Optimizing Umkehr ozone profile Retrievals during the Mt. Pinatubo volcanic eruption

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Abstract

The Umkehr method is based on a sequence of zenith sky observations during sunrise/sunset. NOAA Umkehr ozone profile records have been collected since the 1970s. Umkehr ozone profiles are used to monitor and guide stratospheric ozone recovery predicted by 2050s. Current operational Umkehr profile algorithm produces data that have uncertainty on the order of ~ 5 % in the stratosphere. However, when large volcanic eruptions inject aerosols into the stratosphere, the errors can be as large as 70 %. In order to evaluate Umkehr record for aerosol-related and instrumental errors, we compare observations with a Hindcast simulation of the NASA Global Modeling Initiative (GMI) chemistry transport model (CTM, PI S. Strahan) that provides hourly sampled vertical profiles of ozone and temperatures matched to the location of the Umkehr station. In addition, GMI ozone and temperature profiles are used for simulations of Umkehr observations. The biases found between the model and observations are summarized for each Dobson calibration period, thus providing a reference for homogenization of the Umkehr time series and successful removal of aerosol errors.

N-value correction optimized using the GMI model

Dobson Umkehr measurements are made by comparing the intensity of two UV wavelengths measured from the zenith sky between 0 (sunrise/sunset) solar elevation and 20 (70 SZA). The ratio of the zenith sky are converted to N-value ($100*\log_{10}(I_{332.4}/I_{310.5})$). Figure 1 estimates the difference between the observed and modeled N-values in volcanic eruption period. Modeled correction is based on GMI model ozone profile data matched to the Umkehr observations.

