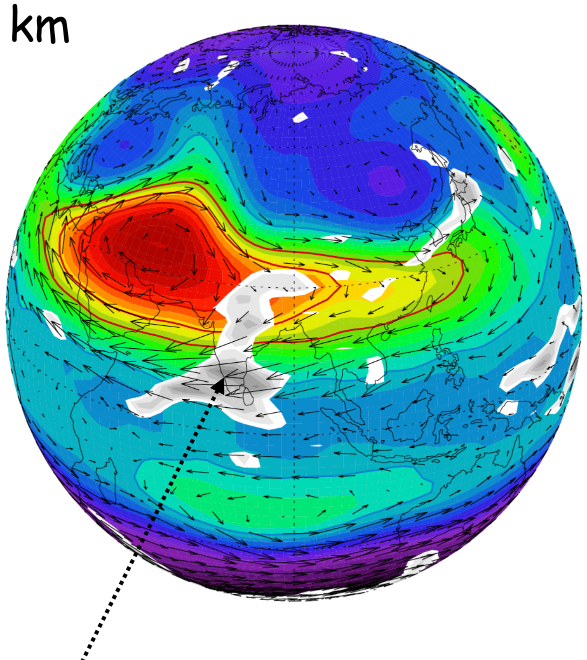
Transport and the Asian monsoon anticyclone

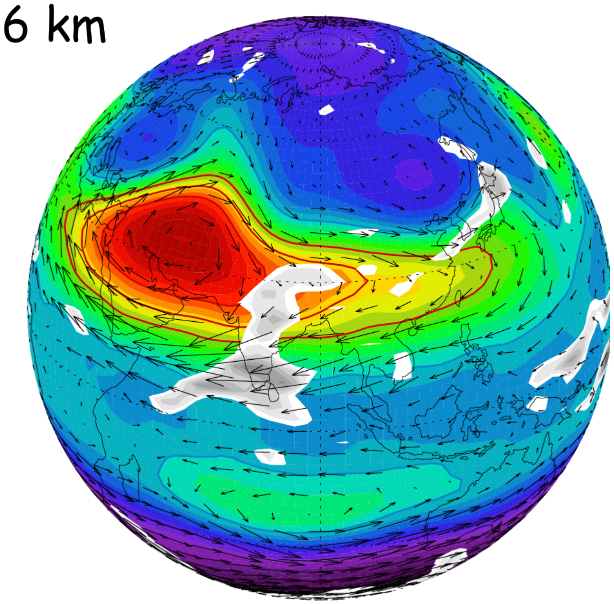
monsoon
circulation
near 16 km



deep
convection

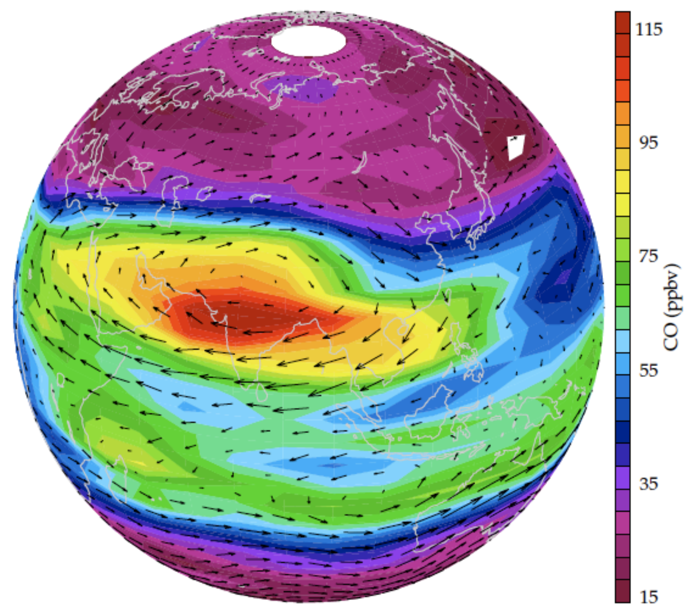
- dominant circulation feature of NH summer UTLS, linked to monsoon deep convection
- associated with local maxima in trace constituents (water vapor, ozone, pollutants)
- active region for stratosphere-troposphere coupling

