Center for Western Weather and Water Extremes

SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

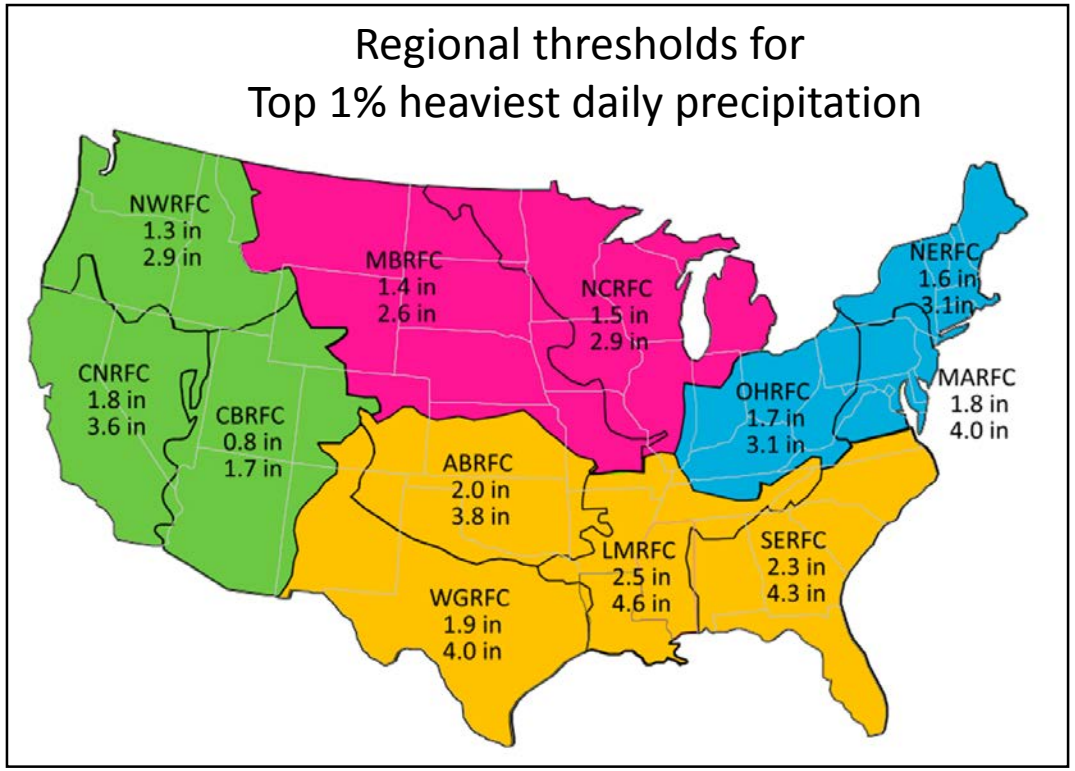
FIRO Science Highlight: Mesoscale Frontal Waves and AR Recon Campaign

F. Martin Ralph

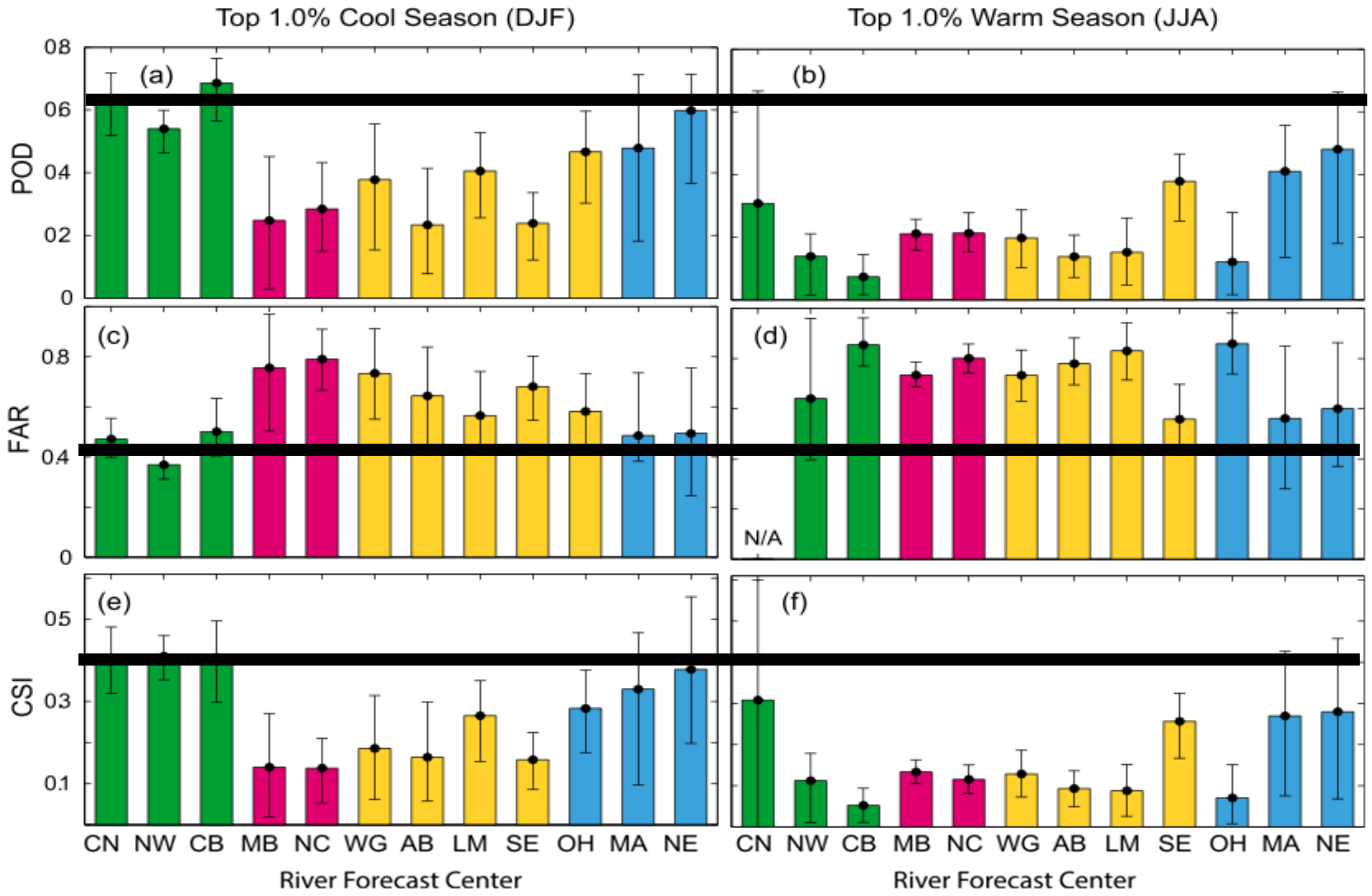
FIRO Workshop, La Jolla, CA
28 June 2016

Extreme quantitative precipitation forecast performance at the Weather Prediction Center from 2001 to 2011

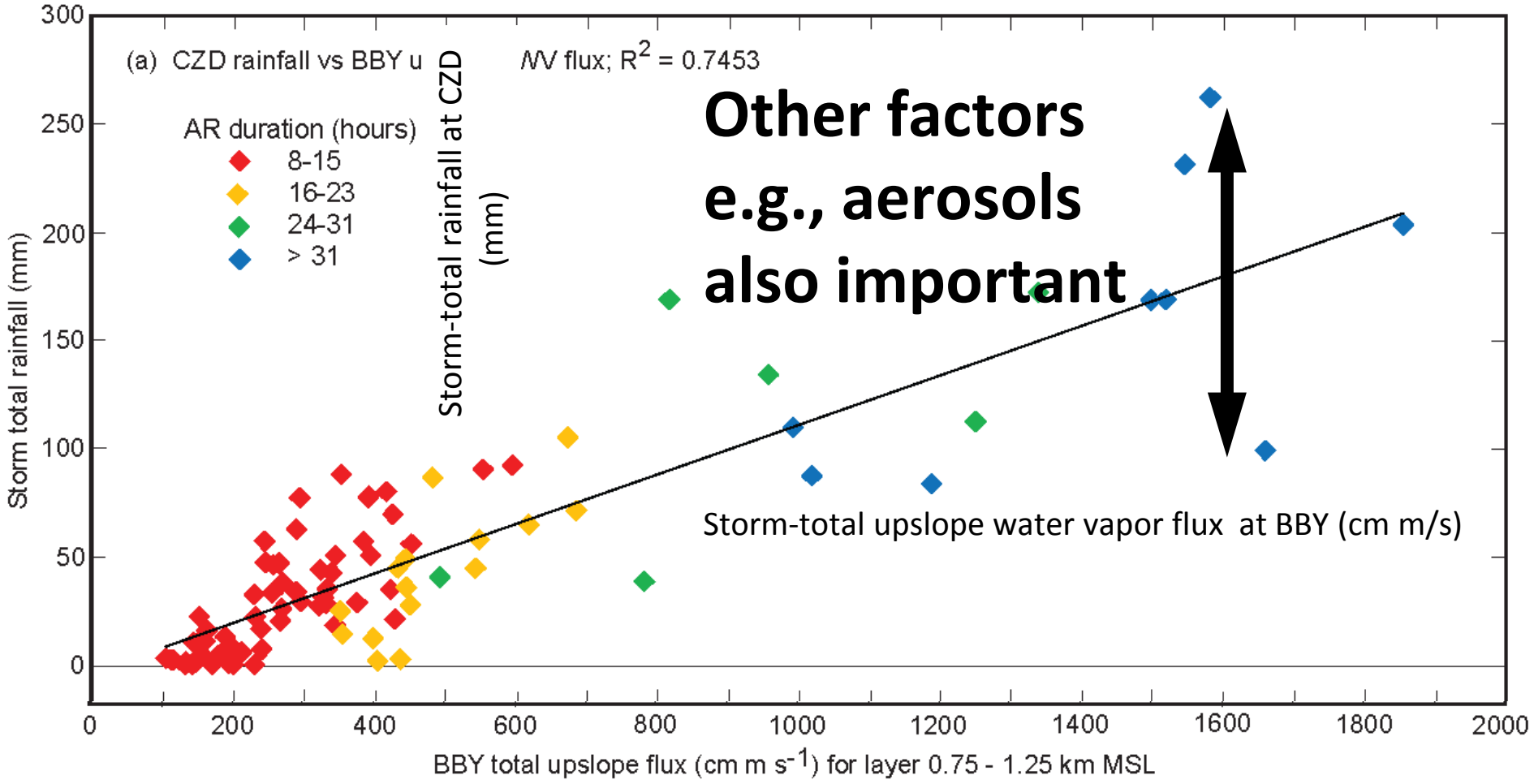
Sukovich, E. M., F. M. Ralph, F. E. Barthold, D. W. Reynolds and D. R. Novak *Wea. Forecast.* (2014)



Used 32 km gridded QPE from NCEP/WPC from 2001-2011
>12,000,000 wet days



Used 32 km gridded QPE and QPF from NCEP/WPC from 2007-2011. For 1-day lead time. Note QPF for Western RFC's and New England are best.

