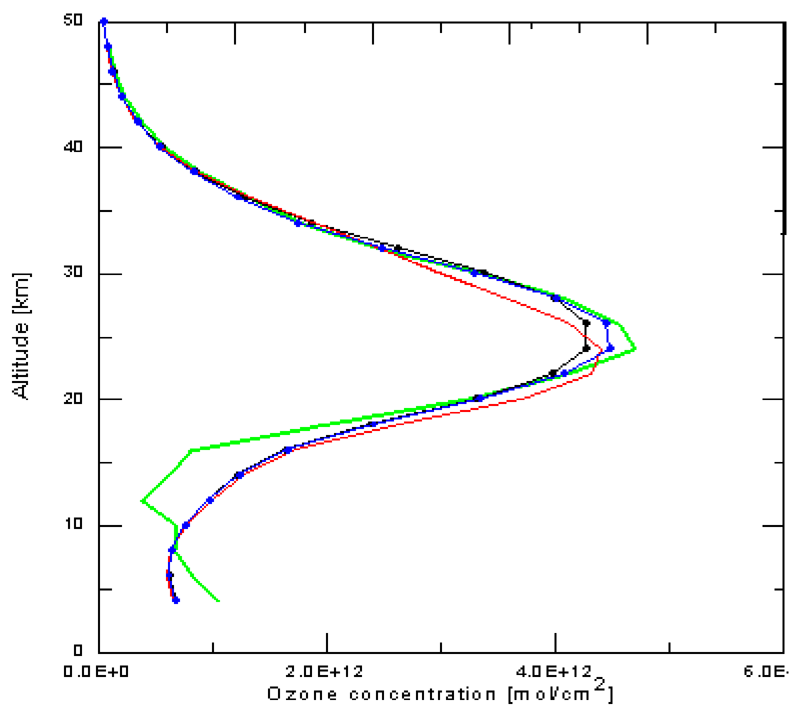
World Ozone and Ultraviolet Radiation Data Centre

Report on the Meeting of the WOUDC Umkehr Sub-Committee November 17-18, 1999

Meteorological Service of Canada
Toronto, Canada

ACSD Internal Report
ACSD-00-001



Prepared by
C.T. McElroy and E.W. Hare

Environment Canada　Environnement Canada

Canada

World Ozone and Ultraviolet Radiation Data Centre

Report on the Meeting of the WOUDC Umkehr Sub-Committee November 17-18, 1999

Meteorological Service of Canada
Toronto, Canada

ACSD Internal Report
ACSD-00-001

Prepared
by
C.T. McElroy and E.W. Hare

Environment Canada Environnement Canada

Canada

World Ozone and Ultraviolet Radiation Data Centre
Report on the Meeting of the WOUDC Umkehr Sub-Committee
November 17-18, 1999
Meteorological Service of Canada
Toronto, Canada

Foreword to the Proceedings of the First WOUDC Umkehr Steering Committee Meeting

Two important events have taken place in the last two decades, which have necessitated changes in how the World Ozone and UV radiation Data Centre (WOUDC) handles Umkehr data. One was the retirement of Carl Mateer from the Atmospheric Environment Service (which is now the Meteorological Service of Canada), an event which required a complete change in how the data Centre was operated, and the other was the eventual withdraw of Carl from the analysis of the Umkehr data collected by the Dobson network around the world. For approximately 40 years Carl personally developed algorithms and provided a uniform analysis of the global Dobson Umkehr observations and made them available to the ozone community through the WOUDC. This important contribution of ozone profile data to the community has been of great significance to the process of ozone trend analysis as reflected in the heavy dependence of the International Ozone Trends Panel assessments on Umkehr data for the determination of ozone trends at high altitude. Carl's work continued a legacy of important research started by Götz and extended by Dütsch, DeLuisi and himself.

Because Carl Mateer is no longer providing this service to the community and because there now exists the potential for the development of independent analysis activities, particularly in the case of the Brewer Spectrophotometer Umkher observations, there is a risk that the high-quality, uniformly-evaluated data set maintained at the WOUDC as a result of Carl's efforts might not continue to be available. For Umkehr data to have maximum value in trend assessments and in the determination of the global, spatial distribution of ozone and ozone trends it is imperative that the entire data set be evaluated by the same version of the same algorithm. Because the Umkehr retrieval is, like virtually all remote sensing techniques, under-constrained, the exact solution values are dependent on the details of the algorithm. If different algorithms or different versions of the same algorithm are used to process data from different observing sites, differences in the resulting profiles may be due to algorithm differences not because of actual ozone differences.

The purpose of the WOUDC Umkehr Steering Committee is to provide a contact point between the management of the WOUDC and scientists in the community who are interested in ensuring that Umkehr profiles data are maintained at the high quality level of the historical data set. The Data Centre will continue to analyse, archive and make available Umkehr profile data. In future, the algorithms to carry out that task will be chosen with the considered input of the Umkehr Steering Committee. The list of recommendations from the First Steering Committee meeting expresses the desires and needs of the community in that regard.

C.T. McElroy

November 1999

List of Abbreviations and Acronyms

AUTH	Aristotle University of Thessaloniki (Greece)
MSC	Meteorological Service of Canada
BDMS	Brewer Data Management System
CMDL	Climate Monitoring and Diagnostics Laboratory
DU	Dobson Unit
EPA	US Environmental Protection Agency
GO_3OS	Global Ozone Observing System
GSFC	Goddard Space Flight Centre
JMA	Japan Meteorological Agency
NASA	National Aeronautical and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
QBO	Quasi-Biennial Oscillation
RAS	Russian Academy of Science
SAG	Scientific Advisory Group
SAGE	Stratospheric Aerosol and Gas Experiment
SBUV	Solar Backscatter Ultraviolet experiment
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SSBUV	Shuttle Solar Backscatter Ultraviolet experiment
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
SZA	Solar Zenith Angle
UAH	University of Alabama at Huntsville (USA)
UGA	University of Georgia at Athens (USA)
WMO	World Meteorological Organization
WOUDC	World Ozone and Ultraviolet Radiation Data Centre
ZS	Zenith Sky

Agenda for the Umkehr Algorithm meeting, MSC, November 17-18, 1999

Wednesday, November 17, 1999

Introduction

0830-0915	Arrive at MSC.
0930-0945	Welcome by ***D. I. Wardle***, Chief, Experimental Studies Division
1000-1030	Introuction - ***C.T. McElroy (MSC)***
1030-1045	Current status of the data in the WOUDC - ***E.W. Hare*** **(MSC-WOUDC)**

Presentations I

1100-1120	A new technique for using ground-based zenith sky radiance measurements to verify long-term calibration of satellite ozone profiling instruments. ***P.K. Bhartia (NASA)***
1120-1140	Developing Methods for Understanding Umkehr/Brewer radiance data: Application for Satellite Validation. ***I. Petropavlovskikh (NOAA)***
1140-1200	Development of A Global Stratospheric Aerosol Climatology. ***J. Deluisi (NOAA)***
1200-1220	The tasks and achievements of the European Commission/WMO REVUE project. ***R. Bojkov (WMO)***

Presentations II

1330-1350	EPA/UGA Umkehr activities ***J Sabburg (UGA)***
1350-1410	Umkehr Ozone Validation ***M. Newchurch (UAH)***
1410-1430	Umkehr activities at NOAA-CMDL ***S. Oltmans and G. Koenig (NOAA)***
1430-1450	Umkehr Measurements at JMA ***T. Fujimoto (JMA)***
1450-1515	Brewer Umkehr Sensitivity in the Stratosphere ***N. Elansky (RAS)***

Thursday, November 18, 1999

Presentations III

0915-1100	Update on the Brewer Umkehr algorithm - ***C.T. McElroy (MSC)***
1130-1300	Group discussions on the on the 1999 algorithm, nomination of the Steering Committee membership and the formulation of meeting recommendations.
1300-	Wrap up

Wednesday, November 17, 1999

Welcome - *Dr. David I. Wardle*

D. Wardle, Chief of the Experimental Studies Division (ARQX) at the Meteorological Service of Canada (MSC), welcomed the group to the MSC and Toronto.

