The tropical tropopause layer

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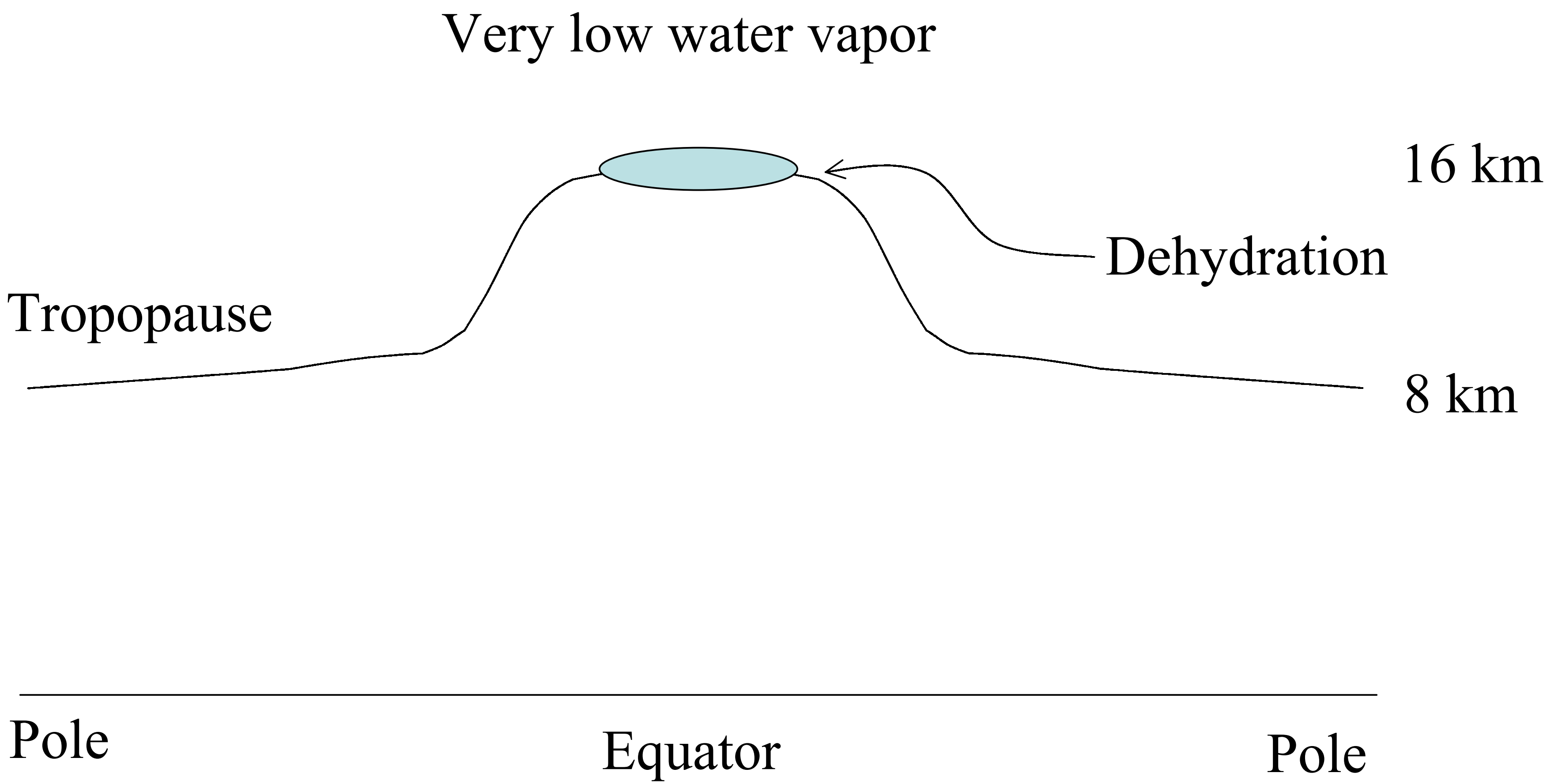
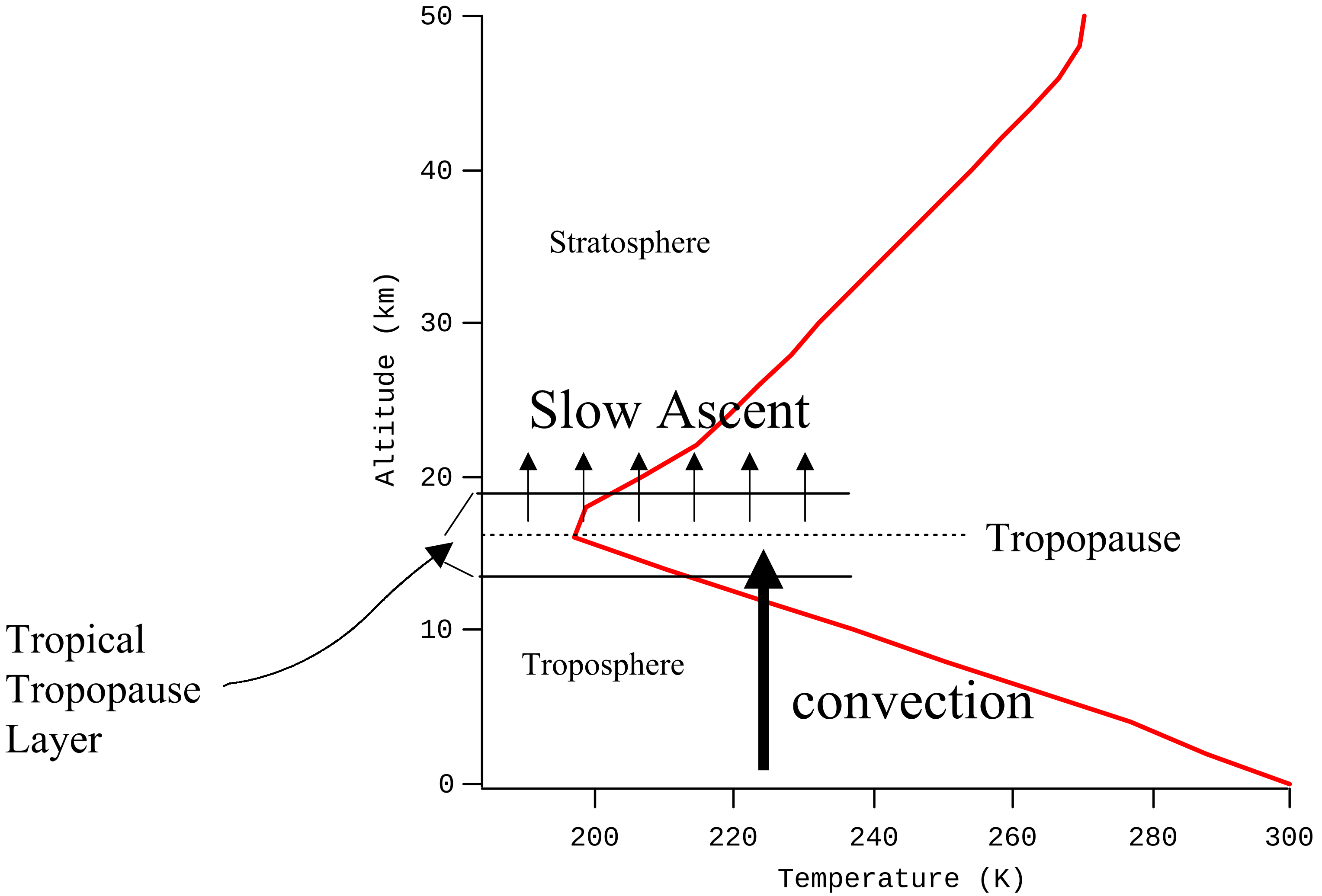
Brewer, A.W., Evidence for a world circulation provided by the measurements of helium and water vapour distribution in the stratosphere, *Q. J. R. Meteorol. Soc.*, 1949.



