Ozone in the Tropical Tropopause Layer (TTL) over the Western Pacific

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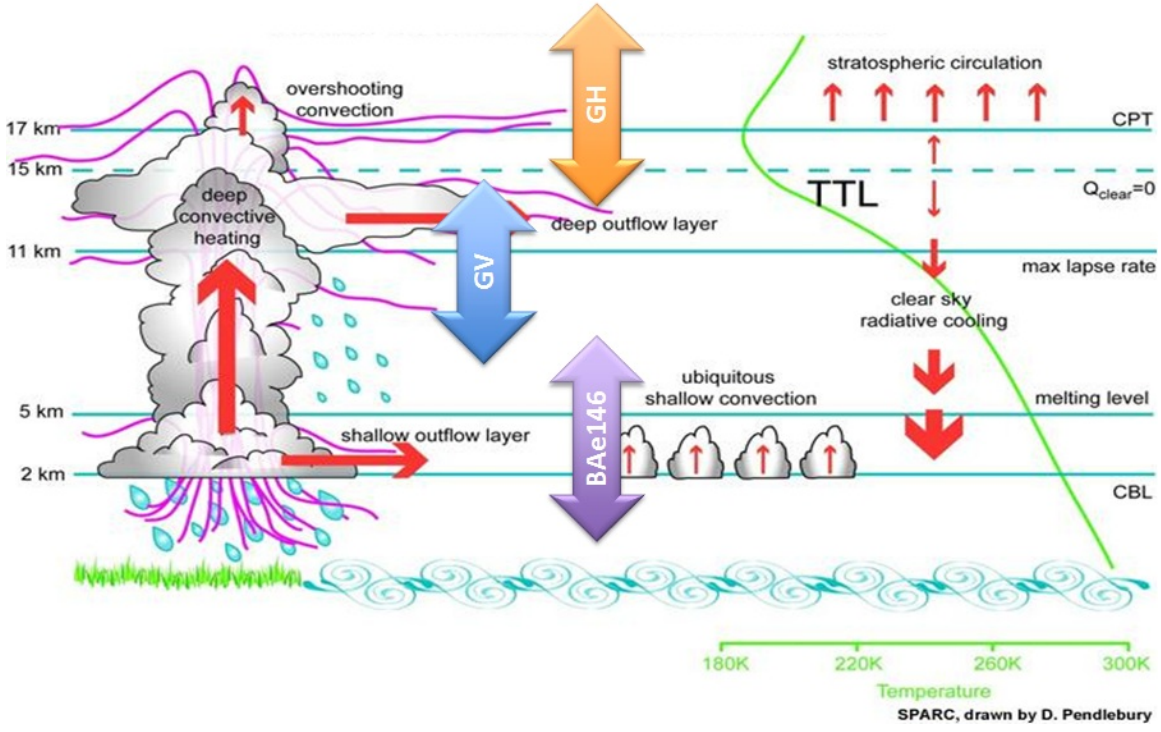
ATTREX – Airborne Tropical TRopopause EXperiment, 2011-2014



- Western tropical Pacific is a major entry point of air into stratosphere
- ATTREX-3 based in Guam (14°N, 145°E); 3 aircraft + balloon launches, Jan-March 2014

- Global Hawk flights 13-19 km (entire TTL)
- GV (CONTRAST) and BAe-146 (CAST) at lower altitudes; coverage from surface to 19 km

Background

- Low ozone has been previously observed over the tropical Pacific Ocean (Kley et al., 1996; reanalysis by Vömel and Diaz, 2010; Takashima et al., 2007, 2008 – sonde profiles).
- This has been hypothesized to lead to an “OH hole”, which could more easily allow short-lived ozone depleting substances to reach the stratosphere (Rex et al., 2014; Gao et al., 2014).

ATTREX Global Hawk Payload

Ozone from NOAA/CSD photometer (ATTREX-1 and 2 only) and UCATS 2B photometers (±5 ppb uncertainty in TTL).

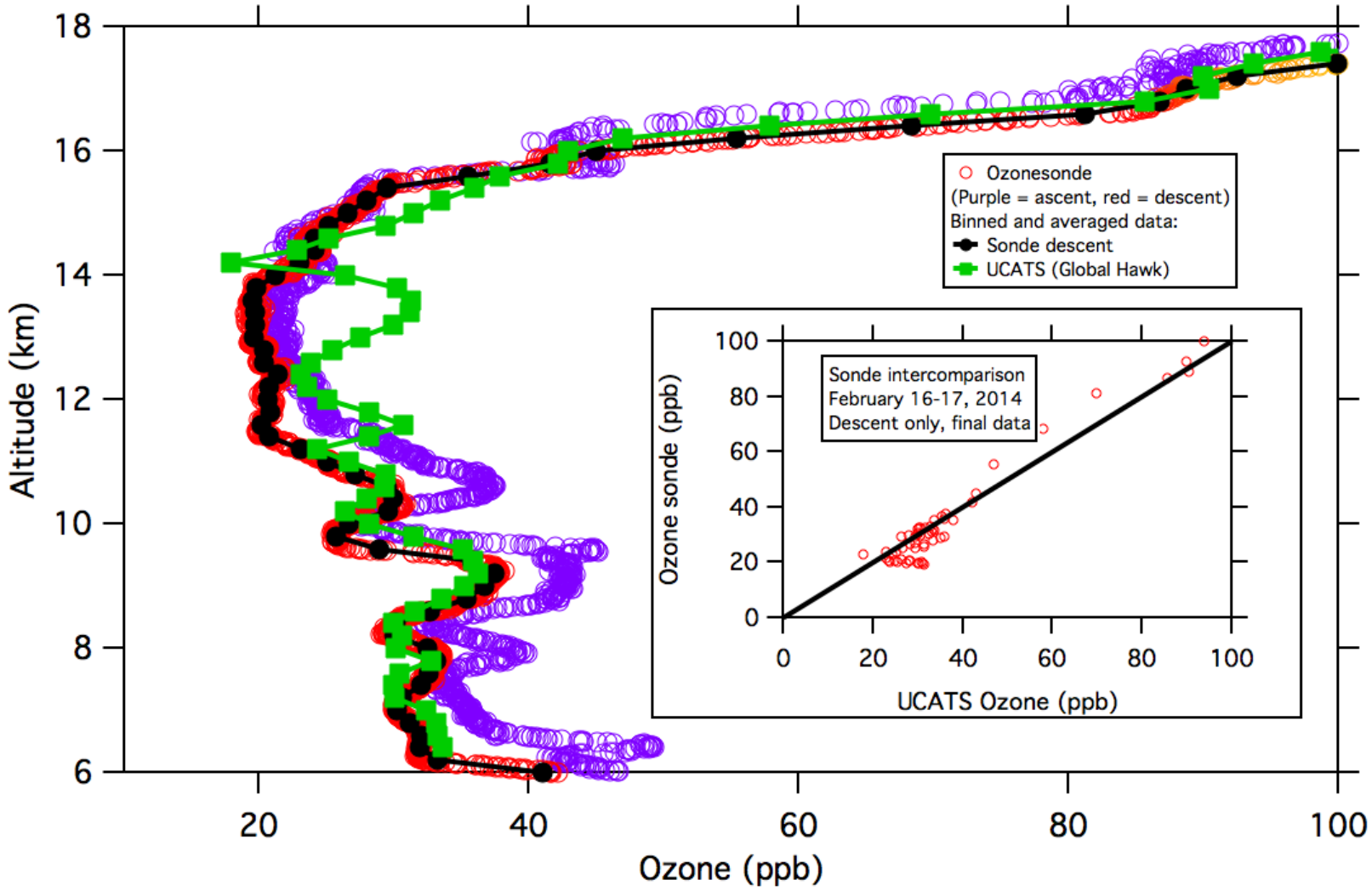
Tracers from UCATS (N_2O, SF_6, CH_4, CO), Harvard University Picarro (CH_4, CO, CO_2), University of Miami Whole Air Sampler (Organic bromine).

Meteorological data from MMS.

