Why do we care about stratospheric circulation changes? 

The stratospheric mean meridional, or Brewer-Dobson, circulation and horizontal mixing between the tropics and extratropics impact polar ozone depletion and determine the distribution of radiatively important trace gases within the stratosphere. Both the mean stratospheric circulation and horizontal mixing are driven by wave activity generated in the troposphere primarily by extratropical weather patterns, the strength and position of the subtropical jets and tropical convective activity. Thus, changes in the stratospheric circulation not only affect important processes in the stratosphere but are also an important indicator of changes in a variety of tropospheric processes.

How is the stratospheric circulation measured? 

It cannot be measured directly but can be inferred, for example, from measurements of certain trace gases such as SF6 and CO2 that have increasing concentrations in the atmosphere. From these trace gases the stratospheric age of air can be calculated. The age of air reveals characteristics of both the mean circulation and mixing as shown in the schematic below.

Observations and Reanalysis 

Verifiable trends are calculated.

TLP Model Basics 

Three coupled 1-D regions including advection, mixing, diffusion and photochemistry (Nau and Plumb, 1999).

Inputs 

We use observationally based profiles for vertical velocity and in-mixing rate and an ozone tracer initialized with SAGE average tropical and mid latitude profiles.

Output with Reanalysis and CCMVal vertical velocity (w) trends — mixing (r) constant

Larger positive w trends seen from top to bottom result in larger negative mean age and tropical lower stratospheric ozone trends.

Note that mean age trends from CCMVal models (dotted red line on bottom plot) are more negative than TLP model trends.

Output with CCMVal w mixing trends – w constant

Larger positive mixing (negative r) trends seen from top to bottom cause larger positive mean age and tropical ozone trends.

4.2%/dec mean age trend roughly as large as observed, but tropical total ozone trend is much larger than observed.

Output with CCMVal w trends - theoretical mixing trends

Top plot shows inferred mixing trend profile such that the TLP model and CCMVal age trends match. Bottom plot shows NCEP-like mixing trend reverses the sign of the CCMVal mean age and tropical ozone trends from negative to positive.

Conclusions

• Observed indicators of stratospheric circulation changes disagree with simulated changes from CCMs.

• Recent MIPAS measurements greatly enhance our ability to observe the variability of the stratospheric circulation.

• Simulations with the TLP model show that it is possible to have mean circulation and mixing trends in the stratosphere that are consistent with the observed NH mean age and total ozone “residual” trends.

• The discrepancy between CCM and observed mean age trends may be largely due to inadequately modeled mixing trends.

References

Engel, A., et al. (2009), Age of stratospheric air unchanged with uncertainties over the past 30 years, Nature Geosci., 2, doi:10.1038/ngeo238.