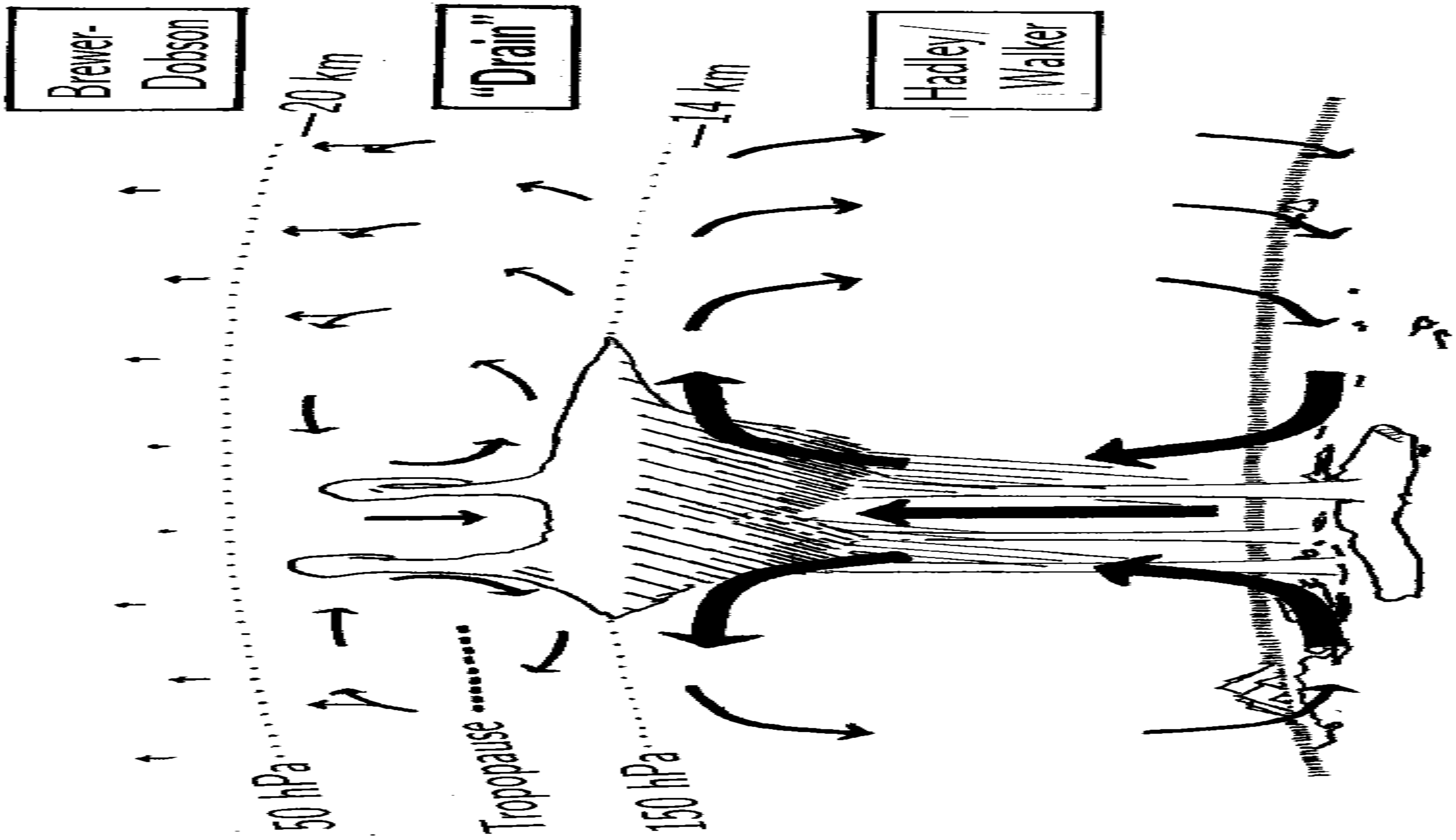
Theories of TTL processes

- Slow ascent
- Convective dehydration

Atmospheric Structure



The stratospheric “drain”

