ATom-4 RF01 Log, Prather (2018-04-24)

ATom-4 RF01 the Palmdale to Equator route began the last scheduled ATom deployment. Wheels up at 14:44:57. Climb out and ascent to FL300 was smooth. After takeoff O3 ~57, NOy~0.5, CO ~108, HCHO ~400, CO2 ~414. Here is my log of the flight with the timeline of UTC down the left. I have tried to highlight, some with figures, the interesting features of the air masses we sample. I briefly started doing my own analysis of scatter plots and correlations, but then started missing some of the interesting air masses and so resorted to a focused following using mainly the standard time series and parameter tables. The altitude estimates here are just from a quick eyeball at the running tables and so have a bit of uncertainty. The time logs are usually to the nearest minute. The aircraft data system worked flawlessly and well, except for the lack of viewing of the nadir camera.

Summary. This was an excellent flight mechanically. All the instruments ran at 100% or, in one worst case, 90% of the time. The flight showed a large number of different air masses. In most cases these air masses were not just a 'sniff' or small plume, but were typically 1-3+ min in extent (40 – 120+ km) and thus are the type of chemical granularity that can and should be simulated by the new generation of 3D chemistry-transport models. We came across such variability on level flight and during vertical ascent. Several times it was clear that some layers were extensive and seen in more than one dip or in the flight out (FL300) and the return (FL 390). Some of the patterns had not be obviously identified before (as noted by the investigators at the time). This log is extensive and long because there were so many 'new' features. We cut through a number of interesting air masses and air-mass boundaries. It is often the boundaries that have the most surprising mix (e.g., in the ATom-2 ANC-KOA route we saw the wrap-around of very dry descending sub-tropical air (RHW <5%) with wet polluted Asian 'mix'). Two big items are noted here, see the log for more details.

1. 1601 UTC. One most interesting, exotic large-scale chemical feature was the air mass that looked like polluted Asian air, traveling rapidly along and immediately underneath the jet stream and containing 20-30% stratospheric air that was shredded from the stratosphere where the jet turns. There may be another explanation for this very large, repeatable air mass that defies other well known tracer correlation patterns.

2. 1855 UTC. The first (southernmost) dip found unusual layering that was horizontally extensive. Some features extended to the 2nd dip and others to the 3rd. First, at about 12 kft we pass through a thin layer (~500 ft) with large, opposite shifts and CO2 and CH4. Then clear air, and then we hit a very polluted layer at 5 kft extending down to the surface. With repeated dips the first layer was seen to extend only a few hundred km but the pollution was over almost a thousand km – the GSFC forecast showed such a large extensive plume from Mexico. With farther north dips the pollution above and below the boundary split with a very thin, odd-O3 layer intervening. Also with more active marine cumulus and mixing in the northern dip, the pollution above remained, but the MBL looked scrubbed.

Log 1504 (UTC)

Climbing through FL~290, turbulence, spikes in NOy (16 ppb?), particle Iodine, NOx, SP2,OA+nitrate, but O3 dropping along with CO2 (-2 ppm), CH4 (-80 ppb), N2O (-1 ppb) [did not catch H2O].
Possible boundary between NMidLat air and SubTropical. Emphasizes latitudinal gradients, but where did the spikes come from?

1514

hit cirrus at FL300 – stayed at this alt through much of southward trip

1520 - 1523

Turbulence at start, O3 jumps 48 to 75. For 1515-1520 very big OA, nitrate, SP2. Then drops back.
Possible a slug of NMidLat air wrapped by SubTrop

1530 FL300, reach GUAPO, turn south.

1531-1535

O3 pops up briefly (40 to 50 ppb), RHw drops 38% to 28%
Possible higher altitude descent

1537

CO2, CH4, CO pop up, O3 from 40 to 55 ppb, RHw 25% (dry) and large amounts of OA, nitrate, SP2

1541-1542

VERY very clean, no particles, scavenged, H2O drops 300 to 200 ppm
Very clean convective outflow?

1547-1550

H2O increasing 150 to 350 ppm, O3 rock steady at 52. Chemistry seems constant. Must be differential dehydration in the air-mass ascent stage.

1553

O3 spike 40 to 70, particles drop! H2O smooth but very wet, RHi = 90-100+% at 500 ppm. CO2&CH4 look NMidLat.
SubTrop ascending air?

1601

O3 jumps from ~50 to ~80, H2O drops 450 to 200. Still far from strat air but begin to see evidence of STE flux.

1607-

Turbulence at 1607! O3 jumps to 120 ppb, eventually reaching 140. H2O low, RHw ~ 10%

1616

Rapid drop in O3 to 70, rising to 80-90. Turbulence (mild) RHw <10%, no particles.
? CO2&CH4 show more NMidLat. Possible Asian outflow wrapped around the strat folds being mixed in along the jet.

1630

Still very dry, but not really stratospheric.

1632

Turbulence. No change in chemistry –jet shear?

1639

Still large homogeneous descending air mass

1648

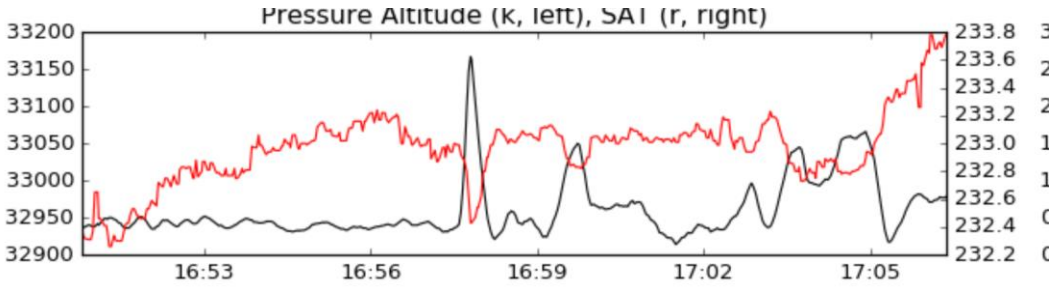
Start climb to FL330. O3 drops from 85 to 50! RHw jumps to 60% (100 to 400 ppm). Convective outflow on top of descending air at FL300?

1653

Reach 20N, O3 drops to 30 ! totally scavenged, no particles, Clean, nearly
? ITCZoutflow.

