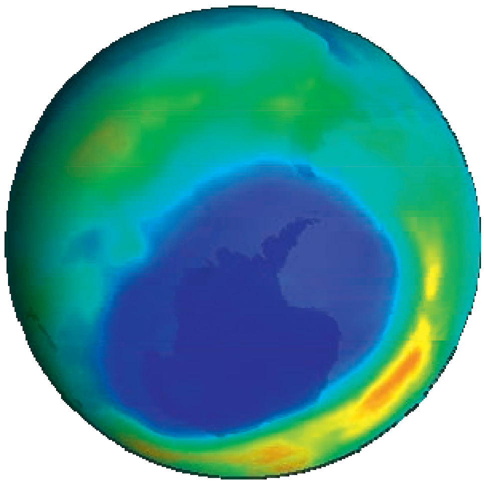
International Association of
Meteorology and
Atmospheric Sciences

IAMAS Publication Series
No. 2

International Ozone Commission: History and activities

compiled by

Rumen D. Bojkov



Oberpfaffenhofen, Germany
August 2012

IO_3C

IAMAS in brief

The International Association of Meteorology and Atmospheric Sciences is one of eight international associations which form the International Union of Geodesy and Geophysics. It has been in existence under changing names since 1919 and promotes research in all topics relevant for the gaseous envelope of the Earth and other planets. Fields of special interest within IAMAS are those addressed by its 10 International Commissions:

* Atmospheric Chemistry and Global Pollution (ICACGP)
* Atmospheric Electricity (ICAE)
* Climate (ICCL)
* Clouds and Precipitation (ICCP)
* Dynamic Meteorology (ICDM)
* Meteorology of the Middle Atmosphere (ICMA)
* Ozone (IO_3C)
* Planetary Atmospheres and their Evolution (ICPAE)
* Polar Meteorology (ICPM)
* Radiation (IRC)

IAMAS acts globally, as indicated in its logo that carries a schematic cyclone in each hemisphere separated by clouds within the tropical convergence zone. A co-operative regular activity is the organisation of large international conferences, either as part of the quadrennial IUGG Assemblies (e.g. 2007 in Perugia, Italy; 2011 in Melbourne, Australia; 2015 scheduled for Prague, Czech Republic) or in their own right (2009 in Montréal, Canada in conjunction with IAPSO for the oceans and IACS for the cryosphere; 2013 scheduled for Davos, Switzerland again with IACS).

More details can be found on the web-site: http://www.IAMAS.org

IO_3C in brief

The International Ozone Commission constitutes an old grouping within IAMAS. Its development over more than eight decades is chronicled in this publication. The role of IO_3C is to promote research into atmospheric ozone as well as application of this research to practical problems. Topics of concern to IO_3C include ground-based and satellite measurement programmes and analyses of the atmospheric chemistry and dynamical processes affecting ozone. The 'ozone hole' over Antarctica in austral spring gained iconic status also for the general public, both in word and depiction (see front and back covers).

More details can be found on the web-site: http://ioc.atmos.illinois.edu

IAMAS Publication Series

This publication continues the IAMAS Publication Series. It serves as a medium for the communication and conservation of material from the Association and its Commissions, which carries sufficient general interest, but is not suited for articles in research journals or scientific monographs. Issues appear when suitable manuscripts are available. Each issue is separately registered with an ISBN from the International Standard Numbering System for Books. Contact the editor for enquiries.

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Foreword

„Gute Zukunft braucht Erinnerung“

A good future requires recollection

Richard von Weizäcker
(German federal president, 1984-1994)

Science marches forward. Nevertheless Richard von Weizäcker's recommendation from a political or general historical perspective also holds in our field.

IAMAS can be fortunate indeed that there exists a sound interest within its International Commissions to compile condensed historical accounts, e.g. from minutes of business meetings and proceedings of scientific symposia. Hans-Jürgen BOLLE set the scene with a detailed illustrated chronology of the International Radiation Commission (IRC) and its predecessors that appeared in 2008 as IAMAS Publication Series (IPS) No. 1.

Rumen D. BOJKOV had started at approximately the same time to compile a similar account for the International Ozone Commission (IO_3C), which he managed as Secretary for no less than 16 years (1984-2000). A first edition was published in 2010 as Publication No. 18 of the Academy of Athens. In parallel to the information available for IRC, Rumen Bojkov amended his material by assembling detailed membership tables and selecting material for appendices. He also provided a number of group photographs, helped to identify on them as many persons as possible, and extended portions of his original text. Hans-Jürgen Bolle read the amended manuscript and made editorial suggestions. On behalf on the entire IAMAS community I am expressing our sincere thanks to both colleagues for their incessant voluntary service.

Organizational matters at the IAMAS Secretariat induced unfortunate delays during the final production of IPS No. 2. Yet, it is anticipated that the participants at the regular Quadrennial Ozone Symposium (QO_3S) scheduled for 27-31 August 2012 in Toronto, Canada, will join me in congratulating Rumen Bojkov for his vivid account and personal perspective about the technical, organizational and cooperative aspects of ozone research around the globe during the past century. It is planned to send a number of copies hot from the press to the QO_3S-secretariat for information and distribution.

As newly elected “atmosphere liaison” of IUGG to the World Meteorological Organization (WMO), it is my special pleasure to witness from the following pages how old and how strong a link used to exist between IAMAS/IO_3C and WMO, not the least through Rumen Bojkov himself. I am confident that factual knowledge contained in IPS No. 2 stemming from the past eight decades will assist all of us in progressing together into a good future for the atmospheric sciences.

Hans VOLKERT

Secretary-General of IAMAS

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Introduction

Even in ancient times, first written descriptions of thunderstorms referred to the appearance of a particular "divine odor". *Homer* refers, both in the Odyssey and the Iliad, to the odor accompanying the thunderbolts. *Jupiter* is said to strike a ship with *"a thunderbolt quite full of sulphurous** odor"* (Odyssey chapter XII and XIV); and to hurls a bolt *"with the flame of the burning sulphur*"* into the ground before *Diomede*'s chariot (Iliad, chapter VIII). We now know that this "divine odor" is due to increased concentration of ozone generated by electric discharges during thunderstorms.

The scientific discovery of atmospheric ozone and the initiation of the first systematic measurements of ozone near the ground dated back to the middle of the 19th century were connected with the name of Christian F. Schönbein (Professor of Chemistry at the University of Basel). While engaged in experiments on the decomposition of water by electricity, he noticed a peculiar odor and aimed at discovering its cause. His communications to the French Academy (Schönbein, 1840a) and to Poggendorf's Annalen (Schönbein, 1840b, 1845) drew the attention of the scientific world to the existence of an atmospheric constituent having a particular odor which he call it ozone (in Greek *'ozein'* means to smell). He considered it to belong to the halogens. Marignac and de la Rive (1845) showed that ozone contained nothing but oxygen. Houzeau (1858) chemically proved that ozone exists in the troposphere, at ground level, and that it must be denser than oxygen (Houzeau, 1865). The latter result was explained theoretically by Odling who described the ozone molecule as *triatomic oxygen*, which was experimentally proven by Soret (1863, 1865). Using the oxidizing capacity of ozone, Schönbein initiated ground-based ozone measurements which spread after the mid-1850s to more than 300 places. Reliable chemical measurements of ground ozone in Montsouris (Paris) were carried by A. Levy from 1877 to 1907 (Levy, 1907). These data show that ground ozone concentrations a century ago were three times smaller than at the present time (e.g. Bojkov, 1986).

The development of the first network of total ozone observing stations was the result of the activities of a small group of enthusiastic scientists guided by the Ozone Commission of the International Association of Meteorology (now IAMAS). Since the beginning of International Geophysical Year (IGY) the development of the ozone observing network, was overseen by the World Meteorological Organization (WMO). To avoid repetitive statements in the text it is emphasised here that since 1956 all intercomparisons of instruments, ozone data collection, scientific assessments, international symposia, and numerous ozone related meetings have been sponsored by WMO. It was playing a leading role in assuring uniformity of procedures, and coordination of ozone studies, including arranging for organization of International Scientific Assessments conducted periodically since 1975 (some with UNEP participation). A formal agreement for collaboration between WMO and the International Association for Meteorology and Atmospheric Physics (IAMAP) has been serving as base for a close coordination of IO_3C activities ever since IGY.

In the following, after a few remarks on the physical basis of the ozone measurements, the history of the IO_3C and related ozone activities are discussed chronologically within the context of 33 conferences and ozone symposia organized from 1929 (Paris) until 2008 (Tromsø).

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* Christos Zerefos considers that the translations referring to sulphur odor should be corrected to refer to divine odor, as the Gods were supposed to possess thunderbolts to hurl around with them.

The Terms of References of IO_3C as determined by its parent bodies IAMAS-IUGG were evolving in line with the developments of the ozone science. The evolution of keys tasks is summarized on page 66.

Physical basis for quantitative ozone measurements

Cornu (1879) noted the sharp limit of UV end in the solar spectrum (<300nm) received at the ground. Hartley (1881a, b) explained the cut-off in UV radiation at 293 nm as due to ozone most of which is located in the stratosphere. The UV absorption by ozone provided the basis for the development of optical instruments for measuring total ozone in a vertical column above the observing point. That was done first by Charles Fabry and Henry Buisson (1913) who made the first careful measurements of the ozone absorption coefficients and estimated its total amount to be ~500 matm-cm. Few years later they returned to the subject and made the first systematic quantitative measurements of total ozone in Marseilles in May-June 1920. They used a double spectrograph able to compare the intensity of two UV wavelengths in the 305-330nm band (one strongly absorbed by the ozone and the other not absorbed) from which reasonable total ozone values of ~300matm-cm in a vertical column of the atmosphere were deduced (Fabry and Buisson, 1921). They thought *correctly* that ozone was formed by solar UV radiation and that if this was so its maximum would be situated at a height of about 40km (later, in the 1930s was corrected to ~22 km).

The first network for daily ozone measurements was initiated by Gordon M. B. Dobson from Clarendon Lab of University of Oxford. Following the method established by Fabry and Buisson he adopted a UV quartz spectrograph using the *Fèry curved-prism* and did built six such ozone spectrographs with a grand from the Royal Society London (Dobson and Harrison, 1926; Fèry, 1911). After 1925 he dispatched these to different Meteorological Services for a year or two in order to study the behaviour of atmospheric ozone in the world and its eventual use in the weather forecasting. Thus, observations were collected in 1926-27 from Abisko (SW), Lerwick (UK), Valentia (IR), Oxford (UK), Lindenberg (GE), Arosa (CH) and Montezuma (Chili); in 1928-29-30 from Oxford (UK), Arosa (CH), Table Mountain (USA), Helwan (EG), Kodaikanal (IN) and Christchurch (NZ). More than 6000 plates of the spectrographs have been developed and analysed in Oxford. From this data

Figure 1.

Charles Fabry (1867-1945), a world authority in the fields of optics and spectroscopy, developer of Fabry-Pérot interferometer, member of the French Academy of Sciences, professor in Marseilles (1894-1920) and after 1921 in Paris, Director of École Supérior d'optique. Together with Henry Buisson he provided the double-wavelength method and the first quantitative measurements of total ozone.

(Credit: George Grantham Bain Collection / Library of Congress, Washington, D.C.)

Figure 2.

Gordon M. B. Dobson (1889-1976) as host at the joint symposium of the IAMAP Ozone and Radiation Commission, July 1959 in Oxford, UK. Dobson was the Chairman of the Committee on Ozone (1933-1948) and first President of IO_3C (1948-1959). He was a remarkable physicist, professor in Oxford, Fellow of the Royal Society. He developed the double quartz spectrophotometer used until today and pursued with unrelenting vigour ozone study all his life establishing the nuclei of the Global Ozone Observing System (GO_3OS). Elected Honorary member of IO_3C in 1963.

(Photo: B.J. Harris, Oxford)

base Dobson et al., (1927, 1929) deduced the basic knowledge of meridional and seasonal ozone distribution: less ozone in the tropics and during the summer and more ozone poleward and during the spring season. In 1930 he did design his own double quartz spectrophotometer from which in the next twenty years about a dozen were produced by a firm for science-instruments *Ealing-Beck Ltd of London* (Dobson, 1931). Before 1951, when the IO_3C started to prepare for the International Geophysical Year (IGY), only less than a dozen stations were having more than 3-years of mostly sporadic observations with the standard Dobson spectrophotometer (Broennimann et al., 2003). Longer records were available only from Arosa, Oxford, Tromsø and Shanghais Zi-Ka-Wey Observatory.

The Commission succeeded to stimulate interest particularly within the meteorological services, and at the start of the IGY there were 32 *reporting* stations increasing for the International Quit Sun Year (IQSY) in 1964-65 to more than 50 and to ~100 in the late 1960s. Until today they form the backbone of the Global Ozone Observing System (GO_3OS) providing ground truth for the more sophisticated satellite observations beginning their global coverage in the early 1970s and more regularly since 1979. The Ozone Commission President (Gordon M. B. Dobson) and Secretary (Sir Charles Normand) were directly supervising production, calibrations and distribution in a global network of the spectrophotometers to be ready for IGY ozone programme (Dobson, 1960). IO_3C until the end of IGY was developing detailed operation manuals, assessing absorption coefficients to be used, providing inspections and advice on how to make vertical ozone distribution measurements using the Umkehr effect (Dobson, 1957a, b). The latter was discovered by F. W. Paul Götz (1931) during his ozone measurements at Spitsbergen starting in 1929. It consists of measurements of the ratio of zenith-sky UV intensities of two wavelengths at 12 solar zenith angles between 60^0 and 90^0. Starting in IGY in USSR (and now in Russia) have been in operation about 30 stations using ozonometers with optical filters (Gushtin, 1963; Gushtin and Sokolenko, 1984). In the last two decades also the use of a more sophisticated Brewer-type spectral instrument started to provide total ozone data from a few dozen stations. Bojkov and Balis (2009) give a review of the development of the global ozone observing network and of ozone trends.

Ozone conferences and symposia (1929-2012)

One convenient way to follow the development of ozone studies and the role played by the group of enthusiastic scientists forming the Committee on Ozone and later the IO_3C is by reviewing the numerous ozone symposia and relevant discussions and recommendations in a chronological order. In Table 1 are listed conferences and symposia on atmospheric ozone organized and/or attended by most members of the Commission. The limited space here does not permit more than scanning through the records and presented papers with emphasis on the first few decades.

The first years of ozone observations and studies are actually less known today for thousands of ozone scientists, because they are mostly not included in commonly available publications of IAM-IUGG. This actually was part of my motivation to prepare this paper, identifying activities and personalities involved and providing interesting information. Starting with the 1968 symposia, presentations were published regularly in voluminous proceedings which are available but can not be summarized in such an article. This is true especially for the booming ozone research period starting in the 1970s, including multi-volume proceedings exceeding thousand pages for most of which references are provided under the common name "Ozone" followed by the year of the symposium. Although IO_3C meetings were coinciding with the symposia the recommendations made are to be found only in protocols and notes prepared by the Secretaries of the Commission scattered in various limited distribution publications of the mother Association (IAM, IAMAP, IAMAS) which are difficult to obtain. In this work brief references are made to the Commission meetings held along with the various symposia aiming to throw light on IO_3C discussions and to mention names of scientists who have made significant contributions. Some more details will be posted on the IO_3C web site (http://ioc.atmos.uiuc.edu) as they become available.

It should be noted as disclaimer that in such historical review mentioning names of active scientists in most cases is without their academic degrees and/or titles and usually their overall contributions to the development of ozone science are not discussed in detail except in relation to the of activities of the Commission.

Committee on Ozone (1933-1948)

The first international scientific *Conference on Ozone and Atmospheric Absorption* was organized by Charles Fabry in May of 1929 in Paris and it had 29 presentations (Ozone, 1929). It was attended by 35 enthusiastic scientists participating in the Dobson and Fabry investigations including meteorologists and few spectroscopists (details in *Appendix 1*). They did form the nucleus of the first society of professionals interested of discussing ozone related questions. Following the Conference, Charles Fabry approached the Forth IUGG General Assembly (Stockholm, **1930**) to establish *"an affiliation to assist exchange of scientific results in the field".* The Assembly expressed interest in the continuation of ozone observations and authorised the establishment of a sub-commission, within the existing Radiation Commission charging Charles Fabry and Gordon Dobson, to layout plans for the future and select other members notable among which were Charles G. Abbot, Anders K. Angström, Daniel Chalonge, F. W. Paul Götz, David Kimball, Rudolf Ladenburg.

No	Title of conference or session in assembly	Location	Duration	#ab	#pa
1	Conference on Ozone & Atmospheric Absorption	Paris	15-17 May 1929	27	
2	Conference on Atmospheric Ozone	Oxford	9-11 Sep. 1936	29	
3	Special meeting on Ozone	Tharant	17-18 April 1944	14	
4	Symposium on Ozone	Oslo	30-31 Aug. 1948	18	
5	Symposium on Atmospheric Ozone	Brussels	30-31 Aug. 1951	15	
6	Symposium on Ozone	Oxford	2-4 Sep. 1954	16	
7	Symposium on Atmospheric Ozone	Rome	10-11Sep. 1954	18	
8	Conference on Ozone	Ravensburg	25-29 June 1956	25	
9	Symposium on Atmospheric Ozone and problems of the Upper Atmosphere	Toronto	10. Sep 1957	10	
10	Symposium on Atmospheric Ozone	Oxford	20-25 July 1959	50	
11	Symposium on Atmospheric Ozone	Arosa	7-11 Aug. 1961	40	60
12	Session on Ozone & Circulation above 20km	Berkley	22-23 Aug. 1963	24	70
13	Symposium on Atmospheric Ozone	Albaquerque	1-5 Sep. 1964	59	83
14	Session on Atmospheric Ozone	Lucerne	27. Sep 1967	17	
15	Symposium on Atmospheric Ozone	Monaco	1-6 Sep. 1968	60	75
16	Symposium on Atmospheric Ozone	Arosa	21-26 Aug. 1972	70	90
17	Sessions on stratospheric composition and anthropogenic perturbations (IAMAS assembly)	Melbourne	12. Jan. 1974	10	100
18	Sessions on fluorocarbons in the stratosphere and dynamic models	Grenoble	27-28 Aug. 1975	18	90
19	Symposium on Atmospheric Ozone	Dresden	9-17 Aug. 1976	100	146
20	Symposium „Consequences of changes in the composition of the stratosphere“	Toronto	26-30 June 1978	65	130
21	NATO Adv. Study Institute „Atmosph. Ozone, its variations, and human influences“	Algarve	1-13 Oct. 1979	53	120
22	Sessions on stratospheric & mesospheric composition, circulation and modeling (IUGG assembly)	Canberra	5-7 Dec. 1979	27	90
23	Symposium on Atmospheric Ozone	Boulder	4-13 Aug. 1980	190	275
24	Symposium on Atmospheric Ozone	Halkidiki	3-7 Sep. 1984	161	220
25	Symposium on Atmospheric Ozone	Göttingen	4-13 Aug. 1988	198	550
26	Symposium on Atmospheric Ozone	Charlottesville	4-13 June 1992	415	520
27	Conference „Ozone in the Lower Stratosphere“	Halkidiki	15-20 May 1995	130	300
28	Symposium on Atmospheric Ozone	L'Aquila	12-21 Sep. 1996	252	622
29	Symposium on Atmospheric Ozone	Sapporo	3-8 July 2000	403	566
30	Symposium on Atmospheric Ozone	Kos	6-12 June 2004	694	700
31	Conference „Ozone Depletion & 20 years Montreal protocol”	Athens	21-27 Sep. 2007	49	120
32	Symposium on Atmospheric Ozone	Tromsø	29 Jun. - 5 Jul. 2008	470	500
33	Symposium on Atmospheric Ozone	Toronto	27-31 Aug. 2012	*planned*	

Table 1.

International Ozone Symposia and Conferences organized by IO_3C, partly within IUGG and IAMAS assemblies (# ab / #pa: no. of abstracts / participants). Since 1964 Ozone symposia have taken place at four-year intervals; they became known as Quadrennial Ozone Symposia (QO_3S).

At the First Conference Dobson had introduced the real meteorological significance of atmospheric ozone with respect to its changes with the weather systems, latitude and seasons. Daniel Chalonge and Paul Götz had reported that they did not detect any diurnal variation in the total ozone content. This was important for the scientists trying to explain generation of ozone. Ozone absorption cross-section was discussed (Charles Fabry, O. Hoelper, M. Lambrey with Daniel Chalonge, Rudolf Ladenburg, and Erich Regener). Total ozone measuring spectrographs were described by Henry Buisson, F. W. Paul Götz, and H. Dember. The relationship between ozone and tropospheric motions was outlined by Vilhelm Bjerknes and its dependence on the climate of the stratosphere by Anders K. Angström. The effect of ozone on the temperature of the stratosphere was discussed by Edward H. Gowan, Beno Gutenberg, and Svein Rosseland. Owing to the then fairly new discovery of the large amounts of total ozone present in the atmosphere at high latitudes, some considered possible that solar corpuscular radiation and magnetic field in the Polar Regions might be a major factor in the production of atmospheric ozone which, after the work on oxygen photochemistry of Sidney Chapman (1930), was understood not to be the case.

Little was known at that time about the vertical ozone distribution (VO_3D) except the wrong impression that ozone maximum is located at 45 km above the ground (Svein Rosseland). Also little was known about the shortwave solar spectrum and the parameters determining the dissociation and recombination of O^1, O_2, and O_3. With a judicious choice of coefficients, partly based on the empirical fact that no diurnal variation was observed in the total ozone amount, Sidney Chapman showed that some of the known facts concerning atmospheric ozone could be explained by a pure oxygen photochemistry:

$$O_2 + hv\ (\lambda < 242.4\ \text{nm}) \rightarrow O + O^1$$

$$O_2 + O^1 + M \rightarrow O_3 + M$$

$$O_3 + O \rightarrow 2O_2$$

$$O_3 + hv\ (\lambda < 1180\ \text{nm}) \rightarrow O_2 + O^1$$

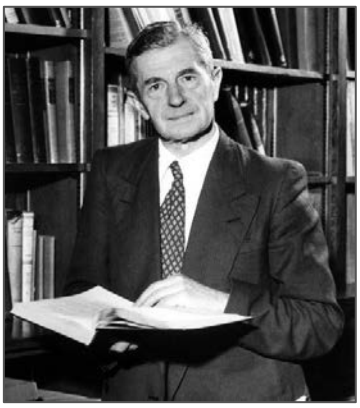


Figure 3.

Sidney Chapman (1888-1970), a renowned mathematician, Fellow of the Royal Society, professor in Oxford, Fairbanks, and Boulder, major contributor to atmospheric physics, geophysics and astronomy. In 1929 he outlined four simple oxygen gas-photochemical equations for the formation and destruction of the ozone layer. He served as President of IUGG (1951-54), was a leading figure behind IGY (1957/58), participated in many IO_3C activities, and had an immense influence on ozone studies until refined theories emerged in the 1960s.

(Credit: http://celebrating200years.noaa.gov).

In Chapman's hypothesis no account was taken of the transport of ozone in the atmosphere, since it could not be quantitatively determined at the time. His model led to a prediction of much greater concentrations of ozone in the tropical atmosphere and much less in the polar, in reverse of those actually observed. Since that time, Chapman has continued from time to time his contributions to the understanding of the photochemistry of atmospheric oxygen and of the ozone distribution in the atmosphere, but his first paper on the subject (Chapman, 1930) deserves special mention because it was the first theoretical interpretation of the distribution and time variation of ozone, and it set the pattern for later work, leading him to the prediction that in the ionosphere the oxygen is largely dissociated, an entirely novel conception.

In September **1933** at the Fifth Assembly of IUGG in Lisbon, one of the themes for discussion at the International Association of Meteorology (IAM, meanwhile IAMAS) was the *"Geophysical knowledge of the stratosphere".* The great Master of Optics, Charles Fabry, with Henry Buisson co-founder of the modern observations of atmospheric ozone, spoke on the ozone absorption spectrum and absorption coefficients. He emphasised their fundamental importance in ozone studies. He stressed the need to understand better the vertical ozone distribution and the potential of using the light from the zenith sky for this purpose. The technique was proposed by F. W. Paul Götz and termed "Umkehreffekt". Dobson and Götz reported that the first "Umkehr"-observations led to the conclusion that the height of the centre of gravity of ozone in the atmosphere was at about 22 km instead of 45 km as had been thought before (Ozone, 1935). This finding made easier to understand the connection between the ozone changes and the weather systems, as well as the impact in improving of Sidney Chapman's postulated ozone photochemistry.

The IUGG Assembly recognized the importance of ozone research for understanding the stratospheric processes. To assist exchange of scientific results in the field it established the *Committee on Ozone* within the Radiation Commission of IAM as was requested by Charles Fabry and recommended by the Fourth IUGG Assembly at Stockholm (1930). The Committee included Gordon M. B. Dobson (chairman), Charles Fabry and F. W. Paul Götz. This Committee was assuring an informal connection between the few dozen scientists interested in atmospheric ozone up to the time after the Second World War when IO_3C was formally established by IUGG in Oslo in 1948.

The Fifth IUGG Assembly recognising the importance of Paul Götz studies on the vertical ozone distribution using the Umkehr effect, added 1000 Sw.Fr. to the previously allocated 4912 Fr.Fr. grant of support which had enabled his expeditions to Spitsbergen and maintained the ozone activities at Arosa (Ozone, 1935).

In September **1936** a, for the time, rather large second Ozone Conference took place in Oxford with 58 participants. It was organized by the Committee on Ozone. Titlepage and table of contents of the proceeding are given in *Appendix 2*. They were published in a Supplement to the *Quarterly Journal of Royal Meteorological Society* with financial assistance by the IAM (Ozone, 1936a). The 29 presented papers did cover methods of measurements of total and vertical ozone distribution (VO_3D), absorption of radiation and temperature of the upper atmosphere, ozone and weather conditions and finally few interesting but diverging views on ozone photochemistry. In the next week the Sixth IUGG General Assembly was held in Edinburg. Two impressive papers on the role of ozone in absorbing radiation and warming stratospheric temperatures were presented by Rudolf Penndorf (Leipzig) and by Oliver R. Wolf & Lola S. Deming (Washington, DC) (Ozone, 1936b).

Acting on the proposal by the Committee on Ozone *"in order to determine the relations between the ozone variations and the meteorological conditions"* the Sixth IUGG Assembly in 1936 allocated to the Committee on Ozone international funds (initially 1200£) for stepwise purchasing of three Dobson spectrophotometers (Ozone, 1936c). That was done but they were distributed, together with two more instruments both by the Commission with grant from the Science programme of UNESCO, only after the end of Second World War as follows:

#**13** lent to Lisbon (before was shortly in Azores) used until 2002, then lent to Arosa;

#**14** lent to Tromsø / Spitsbergen until 2000. In 2008 was still there unused;

#**15** lent to Arosa (used until 1992, then in 2001 lent to Botswana);

#**50** lent to Reykjavík where is used until present;

#51 lent to Aarhus, then in 1964/65 to Belgian-Dutch Antarctic base and in late 1960s lent to Arosa, automated in early 1970s and used until present.

It should be noted that from the mid-1930s up to 1951 only 12 stations have been taking ozone measurements for more than 3 years although irregularly. Longer series were available from Arosa and for some periods from Oxford, Tromsø and Zi-Ka-Wey (Shanghai). Gordon Dobson was taking care for improving the operation and sensitivity of his instrument and providing guidance to observers. Outside UK, particularly in India, France and Germany more studies started to be directed towards various theoretical aspects related to the ozone distribution.

During the Second World War activities and communications between scientists were very limited. However, on 17-18 April **1944** despite the War situation one of the Committee on Ozone members (Paul Götz) participated in Tharandt (Germany) at an, regarding its content, important two-day Special Meeting on Ozone with more than 25 participants presenting 14 papers (Ozone, 1944). This meeting was organised with the leadership by Ludwig Weickmann, Professor at University of Leipzig and long-time supporter of ozone studies. Paul Götz provided an extensive review on the state of ozone research with emphasis on the possibilities offered by the Umkehr method for studies of the vertical ozone distribution (VO_3D). Such data together with the newly detected by German colleagues' very cold stratosphere could assist the explanation of the observed annual, latitudinal and VO_3Ds. There were detailed reviews of photochemistry by O. Hoelper and E. Schröer.

The first VO_3D direct measurements by stratospheric balloons establishing that the ozone maximum at middle latitudes is at ~22km, and the role of turbulence were presented by Erich and Victor H. Regener. An optical-filter radiosonde with Cadmium photocell receiver constructed in Leipzig was described by Dietrich Stranz. Other papers concerned: Weather systems and related ozone changes (Moser); Radiation

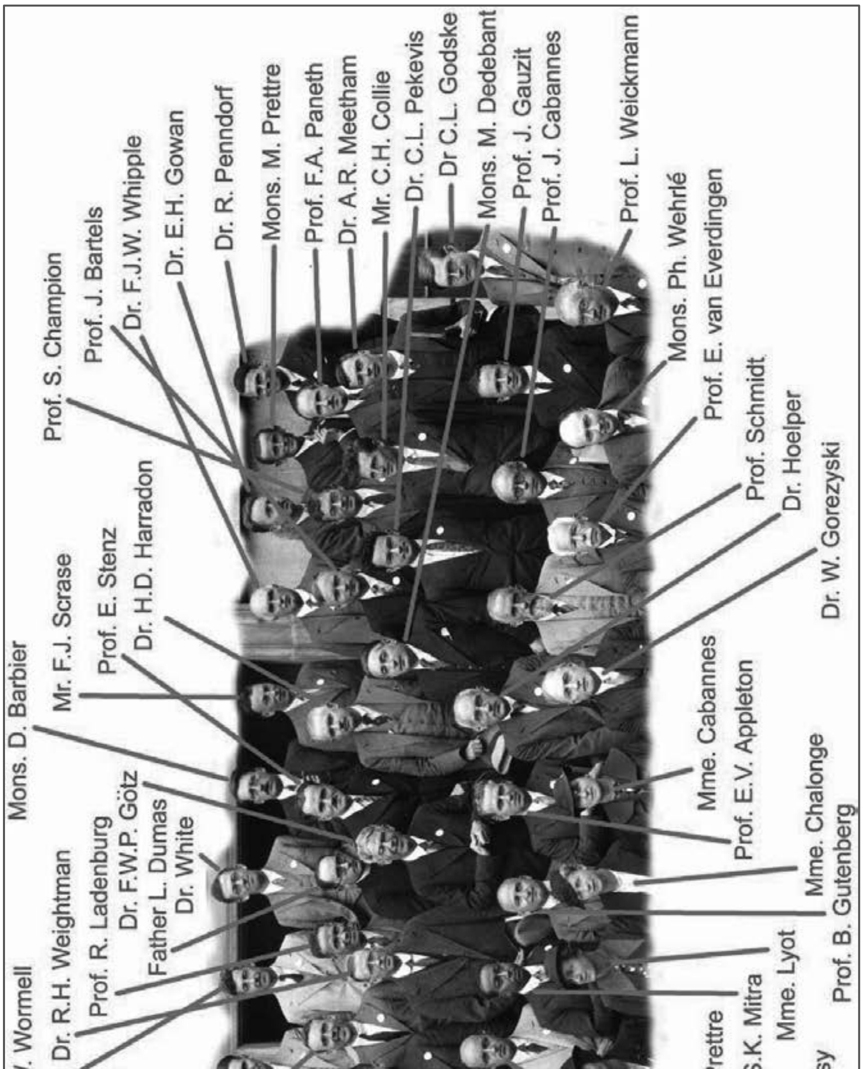


Figure 4.

Participants of the Ozone Conference held in Oxford, 9-11 September 1936. Remarkable is the mixture of many pioneers in ozone studies with prominent figures of general meteorology and national meteorological services. (Courtesy: Oxford university) and stratospheric temperature (Rudolf Penndorf); Strato-tropospheric transport, and tropospheric ozone (Alfred and Hedwig Ehmert). The high scientific level of the articles was impressive for their time. This was practically the first ozone meeting with detailed discussions on basic issues of ozone photochemistry, vertical and horizontal distribution and changes, without spending too much time on instrumentation and methods of measurements.

International Ozone Commission and preparation of International Geophysical Year (1951-1958)

In August **1948** the Seventh IUGG Assembly was held in Oslo. It formally established the International Ozone Commission with President Gordon M. B. Dobson and Secretary Sir Charles Normand (both from University of Oxford) and six other members: Daniel Chalonge (l'Observatoire de Paris), F. W. Paul Götz (Arosa Observatory), Kalpathi Ramakrishnan Ramanathan (PRL, Ahmedabad), Einar Tönsberg (Tromsø Observatory), Etienne Vassy (Sorbonne, Paris), and Oliver R. Wolf (US Weather Bureau, Washington DC). This was a very significant event giving official recognition to the importance of ozone monitoring and research. The aims of the Commission were defined as *"In accordance with the programme of the Association to organise an ozone survey for Western Europe and at the same time assist the establishment of ozone stations in other parts of the world as opportunity presented itself"* and "*to guide the stations operations to be conducted in comparable manner"* (Ozone, 1948a). We note that the IO_3C was only the second commission within the International Association of Meteorology (now IAMAS has ten). Detailed listings of all members of the IO_3C from 1948-2008 are given in *Appendix 3* (sorted by election period, honorary membership, and alphabetical).

An Ozone Symposium was held at Oslo at which a total of 18 papers were presented: On the ozone photochemistry, turbulence and transport in lower stratosphere (Sidney Chapman, Hans U. Dütsch, and Richard J. Reed with A L. Julius); On the vertical ozone distribution (Paul Götz, G. Walton, Heinz-Karl Paetzold and R. Tousey with K. Watanabe, J. D. Purcell, F. S. Johnson); The temperature of the ozonosphere, Huggins band absorption and ozone at Edmonton (Edward H. Gowan, R. H. Kay); Tropospheric ozone (Erich Regener, Alfred Ehmert, H. Ungeheuer); Ozone and meteorological conditions (Charles Normand, Einar Tönsberg, Alan W. Brewer, Sigmund Fritz, Yoshio Miyake with K. Saruhashi, and by Gordon Dobson with Charles Normand and R. H. Kay). Dobson reported on European ozone network studies done since 1936 *(*Ozone, 1948b*).* A summary of the recent work on ozone was published by Charles Normand (1951).

