Cloud System Evolution in the Trades--CSET

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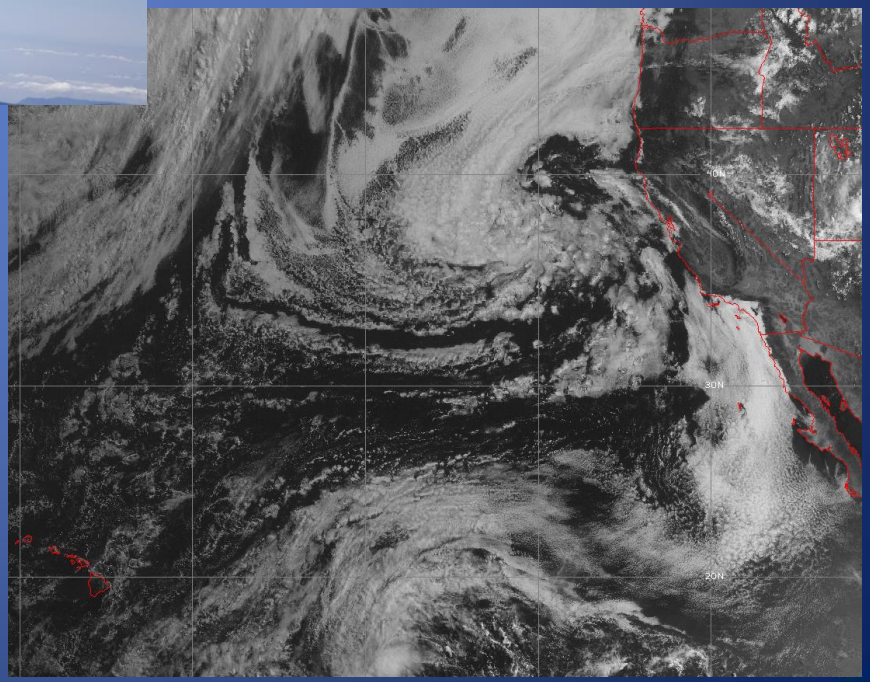
University of Washington
Virendra Ghate
Argonne National Laboratory

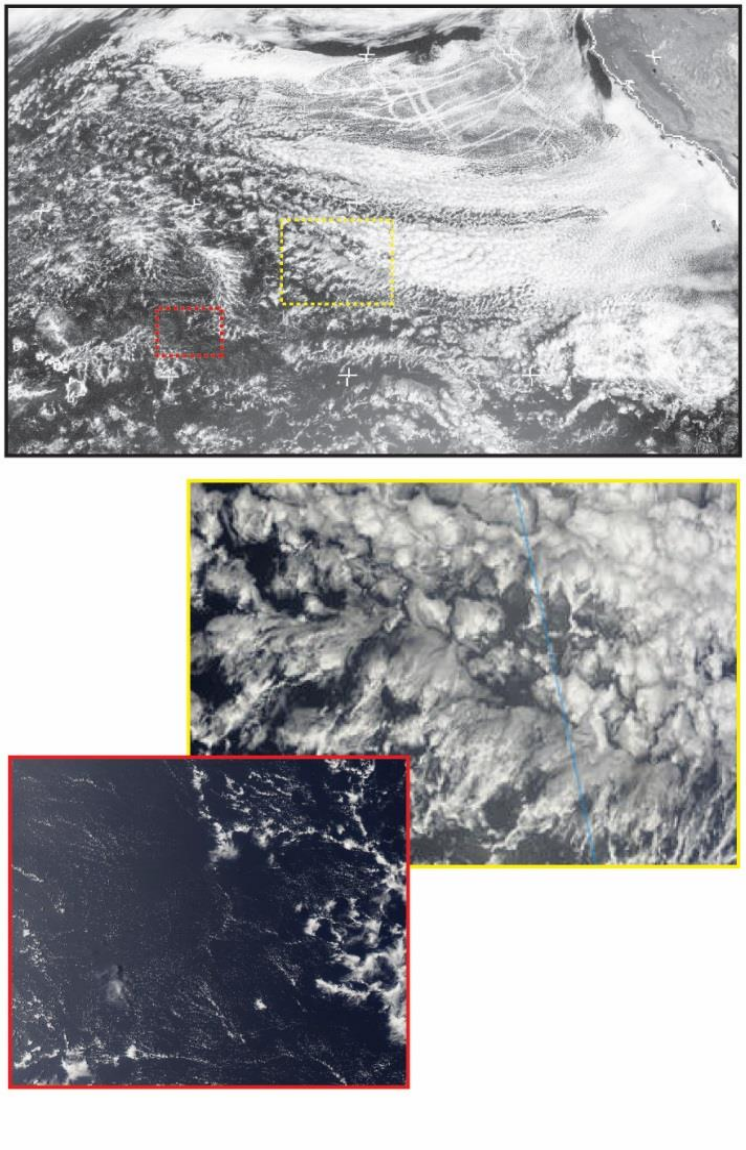
The Team:
Scientists, graduate students, post docs
EOL NCAR:
Scientists, engineers, technicians, and pilots



Cloud System Evolution in the Trades--CSET

Purpose: To study cloud and boundary layer evolution along trajectories within the north-Pacific trade-winds using the NSF/NCAR Gulfstream G-V (HIAPER).

These characterizations along trajectories will be designed to aid in our understanding and simulation of the transitions between the two convective regimes.



Scientific Objectives:

- Define the evolution of the cloud, precipitation and aerosol fields in marine stratocumulus as they transition into the cumulus regimes within the subtropical easterlies over the northern Pacific
- Examine the cloud microphysical properties and processes of boundary-layer clouds to assess the relative contributions of internal and external processes to cloud system evolution
- Provide comprehensive case studies to evaluate and improve process models, LES, and GCMs of Sc-Cu transition

Experiment Design-- Lagrangian Approach

Sample aerosol, cloud, precipitation, and boundary layer properties upwind from the transition zone over the North Pacific and sample these same areas two days later on flights between California and Hawaii with NSF/NCAR G-V

--Lagrangian approach minimizes uncertainties in the large-scale forcing due to horizontal advection in the lower troposphere to facilitate model simulations and isolate critical physical processes

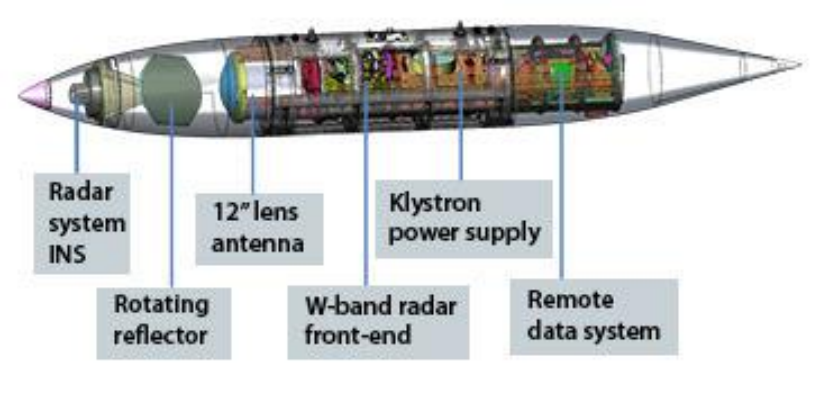
--Approach enabled by GV performance and new remote sensing capabilities

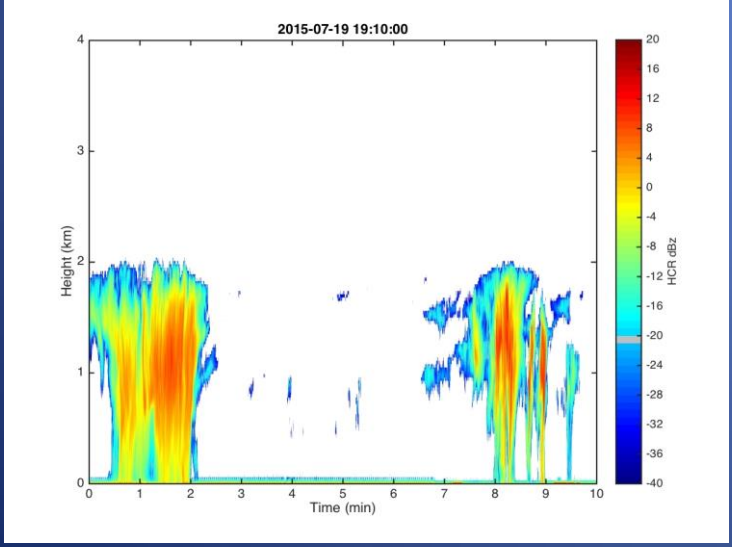
Instrumentation

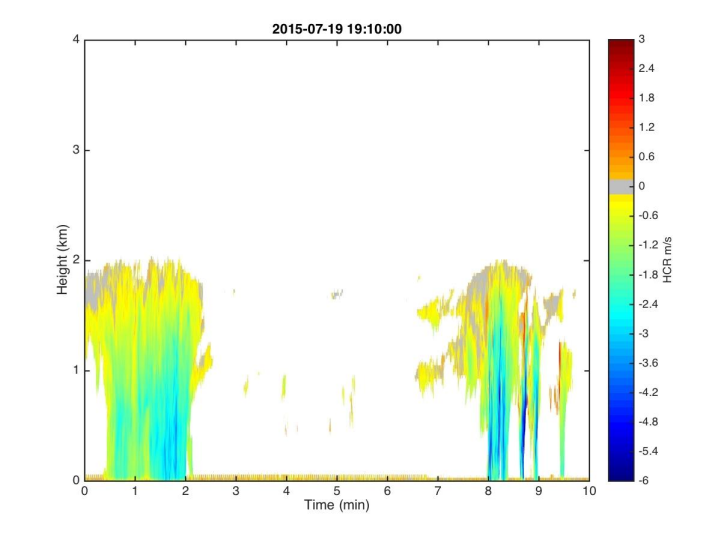
- Remote sensing instruments--define macroscopic and microscopic cloud properties
  - **HIAPER Cloud Radar (HCR)**
  - **High Spectral Resolution Lidar (HSRL)**
  - GVR microwave radiometer (liquid water path)
  - MTP microwave temperature profiler
- Meteorology and turbulence sensors
- Cloud microphysics, aerosol, and precipitation probes
  - 3V-CPI cloud particle counter/imager; CDP cloud droplet probe
  - UHSAS aerosol size distribution (0.05-1.0 µm)
  - CN
  - HOLODEC (Raymond Shaw; Susanne Glienke)-- holographic multiparticle cloud imager
- Radiation sensors (HARP; pyranometers and pygeometers)
- Chemistry—CO and O3
- Dropsondes (~120; remotely launched)

Instrumentation

HIAPER Cloud Radar (HCR)- 3mm Doppler radar with polarization developed by NCAR EOL for deployment on GV specially designed wing pod

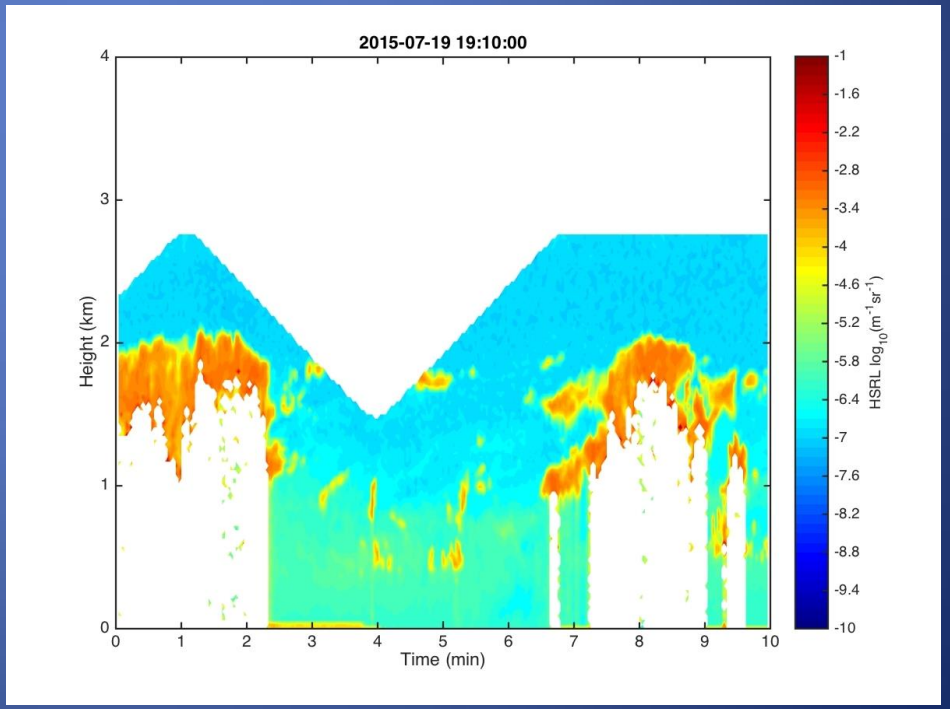






Instrumentation

- High Spectral Resolution Lidar (HSRL) that was developed under the NSF HIAPER Aircraft Instrumentation Solicitation (HIAS; PI: Ed Eloranta)



Instrumentation

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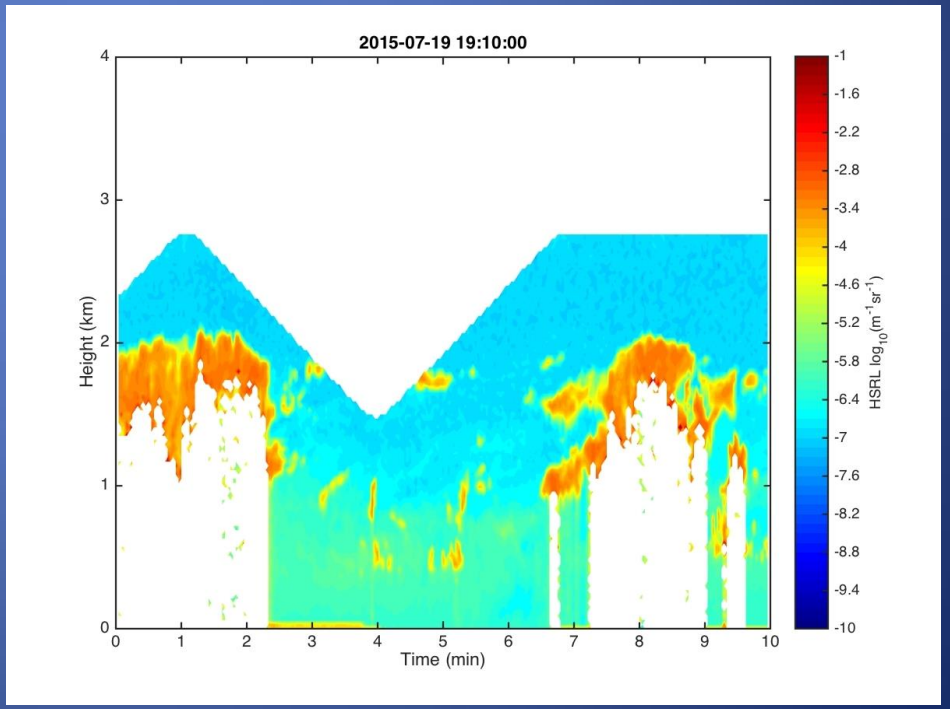
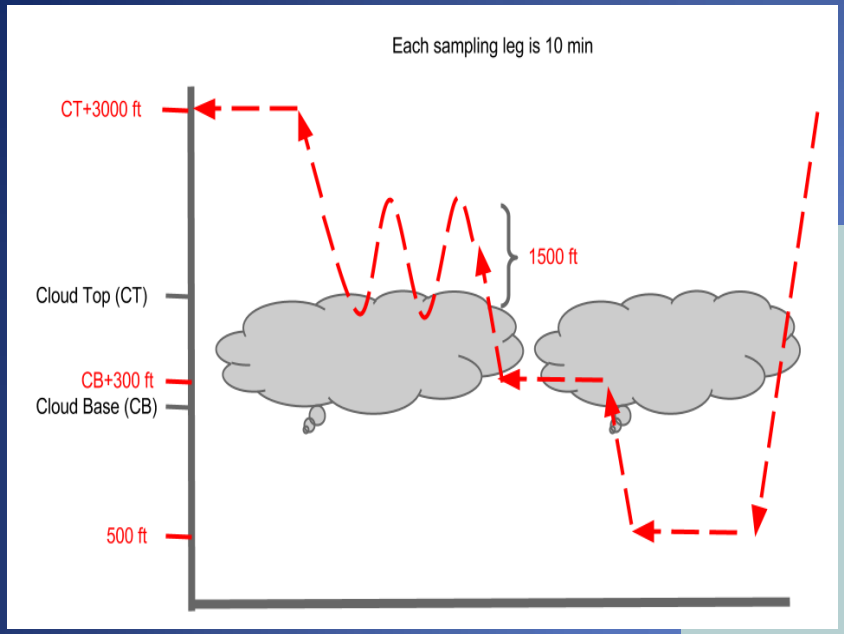


CSET Field Operations
1 July-12 August 2015



Typical Flight
(7-8 hours)

