WORLD METEOROLOGICAL ORGANIZATION

WORLD WEATHER WATCH

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

Developed by the CBS Open Programme Area Group on the Integrated Observing Systems (OPAG-IOS)

WMO/TD No. 1267

CONTENTS

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1. Background

1.1 CBS requested the OPAG-IOS and specifically the Expert Team on Observational Data Requirements and Redesign of the Global Observing System (ET-ODRRGOS) to: (a) to continue the Rolling Requirements Review (RRR), under which requirements for observations to meet the needs of all WMO Programmes are compared with the capabilities of present and planned observing systems to provide them; (b) to suggest changes in the Global Observing System (GOS) filling gaps identified by the RRR; and (c) to draft an implementation plan for the re-design (or more appropriately the evolution) of the GOS.

1.2 The significant findings that have formed the basis for the implementation plan were:

a. The RRR is readily applied to a diversity of applications areas, provided the data base of user requirements and observing system capabilities is accurate;

b. Working with the Rapporteurs on Regional and Global Observing System Experiments (OSEs), it was found that hypothetical changes to the GOS can be explored in OSEs with NWP centre assistance, provided data assimilation procedures are well understood and impact studies are conducted in a statistically significant way. Further it was made apparent that Observing System Simulation Experiments (OSSEs) require huge human and computer resources and were beyond the available resources;

c. The future GOS should build upon existing sub-systems, both surface and space based, and 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);

d. The scope of the next decades changes to the GOS will be so massive that new revolutionary approaches for science, data handling, product development, training, and utilization will be required. There is an urgent need to study comprehensive strategies for anticipating and evaluating changes to the GOS.

1.3 Several major additional working results by the ET-ODRRGOS influenced the content of the Plan. They were:

a. Users Requirements and Observing System Capabilities were charted in ten application areas (after engaging experts in each area). The RRR was pursued, and Statements of Guidance were issued in all ten areas (available in WMO/TD-Nos. 913, 992, 1052 and summarized in the final report of the July 2002 ET-ODRRGOS meeting);

b. Several Observing System Experiments were pursued to test possible re-configurations of the GOS (these are summarized in section 5 of this Annex);

c. Candidate Observing Systems (space-based and ground-based) for the coming decade were studied (reported in WMO/TD-No.1040);

d. Special challenges and issues concerning developing countries were considered and addressed (see section 4 of this Annex);

e. Recommendations for the evolution of space-based and surface-based sub-systems of the GOS were drafted and endorsed by CBS (available in the final report of the October 2002 ICT meeting);

f. A vision for the GOS of 2015 and beyond was drafted and endorsed by CBS and EC.

1.4 Beneficial input was received from the Expert Team on Satellite System Utilization and Products (ET-SSUP) stemming from their evaluations of the Biennial Questionnaire for the WMO Strategy to Improve Satellite System Utilization, training experiences with the CGMS/WMO Virtual Laboratory, and recommendations on Advanced Dissemination Methods (ADM). The Expert Team on Automatic Weather Systems (ET-AWS) offered guidance with regard to measurement standards and technology developments in ground based observations.

1.5 The resulting Implementation Plan for the Evolution of the GOS (see section 3) presents a coherent approach for implementing the necessary changes to the space-based and surface-based sub-systems of the GOS so that the vision for the GOS of 2015 can be realized.

2. CBS Recommendations on the Implementation Plan

2.1 Forty-seven recommendations included in the Implementation Plan provided the framework for the evolution of the GOS. Those recommendations reflect: the Statements of Guidance produced in ten applications areas, results from regional programmes (such as COSNA, EUCOS and NAOS), conclusions from the Toulouse and Alpbach Workshops on Impact of Various Observing Systems on NWP (see WMO/TD No. 1034 and 1228 respectively), and results of Specific OSEs carried out to asses possible reconfiguration of the GOS.

2.2 CBS-XIII (St.- Petersburg, Russian Federation, 23 February-3 March 2005) expressed its gratitude to all experts who had been involved in preparation and reviewing the Implementation Plan and requested the Secretary-General to publish it and arrange for its circulation, as a guidance material to Members, appropriate working bodies of regional associations and technical commissions. The Commission felt that on circulating guidance material to Members, it would be helpful to request Members to identify implementation impediments and difficulties as a means of assessing implementation progress and identifying where further work may be required.

