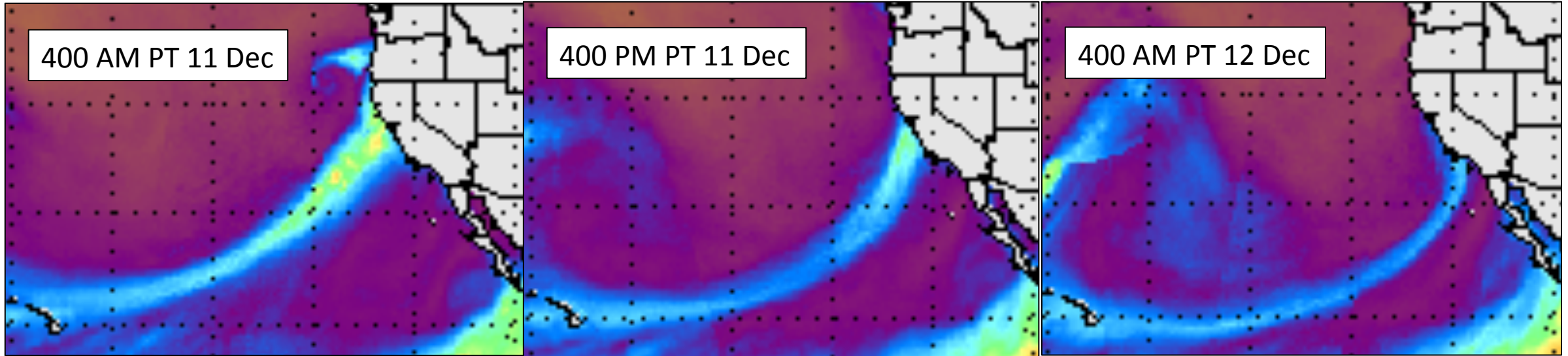
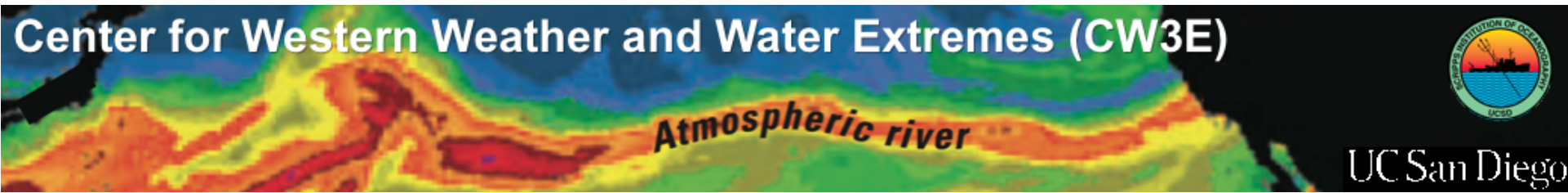
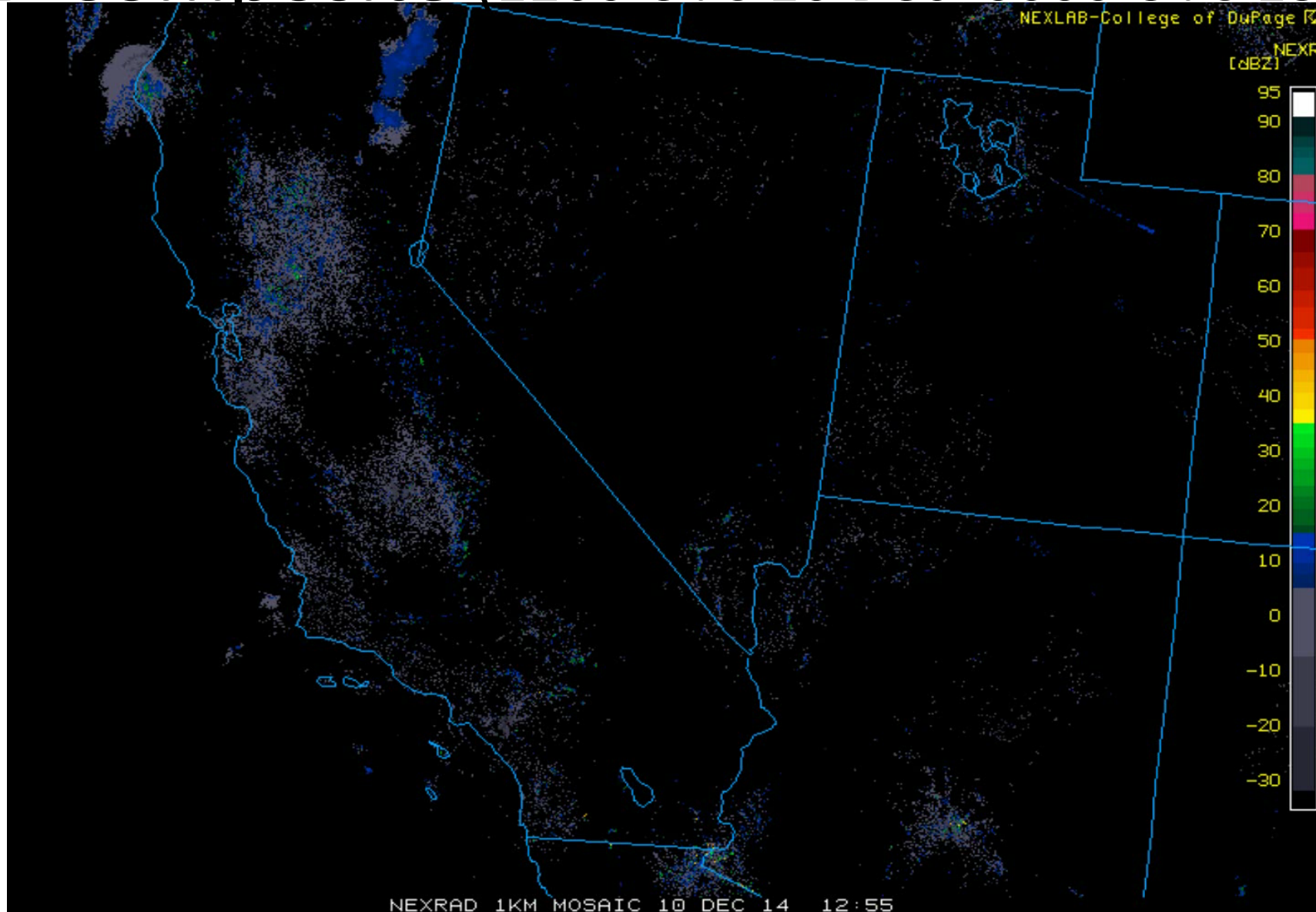




California Storm of 10–12 December 2014: A Synopsis Including Landfalling Atmospheric River Conditions

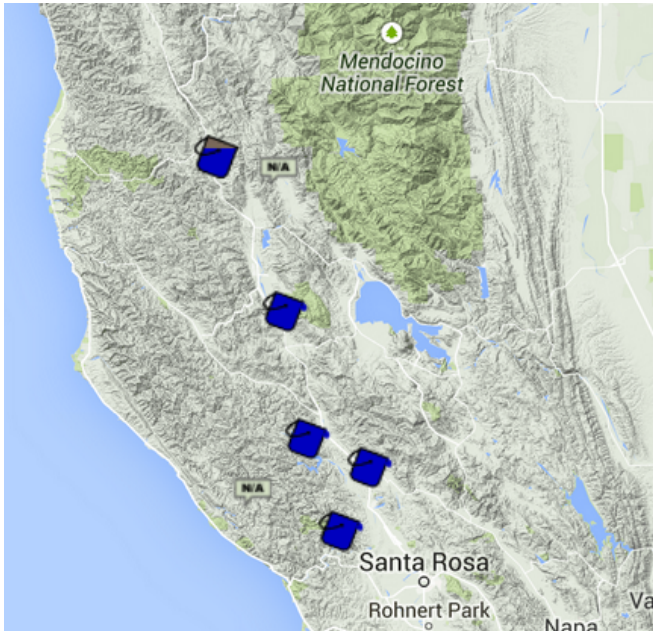
Prepared by Marty Ralph and Brian Kawzenuk, CW3E at UC San Diego/Scripps Institution of Oceanography

NEXRAD Composite (1200 UTC 10 Dec–0000 UTC 13 Dec)

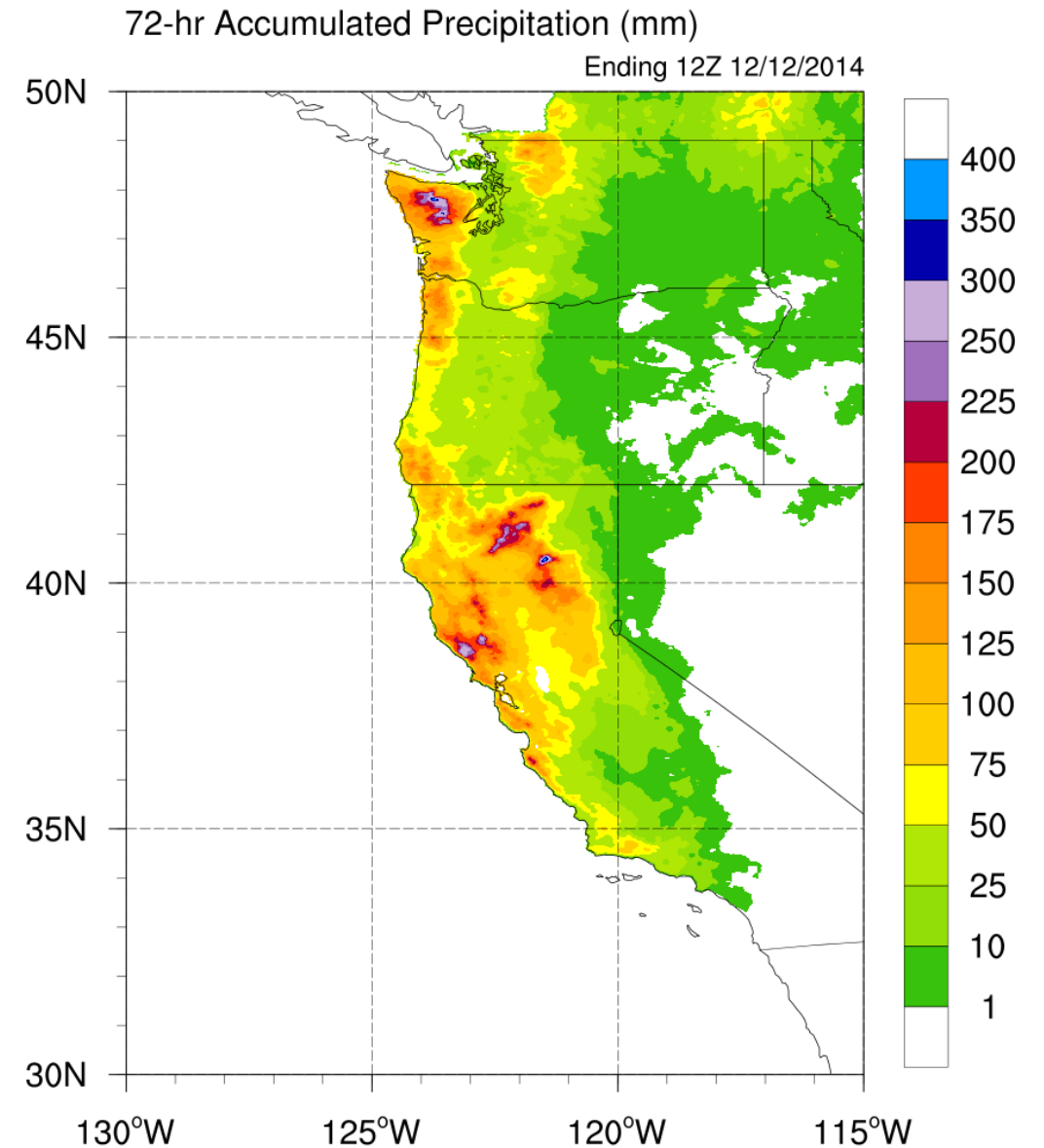


Precipitation – 72-hour accumulated

- Maximum 3-day precipitation totals reached over 350 mm (~14 inches) in northern California and northwest Washington
- Up to 300 mm of precipitation fell over Sonoma County
- Nearly all of central and northern California received over 50 mm of precipitation



DWR instrumentation indicate high soil saturation prior to the event

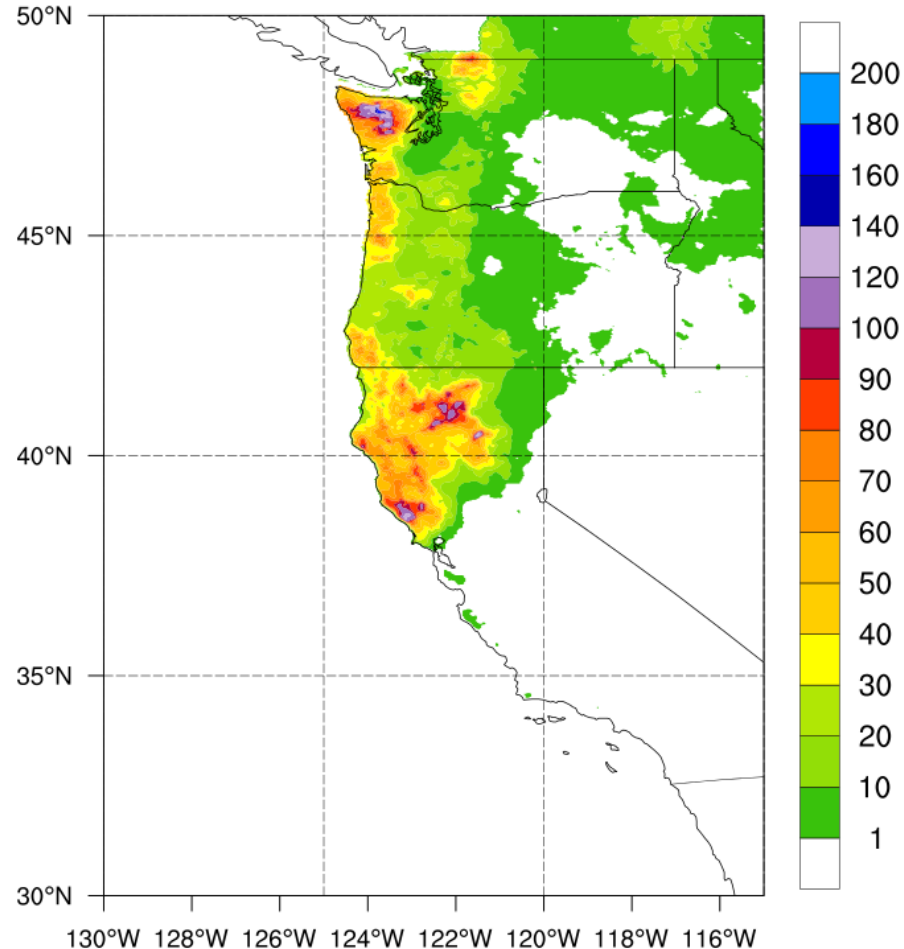


NCEP Stage IV Precipitation data

Precipitation – 24-hour accumulated

24-hr Accumulated Precipitation (mm)

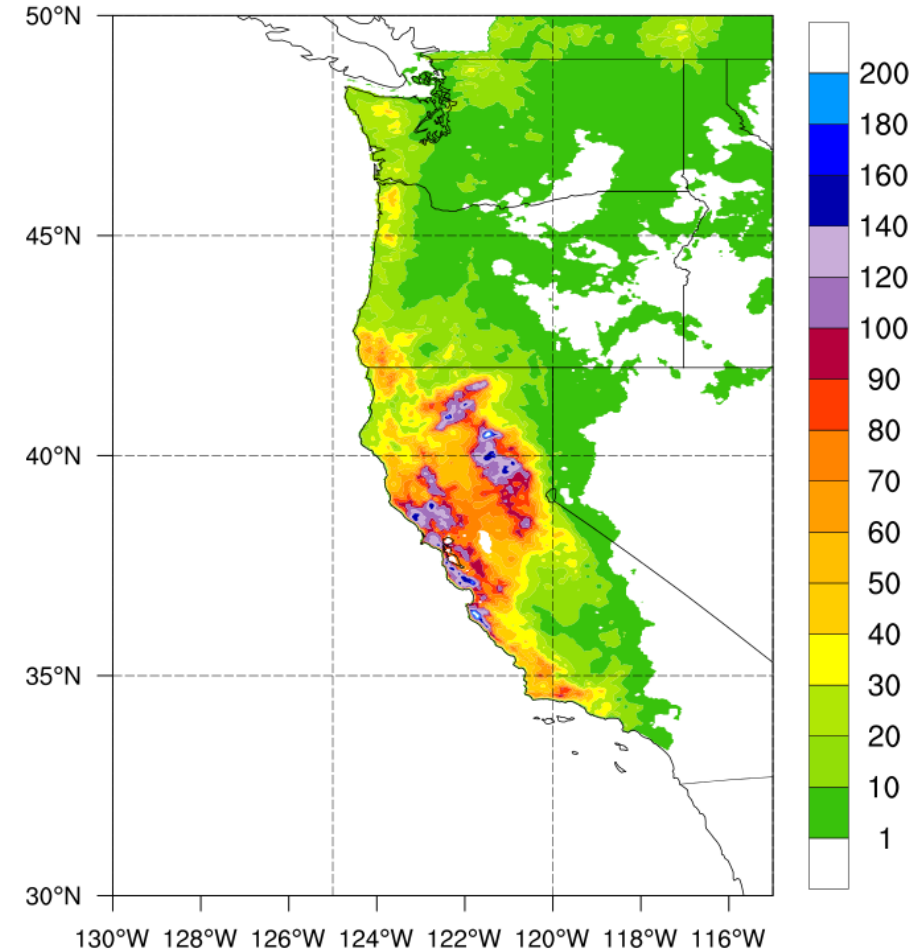
Ending 12Z 12/11/2014



- Over 200 mm of precipitation occurred over the northern Sierra Nevada in 24 hours
- Sonoma County received up to 160 mm of precipitation in 24 hours

24-hr Accumulated Precipitation (mm)

