Preliminary investigation: The effect of field of view restrictions on retrieved total column ozone amounts in Dobson Ozone Spectrophotometer #72, Lauder New Zealand.

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Abstract. The effect of Field of View restrictions on retrieved total column Ozone amounts in a Dobson spectrophotometer is investigated.

Introduction. Dobson Ozone spectrophotometer #17, Arrival Heights Antarctica, has a unique optical front-end that allows operation of the Dobson indoors. The optical front end operates in a similar fashion to that of a periscope, directing light from outside the laboratory into the instrument. Zenith sky observations are possible in adverse weather conditions that otherwise would not allow any Dobson measurements at all (Figure 1). The optical front end consists of a length of PVC tubing that houses the focusing lens and allows the sun-director to be mounted on the top of the tubing for direct sun observations. Zenith Sky measurements can be conducted by removing the sun-director from the top of the tubing.

Figure 1. Dobson #17, Arrival Heights, Antarctica.

The optical front end of this system limits the field of view(FOV) to approximately 7.7 degrees for zenith sky measurements, this is in good agreement with the nominal FOV of 7.0-8.0 degrees [*Robert Evans, personal comms*, 2006] when the dobson operates in its original configuration.

The optical front end has been custom built to the physical specifications of the current Arrival Heights laboratory. The laboratory is to be replaced in the spring and summer of 2006, requiring the relocation of the Dobson to the new laboratory. Since the new laboratory has differing internal and external dimensions a new optical front-end of the Dobson is required. The new optical front end will require redesign and fabrication. The FOV needs to be taken into account. Various designs for the new optical front end have been discussed, with the majority of the designs having smaller FOVs than the status quo (7.7 degrees). FOVs range from approximately 4.2 to 7.9 degrees. Before finalising on the new design of the optical front end it was decided to quantify the effect of FOV restrictions on the retrieved total column Ozone amounts. This information will allow us to design the new optical front end with confidence that any change in the FOV will not effect the quality of measurements and preserve continuity with previous observations.

Optical stop and focusing effects have been investigated in the past [*Basher*, 1980], but concentrate on measurements made with standard lamps to calibrate and fix systematic faults in the internal optical alignment of the instrument. No empirical relationships between FOV restrictions and retrieved total column Ozone amounts were established.

Measurements obtained with restricted FOVs were performed with Dobson #72, Lauder New Zealand. It is assumed that the FOV of Dobson #72 and Dobson #17 are the same.

Method. ADZB measurements were taken under clear sky conditions spanning solar noon on the 7th September 2006 at NIWA, Lauder New Zealand. Measurements were made over solar noon because this is the time of day of least change in airmass.

Aperture Stops of differing sizes were placed above the optical entrance of the dobson to limit the FOV. A series of 35 ADZC measurements were conducted, alternating between measurements made with a restricted FOV and a measurement performed with the original FOV configuration. Two measurements for each aperture were conducted. The experiment took less than two hours to complete, during this time sky conditions were constant.

The FOV is defined as:

$FOV = 2\tan^{-1}[d/2f]$ (1)

d = diameter of the circular aperture stop (mm)
f= distance of the aperture to entrance optical focal point or focal plane (mm)

Since the focal plane is located inside the dobson and the focal plane specifications (or focal length , as a proxy) could not be obtained, i've defined the effective field of view (EFOV) as:

$EFOV = 2\tan^{-1}[d/2l]$ (2)

d = diameter of the circular aperture stop (mm)
l = distance of the aperture stop to the optical entrance hole of the dobson (mm)

The EFOV can be calculated. The EFOV will have values consistently larger than the FOV. The EFOV for the Lauder Dobson is 12.2 degrees, well outside the nominal FOV specifications of 7.0-8.0 degrees.

Eight apertures with diameters ranging from 6mm to 48mm were constructed. The apertures were mounted 177mm above the optical entrance of the Dobson. An error of 1mm is assumed in the diameter of the aperture and an error of 1mm is assumed in the 177mm distance the aperture is mounted from the optical entrance of the dobson. The EFOVs and associated uncertainties are given in table 1.

EFOV (degrees)	**Uncertainty (+/- %)**
15.4	2.6
9.0	4.2
7.7	4.8
7.0	5.0
6.5	5.6
5.8	6.0
4.5	7.7
3.9	9.0

Table 1. EFOVs and uncertainties.

