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Third Session

and

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THE VISION FOR THE GOS IN 2025

Submitted by the WMO Secretariat

Summary and Purpose of Document

The document contains a revision of the draft Vision for the GOS approved by ET-AWS-5, 5 – 9 May 2008.

ACTION PROPOSED

The meeting is invited to elaborate its contribution to the Vision for the GOS in 2025 for its further consideration by CBS/OPAG-IOS ET-EGOS-4, July 2008 with a special focus on Upper-air and remote-sensing measurements.

References:

1. Final Report, CBS/OPAG-IOS ET-EGOS-3, Geneva, 9 - 13 July 2007 (http://www.wmo.int/pages/prog/www/OSY/Reports/ET-EGOS-3_Final-Report.pdf)
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3. Implementation Plan for evolution of space-based and surface-based sub-systems of the GOS, WMO/TD No. 1267 (www.wmo.ch/pages/prog/www/OSY/Publications/TD1267_Impl-Plan_Evol-GOS.pdf)
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6. National Weather Service Science and Technology Infusion Plan, A Roadmap to 2025 (http://www.nws.noaa.gov/ost/NWS_TIP.pdf, www.nws.noaa.gov/ost/STIP2004.pdf)
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The Vision for the GOS in 2025

Background

The CBS/OPAG-IOS ET-EGOS-3, Geneva, 9 - 13 July 2007 developed a preliminary draft of a "Vision for the GOS in 2025"; ET-EGOS also proposed a schedule of activities involving itself and other CBS ETs to prepare a revised draft Vision for consideration by CBS-XIV. The preliminary draft was reproduced in the Final report of the ET-EGOS-3 session.

In March 2008, Dr Eyre distributed a new draft Vision. A new structure has been adopted for the Vision for the GOS in 2025 as follows:

1. General trends and issues
2. Space-based component
3. Surface-based component
4. System-specific trends and issues

This version of the draft was further revised by CBS/OPAG-IOS/ET-AWS-5, Switzerland, Geneva, 5 – 9 May 2008, and is reproduced in the Annex 1. As the ET-AWS is focused specifically on the surface-based subsystem, the parts 2 and 4.1 of the draft Vision dealing with the space-based component had been omitted from the revision. The draft distributed by Dr E. Eyre, chairperson of the ET-EGOS, in March is reproduced in the Annex 2 for the reference.

The ET-UASI-3 is invited to discuss and update the draft in the Annex 1, with special focus on upper-air and remote-sensing measurements; in doing so, the following thoughts should be taken into account when considering the draft Vision for the GOS in 2025:

(a) The Vision is seen as a balance between requirements for data and observations by different WMO Programmes, various applications and users on one hand and science and technology developments on the other hand.

(b) Regarding the requirements for data and observation, it should be considered that:

- Observational needs for future models that will be used for different time-range forecasts;
- Deficiencies of today's models that show that current observations are not sufficient for most mesoscale applications;
- Critical atmospheric observations that are not adequately met by current and planned observing systems but are required for more accurate and timely Earth monitoring and decision-making;

(c) Regarding the observing technologies and techniques, it should be considered that:

- Better understanding of the processes that govern weather requires advances in sensors and observing networks;
- All observational data should be traceable to international standards;
- Instruments should be interoperable as far as possible;
- Integrated observing systems may overcome gaps in existing observations;

(d) The availability of test-beds for a successful transition from R&D to operations may be a critical aspect.

Annex 1

VISION FOR THE GOS IN 2025

1. General trends and issues

1.1 Response to user needs

a) The GOS will provide comprehensive three-dimensional observations in response to the needs of all WMO Members and Programmes.

b) It will provide data for fundamental understanding of physical processes and variability of the atmosphere with emphasis on Planetary Boundary Layer (PBL), oceans (with emphasis on the mixed layer), inland water systems, and the upper-layers of the land surface for refining and improving all elements of the forecast process.

c) It will provide adaptable[1] observations when and where they are needed in a reliable and sustained manner.

d) It will respond in cost effective manner to user requirements for observations of specified spatial and temporal resolution, accuracy, timeliness and lead time.

e) It will continue to facilitate effective global collaboration in the making and dissemination of observations, through a composite and increasingly complementary system of observing systems.

f) Additional data integration and model calculation will also be used to response to user needs, as an alternative to network expansion.

