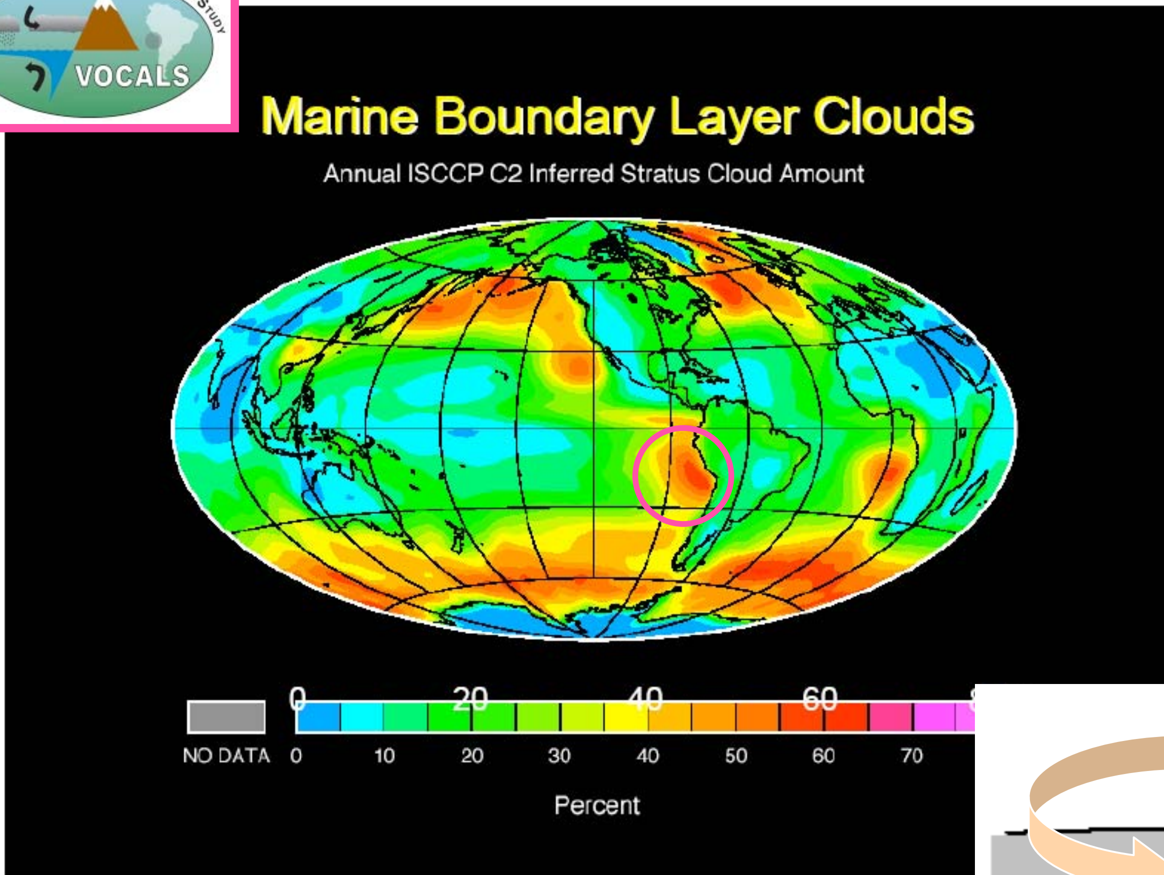
Aerosol Physiochemical Properties and Dynamics during VOCALS: Advection, Removal and Entrainment

VOCALS Workshop July 12-14, 2009

A. Clarke, S. Howell, C. McNaughton,
V. Kapustin, S. Freitag, L. Shank, V. Brekhovskikh
and
J. Snyder, T. Campos, D. Leon …and more

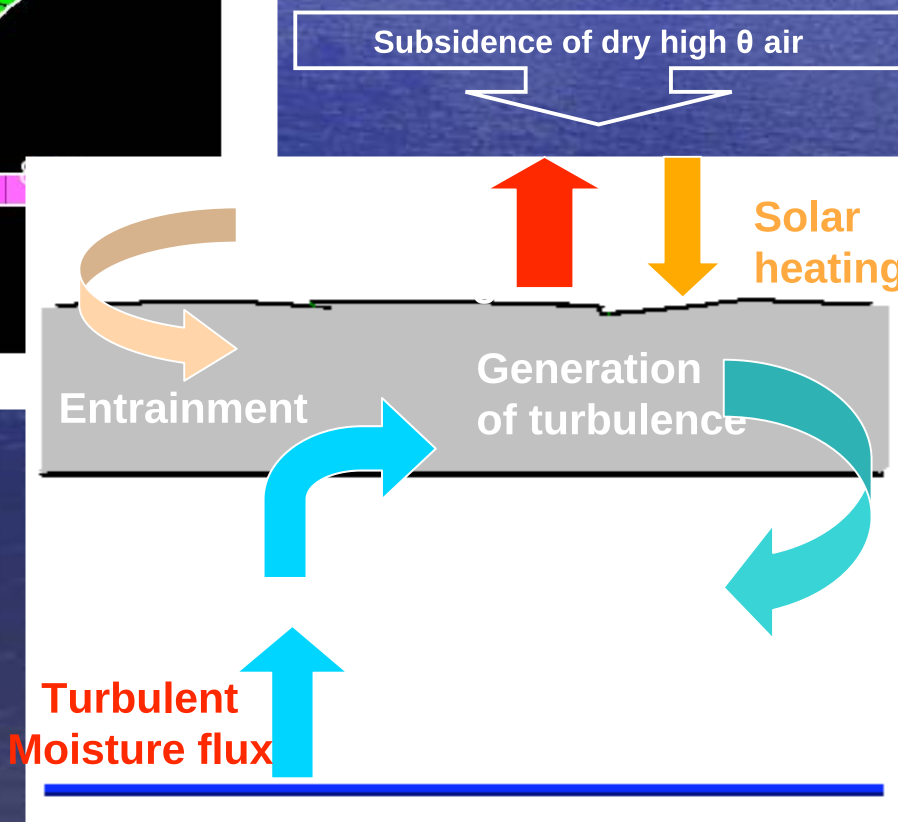
Preliminary Observations

Photo A. Clarke



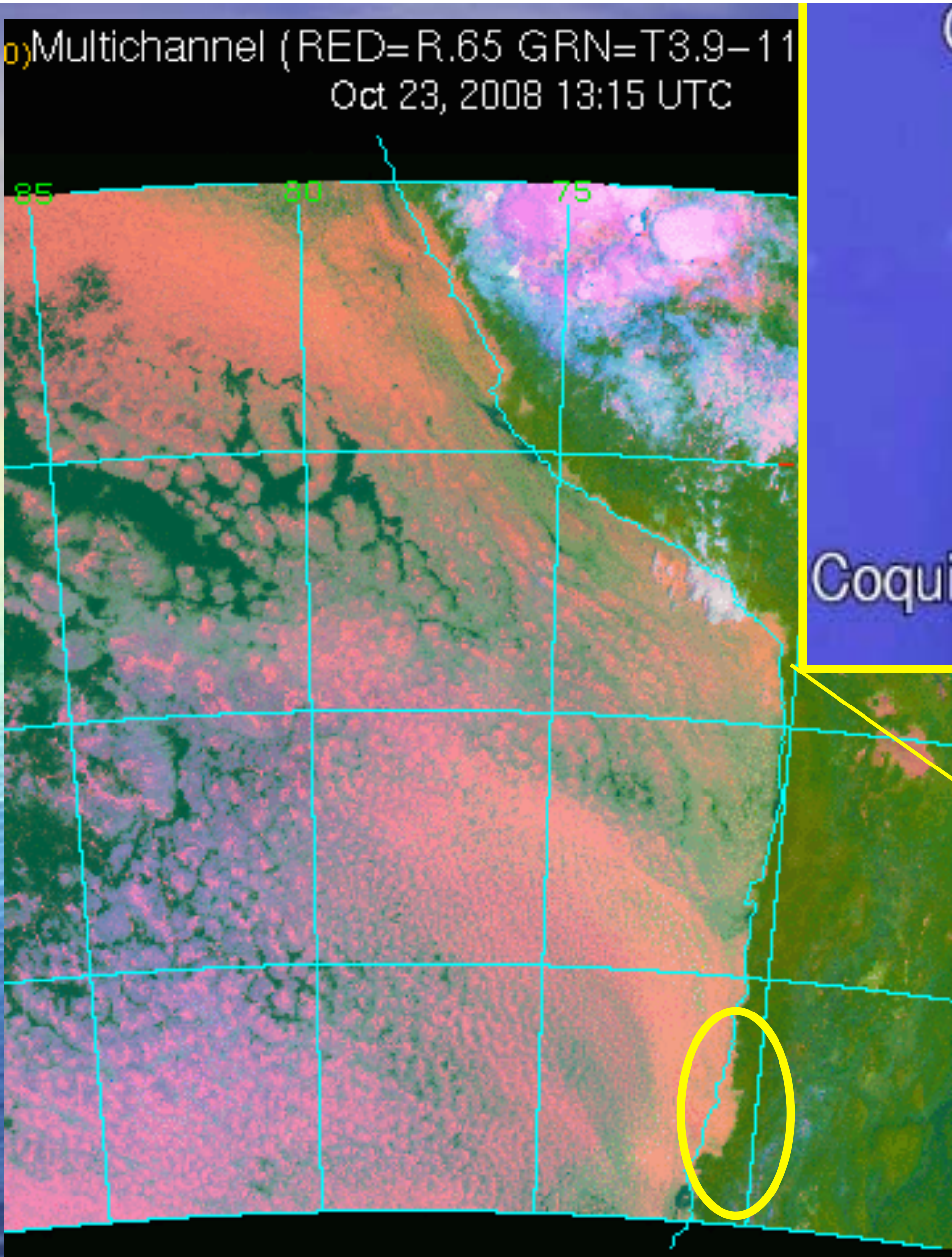
• Form at top of the boundary layer beneath a capping inversion, sustained by turbulent moisture fluxes

• Particularly sensitive to absorption of solar radiation!

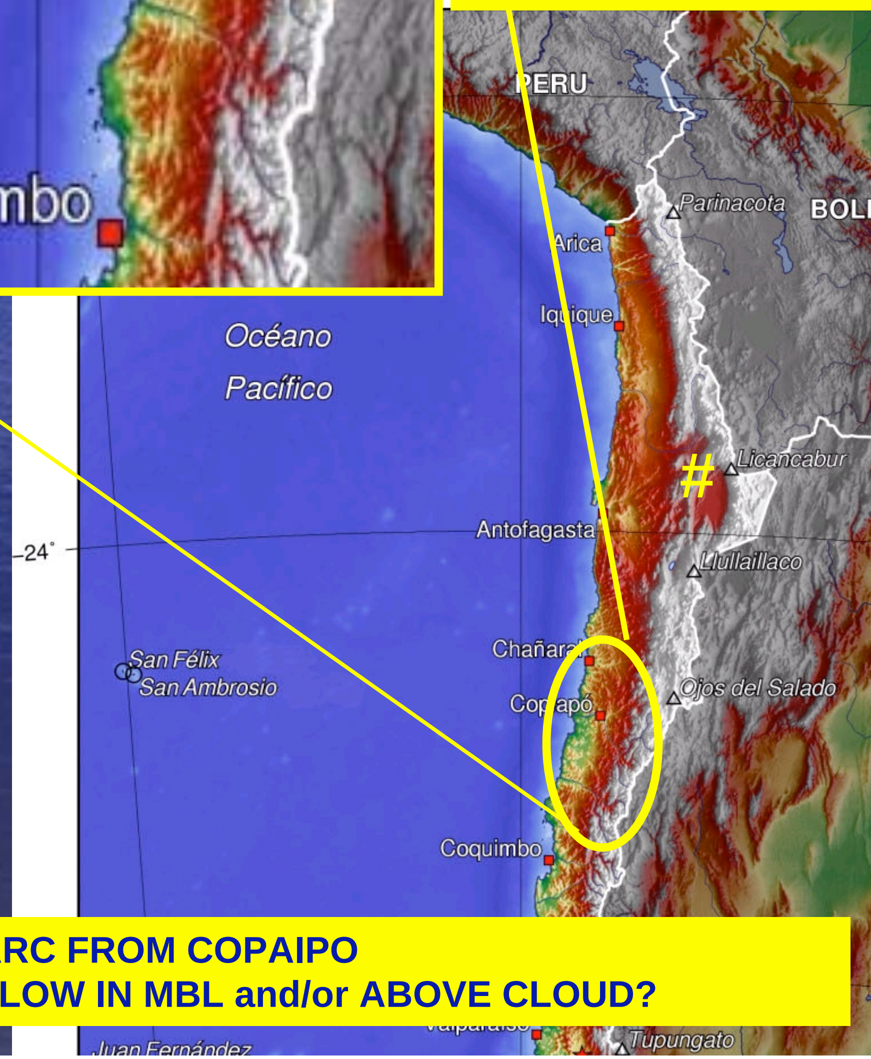


Drizzle removes MBL aerosol.

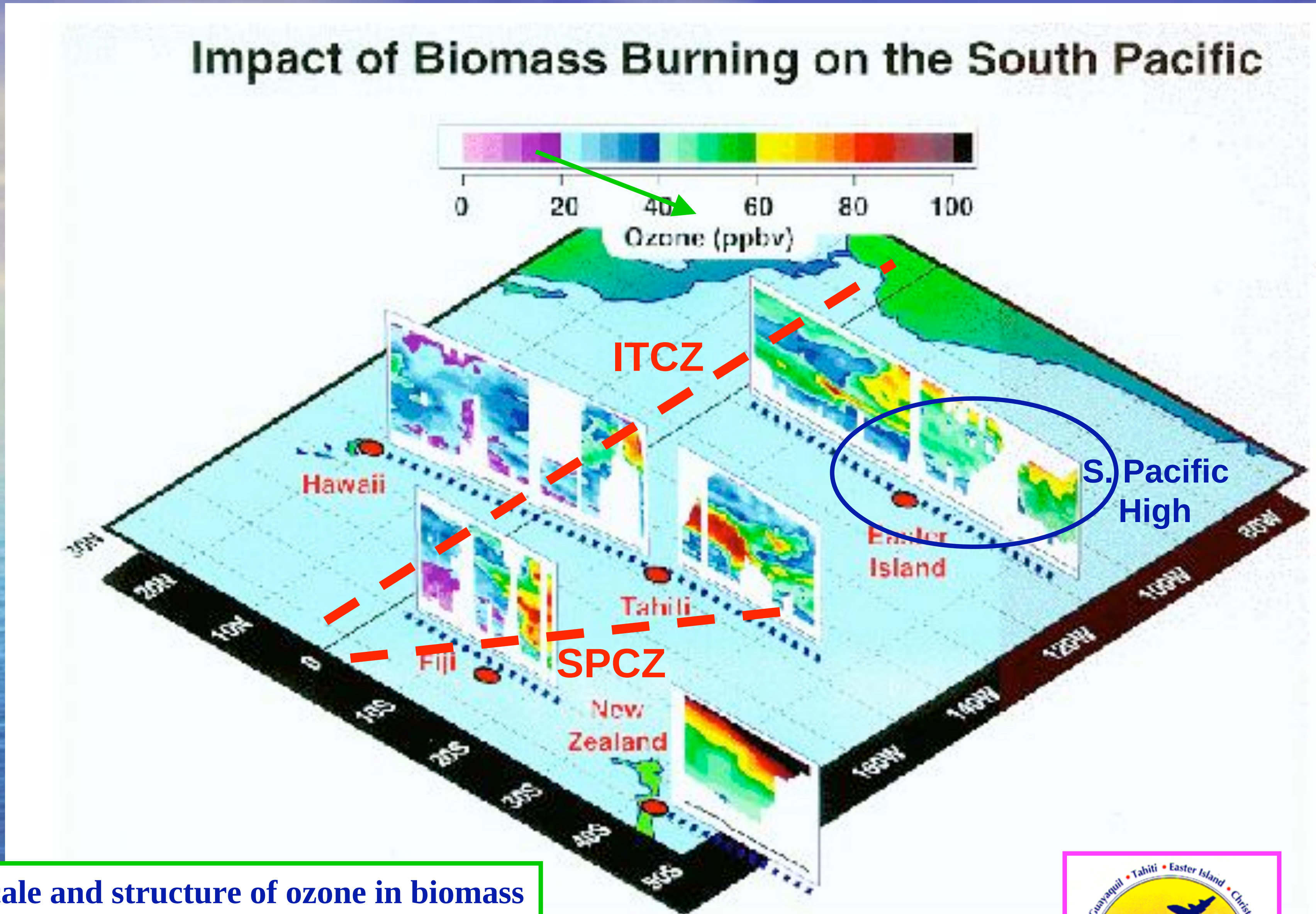
Replenished by:
Sea-salt?
Nucleation?
Entrainment?
Advection?