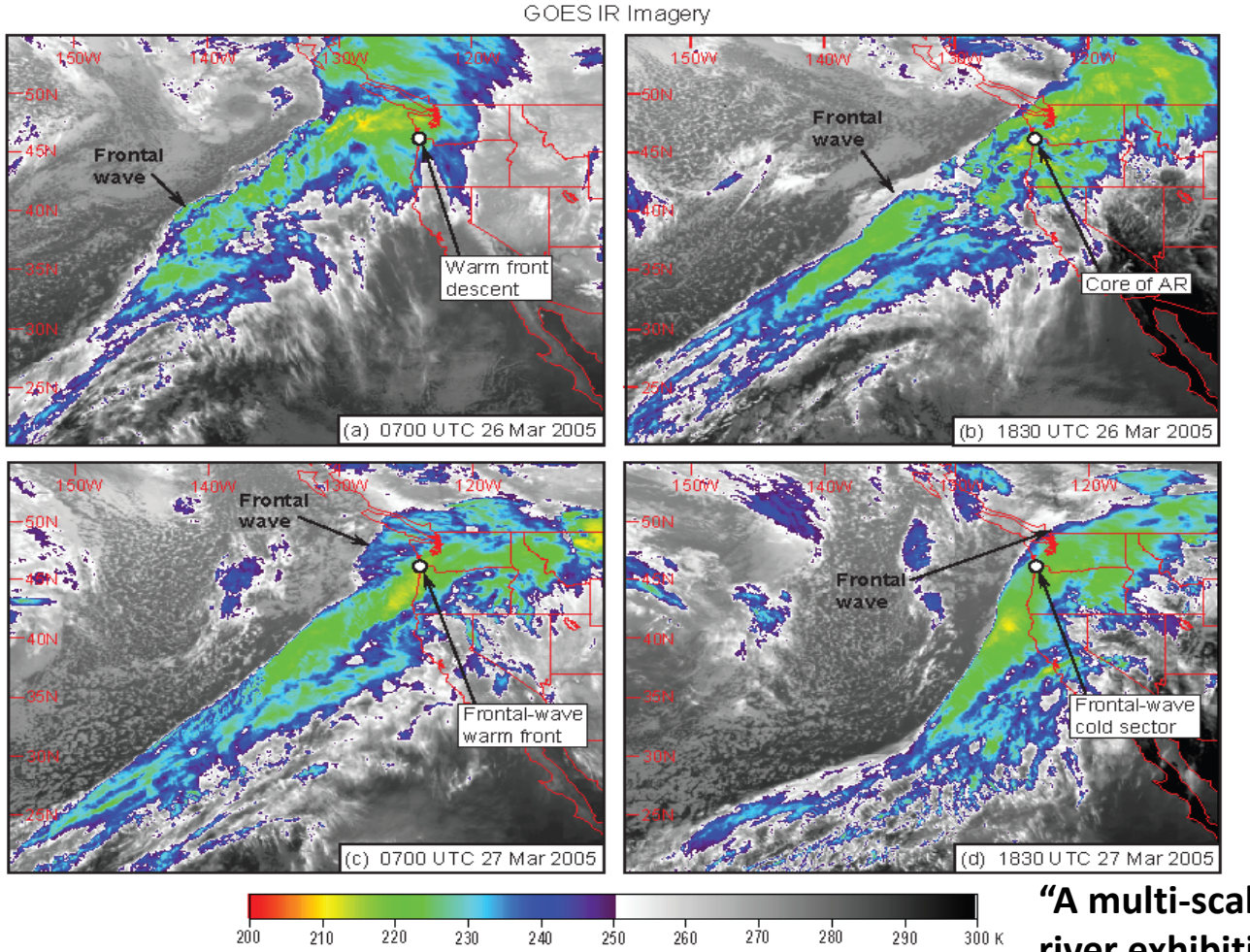


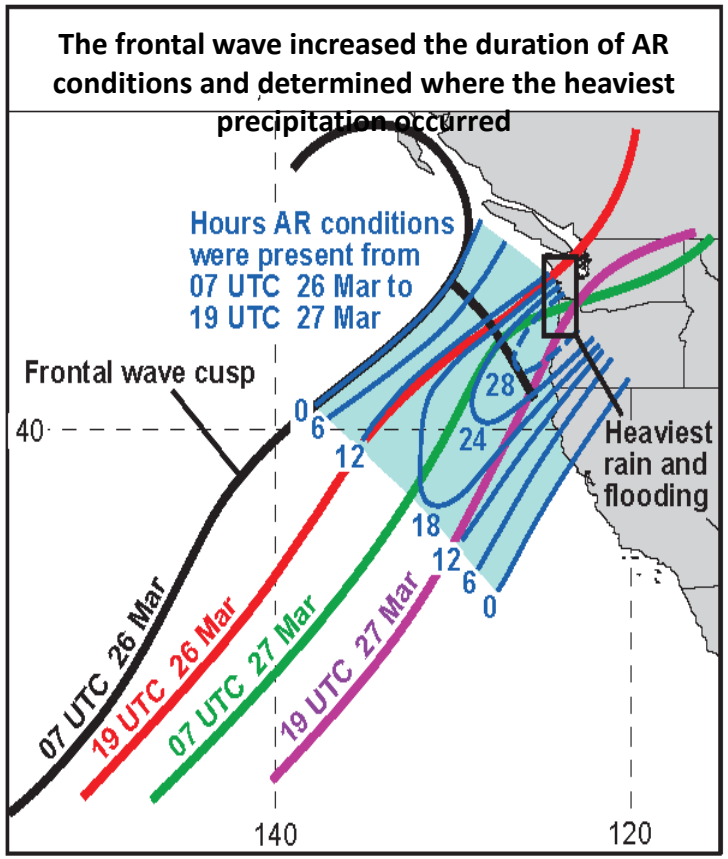
The greater the precipitation

The greater the AR strength and duration

From Ralph et al. 2013, *J. Hydrometeorology*

Investigating Mesoscale Frontal Waves and the Impact on Forecasts





"A multi-scale observational case study of a Pacific atmospheric river exhibiting tropical-extratropical connections and a mesoscale frontal wave"

*Ralph et al., *Mon. Wea. Rev.* (2011)

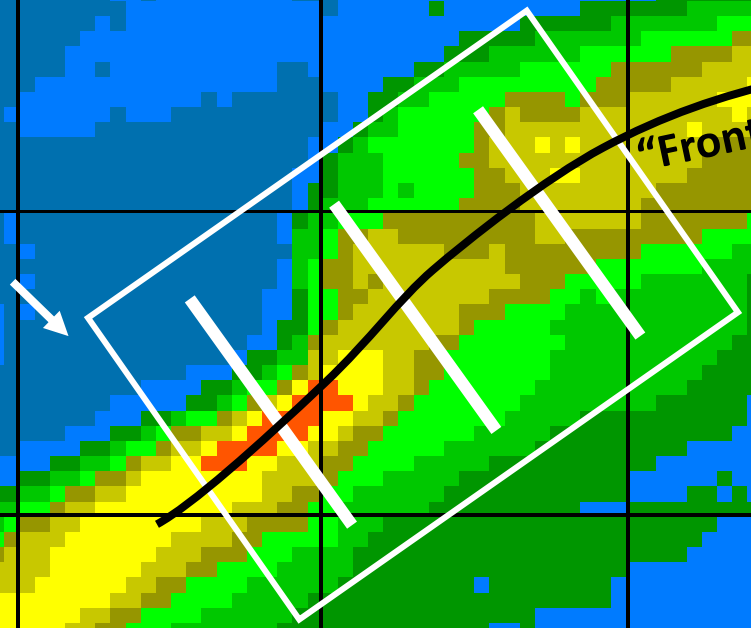
CalWater

Ralph et al. 2016 (Bull. Amer. Meteor. Soc.)

This AR increased precipitation-to-date from 16% to 40% of normal in < 4 days in key Northern California watersheds, but runoff was muted due to dry soils.

Up to > 12 inches of rain – some drought relief

Flight area for NOAA's G-IV aircraft on 8 Feb 2014
Goal: developing AR flight method to sample a "frontal wave" that can cause an AR to stall over one area at landfall (Mission Scientist: Marty Ralph)



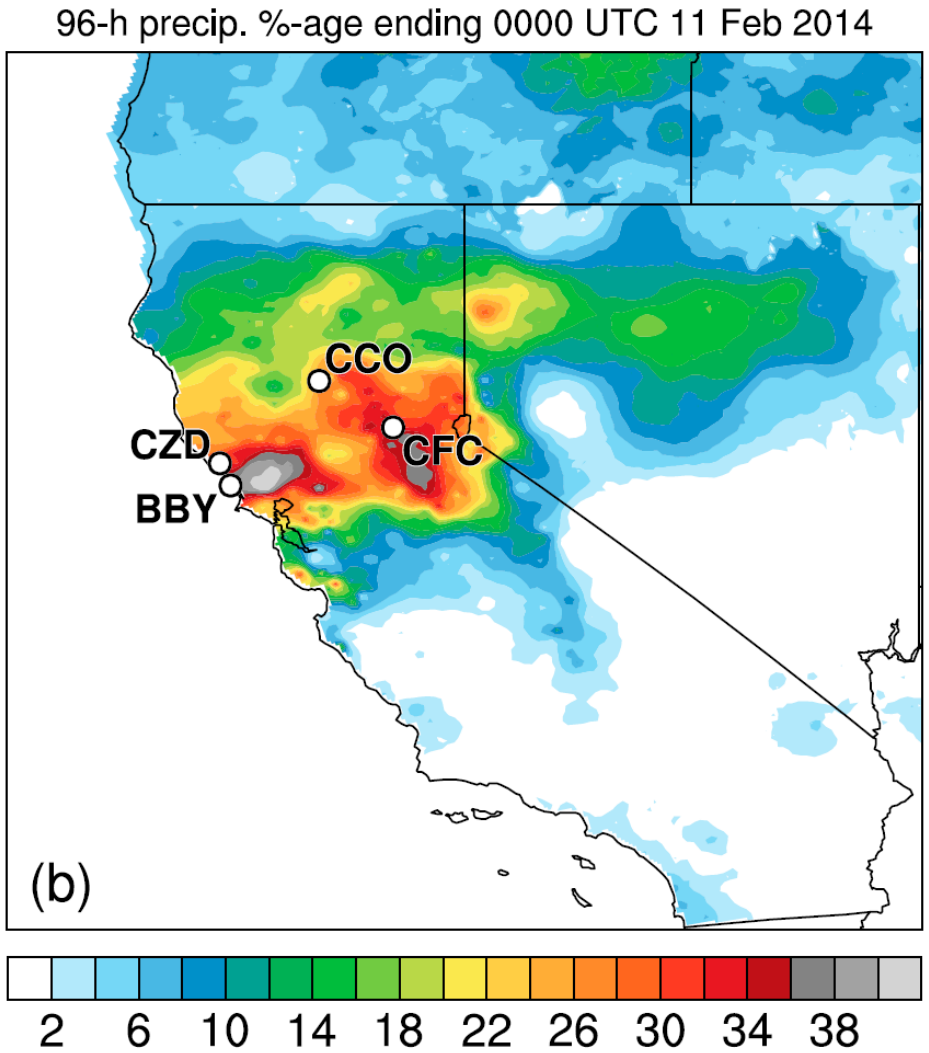
Russian River's highest flow in > 1 year

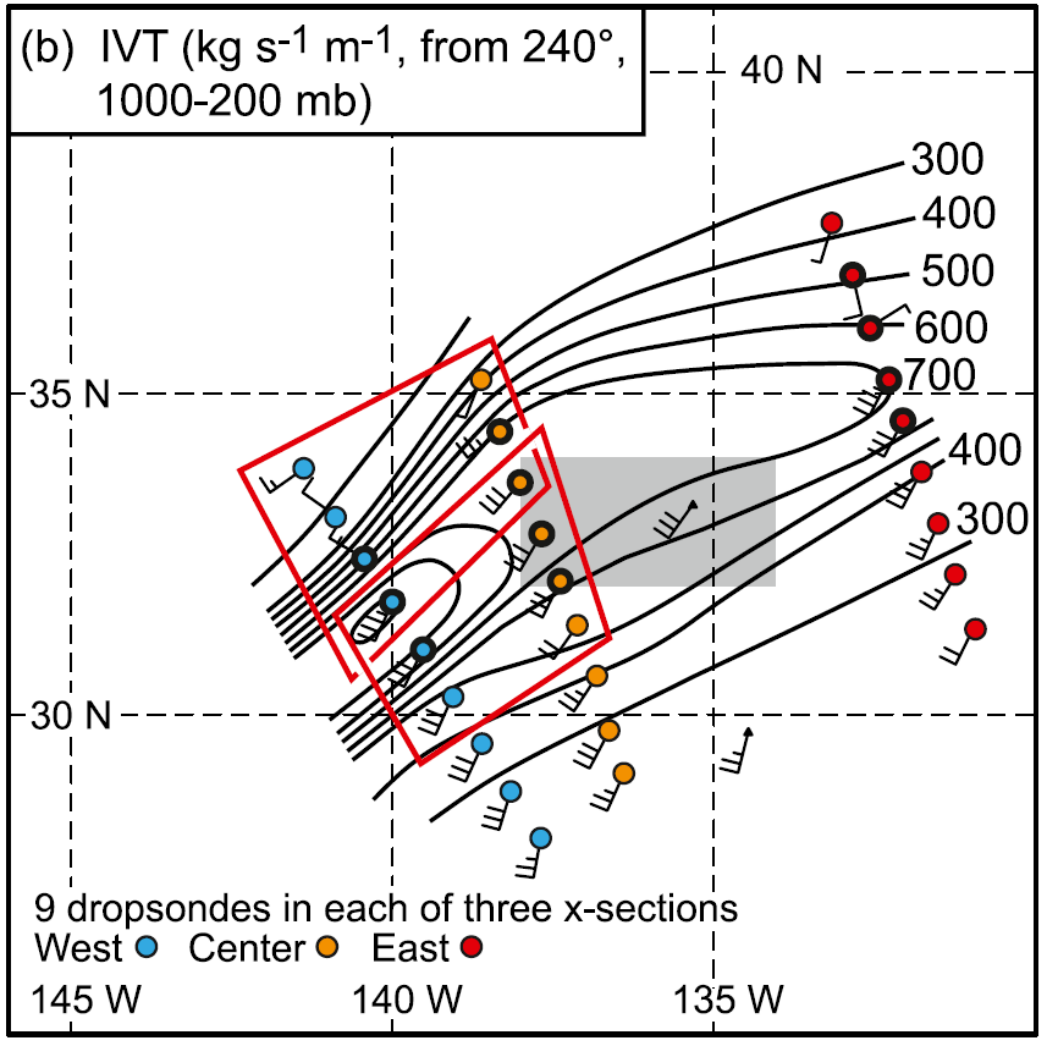
*CalWater-2 is a multi-year program focused on West Coast precipitation processes and how a changing climate will affect them. It is led by UCSD/Scripps with partners from DWR, CEC, NOAA, NASA, DOE and others.

