Transport in the Tropical Upper Troposphere / Lower Stratosphere (UT/LS).

Darryn Waugh
Johns Hopkins University

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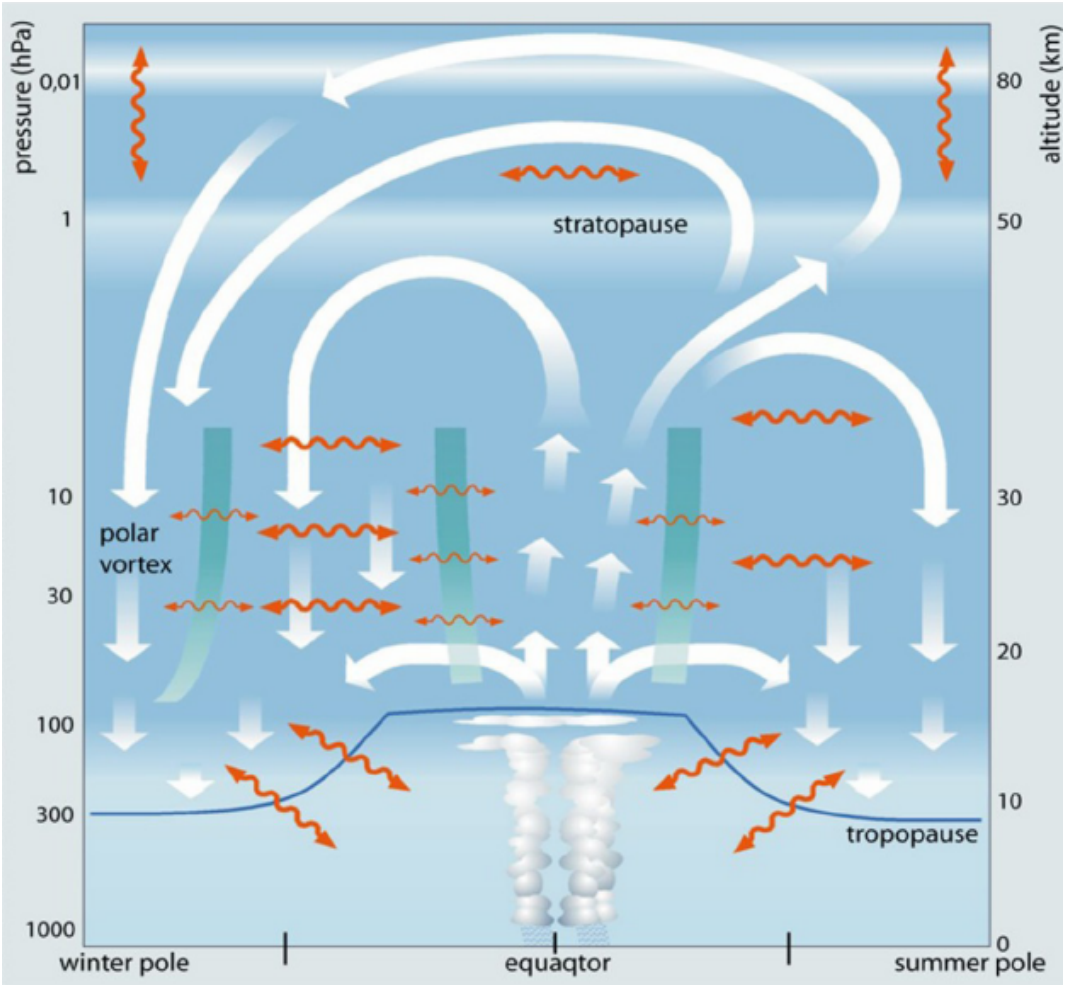
- Overview of transport in the Tropical UT / LS

- Relevance for stratospheric ozone and climate.

- Uncertainties in meteorological analyzes and transport calculations.

- Example studies.

Stratospheric Transport

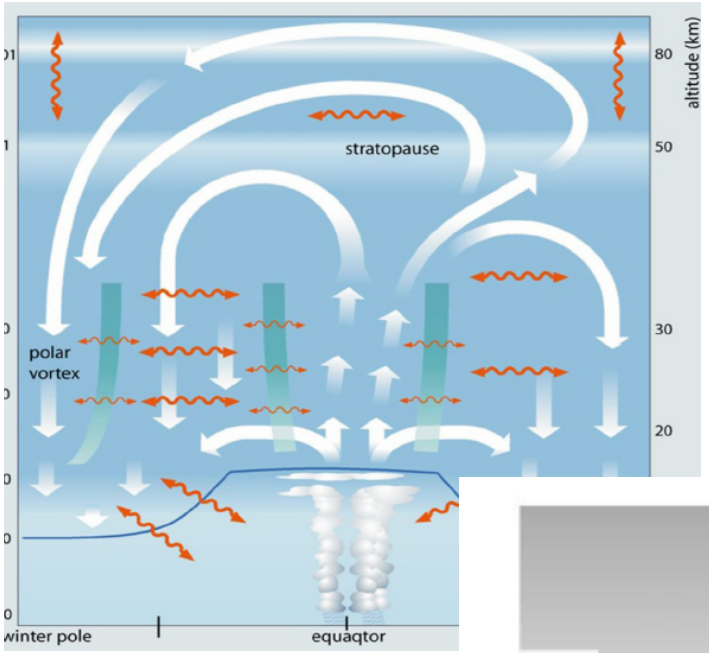


Stratospheric transport is combination of

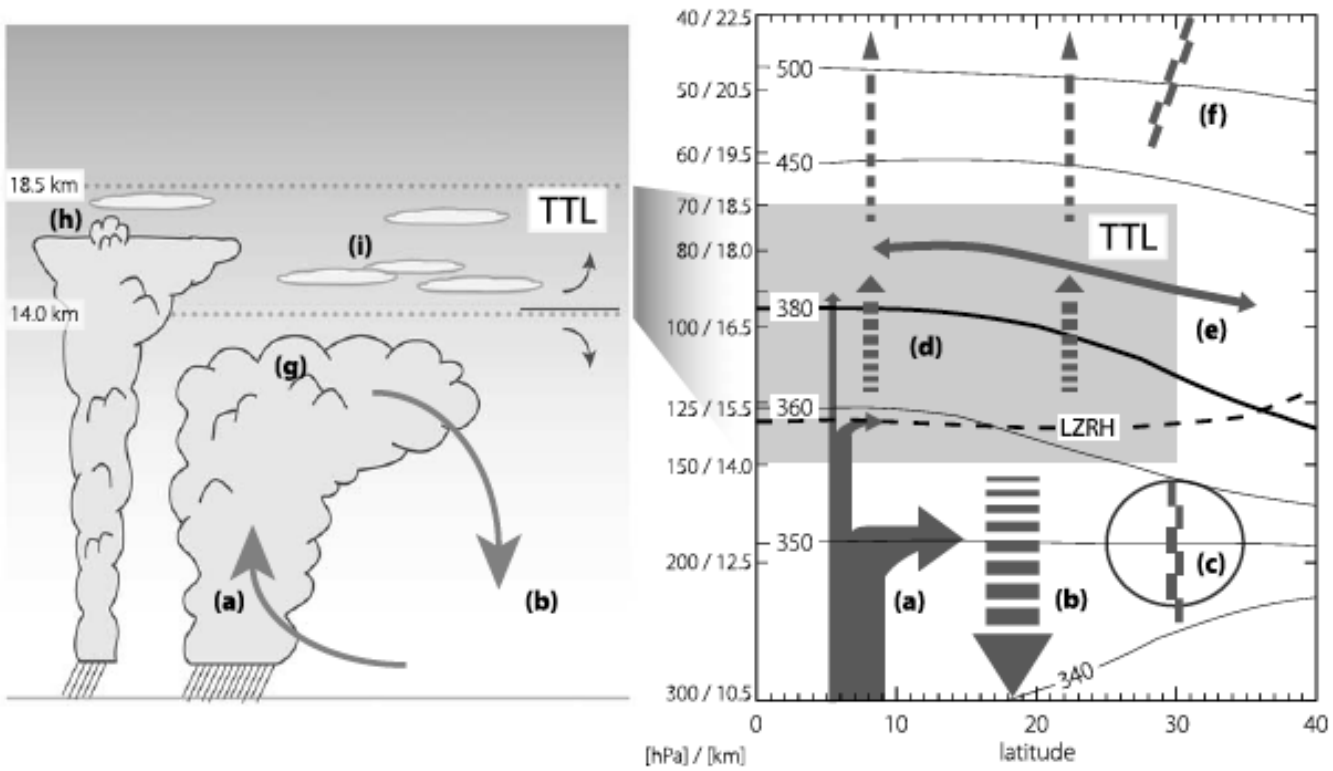
- (slow) meridional overturning circulation, and
- (rapid) quasi-horizontal mixing.

