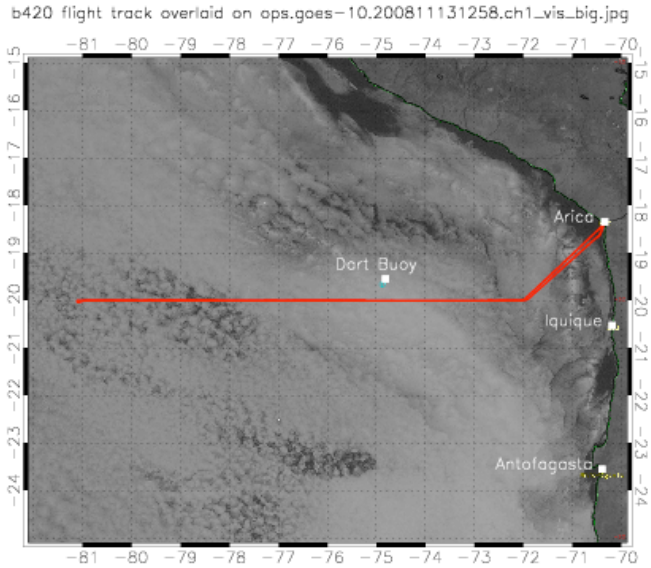
BAe-146 20º S Composition Statistics

Grant Allen and the VOCALS-UK team

Seattle Meeting – 13th July 2009

Rationale I

- The 20 South flights were conceived to provide a statistically representative cloud, thermodynamic and composition dataset for modellers.



•To have meaning, any derived statistics must be internally consistent with respect to the prevailing meteorology and pollution sources

•Total of six 20 deg S flights by the BAe-146 with non-consistent flight patterns (a good thing!)

•Total of 4 (potentially 7) suitable Dornier flights to complement the coastal aerosol dataset (particularly above cloud/free trop)

•Up to 10 suitable C-130 flights across a longer period than VOCALS-UK

•Potential to include data from the G-1 and RHB and possibly Aeronet site.

•Concentrate here on BAe-146 data only

Rationale II

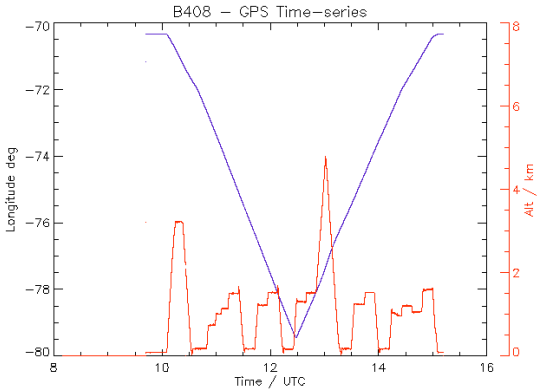
- Use two of the three currently defined meteorological periods (c/o T. Toniazzo) to cover all UK measurements

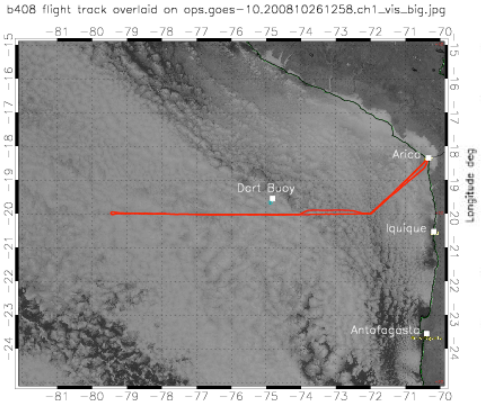
  - 15^{th}-31^{st} Oct → Surface anti-cyclone, unstable STJ

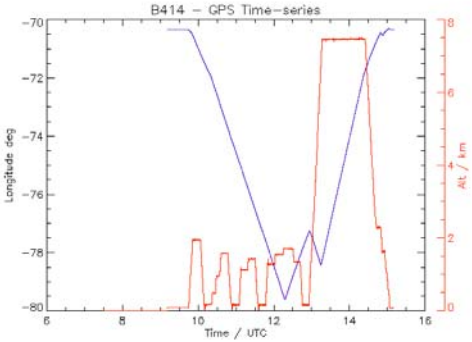
  - 3^{rd}-12^{th} Nov → UT anti-cyclone, steady STJ

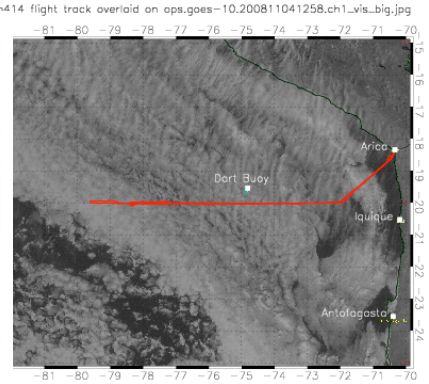
- Meaning BAe-146 flights per period: B408 – B412; and B414 - B420, respectively

- Look for signals in composition and thermodynamic statistics which represent these periods and feedback and iterate if necessary


B408 – GPS Time–series
Longitude deg
Alt / km
Time / UTC


b408 flight track overlaid on ops.goes–10.200810261258.ch1_vis_big.jpg
Arica
Dart Buoy
Iquique
Antofagasta


B414 – GPS Time–series
Longitude deg
Alt / km
Time / UTC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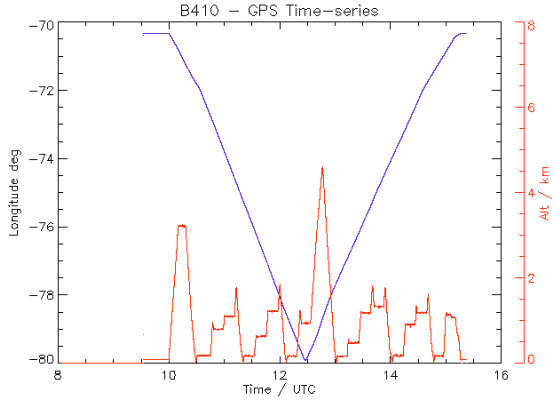
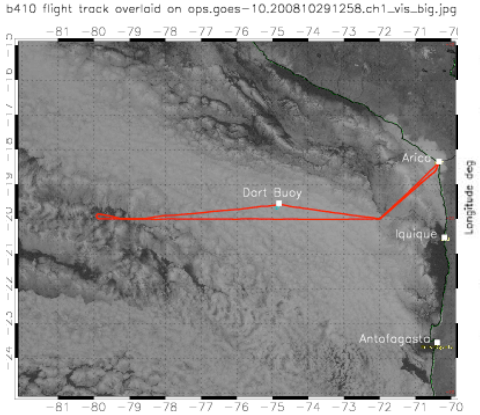
Dart Buoy
Iquique
Antofagasta


B410 – GPS Time–series
Longitude deg
Alt / km
Time / UTC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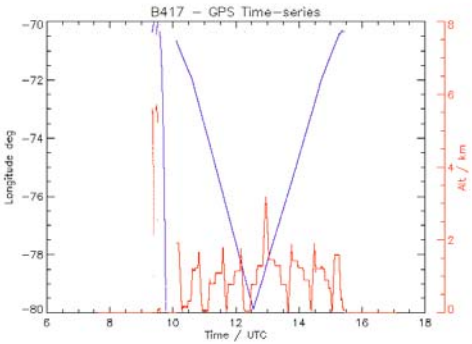
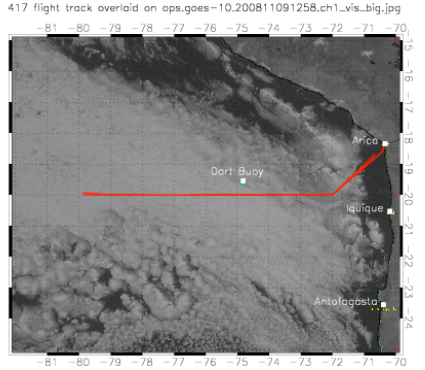
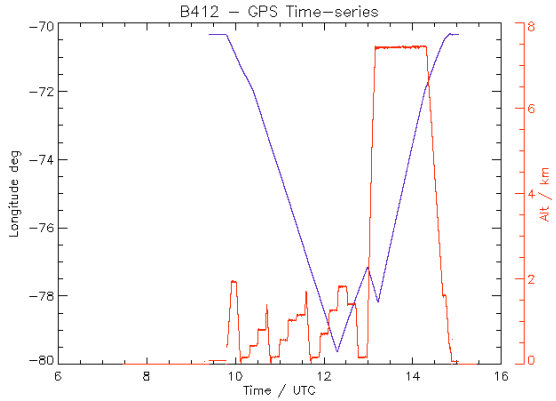
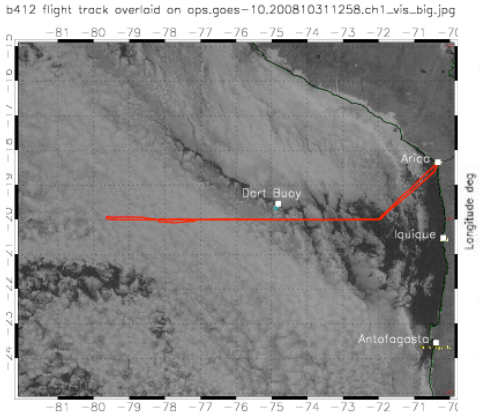
Dart Buoy
Iquique
Antofagasta


B417 – GPS Time–series
Longitude deg
Alt / km
Time / UTC


417 flight track overlaid on ops.goes–10.200811091258.ch1_vis_big.jpg
Arica
Dart Buoy
Iquique
Antofagasta


B412 – GPS Time–series
Longitude deg
Alt / km
Time / UTC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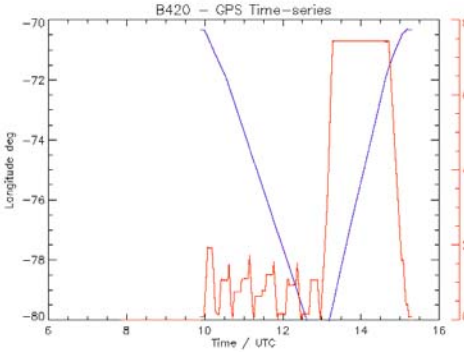
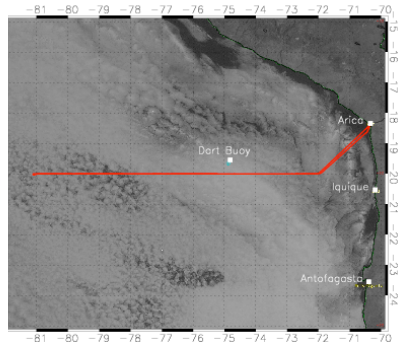
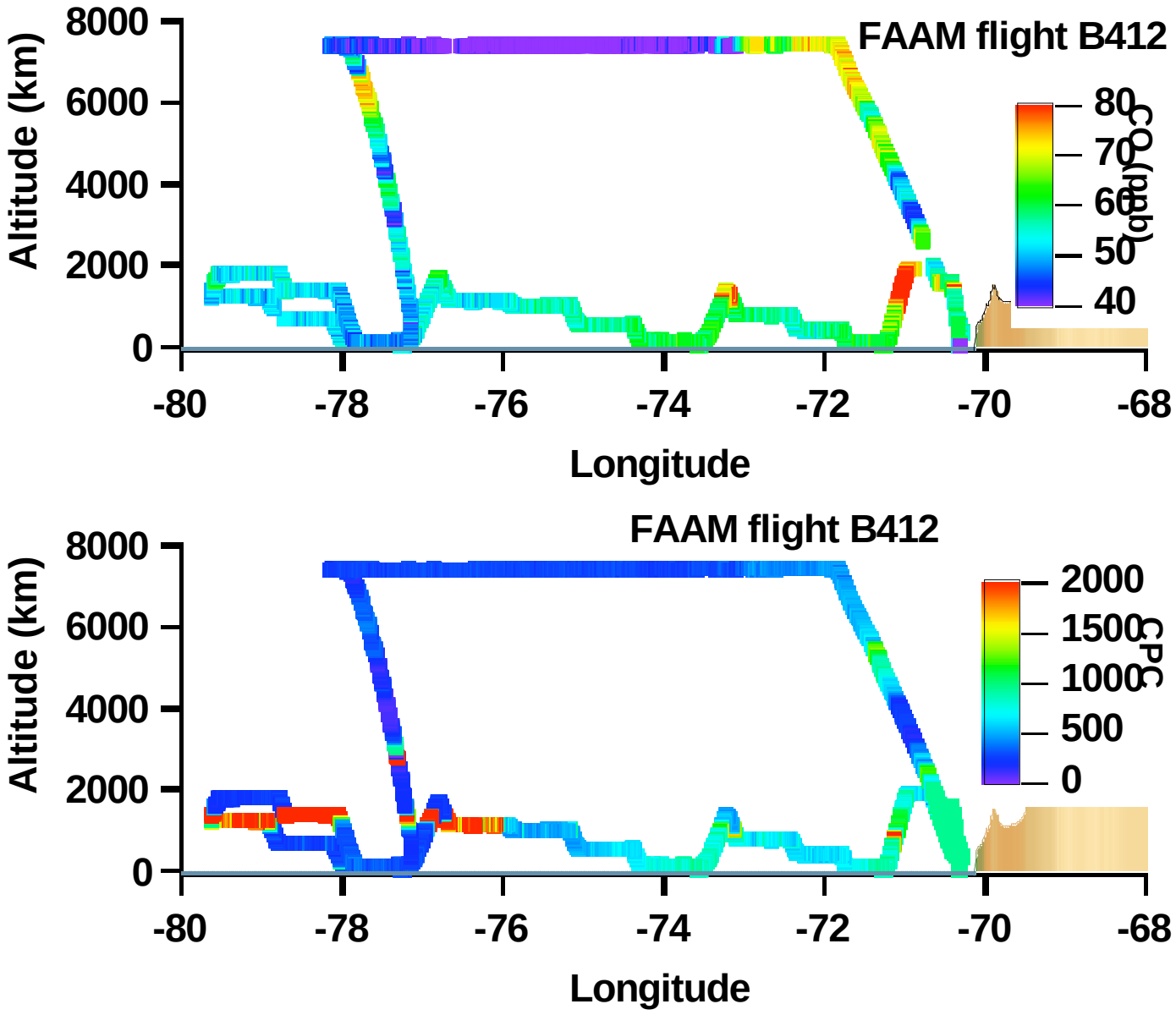
Arica
Dart Buoy
Iquique
Antofagasta

