Comparison of new characterized bandpass and wavelengths of Dobsons

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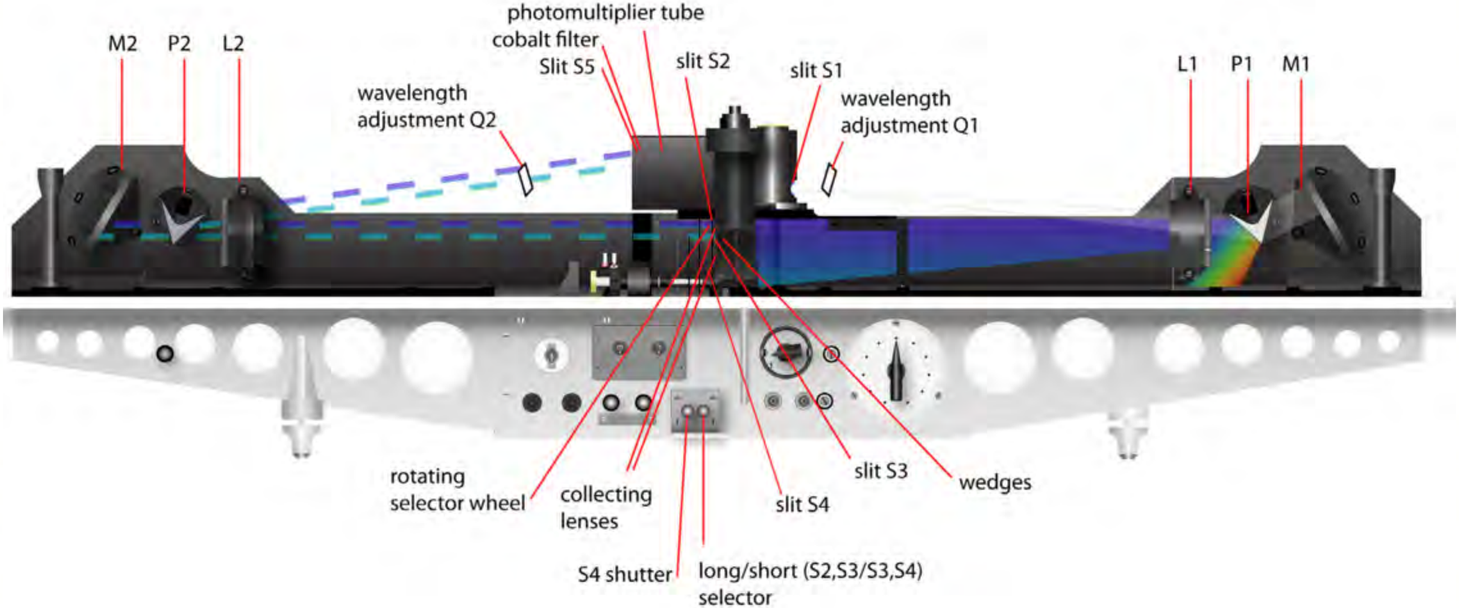
Brewer Dobson Spectrophotometers

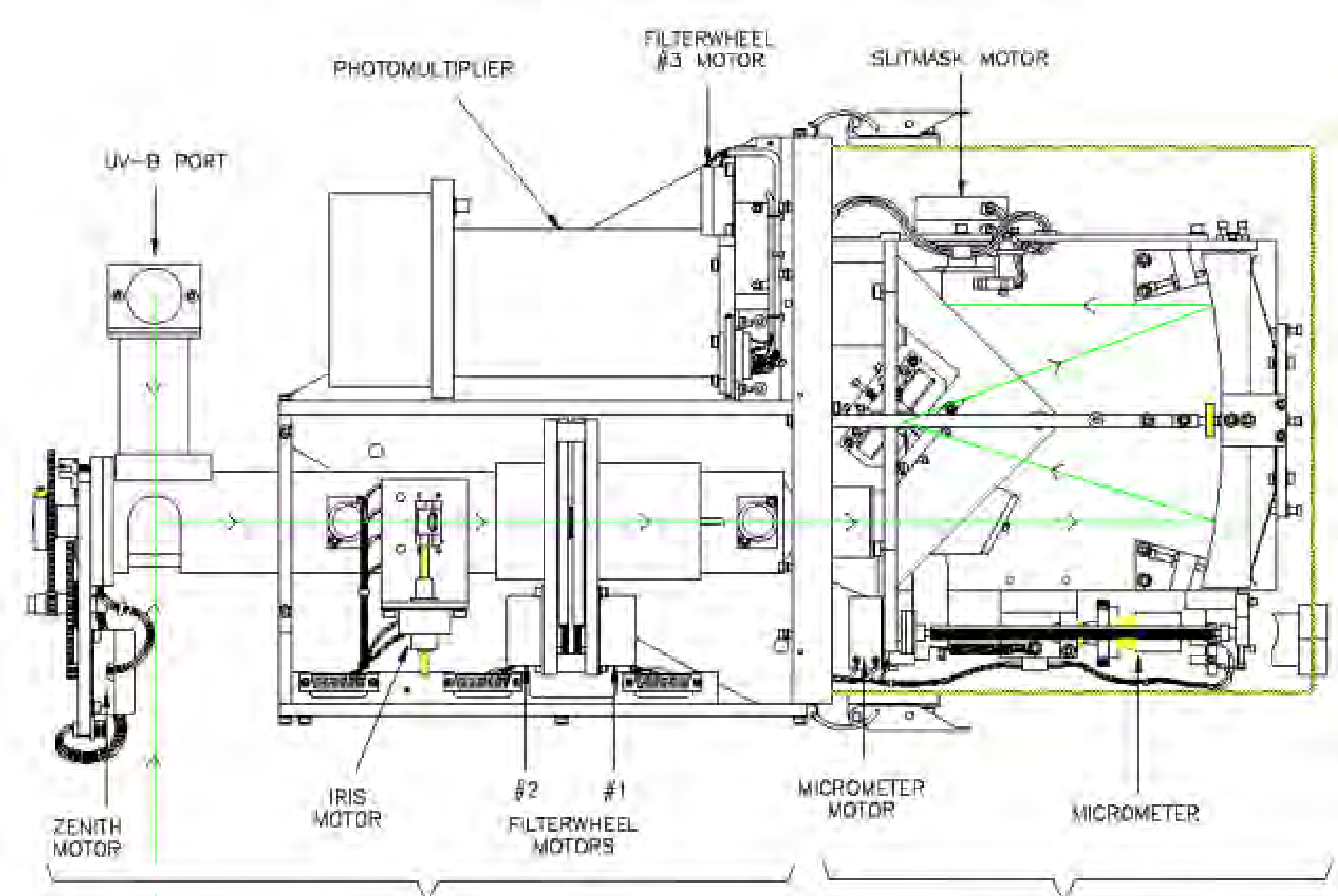
- The primary ground-based instruments used to report total column ozone (TOC) are Brewer and Dobson Spectrometers, in separate networks. These instruments make measurements of the UV irradiances, and through a well-defined process a TOC value is produced. Inherent in the algorithm is the use of a laboratory determined cross-section data set.
- The routine measurement of TOC started in the mid-1920s with a prototype of the Dobson instrument. A world-wide network grew up after the instrument re-design in 1947 and the International Geophysical Year in 1957.
- The Brewer Ozone Spectrometer was developed in Canada during the 1970s, and a commercial, automated version became available in the early 1980s.
- As observing organizations purchased these instruments and placed them in service alongside the Dobson instrument for long term measurements, the **seasonal and offset differences** in the results became evident.
- The Initial differences of 4% were removed with the adoption of Bass & Paur absorption coefficients. As measurements continued, a seasonal and offset difference was still evident

Introduction



Introduction

- Measurements by both types of instruments are based on sun photometry and the TO3 is derived from the absorption of solar light in the Huggins band.
- The Dobson spectrophotometer is based on the measurements of the ratios of two wavelength pairs, while the Brewer spectrophotometer measures photon counts at 5 wavelengths allowing the simultaneous measurement of ozone and of SO2 column amount.
- For the separation of the wavelengths the Dobson instruments use 2 and the Brewer 5 slits.
- The field of view is 8° for Dobson and 3° for Brewer instruments.
- Dobson instruments have two prisms to separate the respective wavelengths, while Brewer instruments use one or two dispersive elements (holographic gratings).
- The Dobson assumes all the instrument have the same wavelengths and slits where the Brewer instruments are slightly different from instrument to instrument and determined during calibration.


