Looking at the Springtime Troposphere and Lower Stratosphere over the Central North Pacific Through Many Pairs of Glasses: Combining Aircraft and Satellite Ozone and Carbon Monoxide Observations from INTEX-B

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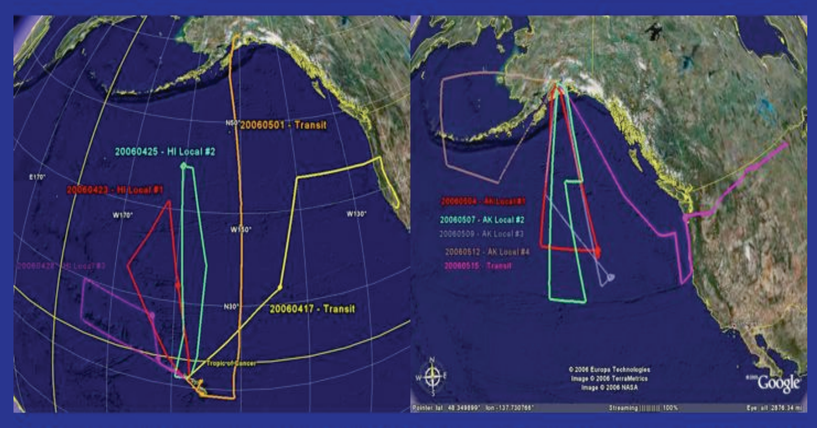
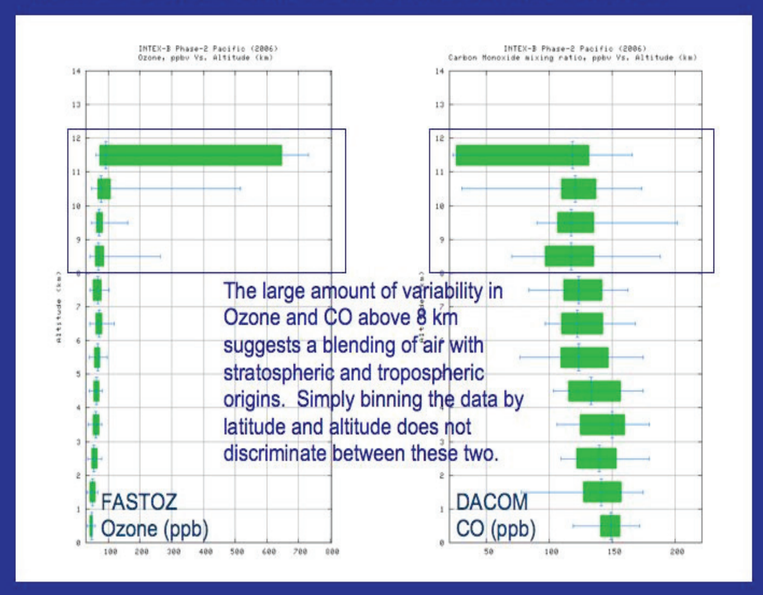
INTEX-B Pacific DC-8 Flight Tracks



During the recent Intercontinental Chemical Transport Experiment – Phase B (INTEX-B) aircraft intensive, the NASA DC-8 flew ten sorties from Oahu, Hawaii and Anchorage, Alaska. Two important science objectives were to characterize the composition of the upper troposphere and lower stratosphere (UT/LS) in the Central Pacific, and to obtain correlative data for AURA satellite instruments TES, MLS and HIRDLS.

INTEXB Central Pacific Ozone and CO Profile Statistics



Research Objectives:

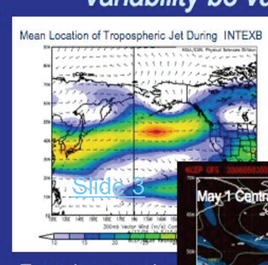
The DC-8 sampled the UT/LS (pressures < 300 hPa) between April 17 and May 15 of 2007, including the tropical troposphere, frequently crossing the midlatitude jet and into the stratospheric "middle world" at northern latitudes. The interesting synoptic-scale flow pattern is ideal for testing our ability to answer tough science questions by combining satellite observations with remote and in situ aircraft data.