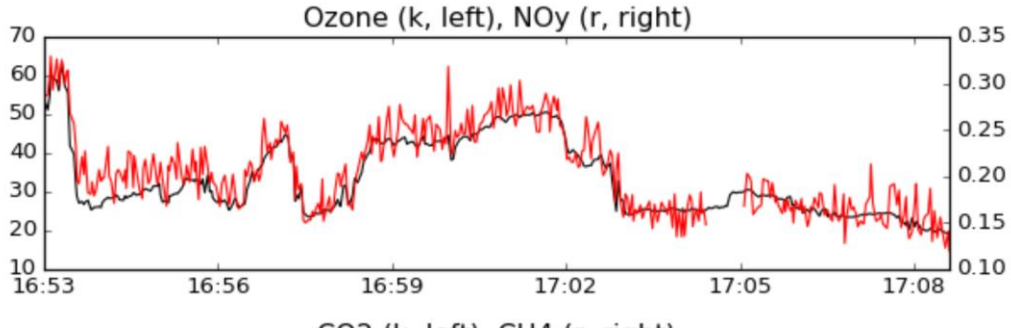
1658

Jack's favorite – a stealth MMS maneuver – check the 200 ft jump in altitude



Very long stretch of low O3, fairly wet, highly scavenged air (no SP2, OA, nitrate), CO drops 78—66.

Broad convective outflow from tropical BL air.



1713-1728

Extensive low O3 (18-20 ppb) persists, H2O ~ 24% RHW, 200 ppm, all particles scavenged, HCHO level at 80-100 ppt.

1743 – still scavenged, O3 up to 26 ppb

1748 – H2O rises steadily, from 150 to 500 (1754), now RHi > 100%, but drops back by

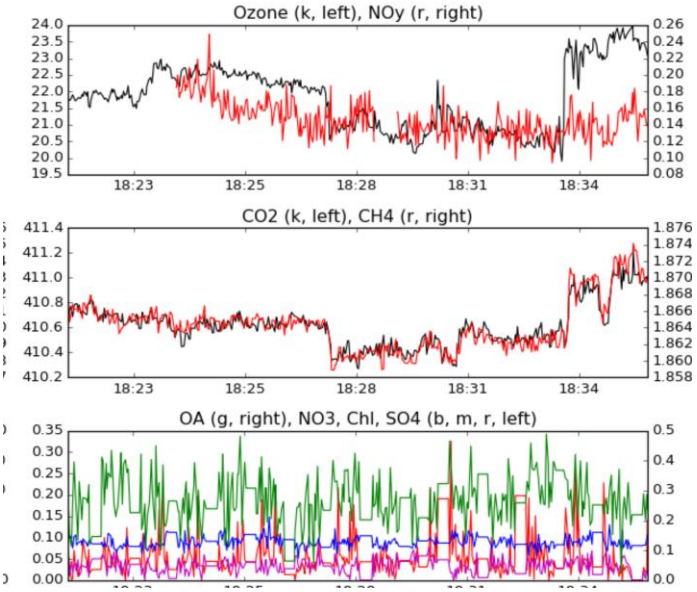
1755 – did we catch a whiff of cirrus based on RHi? – Yes

1810-1814 – climb to FL350

no big changes, O3=22 (drops 1 ppb), RHw=26%, H2O=140 ppm, CO=79.

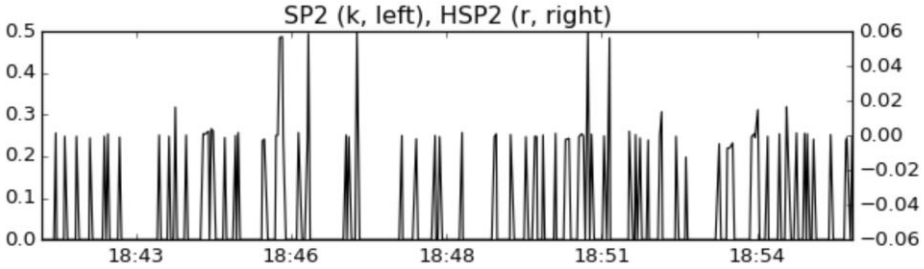
1823-1837

Encounter a mix of different air masses (subtle but clear) as we approach 7N



Start with NH tropics (from CO2&CH4) and then pick up more SH tropics, then back to even more northern NH tropics, see effective gradient in O3 with CO2&CH4. Will we find it in MBL when we descend.

Quantum effect of BC particles from SP2: " one particle, one particle, two particles!, one particle, …."



1854

Start descent to the deck at ~5N, will get halfway down at 3N (Oakland limit), turn at mid level and continue to the deck.

1855-1859

O3 increases from 25 to 37, drops back to 25 and then 22. Mid-level (FL200) has slug of sub-tropical air between upper and lower

1907 FL140 turn back to north at 3 33' N

1909

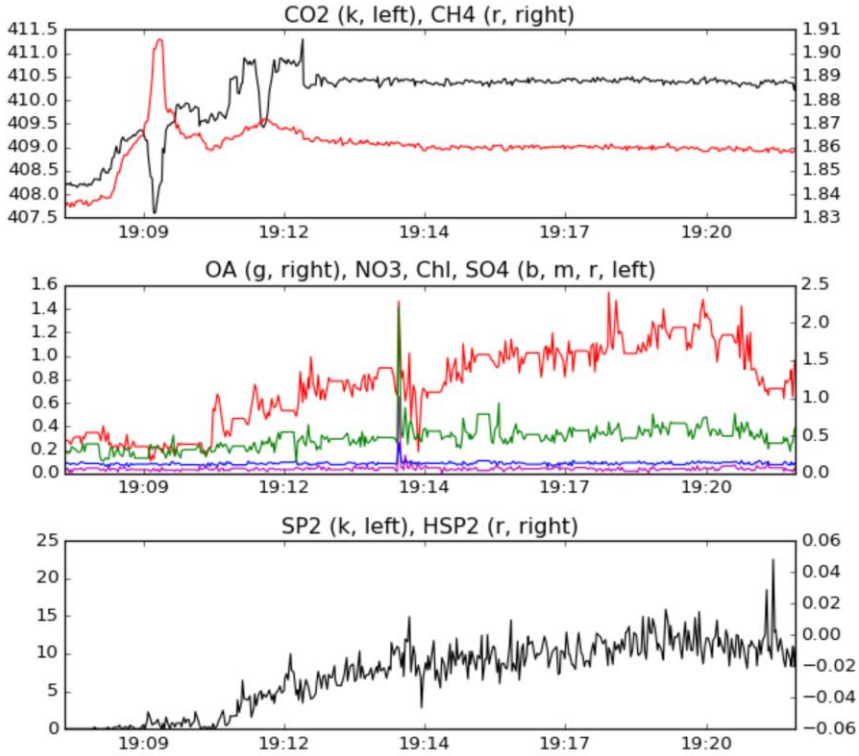
SP2 and others start rapid linear rise

1916

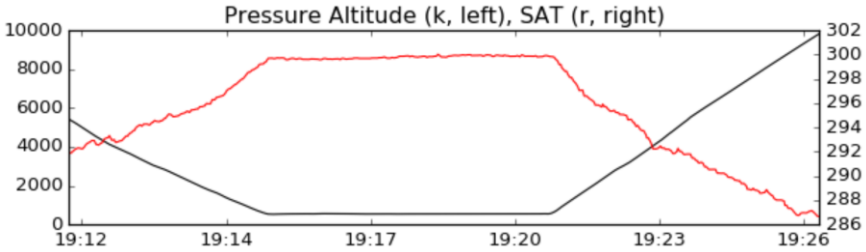
ATom-4 on the deck at 510 ft, 121 W, 3 deg 50' N. O3 down to 5 ppb.