FILTERWHEEL
#3 MOTOR
PHOTOMULTIPLIER
SLITMASK MOTOR
UV-B PORT
ZENITH
MOTOR
IRIS
MOTOR
#2
#1
FILTERWHEEL
MOTORS
MICROMETER
MOTOR
MICROMETER

Dobson & Brewer Algorithm

The Dobson and Brewer ozone spectrophotometers measure solar direct irradiances at selected UV wavelengths. The ozone calculation in Dobson and Brewer can be summarized by this expression

$$X = \frac{N - B}{A\mu} \tag{1}$$

Where N is a linear combination of the logarithm of the measured spectral direct irradiances, extra-terrestrial (I_o) and ground (textbfI) at selected n wavelengths.

$$N = \sum_{i}^{n} w_i \log(\frac{I_i}{I o_i}) \tag{2}$$

Dobson & Brewer Algorithm

A are the ozone absorption coefficient or Differential Cross Section (DXS) and B the Rayleigh coefficient, which are linear combinations of the ozone absorption (α) and Rayleigh molecular scattering (β), respectively, at corresponding wavelengths.

$$A = \sum_{i=1}^{n} w_i \alpha_i \tag{3}$$

$$B = \nu \frac{p}{p_o} \sum_{i=1}^{n} w_i \beta_i \tag{4}$$

All the instruments have a certain bandpass or slit function, the measured irradiances I , α_i and β_i are the convolution of the instrument slit function (S) with the corresponding cross sections (xs) or spectral irradiances.

$$\alpha_i = \frac{\int \sigma(\lambda)\, S_i(\lambda, \lambda')\, d\lambda}{\int S_i(\lambda, \lambda') d\lambda} \tag{5}$$

$$\int S_i(\lambda, \lambda') d\lambda = 1 \tag{6}$$

Finally the airmass is defined on the standard algorithm:

$$\mu_x = \sec\left\{\arcsin\left[\frac{R}{R+h_x}\cdot\sin(\theta)\right]\right\} \tag{7}$$

R : Earth Radius (6370km)

h_x : is the effective height set to $h_{sca} = 5km$ and $h_{O3} = 22km$)

θ : Solar zenith angle

$$\mu_x = \sec\left\{\arcsin\left[\frac{R}{R+h_x}\cdot\sin(\theta)\right]\right\} \tag{8}$$

$$\tag{9}$$

Calibration Constants

I_o : Extraterrestrial constant: Langley or transferred

$B, A,$: Are calculated and depend of the wavelength calibration

I : Solar irradiance are measured and depend of the instrumental calibration

μ : Are calculated

Table 1: Wavelengths and weighting coefficients used in the Dobson and Brewer operative algorithms.

Brewer slits	W	SD	FW	SD	w_i	Dobson slits	W	FW	w_i
0	303.001				0	A1	305.5	0.9	1
2	306.301	0.014	0.548	0.016	0	C1	311.5	0.9	0
3	310.051	0.014	0.539	0.015	1	D1	317.5	0.9	1
4	313.501	0.015	0.555	0.012	−0.5	A2	325.0	2.9	−1
5	316.801	0.017	0.545	0.012	−2.2	C2	332.4	2.9	0
6	320.002	0.019	0.538	0.012	1.7	D2	339.9	2.9	−1

Algorithm asumptions

- Diffuse radiation is not considered $I_{measured} = I_{direct} + I_{diffuse}$
- Slits are parametrized, (no wings , no out-bands)
- Temperature in ozone cross section is set to constant value. (-44C / -45C Brewer)
- Height in the ozone layer is constant in Brewer /latitude dependent in Dobson.
- Rayleigh molecular scattering are fixed for all instruments (Bates 1984)
- Absorber profile is considered a delta at h effective.
- Additional absorvers are not considered $(SO_2, NO_2, HCLO)$

Ozone cross section asumptions

The temperature dependence of the cross section is not considered (common temperature is assumed)

- Effective Tememperature

$$Teff_{O_3} = \frac{\int_{Det}^{ToA} n_{O3}(h)T(h) \cdot dh}{\int_{Det}^{ToA} n_{O3}(h) \cdot dh}$$

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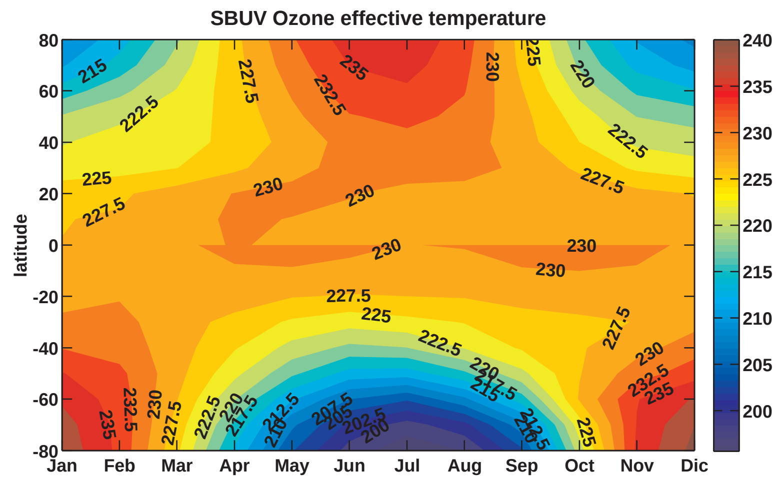
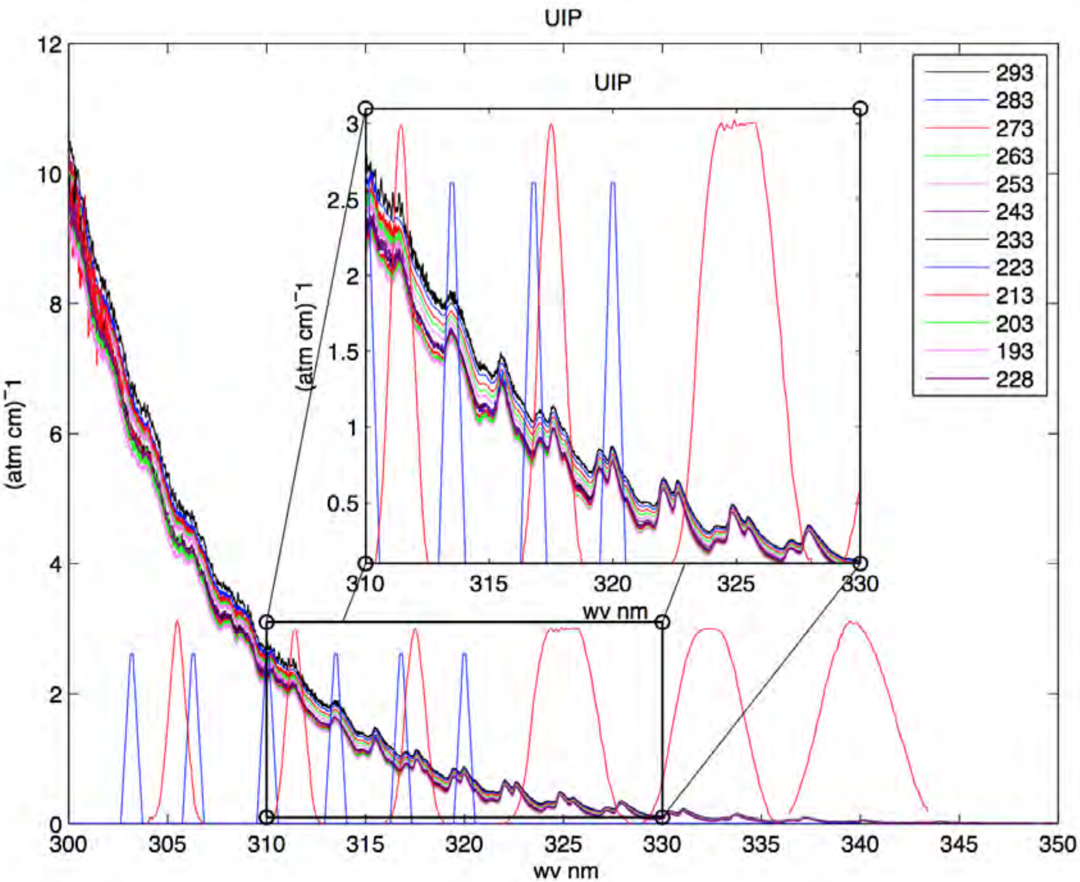