Reduced mixing in subtropics and polar vortex edges.

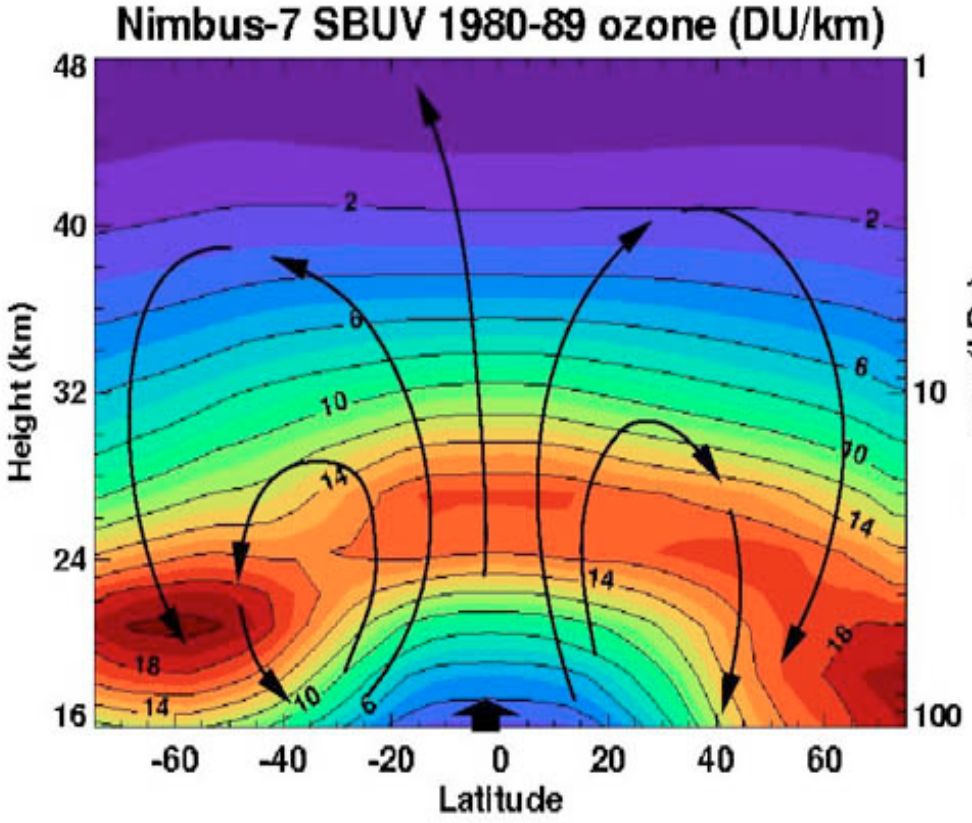
Tropical Transition Layer



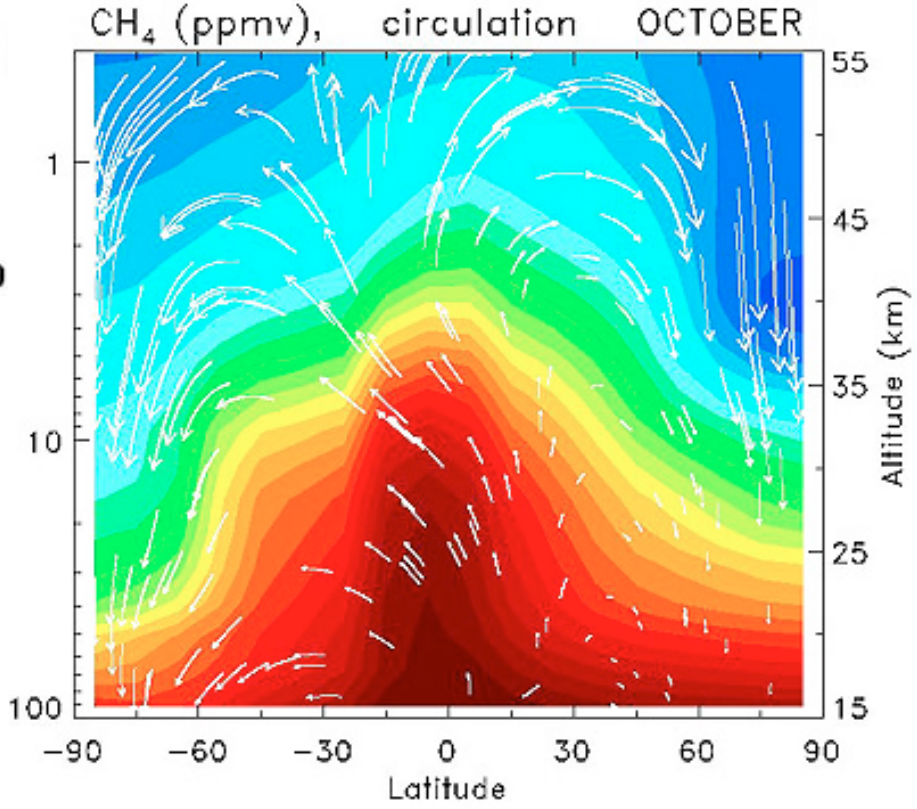
Transition layer around tropical tropopause where transport transitions from tropospheric to stratospheric.



