Stratosphere-Troposphere Analyses of Regional Transport Experiment

(START08)

Overview

Laura Pan

Outline

- Motivations of the START08 -UTLS initiative goals, CCMVal needs
- Objectives – primary and secondary
- Scientific questions
- Planned GV investigations
- Satellite data and modeling activities

Motivations I: UTLS initiative goals

- **NCAR UTLS initiative – Integrated studies of coupled dynamics, chemistry, microphysics and radiation in the UTLS region (formed since 2003)**

- **Important role of the UTLS region in the Earth system**

  - **Water vapor, ozone, clouds and aerosols – species of significant climate impact, their distribution and variability are controlled by:**

  - **Transport and mixing – dynamical processes of a range of scales (planetary – synoptic – meso)**

  - **Transformation– Multi-phase chemistry and cloud microphysics**

UTLS Initiative Goals, cont.

- **Climate-chemistry interaction**
  - How do multi-scale dynamics (i.e., stratospheric circulation and tropospheric weather systems), controls chemical and microphysical distribution of UTLS in a changing climate?

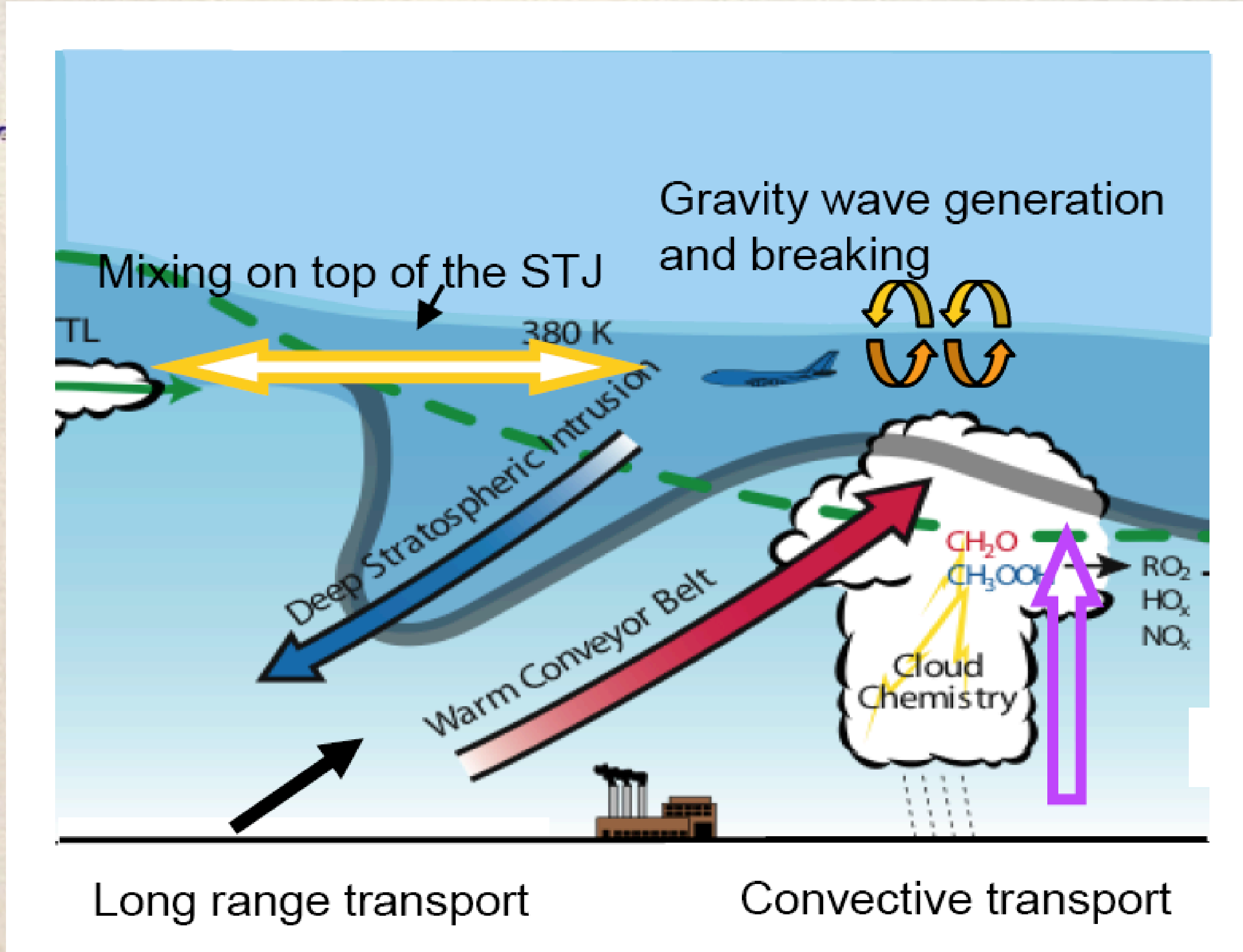
- **HIAPER infrastructure**
  - the need of instrumentation development for the new platform
  - the need of exercises to put chemistry instruments on the plane.
  - the need for experiences of challenging flight patterns

Motivations II: CCMVal

Process-oriented validation for the Chemistry-Climate Models (CCMs) (SPARC)

- How well is the new generation of CCMs representing the coupled dynamics and chemistry in the UTLS?
- How do we use the sparsely sampled aircraft data to form a climatology and to provide model diagnostics?
- What are key observations that can provide the diagnostics needed?

Transport Boundaries and Pathways in the Ex-UTLS



Primary Objectives of START08

- Investigate key transport processes that impact the chemical-microphysical distribution of the Ex-UTLS

- Characterize the transport boundaries and transport pathways in the Ex-UTLS using tracer-tracer correlations

Secondary Objectives

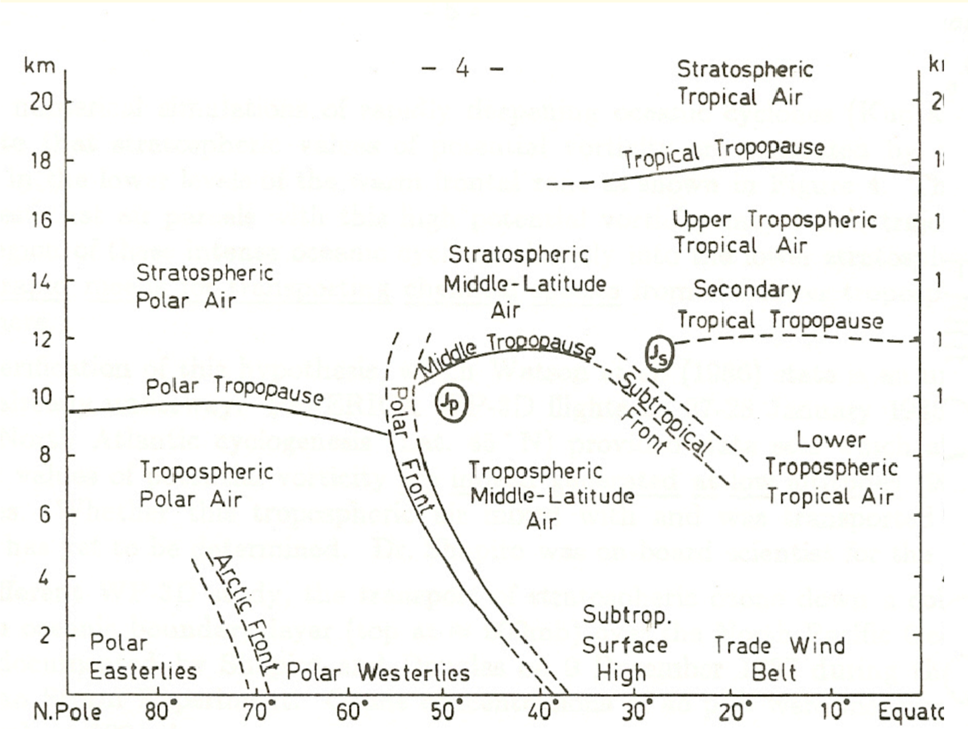
- Assist in the development and testing of the HIAPER aircraft payload and flight capabilities.

