UTLS Transport Associated with the Asian Summer Monsoon
A model Investigation and Hypotheses for in situ Observations

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ASM Anticyclone: a dominant system at the UTLS level during NH Summer

HCN from ACE Satellite (JJA, 16.5 km) [Randel et al., 2010]

CPT Hgt from COSMIC GPS data JJA [Munchak and Pan, 2014]

Highest and Coldest Tropopause in JJA
Motivations of this study

• **Pre-Campaign Study**
  - Identify what airborne studies can do to fill in the gaps in our understanding of the ASM transport process
  - Initiated for the SEAC4RS airborne study and now the StratoClim.

• **Gaps of understanding from satellite and Lagrangian model studies:**
  - Satellite studies mostly show seasonal, multi-year aggregated impact of the ASM at UTLS level
  - Lagrangian/Trajectory model studies have contributed information of transport pathways but have little information on chemical impact

• **Identify key questions and formulate hypotheses**
  - Using WACCM-SD model output
Outline:

Outstanding questions of ASM transport:

• The ASM as the most important alternative pathway (to the tropical tropopause):
  – How does ASM UT air, with enhanced BL tracers, enter the overworld stratosphere and the tropical pipe? (*chimney vs blower*)
  – What is the primary mode of transport across the ASM tropopause? Vertical and diabatically or quasi-isentropically?

• Day-to-Day variability of the UT composition:
  – How is the day-to-day variability of the UTLS composition related to the dynamical variability of the ASM anticyclone? (*confinement and shedding*)

• The transport processes control the uplifting from BL to UT:
  – What is the role of large scale ascent vs convective lifting? How do we diagnose the role of the two processes?
  – Where and how the BL CO (surrogates of pollutants) is pumped up to the near 400 K level near the ASM tropopause? (*Is there a “conduit”? what are the leading physical processes that created the “conduit”?*)
Pathway for Pollutants Transport into the Stratosphere

Overturning circulation “B-D”

“Tropical Pipe”

Global diffuser

Randel et al., 2010
Transport by the ASM AC: a “chimney”? 

HCN from ACE Satellite (JJA, 16.5 km) 

A “chimney” or a tropospheric “bubble” in the stratosphere background?
ASM as an *Alternative* Pathway to Tropical Tropopause

Dethof et al., 1999
"chimney" or a "blower"

"Tropics" (12S-12N, 0-360E)

Following Scheoberl et al. 2003

"ASM", (15N-35N, 0-120 E)

WACCM-SD, 11 year mean (2000-2010)
“Blower” model as seen from bi-modal oscillation

ASM anticyclone: Quasi-Bi-Weekly Oscillation between two modes
Zhang et al., 2002

Fig. 2. The longitude-frequency distribution of the SAH major center during midsummer from the pentad mean data. For 15 summers there are totally 180 pentads involved in the statistics.

Fig. 3. The 100 hPa streamline composite corresponding to the TM (a) and Tibetan Mode (b)
“dynamical and chemical variability”

Quasi-Bi-Weekly Oscillation of the Anticyclone
"dynamical and chemical variability"

UT CO variability associated with the bi-modal oscillation
Enhanced CO in relation to the tropopause and easterly jet

2005/08/22 100 hPa

“confinement and shedding”
Characterization of the Anticyclone East-West Oscillation

“dynamical and chemical variability”
“dynamical and chemical variability”
Is there a “conduit”? what are the leading physical processes that creates the “conduit”?

BERGMAN ET AL.: VERTICAL CON

The vertical conduit

Anticyclone at 200 mb (100 mb)

20-50 mb below the anticyclone

Mid-tropospheric conduit

σ = 0.75

Planetary boundary layer (σ = 0.85)

Bergman et al., 2013
“Conduit?”

WACCM CO, Tibetan mode
2005/08/11

WACCM CO, Iranian mode
2005/08/18

The diagrams show the distribution of CO [ppbv] with respect to latitude (Lat) and pressure (hPa). The color bar indicates the concentration levels ranging from 0 to 200 ppbv.
“Conduit?”

WACCM CO anomaly, 11 year mean (2000-2010)

Tibetan mode

Iranian mode
WACCM 11-year Frequency of Occurrence of CO>100 ppb at every level P> 100 hPa
Summary and Conclusions

Hypotheses:

• ASM creates a “Bubble” of tropospheric air above the mean tropopause. The potential temperature of the ASM tropopause is higher than that in the equatorial tropics, which allows the air in the bubble to shed into the overworld stratosphere isentropically.

• The shedding associated with the east-west oscillation is the primary mode for filling the uplifted BL air mass in the entire anticyclone and to transport into the stratosphere.

• The ASM does not connect directly with the Brewer-Dobson ascending branch in the stratosphere. Quasi-isentropic mixing may be a key process for air getting into the “tropical pipe” or the “tape recorder” region (12S-12N) from the anticyclone (30°N).

• The deepest uplifting of the BL pollutants to the tropopause level occurs primarily at the southern edge of the Tibetan plateau, NE India and Nepal, directly north of the Bay of Bengal.
Thank you!