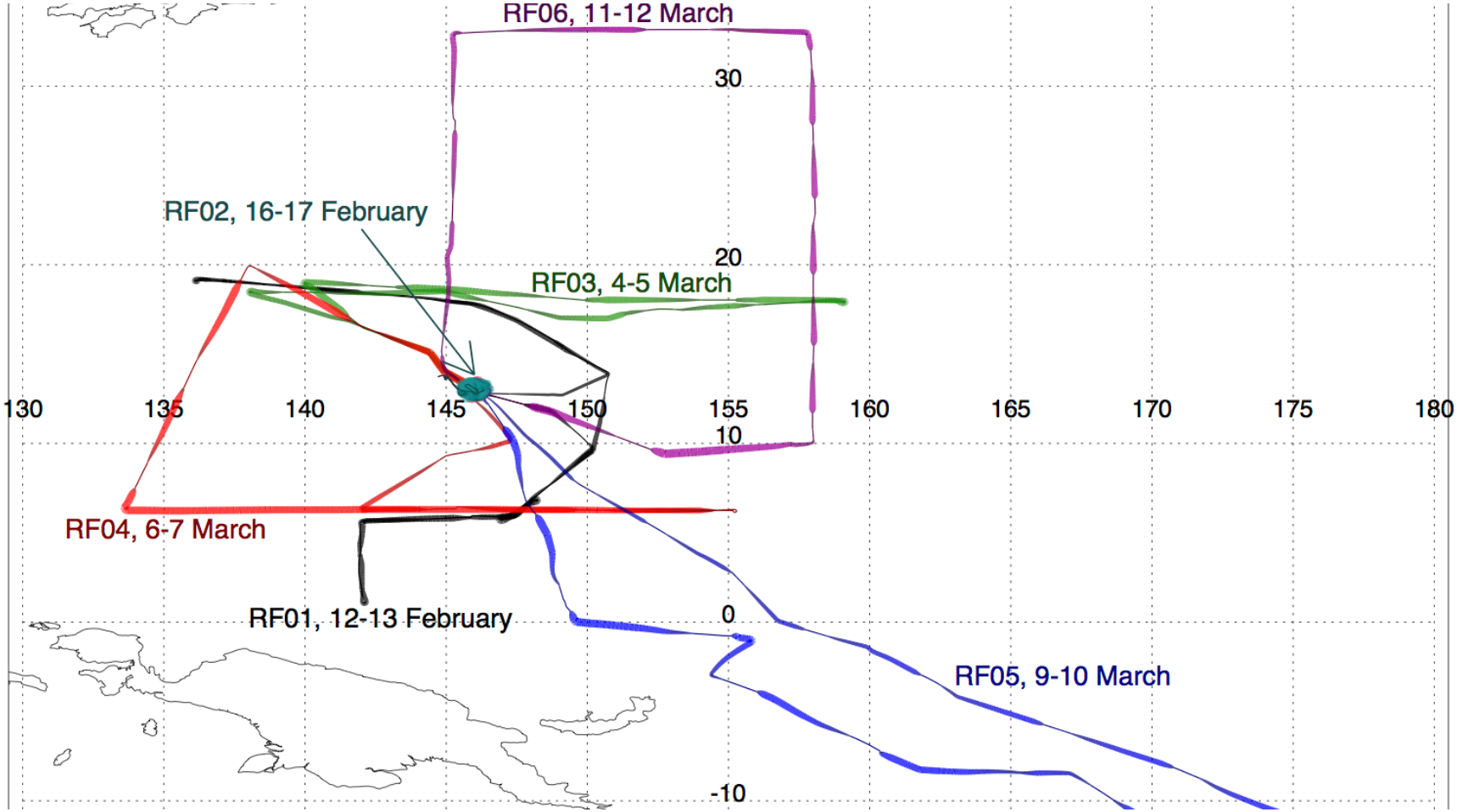
Ozone, CO and Whole Air Sampler on GV.

Back trajectory and convection calculations.

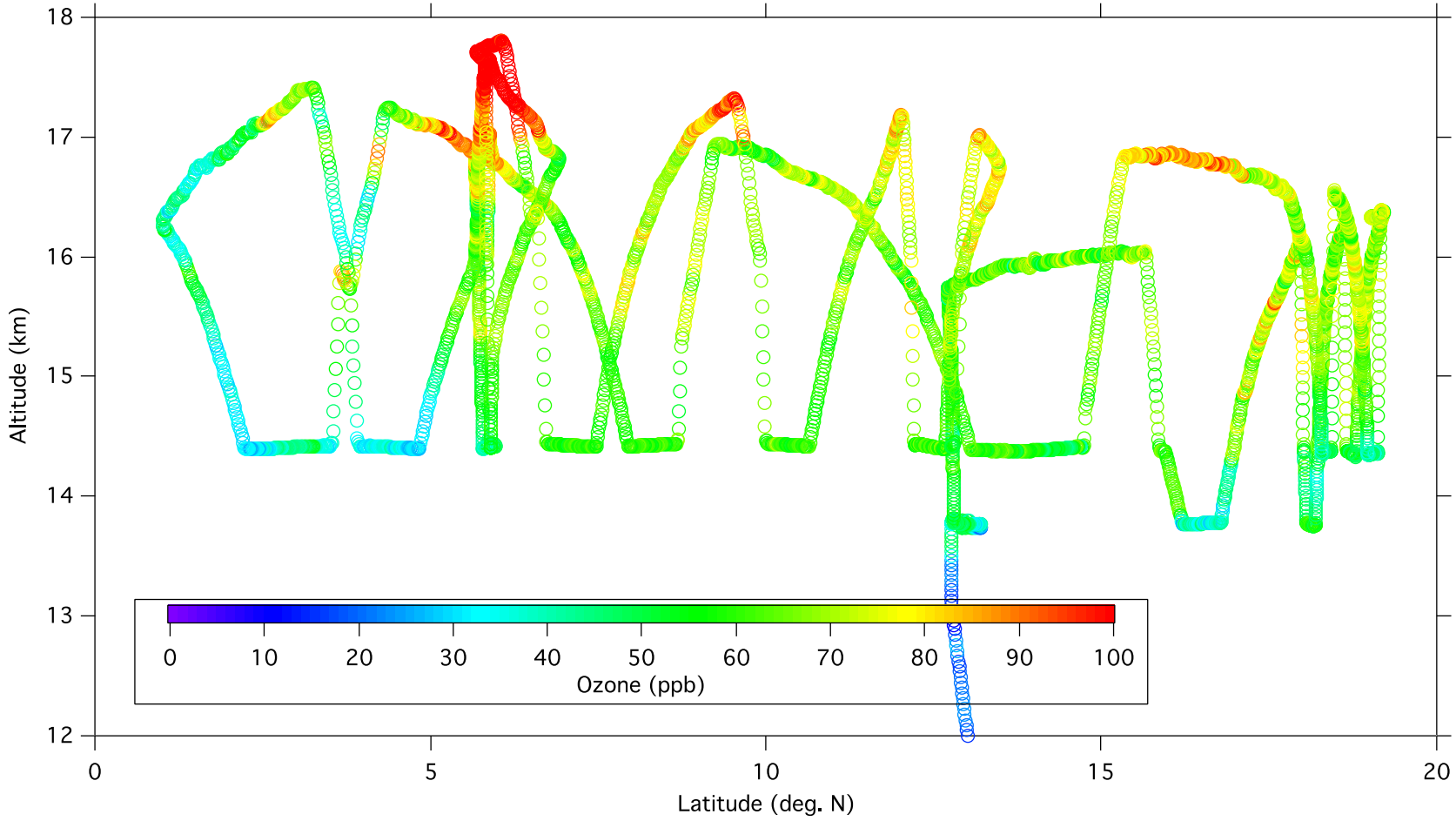
ATTREX-3, February 17, 2014 sonde launch at Guam
Global Hawk landing closest in time to sonde descent



