PRF03 2 October 2018 **Mission Report**

flight scientist: Greg McFarquhar
mission scientists: Rob Wood and Michael Diamond

Flight plan and objective: The goal of the mission was to conduct a routine flight along the N-S line at 5˚E transiting at high altitude to map the complete cloud-aerosol column with HSRL and with the other remote sensors, and then to execute a series of profiling legs (legs below, within, above cloud, sawtooths through cloud and profiles/constant altitude legs of free tropospheric aerosols). The meteorological target was pockets of open cells (hereafter POCs) that were expected between 6.5˚ and 10.5˚S along the 5˚E line, so that the same clouds could be targeted on the next flight which would concentrate on Lagrangian sampling. From the forecast, some high clouds were expected north of 4˚S, with not much expected further south. A thick layer of aerosols was also expected, with more aged aerosols closer to cloud top and fresher aerosols at higher altitudes (with maybe some more aged aerosols above these fresher aerosols).

Flight Summary: Upon departure from Sao Tome, the P-3 traveled towards point EREGA while ascending to 16 kft, and then started the southward leg along 5˚. During transit on this line a very thick aerosol layer was noted with aerosol optical depths of 0.45 estimated from the HSRL. During the leg the P-3 ascended to 19 kft to try to stay above the aerosol layer. At approximately 6.7˚S there was a transition from closed cells to POCs that was evident on the visible satellite imagery; however, with the thick aerosol layer it was harder to visually note this transition on the P-3. While over the POCs, there was some variation in the cloud top heights typically ranging from 2 to 2.5 kft, with a transition to higher heights as we moved away from the northern edge of the POCs. HSRL suggested that there as a clear aerosol slot immediately above the clouds (perhaps as a consequence of a collapsing PBL), but on rare occasion the tops of one of the clouds seemed to reach into the aerosol layer. Drizzle was noted on the APR. A square spiral was then executed at 10.5˚S, but only after extending 3 minutes beyond this point in order that RSP and other remote sensors could have a level leg to help interpret their signal on the square spiral. During the square spiral, the aerosol top was noted at 17.7 kft with variations in the intensity of the layers while descending. There was a thicker layer at 13kft (1.3ug m^{-3} of black carbon at the heart), a layer between 10 to 12 kft with good organic carbon concentrations but nitrates dropping off, higher black carbon of 1.5 mg m-3 at 9. 5 kft, and then the thickest aerosols at 8.7 kft, which were reportedly likely to be older aerosols.

At the bottom of the spiral, boundary layer sampling commenced. At first, the P-3 headed along the 10.5˚S line to 5.5˚E in order to intersect a patch of closed cells, with a plan of heading north on the N-S line in order to get better sampling of the POCs and also to intersect a ship track that was along this line. Upon reaching 5.5˚E, the P-3 turned and headed north, extending the boundary layer leg to another 12 minutes in order to get better aerosol sampling and to ensure that the below-cloud sampling continued across the boundary. The boundary layer was quite clean with a few big particles, low CN, CO < 70 ppb and O3 < 20 ppb. The aerosol was bimodal suggesting the cloud processing had occurred and some hairlike images on the 2DS were noted. Following the boundary layer leg, a series of 2.5 dull sawtooths were executed, where 2 minute leg flying above the clouds was executed. It was noted that there was a clean slot right above the cloud (~200 feet) and big drops were noted on the upward sawtooths. After the sawtooths, the aircraft ascended into the aerosol layer for a brief intrusion before descending to cloud level where a 15-minute level leg in cloud was executed so that the aircraft would be in cloud while at the location of the ship track.

Thereafter three constant altitude legs were flown in aerosol layers in the free troposphere. The three aerosol legs were flown at altitudes of 4, 8 and 11 kft (with a brief time spent at 14 kft to ascertain that the densest aerosols with peaks in aerosol mass and black carbon at 11 kft). Some of the following features

were noted during the aerosol legs: the bottom of the thick young aerosol layer was at 7 kft; at 8 kft, there was still a high above cloud aerosol optical depth of 0.45; there was some increase in water vapor coinciding with decreasing aerosol optical depth; and the ship track was crossed at 7.6˚S.

After these aerosol legs, a second square spiral was executed after ascending to 19 kft so that the entire vertical column could be sampled. A 3-minute constant altitude leg headed westward was performed before the square spiral for RSP. Observations during the descent included the following: at the thickest part of the aerosol layer ccn ~2000 cm^{-3} at 0.2-0.3SS%, with CN 2500 cm^{-3}; peak aerosol at 10 kft, 421 CO, high BC, scattering ~150/Mm in blue; big particles being seen on the 2DS; and a clean slot at 3 kft. Finally, a 40-minute constant altitude leg was flown at 11 kft on transit back to base sampling the densest aerosol layer. During this leg, four different speeds between min and max speed were flown for 2-minutes to give needed data to the winds instrument.

Forecast: POCs expected between 6.5˚ and 10.5˚S along the 5˚E line. Some high clouds expected north of 4˚S, but not much expected further south. Thick layer of aerosols expected, with more aged aerosols closer to cloud top and fresher aerosols at higher altitudes. Low clouds also expected from forecast.

Manifest (full flight)
Science (17): Greg McFarquhar [flight scientist]; Andrew Dzambo, Ousmane Sy; Kirk Knobelspiesse; Steve Howell, Cody Winchester, Amie Dobracki; Jenny Wong; Art Sedlacek; Jim Podolske; Siddhant Gupta; Sabrina Cochrane; Eric Stith; Sam LeBlanc, Ian Chang; Tony Cook, Dave Harper, Sarah Purdue
Ground mission scientist: Rob Wood and Michael Diamond

Instrument Status and Highlights:

4STAR: Above cloud aerosol optical depths up to 0.6
HIGEAR: Spike in black carbon over ship track (matching SP2); good CVI & TDMI data
HIGEAR-AMS: Multiple plume ages & ratios of nitrates/organics
PTI: Slight difference between SSA in aged and younger plume (.85 vs. .82); SP2 slight difference in coating (to be confirmed)
RSP: hi-level cloud bow observations before first spiral
APR: Drizzling between 7.5 and 8.5S in POCs
CCN: Active CCN in plume
COMA: High CO values correlated with PCASP, PTI and AMS
WISPR: Water isotopes seemed different for some shafts
HSRL: Aerosol layer 1000s ft thick; scattering ratio as high as 6 early on in flight, 3 later on
Cloud Probes: ~200 ft between cloud top and aerosol bottom; LWCs .3 to .45 g/m3, 10 mm size mode on CAS in-cloud leg; few large aerosols

Run Table [UTC; times are approximate]

Run Number	Start time	End time	Altitude	Notes
1	0701	0717		Takeoff until reach initial transit altitude
2	0717	0725	16 kft	Point EREGA until turned onto routine track

3	0725	0800	16 kft	Routine track at 16 kft
4	0800	0940	19 kft	Ascend to 19 kft to stay above aerosols and continue until reach 10.5 S
5	0940	1008	20 kft to 200 feet	Square spiral at 10.5 S
6	1008	1014	200 feet	Boundary layer run at 10.5 S from 5 E to 5.5 E
7	1014	1026	200 feet	Boundary layer extended to stay underneath cloud until past transition
8	1026	1045		Dull saw tooths that included an ascent into aerosol layer at end to siff out air above cloud layer
9	1045	1100		In-cloud leg
10	1100	1103		Ascend to sample aerosol layer in free troposphere at 4 kft
11	1103	1123	4 kft	Free troposphere aerosol leg at 4 kft.
12	1123	1126		Ascend to 8 kft for another aerosol leg
13	1126	1146	8 kft	Free troposphere aerosol leg at 8 kft
14	1146	1152		Ascend to 14 kft to sniff top of aerosol layer before descending to 11 kft for third aerosol leg
15	1152	1208		Free troposphere aerosol leg at 11 kft
16	1208	1219		Square spiral up to 19 kft to position P-3 for square spiral through whole column
17	1219	1228		Constant altitude runs at 19 kft to acquire data for RSP
18	1228	1249		Square spiral to boundary layer

