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Uncertainty improvement optimized using the GMI model for Umkehr ozone profile retrieval

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Introduction

Modifications to the Umkehr ozone profile retrievals are needed for reducing the relative bias between satellites and ground based data. The standardized stray light correction (SLC) applied at some stations shows an improvement, which can be used to reduce Umkehr bias in the upper stratosphere. However, applying SLC increases bias in the mid-stratosphere and low-stratosphere. Furthermore, the issue of an individual instrument characteristic and the relative bias in instrument calibration remains in the record. In this study, we use GMI model hourly vertical profile data for creating corrections for each Dobson instrument in the record.

- The new correction value is optimized with SLC, and reduces bias caused by the individual instrument optical characteristic.
- UMK04 a priori for the updated retrieval uses latitude-dependent new climatology (fstguess.11b) of a monthly averages to capture variations of the typical season in ozone profile.

Comparison with a satellites ozone profile

First, we show comparison of Umkehr profiles at Boulder and MLO stations with several satellite overpass records (Figure 1). The averaged bias is shown for ozone profile (panel a) and as time-dependent offset in time series for upper stratosphere (panel b). Operational UMK04 retrieval (upper row in panel a) and Standardized Stray Light correction (lower row of figures in panel a) are shown relative to satellite records (CM, color legend indicates satellite record). The overpass satellite data are spatially (less than 200 km) and temporally (within 24 hours) matched with Umkehr measurements at the station. The Umkehr Averaging Kernels (AKs) are applied to smooth the overpass satellite profiles prior to comparisons.