monsoon
circulation
near 16 km



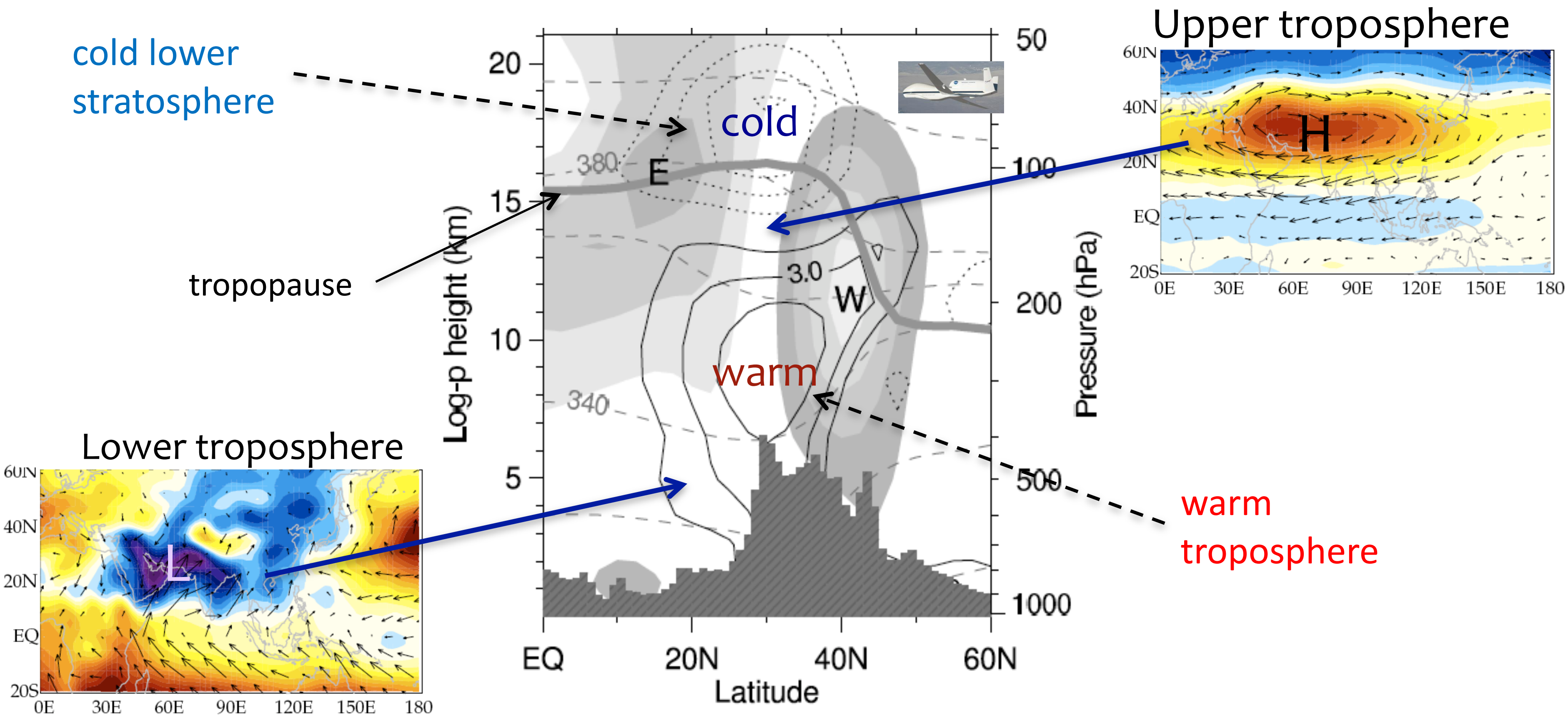
carbon monoxide
near 16 km

MLS satellite data



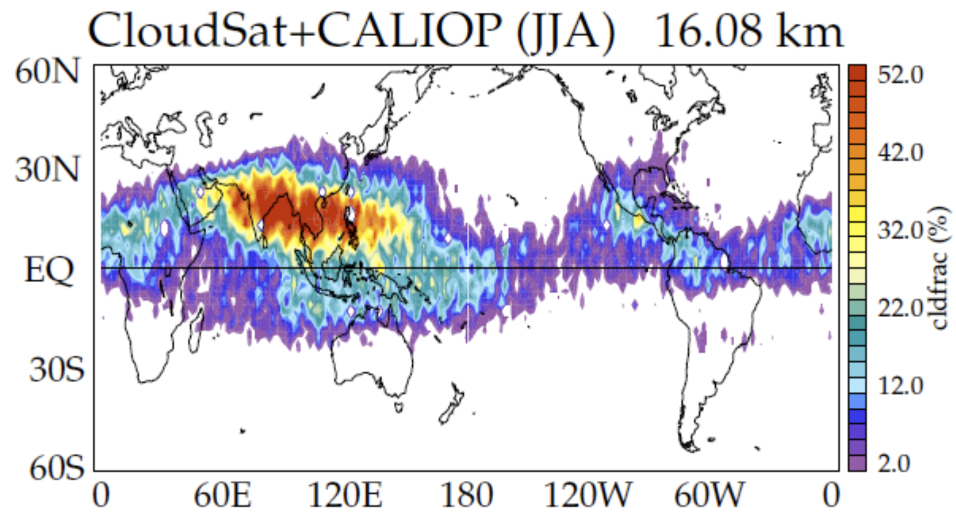
Dynamical Background

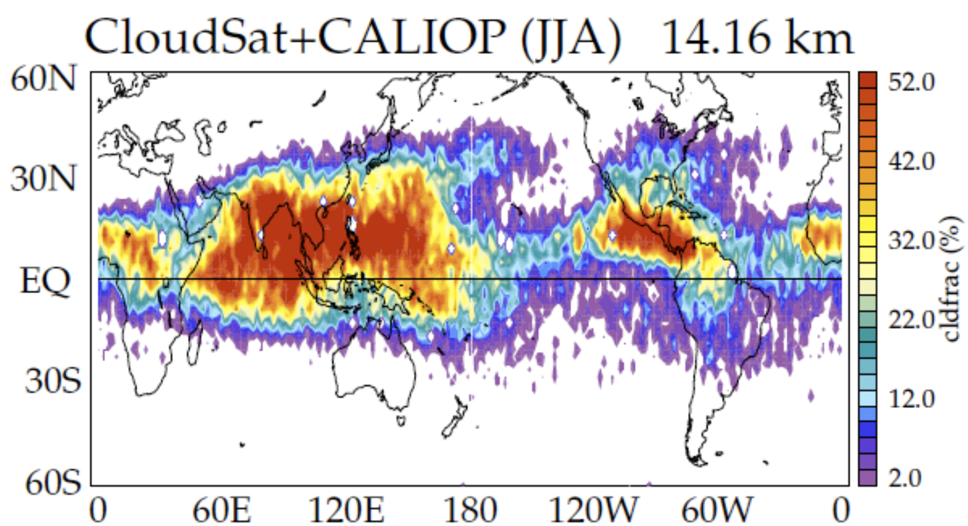
Anticyclonic circulation extends into lower stratosphere



