Flight report: 24 September 2016, PRF10

Flight Scientist: Steven Howell,
Ground Scientists: Jens Redemann, Lenny Pfister

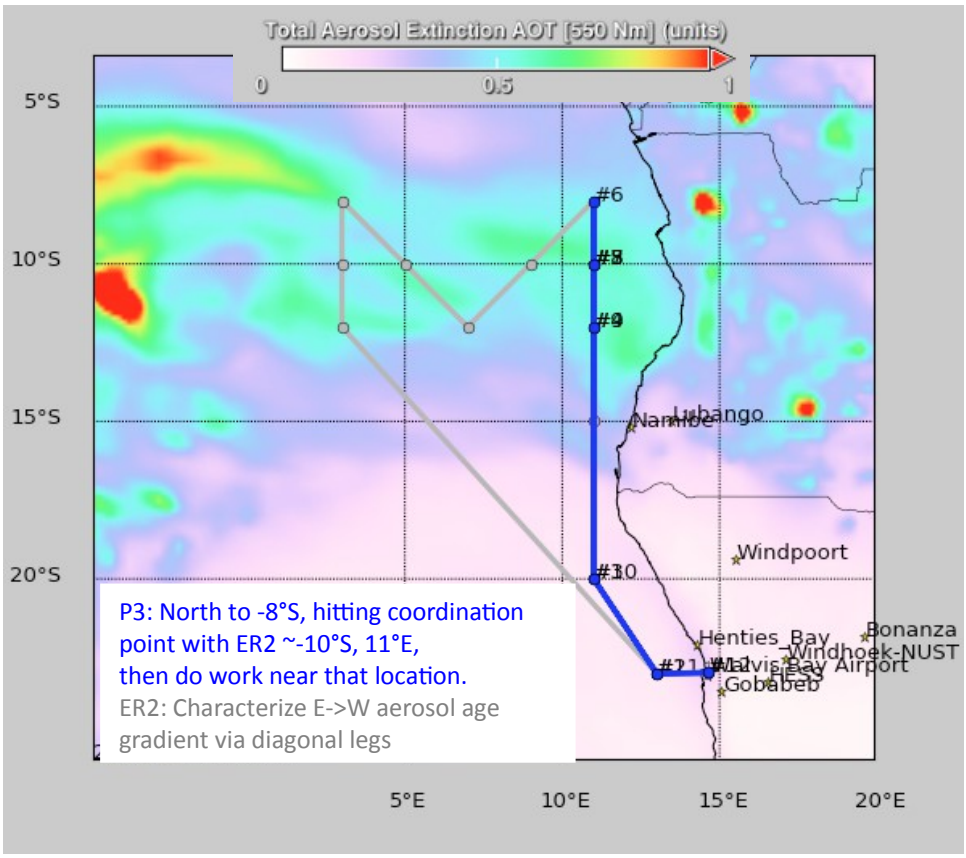
Walvis Bay local flight

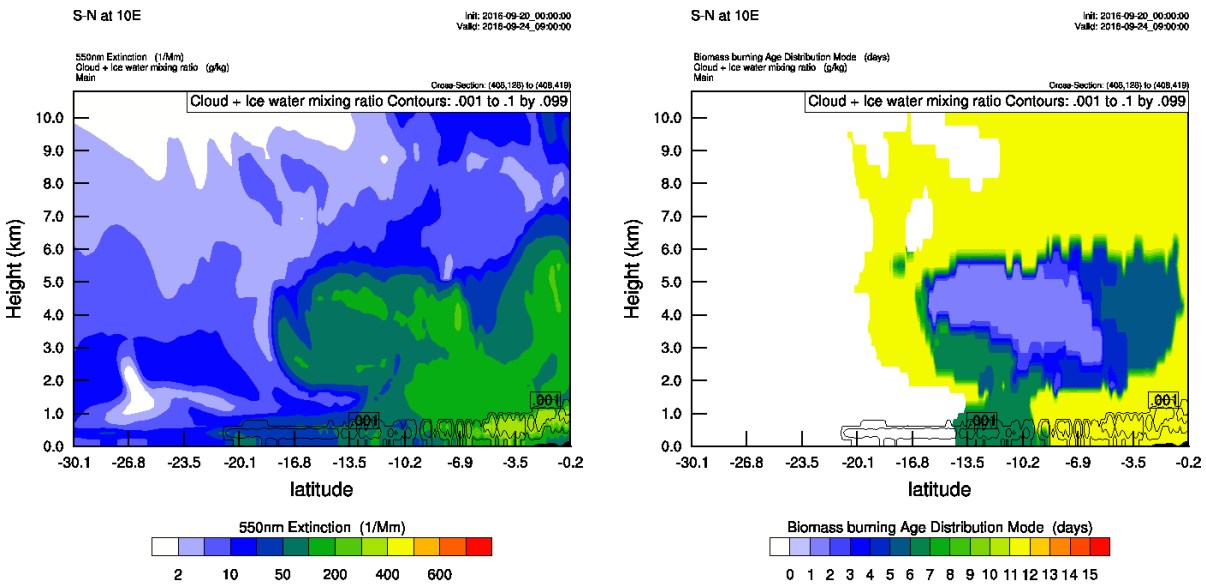
Overview:

