An Overview of the 2008 Stratosphere-Troposphere Analyses of Regional Transport (START08) Experiment

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[project information: http://www.acd.ucar.edu/start/ and http://catalog.eol.ucar.edu/start08/index.html]

BACKGROUND

Investigation of chemical, dynamical, and microphysical processes occurring in the extratropical upper troposphere (UT) and lower stratosphere (LS) (referred to here as the ExUTLS), the altitude region from ~5 to 15 km, is crucial for understanding long term global climate change and tropospheric air quality. It is a region where ozone is an effective greenhouse gas, and where water vapor, cirrus clouds, and aerosols have a strong influence not only on the atmospheric radiation budget, but also on chemical budgets. The ExUTLS is also a region where transport processes that couple the stratosphere and troposphere occur on a multitude of space and time scales. These transport processes, combined with the strong vertical gradients in many chemical constituents, present a challenge to observational techniques and numerical models. The UT, and in some cases the LS, receive a variety of chemical constituents transported rapidly from the lower troposphere/boundary layer or produced by electrical activity in deep convection. Such input presents a strong perturbation to ozone and hydroxyl radical production and loss processes. The new NCAR Gulfstream V (GV) aircraft, with its high altitude and long-range capabilities, combined with new, improved instrumentation for chemical and aerosol measurement, offered exciting opportunities for photochemistry, cloud, aerosol, radiation, and transport research in the ExUTLS.

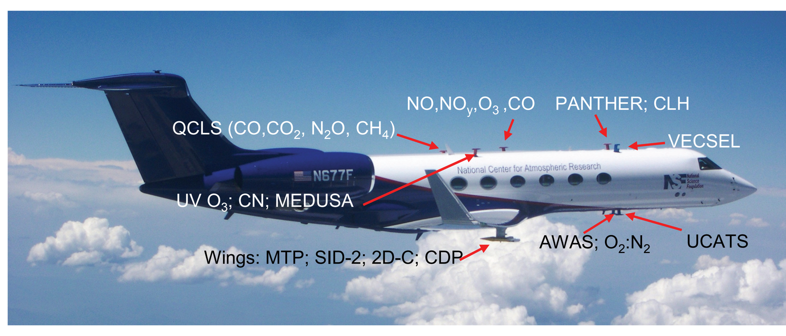
To better understand the dynamical processes that control the chemical composition and microphysics of the ExUTLS, a research mission, the Stratosphere-Troposphere Analyses of Regional Transport (START08) Experiment, was conducted during the spring and summer of 2008. The START08 experiment used *in situ* chemical, microphysical, and dynamical measurements, satellite data, and models to examine chemical, dynamical and microphysical processes in the ExUTLS. The flights were designed to survey the ExUTLS and to target specific transport pathways in that region. In the dynamically active region near the subtropical jet, a number of processes related to planetary waves and lifecycles of extratropical cyclones are important. These include: breaking of Rossby waves, the growth and decay of synoptic-scale waves, tropopause folds and warm conveyor belts, the development of frontal systems, initiation and breaking of gravity waves, and deep convection. Exceptionally active weather patterns in the spring of 2008 provided extended opportunities to characterize stratosphere/troposphere interactions.

The START08 campaign was combined with the HIAPER Pole-to-Pole Observations of Atmospheric Tracers (HIPPO) project due to complementary research goals and airborne instrumentation. The major emphasis of the HIPPO research was to characterize the vertical and latitudinal distributions of carbon cycle gases and other trace atmospheric gases and aerosols. The flights during this period were used to establish protocols and evaluate instrument performance in preparation for global flight coverage in the future.

This poster provides a brief overview of this recently completed experiment. Representative data and trace gas correlations are shown here for selected flights. Interpretation of the results is just beginning, and we expect to discuss these results over the coming months.

MISSION DESCRIPTION

The START08 mission was based at the NCAR Research Aviation facility located at the Rocky Mountain Metropolitan Airport in Broomfield, Colorado. The research aircraft was the NSF Gulfstream V (GV); flight durations were typically 7 - 8 hours, and maximum altitude of 47000 ft. was routinely achieved. The mission was conducted over approximately six weeks in two intensive periods: 1) 12 research flights from 18 April to 16 May and 2) 6 research flights from 16 – 30 June 2008. The aircraft payload is described in Table 1 (right). As can be seen from the Table, the instrumentation included replicate measurements that provided redundancy for critical measurements and an opportunity to evaluate new instrumentation. The payload included a large number of chemical tracers measured with both fast and slower sensors. The wide range of trace gases measured by grab-sampling and in-situ chromatography is given in Table 2, and selected correlations are illustrated below Table 2. Probe locations of the various instruments is shown in the figure below. (TDL water vapor instrument, normally mounted on the aircraft exterior, is not shown).