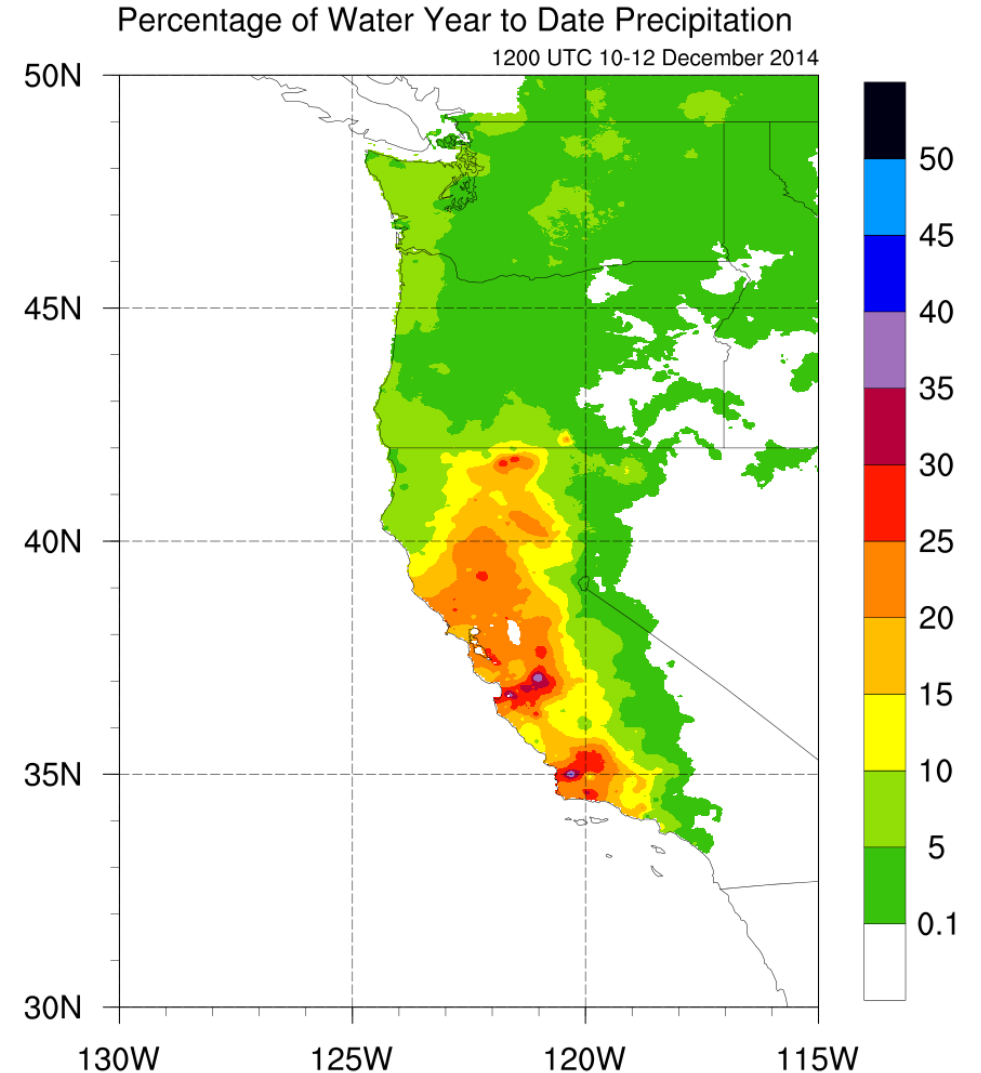
Ending 12Z 12/12/2014



NCEP Stage IV Precipitation data

Precipitation – Percentage of water year to date (Oct 14 – May 15)

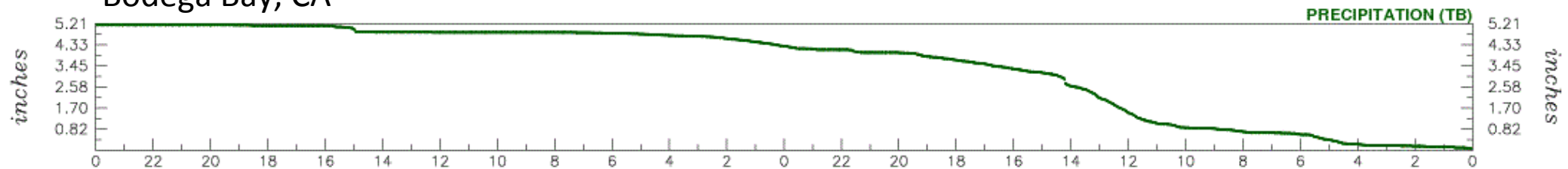
- 72-h precipitation from this event represented up to 45% of total water year to date (Oct – May) precipitation
- A majority of central Ca received at least 20% of water year to date precipitation
- The Russian River Watershed received up to 30% of water year to date precipitation



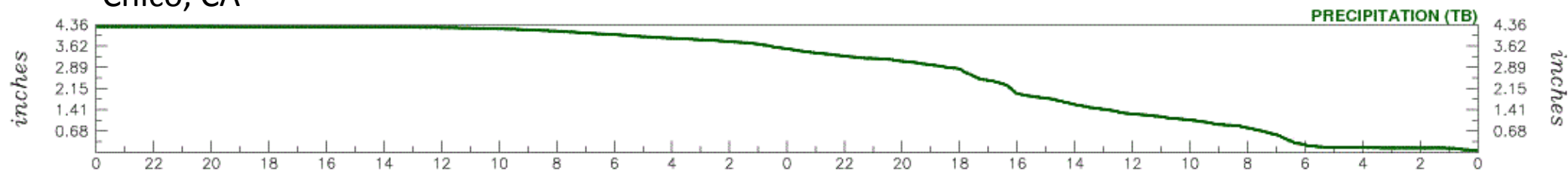
NCEP Stage IV Precipitation data

Precipitation

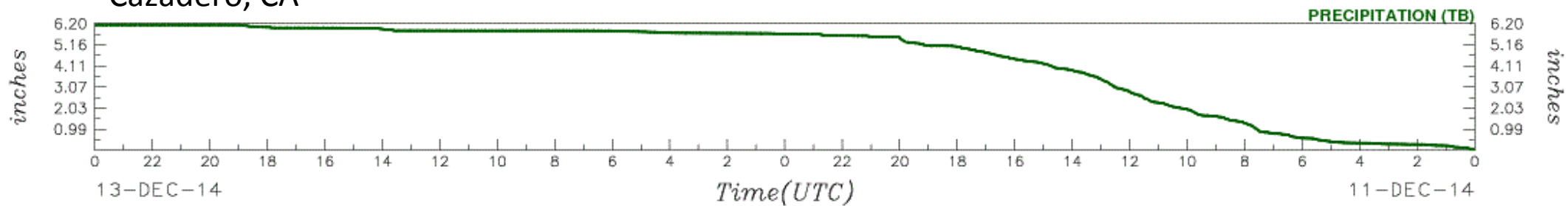
Bodega Bay, CA



Chico, CA

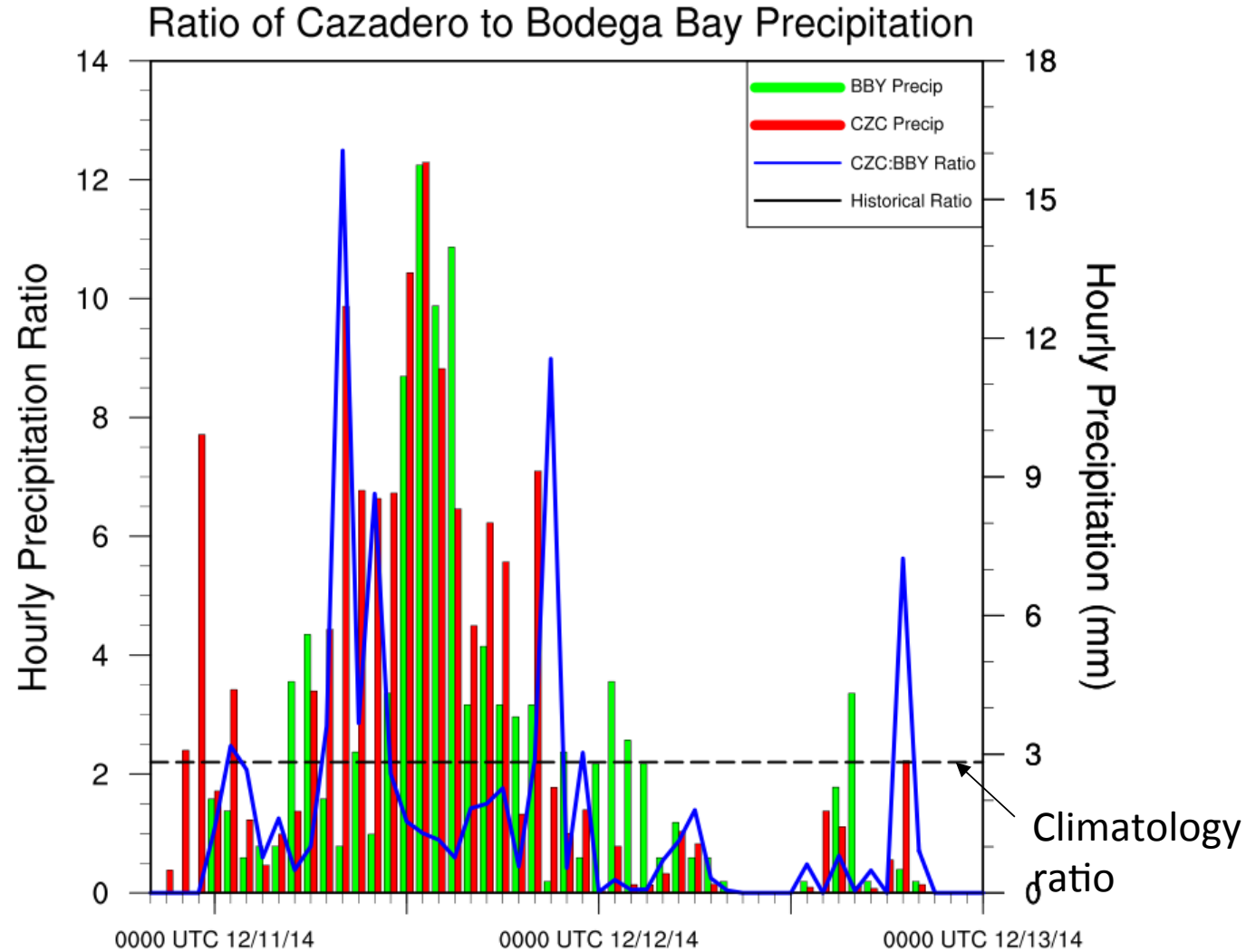


Cazadero, CA

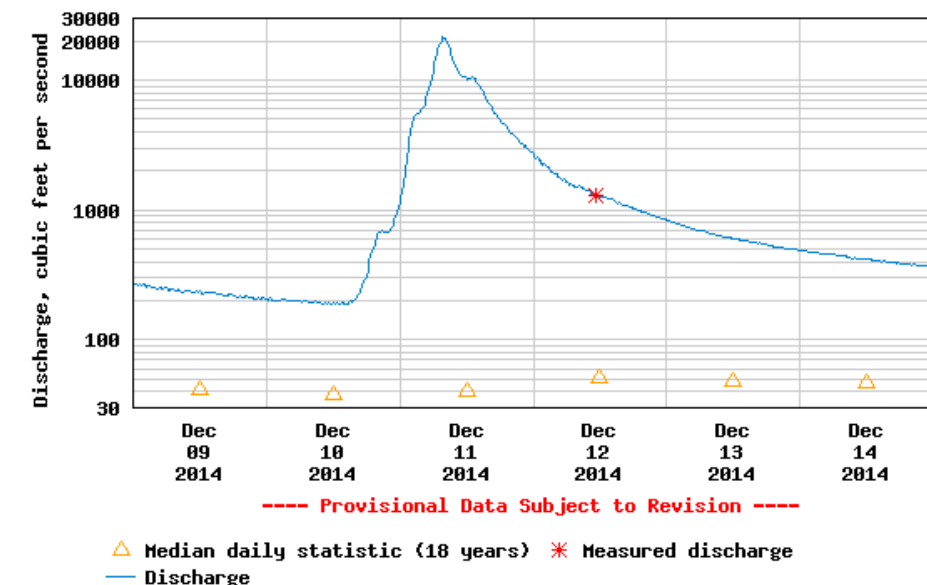


Precipitation – Ratio of Cazadero to Bodega Bay

- Climatologically, the ratio of precipitation at Cazadero to Bodega Bay is 2.2
- During this event, this ratio was only met or exceeded during 9 of 48 hours
- On 12 Dec, hourly precipitation was higher at Bodega Bay during 12 of the 14 hours when precipitation occurred



USGS 11467200 AUSTIN C NR CAZADERO CA

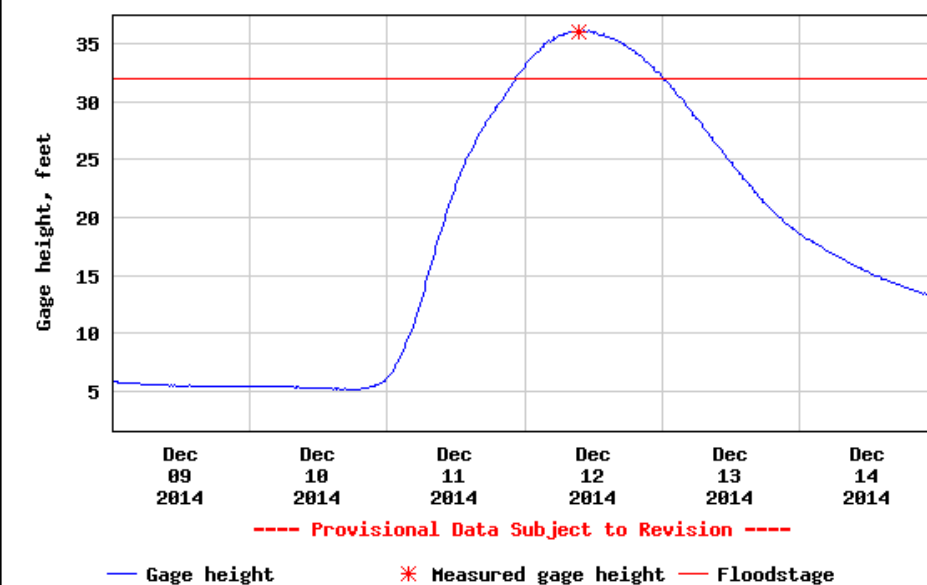


Streamflow

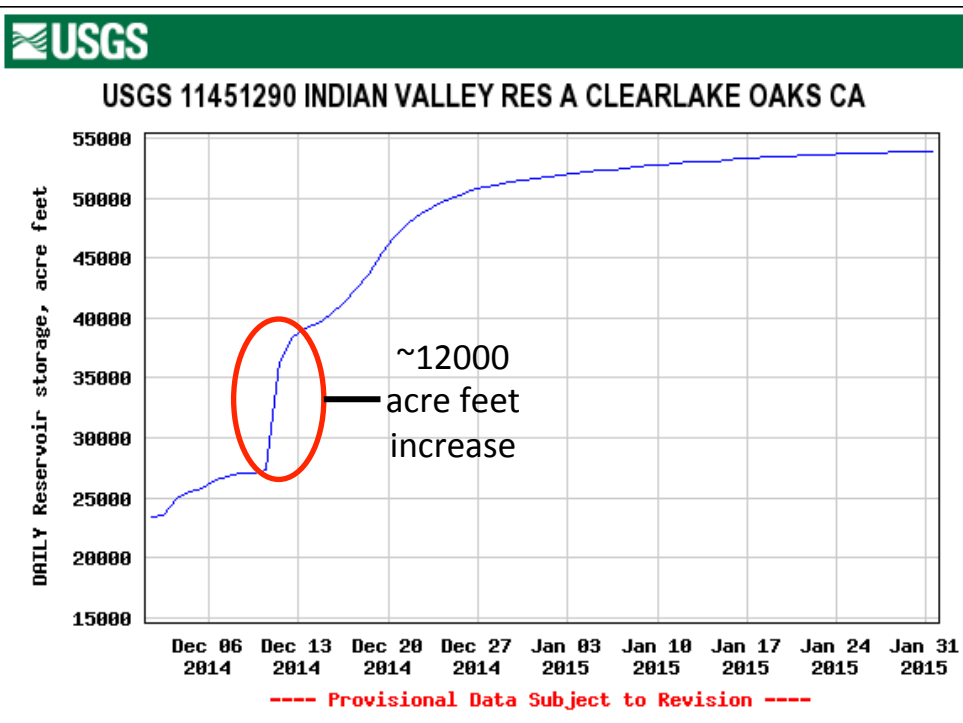
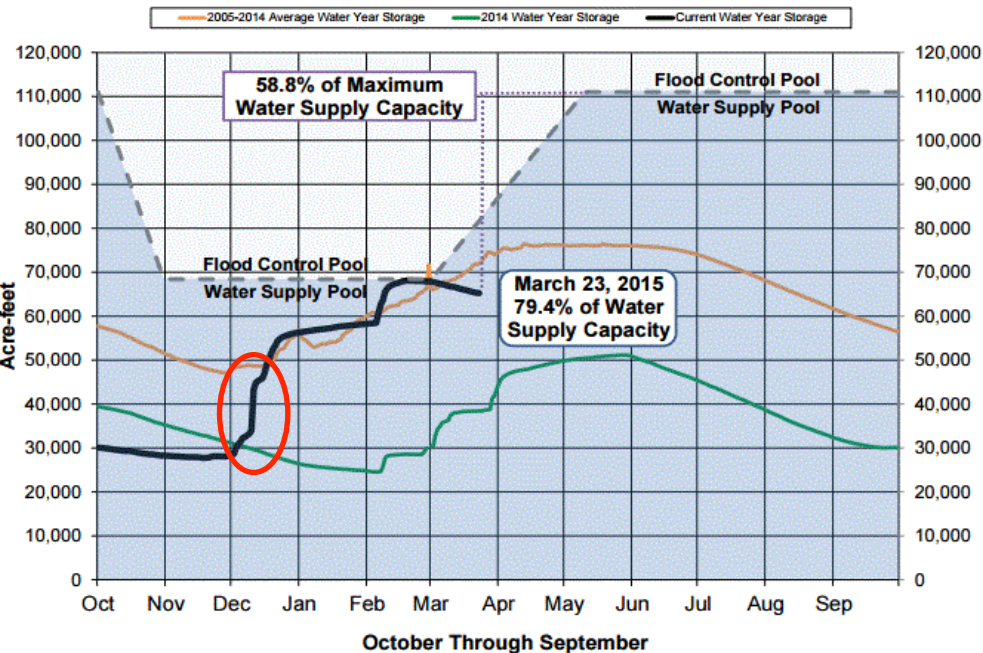
Many rivers and streams experienced flood conditions in northern California. The Russian River area was hit especially hard. For example:

- Austin Creek set a new record of 21,600 cfs (previous record was 17,700 CFS on 31 Dec 2005)
- The Russian River at Guerneville reached 36.10 feet, 4 feet above flood level
- Sonoma County declared a state of emergency
- Schools were closed
- Many roads were closed

USGS 11467000 RUSSIAN R NR GUERNEVILLE CA



Lake Mendocino Water Supply Storage

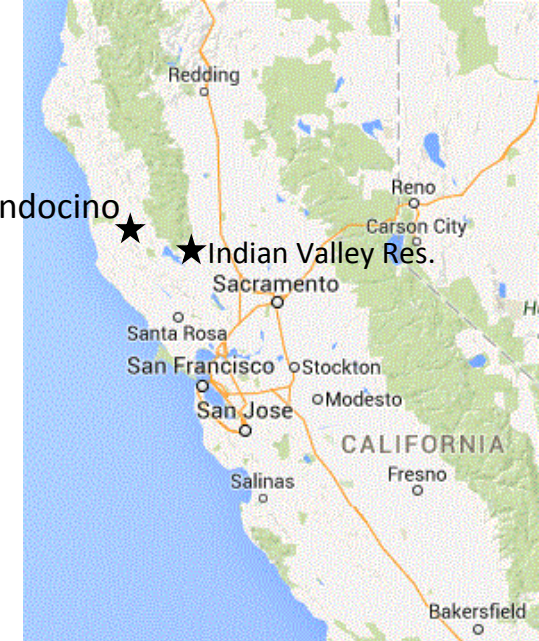


Water Supply

While the storm produced damaging flooding, it also provided beneficial water supply.

