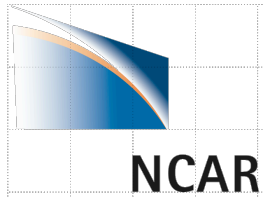
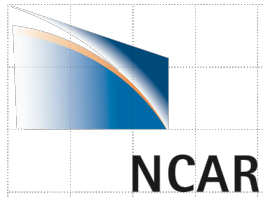


UTLS Transport Studies using START08 Observations and SD WACCM run Results

Laura Pan (NCAR) and Dalon Stone (TAMU)

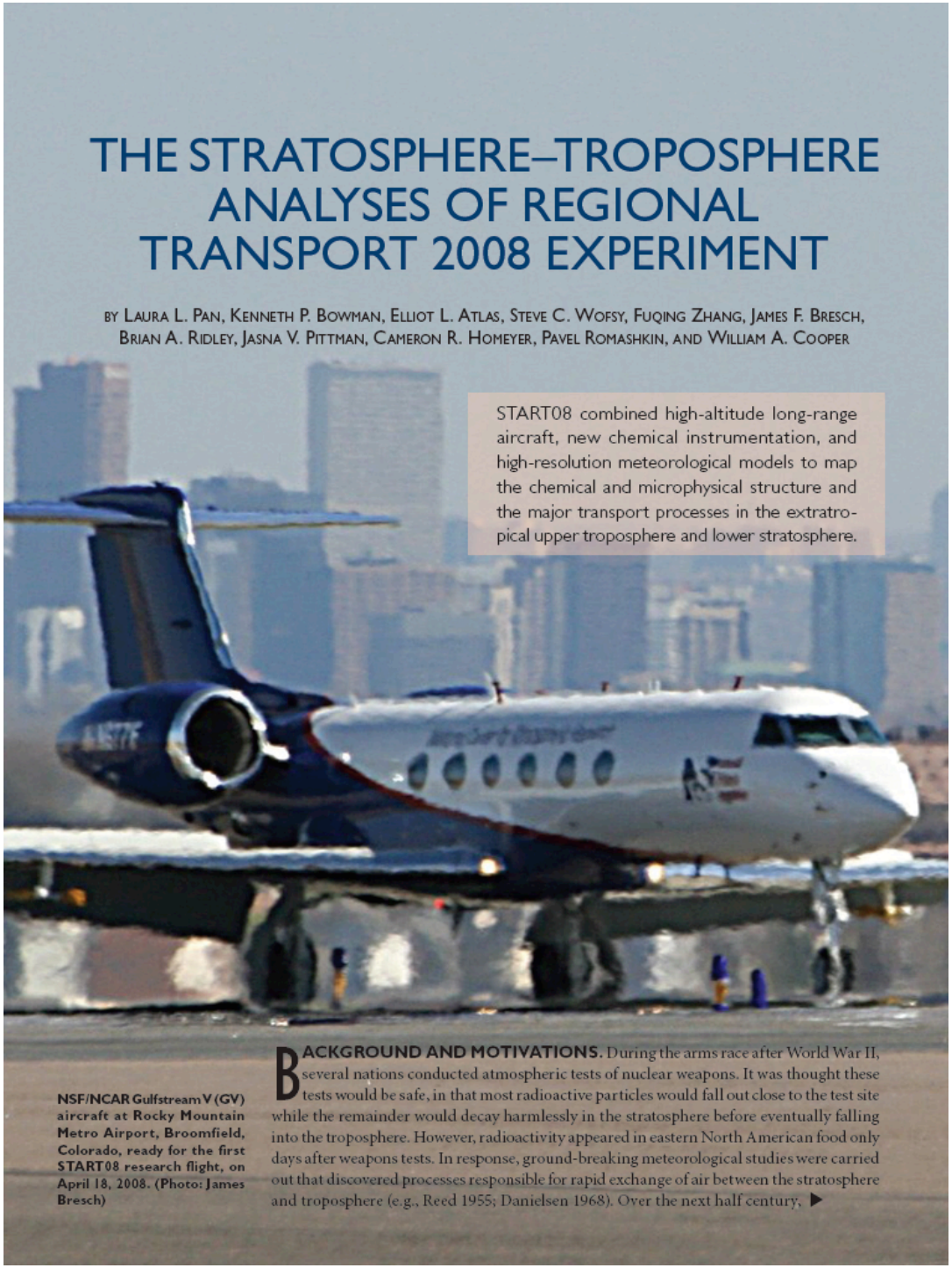
In collaboration with :

Doug Kinnison & Simone Tilmes (NCAR)
Elliot Atlas (U. Miami),
Kenneth P. Bowman (TAMU),
Paul Konopka (Juelich-ICG1)



Plan:

- START08 Campaign
- Integration of START08 data and WACCM-SD for event studies
- Diagnostics using Tracer-Tracer correlations
- Comparisons of Lagrangian vs Eularian framework



THE STRATOSPHERE–TROPOSPHERE ANALYSES OF REGIONAL TRANSPORT 2008 EXPERIMENT

BY LAURA L. PAN, KENNETH P. BOWMAN, ELLIOT L. ATLAS, STEVE C. WOFSY, FUQING ZHANG, JAMES F. BRESCH, BRIAN A. RIDLEY, JASNA V. PITTMAN, CAMERON R. HOMEYER, PAVEL ROMASHKIN, AND WILLIAM A. COOPER

START08 combined high-altitude long-range aircraft, new chemical instrumentation, and high-resolution meteorological models to map the chemical and microphysical structure and the major transport processes in the extratropical upper troposphere and lower stratosphere.

NSF/NCAR Gulfstream V (GV) aircraft at Rocky Mountain Metro Airport, Broomfield, Colorado, ready for the first START08 research flight, on April 18, 2008. (Photo: James Bresch)

BACKGROUND AND MOTIVATIONS. During the arms race after World War II, several nations conducted atmospheric tests of nuclear weapons. It was thought these tests would be safe, in that most radioactive particles would fall out close to the test site while the remainder would decay harmlessly in the stratosphere before eventually falling into the troposphere. However, radioactivity appeared in eastern North American food only days after weapons tests. In response, ground-breaking meteorological studies were carried out that discovered processes responsible for rapid exchange of air between the stratosphere and troposphere (e.g., Reed 1955; Danielsen 1968). Over the next half century, ▶

START08 Campaign

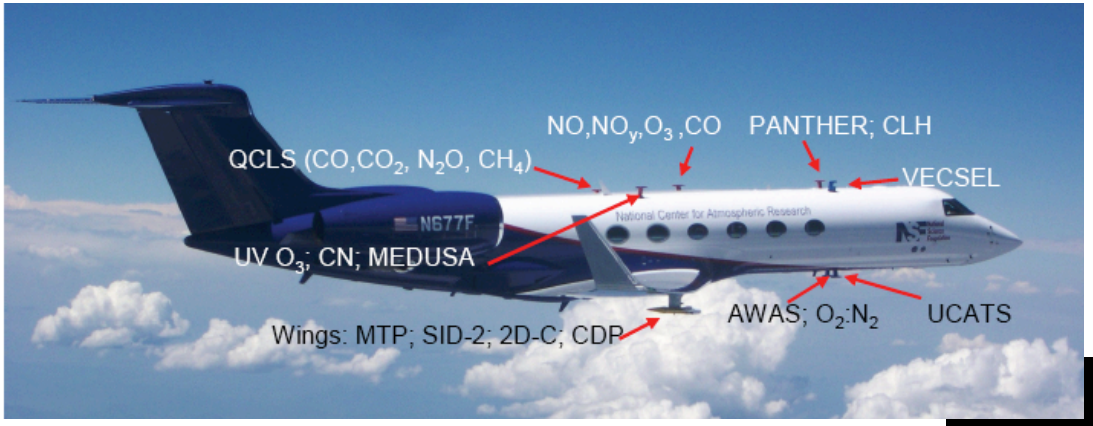
- **April – June, 2008 operated from Colorado (RAF)**
- **Participated by NCAR, TAMU, Univ. Miami, Univ. Colorado, Harvard U., and NOAA**

Principal Investigators:

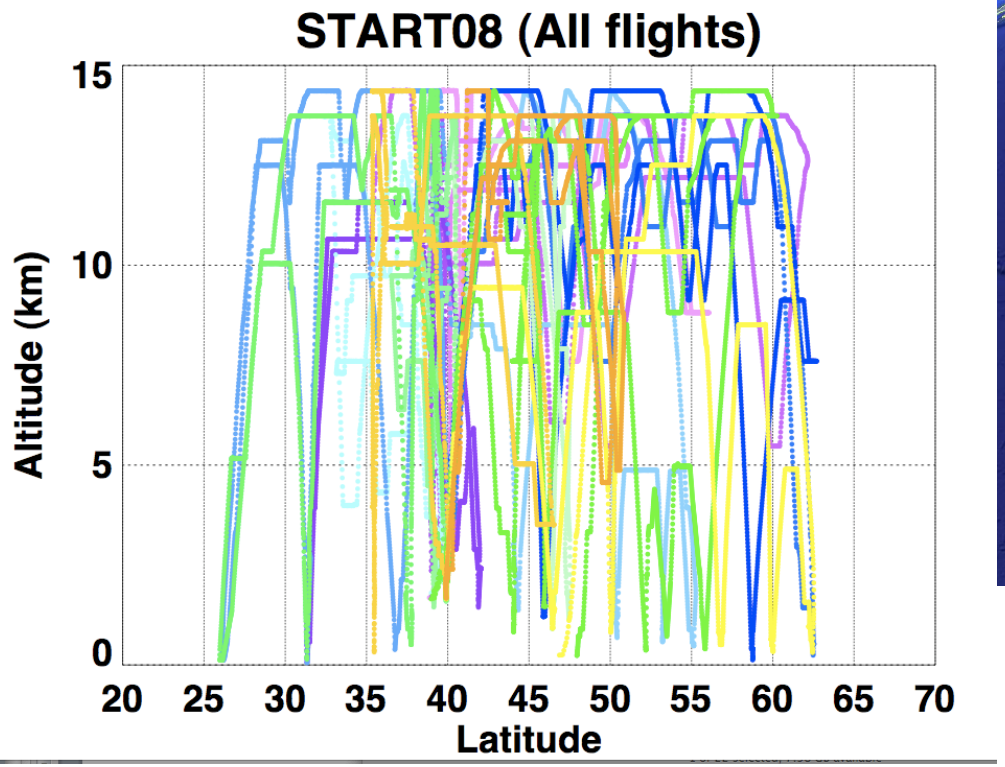
Laura Pan, Elliot Atlas (Miami U), Kenneth Bowman (TAMU)