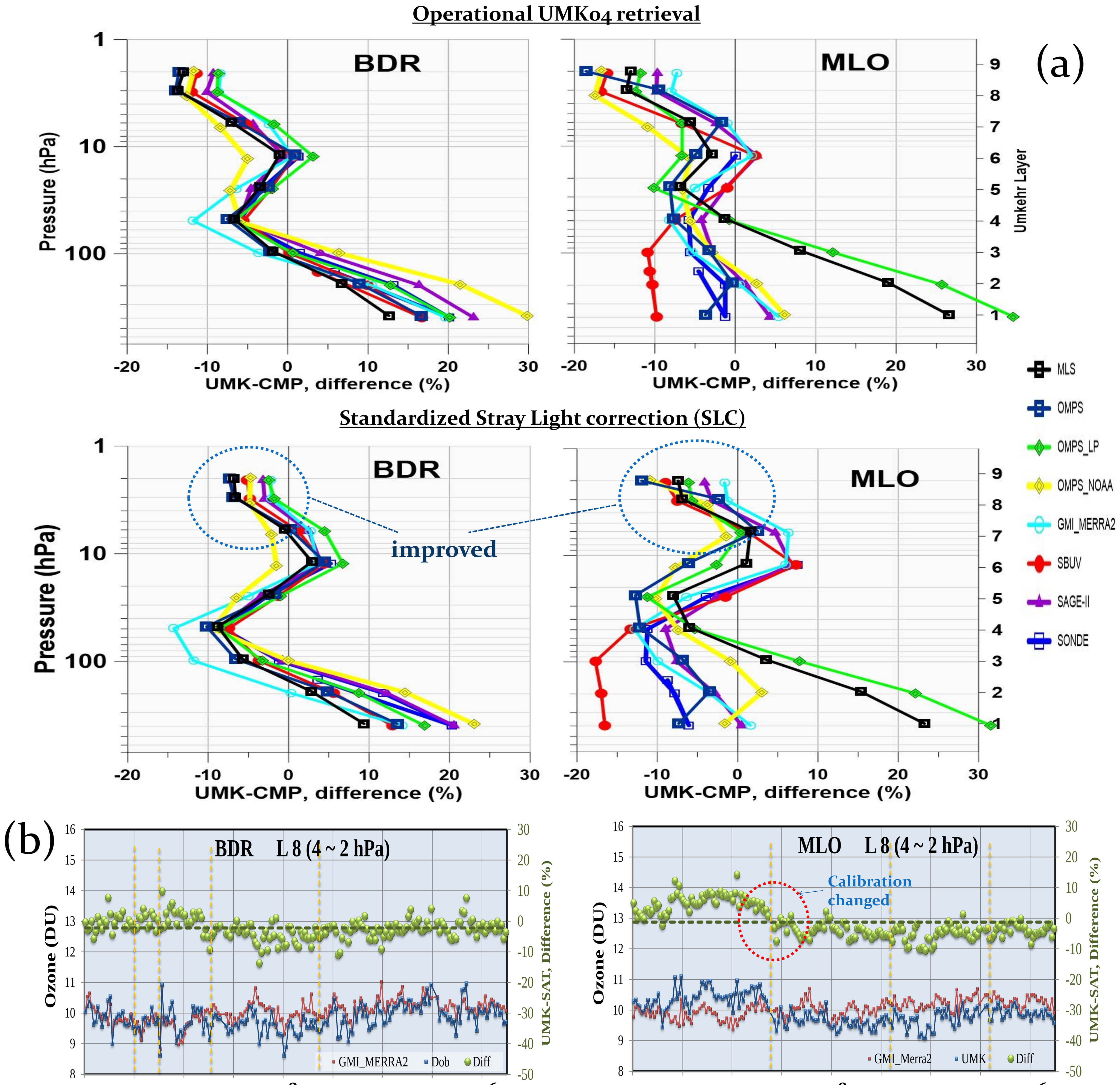


Figure 1. Comparison between overpass satellites and Umkehr retrieved ozone. (a) Operational UMK04 retrieval (upper row) and Standardized Stray Light correction (bottom row). BDR-Boulder, CO, MLO - Mauna Loa observatory, Hawaii. Comparison periods are different depending on satellite record. The period of volcanic aerosol interference is removed for an average. (b) The time series for ozone in layer 8 (4-2 hPa) are shown for Boulder (left) and MLO (right). Standardized Stray Light correction is applied to correct Umkehr record. Dobson instrument calibration dates are shown as orange dotted line.

Results

Optimized from the GMI model

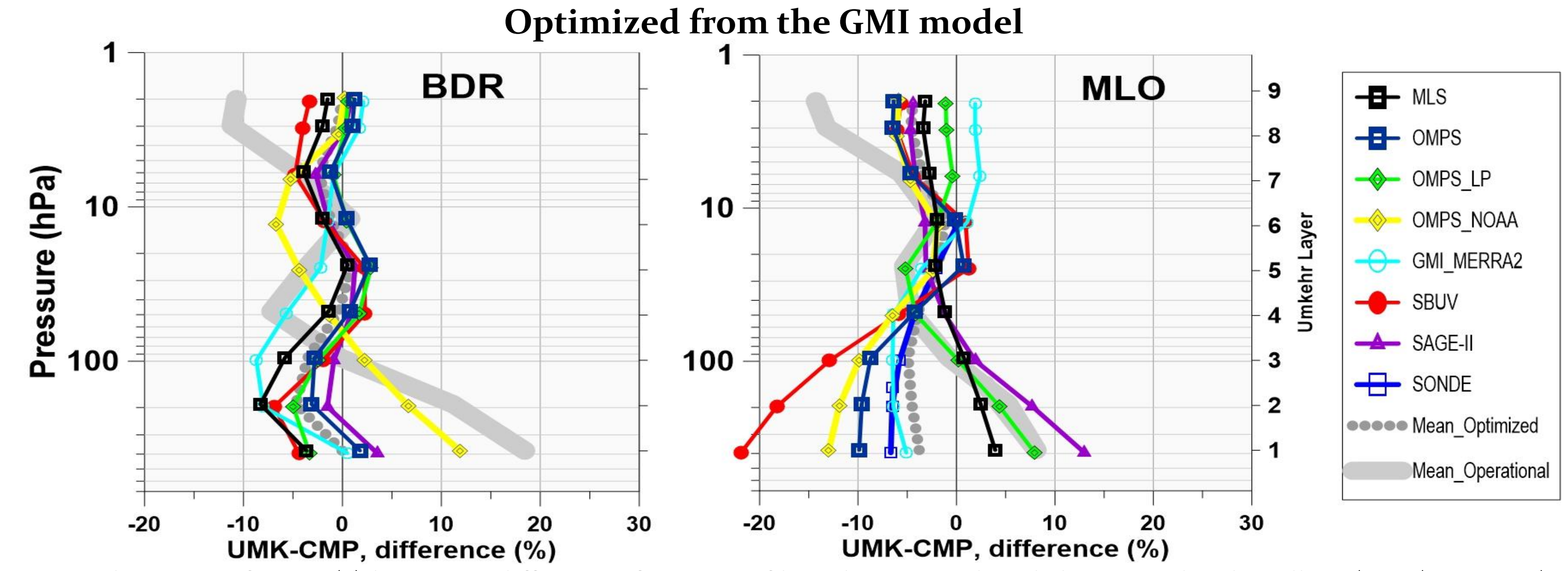
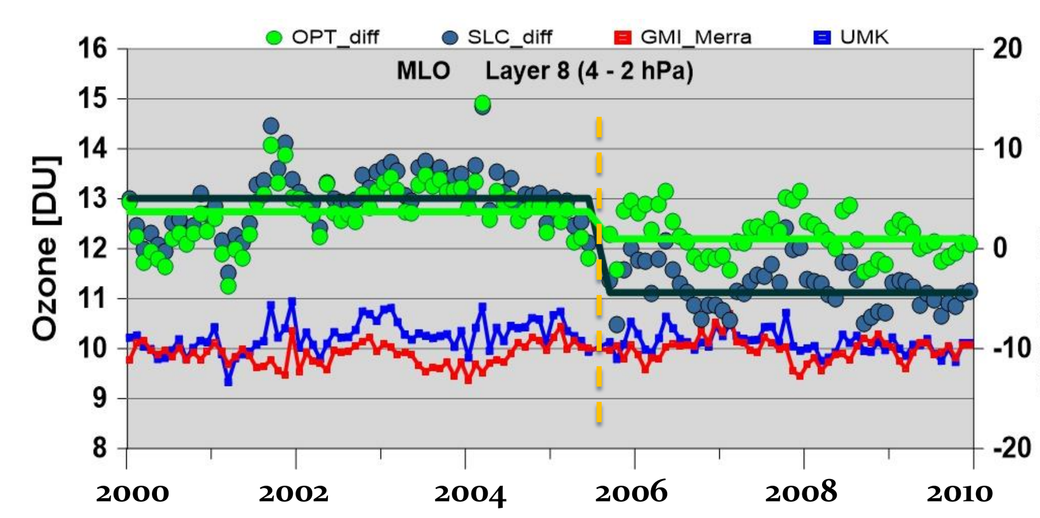