This flight was another attempt to find the youngest, densest plume we could by flying up the coast. The models were predicting the youngest plume yet, near the northern limit of our range. There was hope that we could get beyond the heart of the plume a full-column radiation spiral in a cloud-free region (there were many over cloud, but a paucity without cloud). Rather than dogleg east as we had done in flight 10, we stayed on 11ºE to avoid airspace near Luanda, Angola and its airport.

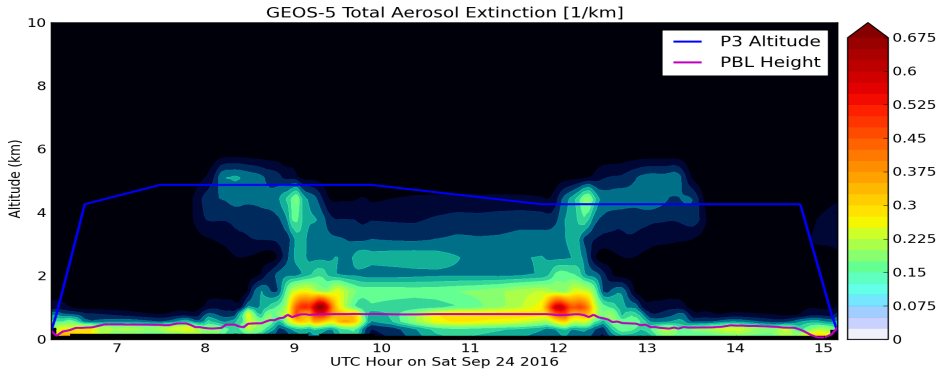
The goals of the flight were:

- Transit high to between 20º and 15ºS, 11ºE
- In-progress profile to below plume.
- Pick altitudes for transit to ~12ºS
- Profile to MBL, then in/above cloud until ER-2 overpass, when we'll be at 600' over cloud.
- If clouds cooperate, "quick" radiation wall
- Continue N to 8ºS in plume, profile there.
- Choose altitudes, latitudes for further work
- Return in the plume.



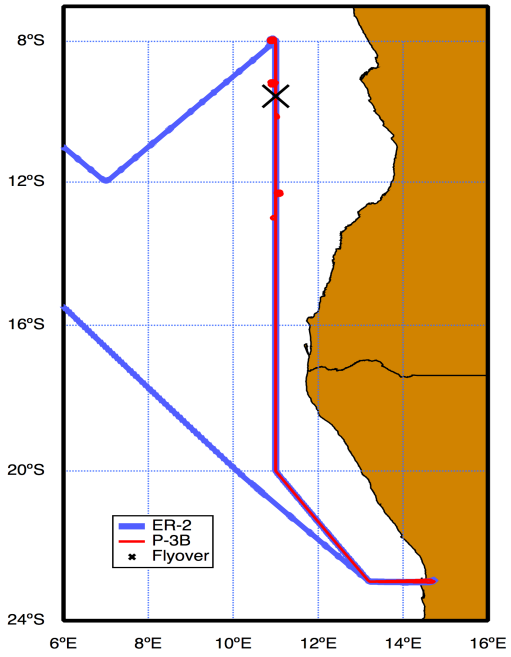


The WRF model run by Pablo Saide predicts an elevated plume <2 days old. In contrast, GEOS-5 predicted an intense plume just above cloud level:



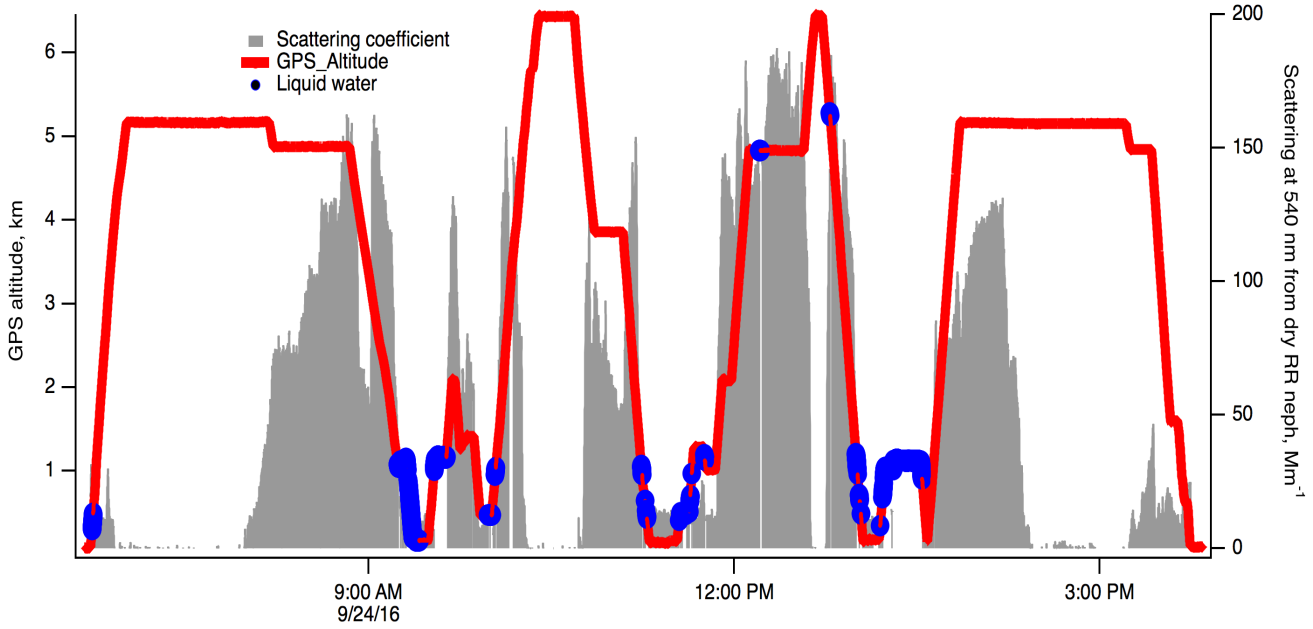
P-3 flight manifest 9/24

PIC: Mike Singer
SIC: Mark Russell
TIC: Scott Farley
Flight Engineer: Brian Yates
Aft Crew: Todd Brophy
Aft Crew: Mike Terrell



Science Team:

Project Scientist:
1) Steve Howell [flight scientist],
Instrumenters:
2) Simone Tanelli [APR3]
3) Elin McIlhattan [APR3]
4) Kirk Knobelspeisse [RSP]
5) Steffen Freitag [HiGEAR]
6) Nikolai Smirnow [HiGEAR]
7) Amie Dobracki [HiGEAR]
8) Mary Kacarab [CCN, Isotopes]
9) Art Sedlacek [PTI]
10) Jim Podolske [COMA]
11) Joe O'Brien [cloud probes, PDI]
12) Sabrina Cochrane [SSFR]
13) Eric Stith [data]
14) Herb Sims [AMPR]
15) Kristina Pistone [4STAR]
16) David Noone [isotopes]
17) David Shipepe (flight scientist training)
18) Jianhao Zhang



Event	Start	End	Alt	Description
1	06:43:04	07:01	16,000'	Takeoff, ascend to transit altitude through point α
2	07:01	08:11	16,000'	Transit
3	08:11	08:50	15,000'	Appeared to be touching top of plume, drop 1000' for remainder of transit.
4	08:50	09:14	3200'	Slant profile to top of cloud. Hit cloud 09:14:50
5	09:14	09:18	3550'	Leg just above cloud. Had to nudge upward to stay above. Intermediate-level clouds overhead, so lousy for radiation.
6	09:18	09:22	500"	Profile through cloud to 500'. Cloud deck only 500' thick but decoupled boundary layer with extensive small Cu at this altitude extending to in or near Sc deck. Almost a second Sc deck.
7	09:22	09:29	400'	500', dropping to 400' MBL leg. Lots of drizzle. Emerged from cloud 09:25. Lower cloud level gone.
8	09:29:27	09:33:03	3500'	Profile up into cloud. MBL no longer decoupled.
9	09:33:03	09:38:20	3500'	In cloud run
10	09:38:20	09:41:22	6500'	Ascend into plume, trying to increase airspeed to meet P-3 beyond cloud back. Bad idea, since climbing slows plane so much.
11	09:41:22	09:45:16	3900'	Drop back down to cloud top for ER-2 overpass.
12	09:45:16	09:51:47	4400'	Above cloud, ready for ER-2 overpass. Adjusting altitude. Ran out of cloud at 09:51:35.
13	09:51:47	09:55:14	1375'	Profile down for ER-2 overpass. Can't get to just above surface in time, but there is a very tenuous cloud layer at about 3000'. There is no good altitude for this.
14	09:54:46		1650'	ER-2 overpass at 9.56ºS, 11ºE. Still descending.
15	09:55:14	10:00:43	1400'	Level leg. First half below tenuous clouds, second half just above, occasionally touching even sparser cloud.
16	10:00:43	10:24:11	20,000'	Square spiral up through entire plume.
17	10:24:11	10:38:18	20,000'	Level leg heading S over previous legs.
18	10:38:18	10:51:30	12,000'	Turn back N and slant into heart of plume.
19	10:51:30	11:05:29	12,000'	Level leg heading N. Scattering 100 Mm^{-1}, but drops.
20	11:05:29	11:18:32	350'	Farthest N point, 8ºS. Square spiral down. 2 cloud levels, 3200' and 1700'. Both more Cu than Sc.
21	11:18:32	11:32:03	450'	MBL leg, heading back N.
22	11:32:03	11:33:12	1500'	Up to lower cloud level
23	11:33:12	11:37:55	1500'	Cloud leg, punching individual small, broken Cu.