Copiapo, 1450m
130,000pop
Coquimbo, 50m
160,000C
Cuiacamata Cu
Smelter # – worlds
largest 2800m



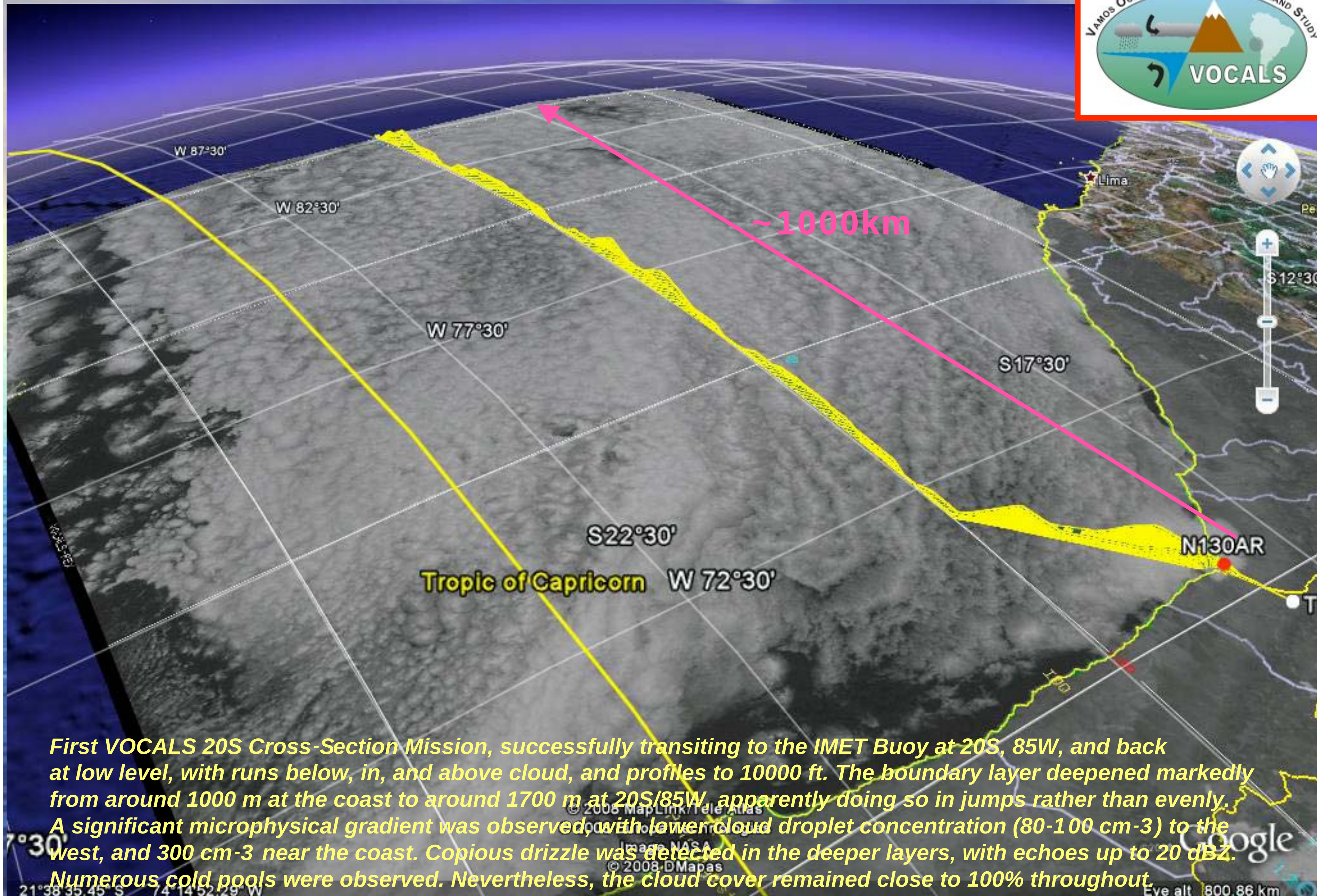
EXAMPLE OF APARRENT CLOUD ENHANCEMENT IN ARC FROM COPAIPO
?ARE SUCH FEATURES RELATED TO AEROSOL OUTFLOW IN MBL and/or ABOVE CLOUD?



The scale and structure of ozone in biomass and combustion plumes seen over the south Pacific on PEMT-A with DIAL Lidar [E. Browell, NASA]

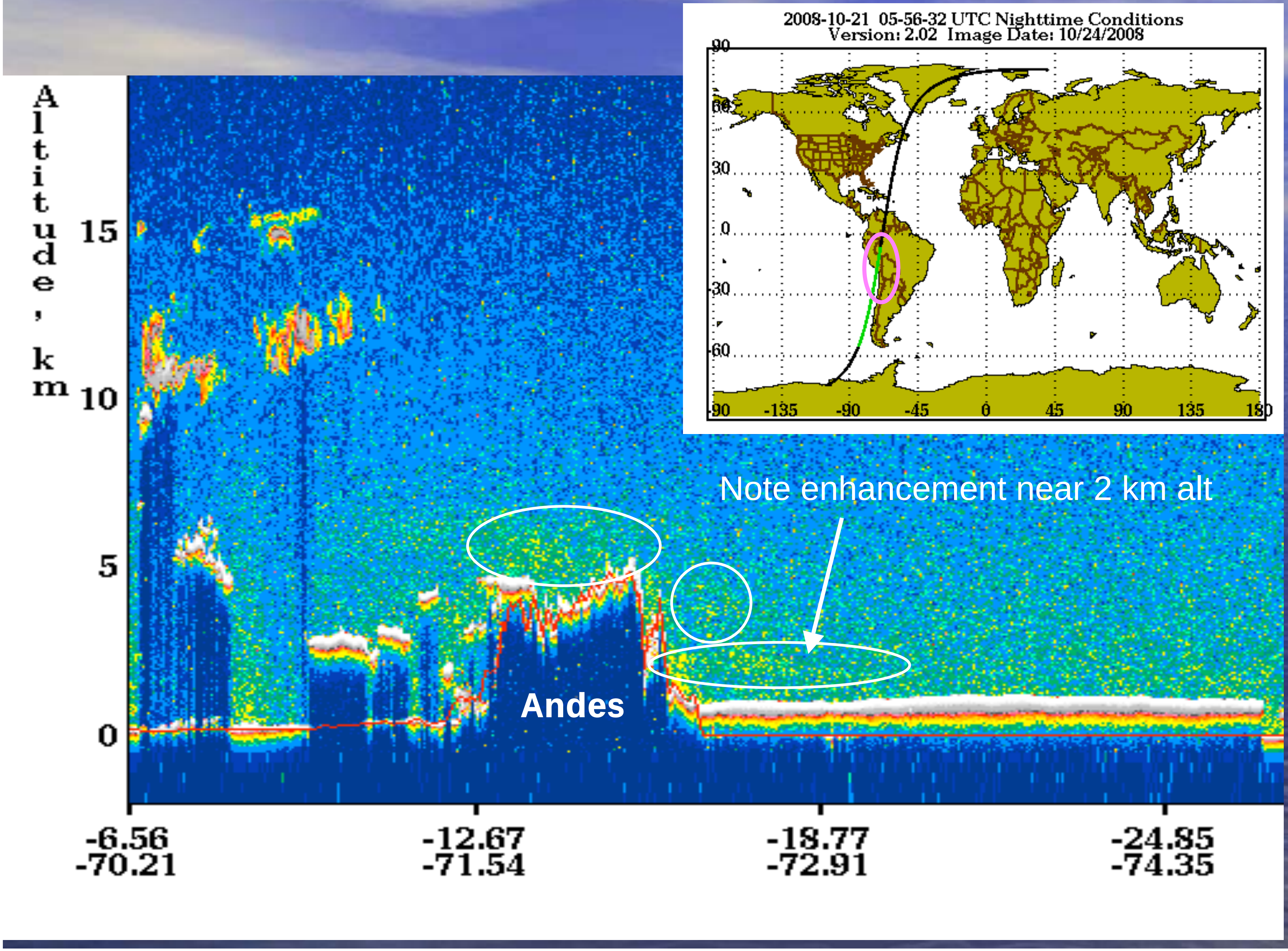
Christchurch • Guayaquil • Tahiti • Easter Island • Christmas Island • Fiji
NASA PEM-TROPICS 1996

VOCALS RF03 10/21/2008



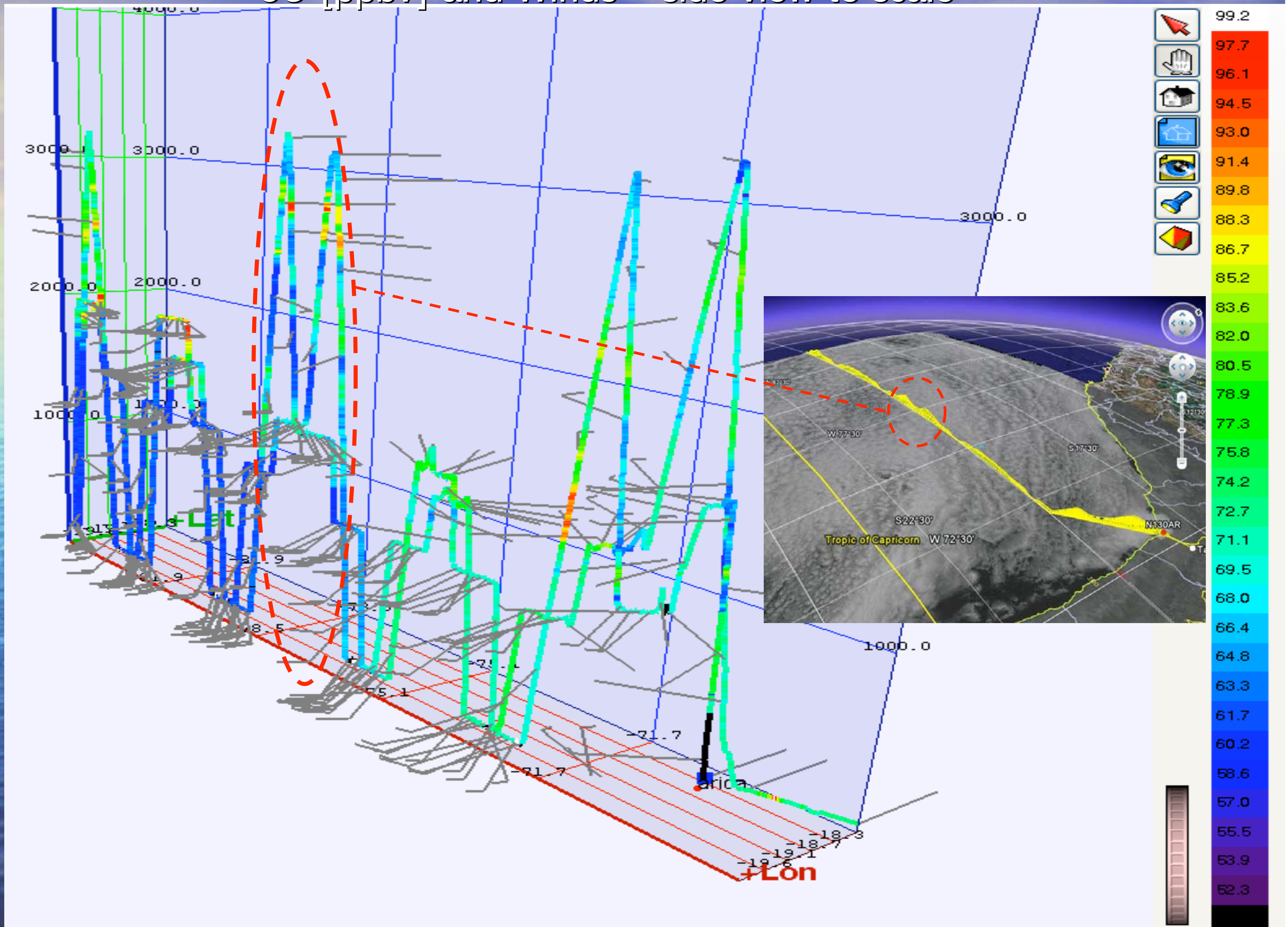
First VOCALS 20S Cross-Section Mission, successfully transiting to the IMET Buoy at 20S, 85W, and back at low level, with runs below, in, and above cloud, and profiles to 10000 ft. The boundary layer deepened markedly from around 1000 m at the coast to around 1700 m at 20S/85W, apparently doing so in jumps rather than evenly. A significant microphysical gradient was observed, with lower cloud droplet concentration (80-100 cm-3) to the west, and 300 cm-3 near the coast. Copious drizzle was detected in the deeper layers, with echoes up to 20 dBZ. Numerous cold pools were observed. Nevertheless, the cloud cover remained close to 100% throughout.

VOCALS RF03 10/21/2008 Calipso attenuated backscatter

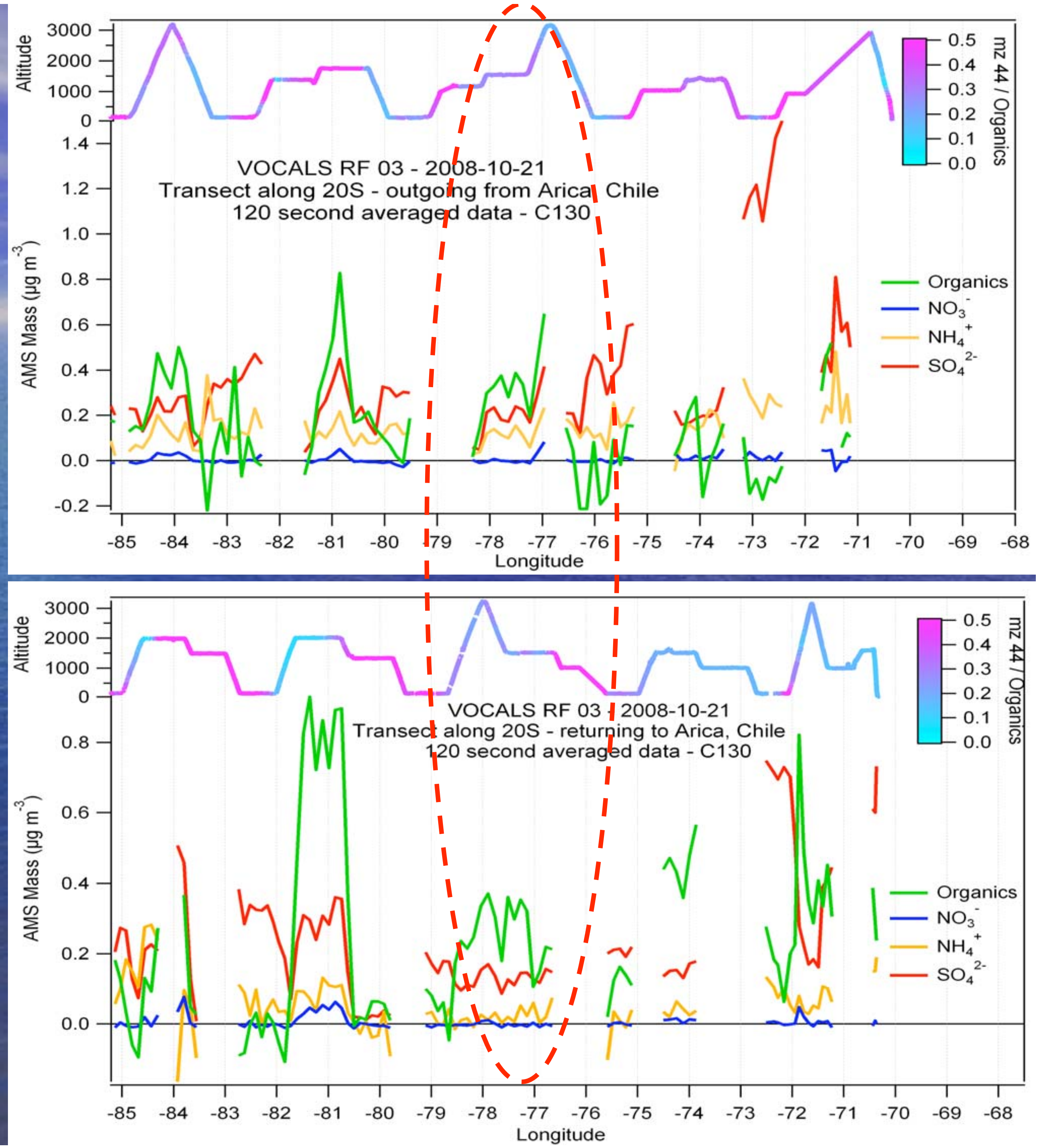


VOCALS RF03 10/21/2008

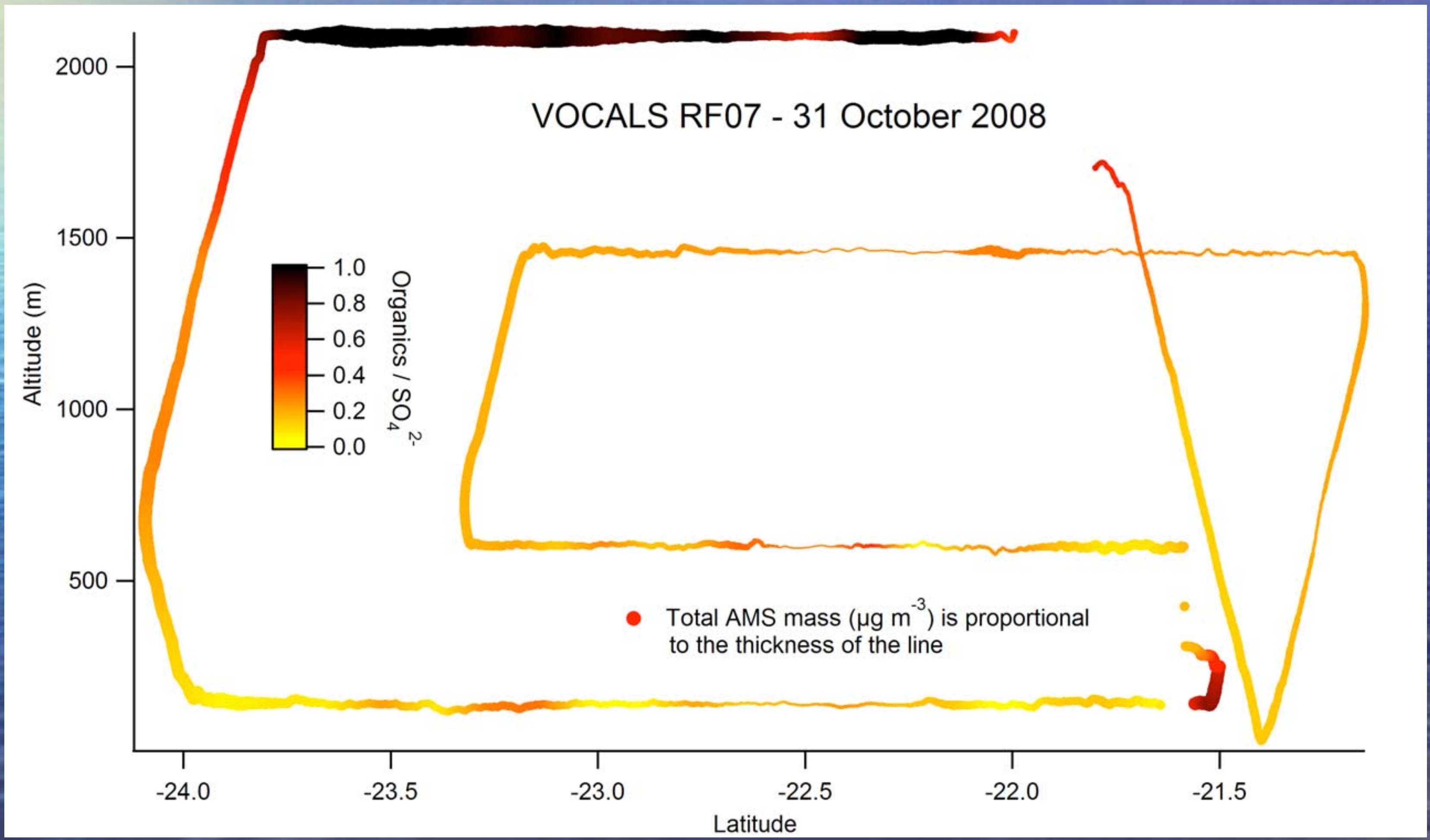
CO [ppbv] and Winds – side view to scale



AMS chemistry typically shows higher organics aloft in these enhanced CO layers and more sulfate near surface and toward the coast.

