Capturing Atmospheric Rivers: Alpha Jet Atmospheric eXperiment (AJAX) Flights in support of CalWater/El Nino Rapid Response 2016

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International Atmospheric River Conference

Scripps, La Jolla, CA

August 8-11, 2016

Flight Objectives

To examine the characteristics of dynamics and thermodynamics during various stages of atmospheric rivers (ARs), which contribute to intense precipitation along the U.S. west coast.

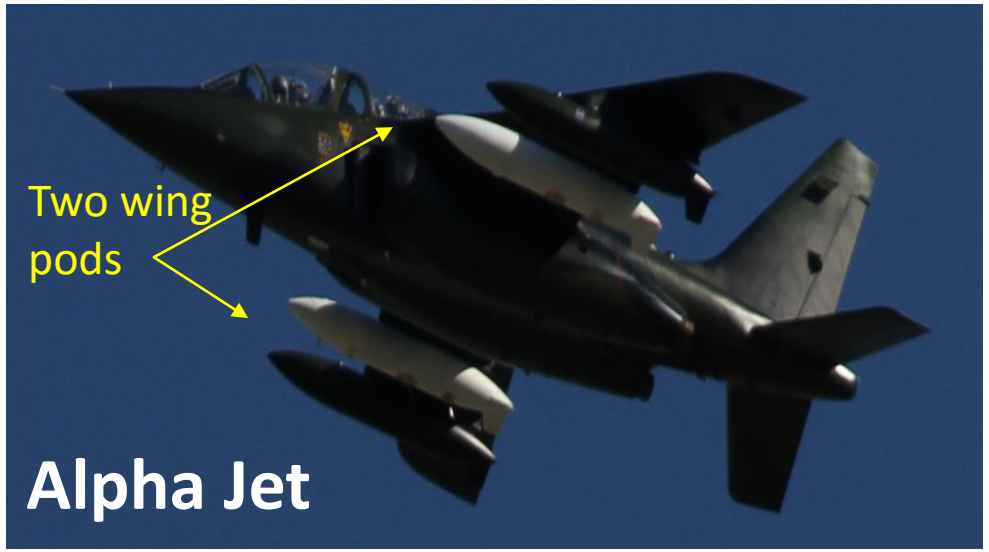
1) **Coastal Barrier Jet**:

- Map out the structure of the barrier jet at varying altitudes and horizontal displacement from the coastal range during the early stages of an Atmospheric River (AR) event

2) Pollution transport:

- Long-range transport of pollution aerosols to the Central Valley and Bay Area

AJAX Platform & Payload



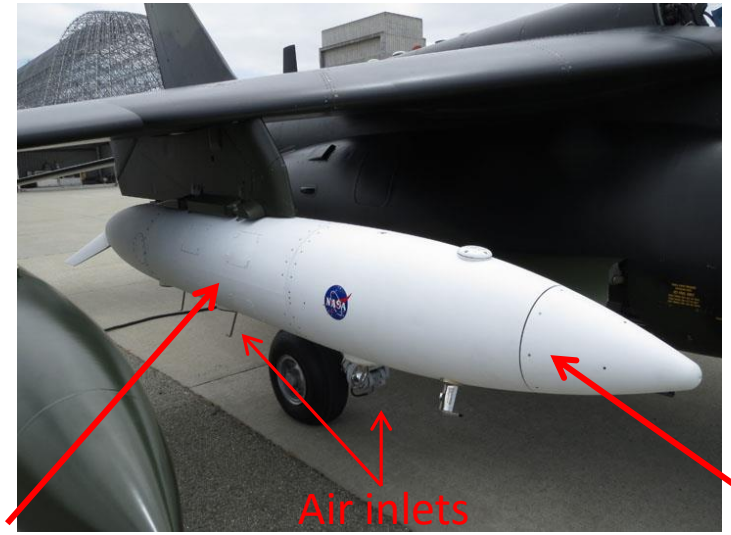
- Speed: 150 - 550 knts
- Range: ~1,200 miles, Ceiling: 40,000 ft
- Flight duration: ~ 2.25 hrs
- **Payload: two wing pods**, one centerline
- Lowest altitude: normally 1000 ft, but dictated by safety

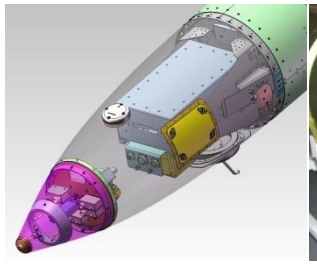
Total 196 Science Flights (June 2011 – August 2016)

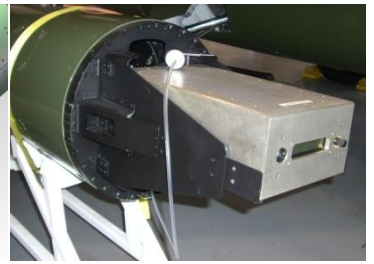
Common Types:

- Vertical Profiles
- Boundary Layer Legs
- Downwind “Curtains”
- For ENRR 2015/2016, 3 flights were conducted (demonstration, weak AR, and moderate AR).

Atmospheric Sensors (Two wind pods)





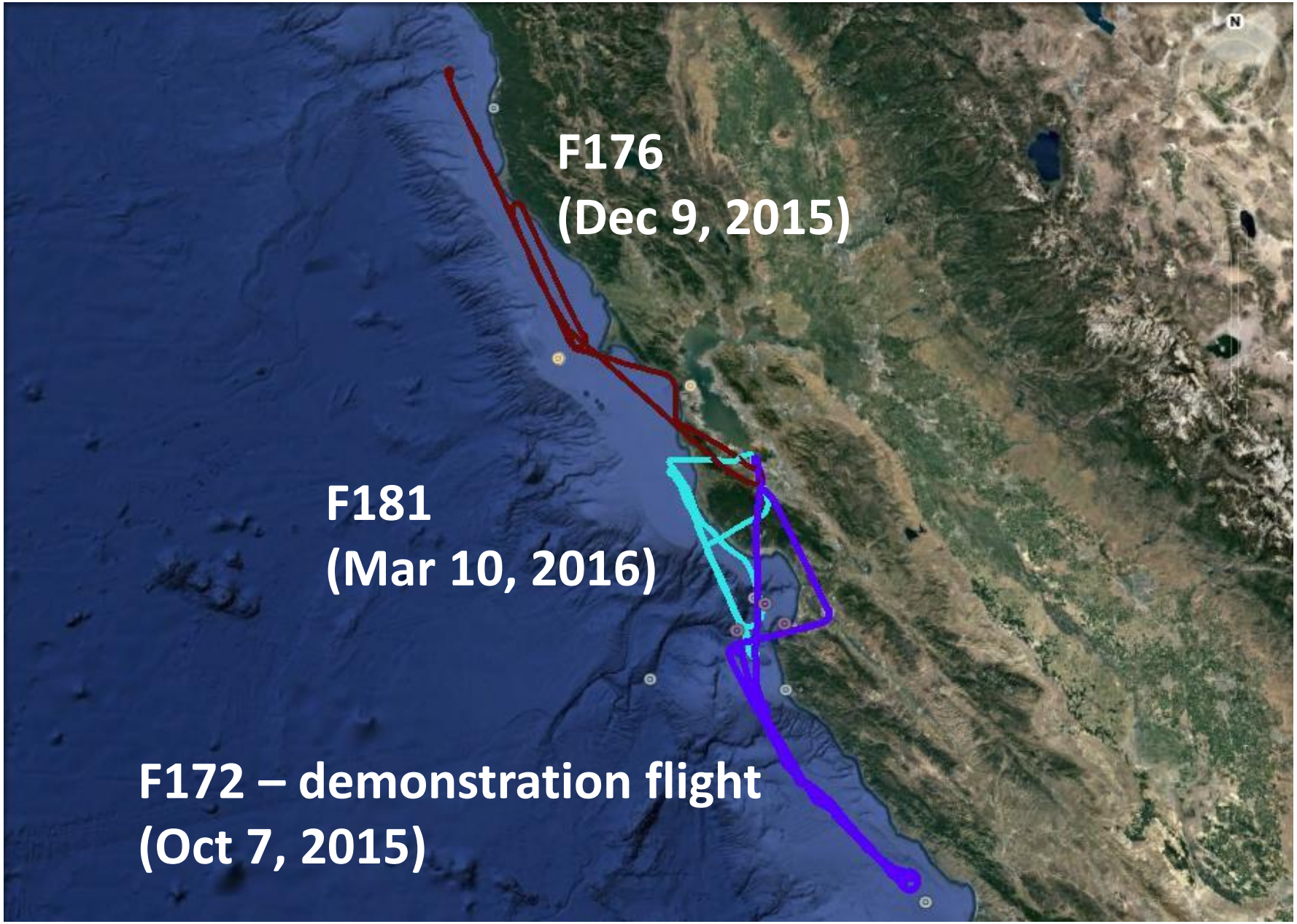


Modified Picarro (2301-*m)* **measures CO_2 and CH_4** located in center- and tail-sections of the wing-pod

Modified 2B technologies (model 205*)* **measures O_3 and Meteorological Measurement System (MMS)** located in the front/nose section of the wing-pod

GSFC Compact Formaldehyde FluorescencE Experiment (COFFEE) **measures atmospheric HCHO** located in the center of the pod

AJAX Flight Tracks

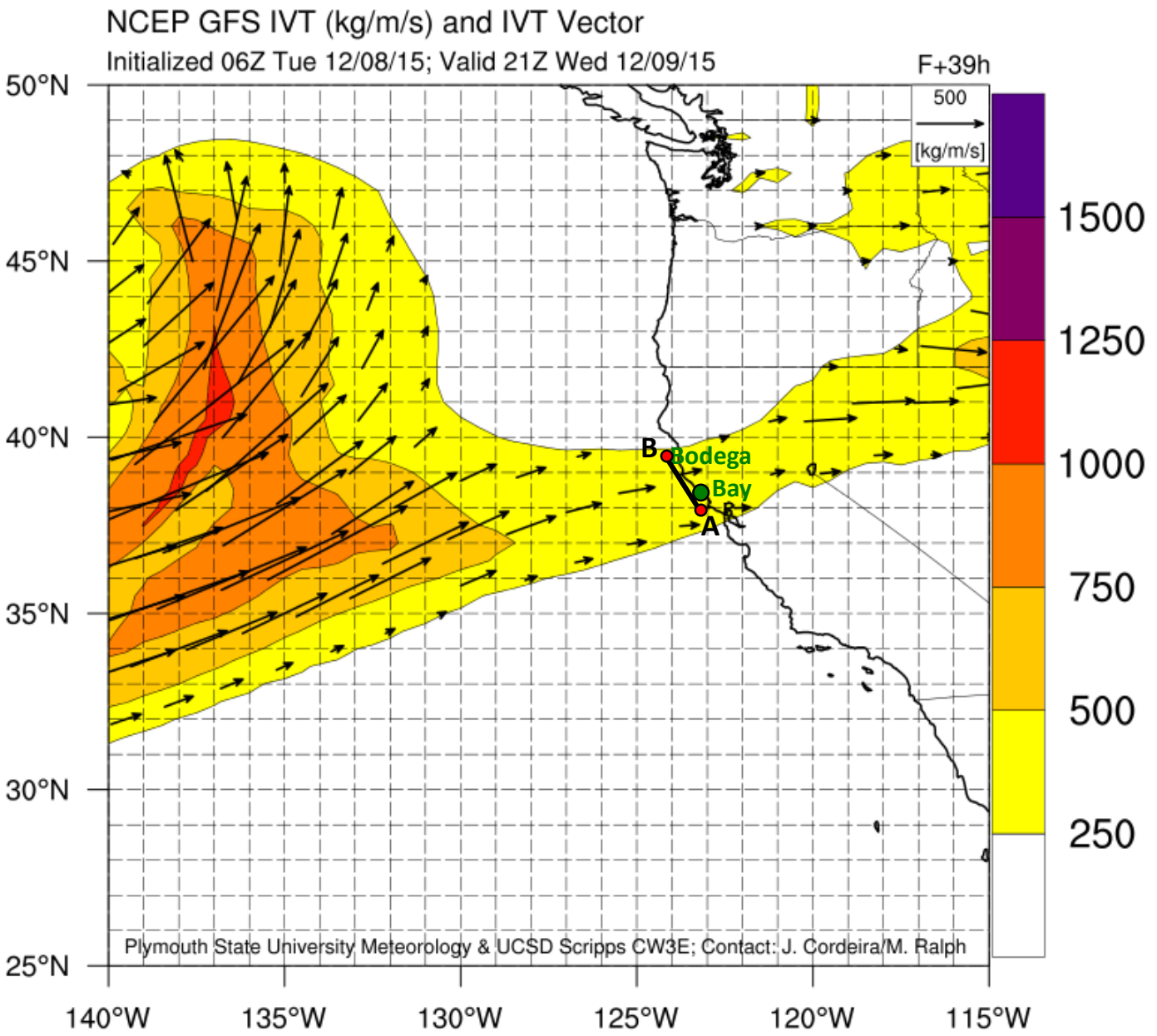


Example:
F172 (9 Dec, 2015)

Coastal Barrier Jet Flight Module

WED/9 Dec 2015
Take Off 1400 PT
Duration 2 h

Point	Lat	Lon	Flight Level
A	38.0°	123.3°	8 kft
B	39.5°	124.1°	8 kft
B	39.5°	124.1°	4 kft
A	38.0°	123.3°	4 kft
A	38.0°	123.3°	1 kft
B	39.5°	124.1°	1 kft
C	39.5°	123.9°	1 kft
D	38.0°	123.1°	1 kft



(courtesy of J. Ryan Spackman)

Offshore Stacked Flight Plan

Stacked transects A-B are offset from single leg C-D by 10 nmi with C-D closer to and immediately offshore

(coordinated by J. Ryan Spackman)

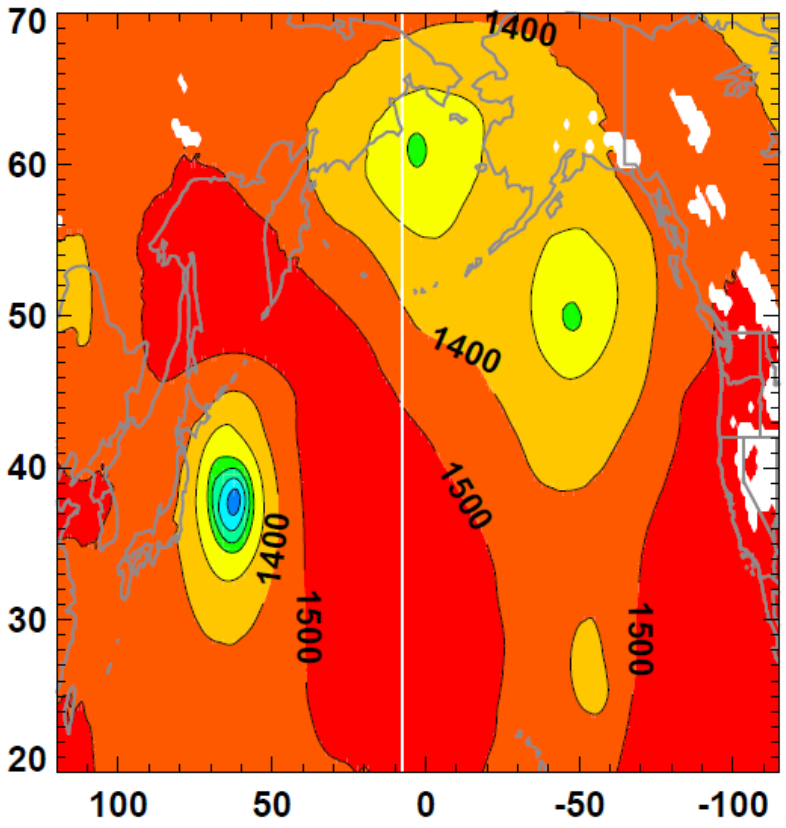
Large scale characteristics

- **F172 : October 7, 2015 (Pre-AR : benign condition)**
- **F176 : December 9, 2015 (weak AR)**
- **F181: March 10, 2016 (moderate AR, Coastal Barrier jet detected, Pollution transport)**

Geopotential height at 850 hPa

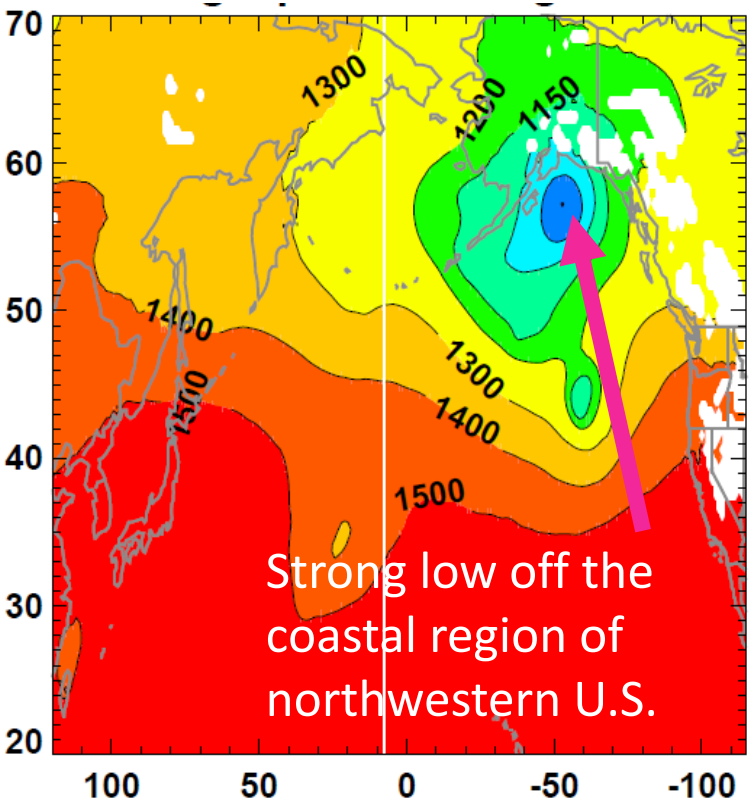
Pre-AR

(Oct 7, 2015)



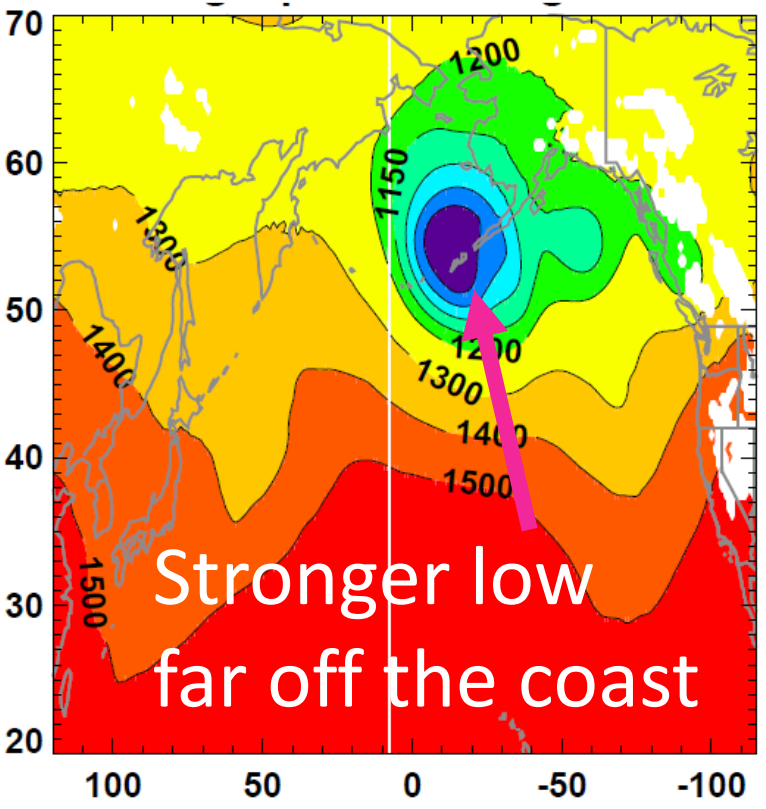
weak-AR

(Dec 9, 2015)



moderate-AR

(Mar 10, 2016)



Geopotential height at 500 hPa

Pre-AR

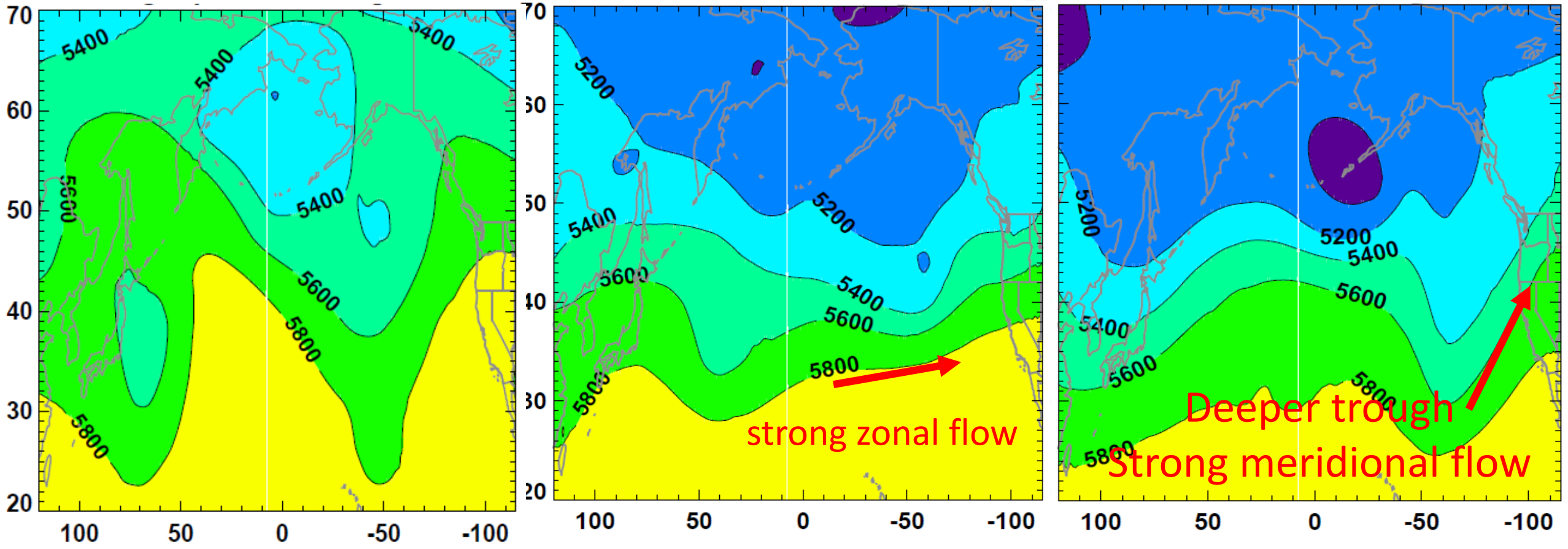
(Oct 7, 2015)