UW Operations Center
Seattle

Low-Level
Sampling
~1500 km

Sacramento
TO 800 LT

Dropsondes

Ferry at 20 kft

Ferry at 20 kft

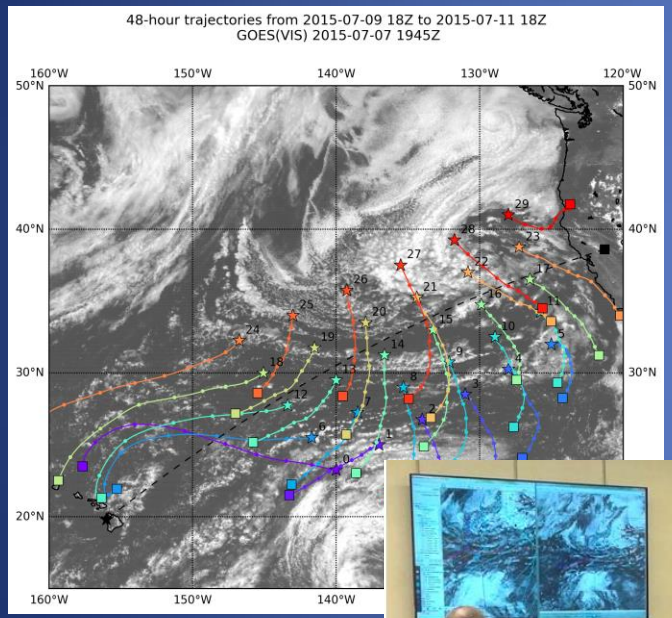
Kona
TO 630 LT

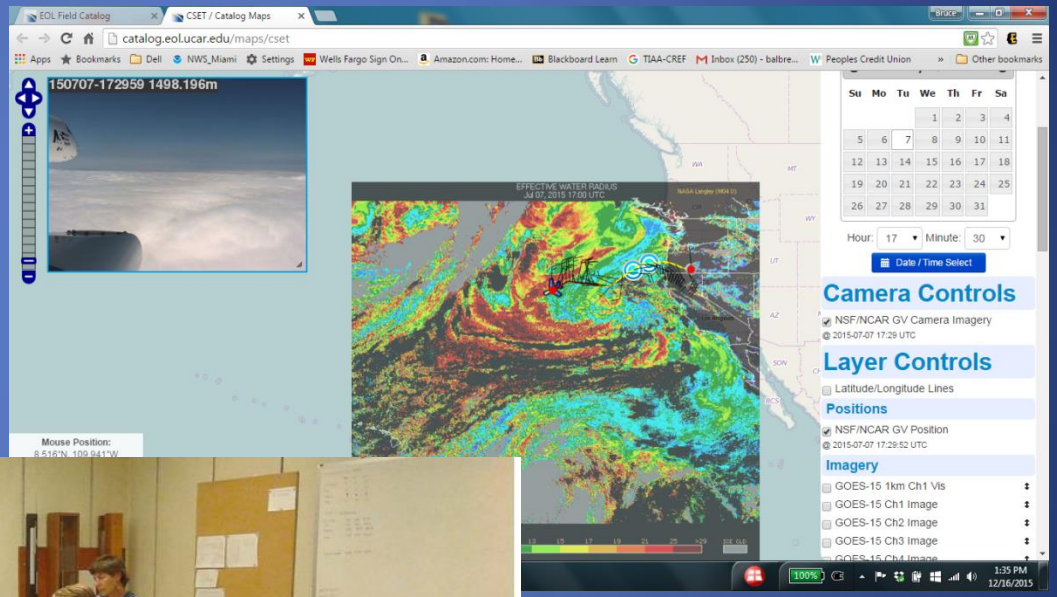
Mission Planning and Operations:

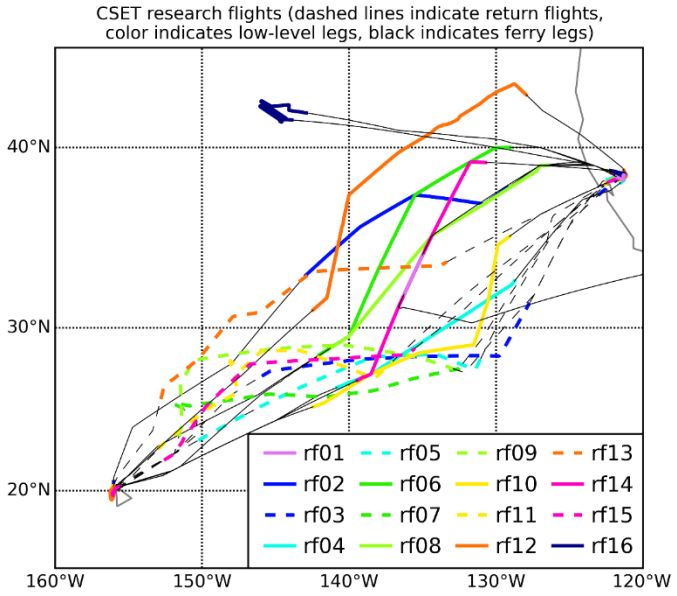
Trajectory Forecasts (Johannes Mohrmann*; UW)

EOL Field Catalog

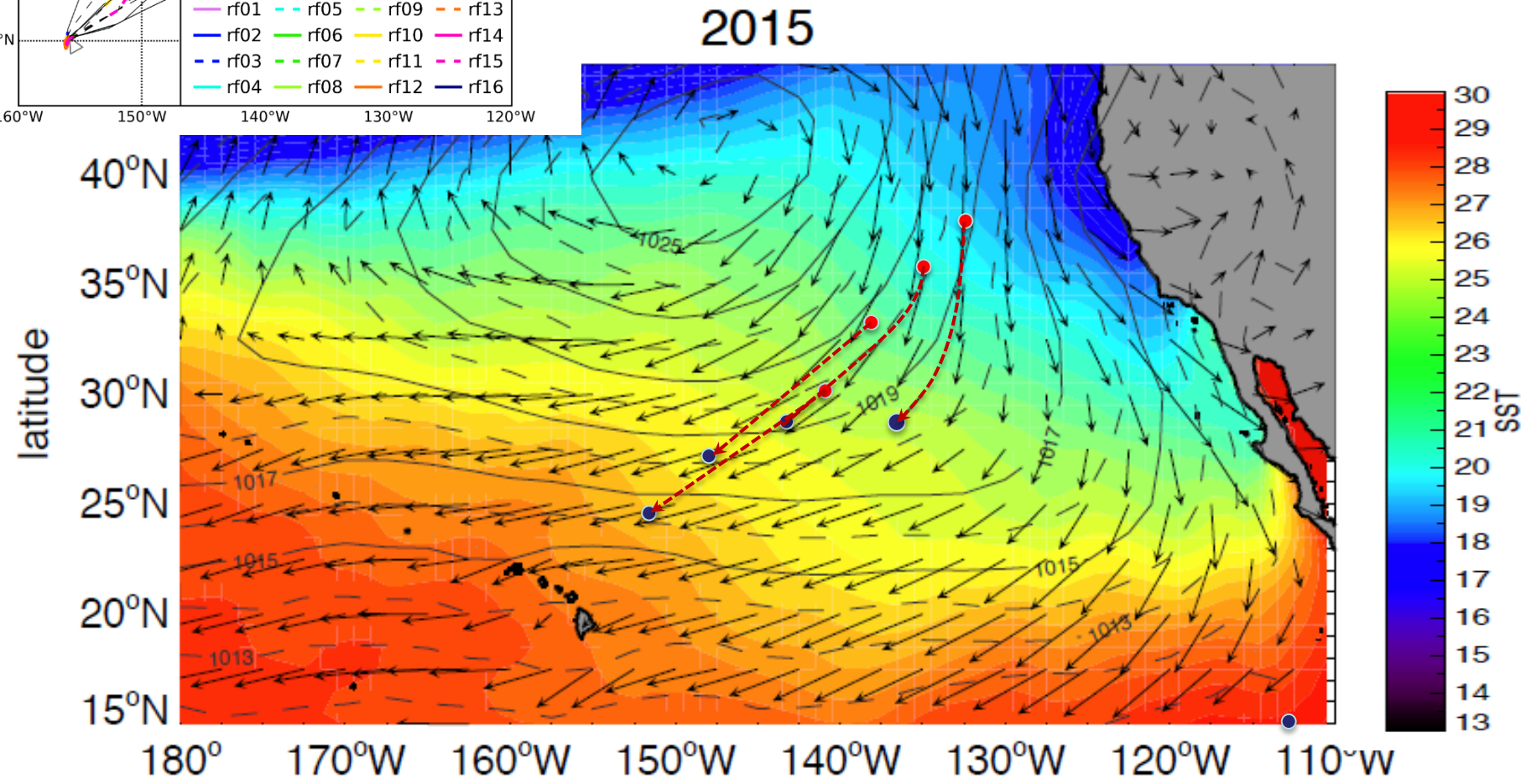
Satellite Cloud Products (Patrick Minnis; NASA Langley)

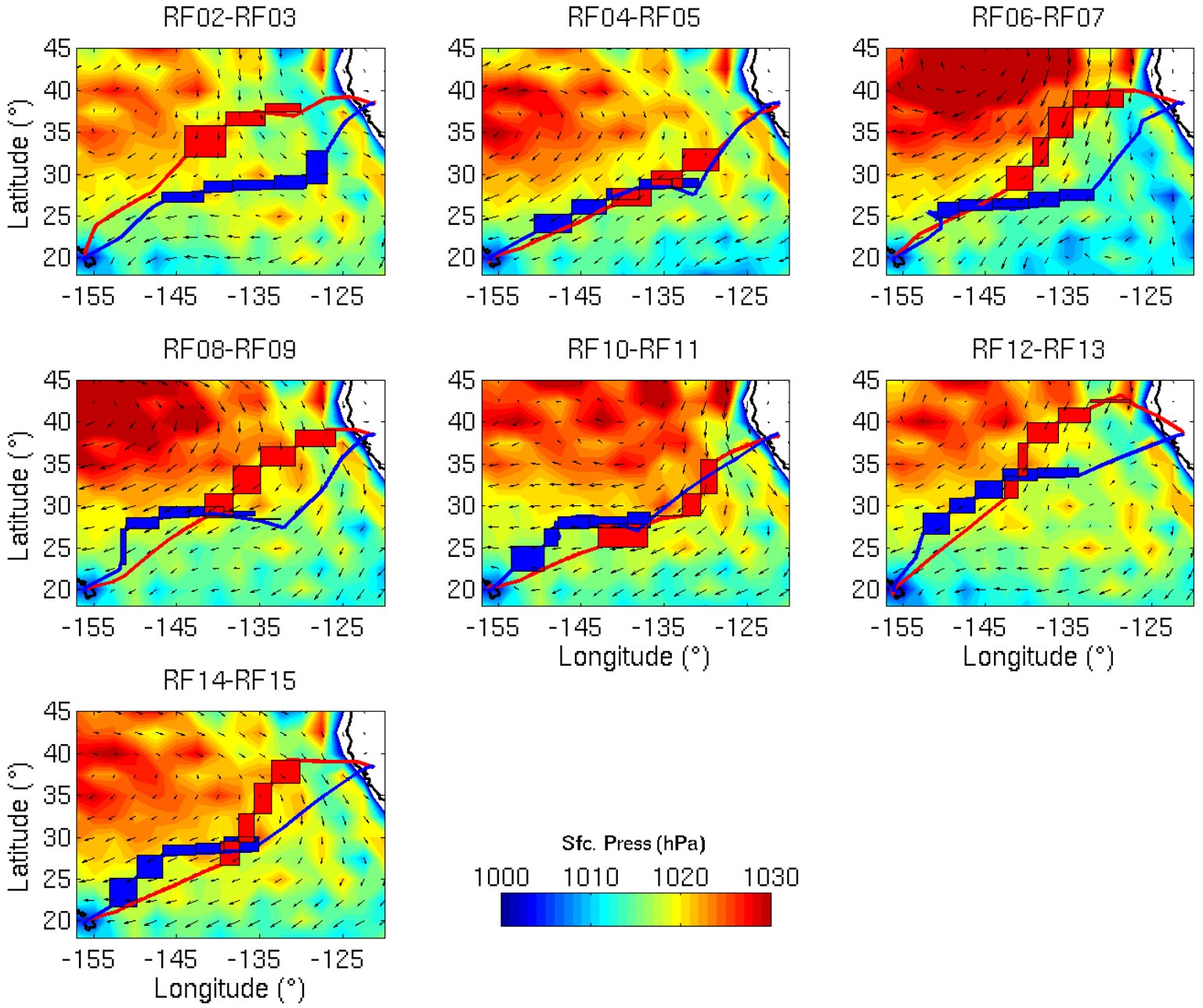


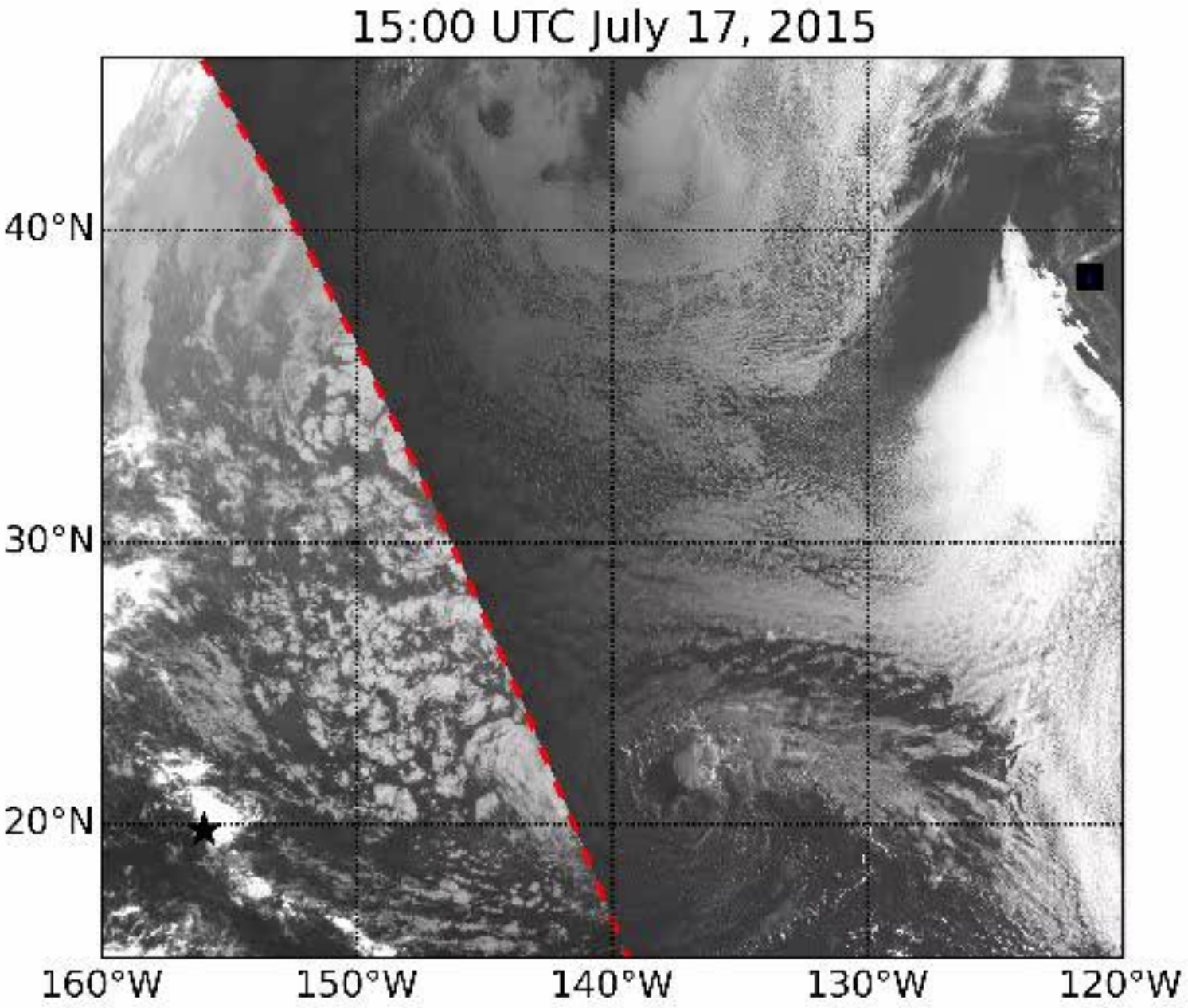




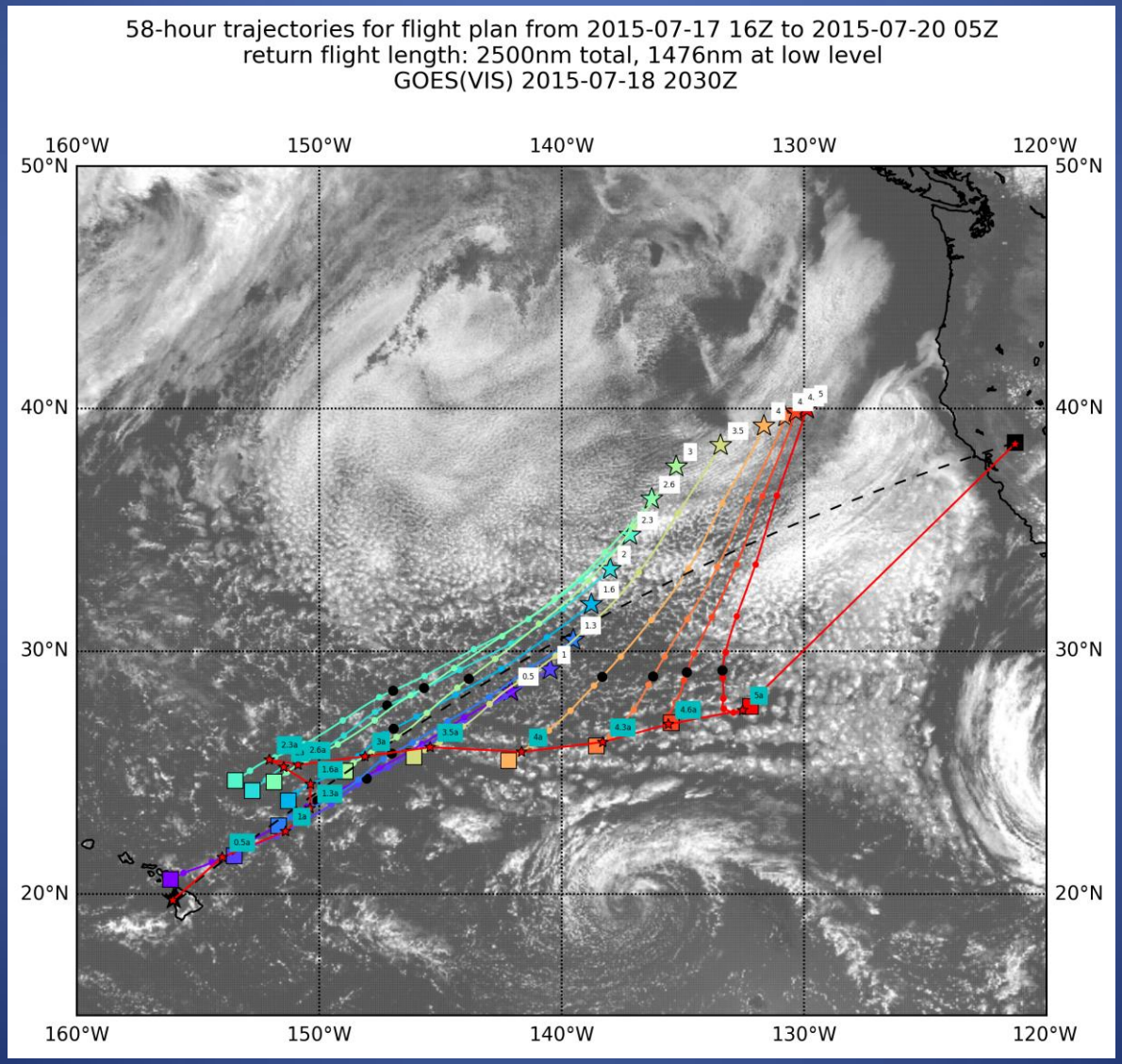
CSET G-V
16 Research Flights
7 Lagrangian Missions
(~20,000 km low-level sampling)
(~20,000 km higher-level sampling)

