Brewer-Dobson Circulation

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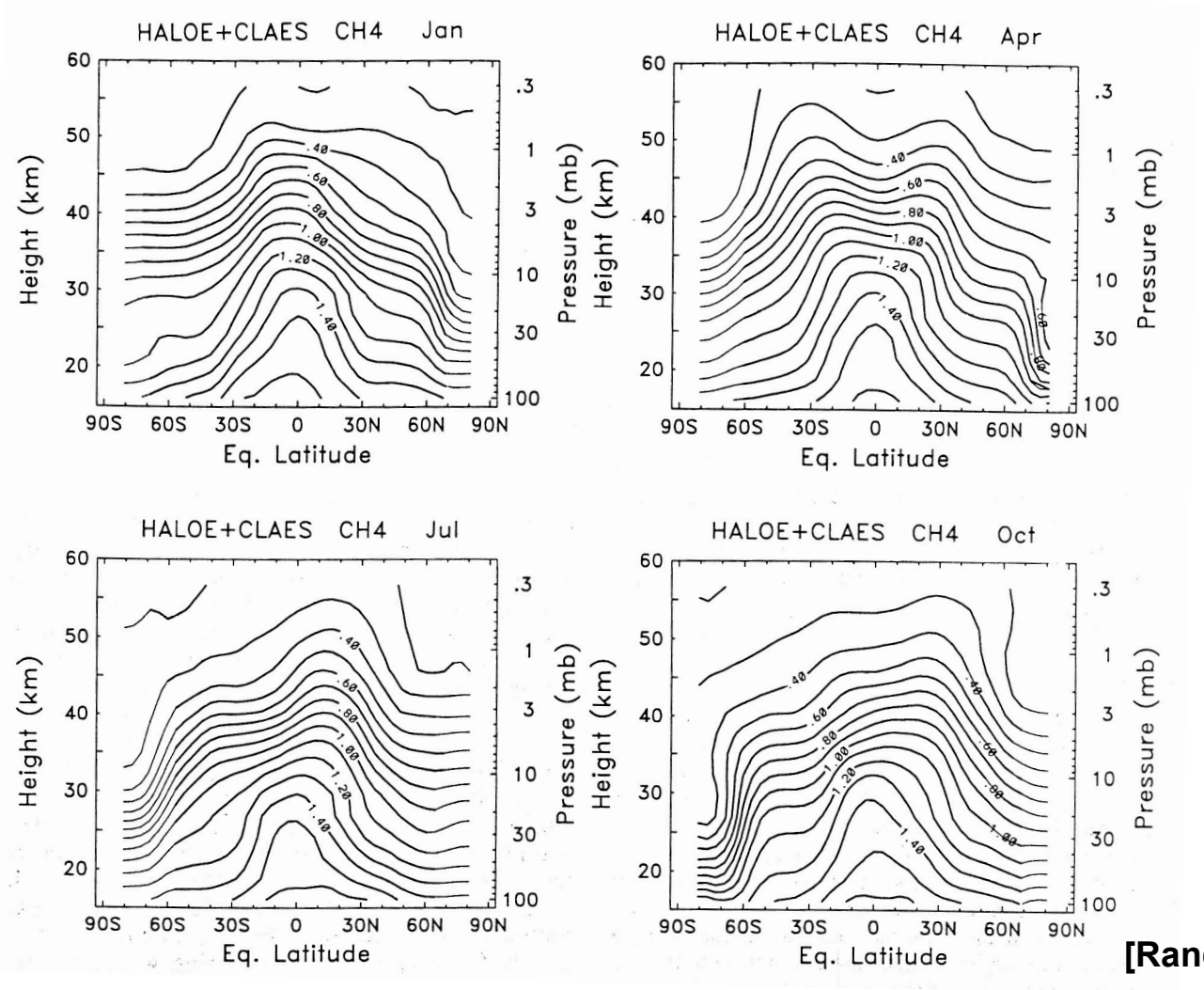
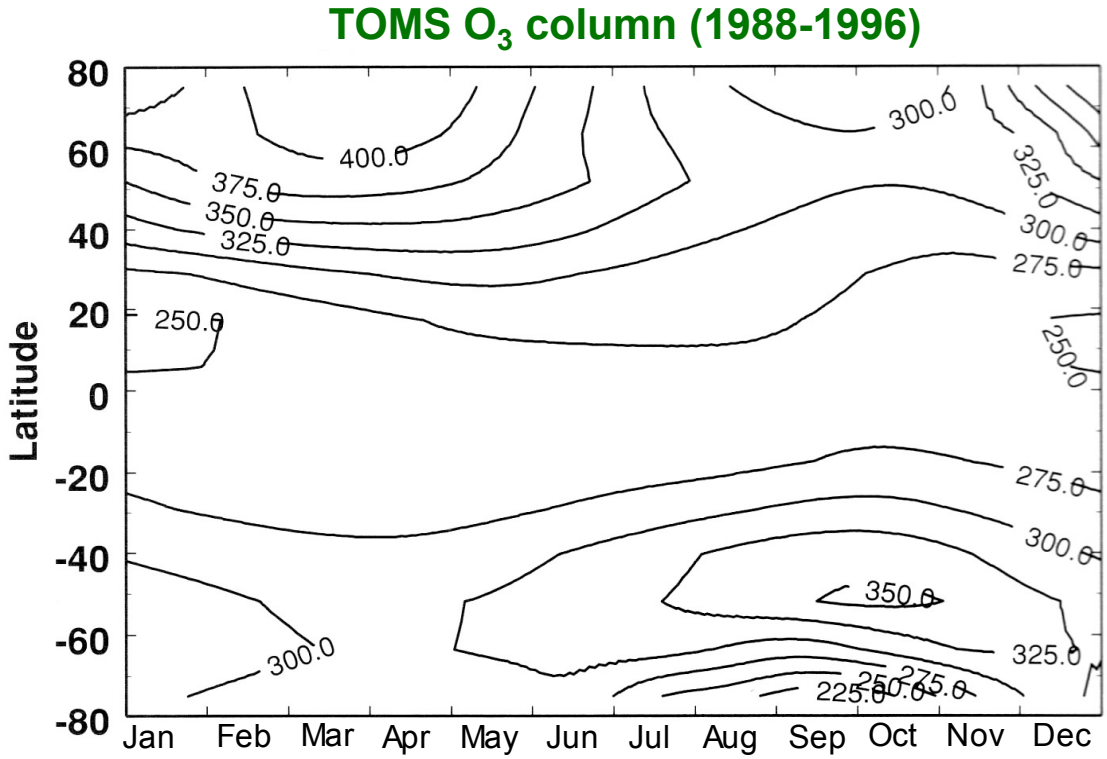
Influence of B-D Circulation on CH_4 Distribution



[Randel et al., 1998]

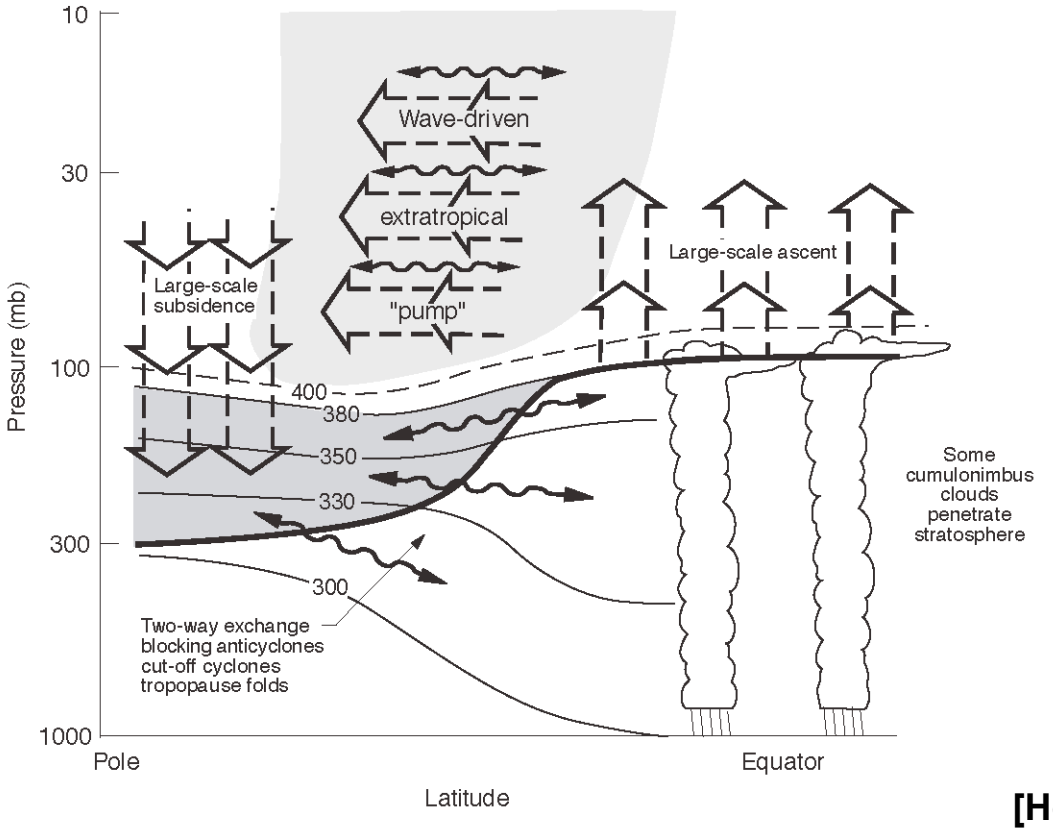
Mixing ratio (ppm)