Scientific Questions I:
Transport Boundaries in the Ex-UTLS
(*i.e.*, the tropopause)

- **Are there discontinuities the structure of the Ex-UTLS composition?**
- **How well do the various tropopause definitions locate the chemical and microphysical discontinuities between UT and LS?**
- **Is the extratropical tropopause better characterized as a surface or a layer? ExTL?**
- **If a layer, how do we identify/define it? What controls its existence/depth?**
- **What is the lifetime of the air mass associated with the ExTL? Stratospheric age spectrum? Photochemical age?**

Historical Models of the Tropopause

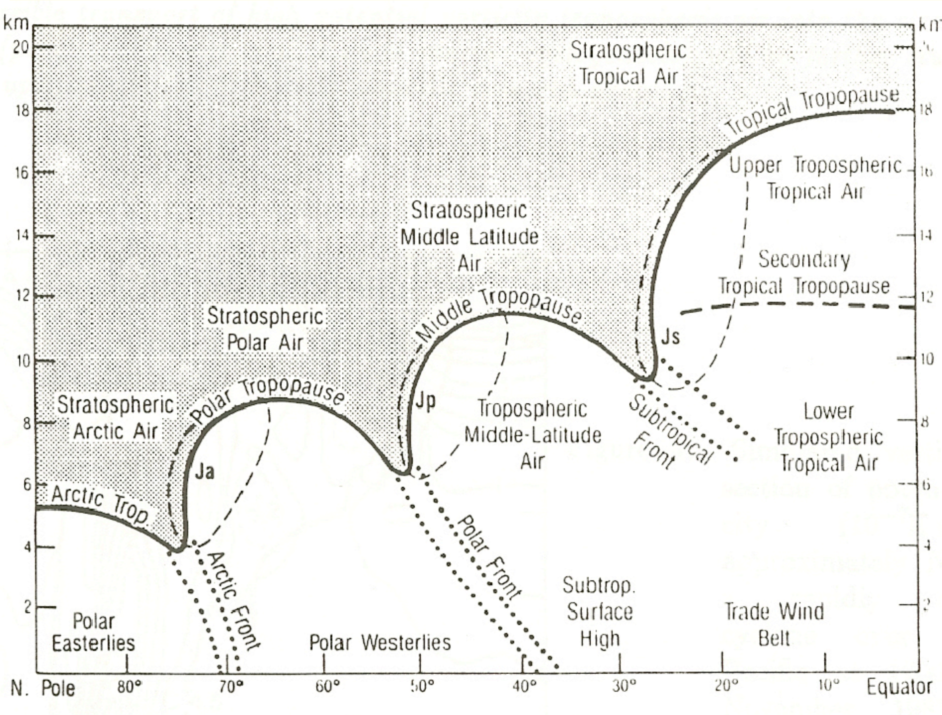
"The Thermal Tropopause"



Palmen & Newton, 1969

(WMO, 1957)

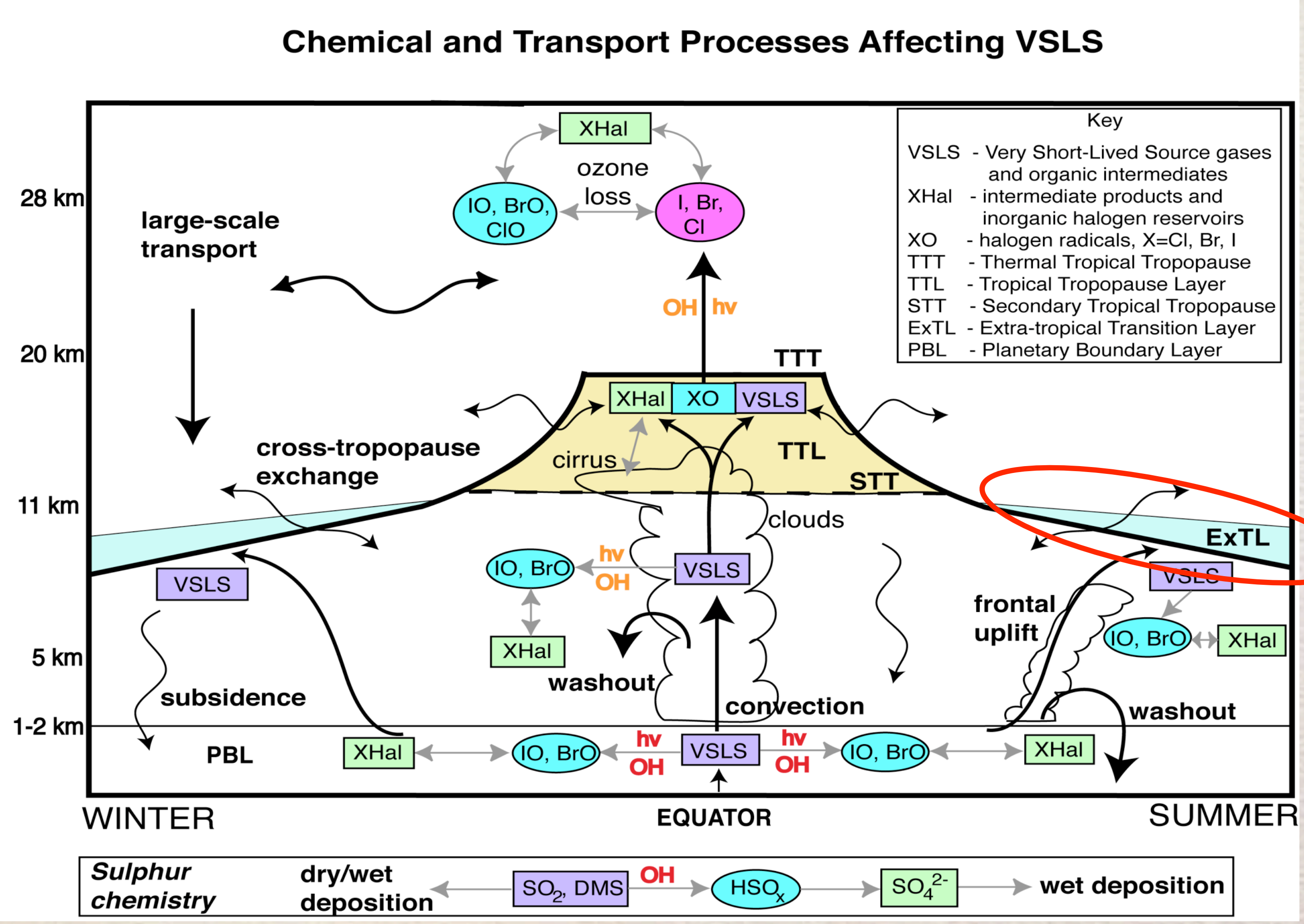
"The Dynamical Tropopause"



Shapiro & Keyser, 1990

(Reed, 1955, Shapiro, 1980; Danielsen etal., 1987; WMO, 1986; Holton et al., 1995;…)

Extratropical Transition Layer – ExTL?