Science Questions:

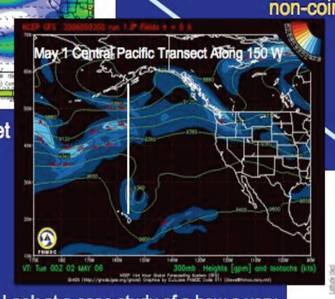
- How much of the ozone we observe in the Upper Troposphere/ Lower Stratosphere is produced/destroyed by photochemistry (anthropogenic component) or transferred by STE (natural)?
- What is the horizontal and vertical variability of ozone in the lower stratosphere, tropopause, and upper troposphere?
- What is the impact of small-scale processes on inhomogeneity and ozone distributions diagnosed from lower resolution models and satellite instruments?

How can space-based measurements of geophysical parameters with significant fine-scale variability be validated in a meaningful fashion?

- In situ process case studies
- Identify significant relationships
- Extrapolate to geophysically similar places and times for a meaningful non-coincident data comparison

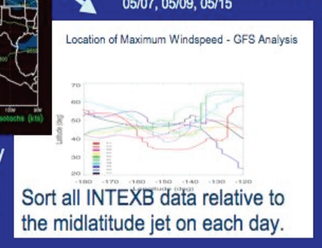


Even the mean jet location is not zonal!



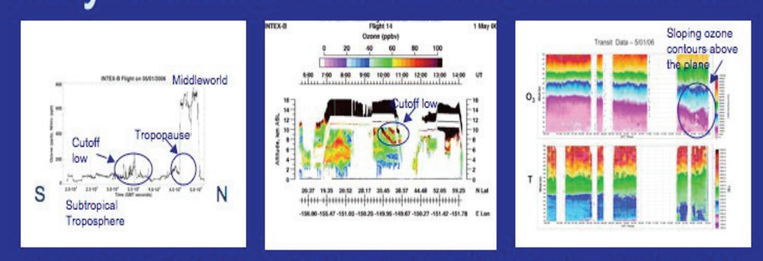
Look at a case study of a how a very simple system - O3:CO - behaves relative to the jet/tropopause break.

INTEXB Pacific Flights: 04/17, 04/23, 04/25, 04/28, 05/01 05/04, 05/07, 05/09, 05/15

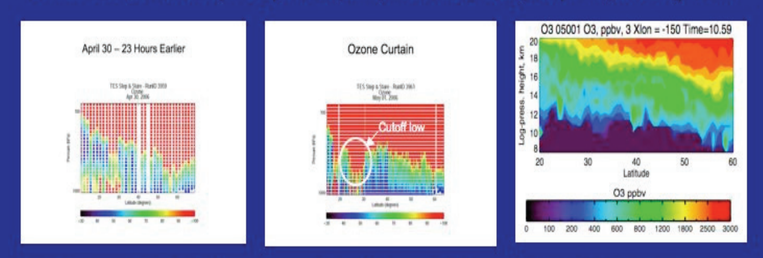


Sort all INTEXB data relative to the midlatitude jet on each day.

May 1: N-S Central Pacific Transect



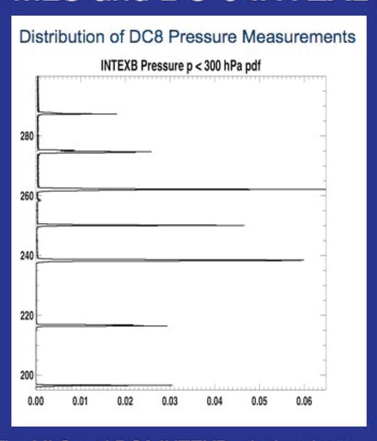
On the DC8, FASTOZ (in situ), DIAL (lidar) and AEROTAL (lidar) sample along 150W