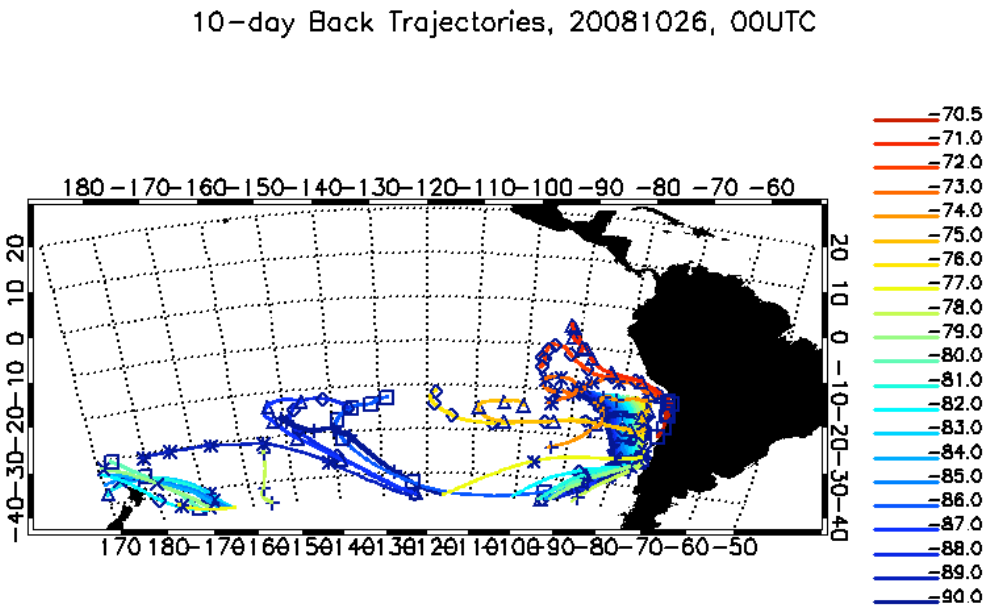

B420 – GPS Time–series
Longitude deg
Alt / km
Time / UTC


:0 flight track overlaid on ops.goes–10.200811131258.ch1_vis_big.jpg
Arica
Dart Buoy
Iquique
Antofagasta

An example of a 20S Lagrangian (B412)

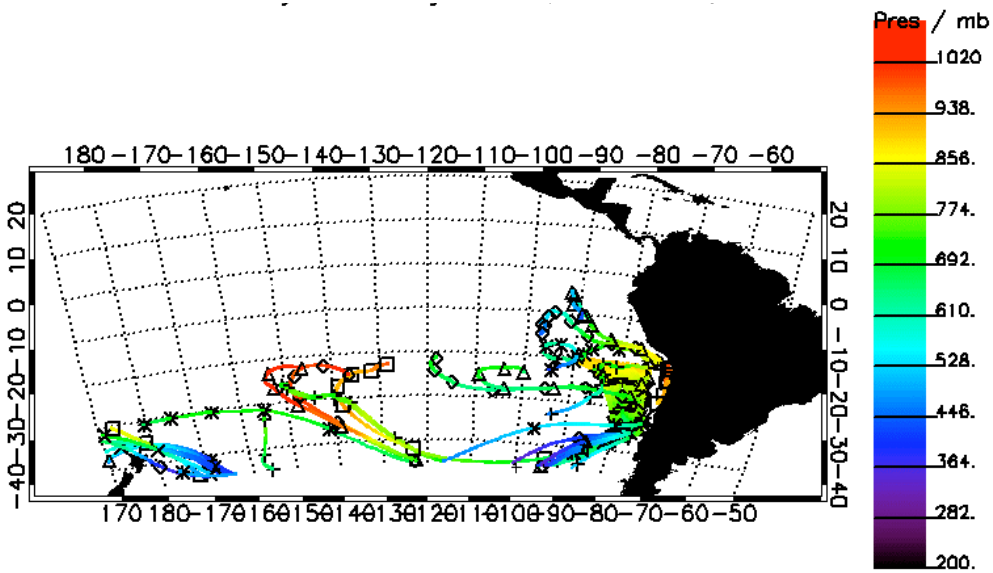
Figure c/o
Jonny Crosier

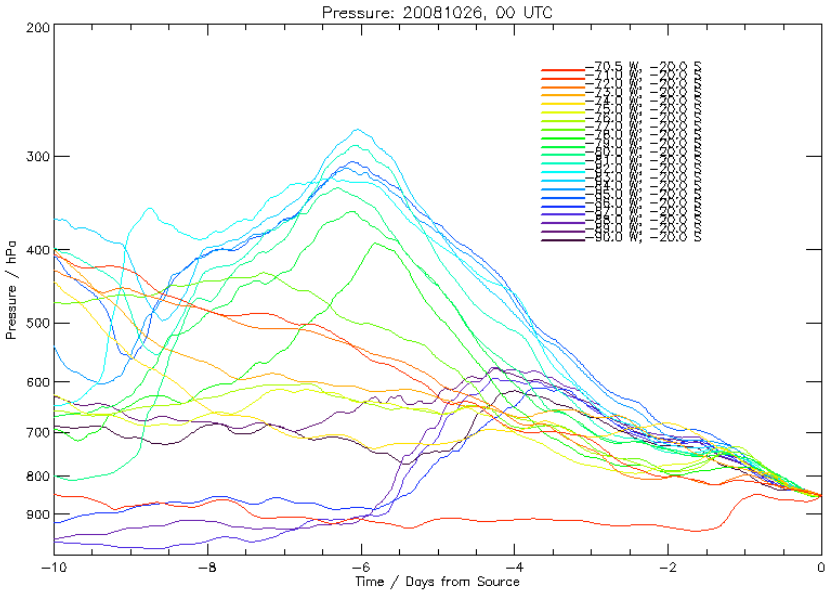


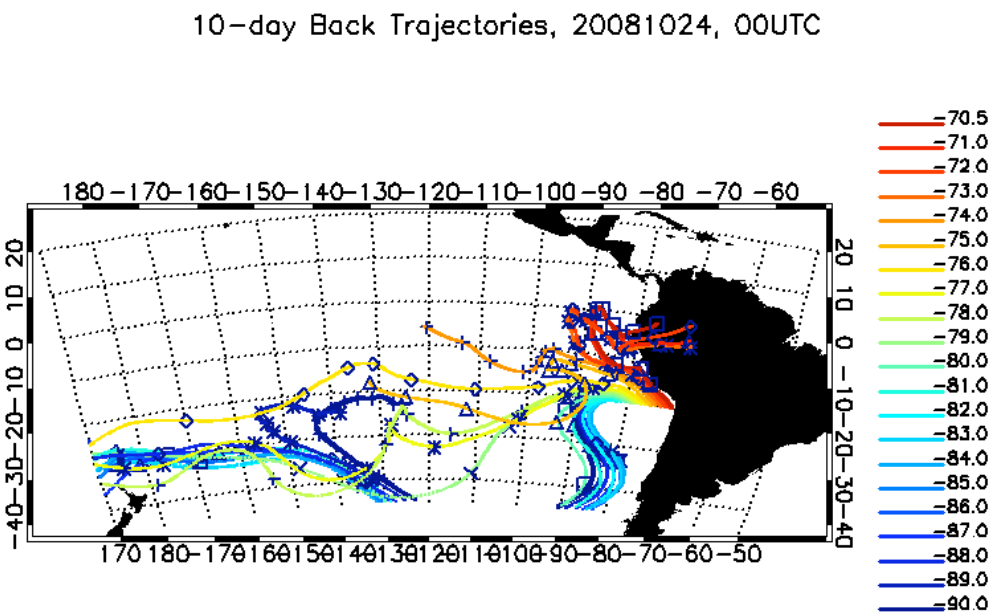


Period 1 – Boundary layer

10-day ECMWF 3D back trajectories along 20 S, initiated at 850 mb at 0.5 degree intervals show contrast in sources, sometimes lofted, dries and descended air (e.g. 90 W), sometimes, resident in MBL for many days.