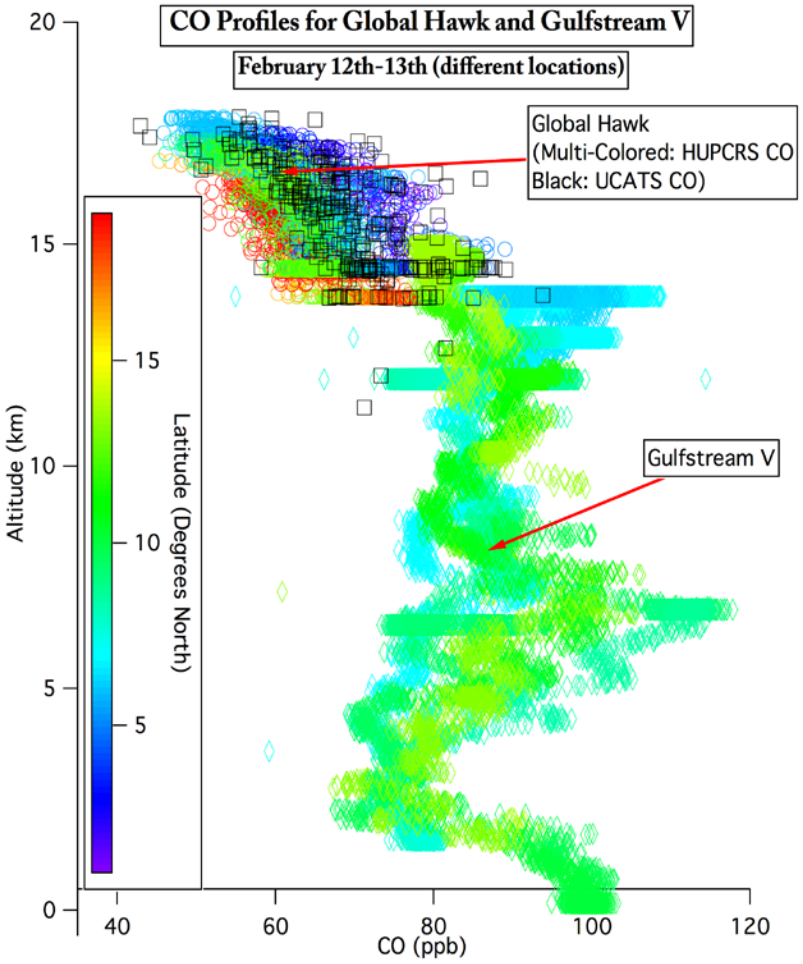
ATTREX-3 Flight Tracks, 2014

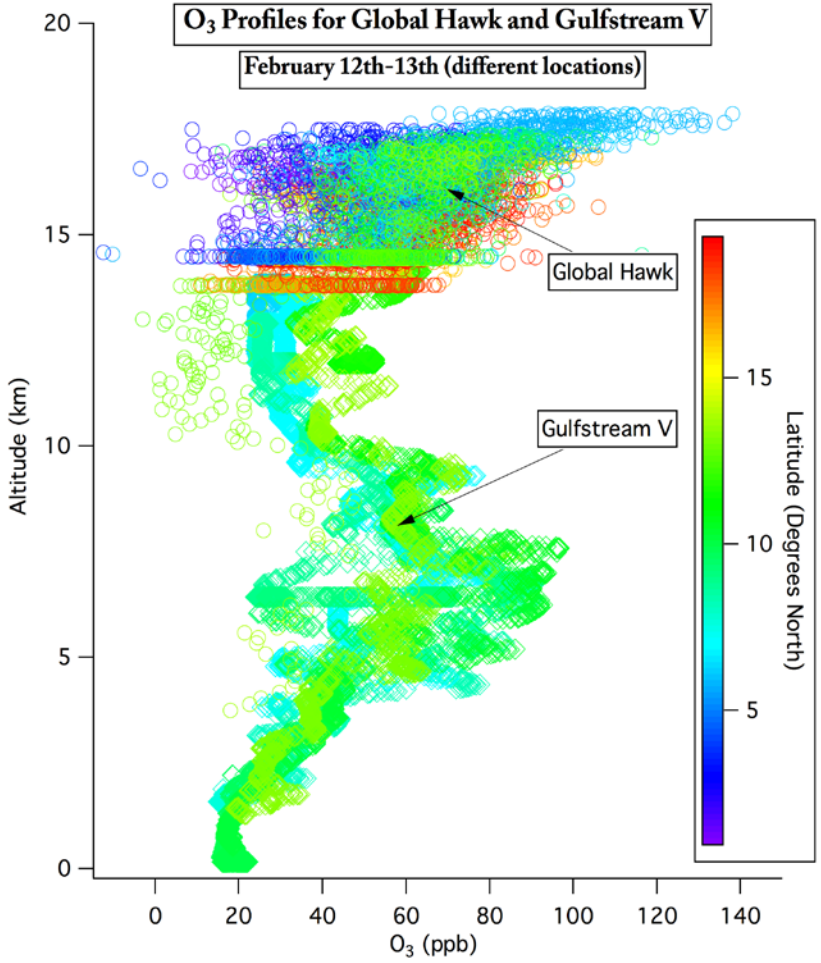


ATTREX-3 Ozone, February 12, 2014

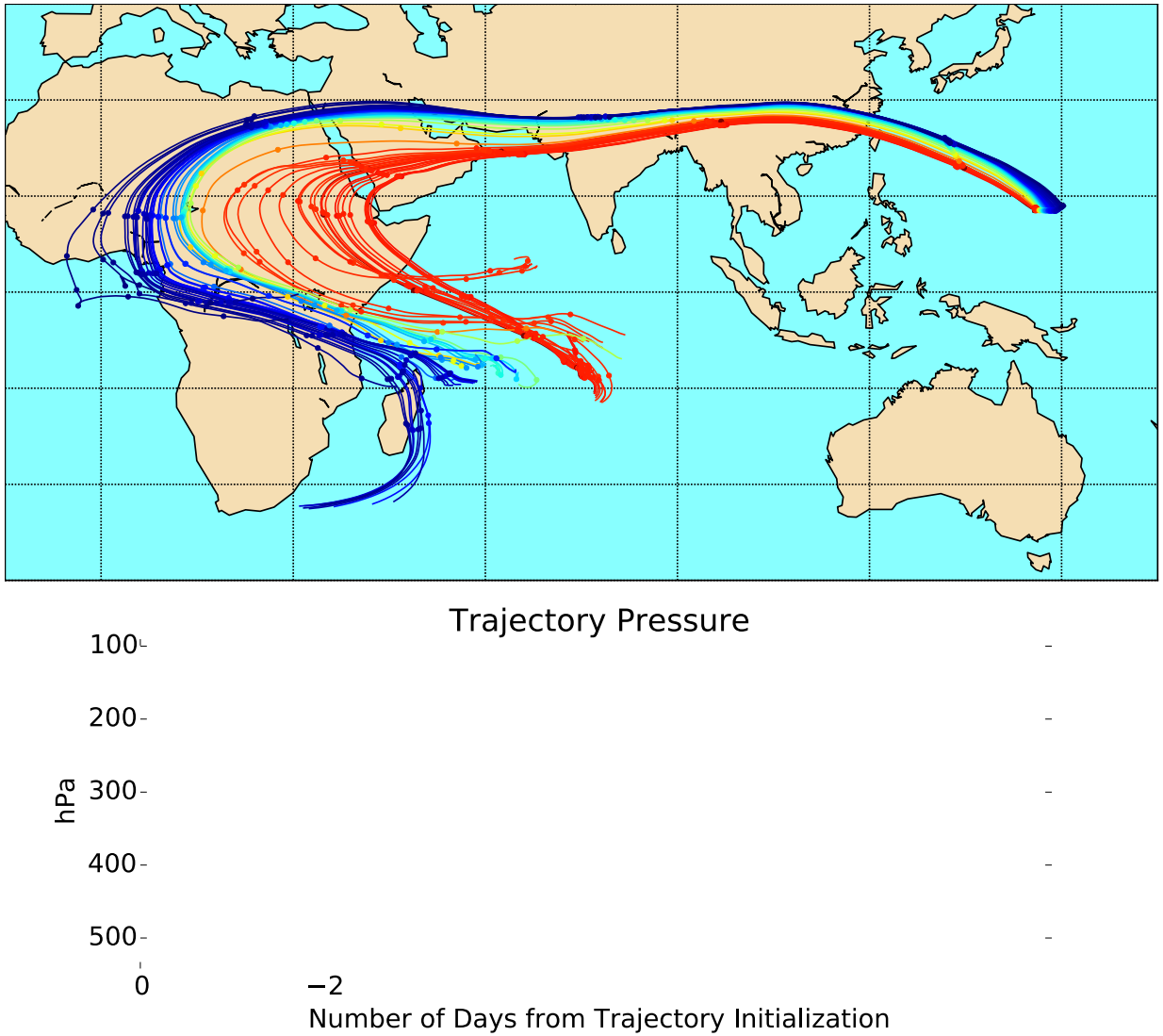


Combined ATTREX and CONTRAST data





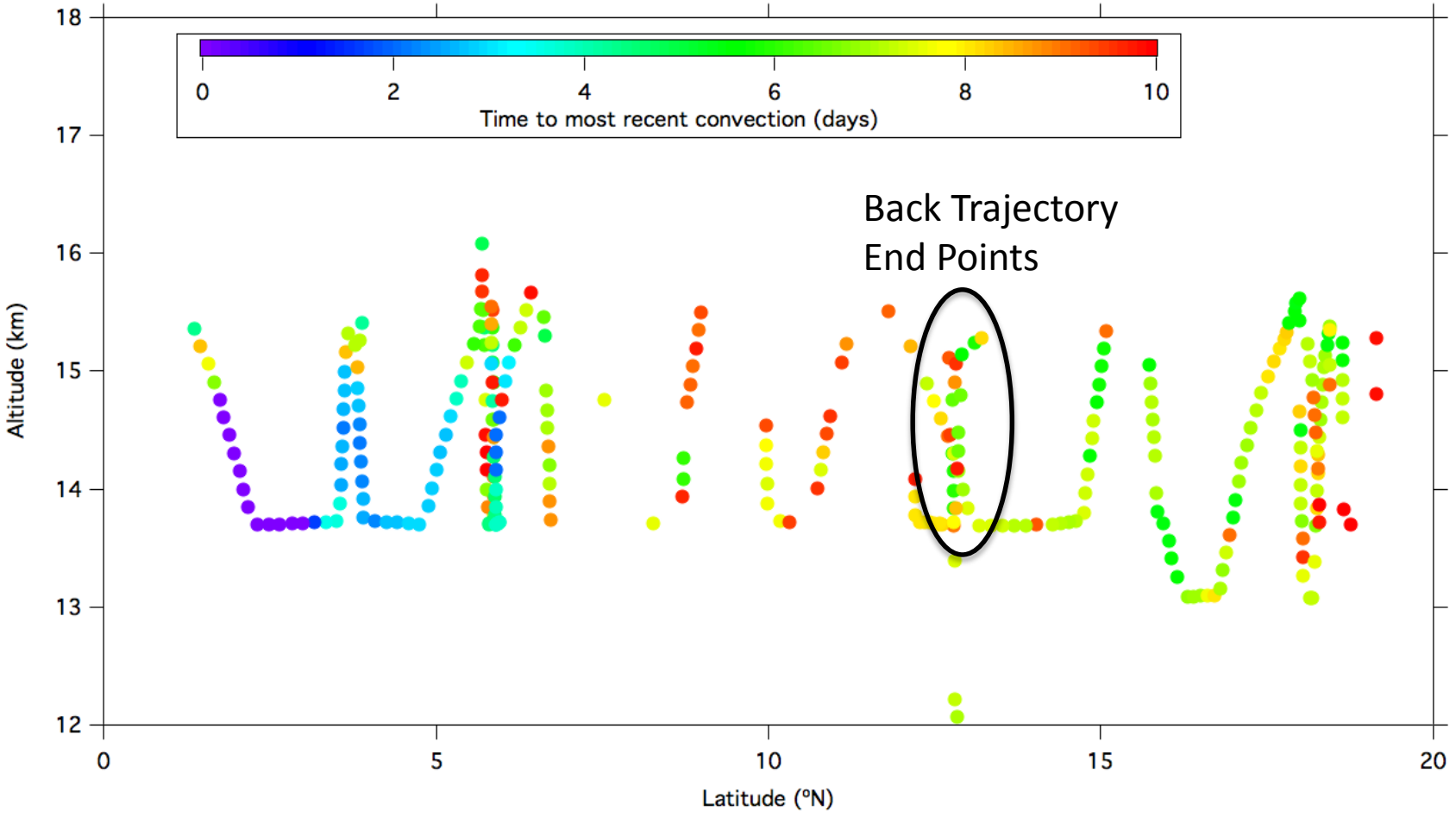