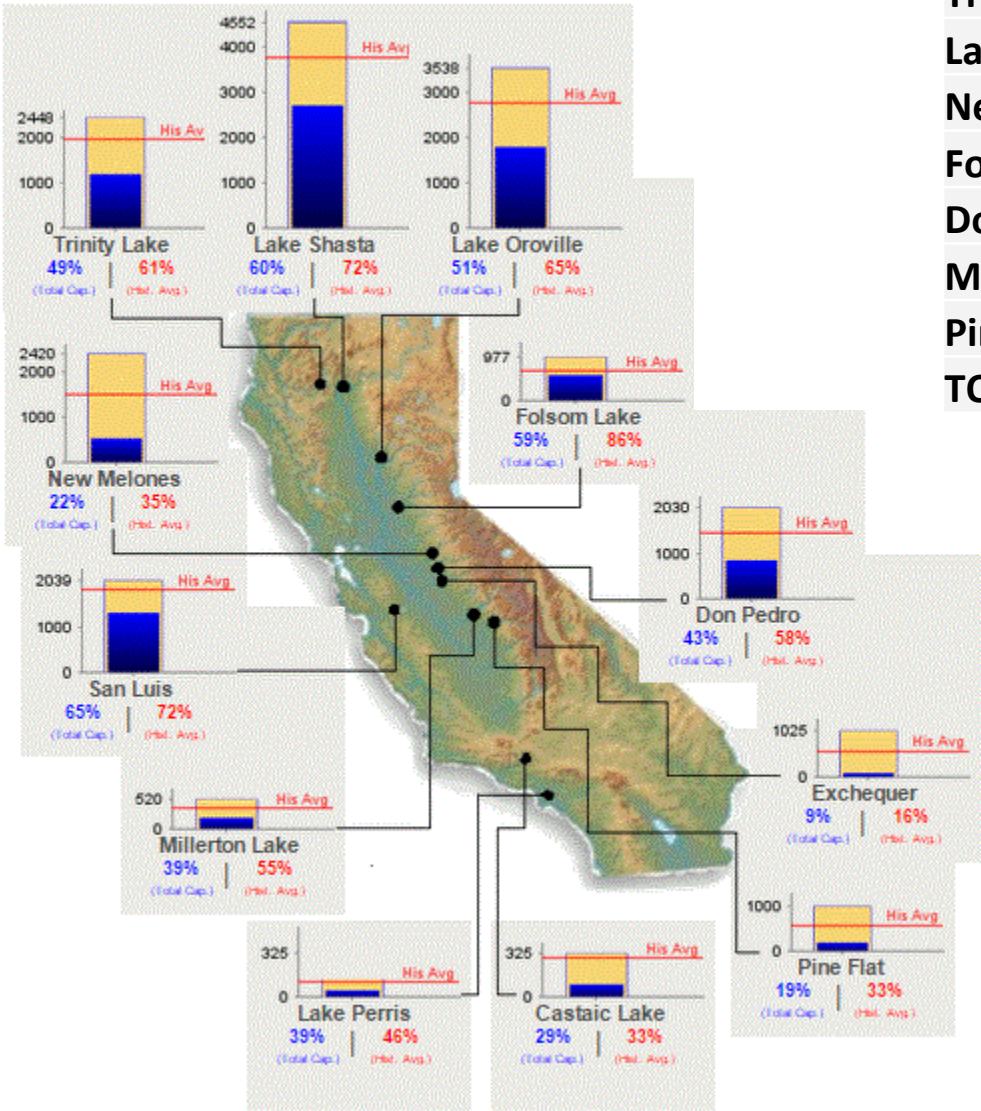
- 15,000 acre feet of water flowed into Lake Mendocino, a key water supply reservoir in Sonoma County.
- The reservoir in winter normally holds 60,000 acre feet, which leaves over 50,000 acre feet of empty space to provide flood control.
- This storm raised the water level to about 45,000 acre feet, filling roughly half the space available for water supply.
- The Indian Valley Reservoir gained about 12,000 acre feet of water.

Lake Mendocino



Reservoir Inflow

Data as of Midnight: 12-Apr-2015



While many major reservoirs received high amounts of inflow, the percentage of drought relief was small for most

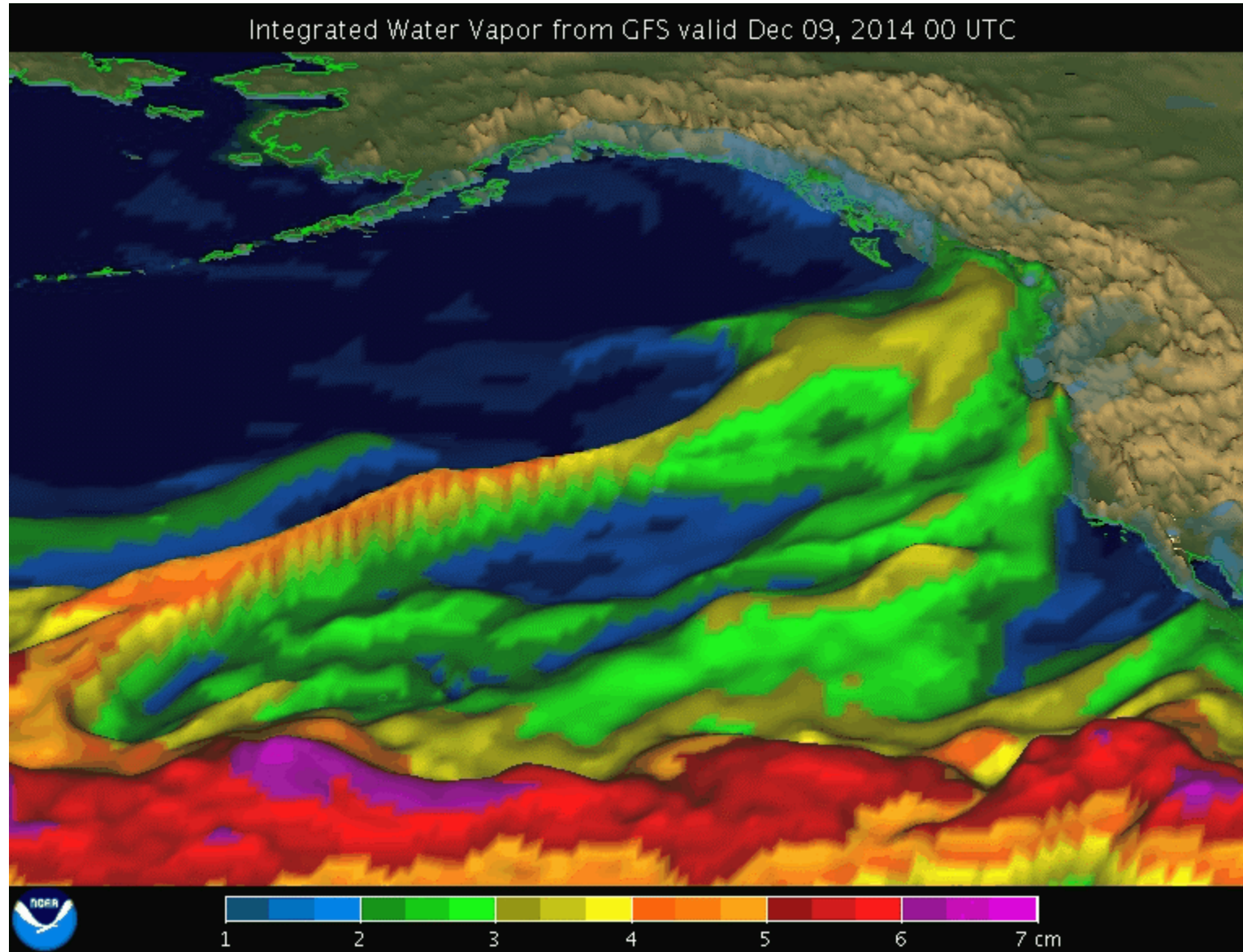
- California’s major reservoirs received ~565000 AF of inflow during the AR
- The inflow represented 9% of the storage deficit due to the drought

Reservoir Storage

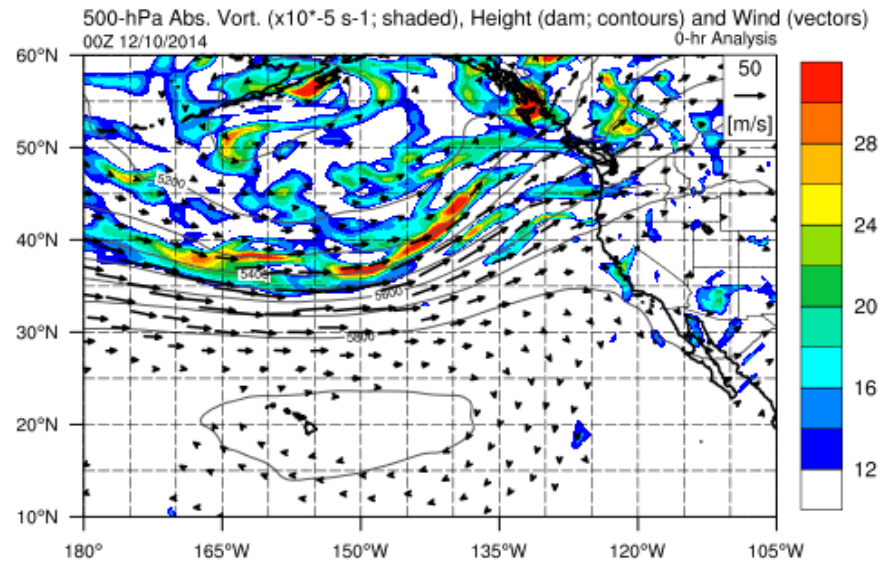
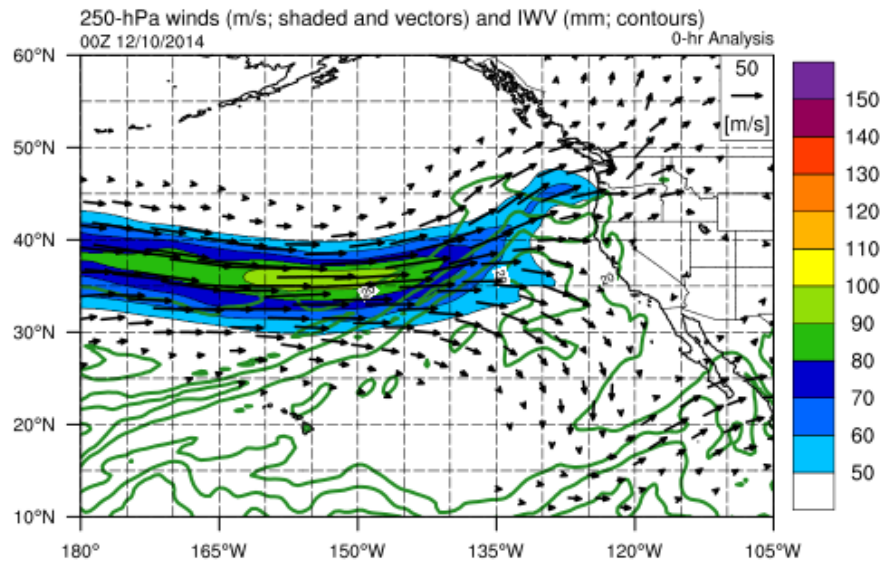
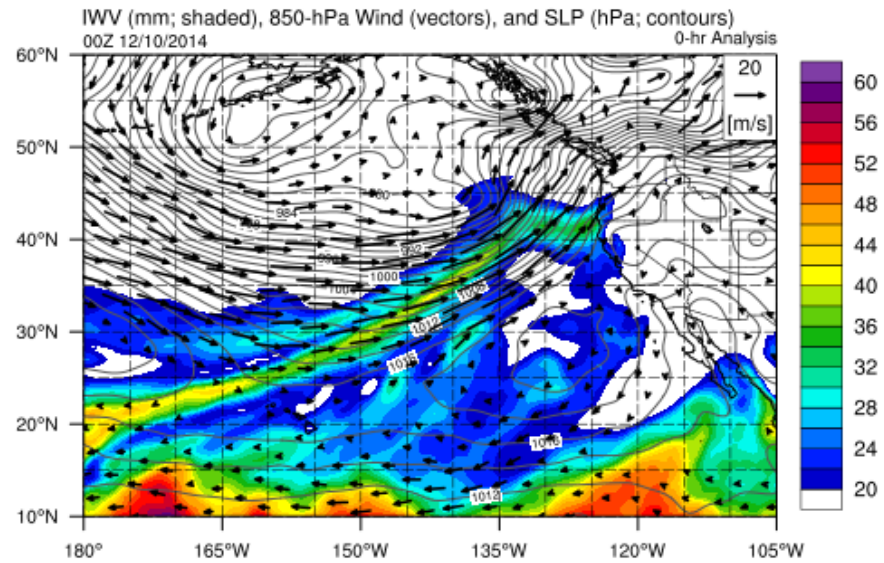
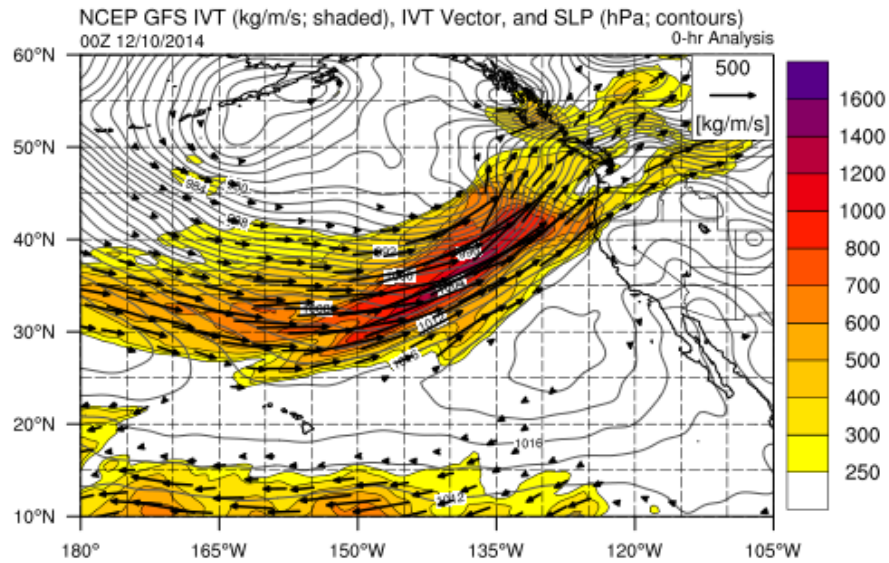
Reservoir	Percent of normal storage prior to AR	Percent of normal storage after AR	Change in storage (AF) during AR	Percent of storage deficit	Percent of WYTD (Oct-Apr) storage change during 12/10 AR
Lake Shasta	42.7	51.6	255795	16.3	16.3
Trinity Lake	36.8	43.6	79971	7.5	13.4
Lake Oroville	48.1	53.0	109399	9.8	15.0
New Melones	38.4	38.7	7086	0.8	52.2
Folsom Lake	69.4	77.6	39860	27.7	17.3
San Luis	45.9	49.8	65934	9.6	7.6
Don Pedro	58.0	58.5	6361	1.1	7.2
Millerton Lake	75.7	73.4	1931	3.4	11.5
Lake Perris	43.9	47.7	4052	7.0	-96.0
Castaic Lake	41.3	44.7	9463	6.4	-71.9
Pine Flat	32.0	31.9	1932	0.7	2.4
TOTAL	45.7	50.5	581784	8.9	14.0

- Total reservoir storage increased ~582000 AF, representing a 5% increase in normal storage percentage and 9% of the total storage deficit
- The storage increase that occurred during this event represents 14% of the total water year to date (WYTD; Oct 2014–Apr 2015) storage increase