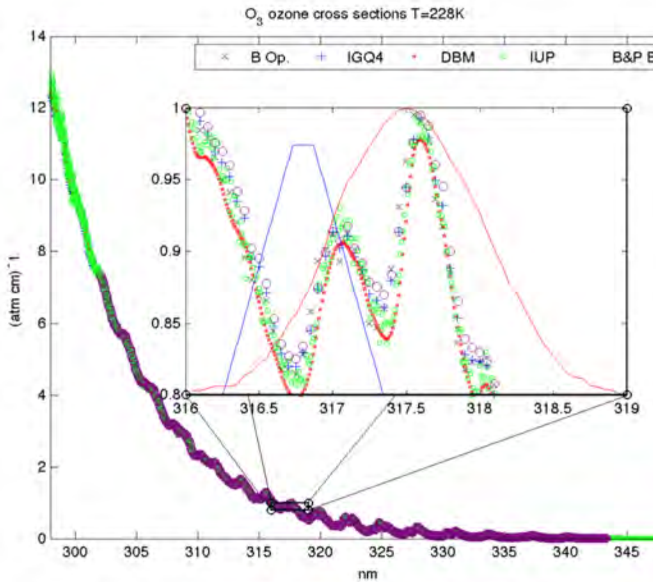
Ozone cross section asumptions

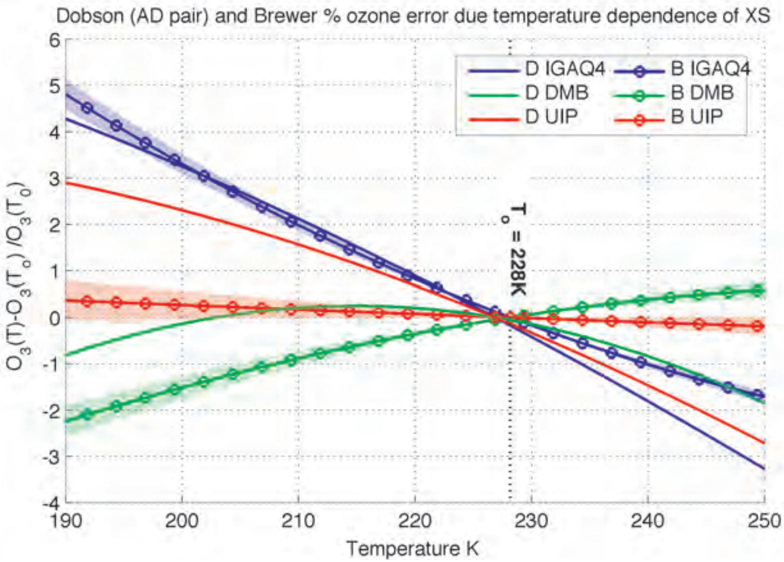
The temperature dependence of the ozone cross section is not considered.



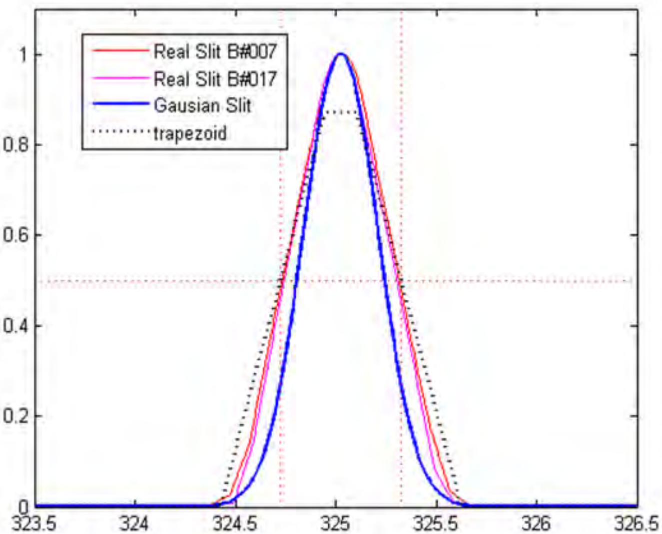
Ozone cross section asumptions

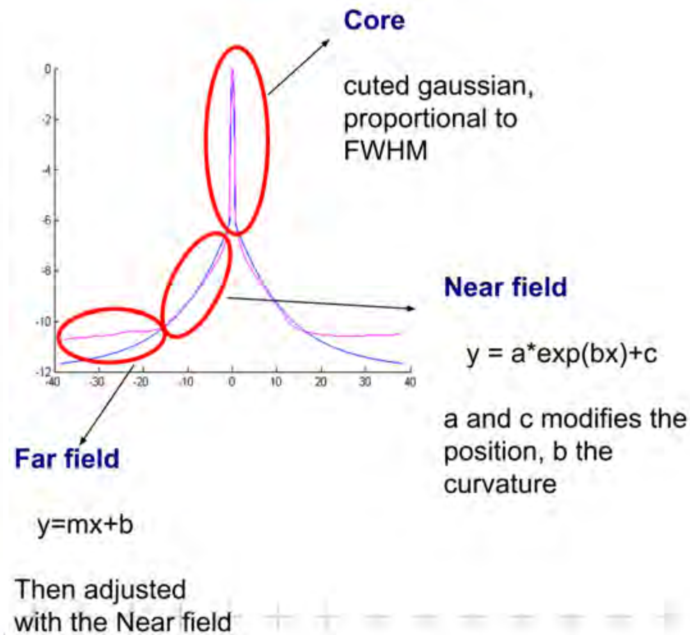
Different cross sections gives signifiant different scales and shows different temperature dependences





Slits are parametrized on the Brewer, trapezoidal with central wavelength and FWHM set for every instrument and every slit. For Dobson only reference instrument were available.





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Calculation

The ozone absorption coefficient is calculated using the Brewer operative method witch is the same that 'approximation method' used by Bernhard for Dobson in 2005.

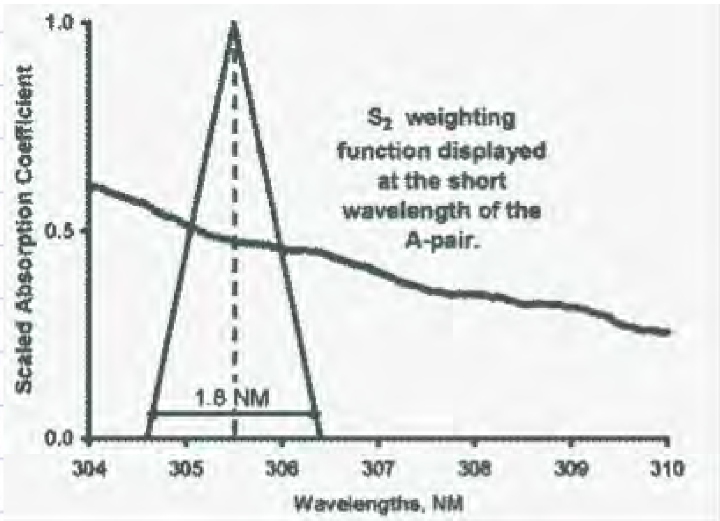
$$\alpha_i = \frac{\int \sigma(\lambda)\, S_i(\lambda, \lambda')\, d\lambda}{\int S_i(\lambda, \lambda') d\lambda} \tag{10}$$

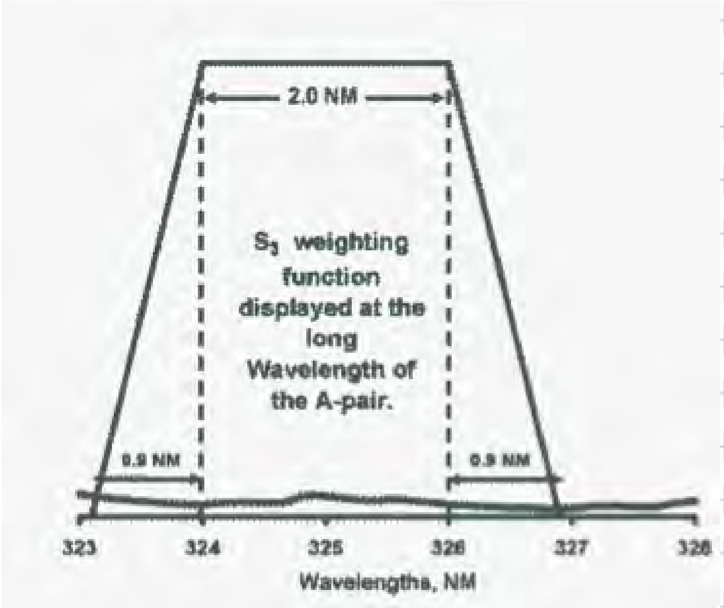
- S is the instrument slit function for the corresponding wavelength
- σ the ozone cross section at `Fixed` temperature, -46.3 C for Dobson Network and -45C for Brewer instruments

* The Dobson's assumes that all the instruments have the same slit function and wavelength center as reference instrument #083.
* Brewer network every instrument have a measured slit and central wavelengths calculated during calibration.

