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Interactive comment on "An unusual stratospheric ozone decrease linked to isentropic air-mass transport as observed over Irene (25.5° S, 28.1° E) in mid-May 2002" *by* N. Semane et al.

N. Semane et al.

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We thank the referee for his/her remarks. We will quote the comments of the referee and provide our reply below.

- P12619 l7: " best locations for detecting a possible recovery of the ozone layer - but has there actually been identifiable depletion in tropics? Apparently not - see 4.2.2.1 of WMO Ozone Assessment 2002 "

≻≻ **Following the referee's comment, the following sentence: «the tropical Southern Hemisphere latitudes are among the best locations for detecting a**

possible recovery of the ozone layer.», has been modified as follows:
the southern tropical and subtropical latitudes are among locations where a possible recovery of the ozone layer may be detected.

- P12626 l6- "simultaneously in the lower and upper stratosphere- more middle stratosphere than upper stratosphere? Presumably the biggest contribution to the column comes from below 35 km or so."

≻≻ **Following the referee's comment, the sentence has been changed as follows:**
Thus, the unusual reduction of total ozone observed over Irene by mid-May 2002 seems to be related to isentropic transport of air masses simultaneously in the lower and middle stratosphere, respectively from the tropics to the mid-latitudes and from the pole to the subtropics.

- P12626 l14: "less ozone in the polar region at this time of the year? - presumably later in the year, above the region of chemical depletion, ozone concentrations are relatively large at the pole?"

≻≻ **Following the referee's comment, we have added some references in our argumentation: The low concentrations of ozone in the upper part of the profile (above 625 K) can be attributed to air-mass advection from pole to tropics as the climatological ozone decreases towards high latitude in the middle stratosphere of both hemispheres (Koch et al., 2002; Godin et al., 2002).**

- P12627 l22: "changed from easterlies to westerlies early...etc. Firstly, we can't

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tell if this transition is 'early' because we have no information on other years. In fact, if this year is unusually disturbed then one might, in the absence of detailed information, expect that low-latitude winds would be more easterly that normal. Secondly, the relevance of the high values of effective diffusivity in the 20-30 S latitude band for the transport shown in Figure 3 is not so clear. In figure 3 it looks as though high-latitude PV values are advected to the region of the observations- therefore the values of equivalent latitude in the region of the observations would be more like 50-60 than 20-30. Again, as noted in general comments above, the relation of effective diffusivity to individual filamentary feature is rather subtle"

≻≻**The point has been clarified by modifying our argumentation in p12627, from L20 to L26 as follows:**
>From the superimposed contours on Fig. 5 illustrating ECMWF ERA-40 zonal winds as a function of equivalent latitude, it can be seen that the southern stratospheric zonal circulation changed from easterlies to westerlies, allowing the planetary waves to spread and bend equatorward nearby the subtropics (as shown by EP-flux on Fig. 4). According to Newman and Nash (2005), the subtropical zonal wind in the upper stratosphere in April 2002 (prior to any wave events) was anomalously easterly. Subtropical easterlies were also observed in April 2002 in the middle stratosphere (as shown on Fig. 5). Therefore, the anomalous easterlies in the mid-to-upper stratosphere in April corroborated by a particular reversal to westerlies in early May, suggests that wave propagation was highly anomalous during the early winter of 2002. The mechanism for this appears to be the dependence of planetary wave propagation and breaking on the structure of the mean zonal wind (Brasseur et al., 1999). In fact, when the subtropical wind is westerly, waves can propagate as far as toward the equator, and the surf zone is shifted to lower latitudes.
Thus, the two anomalous features both in the zonal wind and in the planetary-wave activity contribute to the increase in isentropic mixing over the subtropics

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by mid-May 2002. This is a result of mixing by planetary waves breaking in the surf zone. Indeed, one notices that mixing (K_{eff}) has increased in the 20-30°S equivalent latitude range by mid-May as underlined by the dotted circle, which also denotes the region of wave breaking.

$\succ\succ$ For the sick of clearness, more information about the use of the effective diffusivity as function of equivalent latitude is given in the following sentences:

In our paper, the transport and mixing properties of the isentropic flow are investigated using the effective diffusivity K_{eff} (Nakamura and Ma, 1997; Haynes and Shuckburgh, 2000; Hauchecorne et al., 2002; Morel et al., 2005) which is related to a q contour and the derivative of q with respect to area A enclosed by the contour $(\partial q/\partial A)$ (Nakamura, 1996).

$$K_{eff} = K \frac{\overline{|\nabla q|^2}}{(\partial q/\partial A)^2}$$

Where $\overline{|\nabla q|^2}$ is the average over the area between adjacent contours of $|\nabla q|^2$ and K is the local diffusivity.
The effective diffusivity is larger where the tracer contours are longer, i.e., where their geometric structure is more complex. Therefore, mixing barriers and regions of large mixing can be identified by relative minima and maxima in the effective diffusivity.
In our paper, the effective diffusivity is calculated from the Epv provided by the ECMWF ERA40 re-analyses. Results are presented in the form of $\left(\ln \frac{K_{eff}}{K}\right)$ as a

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function of equivalent latitude (Φ_e).

$$\Phi_e = \arcsin\left(1 - \frac{A}{2\pi R^2}\right)$$

Where R is the Earth's radius.

$\succ\succ$With regard to the Referee's comment about the Southern Hemisphere low-latitude winds during the early winter of 2002, we give the following remarks :
- The Quasi-biennial oscillation (QBO) was in the westerly phase in 2002 (Newman and Nash 2005).
- The easterlies observed in the Southern Hemisphere subtropical stratosphere during April 2002 are linked to the westerly phase of the QBO.
- According to Scott and Haynes (1998) the disturbed winters are accompanied by late-fall, early-winter easterlies in the subtropics. Indeed, such easterlies were observed in 2002 in the tropics in association with a westerly QBO at 30 hPa (Newman and Nash 2005).
- Global analysis reveals that Quasi-biennial oscillation is linked to variability in high latitude winter. Winters tend to be colder and have less planetary wave activity during years when the QBO is westerly (Brasseur et al., 1999). Although the QBO was westerly the 2002 winter was unusually disturbed. The use of the dynamical diagnostics (EP fluxes and effective diffusivity) was performed in our paper in order to support and to confirm the anomalously disturbed dynamics and anomalous transport during the early winter of 2002.

Please find below the new cited references:

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