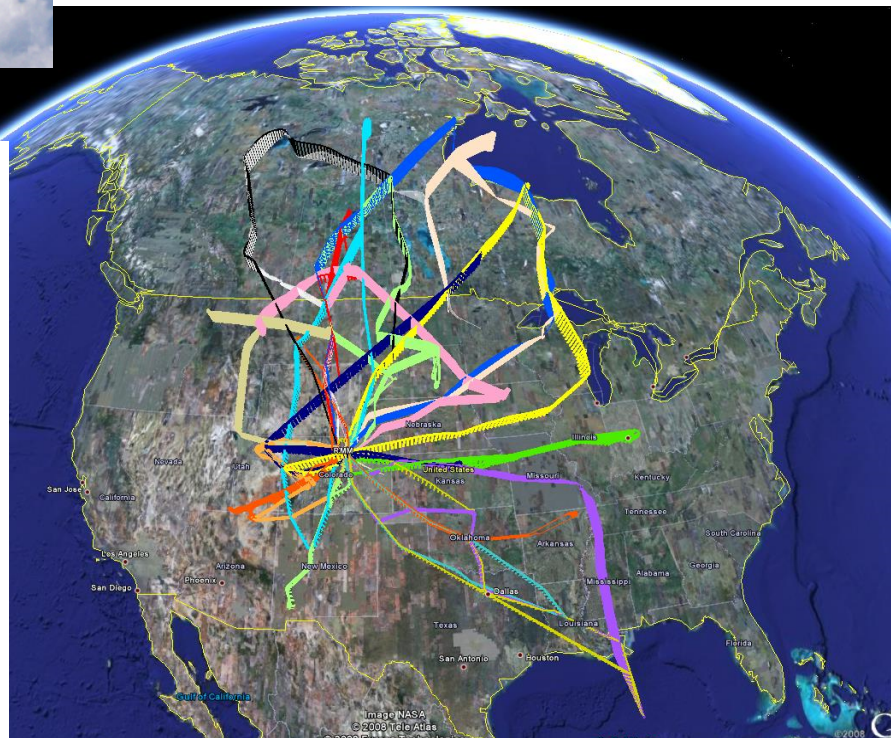
Pan et al., BAMS, March 2010 issue

START08/PreHIPPO April-June 2008

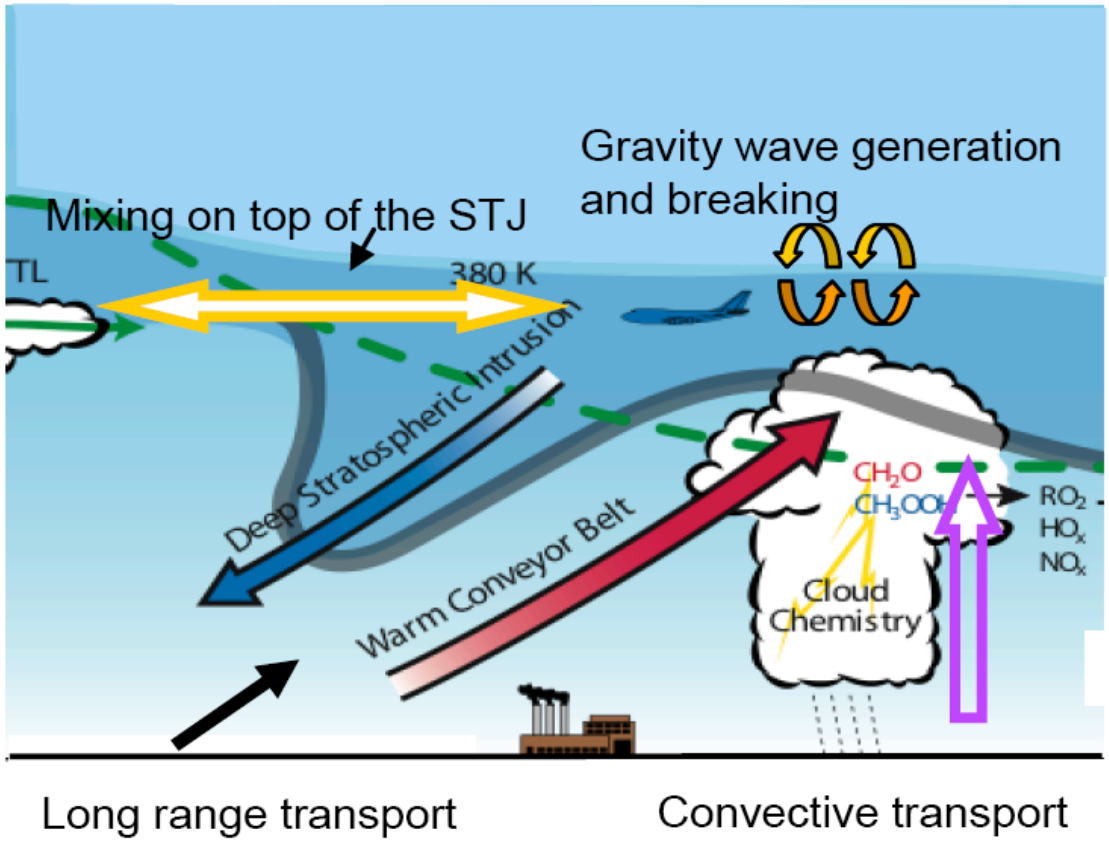


- > 120 hours of measurements
- > 1000 whole air samples



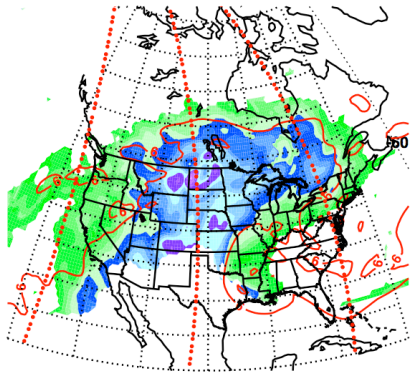


Sampling Strategy: Targeting Major Transport Pathways in the Ex-UTLS

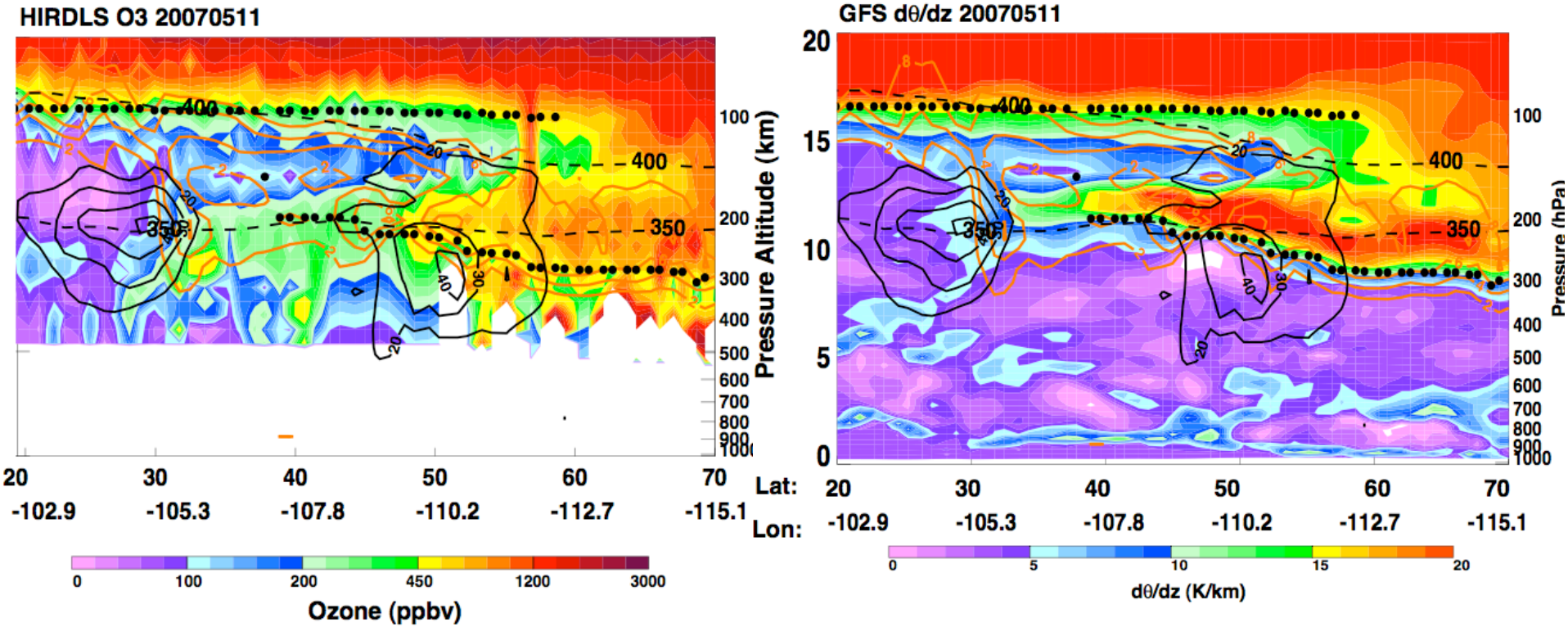


1. **Extratropical UT/LS Survey (including cirrus clouds) (RF 03, 09, 14, 17, 18)**
2. **Stratospheric Intrusion (Tropopause Fold) (RF 04, 06, 11, 12)**
3. **Tropospheric Intrusion (RF 01, 07, 08, 09, 14)**
4. **Convective Influence (RF 08, 13, 14, 18)**
5. **Gravity Wave (RF 02)**
6. **HIPPO (RF 05,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

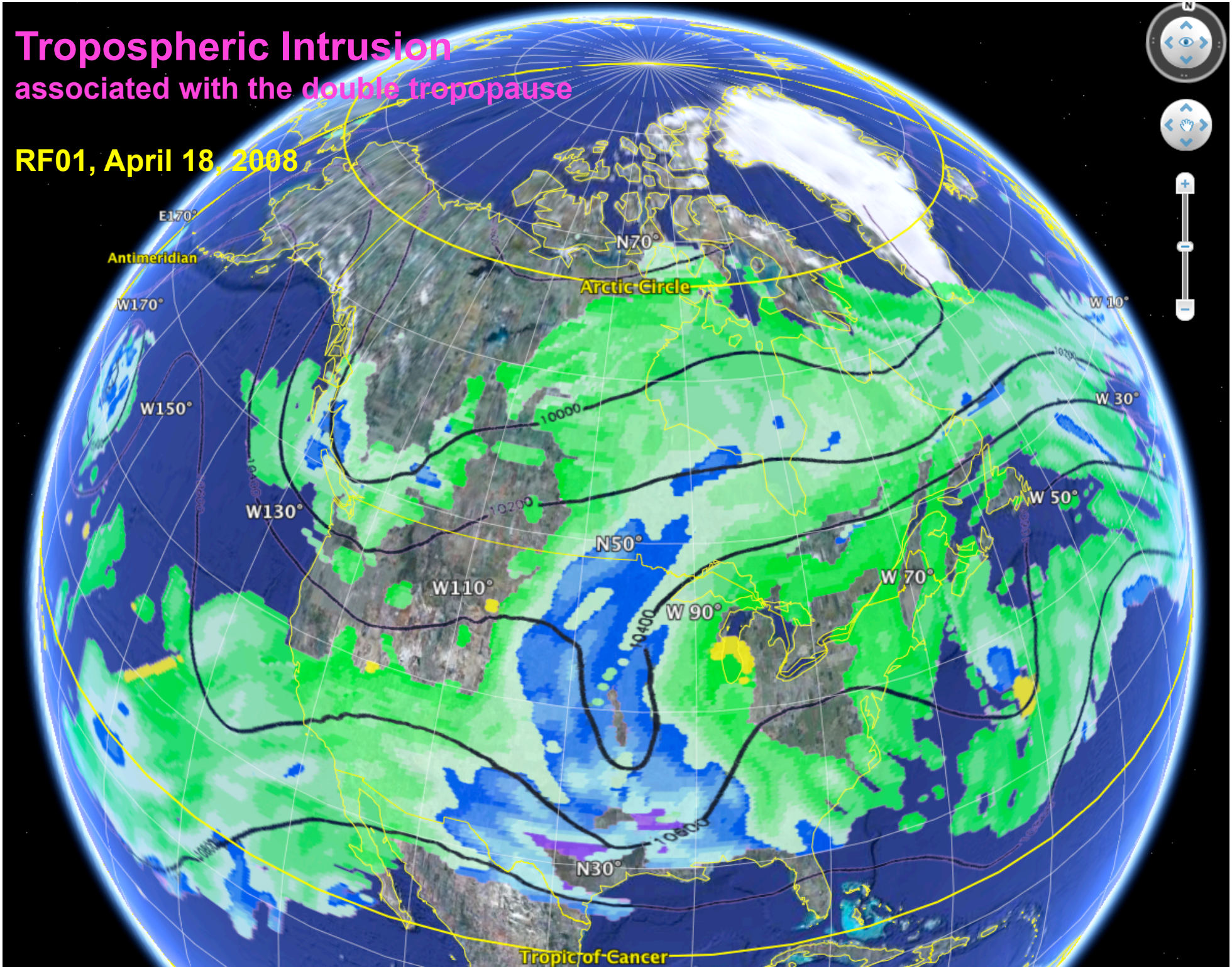
Tropspheric Intrusion associated with the Double tropopause

