WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

REPORT OF THE FIFTH SESSION OF THE

GCOS/WCRP ATMOSPHERIC OBSERVATION PANEL FOR CLIMATE (AOPC)

(Silver Spring, MD, USA, 20–23 April 1999)

GCOS - 55

UNITED NATIONS ENVIRONMENT PROGRAMME

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REPORT OF AOPC-V

1. Introduction

The Fifth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) began at 09:00 on Tuesday 20 April 1999 at the NOAA Office of Global Programs in Silver Spring, Maryland, USA. Dr Mike Manton, AOPC Chairman, welcomed participants to the meeting (see Annex I for list) and reviewed the Agenda (Annex II).

2. GCOS Surface Network - Status of GSN Implementation

Dr Sarukhanian informed the session that the list of proposed GSN stations after consultation with the Members concerned has been divided by Regions and sent for approval to the Presidents of all WMO Regional Associations. At present, all Presidents except one have approved the lists of the GSN stations within their appropriate regions. The list of GSN stations in the Antarctic was approved with some amendments by the EC Working Group on Antarctic Meteorology. According to these amendments three Antarctic stations operated by Chile, China and India were proposed to be included in the GSN. In addition, three stations in the Democratic Republic of the Congo and two stations in Nigeria were transferred to the "final" GSN list from the stand-by list to cover gaps in central and western parts of Africa. With this, the GSN at present is composed of 988 stations.

The Panel agreed with all amendments and proposed to identify extra sites for GSN in France and the monsoon region in Somalia. It also proposed that the EC Working Group on Antarctic Meteorology would continue to investigate the possibility of the inclusion the Automatic Weather Stations in Antarctica in the GSN.

Dr Sarukhanian also informed the session of the results of the preliminary evaluation of the GSN implementation based on the results of global WWW monitoring of SYNOP and CLIMAT reports. According to the results of the monitoring carried out from 1 to 15 October 1998, 685 (or 70%) stations provided from 75 to 100% of expected SYNOP reports, 217 (or 22%) of stations provided from 1 to 74% of expected reports, and 86 (or 9%) were considered as "silent" stations. The average percentage of expected reports varied from 56% in South America to 92% in Antarctica with a global average of 78%. The percentage of stations producing CLIMAT messages varied from 44% in South America to 75% in Antarctica with a global average of 56%. This means that 44% of GSN stations did not transmit CLIMAT messages in October 1998.

The Panel recommended that the Members concerned be requested to provide regularly CLIMAT messages from their GSN stations. It was noted with concern that some of the GSN stations have no WMO index numbers and they were not therefore available on the GTS, and about 30 GSN stations were not recorded in the VWO Publication 9 Vol. A. The Panel requested the WMO Secretariat (VWW Department) to take appropriate actions in this regard.

“Best practices”

The Panel recalled that the former CBS Working Group on Observations had developed a set of "best practices" to be implemented at GSN stations which had been reviewed by AOPC-IV and approved with amendments by CBS-Ext(98). The formulation of "best practices" as given in Annex IV will be included in the Manual on the Global Observing System and also distributed among Members concerned by a circular letter.

3. Summary from the DWD-JMA Workshop on GSN (Offenbach, Germany, January 1999)

The meeting was held in Offenbach, Germany, 19-20 January 1999. The report of the meeting, GCOS Surface Network (GSN) Monitoring Centre Implementation Meeting, is available (GCOS-53, WMO/TD No. 958).

There were two principal aspects to the meeting - the real-time (RT) monitoring of timeliness and quality of CLIMAT data from the GSN and the availability/homogeneity (QC) of historic daily and monthly time series from GSN sites.

RT

DWD and JMA outlined their proposals for working together on the assessment of timeliness and quality of GSN data. Complete details are given in the meeting report. Bad data will be corrected by DWD and JMA using their quality control algorithms and by liaising with focal points in the countries/regions. During the rest of 1999 the two centres will be refining their working arrangements. The two major outcomes each month (from January 2000) will be:

1. CLIMAT data from the GSN (after online quality control) will be made available to WDC-A for Meteorology by the 25th of the month after that being analysed. WDC-A Meteorology will then make the data available to the scientific community using both their web site and ftp.

2. Bi-annual report to the GCOS Secretariat, giving lists of timeliness/quality of the GSN reports received. This information may be released by GCOS as counts per region through the GCOS-DWD-JMA web sites.

