Sensitivity of Dobson and Brewer Umkehr ozone profile retrievals to the choice of the ozone cross-section.

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Umkehr ozone profile retrieval

- Single pair zenith sky measurement or N-value=$100\times\log_{10}(I)$: UMK04 – Dobson C-pair, O3BUmkehr – 310/326 nm for Brewer
- Optimal statistical retrieval is used for solution – iterative process
- SZA between 70 and 90 degrees
- RT forward model for SS N-values
  - spectrally resolved line-by-line calculations across both band-passes
  - $O_3$ absorption and Rayleigh scattering database
  - Ozone profile climatology
  - Band-pass functions
- Multiple scattering correction (total ozone and latitude profile dependent, profile adjustment based on MS Jacobian)
- Refraction in air correction
- Temperature correction (seasonal climatology)
- Out-of-band stray light correction
- Spectral shift in band-pass center registration
Slit and Solar Flux weighted intensity at 70 SZA, Dobson C-short, B&P and DMB x-sections similar at both short and long
Slit and Solar Flux weighted intensity at 85 SZA, Dobson C-short B&P and DMB x-sections similar at both short and long.
Temperature dependence at Dobson C-pair short and long wavelengths for B&P and DMB x-sections similar at short and some difference at long.
Depiction of stray light by A. Cede (NASA/Goddard)

Example of the spectral transmittance for the double (MKIII) and single (MKIV) Brewer

Examples of a Brewer slit functions for double and two single Brewers. The far, near fields and core are indicated, and the errors bars are provided
Stray light measurements in Boulder ~ 1 N-value change
Stray light estimates for different TO values

- 375 DU, 45N, Sea Level, difference straylight at .01% and .02%
- 275 DU, 45N, Sea Level, difference straylight at .01% and .02%
- 225 DU, 45N, Sea Level, difference straylight at .01% and .02%
Boulder, Fall (09/27/2007), TO 271 DU, D083, relative to UMK04 with B&P x-sec

Daumont x-section
Temperature correction
band-pass shift (0.08 nm)
Stray light correction
Boulder, **Spring** (04/07/2009), TO 330 DU, D083, relative to UMK04 with B&P x-sec

- Daumont x-section
- Temperature correction
- Band-pass shift (0.08 nm)
- Stray light correction
Boulder, Dobson 061, 1979-2008, relative changes in layers

X-section (DMB-BP)
Band-pass spectral shift
Stray light correction
Temperature climatology correction
Conclusions for Dobson Umkehrs

- Effect of X-section change – very small
- Effect of band-pass shift (0.1nm) is very small (wide band-passes)
- Effect of temperature corrections (climatology based) is small
- Stray light effect in Dobsons (10^{-5}) is significant, but needs to be further evaluated for individual instruments
- Errors in Dobson Umkehr ozone profile retrievals related to the uncertainties in instrumental parameters are larger than due to X-section choice
## Dobson vs. Brewer

<table>
<thead>
<tr>
<th></th>
<th>Dobson</th>
<th>Brewer</th>
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<tbody>
<tr>
<td><strong>Spectral channels (nm)</strong></td>
<td>311.4/332.5</td>
<td>310.1/326.5</td>
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<tr>
<td><strong>Spectral band-pass</strong></td>
<td>Wide. Short channel: triangular 1.5 FWHM Long channel: trapezoid, about 3.8 nm at the base and and 2 nm at the top</td>
<td>Narrow. Both channels have similar triangle shape, ~0.6 nm FWHM</td>
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<td><strong>Other filters</strong></td>
<td>Cobalt filter (cuts off light above ~360 nm)</td>
<td>Double: Grating, PMT set zero below 250 nm and above 800 nm Single: UG-11 and NiSO4 filters – zero below 280 and above 330 nm</td>
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<td><strong>Stray light (far field)</strong></td>
<td>~2*10^{-5}, 0.005 %</td>
<td>Single, class II: ~10^{-4} for Mark IV at NEUBrew Double, Mark III: ~10^{-7} for Double B171</td>
</tr>
</tbody>
</table>
Slit and Solar Flux weighted intensity at 70 SZA, *Brewer* C-short, B&P and DMB x-sections similar at both short and long
Slit and Solar Flux weighted intensity at 85 SZA, Brewer C-short, B&P and DMB x-sections similar at both short and long
Effects on Brewer Umkehr RT
Boulder, 09/27/07

- Daumont x-section
- T correction
- Band-pass shift (0.08nm)
- Stray light correction
MLO, Brewer 009 (Environment Canada), 1998-2005, relative changes in layers

X-section (DMB-BP)
Band-pass spectral shift
Stray light correction
Temperature climatology correction
Conclusion for Brewer Umkehrs

