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VISION FOR THE GOS TO 2025

An introduction to this activity from a CGMS perspective was covered in detail at CGMS-35. Since that time the new Vision for the GOS has been developed using additional input from special workshops and OPAG-IOS Expert Teams. The Vision was endorsed by the CBS OPAG-IOS-ICT. The word “new” is used in the context that this Vision represents an evolution of the Vision as the original Vision to 2015 was first adopted by CBS in 2001 and subsequently endorsed by CGMS.

The Vision provides high-level goals to guide the evolution of the Global Observing System in the coming decades. These goals are intended to be challenging but achievable. System specific recommendations are given for evolution of both the surface and space-based sub-systems of the GOS.

CGMS satellite operators are invited to comment on this development, to support its refinement until CBS 2009 and after CBS 2009 contribute to its implementation in the coming decade.

Actions: CGMS satellite operators are invited to:
1) Comment on this new vision,
2) Support its refinement until CBS 2009
3) After CBS 2009 contribute to its implementation in the coming decade.

VISION FOR THE GOS TO 2025

1 BACKGROUND

The following briefly describes the activities that preceded the development of the new Vision for the GOS to 2025:

From 2002 to 2006

CBS-Ext.02, in December 2002, adopted a Vision for the GOS to 2015.

CBS-XIII, in October 2005, adopted the corresponding "Implementation Plan for the Evolution of the Space and Surface-based Sub-systems of the GOS" that was subsequently published as WMO TD No. 1267.

CGMS-34: agreed on Action 34.04 which requested "WMO to organize a second workshop on optimization of GEO and LEO satellite plans [and to] involve R&D agencies in addition to operationally-oriented ones." CGMS enters into discussions on the optimization of the space-based GOS taking into account GCOS requirements.

In November 2006, CBS-Ext 2006: requested "*OPAG-IOS to commence an update of the baseline of the space-based GOS up to 2025 as a new horizon, and expand its scope beyond the World Weather Watch in order to include sustained observations of additional variables required for climate monitoring, and ultimately to address the needs of other WMO Programmes.*"

Year 2007

WMO "Workshop on Re-design and Optimization of the Space-based GOS" (referred to as OPT-2) took place on 21 and 22 June 2007. Participants included operational and R&D space agencies: CMA, CNSA, ESA, EUMETSAT, JAXA, JMA, NASA, NOAA, USGS, as well as representatives of GCOS, of the Committee on Earth Observation (CEOS), the Chairman of OPAG-IOS, the Chairman of ET-EGOS, and the WMO Space Programme. The results from the workshop were the basis for developing a draft Vision for the space based sub-system of the GOS to 2025.

ET-EGOS-3, in July 2007, developed a draft Vision for the GOS to 2025 addressing both the surface and space-based components.

CGMS-35 reviewed the space-based aspects of the draft Vision which calls upon optimizing the existing operational GEO and LEO components, consolidating the altimetry measurement strategy, enhancing atmospheric sounding with an operational radio occultation constellation, refining sea surface wind observation, and bringing several new missions to an operational status: global precipitation, Earth Radiation Budget, atmospheric composition, specific imagery for ocean colour and vegetation and possibly missions in Molniya orbits.

The eighth session of Consultative Meetings commented on the draft Vision and encouraged its refinement in a forward-looking way, highlighting the benefit of scatterometry and of lightning detection.

The Vision was presented in April 2008 to the Strategy Implementation Team (SIT) of the Committee on Earth Observation Satellites (CEOS). Comments were subsequently forwarded by the CEOS Chair to the WMO Space Programme.

The draft Vision was presented to the WCRP-GCOS Atmospheric Observation Panel for Climate (AOPC) that reviewed Earth Radiation Budget issues in particular depth; and in May to the 14th International TOVS Study Conference (ITSC-XIV) for comments.

The 4th Workshop on the Impact of Various Observing Systems on NWP was held in Geneva in May 2008. Compared to the previous workshop (Alpbach, 2004), the main conclusion was about the emergence of new satellite systems (hyperspectral infra-red sounders, GPS radio-occultation systems) whose global impact has now the same magnitude as (e.g.) AMSU-A. The Workshop found that an important tendency of the period 2004-2008 has been the appearance of new observing systems (especially from satellites). The individual impact of most individual observing systems has decreased compared to 2004; but the total impact of the combined observing systems has improved and the GOS is now more robust because of the variety and quality of instruments available.