3. Implementation Plan for the Evolution of GOS

3.1 Recommendations for the evolution of *Space-Based Sub-system* of GOS

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. The advent of high spectral resolution infrared sensors will enhance accurate intercalibration.

Progress: CGMS-XXXI discussed GCOS Climate Monitoring Principles, inter-calibration of visible sensors, and inter-calibration of IR sensors on all GEOs with HIRS and AVHRR (reporting on the last item remains as a permanent action of CGMS). CGMS-XXXII considered improved infrared inter-calibration capabilities using AIRS data; the

implications for GCOS Climate Monitoring Principles were discussed. CEOS hosted a calibration workshop in October 2004.

Next Action: WMO Space Programme to continue discussions with space agencies, via CGMS.

Schedule: Continue activity with current sensors and expand to IASI by CGMS in 2006.

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: All operators reported plans at CGMS: NOAA, EUMETSAT and Russia reported plans for a SEVIRI-like capability by 2015.

Next Action: WMO Space Programme to continue discussions with space agencies, via CGMS.

Schedule: Firm plans to reach this goal should be in place by CGMS in 2006.

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: This was to be demonstrated by GIFTS. However, for budgetary reasons, NASA has recently curtailed the GIFTS mission to assemble and vacuum test Engineering Design Unit; realization of a GIFTS demonstration in geostationary orbit is a task to be undertaken by the international community, possibly within the International Geostationary Laboratory (IGeoLab).

Progress: All operators reported plans at CGMS: NOAA has firm plans including this capability for the GOES-R series; EUMETSAT has it under consideration for the MTG series; China and India have plans for capability similar to current GOES sounder before 2010. CGMS endorsed the concept of the International Geostationary Laboratory (IGeoLab) that would be a joint undertaking to provide a platform for demonstrations from geostationary orbit of new sensors and capabilities. GIFTS is one of two systems being considered for IGeoLab. Roshydromet and Roskosmos are negotiating with NOAA the possibility to install GIFTS on board of the subsequent geostationary satellite “ELEKTRO”.

Next Action: WMO Space Programme to coordinate a GIFTS demonstration on IGeoLab with space agencies and to report plans at CGMS in 2005 (note Next Action on S-13).
Schedule: Plans from all space agencies for hyperspectral geostationary sounding should be in place by CGMS 2006.

S4. GEO Imagers and Sounders - 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.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, the strategy for implementation with attention to the problems of achieving required system reliability and product accuracy.

Schedule: Plan should be available by CGMS in 2006

LEO satellites

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

Progress: EARS 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. NPOESS plans are for data delivery in less than 30 min and thus consistent with this requirement.

Next Actions: WMO Space Programme to plan, with Members and CGMS, the development of Advanced Dissemination Methods (ADMs) and an Integrated Global Data Dissemination Service (IGDDS), to include: (1) the extension and enhancement of EARS; (2) the implementation of similar systems, with a goal of achieving timely retransmission of local data sets covering the globe; (3) an equivalent system for NPP data; (4) expansion of EARS and equivalent systems to include IASI data; and (5) establishment of equivalent systems for the LEO data from satellites of other agencies.

Schedule: Plan for IGDDS, including above elements, prepared by mid-2005, with goal for completion of phased implementation of global ATOVS retransmission service by mid-2006.

S6. LEO temporal coverage - Coordination of orbits for 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.
Next Action: WMO Space Programme to collaborate with space agencies, via CGMS, on a target system that will be implemented and to take steps towards achieving it.

Schedule: Target system agreed upon by CGMS in 2006.

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. In the NPOESS and METOP era, sea surface wind should be observed in a fully operational framework. Therefore it is urgent to assess whether the multi-polarisation passive MW radiometry is competitive with scatterometry.

Progress: 3 months of data has been made available to Windsat science team.

Next Action: WMO Space Programme, via CGMS, to request assessment of Windsat performance and to consider the implications for the evolved GOS.

Schedule: Assess Windsat performance by 2005. Assess implications and provide feedback to NOAA by 2005.

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

Progress: Agreement has been reached to proceed with JASON-2.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, the continuity of operational provision after JASON-2.
Schedule: Plans for operational follow-on should be reported at CGMS in 2006.