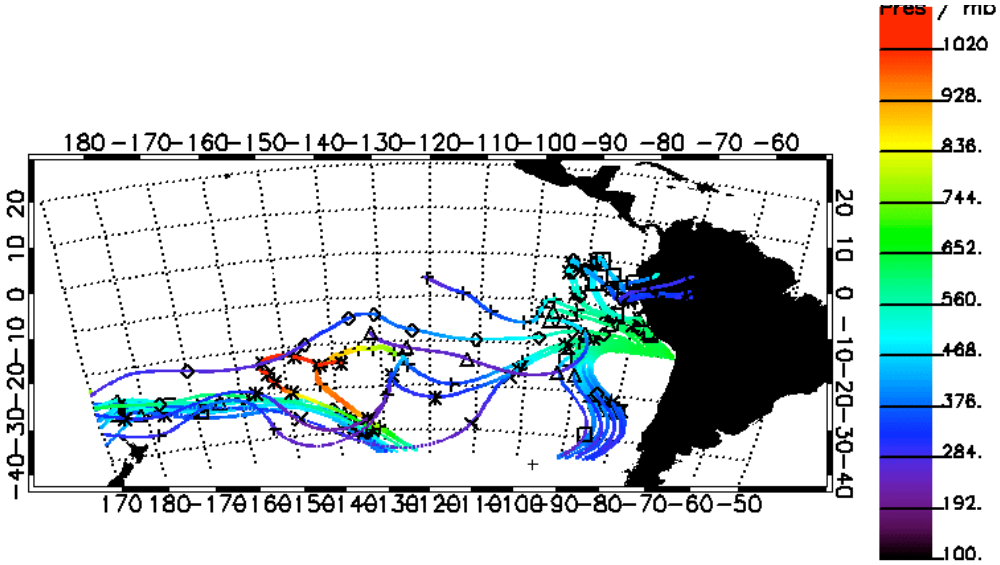


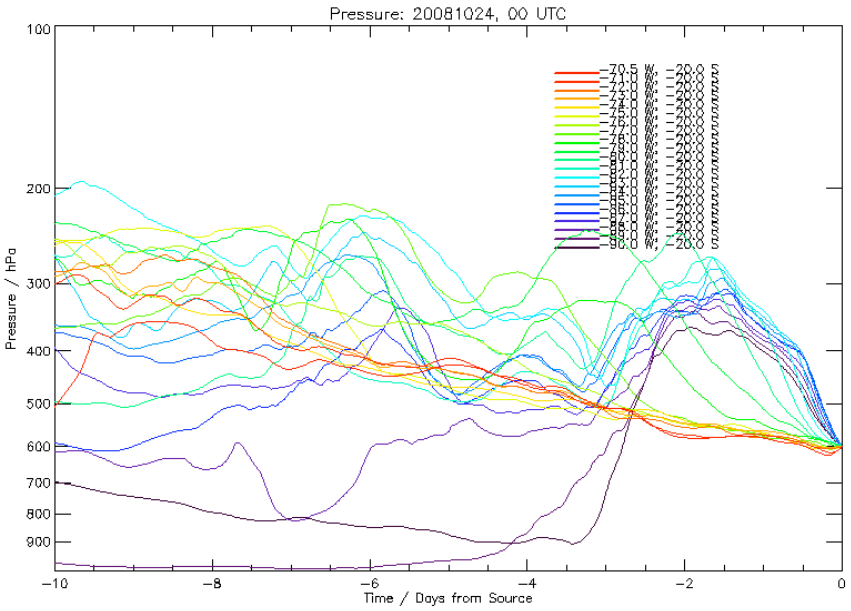


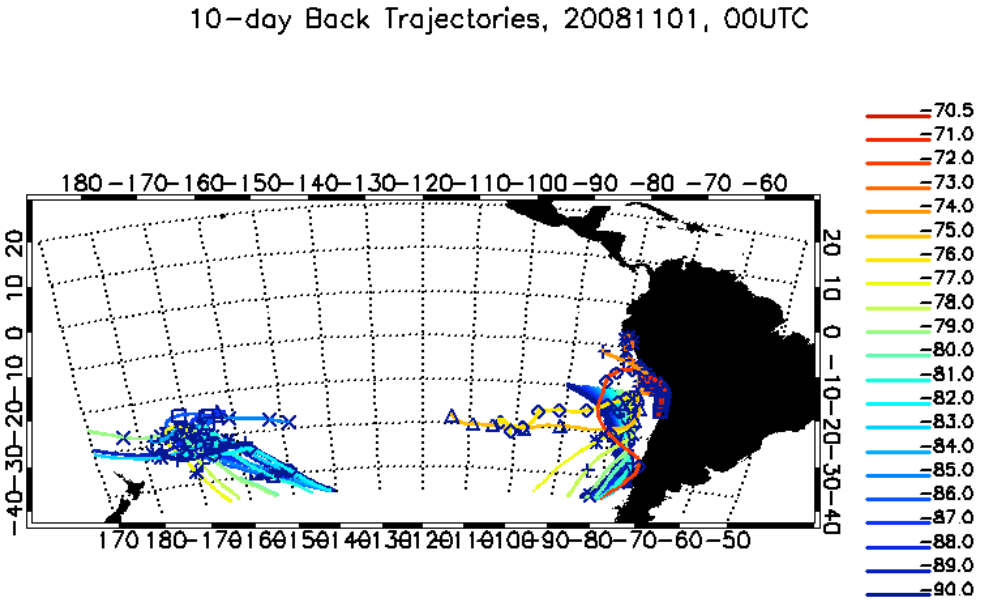
Period 1 – Free troposphere

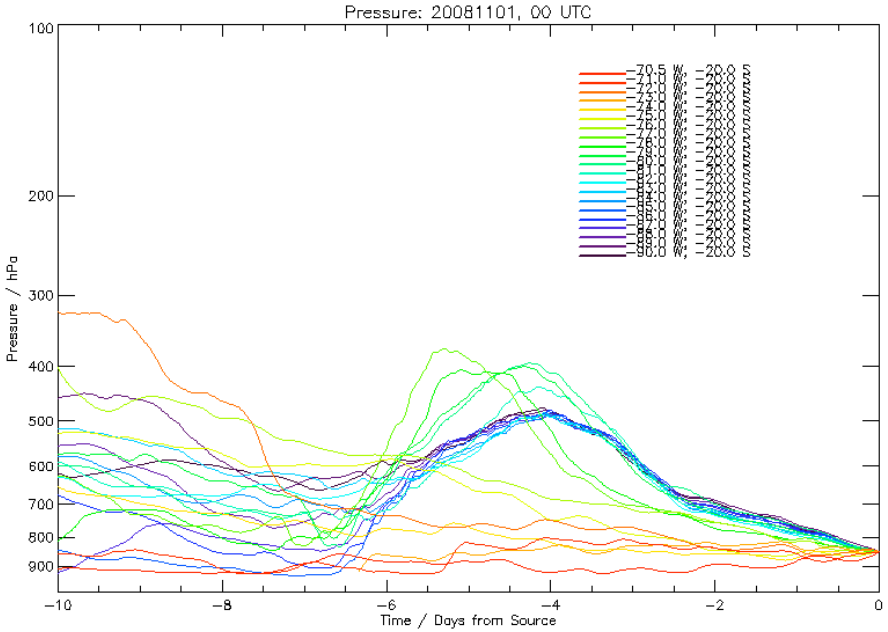
Mid-trop has a gradient in source direction in period 1, going out to sea with continental PBL sources near the coast and descended long-range remote sources west of 75 W.

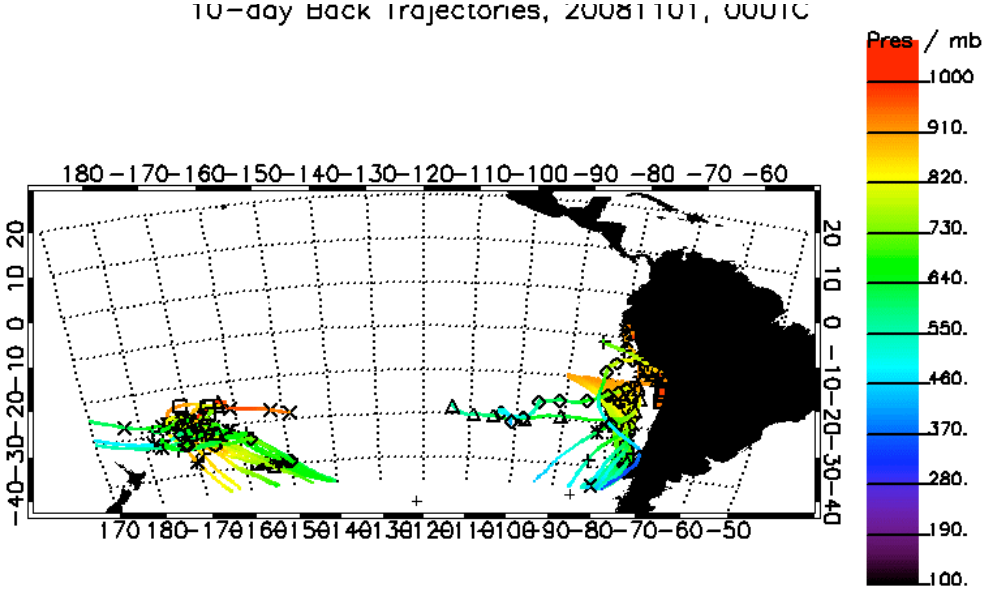
Uplift to UT may have frozen in some pollution signatures and removed others





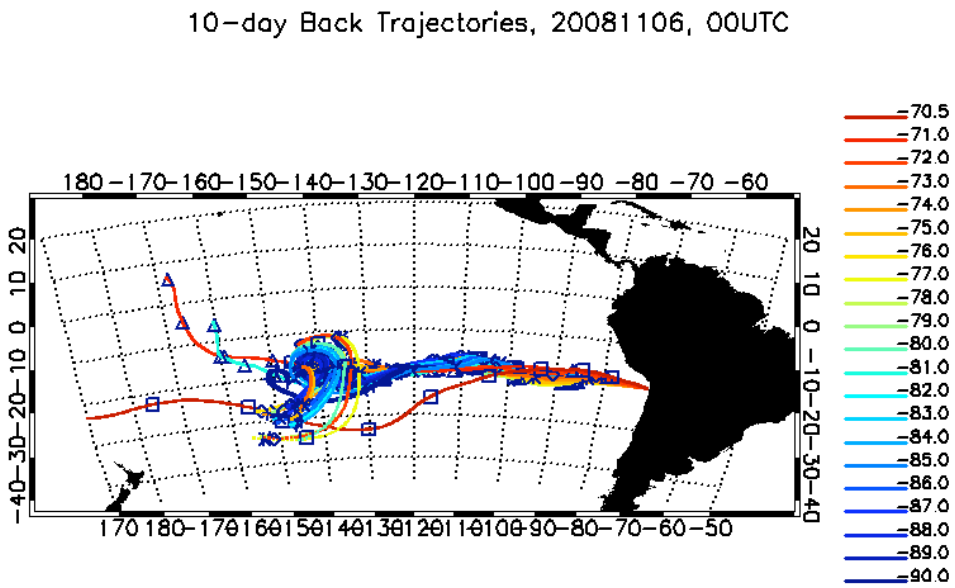


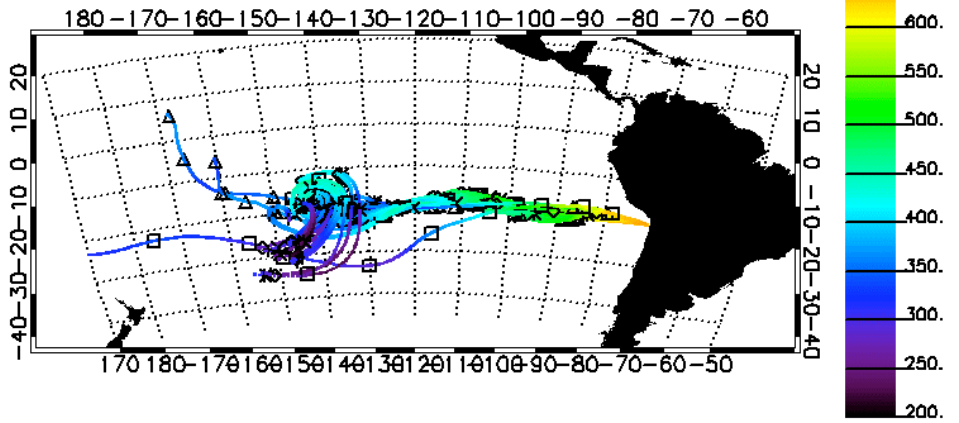




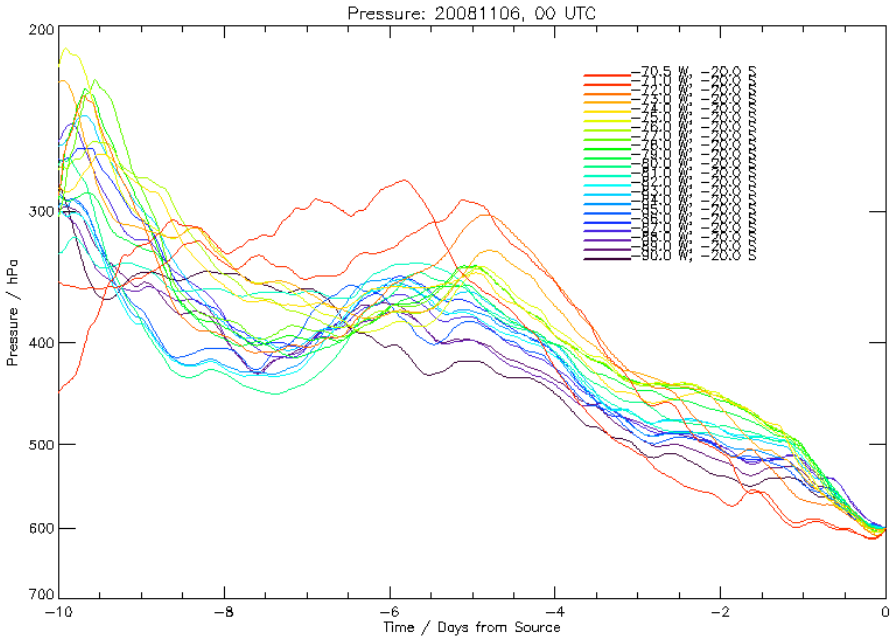
Period 2 – Boundary layer

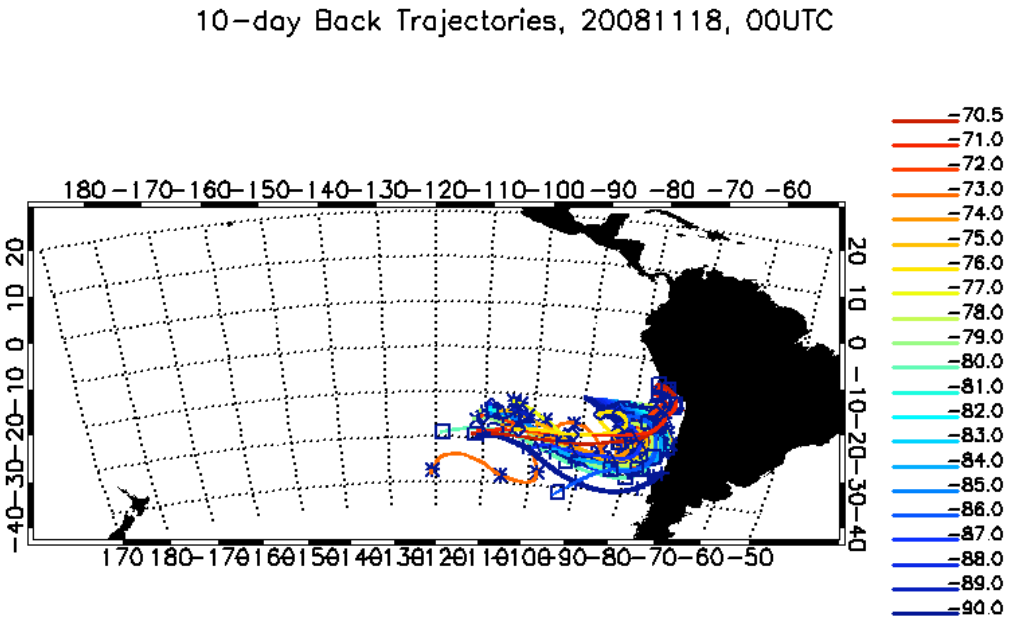
Trough region well-defined around 1st Nov with well-confined uplift representing the origins of air across the whole of the 20 S line except just off the coast, where air has advected in the PBL/MBL from the North.