1.2 Integration

a) The GOS will be an essential part of the WIGOS that will build further on current GOS functionalities. Within WIGOS, further integration of various observing components will demand interoperable arrangements and common standards.

b) Future GOS will be characterized by optimal integration of different observing platforms, especially various ground-based remote-sensing systems.

c) Future GOS will be characterized by improved system integration of meteorological and hydrological observing systems allowing the development of innovative integrated information products based on multivariate observations in real/near-real time.

1.3 Expansion

a) There will be an expansion in both the user applications and the variables observed.

b) The GOS will support the production of Essential Climate Variables, adhering to GCOS climate monitoring principles.

c) Sustainability of new components of the GOS will be secured, with Research and Development (R&D), Observing System Experiment (OSE), Observing System Simulation Experiment (OSSE) and test-bed systems integrated as operational systems when proved.

d) Expansion in observing technologies and techniques will focus on “intelligent” (smart) integration of existing or improved systems.

e) To optimize the cost-efficiency of the GOS, 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.

f) It will evolve in response to changing user and technological development based on improved scientific understanding and advances in observational and data-processing technologies.

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[1] Easily increasing and expanding spatial and temporal data densities, and the number and type of measured elements to meet emerging user needs.

1.4 Automation

a) The trend to develop cost-effective fully automatic observing systems, using “intelligent” integration of existing ones and new observing and information technologies will continue.

b) There will be improved access to real-time and unprocessed data.

c) Observing system test-beds will be used to intercompare and evaluate new automatic systems and develop guidelines for integration of observing platforms and their implementation.

1.5 Standardization

a) There will be further progress in standardization of instruments and observing methods within the GOS and WIGOS.

b) There will be significant improvements in traceability of measurements to System International (SI units; certified international standards) to ensure better data compatibility and homogeneity.

c) There will be increased interoperability, between existing observing systems and with newly implemented systems.

d) There will be improved standardization of data management, data archive, data and metadata formats, and their accessibility via WIS.

2. Space-based subsystem (...)

3. Surface-based subsystem

➢ **Variables of future GOS not adequately measured or observed by current systems:**

- PBL measurements, especially wind and moisture profiles;
- 3-D fields of temperature, water vapour, wind, mainly over ocean and sparsely-inhabited land areas with adequate space and temporal resolutions;
- 3-D mass, hydrometeor cloud fields, cloud microphysics;
- Surface energy balance components (soil, sensible and latent heat and moisture fluxes);
- Total column water;
- Moisture profiles, in particular in the upper troposphere and lower stratosphere.
- Measurement of subjective observations (state of the ground, present weather)
- Surface radiation components;
- UV radiation;
- Snow/ice cover and depth, snow water equivalent;
- Thermal profiling of the ocean mixed layer;

With regard to hydrology and water resources:

- Global river discharge,
- Fresh water fluxes into the world ocean,
- Discharge in mountainous regions including runoff from snow and glacier fields,
- Variables needed for Glacier Lake Outburst Flood (GLOF) Hazards,
- Variables needed for Flash-floods (rain-induced, precipitation intensity/duration, probable maximum precipitation),
- Discharge in deltas and large estuaries,
- Ice-Jams and resulting floods,
- Variables needed for Flooded areas and wetlands,

- Volume changes of large lakes and reservoirs,
- Groundwater recharge on national, river-basin and regional scales,
- Volume changes of large aquifers,
- Water quality on all scales, multitude of variables, observation adequacy dependant on use of information,
- Water use (in particular, this variable is essential to be included in national statistics and is also an essential climate variable),

➢ Regarding atmospheric composition measurements, reference is made to the Global Atmosphere Watch (GAW) Programme. The long-term objectives of GAW, as stated in the WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008-2015, GAW Report No. 172 (The Plan is being updated as per changing requirements and a revision will be provided in due time for the years beyond 2015), are to:

- Develop GAW into a three-dimensional global atmospheric chemistry measurement network through the integration of observations of surface-based, balloon-borne, aircraft, satellite and other remote sensing observations.
- Make certain sectors of GAW, such as total ozone, ozone sounding and aerosol observations, compatible with near-real-time (NRT) delivery of data. Increase the usage of the WMO Global Telecommunication System/WMO Information System (GTS/WIS) for exchange of GAW data.
- Fuse observational systems, data assimilation and modelling, databases and product delivery, and quality assurance and validation into coherent data processing chains, related to a defined GAW quality management system within the WMO Quality Management Framework (QMF).
- Support research and development leading to assimilation of the essential climate variables – aerosols, ozone and greenhouse gases – in atmospheric transport and numerical weather prediction models and the production of related products and services.

