Comparison of new characterized bandpass and wavelengths of Dobsons

Alberto Redondas, [1]

[1] Izaña Atmospheric Research Center, AEMET, Tenerife, Canary Islands, Spain.

October 27, 2015

Outline

EURAMET

EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Traceability for atmospheric total column ozone

ATMOZ

A Joint Research Project within the European Metrology Research Programme (EMRP)

Julian Gröbner & JRP consortium

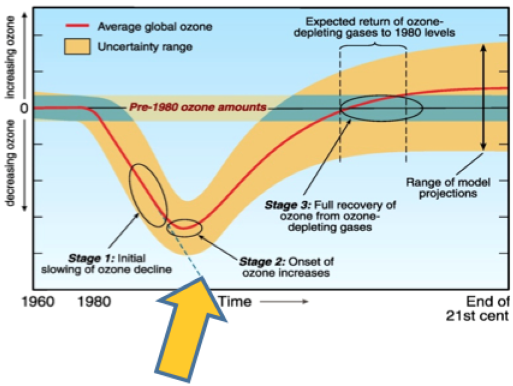
Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center

EMRP-ENV59 "ATMOZ"

A traceable and harmonized Global Total Column Ozone Network

- Provide traceability of total column ozone to 1%,
- Radiometric characterisation of Dobson and Brewer spectrophotometers,
- Development of array-based solar UV spectroradiometers,
- Improved and consistent ozone absorption x-sections,
- Comprehensive uncertainty budget incorporating instrumental and atmospheric uncertainties

Recovery Stages of Global Ozone



Present

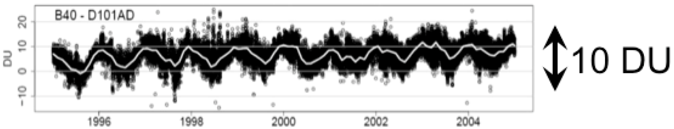
- **Project Coordination:** PMOD/WRC, *Julian Gröbner*
- **Duration:** 10/2014 – 9/2017
- **Total Budget:** 2.5 M€
- **9 Partners** NMI-DI, Industry, Universities

Stakeholders and Collaborators

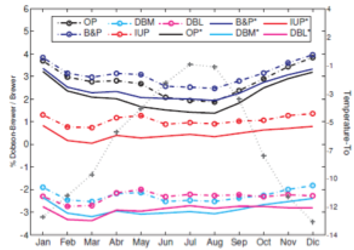
What are the main challenges?

A comprehensive uncertainty assessment of total column ozone measurements from Dobson and Brewer spectrophotometers has not been made so far.

1) Seasonal total ozone differences between Brewer and Dobson in Arosa, Switzerland.



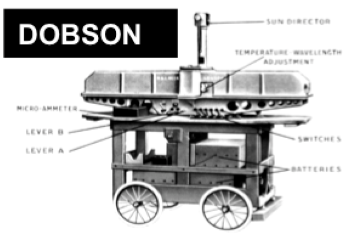
Scarnato et al., 2009



Redondas et al., 2014

2) Dobson spectroscopy (slit functions and wavelength dispersion) are only known for Dobson #083

3) Eventual phase-out of Dobson (Brewer) requires introduction of new total ozone measuring instruments



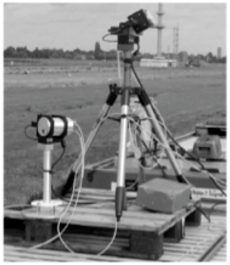
Pure and Applied Geophysics (PAGEOPH)
Vol. 106–108 (1973/V–VII)

Birkhäuser Verlag, Basel

A Replacement for the Dobson Spectrophotometer?

By A. W. Brewer[1])

Brewer, 1973



Tzortziou et al.

How to address these issues?

1) **Radiometric characterisation of current reference ozone spectroradiometers**
   - Dobson 083 – World standard (NOAA)
   - Dobson 064 / 074 – Regional Standards RA VI (DWD, CHMI)
   - Brewer #18x – RBCC-E reference Triad instrument (AEMET)

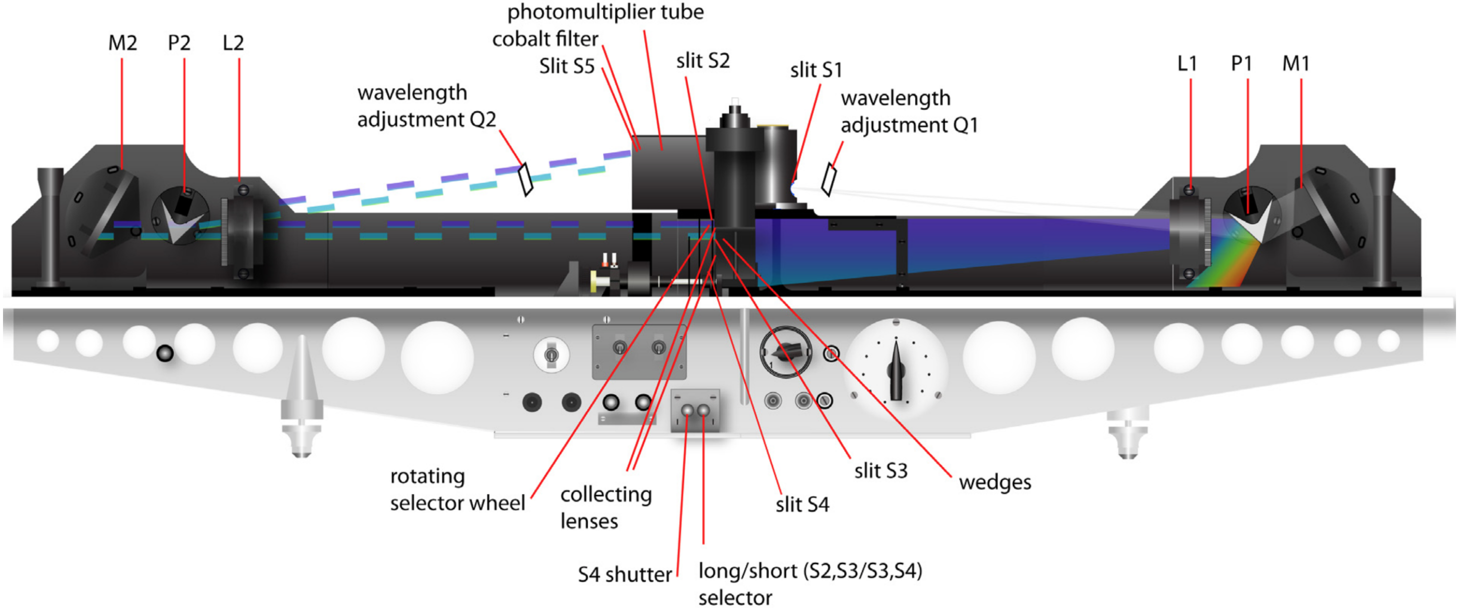
2) **Development and characterisation of array spectroradiometers**
   - Development of a UV optimised spectroradiometer (UV-PSR) PMOD
   - Characterisation and operation of a Pandora system (ULL)
   - Characterisation and operation of a Phaeton system (LAP)

3) **Comprehensive uncertainty budget for total column ozone**
   - Measurement and uncertainty evaluation of ozone x-sections (Univ. Bremen)
   - Uncertainty budgets for Brewer/Dobson & DOAS algorithms (All)

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

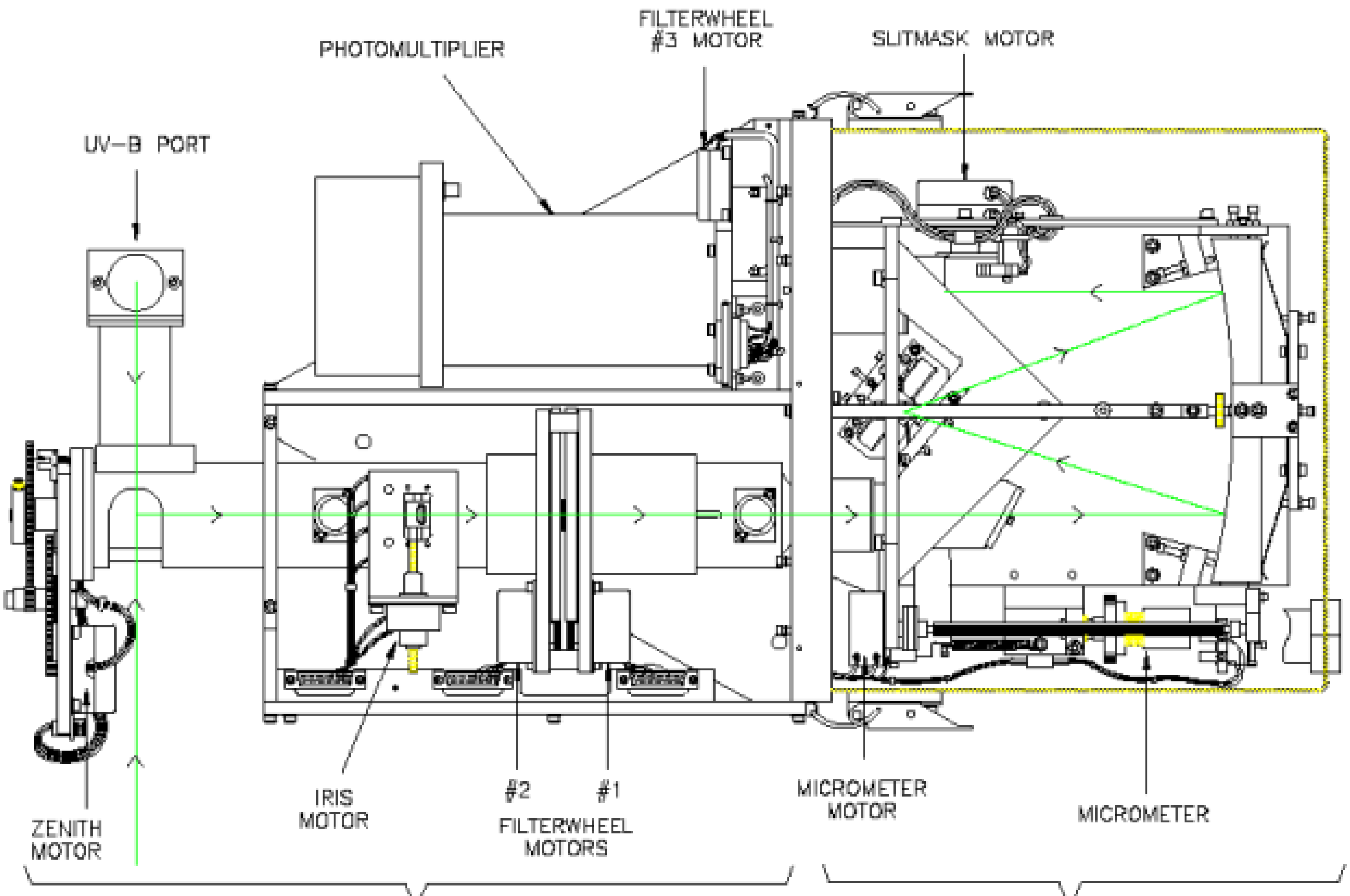
Introduction



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.