Stratospheric Ozone and Traces

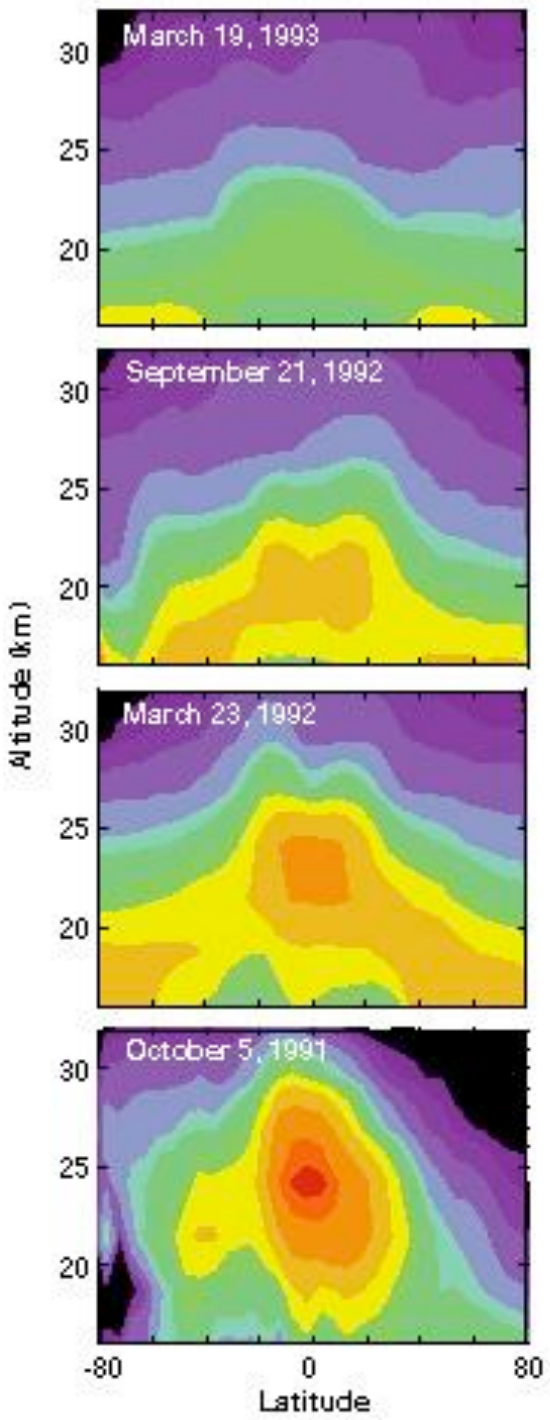


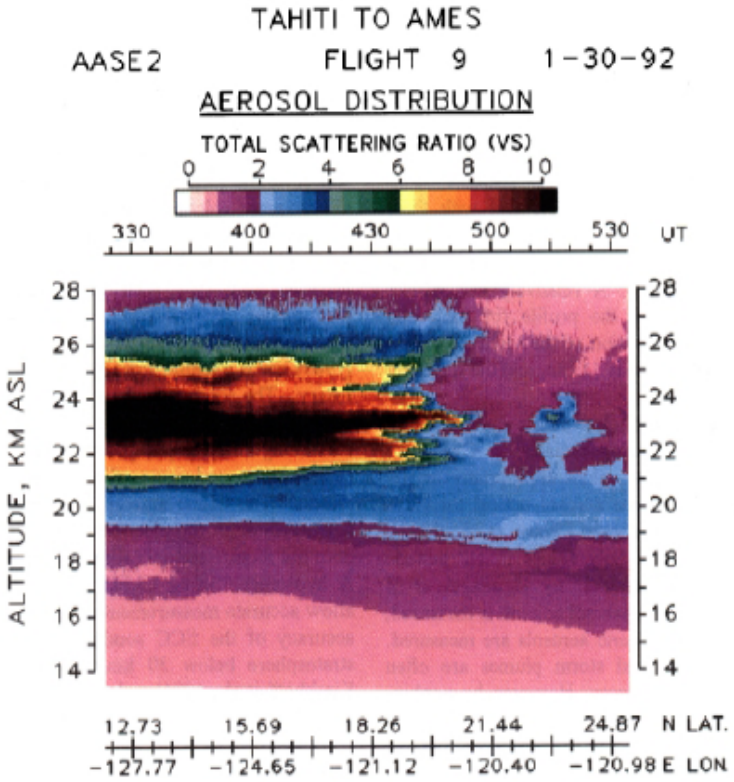
Transport plays a major role in determining distribution of ozone and other trace gases in the stratosphere.



Volcanic Aerosols

Slow Tropical to Mid-latitude transport clearly visible in spreading of aerosols from Mt Pinatubo.

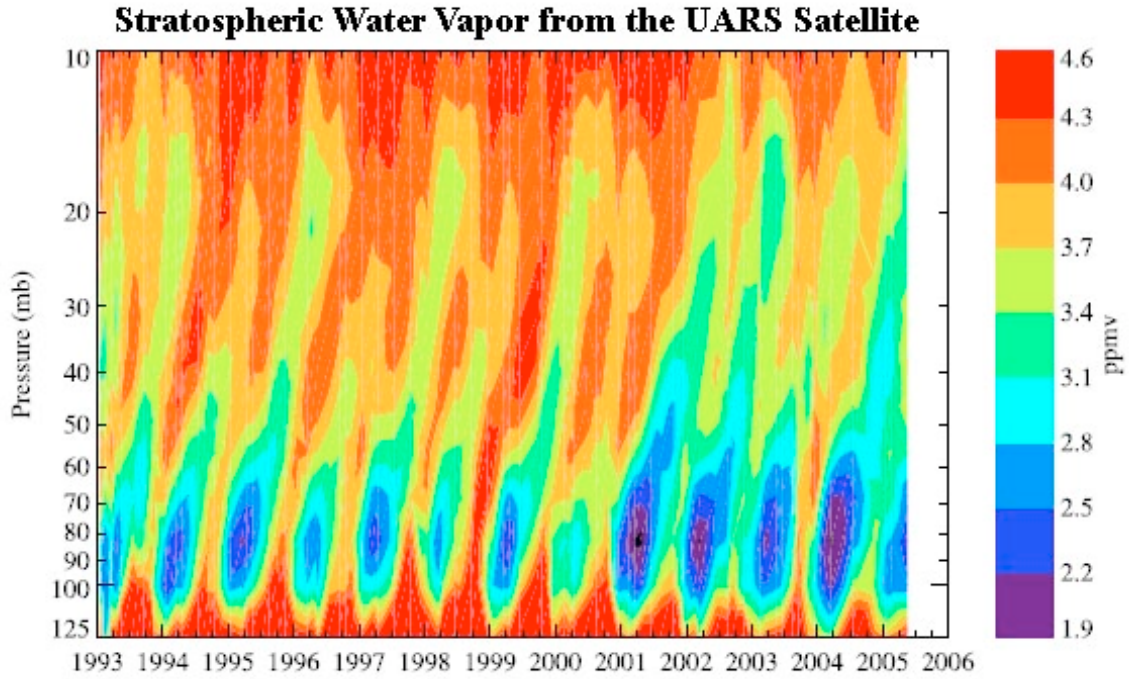


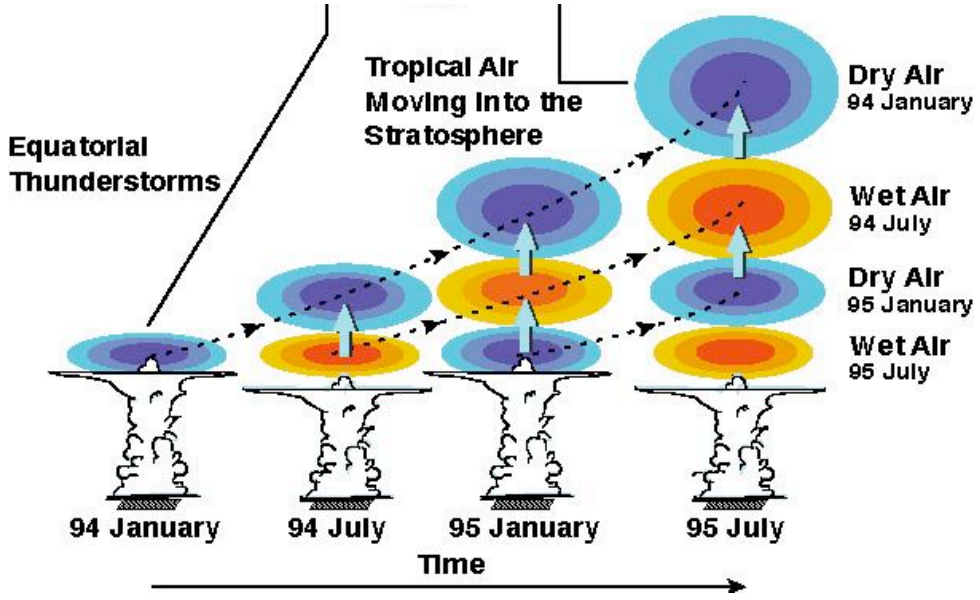


Grant et al. (1994 JGR)