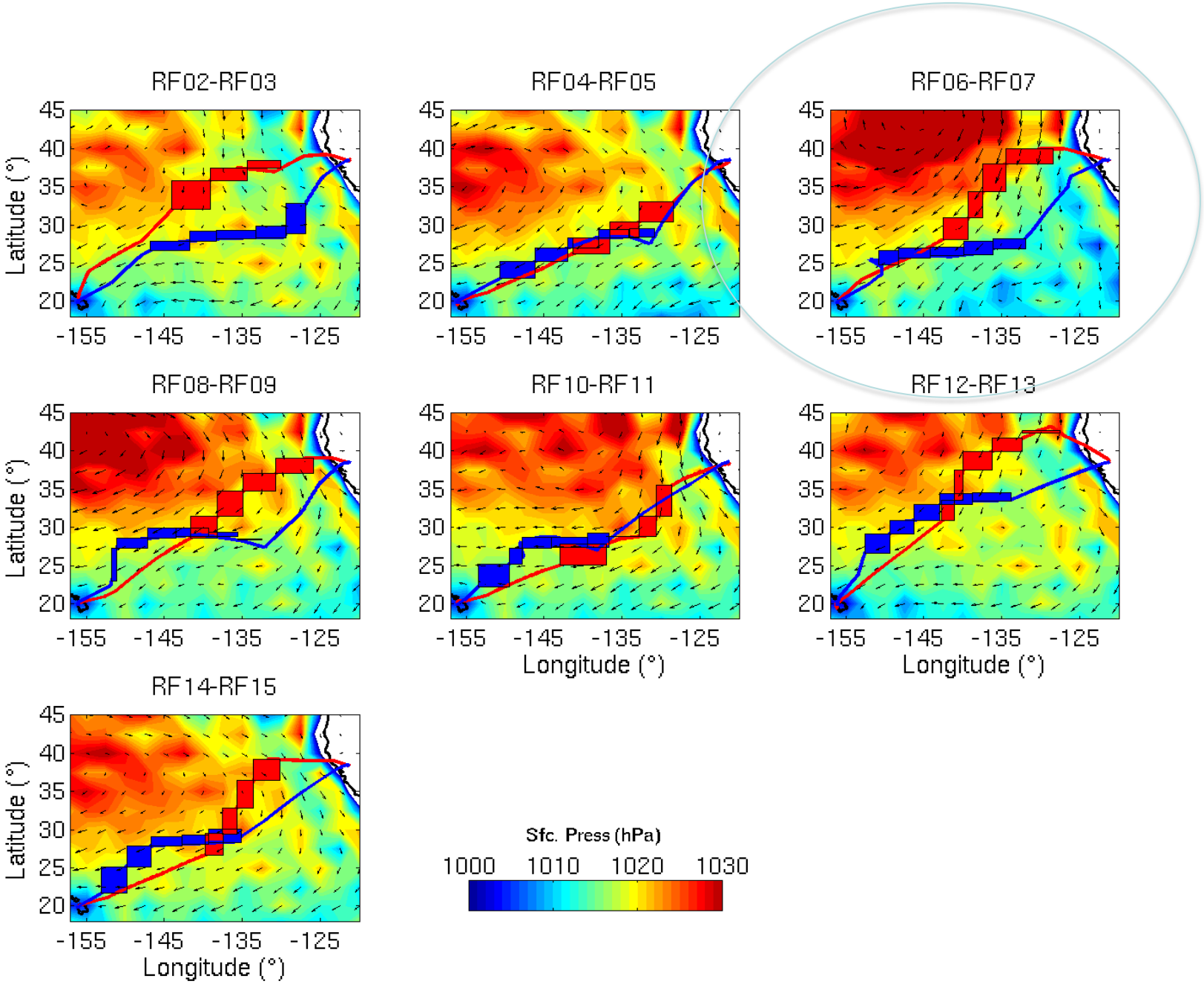


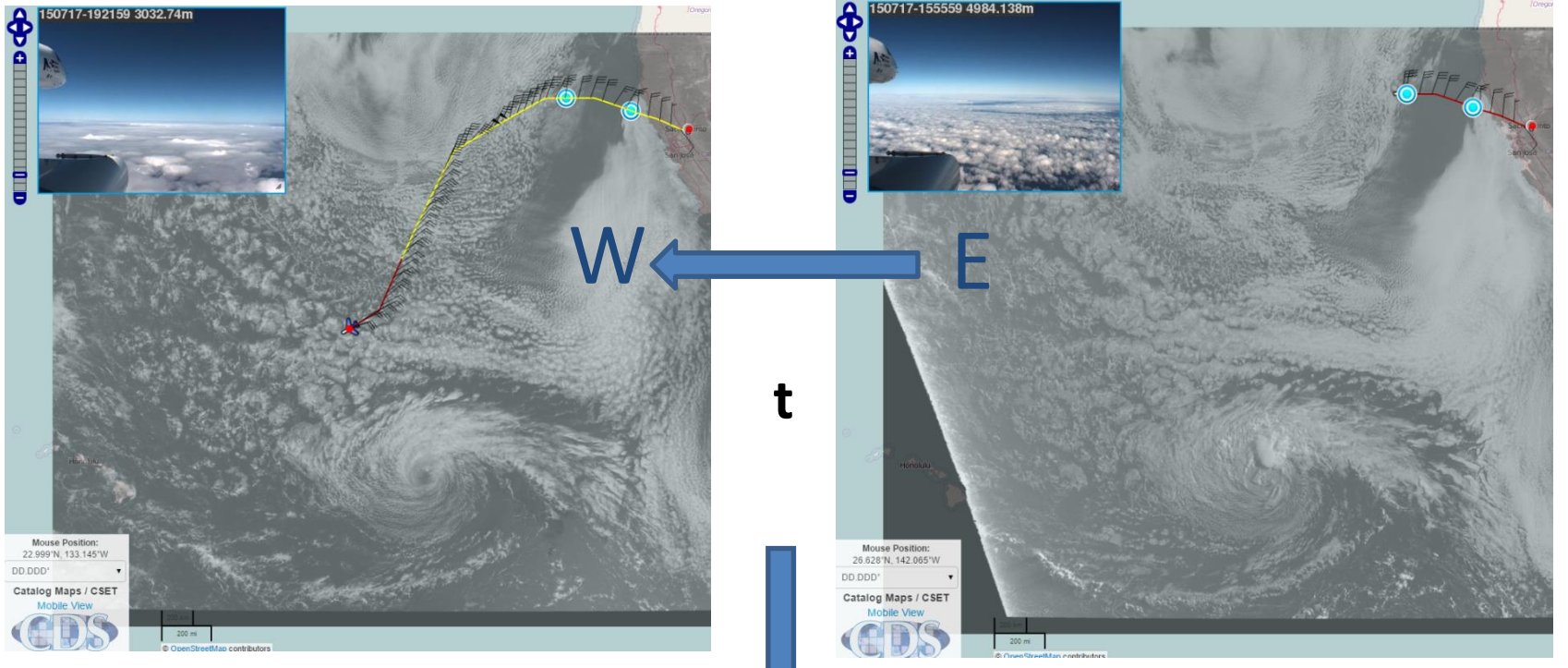

RF02-RF03
RF04-RF05
RF06-RF07
RF08-RF09
RF10-RF11
RF12-RF13
RF14-RF15
Latitude (°)
Longitude (°)
45
40
35
30
25
20
-155
-145
-135
-125
Sfc. Press (hPa)
1000
1010
1020
1030