Influence of the Brewer-Dobson Circulation on O_3



O_3 maxima occur toward high latitudes in late winter/early spring as a result of descent associated with the circulation

Wave-driven Circulation

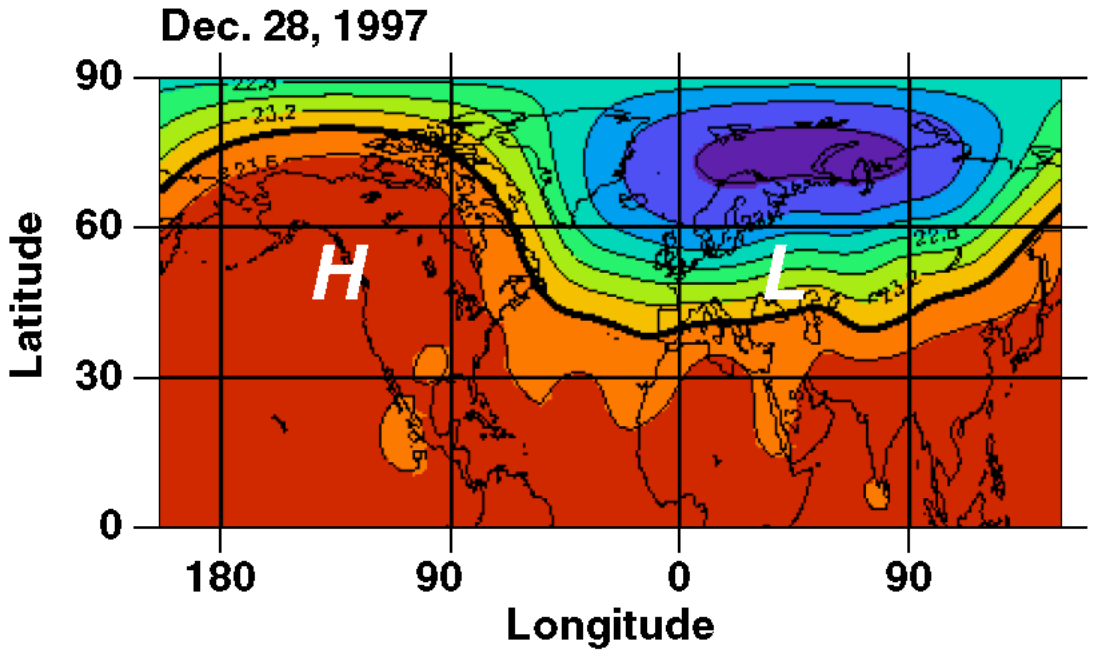


[Holton et al., 1995]

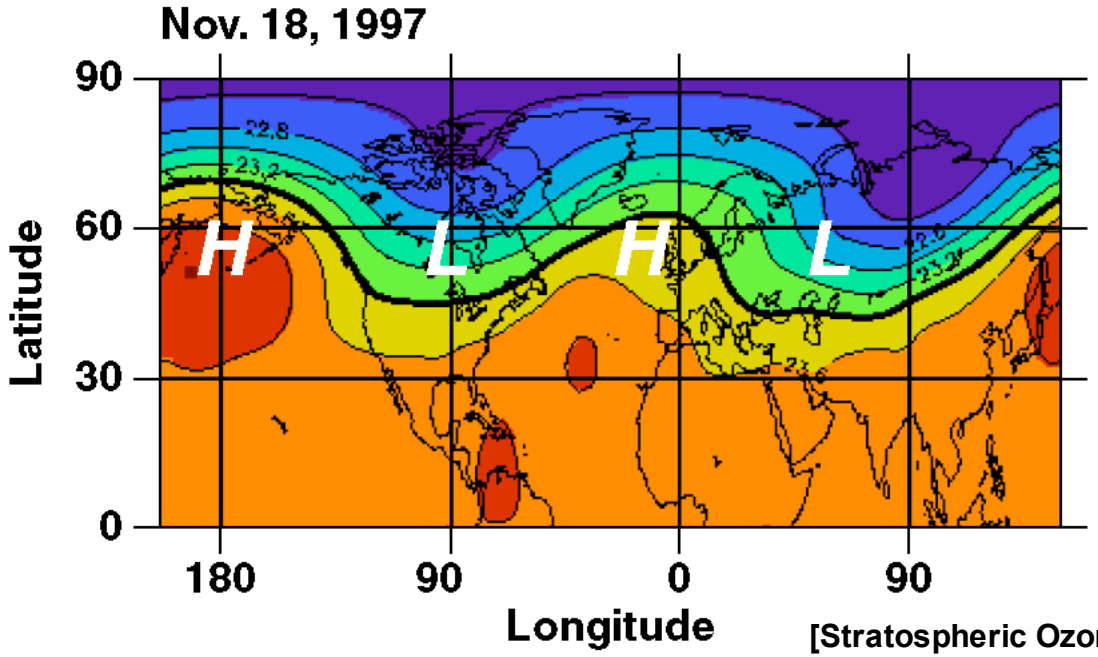
Meridional transport of trace constituents

- Advective transport by circulation
- Mixing due to eddies

Stratospheric Waves (30 mb)

