ORACLES P3 Flight Scientist Post-Flight Status

Date: 08/13/2017

Flight number: PRF02Y17

Routine flight or target of opportunity? Opportunity; joint cloud-radiation flight sampling gradient of overcast and broken clouds along the CALIPSO satellite track; aerosol radiative effects in presence of broken cloud; mixing of aerosols into clouds. In some ways, this was a hybrid of routine and target flights since the flight track was so close to the routine track.

Flight scientist: Greg McFarquhar

Assistant flight scientist: Sebastian Schmidt

Take-off: 7:57 UTC

Landing: 16:55 UTC

Quick summary:

Representative ACAOD or ACAOD range for flight: 0.27

Do the models predict crossing a gradient in aerosol age?
Yes/No/Unclear

Did the flight cross a gradient in macroscopic cloud properties, like cloud fraction?
Yes/No/Unclear

Did the flight cross a gradient in aerosol loading?
Yes/No/**Unclear**

At any point during the flight, was there a clear separation between the smoke plume(s) and cloud tops?
Yes/No/**Unclear**

How many of the following maneuvers took place?

Ramps 1 (below-cloud to 6kft only)____	Above cloud legs __1_____
Square spirals _1_____	Sawtooth legs ___1_____
MBL legs __1 (at 2 altitude)_____	Plume legs ____2_____
Cloud legs ___1_____	Above plume legs ____2_____

Instrument status:

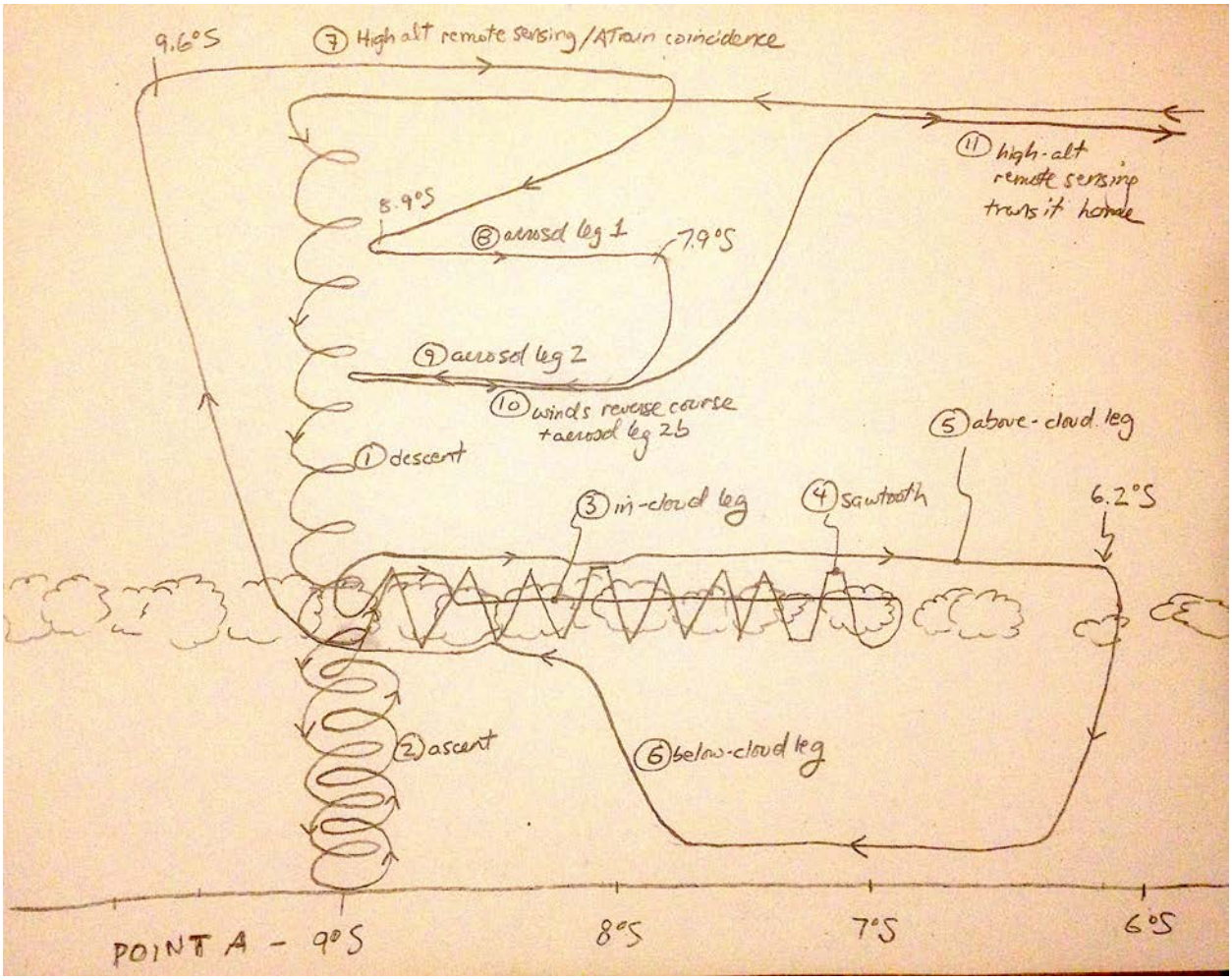
Instrument	Comments
P3	Communications went well and were able to execute all of the maneuvers that we wanted.
4STAR	flight went well, did not encounter problems, monitors working, highest AOD Sao Tome under .7 at 900 nm, got a lot of above cloud AOD, consistently around .27, quite a bit of sky scans, not much time (get data), not much gradient between 7 and 9 N, biggest gradient in holes of lowest leg where went to 0.4
HiGEAR	without monitor for bit, but recovered quickly, performed well, communication issues with PSAP were fixed, USHAS back up and running, got good sampling in all regions (plume, cloud, MBL, above/below cloud, TDMA, got CVI stuff)
HiGEAR-AMS	great flight, great in-situ data, great profiles of plume, saw same chemical structure with elevated nitrate in upper layer as opposed to lower layer, saw pretty dirty MBL want to see if there is difference from MBLs sampled last year
HSRL-2	good flight; instrument worked well but extended runs at low level caused heating, will turn off in extensive low-level runs in future; saw variability between north and southern ends in both horizontal and vertical, and also seeing variability as approach Sao Tome; CALIPSO overpass will provide good comparison
RSP	Good flight, worked well; CALIPSO track gave good heading for cloud/aerosol retrieval; in and out bound track don't get good geometry so not as much that can be done with that data, some clear sky and cloud measurements, not sure if good cloud retrieval leg close to in-situ leg; still don't have liquid nitrogen so measurement at shortwave-infrared not usable; failure after about 3:30 will look into
APR3	Instrument worked fine (all 3 frequencies); number of cases on way out where strong enough return at Ka that can use W/K for double frequency retrievals; low-level with W band interesting structure could be some interesting comparison
Cloud probes	Great flight; UND CDP not working, not sure if got CIP images; in most of profiles no gap between cloud and aerosol layers, 500 feet between juicy part of plume and cloud layer; first half saw tooth 400-500 cc, as moved into saw tooth reduced to 300 cc, fluctuating quite a bit, LWC .4 max, drop to lower values of .3 later; mean diameters 30 um on CIP; near cloud base or below saw drizzle/rain
CCN	worked well, in both scanning mode and constant flow mode

PDI	Worked well
Vertical winds	Worked well
WISPR/CVI	Great day of science; saw tooths produced great vertical symmetric profiles with lots of structure; heater preventing condensation; cloud top run dipping in and out of clouds was a golden run; low altitude run at 200 ft was low wind speed so hopefully will get results emerging from this on isotopic fractionation; continuing to work on coordination with CVI operation, getting timing to working on saw tooths; potential instrument problem from previous flight did not show today;
COMA	Worked well, biggest CO in whole mission when left Sao Tome (big plume), some potential gradients of CO2 both vertical and latitudinal and saw some interesting structures on the boundaries between pollution and cloud layers so will dig into
SSFR	Worked well
data	Worked well

PRF02 08/13 2017 Sunday Mission Report

flight scientist: Greg McFarquhar (FS), Sebastian Schmidt (AFS)
ground scientist: Sarah Doherty (GS), Michael Diamond (AGS)

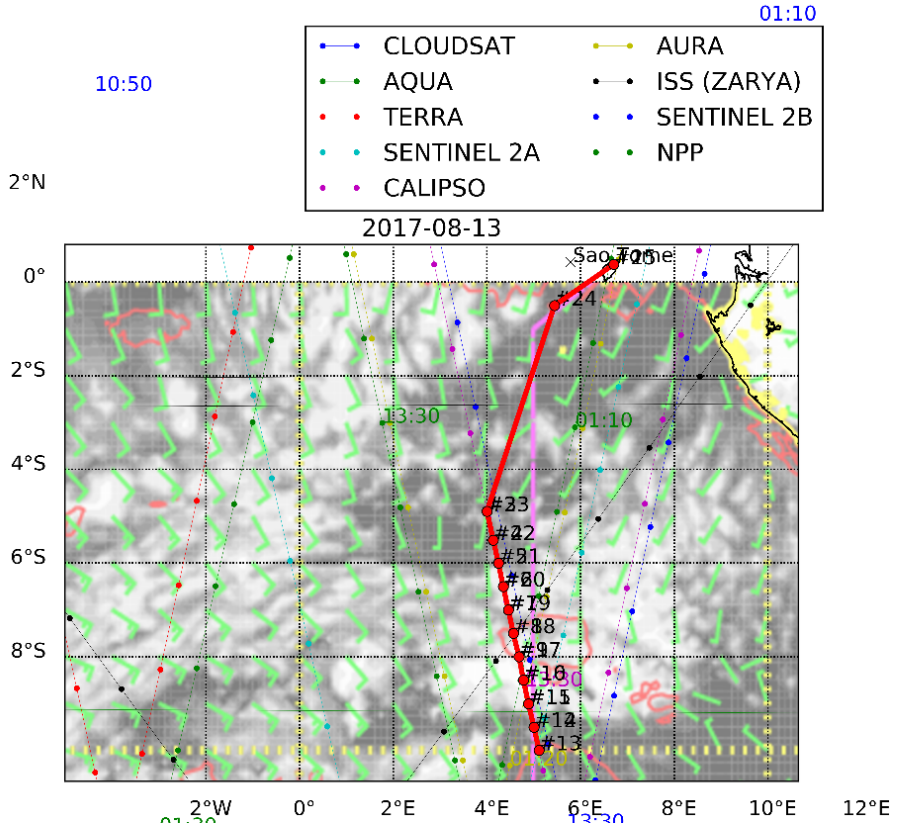
Flight plan and objective: Joint cloud-radiation flight: run a wall on the A-train track (which also conveniently happens to be a semi-Lagrangian surface wind line) to satisfy both radiation and cloud microphysical objectives. Aim is to work a line with a transition between homogeneous and broken clouds, and if possible between aerosol mixing states. The legs will drift slowly northward with the winds (~ 1/3 degree per hour). Post-module, if possible, fly at altitude around A-train overpass time to get HSRL-2 curtain/comparison.