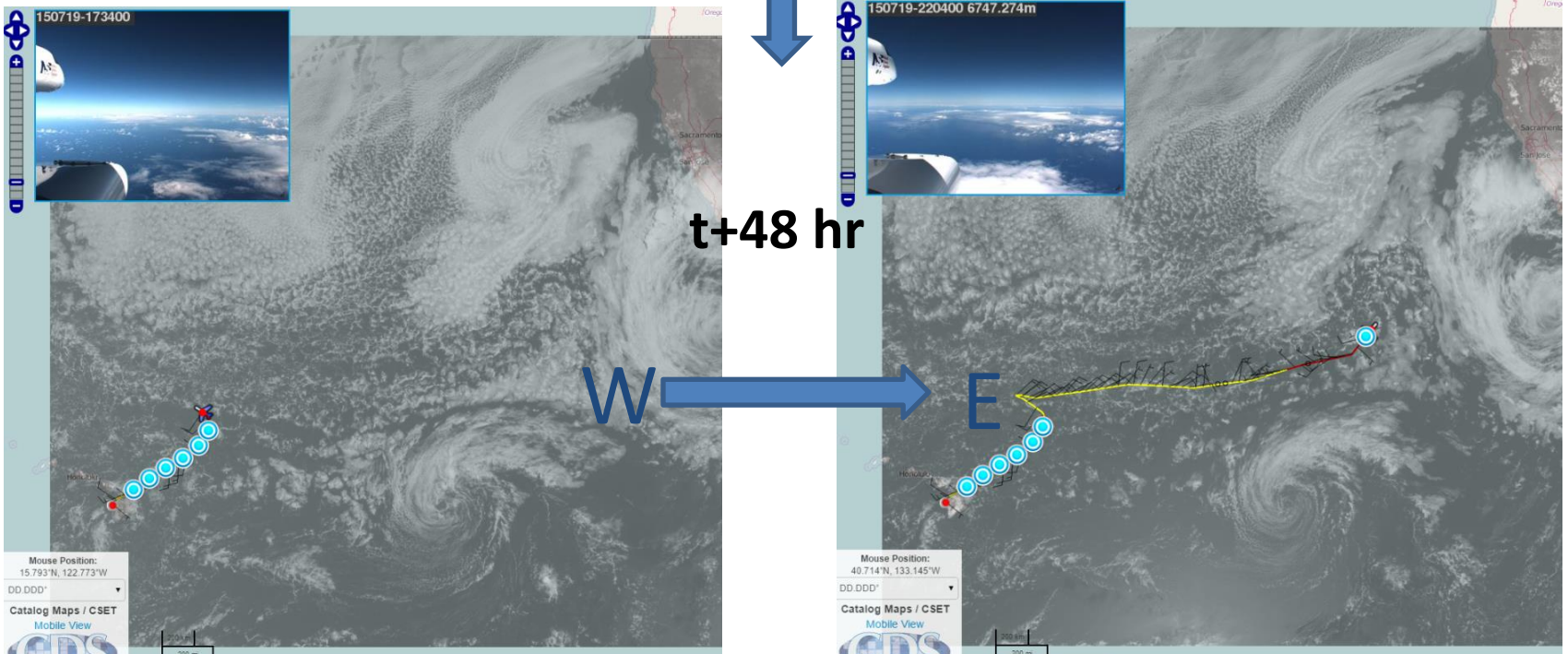

15:00 UTC July 17, 2015
40°N
30°N
20°N
160°W
150°W
140°W
130°W
120°W

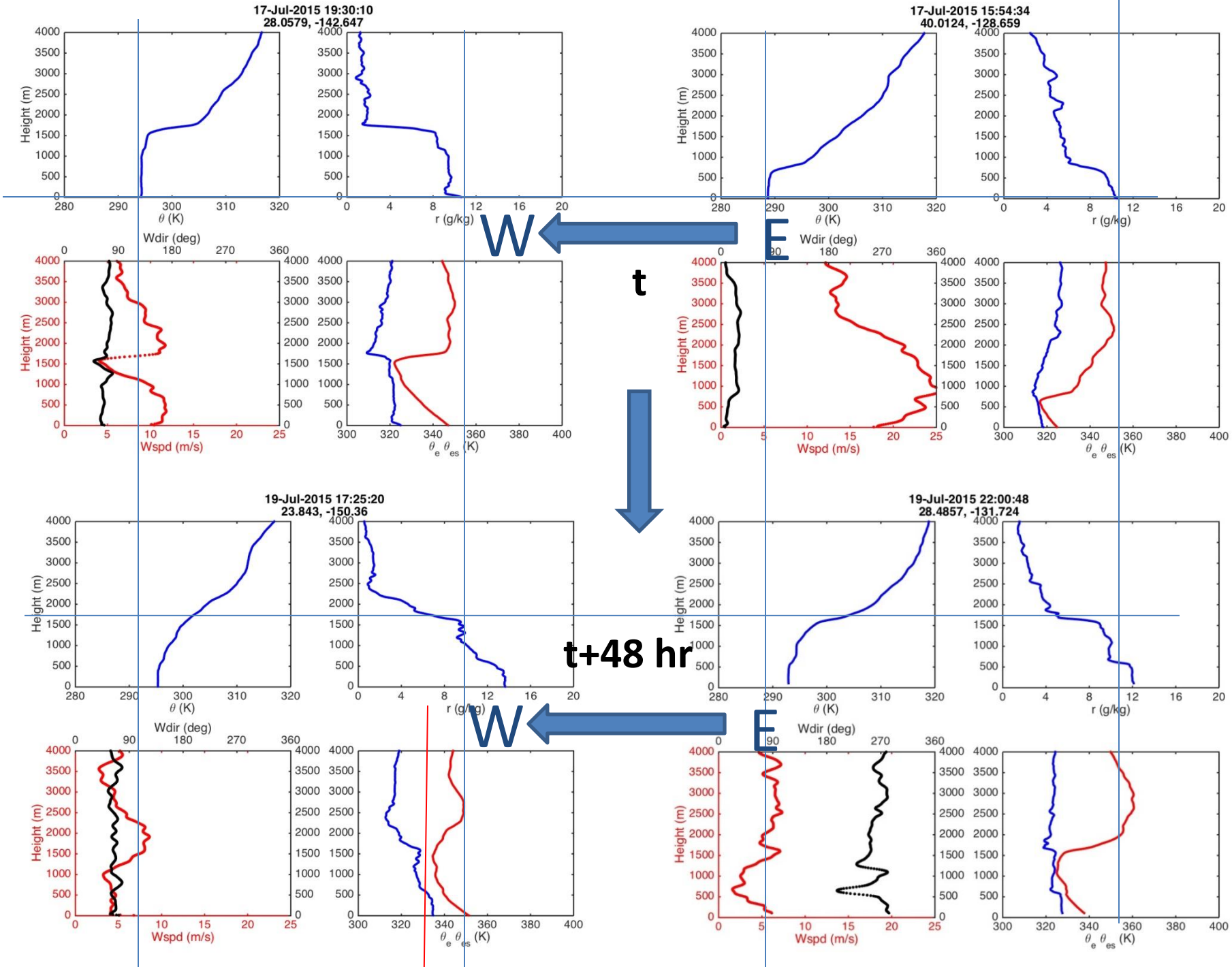
RF06 and RF07 Flights

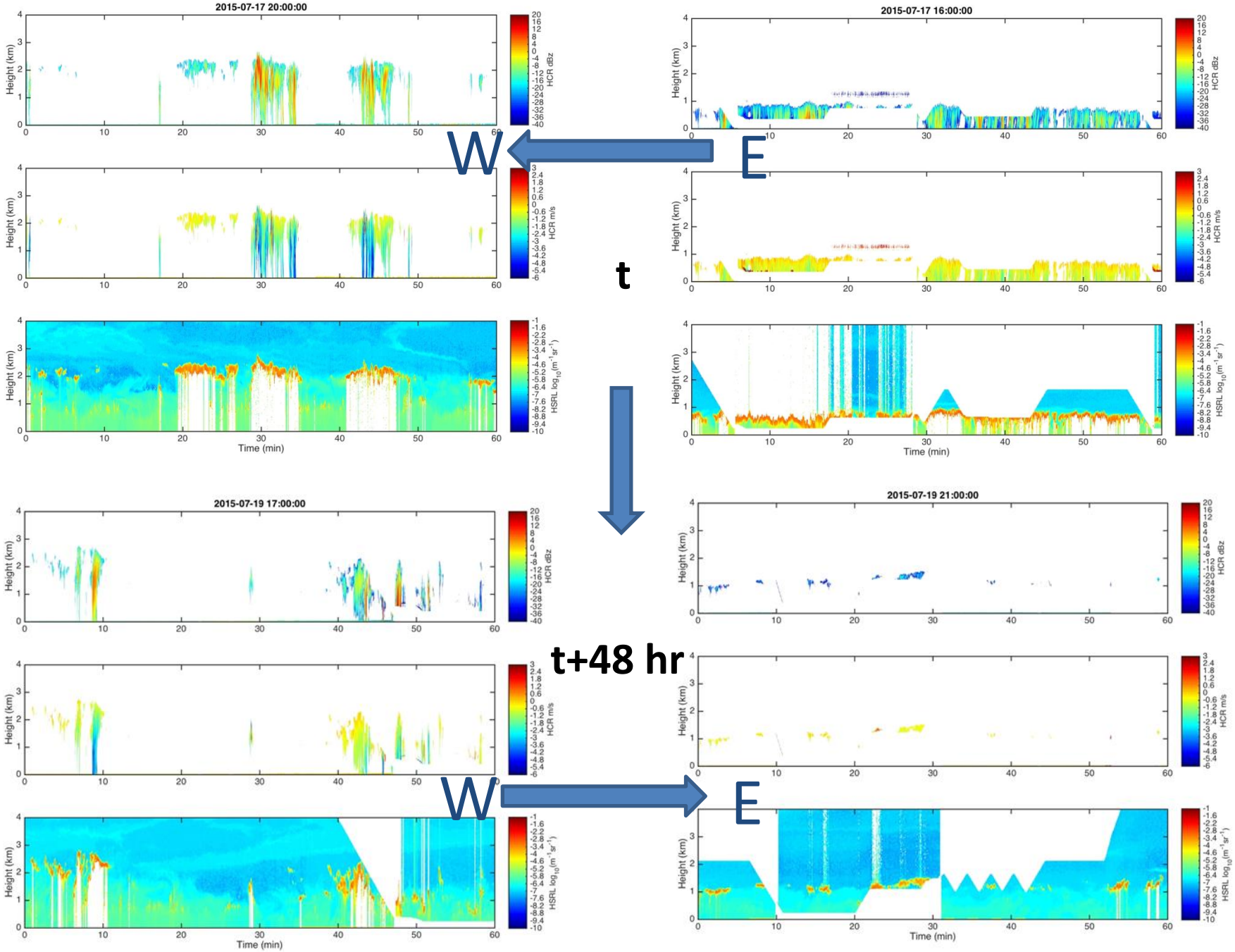


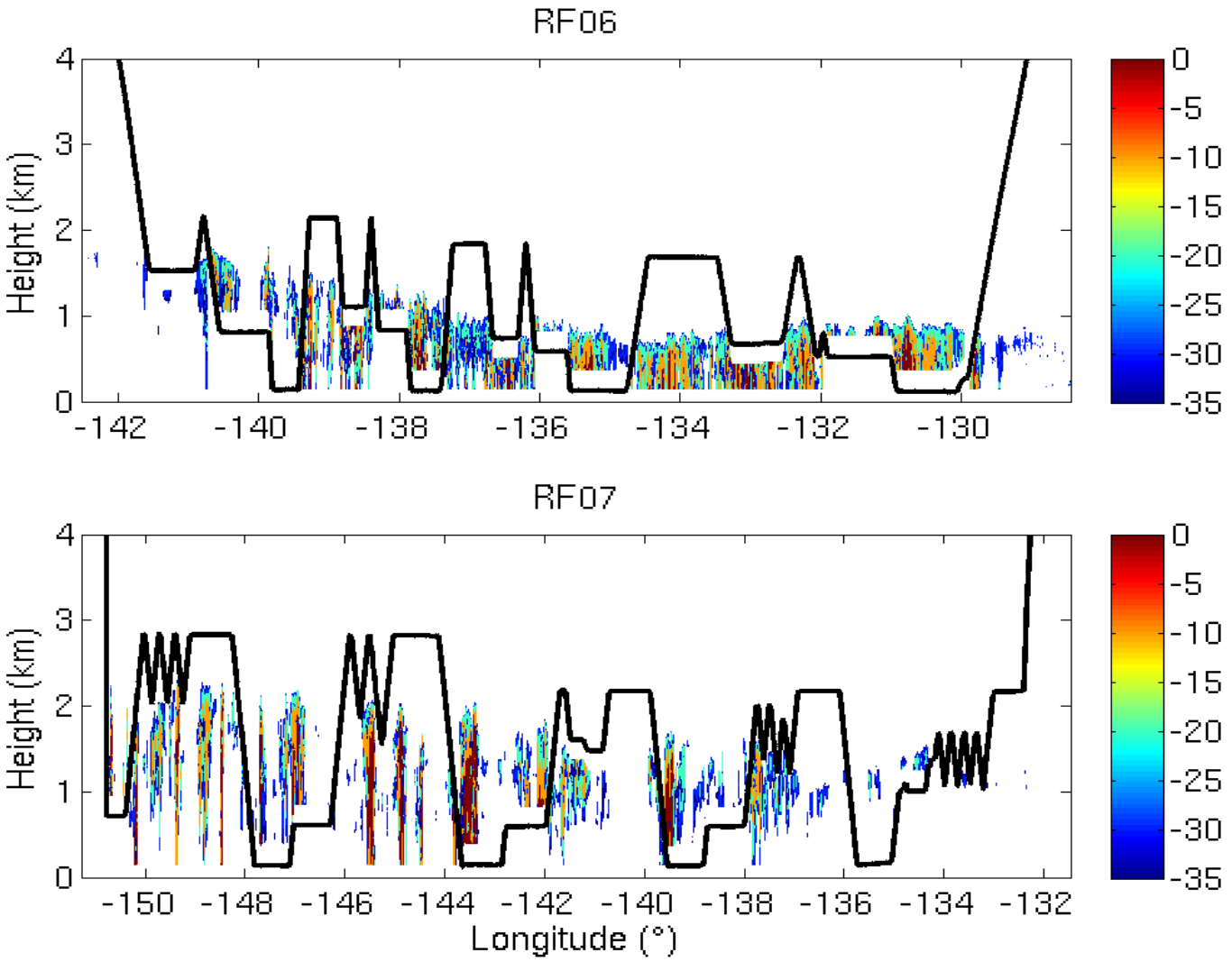

RF02-RF03
RF04-RF05
RF06-RF07
RF08-RF09
RF10-RF11
RF12-RF13
RF14-RF15
Latitude (°)
Longitude (°)
45
40
35
30
25
20
-155
-145
-135
-125
Sfc. Press (hPa)
1000
1010
1020
1030

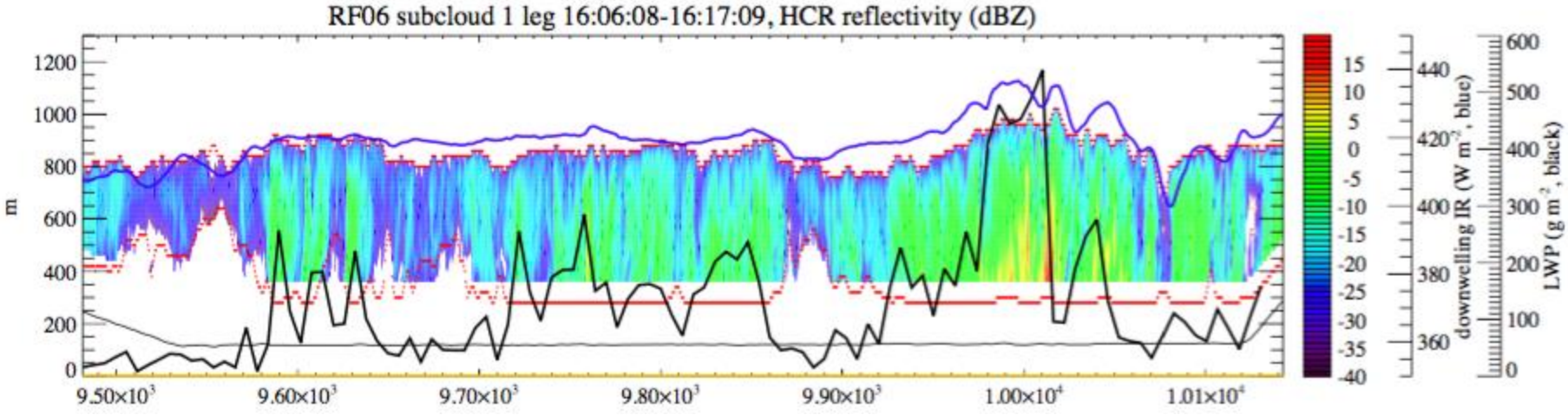

150717-192159 3032.74m
150717-155559 4984.138m
W
E
t
Mouse Position:
22.999°N, 133.145°W
Mouse Position:
26.628°N, 142.065°W
DD.DDD°
Catalog Maps / CSET
Mobile View
CDS
200 mi
© OpenStreetMap contributors

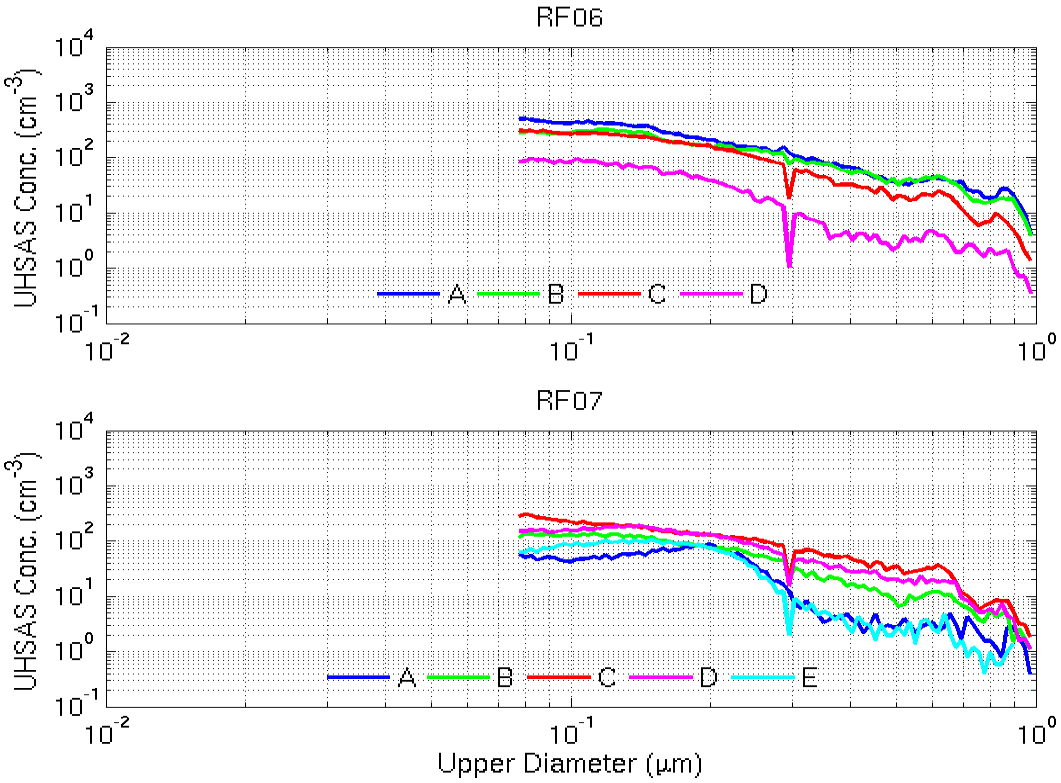

150719-173400
150719-220400 6747.274m
t+48 hr
W
E
Mouse Position:
15.793°N, 122.773°W
Mouse Position:
40.714°N, 133.145°W
DD.DDD°
Catalog Maps / CSET
Mobile View
CDS


17-Jul-2015 19:30:10
28.0579, -142.647
17-Jul-2015 15:54:34
40.0124, -128.659
W
E
t
t+48 hr
19-Jul-2015 17:25:20
23.843, -150.36
19-Jul-2015 22:00:48
28.4857, -131.724
Height (m)
θ (K)
r (g/kg)
Wdir (deg)
Wspd (m/s)
θe θes (K)

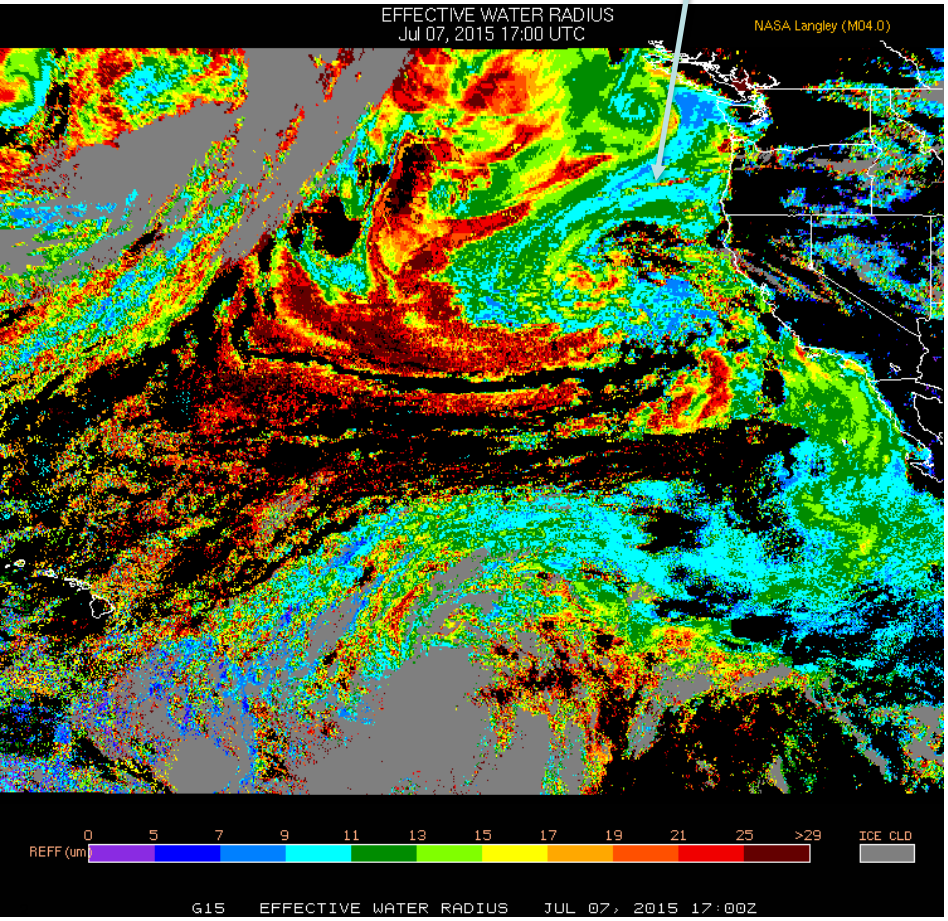

2015-07-17 20:00:00
2015-07-17 16:00:00
W
E
t
2015-07-19 17:00:00
2015-07-19 21:00:00
t+48 hr
W
E
Height (km)
Time (min)
HCR dBz
HCR m/s
HSRL log10(m-1sr-1)

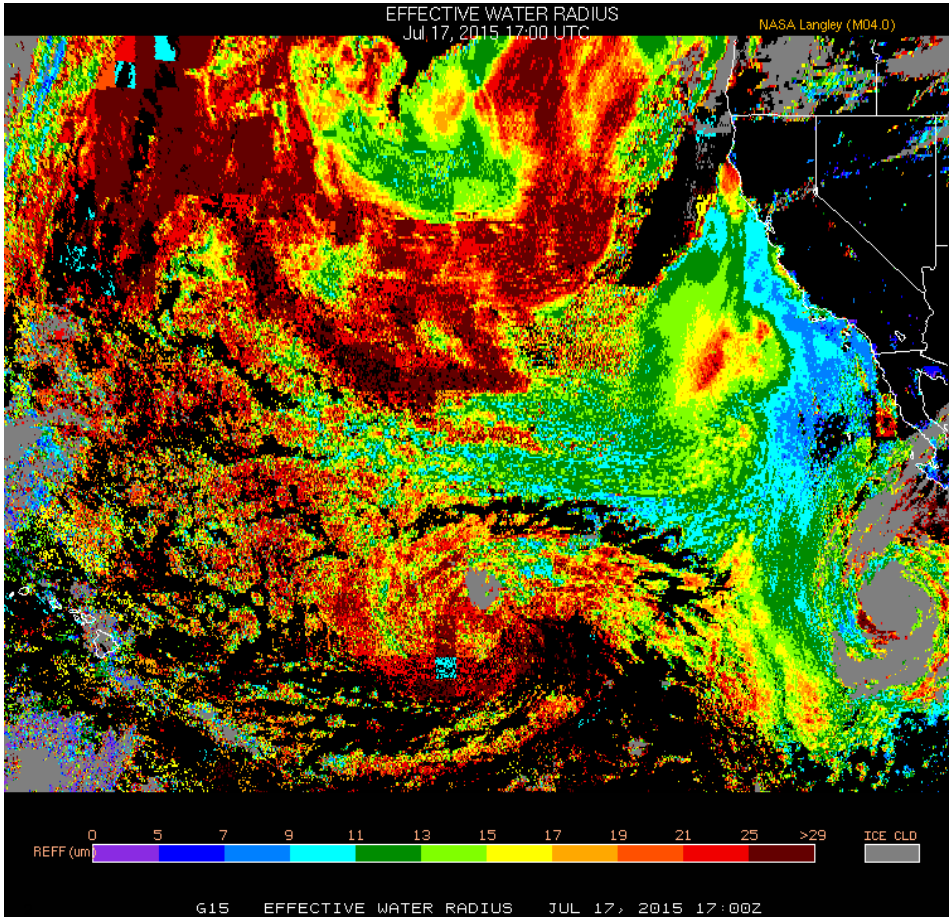

RF06
Height (km)
0
1
2
3
4
-142
-140
-138
-136
-134
-132
-130
0
-5
-10
-15
-20
-25
-30
-35
RF07
Height (km)
0
1
2
3
4
-150
-148
-146
-144
-142
-140
-138
-136
-134
-132
Longitude (°)
0
-5
-10
-15
-20
-25
-30
-35


RF06 subcloud 1 leg 16:06:08-16:17:09, HCR reflectivity (dBZ)
m
1200
1000
800
600
400
200
0
9.50×10³
9.60×10³
9.70×10³
9.80×10³
9.90×10³
1.00×10⁴
1.01×10⁴
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
440
420
400
380
360
downwelling IR (W m⁻², blue)
600
500
400
300
200
100
0
LWP (g m⁻², black)


RF06
UHSAS Conc. (cm⁻³)
A
B
C
D
RF07
UHSAS Conc. (cm⁻³)
A
B
C
D
E
Upper Diameter (µm)