Brewer Optics



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

Introduction

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

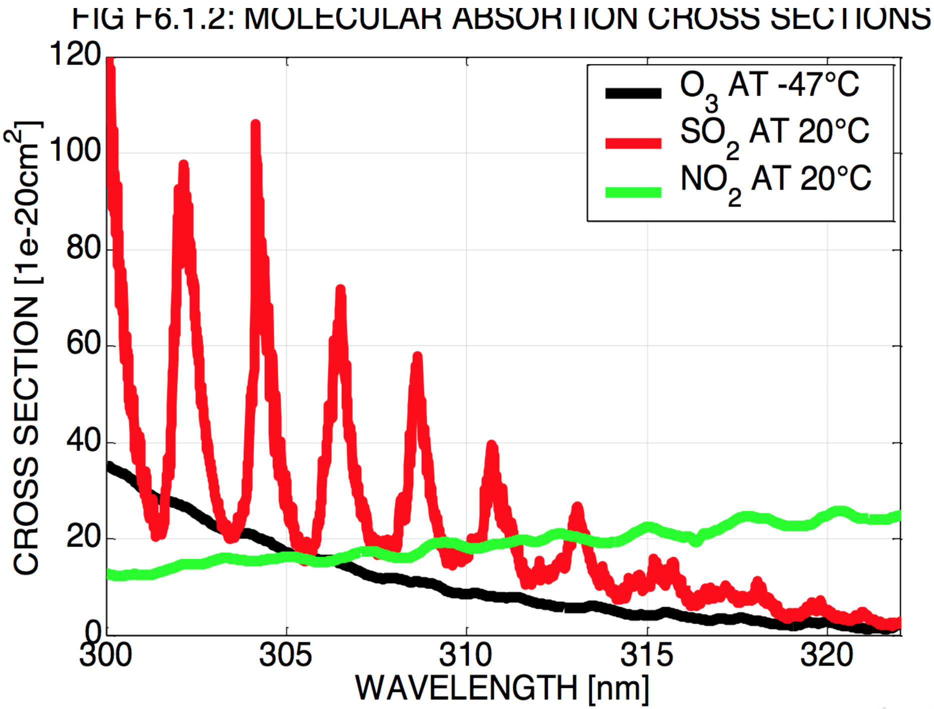
Brewer slits	W	SD	FW	SD	w_i	Dobson slits	W	FW	w_i
0	303.001				0	A1	305.5	0.9	1
2	306.301	0.014	0.548	0.016	0	C1	311.5	0.9	0
3	310.051	0.014	0.539	0.015	1	D1	317.5	0.9	1
4	313.501	0.015	0.555	0.012	−0.5	A2	325.0	2.9	−1
5	316.801	0.017	0.545	0.012	−2.2	C2	332.4	2.9	0
6	320.002	0.019	0.538	0.012	1.7	D2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

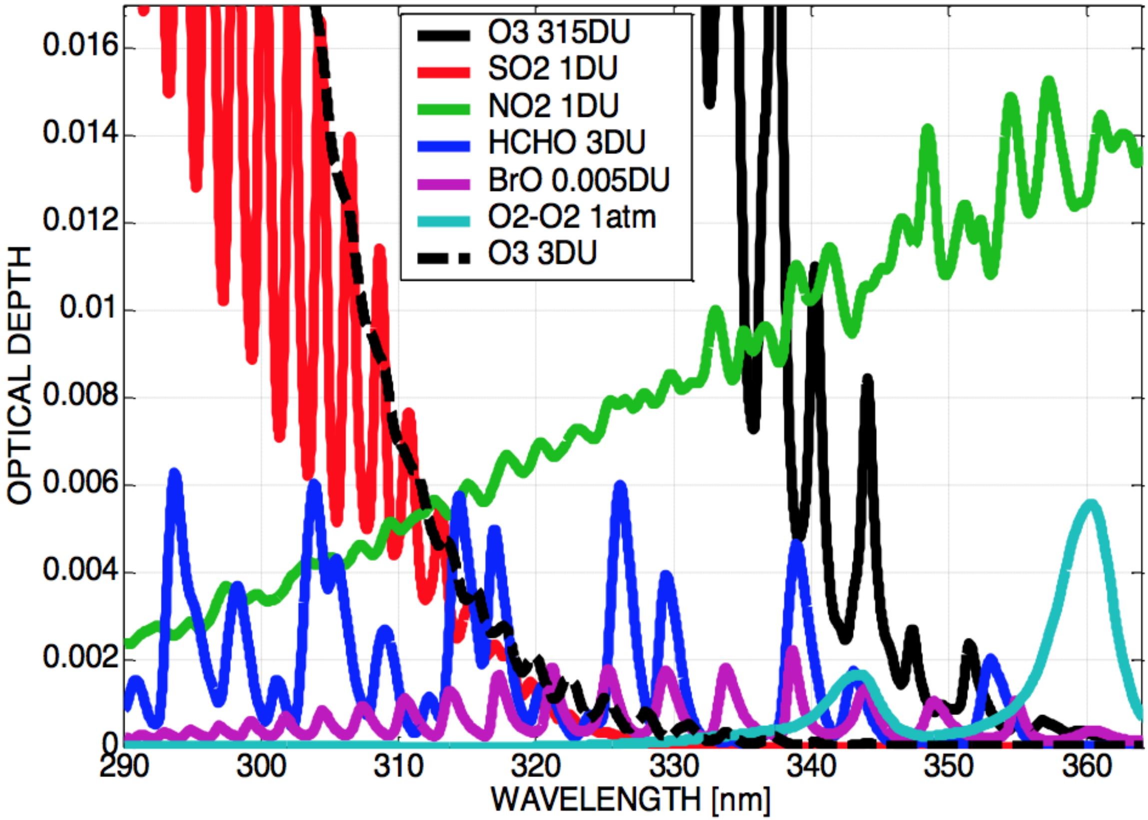
Algorithm asumptions

- 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 $(SO_2, NO_2, HCLO)$

Aditional Absorbvers

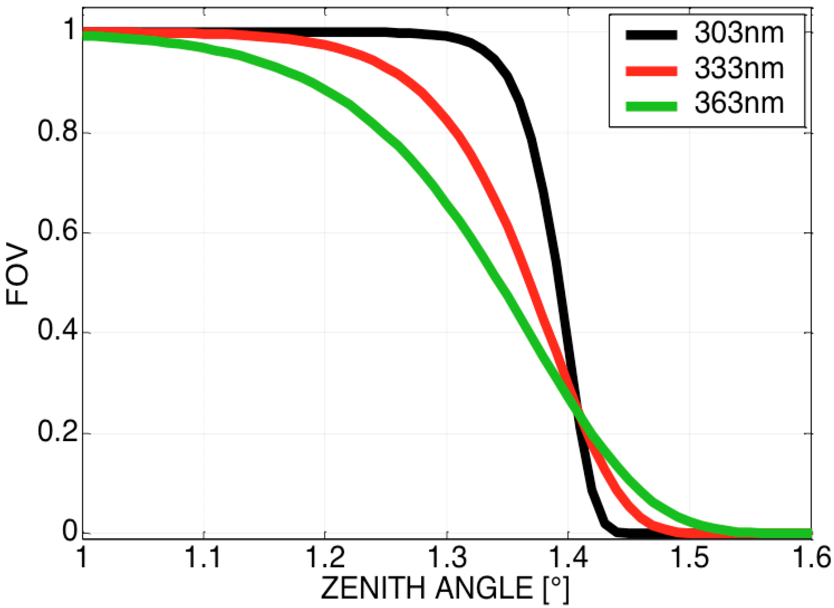
- XS are comparable but not the optical depth : $O_3 \approx 100 - 600DU$, $SO_2 \approx 0 - 20DU$, $NO_2 \approx 0 - 3DU$.
- Brewer algorithm account for SO_2 but not Dobson.




O3 315DU
SO2 1DU
NO2 1DU
HCHO 3DU
BrO 0.005DU
O2-O2 1atm
O3 3DU
OPTICAL DEPTH
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
290
300
310
320
330
340
350
360
WAVELENGTH [nm]

Atmospheric Scattered light

Atmospheric scattered light (ASL):
The Brewer's field of view (FOV) is about 2.7° full angle. Therefore a fraction of the diffuse radiance (circumsolar) is measured together with the direct irradiance. This signal-increase increases with the amount of scattering, i.e. mainly with SZA and aerosols. The net effect is an underestimation of the true ozone (see Bernhard et al. [2005] Arola et al [2004]).



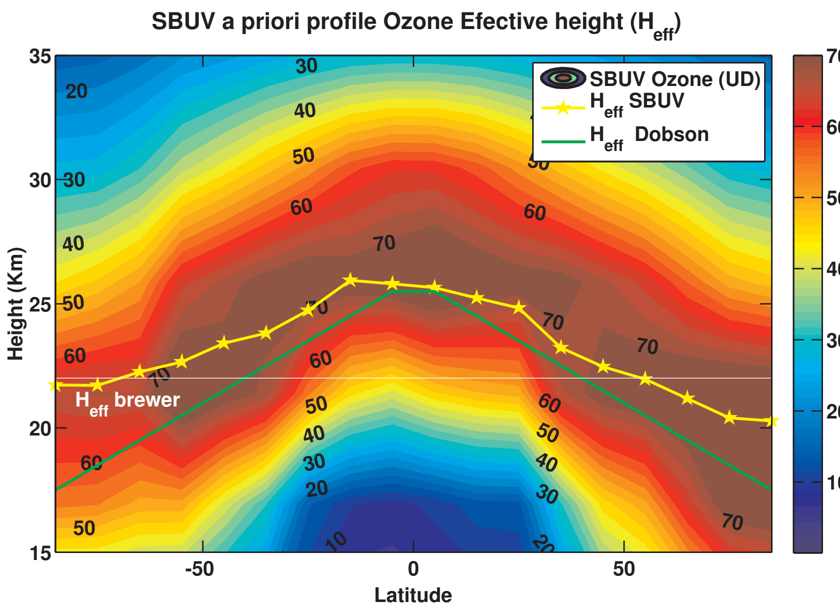
Ozone effective heigth

- We can define the effective height

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

.