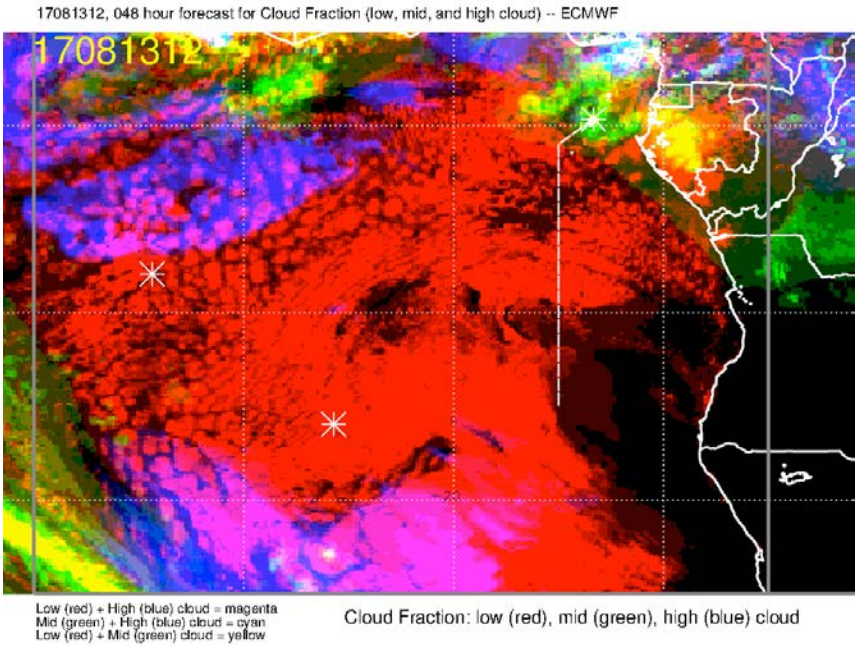
Flight Summary: The planned mission was flown in a manner very close to the way it was planned. Aerosol radiative effects were sampled in presence of broken cloud, and mixing of aerosols into clouds was sampled, with about 500 m distance between the thickest part of the plume and the top of cloud. A transition between overcast and broken clouds was sampled along the 7 to 9˚S line oriented along the direction of the A-train track that was sampled. It was also determined that the line was oriented approximately parallel with the surface wind, though winds aloft were in a more easterly direction. This allowed both the radiation and microphysics

objectives to be achieved. The line did exhibit a transition between homogeneous and broken clouds, and there was likely some gradient in the mixing mechanism into cloud and the boundary layer. The final part of the flight involved sampling at 20 kft during an A-train overpass to get HSRL-2/RSP curtain/comparison. The above and below cloud legs were extended slightly northward compared to the earlier in-cloud legs because of motion of winds which was estimated to be ~ 12 knots.

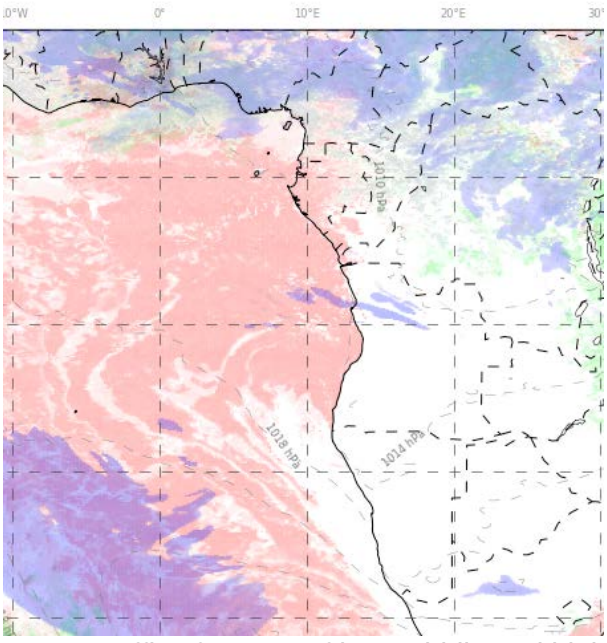
A-Priori Forecast: The goal was to sample low-level clouds along a transition between overcast and broken clouds that was forecast to be somewhere in the 5 to 10˚S range along the A-train overpass line for 13 August at 1330 UTC (this line was in very close proximity to our routine track). There was expected to be a gap in the low clouds north of 5˚S and it was expected that the low clouds would gradually dissipate and evaporate during the course of the flight. Past experience also suggested that the gap in the low clouds would be larger than that forecast. Although high and middle clouds were forecast to be more prevalent than the last couple of days, they were forecast to stay north of the equator and to not interfere with the low clouds to be operated. There was expected to be an intrusion of 700 mb moisture (no cloud) near 10˚S, as well as a 600 mbar moisture surge reaching the equator to the north. At the southern end of the track, surface winds were forecast to be SSE, more easterly at 900 mb, and easterly at 600 mb with a speed of approximately 15 knots.
Forecast products, examples of which are shown below, are available at http://bocachica.arc.nasa.gov/ORACLES/oracles_2017.html,



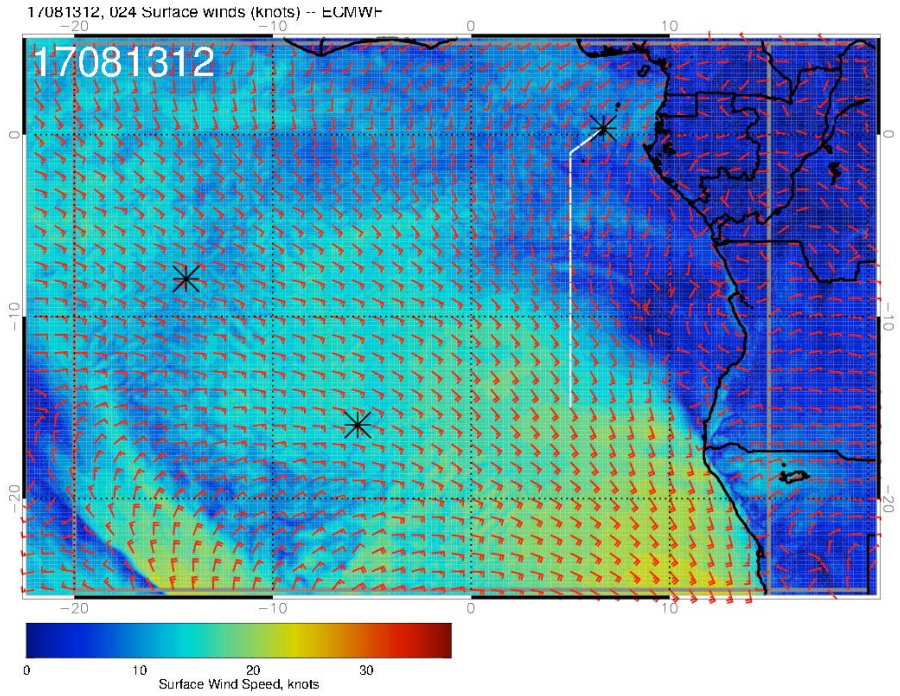
Low-cloud forecast with planned flight track superimposed



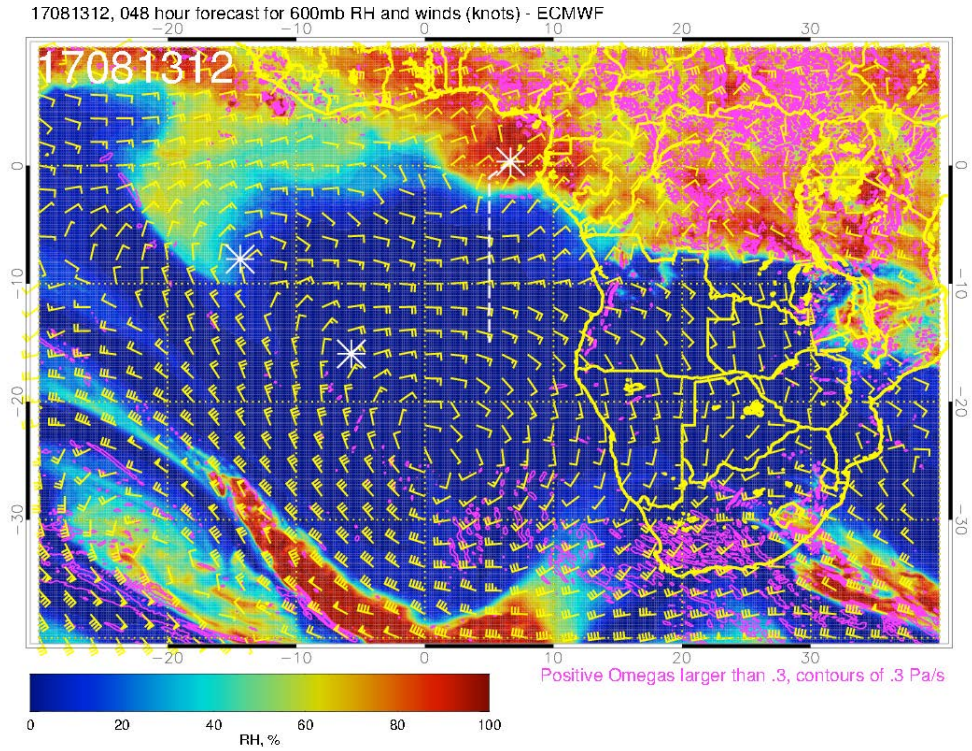
ECMWF forecast of low, middle and high clouds for time of flight. Note that the routine flight track rather than the A-train flight track (at small angle to routine flight track) is drawn on figure.



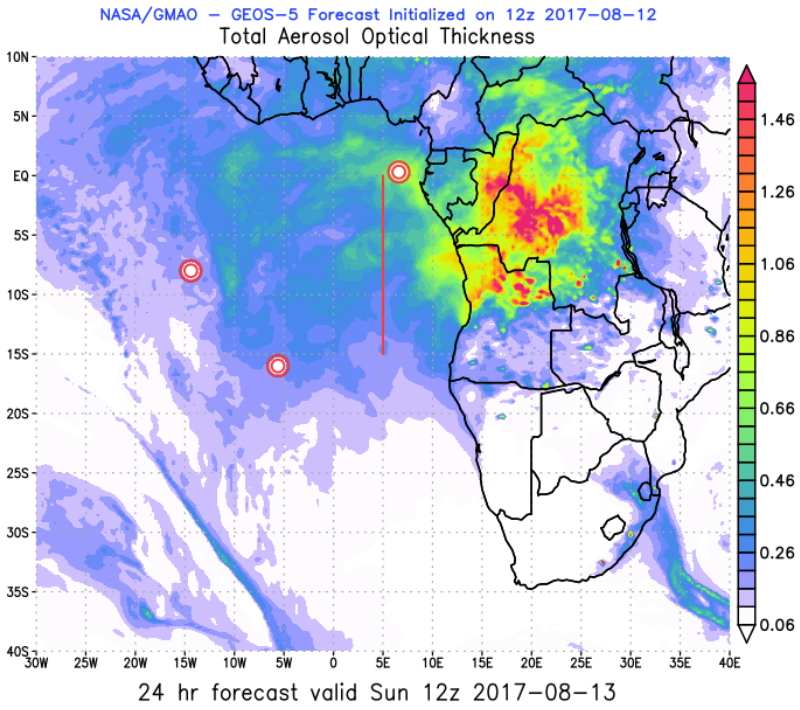
UK Met Office forecast of low, middle and high clouds for time of flight. Note that the routine flight track rather than the A-train flight track (at small angle to routine flight track) is drawn on figure



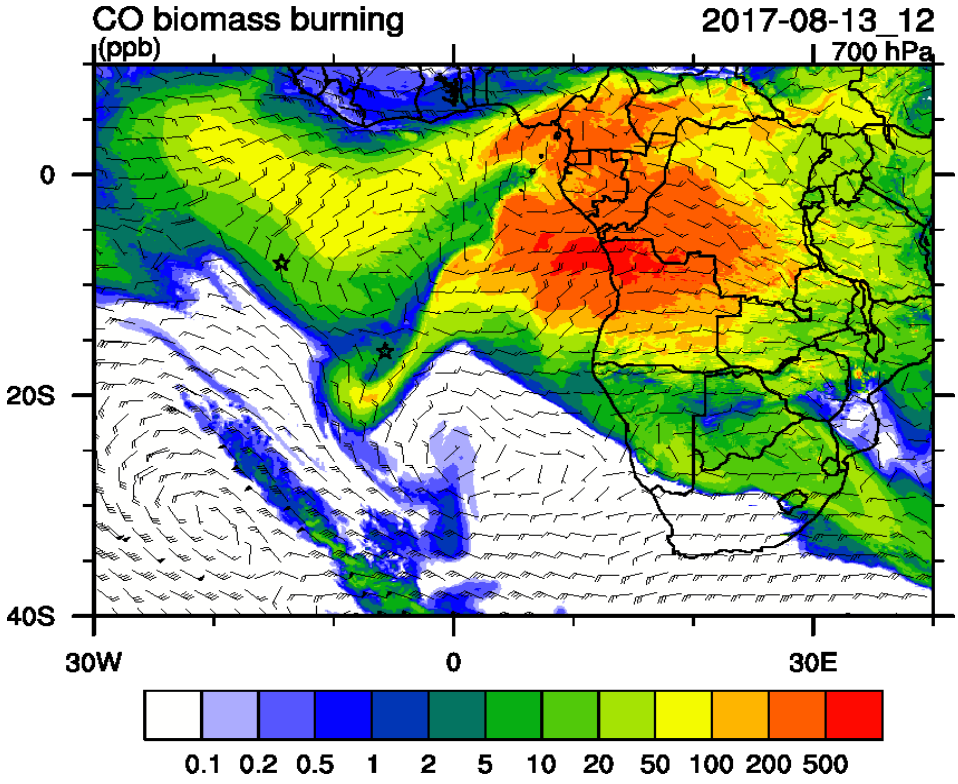
Forecast surface wind speeds at noon for time of flight (note our flight track is oriented at small angle to routine flight track depicted)



