Wintertime reactive nitrogen chemistry: The state of the data, $ClNO_2$ production, and power plants

WINTER Data Meeting

September 2015

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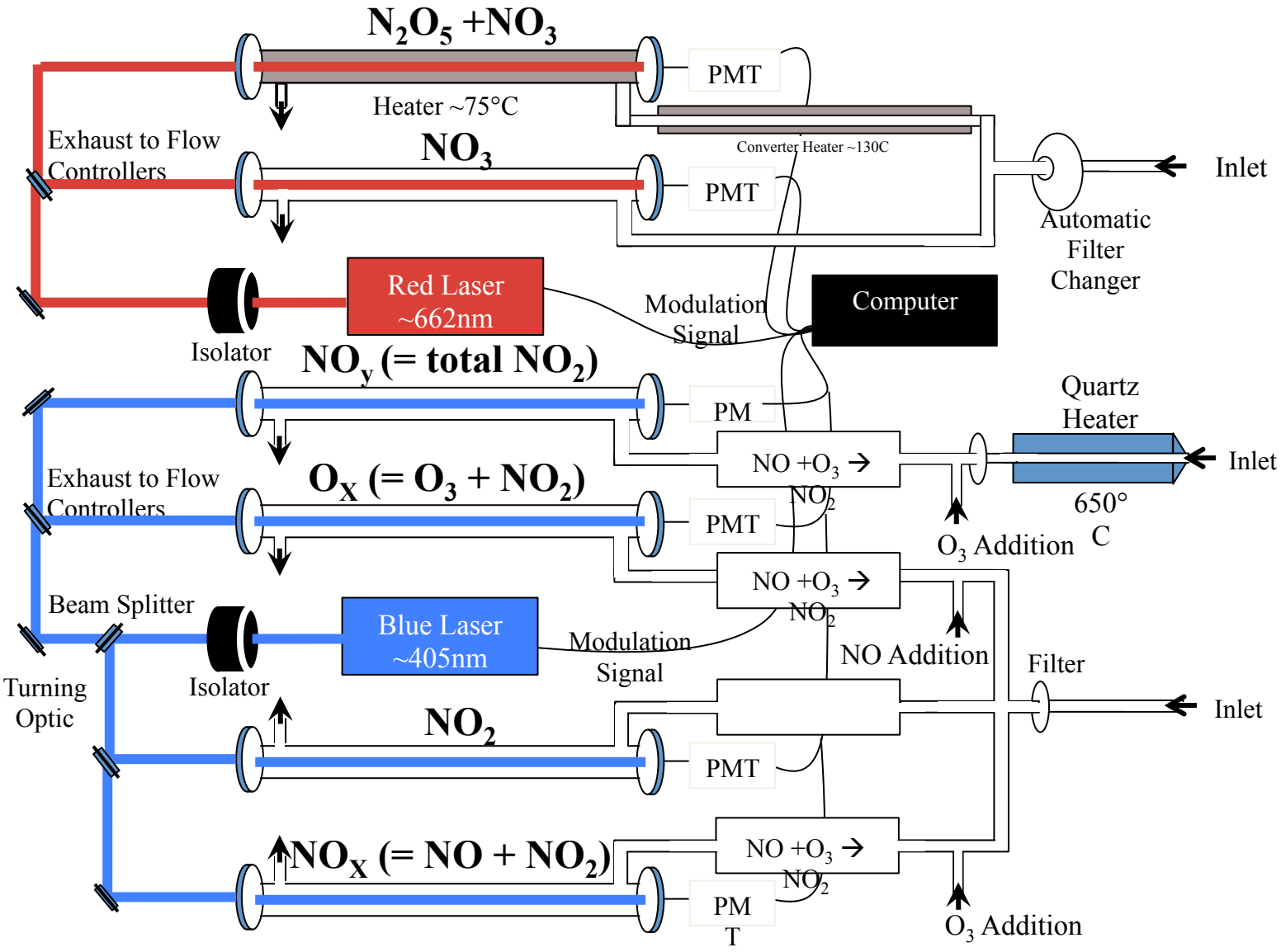
ARNOLD – 6 Channel cavity ring-down

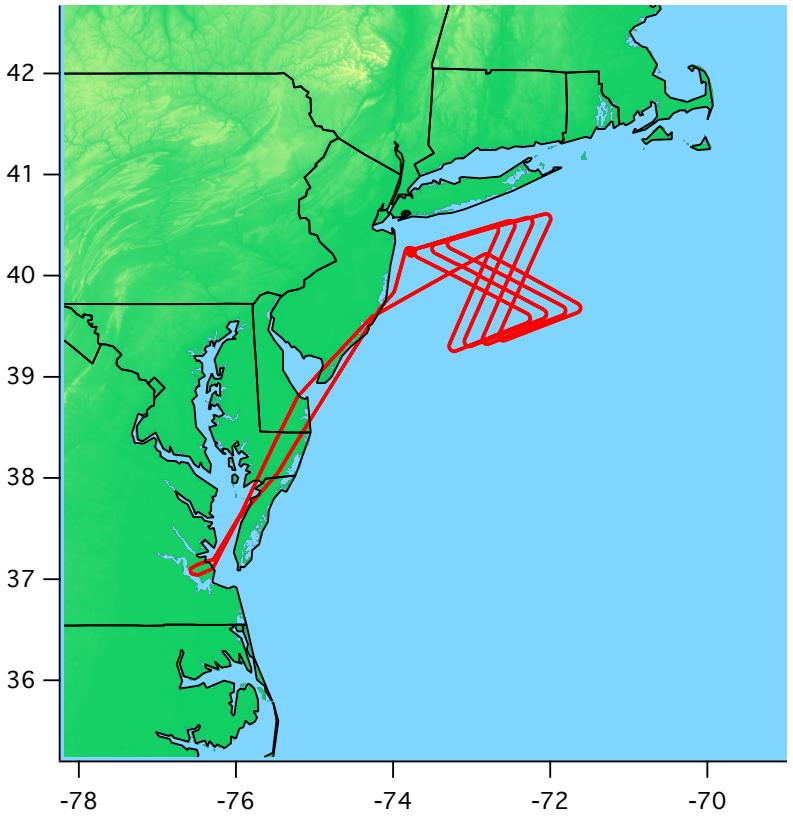


ARNOLD Data

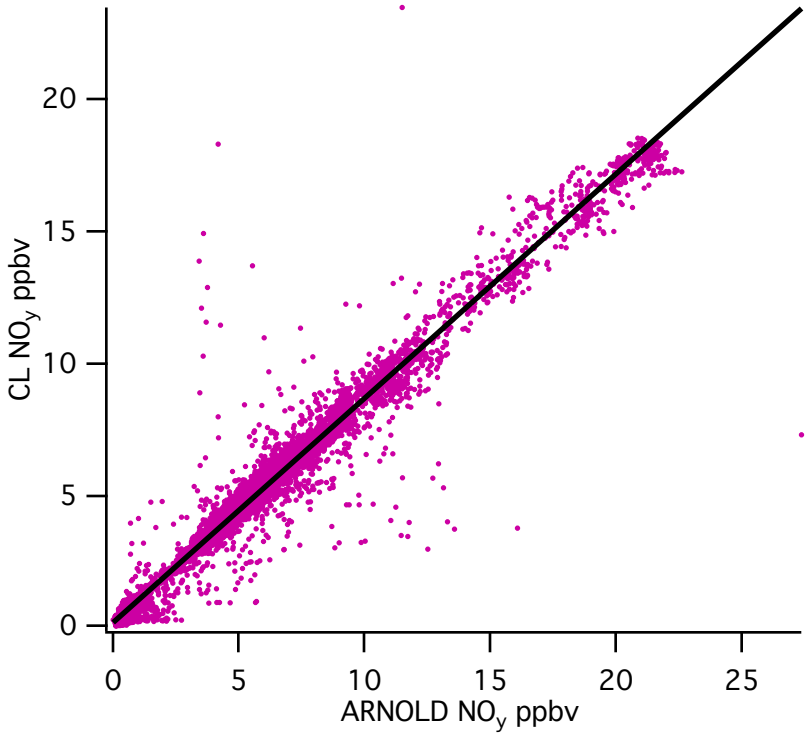
- NO_2, NO, NO_y, O_3, N_2O_5, ~~NO_3~~
- No O_3 on flight 05
- All data nearly finalized- waiting on final RH data from RAF and final O_3 from CL
- Flights 5-13 will change very little from currently posted- waiting on final RAF data
- Flights 1-4, NO, NO_2 and O_3 will change significantly- will be scaled to CL O_3, so those flights will not have independent data
- Unknown how much aerosol nitrate may be in NO_y

Research Flight 08 (“hourglass”)

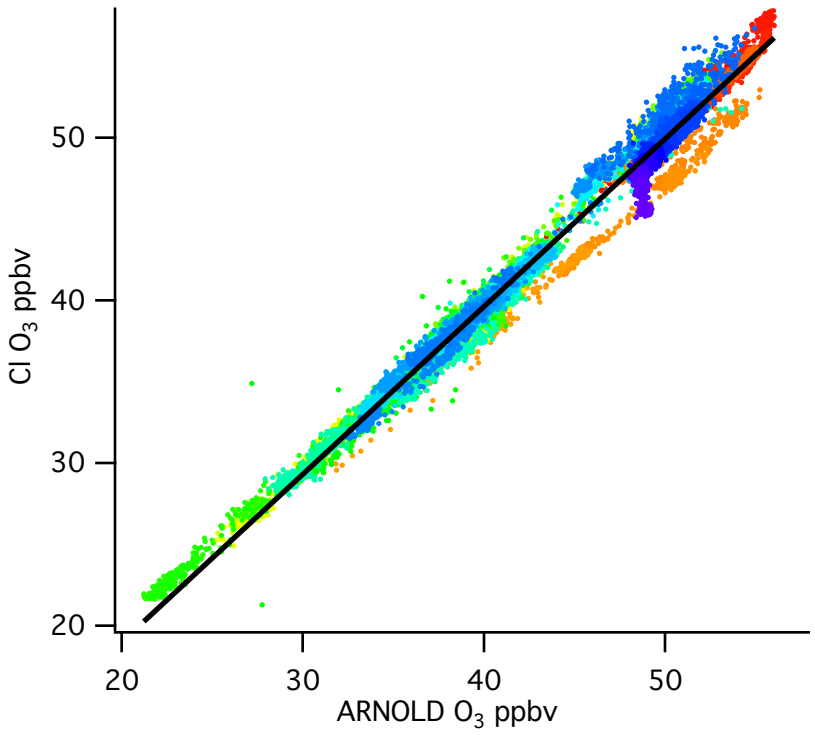
- Night into day
- Mostly in “soup” with some higher concentration plumes



