

INTERCOMPARISON OF GROUND-BASED UV-VISIBLE SENSORS OF O₃ AND NO₂

G. Vaughan¹, H. K. Roscoe², L. M Bartlett¹, F. M. O'Connor¹, A. Sarkissian², M. Van Roozendaal³, J-C Lambert³, P. C. Simon³, K. Karlsen⁴, B. A. Kåstad Høiskar⁴, D. J. Fish⁵, R. L. Jones⁵, R. Freshwater⁵, J.-P. Pommereau⁶, F. Goutail⁶, S. B. Andersen⁷, D. G. Drew⁸, P. A. Hughes⁹, D. Moore⁹, J. Mellqvist¹⁰, E. Hegels¹¹, T. Klupfel¹¹, F. Erle¹², K. Pfeilsticker¹², U. Platt¹²

1. Physics Dept, University of Wales, Aberystwyth, UK.
2. British Antarctic Survey, Madingley Rd, Cambridge, UK.
3. IASB, 3 Ave. Circulaire, B-1180 Brussels, Belgium
4. NILU, P.O.Box 100, N-2007 Kjeller, Norway.
5. CCAS, Dept. Chemistry, University of Cambridge, Lensfield Rd, Cambridge, UK.
6. Service d'Aeronomie du CNRS, BP3, 91371 Verrieres le Buisson, France.
7. DMI, Lyngbyvej 100, DK-2100 Copenhagen, Denmark
8. Met Office - Radio Sonde, Kehelland, Camborne, Cornwall, UK.
9. Met Office, London Road, Bracknell, Berks, UK
10. IVL, P.O.Box 47086, Dagjammingsgatan 1, S-402 58 Göteborg, Sweden.
11. MPI fur Chemie, Saarstrasse 23, D-6500 Mainz, Germany
12. Institut fur Umweltphysik, INF 366, D-6900 Heidelberg, Germany.

1. INTRODUCTION

An intercomparison of ground-based zenith-sky UV-visible spectrometers took place from September 12 - 23 1994 at the UK Met Office's station at Camborne, UK (50.2°N, 5.3°W). These instruments formed part of the ground-based network of SESAME. The purpose of the intercomparison was therefore to ensure the self-consistency of the resulting measurements. Nine UV-visible groups participated, with twelve spectrometers. The UK Met Office provided Dobson and Brewer spectrophotometer measurements of total ozone, as well as ozonesonde profiles and standard meteorological observations.

2. APPARATUS

A summary of the instruments used by each group is given in Table 1. For ease of reference in the text and figures, a short code is defined in the Table for each instrument. The first four instruments in the Table were of the SAOZ type; three of these used a 512-pixel detector and the fourth (that of the Service d'Aeronomie) a new detector with 1024 pixels. Note that the SE and IA2 instruments were only designed to measure NO₂: their spectral range did not cover the ozone bands.

3.1 RESULTS: OZONE

For all but one instrument, slant columns were converted to vertical columns using air mass factors (AMFs) calculated for the appropriate solar zenith angle θ . A single vertical column for each twilight period was obtained by averaging individual vertical columns between $\theta = 87$ and 91° , weighted according to the standard error of each measurement. A different procedure was adopted by the HD group, who derived the twilight ozone column from the slope of the corresponding Langley plot.

AB SAOZ measurements analysed with respect to the 15 Sept reference spectrum are compared with the Dobson, Brewer, TOMS and integrated ozonesonde measurements in fig. 1. The SAOZ is clearly 10 - 15 DU lower than the other techniques. In fact, this is entirely

accounted for by the difference in air-mass factors discussed above: the standard SAOZ algorithms use AMFs calculated for 60°N in winter. The conclusion from this is that the SAOZ measurements with daily air-mass factors are consistent with the other techniques to ± 10 DU, but that with standard AMFs there was an offset of around -10 DU at Camborne in September.

TABLE 1: SUMMARY OF INSTRUMENTS INVOLVED IN THE INTERCOMPARISON

Group	Code	Grating (g/mm)	Spectral range (nm)	No of pixels	Resolution nm	Sampling ratio	Detector type	Field of view, °
Aberystwyth	AB	200	300-600	512	1.0	1.6	NMOS	30
NILU	NI	200	300-600	512	1.0	1.6	NMOS	30
DMI	DM	200	300-600	512	1.0	1.6	NMOS	30
Service d'Aeronomie	SA	360	300-635	1024	1.2	3.5	NMOS	30
IASB	IA1	1200	400-551	1024	0.6	4.0	diode	15
IASB	IA2	1200	332-451	1024 x256	0.6	6.0	CCD	15
Cambridge	CB1	600	130*	1152 x320	0.7	9.0	CCD	1
Cambridge	CB2	600	130*	1152 x320	0.7	9.0	CCD	1
IVL	SE	600	400-485	1024	1.3	15.8	diode	2.9
MPI	MP1	600	316-517	1024	1.0	5.0	diode	1
Heidelberg	HD	600	362-677	1024	1.2	6.0	diode	1

