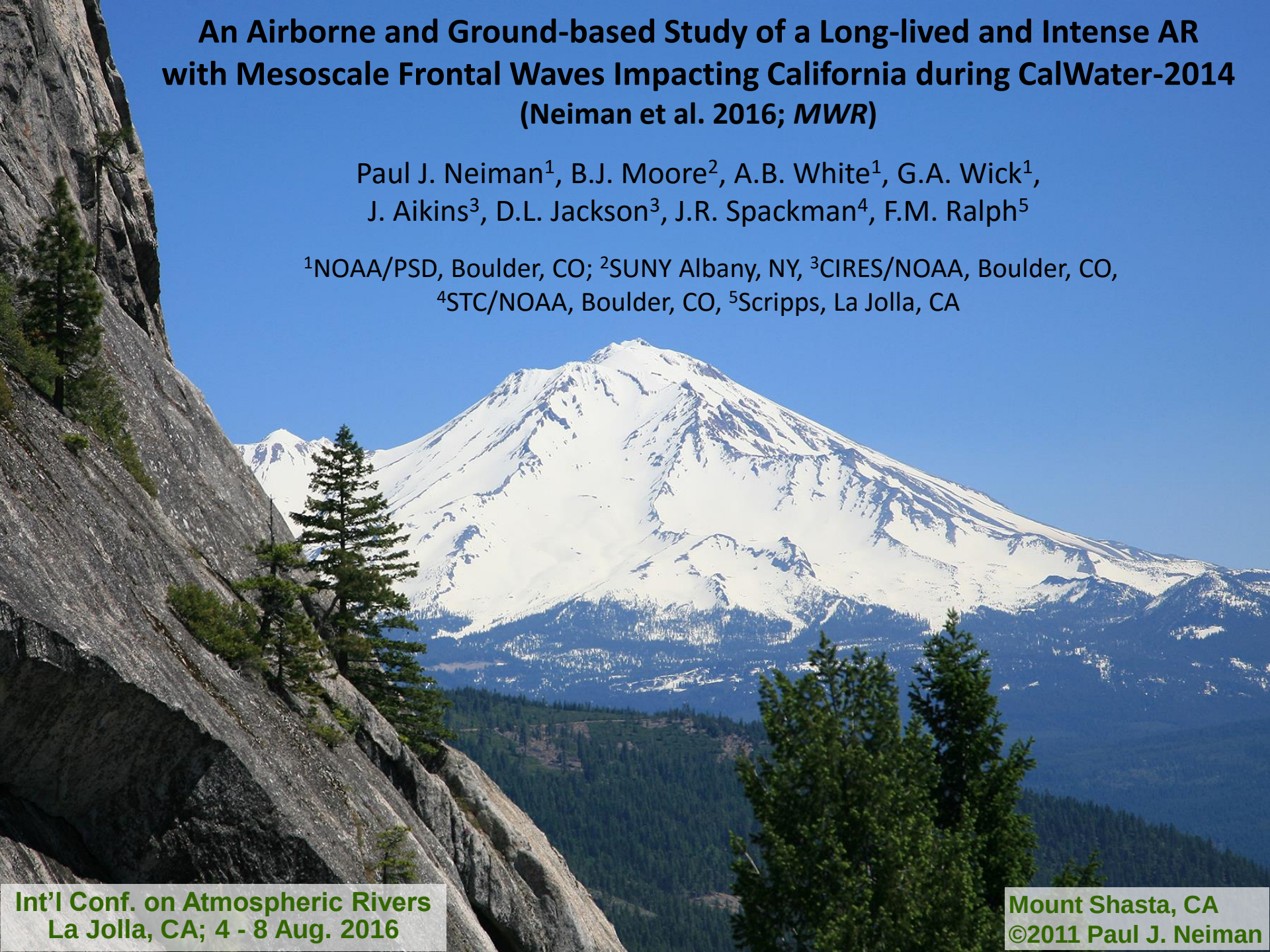
An Airborne and Ground-based Study of a Long-lived and Intense AR with Mesoscale Frontal Waves Impacting California during CalWater-2014 (Neiman et al. 2016; *MWR*)

Paul J. Neiman[1], B.J. Moore[2], A.B. White[1], G.A. Wick[1],
J. Aikins[3], D.L. Jackson[3], J.R. Spackman[4], F.M. Ralph[5]

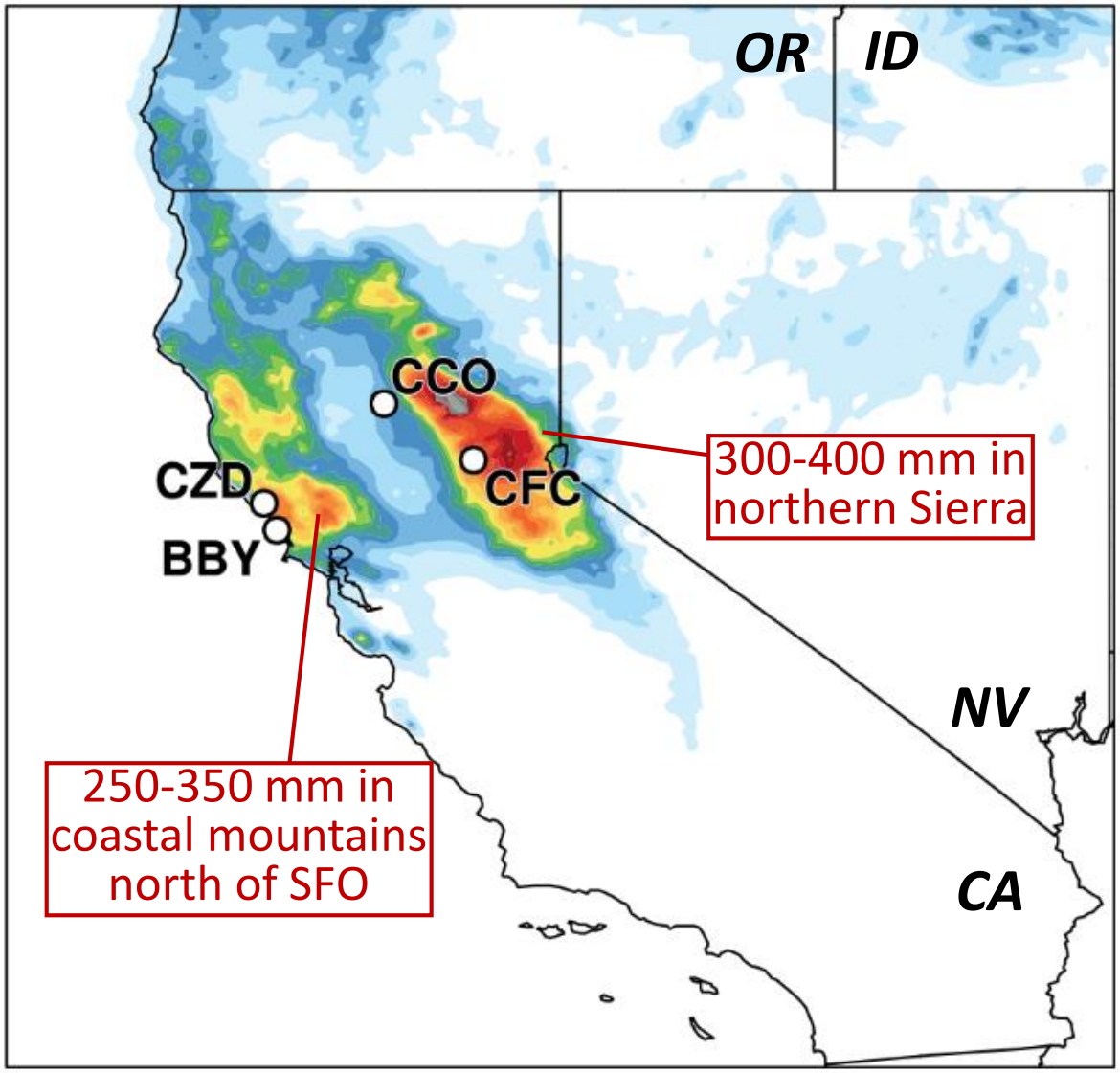
[1]NOAA/PSD, Boulder, CO; [2]SUNY Albany, NY, [3]CIRES/NOAA, Boulder, CO,
[4]STC/NOAA, Boulder, CO, [5]Scripps, La Jolla, CA