- Dobson mostly account for the observer variation but not Brewer.



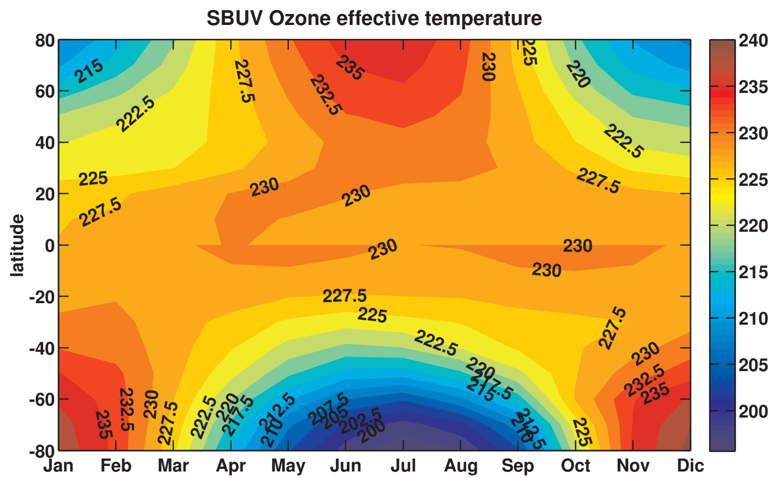
Ozone cross section asumptions

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

- Effective Temeperature

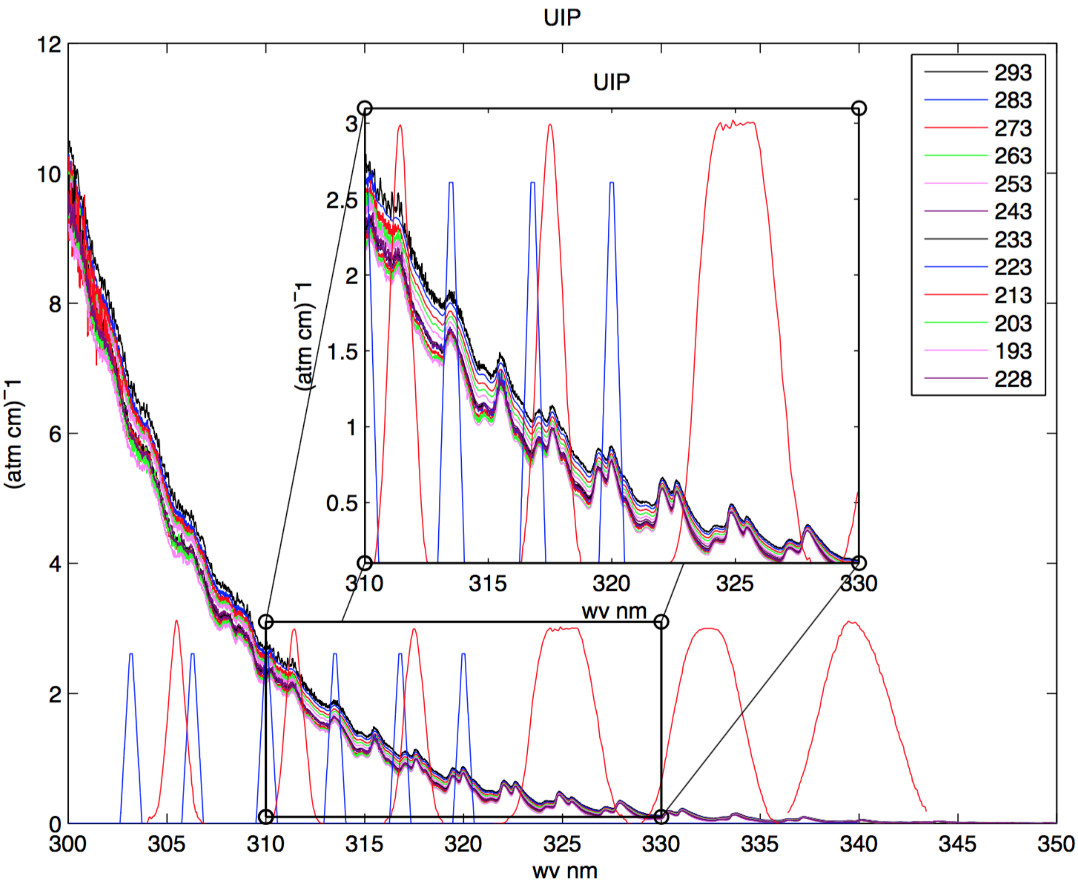
$$Teff_{O_3} = \frac{\int_{Det}^{ToA} n_{O3}(h)T(h) \cdot dh}{\int_{Det}^{ToA} n_{O3}(h) \cdot dh}$$

.



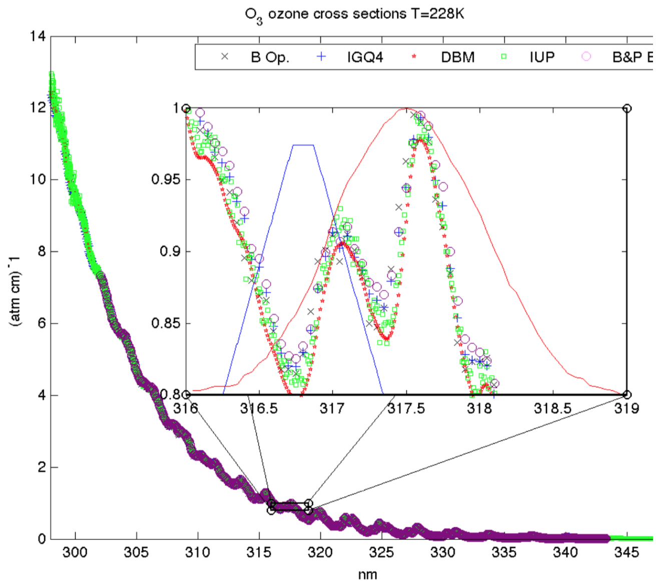
Ozone cross section asumptions

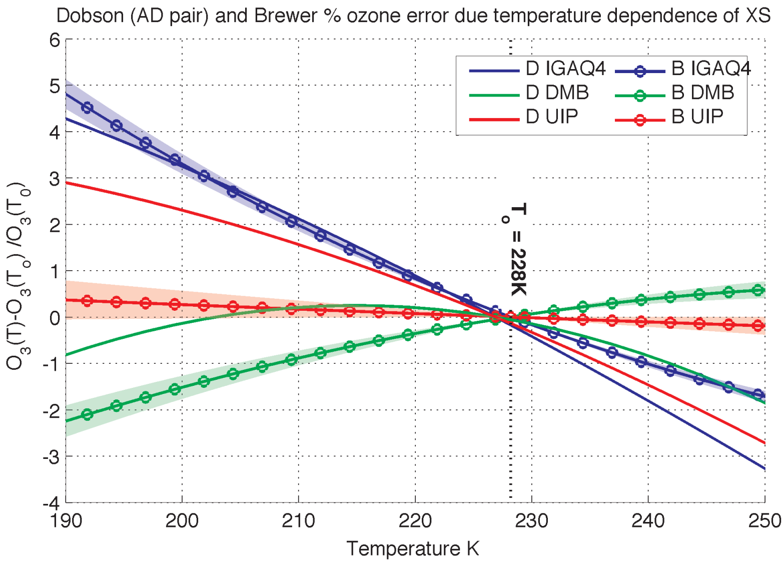
The temperature dependence of the ozone cross section is not considered.



Ozone cross section asumptions

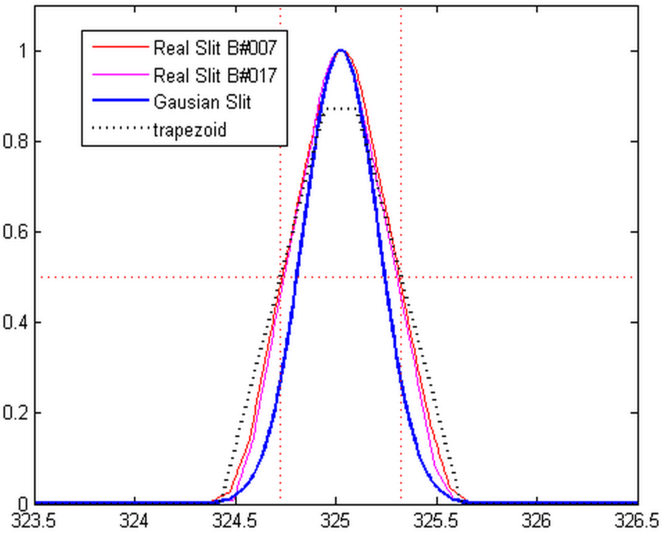
Different cross sections gives signifiant different scales and shows different temperature dependences

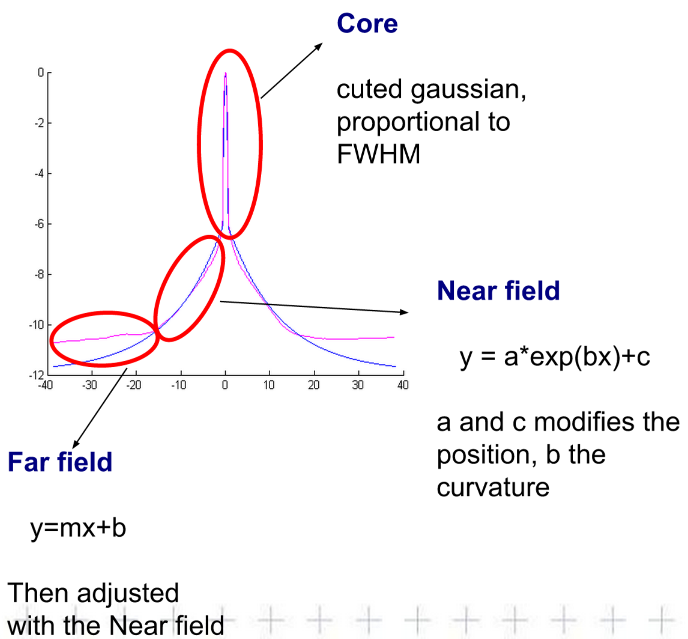




Instrument Slit

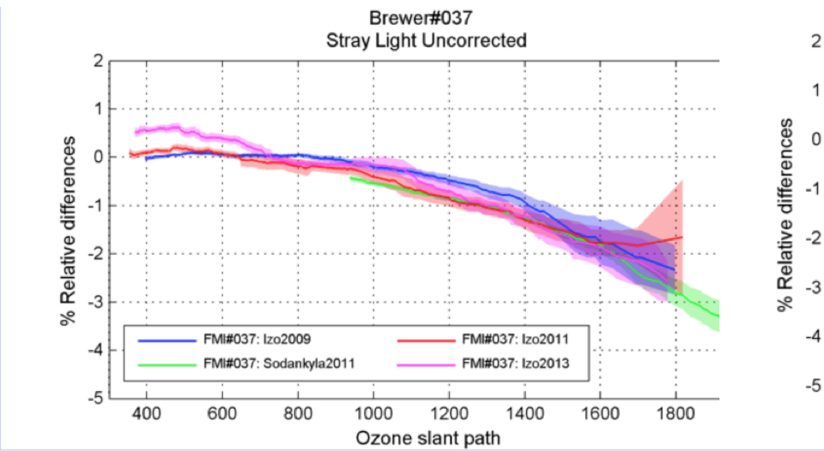
Slits are parametrized on the Brewer, trapezoidal with central wavelength and FWHM set for every instrument and every slit. For Dobson only reference instrument were available.

