WORLD METEOROLOGICAL ORGANIZATION
GLOBAL ATMOSPHERE WATCH

No. 152

CURRENT ACTIVITIES OF THE

GLOBAL ATMOSPHERE WATCH PROGRAMME

as presented at the
14th World Meteorological Congress, May 2003

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WMO TD No. 1168

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Environment Division, AREP, World Meteorological Organization

1. INTRODUCTION

The Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) was established in 1989. It focuses upon the role of atmospheric chemistry in global change (Strategic Plan, 2001). Consisting of a partnership of managers, scientists and technical expertise from 80 countries, GAW is coordinated by the WMO secretariat in Geneva and the Working Group on Environmental Pollution and Atmospheric Chemistry of the Commission for Atmospheric Science (CAS). Recognizing the need to bring scientific data and information to bear in the formulation of national and international policy, the GAW mission is threefold:

1. **Systematic monitoring** of atmospheric chemical composition and related physical parameters on a global to regional scale
2. **Analysis and Assessment** in support of environmental conventions and future policy development
3. **Development of a predictive capability** for future atmospheric states

In this paper, ongoing activities of GAW related to these missions are briefly described. A subset of the comprehensive networks of GAW forms the baseline network for atmospheric composition measurements in the Global Climate Observing System (GCOS) that is currently under development.

2. MONITORING

The development of information for science assessments and the associated agreements/conventions rely heavily on the information derived from GAW's monitoring. Figure 1 shows the major activities and facilities in this part of the GAW programme. Support for these is provided, in large part, by WMO member countries that participate in the GAW programme, augmented by outside international funding, and the WMO Secretariat's budget. A network of measurement stations is the backbone of GAW monitoring. It consists of GAW G*lobal* and R*egional* stations with additional observations made at *Contributing* stations. Approximately 80 countries host GAW Global and Regional stations through either their National Hydrological and Meteorological Services (NHMSs) or through collaboration with other national scientific organizations. The present network of 22 GAW Global stations is shown in Figure 2. They are situated near an upper air synoptic station in remote locations, representative of large geographic areas and routinely measure a variety of atmospheric chemicals over decades. Data are typically applied to global issues such as climate change and stratospheric ozone depletion, regional issues and satellite calibration/validation. An often under-stated function of the global GAW network is that its core measurements and facilities in remote regions enable shorter-term process-oriented multi-disciplinary studies to take place that otherwise could not have happened. GAW Regional stations are usually representative of smaller geographic regions. A data base of network station information is maintained in the GAW Station Information System (GAWSIS) (see GAW website: http://www.wmo.ch/web/arep/gaw/gaw_home.html).

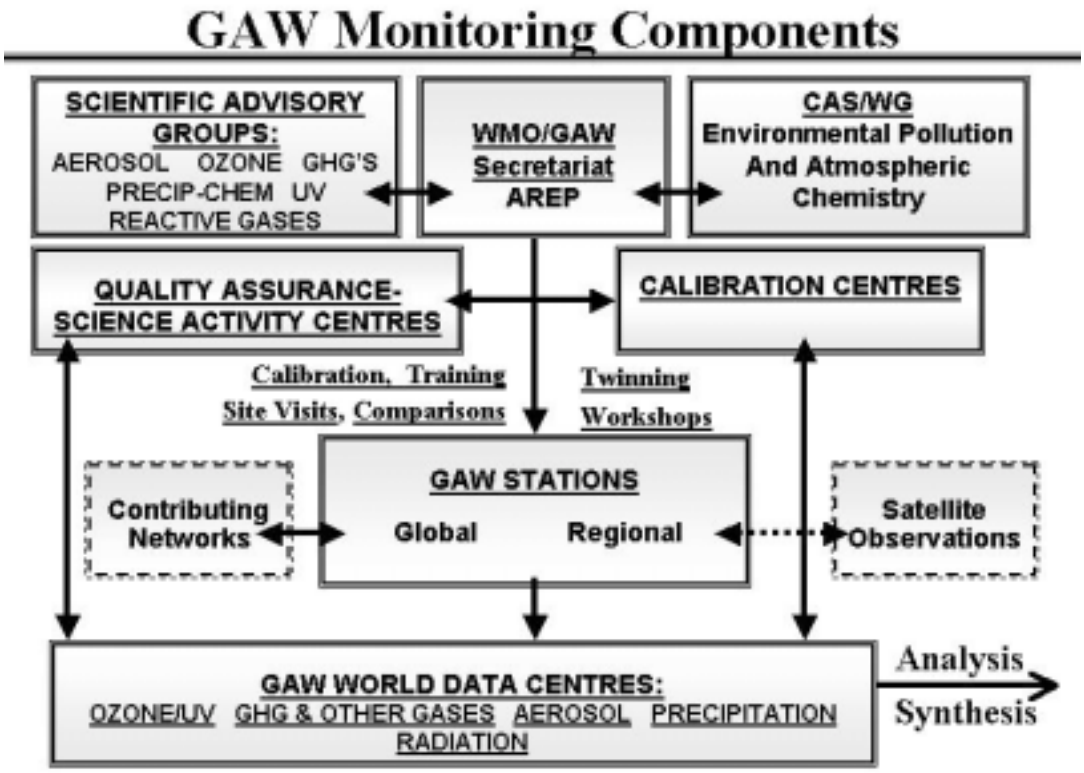

Figure 1: Components of GAW Monitoring. The dashed lines represent partners that combine with GAW to constitute the global atmospheric composition monitoring system.