Back Trajectories – ERA Interim met fields
Trajectory end points at 13°N, 148°E, 13.7-16 km



Time since convection, Feb. 12, 2014 (L. Pfister)

Most convection 5-10 days previous

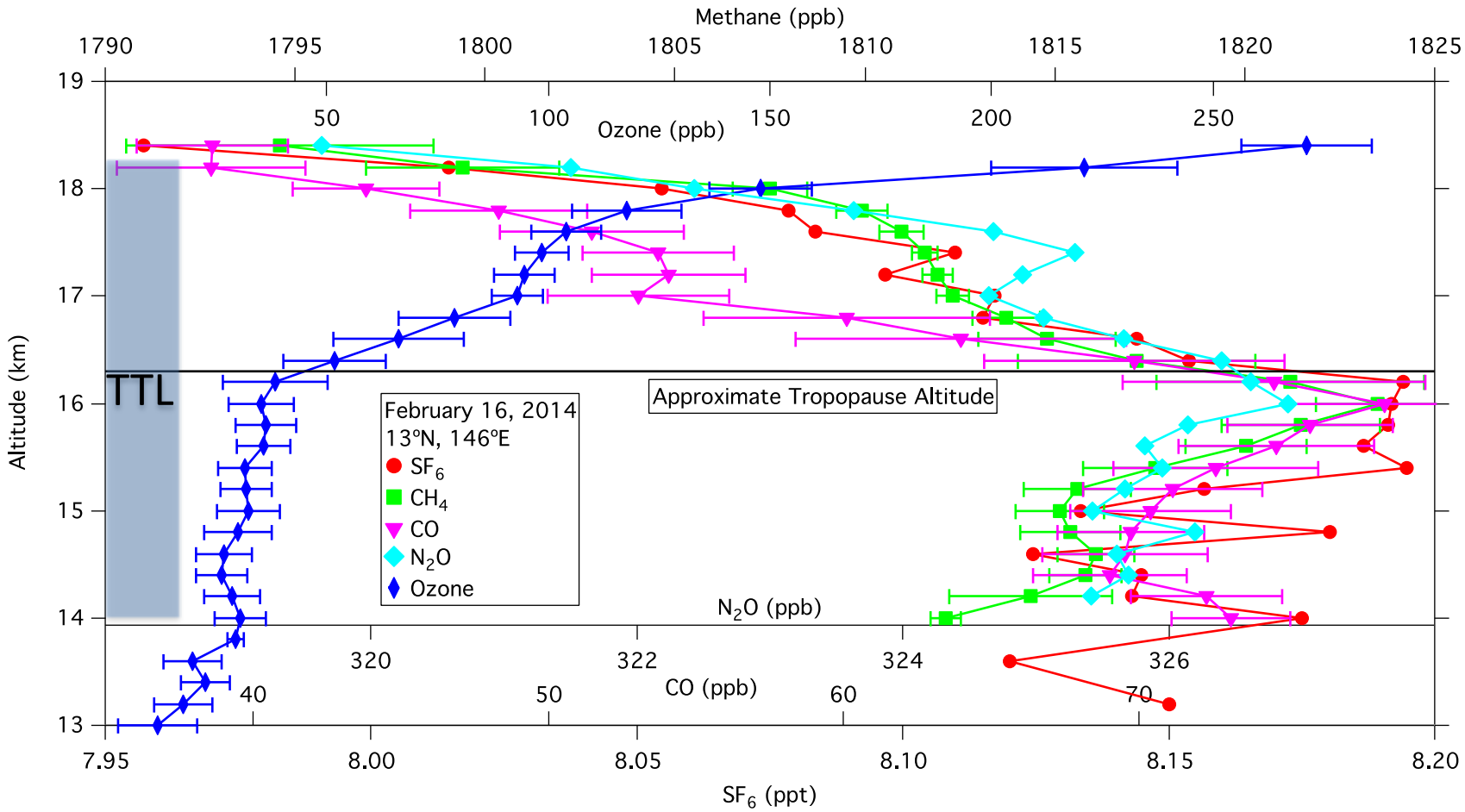
Convection at locations far to west of Guam