CL comparison with ARNOLD

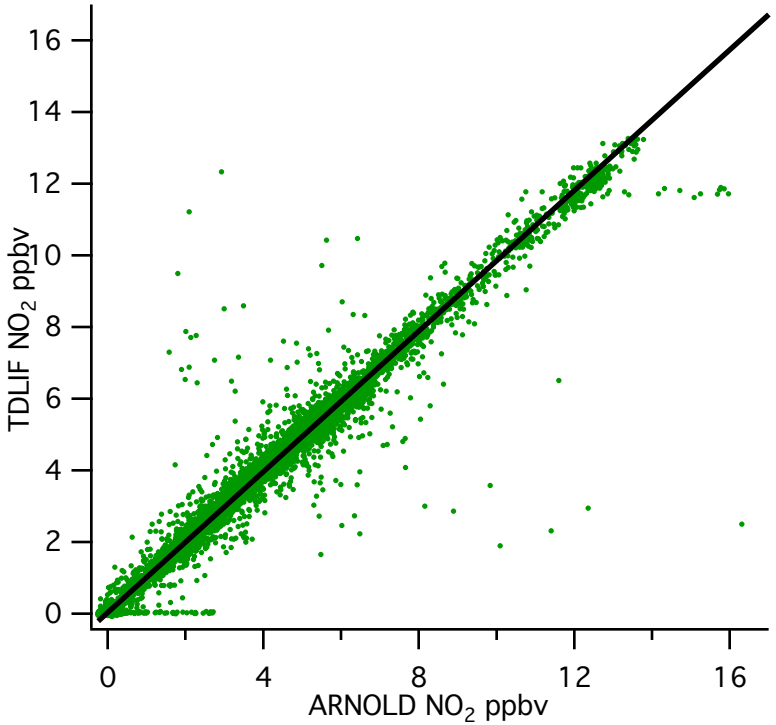


CL = 0.86*ARNOLD + 0.18



CL = 1.03*ARNOLD – 1.6

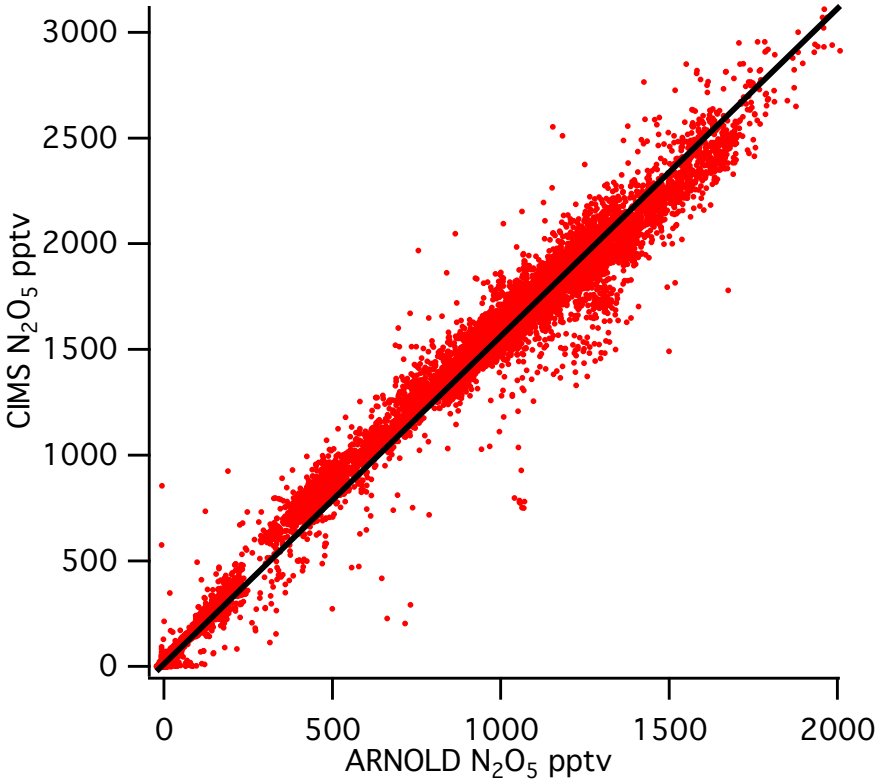
TDLIF comparison with ARNOLD



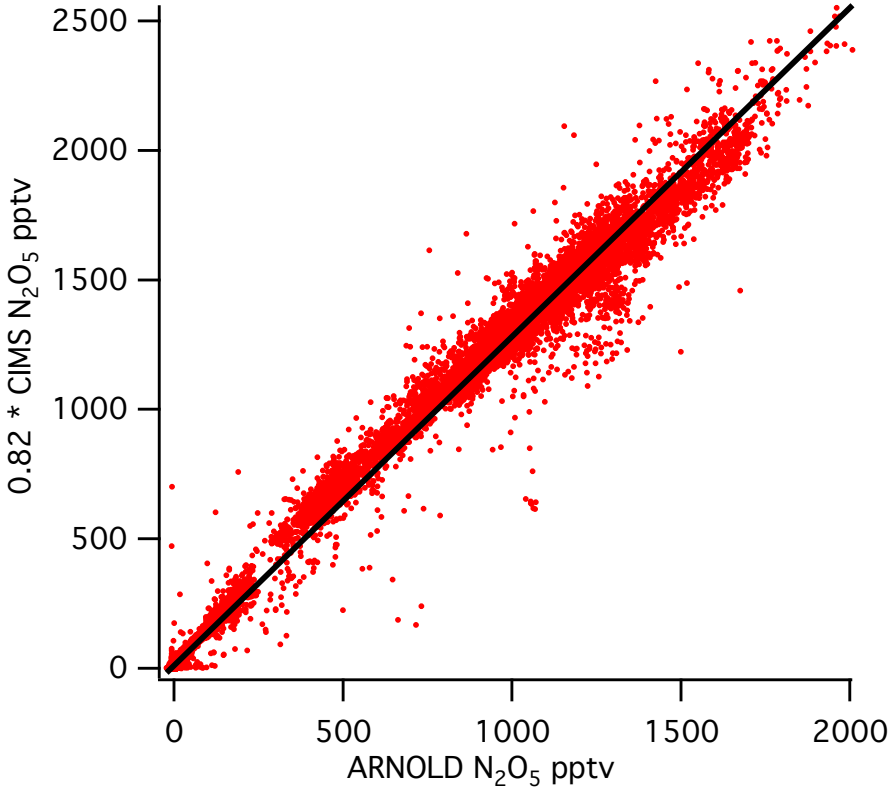
TDLIF = 0.98*ARNOLD + 0.05

TDLIF data *0.82

CIMS comparison with ARNOLD