The GAW secretariat has established Scientific Advisory Groups (SAGs) to organize and co-ordinate monitoring activities for six parameter types (Figure 1). The SAGs advise on matters related to the science issue they represent. SAGs are responsible for assigning variables to be measured, preparing measurement quidelines, defining data quality objectives, developing

Figure 2: The network of GAW Global atmospheric chemistry observatories. It is augmented by a large number of Regional GAW stations. The comprehensive global network configuration depends on the parameter measured (see Figures 3 to 5).

standard operating procedures and overseeing the implementation of data quality criteria and standard operating procedures. To this end, they are assisted by GAW World Calibration Centres (WCC) and Quality Assurance/Scientific Activity Centres (QA/SAC). These centres and partners perform the vital function of helping to ensure that the data submitted to the GAW World Data Centres (WDC) is of high quality. The WCC activities include (a) maintenance of world standards for selected chemicals (b) calibration of instruments through station visits, (c) instrument comparisons and calibration campaigns, (d) laboratory measurement comparisons of circulated standard gases or reference samples, and (e) systematic and frequent calibration checks of the world standards (see detailed summary in Annex). In addition, there are GAW training activities particularly for developing countries (e.g. the Dobson ozone measurement training centre in the Czech Republic and the GAWTEC training courses conducted in Germany).

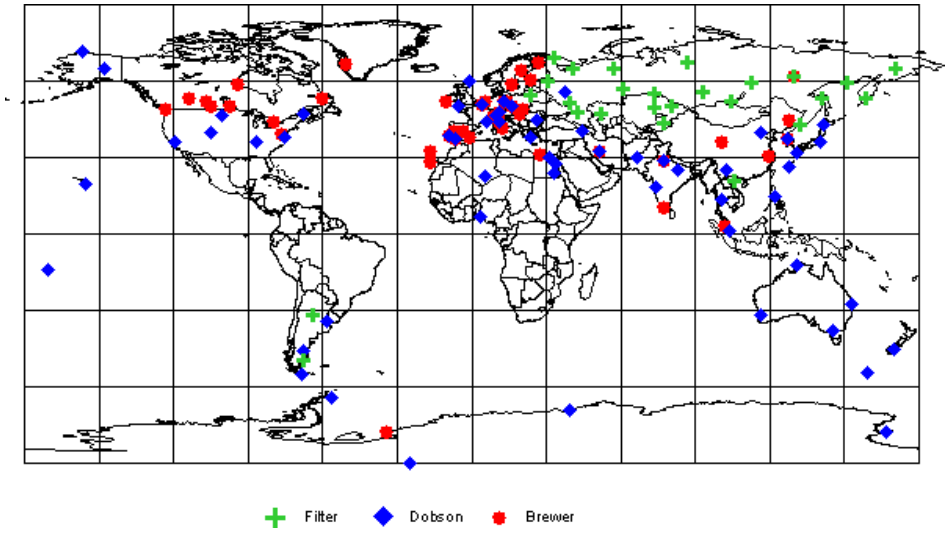

Figure 3: A map of currently operating stations in the GAW global network for total column ozone for which regular observations since at least 1999 have been submitted to the World Ozone and UV Data Centre (WOUDC). Three types of instrument networks comprise this network as indicated by the symbols (Courtesy of Ed Hare of WOUDC, Canada).

It is very important to emphasize that the network of GAW Global stations shown in Figure 2 is but one aspect of the GAW global monitoring programme. Depending on the variable measured, the world network of GAW Global, Regional and Contributing stations has a very different configuration. The GAW total column ozone network is shown in Figure 3. The task of ensuring that the data sets can be merged falls to GAW and requires substantial international collaboration and resources (e.g. routinely conducted instrument intercomparisons). It is comprised of data from three different instruments.

The GAW global network of currently operating ozone vertical profiles with balloon sondes is shown in Figure 4. It is a good example of a global network in which contributing partners, namely the NASA SHADOZ network combine with the GAW network utilizing similar measurement protocols and the GAW World Ozone and UV Data Center (WOUDC) to yield more comprehensive global observations of ozone in the troposphere and stratosphere. The total column and vertical profile ozone networks are essential in the calibration and validation of satellite ozone measurements as well as in detecting trends.

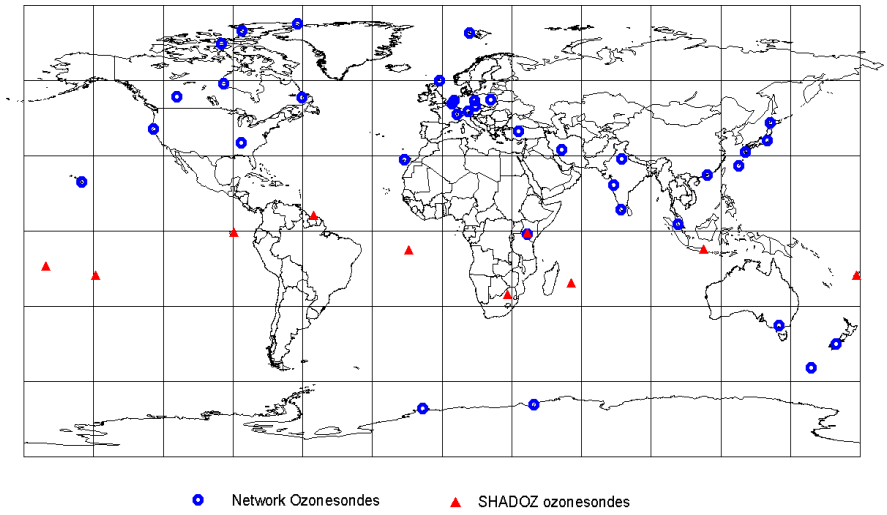

Figure 4: ***Currently operating stations in the GAW global network for ozone vertical profiles made with balloon sondes for which regular observations since at least 1999 have been submitted to the World Ozone and UV Data Centre (WOUDC). Blue dots are GAW stations and red triangles are stations of the NASA SHADOZ network, a Contributing network of GAW. (Courtesy of Ed Hare of WOUDC, Canada).***

The GAW global network of surface measurement stations for the greenhouse gas CO_2 is shown in Figure 5. This network is a composite of a world-wide flask sampling network operated by a number of laboratories at GAW global and regional stations as well as continuous measurements made at many of the global stations in Figure 2. A routine vertical profiling network based on small aircraft will soon be in place. The global measurement networks for CH_4, N_2O and CFCs are comprehensive but not as well organized as those for CO_2. Assisting the global community to do this will be a priority of GAW.