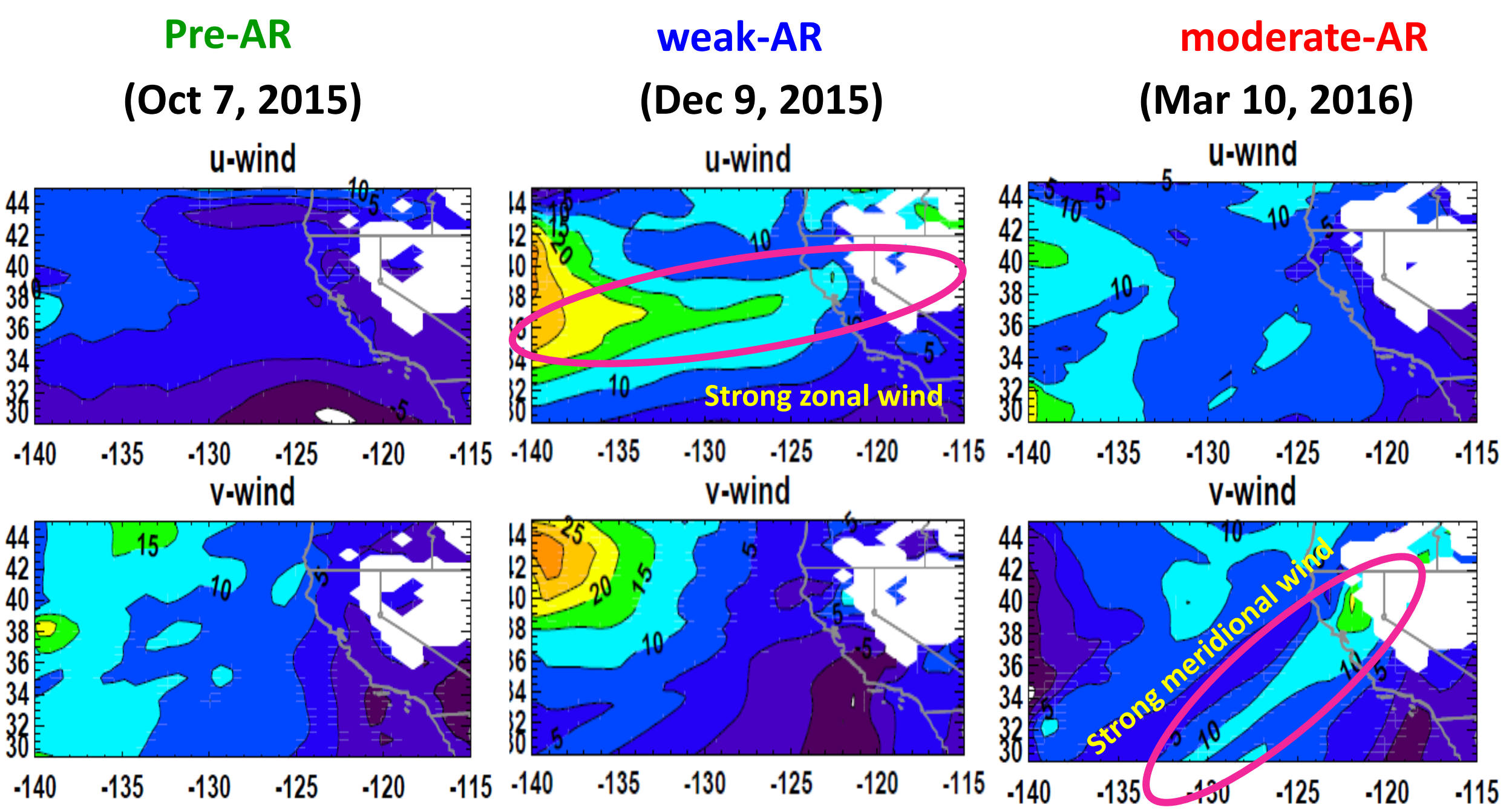
weak-AR

(Dec 9, 2015)

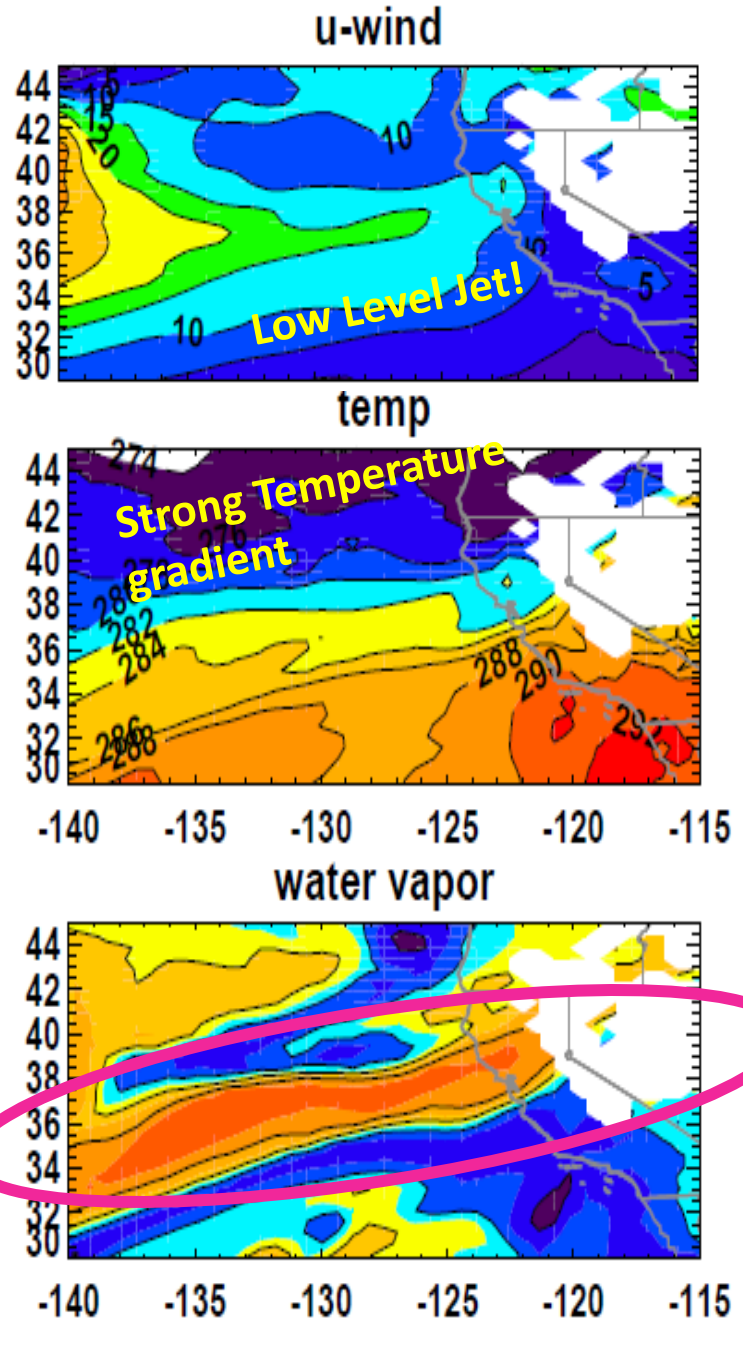
moderate-AR

(Mar 10, 2016)

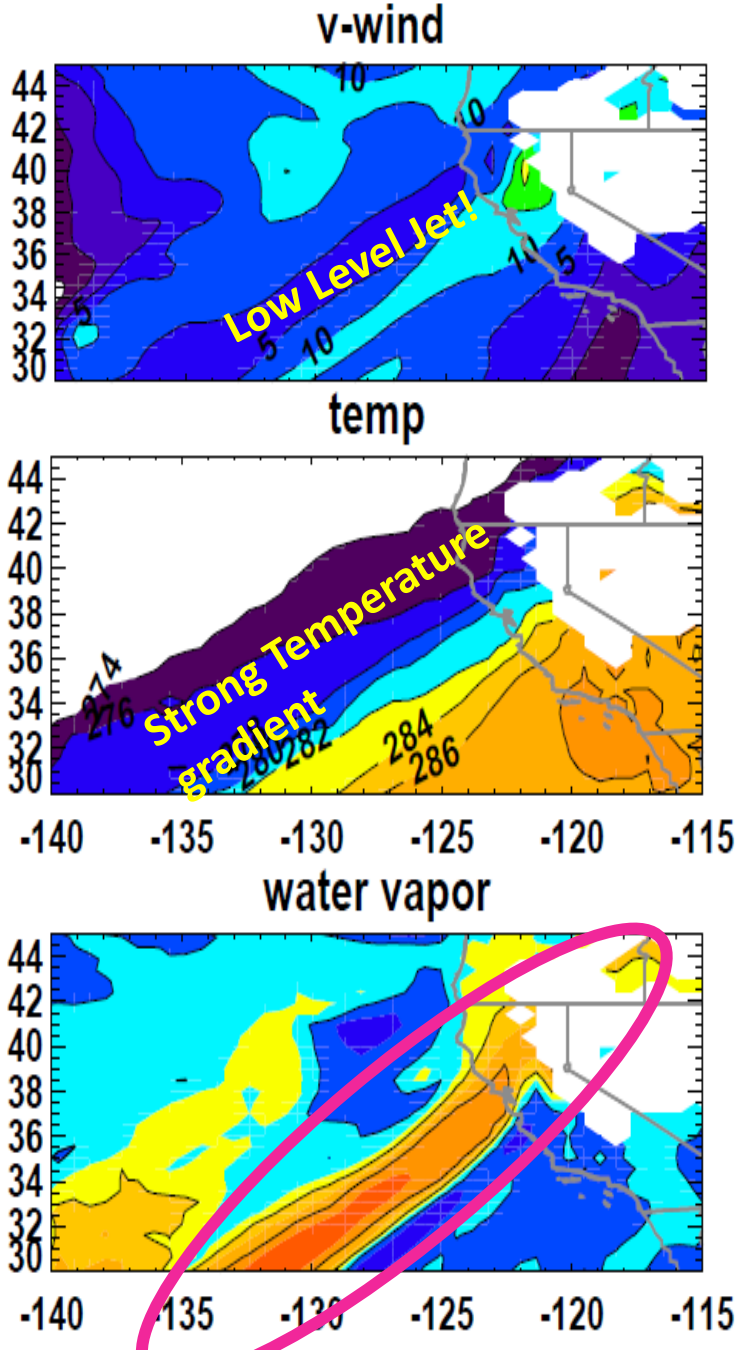



Pre-AR
(Oct 7, 2015)
weak-AR
(Dec 9, 2015)
moderate-AR
(Mar 10, 2016)
u-wind
v-wind
Strong zonal wind
Strong meridional wind
-140
-135
-130
-125
-120
-115
44
42
40
38
36
34
32
30

weak-AR(Dec 9, 2015)



moderate-AR (Mar 10, 2016)



Stratospheric intrusions (Rossby wave breakings)

Pre-AR

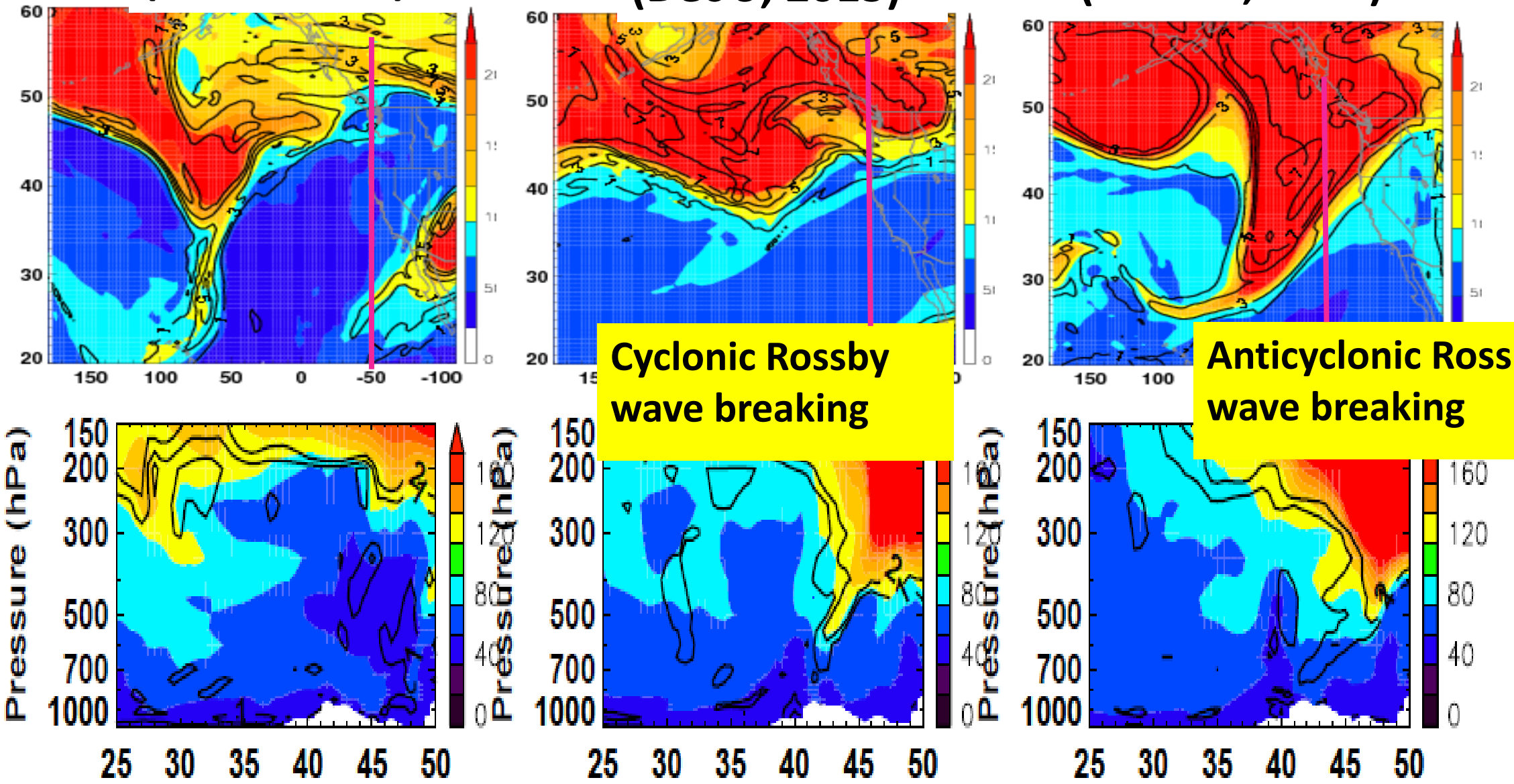
(Oct 7, 2015)

weak-AR

(Dec 9, 2015)

moderate-AR

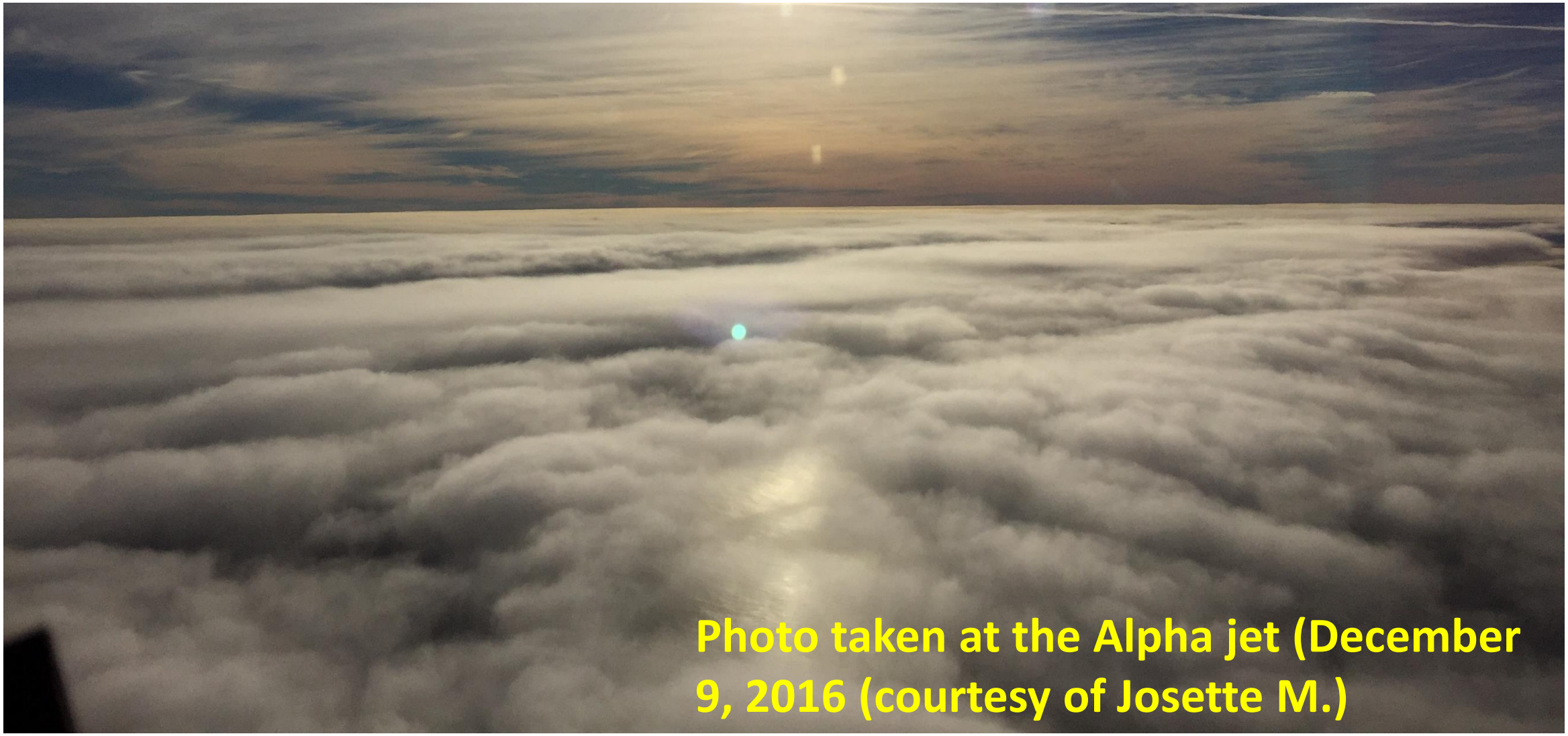
(Mar 10, 2016)



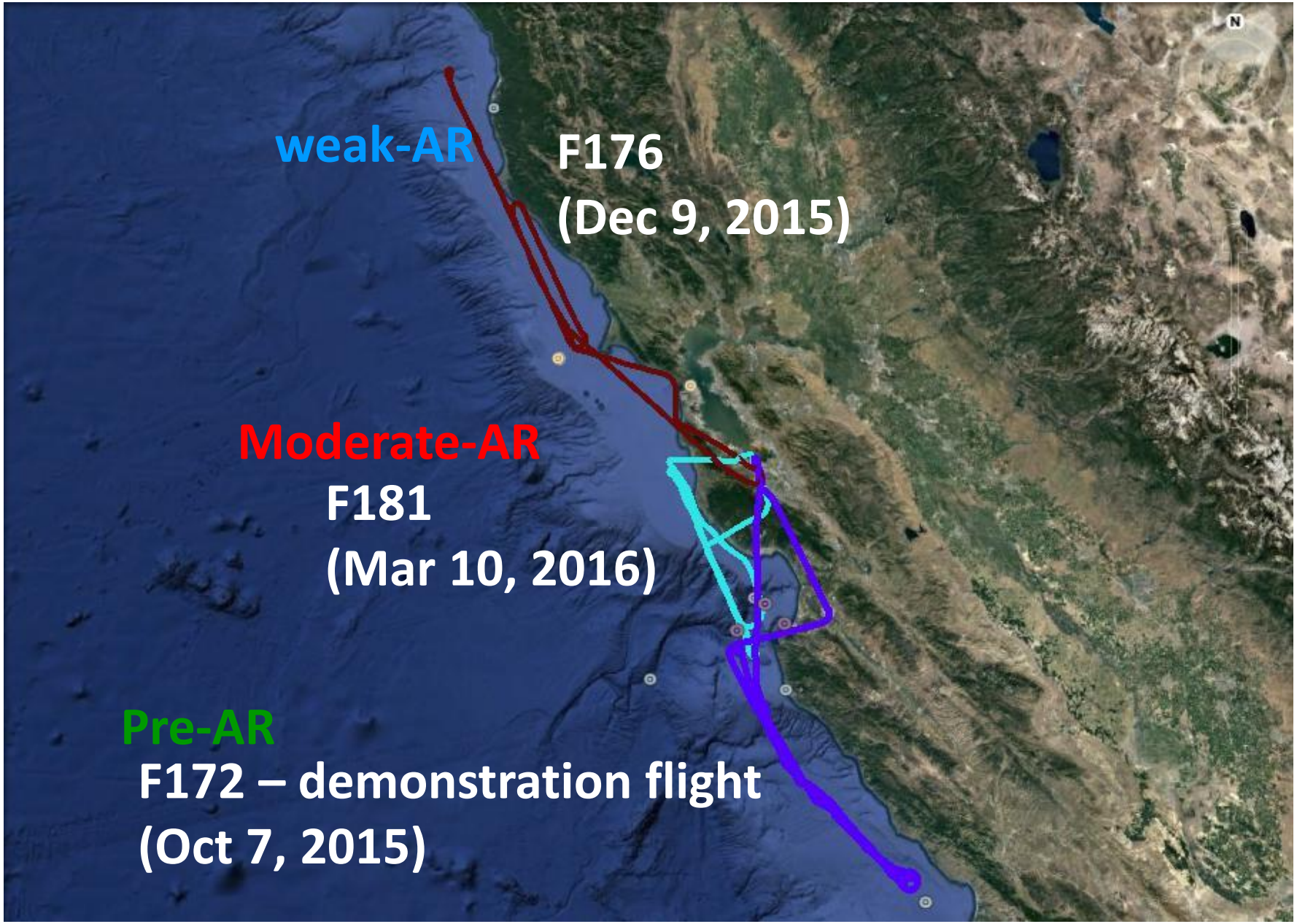
Cyclonic Rossby wave breaking

Anticyclonic Rossby wave breaking

AJAX data characteristics



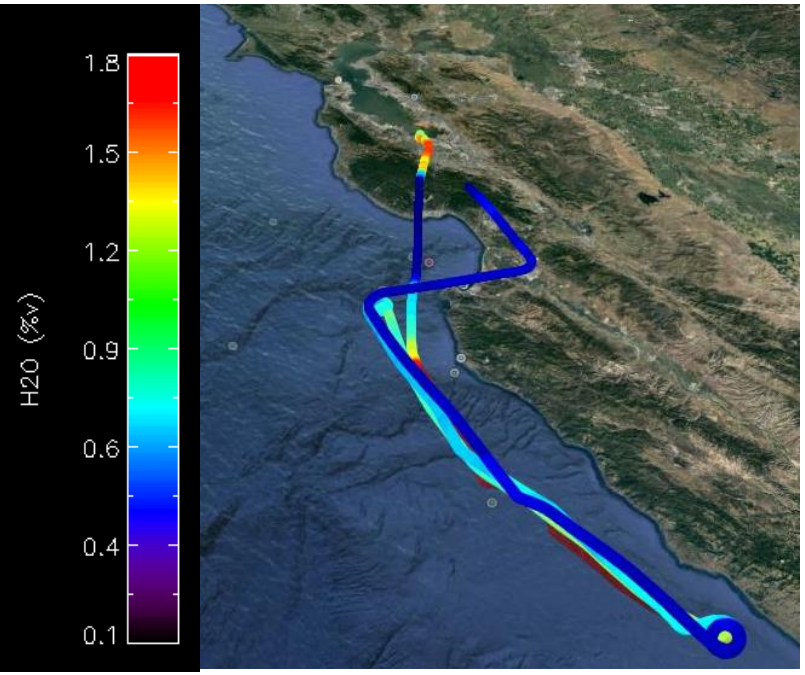
AJAX Flight Tracks



AJAX Flight map of water vapor

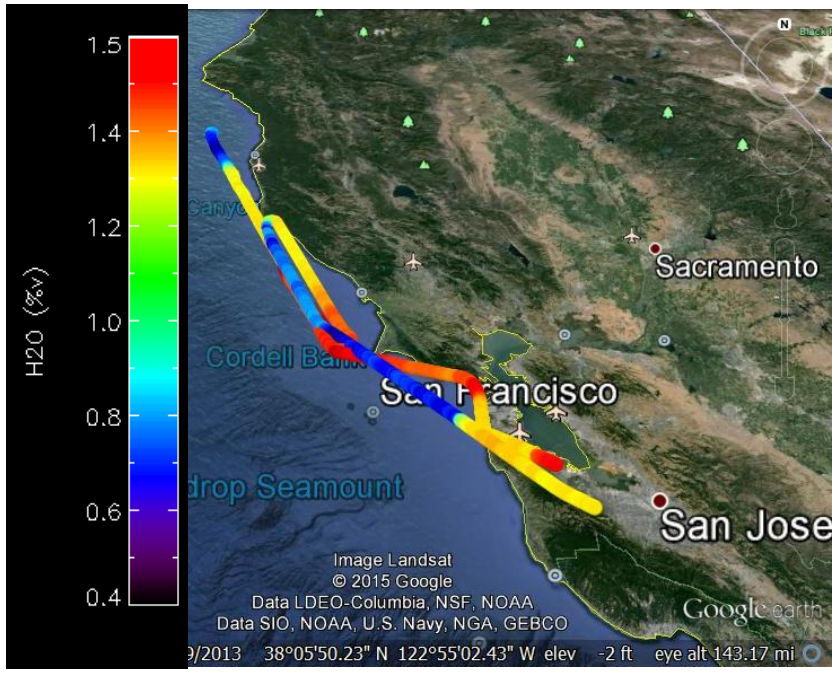
Pre-AR

(Oct 7, 2015)