A Strong Atmospheric River made landfall associated with the heavy precipitation

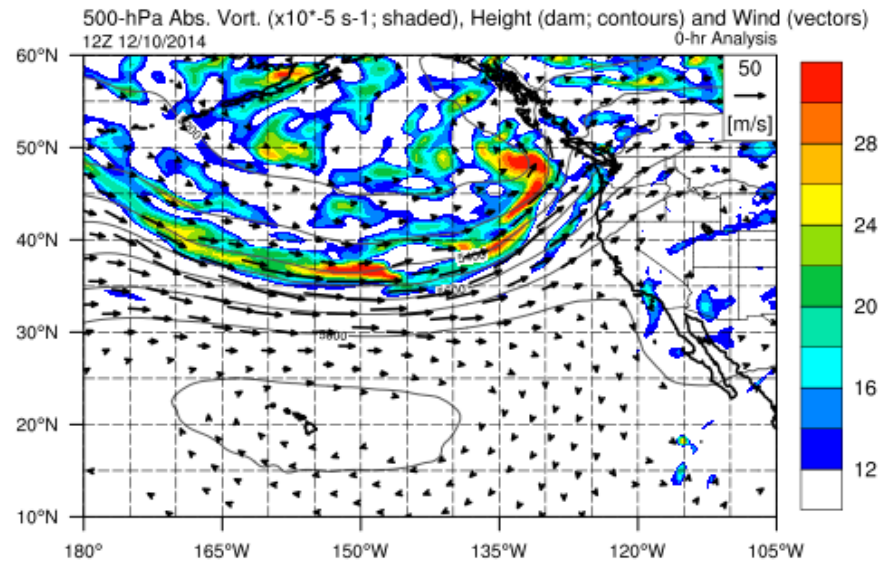
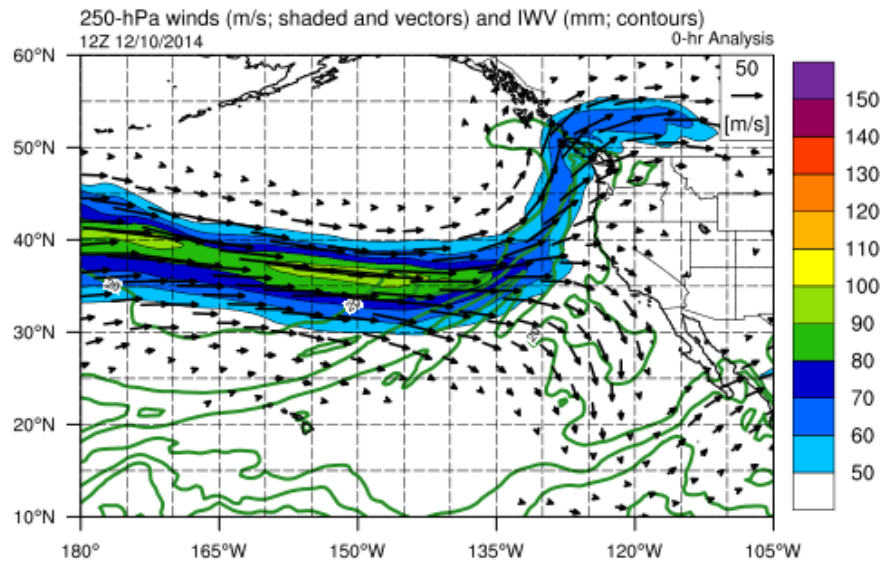
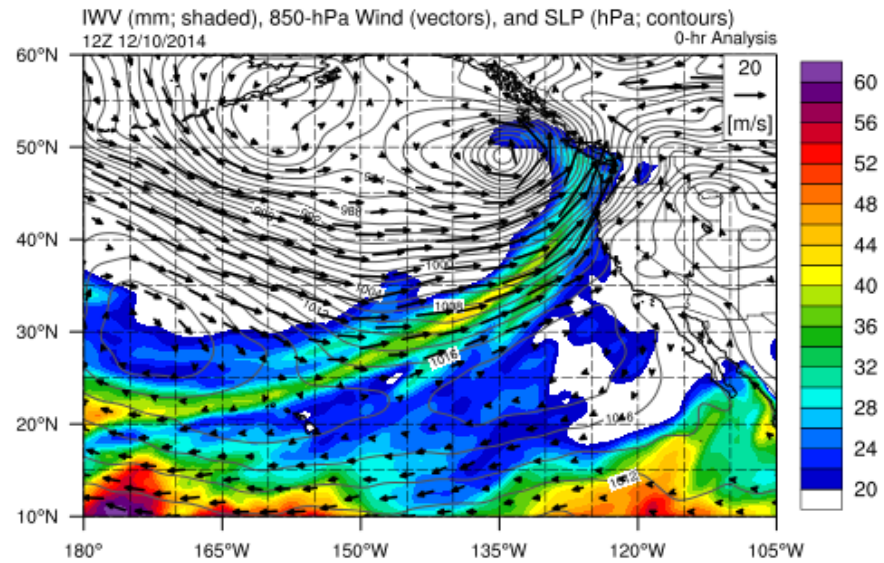
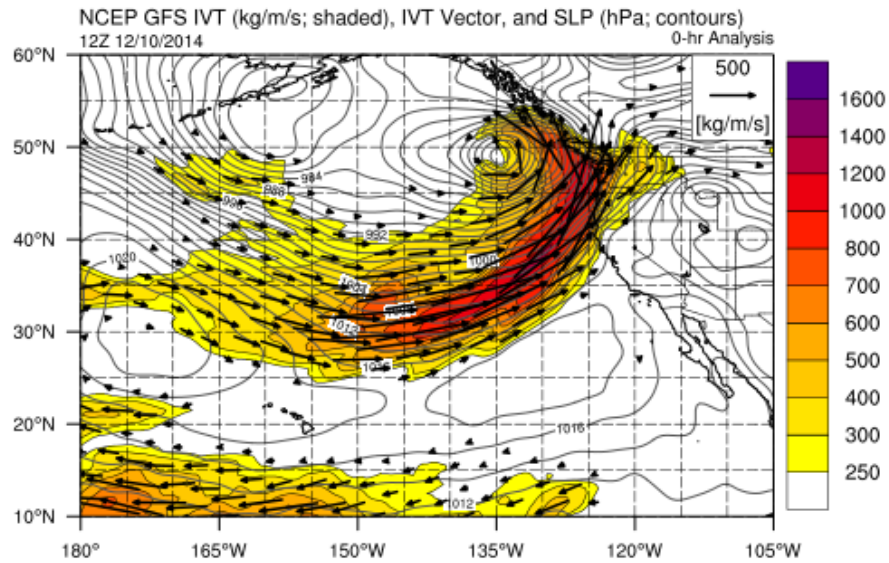


NCEP GFS Analysis – Valid 0000 UTC 10 Dec 2014



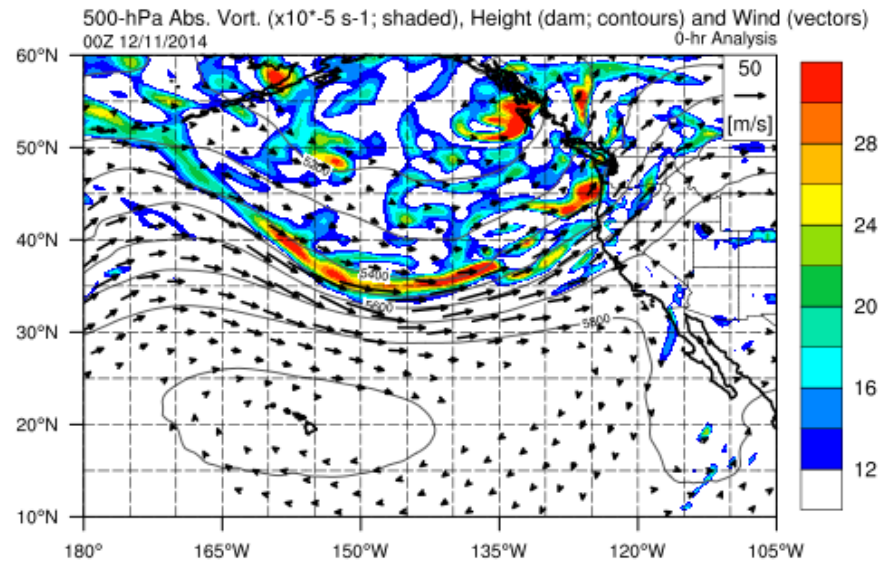
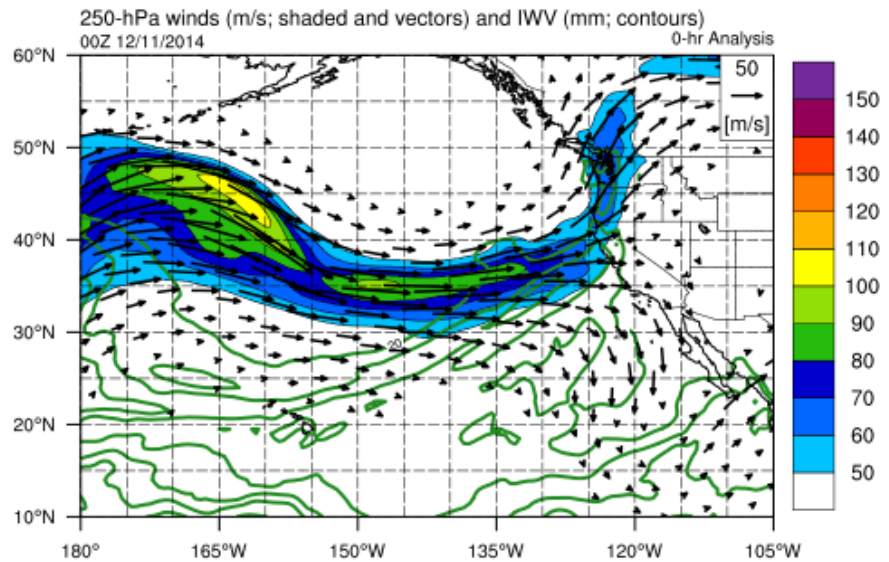
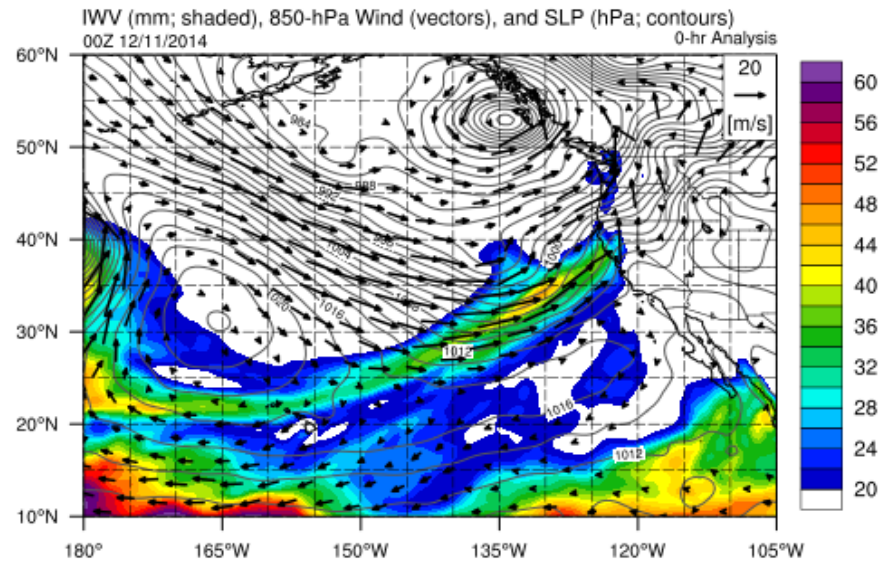
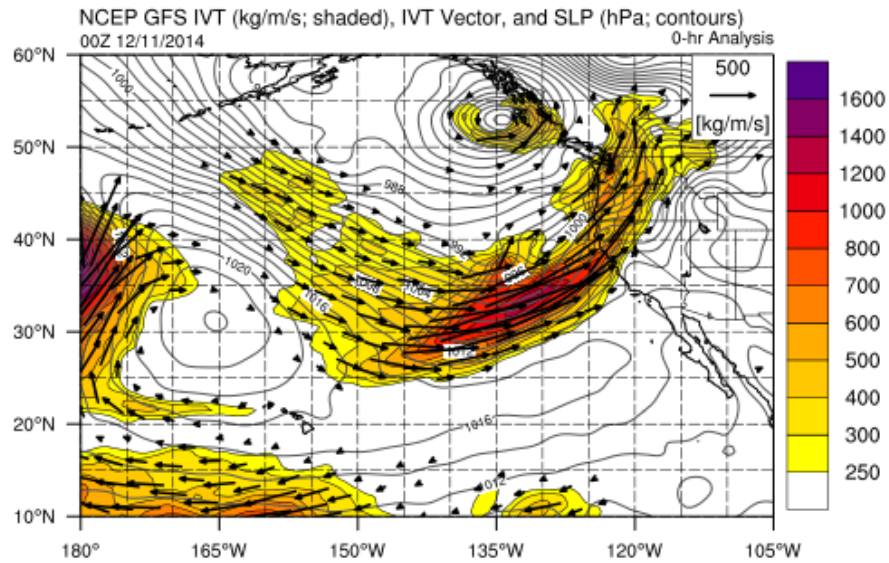
- AR made landfall over Oregon Coast
- Associated low pressure system was located in the exit region of a 90–100 m s⁻¹ jet streak

NCEP GFS Analysis – Valid 1200 UTC 10 Dec 2014



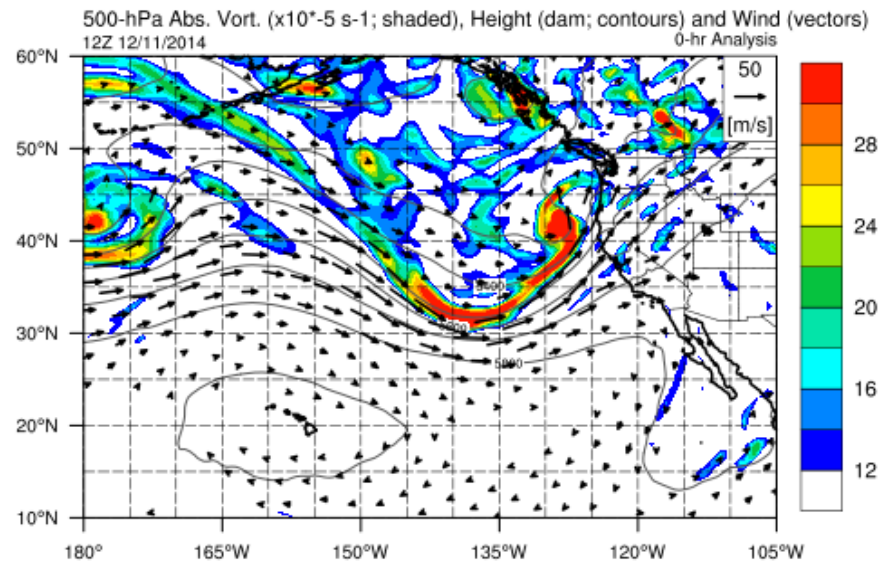
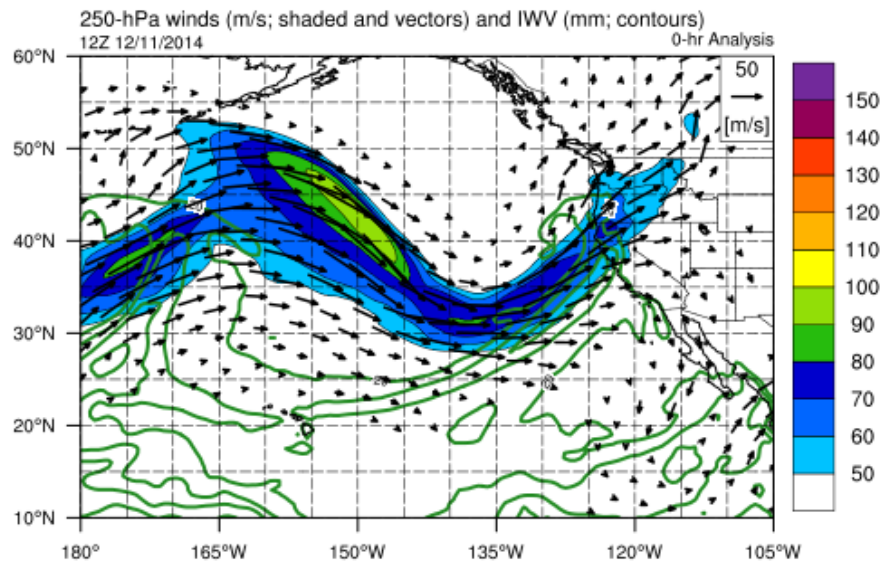
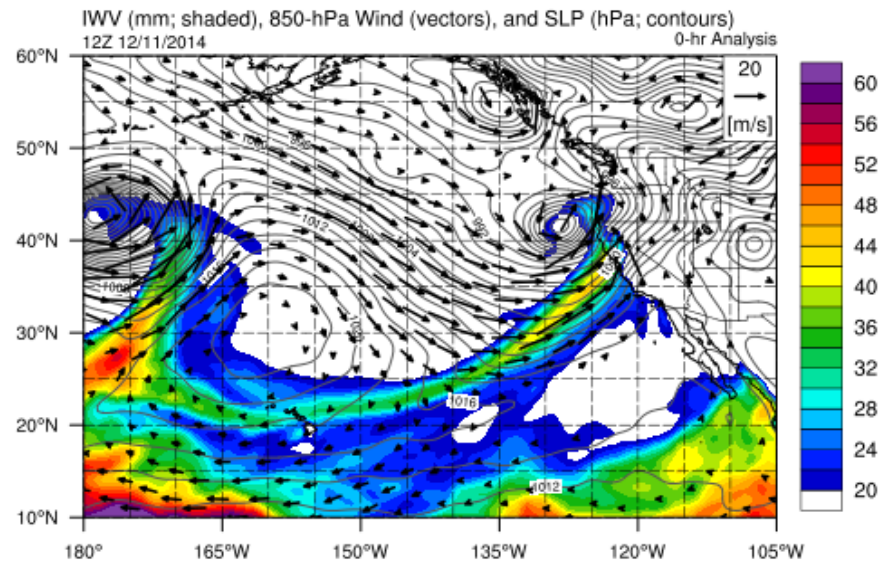
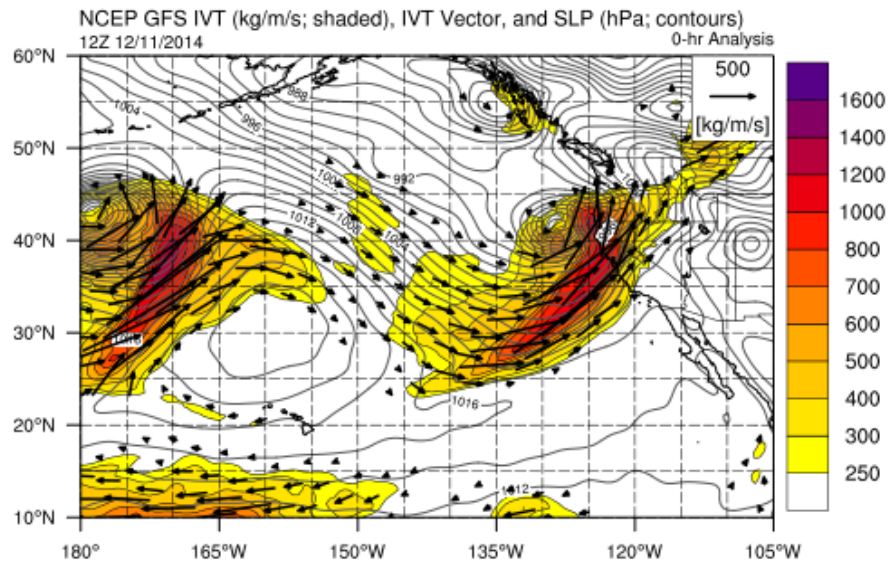
- High values of IWV (~ 30 mm) and IVT ($>700 \text{ kg m}^{-1} \text{ s}^{-1}$) moved inland over the Pacific Northwest and precipitation rate increased

