WMO VIEWS ON FUTURE METEOROLOGICAL SATELLITES

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Dr Anthony Rea
Director, Infrastructure Department

Community Meeting on NOAA Satellites
Session 5: Engagement with International and National Partners and Discussion

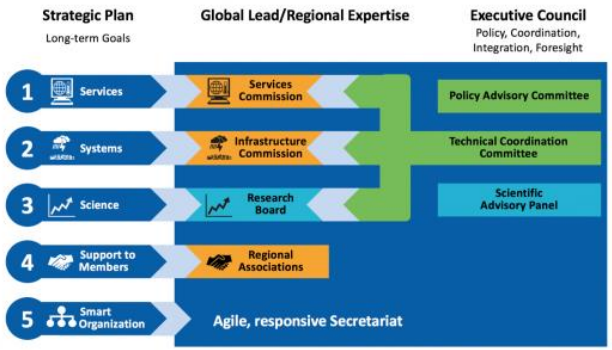
1 October 2020

WMO OMM

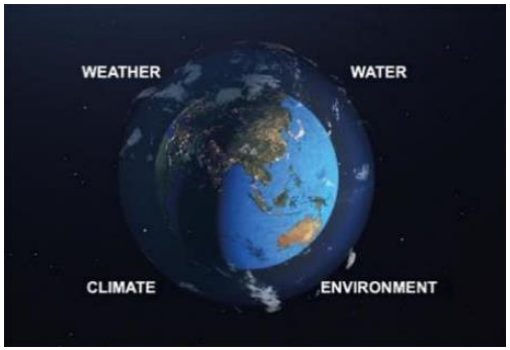
World Meteorological Organization
Organisation météorologique mondiale

Contents

- WMO Convention
- Resolution 40
- WMO Strategic Plan and reform
- Vision WIGOS 2040
- Data Policy
  - Res 42
  - GBON and SOFF
- Critical Satellite Data for NWP
- Engagement with CGMS and CEOS, and bilaterally



World Meteorological Organization



- Originated from the International Meteorological Organization (IMO), established in 1879
- In 1950, IMO was transformed into the **World Meteorological Organization (WMO)**, when the WMO Convention entered into force
- Since 1951, WMO is a UN specialized agency and the UN authoritative voice for weather, climate, water and related environmental services

See https://public.wmo.int/en/about-us/who-we-are/history-of-wmo

CONVENTION OF THE WORLD METEOROLOGICAL ORGANIZATION

PART II

ARTICLE 2

Purposes

The purposes of the Organization shall be:

(a) To facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services;

(b) To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;

(c) To promote standardization of meteorological and related observations and to ensure the uniform publication of observations and statistics;

(d) To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;

(e) To promote activities in operational hydrology and to further close cooperation between Meteorological and Hydrological Services; and

(f) To encourage research and training in meteorology and, as appropriate, in related fields and to assist in coordinating the international aspects of such research and training.

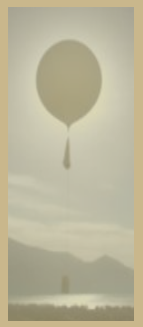
Resolution 40

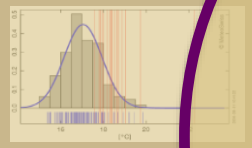
ADOPTS the following policy on the international exchange of meteorological and related data and products:

As a fundamental principle of the World Meteorological Organization (WMO), and in consonance with the expanding requirements for its scientific and technical expertise, WMO commits itself to broadening and enhancing the free and unrestricted[1] *international exchange of meteorological and related data and products;*

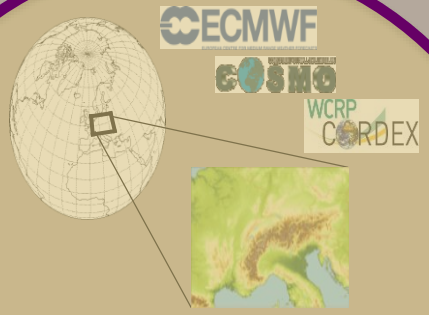
---

1 "Free and unrestricted" means non-discriminatory and without charge [Resolution 23 (EC-XLII) – Guidelines on international aspects of provision of basic and special meteorological services]. "Without charge", in the context of this resolution means at no more than the cost of reproduction and delivery, without charge for the data and products themselves.

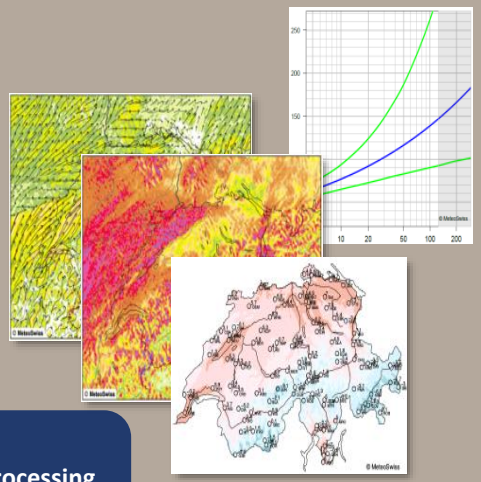






Data collection and analysis



Modelling for prediction



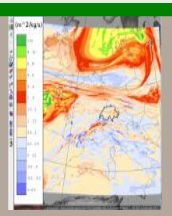
Post-processing and automatic

This is where value and socioeconomic benefits are generated; done nationally, typically by NMHS

This needs to be done globally

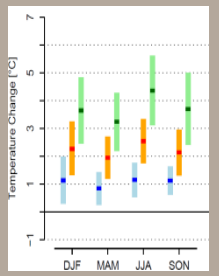
This needs to be done globally

Forecast interpretation and decision




Understanding and use of forecasts

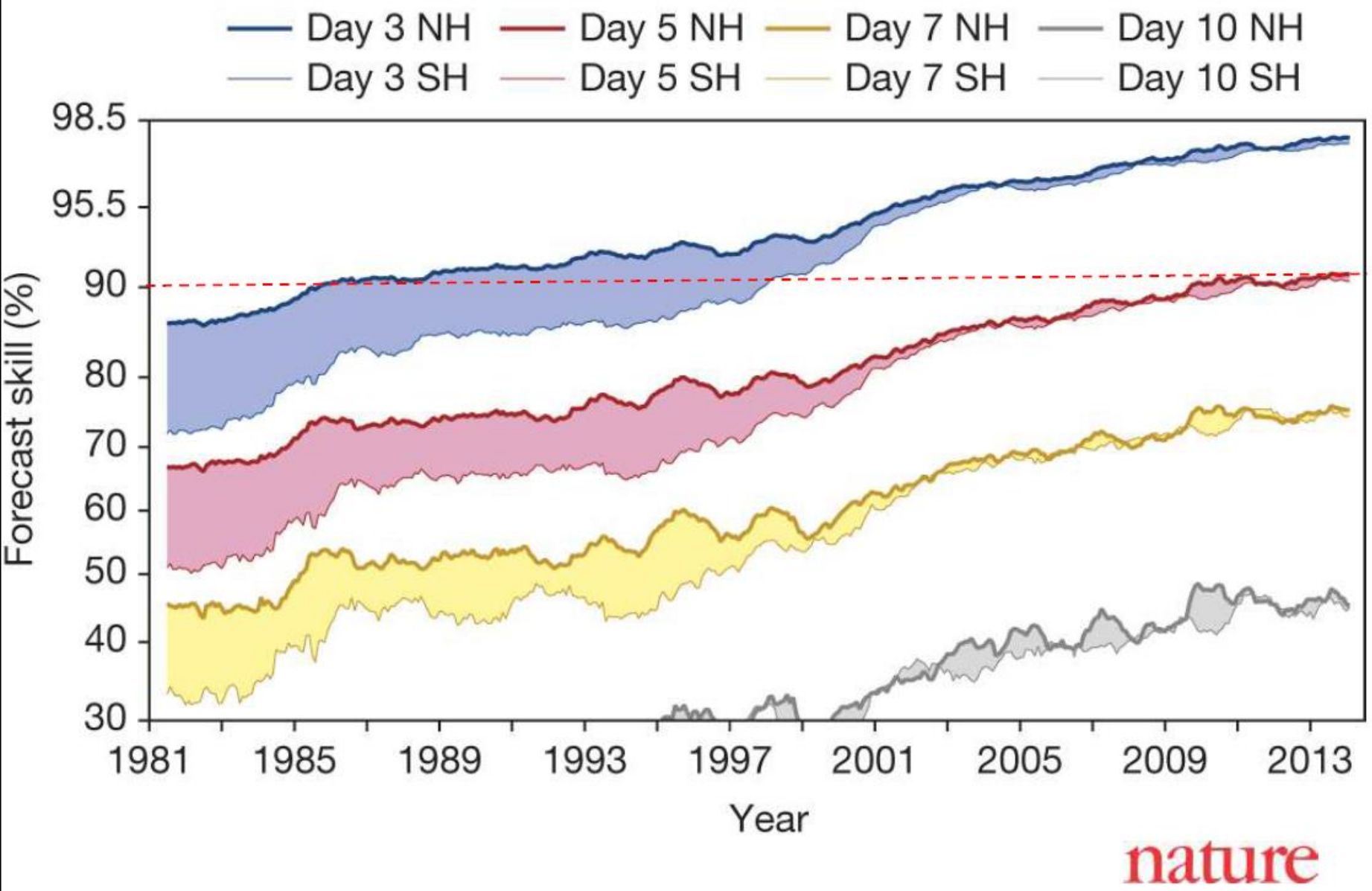
Dissemination of products and services to users

Basic WMO infrastructure underpinning all weather and climate-related actitivies; this can ONLY be implemented globally

WMO (2014) , No.1129 (courtesy Ch. Appenzeller)