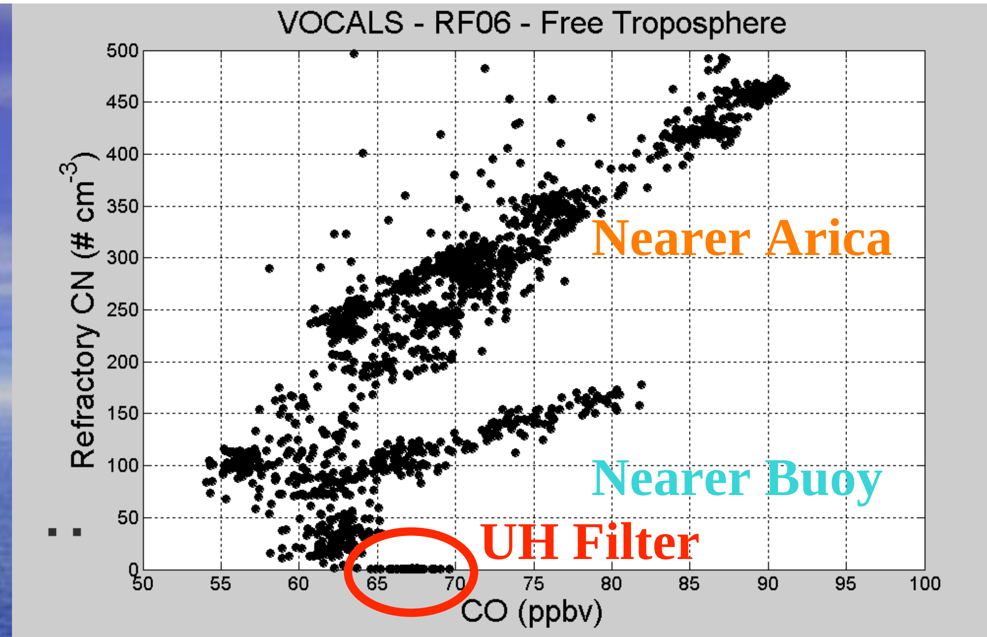


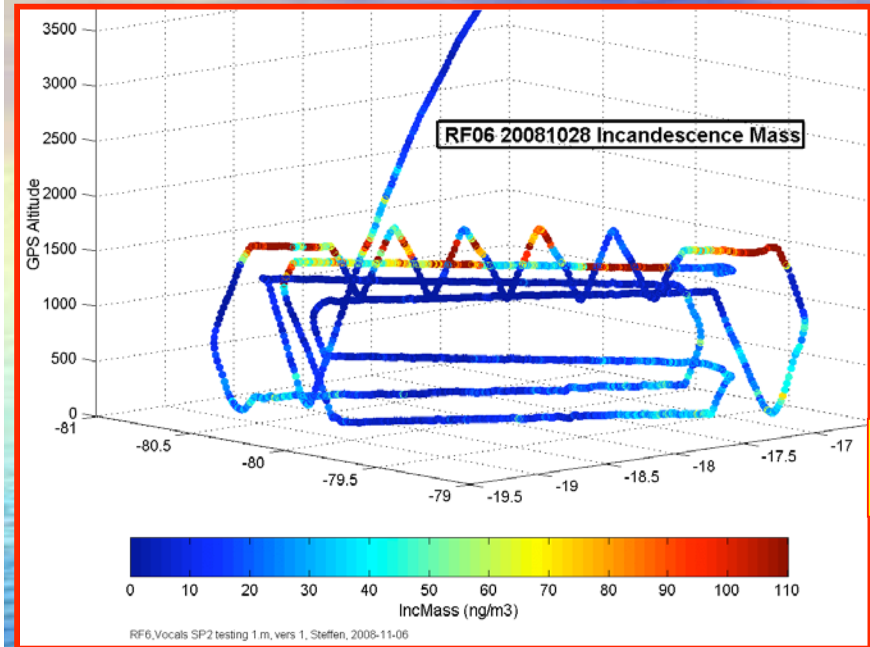
AMS ratio of Organic to Sulfate mass often reveal enhanced organics (biomass burning) aloft. RF07 - POC



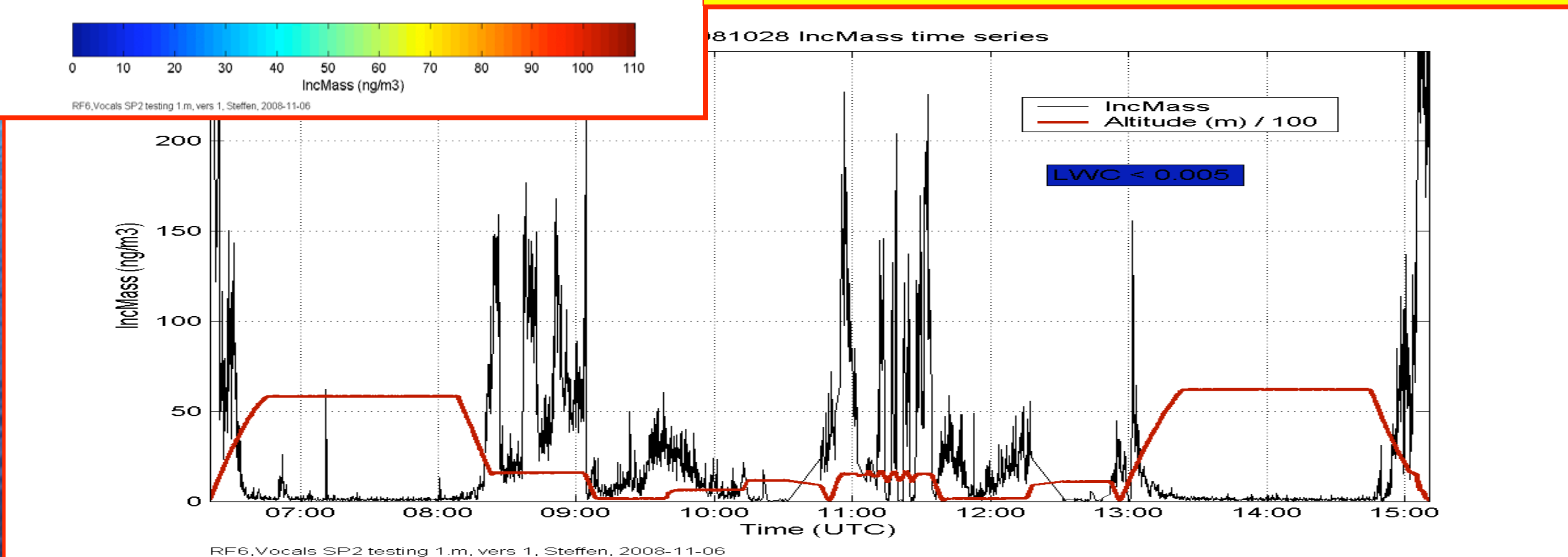
Refractory "soot" aerosol show robust correlations with CO.

Differing slopes are often indicative of airmasses of different origins and/or type.

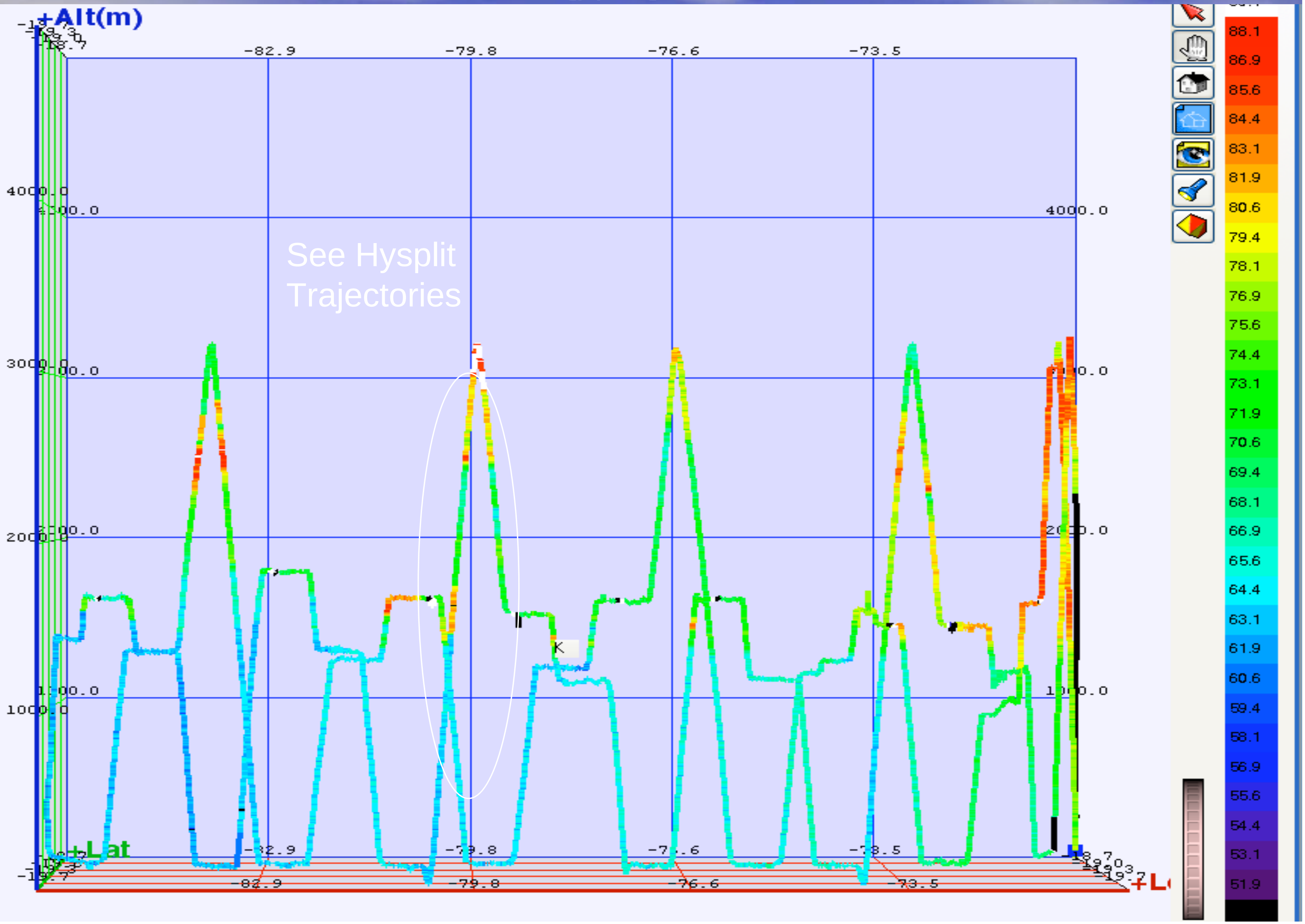




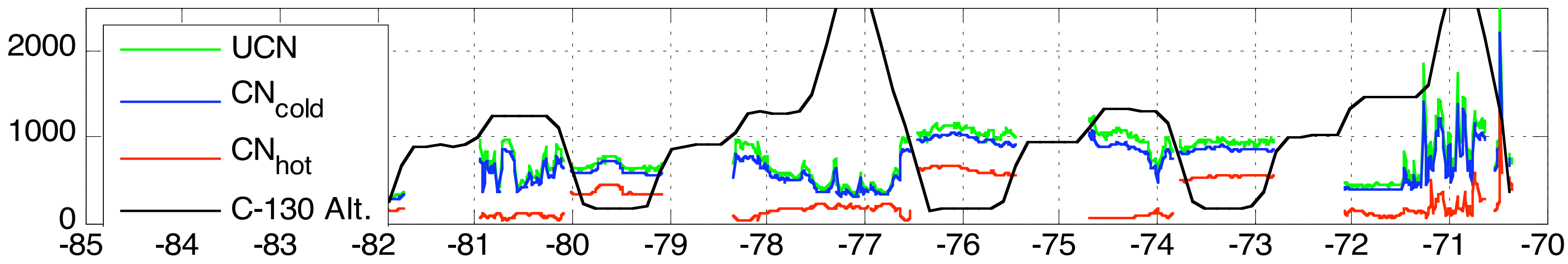
SP2 Black Carbon on POC Flight RF06



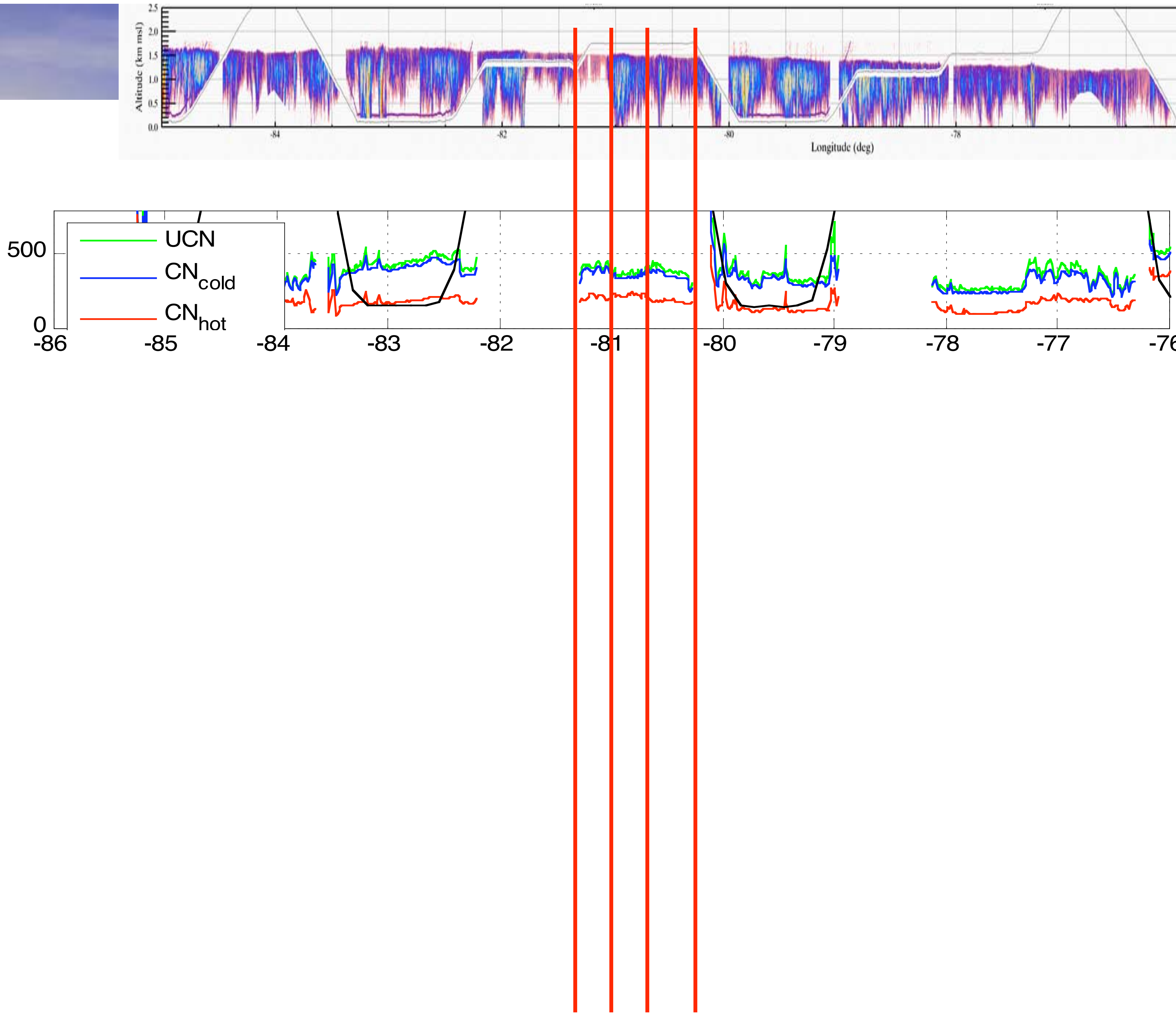
VOCALS RF05 10/26/2008
CO [ppbv]