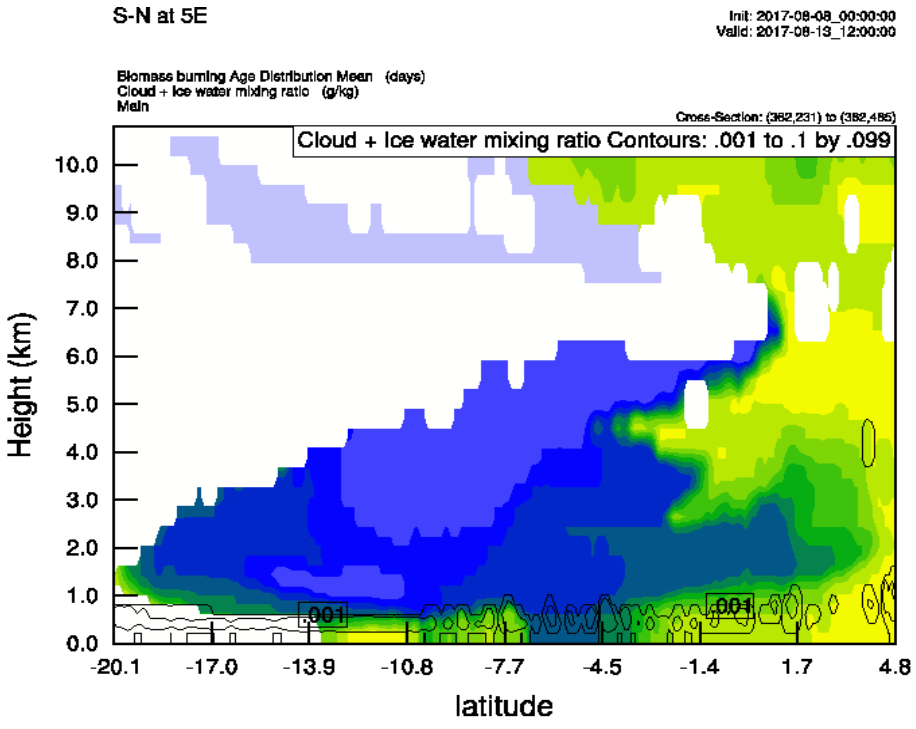
600 mb RH and winds forecast from ECMWF (note our flight track is oriented at small angle to routine flight track depicted)



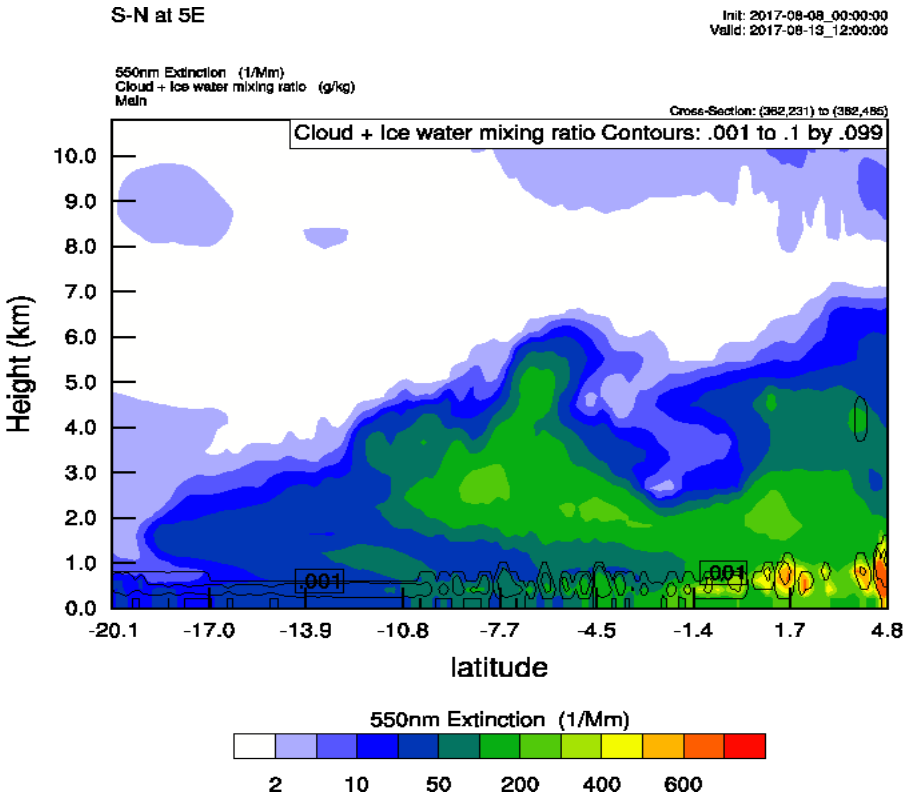
Total aerosol optical thickness forecast (note our flight track is oriented at small angle to routine flight track depicted)



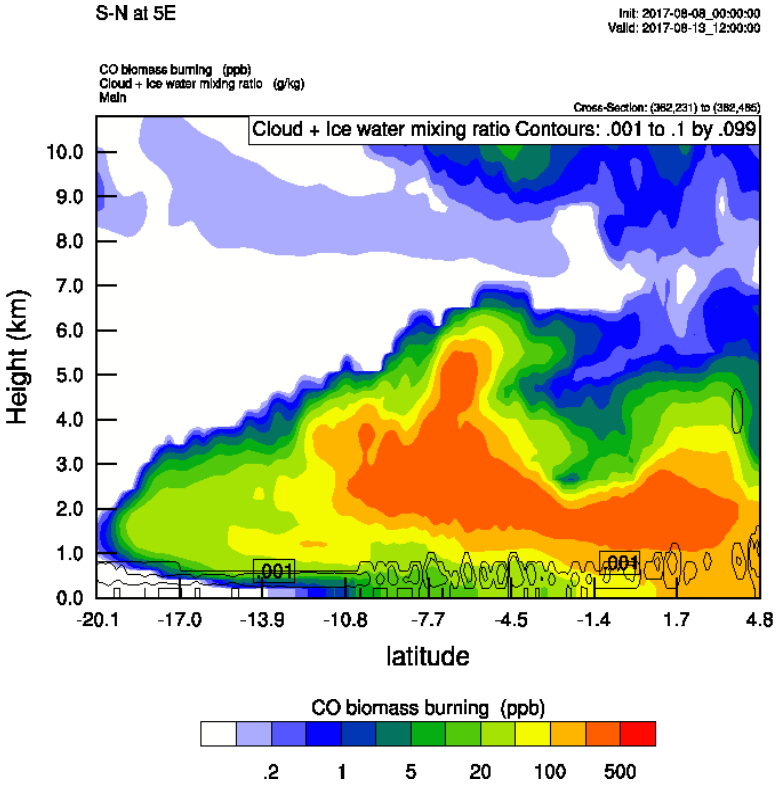
CO biomass burning at 700 mbar in ppb



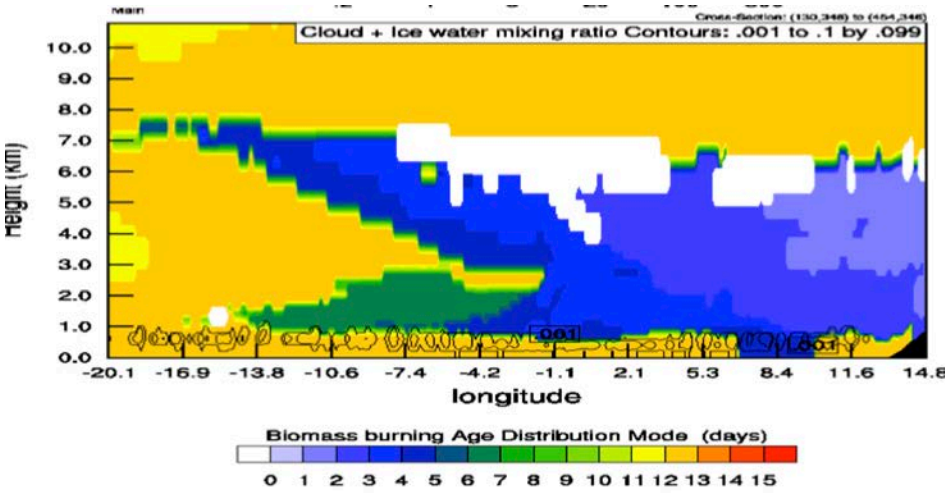
Cross-section along routine flight track (note that our A-train overpass oriented at small angle to the routine flight track) of biomass burning age distribution. See the gradient in boundary-layer air age between about 4.5 and 7.7˚S that we hoped to sample.



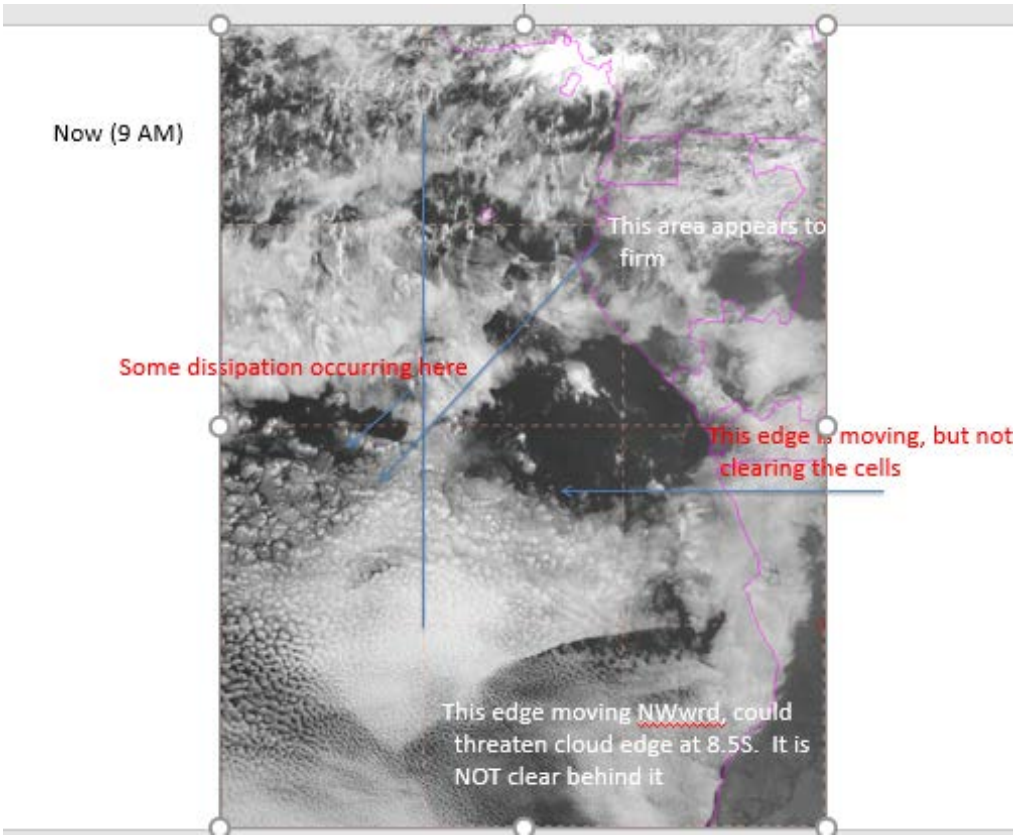
Vertical distribution of extinction along routine flight track (we sampled along A-train overpass that was oriented at small angle to the routine flight track) of biomass burning age distribution. There is a gradient between about 8 and 11˚S that we hoped to sample.



Vertical distribution of CO biomass burning along routine flight track (we sampled along A-train overpass that was oriented at small angle to the routine flight track).