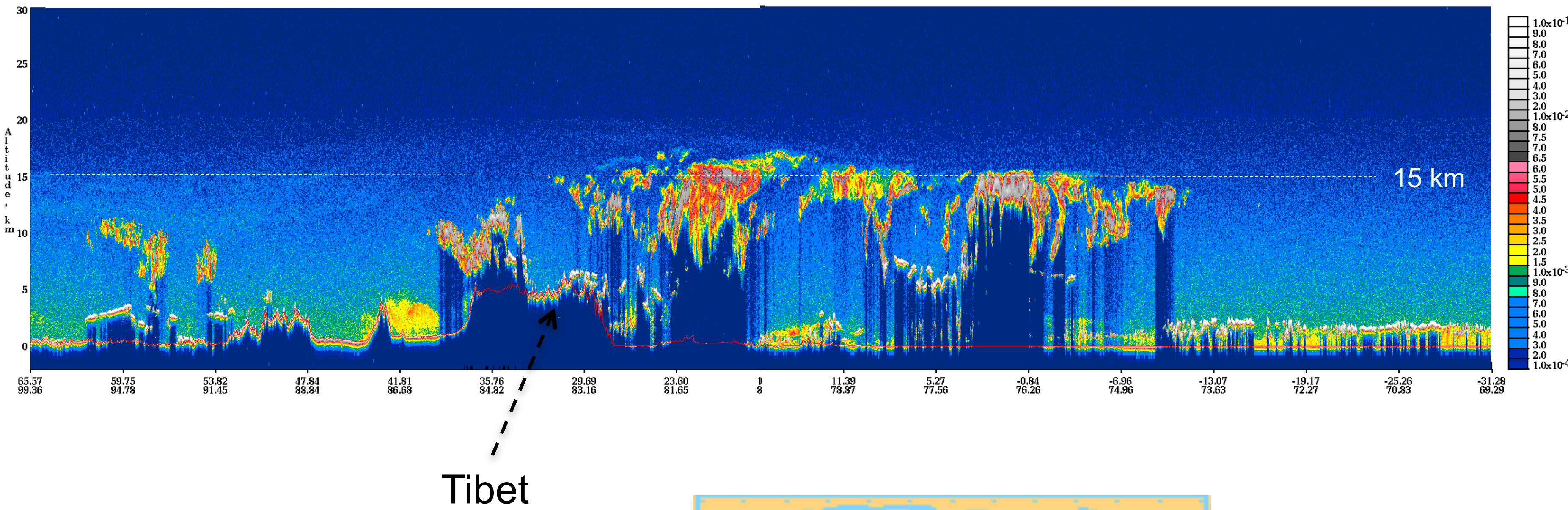
Randel and Park, JGR, 2006

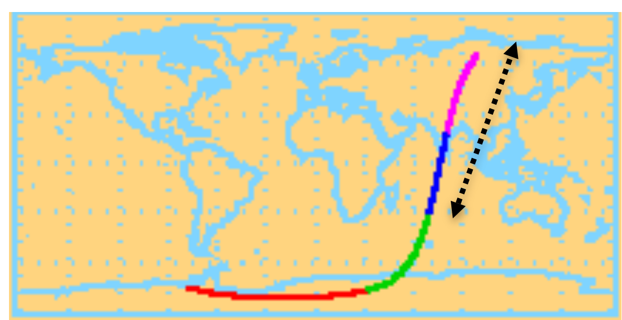
Cloud frequency from CloudSat+CALIOP



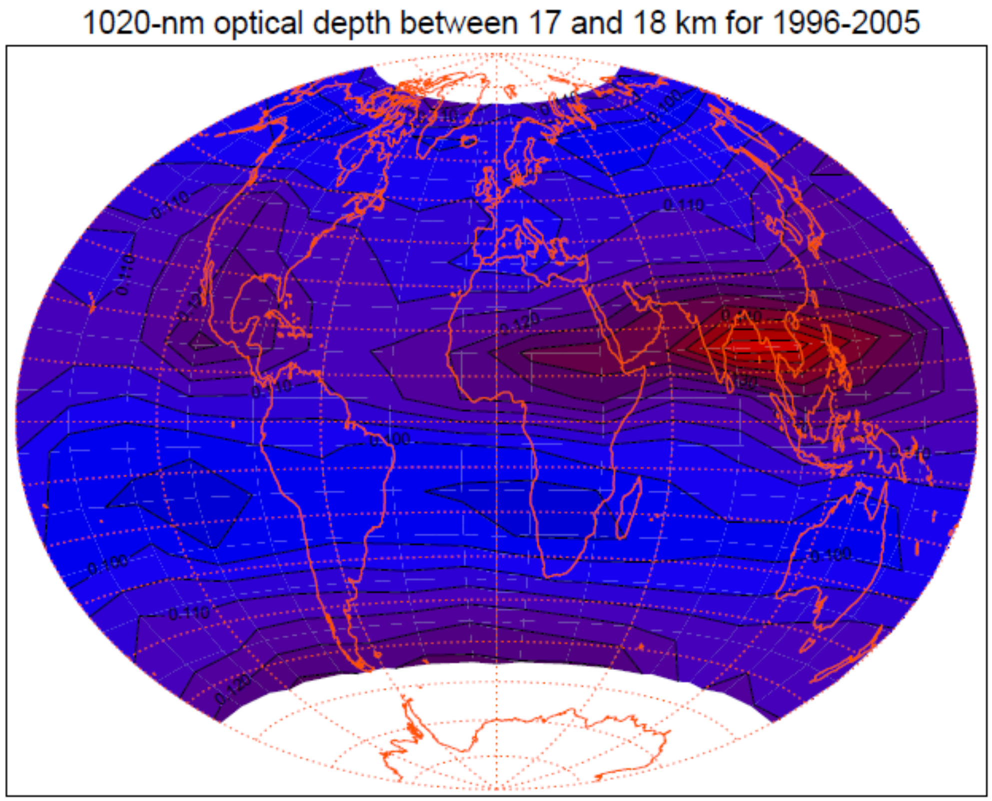


CALIPSO satellite lidar cloud observations





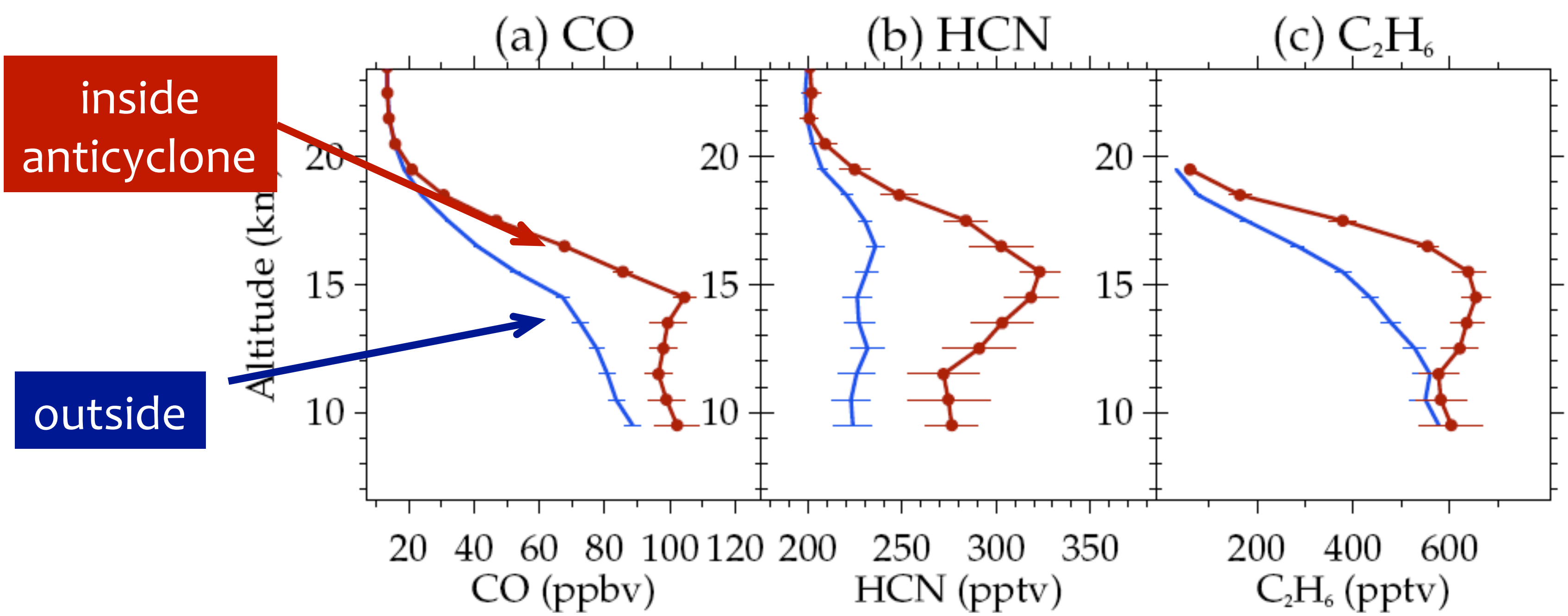
SAGE II satellite observations (cloud cleared; likely due to aerosols)



from Larry Thomason and Jean-Paul Vernier