Results. The first test was to compare retrieved Ozone amounts between ADZB measurements made under the normal operating configuration (EFOV of 12.2 degrees) and measurements conducted with the aperture mounting system with out any apertures. The EFOV of the aperture mounting system is 15.44 degrees. Student T-test was performed on the two measurement sets. Results indicate they are, statistically, from the same distribution. This proves the aperture mounting system does not effect measurements.

Figure 2 displays the retrieved Ozone amounts for different EFOV's and interlaced normal ADZB measurements. A trend line was fitted to data taken without any EFOV restriction and then interpolated to the times that restricted EFOV measurements were made.

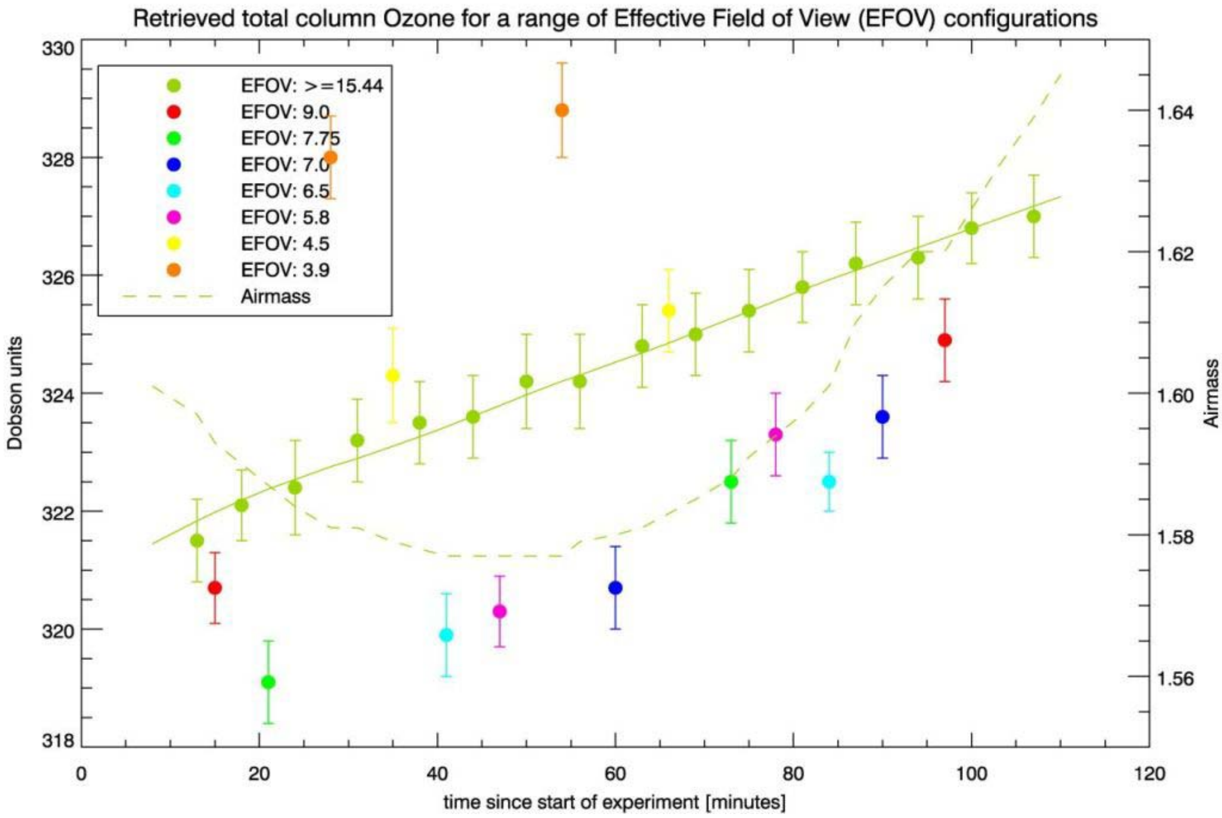

Figure 2. Total column Ozone retrievals for differing EFOVs.

Ozone was steadily increasing over solar noon and is not correlated with Airmass. Since Ozone was not constant any comparisons between retrieved ozone amounts measured with different EFOVs need to be first detrended, ie a comparison of ozone anomalies instead of total column ozone. Figure 3 shows the detrended ozone amounts.