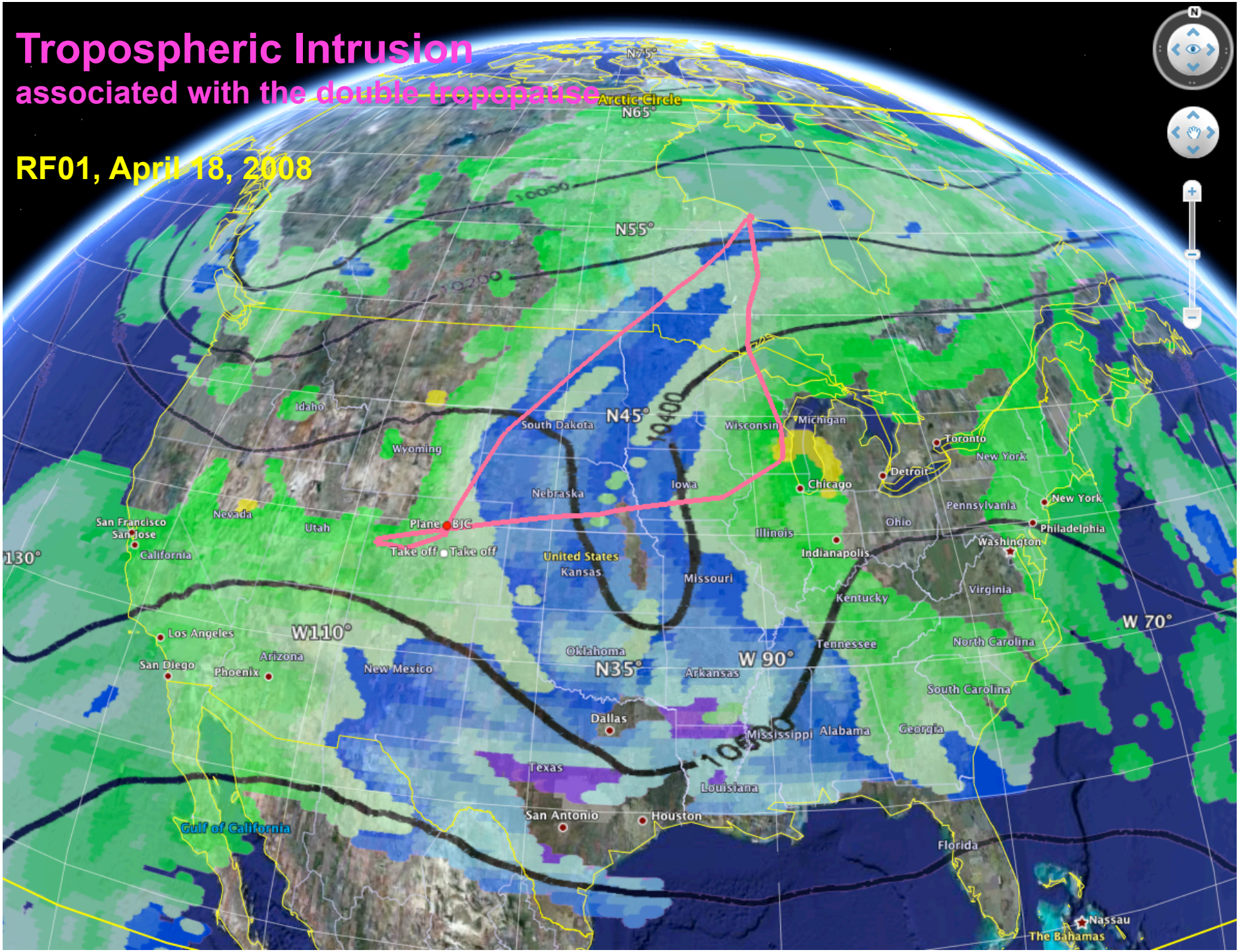


HIRDLS O_3 and GFS dθ/dz, May 11, 2007

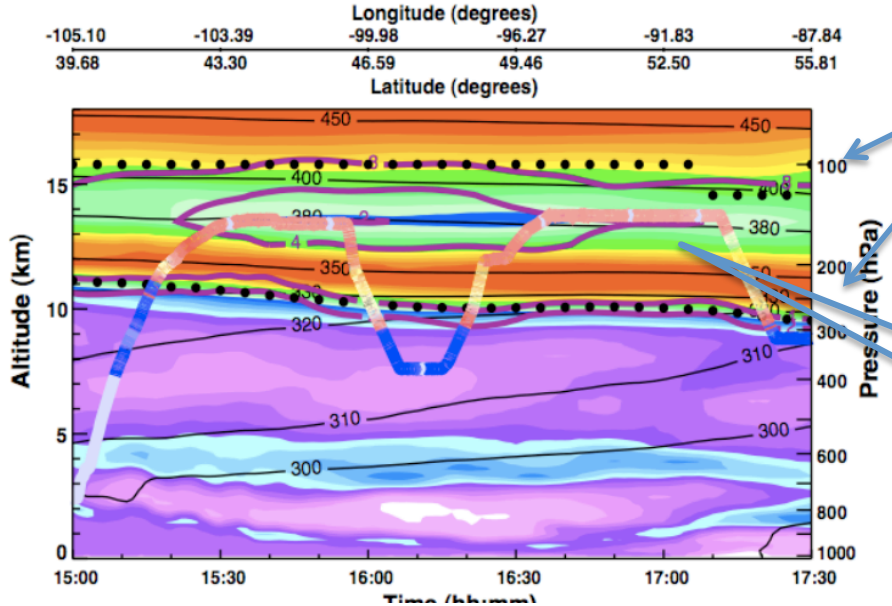


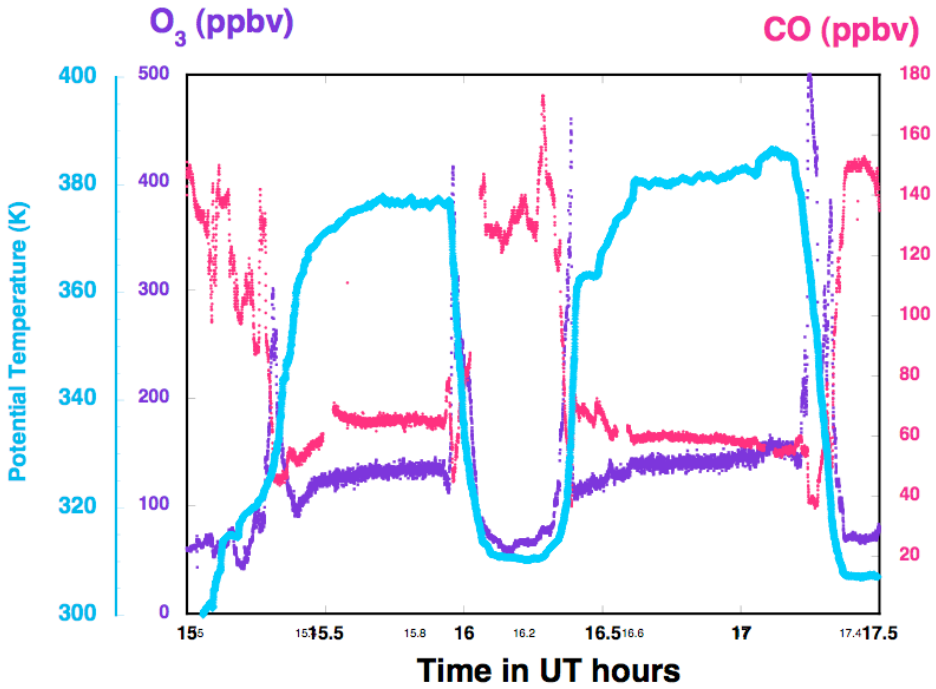
Pan et al., 2009


Tropospheric Intrusion
associated with the double tropopause
RF01, April 18, 2008
E170°
Antimeridian
W170°
W150°
W130°
W110°
W 90°
W 70°
W 50°
W 30°
W 10°
N70°
Arctic Circle
N50°
N30°
Tropic of Cancer
10000
10200
10400
10600


Tropospheric Intrusion
associated with the double tropopause
RF01, April 18, 2008
N75°
Arctic Circle
N65°
N55°
10000
10200
10400
10600
N45°
N35°
W110°
W 90°
W 70°
130°
Idaho
Wyoming
South Dakota
Nebraska
Iowa
Wisconsin
Michigan
Toronto
New York
Detroit
Chicago
Pennsylvania
New York
Ohio
Philadelphia
Washington
Indianapolis
Illinois
Missouri
Kansas
United States
Kentucky
Virginia
Tennessee
North Carolina
South Carolina
Georgia
Mississippi
Alabama
Arkansas
Oklahoma
Texas
Louisiana
Dallas
San Antonio
Houston
New Mexico
Arizona
Phoenix
Los Angeles
San Diego
San Francisco
San Jose
California
Nevada
Utah
Plane
BJC
Take off
Take off
Gulf of California
Florida
Nassau
The Bahamas

RF01, April 18, 2008





Sandwiched stratosphere?

