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Interactive comment on "Problems regarding the tropospheric O_3 residual method and its interpretation in Fishman et al. (2003)" *by* A. T. J. de Laat and I. Aben

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deLaat and Aben have provided ACPD with an interesting study and we feel obliged to summarize and comment on what they have said. They bring out some points that are accurate and others that distort the methodology that we have used to derive tropospheric ozone using TOMS and SBUV measurements. There are three parts of their discussion which deserve comment:

1. they point out that the derivation of our algorithm is faulted;
2. they claim that no satellite data are needed to derive the distribution we have derived using SBUV and TOMS measurements; and
3. they claim that the amount of variability in the stratosphere on a daily basis is

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too large that a 5-day average of SBUV measurements is not the proper method of defining the stratospheric contribution.

We plan to contribute a detailed interactive discussion in a few weeks to address all these points in detail, but based on the degrading nature of the title of their paper, and based on their blatant claim that "it is possible to obtain a tropospheric O_3 column that is very similar to what is being presented in Fishman et al. (2003), solely based on the Logan (1999) tropospheric O_3 climatology and an estimate for the tropopause heights without using satellite data," we feel compelled to offer this immediate response showing the inaccuracy of their assertion. These facts should have been readily seen by the editorial staff at ACPD or by the reviewers of this paper.

Regarding the first point, we find that their analysis is correct regarding our ŞcorrectionŤ to the observed total column from SBUV. However, there is still a misunderstanding as to how this correction is applied. It is never used to compute a TOR value for the troposphere; it is used only to compute a stratospheric component to the SBUV total column. The philosophy behind the methodology is straightforward and is predicated by the fact that SBUV measurements do not have enough spatial resolution to isolate tropospheric variability, but they do have enough resolution to produce a field of data that can define the distribution of ozone in stratosphere. The method is simple (and we think sufficiently explained in Appendix A of Fishman et al., 2003). As an example, let's assume that a given SBUV measurement is 300 DU and the tropopause height is 125 hPa (for simplicity, the top of the first two SBUV levels, or the quantity A+B as depicted in Figure 6 in Fishman et al., 2003). Furthermore, let's assume that the Logan climatology at this location (as a function of latitude, longitude and time of year) is 30 DU from the surface to 125 hPa (corresponding to her Layers X+Y in the same figure). Note that deLaat and Aben are entirely correct saying that in this particular case, the corrected layer (A^*+B^*) are identically equal to the Logan climatological values (X+Y). Applying this correction results in a stratospheric value of 270 DU. If, at a nearby TOMS

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grid point the total ozone is 305 DU, then our algorithm assumes that the SCO value is also 270 DU implying a TOR value of 35 DU. The technique works reasonably well if 30 DU is an accurate representation of the background. If the stratospheric distribution is most dependent on large scale planetary waves, then a subsequent SBUV measurement several thousand km apart from the first point (and at the same latitude) may measure 310 DU. Again, if the tropospheric climatology defines a value of 30 DU in the troposphere (and for simplicity, the tropopause height is again located at 125 hPa), then our technique puts 280 DU in the stratosphere. Similarly, if at a nearby pixel, TOMS measures 308 DU, then the TOR is 28 DU. Thus, even though the TOMS total ozone at the two points are 305 and 308 DU respectively (an increase of 3 DU), the TOR decreases from 35 to 28. Also, it is important to note that neither of the derived TOR values equals the Logan climatology, illustrating the fallacy of the reasoning in deLaat and Aben. In this particular example, the Logan climatology and tropopause heights are equal, which, according to their rationale would lead to equal TOR values. The value added by the SBUV measurement is that the SBUV total ozone must have captured the relatively larger scale spatial variability in the stratosphere – the primary reason the data set is used. The "correction" initially refers to correcting the lowest two (or three) layers in the SBUV data archive, where the archived layers likely contained too little ozone below 126 hPa. Without the empirical correction (as initially shown in Fishman and Balok, 1999), the SBUV (A+B) average value in the troposphere would have likely been a value inconsistent with the Logan climatology.

With respect to the second point (and most troubling aspect of their paper), either the ACPD editorial staff or the reviewers should have readily seen that a comparison of the two published figures showing the distribution over India and China clearly illustrates that these two distributions of tropospheric ozone are vastly different (refer to Figure 5 in Fishman et al. and Figure 2 from deLaat and Aben). These figures show considerable differences between both the winter and summer TOR depictions using only the Logan climatology vis-à-vis our residual technique. At the very least, deLaat and Aben should have quantified the similarities (or differ-

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ences) to which they refer. Our TOMS/SBUV TOR dataset is readily accessible at http://asd-www.larc.nasa.gov/TOR/data.html (Fishman et al., 2003) and, in our opinion, it would not have required much effort for deLaat and Aben to duplicate our results and then offer an appropriate quantitative analysis.