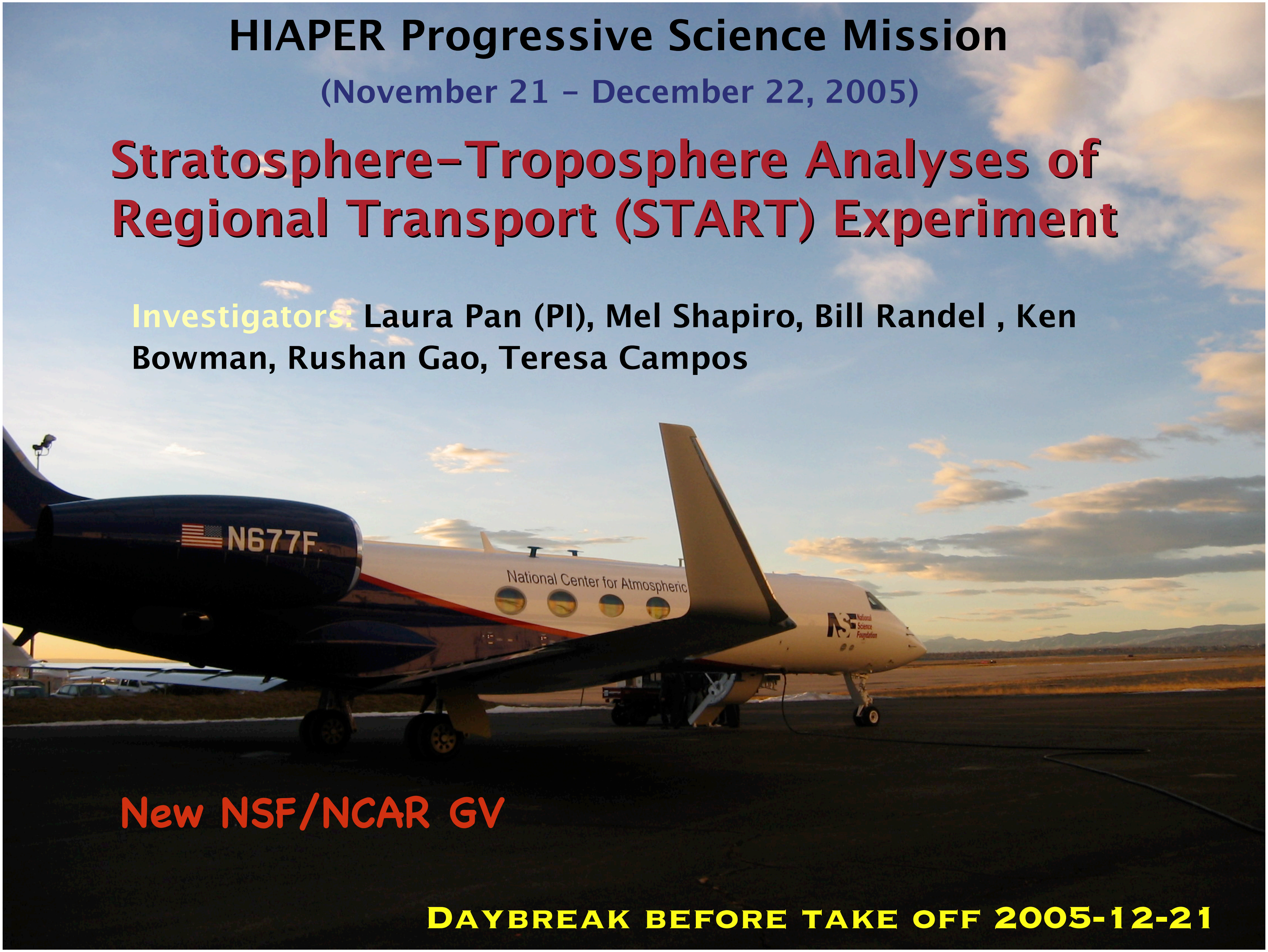
Adapted from Chapter 2 WMO (2002), Law, Cox & Haynes

HIAPER Progressive Science Mission

(November 21 - December 22, 2005)

Stratosphere-Troposphere Analyses of Regional Transport (START) Experiment

Investigators: Laura Pan (PI), Mel Shapiro, Bill Randel , Ken Bowman, Rushan Gao, Teresa Campos



New NSF/NCAR GV

Daybreak before take off 2005-12-21

Results from START05 (Pan et al., 2007)

(How does the tropopause behave as a chemical transport boundary?)

- In the region of cyclonic flow, the tropopause is a lesser transport barrier
- The disagreement of the two definitions highlights the locations of indefinite tropopause and preferred mixing
- The tropopause (or ExTL) does not have a uniform "sharpness/thickness" everywhere

Expectations for START08

Characterizing ExTL: wide range of met conditions and large suit of tracers

Scientific Questions II:

STE and Transport pathways in the Ex-UTLS

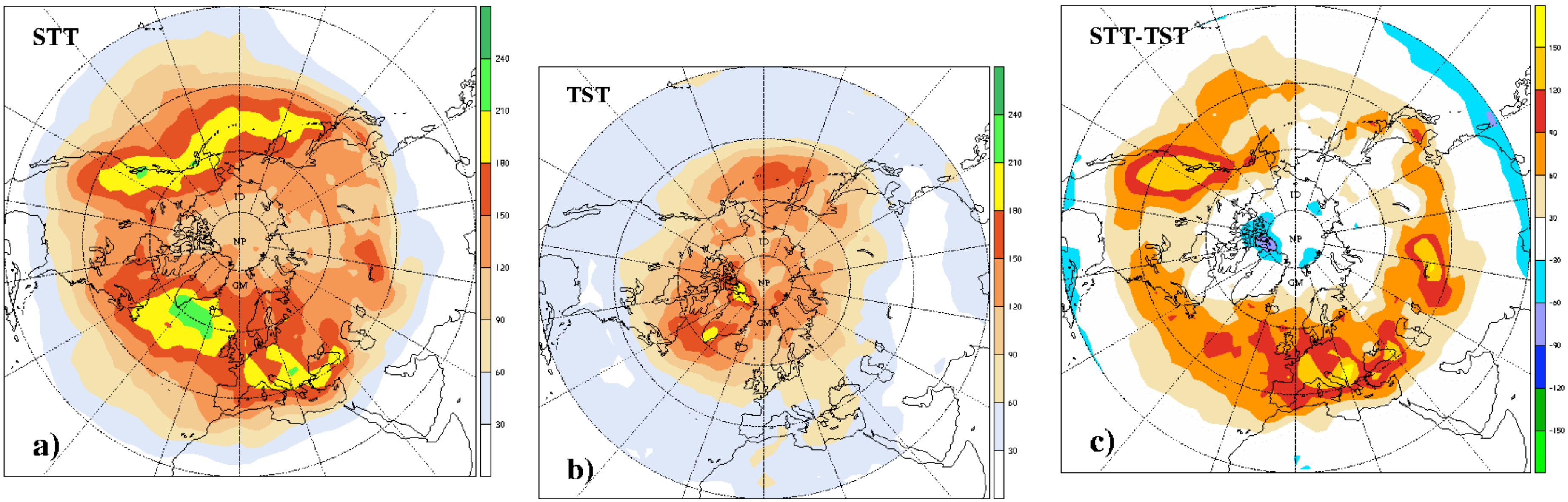
How do we characterize or quantify STE?

- **STE is an old problem, but quantitative study has been difficult**
  - **Large differences in estimated flux from different methods and transport boundaries used**
- **Is flux the right number to go after? (not an observable)**
- **What are the right observables to quantify?**
- **Latest progress largely based on meteorological analyses *i.e.,* trajectory calculations and PV streamers (Wernli, Bourqui, Sprenger and colleagues)**
- **These analyses largely focused on the lower half of the lowermost stratosphere (350K or lower)**
- **Information on chemical impact is lacking**

Trajectory/Residence time based STE

ERA15 climatology

Annual mean geographical distribution of mass fluxes



Net (STT-TST): pos. in mid-latitudes
weakly neg. in Arctic / subtropics
maxima towards end of storm-tracks

Sprenger and Wernli 2003 (JGR)