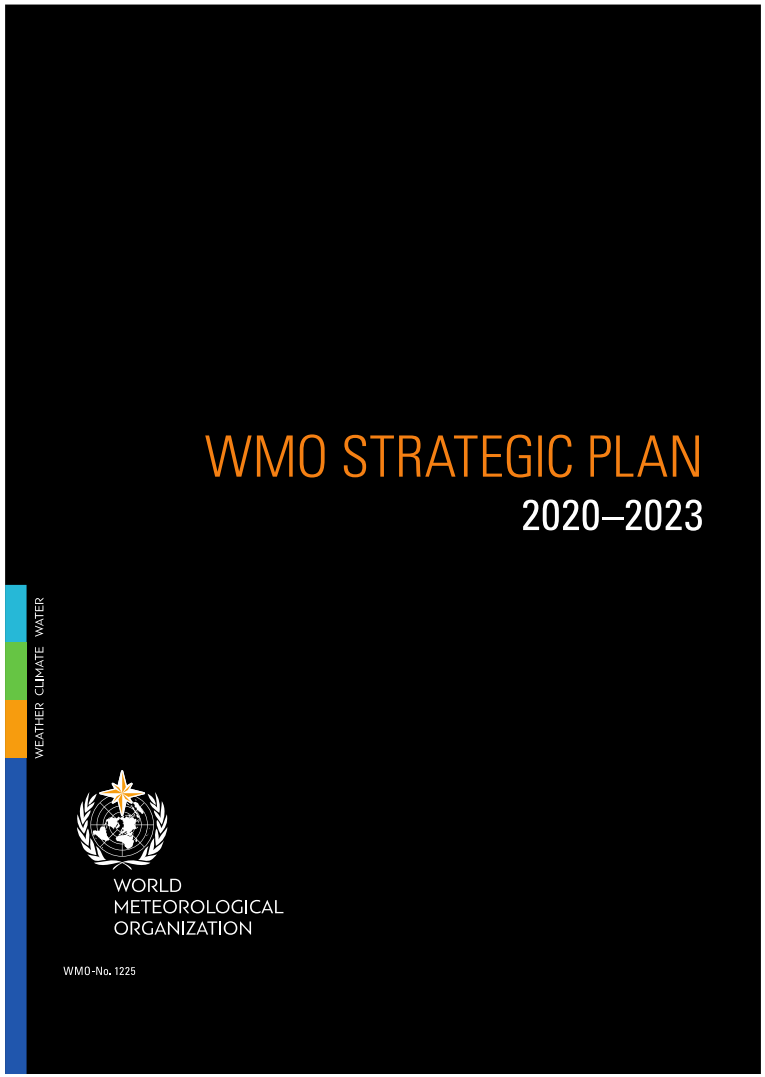
A measure of forecast skill at three-, five-, seven- and ten-day ranges, computed over the extra-tropical northern and southern hemispheres.



nature

P Bauer *et al. Nature* **525**, 47-55 (2015) doi:10.1038/nature14956

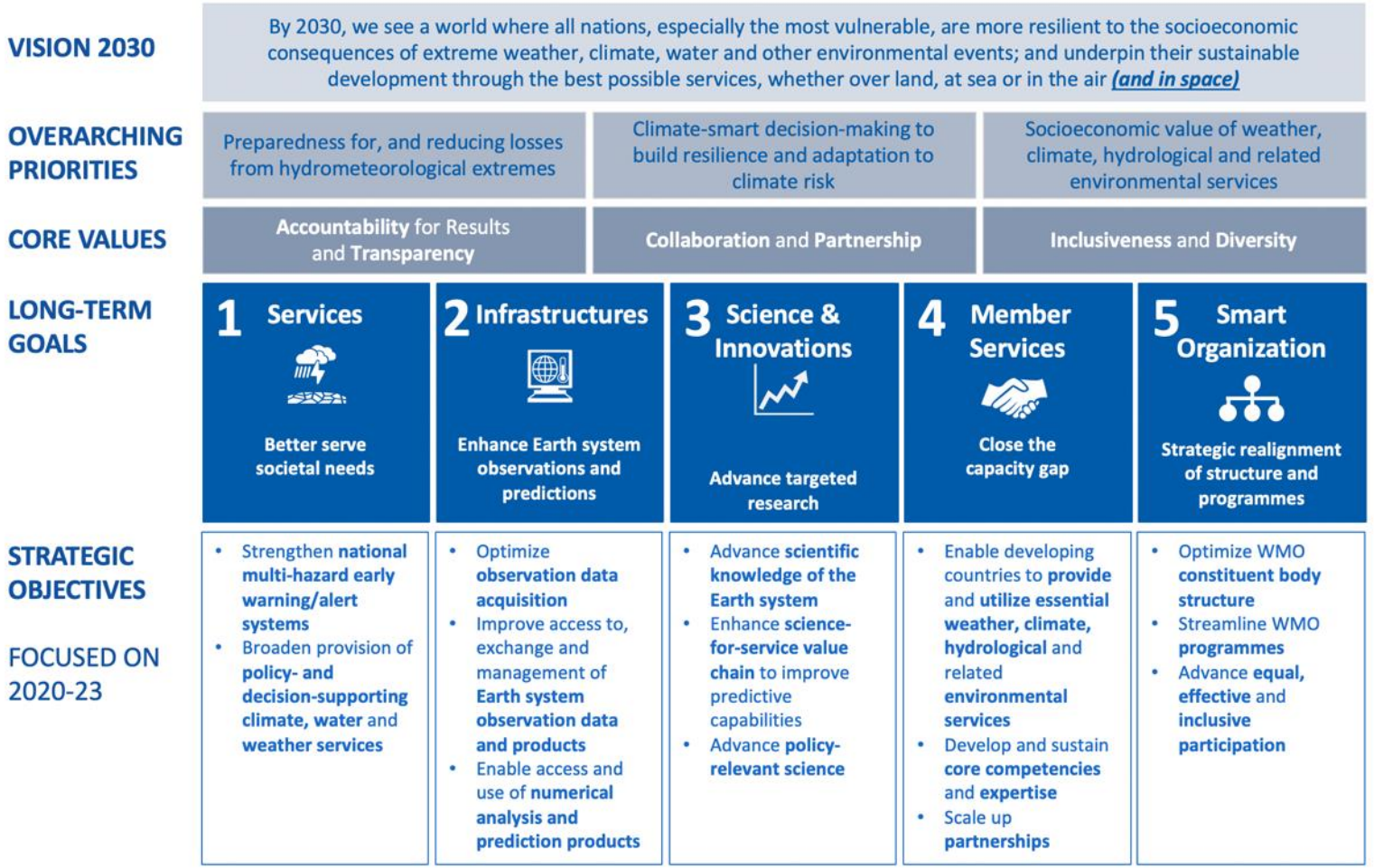
WMO Strategic Plan 2020-2023



By 2030, we see a world where all nations, especially the most vulnerable, are more resilient to the socioeconomic consequences of extreme weather, climate, water and other environmental events; and underpin their sustainable development through the best possible services, whether over land, at sea or in the air ***(and in space)***

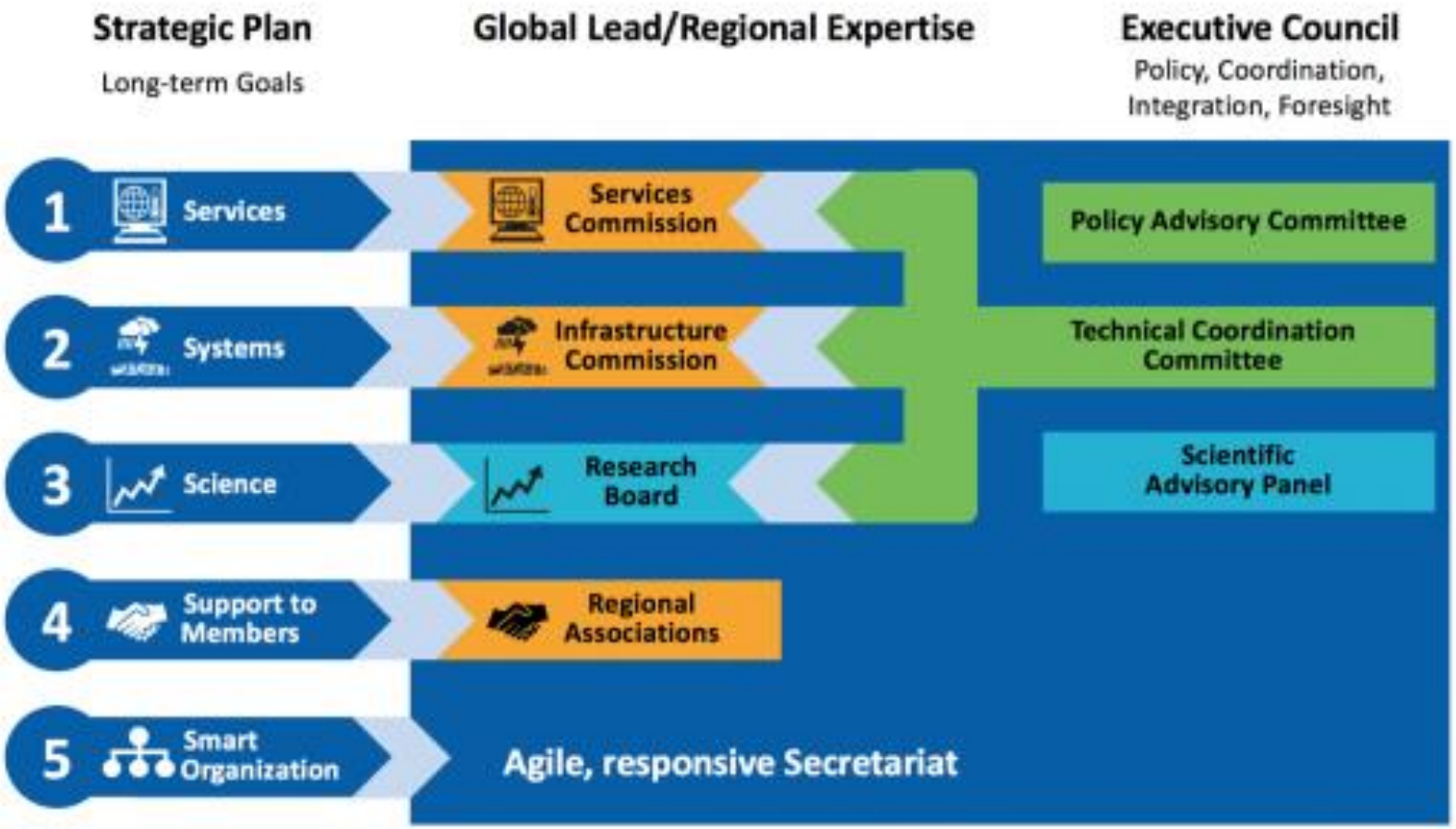
See https://library.wmo.int/index.php?lvl=notice_display&id=21525