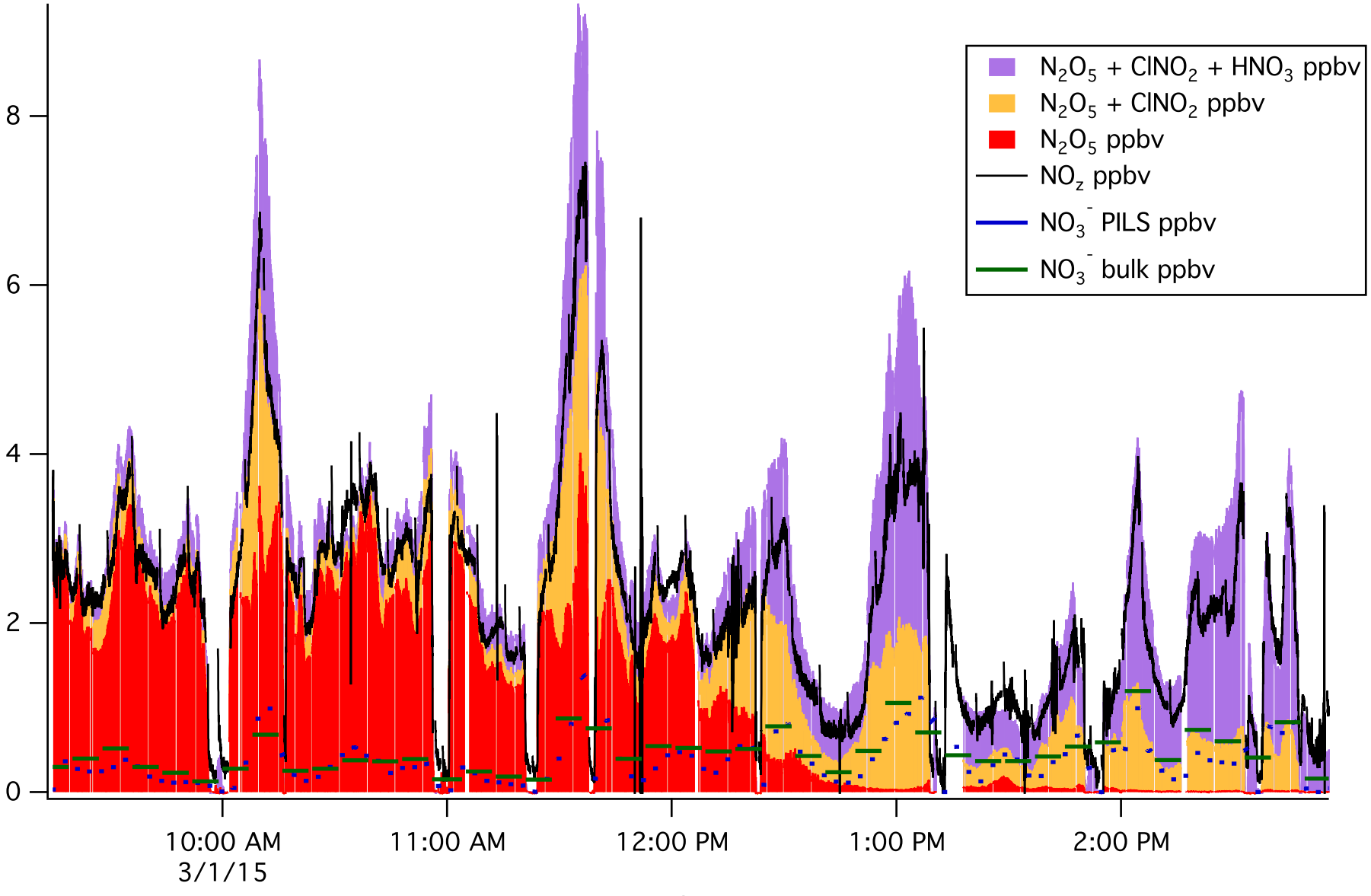
CIMS = 1.55*ARNOLD + 14.2



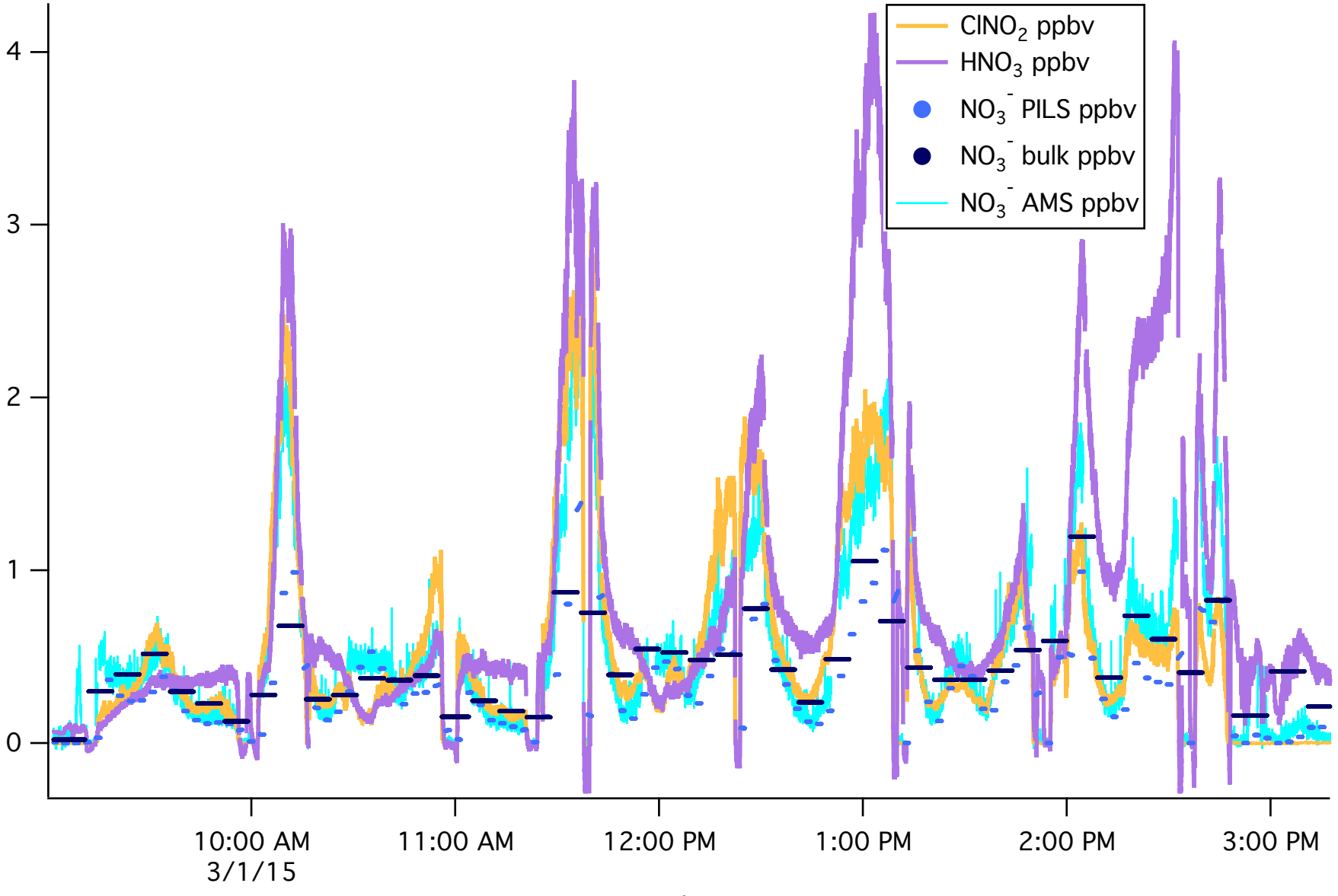
CIMS = 1.27*ARNOLD + 12.0

CIMS * 0.82

N_2O_5, $ClNO_2$, various NO_3^-, flight 08

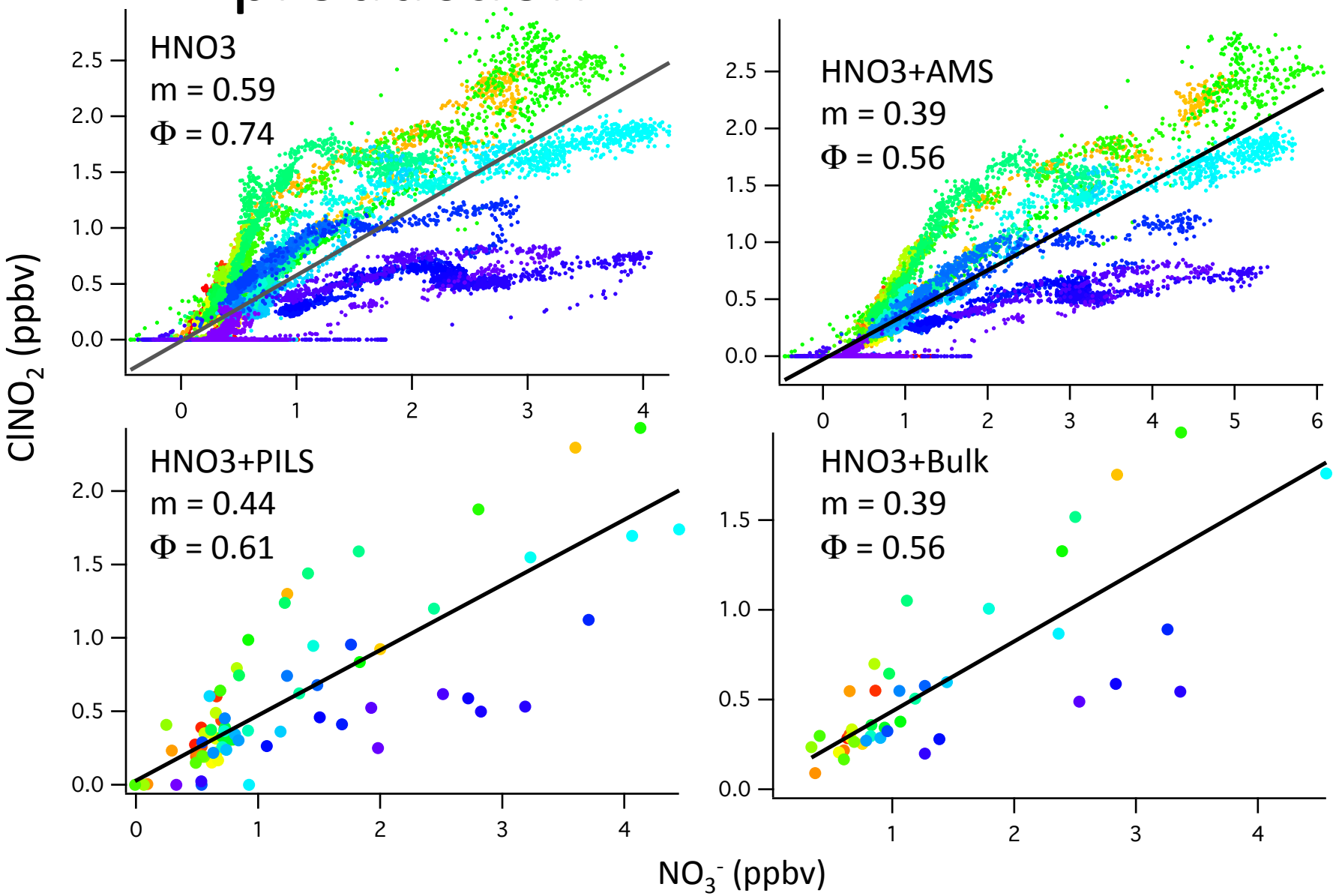


$ClNO_2$ and nitrate, flight 08

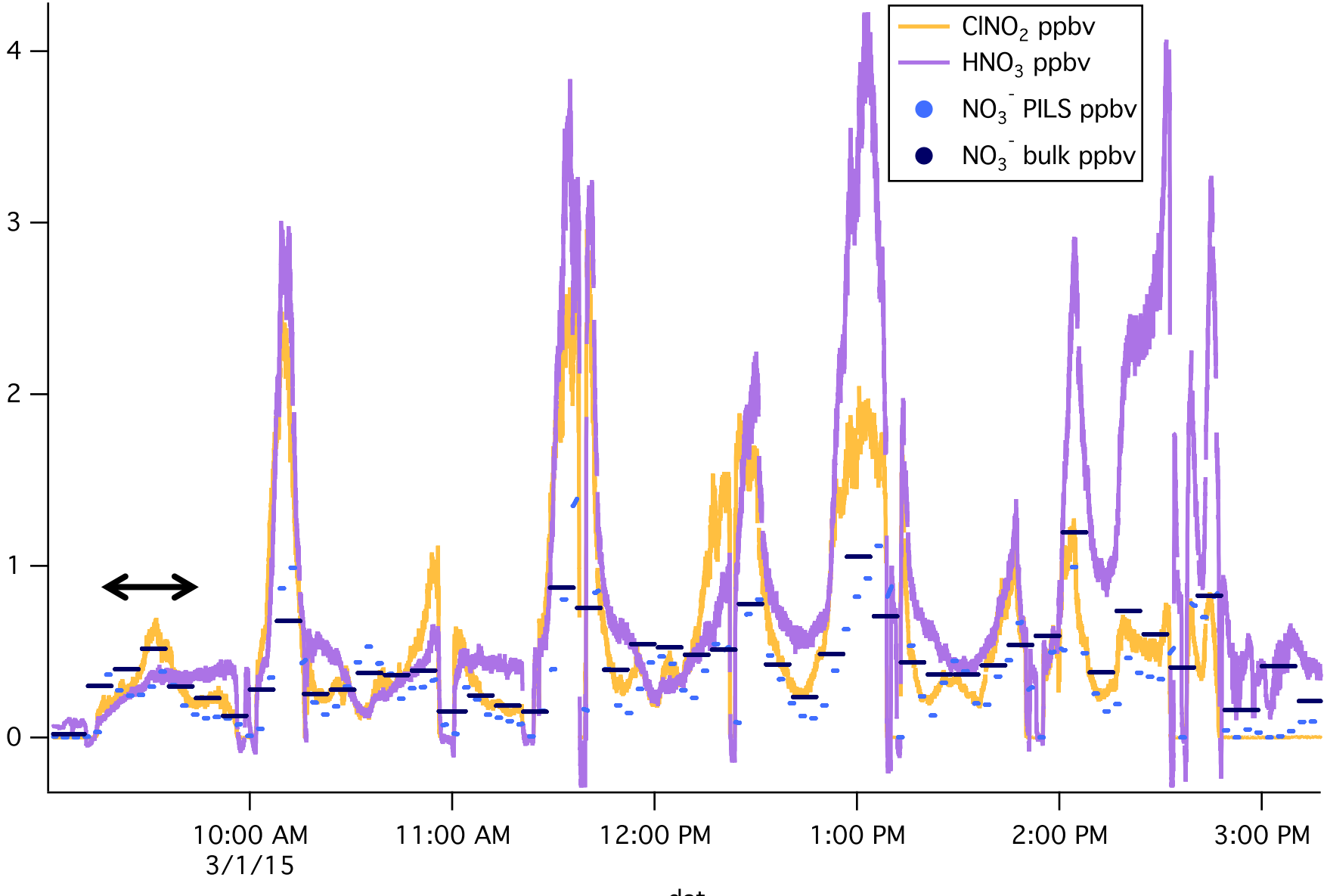


Average ClNO2 production