Figure 4. The same as figure 1 (a) but, mean difference of ozone profile with optimized Umkehr retrieval and satellites (MLS(2004-2017), OMPS(2012-2017), OMPS_LP(2012-2017), OMPS_NOAA(2012-2017), GMI_Merra2(2000-2016), SBUV(1982-2017), SAGEII(1987-2005) and Ozonesonde(1982-2017)).

Relative bias in instrument calibration reduces



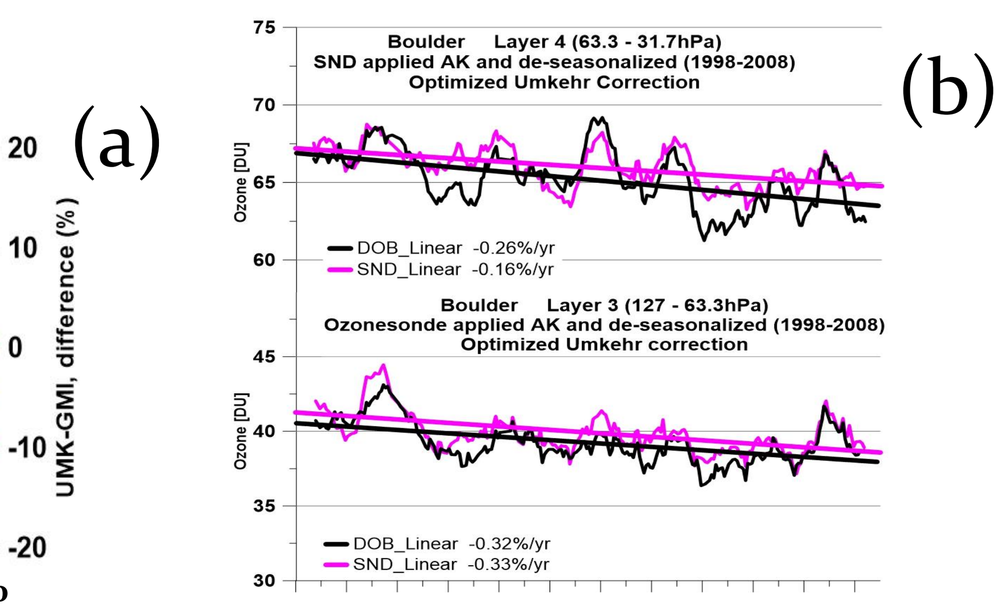


Figure 5. (a) Instrument calibration shows the layer 8 which influenced the time-series ozone. Green dots optimized. (b) Time series of the optimized Umkehr retrieval and ozonesonde in Boulder.