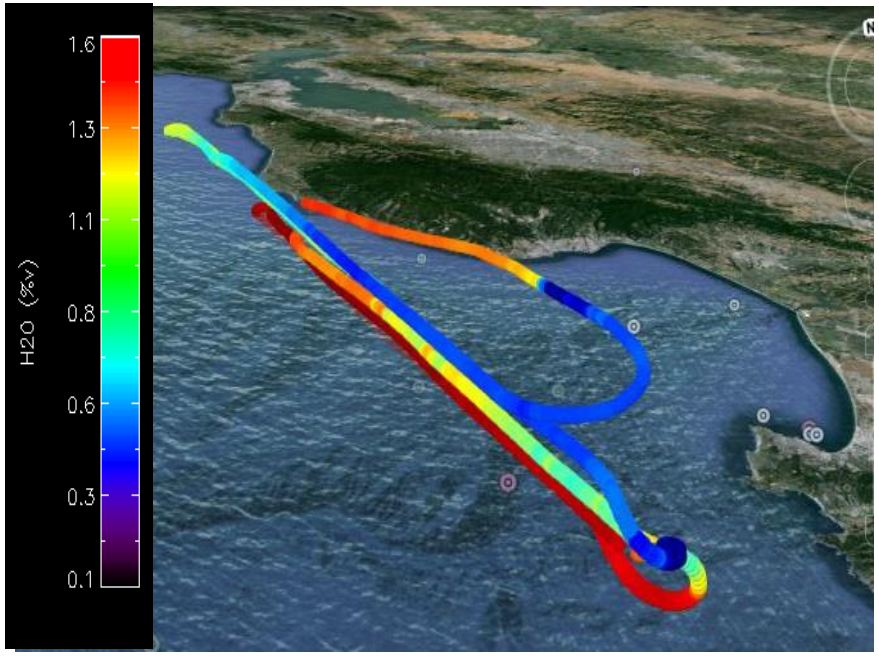
weak-AR

(Dec 9, 2015)



Moderate-AR

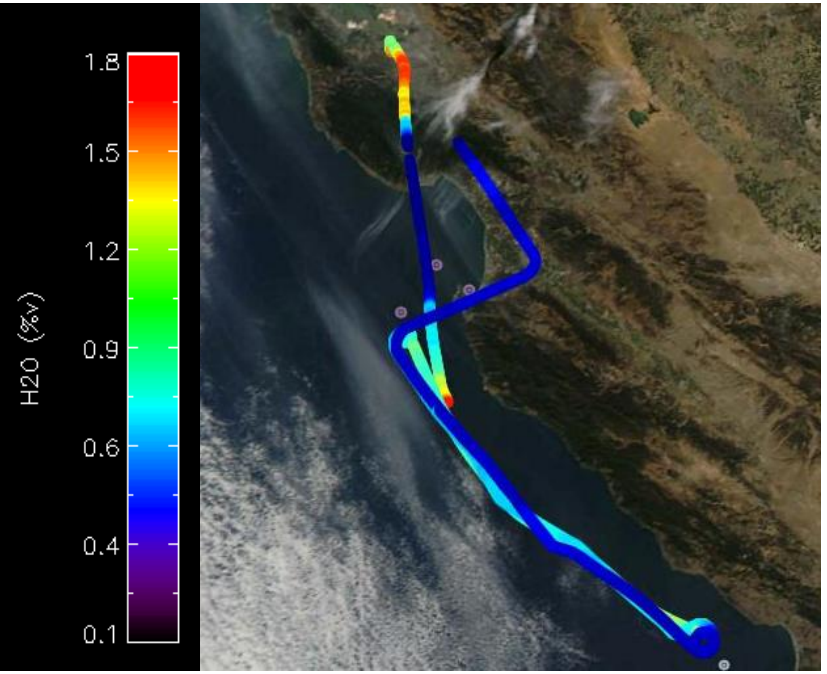
(Mar 10, 2016)



AJAX Flight map of water vapor *with MODIS Aqua image*

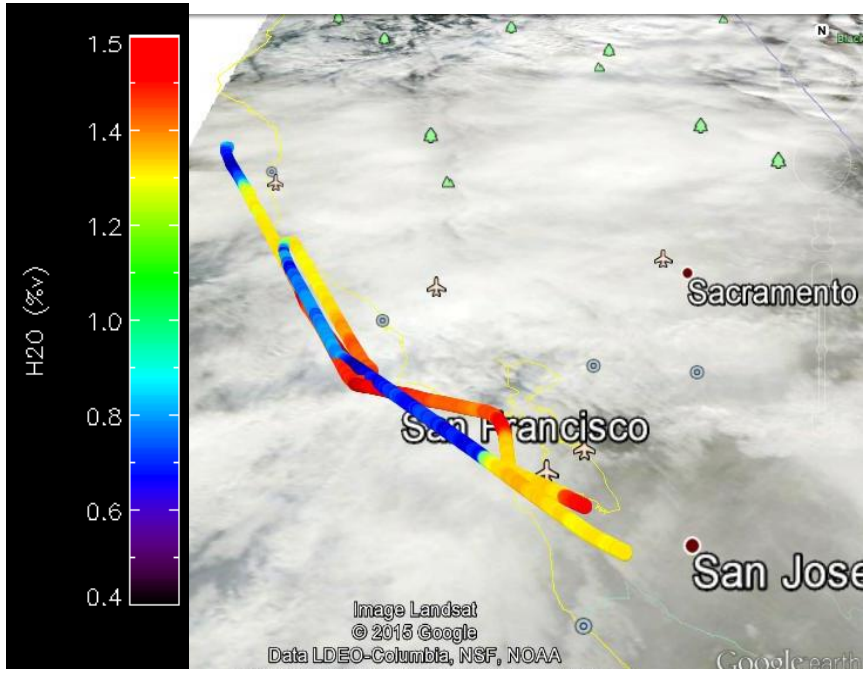
Pre-AR

(Oct 7, 2015)



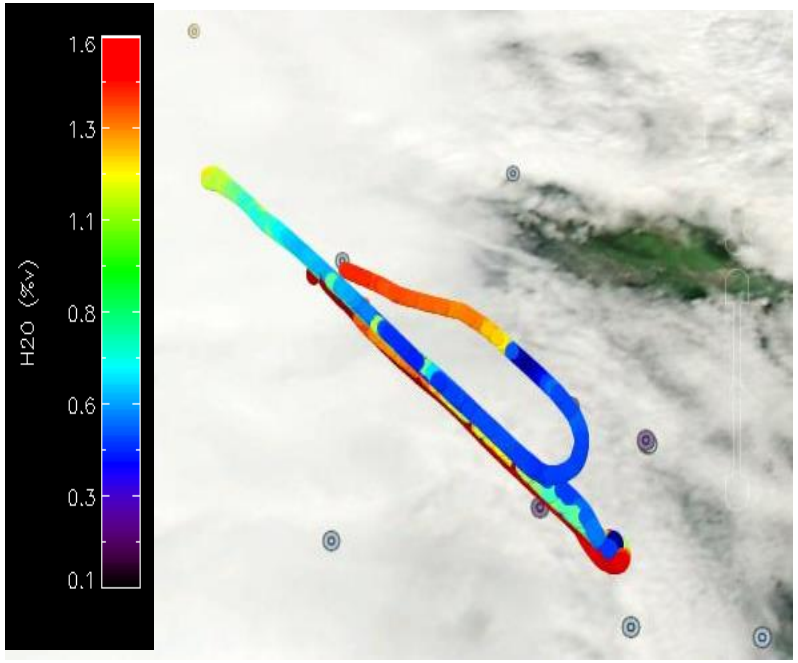
weak-AR

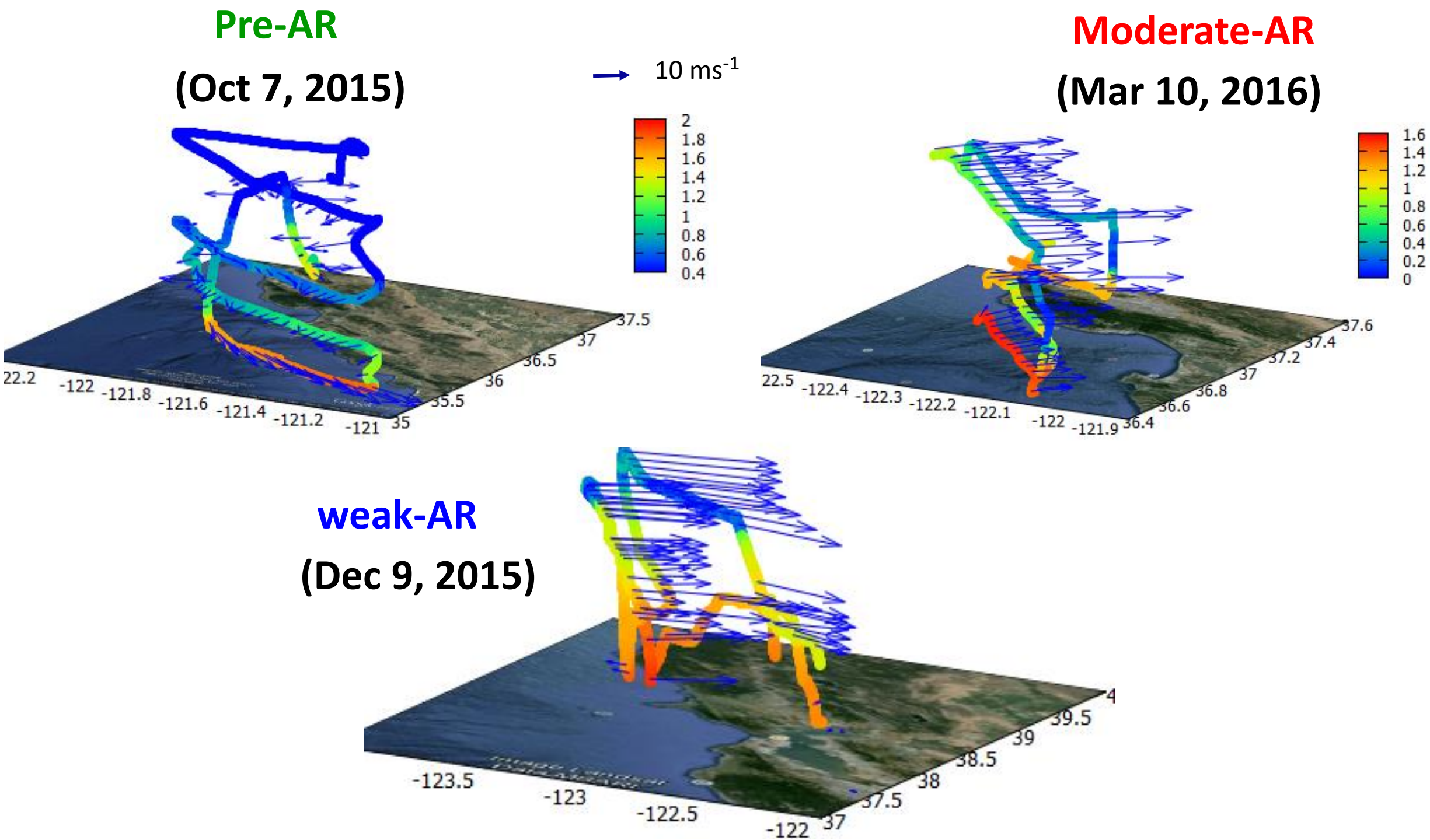
(Dec 9, 2015)



Moderate-AR

(Mar 10, 2016)

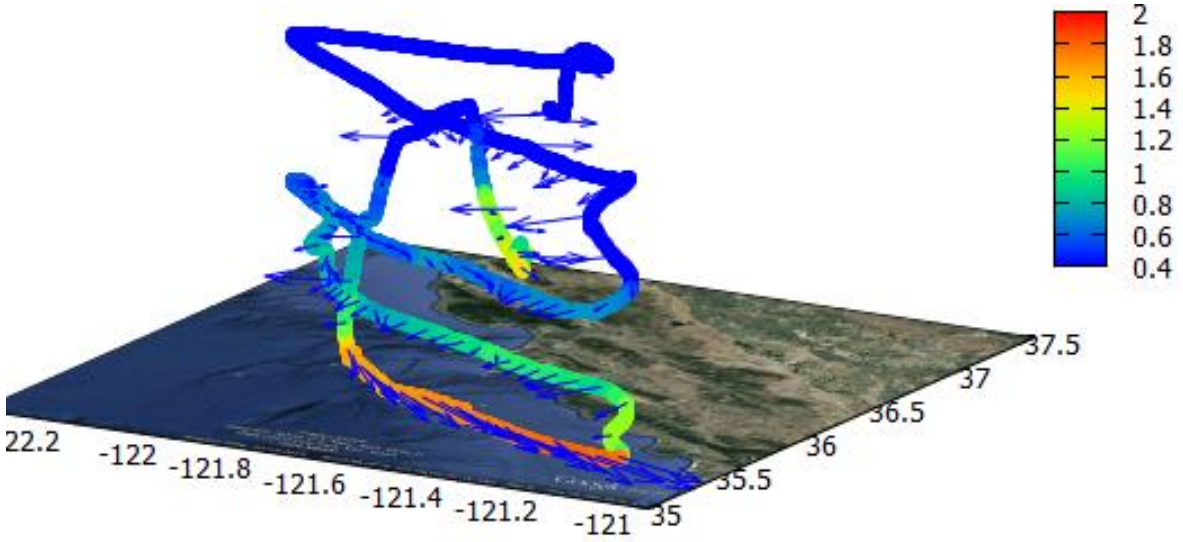



Pre-AR
(Oct 7, 2015)
10 ms-1
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
22.2
-122
-121.8
-121.6
-121.4
-121.2
-121
35
35.5
36
36.5
37
37.5
Moderate-AR
(Mar 10, 2016)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
22.5
-122.4
-122.3
-122.2
-122.1
-122
-121.9
36.4
36.6
36.8
37
37.2
37.4
37.6
weak-AR
(Dec 9, 2015)
-123.5
-123
-122.5
-122
37
37.5
38
38.5
39
39.5
4

Pre-AR

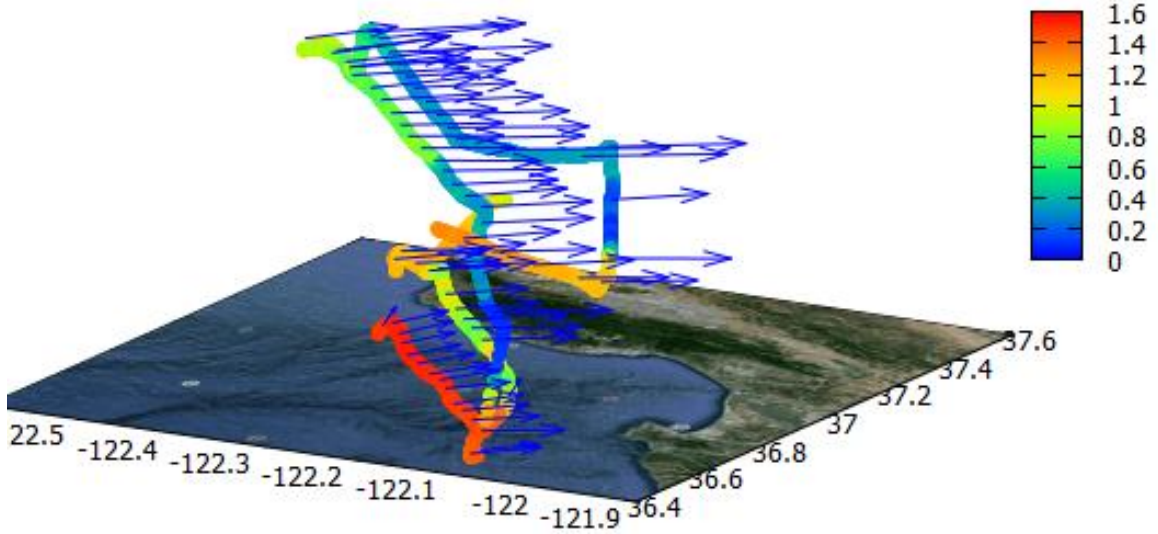
(Oct 7, 2015)

10 ms^{-1}



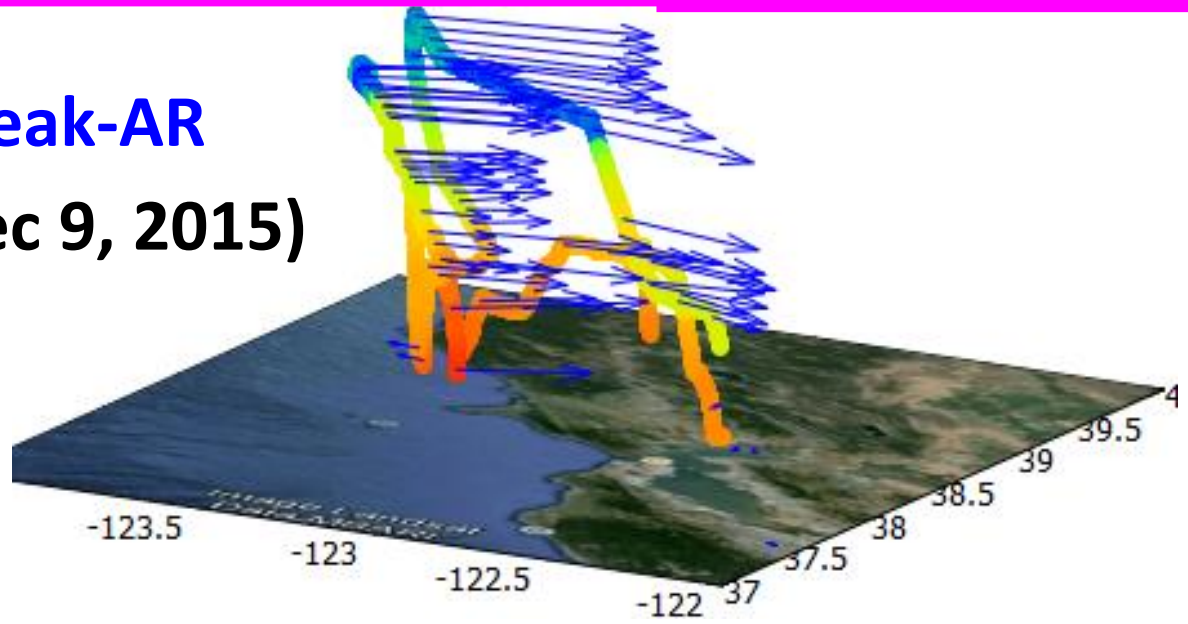
Moderate-AR

(Mar 10, 2016)



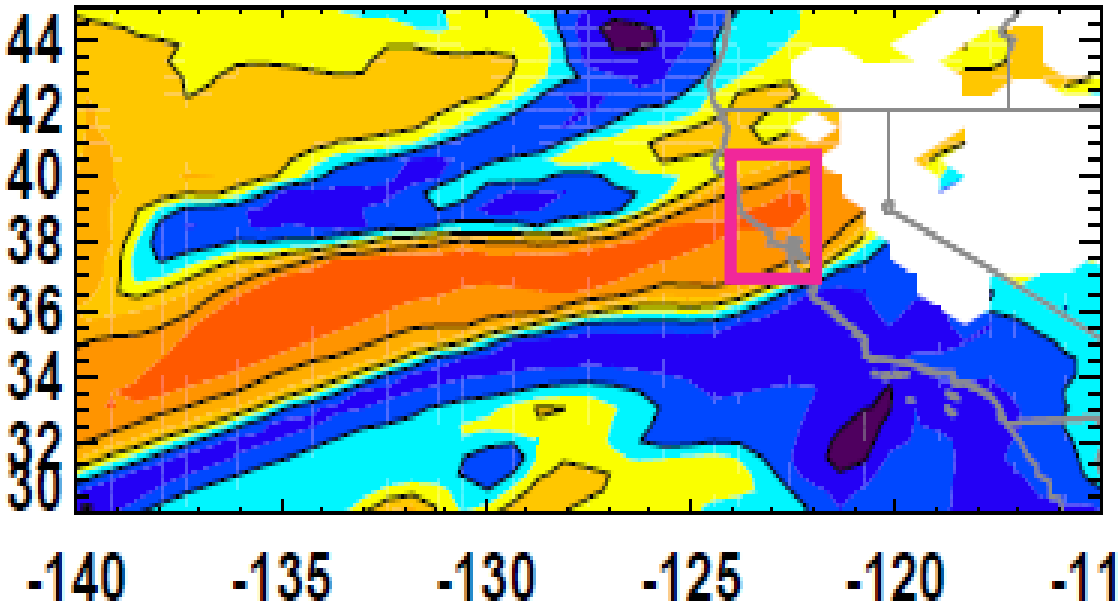
weak-AR

(Dec 9, 2015)