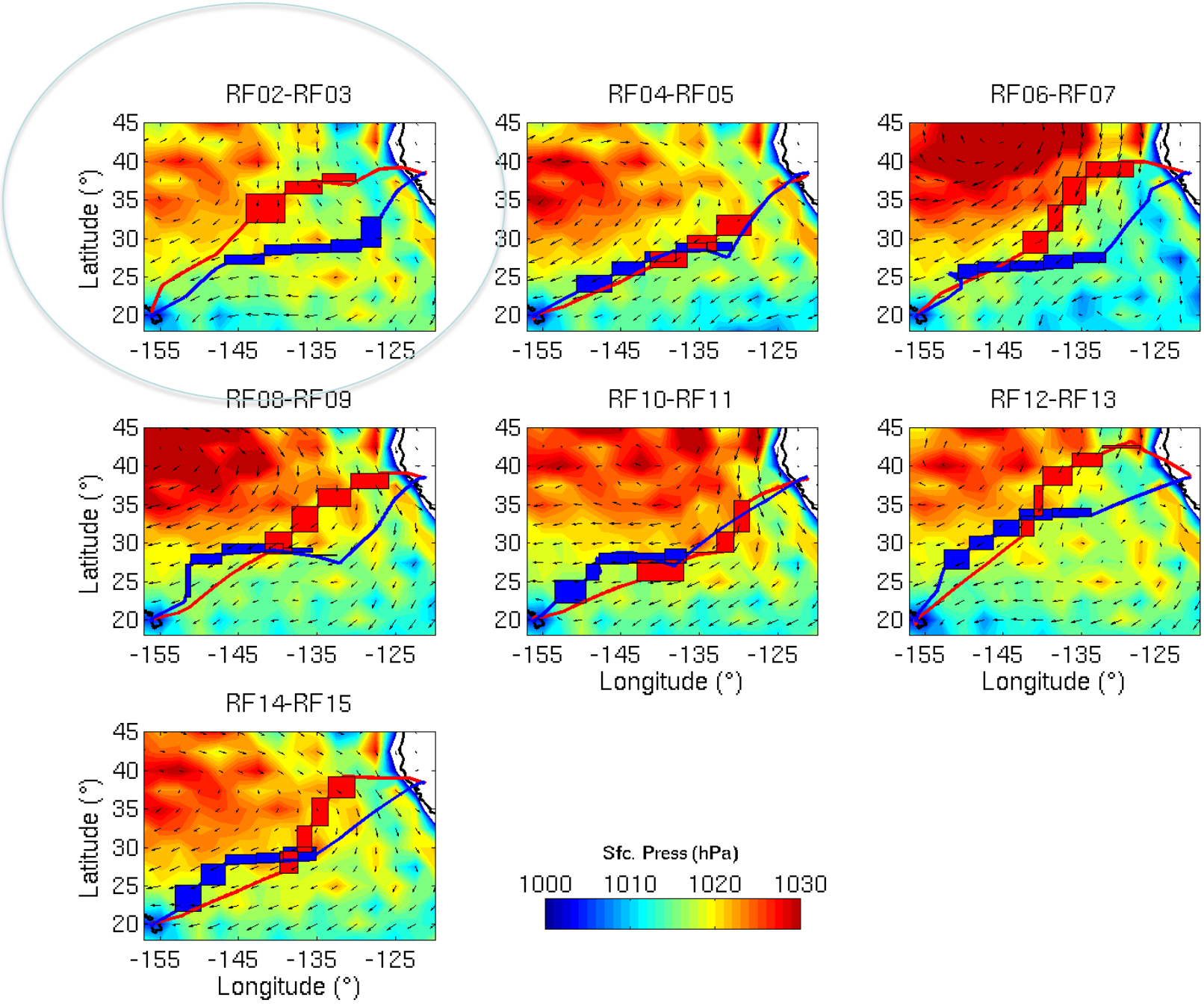
Substantial Variability in the Cloud Microphysics Associated with Aerosol Variability

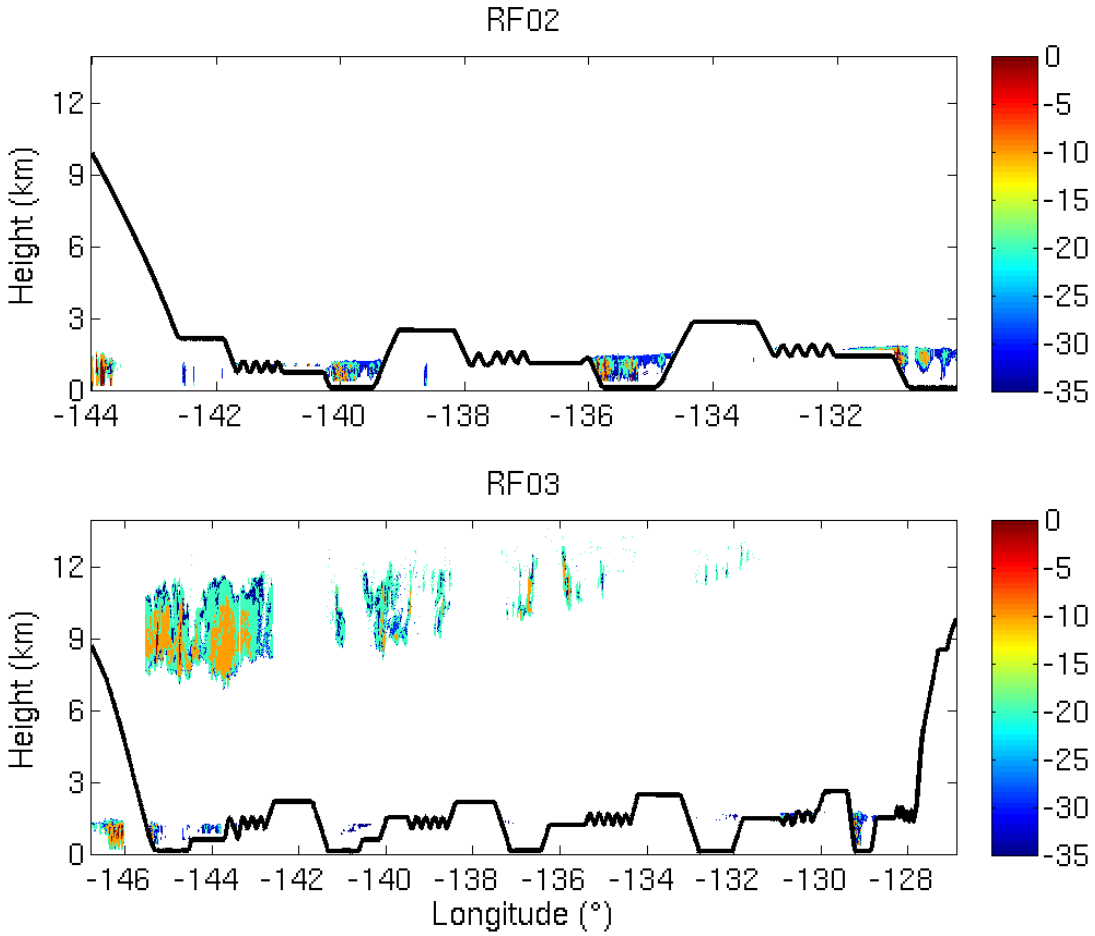


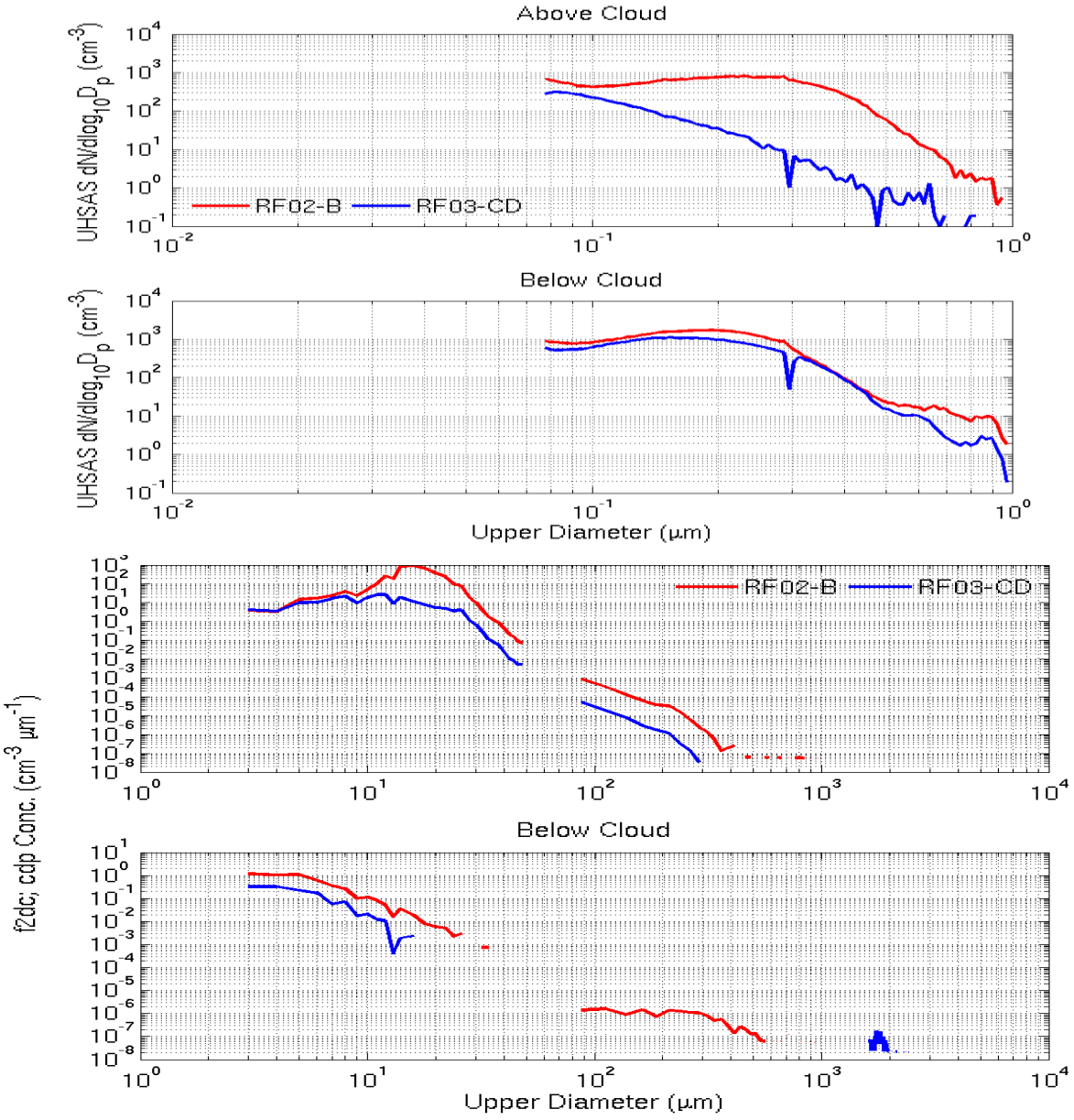


Effective Droplet Radius

(Minnis NASA Langley)

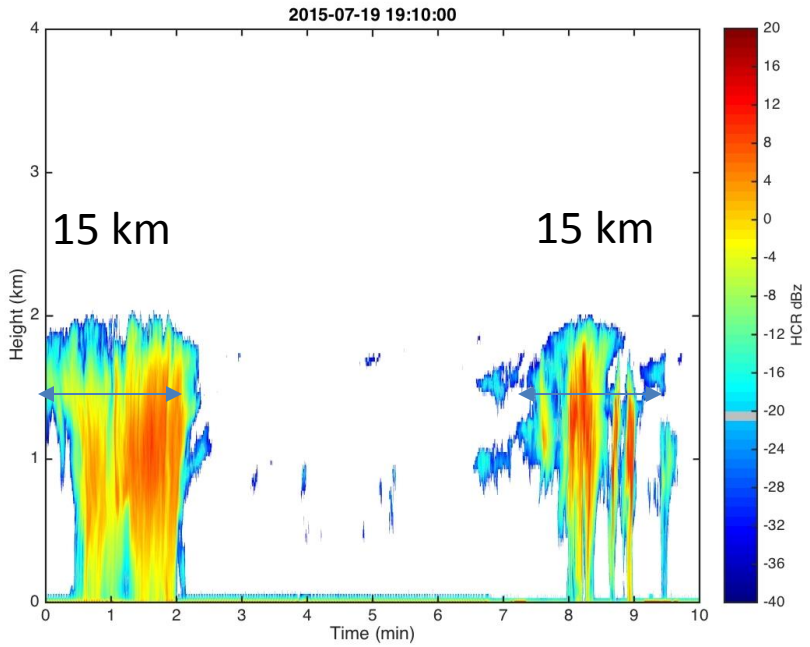

RF02-RF03
RF04-RF05
RF06-RF07
RF08-RF09
RF10-RF11
RF12-RF13
RF14-RF15
Latitude (°)
Longitude (°)
45
40
35
30
25
20
-155
-145
-135
-125
Sfc. Press (hPa)
1000
1010
1020
1030

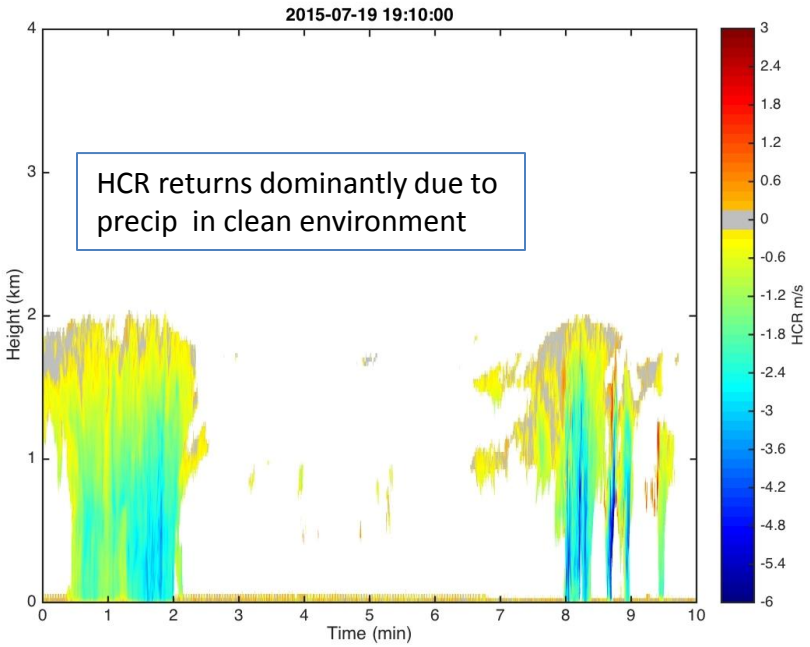

RF02
Height (km)
0
3
6
9
12
-144
-142
-140
-138
-136
-134
-132
0
-5
-10
-15
-20
-25
-30
-35
RF03
Height (km)
0
3
6
9
12
-146
-144
-142
-140
-138
-136
-134
-132
-130
-128
Longitude (°)
0
-5
-10
-15
-20
-25
-30
-35

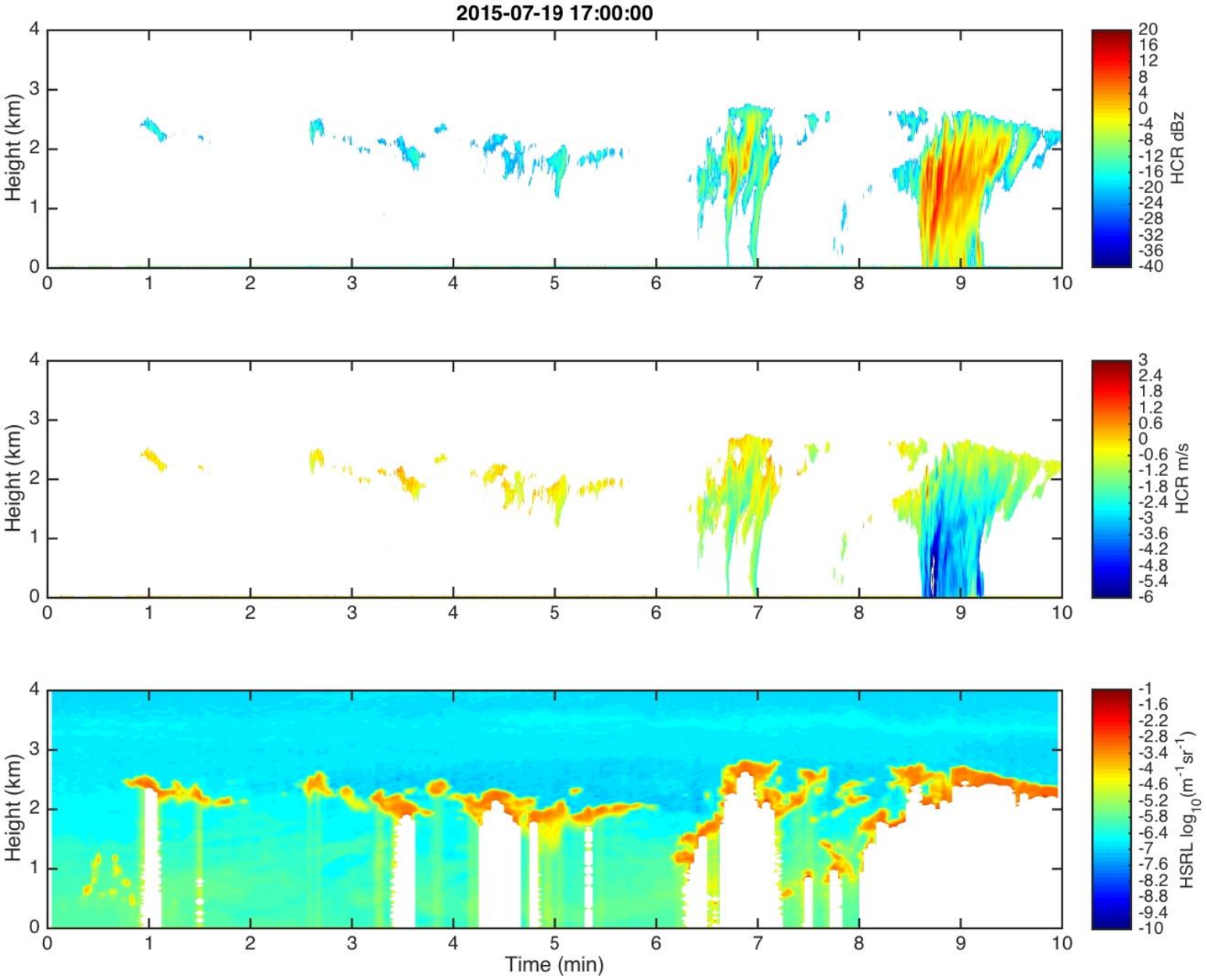

Above Cloud
UHSAS dN/dlog10Dp (cm-3)
RF02-B
RF03-CD
Below Cloud
UHSAS dN/dlog10Dp (cm-3)
Upper Diameter (µm)
f2dc; cdp Conc. (cm-3 µm-1)
RF02-B
RF03-CD
Below Cloud
Upper Diameter (µm)