WMO Strategic Plan 2020-2023



See WMO Strategic Plan 2020-2023 https://library.wmo.int/index.php?lvl=notice_display&id=21525

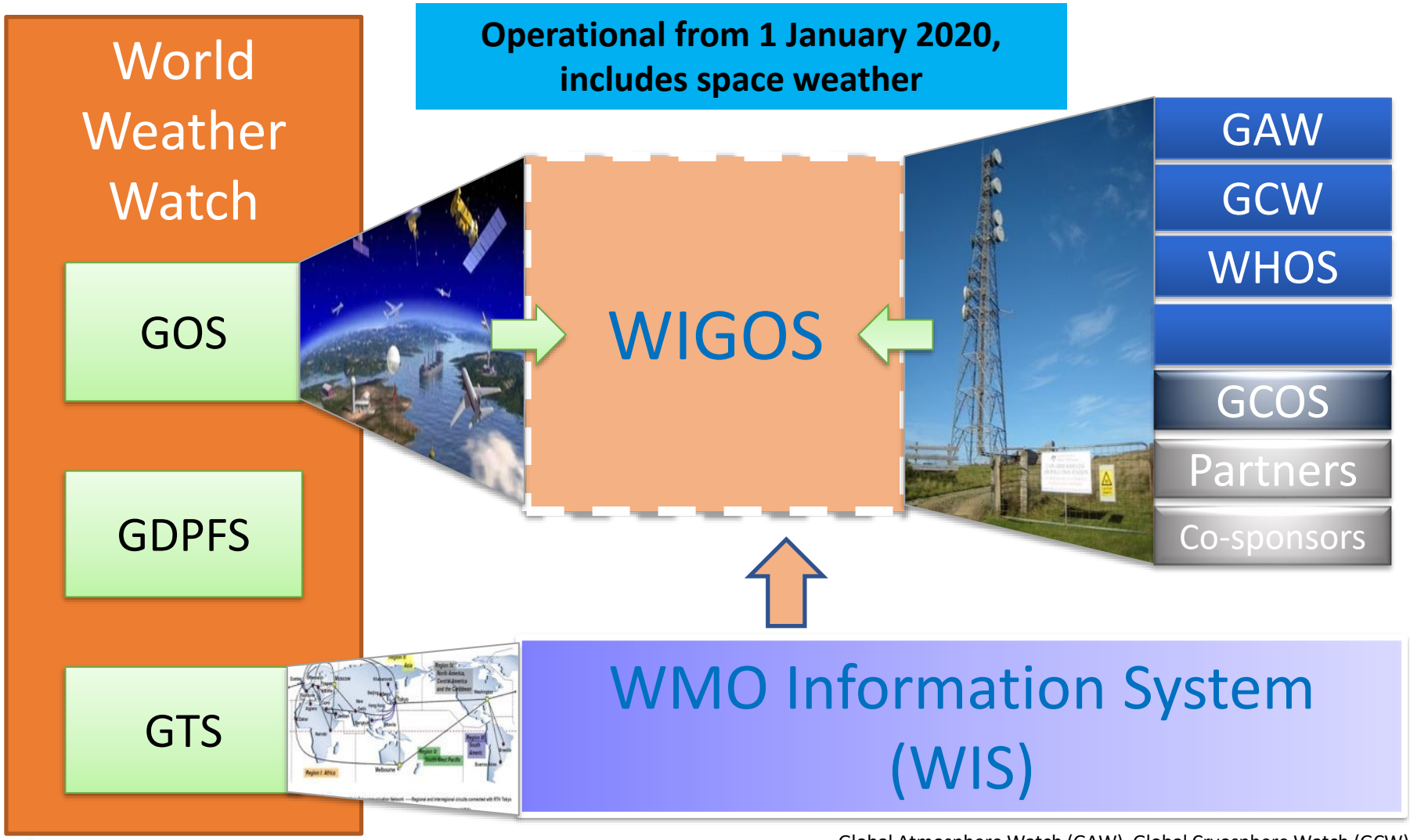
WMO Constituent Body Reform



INFCOM Expert Teams (space-related)

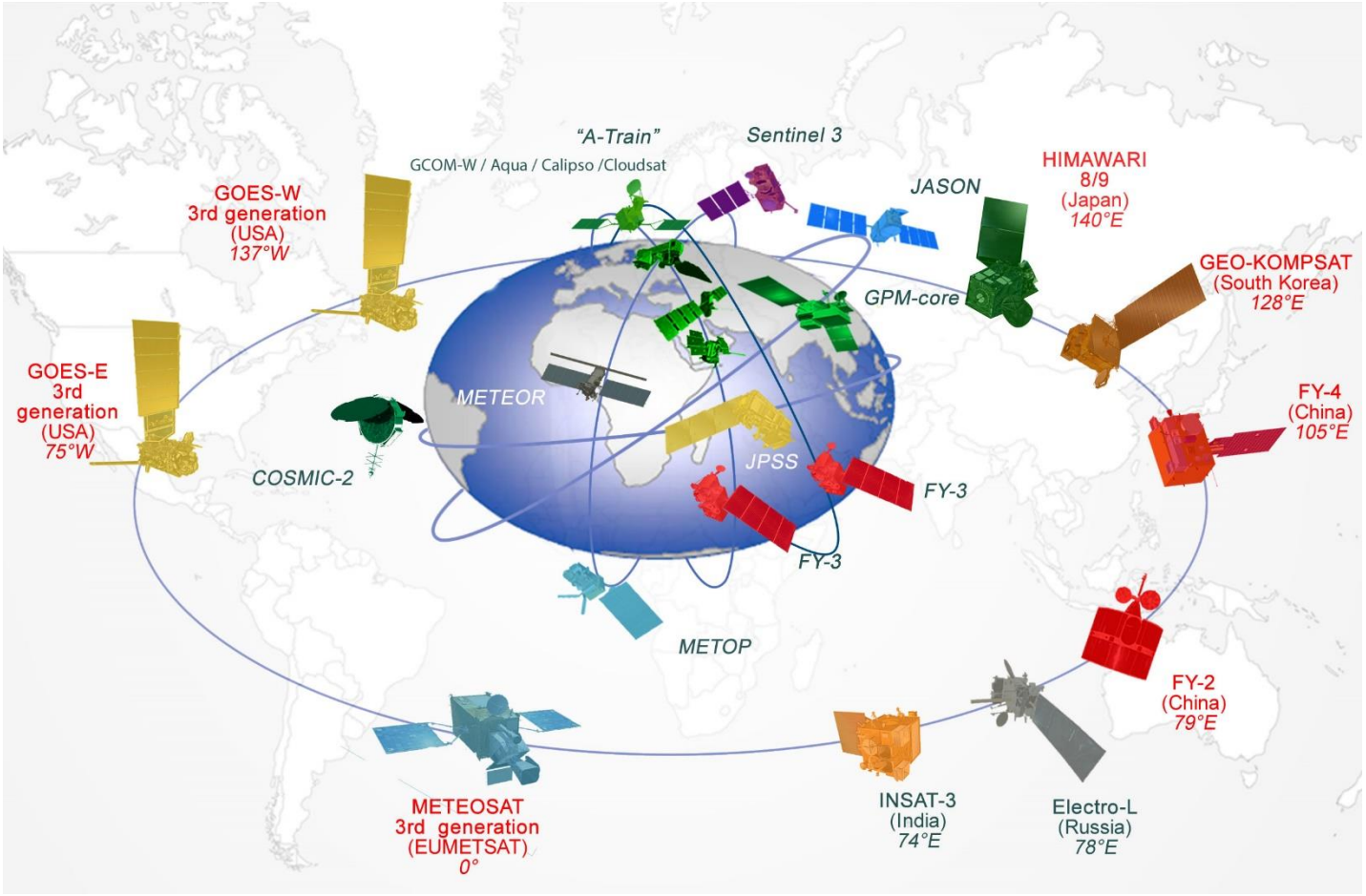
- Expert Teams on **Space Systems and Utilization** (ET-SSU)
- Joint Expert Team On **Earth Observing Systems Design And Evolution** (JET-OSDE)
- Expert Team on **Radio Frequency Coordination** (ET-RFC)
- Proposed Expert Team on **Space Weather** (ET-SWX)
  - to be confirmed

WMO Integrated Global Observing System



Global Atmosphere Watch (GAW), Global Cryosphere Watch (GCW), Hydro Observing System, Global Climate Observing System (GCOS)