19	1249	1302	200 feet	Boundary layer leg to sample aerosol
20	1302	1317		Sawtooths through cloud heading south
21	1317	1332		Above cloud leg
22	1332	1340		Ramp ascent heading north
23	~1340	~1420		Constant altitude run at 11 kft in free troposphere (included speed runs)
24	~1420	1517		Ascend to altitude for transit home

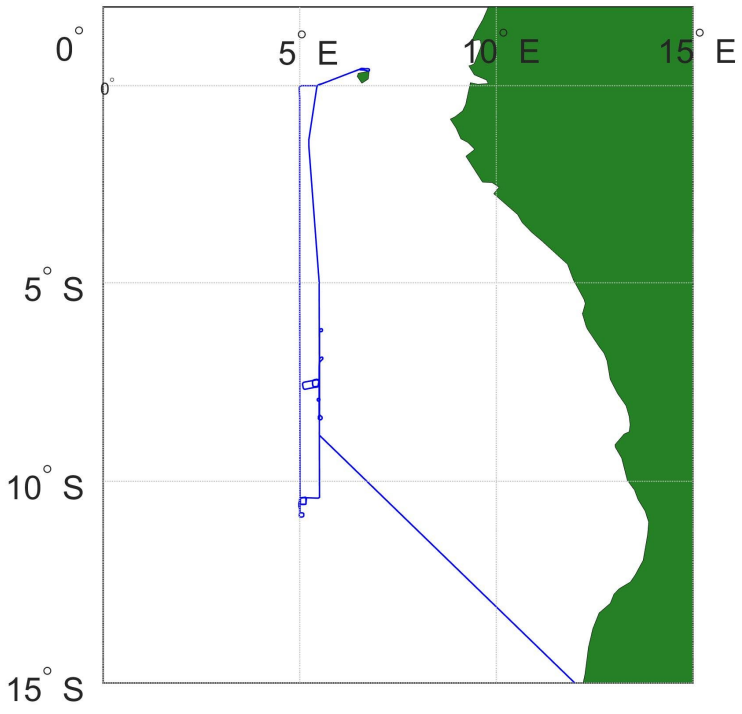

Figure 1: Flight path.

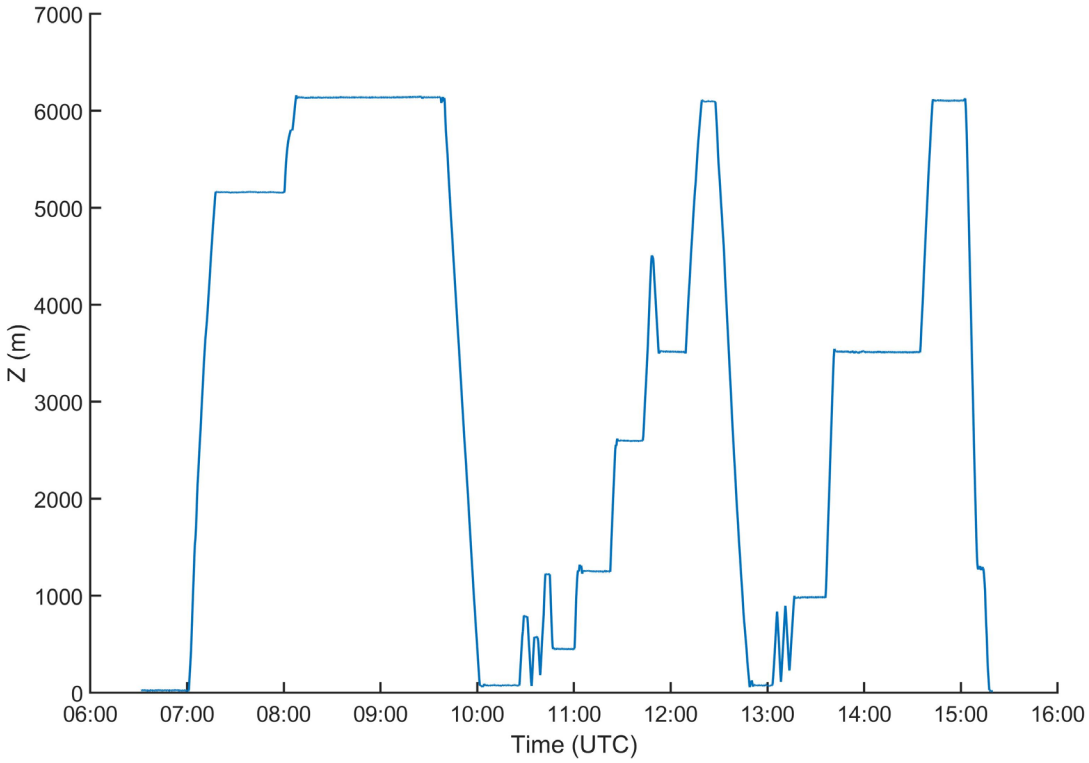

Figure 2: Flight profile.