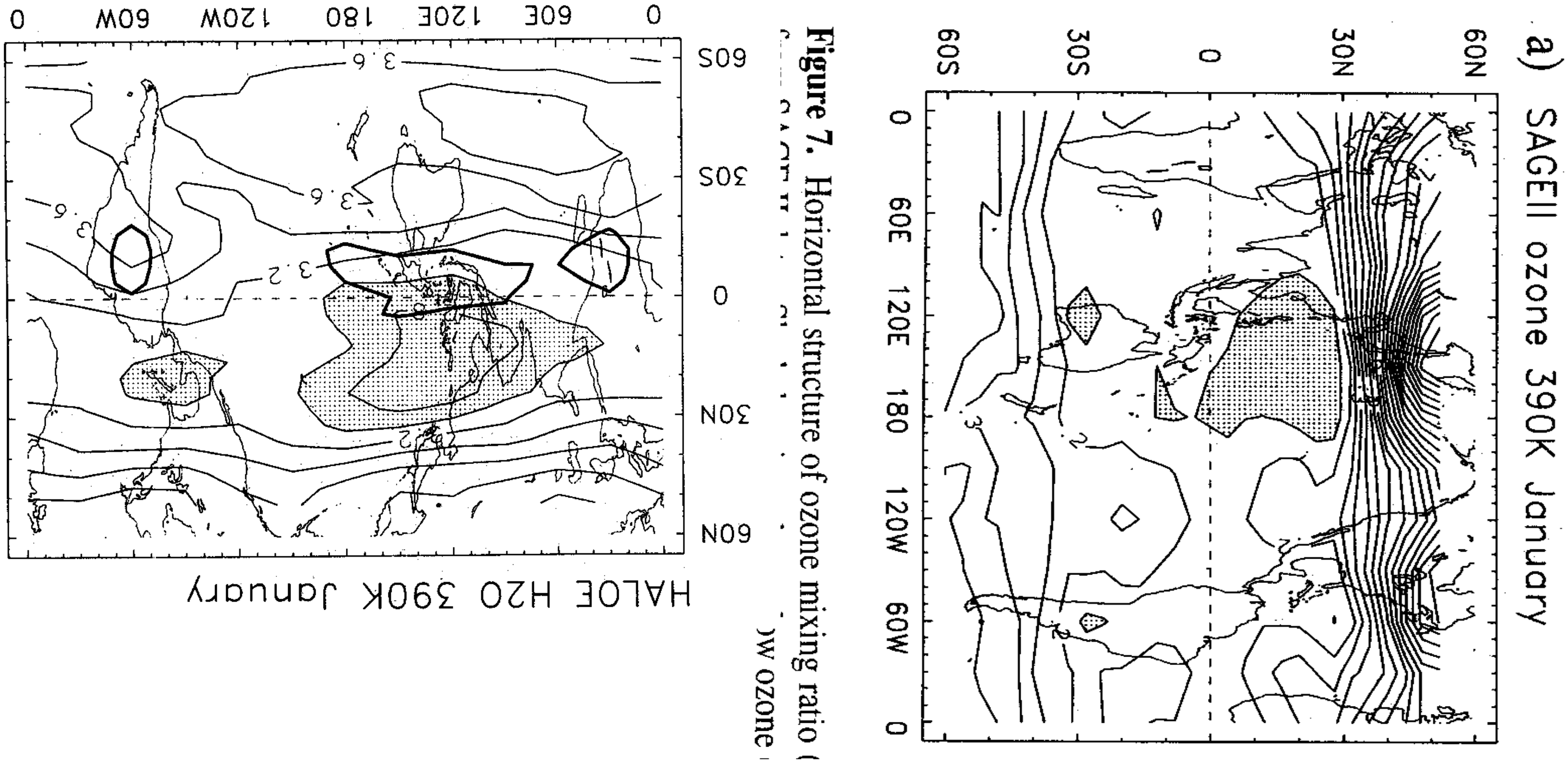


Sherwood, S.C., A stratospheric "drain" over the maritime continent, *Geophys. Res. Lett.*, 2000.