Significant Aerosol, Cloud, and Precipitation Features Sampled

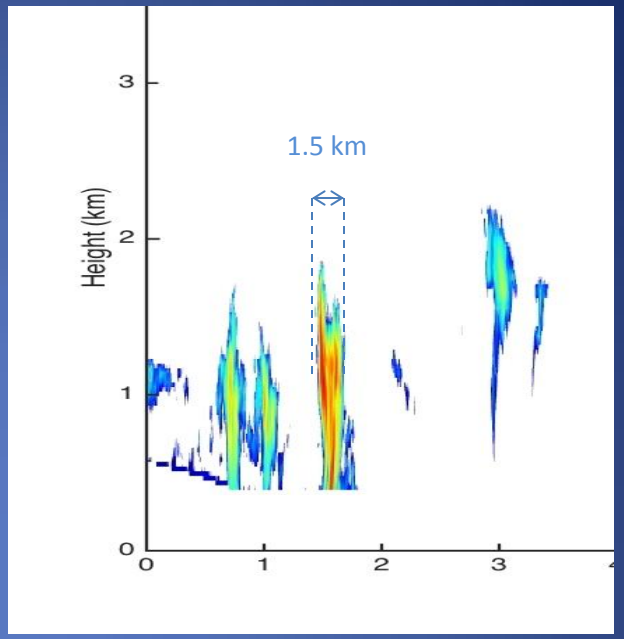
Mesoscale Cloud and Precipitation Complexes

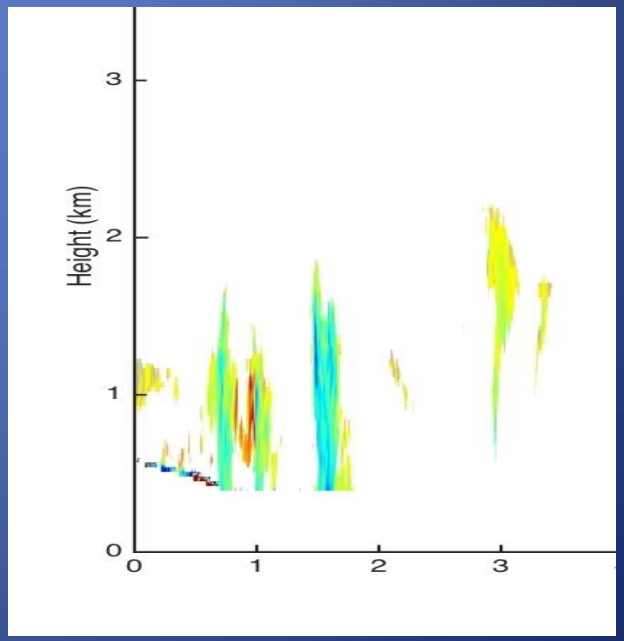





2015-07-19 17:00:00
Height (km)
Time (min)
HCR dBz
HCR m/s
HSRL log10(m-1sr-1)

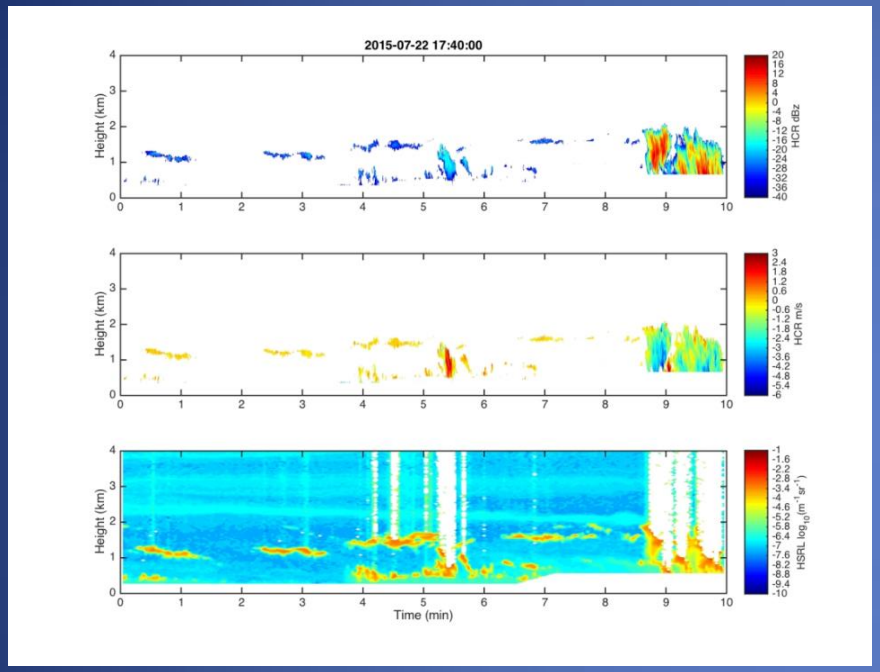
Substantial precip in individual cumuli

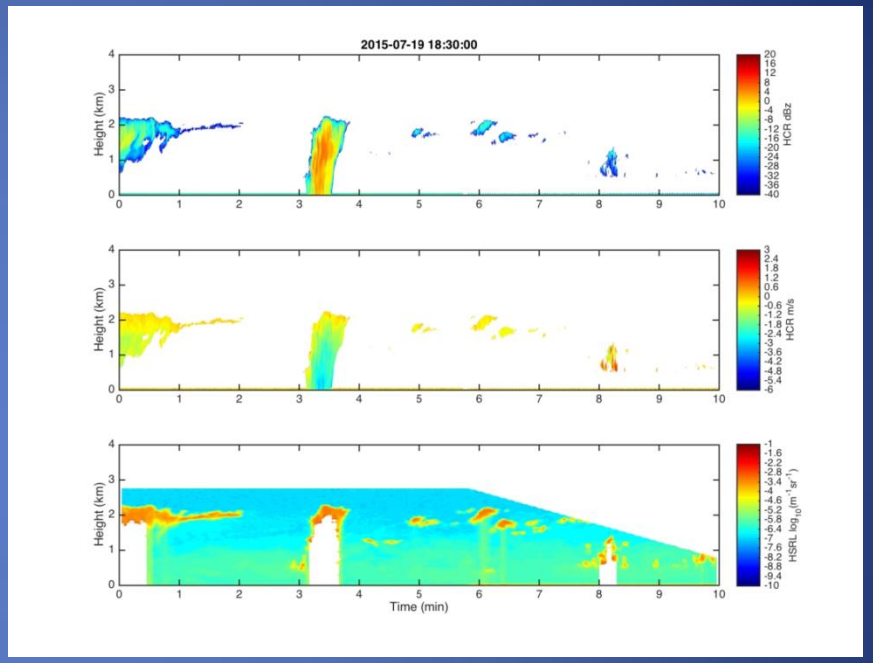




Significant Aerosol, Cloud, and Precipitation Features Sampled

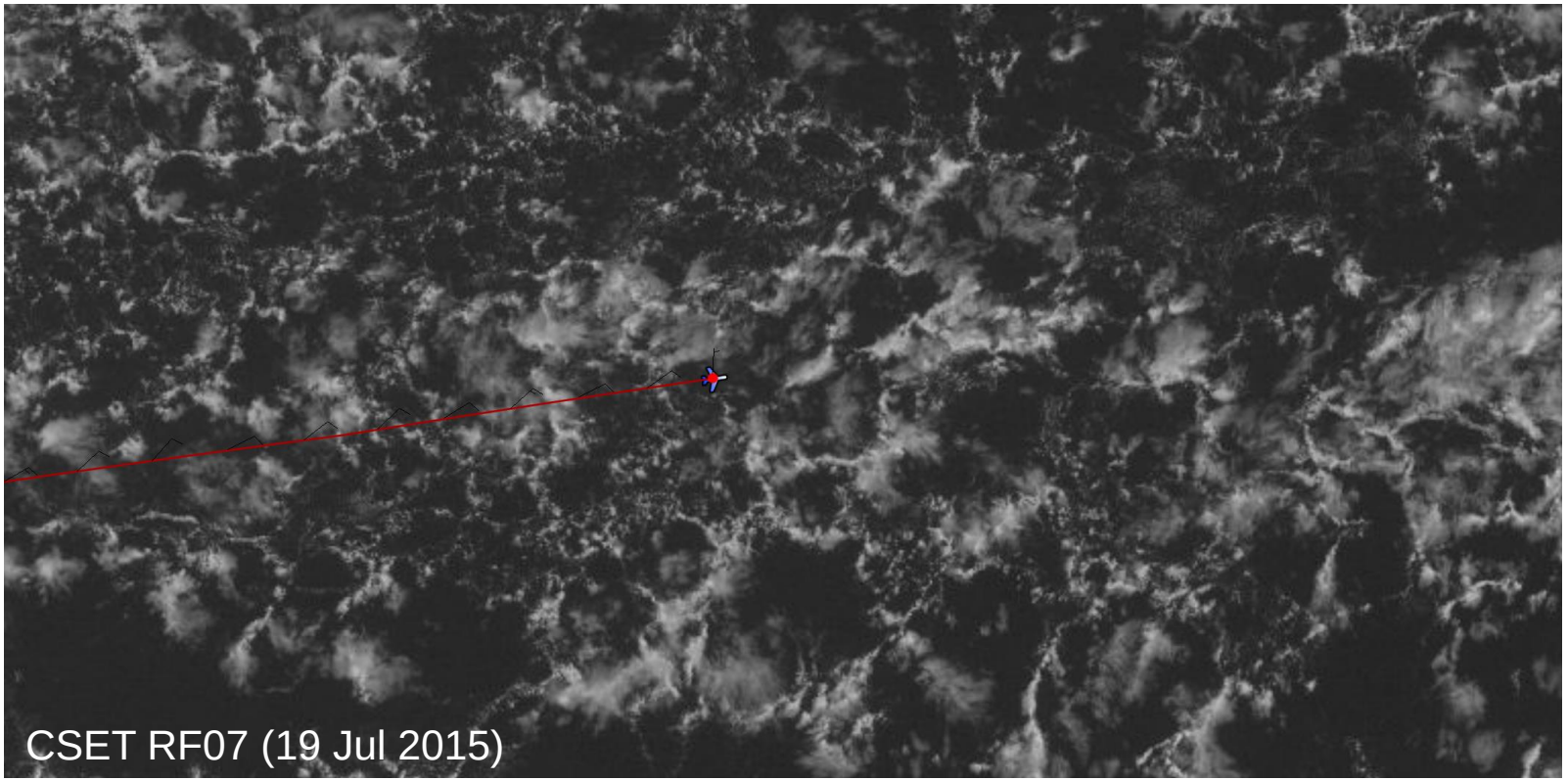
High Occurrence of Shallow Grey Cloud Layers and Ultra Clean Layers at Top of Boundary Layer

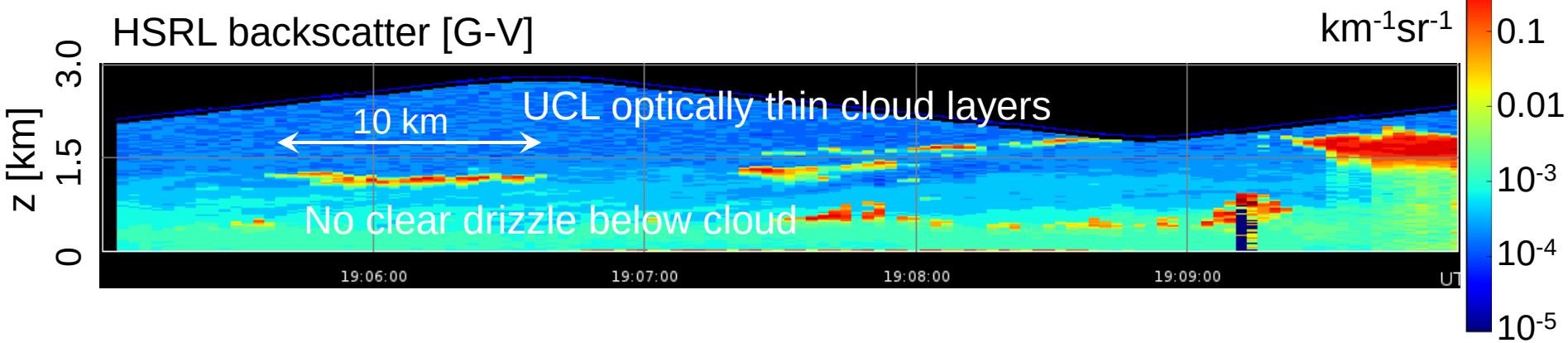




Poster 790—Wood et al. Ultra-clean Layers and Low Albedo Clouds in the Marine Boundary Layer

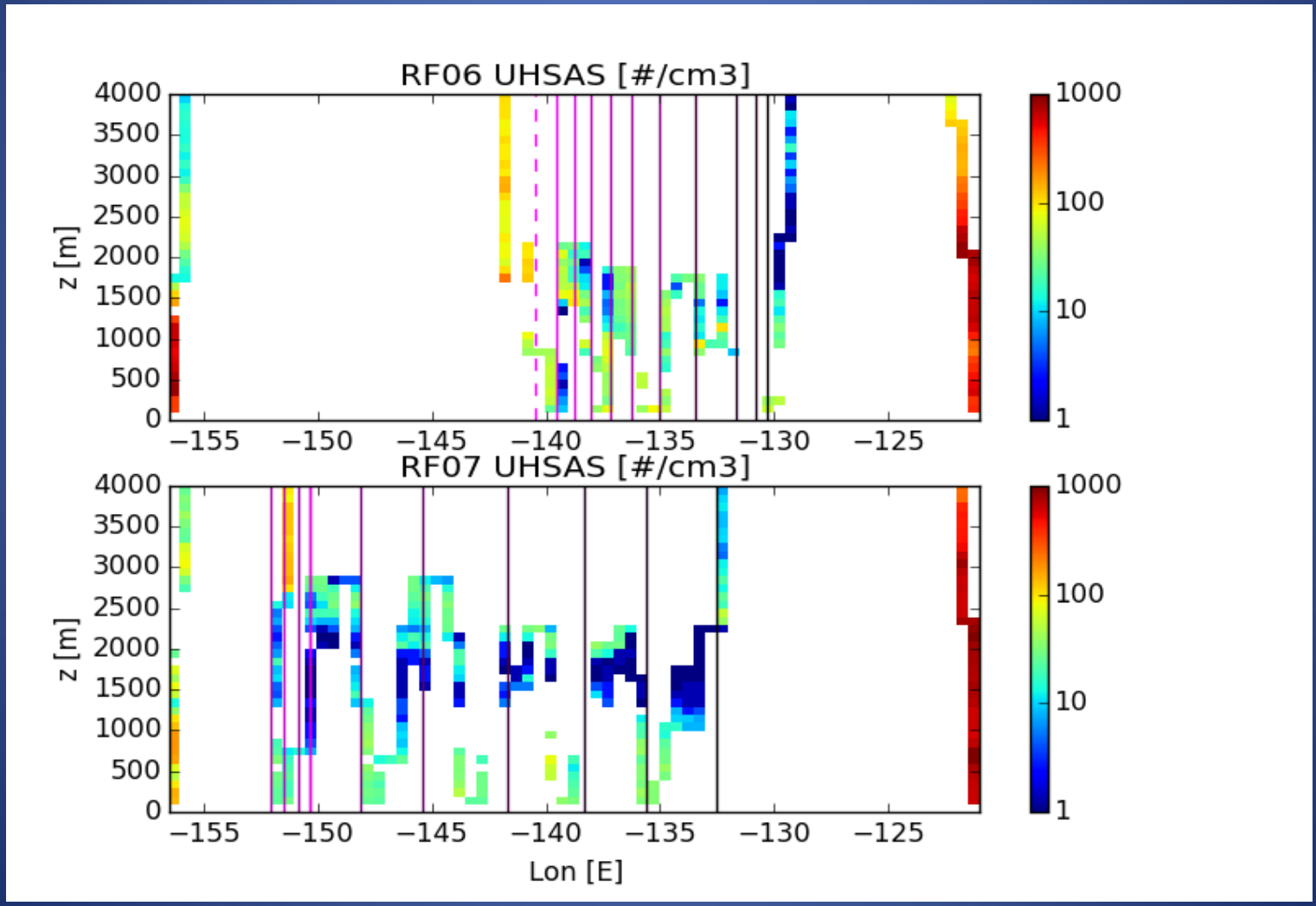
Optically thin layer clouds in open cells