Dobson #083 Slit measurement

Dobson Manual :

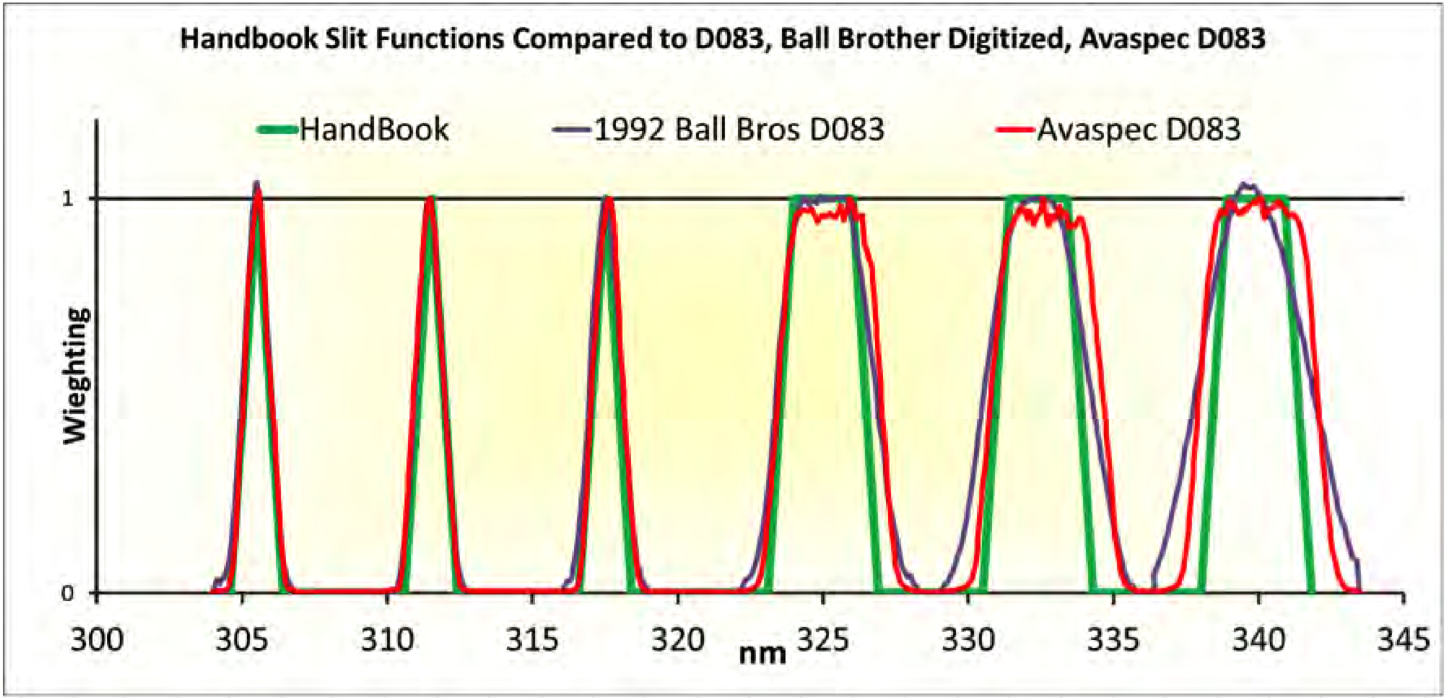




Dobson #083 Slit measurement

Dobson Slit Measurements :

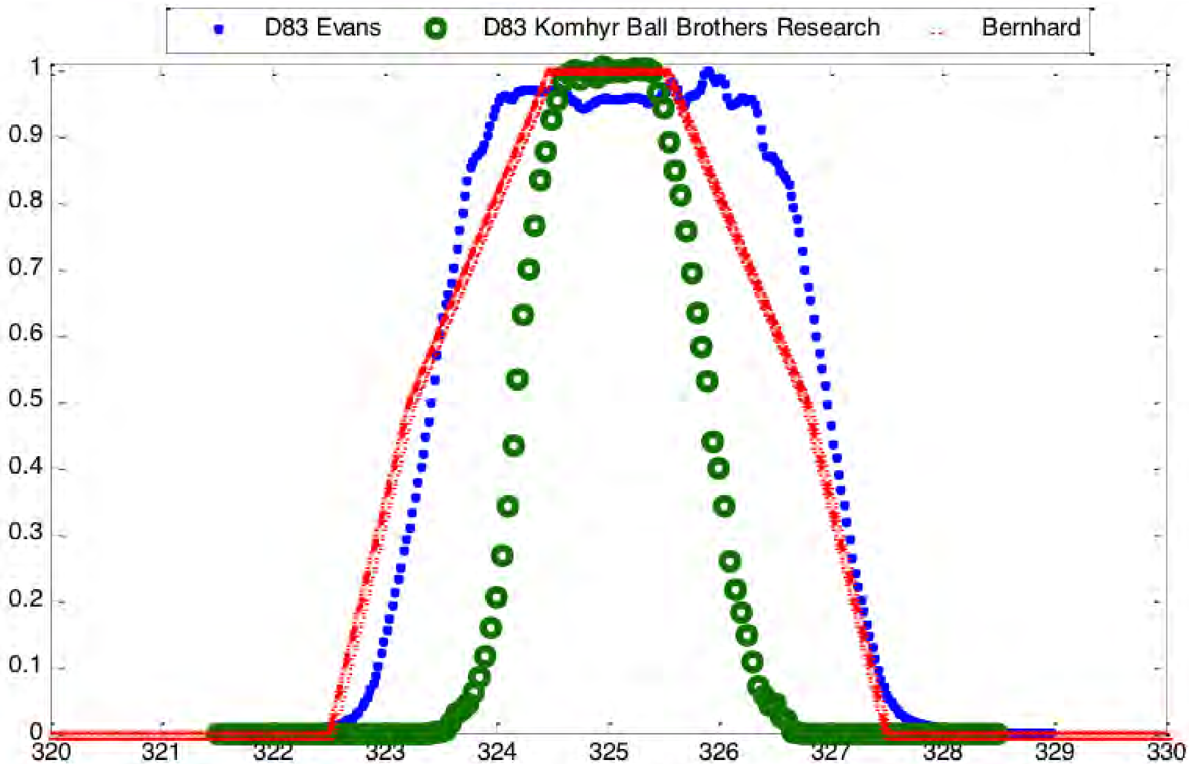
- Bell Brothers Digitalised 1992, (Komhyr 1898) Dobson #083
- Evans et all 2012 (Avaspec) Dobson #083



QOS 2012 Determination of Dobson Instrument Spectral Characteristics a new method

Dobson #083 Slit measurement

- Bernhard 2005 , use a new parametrisation.