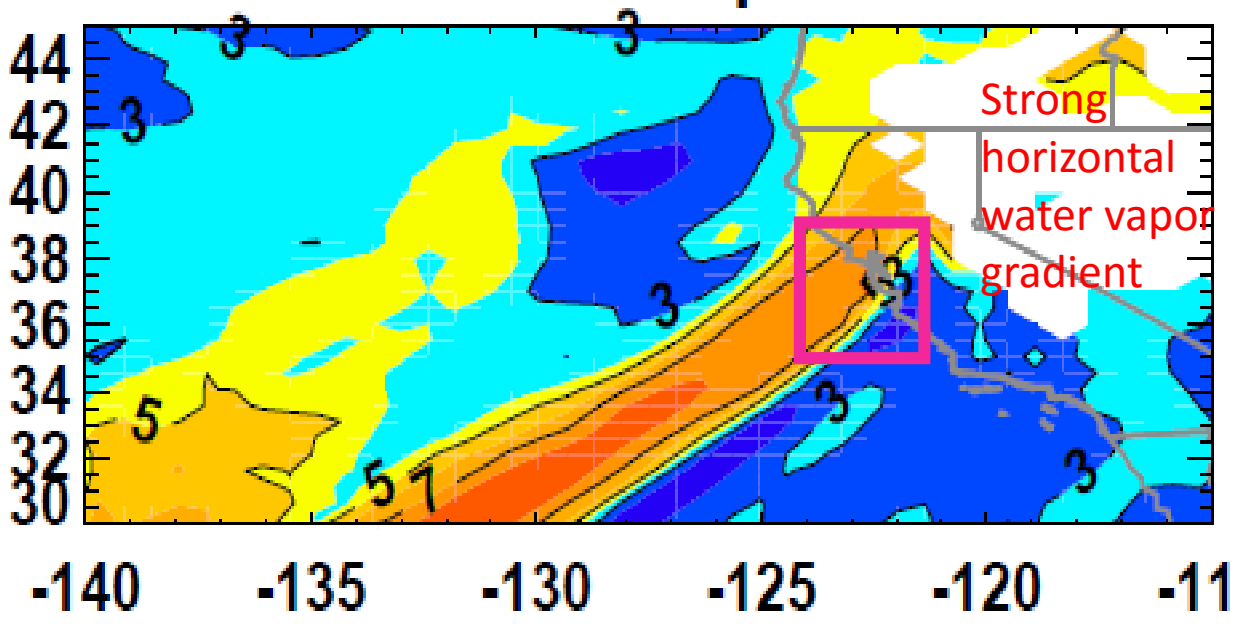


MERRA-2

weak-AR water vapor

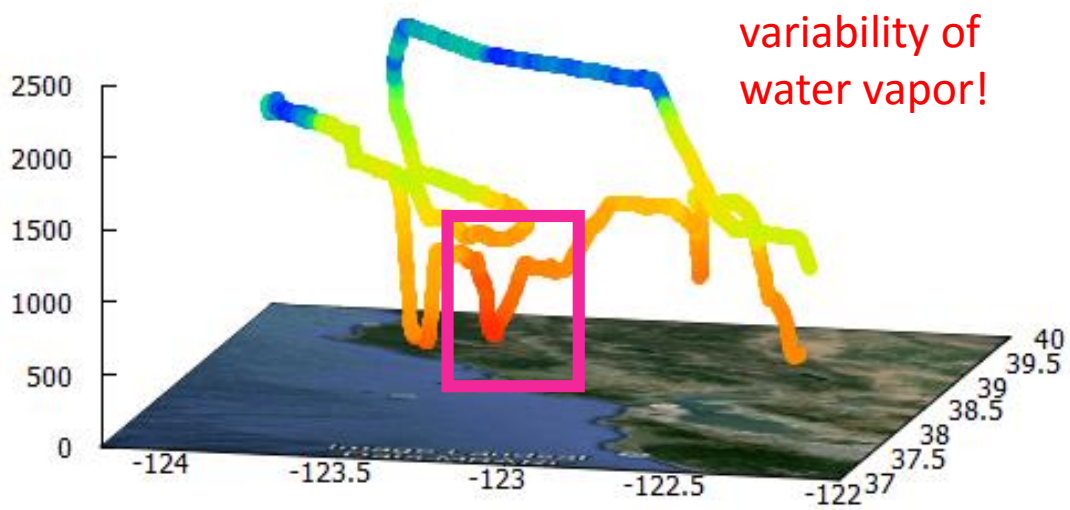


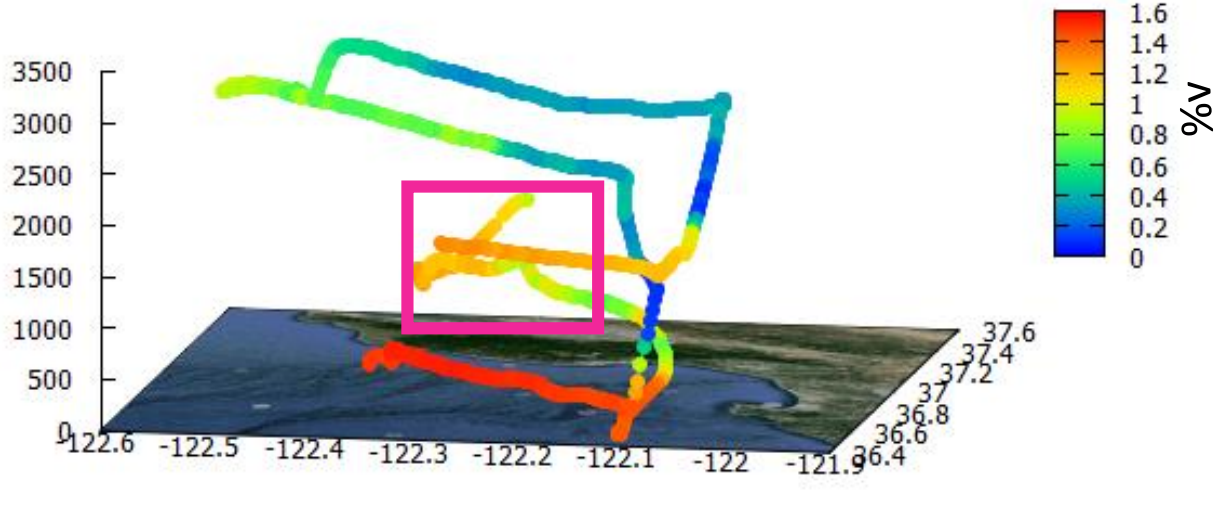
Moderate-AR water vapor



AJAX

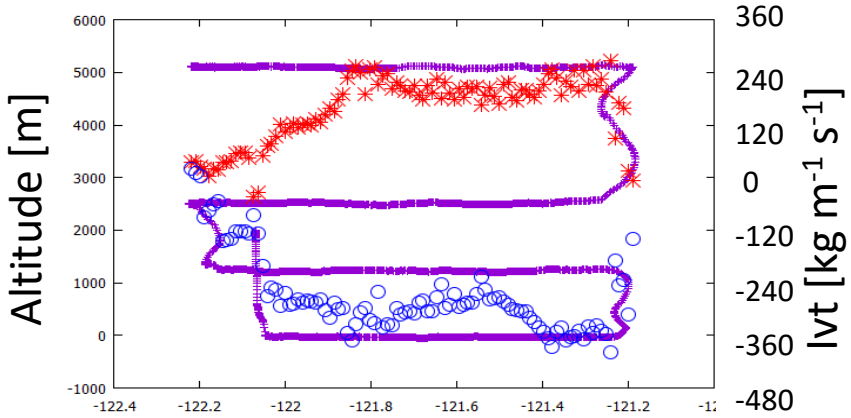
AJAX captures variability of water vapor!

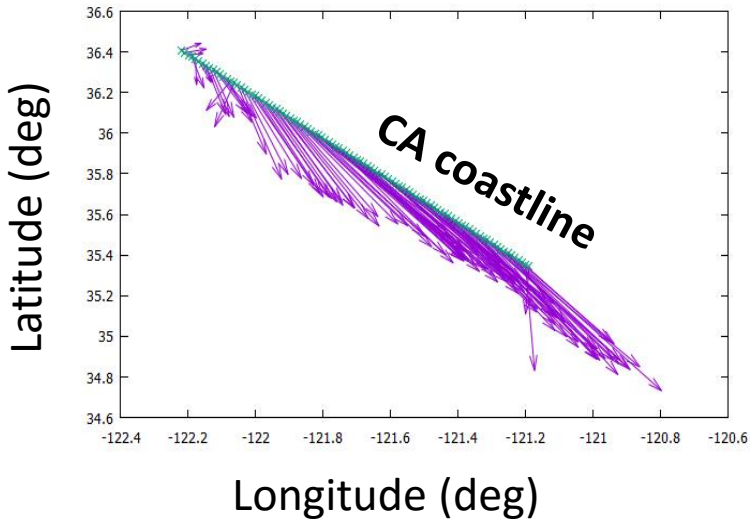




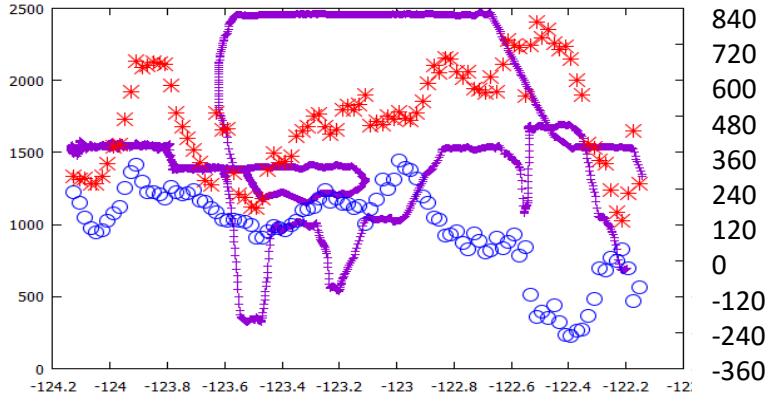
AJAX vertically integrated water vapor transport

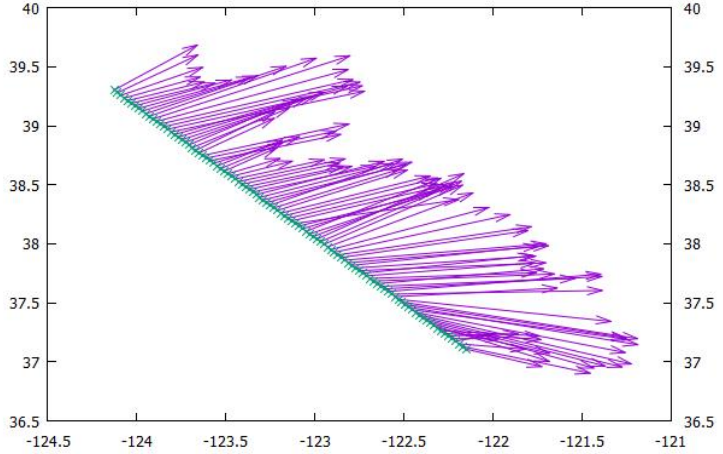
Pre-AR (Oct 7, 2015)



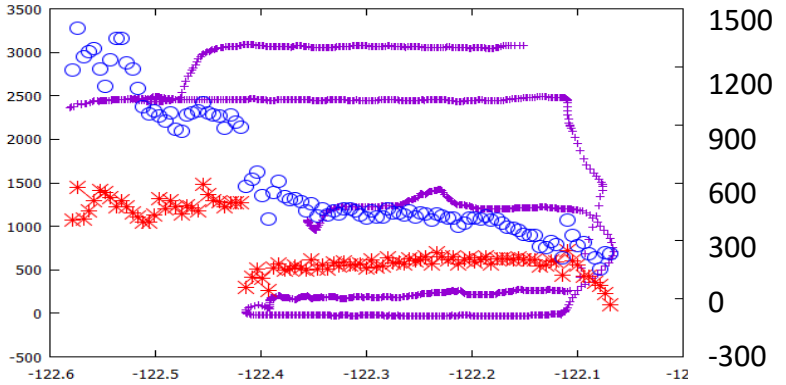


weak-AR (Dec 9, 2015)

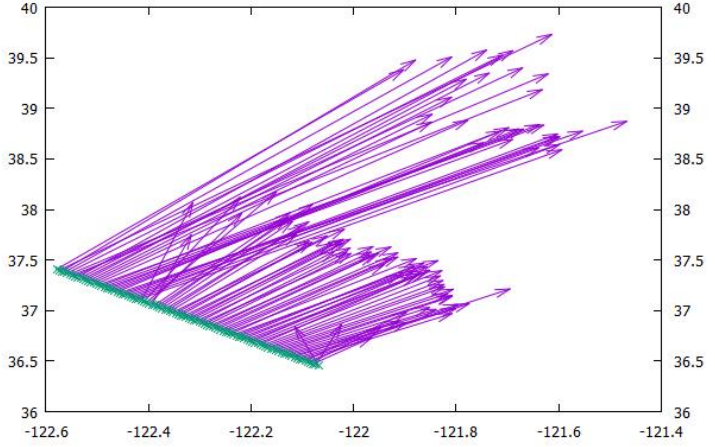




moderate-AR (Mar 10, 2016)



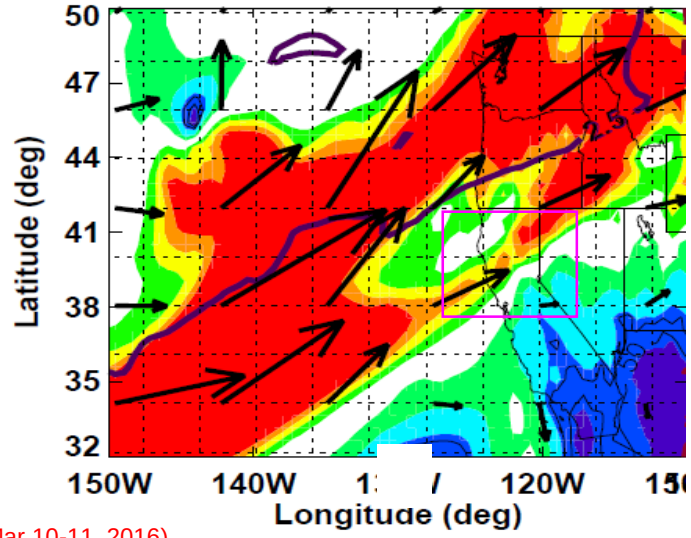
----- flight track, * U-flux, o V-flux

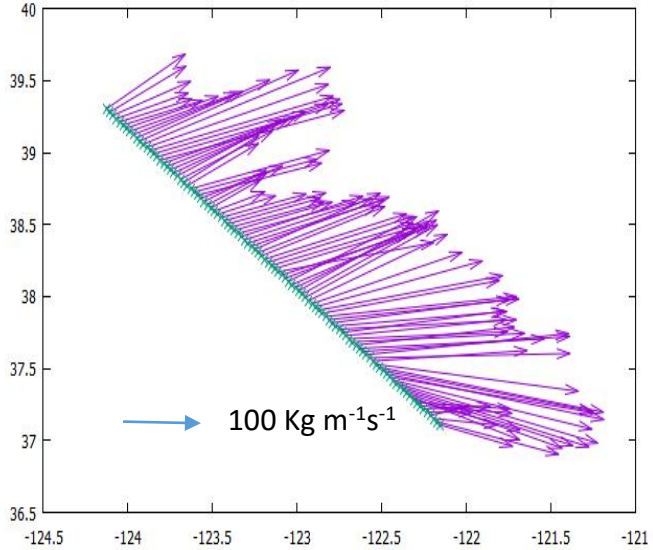


MERRA-2 2-day IVT ARs

AJAX water vapor flux

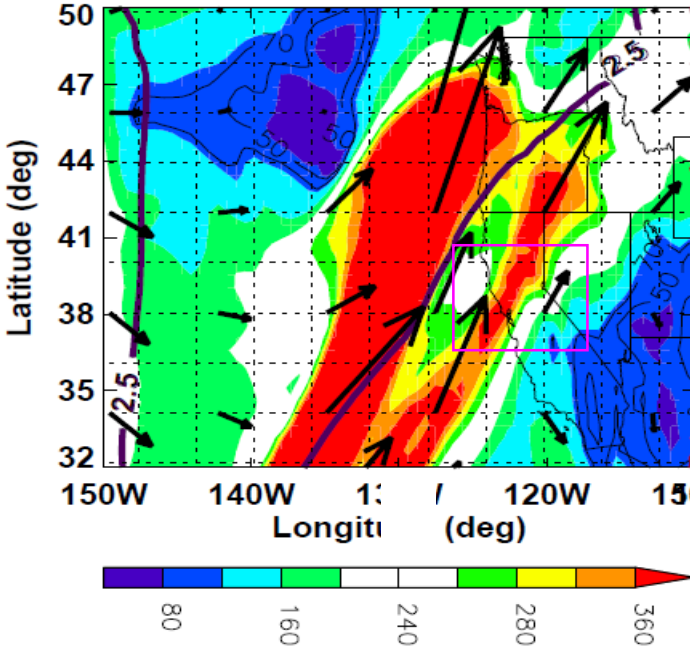
weak-AR

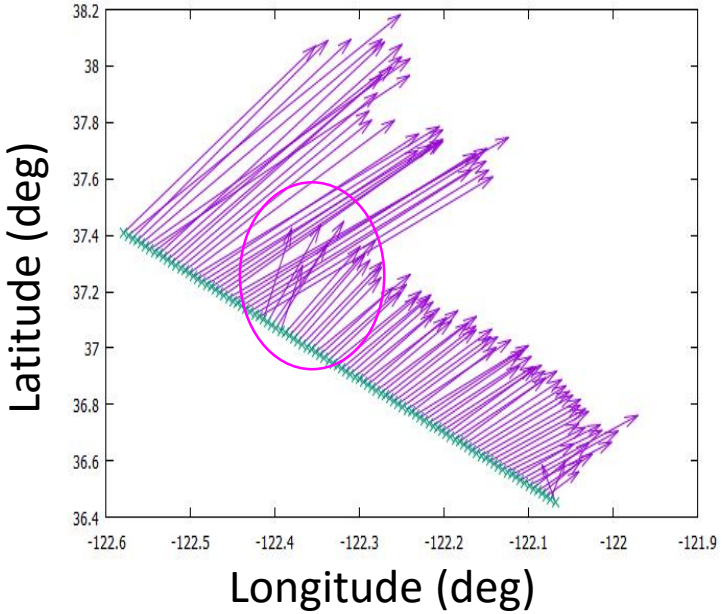




→ 100 Kgm^{-1}s^{-1} (Mar 10-11, 2016)

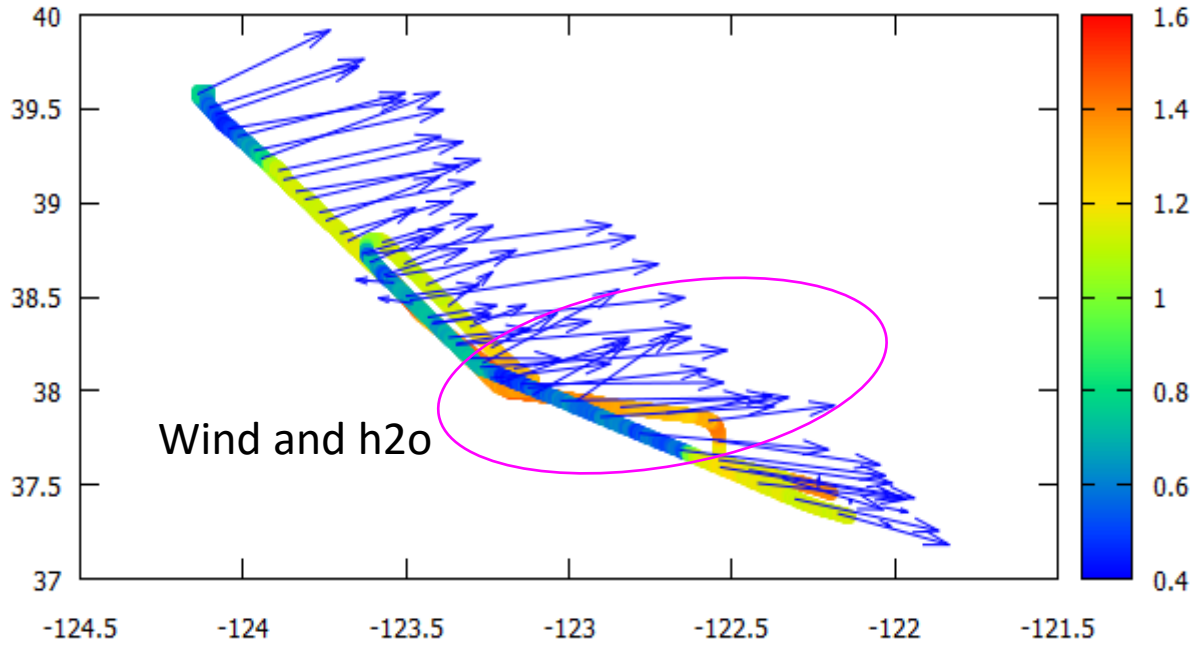
moderate-AR

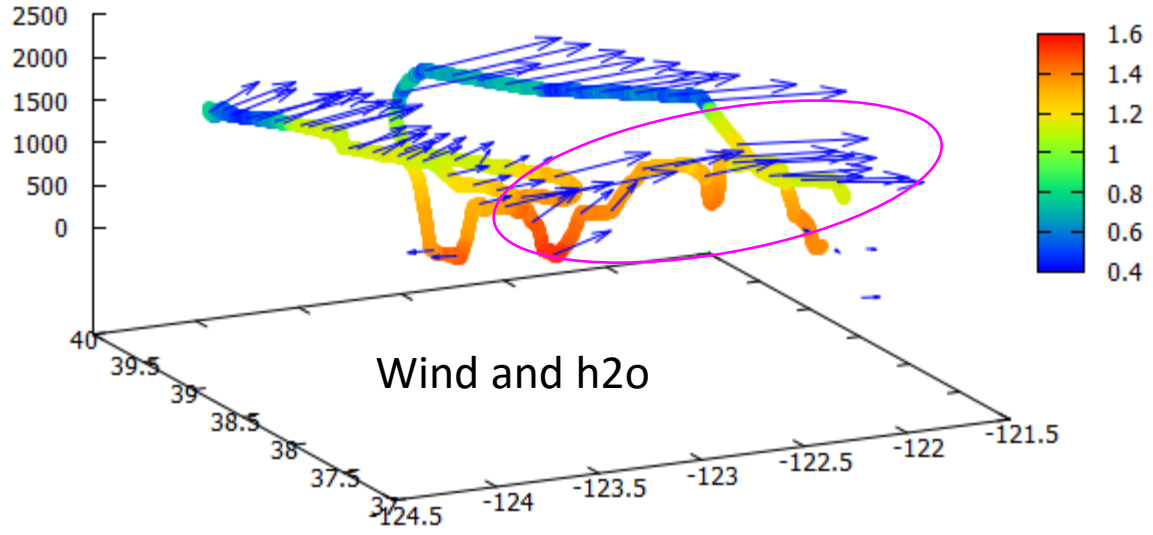


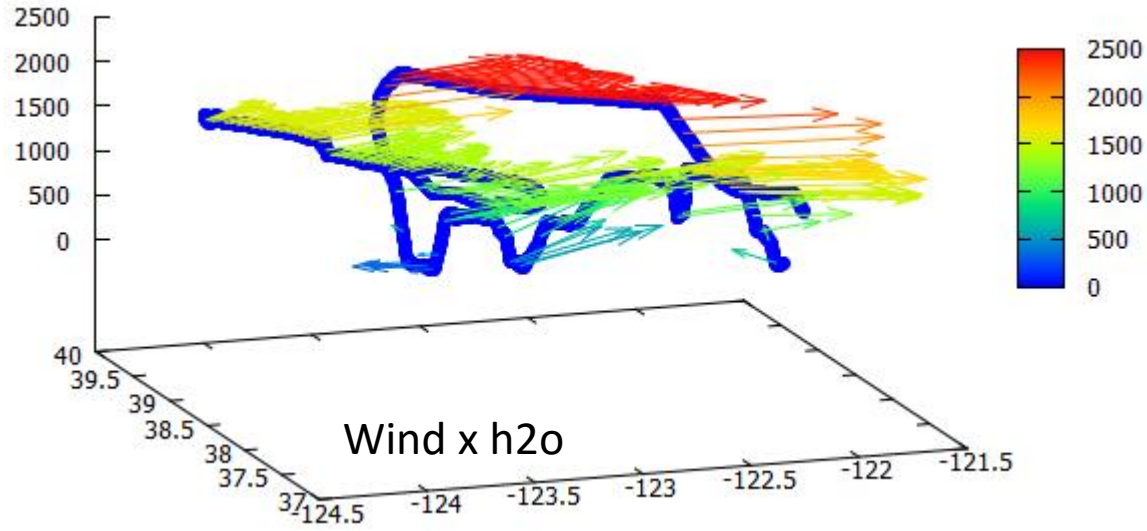


Developing coastal barrier jet?