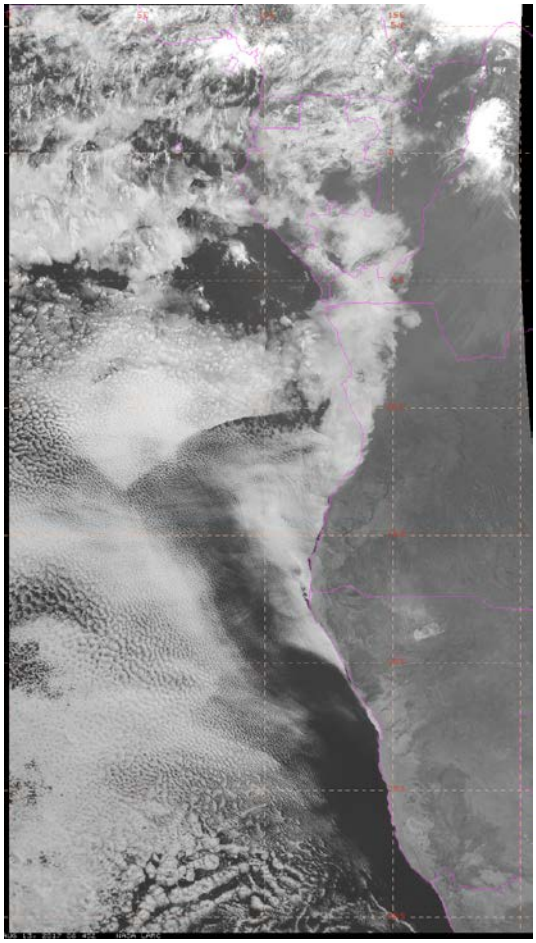


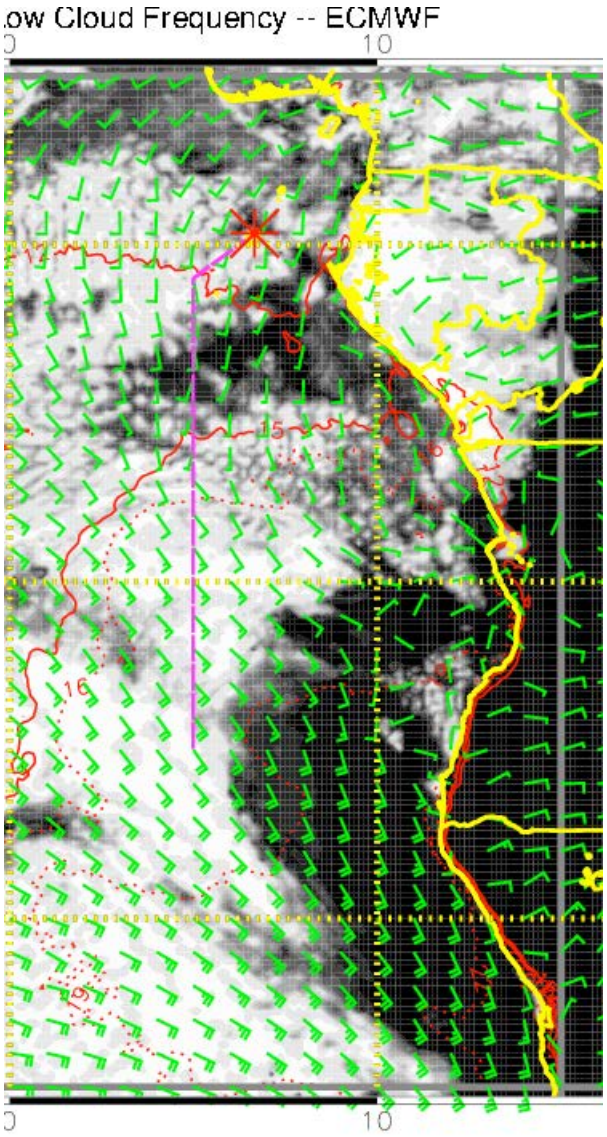
Longitudinal cross section along 8S of biomass burning age distribution in vicinity of flight measurements. There is a significant gradient in age (12 vs. 6 days) forecast that may be seen in the HIGEAR-AMS data. The layer above cloud looked optically homogeneous from the HSRL, but chemical composition (contrast between 5000 and 8000 ft) added important information.



Forecast Verification:

The forecast for 9 AM showed a favorable cloudy area in the region of interest (north of 10S), roughly along the blue N-S line – the Routine flight track). Concerns were: 1) Desired was broken cloud to the north end, and the clouds might remain too solid. 2) retreat of the southern cloud edge northward.





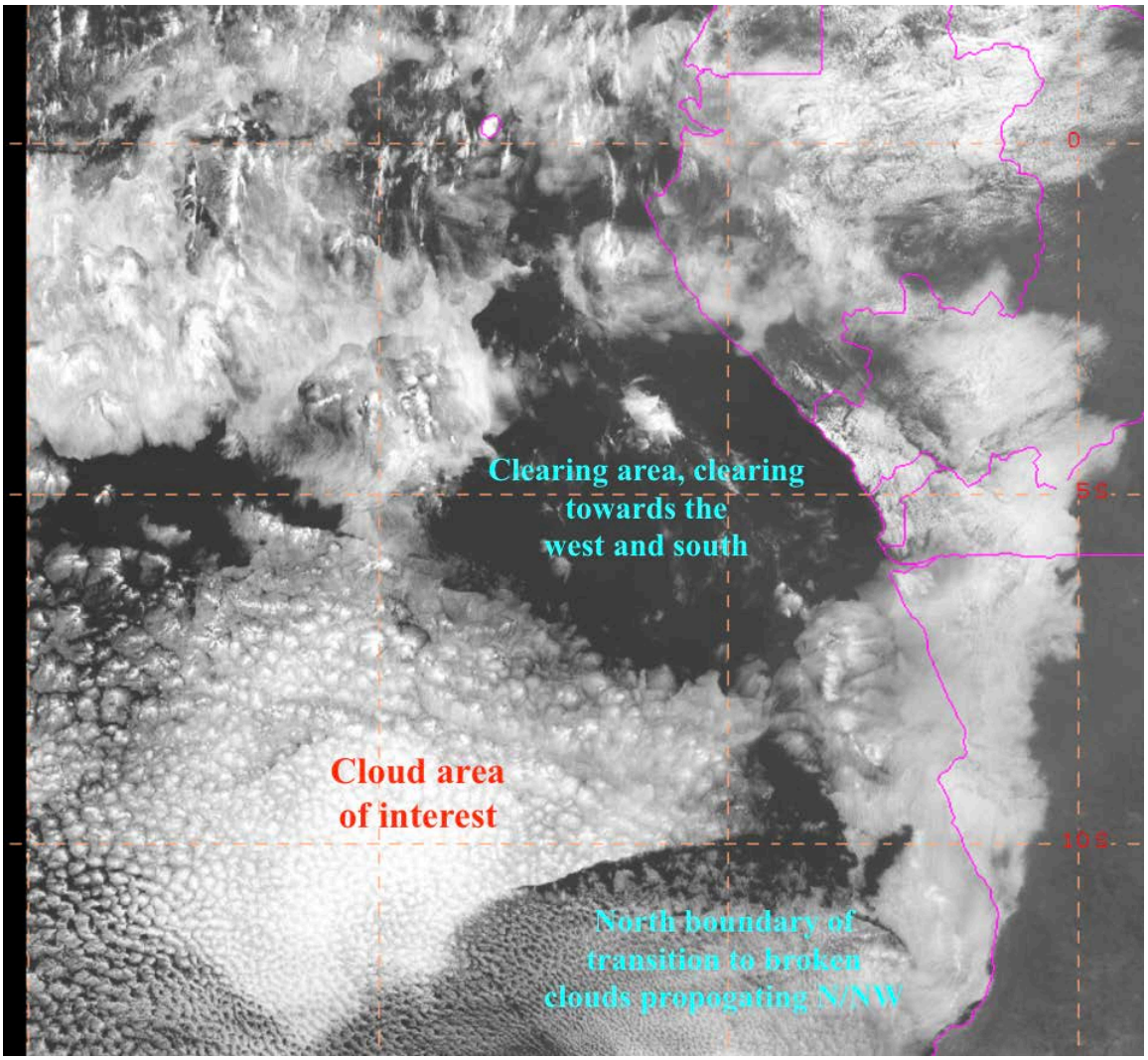
Theta differential between 800 mbar and

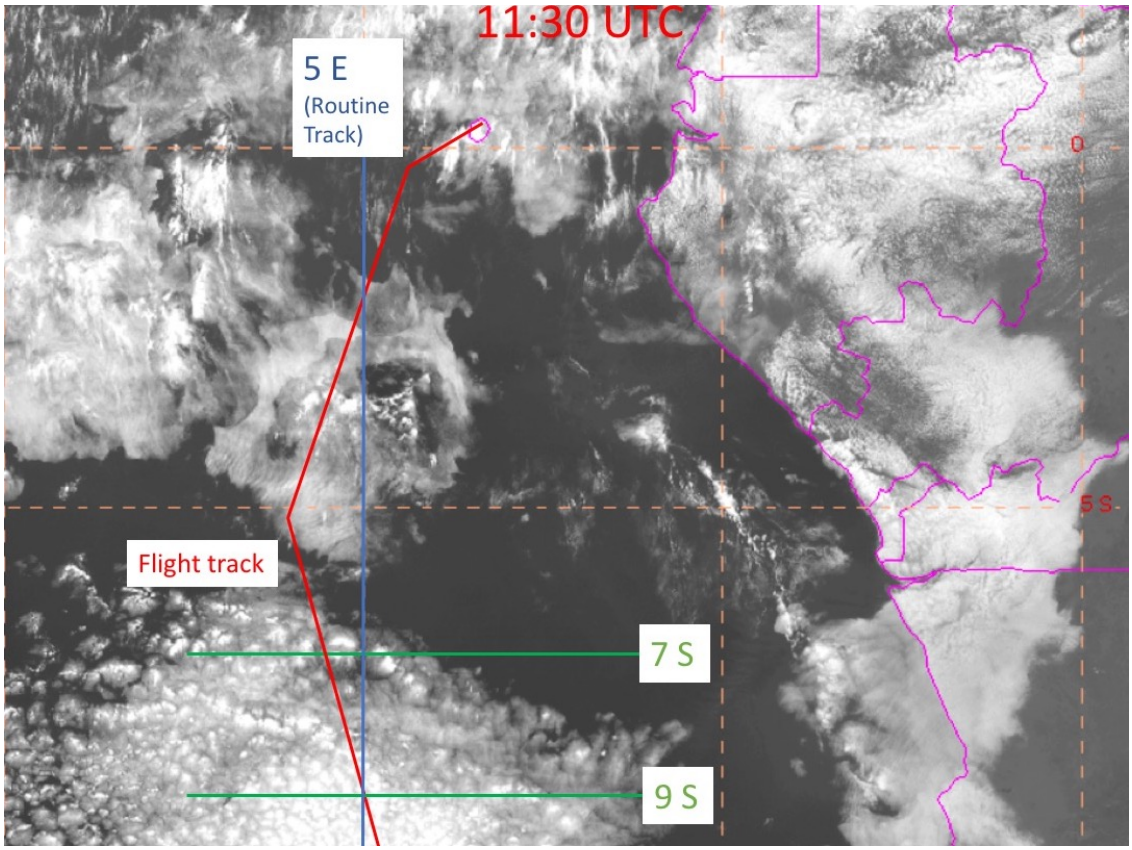
Flight Instrument status: The majority of the instruments worked well during the flight, with the following minor issues noted: HiGEAR lost monitor for a very small portion of the flight but quickly recovered; RSP did not obtain data for the final ~30 minutes of flight, with flights along the A-train track giving the best orientation for future analysis; HSRL overheated during the extended low-level legs and will be turned off in future low-level legs; UND CDP did not function and no CIP images were obtained during the flight, otherwise the microphysics probes worked well.