ET-EGOS-4 met in July 2008. Results of impact studies conducted by NWP centres and by participants in THORPEX were reviewed. Outcomes of the 4th Workshop were analyzed in terms of their implications for the evolution of the GOS. Suggestions on the draft Vision from ET-SAT and ET-SUP were taken into consideration. A revised draft of the new Vision for GOS was developed for further consideration by ET-SAT and ET-SUP and subsequently OPAG-IOS.

The joint ET-SAT and ET-SUP session in early September reviewed the status of operational and R&D satellite programmes and the gap analysis with respect to WMO requirements; discussed satellite products availability; and refined the new Vision to 2025 for the space-based component of the GOS for presentation at the OPAG-IOS ICT meeting held later that month.

The OPAG-IOS ICT was briefed in the development of the “Vision for the GOS in 2025” being undertaken by ET-EGOS. The many comments received from the ICT-IOS expert teams and other collaborators have been incorporated into the current version of the Vision which is expected to be submitted to CBS-XIV in March 2009 for consideration.

2 DISCUSSION

The current version of the new Vision for the GOS to 2025 is attached as Annex 1. Section 1 addresses general trends and issues including: responses to user needs; integration; expansion; automation; and consistency and homogeneity. Section 2 addresses specifics concerning the space-based and surface-based components.

> The Vision provides high-level goals to guide the evolution of the Global Observing System in the coming decades. These goals are intended to be challenging but achievable.

The future GOS will build upon existing sub-systems, both surface- and space-based, and capitalize on existing and new observing technologies not presently incorporated or fully exploited.

The scope of these changes to the GOS will be major and will involve new approaches in science, data handling, product development and utilization, and training.

The space based component envisions (table in annex provides details):

Operational geostationary satellites with at least six, separated by no more than 70 degree longitude;

Operational polar-orbiting sun-synchronous satellites distributed within three orbital planes (~13:30, 17:30, 21:30 ECT);

Additional operational missions in appropriate orbits (classical polar-orbiting, geostationary, others);

Operational pathfinders and technology demonstrators;

Polar and GEO platforms / instruments for Space Weather.

2.3 Implementing such a new Vision will require enhanced cooperation and coordination among operational and R&D agencies in order to optimize the effort, and to ensure timely availability and consistent quality of data worldwide. This new Vision, which contributes to the integration of the WMO Global Observing Systems, further reinforces the importance of the space-based GOS as a major component of the GEOSS.

3. CONCLUSIONS AND RECOMMENDATIONS

CGMS satellite operators are invited to comment on this development, to support its refinement until CBS 2009 and after CBS 2009 contribute to its implementation in the coming decade.

ANNEX

VISION FOR THE GOS IN 2025
(Draft dated 18 September 2008)

PREAMBLE

This Vision provides high-level goals to guide the evolution of the Global Observing System in the coming decades. These goals are intended to be challenging but achievable.

The future GOS will build upon existing sub-systems, both surface- and space-based, and capitalize on existing and new observing technologies not presently incorporated or fully exploited. Incremental additions to the GOS will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs); this will be particularly true for developing countries and LDCs.

The scope of these changes to the GOS will be major and will involve new approaches in science, data handling, product development and utilization, and training.

1. GENERAL TRENDS AND ISSUES

Response to user needs

- The GOS will provide comprehensive observations in response to the needs of all WMO Members and Programmes for improved data products and services, for weather, water and climate;
- It will continue to provide effective global collaboration in the making and dissemination of observations, through a composite and increasingly complementary system of observing systems;
- It will provide observations when and where they are needed in a reliable, stable, sustained and cost-effective manner;
- It will respond to user requirements for observations of specified spatial and temporal resolution, accuracy and timeliness; and,
- It will evolve in response to a rapidly changing user and technological environment, based on improved scientific understanding and advances in observational and data-processing technologies.

Integration

- The GOS will have evolved to become part of the WIGOS 1, which will integrate current GOS functionalities, which are intended primarily to support operational weather forecasting, with those of other applications: climate monitoring, oceanography, atmospheric composition, hydrology, and weather and climate research;
- Integration will be developed through the a nalysis of requirements and, where appropriate, through sharing observational infrastructure, platforms and sensors, across systems and with WMO Members and other partners.