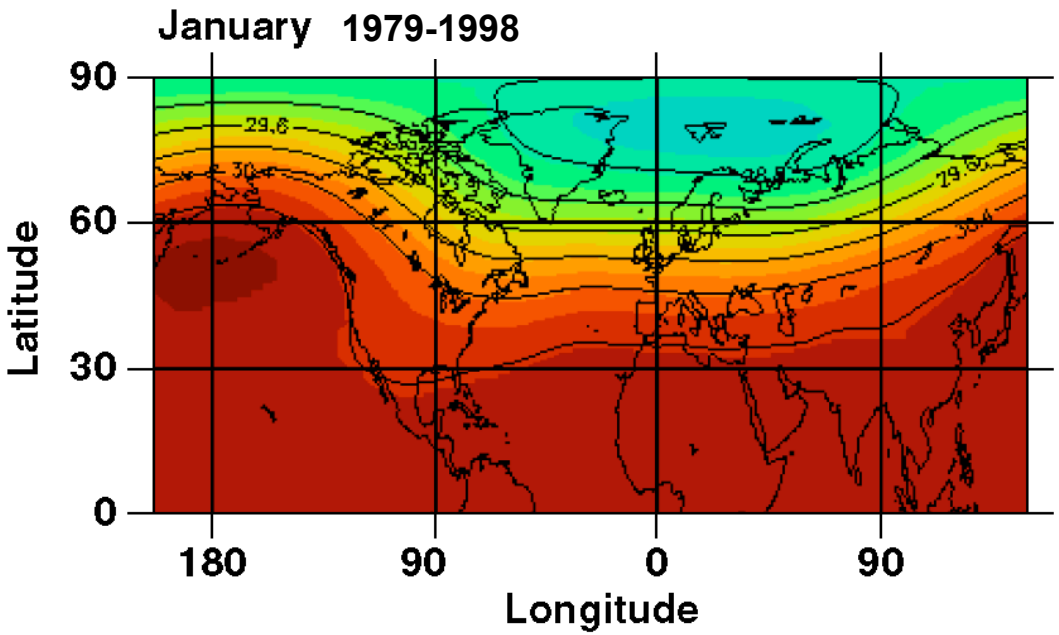


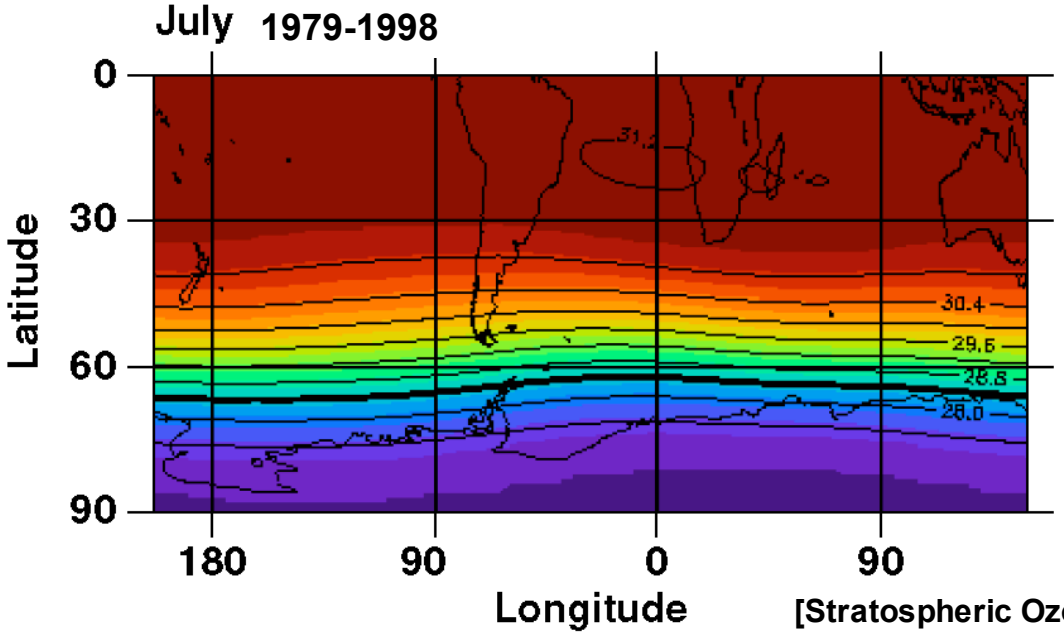
High-Low Wave 1 pattern



Wave 2 pattern

[Stratospheric Ozone Electronic Textbook]





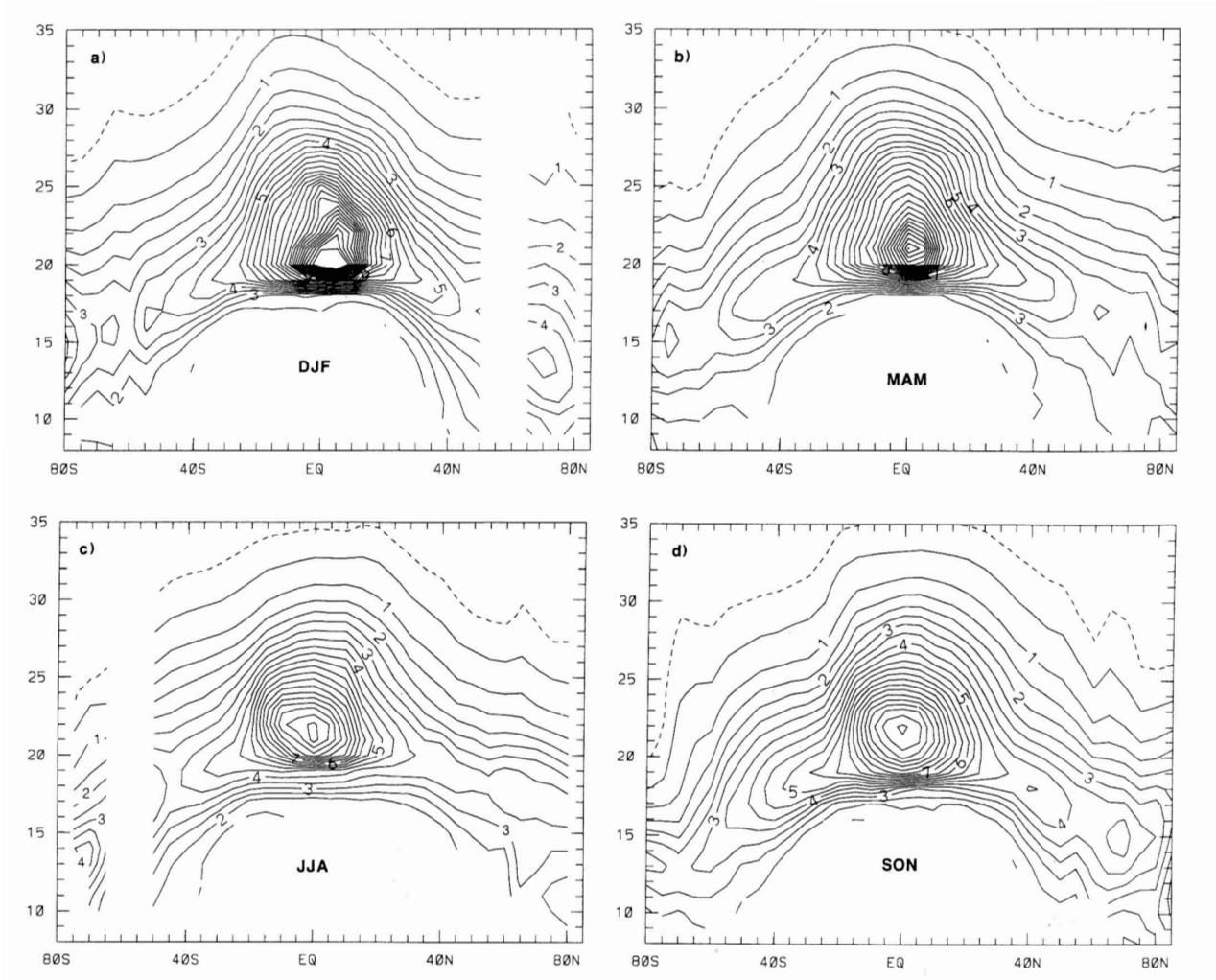
Hemispheric Asymmetry in Wave Driving

Climatology of geopotential heights

Southern hemisphere less perturbed than NH

[Stratospheric Ozone Electronic Textbook]

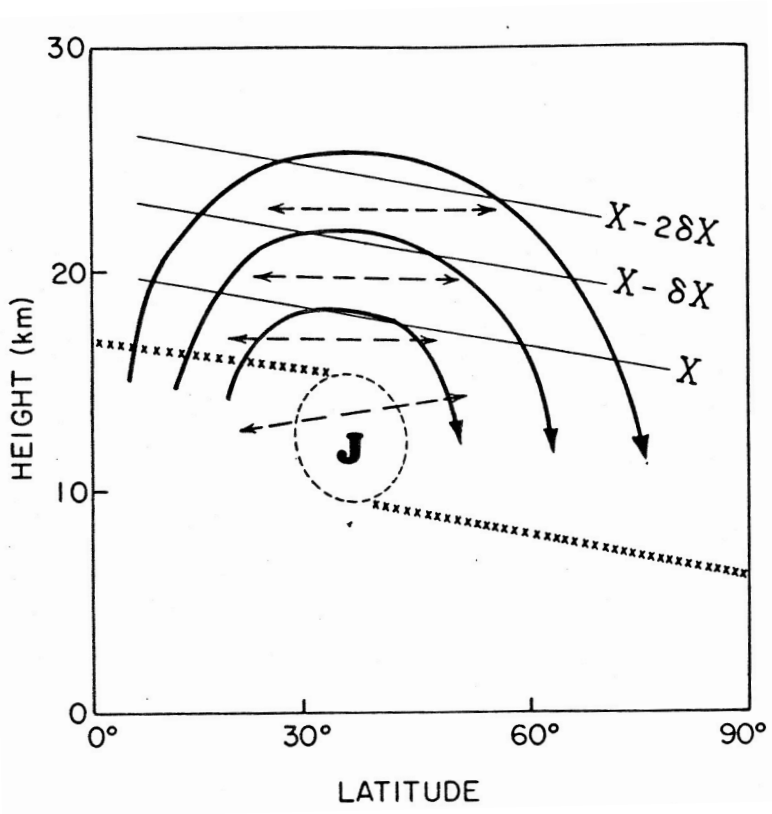
Tropical Reservoir



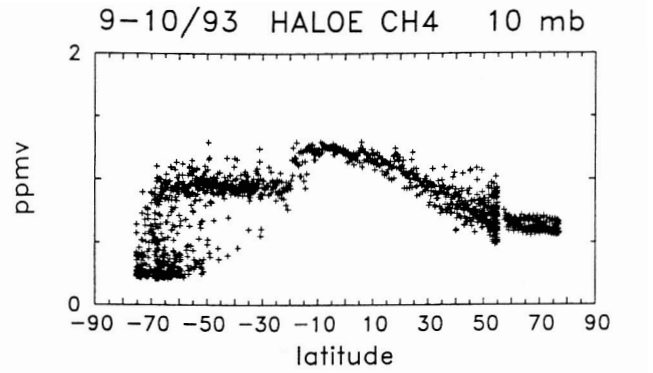
[Hitchman et al, 1994]