- Effect of X-section change – small
- Effect of band-pass shift is small
- Effect of temperature corrections (climatology based) is small
- Stray light effect in single Brewers (1x10^-4 level for Mark IV) is significant, but needs to be further evaluated
- Errors in Brewer Umkehr ozone profile retrievals related to the uncertainties in instrumental parameters are larger than errors due to X-section choice
- X-section sensitivity in Brewer Umkehr retrievals is similar to Dobson Umkehr retrievals (although Brewers have more narrow band-pass)
Further work

• Out-of-band contribution into Umkehr measurement (due to non-zero transmission in the far field of the slit band) needs to be evaluated for both Dobsons ($2 \times 10^{-5}$?) and single Brewers ($1 \times 10^{-4}$?)
• Band-pass centers (shift from nominal) and widths need to be carefully evaluated for all instruments
• NiSO$_4$ - UG11 filter transmission in single Brewers needs to be measured and utilized in Umkehr profile retrievals
• As we develop the Brewer Umkehr profile retrieval software for satellite validation activities – proper ozone x-sections would be of great importance.
Thanks!
I hope to learn more...
Auxiliary slides
Slit and Solar Flux weighted intensity at 70 SZA
C-long, B&P and DMB x-sections – similar at both short and long
Slit and Solar Flux weighted intensity at 85 SZA
C-long, B&P and DMB x-sections – similar at both short and long
Stray light treatment

• The Brewer intensities in zenith sky view can be represented by the following equation (A. Cede, private communications):

\[ N(O_3, \lambda_i, \theta) = 100 \times \log_{10} \left[ \int_0^\infty I(O_3, \lambda', \theta) \times S(\lambda_i - \lambda') \times T(\lambda') d\lambda' \right] \]

• \( \lambda_i \) Center wavelength at slit i and fixed grating position
• O3 Total ozone column
• \( \Theta \) Solar zenith angle
• \( N(O_3, \lambda_i, \theta) \) Umkehr N-value
• \( I(O_3, \lambda', \theta) \) Zenith intensity at wavelength \( \lambda' \), depends on other atmospheric parameters as well (e.g. aerosols)
• \( T(\lambda') \) Spectral sensitivity
• \( S(\lambda_i - \lambda') \) Slit function.
A. Cede depiction of stray light

Example of the spectral transmittance for the double (MKIII) and single (MKIV) Brewer

Examples of a Brewer slit functions for double and two single Brewers. The far, near fields and core are indicated, and the errors bars are provided.
OOB in Umkehrs as compared to reference (MLS+ sond synthetic on 09/27/07) – similar effect in single Brewer and Dobson
Change of the **band-pass center** – results in maximum 1 N-value Umkehr change

Only short is shifted by 0.15 nm

Both short and long shifted by +/- 0.15 nm
Change of the band-pass width – small change in Umkehr curve

Only short is changed by 0.15 nm to make it wider/narrower
OOB in measured Dobson Umkehrs as compared to the reference (MLS+sond synthetic on 09/27/07)
Comparisons of Dobsons in Boulder, September 20 and 27, 2007

Reference, MLS+sond
Daumont x-section
Temperature correction
0.08 nm air-vacuum shift
Stray light correction 2e-5
Stray light correction 1e-4
Effects of x-section and other changes on Dobson Umkehr retrievals, September 20, 2007, Boulder
Brewer 134, Boulder, Sept 20 2007

Reference, MLS+sond
Daumont x-section
Temperature correction
0.08 nm air-vacuum shift
Stray light correction 2e-5
Stray light correction 1e-4
BOULDER 20070920, BR 134, 271 DU, MLS(040709)+sond(040709)

Reference, MLS+sond
Daumont x-section+OOB
Temperature + 1e-4 OOB
Spectral shift + 1e-4 OOB
Stray light, OOB 2e-5
Stray light, OOB 1e-4
Temp Effects on Brewer Umkehr RT with BP and Daumont x-sec

Daumont x-section, BP (Temp corr), DMB (Temp corr)
Stray light correction
Boulder, Dobson 061, 1979-2008

UMK04, X-section (DMB), Stray light, Stray light and band-pass shift, Stray light and w/o Temperature climatology
Boulder, Dobson 061, 1979-2008, annual cycle changes in layers

X-section (DMB-BP), Band-pass spectral shift, Stray light correction, Temperature climatology correction
MLO, Brewer 009, 1998-2005

UMK04, X-section (DMB), Stray light, Stray light and band-pass shift, Stray light and w/o Temperature climatology
MLO, Brewer 009, 1998-2005, annual cycle changes in layers

X-section (DMB-BP), Band-pass spectral shift, Stray light correction, Temperature climatology correction
Ozone x-section coefficient C0, A long

- band-pass for A-long
- BP (vac) C0 A long
- BP (air) C0 in A long
- BP (vac, not interp)
- A-long BP at 38 A width
- Along, interpolated to widen