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Interactive comment on "Retrieval of ozone column content from airborne Sun photometer measurements during SOLVE II: comparison with coincident satellite and aircraft measurements" *by* J. M. Livingston et al.

J. M. Livingston et al.

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Author response to referee comments

We thank both referees for their helpful comments.

General

Table 3 now includes information both for AATS/POAM and AATS/SAGE coincidences. The AATS/POAM information was inadvertently omitted from the ACPD version by the typesetter, and we did not catch this omission during our final check.

The GAMS team provided us with revised GAMS ozone retrievals in early April 2005. AATS-GAMS comparisons have been rerun using these new results, and the manuscript has been edited accordingly. Figure 6 has been revised, as have some of the text labels in Figure 5. For the record, the revised GAMS retrievals agree more closely with the corresponding AATS retrievals.

Four new references have been included in the Conclusions section and added to the References section: Randall et al. (2003), Randall et al. (2005), Taha et al. (2004), EOS Aura Science Data Validation Needs (2004).

Referee 1

The only issue that bothered me a bit concerned the authors' use of the SAGE and POAM vertical profiles of ozone and aerosol extinction to derive the airmass factors used in the AATS-14 analysis. This seems a bit circular, using the SAGE and POAM profiles to derive airmass factors for the derivation of column ozone from AATS-14 that are then compared to the column ozone from SAGE and POAM. Does this bias the comparisons toward better agreement? Does this method limit the usefulness of the Sunphotometer measurements for satellite cal/val purposes?

These are good questions that have prompted us to append most of the remainder of this paragraph to Section 3.1 of the manuscript. Of course, the retrieval of vertical column ozone from AATS-measured transmission depends critically on the use of appropriate airmass values both for aerosol and for ozone. While it may seem circular, our use of satellite profiles to derive these airmass factors does provide a check on the mutual consistency of the sunphotometer and the satellite data sets. The most basic parameter that is calculated directly from the AATS-14 voltage measurement in each channel is slant path total solar transmission, which is just the measured detector voltage divided by the exoatmospheric detector voltage that was derived from the Mauna Loa measurements (corrected for the actual Earth-Sun distance at

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the time of observation). This AATS-14 measurement of slant path solar transmission is independent of airmass. We considered keeping the AATS-14 analyses wholly independent of the satellite results by reporting only AATS-14 path transmission or path ozone values, and comparing these to analogous path transmission or path ozone values computed from the satellite profiles for each AATS-viewed path. However, this would have produced results very unfamiliar to readers, since each would have depended on the viewing path for each individual AATS measurement. Since our goal was to provide a test of the consistency between the AATS and satellite ozone results, and since using satellite ozone relative vertical profiles to convert AATS path transmission to vertical column ozone does not invalidate this consistency check, we chose this approach in the interest of providing results (ozone vertical column content) more familiar to the typical reader. We stress that using satellite ozone relative vertical profiles to compute airmasses (used to convert AATS transmission to ozone vertical column content) does not invalidate the test of consistency between the satellite and AATS results–it just converts the test products into a more familiar form.

Referee 2

"Just how good do ozone validation measurements need to be to [be] useful in this validation exercise?" The differences between the Sun photometer and other methods are given for several different times but without discussion of the meaningfulness of the comparison. After each comparison, the reader is left asking "So?"
The reader might be left with the impression that the satellite measurements were used to validate the Sun photometer measurements. Some sort of table or graphic showing validation comparisons at times the Sun photometer was producing the best results would be very helpful and a logical result from this work, as would be some indication of the stated accuracy of the satellite and other data ozone.

We have rewritten the conclusions section in an attempt to address the comments above. In particular, we now give mean SAGE-AATS and POAM-AATS ozone differences (3.1% and -2.6%, respectively) in addition to the previously given RMS values (7% and 3%, respectively); we have added Table 4 giving mean differences by occultation event and DC-8 altitude; we cite results of previous POAM-SAGE, POAM-SAGE-ozonsonde, and POAM-HALOE-SAGE comparisons to provide context; and we now conclude that discussion by stating: "The magnitudes of the RMS and mean relative differences for the SAGE-AATS and POAM-AATS comparisons during SOLVE II are similar to the results of these previous studies, which include many more cases. It is probably unrealistic to expect agreement to better than a few percent in comparisons of satellite-satellite or satellite-airborne sensor measurements, because of uncertainties resulting solely from atmospheric spatial and/or temporal variability."

Although we now reference the Aura science validation needs document that specifies a requirement for 2% accuracy for the validation of the OMI columnar ozone product, we have not compiled a table that specifies analogous accuracy requirements for POAM, SAGE, and GOME, as we feel that it is beyond the scope of this paper to do so.