Introduction – *C.T. McElroy*

T. McElroy reviewed the agenda and the purpose of the meting as indicated in the foreward of this report. S. Oltmans noted that the quality of the measurement and adta collection is very important. Although several people present had repsonisibilities for some measurements, it would be appraopriate to have a representative for data collection and measurement activities.

Current status of the data in the WOUDC – *E.W. Hare*

E. Hare of the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) presented a "snapshot" of the current status of the WOUDC Umkehr data archive. Table 1 shows the temporal range and number of submitted N-value data and the resulting, processed profiles that are currently available. Tables 2 and 3 give the number of Umkehr days available from the both the International and Canadian Brewer instruments in the Brewer Data Management System (BDMS).

Stn	Station Name	Country	Begin Date	End Date	N-value data	Profiles
7	KAGOSHIMA	JAPAN	19-Mar-58	30-Sep-99	1599	1589
8	KODAIKANAL	INDIA	19-Jan-58	2-Feb-89	184	172
9	MOUNT ABU	INDIA	21-Oct-51	19-Jun-80	732	731
10	NEW DELHI	INDIA	9-Sep-57	7-Feb-98	1756	1383
12	SAPPORO	JAPAN	23-Mar-58	29-Sep-99	1351	1348
13	SPRINAGAR	INDIA	8-Nov-55	6-Aug-89	237	227
14	TATENO	JAPAN	1-Aug-57	28-Sep-99	6130	6124
15	TORISHIMA	JAPAN	11-Feb-58	28-Dec-59	51	
17	ARGENTINE ISLANDS	ANTARCTICA (GBR)	7-Oct-57	24-Nov-72	65	64
21	EDMONTON (STONY PL.)	CANADA	9-Oct-58	12-Mar-88	399	346
23	MOOSONEE	CANADA	20-Jul-57	5-May-61	64	52
24	RESOLUTE	CANADA	23-Aug-57	27-Apr-84	185	165
26	ASPENDALE	AUSTRALIA	9-Jan-62	22-Dec-82	940	888
27	BRISBANE	AUSTRALIA	25-Jun-62	16-Nov-98	1760	1141
29	MACQUARIE ISLAND	AUSTRALIA	13-Jan-66	6-Jun-92	524	302
30	MINAMI TORISHIMA	JAPAN	3-Feb-58	23-Jun-63	73	
31	MAUNA LOA	USA	17-May-82	31-Dec-98	16663	5337
35	AROSA	SWITZERLAND	3-Jan-56	31-Jul-99	10892	10464
40	HAUTE PROVENCE	FRANCE	3-Sep-83	22-Dec-98	9942	3157
50	POTSDAM	GERMANY	25-Feb-64	15-Nov-65	63	58

57	HALLEY BAY	ANTARCTICA (GBR))	18-Oct-57	19-Oct-72	35	30
64	STERLING	USA	8-Mar-63	21-May-64	11	
65	TORONTO	CANADA	17-Dec-59	12-Feb-73	180	167
66	FORT COLLINS	USA	1-Jan-63	3-Nov-65	195	
67	BOULDER	USA	23-Feb-78	1-Nov-98	9382	3137
68	BELSK	POLAND	5-Apr-63	27-Aug-99	3369	1932
70	MONT LOUIS	FRANCE	22-Jun-63	29-May-78	563	557
71	PRETORIA	SOUTH AFRICA	1-Aug-64	16-Feb-72	1252	1227
73	AHMEDABAD	INDIA	4-Nov-60	19-Dec-84	581	580
74	VARANASI	INDIA	1-Feb-64	22-Dec-96	1352	1187
75	DUM DUM	INDIA	13-Nov-63	2-Jan-73	222	218
76	GOOSE BAY	CANADA	27-Feb-63	14-Aug-84	199	171
77	CHURCHILL	CANADA	10-Feb-65	26-Apr-76	84	76
79	TALLAHASSEE	USA	15-May-64	16-Apr-79	181	
81	BASE KING BAUDOIN	ANTARCTICA (BEL)	6-Sep-65	9-Nov-66	41	31
82	LISBON	PORTUGAL	30-Jun-67	21-May-99	1925	1818
84	DARWIN	AUSTRALIA	30-Apr-66	22-Dec-98	755	460
91	BUENOS AIRES	ARGENTINA	6-Jan-95	30-Sep-99	641	218
92	HOBART	AUSTRALIA	9-Jan-69	25-Nov-91	241	186
101	SYOWA	JAPAN	23-Feb-77	30-Sep-99	1641	271
102	BRACKNELL	U.K.	13-Feb-86	26-Feb-86	6	1
105	FAIRBANKS	USA	23-Apr-93	28-Aug-98	1254	330
110	HUANCAYO	PERU	1-Nov-85	21-Sep-90	108	108
152	CAIRO	EGYPT	21-Mar-69	13-Jul-99	724	670
159	PERTH	AUSTRALIA	25-Mar-69	30-Dec-98	12033	3863
175	NAIROBI	KENYA	10-May-84	17-May-84	2	2
180	INVERCARGILL	NEW ZEALAND	19-Mar-71	1-Sep-87	371	353
187	POONA	INDIA	4-Apr-73	14-May-99	1647	997
190	NAHA	JAPAN	1-Jul-74	9-Sep-99	841	840
192	MEXICO CITY	MEXICO	25-Oct-94	3-Mar-96	88	32
205	THIVANDRUM	INDIA	22-Nov-82	2-Apr-83	66	22
214	SINGAPORE	SINGAPORE	1-Apr-79	3-Aug-99	726	411
217	POKER FLAT	USA	6-Mar-84	27-Apr-92	1703	443
218	MANILA	PHILIPPINES	2-Mar-83	19-Mar-83	7	
245	ASWAN	EGYPT	14-Apr-85	27-Jun-99	2894	2723
252	SEOUL	KOREA	6-Feb-86	24-Oct-98	906	871
253	MELBOURNE	AUSTRALIA	6-Jan-85	13-Oct-97	221	129
256	LAUDER	NEW ZEALAND	4-Feb-87	30-Dec-98	4932	1459
260	TABLE MOUNTAIN	USA	19-Jul-89	1-Aug-89	60	19
265	IRENE	SOUTH AFRICA	9-Jul-90	26-Dec-96	1917	627
340	SPRINGBOK	SOUTH AFRICA	1-Mar-95	20-Dec-96	511	161
342	COMODORO RIVADAVIA	ARGENTINA	1-Aug-97	22-Aug-97	21	5
343	SALTO	URUGUAY	8-Aug-97	30-Aug-97	3	2
				Totals	107501	59882

Table 1: A summary of the Dobson Umkehr data (up to September 1999), currently available in the WOUDC archive.

