Deep convection over the Tibetan Plateau and global stratospheric water vapor

Jonathon Wright and Stephan Fueglistaler
Department of Applied Mathematics and Theoretical Physics
University of Cambridge

Rong Fu
Jackson School of Geosciences
University of Texas

Yan Zhang
Goddard Earth Sciences and Technology Center
University of Maryland-Baltimore County
Deep convective activity over the Tibetan Plateau

- Large CAPE accumulation: 4000-6000 J/kg (TIPEX-IOP)
- Higher LCL: 5-7.5 km

Monsoon region tropopause

- $\Theta = 380K$
- TIB :: $T = 203K$
- MON :: $T = 197K$

Tibetan Plateau tropopause

- $\Theta = 360K$
- lower & warmer - more vapor transport

allows 7-8 ppmv more vapor at the tropopause

Fu et al., PNAS, 2006
IR cloud top temperature from CLAUS project
Aura MLS along-track water vapor and ice water content

380K (tropopause)

Water vapor has to go through the ‘cold trap’

Monsoon Region

Holton & Gettelman 2002

Water vapor transported directly to the tropopause

Tibetan Plateau

IWC (shaded, mb/m^3) and H2O (contours, ppmv)
Change of MLS water vapor from clear sky to deep convective scene

Fu et al., PNAS, 2006
The global stratospheric circulation

Deep convection over the Tibetan Plateau contributes water vapor to the local lower stratosphere

Fu et al., PNAS, 2006
The global stratospheric circulation

Does it also influence the global stratosphere?
The global stratospheric circulation

If so, what is its influence relative to other pathways?
meanwhile, at the base of the tropical pipe...

(a) 68 hPa MLS Tropical Mean Water Vapor

...there is a strong seasonal cycle in water vapor
This annual cycle propagates upward in the tape recorder
To assess the relative importance of convection over Tibet:

(a) 68 hPa MLS Tropical Mean Water Vapor

![Graph showing water vapor variations from 2004 to 2009 with shaded areas indicating annual maxima.]

- Start back trajectories at annual maximum
- NCEP/NCAR (2.5°x2.5°)
- GMAO MERRA (1.25°x1.25°)

horizontal winds and diabatic heating
To assess the relative importance of convection over Tibet:

(a) 68 hPa MLS Tropical Mean Water Vapor

end trajectories at 1 June

encompasses full monsoon season
Start back trajectories at Aura MLS observations... effectively reverse domain filling
Where do trajectories enter the deep convective detrainment zone?

$p = 215$ hPa

Similar results by:
• Intersecting with CLAUS cloud top temperatures colder than 240K (rather than $p = 215$ hPa) (2 years)
• Using the UKMO reanalysis (2 years)
Identify primary source regions...

Tibetan Plateau and South Slope
Identify primary source regions...
Identify primary source regions...
Identify primary source regions...
Identify primary source regions...
What is the relative transport from each source region?

Trajectory Fraction

NCEP/NCAR

Transit Time [days]

TIB ~ 20%
What is the relative transport from each source region?

TIB ~ 10%
Water vapor at any point is determined to leading order by its location of last saturation...

This drives the tropopause cold trap

\[ RH(x^*) = 100\% \]

\[ q(x) = q^*(x^*) \]

The Lagrangian dry point (LDP)
Reconstructing stratospheric water vapor using the LDP

Water Vapor VMR [ppmv]
TIB trajectories have systematically wetter LDPs...
...especially the fastest trajectories

NCEP/NCAR

GMAO MERRA

Frequency of Occurrence

Lagrangian Dry Point q* [ppmv]

120 days
How does the mean water vapor transport from each source region evolve?
How does the mean water vapor transport from each source region evolve?
What is the typical path from TIB to the tropical pipe?

The fraction of trajectories that pass through each gridded area during transport is 220 days.

The NCEP/NCAR dataset provides this information.
Difference [220d] - [120d]

NCEP/NCAR
What is the typical path from TIB to the tropical pipe?

220 days

GMAO MERRA
Difference [220d] - [120d]

GMAO MERRA
Summary

- 10% to 20% of the air at the base of the Brewer-Dobson circulation during the annual maximum (OND) can be traced back to the upper troposphere over the Tibetan Plateau and the South Slope of the Himalayas (TIB).

- Transport from TIB exhibits comparable or greater moisture loading relative to other source regions, according to Lagrangian dry points.

- Moisture loading depends on transit time: the most rapid transport from the TIB region provides the greatest amount of water vapor.

- These rapid trajectories stay largely trapped in the very center of the monsoon anticyclone until they are above the coldest temperatures.

- At longer transit times, trajectory moisture contents from the various source regions collapse toward a common value (~4.1 ppmv), which accurately reproduces the mean at 68 hPa according to MLS.