Flight Instrument/logistics notes: A calibration speed run in clear air was executed at about 500 feet above cloud as needed to interpret data from the hot-wire cloud probes (normal speed, 30 seconds at maximum speed, 30 seconds at minimum speed). For winds, a run was obtained

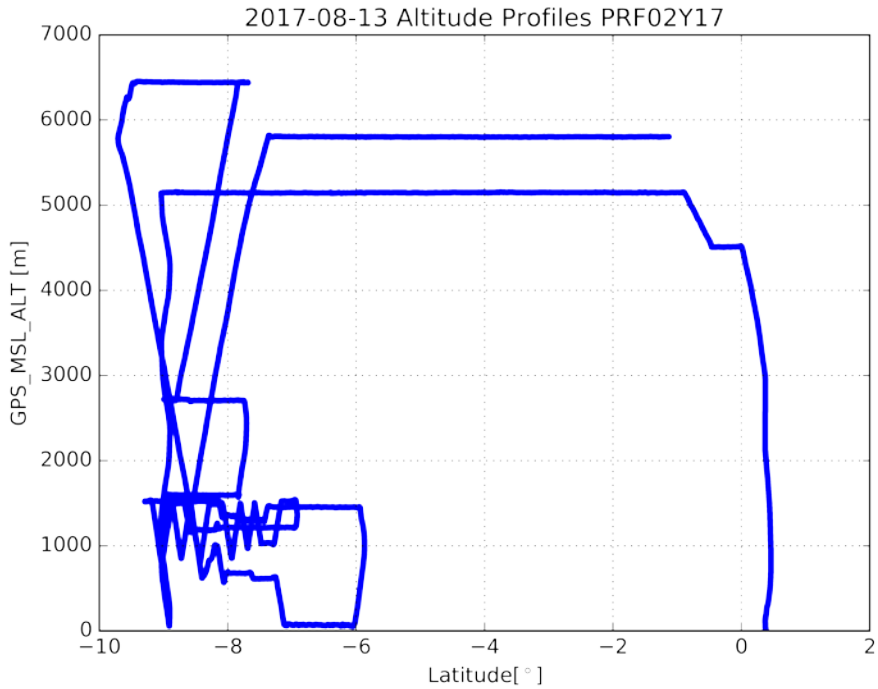
where data were obtained at 5000 feet oriented against the wind, and then on reverse course at same altitude/location into the wind. HSRL-2 should be turned off during future extended low-level runs.

Selection of cloud for sampling:
The area between 7 and 9˚S was selected for sampling. There were two clearing areas that were expanding slowly towards the cloud area of interest: one to the NE of the A-train line (~5S, 5E) and to the SE (a long north-south band along 5E and 10-20 S). Three was also a narrow gap around 8˚S which seemed to mark a bit of a transition in cloud morphology. Because there was worry about encouraging of clear areas both north of 5˚S and south of 10˚S, it was decided to work between 7 and 9˚S that would give variations in cloud fraction (from overcast to broken south to north, and also variation in cloud properties with presumably deeper and higher LWCs to the south) and also maybe more of a transition in cloud/aerosol properties. Thus, it was decided to fly to 9˚S where the overcast cloud layer was for the initial square spiral. The clear sky area ultimately filled in somewhat, but cloud was definitely thinner and more variable in this area.





Altitude Profile flown:



Run Table [UTC; approximate times okay, lack of detail okay. Just note major transitions, such as takeoff, time at point of furthest extent, time at beginning and end of major profiles with their detail relegated to the notes, such as spirals, level legs, straight profiling, and landing time**]**

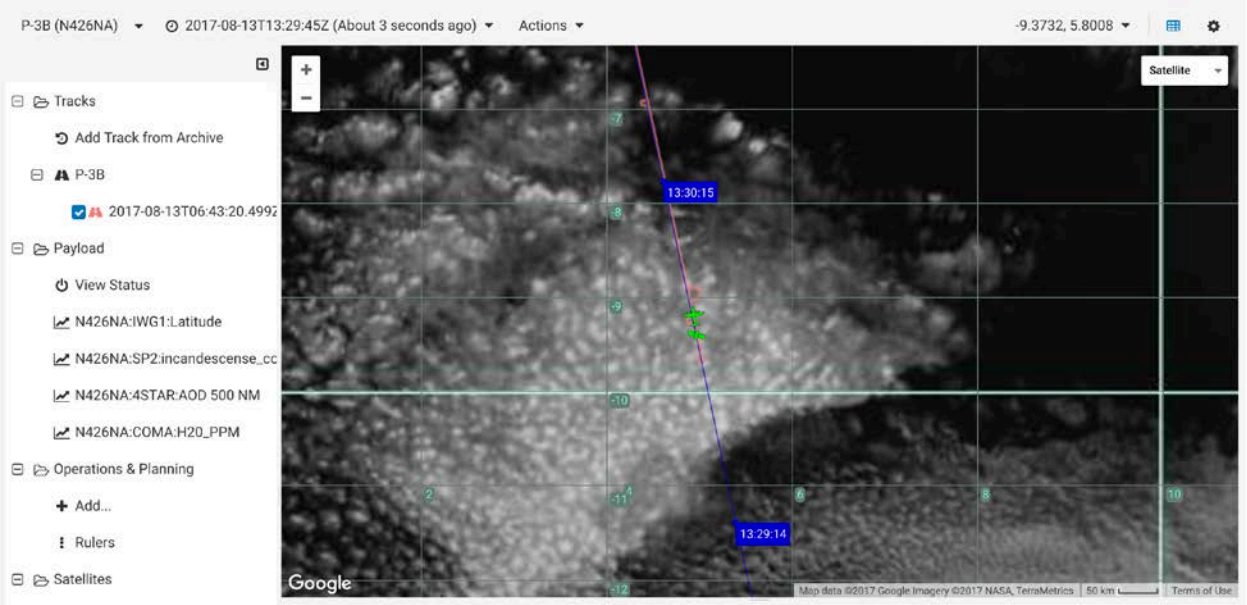
description	beginning time	end time	altitude	notes
Takeoff	7:57	X		Big plume with biggest CO sampled in whole mission when left Sao Tome; 4-STAR noted AODs of .7 at 900 nm in this region. Aerosol was elevated in layer at about 6.3 kft and 40 μg or organics alone. Seemed to be two layers, one centered at 2 km descending to north and a lighter one at 3 km ;Plume top at 15.3 kft.
Ferry leg	8:23	9:26	5000 m	AOD 0.04 to 0.05 at 500 nm on ferry leg (either dust or thin BB layer)
Remote sensing leg	9:26	10:03	5000 m	Starting at 6 S, south along CALIPSO track. Aerosol above cloud at 6 S, slope down to touching cloud tops by 9 S.
Square spiral down	10:04	10:21	5150 m – 60 m	Cloud top about 4200 feet, aerosol layer 11000 feet with AOD of 0.3; some drizzle and a few drops; small gap between aerosol and cloud top
Square spiral up	10:21	10:26	60 m – 1500 m	No gap between aerosol and cloud when spiraled back up and above-cloud AOD of 0.25
Sky scan	10:26	10:31	1500 m	AOD 0.25 from Sky Scan
Cloud leg	10:32	10:55	1200 m	Clouds thin, especially north of 8S with LWC < 0.1 g/m3 and CDP concentrations of 300 to 400 cm^{-3}

description	beginning time	end time	altitude	notes
Sky scan	10:55	11:02	1525	AOD of 0.25
Sawtooths	11:02	11:37	800 m - 1500 m	Dull saw tooths at north end (7S) and mid-way through leg (8S); rest were normal saw tooths with 500 feet above/below cloud sampled; Polluted MBL, but very high sulfate as compared to nitrate/organics (from AMS). Big nitrate jump above/below cloud. CDP CDNC ~300/cc at start of leg and ~200 at end (opposite of aerosol gradient…), LWCs up to 0.4 g/m3 at top of cloud; 500 foot gap (tenuous) between cloud top and aerosol seen in PCASP but not AMS
Above-cloud leg	11:37	12:29	1350-1550 m	Speed runs for microphysics included during first part of leg at 500' above cloud top. Middle part of leg was about (~100) above cloud top from 11:53 to 12:05 (tried to dip in and out of cloud to get data on mixing processes), and then ~500' above for rest of leg. Went north to 6 S for broken cloud; above cloud did not seem to be gap with aerosols, but was much stronger aerosol signal 500 feet above cloud; above cloud AOD was 0.5 at 6.2 S
Below-cloud leg	12:29	13:05	73 m – 650 m	12:29-12:45 at minimum safe altitude, rest of leg below cloud at 600-650 m (aimed for about 500 ' below cloud base). Final part of leg included time when skirted cloud base, going in and out of cloud.
Ramp up	13:05	13:27	650 m – 6500 m	Ascend at 1000 feet/minute to catch A-train overpass

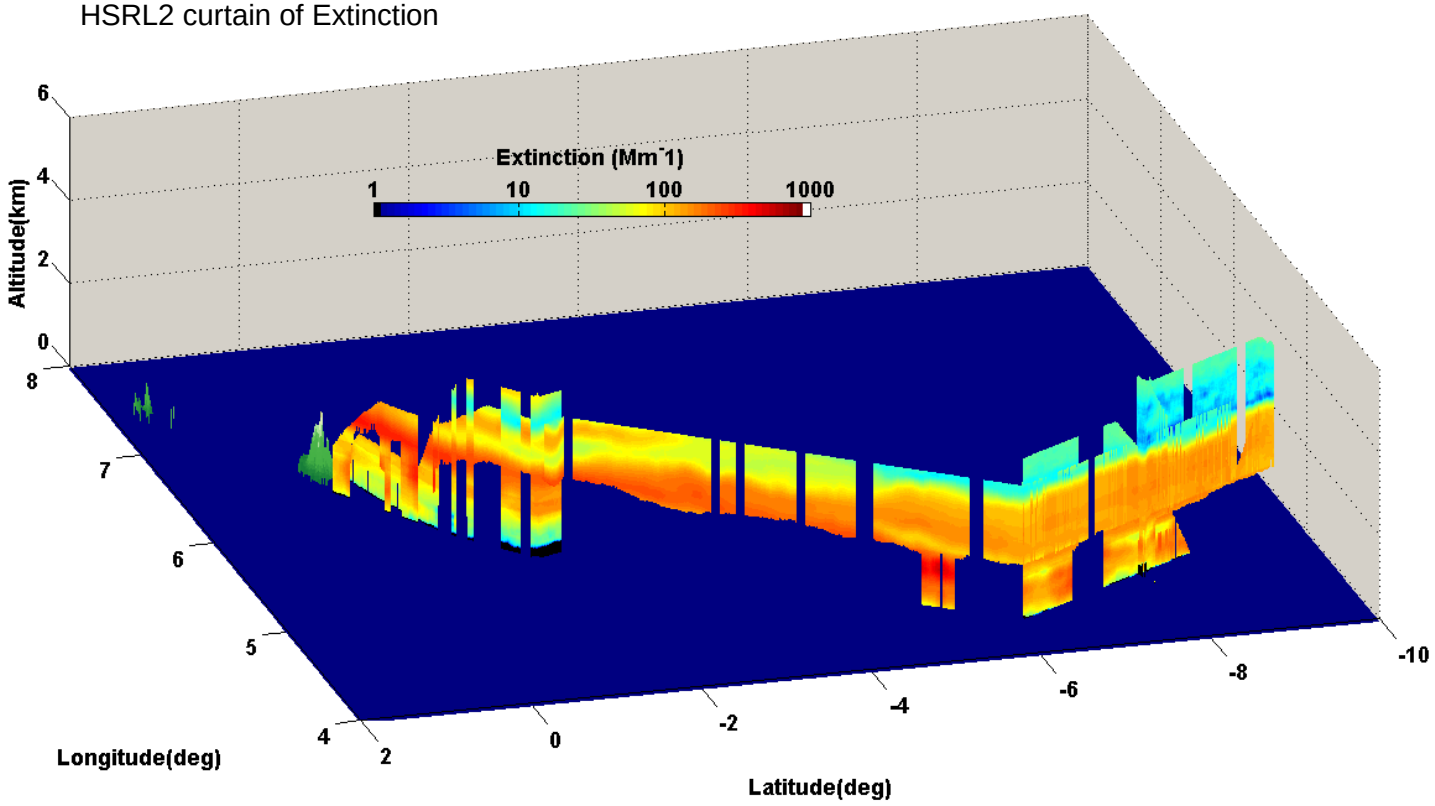
description	beginning time	end time	altitude	notes
Remote sensing leg	13:27	13:50	6500 m	A-trainoverpass at 13:29. HSRL2 shows very sharp plume top boundary.
Ramp down	13:50	14:02	6500 m – 2700 m	SP2 rBC count also shows very sharp plume top boundary
In plume leg 1	14:02	14:22	2700 m (8500”)	Including ramp down to plume leg 2 in time
Spiral down to plume leg 2	14:22	14:29	2700 – 1600 m	Short spiral to 5000 feet for plume leg 1
In plume leg 2	14:29	14:43	1600 m	Including ramp back up to altitude in leg
Return in plume leg 2	14:43	14:52	1600 m	Constant altitude run at 5000 feet for 5 minutes for speed run needed for winds calibration
Transit back	14:52	16:27	5800 m	Includes ascent to 20 kft to transit home. At 2 S, cirrus was seen, and was also abundant mid-level cloud around TMS that had been coming in all day
landing				