Latitudes: > 50° N

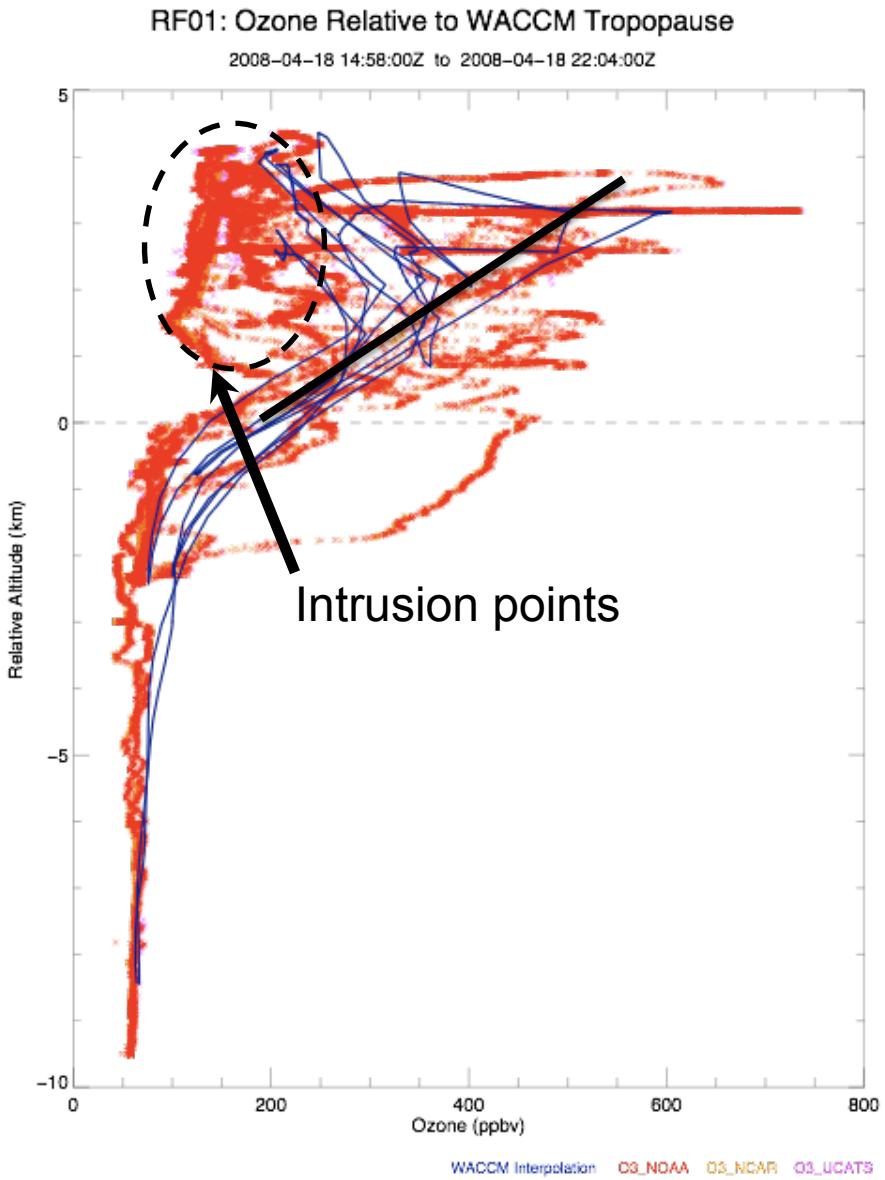
PT: ~ 380 K

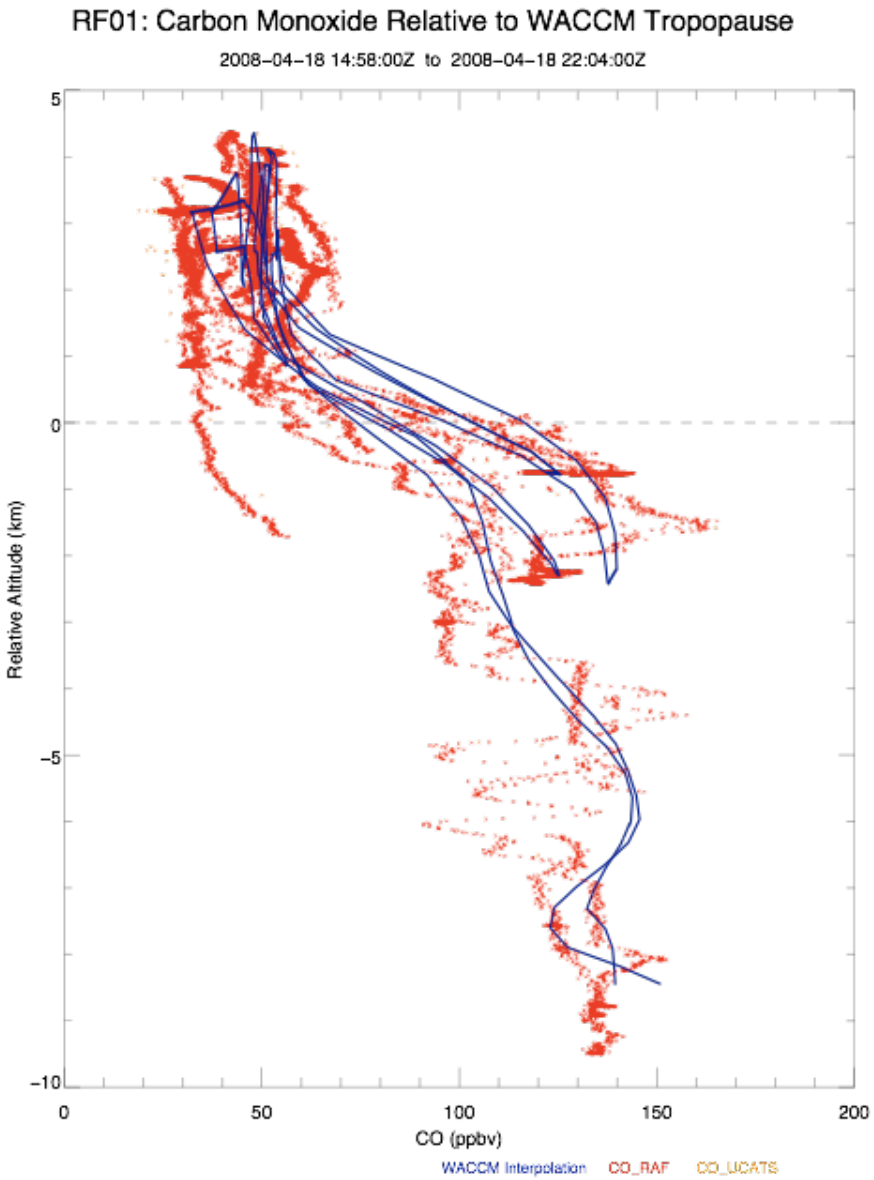
PV: < 4 pvu

O3: <150 ppbv

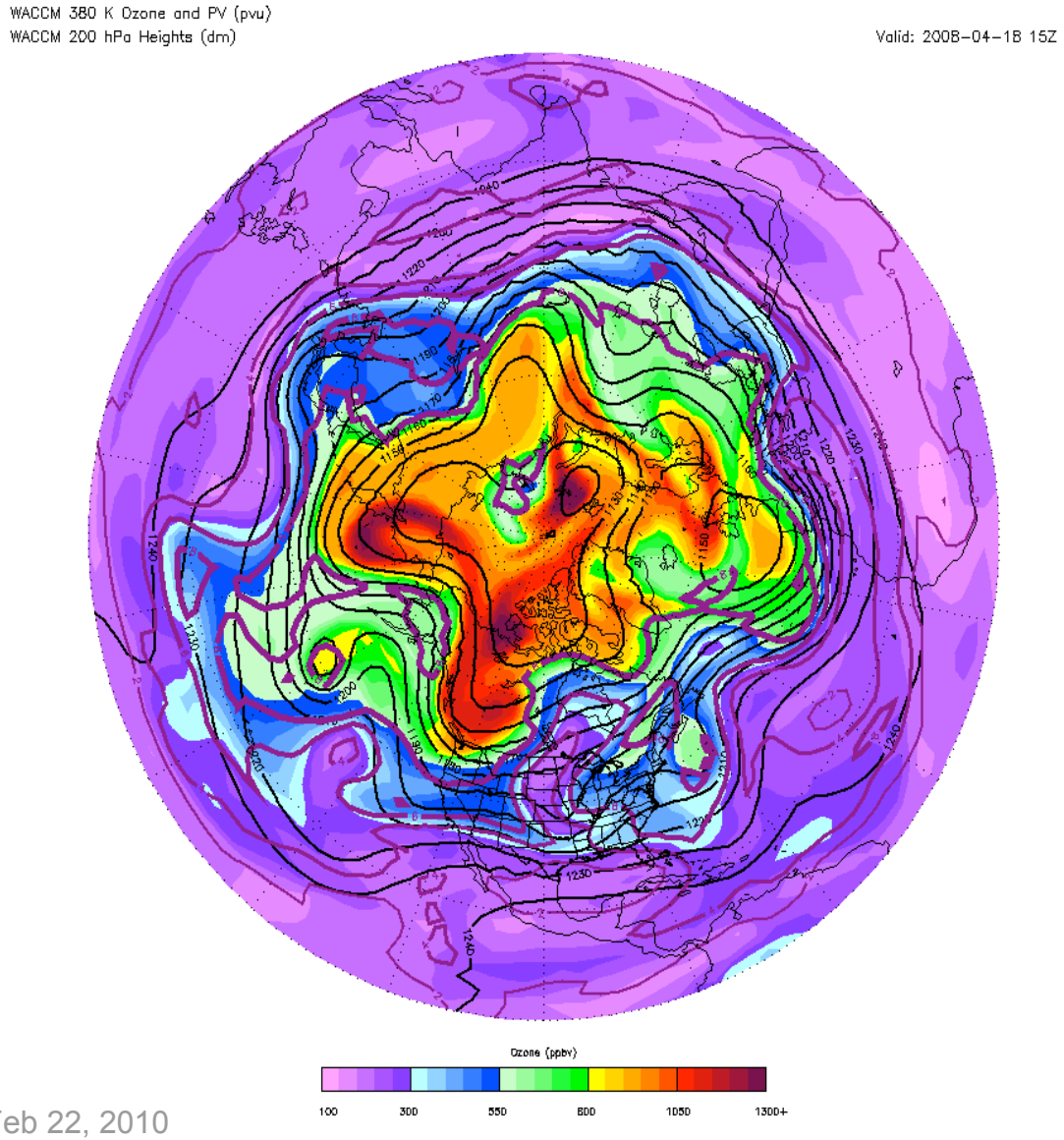
CO: ~ 50 ppbv

RF01 Tracer Comparison



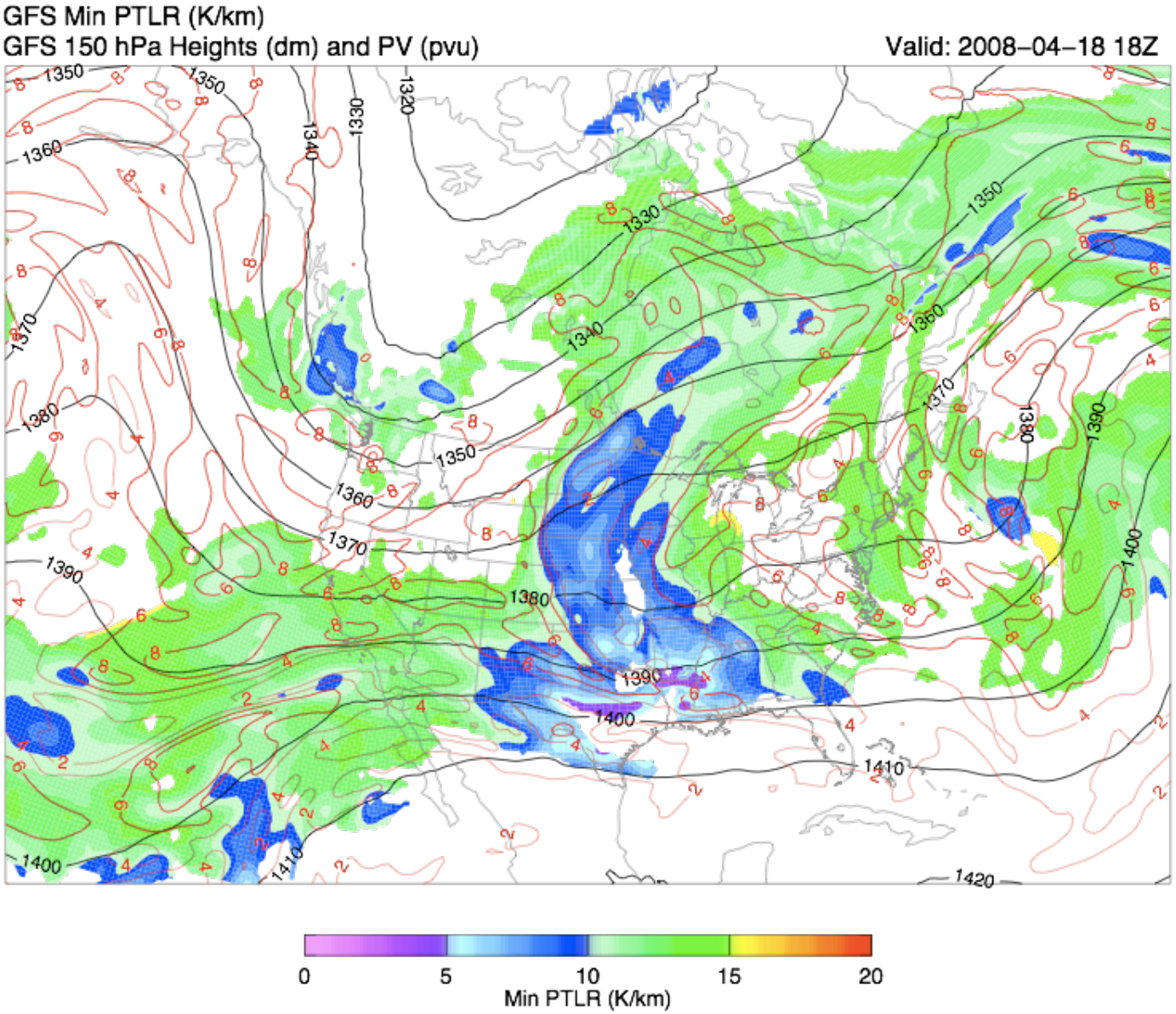