Agency	Country	Brewer	Min Date	Max Date	Umkehr Days
AUTH	**GRC**	**BR#005**	**1989-12-04**	**1992-12-31**	**702**
SMHI	**SWE**	**BR#006**	**-**	**-**	
DWD_MOHp	**DEU**	**BR#010**	**-**	**-**	
CWBT	**TWN**	**BR#023**	**-**	**-**	
FMI	**FIN**	**BR#037**	**-**	**-**	
SMI	**CHE**	**BR#040**	**-**	**-**	
RAS-IAP	**RUS**	**BR#043**	**1993-01-29**	**1995-12-31**	**438**
IEM-SPA	**RUS**	**BR#044**	**1991-05-12**	**1998-12-31**	**75**
CAO	**RUS**	**BR#045**	**-**	**-**	
PIM	**POR**	**BR#048**			
CAO	**RUS**	**BR#049**	**-**	**-**	
CWBT	**TWN**	**BR#061**	**1999-01-12**	**1999-01-12**	**1**
JRC_EU	**ITA**	**BR#066**	**1992-06-13**	**1993-08-12**	**90**
U_Rome	**ITA**	**BR#067**	**1992-12-01**	**1997-12-31**	**1612**
SMI	**CHE**	**BR#072**	**-**	**-**	
CAMS-IAC???	**CHN**	**BR#074**	**-**	**-**	
UKMO	**GBR**	**BR#075**	**-**	**-**	
CAMS-IAC	**CHN**	**BR#076**	**1997-01-01**	**1997-06-26**	**165**
CAMS-IAC	**CHN**	**BR#077**	**1997-01-02**	**1997-06-17**	**103**
DWD_MOL	**DEU**	**BR#078**	**-**	**-**	
AUTH	**GRC**	**BR#086**	**-**	**-**	
EPA	**USA**	**BR#087**	**-**	**-**	
ME	**IRE**	**BR#088**	**1993-02-17**	**1995-02-03**	**522**
MMS	**MYS**	**BR#090**	**-**	**-**	
SHMI	**SVK**	**BR#097**	**1993-08-19**	**1997-12-31**	**717**
EPA	**USA**	**Br#101**	**1996-06-24**	**1998-07-24**	**604**
EPA	**USA**	**Br#103**	**1996-01-01**	**1998-07-30**	**870**
EPA	**USA**	**Br#105**	**1996-01-01**	**1996-02-01**	**32**
EPA	**USA**	**Br#106**	**1996-03-13**	**1997-03-13**	**134**
FMI	**FIN**	**BR#107**	**-**	**-**	
EPA	**USA**	**Br#108**	**1996-05-23**	**1998-07-27**	**686**
EPA	**USA**	**Br#109**	**1994-09-23**	**1998-01-27**	**534**
EPA	**USA**	**Br#112**	**1995-10-05**	**1997-06-16**	**557**
JMA	**JPN**	**Br#113**	**-**	**-**	
DWD_MOP	**DEU**	**BR#118**	**-**	**-**	
TMD	**THD**	**BR#121**	**-**	**-**	
UMKO	**GBR**	**BR#126**	**1995-11-27**	**1995-11-29**	**3**
CWBT	**TWN**	**Br#129**	**1997-02-25**	**1997-02-25**	**1**
EPA	**USA**	**Br#130**	**1997-02-20**	**1998-07-30**	**403**
EPA	**USA**	**Br#132**	**1996-12-26**	**1998-07-30**	**466**
EPA	**USA**	**Br#133**	**1997-07-31**	**1998-07-30**	**301**
EPA	**USA**	**Br#134**	**1997-09-18**	**1998-07-30**	**268**
EPA	**USA**	**Br#135**	**1997-01-18**	**1998-02-20**	**291**
EPA	**USA**	**Br#137**	**1997-03-05**	**1998-07-30**	**470**
EPA	**USA**	**Br#138**	**1998-03-04**	**1998-07-30**	**149**
EPA	**USA**	**Br#141**	**1997-10-03**	**1998-07-30**	**119**
EPA	**USA**	**Br#144**	**1998-05-25**	**1998-07-30**	**67**
EPA	**USA**	**Br#146**	**1998-05-13**	**1998-07-31**	**79**
EPA	**USA**	**Br#147**	**1997-12-09**	**1998-07-30**	**227**
				Total	**10686**

Table 2: A summary of the International Brewer Umkehr data in the BDMS, up to August 1999.

Agency	Country	Brewer	Min Date	Max Date	Total # of Days
MSC	**CAN**	**Br#007**	**1995-12-04**	**1997-09-23**	**75**
MSC	**CAN**	**Br#008**	**1985-05-23**	**1992-02-21**	
MSC	**CAN**	**Br#009**	**1996-01-27**	**to Present**	**>250**
MSC	**CAN**	**Br#011**	**1996-01-11**	**to Present**	**~1450**
MSC	**CAN**	**Br#012**	**1992-02-14**	**to Present**	
MSC	**CAN**	**BR#013**	**1984-10-17**	**1995-10-25**	**~3400**
MSC	**CAN**	**Br#014**	**1984-09-18**	**1991-12-04**	**~450**
MSC	**CAN**	**Br#015**	**1984-11-08**	**to Present**	**~4500**
MSC	**CAN**	**BR#017**	**1985-07-22**	**1998-03-11**	**~250**
MSC	**CAN**	**Br#018**	**1985-03-26**	**to Present**	**>3300**
MSC	**CAN**	**Br#019**	**1989-07-19**	**to Present**	**>1000**
MSC	**CAN**	**Br#020**	**1987-04-02**	**to Present**	**~700**
MSC	**CAN**	**Br#021**	**1997-03-07**	**1997-10-27**	**182**
MSC	**CAN**	**Br#022**	**-**	**-**	
MSC	**CAN**	**Br#026**	**1986-04-15**	**to Present**	**>2700**
MSC	**CAN**	**Br#029**	**1998-04-16**	**to Present**	**~300**
MSC	**CAN**	**Br#031**	**1987-07-17**	**to Present**	**>500**
MSC	**CAN**	**Br#032**	**-**	**-**	
MSC	**CAN**	**Br#039**	**1989-01-16**	**to Present**	**>700**
MSC	**CAN**	**Br#055**	**1990-09-18**	**to Present**	**>1600**
MSC	**CAN**	**Br#069**	**1997-04-22**	**1997-08-21**	**23**
MSC	**CAN**	**Br#071**	**1997-11-07**	**1997-11-12**	**6**
MSC	**CAN**	**Br#079**	**-**	**-**	
MSC	**CAN**	**BR#080**	**-**	**-**	
MSC	**CAN**	**Br#083**	**-**	**-**	
MSC	**CAN**	**Br#084**	**1992-07-17**	**1992-08-07**	**12**
MSC	**CAN**	**Br#085**	**1994-10-11**	**1994-10-15**	**5**
MSC	**CAN**	**Br#111**	**-**	**-**	
MSC	**CAN**	**Br#119**	**1997-05-09**	**1997-06-03**	**14**
MSC	**CAN**	**Br#145**	**-**		
MSC	**CAN**	**Br#158**	**1999-04-27**	**1999-05-03**	**6**
				Total	**~21500**

Table 3: A summary of the Canadian Brewer Umkehr data in the BDMS, current to August 1999.