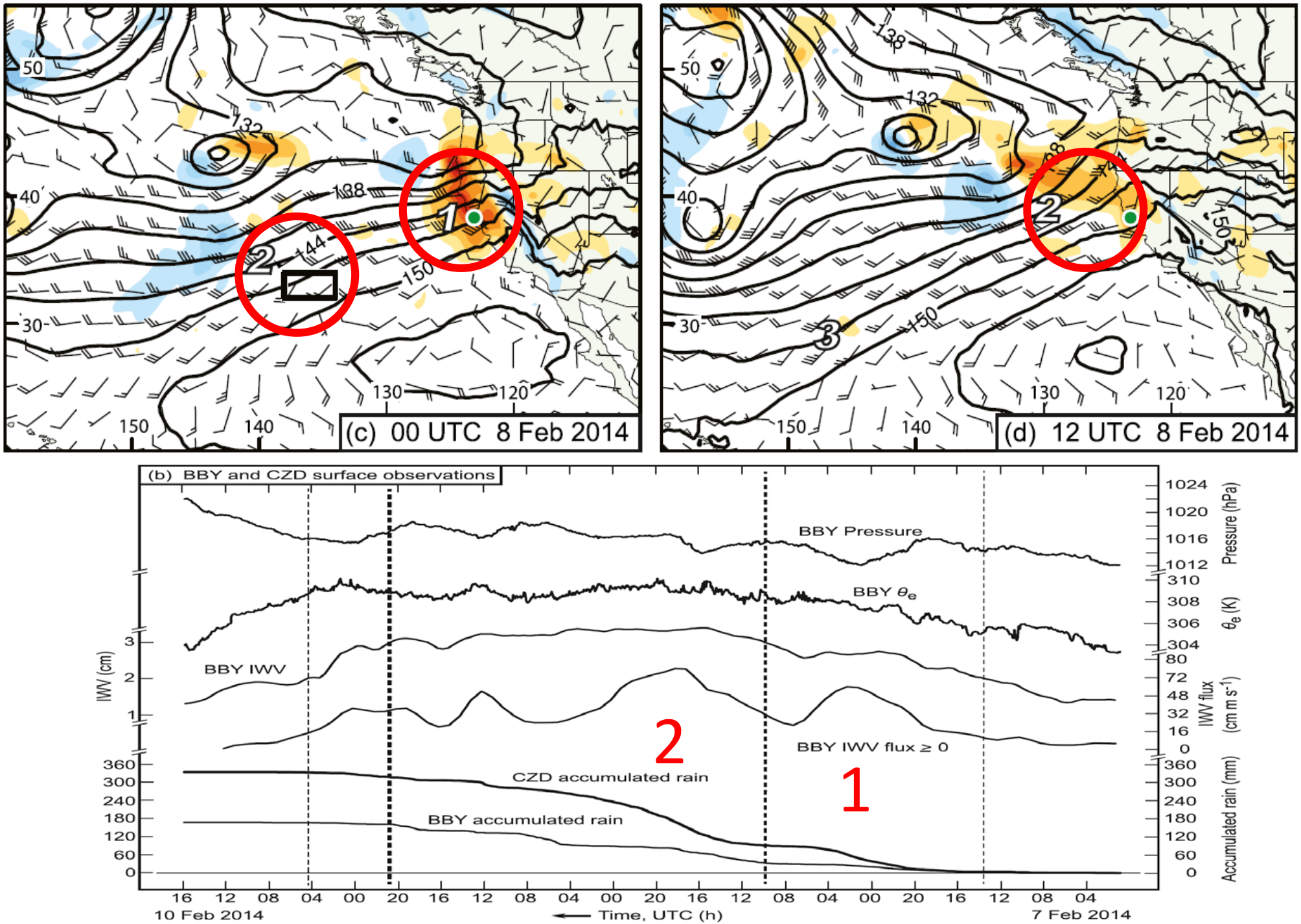
SSM/I satellite observations of water vapor on 8 Feb 2014 (Courtesy G. Wick, NOAA)

An Airborne and Ground-Based Study of a Long-Lived and Intense Atmospheric River with Mesoscale Frontal Waves Impacting California during CalWater-2014

Neiman, P. J., B.J. Moore, A.B. White, G.A. Wick, J. Aikins, D.L. Jackson, J.R. Spackman, F.M. Ralph, *Mon. Wea. Rev. (2016)*






(c) 00 UTC 8 Feb 2014
(d) 12 UTC 8 Feb 2014
(b) BBY and CZD surface observations
BBY Pressure
BBY θ_e
BBY IWV
BBY IWV flux ≥ 0
CZD accumulated rain
BBY accumulated rain
Pressure (hPa)
θ_e (K)
IWV flux (cm m s^{-1})
Accumulated rain (mm)
IWV (cm)
Time, UTC (h)
10 Feb 2014
7 Feb 2014
1
2

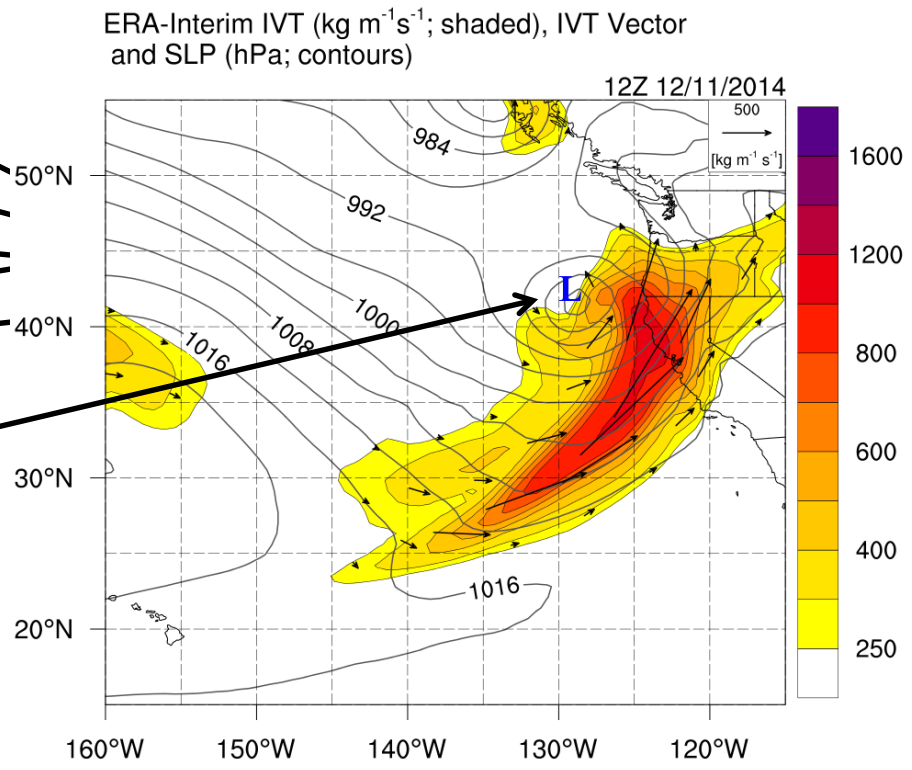
Analysis of Several Mesoscale Frontal Waves

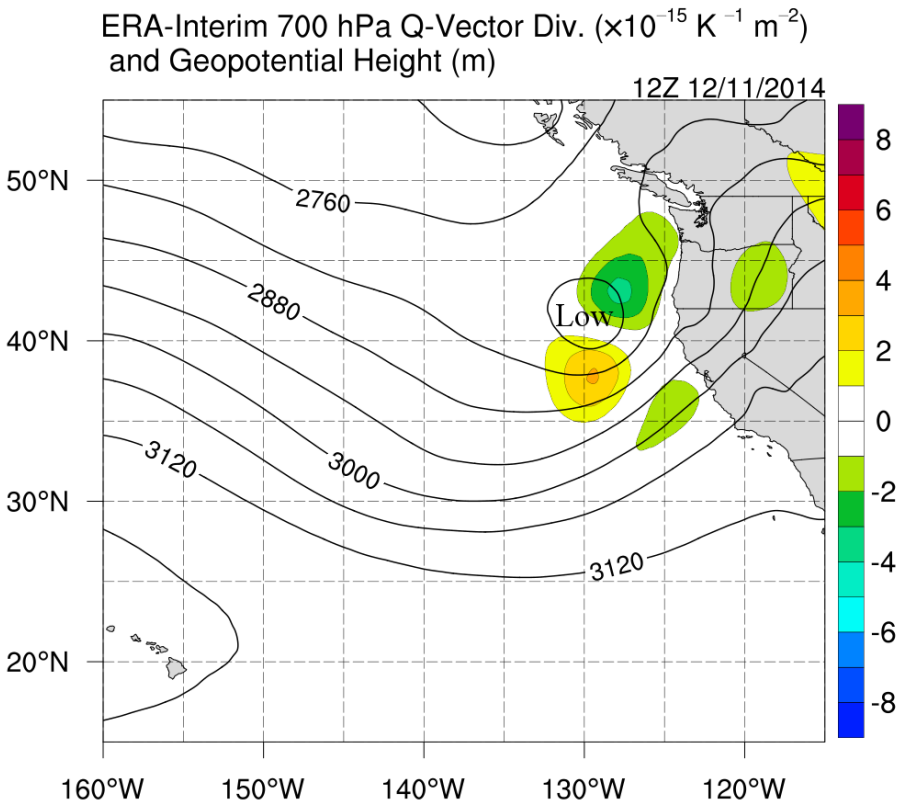
A.Martin, B. Kawzenuk, J. Kalansky, A. Wilson, S. Iacobellus, M. Ralph

A moderate t Maximum AR strength reaches L. Mendocino near 12/11/2014 @ 12 UTC @ 06 UTC

Moderate AR conditions reach L. Mendocino near 12/11/2014 @ 00 UTC

The former mesoscale wave has grown larger than meso-scales.
It is now appropriately referred to as a secondary frontal wave (SFW).





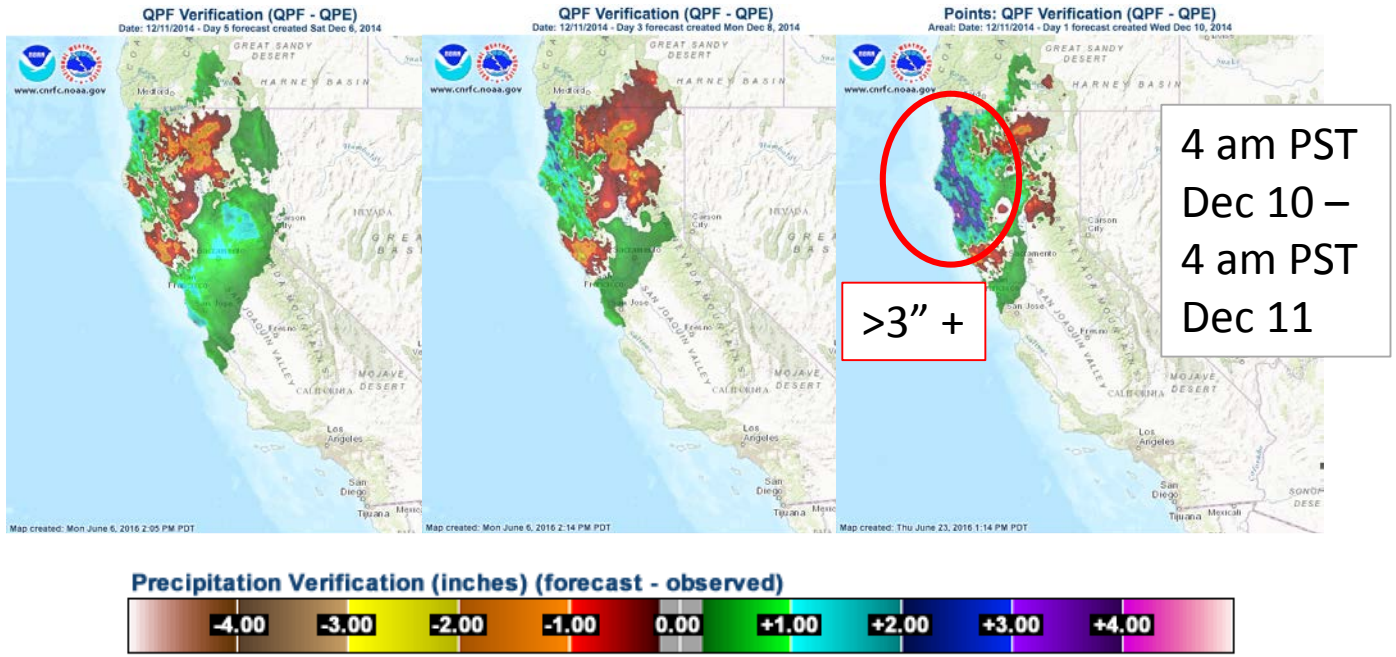
Mid-tropospheric analysis shows a mature cyclone. Its development imposed a second moderate/strong AR period at L. Mendocino.