Though each research flight could have multiple objectives, the flights generally could be grouped in several categories. These categories and associated research flights (RF) were:

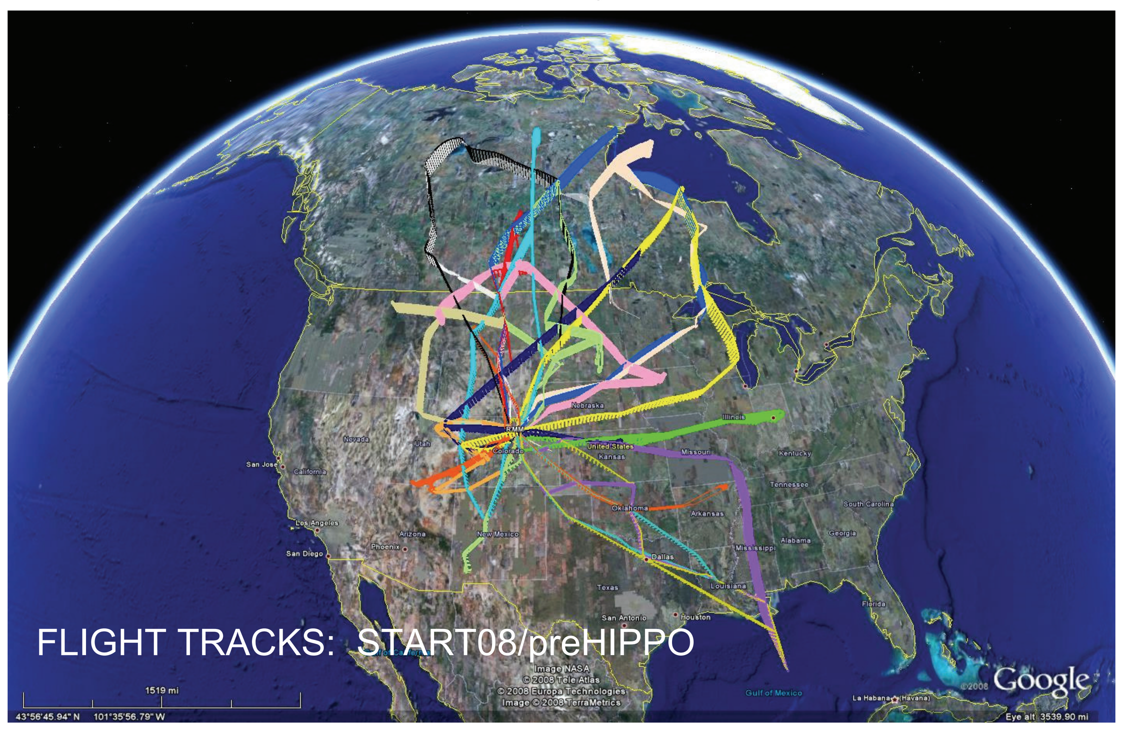
1) Extratropical UT/LS Survey (RF 03, 05, 09, 17, 18)
2) Stratospheric Intrusion (Tropopause Fold) (RF 04, 06, 07, 11, 12)
3) Tropospheric Intrusion (RF 01, 08)
4) Gravity Wave (RF 02)
5) Convective Influence (RF 14, 18)
6) HIPPO (RF 05, 10, 13, 15, 16)