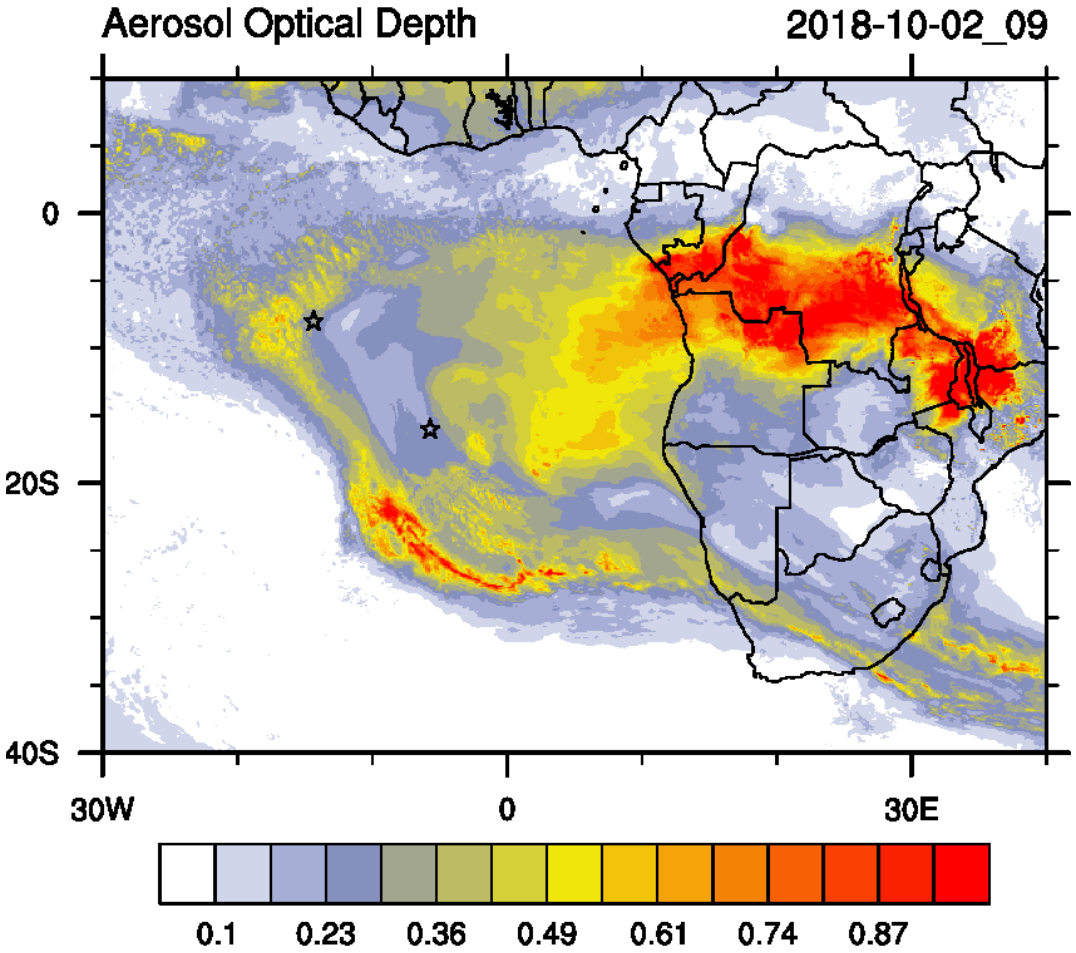

Figure 3: Forecast distribution of optical depth

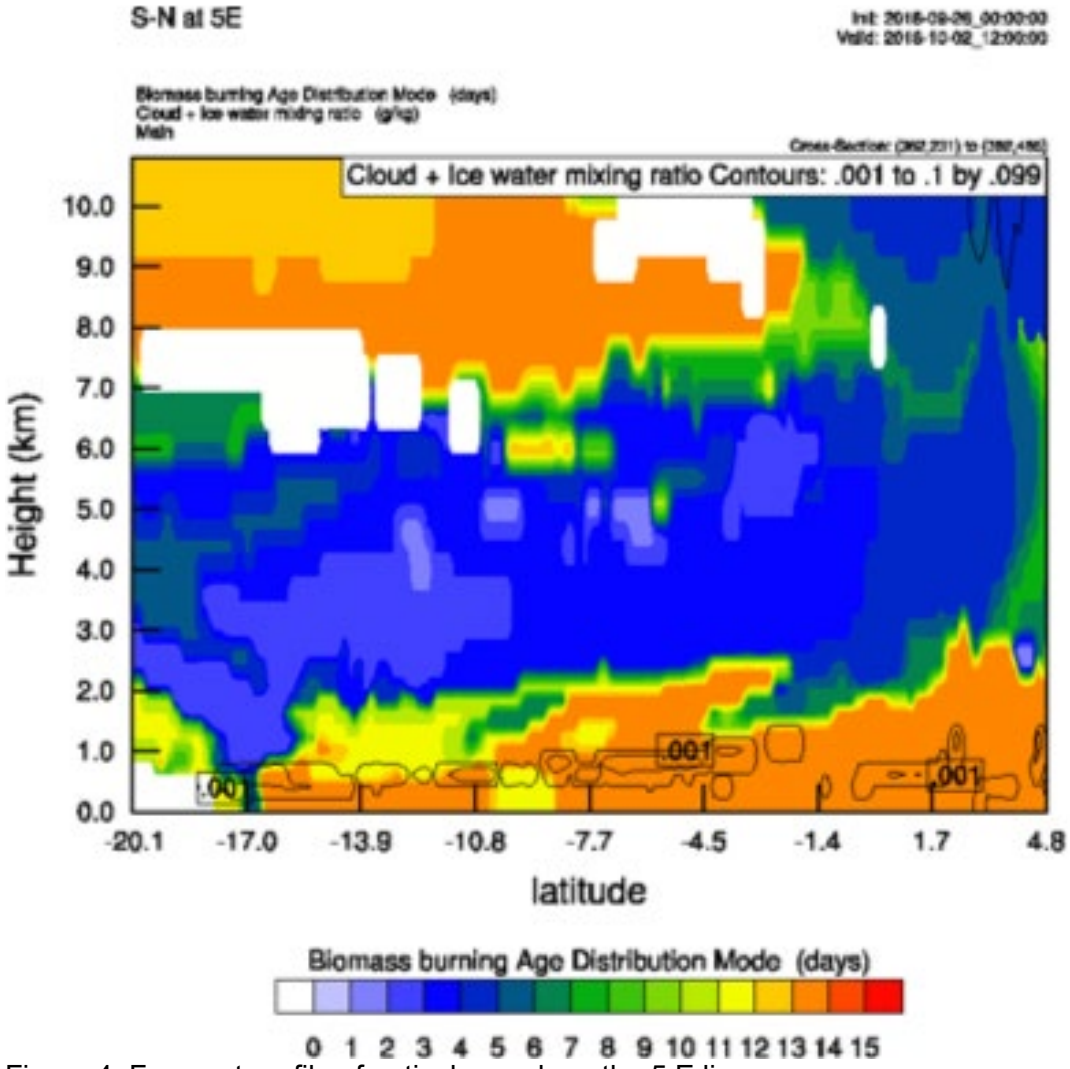

Figure 4: Forecast profile of optical age along the 5 E line

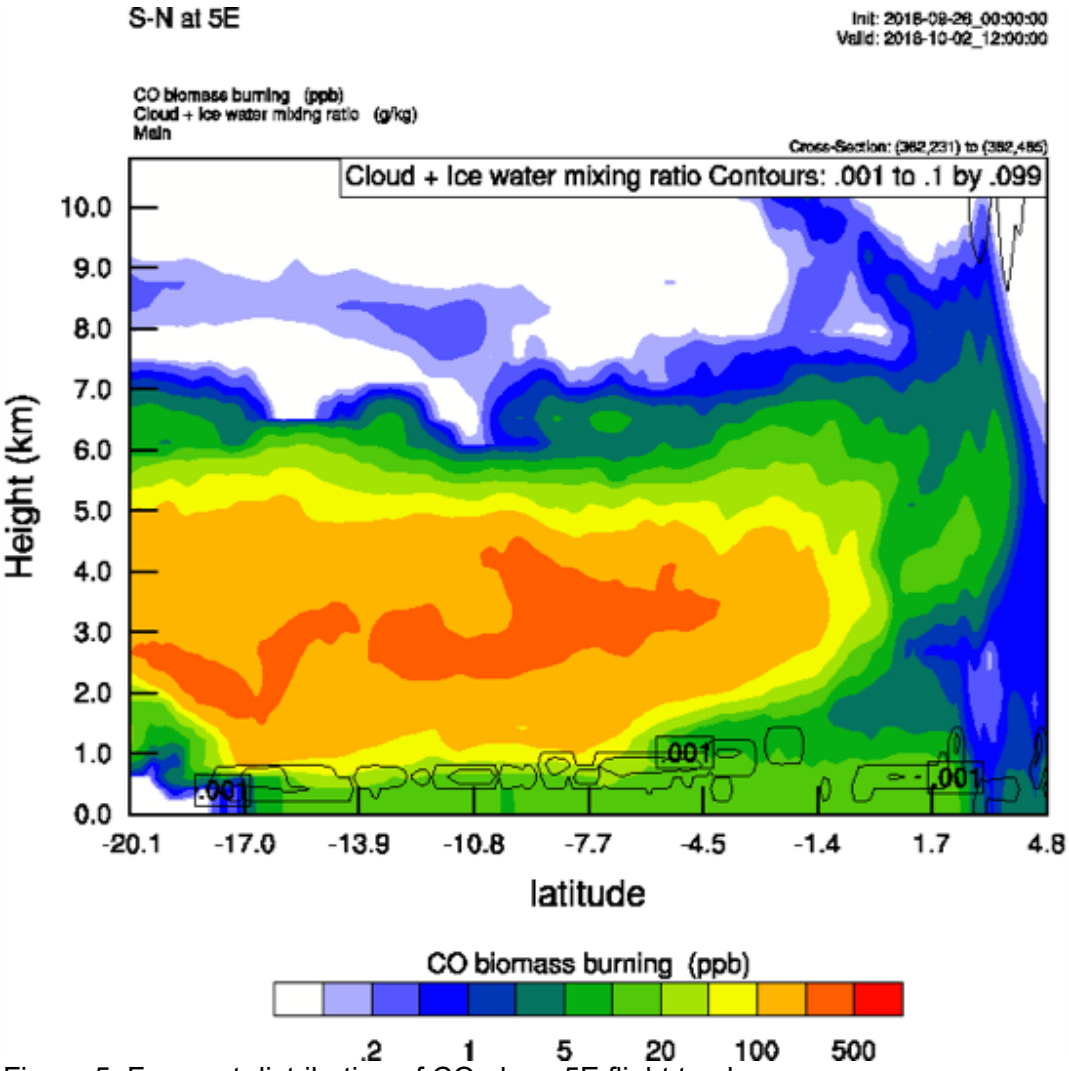

Figure 5: Forecast distribution of CO along 5E flight track