- Graphs colored by time red → violet
- Φ is ClNO2 production (2m/(1+m))

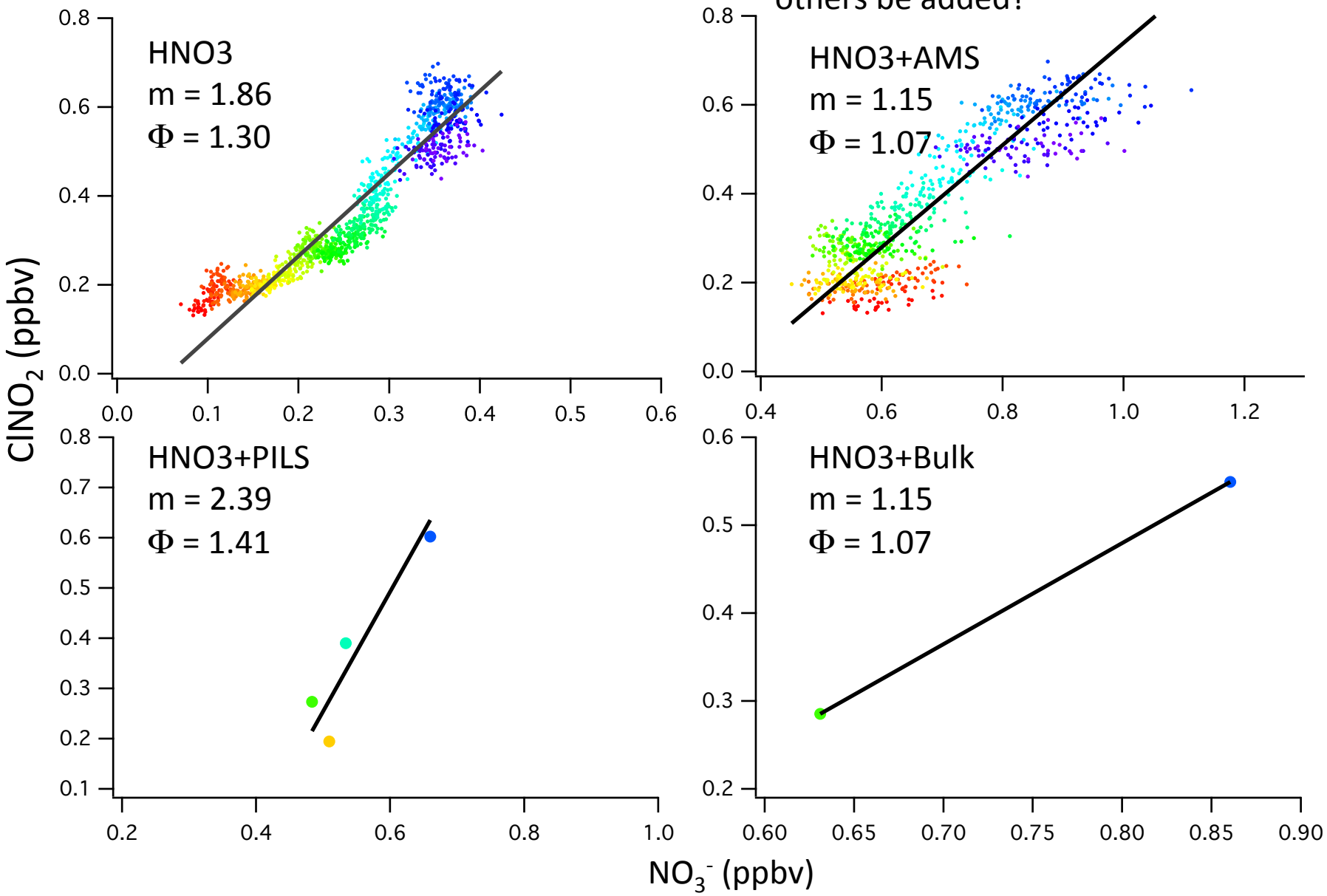


Initial $ClNO_2$ yield

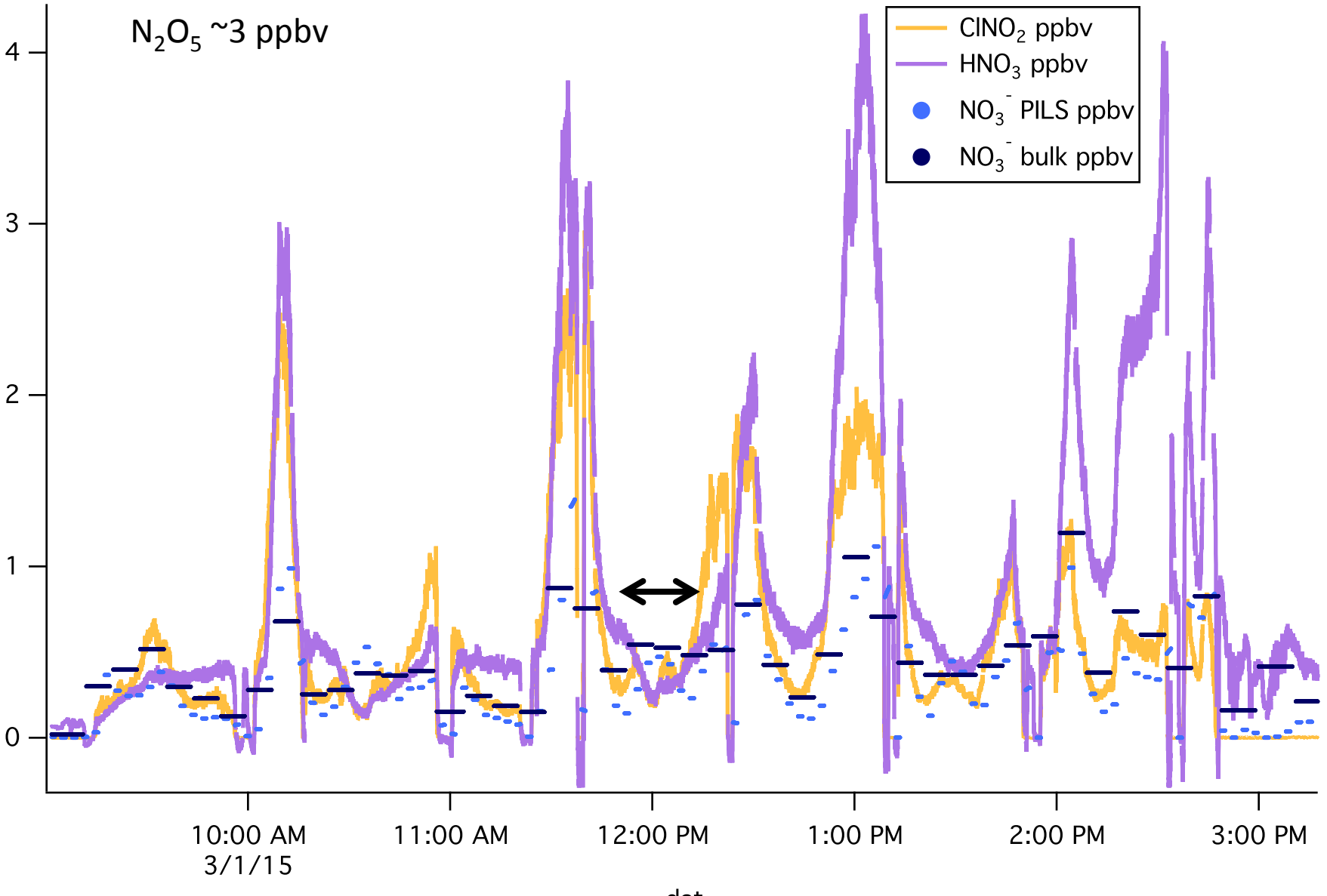


Initial $ClNO_2$ yield

- Graphs colored by time, red → violet
- Slope > 1 is unphysical
- Adding bulk gets slope < 1, but should others be added?