Local Guam flight, February 16, 2014

Long-lived tracers peak just below tropopause

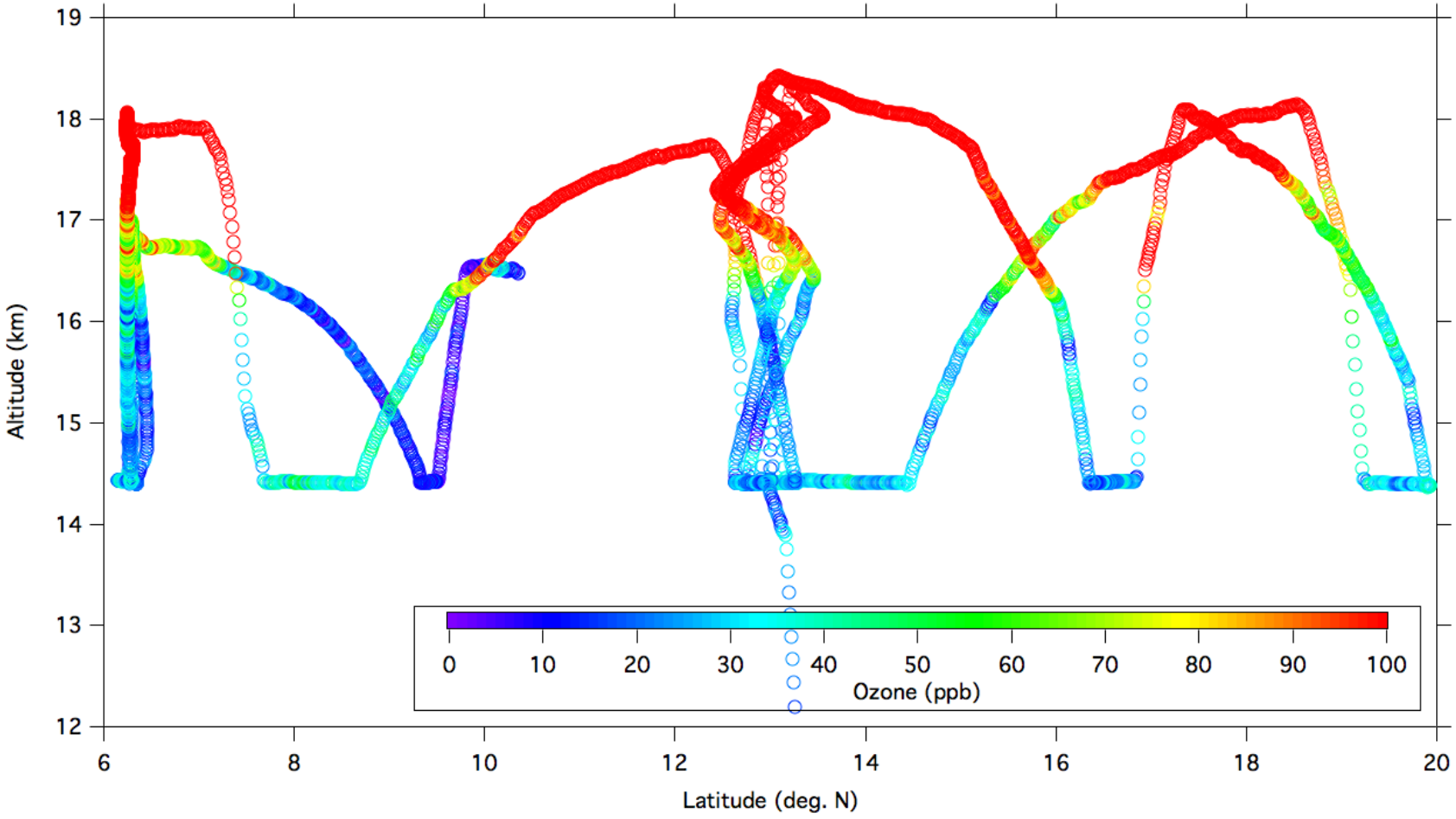
Ozone and tracers nearly constant at 17-18 km