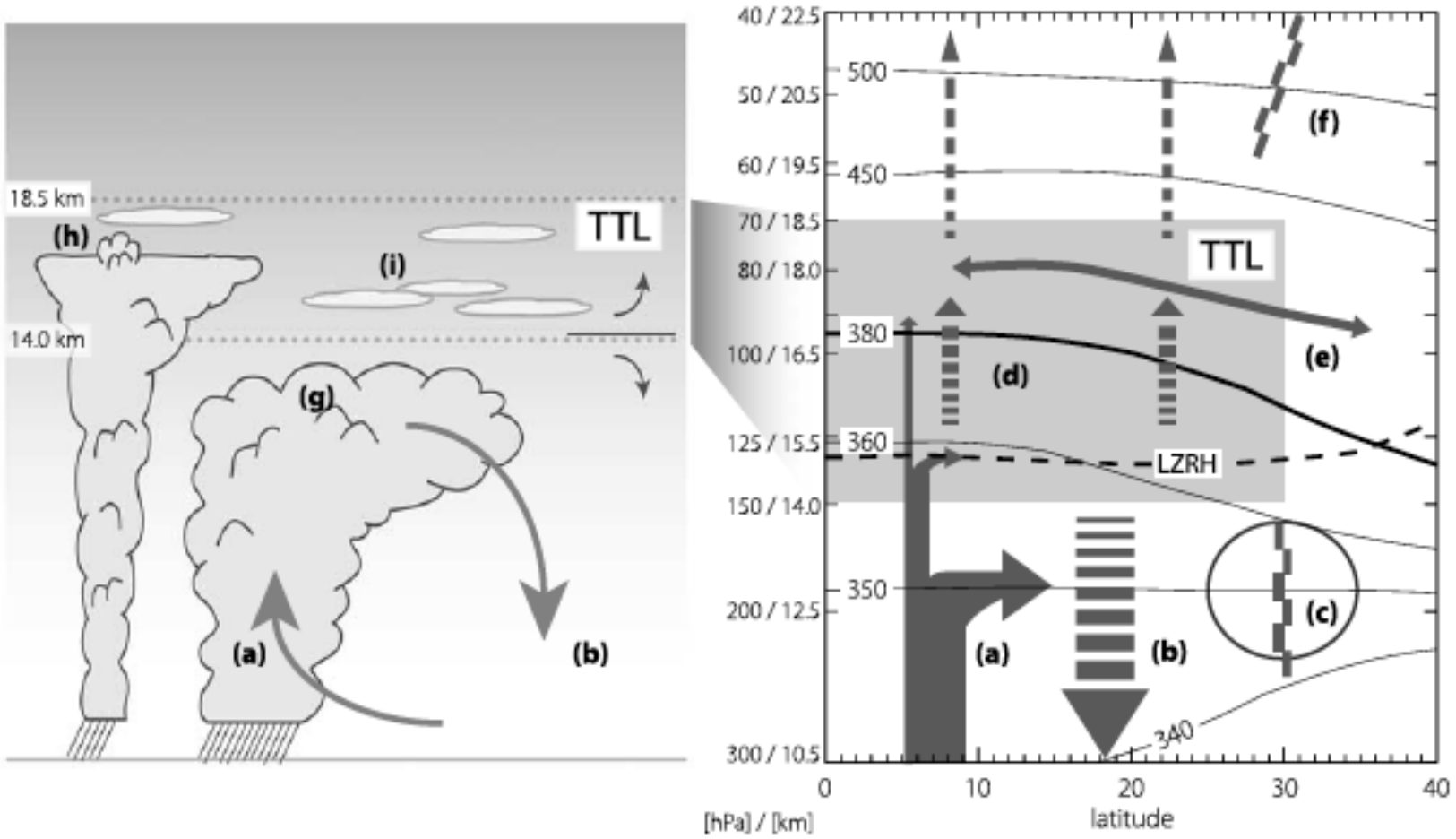
Stratospheric Water Vapor

Entry values of water vapor set at tropical tropopause, then propagate up into the stratosphere.
"Tape Recorder" also observed in CO, HCN…