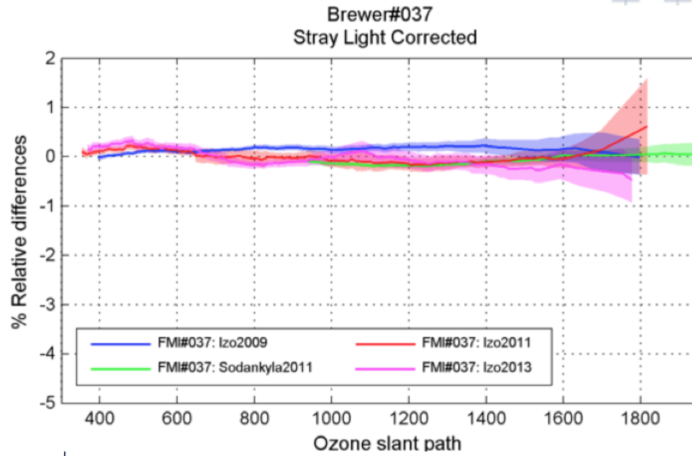




Stray Light

Due to not perfect slit function the measurements at one wavelength “leak” into those at other wavelengths. Since the stray light level of double Brewers is below 10-7 the ISL is negligible. For single Brewers (3x10-5) this is important.
An empirical correction were developed and can be transferred from calibrations and a model who use out of band measurements are also available.

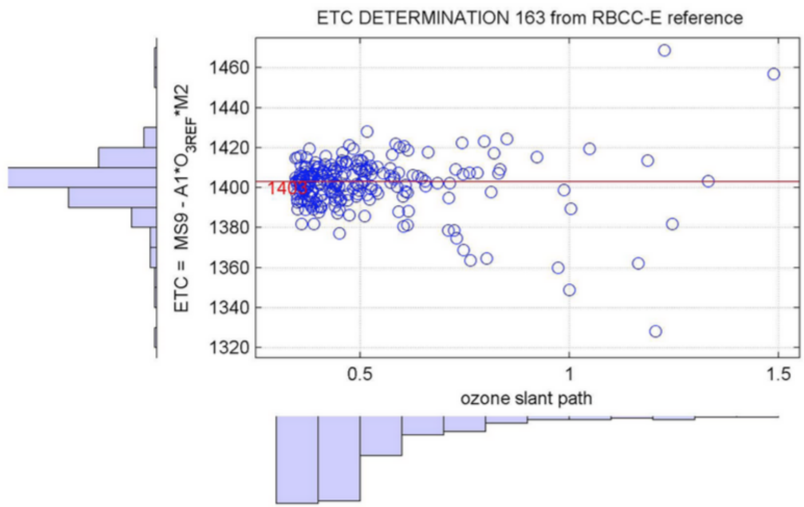




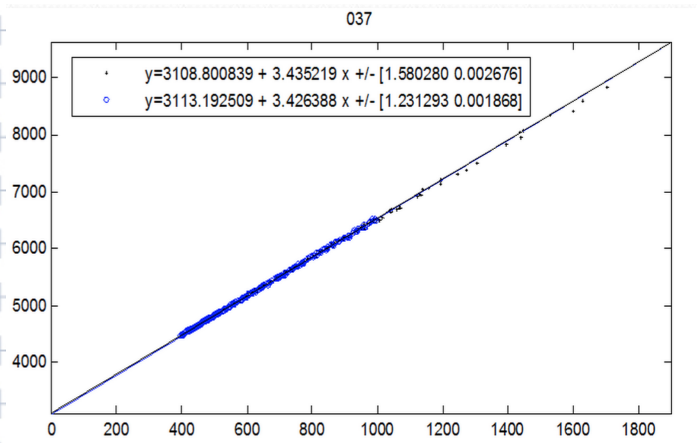
Calibration transfer

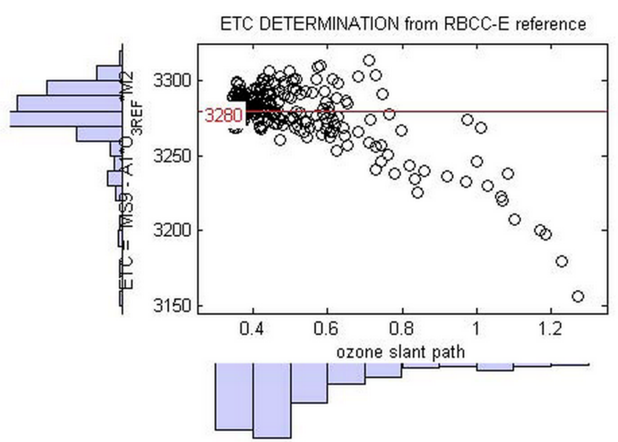
Two methods of calibration has ben used : Two parameters calibration until year 2000 and one Parameter calibration after that.
Analysis of the errors due calibration transfer are not done yet.

ETC= Median (MS9(inst)- OSC(ref) * O3abs(inst)*10)



Two methods of calibration has ben used on Brewer : Two parameters calibration until year 2000 and one Parameter calibration after that.





Direct Model (Brewer Dobson)

$$F_{DIR} = F_0 \cdot \exp\left[-\mu \cdot \tau\right] \tag{10}$$

F_{DIR} : Direct sun irradiance (at wavelength λ).
F_0 : Extraterrestrial irradiance corrected for Sun-Earth distance.
τ : Total vertical extinction optical depth.
μ : Air mass factors

$$\mu \cdot \tau = \mu_{O_3} \cdot \tau_{O_3} + \mu_{SCA} \cdot \tau_{SCA} + \mu_{AER} \cdot \tau_{AER} + \mu_{SO_2} \cdot \tau_{SO_2} + \mu_{REST} \cdot \tau_{REST}$$

O_3, SO_2, SCA : O_3 and SO_2 absorption, Molecular scattering
AER, REST : Aerosol extinction and everything else. . . (NO2, HCHO, . . .)

$$\ln I_{DIR} = \ln I_0 - \mu_{O3} \cdot \tau*_{O3} \cdot \Omega_{O3} - \mu_{SCA} \cdot \tau_{SCA} - \ldots$$
$$\mu_{AER} \cdot \tau_{AER} - \mu_{SO2} \cdot \tau*_{SO2} \cdot \Omega_{SO2} - \mu_{REST} \cdot \tau*_{REST} \cdot \Omega_{REST}$$

$\tau_x = \Omega_x \cdot \tau_x^*$
Ω_x : Total Column for gas x
$\tau*_x$: Optical Depth for 1DU.

Direct Model Brewer Dobson

$$\Omega_{O_3} = \frac{\ln I_{DIR} - \ln I_0 - \mu_{SCA} \cdot \frac{p}{p_o} \cdot \tau_{SCA} - \mu_{aer} \cdot \tau_{aer} - \mu_{SO_2} \cdot \tau^*_{SO_2} \cdot \Omega_{SO_2} - \mu_x \cdot \tau^*_x \cdot \Omega_x}{\mu_{O_3} \cdot \tau * _{O_3}}$$

p : Station pressure $\quad$ p_o : Standard pressure

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

R : Earth Radius

h_x : Effective height abs x.

θ : Solar zenith angle

Direct Model Brewer Dobson

$$\Omega_{O3} = \frac{P6 - P7 - P2 \cdot P9 - P3 \cdot P10 - P4 \cdot P11 - P5 \cdot P12}{P1 \cdot P8}$$

Parameter	Source	
P1-P2	μ_x	$h_{O_3} = 22km, h_{SCA} = 5km,$
P3-P5	μ_x	$h_{AER} = 2km, h_{SO_2} = 2km, h_{REST} = 2km$
P6	lnF_o	Assume obtained by Langley extrapolations at high mountain
P7	lnF_{DIR}	Measured corrected count rates (ISL, ASL!)
P8	$\tau^*_{O_3}$	Use Bass Paur [1985] cross sections, $(Teff_{O_3} = -45^\circ C)$
P9	τ^*_{SCA}	Use Bodhaine et al. [1999], standard pressure
P10	τ^*_{aer}	Assume Angstrom behavior
P11	$\tau^*_{SO_2}$	Use Vandaele et al. [1994] cross sections and $\Omega_{SO_2} = 1DU$
P12	τ^*_{REST}	$\Omega_{NO_2} = 0.7DUand\Omega_{HCLO} = 1DU$ and ... (=urban polluted)

Direct Model (Independent Variables)