1921 up to FL 36

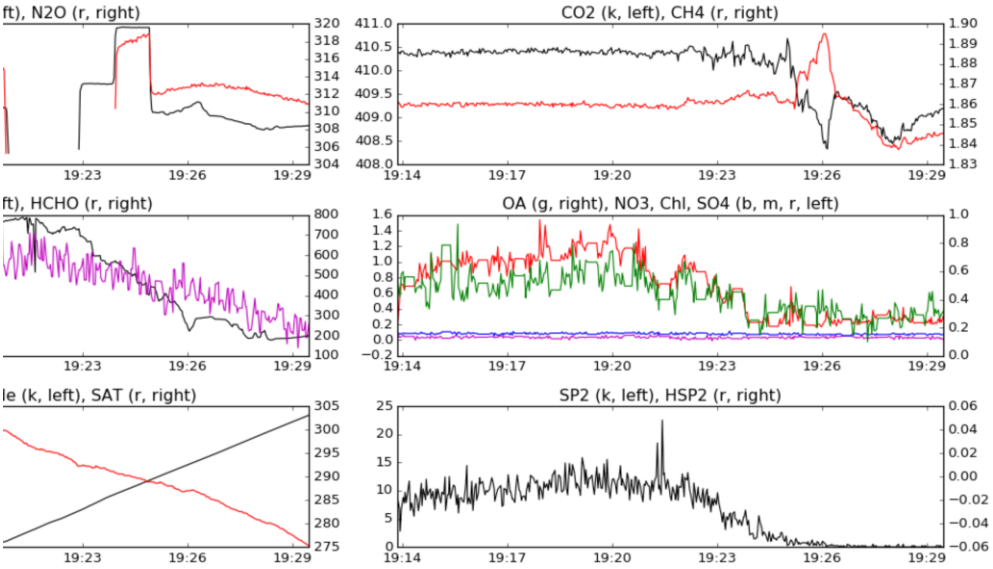
Note the possible Mexican BB plume is throughout the MBL



Note the aerosol spikes occur as we cross the top of the MBL



Same funny spike in CO2 and CH4 on way out as during funny turn on way down

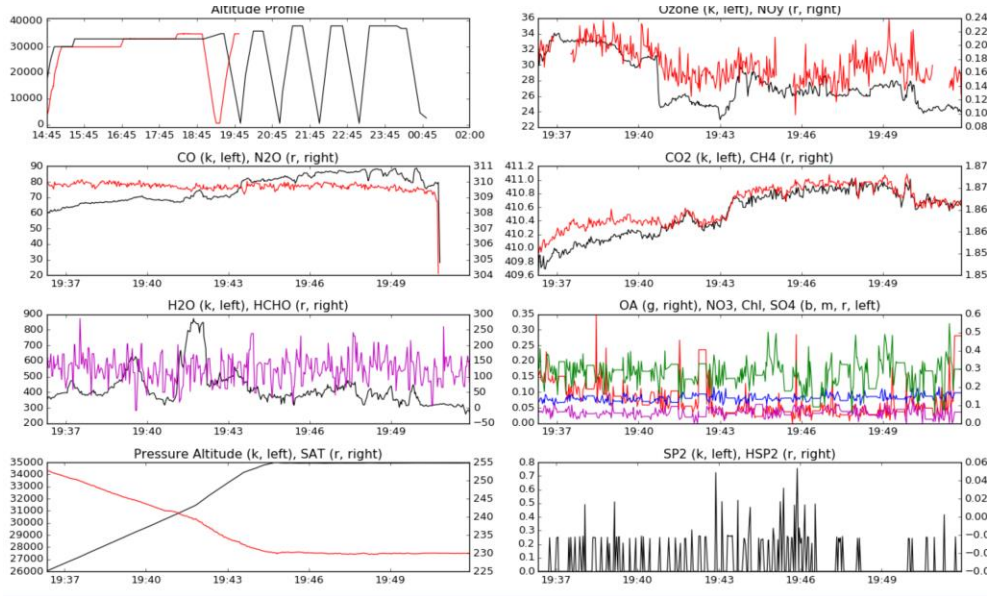


1943

Under cirrus, fluctuations in light field obvious on wing. J-NO2 nadir varies hardly at all (0.005 to 0.003 slowly), but J-NO2 zenith ranges on a 1sec basis from 0.0095 to 0.0125 /s.

1937-1945 reach FL 350 at end.

in cirrus (1937-1941), RHi consistently 100% up to 113%
during climb O3 = 34 ppb, but in cirrus, it is 26 ppb
RHi ~100% continues to 1950. SP2 down to single particles.
CO2&CH4 increase as we climb from mFL260 to FL350 (??)

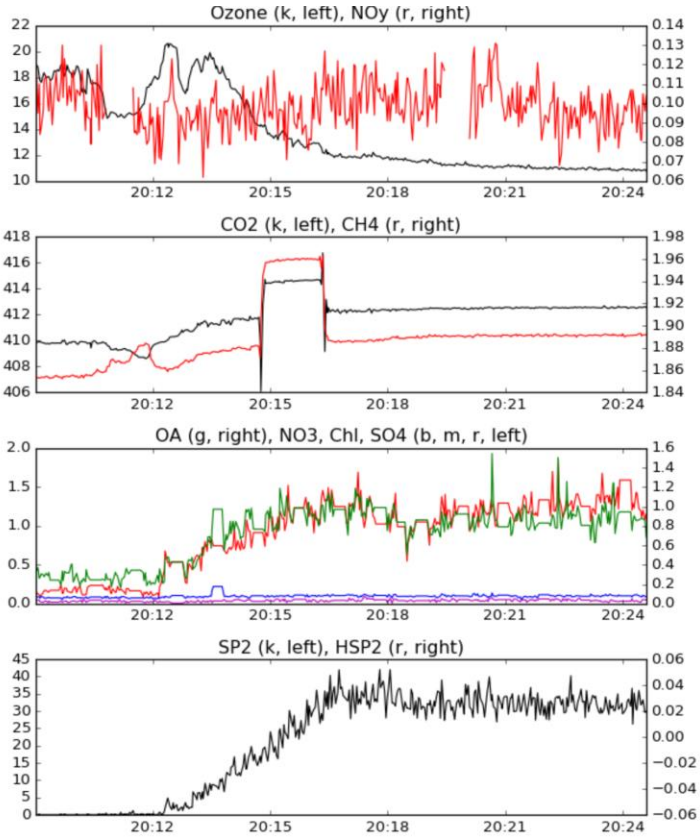


1956 start descent to deck, 8d18 N from FL350

2012

CO2-CH4 hiccup (anti-corr) occurs again at FL120 about, just above the rapid rise in SP2, OA, nitrate.