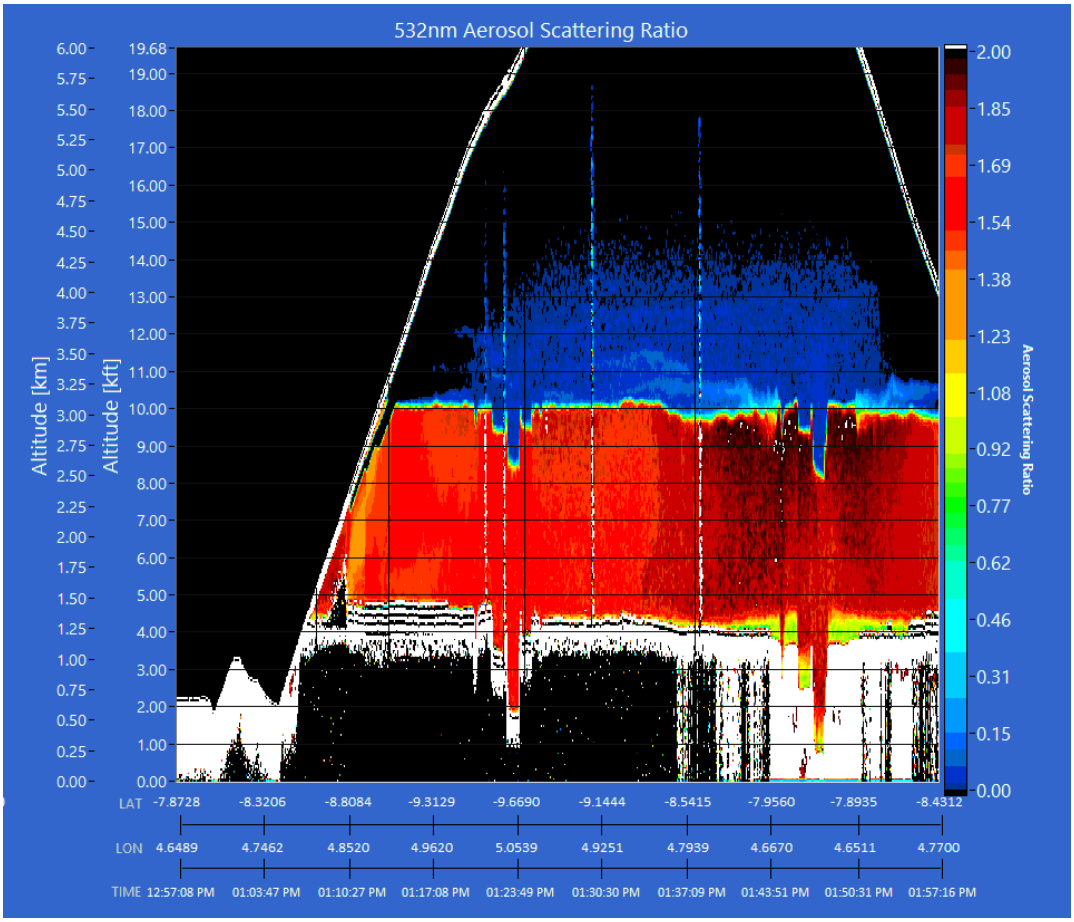
visual notes: any photographs, additional images

P3 / ATrain (CALIPSO) coincidence, with P3 at ~6k' for remote sensing (HSRL2 & RSP) leg.



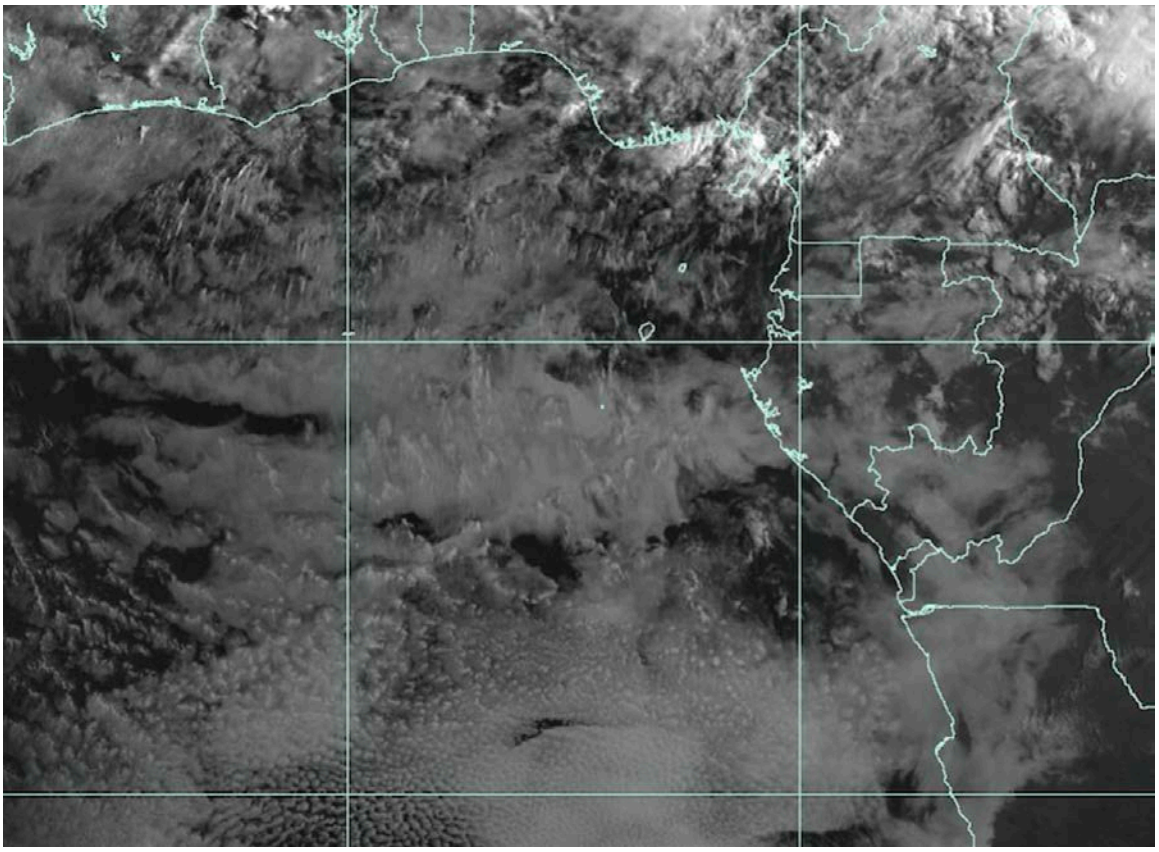
HSRL2 curtain of Extinction



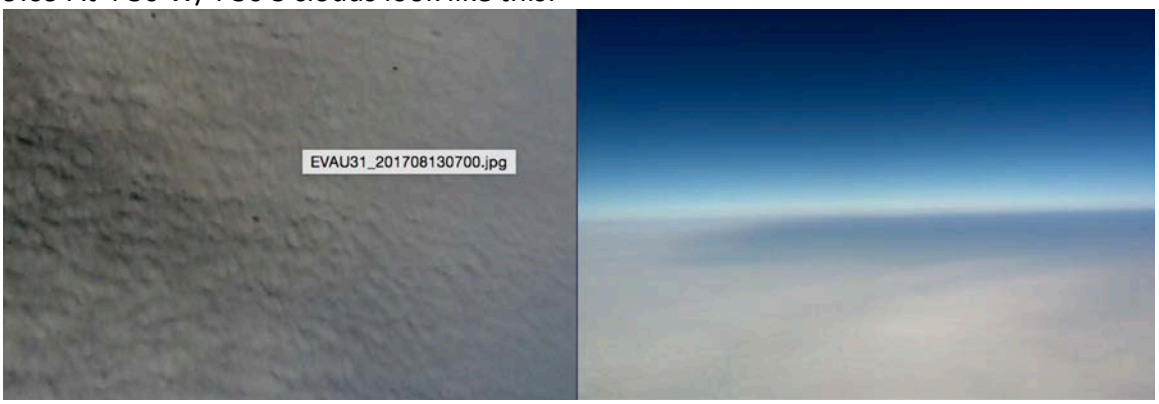


HSRL2 Aerosol Scattering Ratio on transect southbound to 9S then northbound to 8S. (Note that the mirrored abrupt “dips” in the altitude of the signal are an artefact that occurs when the plane is turning.)

HI-RES VIS imagery (7 UTC)



9:09 At 4 30 W/4 30 S clouds look like this:

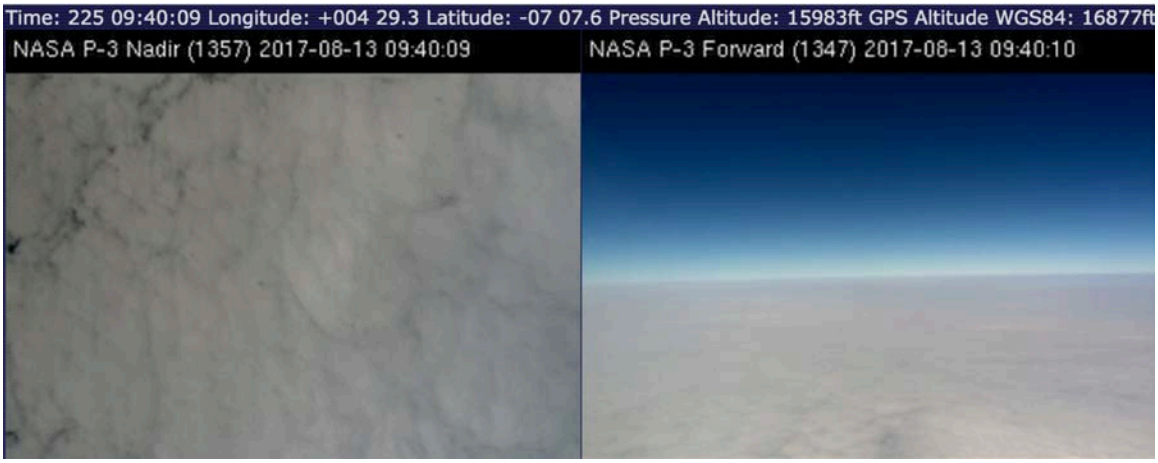


Looks like we have some clearing ahead, exactly as expected.

9:14 Just crossed a boundary, got different morphology before getting into clear:

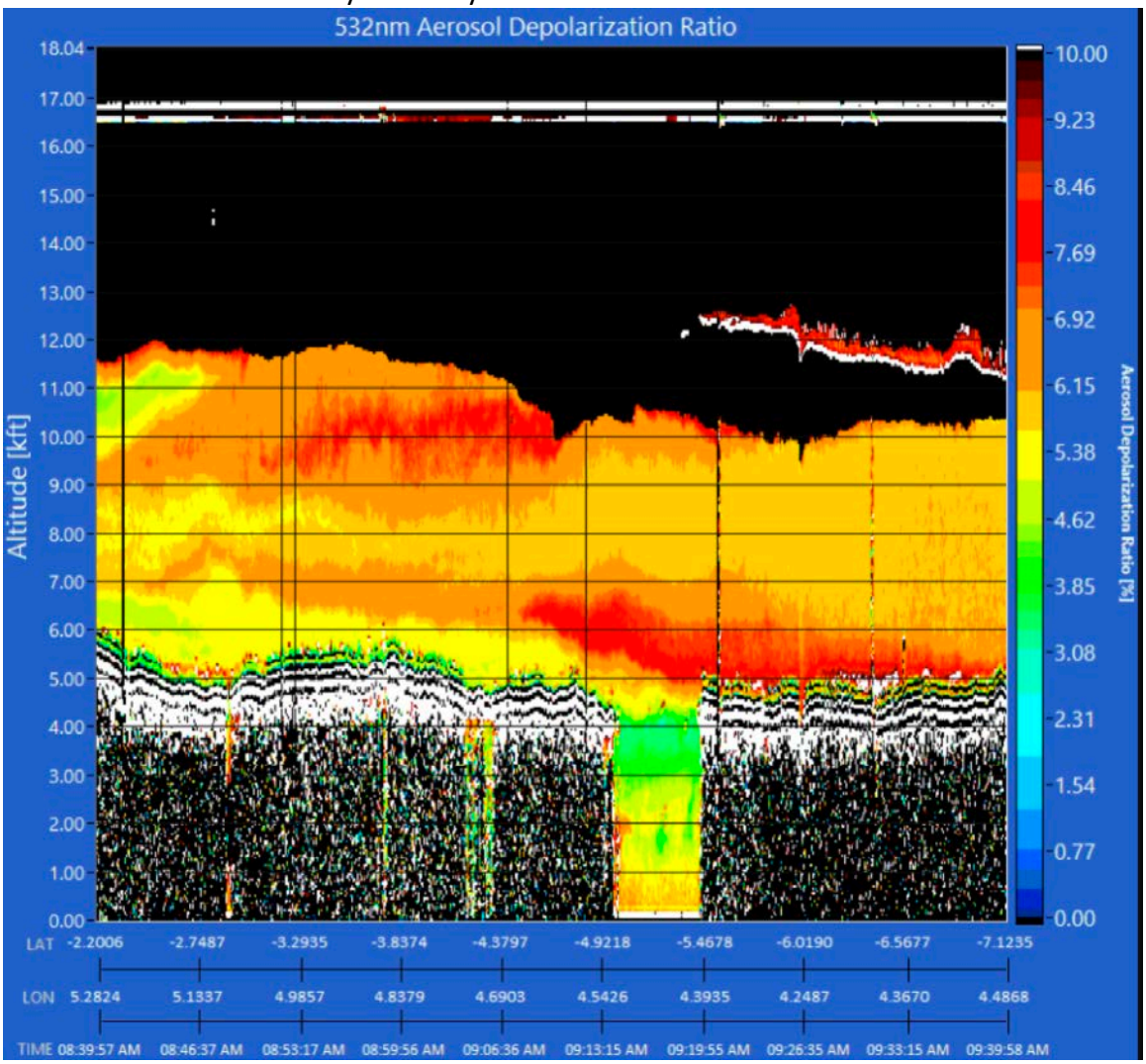
9:15 Now in clear. Boundary @ 5S

9:40 Cloud structure

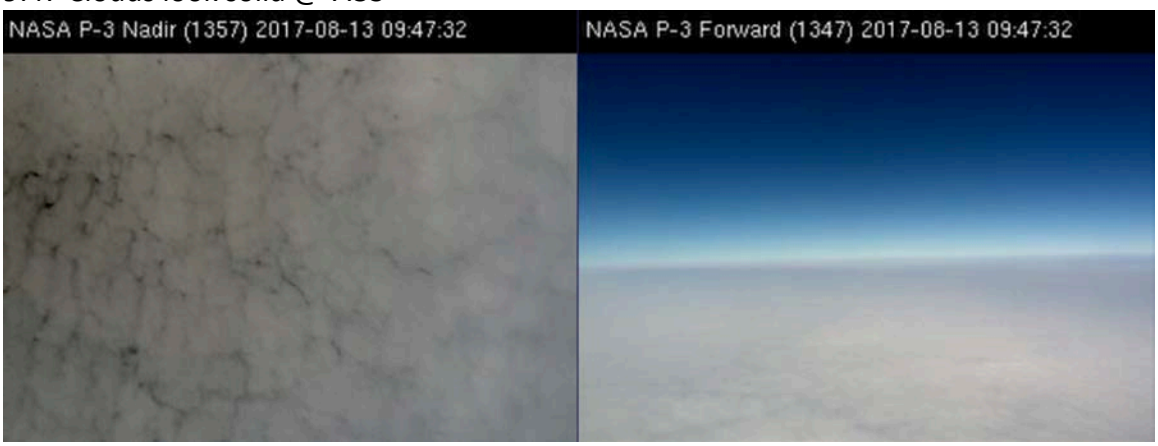


…expecting clearing very soon!

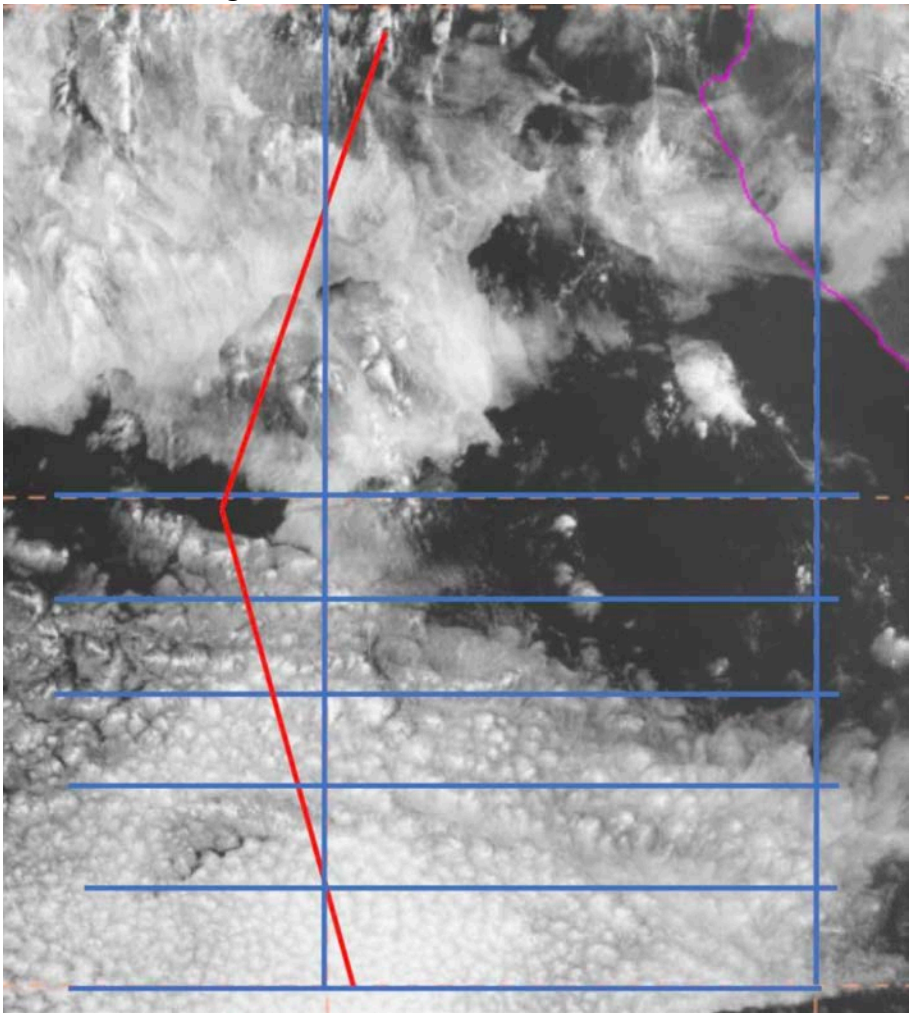
9:42/HSRL – look down into the short clearing. The layer at 2kft could be humidified aerosol that's left from a secondary cloud layer