NCEP GFS Analysis – Valid 0000 UTC 11 Dec 2014



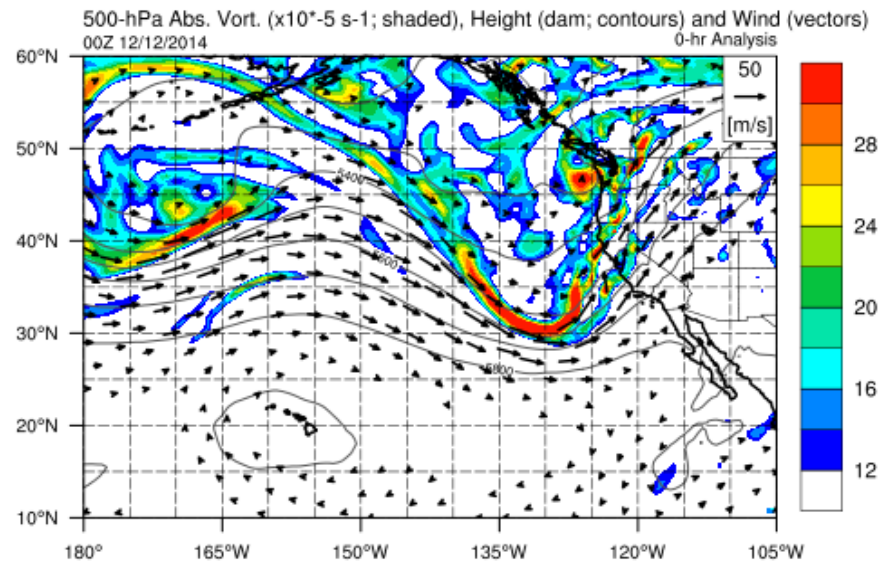
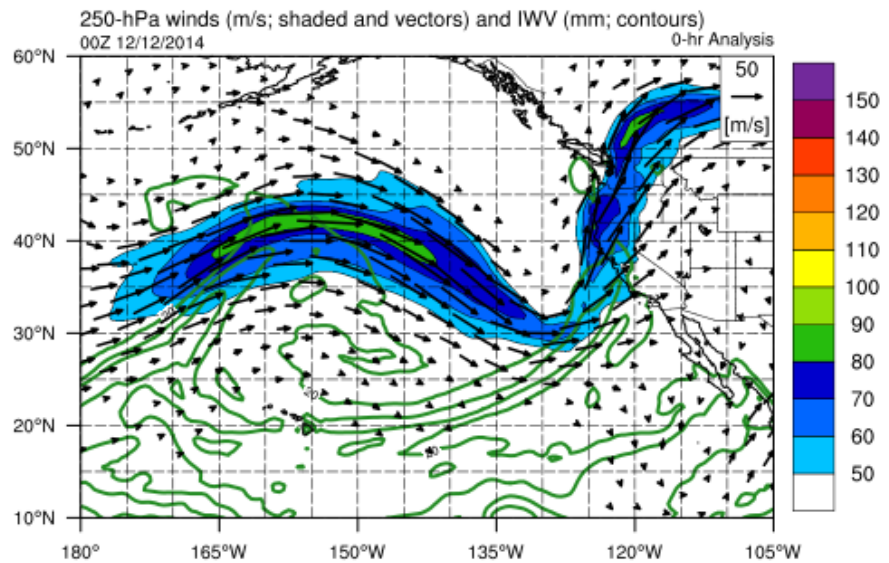
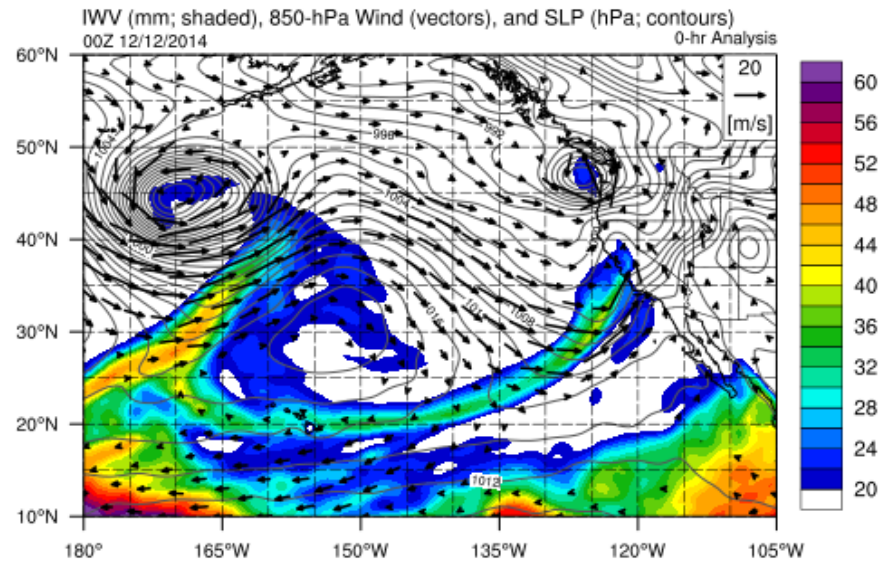
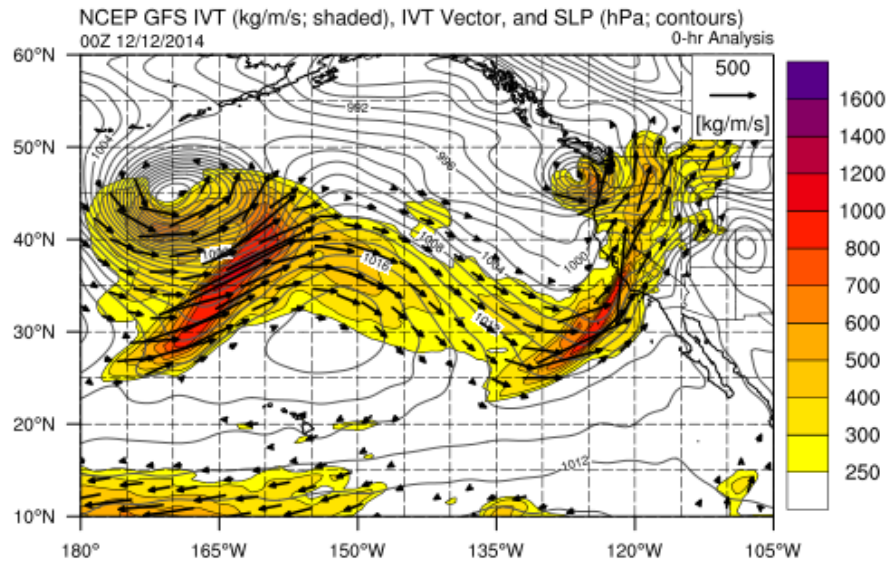
- Initial low pressure system moved North and AR dissipated
- Secondary low pressure system began to develop near 38°N, 136°W in the left exit region of the North Pacific Jet Streak

NCEP GFS Analysis – Valid 1200 UTC 11 Dec 2014



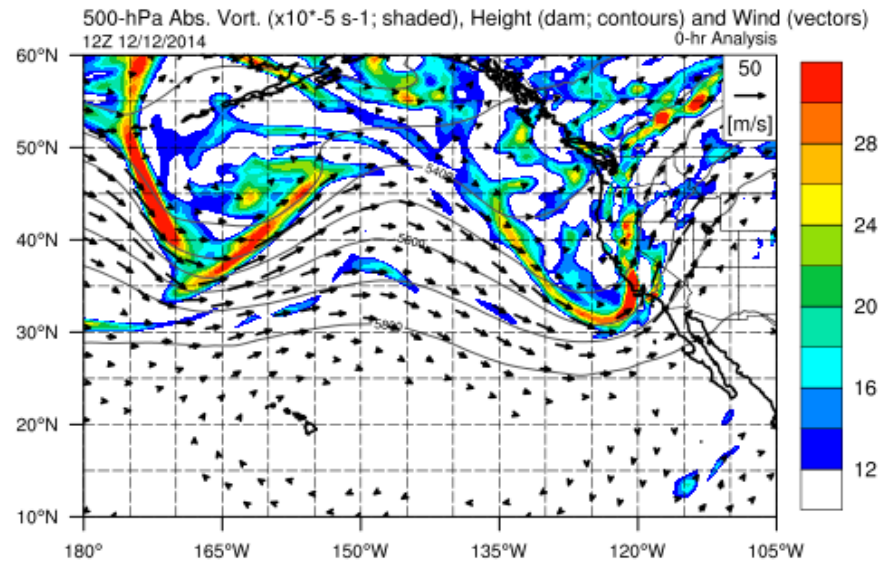
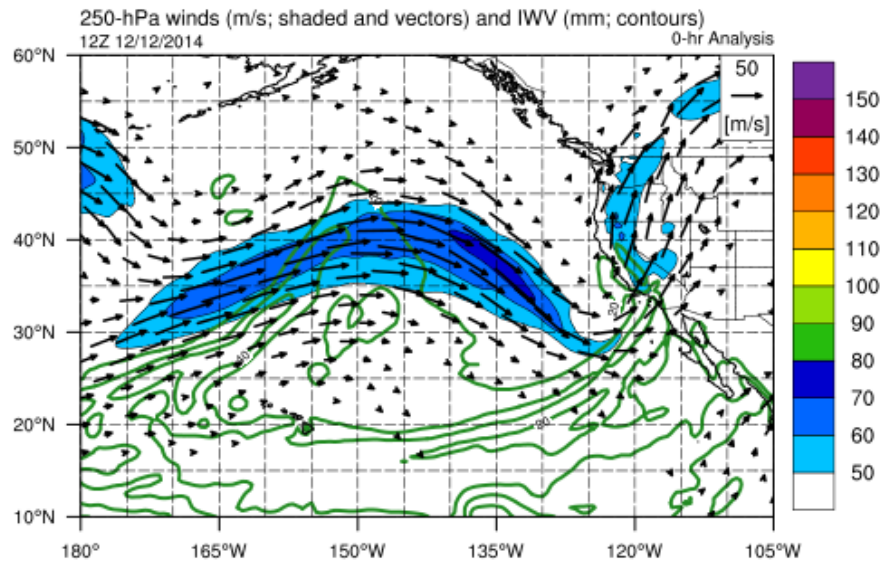
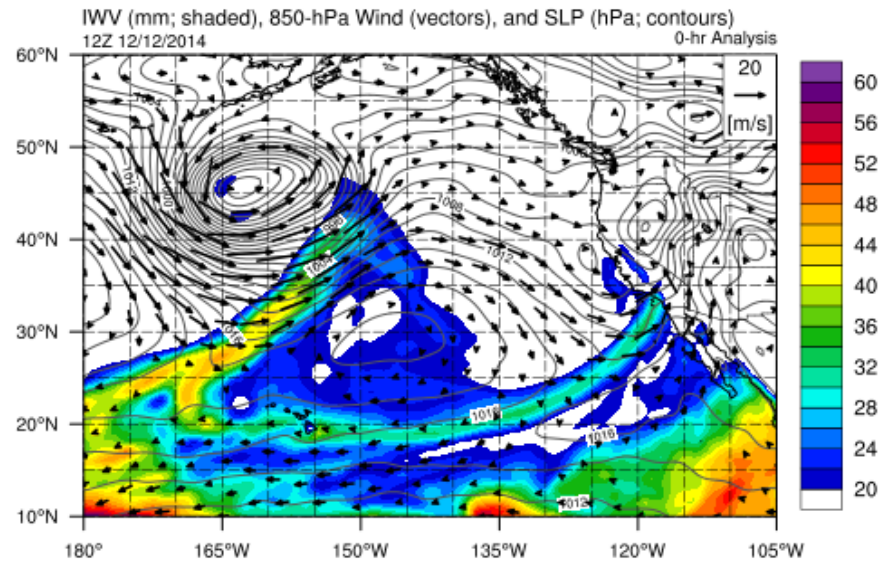
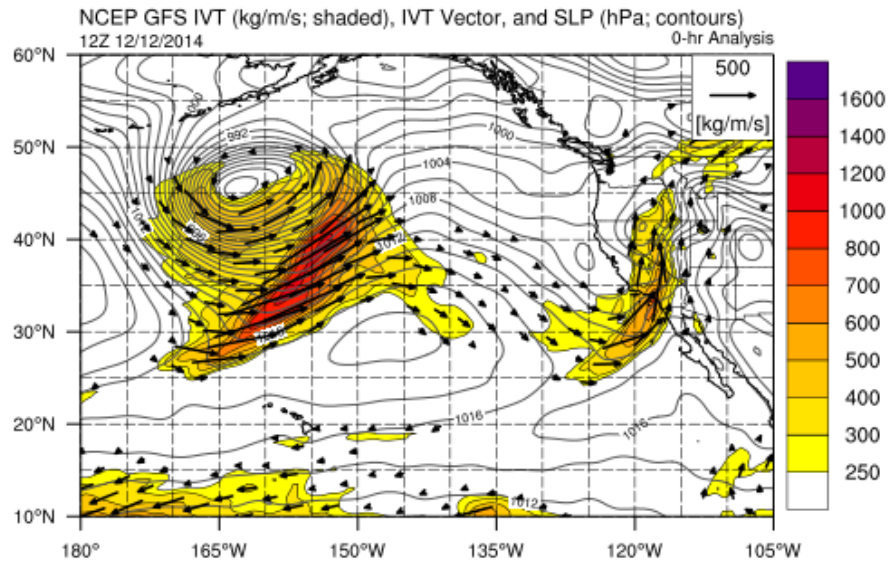
- Low pressure system deepened to >974 hPa
- Secondary region of strong IWV/IVT made landfall over northern Ca associated with a mesoscale frontal wave

NCEP GFS Analysis – Valid 0000 UTC 12 Dec 2014



- High IWV/IVT values moved inland to the Sierra Nevada, producing precipitation throughout central and northern Ca

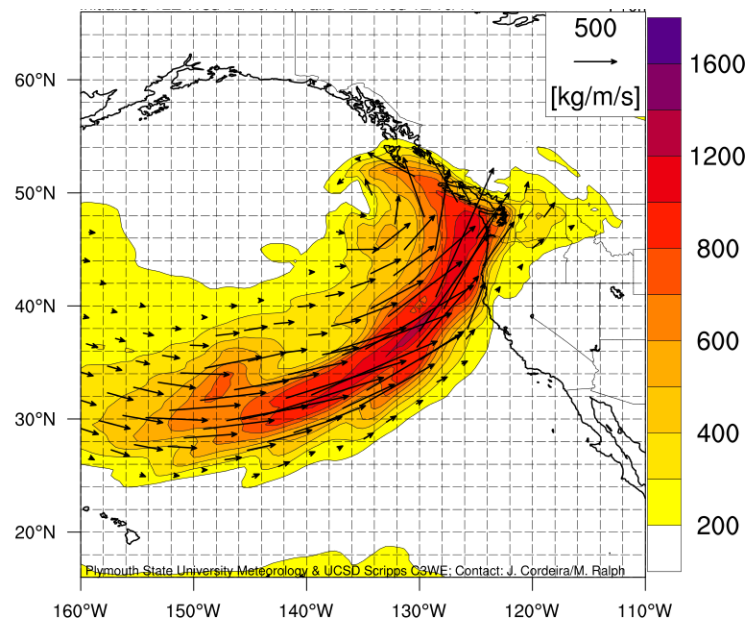
NCEP GFS Analysis – Valid 1200 UTC 12 Dec 2014



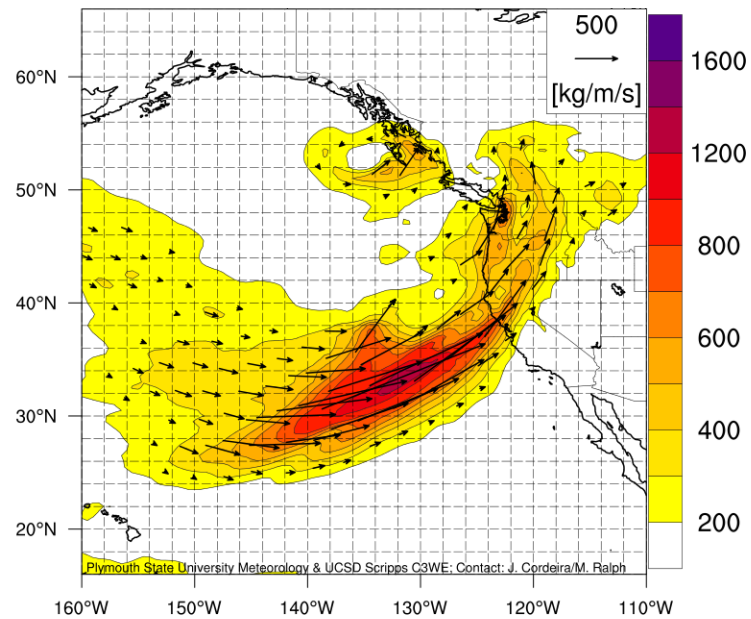
- AR translated south over Baja California and continued to dissipate