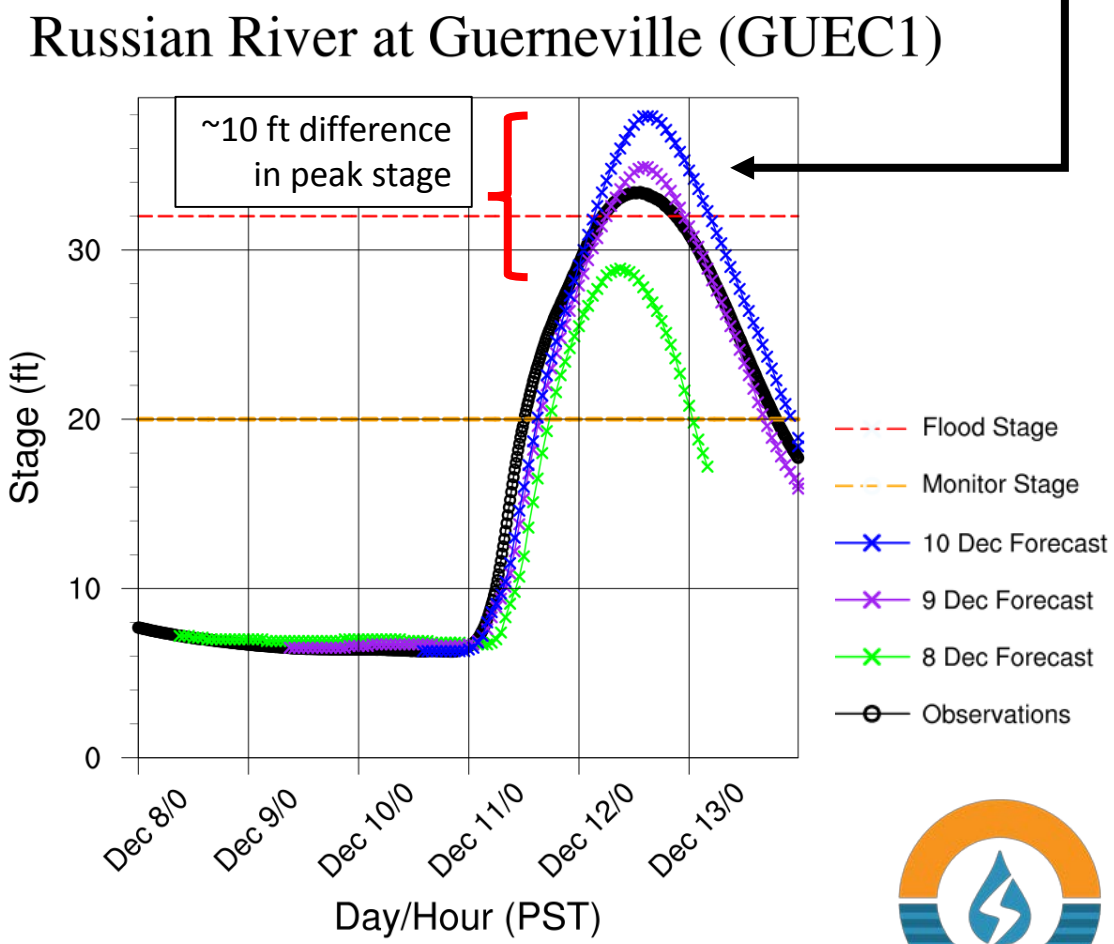
Impact of Dec 2014 SFW on Forecasts

15 PST on 10 Dec: first forecast after the SFW developed.

Poorest precipitation and streamflow forecasts were issued less than 24 hr prior to event!
What changed? SFW developed along landfalling AR.

5 – Day | 3 – Day | 1 - Day

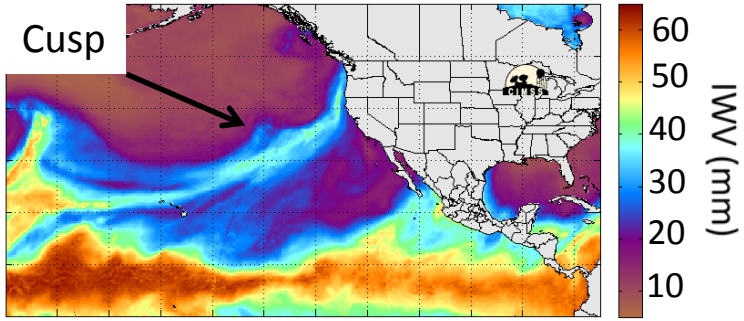




Developing the First List of AR+SFW Cases for Russian River Watershed

Methods

- Observations Only:
  - SSM/I Composite
  - BBY ARO IWV, Vapor Flux, Precip.
  - CW3E Balloon Soundings if available.
- SFW vs. AR w/o SFW criteria were later verified using ERA-Interim Reanalysis



Criteria

- ARO and SSM/I must indicate AR conditions and AR geometry.
- AR must impact Russian River Watershed.
- AR must meet or exceed moderate AR thresholds using ARO vapor flux or sounding IVT.
- For SFW case:
  SSM/I must indicate "cusp" on primary landfalling AR.
- For "AR w/o SFW" case:
  Any cusp or secondary trough indicated in SSM/I must not occur on primary landfalling AR.

SFW	AR w/o SFW
05/04/2009	01/03/2008
01/24/2010	04/27/2010
12/28/2010	03/15/2011
02/22/2012	01/19/2012
02/07/2014	03/27/2012
12/20/2014	11/19/2013
01/29/2016	03/28/2014
03/05/2016	11/22/2014
03/09/2016	03/12/2016

Synoptic Pattern May Aid Prediction of SFW on AR

Each Composite mean is calculated at beginning of AR conditions measured at the BBY ARO.

IVT (kg m^{-1} s^{-1}; shaded), IVT Vector, and SLP (hPa)

300-hPa Winds (m s^{-1}; shaded) and Geopotential Heights (dam)

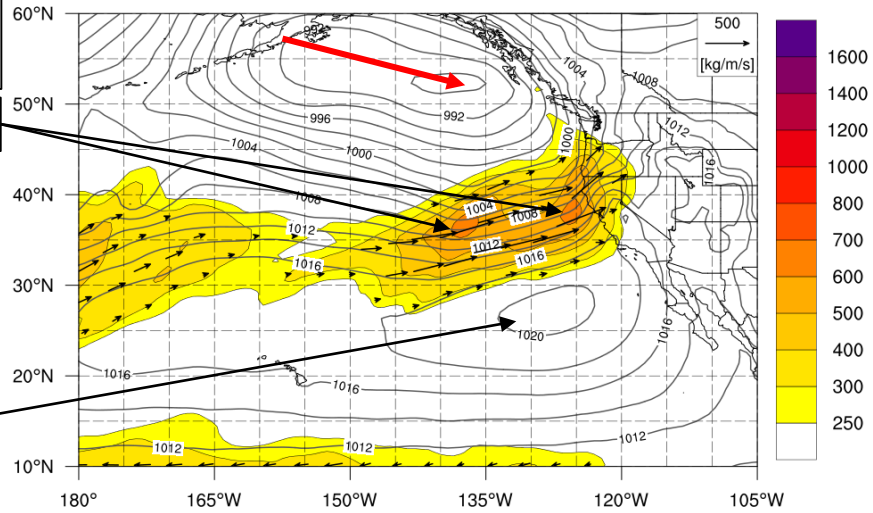
Aleutian/Gulf of Alaska low moves SE prior to landfall (movement indicated by red arrow)

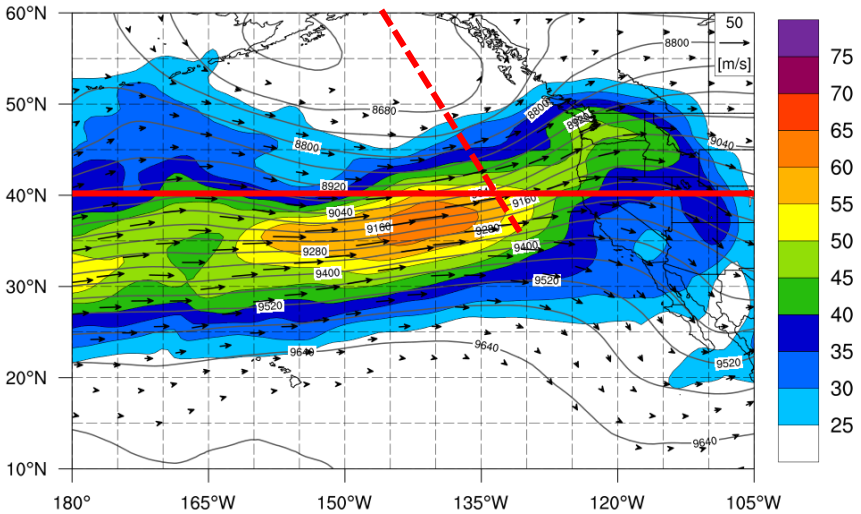
Split IVT Maxima

Secondary Frontal Wave Composites

WSW oriented AR

Strong subtropical high off Baja Coast





Jet in SFW cases slightly stronger than CTL cases

Mostly SSW orientation

Slightly negatively/ almost neutrally tilted trough

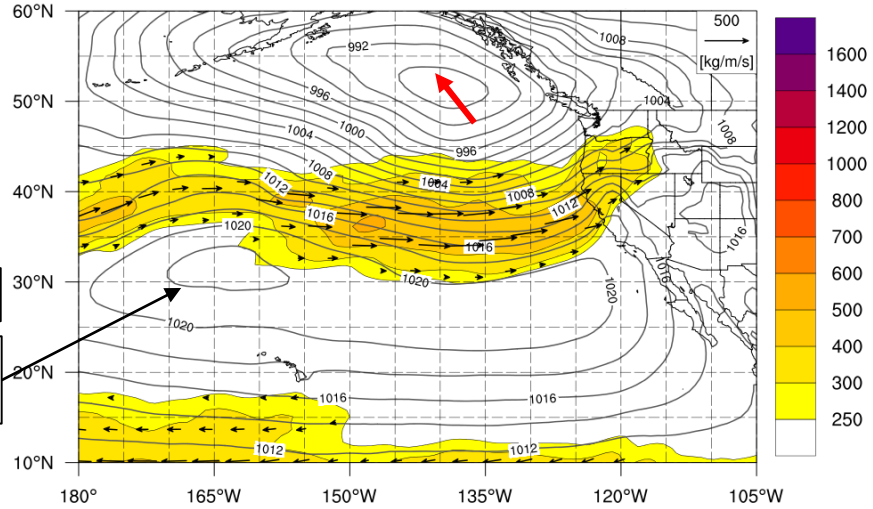
Majority of jet south of 40°N

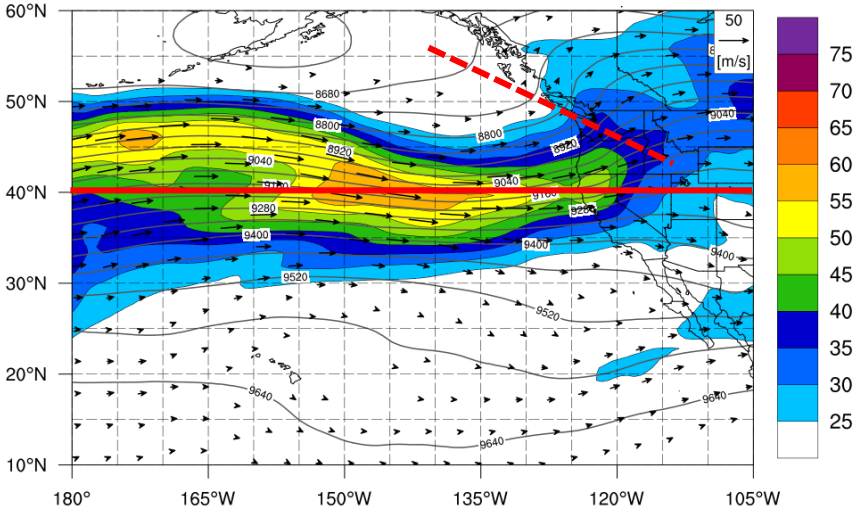
Aleutian/Gulf of Alaska low moves NW prior to landfall (movement indicated by red arrow)

AR w/o SFW Composites

W oriented AR

Strong subtropical high NW of Hawaii





Mostly W orientation

Very negatively tilted trough

Majority of jet north or along 40°N

*Data from ERA-Interim Reanalysis

Center for Western Weather and Water Extremes

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FIRO Science: C-130 AR Recon Mission February 2016 and Investigating Mesoscale Frontal Waves

F. M. Ralph – Lead (Scripps Inst. of Oceanography/CW3E; mralph@ucsd.edu)

Cmdr. M. Silah and V. Tallapragada (NOAA/NCEP)

Lt. Col. J. Talbot (US Air Force/53rd Weather Reconnaissance Squadron)

J. Doyle (Naval Research Laboratory)

Acknowledgments

Air Force field team (Capt. A. Lundry, L. Froilich, C-130 crews)