QC

In order to make best use of the real time GSN data, it is vital to place the current data in a long-term context. To achieve this, a letter should be sent from WM0/GCOS to all nations with GSN sites requesting all available historic data and metadata for each site. The time series data requested will be:

daily mean temperatures
daily maximum temperatures
daily minimum temperatures
daily precipitation totals
daily sea level pressures
mean monthly temperatures
mean monthly maximum temperatures
mean monthly minimum temperatures
total monthly precipitation totals
monthly mean sea level pressures.

Both daily and monthly time series are requested, as digital hard-copy data may be available for a longer time frame than for the monthly time scale.

WDC-A Meteorology has offered to archive all digital and hard-copy data received. The letter will contain details of the digital formats that can be accommodated.

Once enough data are received WDC-A Meteorology will begin long-term homogeneity assessment of the GSN time series. Non-homogeneous time series will be referred back to the countries through the GCOS Secretariat. Homogeneous GSN time series will be made available

to countries/researchers via CD-ROM and ftp. It was anticipated that update requests would be made to all countries every two years, with relevant updating of the CD-ROM.

4. OOPC/AOPC Workshop on Global Sea-Surface Temperature Data Sets (Workshop Report)

I. Introduction

At the fourth meeting of the Atmospheric Observation Panel for Climate (AOPC) of the Global Climate Observing System (GCOS) in Honolulu during April 1998, the Panel recommended that a workshop on global sea surface temperature (SST) data sets be held. The goals of the workshop would be to assess global SST data sets, and to recommend to the AOPC and its companion Ocean Observations Panel for Climate (OOPC) criteria to be satisfied by GCOS SST analyses.

The workshop was asked to accomplish several actions, and to produce a report with recommendations to its sponsors. In this report, we summarize the characteristics of the observations used to produce analyses (gridded fields) of SST, and assess the differences among various sea ice analyses and recommend methods for using them to produce high-latitude SST fields. The report further assesses differences among, and strengths and weaknesses of, the various SST analysis products available, including both historical time series and current near-real-time analyses. Finally, the group considered whether it could establish specific criteria to be satisfied by SST analyses that can be certified as adequate for GCOS.

II. Meeting Summary

The meeting was hosted by the International Research Institute for Climate Prediction (IRI), and was held at the campus of the Lamont-Doherty Earth Observatory of Columbia University from 2-4 November 1998. Twenty-two scientists from 6 countries attended, and many useful and productive discussions, both within the meeting and outside, resulted. All the members of the Organizing Committee felt that the Workshop was extremely useful, and one of our strongest recommendations is that the working level discussions that were initiated and facilitated by this meeting should be encouraged to continue.

Topics addressed by the Workshop included applications, analyses and observations. The meeting began with relevant presentations, continued with working sessions during which substance for this report began to be developed, and concluded with a plenary where draft reports were presented. Three Working Groups were defined: Analyses, led by R. Reynolds, Observations, chaired by P. Taylor, and Sea Ice, led by N. Rayner.

E. Harrison and D. Parker discussed the requirements that led AOPC and OOPC to organize the workshop, as well as aspects of the state of SST analysis and observation in general. J. Hansen described the needs of global circulation models for SST analyses, and presented the results of some experiments that illustrated the sensitivity of models to differences in SST analyses. M. Crowe described efforts to produce global surface temperature time series for the investigation of global change, and the dependence of those efforts on SST analyses.

This opening was followed by a sequence of reports on the status and practice of SST analysis at various centres. T. Manabe, E. Ebert, R. Reynolds and J. Cummings presented the operational SST analyses at the Japan Meteorological Agency, the Australian Bureau of Meteorology, the U.S. National Centers for Environmental Prediction, and the U.S. Navy Fleet Numerical Meteorology and Oceanography Center, respectively. R. Reynolds also compared results from 6 different SST analyses. N. Rayner and A. Kaplan described efforts at the U. K.

Meteorological Office and the Lamont-Doherty Earth Observatory to develop and implement methods to extend SST analyses throughout the past century, an effort vital to the diagnosis of long time scale climate variability.

The Workshop then received a set of presentations on various aspects of the global observing system that is used for SST, including *in situ* (ship and buoy), and satellite observations. P. Taylor discussed errors in, and possible corrections for, SST observations from ships. D. Parker described the experience of the U.K. Meteorological Office in correcting errors in and using ship observations. R. Evans presented results of highly-accurate radiometric experimental observations of SST. H. Roquet described the planned operational system being developed for SST and other oceanic parameters derived from the Meteosat Second Generation geostationary satellites and the Meteosat Operational Program polar orbiting system. W. Emery discussed the problems involved in using radiometric observations of SST from satellites, which reflect the extreme upper surface, or skin, with *in situ* measurements from ships and buoys, which are more representative of the temperature at depths of 1 to several metres.