Spatial distribution of the stratospheric/tropospheric streamers

Wernli and Sprenger, 2007

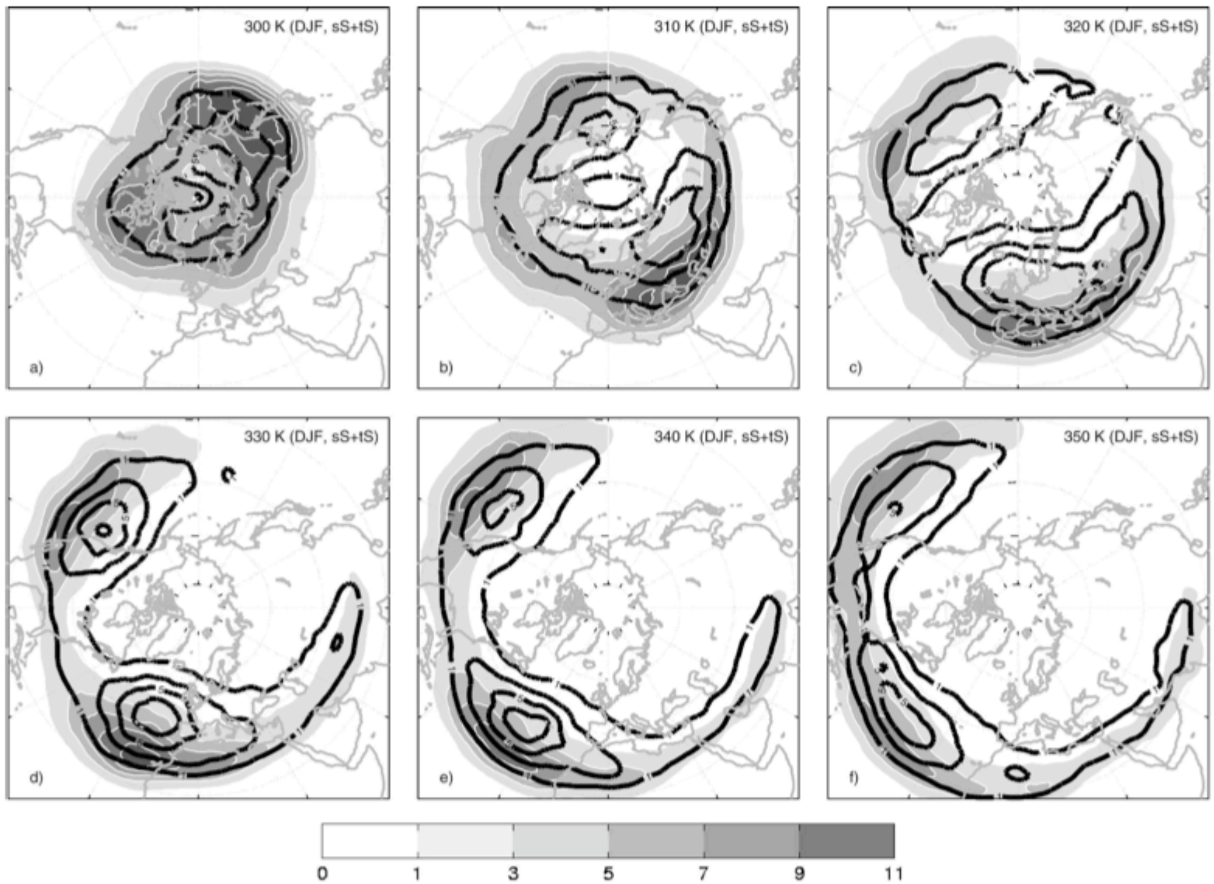


FIG. 4. Winter mean frequency (%) of streamers on (a) 300, (b) 310, (c) 320, (d) 330, (e) 340, and (f) 350 K for the ERA-15 time period of 1979–93. Gray shading is for stratospheric streamers and contours are for tropospheric streamers [contour interval (CI) is 2% starting from 1%].

Residence time based mass flux calculations, sensitivities to the choice of transport boundary

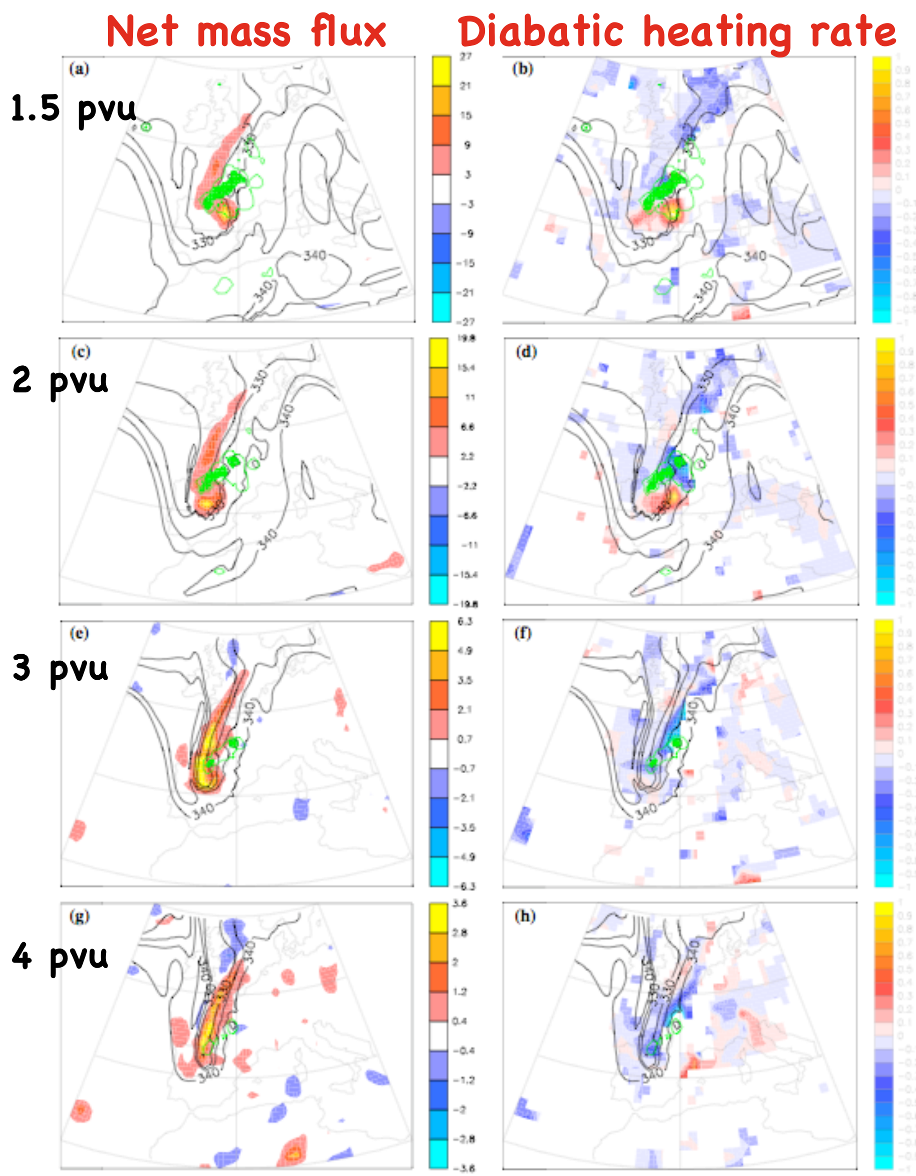


Fig. 10. Left: Estimated net mass flux (STT-TST), for the period 1 September 12:00–24:00 UTC, in $10^{-3}\,kg\,s^{-1}\,m^{-2}$, across different iso-PV surfaces: **(a)** 1.5 PVU, **(c)** 2 PVU, **(e)** 3 PVU, **(g)** 4 PVU. Right: Diabatic heating rates (K/h) calculated at the exchange location by differentiating the potential temperature along each trajectory. Bold lines represent the 325, 330, 335 and 340 K isentropic contours at the corresponding PV surface on 1 September 13:00 UTC. Green lines: Cloud water content contours for 0.05×10^{-5} at the corresponding PV surface at 13:00 UTC. Green shaded regions: Cloud water content larger than 1×10^{-5} kg/kg at the corresponding PV surface at 13:00 UTC.

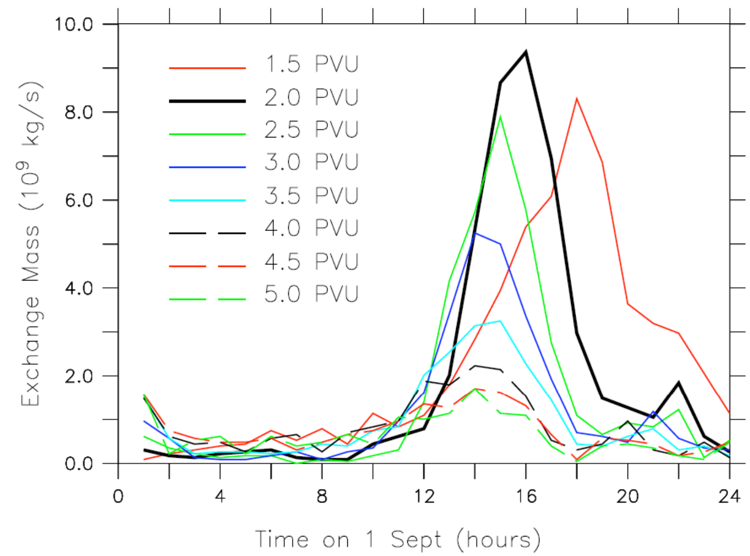


Fig. 9. Hourly evolution of the STT mass flux at various PV levels for the period 1 September 00:00–24:00 UTC within the zone of large STT associated with the streamer break-up (see Fig. 4b). Mass flux is in units of $10^9\,kg\,s^{-1}$, integrated over the domain 10 W–0 E, 39 N–50 N.