Summary and Discussion

The OMPS_NASA difference with all the satellites from three UMK04 retrievals

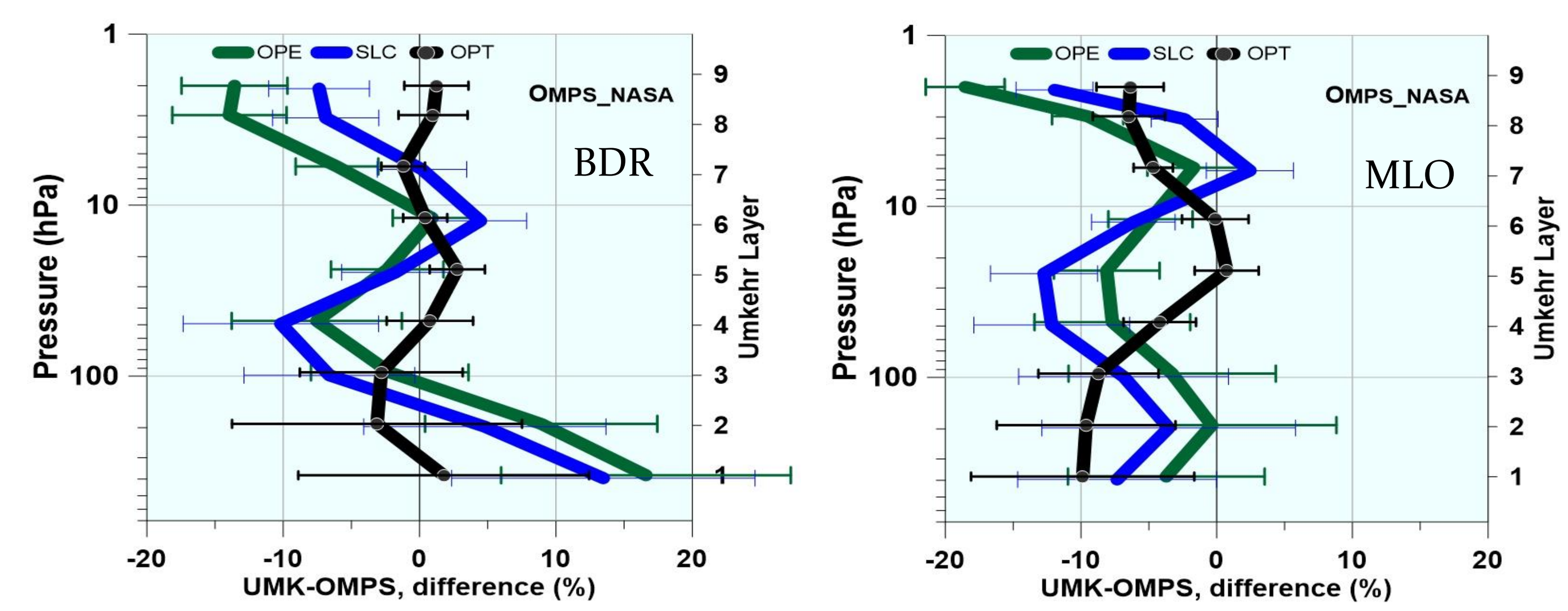


Figure 6. The same as figure 4 but, mean difference with OMPS_NASA satellites from three UMK04 retrieval.