Space-based Component of WIGOS

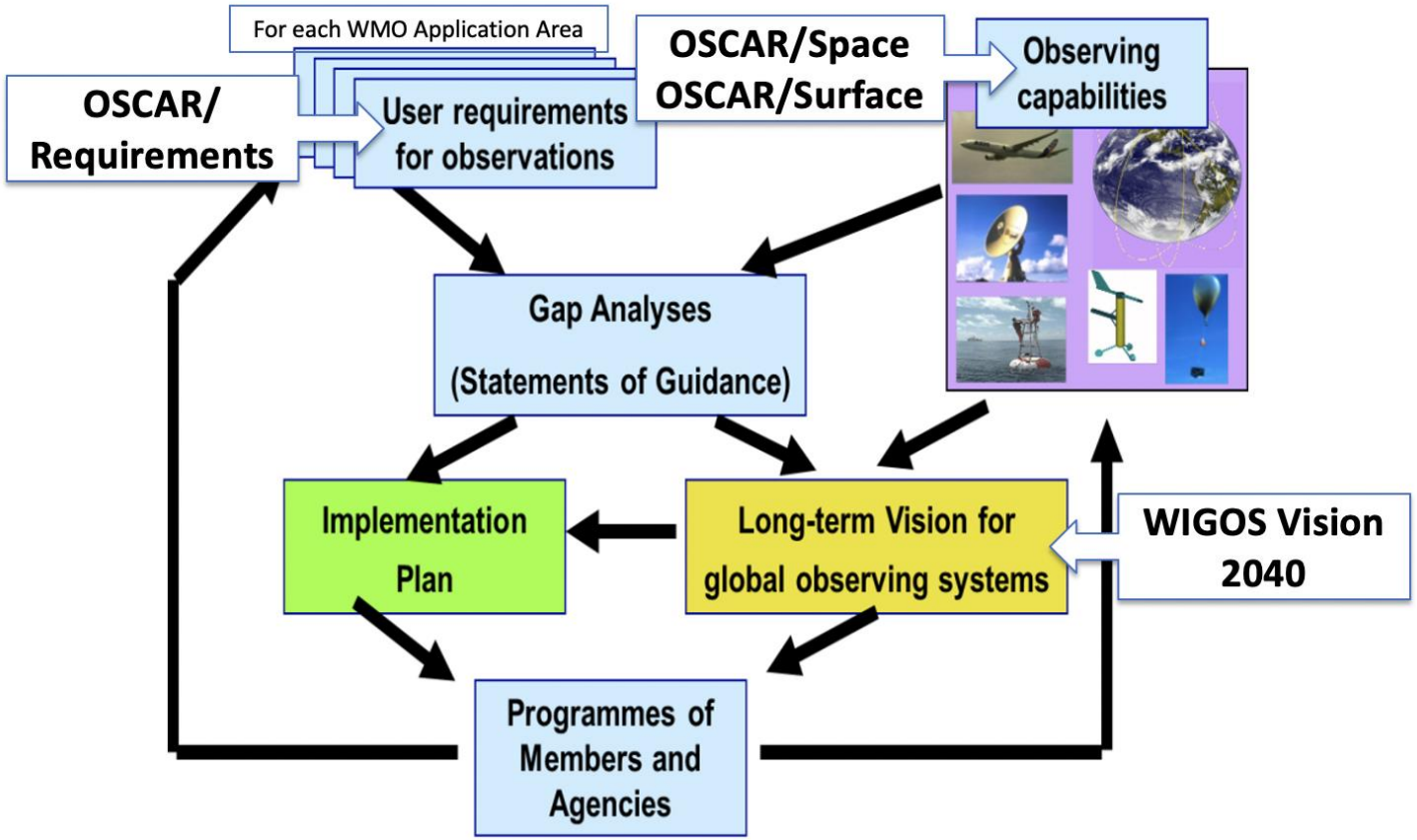


As of September 2020 approx. 207 operational satellites

See https://www.wmo-sat.info/oscar/spacecapabilities

Evolution of WIGOS

- The design and evolution of WIGOS is driven by the Rolling Review of Requirements (RRR) process



See https://community.wmo.int/rolling-review-requirements-process

Support to All WMO Application Areas

- The Vision for WIGOS in 2040 takes into account the observing requirements of all 14 WMO Application Areas

No.	*WMO application area*
1	Global NWP
2	High-resolution NWP
3	Nowcasting and very short-range forecasting (see Note 1 below)
4	Sub-seasonal to longer predictions
5	Aeronautical meteorology
6	Forecasting atmospheric composition (see Note 2 below)
7	Monitoring atmospheric composition (see Note 2 below)
8	Providing atmospheric composition information to support services in urban and populated areas (see Note 2 below)
9	Ocean applications
10	Agricultural meteorology
11	Hydrology
12	Climate monitoring (Global Climate Observing System (GCOS)) The following GCOS reports are considered Statements of Guidance: - Status of the Global Observing System for Climate - GCOS-195 - The Global Observing System for Climate: Implementation Needs - GCOS-200
13	Space weather
14	Climate science
n/a	Climate applications (other aspects, addressed by the Commission for Climatology) (See Note 3 below)

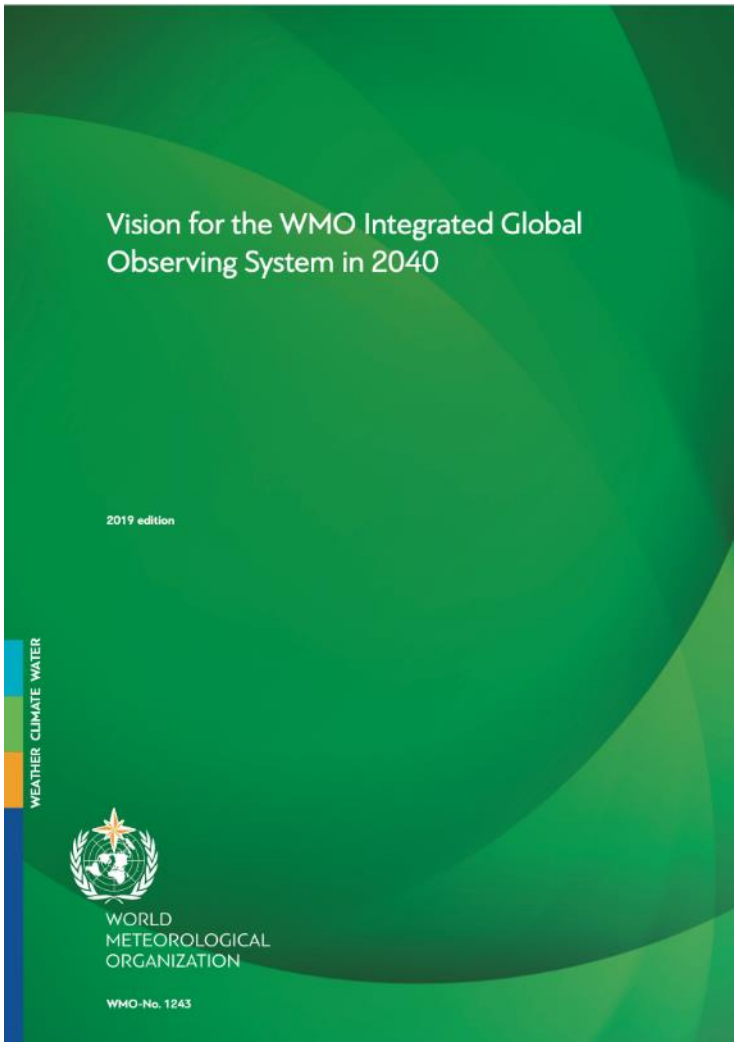
Notes:

1 The Synoptic meteorology application area has been merged into the Nowcasting and very short-range forecasting application area.

2 The Atmospheric chemistry application area has been replaced and split into three new application areas: (i) Forecasting atmospheric composition, (ii) Monitoring atmospheric composition, and (iii) Providing atmospheric composition information to support services in urban and populated areas. Statements of Guidance for the three new application areas are under preparation. The old version of the Statement of Guidance for Atmospheric Chemistry is available here.

3 At the third meeting of the Commission for Basic Systems Inter-programme Expert Team on Observing System Design and Evolution (January 2018), it was decided that the Climate applications (other aspects, addressed by the Commission for Climatology) application area would be discontinued, but that the Statement of Guidance would be kept updated and would be accessible from this webpage. The Commission for Climatology was responsible for keeping the Statement of Guidance updated and ensuring that requirements that were important from a Commission for Climatology/climate applications perspective were not missing. However, there is no intention to submit quantitative observational user requirements to the Statement of Guidance since it is assumed that such requirements are principally addressed in the GCOS 'Climate Monitoring' application area as well as in other existing application areas.

Vision for WIGOS in 2040



- Describes the space- and surface based observing networks we desire to operate by 2040
- Adopted by Congress in 2019, replaces the "Vision for the Global Observing System in 2025", adopted by the Executive Council in 2009.
  - the 2025 Vision foreshadowed the development of WIGOS, the 2040 Vision anticipates a fully developed and implemented WIGOS framework within the general areas of weather, climate and water and related environmental services.

See https://community.wmo.int/vision2040

Evolution of WIGOS

- The **"Vision for WIGOS in 2040"** describes high-level targets to guide the evolution of WIGOS towards a desired, future state of the space- and in-situ based observing system.
- The new vision, adopted by Congress in 2019, replaces the "Vision for the Global Observing System in 2025", adopted by the Executive Council in 2009.
  - While the 2025 Vision foreshadowed the development of WIGOS, the 2040 Vision anticipates a fully developed and implemented WIGOS framework within the general areas of weather, climate and water and related environmental services.
  - Which key user requirements remain unfulfilled if Vision for GOS in 2025 is fully achieved?
  - Which new observing technologies will become available operationally during the period 2025 to 2040?

Space-based Observing System Component

- **Subcomponent 1: Backbone system with specified orbital configuration and measurement approaches**
  - This subcomponent shall provide the basis for Members' commitments and should respond to their vital data needs;
  - It shall build on the current CGMS baseline (CGMS Baseline – Sustained contributions to the Global Observing System, Endorsed by CGMS-46 in Bengaluru, June 2018, CGMS/ DOC/18/1028862, v.1, 20 December 2018) but have fully deployed (global) coverage and newly maturing capabilities.
- **Subcomponent 2: Backbone system with open orbit configuration and flexibility to optimize implementation**
  - This subcomponent shall be the basis for the open contributions of WMO Members and shall respond to target data goals.
- **Subcomponent 3: Operational pathfinders and technology and science demonstrators**
  - This subcomponent shall respond to research and development needs.
- **Subcomponent 4: Additional capabilities**
  - This subcomponent shall include additional contributions by WMO Members, as well as from the academic and private sectors.

Additional Needed Observations

Even in the near term, certain additional observations using existing technology are required to address immediate needs and gaps in several specific WMO application areas. These include:

a) Atmospheric composition: limb sounding for the upper troposphere and stratosphere/ mesosphere, nadir sounding using short-wave infrared (SWIR) spectrometry, trace gas light detection and ranging (lidar);

b) Hydrology and cryosphere: laser and radar altimetry, visible multifrequency synthetic aperture radar (SAR) and passive microwave imagery;

c) Cloud phase detection for NWP: sub-mm imagery;

d) Aerosol and radiation budget: multiangle, multipolarization radiometry; lidar;

e) Wind: lidar and hyperspectral capabilities;

f) Solar wind/solar eruptions: solar wind monitor, magnetometer, energetic particle sensor, solar extreme ultraviolet (EUV) imagery, heliospheric imagery (at L5) and in situ energetic particle flux (at L1).