Bourqui, 2006

START08 Strategy

Right questions first, then right answers

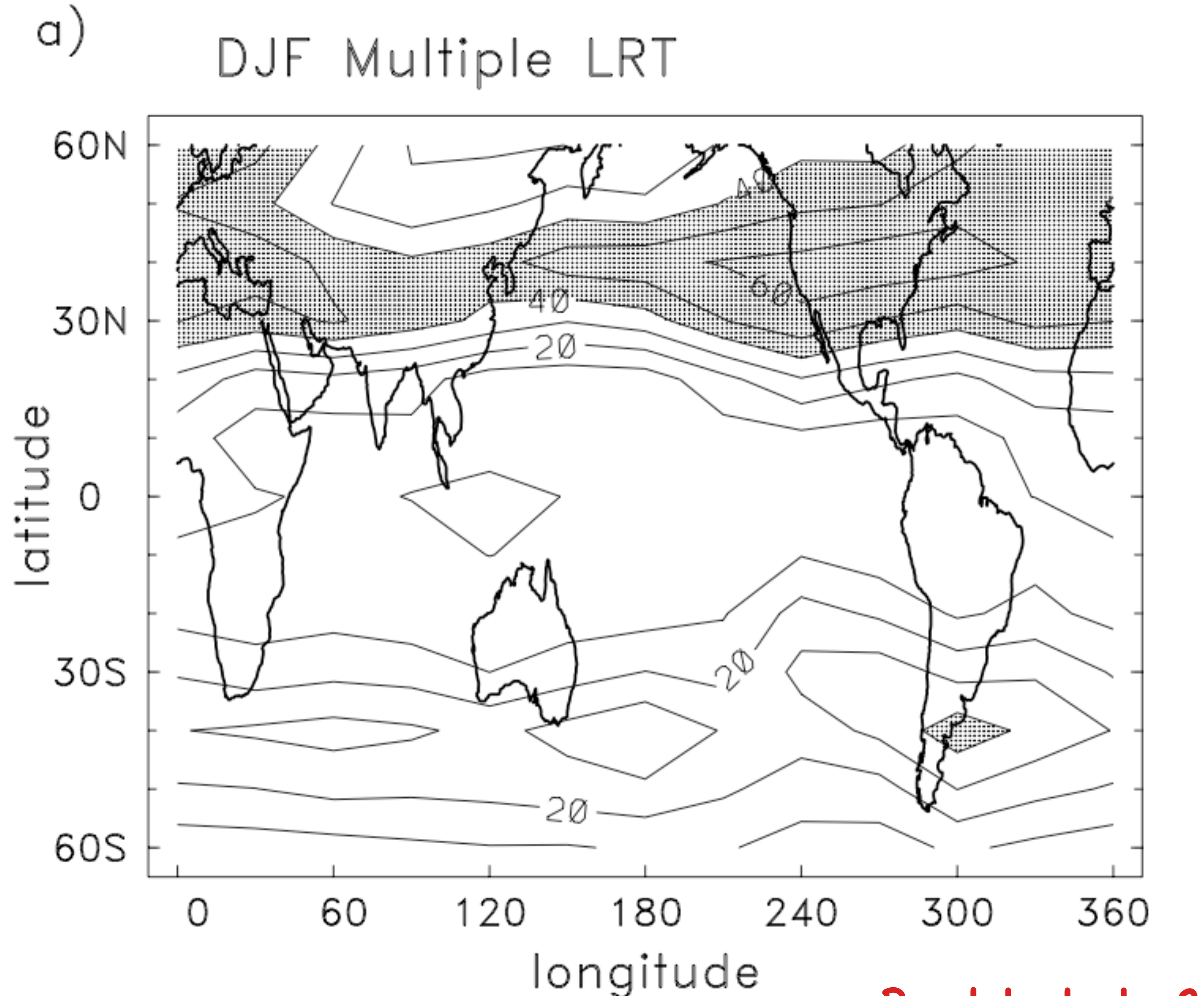
- Identify key observables (dynamical variability, tracer correlations, age spectrum…)
- Use physical evidence to identify the transport boundary
- Relate dynamical variables to chemical compositions (for example, what is PV-ozone correlation in the tropopause region? How is it vary with space (lat/isentropes) and time (seasons) ? The role of other dynamical variables?)

Scientific Questions III:

The Behavior of the Secondary Tropopause

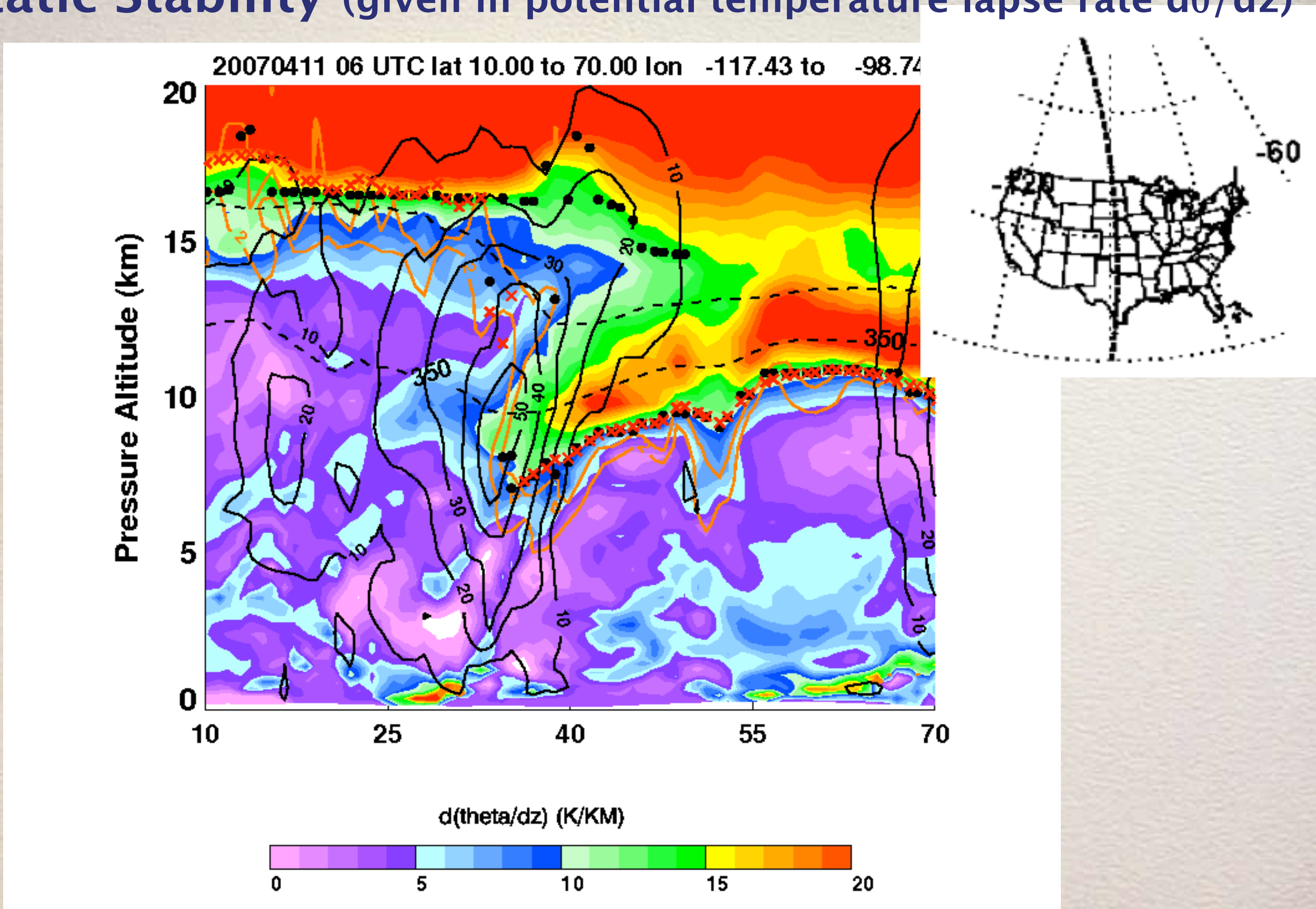
- Does the secondary tropopause derived from the WMO definition have physical meaning?
- Are there chemical transport processes associated with the secondary tropopause?
- What are the microphysical behavior of the region of multiple tropopauses?
- What dynamical processes control or contribute to the occurrence of the secondary tropopause?