ATTREX-3 Ozone, March 6, 2014

Much lower ozone; often 10-20 ppb in lower TTL

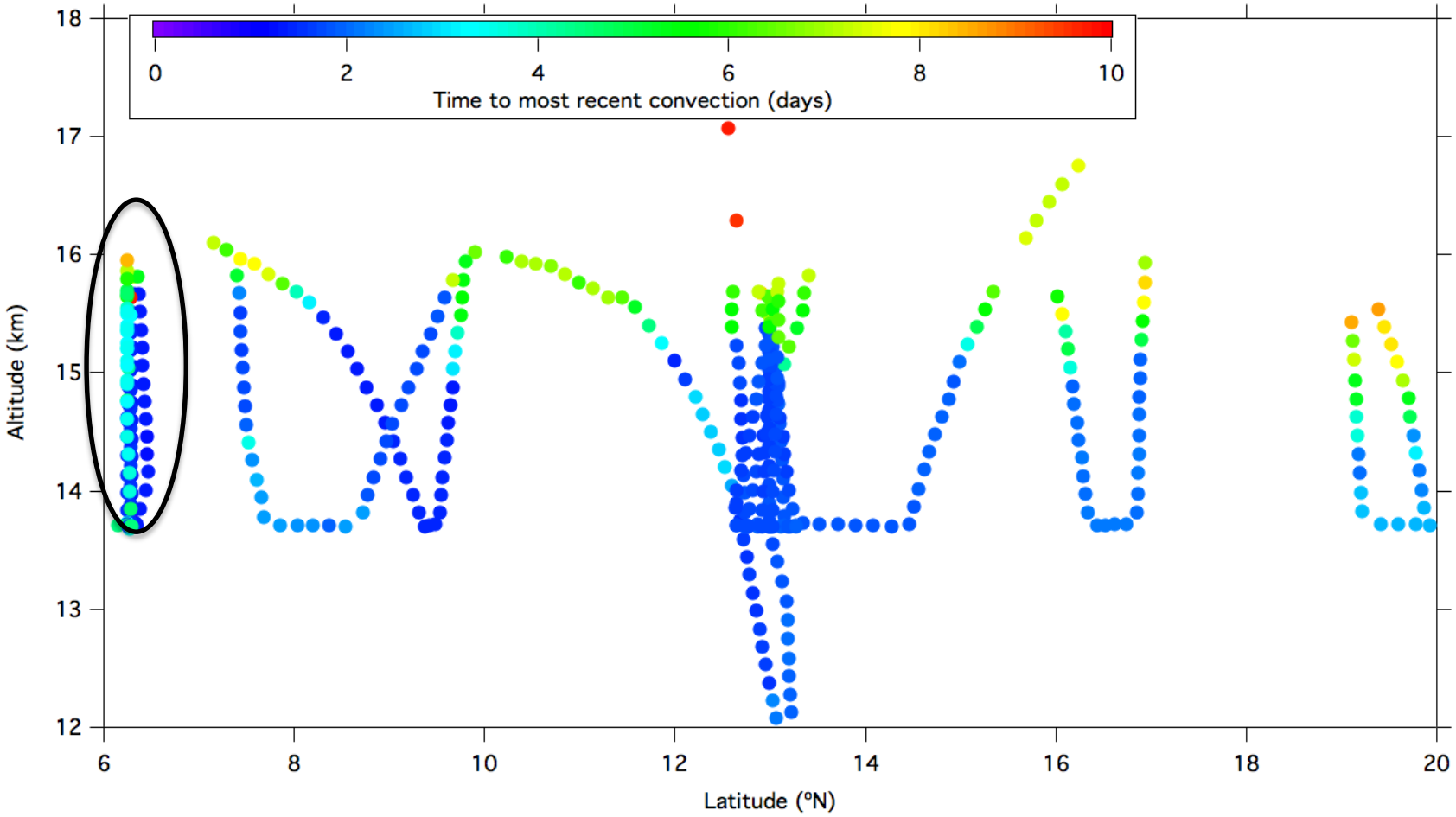
Ozone increases sharply at tropopause



Time since convection, March 6, 2014

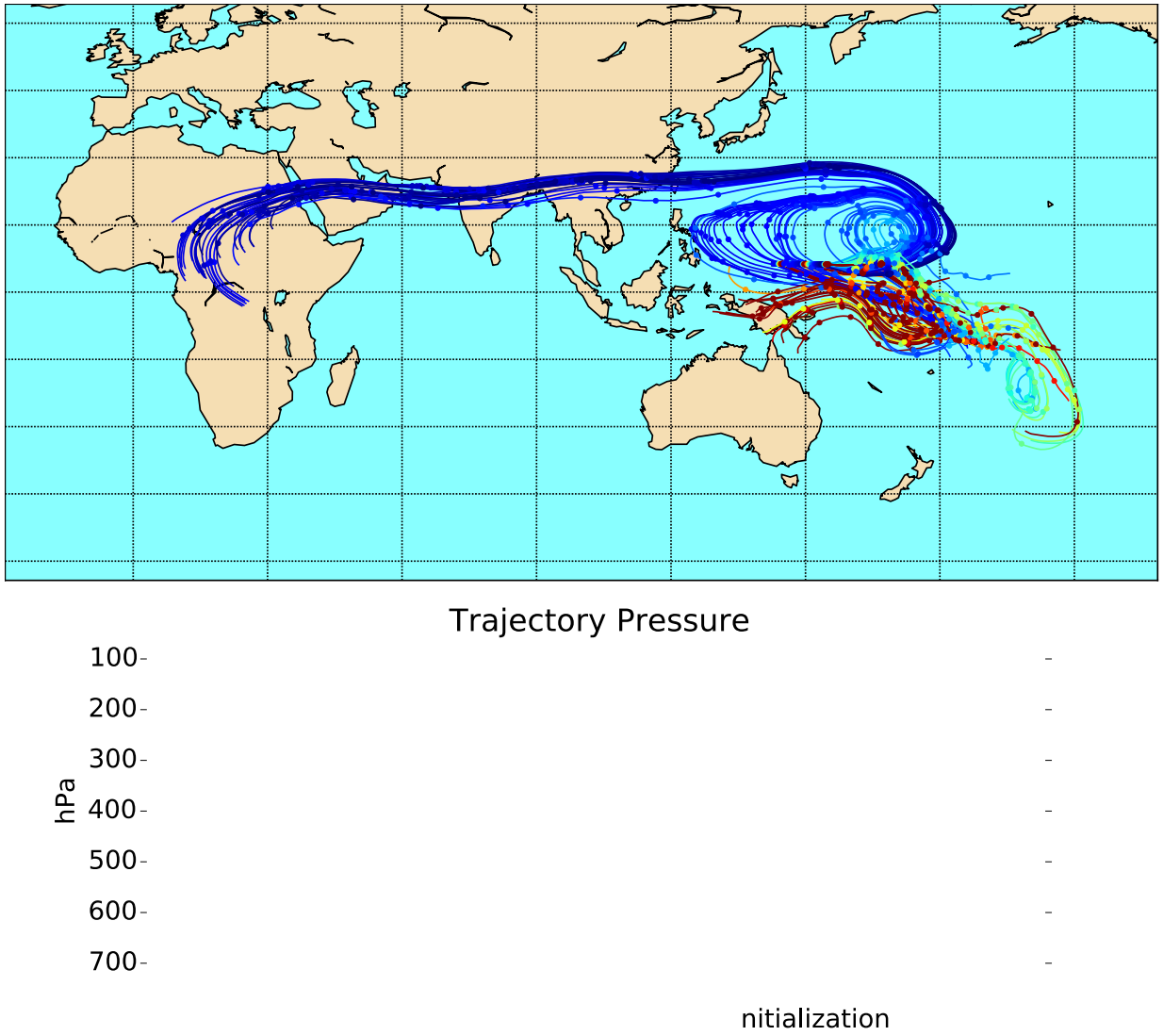
Lots of recent convection

Local convection and over central equatorial Pacific



March 6, 2014 Back Trajectories

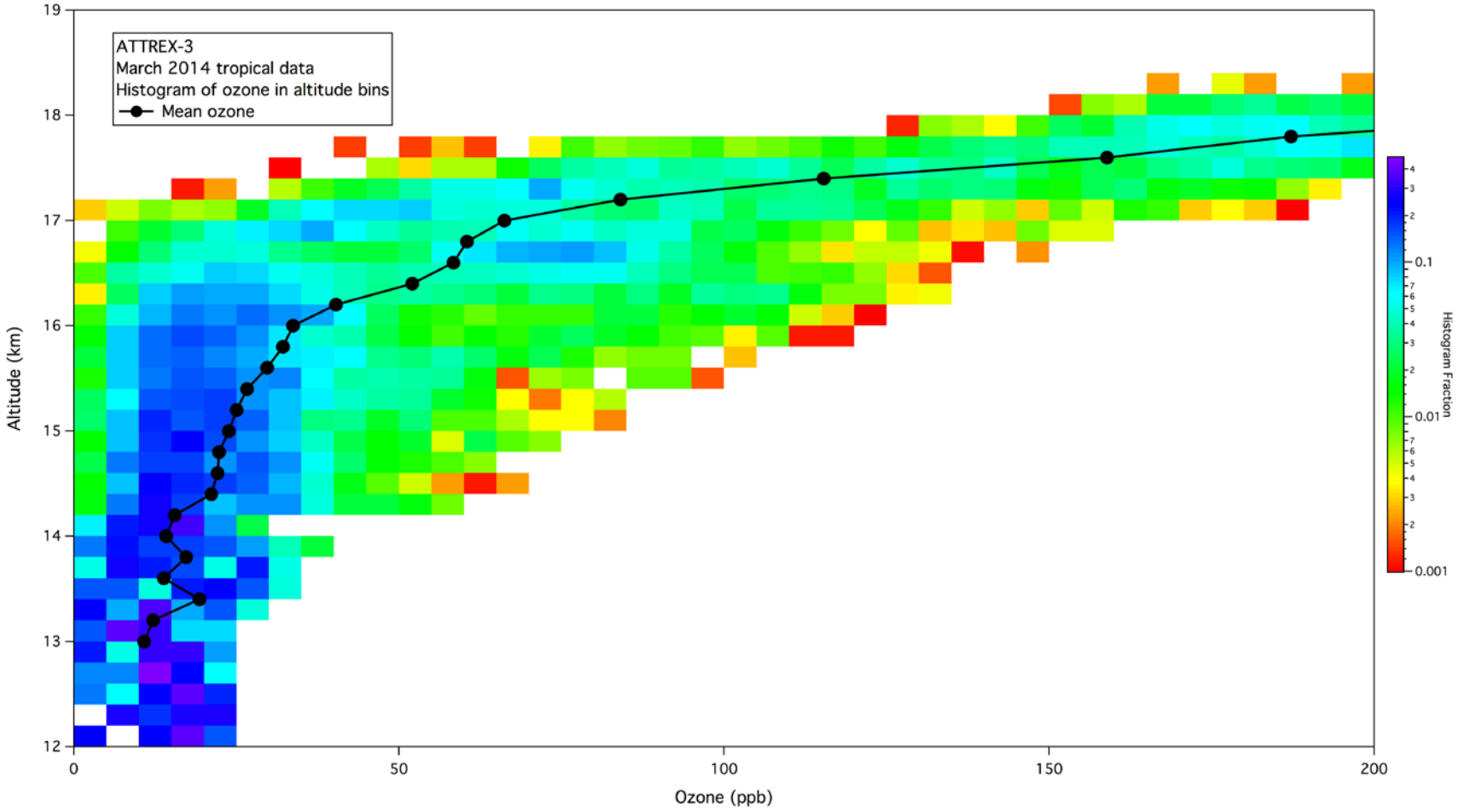
End points at 6°N, 144-155°E, 14.4-17 km



ATTREX-3 Ozone, March 2014 (five flights)