Constraints

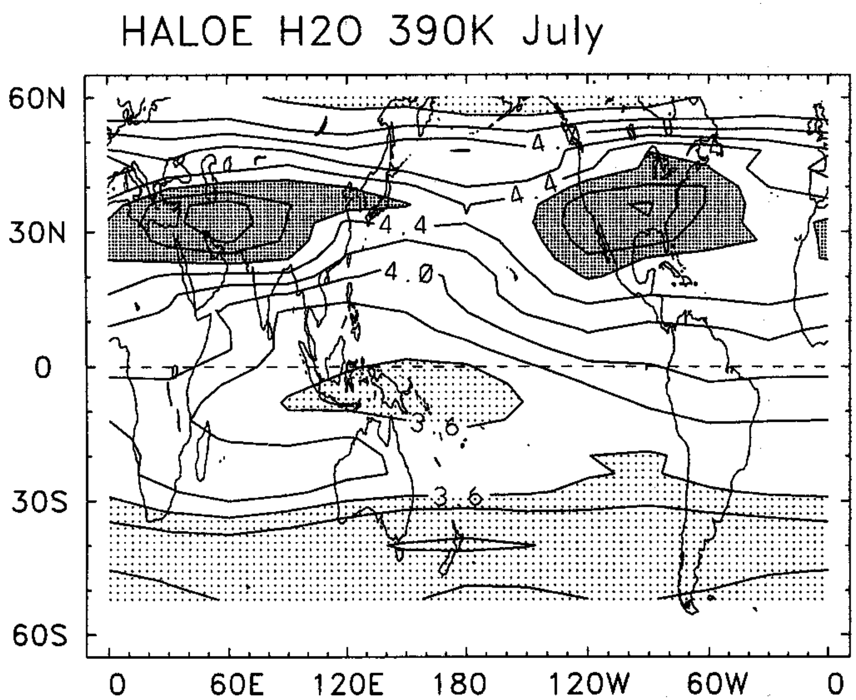
Water vapor entering the stratosphere	3.85 ppmv (±5%) in the mid 1990s [Dessler and Kim, 1999, SPARC Water Vapor Assessment, 2000]
Isotopic abundance of HDO and H2Q	HDO: -679±20 per mil, H2Q: -128±31 per mil [Johnson et al., 2001]
Water-ozone correlation	Positive or negative?

Randel et al., JGR, 2001

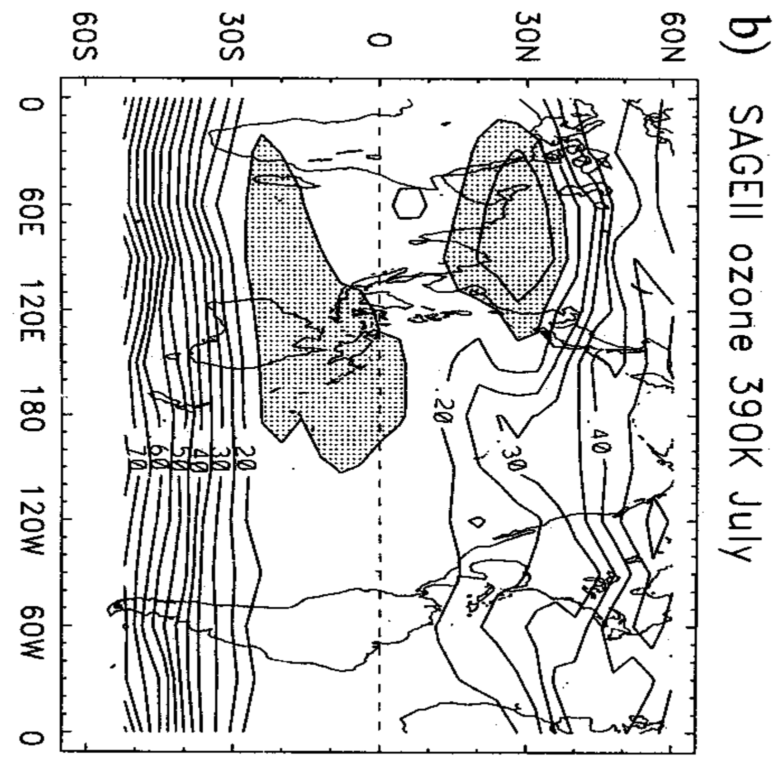


January

Randel et al., JGR, 2001



ppmv) at 390 K for (left) January and (right) July, derived (<0.15 ppmv).