ATMOZ Slit measurement

ATMOZ 2014-2015, tunneable lasser measuremetns at PTB

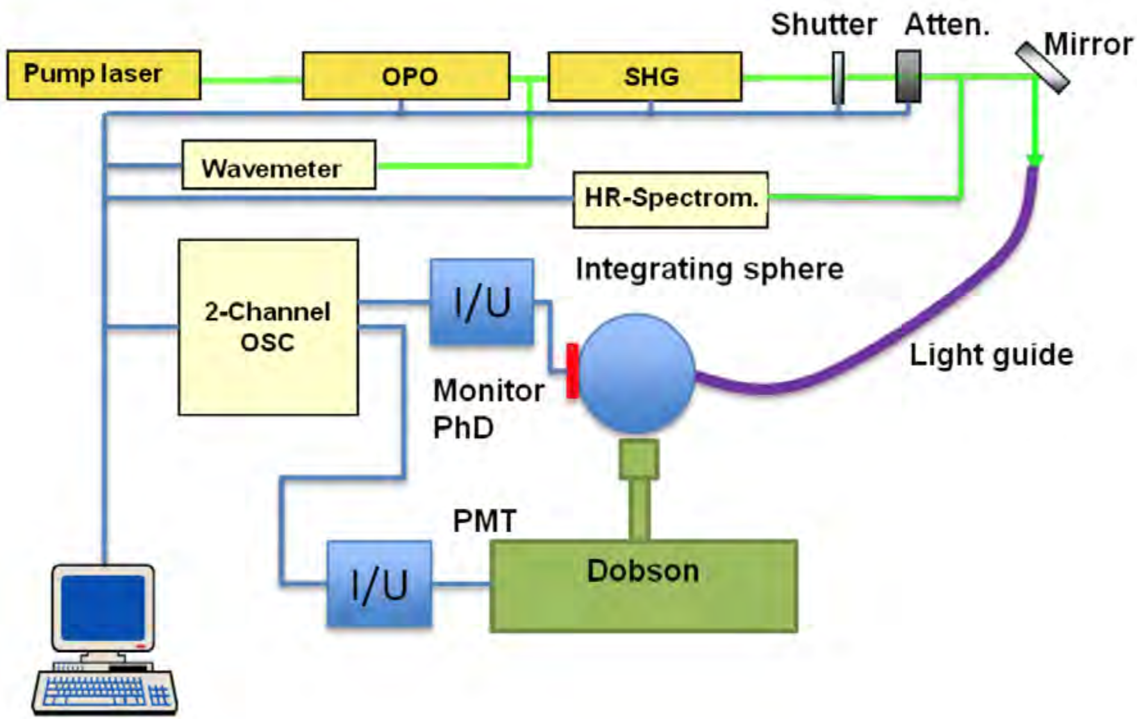
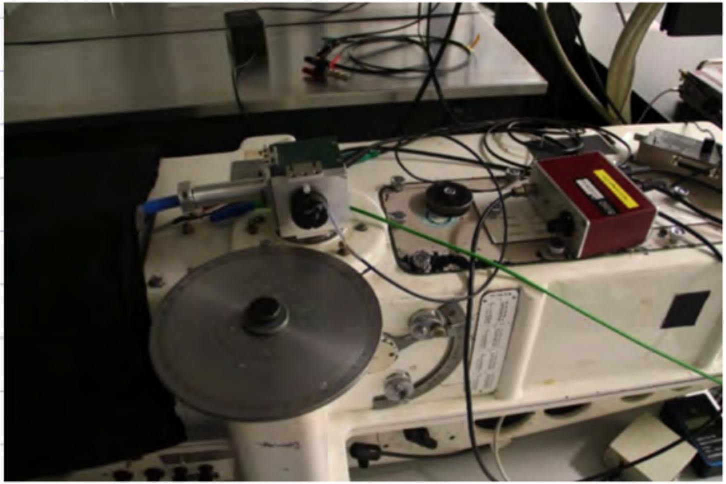
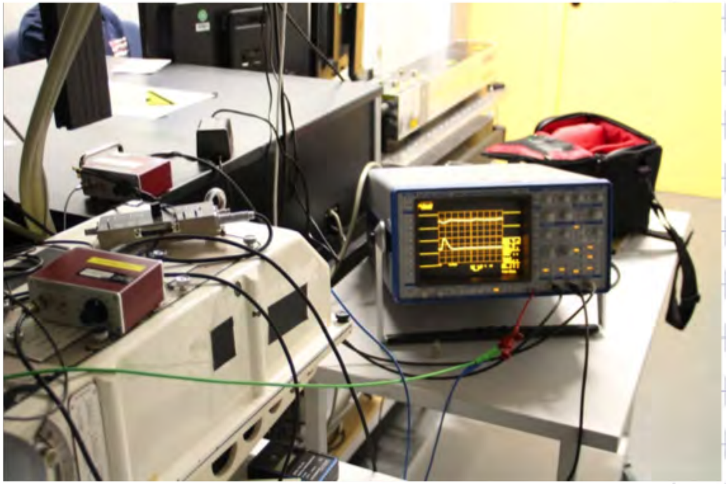


Figure 1. Bandpass function measurements at the PLACOS setup

ATMOZ Slit measurement

ATMOZ 2014-2015, tunneable lasser measuremetns at PTB





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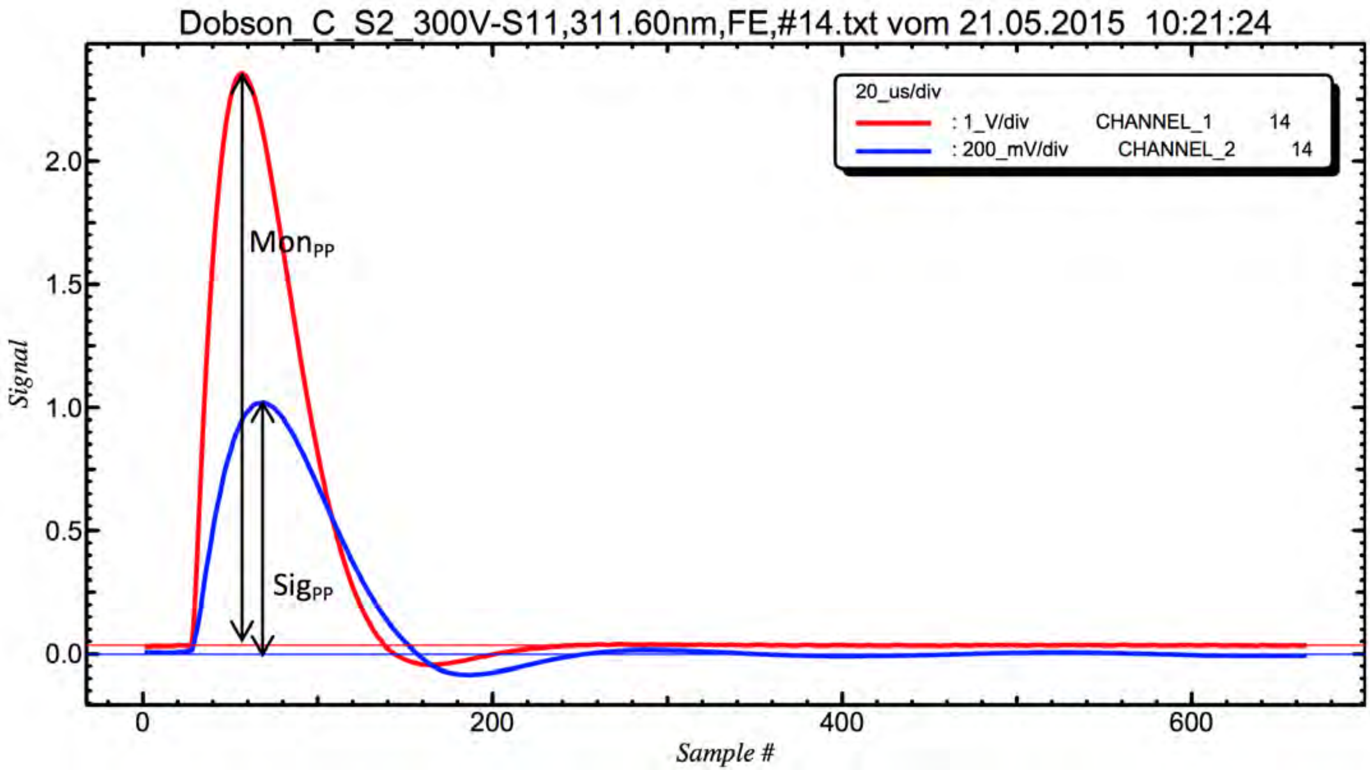

