change  
OCT 16, 2016 from SEP.30



Large portions of the U.S. West Coast show >35% soil moisture

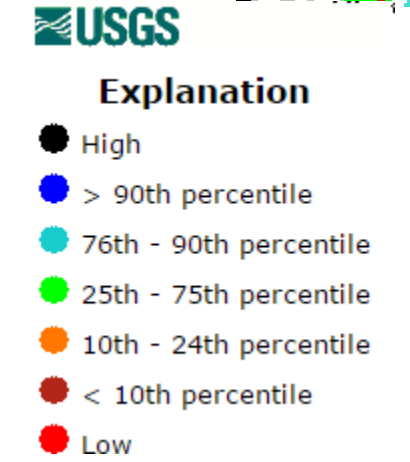
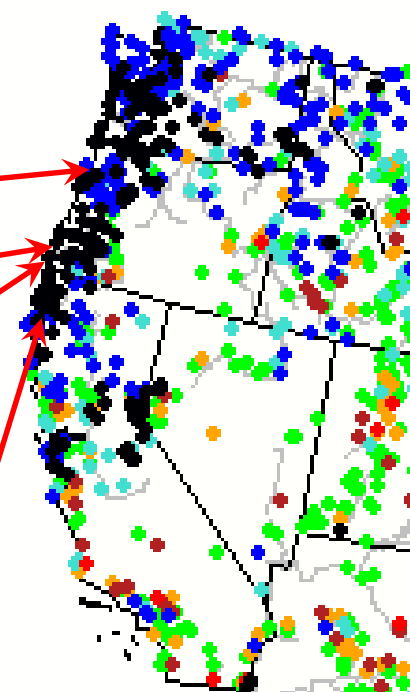