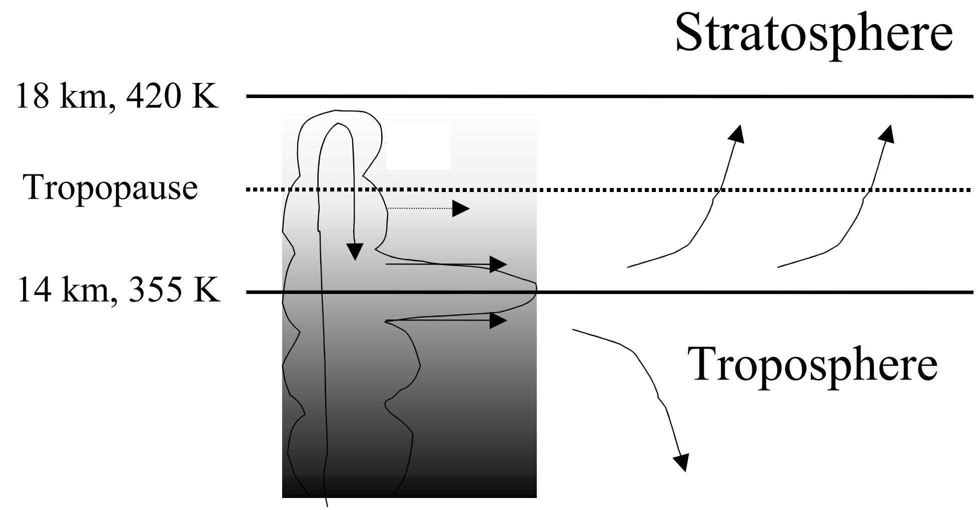
July

Chemistry

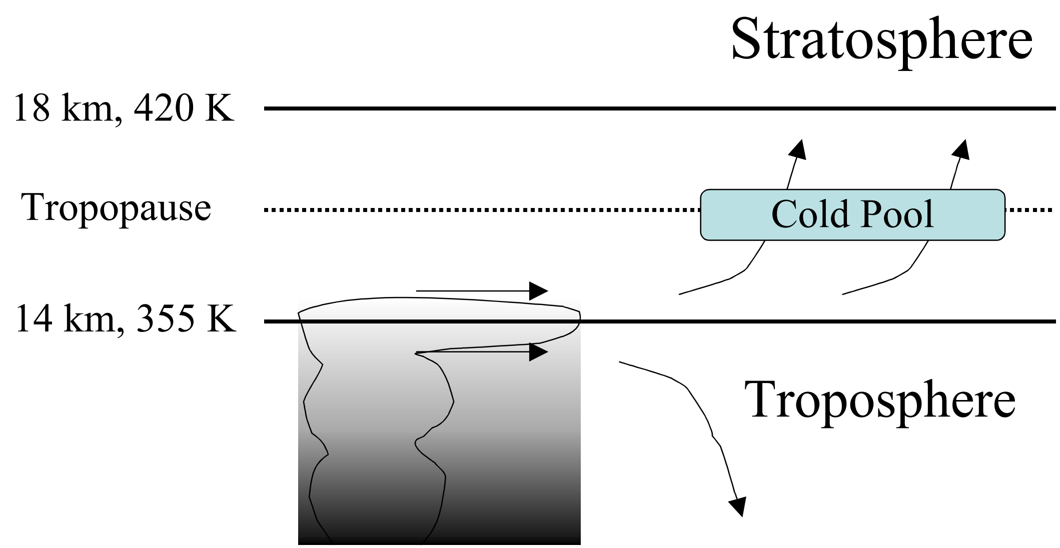
- Mix of troposphere and stratosphere
- O_3 is produced by both photolysis and HO_x+NO_x
- CO is destroyed by oxidation
  - CO & O_3: photochemical clock (e.g., Weinstock et al., 2001)
- CH_4 and N_2O are essentially inert

Theories of Dehydration

Convective Dehydration



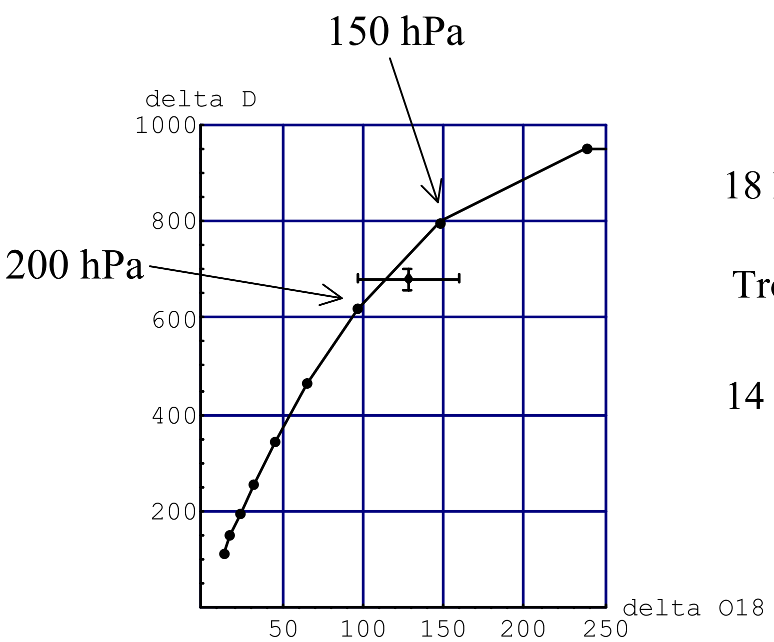
"Cold Trap" Dehydration

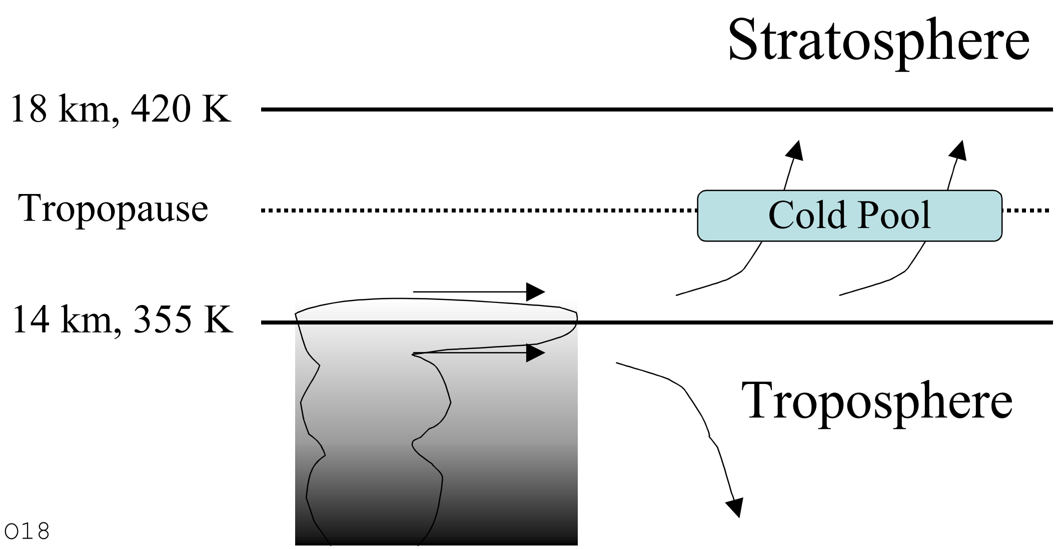


Isotope fundamentals

- R=[HDO]/[H2O]
- delta D = 1000(R/Ro-1)
- Only changes in HDO relative to H2O change these values
- Condensation preferentially reduces HDO