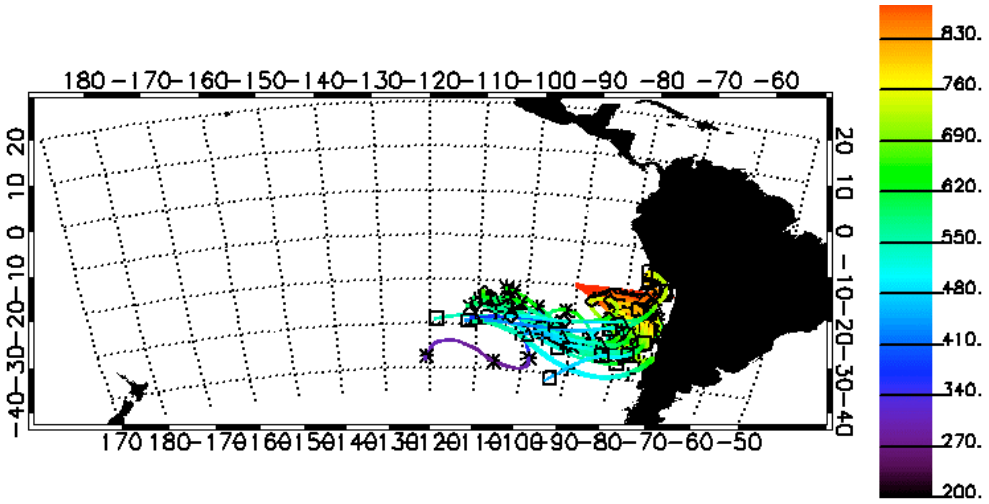




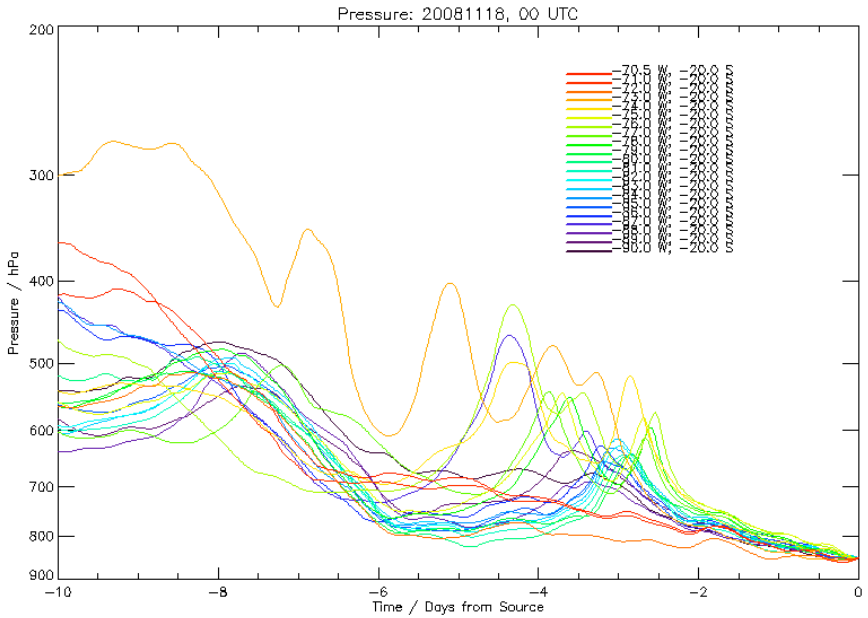
In period 2, in the free troposphere, sources are coherent along the 20 S strip, all uplifted and transported in the STJ from the mid-Pacific, descending slowly as approaching the SA coast.

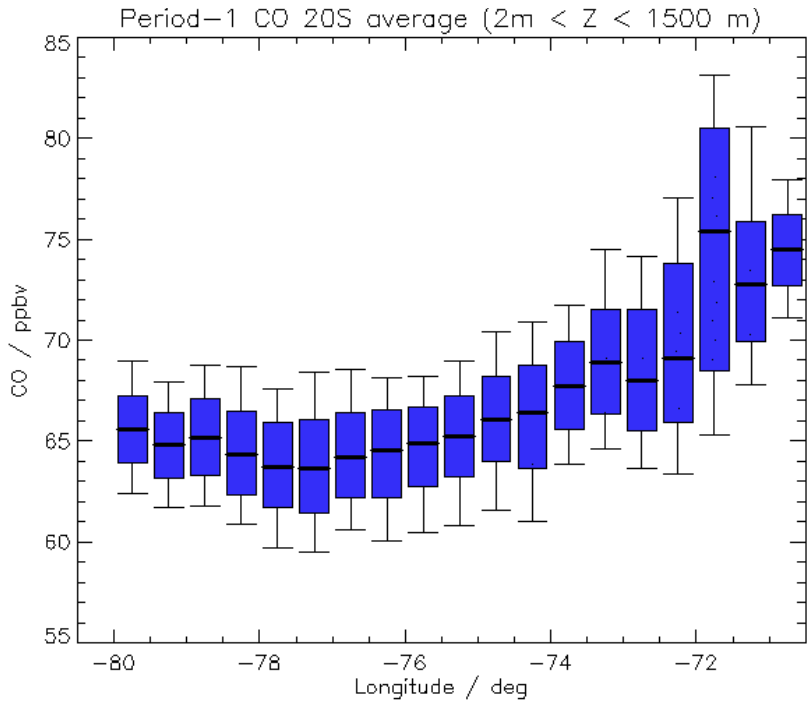


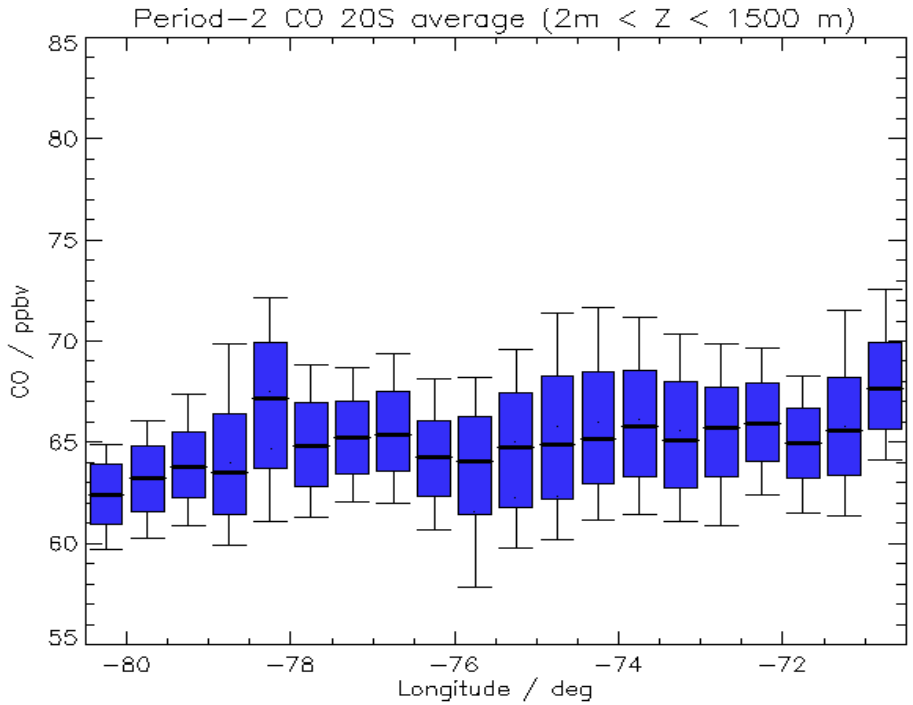


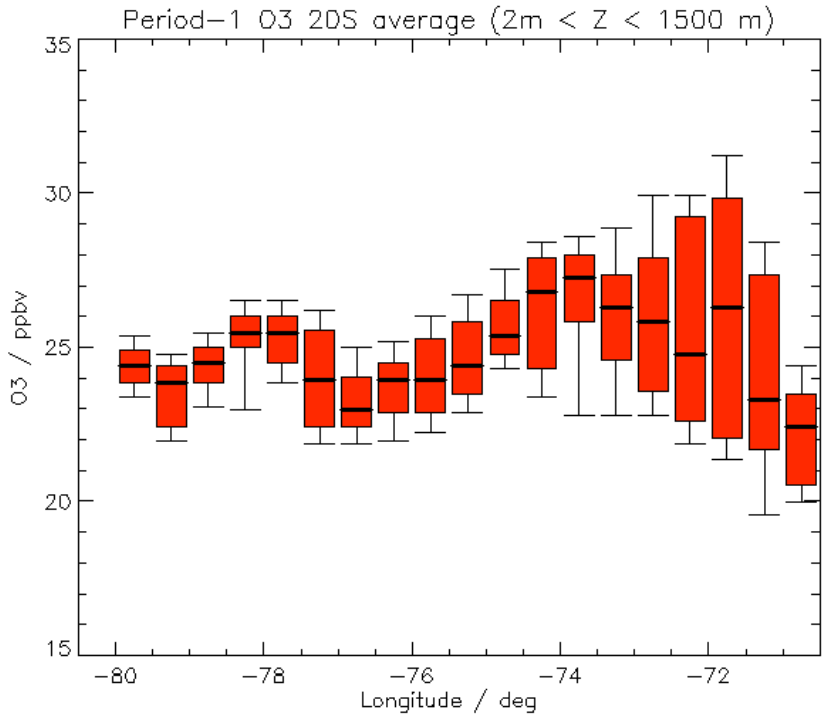


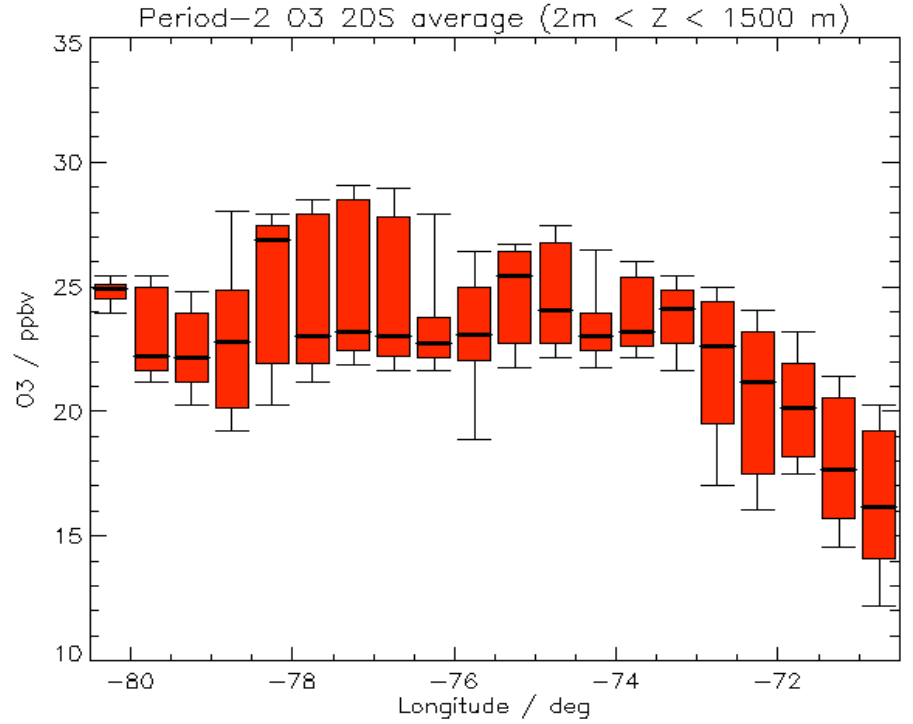
In Period 3, after end of flying (18th Nov), descent weakened, with air having resided in the MBL or free trop for the past 10 days – very different likely airmass to that sampled during REx