4. System-specific trends and issues

4.1 Space-based (...)

4.2 Surface-based

➢ **The surface-based GOS will provide:**

- Improved detection of mesoscale phenomena, such as flow in complex terrain, the detailed structure of fronts and mesoscale convective systems (severe storms), the detailed evolution of the structure of the planetary boundary layer, cloud distributions and their interaction with radiation, the transport of heat, moisture and momentum,
- Integrated atmospheric profiles,
- Reference data for calibration and validation of space-based data,
- Long-term datasets for the detection and understanding of environmental trends and changes;

➢ Additional surface observations will come from a wide variety of surface networks (e.g.: agricultural meteorological, road, urban and other multi-application fixed and mobile networks).

➢ Increased data access from national meteorological networks that are not currently exchanges through GTS.

➢ Optimised Regional Basic Synoptic/Climatological Networks (RBSN/RBCN) will be the essential components of the integrated global observing systems.

➢ Radiosondes networks will be optimised, particularly in terms of horizontal resolution which will decrease in data-dense areas. They will be complemented by aircraft (AMDAR) ascent/descents profiles for most of the airports worldwide and supplemented by profilers and GPS MET in some regions.

- A GCOS Reference Upper Air Network (GRUAN) (a part of the RBCN) will serve as a reference network for climate trends. Reference radiosondes capable of measuring temperature and humidity in both troposphere and stratosphere will be developed for use within GRUAN.
- Aircraft observations will be fully integrated into the GOS with aircraft humidity measurements.
- Aircraft observations (flight-level and ascent/descent data) will be available at user-selected temporal and space resolution.
- Weather Radar observing systems will provide enhanced cloud, precipitation Quantitative Precipitation Estimation (QPE) and radial wind products with increased data coverage. There will be much improved data consistency, with defined minimum standards for quality control and accuracy. New radar technology, e.g. phased array, polarimetric and multi-channel radars for full 3-D wind fields will be available.
- Different types of radars will be integrated into national and regional radar networks. Current regional radar data exchanges will be supplemented by global exchanges for NWP centres.
- Integrated Profiling Systems will be developed and used by more applications. A wider variety of techniques and technologies will be used. Wind profilers, Raman, Elastic Backscatter and Differential Absorption Lidars, weather and cloud radars, microwave and multi-wavelength radiometers and GPS Met will mostly dominate. These systems' technologies will be integrated into "intelligent" profiling systems and integrated with other surface observing technologies.
- Ground based Global Navigation Satellite System (GNSS), which includes the Global Positioning System (GPS, USA), GALILEO and GLONASS, will be used for water vapour measurements.
- Long-range lightning detection systems will provide cost-effective, homogenized, global data with a location accuracy of about 2 km, significantly improving coverage in data sparse regions including oceanic and polar areas.
- Sustained systems will provide ocean sub-surface profiles of high vertical resolution data.
- Communications for marine observations will be improved through two-way, high data rate cost-effective satellite data telecommunication systems, which will collect the in situ observational data, and permit remote programming / control of the observing platforms.
- Marine observing technology will be improved, including cost-effective multi-purpose in situ observing platforms, profiling floats (with added sensors), ocean gliders, deep ocean time series reference stations, HF Radars, Ice Tethered Platforms & Ice Mass Balance buoys, and cost-effective *in-situ* wave observations.
- AWS will fulfil multiple functionalities. More meteorological observing platforms will be shared by instruments for different applications, and more meteorological observations will be performed on "platforms of opportunities", or using some infrastructures which have been set up for non-meteorological purposes.
- In response to economic and other pressures, observing systems will continue to exist with:
    - A broader range of station siting options including siting classifications;
    - A broader range of low-cost, low-maintenance, reliable sensors providing data critical for operational applications;
    - Increased attention to IT security. As more private sector networks join the global system of systems, issues concerning the proprietary rights of the data and the protection of the data should be addressed.
- Surface-based systems with regard to hydrological observations will see a number of developments such as:

- Improvements of water level observations (needed to calculate discharge), such as radar-gauges, acoustic gauges, Acoustic Doppler Current Profilers, dye tracer discharge instruments in turbulent rivers, and use of isotopic observations especially in observations of glaciers, groundwater, large lakes and reservoirs.
- Increased coupling of hydrological observations with other observing platforms including those for rainfall, evaporation, groundwater, soil moisture;
- As a result of increasingly complex observing systems (i.e. coupling meteorological variables with hydrological variables in (near) real-time for forecasting, coupling water quantity and quality data and information etc.), integrated observing systems solutions will gain popularity in use.

