IMPLEMENTATION PLAN FOR THE EVOLUTION OF THE SURFACE- AND SPACE-BASED SUB-SYSTEMS OF THE GOS

(Version 1.4, July 2007)

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IMPLEMENTATION PLAN FOR THE EVOLUTION OF THE SURFACE- AND SPACE-BASED SUB-SYSTEMS OF THE GOS

1. Introduction

1.1 This Implementation Plan has been prepared by the WMO/CBS/OPAG-IOS Expert Team on the Evolution of the Global Observing System (ET-EGOS, formerly the Expert Team on Observational Data Requirements and Redesign of the Global Observing System, ET-ODRRGOS).

1.2 The Plan is prepared and updated in the following way:

1.2.1 Using the CBS Rolling Review of Requirements (RRR) process, user requirements for observations are compared with the capabilities of present and planned observing systems to provide them. Both user requirements and observing system capabilities are collated in a comprehensive, systematic and quantitative way in the WMO/CEOS database, which attempts to capture observational requirements to meet the needs of all WMO programmes. The comparison of user requirements with observing system capabilities for a given "application area" is called a "Critical Review". The output of the Critical Review process is reviewed by experts in the relevant application and used to prepare a Statement of Guidance (SOG), the main aim of which is to draw attention to the most important gaps between user requirements and observing system capabilities, in the context of the application. This has been done systematically for (currently) 11 "application areas": global NWP, regional NWP, synoptic meteorology, nowcasting and very short range forecasting, seasonal and inter-annual forecasting, aeronautical meteorology, climate monitoring, ocean applications, agrometeorology, hydrology and water resources, and atmospheric chemistry. Thus a wide range of applications within WMO programmes have already been addressed. The latest versions of SOGs are available through the WMO web site.

1.2.2 The "gap-analysis" provided by these SOGs is then reviewed by ET-EGOS. The key issues emerging from them are used to formulate recommendations for action and, following endorsement by CBS, these recommendations form the basis of an Implementation Plan (IP), through which progress to meet the recommendation is recorded and appropriate actions are proposed. The IP is a living document and is reviewed regularly to take account of progress in implementation, and of changes in user requirements and observing system networks and technologies.

1.2.3 In drafting the IP, ET-EGOS has been guided by the vision for the GOS in 2015, as adopted by CBS (CBS Extr., Cairns, 1-12 December 2002). This vision is recalled in Annex B.

1.3 The IP is also informed from a number of other sources:

1.3.1 ET-EGOS works closely with the CBS Rapporteurs on Global and Regional Observing System Experiments (OSEs) to take note of conclusions emerging from impact studies, through which real and hypothetical changes to the GOS are assessed for their impact on NWP performance. In particular ET-EGOS takes note of the conclusions of the WMO-sponsored Workshops on "the Impact of Various Observing Systems on NWP". The conclusions of the workshops in Toulouse (2000) and Alpbach (2004) are recorded in WMO/TDs 1034 and 1228 respectively. In addition, ET-EGOS commissions impact studies to answer specific questions when necessary.

1.3.2 ET-EGOS takes note of developments in observing system technology. Candidate observing systems (space-based and surface-based) for the coming decade were studied and reported in WMO/TD 1040.

1.3.3 The IP is informed by advice from a number of other bodies including: other CBS Expert Teams, the World Weather Watch Programme, the WMO Space Programme, JCOMM, the WMO AMDAR Panel, GCOS and representatives of the WMO Regions.

1.3.4 The scope and assumptions of the IP are as follows:

- It addresses both surface-based and space-based sub-systems of the GOS.
- It responds to observational requirements of all WMO programmes to which the GOS might reasonably be expected to contribute.
- It responds to a vision of the GOS in 2015 and beyond as set out in section 5.
- It envisages that the future GOS will build upon existing sub-systems, both surface- and space-based, and will capitalize on existing and new observing technologies not presently incorporated or fully exploited; each incremental addition to the GOS will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs).
- It responds to those elements of the GCOS Implementation Plan which call for action by WMO Members (through CBS) or by the WMO Space Programme. (A cross-check between the GCOS Implementation Plan and this IP has been performed.)
- It takes note of the GAW Strategic Implementation Plan but does not attempt to duplicate its actions.
- It does not explicitly express the need for aspects of continuity of current observing systems – it is concerned primarily with evolution rather than continuity. However it is recognized that aspects of continuity of observing systems are of key importance for many applications, including operational weather forecasting and climate monitoring.
- It recognises the special challenges and issues concerning developing countries (see section 4).

1.5 In preparing this IP it has become clear the scope of changes required to the GOS in the next decade are massive and will need new approaches for science, data handling, product development, training and utilization.

1.6 The IP currently contains a set of 44 recommendations, each with corresponding comments on progress and accompanying actions. There are 22 recommendations for the surface-based sub-system of the GOS (see section 2) and 22 for the space-based sub-system of the GOS (see section 3).

2. Evolution of surface-based sub-system of GOS

Data coverage, distribution and coding

G1. Distribution - Some observations made routinely are not distributed in near real-time but are of interest for use in meteorological applications.

(a) Observations made with high temporal frequency should be distributed globally at least hourly.

> **Comment:** Studies have shown that 4D-Var data assimilation systems or analysis systems with frequent update cycles can make excellent use of hourly data, e.g. from SYNOPs, buoys, profilers, and other automated systems, in particular AWS.
>
> **Completed Action:** CBS to urge WMO Members to implement this recommendation at the earliest possible date. Drifting buoy hourly pressure data now exchanged routinely, but little progress otherwise
>
> **New action July 2007:** ongoing activity.

(b) Observational data that are useful for meteorological applications at other NMHSs should be exchanged internationally. Examples include high resolution radar measurements (i.e. products, both reflectivity and radial winds, where available) to provide information on precipitation and wind, surface observations, including those from local or regional mesonets, such as high spatial resolution precipitation networks, but also other observations, such as soil temperature and soil moisture, and observations from wave rider buoys. WMO Members in regions where these data are collected should make them available via WMO real time or near-real-time information systems, whenever feasible.

> **Comment:** CBS agreed that the Commission working through Regional Rapporteurs, would urge all Members with existing operational observing capabilities and networks to distribute their full information content as quickly as possible. CBS further agreed that the OPAG-IOS Chairman, in consultation with the Chairs of the regional Working Group on Planning and Implementation of the WWW, should ensure that operators and managers of regional observing systems were made aware of GOS requirements (CBS-XIII Report)
>
> **Update July 2007:** continuing activity, no information available to ET-EGOS at this stage. SYNOP code, and its BUFR implementation, are inadequate for the transmission of a variety of surface observations currently not exchanged on the GTS, but are of interest to application areas. In particular, snow cover and snowfall data, which are to some extent flowing on the GTS in the regions would be of interest for global applications.
>
> The global exchange of radar data will require substantial development work concerning data specification and formatting.
>
> **New action July 2007:** Based on inventory of new data, consideration should be given to the development of expanded BUFR templates for the exchange of these observations (WMO Secretariat to raise with ET-DRC)

(c) The need for good metadata exchange in support of observational data, sometimes in real time, is essential.

> OPAGs IOS and ISS and JCOMM DMPA were encouraged to progress the development of an integrated metadata distribution system to support the needs of the GOS.
>
> **New action July 2007**: ongoing action of ET-EGOS, to be reviewed in the light of the evolving WIS and WIGOS .

G2. Documentation - All observational data sources should be accompanied by good documentation including metadata, careful QC, and monitoring.

> **New action July 2007**: ongoing action of ET-EGOS, to be reviewed in the light of the evolving WIS and WIGOS

G3. Timeliness and Completeness

(a) There should be a timely distribution of radiosonde observations with all observation points included in the message (together with the time and the position of each data point; information on instrument calibration prior to launch, and information on sensor type and sub-sensor type). Appropriate coding standards should be used to assure that the content (e.g. vertical resolution) of the original measurements, sufficient to meet the user requirements, is retained during transmission.

Comment: NWP OSEs have demonstrated the usefulness of full resolution data for NWP. The NWP OSE Workshop (Alpbach, 2004) reiterated the need for near real time distribution of full resolution RAOB data.

CBS to ask all Members to generate, as soon as possible, sounding data in Table Driven Code Forms (BUFR or CREX), following the technical specifications defined by CBS in the Guidance for Migration (See http://www.wmo.ch/web/www/documents.html#CodeTables). In the interest of timely data delivery, the first BUFR message should be sent when level 100 hPa is reached and the second message should be sent when the whole sounding is completed (containing all observation points). The delivery of the profile data in several stages may be necessary to accommodate the interests of other application areas, such as Nowcasting and aeronautical meteorology.

CBS encouraged Members with existing observing capabilities and networks to distribute their full information content as quickly as possible (CBS XIII Report).

To date only few radiosonde profile data in BUFR have been made available.

Update July 2007: ET-DRC developed a BUFR template for migration from FM 35 TEMP to BUFR template 309052 which allows the reporting of high resolution data points in the vertical including position and time for each level. At their recent session the ET-DRC also developed a BUFR template which allows the use of height in metres as vertical coordinate and the reporting additional information such as surface station measurements, cloud information, and type of instrumentation used (sensors, balloon etc).

New action July 2007: ongoing activity, WMO Secretariat to inform Members of available BUFR encoding/decoding software for use with validated BUFR templates.