Strong meridional gradients in subtropics ⇒isolation from eddy mixing in extratropics

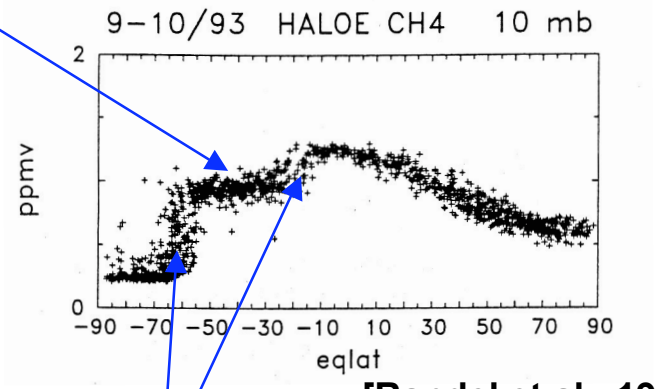
The Surf Zone



[Holton, 1986]



Surf zone

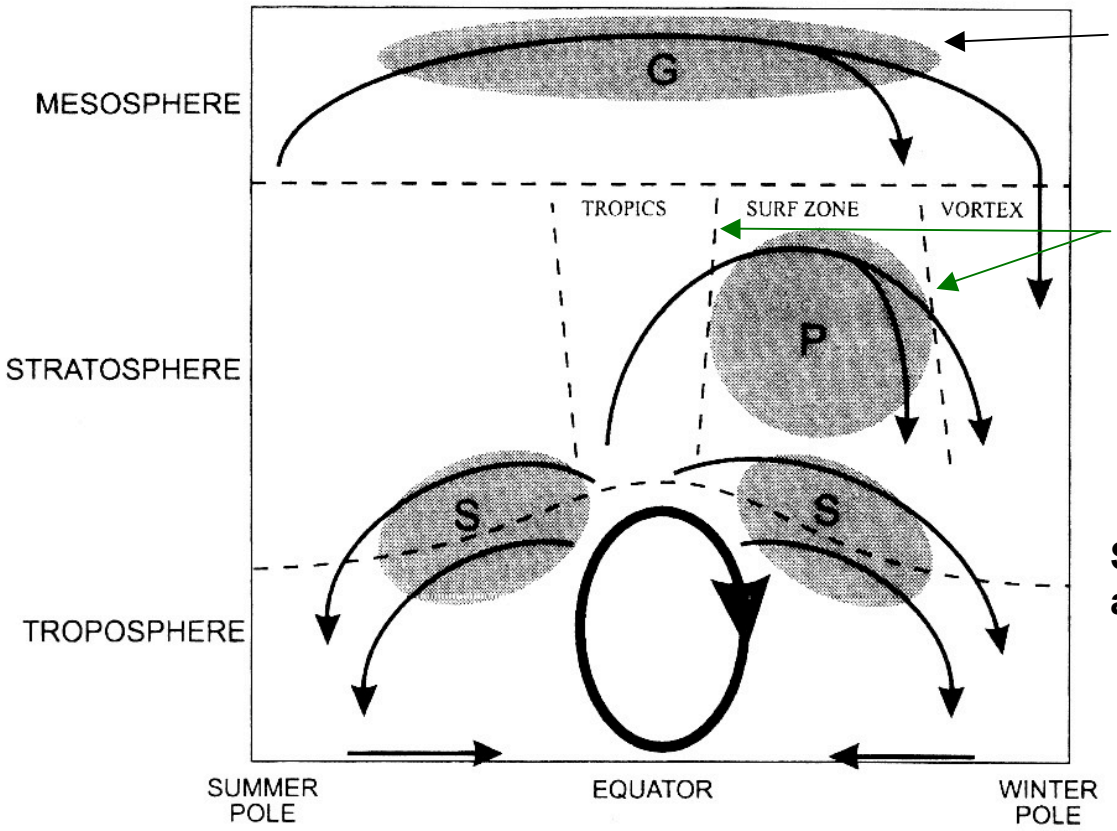


[Randel et al., 1998]

Mixing barriers

The circulation acts to steepen the mixing ratio slopes, while the mixing flattens the slopes

Composite Description of the Circulation



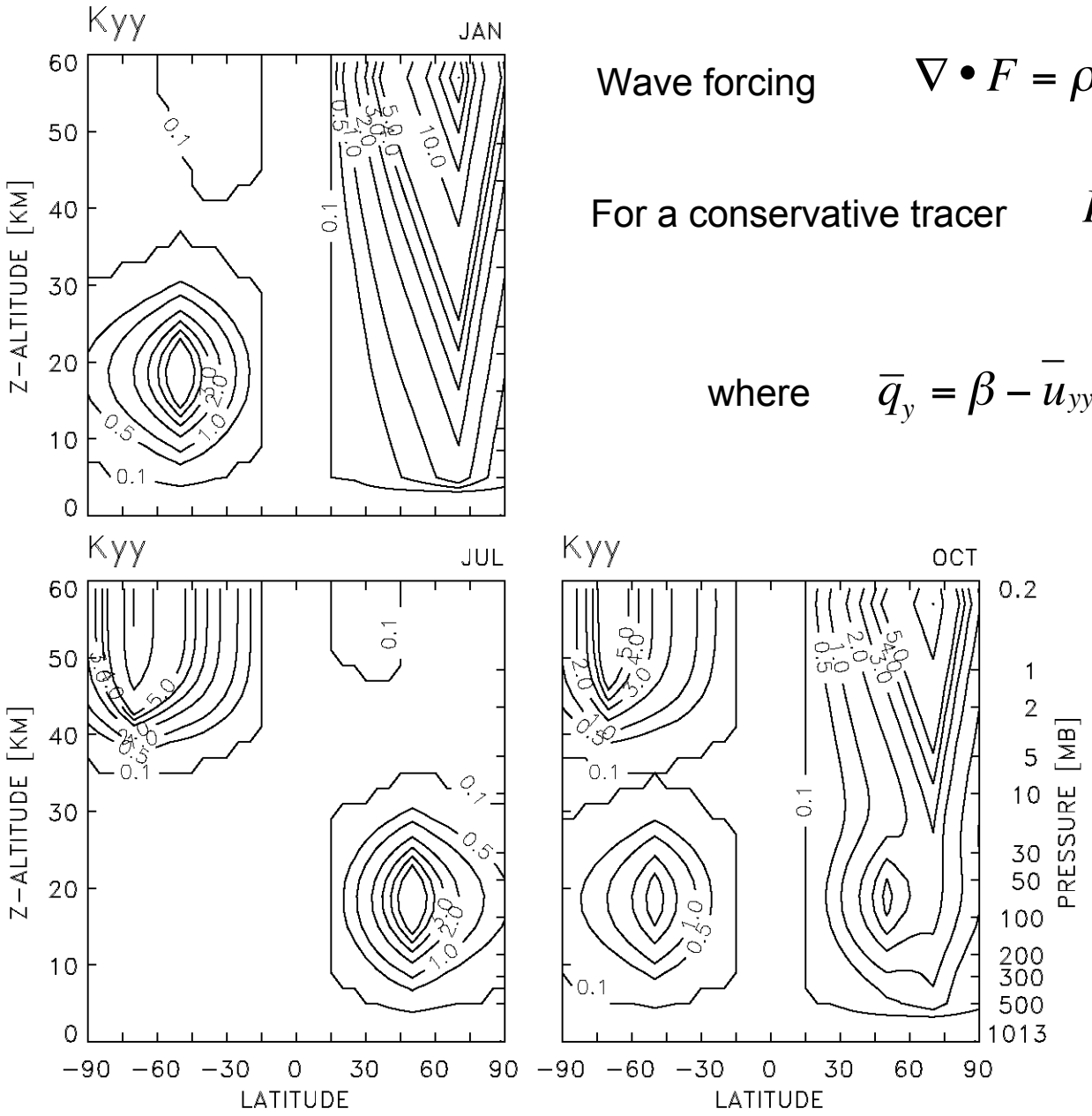
Gravity waves

Mixing barriers

Synoptic scale waves are trapped

[Plumb, 2002]

