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Discussions

Interactive comment on "Antarctic ozone variability inside the Polar Vortex estimated from balloon measurements" *by* M. C. Parrondo et al.

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This work should clearly be published after revision. It contains an important data set for the study of the ozone hole, which still has important aspects despite the success of the Montreal Protocol that should lead to the eventual disappearance of the ozone hole. This data set is particularly useful as it is almost exclusively in the core of the vortex, unlike Neumayer that is often in the edge region of the vortex. However, I am disappointed in the data-providers' analysis of their own measurements: in its lack of profundity; in the lack of complete back-up data; and in its many small errors.

Major Comments:

1. There is no major new discovery from this analysis of the data. If the authors cannot

find one, and I have nothing to suggest, then the manuscript should contain a lot more statements to say "this confirms...". They should also say why this is a major and important new data set by contrasting it with similar data sets of longer duration from Neumayer and South Pole.

2. Section 4.1 discusses the lack of seasonal evolution in total ozone column, but we are not shown this evolution, even in the partial ozone column whose annual variability we are shown. This evolution and its error are important quantities, helping to identify descent and chemical depletion as later discussed in analysis of profile data. The manuscript should include a figure of this evolution, and a table of the seasonal trends and their error bars.

3. We are not told of any data bases where the individual data values and the various climatologies shown in the paper are lodged or will be lodged, so the rest of us can make use of them. There appears to be no Supplementary Data that might contain the values. This is important primary information and if it is not deposited at NDACC, WODC or a SCAR data centre, it should be. This would also then be a significant improvement to South Pole data, which is only available in summary form.

4. Important details, essential in a serious analysis of the data, appear to be absent:

(a) there is very little detail of how ozone loss and loss rates are calculated, in the text or in the captions to Figures 4, 5 or 8 - we are not told from which date to which;

(b) there are no details about how descent rates are calculated (quoted in the Conclusions), from which level to which level, or from which date to which date.

(c) the ozone recovery in the late winter is discussed in the earlier text and in the last paragraph of the Conclusions, but there are no details of how it is calculated, nor from which date to which date.

5. Section 4.4 misses a major point of my work on the edge region of the vortex, started in Lee et al. (2001) and concluded in Roscoe et al. (2012). The mixing within the core

of the vortex is good but not perfect; ozone-poor air takes about 12 days to travel from 78°S to 90°S after the terminator reaches the outside of the vortex core, so we would expect the black curve in Figure 9 to lag the red curve by about 12 days in late August, as shown. This process can be clearly seen in the model calculations of Figure 7 of Lee et al. (2001), reproduced in colour in Figure 1 below. Here, accumulated ozone loss at 70 to 75°S in the vortex core starts soon after the arrival of sunlight there, but mixes to the Pole ahead of the movement of the terminator. At 78°S and poleward, the contours in Figure should be seen as tracer contours, thereby expressing mixing. Contours move from 78°S equivalent latitude to 88°S in just over 10 days, as observed in Figure 9 of the current manuscript. Finally, by the end of September, all the vortex has been exposed to sunlight for over 12 days, so the amounts of ozone loss at 78°S and 90°S should be equal, as observed in Figure 9 of the current manuscript. Such a discussion should replace much of the current content of Section 4.4.

Minor comments:

6. The words "region" and "layer" are used alternately for the same quantity, namely the layers defined in Figure 1. This is dangerous as readers may think you are referring to different things. It is yet more dangerous as "region" can also refer to the horizontal, so is ambiguous. Change "region" to "layer" throughout, including the panel of Fig. 1.

7. Section 4.1 and Figure 2 do not tell us what interpolation is used in Figure 2. Clearly these are not the monthly-mean values defined in Section 4.1 (though the figure caption leaves us guessing as to whether this is what they should be). Furthermore, the character of the figure suggests that some vertical smoothing was also used, but we are not told in either the text or the caption..

8. What is the statement in Section 4.1 that year to year variations "tend to cancel" in a climatology supposed to mean? Such variations are completely absent, by definition.

9. The end of Section 4.1 and paragraph 1 of the Conclusions assert that "By the beginning of March the lower stratosphere remains essentially isothermal". Apart from the

contradiction in the wording "By the beginning, it remains", which presumably should be "From the beginning", this is not the case by the normal meaning of isothermal. Isothermal normally refers to the vertical temperature gradient being zero, which is far from the case at the beginning of March. Presumably the authors mean that the temperature in the lower stratosphere does not change after the beginning of March: if so, they should say so and give an end date; if not they should say what they do mean and ensure that Figure 2 does indeed show it.