Histogram at each altitude, black line = mean

Ozone in lower TTL 10-20 ppb

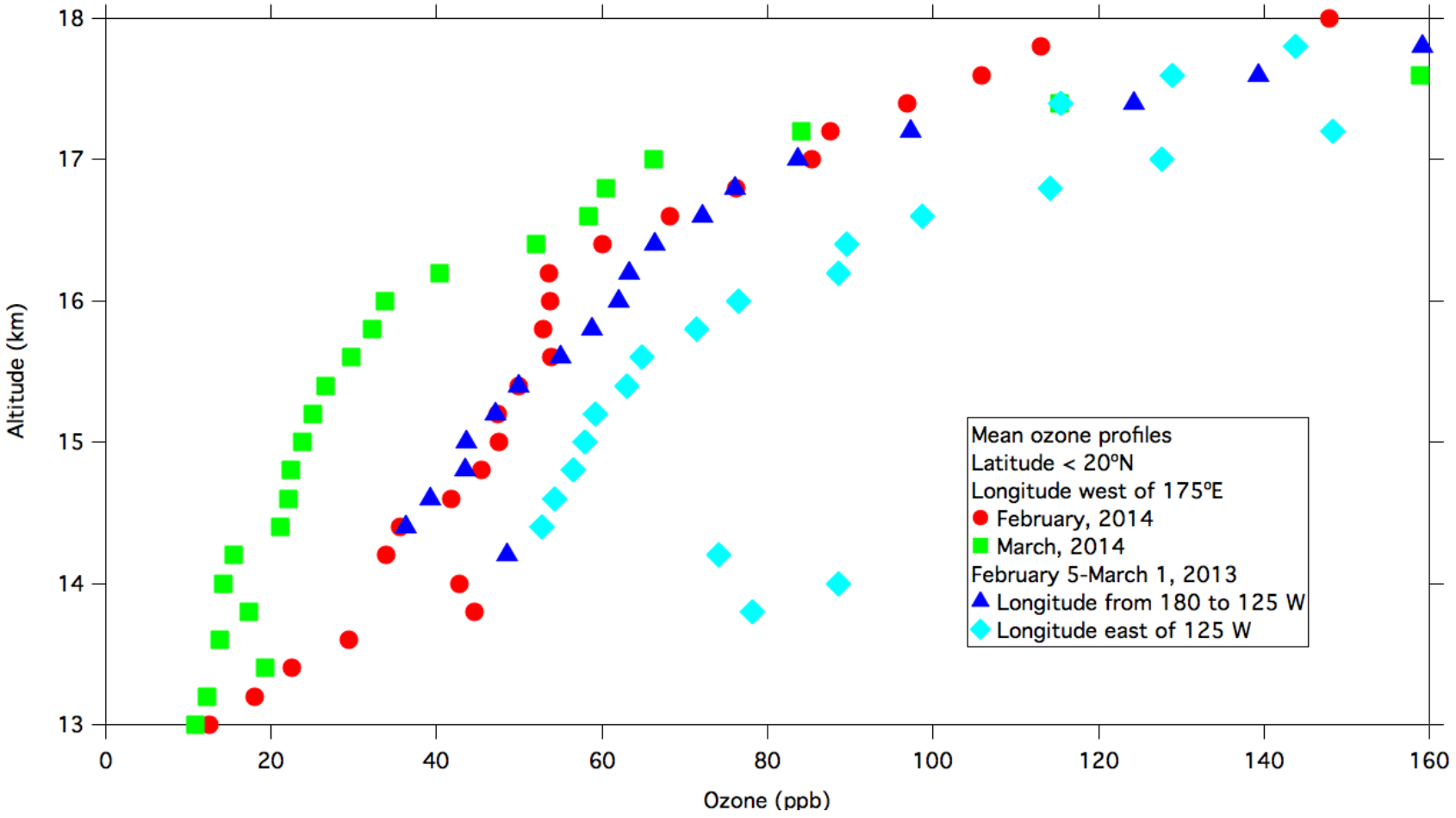


ATTREX-2 and 3 tropical ozone

Lowest ozone over western Pacific in March 2014

Higher in upper trop. in February 2014, and central Pacific

Highest ozone over eastern Pacific

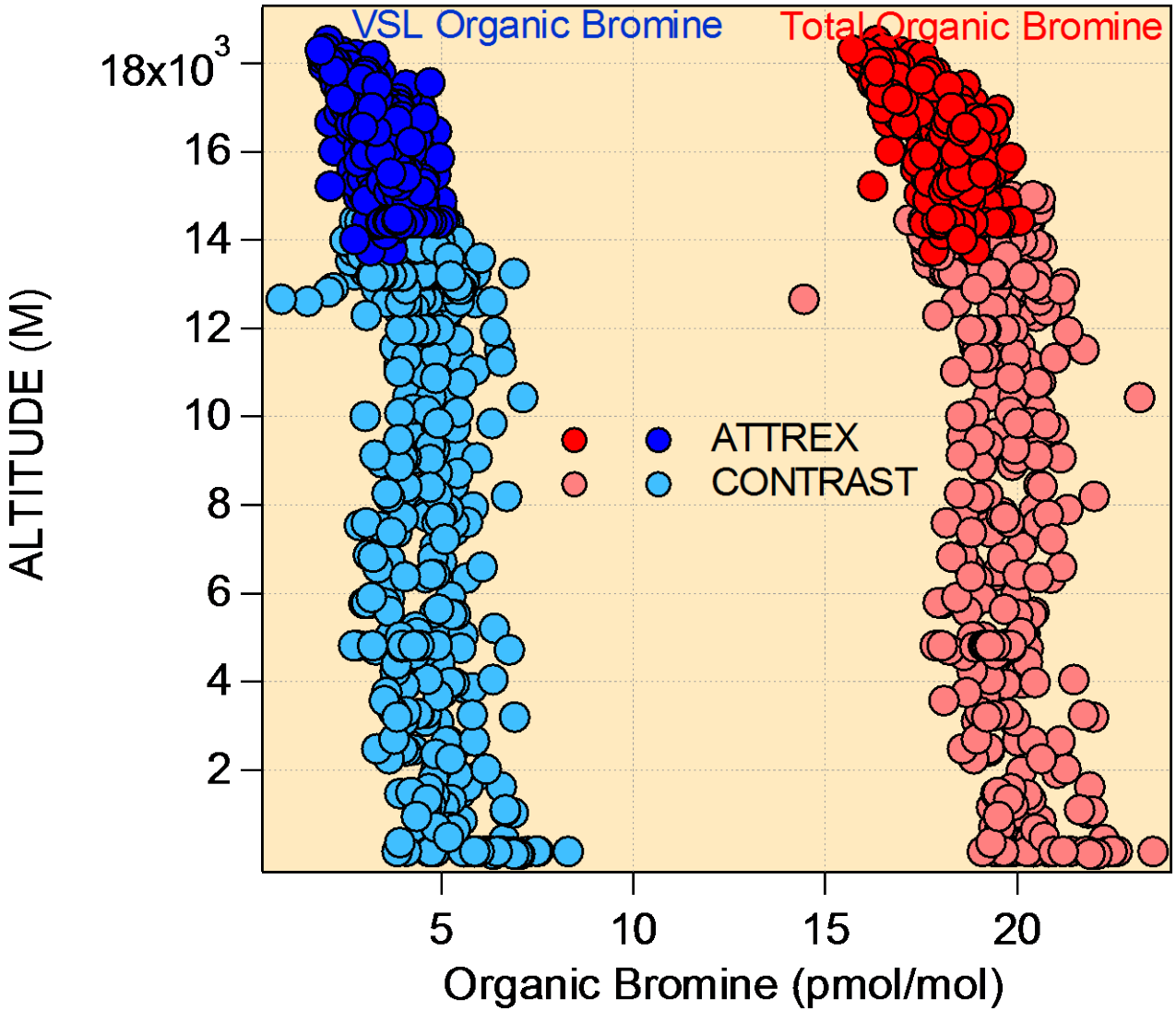


Organic Bromine – CONTRAST/ATTREX

Plot and data from Elliot Atlas/WAS

Total Organic Bromine = Halons + CH_3Br + VSL Organic Br

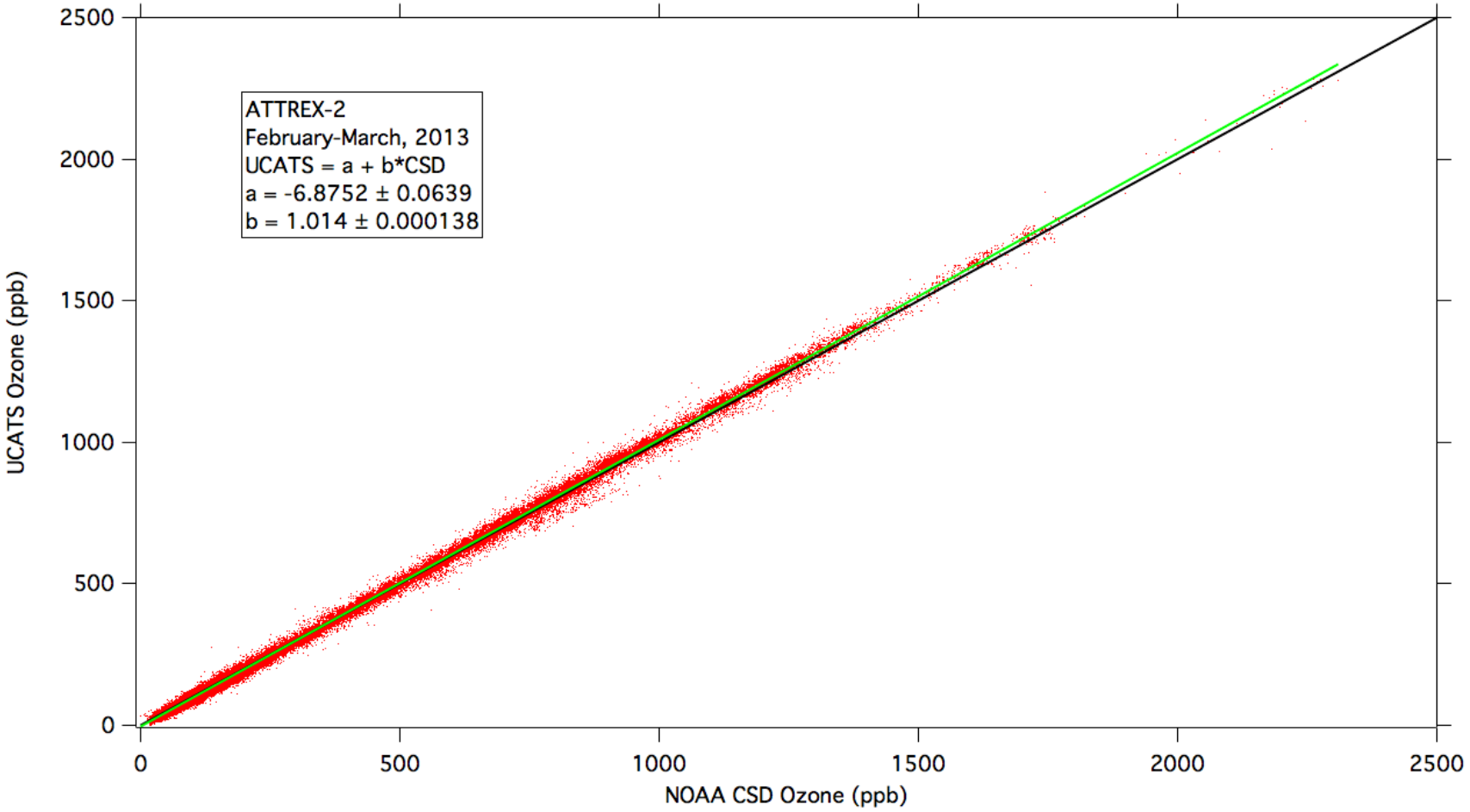
VSL = $CHBr_3$, CH_2Br_2, CH_2BrCl, $CHBr_2Cl$, $CHBrCl_2$ (τ = weeks-months)



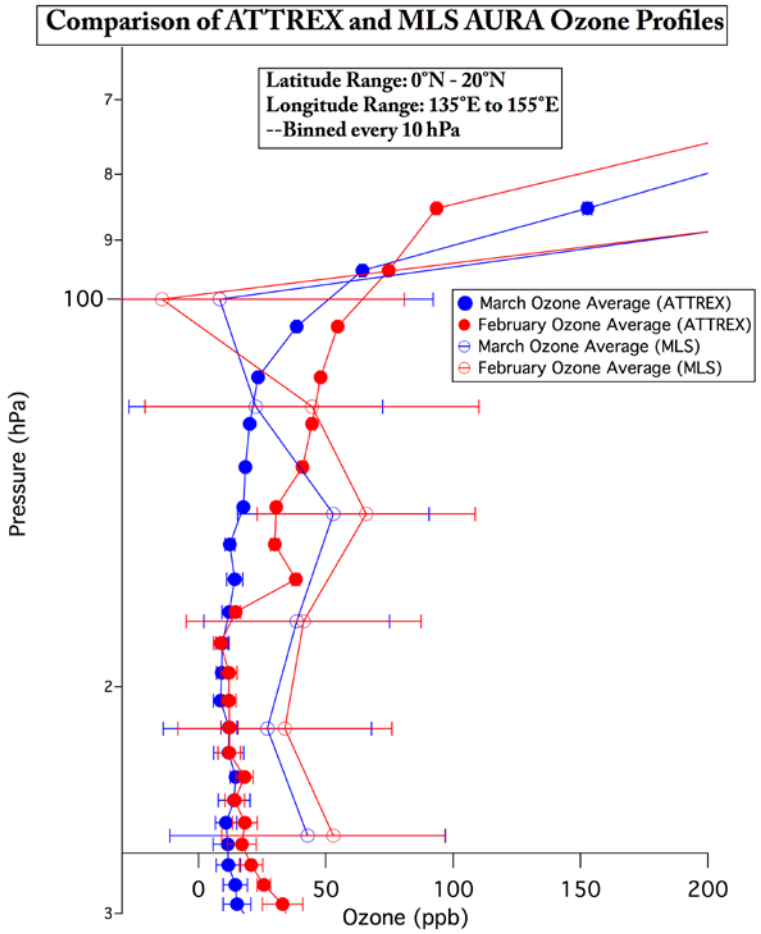
Summary

- Ozone was lower in ATTREX-3, particularly in March 2014 (~20 ppb), compared to ATTREX-1 and 2. Lower ozone over the western tropical Pacific than the eastern tropical Pacific.