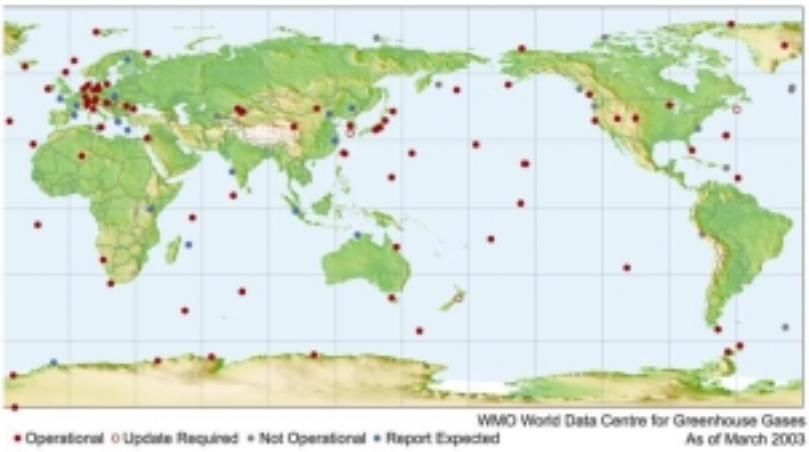

Figure 5: ***The GAW global network of stations contributing carbon dioxide surface observations to the World Data Centre for Greenhouse Gases (WDCGG) in Japan.***

The WDCs are operated and maintained by their individual host institutions and focus on selected atmospheric chemical constitutents. They collect, document and archive atmospheric measurements, the associated metadata from measurement stations world-wide and quality assurance information. They make the data freely available to the scientific community. In some cases, WDCs also provide additional products including data analyses, maps of data distributions, and data summaries:

1. The World Ozone and Ultraviolet Radiation Data Centre WOUDC (Toronto, Canada)

WOUDC, operated by the Meteorological Service of Canada (MSC), began as the World Ozone Data Centre (WODC) in 1960 and in June 1993 began receiving data on ultraviolet radiation. At present, there are over 400 registered stations represented in the WOUDC archive (website http://www.msc-smc.ec.gc.ca/woudc).

2. The World Data Centre for Greenhouse Gases WDCGG (Tokyo, Japan)

WDCGG was established at the Japan Meteorological Agency (JMA) in October 1990. It collects and distributes data on the mixing ratios of greenhouse (CO_2, CH_4, CFCs, N_2O, O_3 etc.), other related reactive gases (CO, NOx, SO_2, VOC, etc.) and associated meteorological parameters. As of February 2000, 182 stations in 42 countries submitted observational data for 13 species of greenhouse and related gases to the WDCGG. (http://gaw.kishou.go.jp/wdcgg.html).

3. The World Data Centre for Precipitation Chemistry WDCPC (Albany, USA)

This centre is operated by the Atmospheric Sciences Research Center (ASRC) of the State University of New York at Albany, and is supported by US and Canadian government agencies. Data includes precipitation acidity or alkalinity, the major cations ammonium, calcium, potassium, magnesium, sodium and the major anions: sulphate, nitrate, chloride. The website is http://qasac-americas.org

4. The World Data Centre for Aerosols WDCA (Ispra, Italy)

The WDCA is operated by the European Union's Joint Research Centre (JRC), Ispra, Italy, and was set up to archive aerosol related observations made under GAW. Its website is http://www.ei.jrc.it/wdca/.

5. The World Radiation Data Centre WRDC (St. Petersburg, Russian Federation)

WRDC was established in 1964 at the Main Geophysical Observatory of the Russian Federal Service for Hydrometeorology and Environmental Monitoring. It is the central repository of global, diffuse and direct solar radiation, downward atmospheric radiation, net total and terrestrial surface radiation (upward), spectral radiation components (instantaneous fluxes), and sunshine duration, on hourly, daily or monthly basis. The WRDC web site is http://wrdc.mgo.rssi.ru.

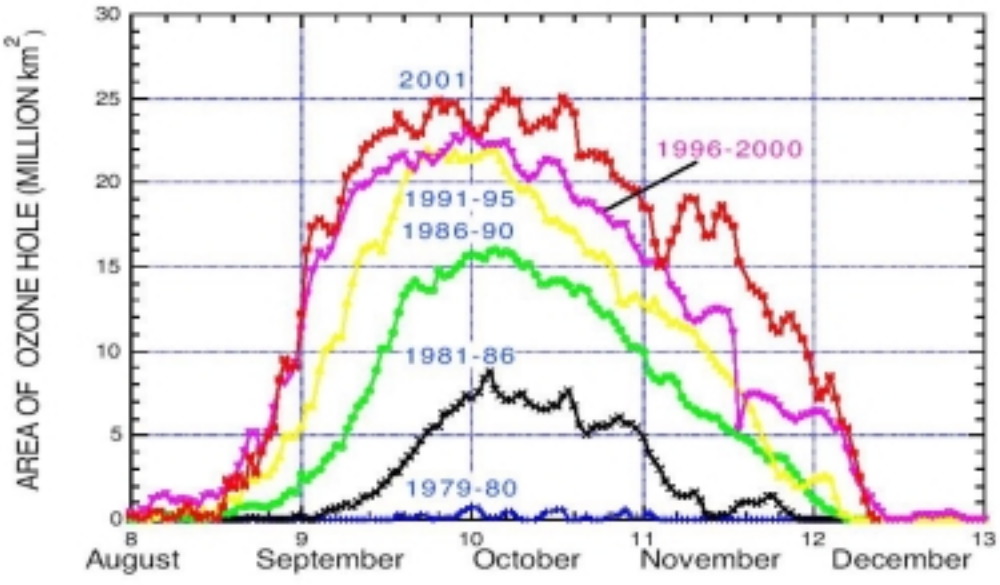

Figure 6: ***Trends in the area (i.e within 220 DU contour) of the Antarctic ozone hole.***

3. ASSESSMENT AND SYNTHESIS

Stratospheric Ozone

The GAW programme includes active support for the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol on Substances that Deplete the Ozone Layer through established partnerships with the Ozone Secretariat of UNEP headquarters in Nairobi. One of these important activities is support of the WMO/UNEP Scientific Assessment of Ozone Depletion. A second major joint WMO /UNEP responsibility is to organize and support the triennial meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer. An important product provided by the GAW programme is a series of biweekly Antarctic Ozone Hole bulletins issued annually from August to November. The bulletins are assembled, written and published by the GAW secretariat with the assistance of the Norwegian Institute for Air Research (NILU) and the WOUDC data centre in Toronto. Figure 6 is an example of one product of these analyses.