(b) The timely availability of ocean observations for meteorological use is very important.

Comment: The DBCP noted that the drifting buoy data timeliness was poor in a number of ocean areas as less than 50% of the data collected by Argos through its global system were received in real time. Whereas elsewhere more than 80% was received in real-time.

Action July 2007: JCOMM and DBCP to pursue improvements of drifting buoy data timeliness especially in South Atlantic and South East Pacific (ongoing activity)

G4. **Baseline system** - Provide comprehensive and uniform coverage with at least 12-hour frequency of temperature, wind, and moisture profiles over mid-latitude continental areas and coastal regions. In tropical regions the wind profile information is particularly import.

Comment: Regional forecasting systems continue to show benefit from a comprehensive and uniform coverage with at least 12-hour frequency of temperature, wind, and moisture profiles over mid-latitude continental areas and coastal regions. In tropical regions the wind profile information is considered to be of particular importance. At this stage the radiosonde and PILOT network still plays an important role in meeting these requirements (NWP OSE Workshop, Alpbach 2004). Profile data are now and will in future, to an increasing extent, be provided from a mix of observing system components and will be complemented by the utilization of satellite data over land. In polar regions, this need has not been addressed, however the linkage between CBS, CAS's THORPEX, and IPY should give guidance for that data sparse region.

Members have been suitably informed of these requirements through CBS (CBS XIII Report). This is more easily achievable where sub Regional programmes, such as

EUCOS, or large national programmes exist. However it is acknowledged this is more of a challenge with a collection of small national programmes.

WWW monitoring activities should reflect the baseline systems requirements and provide suitable feedback to Members concerning their baseline systems commitments.

New action July 2007: (i) WMO Secretariat to pursue and adjust suitable monitoring practices

(ii) Next Workshop on impact studies to address the question of best mix of vertical atmospheric profiles to be obtained from different observing systems.

G5. Stratospheric observations - Requirements for a stratospheric global observing system should be refined (document need for radiosondes, radiances, wind data, humidity data, noting the availability and required density of existing data sources, including GPS sounders, MODIS winds and other satellite data).

Comment: NWP OSE Workshop, Alpbach 2004, suggested that OSE results on the usefulness of stratospheric observations should be consolidated. It also noted that the COSMIC mission likely will provide a substantial enhancement to the stratospheric observing system. Further, AOPC has noted that current in situ measurement capabilities for UT and LS water vapour are not meeting climate requirements and stressed need for further development. Impact studies have shown the benefit of high reaching radiosonde data.

COSMIC data are now in operational use at ECMWF, the Met Office and are actively tested at several NWP centres with a view towards using the data in operations. Impact of the data has been demonstrated

New action July 2007: Workshop to address the question of the best mix of observations required from radiosondes and satellites in the stratosphere for NWP, but also for GCOS purposes

Broader use of ground-based and in situ observations

G6. Ozone Sondes - Near real-time distribution of ozone sonde data is required for calibration and validation of newly launched instruments and for potential use in NWP. [recommendation is supported by information from the Joint ECMWF / WMO expert team meeting on real time exchange of ground based ozone measurements, ECMWF, 17-18 October 1996, WMO NWP OSE Workshop, Alpbach, 2004]

Comment: This requires close inter-commission co-ordination between CAS and CBS to be facilitated by the WMO Secretariat. GAW meeting Payerne October 2005 stressed importance of real time distribution of ozone data and total column ozone data on the GTS. BUFR formats have been developed and Members are encouraged to make use of them for data exchange.

Update July 2007: Canada recently re-introduced the transmission of ozone soundings from four stations in CREX. Sample data encoded in BUFR can be made available, e.g. by ECMWF.

Action July 2007: ongoing action, WMO Secretariat to remind Members that all available ozone soundings be made available in near-real time on the GTS.

Moving towards operational use of targeted observations

G7. Targeted Observations - Observation targeting to improve the observation coverage in data sensitive areas for NWP should be transferred into operations once the methodology has matured. Non-linear methods in targeting have been studied and should also be considered. The operational framework for providing information on the sensitive areas and responding to such information needs to be developed. Negative targeting, to release resources for use elsewhere in the GOS are also of value.

Comment: The proof of the observation targeting concept was given by US Weather Service in the north-eastern Pacific for winter storms. THORPEX has declared observation targeting a core research activity in its implementation plan (2.3 ii), has successfully carried out jointly with EUCOS the NA-TreC campaign, and has benefited from the lessons learned from FASTEX.

CBS XIII requested the OPAG-IOS to maintain liaison and to ensure that targeting methodologies developed by programmes such as EUMETNET and targeting strategies developed by programmes such as THORPEX were carried through to operational implementation. A targeting campaign for the Atlantic and Europe is planned for nine months in 2008. It will be run as a EUMETNET/EUCOS activity carried out under the joint EUMETNET / European Commission funded EURORISK PREVIEW Programme. A short targeting campaign will be undertaken as part of the Greenland Flow Distortion experiment with sensitive area predications provided by the Met Office and ECMWF.

The THORPEX Implementation Plan stipulates that the concept of interactivity will be tested in the TIGGE (THORPEX Interactive Grand Global Ensemble) framework. Observation targeting is expected to benefit from the large ensemble size available in TIGGE, from which some methods of sensitive area prediction may benefit. The exploration of innovative uses (e.g. targeting) of operational observing systems is part of the planned THORPEX observing system tests. DSG, in letter dated 19 July 2005, to President CBS advised him of the EC recommendation to organize a joint workshop between CBS and CAS to investigate the concept of targeted (adaptive) observing systems.

Action July 2007: The Workshop on impact studies to address the feasibility and operational benefit of observation targeting.

Optimization of vertical profile distribution

G8. **RAOBs** - Optimize the distribution and the launch times of the radiosonde sub-system (allowing flexible operation while preserving the GUAN network and taking into consideration regional climate requirements). Examples include avoiding duplication of Automated Ship-borne Aerological Program (ASAP) soundings whenever ships are near a fixed rawinsonde site (freeing resources for observations at critical times) and optimizing rawinsonde launches to meet the local forecasting requirements. [recommendation is supported by information from the EUCOS Studies]

Comment: Observation targeting requires a flexible observing practice. THORPEX has included this concept in their considerations. ET to follow the THORPEX Implementation Plan and to learn from the THORPEX experience whilst remembering the importance of safe-guarding the integrity of the baseline observing system.

The EUCOS plans for the redesign of the upper air network in Europe will address the issue of best mix of radiosonde and AMDAR profile data. Although EUCOS is focused on regional aspects for NWP in Europe, their findings may be applicable elsewhere.

New action July 2007: Next Workshop on impact studies to address the implication of RAOB network optimization for NWP.

G9. **AMDAR** - AMDAR technology should provide more ascent/descent profiles, with improved vertical resolution, where vertical profile data from radiosondes and pilot balloons are sparse as well as into times that are currently not well observed, such as 2300 to 0500 local times.

Comment: This recommendation is supported by information from the Toulouse and Alpbach NWP Workshop reports and by the ECMWF northern hemisphere AMDAR impact study. The AMDAR Panel objective is to coordinate homogeneous coverage of AMDAR data over 24 hours over as many regions as possible and to improve the value of upper air data through a combination of:

- Expanding the number of operational national and regional programmes;

Update July 2007: Existing programmes in Australia, Asia, Southern Africa, the USA and Europe continue to expand coverage both domestically and internationally. The Republic of Korea AMDAR Programme should become operational by mid 2007.

- Development and use of new onboard software and alternative AMDAR technologies;

  Update July 2007: Discussions are still ongoing for the development and implementation of new ARINC 620V4 software. New technologies (TAMDAR) are nearing completion. Problems with TAMDAR data ownership are still to be solved. The upgraded of the AAA specification to support water vapour measurement and reporting is completed and a software package supporting some Boeing models is due to be completed by late 2007. The ADS-B system is under development and an ADS-C system operates over the North Atlantic and SW Pacific Ocean areas.

  New Action July 2007: The AMDAR Panel to prepare a work plan to develop a standardized software solution for larger aircraft makes and models. This will be a longer term perspective.

- Selective deployment of humidity/water vapour sensors;

  Update July 2007: WVSSII water vapour sensors installed on a number of UPS B757 freighter aircraft is undergoing additional operational testing before the release of a final report. E-AMDAR has commenced a European based WVSSII evaluation programme on 3 Lufthansa A319 aircraft, with the results expected to become available towards the end of 2007. Discussions are ongoing for the development and installation of the ARINC 620V4 software and WVSSII sensor on a number of commercial aircraft makes and models, including Airbus and Boeing.

  New action July 2007: (i) AMDAR Panel to make available and ET-EGOS to consider the evaluation reports of both trials.

  (ii) The AMDAR Panel to prepare a work plan to develop a standardized humidity sensor solution for larger aircraft makes and models. This again will be a longer term perspective.

- Provision of additional observations into data sparse areas and special weather situations;

  Update July 2007: E-AMDAR continues to provide targeted data into Southern Africa and is planning to provide some targeted data into India and Singapore as part of a data agreement. Work continues on the establishment of a substantial programme for the ASECNA area. Plans are under way to develop a pilot Regional Programme for the South West Pacific.

  New action July 2007: AMDAR Panel to continue exploring opportunities for providing additional observations and implement the plans.