M. Newchurch recommended that data quality be discussed further and mentioned the need for more information about the calibration histories of the instruments and an examination of the long-term stability of instruments.

Discussion ensued about instruments being calibrated for total ozone, but not necessarily for Umkehr measurements. E. Hare mentioned that the WOUDC had adopted the recommendation from the Science Advisory Group on UV (SAG_UV) on the use of a Scientific Sponsorship Statement or “Data Passport”. The idea of a Data Passport is being considered by the ozone community as at least a first step toward better describing an instrument’s calibration history. The data passport concept was presented by Hare at a recent SAG_O_3 meeting in May of 1999.

T. McElroy mentioned that a variety of data originators have various ideas on what should be done to the data. He suggests that data flags be added to data to provide some form of uniformity in the database. If nothing else, the flags could be used to indicate departures from the "norm" established by long-term records. However, it was suggested that caution should be exercised here because there is a fine line between data not being sent and the data centre over-stepping its "bounds" in terms what it can do to get data submitted. The SAG_O3 and an Umkehr Steering Committee would go a long way to assist in this process. S. Oltmans mentioned that there are Dobson instruments that are not making Umkehr measurements and others that are, but not submitting data to the WOUDC.

A group discussion followed with the recommendations that an Umkehr Steering Committee would be able to provide a common voice (and a message) to the ozone community in order to better qualify data records.

Summary of Presentations

A new technique for using ground-based zenith sky radiance measurements to verify long-term calibration of satellite ozone profiling instruments. - *P.K. Bhartia*

P.K. Bhartia of the NASA Goddard Space Flight Center (GSFC) discussed the Solar Back scatter UltraViolet experiment (SBUV) and the data from the Dobson instruments and mentioned that Carl Mateer had worked on both of these algorithms. Umkehr Zenith Sky measurements can be thought of as the inverse of satellite observations and vice versa. SBUV and Umkehr measurements are closely related, since they measure skylight scattered vertically by the sky. The Umkehr measurement looks at the zenith sky from the ground (vertically upwards) while the SBUV views the sky from above looking in the nadir direction. Both the Umkehr and SBUV technique use absolute radiances and so calibrations must reflect this fact. The space shuttle SBUV (SSBUV) was flown onboard the space shuttle in order to calibrate the SBUV.

Zenith Sky data from Dobson instruments can perhaps be used to assist in this process. Some researchers at NOAA and within the European community are using "simulated" radiance data to aid in the calibration.

If single scattering models are used, then the results are quite similar. Bhartia acknowledged the efforts of J. Deluisi and I. Petropavloskikh who have been working on this problem.
A comparison of the zenith sky UV to the backscattered UV radiances was presented. For a given wavelength and SZA, the Zenith Sky UV radiances were shown to be less sensitive to the ozone profile than the corresponding backscatter UV radiances. The Umkehr C wavelength pair at 74^o is related to the SBUV/TOMS A pair at 52^o. A large fraction of the Zenith Sky UV variance (for most SZAs) comes from the total ozone and not from the ozone profile. The backscatter UV radiances that provide the profile information are essentially insensitive to the total ozone. The variance in the C wavelength pair N-values, due to changes in total ozone, is >95% at SZAs<80^o and is approximately 50% at a SZA of 90^o.

An analysis of the Zenith Sky UV radiances was examined and it was shown that this analysis is simplified considerably if the radiances are first normalised to a fixed total ozone amount using the following relation:

$$N' = N - b*(\Omega-325) - c*(\Omega-325)^2,$$

where Ω is the total ozone amount and b, c are determined from radiative transfer theory.

The C wavelength pair N' values at SZAs $\leq 77^o$ should be very nearly constant (that is $\sigma(N') < 0.5$) with no seasonal or long term variations. There is no profile information in the C pair Umkehr at SZAs $\leq 77^o$. The C wavelength pair N' values at SZAs $\leq 77^o$ can be used to study absolute errors, drifts and discontinuities in the Umkehr calibration.

The question was asked, "Can you take a Dobson total ozone value and derive the N'?" One can learn much about the extraterrestrial coefficient from N'. There are some intensity features of N' based on balloon data that should be constant. For the C pair N' values at zenith angles less than or equal to 77 degrees this is true. There are no seasonal or long-term variations. But, Bhartia contends there is virtually no profile information in the C-pair Umkehr data at angles less than 77 degrees. The N'(77)-N'(60) provide a "stringent test of the 'Mateer Conjecture'" that the Umkehr N-value errors are independent of SZA.

The effects of clouds on Zenith Sky UV radiances were also presented. Thin clouds effect the Zenith Sky UV intensity ratios more than thick clouds. The Dobson single-pair N-values increase with cloud optical thickness while the double-pairs decrease. The clouds have less of an effect on the single-pair N-values as the SZA increase. This is not consistent with the Mateer conjecture. The Dobson Zenith Sky double-pair ozone values can have 20-Dobson-unit errors under cloudy conditions, but the error does not vary monotonically with cloud optical thickness. It should be possible to derive accurate total ozone values from the Zenith Sky UV under all sky conditions (except thunderstorms), up to SZAs of approximately 85^o, using 2 Dobson pairs (C and D) or three separate wavelengths.

Satellite data can also be used to derive tropospheric ozone data. However, errors are magnified by an order of magnitude so that a 1 % error in total ozone translates to a 10% error in the predicted tropospheric ozone value.

Satellite Total O_3 – Stratospheric O_3 = Tropospheric O_3.

Radiances are large in the presence of thin clouds and will approach zero for optically thick situations. Bhartia believes it is not a signal-to-noise issue, but how does one process the data? The cloud effect is still seen in the double-pair data. Using a Dobson or Brewer, one can expect to get better zenith sky data which in turn may assist us in understanding tropospheric aerosols.

Some discussion followed and D. Wardle mentioned that the Brewer instrument is adjusted for Umkehr versus zenith sky observations by selecting the plane of polarisation. Umkehr measurements are made using the strong polarisation which favours single scattered light. Global radiation is not used to calculate the total ozone operationally, although an algorithm has been developed in Finland to due so. T. McElroy asked about Raman scattering. Bhartia had not yet considered this, but acknowledged that non-spherical scattering needs to be considered. Bhartia endorsed and re-iterated S. Oltmans point about the need for more accurate N-values and that the inversion algorithm is so dependent on these data that this should be viewed as a critical issue.

Developing methods for understanding Umkehr/Brewer radiance data: Application for satellite validation. - *I. Petropavlovskikh*

I. Petropavlovskikh from NOAA presented the results of work investigating high-spectral-resolution (0.05 nm) Zenith Sky (ZS) intensities that were modeled for TOMS standard ozone profiles. This investigation was made in conjunction with the work by P.K. Bhartia et al., previously presented.