1. What is the filter blocking in the out-of-band rejection regions? At the extreme zenith angles and shortest of your wavelengths it would need to be nearly 10^{-7}*, which is difficult to achieve and verify.*

Data provided by the filter manufacturer(s) indicate that blocking in the out-of-band rejection region is between 10^{-7} and 10^{-6} for each filter. The total optical depth in the AATS-14 short wavelength channels (353.5, 380.0, 452.6 nm) was dominated by contributions from Rayleigh scattering and aerosol extinction . If we assume that the log(AOD)-log(wavelength) quadratic fitting function accurately described the spectral dependence of the AOD (the basic tenet of the King ozone retrieval technique), then if out-of-band leakage had contaminated the AATS measurements in those channels, we would expect the calculated AOD values at these wavelengths (e.g., in Figure 2) to have systematically underestimated the curve fit because of a systematic overestimate

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of Rayleigh optical depth (due to the effective shift, which would not have been taken into account, of the channel center wavelengths to longer wavelengths). No such deviations were observed for the measurements included in our analyses presented in this paper. Also, in a companion paper, Russell et al. [2005] report that AATS-14 and DIAS line-of-sight (LOS) aerosol optical thickness (AOT) results at wavelength 400 nm agree to within 12% of the AATS value, with mean and RMS differences of -2.3% and 7.7%, respectively. They note that for the DC-8 altitudes, AATS-satellite comparisons of LOS AOT were possible only for wavelengths > 440 nm because of signal depletion for shorter wavelengths on the satellite full-limb LOS.

2. At about line 1 on page 254 you state that the eigenanalysis approach gave better results than King and Byrne but then go on to use King and Byrne without further explanation. Would be good to fill the missing justification.

We have added a sentence to that discussion, so it now reads:

"Unlike the King and Byrne approach, the Taha and Box method requires a priori assumptions of the type and optical properties of the aerosol in order to construct the kernel covariance matrix necessary for the eigenvalue analysis. They applied both methods to one year of ground-based daily measurements obtained at Sydney, Australia with a Multifilter Rotating Shadowband Radiometer (MFRSR) (Harrison et al., 1994) and found that the eigenvalue approach gave better agreement with TOMS overpass ozone retrievals than the King and Byrne least squares method. Prior to SOLVE II, we investigated the applicability of the Taha and Box (1999) method to synthetic SOLVE II AATS-14 measurements, but we found that their algorithm provided useful results only if the AATS-14 measurements were reduced to the wavelengths used in their paper."

3. At line 25 page 258, retrieval errors of up to 30 DU are mentioned for smaller zenith *angles. Is this result in agreement with earlier applications of the King and Byrne method? References?*

We know of no other published results with which to compare our findings. King and Byrne (1976) and King et al. (1980) cite 20 DU as the uncertainty in a single ozone retrieval using their method. Although they do not specifically mention the range of SZAs or airmass values for which their measurements were acquired, we can probably safely assume no data were used for large (double digit) airmass values, since such airmass values can produce biased results for ground-based sunphotometers. Our results (both the AATS MLO data compared with coincident Brewer and Dobson measurements, and the AATS 6 Feb 2003 low airmass/low altitude DC-8 based data compared with coincident DC-8 based in-situ FASTOZ data) are certainly not inconsistent with the Taha and Box (1999) finding that the KB method underestimated the TOMS values by 10-11%, which would be ∼30 DU, (based on our examination of the time series of total ozone values shown in their Figure 1). The Taha and Box measurements were taken over an airmass range of 2-6 (Taha, personal communication).

A primary determinant of the accuracy of ozone-aerosol separation in the vicinity of 600 nm is the relative size of ozone and aerosol line-of-sight optical depths there. As we note in our manuscript, the majority of our SOLVE II measurements were taken at altitudes where the overlying ozone optical depth comprised a significant fraction of the total (aerosol plus ozone) optical depth and at large SZAs. Hence, the uncertainty of AOD at 600 nm as estimated from other wavelengths is small compared to the ozone optical depth, and constitutes a small source of error in retrieved ozone. Even for data obtained under conditions (e.g., elevated sensor platform or small-AOD ground-based) where the ozone optical depth comprises a significant fraction of the total (aerosol plus ozone) optical depth, at small SZAs (small airmass values) a seemingly relatively small uncertainty (∼1% or less) in the channel-dependent exoatmospheric calibration voltages becomes the dominant source of error and leads to larger uncertainty in the ozone retrieval.

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4. Item 1. in the conclusions (line 11, page 268) - How was this 0.04 limit determined? There isn't a discussion of this limit in the body of the paper.

We thank the reviewer for drawing our attention to this, as the conclusion was not worded precisely. We have changed this conclusion to be more consistent with our wording in the last paragraph of Section 3.0 of the original (and current) version of the manuscript. There we state that "an ozone overburden of 0.3 atm-cm (300 DU) translates to ozone optical depths of 0.009, 0.014, 0.041, and 0.012, respectively, at these same wavelengths", where the "same wavelengths" refer to the AATS-14 channels centered at 499.4, 519.4, 604.4, and 675.1 nm.

Our rewording of the conclusion follows: "The spectral aerosol optical depth near the center of the Chappuis ozone absorption band is less than or equal to the corresponding overlying ozone optical depth, which, for an ozone overburden of 0.3 atm-cm (300 DU), corresponds to 0.014, 0.041, and 0.012 for the AATS-14 channels centered at 519.4, 604.4, and 675.1 nm, respectively."

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 243, 2005.