In the next three years the IO_3C carried in Oxford the rebuilding of nine pre-war instruments to the new standard design using photomultiplier, and a total of 24 newly build instruments were calibrated and compared in order to start the European ozone study with updated instruments. In the meantime the Meteorological Offices at number of countries had ordered new instruments i.e. Belgium (1), Canada (4), India (3), Italy (3), Japan (1), Spain (1), UK (3), and USA (5). Also the University of Uppsala (1) and the IO_3C by itself purchased 2 more instruments for eventual loan to stations of interest. At that time the price of a new Dobson spectrophotometer was 1275 £. The main grants for instruments and meetings of the Commission were coming from IAM and UNESCO. This is exemplified through the published Financial

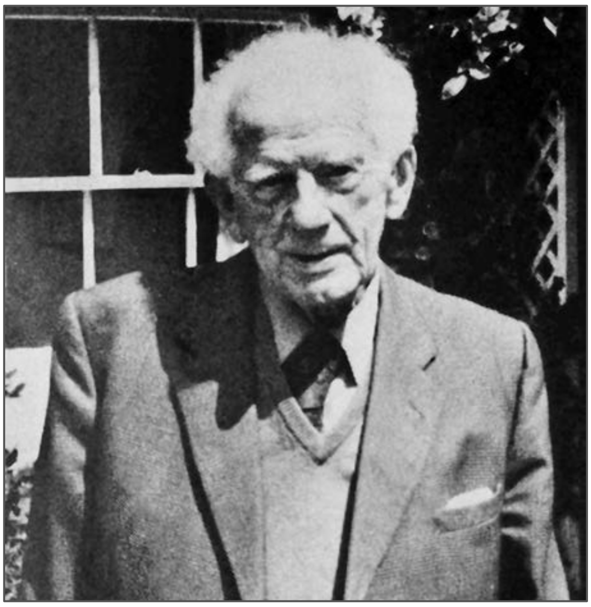


Figure 5.

Sir Charles Normand (1889-1982) was the first Secretary of the IO_3C. Educated as atmospheric physicist in Edinburgh, he made a carrier in India (Director General of the Meteorol. Office 1927-1944, founding member of the Science Academy of India). With K. R. Ramanathan he introduced ozone observations already in the 1930s. From 1946 to 1959 he worked with Gordon Dobson in Oxford on im-proving and calibrating practically all Dobson instruments for the IGY. He wrote the instructions for the measurements using AD wavelengths, guided the operations and performed first analyses of the data from European Ozone Project sponsored by IAM-IUGG, and served as President of the Royal Meteorological Society (1951-1953).

(Photo credit: WMO Bulletin)

Statement of the IO_3C for 1949-1951 (see *Appendix 4*; Ozone, 1948a). Additionally, IO_3C received for some years a grant of ~200 £ for clerical assistance at Oxford related to its main task – the west European ozone survey with participation of 16 stations. Some similar annual grants were made also available by the Royal Society London. The President and Secretary were not paid extra although they were working full time on upgrading and calibrating each one of the instruments produced by Ealing-Beck Ltd. of London. They prepared also instructions for the observers.

In August **1951** a two-day Ozone Symposium was held in Brussels at the time of the Ninth IUGG Assembly. There were 15 presentations (Ozone, 1951). These papers discussed the formation of ozone (Sidney Chapman, Hans U. Dütsch, Marcel Nicolet); the VO_3D (Paul Götz, Heinz-Carl Paetzold); the mechanisms for transport in the lower stratosphere (Richard J. Reed with A. L. Julius); and ozone vertical distribution up to 70km (R. Tousey with K. Watanabe, J. D. Purcell and F. S. Johnson). In addition there were reports on tropospheric ozone studies (Erich Regener, Alfred Ehmert, H. Ungeheuer); ozone in Tromsø (Einar Tönsberg); temperature of the ozonosphere and ozone in Edmonton (Edward H. Gowan); meridional variations of atmospheric ozone (Yoshio Miyake with K. Saruhashi). At that Commission meeting as well as at the following in Oxford in September 1952, attention was given exclusively on ozone measurements (incl. zenith sky readings) their reductions (incl. absorption coefficients, haze and temperature effects) and instruments maintenance. At the latter ozone meeting participants from 9 European countries discussed progress of the European Survey of Ozone which concentrated mainly on relations with the weather systems. The membership of IO_3C was kept to members elected in Oslo but instead of Oliver R. Wolf (US Weather Bureau) was elected Victor H. Regener (University of New Mexico). His father Erich Regener (Professor in Stuttgart) was co-opted in 1951 for his extraordinary expertise in ozone measurements with balloons and in tropo-stratosphere turbulence exchange affecting ozone distribution. For membership listing see *Appendix 3a.*

At that time plans for organizing the International Geophysical Year (IGY 1957/58) were initiated and Marcel Nicolet as Secretary-General of the Scientific Committee for IGY urged the IO_3C to start implementing broad global coverage of ozone measurements.

For implementing this formidable task in Marcel Nicolet approached and convinced the World Meteorological Organization in **1953**, as co-organizer of IGY, to use its influence with the national meteorological services for arranging the ozone measurements and calibrations following uniform operational procedures with the understanding that the IO_3C will be providing the methodological guidance. These relations were formalized in 1957 and successfully implemented ever since. By 1953 the IO_3C did have its own five Dobson spectrophotometers used for improving the data coverage in the European region as mention above.

In September **1954** in Rome in connection with the Tenth-IUGG Assembly the next Ozone Symposium was held with 32 participants from 11 countries. Presented were 18 papers on ongoing ozone research (Ozone, 1954a). These included an extensive review on “Atmospheric ozone and the general circulation of the atmosphere” by K. R. Ramanathan (as his IAMAP Presidential Address). Using availability of new VO_3D profiles observations he raised for the first time quantitatively the subject of possible meridional transport of ozone from the Equatorial generating region toward the polar latitudes. In the tropopause discontinuity around sub-tropical and polar jet-streams he assumed the possibility for stratospheric ozone being injected into the tropopause. He demonstrated that “the steep increase in ozone amount to the north of 30^0 is associated with the steep lowering of the tropopause in the same direction”. Particular case for the insufficiency of the oxygen-photochemistry to explain alone the annual distribution without involving meridional transport of ozone was made also by Hans U. Dütsch and by Heinz-Karl Paetzold. Charles Normand presented detailed results including plots of seasonal and latitudinal changes derived from European ozone studies carried in 1950-54. He has emphasis that the passing of major meteorological disturbances (e.g. depressions) are detected in the data of all 16 stations. Measurements and theory of the nocturnal ozone were reported by E. M. Fournier D’Albe, and Daniel Chalonge. Study of the ozone above 50 km made by rockets in USA was reported by F. S. Johnston.

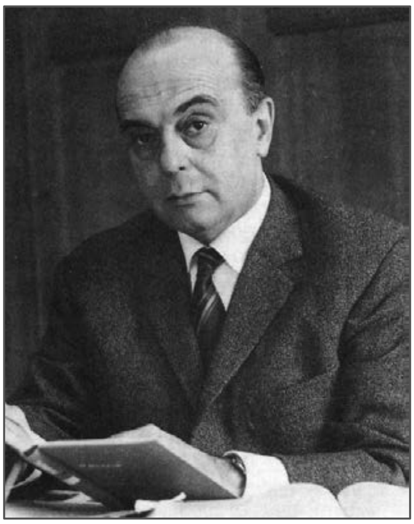


Figure 6.

Baron Marcel Nicolet (1912-1996). Trained as meteorologist, he enjoyed a wide reputation in radiation, ozone, ionosphere (he postulated the D-region) and established the subject of aeronomy. As Secretary-General of the Scientific Committee for IGY (1952-1959) played a decisive role for inter-national co-operation and induced the WMO to lead the GO_3OS. He was founding Director of Institute of Space Aeronomy in Brussels (1964-1986), President of IAGA, member of the Science Advisory Committee of WMO (1962-1969), member of the Belgian, French and USA Academies of Sciences and participated in the work of IO_3C from its beginning (Honorary member since 1987).

(Photo credit: WMO Bulletin)

The interest to the role of hydroxyl radical (OH) in the day/night regime and possible catalytic ozone destruction by HOx in the upper stratosphere was discussed by Marcel Nicolet. His idea first outlined by Bates and Nicolet (1950) was probably the first hint to the role of catalytic reactions in the destruction of the stratospheric ozone. It was twenty years later when Paul J. Crutzen (1970) did show that this is not sufficient to explain the state of ozone in the middle stratosphere and evoked the role of NO and NO_2 as catalysers.

The meeting of the IO_3C was held at the same time (Ozone, 1954b). In the past few years in accordance with the tasks outlined by IAM in 1948 and 1951 the basic aim of the IO_3C has been to promote and help to maintain the ozone survey in Western Europe and to give such assistance as may be possible to ozone observers elsewhere. Analyses of the collected data were presented by the Commission Secretary Charles Normand as mentioned above. At this time the main issues discussed by the IO_3C were related to the preparations for the ozone measurements in the forthcoming International Geophysical Year (IGY). A revised Handbook for Operation of Dobson Spectrophotometers during IGY was prepared by Dobson (1957a). The use of double wavelengths method (A-D) as proposed by Charles Normand, was agreed to be the standard method for observations since it is nearly eliminating the effect of aerosol scattering. New absorption coefficients based on Ernest Vigroux (1953) studies were adopted to be used from 1 January 1956. To transfer data calculated using Ny and Choong (1932) absorption coefficients to the new Vigroux absorption coefficients scale, they should be multiplied as follows: These obtained using C[1] wavelength of the Dobson instrument x 1.45 and if A-D wavelengths were used x 1.37.

Alfred Ehmert emphasised the usefulness of ozone-soundings. It was clear that an adequate explanation of ozone changes and transport was hopeless until more and better data on the vertical ozone distribution (VO_3D) are accumulated and the Commission appeal that this should be done wherever it is possible.

IO_3C noted that there are totally 34 instruments completed and 7 are under construction to be ready before the IGY. The problem with the deterioration of the densities on the optical wages of carbon-in-gelatine type required replacement by new type of metal-coated wages. There was some urgency in this issue, since the wages are an essential part for stability of the measurements with Dobson spectrophotometers.

As it was mentioned the collaboration with WMO for the encouragement of expansion of the ozone network started in 1953. The combined efforts by IO_3C and WMO were considered very fruitful. At the time of the beginning of IGY already 32 stations were reporting ozone data. At the request by the Commission WMO took the responsibilities of collecting and publishing the data and organizing periodic intercomparisons.

With WMO and UNESCO support the President was able to make a part-time appointment of a travelling physicist (C. Desmond Walshaw, from October 1955 to July 1957) with the duty to inspect and improve operations of most of the European instruments before the start and during the IGY. The Commission noted with regret that one of the pioneers of ozone research, Paul Götz, has died just before its meeting in Rome. The elected members of IO_3C included: Arthur Adel (University of

[1] The most frequently used pairs of wavelengths (in nm) in the Dobson spectrophotometers are: A (305.5/325.4), C (311.4./332) and D (317.6/339.8). The AD method uses the differences between A and D measurements.

Figure 7.

Stations with Dobson type spectrophotometers 1951-1956. With the efforts of IO_3C they increased from less than 12 (before 1951) to 32 at the start of the IGY (currently there are more than 100 stations, see Figure 17).

Arizona), Daniel Chalonge (l'Observatoire de Paris), Gordon M. B. Dobson (re-elected President), Alfred Ehmert (Max-Planck Institute for Physics of the Stratosphere, Weissenau), Edward H. Gowan (University of Edmonton), H. Köhler (D), Yoshio Miyake (MRI, Tzukuba)), Charles Normand (re-elected Secretary), K. R. Ramanathan, Erich Regener (University of Stuttgart), Victor H. Regener (University of New Mexico), W. C. Swinbank (Weather Bureau, Melbourne), Einar Tönsberg (Tromso Observatory), Etienne Vassy (Sorbonne, Paris) and Harry Wexler (US Weather Bureau). Also Marcel Nicolet (Brussels) was co-opted as having a leading role in research and arrangements for ozone measurements during the IGY *(see Appendix 3a, c).*

In **1956** the interest toward better understanding of the behaviour of atmospheric ozone was inspired in part by the increased observational activities in preparation for the IGY. That stimulated the holding of another IO_3C Ozone Symposium. This was hosted by Alfred Ehmert from the Max-Planck Institute for Physics of the Stratosphere, Weissenau near Ravensburg (25-29 June 1956). About 40 scientists from 15 mostly Central European countries but also 4 from USA, 2 from India, 1 each from Canada, Pakistan, Japan and Island attended and discussed both total and vertical ozone measurements, standardising the procedures for IGY. The President of IAM, K. R. Ramanathan reported that in India they achieved an improvement in the retrieved ozone profiles from Umkehr observations when consider also the secondary light scattering. K. R. Ramanathan and G. F. Walton have completed writing a monograph for use of two methods for retrieving of VO_3D from Umkehr measurements (their papers were included in the IGY Annalen, Vol. 5, p. 9-45). Gordon Dobson with Charles Normand had distributed two Handbooks with guidance for ozone observations during IGY. One is intended for helping technical assistants (Dobson, 1957a) and the second is for physicists supervising the stations (Dobson, 1957b). Some prototypes for balloon-borne ozonesondes were presented (e.g. Victor H. Regener's photoluminiscent, Heinz-Karl Paetzold's optical filters, and Arlette Vassy's spectral). The Commission has appeal to all stations for conducting as many as possible Umkehr observations during the IGY. Kaare Langlo from WMO informed the meeting that his Organization has accepted to collect and publish all ozone data from IGY. The special forms for submission were discussed.

The IO_3C set up 3 Panels: on infra-red methods for determination of the VO_3D, on Umkehr evaluation methods and on measuring of ozone concentrations near the ground, which were expected to report to its next meeting. The Commission elected Heinz-Karl Paetzold (Max-Plank Institute Weissenau, later Professor in University of Köln) and Giorgio Fea (Director-General of Italian Meteorol. Service) to its members.

In September **1957** at the Eleventh IUGG Assembly in Toronto a one-day Symposium on Atmospheric Ozone and Problems of the Upper Atmosphere was held jointly with IAGA under the chairmanship of K. R. Ramanathan (Ozone, 1959b). He has made detailed review of the expansion of the ozone network during the IGY and some of the results. Four of the ten presentations (F. N. Frenkel, Heinz-Karl Paetzold, Hans U. Dütsch and G. F. Walton,) covered VO_3D measurements with applications to atmospheric circulation for ozone and water vapour. Tree other papers described total ozone data analyses over Kashmir 34^oN (R. N. Kulkarni with K. R. Ramanathan), Quetta, Pakistan (Abdul Halim) and over Weissenau and Zugspitze in Germany (Heinz-Karl Paetzold with H. Zschörner). Alan W. Brewer reported that UK observations showed remarkably unvarying low water vapor content in the lower stratosphere and that at 48,000 feet the frost-point is always very close to 190^oK. This was important for applying the Brewer-Dobson circulation scheme for ozone distribution in the stratosphere poleward from the tropical ozone-source-region.

At that time the open air tests of hydrogen bombs were reaching the altitude of the maximum density of the ozonosphere injecting dust, vapour and various gasses which was discussed by Anatol J. Schneiderov (USA). The explosions were emitting both corpuscular and ultra-short energy radiation which, under certain conditions, can dissociate O_2 and generate O_3. Much later, in the early 1970s, higher concern for the Commission was the generation of NO and NOx produced in the heated air by the stratospheric nuclear explosions, and their harmful effect on ozonosphere which was explained by Crutzen (1970) and Crutzen et al. (1975). The Commission noted that progress was made in (a) the evaluation of the contribution by the secondary UV scattering to the Umkehr retrieval; (b) the development of photo-cell and optical filters for use in radio-sondes; (c) the improvements of the technique for chemical measurements of ozone by airplanes and radio-sondes and (d) studies of the infra-red method of deter- mining VO_3D. Accurate knowledge of ozone, upper air temperature and water vapor are expected to contribute toward the better understanding of circulation of upper troposphere and lower stratosphere. To the membership from Rome-Ravensburg the following scientists were added:

Figure 8.

Participants to the Ozone Symposium held in Ravensburg, 25-29 June, 1956. (Partial identification of persons and their countries of affiliation in 2011. Source: Dobson, 1968, Fig. 18, p.405)

Richard A. Craig (Professor at University of Tallahassee, FL), Hans U. Dütsch (University of Zürich and Arosa Observatory), Warren L. Godson (Director of Research, Meteorological Service of Canada), Genady P. Gushtin (Main Geophysical Observatory, Leningrad), Alexandar Khr. Khrgian (Professor of Physics, University of Moscow) and Marcel Migeotte (Belgium). Those changes were bringing the total number of scientists to 20 after the passing away in previous year of Erich Regener the pioneer for spectral ozone measurements by balloons and rockets. For a listing of all members see *Appendix 3a.*

In Toronto the IO_3C and then IAM-IUGG (1957) adopted Resolution IV formally appealing to WMO in view of the global expansion of ozone observing stations to take over the standardization, analysis, calibrations, data publications and related activities which will be of interest to many national Meteorological Services (Ozone, 1959b). WMO was already collaborating with IO_3C since 1953. It has also appointed the Commission member Warren L. Godson as Chairman of a small Working Group for advice on Atmospheric Ozone within WMO research arm the Commission for Atmospheric Sciences (CAS). Following the IAM-IUGG request and on proposal by its Working Group, the WMO Congress (1959) formally agreed to extend WMO activities to include international ozone work. The WMO obligations referred to:

(i) maintenance of catalogue of stations and observations;
(ii) organizing intercomparisons of instruments;
(iii) development of instructions, handbooks for standard observations and instrument calibrations and
(iv) provision of general guidance on instrumental and observational problems.

The IO_3C retained its general scientific interest in ozone work and mainly for organizing symposia on atmospheric ozone and for developments of fields which are not yet routine and also retained the ownership of the five Dobson spectrophotometers which were on loan to various stations, at that time, at Spitsbergen, Aarhus, Arosa, Santa Maria in the Azores and Reykjavik (Ozone, 1959b).

The Toronto IUGG Assembly also decided to change the name of the International Association for Meteorology (IAM) to International Association for Meteorology and Atmospheric Physics (IAMAP) in order to better reflect its actual activities and responsibilities within the IUGG and to avoid some potential overlapping with International Association for Geophysics and Aeronomy (IAGA).

In the next years the IGY gave a great impetus to the study of atmospheric ozone. The network of stations for the observations of both total and vertical ozone distribution (VO_3D) widened, particularly in the polar regions of Canada, USSR and Antarctica. There has been a considerable increase in the knowledge about polar ozone and about its vertical distribution at various latitudes.

Oxford symposium fostering inter-commission cooperation (1959-1965)

In July **1959,** after the end of IGY, about 160 scientists from 17 countries met in Oxford at a Joint Symposium with the Radiation Commission to discuss preliminary results. The Joint Symposium was sponsored by WMO and ICSU (Ohring et al., 2009). At the ozone part the participants presented 50 papers (Ozone 1959a). Along the usual topic for accuracy and improvements of total and VO_3D (Umkehr, balloon-borne-sondes, aircraft) measurements, for the first time in more details were

Figure 9.

Kalpathi R. Ramanathan (1893-1984), physicist, honorary fellow of Royal Meteorological Society, Director-General Meteorological Service of India (up to 1948), and of Physical Research Laboratory in Ahmedabad (1947-1969). Elected President of IAM (1951-54), IUGG (1954-58), IO_3C (1959-68). In the late 1930s he introduced the ozone monitoring and research in India, made major contributions to ozone in relations with atmospheric circulation including the concept for meridional transport of ozone from the tropics towards to poles, biennial oscillations and to the evaluation of Umkehr obser-vations. In 1971 elected Honorary member of IO_3C.

(Photo credit: WMO Bulletin)

considered their relations with the 100 and 25 hPa temperatures and wave disturbances in the stratosphere on a synoptic scale (F. Ken Hare). The explosive increase of ozone by abrupt termination of the Arctic winter circulation with a final warming and transition to the summer easterly transport when there is practically no phase difference between ozone and 100hPa temperatures was discussed by Warren L. Godson (1960, 1963). Special attention was given by K. R. Ramanathan to the ozone distribution and stratospheric circulation with illustration for the winter vs. summer circulation in the Northern Hemisphere reflecting a very highly asymmetric distribution of the ozone in exactly opposite sense from that expected by the photochemical theory. Further he considered that the noted differences in the annual course between the Arctic and Antarctic strongly suggests that the meridional mixing of stratospheric air in winter-spring *is more efficient in the northern polar region than in the southern*. Robert J. Murgatroyd reported that measurements by aircraft up to 50 000 feet from the equator to 70^0N are demonstrating rapid ozone increase and humidity decrease in the stratosphere immediately above the tropopause. The evidence of moist air rising in the upper part of the equatorial troposphere and spreading poleward between 40-50,000 feet with distinct subsidence over the subtropics was important for understanding the global ozone transport within the general circulation as suggested by K. R. Ramanathan.

Results of calculations of total ozone by using measurements of individual UV wavelengths utilized by the Dobson spectrophotometer (e.g. A, C, D, AD) with Vigroux (1953) absorption coefficients adopted since the beginning of IGY *were not self-consistent.* Some differences were up to 10%. The IO_3C recognized that the absorption coefficients derived by Ernest Vigroux (1953) are better than the old Ny and Choong (1932) coefficients and did call for further study of the noted discrepancies. This task was completed by Vigroux (1967) and from January 1968 new set of absorption coefficients started to be used. In order to convert data from V-1953 to V-1968 one should multiply values derived from C x 1.072 and from CD x 1.116.The values derived using AD wavelengths are left the same in both coefficients scales.

Ozone sondes were flown by Heinz-Karl Paetzold’s group (University of Köln) in Tromsø, Weissenau, Sahara and Belgium Congo; by Alan Brewer and James Milford

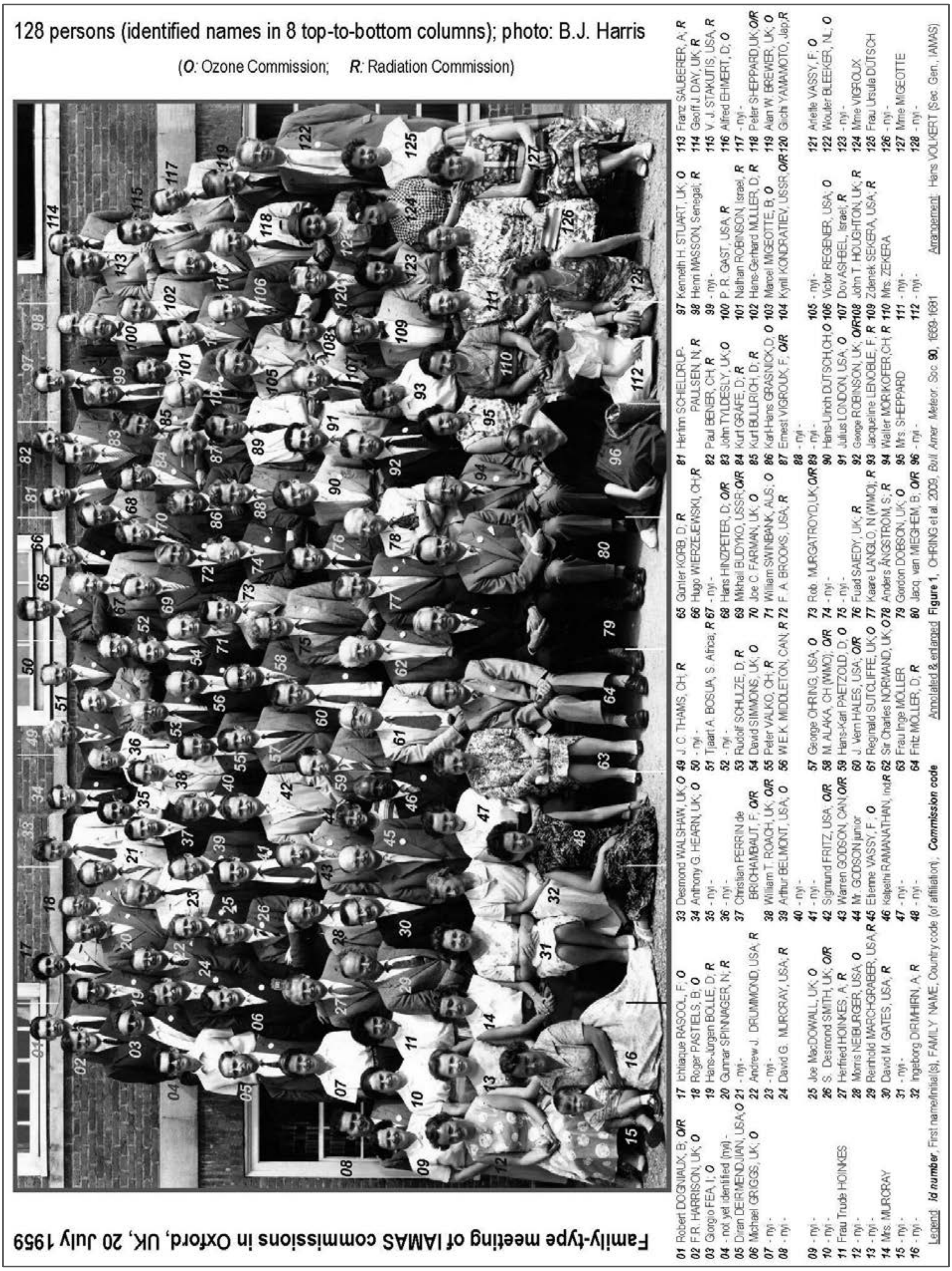


Figure 10.

Participants, spouses and children at the joint symposium of the IAMAP commissions on Ozone and Radiation, Oxford, UK, 20-25 July 1959 (Ohring et al., 2009).

(Photo: B.J. Harris)

(1960) in Liverpool and only few in Tromsø, Malta and Antarctica and chemiluminiscent type by Viktor H. Regener in New Mexico. To avoid proliferations of different units used to represent the VO_3D the IO_3C appointed Warren L. Godson to propose a unifying method for analyses. One year later the *Godson's ozonogramme* with ozone partial pressure as abscissa and log of air-pressure as ordinate with curves for instant mixing ratio and other calculations was adopted (Godson, 1962).

By the time of the Oxford Symposium, Gordon M. B. Dobson and Sir Charles Normand had reached the age of 70 and rendered their resignations as President and Secretary (Ozone, 1959b). From the Commission retired also Etienne Vassy (F) and H. Köhler (D). Then K. R. Ramanathan was elected President with Hans U. Dütsch as Secretary of the IO_3C. As new members were added: Alan W. Brewer (Oxford), Kaare Langlo (NO and WMO), G. H. Liljequist (University of Uppsala) and Mme. Arlette Vassy (Sorbonne, Paris), bringing the membership to 23 scientists with competence in various aspects of ozone studies. After this meeting also the geographical distribution of members became better balanced (complete membership lists are available in *Appendix 3a)*.

In August **1961** the next Ozone Symposium was held at Arosa with 75 participants from 15 countries (Ozone, 1961a; WMO, 1961). In its Presidential address K. R. Ramanathan presented a reasonably correct picture of the monthly latitudinal distribution of total ozone over the Earth deduced from last 3-years of observations and brought the attention to the explosive changes of total ozone associated with the spring polar warming of the stratosphere. He elaborated also on the interesting information on the vertical ozone distribution provided by accurately made Umkehr measurements. More than half of the presentations still dealt with methods of observations and analyses of data from close to 50 regularly operating stations. Relations between ozone and solar activity were reported, however due to incomplete state of ozone photochemistry no conclusions were possible. At that time the Chapman cycle was accepted as the basic photochemistry of ozone, but water was considered to be involved in the mesosphere as established earlier by Marcel Nicolet and D. R. Bartels. Some relevant papers were presented by Heinz-Karl Paetzold, and by Baliff and S. V. Venkateswaran. In fact, J. Hampson presented a catalytic cycle involving OH, HO2, O, and O3. This has historical value as the first ozone symposium discussion of catalytic, post-Chapman cycle ozone chemistry. The NOx cycle was unknown at this time.

P. A. Sheppard guided discussion on seasonal and latitudinal variability of ozone. Warren L. Godson reported on rapid increase of ozone accompanying the spring time sudden stratospheric warming observed over Arctic and sub-Arctic regions. Simultaneous increases indicate existence of large scale mixing due to strong south to north transport and descending motions. Jacques van Mieghem and Bernard Haurwitz further contributed to the discussion on the general circulation of the stratosphere. The high variability of total ozone seemed related to meteorology but the sparse network of Dobson stations did not yield definitive conclusions. The mechanisms for polar, seasonal, and short-term variability were further discussed in presentations by Byron W. Boville, Heinz-Karl Paetzold, Hans U. Dütsch, Carl L. Mateer, and others.

Papers about indirect vertical ozone profile data included some corrections to Umkehr retrievals by Z. Sekera and J. V. Dave, by K. R. Ramanathan and G. M. Shah, and by Hans U. Dütsch. Arlin J. Krueger (with S. V. Venkateswaran and J. G.

Moore) reported on Echo balloon satellite observations of the ozone distribution. This used photometric observations of Chappuis band sunlight reflected from a balloon in orbit at about 1600 km during occultation by the limb of the Earth and has historic value as the first demonstrated use of artificial earth satellites for ozone profile retrievals. Possibility for a satellite ozone profiling method using backscattered UV was presented by L. D. Kaplan, while Z. Sekera and J. V. Dave presented radiative transfer calculations needed to do BUV ozone retrievals when satellite data became available. This symposium was to be noted because of its timing just at the start of the satellite age.

As achievements, the meeting noted that work on development of useful methods for observing vertical ozone distribution had been intensified and a synoptic network of ozone radio-soundings would become operational guided by Wayne S. Hering from Air Force Cambridge Research Laboratories (AFCRL) in North America in 1963. In use would be Victor H. Regener's chemiluminiscent type of ozonesondes. It was recommended that measurements in the ozone-production region (>25km) should be initiated soonest.

Extensive discussions were held and concrete recommendations were made on the preparations of better global coverage of ozone measurements for the advent of International Quit Sun Year (IQSY) in 1964/65. In particular more Dobson equipped stations were recommended for Siberia (2-4), China (3-4), and one each in Alaska, Philippines, and southern parts of New Zealand, South Africa and Argentina. It was emphasised that if measurements with other type instruments would be initiated they *should be calibrated against long-term parallel measurements with Dobson using AD wavelengths on direct sun before any field measurements are initiated.* The Commission did recall that its five instruments are currently located in: Spitsbergen, Reykjavik, Aarhus, Arosa and Lisbon and requested from the President and/or Secretary to explore whether Denmark and Portugal could buy their own Dobson spectrophotometers and release the IO_3C instruments for use elsewhere (Ozone, 1961b).

It was noted that following the transfer of responsibility for the stations routine observations from IO_3C to WMO, the Meteorological Services in most countries have assumed obligations for observations assuring their uniformity. It was further appreciated that WMO Commission for Atmospheric Sciences, after Warren Godson completed his duties as Chairman of their Working Group, has appointed as Reporter on Ozone Hans U. Dütsch also member of IO_3C thus assuring good coordination of related activities. It was also noted that Warren Godson has prepared and WMO approved definitions of most frequently used ozone parameters *(see Appendix 5).* They will be very useful for all workers in the field to introduce uniformity in their expressions. The IO_3C appreciated that WMO has funded two intercomparisons of VO_3D methods held in Arosa in the summer of 1961 and spring of 1962. WMO also collected and published all ozone data from IGY and for continuation of that work has sign a formal Agreement with the Canadian Meteorological Service to collect and distribute all ozone data starting with 1960 and later acting as the *WMO World Ozone Data Centre*. The Commission tasks were directed now mainly toward organizing symposia and stimulating ozone studies within the community.

The Commission co-opted Wayne S. Hering as new member and recommended to IAMAS to agree Gordon M. B. Dobson to be designated *Honorary President* of IO_3C in recognition of his enormous contributions to developments of ozone observations and studies.

In August **1963** at the XIII-IUGG Assembly at Berkley a two-day session on ozone and circulation above 20 km was held with 24 presentations (Ozone, 1963). Three were covering for the first time the 26-month wind/ozone oscillations (Warren L. Godson, K. R. Ramanathan and Richard Reed). Continental-scale ozone distribution over North America, Europe, and Northern Hemisphere were discussed respectively by Wayne S. Hering, Rumen D. Bojkov and Alexandar Khr. Khrgian. VO_3D and stratospheric warming were addressed by Heinz-Karl Paetzold and by I.G. Breiland. Intercomparisons of methods for measuring VO_3D were reported by Hans U. Dütsch, and UV changes and mesospheric ozone by S. Ichtiaque Rasool. Abstracts from this Symposium are available in IAMAP Publication No 13 (Ozone, 1963).

The meeting of the IO_3C in Berkley put great emphasis on expanding the measurements of the VO_3D during IQSY and in particular to measurements in the ozone production region **>**25 km. It was appreciated that WMO assisted further ozone research by sponsoring through IAMAP a project in Canada for *uniform evaluation* of existing Umkehr observations (with leader Carl L. Mateer). Furthermore it was appreciated that WMO on proposal by Warren L. Godson as Chairman of the previous WMO-CAS working group on ozone, has started to establish ozone working groups in each of its six Regional Associations. IO_3C recommended one better equipped station in each of these Regional Associations to be designated as WMO Regional Ozone Centre to assist calibrations and intercomparisons of instruments. In view of the increased ozone network of over 30 stations in the USSR the Commission appointed Alexandar Khr. Khrgian as *Special Correspondent* for liaison with authorities. Finally at the meeting in Berkley the IAMAS-IUGG accepted, as one exemption, the IO_3C 1961 nomination of Gordon M. B. Dobson as its *Honorary President*.

In September **1964** a one week Quadrennial Ozone Symposium was held in Albuquerque (New Mexico) with 83 participants from 12 countries presenting 59 papers (Ozone, 1964). In his Presidential Address K. R. Ramanathan and after him Warren L. Godson expanded their presentations from Berkley bringing to attention the existence of ~26-month fluctuations in the ozone amount both in the tropics and middle latitudes and of their relations with the stratospheric circulation. In addition the meeting enjoyed a survey given by the host Victor H. Regener on 30-years of development in the quantitative detection of ozone. He was admired that together with his father Erich Regener did made ascents of quartz-spectrographs on big rubber balloons reaching up to 33km first determining the height of ozone maximum as ~22 km, as early as 1934.

Other subjects discussed included presentations on: elementary instrumental issues of total ozone measurements (13); VO_3D (22) including introduction of new numerical method for calculation of VO_3D from Umkehr observations by Carl Mateer; photochemistry (6) including results of a 2-D ozone model by Eigil Hesstvedt; application of ozone observations in general circulation (14) including the paper by Wayne Hering and Thomas Borden Jr. on analyses of VO_3D from the North American network down to the Equatorial zone indicating that ozone transfer is affected primarily by eddy processes and by long, quasi-stationery (*Rossby*) waves which are so prominent in the upper troposphere–lower stratosphere region; the Reginald E. Newell paper on the relationship between energy changes and mass transport based on IGY ozone data in which it was suggested that the basic reason for the spring ozone maximum is the occurrence of a greater tropospheric-strato-

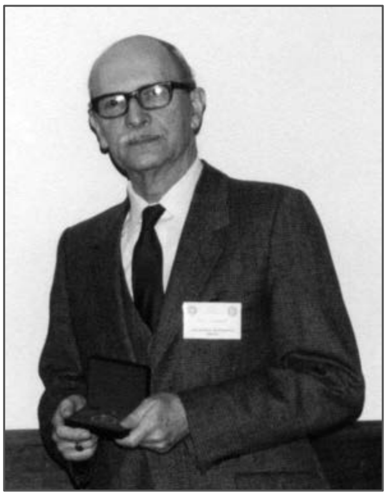


Figure 11.