- Use of optimization systems to improve cost effectiveness;

  Update July 2007: E-AMDAR continues to develop and refine its optimization schemes. Canada also has established an operational optimization scheme. The USA has conducted an investigation into the impact of an optimization system on the RUC model and are now planning to develop a system for the USA Programme. Australia is planning to develop an appropriate system in the near future.

  There is a need to specify, based on the advice from the various application areas, the GOS requirements for the optimization of data collection. This task will benefit from experience in some areas where optimization is in operation, e.g. E-AMDAR

  New action July 2007: (i) AMDAR Panel to continue with the development and the implementation of the optimization schemes.

  (ii) AMDAR Panel to request input via the WMO Secretariat from various application areas on the optimization requirements for AMDAR data collection

- Improvements in the monitoring, quality control;

Update July 2007: All monitoring centres have made substantial improvements to their AMDAR data quality monitoring systems A series of studies have shown that temperature data quality is very clearly linked to individual aircraft types and models and that there are clear differences in the bias seen between ascent and descent profiles on many aircraft types. The AMDAR Panel Science Sub Group (SSG) is planning to conduct a study to investigate and develop a solution for these problems. The AMDAR Panel SSG is also planning to investigate and develop a solution for the poor wind quality derived from aircraft at high latitudes that results from the use of magnetic heading, which is unreliable at these latitudes.

New action July 2007: Continuing activity of the AMDAR Panel.

- Efforts to encourage and pursue the free exchange of data;

Update July 2007: Discussions continue with the provider of the TAMDAR system to allow for the provision of data free of charge to NMHSs.

New action July 2007: The AMDAR Panel to develop a standard text on data ownership and usage which can serve as the basis of agreements between NMHSs and data providers.

- Improvements in user awareness & training plus operational forecasting tools & systems

Update July 2007: The AMDAR Panel webpage is now operational and the new and updated AMDAR Panel Flyer has also been completed. Discussions are ongoing for the development and implementation of an operational stand alone AMDAR data visualization for the ASECNA group of countries. AMDAR Technical workshops have been formally requested by the Malaysia, Romania, Mexico and Kenya and interest has been expressed by Brazil, Bulgaria, India, Pakistan, Sri Lanka and the Russian Federation.

New action July 2007: ongoing activity of the AMDAR Panel

Atmospheric moisture measurements

G13. Ground-based GPS measurements for total water vapour - Develop further the capability of ground-based GPS systems for the inference of vertically integrated moisture towards operational implementation. Ground-based GPS processing (ZTD and PW, priority for ZTD) should be standardized to provide more consistent data sets. Data should be exchanged globally. [Recommendation is supported by information from the NWP OSE Workshop in Alpbach.]

Comment: Such observations are currently made in Europe, North America and Asia. It is expected that the global coverage will expand over the coming years. The historical COSNA/SEG, NAOS, JMA reports provide useful background information.

CBS urged Members to collect and exchange the ground-based GPS data. Members were to take the appropriate action to ensure that the data processing be standardized by November 2005.

GPS data message type in BUFR has been developed and approved. Ground-based GPS data are inserted on the GTS from Europe, by the Met Office in Exeter, UK, sample encoding information can be provided

New action July 2007: ongoing action, WMO Secretariat to remind Members that all available ground-based GPS data be made available in near-real time on the GTS.

Improved observations in ocean areas

G14. More profiles over oceans - Increase the availability of high vertical resolution temperature, humidity, and wind profiles over the oceans. Consider as options ASAP and dropsondes by designated aircraft.

Update July 2007: The main concentration of the ASAP operations continues to be over the Northern Atlantic (5153 launches in 2006), an important contribution is also made by Japanese research ships operating primarily in the North Western Pacific areas and seas adjacent to Japan (938 launches in 2006). Fewer manual soundings are made by South

Africa from ships sailing in the South Atlantic. Radio sondes generally provided better high vertical resolution information than the aircraft data (AMDAR) over the oceans. Radio sondes data are particularly needed for the calibration of the satellite products, especially in the North Pacific and the Southern Hemisphere. The SOT-IV asked the ECMWF to provide materials showing impact of radio-sonde data over the oceans. The transition of high vertical resolution data will be achieved by the migration from TEMP-SHIP to BUFR. However, this remains a concern because TEMP-SHIP files are much smaller and less expensive to transmit from ships via Inmarsat-C than BUFR reports. As long as there is no agreed template for ASAP radio sounding data of practicable file size the ASAP units should continue to transmit TEMP files. These files can be decoded to BUFR at the receiving Met Service and transmitted to the GTS in BUFR format. Further benefit of alphanumeric files is the option to transmit the data manually by e-mail, if required.

New action July 2007: (i) ET-EGOS to solicit, e.g. through impact studies, further guidance on the desirable coverage of ASAP soundings over the oceans. (ongoing activity, to be addressed at the Workshop)

(ii) SOT to continue efforts for achieving transmission of higher resolution ASAP data in either BUFR or CREX.

G15. Improvements in marine observation telecommunications - Considering the expected increase in spatial and temporal resolution of *in situ* marine observing platforms (from include drifting buoys, profiling floats, XBTs for example) and the need for network management, the bandwidth of existing telecommunication systems should be increased (in both directions) or new relevant satellite telecommunications facilities should be established for timely collection and distribution.

Comment: The JCOMM Operations Plan provides background for actions in this area.

Iridium provides for high resolution data transmission and is global. Experiments still being conducted with small number of Argo profiling floats. Argos 3 generation is onboard METOP and provides higher bandwidth and downlink capability. High resolution XBT data collected via Inmarsat are made available through Global Temperature and Salinity Profile Programme (GTSPP). BUFR distribution of high resolution XBT data is under development in the USA. Iridium and other providers also offer substantially reduced telecoms tariffs, with no reduction in performance.

Update July 2007: The DBCP has established a DBCP drifter Iridium Pilot Project to evaluate the Iridium satellite data telecommunication system for use with drifting buoys. The Pilot Project is targeting the deployment of about 50 units in the world oceans in the period 2007/2008. Similarly, the SOT has also engaged in the evaluation of the Iridium system for use from VOS ships. Iridium, which is a global system, provides potentially the cost-effectiveness, telecommunication bandwidth and the timeliness needed for applications of ocean data. Iridium could also potentially solve the problem of transmitting in real-time high vertical resolution ASAP soundings to shore.

New action, July 2007: JCOMM to report on the developments of the DBCP and SOT Iridium Pilot Projects. ET-EGOS to propose pilot project for WIGOS to provide for high rate satellite data communication for marine observations.

G16. Tropical moorings - For both NWP (wind) and climate variability/climate change (sub-surface temperature profiles), the tropical mooring array should be extended into the tropical Indian Ocean at resolution consistent with that presently achieved in the tropical Pacific and Atlantic Oceans. [The JCOMM Operations Plan provides background for actions in this area].

Update June 2007: Overall target for the tropical moorings under the JCOMM/OPA strategic work plan is for 76 moorings in the Tropical Pacific Ocean, 18 in the Tropical Atlantic Ocean, and 47 moorings in the Tropical Indian Ocean. Tropical Pacific Ocean array is complete. Implementation of the Indian Ocean Array continued; 15 moorings were in place in June 2007. Southwest (3 moorings) Northeast (4 moorings) and Southwest (1 mooring) extensions of the PIRATA array in the Tropical Atlantic ocean were implemented; 19 moorings were operation in the PIRATA array in June 2007. Operations and maintenance of most of the Tropical Pacific Ocean array has been transferred to an operational agency in USA. However, sustainability is still an issue for the rest of the network. Vandalism remains a concern.

New action, July 2007: JCOMM to continue working towards developing the Indian Ocean array and sustaining both the Indian Ocean and Atlantic Ocean arrays.

G17. Drifting buoys - Adequate coverage of wind and surface pressure observations from drifting buoys in the Southern Ocean in areas between 40S and the Antarctic Circle should be assured using an adequate mix of SVPB (surface pressure) and WOTAN technology (surface wind). The pressure observations are a valuable complement to the high-density surface winds provided by satellite. [Recommendation is supported by information in the Toulouse NWP OSE Workshop Report and the ET-EGOS OSE studies.]

Update July 2007: DBCP maintains an array of about 1250 drifting buoys globally. About 450 of them report air pressure. It maintains an array of about 80 barometer drifters South of 40S. The JCOMM strategic work plan is targeting to install barometers on all operational 1250 drifters globally by 2010. This involves maintaining a network of about 300 drifters with barometers in the Southern Ocean. Hourly air pressure data are recorded by the instruments and distributed on GTS. Efforts are being made in Southeast Pacific, and the South Atlantic to improve data timeliness by installing and/or connecting of Argos receiving stations to the Argos System.

The number of drifting buoys making wind is insignificant. Global coverage of near surface wind observations is achieved through satellites. Cost of wind measuring drifters is twice as much as barometer drifters. Guidance is needed whether additional wind observations from drifters in the Southern Ocean would have a positive impact as part of a network already providing pressure observations at a horizontal resolution of 500km x 500 km. Wind drifters with WOTAN technology are deployed in small quantities and in conjunction with hurricanes. There are no plans to increase substantially the number of such drifters unless strong requirements are expressed by the users with an indication of the network density and targeted areas.

ET-EGOS endorsed the JCOMM/OPA strategic work plan for the DBCP. It was recommended to carry out any OSE concerning the impact of Arctic buoy observations after IPY.