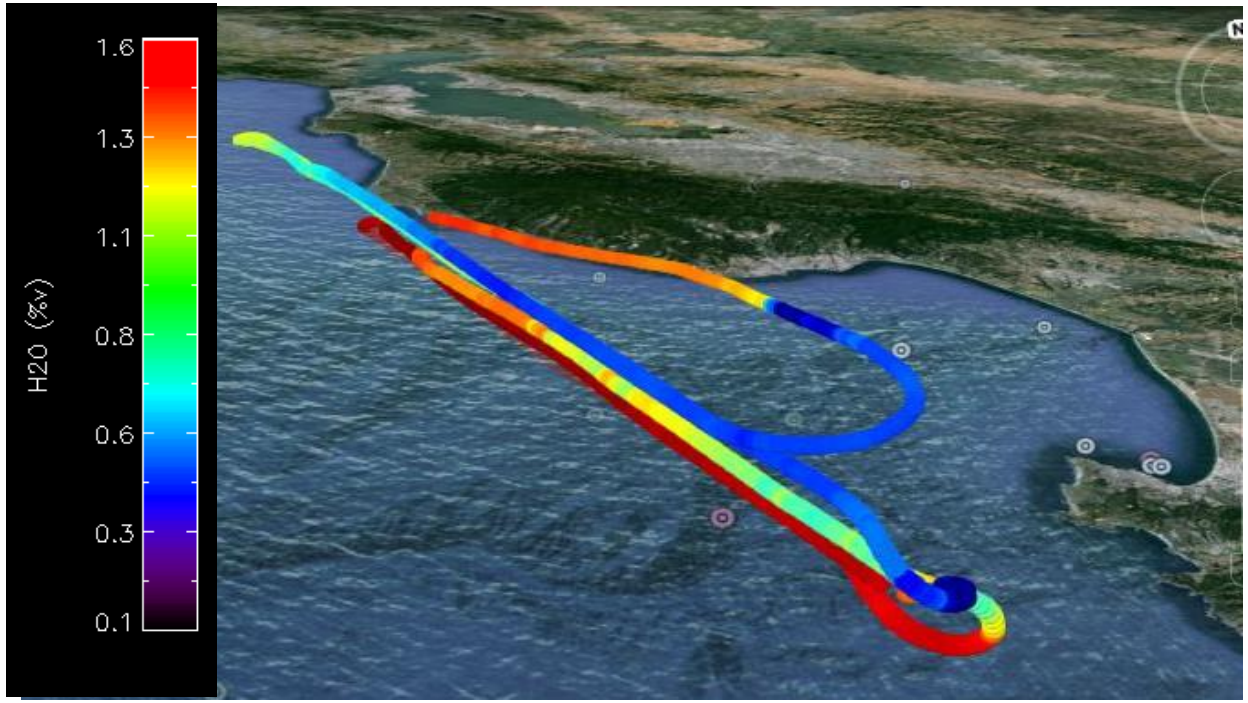
F176 (Dec 9, 2016)

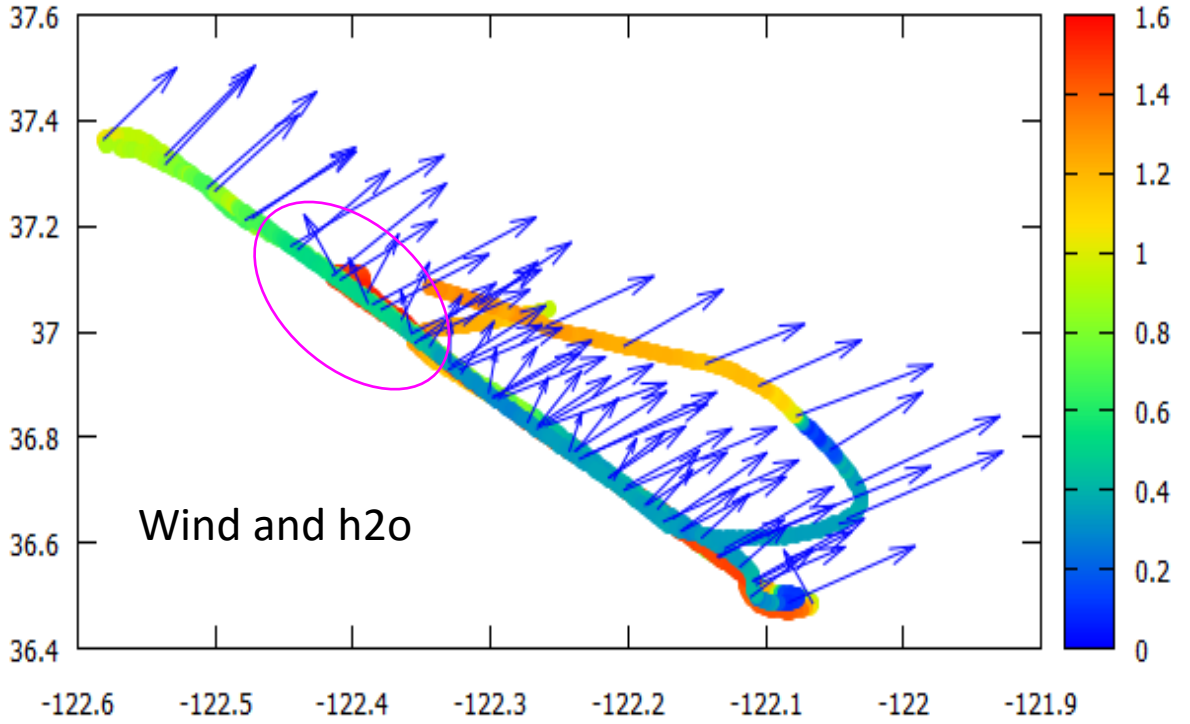


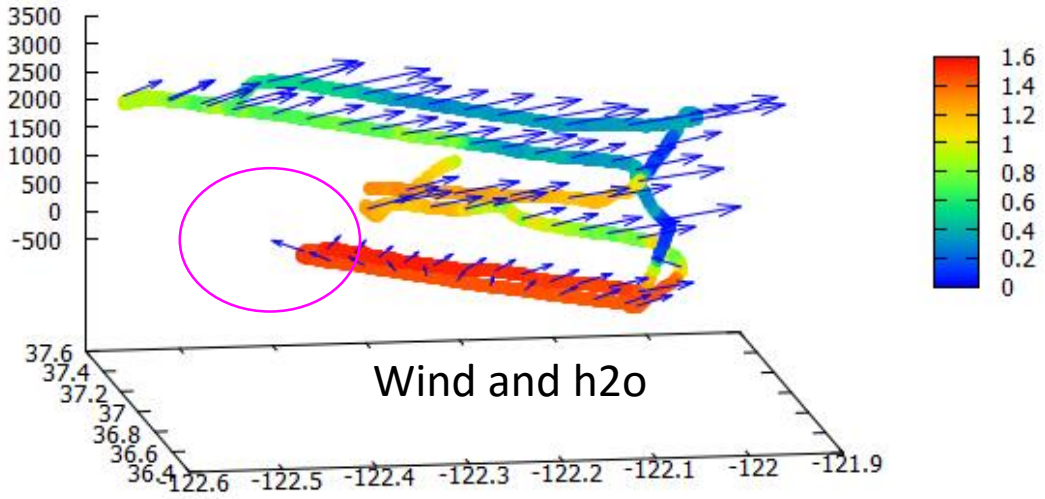


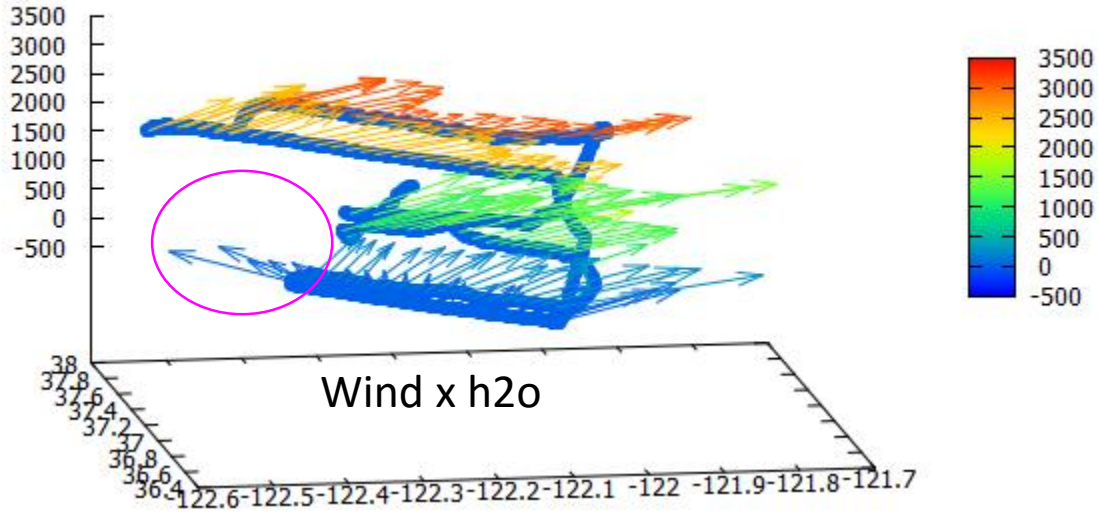


F181 (Mar 10, 2016)







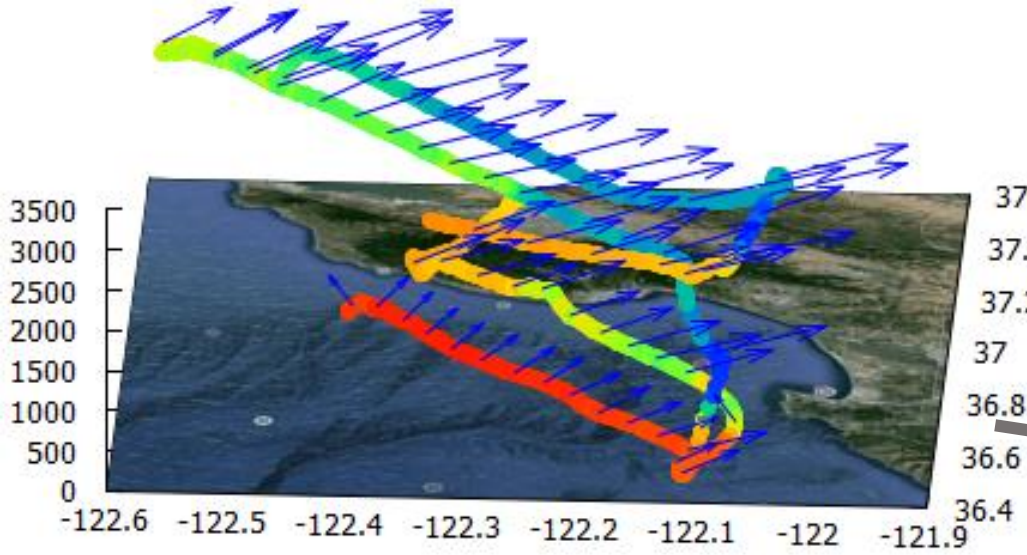


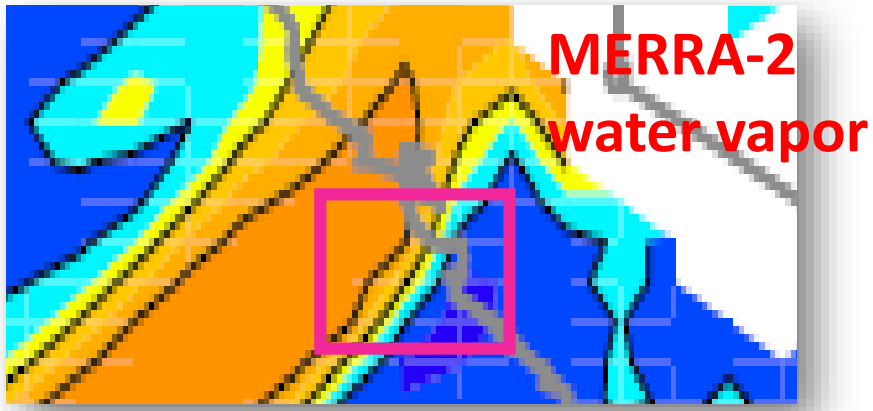
AJAX data characteristics (Barrier Jet structure)

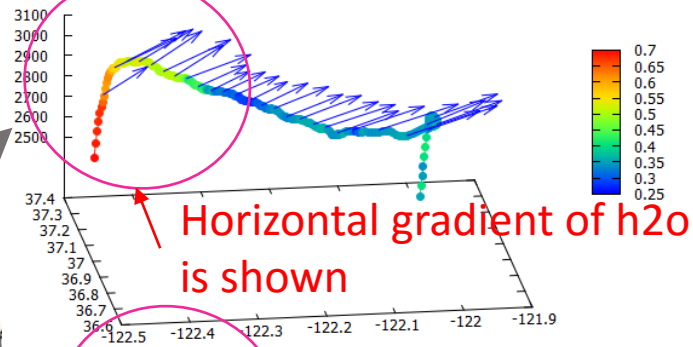
Water vapor and Wind

moderate-AR

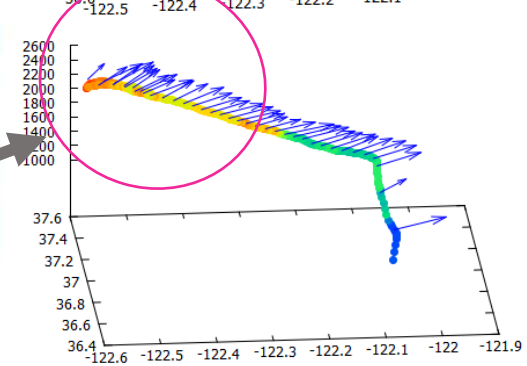
(Mar 10, 2016)



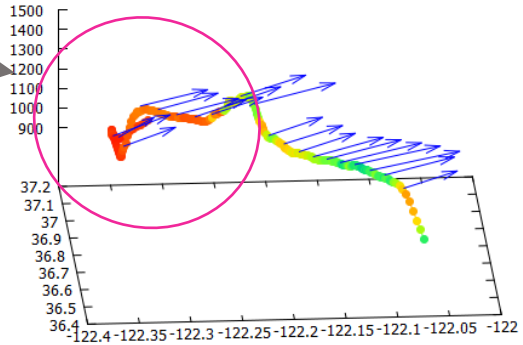


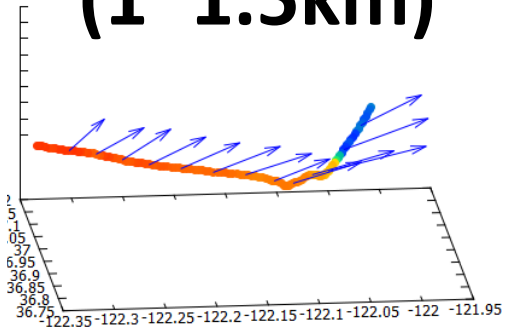


(3 ~ 3.5 km)

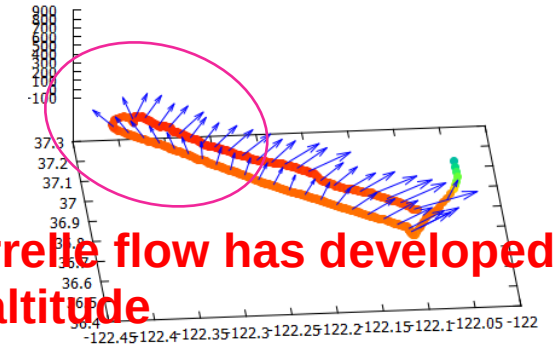


(2~2.5km)





(1~1.5km)



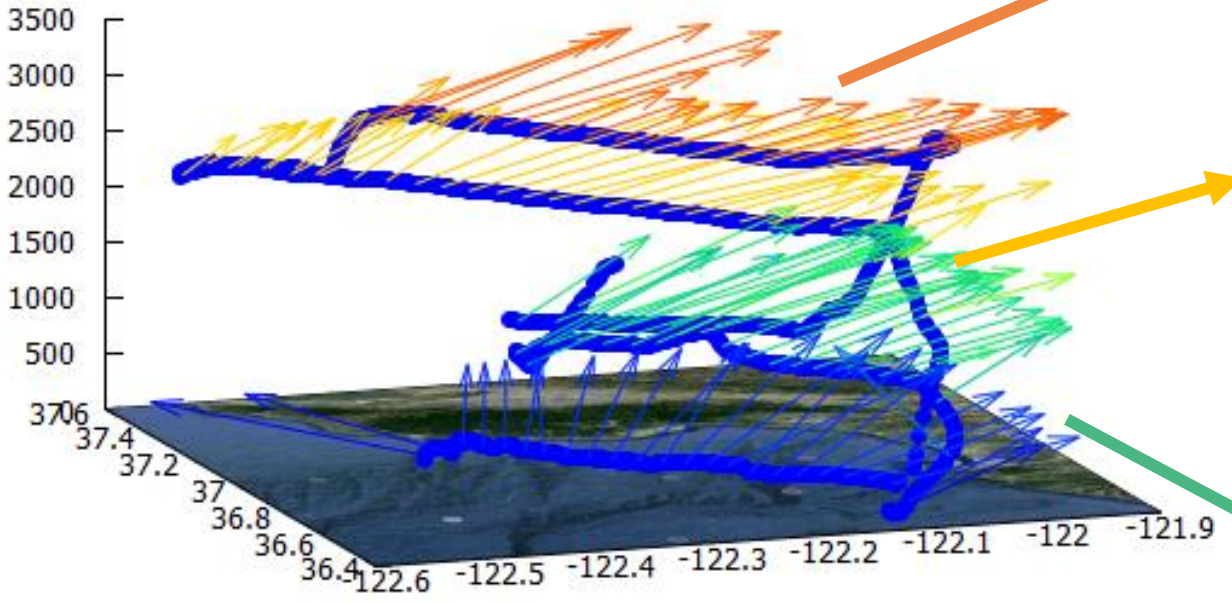
(0~0.5km)

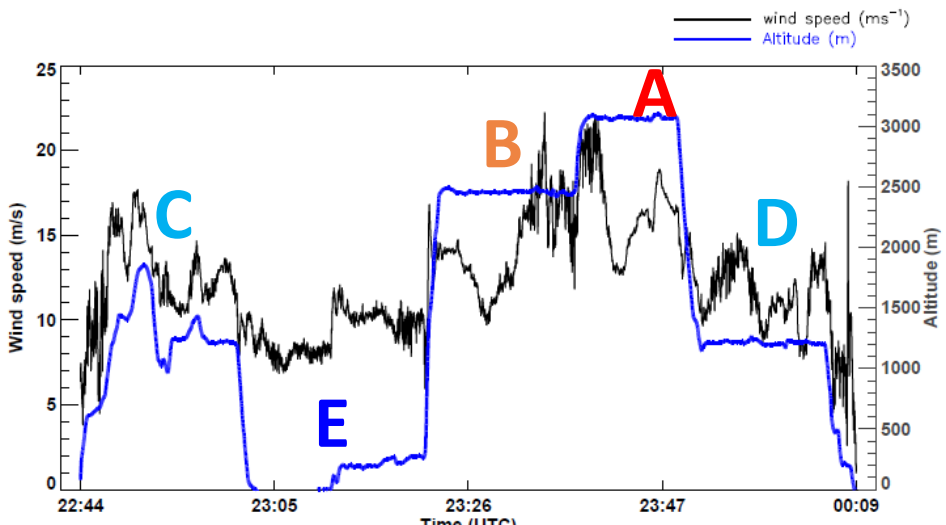
coastal-parrelle flow has developed
at the low altitude

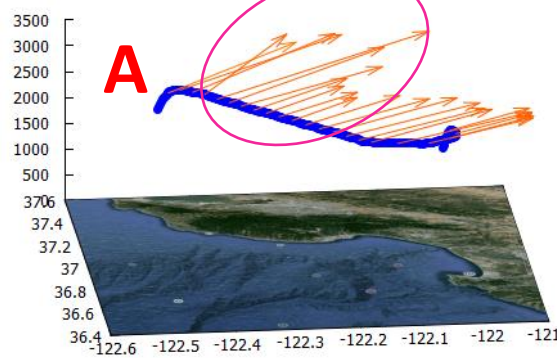
Water vapor x Wind

moderate-AR

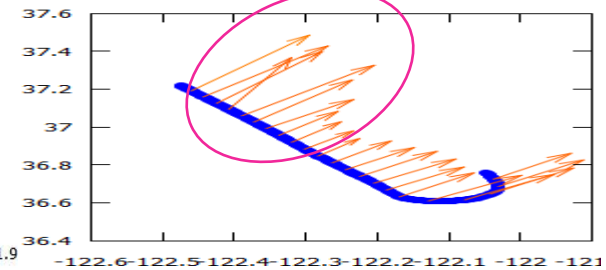
(Mar 10, 2016)

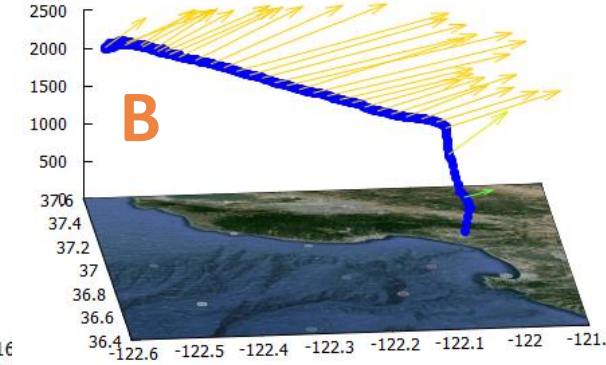




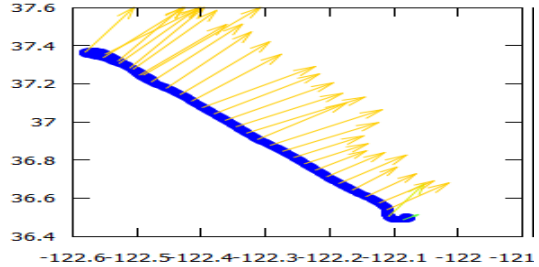


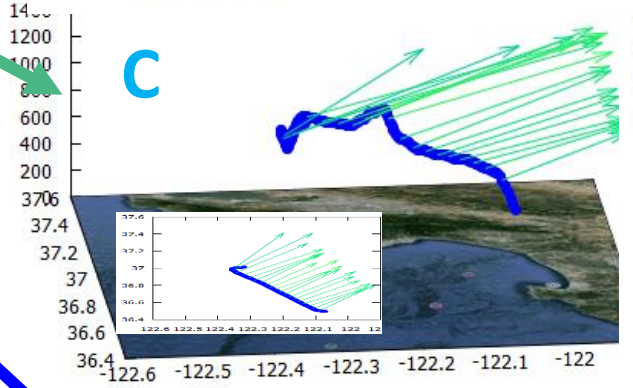
(3 ~ 3.5 km)



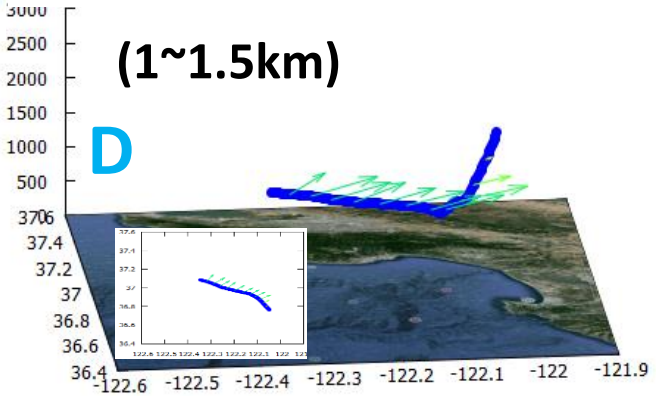


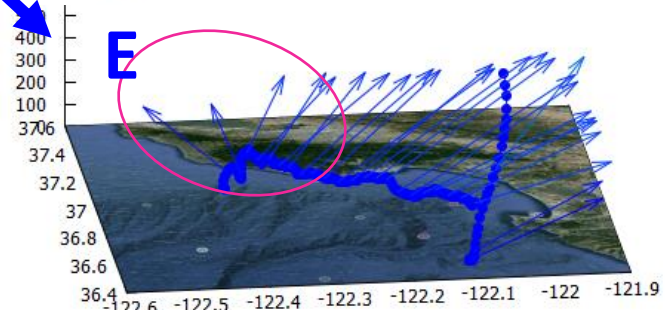
(2~2.5km)



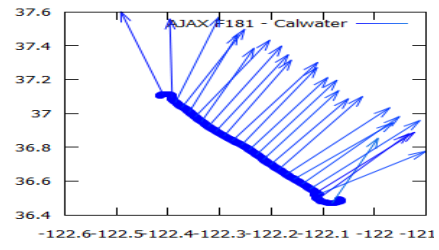


(1~1.5km)