10. In paragraph 1 of Section 4.2, the authors mis-state the relevant conclusion of my work in Lee et al. (2001) and Roscoe et al. (2012). They should say that a low but not negligible mixing takes place between the edge region of the vortex and the core, not "inside the vortex" as given. The relevant mixing is of air from lower latitudes than the vortex core. Furthermore, the actual quote is from Roscoe et al. (2012) and said that the mixing is "small but not zero"; in Lee et al. (2001) we did not discuss whether there was non-zero mixing.

11. The final sentence in Section 4.2 is not obvious from Figure 3, where there is no height information. Instead it can be better seen in Figure 2. The final sentence of Section 4.2 is an important point because some past workers have asserted that such an increase in the total or partial ozone column before the final warming in the lower stratosphere is evidence of de-activation of chlorine compounds allowing a chemical recovery, rather than almost exclusively caused by the descent of vortex collapse as shown by Figure 2.

12. Section 4.3 paragraph 2 asserts that Figure 5 shows the main pattern in interannual variability of ozone loss rate is observed at all levels. This is only true if 2002 is included. Hence the follow-on conclusion that loss rates are mainly affected by deep vortex structure is only true of 2002, as expected in that year, and that in other years loss rates are NOT affected by deep vortex structure, contrary to the assertion.

13. What evidence is there that stratospheric minor warmings, in the plural, occur at

higher altitude in Antarctica (p15673 line6)? There is evidence of one in July 2010 cited later on p15673, and to my knowledge that is all.

14. The paper is contradictory about whether ozone loss rate is positive or negative if ozone is being lost, starting on p15673 line 17 (negative), extending to Figure 4 right-hand vertical axis (positive), and other figure axes (negative). It is clearly a positive quantity if ozone is being lost, so text and figures should be amended accordingly.

15. Surely, the argument in p15674 lines 10 to 18 that more winter ozone should be correlated with less ozone loss is incorrect. More total ozone in winter implies that more descent has occurred during the previous year's meridional transport by the Brewer-Dobson circulation. This would lead to more HCl being brought down to altitudes of PSCs, for conversion to reactive chlorine, and so to more ozone loss. This was Joe Farman's rationalisation for his famous $10 bet in 1988 as to whether the ozone loss that year would be small or large, a bet that he won.

16. Ozone recovery was also identified from station data by Kuttippurath et al., ACP 2013, a paper he was nice enough to put my name on. This should perhaps be included in the last paragraph of Section 4.3.

17. The caption to Figure 1 does not say over what years these are mean profiles (presumably the 13 years of data but we are not told), nor over what period is "winter" (the text says 15 June to 15 July but we should be reminded). Nor does it say how the standard deviations are calculated – are they the standard deviations of the monthly means within the 13-year average, or the means of the standard deviations of the near-daily values within each month, or some other quantity?

18. If the ozone loss (DU) and the ozone loss rate (DU/day) in Figure 4 are measured over the same date intervals, why do the numbers written above each bar not scale with the red points? If they are not over the same date intervals, why not?

19. Why is 2009 data absent in Figure 4 yet present in Figure 5 and Figure 7?

20. Figure 10 is far too small, its caption does not say why data is missing from December's upper panel in some years, it does not remind us that the layer 12-24 km is layers I+II+III of Fig 1, it does not say that what the standard deviation is of, the vertical axis of the middle panel says the units are PVU/°lon when they are PVU/°lat, and there are five other points in the figure and its caption worthy of editorial comment below.

Editorial comments:

p15664 lines8 & 9 – should surely come after lines 10 & 11, not before.

p15664 line 26 – insert "place" after "took", replace "rises" by "rose".

p15664 line 26 – replace "up to" by "by" – one cannot have a quantity "up to" a range.

p15665 line 1 – delete "late" – 1985 is not the late 1980s.

p15665 line 21 – delete "in".

p15666 line 9 – insert "the" before "polar".

p15668 line 24 – replace "deviation" by "deviations".

p15668 line 25 – replace "provide" by "provides".

p15670 line 1 – insert "the" before "next".

p15670 line 19 – insert "in" before "summer".

p15672 line 6 – insert "at the end of this phase" after "residual".

p15672 lines 6&7 – move the sentence "Typical.. values" to follow the next sentence.

p15672 line 17 – insert "to" after "respect".

p15672 line 21 – delete "about" or the range – "about 140 to 160" is a tautology.

p15672 line 24 – Charlton et al. (2005) is concerned with downward propagation of the 2002 sudden warming to the Antarctic troposphere, rather than the fact of the warming.