New action July 2007: Next Workshop on impact studies to address the requirements for global coverage of wind observations from drifting buoys and provide guidance to JCOMM.

G18. XBT and Argo - For Ocean Weather Forecasting purposes, improve timely delivery and distribution of high vertical resolution data for sub-surface temperature/salinity profile data from XBTs and Argo floats.

Note: The JCOMM Operations Plan provides background for actions in this area.

Update July 2007: Argo network is now nearing completion with 2886 floats operational in June 2007 (96%) for a target of 3000. 22 countries and the European Union are participating in the effort. All operational floats report their data in real time. Most Argo national programs continue to be supported by research funding, which poses difficulties for sustaining the observations over decadal timescales. Mechanisms for long-term support are required. Support from operational agencies and users are needed to justify the long term funding. Regarding the XBT network managed by the SOOPIP under the JCOMM SOT, between 2004 and 2006 there has been a gradual decrease in the annual number of XBT observations transmitted in real-time to the national data centres, from just over 25,000 in 2004 to about 18,000 in 2006. The target for 2010 is to sample 26 high density ship lines (4 transects per year a high horizontal res.) and 25 frequently repeated ship lines (18 transects per year at low horizontal res.). Significant progress has been made in improving the quality of the XBT observations (automated systems, improved real time QC), and in enhancing the real-time transmission of XBT observations in high vertical resolution. USA is now developing software to permit the distribution of the XBT data in BUFR format. OOPC is now planning to organize a conference focused on global ocean observations, in about 2009, ten years after the OceanObs99 conference that defined the implementation strategy for the SOOPIP, Argo, and the Tropical moored buoy array in support of upper ocean thermal applications.

New action, July 2007: JCOMM is encouraged to continue its actions to ensure a sustained status for upper ocean thermal networks. JCOMM to solicit from operational users to document the benefits they gain from Argo data and ocean thermal profile data. Such information could be provided e.g. through monitoring statistics or impact studies.

G19. **Ice buoys** - For NWP purposes, coverage of ice buoys should be increased (500 km horizontal resolution recommended) to provide surface air pressure and surface wind data.

Note: The JCOMM Operations Plan provides background for actions in this area.

Update July 2007: After reviewing the requirements established by the WMO and NOAA for meteorological and oceanographic observations, it was determined that the IABP will strive for a spatial resolution of 250 km for the IABP buoy network. About 190 buoys are needed to achieve this resolution. On the other hand, the WCRP-SCAR International Programme for Antarctic Buoys (IPAB) is still targeting 500km*500km horizontal resolution in the sea-ice zone while actual resolution is actually substantially lower.

There are currently 150 buoys deployed in the Arctic Ocean. For the International Polar Year, the Participants of the IABP plan to deploy over 170 buoys, which provide critical atmospheric, sea ice, and upper ocean hydrographic measurements on various space and time scales that cannot be obtained by other means. Challenges will be to maintain some of the momentum obtained during the IPY, and maintaining the array. The Eurasian side of the Arctic Ocean appears to be data sparse. With the reduction of the sea ice extend due to global warming, development of seasonal ice buoys is becoming essential.

New action July 2007: Impact of the expected increased Ice buoy deployment to be reviewed at next OSE/OSSE Workshop. Stress the importance of the IPY legacy.

Improved observations over tropical land areas

G20. **More profiles in Tropics** - Temperature, wind and if possible the humidity profile measurements (from radiosondes, PILOTs, and aircraft) should be enhanced in the tropical belt, in particular over Africa and tropical America.

Comment: There is evidence from recent impact studies with the radiosonde / PILOT balloon network over the Indonesian / Australian region that such data give a better depiction of winds in the tropics and occasionally strongly influence the adjacent mid-latitude regions.

Information on the collection of additional profile data from aircraft and ASAP is provided under G9 and G14. In addition, the AMMA (African Monsoon Multidisciplinary Analysis) project in West Africa is operating at various stages and during field phases a number of additional TEMP and PILOT stations. The AMMA Programme provides an opportunity for impact studies and subsequent network design. Sustaining an operational network in the region will be a challenging task.

An AMMA workshop was held in Météo France (Toulouse) during the first week of November 2006, with a special session dedicated to this topic. Some preliminary OSEs have been performed with AMMA data captured on the GTS.

New action July 2007: ET-EGOS to prioritize OSEs which are the most relevant for the evolution of GOS in Africa (to be addressed at the Workshop).

New Observing Technologies

G21. **AWS** - Noting the widespread adoption of AWS and their importance in the measurement of ECVs,

(a) there should be coordinated planning that includes:

- appropriate codes and reporting standards;

- global standard for quality management and the collection / sharing of metadata; and
- expanded range of measured parameters;
- ensuring recommended practices are complied with.

New action July 2007: ongoing action, ET-AWS to be asked to summarize advances in AWS technology for ET-EGOS, and to formulate how the operational implementation of this technology might be formulated and promoted within the EGOS-IP.

(b) exact time of observation, as distinct from a notional time or time period, should be reported.

New action July 2007: The evolution of the AWS network needs to be addressed. OPAG/IOS needs to consider how best to carry this forward. ET-EGOS chair to liaise with ET-AWS chair on future co-operation.

G22. **New systems** - The feasibility of new systems should be demonstrated as much as possible. These possible operational sub-systems include but are not limited to:

- ground based interferometers and radiometers (e.g. microwave) that could provide continuous;
- vertical profiles of temperature and humidity in selected areas;
- Unmanned Aeronautical Vehicles (UAVs);
- high altitude balloons;
- TAMDAR;
- Ocean Gliders;
- Deep ocean time series reference stations (oceanSITES).

The OceanSITES is a worldwide system of long-term, deepwater reference stations measuring dozens of variables and monitoring the full depth of the ocean from air-sea interactions down to 5,000 meters. OceanSITES is installing meteorological instruments on most of its sites. While data are public for most of these southern ocean sites, the data are only being distributed in delayed mode.

- Lightning detection

Long-range ground-based remote sensing lightning detection systems have now an accepted role as a cost effective component of the evolving GOS. Such systems should be considered complementary to existing lightning detection systems for improving coverage in data sparse regions, including the oceans and polar areas.

New action July 2007:

(i) ET-EGOS chair to ensure that any impact studies for new technologies carried out by THORPEX or other groups are made available.

(ii) JCOMM to encourage OceanSITES to distribute their data in real-time.

(iii) ET-EGOS to include remote sensing lightning detection systems in the revised “Vision for the GOS in 2025” and WMO Secretariat to encourage Members to collaborate on the realization of a truly global system for sharing real time data with all Members.

NEW ACTIONS TO BE ADDED BASED ON NEW REQUIREMENTS SPECIFIED IN SEVERAL APPLICATION AREAS:

Develop in-situ wave observation capability. In situ wave observations are needed to meet the requirements for maritime safety services, and in particular for (i) assimilation into offshore wave forecast models, (ii) validation of wave forecast models, (iii) calibration/validation of satellite wave sensors, (iv) description of the ocean wave climate and its variability on seasonal to decadal time scales. Some coastal buoys are presently making directional wave observations and some open ocean buoys are making significant wave height measurements. However, practically none are reporting directional or spectral wave data from the open ocean. Observations are needed at a minimum, significant wave height, peak period and 1-D spectra, hourly in real-time, for assimilation into coupled atmosphere-ocean wave models for real-time forecasting activities, and subsequent verification.

Action July 2007: JCOMM to set up a Pilot Project with a view towards integrating the in-situ wave observation capability into WIGOS.

Increase time resolution of SST data (in-situ observations from drifters). Increased time resolution SST data, at least hourly, are needed in order to better resolve the diurnal cycle of the SST. In-situ SST data are being used by the GHRSST together with satellite data. Relatively minor technological developments should eventually permit to meet these requirements for all global drifters.

Action July 2007: DBCP to develop the technology, pursue its implementation and report to ET-EGOS

Develop and consolidate the VOSClim fleet. Climate variability and predictability applications require better quality data from the VOS fleet (better QC and flags, additional metadata). The fleet is currently comprised of about 220 ships but not all of them do report the required additional parameters and could increase the frequency of observations by using more automated systems together with the recording of traditional variables that can only be observed manually. The SOT has recommended increasing the number of ships participating in the VOSClim fleet which is now targeting a total of 250 ships. At the same time, efforts should be made to increase the number of observations and the number of VOS ships recording the additional parameters required by the VOSClim.

Action July 2007: SOT to seek additional commitments from WMO Members and to report back to ET-EGOS.

Develop operational procedures for the GRUAN. The proposal for the GCOS Reference Upper Air Network (GRUAN) has been endorsed by the AOPC. The Lead Centre for the GRUAN will develop operational procedures in consultation with appropriate CBS and CIMO expert team, GSICS and other relevant partners.

Action July 2007: GCOS to keep ET-EGOS informed about the progress

Maintain and expand the Baseline Surface Radiation Network to obtain global coverage. Data are used for climate monitoring and provide valuable observations for the validation of earth radiation budget satellite data.

Action July 2007: WMO Secretariat to seek commitment from Members to provide continuity for these measurements.

Provide surface data for calibration and inter-comparison with satellite data. The hydrology applications, but also GCOS, will benefit from in-situ observation parameters such as snow cover, snowfall, snow cover water content, soil moisture and run-off data to be used in combination with satellite data.