Integrated Global Atmospheric Chemistry Observations (IGACO): GAW and the Satellite Community

Space-based observations offer a partial solution to the problem of obtaining a global measurement of gas, aerosols and associated meteorological parameters important to the atmospheric issues of GAW. Integration of satellite observations with non-satellite observations from the GAW programme is highly desirable. In addition, satellite systems can best meet their established requirements if they are checked against highly accurate ground based or airborne measurements of known quality. For instance for the past few decades, the GAW network of stations has provided to space agencies both total column ozone and vertical profile ozone data to be used for satellite validation. In future, surface-based measurements of aerosol optical depth and other constituents by GAW and partners will play a similar role for other satellite observations.
In June 1998, a partnership of 13 organizations including WMO and the Committee on Earth Observation Satellites (CEOS) initiated the Integrated Global Observing Strategy (IGOS;) http://www.igospartners.org. Two of the goals were to identify gaps in existing observation systems and to encourage specific activities to develop and enhance components that will demonstrate the value of the strategy. In June 2001, WMO/GAW was instrumental in adding the "Integrated Global Atmospheric Chemistry Observation (IGACO)" theme to the three other established IGOS themes: the "Global Water Cycle", the "Ocean" and the "Global Carbon Cycle" (see Integration Strategy, 2001). IGOS has established an IGACO theme team co-convened by WMO/GAW and the European Space Agency (ESA) which met January 2003 and began the process of developing a Theme Report on IGACO for IGOS. Figure 7 summarizes the system of data generation, analysis and product generation supported by the IGACO strategy for integrating global atmospheric chemistry observations by satellite and non-satellite communities. A comprehensive set of integrated global observations of atmospheric ozone (troposphere as well as stratosphere) and of aerosol optical properties (e.g. optical depth, single scattering albedo etc.) are examples of products that may result from such activities. These would be invaluable in evaluating global climate and chemical transport models. A major challenge is how best to integrate routine air quality observations from commercial aircraft into this activity.

4. DEVELOPMENT OF PREDICTIVE CAPABILITY

An overall objective of GAW is to assist in the advancement of the prediction of future atmospheric states. Climate models and air quality predictions based on weather forecast techniques are under development in many National Meteorological and Hydrological Services. Because of the recognized importance of gases and aerosols in the climate system, global observations provided by GAW monitoring have and will play an important role in this development. An example of this is the use of global aerosol data assembled by the WDCA (see Section 2) in a Comparison of Large Scale Sulphate Aerosol Models (COSAM) sponsored by the World Climate Research Programme (WCRP) and the International Global Atmospheric Chemistry programme (Barrie et al, 2001). An integrated atmospheric ozone and related chemistry data set or an aerosol optical property data set such as that made possible through future IGACO efforts of GAW will prove useful to global modellers.

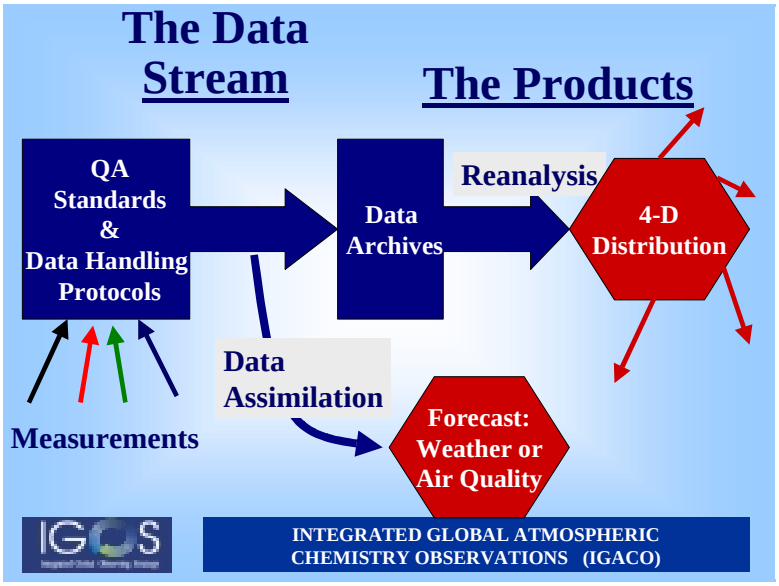

Figure 7: ***A system diagram of the components and products of an Integrated Global Atmospheric Chemistry Observation (IGACO) system involving satellite and non-satellite atmospheric composition observations.***

GURME

The need for a quite different capability on the urban to regional scale has been flagged by the NHMSs. In 1999, the GAW Urban Research Meteorology and Environment (GURME) project was added to GAW by the thirteenth WMO Congress in response to the requests of the NMHSs many of which have an important role to play in the study and management of urban environments. WMO established GURME as a means to help NMHSs enhance their capabilities in dealing with the air chemistry and meteorology of urban pollution. This will be done by the coordination and focussing of present activities, as well as initiation of new ones. The lead responsibility for GURME rests with the Scientific Advisory Group (SAG GURME). A detailed description of GURME is at the website http://www.wmo.ch/web/arep/gaw/urban.html.