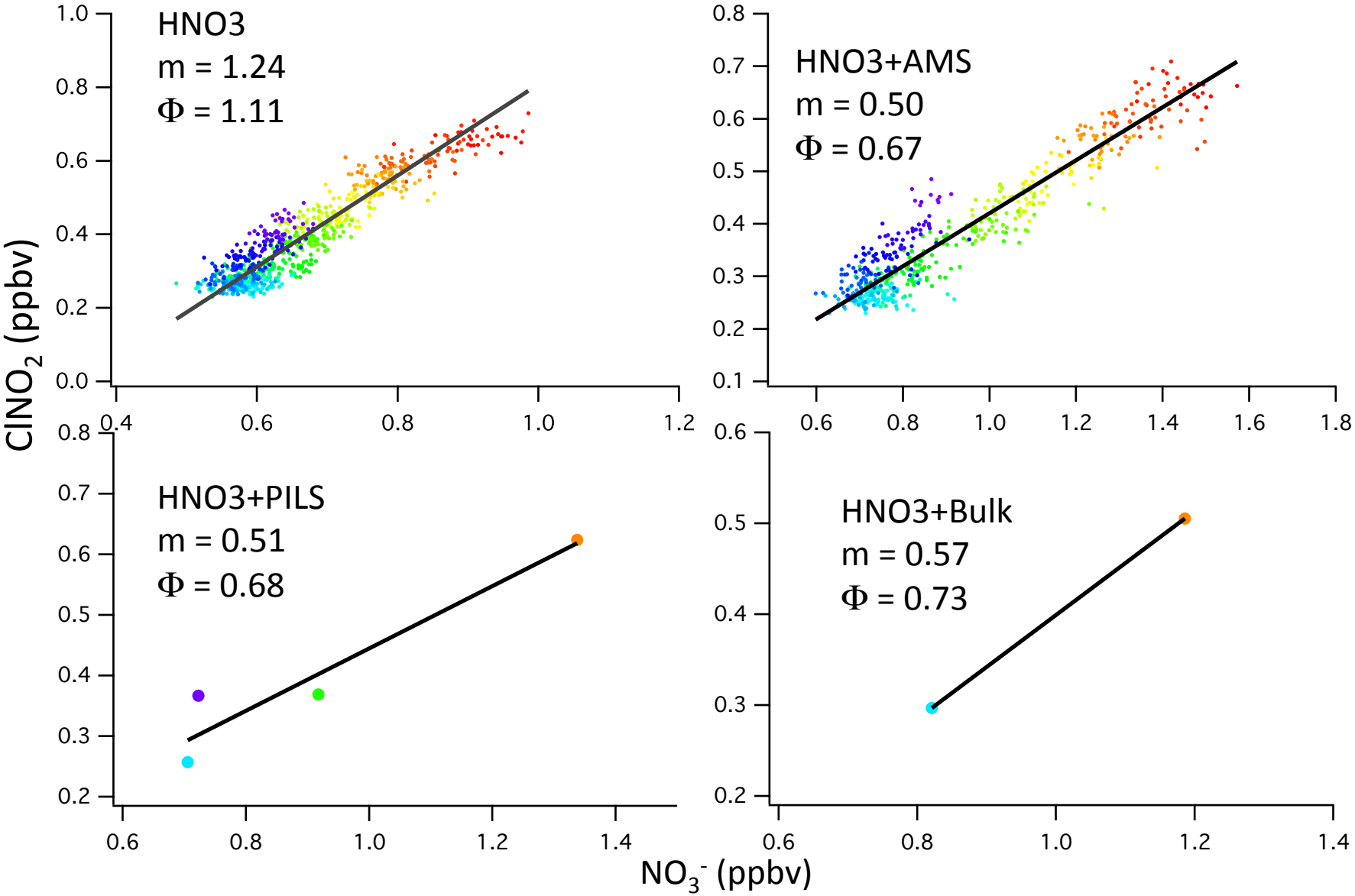


Background $ClNO_2$ yield

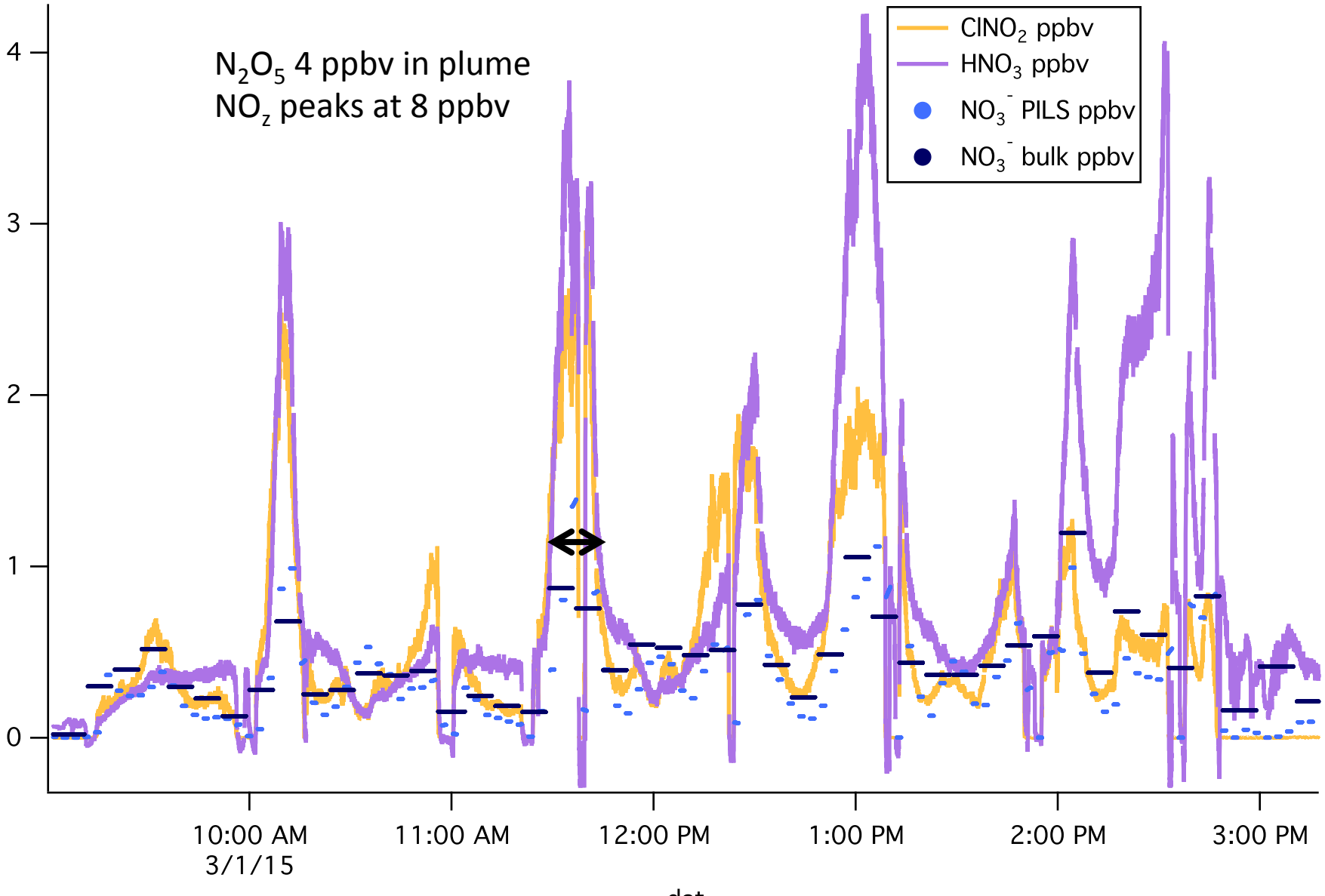


Background

- Background $ClNO_2$ yield much higher than in plume
- All aerosol NO_3^- give similar result- no supermicron NO_3^-?

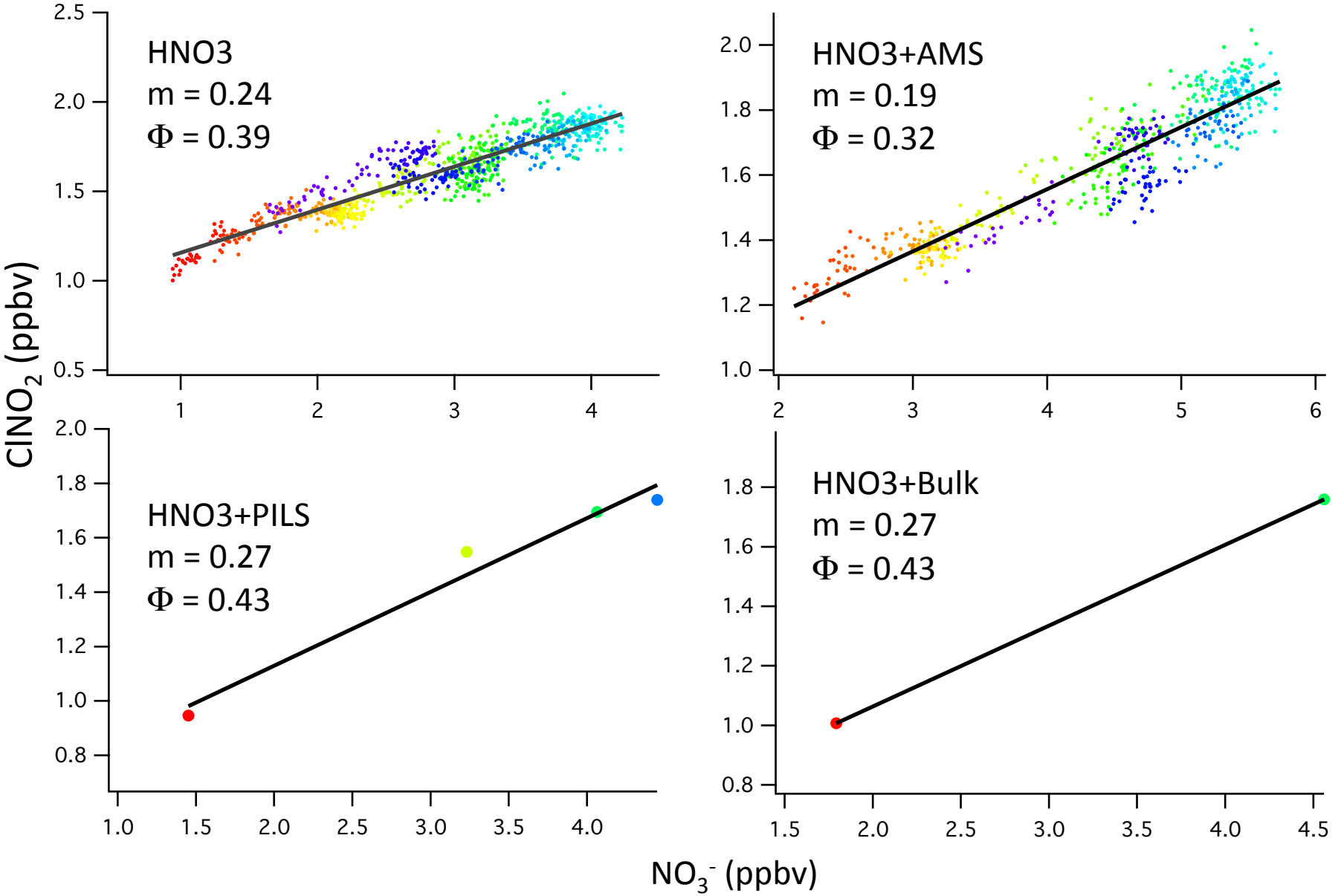


In plume $ClNO_2$ yield



In plume

- Graphs colored by time, red → violet
- In plume is much lower ClNO2 yield
- Limited by Cl?