Tropospheric Tracers from ACE-FTS

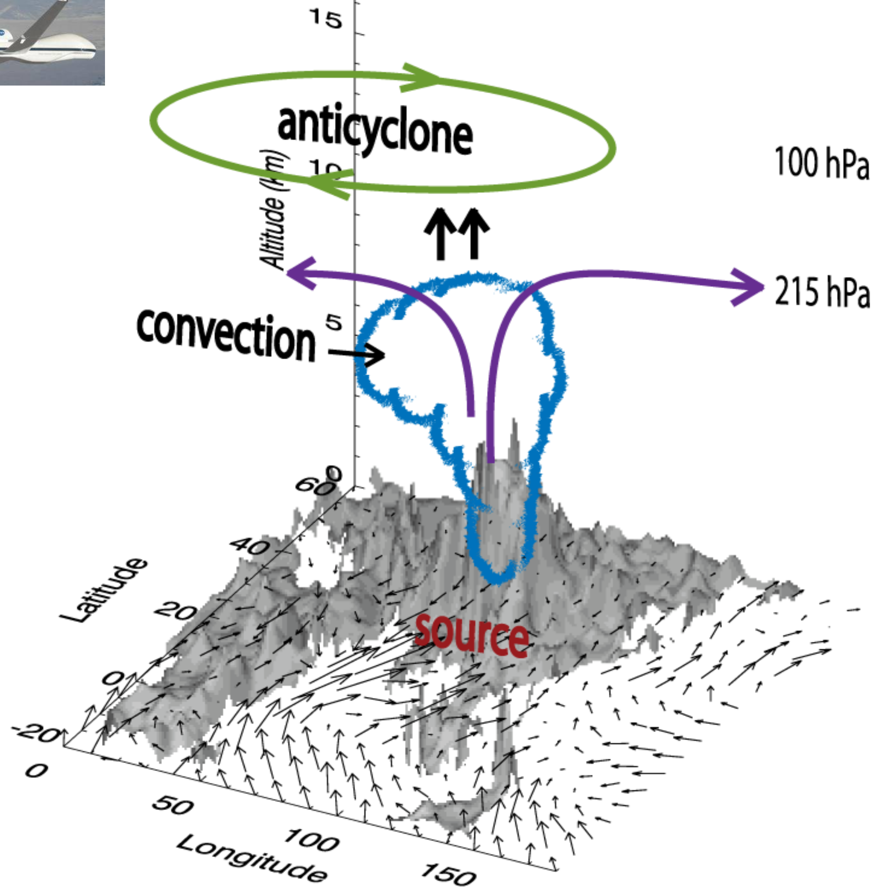
enhancement inside the anticyclone up to ~20 km



Park et al, ACP, 2009

Transport pathways

Diagnosed from
chemical transport model
Park et al, JGR, 2009



confinement by anticyclone
(transport to stratosphere?)

↑

Transport above 200 hPa
by large-scale circulation
(+overshooting convection?)