Warren L. Godson (1920-2003) renowned atmospheric scientist, Fellow of the Royal Society of Canada, head of the Research Branch of the Canadian Meteorological Service. For IGY he organised 5 new Dobson stations, later a network of ozone sounding stations, and supported the use of Brewer spectrometers in the 1980s. As member of the IO_3C (1957-76) he arranged the hosting of the WMO World Ozone Data Center in Toronto, developed the Ozonogramme for uniform analyses of the VO_3D, defined the ozone parameters and their SI units. As chairman of WMO Ozone working group and later as President of WMO Commission for Atmospheric Sciences he developed a number of regulations for the Global Ozone Observing System (GO_3OS) and negotiated their international acceptance. He was elected Secretary-General (1960-1975) and President (1979-83) of IAMAS. He especially supported atmospheric environment protection research.

(Photo credit: Canadian Meteorological and Oceanic Society)

spheric energy exchange in that season with increase of the energy flux into the stratosphere; There were also two papers on ozone and solar activities by H.C. Willet and Kyo Sekihara.

For the first time, the active *influence of ozone on stratospheric dynamics* due to its radiative properties was identified to be of growing importance for circulation studies in the future. The discussion made it obvious that convincing solutions of circulation problems in connection with tracer studies can only be reached by careful *quantitative* calculations. For ozone this means that its photochemistry has to be taken into account in any attempt to use recent observations of VO_3D to derive a model of the general circulation in the stratosphere. However, it was stated that the knowledge of the photochemical theory is not adequate yet.

At the Commission meeting in Albuquerque it was noted with satisfaction that there has been development of large scale observational programme of VO_3D by reliable chemical sondes. If after archiving IQSY data it were extended to a more global coverage, the programme would facilitate answering questions about the general circulation of the stratosphere. However the need of *parallel measurements of the total amount* with Dobson instruments was indispensable for homogenous sondes-profile evaluations. The Commission considered that in addition to the sondes the indirect *Umkehr method is useful* to provide the climatology of ozone in particular at higher levels than those provided by the sondes. In this respect the uniform evaluation of the Umkehr observations from all stations undertaken by Carl L. Mateer in the WMO World Ozone Data Centre in Canada with support by WMO was considered very useful.

The understanding of the lower stratosphere circulation would have a benefit also by the number of studies of tracers other than ozone, since an acceptable model of stratospheric circulation will have to take into account the distributions of all of them in a quantitative manner. However the Commission was concerned that knowledge of the *photochemical theory is not adequate* mainly due to the uncertainty in the values of reactions constants, their temperature dependence, and the solar spectrum in the critical region around 200nm and in the region important for ozone equilibrium (150-300nm). An extended period of monitoring from a satellite is needed to establish its possible variability within a solar cycle. It was noted with satisfaction that better cooperation between physical chemists and atmospheric physicists has been obtained recently and that more reliable values of reaction constants may be established in the near future.

It was noted that in response to the call by the IO_3C, Denmark has purchased its own Dobson type instrument and returned to the Commission its property #51. This was lent to the Belgium Antarctic expedition for two years and then lent to Arosa.

The exchange of ozone data using the WMO telecommunication network was considered to be of interest to synoptic meteorology; however the proposal of Genady P. Gushtin for daily exchange of ozone data from more than 25 USSR stations was not supported. This short-sighting of the IO_3C was corrected only after the surprising appearance of the Antarctic spring ozone decline when near-real time data from both satellites and ground stations started to be exchanged routinely within the WMO system and the WMO Ozone Mapping Centre was established at the University of Thessaloniki (see http://lap.physics.auth.gr/ozonemaps).

The Commission co-opted Yoshiro Sekiguchi (Meteorological Service, Tokyo), Desmond Walshaw (Oxford) and R. Frith (UK Met.Office) as members to be approved by the next IAMAP Assembly (cf. *Appendix 3a).*

The ozone photochemistry in unsettled state (1965-1971)

In September **1967** at the XIV-IUGG Assembly in Lucerne (Switzerland) the Commission organized only a one-day symposium since a full week quadrennial symposium was planned for 1968 in France. At that meeting 17 papers were presented (Ozone, 1967). Five of the papers were on total ozone (Julius London, Alexandar Khr. Khrgian, Alan W. Brewer, Peter Fabian and Karl-H. Grasnick with Hoebbel); eight on VO_3D (Rumen D. Bojkov, I.G. Breiland, Wayne S. Hering, Arlin J. Krueger, Heinz-Karl Paetzold with Piscalar, Jagir S. Randhawa, Yoshiro Sekiguchi, C. R. Sredharan with Anna Mani); two on surface ozone (Luis Aldaz with Victor H. Regener, Ripperton with Worth) and one extensive review on ozone absorption (Ernest Vigroux) and one on photochemistry (Hans U. Dütsch). Using larger amount of data available since IGY and IQSY three of the presentations considered global distribution and circulation patterns (Julius London, Rumen D. Bojkov and Wayne S. Hering).

At the Commission meeting concern was expressed that improved VO_3D data have raised more questions concerning the photochemical theory which seemed to be well established ten years ago but it was in a rather *unsettled state*. Already D. R. Bates and Marcel Nicolet in (1950) had suggested that reactions involving H, OH and HO_2 radicals may have considerable interference with the odd oxygen (O and O_3) distributions. Following their idea J. Hampson (1964) suggested H*Ox*-catalysed reactions would lead to significant catalytic ozone loss in the stratosphere which was tested in model calculations by J. Barry Hunt (1966). The reaction rates were very doubtful and conclusions were not possible. IO_3C recommended that all suitable persons should be encouraged to measure the relevant reaction rate coefficients. Also the knowledge of the extraterrestrial solar spectrum is inadequate. Numbers of authors were encountering difficulties in reconciling theoretical values with the improved knowledge of VO_3D and dropped the use of pure oxygen photochemistry.

It has been clear since few years that the absorption coefficients used in the Dobson instruments provided total ozone values which are not mutually consistent. The problem seemed to be the results of too low values for the A wavelength

(305.5/325.4nm) coefficients. In order to improve consistency of the values obtained by observations with different wavelengths, the Commission accepted the newly measured coefficients by Ernest Vigroux (1967). The Commission asked WMO to inform the stations that from 1 January 1968 they had to use the following absorption coefficients: A = 1.748; B = 1.140; C = 0.800; D = 0.360 and AD = 1.388 (last not changed). Thus to convert data using the V-1953 to the new V-1968 scale they had to be multiplied as follows: C x 1.072 and CD x 1.116; AD was left unchanged.

Another recommendation made by IO_3C referred to the planned WMO/ICSU Global Atmospheric Research Programme (GARP) requesting the Joint Scientific Committee of WMO/ICSU to include ozone measurements and in particular to support extension of the ozone sondes network which data will be of benefit to stratospheric heat balance and dynamic studies.

New members to IO_3C were elected as follows: R. Berggren (SW), A.S. Britaev (CAO, Moscow), Karl-H. Grasnick (Potsdam Observatory), Eigil Hesstvedt (University of Oslo), Søren H.H. Larsen (Meteorological Service, Oslo), Lester Machta (NOAA, Washington DC), Anna Mani (Meteorological Service, New Delhi) and Carl L. Mateer (Meteorological Service, Toronto). All members are listed in *Appendix 3a.*

In September **1968** in Monte Carlo was held the Quadrennial Ozone Symposium. It was marking the 40-anniversery from the first Ozone Conference organised by Charles Fabry in Paris. It was hosted by Mme Arlette Vassy and the late Etienne Vassy (Professor in Sorbonne and one of the pioneers of ozone studies). Over 60 papers were presented. Good half of them dealt with issues of ozone transport and the atmospheric circulation utilizing VO_3D and total ozone data.

Interesting studies of modelled ozone photochemistry were presented (e.g. Paul J. Crutzen, Eigil Hesstvedt, Kyo Sekihara), some including “dry” – (when only destruction of ozone is by the Chapman reaction of recombination of oxygen atom with ozone molecule) and “wet” – (when destruction is by reactions of ozone with OH and HO_2). However they still could not explain the ozone concentrations particularly in the 25-35 km region. It was two years later when Paul J. Crutzen (1970) discovered the NOx catalysed reactions control the ozone in the middle stratosphere. Preparation of satellite total and VO_3D measurements utilizing UV back-scattered radiation instrument on Nimbus-4 was expected to improve tremendously the global coverage (Carl L. Mateer with Donald F. Heath). Rocket measurements provided new information for the region between 38 and 52 km over Hawaii (Arlin Krueger) and over White Sands (Jagir S. Randhawa). The global distribution of total and vertical ozone since 1957 and their relation to atmospheric circulation (Julius London with Rumen D. Bojkov) and over India (Anna Mani with C. R. Sredharan) were presented. Discrepancies of mostly USSR used M-83 type broad-band-filter ozonometer data with Dobson instruments and suggestions for improvements were reported by Rumen D. Bojkov (1969). All submitted papers of this Symposium were published in Annales de Geophysiques (Ozone, 1968a).

One of the exciting research in the past few years was the inclusion of photochemically produced and destroyed ozone as a tracer in a numerical model of the general circulation of the atmosphere which opens a very promising field of work, including testing validity of GCM when extended into the stratosphere (J. Barry Hunt and Sikuro Manabe). A prerequisite for the application of such methods is an expedient solution of the pending problems with the ozone photochemistry.

Figure 12.

Alan W. Brewer (1915-2007) renowned physicist at the Clarendon Laboratory in Oxford with great skills for building scientific instrumentation. In the 1940s he carried out airborne water-vapour measurements, found the dryness of the stratosphere and contributed to the development of the Brewer-Dobson circulation scheme of poleward ozone transport from the tropics region. In late 1950s he developed with Milford the Brewer-MAST ozone sonde to be widely used for studies of vertical ozone distribution. In the 1960s he moved to University of Toronto and elaborated the scheme for the Brewer spectro-photometer for measurements of total ozone. It was further developed in the 1980s and still used at many stations, also for UV-B measurements. President of IO_3C. (1968-71). Elected Honorary member in 1996.

The IO_3C put emphasis on the fruitful cooperation with WMO and on the need to include an adequate ozone-sondes network in the GARP Global Experiment. It was noted that one of the instruments belonging to the Commission (#51) was returned from the Belgian-Dutch Antarctic expedition. It was agreed that instrument to be lent to Arosa where it will be automated (Ozone, 1968b).

IO_3C elected Alan W. Brewer for President and did ask Hans U. Dütsch to continue his services as Secretary to the Commission. Four new members were elected: Peter Fabian (Max-Plank Institute for Aeronomy), Walter Komhyr (NOAA, Boulder), R. W. Kulkarni (CISRO, Aspendale) and Genady Iv. Kuznetzow (University of Moscow).

In **1971** at the XV-IUGG Assembly in Moscow a separate symposium was not held since the Quadrennial was already being planned for next year in Arosa. The attending 15 members of the IO_3C met and considered briefly the results of the ozone sondes intercomparisons held previous year under the supervision of Walter Attmannspacher in Hohenpeissenberg Observatory (Ozone, 1971). Compared were wet electrochemical sondes of the Brewer-MAST type (used in DDR, FRG, Italy and India) and the Komhyr-ECC type (used in USA and Japan). Simultaneous flights on big balloons did show that the integrated ozone from the VO_3D with Brewer's is with 15-40% less that the total ozone measured by Dobson. The differences with the Komhyr-ECC were ±10%. The quality of the soundings depends very much on thorough pre-flight calibration. The results proofed the necessity of *simultaneous* total ozone measurements to facilitate the data evaluations, which was strongly recommended by the IO_3C.

The Commission noted that although considerable progress has been made in the ozone photochemistry of a moist atmosphere, the reliability is still not adequate. Complications arose by the indicated possibility of the importance of nitrogen oxides for odd-oxygen particle destruction in the stratosphere (Crutzen, 1970).

On the membership issue the Commission was informed that Kaare Langlo who was permanent representative of WMO has resigned and he proposed Rumen D. Bojkov (WMO) to take over these functions, which was so agreed. Walter

Attmannspacher (Hohenpeissenberg Observatory) and M. F. Figueira (Meteorological Service, Lisbon) were also elected as new members. Finally in view of the tremendous contributions made to ozone science by K. R. Ramanathan and Ernest Vigroux they were elected *honorary members* of the Commission.

In view of the successful launch of the backscattered UV radiation measuring instrument for determination of total ozone (theoretical design by J. V. Dave and Carl L. Mateer, and implemented with Donnald F. Heath) on Nimbus-4, IO_3C accepted resolution requesting ozone measurements to be included with high priority in future satellite programmes. Carl L. Mateer was to represent the Commission on the satellite related discussions in NASA.

President Brewer informed that he has made a prototype spectrophotometer of new design for total ozone measurements which now should be tested. Further he commented that the growing WMO involvement with establishing of Regional Centres with Rapporteurs or working groups for supporting ozone measurements in the six WMO Regional Associations was taking care for big portion of previous IO_3C activities. Therefore, he did open a discussion on *the future of the Commission*. The members *did not agree* with him to curtail Commission independent status within the IAMAP. It was decided to appoint a committee (Alan W. Brewer, Alexandar Khr. Khrgian, Julius London and K. R. Ramanathan) to consider the relation of ozone studies to those of the upper atmosphere and atmospheric chemistry and advise whether this purpose would be better served if the IO_3C would be united with some other commission of IAMAP as the President has proposed. This committee was supposed to report to IO_3C at the next symposium. *However* dramatic developments related to the ozone budget in relation to the supersonic transport (SST) and further anthropogenic influences which could destroy the ozone caused explosive increase of ozone related studies as reported to the Arosa Symposium (Ozone, 1972a) and other international meetings (e.g. CIAP) and made the existence of IO_3C indispensable.

The study of anthropogenic influences on the ozone layer (1972-1984)

Indeed Harold Johnston (1971) raised the concern about depletion of the ozone layer from human sources by suggesting that flying a fleet of supersonic transport (SST) planes in the stratosphere might produce enough NOx to do significant damage to the ozone layer from the catalytic reactions as suggested a year earlier independently by Paul J. Crutzen (1970). This fleet of SST was never built, but Johnston's and Crutzen suggestions raised the awareness that it was possible for *humans to have a serious negative effect on the ozone layer.* Paul J. Crutzen discovery was that nonreactive nitrous oxide (N_2O), produced naturally by soil bacteria, rises into the stratosphere, where solar energy splits it into two reactive compounds, NO and NO_2. These compounds, which remain active for some time, react catalytically with ozone (O_3), breaking it down into molecular oxygen (O_2). In this way they contribute to a reduction of the ozone content in the stratosphere. Tree years later Sherwood Rowland and graduate student Mario Molina (1974) showed that there was a *threat to the ozone layer from chlorofluorocarbons (CFCs).* The CFC molecules would almost all reach the stratosphere where they would decompose and liberate chlorine atoms that would then destroy ozone in a catalytic reaction involving chlorine as described by Stolarski and Cicerone (1974) similar to that involving NO_x.

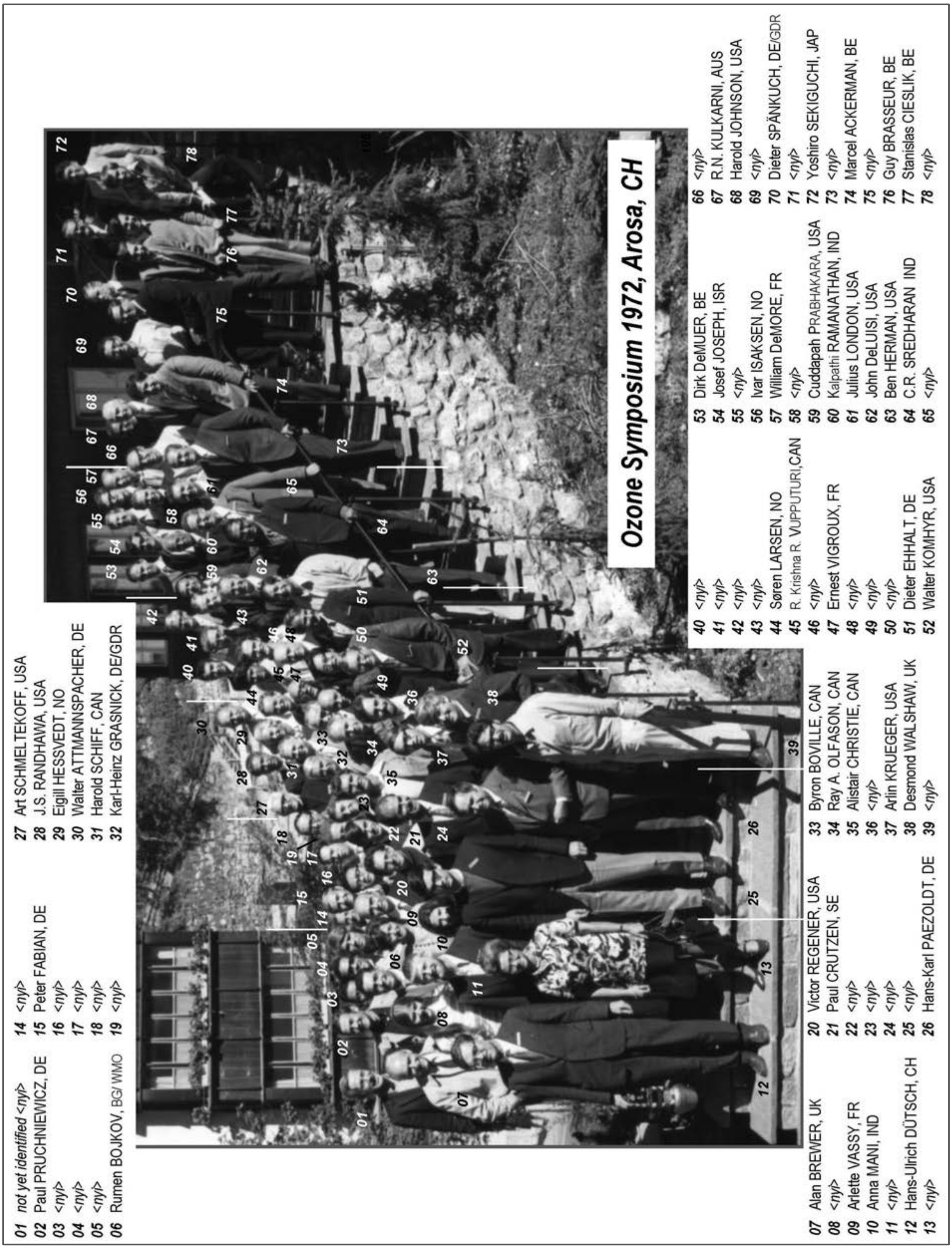


***Figure 13**.*

Participants at Ozone Symposium in Arosa, Switzerland, August 1972 (partially identified in 2011; entries in six columns with number, first name, FAMILY name, country code of affiliation).

In August **1972** the Quadrennial Ozone Symposium was held in Arosa with 90 participants and 70 papers (Ozone, 1972a). It was hosted by Hans U. Dütsch. The most innovative papers were on stratospheric measurements of trace substances such as CH_4, H_2, N_2O, H_2O, (e.g. Marcel Ackerman with C. Muller, Dieter H. Ehhalt with L. E. Heidt, Rodolfo Zander), and 11 papers on new approach to ozone photochemistry which included the role of catalytic chains of reactions involving NOx and HOx which may lead to ozone destruction *making NOx the most important factor in the global, natural ozone balance* (e.g. Paul J. Crutzen, Marcel Nicolet with W. Peetermans, Guy Brasseur, Eigil Hesstvedt). The modelled abundance of NOx in the stratosphere was also discussed (e.g. Ivar Isaksen; Harold Johnston with Gary Whitten, T. Shimasaki with Don J. Wuebbles).

Another large part of presentations dealt with analyses of observational result with emphasis on VO_3D and atmospheric circulation. Few papers covered the tropospheric ozone measured on a meridional stretch 70^0N to the Equator (P. G. Pruchniewicz, Peter Fabian). Of particular interest were reports on first two years data from the UVB instrument on Nimbus-4 satellite (Donald F. Heath with Carl L. Mateer and Arlin Krueger) demonstrating good data quality. The Commission encouraged satellite operators to make their total and VO_3D data available without undue delay. Such global coverage could be of great use also for checking results of photochemical and circulation models.

The Commission stated that it has become clear that *the ozone layer could be anthropogenically influenced* (Ozone, 1972b). At that time the ongoing Climatic Impact Assessment Programme (CIAP) project in USA, in which many members were actively participating, was addressing the issue of the role of NOx from supersonic transport (SST). The Commission strongly felt that an *international monitoring and research programme within WMO* should deal with threats to the ozone layer in the future and IO_3C will have to take an active part in its organization. With the new developments in the field of photochemistry, transport models not only for ozone itself but also for other trace substances have become of great importance. 1-D models which have very largely been used are obviously unsatisfactory in the case of ozone where latitudinal transport is of great importance. The few available 2-D models were hampered by the fact that the parameterization of large scale exchange by mixing coefficients is not fully adequate.

The Commission noted the results of inter-comparisons of Dobson instruments from 7 countries organized in 1969 by WMO and conducted by members of IO_3C at Siofok-Hungary. Other intercomparisons between Australian, one instrument from Japan, and the USA Reference Dobson #83 took place in Aspendale in 1972 under the supervision of Walter D. Komhyr and Rumen D. Bojkov. Still small discrepancies in the derived total ozone when using different wavelengths, with their current absorption coefficients, was reported by John J. DeLuisi and Walter D. Komhyr. This prompted the Commission to call for continuous study of this issue. To the membership of the Commission were added: Marcel Ackerman (Institute for Aeronomy, Brussels) and Byron W. Boville (McGill University, Montreal). Complete listing of members is given in *Appendix 3a*.

In January **1974** the IO_3C participated with other IAMAP Commissions in a joint organization of a major Symposium on "Structure and Composition and General Circulation of the Upper and Lower Atmosphere and Possible Anthropogenic Perturbations" in Melbourne which especially dealt with the problem of the interaction between ozone and other trace substances. More than 50 out of total 87 of the presentations dealt with ozone photochemistry modelling. The explosive increase of studies confirmed the growing concerns of the IO_3C building since 1972 for possibility of anthropogenic ozone destruction. The Proceedings were published in two volumes of in total 1294 pages by Warren Godson IAMAP Secretariat Toronto (Ozone, 1974).

During the same year a major Dobson instruments intercomparison with the NOAA Reference #83 was organized by WMO with IO_3C in Belsk (Poland) which did show the unsatisfactory state of some of the instruments in operation. More details on Dobson performances and differences noted at a number of WMO intercomparisons are given in (WMO, 1982) and Basher (1995). The Commission requested that more attention be given to the quality of the ozone measurements and their homogeneity as persuaded by Rumen D. Bojkov through the WMO network.

In August **1975** at the XV-IUGG Assembly in Grenoble IO_3C organized two sessions on Fluorocarbons in the Stratosphere by Marcel Nicolet and on Dynamic Models by Richard J. Murgatroyd with emphasis on possible ozone reduction due to anthropogenic pollution at which were presented 18 papers. Authors and participants were well aware of the ongoing CIAP studies and in particular of the fundamental NOx effect studies of Crutzen (1970). Furthermore recently Richard S. Stolarski and Ralph Cicerone (1974) found that chlorine as well as bromine Stephen C. Wofsy and Michael B. McElroy (1974) may catalyze ozone decomposition even more effectively than NOx. Future Space Shuttle flights (function of their frequencies) may introduce few thousand tons of chlorine species into the upper atmosphere. An existing and growing source of chlorine in the stratosphere through dissociation of chlorofluoromethanes (CFCs) was identified by Mario Molina and Sherwood Rowland (1974) who warned this may have a significant ozone-destructive effect.

The Commission discussed the explosive increase of interest in ozone studies related to the new aspects for photochemical ozone destruction. It felt that the relevant studies should be strongly supported. IO_3C recognized that the presently available sounding material is not sufficient to establish a secured climatology of the world wide VO_3D and again recommended improvement of the ozone-sondes network to assist modelling work and monitoring long-term trends. It felt that for the upper stratosphere information should come from satellites and also from Umkehr techniques being important as ground truth for satellite results and especially for long-term monitoring. The Commission felt that despite the availability of satellites it was essential over long periods to keep and enforce the surface part of the WMO Global Ozone Observing System (GO_3OS) to be used for ground truth and for determination of long term trends (Ozone, 1972b).

The Commission was informed that unfortunately already in early 1974 Alan W. Brewer has informed the Secretary that he is retiring and he is not interested to be involved with the Commission any longer despite that his term as President would have been until the 1976 Dresden Symposium. Thereafter, Hans U. Dütsch was elected President and C. Desmond Walshaw Secretary of the Commission. Five new members of IO_3C were elected: Paul J. Crutzen (NCAR, Boulder), Donald F. Heath (NASA, Goddard SFC), A. Losiowa (Institute for Geophysics, Warsaw), Andy Matthews (NIVA, NZ) and Harold I. Schiff (University of York, Toronto), bringing the membership total to 28 plus 3 honorary (Dobson, Ramanathan and Vigroux; see *Appendix 3a)* All the above concerns and recommendations from the Grenoble meeting were submitted to WMO Commission for Atmospheric Sciences (CAS).

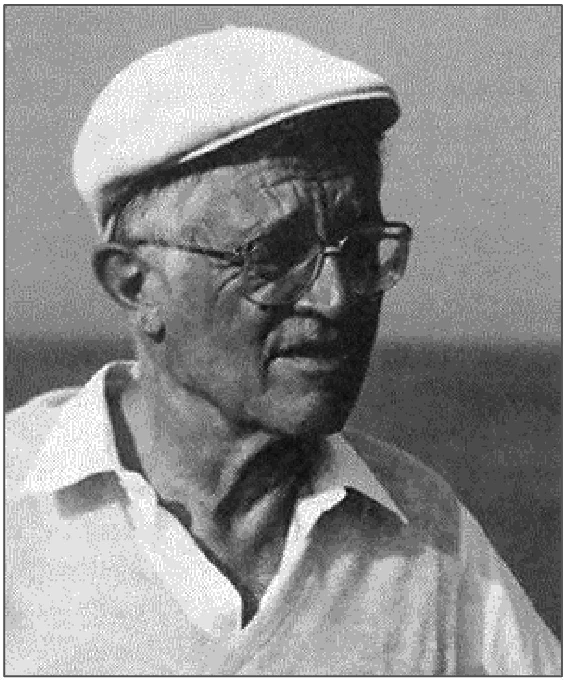


Figure 14.

Hans Ulrich Dütsch (1917-2003). He guided the Arosa total and vertical ozone distribution observations for more than 40 years; when in NCAR (1960-64) assisted Carl Mateer for implementing the first numerical scheme for Umkehr profile retrieval; He served as Secretary of the IO_3C for 15 years before elected President (1975-1980) keeping close contacts with WMO on ozone activities. Always strived for improving ozone photo-chemistry, for quality ozone measurements and organized numerous ozone-instrument intercomparisons and symposia. Elected Honorary member 1984.

Upon an initiative by Rumen D. Bojkov a meeting of distinguished scientists was convened in WMO-Geneva immediately after the Grenoble Assembly to discuss the problem of stratospheric pollution and its possible influence on the ozone layer and to elaborate on a draft of an appropriate policy for intergovernmental action. The eight IO_3C nominated members (Byron W. Boville, Rumen D. Bojkov, Paul J. Crutzen, Hans U. Dütsch, Lester Machta, Richard Murgatroyd, Marcel Nicolet, and Sherwood Rowland) together with four other CAS nominated experts: Fred Finger (NOAA), Karin Labitzke (Freie Universität, Berlin), Michael B. McElroy (Harvard), and William W. Kellogg (NCAR) drafted a statement *"Modification of the ozone layer due to human activities and some possible geophysical consequences".* This was immediately accepted by the WMO Executive Council and distributed to all Governments as *the first* intergovernmental statement "presenting in an authoritative and well-balanced manner the current state in this highly important subject" (*see Appendix 6*).

After this action, in May **1976** as previously recommended by IO_3C, WMO initiated the *WMO Global Ozone Research and Monitoring Project* aimed to clarify the role of anthropogenic pollutants (particularly CFCs and NOx) in reducing the quantity of ozone in the atmosphere and to prepare assessments. This Project is very active until today with publication of the periodic International Assessment Reports and guidance material on the GO_3OS. It is implemented with participation of IO_3C members and hundreds of other scientists.

In August 1976 the Quadrennial Ozone Symposium (jointly organized with the Commission on Atmospheric Chemistry of IAMAP) was held in Dresden with 146 participants from 28 countries presenting over 100 papers (Ozone, 1976a). The distribution by subject of the papers shows the shifting emphasis: for the first time 37 were dealing with anthropogenic influence, modelling, the necessary trace substances and one on the ozone heating of the stratosphere. The distribution of both total and VO_3D were discussed in 24, general circulation in 8 and tropospheric ozone in 12. Those discussing actual measuring practices - a dominant subject in the past Quadrennials - were now only 19 papers.

The Commission noted that the past few years brought a rapid expansion of ozone research showing the importance of that trace gas to mankind in a new light. It recalled in this connection few important dates dealing with milestones in the stratospheric ozone photochemistry and ozone destruction: (i) 1964/65 introduction of the hydrogen-oxygen radicals (e.g. J. Hampson, B. G. Hunt, Marcel Nicolet); (ii) 1970/71 introduction of the nitrogen-oxide radicals by Paul J. Crutzen and independently by Harold S. Johnston; (iii) 1974 introduction of ozone destruction role of chlorine radicals by Richard S. Stolarski and Ralph Cicerone and the potential ozone destruction by chlorine released in decomposition of CFCs by Sherwood Rowland and Mario Molina. Naturally the main discussion evolved on the role played by *anthropogenic pollution* on the ozone regime. Highlighting the ozone destructive potential of increasing release of CFCs was presented by Sherwood Rowland and Paul J. Crutzen. In this connection it was appreciated that WMO has approved the Global Ozone Research and Monitoring Project concerning with:

(i) The extent to which man-made pollutants might be responsible for reducing the O_3, in particular the role of CFCs and NOx;
(ii) The possible impact of the O_3 changes on climate and UV reaching the surface; and
(iii) The strengthening of the long-term monitoring quality and data reviews for detection of trends and future threats.

Since these activities are of direct interest also to IO_3C it was strongly recommended to the members to assist implementation of Project tasks as completely and as quickly as possible (Ozone, 1976b).

Further the IO_3C recommended the USA Dobson instrument #83 be designated as WMO Primary Reference Standard and be regularly calibrated at the clean air conditions of Mauna Loa and then compared with the Regional reference instruments and all other field stations as soon as practical. The results from all intercomparisons should be deposited to the WMO-WO_3DC in Toronto. The Commission considered also that flight-comparison between the most used ozone sondes as well as between the sondes flown on rockets is necessary. Long-term (minimum one year) comparisons between Dobson and different type new instruments were considered essential *before* such instruments are approved for use in the GO_3OS. With supporting reference to the few years of ozone observations from satellites NASA was asked to ensure rapid processing and dissemination of the data.

Considering that there is still some internal inconsistency with respect to higher ozone amount (~3 to 5%) when calculated with the A-wavelength pair observations even with the improved Vigroux-1968 absorption coefficients a small group under Walter D. Komhyr was requested to look in to more details of this problem.

In September **1977** during the Second extraordinary Assembly of IAMAP at Seattle, a symposium on “Meteorology of Middle Atmosphere”, was held. Few presentations were made discussing the ozone problem probably because of the big Quadrennial Symposium held the previous year in Dresden and ongoing national ozone assessment activities (i.e. in France, UK, USA). One important paper on standard ozone profiles derived from balloon and rocket data to be used as input for satellite and theoretical models was presented by Ernest Hilsenrath, Dunn and Carl L. Mateer and should be mentioned. Not many members of IO_3C attended and only an informal meeting of the Commission reviewed activities but did not make recommendations.

In June **1978** in Toronto WMO and the IO_3C organized a “Symposium on Geophysical Aspects and Consequences of Changes in the Composition of the Stratosphere” in order to respond to the booming interest on anthropogenic ozone changes. The meeting was hosted by the Canadian Atmospheric Environment Service (Byron W. Boville) and co-sponsored by NASA (Shelby Tilford). In attendance were 130 scientists including most of the IO_3C members. The 64 of presented papers were published by WMO (Ozone, 1978). More than half of the papers were on chemistry, trace measurements and sources and sinks; modelling and prediction papers were 18, and ozone trends and satellite measurements were 12. That distribution by itself demonstrates that the *most active ozone researchers have started to dedicate their studies on the issue for anthropogenic effects on the ozone layer.* That message underlined the need recognized by the Commission, to concentrate even more on further promotion of theoretical studies on the ozone issue.

In December **1979** at the XVII-IUGG Assembly in Canberra within the framework of a symposium on Middle Atmosphere, the IO_3C members organized two sessions on trace species of direct interest to ozone with 16 papers. Another 11 papers including few on satellite measurements of ozone were spread within two other sessions. The great distance, and planning already for the next Quadrennial symposium to be held in Boulder in 1980, prevented majority of the members to attend. Therefore no formal meeting of the Commission was held. *IAMAP adopted its Statute* which “mutates mutandis” should be applied by its Commissions. Furthermore on the proposal by IO_3C supported by the Commissions on Upper Atmosphere and on Chemistry and Global Pollution, *IAMAP,* considering the worldwide concern that human activities may be producing important changes in stratospheric composition leading to serious deterioration of human environment *recommended that all nations:*

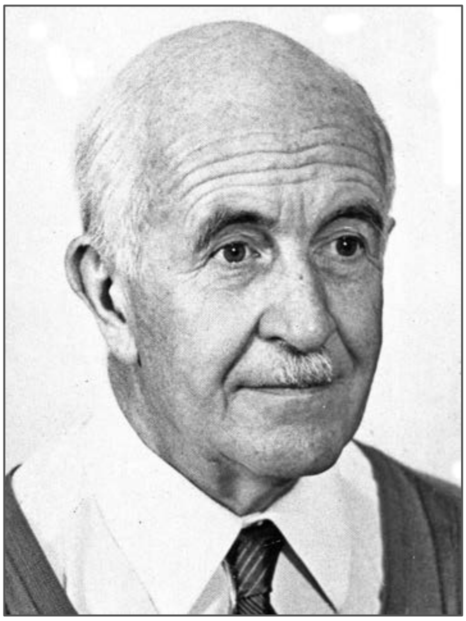


Figure 15.

Alexandar Khr. Khrgian (1910-1993), professor in atmospheric physics at prestigious Moscow State University (1943-1993), established the national ozone network and trained generations of researchers also in other fields such as cloud physics. Proliferated writer of research papers and University textbooks on Atmospheric Physics and History of Meteorology, actively participated in IAMAP and IO_3C activities for 36 years (since IGY until his last days). Elected Honorary member 1980.

(Photo credit: Depart. of Physics, Univ. of Moscow)

(i) Perform their own evaluations;
(ii) Expand long-term research programs to increase knowledge of processes affecting particularly stratosphere;
(iii) Cooperate fully in international monitoring to detect any long-term trends in the stratosphere and
(iv) Intergovernmental organizations, particularly WMO, consider to provide encouragement, support and co-ordination to the above mentioned endeavours.