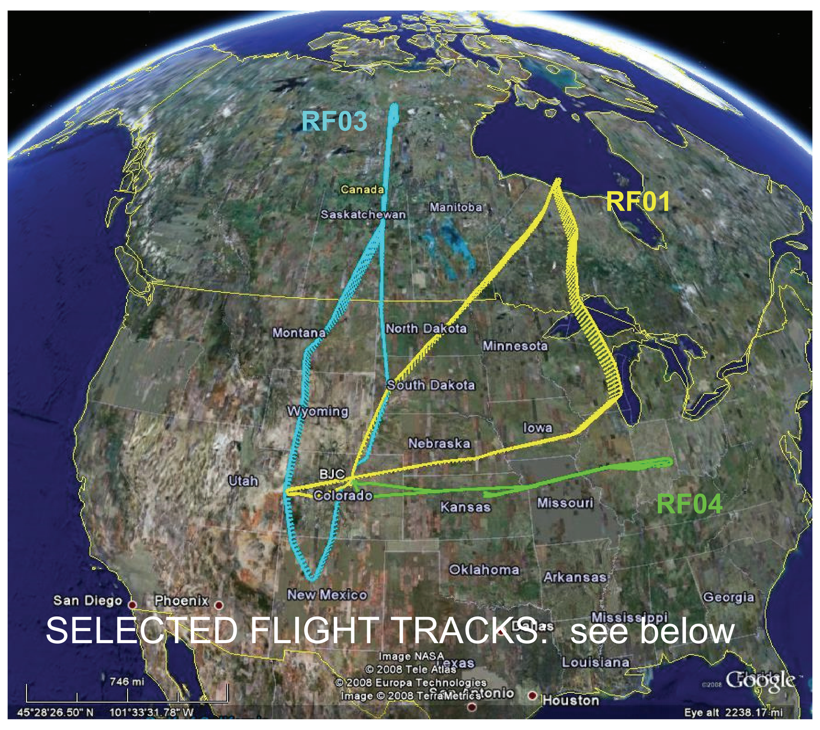
Thus, for most of the science objectives, multiple flights were conducted. Examples from the first three categories are presented below. Note that all data presented here is only preliminary. Final data will be available in a public archive in summer, 2009.

START08 Science Team in front of NSF GV prior to research flight #17

TABLE 1. Measurements and modeling employed during START08.

Instrument/Model	*Data product*	*Mission Objective*
HAIS Twin QCL	High resolution CO, CO_2, CH_4, N_2O	Tracer studies; transport rates
HAIS AWAS	Grab sampling: NMHC, HCFC, $RONO_2$, etc., see Table 2.	Tracer studies; source characterization; lifetimes
PANTHER GC/MS	Medium resolution: selected trace gases (OCS, MeI, etc.) See Table 2.	Tracer studies; source characterization; lifetimes
UCATS	GC analysis:$N_2O/SF_6/H_2/CO/CH_4$; continuous O_3 & H_2O	Tracer studies
NCAR fast O3	High resolution O_3	Multiscale analyses ; strat-trop processes
NOAA UV O3	1 Hz ozone measurement	Strat-trop mixing
NCAR NO/NO_y	High resolution NO, NO_y	Strat-trop mixing, convective NO sources
RAF TDL H_2O	High resolution H_2O	Microphysics, strat-trop processes
HAIS VECSEL	High resolution, fast H_2O	Microphysics ; multiscale analyses ; strat-trop processes
HAIS MTP	Atmospheric temperature structure	Strat-trop processes; tropopause location
CU-CLH	Total water measurement; thin cloud detection	Microphysics, strat-trop processes
NCAR O_2:N_2	Measure of O_2:N_2 ratio	Strat-trop exchange; carbon cycle objective
NCAR MEDUSA	Grab sampling for C isotope ratio measurement; O2:N2 ratio	Strat-trop exchange; carbon cycle objective
HAIS SID-2	Small ice particle detector	Cirrus microphysics
RAF CN	Condensation nuclei count	Source characterization ; tracer studies
RAF Particle Probes	CDP (Cloud Droplet Probe), 2D-C (Two dimensional optical cloud probe)	microphysics
MOZART3	Global scale model	Flight planning/post mission analyses
MM5/WRF	High resolution regional model	Flight planning/post mission analyses
CLaMS	Lagrangian chemical transport model	Tropopause mixing processes
Trajectory Model TRAJ3D	Air mass trajectories	Source characterization/ transport pathways
Satellite Data	AIRS/IASI High Resolution Ozone and Water	Flight planning/post mission analyses
Satellite Data	AURA (OMI and MLS)	Trace gas distributions





