The Impact of Tropospheric Planetary Wave Variability on Stratospheric Ozone.

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The goal of our project was to improve our understanding of the role of the stratosphere in inducing long term variations of the chemical composition of the troposphere. Changes in stratospheric transport occur on decadel timescales in response to changes in the structure of planetary wave patterns, forced in the troposphere. For many important tracers, such as column amounts of ozone, this variability of the transport leads to changes with signatures very similar to those induced by anthropogenic releases of chemicals into the atmosphere.

Air enters the stratosphere at the tropical tropopause. Part of this air is transported fairly quickly (on a timescale of less than a year) to midlatitudes and recirculated back into the troposphere. The remaining air is lofted to high altitudes in the tropics and returned in the downward branch of the Brewer-Dobson circulation after about 5 years. Measurements of long lived tracers in recent years have shown that these two branches of the circulation are fairly distinct. The outflow of air from tropics to midlatitudes occurs predominantly at low and at high stratospheric altitudes. It is reduced significantly in the altitude region between approximately 18 and 30 km.

Both two- and three-dimensional models have difficulties in accurately representing the two branches of the stratospheric circulation and, therefore, tracer gradients in the lower stratosphere. Over the course of this project, we developed a new interactive two-dimensional model of the dynamics, chemistry and radiation of the stratosphere. The meridional circulation of the stratosphere is driven by dissipating Rossby waves and small scale gravity waves. In our model, the Rossby wave forcing is parameterized following the residual circulation theory as consistently as possible. Gravity wave forcing is implemented as a simple Rayleigh drag.

The model has been used to interpret available data of tracers. Particular emphasis has been placed on long lived tracers in the lower stratosphere because those are most sensitive to the description of dynamics and transport in a model. We found that a fairly coherent picture of tracer distributions is obtained when a layer of reduced gravity wave drag is assumed for the lower stratosphere. This assumption, combined with the use of the nonlinear momentum advection terms in the zonal mean wind equation allows not only for the interpretation of long term annual means, but also variability observed on seasonal time scales and tracer fluctuations associated with the quasi-biennial oscillation (QBO). The effects of gravity waves are parameterized as subgrid scale processes in all atmospheric models. Our results suggest that the power of models to predict variability in tracer transport in the upper troposphere and lower stratosphere is limited until current theories of gravity wave breaking have been refined.

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Publications supported by the project:

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