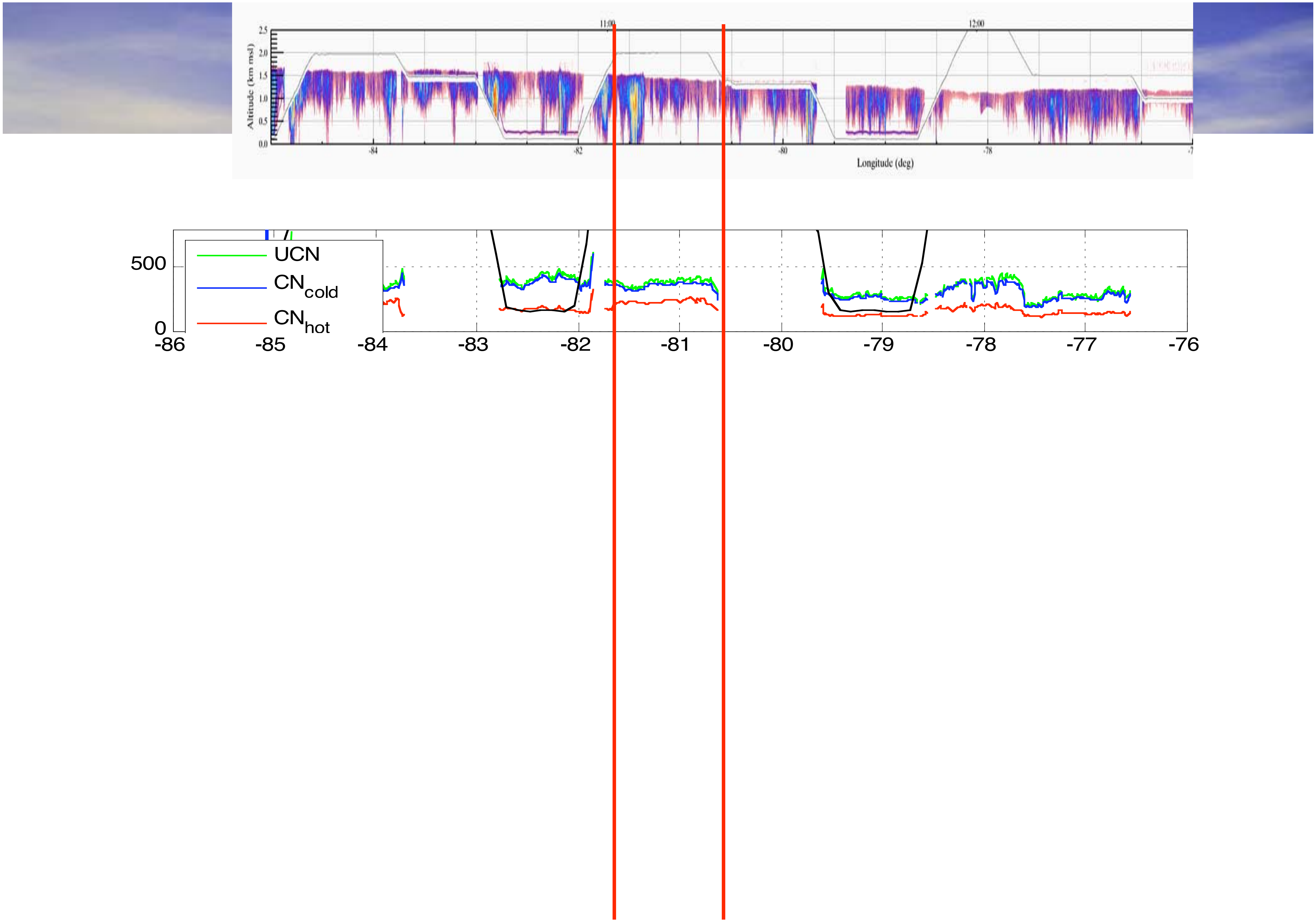
Example of aerosol variability with altitude



VO_disttseries1_RF02-Outbound.fig, VO_20S_dists_rev1.mCam, Cam, 2009-07-06



VO_casestudy1_RF03-Outbound.fig, VO_20S_dists_rev1.mCam, Cam, 2009-07-06



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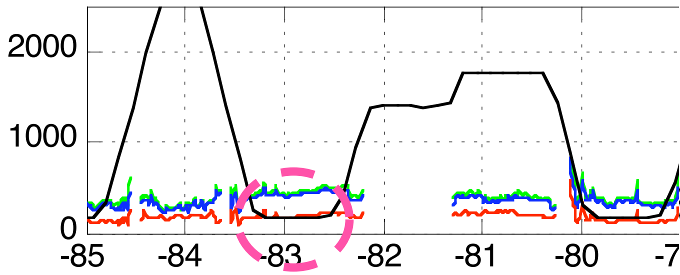
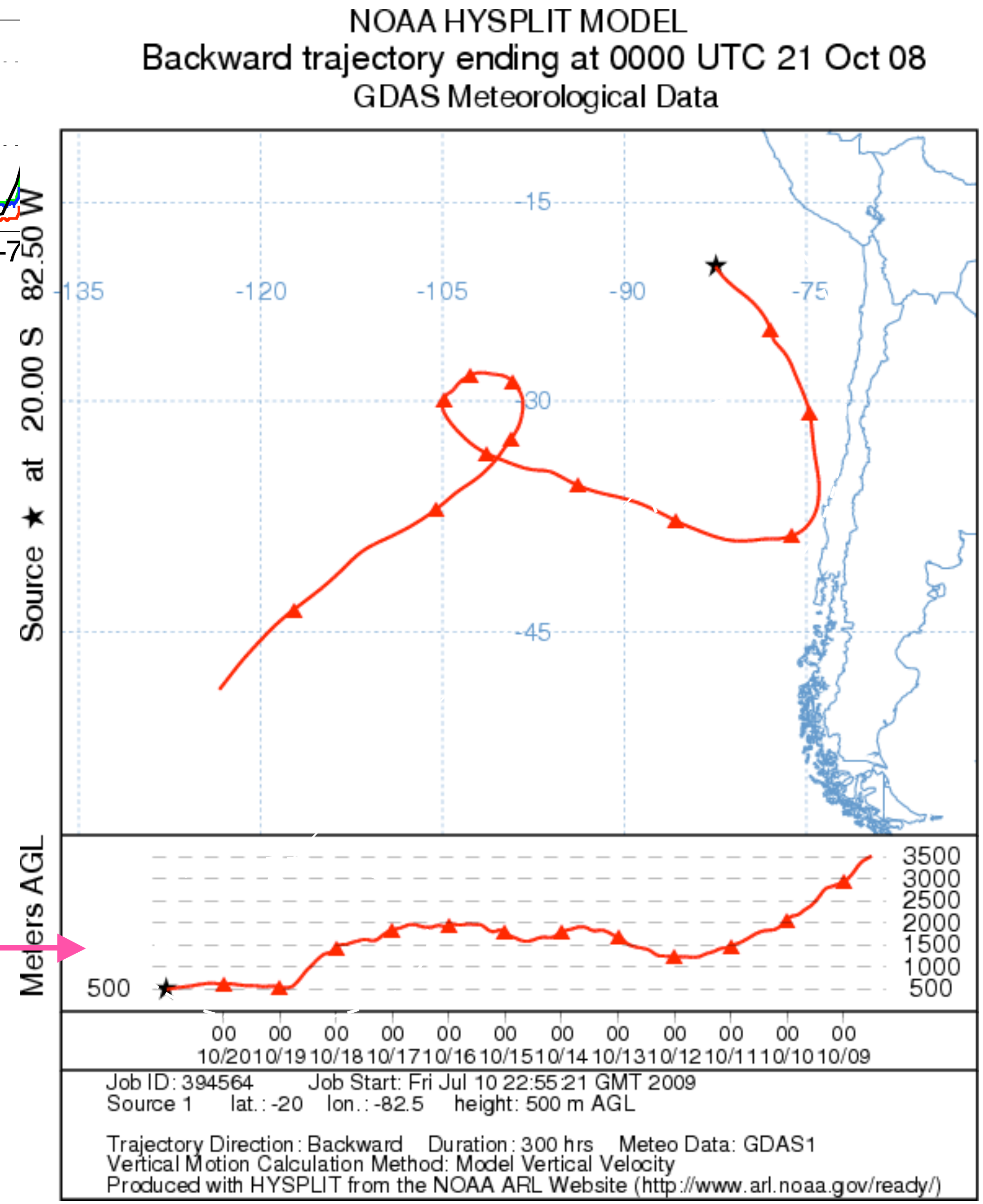
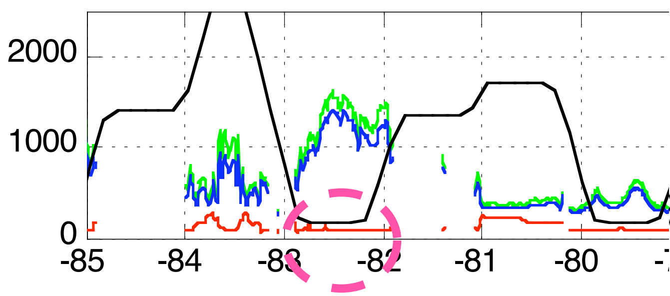
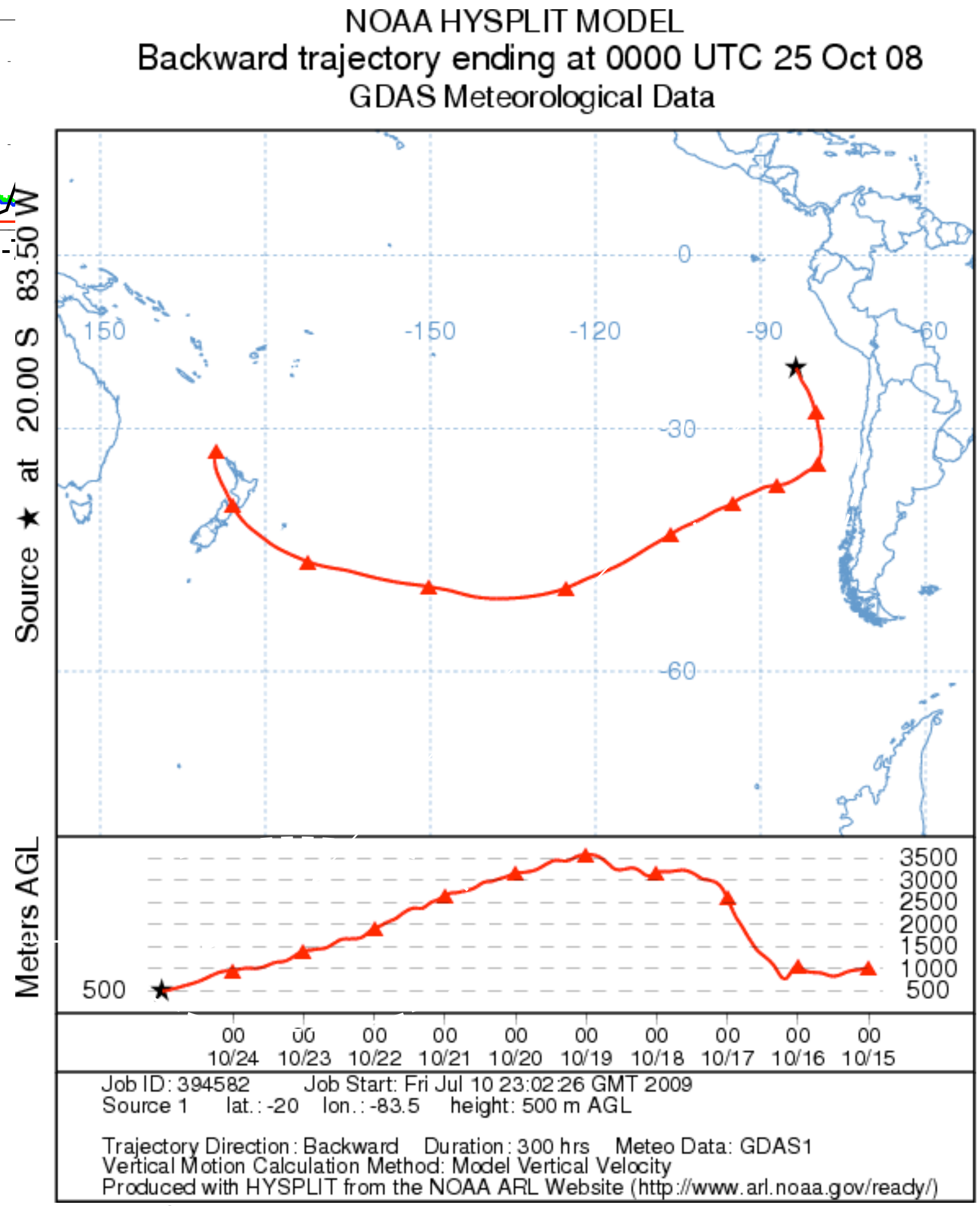




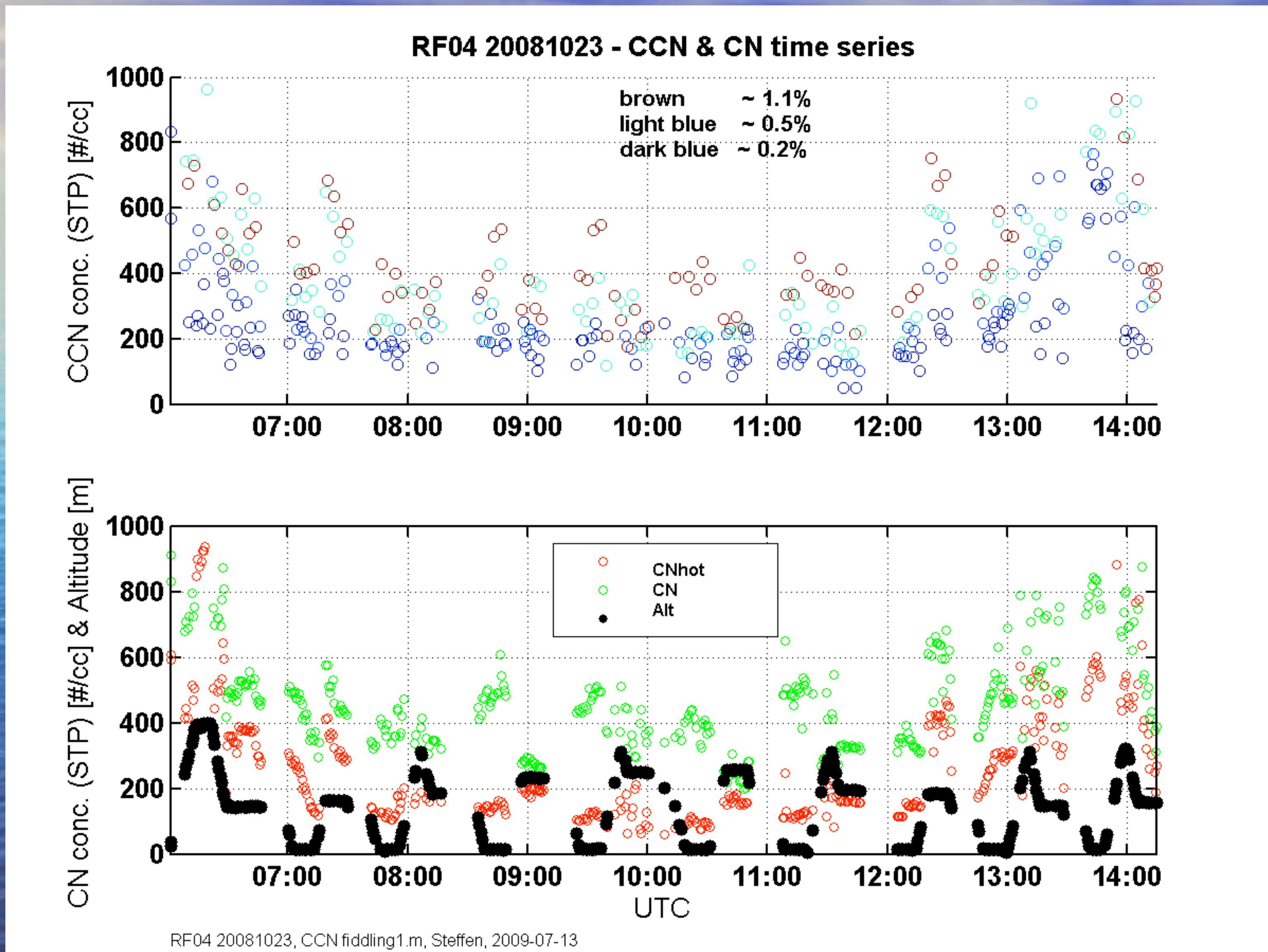
VO_disttseries1_RF03-Outbound.fig, VO_20S_dists_rev1.m, Cam, 2009-07-06