Expansion

- There will be an expansion in both the user applications served and thevariables observed;
- This will include observations to support the production of Essential Climate Variables, adhering to the GCOS climate monitoring principles;
- Sustainability of new components of the GOS will be secured, with some R&D systems integrated as operational systems;

1 Assuming CBS endorse the move to the WIGOS structure

- The range and volume of observations exchanged globally (rather than locally) will be increased;
- Some level of targeted observations will be achieved, whereby additional observations are acquired or usual observations are not acquired, in response to the local meteorological situation.

Automation

- The trend to develop fully automatic observing systems, using new observing and information technologies will continue, where it can be shown to be cost-effective;
- Access to real-time and raw data will be improved;
- Observing system test-beds will be used to intercompare and evaluate new systems and develop guidelines for integration of observing platforms and their implementation; and
- Observational data will be collected and transmitted in digital forms, highly compressed where necessary. Data processing will be highly computerised.

Consistency and homogeneity

- There will be increased standardization of instruments and observing methods;
- There will be improvements in calibration of observations and the provision of metadata, to ensure data consistency and traceability to absolute standards;
- There will be increased interoperability, between existing observing systems and with newly implemented systems; and,
- There will be improved homogeneity of data formats and dissemination via the WIS.

2. THE SPACE-BASED COMPONENT

Instruments:	**Geophysical variables and phenomena:**
Operational geostationary satellites. At least 6, separated by no more than 70 deg longitude	
High-resolution multi-spectral Vis/IR imagers	Cloud amount, type, top height/temperature; wind (through tracking cloud and water vapour features); sea / land surface temperature; precipitation; aerosols; snow cover; vegetation cover; albedo; atmospheric stability; fires; volcanic ash
IR hyper-spectral sounders	Atmospheric temperature, humidity; wind (through tracking cloud and water vapour features); rapidly evolving mesoscale features; sea / land surface temperature; cloud amount and top height / temperature; atmospheric composition
Lightning imagers	Lightning (in particular cloud to cloud), location of intense convection.
Operational polar-orbiting sun-synchronous satellites distributed within 3 orbital planes (~13:30, 17:30, 21:30 ECT)	
IR hyper-spectral sounders	Atmospheric temperature, humidity and wind; sea / land surface temperature; cloud amount, water content and top height / temperature; atmospheric composition
MW sounders	
High-resolution multi-spectral Vis/IR imagers (including thermal IR water vapour absorption channel)	Cloud amount, type, top height / temperature; wind (high latitudes, through tracking cloud and water vapour features); sea / land surface temperature; precipitation; aerosols; snow and ice cover; vegetation cover; albedo; atmospheric stability
Additional operational missions in appropriate orbits (classical polar-orbiting, geostationary, others)	
MW imagers – at least 3 – some polarimetric	Sea ice; total column water vapour; precipitation; sea surface wind speed [and direction]; cloud liquid water; sea/land surface temperature; soil moisture
Scatterometers - at least 2 on well	Sea surface wind speed and direction; sea ice; soil moisture

separated orbital planes	
Radio occultation constellation – at least 8 receivers	Atmospheric temperature and humidity; ionospheric electron density
Altimeter constellation including a reference mission in a precise orbit, and polar-orbiting altimeters for global coverage	Ocean surface topography; sea level; ocean wave height; lake levels; sea and land ice topography
IR dual-angle view imager	Sea surface temperature (of climate monitoring quality); aerosols; cloud properties
Narrow-band high-spectral and hyperspectral resolution Vis/NIR imagers	Ocean colour; vegetation (including burnt areas); aerosols; cloud properties; albedo
High-resolution multi-spectral Vis/IR imagers – constellation	Land-surface imaging for land use and vegetation; flood monitoring
Precipitation radars operated in conjunction with passive MW imagers in various orbits	Precipitation (liquid and solid)
Broad-band Vis/IR radiometer + total solar irradiance sensor - at least 1	Earth radiation budget (supported by imagers and sounders on polar-orbiting and geostationary satellites) and collocated aerosols and cloud properties measurements
Atmospheric composition instruments constellation, including high spectral resolution UV sounder on geostationary orbit and at least a UV sounder on am + pm orbit	Ozone; other atmospheric chemical species; aerosols – for greenhouse gas monitoring, ozone/UV monitoring, air quality monitoring
Synthetic aperture radar	Wave heights, directions and spectra; floods; sea ice leads; ice shelf and icebergs
Operational pathfinders and technology demonstrators, including	
Doppler wind lidar on LEO	Wind; aerosol; cloud-top height [and base]
Low-frequency MW radiometer on LEO	Ocean surface salinity; soil moisture
MW imager / sounder on GEO	Precipitation; cloud water / ice; atmospheric humidity and temperature
High-resolution, multi-spectral narrow-band Vis/NIR and CCD imagers on GEOs	Ocean colour, cloud studies and disaster monitoring
Vis / IR imagers on satellites in high inclination, highly elliptical orbits (HEO)	Winds and clouds at high latitudes; sea ice; high latitude volcanic ash plumes; snow cover; vegetation; fires
Gravimetric sensors	Water volume in lakes, rivers, ground, etc.
Polar and geo platforms / instruments for space weather	
Solar imagery Particle detection Electron density	Solar radiation storms, high-energy particle rain, ionospheric and geomagnetic storms, radio black-out by X-ray photons