In August **1980** the Quadrennial Ozone Symposium was held in University of Boulder, Boulder, Colorado, with the local host Julius London. It was attended by 275 participants from 21 countries and was so far the biggest. More than 190 papers were presented. Proceedings were published thanks to support by WMO, NCAR and University of Colorado (Ozone, 1980a). They covered in addition to the previously traditional fields such as observational techniques (49), results and ozone data analyses (59), *also* photochemistry of ozone and related chemical systems with interacting dynamics (35), observations of relevant trace gases (31), ozone interaction with climate and solar variability (11). Considerable extension of the ground based observing system was reported. Of course the major break-through in global observations of total and VO_3D has been the *successful employment of various satellite observations* during the past decade and in particular of the TOMS instrument, designed by scientists from NASA Goddard SFC, and flown since November 1978. At the same time laboratory and theoretical studies have led to the realization that ozone photochemistry and the interactions with radiative and dynamic processes *are woefully complex*. They require communication among specialists working in various sub-disciplines dealing with these physical and chemical processes with *the common aim* – understanding the ozone behaviour.

The Commission accepted the resignation of Hans U. Dütsch (due to his retirement from University of Zürich) and elected unanimously for President Carl L. Mateer from Toronto. In recognition of the enormous contribution to the studies of atmospheric ozone and of ozone monitoring and research in USSR Alexandar Khr. Khrgian (Professor of Physics, University of Moscow) was unanimously elected *honorary member*.

Appreciation of the diligent work by Walter Attmannspacher, Director of Hohenpeissenberg Observatory in Germany, for arranging and conducting number of international intercomparisons of commonly used ozone sondes and over a year-long comparison of surface ozone measuring instruments (wet ECC sensor, Hp-sensor, dry ethylene sensor and optical –UV absorption –Dasibi sensor) was recorded. Results confirm that the MAST-Brewer and the ECC-Komhyr type sondes are the two most robust and suitable for operational use if thoroughly pre-flight calibrated. The ECC sondes showed somewhat higher values in the troposphere and the carbon-iodine sonde of Japan tended to read slightly low at the top (~14 hPa).

In response to a previous call by IO_3C, series of 57 rocket firings in triads were conducted from Wallops Island (USA) in 1979 for intercomparisons of ozone sondes that have been used over the last several years by Australia, Canada, India, Japan and USA (NASA). Ernest Hilsenrath from NASA Goddard SFC was coordinating with participants the preparation of report for publication by WMO.

Intercomparisons of >40 Dobson instruments with reference to #83 (maintained as reference by Walter D. Komhyr in NOAA-Boulder) and their upgrading were

Figure 16.

Carlton L. Mateer (1926-2011) has made major contributions to the ozone science which includes the theory and uniform numerical processing of the Umkehr profiles, theoretical design (with J. W. Dave) and development of the retrieval algorithm for total ozone and ozone profile from satellite measured backscatter UV, active contributor to the development and the implementation of BUV and SBUV satellite instruments with Don F. Heath and TOMS with Arlin Krueger together bringing the few decade-long use of these instruments to great scientific success. He served as President of the IO3C (1980-1984) and as early as 1984 Presidential address call to the need to focus future research on ozone-climate interactions. Elected Honorary member 1992.

sponsored by WMO in the past few years (e.g. Belsk-1974, Boulder-1977, Arosa-1978, Potsdam-1979) and IO_3C recommended that this vigorous activity for improving the performance of GO_3OS should be further expanded if we wish to have a solid base for ozone trends studies. The reference instruments of UK (#41) and of GDR (#71) were considered not representative and their managers were urged to plan another calibration with World Reference #83. IO_3C appreciated the preparation of Operations Handbook for Dobson Spectrophotometers by Walter D. Komhyr published and widely distributed by WMO as Ozone Project Report #6 (Komhyr,1980a) and recommended his laboratory at NOAA, Boulder, to be designated the *Central Ozone Laboratory*.

The uncertainty of the present absorption coefficients used for ozone evaluations due to a possible error in the value of 305.5 nm (from the A-pair) was discussed (Komhyr, 1980b). In view of ongoing thorough work in the US National Bureau of Standards by Arnold M. Bass and R. J. Paur (1985) on the UV absorption at low temperatures, the Commission decided to postpone its decision and to establish a small working group (Robert D. Hudson, John J. DeLuisi, Carl L. Mateer) to follow developments and asses the implications of the new values and report. For Rapporteur on IR ozone absorption coefficient was appointed Alain Barbe (Professor at Reims).

A prototype of a Brewer instrument which underwent comparisons with the Toronto Dobson #77 was shown and the Commission recommended that a number of them should be manufactured and operated under the supervision of the Atmospheric Environment Service (AES), and report on their performance presented *before recommended for network use.*

The IO_3C expressed appreciation of the work on the UV solar spectrum at high resolution by John J. DeLuisi from NOAA Boulder Laboratory and recommended to be further pursued with a view to improving our knowledge of the physical processes contributing to the observed spectrum and taking them into account in ozone measurements.

Furthermore in order to encourage further work on microwave measurements of atmospheric ozone which offers some advantages (e.g. cloud penetration), it was recommended that Klaus F. Künzi (University of Kiel) and J. W. Waters (NASA – JPL) report to the next meeting. For advice on the most important observations required of trace constituents related to ozone a small working group (Sherry Rowland and Peter Fabian) was charged to report to the next meeting.

In line with the Statutes of IAMAP the IO_3C decided *from now on the election of a member to be for one term with possibility to be extended once* and with the understanding that at the end of the second term the member should step down. The officers of the Commission could keep membership for one more term after they are out of duties. It was felt these arrangements would help to maintain membership of active workers on ozone, and open possibility for securing representations of new fields of developments. Following the new rules it was expected that long-term members (Ackerman, Attmannspacher, Boville, Britaev, Crutzen, Fabian, Figueira, Grasnick, Gushtin, Heath, Hesstvedt, Karol, Komhyr, Kulkarni, London, Losiowa, Matthews, and Sekiguchi) would step down by the 1984 Symposium. As new members were elected: Ian Galbally (CISRO, Melbourne), Dieter H. Ehhalt (Institute of Stratospheric Chemistry, FC Jülich), Ivar Isaksen (University of Oslo), Klaus F. Künzi (University of Kiel), Jérard Mégie (Service d'Aeronomie du CNRS, IPSL, Paris), Yanai Sahai (INPE, Sao Paolo), Toshihiro Ogawa (University of Tokyo), Masayoshi Shimizu (MRI, Tzukuba) and C. R. Sreedharan (Meteorological Service, New Delhi). For complete membership see *Appendix 3a*.

In the week before the Symposium the WMO jointly with IO_3C hold in NCAR a meeting of experts on *Assessment the Performances of the Ozone Observing Systems* (WMO, 1980) and made a number of recommendations for improvement of the GO_3OS. These included: a request for preparation of a *"Manual for ozonesondes"*; publication of previous rocket-ozone soundings by the WMO-WO_3DC in Toronto; a test of the improved 3-wavelengst (300, 326 and 348±2nm) ozonometer by Genady P. Gushtin and S. A. Sokolenko (1984) for entire scan of solar zenith angle measurements before introducing it in the USSR network; improvement of the empirical charts used in reducing zenith-sky observations for optimum quality ozone data as obtained from observations on clear and cloudy zenith-skies.

A Resolution expressing appreciation to WMO for the excellent conduct of the Global Ozone Research and Monitoring Project guided by Rumen D. Bojkov was adopted by the Commission.

President Carl L. Mateer was asked to do all which was necessary to facilitate contributions by the Commission to the evolving Middle Atmosphere Programme (MAP) and offer the co-sponsorship to their symposia by IO_3C. At the steering Committee for MAP the IO_3C was represented by Rumen D. Bojkov, who was also representing the WMO and thus assuring smooth cooperation with this for the Commission important international MAP Programme carried out under the framework of COSTEP.

The Commission also dealt with a threat that CISRO may terminate the Australian ozone observations. Letter to the Minister of Science was prepared expressing the seriousness of such action in a situation when we need every observation to asses the possible environmental consequences to the ozone layer.

Finally a recommendation was made that the unit of total ozone (milli-atm-cm) be given the *alternative* name of Dobson (D), thereby defining one D as the amount of ozone in the vertical column which when reduced to temperature of 15^0C and a

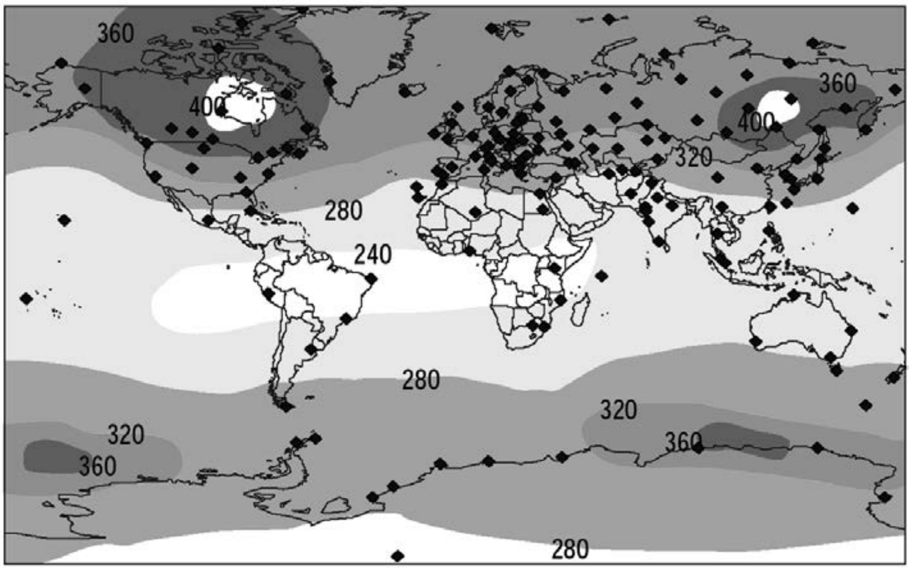


Figure 17.

Active GO_3OS ground stations operating through the 1980s. Together with the first satellite instruments they permitted to obtain the average ozone distribution: low at the Equator, higher over the northern hemisphere, and lower over the southern hemisphere.
(from WMO, 1995)

pressure of 1013hPa, will have a depth of 10^{-5} m. It was brought to the attention of IO_3C that this could be only *informally* because *it is not a basic SI unit* and will be impossible to get sanctioned by the International Standardization Organization (ISO) in Geneva as a preliminary inquire has shown. This recommendation was not approved by IUGG in its Resolution (August, 1983) when other units were considered. Discussion on application of the SI system for ozone was prepared by the Commission member Reid E. Basher (1982). If total ozone amount is expressed in SI derived units it will be mole/m^2. In that way the 1 matm-cm = 0.4462 mol/m^2. The average ozone of 300 matm-cm = 134 mmol/m^2. The “mole” as defined by ISO is “the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg (exactly) of ^{12}C”.It was obvious that use of strictly SI unit for the total ozone is clumsy and there is always possible confusion between “mole” and “molec”. Actually 1 matm-cm = 1 D = $2.68x10^{16}$ molec/cm^2. As consequence the total ozone continues to be expressed in matm-cm or Dobson units although they are both not SI Units.

In May **1981** a major international evaluation meeting (102 scientists from 12 countries) was held in Hampton, Virginia. It was jointly called by WMO and NASA in cooperation with NOAA and FAA to evaluate the state of the stratosphere. The over 500 pages Report “The Stratosphere 1981–Theory and Measurements” (WMO, 1981) was widely distributed. It is considered as the first in the series of *international assessments* reports providing background for at that time ongoing negotiations for concluding of an Ozone Convention for Protection of the Ozone Layer and, in the years after for assessment the effects of measures taken by the Montreal Protocol. 18 members of the IO_3C took active part and as chapter leaders, two of them (Robert D. Hudson and Rumen D. Bojkov) were appointed joint chairmen of the meeting and co-editors of the voluminous Proceedings: *The Stratosphere 1981.* An essential part of the Report is dedicated to understanding of the delicate *interplay between chemistry and dynamics* using complex mathematical models. Results of 1-D and few 2-D models (including effects of tropospheric NOx, N_2O and CO_2 changes) were function of changing chemical kinetics thus predicting at steady-state total ozone decline of -5 to -18% due mainly to CFCs perturbation at ~40 km.

In August 1981 at the XVIII General Assembly of IUGG in Hamburg the Commission did not organize separate symposium but cosponsored related sessions of other Commissions symposia. At the Commission meeting Rumen D. Bojkov reported the conclusions of the assessment meeting held in Hampton, VG. previous May *recognizing imminent threat for the ozone layer*. He informed that the WMO Executive Committee had approved the recommendations of Boulder meeting. Specifically the concept of Global Ozone Observing System (GO_3OS) to include ground and space based observations and analyses; and also Walter D. Komhyr Laboratory to serve as World Dobson Spectrophotometer Central Laboratory and that NOAA accepted responsibility for the work involved.

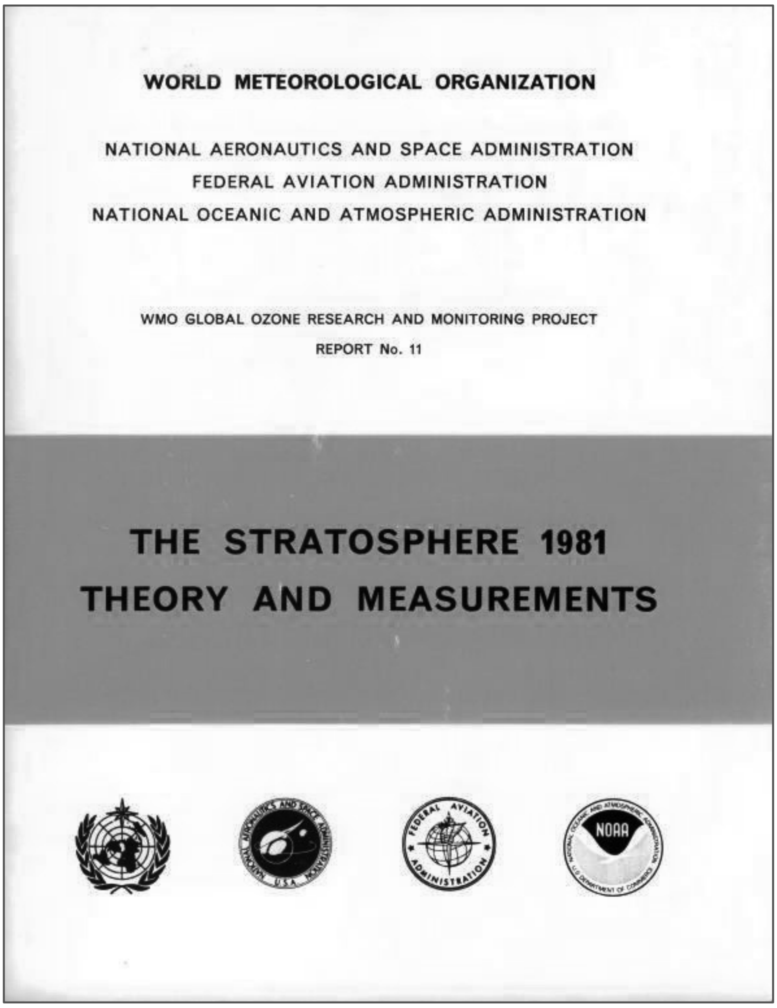
Report of the latest ozone sondes intercomparisons in Hohenpeissenberg (October, 1980) by Walter Attmannspacher was accepted with appreciations. Disappointment was expressed of the failure by Walter D. Komhyr to conduct the next already funded by WMO Dobson intercomparisons during summer of 1981. It was noted that NASA (Edith Reed) has compared, ECC sondes, Dasibi and ROCOZ instruments in September 1979. Gérard Mégie informed on intercomparisons of various VO_3D methods (incl. lidar, Umkehr) carried in France. Reports on previous Dobson intercomparisons (Belsk-1974, Arosa-1978, Potsdam-1979) were still pending from Desmond Walshaw. WMO purchased 7 sets of standard lamp equipment to be circulated by the Boulder Laboratory through the stations for deductions of the state of the instruments. President Carl L. Mateer will take action all information and changes due to calibration as well as those steaming from intercomparisons are published by the WMO-WO_3DC in Toronto so the researchers to get easy access to such information.

Robert D. Hudson, chairman of the working group on UV Absorption Coefficients, informed that the work of Arnold M. Bass and R. J. Paur (from US National Bureau of Standards) on determination of the ozone absorption coefficients at low temperatures is progressing well. He has contacted the few other interested scientists and he will arrange a small meeting of experts in 1983 to review the results.

The president encouraged members to participate in the Middle Atmosphere Programme (MAP) with SCOSTEP keeping the identity of IO_3C since lately meetings organized by MAP are sometimes competing with the Commission activities without giving proper credit. The invitation from Greece to hold next Quadrennial Symposium in Halkidiki in September 1984 was accepted and the Secretary was asked to negotiate details with the local host - Christos Zerefos.

Discovery of drastic ozone depletion during Antarctic springs (1984-1988)

In September **1984** a week long Quadrennial Ozone Symposium (QO_3S) was held in Halkidiki, Greece hosted by Christos Zerefos. More than 200 scientists from 30 countries attended. All 161 presentations were published with support from the European Commission in one volume (Ozone, 1984). In his Presidential address Carl Mateer noted that, despite the enormous advances of ozone science over the past 5-6 years and use of sophisticated models, the uncertainty which must be attached to the model-predictions of long-term ozone changes have not decreased. Improvement of knowledge of reaction rates used, as well as of the projected emissions of substances affecting ozone are pending before this scientifically complex question for


WORLD METEOROLOGICAL ORGANIZATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FEDERAL AVIATION ADMINISTRATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

WMO GLOBAL OZONE RESEARCH AND MONITORING PROJECT
REPORT No. 11

THE STRATOSPHERE 1981
THEORY AND MEASUREMENTS

Figure 18.

In 1981 the first truly international Assessment Report (500 pages) was drafted by 102 scientists from 12 countries at a meeting held in Hampton. It starts with a review of the source gases and reactive trace species (e.g. HO_2, NOx, ClO) and confirmed imminent threat for ozone catalytic destruction by chlorine in the stratosphere. At that time only 36 stations were having data longer than 15 years, mostly of unproven quality. Satellite coverage was available just for few years. Descriptive and statistical studies indicated a neutral or slightly positive global ozone trend for 1958-1979.

future ozone trends could be solved. He emphasized that ozone changes, and the changes in minor constituents which must accompany them will have *an impact on climate and vice versa*. Therefore it became clear that the ozone and climate changes should be studied with 3-D models which would married the complexities of the photochemical and meteorological processes.

In the presentations there were 19 papers on the chemical-radiative-dynamical models (including 3 on ozone-climate relation) and 24 papers on observations of relevant to ozone trace constituents. These 43 presentations attracted high attention in view of increasing concerns about long term ozone depletion due to anthropogenic perturbations. The nonlinear dependence of the ozone column to changes of ClOx and NOx concentrations were studied in multiple numerical scenarios.

One of the most important but at the time unfortunately unnoticed was a paper by Shigeru Chubachi (MRI, Tzukuba) including plots of drastic total *and* stratospheric ozone decline during September-October 1982 over Syowa station in Antarctica, and referring also to similar total ozone behaviour over the South Pole station. Those were the first plots of severe ozone depletion season which later, after Farman et al. (1985), paper started to be referred to as the Antarctic spring "ozone hole". Chubachi plots did not attract attention possibly because everybody was expecting to see ozone depletion in about 40km altitude – not in the lower stratosphere where it is clearly seen on the vertical cross-section above Syowa on page 286 of the

Proceedings. Furthermore, in all models due to the lower sun position during the polar winter-spring, the ozone was considered to be almost chemically inert, and no such drastic ozone decline was foreseen. The discovery of the “ozone hole” came as complete surprise to everybody in the ozone scientific community. For the record it should be noted that in early 1995 the NASA TOMS Evaluation Team (Pawan K. Bhartia et al., 1985) have submitted and few months later presented at IAGA Assembly in Prague the *first space view* of the Antarctic ozone depletion for October 1983. That presentation was followed by detailed analyses of the satellite information on the ozone hole phenomenon by Stolarski et al., (1986).

In the Halkidiki QO_3S the number of papers on analysis of ozone observations and relations with atmospheric circulation (39), plus those on developments of observational techniques incl. intercomparisons (34) was as substantial as at previous symposia. The first group of these presentations discussed the available five-year long series of satellite data (TOMS instrument) which provide a unique global coverage and in few the noticeable ozone decline as result of the 1982 eruption of El Chichon volcano. In the second group results was presented by Bob Watson of important field Balloon Intercomparisons Campaign (BIC) of measuring the trace constituents of interest to the ozone balance. In number of oral and poster presentations 20 papers addressed chemical rate constants, laboratory measurements of absorption cross-sections, and other radiation topics. In few of them by A. M. Bass and R. J. Paur (1985) were presented new detailed determinations of ozone absorption coefficients at low temperatures which will be replacing those presently used. On the same subject Bob Hudson, reported on the discussions of a meeting of experts held just before the Symposium and chaired by Rumen D. Bojkov which paved the way for introducing the new Bass and Pour absorption coefficients in the Dobson retrievals. Much more work was left which would be completed by the group of Robert D. Hudson, Carl L. Mateer, Walter D. Komhyr and Rumen D. Bojkov.

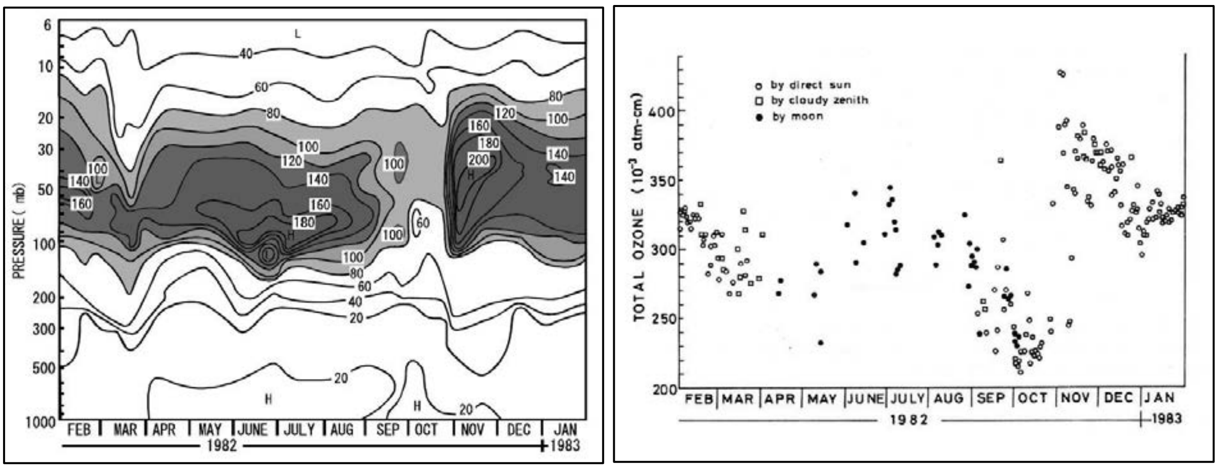


Figure 19.

The first plots of the rapid Antarctic-spring decline of ozone over Syowa station published by Shigeru Chubachi (1985; proceedings of the quadrennial ozone symposium in Halkidiki, 1984). Right: total ozone from 3 classes of measurement. Left: vertical ozone distribution. The latter showed for the first time that the ozone decline during Sep./Oct. 1982 occurred in the lower stratosphere (around the 50 mbar pressure level).

A special mention deserves Marcel Nicolet for an excellent review of solar UV irradiance of importance to the photochemistry of the stratosphere and mesosphere. .

In 22 papers on non-urban tropospheric ozone, observations from numerous stations were reported. Observed *increasing trends in tropospheric ozone* of the order of up to 1% per year resulting from release of nitrogen oxides and hydrocarbons were of major concern, both because of their possible influence on climate and on tropospheric chemistry in conditions of changing UV-B penetration.

At the Commission meeting in Halkidiki Rumen D. Bojkov informed on the successful implementation of the WMO Ozone Research and Monitoring Project and listed the large number of members who were participating in the UNEP guided discussions on development of a Convention for Protection of the Ozone Layer.

The small Nomination Committee (Walter Attmannspacher, Julius S. Chang and Hans U. Dütsch) proposed for President Julius S. Chang and for Secretary Rumen D. Bojkov. The latter was elected unanimously. However, a number of members considered "very unusual" that a member of the Nomination Committee was proposed for President. Furthermore, that in fact he was leaving the field of active ozone study. An alternative proposal was tabled (Gérard Mégie for President) but in the voting he got 36% and Julius S. Chang was elected. Then for more evenly distribution of responsibility IO_3C created the position of Vice-President to which Gérard Mégie was elected. It was done with understanding that the Vice-President is not necessarily the next President.

New members of the IO_3C were elected: Daniel Albritton (NOAA, Boulder), Reid E. Basher (Meteorological Service, Wellington), Anver Ghazi (European Commission, Brussels), Jim Kerr (AES, Toronto), Arlin Kruger (NASA-Goddard SFC), A. Jim Miller (NOAA, Washington DC), John A. Pyle (Cambridge), Paul Simon (Institute for Aeronomy, Brussels), Wei-Chyung Wang (NY State University at Albany) and Christos S. Zerefos (University of Thessaloniki). The Secretary was requested to solicit in the future and circulate the list of names proposed for members *well before* the meetings. In order to utilize the existing pool of knowledge outside of IO_3C and realizing that only small number of active scientists could be elected as members, it was decided as one possible way to appoint more Rapporteurs for clearly defined tasks, with consulting status, as already done in the two previous meetings.

The Commission re-appointed Alain Barbe (University of Reims) to represent the IO_3C in a joint with IRC working group on Infrared Absorption Coefficients where he will co-chair with Rodolpho Zander (University of Liége). Other Rapporteurs were Klaus Künzi (University of Kiel) on Microwave methods of observations; Sherwood Rowland (University of California at Irving) on trace species; Robert D. Hudson (NASA-Goddard SFC) on UV ozone absorption coefficients.

In recognition of the long services to the IO_3C and contributions to ozone research Hans U. Dütsch was elected unanimously *honorary member*. Another proposal was made from the floor to elect honorary member also Julius London who has contributed to ozone research for many years. This was approved with 62% of the vote. Members requested the Secretary to circulate *long in advance* names for possible consideration for honorary members. It was emphasized that considerations should be *restricted to very few extremely respected scientists*.

After the Symposium toward the end of 1984 the new President drafted procedures which were not always in concurrence with the previous Commission practice and IAMAP Statutes and have had the potential for delaying the communication and the work of the Commission. At the initiative of the past-

President and the Vice-President the four Officers met in Washington D.C. on 10 June 1985. They agreed that the nearly 40 years long successful operation of the Commission and the wisdom IAMAP Statutes offered should be carefully considered *before* any attempt is made, to establish more specific principles for operation of the Commission as proposed by the Presidents letter - which failed to get approval by the majority of the members. The Officers keeping in mind their collective responsibility for the better execution of the Commission affairs confirmed they will adhere to the principle of mutual collaboration and the work of the Commission proceeded. It was agreed to initiate procedures for adoption of Commission By-laws exactly in lines with the IAMAP Statutes and the Vice-President would collect the members' opinion for prepation of a draft.

When discussing the location for the 1988 Quadrennial Symposium it was noted that there is an offer from University of Göttingen; the President has sensed some interest by China; however, due to the high costs of both travel and lodging an inquiry to members exploring how many ozone researchers from their country would not be prevented to attend appeared in order. Thereafter the final location will be decided.

In August **1987** the XIX-IUGG Assembly was held in Vancouver. At a MAP "Symposium on Differences between Arctic and Antarctic Middle Atmosphere" at a special session dealing directly with the ozone behaviour were presented 17 papers (see page *190-192,* Ozone, 1987*).* IO_3C did not have separate symposia due to preparations for the 1988-Quadrenial in Göttingen.

The Commission meeting in Vancouver was chaired by the Vice-President Gérard Mégie since the President has asked the members to be informed that he definitely will not seek re-election in 1988 and not attend the meeting (Ozone, 1987). Members did noted that the outgoing President of IAMAP (Hans-Jürgen Bolle) put for consideration future activities to be carried not by the existing eight Commissions but by four divisions: Meteorological processes, Climate studies, Atmospheric physics and Atmospheric chemistry and pollution. The Executive Committee of the Association decided that a new structure is *not necessary* however cooperation between the Commissions on interdisciplinary issues should be strengthened. Members of IO_3C recalled that they already expressed their deep disagreement with such restructuring at the IAMAP Executive Committee discussion in Hawaii in 1985.

All small working groups charged with specific tasks at Halkidiki were asked to submit a one-page report to the Secretary before June 1988 in order to prepare a consolidated report for Göttingen. In this connection appreciation was expressed to Uwe Feister (Potsdam Observatory) who has already completed a draft for position paper on the need to continue the practice of adjusting the vertical ozone-sonde profiles to the measured total ozone amount. It was decided that Carl L. Mateer and Rumen D. Bojkov prepared formal letters to the Secretary-General of WMO for further communication with the interested countries. Following a recommendation by IUGG it was decided that the papers, which will be submitted for the Göttingen symposium, have to be subject to peer review.

With reference to the five Dobson spectrophotometers owned by the IO_3C and lent to Arosa (2), Lisbon, Reykjavik and Spitsbergen/Tromso for over 30 years it was decided that operating countries should consider purchasing their own instruments and releasing the Commission owned for distribution to other more desirable locations and anyway the lending agreement should be formalized in order to keep the books in order.

The Vice-President Mégie informed the meeting that in response to the call by IUGG/IAMAP to commemorate the 30th Anniversary of the IGY, the Officers considered all proposals made by members and decided to offer a formal *recognition certificate* to 25 scientists who had publications in the field of atmospheric ozone in 1957 (or earlier), and/or have been actively engaged in organizing ozone research at that time, and continue to contribute to this field up to the most recent years. The scientists recognized were: *Marcel Nicolet, Ernest Vigroux, Victor H. Regener, Rudolf Penndorf, Hans-Karl Paetzold, Hans U. Dütsch, Sorren H. H. Larsen, Arlette Vassy, Anna Mani, Alexander Khr. Khrgian, Warren L. Godson, Julius London, Carlton L. Mateer, C. Desmond Walshaw, Genady Iv. Gushtin, Walter K. Komhyr, Rumen D. Bojkov, Wolfgang Warmbt, S. Ichtiaque Rasool, John C. Farman, R. N. Kulkarni, Edith Farkas, Tatsumi Kitaoka, Yoshiro Sekiguchi, and Karl-Heinz Grasnick.* Certificates of recognition will be handled in Göttingen. The Officers recognized that there are a number of other scientists who have made significant contributions to ozone study during the past 20-25 years but could not include them to this list which is strictly devoted to the 30th anniversary of IGY. Proposals for their recognition will be considered in due time.

It was recalled that the IO_3C has elected by correspondence Marcel Nicolet for *honorary membership* Marcel Nicolet in recognition of his extraordinary contributions to ozone science and continuous support to the Commission activities in nearly 40 years. The decision for recognition was handled to him on the occasion of his 75 birthday.

Finally the Commission discussed how to highlight the IO_3C role in the numerous activities (e.g. assessments) and/or formal programmes (e.g. MAP, IGBP) in which most members are actively contributing. The view was that the Commission should be involved formally in order to build better support and positioning for ozone scientists as a whole.

Ozone decline established as a global phenomenon (1988)

In August **1988** the Quadrennial Ozone Symposium was held in University of Göttingen with close to 500 participants from 34 countries who presented ~340 papers from which after pear review 198 were published in one volume (Ozone, 1988). It was so far the largest scientific gathering of ozone scientists demonstrating the increasing importance given to the ozone issue. The impact of anthropogenic emissions on stratospheric ozone regime was the major issue of this Symposium discussed in more than 160 presentations. With chemical dynamic models were dealing more than 50 presentations. Another 30 were discussing the accumulated wealth of satellite data. There were only 20 papers on standard observational techniques demonstrating the real shift in the field of ozone research.

Two invited papers review the state of the ozone depletion (F. Sherry Rowland et al., 1988) and the findings of the NASA/WMO Ozone-Trends Panel (Dan Albritton) in which preparation many of the IO_3C members have participated (see WMO, 1988). It was demonstrated that the ozone layer has already been modified by human activities and that these changes are bound to grow during coming years. The Panel under the chairmanship of Robert T. Watson critically reanalyse and asses the present knowledge on the chemical composition and physical structure of the stratosphere and concluded:

• There is *undisputed observational evidence* that the atmospheric concentrations of source gases important in controlling stratospheric ozone levels (CFCs, halons, CH_4, N_2O, CO_2) *continue to increase on global scale because of human activities;*

• *Re-evaluated* ground-based as well as satellite data *show measurable decreases* from 1969 to 1986 in the annual average total ozone (1.7 to 3.0%) at 30-64^{0}N. The decreases are most pronounced (2.3 to 6.2%) during the winter spring months. On the re-evaluation of all published total ozone records considering corrections deduced from instrument calibrations was given high priority;

• During Antarctic-spring large, sudden ozone decrease of more than 50% in the column (and 95% between 15 and 20 km altitude) have been observed. The weight of evidence strongly indicates that *manmade chlorine species are primarily responsible for the observed ozone decrease* within the polar vortex.

At the QO_3S in more than 40 presentations was discussed the Antarctic-spring ozone decline. It was confirmed that the unique features of atmospheric circulation establish an isolated circumpolar stratospheric vortex with temperatures lower than -80^{0}C leading to the condensation of water and nitric acid to form “polar stratospheric clouds” (PSCs). are liberated facilitating heterogeneous ozone destructive reactions. It was Solomon et al. (1986) who first proposed that the reaction of HCl and $ClONO_2$ on the surfaces of PSCs plays an important role in bringing about the perturbed polar chlorine chemistry. In the same year Crutzen and Arnold (1986) suggested that PSCs could contain crystalline particles consisting of nitric acid trihydrate rather than only of ice as was previously thought. As the ultraviolet light increases during the spring months reactions are activated and there is an increased depletion of ozone. For a few weeks in September through

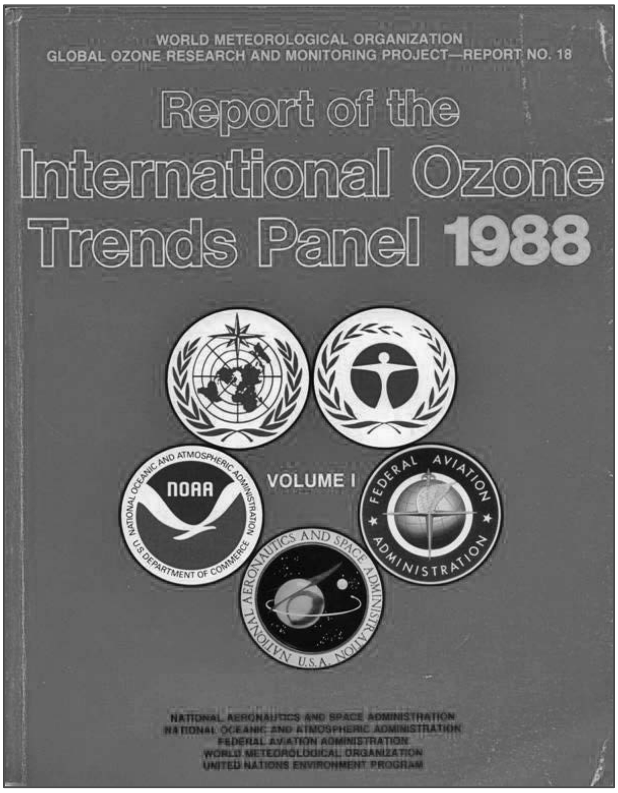


Figure 20.