Annex 2

Draft VISION FOR THE GOS IN 2025

(The draft by Dr J. Eyre, ET-EGOS chair, distributed on March 2008)

1. General trends and issues

Response to user needs

- The GOS will provide observations in response to the needs of all WMO Members and Programmes.
- It will provide observations when and where they are needed in a reliable, stable and sustained manner.
- It will respond to user requirements for observations of specified spatial and temporal resolution, accuracy and timeliness.
- 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 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 evolve to become part of the WIGOS, 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.

Expansion

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

Consistency and homogeneity

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

2. The space-based component

Platform	Instruments	Observed variables	WMO programme
Operational geostationary satellites At least 6, nearly equally spaced	Vis/IR imagers	Cloud amount, type, top height/temperature; wind; sea/land surface temperature; precipitation; aerosols; snow cover; vegetation cover; atmospheric stability; fire detection	WWW, GCOS, WCP, WCRP, DRR
	IR sounders (some hyperspectral)	Atmospheric temperature, humidity and wind; sea/land surface temperature; cloud amount and top height/temperature; atmospheric composition	
Operational polar-orbiting sun-synchronous satellites 3 orbital planes (~13:30, 17:30, 21:30 ECT)	IR sounders (hyperspectral) MW sounders	Atmospheric temperature, humidity and wind; sea/land surface temperature; cloud amount, water content and top height/temperature; atmospheric composition	All major WMO programmes
	Vis/IR imagers	Cloud amount, type, top height/temperature; wind (high latitudes); sea/land surface temperature; precipitation; aerosols; snow and ice cover; vegetation cover; atmospheric stability	
Other LEO capability on primary operational or other satellites	MW imagers – at least 3? – [some polarimetric]	Sea ice; total column water vapour; precipitation; sea surface wind speed [and direction]; precipitation; cloud liquid water	WWW, GOOS, GCOS
	Scatterometers - at least 2	Sea surface wind speed and direction; sea ice; soil moisture	WWW, GCOS, GOOS
	UV sounders - at least 2	Ozone and other atmospheric composition variables; aerosols	WWW, GCOS
	Radio occultation constellation – at least 6	Atmospheric temperature and humidity; ionospheric electron density	WWW, GCOS
	Altimeter constellation	Ocean surface topography; sea level; ocean wave height	WWW, GCOS, GOOS
	IR dual-angle view imager	Sea surface temperature (of climate monitoring quality); aerosols; cloud properties	GCOS, WWW, GOOS, …?
	Narrow-band Vis/NIR imager	Ocean colour; vegetation (including burnt areas); aerosols; cloud properties	WWW, GCOS, GOOS, DRR, AREP, WCRP
	High-resolution VIS/IR imagers – constellation	Land surface imaging for land use and vegetation	WWW, GCOS, AMP/AgM, DRR, HWRP
	Active and passive MW instruments - constellation	Precipitation	GCOS, WWW, HWRP, DRR, WCRP

	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)	GCOS, WCRP, WWW(SIA)
	Atmospheric composition instruments – constellation	Ozone; other atmospheric chemical species; aerosols – for greenhouse gas monitoring, ozone/UV monitoring, air quality monitoring	GCOS, AREP, WWW
	Synthetic aperture radar	Wave heights, directions and spectra; oil spills; floods; other hazards; earthquake and faults monitoring; sea ice leads; damage assessment; ice shelf and icebergs	WWW, DRR, GOOS
Capability on R&D satellites and operational pathfinders including:	Doppler wind lidar on LEO	Wind; aerosol; cloud-top height [and base]	WWW, GCPS, AMP/AeM
	Low-frequency MW radiometer on LEO	Ocean surface salinity; soil moisture	WWW, GCOS, …?
	MW imager / sounder on GEO	Precipitation; cloud water/ice; atmospheric humidity and temperature	WWW
	Lightning imager on GEO	Lightning	AMP/AEM, DRR, WWW
	Vis/IR imagers on satellites in highly elliptical orbit (HEO) missions ? justification ?	Winds and clouds at high latitudes; sea ice	WWW, ??
Others? – to be discussed		Three-dimensional cloud water/ice fields; Sea and land ice topography; Flood monitoring;	