Through a series of workshops, the GURME SAG and the GAW secretariat has developed a set of guidelines to help NMHSs in effectively dealing with urban pollution matters. The main points *or* recommendations are to:

1. identify the urban environmental problem to be solved
2. consider all components of the environmental system in addressing urban air quality issues.
3. develop an air quality forecast capability for the urban environment

4. implement measurements that support the development and evaluation of the air quality forecast. Air quality measurements implemented for the evaluation of air quality forecasts also provide a long term data base for the assessment of health and other environmental effects.
5. develop local expertise and facilities essential to steps 3 and 4 above. In order to succeed, it is important to face the need for considerable local resources. The mechanisms of achieving this include partnership, access to tools and information that encourage self-help, training and information exchange through workshops.
6. conduct pilot projects that demonstrate how NMHSs can successfully expand their activities into urban environment issues, showcase new technologies and develop illustrative examples. Presently, pilot projects have been initiated under GURME for in Beijing, Moscow and Latin American cities (see website). In addition, a pilot project on the use of passive samplers for urban measurements has been conducted involving several cities.

GURME will assist NMHSs to implement these guidelines. To this end, "The First WMO/GAW GURME Air Quality Forecasting Workshop" was organized in Kuching, Malaysia, August 2002. This regional workshop served to introduce world experts to regional scientists involved in applications of air quality forecast models. The first "GURME Expert Workshop on Air Quality Forecasting" was held in Mexico in October 2002. The current status of operational models and their expected short-term improvements was reviewed, documented and used to update existing information on air quality modelling on the GURME website.

ACKNOWLEDGEMENTS

The GAW Programme wishes to acknowledge with thanks the support of the WMO and the member NHMSs, the WMO/ Commission for Atmospheric Science (President Dr A. Eliassen) and the CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Chair Dr O. Hov). In addition, the GAW programme is grateful for the support of innumerable other organizations and individuals that contribute so much to the cause.

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ANNEX

TABLE 1. A summary of the facilities responsible for components of the GAW calibration and quality assurance system as of May 2003. The facilities have assumed global responsibilities, unless indicated (Am: Americas; E/Af: Europe and Africa; As/O: Asia and the South-West Pacific). It should be emphasized that several major network operators contribute substantially to quality assurance of global atmospheric composition measurements in addition to those facilities listed below. {! mark represents missing components that the WMO/GAW secretariat with members and partners are close to filling}

SPECIES	QA/SAC	WORLD CALIBRATION CENTRE	REFERENCE STANDARD HOST	WORLD DATA CENTRE
CO_2	JMA (As/O)	CMDL	CMDL	JMA
CH_4	EMPA(Am, E/Af), JMA(A/O)	EMPA(Am, E/Af), JMA(As/O)	!	JMA
N_2O	UBA	IMK-IFU	!	JMA
CFCs	!			JMA
Total Ozone	JMA (As/O)	CMDL[1], MSC[2], MGO[3]	CMDL[1], MSC[2]	MSC
Ozone Sondes	FZ-Jülich	FZ-Jülich	FZ-Jülich	MSC
Surface Ozone	EMPA	EMPA	NIST	JMA
Precipitation Chemistry	ASRC	ASRC	ISWS	ASRC
CO	EMPA	EMPA	CMDL	JMA
VOC	UBA	IMK-IFU	NCAR	JMA
SO_2				JMA
NO_x				JMA
Aerosol Phys. Characteristics	UBA	WCCAP		JRC
Optical Depth		WORCC	WORCC	JRC
UV Radiation	ASRC-SUNY (Am)	SRRB (Am)		MSC
Solar Radiation		PMOD/WRC	PMOD/WRC	MGO
85Kr, 222Rn		EML		JMA
7Be, 210Pb		EML		EML

- ASRC- Atmospheric Science Research Centre Albany, NY (US NOAA GCOS;
- CMDL, Climate and Monitoring Diagnostics Laboratory, NOAA, USA;
- EML, Environmental Measurements Laboratory, DHS, USA.
- EMPA, Zurich, Swiss GAW;
- FZ-Juelich, Forschungs Zentrum Juelich, Germany;
- IMK-IFU, Institute fur Umwelt Forschung, Garmisch-Partenkirchen, Germany (UBA supported);
- ISWS, Illinois State Water Survey, USA
- JRC European Joint Research Centre, Ispra, Italy;
- JMA Japan Meteorological Agency GAW,
- MSC Meteorological Service, Research Directorate, Canada;
- MGO Main Geophysical Observatory, St. Petersburg, Russia;
- NIST, US National Institute for Standards and Technology;
- NCAR National Centre for Atmospheric Research USA;
- SRRB Surface Radiation Research Branch of NOAA ARL, USA;
- UBA Federal Environmental Agency, Germany;
- WCCAP: World Calibration Centre for Physical Aerosol Properties, Leibniz Institute for Tropospheric Research, Leipzig, Germany (UBA supported)
- WORCC: World Optical Depth Research and Calibration Centre and WRC World Radiation Centre,,Swiss GAW, Physikalisch-Meteorologisches Observatorium, Davos, Switzerland.

1. Dobson instrument
2. Brewer Instrument
3. Russian filter instrument

GLOBAL ATMOSPHERE WATCH REPORT SERIES

1. Final Report of the Expert Meeting on the Operation of Integrated Monitoring Programmes, Geneva, 2-5 September 1980

2. Report of the Third Session of the GESAMP Working Group on the Interchange of Pollutants Between the Atmosphere and the Oceans (INTERPOLL-III), Miami, USA, 27-31 October 1980

3. Report of the Expert Meeting on the Assessment of the Meteorological Aspects of the First Phase of EMEP, Shinfield Park, U.K., 30 March - 2 April 1981

4. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at April 1981

5. Report of the WMO/UNEP/ICSU Meeting on Instruments, Standardization and Measurements Techniques for Atmospheric CO_2, Geneva, 8-11; September 1981