The NASA/WMO Ozone Trends Panel chaired by Bob Watson produced Report in two volumes (WMO, 1988) which was the most thorough scientific evaluation of the ozone issue provided significant and undisputable evidence that the ozone is decreasing not only in Antarctica but also over the Northern middle and upper latitudes. It provided support for the need of strengthening of the Montreal Protocol which was signed September 1987. Many members of IO_3C made substantial contributions to its content.

early October practically all ozone is destroyed in the 12 - 22 km height range. Indeed the Airborne Antarctic Ozone Experiment (AAOE) carried out in the previous two Austral-springs with aircraft measurements in the stratosphere provided clearer evidence that the Antarctic ozone hole is indeed caused by strongly perturbed chlorine chemistry (WMO, 1994b).

Whereas four years ago less than twenty papers were discussing the tropospheric ozone, in Göttingen there were more than 70 presentations demonstrating increased importance given to its regime showing an *increase by 1 to 3% per year* in the Northern middle latitudes during past two decades. Concerns about further tropospheric ozone modification by human activities releasing precursors such as NOx, CO and gaseous hydrocarbons have increased also due to its noticeable contribution to augment the greenhouse effect. The precursors release is mainly from vehicles and industrial plants. They can lead to greatly increased concentrations of ozone in the lowest layer of the atmosphere, eventually causing damage to plants and humans. The methane released from livestock, rice cultivation and other sources, spread over large parts of the earth and affect the ozone content of the troposphere worldwide. More ozone in the troposphere contributes to a warmer climate.

The Commission meeting on recommendation by the Nomination Committee chaired by Marcel Nicolet elected unanimously Gérard Mégie for President, Alvin Jim Miller for Vice-President and re-elected Rumen D. Bojkov for Secretary. New elected members were: John J. DeLuisi (NOAA, Bolder), Peter Fabian (Max-Plank Inst. für Aeronomie), Paul Fraser (CISRO, Melbourne), Robert D. Hudson (NASA-Goddard SFC) Volker W. Kirchhoff (INPE, Sao Paolo), Dieter Kley (Institute for Chemistry, KFA-Jülich) Shaw Liu (NOAA, Bolder), Yukio Makino (MRI, Tsukuba), Carl L. Mateer (AES, Toronto), Stanislav Perov (CAO, Moscow) Ulrich Schmidt (Institute for Chemistry, KFA-Jülich), B. H. Subbaraya (PRL, Ahmedabad) and Ding-Wen Wei (Academia Sinica, Atmos. Physics, Beijing). For complete listing see *Appendix 3a.*

IO_3C adopted its own By-Laws for operations which were approved by IAMAP. It was noted that they are based on the 40-years experience of IO_3C and IAMAP Statutes and thus would not necessitate any changes. The By-Laws are given in *Appendix 7.* They are posted on the IO_3C web page (cf. http://ioc.atmos.uiuc.edu).

Review of the work performed by IO_3C numerous Rapporteurs did follow. On new UV absorption coefficients Bob Hudson has compared values of Bass-Pour (1985) with Brion et al., Freeman et al., and Molina and Molina concluding they are in agreement (relative ±1%, absolute ±2.5%). With reference to the wavelengths used in the Dobson spectrophotometer the temperature dependence at 253.7nm, taken as average, provides best data set. He would need the instrument slit-function from Walter D. Komhyr and would then, jointly with Carl L. Mateer provide final recommendation.

Rapporteurs on IR Spectroscopic Applications (Alain Barbe, Rodolpho Zander) were asked to continue their studies as until now jointly with the Radiation Commission.

The Rapporteur on performance of the Brewer type instrument Jim Kerr informed that 4-years inter-comparisons in Toronto and Edmonton with the Dobson spectrophotometers showed agreement within ±1%.

The Rapporteur on Climatic Effects of Trace Constituents Wey Chyung Wang informed that the radiative aspects of ozone are not jet fully recognized. He was asked to contact the Radiation Commission group on a similar subject to produce

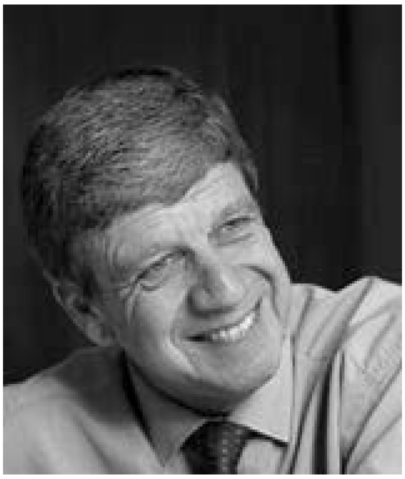


Figure 21.

Gérard Mégie (1946-2004), an internationally renowned scientist who contributed to the development and operation of laser for observations of ozone and other atmospheric components and worked enthusiastically for European and global co-operation in atmospheric sciences. As Vice-President (1984-1988) and as President of IO_3C (1988-1996) he assured active participation of its members in the WMO-Ozone Assessments, in comparisons of VO_3D methods, in joint work with SPARC and IGAC, and in support to NDSC. In 2000 he was appointed as Chairman of CNRS, the top science position in France.

a joint list of necessary actions referring specifically to the ozone effect. On a related issue on model comparisons Ivar Isaksen agreed to be the focal point.

The idea of a network of dozen stations with more sophisticated observational technique (lidar, microwave, IR/Visible/UV spectrometers) for *Detection of Stratospheric Change (NDSC)* was evolving rapidly. It has been endorsed by WMO as contributing network to the WMO Global Atmosphere Watch (GAW). A number of Commission members were involved in its planning and in the Steering body and all others were encouraged to participate when occasion arise.

Noting that the International Geosphere Biosphere Programme (IGBP) is in its definition phase and many members are associated at national and international levels since the ozone problem is one of its corner stones the IO_3C should act to promote the ozone research in IGBP and be represented to the relevant Steering Groups. In this connection IO_3C was informed that the Commission on Atmospheric Chemistry and Global Pollution was proceeding unilaterally of formulation of International Global Atmospheric Chemistry activities (IGAC) although in Vancouver (Ozone, 1987) it was agreed between the two Presidents that a joint approach was needed. The Secretary of IO_3C has send letter to their Secretary (Henning Rhode) underlining the interest of IO_3C and demanding to be considered for active contribution to the coming planning meeting in Australia (November 1988).

The new President suggested that the IO_3C should be considered as an independent reviewer of future WMO/UNEP International Ozone Assessments to give some recognition to the numerous members' contributions in the process of their preparations. This has been accepted by WMO.

In connection with the proposed IAMAP reorganization amalgamating the existing Commissions, the IO_3C reconfirmed its deep disagreement and adopted a formal Resolution to be send to the IAMAP Officers in which explained its strong stand against modification of this Commission charter. The Resolution is published by IAMAP (Ozone, 1989) and considering its valid arguments is attached as *Appendix 8.* There were no objections to the proposal for a change of the name of the Association from IAMAP to IAMAS (to replace the word 'Physics' by 'Sciences'). The need was necessary in order also atmospheric chemists who became major players also for IO_3C to feel at home in IAMAS.

As venue for the next Quadrennial Ozone Symposium on behalf of the US science community, Bob Hudson offered, the University of South Carolina in Charlottesville to be considered. The understanding was that the responsible host will be NASA. This proposal was very much appreciated. However the Officers were asked to explore opportunity, if any, for a Far East location and then to decide.

Finally the Commission benefiting from the reported new findings on the ozone issue after many years of research concluded that *there is now clear evidence of mankind having affected the global ozone layer*. This is the first firm evidence that humans have significantly and harmfully altered the atmosphere on global scale. IO_3C urged all national and international Agencies to continue to support and develop further their programmes on research and monitoring of ozone and associated atmospheric parameters. After further considerations by mail IO_3C adopted a Statement on "The State of the Ozone Layer" for wide distribution *(see Appendix 9).*

Large symposia, assessments and international projects (1989-2008)

In August **1989** during the IAMAP/IUGG Assembly in Reading the Commission held a short meeting for exchange of information. More than half of the IO_3C members have been actively participating in the writing and review of the WMO/UNEP Ozone Assessment–1988 which was published as WMO Ozone Project Report #20 toward the end of the year. For the IUGG Assembly in Vienna in 1991 were planned two symposia of potential interest to IO_3C. Especially relevant would be 6-days symposium on Middle Atmosphere Sciences to which ozone papers would be welcomed. Paul Simon will represent the Commission on the programme committee.

Formal invitation for 1992 Ozone Symposium at the University of South Carolina was received from the chairman of US Organizing Committee Bob D. Hudson. At the University campus in early June, will be available more than 600 units, all with kitchenette, at a price per room of 20-30$ per night. In the meantime Officers also received a tentative invitation from Ding-Wen Wei for Beijing, however he could not provide commitment for support by Meteorological Administration and/or Academia Sinica (needed for visa and assuring proper accommodations). Therefore he withdrew, hoping to master support for 1996. In view of above, the Secretary would ask all members to express their approval for holding the next symposium in U.S.A.

In the planning for the IGAC more than half of IO_3C members have participated as subject-group leaders and reviewers. Although Bob Duce the President of the sister Commission (ICACGP) has assured in letter the Secretary that the active collaboration of IO_3C will be reflected, recognition was missing in the final draft. Neither the 4-pages of suggestions provided by the Secretary were taken into consideration. Since ozone figures prominently in a number of IGAC projects, the Officers were asked to re-emphasise the interest of the Ozone Commission on earliest occasion.

The brief report by Robert D. Hudson - Rapporteur on ozone UV absorption coefficients indicated that he is preparing a normalized data set and will send it in very near future first to Carl L. Mateer who needs it for finalizing the new algorithm and Umkehr retrieval. Indeed the application of the Bass-Paur (1984) ozone absorption coefficients to ozone measurements with Dobson spectrophotometers was elaborated by Carl L. Mateer (13 pages) and is available from www.esrl.noaa.gov/gmd/ozwv/dobson/papers/bass-paur_1984_abs_coeffs.html.

In November 1989 WMO hosted the planning meeting for Network for Detection of Stratospheric Change (NDSC), organized by NASA, other national agencies and with participation of IO_3C. More than 60 scientists attended from all over the world, including number of IO_3C members. Potential sites, instruments, data protocol and near-term tasks were discussed. For Chairman was elected Mike Kurylo from NASA (later member of IO_3C). Vice-Chairman was Rodolpho Zander also member of IO_3C. Four of the six Principal Investigators were from the IO_3C (Jérard Mégie, Andy Matthews, Susan Solomon and A. Jim Miller). From the ten Peers for standing review the affairs of NDSC five were IO_3C affiliated (Dan Albritton, Rumen D. Bojkov, Dieter Ehhalt, Vjacheslav Khattatov and Cliff Rodgers). The network is established on an international base under the auspices of international societies and programmes (e.g. WMO-GAW, IO_3C, NASA, NOAA, CNRS, CMA). Its Goals were defined as: (a) to make observations with which changes in the physical state of the stratosphere can be determined and understood; (b) to provide independent calibration of satellite sensors and (c) to obtain data that can be used to assess multidimensional stratospheric chemical and dynamical models.

In June **1992** in Charlottesville, SC, more than 500 participants from 35 countries presented 415 papers covering: stratospheric ozone and climate, ozone in Arctic and Antarctic, measurements, trends, theory and modelling, volcanic effects, tropospheric ozone trends, global and regional modelling and the human impact. The Proceedings of the Symposium contained 332 peer-reviewed papers and was published by NASA (Ozone, 1992). By its size this Symposium was slightly bigger than the Göttingen-1988. The emphasis of ongoing studies was on observed ozone changes. They presented a useful background for the next international review prepared for the Parties to the Montreal Protocol - Scientific Assessment of Ozone Depletion–1994 in which preparations most of the IO_3C members participated (WMO, 1994b). The enormous volume and variety of presented papers make it difficult to provide a sensible summary in the limited space here. The interested researchers should refer to the mentioned NASA publication #3266.

The Commission meeting appreciated that (as decided earlier at the Vienna IAMAP-IUGG General Assembly,1991) its members have organized ozone session in Middle Atmosphere Sciences symposium (convener Paul Simon), on Modelling of Tropospheric Ozone and its Precursors with 43 papers presented (conveners Julius Chang and Shaw Liu), and a two days Workshop on Climatic Effects of Atmospheric Trace Constituents incl. Ozone (conveners Wei-Chyung Wang, Ivar Isaksen, Julius London and Anver Ghazi).

At the 1991 IUGG Assembly the Officers again made the point that there is no reason to amalgamate the IO_3C with its sister Commission on Chemistry and Global Pollution (ICACGP) as suggested by the latter, possibly looking for involvement in the most attractive current field of research. Ozone is not only ‘pollutant’ but the unique species which link chemistry, dynamics and radiation in the stratosphere and the IO_3C has specific traditional tasks carried out successfully since the 1930s which could not be absorbed in an amalgamation. The important role played by the IO_3C in the international science including preparations of scientific backgrounds for the Vienna Convention for Protection of the Ozone Layer and its Montreal Protocol was emphasized as a strong rationale for not modifying the IAMAP Commissions structure.

In winter **1991/1992** very large efforts were made to organize co-ordinated experiment in the Arctic to study the potential depletion of the ozone layer and its influence on middle latitudes. The Commission was strongly involved through its members from Europe, US and Canada. The results were reported in hundreds of papers in JGR, JRL and other major journals as well as being used in the Ozone Assessment-1994 (WMO, 1994b). WMO and IO_3C did collaborate to assure daily submissions, mapping and redistribution of total ozone data from GO_3OS by the WMO Ozone Mapping Centre operated by University of Thessaloniki (cf. http://lap.physics. auth.gr/ozonemaps).

In an effort to create the best possible quality assured ozone records, a joint project between NOAA, WMO and the IO_3C was initiated to prepare a *"Handbook for Dobson Ozone Data Re-evaluation"*. The first meeting of experts was held in Greenbelt MD in September 1991 (WMO, 1991a); the second in Charlottesville (before the Ozone Symposium) and the third meeting was planned and held in Hradec Kralove in May 1993. The convener of all three meetings was Walter G. Planet (NOAA, NESDIS) and was chaired by Robert D. Hudson (University of Maryland). As final result the Handbook was prepared by Rumen D. Bojkov, Walter D. Komhyr, Alan Lapworth and Karel Vanicek, published by WMO, (1993) and widely used by the stations with long observational records for their data re-evaluation. The corrected data were deposited by the stations to the WMO-WO_3DC in Toronto, thus improving the precision and homogeneity of the archived data bank.

With reference to the *introduction of the Bass and Pour ozone absorption coefficients*, the responsible Commission members (Robert D. Hudson, Carl L. Mateer, Walter D. Komhyr) in collaboration with WMO (Rumen D. Bojkov), have prepared the necessary instruction which was introduced worldwide by WMO starting 1st January 1992 (see transfer instruction at http://www.esrl.noaa.gov/gmd/ ozwv/dobson/papers/_coeffs.html).

For uniformity and improvement of observations by Brewer type spectrophotometers the newly introduced in GO_3OS, WMO jointly with members of IO_3C have organized Consultations between the operators in Arosa in August 1990 and in Charlottesville in June 1992, chaired by Jim B. Kerr and Thomas McElroy The reports of these Consultations were published in the WMO Ozone Project Reports # 22, and # 30 respectively (WMO, 1990, 1992).

The upgrading of WMO GO_3OS stations, which are presently the only ground stations continuously providing data for trend assessments, was performed with efforts by numerous members of IO_3C. In August 1990, 18 Dobson spectrophotometers were intercompared in Arosa under the supervision of Robert Evans (NOAA, Boulder). The results were very good. Detected differences between participating instruments were no greater than ±1%. Also one ozonesonde intercomparison between four most used types (Brewer-MAST, Komhyr-ECC, Japanese RS11-KC79, and the Indian) was hosted by AES and carried out in Vanscoy, Saskatoon, Canada, in May 1991 (WMO, 1991b). It was jointly organized by WMO and IO_3C and supervised by Jim B. Kerr and C. Thomas McElroy.

A critical *assessment of the information content in the Umkehr observations* for the ozone profile has been carried by WMO in collaboration with the Commission (by Bojkov, Mateer, Kosmidis, Zerefos, DeLuisi, Petropavlovskikh and Godin). Meeting of experts were held in Toronto, Tenerife and in NASA-Goddard and new algorithm was tested. The undisputable usefulness of Umkehr derived information was established and the reanalysis of more than 44000 ozone profiles including the necessary aerosol and total ozone re-evaluation corrections was progressing and later an extensive review was published Bojkov et al., (2002).

After the above review of the work of IO_3C and its Officers (Gérard Mégie, Alvin Jim Miller and Rumen D. Bojkov) in the past four years, the Commission unanimously re-elected them for the next period (1992-1996).

In recognition of nearly 40-years, of continuous ozone research and in particular for major contributions to the Umkehr retrieval and work with the IO_3C Carl L. Mateer was unanimously elected *honorary member*. The following new members were elected: Guy Brasseur (NCAR, Boulder), Malgorzata Degorska (Institute of Geophysics, Warsaw), Giorgio Fiocco (University La Sapienza, Rome), Galal K. Y. Hassan (Meteorological Service, Cairo), Oystein Hov (NILU, Oslo), Tomoyuki Ito (Meteorological Office, Tokyo), Vjacheslav Khattatov (CAO, Moscow), W. A. Matthews (NIVA, NZ), C. Thomas McElroy (AES, Toronto), Steward Penkett (University of East Anglia), Jean-Pierre Pomereau (CNRS, Paris), Cliff Rodgers (University of Oxford), Susan Solomon (NOAA, Boulder), Johannes Staehelin (University of Zürich), Richard S. Stolarski (NASA, Goddard SFC), Karel Vanicek (Hr. Kralove Observatory), Robert DeZafra (SUNY at Stony Brook) and Xiuj Zhou (Meteorological Academy, Beijing).

In July **1994** in Tenerife the IO_3C jointly with NOAA, Environment Canada and WMO has organized workshops on Brewer operations and on Ozone Data Re-evaluation and Use of Dobson and Brewer instruments in the GO_3OS. About 70 scientists from 27 countries participated. Emphasis was on quality of data and on vertical ozone distribution evaluations. The Brewer consultation was guided by three Commission members: Jim Kerr, Thomas McElroy and Emilio Cuevas who published the results in WMO Ozone Project Report #36 (WMO, 1994a). One important recommendation was directed to the IO_3C to organize a small group to prepare a *Handbook on Brewers Operations*. Robert D. Hudson and Walter Planet (NOAA, NESDIS) attended in particular the data re-evaluation and VO_3D workshop. Their satellites groups provided essential data support. The attending dozen Commission members strongly endorsed the proposal to be organized special workshop to discuss together with modellers the VO_3D profile issues probably before the Quadrennial Symposium-1996. Later a detailed study of the state of the VO_3D was completed in collaboration with SPARC and GAW (WMO, 1998).

In May **1995,** in Halkidiki was held an International Conference on “Ozone in the Lower Stratosphere”. It was jointly organized by the European Commission, NASA, NOAA, IO_3C and WMO and hosted by Christos Zerefos. The newly established within the WMO/ICSU Climate Research Programme SPARC project (Stratospheric Processes And their Relation to Climate) has also assisted in preparation of the programme. More than 300 scientists from 40 countries attended. The emphasis by this international forum was on interpretation of new measurements and trends of ozone, NOy, HOx, halogen compounds, aerosols and on critical uncertainties in atmospheric chemistry and transport models. In recent years, ozone depletion has reached *unprecedented* levels. Considerable progress in both measurements and theory has been made, allowing an improved understanding of the processes responsible for the ozone loss. The participants reported on and discussed results from major field campaigns (e.g. EASOE, AASE, SESAME, ASHOE) and from space-based atmospheric chemistry measuring instruments or platforms such as UARS, ATLAS, POAM, TOMS, SAGE and SBUV/2 all of which have provided essential information.

With reference to the global decline of the ozone the availability of more data both from ground-based and satellite instruments permitted the establishment of long-term zonal as well as hemispheric and globa l variations for the 1964-1994 period (e.g.

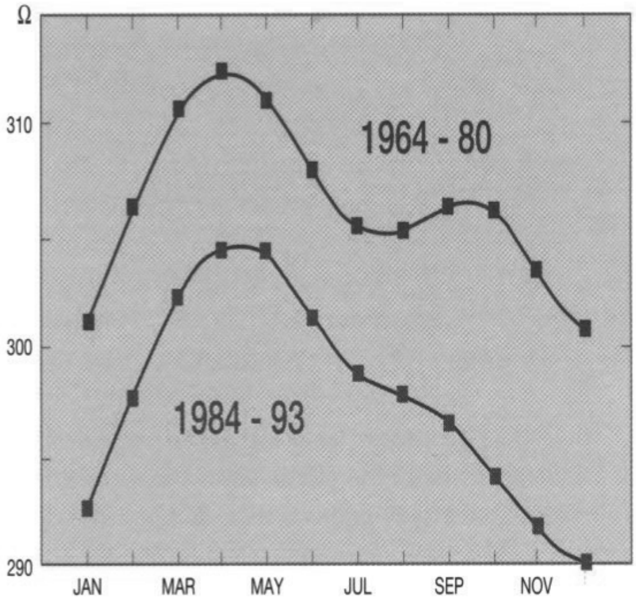


Figure 22.

Global monthly difference between total ozone values (in DU or matm cm) for two periods (1964-1980 and 1984-1993) estimated from ground-based and satellite instrument data. Noticeable is the levelling of the secondary ozone maximum during Sep-Nov of the later period due to the drastic Antarctic-spring decline. The global average for the second period (1984-93) is lower by ~3% (from 306.4±1.0 down to 297.7±2.2 matm cm).
(Adapted from Bojkov and Fioletov, 1995).

Stolarski et al., 1992; Bojkov and Fioletov, 1995). The difference between the estimations of monthly zonal variations from ground-based and TOMS data for the overlapping period of 1979-1993 is less than 1% in latitudes 40°S-60°N. The *ozone changes are several times larger than possible errors* of the estimated values; therefore the observed decline is highly reliable. The changes show that the northern hemisphere average ozone was ~312 and the southern average was ~300 matm-cm in the pre-ozone-hole decades (1964-1980) and that the global average for the 1984-1993 period was lower by ~3% (from 306.4 ± 1.0 down to 297.7 ± 2.2 matm-cm. Noticeable is the *levelling of the secondary ozone maximum* during Sep-Nov of the later period due to the drastic Antarctic-spring decline (see Figure 22). The levels of annual ozone maximum have been reduced by 5.8% in the southern hemisphere and 3.2% in the northern hemisphere, and the levels of ozone minimum have been reduced by 2.1% and 1.2%, respectively. The cumulative year-round global ozone decline is 4.8±0.6%. However, the cumulative year-round decline over middle and polar latitudes is close to 8%. In the northern belt it is higher in the winter-spring and is 4-6% in summer and fall. In the southern belt the cumulative decline is ~10%, reaching 40% in Sep-Nov in Antarctica. The southern hemisphere contributed ~64% of the overall ozone decline.

In October 1995 the Nobel Prize for Chemistry was granted to *Paul J. Crutzen, Mario Molina and Sherwood Rowland.* This was an unprecedented recognition of the pioneering work on the ozone issue carried out by those colleagues. This was accepted with admiration by all ozone scientists as recognition of the efforts of the whole ozone community.

Later in December 1995 the Intergovernmental Conference of the Parties to the Vienna Convention for Protection of the Ozone Layer on occasion of its 10-years anniversary has recognized 7 atmospheric and 2 biology scientists, as well as a few negotiators and technology transfer assisting institutions by granting them the "United Nations Award for Outstanding Contribution to the Protection of the Ozone Layer". In the field of atmospheric sciences those recognized were: *Dan Albritton, Rumen D. Bojkov, Paul J. Crutzen, Joseph Farman, Mario Molina, Sherwood Rowland and Robert Watson* (five of them members of IO_3C).

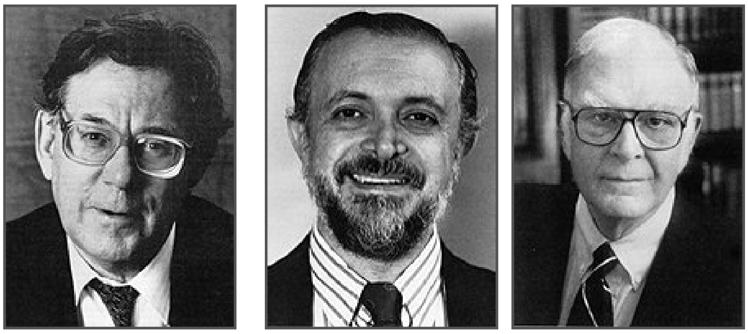


Figure 23.

The three Nobel Prize winners for Chemistry in 1995 (from the left): Paul J. Crutzen, Mario Molina and F. Sherwood Rowland. They have been members actively supporting the work of the Commission for many years and were later elected as Honorary members.

In September **1996** the Quadrennial Ozone Symposium was held at the University of L'Aquila (Italy) with local host Guido Visconti. 622 participants submitted 486 abstracts and 252 peer-review papers were published in two volumes (Ozone, 1996). The two opening talks were given by the Nobelists Paul J. Crutzen and Sherwood Rowland. Those were moving moments which lifted the spirit of the hundreds of attending ozone scientists. At the symposium in Charlottesville the effect of the Mt. Pinatubo eruption in 1991 was barely discussed. In L'Aquila there was an occasion to review the changes induced on the composition of the stratosphere by this eruption which turned out to have only one-two year's long effect on the ozone. Here was the first time when indications of reduced growing and even *start of levelling* in the concentrations of some harmful to the ozone compounds were reported and interpreted as positive result of the Montreal Protocol measures to contain the ozone losses.

About 30% of the papers were devoted to observations and analysis of total and vertical ozone distributions. Results for polar ozone changes mainly referred to Antarctica where the surface of the ozone hole has been expanding, reaching 24-25 million km^2 during September-October, and nearly 70% ozone decline during week's long intervals when in the 14-20 km layer 95% of the ozone has been destroyed. A very interesting study of the behaviour over sub-Arctic regions did show that in the last seven winter-springs the deficiencies over Siberia have been ~15% and for short time have exceeded 30%; in Europe or North America in the same time deficiencies were somewhat smaller (see Figure 24). The negative decadal trend is estimated to be of the order of a few percent. Typical ozone changes over North America and Eurasia range between -7 and -3% per decade. Over the Tropics the trend is not significant and almost negligible.

Data on trace gases which determine the ozone concentrations were still sparse, however more than 50 papers were on such data analysis or demonstration of new instruments for trace gas measurements. In the modelling section there are 33 papers. Results presented in a number of them were using the Chemical Transport Model (CTM). A few dealt with reconstruction of composition before the industrial era and a few with effects of aviation the overall effect of which seems to be quite small. Although the observational data increased, they remain still too sparse to be useful for realistic verification of most of the modelling results. A particular lack of data was noted in connection with heterogeneous chemistry.

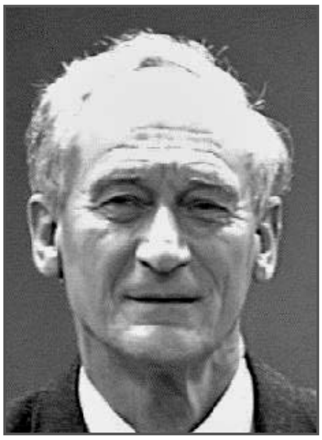


Figure 24.

Robert D. Hudson was leader of NASA satellite ozone measurements, analysis and calibrations for nearly two decades. Internationally respected scientist he organized number of stratospheric-ozone national and international assessments which have had great impact on the ozone science and the move to save the ozone layer. He played the leading role for the physical model and adjustments of the Bass-Pour ozone absorption coefficients for use in the GO_3OS and in the efforts for keeping high quality of ozone measurements from the ground and from the space. He served as President of the IO_3C 1996-2004.

The section on tropospheric ozone contains also papers on more general aspect of tropospheric chemistry as connected to the ozone problem. The reported ozone increase mostly over Northern Middle latitudes is difficult to generalize due to lack of sufficient observations, although it is well established that the increase is related to the urban pollution which can be transported to long distances. Another important report concerns the influence on tropospheric ozone by large and wide-spread tropical fires obtained using satellites data (e.g. UARS, TOMS).

At the end of the Proceedings are included 33 papers dealing with experimental techniques and results of intercomparisons and problems of calibrations of Dobson's, Brewers, ozonesondes, etc).

At the Commission meeting in L'Aquila the President's report on the past activities was accepted with appreciation for the Commission Officers' dedicated services to the ozone community. The Proposal of the Nomination Committee (Gérard Mégie, Susan Solomon, and Carl L. Mateer) for election of Officers was Robert D. Hudson for President, Andy Matthews for Vice-President and Rumen D. Bojkov for Secretary. After some discussions these proposals were accepted with a secret balloting. The Commission noted the continuous and significant contributions to the work of the Commission during the past twenty years by the two Nobel laureates Paul Crutzen and Sherwood Rowland and was pleased to elect them as *honorary members*. Furthermore, recognizing the pioneering work in the ozone field done in 1950-1974 by one of the past presidents, Alan W. Brewer, the Commission also elected him as an *honorary member*. The following new members were elected: Roger Atkinson (Weather Bureau, Melbourne), Hans Claude (Hohenpeissenberg Observatory), Nikolay Elanski (Inst. for Physics of the Atmosphere, Moscow), Maximo Ginzburg (Buenos Aires Observatory, Villa Ortuza), Ivar Isaksen (University of Oslo), Conrad Mauersberger (Max-Plank Inst. for Kernphysik, Heidelberg), Daniel S. McKenna (Inst. Stratosphärische Chemie KFC, Jülich), Toshihiro Ogawa (University of Tokyo and NASDA), Michael Prather (University of California at Irvine), Paul C. Simon (Inst. d'Aeronomie Spatiale, Brussels), Anne Thompson (NASA, Goddard SFC), Guido Visconti (University of L'Aquila) and Christos S. Zerefos (University of Thessaloniki).

As concern the location of the next Symposium the Secretary has received only one written proposal by Japan which includes promises for substantial local support. From the floor were made two tentative proposals offering Montreal and Melbourne. It was agreed each of the groups should submit to the Secretary of the Commission written offers describing the conditions and clearly stating the expected national support before the end of November 1996. Then a summary would be circulated to the members for a final decision.

On the related issue for the publication policy of the Proceedings and organizing the future QO_3S discussion revealed that the Quadrennial Symposiums became extremely big and their organization lately escalated to more than 400, 000 $ plus work and cost of publishing the proceedings which is a big burden for the organizers. Question raised included: duration to be 5.5 days with no more than two invited reviews; availability of University accommodations and/or not expensive lodging facilities; to publish presented papers with long time taking peer-review (in such case many scientists prefer to submit in refereed journals), or to publish short (four page) papers or two page extended abstracts; consider use of internet for submissions and then CD ROM instead costly printing. However, it was recalled that for many scientists the Proceedings are the only updated summary of the state of the ozone. It was decided the last Vice-President A. Jim Miller, collect opinions and prepare summary before May 1997 for decision by mail of the Commission.

Concern was expressed that ozonesonde data from important stations like South Pole and Mauna Loa are not deposited to the WMO-WO_3DC. The ozone data from the British Antarctic Survey, although available on personal request, are also not deposited in the World Data Centre. This is in contradiction with the Vienna Convention requirement for immediate exchange of ozone information for research purposes and the respected national institutions should be asked to amend their practice.

The need for expanding ground based ozone and related species observations in the tropical belt and southern hemisphere was stressed. In connection with the later, it was noted that WMO Ozone Project has received about 2 million US$ from the Global Environment Facility (GEF) for expanding the ozone network in South America and that the establishment of total and surface ozone stations along with some GAW programme measuring stations in Argentina, Brazil, Chile, Paraguay and Uruguay was in progress under the supervision of the IO_3C Secretary.

In the Ozone Assessment of 1994, large discrepancies were reported between ozone trends in the lower stratosphere estimated by sondes (0±3% per decade), Umkehr and SAGE (0±8% per decade) as was already recorded at the WMO/IO_3C meetings at Tenerife (1994). Therefore strong recommendation was made to consider detailed review of the quality of the different VO_3D profiles. The outline of the VO_3D assessment was determined by an international group of scientists during a WMO/IO_3C/SPARC sponsored Workshop held at the Observatory at Haute Provence in France in July 1996. Robert Hudson and Neil Harris were the co-chairs. The drafts of the chapters were prepared in the following year. The draft report was examined by an international panel of reviewers both by mail and at a meeting at Abingdon, UK in October 1997. The resulting 298 pages document SPARC/IO_3C/GAW *Assessment of Trends in the VO_3D* was published in May 1998 (WMO, 1998). The re-analysis provided for the first time also confidence limits for the different systems measuring VO_3D very useful for the next assessments on the state of the ozone.

In September **1997** the United Nations Environment Programme on the occasion of the 10th anniversary of the Montreal Protocol has recognized the contribution to the protection of the ozone layer by presenting *The Global Ozone Award*, among others, to IO_3C related scientists: *Ralph Cicerone, Susan Solomon, Richard Stolarski*, and *Christos Zerefos* at an official ceremony in Montreal.

In July **2000** the Quadrennial Ozone Symposium was held in Hokkaido University, Sapporo on a kind invitation by the ozone researchers of Japan. Registered were 566 participants and the Proceedings of the Ozone Symposium-2000 contained 403 two-page extended abstracts out of more than 600 originally submitted titles (Ozone, 2000). Organizers were faced with enormous workload both in preparation of the Programme and in the actual conduct of such size of scientific gathering. Fortunately the content of the Proceedings was made available also on the internet after the event and is posted on the IO_3C web site.