Since the distribution and density of ice cover has strong implications for the analysis of SST in high latitudes, the Workshop was fortunate to hear several presentations on methods for deriving such information. R. Grumbine described the operational system for deriving sea ice data for use at NCEP. J. Maslanik followed with a presentation that summarized the various sources of historical and current information on the extent and density of sea ice. D. Parker discussed how sea ice information from these sources might be made more homogeneous.

III. Recommendations

A number of important recommendations were put forward by the Working Groups. They are described in detail in the Working Group reports, and are summarized here. Of these recommendations, an implicit one stands out as particularly relevant to the future of the Global Climate Observing System.

In order to assure the availability of sea surface temperature and sea ice analyses that are suitable for the goals of the Global Climate Observing System, a Sea Surface Temperature (SST)/Sea Ice (SI) Project should be initiated. The primary objective of this project will be to ensure that continuing effective communication among the scientists and institutions working on SST and SI analyses leads to GCOS-quality SST and SI products.

A summary of the other recommendations follows:

Historic data sets

- Recognising that the identification and digitisation of historical SST data sets has the potential to add significantly to the SST data base and therefore is crucial for climate research, the WG recommends that the present activities (for example digitisation of the Kobe collection) be continued.
- However the WG noted that it is important that a quality assessment of newly-digitised data sets be made and that the errors be characterised before such data sets are inserted into the SST database.
- As far as is possible, historical data sets must be accompanied by metadata detailing the methods of observation, instrumentation, etc.

Characteristics of SST measurements

- Given that we do not have a globally robust formula for the surface skin effect and that such a formula is required for compatibility between satellite and *in situ* temperature measurements, the WG recommends the deployment of a limited number (about 20) of ship-borne instruments capable of skin temperature measurement together with near surface (trailed thermistor) and hull contact SST sensors and good mean meteorological measurements to allow estimation of the surface heat fluxes and wind stress.
- The WG noted that there is a need to better determine the error characteristics of the different methods of *in situ* SST measurements - bucket, Engine Room Intake, hull contact sensor, etc. and in particular different types of drifting buoy - as has presently been done for the ship-borne sensors as a class.

Satellite SST data

- The WG noted that the new multi-channel satellite sensors (for example the SEVIRI on MSG, and the VIIRS on NPOEMS) offer future potential for improved SST determination; however these changes in observing technique and the continuing problems besetting SST retrieval (for example, due to clouds, aerosol etc.) imply that there will be a continuing need for *in situ* data for calibration adjustment for the foreseeable future. The WG recommended that such need would be met by maintaining an array of surface drifting buoys (but not by profiling floats of the type envisaged, for example, for the ARGO project). Further the WG recommended that these drifting buoys report on a frequent basis; 8 times daily is desirable to resolve the diurnal cycle.
- Noting that, for example, exploitation of the ATSR sensor had been limited due to the lack of an accessible real time product, the WG urged that future satellite products be made readily available to all potential users.

***In situ* SST data**

- The WG considered that there is an urgent need for metadata with regard to the characteristics and calibration details of the many types of drifting buoys. While the WG understood, and welcomed, that a WMO-47 type publication was to be made available for drifting buoys in the near future, the WG recommended that information on the buoy type should be transmitted in the data message along with the buoy identification number.
- The WG urged that the calibration procedures for drifting buoys be adequately documented and archived through WMO; furthermore that an open ocean comparison of the characteristics of the different drifting buoy designs should be performed.
- The WG recommended that potential users be made aware that, while XBT's (expendable bathythermographs) may be used to obtain the sea temperature at a few metres depth in a similar manner to Engine Room Intake SST data, they do not provide a well-calibrated surface SST value.
- The WG recommended that the accuracy of SST data from Voluntary Observing Ships be improved by provision of more complete and accurate metadata for the individual ships. Noting further that the use of acoustic through-hull data transmission offered the potential for low cost installation of single or multiple hull contact sensors on Voluntary Observing Ships (VOS) the WG recommended the installation and maintenance of well-calibrated hull contact sensors on VOS as the preferred method of SST measurement.

Availability of Metadata

The WG noted that all data from all sensor types were likely to be biased to a varying extent and that this bias should be removed before use in an SST analysis; however this requires that the relevant metadata be available in real time at the analysis centres and the WG recommended the more general use of the electronic version of the List of Selected Ships.

SST Analysis Comparisons

- Careful examination of the method of converting from ice to SST is needed. A combination of the NCEP and UKMO methods could give better results than either alone.
- SST intercomparisons (1982-present) should be extended into earlier years.
- Further SST analysis comparison criteria such as the location and spatial extent of the 18^{o}C water and the equatorial warm pool were also needed.
- SST analysis error estimates should be computed along with the means.
- There should be an archive of the SST analyses so that users interested in special applications, e.g., fisheries, could have access to the products.