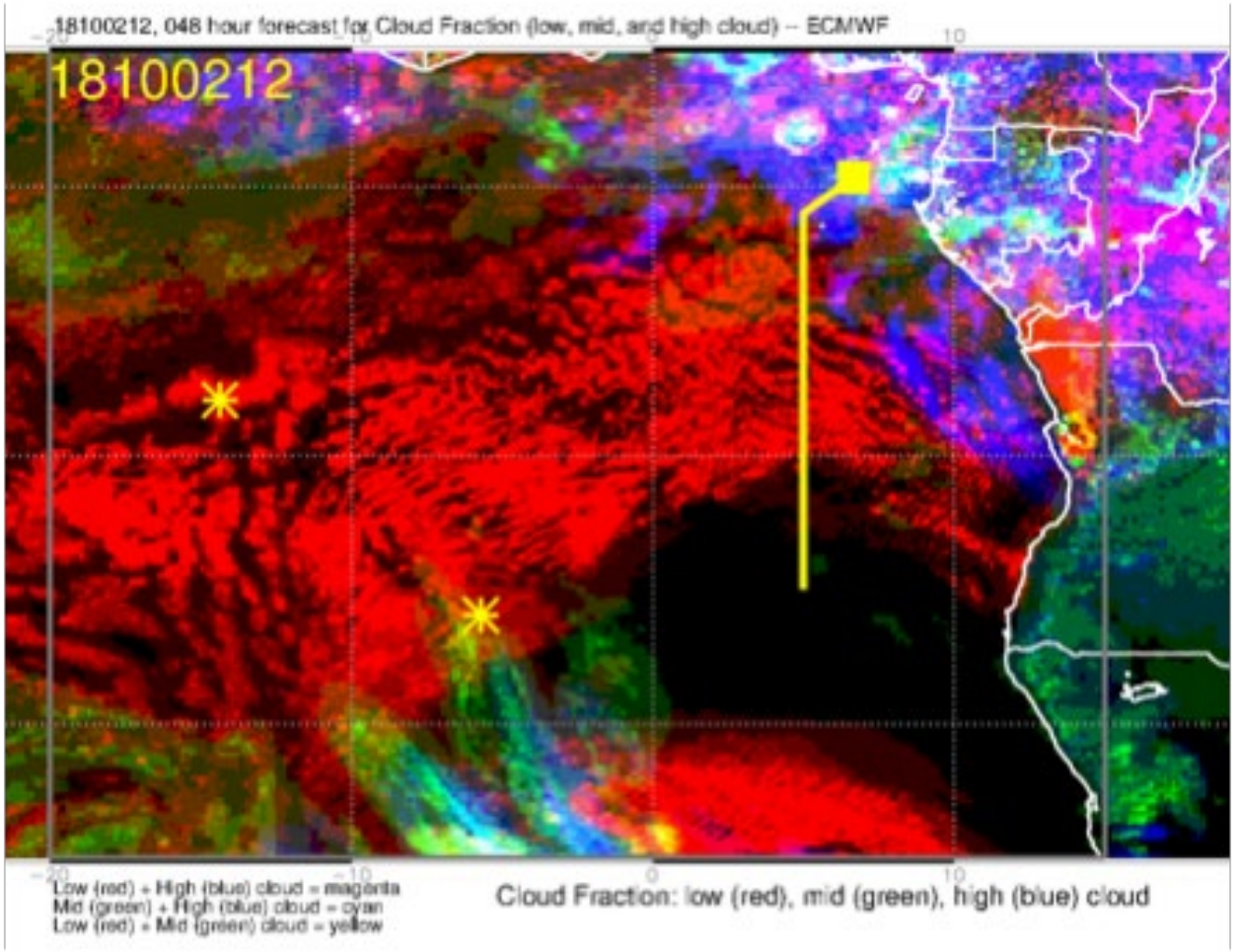

Figure 6: Forecast distribution of low, middle and high cloud

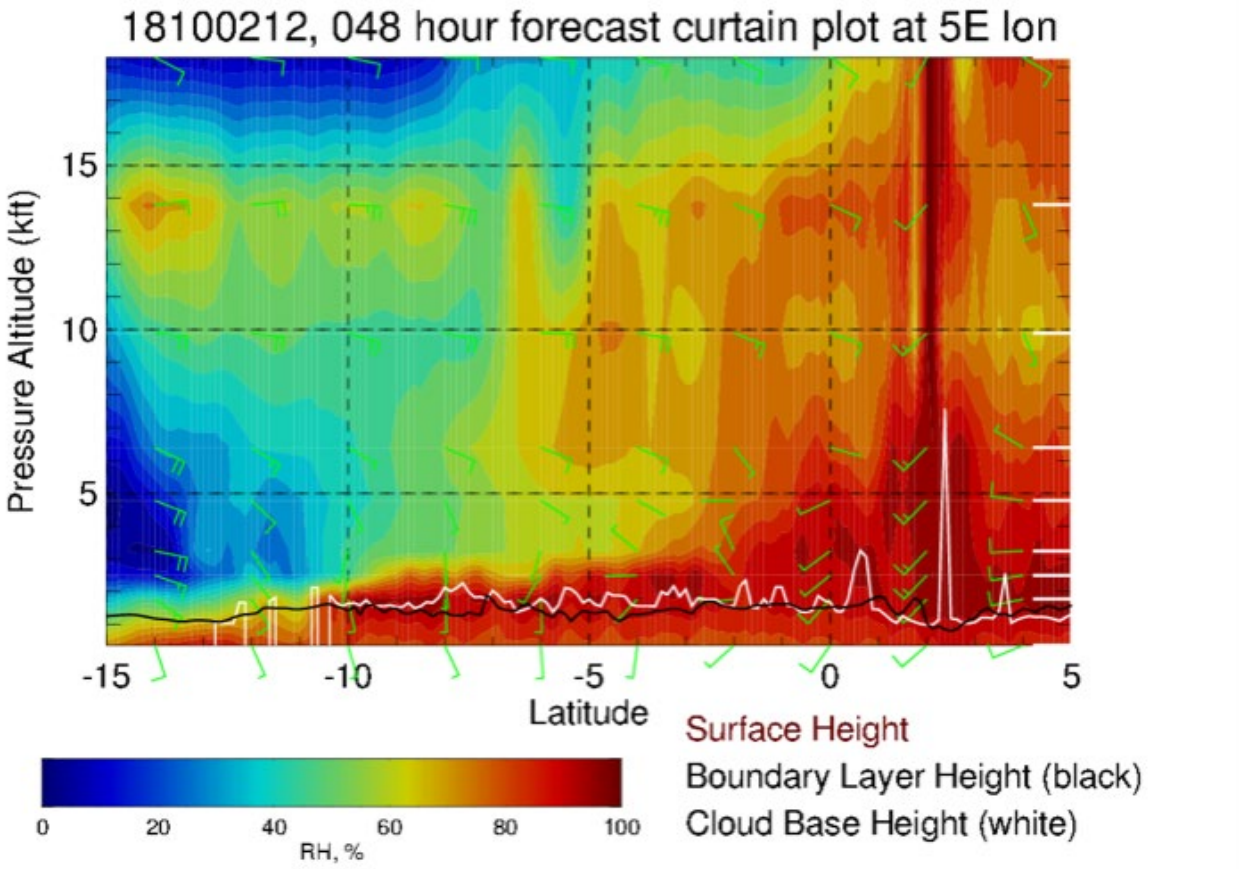

Figure 7: Forecast distribution of relative humidity, boundary layer height and cloud base height along 5E routine flight track.