A set of thirteen Zenith Sky intensities were modeled for each of the thirteen TOMS standard ozone profiles (3 for 15^o N, 5 for 45^o N and 5 for 75^o N) using TOMRAD RT code (which is the Mateer code modified to account for polarisation effects and the variation of the acceleration due to gravity with altitude). The intensities were normalized to the one at the top of the atmosphere. The extra-terrestrial (ET) solar flux measurements (with the same spectral resolution) and slit functions for 311.46 and 332.4-nm band-passes of the Dobson C-pair (Komhyr et al. [1]) were applied to the normalized spectrum to calculate Umkehr observations. The N-values were calculated by taking $\log_{10}$ (I F_o K / I' F_o' K'), where I and I' are Zenith Sky intensities. The knowledge of an absolute value which includes the ET flux and instrument constants ($\log_{10}$ (F_o K/ F_o' K')) had not been required in the algorithm since all measurements were normalized to N_{60}, thus subtracting the unknown parameters. The ET flux is known to about 1% accuracy (at 1 nm resolution) based on measurements by SSBUV, SUSIM, and SOLSTICE. Bhartia [2] suggests that "there should have been a parallel effort to understand the calibration of the Zenith Sky instruments to see whether the calculated and measured Zenith Sky intensities agree, given the Dobson direct sun, total ozone". The dependence of the N-values on total ozone had been found by regression of modeled N-values to (total ozone - 325 DU) values. Radiative transfer tables were used to take out the effects of total ozone from Umkehr N-values, then analyse the residues to learn about instrument calibration. This can be done readily at SZAs where there is no significant profile effect, which includes N_{60}, N_{65}, N_{70}, N_{75} and N_{77}.

The difference between the N-values measured at the five SZAs (adjusted to 325 DU using a polynomial formula), and the calculated 325 DU N-value is an estimate of an error in the Umkehr instrument constant. Although there may be some residual errors left, due to the ET flux and radiative-transfer model uncertainties, the error should not have any temporal dependence. The residuals were studied to see if there is any calibration/geophysical shift in the time-series. Tateno, Japan and Arosa, Switzerland data seem to have a number of "shifts". After subtraction of normalised N_{60} from the normalised N-values at the rest of SZAs, the magnitude of the shifts had been largely reduced. T. McElroy asked if there were any second order effects such as thermal effects or effects due to the annual cycle? The remaining "unexplained" shifts could be related to the calibration of the instrument (seasonal effect of temperature change as suggested by McElroy) or geophysical (local pollution, volcanoes etc.). P.K. Bhartia also suggested a further examination of the effect of the solar cycle and QBO on the remaining variations in the normalized Umkehr data in order to assess if the remaining shifts are of calibration or geophysical nature.

Development of a global stratospheric aerosol climatology. - *J. Deluisi*

J. Deluisi from NOAA began with a general comment and concern about the need for better "engineering" data on the optical characteristics of instruments, a better understanding of the processing problems, field operations and operator errors introduced into each observation and/or measurement. In the case of the Dobson instruments, records of the wedge calibration is typically kept throughout the use of the instrument. Inter-comparisons make use of Langley analysis for total column ozone and this is a different part of the wedge. Without a good understanding of these problems, much time will be spent analysing these "blips" in data records. A list depicting all the factors that can affect the data was presented and is given in Table 4.

Instrument Make-Up

Element	Effect
Fore Optics	View Angle
Wavelength Discriminator	Accuray
Photon Detector	Sesnsitivity and Linearity
Amplifier	Stability and Linearity
Recorder	Reliability

Aerosol Error Problem Requirements

Optical Depth
Profile
Aerosol Optical Properties
Accurate Radiative Transfer Code

A Priori Information

Climatological Ozone Profile
Profile Error Covariance Matrix

First Guess Ozone Profile

Table 4. Factors affecting Umkehr measurements.

The presentation then shifted to a discussion of stratospheric aerosol climatology and a brief overview of the results of an upcoming paper (in press). A long-term stratospheric aerosol climatology has been constructed from SAGE II spectral extinction measurements, worldwide lidar observations and times series of atmospheric turbidity and transmission data. The results of this study provide important information about the stratospheric aerosol effects on UV radiation and will also provide a more accurate stratospheric aerosol correction for the Umkehr retrieved profiles. The data used for this study is from 1953-1997 and is also useful in estimating errors on other remote sensed data, including climate data.

Much of this study has examined the relationships between aerosol size distributions and extinction as well as other optical properties as a function of wavelength. These relationships provide empirical means for estimating aerosol extinction at various wavelengths, including the UV-B spectrum, from a single lidar backscatter value, or from an extinction value at a different wavelength.

Task and achievements of the European Commission/WMO REVUE project - *R. Bojkov*

R. Bojkov from the WMO gave a brief history and review of the European Reconstruction of Vertical ozone distribution from Umkehr Estimates (REVUE) outlining the working group and its primary members: R. Bojkov (WMO), T. McElroy (Canada), J. Deluisi (USA), J. Miller (USA), S. Godin (France), E. Cuevas (Spain) and C. Zerefos (Greece). The main goal of REVUE has been to assess the quality of Dobson Umkehr data in order to improve the algorithm and the first guess profiles derived from ozonesonde data in order to a produce long-term homogenous data of vertical ozone profiles.

The REVUE committee wanted to look at long station records of both total ozone and Umkehr N-values in order to examine the instrument history and calibration information. Several time series plots were shown indicating a shift in the data sets due to instrument changes. The ratio of the N at SZA = 60 divided by the total ozone value was examined with particular attention given to changes in the ratio of order of 10%.

There are seven main tasks:

1. Total ozone re-evaluation at the Umkehr stations with long records based on instruments calibrations;
2. Analysis of the sensitivity of the retrieval method to temperature changes;
3. Improving the first guess profiles;
4. Complete aerosol corrections to be included in the new algorithm;
5. Using the new data to produce comprehensive analysis of the VO_3D during the past 30-35 years.;
6. Comparisons with VO_3D profiles derived from satellites;
7. Analysis of spatial and temporal variability of ozone oscillations in the vertical (e.g. QBO, ENSO).

The REVUE committee intends to re-analyse the data set with the new processing algorithm called the “Umkehr 99 algorithm” and this new approach will take into account aerosols.

EPA/UGA Umkehr activities - *J Sabburg*

J. Sabburg from the University of Georgia at Athens (UGA) began his presentation with an overview of the Brewer network activities at the UGA in conjunction with the US EPA. There are 21 Brewer sites in the US EPS network and all the Brewer instruments are the MKIV models which means these Brewers are capable of both column ozone and nitrogen dioxide measurements. The EPA Brewer network is currently configured for UV measurements with filters designed for a narrow pass band out to 325 nm and broader filters beyond this wavelength. Current activities are underway to determine the slit function (stray light characterisation) and improve the data processing and quality control/assurance procedures.

Data from several of the Brewer sites were shown with emphasis on the UV portion of the observations. Much discussion ensued regarding the network calibration for ozone and Umkehr measurements and how the EPA/UGA intends to improve the data quality. Sabburg informed the group that he is now in charge of the data quality and he will endeavour to form new contacts and lines of communication with the WOUDC and the Umkehr Steering Committee to improve the status of the network as a whole. An important issue was the operating costs of running such a large network. The EPA Brewer network is the largest of its kind in the world, but the group suggested that a smaller, more manageable network with emphasis on good data would improve the state of the data collected from within the USA.

Sabburg summarised the EPA/UGA activities by indicating that Umkehr measurements are being made at all the Brewer sites but that the ozone data has not been intercompared since the instruments were installed. The question was asked: "Even though the ozone data may not be accurate to +/- 10%, can the research community still use these Umkehr data?"

Umkehr ozone validation - *M. Newchurch*

M. Newchurch of the University of Alabama at Huntsville (USA) presented a variety of topics including his concerns about the state of the data processing of Umkehr data, ozone profile comparisons, Umkehr N-value analysis. And a brief discussion of the 1995 stratospheric ozone profile inter-comparison.