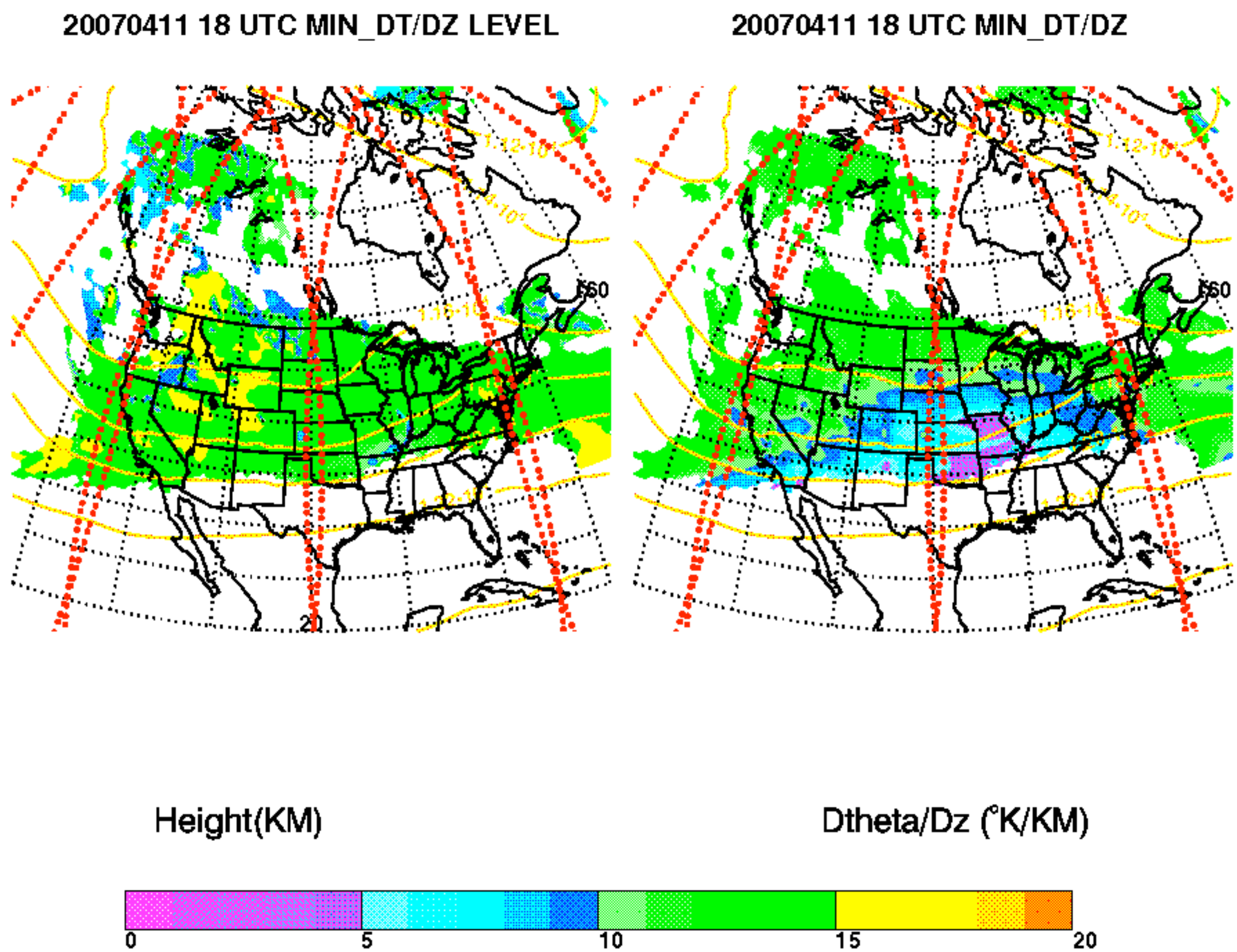
Extensive/frequent occurrence of the multiple tropopause



Randel et al., 2007

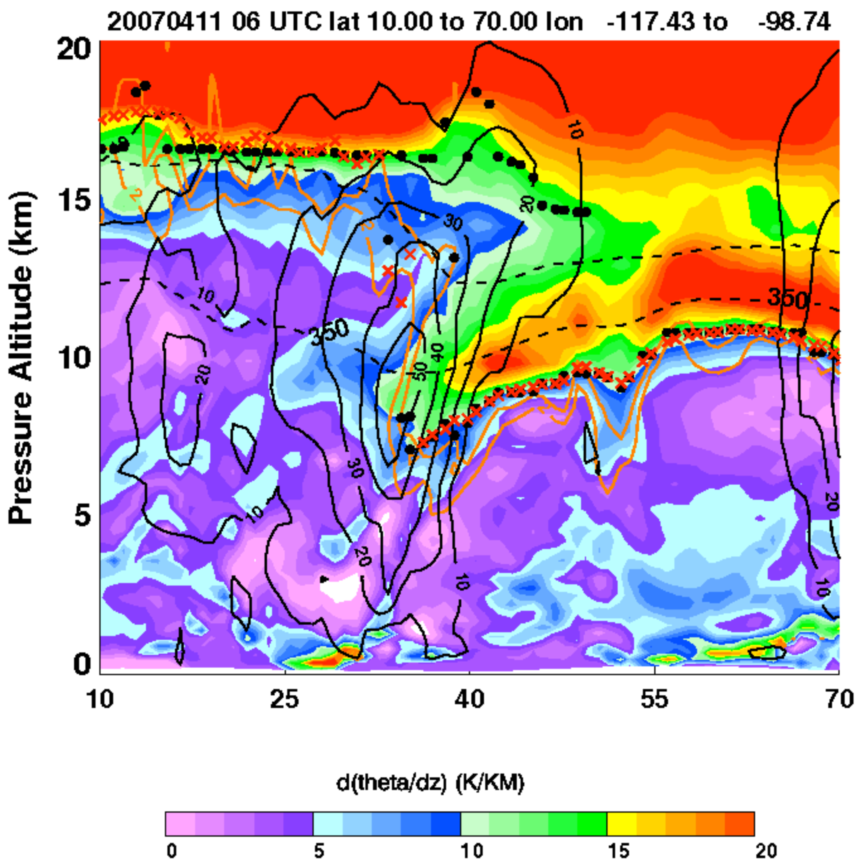
Static Stability (given in potential temperature lapse rate dθ/dz)