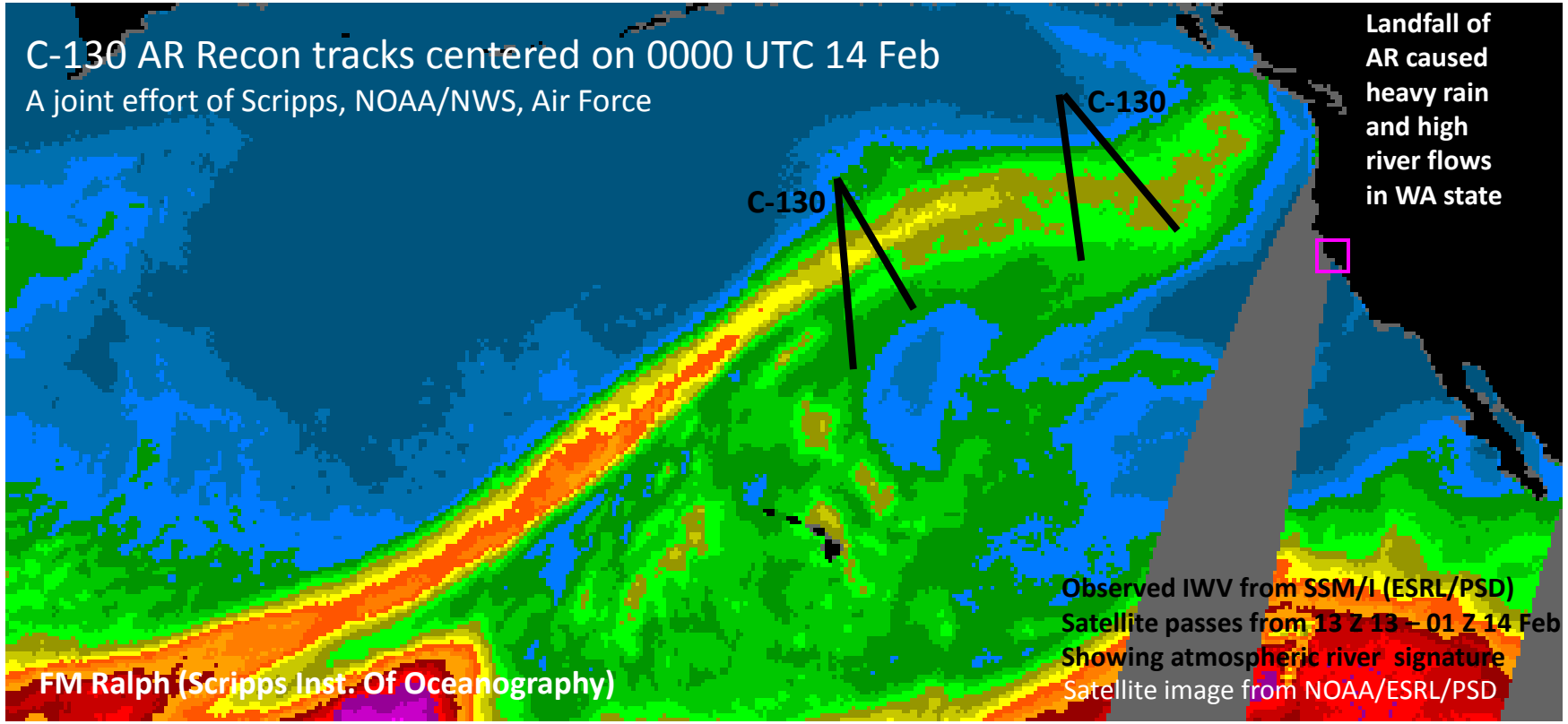
AR Recon Forecast team (J. Cordeira, J. Rutz, S. Sellars, A. Martin, B. Kawzenuk)

NCEP/CARCAH (J. Pavone, S. Feuer, W. Madden)

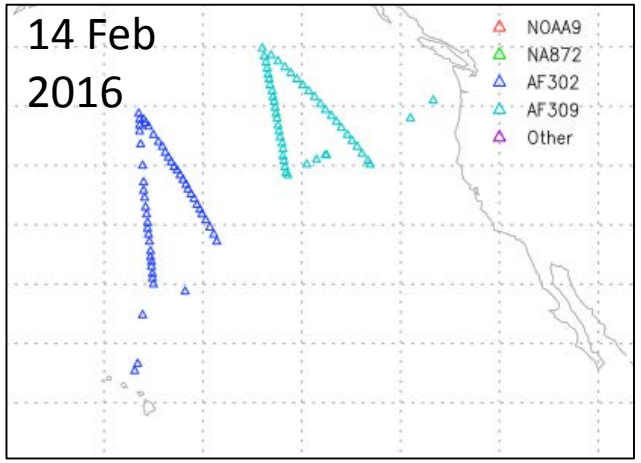
Overview of C-130 AR Recon operations

- Three storms were observed simultaneously by both C-130 weather reconnaissance aircraft flown by the Air Force.
  - 13-14 Feb 2016; 15-16 Feb 2016, and 21-22 Feb 2016
- In each storm the primary target was sampling an atmospheric river, offshore.
- Targets were identified by the mission's lead scientist at Scripps Institution of Oceanography and coordinated with NWS.
- Each aircraft released dropsondes that measured the detailed vertical profiles of wind, water vapor, temperature and pressure below the aircraft.
- Each flight focused on collecting dropsonde data during the 6-hour assimilation window of the GFS centered on 0000 UTC.
- These data were transmitted in real-time to a communications hub where they were quality controlled and then assimilated into the NWS global weather prediction model (GFS) to improve forecasts of landfalling atmospheric river conditions and other weather.
- The measurements helped determine subtle differences in the moisture, winds and temperatures in the atmospheric rivers. Without those data, errors in the weather prediction model's initial condition then can grow and cause important errors in storm predictions over the next few days.

AFRC
Hurricane Hunters
75303



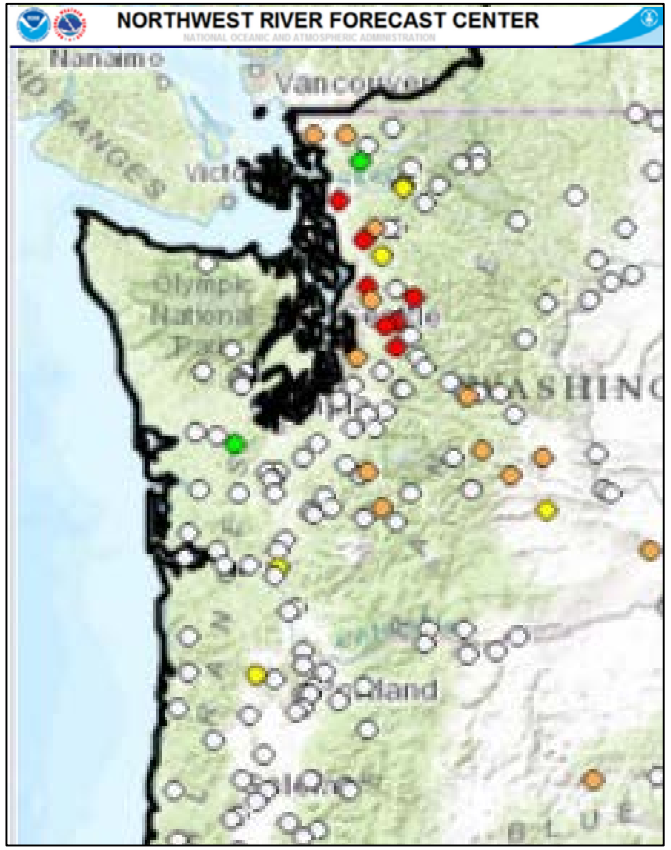
1st C-130 AR Recon Mission
13-14 Feb 2016
Dropsondes released for the 0000 UTC 14 Feb 2016 GFS data assimilation window



http://www.emc.ncep.noaa.gov/cmb/stokes/drops/maps/

Locations of C-130 AR Recon dropsondes received and successfully decoded into NCEP's production bufr data tanks for assimilation into NCEP/GFS

NWRFC flood forecast map as of 1500 UTC 15 Feb showing several rivers predicted to reach flood stage on 15-16 Feb (red dots)

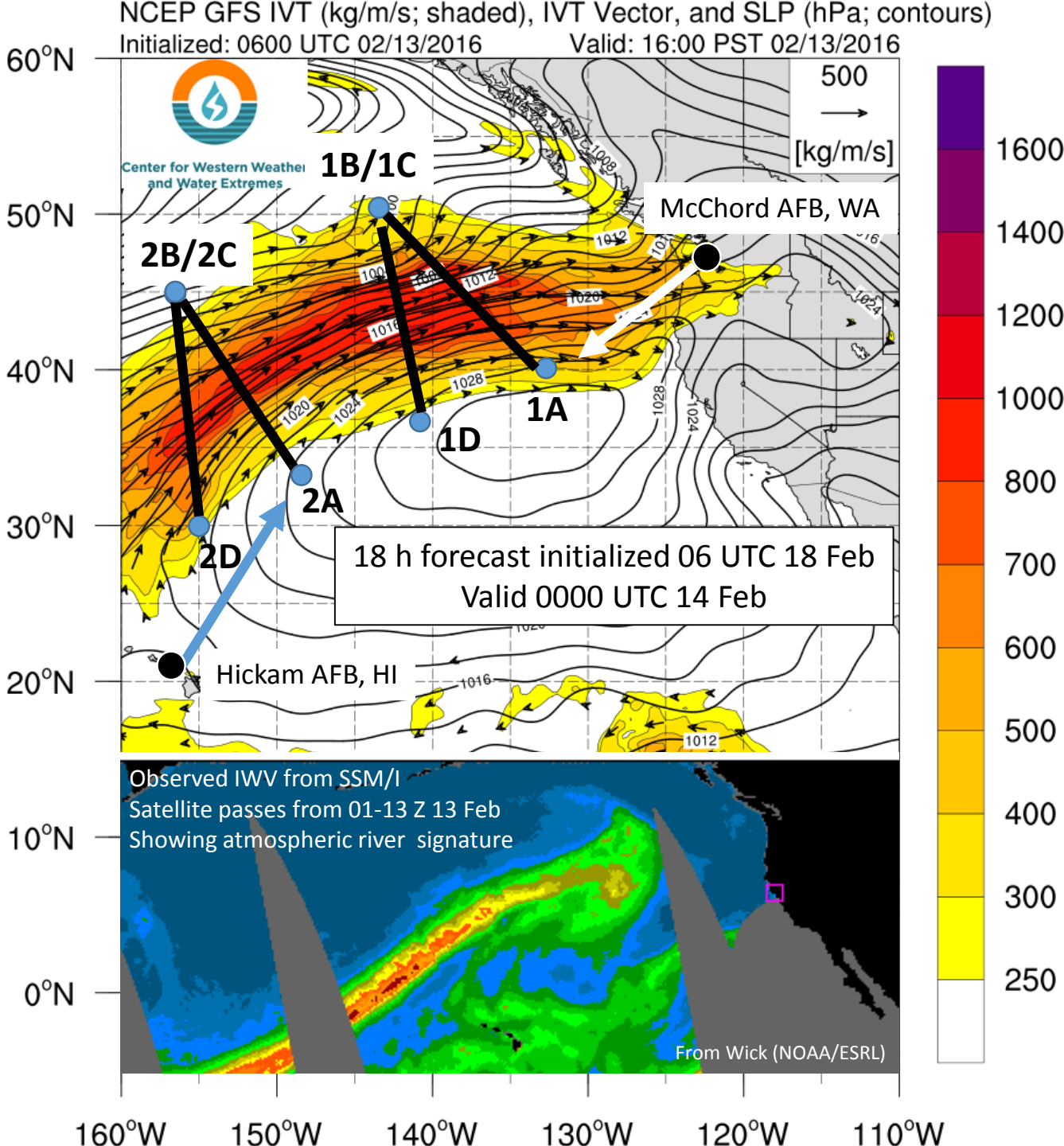


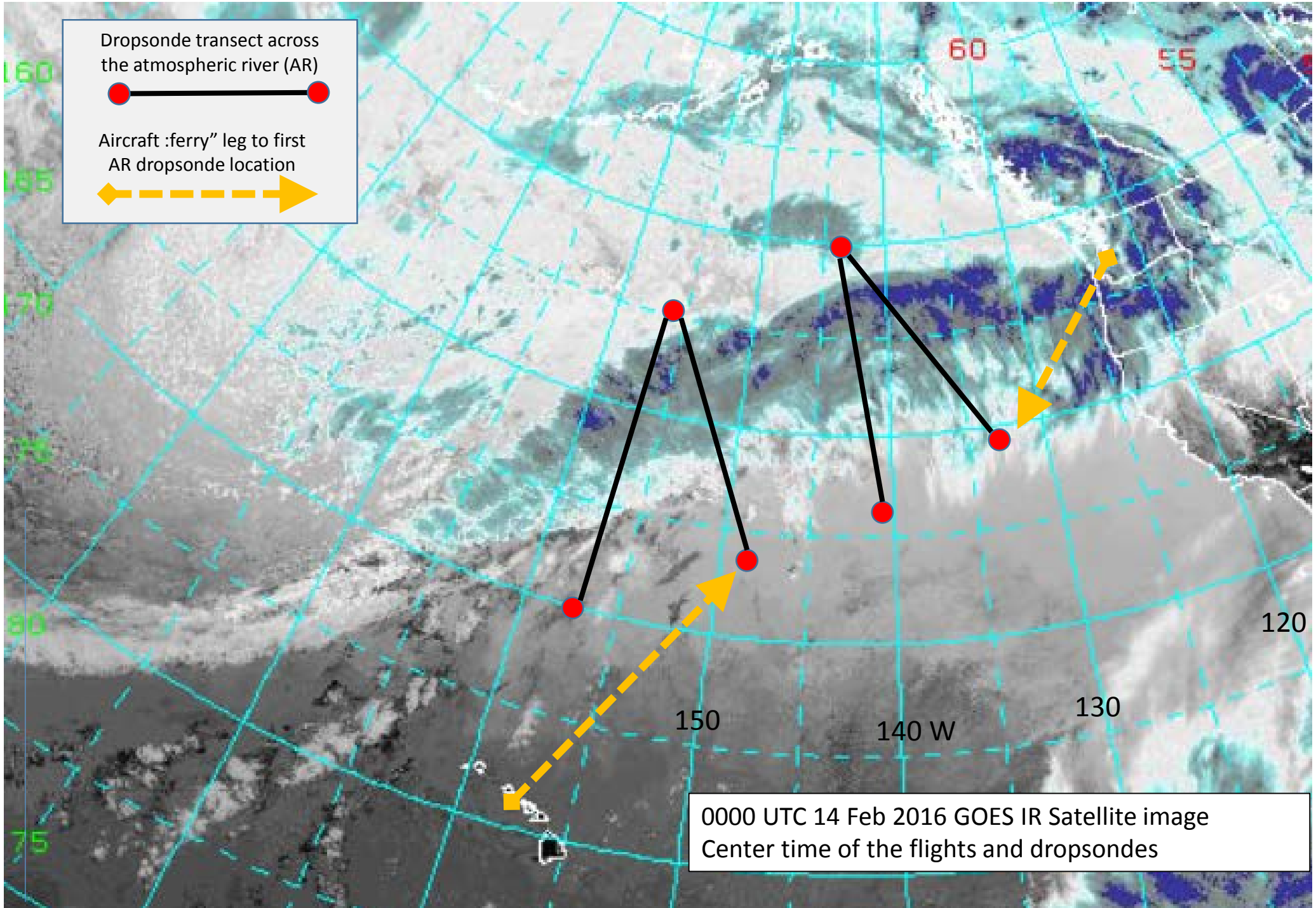
C-130 Atmospheric River Reconnaissance Mission Flights centered on 0000 UTC 14 Feb