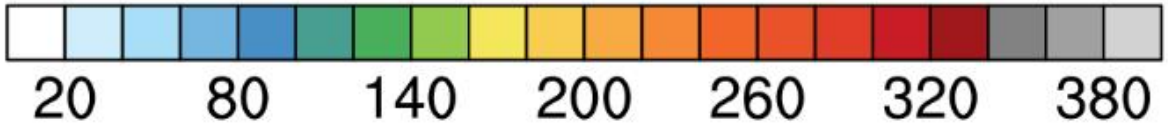


Int'l Conf. on Atmospheric Rivers
La Jolla, CA; 4 - 8 Aug. 2016

Mount Shasta, CA

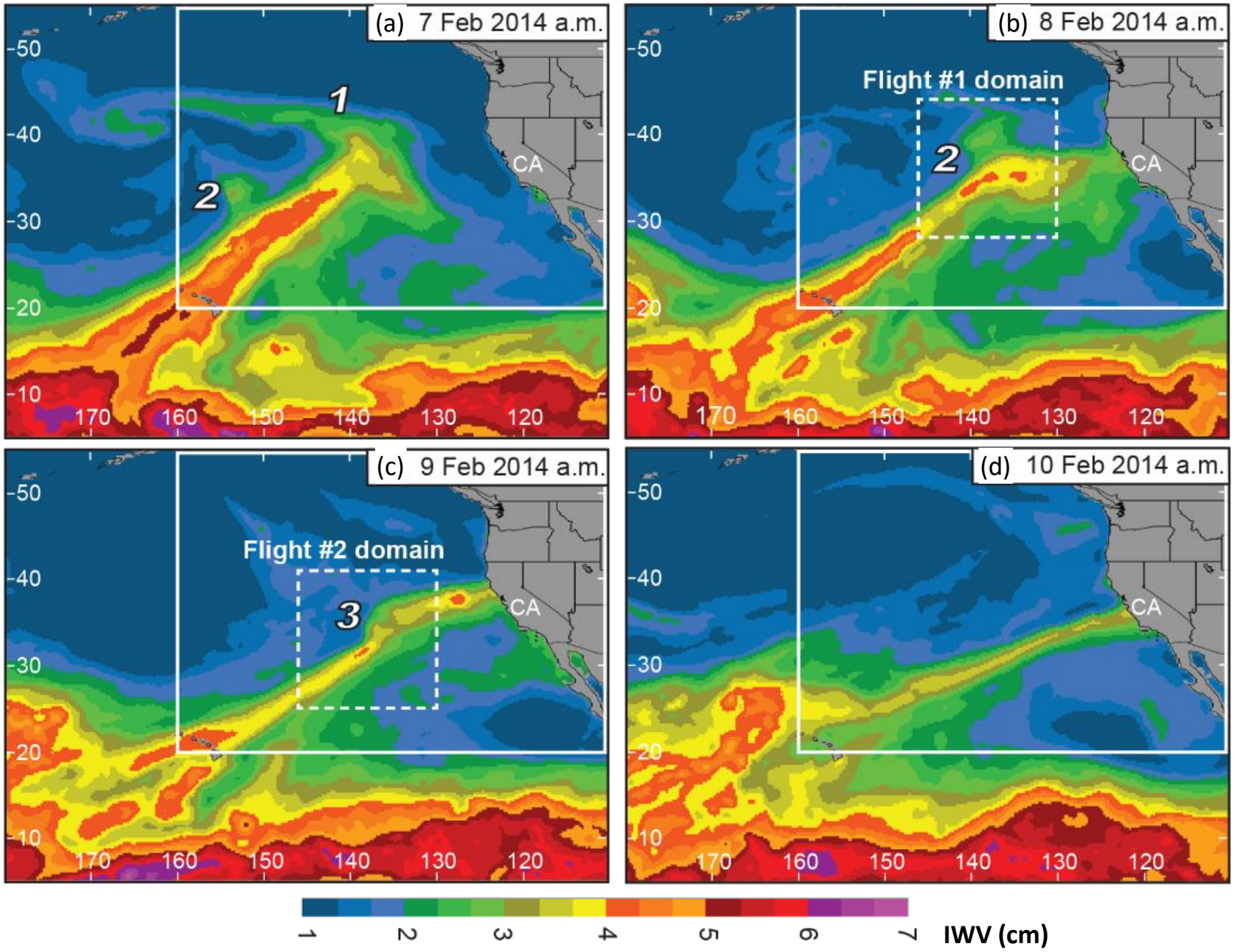
96-h Stage-IV precipitation accumulation: 00Z 7-Feb-2014 to 00Z 11-Feb-2014



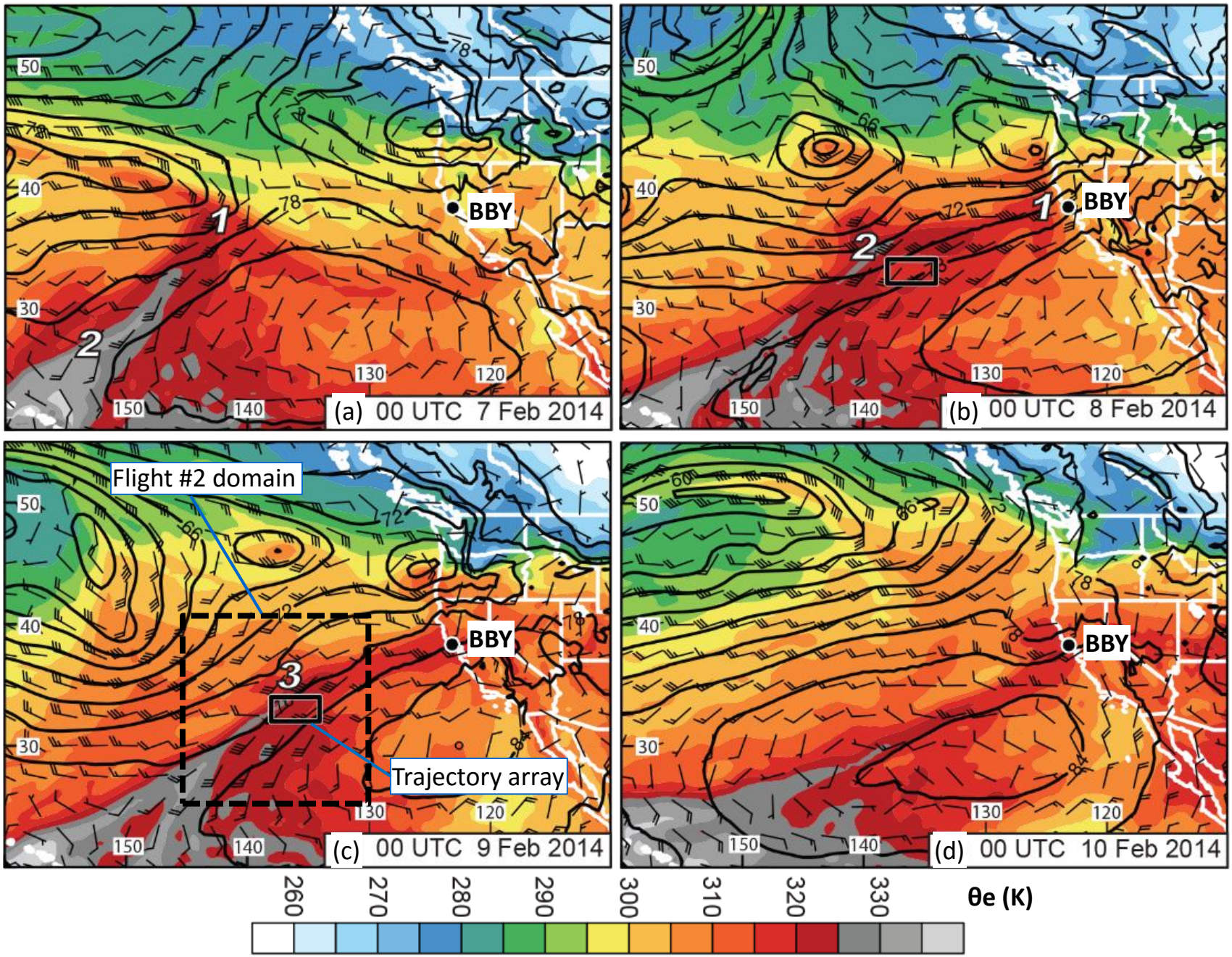


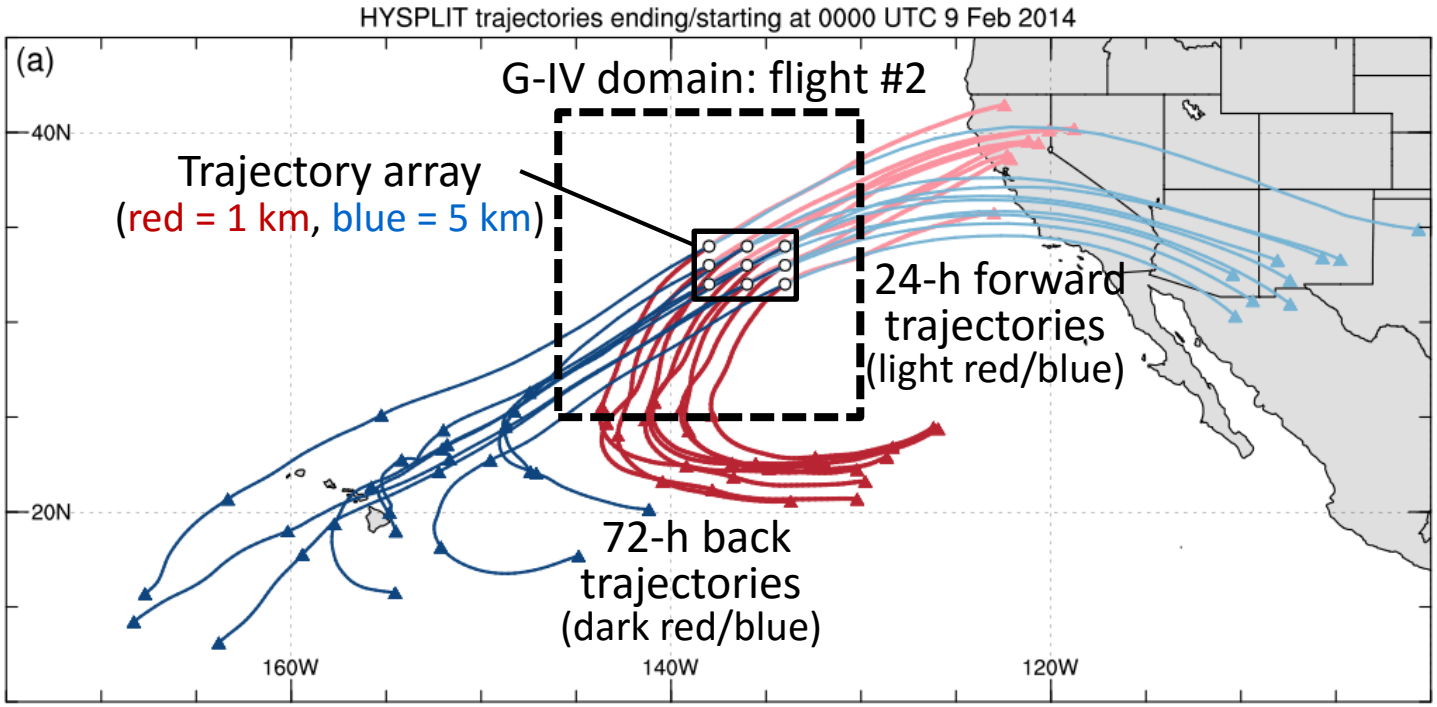
- By far the wettest period during the 2014 winter in CA.
- From 7 thru 10 Feb. 2014, a quasi-stationary AR with three frontal waves impacted N CA.
- In 4 days, 250-350 mm precip in coastal mtns & 300-400 mm in northern Sierra.
- Key land-based observing sites are labeled – discussed later.
- Offshore, two NOAA G-IV flights released dozens of dropsondes thru the AR – also discussed later.