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

Comment: There are no current plans for ERB-like measurements after Aqua. There are also concerns about the continuity of absolute measurements of incoming solar radiation.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS.
Schedule: Plans for continuity of capability should be available by CGMS in 2006.

R&D satellites

S10. LEO Doppler Winds - Wind profiles from Doppler lidar technology demonstration programme (such as Atmospheric Dynamics Mission - 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.

Comment: Plans for Aeolus demonstration are proceeding on schedule, but there are no plans for operational follow on.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, to assure demonstration with Aeolus and initiation of operational systems for wind profile measurement.

Schedule: To confirm plans for near real time (NRT) data distribution by CGMS in 2005. Plans for continuity of a Doppler Winds capability following Aeolus should be formed by CGMS in 2006.

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.

Progress: TRMM continues to provide valuable data for operational use. Early termination of TRMM after 2004 will adversely affect WMO Members. At CGMS-XXXII, NASA, ESA and JAXA reported plans for a GPM mission in 2008. ESA's EGPM launch will be decided if and when this mission is selected.

Next Action: WMO Space Programme to continue discussions with space agencies, via CGMS.

Schedule: Plans should be reported at CGMS in 2006.

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

Progress: CHAMP and SAC-C data have been available to some centres but not in near real time (NRT). NWP OSE has shown positive impact with small number of occultations. Climate applications are being explored. There has been good progress in planning for NRT distribution of METOP/GRAS and COSMIC data.

Next Actions: WMO Space Programme to discuss with space agencies, via CGMS, (1) the proposal to develop a shared ground network system and (2) operational constellations following COSMIC.

Schedule: Plan for shared ground network should be available by CGMS in 2006. Plan for operational follow-on should be drafted by CGMS in 2006.

S13. GEO Sub-mm - 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: EUMETSAT, NESDIS and WMO prepared a paper for CGMS on the International Geostationary Laboratory (IGeoLab) that would be a joint undertaking to provide a platform for demonstrations from geostationary orbit of new sensors and capabilities. Geo sub-mm is one of two systems being considered for IGeoLab.

Next Action: WMO Space Programme to continue dialogue with space agencies, via CGMS

Schedule: Plan for IGeoLab should be drafted by CGMS in 2005.

S14. LEO MW - 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 OCE) 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.

Recent Progress: ERS data sets have provided monthly global soil moisture maps since 1991 at 50 km resolution.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS

Schedule: WMO Space Programme to report to ET following CGMS in 2006.

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, land surface cover.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS, (1) access by WMO Members to ENVISAT SAR data, and (2) continuity of such missions.

Schedule: Assessment of status and plans completed by CGMS in 2006.

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.

Progress: Cloudsat will carry a R&D aerosol instrument. NPOESS is adding an aerosol instrument. This issue has been referred to the CEOS SIT and CGMS.

Next Action: WMO Space Programme to continue discussions with space agencies, via CGMS and CEOS.

Schedule: Plans for data distribution should be drafted by CGMS in 2006. WMO Space Programme to report to the Expert Team following CGMS in 2006.

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.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS

Schedule: WMO Space Programme to report to the Expert Team following CGMS in 2005.

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.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS

Schedule: WMO Space Programme to report to the Expert Team following CGMS in 2005.

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.

Next Action: WMO Space Programme to 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.

Schedule: Plans for data distribution should be documented by CGMS in 2006.

S20. Active Water Vapour Sensing - There is need for an exploratory mission demonstrating 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.

Next Action: WMO Space Programme to discuss with space agencies, via CGMS.

Schedule: WMO Space Programme to report to the Expert Team following CGMS in 2005.

3.2 Recommendations for the 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: Recent 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 Automatic Weather Systems (AWS).

Next Actions: CBS to urge WMO Members to implement this recommendation at the earliest possible date.

(b) Observational data that are useful for meteorological applications at other NMHSs should be exchanged internationally, taking into account Res. 40 (Cg-XII). 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 summarize the data available in their regions and strive to make these data available via WMO real time or near-real-time information systems, whenever feasible.

Next Actions: Rapporteurs/Coordinators on Regional Aspects of the GOS, via letter from Secretariat, be requested to provide information on data potentially available in this category. [The letter should request supply and alert potential users to plans]. ET-ODRRGOS in 2005 should review input and consider which potentially available data merit further action.