NCEP GFS IVT Evolution

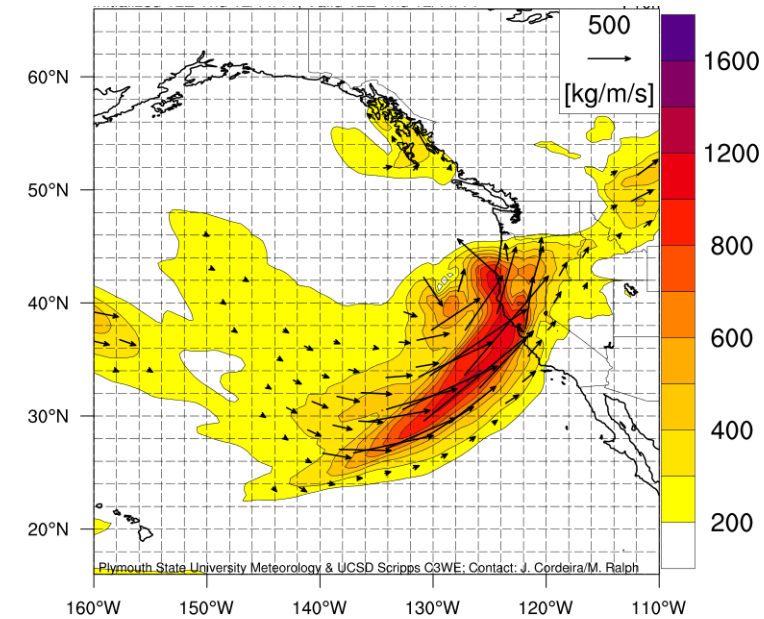
4 AM PT 10 Dec



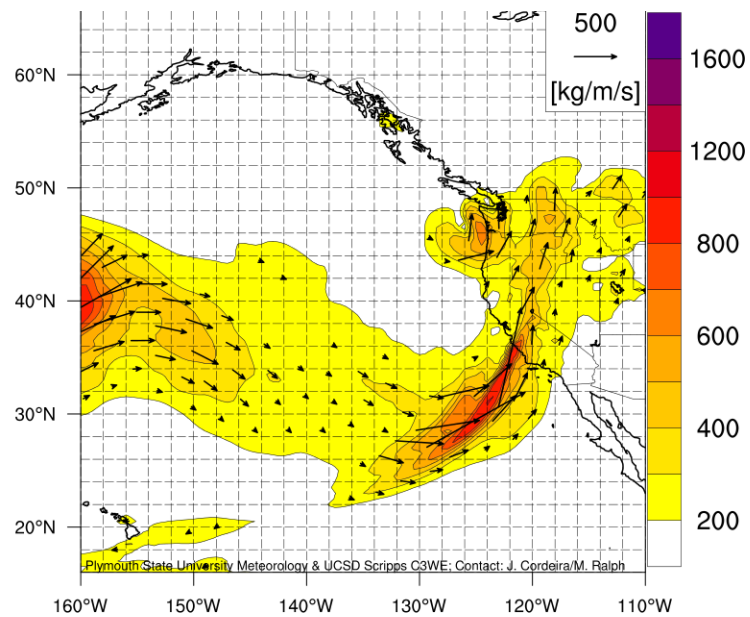
4 PM PT 10 Dec



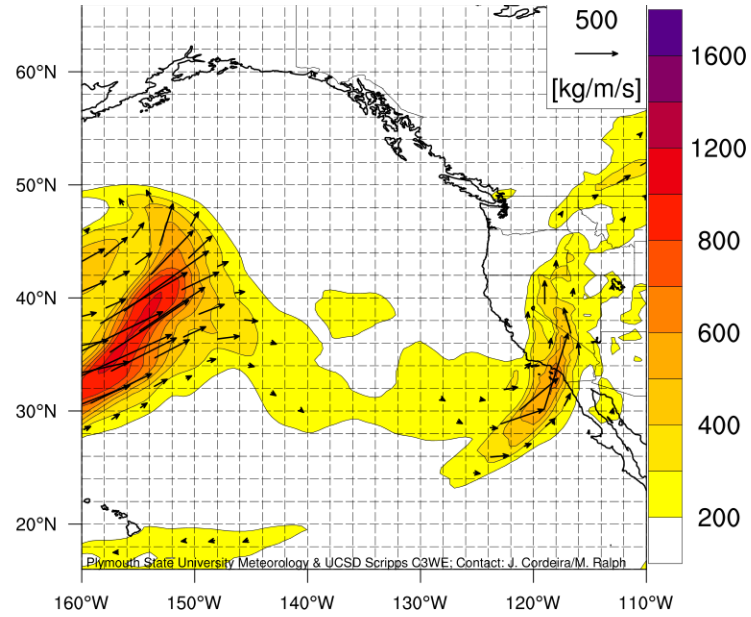
4 AM PT 11 Dec



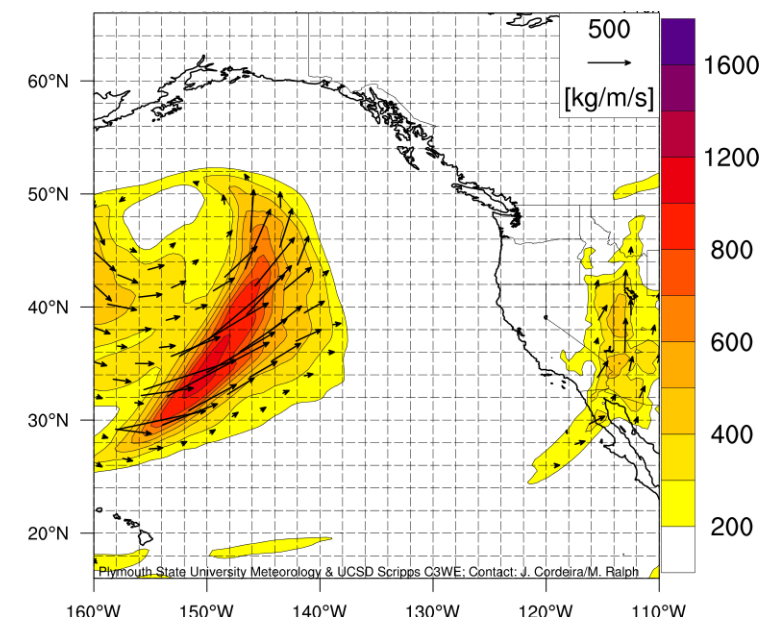
4 PM PT 11 Dec



4 AM PT 12 Dec

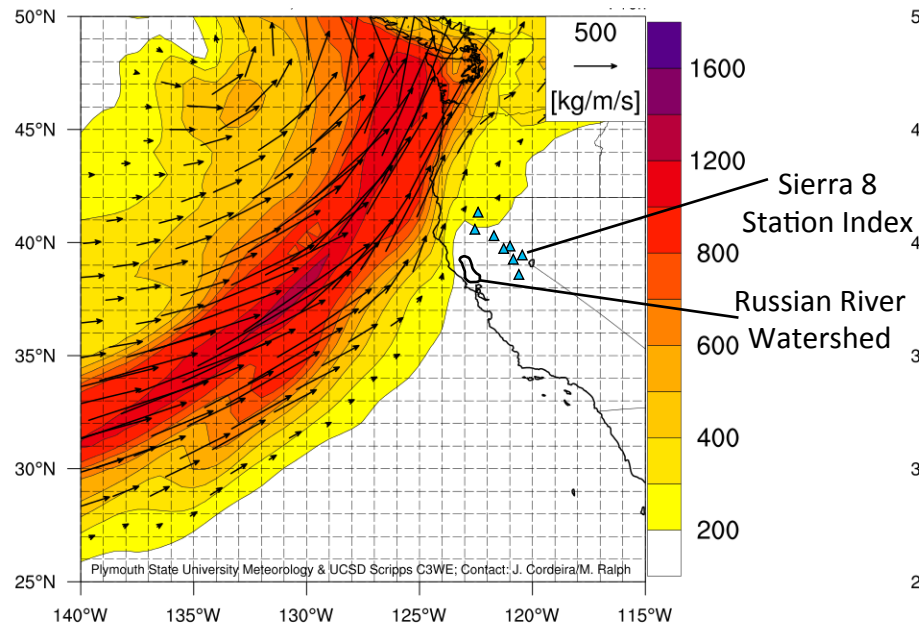


4 PM PT 12 Dec

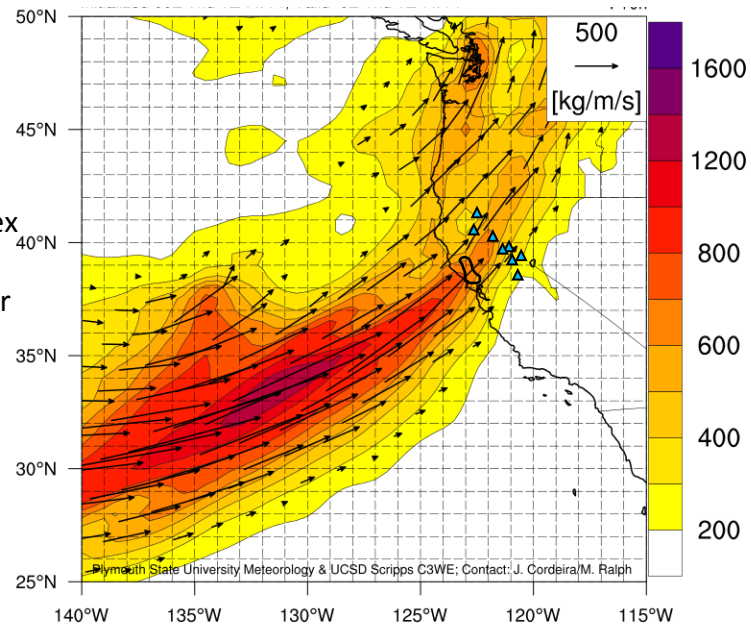


NCEP GFS IVT Evolution

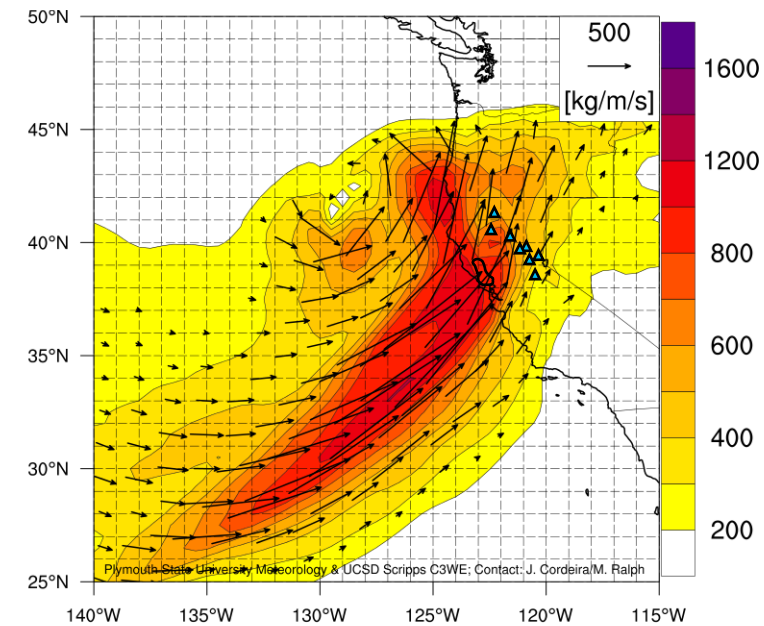
4 AM PT 10 Dec



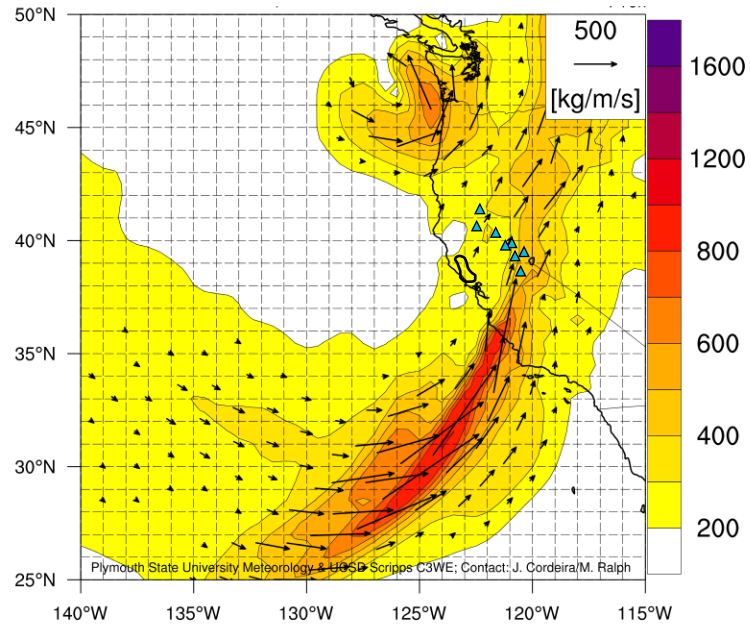
4 PM PT 10 Dec



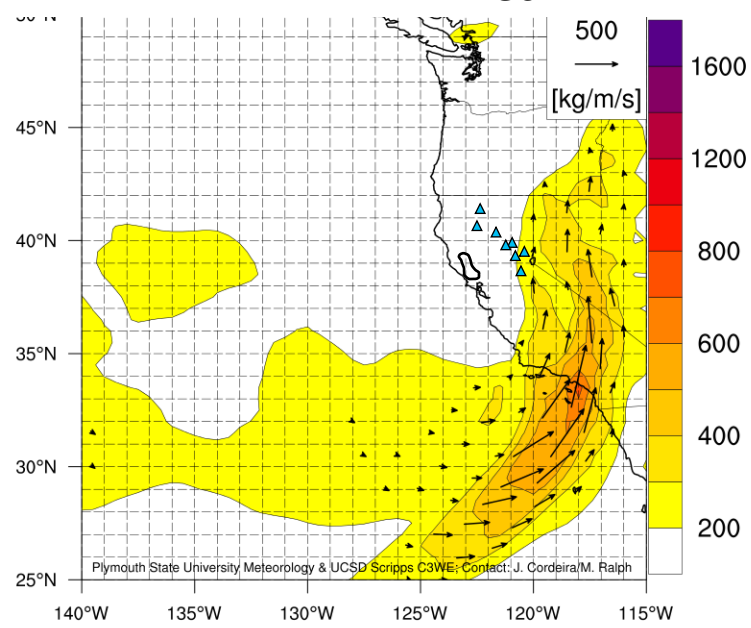
4 AM PT 11 Dec



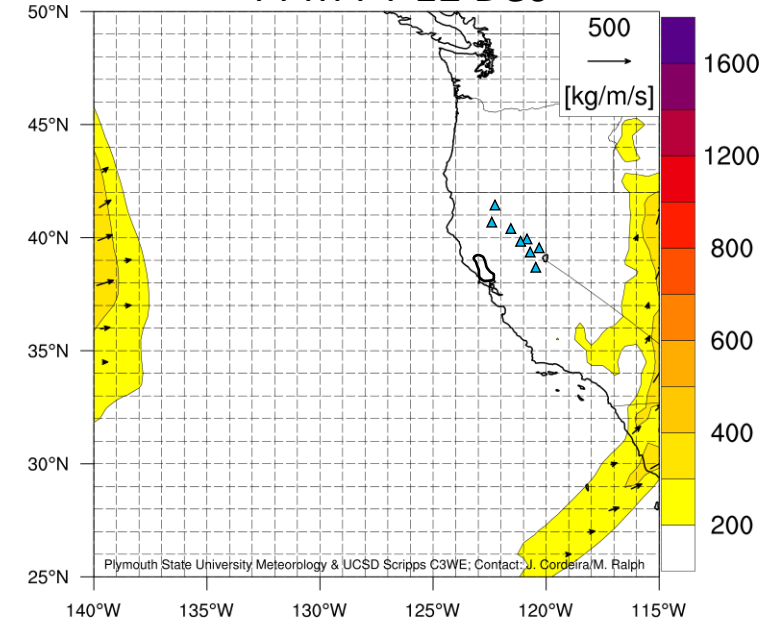
4 PM PT 11 Dec



4 AM PT 12 Dec

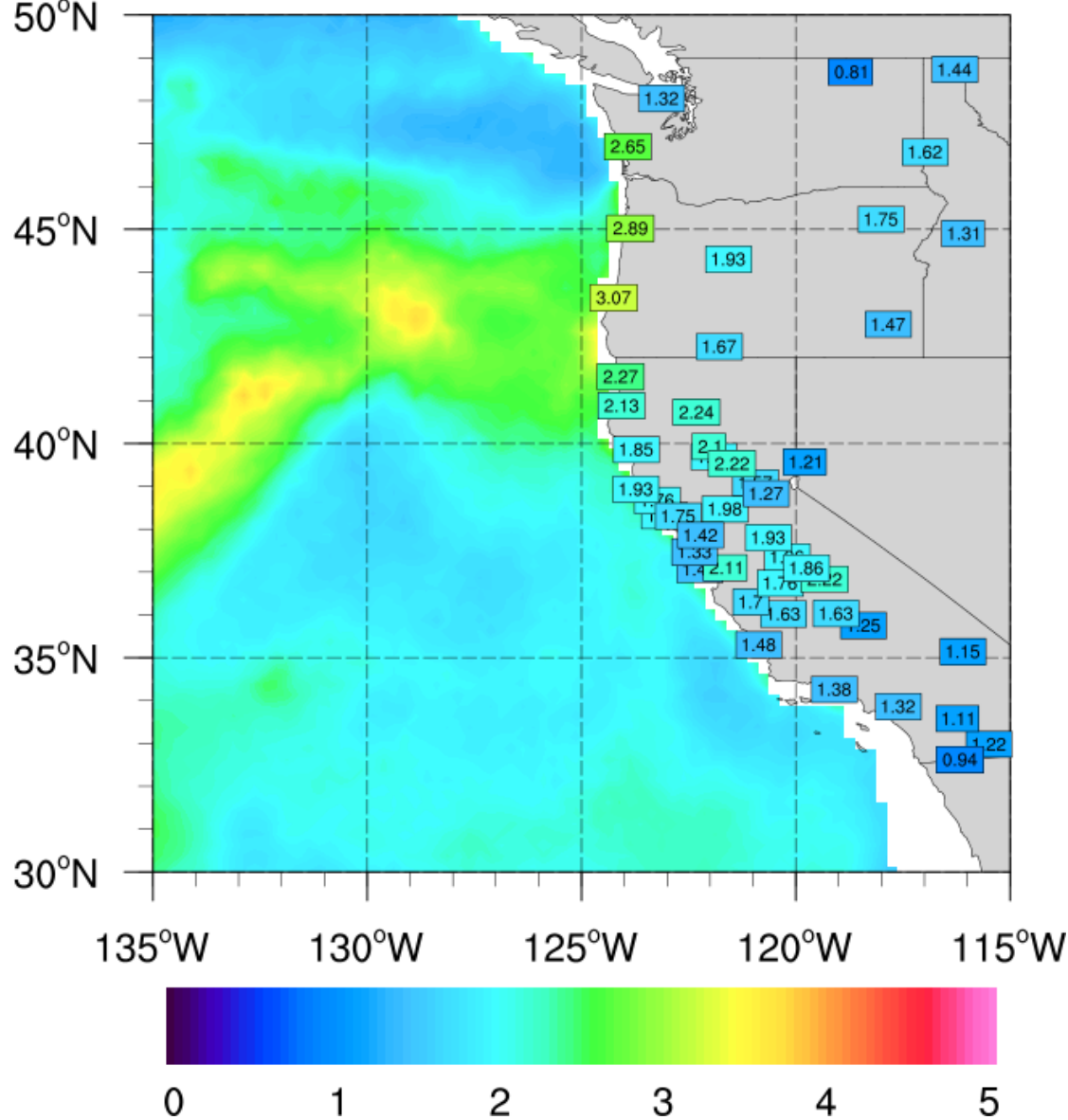


4 PM PT 12 Dec

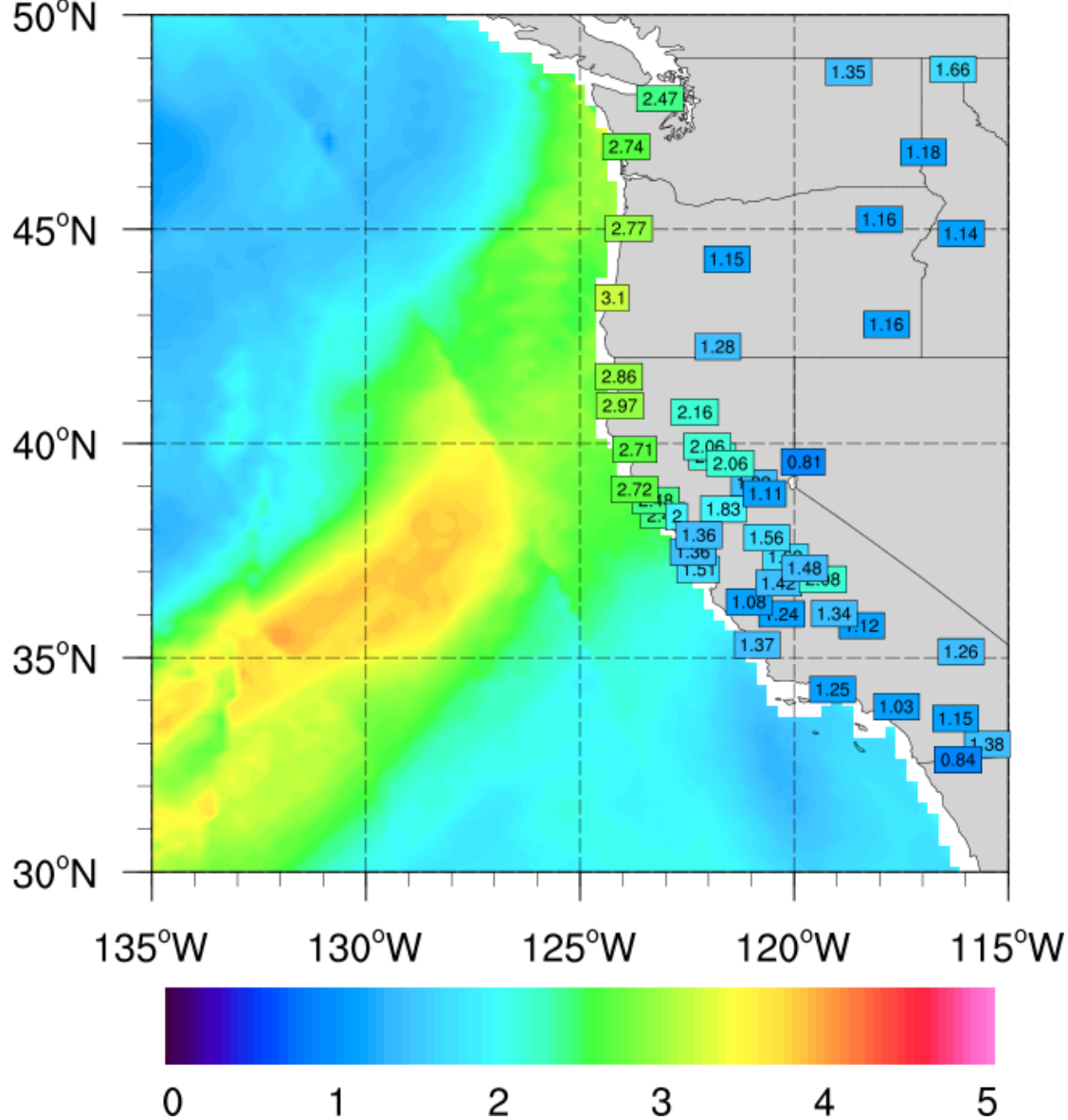


GPS-Met and SSMIS Derived IWV

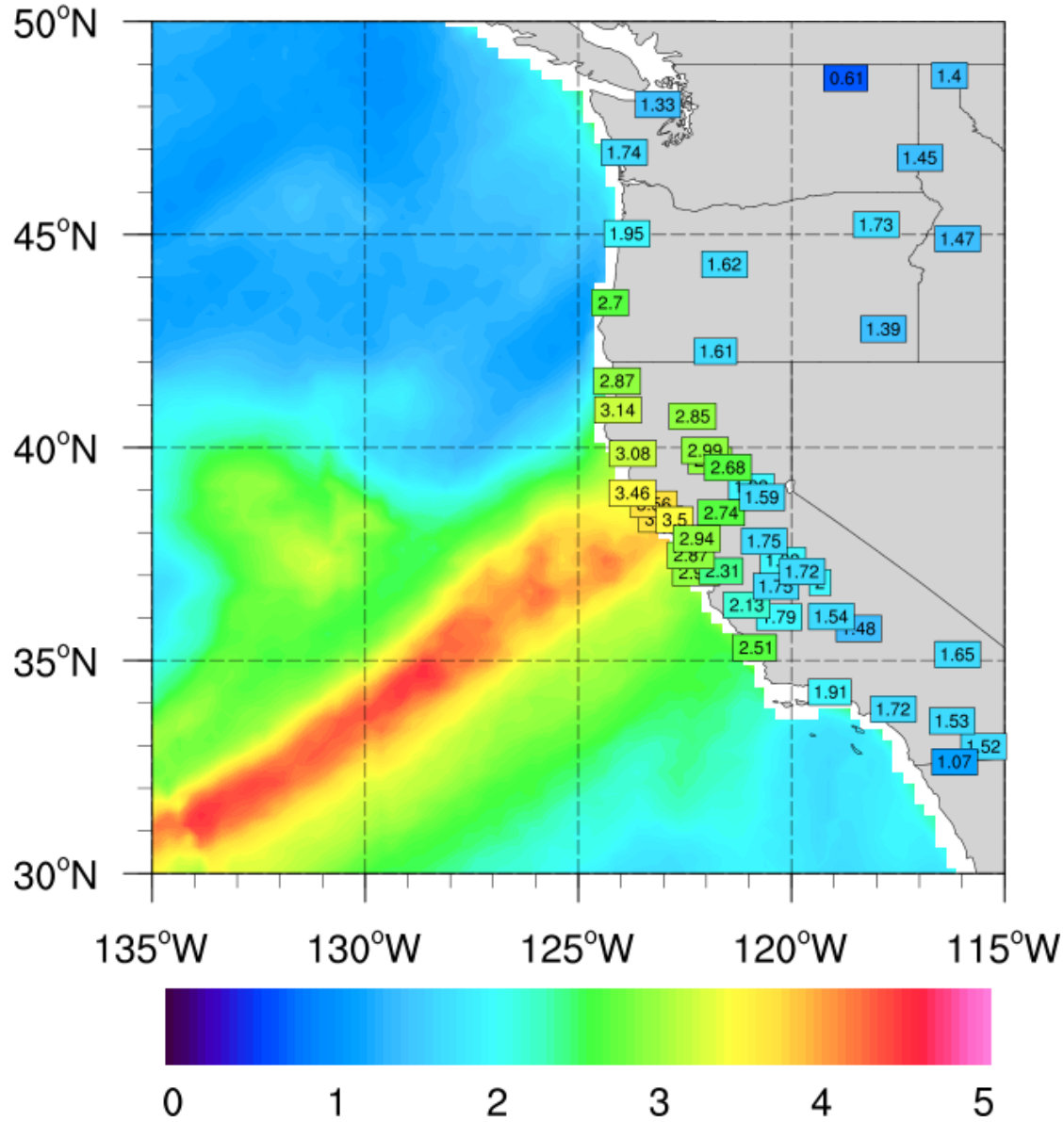
0500 UTC 10 Dec 2014



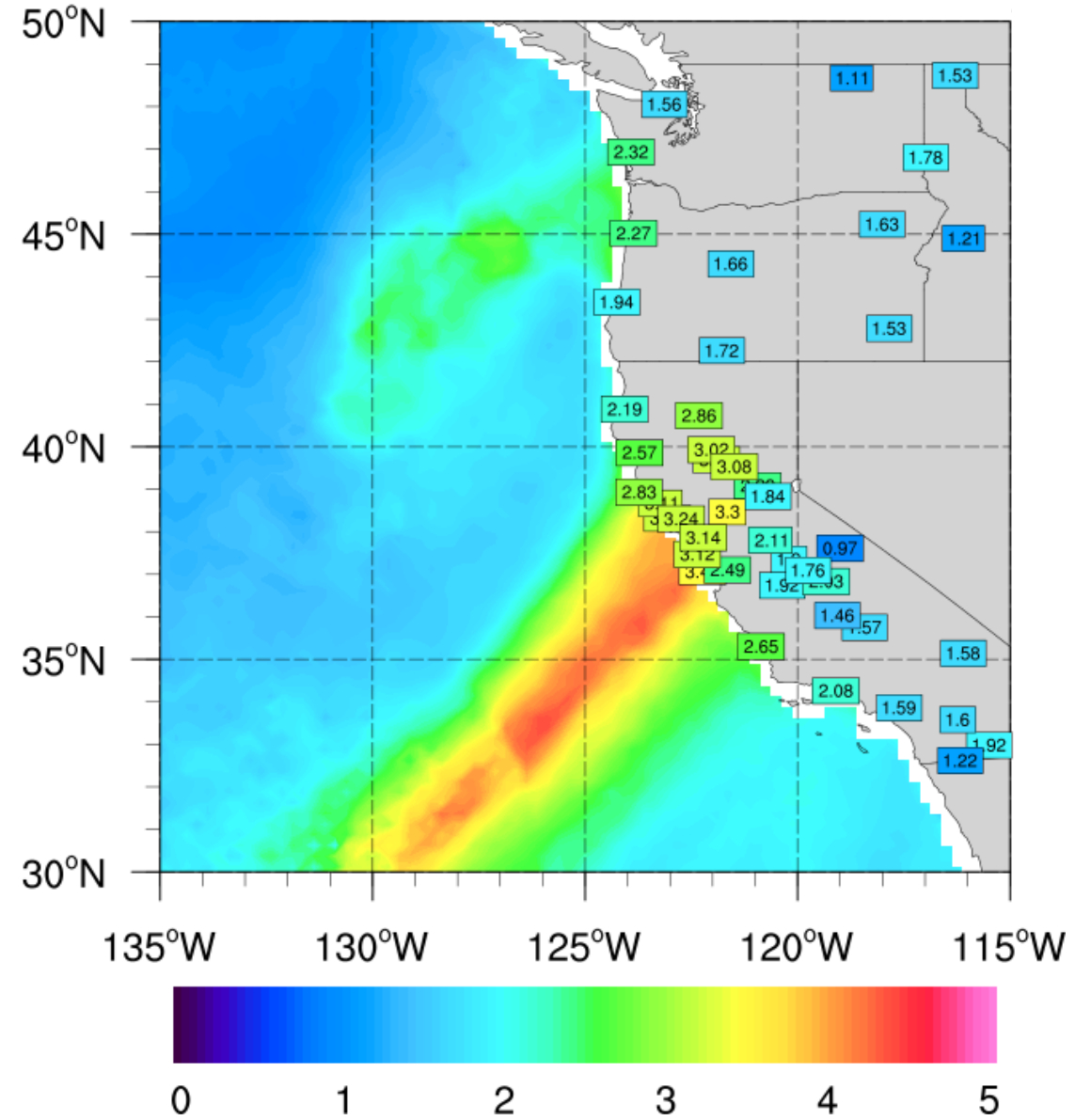
1900 UTC 10 Dec 2014



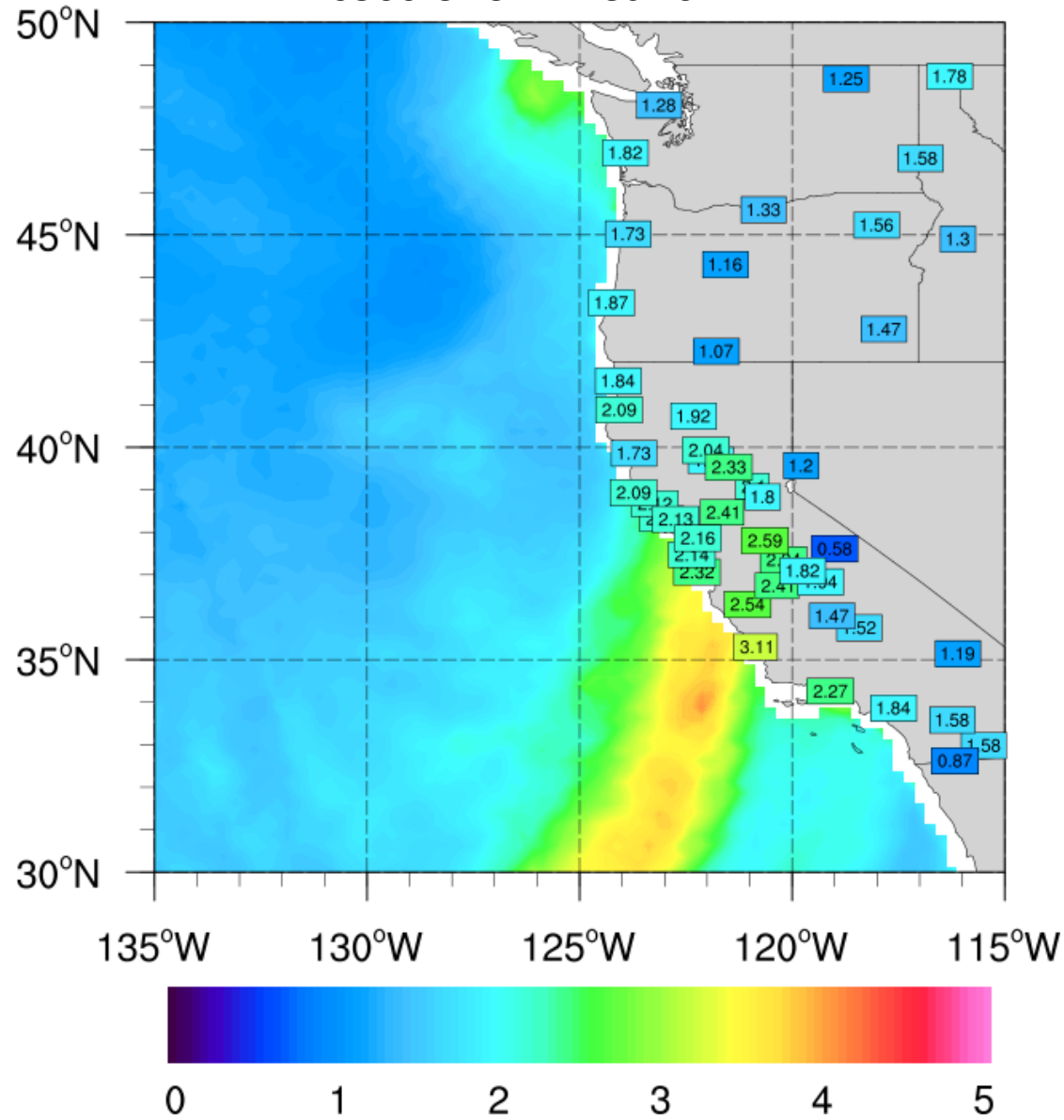
1100 UTC 11 Dec 2014



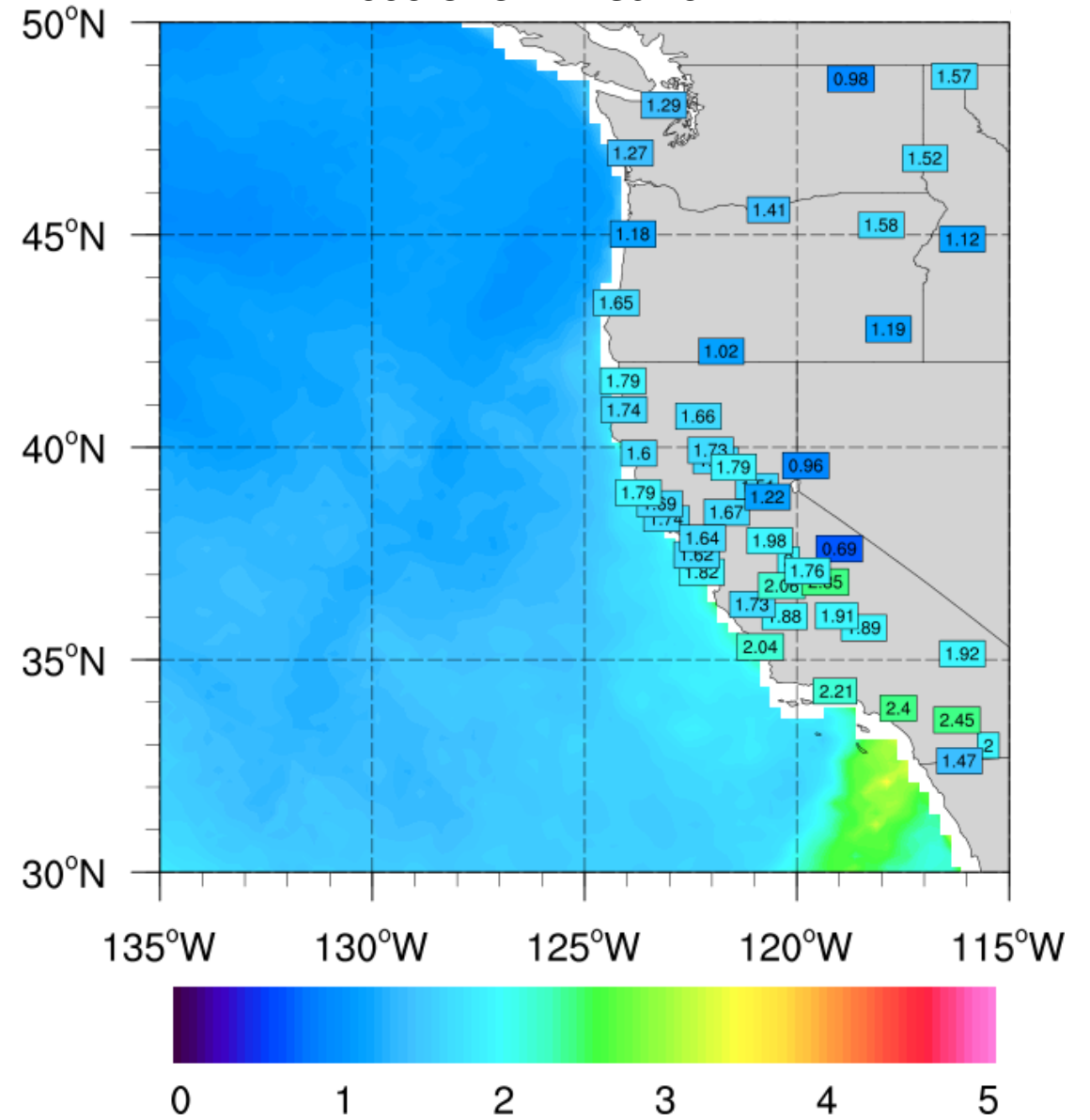
1600 UTC 11 Dec 2014



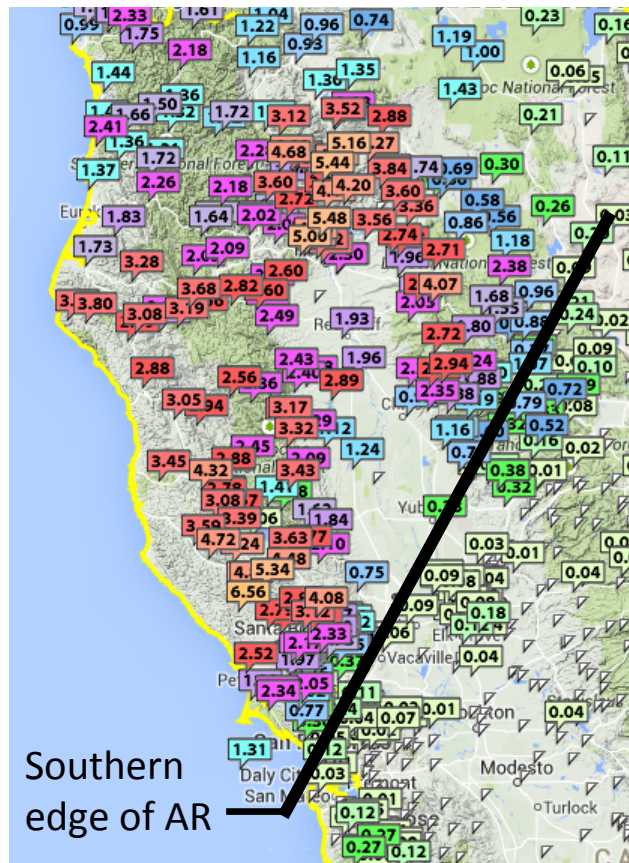
0500 UTC 12 Dec 2014



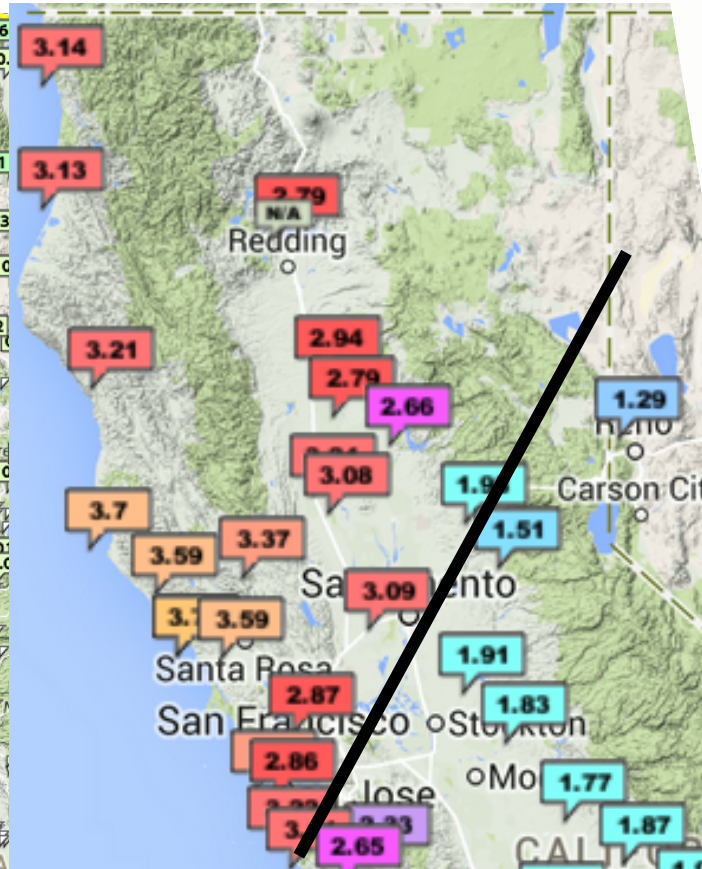
1600 UTC 12 Dec 2014