SSMIS IWV (cm) composite satellite imagery

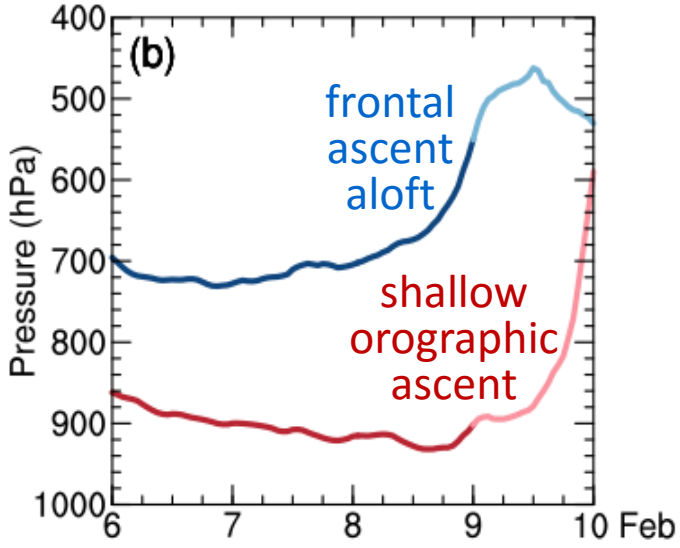


925-hPa Heights (dam, black contours) and θe (K, color fill)



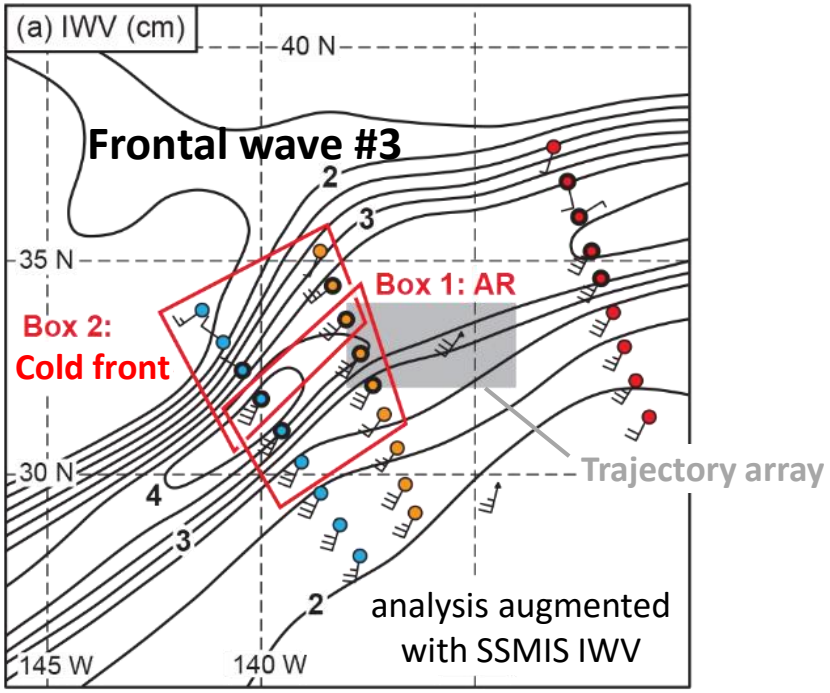


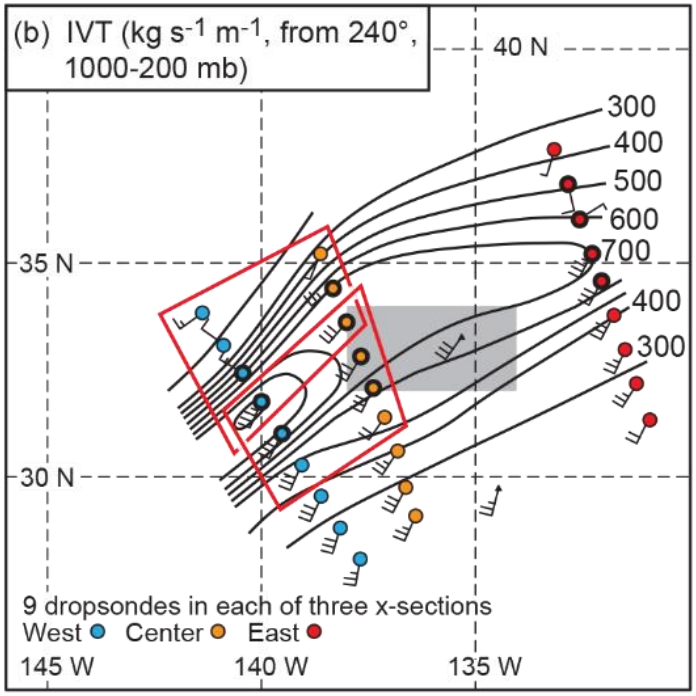
Trajectory-averaged pressure altitude

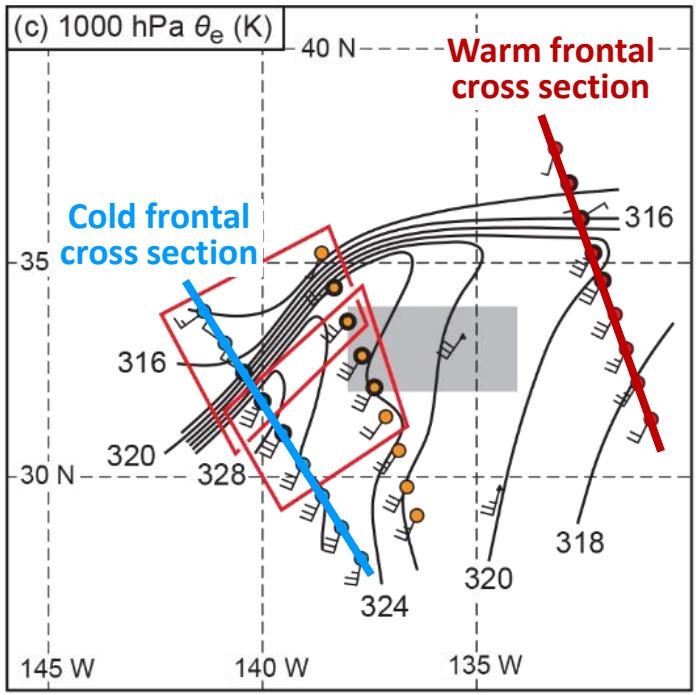


NOAA G-IV offshore flight #2 through frontal wave #3:

Dropsondes adjusted to 2310 UTC 8 Feb. 2014





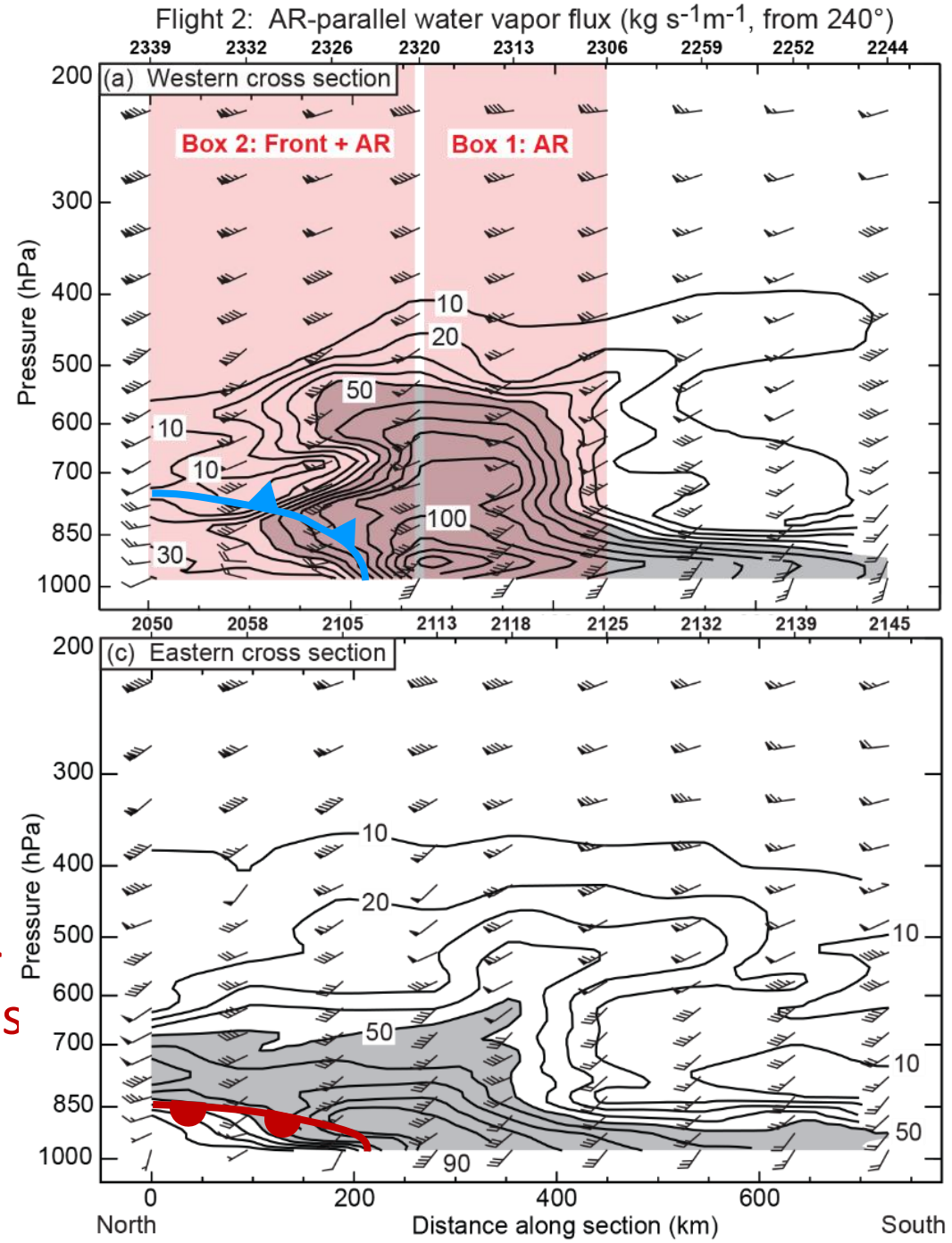


Cold frontal cross section

Strong & deep upright vapor fluxes

Warm frontal cross section

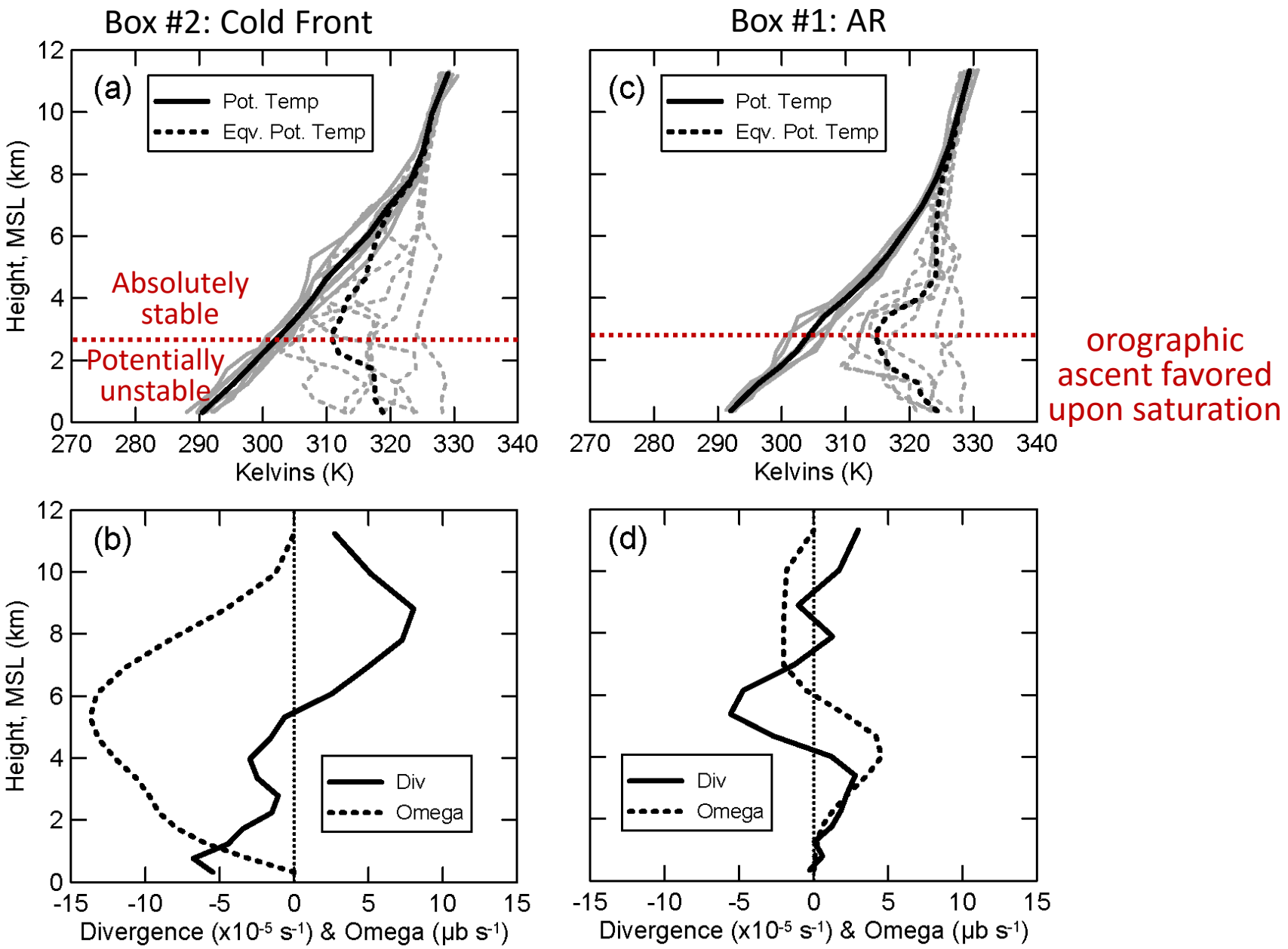
Weaker & shallower slantwise vapor fluxes



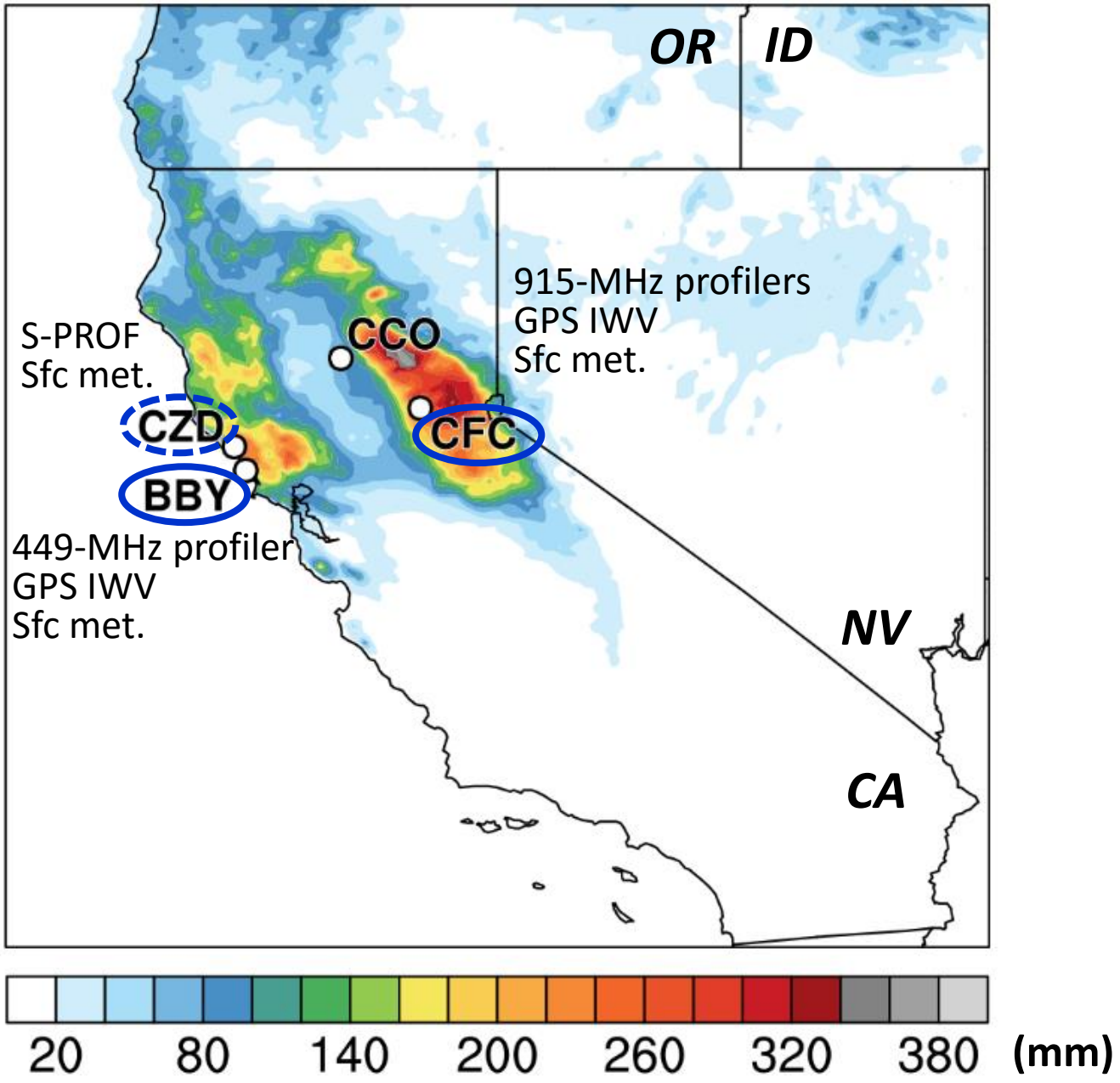
NOAA G-IV flight #2: Thermodynamic and kinematic diagnostics