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

Next Actions: (1) WMO Secretariat to draft a letter to Members (NWP centres) requesting report of specific problems inhibiting effective use of available data. [In these letters Members should be asked to address problem areas for each data type. Reports should be specific and indicate what problems are preventing users from using data effectively.]; (2) ET-ODRRGOS will review responses; (3) Based on the analysis of 1 and 2 above, such information should become accessible through a centralized WMO web page (late 2005).

G3. Timeliness and Completeness - There should be a timely distribution of radiosonde observations with all observation points (not just mandatory levels) 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.

Next Actions: CBS to urge all Members with the existing capability of producing full vertical resolution sounding data to implement the transmission as soon as possible, starting in November 2005. Further, 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 (or CREX) 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. Collaboration with CIMO and various code groups should be established.

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 important.

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 will continue to be collected from a mix of observing system components and will in the future 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 the International Polar Year should give guidance for that data sparse region.

Next Action: OPAG-IOS chair in consultation with the chairs of the Regional Working Group on Planning and Implementation of WWW to ensure that operators and managers of regional observing systems are made aware of developments in this area (CBS in 2005).

G5. Stratospheric observations - Requirements for a stratospheric global observing system should be refined. The need for radiosonde, radiance, wind, and humidity data should be documented, 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 satellite mission likely will provide a substantial enhancement to the stratospheric observing system. Further, AOPC has noted that current *in situ* measurement capabilities for upper tropospheric and lower stratospheric water vapour are not meeting climate requirements and stressed need for further technology development.

Next Action: ET-ODRRGOS to initiate further OSEs to include the use of COSMIC data when available. Results of OSEs to be reviewed and consolidated at that stage (2008).

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. [This 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]

Next Action: CBS and CAS to request WMO Members making ozone profile measurements to place data on the GTS in near real time in BUFR/CREX format at the earliest possible date. Secretariat to inform Members of this requirement and request Members to inform WMO of their implementation plans (November 2005).

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.

Comment: The proof of the observation targeting concept was given by US Weather Service in the northeastern Pacific winter storms and land-falling hurricane situations. 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.

Next Action: The OPAG-IOS Chair to maintain liaison and ensure targeting strategies developed by THORPEX are made available to the CBS.

Optimization of rawinsonde distribution and launches

G8. RAOBs - Optimize the distribution and the launch times of the rawinsonde sub-system (allowing flexible operation while preserving the GUAN network and taking into consideration regional climate requirements of the RBCN). 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. [This 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.

Next Actions: ET-ODRRGOS to follow the THORPEX Implementation Plan and to learn from the THORPEX experience. When appropriate, ET-ODRRGOS to request Secretariat to inform Rapporteurs/Coordinators on Regional Aspects of the GOS and managers of observing systems of the requirements for adapting to flexible observing practices including taking observations on demand, while safe-guarding the integrity of the baseline observing system.

Development of the AMDAR Programme

G9. 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. [This recommendation is supported by information from the Toulouse report, ECMWF northern hemisphere AMDAR impact study, OSEs 4, 5, 8]

Progress: The AMDAR Panel plans 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;
- Development and use of new onboard software and alternative AMDAR technologies;
- Selective deployment of humidity/water vapour sensors;

- Provision of targeted observations into data sparse areas and special weather situations;
- Use of optimisation systems to improve cost effectiveness;
- Improvements in the monitoring, quality control;
- Efforts to encourage and pursue the free exchange of data; and
- Improvements in user awareness & training plus operational forecasting tools and systems.

The AMDAR Programme Implementation Table follows.

Programme Items	2005-2006	2008	2010
Operational programmes (Australia, E-AMDAR*, New Zealand, USA, South Africa)	Expanding	Stable	Stable
Emerging programmes (Hong Kong China, Saudi Arabia, Japan, Canada, Central-western Africa)	Expanding	expanding/ stable	Stable
Developing programmes (Chili, Argentina, UAE, Rep. of Korea, China)	first data	expanding	Stable
Planned programmes (Eastern-central Europe#, Russian Federation, Oman, Egypt, Morocco, Kenya, Pakistan, India, Iran, Israel, Libya))		first data	expanding
Development software and technologies	work in progress	operational	Stable
Humidity/water vapour sensors	operational trials	expanding	operational
Targeted data	Partly operational	expanding	expanding
Optimisation systems	Partly operational	expanding	expanding
Data monitoring, QC and data exchange	Ongoing	Ongoing	ongoing
Awareness and training	Ongoing	Ongoing	Stable
Development of operational forecasting tools	in progress	operational	operational

*E-AMDAR: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK

Eastern-central Europe: Poland, Romania, Ukraine, Czech Republic

Next Actions: ET-ODRRGOS to continue to monitor progress of the AMDAR Programme in the above activities. Several Members expressed their willingness to actively participate in the AMDAR programme supporting the need for training experts from developing countries.