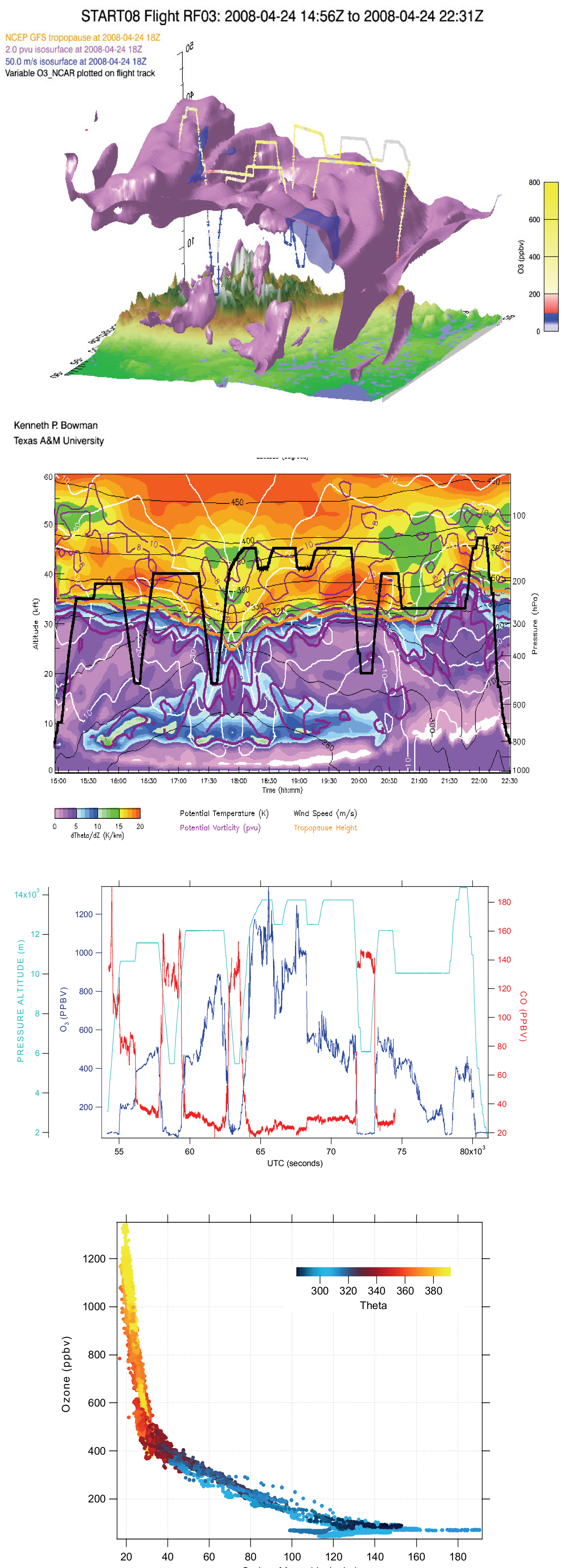
Panels below:
The figures below highlight early data from some of the major types of research flights during START08. The selected research flights are shown in the figure to the left; they are examples of UT/LS Survey, Stratospheric Intrusion, and Tropospheric Intrusion missions. The figures show (from top to bottom): Dynamical context (3-D flight track, 2 PVU surface); GFS curtain (PV, wind, stability, flight track); time series of CO, ozone, altitude; and CO:ozone correlation.

TABLE 2. Trace gas measurements by on-board gas chromatography and grab sampling (60 /flight) (PANTHER =PAN and other Trace Hydrohalocarbon Experiment; UCATS=Unmanned Aircraft Systems Chromatograph for Atmospheric Trace Species; AWAS= Advanced Whole Air Sampler)