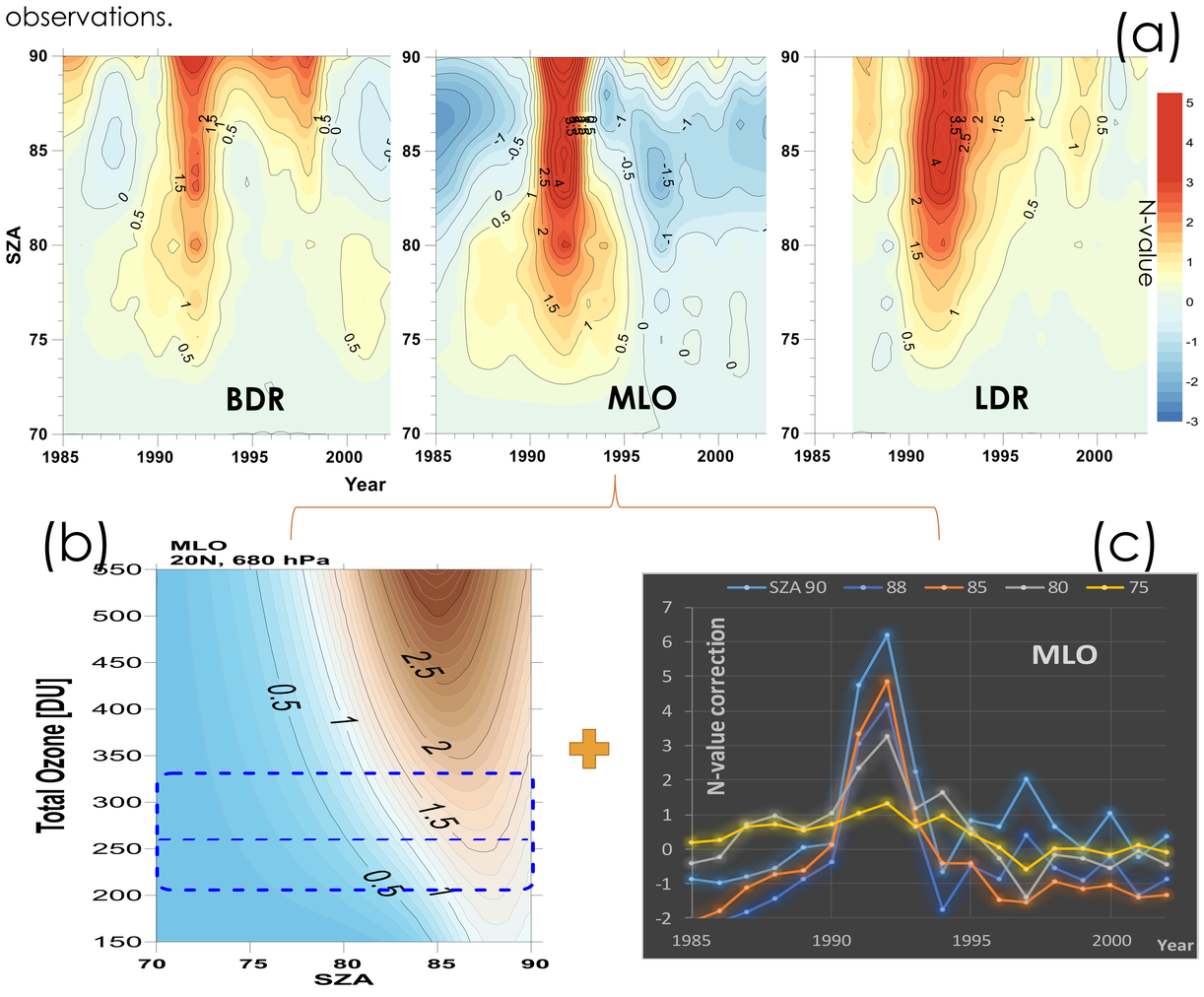


Figure 1. The difference between simulated and observed N values. The simulated N-values are based on the GMI CTM model ozone profile data matched with station observations in time and space. Umkehr observation correction for aerosols is shown as function of solar zenith angle. (a) A time-series correction N value for Boulder (BDR, 40 N), Mauna Loa Observatory (MLO, 20 N) and Lauder (LDR, 45 S). (b) Operational Stray light correction for MLO is shown as function of solar zenith angle. A dashed box indicated typical range of total ozone observed at MLO. (c) Same as Figure 1a, but shown as annual mean for several SZAs.

Umkehr ozone profile during the period of 1991 Eruption of Mt. Pinatubo volcano: before and after correction

Umkehr measurements are made by Dobson comparing the Solar zenith intensity in two spectral regions Sequential measurements are taken within 70-90 degrees SZA range.