It is important that this SST analysis intercomparison continue so that differences can be better quantified and methods can be developed to minimize these differences. Furthermore, analyses continue to change, which requires a continued re-evaluation of the differences. Thus, **an international group should be established as part of the AOPC or OOPC to continue the SST intercomparisons and to develop better standards for these comparisons.**

Ice-zone Buoys

- For measuring the SST near sea ice the WG suggested consideration, by those more expert in making observations in sea-ice areas, of the deployment from aircraft of low cost disposable SST buoys which exploit the recent development of relatively cheap GPS and satellite communications systems.

Sea-ice Data

- Hemispheric scale comparisons between sea-ice data sets utilizing different microwave algorithms and between these data and aircraft or *in situ* observations are needed. These will inform users what they are gaining or losing by using one algorithm rather than another.
- Processing differences between sea-ice microwave products are non-negligible, but their importance on climatic space and time scales needs to be assessed.
- A complete, self-consistent reanalysis of the whole microwave sea-ice period needs to be done and brought up to date.
- As SST data sets are generally created on latitude/longitude grids, sea-ice products should also be provided on regular grids (as well as polar-stereographic), so customers do not introduce errors during re-gridding.
- Detailed research into the differences between sea-ice data from different sources is needed.
- Hemispheric-scale observations of actual melt-pond areas are required, so that the effect of these on microwave derived sea-ice data can be better understood.
- Historical information on Antarctic sea-ice variability pre-1973 must be identified and processed into a useful form. Current reconstruction techniques may provide a more useful assessment of the position of the ice edge than contemporary hand drawn-climatologies, which may be too poorly understood to use.

5. Atmospheric Constituents

In view of the potential linkages between increasing carbon dioxide, its associated stratospheric cooling and ozone depletion, together with the possibility of further ozone depletion associated with unexpected volcanic activity in a chlorine-rich atmosphere, it is essential to continue monitoring both total ozone and the vertical profile of ozone and other relevant key atmospheric constituents (temperature, height of tropopause, water vapour).

AOPC will take oversight responsibility for sustained measurements of ozone and other atmospheric constituents, as well as for relevant meteorological parameters. AOPC needs to revise its statements of requirements to fulfil this role.

Meeting these needs will require complementary measurements from satellite (both operational and research), *in situ*, and ground-based systems, as well as appropriate continuity and coordination. Because of instrument degradation and changing background conditions, it is essential that validation occurs during the entire lifetime of satellite instruments by intercomparison with ground-based measurements.

Because of the anticipated delay in the launch of Meteor 3/TOMS and Meteor 3/SAGE 3, every effort should be made to extend the operating life of GOME in order to ensure adequate overlap with existing measurements of total and vertical-profile ozone.

There is still a need for additional ground-based ozone observing stations (NDSC) in the tropics and sub-tropics.

AOPC should liaise with GAW and NDSC to ensure high-quality ground-based monitoring of UV-B.

Full advantage should be taken to extend observations of water vapour, particularly in the upper troposphere and lower stratosphere, from all available platforms, specifically using suitably-equipped commercial aircraft. The feasibility of this latter approach has been demonstrated in the MOZAIC program. The inclusion of water vapour measurement in the NDSC list of parameters is strongly recommended.

Recognizing that characterization of the size distribution, chemical composition and global distribution is still in the research domain, AOPC should examine existing arrangements for the assembly and distribution of relevant data sets.

With respect to the determination of sources and sinks of carbon dioxide, the AOPC needs to ensure that adequate attention is being given to vertical mixing and diurnal structure of CO_2 in the lower atmosphere.

6. Next Meeting

It was agreed that the sixth session of the AOPC would be held in Geneva, Switzerland from 10–13 April, 2000.

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ANNEXES

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ANNEX I

PARTICIPANTS

AOPC Members

P. Arkin
A. Baede
M.L. Chanin
R. Fleming
E. Harrison
P. Jones
M. Manton
R. Okoola
D. Parker
T. Peterson
N. Sato
D. Whelpdale

Invited Experts

J. Christy (GOSSP)
F. Bretherton (GOSSP)
A. Gruber (NESDIS)
R. Reynolds (NCEP)
W. Rossow (NASA)
P. Try (GEWEX)

GCOS Secretariat

A. Thomas (NOAA)
E. Sarukhanian (WMO/WWW)

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ANNEX II

AOPC Meeting
20-23 April 1999
NOAA/OGP, Silver Spring, MD, USA

AGENDA

Tuesday 20 April

1. Introductions

2. Operation of meeting (Manton)

3. Outcomes of GCOS SC meeting (Manton)
   - 3.1 Decisions on AOPC

4. AOPC system strategy for baseline observations (Manton)
   - 4.1 Detailed functions and responsibilities for end-to-end system