WACCM ozone field at 380 K

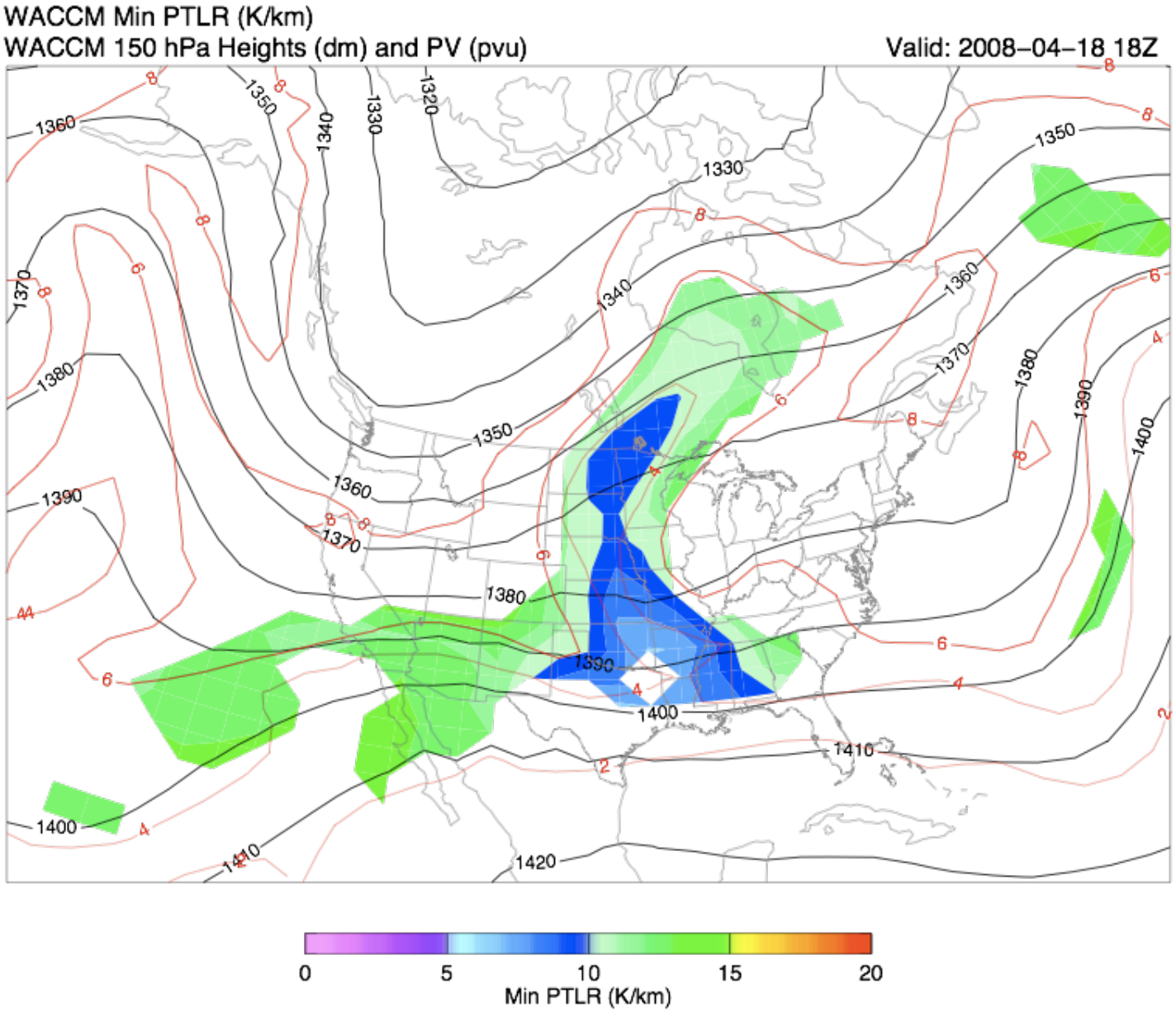


Laura Pan, Feb 22, 2010

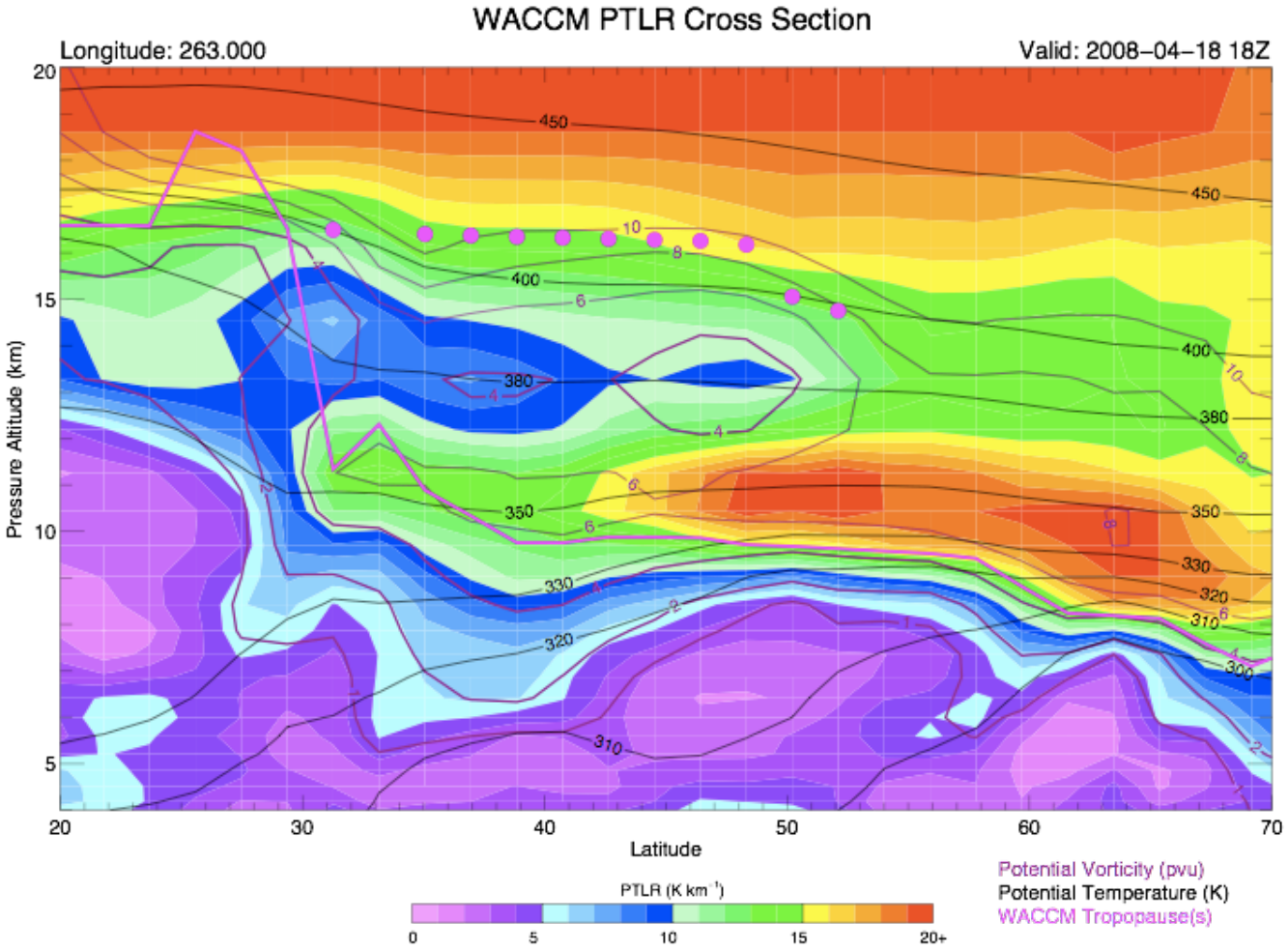
GFS Double Tropopause

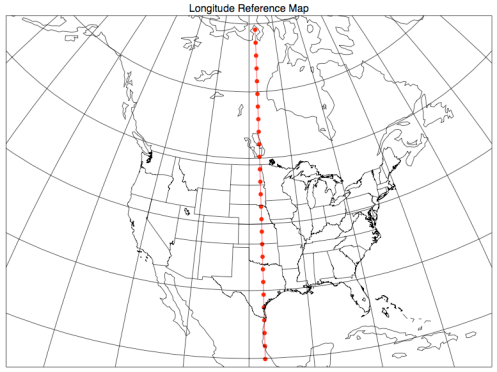


WACCM Double Tropopause

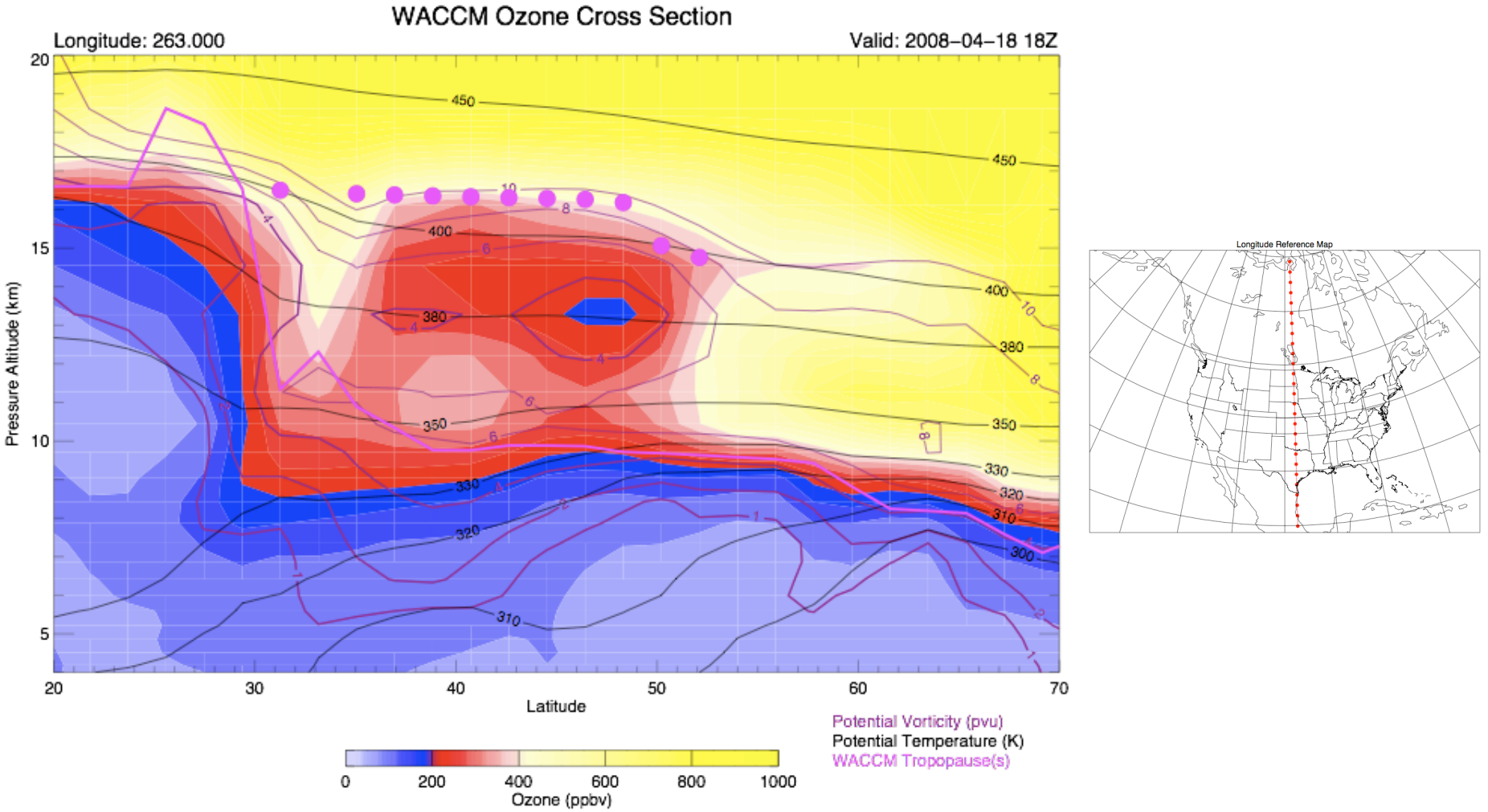