2020 – on the deck 2025 ascend, 10d55m N

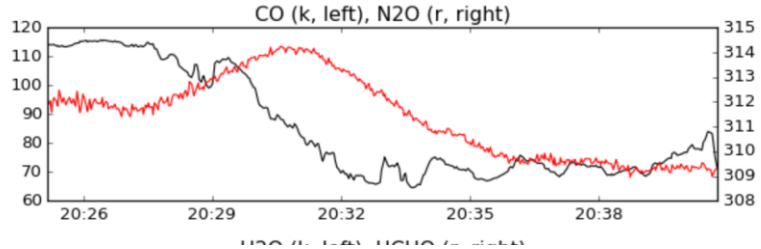


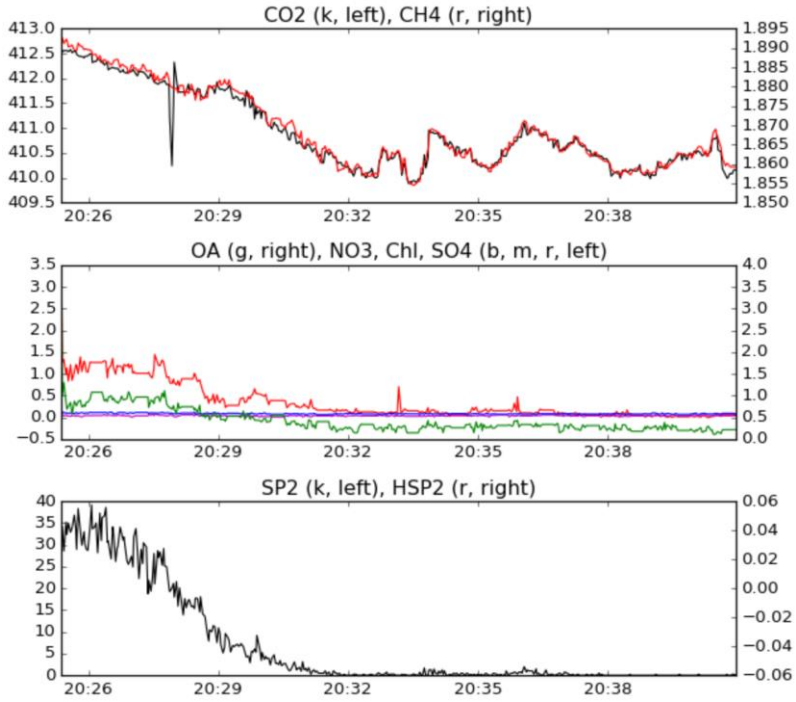
2033

No obvious CH4-CO2 hiccup on the way up at FL120 as before.

CO is very high within MBL BB region (110 ppb) then drops to 70 aloft as we climb out.

CO2 & CH4 drop likewise and remain tightly correlated in the different layers we climb through.