G10. Transmission of AMDAR reports - Optimize the transmission of AMDAR reports taking into account, en route coverage in data-sparse regions, vertical resolution of ascent/descent reports, and targeting related to the weather situation. [This recommendation is supported by information from the Toulouse and Alpbach NWP OSE Workshop reports, ECMWF northern hemisphere AMDAR impact study].

Comment: AMDAR coverage is both possible and sorely needed in several currently data-sparse regions, especially Africa and South America, Canadian arctic, northern Asia and most of the world's oceans. More T, U/V, Q profiles, but especially winds, are needed

in the tropics. Moreover, the timing and location of reports, whose number is potentially very large, can be optimized while controlling communications costs.

Next Action: Rapporteur on AMDAR Matters to report progress to ET-ODRRGOS. Members in the Regions must assume responsibility of implementation.

G11. Humidity sensors on AMDAR - Further development and testing of water vapour sensing systems is strongly encouraged to supplement the temperature and wind reports from AMDAR. [This recommendation is supported by information from the Toulouse and Alpbach NWP OSE Workshop reports]

Progress: Demonstration of WVSS-2 is expected in 2004-05. This system employs an absolute measurement of water vapour content that is expected to be accurate from the ground to flight altitudes.

Next Action: Rapporteur on AMDAR Matters to report progress of AMDAR programme to ET-ODRRGOS.

Alternative AMDAR systems

G12. TAMDAR & AFIRS - To expand ascent/descent profile coverage to regional airports, the development of TAMDAR, and use of AFIRS should be monitored with a view towards operational use.

Comment: A range of systems including TAMDAR, AFIRS and MDS could supplement conventional AMDAR and radiosonde data by providing lower level en route observations and profiles over additional, regional airports not served by larger AMDAR compatible aircraft. Instrumentation would not necessarily be designed to function in the high troposphere and would therefore be less expensive.

Next Action: ET-ODRRGOS to review progress under AMDAR and EUCOS Programmes. First data from TAMDAR and AFIRS are expected in late 2004.

Atmospheric moisture measurements

G13. Ground GPS - Develop further the capability of ground-based GPS systems for the inference of vertically integrated moisture with an eye toward operational implementation. Ground based GPS processing (Zenith Total Delay and Precipitable Water, priority for ZTD) should be standardized to provide more consistent data sets. Data should be exchanged globally. [This 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 COSNA/SEG, NAOS, JMA reports provide useful background information.

Next Actions: CBS to urge Members to collect and exchange the ground-based GPS data. Members should take the appropriate action to ensure that the data processing be standardized by November 2005. Collaboration with CIMO should be established.

Regarding 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.

Next Action: ET-ODRRGOS to request a review from JCOMM on the current status and plans of ASAP.

G15. 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.

Next Action: ET-ODRRGOS to request information on progress regarding distribution of increased temporal and spatial resolution in situ marine observations from JCOMM.

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.]

Next Action: ET-ODRRGOS to request information on progress in extending the tropical mooring array from JCOMM.

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. [This recommendation is supported by information in the Toulouse NWP OSE Workshop Report and the ET-ODRRGOS OSE studies.]

Comment: Plans from agencies other than JCOMM need to be considered.

Next Actions: (1) ET-ODRRGOS to request information from JCOMM on plans for preserving/enhancing the network; (2) ET-ODRRGOS to review requirement for surface pressure observations in ocean areas based in results of OSE studies (EUCOS).

G18. XBT and Argo - For Ocean Weather Forecasting purposes, improve timely delivery and distribute 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.

Next Actions: (1) ET-ODDRGOS to request information on progress from JCOMM for the next ET-ODRRGOS meeting. (2) ET-ODRRGOS to review adequacy for WMO requirements.