The discussion on data processing concerns began with how the standard Umkehr curves are derived (extracted) from the observed data proceeding to the curve fitting algorithm using the standard 14 SZAs as the standard practice for reporting the N-values. It was suggested that the R-values (the actual R-dial readings from the Dobson) be used, since the N-values are derived from them. Systematic problems were cited in the actual R-value data that cannot be seen in the data reported. When observations are made in cloudy conditions, how do stations estimate cloud cover? The Arosa station was cited as using a Luxmeter for such a purpose. Another concern is the curve fitting procedure. Is this process done at individual stations? And is it a manual process?

Ozone profile comparisons were presented. The Mauna Loa 1995 comparisons showed that Dobson #76 and #83 Umkehr observations were lower than the mean. The SAGE/Umkehr comparison showed a bias with increasing altitude up to 10-15% (Umkehr low) in layer 8, integrated to 5% column bias (Newchurch et al.[3]). This was common to many stations. Step changes with respect to SAGE at Kagoshima station in Japan, in1990 and a drift at the Mauna Loa station, USA for the years 1987-92. The Herman/Mateer forward calculation differences were never resolved. The gravity (z) error of ~2% at 40 kilometres remains in the Umkehr inversion. Empirical (Newchurch and Cunnold [4]) and statistical (Reinsel et al. [5], [6]) aerosol corrections return similar trend results (WMO [7]; Newchurch et al. [8]).

Results from the Umkehr N-value analysis were presented. The time series of N_{60} reveals distribution and abrupt changes. For example: New Delhi in 1973 and 1974, Tateno in 1985, Brisbane in 1976 and 1982, Varanasi in 1976 and Naha in 1987. The time series of N_i-N_{60} in each layer reveals additional discontinuities and aerosol effects. For example: Kagoshima in 198 and 1990 in the upper layers, Arosa shows evidences of the effects from El Chichon and Mt. Pinatubo, there are steep trends at Lisbon in the 1990s. These effects propagate into inverted layer ozone. It was mentioned that difference techniques are difficult to interpret. Sometimes a subset of different observations (e.g. Perth, Australia) is revealed when all the Umkehrs are plotted as an "over plot".

Ozone profile comparisons were presented with a comparison o f the1964 Umkehr model data compared to the currently used, 1992 model. A paper by Burrows et al. [9] was cited as a reference for work currently underway in the area of ozone cross-sections and the determination of new absorption coefficients.

Newchurch concluded his presentation by asserting the aerosol contributions are not significant to the ozone trends seen in the Umkehr data.

Umkehr activities at NOAA-CMDL - *G. Koenig and S. Oltmans*

G. Koenig from the Climate Monitoring and Diagnostics Laboratory of NOAA (USA) described the Umkehr data processing methods used by the CMDL. The CMDL has one of the longest Umkehr records with instruments operating continuously for the last 12-17 years observing two Umkehrs per day. NOAA-CDML is also responsible for the World Dobson standard (#82). There are six Dobson instruments in the NOAA-CMDL network and are summarised in Table 5.

Instrument Number	Location
63	Fairbanks, Alaska (USA)
61	Boulder, Colorado (USA)
85	Haute Provence, France
76	Mauna Loa, Hawaii (USA)
81	Perth, Western Australia
72	Lauder, New Zealand

Table 5: NOAA-CMDL Dobson Umkehr Network

Clear days were used in an attempt see the effects of tropospheric aerosol. The differences between Dobson #65 and other Dobson instruments at inter-comparisons were shown.

In 1996, all Dobson instruments within the CMDL network, were switched over to the current program whereby observations were modified to observe every half degree of SZA. Every Dobson in the network sends the data and lamp tests to the Boulder office, on a monthly basis. The data are edited using Zenith Sky Cloud Detector data collect together with the ozone data measured by each instrument. The files of the N-values for the standard 14 SZA are created and the total ozone is incorporated. The Umkehrs are then inverted, in-house, using the 1992 algorithm as a QA step and the final N-values for the standard SZAs are submitted to the WOUDC where the final inversions are generated by the WOUDC and published. It took approximately one year to get all six instruments converted to the new processing algorithm.

Umkehr Measurements at the Japan Meteorological Agency - *T. Fujimoto*

T. Fujimoto of the Japan Meteorological Agency (JMA) began the presentation by giving an overview of the hierarchy of the JMA and a brief history and description of the observing stations within the network. The ozone and UV activities were also presented. There are six main stations within the JMA network which provides one of the longest Dobson total ozone and Umkehr records in the Global Ozone Observing System (GO_3OS). Information about these stations is given in Table 6. There are several sites that operate both Brewer and Dobson instruments. The Brewer instruments are used exclusively for UV measurements while the Dobson instruments provide total ozone and Umkehr data. The Brewers are calibrated annually and are compared to a standard in Tokyo while the Dobson instruments are calibrated every three years.

Station	Location	In Operation	Instruments	Measurements
Kagoshima	31.6N, 130.6E	March 1958	Dobson/Brewer	Total O3,UV, Umkehr
Sapporo	43.1N, 141E	March 1958	Dobson /Brewer	Total O3,UV, Umkehr
Tateno (Tsukuba)	36.1N, 140.1E	July 1957	Dobson/Brewer	Total O3,UV, Umkehr
Naha	26,2N, 127.7E	July 1974	Dobson/Brewer	Total O3,UV, Umkehr
Syowa	69.0S, 39.6E	January 1977	Dobson	Total O3,UV
Minami Torishima	24.3N, 154.0E	January 1994	Brewer	Total O3,UV, Umkehr

Table 6: Stations and observing systems operated by JMA.

Brewer Umkehr Sensitivity in the Stratosphere - *N. Elansky*

N. Elansky of the Russian Academy of Sciences presented a study investigating the sensitivity of the Brewer Umkehr in the lower stratosphere. The analysis was done using six wavelengths, although the data from eight wavelengths were collected. A paper by McElroy and Kerr [10] was cited for investigating the insensitivity of the Umkehr technique in the lower stratosphere, below 20 kilometres. The main reasons for this insensitivity are:

1. the transformation of their ratios;
2. the normalisation to the first observational angle.

The combination of the weighting functions for intensities and measurement precision are rather good for ozone retrieval with rms errors better than $2x10^{11}$ mol/cm3 from 10 km as reported from Elansky et al. [11], [12].

Comparison of the Measuring-Computer System Theory (MCST) method to the Brewer modification of the Mateer-Deluisi (BMMD) method was presented and the results are given in Table 7. The conclusions of the study show that the MCST method used weighting functions calculated for multiple scattering and the model improved measurement noise. This method provides the opportunity to optimise the procedure for the Brewer Umkehr measurements and the opportunity of express Umkehr observations. A known, minor shortcoming is that refraction was not taken into account.

Brewer characteristics in comparison with Dobson	**Brewer modification of the Mateer Deluisi (BMMD) method**	**Measuring-Computer System Theory (MCST) method**
Measure intensities of zenith sky	Not taken into account: intensities that are transformed to a ratio	Method is optimised for processing intensities
Calibration of relative spectral sensitivity is possible	Not taken into account: normalisation to the first observational angle	Method is optimised for instruments with known relative spectral sensitivity. Could be optimnised for instrument with unknown sensitivity.
Measurement at 8-10 wavelengths	Process 5-6 wavelengths	Process all wavelengths (8 or more spectral measurements

Table 7: Comparison of the BMMD and MCST retrieval methods for Umkehr observations.