24	11:37:55	11:40:18	4000'	Up to leg above upper clouds. Still 2 cloud layers.
25	11:40:18	11:45:11	4000'	Above cloud leg. Upper clouds thinning.
26	11:45:11	11:46:06	3200"	Try to descend into upper cloud level.
27	11:46:06	11:50:53	3200"	Attempted cloud leg. Too low at first, then clouds gone.
28	11:50:53	11:54:10	6500'	Climb into lower plume.
29	11:54:10	11:58:44	6500'	Lower plume. Scattering ~100 Mm^{-1}
30	11:58:44	12:07:32	15,000'	Ascend to heavy plume indicated by HSRL-2
31	12:07:32	12:34:20	15,000'	Yes, lots of pollution, dry scattering 150 Mm-1, but also clouds embedded in pollution layer. Hit at 12:12:28.
32	12:34:20	12:40:08	20,000'	Turn back N, profile up above plume.
33	12:40:08	12:43:20	20,000'	Level leg heading N above pollution layer.
34	12:43:20	13:03:41	500'	Square spiral down to near surface. Cloud layers at 16,000', 3500', 2100', and 1600'. Tug and barge appear as we clear lowest clouds.
35	13:03:41	13:11:22	500'	End spiral and turn S in MBL
36	13:08:12	13:09:50	500'	Hit plume of tugboat.
37	13:11:22	13:14:18	3200'	Up into cloud
38	13:13:07	13:19:35	3500'	In-cloud speed run, ~210 kts TAS, nudged altitude up.
39	13:20:37	13:25:41	3500'	In-cloud speed run, 266 kts TAS.
40	13:26:38	13:31:37	3500'	In-cloud speed run, 300 kts TAS.
41	13:31:58	13:35:14	400'	Profile down near surface
42	13:35:14	13:51:32	16,000'	In-progress profile up to plume max
43	13:51:32	15:13:15	16,000'	Transit back. Plume quit about 14:20
44	15:13:15	15:44:45	0	Descend and land.

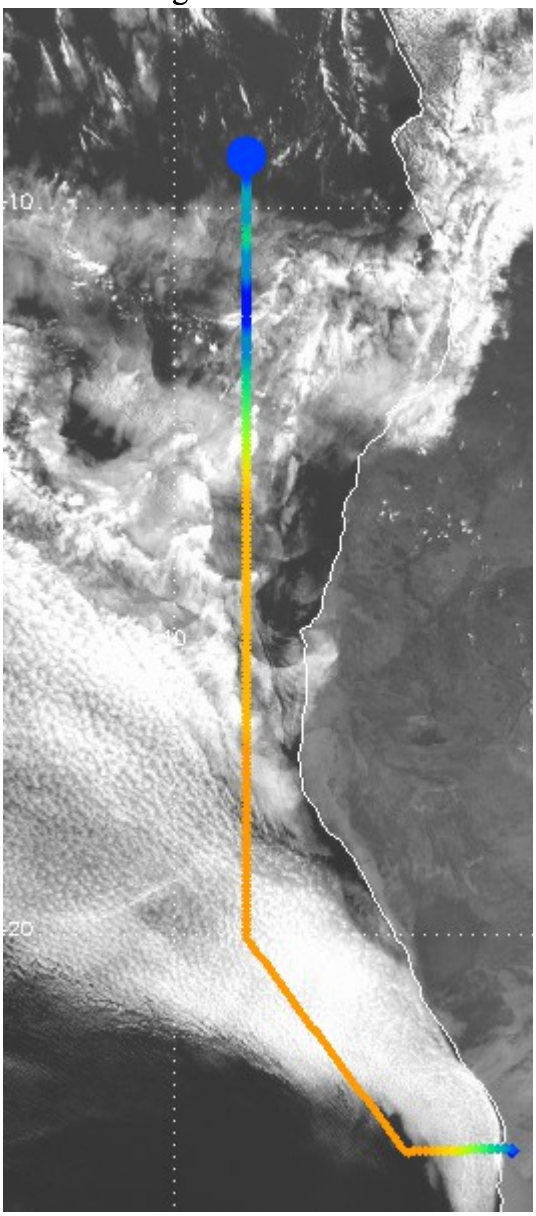
Highlights:

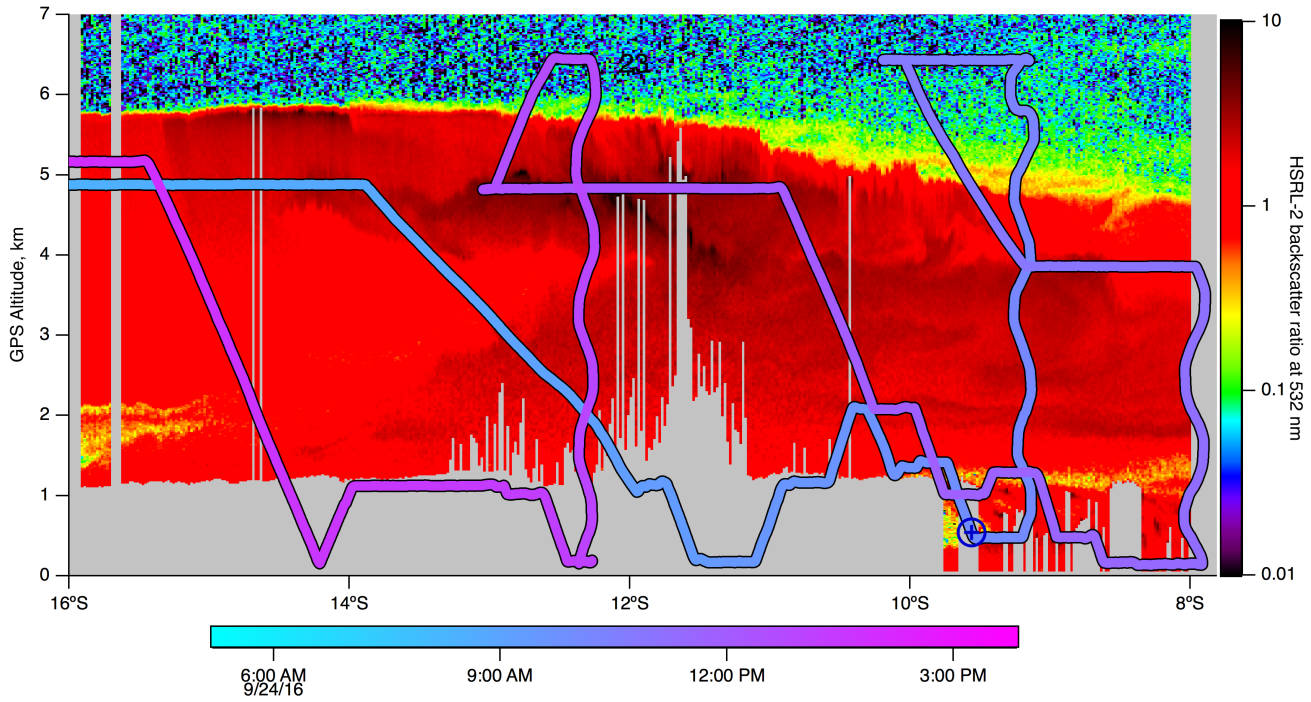
- We went farther north than any other flight, and seemed to have crossed much of the plume.
- Found very polluted layers at altitude
- HSRL-2 data exceedingly useful for finding layers, though by the time we got to the thickest part, clouds had developed.
- Speed runs in cloud should help troubleshoot cloud probes.
- Penetrated a couple of intermediate level clouds. Enough to get droplet size distributions.
- Confirmed high altitude plume predicted by WRF; GEOS-5 showed low altitude plumes that weren't there. Excellent model testing!
- One ER-2 overpass, in almost precisely the anticipated location.
- Spent about a half hour in clouds of various sorts, including Sc, MBL Cu and scud, and intermediate level clouds.
- AODs up to 0.9!

Lowlights:

- Plane intercom system behaved badly, making communication with the back of the plane very difficult. That combined with a lack of an assistant flight scientist on board made coordination difficult. I got kind of overwhelmed carrying on conversations w/ pilots, ground scientists, and trying to hear the people in back. It was a much more stressful flight than PRF10.
- Ground scientists tried to be helpful, but didn't have the tools to tell me the timing implications of altitude changes. (I could have made such a tool, but hadn't.)
- It had been hoped that the ER-2 overpass and the subsequent radiation square spiral could happen in a cloud-free area visible in the satellite imagery. Due to my timing mistakes, overpass and spiral were very close to the edge of the cloud bank, undoubtedly complicating radiation analysis. To make things worse, there were no extensive cloud-free regions; scattered clouds not visible in the imagery were common. I did not know whether to attempt the radiation spiral from above or below those clouds. I wound up choosing badly; it would have been an additional 3-6 minutes to do a complete profile from surface to 20,000'.
- The AMS died near the end of the flight.