I	Var		Remark
V1	θ	0.12° (0.01°)	Assume 30s registration time uncertainty (
V2	RAD	4%	Radiometric calibration (all slits)
V3	RADIND	0%	Radiometric calibration for each slit, I-inde
V4	F noise	Figure	Photon count noise, I-independent
V5	$\Delta\lambda$	0.01nm (0.004nm)	Wavelength shift, (directly after Hg-test)
V6	$Teff_{O_3}$	20° (5°, 1°)	Effective Temp. O_3 temperature (5° climat
V7	P/P0	1% (0.1%)	Surface pressure (if measured)
V8	τ_{340}	0.75 (0.04)	AOD at 340nm (if measured)
V9	α_{340}	0.7 (0.1)	Angstrom parameter at 340nm (if measure
V10	Ω_{SO_2}	100%	Total SO2 column
V11	Ω_{REST}	100%	Total column of other gases (mainly NO2)
V12	h_{O3}	5km (2km, 0.5km)	Eff O3 height (2km climatology, 0.5km son
V13	h_{SCA}	0.2km	Effective scattering height
V14	h_{AER}	4km	Effective aerosol height
V15	h_{SO_2}	10km	Effective SO2 height
V16	h_{REST}	10km	Effective height of other gases

$$\Omega_{O_3} = \frac{\ln I_{DIR} - \ln I_0 - \mu_{SCA} \cdot \frac{p}{p_o} \cdot \tau_{SCA} - \mu_{aer} \cdot \tau_{aer} - \mu_{SO_2} \cdot \tau^*_{SO_2} \cdot \Omega_{SO_2} - \mu_x \cdot \tau^*_x \cdot \Omega_x}{\mu_{O_3} \cdot \tau * _{O_3}}$$

$$\Omega_{O3} = \frac{P6 - P7 - P2 \cdot P9 - P3 \cdot P10 - P4 \cdot P11 - P5 \cdot P12}{P1 \cdot P8}$$

$$\sigma^2_{\Omega O3} = \sum_i \left(\frac{\partial \Omega_{O3}}{\partial Vi} \right)^2 \cdot \sigma^2_{Vi}$$

$$\frac{\partial \Omega_{O3}}{\partial Vi} = \sum_j \frac{\partial \Omega_{O3}}{\partial Pj} \cdot \frac{\partial Pj}{\partial Vi}$$

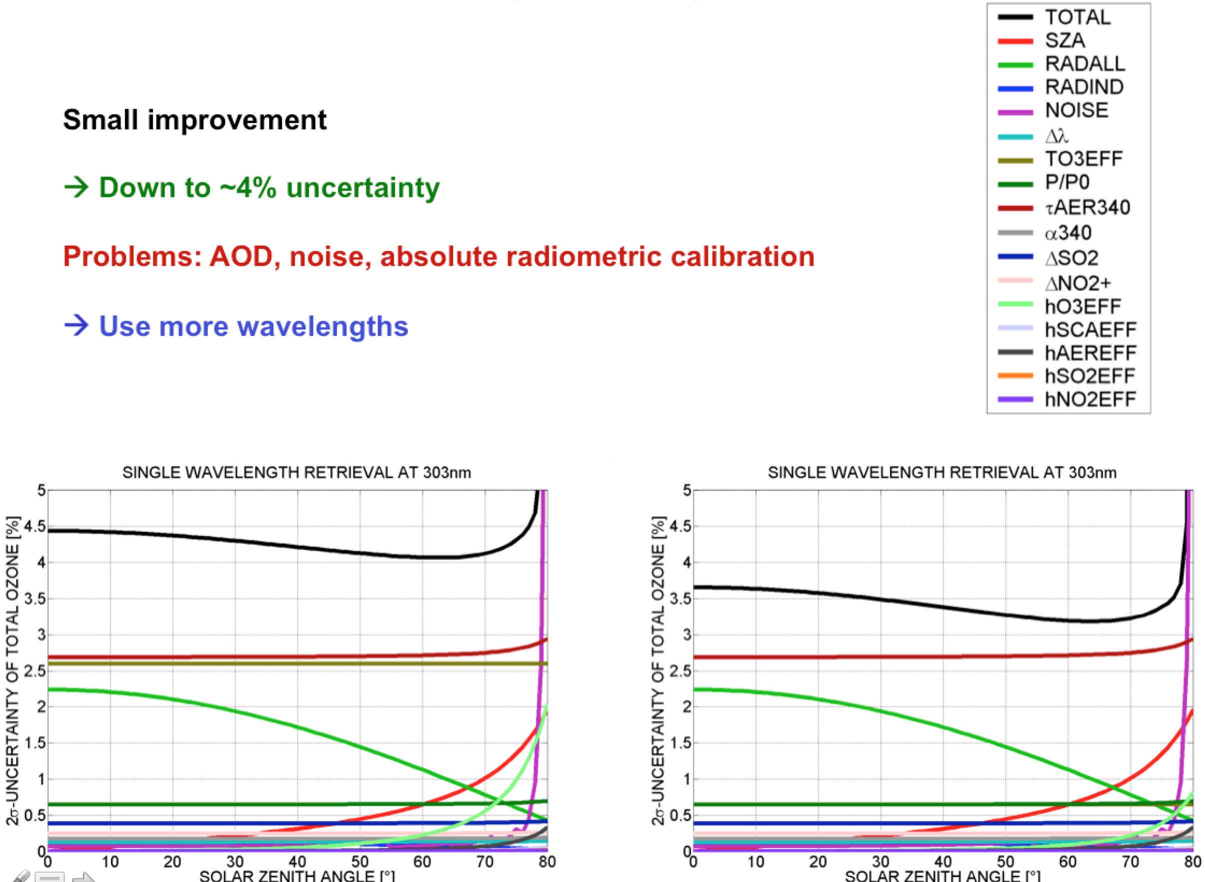
Total ozone from single wavelength

Small improvement

→ Down to ~4% uncertainty

Problems: AOD, noise, absolute radiometric calibration

→ Use more wavelengths



Direct Model (Brewer #171 results)

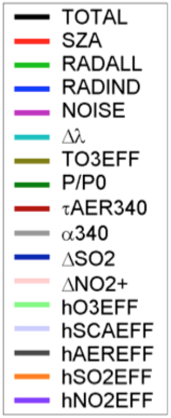
Total ozone from 4 wavelengths 310, 313, 317, 320nm

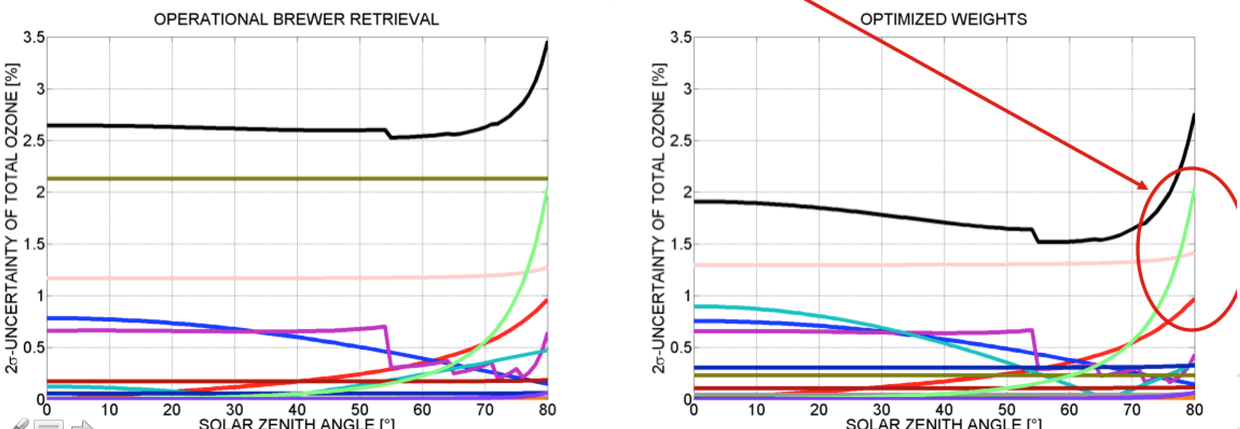
Without climatological input:
Brewer w=[0.58, -0.29, -1.29, 1]
Here w=[0.31, 0.31, -1.62, 1]

TO3EFF sensitivity reduced
→From ~3% uncertainty to ~2% uncertainty

Problems: hO3EFF, other gases, SZA

→ Use climatological input and internet time





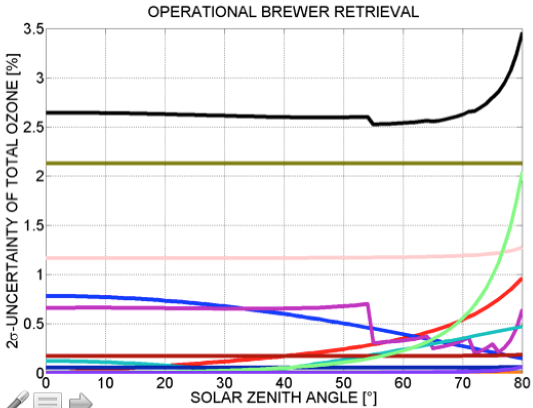
Total ozone from 6 wavelengths 303, 306, 310, 313, 317, 320nm

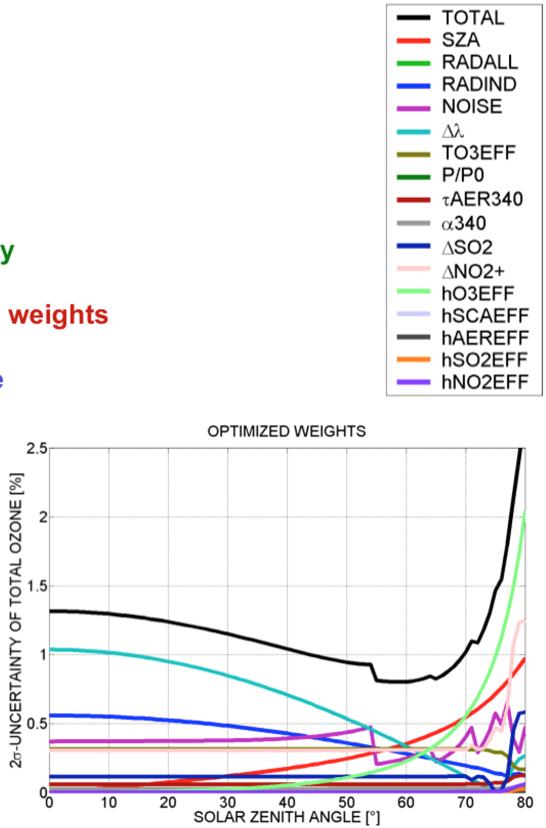
Without climatological input:
Brewer w=[0 , 0 , 0.58, -0.29, -1.29, 1]
SZA<70° w=[0.50, -0.14, -0.99, 1.30, -1.67, 1]
SZA=80 ° w=[0 , 0.06 , 0.19, 0.36, -1.61, 1]

TO3EFF sensitivity reduced
→From ~3% uncertainty to <0.5% uncertainty

Problem: wavelength shift, noise dependent weights

→ Use climatological input and internet time





Future works

- Radiometric calibration need to be revised.
- Wavelength calibration
- Langley and Calibration transfer errors has to be addressed.
- Stray Light
- EUBREWNET database can be used to get the error parameters several instruments.