* The wavelength range for these instruments was variable

Vertical column averages from the other spectrometers are expressed as fractional differences from the AB measurements in fig. 2. The differences are summarised in Table 2. The four SAOZs and the IA1 instrument agree to about $\pm 3\%$ (10 DU), with very small mean discrepancies, of the order of 1%. The values for MP1, on the other hand, were much smaller than those for AB - an average offset of -10% which appears to be largely attributable to the cross-sections used in the analysis. A similar offset in the opposite direction is seen for HD.

TABLE 2. DIFFERENCES IN OZONE MEASUREMENTS (% DEVIATION FROM AB) WITH REFERENCE SPECTRUM OF 15 SEPTEMBER

Instrument	Slant column difference		AMF ratio to SAOZ	Vertical column difference	
	mean	st.dev		mean	st.dev
SA	2.3	1.5	1.0	1.4	1.2
NI	3.7	2.4	1.0	-0.3	1.2
DM	3.7	1.3	1.0	1.8	1.0
IA1	4.7	1.8	0.97	-0.9	2.0
MP1	-13.7	5.3	0.955	-10.1	4.4
HD	13.6	5.0	0.955	6.4	4.3

3.2 Results: NO₂

The comparison of NO₂ total columns is shown in figs. 3 and 4 and summarised in Table 3. The SAOZ instruments agree to about 5% with one another. The difference of about 10% between AB and the IA instruments arises partly from the difference in AMF (4%) and partly

from the different estimates of the amount in the reference spectrum, R: there is very little scatter in the differences shown in figs.3 and 4. The mean offset in the slant columns for SE may also be attributed to a larger value of R. In contrast, the differences with MP1 and HD arise conclusively from differences in the slant columns derived from the spectra, and are attributable mainly to differences in the absorption cross-sections.

TABLE 3. DIFFERENCES BETWEEN UV-VISIBLE MEASUREMENTS OF NO₂ (% DEVIATION FROM AB) WITH REFERENCE SPECTRUM OF 15 SEPTEMBER

Instrument	Slant column difference		AMF ratio to SAOZ	Vertical column differences			
	mean	st.dev		morning		evening	
				mean	s.dev	mean	s.dev
SA	-1.2	4.1	1.0	0.9	2.8	-3.4	2.4
NI	-3.6	2.4	1.0	5.4	3.2	2.0	3.0
DM	-3.6	1.2	1.0	-1.0	1.6	-3.3	1.5
IA1	-1.3	5.3	0.957	8.1	3.5	13.8	1.5
IA2	0.3	2.8	0.957	10.1	1.9	9.9	2.3
MP1	-8.1	1.6	0.972	-7.9	-	-4.1	-
HD	-28.4	6.3	0.972	-30.0	-	-23.0	-
SE	-4.6	11.5	1.019	-0.1	3.2	2.1	11.3

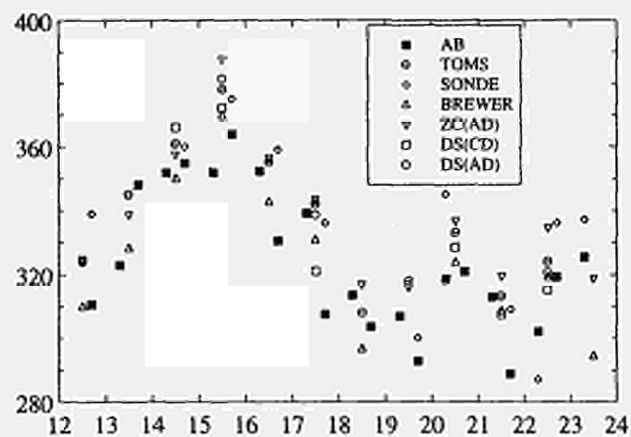
4. CONCLUSIONS

Agreement in the vertical columns between instruments of the SAOZ type was generally within 10 DU (3%) for ozone and 5% for NO₂. The IASB instrument was consistent with the SAOZ to 3% for O₃ and 10% for NO₂, with the SE and MPI instruments also consistent to within 10% for NO₂. For ozone, both the MPI and HD instruments differed by > 6% from the others. For MPI, this probably arises from differences in cross-sections, but for HD the cause appears to involve a different sensitivity to low clouds. The large differences in NO₂ slant columns between the CB and HD instruments and the others is directly attributable to the cross-sections used. There is laboratory evidence that the cross-section of NO₂ is 20% larger at low temperatures such as pertain in the stratosphere than it is at room temperature. The results of this paper for NO₂ therefore relate to the relative accuracy of the different instruments, and not to the absolute accuracy.

