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*\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
  - \ce{O_3} absorption and Rayleigh scattering database
  - Ozone profile climatology
  - Band-pass functions (re-defined using Pandora measurements)
- 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 C-short, weighted Intensity at 70 SZA, 325 DU 45N

- BP
- DM
- DM-BP

Wavelength, nm

ZS1*S1*ETS

(DM-BP),%
Slit and Solar Flux weighted intensity at 85 SZA, Dobson C-short B&P and DMB x-sections similar at both short and long

![Graph](image-url)

Slit C-short, weighted Intensity at 85 SZA, 325 DU 45N

- BP
- DM
- DM-BP
Slit functions, **Dobson 083**, March 17 2010
Pandora measurements, C-short

**Attempt to determine the slit function of the S2 at C pair setting, 16 Mar 2010, D083**

Ball Bros slit functions shifted, if needed to help compare shape.
Slit functions, Dobson 083, March 17 2010
Pandora measurements, C-long

Attempt to determine the slit function of the S3 at C pair setting, 16 Mar 2010, D083

BallBros Slit functions shifted, if needed to help compare shape.
Slit functions, Dobson 102 and 083, March 2010
Pandora measurements, C-long, shape
Slit and Solar Flux weighted intensity at 85 SZA, Dobson C-long, B&P and DMB x-sections similar, band-pass effect in zenith sky convolution.
Slit and Solar Flux weighted intensity at 85 SZA, Dobson C-long, B&P and DMB x-sections similar, band-pass effect in zenith sky convolution
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.

**Band-pass weighted linear temp O3 coef for short C-pair**

**Band-pass weighted linear temp coef for long C-pair**
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

Solar zenith angle (degrees)

N difference from Normalized reference

275 DU, 45N, Sea Level, difference straylight at .01% and .02%

375 DU, 45N, Sea Level, difference straylight at .01% and .02%

225 DU, 45N, Sea Level, difference straylight at .01% and .02%
Boulder, Fall (09/20/007), TO 271 DU, D061, 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, D061, relative to UMK04 with B&P x-sec.

- Daumont x-section
- Temperature correction
- Band-pass shift (0.08 nm)
- Stray light correction

![Graph showing ozone differences](image-url)
Boulder, Fall (09/20/007), TO 271 DU, D061 (BLD), new slit C-long (dashed line), reference profile (sonde+MLS)
Boulder, Fall (09/20/007), TO 271 DU, D116, new slit at C-long (dashed line), reference profile (sonde+MLS)
Boulder, Dobson 061, 1979-2008, relative changes in layers

- X-section (DMB-BP)
- Band-pass spectral shift
- Stray light correction
- Temperature climatology correction
Boulder, Dobson 061, 1979-2008, relative changes in layers

- X-section (DMB-BP)
- Stray light correction
- Stray light and C-long band-pass change
- Temperature correction (climatology)
- Band-pass spectral shift (-0.08 nm)
Conclusions for Dobson Umkehrs

- Effect of X-section data set change – very small
- Effect of band-pass (BP): shift (0.1nm) error is small (wide BP), but the appropriate BP shape increases Umkehr retrieved ozone in upper stratosphere
- Effect of temperature corrections (climatology based) is small
- Stray light effect in Dobson Umkehr measurements ($10^{-5}$) is significant for retrieval error, 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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</thead>
<tbody>
<tr>
<td><strong>Spectral channels (nm)</strong></td>
<td>311.4/332.5</td>
<td>310.1/326.5</td>
</tr>
<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 2 nm at the top</td>
<td>Narrow. Both channels have similar triangle shape, ~0.6 nm FWHM</td>
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<tr>
<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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<tr>
<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 C-short, weighted Intensity at 70 SZA, 325 DU 45N

BP  DM  DM-BP
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, 09/20/07

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

![Graph showing relative changes in layers](image-url)
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 for ozone profile retrieval, 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), wavelength separation, and BP widths need to be carefully evaluated for all instruments – implication to ozone profile retrieval
- 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.
- Total ozone from zenith sky measurements is of interest for satellite validation at low sun conditions (increase in stray light in direct sun measurements).