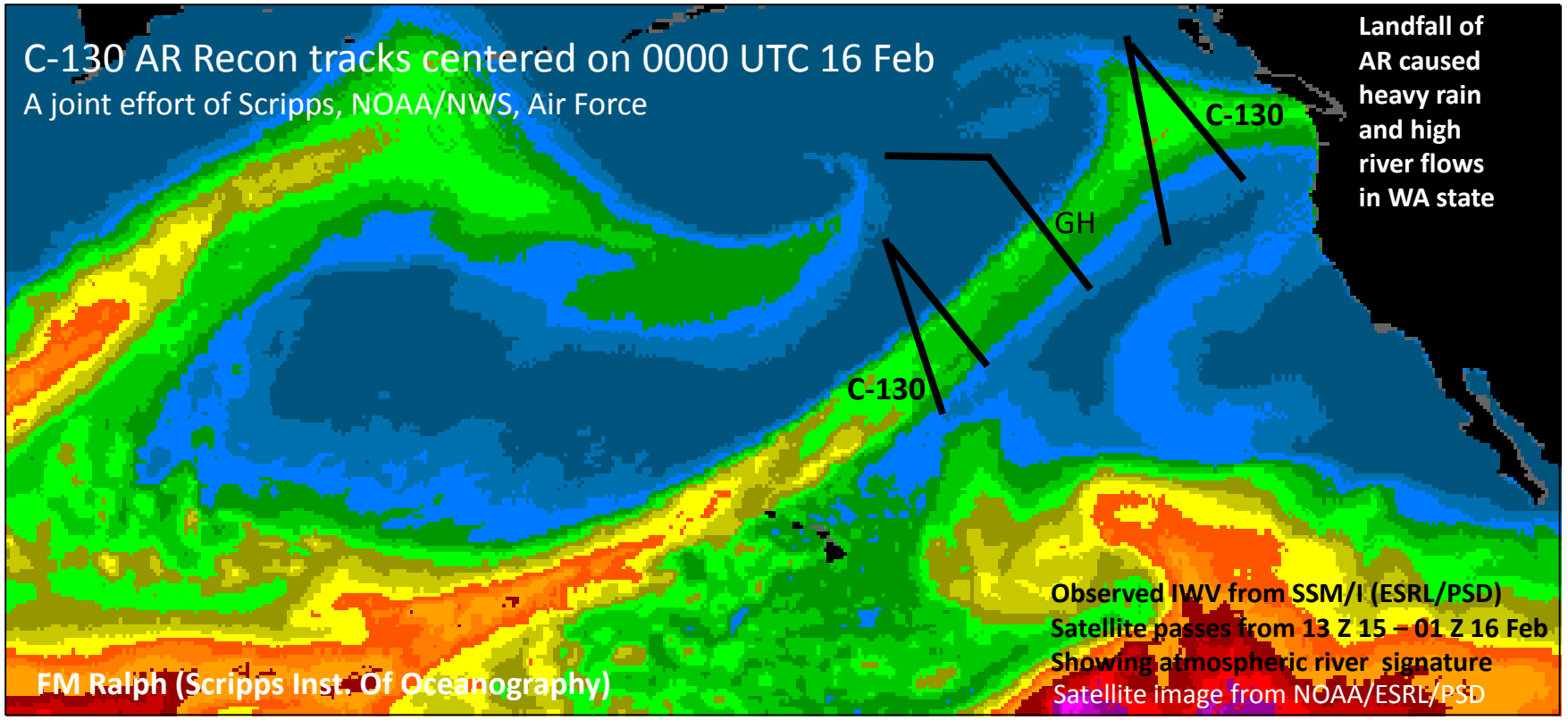
A joint effort of Scripps Institution of Oceanography/CW3E, US Air Force/Weather Recon. Squadron and NOAA/NWS

Summary by F. Martin Ralph

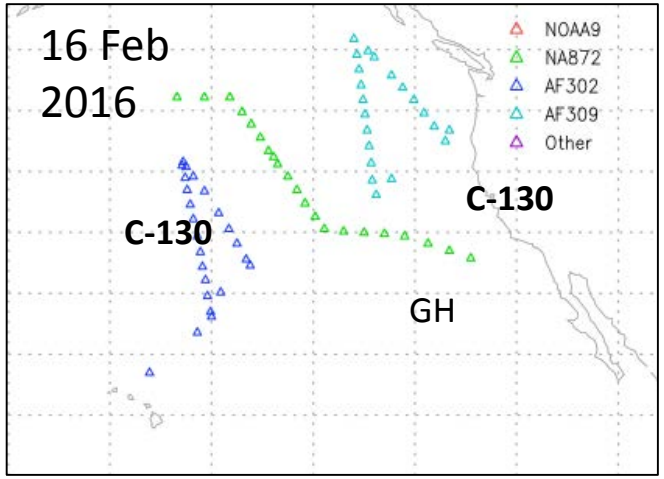
C-130 base	Waypoint	Lat (deg N)	Long (deg W)	Distance (time at 300 kt)
McChord AFB WA	TO: 1810 UTC	47.14	122.48	To 1A:
	1A: 2041	40	133	
	No Pt 1B			
	1C: 2340	50	144	
49 sondes	1D: 0157	39.1	141.6	
10.6 h	Ld: 0445			To McChord:
Hickam AFB HI	TO: 1721 UTC	21.34	157.95	To 2A:
	2A: 2032	33.5	148.5	
	No pt 2B			
	2C: 2322	45	157	
53 sondes	2D: 0318	30	155	
12.3 h	Ld: 0537			To Hickam:




Dropsonde transect across the atmospheric river (AR)
Aircraft :ferry" leg to first AR dropsonde location
60
55
120
130
140 W
150
0000 UTC 14 Feb 2016 GOES IR Satellite image
Center time of the flights and dropsondes



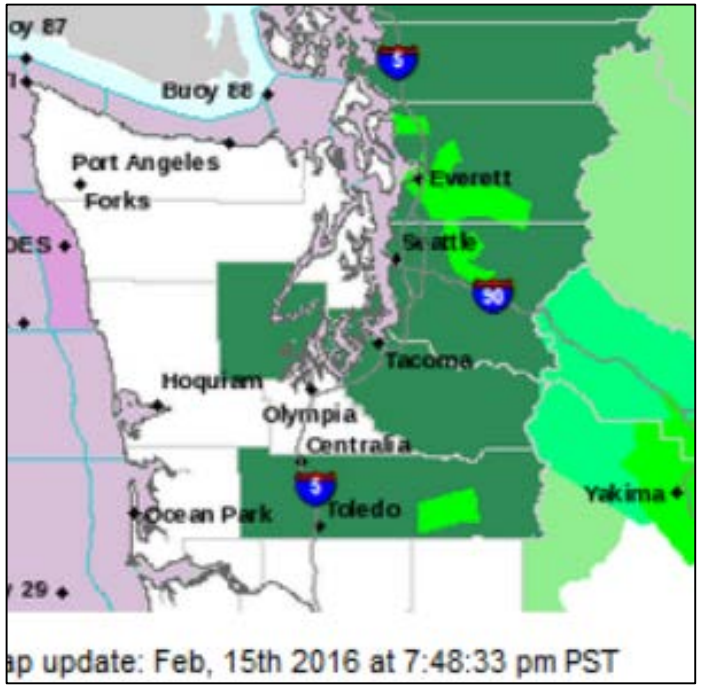
2nd C-130 AR Recon Mission
15-16 Feb 2016
Dropsondes released for the 0000 UTC 16 Feb 2016 GFS data assimilation window



http://www.emc.ncep.noaa.gov/cmb/stokes/drops/maps/

Locations of C-130 AR Recon dropsondes received and successfully decoded into NCEP's production bufr data tanks for assimilation into NCEP/GFS

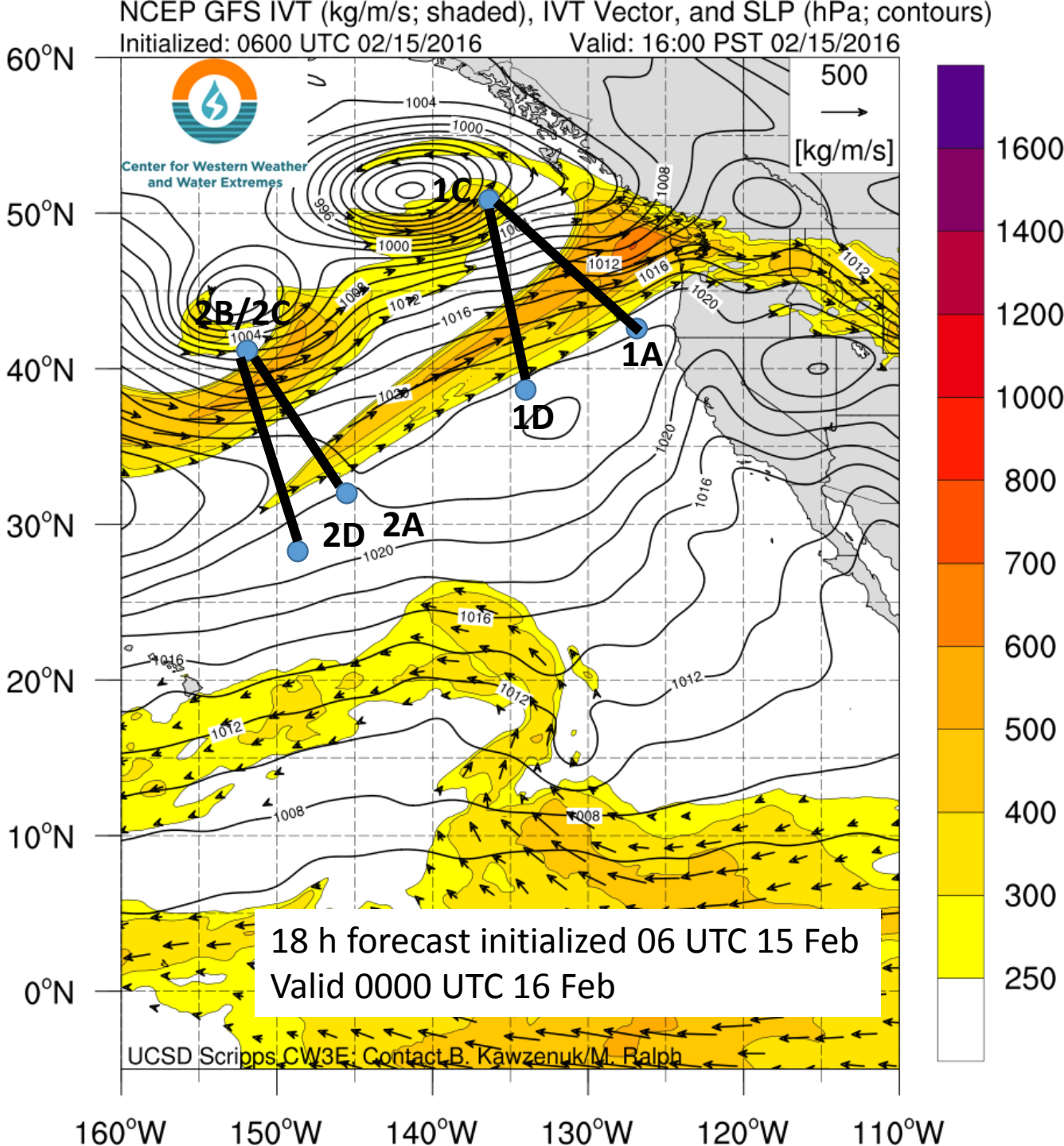
Seattle NWS Office flood warnings, watches and advisories at 0400 UTC 16 Feb 2016