WACCM Stability Section





WACCM Ozone Section



WACCM 380 K Ozone

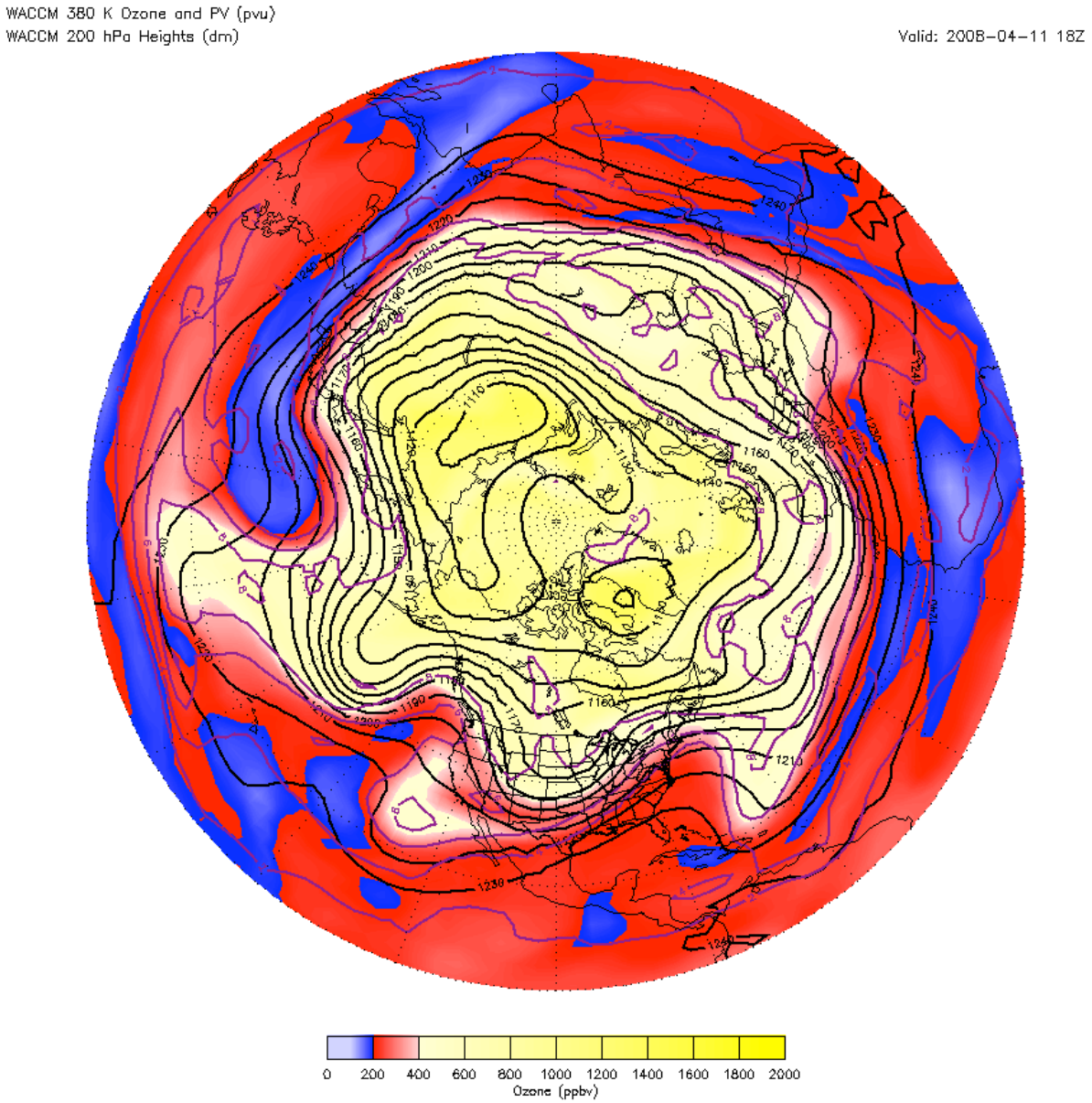
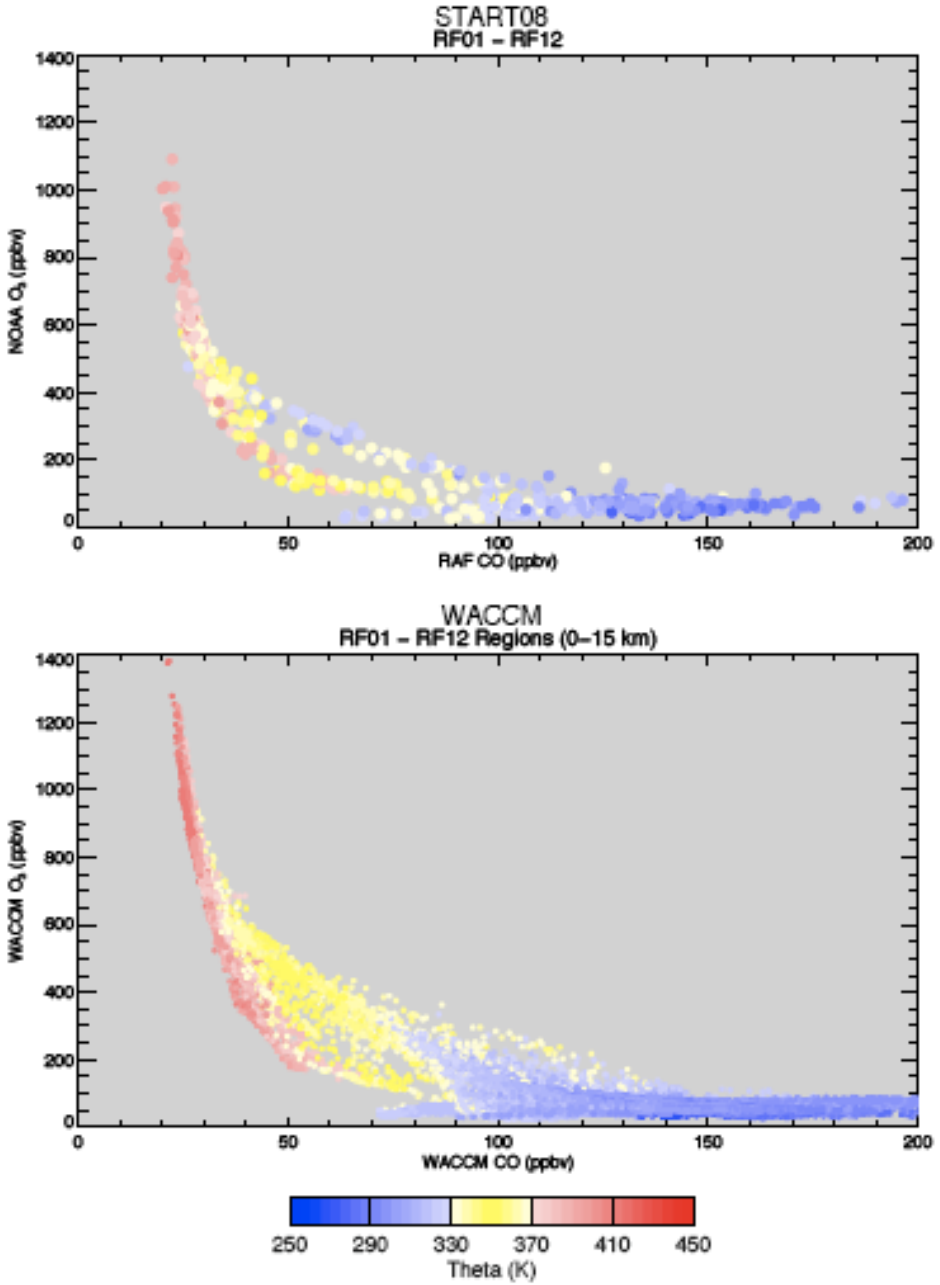


Table 2. Trace gas measurements from the HAIS AWAS and PANTHER/UCATS instruments.