5. Support for FCCC COP (Thomas)
   - 5.1 National plans
   - 5.2 Baseline observations

6. Data base issues (Manton)
   - 6.1 WMO-CEOS database for parameters under study
   - 6.2 JDIMP database for parameters under study

7. Development of AOPC plan (Manton)
   - 7.1 Schedule

8. GSN (Jones, Sarukhanian)
   - 8.1 Status, including observation statistics, GSN workshop, historic data, products
   - 8.2 Analysis of data system
   - 8.3 Performance indicators

9. GUAN (Parker, Sarukhanian)
   - 9.1 Status, including observation statistics, products
   - 9.2 Development in Japan (Sato)
   - 9.3 Analysis of data system
   - 9.4 Performance indicators

10. Project office for GSN and GUAN (Manton, Thomas)

Wednesday 21 April

11. GPCP and marine precipitation (Gruber, Arkin, Jones, Try)
    - 11.1 GPCP role for GCOS
    - 11.2 Rainfall over the ocean cf GSN observations

12. Satellite observations for GUAN (Parker, Christy, Bretherton)
    - 12.1 USA study of MSU
    - 12.2 Future needs
    - 12.3 Role of GOSSP

13. Cloud and TOA radiation (Rossow, Whelpdale, Bretherton, Try)
    - 13.1 ISCCP role for GCOS
    - 13.2 Observation of TOA - radiation budget
    - 13.3 Role of GOSSP

Thursday 22 April

14. SST workshop (Arkin, Harrison, Reynolds)
    - 14.1 Outcomes of workshop
    - 14.2 Future project

15. Atmospheric constituents (Chanin, Whelpdale, Bretherton)
    - 15.1 Ozone monitoring
    - 15.2 Water vapour
    - 15.3 Aerosols
    - 15.4 Greenhouse gases
    - 15.5 Total Cl and Br
    - 15.6 Other species

16. Environmental indicators
    - 16.1 Asheville workshop (Peterson)
    - 16.2 SE Asia workshop (Manton)
    - 16.3 Future project (Manton)

17. Future activities
    - 17.1 Surface pressure (Harrison)
    - 17.2 Snow (Sato)
    - 17.3 Total precipitable water (Sato)
    - 17.4 Other parameters
    - 17.5 International conference

18. Writing groups

Friday 23 April

19. Summary of actions (Manton)
20. Next meeting

ANNEX III

AOPC-V DECISIONS AND ACTION ITEMS

Item 3

- Parker/Jones to liaise with CLIVAR data group
- Thomas to liaise with WMO Commissions on SI infrastructure
- Peterson nominated as AOPC representative for CBS expert team on GOS meeting (23-25 June)

Item 4

- Manton to refine GCOS data flow diagram

Item 5

- Changes to FCCC draft paper on national plans to be coordinated by Whelpdale

Item 6

- GSN monitoring centres will maintain Web pages (Sarukhanian and Wilson)
- NCDC will maintain web pages for the analysis centres for GSN and GUAN (Peterson and Wilson)
- AOPC requests the GSC to investigate the issue of data-access costs (Bretherton)
- Wilson to liaise with Parker, Jones and Peterson re data needs for JDIMP web page
- AOPC strongly supports the JDIMP activity as a model for overall GCOS data management and access
- Manton to liaise with Hinsman re WMO-CEOS database, including constituents (Members to respond to draft from Bretherton)

Item 7

- Manton to revise structure of AOPC plan, and then to work with members and Secretariat to finalise the plan

Item 8

- GSN-GUAN advisory group formed, to include Peterson (convenor), Parker, Jones and Daan; Thomas to draft terms of reference
- Sarukhanian to document extra GSN sites in Africa
- AOPC notes the continuing gaps in GSN, especially in the Somalia monsoon region
- Jones to draft a request to CBS re CLIMAT reports
- Sarukhanian to liaise with CBS about the inclusion of ID numbers for all GSN sites
- Peterson to identify new sites for GSN in France, in consultation with Sarukhanian
- Jones to summarise the outcomes of the GSN workshop in Germany
- Jones to revise the letter on GSN historical data
- Sarukhanian to liaise with UWM on extra Antarctic GSN sites
- Performance indicators for GSN were decided at the GSN workshop in Germany
- The role and TOR for the GSN analysis centre will be refined (Peterson, Thomas and Manton)
- GSN sites to be identified explicitly in MCDW (Peterson)