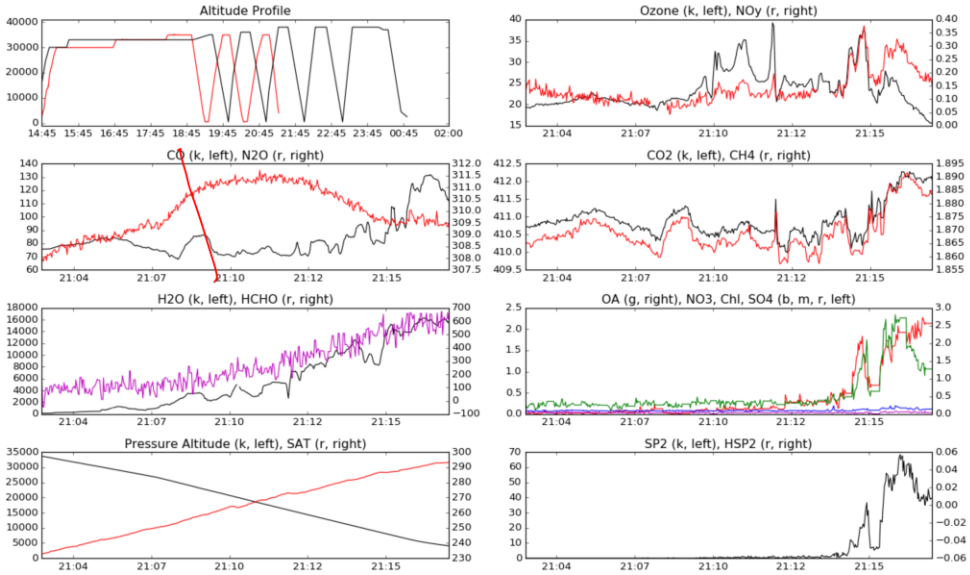


2052 – level at FL350

2101 – heading down 15d4m N

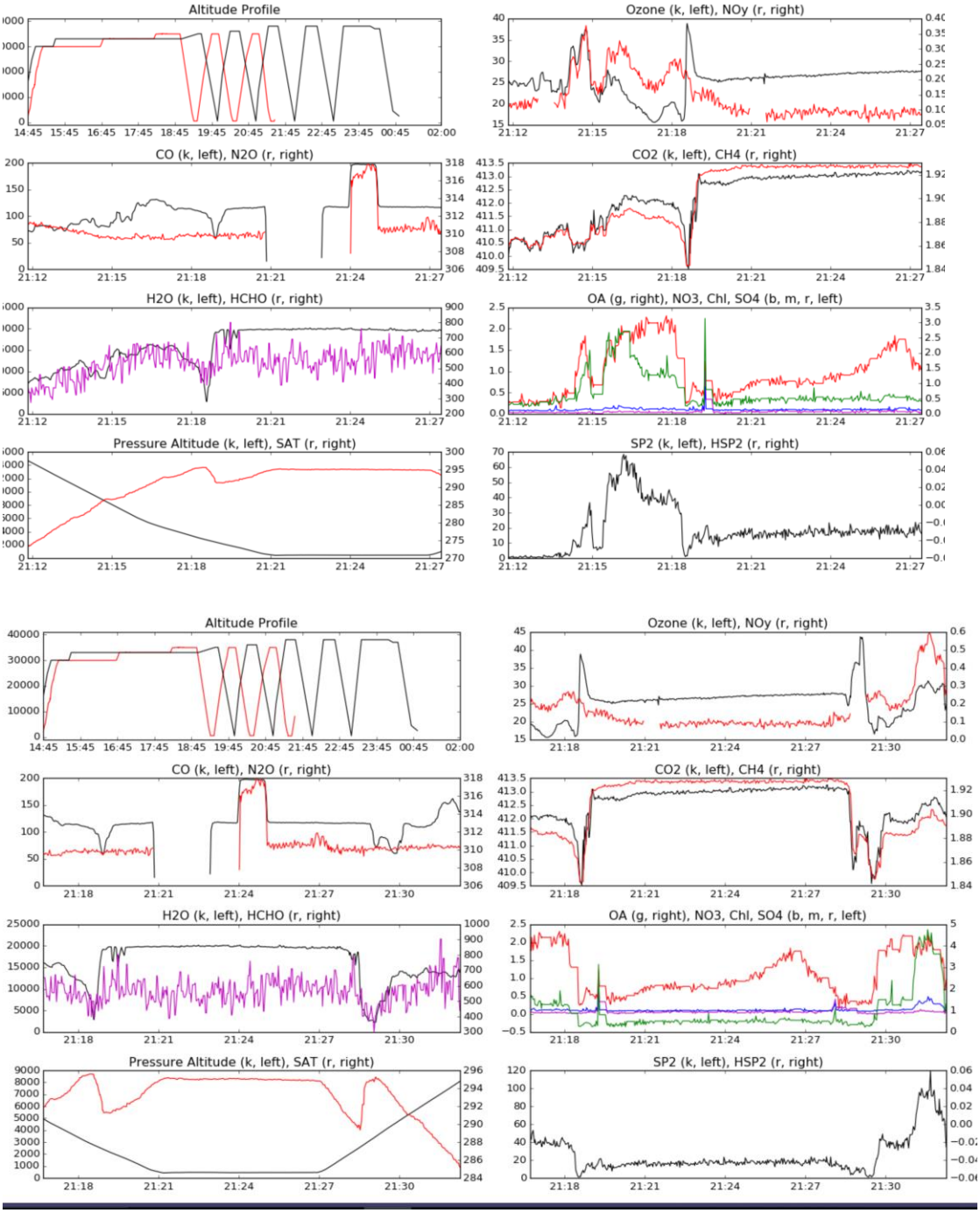
2105 -2117

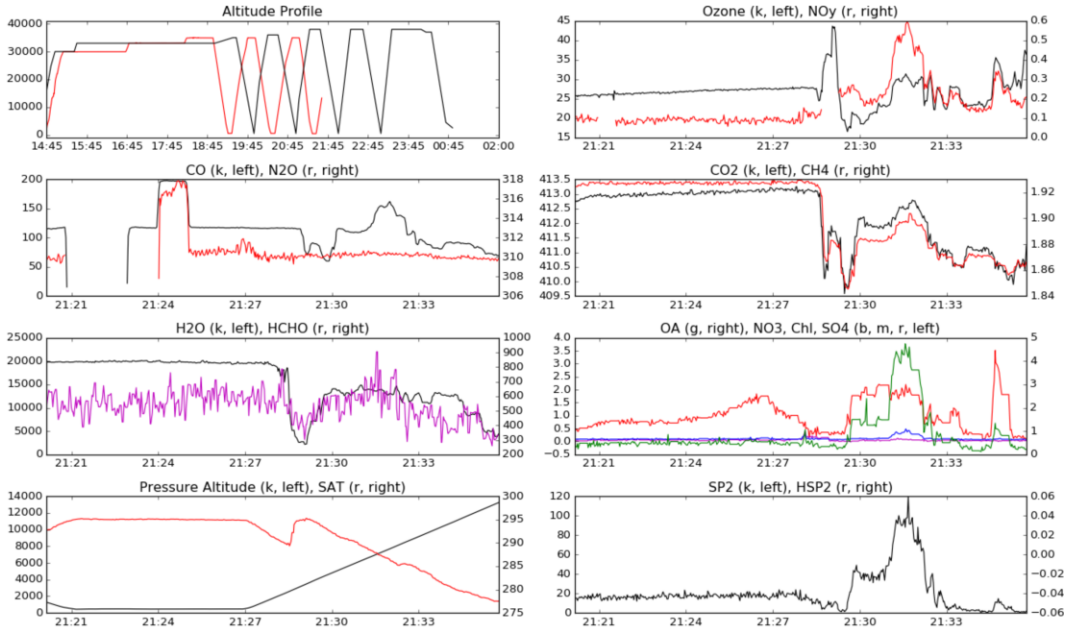
some interesting CO layering that sometimes correlates with O3 and CO2/CH4
big pickup of aerosols above the MBL, starting ~FL050



2112-2133 (sequence of 3 plots to fit in the dip)

VERY interesting MBL, dry layer, O3 spike dot directly with pollution.





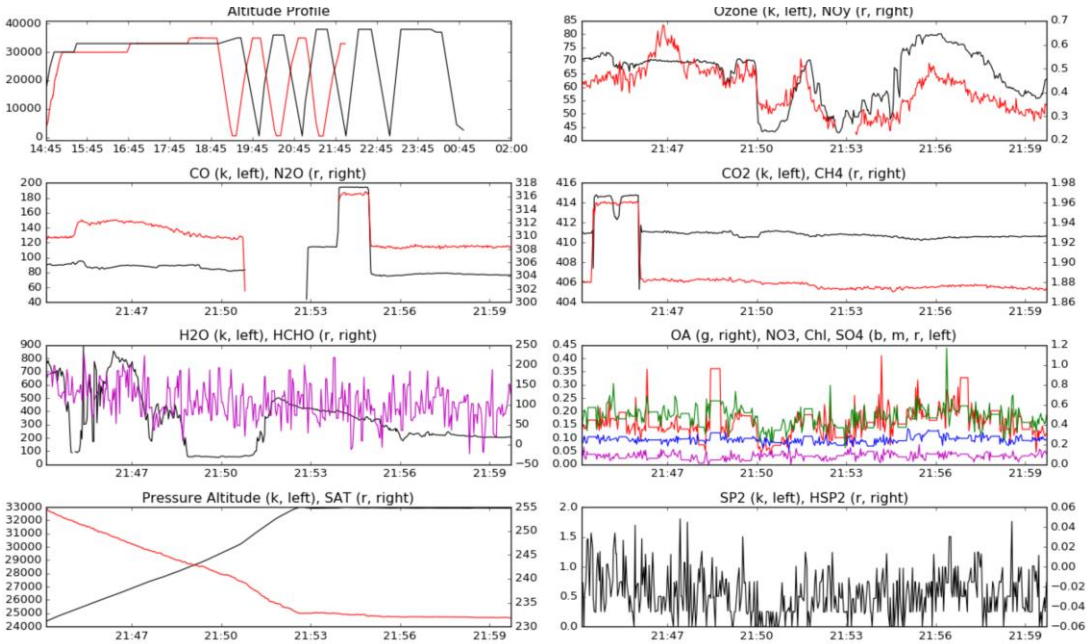
2127 – start climb to FL330 (skip top to fit the dips in).