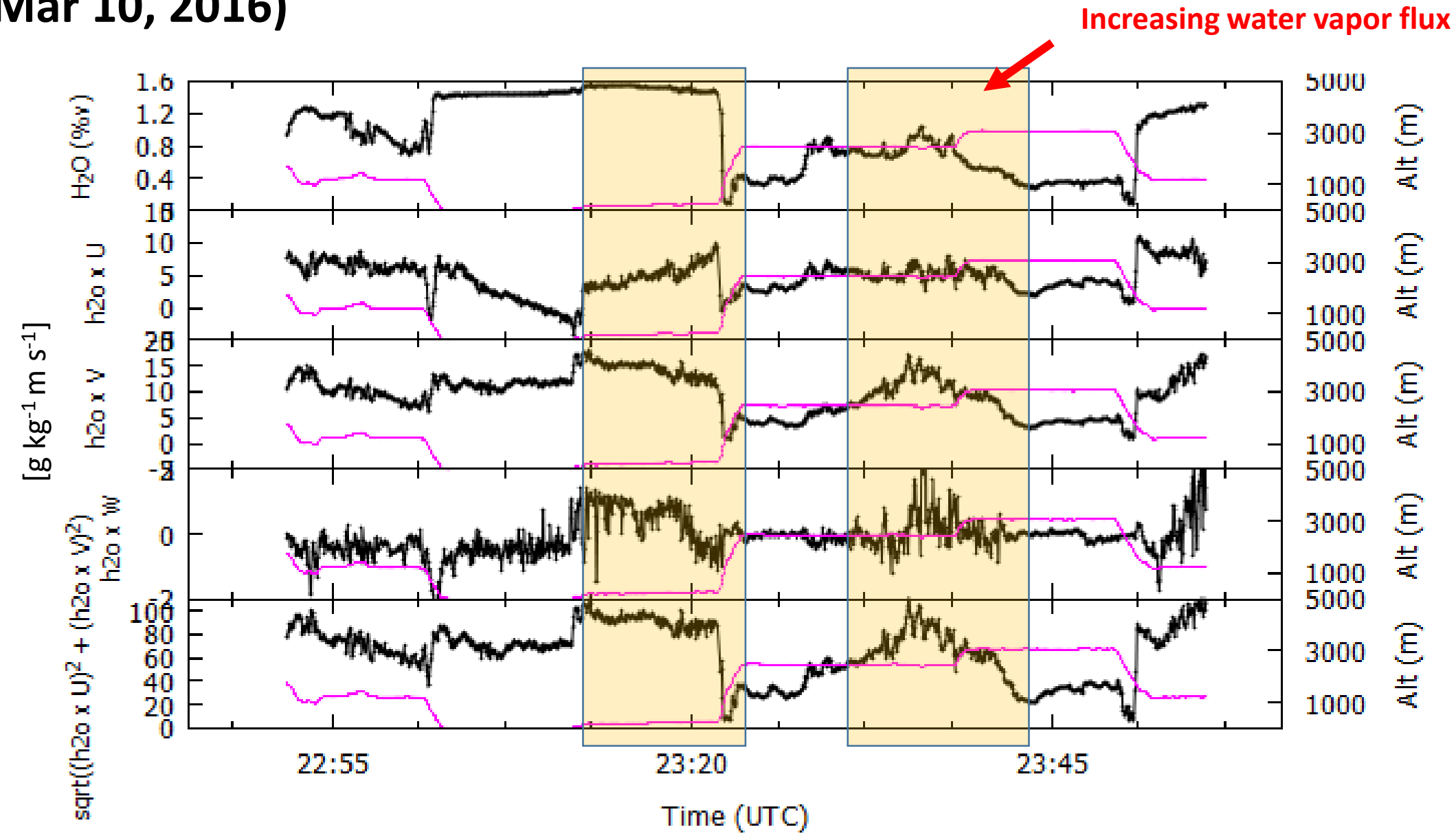


(0~0.5km)



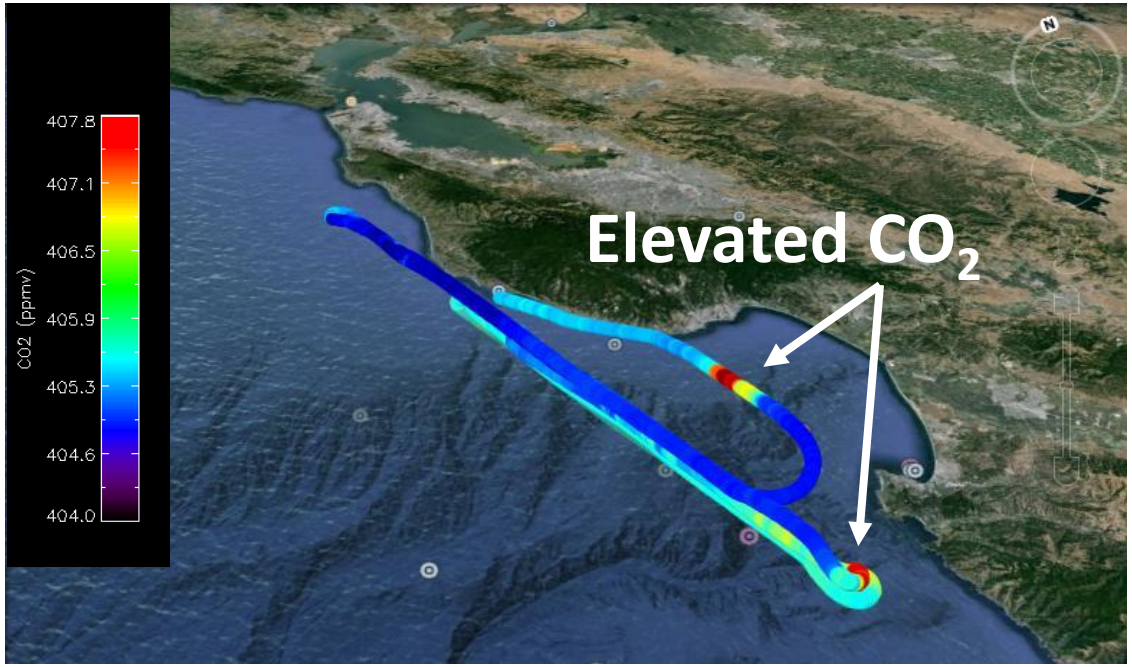
moderate-AR

(Mar 10, 2016)

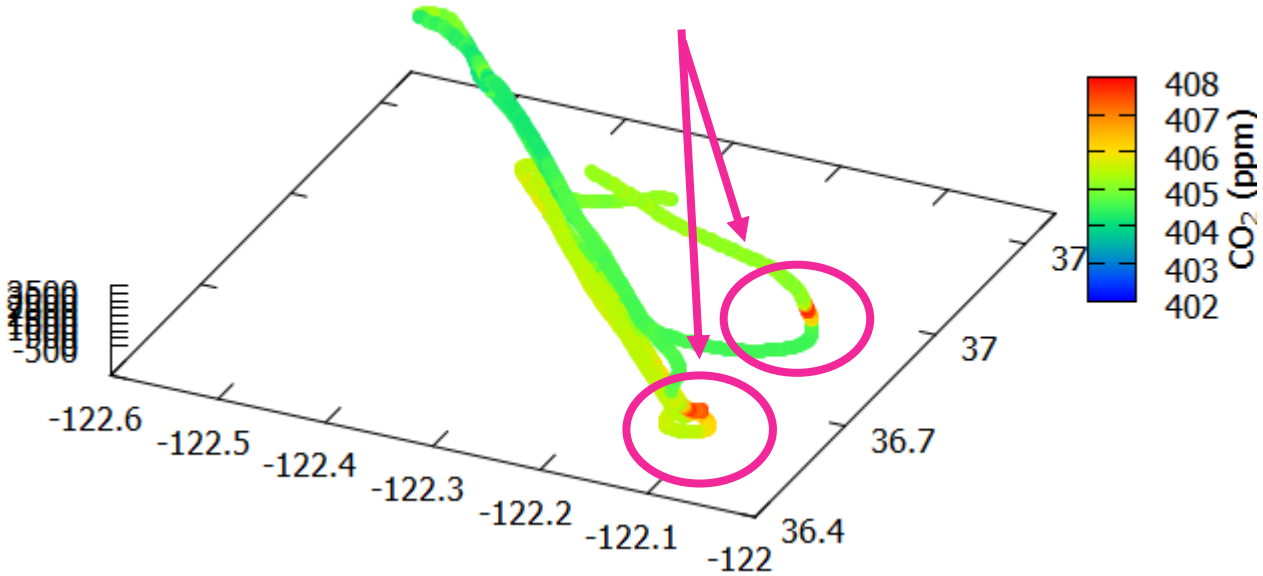


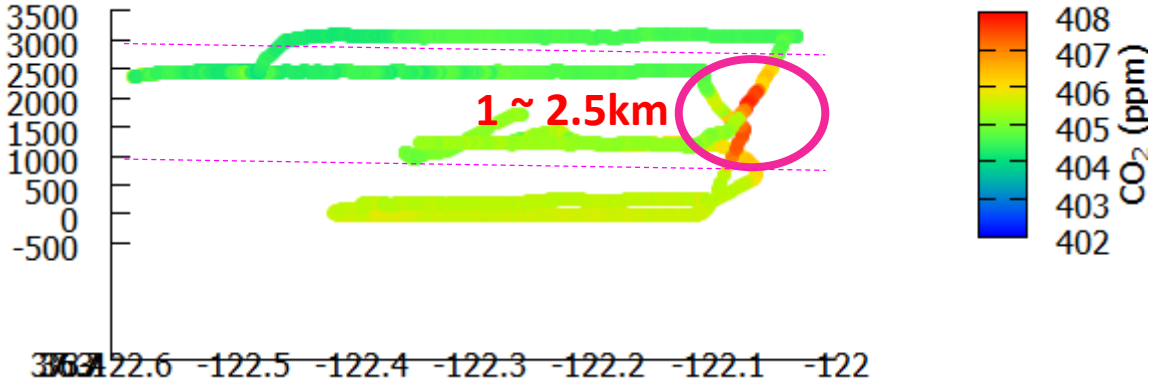
Pollution transport

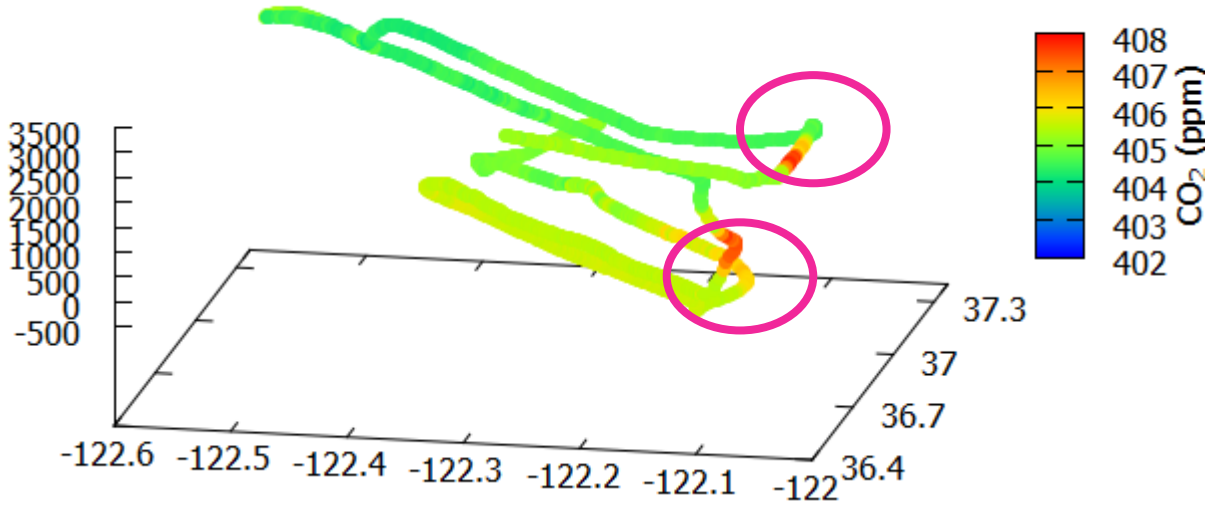
F181 CO_2



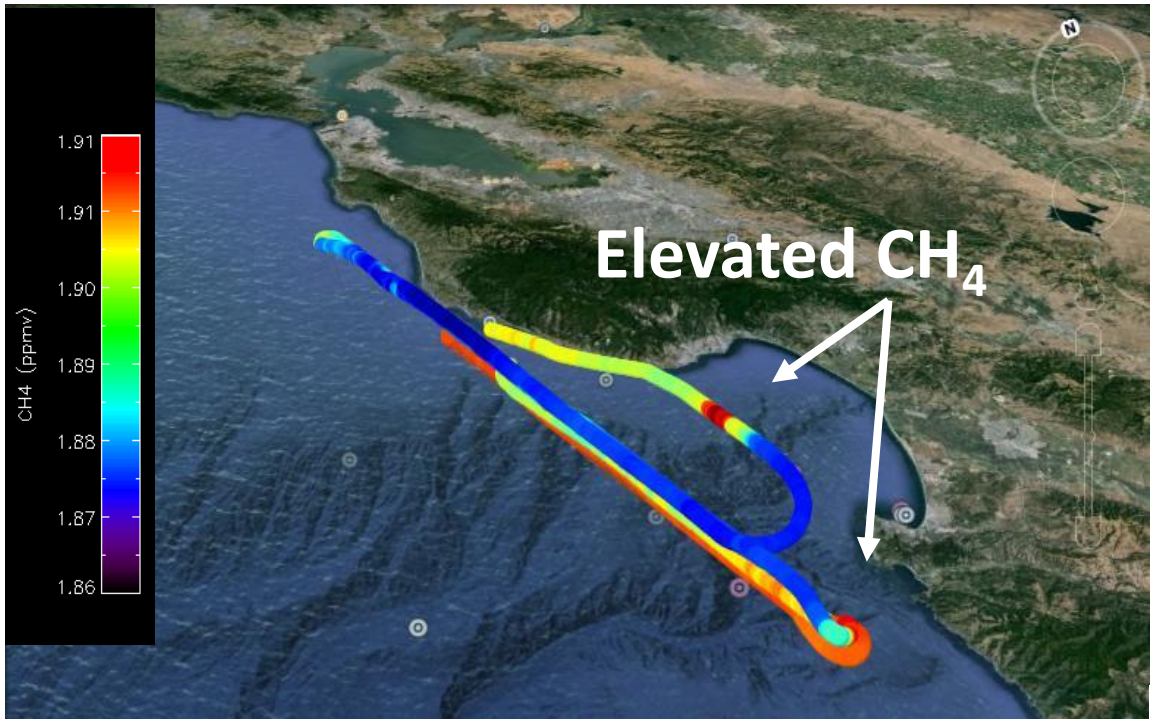
High concentration of CO_2

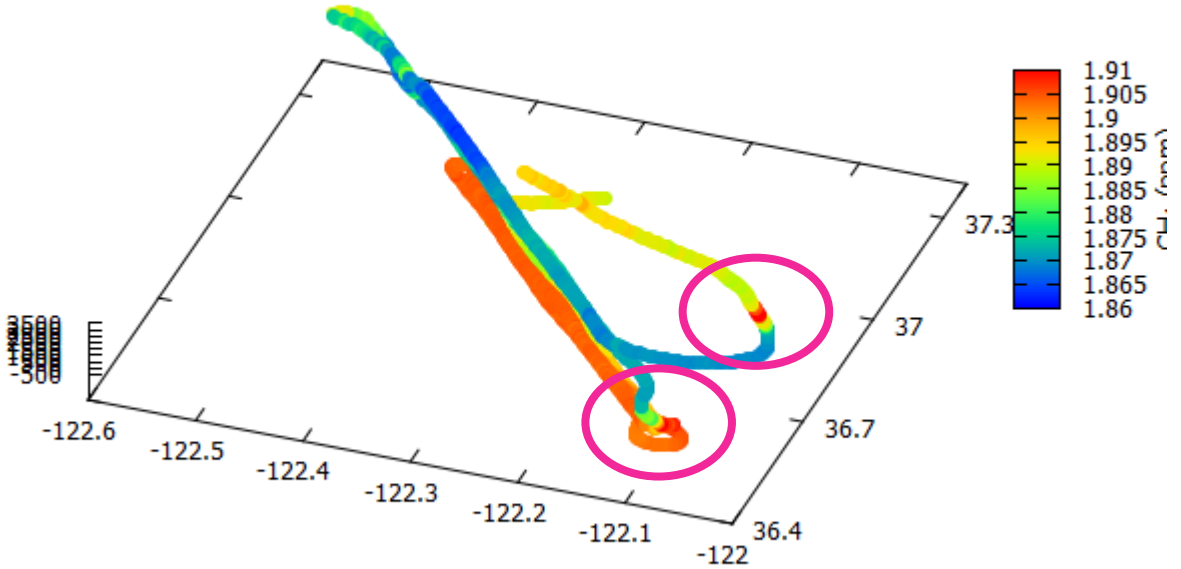


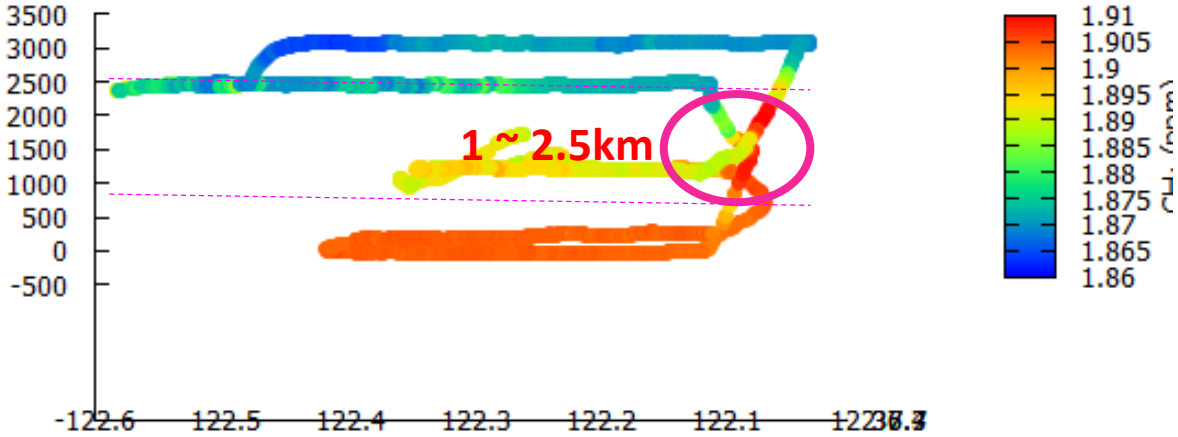




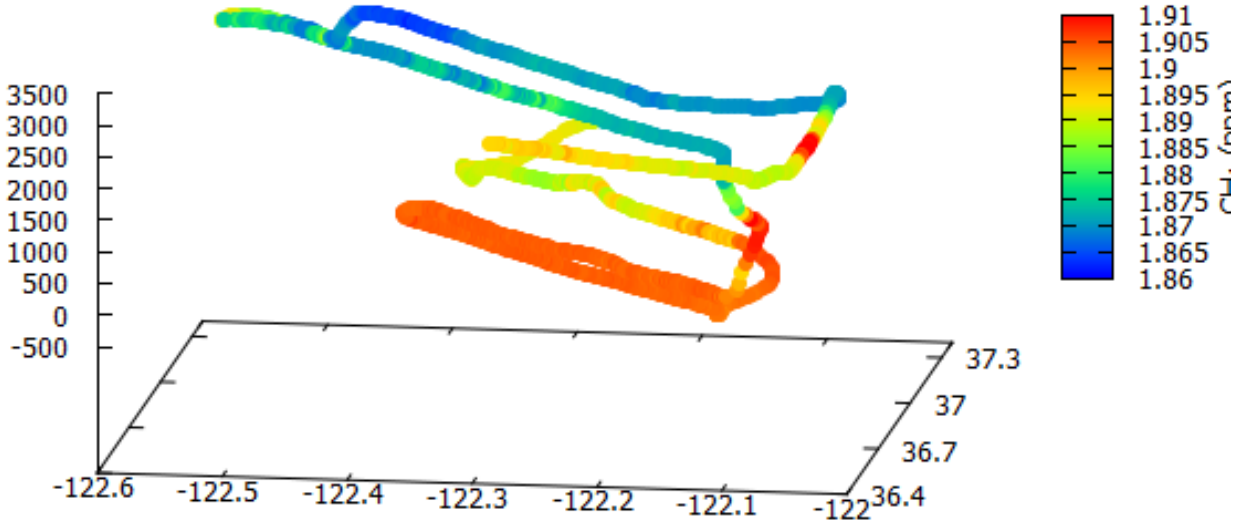
F181 CH_4


CH4 (ppmv)
1.91
1.91
1.90
1.89
1.88
1.87
1.86
Elevated CH_4


1.91
1.905
1.9
1.895
1.89
1.885
1.88
1.875
1.87
1.865
1.86
37.3
37
36.7
36.4
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122

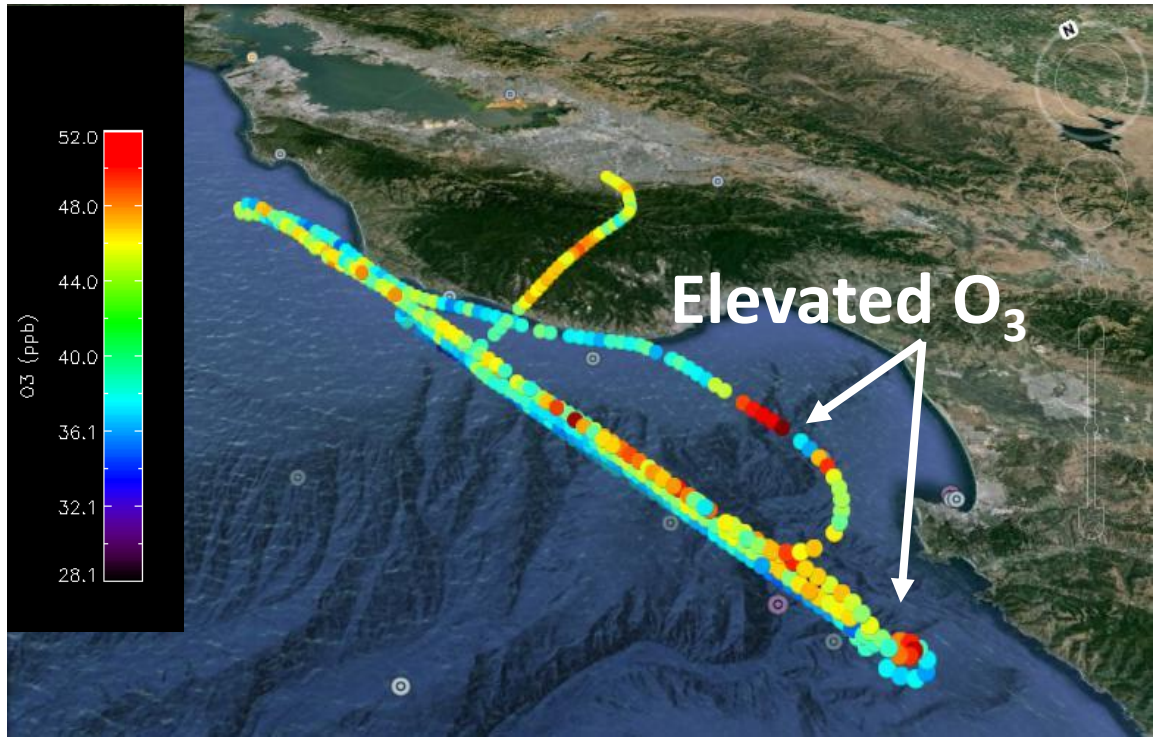

3500
3000
2500
2000
1500
1000
500
0
-500
1 ~ 2.5km
-122.6
122.5
122.4
122.3
122.2
122.1