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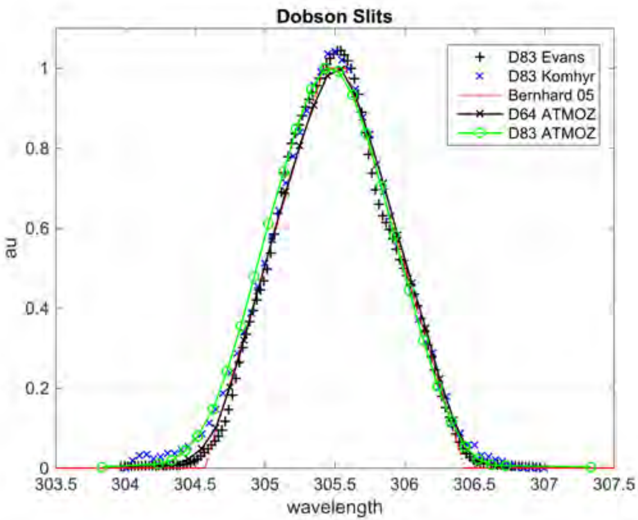

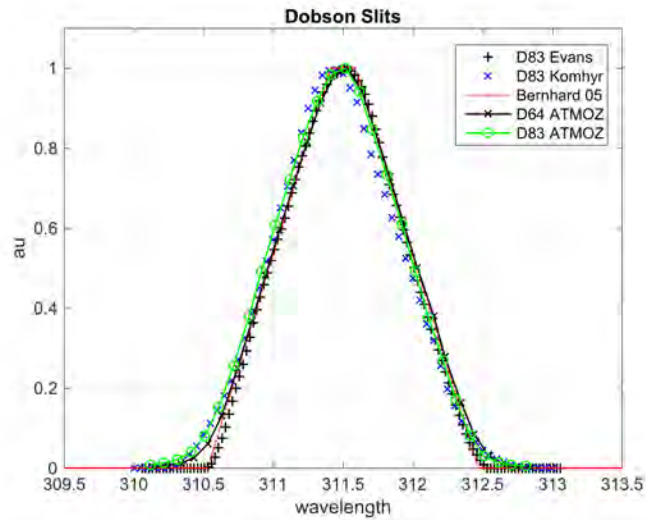

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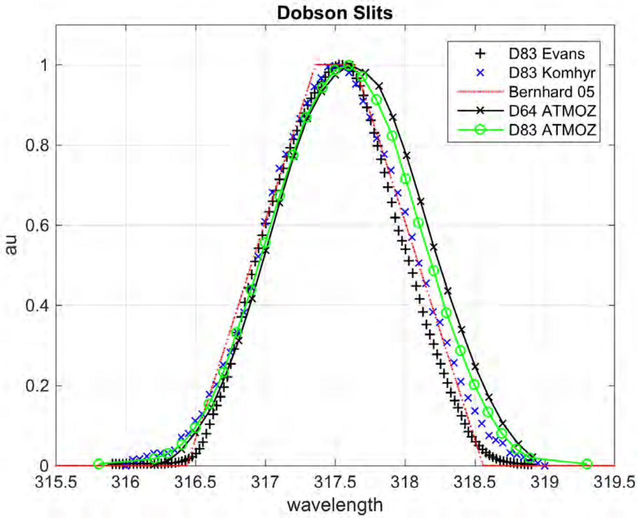

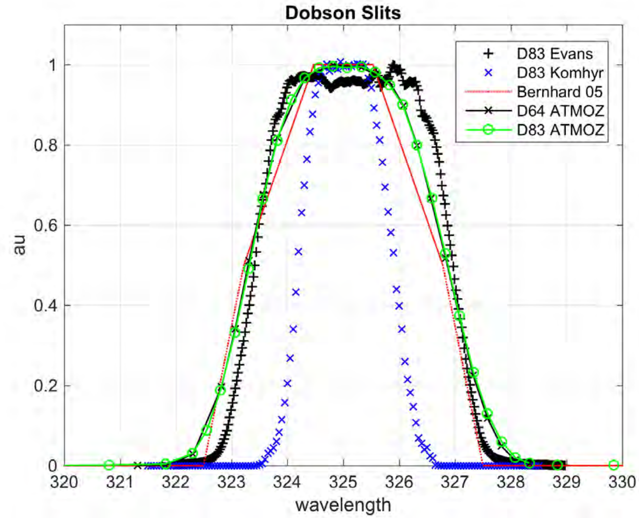

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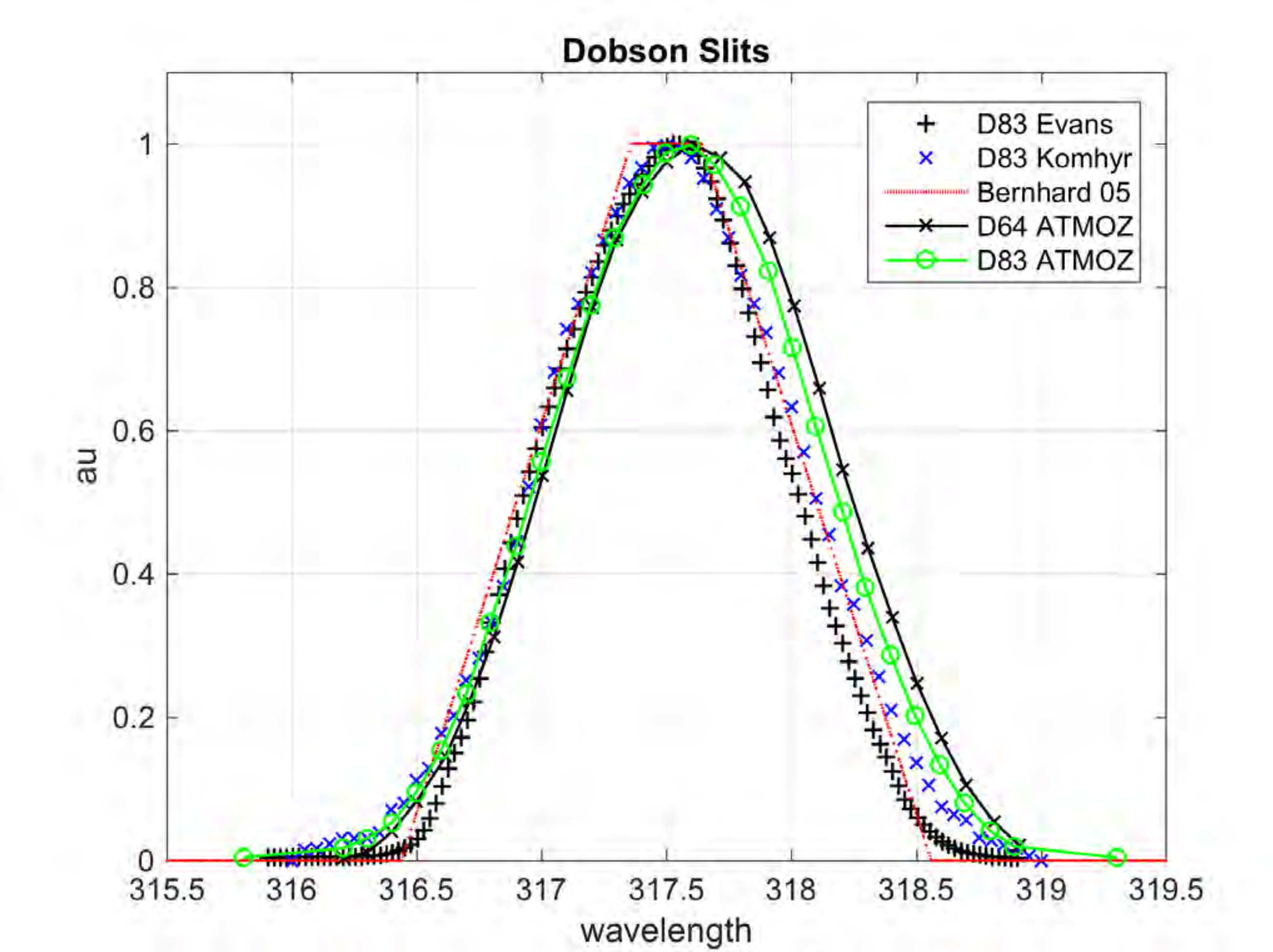