Figure captions

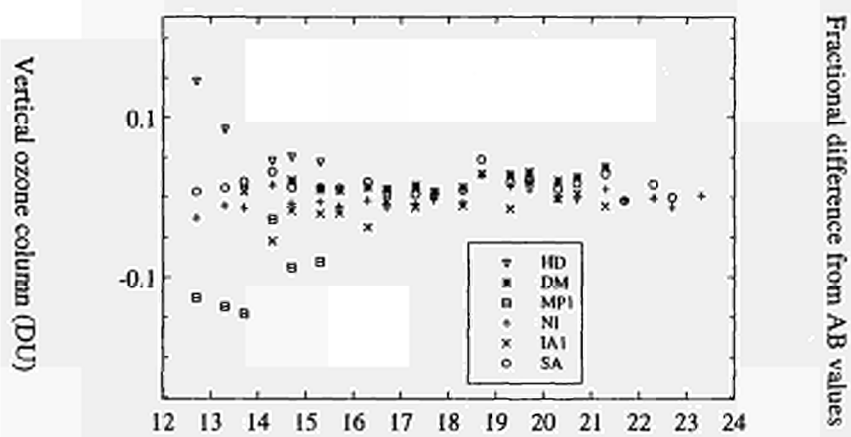
- Fig. 1. Vertical columns of ozone from AB, compared with values from the TOMS, Dobson, Brewer, and vertically integrated ozonesondes. Separate symbols are used for direct sun (DS) and zenith cloud (ZC) Dobson observations, and for different wavelength pairs.
- Fig. 2. Comparison between zenith-sky spectrometer measurements of vertical ozone column, using the 15 Sept reference spectra. The values shown are fractional differences from the AB values shown in fig. 1.
- Fig. 3. Zenith-sky spectrometer measurements of NO₂ for the mornings, calculated using the 15 Sept reference spectra. Heavily polluted days have been excluded from this plot.
- Fig. 4 As fig.3 for afternoon NO₂ measurements

Fig. 1



Midnight of date in September

Fig. 2



Midnight of date in September

Fig. 3

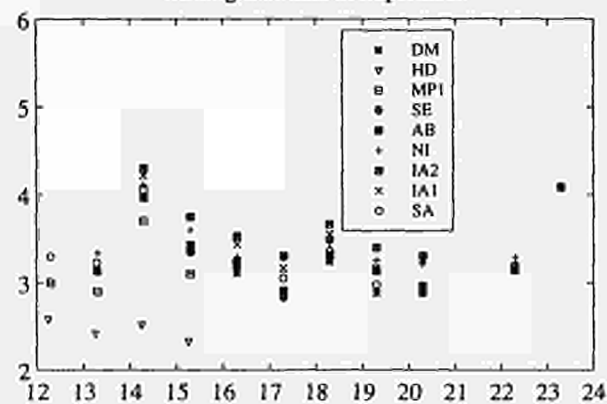
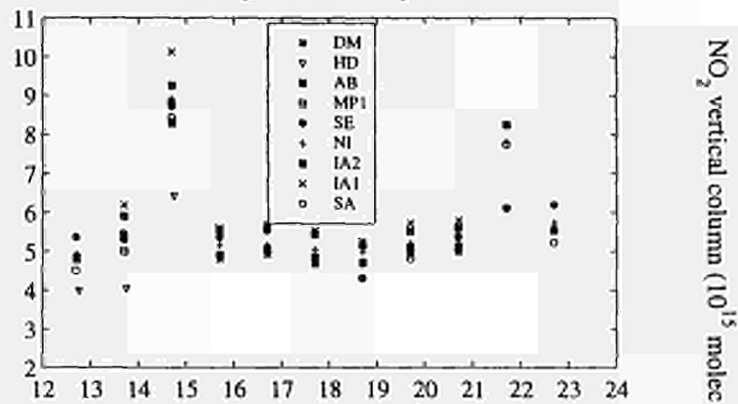
 NO_2 vertical column (10^{15} molec cm^{-2})

Fig. 4

 NO_2 vertical column (10^{15} molec cm^{-2})