Comparison of new characterized bandpass and wavelengths of Dobsons

Alberto Redondas, [1]

[1] Izaña Atmospheric Research Center, AEMET, Tenerife, Canary Islands, Spain.

October 27, 2015

MINISTERIO
DE AGRICULTURA, ALIMENTACIÓN
Y MEDIO AMBIENTE

AEMet
Agencia Estatal de Meteorología

ULL Universidad de La Laguna

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.

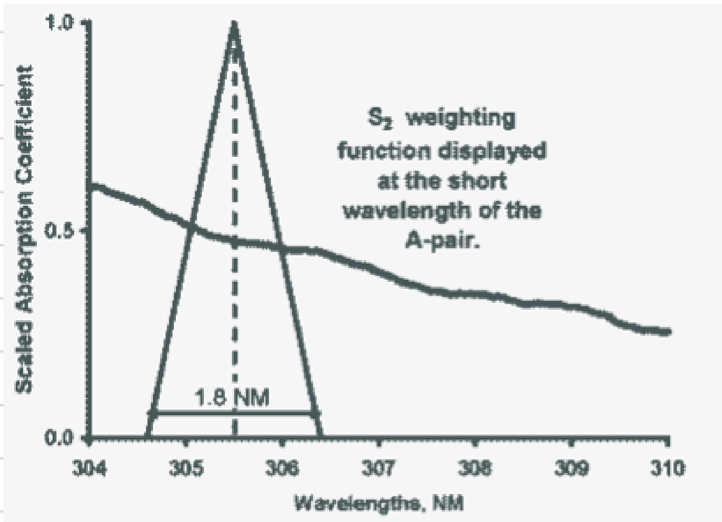
$$\alpha_i = \frac{\int \sigma(\lambda)\, S_i(\lambda, \lambda')\, d\lambda}{\int S_i(\lambda, \lambda') d\lambda} \tag{11}$$

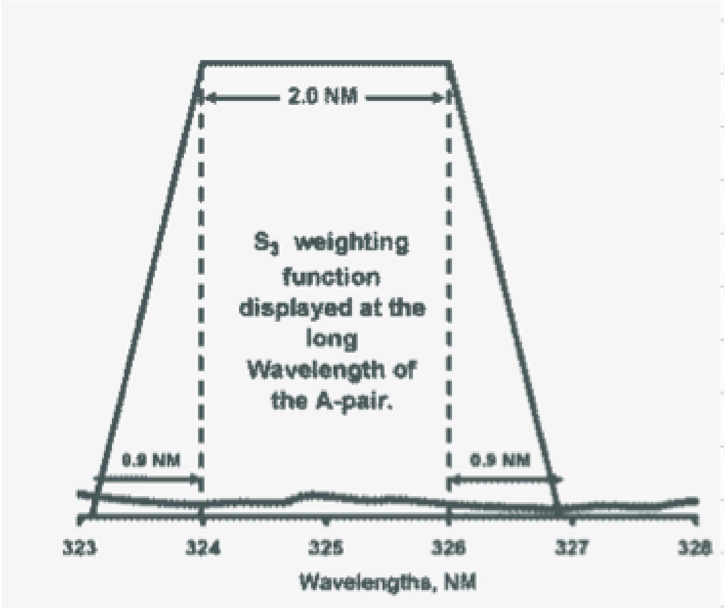
- S is the instrument slit function for the corresponding wavelength
- σ the ozone cross section at `Fixed` temperature, -46.3 C for Dobson Network and -45C for Brewer instruments

* 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 :

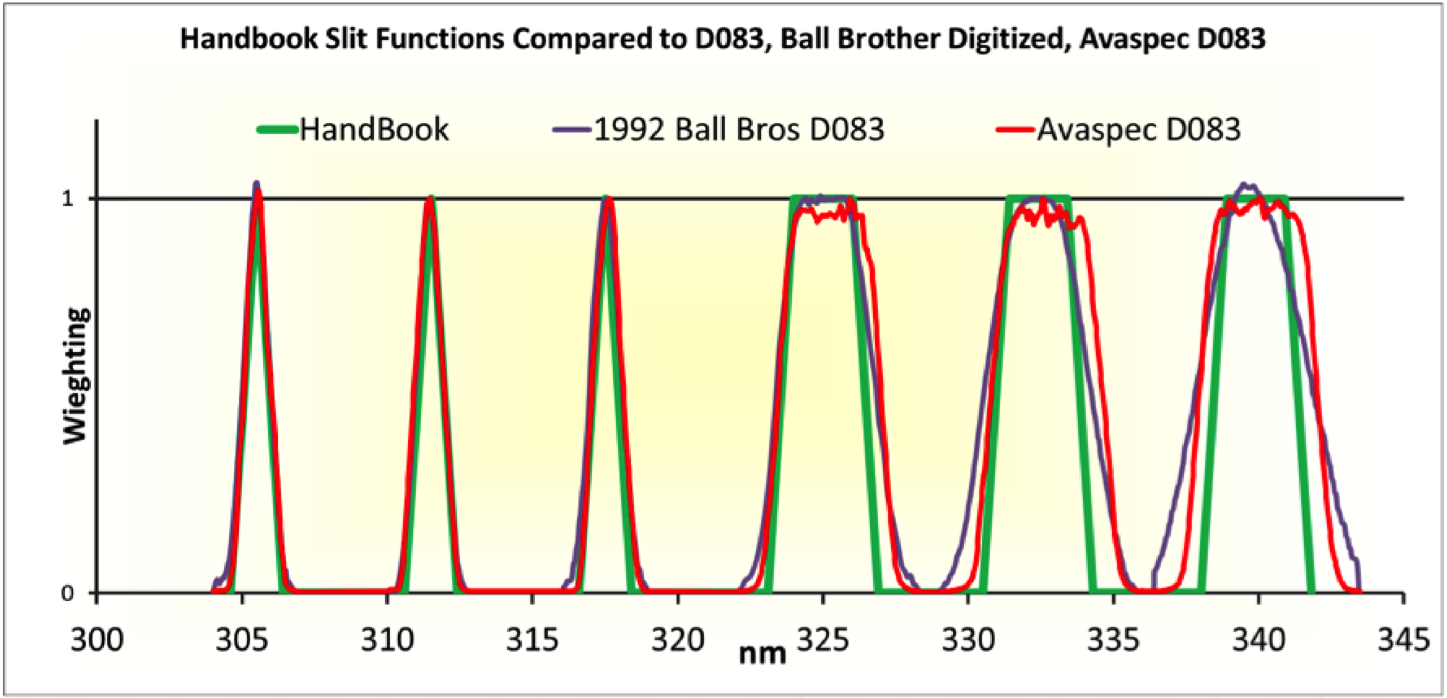




Dobson #083 Slit measurement

Dobson Slit Measurements :

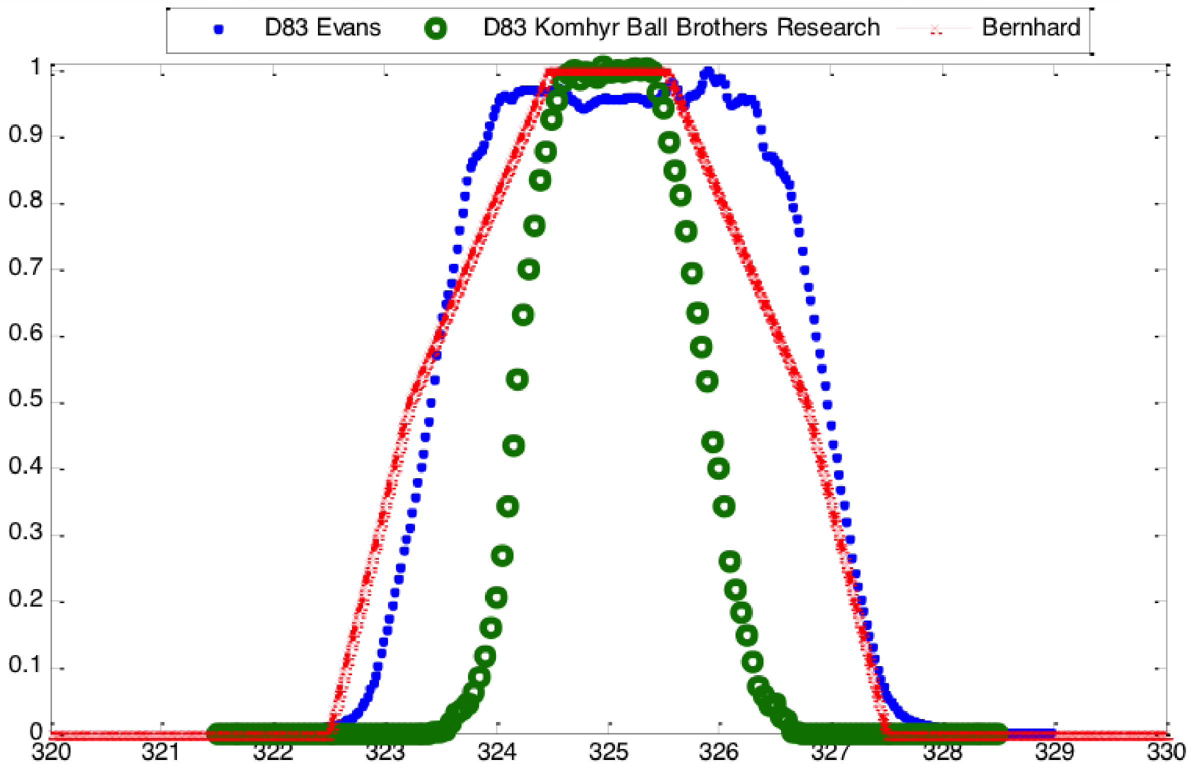
- Bell Brothers Digitalised 1992, (Komhyr 1898) Dobson #083
- Evans et all 2012 (Avaspec) Dobson #083