Action July 2007: Points of Contact for Hydrology and GCOS to provide an inventory of observation requirements to ET-EGOS via the Secretariat.

Improve the accuracy of precipitation estimates from remotely sensing systems. This applies in particular to rain estimates from satellites and weather radar.

Action July 2007: ET-EGOS chair to bring this to the attention of ET-SAT and the developers working on the algorithms to exploit radar measurements**.**

3. Evolution of space-based sub-system of GOS

A balanced GOS - Concern 1 - LEO/GEO balance

There has been commendable progress in planning for future operational geostationary satellites. In addition to the plans of China, EUMETSAT, India, Japan, Russian Federation and USA, WMO has been informed of the plans of the Republic of Korea to provide geostationary satellites. The Republic of Korea has made a formal declaration to WMO and is now considered part of the space-based component of the GOS. These developments increase the probability of good coverage of imagery and sounding data from this orbit, together with options for adequate back-up in case of failure. On the other hand, current plans for LEO missions are unlikely to fulfil all identified requirements. It would be timely for the WMO Space Programme and/or CGMS to study the balance between polar and geostationary systems and to advise if there is scope for optimizing this balance between the two systems in the long term.

> **Progress**: The issue of GEO-LEO optimization was raised by WMO at the “CGMS-WMO optimization workshop” held with CGMS satellite operators on 28-29 August 2006. The workshop has reviewed the planned locations of geostationary satellites and proposed to take advantage of additional satellite capabilities to increase robustness of the geostationary constellation.
>
> **New Action:** To bear in mind the desirable balance between GEO and LEO components in future global planning activities.

A balanced GOS - Concern 2 – Achieving complementary polar satellite systems

EUMETSAT has recently initiated planning for the post-EPS era (i.e., first element in orbit in ~2019) through a thorough assessment of the user requirements for all observations that might usefully be made from low earth orbit. This is to be complemented with a remote sensing assessment of the missions needed to meet these requirements. It is expected that some of these missions will be implemented through satellite missions/systems provided by EUMETSAT, whilst other “missions” may be achieved by cooperation with other partners (e.g., NOAA/EUMETSAT Joint Polar System, complementarity with GMES missions, or acquisition of data in partnership with other space agencies). Through this process, the goals of GEOSS could be greatly advanced. WMO Space Programme Office is encouraged to consider how this process might best be facilitated, to discuss any obstacles to progress, and to identify short-term opportunities for engagement with this process. In addition, noting the polar plans of China and the Russian Federation, WMO Space Programme should also extend coordination efforts to include these agencies.

> **Progress**: Global optimization of the satellite mission plans was recognized as an important objective and has led to convene the first WMO/CGMS Optimization workshop mentioned above. It was central to the scope of the Re-design and Optimization workshop convened by WMO on 21-22 June 2007.
>
> **New action:** To refine and adopt a new vision for the GOS in 2025 that would provide guidance on how individual agencies’ plans can best contribute to a globally optimized system, e.g. in defining thematic constellations as is currently considered for altimetry.

Calibration

S1. Calibration - There should be more common spectral bands on GEO and LEO sensors to facilitate inter-comparison and calibration adjustments; globally distributed GEO sensors should be routinely inter-calibrated using a given LEO sensor and a succession of LEO sensors in a given orbit (even with out the benefit of overlap) should be routinely inter-calibrated with a given GEO sensor.

> **Comment:** A major issue for effective use of satellite data, especially for climate applications, is calibration. GCOS Implementation Plan (GIP) Action C10 calls for continuity and overlap of key satellite sensors. The advent of high spectral resolution infrared sensors (AIRS, IASI, CrIS) will enhance accurate intercalibration. Also regarding visible intercalibration, MODIS offers very comprehensive onboard shortwave solar diffuser, solar diffuser stability monitor, spectral radiometric calibration facility, that can be

considered for inter-comparison with geosynchronous satellite data at visible wavelengths. MERIS appears to have merit in this area due to its programmable spectral capability, if implemented. GOES-R selected ABI channels have been selected to be compatible with VIIRS on NPOESS. This only deals with optical sensors, and other sensor types (e.g., active, passive, MW) should be considered.

Progress: The Global Space-based Inter-Calibration System (GSICS) has been established to ensure comparability of satellite measurements provided through different instruments and satellite programmes and to tie these measurements to absolute references. GSICS activities will ultimately include: regular processing of VIS-IR-MW radiances from co-located scenes of GEO and LEO satellites, with common software tools as well as: pre-launch instrument characterization; on-orbit calibration against on-board, space or earth-based references; calibration sites and field campaigns; radiative transfer modelling. The GSICS Implementation Plan was adopted at the GSICS Implementation Meeting on 23 June 2006 and endorsed by CGMS 34 in November 2006. A GSICS Executive Panel was nominated, led by Dr Mitch Goldberg from NOAA, as well as a GSICS Research Working Group and a GSICS Data Working Group. All groups had at least one meeting already. The Executive Panel has agreed on a first Operation Plan for 2007. LEO to LEO intercalibration is performed on a routine basis by NOAA. A common procedure is being developed and will be implemented by the end of 2007 by each operator of geostationary satellite in order to perform GEO to LEO IR intercalibration in a similar way. Hyperspectral sensors such as MODIS and IASI will be taken as the references in order to account for differences in Spectral Response Functions of the various broadband instrument channels. A GSICS website was established (http://www.wmo.int/pages/prog/sat/Calibration.html)

Next Action: To pursue the implementation of GSICS with the expectation that GEO to LEO IR intercalibration becomes operational early 2008, and then extended to visible channels.

GEO satellites

S2. GEO Imagers - Imagers of future geostationary satellites should have improved spatial and temporal resolution (appropriate to the phenomena being observed), in particular for those spectral bands relevant for depiction of rapidly developing small-scale events and retrieval of wind information.

Progress: The following geostationary satellite operators have reported at CGMS that they will have at least SEVIRI-like capability by 2015: NOAA (2012), EUMETSAT (present), Russian Federation (2007), and CMA (2012). Further improved imaging capabilities are being planned for the future generation (GOES-R, MTG, MTSAT-FO, FY-4).

New action: WMO Space Programme will continue discussions with space agencies, via CGMS, especially with IMD and JMA.

S3. GEO Sounders - All meteorological geostationary satellites should be equipped with hyper-spectral infrared sensors for frequent temperature/humidity sounding as well as tracer wind profiling with adequately high resolution (horizontal, vertical and time).

Comment: Instruments of this type in geosynchronous orbit are high priority enhancements to the Global Observing System (GOS) for meeting existing user requirements in numerical weather prediction (NWP), nowcasting, hydrology and other applications areas. Based on the experience gained from classical IR sounding from GEO satellites and from hyper-spectral Infrared sounding from LEO satellites, the impact of hyper-spectral sensors on GEO satellites is expected to be very positive. In addition, in order to optimize this impact, it would be useful to proceed with a direct demonstration mission based e.g. on the USA's GIFTS development in advance of the planned operational series.

Progress: EUMETSAT has included IRS in its baseline for the MTG series around 2016; CMA has plans for its FY-4/Optical series by 2012; NOAA is re-considering options for a hyperspectral sounding instrument on the GOES-R series; JMA is exploring the possibility of such development for MTSAT-Follow-on. For the meantime, opportunities for international cooperation on a demonstration mission are being explored by CGMS in the context of the International Geostationary Laboratory (IGeoLab), noting a flight opportunity for GIFTS on board of the geostationary satellite “ELEKTRO-L 2” planned for launch in 2010, but there remains a funding issue to manufacture a space qualified instrument on the basis of the current engineering model.

New action: To encourage geostationary satellite operators to confirm and implement their plans for GEO hyperspectral instruments; to pursue in the meantime the IGeoLab proposal for a demonstration or pre-operational hyperspectral sounding mission from the GEO orbit.

S4. GEO System Orbital Spacing - To maximize the information available from the geostationary satellite systems, they should be placed “nominally” at a 60-degree sub-point separation across the equatorial belt. This will provide global coverage without serious loss of spatial resolution (with the exception of Polar Regions). In addition this provides for a more substantial backup capability, should one satellite fail. In particular, continuity of coverage over the Indian Ocean region is of concern.

Comment: In recent years, contingency planning has maintained a 5-satellite system, but this is not a desirable long-term solution.

Progress: WMO Space Programme continues to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, the strategy for implementation towards a nominal configuration with attention to the problems of achieving required system reliability and product accuracy. This issue was addressed as part of the gap analysis at the GOS re-design and optimization workshop, although no precise recommendation was formulated at that stage.

New action: WMO Space Programme to develop and propose to CGMS a geostationary coverage scheme where inter-satellite separation would not exceed 60° longitude.

LEO satellites

S5. LEO data timeliness - More timely data are needed to improve utilization, especially in NWP. Improved communication and processing systems should be explored to meet the timeliness requirements in some applications areas (e.g. Regional and Global NWP).