Forcing the circulation in a zonal mean model (Kyy)



Wave forcing $\nabla \bullet F = \rho_o \overline{v'q'}$

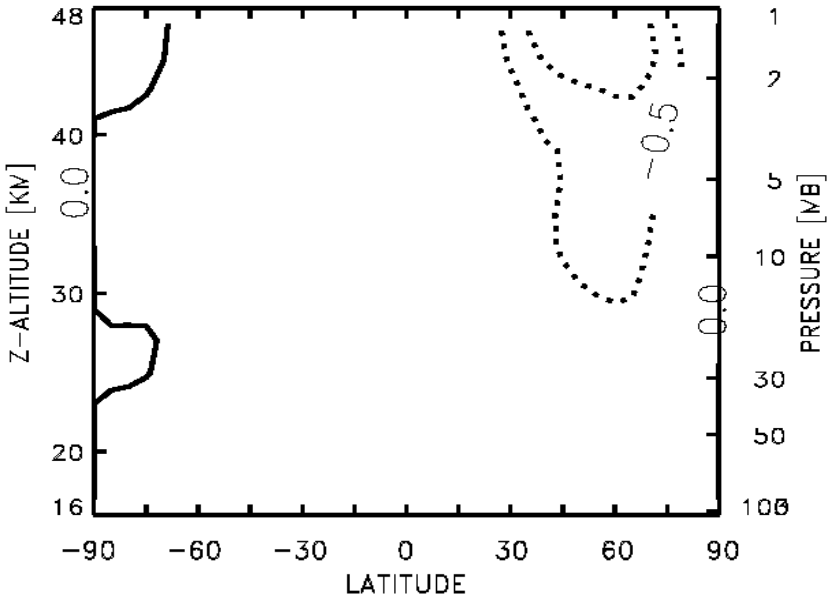
For a conservative tracer $K_{yy}\bar{q}_y = -\overline{v'q'}$

where $\bar{q}_y = \beta - \bar{u}_{yy} - \frac{f^2}{N^2}\frac{1}{\rho_o}\partial_z(\rho_o \bar{u}_y)$

Units: 10^5 m s^{-2}

[Schneider et al., 2000]

Jan. Zonal Mean Forcing in the Model



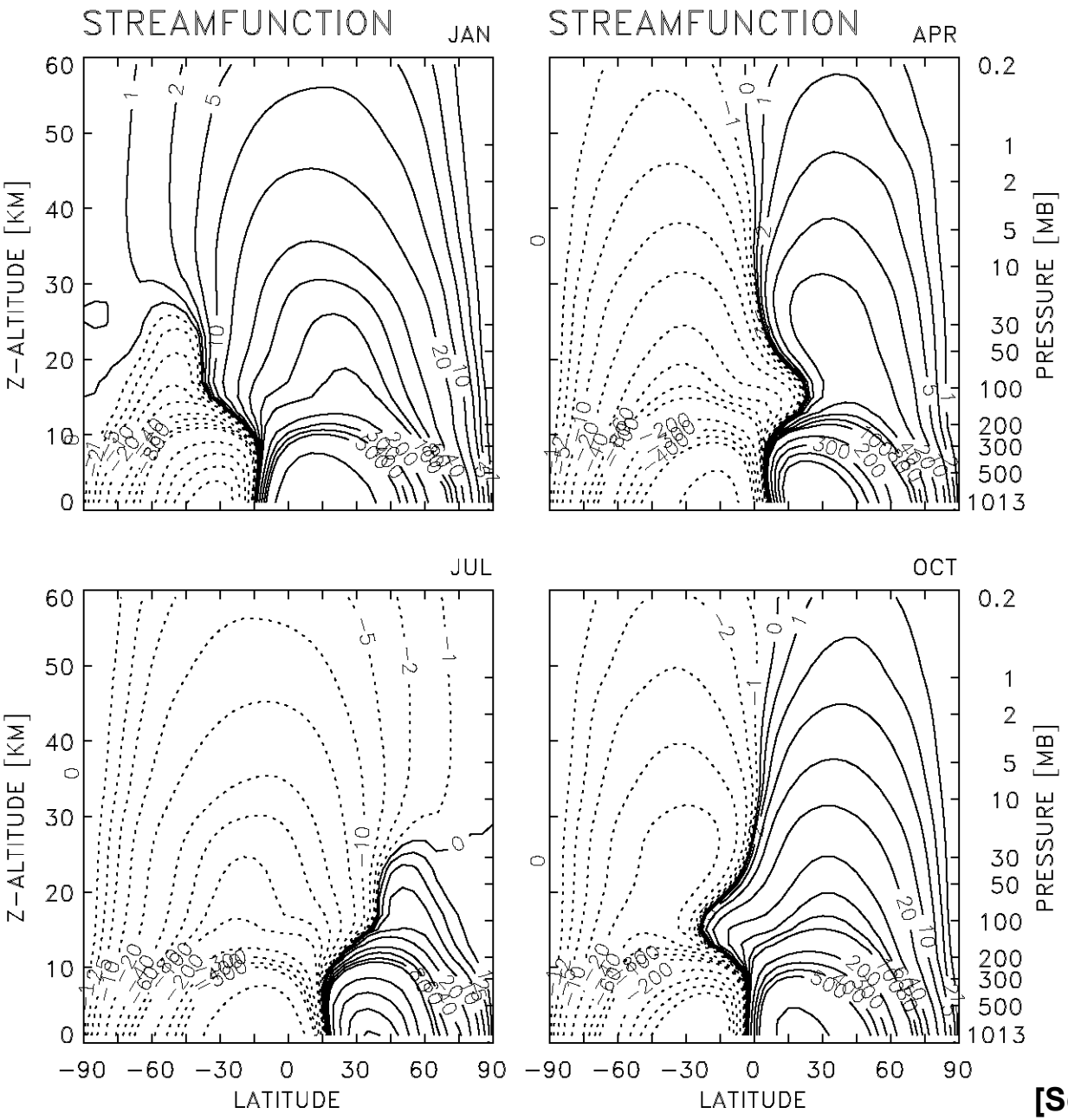
Units: m s^{-1} d^{-1}

Forcing: $K_{yy}\bar{q}_y$

Forcing is localized in vicinity of westerly jet in winter stratosphere

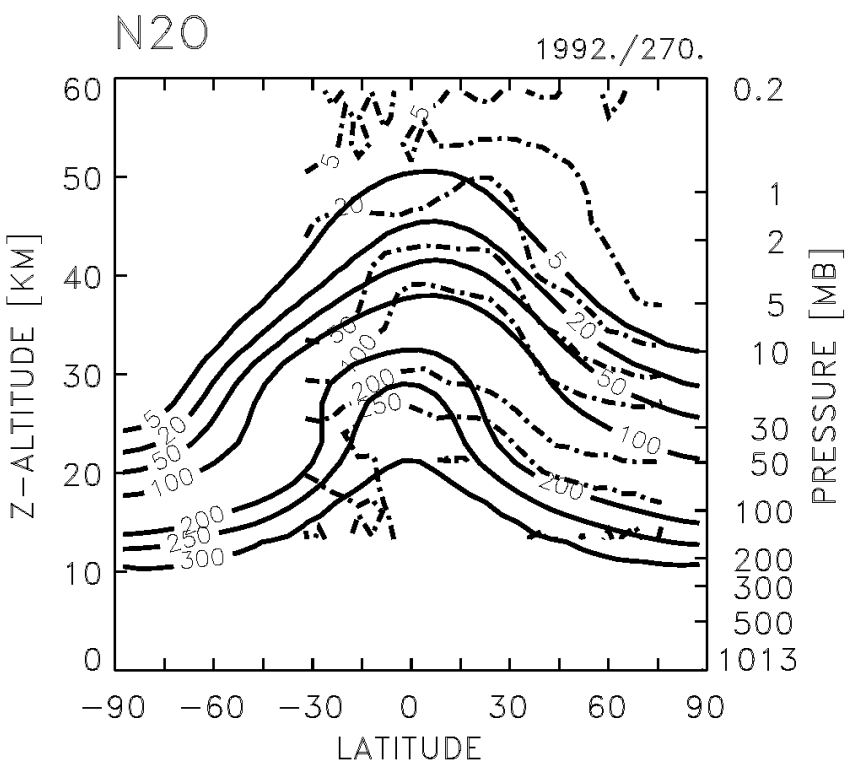
[Schneider et al., 2000]