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

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

*Actio*n: ET-ODRRGOS to request information on progress regarding ice buoys from JCOMM.

Improved observations over tropical land areas

G20. More profiles in Tropics - Temperature, wind and if possible 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.

Action: Rapporteurs on AMDAR and GCOS Matters to report to ET-ODRRGOS. CBS to urge Members to consider activation of silent stations through a shared funding programme.

New Observing Technologies

G21. AWS - Noting the widespread adoption of AWS, 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;

Next Action: ET-AWS to be asked to provide a summary of standards for coding and reporting, sharing of metadata, and advances in technology for ET-ODRRGOS.

G22. New systems - In the context of THORPEX, 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;
- Lidars.

Action: OPAG IOS Chair to liaise with the THORPEX ICSC and keep the relevant ETs informed. Collaboration with CIMO should be established.

3.3 Additional High Priority Recommendations for Evolution of the GOS

Interaction between NWP centres, data providers and users

N1. New data types - NWP centres should receive early (advance) information about and experience with new data types; this includes: (a) early access to test data and observations during the cal/val phase to prepare for the operational use of the data; and (b) information on the characteristics of the data and products (e.g. AMVs which may be representative of atmospheric layers rather than just one level over layers). [This recommendation is supported by information contained in the report from the Alpbach NWP OSE Workshop.]

Comment: Data assimilation and modelling capabilities have grown and are under constant development to make optimal use of current and future observing systems.

Action: ET-ODRRGOS through OPAG-IOS chair and CBS/CGMS to encourage data producers to provide metadata on observations and observing systems as early as possible. Several Members expressed their willingness to actively participate in providing Regional ATOVS retransmission services with other NMHSs concerned.

N2. Data from research satellites – R&D systems provide valuable data for NWP, which should be made available in a timely fashion. Research satellite data provide NWP centres with an excellent opportunity to prepare for new satellite data streams, which will become part of the operational global observing system. Effective learning of how to make use of new data types can best be achieved through operational use of any experimental data streams. [This recommendation is supported by information contained in the report from the Alpbach NWP OSE Workshop.]

Action: WMO Space Programme, in coordination with ET-ODRRGOS, through CBS and CGMS, to encourage operators of R&D satellites to provide early access to observations.

N3. Timely data delivery – Data processing and delivery systems should strive to meet NWP requirements of 30 minutes as much as possible.

Comment: The requirements for early delivery and frequent updates of forecast guidance have evolved over recent years. NWP centres have significantly reduced their data cut-off times at the expense of available observations in their data assimilation processes. Timeliness requirements for observational data are becoming more stringent for NWP centres. HH + 20 to 90 minute data cut-off times are currently applied for many NWP short-range runs. Late data can only be assimilated in update runs with long data collection times (several hours). Within the next few years, a data processing and delivery time of approximately 20 to 30 minutes is expected to be the operational requirement used in medium and short-range forecasts. Any minute gained is useful because observation arrival drives the rest of the forecast production chain.

Action: WMO Space Programme, in coordination with ET-ODRRGOS, through CBS and CGMS, bring to the attention of data producers the more stringent timeliness requirements for observational data at NWP centres, (NWP OSE workshop, Alpbach 2004).

O1. Observing System Study - Support well-resourced studies of re-designed observing systems. This is an ongoing process.

Next Actions: ET-ODRRGOS to monitor and learn from EUCOS and THORPEX demonstration studies of observing system capabilities. EUCOS studies evaluating the relative importance and the impact of the ground-based and space-based sub-systems will soon be commissioned (2005). This will result in an information exchange through documentation and workshops as appropriate.

T1. Training and information exchange for GOS Utilization – Support for sustained training must be realized as a primary means to assist WMO Members towards full exploitation of surface-based and satellite-based sub-systems of the GOS. Training must address data access, data use, and training of trainers. Networks for information exchange toward improved utilization of the GOS must be encouraged.

Recent Progress: A review process has been initiated and will be continued by the ET-SSUP with the issuance of a biennial questionnaire. Analysis of the questionnaire provides input to the CBS for WWW utilization.

Next Actions: For sustained training and education programme, CBS continue to solicit support from Members (e.g. capacity building training) and space agencies (e.g. CGMS/WMO Virtual Laboratory). WMO Space Programme, in collaboration with WMO Members and CGMS, continue to foster international groups and networks such as International TOVS Working Group, International Winds Workshops, and International Precipitation Working Group that provide fora for information and algorithm exchange.