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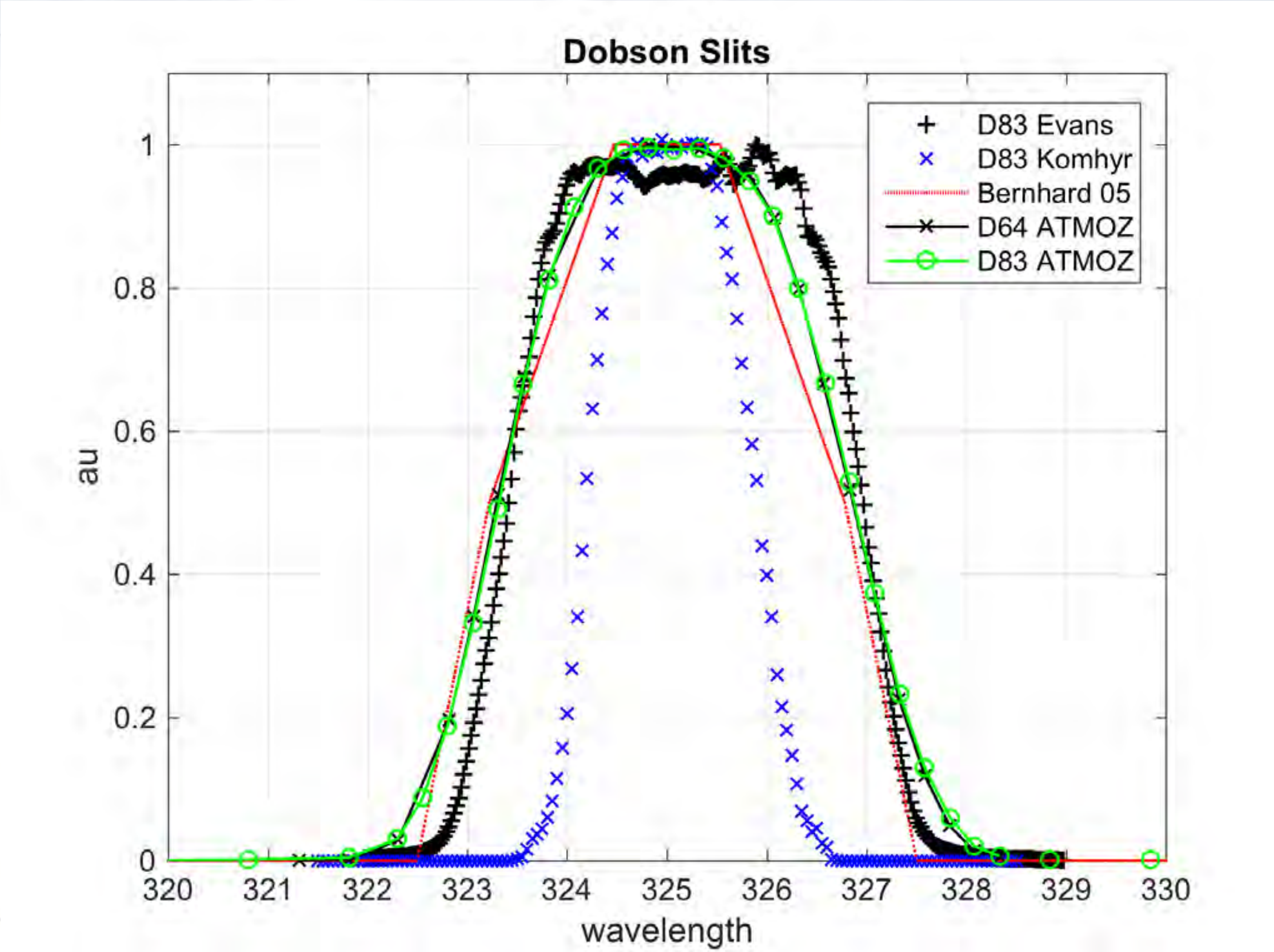

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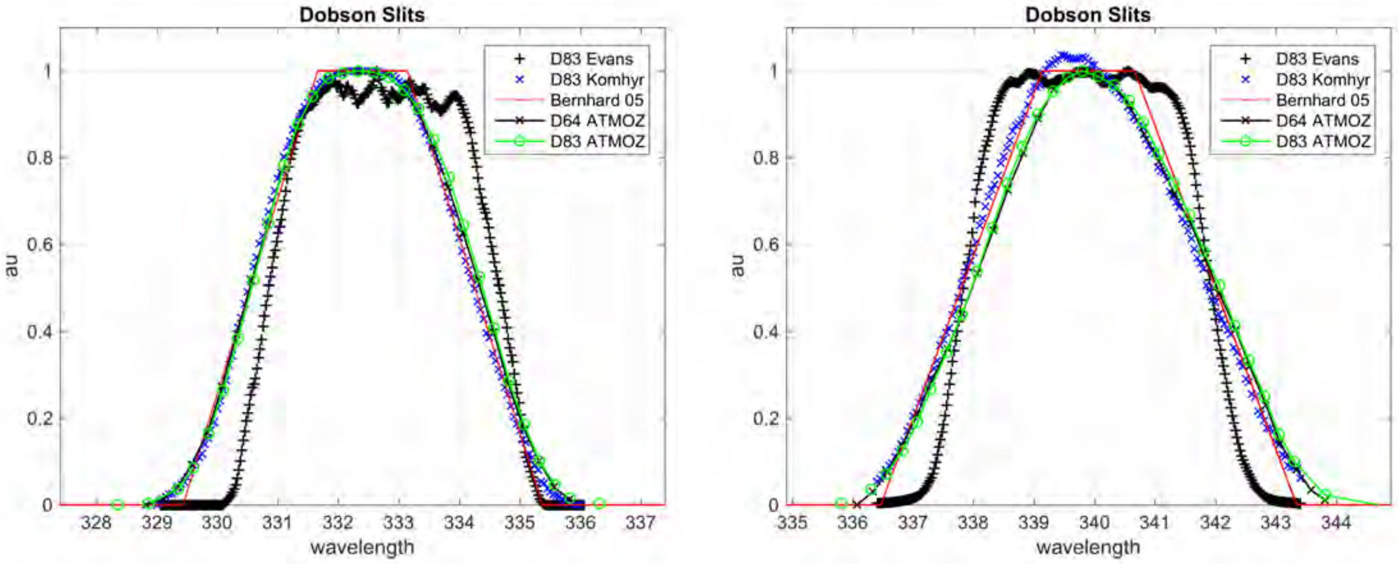

Slits & Cross Sections used

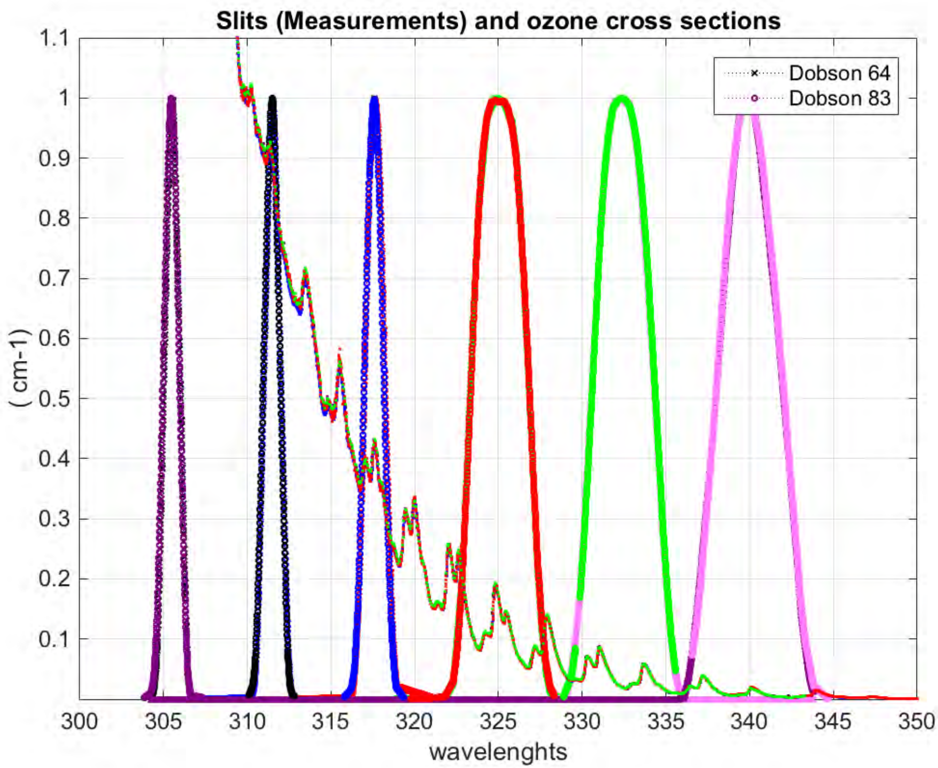

Figure 1: Studied XS at 228K and slit functions of Dobson

Ozone Cross Sections Analyzed

Three Bass &Paur cross sections:

- **Brewer Operative (BOp)** : Is the B&P at 228K without any adjustment. `'Not available at IGACO but at -Mainz Spectral Database-.`
- **IGACO B&P IGQ4** Individual temperatures: Six individual temperatures. `This files do not agree with B&P paper and do not include -45 C set.` This dataset appears to be spectra at selected temperatures calculated from the polynomial fitted to the original data excluding 218K (Weber 2011),
- **Quadratic coefficients on the file "Bp.par"** Used In this work to be consistent with the Komhyr determination of Bass & Paur on Dobson.