Isotopic Constraint





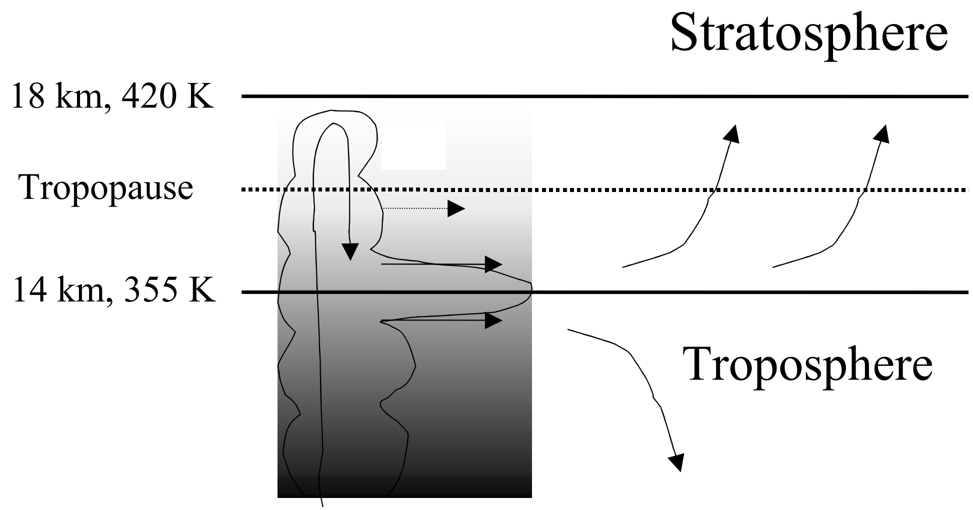
Johnson et al., Isotopic composition of stratospheric water vapor: Implications for transport, *J. Geophys. Res.*, 2001.

Keith, D.W., Stratosphere-Troposphere exchange: Inferences from the isotopic composition of water vapor, *J. Geophys. Res.*, 2000.

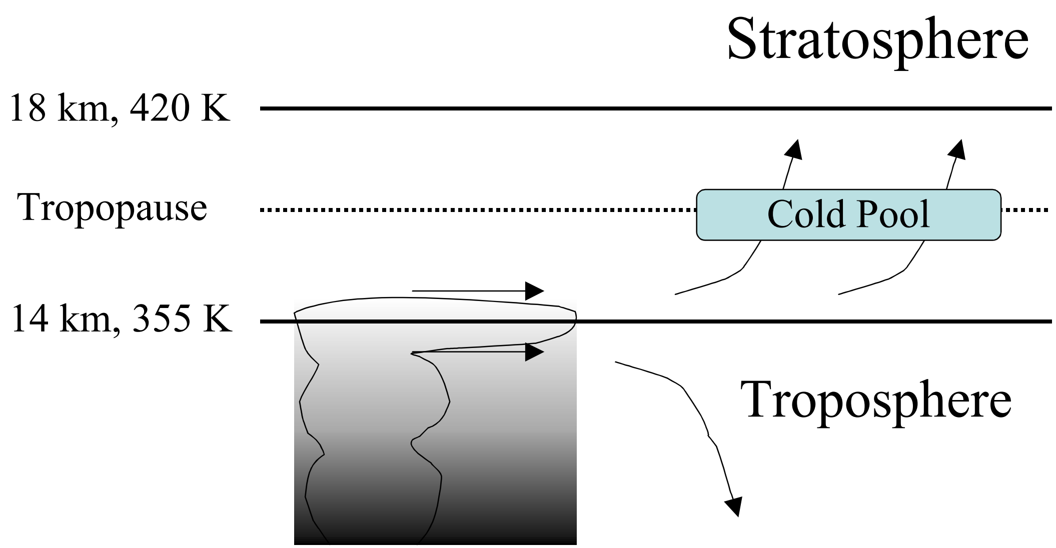
Moyer et al., ATMOS stratospheric deuterated water and implications for troposphere-stratosphere transport, *Geophys. Res. Lett.*, 1996.