↑

convective transport
(main outflow near 200 hPa)

↑

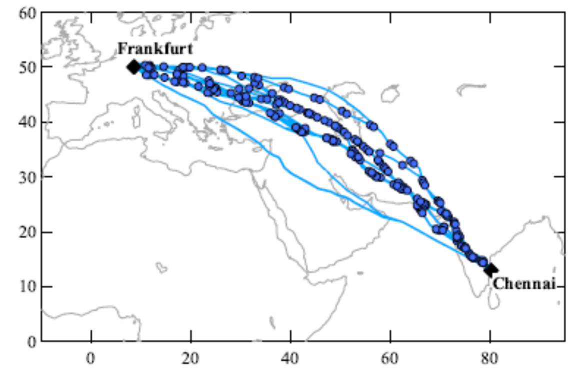
CO surface emission
(India and South China)

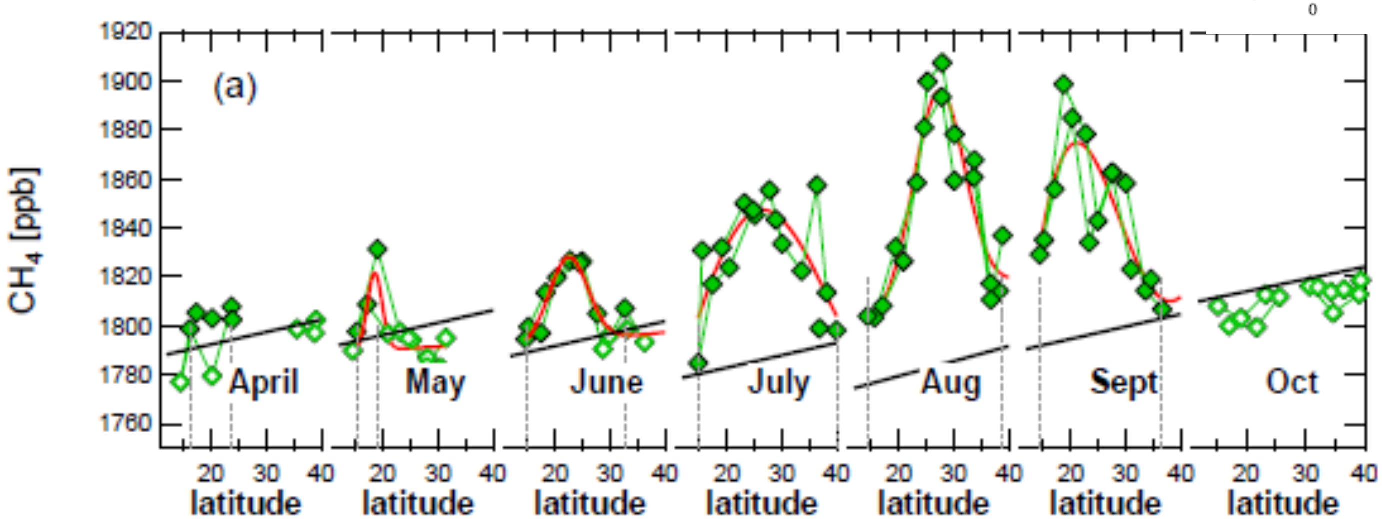
Atmos. Chem. Phys., 10, 3965–3984, 2010
www.atmos-chem-phys.net/10/3965/2010/

Atmospheric Chemistry and Physics

Greenhouse gas relationships in the Indian summer monsoon plume measured by the CARIBIC passenger aircraft

T. J. Schuck[1], C. A. M. Brenninkmeijer[1], A. K. Baker[1], F. Slemr[1], P. F. J. von Velthoven[2], and A. Zahn[3]

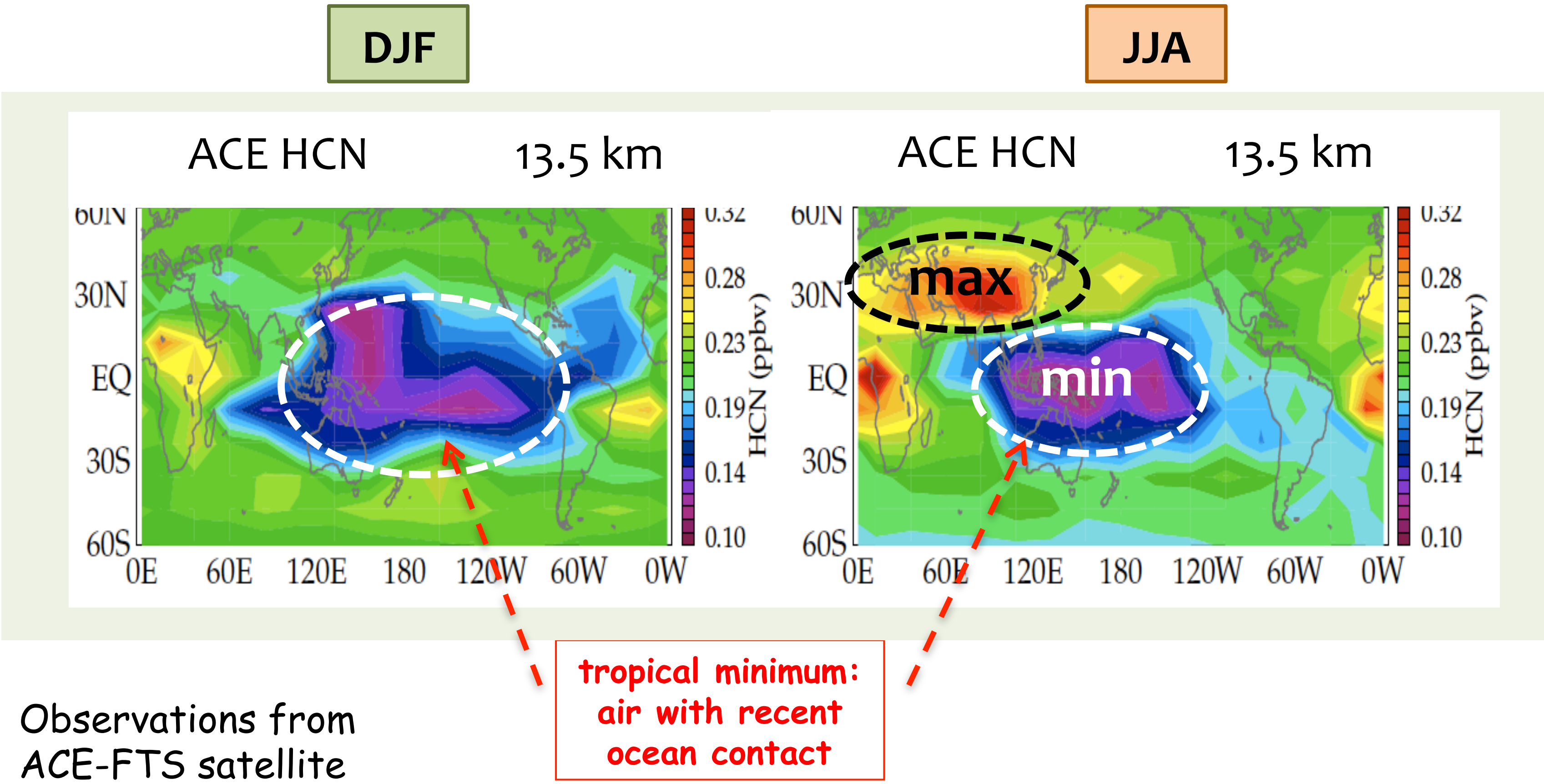




Hydrogen cyanide (HCN)