Additional Needed Observations

- To monitor climate change and assist in mitigation efforts in support of the Paris Agreement, observations of greenhouse gases and other factors affecting the carbon budget must be integrated into a global carbon monitoring system.
- In addition, new and better information relevant for renewable energy generation, such as near- surface wind and solar irradiance, will be required.
- These and other emerging needs, including the monitoring of air pollution, which has grown increasingly important due to the impact of air pollution on human health, and the monitoring of global precipitation will require significant augmentations to existing operational satellite constellations.

Orbital Scenarios

A future space-based observing system will rely on proven geostationary and low-Earth orbit (LEO) sun-synchronous constellations and will include:

a) Highly elliptical orbits providing permanent coverage to the polar regions;

b) LEO satellites with a low or high inclination for a comprehensive sampling of the global atmosphere;

c) Lower-flying platforms, for example, platforms with small satellites serving as gap fillers or platforms that are specially designed for specific missions; and

d) Constellations, including low-cost CubeSats.

Evolution of Satellite Programmes

In addressing how the space-based observing system component will form a part of the Vision for WIGOS in 2040, the following assumptions were made with regard to the evolution of satellite programmes:

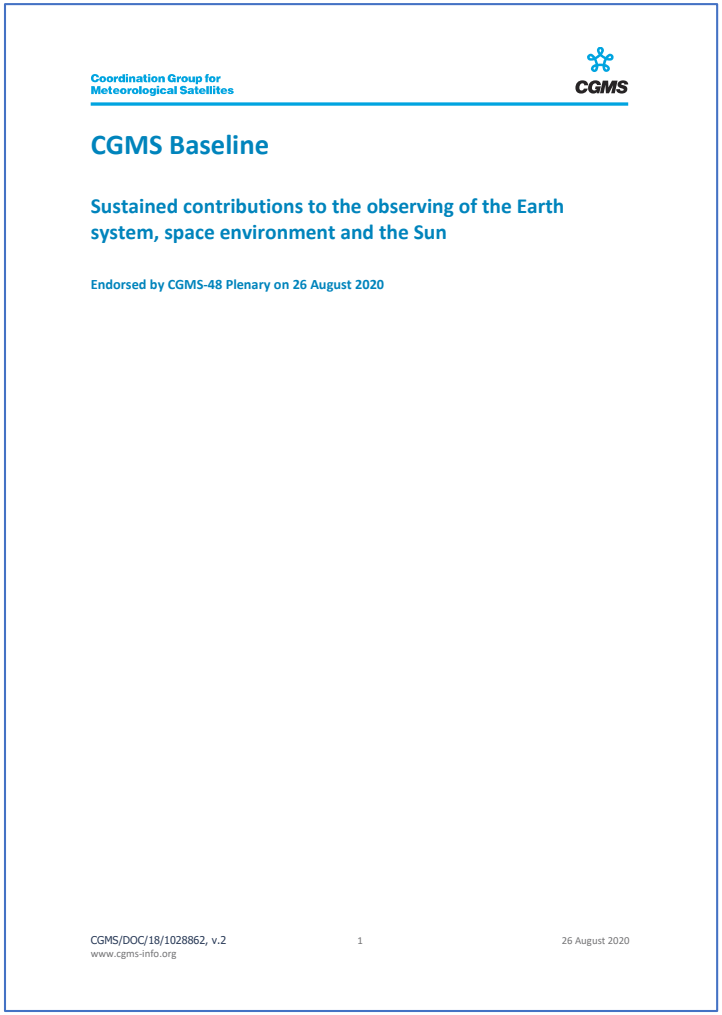
a) The space-based observing system will continue to rely on both operational and research and development missions pursuing different objectives and having different priorities;

b) Growing numbers of satellites and space-faring nations will lead to increased diversity of data sources, which will require improved documentation, processing and real-time data delivery mechanisms;

c) International fora such as CGMS and CEOS will provide regular and formal opportunities to address joint planning, coordination and cooperation issues.

CGMS and Vision for WIGOS in 2040

- WMO Members rely on the space-based observing system provided and operated by CGMS Members (mainly Subcomponents 1 and 2)
- WMO welcomes the updated CGMS baseline and efforts by CGMS to provide additional capabilities towards implementing the Vision for WIGOS in 2040
- **NOAA contributions through CGMS are essential for implementing WIGOS**



Coordination Group for Meteorological Satellites

CGMS

CGMS Baseline

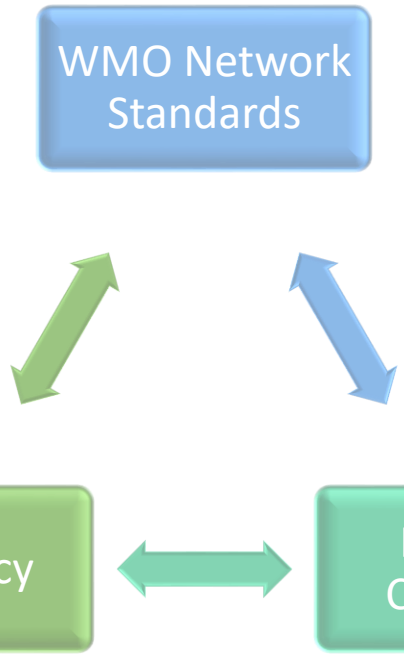
Sustained contributions to the observing of the Earth system, space environment and the Sun

Endorsed by CGMS-48 Plenary on 26 August 2020

CGMS/DOC/18/1028862, v.2 1 26 August 2020
www.cgms-info.org

See https://www.cgms-info.org/index_.php/cgms/page?cat=SATELLITES&page=CGMS+Baseline

Major WMO Initiatives



- What observing networks are required
- Resolution 40 (Annex)
- Global Basic Observing Network (GBON)

- What data is shared
- Intellectual property
- Resolution 40, 60, 25

- Capability gaps
- Capacity gaps
- Funding limitations
- Systematic Observations Funding Facility (SOFF)

“Res. 42” development timeline

- **INFCOM** (May-June 2020); SG-DIP formally established, with updated ToRs and core membership;
- **PAC-1** (May 2020): Report from SG-DIP-1, focusing on principles and future work plan;
- June 2020; Working groups established to prepare themed sessions for the WMO Data Conference and draft conference output;
- SG-DIP teleconferences (tentatively),
  - July 1; Review of Res. 40/25/60; Res. 42 outline agreed; drafting assignments distributed;
  - July 21; Mid-term status update on drafting of Res. 42;
  - August 19; Zero draft distributed and available for discussion;
  - September 9; Second round of discussion; preparation of input to EC-72;
- **EC-72** (September 2020): Report from SG-DIP endorsed, including overarching principles, work plan, first draft of Res. 42

- **Stakeholder consultations** (Sep-Oct 2020) involving RA’s, RB, HMEI, broader private sector, CGMS; CEOS; GOOS, GCOS co-sponsors, Hydromet Alliance partners,…
- **INFCOM-1** (Nov 2020); review of draft Res. 42, recommendation to EC-73;
- **WMO Data Conference** (16-19 November 2020); draft resolution socialized, discussed; feedback recorded as Conference output;
- *SG-DIP informal meeting immediately following the Data Conference*
- **SG-DIP-2** (January 2021); Input from Data Conference included in draft Res. 42;
- **PAC-2** (spring 2021); final adjustments to draft Congress resolution;
- *EC-73 prior to Cg (Ext)-21?*
- **Cg (Ext)-21**: New resolution on WMO Data Policy;

Current status of drafting work

- Single, overarching dat policy resolution; existing Res. 40 used as 'strawman'
  - Modernized language and context;
  - Emphasis on earth system monitoring and prediction;
  - New elements with respect to Res. 40, 25 and 60:
    - Built-in cycle for reviewing and updating as requirements change;
    - Call for subsequent implementation activities (regulatory material, capacity development);
    - Request for systems and procedures to review of compliance.
- Open issues (among others):
  - Scope of resolution; emphasis on "Members" versus emphasis on NMHSs;
  - Emphasis on international vs. more general data exchange;
  - Right balance of policy language for Members and partners

"Critical Satellite Data"

- Following a presentation from WMO on the plans for GBON in Sochi (CGMS-47-WMO-WP-06**):** *"CGMS noted the importance of GBON and the need to identify ways for CGMS members to contribute to its implementation"*
- This led to
  - **Action A47.02***: WMO to provide a report at next CGMS on baseline requirements for satellite products for global NWP, to trigger a CGMS discussion on status of delivery of such observations and possible improvements in the future and inclusion in the CGMS baseline document.*

"Critical Satellite Data"

- WMO to revise the Critical Satellite Data Paper per action given to CBS *(never completed)* and submit to 1st Session of the Infrastructure Commission Session for approval in Nov 2020;
- CGMS WG-III to integrate relevant text from approved version of Critical Satellite Data paper into revised version of CGMS Baseline at its workshop to be held in Feb 2021;
- WMO Secretariat to integrate revised CGMS Baseline into draft Manual on WIGOS in March 2021;
- **CGMS-49 to approve new version of CGMS Baseline**, May 2021;
- **Draft Manual on WIGOS, including revised CGMS Baseline to be approved by WMO Extraordinary Congress** in June 2021;
  - *The inclusion of the new CGMS Baseline will be conditional on its approval by CGMS-49, which will have taken place one month prior to Congress;*

WMO Data Conference

- **Why?** Resolution 55 (Cg-18): Members requested the Secretary-General to:
  - *Convene a global "WMO Data Conference" {…}, with the aim of exploring the evolution and sustainability of systems for the acquisition and exchange of meteorological data, including possible pathways toward establishing innovative modes of collaboration, and to provide input to ongoing WMO assessment and associated actions in relation to emerging data issues {…};*
- **When?** November 16-18 2020;
- **Where?** WMO Headquarters, Geneva;
- **Who?** Broad group of stakeholders representing both data providers and data users from all relevant sectors.