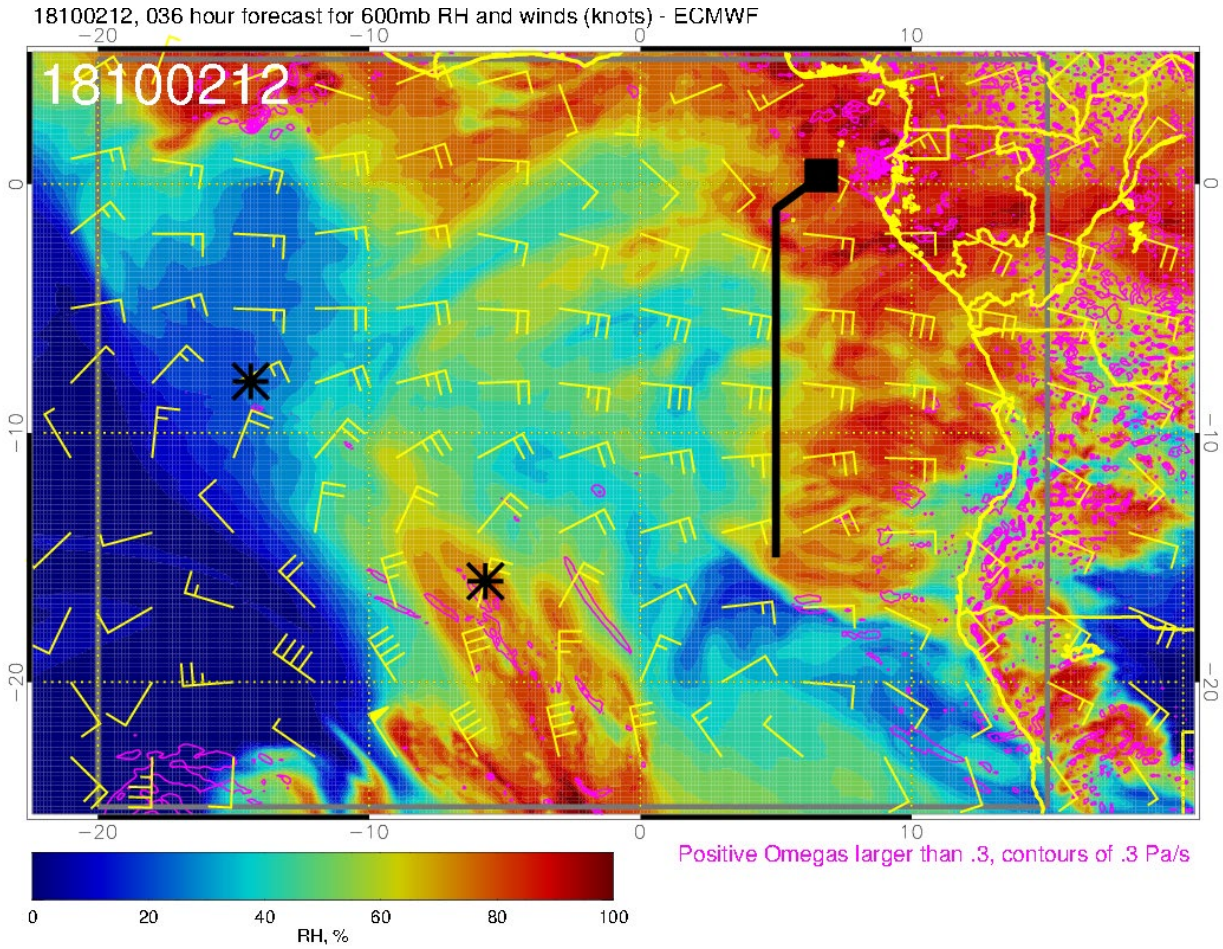

Figure 8: Forecast distribution of relative humidity and winds at 600 hPa

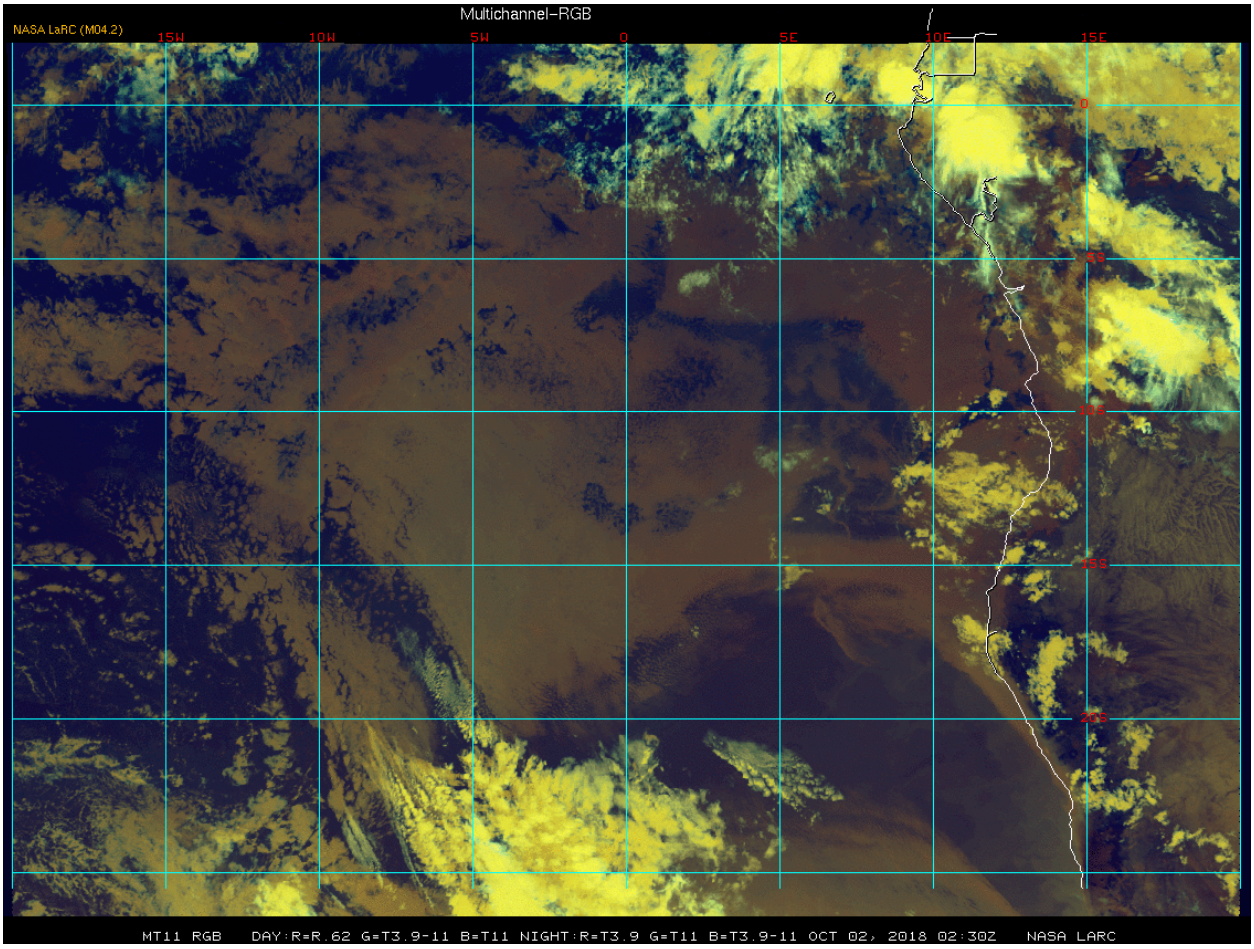

Figure 9: Multichannel RGB image near takeoff time

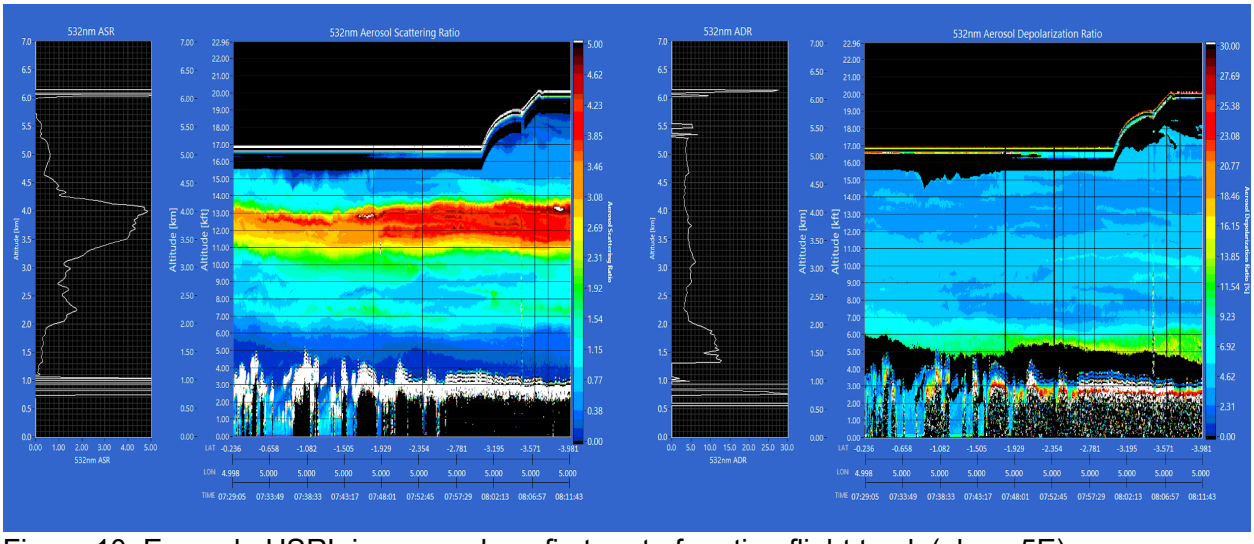

Figure 10: Example HSRL imagery along first part of routine flight track (along 5E)

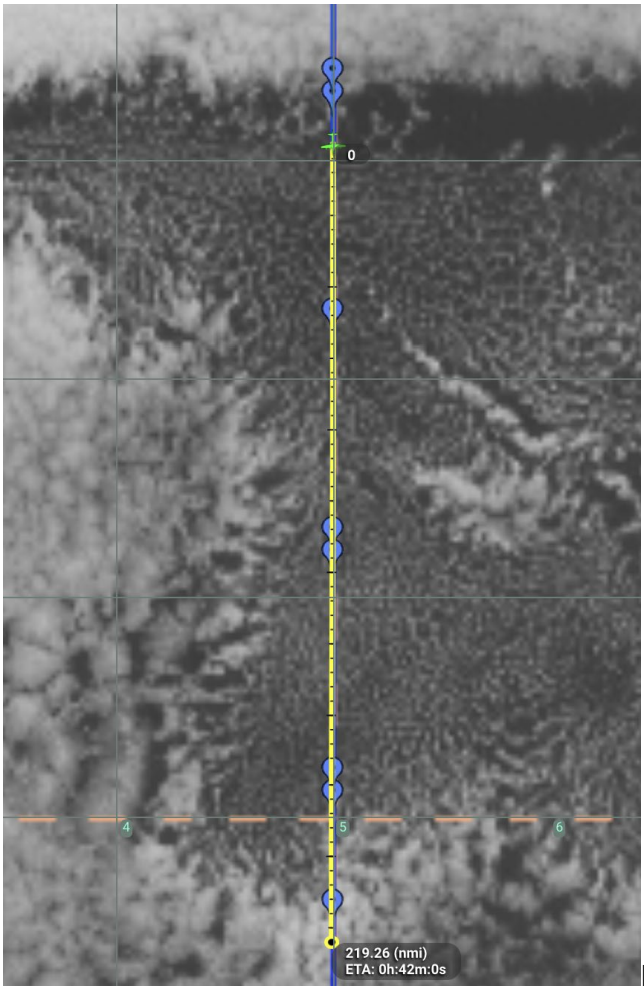