Progress: The successful EUMETSAT ATOVS Retransmission Service (EARS) has been renamed the EUMETSAT Advanced Retransmission Service and will carry AVHRR and ASCAT products in addition to ATOVS. EARS ATOVS data are now available with a delay of less than 30 minutes; the data are used operationally at some NWP centres and planned at others. A RARS has started operations in Asia-Pacific area, and testing has begun for a RARS in South-America. Following the global RARS workshops held in Darmstadt in December 2004, in Geneva in December 2005 and in September 2006, a RARS Implementation Group was set up and held its first meeting on 3-4 July 2007. The primary goal is to achieve quasi-global coverage for timely retransmission of ATOVS datasets. Preliminary contacts with the South African Weather Service indicate a potential for extending the coverage towards South Africa and surrounding seas. The RARS approach is expected to be expanded to IASI and other time-critical data, including an equivalent system for NPP data.

NPOESS initial plans are for 80% of global data acquisition in less than 15 min and would thus be consistent with the stated timeliness requirements for NWP, provided that provisions are made for the timely redistribution of these data towards NWP centres.

As regards polar winds, plans are being developed to improve the timeliness through the use of direct broadcast imagery received at high-latitude stations.

Additionally, ERS-2 GOME and scatterometer data are now available in near real time (within 30 minutes) in the coverage region of ESA (e.g., Europe and North Atlantic) and cooperating ground stations (e.g., Beijing, Perth,..).

New action: WMO Space Programme to pursue further actions to implement RARS at a global scale and to encourage the implementation of similar plans to allow the derivation of polar winds with improved timeliness

S6. **LEO temporal coverage** - Coordination of orbits for operational LEO missions is necessary to optimize temporal coverage while maintaining some orbit redundancy.

Progress: This is now the subject of a permanent action of CGMS. WMO Space Programme collaborates with space agencies, via CGMS, towards a target system defining both nominal and contingency planning in the AM and PM polar-orbits. This was addressed by the GOS Re-design and Optimization workshop on 21-22 June 2007, where a recommendation was made for a 3-orbit configuration, with 4-hour nominal separation between ECT, and back-up.

New action: To formulate a 3-orbit configuration for core LEO sun-synchronous missions, as part of the new vision for the GOS in 2025.

S7. **LEO Sea Surface Wind** - Sea-surface wind data from R&D satellites should continue to be made available for operational use; 6-hourly coverage is required.

Comment: GCOS (GIP, Action A11) calls for continuous operation of AM and PM satellite scatterometers or equivalent. QuikScat scatterometer data have been available to the NWP community since 1999, and will continue through the life of QuikScat (NASA has no current plans for a successor SeaWinds scatterometer). Oceansat-2 has scatterometer capability that may be made available to the world community (this availability needs to be confirmed). The relative performance of the multi-polarisation passive MW radiometry versus scatterometry requires further assessment.

Progress: For scatterometry, ERS-2 scatterometer has been followed by ASCAT on METOP, sea surface wind is thus being observed in an operational framework since 2007.

There are plans for a scatterometer aboard the Indian Oceansat-2 and the Chinese HY-2 series, although data availability still needs confirmation.

As concerns MWI, Windsat data have been distributed to several NWP centres in 2005. Early assessments of its polarimetric capabilities to provide information on sea surface wind direction suggest that, while this technology will not be competitive with scatterometry at low wind speed, good information is available at high wind speed.

The revised NPOESS baseline includes a microwave imager/sounder (MIS) expected to provide wind speed and direction information at sea surface starting with NPOESS-C2 in 2016.

The GOS Re-design and Optimization workshop recommended maintaining at least 2 scatterometers and 2 full polarimetric microwave imaging missions in order to achieve both sufficient accuracy and coverage.

New action: The recommended configuration should be included into the new vision for the GOS in 2025, and brought to the attention of CGMS 35.

S8. **LEO Altimeter** - Missions for ocean topography should become an integral part of the operational system.

Comment: GCOS (GIP, Action O12) requires continuous coverage from one high-precision altimeter and two lower-precision but higher-resolution altimeters.

Progress: Agreement has been reached to proceed with Jason-2 (2008). Jason-1 continues to provide global ocean topography data to the NWP community. ESA has plans for a Sentinel-3 ocean mission that will include an altimeter. Observation strategy for altimetry was addressed at the GOS Re-design and Optimization workshop mentioned above. Large agreement of the community was achieved around the concept of a constellation for Ocean Surface Topography including at least one reference altimetry mission plus 2 additional altimeter systems on higher inclination to ensure global coverage.

New action: WMO Space Programme to continue to work with CGMS Satellite operators and CEOS Constellation on Ocean Surface Topography in order to confirm the plans and ensure continuity of at least one reference altimetry mission plus 2 additional altimeter systems on higher inclination to ensure global coverage.

S9. LEO Earth Radiation Budget - Continuity of ERB type global measurements for climate records requires immediate planning to maintain broadband radiometers on at least one LEO satellite.

Comment: Plans for ERB-like measurements after Aqua remain uncertain. There are also concerns about the continuity of absolute measurements of incoming solar radiation. This is a high priority item for GCOS (GIP, Action A24).

Progress: FY-3A and FY-3B will have a prototype Earth Radiation Budget Unit (ERBU) in 2007. Either NPP or the first NPOESS satellite (likely launch in 2013) are expected to carry the CERES instrument. An observation strategy was proposed by the GOS Re-design and Optimization workshop, based on one LEO broad-band multi-angle viewing radiometer, collocated cloud/aerosol/water vapour measurements, complementary geostationary diurnal cycle information, as well as Total Solar Irradiance measurement.

New action: To confirm or refine the recommended observation strategy with support of GCOS and the science community and to work with satellite operators towards its implementation.

R&D satellites

S10. LEO Doppler Winds - Wind profiles from Doppler lidar technology demonstration programmes (such as ADM-Aeolus) should be made available for initial operational testing; a follow-on long-standing technological programme is solicited to achieve improved coverage characteristics for operational implementation.

Progress: Plans for ADM-Aeolus demonstration are proceeding with a launch now planned for June 2009, and ESA and ECMWF are developing software for the assimilation of Doppler winds into NWP models. There are currently no plans for either a preparatory mission or an operational follow on. EUMETSAT is considering the requirements for observations of the 3D wind field as part of their planning for post-EPS missions. Preliminary considerations for a preparatory mission based on ADM-Aeolus were mentioned at the ESA/ESTEC ADM-Aeolus workshop on 25-27 September 2006.

New action: WMO Space Programme will continue to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, to ensure that the demonstration with ADM-Aeolus can be followed by a transition to operational systems for wind profile measurement. Plans for continuity of a Doppler Winds capability following ADM-Aeolus should be further discussed by CGMS satellite operators in 2007.

S11. GPM - The concept of the Global Precipitation Measurement Missions (combining active precipitation measurements with a constellation of passive microwave imagers) should be supported and the data realized should be available for operational use, thereupon, arrangements should be sought to ensure long-term continuity to the system.

Comment: GCOS (GIP Action A7) requires stable operation of relevant operational satellite instruments for precipitation and associated products.

Progress: TRMM continues to provide valuable data for operational use. Early termination of TRMM after 2004 was averted after user community appeals for its continuation. NASA has assured continued operation into 2009. In 2005, ESA's European GPM was not selected as the next Earth Explorer Mission. At the fifth International planning workshop WMO expressed it support and its readiness to facilitate partnerships to expand the GPM constellation. It was recognized that ISRO's Megha-tropique has a passive microwave capability that is not yet part of the GOS but could be useful in the GPM constellation (availability needs to be confirmed). Other R&D and operational satellites in polar orbit may contribute to the constellation with their microwave radiometers. GPM was addressed at the 6th Consultative Meeting (Buenos Aires, January 2006) and its importance was stressed. The GPM core satellite is now planned for launch in December 2012. Timely implementation of the GPM mission was identified as an action in the GEO work plan. CEOS has launched a “Global Precipitation Constellation” initiative in order to coordinate efforts to take advantage of existing instruments while preparing the GPM mission.

New action: WMO Space Programme to continue to support initiatives for the timely implementation of GPM.

S12. RO-Sounders - The opportunities for a constellation of radio occultation sounders should be explored and operational implementation planned. International sharing of ground support network systems (necessary for accurate positioning in real time) should be achieved to minimize development and running costs.

Comment: GCOS (GIP Action A20) requires sustained, operational, real-time availability of GPS RO measurements.

Progress: SAC-C, CHAMP and COSMIC data have been successfully used in an operational context and the use of METOP/GRAS is being prepared. NWP OSEs have shown positive impact with small number of occultations. Climate applications are being explored. The GOS Re-design and optimization workshop clearly recommended planning constellations of small satellites with radio-occultation sensors. Upon proposal by WMO, CGMS-34 took an action to explore opportunities for cooperation on ground support network.

New action: Plan for a constellation providing operational follow-on to COSMIC should be discussed by CGMS in 2007.

S13. GEO Sub-mm for precipitation and cloud observation- An early demonstration mission on the applicability of sub-mm radiometry for precipitation estimation and cloud property definition from geostationary orbit should be provided, with a view to possible operational follow-on.

Progress: Geo sub-mm is one of two systems being considered for IGeoLab. A task team evaluated the IGeoLab possibilities for a Geostationary Observatory for Microwave Atmospheric Sounding (GOMAS) as well as other possible instruments. This type of instrument in geosynchronous orbit is high priority for meeting existing user requirements in numerical weather prediction (NWP), nowcasting, hydrology and other applications areas. GOMAS was not accepted by ESA as a core Explorer mission. Alternative projects may be discussed at CGMS XXXIV.