2139

O3 jumps to 70 ppb, PAN is here. Jump in CO2/CH4/CO and OA, SP2 also old pollution at FL200.

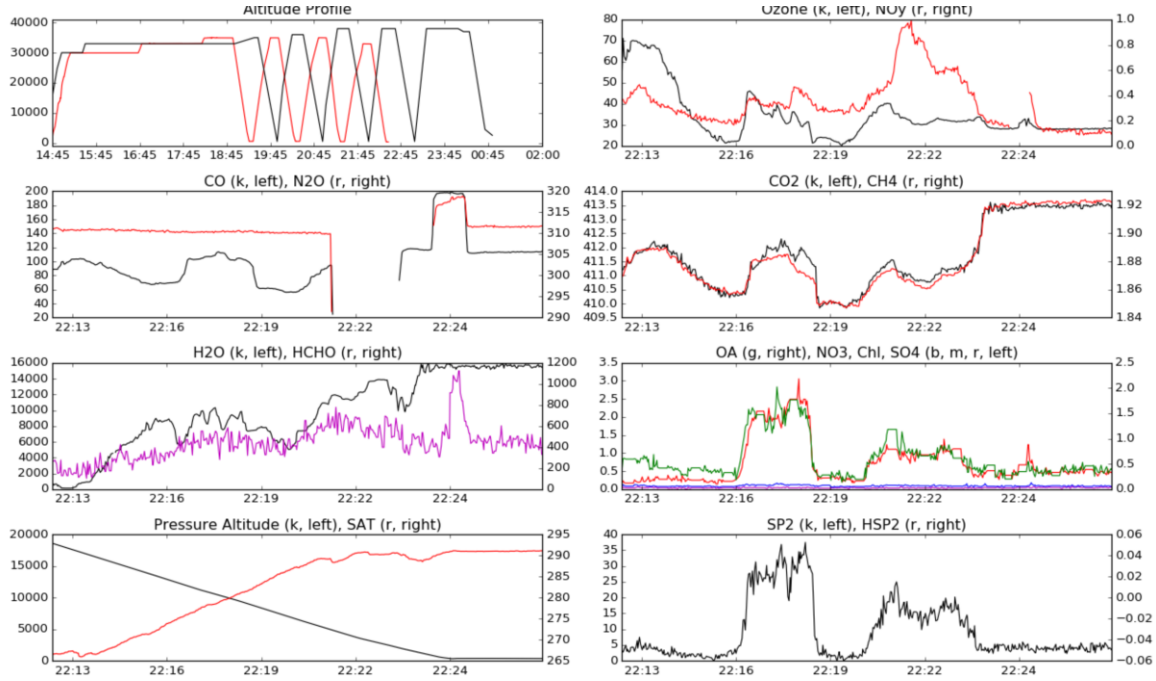
2152 – reach altitude

Have a ‘cinnamon swirl’ of O3 (45 to 80 ppb) at level flight



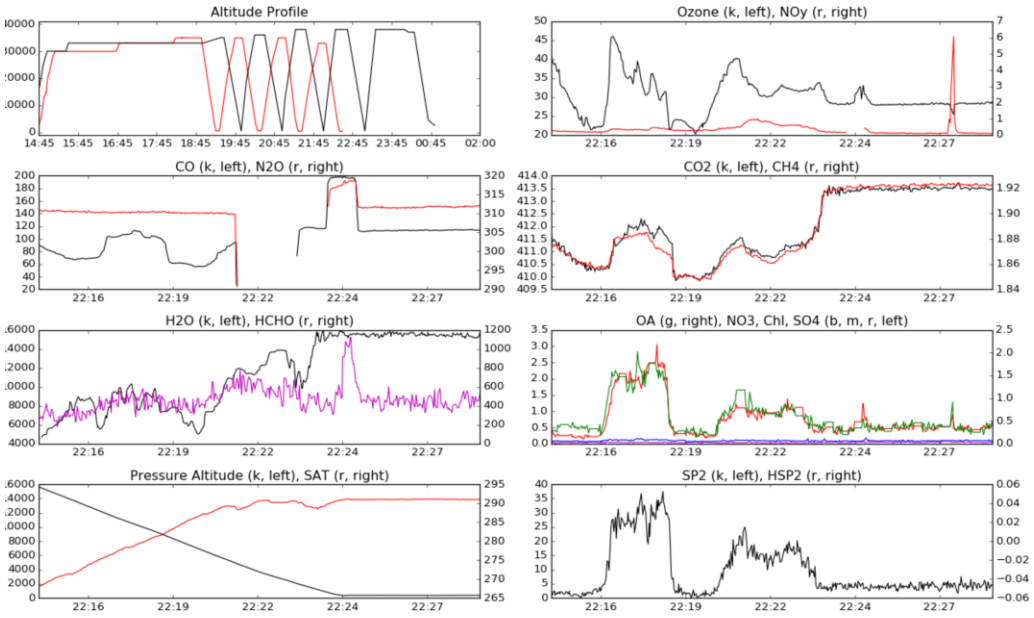
2216

On descent, passed thru very thick (5,000 ft) pollution (BB?) layer, CO, CO2, all particles, then another 5,000 ft layer just above the MBL. Final dip at 24d25m N Odd CO2 correlation with these two layers – indicate different sources of pollution. Note CO2 and CH4 highest in MBL.