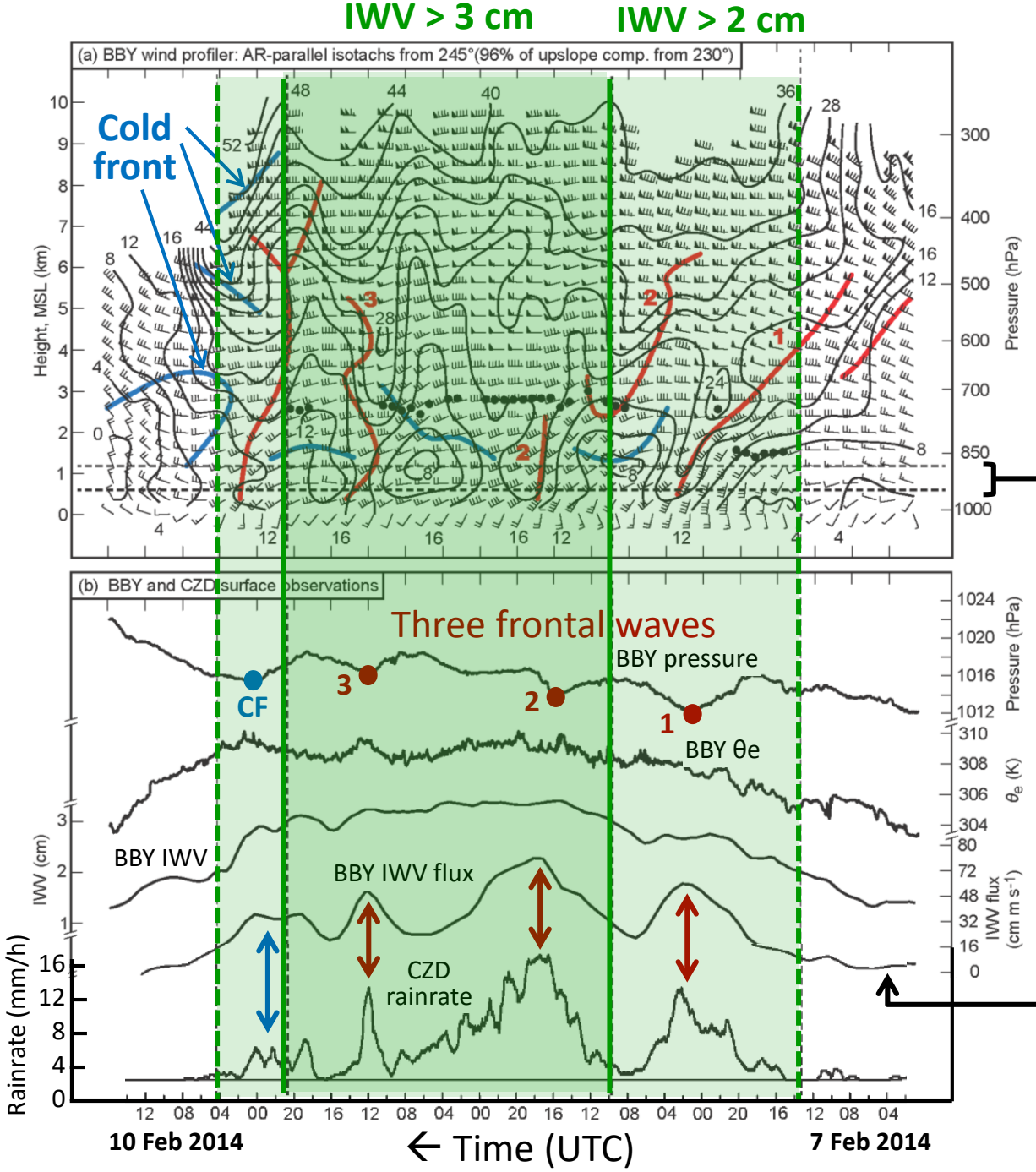
Thermodynamic profiles

Kinematic profiles



96-h Stage-IV precipitation accumulation: 00Z 7-Feb-2014 to 00Z 11-Feb-2014



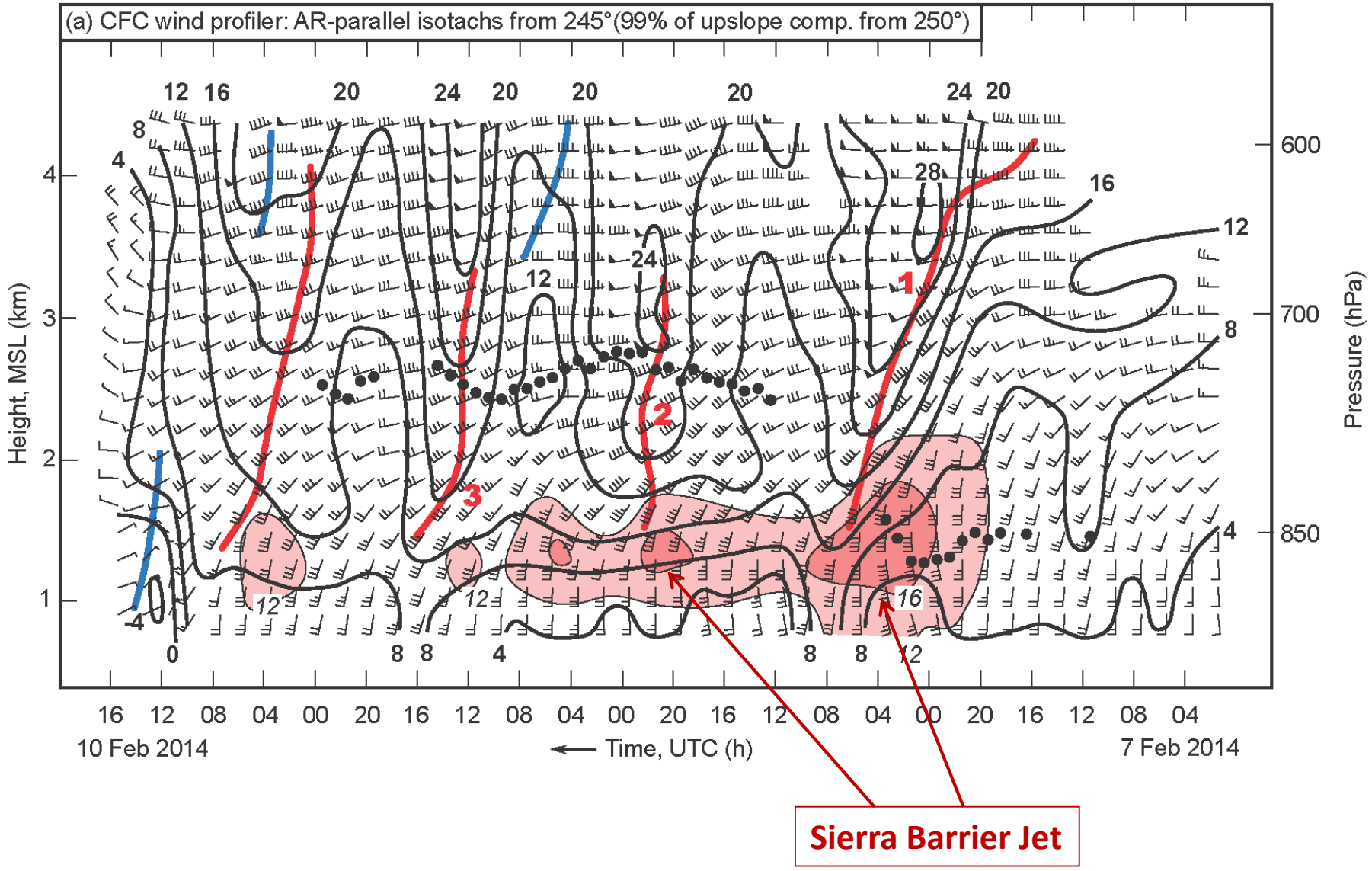


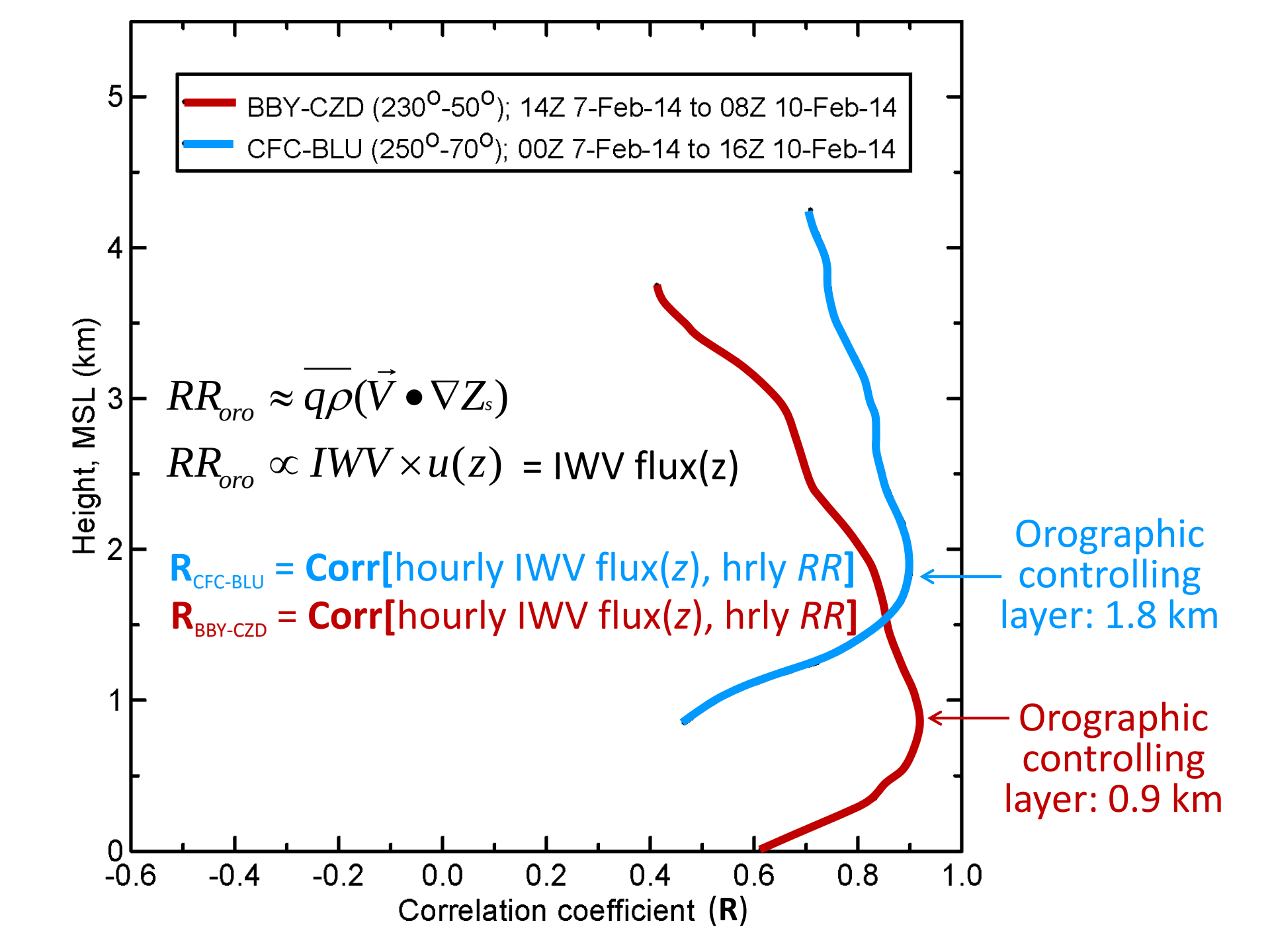
Axis of geostrophic warm advection

Axis of geostrophic cold advection

Upslope IWV flux in the orographic controlling layer (~1 km MSL) at BBY is highly correlated with the rainrate in the downwind coastal mtns at CZD.

IWV flux and rainrate peaks with each frontal wave and the cold front.


(a) CFC wind profiler: AR-parallel isotachs from 245°(99% of upslope comp. from 250°)
Height, MSL (km)
Pressure (hPa)
600
700
850
1
2
3
4
Time, UTC (h)
10 Feb 2014
7 Feb 2014
Sierra Barrier Jet


BBY-CZD (230°-50°); 14Z 7-Feb-14 to 08Z 10-Feb-14
CFC-BLU (250°-70°); 00Z 7-Feb-14 to 16Z 10-Feb-14
$RR_{oro} \approx \overline{q\rho}(\vec{V} \bullet \nabla Z_s)$
$RR_{oro} \propto IWV \times u(z)$ = IWV flux(z)
$R_{CFC\text{-}BLU}$ = Corr[hourly IWV flux(z), hrly RR]
$R_{BBY\text{-}CZD}$ = Corr[hourly IWV flux(z), hrly RR]
Orographic controlling layer: 1.8 km
Orographic controlling layer: 0.9 km
Height, MSL (km)
Correlation coefficient (R)
0
1
2
3
4
5
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0

Concluding Remarks

- This study focuses on the wettest period during the CalWater-2014 field program when a long-lived, intense AR deluged northern California with 200-400 mm of precipitation on 7-10 February 2014.

- Multiple observing assets (*e.g., two NOAA G-IV flights with 52 dropsondes, 449- and 915-MHz wind profilers, S-PROF radar, GPS IWV receivers, sfc met., satellites*) provided a detailed account of this AR, from well offshore of California to landfall.

- Three transient mesoscale frontal waves modulated the AR environment both offshore and over northern California. These frontal waves stalled the front, thus prolonging AR conditions and heavy precipitation upon landfall.

- The orography played a major role in enhancing precip. in California, both in the coastal mountains and in the interior Sierra Nevada.

- Preliminary observing strategies and analysis results from this study helped guide field activities during CalWater-2015.

Thank you!