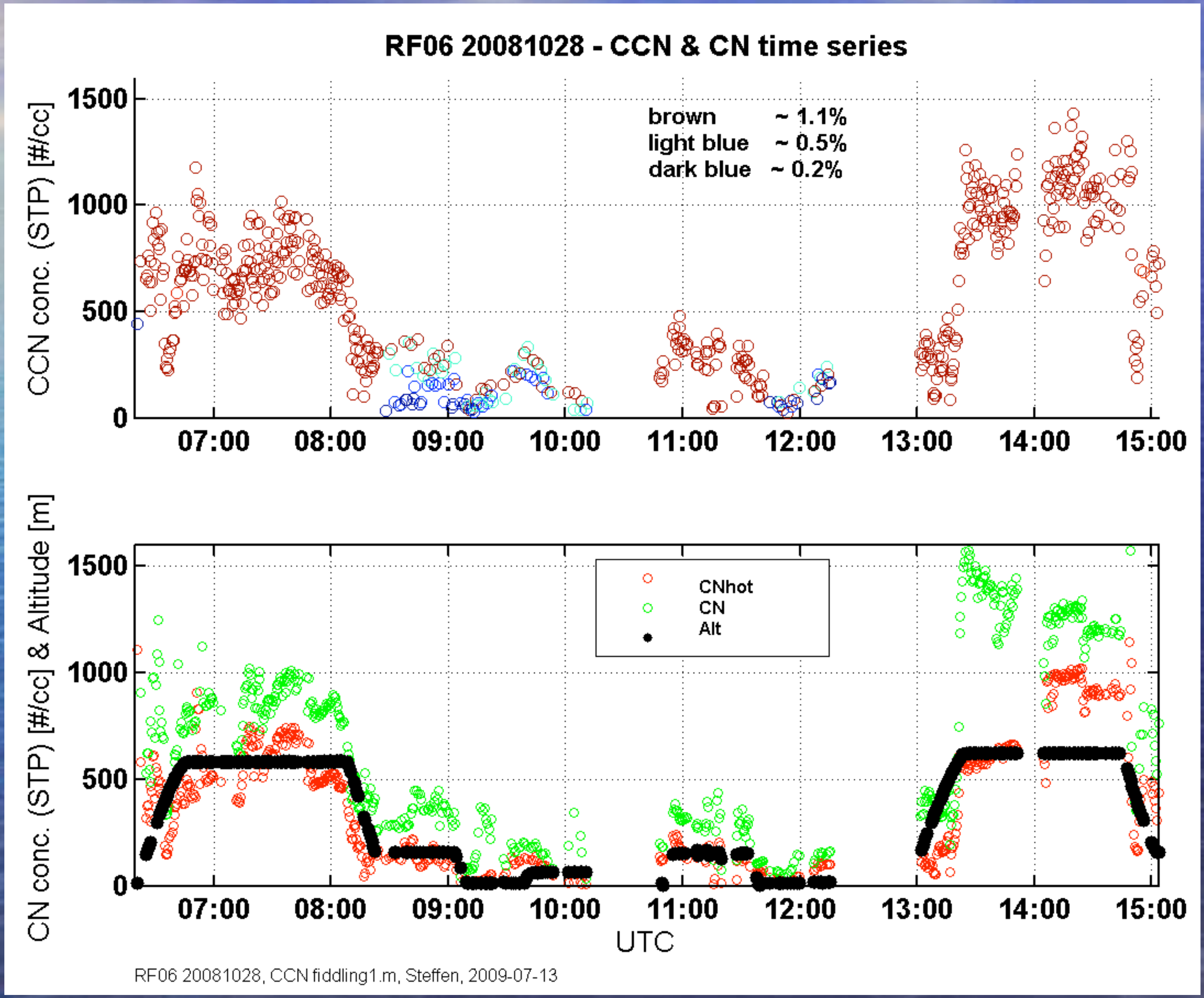


VO_disttseries1_RF05-Outbound.fig, VO_20S_dists_rev1.m, Cam, 2009-07-06

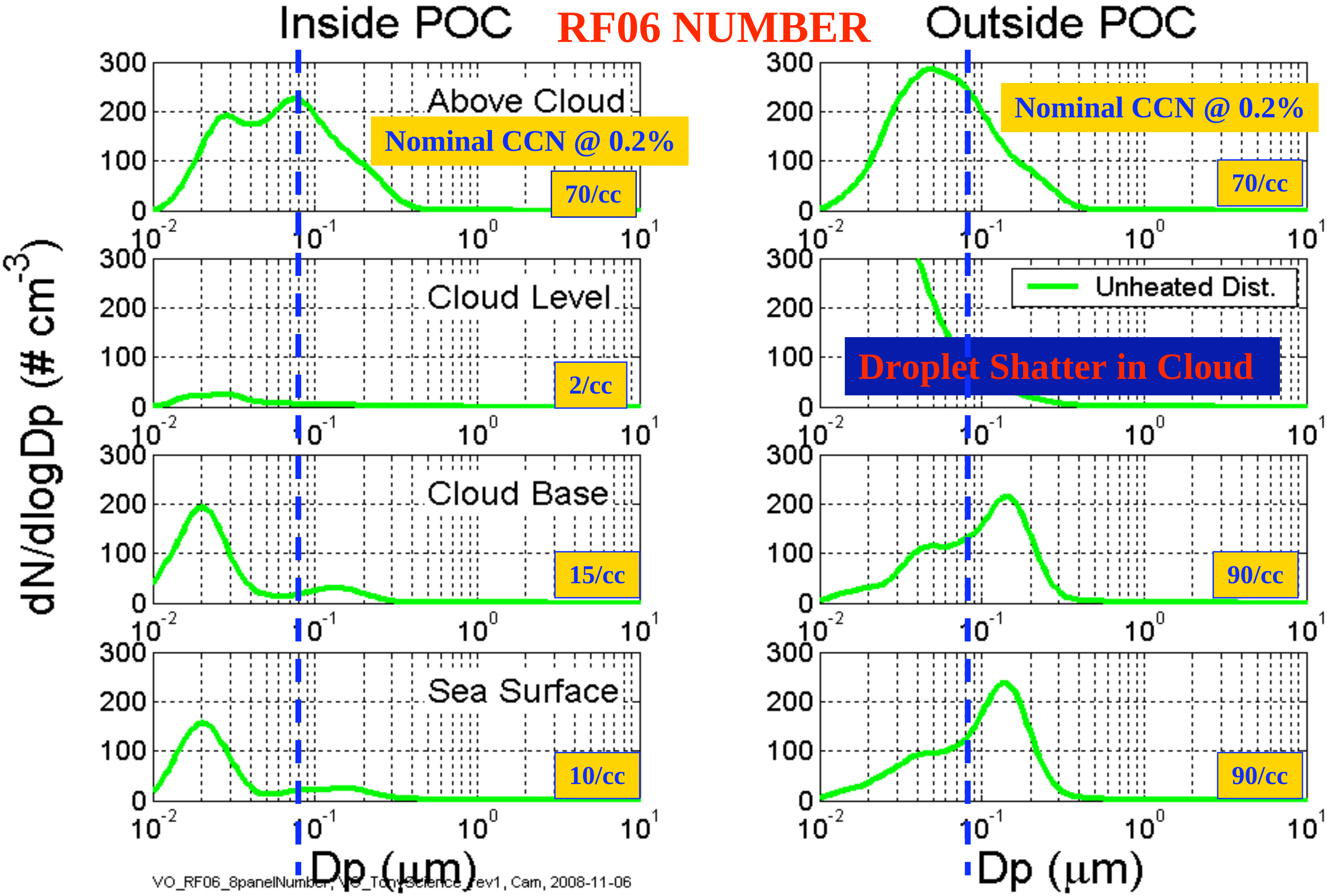
Larger refractory aerosol dominate CCN at low supersaturations



Larger refractory aerosol dominate CCN at low supersaturations
RF06 POC



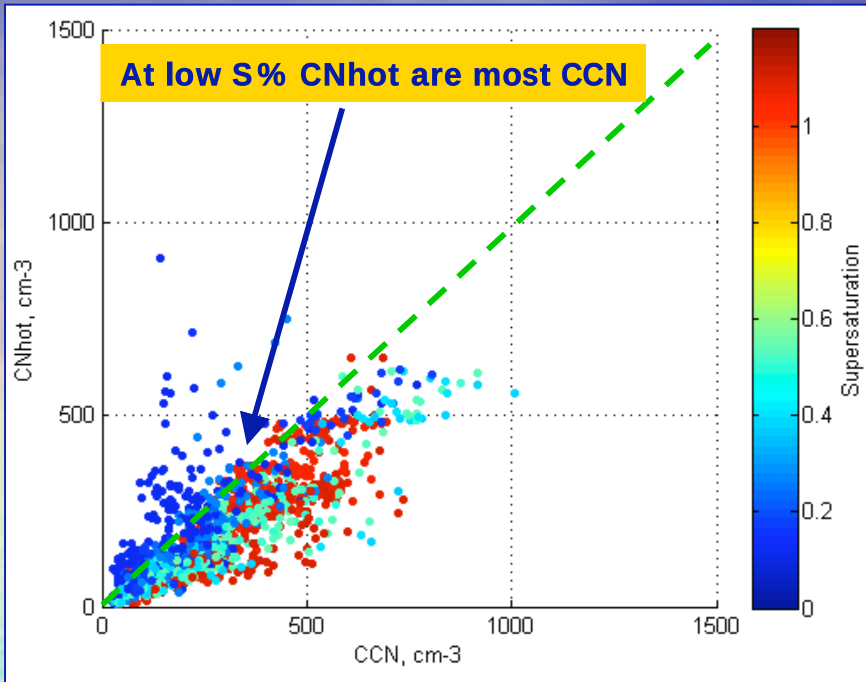
RF06 NUMBER

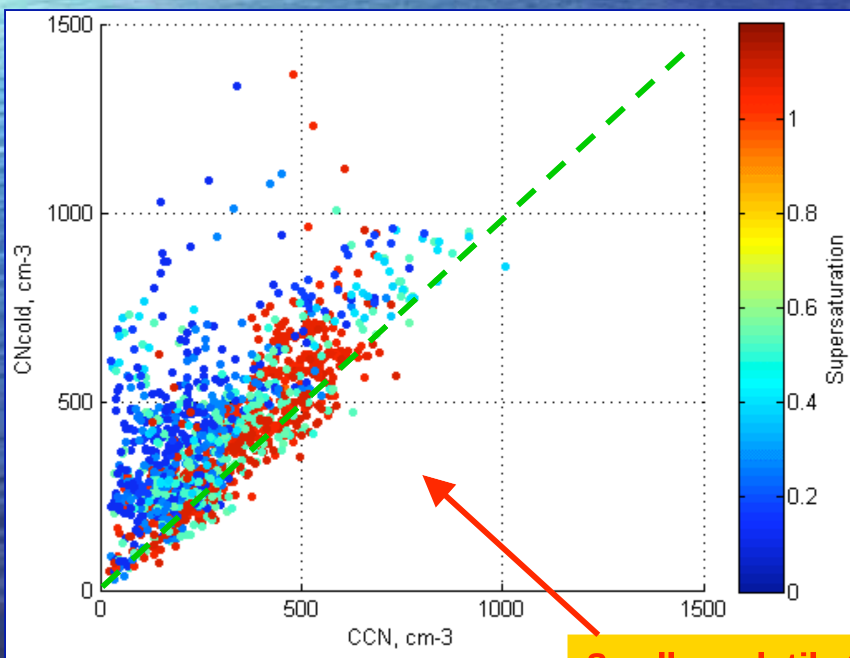


More scavenging of aerosol in POC
Lower entrainment of aerosol from aloft??

More processing/growth out of POC
Higher entrainment of aerosol from aloft??

Relations of CCN to CN Population
Preliminary Observations for RF2,4,&6



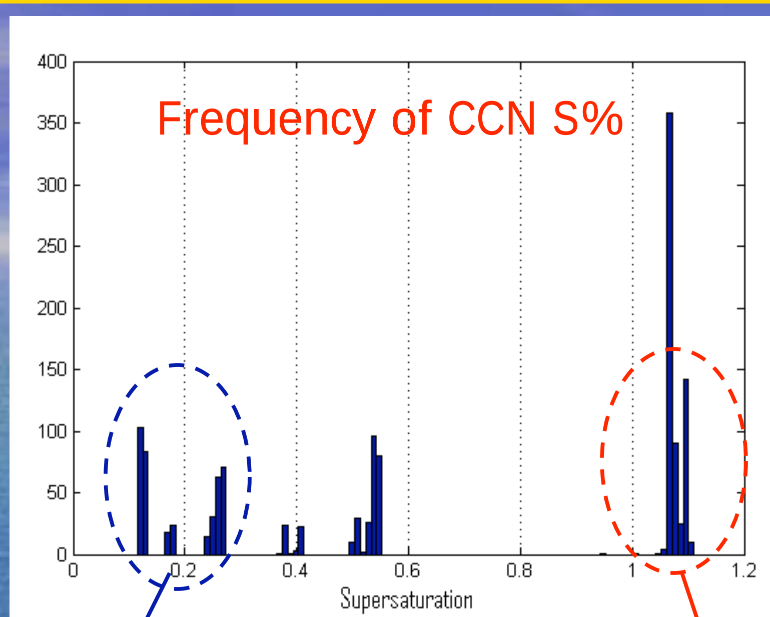


Smaller volatile CN and UCN only activated at high S%

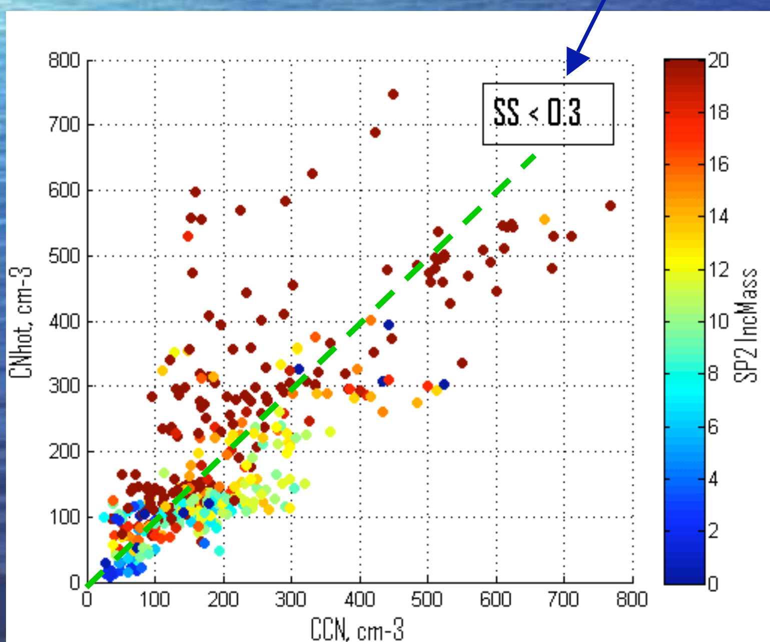
CNhot (heated to 3005C) are generally larger refractory aerosol often with a combustion origin. These dominate CCN activated at low supersaturations (blue points to left).

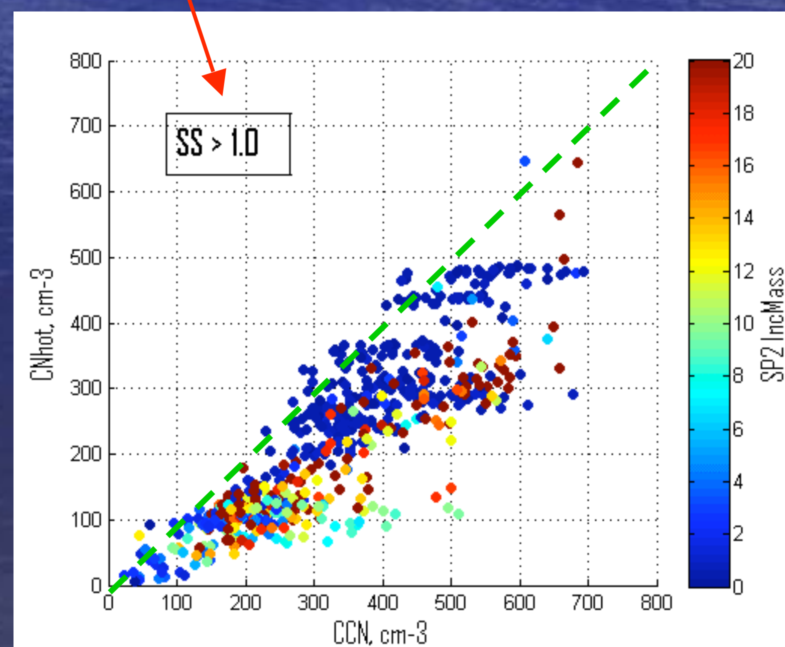
At higher supersaturations (red below) more smaller more volatile and smaller CN and UCN are activated but few of these are activated at lower supersaturations (blue below).