- Tracers and back trajectory calculations consistent with deep convection into the TTL, bringing air with low ozone up to the tropopause.
- Organic bromine begins to decline (and ozone increases) above 16 km, which is also the approximate highest altitude influenced by recent convection.
- Understanding OH chemistry in the western tropical Pacific requires a dedicated mission.

ATTREX-2, all science flights
Merged and averaged data from both 2B instruments vs. NOAA CSD ozone

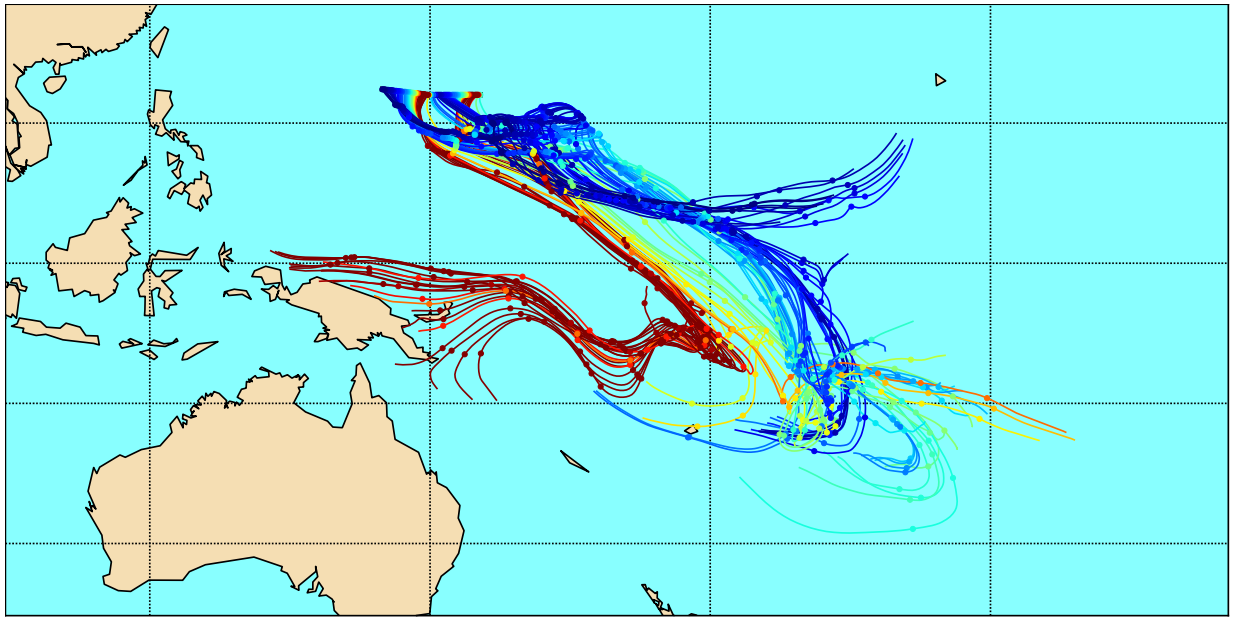


ATTREX-3 Satellite Comparison



- MLS uncertainty overlaps UCATS ozone data
  - Large error bars
  - ~3 km vert. resolution
  - UCATS lower than MLS
- March vs. February
  - Ozone lower in TTL
  - Higher in stratosphere

March 4, 2014; 18-19°N



Trajectory Pressure