In the deLaat and Aben depictions, we note the nearly zonal structure of the TOR except where the influence of the Himalaya Mountains is obvious. The zonal nature of these calculations mirrors the zonal nature of the Logan climatology, although in the tropics, Logan used the TOR distribution from Fishman et al. (1990) to generate some longitudinal dependence in her distribution (which is also seen in the deLaat and Aben depictions). The depictions in Fishman et al. (2003), on the other hand, do not display such zonal structure and are much more in line with the distribution of the surface emissions (i.e., population distribution, also in Figure 5 of Fishman et al., 2003) that should lead to *in situ* ozone formation. Furthermore, perhaps the most important utility of the Fishman et al. methodology is the relatively small-scale regional nature of the product derived.

Table 1 is presented to illustrate two points: The high spatial resolution of the derived TOR field from the Fishman et al. (2003) methodology; and the considerable difference between the TOMS/SBUV TOR and the tropospheric column amount of ozone (TCO) in the Logan climatology. The Logan climatology is presented as a matrix with a 4°-latitude by 5°-longitude resolution. Table 1a illustrates the data that would comprise the TCO for the June-July-August (JJA) climatology over the region (primarily over India) defined by 16° N–26° N and 70° E–95° E ($\sim$1000 km by $\sim$2500 km). Along each latitude belt, the input data are nearly invariant and the TCO integral is primarily a function of average tropopause height. As can be seen in this table, the range of the east-west TCO values is no more than 1 DU across any one latitude belt. The resultant TOR values (Table 1b) calculated along the same latitude belts vary by 10 DU at 26°, 6 DU at 22°, and 10 DU at 18°. Thus, in this particular region, at this particular time of year, the Fishman et al. TOR exhibits a regional enhancement of 20–25% which

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cannot be picked up by Logan's climatology because the input data used to construct her data base does not have the resolution to do so. The regional variability due to tropopause height variability likewise is so small that it is insignificant to explain what the satellite reveals.

Such a region results in a TOR matrix of 231 points compared with the Logan input from 18 points. The range of the data is 32–52 DU, meaning that within this regional domain, some values are more than $\sim$60% higher than others. It is precisely this regional variability captured by the Fishman technique that is so notable (note the title of the paper), and which cannot be captured at the current time by climatologies of the type produced by Logan. Each of the numbers presented in Table 1b represents an average of more than 1600 points, but the differences between the individual locations cannot be validated with existing in situ data. However, the analysis provided in Creilson et al. (2003) comparing the observed monthly differences between two locations where robust ozonesonde climatologies exist, confirm that the climatological monthly TCO values are captured extremely accurately by the TOR data (correlation coefficient of 0.87). Creilson et al.'s analysis also suggests that the gradient is underestimated, in a manner consistent with the error analysis described by Fishman et al. (2003) in their Appendix.

Furthermore, to believe that the variability in the TOR or TCO fields is primarily a result of variability in tropopause height is grossly incorrect. A preliminary analysis of gridded tropopause height data for 1996 (the year of the deLaat and Aben simulation) shows that tropopause height variability across this region during the summer is $\sim$5 hPa and that such variability contributes $<$1 DU to the TCO amounts. This point will be examined in more detail in a discussion currently in preparation.

For now, however, we feel that it is most important to dispel the myth that the Logan methodology can be used in conjunction with a knowledge of tropopause height to produce the same results as those in Fishman et al. (2003). The Logan climatology was derived as the benchmark against which global-scale chemical transport models

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Table 1: TCO from Logan Climatology (June-July-August)

	Longitude →						
		70° E	**75° E**	**80° E**	**85° E**	**90° E**	**95° E**
Latitude	**26° N**	41	41	41	41	41	41
	24° N						
	22° N	34	34	34	34	34	34
	20° N						
	18° N	32	33	33	33	33	33
	16° N						

can be compared (and it serves that purpose extremely well). It was never intended to define the regional distribution that our satellite method is capable of providing.

For a visual comparison of the features described herein, figures for direct comparison can be found at the web URL previously mentioned: http://asd-www.larc.nasa.gov/TOR/data.html; click on ACPD response to deLaat and Aben.

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Table 2: TOMS/SBUV TOR (June-July-August)

	Longitude →	70° E			75° E			80° E			85° E			90° E			95° E			
	26° N	42	43	43	43	43	45	45	47	47	49	49	50	51	51	52	52	51	51	51	49	49
L		42	43	42	42	43	44	44	45	46	48	48	49	49	50	50	50	50	49	48	46	49
a	24° N	39	40	41	42	41	41	42	42	42	44	44	45	44	44	44	44	44	45	42	44	45
t		39	39	39	40	40	41	40	41	42	43	44	44	43	42	42	42	42	43	44	44	43
i	22° N	36	37	38	39	39	39	40	41	42	42	43	43	42	41	40	40	40	42	44	44	42
t		34	35	37	38	37	38	38	40	42	42	42	41	40	39	39	39	39	40	42	44	43
u	20° N	33	34	36	36	36	36	37	38	40	41	40	39	38	38	38	38	38	39	40	42	43
d		34	35	37	38	37	38	38	40	42	42	42	41	40	39	39	39	39	40	42	44	43
e	18° N	33	34	36	36	36	36	37	38	40	41	40	39	38	38	38	38	38	39	40	42	43
		32	33	35	36	35	36	36	36	38	39	38	38	38	37	37	38	38	38	39	40	41
	16° N	32	32	34	36	35	36	36	36	36	37	37	37	37	37	37	37	37	38	38	39	40

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