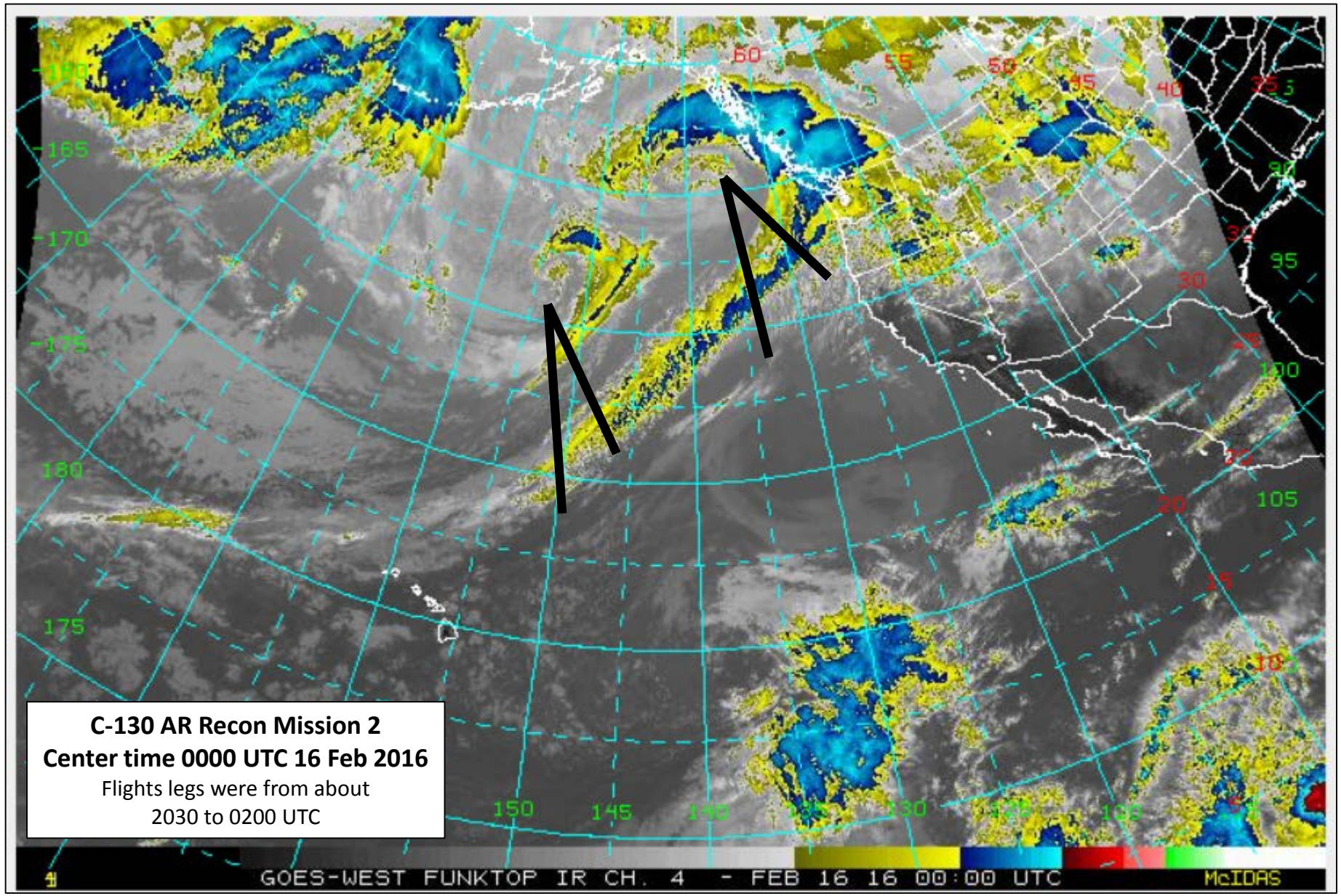


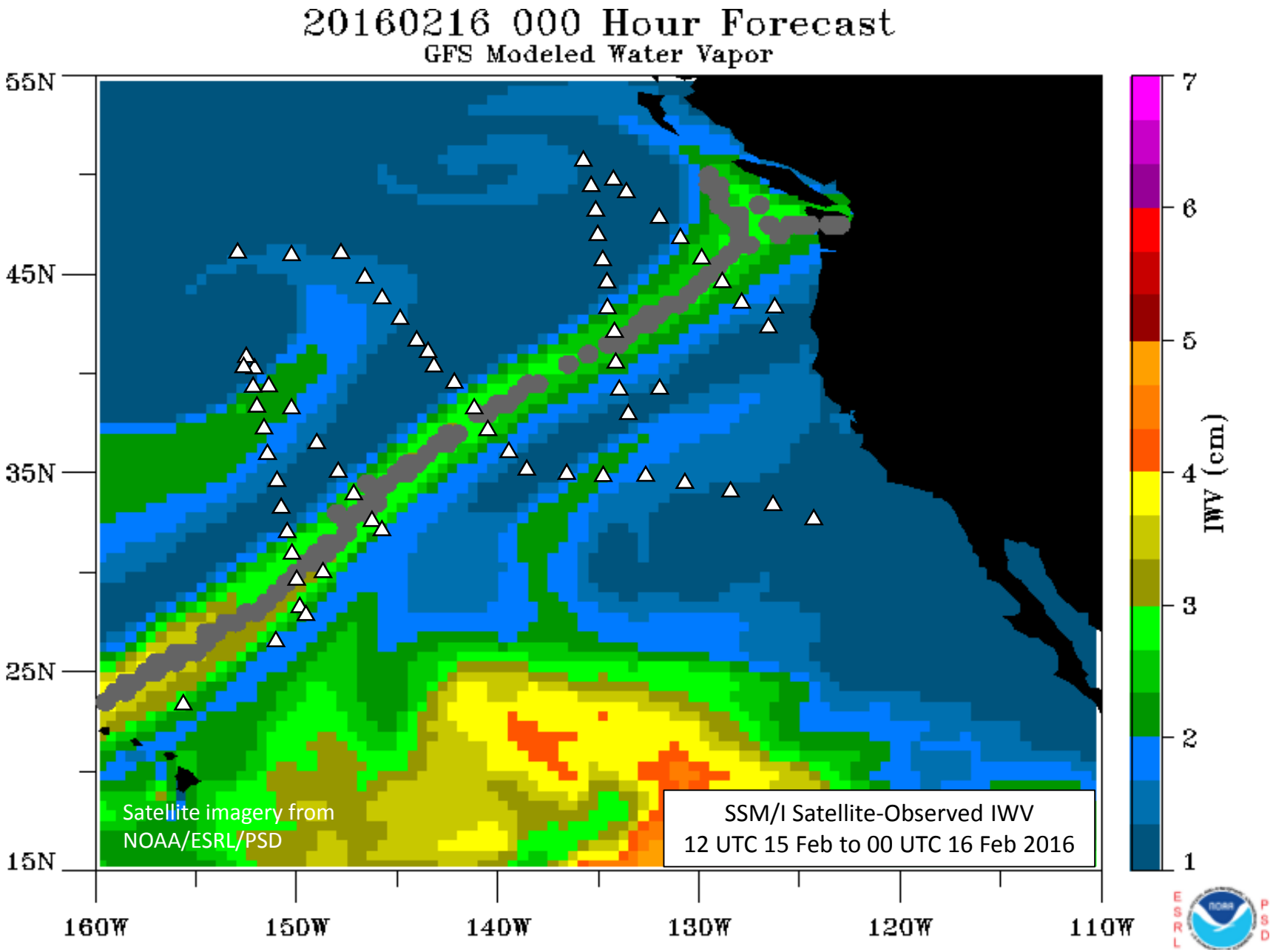
C-130 Atmospheric River Reconnaissance Mission*
Flights centered on 0000 UTC 16 Feb

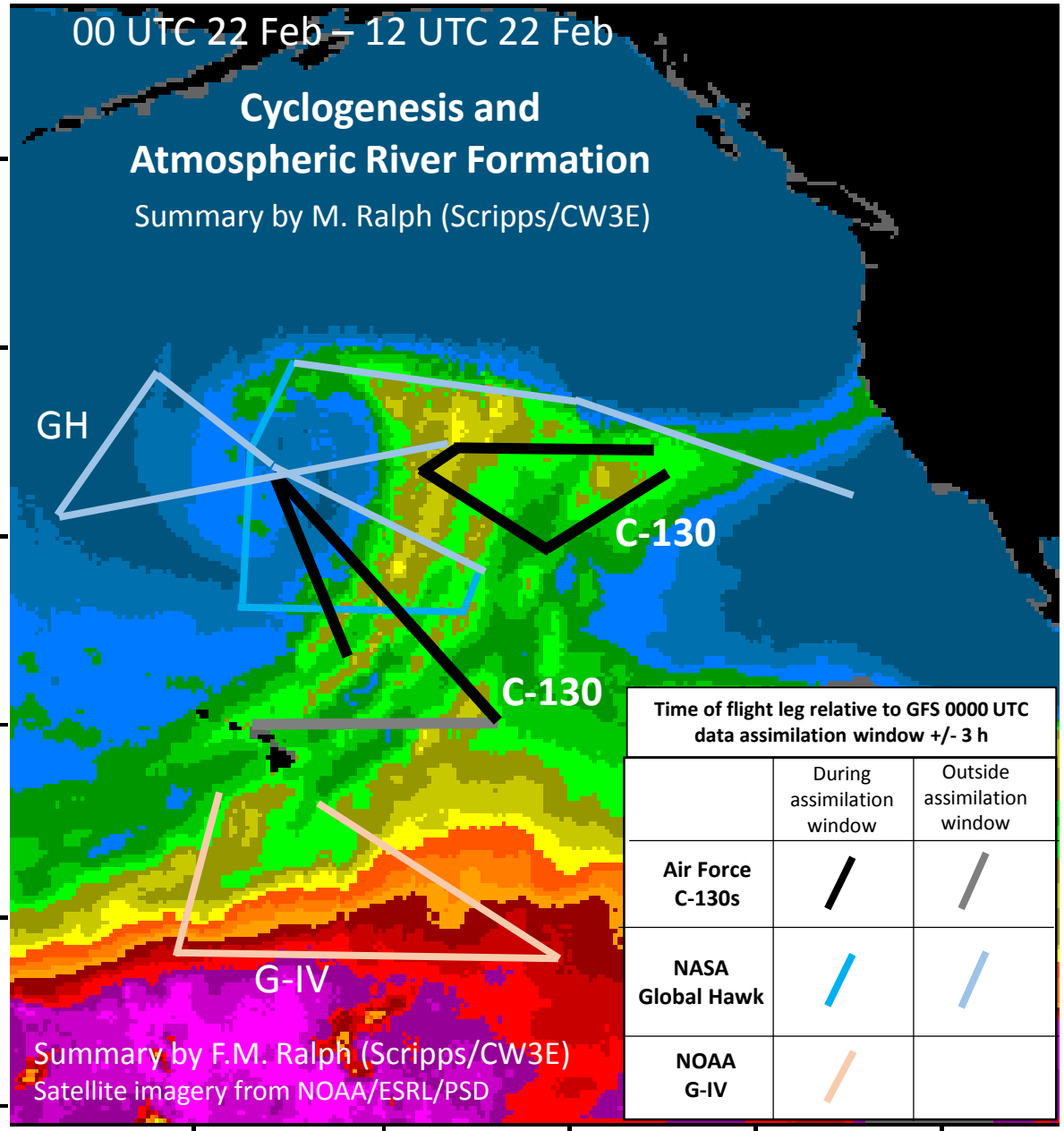
**A joint effort of Scripps Institution of Oceanography/CW3E, US Air Force/Weather Recon. Squadron and NOAA/NWS*

C-130 base	Waypoint	Lat (deg N)	Long (deg W)	Distance (time at 300 kt)
McChord AFB WA	TO: 1914 UTC	47.14	122.48	To 1A:
	1A: 2047	42.5	127	
	SKIP 1B			
	1C: 2259	51	136	
42 sondes	1D: 0201	38	134	
9.0 h	Ld: 0412			To McChord:
Hickam AFB HI	TO: 1738 UTC	21.34	157.95	To 2A:
	2A: 2031	32	146	
	Skip 2B			
	2C: 2250	41	153	
43 sondes	2D: 0152	28	150	
11.1 h	Ld: 0442			To Hickam:



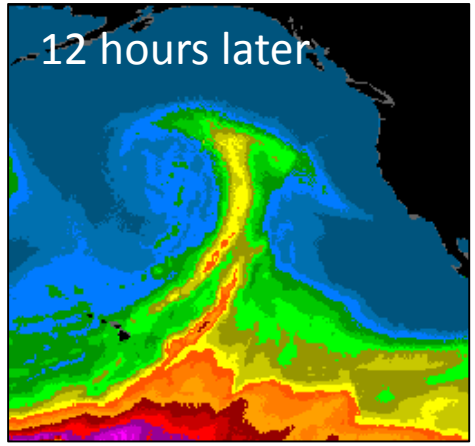

C-130 AR Recon Mission 2
Center time 0000 UTC 16 Feb 2016
Flights legs were from about
2030 to 0200 UTC
GOES-WEST FUNKTOP IR CH. 4 - FEB 16 16 00:00 UTC
McIDAS


20160216 000 Hour Forecast
GFS Modeled Water Vapor
55N
45N
35N
25N
15N
160W
150W
140W
130W
120W
110W
IWV (cm)
7
6
5
4
3
2
1
Satellite imagery from
NOAA/ESRL/PSD
SSM/I Satellite-Observed IWV
12 UTC 15 Feb to 00 UTC 16 Feb 2016



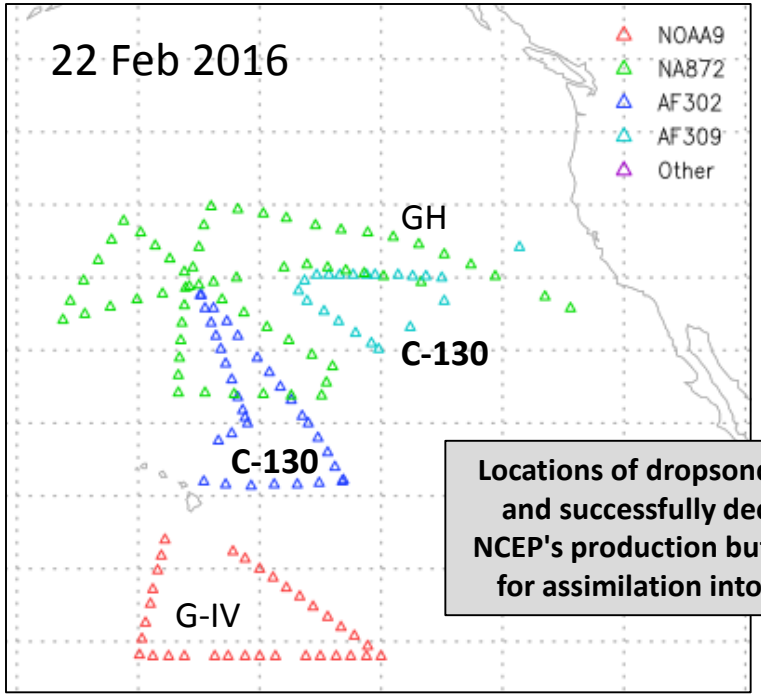
Time of flight leg relative to GFS 0000 UTC data assimilation window +/- 3 h