Seasonal difference NASA OMPS from three UMK04 retrieval

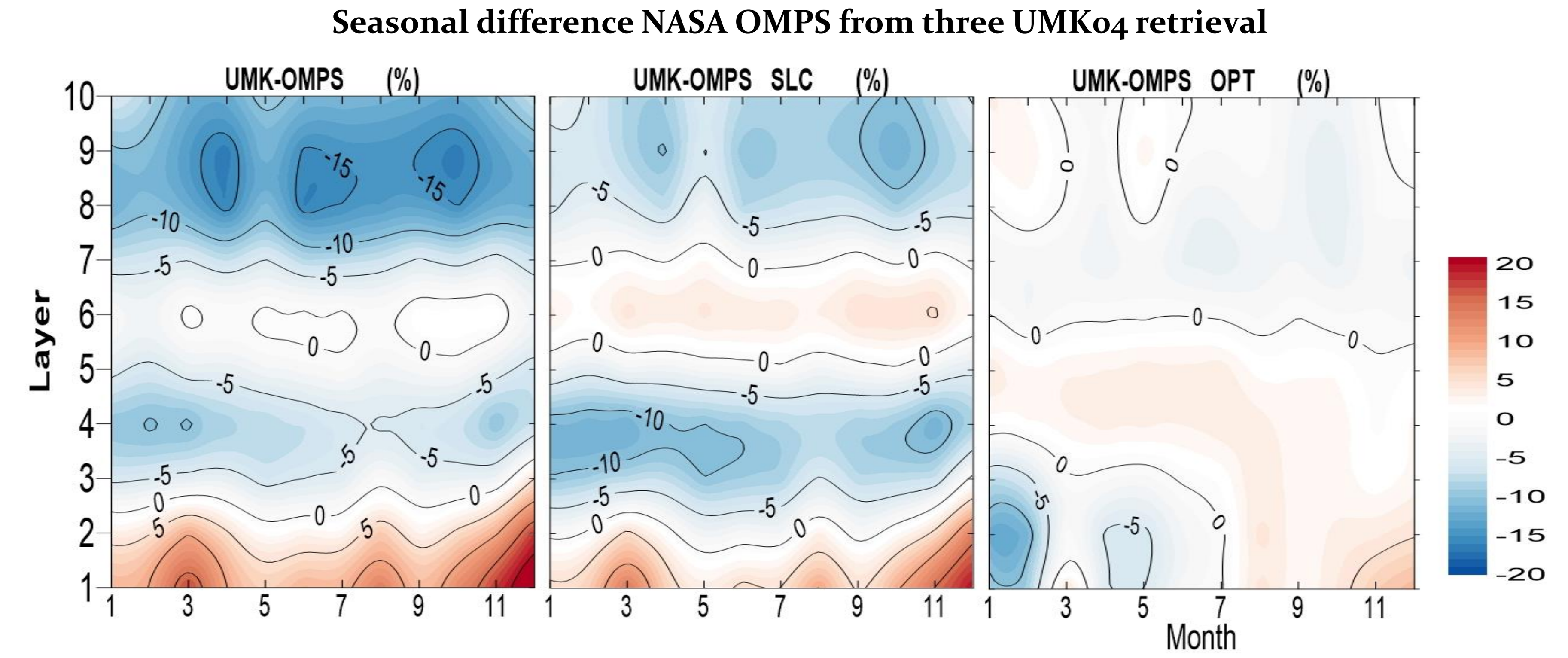


Figure 7. Seasonal biases between Umkehr in Boulder and JPSS/OMPS satellite overpass record. Three panels show results for three Umkehr retrievals: operational (left), standardized correction (middle) , Optimized correction (right). The biases are significantly reduced in case of the Optimized correction.

Uncertainty improvement optimized using the GMI model

Umkehr Retrievals (Operational)

Dobson Umkehr measurements are made using the information from the C wavelength pair (311.5, 332.4 nm). The algorithm for ozone retrieval, UMK04 (Petropavlovskikh et al., 2005) is provided with the ozone profile from two models (forward and inverse). Independent zenith sky cloud detector data are used for screening of N-value measurements for interference od clouds in the zenith view. N-value measured is described (as I/F are zenith-sky intensity/Solar flux) at 2 spectral channels.

$$N(w,Z) = 100 * log_{10}\{\frac{I_{(w,z,Ls)}}{I_{(w,z,Ll)}} / \frac{F_{(w,z,Ls)}}{F_{(w,z,Ll)}}\} + k$$

Stray light correction (Standardized)

The Umkehr ozone profile processing is biased by the interference of out-of-band stray light into the measurement (Petropavlovskikh et al., 2011). The algorithm takes into account the stray light correction (d*Nslc*).

$$N_{slc} = N(w,Z) + dNslc(O_3, P, Z)$$

dN_{slc} is estimated from look up tables that are dependent on latitude, altitude (*p*), solar zenith angle (*z*), and total ozone (O_3). Figure 2 is applied for Boulder.