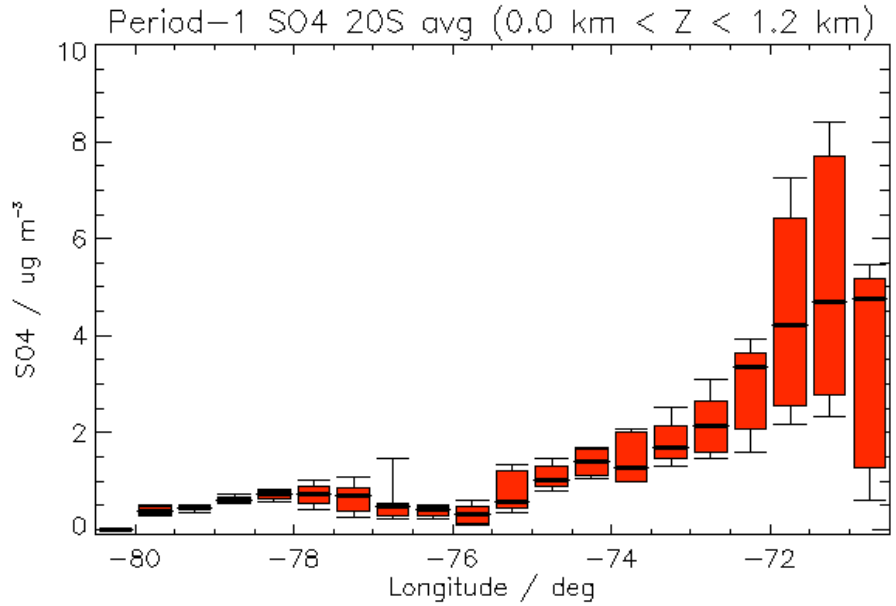

Period−1 CO 20S average (2m < Z < 1500 m)
CO / ppbv
Longitude / deg

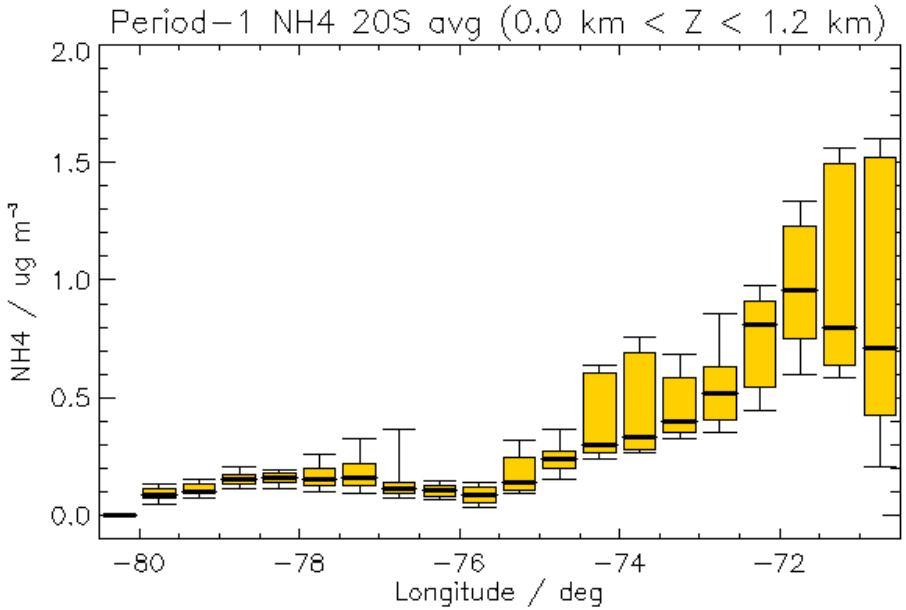

Period−2 CO 20S average (2m < Z < 1500 m)
CO / ppbv
Longitude / deg

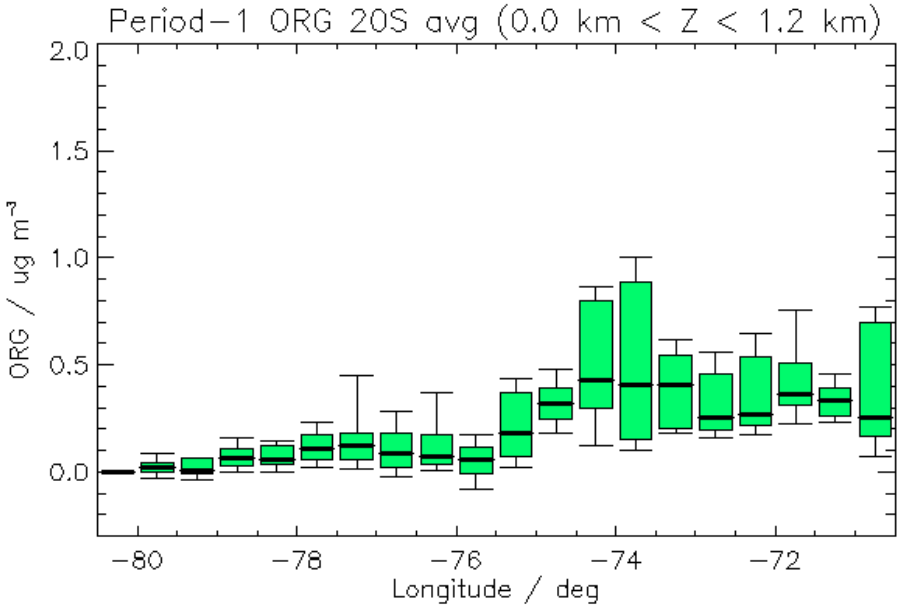

Period−1 O3 20S average (2m < Z < 1500 m)
O3 / ppbv
Longitude / deg

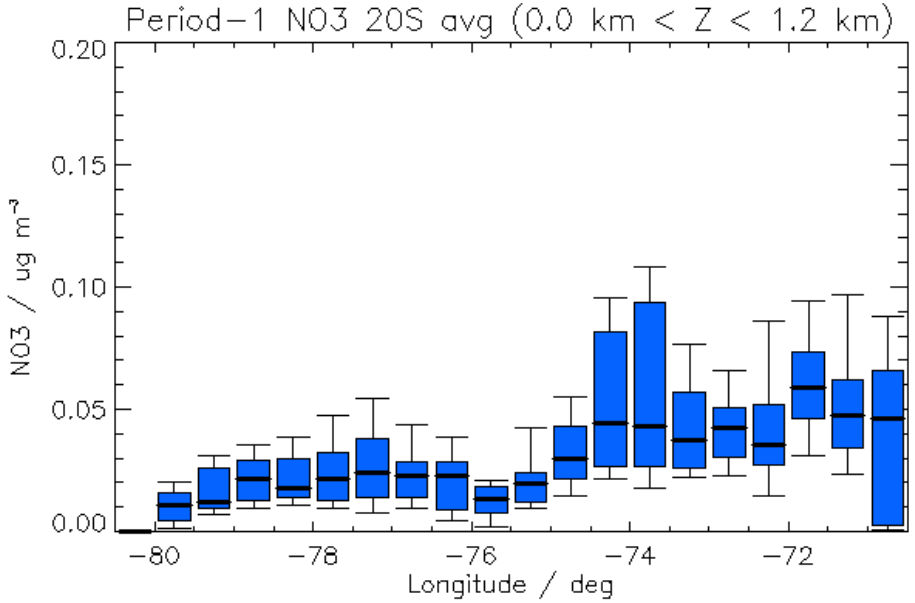

Period−2 O3 20S average (2m < Z < 1500 m)
O3 / ppbv
Longitude / deg

Period 1 (15th – 31st Oct) – Below cloud

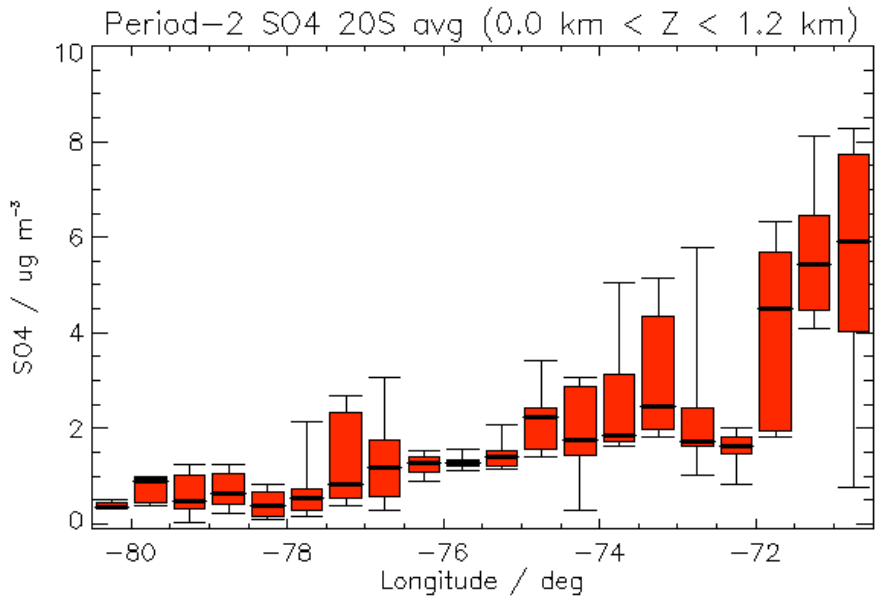


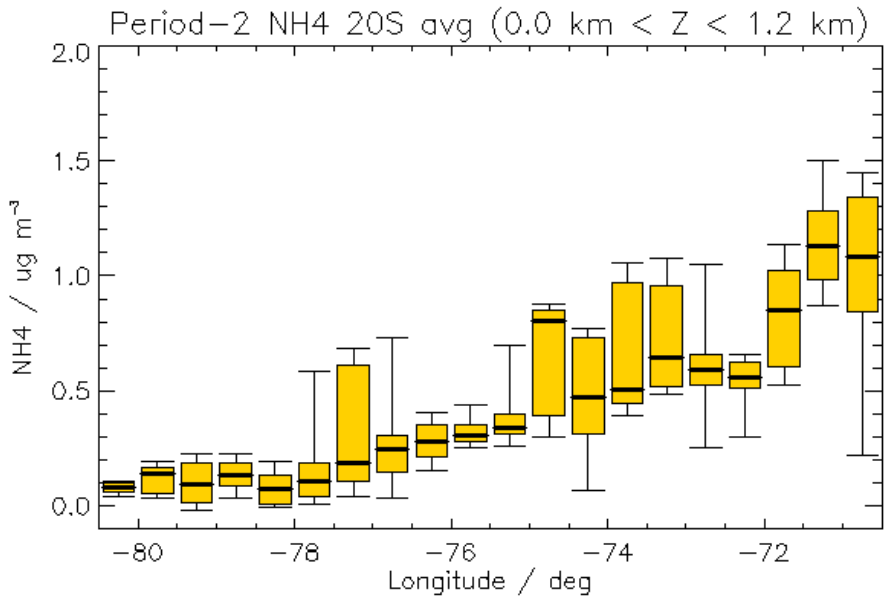


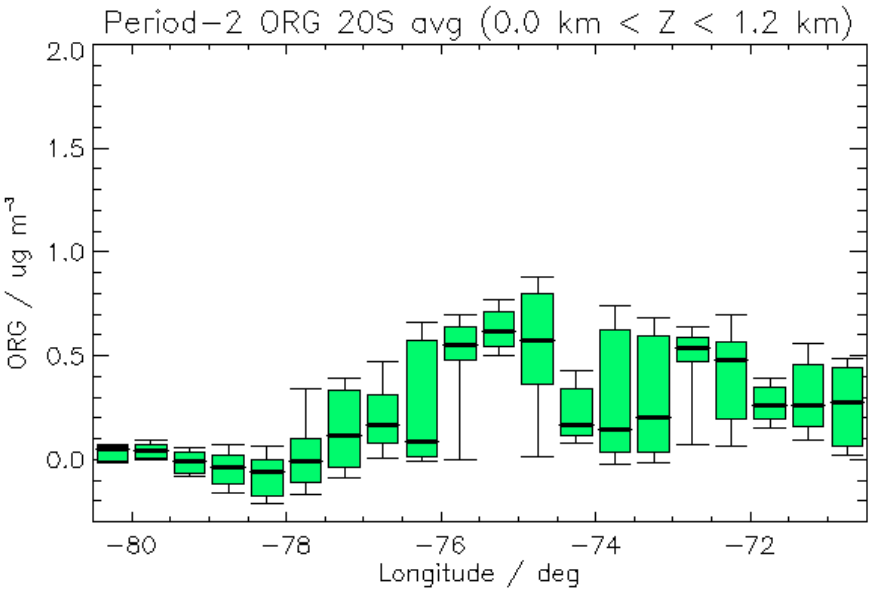