Studies on GEO MW have continued in the context of IGeoLab. A GEO MW IGeoLab Focus Group workshop was held in April 2007 in Beijing and proposed to investigate two scenarios for consideration by CGMS 35, one based on filled aperture antenna and the other based on synthetic aperture antenna. Choice between the two technologies is also linked to the relative priority given to the detection of precipitation and rapid vertical sounding.

New action: WMO Space Programme will continue supporting this IGeoLab action and subsequent dialogue with space agencies, via CGMS.

S14. LEO soil moisture and ocean salinity - The capability to observe ocean salinity and soil moisture for weather and climate applications (possibly with limited horizontal resolution) should be demonstrated in a research mode (as with ESA’s SMOS and NASA’s Aqua, and NASA/CONAE Aquarius/SAC-D) for possible operational follow-on. Note that the horizontal resolution from these instruments is unlikely to be adequate for salinity in coastal zones and soil moisture on the mesoscale.

Progress: ERS scatterometer data sets have provided monthly global soil moisture maps since 1991 at 50 km resolution. EUMETSAT plan an operational global NRT soil moisture product from Metop/ASCAT data. WindSat and AMSR-E are being studied for possible utility of 6 and 10 GHz measurements for soil moisture for sparsely vegetated surfaces. SMOS is scheduled for launch in late 2007. Aquarius is scheduled for launch in 2009.

New action: WMO Space Programme will discuss at CGMS progress and options for provision of soil moisture and salinity products including real time delivery of soil moisture products for NWP.

S15. LEO SAR - Data from SAR should be acquired from R&D satellite programmes and made available for operational observation of a range of geophysical parameters such as wave spectra, sea ice, and land surface cover.

Progress: The wave spectra from ENVISAT are available in near real time from an ESA ftp server. CSA's RADARSAT data are used in deriving ice products by the National Ice Center. Continuity of ESA SAR mission is considered as part of the Sentinel programme.

New action: WMO Space Programme to continue to discuss with space agencies, via CGMS, (1) broader access by WMO Members to ENVISAT SAR data, (2) availability of SAR data from other agencies, and (3) continuity of such missions.

S16. LEO Aerosol - Data from process study missions on clouds and radiation as well as from R&D multi-purpose satellites addressing aerosol distribution and properties should be made available for operational use.

Comment: Terra and Aqua carry the MODIS sensor that is providing global aerosol products over ocean and most land regions of the world at 10 km spatial resolution. Additional R&D satellites currently providing aerosol optical thickness and optical properties include Terra/MISR, PARASOL, EP-TOMS, and Aura/OMI. CALIPSO carries an R&D lidar for monitoring the vertical distribution of aerosols along the orbital ground track of the spacecraft, which is in the A-train orbit along with Aqua, PARASOL, CloudSat, and Aura. NASA's Glory mission (2008) has added APS, an aerosol polarimetry sensor. ESA and JAXA are preparing the Earthcare (cloud/aerosol mission) for launch in 2012.

New action WMO Space Programme will continue discussions with space agencies, via CGMS, CM, and via CEOS Constellation for Atmospheric Composition, regarding availability of these data for operational use.

S17. Cloud Lidar - Given the potential of cloud lidar systems to provide accurate measurements of cloud top height and to observe cloud base height in some instances (stratocumulus, for example), data from R&D satellites should be made available for operational use.

Comment: GLAS data are currently able to determine vertical distribution of cloud top altitude along the nadir ground track of ICESat, but this spacecraft operates in ~100 day epochs and is not continuous. CALIOP on CALIPSO should make these data routinely available in the A-train orbit (Aqua, PARASOL, CloudSat, and Aura). ADM;-Aeolus is expected to contribute to cloud measurements.

New action: WMO Space Programme will discuss with space agencies, via CGMS and at CM, near real time operational use of these data and operational follow-on planning.

S18. Recommendation S18 is to be found in Section "Process studies" below

S19. Limb Sounders - Temperature profiles in the higher stratosphere from already planned missions oriented to atmospheric chemistry exploiting limb sounders should be made operationally available for environmental monitoring.

Progress: MIPAS and SCIAMACHY data are available in near real time from the ESA ftp server.

New action: WMO Space Programme will discuss with space agencies, via CGMS, progress/plans for distribution of data from MIPAS and SCIAMACHY on ENVISAT, from MLS and HIRDLS on Aura, and from similar instruments.

S20. Active Water Vapour Sensing - There is need for a demonstration mission of the potential of high-vertical resolution water vapour profiles by active remote sensing (for example by DIAL) for climate monitoring and, in combination with hyper-spectral passive sensing, for operational NWP.

New action: WMO Space Programme will discuss with space agencies, via CGMS.

S21. Lightning Observation – There is a requirement for global observations of lightning. Several initiatives for operational space-based implementation exist. These should be encouraged to fruition.

Comment: NASA's observations of lightning from OrbView-1/OTD and TRMM/LIS have demonstrated that 90% of lightning occurs over land, and that it is heavily tied to deep convection. In addition to its importance in severe storms and warnings for safety, lightning is an importance source of NO_X and thus contributes to elevated levels of tropospheric ozone.

Progress: The dynamics of lightning occurrence and its importance for nowcasting has been recognized by NOAA that plans to include a lightning sensor on GOES-R and CMA that plans a lightning mapper on FY-4. It is under consideration by EUMETSAT for MTG however EUMETSAT are reviewing requirements and implementation options for lightning observations and the potential role of ground-based observations to meet requirements is being re-assessed.

New action: WMO Space Programme will continue to monitor the issue with space agencies, via CGMS.

S22. Formation Flying – Advantages of formation flying need to be investigated.

Comment: NASA has already demonstrated both a morning constellation (involving Landsat 7, EO-1, SAC-C, and Terra) and an afternoon constellation (Aqua, PARASOL, Aura, CloudSat (2006) and CALIPSO (2006), soon to by joined by OCO (2008)). These multi-agency and multi-country constellations demonstrate the added value of coordination of Earth observations to make a polar orbiting system greater than the sum of the parts, but able to launch when sensors and spacecraft are ready and available.

New action: The utility of data from sensors flying in formation need to be assessed. WMO Space Programme will discuss with space agencies, via CGMS

Process studies

In reviewing the Implementation Plan for the Evolution of the Global Observing System, and not withstanding other potential requirements, the need for following process study mission was identified:

S18. LEO Far IR - An exploratory mission should be implemented, to collect spectral information in the Far IR region, with a view to improve understanding of water vapour spectroscopy (and its effects on the radiation budget) and the radiative properties of ice clouds.

New action: WMO Space Programme to discuss with space agencies, via CGMS

Additional recommendations for Climate Monitoring

Long-term continuity of observations shall be ensured for the following Essential Climate Variables, which are not addressed within the recommendations above:

- Ocean colour (GIP, Action O18)
- Sea ice (GIP, Action O23)
- Cryosphere (GIP, Action T14)
- Land cover (GIP, Action T24)

Detailed requirements for these observations are contained in the Satellite Supplement to the GCOS Implementation Plan (GIP) "GCOS Systematic Observations Requirements for Satellite-based Products for Climate" (GCOS-107, September 2006, WMO/TD N°1338)

4. Considerations for evolution of the GOS in developing countries

4.1 In preparing this Implementation Plan, it was noted that redesign of the GOS included several special considerations and issues that involve developing countries. In many areas of Africa, Asia, and Latin America (Regions I, II, and III and some tropical areas between 25N and 25S), the current GOS provides no observations, whereas in other areas observations should be improved. When looking at candidate observing systems, consideration must be given not only to NWP but also to many other applications, including human forecasting. The evolution of the GOS in developing countries must address some of the issues that fall in three categories: (a) lack of public infrastructure such as electricity, telecommunication, transport facilities, etc., (b) lack of expertise from people to do the job, training, etc., and (c) funding for equipment, consumables, spare parts, manpower, etc. The lack of infrastructure and expertise may be the result of a lack of funding.

4.2 The evolution must take into account upgrading, restoring, substitution and capacity building (especially in the use of new technologies). Two aspects need to be considered: the data production and the data use. It is possible that some countries do not and will not be able to produce data and will therefore only be users of data. To help developing countries produce data for international exchange, due consideration must be given to the three issues previously identified i.e. public infrastructure, expertise and funding.

4.3 Possible approaches towards the redesign have been discussed. A first step should be to identify observing systems that are less dependent on local infrastructure. In some circumstances, these include satellite, AMDAR, dropsondes, and AWS. Nonetheless, a minimum set of reliable RAOBs is required as a backbone to the GUAN and RBCN; these are also used to validate the satellite observations. Migration toward the table-driven codes (BUFR or CREX) as a reliable representation of the data is expected.

4.4 However, obtaining vertical profiles by AMDAR in many data sparse areas is worth testing. It must be recognized that AMDAR ascent/descent and *en route* data will provide little stratospheric information and currently no humidity data (although humidity sensors are being tested). It is imperative that useful approaches be drafted for studying the impact of additional observations (e.g. AMDAR) in regions of scarce conventional observations (e.g. RAOBS) and discuss possible observing system experiments to explore enhancing the observations on these areas. More generally the role of developing countries in the THORPEX through the regional associations should be explored.