Thursday, November 18, 1999

Update on the Brewer Umkehr algorithm - *C.T. McElroy*

T. McElroy presented a brief history of Umkehr measurements made by the Brewer instrument and the development of a Brewer Umkehr analysis, software package. In the early days of the Brewer, data were stored on Commodore PET computers and as a result some of the data for the full suite of 8 wavelengths were lost. So a method was developed to use the standard 5 wavelengths. The standard spline routine was used for the curve fitting and although there are 14 standard SZAs, SZAs between 80^o and 90^o are best. There is not much variation in the curves between SZA angles of 60^o to 80^o. Refer to Figure 1.

If the atmosphere is changing rapidly, then Umkehr information contained in the smaller ranges makes it possible to observe more quickly, without any real loss of information. Typically data are normalised to the start (or first) SZA.

```
double lambda[ N_LAMS ] = { 306.3, 310.0, 313.5, 316.8,\
                            320.0, 323.3, 326.5, 329.6 } ;

L1  L2  L3  L4  L5                  Standard grating angle
            L4  L5  L6  L7  L8      Shifted, Umkehr angle

Standard Umkehr Angles


double thenot[ N_ANGLES ] = { 60.0, 65.0, 70.0, 74.0, 77.0, 80.0,\
                              83.0, 85.0, 86.5, 88.0, 89.0, 90.0 } ;
```

Figure 1. The Brewer wavelengths and standard SZAs.

The Brewer Umkehr analysis is quite similar to the Dobson Umkehr Analysis and is also based on the Mateer & DeLuisi 'short Umkehr'. The current version has 34 optical layers and uses the Rodger's retrieval with the old climatology for the first guess. The Mateer pre-processor step is the same. The differences between the Dobson and Brewer analysis are summarised below:

1. The Brewer analysis handles variable surface pressure.
2. It truncates the first guess at the surface.
3. It produces profiles as an optional output.
4. The code is written in 'C'.

The Brewer Umkehr preprocessing also involves several steps:

1. Correct readings for dark count and dead time.
2. Fit log (counts) with cubic spline.
3. Estimate fitting errors; produce graph file.
4. Look up total ozone value for the day.
5. Calculate values at standard Umkehr angles.
6. Write output file for Umkehr processor.

The various steps in the Umkehr processing stage are given below:

1. Use total ozone, location and date to get first-guess O_3
2. Use total ozone to get multiple scattering corrections

3. Remove estimated scattered light from observations
4. Determine higher-resolution, optical grid O_3 profile
5. Do forward calculation; calculate Jacobean matrix
6. Determine correction using Rodger's method
7. Adjust O_3 profile in Umkehr layers and recycle to 4.
8. When convergence criteria are met - quit.

The following problems have been identified with the current version.

1. Preprocessor works on absolute I's.
2. Preprocessor is unstable with noise.
3. Aerosol not explicitly handled.
4. Covariance matrix not well 'tuned'.
5. Umkehr layer cubic interpolator unstable.
6. Jacobean matrix not correctly determined.

What was investigated were the forward model, the interpolators, the total ozone constraint *vis a vis* differentials, the summing differentials and increasing the signal-to-noise. The Jacobean was revisited and a minor inaccuracy in the calculation of the differentials was noted:

$$\frac{\partial \log(I_j)}{\partial x_n X} = \sum_i \frac{\partial \log(I_j)}{\partial x_i} \frac{\partial x_i}{\partial x_n}$$

where

i - index to fine optical grid
n - index to Umkehr layers

and $\frac{\partial x_i}{\partial x_n}$ Is determined by the interpolation scheme.

The summary of the latest analysis has revealed some interesting issues that may ultimately determine the direction for the algorithm and data analysis development. These points are summarised as follows:

1. Don't interpolate the data!!
2. Interpolate the correction tables.
3. Kick out bad data points (RMS).
4. Include Aerosol explicitly.
5. Use absolute intensities.
6. Possibly include polarization (revisit).
7. (Handle cirrus cloud).

Discussion followed the conclusion of this presentation, focusing primarily on the resulting effect of these findings. J. Deluisi asked the group, that given these new developments, what recommendations should the group make? McElroy suggested changing the covariance matrix and the differentials. S. Oltmans wondered if the residual is used as a diagnostic tool, will this effect be magnified? McElroy replied that the effect should get smaller, but it is not known whether this will improve the Umkehr. It was suggested that a rms residual criterion that eliminates about half of the data be left and then one can proceed from this point. It was also suggested that the observation "noise vector" be left alone for the time being.

Group Discussion, Formation of a Steering Committee and Recommendations

The group as a whole discussed the many issues presented at the meeting. The group agreed that a steering committee for Umkehr would be useful and recommended that all those participants in attendance be on the committee plus those members who were in absentia. Refer to Annex 1. A list of contact information for the meeting participants is given in Annex II.

Following a group discussion about the state of the current algorithm and the proposed new 1999 Dobson Umkehr algorithm, a list of recommendations was drafted and is presented below.

Recommendations

1. Ozone Umkehr data will be processed at the WOUDC; processed data (i.e. profiles) generated elsewhere will not be distributed by the WOUDC.
2. Establish a Steering Committee to oversee the Umkehr algorithm at the WOUDC.
3. Investigate the implications of errors in the Jacobean on Dobson trends.
4. Recommend the resolution of the N-value jumps in the Dobson Umkehr records. Look at ozone standard deviations, slit functions and the effects of stray light.
5. Expand WOUDC record to include information about data quality and instrument history and calibration.
6. Assess the use of multi-wavelength Umkehrs.
7. Call for more Umkehr data to be sent into the WOUDC. This should, perhaps, include R-values along with the N-values already submitted.
8. All Brewer instruments should provide calibrated ozone data to support Umkehr profile analysis.
9. Establish an aerosol correction capability for Umkehr profiles at the WOUDC. Encourage the use of Brewers to determine aerosol optical depth.
10. Determine the value of cloud detection for analysing Umkehr data and recommend their use, if appropriate.
11. Formalise the requirement to compare Dobson instruments for Umkehr observations.
12. Provide information (tutorial) to observers to improve data collection and quality.
13. Maintain dialog between the Umkehr and satellite communities.
14. The re-analysed data using the 1999 Umkehr algorithm should be reproduced by the WOUDC.

References

[1] Komhyr, W.D., C.L. Mateer and R.D. Hudson, Effective Bass-Paur 1985 Ozone Absorption Coefficients for Use With Dobson Ozone Spectrometers, *J. Geophys.Res, 98*(D11), 20451-20465, 1993.

[2] Bhartia, P.K., Personal communication, 1999.

[3] Newchurch, M.J., D.M. Cunnold and J. Cao, Inter-comparison of Stratospheric Aerosol and Gas Experiment (SAGE) with Umkehr[64] and Umkehr[92] ozone profiles and times series: 1979-1991, *J. Geophys.Res, 103*(D23), 31277-31292, 1998.

[4] Newchurch, M.J. and D.M. Cunnold, Aerosol effect on Umkehr profiles using Stratospheric Aerosol and Gas Experiment II measurements, *J. Geophys.Res, 99*(D1), 1383-1388, 1994.

[5] Reinsel, G.C., W-K. Tam and L.H. Ying, Comparison of trend analyses for Umkehr data using new and previous inversion algorithms, *Geophys. Res. Lett., 21*, 1007-1010, 1994.