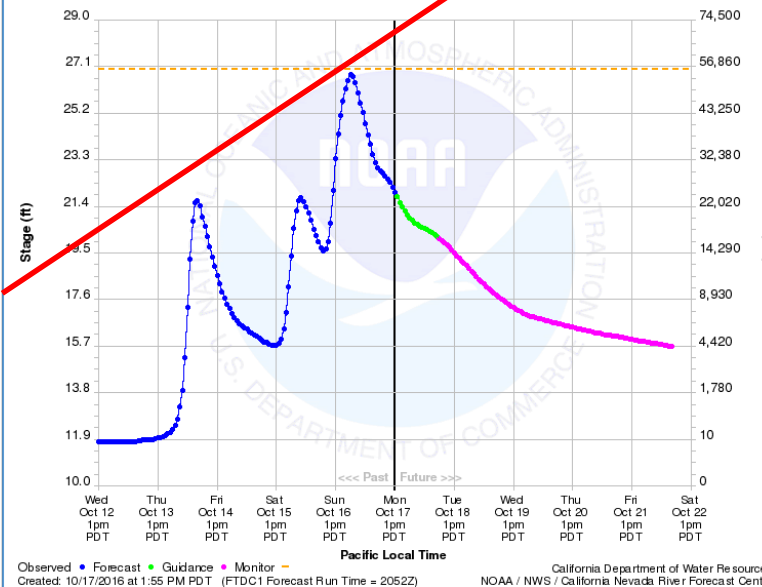
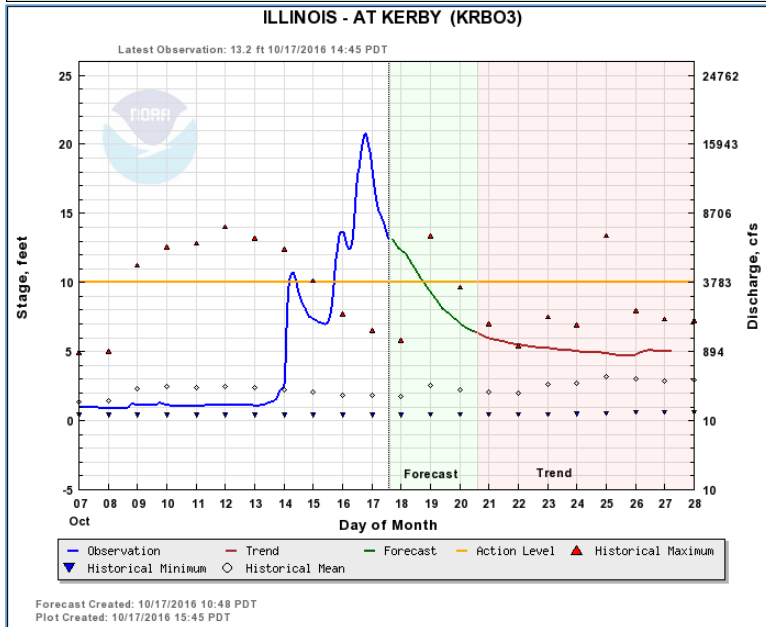
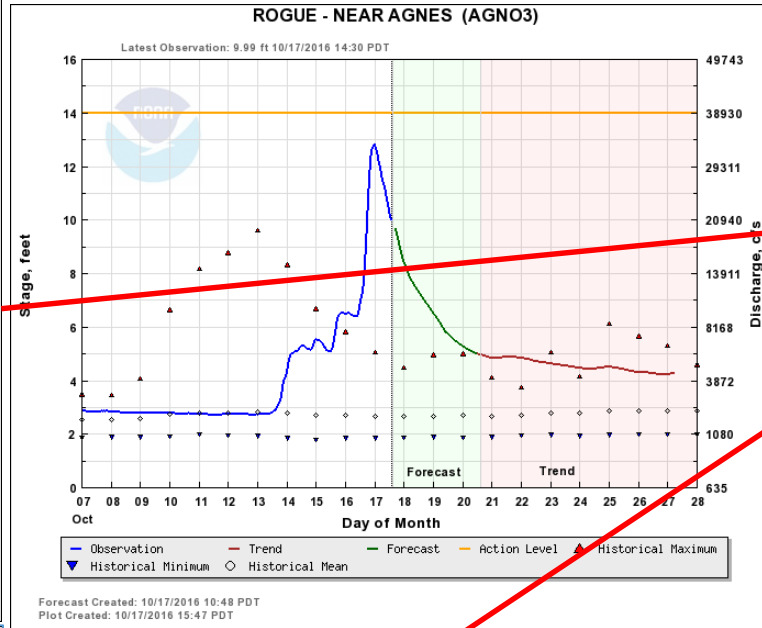
VIC Soil Moisture Percentiles (wrt' 1916-2004)  
for the period: 20161009 to 20161016