24 September 2020	**Workshop on Theme 1: "Changing landscape of weather, climate and water data"**	**Data exchange in the 1960s and today; what has changed and what will need to change? WMO data policy for Members or for their NMHSs?**
7 October 2020	Workshop on Theme 2: "Business models and data policy issues"	External views on WMO data policy; what works and does not work? Increasing the amount of data available to all users; policy as enabler and as a roadblock.
14 October 2020	Workshop on Theme 3: "Filling the gaps in global data coverage"	Strengths and weaknesses of WMOs efforts to address this? GBON/SOFF paradigm; extensions to other domains and disciplines? Access to prediction and analysis products.
19 October 2020	Stakeholder Consultation 1: "Hydrological data and WMO Data Policy"	The role of data exchange and of WMO data policy for hydrology. The implications of moving towards earth system monitoring and prediction.
21 October 2020	Stakeholder Consultation 2: "Research data and WMO data policy"	WMO use of research funded data. Research access to operational data.
23 October 2020	Stakeholder Consultation 3: "Satellite data and WMO data policy"	The role of satellite data in WMO. Ensuring equitable access to critical observations. The role of private sector satellite data.
28 October 2020	Workshop on Theme 4: "Data exchange for Earth System Monitoring and Prediction"	Earth system prediction as a policy driver. Data requirements and data maturity. Moving from requirements to policy.

See https://meetings.wmo.int/WMO-Data-Conference

Important Events

- 28 Sept to 2 Oct 2020 - WMO Executive Council 72nd Session
- 23 Oct – Stakeholder Consultation on on satellite data and WMO Data Policy
- 9 to 13 November 2020 - Joint Session of Infrastructure and Services Commission and Research Board
- 16 to 19 November – WMO Data Conference
- April 2021 – Extraordinary Executive Council
- Mid 2021 – Extraordinary Congress

WEATHER CLIMATE WATER

Thank you

WMO Space Programme
http://www.wmo.int/sat

WORLD
METEOROLOGICAL
ORGANIZATION

Backup Slides

Backbone System (Subcomponent 1)

Instruments	*Geophysical variables and phenomena*
Geostationary core constellation with a minimum of five satellites providing complete Earth coverage	
Multi-spectral VIS/IR imagery with rapid repeat cycles	Cloud amount, type, top height/temperature; wind (by tracking cloud and water vapour features); sea/land surface temperature; precipitation; aerosol content and physical properties; snow cover; vegetation cover; albedo; atmospheric stability; fire properties; volcanic ash; sand and dust storms; convective initiation (combining multispectral imagery with IR sounders data)
IR hyperspectral sounders	Atmospheric temperature, humidity; wind (by tracking cloud and water vapour features); rapidly evolving mesoscale features; sea/land surface temperature; cloud amount and top height/temperature; atmospheric composition (aerosols, ozone, greenhouse gases, trace gases)
Lightning mappers	Total lightning (in particular, cloud to cloud), convective initiation and intensity, life cycle of convective systems, NOx production
UV/VIS/NIR sounders	Ozone, trace gases, aerosol, humidity, cloud top height
Sun-synchronous core constellation satellites in three orbital planes (morning, afternoon, early morning)	
IR hyperspectral sounders	Atmospheric temperature and humidity; sea/land surface temperature; cloud amount, water content and top height/ temperature; precipitation; atmospheric composition (aerosols, ozone, greenhouse gases, trace gases)
MW sounders	
VIS/IR imagery, realization of a day/night band	Cloud amount, type, top height/temperature; wind (high latitudes, by tracking cloud and water vapour features); sea/ land surface temperature; precipitation; aerosol properties; snow and (sea-) ice cover; ice-flow distribution; vegetation cover; albedo; atmospheric stability; volcanic ash; sand and dust storm; convective initiation
MW imagery	Sea-ice extent and concentration and derived parameters, such as ice motion; total column water vapour; water vapour profile; precipitation; sea-surface wind speed and direction; cloud liquid water; sea/land surface temperature; soil moisture; terrestrial snow
Scatterometers	Sea-surface wind speed and direction; surface stress; sea ice; soil moisture; snow cover extent and snow water equivalent (SWE)
Sun-synchronous satellites at three additional equatorial crossing times for improved robustness and improved time sampling, particularly for monitoring precipitation	
Instruments on other satellites in low-Earth orbit	
Wide-swath radar altimeters and high-altitude, inclined, high-precision orbit altimeters	Ocean surface topography; sea level; ocean wave height; lake levels; sea- and land-ice characteristics; snow over sea ice
IR dual-angle view imagers	Sea-surface temperature (of climate monitoring quality); aerosols; cloud properties
MW imagery for surface temperature	Sea-surface temperature (all weather)
Low-frequency MW imagery	Soil moisture; ocean salinity; sea-surface wind; sea-ice thickness; snow cover extent and SWE
MW cross-track upper stratospheric and mesospheric sounders	Atmospheric temperature profiles in the stratosphere and mesosphere

Backbone System (Subcomponent 1)

Instruments	*Geophysical variables and phenomena*
UV/VIS/NIR sounders, nadir and limb	Atmospheric composition (ozone, aerosol, reactive gases)
Precipitation radars and cloud radars	Precipitation (liquid and solid); cloud phase; cloud top height; cloud particle distribution, amount and profiles; aerosol; dust; volcanic ash
MW sounder and imagery in inclined orbits	Total column water vapour; precipitation; sea-surface wind speed and direction; cloud liquid water; sea-/land-surface temperature; soil moisture
Absolutely calibrated broadband radiometers and total solar irradiance and solar spectral irradiance radiometers	Broadband radiative flux; Earth radiation budget; total solar irradiance; spectral solar irradiance
Global Navigation Satellite System (GNSS) radio occultation (basic constellation)	Atmospheric temperature and humidity; ionospheric electron density; zenith ionospheric total electron content; total precipitable water
Narrow-band or hyperspectral imagers	Ocean colour; vegetation (including burned areas); aerosol properties; cloud properties; albedo
High-resolution multi-spectral VIS/IR imagers	Land use, vegetation; flood, landslide monitoring; ice floe distribution; sea-ice extent/concentration; snow cover extent and properties; permafrost
SAR imagers and altimeters	Sea state; sea-surface height; sea-ice motion; sea-ice classification; ice floe geometry; ice sheets; soil moisture; floods; permafrost
Gravimetry missions	Groundwater; oceanography; ice and snow mass
Other missions	
Solar wind, in situ plasma, energetic particles and magnetic field at L1	Particle flux, energy spectrum and magnetic field (radiation storms, geomagnetic storms)
Solar coronagraph and radio spectrograph at L1	Solar imagery and radio wave spectrum (detection of coronal mass ejections and solar activity monitoring)
In situ plasma probes, energetic particle spectrometers and magnetometers at GEO and LEO; magnetic field at GEO	Energetic particle flux and energy spectrum; geomagnetic field (radiation storms, geomagnetic storms)
X-ray spectrograph at GEO	Solar X-ray flux (solar flare)
On-orbit measurement reference standards for VIS/NIR, IR; MW absolute calibration	

Backbone System (Subcomponent 2)

Instruments	*Geophysical variables and phenomena*
GNSS reflectometry (GNSS-R) missions; passive MW; SAR	Surface wind and sea state; permafrost changes/melting; terrestrial water storage variations; ice sheet altimetry; snow depth; SWE; soil moisture
Lidar (Doppler and dual/triple-frequency backscatter)	Wind and aerosol profiling
Lidar (single wavelength) (in addition to radar missions mentioned in Subcomponent 1)	Sea-ice thickness; snow depth (only if pointing accuracy is very precise)
Interferometric radar altimetry	Sea-ice parameters; freeboard/sea-ice freeboard
Sub-mm imagery	Cloud microphysical parameters, for example, cloud phase
NIR/SWIR imaging spectroscopy	Spatially-resolved two-dimensional maps of CO_2, CH_4 and CO over sunlit hemisphere
Trace gas lidars	CO_2 and CH_4 column at night and high latitude winter
Multiangle, multipolarization radiometers	Aerosol properties; radiation budget
Multipolarization SAR; hyperspectral VIS	High-resolution land, ocean, and sea-ice extent; sea-ice types
Constellation of high-temporal frequency MW sounding	Atmospheric temperature, humidity and wind; sea/land surface temperature; cloud amount, water content and top height/temperature; atmospheric composition (aerosols, ozone, trace gases)
UV/VIS/NIR/IR/MW limb sounders	Ozone; reactive trace gases; aerosol properties; humidity; cloud top height
VIS/NIR/SWIR/IR mission for continuous polar coverage (Arctic and Antarctica)	Sea-ice motion; ice type; cloud amount; cloud top height/temperature; cloud microphysics; wind (by tracking cloud and water vapour features); greenhouse gases and other trace gases; sea/land surface temperature; precipitation; aerosols; snow cover; vegetation cover; albedo; atmospheric stability; fires; volcanic ash
Solar magnetograph, solar EUV/X-ray imagery and EUV/X-ray irradiance, both on and off the Earth-Sun line	Solar activity (detection of solar flares, coronal mass ejections and precursor events); geomagnetic activity
Solar wind, in situ plasma, energetic particles and magnetic field off the Earth-Sun line	Solar wind; energetic particles; interplanetary magnetic field; geomagnetic activity
Solar coronagraph and heliospheric imagery, both on and off the Earth-Sun line (for example, at L5)	Solar heliospheric imagery (detection and monitoring of coronal mass ejections travelling to the Earth)
Magnetospheric energetic particles and magnetometers	Energetic particle flux, energy spectrum and geomagnetic field (radiation storm, geomagnetic storms)

Operational Pathfinders (Subcomponent 3)