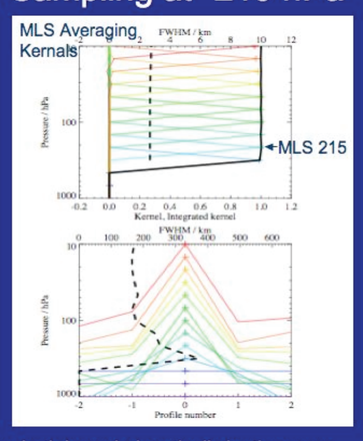


TES "Step and Stare" shows impact Cutoff Low at 30N

HIRDLS High-Resolution

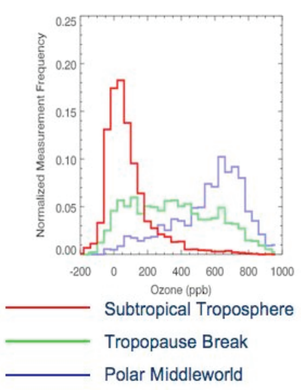
MLS and DC-8 INTEXB Sampling at "215 hPa"





The MLS and DC8 INTEXB mission data were both bounded vertically by the same pressures (167 - 261 hPa), but the sampling of this layer is much different as evidenced by the MLS averaging kernal and the distribution of DC8 pressure measurements. The aircraft auto pilot adjusts by pressure, hence the discrete pressure levels.

MLS 215 Ozone Probability Distribution



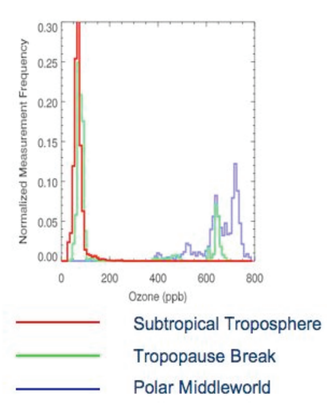
All of the available MLS and DC8 data at "MLS 215" (167-261 hPa) during the INTEX-B mission period (April 15 - May 15 of 2007) and sampled region (19-62 N and 180-263 W) were separated at the jet location for each day, as determined by the maximum winds in the NCEP GFS model analysis.

The three categories used are: 1) Polar Middleworld: Greater than 5 degrees of latitude north of the jet. 2) Tropopause Break: Latitude +/- 5 degrees on either side of the jet maximum. 3) Subtropical Troposphere: Latitude more than 5 degrees south of the jet.

The MLS ozone data probability distribution has 30 bins, with a bin size of 40 ppb, comparable to the precision of the MLS instrument. The MLS data has been quality screened as directed by the MLS data description, with negative values included.

With the data separated at the jet location for each day, one can clearly observe the difference in ozone distributions between the Subtropical Troposphere and the Polar Middleworld at identical pressures. MLS measures an inhomogeneous layer of ozone in the Tropopause Break region, with a very flat distribution of mixed Tropospheric and Stratospheric ozone values.