4. Considerations for Evolution of the GOS in Developing Countries

4.1 In drafting this implementation plan, it was considered that 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 It was felt that capacity building in some countries needed 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).

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:

- Define geographical areas using advanced techniques to help identify where priority should be if additional funding was 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 and radiation 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, it may be more cost-effective to 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 challenged regions.

5. Specific OSEs carried out to assess possible reconfiguration of the GOS

In the course of the development a global approach to redesign of the GOS, the ET-ODRRGOS kept under permanent review the impact assessments studies being conducted by NWP centres under regional programmes such as COSNA, EUCOS and NAOS. The ET-ODRRGOS found that findings of COSNA, EUCOS and NAOS as well as conclusions and recommendations of the Toulouse and Alpbach Workshops on Impact of Various Observing Systems on NWP provided essential input to the redesign process of the GOS. Accordingly, the ET-ODRRGOS strongly supported the workshop recommendation that impact studies should be carried out for a sufficiently long period, preferably in each of four seasons and that the statistical significance of the results should be established. In addition, the ET ODRRGOS suggested nine OSEs for consideration by NWP centres and asked the OSE/OSSE Rapporteurs (Jean Pailleux and Nobuo Sato) to engage as many as possible in this work. Good response was received and results are coming in. The OSEs name and the initial results from the contributing NWP centres are listed below:

5.1. Impact of hourly versus 6-hourly surface pressures. Using 4DVAR assimilation ECMWF found positive impact especially over the north Atlantic and southern oceans.

5.2. Impact of denial of radiosonde data globally above the tropopause. The Canadian AES report found positive impact from RAOB data above the tropopause.

5.3. Information content of the Siberian radiosonde network and its changes during last decades. The Main Geophysical Observatory in St Petersburg found that information content was ascending until 1985, descending thereafter. NCEP related a decrease in performance of 500 hPa height analysis over NA to a decrease in Siberian RAOBs.

5.4. Impact of AMDAR data over Africa through data denial in a 4D-Var analysis and forecasting system. ECMWF showed that denial over NH of observations below 350 hPa

has large significant impact in summer and winter. Investigation of African AMDAR large significant negative impact is pending at Météo-France.

5.5. Impact of tropical radiosonde data. Met Office varied the density of SE Asia RAOBs used in assimilation and produced high impact on winds at all levels with occasional propagation of impact to mid-latitudes. Temperature and wind information is the most important potential measurements from AMDAR in less well-observed tropical areas (e.g. Africa, Central America).

5.6. Impact of three LEO AMSU-like sounders (NOAA –15, - 16, and -17 plus AQUA). ECMWF showed large positive impact from two AMSUs over one MSU. Met Office showed positive impact of three over two AMSU when NOAA-17 was added to the GOS.

5.7. Impact of AIRS data. ECMWF found that addition of one AIRS to a baseline observing system without satellites showed more impact than addition of one AMSU. Further, AIRS impact on the full GOS was positive (but initially small).

5.8. Impact of better than 3 hourly ascent descent AMDAR data. Preliminary NH AMDAR ascent/descent impact suggests positive effect of higher frequency data. EUCOS arranged higher frequency observations in 2003 to enable this study by Met Office and ECMWF.

5.9. Impact of polar winds from MODIS water vapor imagery. Initial 30-day impact study at ECMWF and NASA DAO showed that forecasts of the geopotential height for the Arctic, Northern Hemisphere extratropics, and Antarctica are improved significantly. Subsequent usage at more than ten NWP centres has confirmed positive impact of MODIS polar WV winds.

6. Dates of Update for Statements of Guidance

Synoptic Meteorology (April 2001)
Nowcasting and Very Short Range Forecasting (April 2001)
JCOMM Ocean Applications Areas (Jan. 2002)
Seasonal to Inter-annual Forecasts (Nov. 2003)
Aeronautical Meteorology (Nov. 2003)
Global Numerical Weather Prediction (Dec. 2003)
Numerical Weather Prediction (Jan. 2004)
Agrometeorology (July 2004)
Hydrology (July2004)
Atmospheric Chemistry (July 2004)

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