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Figure 11: Visible satellite imagery showing clear division between solid deck and POCs between 6.5S and 10.5S along routine 5E flight track

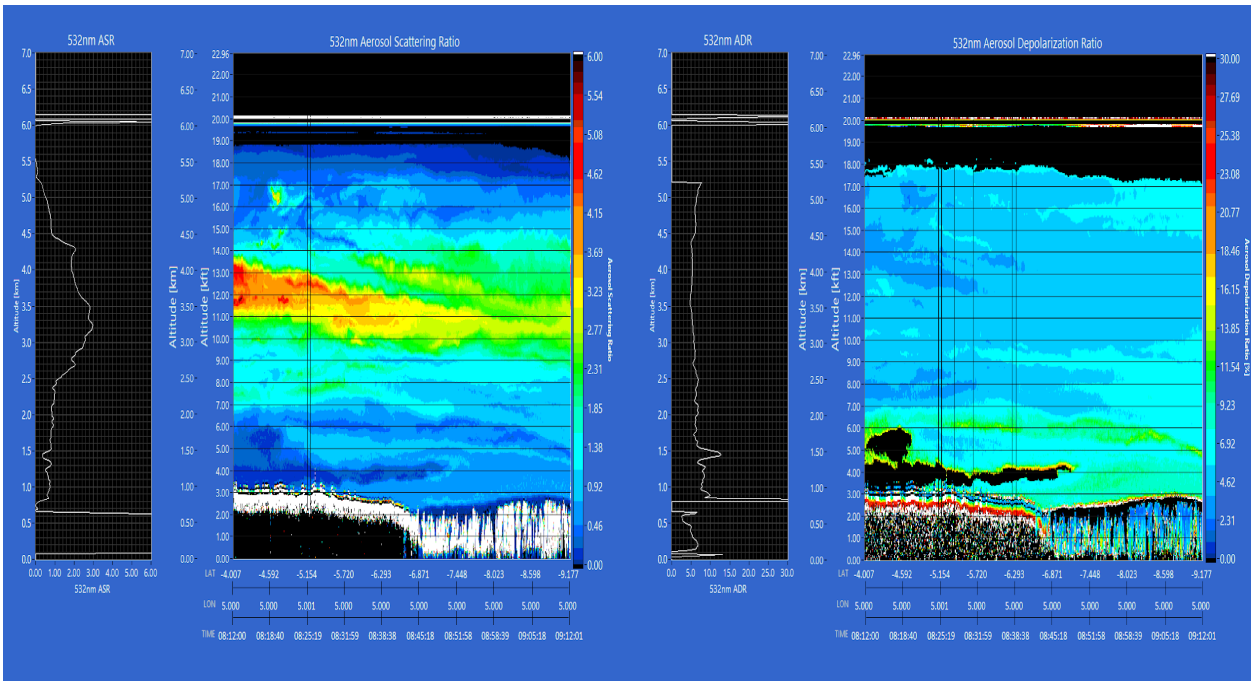

Figure 12: Example HSRL imagery as P-3 cleared cloud transition. See macroscopic changes in height of cumulus in POCs as P-3 moved south along flight track