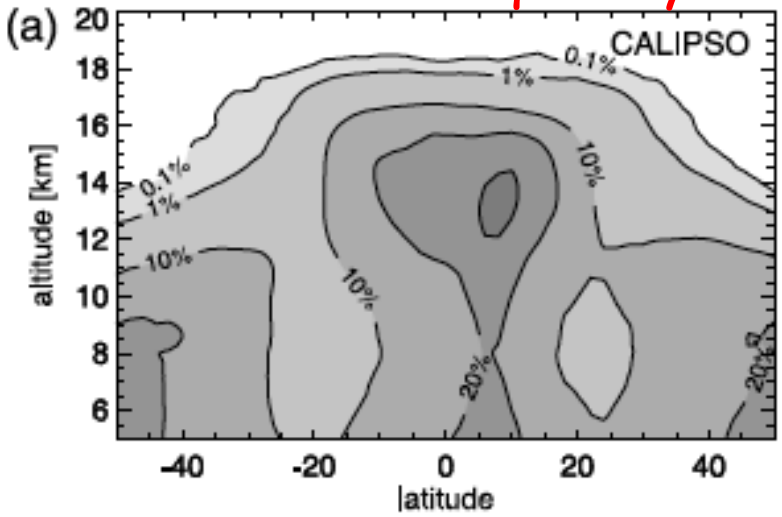


Tropical Transition Layer

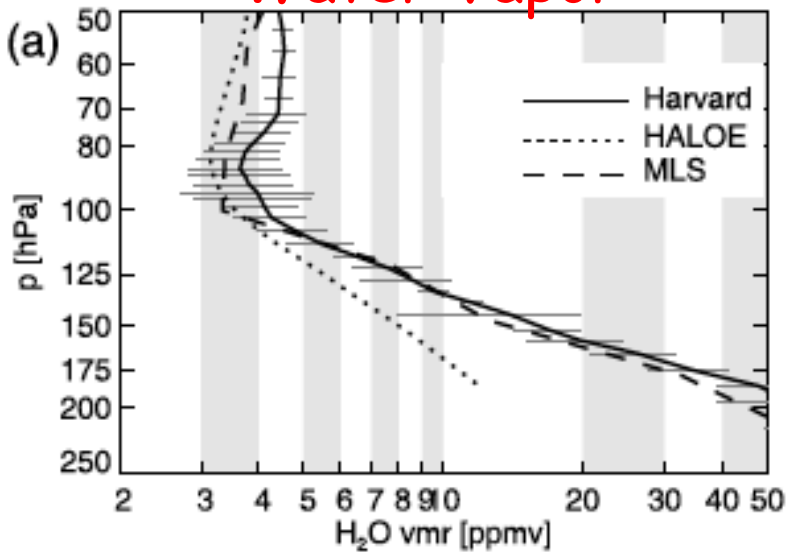


TTL Composition

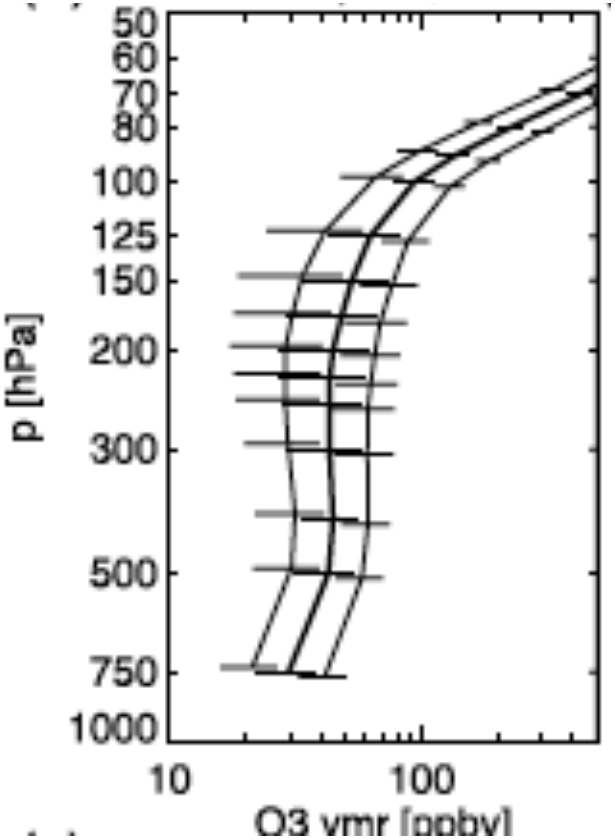
Cloud Frequency



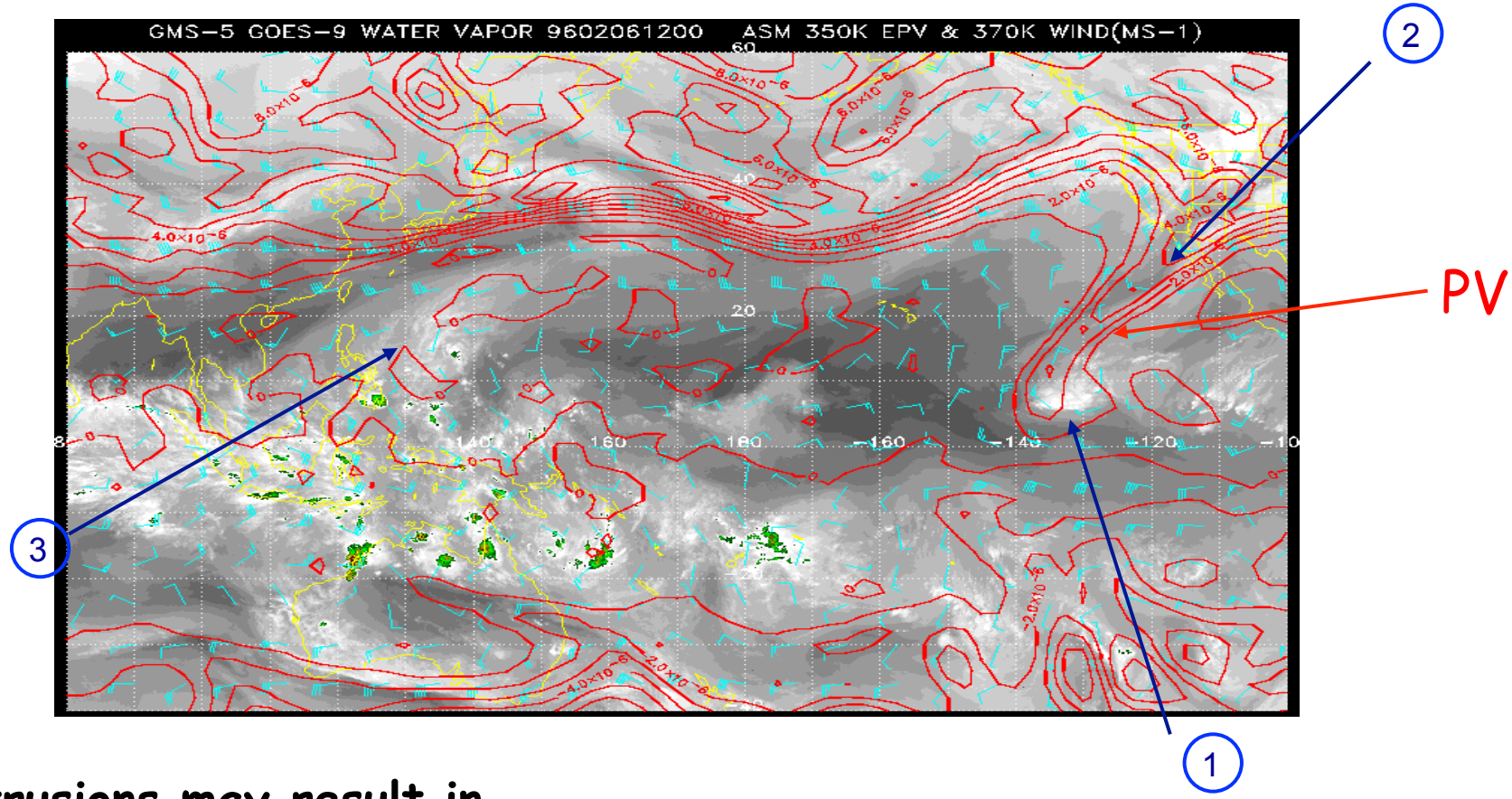
Water Vapor



Ozone



Impact of horizontal transport (PV intrusions) on tropical UT composition



Intrusions may result in

(1) transient tropical convection (+H_2O, -O_3)

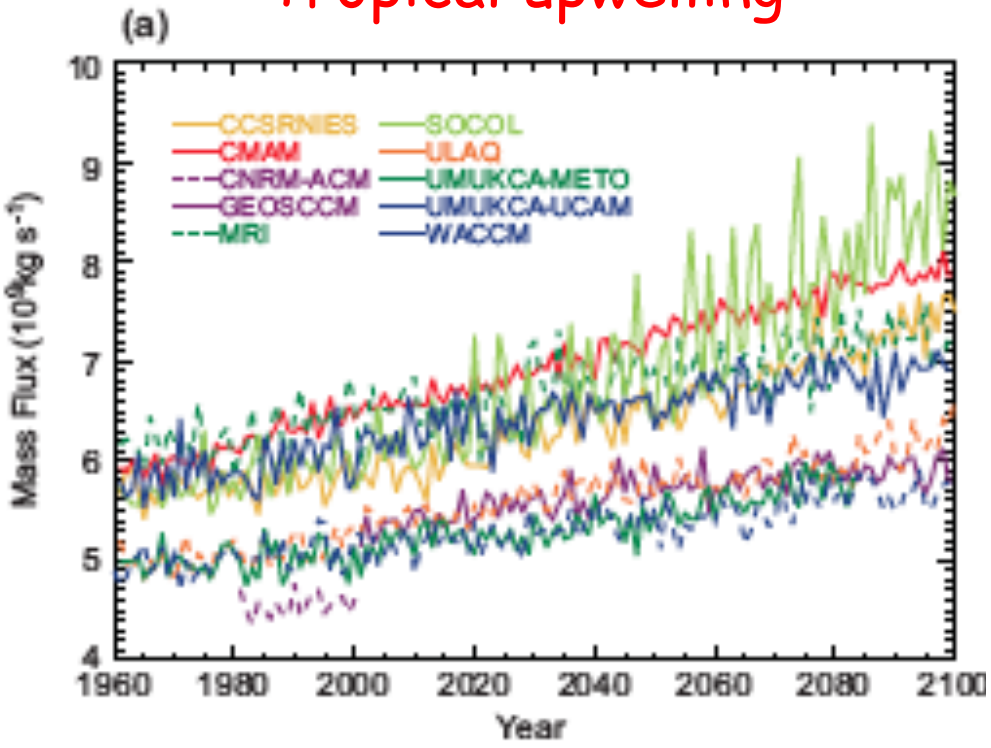
(2) transport of stratospheric air (-H_2O, +O_3)

(3) transport from convective regions into subtropics (+/-H_2O)

Trends

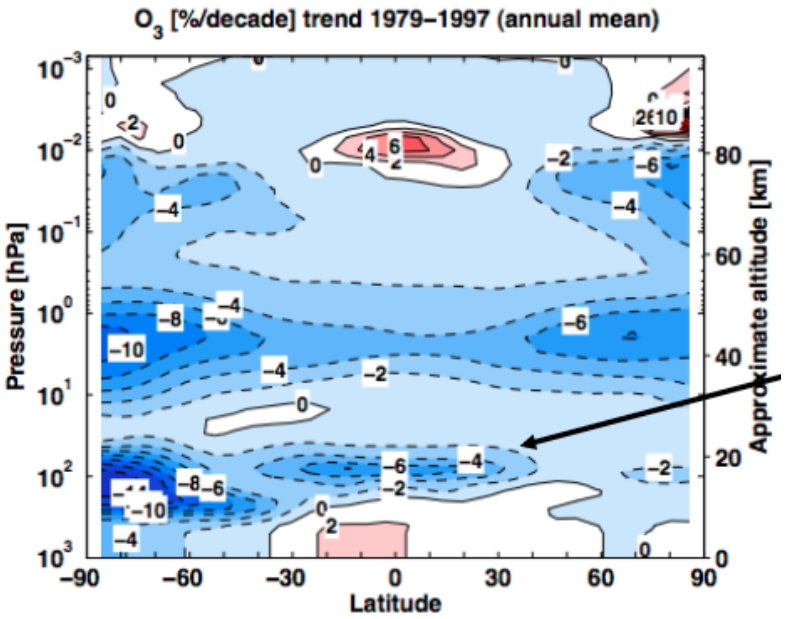
Models, and some observations, indicate trends in transport in tropical LS.

Tropical upwelling



SPARC CCMVal (2010)

Ozone



Science Questions

- What are the rate of vertical ascent and tropical – midlatitude mixing in the LS, and how does this vary with time?

- What processes control stratospheric entry values of water vapor (and other trace species)? What is relative role of large-scale and convective transport? How is this transport changing with time?

- What are the physical mechanisms that control / cause changes in water vapor and ozone in the tropical and subtropical UT?

- What is the fate of short-lived compounds transport from boundary layer into TTL?

Tropical Winds in Met. Analyses.

The errors in UT/LS tropical winds from meteorological analyses are much larger than extra-tropics.