6. Report of the Meeting of Experts on BAPMoN Station Operation, Geneva, 23-26 November, 1981

7. Fourth Analysis on Reference Precipitation Samples by the Participating World Meteorological Organization Laboratories by Robert L. Lampe and John C. Puzak, December 1981*

8. Review of the Chemical Composition of Precipitation as Measured by the WMO BAPMoN by Prof. Dr. Hans-Walter Georgii, February 1982

9. An Assessment of BAPMoN Data Currently Available on the Concentration of CO_2 in the Atmosphere by M.R. Manning, February 1982

10. Report of the Meeting of Experts on Meteorological Aspects of Long-range Transport of Pollutants, Toronto, Canada, 30 November - 4 December 1981

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12. Report on the Mount Kenya Baseline Station Feasibility Study edited by Dr. Russell C. Schnell

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14. Effects of Sulphur Compounds and Other Pollutants on Visibility by Dr. R.F. Pueschel, April 1983

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16. Report of the Expert Meeting on Quality Assurance in BAPMoN, Research Triangle Park, North Carolina, USA, 17-21 January 1983

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18. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1983

19. Forecasting of Air Pollution with Emphasis on Research in the USSR by M.E. Berlyand, August 1983

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21. Fifth Analysis on Reference Precipitation Samples by the Participating World Meteorological Organization Laboratories by Robert L. Lampe and William J. Mitchell, November 1983

22. Report of the Fifth Session of the WMO Executive Council Panel of Experts on Environmental Pollution, Garmisch-Partenkirchen, Federal Republic of Germany, 30 April - 4 May 1984 (TD No. 10)

23. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1982. November 1984 (TD No. 12)

24. Final Report of the Expert Meeting on the Assessment of the Meteorological Aspects of the Second Phase of EMEP, Friedrichshafen, Federal Republic of Germany, 7-10 December 1983. October 1984 (TD No. 11)

25. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1984. November 1984 (TD No. 13)

26. Sulphur and Nitrogen in Precipitation: An Attempt to Use BAPMoN and Other Data to Show Regional and Global Distribution by Dr. C.C. Wallén. April 1986 (TD No. 103)

27. Report on a Study of the Transport of Sahelian Particulate Matter Using Sunphotometer Observations by Dr. Guillaume A. d'Almeida. July 1985 (TD No. 45)

28. Report of the Meeting of Experts on the Eastern Atlantic and Mediterranean Transport Experiment ("EAMTEX"), Madrid and Salamanca, Spain, 6-8 November 1984

29. Recommendations on Sunphotometer Measurements in BAPMoN Based on the Experience of a Dust Transport Study in Africa by Dr. Guillaume A. d'Almeida. September 1985 (TD No. 67)

30. Report of the Ad-hoc Consultation on Quality Assurance Procedures for Inclusion in the BAPMoN Manual, Geneva, 29-31 May 1985

31. Implications of Visibility Reduction by Man-Made Aerosols (Annex to No. 14) by R.M. Hoff and L.A. Barrie. October 1985 (TD No. 59)

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37. Air-Sea Interchange of Pollutants by R.A. Duce. September 1986 (TD No. 126)

38. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at 31 December 1985. September 1986 (TD No. 136)

39. Report of the Third WMO Expert Meeting on Atmospheric Carbon Dioxide Measurement Techniques, Lake Arrowhead, California, USA, 4-8 November 1985. October 1986

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43. Recent progress in sunphotometry (determination of the aerosol optical depth). November 1986

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47. Procedures and Methods for Integrated Global Background Monitoring of Environmental Pollution by F.Ya. Rovinsky, USSR and G.B. Wiersma, USA. August 1987 (TD No. 178)

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49. Proceedings of the WMO Conference on Air Pollution Modelling and its Application (Volumes I-III), Leningrad, USSR, 19-24 May 1986. November 1987 (TD No. 187)

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58. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the years 1986 and 1987 (TD No. 306)

59. Extended Abstracts of Papers Presented at the Third International Conference on Analysis and Evaluation of Atmospheric CO_2 Data - Present and Past, Hinterzarten, Federal Republic of Germany, 16-20 October 1989 (TD No. 340)

60. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1984 and 1985, Volume II: Precipitation chemistry, continuous atmospheric carbon dioxide and suspended particulate matter.

61. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1987 and 1988, Volume I: Atmospheric Aerosol Optical Depth.

62. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the year 1988 (TD No. 355)

63. Report of the Informal Session of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Sofia, Bulgaria, 26 and 28 October 1989

64. Report of the consultation to consider desirable locations and observational practices for BAPMoN stations of global importance, Bermuda Research Station, 27-30 November 1989

65. Report of the Meeting on the Assessment of the Meteorological Aspects of the Fourth Phase of EMEP, Sofia, Bulgaria, 27 and 31 October 1989

66. Summary Report on the Status of the WMO Global Atmosphere Watch Stations as at 31 December 1990 (TD No. 419)

67. Report of the Meeting of Experts on Modelling of Continental, Hemispheric and Global Range Transport, Transformation and Exchange Processes, Geneva, 5-7 November 1990

68. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data For 1989, Volume I: Atmospheric Aerosol Optical Depth

69. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1989 (TD No. 400)

70. Report of the Second Session of EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Santiago, Chile, 9-15 January 1991 (TD No. 633)

71. Report of the Consultation of Experts to Consider Desirable Observational Practices and Distribution of GAW Regional Stations, Halkidiki, Greece, 9-13 April 1991 (TD No. 433)

72. Integrated Background Monitoring of Environmental Pollution in Mid-Latitude Eurasia by Yu.A. Izrael and F.Ya. Rovinsky, USSR (TD No. 434)

73. Report of the Experts Meeting on Global Aerosol Data System (GADS), Hampton, Virginia, 11 to 12 September 1990 (TD No. 438)

74. Report of the Experts Meeting on Aerosol Physics and Chemistry, Hampton, Virginia, 30 to 31 May 1991 (TD No. 439)

75. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1990 (TD No. 447)