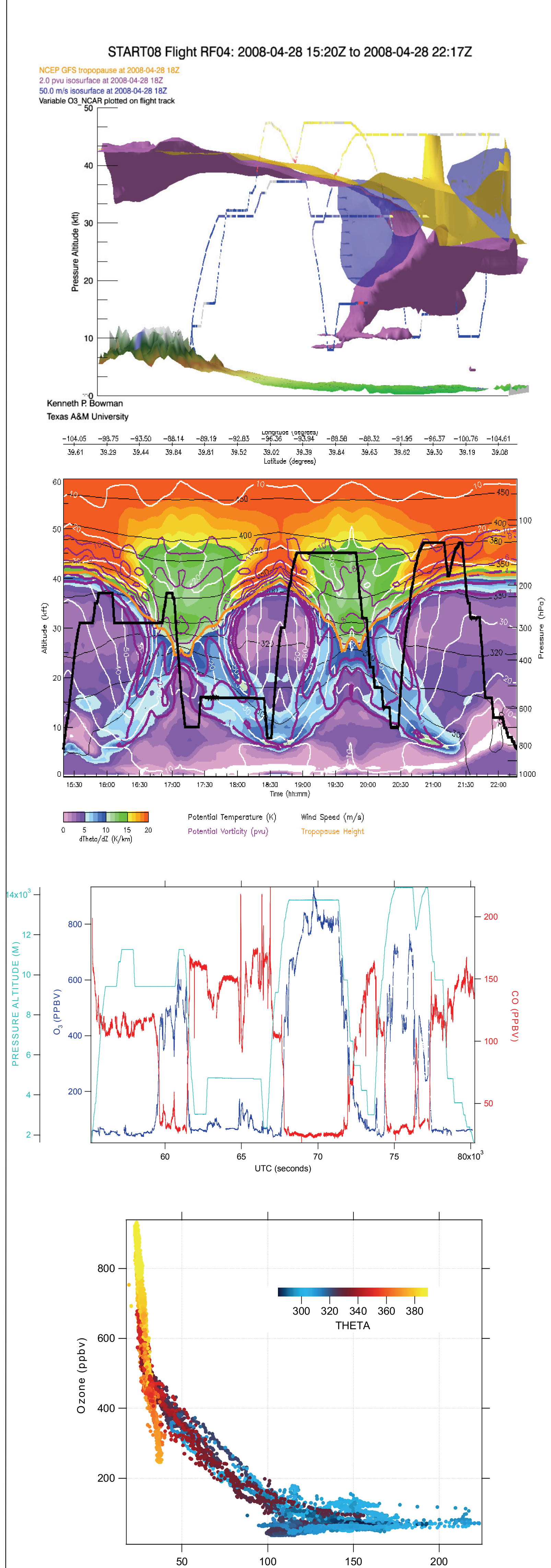
	PANTHER - UCATS	AWAS
Chlorofluorocarbons		
CFC-11 (CCl_3F)	✓	✓
CFC-12 (CCl_2F_2)	✓	✓
CFC-113 (CCl_2FCClF_2)		✓
CFC-114 ($CClF_2CClF_2$)		✓
Halons		
CFC-12b1 (Halon 1211,CF_2ClBr)	✓	✓
CFC-13b1 (Halon 1301, CF_3Br)		✓
CFC-114b2 (Halon 2402, $C_2F_4Br_2$)		✓
Hydrochlorofluorocarbons/ Hydrofluorocarbons		
HCFC-22 (CHF_2Cl)	✓	✓
HCFC-141b (CH_3CFCl_2)	✓	✓
HCFC-142b (CH_3CF_2Cl)	✓	✓
HFC-134a ($C_2H_2F_4$)	✓	✓
HCFC-124 (C_2HClF_4)		✓
HCFC-123 ($C_2HCl_2F_3$)		✓
HFC-152a (CH_3CHF_2)		✓
Solvents		
Carbon Tetrachloride (CCl_4)		✓
Methyl Chloroform(CH_3CCl_3)		✓
Tetrachloroethylene (C_2Cl_4)		✓
Methylene Chloride (CH_2Cl_2)		✓
Chloroform ($CHCl_3$)		✓
Trichloroethylene(C_2HCl_3)		✓
1,2-Dichloroethane ($C_2H_4Cl_2$)		✓
Methyl Halides and related		
Methyl Bromide(CH_3Br)	✓	✓
Methyl Chloride (CH_3Cl)	✓	✓
Methyl Iodide (CH_3I)	✓	✓
Methylene Bromide(CH_2Br_2)		✓
CHxBryClz		✓
Bromoform ($CHBr_3$)		✓
Ethyl Bromide (C_2H_5Br)		✓
n-Propyl Bromide (C_3H_7Br)		✓