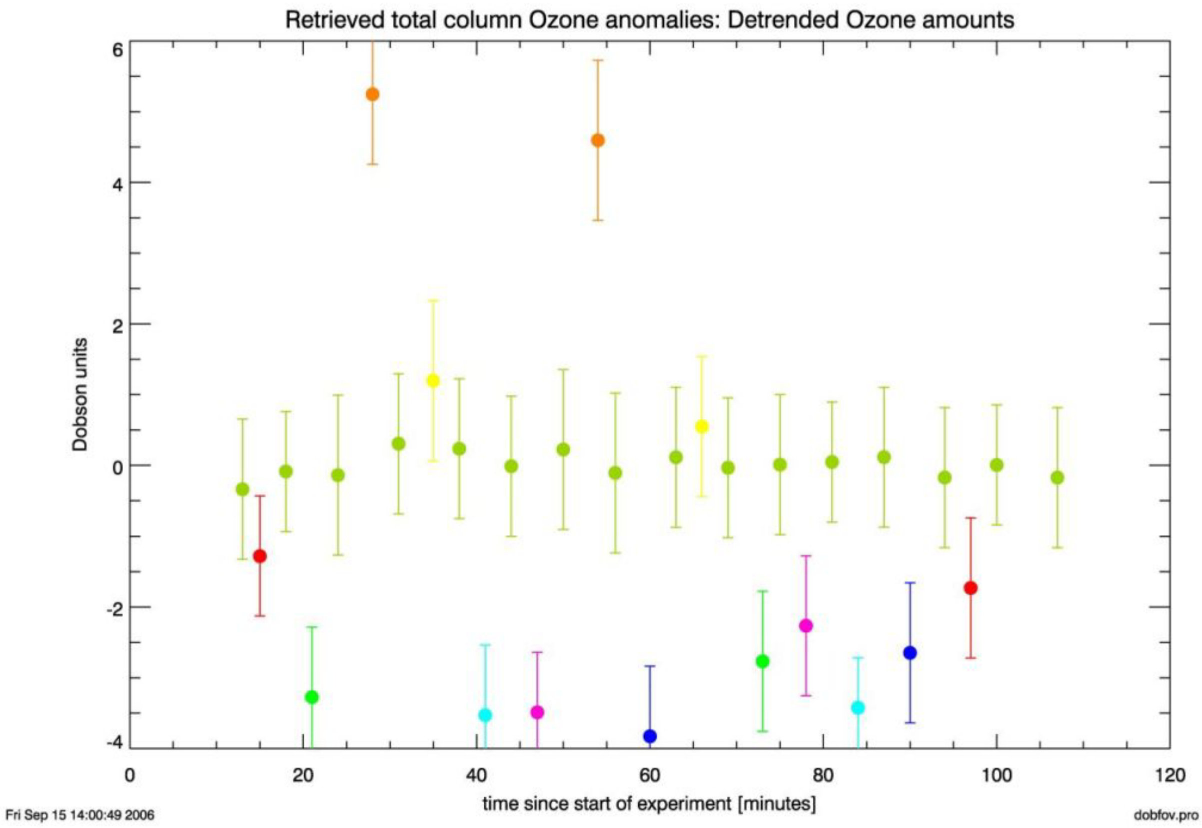

Figure 3. Ozone anomalies.

The relationship between the ozone anomaly and the EFOV of the measurements is shown in Figure 4. A third order polynomial is fitted to the data. A highly non-linear relationship is evident, even with only two measurements for each aperture stop.