Ozone Cross Sections Analyzed

- **Berhard 2005 (B05)**, B&P corrected by temperature dependence and extended with Molina & Molina cross section. Includes **dynamical** effects convolving the XS with temperature profile and ozone profile and top of the atmosphere solar spectrum.
- **Daumont, Brion & Malicet (DBM)**, Measured at 5 temperatures, including 228K also we use the quadratic fit for the temperature dependence studies. We also use the Liu 2007 quadratic fit excluded the 273°K set .
- **HARMONICS :Serdyuchenco et all (IUP)**, The newly determined data set from Bremen University, Institute for e Enviromental Physics (IUP) are also available at IGACO with ten temperatures files and the quadratic fit **(IUPQ)**.

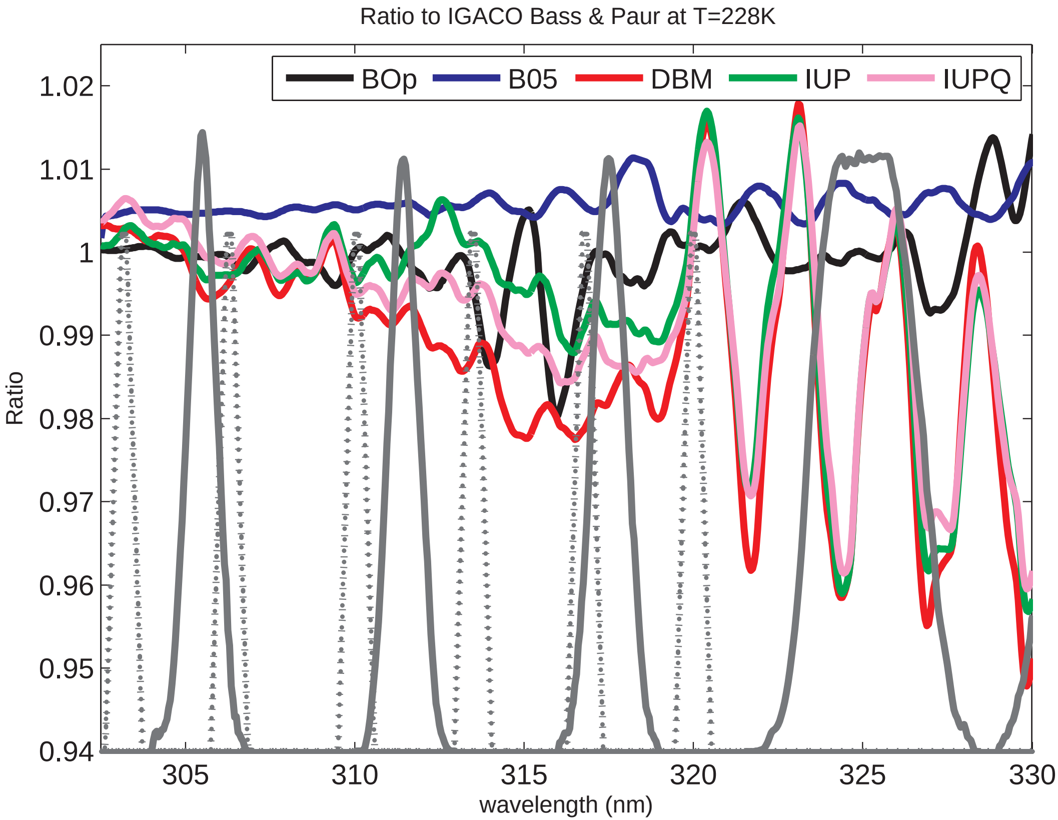

Figure 2: Ratio of the cross-sections of this study to the IGACO Bass & Paur (IGQ4) , the cross section are interpolated to a common resolution (0.1 nm) and smoothed to the Brewer resolution

Central Wavelengths Dobson 064

	Komhyr	Bernhard	Atmoz 64	Komhyr	Bernhard	Atmoz 64
A1	305.51	305.50	305.51	0.99	1.01	1.04
B1	NaN	308.90	NaN	NaN	1.02	NaN
C1	311.50	311.50	311.50	1.04	1.06	1.09
D1	317.50	317.50	**317.64**	1.13	1.20	1.34
A2	325.18	325.00	325.08	3.48	3.30	3.54
B2	NaN	329.10	NaN	NaN	3.50	NaN
C2	332.75	332.40	332.44	3.64	3.71	3.80
D2	339.89	339.90	339.97	4.06	4.20	4.06

Ratio to operative values

D64	Brewer b&p	IGACO BP	D&M	IUP	B&P B	Komhyr apr	Komhyr	Komhyr adj	Bard app	Bernhard
A pair	0.9909	0.9904	0.9888	0.9897	0.9967	0.9978	1.0000	1.0000	0.9967	0.9994
C pair	NaN	0.9862	0.9796	0.9874	0.9934	0.9976	1.0000	1.0000	0.9940	0.9988
D pair	NaN	0.9627	0.9464	0.9540	0.9722	0.9866	0.9813	1.0000	0.9973	1.0080
AD pair	NaN	0.9977	0.9999	0.9990	1.0031	1.0007	1.0049	1.0000	0.9965	0.9972
CD pair	NaN	1.0054	1.0067	1.0146	1.0106	1.0065	1.0153	1.0000	0.9913	0.9913
D83	**Brewer b&p**	**IGACO BP**	**D&M**	**IUP**	**B&P B**	**Komhyr apr**	**Komhyr**	**Komhyr adj**	**Bernhard a**	**Bernhard**
A pair	0.9973	0.9906	0.9889	0.9898	0.9969	0.9978	1.0000	1.0000	0.9967	0.9994
C pair	NaN	0.9911	0.9845	0.9922	0.9983	0.9976	1.0000	1.0000	0.9940	0.9988
D pair	NaN	0.9730	0.9562	0.9642	0.9825	0.9866	0.9813	1.0000	0.9973	1.0080
AD pair	NaN	0.9952	0.9975	0.9965	1.0006	1.0007	1.0049	1.0000	0.9965	0.9972
CD pair	NaN	1.0059	1.0076	1.0150	1.0112	1.0065	1.0153	1.0000	0.9913	0.9913

Ratio to operative values

	Brewer b&p	Brw b&p *	IGACO BP	IGACO BP *	D&M	D&M *	**IUP**	**IUP***	B&P B	B&P B*
A pair	0.991	0.997	0.990	0.991	0.989	0.989	**0.990**	**0.990**	0.997	0.997
C pair			0.986	0.991	0.980	0.985	**0.987**	**0.992**	0.993	0.998
D pair			0.963	0.973	0.946	0.956	**0.954**	**0.964**	0.972	0.983
AD pair			0.998	0.995	1.000	0.997	**0.999**	**0.997**	1.003	1.001
CD pair			1.005	1.006	1.007	1.008	**1.015**	**1.015**	1.011	1.011

(Asterisk values are for Dobson 83)

Conclusions

- The ATMOZ measurements replicates the Komhyr one (but 325 nm) with small differences, 0.1nm in the worst case.
- The cross section ratio to the operational value is directly the change on the calculated ozone. There are minimal changes in AD pair (the most used) 0.3 % in the worst case and something slightly larger on CD 1% pair, this values slightly change depending of the cross section used.