2227

Ship plume, high NOx and NOy (and OA), ship sited off rigth side

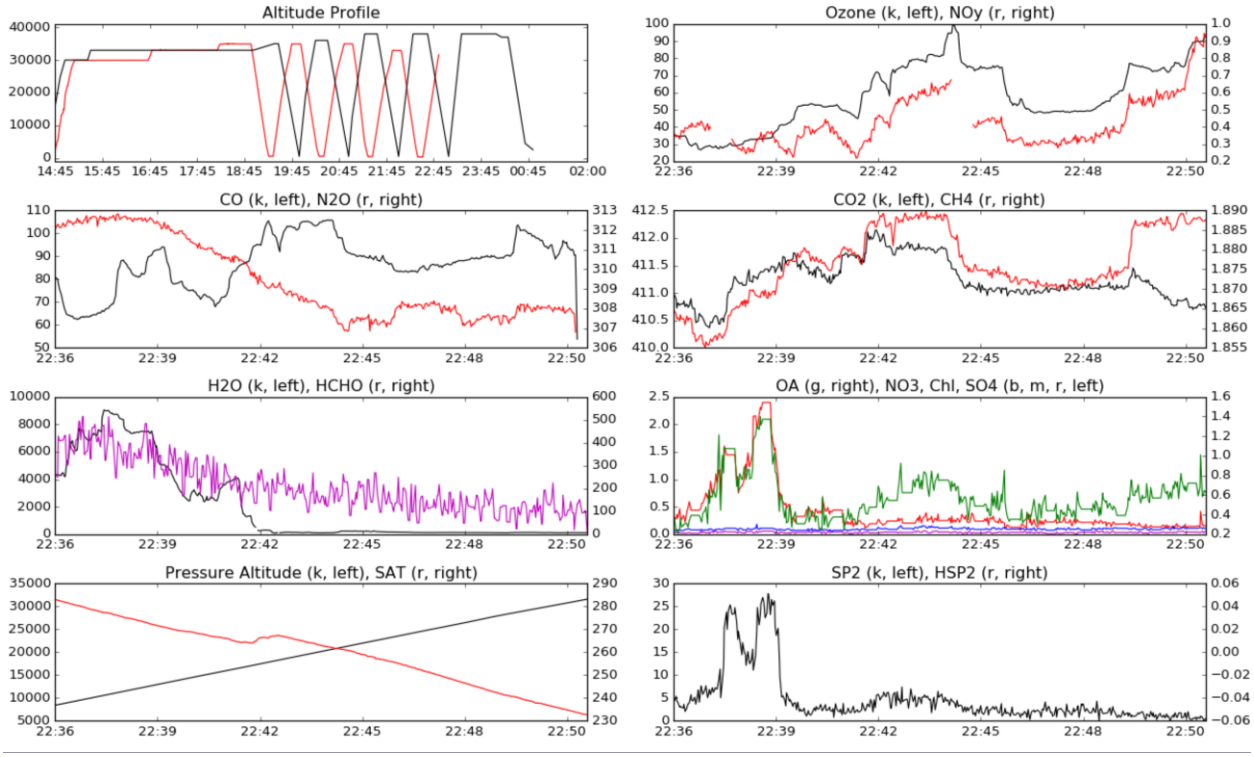


2231-2240 [no figure]

The two very thick aerosol (& NOy?) pollution layers (at 10 and 15 kft?) are separated by 2000 ft and have different origins based on O3 levels.

2245 at FL220, climbing.

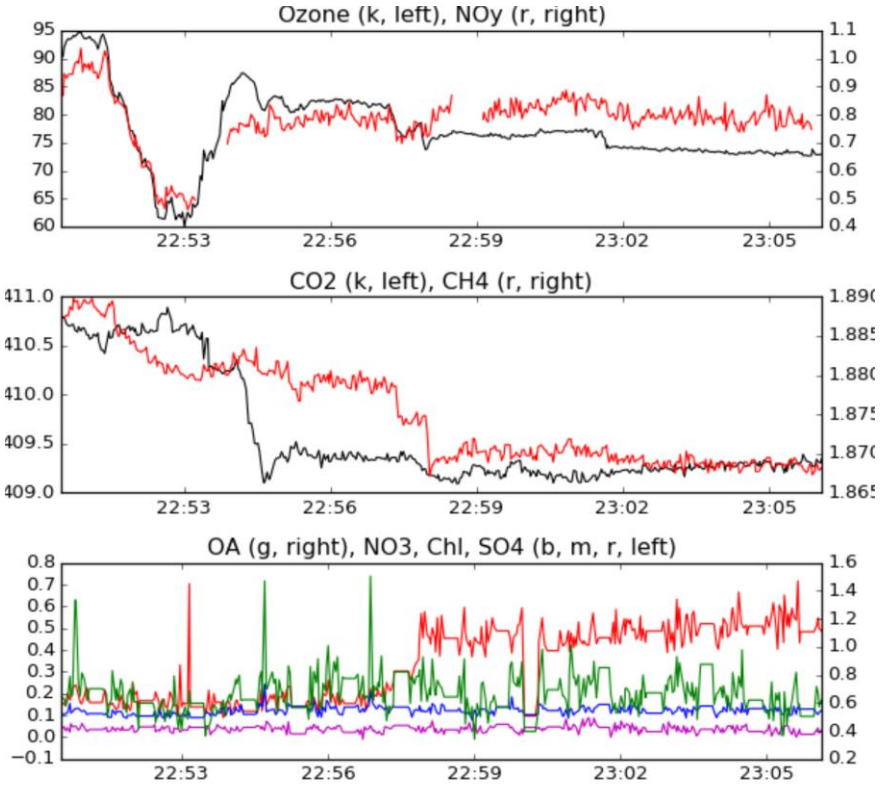
Very old descending air, RHw = 5%, or some strat influx? Probably some pollution with NOy:O3 6e-3. OA is high. CO is also high when O3 is, so either pollution production or pollution stream under jet mixes with strat influx.
GMI predicts high concentration Asian BB – coming in fast along jet, OK.



2257 FL380 27d29m N ETA 1730 PMD (landed at 1715)

2253-2259

Odd CO2/CH4 disconnect



2300-2311

CO2 and CH4 trend oppositely, CH4 and O3 trend alike

2312

big NOy plume (~FL390) also has OA & SP2 parallel

2319

2nd smaller NOy plume again – aircraft corridor to west?