3. The surface-based component

***In situ* observations**			
Land - upper air	Upper air synoptic stations: rawinsondes/radiosondes: - RBSN, plus GUAN and GRUAN	Wind, temperature, humidity, pressure	WWW,GCOS
	Aircraft	Wind, temperature, pressure, [humidity,] turbulence, icing, thunderstorms, dust/sandstorms, volcanic ash/activity	WWW
	UAVs?		WWW
	Ozone sondes	Ozone	WWW, GCOS, …
	Other?		
Land – surface	Surface synoptic stations: - GSN, …?	Surface pressure, temperature, humidity, wind; visibility; cloud amount, type and base-height; precipitation; weather; …?	WWW, GCOS
	Atmospheric composition station	Ozone, …?	WWW, GCOS, …
	Other?		

Land – hydrology	?		
	?		
Ocean – upper air	Rawinsondes/radiosondes: Automated Shipboard Aerological programme with GPS-radiosondes and high data rate satellite data telecommunication Buoymounted wind profilers Unmanned Aerial Vehicle (UAV), including with dropsondes Stratospheric balloons	Wind, temperature, humidity, pressure	WWW GCOS, CLIVAR
	Other?		
Ocean – surface	Ships (VOS, VOSClim, TSG) with advanced instrumentation and satellite data telecommunication	Surface pressure, air temperature, air relative humidity, wind vector; visibility; cloud amount, type and base-height; precipitation; weather; sea surface temperature and salinity; wave direction, period and height; sea ice; ocean partial CO_2, …?	WWW, GCOS, GOOS, CLIVAR
	Moored buoys (meteorological moorings, tropical moorings, OceanSITES, Tsunameters)	Surface pressure, air temperature, air relative humidity, wind vector; visibility; sea surface temperature and salinity; wave sprectrum, wave direction, period and height; precipitation, downwelling longwave and shortwave radiation Air-sea fresh water exchange, Air-sea heat exchange, Air-sea gas exchange Tsunami wave (height, period)	WWW, GCOS, GOOS, CLIVAR, DRR
	Drifting buoys	Surface pressure, sea surface temperature and salinity, surface velocity, wind vector, waves sprectrum, wave direction, period and height, ocean partial CO_2	WWW, GCOS, GOOS, CLIVAR
	Ice buoys, Ice Mass Balance Buoys (IMB)	Surface pressure, air temperature, air relative humidity, wind vector, precipitation, liquid water temperature, ice thickness, ice temperature	WWW, GOOS, GCOS, CLIVAR
	Tide gauges	Tide height, sea level	DRR GOOS CLIVAR
	HF radars	Significant wave height, wave direction, and wave period, sea surface currents	GCOS, CLIVAR, GOOS
	Other?		
Ocean – sub-surface	Profiling floats	Water temperature and salinity profiles; dissolved oxygen, ocean partial CO_2, Chlorophyl	WWW, GCOS, CLIVAR,

			GOOS
	Ice Tethered Platforms	Water temperature and salinity profiles (2000m)	WWW, GOOS, GCOS, CLIVAR
	Upward looking sonars	Ice thickness	
	Tropical Moorings	Water temperature profiles (500m) Ocean currents (ADCP)	WWW, GOOS, GCOS, CLIVAR
	Ships (XBTs)	Water temperature profiles (1000m)	WWW, GOOS, GCOS, CLIVAR
	BT drifters	Water temperature profiles (200m)	WWW, GOOS, GCOS, CLIVAR
	Ocean gliders	Water temperature and salinity profiles	GCOS, GOOS, CLIVAR
	OceanSITES (Deep ocean "time series" reference stations)	Physical oceanography (Current vector, Water temperature, Salinity) Transport of water (Volume of deep ocean currents) Biogeochemistry (Nutrients, Organic sediments, Dissolved inorganic carbon, Oxygen, Chlorophyll) Carbon cycle (ocean partial CO_2) Biology (Phytoplankton, Zooplankton, Fish stocks) Geophysics (Seismic movements, Magnetism)	WWW, GOOS, GCOS, CLIVAR
	Acoustic Tomography	Average water temperatures over large regions of the ocean	GCOS, CLIVAR
	Unmanned cabled sensor systems	Sea bottom conditions	GOOS, GCOS, CLIVAR
Remotely-sensed observations			
	Weather radar	Precipitation (hydrometeor distribution, size, phase), wind (radial component), …?	WWW
	Profilers (radar, lidar, radiometer)	Wind, cloud base, cloud water, temperature, humidity, …?	WWW
	Lightning detection systems	Lightning	WWW
	GPS (and similar) receivers	Total column water vapour	WWW, GCOS
	Others?		