SP2 Black Carbon mass (combustion) associated with CCN activated at low supersaturation. Other aerosol activated at higher supersaturation



Relations of CCN to to Black Carbon Preliminary Observations for RF2,4,& 6





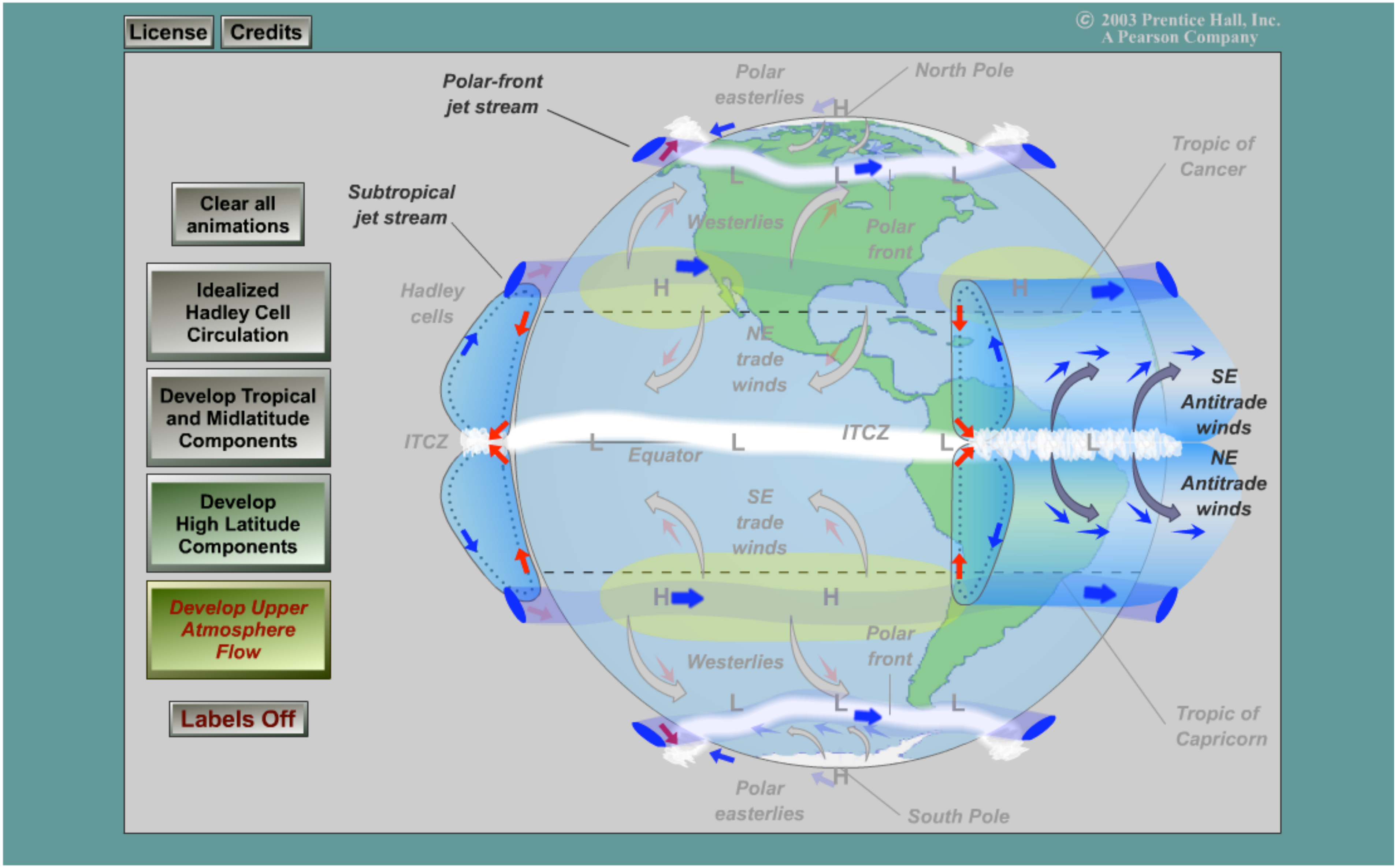
CONCLUSIONS

- Long range transport of continental combustion aerosol (biomass and pollution) is a common over the VOCALS MBL.
- These aerosol are aged size distributions and more effective CCN than the smaller "natural" sizes nucleated in free troposphere or MBL.
- Preferred regions of subsidence (Hadley Cell) are often regions of extensive stratus where subsidence and entrainment of these aerosol will provide CCN from aloft possibly impacting cloud albedo and lifetimes.
- POC's are present in clean airmass regions with lower CO than adjacent cloudy regions.

TO BE TESTED

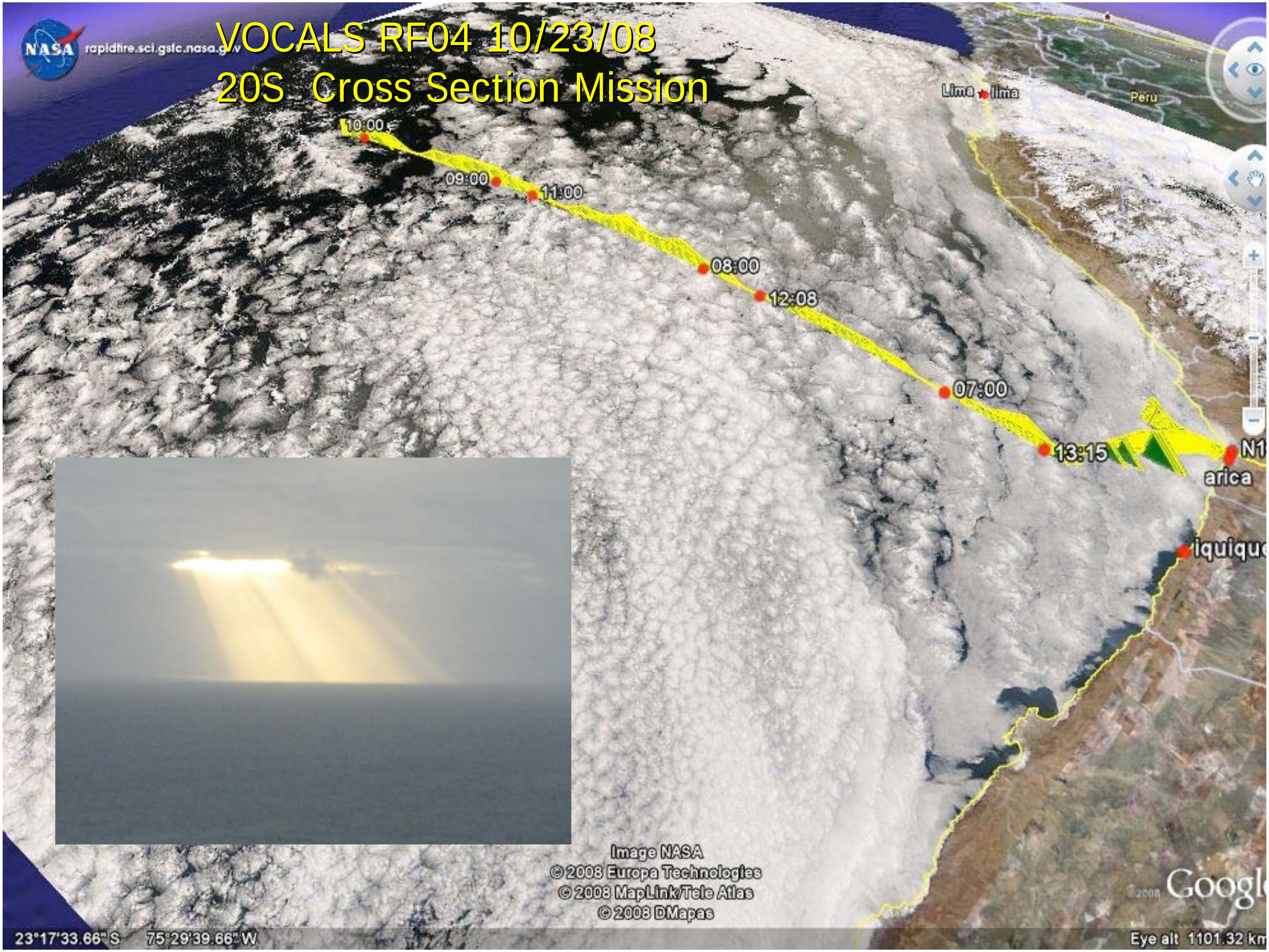
- MBL stratus are depleted by drizzle leading to cloud breakup (POC's).
  Is this process slowed or mitigated by aerosol advected/entrained into cloudy air?
- Is enhanced CO in cloudy regions a result of entrainment?
- To what extent is entrainment vs. MBL sea-salt or in-situ nucleation a source for new aerosol in POC regions?
- To what extent are combustion (Black Carbon) aerosol responsible modulating CCN at stratus supersaturations (0.2-0.3) in the VOCALS environment.

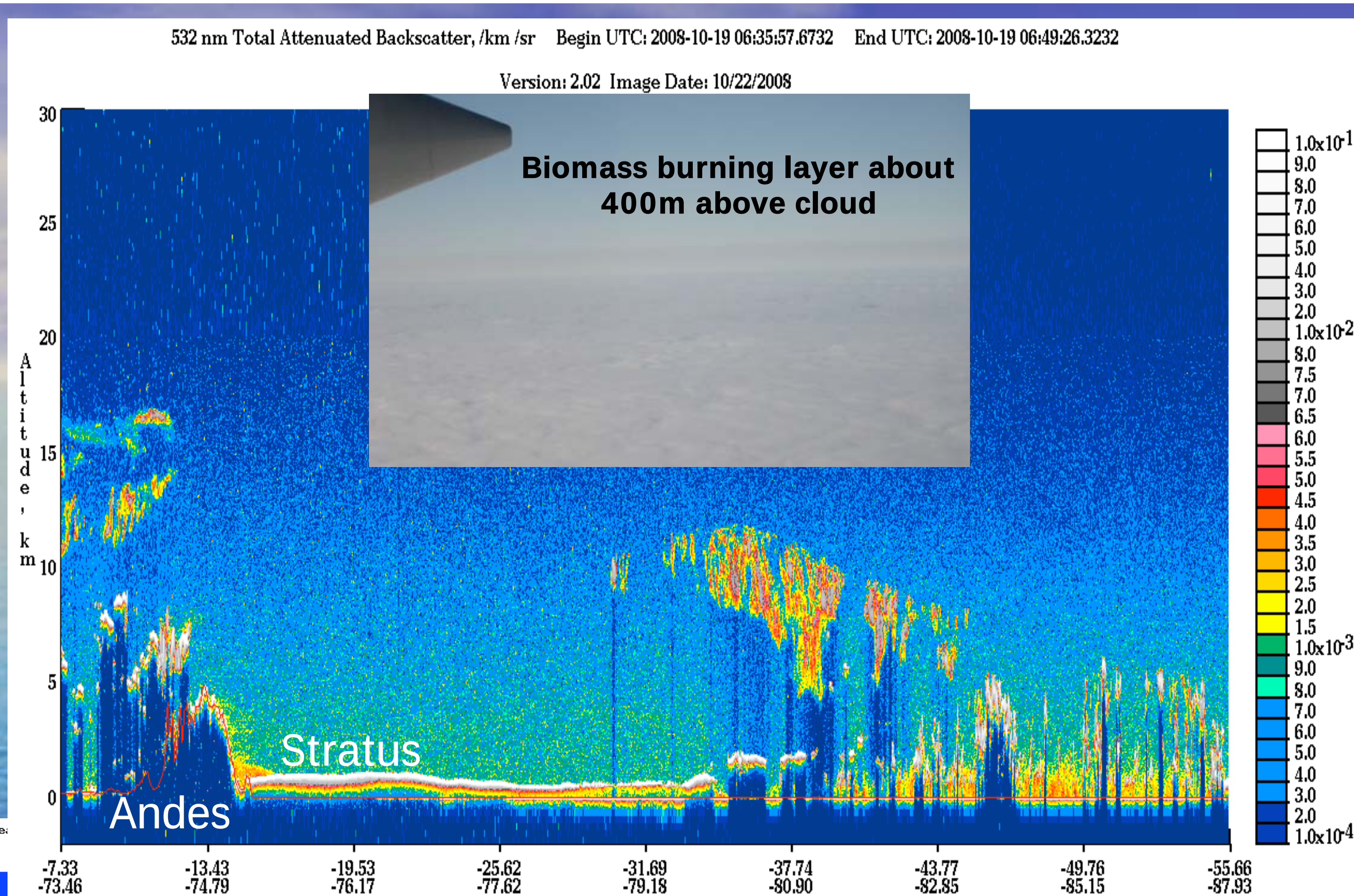
File name: 04_GlobalWind.swf



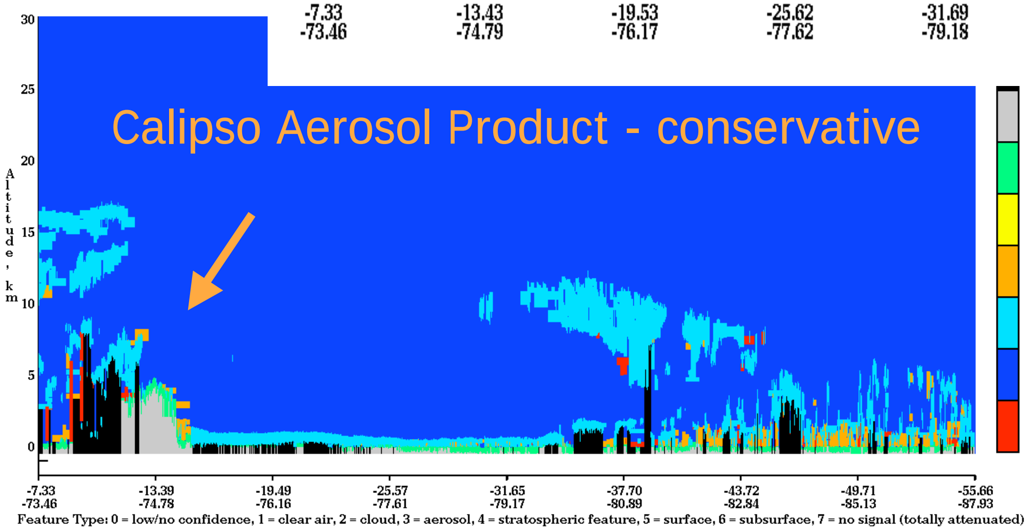
Title: Global Atmospheric Circulation Model

VOCALS RF04 10/23/08
20S Cross Section Mission

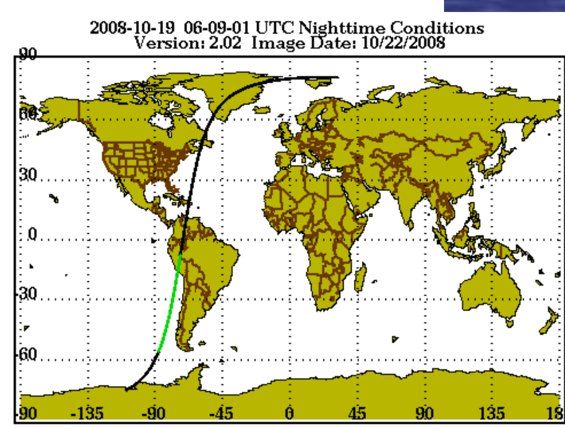




532 nm Total Attenuated Backscatter, /km /sr Begin UTC: 2008-10-19 06:35:57.6732 End UTC: 2008-10-19 06:49:26.3232
Version: 2.02 Image Date: 10/22/2008
Biomass burning layer about 400m above cloud
Stratus
Andes
Altitude, km
30
25
20
15
10
5
0
-7.33 -73.46
-13.43 -74.79
-19.53 -76.17
-25.62 -77.62
-31.69 -79.18
-37.74 -80.90
-43.77 -82.85
-49.76 -85.15
-55.66 -87.93
1.0x10-1
1.0x10-2
1.0x10-3
1.0x10-4

