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Final Report

Studies of Dynamical Processes Affecting the Distribution of Stratospheric Ozone

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Research Objectives

The purpose of the research carried out under this grant has been to understand large-scale tracer transport processes in the stratosphere. Two approaches have been taken. The first is analysis of tracer observations, especially satellite observations of ozone concentration and total column ozone. The second is numerical simulation of tracer transport processes.

Research Accomplishments

The QBO and stratospheric ozone

Three-dimensional correlation fields (correlations as a function of latitude, height, and lag) between the monthly-mean zonal-mean Singapore winds (the QBO reference signal) and the zonal-mean temperature, geopotential height, linear winds, and ozone were prepared for the calendar year and for each season individually. The results clearly show the relationship between the temperature and wind fields in the tropics and subtropics on the QBO time-scale. As is the case for total ozone, the results also reveal the global extent of the QBO circulation through the depth of the stratosphere. (Hollandsworth *et al.*, 1993)

Mixing in the polar vortices

Total Ozone Mapping Spectrometer (TOMS) images of the springtime southern hemisphere commonly show concentric layers in the total ozone field outside the Antarctic polar vortex. The layering results from horizontal folding and stretching of regions on the equatorward flank of the polar vortex near the midlatitude ozone maximum. This folding and stretching interleaves low and high ozone air from the subtropics and mid-latitudes, respectively. Occasional large amplitude wave events can extract very low ozone air from the interior of the polar vortex (the Antarctic ozone hole), but the folding and stretching occurs in midlatitudes even when wave amplitudes are not exceptionally large. This type of Lagrangian behavior may be common in the atmosphere, but is only visible when local tracer gradients are large and observations with high spatial resolution are available. (Bowman and Mangus, 1993)

A series of numerical experiments were conducted to investigate the dynamical factors controlling horizontal mixing in the springtime Antarctic polar vortex. For September, October, and November basic states, there is little or

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no mixing in the interior of the vortex. Mixing occurs near the critical lines for the waves: in the tropics and subtropics for a stationary wave 1, and in mid-latitudes on the equatorward flank of the jet for an eastward moving wave 2. For the December basic state, the wave 2 forcing rapidly mixes the interior of the vortex. In the model there does not appear to be any significant transport of air out of the interior of the polar vortex prior to the vortex breakdown. The principal factor that leads to the vortex breakdown and mixing of the vortex interior is the deceleration of the jet to the point where winds in the interior of the vortex are close to the phase velocity of the wavenumber 2 forcing. The tracer transport is very similar to many aspects of the behavior of the total ozone field during the spring season. (Bowman, 1993)

Nicholas Mangus, a graduate student at the University of Illinois, is investigating the effects of wave transience on the mixing process using the equivalent barotropic model. This research will comprise his Master's thesis, and will be completed by the end of the summer of 1993. (Mangus and Bowman, in prep.)

Observational analysis of tracer trajectories in both hemispheres has demonstrated chaotic mixing by the large-scale stratospheric flow field, but a significant barrier to mixing at the boundary of the polar vortex. These results corroborate the modeling study above and the qualitative interpretation of the TOMS total ozone. (Bowman, 1993; Dahlberg and Bowman, in prep.)

PSC properties from Antarctic lidar data

Data from the lidar show the seasonal evolution of PSC's at the south pole from May 1990, when they first appeared that year, until October 1990, when the observations ceased. The analyses of the cloud distributions agree with theoretical models of PSC formation. (Collins *et al.*, 1993).

Statistical methods for numerical experiments

We developed methods for the design and analysis of numerical experiments that are especially useful and efficient in multi-dimensional parameter spaces. The statistical approach provides a quantitative estimate of the model response to simultaneous changes of multiple parameters, *and* estimates of the uncertainty of the model output. This can lead to major improvements in the efficiency with which numerical experiments are conducted. These methods could have a significant impact in very broad areas of atmospheric science and oceanography, in fact, in any area in which numerical models are important scientific tools. (Bowman *et al.*, 1993)

Publications

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Mangus, Nicholas, and Kenneth P. Bowman, in prep.: Effects of Transience on Mixing by Barotropic Waves.

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