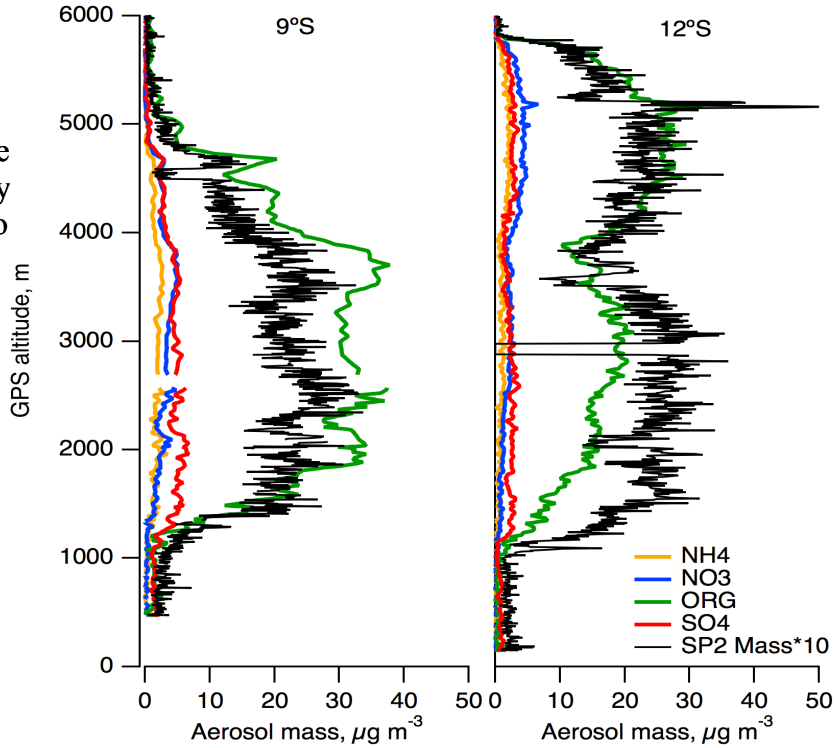
Visible imagery from near the time of the ER-2 overpass. The edge of the cloud deck was real, but there were a lot of MBL clouds not visible here.





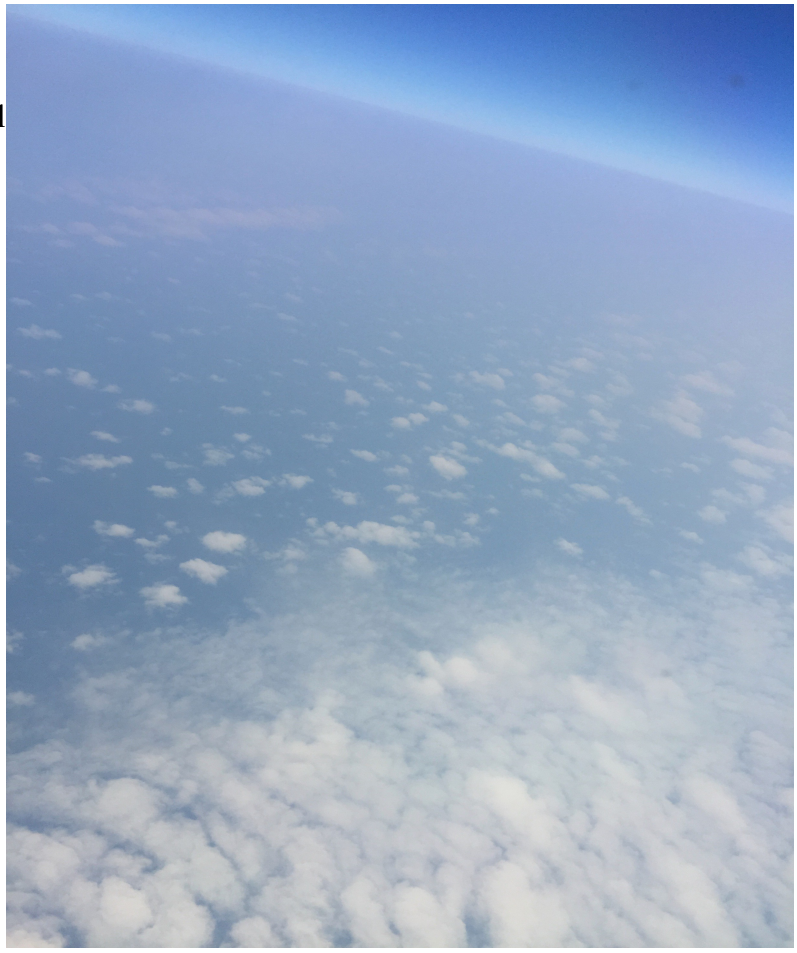
Latitude vs altitude in the study region. HSRL backscatter ratio at 532 nm is superimposed on the P-3B flight path. The P-3B path is colored by time. The black ⊗ is the P3-B position at the ER-2 overpass.