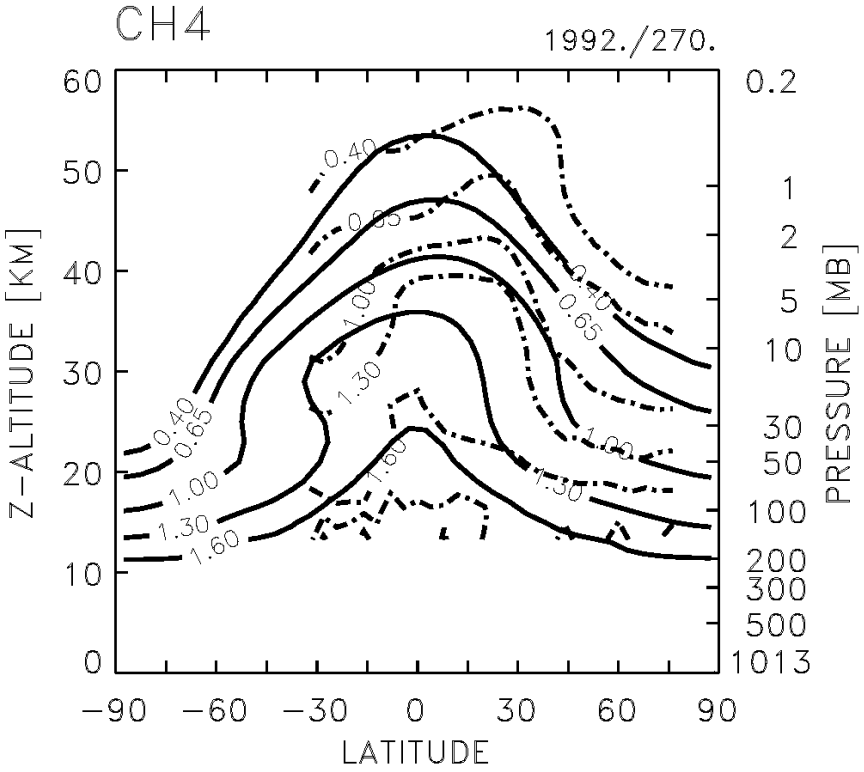
Stream functions in the Harvard 2-D Model



[Schneider et al., 2000]

Comparison between the 2-D model and CLAES (for Sept.)

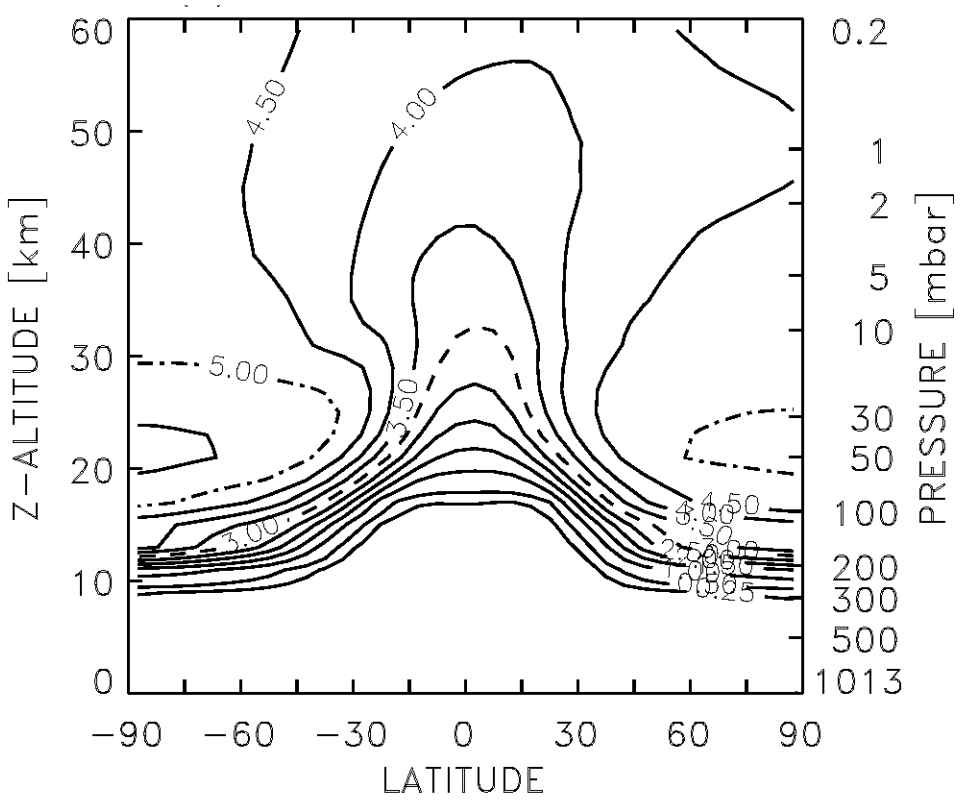




[Schneider et al., 2000]

The model represents an average year and reproduces only the coarse features

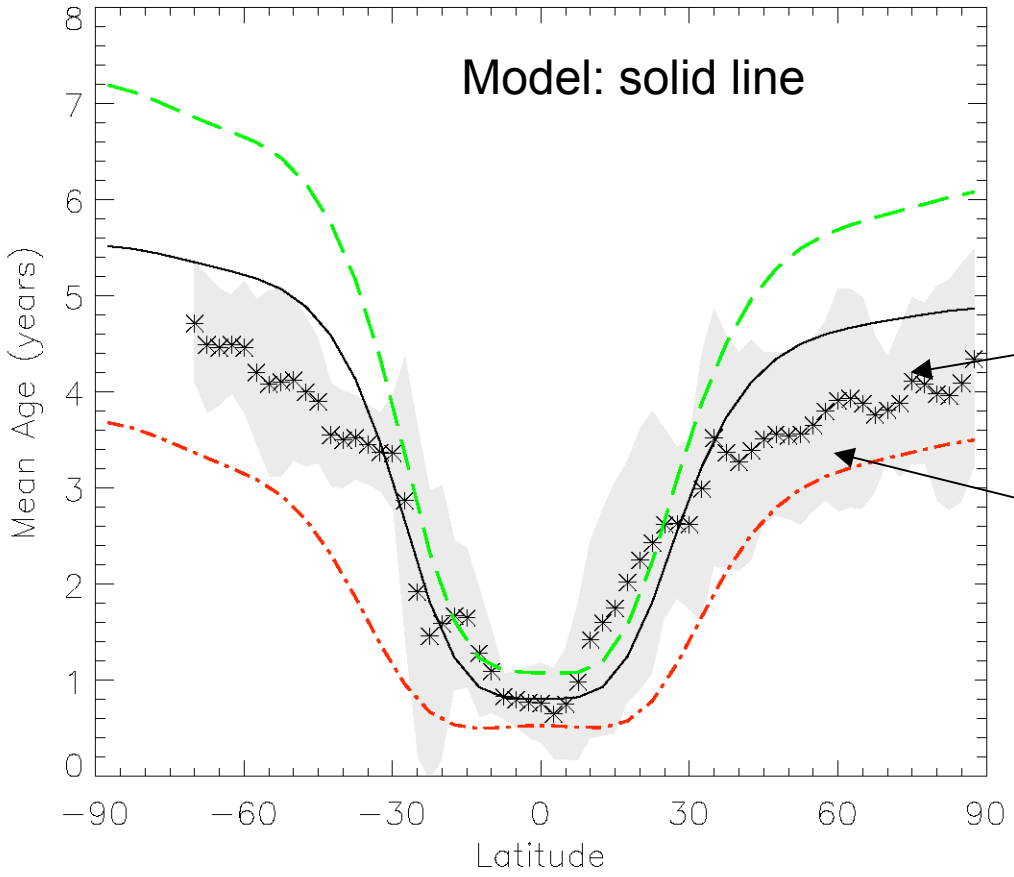
Mean ages of stratospheric air in the 2-D model



[Jones et al., 2001]

Age maximum in extratropical lower stratosphere is a unique feature of this model - is this correct?