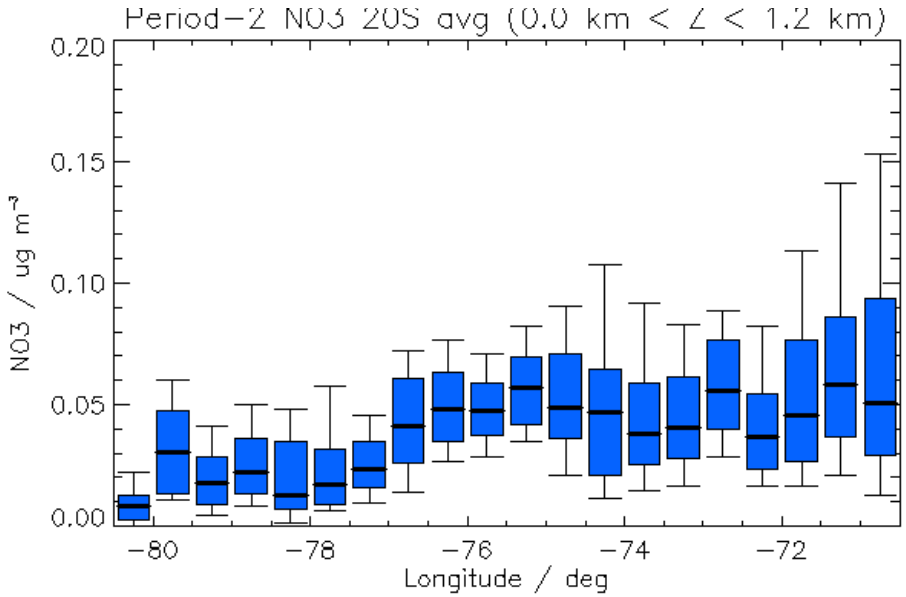


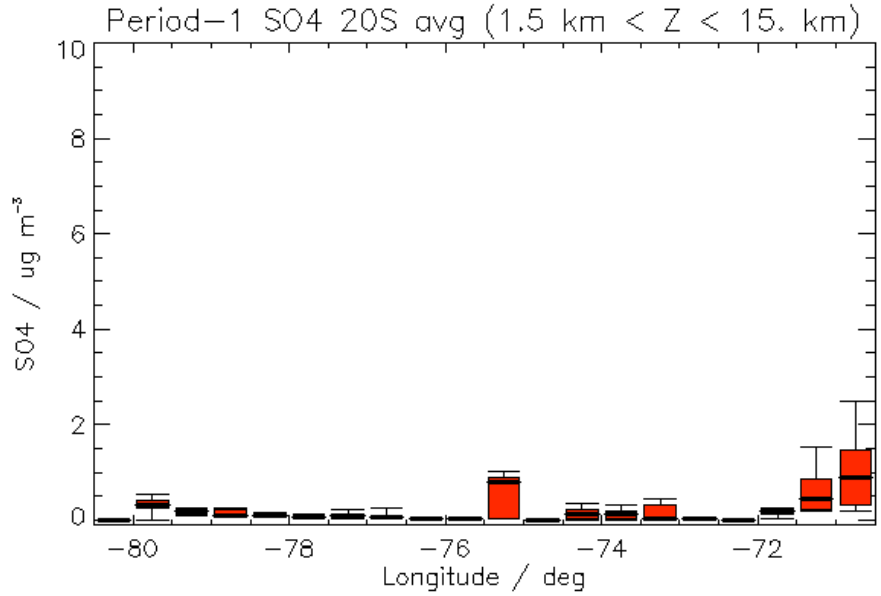
Period 2 (5 - 12th Dec 2008)

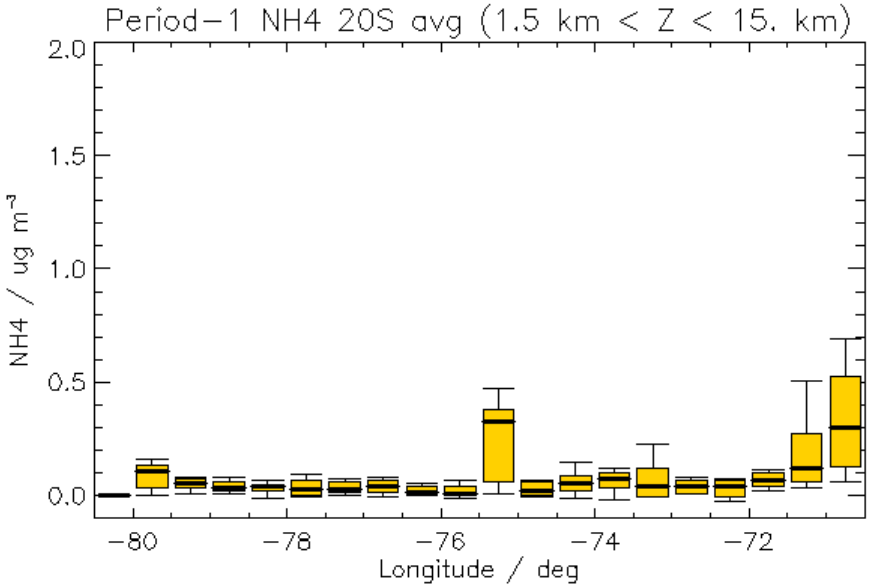


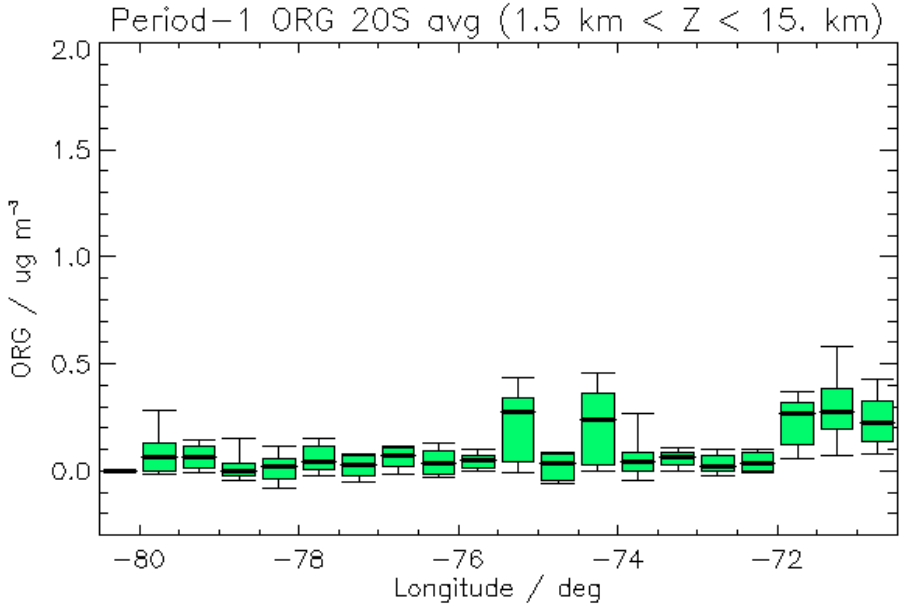


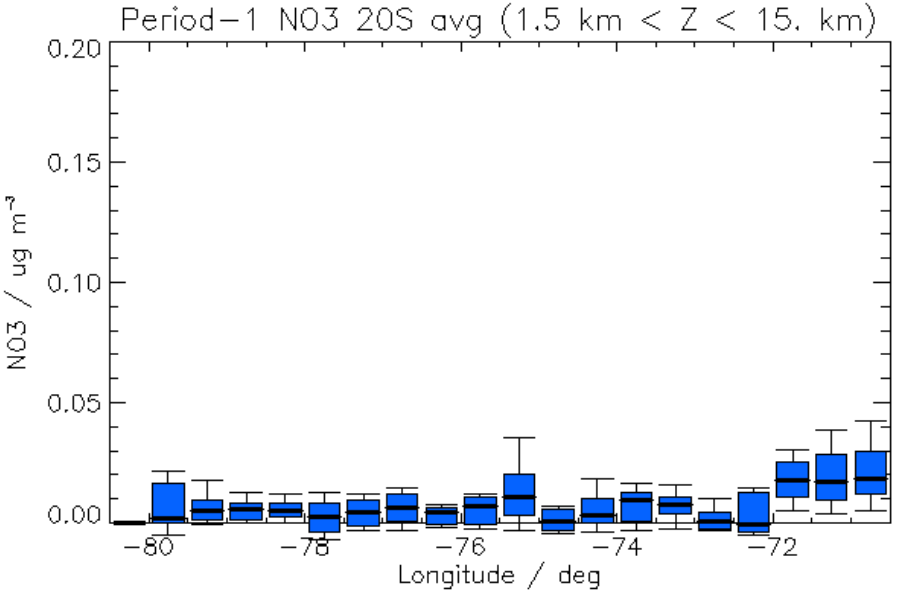


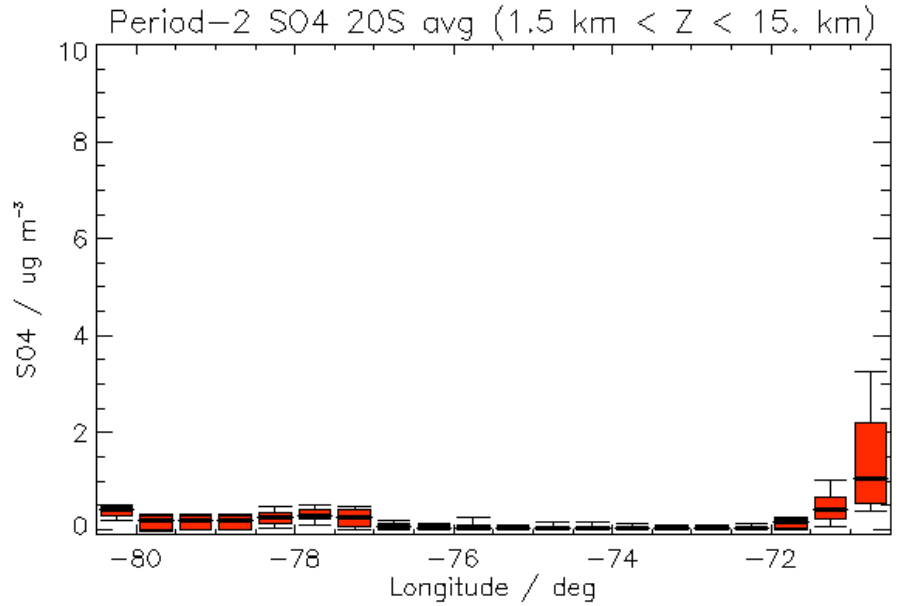


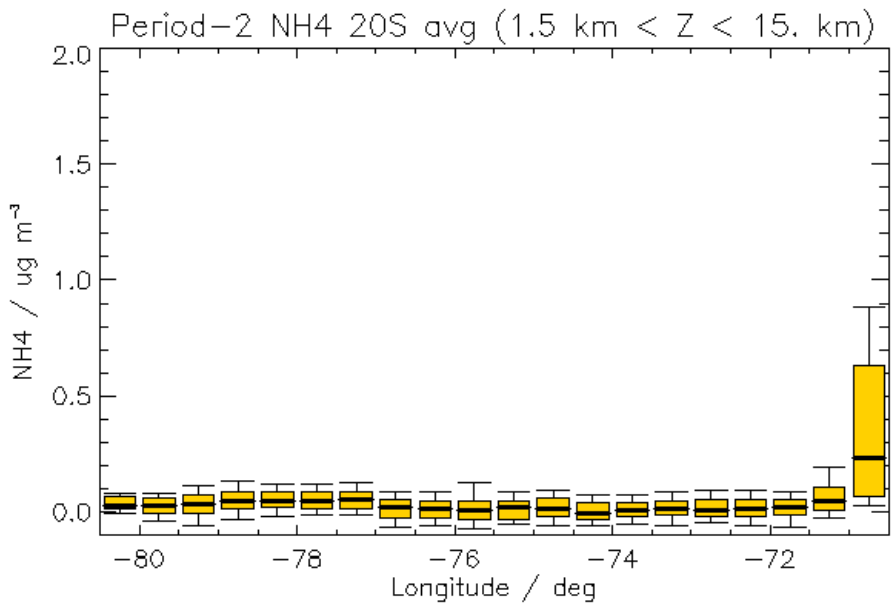

Period−1 SO4 20S avg (1.5 km < Z < 15. km)
SO4 / ug m⁻³
0
2
4
6
8
10
−80
−78
−76
−74
−72
Longitude / deg

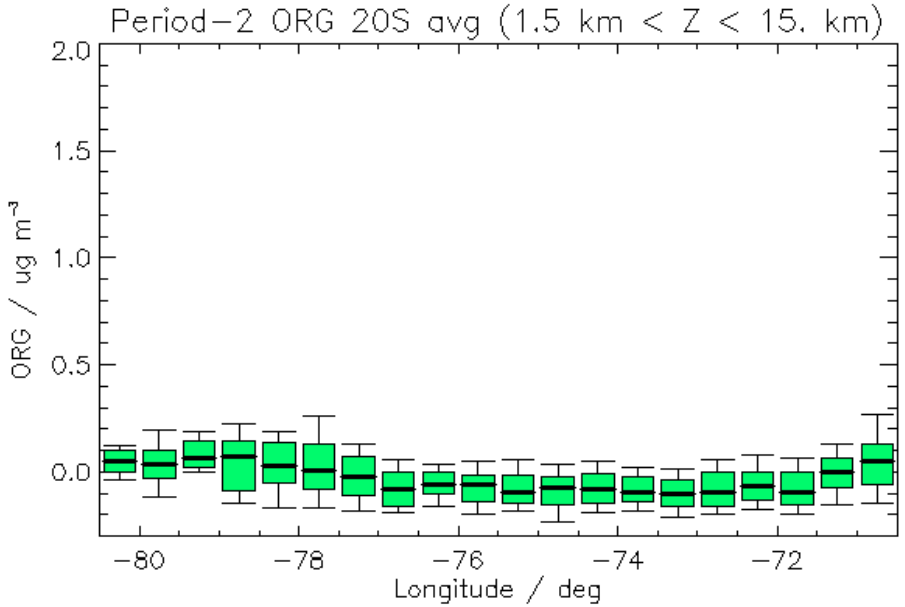

Period−1 NH4 20S avg (1.5 km < Z < 15. km)
NH4 / ug m⁻³
0.0
0.5
1.0
1.5
2.0
−80
−78
−76
−74
−72
Longitude / deg