Item 9

- Sarukhanian to send ECMWF reports on GUAN to all members
- Parker, Sarukhanian and Peterson to draft letter on GUAN data to PRs

- The role and TOR for GUAN analysis centre to be refined (Parker, Peterson, Thomas, Manton)

Item 10

- Role and TOR of the GSN-GUAN co-ordinator to be refined by Thomas and Manton
- Thomas and Manton to investigate the establishment of the co-ordinator position, which may not be in Geneva

Item 11

- AOPC to support GPCP activity (Arkin)
- Note lack of precipitation baseline over the ocean (Arkin)
- Investigate GCOS high-resolution global precipitation climatology (Jones)

Item 12

- Request to GOSSP/CEOS re satellite radiances for GUAN intercomparison (Peterson)

Item 13

- Request to GOSSP/CEOS re solar constant and TOA radiances (Bretherton)

Item 14

- TOR and membership of SST-SI task group (Arkin)
- Recommendation on more drifters in data-sparse areas, especially at high latitudes (Thomas)

Item 15

- Note to CEOS/GOSSP for ground validation throughout lifetime of satellite projects (Chanin)
- Request to NDSC re extension of tropical coverage (Chanin)
- Request to CEOS/GOSSP to follow up ozone report (Chanin)

Item 16

- Note need for more data rehabilitation in Europe (Jones)
- AOPC support for follow-on APN workshop on climate extremes
- Manton to prepare paper on potential project on environmental indicators across G3OS

Item 17

- Thomas/Manton to investigate AOPC conference in 2001 linked to FCCC national plans
- Harrison to continue study of MSLP analyses
- Manton to liaise with WGNE on MSLP intercomparison
- Sarukhanian to resolve problem with snow reports in RA2 with CBS
- AOPC endorses the establishment of a snow analysis intercomparison project
- AOPC endorses the concept of GPS-WV observatories
- Arkin to draft recommendation on climate reanalysis

Item 20

- Next meeting will be in Geneva on 10-13 April 2000

ANNEX IV

GSN "Best Practices"

Amendments to Manual on the Global Observing System - Part III

Insert new section 2.10.3.17

Best Practices for Global Climate Observing System Surface Network Stations

Members should implement the GCOS Surface Network - the global reference network of some 1000 selected surface observation stations established with a density of approximately one station per 250,000 square kilometres to monitor daily global and large-scale climate variability.

In implementing the observing programme at GSN stations, Members should comply with the following best practices:

(a) Long-term continuity should be provided for each GSN station

This requires the provision of the necessary resources, including well-trained staff, and keeping changes of location to a minimum. In the case of significant changes in sensor-devices or station location, Members should provide for a sufficiently long period of overlap (at least one but preferably two years) with dual operation of old and new systems to enable comparisons to be made and the identification of inhomogeneities and other measurement characteristics;

(b) CLIMAT data should be provided in an accurate and timely manner; CLIMAT reports should be transmitted by the fifth day of the month but not later than the eight day of the month;

(c) Rigorous quality control should be exercised on the measurements and their message encoding

CLIMAT reports require quality control of the measurements themselves and their message encoding to ensure their accurate transmission to national, regional and world centres for their use. Quality-control checks should be made on site and at a central location designed to detect equipment faults at the earliest stage possible. The Guide to Instruments and Methods of Observation (WMO-No. 8) provides the appropriate recommendations;

(d) The site layout should follow the recommended form

The layout of the site should follow the recommendations in the Guide on the Global Observing System (WMO-No. 488);

(e) The site and instruments should be inspected regularly and maintained according to WMO recommended practices

To obtain homogeneous data sets, maintenance should be carried out as is documented in the Guide to Instruments and Methods of Observation;

Inspection of sites, instruments and exposure to be based on the procedures given in the Guide. As part of the maintenance, the necessary calibration practices should be traceable to the standards provided by the Guide;

(f) A national plan should be developed to archive daily data from GSN stations for climate and climate research purposes

The archive should include both observational data and metadata pertaining to each climate station. Metadata should include data concerning a station's establishment, subsequent maintenance, and changes in exposure, instrumentation and staff. The data and metadata should be in its original form as well as digital format;

Detailed metadata and historical climate data for each GSN station should be provided;

(g) A GSN Data Centre should have an up-to-date digital copy of the historical climate data and all types of metadata for GSN stations. A current copy of the long-term series of data and metadata from GSN stations should be made available.