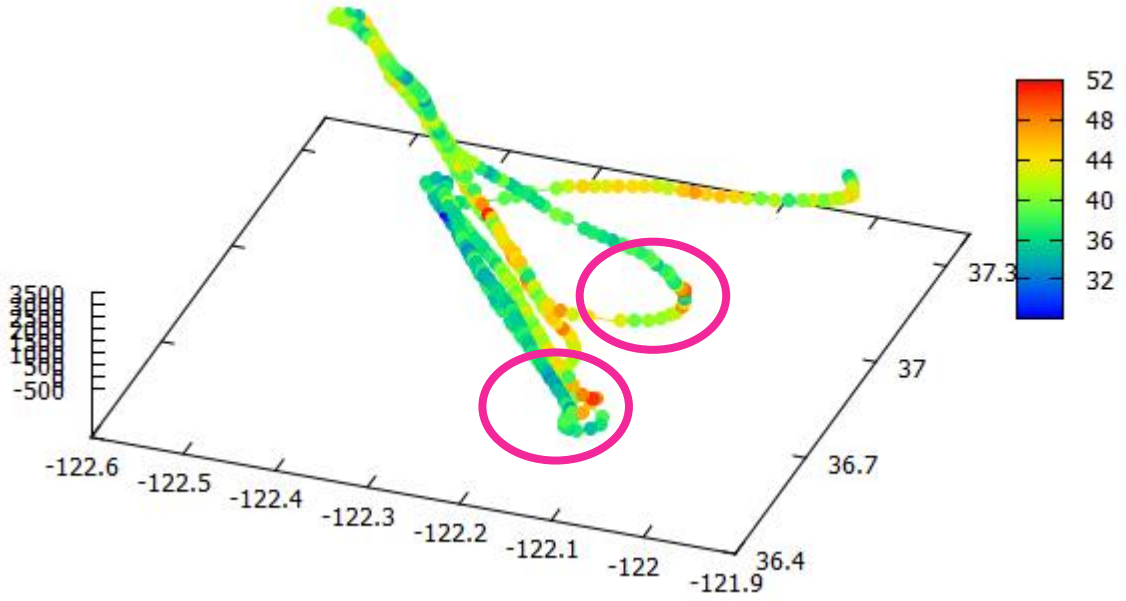
1.91
1.905
1.9
1.895
1.89
1.885
1.88
1.875
1.87
1.865
1.86

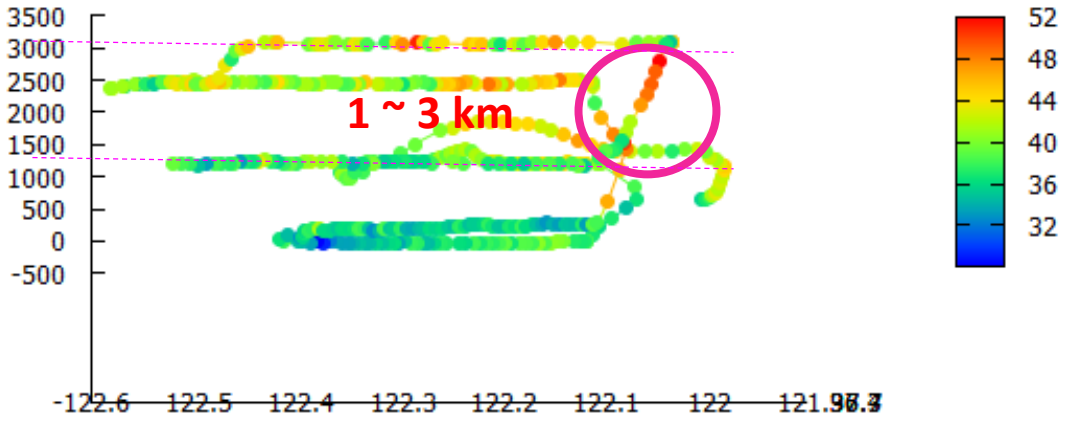

3500
3000
2500
2000
1500
1000
500
0
-500
37.3
37
36.7
36.4
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122

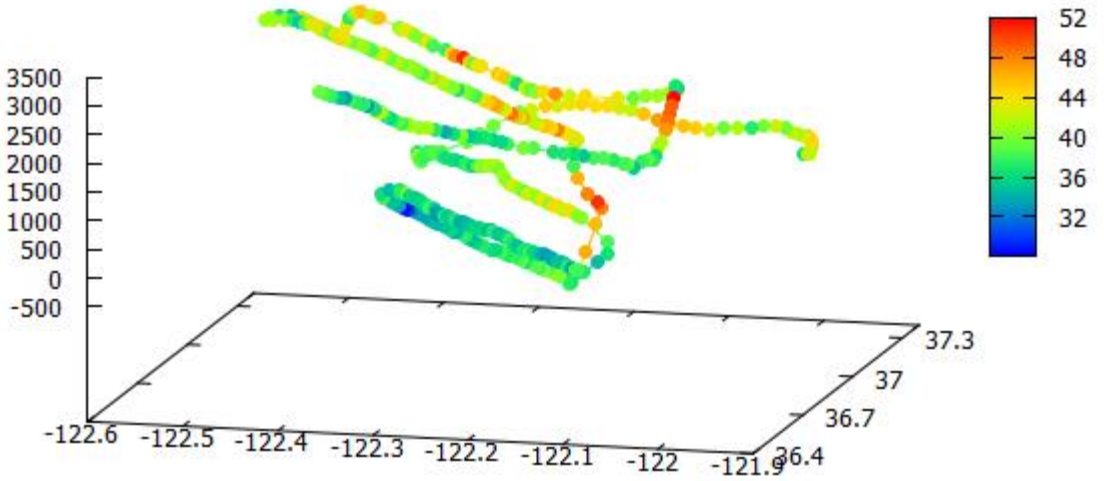
1.91
1.905
1.9
1.895
1.89
1.885
1.88
1.875
1.87
1.865
1.86

F181 O3

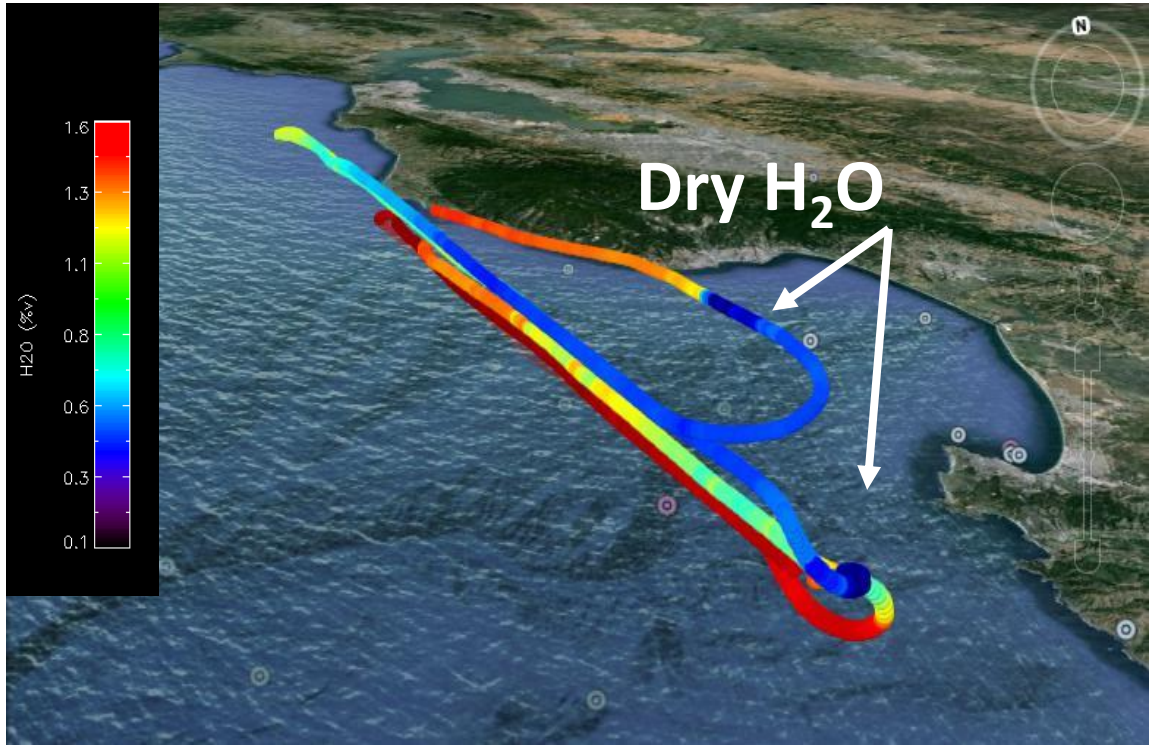

52.0
48.0
44.0
40.0
36.1
32.1
28.1
O3 (ppb)
Elevated O_3

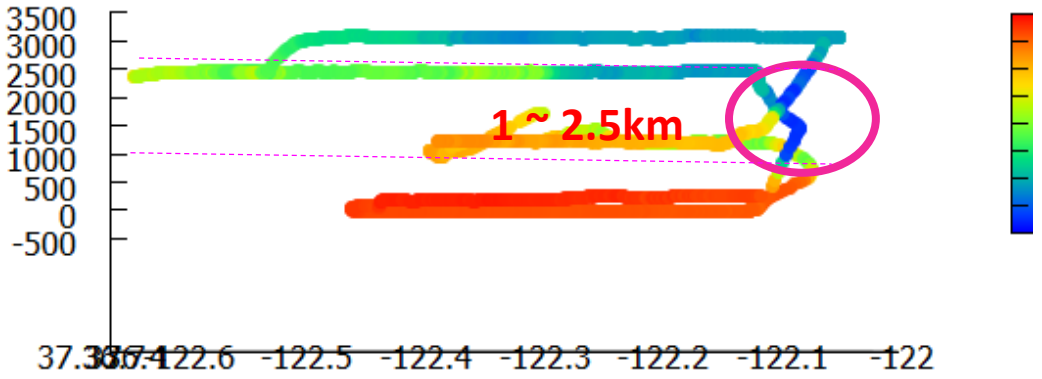

52
48
44
40
36
32
37.3
37
36.7
36.4
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122
-121.9
-500

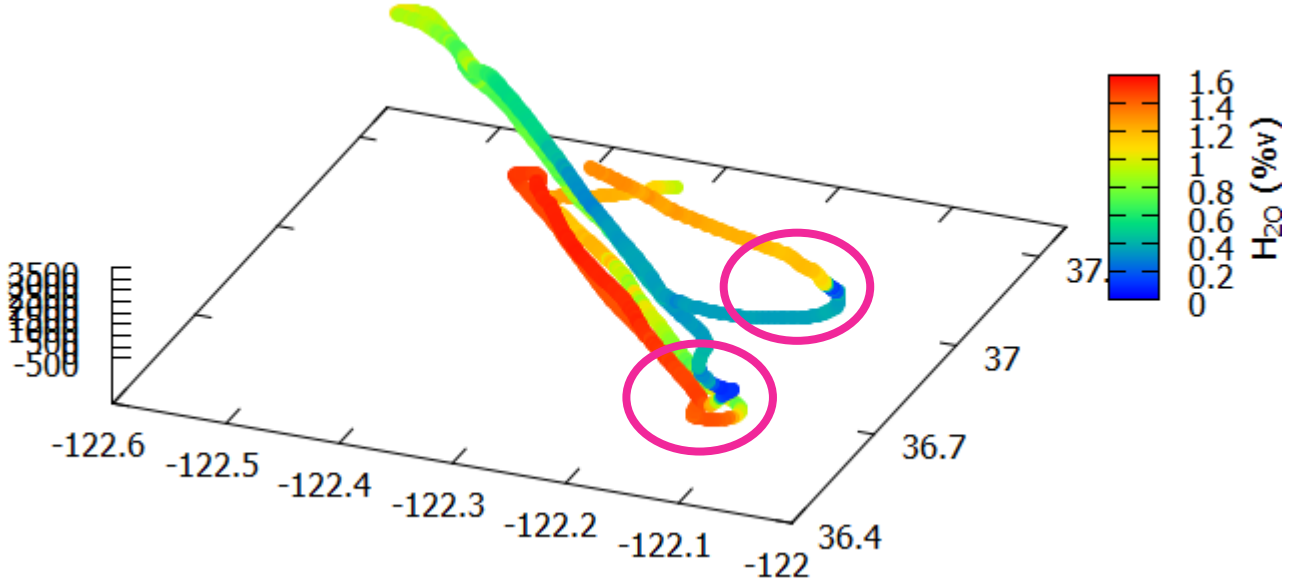

3500
3000
2500
2000
1500
1000
500
0
-500
1 ~ 3 km
52
48
44
40
36
32
-122.6
122.5
122.4
122.3
122.2
122.1
122

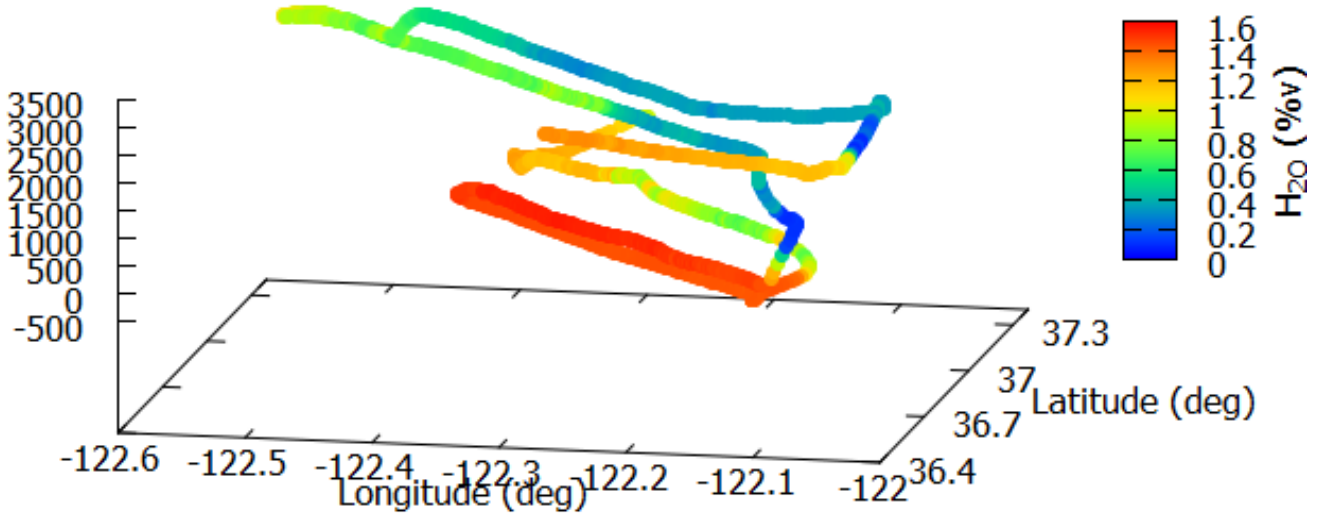

3500
3000
2500
2000
1500
1000
500
0
-500
52
48
44
40
36
32
37.3
37
36.7
36.4
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122
-121.9

F181 H_2O


H2O (%v)
1.6
1.3
1.1
0.8
0.6
0.3
0.1
Dry H_2O


3500
3000
2500
2000
1500
1000
500
0
-500
1 ~ 2.5km
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122


-500
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122
36.4
36.7
37
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
H_{2O} (%v)


3500
3000
2500
2000
1500
1000
500
0
-500
-122.6
-122.5
-122.4
-122.3
-122.2
-122.1
-122
Longitude (deg)
36.4
36.7
37
37.3
Latitude (deg)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
H_{2O} (%v)

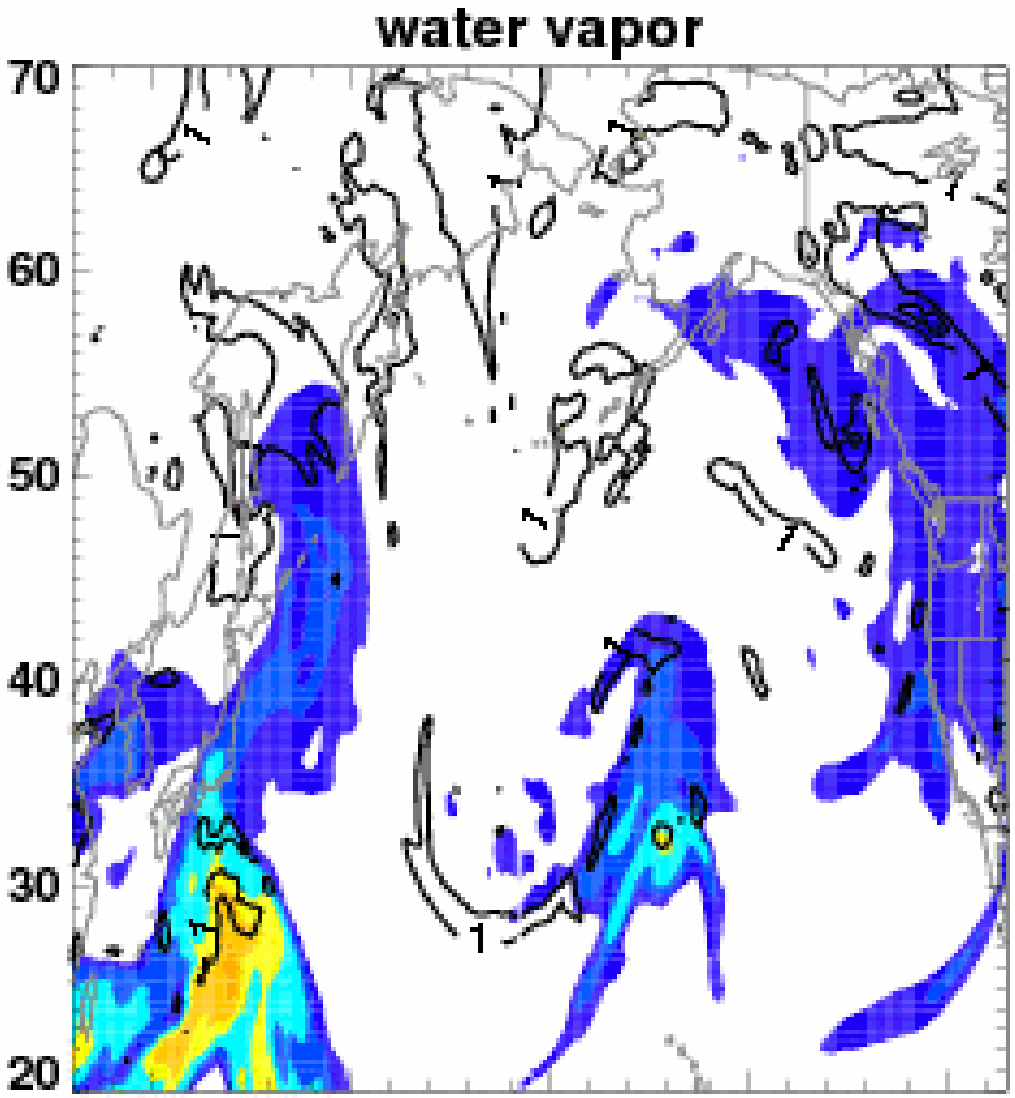
moderate-AR

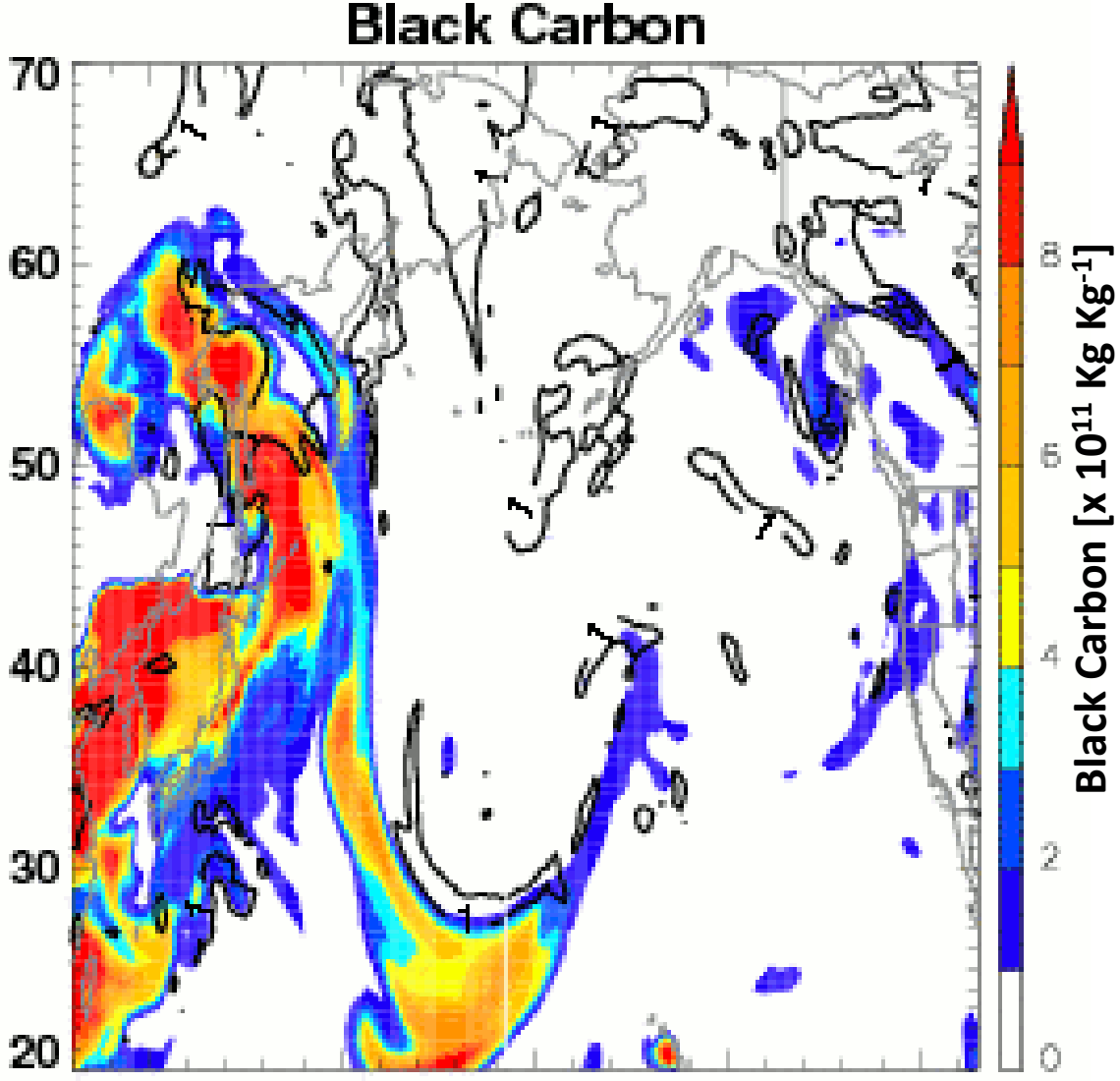
(Mar 10, 2016)

700 hPa

20160307 - 0 hrs

(AJAX flight launched on Mar 10, 21 UTC)