Rean. Wind vs. ER-2 MMS obs. Rean. Vs. Obs. In the Tropics

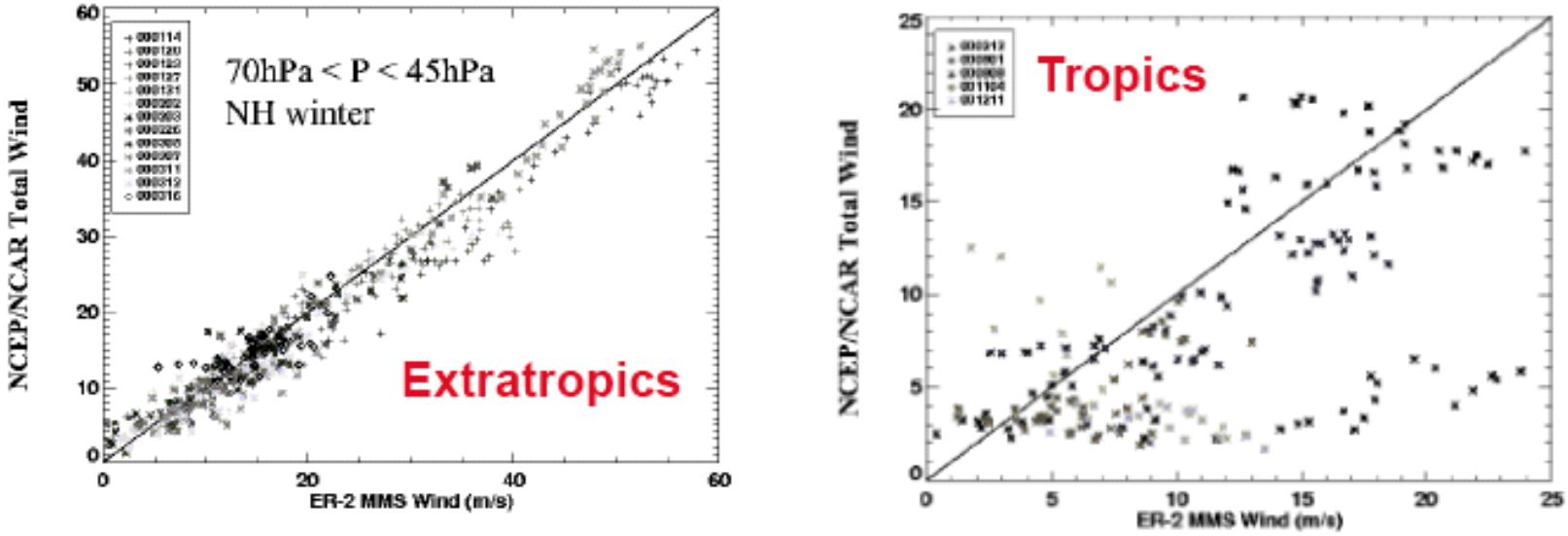
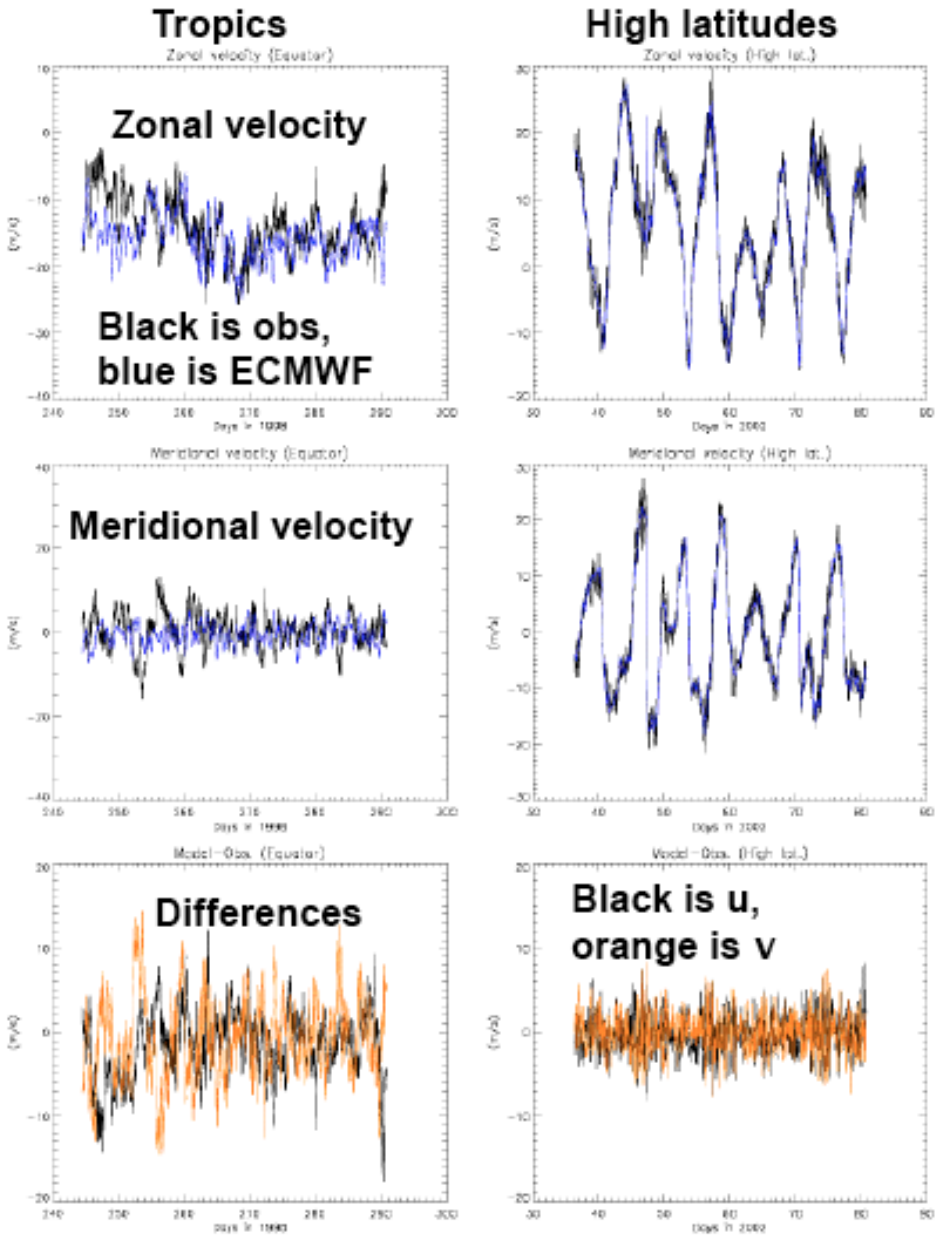


Figure courtesy of Paul Newman, NASA GSFC

Tropical Winds in Met. Analyses.



Comparison of direct wind measurements with ECMWF analysed winds in long-duration stratospheric balloon flights (at 60 hPa) leads to the same conclusion

Figure courtesy of Albert Hertzog, LMD

QBO

The quasi-biennial oscillation (QBO) is major source of variability in tropics, but is not well characterized by different meteorological analyses.