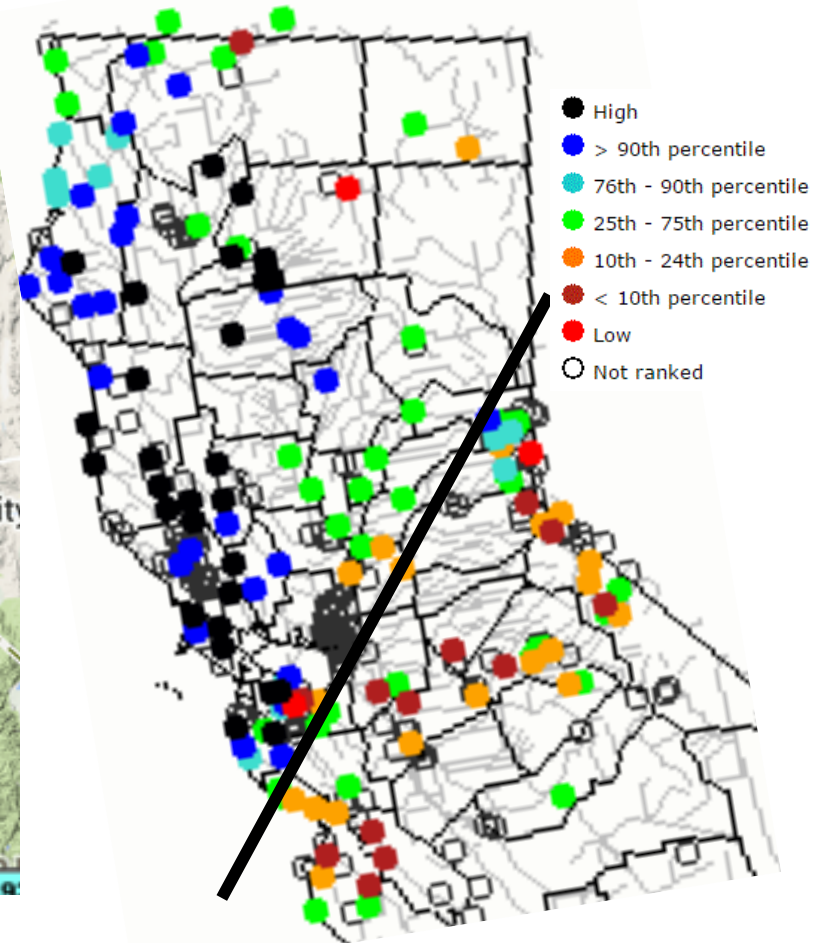
Strong gradient in IWV values associated with strong gradient in precipitation amount and streamflow at 1430 UTC 11 Dec 2014



24-hour precip
(CNRFC)



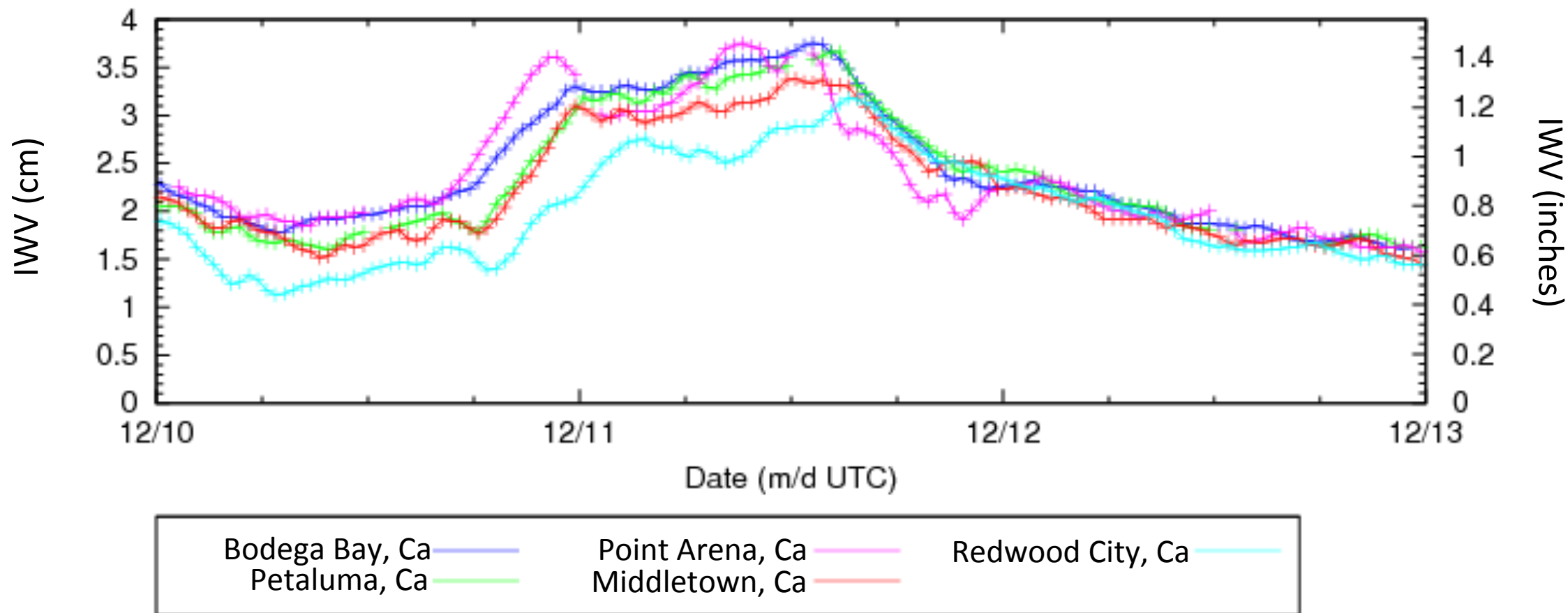
GPS-Met IWV
(PSD)



USGS Streamflow
(USGS)

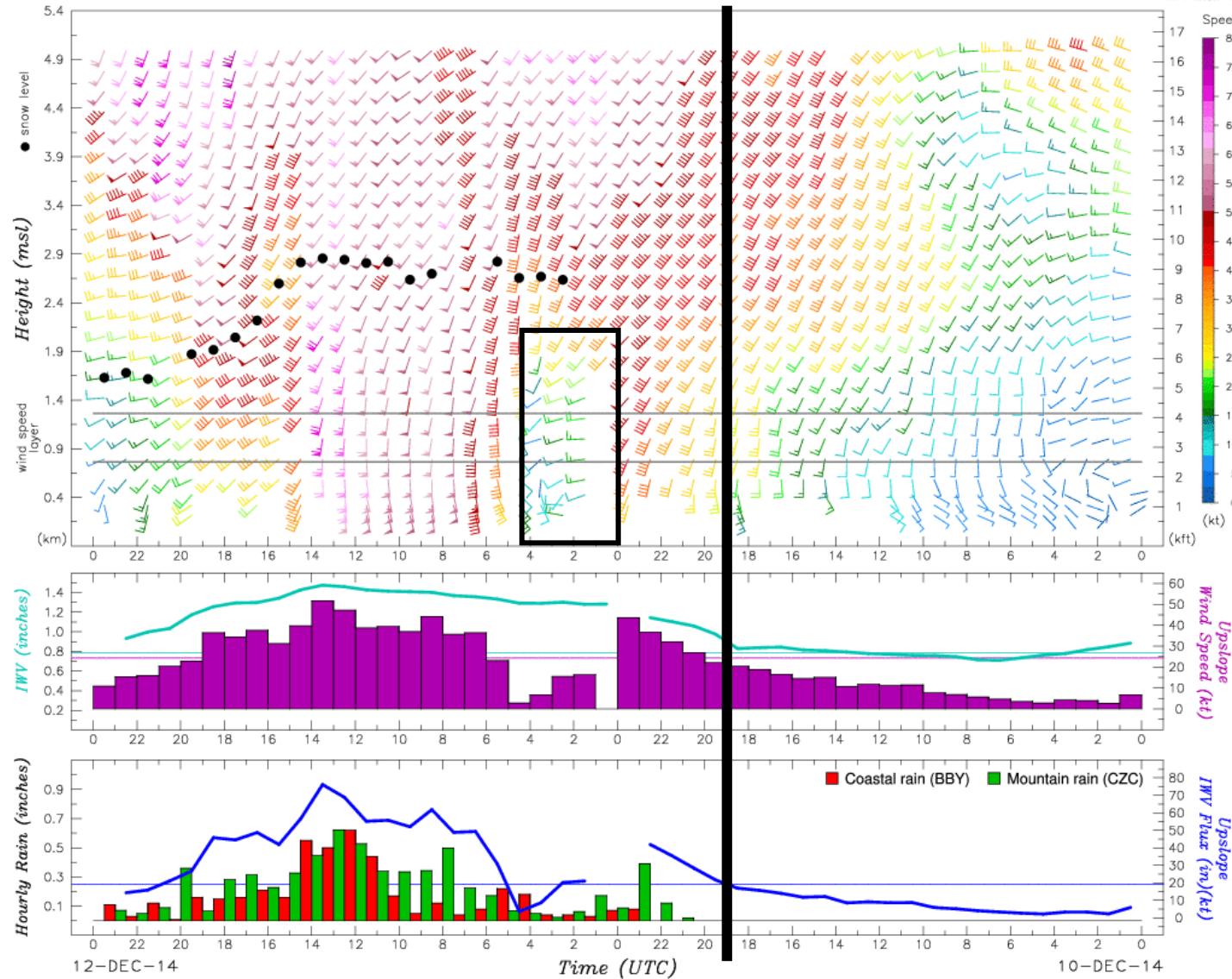
GPS-Met IWV

IWV



AR made landfall over CA at ~1900 UTC 10 Dec 2014 and AR conditions persisted over land for ~25 hours

ESRL Physical Sciences Division
Coastal Atmospheric River Monitoring and Early Warning System



Bodega Bay, CA (BBY)
38.3191 N, 123.0728 W, 15 m
Cazadero, CA (CZC)
38.6107 N, 123.2152 W, 478 m

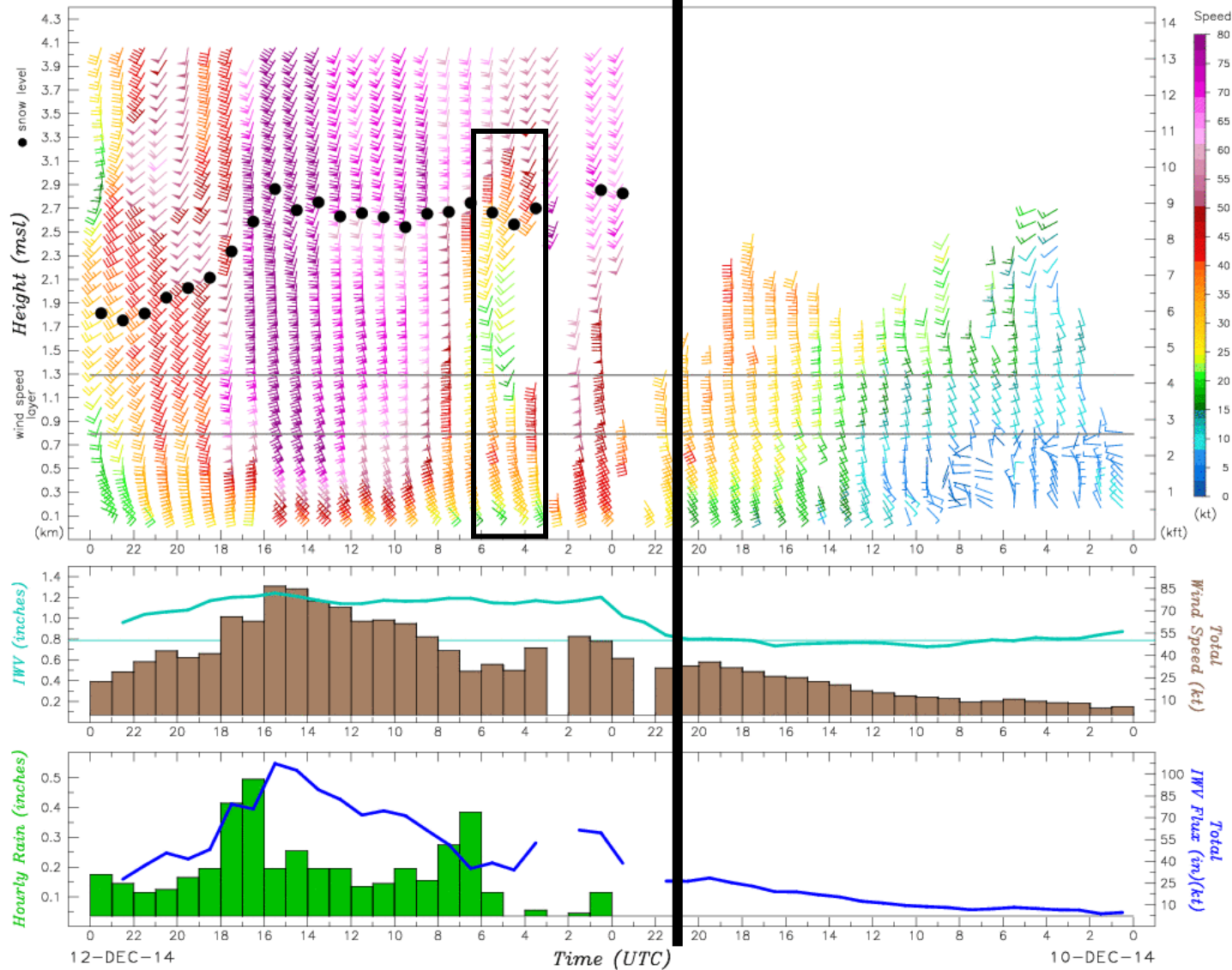
Upslope Direction = 230 deg
BBY 48-hr precip: 4.34 in
CZC 48-hr precip: 6.30 in

Bodega Bay Observations:

- Strong low-level winds began during the evening (PT) of 10 December resulting in increasing water vapor transport.
- SSW low-level winds and high IWP values resulted in strong upslope IWP flux
- Snow level above terrain
- Mesoscale feature caused Low wind speeds during 0000–0500 UTC, causing low upslope IWP flux and a ‘break’ in precipitation