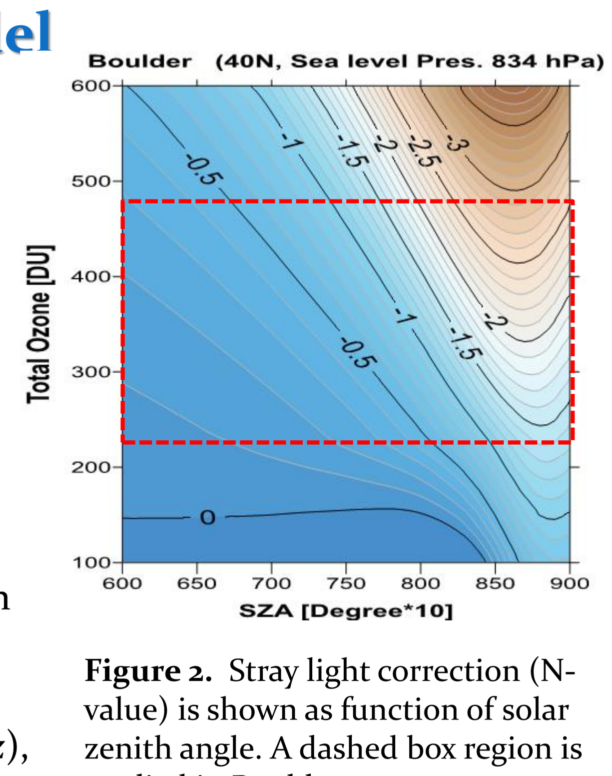


Figure 2. Stray light correction (N-value) is shown as function of solar zenith angle. A dashed box region is applied in Boulder.

Optimized using the GMI model

Instrument calibration or replacement of an instrument occasionally causes the issue of bias. Their cause is not understood, but the optimization using the GMI model improves an uncertainty.

The temperature and ozone pro-file data were obtained from the GMI (Global Modeling Initiative) model calculation for 1992 to 2016 (https://gmi.gsfc.nasa.gov/merra2hindcast/). The GMI model provides atmospheric composition hind casts using MERRA-2 (Modern-Era Retrospective analysis for Research and Applications, Version 2, meteorology (Strahan et al., 2013; Wargan and Coy, 2016); https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/). The simulation with 2 × 2.5 ∘ resolution uses the CCMI (Chemistry–Climate Modelling Initiative; Morgenstern et al., 2017) emissions and boundary conditions. MERRA-2 uses assimilation schemes based on hyperspectral radiation, microwave observations, and ozone satellite measurements.

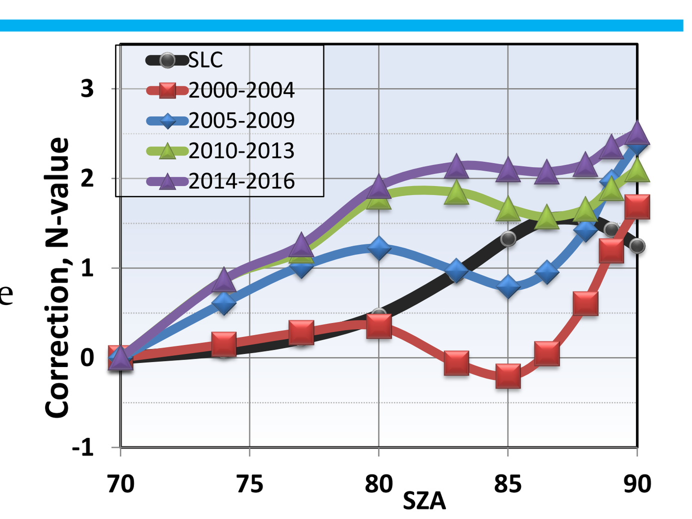


Figure 3. The difference between the observed and modeled N-values. Modeled correction is based on GMI ozone profile data matched to the Umkeh measurement. Different corrections (4 periods) are applied to homogenize MLO Umkehr record. The time periods co-inside with Dobson calibrations and related to the use of different R-N tables (see color legend for time periods).