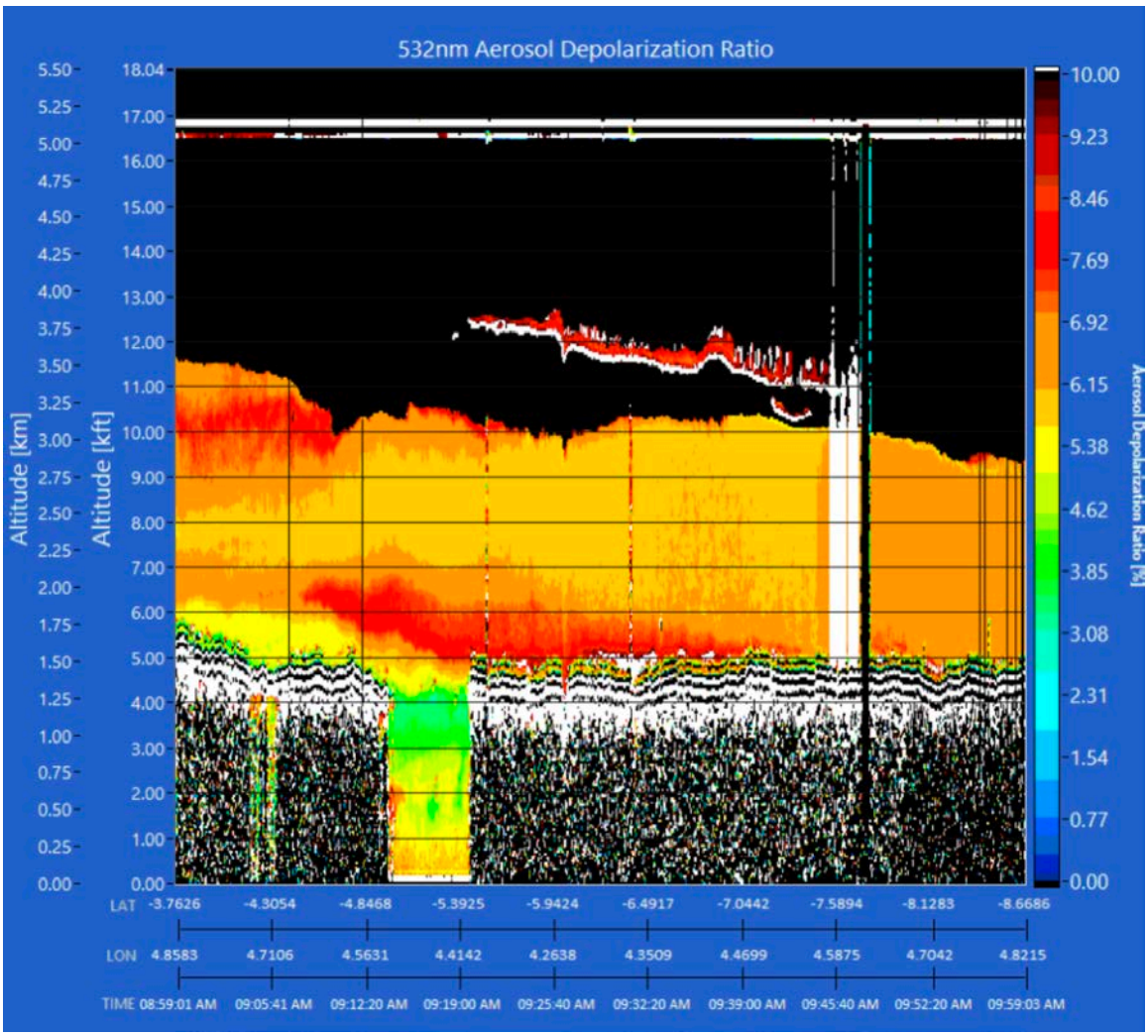
9:47 Clouds look solid @ 7.5S



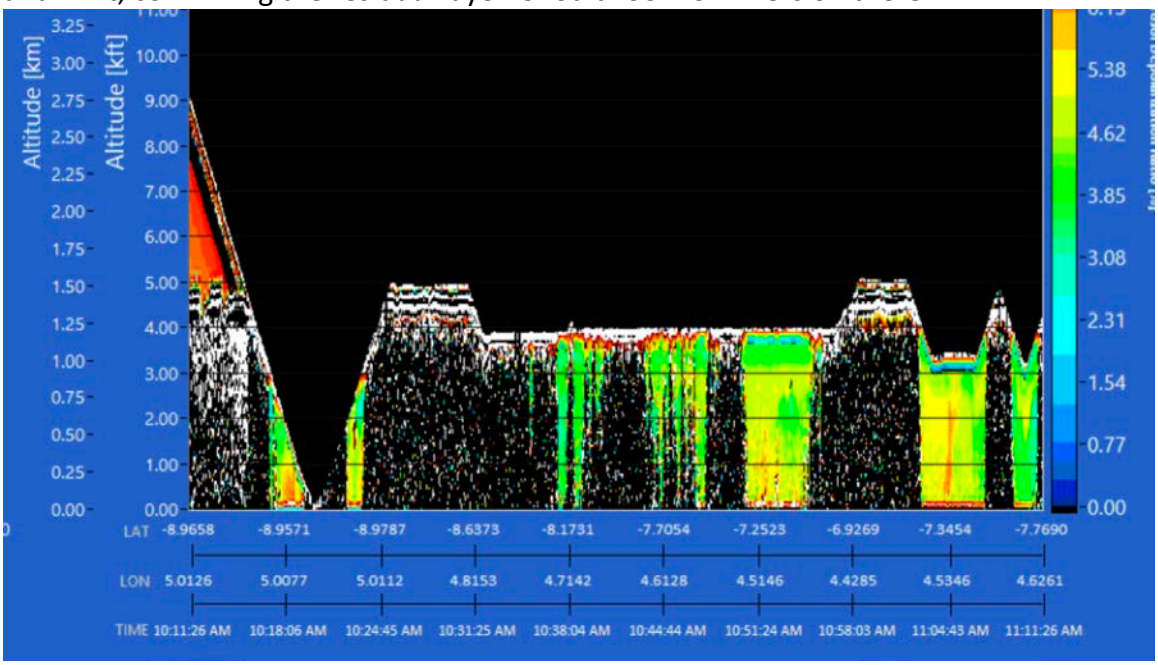
9:53 Wind 100deg

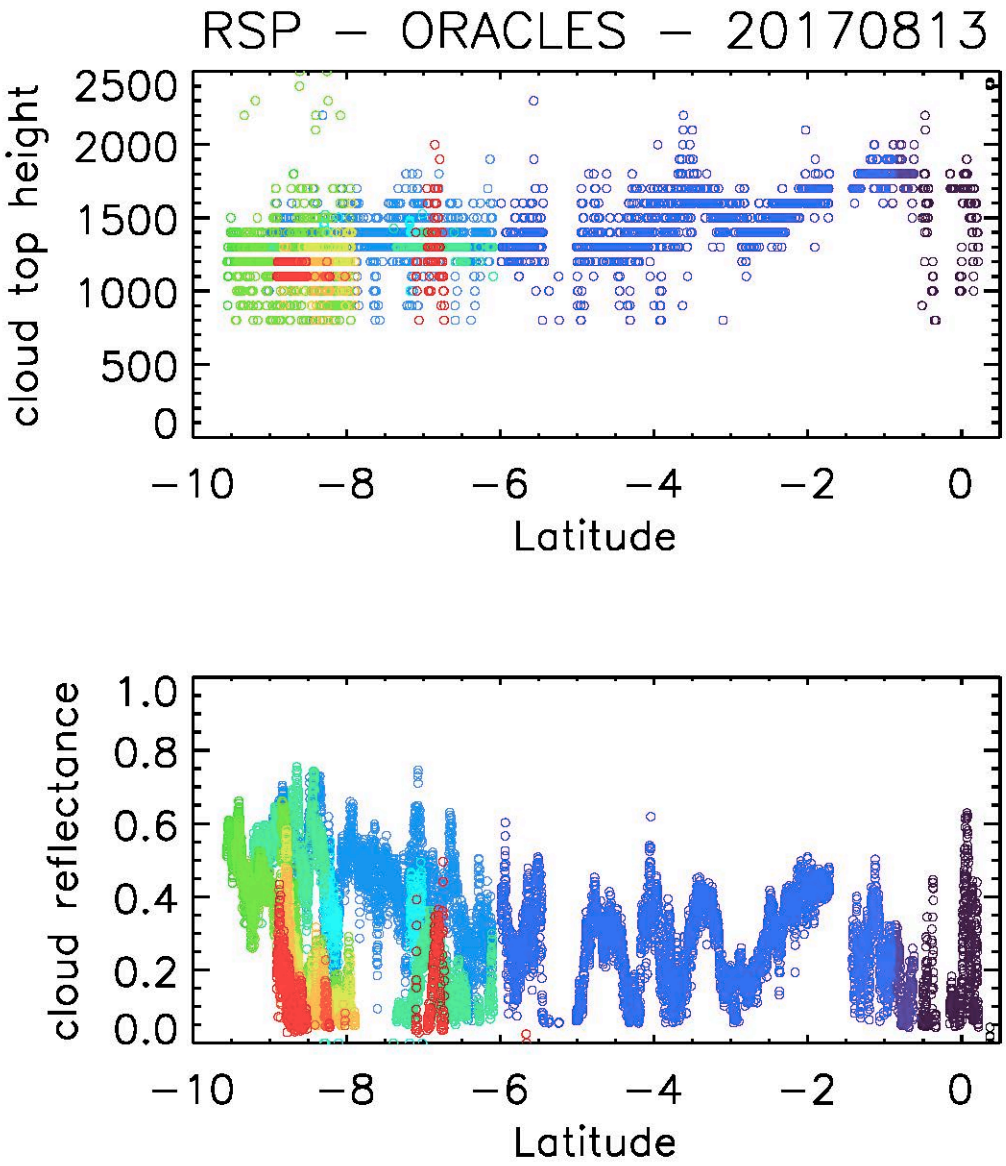


10:00

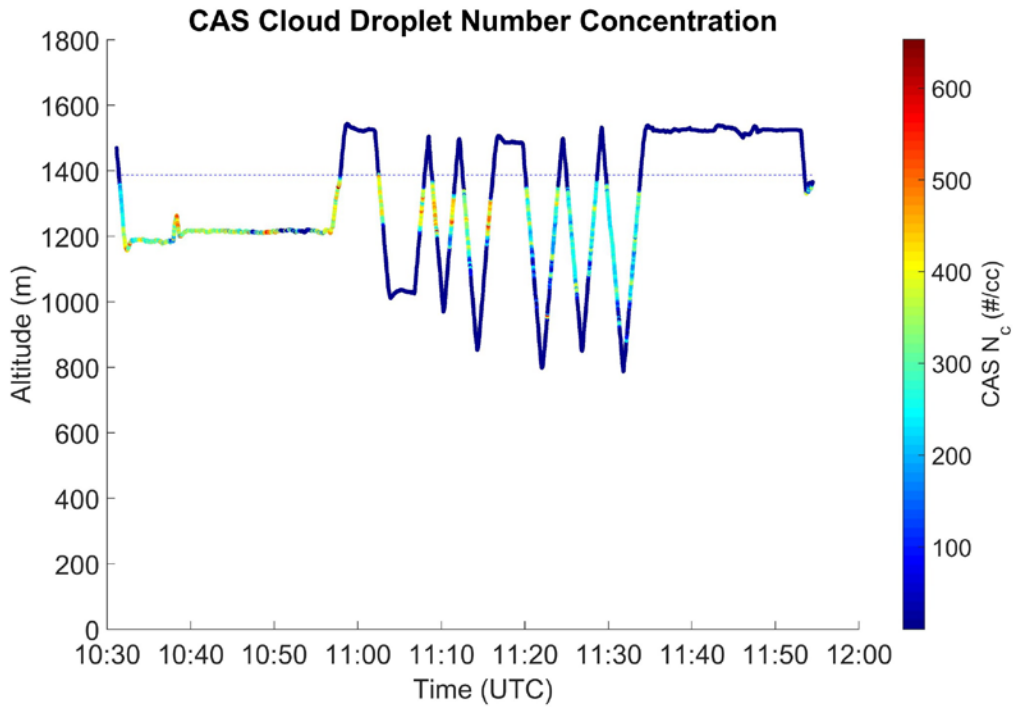

532nm Aerosol Depolarization Ratio
Altitude [km]
Altitude [kft]
Aerosol Depolarization Ratio [%]
LAT -3.7626 -4.3054 -4.8468 -5.3925 -5.9424 -6.4917 -7.0442 -7.5894 -8.1283 -8.6686
LON 4.8583 4.7106 4.5631 4.4142 4.2638 4.3509 4.4699 4.5875 4.7042 4.8215
TIME 08:59:01 AM 09:05:41 AM 09:12:20 AM 09:19:00 AM 09:25:40 AM 09:32:20 AM 09:39:00 AM 09:45:40 AM 09:52:20 AM 09:59:03 AM

HSRL again reveals “residual layer”. Visually, there ARE indeed some puffy clouds between 1 and 2 kft, confirming the residual layer. Should look for inversion there.

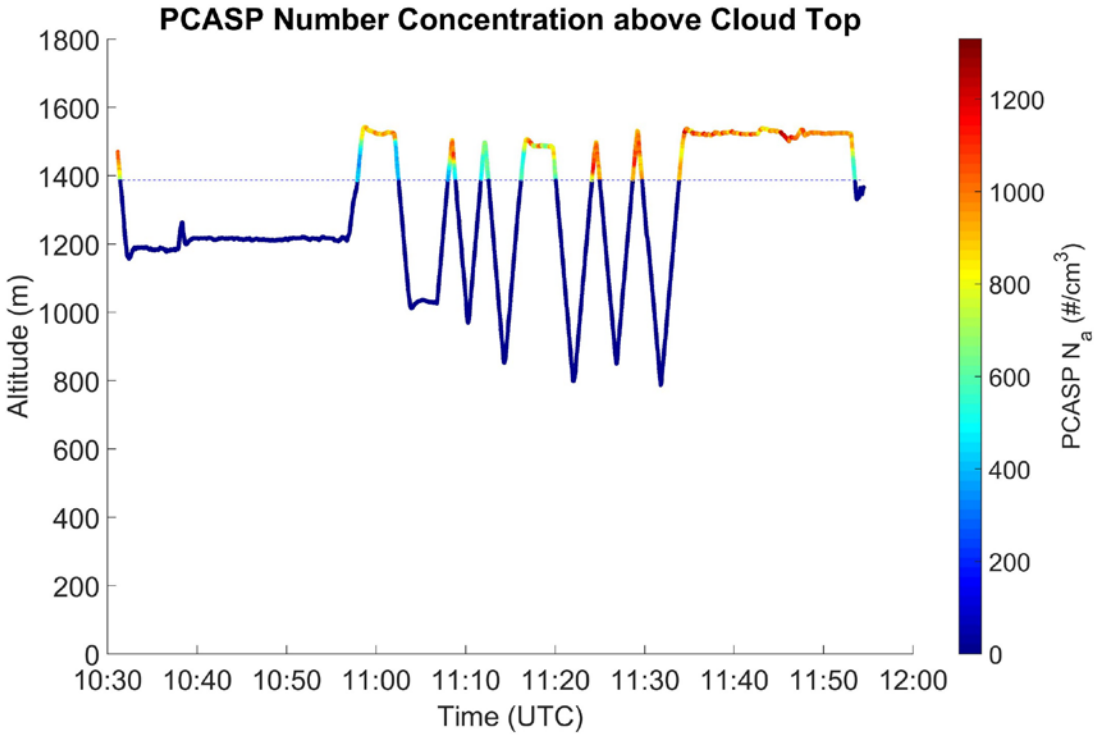




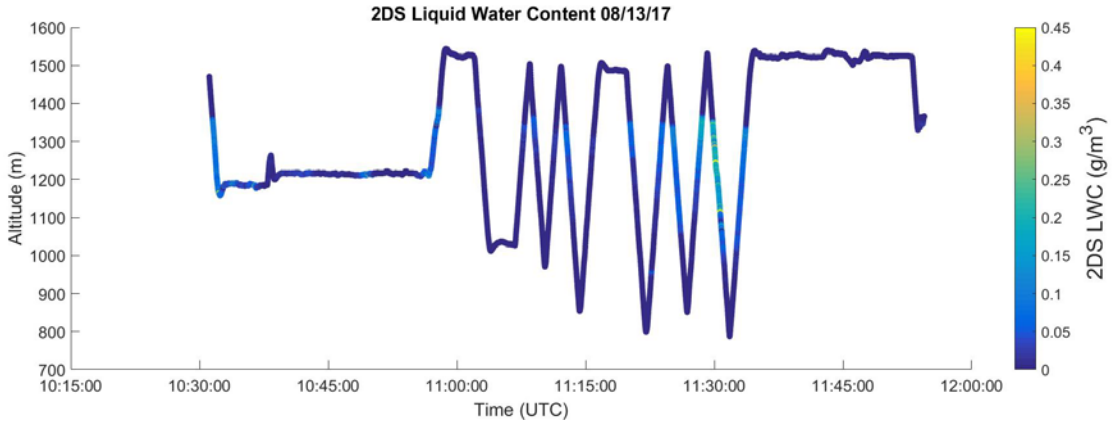
Cloud top altitude and cloud reflectance detected by RSP during the flight; points are colored according to time in flight when they were detected



Cloud droplet concentration measured by CAS as function of time for constant altitude cloud leg, saw tooths and above cloud leg.



PCASP concentration as function of time for cloud top altitude run, saw tooth runs, and above cloud run. Only data from outside of cloud are reliable.



LWC from integrated 2DS size distributions as function of time for constant altitude run, saw tooth run, and above cloud top run.

please upload to https://espo.nasa.gov/ORACLES/node/add/mission-science-report when done, if access is a problem either email to bernadette.luna-1@nasa.gov to upload or ask her to grant access permission.