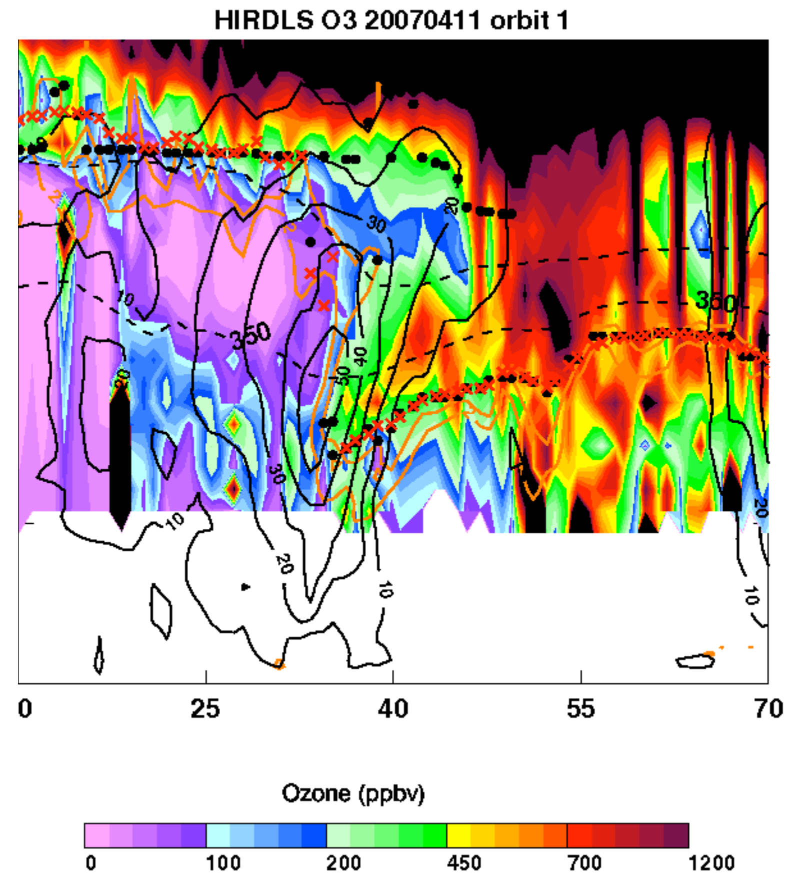


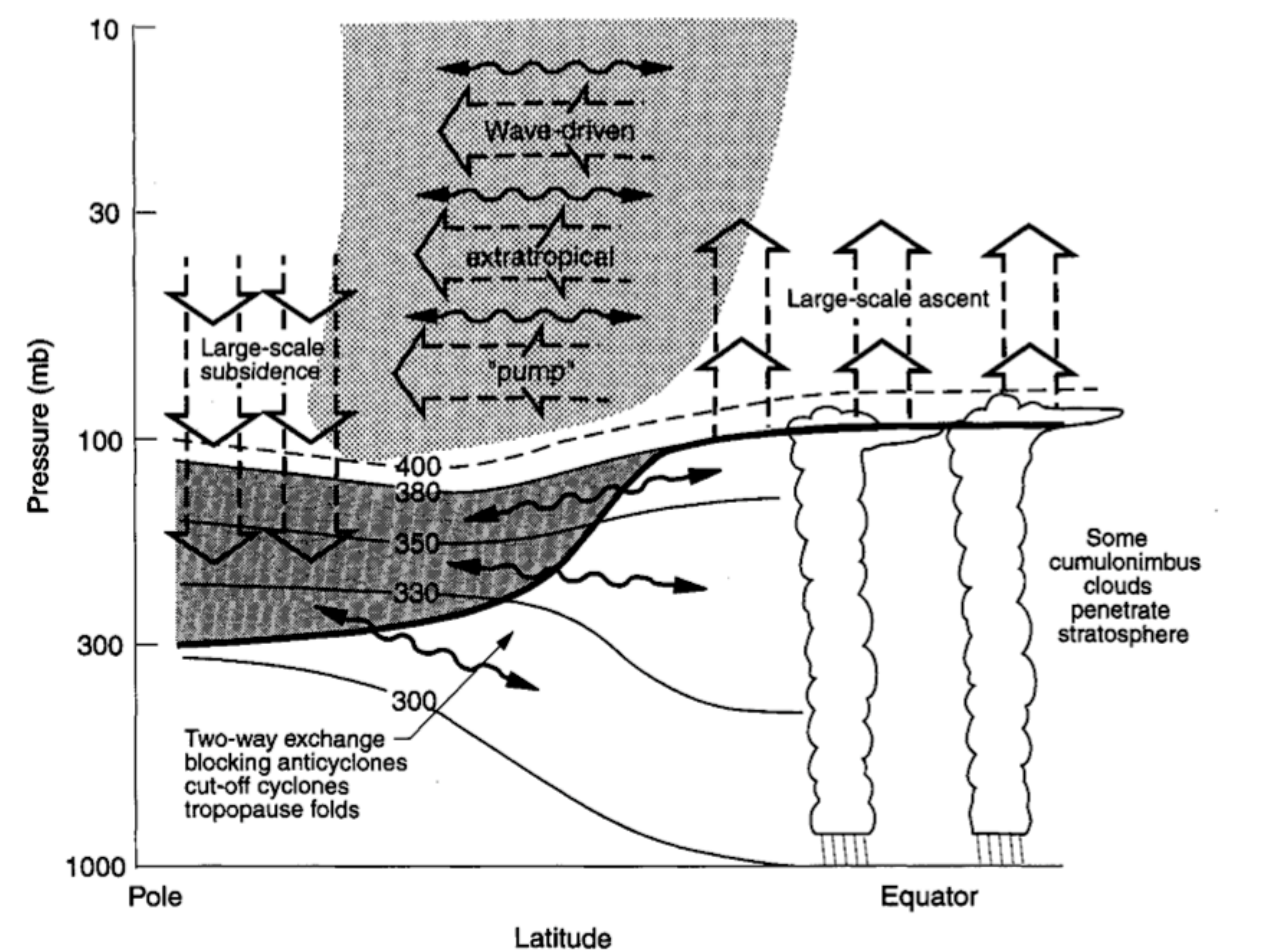


20070411 18 UTC MIN_DT/DZ LEVEL
20070411 18 UTC MIN_DT/DZ
Height(KM)
Dtheta/Dz (°K/KM)
0
5
10
15
20

GFS dθ/dz and HIRDLS Ozone






10
30
100
300
1000
Pressure (mb)
Wave-driven
extratropical
"pump"
Large-scale subsidence
Large-scale ascent
400
380
350
330
300
Some cumulonimbus clouds penetrate stratosphere
Two-way exchange
blocking anticyclones
cut-off cyclones
tropopause folds
Pole
Equator
Latitude

Ja

Microphysical implications of the secondary tropopause?

Noel and Haeffelin, 2007

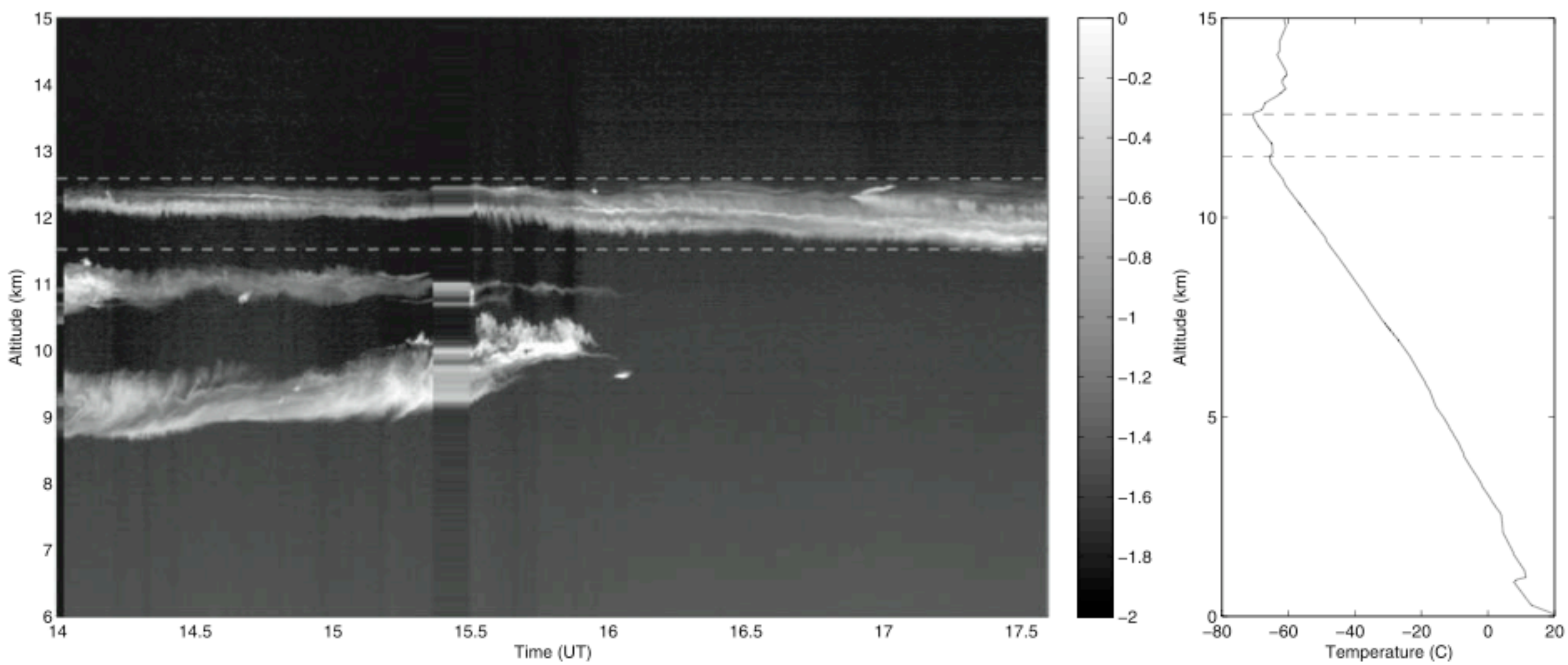


Figure 5. (a) Backscattering coefficients observed by the LNA lidar on 17 March 2005 as a function of time and altitude, using a logarithmic color scale. (b) Temperature profile from radiosoundings on 17 March 2005. On both figures, the first two tropopauses are indicated using dashed lines.

