1. Introduction.

NOAA Dobson Umkehr ozone profile records have been collected since the 1970s. Umkehr ozone profiles are used to monitor stratospheric ozone recovery predicted to occur by the 2050s. Current operational Dobson Umkehr profile algorithms produce data that have uncertainty on the order of ~3% 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 records for aerosol-related and instrumental artifacts, we compare observations with a hindcast simulation of the NASA MERRA-2 Global Modeling Initiative (GMI) Replay (M2GMI, Orbe et al, 2017; Wargan et al, 2018) and Chemistry Transport Model (GMI CTM, Strahan et al, 2013, Strahan et al, 2016). The biases found between the models and observations are summarized for each Dobson calibration and volcanic eruption period, thus providing a reference tool for homogenization of the Umkehr time series and removal of volcanic aerosol errors.

2. N-value correction optimized using the M2GMI simulation.

Umkehr Retrievals (Operational)

Dobson Umkehr measurements are made using information from the C wavelength pair (311.5, 332.4 nm). The algorithm for ozone retrieval, UMKO (Petrovapovskikh et al, 2011), is based on forward (RT simulation) and inverse (Rodgers 2000) models. Independent zenith sky cloud detector data are used for screening of N-value measurements for interference of clouds in the zenith view. N-value is described as:

\[ N(w, Z) = 100 \times \log_{10} \left( \frac{I_{raw}(w, Z)}{I_{solar} \times \cos(Z)} \right) + k \]

where \( I_{raw}(w, Z) \) is zenith-sky intensity divided by solar flux measured at 2 spectral channels.

Stray light correction (Standardized)

The operational Umkehr ozone profiles are biased relative to other ozone observations, i.e. satellite (Petrovapovskikh et al, 2011). The updated algorithm takes into account the standardised stray light correction (SZA). The bias between zenith sky intensities are converted to N-values, 100 log(Iraw/Icos(Z)). Large difference between the observed and modeled N-values are found in the volcanic eruption periods (1982-1988, 1991-1994). Modeled corrections are based on M2GMI model ozone profile data matched to the Umkehr observations.

Optimization with the M2GMI model

Calibration of Dobson instruments and instrument replacements can create bias in Umkehr observations due to changes in the optical characteristics of the instrument. Additional atmospheric scattering due to volcanic aerosols (Fig. 2) is not accounted for in present Umkehr operational data processing and also results in biases.

Optimization involves the use of empirical corrections to reduce differences between observed and simulated Umkehr data, and serves to homogenize time series (Fig. 3). The Umkehr simulations are based on ozone profiles from the independent datasets, i.e. M2GMI. Ozone profile data from the M2GMI are selected for the Boulder location and matched to the date of Umkehr observations. Data are available from 1980 to 2017.


Validation of optimized Umkehr RT

The optimized Umkehr ozone processing includes multiple N-value adjustments for each of instrument calibration periods as shown in Figure 4 where arrows at the bottom indicate dates of the applied corrections and during volcanic eruptions shown as yellow colored periods. The changes in the Umkehr Boulder record are assessed through comparisons to M2GMI, GMI CTM and several satellite datasets (Aura MLS aggregated SBUV series and JPS OMPS VPBO). Figure 4 also shows comparisons of optimized Umkehr data and the M2GMI model where seasonal to sub-seasonal biases are +/-2% and the long-term mean bias is 0%. Figure 5 shows comparisons with other datasets.

4. Summary and Discussion

Findings

- Umkehr mean bias is reduced after optimization (Figs. 6 & 7).
- Seasonal biases are still present and need to be investigated (Fig. 6).
- Mean bias of 5% is found between M2GMI and GMI CTM in the stratosphere (Fig. 5a & Fig. 7).
- Very similar models (MER42 winds and chemistry), biases in the upper stratosphere need to be understood better (Fig. 7, i.e. Stauffer et al, 2019).

- Next step: residuals of the Umkehr retrieval (delta N-value) need evaluation to verify improvement in the Umkehr measurement fit.
- Next step: Other Umkehr stations will be optimized and verified against other instruments including lidar, FIRR and Microwave.