HCN source: biomass burning

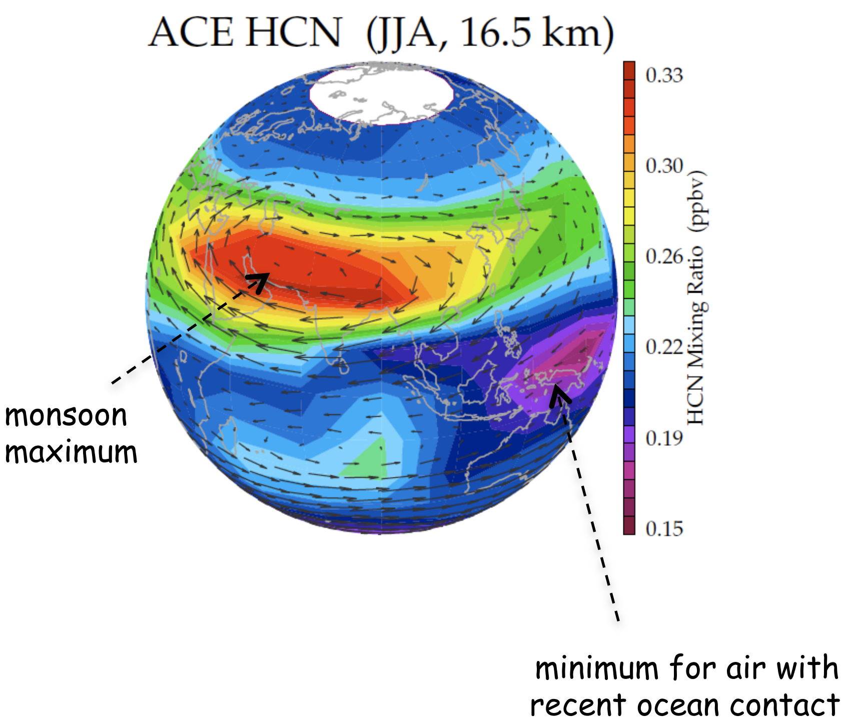
HCN lifetime: ~4 years in free atmosphere, but sink from contact with ocean