Data from NIDIS

Provided by A. Wilson

# Streamflow Response



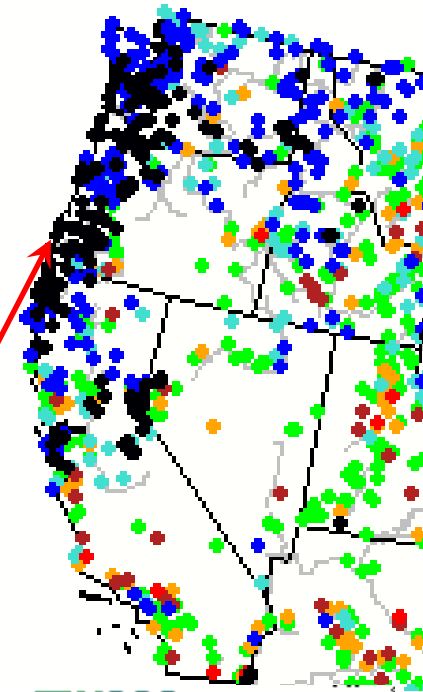
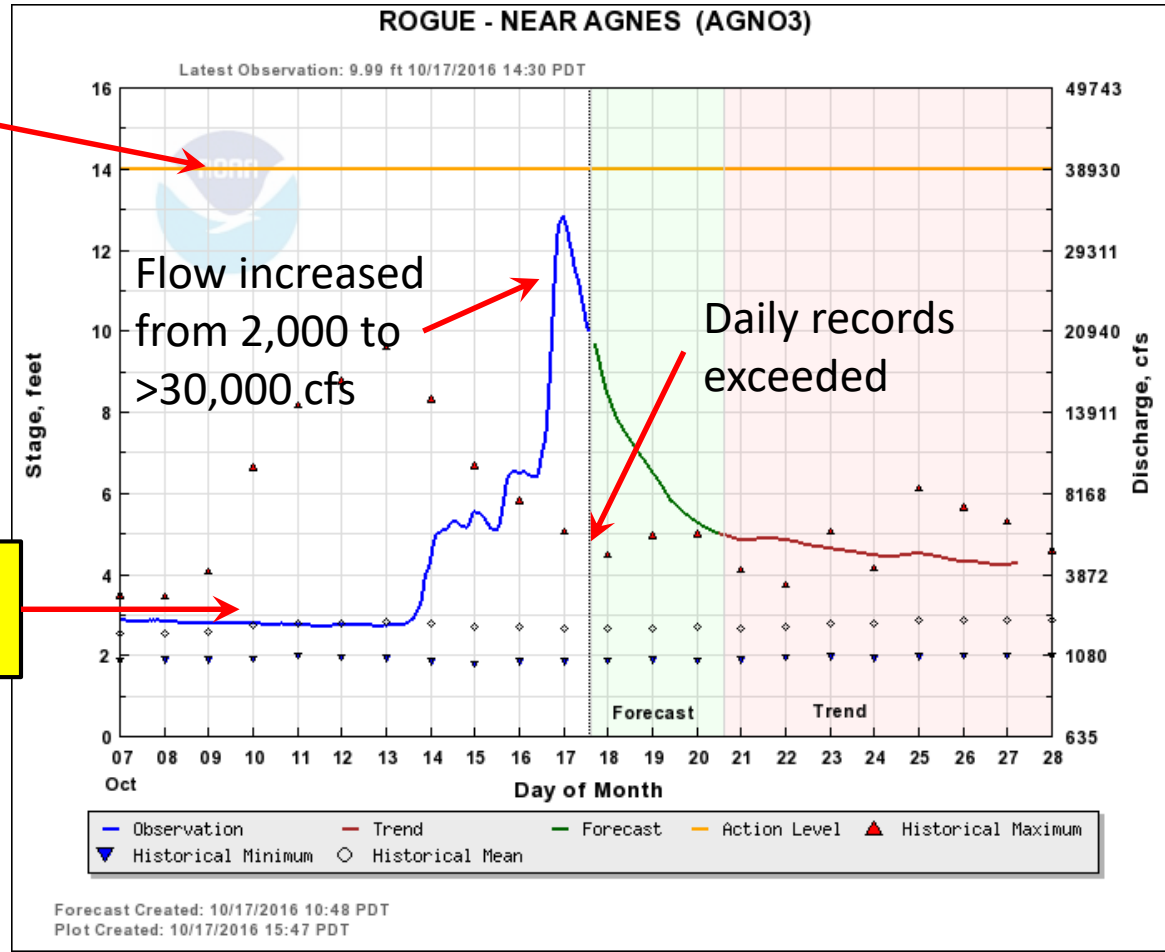
Large streamflow response along a broad region of coastal Washington, Oregon and California [image 3PM, October 17 from USGS real-time conditions]



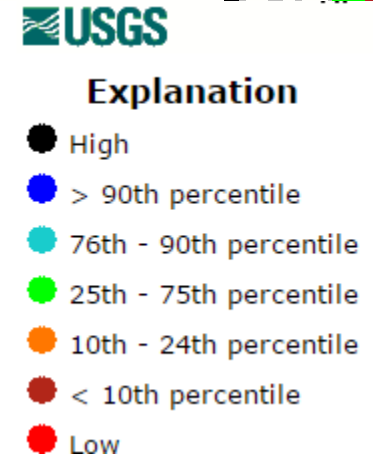
# Streamflow Response

Rivers generally did not exceed warning or flood stage

Prior flows near average for mid-October



Large streamflow response along a broad region of coastal Washington, Oregon and California [image 3PM, October 17 from USGS real-time conditions]