Comparison of model with inferred mean ages

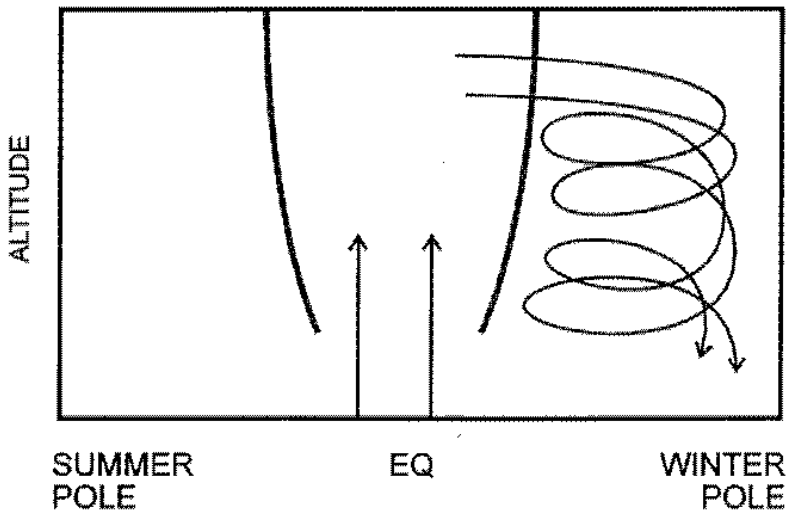


ages inferred from observations of CO_2 between 19-21 km

Shaded region 1-sigma

The model captures the horizontal gradient in the lower strat., but what about the vertical gradient?

Influence of Mixing Transport Pathways



[Plumb, 1996]

There are a multitude of paths for air parcel from the tropical stratosphere to the extratropical lower strat.

Inferred Age Spectrum

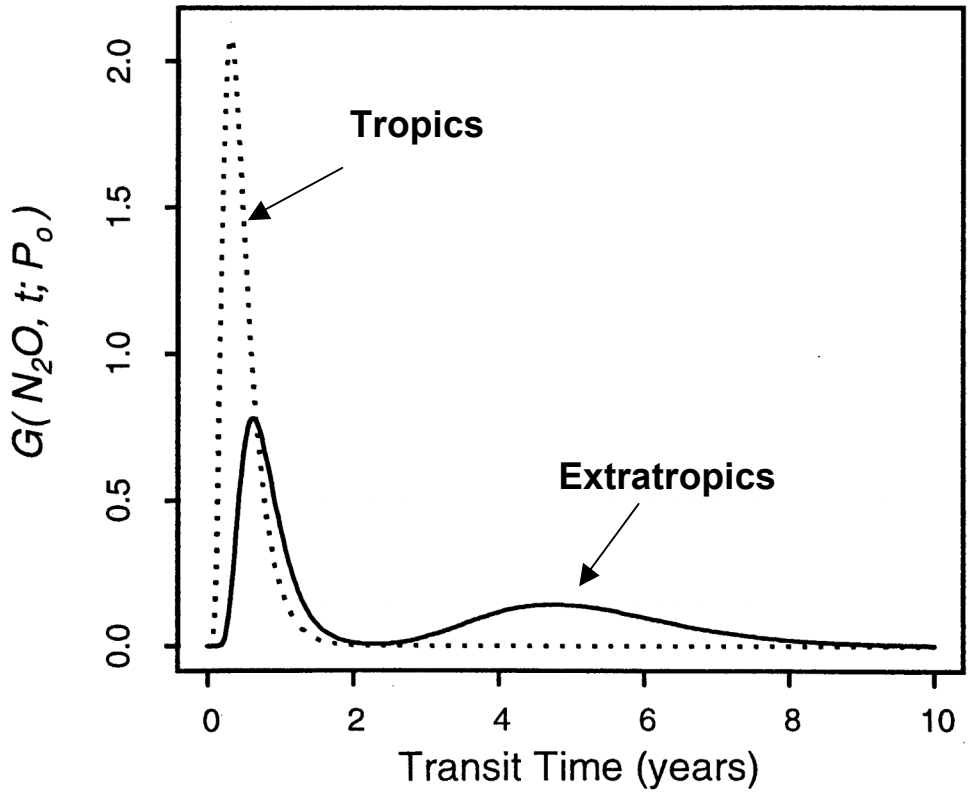
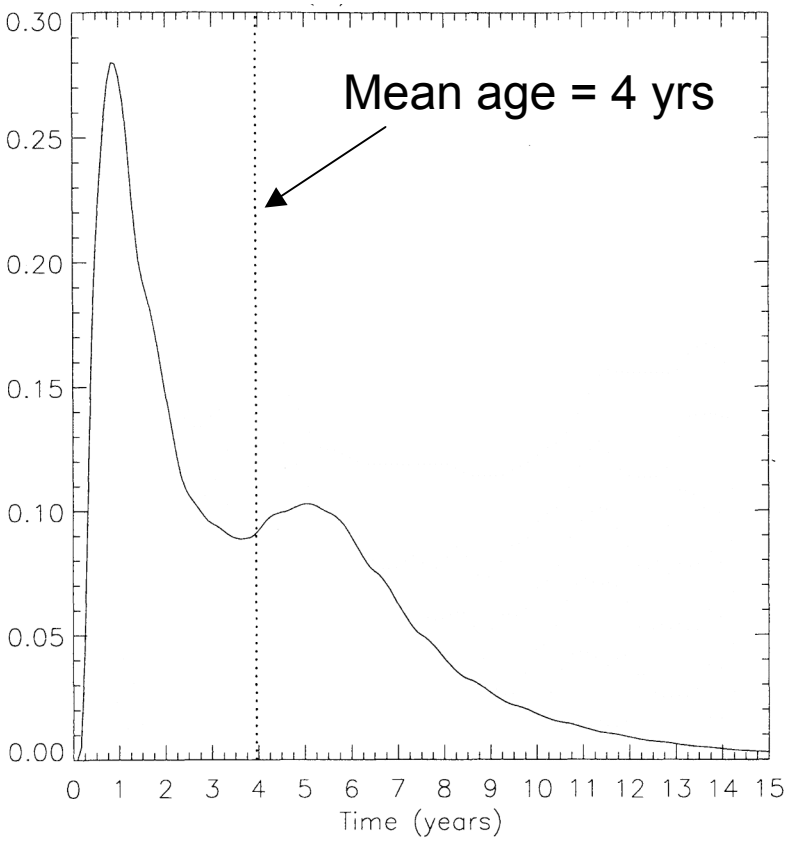


Figure 11. Annual mean tropical age spectrum for 460 K (dotted line) and the midlatitude age spectrum for 245 ppbv N_2O (~460 K, solid line).

[Andrews et al., 2001]

- **Two distinct pathways (a slow and a fast) for transport to extratropical lower stratosphere**
- **Consistent with the description of the tropics as a "leaky" pipe [Neu and Plumb, 1999]**