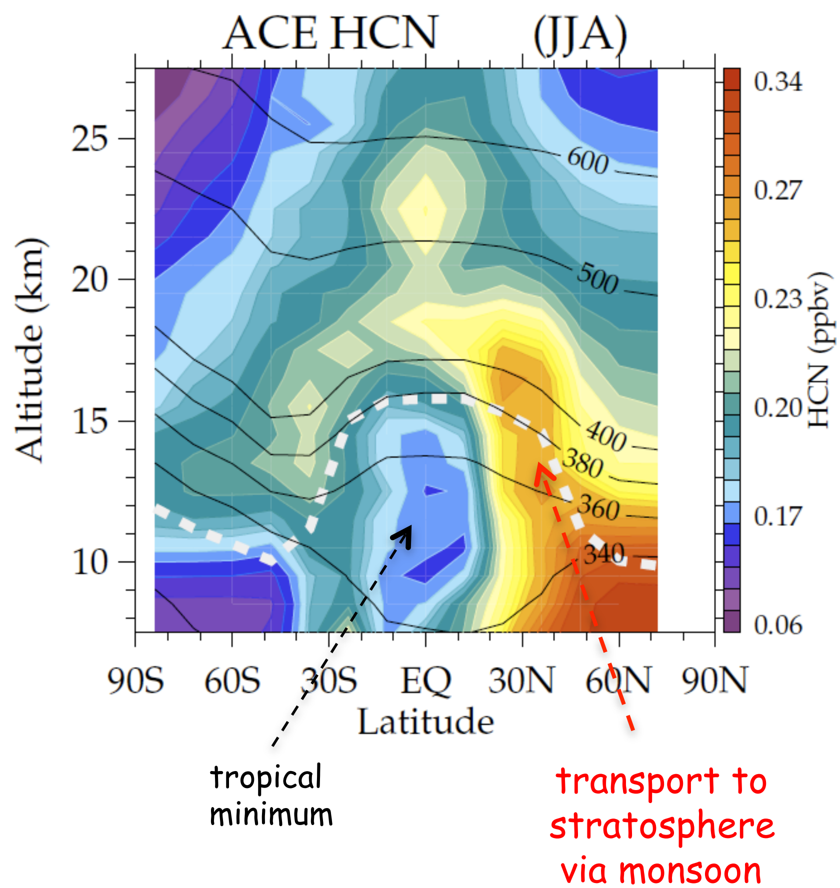


Observations from ACE-FTS satellite

Monsoon transport to the stratosphere deduced via HCN

ACE JJA climatology

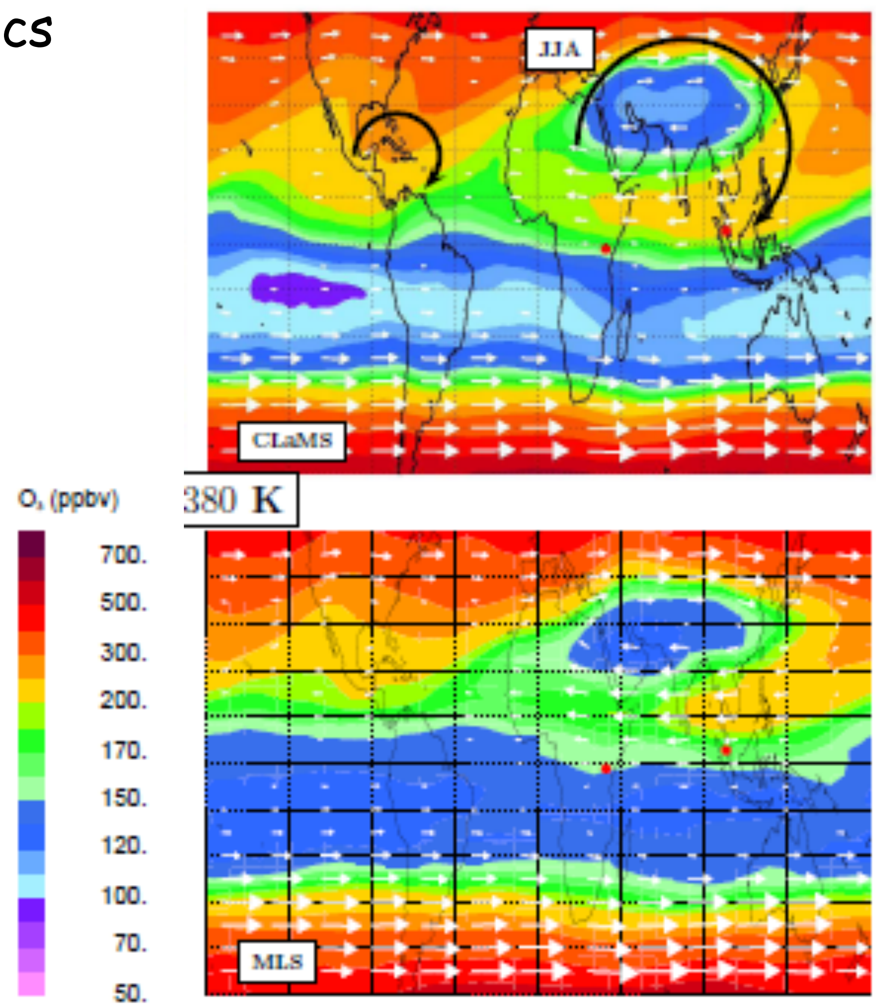




Randel et al, Science, 2010

Anticyclonic circulation contributes to large-scale transport to/from tropics

Kanopka et al, ACP, 2010



CLaMS simulation

MLS observations

<u>Also</u>:

Dunkerton, 1995
Chen, 1995

isentropic summer strat-trop exchange linked to anticyclone

Outstanding issues:

- Very few aircraft/balloon measurements in anticyclone (so far).
  SEAC4RS (summer 2012) will provide experience for ATTREX.

- How important is convective overshooting vs. large-scale transport?
  How does the diurnal cycle influence convective transport?

- What is the detailed behavior of convective and cirrus clouds?
  Are aerosols observed? If so, what optical properties? (absorbing?)
  What is the radiation balance near the tropopause?

- What is the detailed structure across vortex edge? (e.g. filamentation?)
  What are important exchange mechanisms across edge?

- What active chemistry is occurring? Do aerosols nucleate and grow?

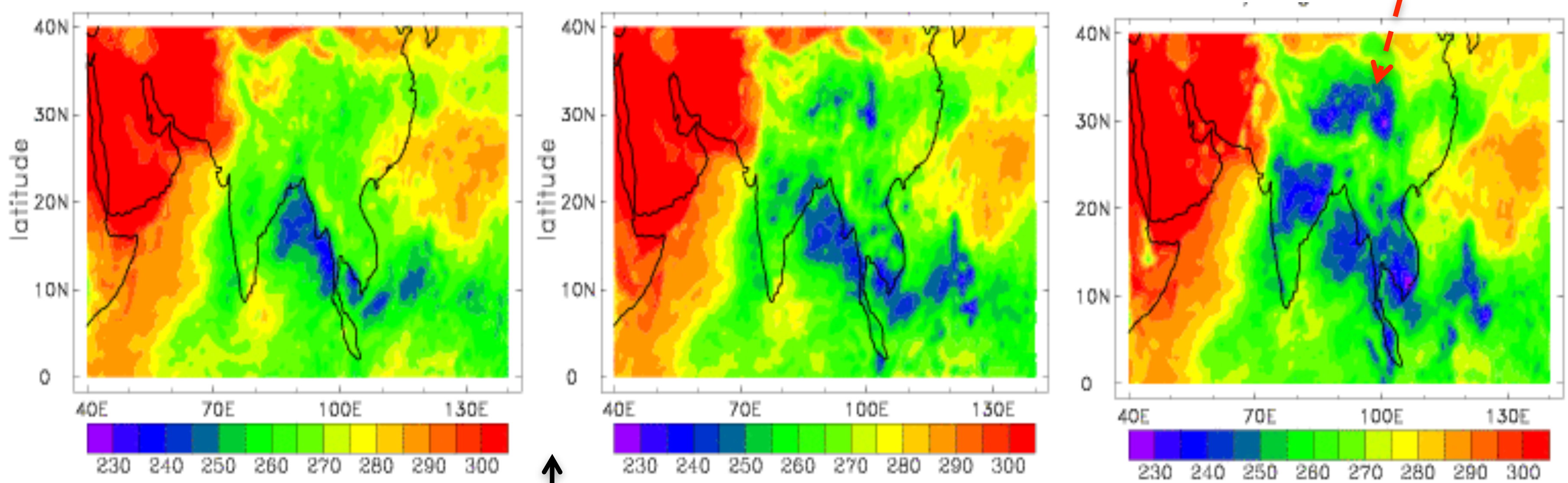
convective cloud statistics from
3-hour geostationary (CLAUS) data