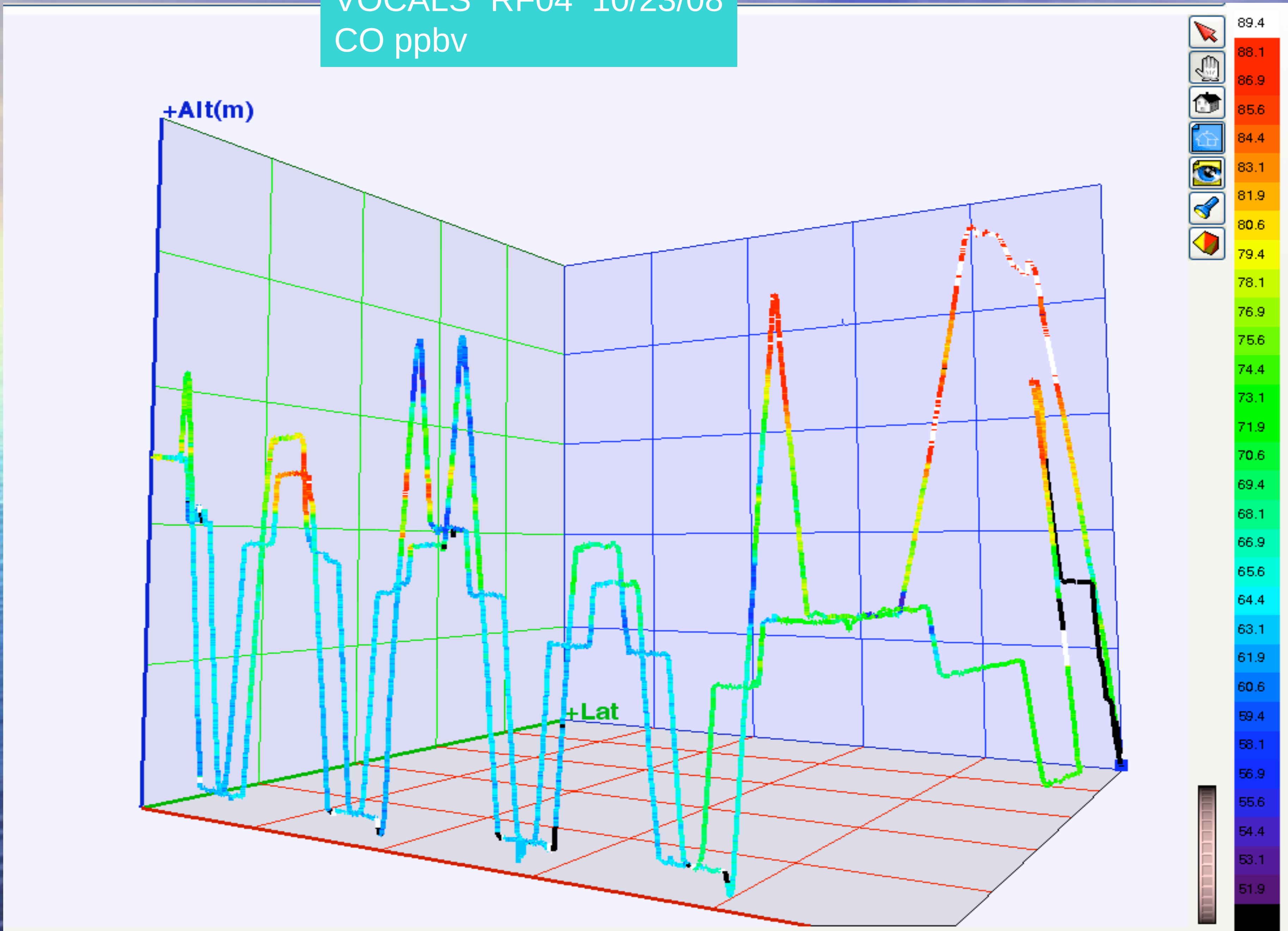


Calipso Aerosol Product - conservative
Altitude, km
-7.33 -73.46
-13.39 -74.78
-19.49 -76.16
-25.57 -77.61
-31.65 -79.17
-37.70 -80.89
-43.72 -82.84
-49.71 -85.13
-55.66 -87.93
Feature Type: 0 = low/no confidence, 1 = clear air, 2 = cloud, 3 = aerosol, 4 = stratospheric feature, 5 = surface, 6 = subsurface, 7 = no signal (totally attenuated)



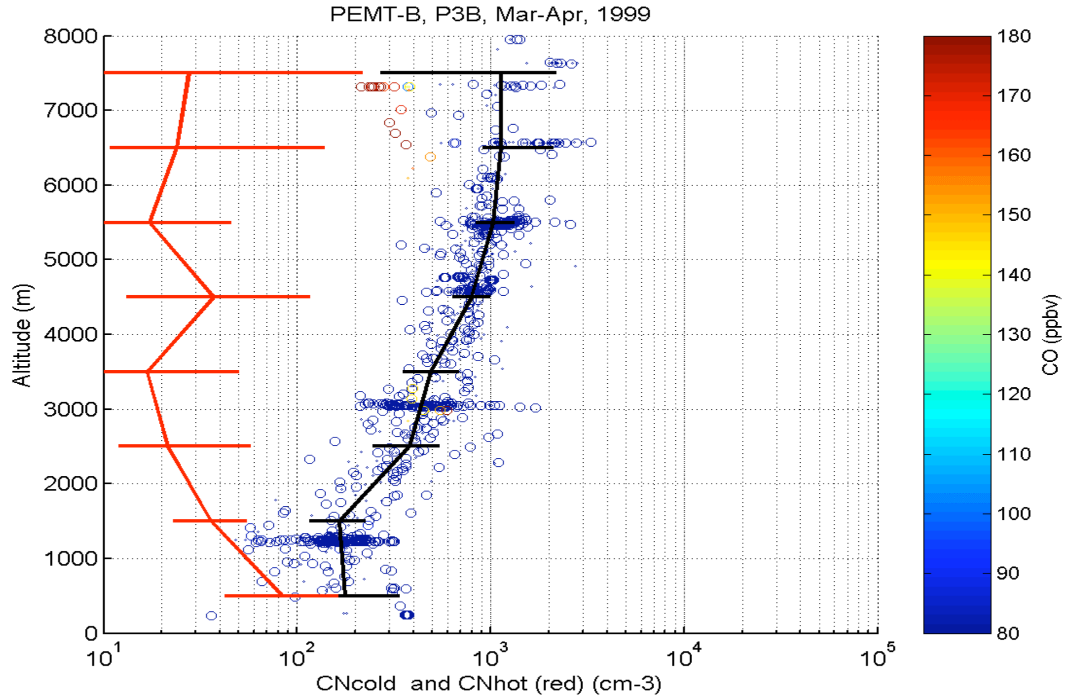
2008-10-19 06-09-01 UTC Nighttime Conditions
Version: 2.02 Image Date: 10/22/2008