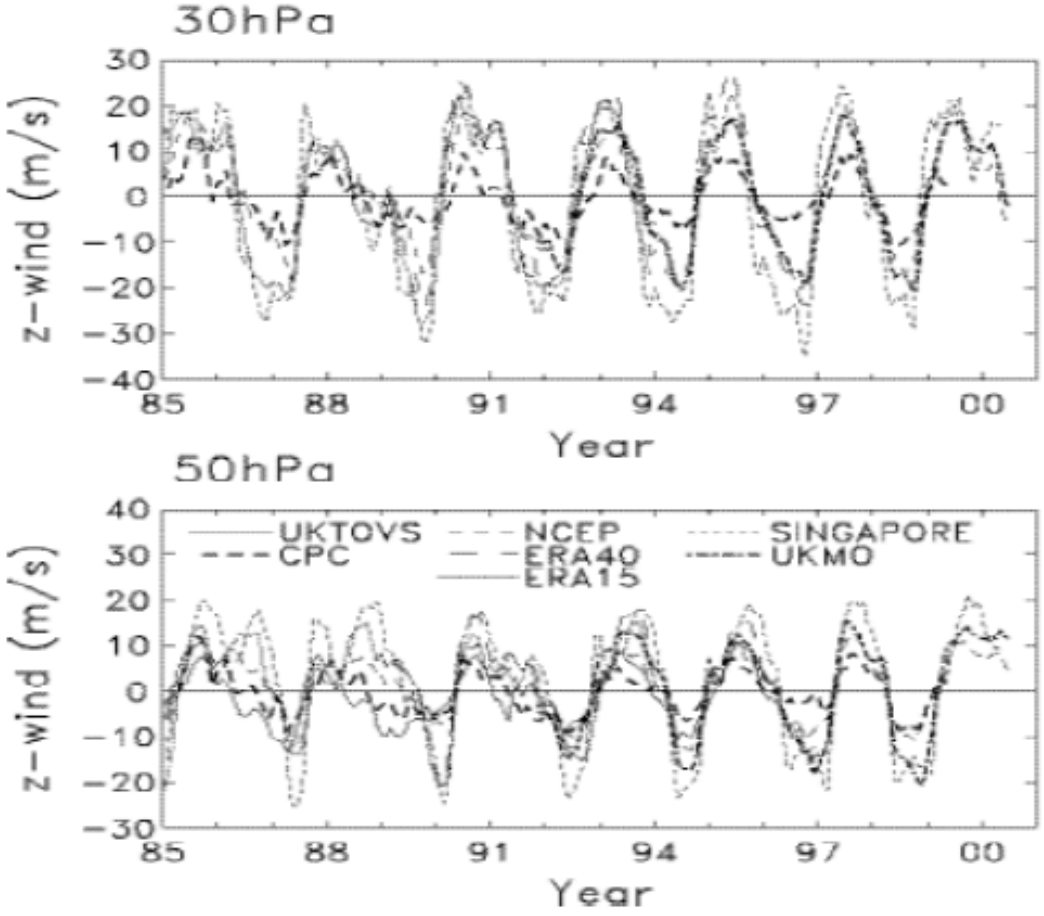


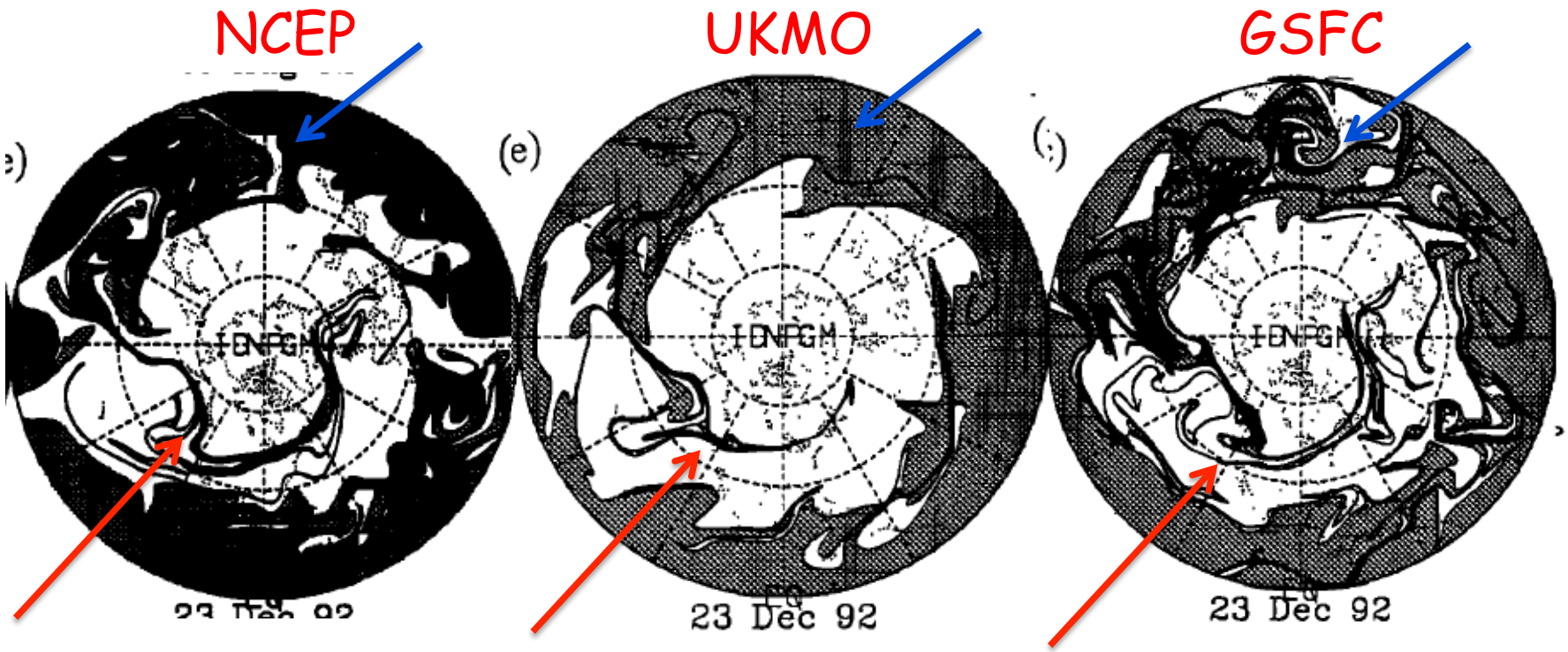
Figure shows zonal wind interannual anomalies at the equator

Meridional gradients are also very poorly characterized

From SPARC Report No. 3 (2002)

Tracer Simulations

The differences (errors) in tropical winds has a large impact on tracer simulations using meteorological analyses: E.g.,

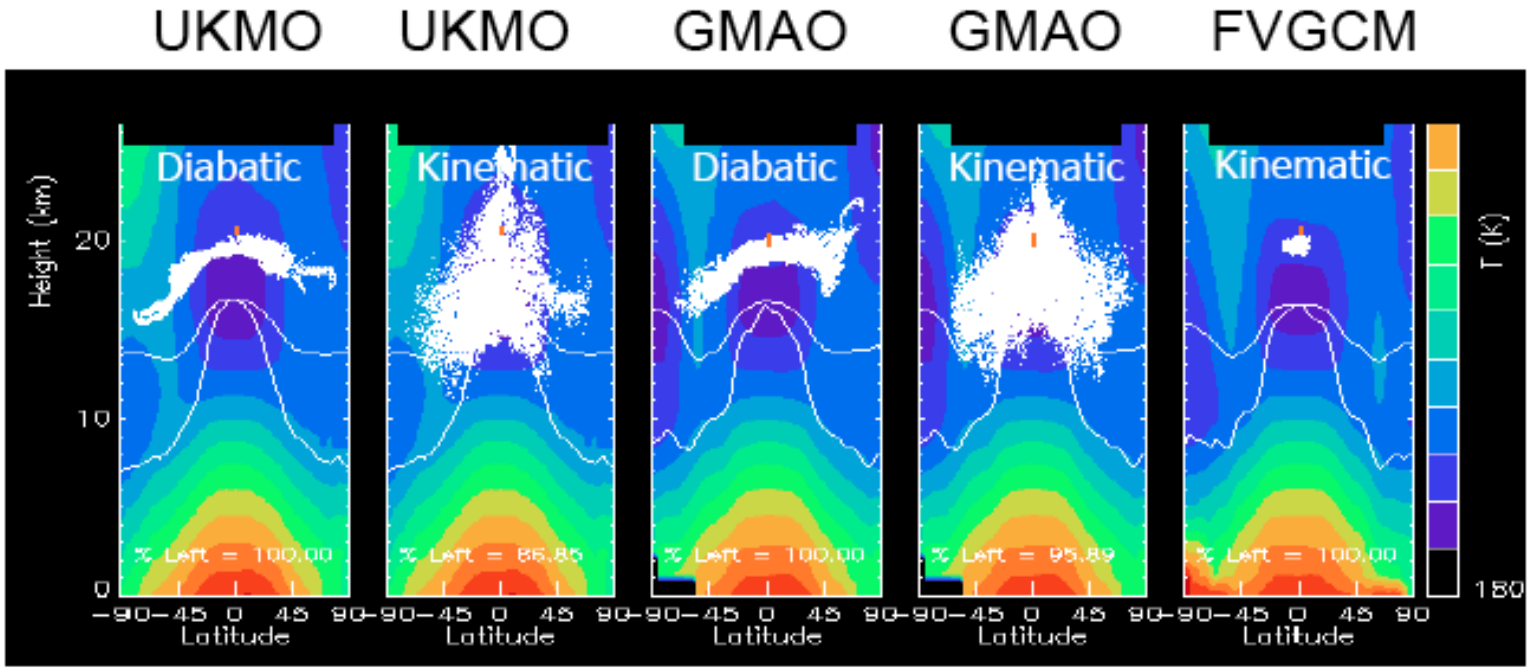


Isentropic Trajectories

Waugh (1996)

Tracer Simulations II

- Winds from data assimilation systems (DAS) tend to produce much more dispersion, both horizontally and vertically, than GCM winds
  - Figures show 50-day trajectory calculations
  - But is the isolation seen in the GCM correct?