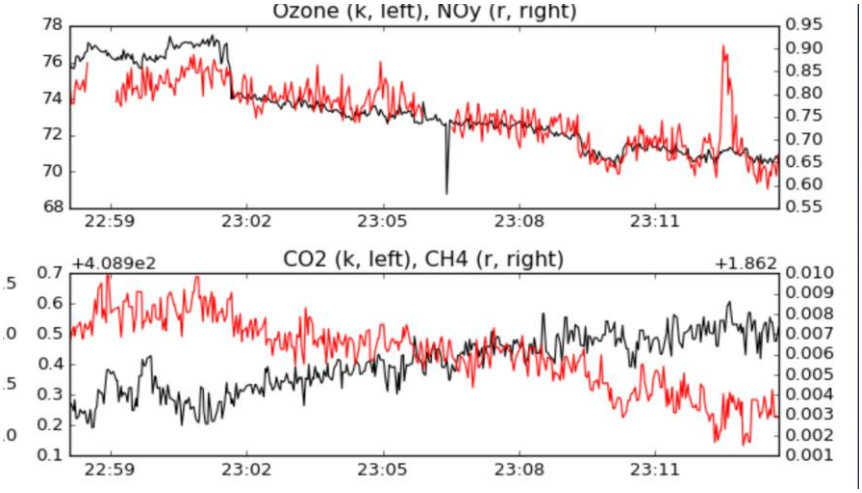
2315 reach FL390 on way home

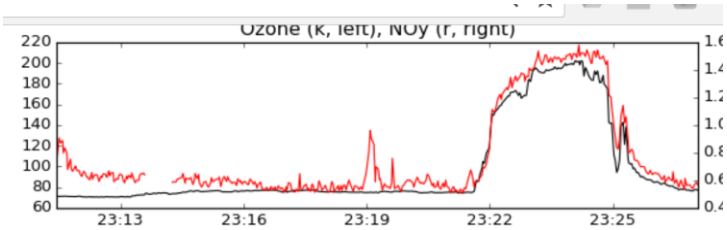
O3 rises to 75 ppb, H2O is low at 50 ppm. NOy drops

2 plumes at FL390 (2312 & 2319) and then very high NOY with strat O3.
Consistent high NO 100-160 ppt for most of the FL390 leg (to 2333 so far)
NO:NOy ratio is 1:4 !!

2322-2325

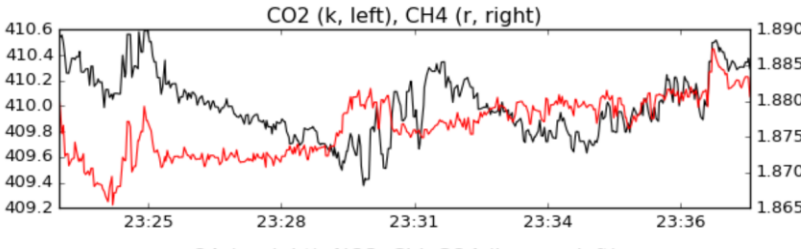
Enter stratosphere or nearly O3 = 190 ppb, H2O = 20 ppm, but very high SP2 (2.0). Is this Asian pollution + some STE influx being mixed?
NB these air masses lasting 3 min are about 40-50 km could be resolved





2329-2335

There are still examples of CO2/CH4 reverse trends over 50 km at FL390

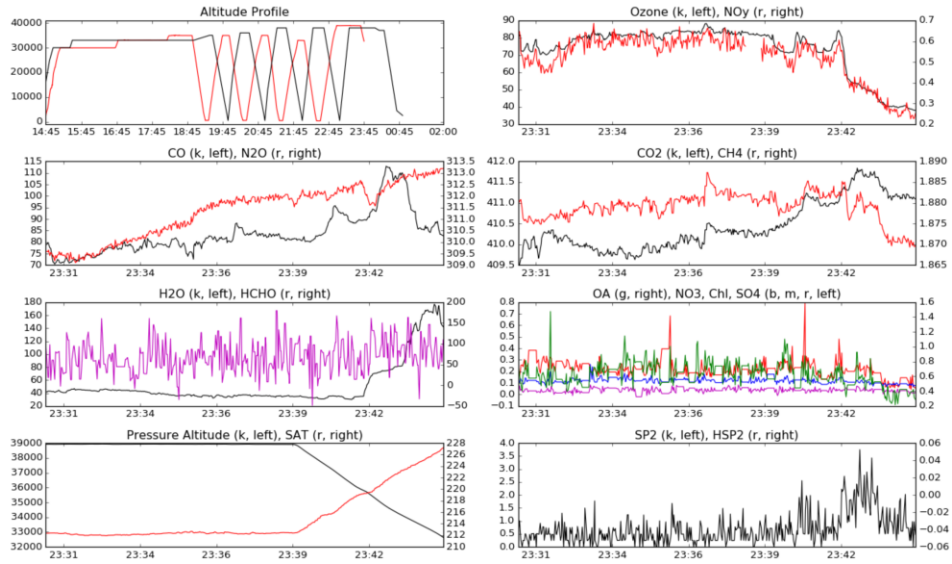


2342

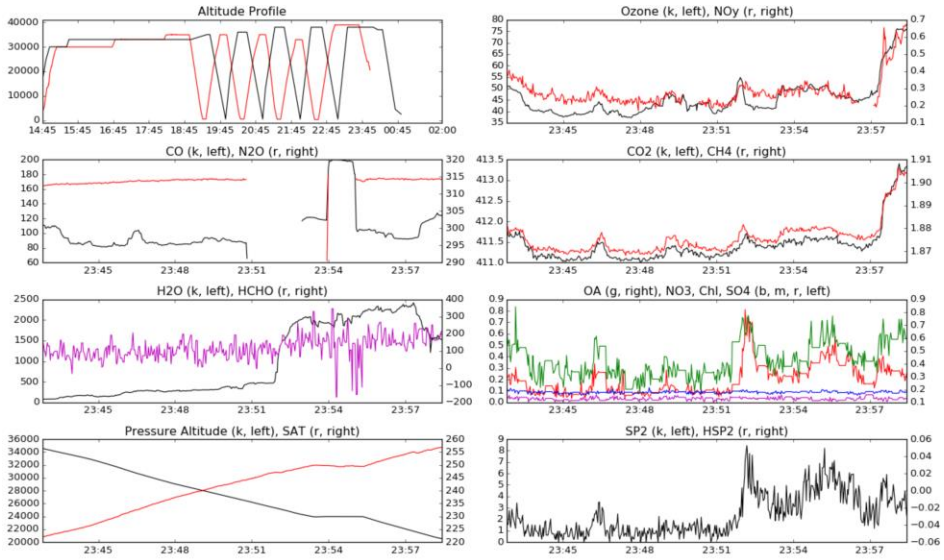
We leave a heavily strat-influence air mass as we go thru FL350 and then suddenly find a highly polluted layer (CO=115, SP2=2.0, CH4 jumps 8 ppb).

2347 (not shown)

Spike in CO, CO2, CH4 all together. Possibly a thin layer from NMidLats. Also SP2 goes with these, probably not just lat gradients, but surface pollution at FL320?



A lot of pollution layers on descent, maybe layers from higher north mid lats



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