There are many other 2005 papers that attest to the fact of the warming.

p15673 line 5 – replace the ambiguous “contribution” by the unambiguous “standard deviation”.

p15674 line 4 – “ozone depleting substances” normally refers to the halon and CFC precursors, e.g. in the Montreal Protocol and its amendments. You mean the activated halogen compounds.

p15674 line 4 –delete “ODS” as the acronym is not used elsewhere.

p15674 line 5 – delete “sunlight available – this cannot influence year to year variability.

p15674 line 9 – insert “2002” – not all readers will realise which year is anomalous.

p15674 line 25 – replace “there is” by “is there”.

p15674 line 28 – replace “larger” by “longer”.

Fig. 3 caption – what are the black dots – the individual points for 13 years?

Fig. 4 caption – insert “(DU)” after “depleted”; replace “shown” by “written”.

Fig. 6 caption – are these from ECMWF-Operational analyses, ERA-Interim reanalyses, or a mixture?

Fig.7 caption – this must include the statement from the text that the R=-0.69 that is written in the figure panel only applies to data without 2002.

Fig. 10 caption – replace “Top panel shows” by “Top panels show”; replace “region” by “layer”; move “mid-panel” to start of third sentence and say “Middle panels show ...”; replace “Lowest graph presents” by “Lowest panel shows”; replace “Julian day” in the vertical axis of the lowest panel by “day of year” – Julian day is days since 1 January 4713 BC (see https://en.wikipedia.org/wiki/Julian_day).

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 15663, 2013.

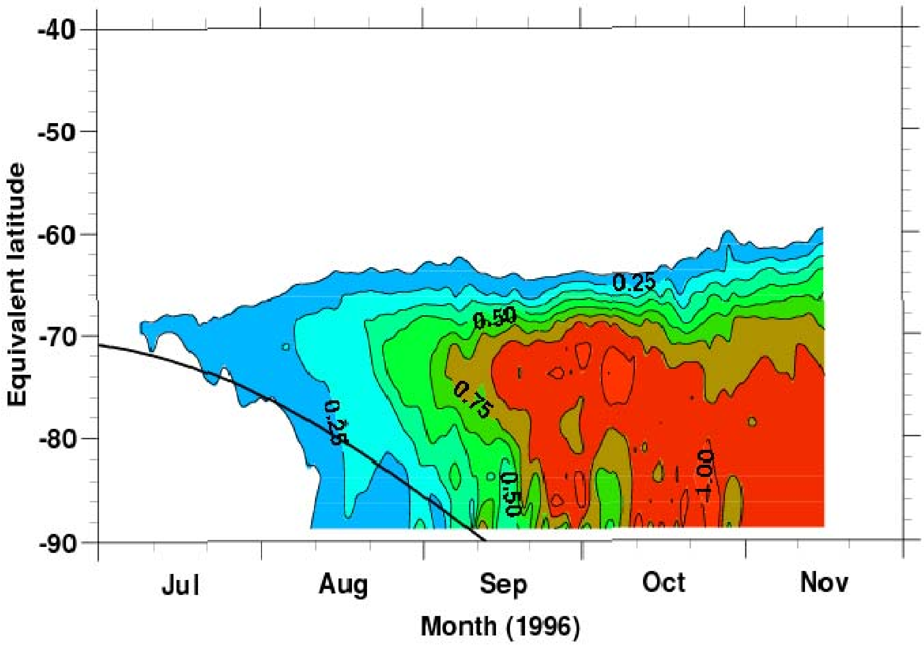

Fig. 1. Evolution of the accumulated model ozone loss due to reactive chlorine and bromine that occurred within 70 to 75°S equivalent latitude, at a potential temperature of 480 K. The bold line shows the location of the terminator in real latitude. This is a colour version of Figur 7 of Lee et al. (*J. Geophys. Res.* **106**, 3203, 2001).