[6] Reinsel, G. C., G.C. Tiao, A.J. Miller, R.M. Nagatani, D.J. Wuebbles, E.C. Weatherhead, W-K Cheang, L. Zhang, L.E. Fynn and J.B. Kerr, Update of Umkehr ozone profile data trend analysis through 1997, *J. Geophys.Res, 104*(D19), 23881-23898, 1999.

[7] WMO Assessment of trends in the vertical distribution of ozone, Stratospheric Processes and their Role in Climate (SPARC) Report No. 1, World Meteorological Organization Global Ozone Research Monitoring Project - *Report No. 43*, Geneva, 1998.

[8] Newchurch, M. J., L. Bishop, D.M. Cunnold, L.E. Flynn, S. Godin, S. Hollandsworth, L. Hood, A.J. Miller, S. Oltmans, W. Randel, G.C. Reinsel, R.S. Stolarski, R.Wang, E-S Yang, Upper-stratospheric ozone trends 1979-1998, (in press), *J. Geophys. Res*., 2000.

[9] Burrows, J.P., A. Richter, A. Dehn, B. Deters, S. Himmelmann, S. Viogt and J. Orphal, Atmospheric Remote-Sensing Reference Data from GOME – 2. Temperature-Dependent Absorption Cross Sections of O3 in the 231-794 nm Range*, J. Qant. Spectrosc. Radiat, Transfer*, *61*, No 4, 509-517, 1999.

[10] McElroy, C.T. and J.B. Kerr, Table Mountain ozone inter-comparison: Brewer ozone spectrometer Umkehr observations, *J. Geophys.Res, 100*(D5), 9293-9300, 1995.

[11] Elansky, N., O.V. Postylyakov, I.V. Mitin, A.F. Bais and C.S. Zerefos, The extended Umkehr method for retrieving ozone profiles from Brewer observations, *Proceedings of the XVIII Quadr. Ozone Symp*., *L'Aquila, Italy, Volume 1*, 119-122, 1996.

[12] Elansky, N. et al., Maximum accuracy of Umkehr measurements …, *Izvestya, Atmospheric and Oceanic Physics*, 1999.

Annex I: The Umkehr Steering Committee for the WOUDC

Graphic image courtesy of T. Fujimoto

From left to right: N. Elansky, P.K. Bhartia, E. Kosmidis, R. Bojkov, J. Sabburg, J. Deluisi, V. Fioletov, T. McElroy, I. Petropavloskikh, R. McPeters, G. Koenig, M. Newchurch, T. Fujimoto, S. Oltmans and E. Hare

Member	Affiliation	Country
M. Proffitt and R. Bojkov	WMO	
P.K. Bhartia and R. McPeters	NASA/GSFC	USA
T. McElroy, V. Fioletov and E. Hare	MSC and WOUDC	Canada
G. Koenig and S. Oltmans	NOAA-CMDL	USA
T. Fujimoto	JMA	Japan
J. Deluisi and I. Petropavloskikh	NOAA	USA
J. Sabburg	UGA/EPA	USA
M. Newchurch	UAH	USA
N. Elansky	RAS (Russia)	Russia
C. Zerefos and E. Kosmidis	AUTH	Greece
K. Lamb	IOS Inc.	Canada

Annex II: List of Participants

Rumen Bojkov
WMO
P.O. Box 2300
Geneva-2
Switzerland-1211
Tel: 4122-730-8455
Fax: 4122-730-8049
Email: bojkov@wmo.ch

P.K. Bhartia
NASA/GSFC
Code 916
Greenbelt, MD 20771
U.S.A.
Tel: 301-614-6038
Fax:
Email: bhartia@gsfc.nasa.gov

John DeLuisi
NOAA/OAR
325 Broadway
Boulder, CO 80303
U.S.A.
Tel: 303-497-6824
Fax: 303-497-5590
Email:deluisi@smb.noaa.gov

Nikolai Elansky
Institute of Atmospheric Physics
Pyzhevsky 3
Moscow,
Russia
Tel: 095-953-36-95
091-953-87
Fax: 095-953-21-58
Email: nikolai@selansky.home.bio.msu.ru

Vitali Fioletov
Meteorological Service of Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Canada
Tel: 416-739-4915
Fax: 416-739-4281
Email: vitali.fioletov@ec.gc.ca

Toshifumi Fujimoto
Japan Meteorological Agency
1-3-4, Ote-machi, Chiyoda-ka
Tokyo, Japan
Tel: 81-3-3281-3439
Fax: 81-3-3211-4640
Email: fujimoto@met.kishou.go.jp

Ed Hare
Meteorological Service of Canada
and the World Ozone and UV Data Centre
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Canada
Tel: 416-739-4635
Fax: 416-739-4281
Email: ed.hare@ec.gc.ca

Gloria Koenig
NOAA Climate Monitoring and Diagnostics Laboratory
325 Broadway
Boulder, CO 80302
U.S.A.
Tel: 303-497-6685
Fax: 303-497-5590
Email: gkoenig@cmdl.noaa.gov

Evagelos Kosmidis
Laboratory of Atmospheric Physics
Aristole University of Thessaloniki
P.O. Box 149
54006 Thessaloniki
Greece
Tel: 1-31-998009
Fax:
Email: ekosmidi@ccf.auth.gr

Ken Lamb
International Ozone Services Inc.
43 Lehar Crescent
Toronto, Ontario M2H 1J4
Canada
Tel: 416-494-4382
Fax: 416-494-7179
Email: klamb@istar.ca

Carl Mateer
1210-255 Bamburgh Circle
Scarborough, Ontario M1W 3T6
Canada
Tel: 416-499-4134
Fax:
Email: carlmateer@aol.com

Tom McElroy
Meteorological Service of Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Canada
Tel: 416-739-4630
Fax: 416-739-4281
Email: tom.mcelroy@ec.gc.ca

Rich McPeters
NASA/GSFC
Code 916
Greenbelt, MD 20771
U.S.A.
Tel: 301-614-6038
Fax:
Email: mcpeters@wrabbit.gsfc.nasa.gov

Mike Newchurch
University of Alabama Huntsville
Huntsville, Alabama 35758
U.S.A.
Tel: 256-922-5825
Fax: 256-922-5723
Email: mike@atmos.uah.edu

Sam Oltmans
NOAA Climate Monitoring and Diagnostics Laboratory
325 Broadway
Boulder, CO 80302
U.S.A.
Tel: 303-497-6676
Fax: 303-497-5590
E-mail: soltmans@cmdl. noaa.gov

Irina Petropavloskikh
NOAA
325 Broadway
Boulder, CO 80302
U.S.A.
Tel: 303-497-6279
Fax: 303-497-6546
Email: irina@srrb.noaa.gov

Jeff Sabburg
NUV/UGA
Athens. GA 30606
U.S.A.
Tel: 706-592-2127
Fax:
Email: sabburg@hal.physast.uga.edu

David Wardle
Meteorological Service of Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Canada
Tel: 416-739-4632
Fax: 416-739-4281
E-mail: david.wardle@ec.gc.ca

Christos Zerefos
LAP-AUTH
Aristotle University of Thessaloniki
54006 Thessaloniki
Greece
Tel: 3031-998041 (office)
3031-343643 (home)
Fax: 3031-283752
Email: zerefos@ccf.auth.gr