VOCALS RF04 10/23/08
CO ppbv

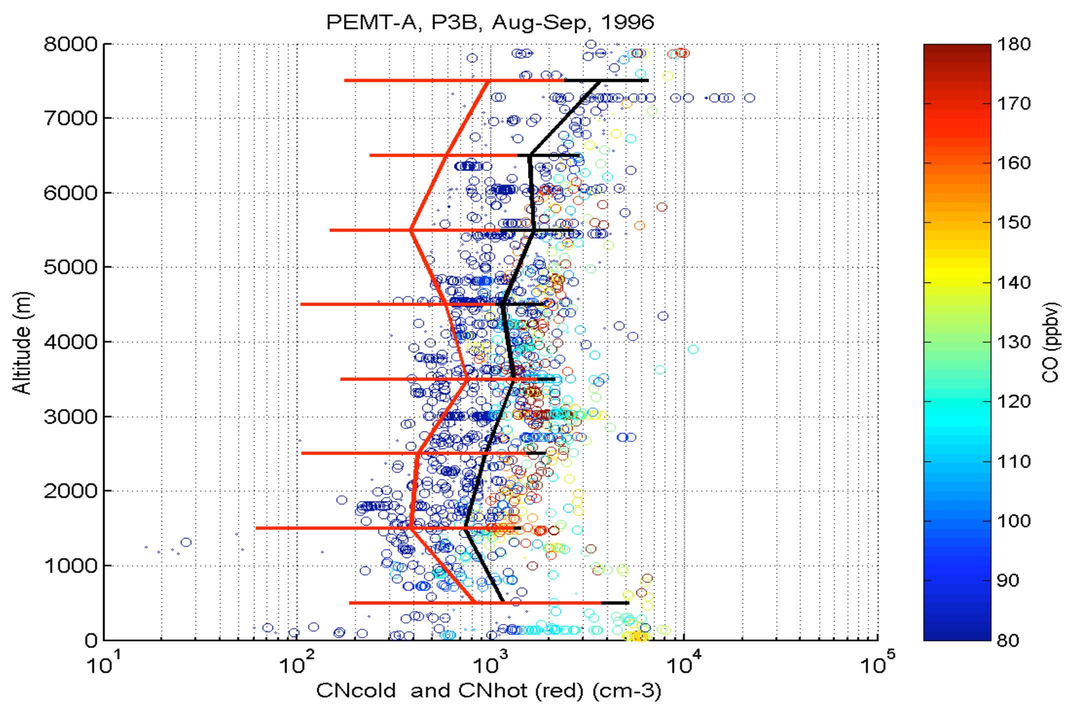


NASA PEM-Tropics South Pacific Particle Number Profiles

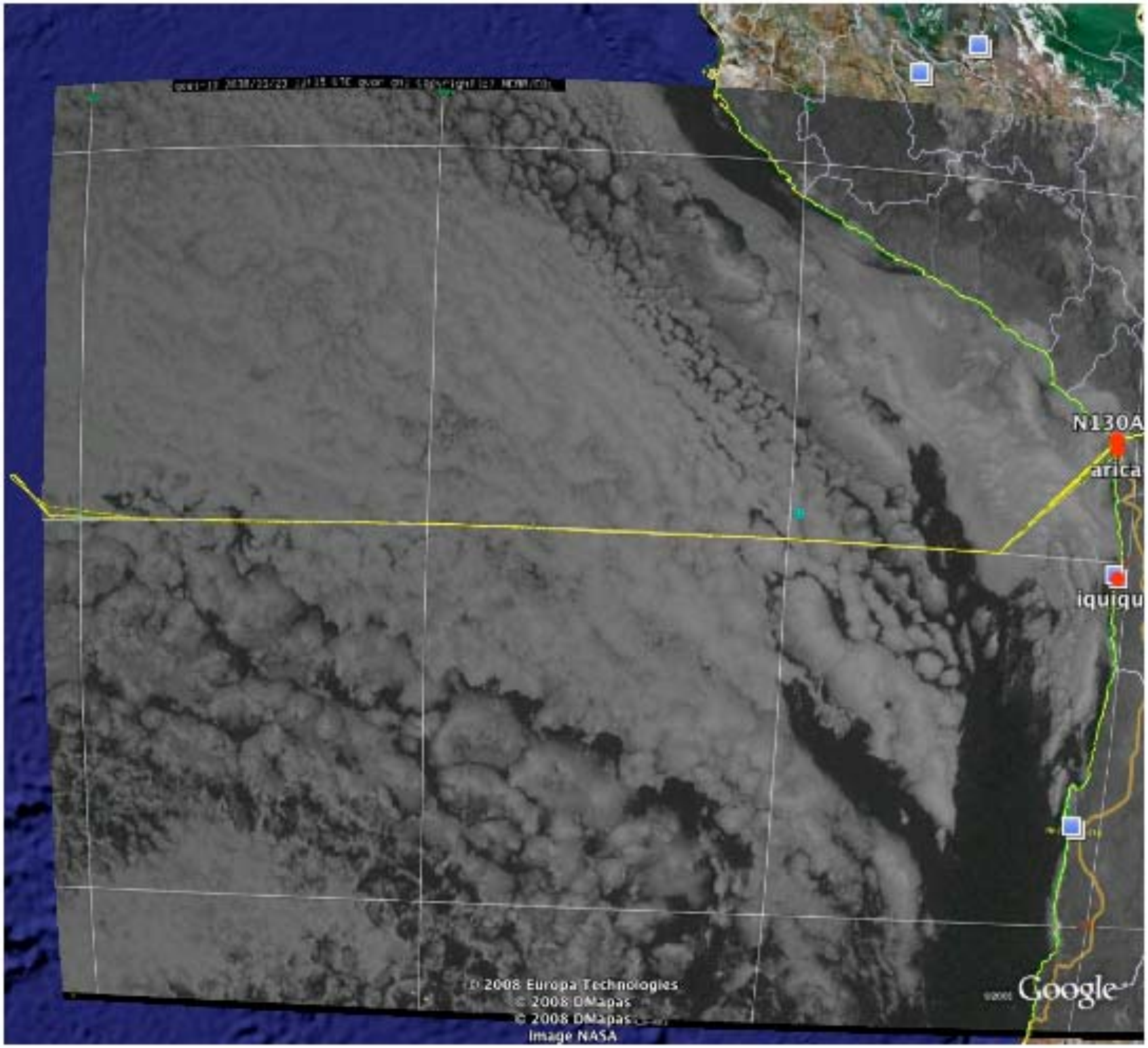
Clean Season



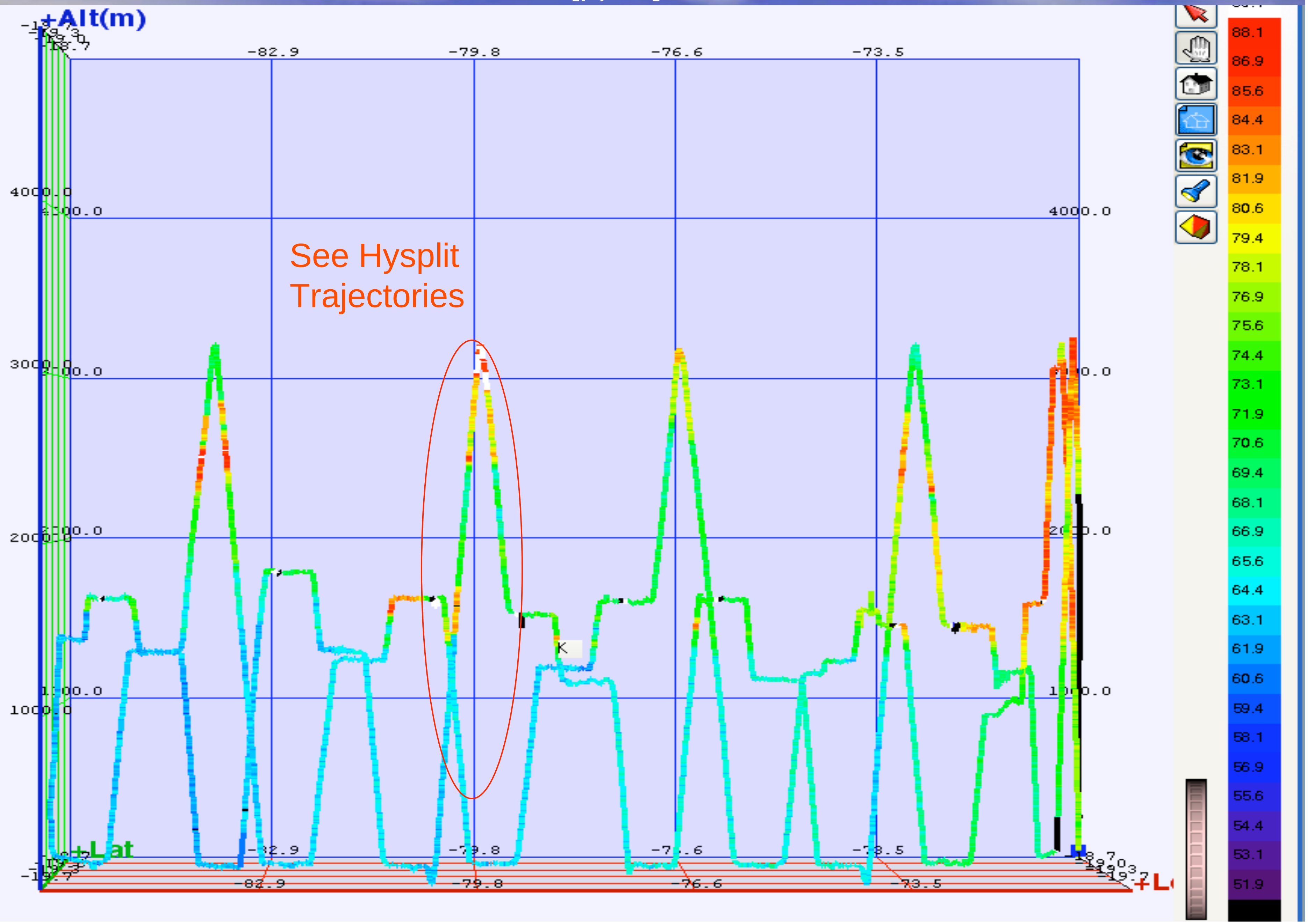
Biomass Burning Season

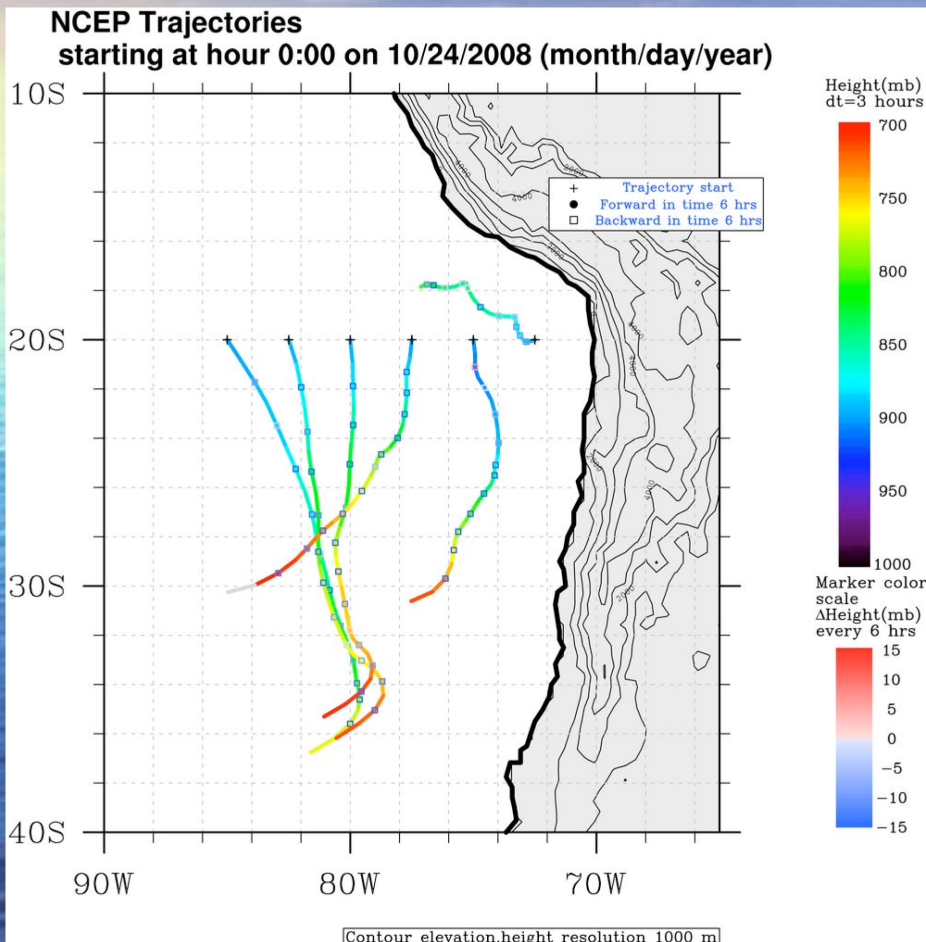


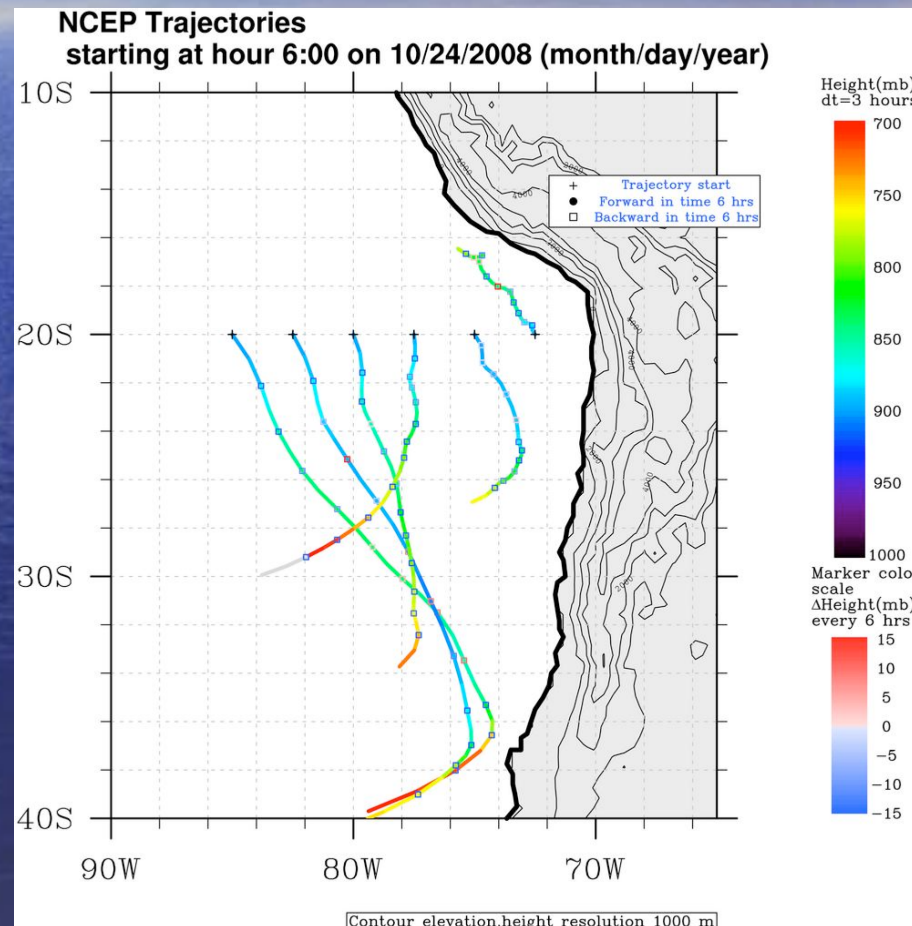
VOCALS RF05 10/26/2008

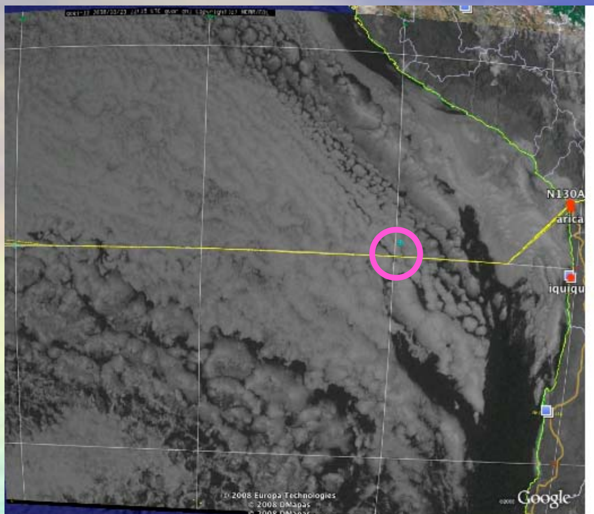


VOCALS RF05 10/26/2008
CO [ppbv]




NCEP Trajectories
starting at hour 0:00 on 10/24/2008 (month/day/year)
10S
20S
30S
40S
90W
80W
70W
Trajectory start
Forward in time 6 hrs
Backward in time 6 hrs
Height(mb)
dt=3 hours
700
750
800
850
900
950
1000
Marker color scale
ΔHeight(mb) every 6 hrs
15
10
5
0
−5
−10
−15
Contour elevation,height resolution 1000 m


NCEP Trajectories
starting at hour 6:00 on 10/24/2008 (month/day/year)
10S
20S
30S
40S
90W
80W
70W
Trajectory start
Forward in time 6 hrs
Backward in time 6 hrs
Height(mb)
dt=3 hours
700
750
800
850
900
950
1000
Marker color scale
ΔHeight(mb) every 6 hrs
15
10
5
0
−5
−10
−15
Contour elevation,height resolution 1000 m



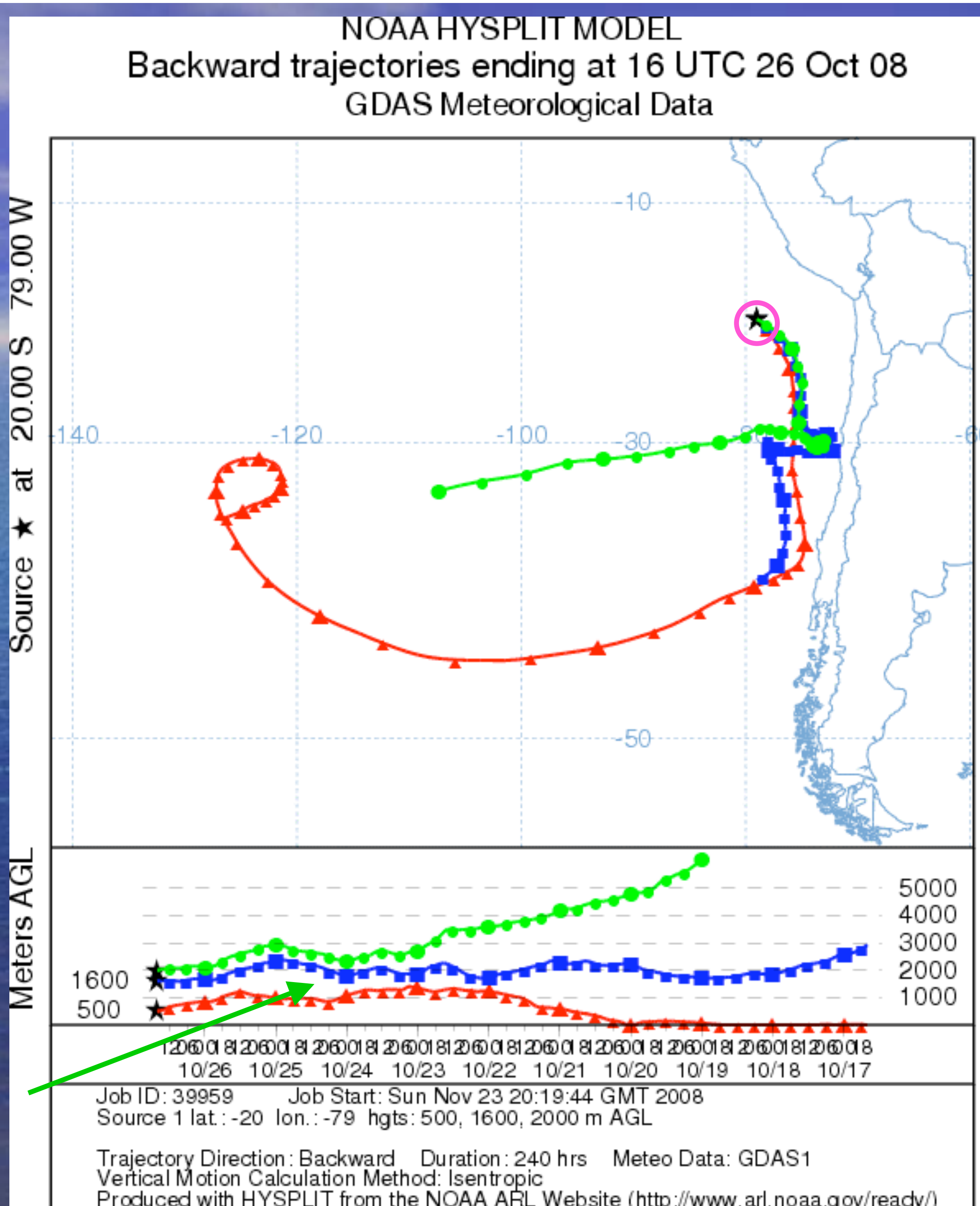
RF05 – 10/26/2008

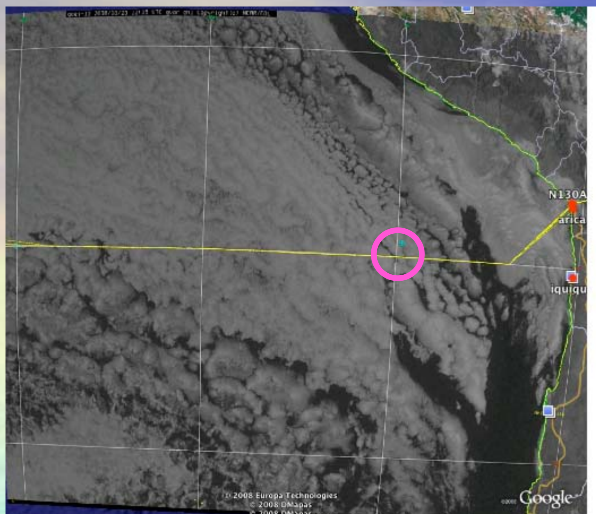
500m - clean SP MBL air

1600m – locally influenced biomass burning?

2000m and higher – long range transport

Note diurnal?? Altitude fluctuations

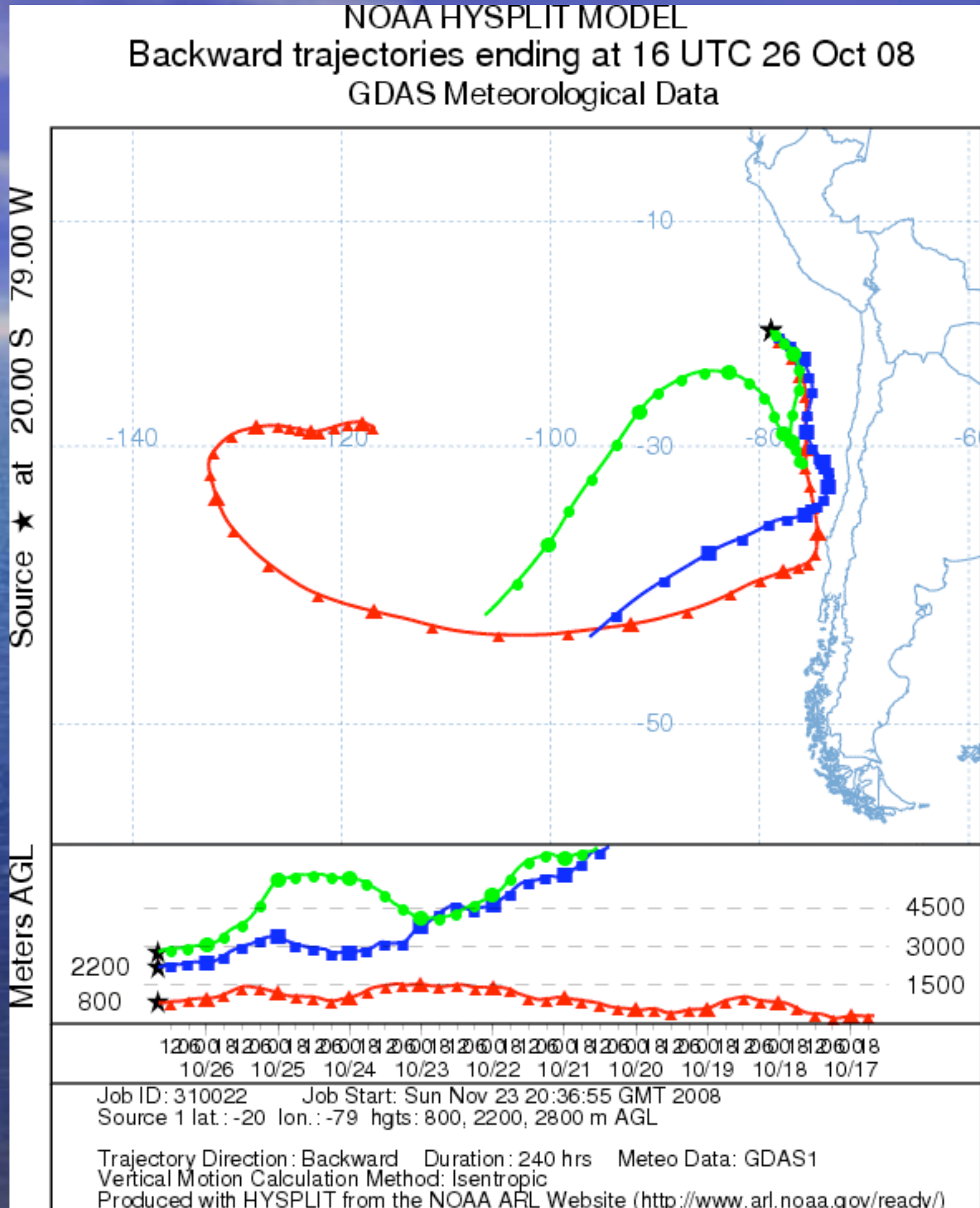


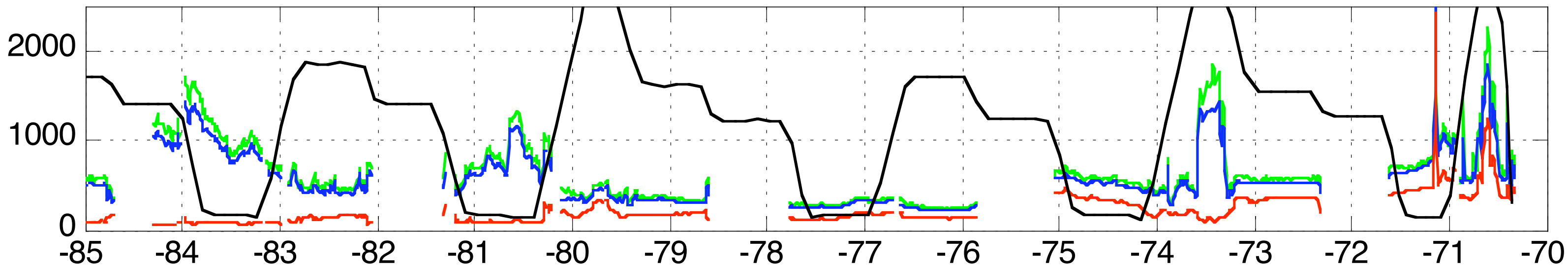


RF05 – 10/26/2008

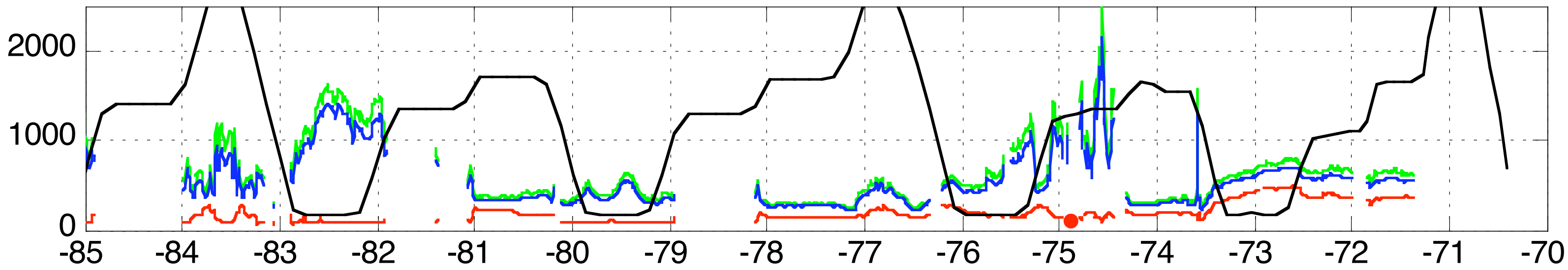
800m - clean SP MBL air

2000m and higher – long range transport?





VO_disttseries1_RF05-Return.fig, VO_20S_dists_rev1.mCam, Cam, 2009-07-06



VO_disttseries1_RF05-Outbound.fig, VO_20S_dists_rev1.m, Cam, 2009-07-06

For 300/cc (200volatile and 100refractory per cm3)
Mixing through inversion @ 4mm/s
Takes ~ 3 days to flux in 1km layer (CN=300/cc)
& acting over 2,000km assuming wind at 8m/s

Mixing and advection faster than these time scales

Rain Removal, Patchy, Episodic, hours?
Most growth in non-precip MBL clouds

For 9m/s wind Sea-Salt Aerosol flux is about 30/cm2/s
Takes 4 days to fill 1 km layer to 100/cm3 (Direct Injection)

10 Day back trajectory from MBL inversion