4.5 Capacity building in some countries needs further attention. Some countries have satellite-receiving stations or receive satellite data through the GTS, but lack the expertise to utilize the information to their benefit. Some countries are acquiring Doppler radar but need training on how to retrieve the information. For example, Region I has benefited with expanded access to conventional data and satellite imagery through the PUMA project. This type of project should be expanded to include other data types for routine application (synoptic, aviation, nowcasting). Developments through the AMMA project offer a proposing route forward in some parts of Region I, and special attention should be paid to maintaining the selected parts of the network once the AMMA project has concluded.

4.6 If resources are available, the highest priority should go to (a) maintaining the RBSN and RBCN, noting that GSN and GUAN stations are part of the RBSN, and (b) to rehabilitate observing sites in critical locations.

4.7 Finally, the following recommendations should be taken into account when addressing the evolution of the GOS in developing countries:

- o Define geographical areas using advanced techniques to help identify where priority should be if additional funding were available;

- Encourage regional associations in concert with CBS to define trial field experiments over data sparse areas, for a limited time, to evaluate how additional data would contribute to improve performance at the regional and global scale. A clearly demonstrated impact might make it easier to agree on some coordinated funding mechanism for areas concerned including funding from GEF (Global Environmental Facilities) for climate stations;
- Examine whether automated stations could become a viable, cost effective alternative to manned stations for the surface network in the future;
- In data-sparse areas of the world, make full use of AMDAR ascent/descent data at major airports; however the RAOB network still plays an important role in human forecasting;
- When changes are made to the climate observing systems, the GCOS Climate Monitoring Principles should be followed;
- The telecommunication problems should be referred to the OPAG on ISS and looked at as a priority;
- Prioritize where the needs are most pressing for VCP or other funding.
- High priority should be given by the region and secretariat to maintain a minimum RAOB network with acceptable performance within data-sparse regions.

ANNEX A

ACRONYMS

4DVAR	Four-Dimensional Variational Assimilation
ADM-Aeolus	Atmospheric Dynamics Mission (ESA)
AES	Atmospheric Environment Service (Canada)
AFIRS	Automated Flight Information Reporting System
AIRS	Advanced Infra-red Sounder
AMDAR	Aircraft Meteorological Data Delay
AMSU	Advanced Microwave Sounding Unit
AMV	Atmospheric Motion Vector
AOPC	Atmospheric Observation Panel for Climate
Argo	Array for Real-time Geostrofic Oceanography
ASCAT	Advanced Scatterometer
ASAP	Automated Shipboard Aerological Programme
ATOVS	Advanced TIROS Operational Vertical Sounder
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automatic Weather Station
BUFR	Binary Universal Form for the Representation of Meteorological Data
CALIOP	Cloud Aerosol Lidar with Orthogonal Polarization
CAS	Commission for Atmospheric Sciences
CBS	Commission for Basic Systems
CGMS	Coordination Group for Meteorological Satellites
CHAMP	CHAllenging Minisatellite Payload
CIMO	Commission for Instruments and Methods of Observation
CMA	China Meteorological Administration
COSMIC	Constellation Observing System for Meteorology, Ionosphere and Climate
COSNA	Composite Observing System for the North Atlantic
CREX	Character Form for the Representation and Exchange of Data
DIAL	Differential Absorption Lidar
E-AMDAR	EUMETNET-AMDAR
EARS	EUMETSAT ATOVS (now Advanced) Retransmission Service
ECMWF	European Centre for Medium-Range Weather Forecasts
EGPM	European (contribution to) Global Precipitation Measurement
ERB	Earth Radiation Budget
ESA	European Space Agency
ET-EGOS	Expert Team (ET) on the Evolution of the Global Observing System (EGOS)
ET-SSUP	Expert Team (ET) on Satellite Systems Utilization and Products (SSUP)
EUCOS	EUMETNET Composite Observing System
EUMETNET	European Meteorological Services Network
FASTEX	Fronts and Atlantic Storm Track Experiment
FY-4	Feng Yun-4 (Chinese geostationary satellite series)
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEO	Geostationary Orbit Satellite
GIFTS	Geosynchronous Imaging Fourier Transform Spectrometer
GLAS	Geoscience Laser Altimeter System

GMES	Global Monitoring of Environment and Security
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GOS	Global Observing System
GPM	Global Precipitation Measurement
GRAS	GNSS Receiver for Atmospheric Sounding
GSICS	Global Space-based Inter-Calibration System
GSN	GCOS Surface Network
GTS	Global Telecommunication System
GUAN	GCOS Upper-Air Network
HIRDLS	High Resolution Dynamic Limb Sounder
HIRS	High Resolution Infra-red Sounder
IASI	Infra-red Atmospheric Sounding Interferometer
IGDDS	Integrated Global Data Dissemination Service
IGEOLab	International Geostationary Laboratory for demonstration missions
IGOSS	Integrated Global Ocean Services System
IMD	India Meteorological Department
IOC	Intergovernmental Oceanographic Commission
IOS	IGOSS Observing System
IP	Implementation Plan
ISRO	Indian Space Research Organization
JASON	Ocean surface topography mission
JAXA	Japan Aerospace Exploration Agency
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
LEO	Low Earth Orbit
LIS	Lightning Imaging Sensor
MDS	Meteorological Data System
MERIS	Medium Resolution Imaging Spectrometer
METOP	Meteorological Operational Satellite (EUMETSAT)
MIPAS	Michelson Interferometer for Passive Instrument Sounding
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectroradiometer
MTG	Meteosat Third Generation
MTSAT-FO	Multi-purpose Transport Satellite Follow-On
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data and Information Service
NMHSs	National Meteorological and Hydrological Service(s)
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program
NRT	Near-Real Time
NWP	Numerical Weather Prediction
OPAG	Open Programme Area Group
OSE	Observing System Experiments
PUMA	Preparation for the Use of Meteosat Second Generation (MSG) in Africa

R&D	Research and Development (satellite)
RAOB	Radiosonde Observations
RBCN	Regional Basic Climatological Network
RRR	Rolling Requirements Review
SAC-C	Earth-observation satellite (CONAE, Argentina)
SAR	Synthetic Aperture Radar
SCHIAMACHY	Scanning Imaging Absorption Spectrometer for Instrumental Cartography
SEG	Scientific Evaluation Group of COSNA
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMOS	Soil Moisture and Ocean Salinity satellite
SVPB	Surface Velocity Program Barometer drifter
TAMDAR	Tropospheric Airborne Meteorological Data Reporting
THORPEX	The Observing System Research and Predictability EXperiment
TRMM	Tropical Rainfall Measuring Mission
UAV	Unmanned Aerial Vehicle
VCP	Voluntary Co-operation Programme
VIIRS	Visible Infrared Imager Radiometer Suite
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WOTAN	Wind Observation Through Ambient Noise
WVSS	Water Vapour Sensing System
WWWW	World Weather Watch
XBT	Expendable Bathy Thermograph
ZTD	Zenith Total Delay

ANNEX B

VISION FOR THE GOS in 2015

In drafting the recommendations for an evolved GOS and then the Implementation Plan, the ET was guided by the following vision for the GOS in 2015 and beyond, as adopted by CBS (CBS Extr., Cairns, 1-12 December 2002).

For the space-based sub-system, there would be:

6 operational GEOs
- all with multi-spectral imager (IR/VIS)
- some with hyper-spectral sounder (IR)

4 operational LEOs
- optimally spaced in time
- all with multi-spectral imager (MW/IR/VIS/UV)
- all with sounder (MW)
- three with hyper-spectral sounder (IR)
- all with radio occultation (RO)
- two with altimeter
- three with conical scan MW or scatterometer

Several R&D satellites serving WMO members
- constellation of small satellites for radio occultation (RO)
- LEO with wind lidar
- LEO with active and passive microwave precipitation instruments
- LEO and GEO with advanced hyper-spectral capabilities
- GEO lightning
- possibly GEO microwave

All with improved inter-calibration and operational continuity.

For the surface-based sub-system, there would be:

Automation to enable
- targeting of observations in data sensitive areas
- optimal operation of
    - o radiosondes
    - o ASAP systems
    - o aircraft in flight

Radiosondes
- optimized utilization
- stable and functioning RBSN, RBCN and GUAN
- supplemented by
    - o AMDAR ascent/descent
    - o ground-based GPS water vapour information
    - o wind profilers
    - o satellite soundings
- automatically launched
- computerized data processing
- real-time data transmission
- high vertical resolution

Commercial aircraft observations
- of temperature & wind plus humidity on some aircraft
- In-flight and ascent/descent data
- high temporal resolution
- available from most airports including currently data void airports in Asia, Africa and South America.
- possibly supplemented with UAVs

Surface observations
- stable and functioning RBSN, RBCN and GSN
- automated systems
- land sensors at high spatial resolution, supporting local applications such as road weather
- ocean platforms (ship, buoys, profiling floats, moorings) in adequate number to complement satellite measurements

Radar observing systems measuring
- radial winds
- hydrometeor distribution and size
- precipitation phase, rate, and accumulation
- multiple cloud layers, including base and top height.

Data collection and transmission
- digital in a highly compressed form
- entirely computerized data processing
- role of humans in observing chain reduced to minimum
- information technology in all areas of life will provide new opportunities for obtaining and communicating observations
- for satellite data in particular
    - use of ADM including regional/special DCPC in the context of FWIS
    - DB for special local applications in need on minimal time delay and as backup