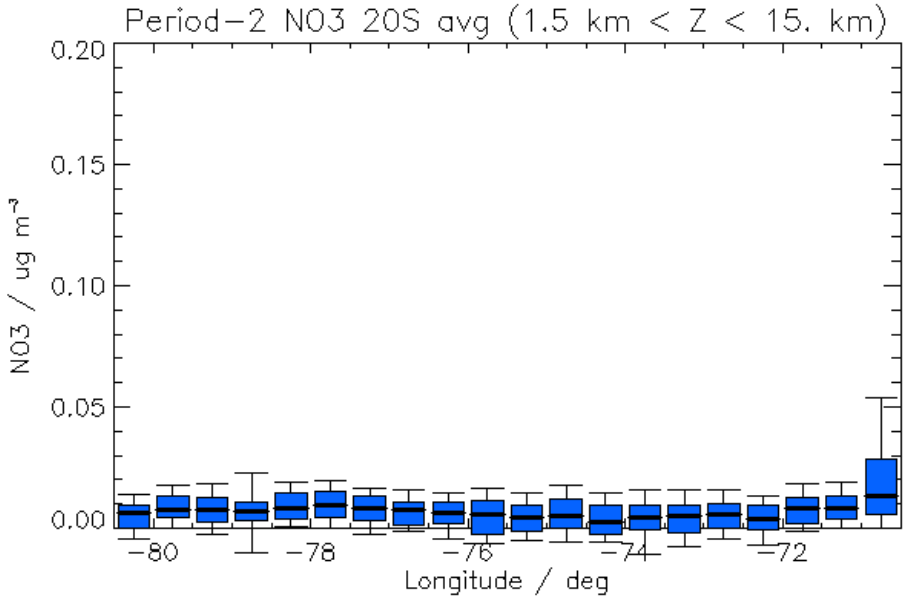

Period−1 ORG 20S avg (1.5 km < Z < 15. km)
ORG / ug m⁻³
0.0
0.5
1.0
1.5
2.0
−80
−78
−76
−74
−72
Longitude / deg

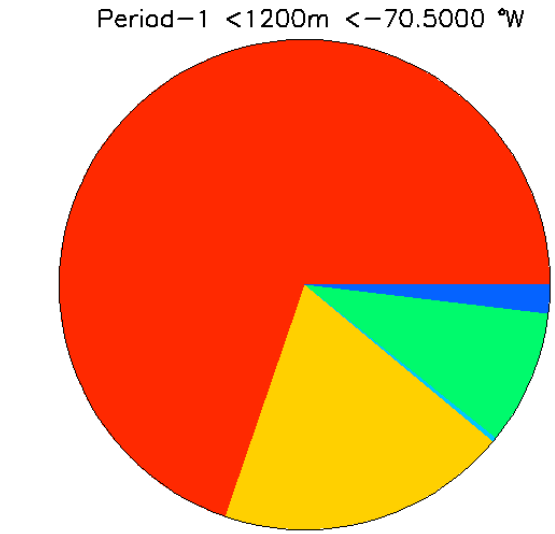

Period−1 NO3 20S avg (1.5 km < Z < 15. km)
NO3 / ug m⁻³
0.00
0.05
0.10
0.15
0.20
−80
−78
−76
−74
−72
Longitude / deg