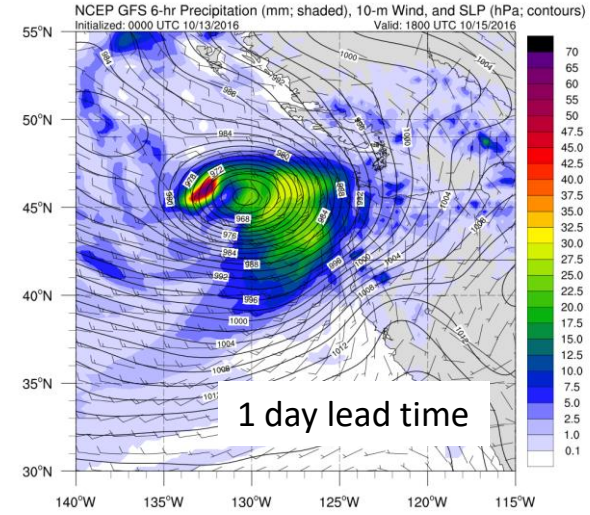
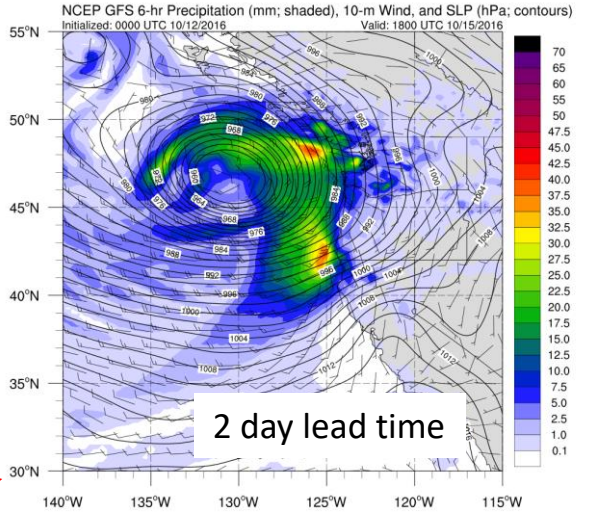
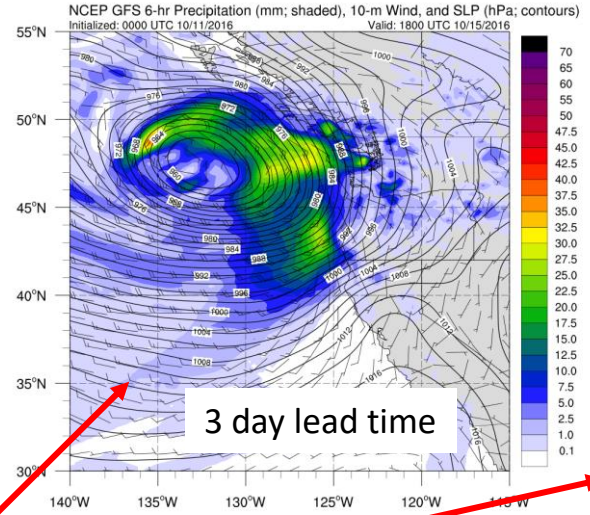
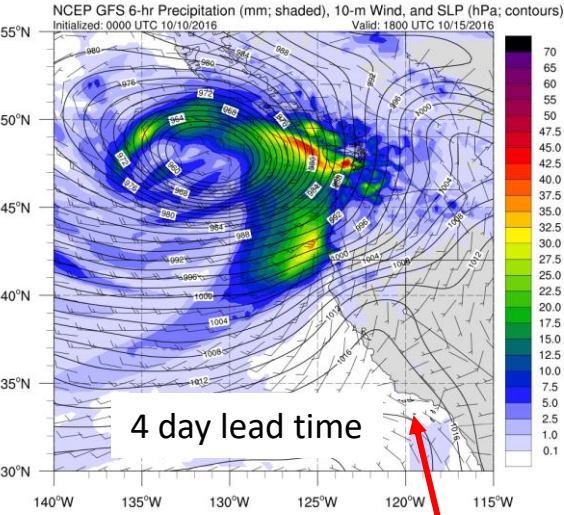