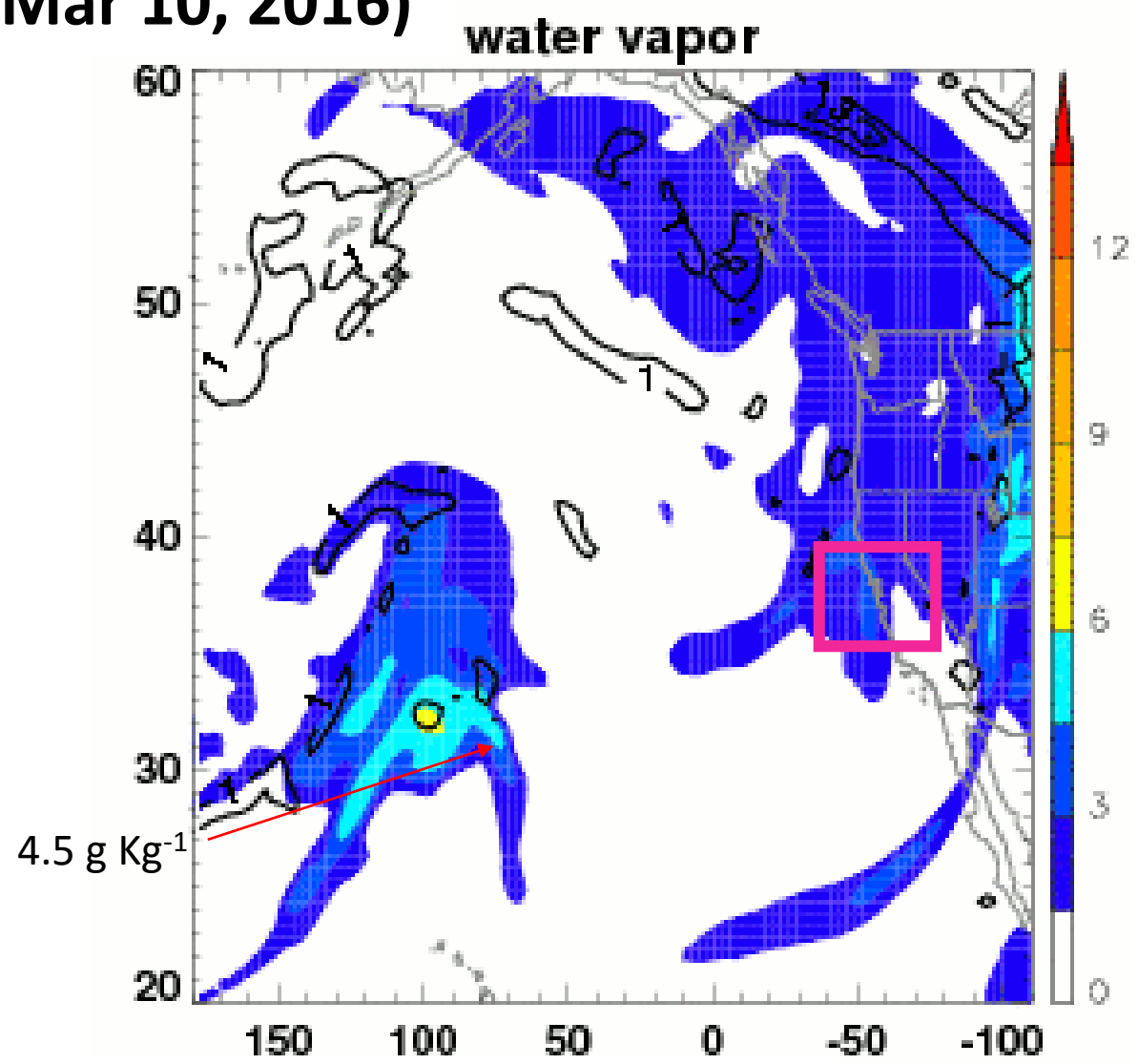
moderate-AR

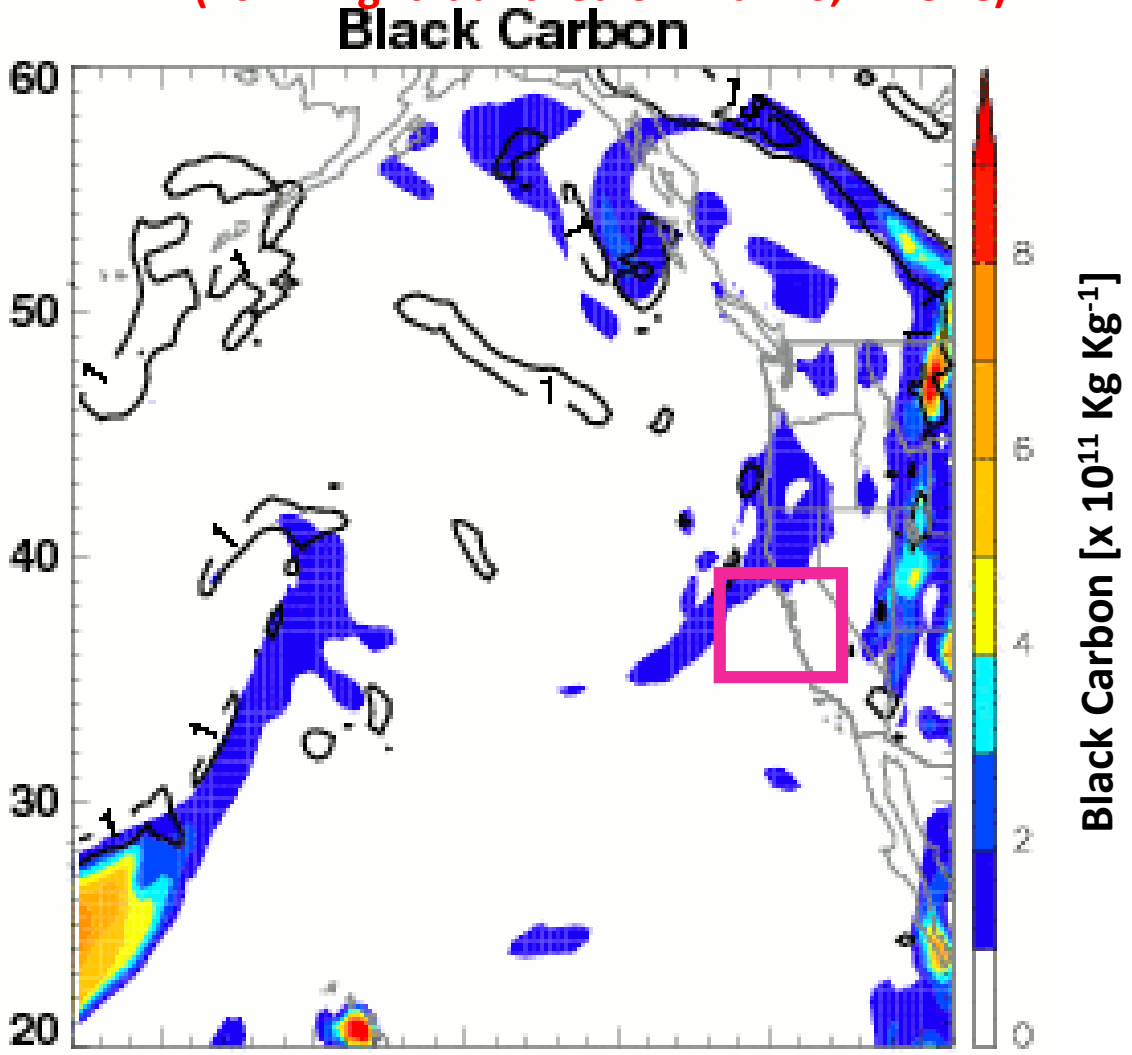
(Mar 10, 2016)

700 hPa

20160307 - 0 hrs

(AJAX flight launched on Mar 10, 21 UTC)





Zoom in the western U.S.

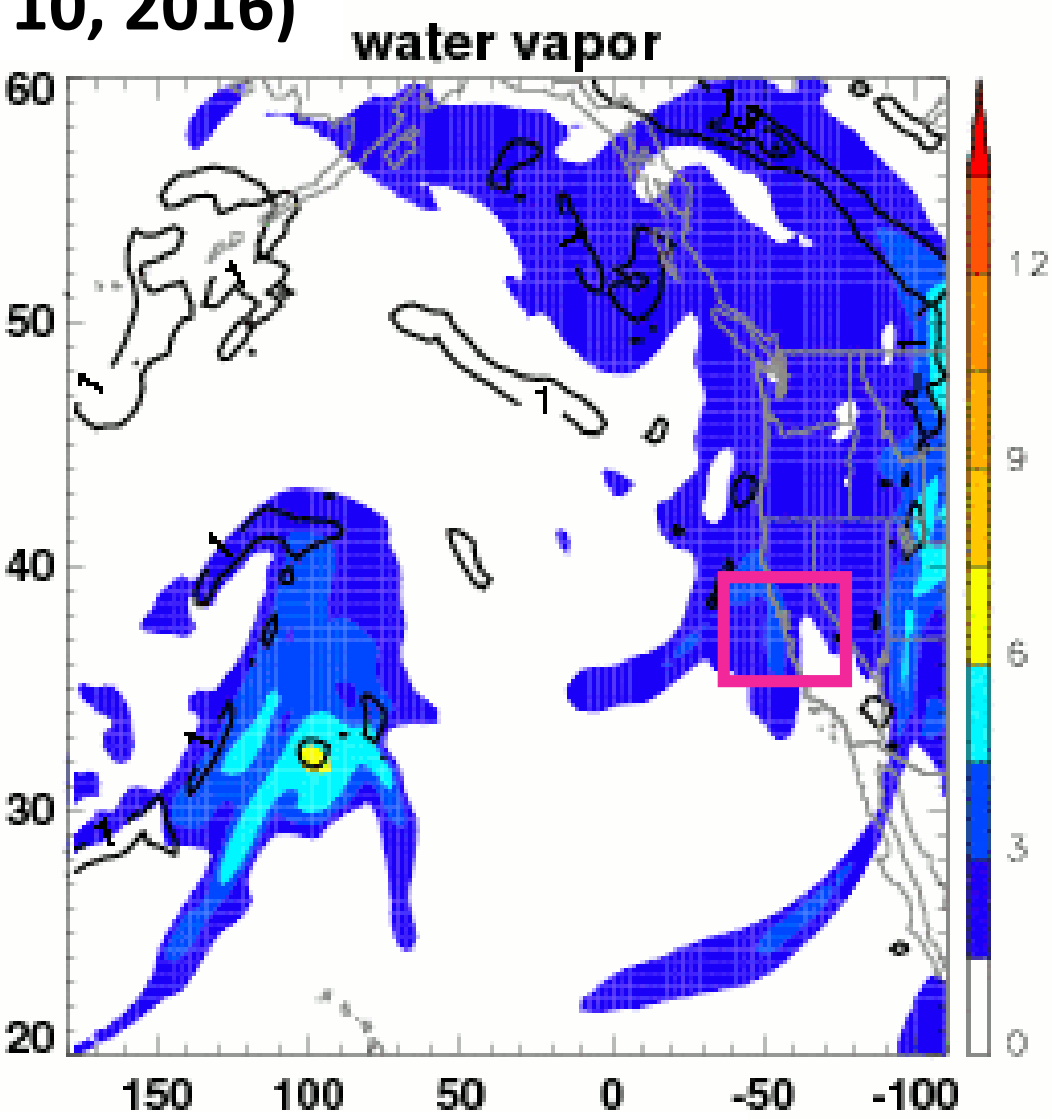
moderate-AR

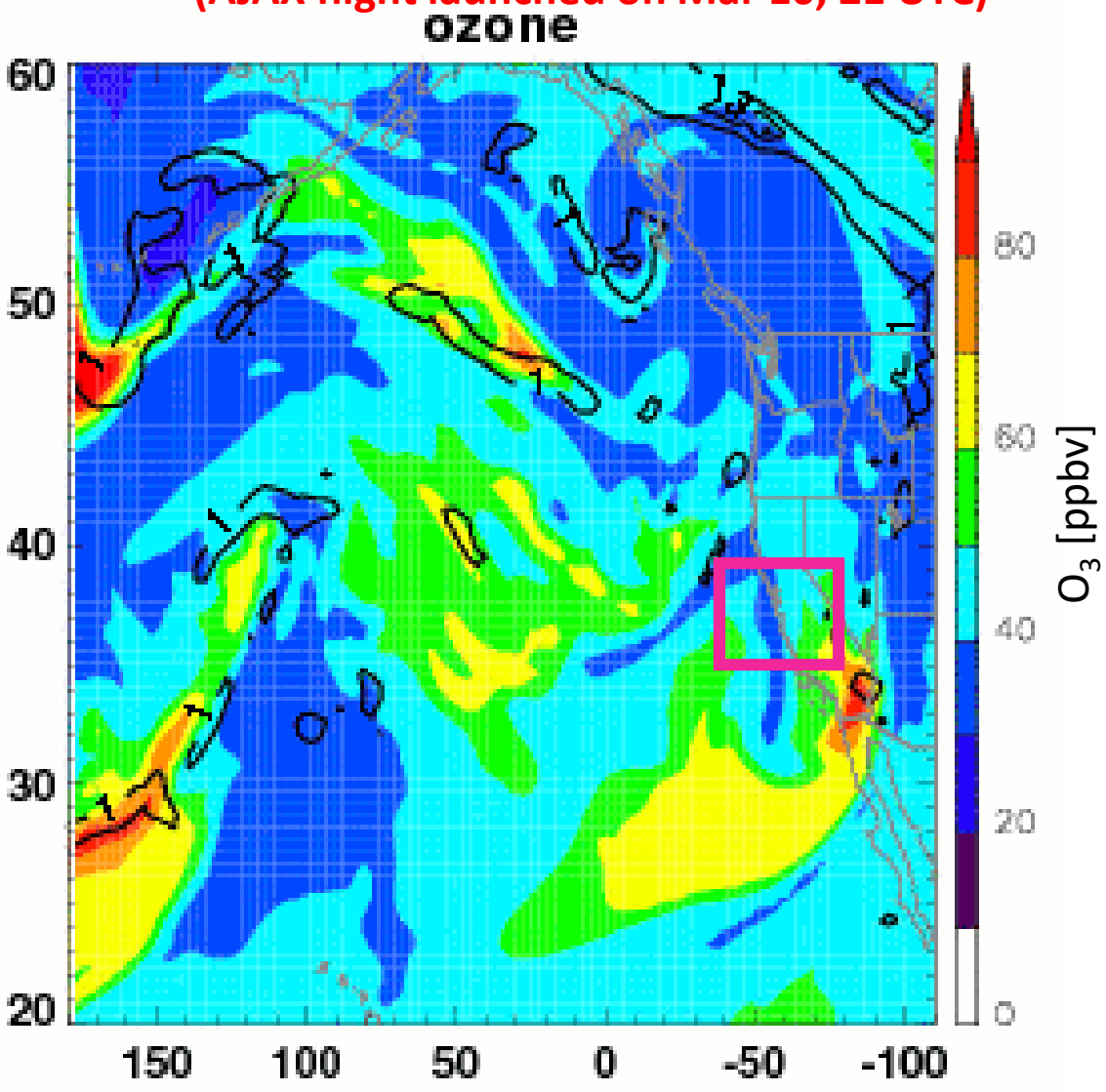
(Mar 10, 2016)

700 hPa

20160307 - 0 hrs

(AJAX flight launched on Mar 10, 21 UTC)





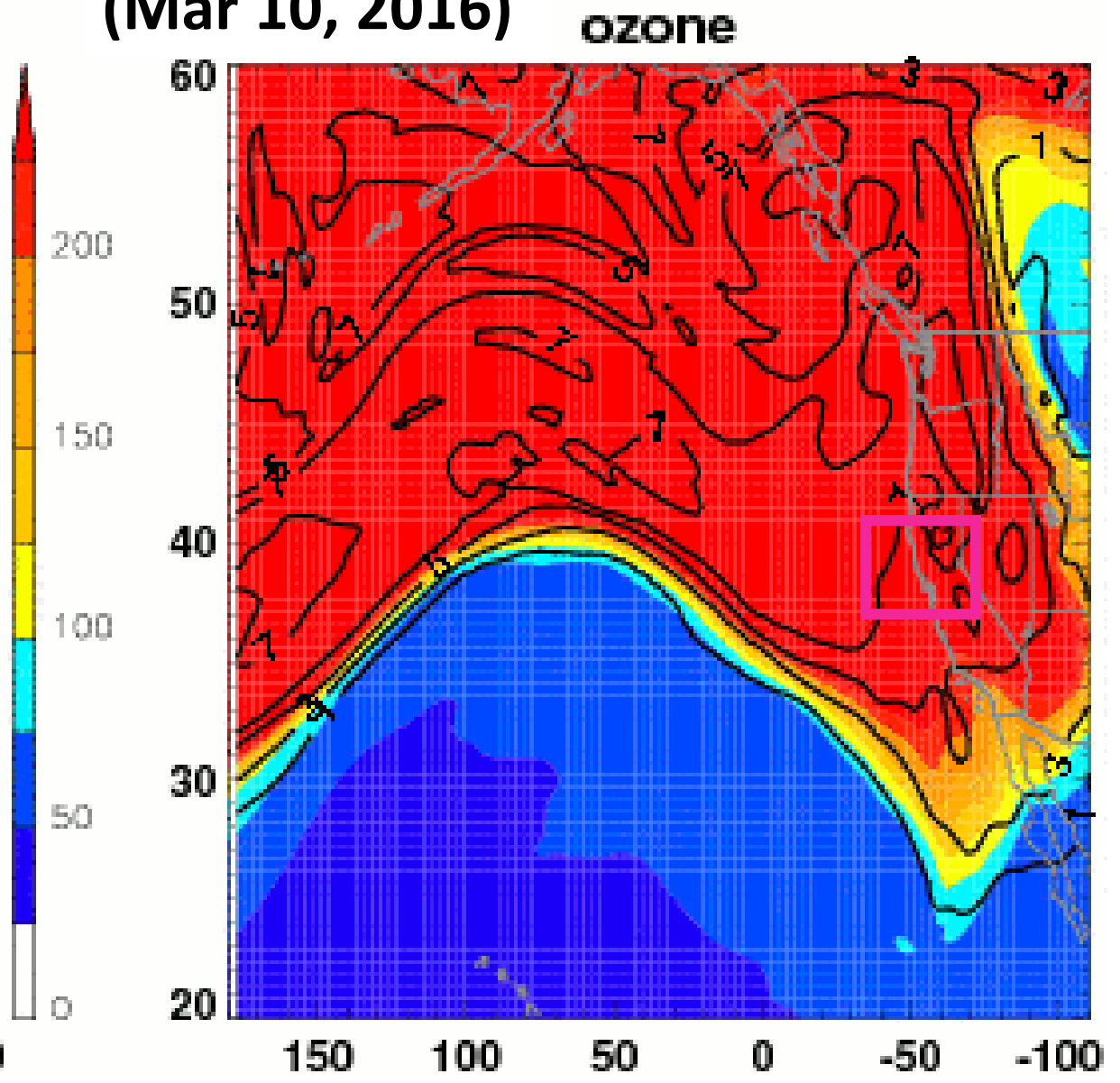
Zoom in the western U.S.

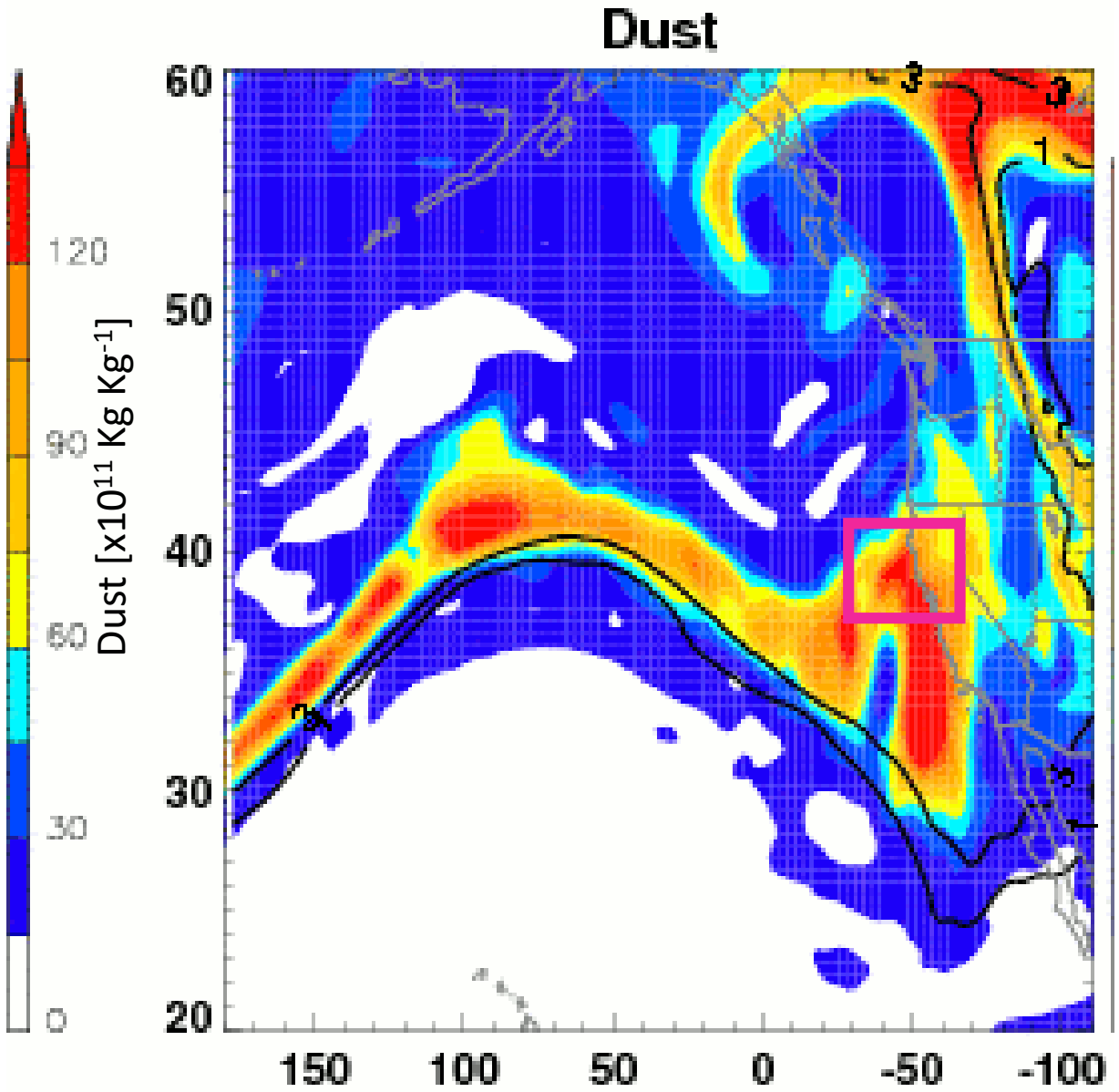
moderate-AR

(Mar 10, 2016)

250 hPa

20160307 - 0 hrs





Summary and Future plan

- This study will highlight the value of capturing the thermodynamic preconditions and features of real-time AR events using a coastal-based aircraft.

- **Weak AR (December 9, 2015)**

I. Stronger Water vapor flux is observed in the lower altitude (500 m)

- **Moderate AR (March 10, 2016)**

i. **Low Let Jet developed and coastal Barrier jet** started to develop => coastline-parallel flow was detected in the lowest altitude

ii. **The coastal mountains appear to contribute to AR moistening & deepening**

iii. **Long-range pollution aerosol transport** to the N. California is captured.

- More detailed analysis will be done to understand the interaction between large scale dynamics, Barrier jet, aerosol and orographic precipitation processes through multi-platform analyses

The AJAX Team

- **Laura Iraci (PI)**
- **Warren Gore**
- **Emma Yates**
- **Ju-Mee Ryoo**
- **Josette Marrero**
- Erica Burrows (SJSU)
- Emmett Quigley
- Matthew Johnson
- Susan Kulawik
- Pat Hamill
- Zion Young, Roy Vogler, Peter Tong
- Pilots & Crew of H211, LLC

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Find out more:

http://geo.arc.nasa.gov/ajax/ajax_index.html
Project Highlights: http://youtu.be/ZtGQLrkepes
August 2014 Seminar:
https://www.youtube.com/watch?v=rjxNZ3CwCFE
Catch us at the opening of the Showtime Documentary
http://yearsoflivingdangerously.com/

Follow us in-flight: http://airbornescience.nasa.gov/tracker/