Instruments	*Geophysical variables and phenomena*
GNSS radio occultation; additional constellation for enhanced atmospheric/ ionospheric soundings (including polarimetric), including LEO-LEO radio occultation for additional frequencies optimized for atmospheric sounding	Atmospheric temperature and humidity; precipitation detection; ionospheric electron density; zenith ionospheric total electron content; total precipitable water
NIR spectrometer	Surface pressure; cloud top height; aerosol property (thickness, height)
Differential absorption lidar (DIAL)	Atmospheric moisture profiling
Radar and lidar for vegetation mapping	Vegetation parameters; above-ground biomass
Hyperspectral MW sensors	Atmospheric temperature, humidity and wind; sea/land surface temperature; cloud amount, water content and top height/temperature; atmospheric composition (aerosols, ozone, trace gases)
	Ocean surface currents and mixed layer depth
	High-resolution surface water and ocean topography measurements
Hyperspectral UV/NIR sensors	Water quality
Solar coronal magnetic field imagery; solar wind beyond L1	Solar wind; geomagnetic activity
UV spectral imagery (for example, GEO, HEO, medium Earth orbit, LEO)	Ionosphere, thermosphere and aurora
Neutral and ion mass spectrometer	Thermospheric neutral and ionospheric constituents
Mass accelerometers	Neutral density
Miniaturized instruments on micro satellites	

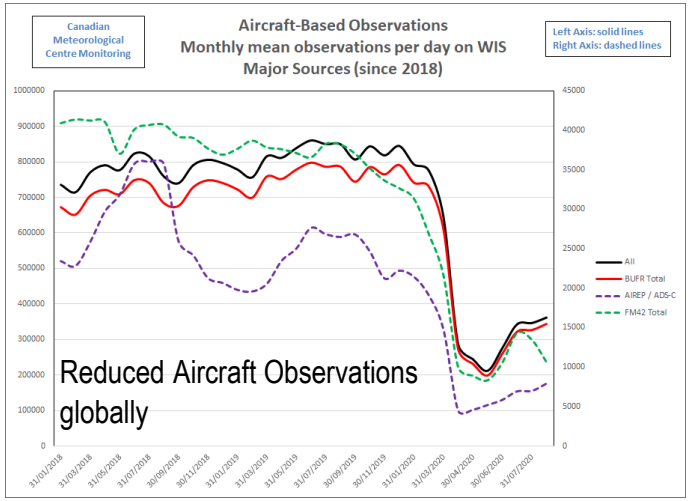
Additional Capabilities (Subcomponent 4)

Instruments	*Geophysical variables and phenomena*
GNSS radio occultation	Atmospheric temperature and humidity; precipitation detection; ionospheric electron density; zenith ionospheric total electron content; total precipitable water

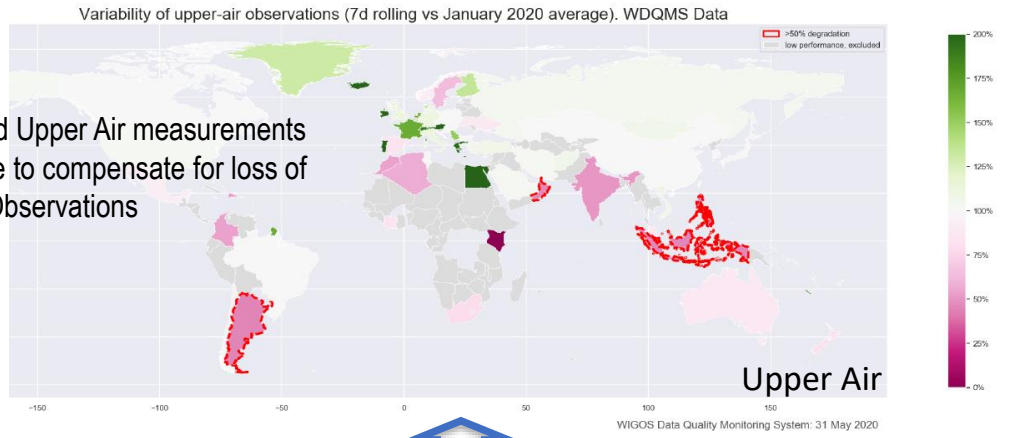
Monitoring of Observing Networks

- WMO has been improving the monitoring of the status of observations and access to the data
- WIGOS Data Quality Management System (WDQMS, https://wdqms.wmo.int), provides information on the status of reporting of observations in near-real time
- WMO and GCOS are extending this to include the GCOS Climate Networks, the GCOS Surface Network (GSN) and the GCOS Upper Air Network (GSRN)
- Work is also underway to provide similar information on ocean observations to complement the work of JCOMMOPS
- Updates at https://public.wmo.int/en/media/press-release/covid-19-impacts-observing-system
- WMO is coordinating global monitoring and working with Members to identify risks
- GCOS will include the impacts of COVID-19 in their upcoming revision of the status report

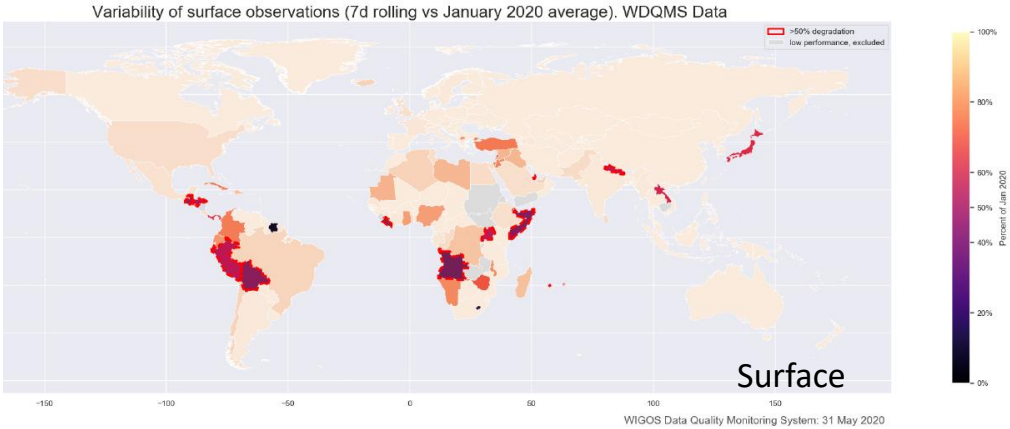
Impact of Covid-19 on Observations



Increased Upper Air measurements in Europe to compensate for loss of Aircraft Observations



Reduced Observations in some countries with manual observations



Other Surface Observations

It is difficult to quantify the impact on other observations (e.g. cryosphere, biosphere), as these are not (yet) monitored daily

Surface observations are being interrupted where they are made manually and there is a slow degradation of automatic measurements where maintenance and calibration cannot be performed.

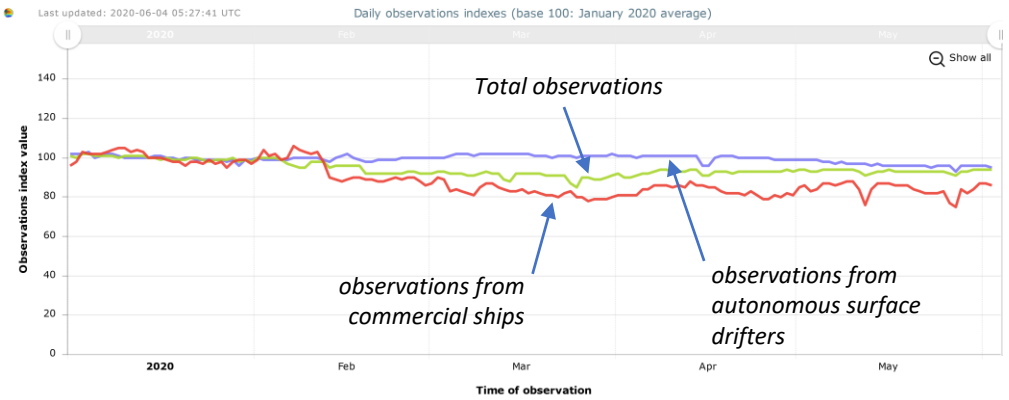
e.g. the Long-Term Ecological Research programme (LTER) in the US, noted that this might lead to the first interruption in more than 40 years at some sites.

GOOS Survey on Covid-19 Impact

Limited immediate impact on data flow

United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission

- **GLOSS:** maintaining function
- **SOT-ASAP:** decreased data but maintaining function
- **SOT-SOOP:** data stream is impacted in the near term
- **SOT VOS:** data flow decreased (~15%)
- **Argo:** deployments impacted
- **DBCP Drifters:** maintained for now
- **OceanSITES:** major risks appear to be unfolding, complex
- **DBCP Moored buoys:** some data flow affected
- **OceanGliders:** heavily impacted in the near term, uncertainty remains
- **GO-SHIP:** major impacts to long established observing lines