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

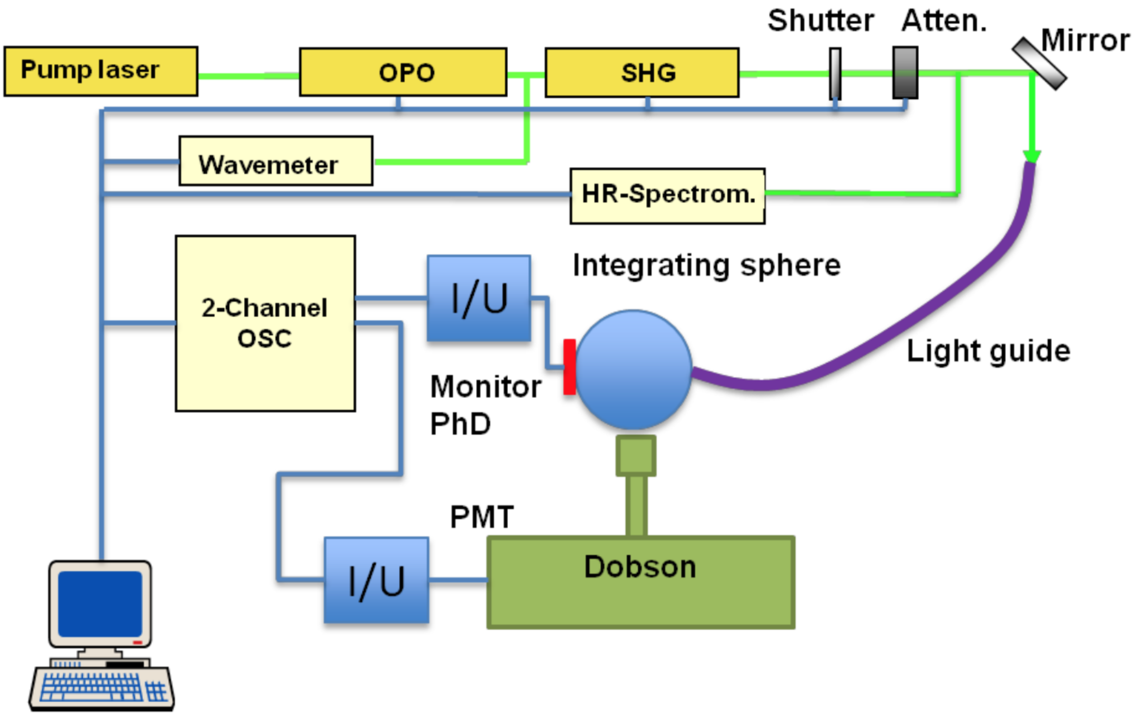
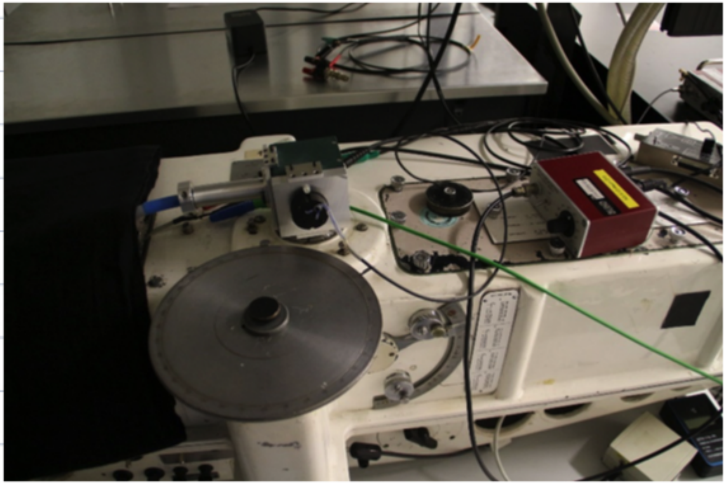
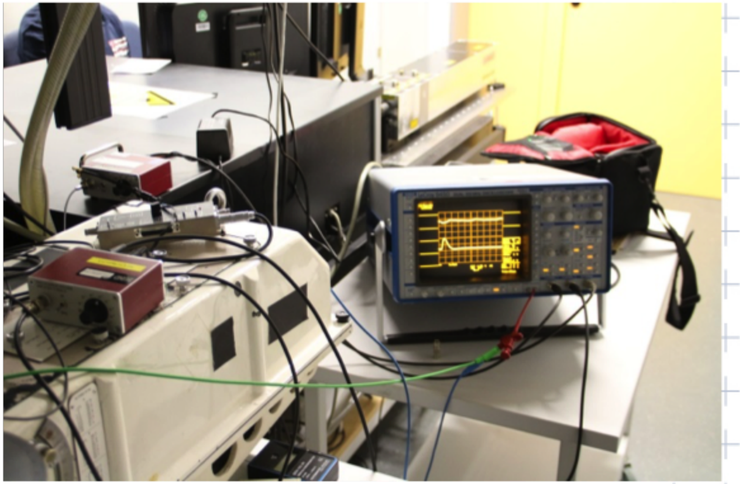


Figure 1. Bandpass function measurements at the PLACOS setup

ATMOZ Slit measurement

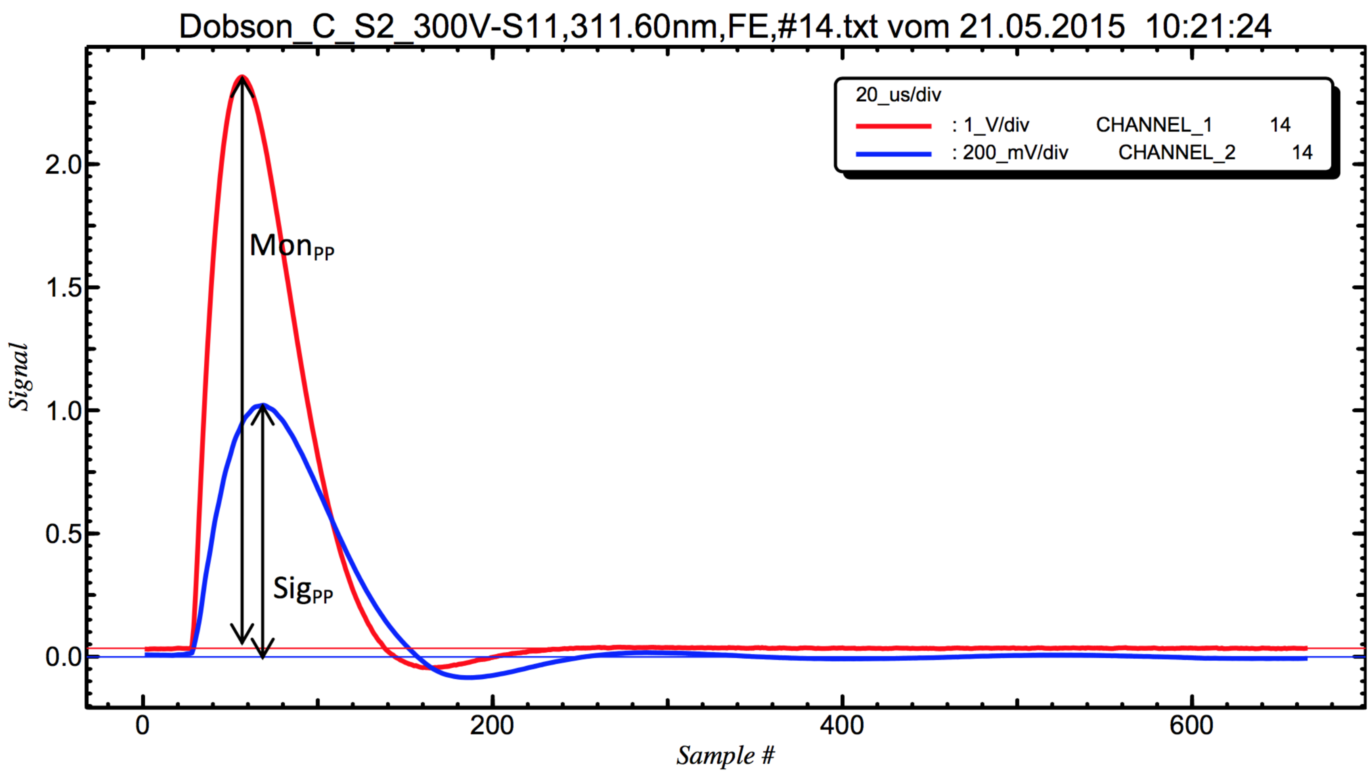
ATMOZ 2014-2015, tunneable lasser measuremetns at PTB