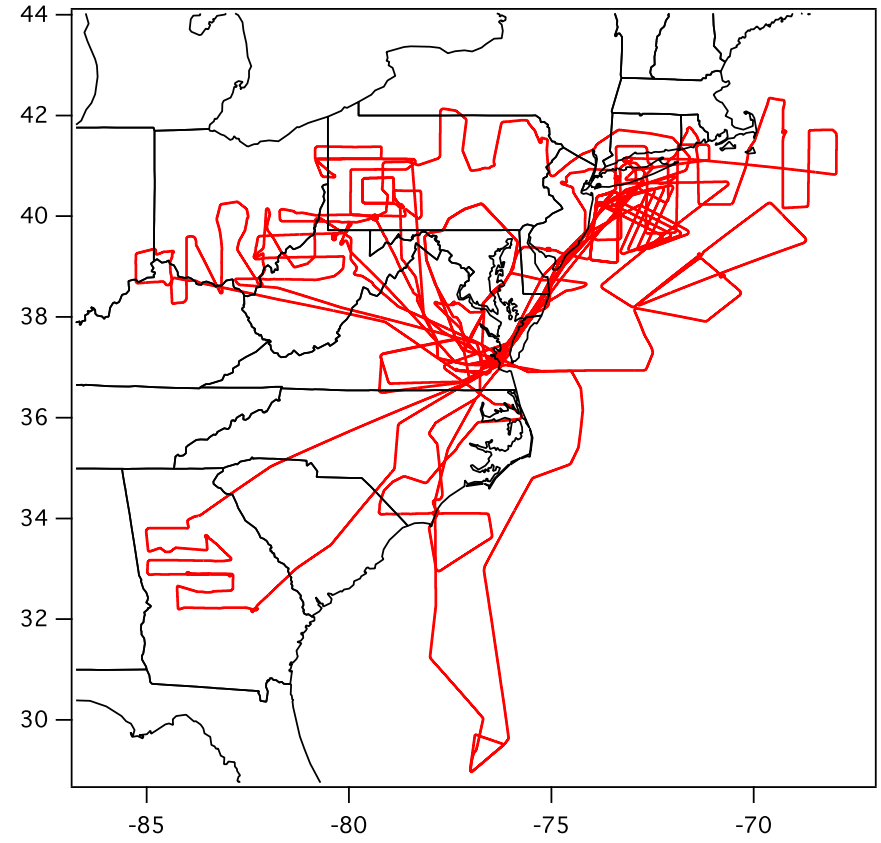


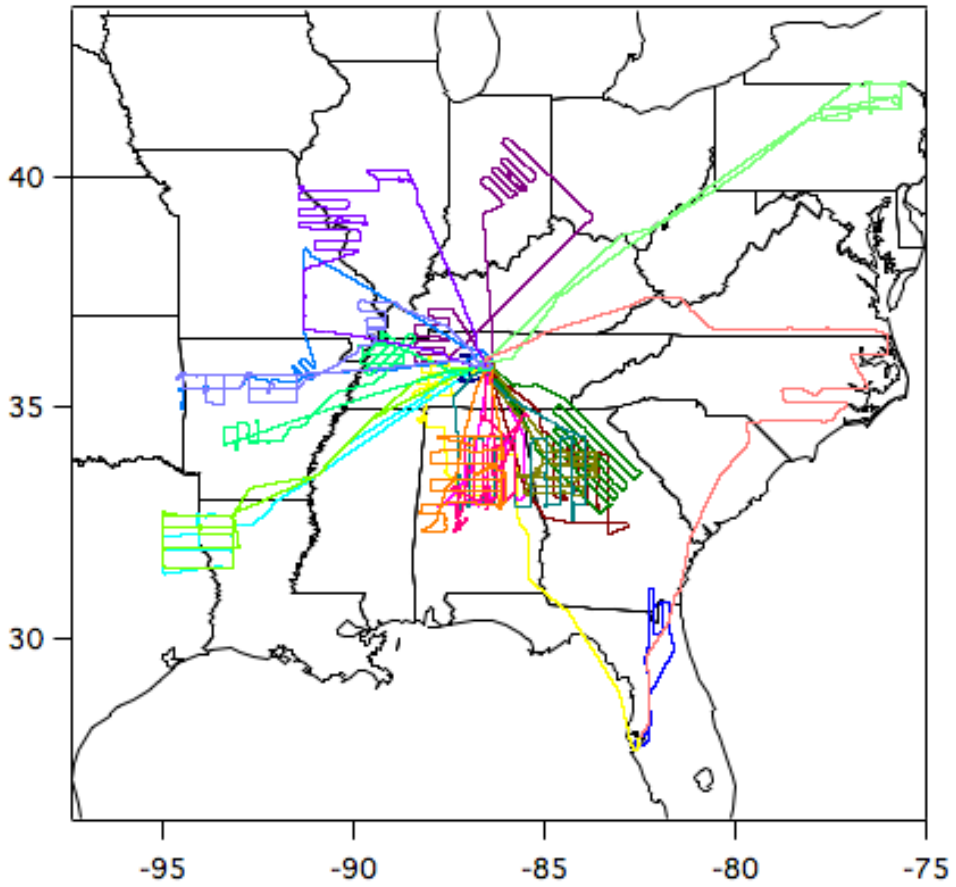
Power plant plumes

- Dispersion rates
- NO oxidation rates
- NOx lifetime
- Formation of N_2O_5 and $ClNO_2$ (night)
- Plumes with and without complete ozone titration