	During assimilation window	Outside assimilation window
Air Force C-130s		
NASA Global Hawk		
NOAA G-IV		



3rd C-130 AR Recon Mission
21-22 Feb 2016
Dropsondes released for the
0000 UTC 22 Feb 2016
GFS data assimilation window

C-130 PI: F.M. Ralph (Scripps/CW3E)
GH lead: G. Wick (NOAA/PSD)
G-IV leads: Dole/Spackman (NOAA/PSD)



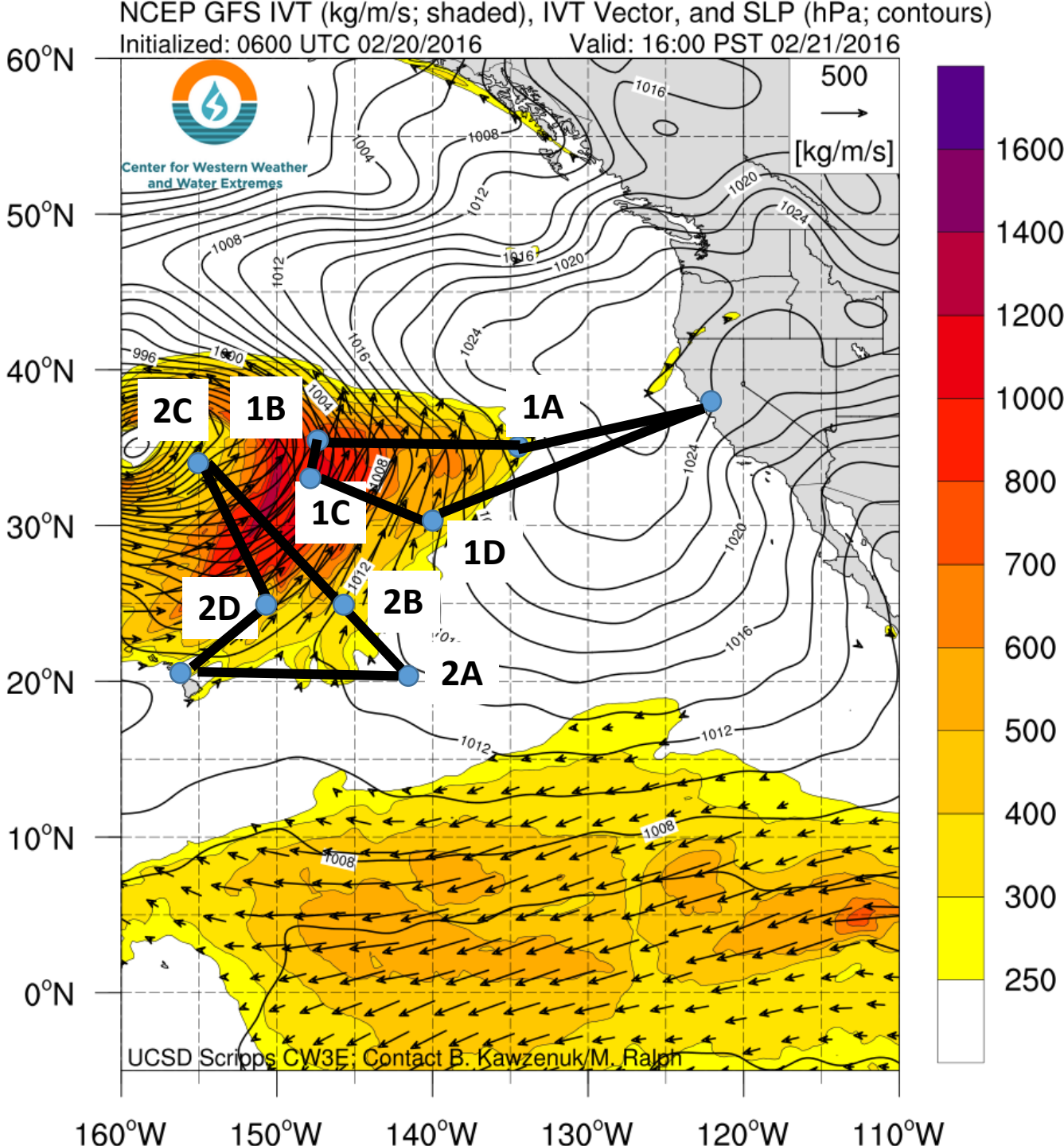
Locations of dropsondes received and successfully decoded into NCEP's production bufr data tanks for assimilation into NCEP/GFS

http://www.emc.ncep.noaa.gov/cmb/stokes/drops/maps/

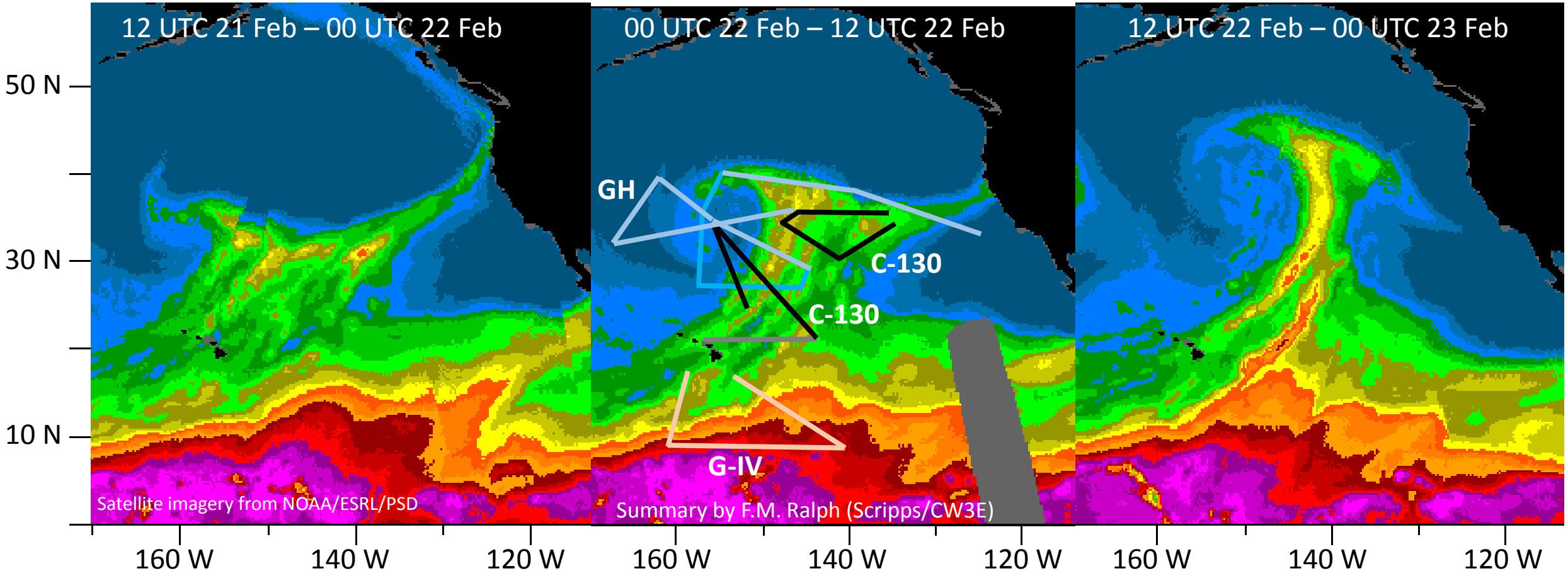
C-130 Atmospheric River Reconnaissance Mission*
Draft plan for Flights centered on 0000 UTC 22 Feb

**A joint effort of Scripps Institution of Oceanography/CW3E, US Air Force/Weather Recon. Squadron and NOAA/NWS*

C-130 base	Waypoint	Lat (deg N)	Long (deg W)	Distance (time at 300 kt)
Travis AFB CA	TO: 1758 UTC	38.26	121.93	
	1A: 2109	35	135	
	1B: 2339	35	146	
	1C: 0004	34	147	
	1D: 0122	30	140	
39 sondes		38.26	121.93	
10.3 h	Ld: 0413			
Hickam AFB HI	TO: 1754 UTC	21.34	157.95	
	2A: 2035	20	142	
	2B: 2136	25	146	
	2C: 0000	34	155	
	2D: 0225	25	151	
59 sondes	Ld: 0425 UTC			
10.5 h				



C-130 AR Recon Coordinated with Global Hawk SHOUT and G-IV ENRR flights
Cyclogenesis and Atmospheric River Genesis on 21-22 Feb 2016



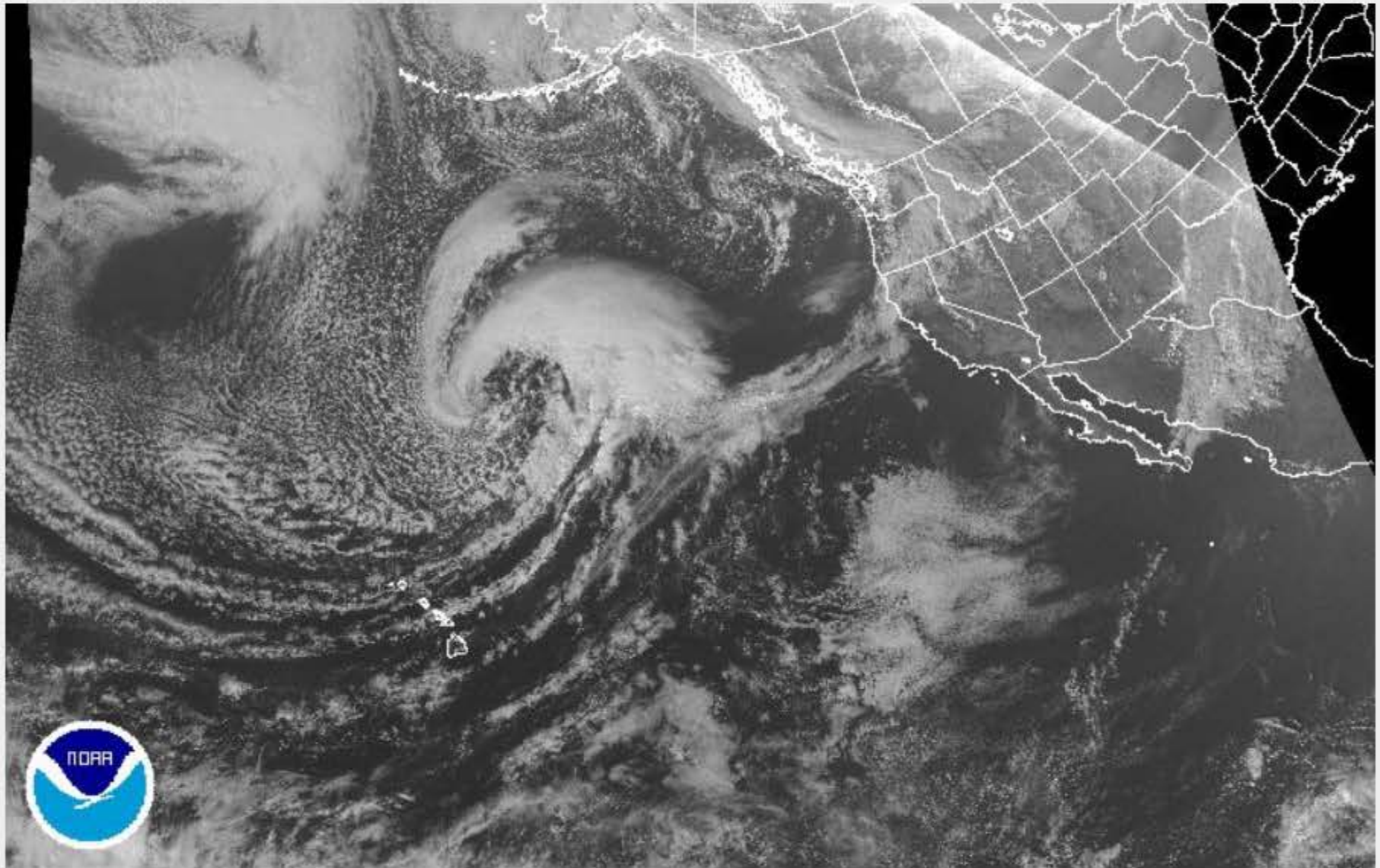
noaa.gov/dmi/west/nhem/nepac/vis.html

sunset la jolla

Water | Webcams | Banking | UCSD | NOAA Gmail | CW3E | AR Portal | MapQuest | NSPIRES - NASA | DSC03372 | Flickr - Ph... | Most Visited | CalWater

< | play | > | slower | faster | rock | refresh

☐ LatLon ☐ HDW-high ☐ HDW-mid ☐ HDW-low ☐ Trop Fcst Pts ☐ NCEP Fronts ☐ Overlay 6



Thank You