AMS and SP2 data from 2 profiles. The two-layer plume structure is much more visible farther south, but in both cases the black carbon (exaggerated here by a factor of 10) is higher relative to other aerosols low in the plume.

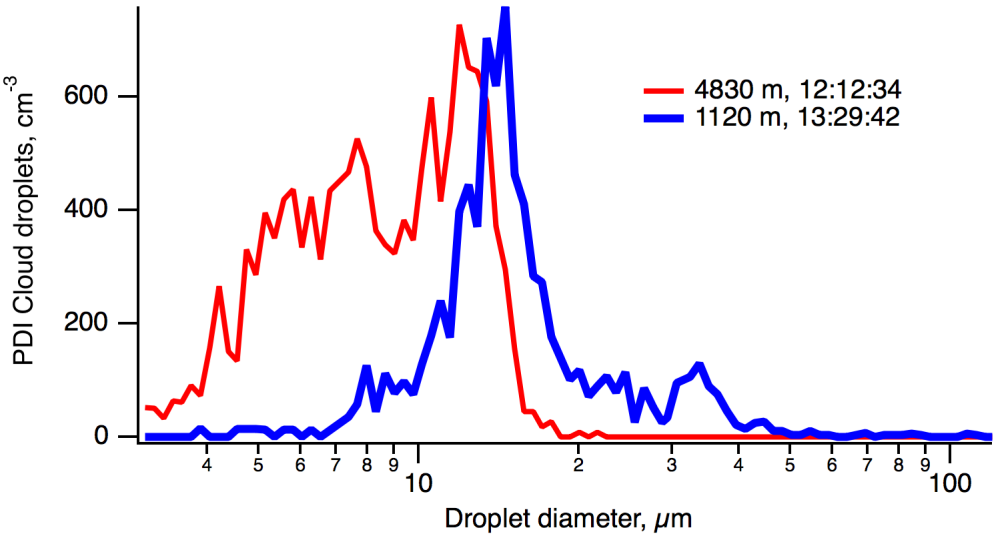


View through the forward camera at the ER-2 overpass. Tenuous clouds overhead are visible, although we had hoped for a cloud-free situation.

Looking down near the top of the spiral after the ER-2 overpass. The boundary of the stratocumulus deck is obvious, as are the low clouds north of the Sc. I expect the contrast between the two areas will complicate radiation work.

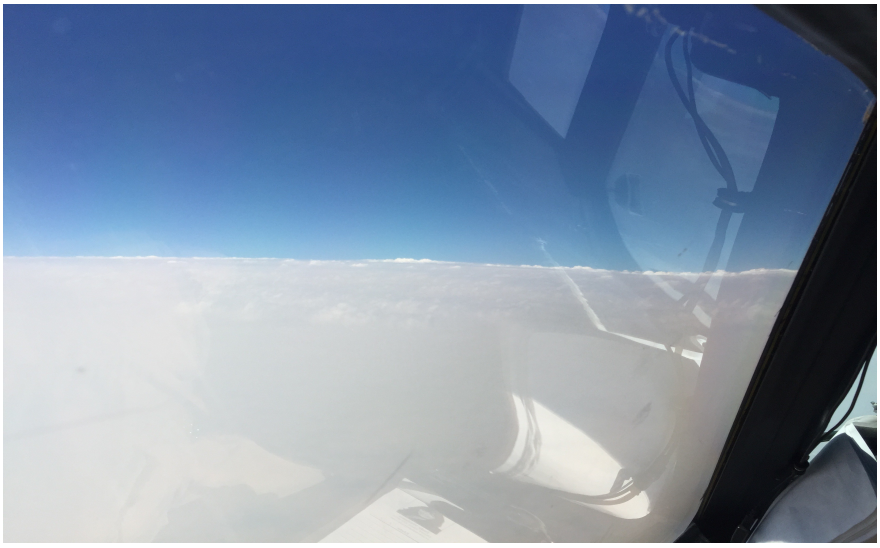


The intermediate level clouds we hit at 12:12:28, near the top of the plume.