AR conditions started at 1900 UTC 10 Dec 2014

AR conditions ended at 2000 UTC 11 Dec 2014
- Duration 25 hours



Chico, CA (CCO)
39.6999 N, 121.9075 W, 42 m

Chico Observations:

- Mesoscale feature observed at BBY, observed at the upper levels at Chico, CA
- Winds above ~1.5 km decrease and turn slightly SW decreasing upslope WV flux and precipitation
- Mesoscale feature appears to be located above Sierra Barrier Jet

AR conditions started at 2100 UTC 10 Dec 2014

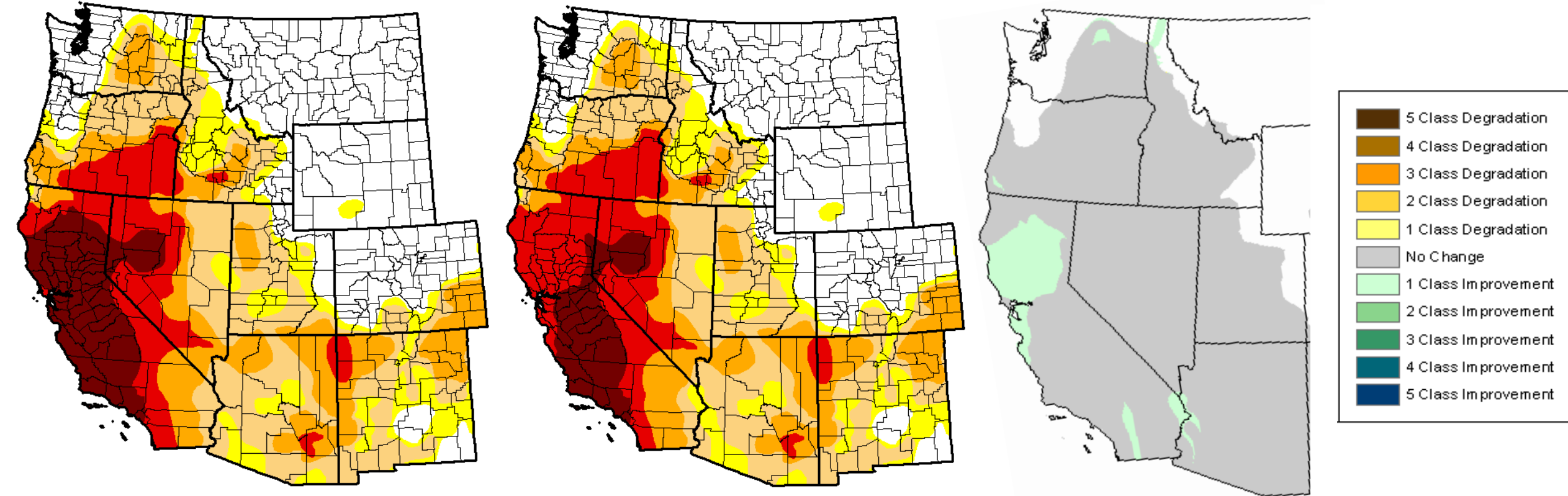
AR conditions ended at 0000 UTC 12 Dec 2014
- Duration 27 hours

Impact on drought – United States Drought Monitor

9 December 2014

16 December 2014

Change in USDM



Intensity:



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Improved most of northern California from Exceptional to Extreme drought

Summary of event

- AR lifetime over land: 1200 UTC 10 Dec 2014–1200 UTC 12 Dec 2014
- Maximum 48-h precipitation: >350 mm over northern California
- Provided significant water supply to many drought-stricken California reservoirs
- Improved drought conditions throughout northern California
- High amounts of flooding and wind damage across the entire U.S. West Coast