OZONE TRANSPORT IN THE SOUTHERN HEMISPHERE

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Extended Abstract

We discuss the mechanism of tracer transport in the stratosphere, with emphasis on the effect of transport on ozone concentration in the Southern Hemisphere.

In the lower to middle stratosphere, it is likely that large-scale planetary waves are responsible for the global scale transport of chemical tracers, angular momentum and heat, and these waves mix predominantly along isentropic surfaces (Mahlman et al, 1984), with planetary wave "breaking" (McIntyre and Palmer, 1983) being one of the processes of irreversible mixing. One consequence of the wave mixing process is that ozone is transported to high latitudes. Another effect is that because of the transport of heat the high (low) latitude region becomes warmer (colder) than it would have been in the absence of wave transport. High latitude region consequently cools radiatively. Thus air subsides diabatically over high latitudes and rises over low latitudes. This diabatic circulation further transports tracers *across* the isentropes. Isentropic wave mixing and diabatic mean circulation are simply two manifestations of the same transport process (See also Haynes and McIntyre, 1987). In the zonally averaged framework, the former is parameterized as diffusion with an isentropic mixing coefficient K_{yy}, and the latter as a diabatic advection proportional to $\bar{Q}$, the net radiative heating rate. The fact that K_{yy} and $\bar{Q}$ are related to each other has already been pointed out previously. (Mahlman, 1985; Newman et al, 1986; and Plumb and Mahlman, 1987).

The validity of the K-theory can be shown for the case of small amplitude waves (Plumb, 1979; Matsuno, 1980; Tung, 1982), and also appears to hold approximately for moderate amplitude waves in a General Circulation Model (Plumb and Mahlman, 1987). However, for the large amplitude atmospheric waves that "break" and mix in the process, it is only a conjecture that the end result can be mimiced by a K-diffusion process in some gross sense. Some tests are needed.

Assuming downgradient diffusion of Ertel's potential vorticity on an isentropic surface, Yang et al (1990a) deduced the K_{yy}-field corresponding to an observed NMC

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temperature (and hence to the real atmospheric angular momentum) field. The relationships between the mean angular momentum budget, the wave driving (E-P flux divergence), and the isentropic flux of Ertel's potential vorticity have been derived by Tung (1986) and Andrews et al (1987) using isentropic coordinate formulation. The same NMC temperature field is also used, together with model determined ozone, to calculate the net radiative heating, $\bar{Q}$.

A coupled 2-D model is constructed that utilizes the consistent set of K_{yy} and $\bar{Q}$ as transport parameters to simulate simultaneously the distributions of a number of tracer gases including ozone. The simulated results are then compared with satellite observations. These are presented in Yang et al (1990b). The overall favorable comparison of the simulated and the observed appears to indicate the reasonableness of the adopted formulation and the approximate validity of the K-theory in simulating the effect of large-scale mixing process.

Although, as mentioned above, the transport process of K_{yy} and $\bar{Q}$ can not be separated, it is useful for diagnostic purposes to assess the contributions of each separately. It appears that major seasonal and latitudinal variations of column ozone are generated by the mean diabatic circulation. The subpolar ozone maximum in the Southern Hemisphere late winter and spring is related to poleward transport from tropics, which is strongest through the winter accumulating into a maximum in early spring. In the Northern Hemisphere, the poleward transport is even stronger as a consequence of stronger wave driving (and larger K_{yy}, see Yang et al, 1990a). These stronger wave events result in mid-winter warmings and ozone transport into the polar region. As a consequence, the ozone maximum occurs over the pole in the Northern Hemisphere and appears earlier in season than in the Southern Hemisphere.

The K_{yy} field that was deduced from NMC temperature field (Yang et al, 1990a) has a maximum in the midlatitude regions and a minimum over the equatorial region as well as a minimum over both poles. If the K_{yy} field is taken to be a constant instead, at a value of the global average of the variable K_{yy}, one finds that the ozone values will be higher in the tropics, at about 300 Dobson units instead of the 260 Dobson units observed and also modeled using a variable K_{yy} field (Yang et al, 1990b). The polar ozone values also become higher. It is thus seen that the high gradient region across the polar vortex in the Southern Hemisphere is maintained only in the absence of strong wave mixing, which is usually the case in the Southern Hemisphere. There are however years when a moderate increase in wave mixing can transport enough heat and ozone into the polar vortex to disrupt the "containment vessel" and the heteorogenous chemical reactions that require cold temperatures. Also, since the polar area is small in comparison with midlatitude area, year-to-year variations of polar ozone can be quite sensitive to moderate fluctuations of wave mixing process outside the polar vortex. Such variations are possibly further amplified in recent years by enhanced chemical destruction of ozone during cold years.

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