LIST OF GCOS PUBLICATIONS*

GCOS-1 (WMO/TD-No. 493)	Report of the first session of the Joint Scientific and Technical Committee for GCOS (Geneva, Switzerland, April 13-15, 1992)
GCOS-2 (WMO/TD-No. 551)	Report of the second session of the Joint Scientific and Technical Committee for GCOS (Washington DC, USA, January 11-14, 1993)
GCOS-3 (WMO/TD-No. 590)	Report of the third session of the Joint Scientific and Technical Committee for GCOS (Abingdon, UK, November 1-3,1993)
GCOS-4 (WMO/TD-No. 637)	Report of the fourth session of the Joint Scientific and Technical Committee for GCOS (Hamburg, Germany, September 19-22, 1994)
GCOS-5 (WMO/TD-No. 639)	Report of the GCOS Data System Task Group (Offenbach, Germany, March 22-25, 1994)
GCOS-6 (WMO/TD-No. 640)	Report of the GCOS Atmospheric Observation Panel, first session (Hamburg, Germany, April 25-28, 1994)
GCOS-7 (WMO/TD No. 641)	Report of the GCOS Space-based Observation Task Group (Darmstadt, Germany, May 3-6, 1994)
GCOS-8 (WMO/TD No. 642) (UNEP/EAP.MR/94-9)	Report of the GCOS/GTOS Terrestrial Observation Panel, first session (Arlington, VA, USA, June 28-30, 1994)
GCOS-9 (WMO/TD-No. 643)	Report of the GCOS Working Group on Socio-economic Benefits, first session (Washington DC, USA, August 1-3, 1994)
GCOS-10 (WMO/TD-No. 666)	Summary of the GCOS Plan, Version 1.0, April 1995
GCOS-11 (WMO/TD-No. 673)	Report of the GCOS Data and Information Management Panel, first session (Washington DC, USA, February 7-10, 1995)
GCOS-12 (WMO/TD-No. 674)	The Socio-economic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socio-economic Benefits), April 1995
GCOS-13 (WMO/TD-No. 677)	GCOS Data and Information Management Plan, Version 1.0, April 1995
GCOS-14 (WMO/TD-No. 681)	Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995
GCOS-16 (WMO/TD-No. 685)	GCOS Guide to Satellite Instruments for Climate, June 1995

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GCOS-17 (WMO/TD-No. 696)	Report of the GCOS Atmospheric Observation Panel, second session (Tokyo, Japan, March 20-23, 1995)
GCOS-18 (WMO/TD-No. 697) (UNEP/EAP.MR/95-10)	Report of the GCOS/GTOS Terrestrial Observation Panel, second session (London, UK, April 19-21, 1995)
GCOS-19 (WMO/TD-No. 709)	Report of the GCOS Data Centre Implementation/Co-ordination Meeting (Offenbach, Germany, June 27-29, 1995)
GCOS-20 (WMO/TD-No. 720)	GCOS Observation Programme for Atmospheric Constituents: Background, Status and Action Plan, September 1995
GCOS-21 (WMO/TD-No. 721) (UNEP/EAP.TR/95-07)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 1.0, November 1995
GCOS-22 (WMO/TD-No. 722)	Report of the fifth session of the Joint Scientific and Technical Committee for GCOS (Hakone, Japan, October 16-19, 1995)
GCOS-23 (WMO/TD-No. 754) (UNEP/DEIA/MR.96-6) (FAO GTOS-1)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, third session (Cape Town, South Africa, March 19-22, 1996)
GCOS-24 (WMO/TD-No. 768) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, first session (Miami, Florida, USA, March 25-27, 1996)
GCOS-25 (WMO/TD-No. 765) (UNEP/DEIA/MR.96-5)	Report of the GCOS Data and Information Management Panel, second session (Ottawa, Ontario, Canada, May 14-17, 1996)
GCOS-26 (WMO/TD-No. 766)	Report of the Joint CCl/CBS Expert Meeting on the GCOS Surface Network (Norwich, UK, March 25-27, 1996)
GCOS-27 (WMO/TD-No. 772) (UNEP/DEIA/MR.96-7)	Report of the Expert Meeting on Hydrological Data for Global Observing Systems (Geneva, Switzerland, April 29-May 1, 1996)
GCOS-28 (WMO/TD-No. 793) (UNEP/DEIA/MR.97-3)	*In Situ* Observations for the Global Observing Systems (Geneva, Switzerland, September 10-13, 1996)
GCOS-29 (WMO/TD-No. 794) (UNEP/DEIA/MR.97-4)	Report of the Global Observing Systems Space Panel, second session (Geneva, Switzerland, October 16-18, 1996)
GCOS-30 (WMO/TD-No. 795)	Report of the sixth session of the Joint Scientific and Technical Committee for GCOS (Victoria, British Columbia, Canada, October 28-November 1, 1996)
GCOS-31 (WMO/TD-No. 803)	Proceedings of the fifth meeting of the TAO Implementation Panel (TIP-5) (Goa, India, November 18-21, 1996)