Summer vs winter

- Comparing plumes from SENEX and WINTER
- Overlap in Atlanta night flights





Nighttime Power Plant Plumes

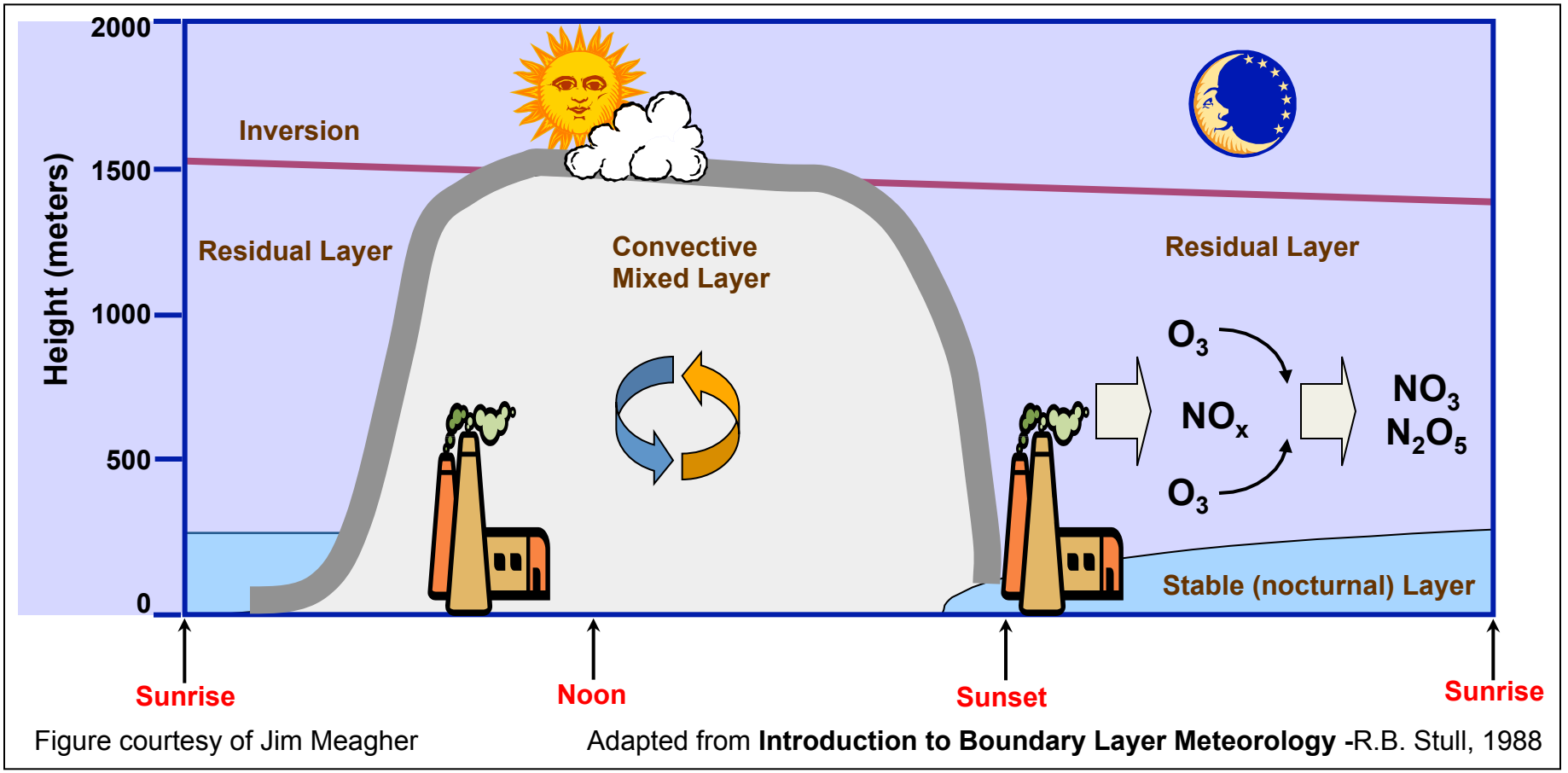


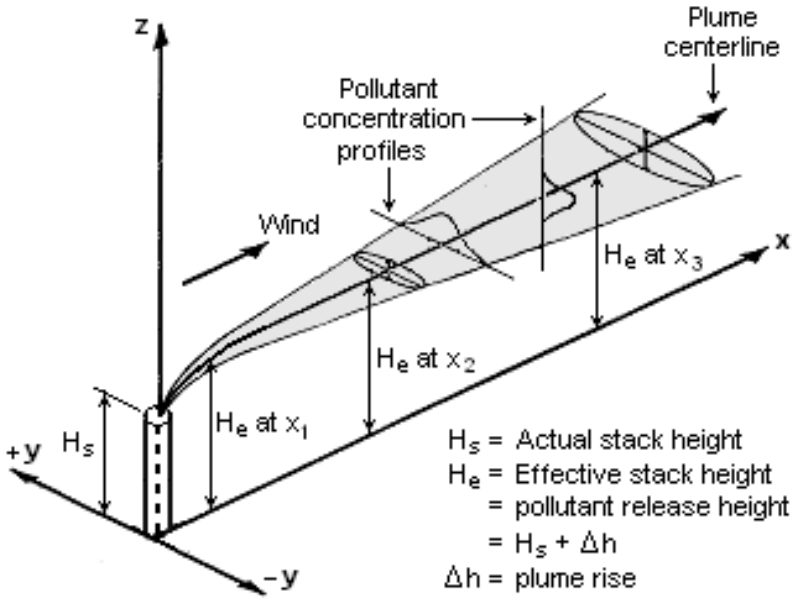
Figure courtesy of Jim Meagher

Adapted from **Introduction to Boundary Layer Meteorology** -R.B. Stull, 1988

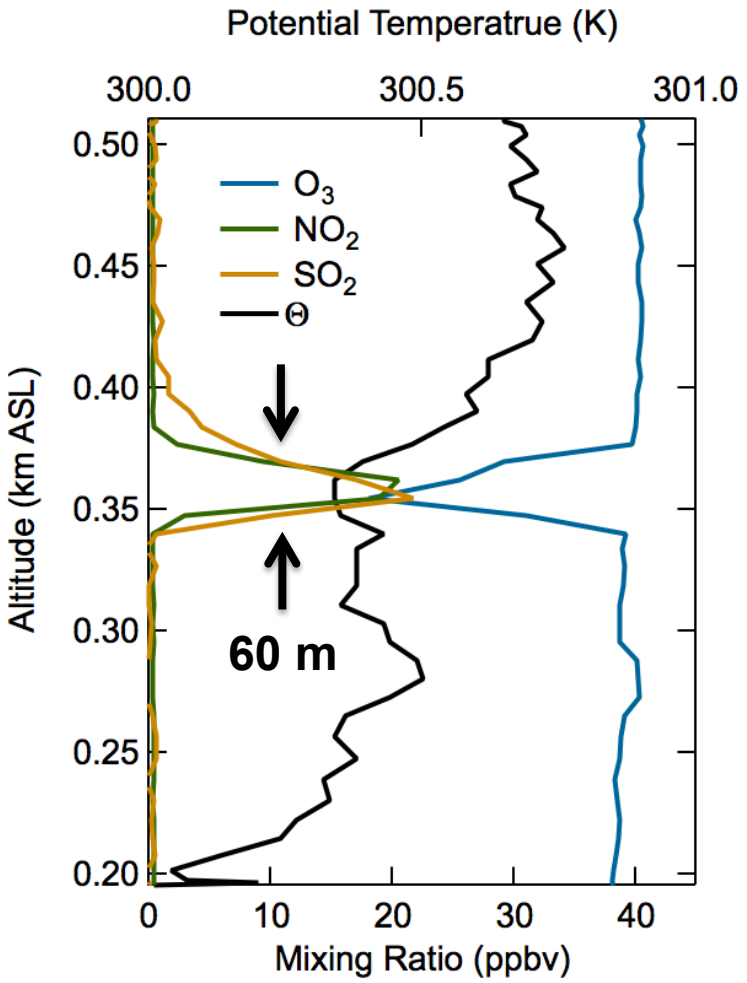
- Coal-fired power plants are commonly used as base-load power – they have roughly constant output (and emissions) day to night
- Daytime emission into well mixed, convective boundary layer
- Nighttime emission into residual layer – not mixed to surface level

Nighttime power plant plumes can only be sampled with aircraft, tower or balloon

Plume Dispersion in Stable Boundary Layers "Fanning Plumes"