	PANTHER - UCATS	AWAS
Organic Nitrates		
Methyl nitrate(CH_3ONO_2)		✓
Ethyl nitrate($C_2H_5ONO_2$)		✓
Propyl nitrates($C_3H_7ONO_2$)		✓
Butyl nitrates ($C_4H_9ONO_2$)		✓
Pentyl nitrates ($C_5H_{11}ONO_2$)		✓
Peroxyacetyl Nitrate ($CH_3C(O)OONO_2$)	✓	
Non-Methane Hydrocarbons		
Ethane (C_2H_6)		✓
Ethyne (C_2H_2)		✓
Propane(C_3H_8)		✓
Isobutane(C_4H_{10})		✓
n-Butane (C_4H_{10})		✓
Isopentane (C_5H_{12})		✓
n-Pentane (C_5H_{12})		✓
Isoprene (C_5H_{10})		✓
Benzene (C_6H_6)		✓
Toluene (C_7H_8)		✓
C_2-Benzenes (C_8H_{10})		✓
Other		
Methane (CH_4)	✓	✓
Carbon Monoxide (CO)	✓	✓
Nitrous Oxide (N_2O)	✓	✓
Hydrogen (H_2)	✓	
Carbonyl Sulfide (COS)	✓	✓
Dimethyl Sulfide (C_2H_6S)		✓
Carbon disulphide (CS_2)	✓	
Methyl-t-butyl ether ($C_5H_{12}O$)		✓
Methyl Acetate/Ethyl Acetate		✓
Acetonitrile (CH_3CN)		✓
1,2 Dichlorobenzene ($C_6H_4Cl_2$)		✓
Perfluorocarbons		
Sulfur Hexafluoride (SF6)	✓	

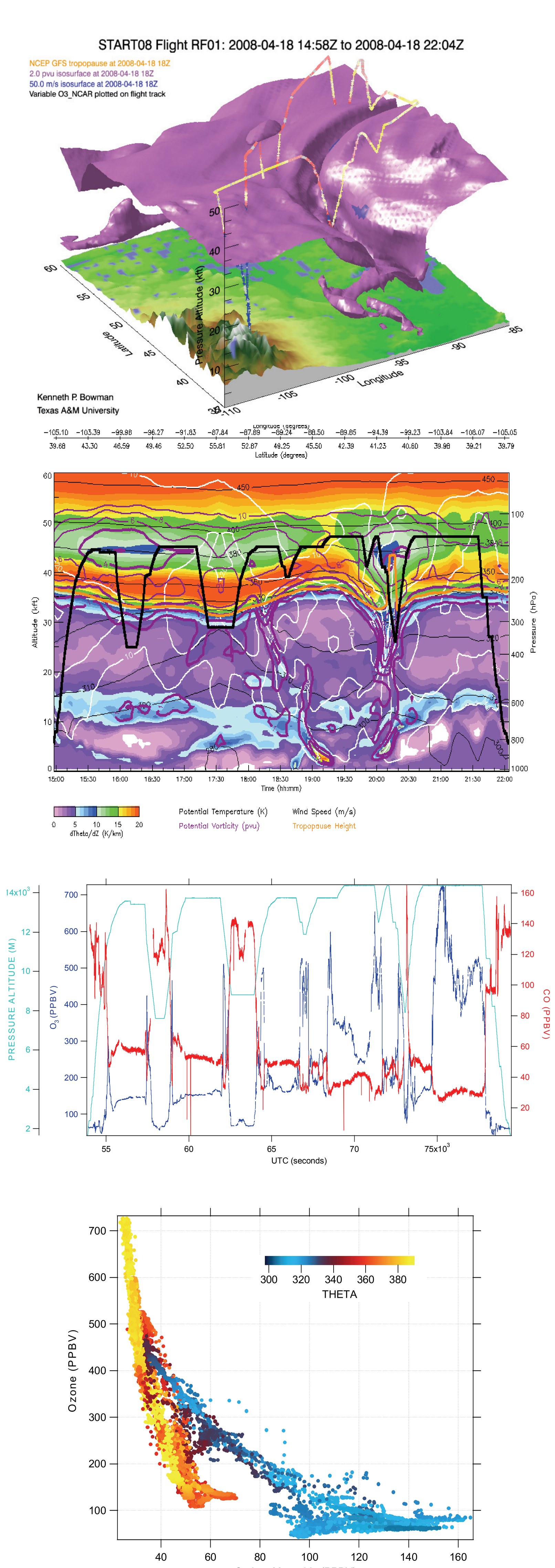
Extratropical UT/LS Survey: Example RF03