76. The International Global Aerosol Programme (IGAP) Plan: Overview (TD No. 445)

77. Report of the WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques, Lake Arrowhead, California, 14-19 October 1990

78. Global Atmospheric Background Monitoring for Selected Environmental Parameters BAPMoN Data for 1990, Volume I: Atmospheric Aerosol Optical Depth (TD No. 446)

79. Report of the Meeting of Experts to Consider the Aerosol Component of GAW, Boulder, 16 to 19 December 1991 (TD No. 485)

80. Report of the WMO Meeting of Experts on the Quality Assurance Plan for the GAW, Garmisch-Partenkirchen, Germany, 26-30 March 1992 (TD No. 513)

81. Report of the Second Meeting of Experts to Assess the Response to and Atmospheric Effects of the Kuwait Oil Fires, Geneva, Switzerland, 25-29 May 1992 (TD No. 512)

82. Global Atmospheric Background Monitoring for Selected Environmental Parameters BAPMoN Data for 1991, Volume I: Atmospheric Aerosol Optical Depth (TD No. 518)

83. Report on the Global Precipitation Chemistry Programme of BAPMoN (TD No. 526)

84. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at GAW-BAPMoN sites for the year 1991 (TD No. 543)

85. Chemical Analysis of Precipitation for GAW: Laboratory Analytical Methods and Sample Collection Standards by Dr Jaroslav Santroch (TD No. 550)

86. The Global Atmosphere Watch Guide, 1993 (TD No. 553)

87. Report of the Third Session of EC Panel/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Geneva, 8-11 March 1993 (TD No. 555)

88. Report of the Seventh WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques, Rome, Italy, 7 - 10 September 1993, (edited by Graeme I. Pearman and James T. Peterson) (TD No. 669)

89. 4th International Conference on CO_2 (Carqueiranne, France, 13-17 September 1993) (TD No. 61)

90. Global Atmospheric Background Monitoring for Selected Environmental Parameters GAW Data for 1992, Volume I: Atmospheric Aerosol Optical Depth (TD No. 562)

91. Extended Abstracts of Papers Presented at the WMO Region VI Conference on the Measurement and Modelling of Atmospheric Composition Changes Including Pollution Transport, Sofia, 4 to 8 October 1993 (TD No. 563)

92. Report of the Second WMO Meeting of Experts on the Quality Assurance/Science Activity Centres of the Global Atmosphere Watch, Garmisch-Partenkirchen, 7-11 December 1992 (TD No. 580)

93. Report of the Third WMO Meeting of Experts on the Quality Assurance/Science Activity Centres of the Global Atmosphere Watch, Garmisch-Partenkirchen, 5-9 July 1993 (TD No. 581)

94. Report on the Measurements of Atmospheric Turbidity in BAPMoN (TD No. 603)

95. Report of the WMO Meeting of Experts on UV-B Measurements, Data Quality and Standardization of UV Indices, Les Diablerets, Switzerland, 25-28 July 1994 (TD No. 625)

96. Global Atmospheric Background Monitoring for Selected Environmental Parameters WMO GAW Data for 1993, Volume I: Atmospheric Aerosol Optical Depth

97. Quality Assurance Project Plan (QAPjP) for Continuous Ground Based Ozone Measurements (TD No. 634)

98. Report of the WMO Meeting of Experts on Global Carbon Monoxide Measurements, Boulder, USA, 7-11 February 1994 (TD No. 645)

99. Status of the WMO Global Atmosphere Watch Programme as at 31 December 1993 (TD No. 636)

100. Report of the Workshop on UV-B for the Americas, Buenos Aires, Argentina, 22-26 August 1994

101. Report of the WMO Workshop on the Measurement of Atmospheric Optical Depth and Turbidity, Silver Spring, USA, 6-10 December 1993, (edited by Bruce Hicks) (TD No. 659)

102. Report of the Workshop on Precipitation Chemistry Laboratory Techniques, Hradec Kralove, Czech Republic, 17-21 October 1994 (TD No. 658)

103. Report of the Meeting of Experts on the WMO World Data Centres, Toronto, Canada, 17-18 February 1995, (prepared by Edward Hare) (TD No. 679)

104. Report of the Fourth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the First Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE, Garmisch-Partenkirchen, Germany, 13 to 17 March 1995 (TD No. 689)

105. Report of the Fourth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Garmisch, Germany, 6-11 March 1995) (TD No. 718)

106. Report of the Global Acid Deposition Assessment (edited by D.M. Whelpdale and M-S. Kaiser) (TD No. 777)

107. Extended Abstracts of Papers Presented at the WMO-IGAC Conference on the Measurement and Assessment of Atmospheric Composition Change (Beijing, China, 9-14 October 1995) (TD No. 710)

108. Report of the Tenth WMO International Comparison of Dobson Spectrophotometers (Arosa, Switzerland, 24 July - 4 August 1995)

109. Report of an Expert Consultation on 85Kr and 222Rn: Measurements, Effects and Applications (Freiburg, Germany, 28-31 March 1995) (TD No. 733)

110. Report of the WMO-NOAA Expert Meeting on GAW Data Acquisition and Archiving (Asheville, NC, USA, 4-8 November 1995) (TD No. 755)

111. Report of the WMO-BMBF Workshop on VOC Establishment of a "World Calibration/Instrument Intercomparison Facility for VOC" to Serve the WMO Global Atmosphere Watch (GAW) Programme (Garmisch-Partenkirchen, Germany, 17-21 December 1995) (TD No. 756)

112. Report of the WMO/STUK Intercomparison of Erythemally-Weighted Solar UV Radiometers, Spring/Summer 1995, Helsinki, Finland (TD No. 781)

113. The Strategic Plan of the Global Atmosphere Watch (GAW) (TD No. 802)

114. Report of the Fifth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the Second Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE^{Ed}, Garmisch-Partenkirchen, Germany, 15-19 July 1996 (TD No. 787)

115. Report of the Meeting of Experts on Atmospheric Urban Pollution and the Role of NMSs (Geneva, 7-11 October 1996) (TD No. 801)