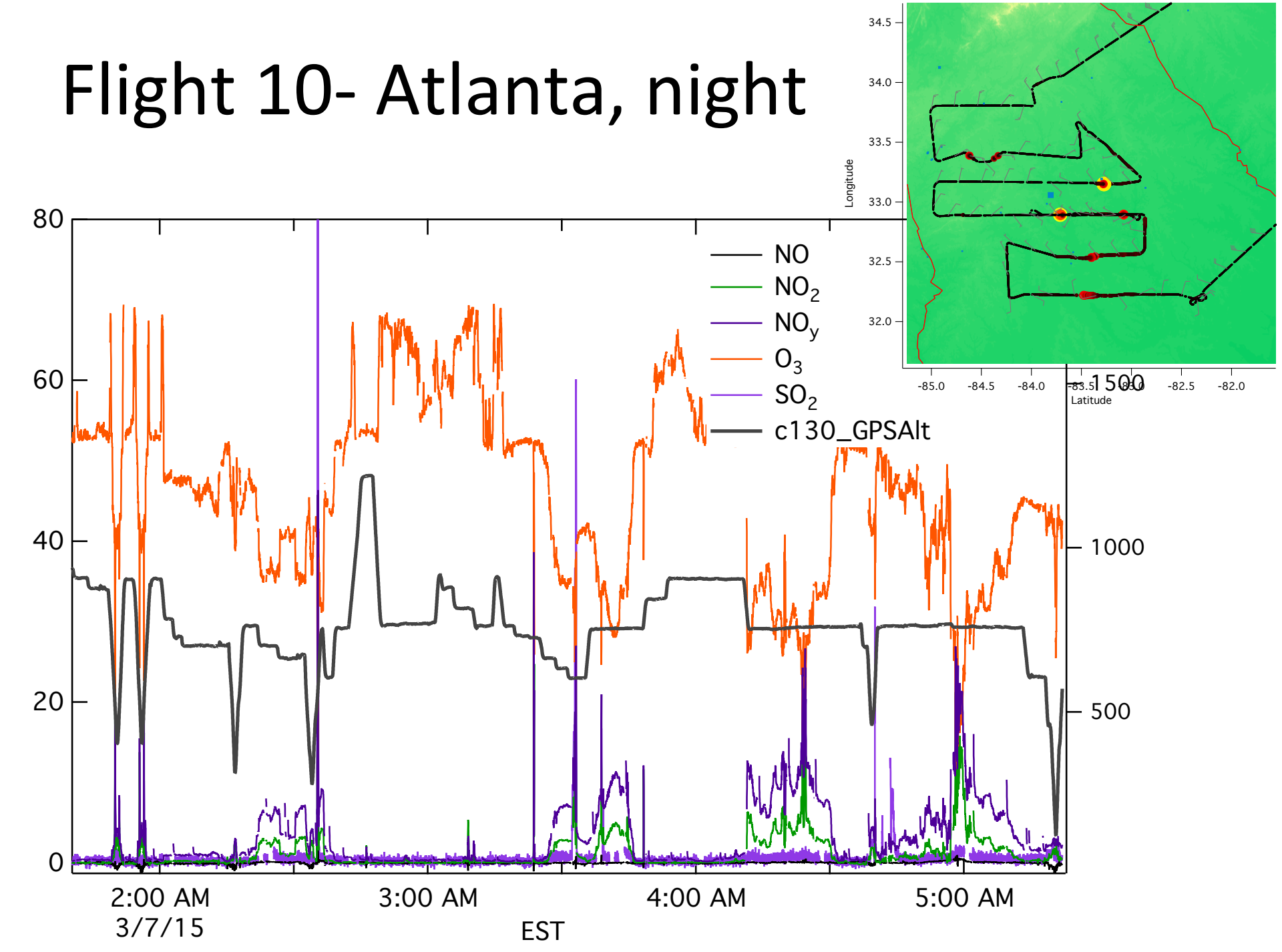
Source: Jeff Lew, UCLA



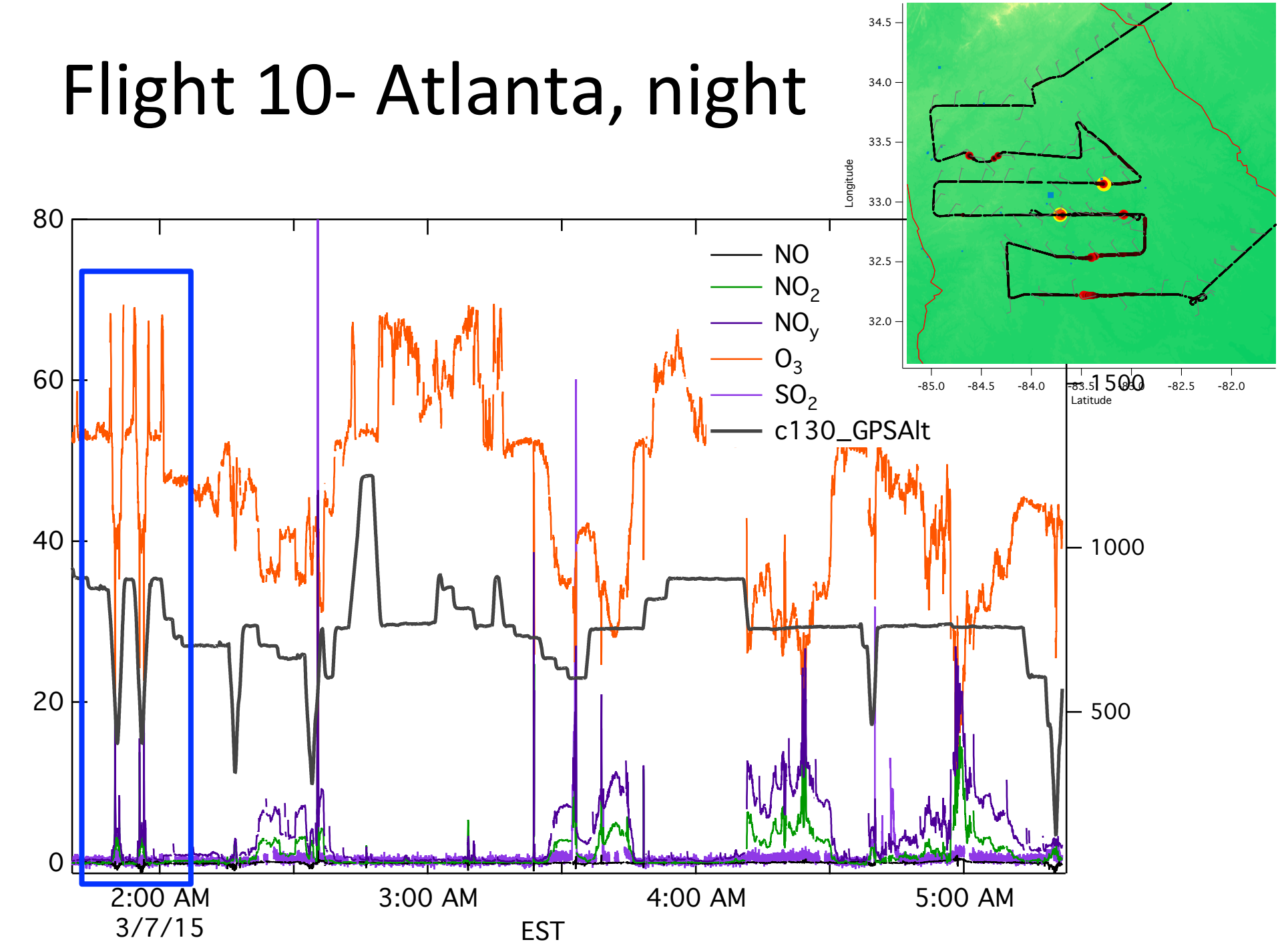
Vertical profile intercept of plume from Green County Power Plant, AL (SENEX)

- Prior NOAA aircraft observations (2004 Northeast, 2006 Texas) consistent with this picture of plume mixing
- Plume chemistry (e.g., N_2O_5 uptake) varied *widely*
- Recent power plant NO_x controls important

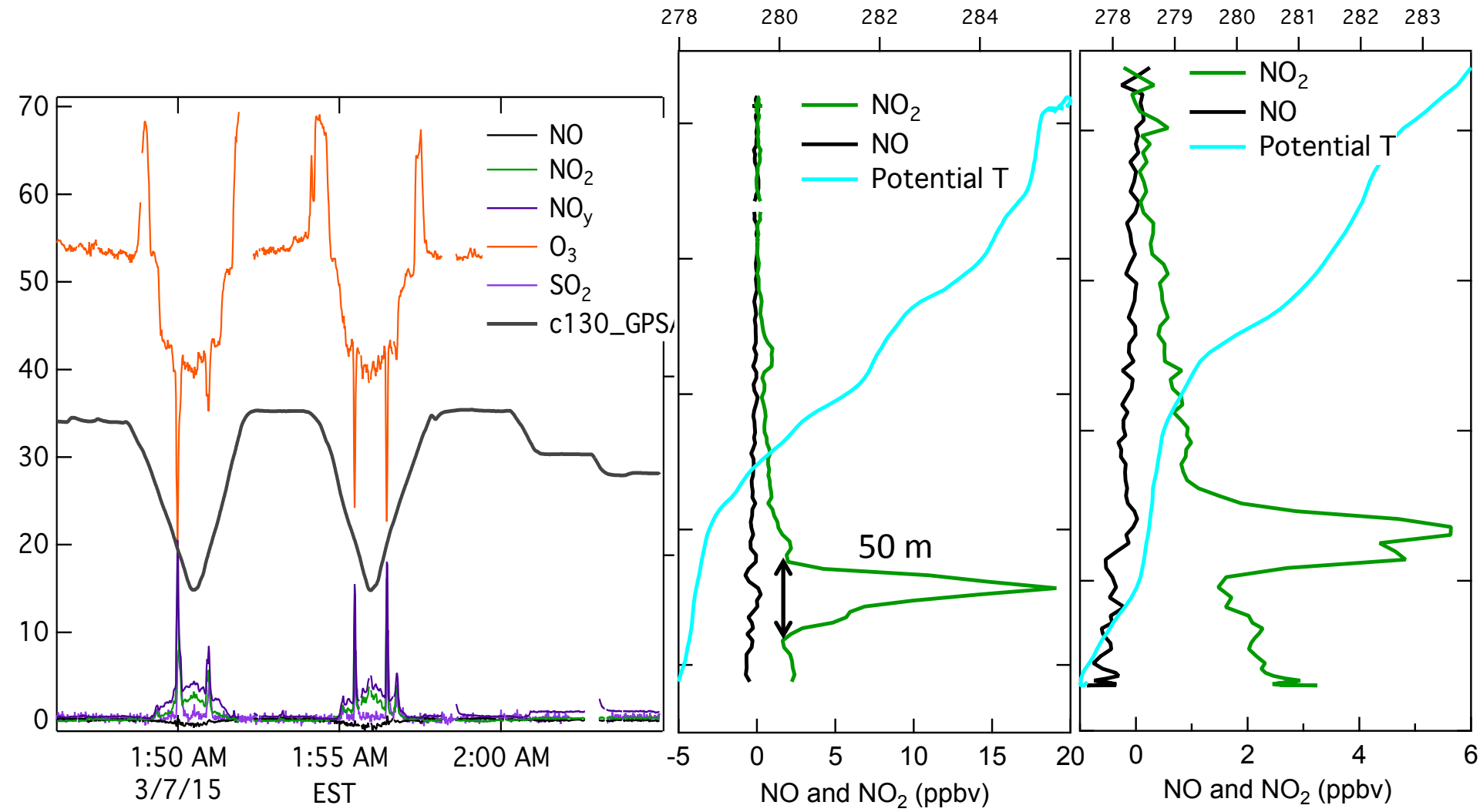
Flight 10- Atlanta, night



Flight 10- Atlanta, night

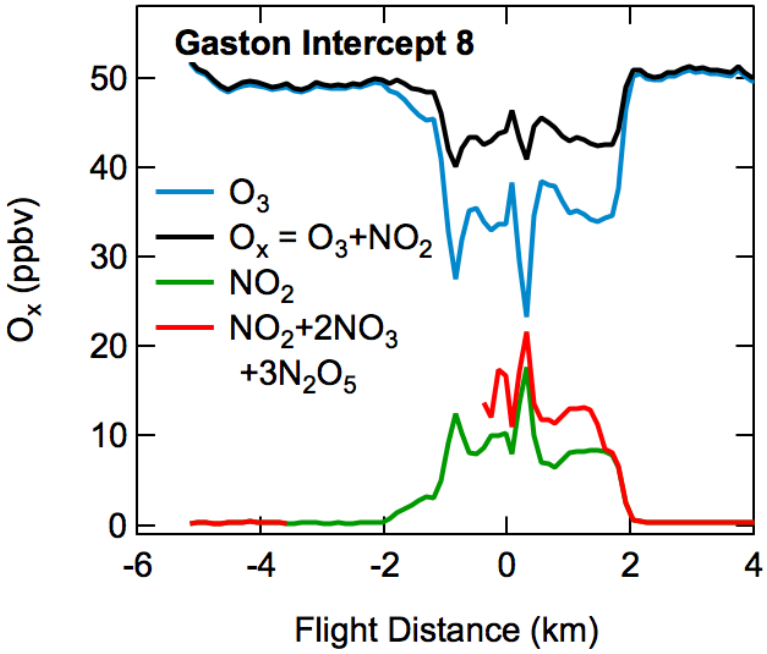


Vertical profiles of plume



Gaston Plume
"Far" Field Intercept

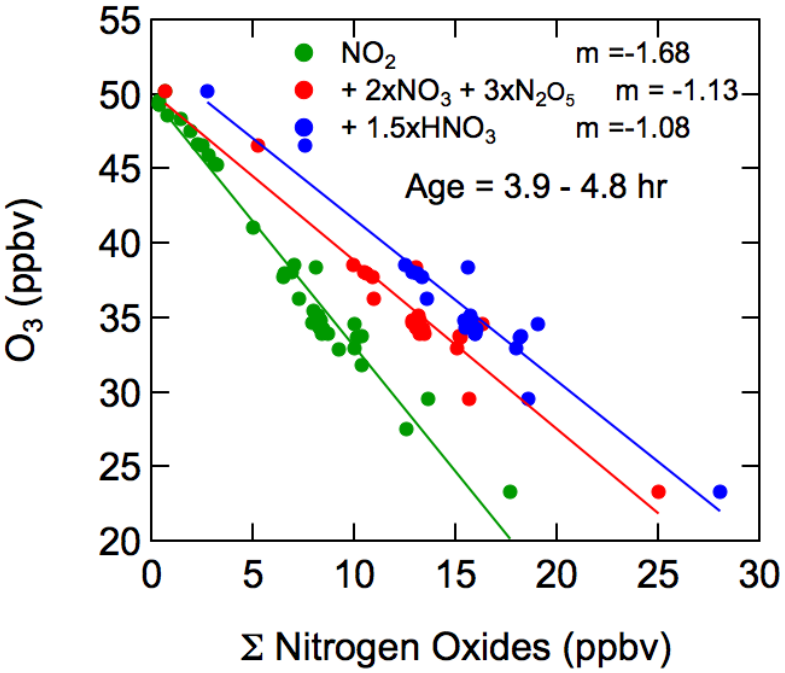
- Plume width @ 55 km downwind from stack similar to near field
- Narrow Features retained even well downwind



- *IF* near field O_x budget is closed, plume can be aged from slope of NO_2 vs O_3 plot

$$t_{plume} \approx \frac{\ln[1 - S(m+1)]}{Sk\overline{O_3}}$$

$\overline{O_3}$ = average O_3
k = rate coefficient for $NO_2 + O_3$
m = slope of O_3 vs NO_2 plot
S = stoichiometric factor
= 1 for NO_3 loss, 2 for N_2O_5 loss



- Aged plume has relatively large N_2O_5 component of O_x