Tibet plateau convection
in late afternoon

12 noon

3 pm

6 pm



CALIPSO, Cloudsat
observations at 1:30

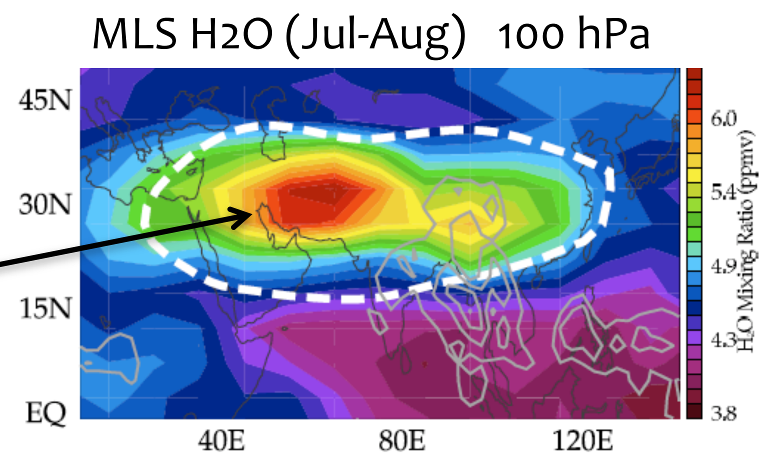
Blue = deep, high convective clouds

(Motivated from Jonathan Wright, Rong Fu)


Thank you

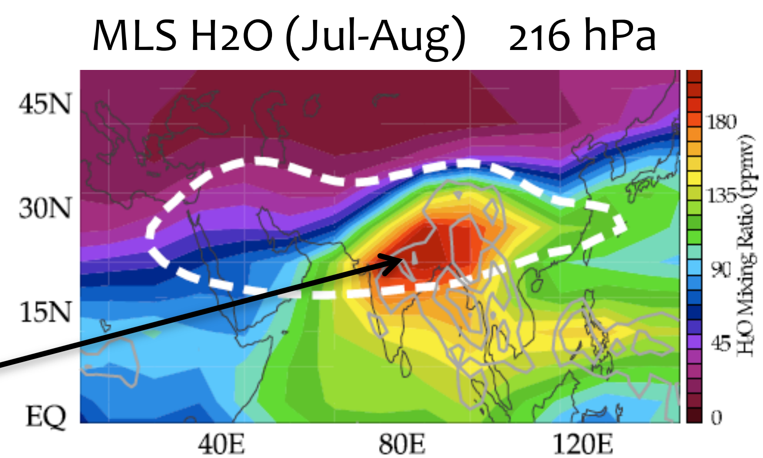
MLS water vapor

max inside the anticyclone



100 hPa

max over deep convection



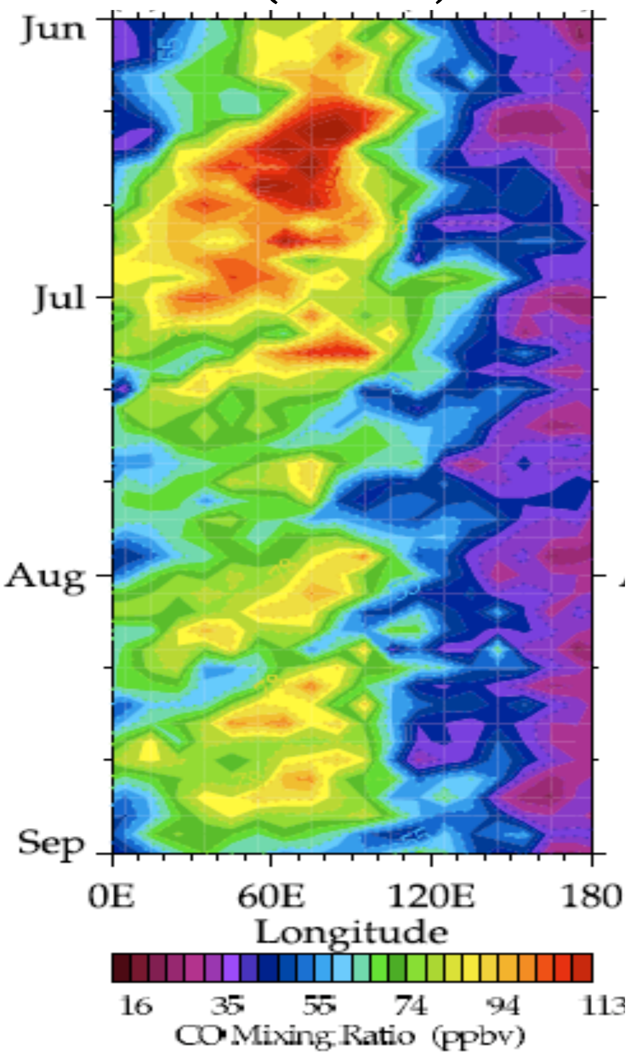
216 hPa

(level of convective outflow)

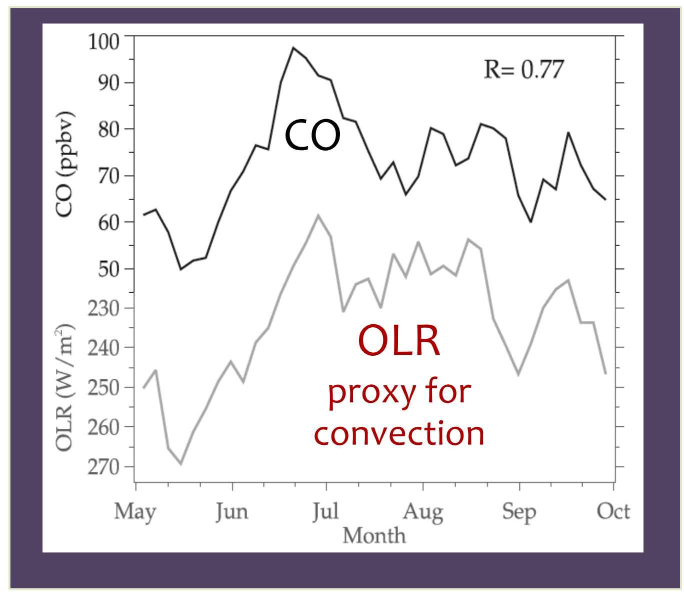
Park et al, JGR, 2007

Synoptic variability

MLS CO (100 hPa)



100 hPa tracers linked to monsoon convection



Park et al, JGR, 2007

Complementary perspectives of CO vs. HCN