Elephant Rock Arch
Pt. Reyes Nat'l Seashore, CA

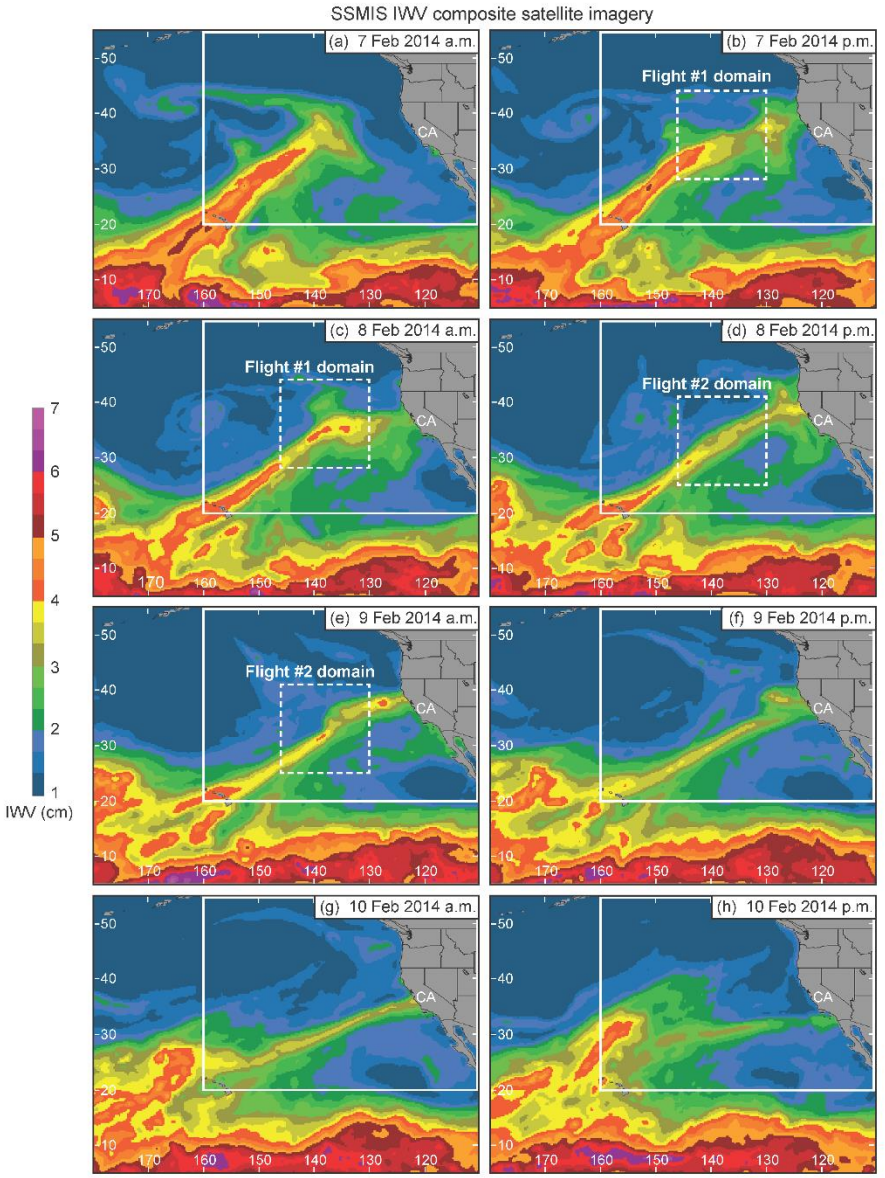
Extras

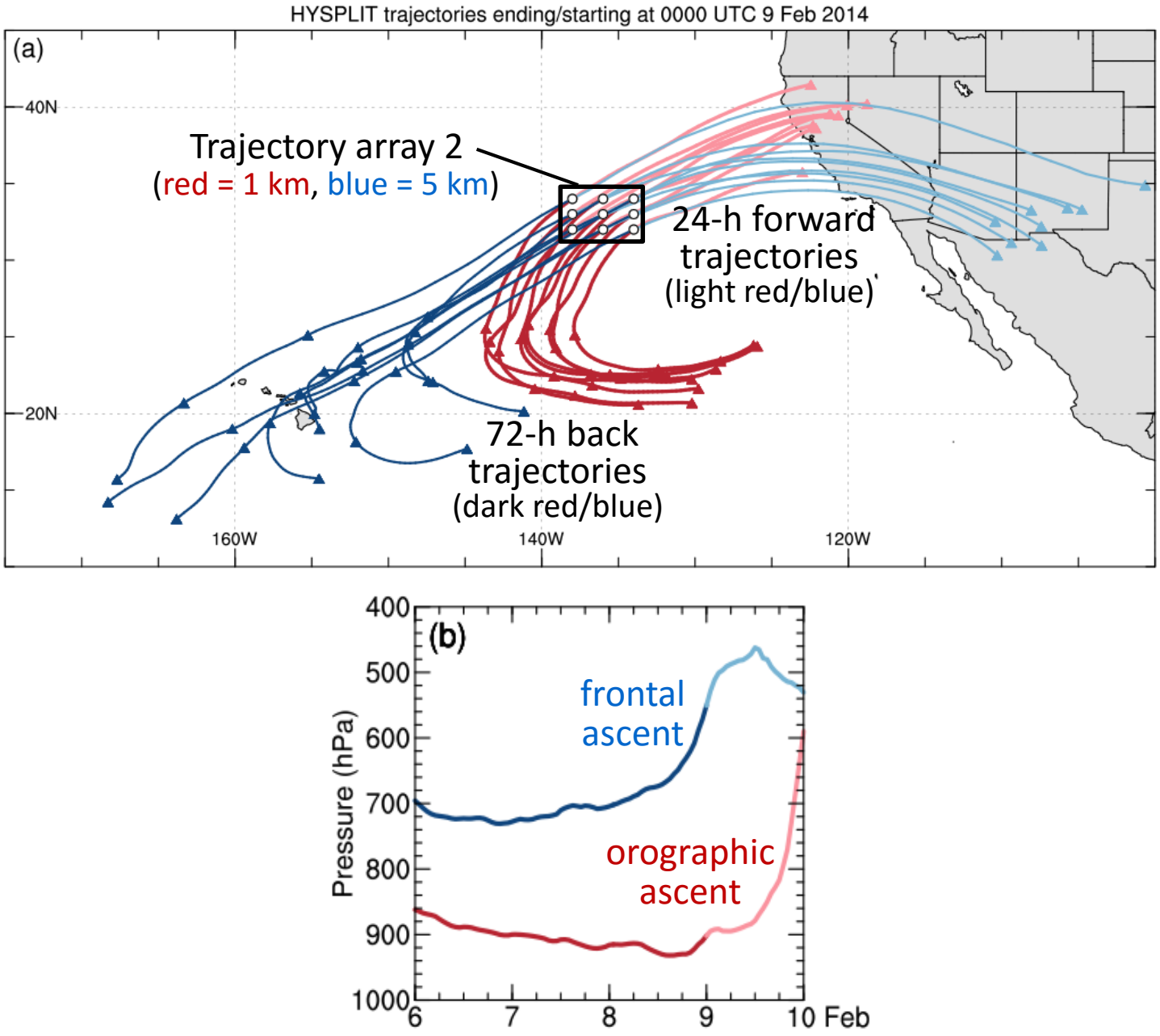
An Airborne and Ground-based Study of a Long-lived and Intense Atmospheric River with Mesoscale Frontal Waves Impacting California during CalWater-2014

Abstract: Int'l Conference on ARs in La Jolla, CA on 4-8 Aug. 2016; oral presentation preferred.

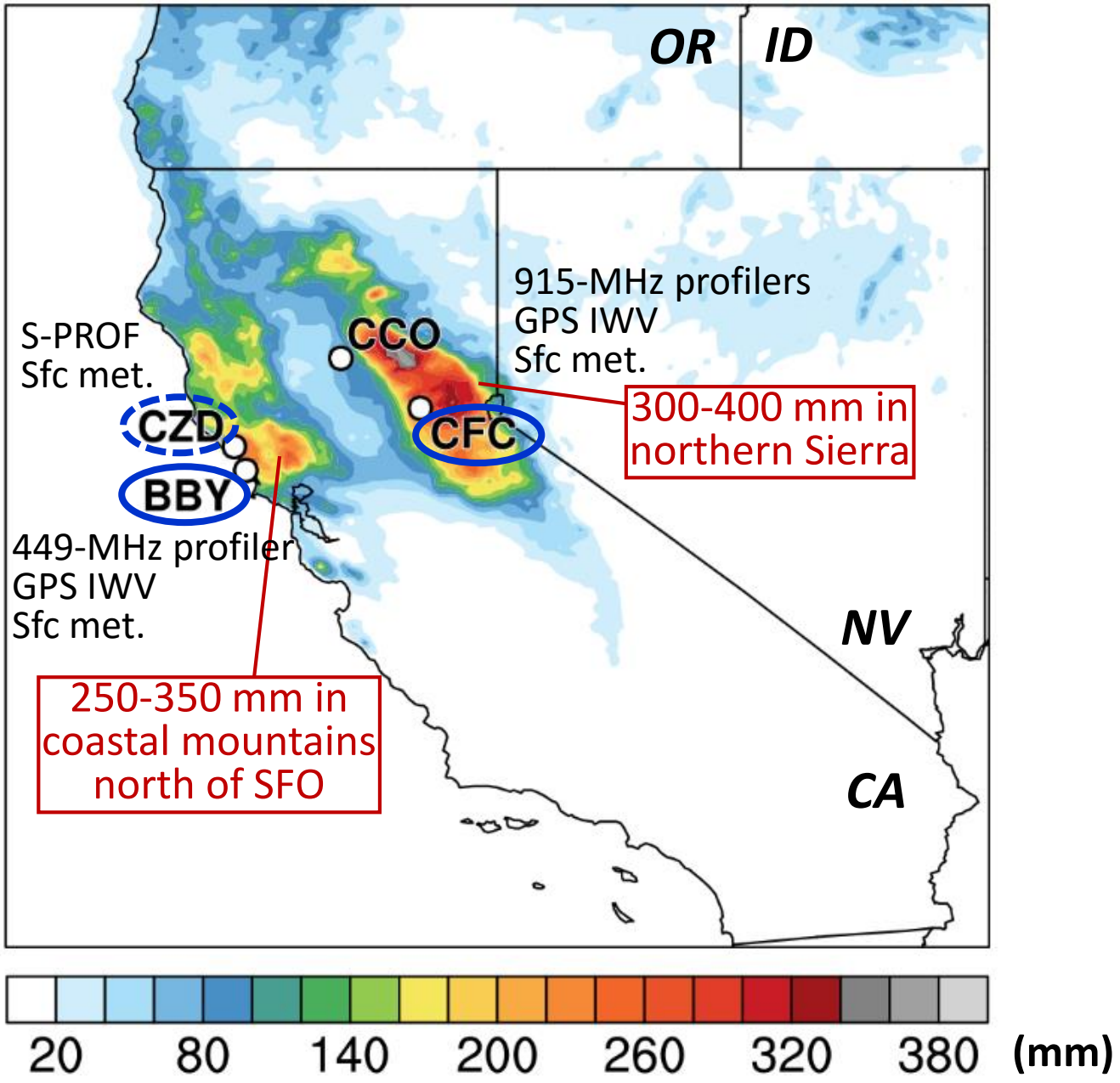
During the CalWater-2014 Early Start winter field campaign, the wettest period occurred with a long-lived, intense atmospheric river (AR) impacting California on 7-10 February. SSMIS satellite imagery of integrated water vapor (see figure) provides a large-scale overview of the event. Based on Lagrangian trajectories, the AR tapped into the tropical water-vapor reservoir, and the water vapor subsequently advected to California. Widespread heavy precipitation (200-400 mm) fell across the coastal mountain ranges northwest of San Francisco and across the northern Sierra Nevada, although only modest flooding ensued due to anomalously dry antecedent conditions. The NOAA G-IV aircraft – which represents the cornerstone observing platform for this study – flew through two mesoscale frontal waves in the AR environment offshore in a ~24-h period. Parallel dropsonde curtains documented key three-dimensional thermodynamic and kinematic characteristics across the AR and frontal waves prior to landfall. Different AR characteristics were evident, depending on the location of the cross section through the frontal waves. A newly-implemented tail-mounted Doppler radar on the G-IV simultaneously captured coherent precipitation features. Along the coast, a 449-MHz wind profiler and collocated global positioning system (GPS) receiver monitored tropospheric winds and water vapor during the AR landfall. These instruments also observed the transient frontal waves – which prolonged AR conditions and heavy precipitation – and highlighted the orographic character of the rainfall in the coastal mountains. A vertically pointing S-PROF radar in the coastal mountains provided detailed information on the bulk microphysical characteristics of the rainfall. Farther inland, a pair of 915-MHz wind profilers and GPS receivers quantified the orographic precipitation forcing as the AR ascended the Sierra Nevada, and as the terrain-induced Sierra barrier jet ascended the northern terminus of California's Central Valley.