DC8 Ozone Probability Distribution, 167-261 hPa

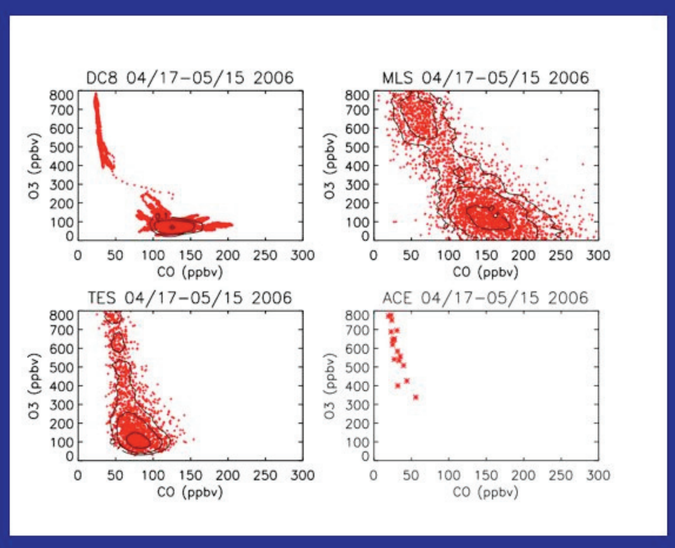


The DC8 pdfs have 80 bins, with a bin size of 10 ppb, larger than the instrument precision while giving a tractable number of bins. The range of measurements is similar, but slightly smaller than MLS.

DC8 ozone distributions in the Subtropical Tropopause and Polar Middleworld are more homogeneous (more tightly distributed around a central vale) but the distribution peak is similar to MLS. One can imagine that the DC8 Middleworld ozone distribution might match MLS with more samples, so this is likely an aircraft sampling representativeness problem.

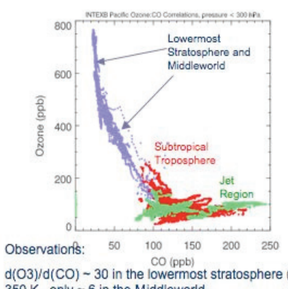
The good agreement suggests that MLS can accurately measure the composition of the UT and LS. However, DC8 ozone measurements in the Tropopause Break region indicate that there is less mixing between the UT/LS than is suggested by MLS. This is most likely due to the coarse MLS vertical and horizontal spatial resolution problem in this area. Aircraft or sonde data are needed to determine more precisely the degree of exchange that occurs here.

Comparison of O3:CO at MLS "215 hPa"



INTEX-B Ozone:Carbon Monoxide Correlation Plots

FASTOZ and DACOM at pressures < 300 hPa

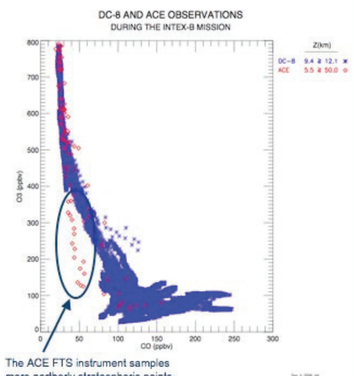


Observations:

d(O3)/d(CO) ~ 30 in the lowermost stratosphere (theta > 350 K,, only ~ 6 in the Middleworld.

Jet Region has more polluted air than the background Subtropical Troposphere. This is probably due to convective lofting from the surface associated with cyclogenesis.

ACE-FTS Ozone and CO Measurements



The ACE FTS instrument samples more northerly stratospheric points than does the DC8

Summary:

During the INTEX-B mission time period, all satellite instruments and the aircraft instruments "see" the same atmosphere. The degree of agreement is encouraging. Combining the measurements can be done successfully in geophysically similar regions (but not necessarily geographically).

The ACE-FTS O3 and CO measurements agree most closely with the highly accurate aircraft data. The occultation data provides information above the DC-8 and augments the data in the Polar Middleworld. MLS captures similar but broader probability distributions as the aggregate aircraft measurements, except for near the tropopause break, which can't be resolved vertically or horizontally by MLS. MLS data is valuable for continental-scale composition assessment and seasonal trends. Upper tropospheric TES O3 and CO observations have significant offsets from the aircraft data but can be useful to capture information about medium-scale mixing features like the cutoff low onserved on May 1, 2007. HIRDLS data can now be compared to the high-resolution lidar data.

The next steeps are to:

- Compare resolution of tracer ratios and to match averaging time to process scale length.
- Define requirements for next generation space-based instruments.

Acknowledgements:

-The authors thank the Tropospheric Chemistry Program for funding this research.

"The Atmospheric Chemistry Experiment (ACE), also known as SCISAT, is aCanadian-led mission mainly supported by the Canadian Space Agency and the Natural Sciences and Engineering Research Council of Canada."