Ozone Profile Retrieval from Global Ozone Monitoring Instrument

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Abstract. Ozone (O_3) profiles are derived from backscattered radiances in the ultraviolet spectra (290-340 nm) measured by the nadir-viewing Global Ozone Monitoring Experiment (GOME), with particular emphasis on improving tropospheric O_3 retrieval using optimal estimation. To optimize the retrieval and improve the fitting precision needed for tropospheric O_3, we perform extensive wavelength and radiometric calibrations and improve forward model inputs. Retrieved O_3 profiles compare well with coincident ozonesonde measurements at Hohenpeißenberg and Lauder, and the integrated total O_3 compares very well with Earth Probe TOMS data. Comparisons with retrievals using Phillips-Tikhonov regularization are also presented.

1. Introduction

The retrieval of O_3 profile down to the troposphere from GOME has been demonstrated in recent years using physics-based approaches [*Munro et al*., 1998; *Hoogen et al*., 1999; *van der A* et al., 2002; *Hasekamp and Landgraf*, 2000]. These algorithms require very accurate radiance and wavelength calibrations. Accurate characterization of the atmosphere other than O_3, including clouds, aerosols, and temperature profiles are also critical for tropospheric O_3 retrieval.

This study performs detailed wavelength and radiometric calibrations, improves forward model inputs using our best available knowledge, and derives O_3 profiles from measured radiances at 290-340 nm using optimal estimation [*Rodgers et al*., 2000]. We use GOME Data Processor data that are collocated with ozonesonde observations and are selected by GOME ozone profiling work group.

2. Methodology

We improve the wavelength and radiometric calibrations as follows. (1) We derive the variable slit widths and shifts between radiances/irradiances at every 2-nm region with a high-resolution solar reference spectrum [*Chance and Spurr*, 1997]. (2) Shifts between trace gas absorption cross-sections and radiances are fitted in the retrieval. (3) We perform on-line correction of the filling in of solar and telluric absorption features using Ring spectra calculated with a first-order rotational Raman scattering model [*Sioris and Evans*, 2000]. Ring spectra are updated when total O_3 changes $\geq$ 20 DU. (4) Undersampling of GOME is corrected using a high-resolution solar spectrum [*Chance*, 1998]. (5) A wavelength-dependent correction is applied to GOME channel-1 irradiances by fitting GOME irradiances to a SOLSTICE spectrum [*Woods et al*., 1996] because a large wavelength- and time-dependent bias occurs [*Siddans*, 2003]; later GOME irradiances are corrected for degradation relative to the first observation. This correction reduces the large and consistent underestimate of 6-8 DU O_3 in retrievals above 35 km, where the column O_3 is known reasonably well.

We improve characterization of the atmosphere with cloud-top height and cloud fraction from GOMECAT [*Kurosu et al*., 1999], monthly mean SAGE II aerosols [*Bauman et al*., 2003] and GEOS-CHEM tropospheric aerosols [*Martin et al*., 2003]; daily ECMWF temperature profiles (http://www.ecmwf.int) for extracting tropospheric O_3 from the temperature-dependent Huggins bands [*Chance et al*., 1997], and daily surface pressure from NCEP/NCAR reanalysis data (http://www.cdc.noaa.gov). Initial surface albedo is derived from reflectance at 370.02 nm where absorption is minimal.

We found that including both channel 1 and channel 2 in the retrievals leads to much larger residuals than using either of the channels and the results do not improve much compared to using channel 1 only, suggesting some systematic differences between these two channels remains unresolved. Instead, a two-step approach [*Siddans*, 2003] is adopted. The retrieval is first done using channel-1 radiances. The TOMS V8 dynamic O_3 climatology together with EP monthly mean total O_3 is used to initialize *a priori* ozone profiles [*McPeters et al*., 2003]. Then retrieved profiles and covariance are used as *a priori* profiles and covariance, respectively, for the second step using channel-2 radiances.

We use LIDORT [*Spurr et al*., 2003] to calculate radiances and weighting functions. The scalar radiances from LIDORT are corrected for neglecting polarization using a look up table [v*an Oss*, Personal Communication, 2003]. The retrieval is typically done on the 11-layer Umkehr grid except in the troposphere, where retrieval grids are modified using daily NCEP/NCAR tropopause pressure and surface pressure.

3. Results and Discussion

With extensive calibrations and available knowledge of the atmosphere, the fitting residuals have been largely reduced. The fitting residual is typically ~0.3% for channel 1 and 0.1% for channel 2 after including a common-mode parameter [*Chance*, 1998] in the retrieval for fitting systematic residuals.

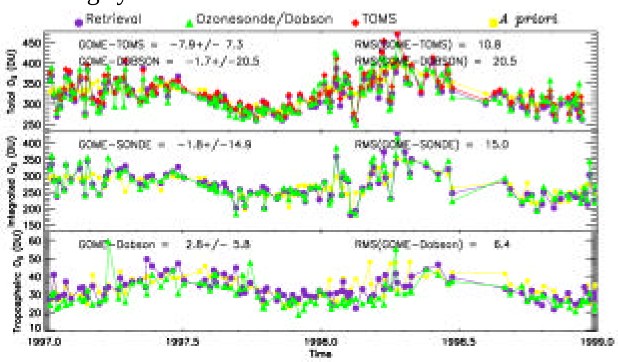

Figure 1. Comparisons of channel-1 retrievals with ozonesonde measurements and Dobson total O_3 at Hohenpeiβerg, and TOMS total O_3. (Top) Total O_3. (Middle) Total O_3 integrated to balloon burst altitude. (Bottom) Integrated troposphere O_3. The *a priori* O_3 is also shown.

The retrieval compares very well with collocated ozonesonde measurements (http://www.msc-smc.ec.gc.ca/woudc/) within 600 km distance from GOME ground pixel center and within 8-hour time period at Hohenpeiβenberg and Lauder, and compares very well with Dobson total O_3, and TOMS total O_3 averaged over the GOME footprint except for a bias of 7-10 DU. Figure 1 shows the comparison at Hohenpeiβenberg during 1997-1998. On average, the GOME integrated total O_3 on is 1.7 DU than Dobson total O_3 and 7.8 DU smaller than EP TOMS total O_3. Some of the GOME-TOMS bias maybe due to errors in TOMS data [*Bramstedt et al*., 2003]. The O_3 column integrated to balloon burst altitude and the tropospheric O_3 are within 3 DU of integrated ozonesonde total O_3 and integrated ozonesonde tropospheric O_3, respectively. The larger standard deviations in differences between retrievals and ozonesonde observations reflect the large spatiotemporal variablity of O_3 at mid-latitudes.

Because Phillips-Tikhonov Regulation (PTR) does not use *a priori* knowledge and there are only 4-6 pieces of information available from the measurements, the PTR retrievals have larger biases with larger standard deviations in the comparison.

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