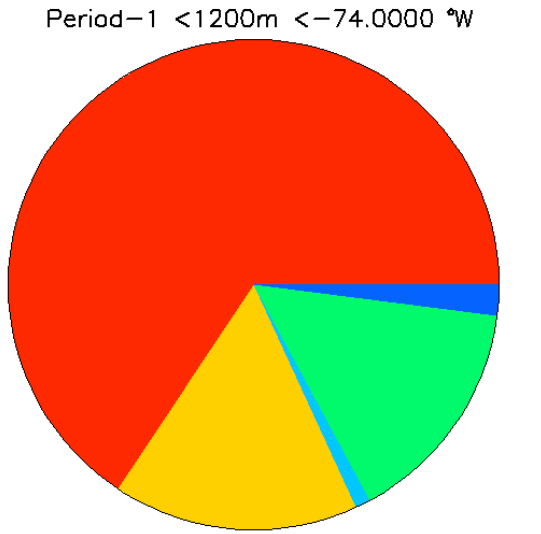

Period−2 SO4 20S avg (1.5 km < Z < 15. km)
SO4 / ug m⁻³
Longitude / deg

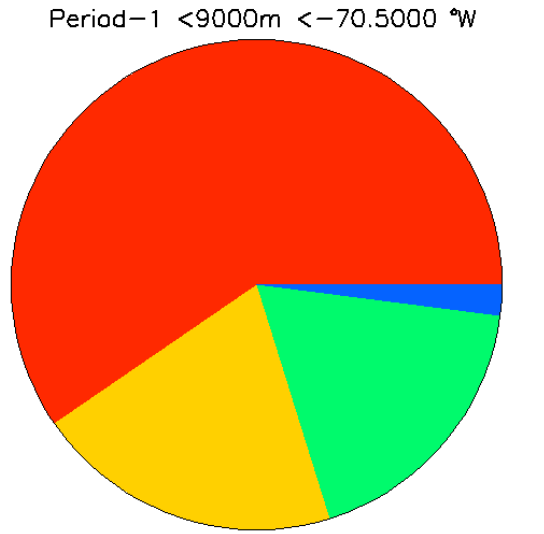

Period−2 NH4 20S avg (1.5 km < Z < 15. km)
NH4 / ug m⁻³
Longitude / deg


Period−2 ORG 20S avg (1.5 km < Z < 15. km)
ORG / ug m⁻³
Longitude / deg

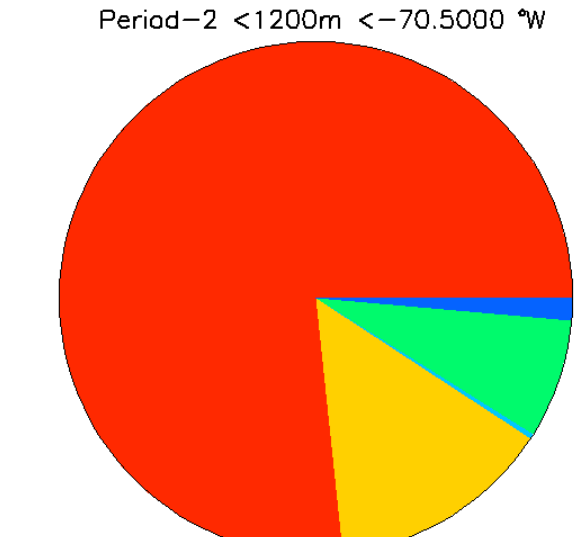

Period−2 NO3 20S avg (1.5 km < Z < 15. km)
NO3 / ug m⁻³
Longitude / deg

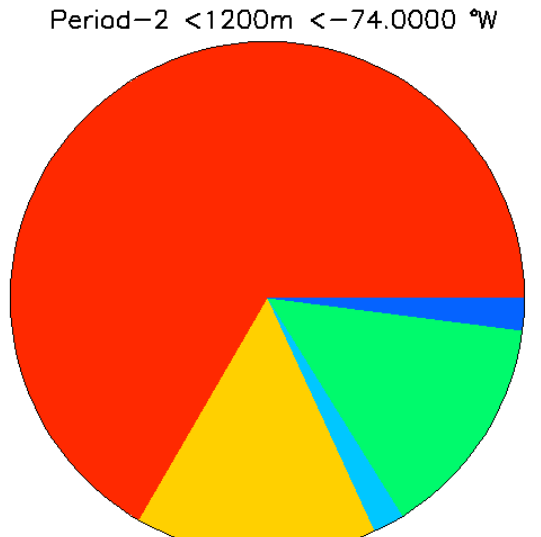


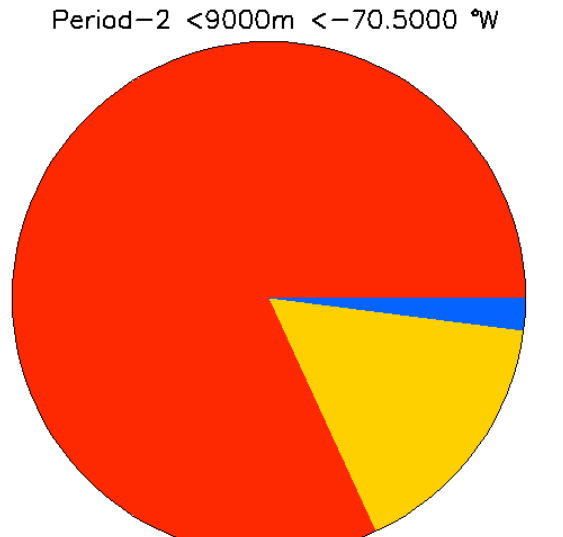




AMS Composition by time-period and location

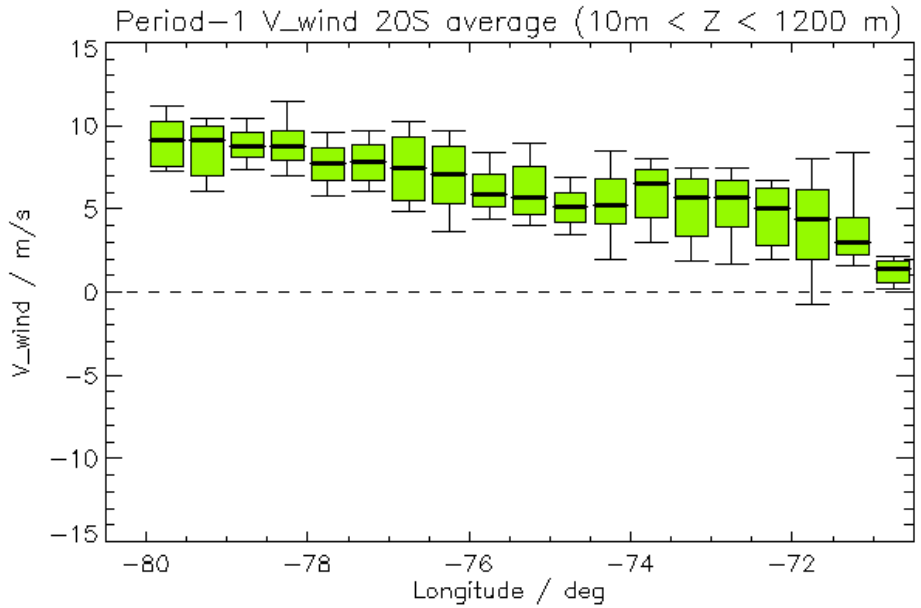


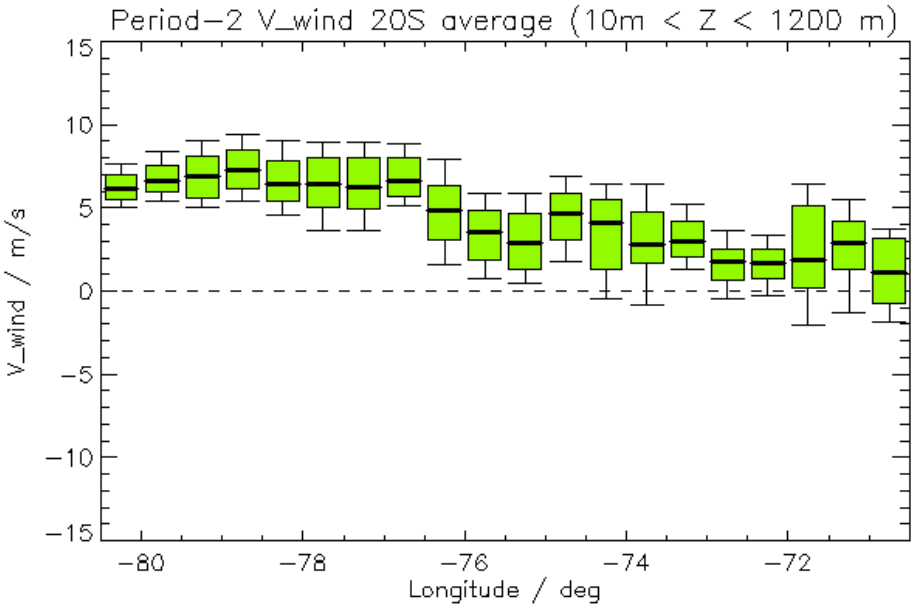


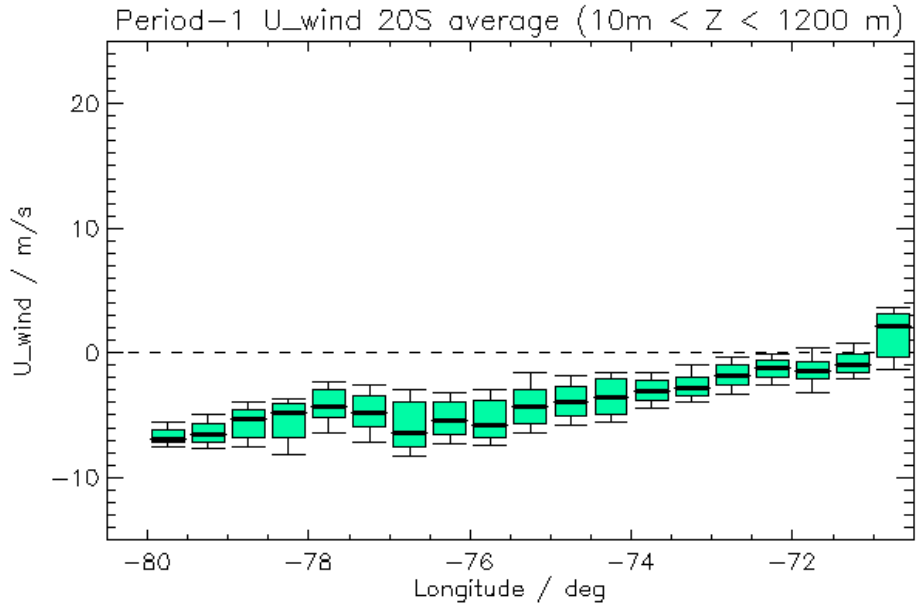


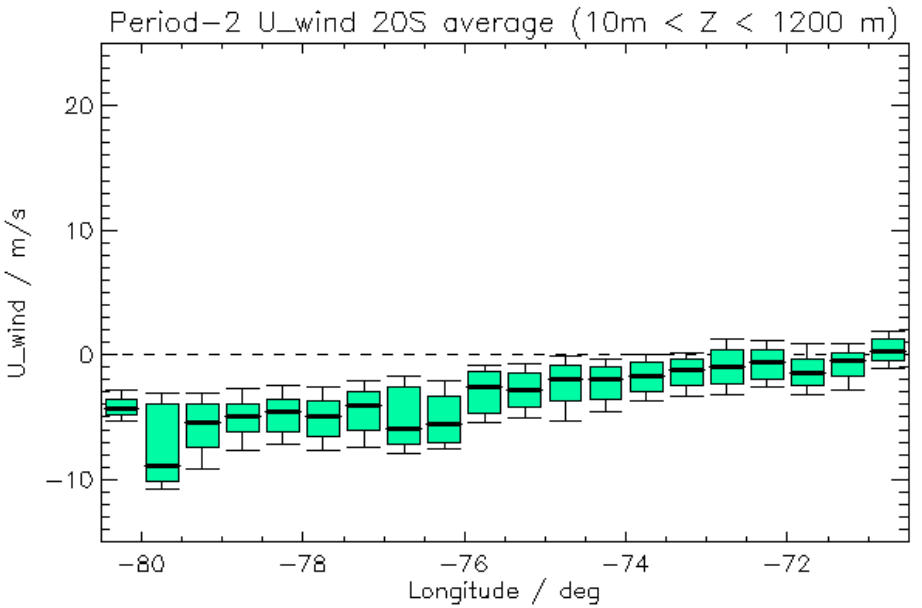
AMS early conclusions

- Aerosol not fully neutralized at any time – SO4/NH4 > 2.6 at all times and often quite acidic.
- Small amount of organics suggests that biomass burning is not the dominant coastal CO source or that organics have been removed from plumes
- Sulphate likely dominated by marine source (DMS) in remote Pacific, but continental (SO2) near the coast.
- Further work needed on AMS mass spectra and ammonium concentrations

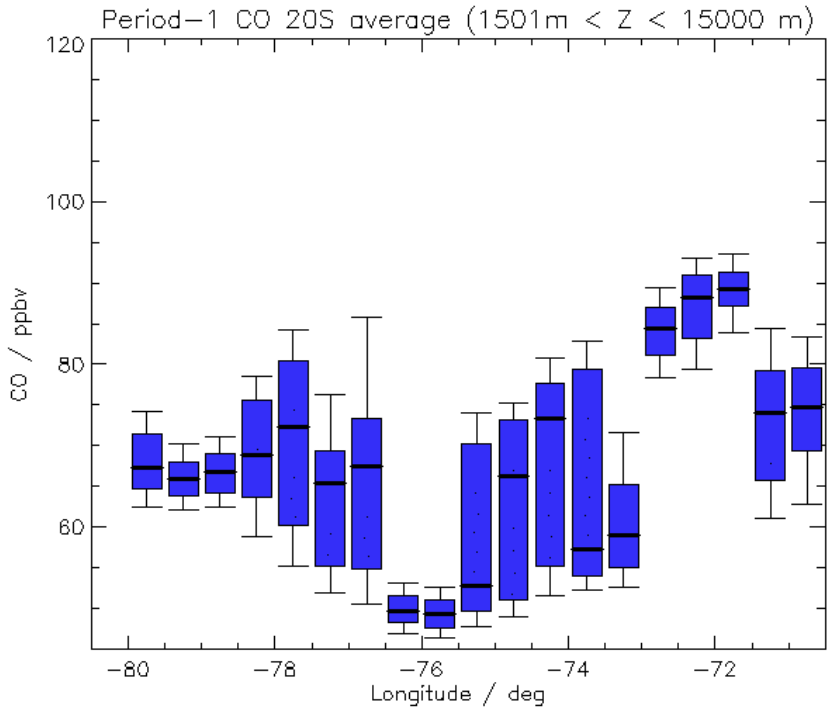

Period−1 V_wind 20S average (10m < Z < 1200 m)
V_wind / m/s
15
10
5
0
−5
−10
−15
−80
−78
−76
−74
−72
Longitude / deg

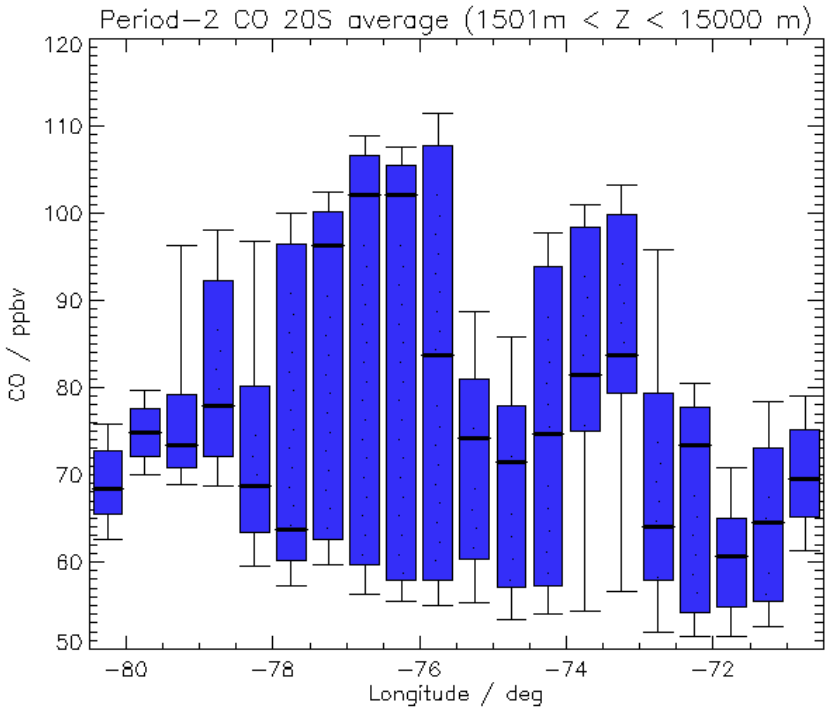

Period−2 V_wind 20S average (10m < Z < 1200 m)
V_wind / m/s
15
10
5
0
−5
−10
−15
−80
−78
−76
−74
−72
Longitude / deg

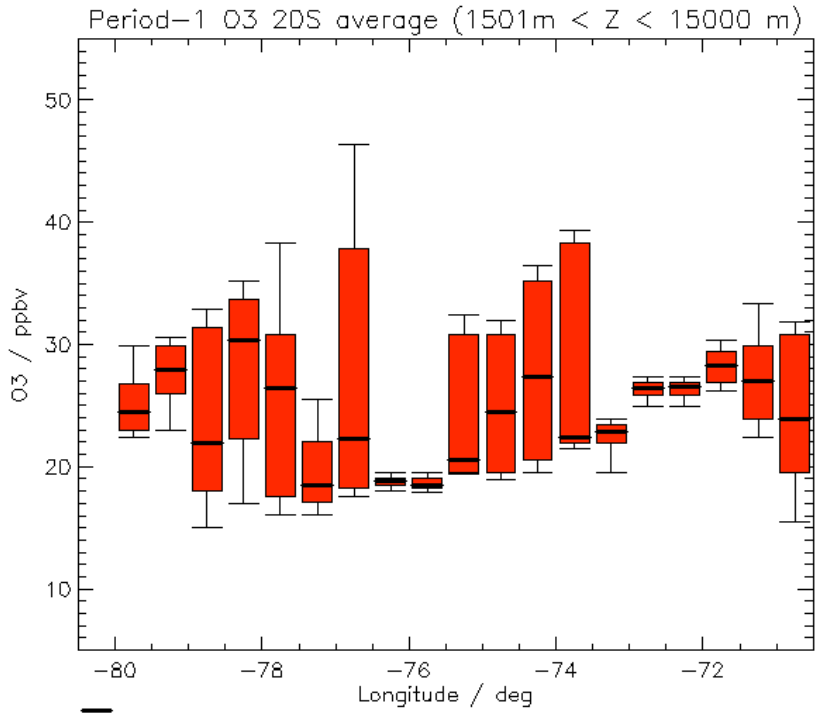

Period−1 U_wind 20S average (10m < Z < 1200 m)
U_wind / m/s
20
10
0
−10
−80
−78
−76
−74
−72
Longitude / deg

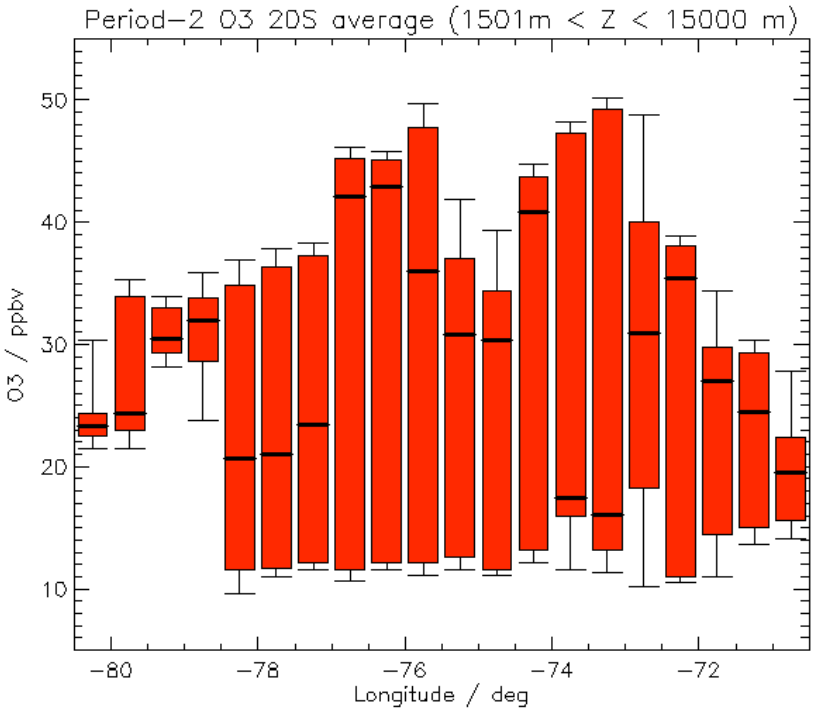

Period−2 U_wind 20S average (10m < Z < 1200 m)
U_wind / m/s
20
10
0
−10
−80
−78
−76
−74
−72
Longitude / deg

Variability in the free troposphere?


Period−1 CO 20S average (1501m < Z < 15000 m)
CO / ppbv
Longitude / deg


Period−2 CO 20S average (1501m < Z < 15000 m)
CO / ppbv
Longitude / deg


Period−1 O3 20S average (1501m < Z < 15000 m)
O3 / ppbv
Longitude / deg


Period−2 O3 20S average (1501m < Z < 15000 m)
O3 / ppbv
Longitude / deg

Early Composition Conclusions

- MBL composition is broadly the same across all periods of VOCALS-UK
- Free troposphere is highly variable with evidence of discrete pollutant layering
- Vertical structure is correlated with changing wind-direction, and hence source area, with high (but variable) gradients at the top of the MBL
- Clear MBL pollution gradient East of 75 W toward the coast – Anti-correlated CO and Ozone suggesting fresh combustion sources
- Very little non-refractory aerosol above cloud-tops, except near coast – consistent with high altitude land-based sources in direct contact with the atmosphere above the MBL

Further work

- Include C-130, Dornier, G-1 data
- Aerosol size spectra statistics
- Investigate the coastal bight dynamics in more detail – does this local influence dominate the near-coastal composition rather than advection from more distant sources in the diagnosed mean flow?