Age Spectrum in 2-D Model

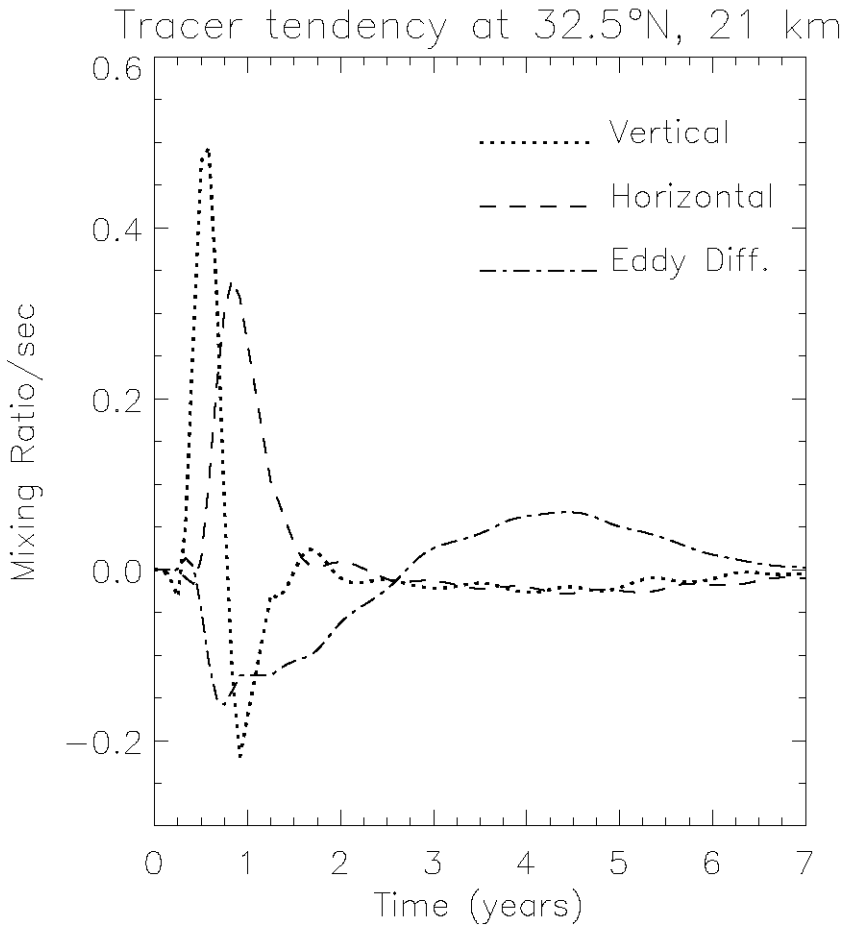


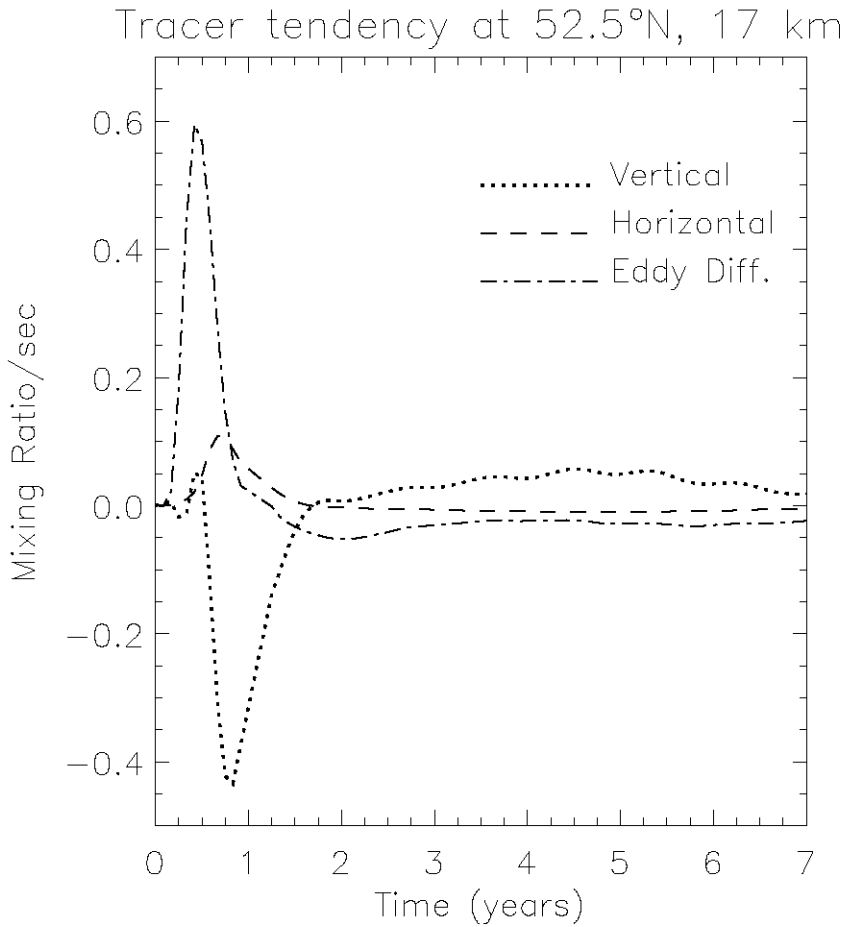
Spectra for 42°N on 205 ppb N_2O surface

[Jones et al., 2001]

Model reproduces the biomodal distribution of transit times in lower strat

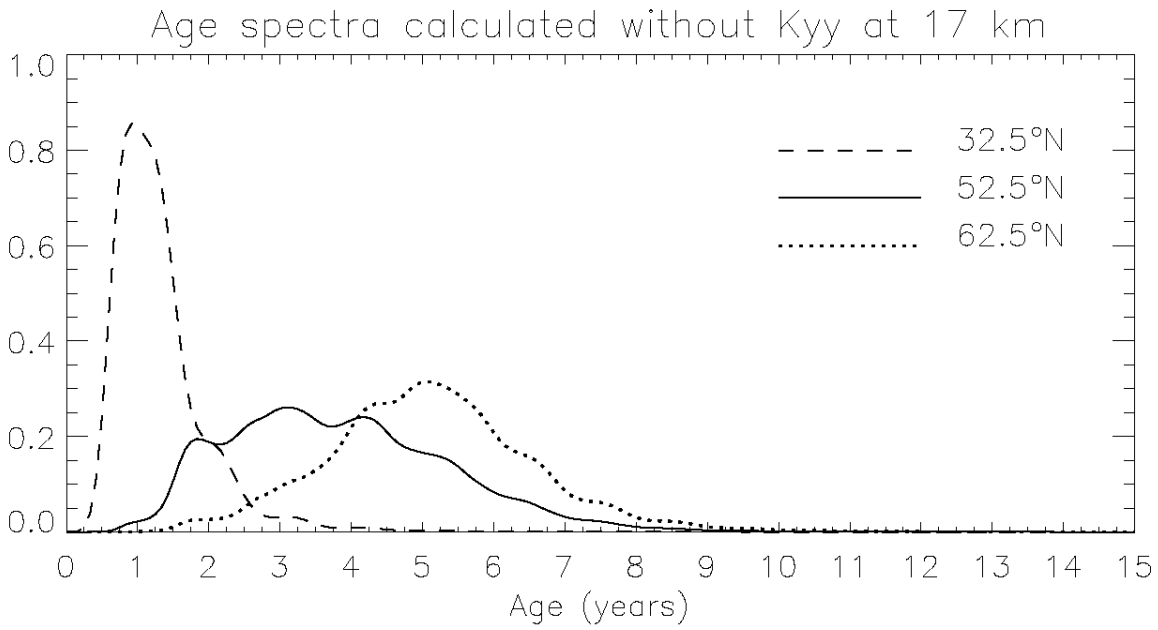
Contribution of Advection and Diffusion to Spectra

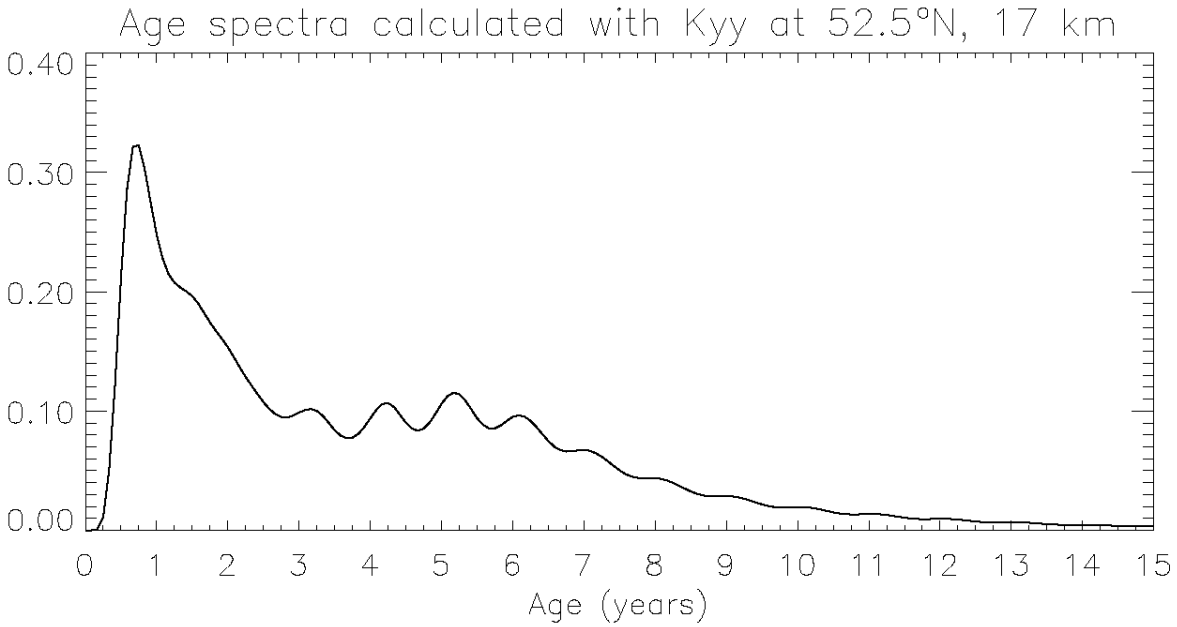




[Jones et al., 2001]

Age Spectrum in Absence of Kyy





Mixing is an important contribution to meridional transport - in the absence of the mixing, mean ages in the extratropics would be much older

Main Points of Lecture

- The distribution of long-lived tracers is strongly influenced by the Brewer-Dobson circulation
- Mixing by planetary waves is an important contribution to the meridional transport of tracers
- The mixing reflects the action of the waves which are also driving the circulation ⇒the mixing and advection are coupled
- The Kyy framework is useful for simulating meridional tracer transport, but provides only a crude presentation of the effects of the eddies
- Specifying Kyy does not enable the model to capture the feedback of changes in the tracer distributions (such as O_3) on the wave driving