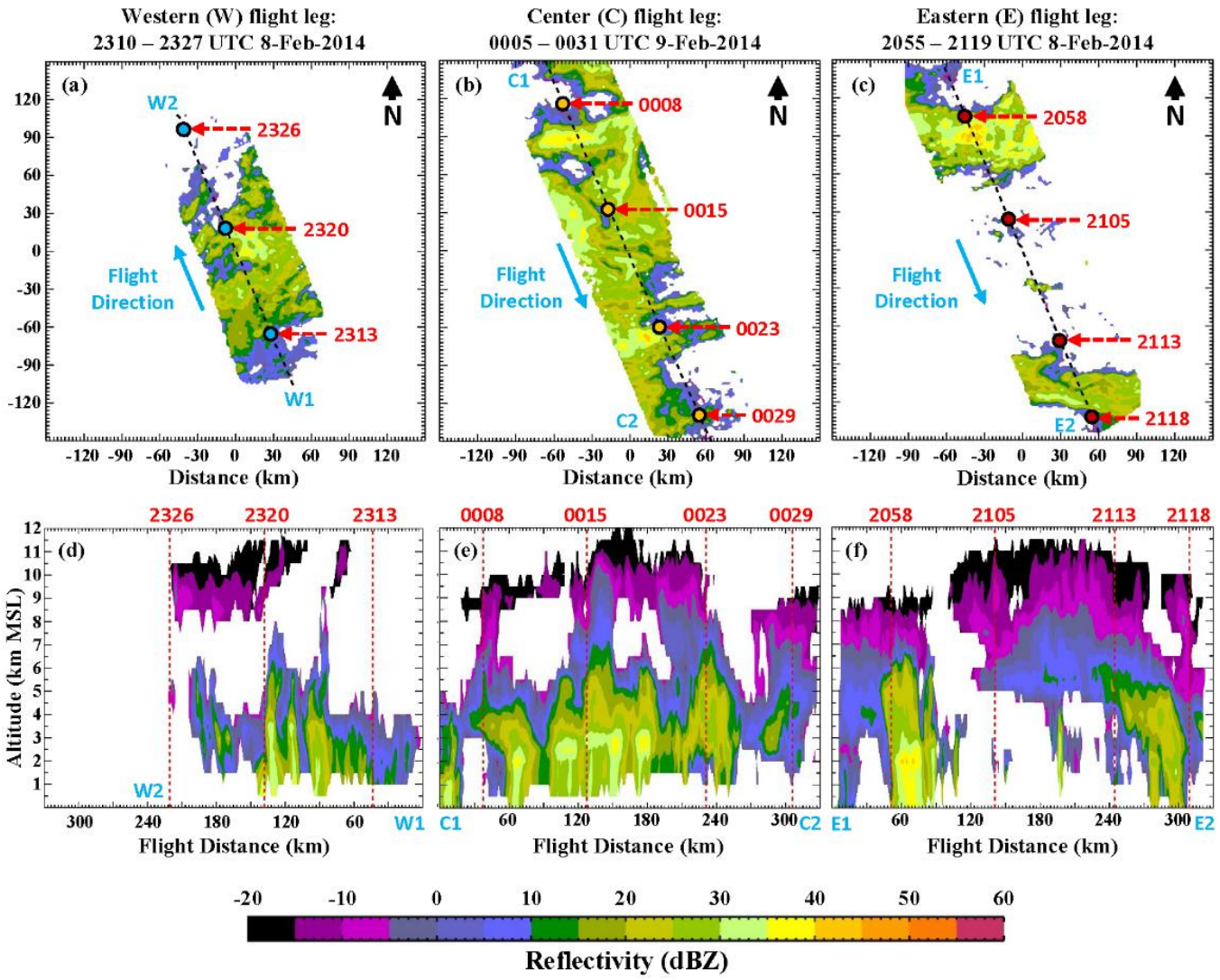
*Material not yet included in presentation

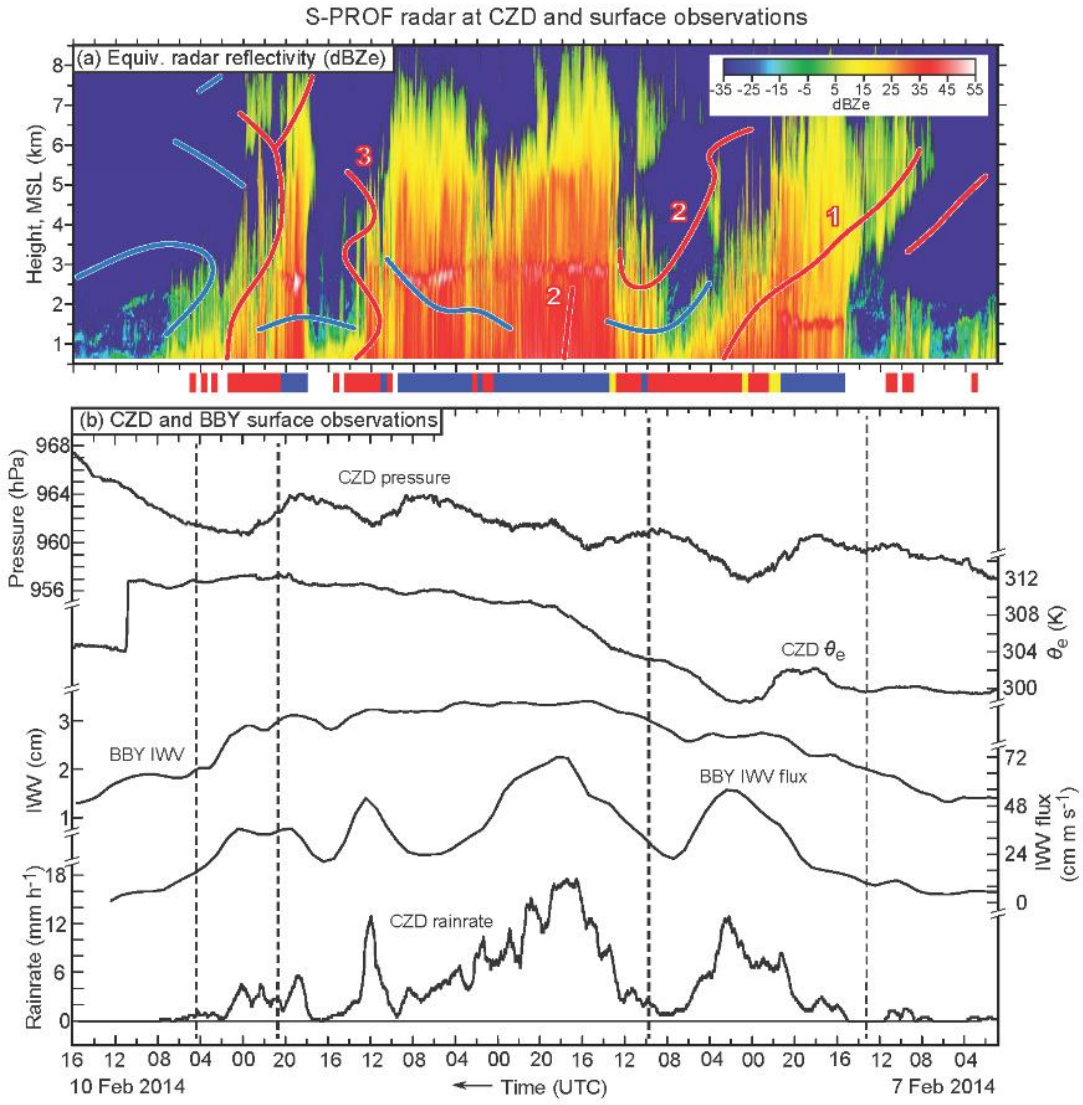



HYSPLIT trajectories ending/starting at 0000 UTC 9 Feb 2014
(a)
40N
20N
160W
140W
120W
Trajectory array 2
(red = 1 km, blue = 5 km)
24-h forward
trajectories
(light red/blue)
72-h back
trajectories
(dark red/blue)
(b)
Pressure (hPa)
400
500
600
700
800
900
1000
6
7
8
9
10 Feb
frontal
ascent
orographic
ascent

96-h Stage-IV precipitation accumulation: 00Z 7-Feb-2014 to 00Z 11-Feb-2014




Western (W) flight leg:
2310 – 2327 UTC 8-Feb-2014
Center (C) flight leg:
0005 – 0031 UTC 9-Feb-2014
Eastern (E) flight leg:
2055 – 2119 UTC 8-Feb-2014
(a)
(b)
(c)
W2
W1
C1
C2
E1
E2
2326
2320
2313
0008
0015
0023
0029
2058
2105
2113
2118
N
Flight Direction
Distance (km)
(d)
(e)
(f)
Altitude (km MSL)
Flight Distance (km)
-20 -10 0 10 20 30 40 50 60
Reflectivity (dBZ)


S-PROF radar at CZD and surface observations
(a) Equiv. radar reflectivity (dBZe)
-35 -25 -15 -5 5 15 25 35 45 55
dBZe
Height, MSL (km)
1
2
3
(b) CZD and BBY surface observations
Pressure (hPa)
CZD pressure
CZD θ_e
θ_e (K)
IWV (cm)
BBY IWV
BBY IWV flux
IWV flux (cm m s^{-1})
Rainrate (mm h^{-1})
CZD rainrate
10 Feb 2014
Time (UTC)
7 Feb 2014

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- This study focuses on the wettest period during the CalWater-2014 field program when a long-lived, intense AR deluged northern California with 200-400 mm of precipitation on 7-10 February 2014.

- Multiple observing assets (*e.g., two NOAA G-IV flights with 52 dropsondes, 449- and 915-MHz wind profilers, S-PROF radar, GPS IWV receivers, sfc met., satellites*) provided a detailed account of this AR, from well offshore of California to landfall.

- Three transient mesoscale frontal waves modulated the AR environment both offshore and over northern California. These frontal waves stalled the front, thus prolonging AR conditions and heavy precipitation upon landfall.

- This is the first study of its kind to observationally track the landfalling migration and impacts of such waves in an AR environment.

- The orography played a major role in enhancing precip. in California, both in the coastal mountains and in the interior Sierra Nevada.

- Preliminary observing strategies and analysis results from this study helped guide field activities during CalWater-2015.