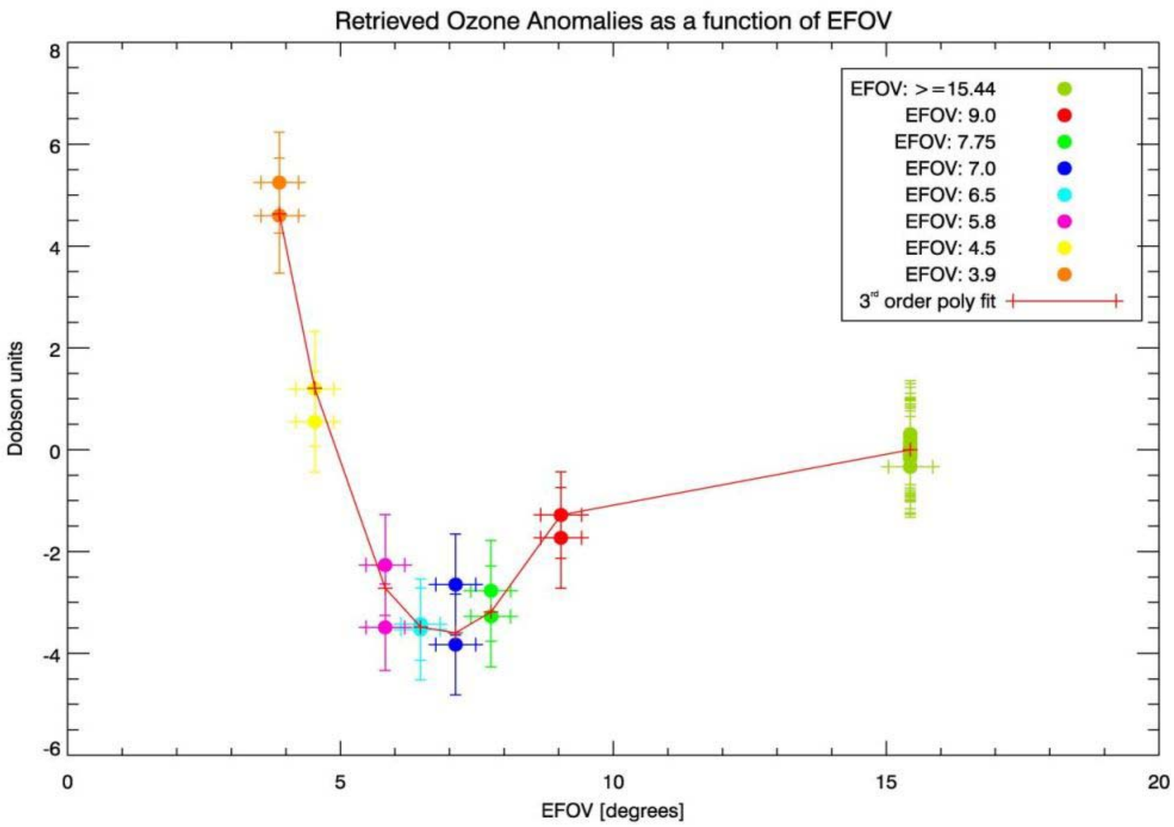

Figure 4. Ozone anomaly as a function of EFOV.

Discussion. A significant change in the anomaly occurs when the EFOV is reduced to approximately 8.5 degrees. This is in agreement with Robert Evan's FOV measurements of ~ 7.0-8.0. An EFOV of 8.5 could be approximately equal to an FOV of 7.0-8.0degrees?

Some very non-linear effects occur small EFOVs. Reasons for this behaviour are outside the scope of this study, but the non-linear behaviour could be related to low signal levels and to a lesser effect, the relationship between FOV and wavelength scattering in the atmosphere. For the purpose of this study its good enough to say the EFOV of Dobson #17 can be approximated to 8.5 degrees.

A design for the optical front-end of the new system that had an EFOV less that 6.5 degrees would be not advisable. Theoretically a design that had an EFOV of approximately 5.0 degrees would give an anomaly of zero, but if any errors are made in the construction and if the EFOV is not 5.0 degrees erroneous ozone values would be retrieved.

The current optical front end has a EFOV of approximately 7.7 degrees. This restricted field of view produces an anomaly of ~-3.2DU. An empirical correction to zenith measurements relative to direct sun measurements has been validated and employed for many years in Dobson#17, thus the anomaly resulting from the restricted EFOV has been accounted for. Any change in the EFOV in the new design should be kept to a minimum. To keep any changes in the retrieved ozone amounts to less than 0.5 DU, the EFOV of the new design should be between 7.25 and 7.9 degrees. If a drastic change in the FOV is unavoidable, then the empirical relationship between zenith and direct-sun measurements should be recalculated.

A more rigorous investigation into FOV effects on Dobson zenith observation should be conducted.

Furthur work. This experiment should be repeated. The experiment can be improved by implementing the following ideas:
-Calculating the FOV instead of the using the proxy EFOV values.
-A repeat of experiment with larger apertures mounted furthur away, this will give a smaller error in the EFOV.
-Increase the number of measurements made with each aperture stop.
-Increase the number of aperture stops and FOV range.
-A repeat of the experiment under different atmospheric conditions(overcast) and seasons(airmass at solar noon).
-Perform CDZB as well as ADZB observations.
-Measure raw signal levels for each FOV. This will help parameterise the effect of signal level on measurements.
-Record and analyse wedge dial values for A,C D pairs when measurements are performed with different FOVs.

References.
Basher R.E., 'Optical stop and focusing effects in Dobson Instrument', J. Phys. E. Instrum., Vol 13, 1980, pg925-927.