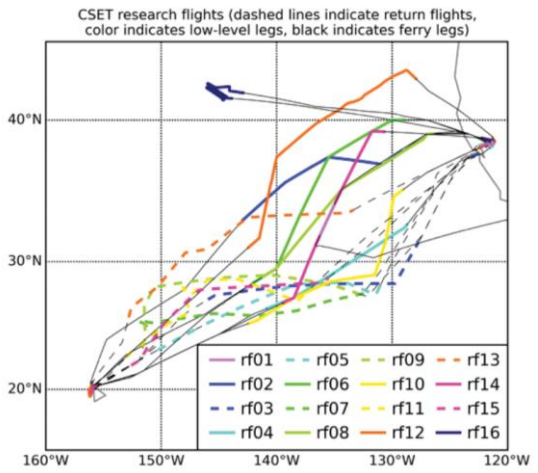


Significant Aerosol, Cloud, and Precipitation Features Sampled

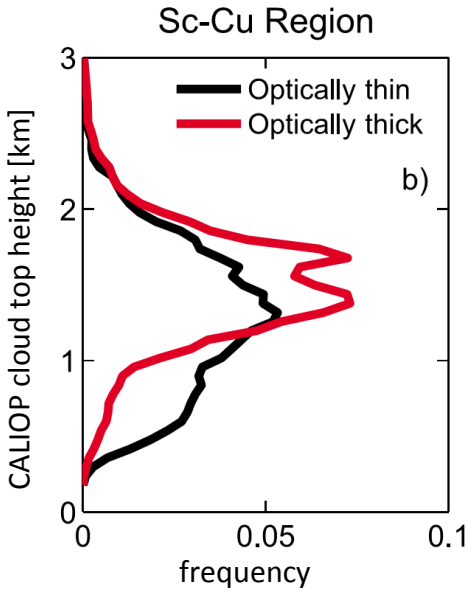
High Occurrence of Shallow Grey Cloud Layers and Ultra Clean Layers at Top of Boundary Layer

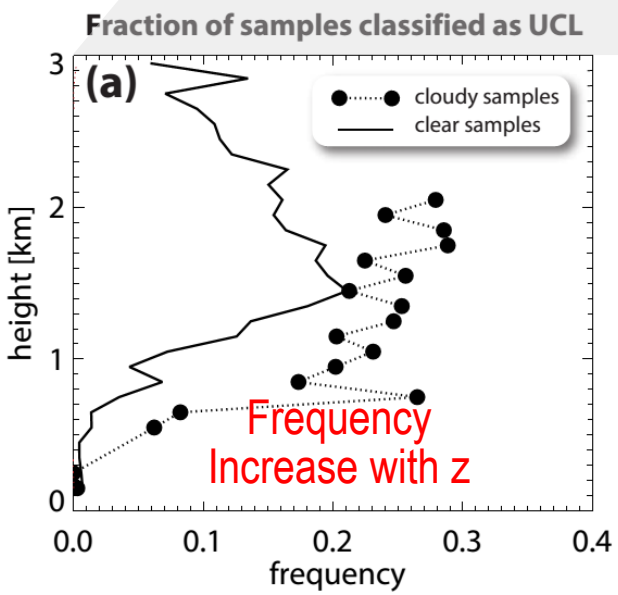


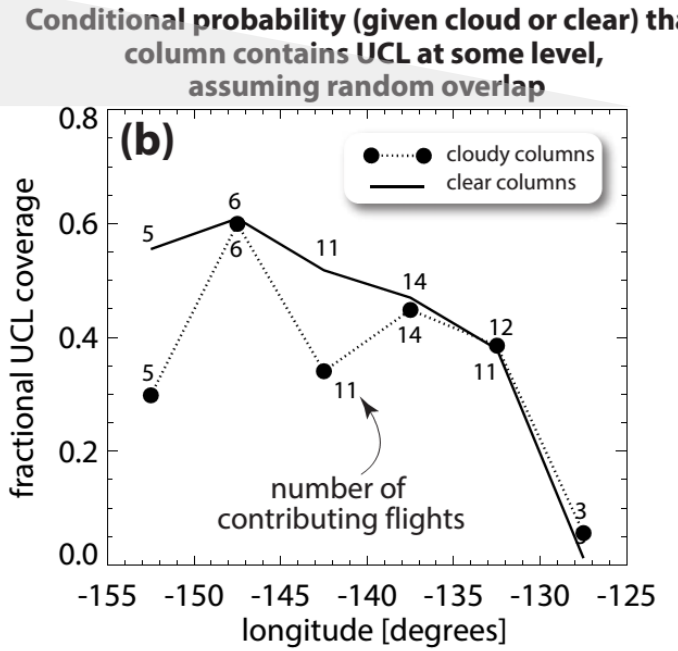
Ultra-clean layers (UCLs) are common over NE Pacific



Cloud System Evolution in the Trades (CSET) project,
NCAR G-V, Jul-Aug 2015





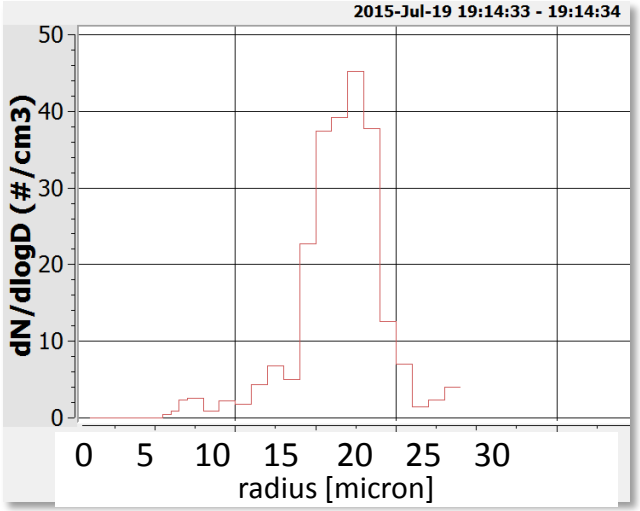


UCLs defined as samples with N_d (cloudy) or N_a (clear) < 10 cm^{-3}

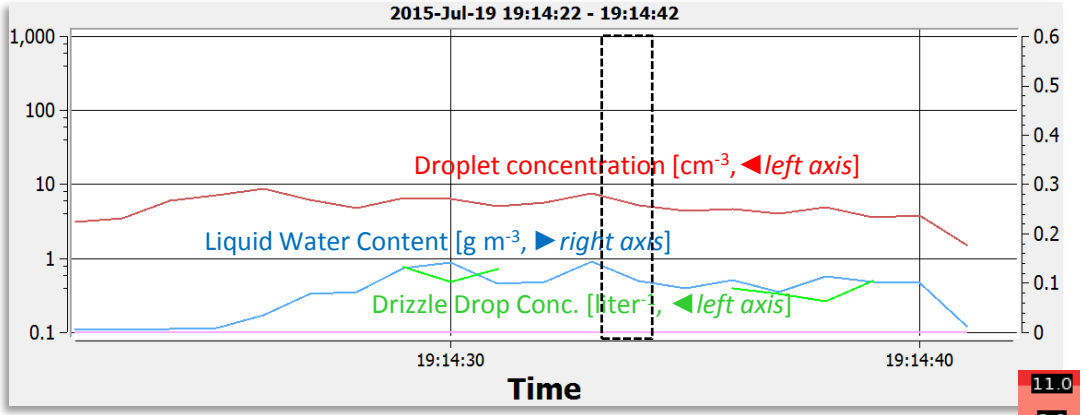
UCL Gray Cloud Microphysics

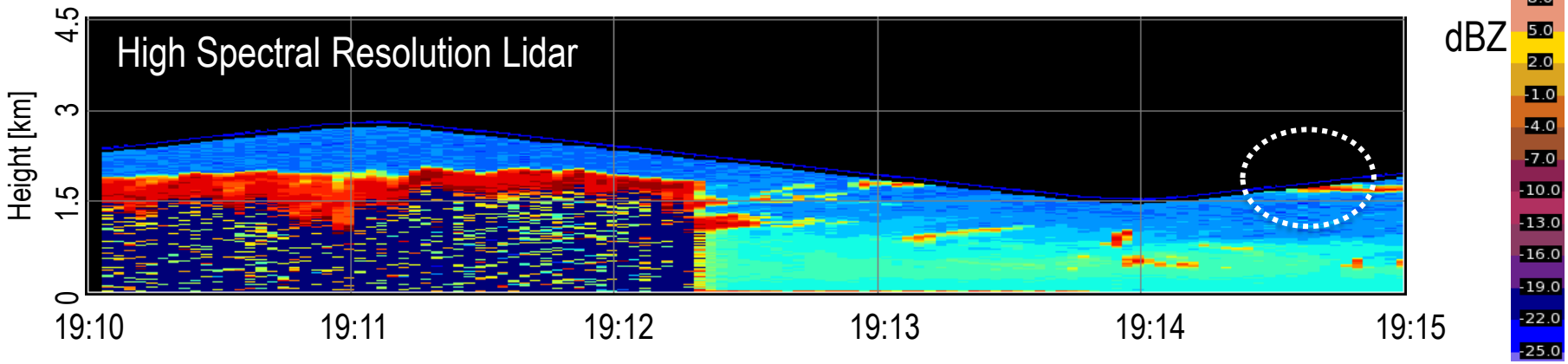
RF07 - July 19th

Droplet size distribution



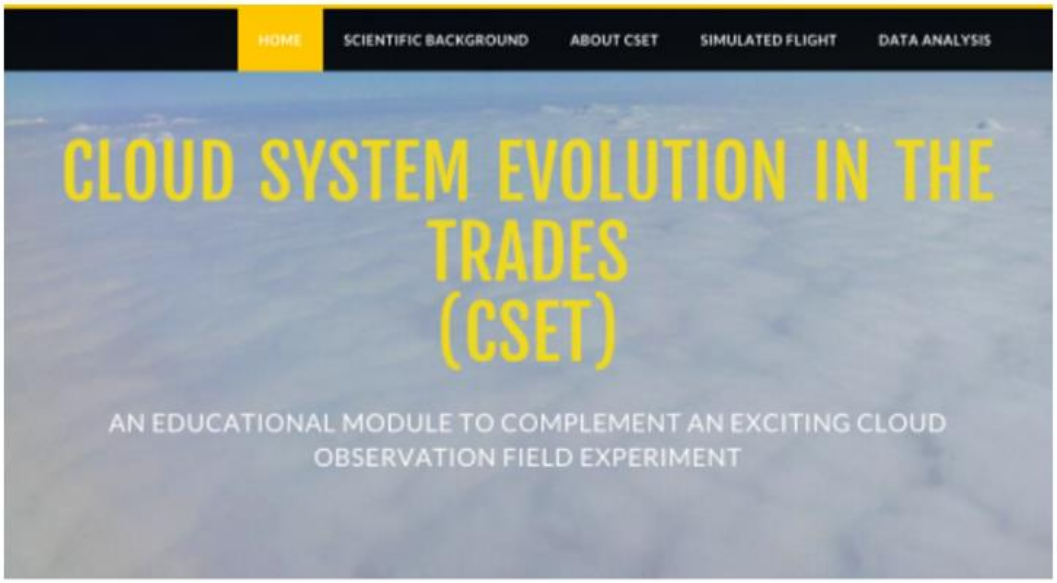
Concentrations and condensate





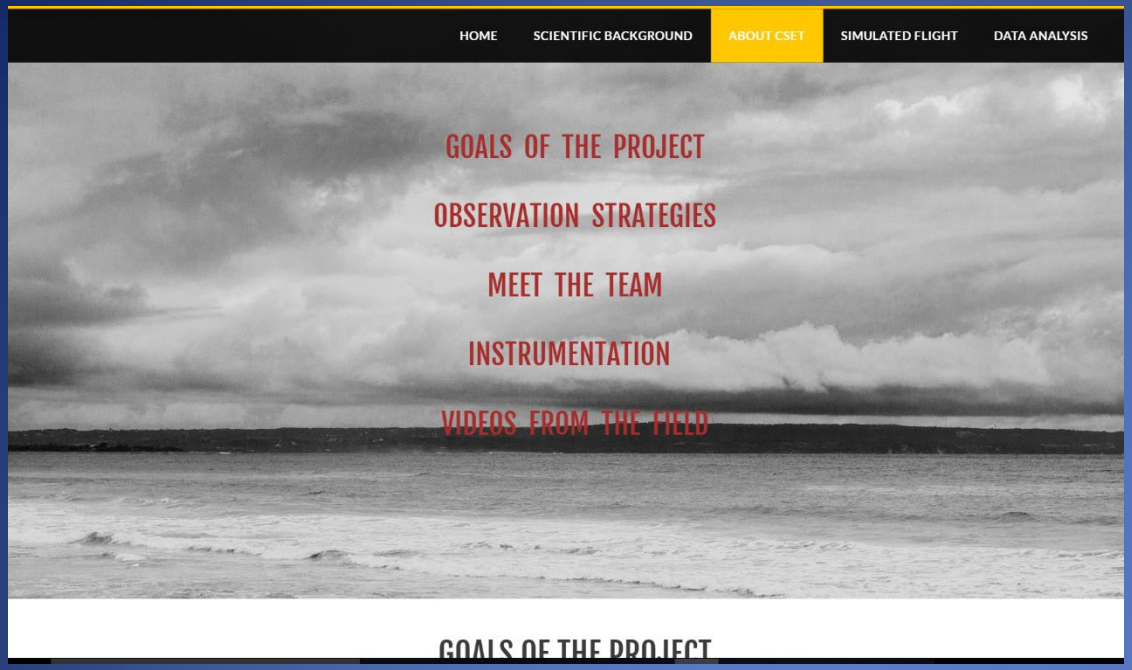
CSET Educational Module

Shaunna Donaher
Emory University



This educational module has been designed for students with at least a basic understanding of meteorology, namely an introductory general education class at the college level (although advanced high school is also possible). Advanced undergraduate or graduate atmospheric science students will also benefit from this module to familiarize them with field research, especially if the simulated flight is combined with data analysis.

The CSET educational module was developed by Dr. Shaunna Donaher, a lecturer at Emory University, and a participant in the CSET study. If you use this module in the classroom and have additional useful hints to add to this list, please email them to shaunna.donaher@emory.edu.


HOME
SCIENTIFIC BACKGROUND
ABOUT CSET
SIMULATED FLIGHT
DATA ANALYSIS
GOALS OF THE PROJECT
OBSERVATION STRATEGIES
MEET THE TEAM
INSTRUMENTATION
VIDEOS FROM THE FIELD
GOALS OF THE PROJECT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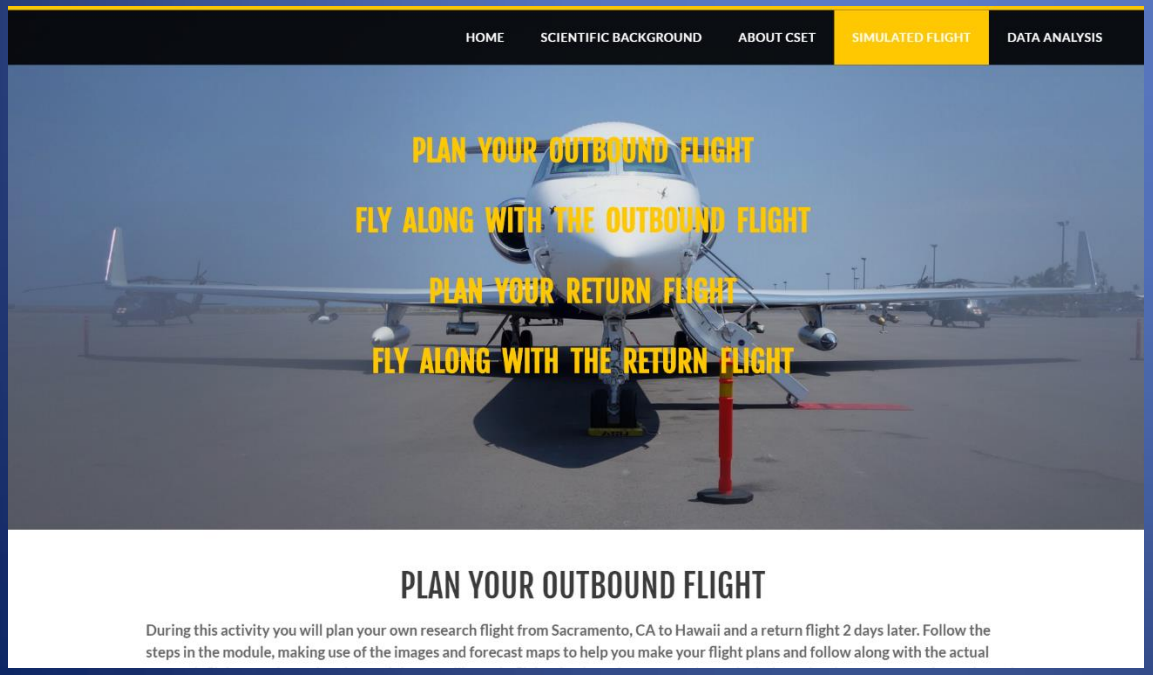
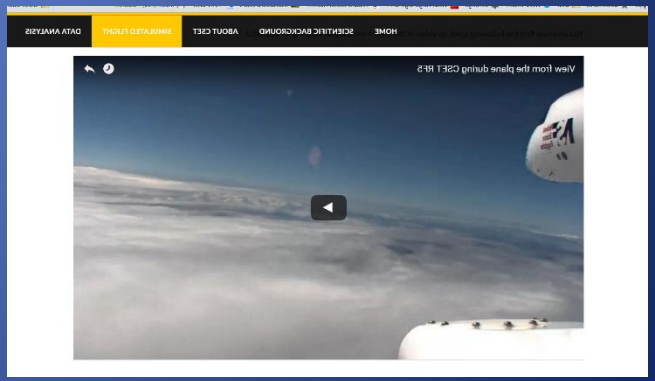
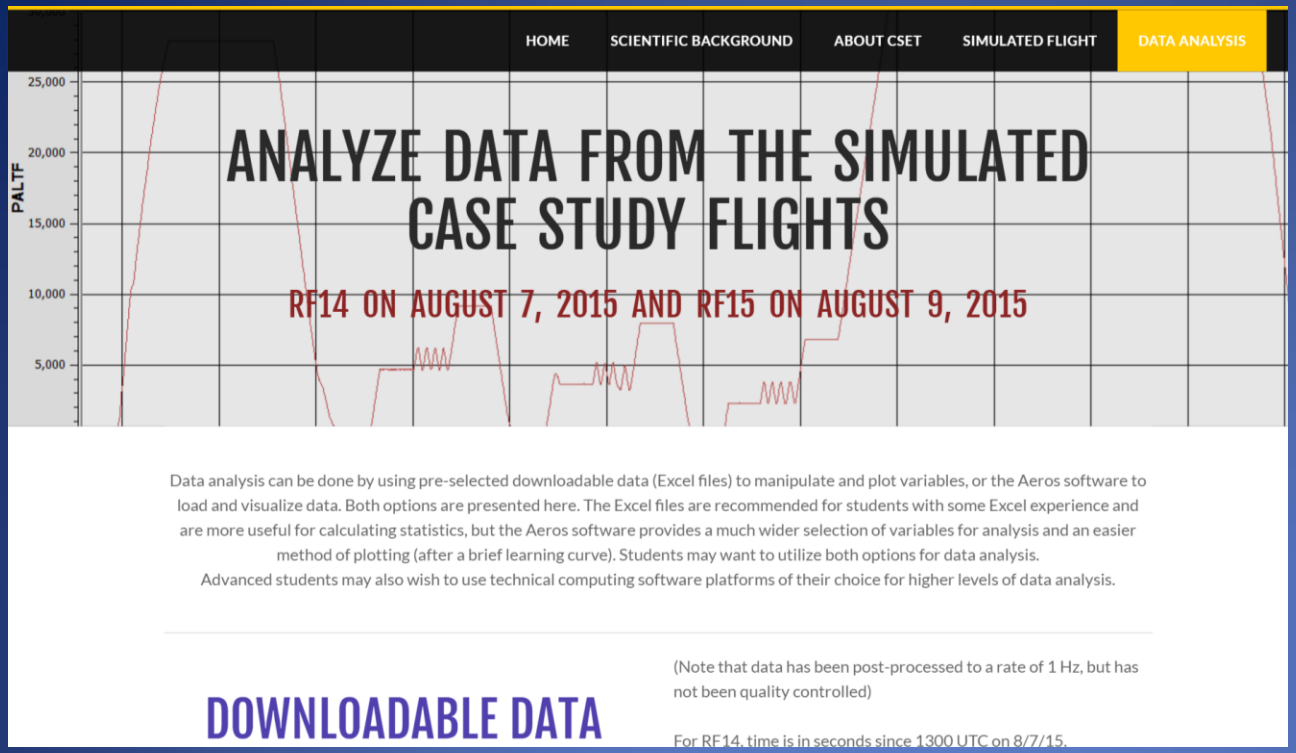
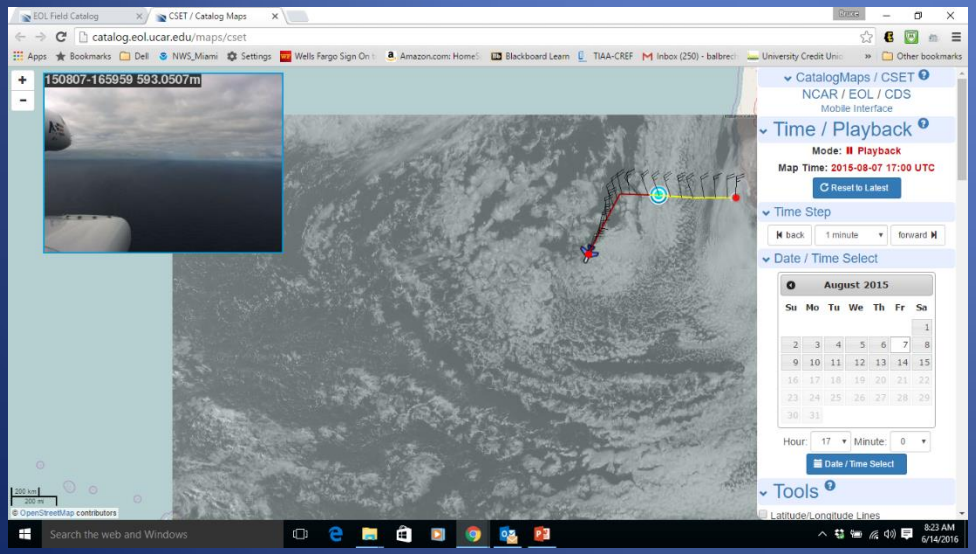