The Commission meeting heard the proposal by the Nomination Committee chairman Gérard Mégie for the next four years to re-elect for President *Robert D. Hudson* and to elect for Vice President *Toshihiro Ogawa* and for Secretary *Christos Zerefos*. From the floor was proposed the name of *Andrew Matthews* to be considered for President; however he received only few votes. Thereafter, the proposal for Officers by the Nomination Committee was carried out with majority. The President proposed that Rumen D. Bojkov who has been an extraordinarily active Secretary for 16 years and as leader in the international scene has guided the expansion of WMO ozone network activities and contributed to the ozone science for more than 35-years be elected *honorary member.* This was unanimously so decided. For new members were elected: Gerry Coetzee (Meteorological Service, Pretoria), Emilio Cuevas (Tenerife Observatory), Vitali Fioletov (AES, Toronto), Paul Fraser (CISRO, Aspendale), Sophie Godin- Beekmann (Service d'Aeronomie du CNRS, IPSL, Paris), Nail Harris (European Ozone Coordination Unit, University of Cambridge), Nicklaus Kaempfer (University of Bern), Henning Kelder (KNMI, DeBild), Janusz Krzyscin (Inst. Geophysics, Warsaw), Shyam Lal (Physical Research Lab., Ahmedabad), Jenifer Logan (University of Harvard), Samuel Oltmans (NOAA, Boulder), Juan-Carlos Pelaez (Meteorological Service, Havana), Mick Proffitt (WMO), Wafik Sharobiem (Meteorological Service, Cairo), Frode Stordal (University of Oslo), Petteri Taalas (Meteorological Service, Helsinki), Don Wuebbles (University of Illinois at Urbana) and Rodolpho Zander (University of Liege).

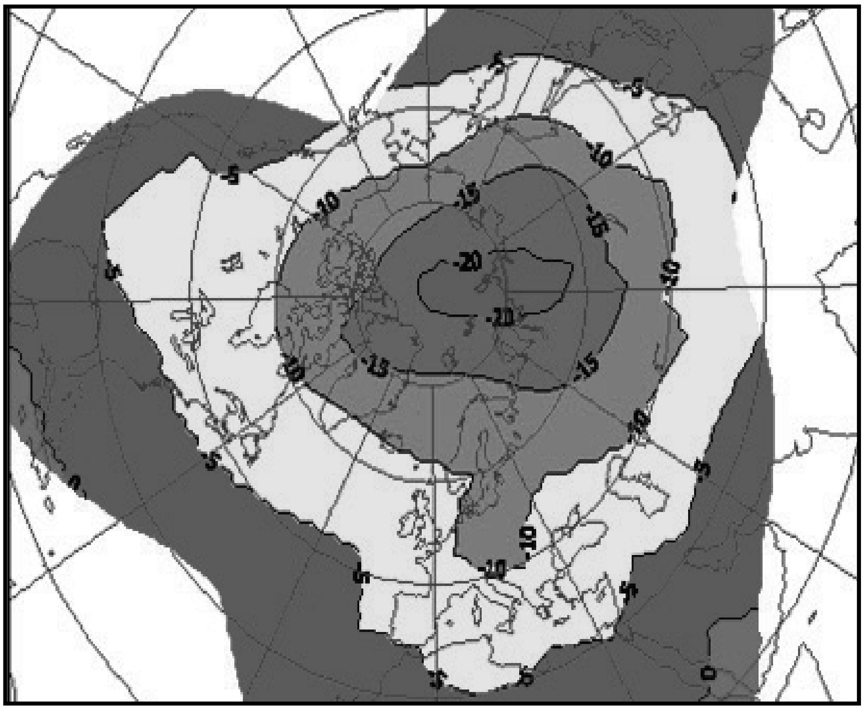


Figure 25.

Northern hemisphere ozone deficiency (in % of the pre-1978 averages) during February-March, averaged for 1990-2000. The area with the strongest departures of 10-20% coincides with the most frequent position of the winter-spring strato-spheric vortex where the stratospheric tempe-ratures are reaching low values – favourable for ozone depletion in the chemically disturbed stratosphere.

(Adapted from Balis and Bojkov, 2004a).

The President suggested that in view of the rapid developments in the overall field of ozone science one should consider *redefining and broadening the role of the IO_3C*. He referred to the history of the IO_3C established by IUGG in 1948 as an upgrading of the Committee on Ozone existing since 1933 (IUGG Lisbon). In the first four decades the main preoccupation of the Committee and the Commission was to build a functioning Dobson network which was one of the main components of the IGY (1956-57). Together with WMO the IO_3C established common observational practices and initiated the central collection of all ozone data. Within the following years the Commission brought together scientists from the observations community with theoreticians and atmospheric chemists and became an Organization concerned with the broad aspects of the ozone issue including the interactions of chemistry-dynamics and radiation. IO_3C is the arm of IAMAS (which is part of IUGG-ICSU science family) providing the authoritative scientific information on the ozone issue and coordinating international scientific activities in this field. What message comes out from the Sapporo symposium was that we have to broaden the scope of what we are doing and demonstrate the leading role of the Commission, concluded the President. For this purpose, the Commission established a small sub-committee consisting of experienced members (Guy Brasseur, Gérard Mégie, Toshi Ogawa and Mick Prather) who were charged to propose for further discussion in 2001 redefining the role of IO_3C.

For hosting of the next Quadrennial Ozone Symposium in 2004 there are two formal proposals: one from Greece (Halkidiki or 80 km from Athens) and the other from Egypt (Cairo). There was also an informal suggestion from New Zealand. To host a Symposium with 500-600 participants is a fairly costly and demanding work as already noted in 1996 and by the review made by A. Jim Miller in 1997 on the conditions for arranging Quadrennial Ozone Symposia. Therefore, the Commission established a small subgroup to define what should be included in any proposal based on what we expect to have in a Symposium. Past symposia requested substantial support to be provided to scientists from developing countries and to graduate students. So availability of less expensive students type accommodation is an important aspect that IO_3C should take into consideration when deciding on the future location. Ivar Isaksen is the chairman of that sub-committee. After collecting the necessary additional information the Commission should decide on place and time possibly at its next meeting at Innsbruck IAMAS Assembly in July 2001. There is planned to be held an IO_3C co-sponsored Symposium on NOx generation by electric discharges jointly with the IAMAS Commission on Atmospheric Electricity.

Following a proposal from the President and Secretary a web site will be created – with some history of the Commission (by Rumen D. Bojkov) – and information on plans and/or ongoing activities. The aim will be to try to make IO_3C more open and visible. Don Wuebbles offered to construct and maintain the site at http://ioc.atmos.uiuc.edu in collaboration with the Secretary of the IO_3C.

It was recalled that IO_3C owns 5 Dobson instruments lent for use to a few stations: #13 Lisbon, #14 Tromso, #15 was in Arosa and without agreement of the IO_3C this year sub-lent to Botswana, #50 Reykjavik and #51 Arosa (automated in 1971). The Commission requested Officers to assure that the instruments are being properly used; otherwise they should be refurbished and placed on loan in data sparse areas like Siberia and/or in developing counties carefully *selected on discretion of the Commission*.

Figure 26.

Ivar S. A. Isaksen, .a respected scientist and University of Oslo professor: His main area of research is modelling of the chemical composition of the stratosphere and the troposphere, and the perturbations caused by human activities with emphases on processes of importance to ozone depletion, changes in greenhouse gases, and climate chemistry interactions. He had assisted Eigil Hesstvedt, further developed two-dimen-sional strato-tropospheric models, contributed to international Ozone Assessments reports and tutored many students. Isaksen was elected in Kos for President of IO_3C, served from 2004 to 2008. Host of Tromsø Symposium 2008.

The Commission decided that it should be involved and took lead in specific projects similarly to the joint WMO SPARC-IO_3C excellent report on assessment of trends in the vertical ozone distribution (WMO, 1998) and that its members involvement in the International Ozone Assessments should be made more visible. Initial proposals in the area of improvements of the Umkehr retrievals, ozone and climate issues etc will be developed by the Officers for further consideration by the Commission. Hans Claude suggested to be prepared a press release with the highlights of Sapporo Symposium which could also be published in EOS and the IGAC newsletter. The newly elected Secretary was asked to take the initiative for this. All these are thought will increase the visibility of the IO_3C.

A discussion followed as to what is the role of the Commission as part of IAMAS and the distinction which should be made between projects with limited longevity (such as SPARC) and an international scientific coordinating body such as the IO_3C. It was felt that the overall structure should not be changed. IO_3C has an obligation to see that scientific activities continue even after SPARC and IGAC come to an end. Speakers were Guy Brasseur, Rumen D. Bojkov, Rich McKenzie, Gérard Mégie, Rich S. Stolarski, and the President Bob D. Hudson.

The attendees were informed that over 20 papers, which were missing in the Proceedings although they had been accepted by the Programme Committee, will be printed as a supplement and will be distributed to the registered participants of the Sapporo Symposium. The Proceedings were made accessible also by internet at the Commission web site.

In June **2004** the Quadrennial Symposium on Atmospheric Ozone was hosted by Christos Zerefos at the island of Kos with nearly 600 participants submitting ~700 abstracts (all available on the IO_3C web page http://ioc.atmos.uiuc.edu).This symposium coincided with the 20th anniversary of the discovery of the springtime drastic ozone decline over Antarctica reported by Chubachi at the Halkidiki Symposium, now commonly called the ozone hole. It also did mark two decades of intense research in atmospheric chemistry and physics and in global atmospheric monitoring. The progress in understanding of the impact of human activities on the chemistry and physics of the global stratosphere since the Ozone Symposium-2000 was presented in hundreds of papers and posters. It is difficult to refer to individual contributions therefore attempt is made to summarize the important topics discussed at the symposium in the following paragraphs:

The search for ozone recovery. Studies were inspired in long-term data records by the observed decline of many of the ozone-depleting CFCs in the troposphere. Levelling off of the chlorine content of the stratosphere started also to be visible. The next step naturally was to search for the response of ozone to this change in chlorine concentrations. Overall, it appears that ozone in the last few years is a percent or two higher than was expected from earlier projections based on sensitivity of ozone to influences of halogen compounds, aerosols and the solar cycle. Making an early detection of ozone response to the levelling off and future decline of chlorine compounds requires a clear definition of terms. In the presentations were defined at least three stages of recovery for ozone. These are: (1) statistically significant slowing of the downward trend; (2) statistically significant upward trend after removal of all other known influences such as solar cycle and volcanic aerosols; and (3) reaching pre-1978 ozone levels in the stratosphere. It has been shown that achieving the second of these stages will take more than few decades of measurements with well-calibrated instruments. The discussion in Kos has centred on the criteria for stage 1. Did the trend slowed down by a statistically significant amount? At that time the answer is negative. It was emphasized that the search for the response of ozone is complicated by a number of factors: (a) year-to-year variability in meteorology and related atmospheric dynamics; (b) response of meteorology to changes in ozone, greenhouse gases and changes in the radiation balance and (c) interference between recovery from volcanic eruptions of El Chichon in 1982 and Pinatubo in 1991 and the 11-year solar cycle. Most participants agreed that the detection of ozone recovery still requires patience and dedicated studies. Its detection will depend on availability of continued quality observations.

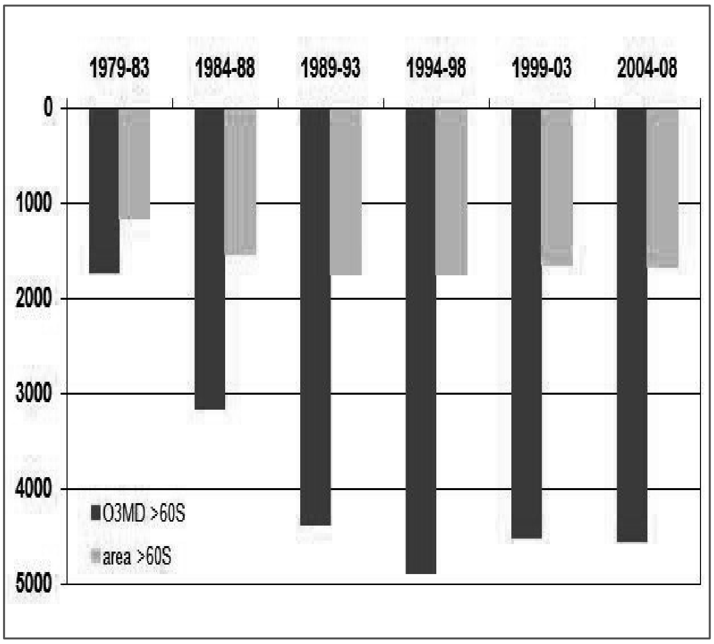


Figure 27.

Five years averaged September/October ozone mass deficiencies from pre-1978 averages [O_3MD in 10^6 Mt] and area [10^6 km^2] with total ozone deficiencies stronger than -10% (compared to the pre-1978 values) poleward from 60^oS. After the known significant increases of the ozone hole during the 1980s in the last 20 years the area with low ozone (here <220 matm cm) was ~$17.1x10^6$ km^2 and did not change. The O_3MD in the same four 5-yearly periods was ~4600 Mt and there are not any signs for weakening of the ozone depletion during the Antarctic springs. (Updated from Bojkov and Balis, 2009).

Use of satellite and ground-based data in model evaluation of ozone loss and recovery. Indeed, in the past four years significant developments have been achieved in quality satellite observations based on the continuation of international collaboration involving ESA, NASA and JAXA. Significant data from European ENVISAT instruments such as SCIAMACHY, MIPAS was reported along with data from the Swedish/Canadian/French ODIN/OSIRIS, the Japanese ILAS/ILAS II, and the United States' TOMS/SBUV, SAGE, HALOE, and AIRS. Several contributions addressed the rapid development of chemical data assimilation techniques. The validation of these measurements has emphasized the need for long term quality ground-based data as provided by the GO_3OS in general and NDSC in particular.

The extension of long-term quality data records made by satellites and by ground-based stations around the world was appreciated. Satellite records of ozone on a global scale are now more than 25 years long. TOMS and SBUV improved version-8 was officially released at the Kos Symposium. The GOME instrument now has 9 years of data that have been evaluated for trend quality and can be added to the record. The ground-based data extends, in a few places, back for five decades (the Dobson spectrophotometers), fewer ozonesondes and only lately of increasing number of Brewer instruments. The continued maintenance of the calibration of the ground stations was discussed with emphasis on expanded intercomparisons, data re-evaluations and comparisons with satellite records.

Evaluation of the future of ozone recovery in an atmosphere with changing climate and the effect of ozone on that climate using coupled climate/chemistry models. Numerous chemistry/climate models were presented. They did address the problem of how changes in the atmospheric circulation and/or climate interact with changes in the chemistry of ozone. One problem is how changes in meteorology over the last 25 years may have contributed to observed ozone changes and feedback mechanisms. Models can then be used to extrapolate that knowledge to what may happen in the future with the expected increase in methane, nitrous oxide, and carbon dioxide and their radiative effects. Understanding of ozone loss and its future recovery requires knowledge of the distributions and budgets of the compounds that contribute to ozone loss. Significant new work that combines satellite and *in situ* observations with model calculations was presented at the Symposium providing an insight into the budget of oxides of nitrogen and a range of halogen species, which are indispensable to our understanding of the global carbon and hydrological cycles. Water vapour presents a particularly important challenge: Satellite data, shown at the meeting, is not consistent in trend with previous ground-based data. Understanding the feedback mechanism between water vapour content, ozone and polar stratospheric clouds is critical to the evaluation of predictions of ozone in a future warmer climate.

Studies of tropospheric ozone budget. The developing capability of satellites to measure the composition of the troposphere and observe the effects of long range transport of pollution was demonstrated in a number of studies. The tropospheric ozone budget is influenced by a variety of, ozone precursor sources, long-range transport in the troposphere and intrusions from the stratosphere. The evaluation of these processes at global scale makes the determination and attribution of the positive trends in tropospheric ozone difficult. Yet, significant progress was made with the development of new satellite retrieval techniques combined with the use of tropospheric models. Numbers of satellite instruments (TOMS, GOME, MOPPIT, SCHIAMACHY, MERIS, MODIS and AIRS) have provided significant new information in monitoring tropospheric pollutants. NASA's satellites and ozone soundings revealed that seasonal episodes of high ozone over south Atlantic begin with pollution sources located thousands of miles away. Examination of the long-range transport of tropospheric pollution and its coupling to climate is being studied using climate/chemistry models. Long-range transport of pollutants maintains regionally high background levels of tropospheric ozone.

Measurement and trends in the UV radiation. This part of the radiation spectrum reaching the surface of the Earth and its complex relationship to ozone change, cloudiness, and aerosols was subject of few papers. UV-B levels for 2000-2019 are predicted to decrease for all seasons but the trends are not statistically significant, except during spring over both hemispheres. UV-B trends are mainly caused by the total ozone trends because in the future cloud changes are predicted to be small in the coupled chemistry climate model used in these studies. Nonetheless, there is a region over Western Europe which is predicted to show an increase in UV-B due primarily to a decrease in cloudiness.

The Montreal Protocol and its amendments led to a fast decrease of the emissions of ozone depleting substances (ODS). There is evidence that the effect of anthropogenic emissions of ODS peaked in the last years of the 20th century. A very slow decrease of stratospheric ODS concentrations is expected to take place in the coming decades. Assuming undisturbed climatological and physical atmospheric conditions, model calculations presented expectations that the full compliances with the requirements of the Montreal Protocol will lead to the recovery of the ozone layer. However, due to the large interannual variability connected with long-term climate variability the identification of the turn around of stratospheric ozone trends is a challenging task. The ozone layer will remain particularly vulnerable during the next two decades or so especially in the Polar Regions, even with full compliance. Relative to the pre-ozone-hole abundances the losses in total column ozone amounts are ~4%/year at northern midlatitudes in wither/spring and ~6%/year at southern midlatitudes on a year-round basis. Continued compliance with the Montreal Protocol is expected to lead to a recovery of the ozone layer in the second half of this century. The meeting highlighted the progress toward that goal and the difficult question how the future of ozone may evolve in a changing climate.

The Commission elected for President Ivar Isaksen, for Vice-President Sophie Godin-Beekmann and re-elected Christos Zerefos for Secretary. In view of the significant contributions to ozone science and to the work of the Commission Mario Molina was elected *honorary member*. The newly elected members of the Commission were: Dimitris Balis (University of Thessaloniki), Lenard Barrie (WMO), Greg Bodeker (NIVA, NZ), Frank Dentener (EU Joint Research Centre, Ispra) , Roseanne Diab (South Africa), Valery Dorokhov (Central Aerological Observatory, Moscow), Clear Grainier (NCAR, Boulder/CNRS Paris), Ulf Koeler (Hohenpeissenberg Observatory), Michael Kurylo (NASA Headquarters), Gloria L. Manney (NASA, JPL), Hideaki Nakane (NIES, Tzukuba), Andreas Richter (Inst. Environmental Physics, Univ. of Bremen) and Richard S. Stolarski (NASA, Goddard SFC).

The Commission was informed that a *"Dobson Award for Young Scientists"* was established upon the initiative of the Officers. It will be granted for one or more outstanding research paper(s) in atmospheric sciences published or accepted in a refereed journal since the preceding QO_3S by a young scientist (within 10 years of

01 Andrew FERRONE, BE
02 Ruud DIRKSEN, NL
03 Dominik SCHÄUBLE, DE
04 Andreas PAXIAN, DE
05 Tiina LAITINEN, FI
06 Stefan BAUER, DE

07 Anuja MAHASHABDE, USA
08 Gabriele ERHARDT, DE
09 Maria KANAKIDOU, GR
10 Gunther SECKMEYER, DE
11 Kati ORAVISJÄRVI, FI
12 Heike EISCHLER, DE

13 Rania KOPALIDOU, GR
14 Quentin ERRERA, BE
15 Corinne VIGOROUX, BE
16 Marvin GELLER, USA
17 Basilis AMERIDIS, GR
18 Evangelos GERASOPOULOS, GR

19 Igor KAROL, RU
20 John PYLE, UK
21 *not yet identified <nyi>*
22 Anne THOMPSON, USA
23 David HOFMANN, USA
24 Stephen O. ANDERSEN, USA

25 Christophe LEROT, BE
26 Paul NEWMAN, USA
27 Kostas ELEFTHERATOS, GR
28 Marie-Lise CHANIN, FR
29 *<nyi>*
30 Michael KURYLO, USA

31 Ravi RAVISHANKARA, USA
32 Akira OKAWA, JP
33 Johannes STÄHELIN, CH
34 Husamuddin AHMADZAI, SE
35 Shigeru CHUBACHI, JP
36 Christos ZEREFOS, GR

37 Donald WUEBBLES, USA
38 Panos HADJINICOLAOU, CY
39 Ivar ISAKSEN, NO
40 Thomas McELROY, CAN
41 Wafik SHAROBIEM, Egypt
42 Mark SCHOEBERL, USA

43 Sophie GODIN-BEEKMANN, FR
44 Rumen BOJKOV, DE
45 Masaaki YAMABE, JP
46 Mario MOLINA, USA
47 Sherwood ROWLAND, USA
48 Pawan K. BHARTIA, USA

49 Mack McFARLAND, USA
50 Richard STOLARSKI, USA
51 Alkis BAIS, GR
52 Cui JUNBO, DE
53 Brian DIFFEY, UK
54 Adrian TUCK, USA

55 Jos LELIEVELD, DE
56 Aleksandra KARDAS, PL
57 Claire GRANIER, FR
58 Marco GONZALEZ, Kenia
59 Anne DOUGLASS, USA
60 Guy BRASSEUR, USA

61 Anne KUNZ, DE
62 Hennie KELDER, NL
63 Robert WALTER, DE
64 Sebastian BAUER, DE
65 Joseph FARMAN, UK
66 Robert SAUSEN, DE

67 Neil HARRIS, UK
68 Jean-Pierre POMMERAU, FR
69 Florence GOUTAIL, FR
70 Kristen N. TADDONIO, USA
71 K. Madhava SARMA, IND

Figure 28.

Participants of the Symposium "20-years Montreal Protocol - Ozone Depletion: from its discovery to ENVISAT and AURA", Athens, September 2007.

their Ph. D). The person nominated for the Award should be the first author of the cited paper. Complete nomination packages (an electronic copy of the paper, brief curriculum vitae of the candidate, and two endorsement letters describing the impact and innovation of the paper) should be e-mailed to the Secretary of the Commission who will arrange for review. The announcement of the winner will be made at the time of QO_3S.

In September **2007** a Symposium on *"Ozone Depletion: from its discovery to ENVISAT and AURA"* was held in Athens at the invitation from the Academy of Athens, the National Observatory of Athens, IO_3C, EESC, UNEP and WMO. It was hosted by Christos Zerefos. The framework was a core group of invited speakers who have played an important role in the preparations and success of the Montreal Protocol from its very beginning to get together to present background reviews and latest scientific results and discuss the success of the 20-years implementation of the Montreal Protocol. The meeting brought together distinguished scientists, policy makers, industry people and NGOs who have contributed to the protection of the ozone layer. They reviewed also scientific progress made since the start of ozone observations in the 1930s, the development of concerns for ozone depletion based on the scientific discoveries of the 1970s leading to the signing of the Protocol in 1987 and the early search for trends. The lessons of this process hold for the continued implementation of the Protocol and for addressing other related global environmental issues. Proceedings were published by Springer (Ozone 2009).

Based on the presentations at the Symposium, a Statement was prepared by 13 world renowned scientists (only three of them not affiliated with IO_3C) and presented to the international community. It highlighted the vital role of scientific contributions of the last few decades in establishing the reality of the ozone threat and drawing attention to the need for action; the necessity for technological innovation in providing solutions; and the value of objective assessment of scientific, environmental, technological and economic factors in fostering consensus and the experience gained to address future global environmental threats. It confirms that the Montreal Protocol is perhaps one of the most illustrious examples of a successful global collaboration between scientific, industrial and environmental organizations and policy makers. The decrease in ozone-depleting substances is a dominant factor in the expected return of ozone levels to pre-1980 values. However *changes in climate* will influence if, when, and to what extent ozone will return to pre-1980 values in different regions. Future increases of greenhouse gas concentrations will contribute to the average cooling in the stratosphere. Chemical reaction rates in the atmosphere are dependent on temperature, and thus the concentration of ozone is sensitive to climate changes. The full text of the Statement can be found on the IO_3C web page (http://ioc.atmos.uiuc.edu).

In July **2008** the Quadrennial Ozone Symposium (QO_3S) was held in Tromsø a place known of its tradition of ozone measurements behind the Polar Circle starting in the 1930s. More than 500 participants have submitted 470 abstracts covering the entire field of ozone science including few on the issue getting more attention lately: The detection of start of ozone recovery and climate change interaction. The Opening session featured tutorial presentations on History of IO_3C, Ozone depletion and CFCs, importance of Montreal Protocol for ozone and climate and how did it work. The oral presentations were distributed in the following sessions: New Developments

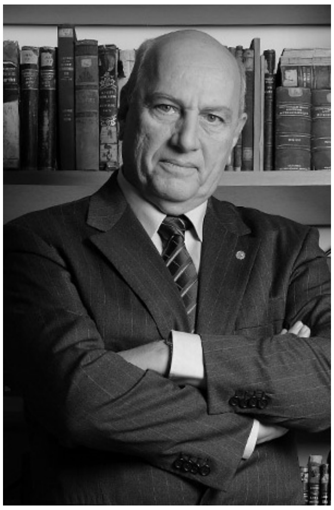


Figure 29.

Christos S. Zerefos has been host to number of the best organized Ozone Commission meetings and Symposia since 1984 for which he is internationaly known and respected. He has contributed to the studies of ozone and the changing UV radiation, organized very active ozone research Laboratory in University of Thessaloniki including the operation of the WMO Ozone Mapping Centre there. Lately as Director of the famous National Observatory of Athens he continued his research activities. He was Secretary of IO_3C (2000-2008) and in Tromsø was elected *President of IO_3C* for the period 2008-2012.

in Observation Techniques -10; Observations from ground and space of total ozone its VO_3D their Analysis and Evaluation -14; Ozone Depleting Substances -8; UV Changes -5; Tropospheric Ozone -14; Climate-ozone Interaction -7; New Processes and Uncertainties -8; Polar Ozone -11; Ozone Recovery -6. The fractional distribution of the oral presentations approximately reflects the topics distribution of the remaining 350 posters. Many of the papers introduced new ideas and it is a petty that their enormous volume prevents us of giving here details. All two-page abstracts were distributed on CD ROM and are posted on the Commission web page (http://ioc.atmos.uiuc.edu)

At the Commission meeting the President Ivar Isaksen informed that he has reached the age of 70 and decided to retire. Then the Nomination Committee (Rumen D. Bojkov, Paul J. Crutzen and Ulf Koeler) reported that after exploring members proposals, eligibility and willingness of the persons to serve as new Officers submitted for decision the following proposal: for President Christos S. Zerefos, for Vice-President Richard S. Stolarski and for the demanding post of Secretary to IO_3C Sophie Godin-Beekmann. They were elected unanimously. Proposal was made by Nail Harris (seconded by Rumen Bojkov) to elect Dan Albritton as *honorary member* in recognition of his outstanding contribution to ozone science and to IO_3C in guiding preparations of numerous international Ozone Assessment Reports. This was unanimously agreed. Then the Commission held a secret balloting for election of new members out of a list of 55 scientists proposed. Elected were: Alkiviadis Bais (University of Thessaloniki), Pawan K. Bhartia (NASA, Goddard SFC), Geir Braathen (WMO), David Fahey (NOAA, Boulder), Jack-Christian Lambert (Institute Aeronomie Spatial, Brussels), Paul A. Newman (NASA, Goddard SFC), John A. Pyle (University of Cambridge), William Randel (NCAR, Boulder), Michelle Santee (NASA, JPL), Masato Shiotani (MRI, Tzukuba) and Karel Vanicek (Hr. Kralove Observatory). Sherry Rowland supported by few other members expressed concern that the membership is too heavily cantered on Europe and North America and the new Officers were requested to explore possibility of approaching active ozone scientists in particular from China, India and Russia with which working contacts could be established.

In order to strengthen the availability and spread of information about the work of the Commission the elected President proposed Don Wuebbles as an ad-hoc member to be named Director of Information of IO_3C. He has served IO_3C for many years and his particular efforts to keep up the website of the Commission are acknowledged by all. This was unanimously accepted. A proposal by the Secretary-General of IAMAS, Dr. Hans Volkert, sent to the Officers inquired of the willingness of Rumen D. Bojkov to expand his opening presentation on the history of the IO_3C which will benefit the atmospheric science community and popularize the nearly 80 years of organized ozone activities. Bojkov agreed to attempt such a task and as first step will expand the part posted on the IO_3C web page and collect relevant inputs.

The outgoing Secretary announced that the Dobson Award Committee has decided to split in two the 2008 Dobson Award. Recipients were B.-M. Sinnhuber for papers on bromine in the stratosphere, and V. Eyring for assessments and use of chemistry-climate models for projections of future levels of stratospheric ozone.

On the question for the location of the next QO_3S Don Wuebbles proposed to be organized in the United States. Some more details were requested to be provided to the Secretary for informing all members. At the same time she should issue a call for other proposals by e-mail, giving a few months time for response.

In the general discussion it has been suggested that in between the consecutive QO_3S would be useful to have a meeting or two, organized by IO_3C and focused on important issues such as the 20th anniversary of the Montreal Protocol meeting which took place in Athens in September 2007.

Concerns were expressed on the short time-span between QO_3S, SPARC and other large meetings (i.e. IGAC) targeted to similar segments of the science community. Timing of the next QO_3S for example will be 2012, but an exact date is desirable to be decided considering also the SPARC assembly (in case the WCRP agrees this project to continue). It was emphasized that IO_3C should play a closer role on ozone-climate interactions and the new President and Secretary will ask for proposals from members for creations of ad-hoc working groups on specific topics. The continuous review of the quality of ozone data and another on ozone trends were examples proposed from the floor.

Concluding remarks

It is amazing how dedicated efforts by only few scientists like Fabry, Buisson, Dobson in the 1920s succeeded to establish reliable methodology for measurements of the total ozone and to deduce some of its basic seasonal, and latitudinal characteristics. During 1930s and 1940s ozone measurements were carried out only by less than a dozen of interested scientists and in most places not regularly. At that time interest was not in systematic long-term measurements but to explore for any weather predicting relations between ozone and weather patterns. The network based on international cooperation was established only 50-years ago in preparation for the International Geophysical Year and it evolved in the WMO Global Ozone Observing System (GO_3OS). It is supplemented by satellites since about 30 years. Without the dedicated efforts of numerous scientists developing and supervising the ozone measurements and starting to control their quality it would have not been possible to make any assessment on the state of the ozone layer when some theory for its possible destruction started to appear.

Until a truly global picture of ozone distribution was obtained, measurements of ozone (instrumentation and theory) were preoccupying the Committee and IO_3C for more than 40 years. This first period of the Commission activities included number of fundamental developments done by members and discussed and promoted by the Commission e.g. perfection of the double quartz spectrophotometer by Dobson (1931-1950); Umkehr method for indirect vertical ozone distribution (VO_3D) by Götz in 1931-1934; balloon spectrograph proof the ozone maximum is at ~22 km provided by Erich and Victor Regener in 1934; sondes for measurements of VO_3D (optical by Stranz, Paetzold in 1940-48; chemiluminiscent by Victor H. Regener in 1960; electro-chemical by Brewer and Milford in 1960s); Rocket-sondes measurements of VO_3D by Ernest Hilsenrath, Arlin J. Krueger, K. Watanabe in the 1960s and 1970s. To these should be added the numerical method for uniform evaluation of the Umkehr profiles developed by Carl L. Mateer and Hans U. Dütsch in mid-1960s providing the base for more than 70,000 compatible profiles available now; Postulate and theory for measurement of ozone from a satellite (e.g. Carl L. Mateer and J. V. Dave in late-1960s), implemented as BUV, SBUV and TOMS instruments by Donald F. Heath and Arlin J. Krueger at NASA Goddard SFC with Carl L. Mateer et al.

On the question of ozone production and destruction Sidney Chapman (1930) developed the ozone-oxygen photochemistry which was not able to explain the ozone minimum in the tropics neither the spring maximum at the polar latitudes. It was K. R. Ramanathan who in 1953-1959 suggested existence of meridional cell poleward from the tropical stratosphere and large-scale transport of ozone in order to explain the observed ozone distribution, an idea further developed in Brewer-Dobson circulation scheme. Since then the developments of ozone photochemistry were an issue permanently on the agenda of the IO_3C with initial contributions by Marcel Nicolet, Hans U. Dütsch and others. The work evolved by including new reactive species (e.g. in mid-1960s HOx chemistry by Hampson, Hunt, Hesstvedt, Nicolet; in 1970 NOx chemistry by Crutzen also Johnston, Nicolet; in 1974 Stolarski and Cicerone published on possible ozone decomposition by ClOx; Rowland and Molina on the role of CFCs). Developments involved directly many IO_3C members, three of whom (Crutzen, Molina and Rowland) got for their achievements the Nobel Prize in Chemistry in 1995.

With the introduction of NOx reactions by Crutzen and of the CFCs role by Rowland and Molina started a new era of understanding of global ozone variations, and the second period of activities of the Commission. The *new photochemistry indicated potential environmental disastrous destruction of ozone layer due to human activities* started an explosive increase in ozone studies after mid-1970s. The discovery of an abrupt and major ozone decline during the Austral spring in the Antarctica (since known as the ozone hole) and its explanation (e.g. Susan Solomon, Crutzen and Arnold, Molina and Molina) passed few stages with numerous contributors, many of whom were members of the IO_3C. It should be recalled also that the Ozone Trends Panel Report (1988) based upon the most thorough scientific evaluation of the ozone data, first provided significant and undisputable evidence that the ozone is decreasing not only in Antarctica but also over the Northern middle and upper latitudes. It provided scientific support for the *need of strengthening* the Montreal Protocol which was signed in September 1987. Many members of IO_3C made also substantial contributions to its content.

The history of ozone research in the last several decades, to use the words of Guy Brasseur (2008), is a good example of the knowledge cycle in geosciences today, where field measurements and laboratory studies are combined to advance the understanding of the processes leading to an improvement of numerical models.

Then the results and forecasts of the numerical models are confronted again with measurements, thus contributing to better understanding of the processes. In particularly since the 1970s the history of IO_3C and ozone research is tightly related to the human impact on the ozone layer: from studies of the scientific insight, contributing to the scientific assessments and their impact on international policy leading to Vienna Convention for Protection of the Ozone Layer and its Montreal Protocol.

The Ozone Committee and later the Commission in the past 80 years until the Tromsø 2008 meeting have been served by *nine* Presidents (Dobson, Ramanathan, Brewer, Dütsch, Mateer, Chang, Mégie, Hudson and Isaksen), *five* Secretaries (Sir Charles Normand, Hans U. Dütsch, Desmond Walshaw, Rumen D. Bojkov and Christos Zerefos). Since 1984 *five* have been serving as Vice-Presidents (Gérard Mégie, A. Jim Miller, Andy Matthews, Toshi Ogawa and Sophie Godin-Beekmann). More than 166 scientists are listed as members (cf. *Appendix 3c*). Three of them (Crutzen, Molina and Rowland) were distinguished with the Nobel Prize in 1995. In IO_3C work on one or the other stage have been *involving hundreds of scientists* who participated in various working groups and/or acted as Rapporteurs on particular issues. Furthermore, there are *numerous other scientists outside of the formal frame of the* IO_3C who contributed to the progress in the ozone studies and have left a permanent mark during the past 80-years of development. In this line of thoughts it should be noted that until now the IO_3C has organized more than 30 international symposia and conferences with close to 4000 scientific presentations. More than 3000 of these were submitted after it became clear there is imminent threat for ozone catalytic destruction by NOx and chlorine in the stratosphere i.e. after mid-1970s.