116. Expert Meeting on Chemistry of Aerosols, Clouds and Atmospheric Precipitation in the Former USSR (Sankt Peterburg, Russian Federation, 13-15 November 1995)

117. Report and Proceedings of the Workshop on the Assessment of EMEP Activities Concerning Heavy Metals and Persistent Organic Pollutants and their Further Development (Moscow, Russian Federation, 24-26 September 1996) (Volumes I and II) (TD No. 806)

118. Report of the International Workshops on Ozone Observation in Asia and the Pacific Region (IWOAP, IWOAP-II), (IWOAP, 27 February-26 March 1996 and IWOAP-II, 20 August-18 September 1996) (TD No. 827)

119. Report on BoM/NOAA/WMO International Comparison of the Dobson Spectrophotometers (Perth Airport, Perth, Australia, 3-14 February 1997), (prepared by Robert Evans and James Easson) (TD No. 828)

120. WMO-UMAP Workshop on Broad-Band UV Radiometers (Garmisch-Partenkirchen, Germany, 22 to 23 April 1996) (TD No. 894)

121. Report of the Eighth WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques (prepared by Thomas Conway) (Boulder, CO, 6-11 July 1995) (TD No. 821)

122 Report of Passive Samplers for Atmospheric Chemistry Measurements and their Role in GAW (prepared by Greg Carmichael) (TD No. 829)

123 Report of WMO Meeting of Experts on GAW Regional Network in RA VI, Budapest, Hungary, 5 to 9 May 1997

124 Fifth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, (Geneva, Switzerland, 7-10 April 1997) (TD No. 898)

125. Instruments to Measure Solar Ultraviolet Radiation, Part 1: Spectral Instruments (lead author G. Seckmeyer) (TD No. 1066)

126. Guidelines for Site Quality Control of UV Monitoring (lead author A.R. Webb) (TD No. 884)

127. Report of the WMO-WHO Meeting of Experts on Standardization of UV Indices and their Dissemination to the Public (Les Diablerets, Switzerland, 21-25 July 1997) (TD No. 921)

128. The Fourth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting, (Rome, Italy, 22-25 September 1996) (TD No. 918)

129. Guidelines for Atmospheric Trace Gas Data Management (Ken Masarie and Pieter Tans), 1998 (TD No. 907)

130. Jülich Ozone Sonde Intercomparison Experiment (JOSIE, 5 February to 8 March 1996), (H.G.J. Smit and D. Kley) (TD No. 926)

131. WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2 to 5 June 1998) (Gregory R. Carmichael). Two volumes

132. Report of the Ninth WMO Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques (Edited by Roger Francey), (Aspendale, Vic., Australia)

133. Workshop on Advanced Statistical Methods and their Application to Air Quality Data Sets (Helsinki, 14-18 September 1998) (TD No.956)

134. Guide on Sampling and Analysis Techniques for Chemical Constituents and Physical Properties in Air and Precipitation as Applied at Stations of the Global Atmosphere Watch. Carbon Dioxide

135. Sixth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Zurich, Switzerland, 8-11 March 1999) (WMO TD No.1002)

136. WMO/EMEP/UNEP Workshop on Modelling of Atmospheric Transport and Deposition of Persistent Organic Pollutants and Heavy Metals (Geneva, Switzerland, 16-19 November 1999) (Volumes I and II) (TD No. 1008)

137. Report and Proceedings of the WMO RA II/RA V GAW Workshop on Urban Environment (Beijing, China, 1-4 November 1999) (WMO-TD. 1014) (Prepared by Greg Carmichael)

138. Reports on WMO International Comparisons of Dobson Spectrophotometers, Parts I – Arosa, Switzerland, 19-31 July 1999, Part II – Buenos Aires, Argentina (29 Nov. – 12 Dec. 1999 and Part III – Pretoria, South Africa (18 March – 10 April 2000).

139. The Fifth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Halkidiki, Greece, September 1998)(WMO TD No. 1019).

140. WMO/CEOS Report on a Strategy for Integrating Satellite and Ground-based Observations of Ozone (WMO TD No. 1046).

141. Report of the LAP/COST/WMO Intercomparison of Erythemal Radiometers (Thessaloniki, Greece, 13-23 September 1999) (WMO TD No. 1051).

142. Strategy for the Implementation of the Global Atmosphere Watch Programme (2001-2007), A Contribution to the Implementation of the Long-Term Plan (WMO TD No.1077)

143. Global Atmosphere Watch Measurements Guide (WMO TD No. 1073)

144. Report of the Seventh Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the GAW 2001 Workshop (Geneva, Switzerland, 2 to 5 April 2001)

145. WMO GAW International Comparisons of Dobson Spectrophotometers at the Meteorological Observatory Hohenpeissenberg, Germany (21 May – 10 June 2000, MOHp2000-1), 23 July – 5 August 2000, MOHp2000-2), (10 – 23 June 2001, MOHp2001-1) and (8 to 21 July 2001, MOHp2001-2). Prepared by Ulf Köhler (WMO TD No. 1114).

146. Quality Assurance in monitoring solar ultraviolet radiation: the state of the art. (not yet published)

147. Workshop on GAW in RA VI (Europe), Riga, Latvia, 27-30 May 2002 (not yet published)

148. Report of the Eleventh WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques (Tokyo, Japan, 25-28 September 2001) (WMO TD No 1138)

149. Comparison of Total Ozone Measurements of Dobson and Brewer Spectrophotometers and Recommended Transfer Functions (prepared by J. Staehelin, J. Kerr, R. Evans and K. Vanicek) WMO TD No. 1147

150. Updated Guidelines for Atmospheric Trace Gas Data Management (Prepared by Ken Maserie and Pieter Tans

151. Report of the First CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 18-19 March 2003)

152. Current Activities of the Global Atmosphere Watch Programme (as presented at the 14th World Meteorological Congress, May 2003). WMO TD No. 1168