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# Incomplete Ozone Loss and Weak Mixing in the outer Antarctic Vortex derived from airborne in situ Observations

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Recent modelling studies have found a broad ring of air in the outer Antarctic vortex to be substantially isolated both from a well-mixed vortex core and from midlatitude air between late winter and mid-spring (Lee et al., J. Geophys. Res., 2001). In the model this ring of weak mixing extends 10-15° poleward from the vortex boundary and experiences only incomplete ozone loss both due to less complete PSC coverage and limited exchange with the ozone-depleted vortex core. In the case of a further cooling of the Antarctic stratosphere ozone losses in this region could increase and thus offset the recovery of the Antarctic ozone hole as atmospheric chlorine levels decline in the coming decades.

Here we analyse the structure of the outer Antarctic vortex and quantify the meridional distribution of ozone loss therein from in situ measurements on board the Russian high-altitude aircraft M-55 "Geophysica" taken in September and October 1999 during the APE-GAIA campaign (Airborne Polar Experiment - Geophysica Aircraft In Antarctica). During 5 southbound flights from Ushuaia, Argentina (54° S) into the Antarctic vortex the Geophysica penetrated the vortex edge at various potential temperatures between 380 K and 480 K and performed dives inside the vortex yielding vertical profiles in one case down to the tropopause. The mission covered equivalent latitudes up to 80°S thus penetrating several times into the vortex core. The University of Frankfurt's High Altitude Gas Analyzer (HAGAR) provided in situ measurements of $N_2O$, CFC-12, CFC-11, halon-1211 every 90 s, $SF_6$ every 45 s, and $CO_2$ every 10

s. Ozone was measured at high resolution by the Fast Ozone Analyzer (FOZAN).

In order to quantify the meridional distribution of ozone loss we first define a quasi-Lagrangian meridional coordinate from N2O and potential temperature observations. Ozone loss is then derived by deviation from an “unperturbed” ozone calculated from early winter vortex O3-N2O relationships based on ILAS satellite data and in situ observations from the ASHOE/MAESA campaign. We find indeed a transition zone extending poleward at least 10° from the vortex edge, in which ozone loss increases from negligible to 100%. Our observations and analysis thus support the existence of a broad weakly-mixed outer vortex ring and confirm that ozone loss is incomplete in a large area of the outer Antarctic vortex. Furthermore, our analysis shows transport of ozone depleted air through the vortex bottom at 390-400K and further mixing into the midlatitude “surf zone” at these low altitudes.