The tasks of the Ozone Committee and the Commission as defined by the parents Associations IAMAS-IUGG are listed in Figure 30. They show the evolution from group of scientists charged by IAMAS-IUGG to establish what the ozone-weather relations are and to assist organization of global observing facilities, later the demands increased to include clarification of questions on ozone variability by rigorous review of measurements and complex photochemical models to make inputs to WMO/UNEP Ozone Assessments and to the development of global control measures.

The IO_3C evolved from a highly specialized group of scientists with common interest in the measurement techniques of atmospheric ozone to the present body representing expanded scope of diverse scientific interests *having the common zeal, to clarify the cause of ozone variability.* This includes meteorology, atmospheric chemistry and physics, laboratory chemistry, statistics and environmental sciences in general. This phenomenal expansion occurred mostly in the last 30 years. The advances in understanding the dynamical and chemical processes involved in atmospheric ozone formation, response and influence made the modern ozone research *a totally interdisciplinary subject* with fully coupled interactions of stratospheric and tropospheric processes having both local and global impacts.

As a final note we like to recall that, as early as in 1984, Carl Mateer brought in his Presidential Address the need to consider *ozone-climate relations* to the attention of the ozone community. He emphasized that "*ozone changes, and the changes in minor constituents which must accompany them will have an impact on climate and vice versa. Therefore it should be clear that the ozone and climate changes should be studied with 3-D models which would marry the complexities of the photochemical*

Tasks of Ozone Committee and IO_3C as formulated by the IUGG:

1933 To explore *the relations between the ozone variations and the meteorological conditions* (IUGG);

1948 To conduct an *ozone-weather survey* over West Europe and assist establishment of ozone stations with *uniform procedures* (IUGG);

1957 To retain its *general scientific interest in ozone*, in developments in fields which are not yet routine and to remain *responsible for organizing international symposia* (IUGG);

1970 To consider the *relation of ozone studies to those of the upper atmosphere and atmospheric chemistry* (accepted); and to decide whether the objects of IO_3C would be better served *by merging* with some other commission of IAMAP (that merging was rejected by science developments and members)

1988 To provide scientific *expertise for the improvement of the GO_3OS,* to *clarify questions of ozone variability* by rigorous review of measurements and photochemical models as *inputs to WMO Ozone Assessments* and *to development of global control measures* (IAMAS);

1990 To promote research in atmospheric ozone-related issues as well as application of that research to practical problems concerning the composition and changes of the earth-atmosphere system (current Commission by-law).

Figure 30.

Evolutionary steps of the core tasks of the International Ozone Commission and its predecessor over the past 80 years.

and meteorological processes". Thereafter the Commission did have a working group on that issue for many years. It is now clear that there are multiple interactions between changes in ozone, UV radiation, aerosols, increased tropospheric photochemical pollution, and the changing climate. As the main environmental issue with potential disastrous consequences for the mankind, it is recognized now to be the climate change, the IO_3C should continued to encourage and vigorously stimulate studies directed to the *ozone and climate change interactions.*

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Appendix 1: Ozone Conference, Paris, 15-17 May 1929

List of participants:

Anders K. **Angström** (Stockholm)
J. **Baillaud** (Paris)
Julius **Bartels** (Berlin)
Bauer (Paris)
Vilhelm **Bjerknes** (Oslo)
Henry **Buisson** (Marseille)
Bureau (Paris)
Jean **Cabannes** (Montpellier)
Daniel **Chalonge** (Paris)
Sidney **Chapman** (London)
G. **Colange** (Paris)
H. **Dember** (Dresden)
Gordon M. B. **Dobson** (Oxford)
J. **Dufay** (Lyon)
Charles **Fabry** (Paris)
L. **Gorczynski** (Warsaw)
F. W. Paul **Götz** (Arosa)
Edward G. **Gowan** (Oxford)
Benno **Gutenberg** (Darmstadt)
O. **Hoelper** (Aachen)
P. **Idrac** (Paris)
M. **Lambrey** (Paris)
Rev. J. **Lawrence** (Old Windsor)
Rudolf **Ladenburg** (Berlin-Dahlem)
J. **Lecomte** (Paris)
F. **Lindholm** (Davos)
Fritz **Linke** (Frankfurt a.M.)
Jean **Lugeon** (Zürich)
C. **Maurain** (Paris)
E. **Meyer** (Zürich)
Erich **Regener** (Stuttgart)
S. **Rosseland** (Oslo)
Y. **Rocard** (Paris)
R. **Ruedy** (Toronto)
F. J. W. **Whipple** (Kew Observatory).

List of presentations:

1. LIESURE NOCTURNE DE L'EPAISSEUR REDUITE DE L'OZONE ATMOSPHERIQUE'
Par Daniel CHALONGE
2. DIFFICULTES D'ORDRE CHIMIQUE DANS LE DOSAGE DE L'OZONE ATMOSPHERIQUE
Par J. **GUERON *et* M. PRETTRE (Faculte des Sciences de Paris)**
3. ETUDE DE L'OZONE ATMOSPHERIQUE PAR SPECTROSCOPIE VISUELLE
Par J. **GAUZIT**
4. An ultra-violet filter with transparency only below an eligible wave-length
By VICTOR H. **REGENER** (Physikalisches Institut der Technischen Hochschule, Stuttgart)
5. MEASUREMENT OF .ATMOSPHERIC OZONE BY PHOTO-ELECTRIC METHODS
By G.M.B. **DOBSON**, D.Sc., F.R.S., (Oxford)
6. THE VERTICAL DISTRIBUTION OF OZONE IN THE ATMOSPHERE
By G. M. B. **DOBSON, D.Sc.,** F.R.S., (Oxford)
7. SPECTROGRAPHIC OBSERVATIONS ON THE NATIONAL GEOGRAPHIC-U.S. ARMY STRATOSPHERE FLIGHT
By BRIAN **O'BRIEN** and F. L. **MOHLER** (Institute of Optics, University of Rochester, N.Y.,and National Bureau of Standards, Washington, D.C.)
8. THE THEORETICAL CALCULATION OF THE DISTRIBUTION OF PHOTOCHEMICALLY-FORMED OZONE IN THE ATMOSPHERE
By OLIVER R. **WULF** and LOLA S. **DEMING** (Bureau of Chemistry and Soils. Washington. D.C.)
9. THE PRESENT STATE OF INVESTIGATIONS OF THE TRANSMISSION OF AIR WAVES TO GREAT DISTANCES.
By F. J. W. **WHIPPLE**, Sc.D., (F.1nst.P)
10. ESTIMATES OF UPPER ATMOSPHERIC TEMPERATURES FROM IONOSPHERIC OBSERVATIONS
By Prof. E.V. **APPLETON,** F.R.S.

11. EFFECT OF TEMPERATURE ON ABSORPTION COEFFICIENTS OF OZONE IN THE LABORATORY AND IN THE ATMOSPHERE
By E. **VASSY** (Laboratoire d'enseignement de physique de la Sorbonne, Paris)

12. TEMPERATURE DE 1'OZONE ATMOSPHERIQUE D'APRES LA STRUCTURE DES BANDES DE HUGGINS DANS LE SPECTRE DU CIEI, BIXU
Par J. **DUFAY** (Observatoire de Lyon)

13. THE EFFECT OF OZONE ON THE TEMPERATURE OF THE UPPER ATMOSPHERE
By E. H. **GOWAN**

14. THE ROLE OF ATMOSPHERIC OZONE IN THE HEAT BALANCE OF THE STRATOSPHERE.
By R. **PENNDORF** (Geophysikalisches Institut der Universitat Leipzig)

15. ABSORPTION VON SONNENENERGIE IN HOHEN
Von F. W. PAUL **GöTZ** (Arosa)

16. THE ABSORPTION OF LIGHT BY OXYGEN IN THE ATMOSPHERE
By RUDOLF **LADENBURG. (**Princeton, N.J.)

17. DIE TEMPERATUR ABHANCIGHEIT DER PHOTOCHEMISCHE OZON BILDUNG
Von **A. EUCKEN** und F. **PATAT** (Physikalisch Chemisches Institut der Universitlt Göttingen)

18. ON REAPPEARANCE OF SOLAR SPECTRUM WITHIN THE RANGE 2000-2200 2,000-2200A.
By E. **VASSY** (Laboratoire d'enseignement de physique de la Sorbonne, Paris)

19. VARIATIONS IN ATMOSPHERIC OZONE AND WEATHER CONDITIONS
By G. M. B. **DOBSON**, **D.Sc.,** F.R.S., (Oxford)

20. PREMIERES DETERMINATIONS DE L'EPAISSEUR REDUITE DE L'OZONE ATMOSPHERIQUE PENDANT L'HIVER POLAIRE
Par DANIEL **CHALONGE**

2 1 OZONE MEASUREMENTS **IN** THE AURORA OBSERVATORY, TROMSO *(70'* N.L.)
By E. **TONSBERG** and D. **CHALONGE**

21. MESURES DE LA QUANTITE D'OZONE CONTENUE DANS L'ATMOSPHERE A SHANGHAI (CHINE)
Par PIERRE **LEJAY** (Directeur de I'Observatoire de Zi Ka Wei)

22. CORRELATIONS OF ATMOSPHERIC OZONE WITH OTHER GEOPHYSICAL PHENOMENA
By A. R. **MEETHAM** M.A., D.Phil.(Oxford)

24. SOME NOTES ON THE THEORY OF ATMOSPHERIC OZONE
By SYDNEY **CHAPMAN** (Imperial College **of** Science, London)

25. ON THE PHOTOCHEMICAL THEORY OF THE FORMATION OF OZONE
By D. **EROPKIN**

26. ON DISSOCIATION OF OZONE : CONSEQUENCES
By E. **VASSY** (Laboratoire d'Enseignement de Physique de la Sorbonne, Paris)

27. L'EXCITATION DE LA RADIATION **6300 A** DE **0** PAR LA LUMIERE DU SOLEIL DANS LES HAUTES COUCHES DE L'ATMOSPHERE
Par JEAN **CABANNES** et HUBERT **GARRIGUE** (Universite de Montpellier. France)

28. OXYGEN CONTENT OF THE STRATOSPHERE
By Erich **REGENER** (Physikalisches Institut der Technischen Hochschule, Stuttgart)

29. DIE .AROSER OZONREIHE (EXTENDED SERIES OF OBSERVATIONS AT AROSA)
Von F.W. PAUL **GÖTZ und** WERNER **ZONTI** (Arosa)

Appendix 2: Conference on Atmospheric Ozone, Oxford, 9-11 September 1936

<u>Titlepage</u>

[*Supplement to the* QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY, Vol. 62, 1936]

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CONFERENCE ON ATMOSPHERIC OZONE

HELD AT OXFORD,

SEPTEMBER 9th to 11th, 1936

Papers read at the Conference

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Appendix 3: Membership of International Ozone Commission (1948-2012)

a) Composition by period: (country, year of first election)

----

composition after the **Oslo 1948** meeting

President: Gordon M. B. Dobson (UK, 48)
Secretary: Charles Normand (UK, 48)

Members (**yr**. elected):

Daniel Chalonge (France, 48)
F.W.Paul Götz (Switzerland, 48)
Kalpathi R. Ramanathan (India, 48)
Einar Tönsberg (Norway, 48)
Etienne Vassy (France, 48)
Oliver R. Wulf (USA, 48)

----

composition after **Brussels 1951**, **London 1952** and **Rome 1954** meetings

President: Gordon M. B. Dobson (UK, 48)
Secretary: Charles Normand (UK, 48)

Members (**yr**. elected):

Arthur Adel (USA, 54)
Daniel Chalonge (France, 48)
Alfred Ehmert (Germany, 54)
Edward H. Gowan (Canada, 54)
H. Köhler (Germany, 54)
Yoshio Miyake (Japan, 54)
Marcel Nicolet (Belgium/IGY, 54)
Kalpathi R. Ramanathan (India 48)
Erich Regener (Germany, 51)
Victor H. Regener (USA, 52)
William C. Swinbank (Australia, 54)
Einar Tönsberg (Norway, 48)
Etienne Vassy (France, 48)
Harry Wexler (USA, 54)

----

composition after **Weissenau 1956** and **Toronto 1957** meetings

President: Gordon M. B. Dobson (UK, 48)
Secretary: Charles Normand (UK, 48)

Members (**yr**. elected):

Arthur Adel (USA, 54)
Richard A. Craig (USA, 57)
Hans U. Dütsch (Switzerland, 57)
Alfred Ehmert (Germany, 54)
Giorgio Fea (Italy, 56)
Warren L. Godson (Canada, 57)
Genady P. Gushtin (USSR, 57)
Alexandar Khr. Khrgian (USSR, 57)
H. Köhler (Germany, 54)
Michel Migeotte (Belgium, 57)
Yasuo Miyake (Japan, 54)
Heinz-Karl Paetzold (Germany, 56)
K. R. Ramanathan (India, 48)
Victor H. Regener (USA, 52)
William C. Swinbank (Australia, 54)
Einar Tönsberg (Norway, 48)
Etienne Vassy (France, 48)
Harry Wexler (USA, 54)

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composition after the **Oxford 1959**, **Helsinki 1960** and **Arosa 1961** meetings

President: Kalpathi R. Ramanathan (India, 48)
Secretary: Hans U. Dütsch (Switzerland, 57)

Members (**yr**. elected):

Arthur Adel (USA, 54)
Alan W. Brewer (UK, 59)
Julius London (USA, 59)
Michel Migeotte (Belgium, 57)

Gordon M.B. Dobson	(UK, 48, Past Presid)	Yasuo Miyake	(Japan, 54)
Alfred Ehmert	(Germany, 54)	Charles Normand	(UK, 48)
Giorgio Fea	(Italy, 56)	Heinz-Karl Paetzold	(Germany, 56)
Warren L. Godson	(Canada, 57)	Victor H. Regener	(USA, 52)
Genady P. Gushtin	(USSR, 57)	William C. Swinbank	(Australia, 54)
Wayne S. Hering	(USA, 61)	Reginald C. Sutcliffe	(UK, 59)
Alexandar Khr. Khrgian	(USSR, 57)	Einar Tönsberg	(Norway, 48)
Kaare Langlo	(Norway/WMO, 59)	Arlette Vassy	(France, 59)
G. H. Liljequist	(Sweden, 59)	Harry Wexler	(USA, 54)

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composition after the **Berkeley 1963** and **Albuquerque 1964** meetings

President: Kalpathi R. Ramanathan (India, 48)
Secretary: Hans U. Dütsch (Switzerland, 57)

Honorary President (**yr**. elected): Gordon M. B. Dobson (UK, ***63***)

Members:

Arthur Adel	(USA, 54)	Lester Machta	(USA, 64)
Alan W. Brewer	(UK/Canada, 59)	Michele Migeotte	(Belgium, 57)
Alfred Ehmert	(Germany, 54)	Yasuo Miyake	(Japan, 54)
Giorgio Fea	(Italy, 57)	Charles Normand	(UK, 48)
R. Frith	(UK, 64)	Heinz-Karl Paetzold	(Germany, 56)
Warren L. Godson	(Canada, 57)	Victor H. Regener	(USA, 52)
Genady P. Gushtin	(USSR, 57)	William C. Swinbank	(Australia, 54)
Wayne S. Hering	(USA, 61)	Yoshiro Sekiguchi	(Japan, 64)
Alexandar Khr. Khrgian	(USSR, 57)	Einar Tönsberg	(Norway, 48)
Kaare Langlo	(Norway/WMO, 59)	Arlette Vassy	(France, 59)
G. H. Liljequist	(Sweden, 59)	Ernest Vigroux	(France, 63)
Julius London	(USA, 59)	C. Desmond Walshaw	(UK, 64)

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composition after **Lucerne 1967** and **Monaco 1968** meetings

President: Alan W. Brewer (Canada/UK, 59)
Secretary: Hans U. Dütsch (Switzerland, 57)

Honorary President (**yr** elected): Gordon M. B. Dobson (UK, ***63***)

Members:

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A. S. Britaev	(USSR, 67)	Julius London	(USA, 59)
Alfred Ehmert	(Germany, 54)	Lester Machta	(USA, 64)
Giorgio Fea	(Italy, 56)	Anna Mani	(India, 67)
R. Frith	(UK, 64)	Carl L. Mateer	(Canada, 67)
Warren L. Godson	(Canada, 57)	Heinz-Karl Paetzold	(Germany, 56)
Karl-H. Grasnick	(GDR, 67)	K.R. Ramanathan	(India, 48, Past Presid)
Genady P. Gushtin	(USSR, 57)	Victor H. Regener	(USA, 52)
Wayne S. Hering	(USA, 61)	Yoshiro Sekiguchi	(Japan, 64)
Eigil Hesstvedt	(Norway, 67)	R. W. Kulkarni	(Australia, 68)

Alexandar Khr. Khrgian	(USSR, 57)	Arlette Vassy	(France, 59)
Genady Iv. Kuznetzov	(USSR, 68)`	Ernest Vigroux	(France, 63)
Walter D. Komhyr	(USA, 68)	C. Desmond Walshaw	(UK, 64)

----

composition after the **Moscow 1971** and **Arosa 1972** meetings

President: Alan W. Brewer (Canada/UK, 59)
Secretary: Hans U. Dütsch (Switzerland, 57)

Honorary President (**yr**. elected): Gordon M. B. Dobson (UK,*63*)
Honorary Members: K.R. Ramanathan (India, *71*), Ernest Vigroux (France, *71*).

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Marcel Ackerman	(Belgium/IAGA, 72)	Walter D. Komhyr	(USA, 68)
Walter Attmannspacher	(Germany, 71)	Genady Iv. Kuznetzov	(USSR, 68)
Rumen D. Bojkov	(Bulgaria/WMO, 71)	R.W. Kulkarni	(Australia, 68)
Bayron W. Boville	(Canada, 72)	Søren H.H. Larsen	(Norway, 67)
A. S. Britaev	(USSR, 67)	Julius London	(USA, 59)
Peter Fabian	(Germany, 71)	Anna Mani	(India, 67)
M. F. Figueira	(Portugal, 71)	Carl L. Mateer	(Canada, 67)
Karl-H. Grasnick	(GDR, 67)	Heinz-Karl Paetzold	(Germany, 57)
Genady P. Gushtin	(USSR, 57)	Yoshiro Sekiguchi	(Japan, 64)
Eigil Hesstvedt	(Norway, 67)	Arlette Vassy	(France, 59)
Ernie Hilsenrath	(USA, 71)	Desmond Walshaw	(UK, 64)
Alexandar Khr. Khrgian	(USSR, 57)		

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composition after **Grenoble 1975** and **Dresden 1976** meetings

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Peter Fabian	(Germany, 71)	Carl L. Mateer	(Canada, 67)
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Ernest Vigroux (France, ***71***)

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Carl L. Mateer	(Canada, 67/Past Presid)
A. Jim Miller	(USA, 84)
Toshihirio Ogawa	(Japan, 80)
John A. Pyle	(UK, 84)
Sherwood Rowland	(USA, 80)
Yanai Sahai	(Brazil, 80)
Masayoshi Shimizu	(Japan, 80)
Paul C. Simon	(Belgium, 84)
C. R. Sreedharan	(India, 80)
Wei-Chyung Wang	(USA, 84)
Christos S. Zerefos	(Greece, 84)

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composition after the **Göttingen 1988** meeting

President: Gerard Mégie (France, 80)
Vice president: A. Jim Miller (USA, 84)
Secretary: Rumen D. Bojkov (Canada/Bulgaria/WMO, 71)

Honorary Members (**yr**. elected): Hans U. Dütsch (Switzerland, ***84***), Alexandar Khr. Khrgian (USSR, ***80***), Julius London (USA, ***84***), Marcel Nicolet (Belgium, ***86***), Ernest Vigroux (France, ***71***)

Members:

Dan L. Albritton	(USA, 84)	Arlin J. Krueger	(USA, 84)
Reid E. Basher	(New Zealand, 84)	Shaw Liu	(USA, 88)
Julius S. Chang	(USA, 80 Past Presid)	Yukio Makino	(Japan, 88)
John J. DeLuisi	(USA, 88)	Carl L. Mateer	(Canada, 67, 88)
Peter Fabian	(Germany, 68, 88)	Toshihiro Ogawa	(Japan, 80)
Uwe Feister	(GDR, 84)	Stanislav P. Perov	(USSR, 88)
Paul Fraser	(Australia, 88)	John A. Pyle	(UK, 84)
Anver Ghazi	(Germany, 84)	Sherwood Rowland	(USA, 76, 88)
Robert D. Hudson	(USA, 88)	Ulrich Schmidt	(Germany, 88)
Mohammad Ilyas	(Malaysia, 84)	Paul C. Simon	(Belgium, 84)
Ivar S. A. Isaksen	(Norway, 80)	B. H. Subbaraya	(India, 88)
Jim B. Kerr	(Canada, 84)	Wey-Chyung Wang	(USA, 84)
Dieter Kley	(Germany, 88)	Ding-Wen Wei	(China, 88)
Volker Kirchchoff	(Brazilia, 88)	Christos S. Zerefos	(Greece, 84)

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composition after the **Charlottesville 1992** meeting

President: Gérard J. Mégie (France, 80) Vice President: A. Jim Miller (USA, 84)
Secretary: Rumen D. Bojkov (Canada/Bulgaria/WMO, 71)

Honorary Members (**yr.** elected): Hans U. Dütsch (Switzerland, ***84***), Alexandar Khr. Khrgian (Russia, ***80***), Julius London (USA, ***84***), Carl L. Mateer (Canada, ***92***), Marcel Nicolet (Belgium, ***86***), Ernest Vigroux (France, ***71***)

Members:

Guy Brasseur	(USA, 92)	W. Andy Matthews	(N. Zealand, 75, 92)
Malgorzata Degorska	(Poland, 92)	C. Thomas McElroy	(Canada, 92)
John J. DeLuisi	(USA, 88)	Stewart A. Penkett	(UK, 92)
Peter Fabian	(Germany, 68, 88)	Stanislav P. Perov	(Russia, 88)
Giorgio Fiocco	(Italy, 92)	Jean-PierrePommereau	(France, 92)
Paul J. Fraser	(Australia, 88)	Cliff Rogers	(UK, 92)
Galal K. Hassan	(Egypt, 92)	Ulrich Schmidt	(Germany, 88)
Robert D. Hudson	(USA, 88)	Susan Solomon	(USA, 92)
Oystein Hov	(Norway, 92)	Johannes Staehelin	(Switzerland, 92)
Tomoyki Ito	(Japan, 92)	Richard S. Stolarski	(USA, 92)
Viktor Khattatov	(Russia, 92)	B. H. Subbaraya	(India, 88)

Volker W. Kirchhoff	(Brazil, 88)	Karel Vanicek	(Czech Rep, 92)
Dieter Kley	(Germany, 88)	Ding-Wen Wei	(China, 88)
Shaw Liu	(USA, 88)	Robert DeZafra	(USA, 92)
Yukio Makino	(Japan, 88)	Xiuj Zhou	(China, 92)

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composition after the **L'Aquila 1996** meeting

President: Robert D. Hudson (USA, 88),
Vice President: W. Andy Matthews (New Zealand, 75, 92)
Secretary: Rumen D. Bojkov (Canada/Bulgaria/WMO, 71)

Honorary Members (**yr.** elected):

Alan Brewer (UK, ***96***),
Paul Crutzen (Netherlands/Germany, ***96***)
Hans U. Dütsch (Switzerland, ***84***),
Julius London (USA, ***84***),
Carl L. Mateer (Canada, ***92***),
Marcel Nicolet (Belgium, ***86***),
Sherwood Rowland (USA, ***96***),
Ernest Vigroux (France, ***71***).

Members:

Roger Atkinson	(Australia, 96)	Gérard Mégie	(France, 80 Past Presid)
Guy Brasseur	(Belgium/USA, 92)	Toshihiro Ogawa	(Japan, 80,96)
Hans Claude	(Germany, 96)	Stewart A. Penkett	(UK, 92)
Malgorzata Degorska	(Poland, 92)	Michael Prather	(USA, 96)
Nikolai Elanski	(Russia, 96)	Jean-P. Pommereau	(France, 92)
Giorgio Fiocco	(Italy, 92)	Cliff Rogers	(UK, 92)
Maximo Ginzburg	(Argentina, 96)	Paul C. Simon	(Belgium, 96)
Gamal K. Hassan	(Egypt, 92)	Susan Solomon	(USA, 92)
Oystein Hov	(Norway, 92)	Johannes Staehelin	(Switzerland, 92)
Ivar S.A. Isaksen	(Norway, 80, 96)	Richard S. Stolarski	(USA, 92)
Tomoyuki Ito	(Japan, 92)	B.H. Subbaraya	(India, 88)
Viktor Khattatov	(Russia, 92)	Anne Thompson	(USA, 96)
Konrad Mauersberger	(Germany, 96)	Guido Visconti	(Italy, 96)
Daniel McKenna	(Germany/UK, 96)	Karel Vanicek	(Czech R. 92)
Gerart J. Megie	(France, 80)	Robert DeZafra	(USA, 92)
A. Jim Miller	(USA, 84)	Christos S. Zerefos	(Greece,84,96)
C. Thomas McElroy	(Canada,92)	Xiuj Zhou	(China, 92)

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composition after the **Sapporo 2000** meeting

President: Robert D. Hudson (USA, 88),
Vice President: Toshihiro Ogawa (Japan, 80,96)
Secretary: Christos S. Zerefos (Greece, 84. 96)

Honorary Members (**yr.** elected):

Rumen D. Bojkov (Canada/Bulgaria, ***00***),
Alan Brewer (UK, ***96***),
Paul Crutzen (Netherlands/Germany, ***96***),
Hans U. Dütsch (Switzerland, ***84***),
Julius London (USA, ***84***),
Carl L. Mateer (Canada, ***92***),
Sherwood Rowland (USA, ***96***).

Members:

Hans Claude	(Germany, 96)	W. Andy Matthews	(New Zealand, 75, 92)
Gerry Coetzee	(South Africa, 00)	Konrad Mauersberger	(Germany, 96)
Emilio Cuevas	(Spain, 00)	Daniel McKenna	(USA/UK, 96)
Nikolai Elanski	(Russia, 96)	Samuel Oltmans	(USA, 00)
Vitali Fioletov	(Canada/Russia, 00)	Juan-Carlos Pelaez	(Cuba, 00)
Paul Fraser	(Australia, 88, 00)	Michael Prather	(USA, 96)
Maximo Ginzburg	(Argentina, 96)	Mick Proffitt	(USA/WMO, 00)
Sophie Godin-Beekmann	(France, 00)	Wafik Sharobiem	(Egypt, 00)
Neil Harris	(UK, 00)	Paul C. Simon	(Belgium, 96)
Ivar S.A. Isaksen	(Norway, 80, 96)	Frode Stordal	(Norway, 00)
Niklaus Kaempfer	(Switzerland, 00)	Peteri Taalas	(Finland, 00)
Heni Kelder	(Netherlands, 00)	Anne Thompson	(USA, 96)
Jan Krzyscin	(Poland, 00)	G. Visconti	(Italy, 96)
Shyam Lal	(India, 00)	Don Wuebbles	(USA, 00)
Jannifer Logan	(USA, 00)	Rodolpho Zander	(Belgium, 00)

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composition after **Cos 2004** meeting

President: Ivar S. A. Isaksen (Norway, 80, 96),
Vice President: Sophie Godin-Beekmann (France, 00)
Secretary: Christos S. Zerefos (Greece, 84, 94)

Honorary Members (**yr.** elected):

Rumen D. Bojkov (Canada/Bulgaria, ***00***),
Alan Brewer (UK, ***96***),
Paul Crutzen (Netherlands/ Germany, ***96***),
Julius London (USA, ***84***),
Carl L. Mateer (Canada, ***92***),
Mario Molina (Mexico/USA, ***04***),
Sherwood Rowland (USA, ***96***).

Members:

Dimitris Balis	(Greece, (04)	Ulf Koehler	(Germany, 04)
Leonard Barrie	(Canada/WMO,04)	Janusz Krzscin	(Poland, 00)
Greg Bodeker	(New Zealand, 04)	Michael Kurylo	(USA, 04)
Gerry J. R. Coetzee	(S. Africa, 00)	Shyam Lal	(India, 00)
Emilio Cuevas	(Spain, 00)	Jennifer Logan	(USA, 00)
Frank Dentener	(Italy, 04)	Gloria Manney	(USA, 04)
Roseanne Diab	(S. Africa, 04)	Hideaki Nakane	(Japan, 04)
Valery Dorokhov	(Russia, 04)	Samuel Oltmans	(USA, 00)
Anne Douglass	(USA, 04)	Juan-Carlos Pelaez	(Cuba, 00)
Vitali Fioletov	(Canada, 00)	Andreas Richter	(Germany, 04)
Claire Granier	(France, 04)	Wafik Sharobiem	(Egypt, 00)
Neil Harris	(UK, 00)	Richard Stolarski	(USA, 92, 04)
Robert D. Hudson	(USA, 88, Past Presid)	Frode Stordal	(Norway, 00)
Niklaus Kaempfer	(Switzerland, 00)	Petteri Taalas	(Finland, 00)
Hennie Kelder	(Netherlands, 04)	Donald Webbles	(USA, 00)
		Rodolpho Zander	(Belgium, 00)

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composition after **Tromsø 2008** meeting

President: Christos S. Zerefos (Greece, 84, 94),
Vice President: Richard Stolarski (92, 04)
Secretary: Sophie Godin-Beekmann (France, 00)

Honorary Members (**yr.** elected):

Daniel Albritton (USA, ***08***),
Rumen D. Bojkov (Canada/Bulgaria, ***00***),
Paul Crutzen (Netherlands/Germany, ***96***),
Julius London (USA, ***84***),
Carl L. Mateer (Canada, ***92***),
Mario Molina (Mexico/USA, ***04***),
Sherwood Rowland (USA, ***96***).