3. THE SURFACE-BASED COMPONENT

Station type:	**Geophysical variables and phenomena:**
Land – upper-air	
Upper-air synoptic and reference stations	Wind, temperature, humidity, pressure
Remote sensing upper-air profiling remote stations	Wind, cloud base and top, cloud water, temperature, humidity, aerosols
Aircraft	Wind, temperature, pressure, humidity, turbulence, icing, thunderstorms, dust / sandstorms, volcanic ash / activity, and atmospheric composition variables (aerosols, greenhouse gases, ozone, air quality, precipitation chemistry, reactive gases)
Atmospheric composition stations	Aerosol optical depth, atmospheric composition variables (aerosols, greenhouse gases, ozone, air quality, precipitation chemistry, reactive gases)
GNSS receiver stations	water vapour
Land – surface	
Surface synoptic and climate reference stations	Surface pressure, temperature, humidity, wind; visibility; clouds; precipitation; present and past weather; radiation; soil temperature; evaporation; soil moisture; obscurations

Atmospheric composition stations	Atmospheric composition variables (aerosols, greenhouse gases, ozone, air quality, precipitation chemistry, reactive gases)
Lightning detection system stations	Lightning (location, density, rate of discharge, polarity, volumetric distribution)
Application specific stations (road weather, airport / heliport weather stations, agromet stations, urban meteorology, etc)	Application specific observations
Land – hydrology	
Hydrological reference stations	Water level
National hydrological network stations	Precipitation, snow depth, snow water content, lake and river ice thickness/date of freezing and break-up, water level, water flow, water quality, soil moisture, soil temperature, sediment loads
Ground water stations	Ground water measurements
Land – weather radar	
Weather radar station	Precipitation (hydrometeor size distribution, phase, type), wind, humidity (from refractivity), sand and dust storms
Ocean – upper air	
Automated Shipboard Aerological Platform (ASAP) ships	Wind, temperature, humidity, pressure
Ocean – surface	
HF Coastal Radars	Surface currents, waves
Synoptic sea stations (ocean, island, coastal and fixed platform)	Surface pressure, temperature, humidity, wind; visibility; cloud amount, type and base-height; precipitation; weather; sea-surface temperature; wave direction, period and height; sea ice
Ships	Surface pressure, temperature, humidity, wind; visibility; cloud amount, type and base-height; precipitation; weather; sea surface temperature; wave direction, period and height; sea ice
Buoys – moored and drifting	Surface pressure, temperature, humidity, wind; visibility; sea surface temperature; 3D & 2D wave spectrum, wave direction, period and height
Ice buoys	Surface pressure, temperature, wind, ice thickness
Tide stations	Sea water height, surface air pressure, wind, salinity, water temperature
Ocean – sub-surface	
Profiling floats	Temperature, salinity, current, dissolved oxygen, CO_2 concentration
Ice tethered platforms	Temperature, salinity, current
Ships of opportunity	Temperature
R&D and Operational pathfinders – examples	
UAVs	Wind, temperature, humidity, atmospheric composition
Gondolas	Wind, temperature, humidity
GRUAN stations	Reference quality climate variables, cloud structure
Aircraft	Chemistry, aerosol, wind (lidar)
Instrumented marine animals	Temperature
Ocean gliders	Temperature, salinity, current, dissolved oxygen, CO_2 concentration

4. SYSTEM-SPECIFIC TRENDS AND ISSUES

4.1 Space-based

There will be an expanded space-based observing capability both on operational and research satellites.
There will be an expanded community of space agencies contributing to the GOS.