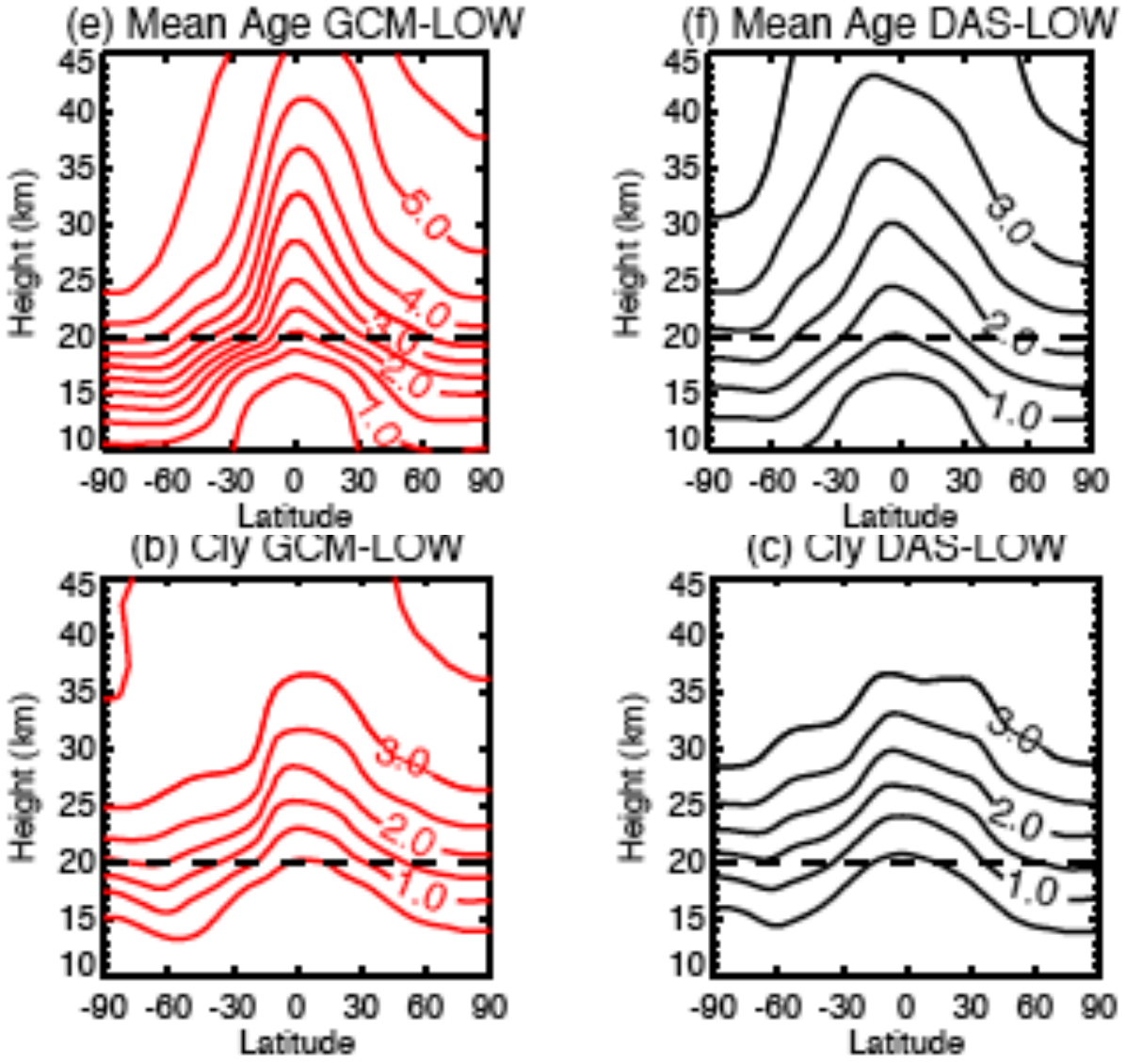


3-D Trajectories

Schoeberl et al. (2003 JGR)

Tracer Simulations IIb

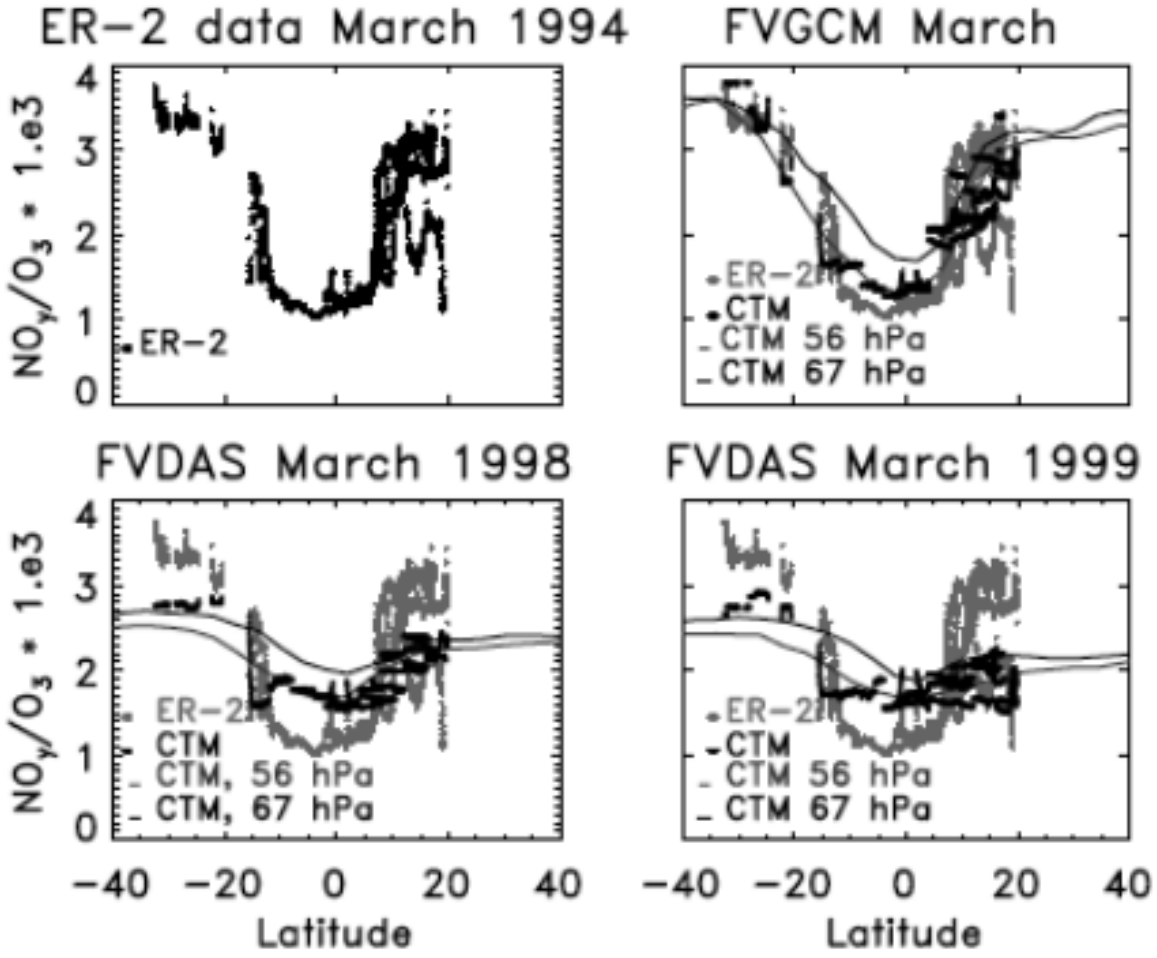
This additional dispersion results in younger "age of air" in model driven by DAS winds, and impacts simulation of chemical tracers involved in ozone destruction (e.g., Cly)



(Waugh et al. 2007)

Tracer Simulations III

– The DAS-driven chemistry transport model destroys the strong horizontal gradients



Douglass et al. (2003 JGR)

3-D CTM simulation

Transport Studies Using Lidar Winds

Ideally would be able to perform transport / tracer simulations using only lidar-observed winds. However, coverage likely insufficient, so need to use data assimilation.

Analysis of waves within lidar-observed winds may also provide insight into transport processes.

Transport Simulations

Trajectory calculations, with accurate winds, can be used to examine, for example,

- rate of vertical ascent and mixing in the LS,
- relative role of large-scale and convective transport in setting stratospheric entry values,
- transport into (and water vapor within) the tropical and subtropical UT, and
- time-scales for transport into UT /LS.

3-D Chemical Transport Models driven by meteorological analyses can be used to examine the processes controlling the distribution of key tracers (e.g., ozone, water vapor) and aerosols in the troposphere and stratosphere.

THE END