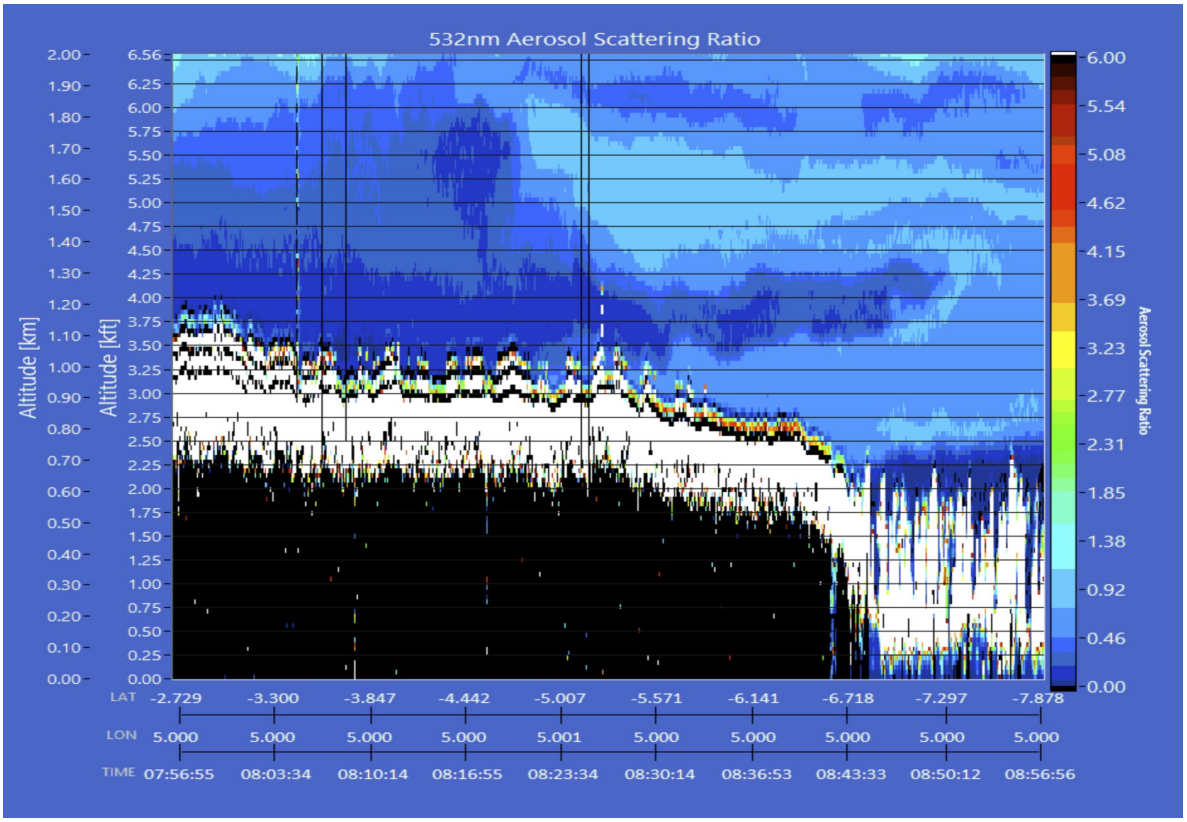

Figure 13: Close up of HSRL imagery showing clear aerosol slot immediately above POCs with occasional convective element penetrating the aerosol layer.

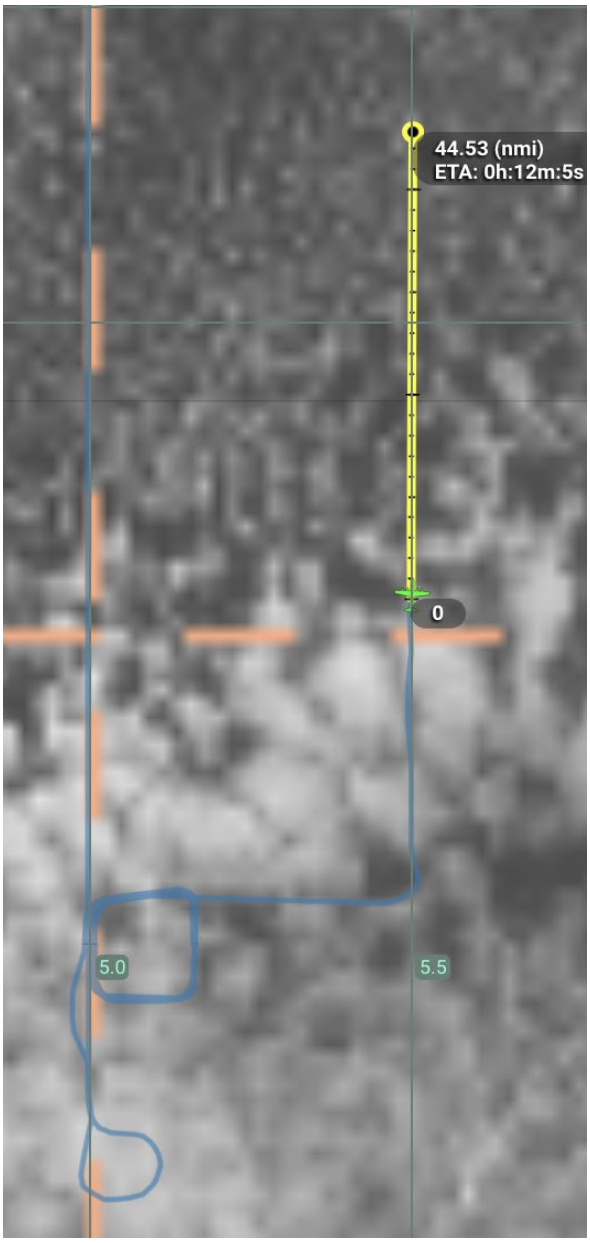

Figure 14: Satellite imagery showing location of square spiral and boundary layer leg flown by P-3.