	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 compounds		
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 ($CH_3C(O)OONO_2$)	✓	
Nonmethane 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)	✓	

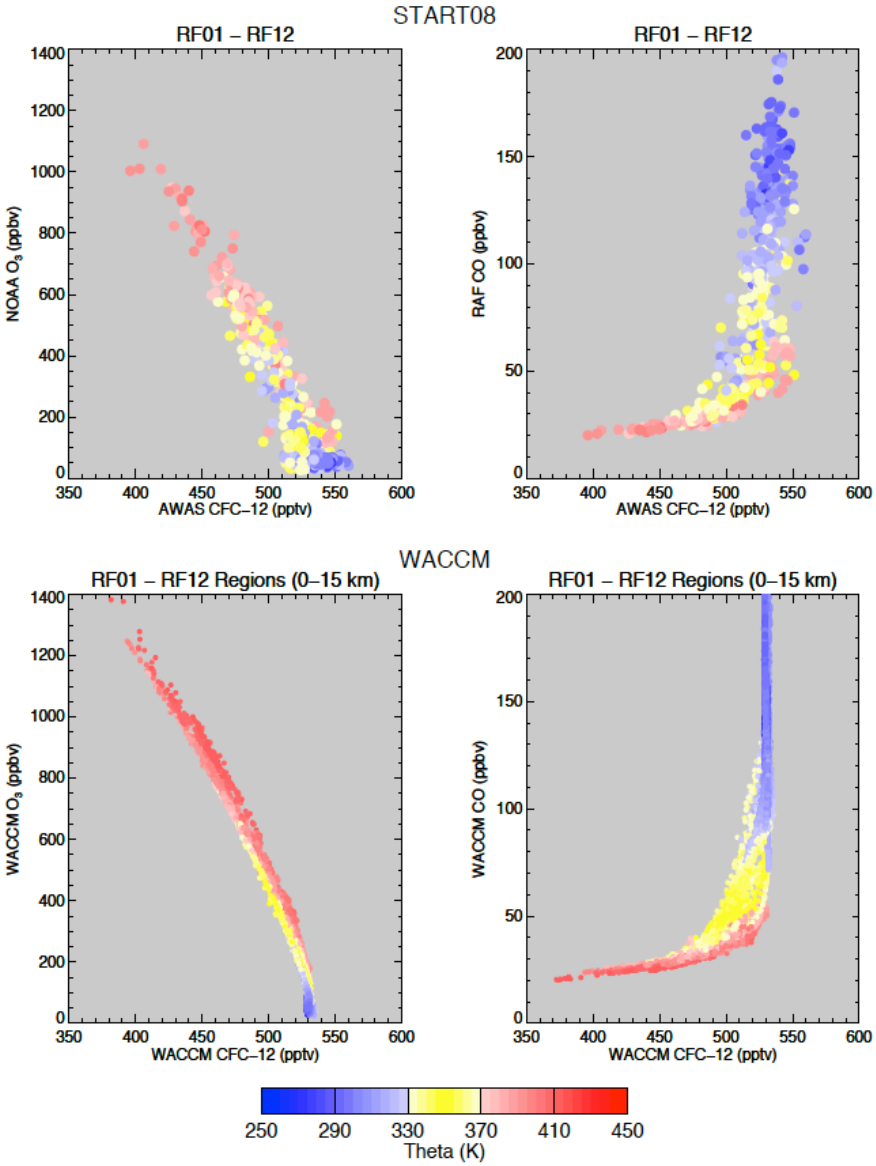
Ozone vs. Carbon Monoxide



Laura Pan, Feb 22, 2010

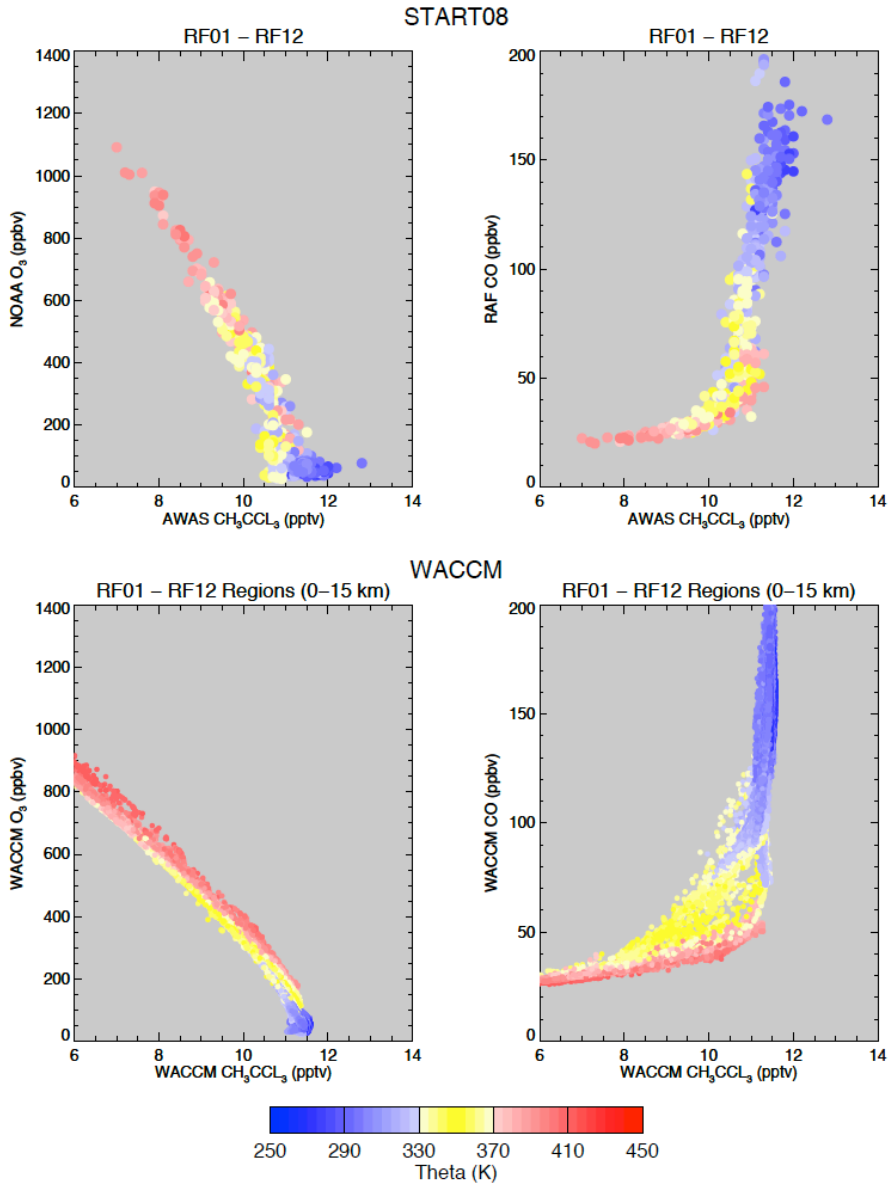
Chlorofluorocarbons

Dichlorodifluoromethane



Solvents

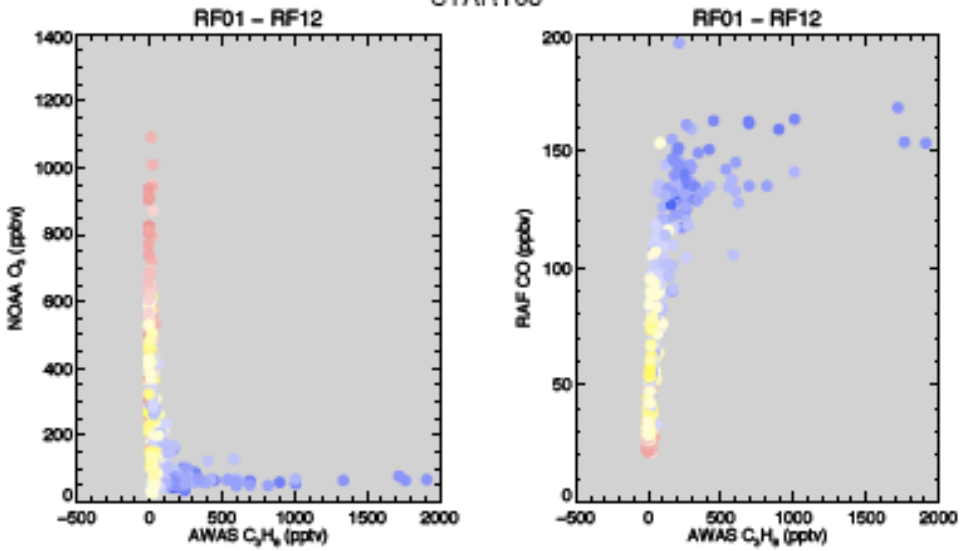
Methyl Chloroform



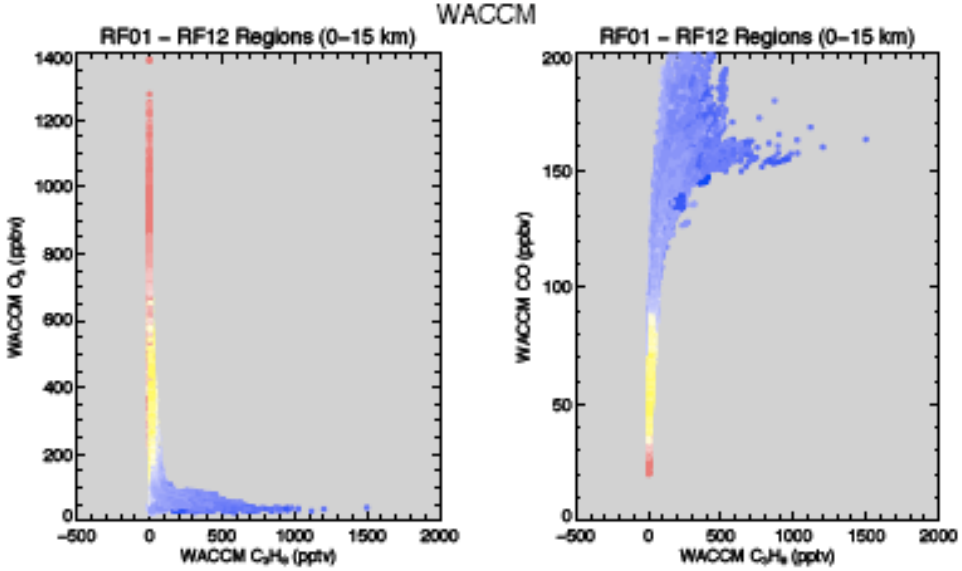
Non–Methane Hydrocarbons

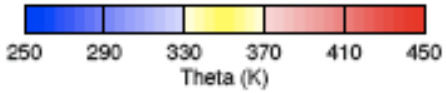
Propane

START08



WACCM

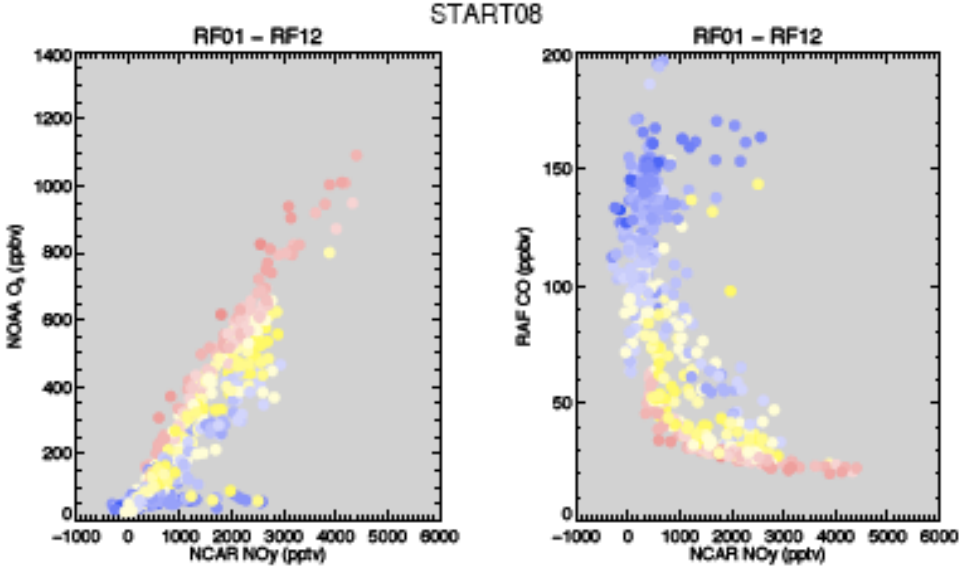




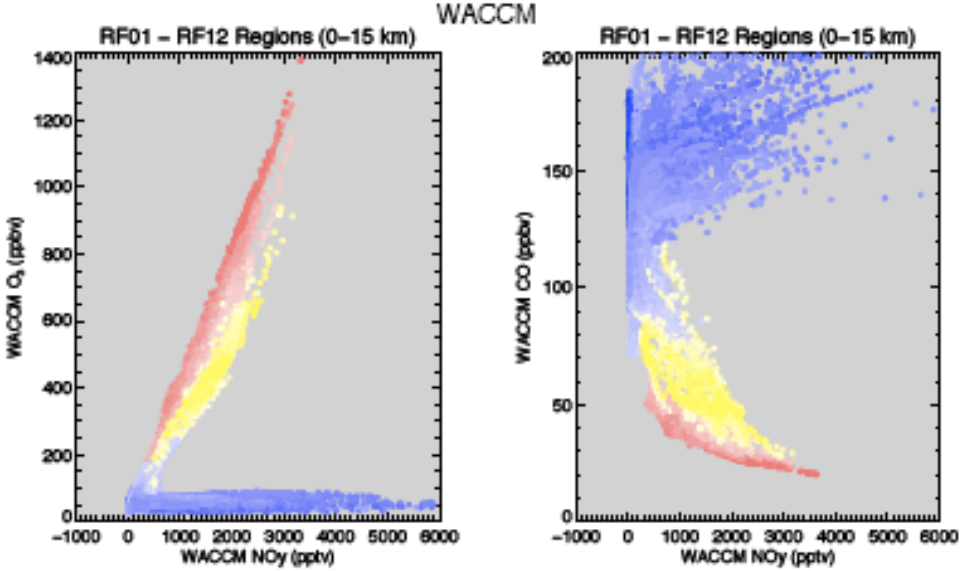
Other

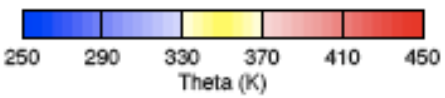
Total Odd Nitrogen (NOy)

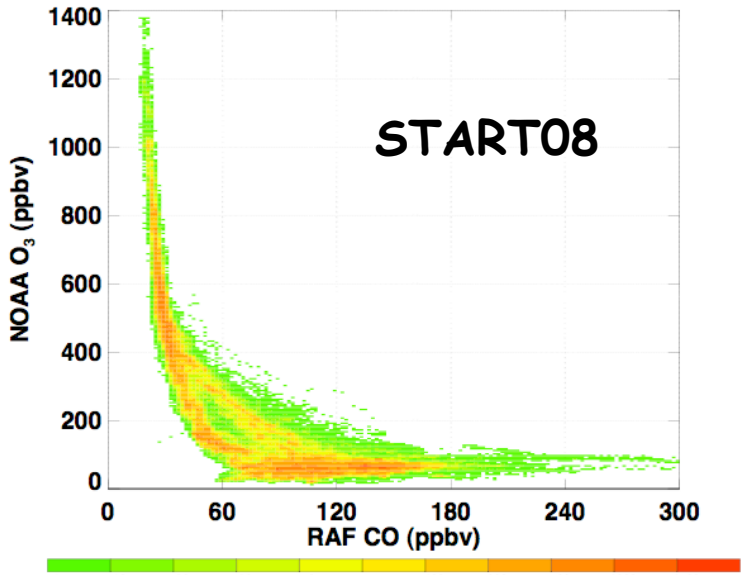
START08

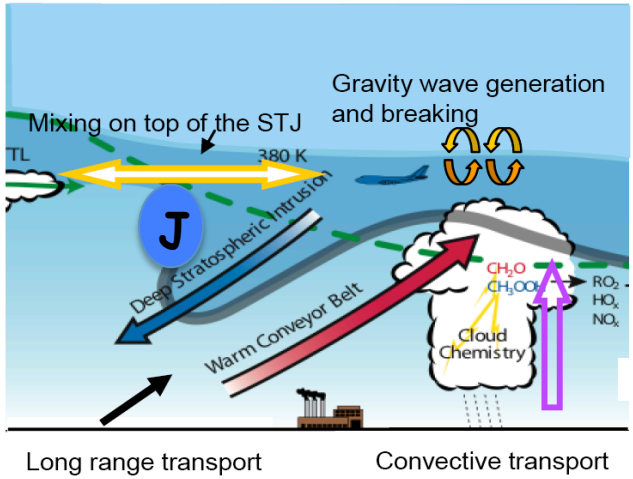


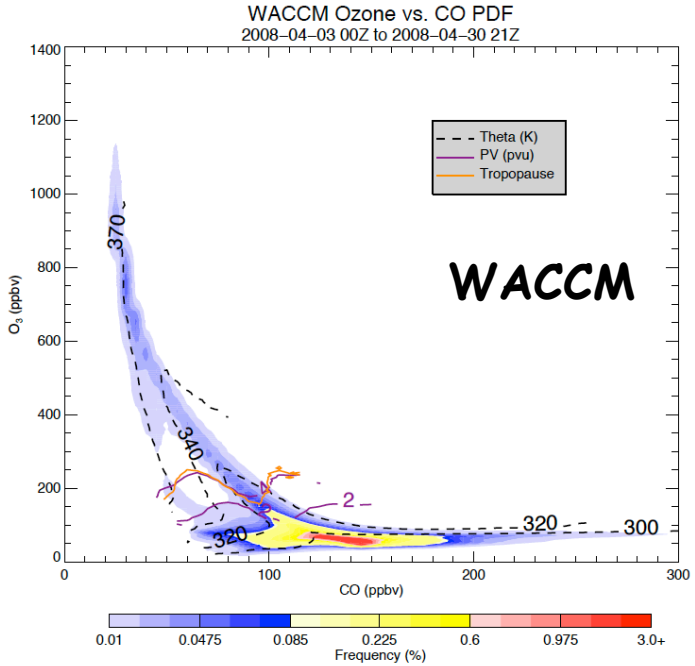
WACCM

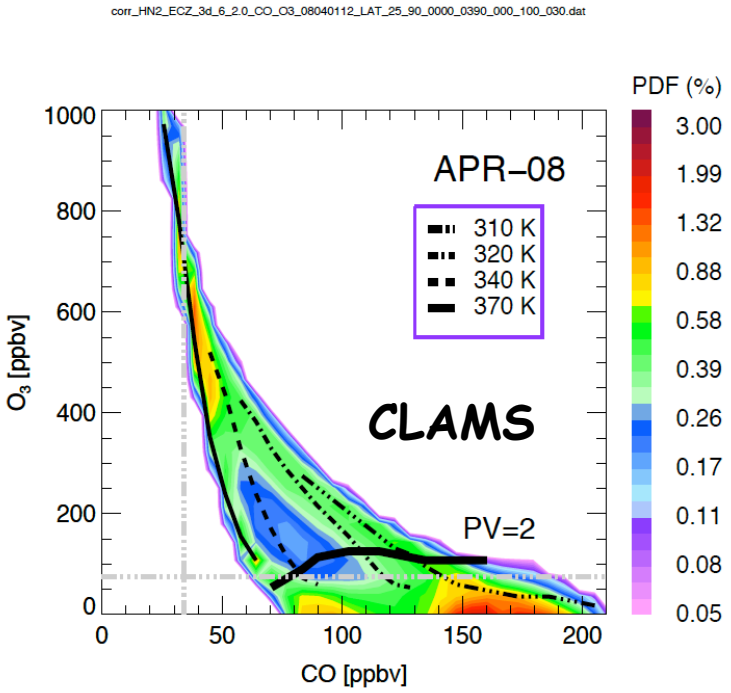





START08
NOAA O_3 (ppbv)
RAF CO (ppbv)
0
200
400
600
800