Science Questions, IV:
Role of Convective Transport

- **Primarily designed to understand the capability of GV for probing active thunderstorm/deep convection, in preparation for future program (DC3)**
- **With participation of cloud resolving models, tracer transport and STE by deep convective storms can be studied using the measurements**
- **May be able to estimate NO production by lightening**

Science Questions V:

Role of gravity waves (GW) in the structure and composition of Ex-UTLS

- **How well do the state-of-art mesoscale models predict the excitation of GW by jet/fronts?**
- **What is the evidence of GW breaking in tracer measurements and the contribution of GW breaking to mixing?**

START08 Measurements I: GV payload

Instrument/Model	*Data product*	*Mission Objective*
HAIS Twin QCL	High resolution CO, CO2, CH4, N2O	Tracer studies
HAIS AWAS	Grab sampling: NMHC, HCFC, RONO2, etc., etc.	Tracer studies
PANTHER GC/MS	Medium resolution: selected trace gases	Tracer studies
UCATS*	GC analysis:CO/CH4; continuous O3 – H2O	Tracer studies
NCAR/HAIS Fast O3	>1 Hz ozone measurement	Strat-trop mixing
NCAR NO/NOy	High resolution NO, NOy	Strat-trop mixing, convective NO sources
RAF TDL H2O	High resolution H2O	Microphysics, strat-trop processes
HAIS SID-2	Small ice particle detector	Cirrus microphysics
HAIS MTP	Atmospheric temperature structure	Strat-trop processes; tropopause location
CU-CLH	Total water measurement; thin cloud detection	Microphysics, strat-trop processes
NCAR O2:N2	Measure of O2:N2 ratio	Strat-trop exchange; carbon cycle objective
NCAR CO		

START08 measurements II:
GV Sampling Strategy

Six flight scenarios in planning (details and discussions on Wed)

1. Extratropical Tropopause and transition layer (ExTP/ExTL) Survey
2. Stratospheric intrusion (tropopause fold)
3. Tropospheric intrusion (poleward into lower stratosphere)
4. Convective transport
5. Gravity wave
6. Cirrus layer (single or multiple) near the tropopause

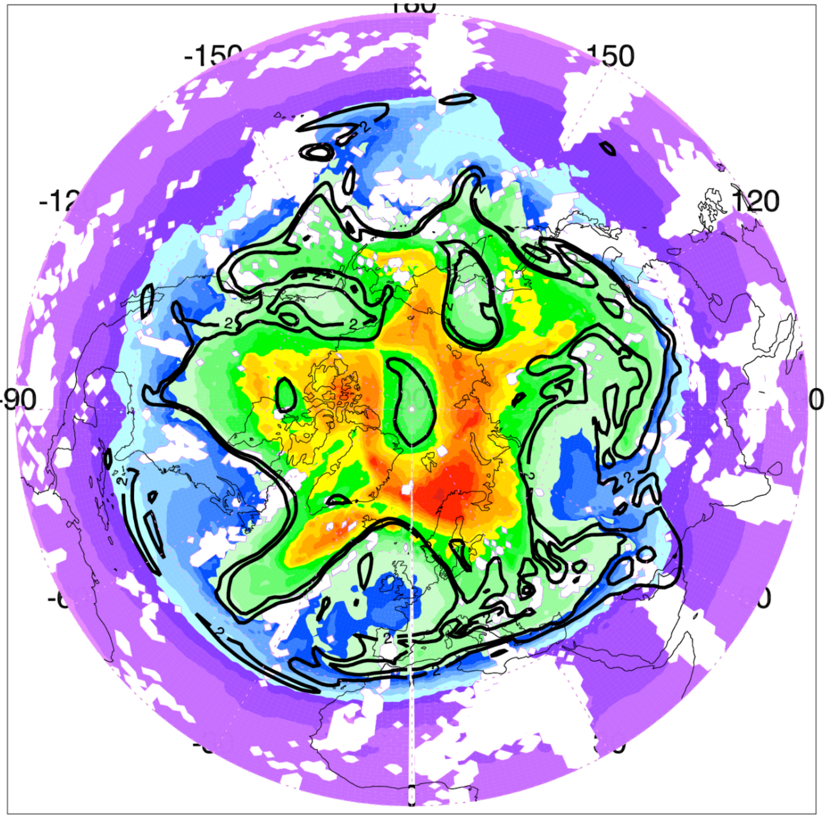
Satellite data

- Participations NRT: HIRDLS, MLS, AIRS/IASI, CALIPSO (TBD)
- Two way interactions: inter-comparison for evaluating satellite data and expand the impact of a/c data
- More discussions on Wednesday

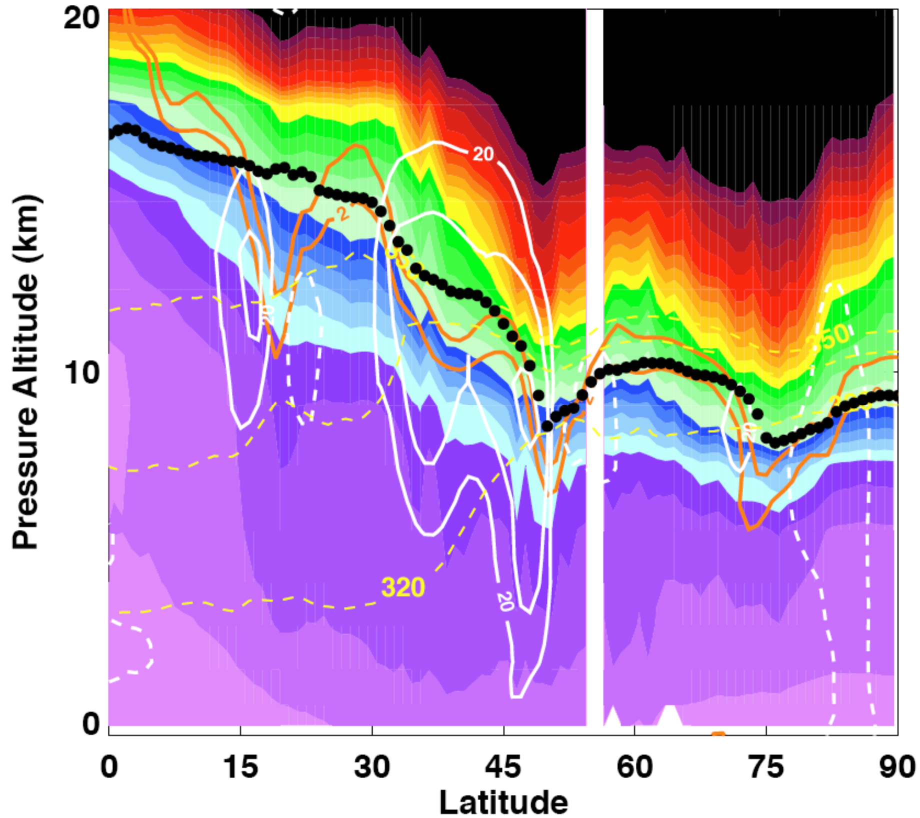
AIRS Level 3 Ozone, May 15, 2004

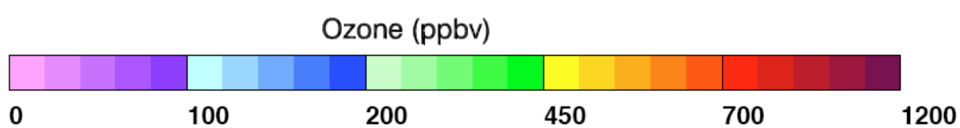
Version 5 retrieval, 1x1 degree average   met field NCEP FNL 1x1 degree

250 hPa



160 E Lon





START08 Modeling Activities

Models involved:

- WACCM (Doug Kinnison, Simone Tilmes, Andrew Gettelman)
- CLaMs (Paul Konopka, Bill Hall)
- Idealized GCM (Lorenzo Polvani)
- Trajectory model (Kenneth Bowman)
- WRF/MM5 (Fuqing Zhang and students)
- Possible involvement of cloud resolving models (Ken Pickering and Pao Wang)

Thank You !

Looking forward to your questions, comments, and your contributions to the project!

Shadows of Monument Valley - GV Flight 051209