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Winter Descent and Mixing in the Northern Hemisphere Illustrated by HIRDLS Ozone Data

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The two processes controlling the distribution of trace species in the stratosphere and upper troposphere are the Brewer-Dobson meridional circulation, which acts to steepen constituent gradients on isentropic surfaces during winters, and mixing processes that act to reduce those gradients. Ozone measurements by the High Resolution Dynamics Limb Sounder (HIRDLS) on NASA's Aura satellite can be used to track these processes in detail. With1 km vertical resolution, 1° along track spacing and daily near global coverage, these data make it possible to follow the vertical motion of ozone contours through the year. Here the focus is on latitudes poleward of 40°N, from early autumn to spring.

At the beginning of September the 1 ppmv contour of ozone mixing ratio is near the 440K potential temperature surface at 40°N and 420K at 80°N. By March the contour has come down a few degrees at 40°N but is down to 360K at 80°N. Contours for lower mixing ratios in the lower stratosphere (LS) show similar behavior. Using heating rates from NCAR's Whole Atmosphere Community Climate Model (WACCM), the contour positions can also be compared to where they would be if only diabatic descent were operating. From September to January (or even later) the LS contours closely follow the dynamics driven by the diabatic circulation. However, when they extend below the 360K level the contour slopes become much lower relative to the isentropic surfaces, showing that rapid mixing is taking place, consistent with calculations of effective diffusivity. With progression through the spring months, the rapid mixing extends to higher altitudes, reducing the slopes of the ozone contours to their summer configuration. Details differ from year to year, notably for the 2006 winter with the strong January sudden stratospheric warming. Our diagnostic results will be compared with WACCM simulations driven by meteorological analyses.