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An unusual stratospheric ozone decrease in the Southern Hemisphere subtropics linked to isentropic air-mass transport as observed over Irene (25.5˚ S, 28.1˚ E) in mid-May 2002

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A prominent ozone minimum of less than 240 Dobson Units (DU) was observed over Irene (25.5˚ S, 28.1˚ E), a subtropical site in the Southern Hemisphere, by the Total Ozone Mapping Spectrometer (TOMS) during May 2002 with an extremely low ozone value of less than 219DU recorded on 12th May, as compared to the climatological mean value of 249DU for May between 1999 and 2005. In this study, the vertical structure of this ozone minimum is examined using ozonesonde measurements performed over Irene on May 15, 2002, when the total ozone (as given by TOMS) was about 226DU. It is found that the ozone minimum is of dynamical origin and is linked to isentropic air-mass transport in the Southern Hemisphere. Indeed, it is shown that this ozone minimum is of Antarctic polar origin with a low-ozone layer in the middle stratosphere above 625K (where the climatological ozone gradient points to the south), and is of tropical origin with a low-ozone layer in the lower stratosphere between the 400-K and 450-K isentropic levels (where the ozone gradient is reversed). The upper and lower depleted parts of the ozonesonde profile for May 15 are then respectively attributed to equatorward and poleward transport of low-ozone air toward the subtropics in the Southern Hemisphere. The tropical air moving over Irene and the polar

one passing over the same area associated with enhanced planetary-wave activity are successfully simulated using the high-resolution advection contour model of Ertel's potential vorticity MIMOSA (Modélisation Isentrope du transport Méso-échelle de l'Ozone Stratosphérique par Advection). In fact, in mid-May 2002, MIMOSA maps show a polar-vortex filament passing over Irene in the middle stratosphere above the 625-K isentropic level along with tropical air-masses moving southward in the lower stratosphere between the 400-K and 450-K isentropic levels. The winter stratospheric wave driving and its associated localized isentropic mixing leading to the ozone minimum are investigated by means of two diagnostic tools: the Eliassen-Palm flux and the effective diffusivity computed from the European Center for Medium-range Weather Forecasts (ECMWF) ERA40 re-analyses.

The unusual distribution of ozone over Irene during May 2002 in the middle stratosphere is closely connected to the anomalously pre-conditioned structure of the polar vortex at that time of the year. Indeed, the perturbed vortex was typically predisposed for easy erosion by dynamical transport processes, which have been driven by pulses in planetary-wave activity that occurred as early as May 2002 and resulted in a minor warming by mid-May (Newman and Nash, 2005). This was followed by a very large latitudinal advection in the middle stratosphere of polar air masses of low ozone content towards the subtropics.

The exceptional presence of polar vortex air over the subtropics during May 2002 can be considered as the first sign of the particular polar vortex disturbances, which after being well reinforced, contributed to the unprecedented behavior of the Antarctic spring ozone hole observed during September 2002.