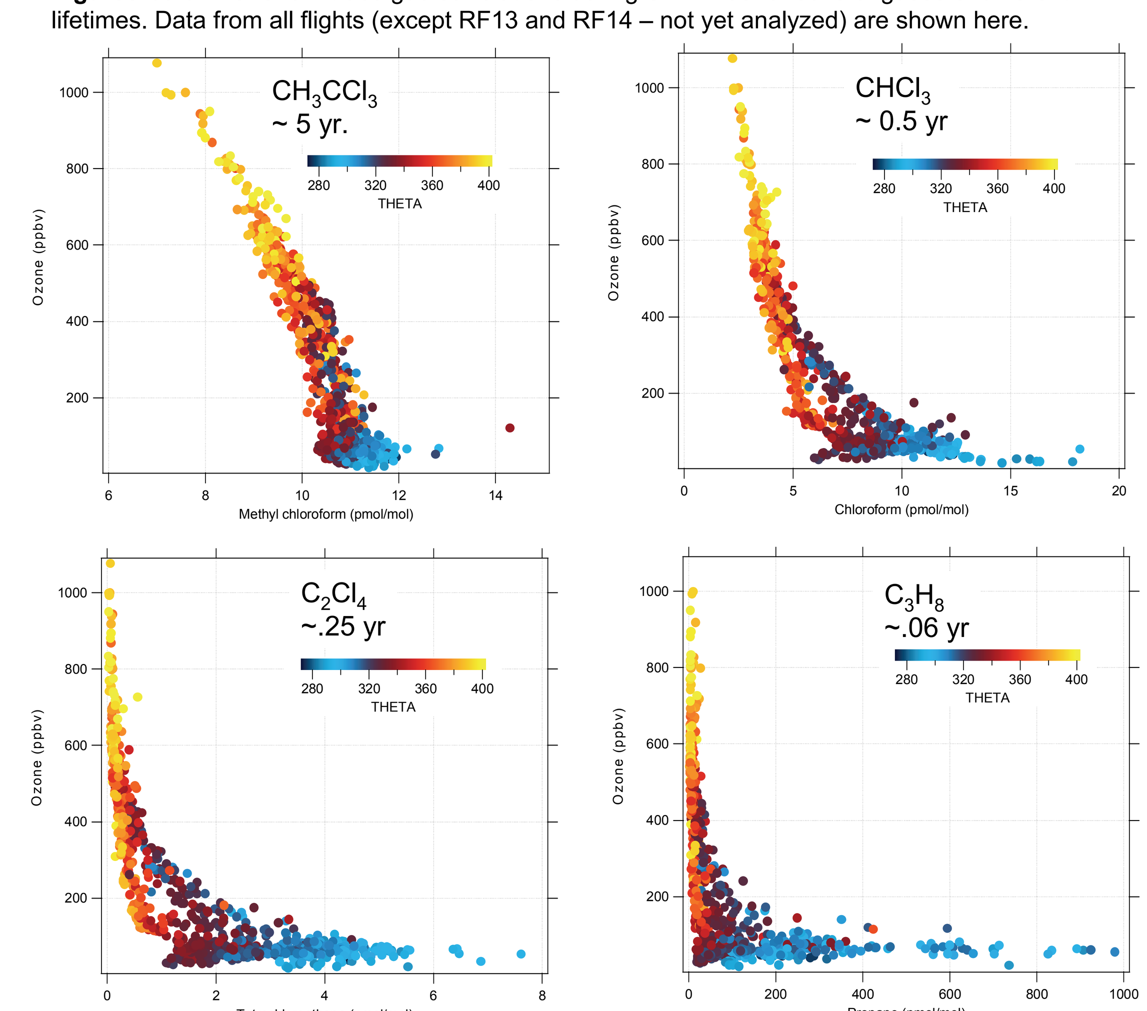
Stratospheric Intrusion (tropopause fold): Example RF04



Tropospheric Intrusion: Example RF01



Figures below: Ozone – trace gas correlations during START08 for several gases of different lifetimes. Data from all flights (except RF13 and RF14 – not yet analyzed) are shown here.



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Project Manager: P. Romashkin[1]. 1: NCAR, 2: Texas A&M U., 3: U. Miami/RSMAS, 4: U. Colorado, 5: NOAA ESRL, 6: CIRES, 7: Harvard U. (also HIPPO PI), 8: Penn State, 9: Princeton U., 10: JPL.

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