HOME
SCIENTIFIC BACKGROUND
ABOUT CSET
SIMULATED FLIGHT
DATA ANALYSIS
PLAN YOUR OUTBOUND FLIGHT
FLY ALONG WITH THE OUTBOUND FLIGHT
PLAN YOUR RETURN FLIGHT
FLY ALONG WITH THE RETURN FLIGHT
PLAN YOUR OUTBOUND FLIGHT
During this activity you will plan your own research flight from Sacramento, CA to Hawaii and a return flight 2 days later. Follow the steps in the module, making use of the images and forecast maps to help you make your flight plans and follow along with the actual


DATA ANALYSIS
SIMULATED FLIGHT
ABOUT CSET
SCIENTIFIC BACKGROUND
HOME
View from the plane during CSET RF5





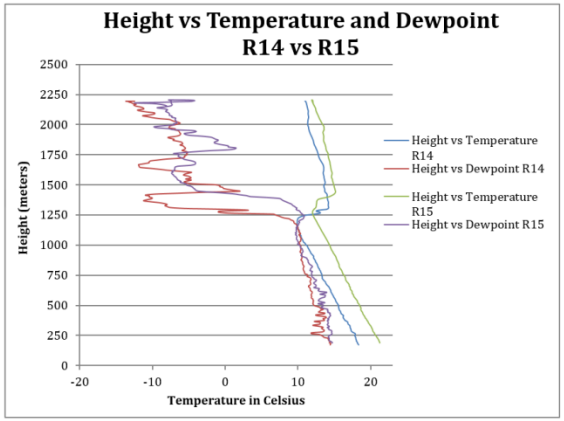


Figure 5 compares the measured temperatures and dewpoints from upstream and downstream soundings, obtained just before the low-level sampling on both RF14 and RF15.

Summary

- Lagrangian sampling strategy with NSF/NCAR G-V aircraft to study cloud system evolution demonstrated

  --extensive cloud areas were sampled and then resampled 48 hrs later along trajectories between California and Hawaii on 7 missions

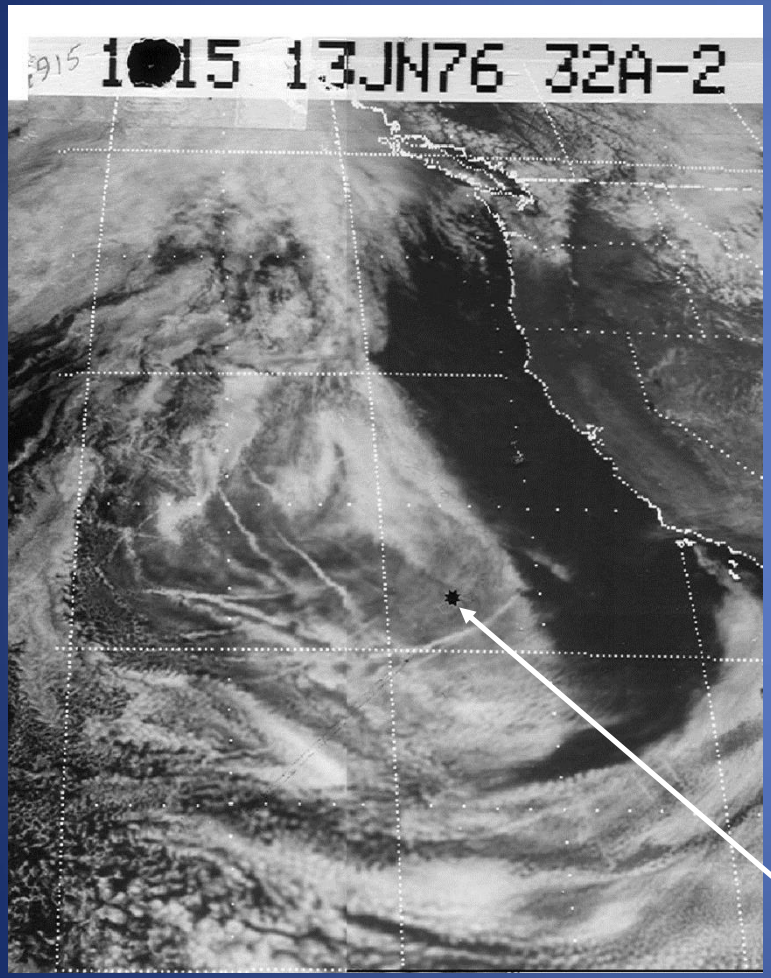
  --unprecedented observations of the evolution of boundary layer structure and cloud and aerosol fields that will provide several cases for model evaluation and development

- Extensive observations of key features of cloud system evolution were made—mesoscale precipitating cloud complexes, gray cloud layers, and ultra clean layers at boundary layer top
- A showcase for aerosol-cloud-precipitation interactions established

EOL Highlights

- Utility of instrumented G-V with HCR and HSRL capabilities for boundary layer cloud studies was demonstrated definitively
- Power of Field Catalog for mission planning, flight operations and teaching and learning experiences was exercised

Some Retrospection---A Little History



First flights in stratocumulus June 1976 with NCAR Electra (5 flights)

Led by Wayne Schubert and Doug Lilly

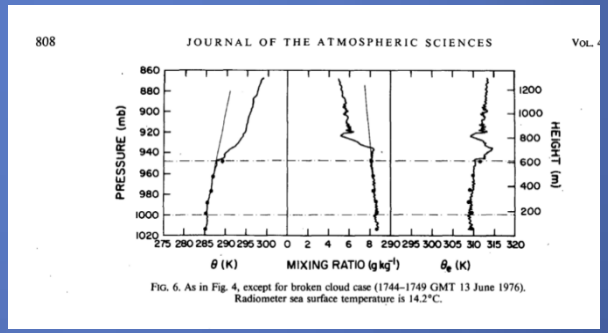


FIG. 6. As in Fig. 4, except for broken cloud case (1744–1749 GMT 13 June 1976). Radiometer sea surface temperature is 14.2°C.

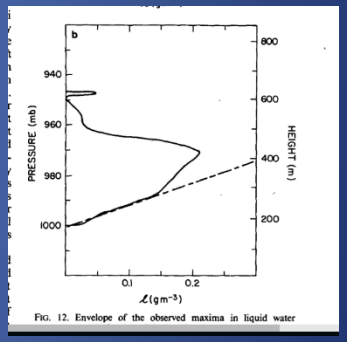


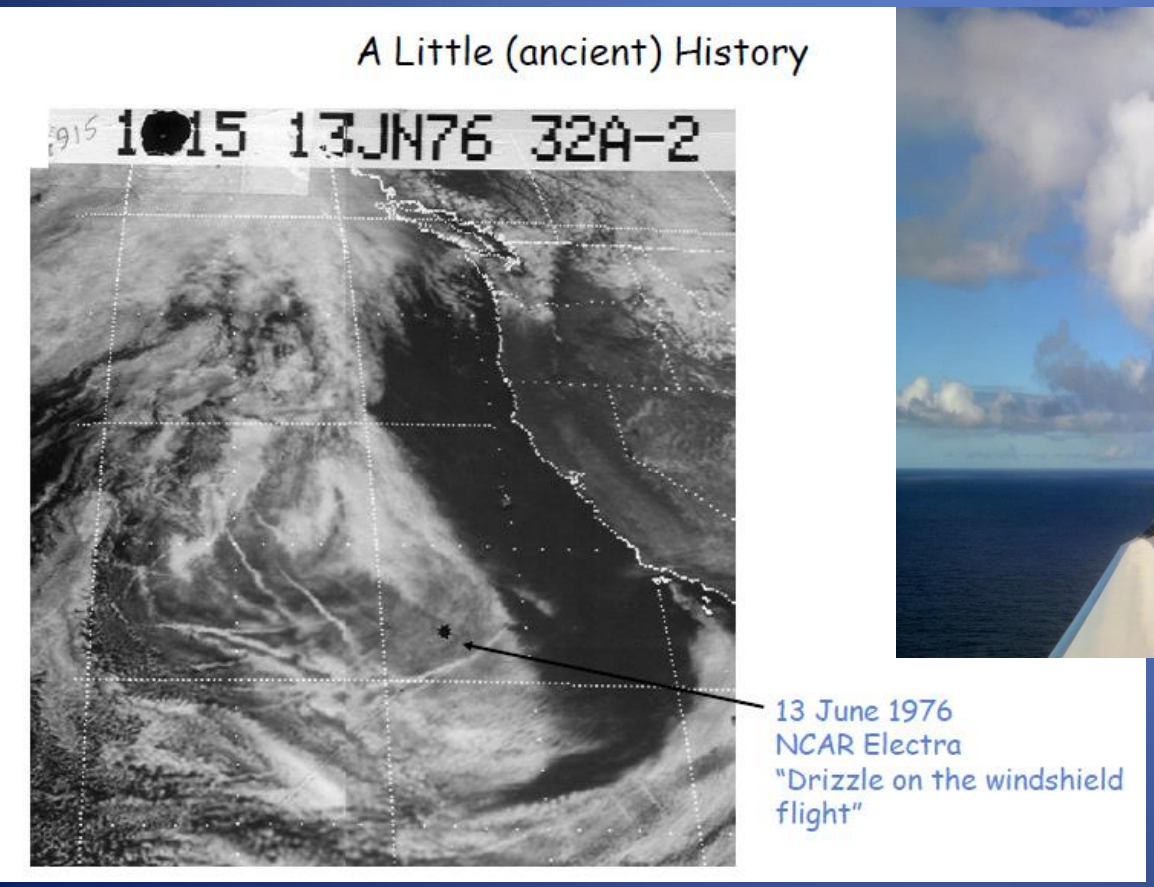
FIG. 12. Envelope of the observed maxima in liquid water

Brost et al, JAS, 1982 a,b
Albrecht et al JAS, 1985

13 June 1976
NCAR Electra
"Drizzle on the windshield flight"

Have we made progress?

CSET 7July 2015



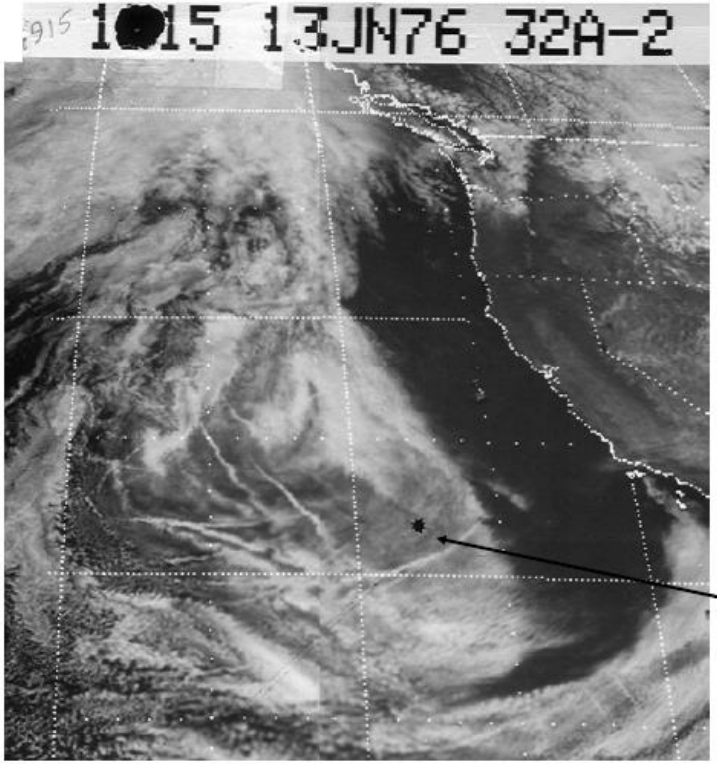
RF07 Jonathan Emmett (1802 UTC)

Progress?—YES!!
We struck gold!!

CSET 7July 205

RF07 Jonathan Emmett (1802 UTC)

A Little (ancient) History



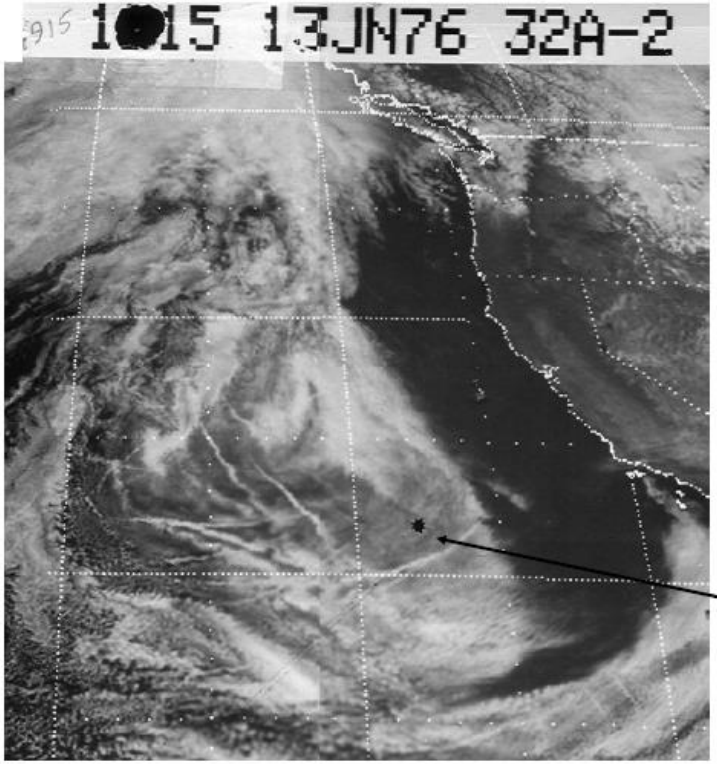
13 June 1976
NCAR Electra
"Drizzle on the windshield flight"

Thanks!

CSET 7July 205

RF07 Jonathan Emmett (1802 UTC)

A Little (ancient) History



13 June 1976
NCAR Electra
"Drizzle on the windshield flight"