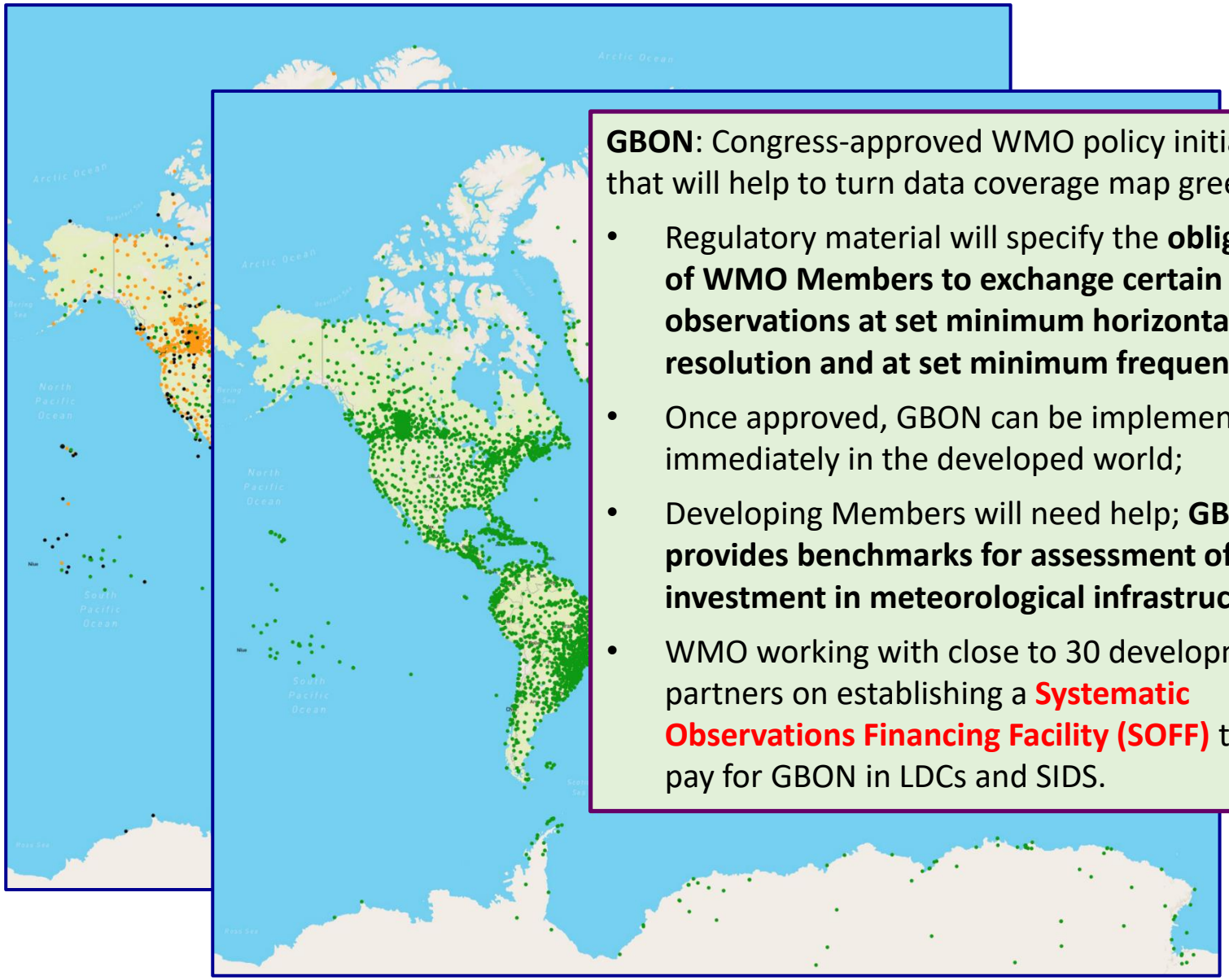


Lessons learned:

- Autonomous platforms and sensors are key
- Need increased international cooperation, sharing of resources such as ship-time
- Prioritize sustained observations can allow them to operate under different conditions

(Slide courtesy Toste Tanhua, GOOS SC Chair)

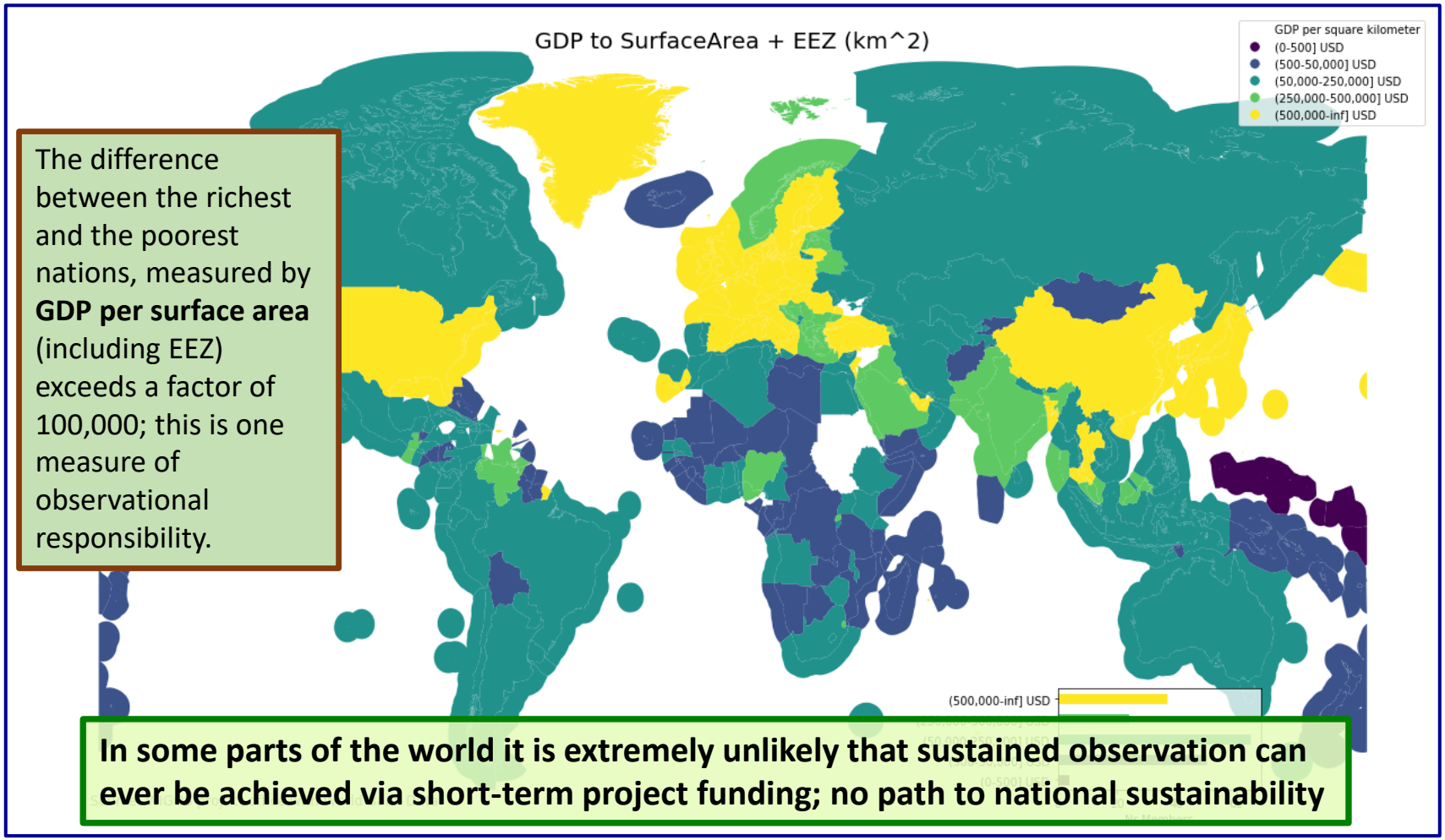
Global Basic Observing Network (GBON)
(see also CGMS-47 WMO-WP-06)



GBON: Congress-approved WMO policy initiative that will help to turn data coverage map green;

- Regulatory material will specify the **obligation of WMO Members to exchange certain observations at set minimum horizontal resolution and at set minimum frequency**;
- Once approved, GBON can be implemented immediately in the developed world;
- Developing Members will need help; **GBON provides benchmarks for assessment of investment in meteorological infrastructure;**
- WMO working with close to 30 development partners on establishing a **Systematic Observations Financing Facility (SOFF)** to help pay for GBON in LDCs and SIDS.

A different look at available resources



The difference between the richest and the poorest nations, measured by **GDP per surface area** (including EEZ) exceeds a factor of 100,000; this is one measure of observational responsibility.

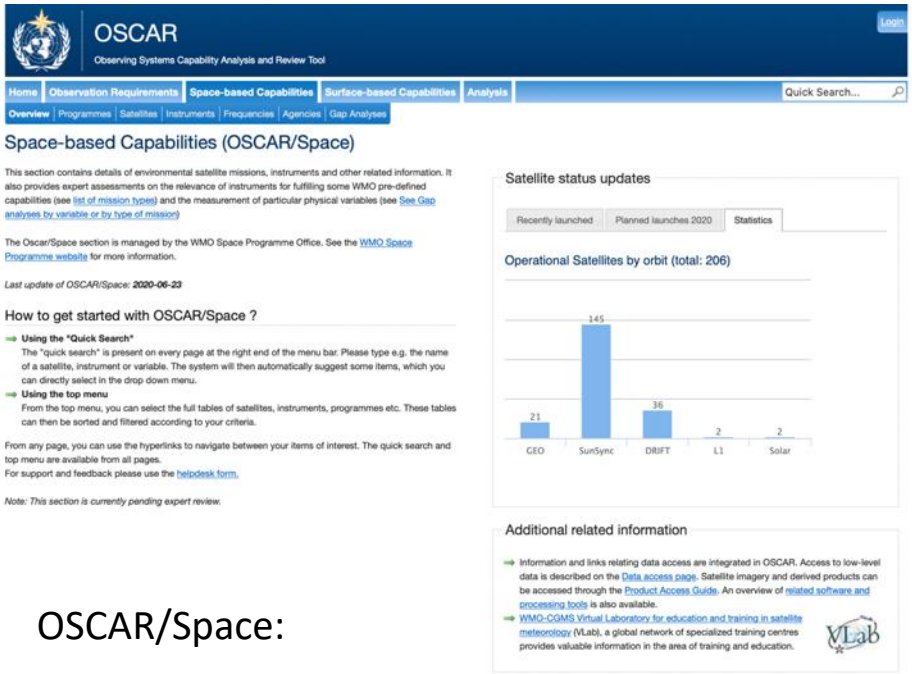
In some parts of the world it is extremely unlikely that sustained observation can ever be achieved via short-term project funding; no path to national sustainability

GDP (World Bank numbers) per surface area (land surface + EEZ)

OSCAR/Space Database

- WMO has established a framework for continuing OSCAR/Space development
- IT company contracted to further develop OSCAR/Space
- **Phase 1:** upgrades to the OSCAR/Space technical stack – presently in user acceptance testing.
- **Phase 2:** upgrades to OSCAR/Space to make it compliant with WIGOS metadata records - to be kicked off in Q2/2020

- Continuous content maintenance with the support of O/SST (OSCAR Space Support Team)



OSCAR/Space:

- 770 satellites
- 1000 instruments: 650 for Earth Observation and 350 for Space Weather.
- Around 4000 individual content edits annually
- On average 200 user visits per day

See https://www.wmo-sat.info/oscar/spacecapabilities

Role of Integration in WIGOS

- Integrated network design
- Integrated, multi-purpose observing networks
- Integrated observing system providers
- WIGOS as a system of tiered observing networks
- Integrated space-based and surface-based observing systems