Many rivers set daily flow records; some peak flows approached ~1 year return period. However, widespread damaging flooding did not occur (despite large precipitation accumulations) because of low antecedent soil moisture and streamflow in the region.

# Forecast Errors

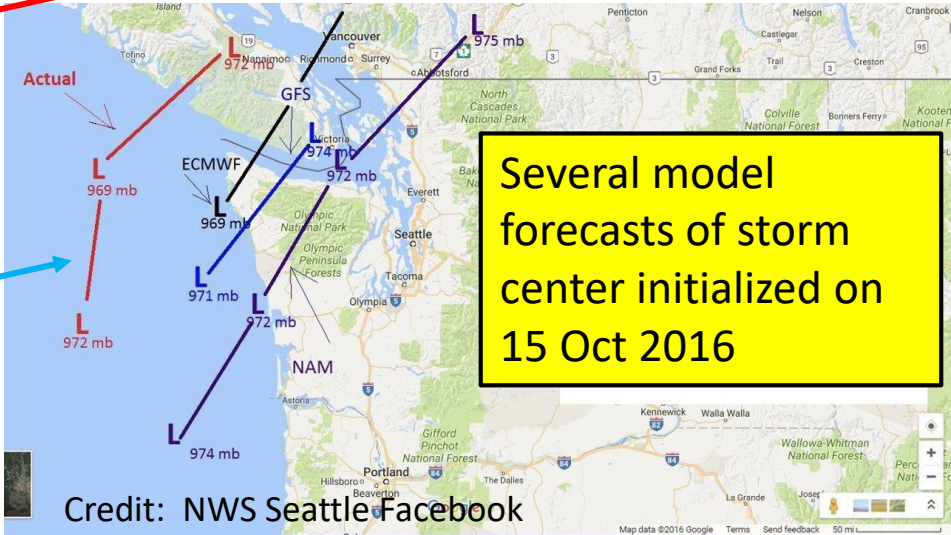


Forecast shifting south



GFS forecast trend indicated a closer trajectory onshore as lead time decreased

Actual storm trajectory



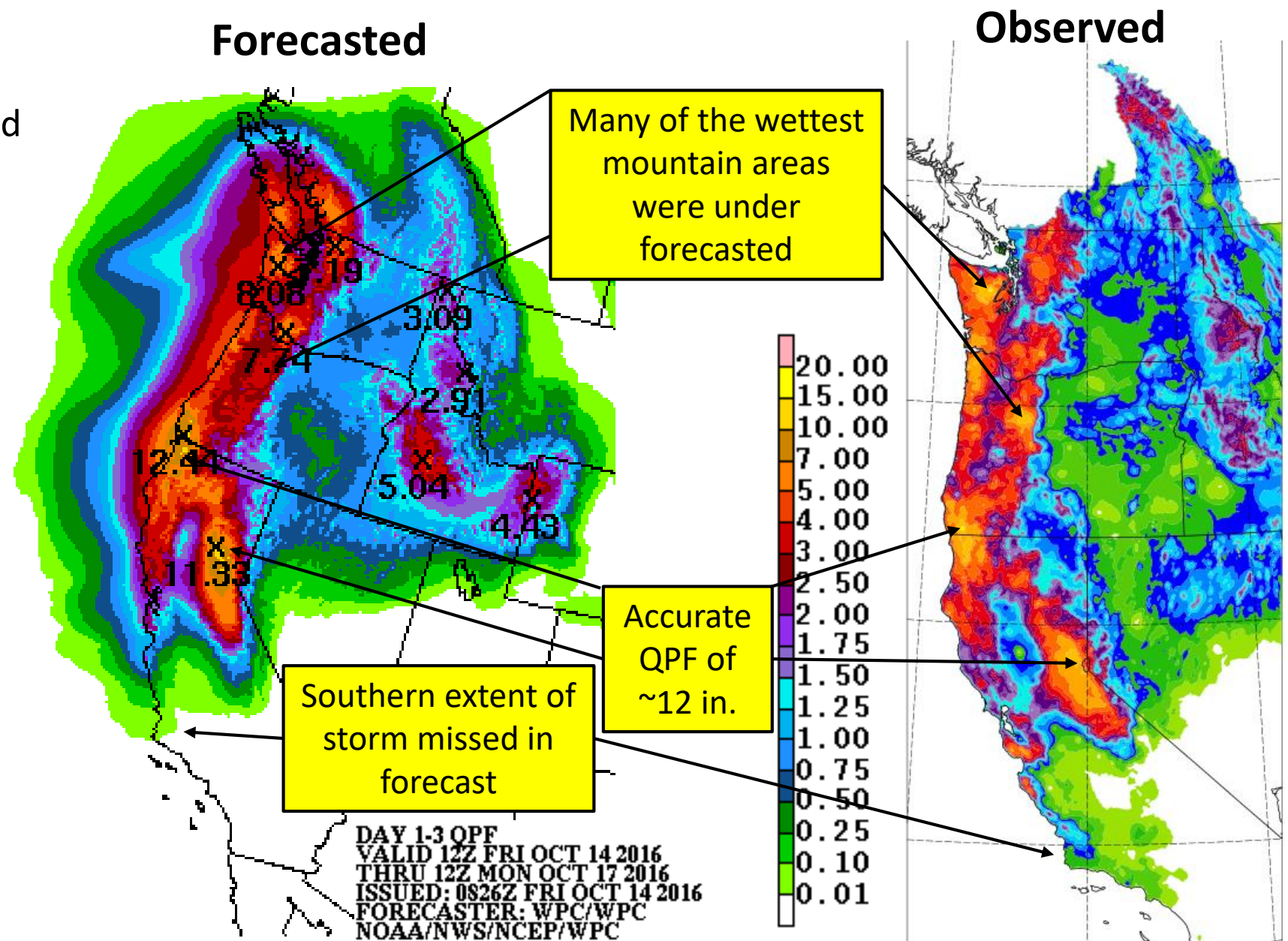
Several model forecasts of storm center initialized on 15 Oct 2016

Northerly track kept strongest winds to the north and offshore of Washington

Credit: NWS Seattle Facebook

# Comparison on WPC QPF issued 1200 UTC 14 Oct 2016 to Stage IV 72-h QPE 1200 UTC 14-17 Oct 2016

- Many mountainous areas were slightly under forecasted while low-lying valley areas were over forecasted
- Southern CA coast under forecasted up to 2 in.
- Maxima over the N. Sierra Nevada and Coastal Range near the OR/CA border were accurately forecasted
- Considering the extreme nature of this event, precipitation amounts and locations were overall well forecasted for the Western U.S.



# Storm Summary

- Two back to back ARs impacted the Western U.S. over the weekend of 14-17 October 2016
- Precipitation >400 mm occurred in some locations, and snow accumulations at high elevations both on the coast and inland (up to 18" according to NWS Reno)
- Wind gusts were as high as 103 mph, with sustained winds 20-40 mph



Tillamook County Pioneer,  
EF-2 tornado damage in  
downtown Manzanita, OR  
14 Oct



Fife, WA (@MattLorchQ13FOX, 15 Oct)



Seattle, WA (@KSeattleWeather, 15 Oct)



Olympia, WA (@Q13FOX, 15 Oct)

*Provided by A. Wilson*