There will be increased collaboration between space agencies, to ensure that a broad spectrum of user requirements for observations are met in the most cost-effective manner, and that system reliability is assured through arrangements for mutual back-up.
Observational capability demonstrated on R&D satellites will be progressively transferred to operational platforms, to assure the reliability and sustainability of measurements.
R & D satellites will continue to play an important role in the GOS; although they cannot guarantee continuity of observations, they offer important contributions beyond the current means of operational systems. Partnerships will be developed between agencies to extend the operation of functional R&D and other satellites to the maximum useful period.
Some user requirements will be met through constellations of satellite, often involving collaboration between space agencies. Expected constellations include: altimetry, precipitation, radio occultation, atmospheric composition and Earth radiation budget.
Higher spatial, temporal and spectral resolution will considerably enhance the information available, particularly to monitor and predict rapidly-evolving, small-scale phenomena, whilst increasing the demand on data exchange, management and processing capability.
Improved availability and timeliness will be achieved through operational cooperation among agencies and new communications infrastructure.
Improved calibration and inter-calibration will be achieved through mechanisms such as GSICS.

4.2 Surface-based

The surface-based GOS will provide:

- improved detection of mesoscale phenomena;
- data that cannot be measured by space-based component;
- data for calibration and validation of space-based data;
- enhanced data exchange of regional scale observing data and product from weather radar, hydrological networks, etc.;
- high vertical resolution profiles from radiosondes and other ground based remote-sensing systems, integrated with other observations to represent the atmospheric structure;
- improved data quality with defined standards on availability, accuracy and quality control; and,
- long-term datasets for the detection and understanding of environmental trends and changes to complement those derived from space-based systems;
- maintenance of stations with long historically-uninterrupted observing records.

Radiosondes networks will:

be optimised, particularly in terms of horizontal spacing which will increase in data-dense areas, and taking account of observations available from other profiling systems;
be complemented by the aircraft (AMDAR) ascent / descents profiles and other ground-based profiling systems;
maintain the GUAN subset of stations for climate monitoring; and
include a GCOS Reference Upper-Air Network (GRUAN) to serve as a reference network for other radiosonde sites, for calibration and validation of satellite records, and for other applications.

Aircraft observing systems

will be available from most airport locations, in all regions of the world;
flight-level and ascent / descent data will be available at user-selected temporal resolution;
will observe humidity and some components of atmospheric composition, in addition to temperature, pressure and wind;

will also be developed for smaller, regional aircraft with flight levels in the mid-troposphere and providing ascent / descent profiles into additional airports.

Land-surface observations systems

will come from a wider variety of surface networks (e.g., road networks, mobile platforms) and multi-application networks;
will be primarily automated and capable of reproducing or substituting for measurements previously obtained subjectively (weather phenomena, cloud type, etc.);
will include the **GSN** subset of surface stations for climate monitoring.

Surface marine observations

from drifting buoys, moored buoys, ice buoys and Voluntary Observing Ships will complement satellite observations;
with improved temporal resolution and timeliness, through reliable and cost-effective satellite data communication systems;

Ocean sub-surface observing technology will be improved, including cost-effective multi-purpose *in-situ* observing platforms, ocean gliders, and instrumented marine animals.

Remote-Sensing observing systems:

Weather radar systems will provide enhanced precipitation products but with increased data coverage. They will increasingly provide information on other atmospheric variables. There will be much improved data consistency and new radar technology. Collaborative multi-national networks will deliver composite products.
Coastal HF Radars will provide for ocean currents and wave data
Profilers will be developed and used by more applications. A wider variety of technologies will be used, including lidars, radars and microwave radiometers. These observing systems will be developed into coherent networks and integrated with other surface networks.
Global Navigation Satellite System (e.g., GPS, GLONASS and GALILEO) receiver networks, for observing total column water vapour, will be extended.
These systems will be integrated into “intelligent” profiling systems and integrated with other surface observing technologies.

Lightning detection systems

Long-range lightning detection systems will provide cost-effective, homogenized, global data with a high location accuracy, significantly improving coverage in data sparse regions including oceanic and polar areas.
High-resolution lightning detection systems with a higher location accuracy, cloud-to-cloud and cloud-to-ground discrimination for special applications.

Surface-based observations of atmospheric composition (complemented by balloon- and aircraft-borne measurements) will contribute to an integrated three-dimensional global atmospheric chemistry measurement network, together with a space-based component. New measurement strategies will be combined to provide near real-time data delivery.

Surface-based observations will support nowcasting and very short-range forecasting through the widespread integration of radar, lightning and other detection systems, with extension to continental and global scales of the networks.