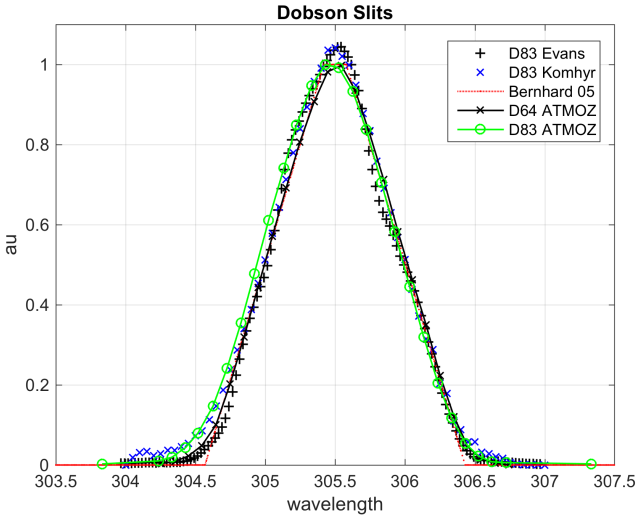


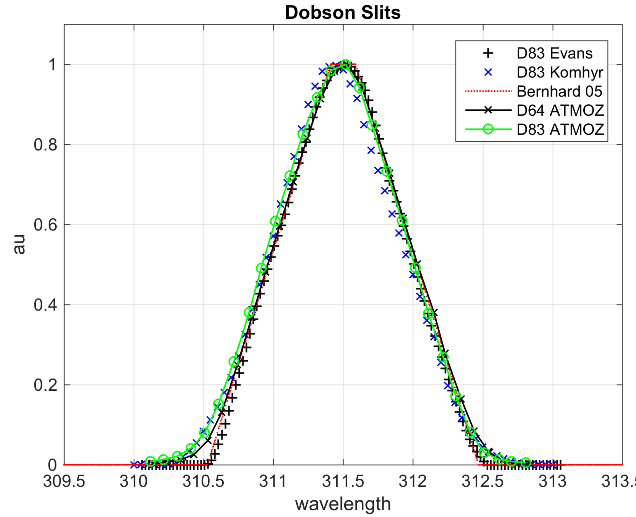
ATMOZ Slit measurement

ATMOZ 2014-2015, tunneable lasser measuremetns at PTB

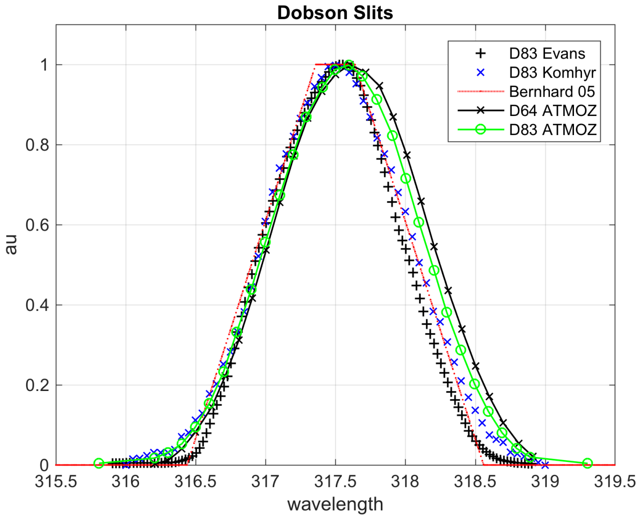


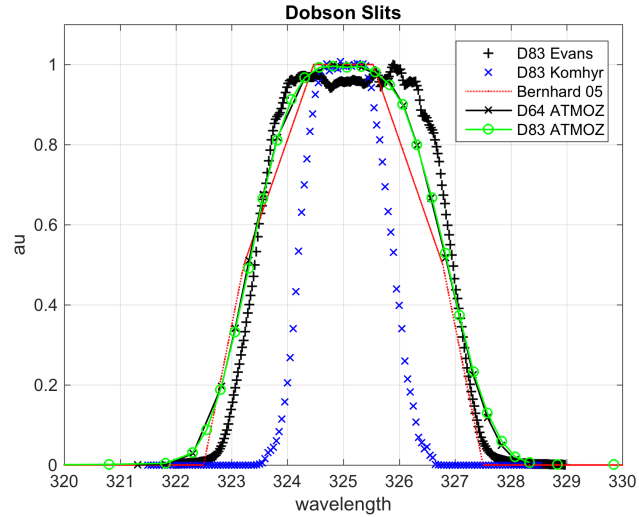
ATMOZ 2014-2015, tunneable lasser measuremetns at PTB



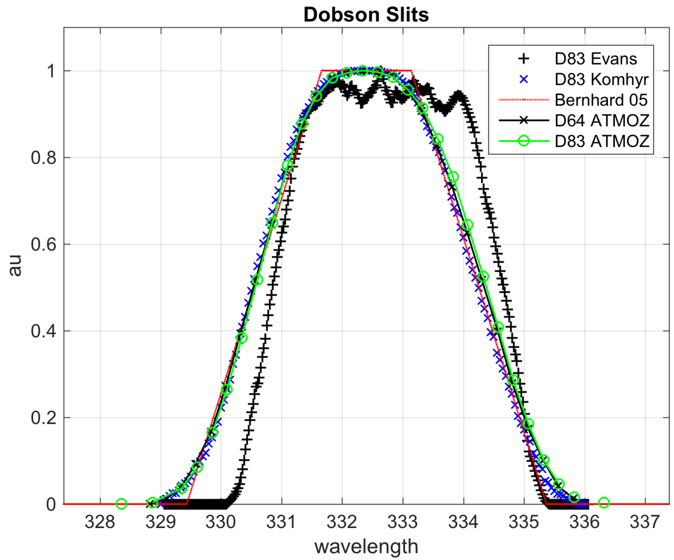


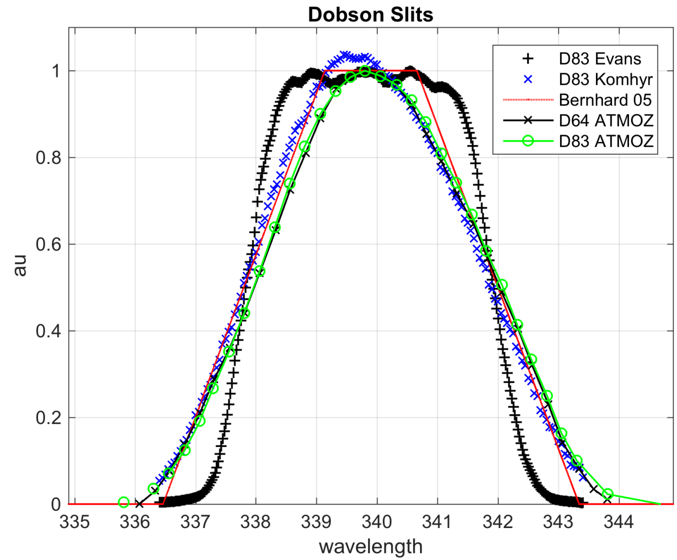
ATMOZ 2014-2015, tunneable lasser measuremetns at PTB





ATMOZ 2014-2015, tunneable lasser measuremetns at PTB





Slits & Cross Sections used

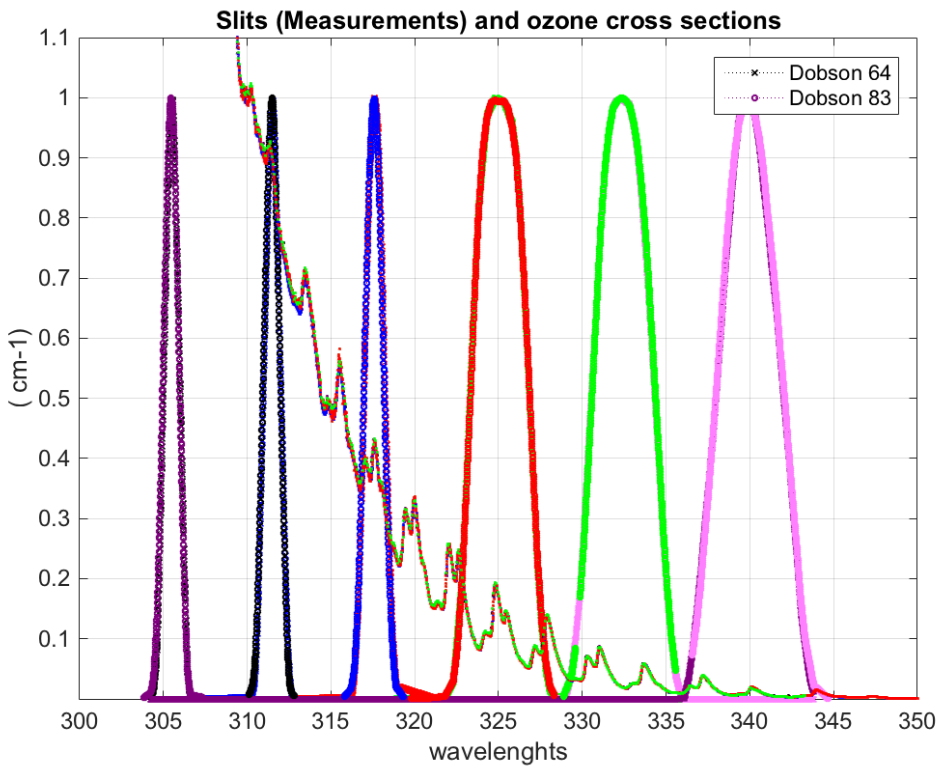


Figure 1: Studied XS at 228K and slit functions of Dobson

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)**.

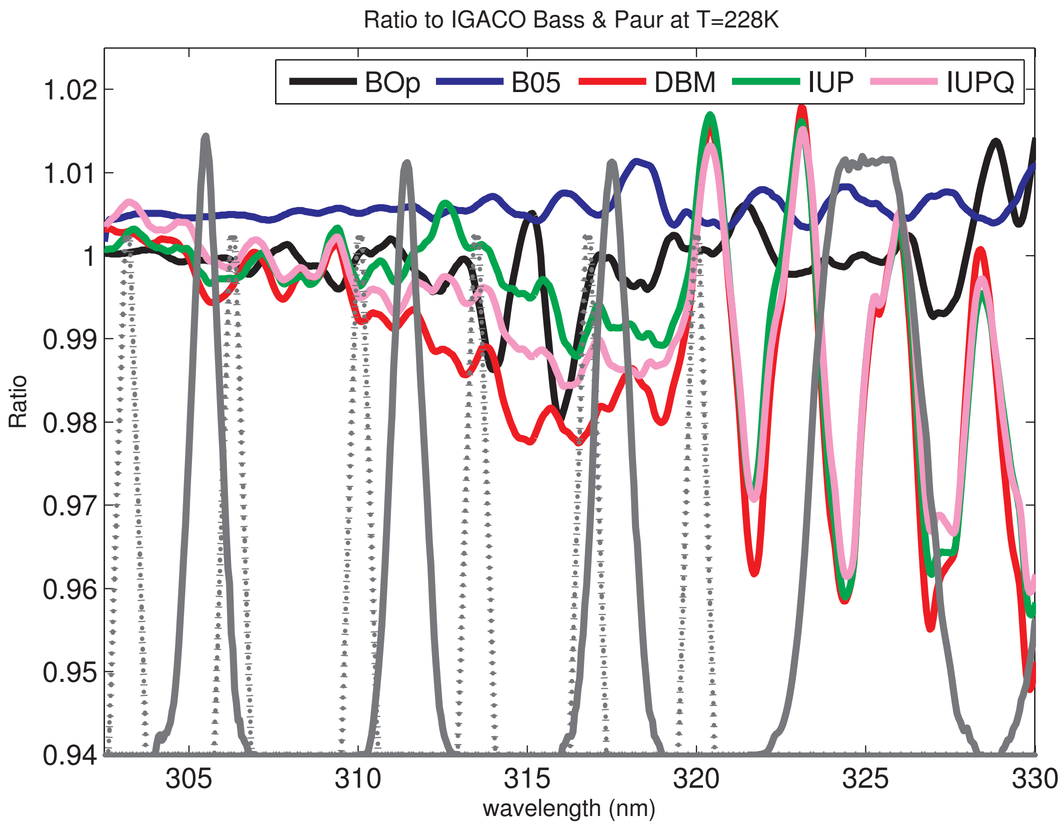


Figure 2: Ratio of the cross-sections of this study to the IGACO Bass & Paur (IGQ4) , the cross section are interpolated to a common resolution (0.1 nm) and smoothed to the Brewer resolution

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 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.