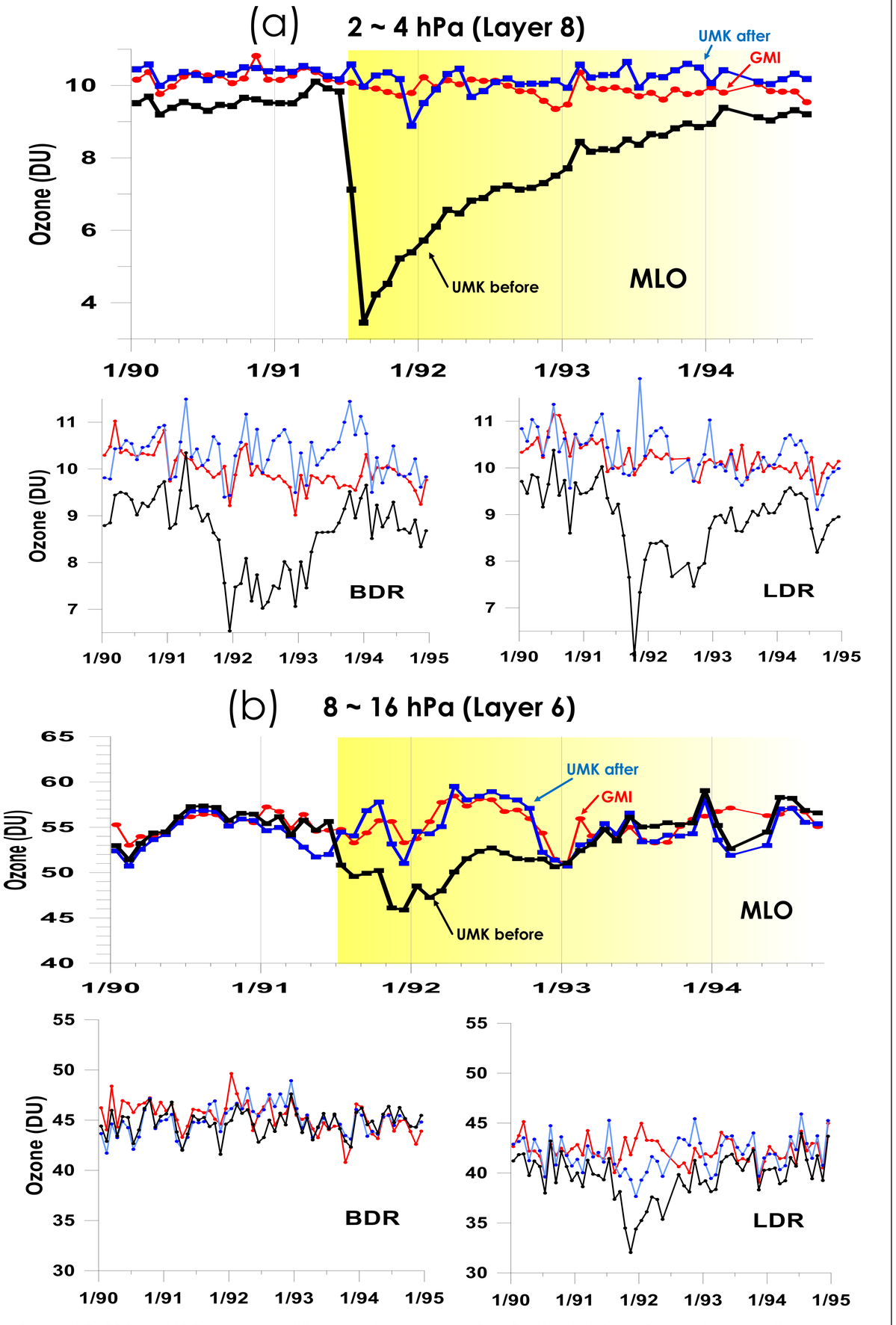


Figure 2. (a) MLO, BDR and LDR ozone monthly-mean time series at 2-4 hPa (Umkehr layer 8) are shown for the Umkehr operational (Black), Umkehr optimized (Blue) algorithms and the station matched GMI (Red) data. GMI data are provided by NDACC Theory and Modeling group project, PI S. Strahan. A yellow grading shows time period of enhanced volcanic aerosol loads in stratosphere over station during the Pinatubo eruption. Aerosols introduced large errors in the Umkehr operational ozone retrievals. (b) same as (a) but for 8-16 hPa layer (Umkehr layer 6) – smaller errors.

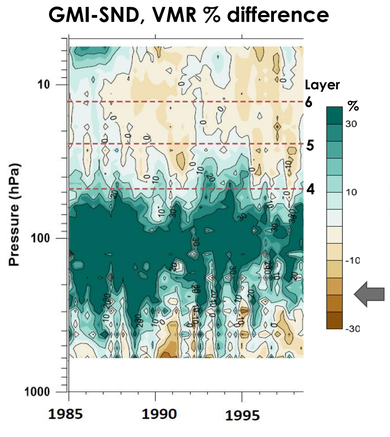
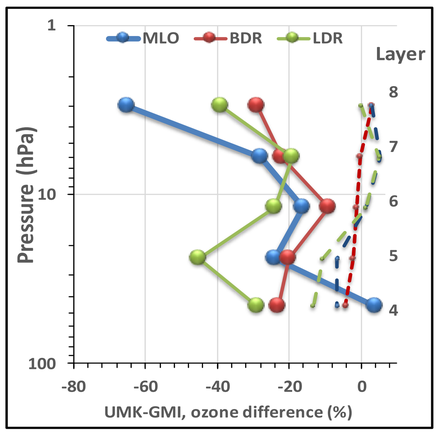


Figure 3. Biases between Umkehr and GMI ozone profiles during period of Pinatubo volcanic eruption. Results are shown for operational (solid lines) and optimized (dashed lines) retrievals in BDR, MLO and LDR records. The % error=(UMK-GMI)/GMI*100.

Figure 4. The % differences in the ozone monthly mean time series between the GMI model and ozonesonde observations are shown for Hawaii (Hilo station).



Summary and Discussion

- Standard Stray light correction (N-value) are included in the optimized Umkehr retrieval.
- Stratospheric volcanic aerosols cause large errors in Umkehr ozone profiles at MLO after Mnt. Pinatubo volcanic eruption. A false ozone depletion up to 65% is found in the Umkehr layer 8 on August, 1991 (Fig. 3). In the past, these data were excluded from ozone trend analyses.
- After Umkehr algorithm optimization re-processed Umkehr records at three stations show good agreement with the GMI model ozone in each Umkehr layer.
- Validation of optimized Umkehr records will be done against other observational records.