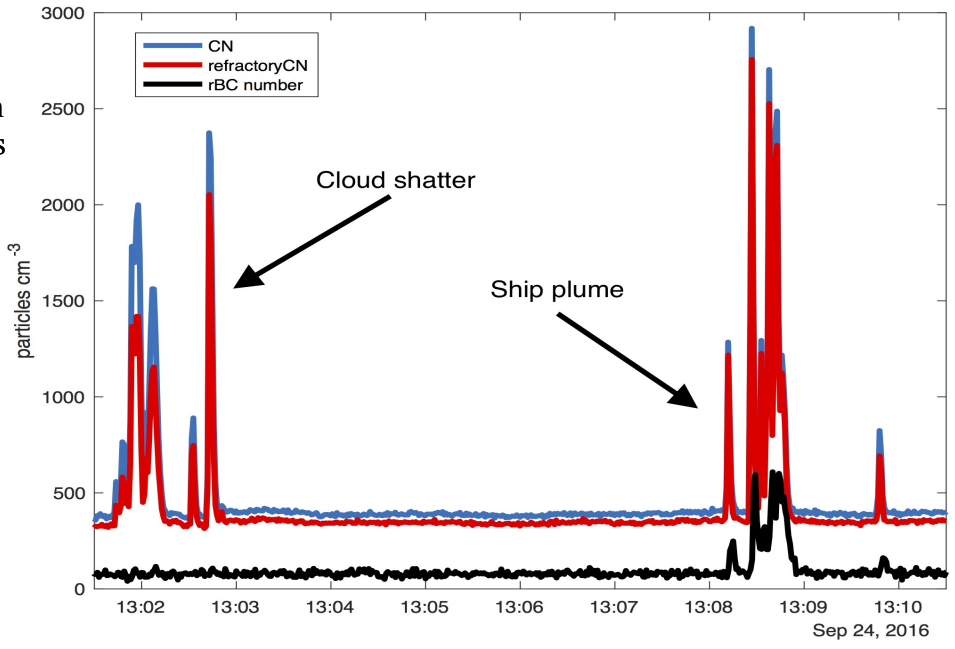
As one might expect, the intermediate level clouds had droplet size distributions (in red), much different than the MBL stratocu. There were actually more droplets, but very small, with tiny LWC.

A view of the intermediate level clouds poking out the top of the plume. Many more were embedded within the plume but were hard to see in the murk.



The tug and barge seen at 13:03. We didn't hit the exhaust until 13:08:12.

The ship plume as seen by CN counters and the SP2. For contrast, an earlier cloud shatter event is shown as well. Soot particles tend not to shatter, so they do not multiply when cloud droplets shatter. In contrast they are strongly enhanced in the plume of the tugboat.



Instrument status:

P3	All good
HiGEAR	Everything worked well. AMS worked most of the flight then died during transit back.
AMPR	Nominal
RSP	Worked well at low speeds except at highest altitudes
APR3	Good flight. Now operation mode possibly more sensitive. Transit up had beautiful front-like systems. Lots of drizzle.
Cloud probes	Worked fine. Interesting mid-level clouds, multiple cloud layers in MBL, lots of drizzle. Liked the speed runs.
CCN	Worked fine. Nothing particularly out of the ordinary.
PTI	Worked, noisy prior to flight, maybe related to backup pump from WISPER. SSA in plume 0.6?!
PDI	Worked, no obvious issues. Got 4 droplets in mid-level cloud!
Vertical winds	Apparently fine (personnel not on flight)
WISPR	Ups & downs. ran most of the flight when below 8000'. Need to replace instrument.
COMA	Worked well. O3 stayed dry
SSFR	Worked fine, liked square spirals, but clouds made things complicated.
data	Worked well; maybe will have new plots next time??

Progress towards Science Objectives:
green-success likely red-success uncertain
Direct Forcing
SO1-1 evolution of BBA properties with transport: ~ 5 hours in study region, ~2 hours in FT BB plume both younger than other flights up high and of various ages
SO1-2 spectral radiative fluxes shaky, due to clouds
SO1-3 factors that control seasonal variation of aerosol Excellent model comparison opportunity
Semi-Direct Effect
SO2-1 relative aerosol-cloud vertical structure Total about 90 minutes near FT/MBL boundary
SO2-2 constrain aerosol heating rates shaky, due to cloud
SO2-3 cloud microphysics Half an hour in various cloud types. Interesting, but complicated

Indirect Effects

SO3-1 aerosol-BL mixing No gap between aerosol and less polluted MBL; Total about 90 minutes near FT/MBL boundary

SO3-2 aerosol-BLcloud microphysics Complicated MBL cloud structure will make this difficult

SO3-3 precipitation susceptibility Lots of drizzle, lots of radar and in-cloud data.