Members:

Alkiviadis Bais	(Greece, 08)	Michael Kurylo	(USA, 04)
Dimitris S. Balis	(Greece, 04)	Jean-Chr. Lambert	(Belgium, 08)
Pawan K Bhartia	(USA, 08)	Gloria Manney	(USA, 04)
Greg Bodeker	(New Zealand, 04)	Thomas McElroy	(Canada, 92, 08)
Geir Braathen	(Norway/WMO, 08)	Hideaki Nakane	(Japan, 04)
Guy Brasseur	(USA/Belgium, 92, 08)	Paul Newman	(USA, 08)
Frank D. Dentener	(Italy, 04)	John A. Pyle	(UK, 84 and 08)
Roseanne Diab	(S. Africa, 04) `	William Randel	(USA, 08) Valery
Dorokhov	(Russia, 04)	Andreas Richter	(Germany, 04)
Anne Douglass	(USA, 04)	Michelle Santee	(USA, 08)
David Fahey	(USA, 08)	Masato Shiotani	(Japan, 08)
Claire Granier	(France, 04)	Karel Vanicek	(Czech R.92, 08)
Ivar Isaksen	(Norway, 80,96 Past Presid)	Donald Webbles	(USA, 00, 08- Info-master)

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b) Honorary membership:

Name	*country*	*elected*	*deceased*
Gordon M. B. Dobson	UK	1964	† 1976
Kalpathi R. Ramanathan	India	1971	† 1984
Ernest Vigroux	France	1971	† 1994
Alexandar Khr. Khrgian	USSR	1980	† 1993
Hans U. Dütsch	Switzerland	1984	† 2003
Julius London	USA	1984	† 2009
Marcel Nicolet	Belgium	1986	† 1996
Carl L. Mateer	Canada	1992	† 2011
Paul J. Crutzen	Netherlands / Germany	1996	
Sherwood Rowland	USA	1996	† 2012
Alan W. Brewer	UK / Canada	1996	† 2007
Rumen D. Bojkov	Bulgaria / Canada	2000	
Mario J. Molina	Mexico / USA	2004	
Daniel L. Albriton	USA	2008	

c) Alphabetic list of members with periods of service and status:

Legend: Pres. = President; Secr. = Secretary; Vice-/HonPres. = Vice-/Honorary president; HonM = Honorary member; † = deceased

remarks

Ackerman, Marcel	1972-1984			IAGA representative	
Adel, Arthur	1954-1972				
Albritton, Daniel L.	1984–1992;		HonM 2008		
Atkinson, Roger	1996-2000				
Attmannspacher, Walter	1972-1984				
Bais, Alkiviadis	2008-				
Balis, Dimitris	2004-2012				
Barrie, Leonard	2004-2008			WMO representative	
Basher, Reid E.	1984-1992				
Berggren, R. ,,,	1968-1972				
Bhartia, Pawan K.	2008-				
Bodeker, Greg	2004-2012				
Bojkov, Rumen	1971-2000	Secr. 1984-2000	HonM 2000	WMO representative	
Boville Byron W.	1972-1980				
Braathen, Geir	2008-			WMO representative	
Brasseur, Guy	1992-2000; 2008-				
Brewer, Alan W.	1959-1974;	Pres. 1968-1974	HonM 1996		†2007
Britaev, A. S.	1967-1984				
Chalonge, Daniel	1948-1956				
Chang, Julius S.	1980-1988;	Pres. 1984-1988			
Claude, Hans	1996-2004				
Coetzee, Gerry	2000-2008				
Craig, Richard A.	1957-1961				
Crutzen, Paul	1976-1984		HonM 1996		
Cuevas, Emilio	2000-2008				
Degorska, Malgorzata	1992-2000				
DeLuisi, John J.	1988-1996				
Denterner, Frank D.	2004-2012				
DeZafra, Robert	1992-2000				
Diab, Rossanne	2004-2012				
Dobson, Gordon M. B.	1948-1959	Pres.1948-1959	HonPres 1963,		†1976
Dorokhov, Valery	2004-2012				
Douglass, Anne	2004-2012				
Dütsch, Hans U.	1957-1975	Secr. 1961-1975; Pres. 1975-1980	HonM 1984		†2003
Ehhalt, Dieter H.	1980-1988				
Ehmert, Alfred	1954-1969				
Elanski, Nikolai	1996-2004				
Fabian, Peter	1972-1984; 1988-1996				
Fahey, David	2008-				
Fea, Giorgio	1957-1971				
Feister, Uwe	1984-1992				
Figueira, M. F.	1971-1984				
Fiocco, Giorgio	1992-2000				
Fioletov, Vitali E.	2000-2008				
Fraser, Paul J.	1988-1996; 2000-2008				
Frith, R.	1964-1972				
Galbally, Jan	1980-1988				
Ghazi, Anver	1984-1992				
Ginzburg, Maximo	1996-2004				
Godin-Beekmann, Sophie	2000-	Vice-Pres. 2004-2008; Secr. 2008-			
Godson, Warren L.	1957-1972				
Götz, Paul F. W.	1948-1954				

Legend: Pres. = President; Secr. = Secretary; Vice-/HonPres. = Vice-/Honorary president; HonM = Honorary member; † = deceased

				remarks
Gowan, Edward H.	1954-1956			
Grainier, Claire	2004-2012			
Grasnick Karl-H.	1967-1984			
Gushtin Genady P.	1957-1984			
Hassan, Galal H.	1992-2000			
Harris, Neill	2000-2008			
Heath, Donald F.	1975-1984			
Hering, Wayne S.	1961-1972			
Hesstvedt Eigil	1967-1984			
Hilsenrath; Ernest	1972-1976			
Hov, Oystein	1992-2000			
Hudson, Robert D.	1988-2008;	Pres. 1996-2004		
Ilyas, Mohammad	1984-1992			
Isaksen, Ivar S. A.	1980-1988; 1996-2004	Pres. 2004-2008		
Ito, Tomoyki	1992-2000			
Kaempfer, Nicklaus	2000-2008			
Karol, Igor L.	1976-1984			
Kelder, Hennie	2000-2008			
Kerr, Jim B.	1984-1992			
Khattatov, Viktor	1992-2000			
Khrgian, Alexandar Khr.	1957-1980;		HonM 1980	†1993
Kirchchoff ,Volker	1988-1996			
Kley, Dieter	1988-1996			
Koehler, Ulf	2004-2012			
Köhler, H.	1954-1961			
Komhyr, Walter D.	1972-1984			
Krueger, Arlin J.	1984-1992			
Krzyscin, Jan	2000-2008			
Kulkarni, R. N.	1968-1980			
Künzi, Klaus F.	1980-1988			
Kurylo, Michael	2004-2012			
Kuznetzov, Genady Iv	1968-1976			
Lal, Shyam	2000-2008			
Lambert, Jan-Christian	2008-			
Langlo, Kaare	1959-1970			WMO representative
Larsen, Soren H. H.	1967-1984			
Lilijequist, G. H.	1959-1967			
Liu, Shaw	1988-1996			
Logan, Jennifer	2000-2008			
London, Julius	1959-1984;		HonM 1984	†2008
Losiova, A.	1975-1984			
Machta, Lester	1964-1971			
Makino, Yukio	1988-1996			
Mani Anna,	1967-1984			
Manney, Gloria	2004-2012			
Mateer, Carl L.	1967-1992	Pres. 1980-1984	HonM 1992	†2011
Matthews, Andy W.	1976-1984; 1992-2000	Vice-Pres. 1996-2000		
Mauersberger, Konrad	1996-2004			
McElroy, Thomas	1992-2000; 2008-			
McKenna, Daniel	1996-2004			
Mégie, Gérard	1980-2003(†)	Vice-Pres. 1984-1988; Pres. 1988-1996		
Migeotte, Michel	1957-1968			
Miller, Jim A.	1984-1996;	Vice-Pres. 1988-1996		
Miyake, Yasuo	1954-1968			
Molina, Mario			HonM 2004	

Legend:	Pres. = President Secr. = Secretary	Vice-/HonPres. = Vice-/Honorary president HonM = Honorary member		† = deceased *remarks*
Nakane, Hideaki	2004-2012			
Newman, Paul	2008-			
Nicolet, Marcel	1954-1962 (Liaison IGY)		HonM 1986	†1996
Normand, Charles	1948-1968	Secr. 1948-1959		
Ogawa, Toshihiro	1980-1992; 1996-2004	Vice-Pres. 2000-2004		
Oltmans, Samuel	2000-2008			
Paetzold, Heinz-Karl	1957-1980			
Pelaez, Juan-Carlos	2000-2008			
Penkett, Stewart	1992-2000			
Perov, Stanislav P.	1988-1996			
Pommereau, Jan-Pierre	1992-2000			
Prather, Michael	1996-2004			
Proffitt, Mick	2000-2004			
Pyle, John A.	1984-1992; 2008-			
Ramanathan Kalpathi R.	1948-1984;	Pres. 1964-1972;	HonM 1971	†1984
Regener, Erich	1951-1954			
Regener, Victor H.	1952-1972			
Randel, William	2008-			
Richter, Andreas	2004-2012			
Rogers, Cliff	1992-2000			
Rowland, Sherwood F.	1980-1988		HonM 1996	†2012
Sahai, Yanai	1980-1988			
Santee, Michelle	2008-			
Schmidt, Ulrich	1988-1996			
Sekiguchi, Yoshiro	1964-1984			
Sharobiem, Wafik	2000-2008			
Shimizu, Masayoshi	1980-1988			
Shiotani, Masato	2008-			
Simon, Paul C.	1984-1992; 1996-2004			
Solomon, Susan	1992-2000			
Sreedharan, C. R.	1980-1988			
Staehelin, Johannes	1992-2000			
Stolarski, Richard S.	1992-2000; 2004-2008	Vice President 2008-		
Stordal, Frode	2000-2008			
Subbaraya, B. H.	1988-2000			
Sutcliffe, Reginald C.	1959-1963			
Swinbank, William C.	1954-1968			
Taalas, Petteri	2000-2008			
Thompson, Anne	1996-2004			
Tonsberg, Einar	1948-1967			
Vanicek, Karel	1992-2000; 2008-			
Vassy, Etienne	1948-1959			
Vassy, Arlette	1959-1976			
Vigroux, Ernest	1963-1997		HonM 1971	†1997
Visconti, Guido	1996-2004			
Walshaw, Desmond C.	1964-1984	Secr. 1976-1984		
Wang, Wen-Chyung	1984-1992			
Wei, Ding-Wen	1984-1996			
Wexler, Harry	1954-1960			
Wuebbles, Donald	2000-2008	Info-Dir. (web) 2008-		
Wulf, Oliver R.	1948-1954			
Zander, Rodolpho	2000-2008			
Zerefos, Christos S.	1984-1992; 1996-	Secr. 2000-2008; Pres. 2008-		
Zhou, Xiuj	1992-2000			

Appendix 4: Financial statement of IO_3C for January 1949 to July 1951

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FINANCIAL STATEMENT

International Ozone Commission
from 1st January, 1949, to 31st July, 1951

RECEIPTS

	$	£ s d
Cash in hand	---	---
Cash in bank	---	---
Allocation from I.M.A.		
1949	(3200)	791. 9.2
		126. 1.1
1950		420. 0.0
1951		---
Allocation from U.N.E.S.C.O.		
1949		---
1950	(3570)	1275. 0.0
1951	(1000)	357. 3.0
Payments from other sources		
1949		100. 0.0
1950		160. 0.0
1951		32.18.4
		£ 3262.11.7

PAYMENTS

	£ s d
New instrument (1951)	1235.12.8
New parts and accessories for old instruments	275. 3.9
Freight & insurance for instruments to and from Oxford .	184.11.4
Contingencies, including cash payments for minor parts, postage, telephones, etc. ...	22. 3.0
Staff: payment for scientific assistant at Arosa for 2 months in 1950 ..	82. 4.7
Balance in Bank on 31/7/51 ..	1462.16.3
	£ 3262.11.7

NOTE

The contingent expenditure is that paid for in cash by the Secretary.
On analysis, this expenditure over the three years is seen to consist of :

£ 7. 4. 0	for minor parts and accessories,
6.15. 0	for postage and telephones,
2. 0. 0	for various Bank charges,
4. 7. 0	for stationery and typing,
1.17. 0	for a Scientific assistant's travel to the Instrument Makers in London (2 visits).
£ 22. 3. 0	

Appendix 5: Recommendation of ozone parameters for WMO/CAe-III (1961)

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A N N E X IX

Annex to Recommendation 11 (CAe-III) 1961

OZONE PARAMETERS

(1) Total ozone, Ω : The total or integrated ozone in a vertical column of unit cross-section, expressed in m atm - cm.

NOTE : The total ozone above a pressure level p (less than surface pressure) will be denoted by Ω_p, the m atm - cm unit was formerly referred to as the 10^{-3} STP cm.

(2) Ozone density, ρ_3 : The mass of ozone per unit volume of air, expressed in $\mu g/m^3$ (i.e., 10^{-12} g/cm^3).

(3) Ozone mixing ratio, r_3 : The mass of ozone per unit mass of air, expressed in $\mu g/g$ (i.e., parts per million by mass).

(4) Ozone partial pressure, p_3 : The product of total pressure and ozone mole fraction, expressed in μmb (i.e. 10^{-6}mb).

NOTE : This is to be regarded as a fundamental definition, and not as a consequence of ideal gas behaviour.

(5) Ozone mole fraction, N_3 : The number of molecules of ozone per molecule of air.

NOTE : This quantity is equivalent, with trivial error, to the volume concentration of ozone, and could therefore be expressed in cm^3/m^3 (i.e., parts per million by volume).

(6) Molar mass of ozone, M_3 = 48.000 g/mole.

NOTE : It follows that the ratio of molar masses of ozone and air, ε_3, has the value 1.6571.

Appendix 6: WMO statement on anthropogenic ozone modification (1975)

W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N

WMO STATEMENT

ON

Modification of the ozone layer due to human activities

and some possible geophysical consequences

General

1. In recent years there has been increasing concern as to the effects of the pollution of the stratosphere, and in particular the possibility of a reduction in the amount of ozone present at these levels due to photochemical reactions involving certain trace substances, the concentrations of which may be increased due to man's activities. This concern arises from the danger of increased solar ultraviolet radiation penetrating to the Earth's surface and from the possibility of adverse climatological consequences.

2. With WMO acting as co-ordinating agency, station networks to measure both total ozone and its vertical distribution have been considerably expanded. During the past two to three decades much work has been done in defining the structure and energetics of the stratosphere, in studying winter warmings and other special phenomena, in developing vertical profiles and global distributions of ozone and in refining photochemical and radiation calculations.

3. Ozone is of major importance in the meteorology of the stratosphere, since by virtue of its absorption of solar ultra-violet radiation and the resulting heating effect it largely determines the basic temperature structure and general circulation of this region. Moreover, since it behaves essentially as an inert tracer in the lower stratosphere, observations of its distribution provide considerable information on transport mechanisms in this region and also transfer between stratosphere and troposphere. If the ozone formation and destruction processes were determined solely by the photochemical reactions involving only the oxygen species (the Chapman reactions) no effects resulting from human activities would be expected.

4. However, improved observations of the vertical distribution of ozone obtained during and after the International Geophysical Year made it clear that the pure oxygen photochemistry did not completely explain the actual processes found to be taking place, and subsequently the importance of stratospheric trace gases was discovered, especially the oxides of nitrogen (NO_x), in controlling the ozone balance. This led to the conclusion that ozone might be less stable against outside man-made influences than had previously been believed.

The role of trace gases in the photochemistry of ozone

5. Ozone is formed at stratospheric levels as a result of the photodissociation of molecular oxygen, and according to present knowledge the oxides of nitrogen (NO_x) through their catalytic cycle represent a considerably greater sink for it than does the classical reaction $O + O_3$ at levels below the stratopause. Oxides of hydrogen (HO_x), which are mainly derived from water vapour have the effect of reducing the amount of ozone above about 40 km; below this level, however, their effect is to reduce the effectiveness of the process of ozone destruction by NO_x by competing reactions which result in the formation of nitric acid (HNO_3). The oxidation chain of methane also plays a role in the photochemical processes.

6. The main natural source of NO_x in the stratosphere is thought to be the oxidation of nitrous oxide (N_2O) (of biological origin at the surface of the earth and the sea) by excited oxygen atoms which themselves are a product of the photodissociation of ozone. Other natural sources of NO_x whose magnitude is not yet well enough established are cosmic rays and solar proton events and downward transport from the thermosphere in high latitudes of the winter hemisphere. The possibility of some direct supply of NO_x from the troposphere below cannot be ruled out.

7. Recently it has been shown that ozone is also destroyed by the catalytic cycle of oxides of chlorine ($Cl-ClO_x$). In this case, ozone destruction is accelerated by increased HO_x, but retarded by the presence of methane and nitric oxide. The amount of naturally produced ClO_x in the stratosphere seems to be small and its effect on ozone considerably smaller than that of NO_x. The role played by the bromine $Br-BrO_x$ cycle could be similar to that of the $Cl-ClO_x$; but given equal amounts of Br and Cl in the stratosphere the former would be the most effective in destroying ozone.

Effects due to human activities

NO_x increase due to aircraft flying in the stratosphere

8. There has already been considerable research conducted into the direct injection of NO_x into the stratosphere by fleets of supersonic aircraft and the consequent effect on the ozone layer. Although there are considerable uncertainties in both measurements and theory (in the latter case being of about a factor of two), the role of NO_x is sufficiently well established to be able to state with reasonable confidence that:

- currently planned SSTs, due to their lower flight altitudes of 17 km and their limited numbers (30-50 projected) are not predicted to have an effect that would be significant or that could be distinguished from natural variations;

- a large fleet of supersonic aircraft flying at greater altitudes is predicted to have a noticeable effect on the ozone layer, and permissible total emission levels may have to be defined by international agreement;

- Whilst the present numbers and flight altitudes of subsonic aircraft in the stratosphere are not expected to have a significant effect, the trend for each new generation subsonic aircraft to fly at higher levels suggests that this source of NO_x should be closely watched.

NO_x increase due to increased production of nitrous oxide at the surface

9. A theory has recently been propounded that increased use of agricultural fertilizers and/or of nitrogen-fixing vegetation might affect the nitrogen cycle and result in an increase in the amounts of nitrous oxide (N_2O) released from the surface into the atmosphere. This would then lead to an increase of NO_x in the stratosphere and hence a decrease in the ozone amount. This source of N_2O might also be stimulated by increases in the acidity of rain.

10. Because of the extreme complexity of this problem, involving as it does the whole global nitrogen cycle, uncertainties regarding the consequences on the ozone layer are still very great. Although there is no likelihood of a significant change in the ozone layer in the near future as a result of changing agricultural practices, the matter deserves thorough study because of the substantial long-term effects which some scientists consider to be possible.

Chlorofluoromethanes

11. The increase in the manufacture and release into the atmosphere of chlorofluoromethanes, especially $CFCl_3$ (Freon 11) and CF_2Cl_2 (Freon 12) is predicted to result in a rapidly increasing amount of ClO_x in the stratosphere. The removal rate of ClO_x is slow, it is to be expected that the stratospheric ClO_x concentration will continue to increase for several years even after all emissions of chlorofluoromethanes into the atmosphere ceased, due to the slow diffusion rates into and through the stratosphere. Thereafter the recovery rate would be very slow (a few decades).

12. Several estimates using one-dimensional models, with transport represented by vertical eddy diffusion, have been made of the time history of the influence of man-made ClO_x on the average amount of ozone. The calculations involve average concentrations of the important atmospheric constituents taken or derived from the limited observations so far available, and the best current estimates of reaction rates for about one hundred chemical reactions.

13. On an average world-wide basis, without allowances for variations with latitude and longitude, these calculations indicate that the present depletion of ozone due to $CFCl_3$ and CF_2Cl_2 already in the stratosphere is of the order of one per cent. The long-term steady-state effect of a continued release at the 1972 world rate of release would be about 10 per cent average ozone depletion, with an uncertainty factor of about two. This is on the assumption that there are no other sinks for the chlorofluoromethanes. Preliminary calculations using models which include latitude variations suggest an ozone depletion of about the same amount.

14. Thus whilst a fuller understanding of the chemistry involving chlorine in the stratosphere will require further measurements and calculations, including naturally produced methyl chloride (CH_3Cl) and possibly other chlorocarbons significant in chlorine chemistry, the present evidence supports the view that a continued release of chlorofluoromethanes into the atmosphere may lead to a significant reduction in stratospheric ozone.

Other threats to the ozone layer

15. All gaseous compounds which can release either chlorine or bromine to the stratosphere are potential agents for the destruction of ozone. Only a small fraction of the world chlorine production is used to produce the two chlorofluoromethanes quoted in paragraph 11. Whilst there is reason to expect that other chlorine bearing gases are largely destroyed or removed in the troposphere and although the man-made bromine gases may be few, the quantitative aspects of their entry into the stratosphere must be evaluated. It is not at all certain that scientists have identified all potential threats to the stratospheric ozone layer.

Possible consequences of ozone depletion

16. Those possible consequences of changes in the ozone layer which have been suggested and estimated on the basis of the limited data available may be divided into the biological influences on man, animals and crops of increased ultraviolet radiation in the wavelength 280-320 nm (UV-B) and climatological consequences.

Biological effects

17. A reduction in the ozone column would result in an increase of UV-B radiation received at the ground, and theoretical calculations using both absorption and scattering by ozone and other atmospheric constituents have indicated an average magnification factor from slightly less than 1.5 to slightly more than 2.0 between percentage changes in the ozone column and percentage changes in UV-B radiation in clear sky conditions. In other words a reduction of 10 per cent in ozone would result in an increase of about 20 per cent in UV-B (or "erythemal" radiation).

Climatological consequences

18. Beaucase solar ultraviolet radiation is very strongly absorbed by ozone, the temperature of the stratosphere is largely maintained by a balance between absorption of solar radiation by ozone and emission of atmospheric infra-red radiation by ozone, carbon dioxide and water vapour. Any change in the stratospheric heating rates will have a direct influence on

the temperature distribution in the stratosphere and possibly in the troposphere, and these temperature changes will have an effect on the patterns of atmospheric circulation and hence on weather and climate. However, such thermodynamic and dynamic changes will themselves have significant interactions or feedback on the stratospheric composition.

19. An average temperature decrease of up to 10°C in the upper stratosphere is expected to result from reduction of ozone due to man's activities of the amount suggested in paragraph 13. Whereas calculations using one-dimensional radiative-convective models indicate that the corresponding temperature change at ground level would be a fraction of a degree (and probably not directly detectable), because of the complexity of stratosphere-troposphere interactions it is not possible to infer with any reliability what the full consequences of these changes would be on the Earth's climate.

20. The chlorofluoromethanes and some other halogen compounds have strong absorption bands in the part of the infra-red spectrum where the other trace gases are quite transparent, and therefore an increase in the amount of these artificial compounds in the troposphere would cause a warming by their additional greenhouse effect. Applying the hypothesis in paragraph 13 of the long-term steady-state effect of a continued release of chlorofluoromethanes at the 1972 rate, it has been estimated that the resulting greenhouse effect (taken in isolation of other factors) could produce an average temperature rise at the surface of 0.9°C, again with an uncertainty factor of about two. Such a change in the mean global temperature is at least comparable to any changes which have occurred during the past several centuries.

<u>The need for more observations and research</u>

21. On the basis of the evidence so far obtained, the potential threat of a considerable depletion of the ozone layer in the future must be recognized. The foregoing review of present knowledge has shown clearly that there is a lack of understanding in a number of important aspects. Whilst this lack of understanding results in a considerable divergence of opinion as regards the urgency of the problem, the prudent course of action at present seems to be to step up efforts immediately so as to reduce the scientific uncertainties as rapidly as possible.

- 6 -

22. Although knowledge of the distribution of ozone is much greater than that of the other trace constituents involved in the stratospheric photochemistry, an intensive observational effort is needed as a matter of urgency to establish the basis for continued long-term monitoring of ozone and for obtaining the necessary detailed knowledge of the vertical distribution which is needed for improved understanding. In addition, knowledge of the vertical distribution of other trace gases in the stratosphere and also in the troposphere is needed. Parent-substances of the ozone-destroying radicals (e.g. N_2O, chlorofluoromethanes and some other halogen compounds) should be monitored both near the ground and in the stratosphere to establish trends. Measurements of the extraterrestrial solar flux as a function of wavelength between 180 and 350 nm and its variations in time are also of fundamental importance. Moreover, to complement biological studies on the effects of solar UV-B radiation, a project to monitor radiation in this spectral range must be established.

23. In order to guarantee the high standard of the observational programme, and to obtain a maximum return on the efforts invested therein, a research programme should be interwoven to endeavour to improve understanding of the various aspects concerning atmospheric ozone. In addition to the various specific problems which can be tackled by fairly small groups, the research programme should facilitate broad scale projects of a strongly inter-disciplinary character to study:

(a) The complete nitrogen cycle, its possible changes due to man's activities and the implications for atmospheric chemistry;

(b) The coupling between the stratospheric chemical composition, heating rates and circulation in conjunction with the transport of relevant gases and tropospheric-stratospheric exchange processes;

(c) The influence on climate of changes in stratospheric composition, involving quantitative treatment of the associated feed-back system;

(d) Biological consequences of changes in solar UV-B radiation on the global ecosystem.

24. Therefore there is a pressing need for a co-ordinated international programme under the leadership of WMO to monitor and study all aspects of the stratospheric environment relevant to ozone. The collaboration of other international bodies such as UNEP and ICSU in such a programme would be necessary.

26 November 1975

Appendix 7: By-Laws of International Ozone Commission (1988)

See also IO3C-website: http://ioc.atmos.illinois.edu/about/about_bylaws.html

I. ROLE AND RESPONSIBILITIES

The role of the IO_3C is:

To promote research in atmospheric ozone-related issues as well as application of that research to practical problems. This role is part of the broad charter of IAMAS concerning the composition and changes of the earth-atmosphere system. It is performed in co-operation with all the IAMAS Commissions and with other appropriate bodies, as necessary.

Topics of concern to the IO_3C include:

- the global budget of atmospheric ozone including production, destruction and distribution of ozone and related species at various temporal and spatial scales,
- the climatic impact of ozone changes and related species,
- the development of methods for direct and remote measurements of ozone and related species in the atmosphere and for the determination of their physical, chemical, spectral and radiative properties,
- the development of simulation models including photochemical, dynamical and radiative processes and climatic impact of atmospheric ozone,
- the anthropogenic impact on the atmospheric ozone budget.

The responsibilities of the IO_3C are as follows:

1. a) to provide a forum to the international community of ozone researchers for the exchange of relevant ideas and results, and to promote international co-operation,
   b) to assess, summarise and publish, as necessary, the status of, and the requirements for, measurement and research in any particular aspect of atmospheric ozone, based on specific studies performed by appropriate ad-hoc working groups,
   c) to organize the Quadrennial Ozone Symposium.
2. a) to address other scientific and/or intergovernmental bodies on matters referring to atmospheric ozone,
   b) to develop formal recommendations for the promotion of particular aspects of ozone studies, as and when necessary,
   c) to collaborate and join with other scientific bodies for the promotion of atmospheric ozone studies.
3. a) to stimulate improvement in the calibration and measurement standards of instruments in use for atmospheric ozone and related species measurements,
   b) to promote and encourage the development of new and more accurate instruments for the measurement of atmospheric ozone and related species,
   c) to participate in the development of Global Ozone Observing Systems and to promote the timely exchange of data.

II. COMPOSITION OF THE IO_3C

1. Members of the IO_3C are elected on the basis of their active participation in, and contribution to, ozone related research as defined by the IO_3C charter. Election of members takes place at the IO_3C meeting held usually during the Quadrennial Ozone Symposium. During the year preceding the elections, the IO_3C members are urged to make proposals for new members keeping in mind the need for broad global representation. The Secretary of the Commission circulates a summary of all proposals two months before the meeting of the IO_3C.
2. The total number of members should not exceed thirty. Election of members is made by a majority of votes for a four-year term, renewable once.
3. The IO_3C Officers - President, Vice-President and Secretary - are elected among the most experienced members of the IO_3C. The term of office is 4 years, renewable once.
4. The past President is an ex-officio officer of the IO_3C. Election to the Vice Presidency does not imply necessarily access to the Presidency.
5. When any of the Officers reaches the end of his term of office or resigns, a small Nomination Committee is set up among the current, honorary and/or past members of the IO_3C to solicit and make proposals for further election. The Secretary circulates all proposals before the meeting of the IO_3C.
6. Honorary membership is awarded to individuals for their outstanding contribution to ozone-related research. It does not require previous membership in the IO_3C. Propositions for honorary membership are made by the IO_3C members to the Officers prior to the IO_3C meeting. Election to honorary membership requires two thirds of all members votes.
7. The IO_3C shall convene, at least every four years, during the Quadrennial Ozone Symposium. Additional meetings (e.g. at IAMAS Assembly) can be convened by the Executive or on request of a majority of IOC members.
8. The IO_3C forms a quorum if at least two thirds of the members are present.

III. ORGANIZATION AND ROLE OF THE IO_3C OFFICERS

1. The President, Vice-President, Secretary and Past President of the IO_3C constitute the Executive Committee which carries out all the customary functions of the IO_3C in furthering the goals and fulfilling the responsibilities of the IO_3C as described in the IO_3C charter. The Executive Committee is responsible for bringing all appropriate matters before the full IO_3C for consideration.
2. The President of the IO_3C is the Chairman of the Executive Committee and he, or a representative designated by the Executive Committee - usually the Secretary, represents the IO_3C on all official communications and functions. In case of resignation or long-term absence of the President, the Vice-President fulfils his role until the next meeting of the Commission.

3. The Secretary maintains records of IO_3C activities, assures timely communications among IO_3C members, serves as the treasurer of the Commission and in concurrence with the other members of the Executive Committee serves as a point of contact with other scientific bodies.
4. The Executive Committee provides an annual report to all IO_3C members on significant recent and upcoming activities involving the Commission.
5. The Officers may assume other specific responsibilities as agreed upon by the entire IO_3C. All decisions submitted to the IO_3C are decided by a majority vote.

Appendix 8: Resolution to maintain status as a Commission (1988)

RESOLUTION I*

THE INTERNATIONAL OZONE COMMISSION

When informed of a proposal discussed at the Vancouver meeting of the IAMAP Executive Committee for a re-evaluation of the relative roles of the existing Commissions and possible merger of selected Commissions and the concern expressed in this respect by Commission officers;

Considering

- the ever increasing public awareness and concern of possible man-made changes of the ozone layer;
- the need to mobilize the scientific community for proper and timely advice for decisive actions;
- the importance of stimulating scientific contributions for the evolving Global Tropospheric Chemistry and Global Change Programmes;

Recognizing the role of the International Ozone Commission in assisting the planning and implementation of many international ozone research and monitoring activities and in particular the call for action by the inter-governmental Executive Council of the World Meteorological Organization for continuous collaboration in the promotion of international activities;

Re-confirms the strong stand against any consideration of modification of this Commission's charter, organization and activities within IAMAP; and

Decides to call the attention of IAMAP officers to this and requests the IAMAP EC to communicate to the officers of other Commissions the firm view of IOC that, although there is a need for co-ordination of symposia and workshops during IAMAP and IUGG Assemblies, there is no need for over-extending such objectives to affect the functioning of many important Commissions;

Furthermore, any re-organization of the IOC would weaken the focus and the possibility of IOC to mobilize the broad scientific community for response to important ozone issues and in turn would weaken the role of IAMAP in the years to come.

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* unanimously approved by the Ozone Commission in Göttingen on 11 August 1988.

(RDP 3788)

Appendix 9: Statement "State of the Ozone Layer" (1988)

OZONE COMMISSION

INTERNATIONAL ASSOCIATION OF METEOROLOGY AND ATMOSPHERIC PHYSICS (IUGG)

S T A T E M E N T

on the

State of the Ozone Layer

The International Ozone Commission (IOC) of the International Association for Meteorology and Atmospheric Physics (IUGG/ICSU), at the conclusion of the Quadriennal Ozone Symposium-88 (August 8-13, 1988) held at the University of Göttingen, Federal Republic of Germany and attended by nearly 500 scientists, briefly summarized the predominant views on the state of the ozone layer in the following statement.

1. IOC confirms the analysis of revised ground-based Dobson spectrophotometer data over the northern hemisphere for the period 1965-1986 by the NASA/WMO International Ozone Trends Panel 1988 which indicates that, after allowing for the known natural variability (e.g. solar cycle, quasi-biennial oscillation), ozone has decreased since 1970 by about 4% in the winter months and about 1% in the summer months over the latitudinal band 30 to 64°N. The winter trends become more negative with increasing latitude and also differ between geographical regions.

2. Meanwhile, the observed increase in tropospheric ozone at the same latitudes of about 1% per year infers that the stratospheric ozone decreases determined from the total ozone column measurements must have been greater.

3. The model calculations are broadly consistent with the observed change in column ozone, except that the mean values of the observed decreases in winter are larger than models had predicted. However, current model calculations do not include the effects of heterogeneous chemistry which might result in an underestimation of the impact of CFCs on ozone. The ozone satellite data from the last nine years are in concurrence with the conclusions deduced from ground-based observations.

4. The IOC also confirms that substantial decreases of total ozone which started in the late 1970's are now occurring every spring over Antarctica, although with variable strength. The main ozone depletion during this season is observed between 12 and 24 km. Scientific research shows that the decreases are strongly linked with the specific circumpolar circulational conditions accompanied by extremely low stratospheric temperatures (favouring generation of polar stratospheric clouds) and greatly enhanced abundance of active chlorine released from substances produced by industries elsewhere in the world.

5. In the absence of other changes, the Antarctic ozone hole will continue to appear each astral spring until stratospheric chlorine levels fall to those of the mid-1970's. Even if no more man-made chlorine were to be released into the atmosphere, the Antarctic ozone recovery would take many decades.

6. The rapid and frequent meridional exchange of air into the Arctic lower stratospheric levels precludes the possibility of a strong closed circumpolar vortex with extremely low stratospheric temperatures, which is typical over the Antarctic region during the polar night. This could at least partly explain why the available observations do not indicate over the Arctic the existence of an extensive ozone reduction similar by scale and magnitude to the one observed over Antarctica since the late 1970's. Also, recent observations indicate a somewhat perturbed state of the chemical composition in the lower stratosphere during the Arctic winter.

7. The IOC wishes it to be noted that, after many years of monitoring and research, there is now clear evidence of mankind having affected the whole global ozone layer. This is a significant point as it is the first firm evidence in history that humans have very noticeably and harmfully altered the atmosphere on a global scale.

8. There is an added climatological effect of the complex of increasing CFC's and changing ozone on the temperatures. The CFCs have a strong greenhouse effect, and at current concentrations they contribute by 10% to 15% to the total surface warming calculated by various modes. The increasing tropospheric ozone also has a similar effect. On the other hand, the decreasing stratospheric ozone amounts would result in a local temperature decrease in the middle stratosphere.

9. Scientific understanding of the processes which control ozone has improved since the last Ozone Symposium-84. However, many more atmospheric measurements and laboratory and modelling studies are needed to test and refine this. The IOC members are ready to play a significant part in the continuing investigation of ozone and other related environmental problems expecting that there will be national and international firm commitments to long-term funding for programmes of instrument development, deployment and calibrations, of analysis of the data obtained, and of studies of processes relevant to their interpretation.

10. The IOC urges all national and international agencies such as the World Meteorological Organization (WMO), the Commission of European Communities (CEC), which support scientific research and monitoring of ozone and associated atmospheric parameters, and such as the United Nations Environment Programme (UNEP) which handles studies of impacts and related public policy, to continue to support these activities. The IOC is ready to collaborate in all these fields, as has been done in the past decades.

11. The IOC supports the need for regular scientific assesment of the ozone problem at an international level under the auspices of the World Meteorological Organization and the United Nations Environment Programme, such as are conducted as part of the Montreal Protocol on Substances that Deplete the Ozone Layer. The IOC anticipates participating in these reviews both as an independent Commission of scientists and as individual scientists.

August 1988

IAMAS Publication Series

Issue no. 1

International Radiation Commissions 1896 to 2008: Research into atmospheric radiation from IMO to IAMAS. Compiled by Hans-Jürgen Bolle with contributions by Fritz Möller and Julius London.
May 2008, iv + 141 pp.

Issue no. 2

International Ozone Commission: History and activities.
Compiled by Rumen D. Bojkov.
August 2012, iv + 100 pp.

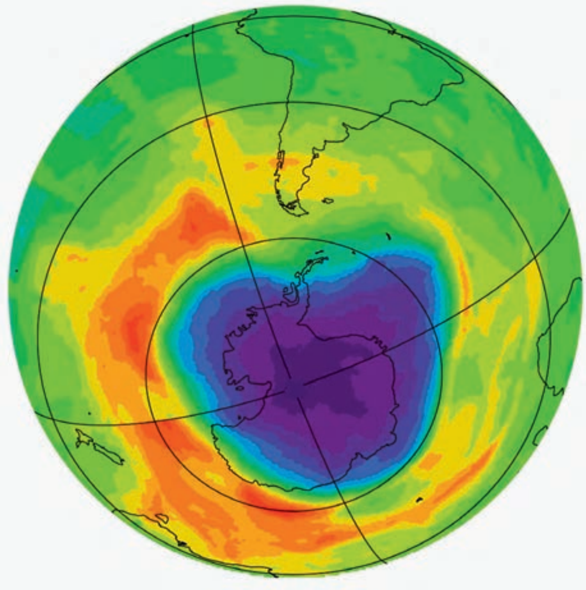
Information about the author

Rumen D. BOJKOV (*1931) is a citizen of Bulgaria and Canada. He obtained his Ph.D. in physics and mathematics from the University of Moscow (USSR, 1964) and a D.Sc. in atmospheric physics from the University of Rostock (Germany, 1971). He taught courses on atmospheric physics at the universities of Sofia (Bulgaria), Albany (NY, USA), Cairo (Egypt) and Thessaloniki (Greece), and held research positions at the Canadian Meteorological Service as well as at the National Center for Atmospheric Research (USA). For many years he worked for WMO in Geneva (Switzerland) as Chief of the Atmospheric Sciences Division and later as Special Advisor to the Secretary-General of WMO on Ozone and Global Environmental Issues. From 1984 to 2000 he served as Secretary of the International Ozone Commission (IO_3C) of IAMAS within IUGG and has been one of IO_3C's honorary members since. Dr. Bojkov published more than 120 refereed scientific papers, a university text-book on atmospheric physics, and he initiated, wrote and edited numerous international reports dealing with ozone issues.

Illustration of the topic

The severe depletion of Antarctic ozone known as the "ozone hole" was first observed in the early 1980s. The depletion is attributable to chemical destruction by reactive halogen gases, which increased in the stratosphere in the latter half of the 20th century. Conditions in the Antarctic winter stratosphere are highly suitable for ozone depletion because of (1) the long periods of extremely low temperatures, which promote PSC formation and removal; (2) the abundance of reactive halogen gases, which chemically destroy ozone; and (3) the isolation of stratospheric air during the winter, which allows time for chemical destruction to occur. The severity of Antarctic ozone depletion can be seen using images of total ozone from space, ozone altitude profiles, and long-term average values of polar total ozone.

***Antarctic ozone hole**. The most widely used images of Antarctic ozone depletion are those from space-based measurements of total ozone. Satellite images made during Antarctic winter and spring show a large region centred near the South Pole in which total ozone is highly depleted. This region has come to be called the "ozone hole". The area of the ozone hole has reached 25 million square kilometres in recent years, which is nearly twice the area of the Antarctic continent. Minimum values of total ozone inside the ozone hole have fallen as low as 100 Dobson units (DU) compared with normal springtime values of about 300 DU). The mass of ozone destroyed over the Antarctic each season has reached ~80 megatons, which is ~ 3% of the global ozone mass.*



Source: Scientific Assessment of Ozone Depletion. WMO, Global Ozone Research and Monitoring Project, Rept. No. 47, 2002

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