1000
1200
1400
0
60
120
180
240
300


Mixing on top of the STJ
Gravity wave generation and breaking
TTL
380 K
J
Deep Stratospheric Intrusion
Warm Conveyor Belt
Cloud Chemistry
CH_2O
CH_3OOH
RO_2
HO_x
NO_x
Long range transport
Convective transport


WACCM Ozone vs. CO PDF
2008–04–03 00Z to 2008–04–30 21Z
Theta (K)
PV (pvu)
Tropopause
WACCM
370
340
320
320
300
2
O_3 (ppbv)
CO (ppbv)
0
200
400
600
800
1000
1200
1400
0
100
200
300
0.01
0.0475
0.085
0.225
0.6
0.975
3.0+
Frequency (%)


corr_HN2_ECZ_3d_6_2.0_CO_O3_08040112_LAT_25_90_0000_0390_000_100_030.dat
APR–08
310 K
320 K
340 K
370 K
CLAMS
PV=2
O_3 [ppbv]
CO [ppbv]
0
200
400
600
800
1000
0
50
100
150
200
PDF (%)
3.00
1.99
1.32
0.88
0.58
0.39
0.26
0.17
0.11
0.08
0.05

Forward from here…

- Selected tracer diagnostics for transport and chemistry
- Impact of the resolutions -
  - nudged run with the full GOES-5 res. (0.5x0.5)?
  - High vertical resolutions?
  - What can we learn from these runs?
- Lagrangian vs Eularian
  - CLAMS runs with WACCM winds