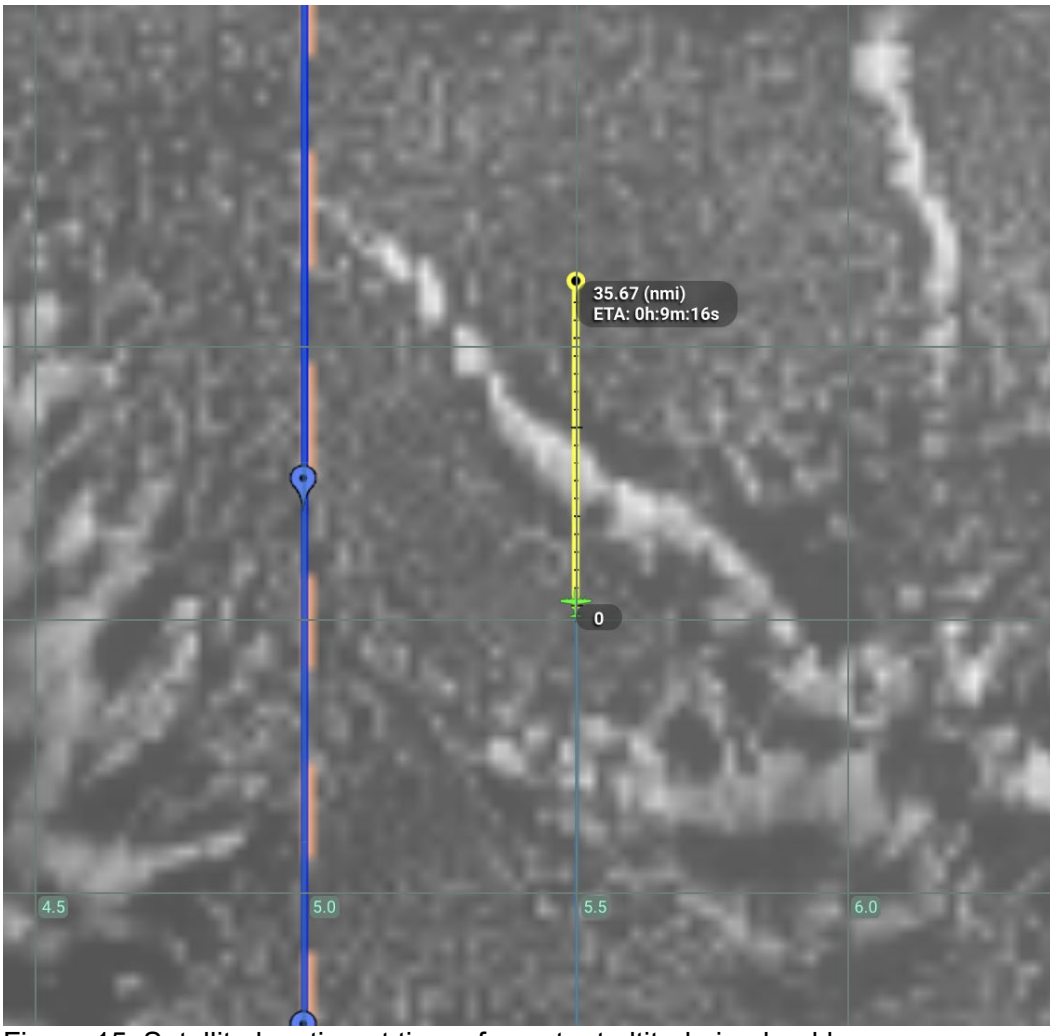

Figure 15: Satellite location at time of constant altitude in-cloud leg

Figure 16: Photo just after in-cloud leg during brief leg in aerosol layer.

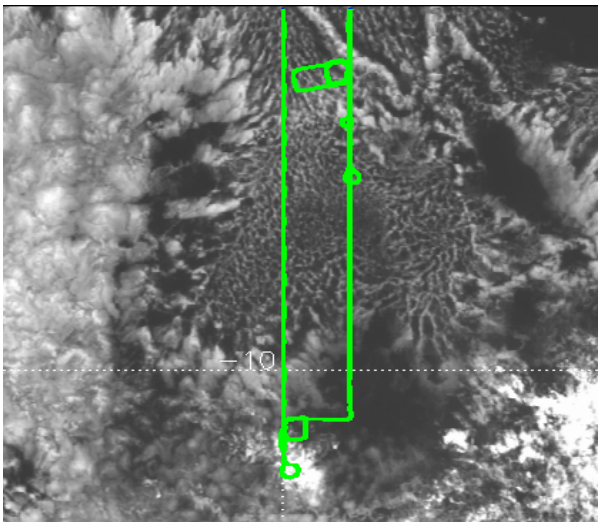

Figure 17: Visible satellite imagery at time period of constant altitude aerosol legs

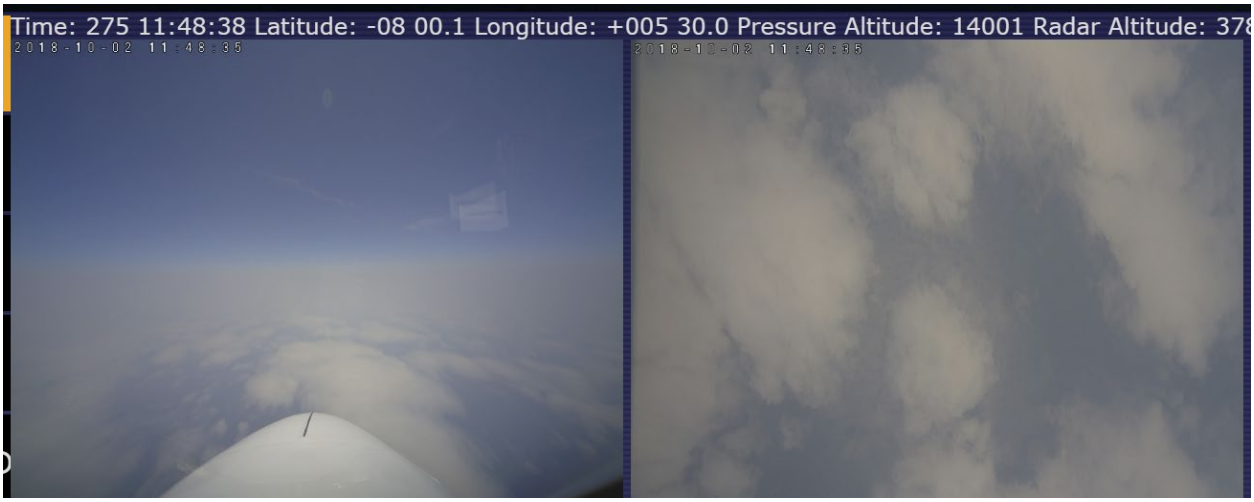

Figure 18: Photos at time period of constant altitude aerosol legs

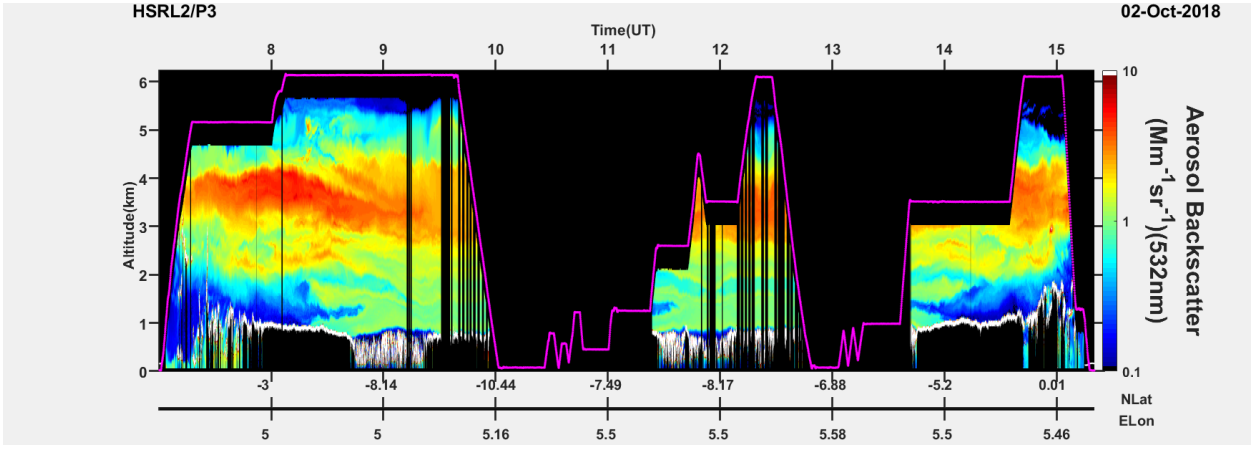

Figure 19: HSRL summary image for whole flight (see long 40 minute constant altitude aerosol leg towards the end of the flight)

Figure 20: Photos near end of flight during constant altitude aerosol leg