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GCOS-32 (WMO/TD-No. 796)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 2.0, June 1997
GCOS-33 (WMO/TD-No. 798)	GHOST - Global Hierarchical Observing Strategy, March 1997
GCOS-34 (WMO/TD-No. 799)	Initial Selection of a GCOS Surface Network, February 1997
GCOS-35 (WMO/TD-No. 839)	Report of the second Joint CCl/CBS Meeting on the GCOS Surface Network (De Bilt, The Netherlands, June 25-27, 1997)
GCOS-36 (WMO/TD-No. 844) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, second session (Cape Town, South Africa, February 11-13, 1997)
GCOS-37 (WMO/TD-No. 845) (GOOS-10) & (GTOS-9)	Report of the Global Observing Systems Space Panel, third session (Paris, France, May 27-30, 1997)
GCOS-38 (WMO/TD-846) (GTOS-10)	Report of the Meeting of Experts on Ecological Networks (Guernica, Spain, June 17-20, 1997)
GCOS-39 (WMO/TD-No. 847) (GOOS-11) & (GTOS-11) (UNEP/DEIA/MR.97-8)	Report of the GCOS/GOOS/GTOS Joint Data and Information Management Panel, third session (Tokyo, Japan, July 15-18, 1997)
GCOS-40 (WMO/TD-No. 848)	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate, third session (Reading, UK, August 19-22, 1997)
GCOS-41 (WMO/TD-No. 849) (GOOS-33)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) Ocean Climate Time-Series Workshop, (Baltimore, MD, USA, March 18-20, 1997)
GCOS-42 (WMO/TD-No. 857)	Report of the seventh session of the Joint Scientific and Technical Committee for GCOS (Eindhoven, The Netherlands, September 22-26, 1997)
GCOS-43a (GOOS-36)	TAO Implementation Panel, sixth session (Reading, U.K., November 4-6, 1997)
GCOS-43b (GOOS-55)	International Sea Level Workshop (Honolulu, Hawaii, USA, June 10-11, 1997)
GCOS-44 (GOOS-61)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC), third session (Grasse, France, April 6-8, 1998)
GCOS-45 (WMO/TD-No. 922) (GOOS-58) & (GTOS-16) (UNEP/DEIA/MR.98-6)	Report of the Joint Meeting of the GCOS/WCRP Atmospheric Observation Panel for Climate and the GCOS/GOOS/GTOS Joint Data and Information Management Panel, fourth session (Honolulu, Hawaii, USA, April 28-May 1, 1998)

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GCOS-46 (GTOS-15)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, fourth session (Corvallis, USA, May 26-29, 1998)
GCOS-47 (WMO/TD-No. 941) (GOOS-67) (GTOS-20)	Report of the Global Observing Systems Space Panel, fourth session, (College Park, Maryland, USA, October 22-23, 1998)
GCOS-48	Report on the Adequacy of the Global Climate Observing Systems (United Nations Framework Convention on Climate Change, November 2-13 1998, Buenos Aires, Argentina)
GCOS-49 (GOOS-64)	Implementation of Global Ocean Observations for GOOS/GCOS, first session (Sydney, Australia, March 4-7, 1998)
GCOS-50 (GOOS-65)	Implementation of Global Ocean Observations for GOOS/GCOS, second session (Paris, France, November 30, 1998)
GCOS-51 (GOOS-66)	Global Ocean Observations for GOOS/GCOS: An Action Plan for Existing Bodies and Mechanisms
GCOS-52 (GOOS-68)	TAO Implementation Panel, 7th Session (Abidjan, Ivory Coast, November 11-13, 1998)
GCOS-53 (WMO/TD-No. 958)	GCOS Surface Network (GSN) Monitoring Centre Implementation Meeting (Offenbach, Germany, January 19-20, 1999)
GCOS-54 (WMO/TD-No. 953)	Report of the eighth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Geneva, Switzerland, February 9-12, 1999)
GCOS-55	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), fifth session (Silver Spring, MD, USA, April 20-23, 1999)

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GCOS Secretariat

Global Climate Observing System
c/o World Meteorological Organization
7 *bis*, Avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland
Tel: +41 22 730 8275/8067
Fax: +41 22 730 8052
Email: gcosjpo@gateway.wmo.ch