4. System-specific trends and issues

4.1 Space-based

- There will be an **expanded community** of space agencies contributing to the GOS.
- There will be **increased collaboration** between space agencies, to ensure that 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.
- **Improved availability and timeliness** through operational cooperation among agencies.

4.2 Surface-based

- **The surface-based GOS will provide:**
  - improved detection of mesoscale phenomena, such as severe storms, lightning, moisture, and clouds, and observations to aid disaster detection, mitigation and prevention,
  - data that cannot be measured by space-based component,
  - data for calibration and validation of space-based data,
  - long-term datasets for the detection and understanding of environmental trends and changes to complement those derived from space-based systems.
- **Radiosondes networks** will be optimised, particularly in terms of horizontal resolution which will decrease in data-dense areas. They will be complemented by **aircraft (AMDAR)** ascent/descents profiles for most of the airports worldwide and supplemented by **profilers** in some regions.
- **Radiosonde profiles** will disseminated at **higher vertical resolution**, commensurate with user needs.
- The **GUAN** subset of radiosonde stations will be maintained for climate monitoring. A GCOS Reference Upper Air Network (GRUAN) will be developed 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 **integrated** into the broader observing framework.
- **Aircraft observations** systems flight-level and ascent/descent data at user-selected temporal resolution. They will be available from most airports, including those regions not currently well covered (Africa, South America and parts of Asia).
- **Aircraft** instruments will be introduced to observe **humidity**, in addition to temperature and wind.
- **Aircraft observing systems** will also be developed **for small aircrafts** with flight levels in the mid troposphere and providing ascent/descent profiles into different airports.
- These observations may be supplemented by **UAVs**, but not on a regular basis (possibly as part of targeting strategies).
- **Surface observations** will come from a wider variety of surface networks (e.g.: road networks) and multi-application networks. They will achieve higher levels of reliability and availability.
- The **GSN** subset of surface stations will be maintained [and improved?] for climate monitoring.
- **Radar** observing systems will continue to provide precipitation products but with an increased data coverage. They will increasingly provide information on other atmospheric variables, such as radial winds. There will be much improved data consistency, with defined minimum standards for quality control and accuracy. There will be new radar technology, e.g. phased array antenna and passive bistatic radars (for full 3D windfields). Collaborative multi-national networks are likely, to control costs and to deal with increasing technological complexity.
- Current regional **radar data exchanges** will be supplemented by global exchanges for NWP centres.
- **Profilers** will be developed and used by more applications. A wider variety of techniques will be used (lidars, radars, microwave radiometers). These observing systems will be developed into coherent networks and integrated with other surface networks.
- **GPS** receiver networks, for observing total column water vapour, will be extended.
- **Long-range lightning detection systems** will provide cost-effective, homogenized, global data with a location accuracy of about 2 km, significantly improving coverage in data sparse regions including oceanic and polar areas.

- Sustained systems will provide **ocean sub-surface profiles** of high vertical resolution data.
- Drifting buoys … moored buoys … ice buoys … other ocean obs [anything to say?]
- **Communications for marine observations** will be improved through two-way, cost-effective high data rate satellite data telecommunication systems, which will collect the in situ observational data and permit remote programming/control of the observing platforms
- **Marine observing technology** will be improved, including cost-effective multi-purpose in situ observing platforms, profiling floats (with added sensors), ocean gliders, deep ocean timeseries reference stations, HF Radars, Ice Tethered Platforms & Ice Mass Balance buoys, and cost-effective *in situ* wave observations.
- 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 of **hydrological parameters** at the global level are expected to diminish. [Why?] However, the exchange of data within the river basins should substantially increase.
- More **meteorological observing platforms** will be **shared** by instruments for different applications, and more meteorological observations will be performed on “platforms of opportunities”, or using some infrastructures which have been set up for non-meteorological purposes.
- In response to **economic and other pressures**, there will be:
    - a broader range of station siting,
    - a broader range of instrumentation quality,
    - less uniformity in networks,
    - increased attention to IT security.
- Observational data will **collected and transmitted** in digital, highly compressed forms. Data processing will be highly computerised.
- Others?