Theories of Dehydration

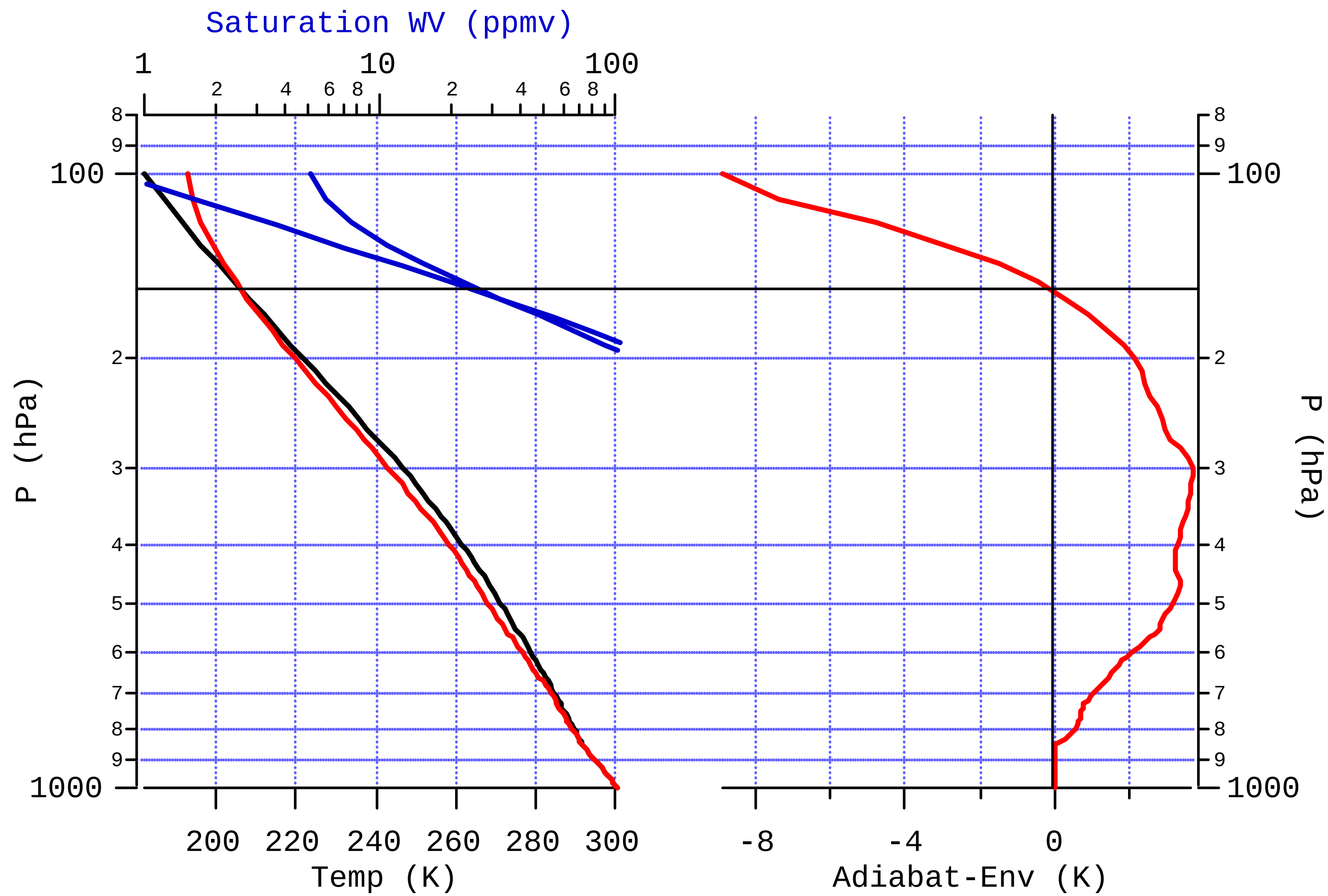
Convective Dehydration



“Cold Trap” Dehydration



Temperature profiles



Feb. 1995 sonde data, avg. between 10N and 10S

Pseudo-adiabatic profile lifted from 850 hPa

Conservation Equation in the TTL

$$\frac{\partial[\chi]}{\partial t} = P_\chi - L_\chi[\chi] - \dot{\theta}\frac{\partial[\chi]}{\partial\theta} - \left(\frac{[\chi]-[\chi]_{PBL}}{\tau}\right)$$

Transport due to slow ascent from mean strat circulation

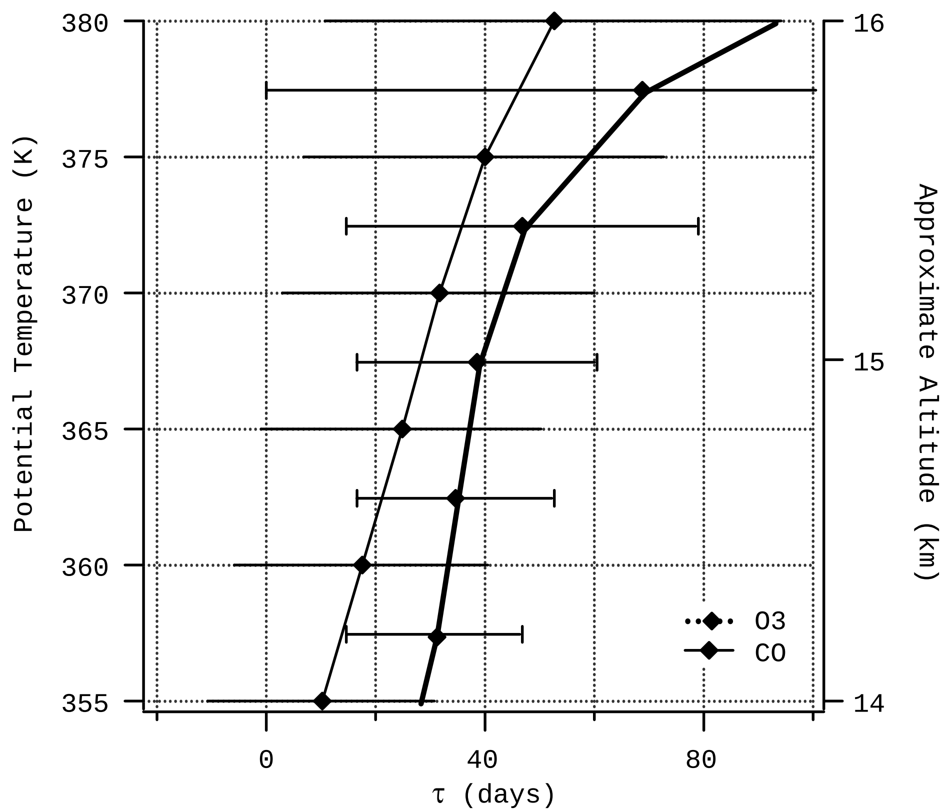
rapid vertical transport via convection of planetary boundary layer (PBL) air into the TTL with a transport time constant of τ.

Note: θ is potential temperature and $\dot{\theta}$ is the vertical velocity in θ coordinates

Calculated mixing time, τ

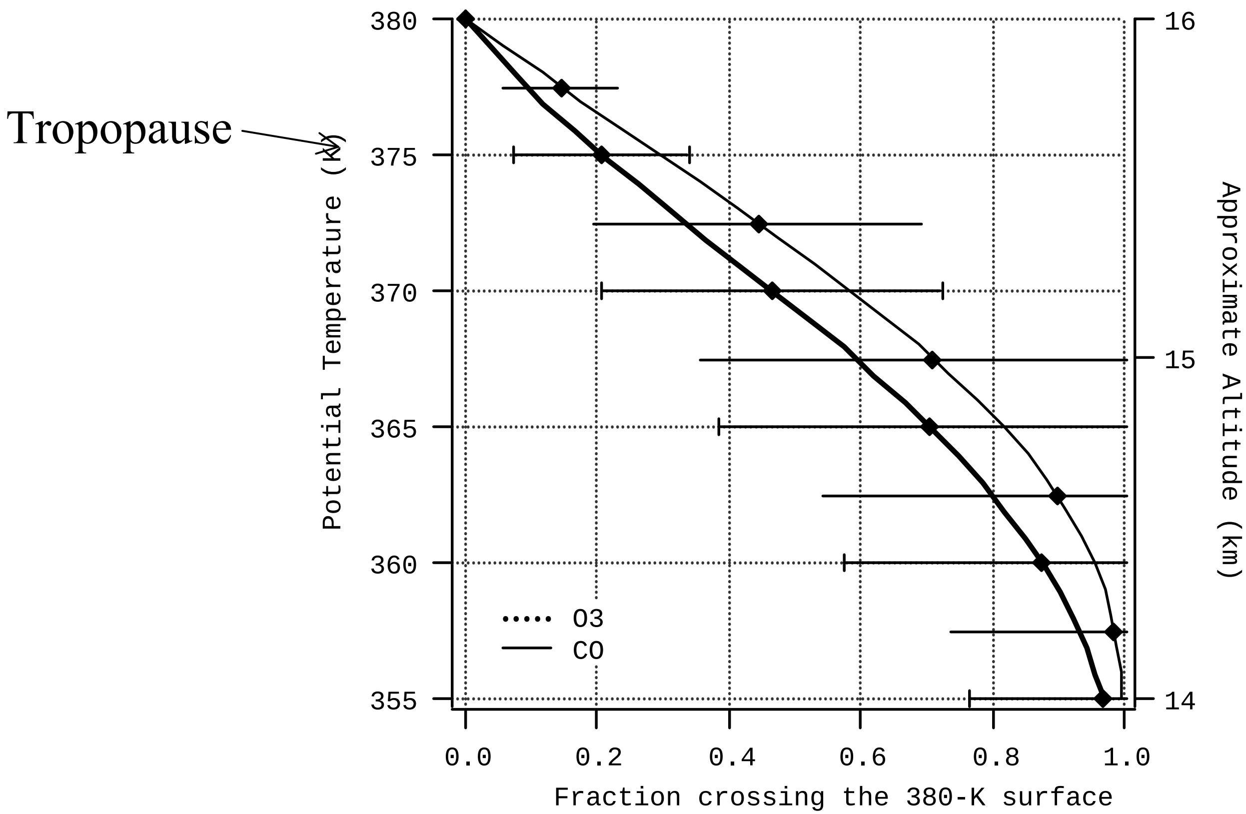
τ is the turnover time for the TTL due to convection.

The increase in τ with altitude is consistent with our view of the thermodynamics of the PBL.



Importantly, our results show that convection does influence the chemistry around the tropical tropopause

Mass crossing the tropopause

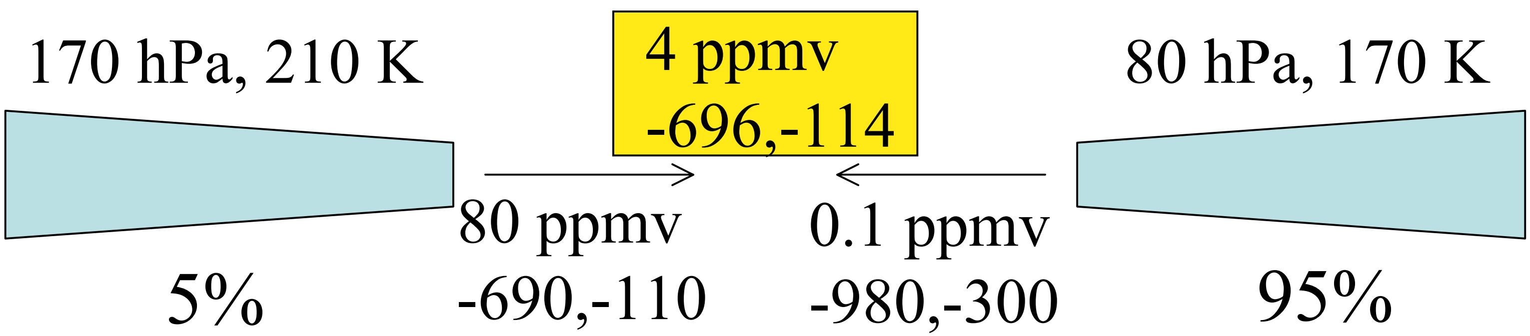


This plot shows the fraction of mass that's crossing the 380-K surface that detrained above each θ surface

As expected, virtually 100% of the mass detrained above 355 K. Surprisingly, 45-60% of the mass crossing the 380-K surface detrained above 370 K.

A solution to the isotopic conundrum

- Johnson et al. [2001]
- Imagine that air going into the stratosphere comes through two pipes.



"most of the moisture comes from convective outflow near 11 km, most of the air in the upper troposphere consists of dehydrated air from convective systems with cloud top temperatures below that of the mean tropical tropopause."

Conclusions

- Dehydration and strat-trop exchange are different processes
- Air is transported to the TTL via convection; transported out of the TTL via Brewer-Dobson circulation
- Tracer data show
  - Air detrains throughout the TTL
  - Positive and negative correlations with H2O
- Isotopic data show that air cannot be dehydrated along ONE path

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