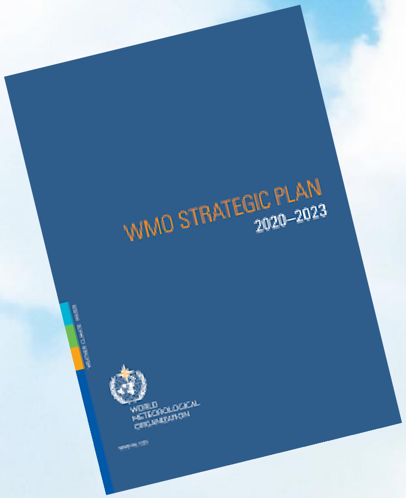
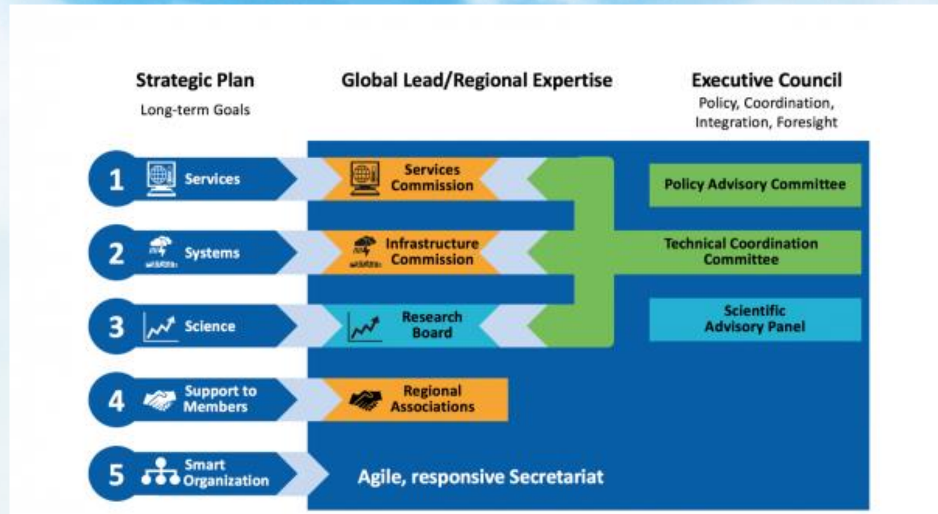




WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Status of the WMO Integrated Global Observing System

Kenneth Holmlund
WMO Space Systems and Utilization Division

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

WMO Long-term Goals

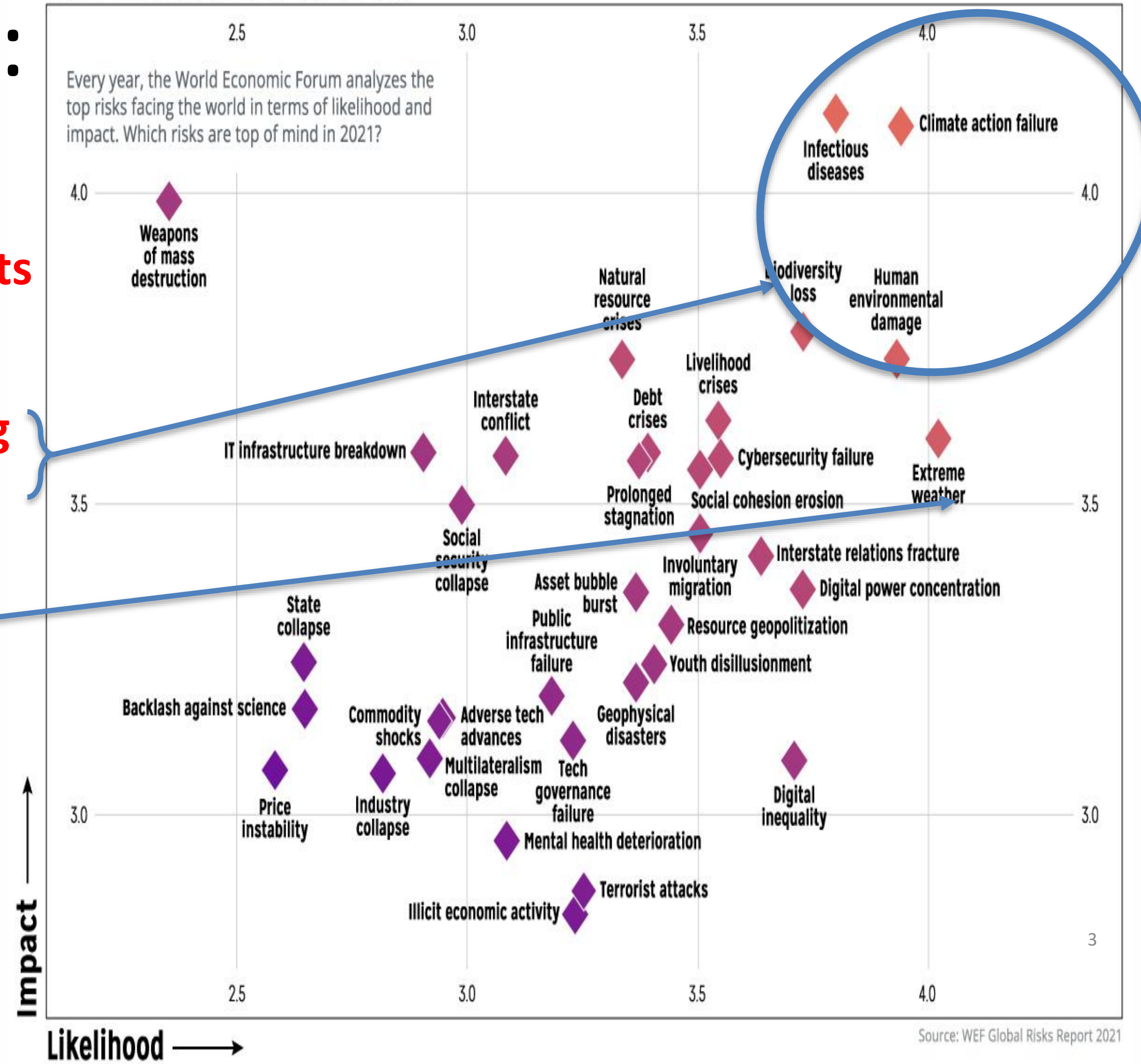
1. **Better serve societal needs;**
2. **Enhance Earth system observations and predictions;**
3. **Advance targeted research;**
4. **Close the capacity gap;**
5. **Strategic realignment of structure and programs.**

Key Challenges:

1. **Earth System modelling and global NWP (supports most WMO application areas)**
2. **GHG/Climate Monitoring (also consider Paris Agreement)**
3. **Monitoring Extreme Weather Events**
4. **Air Quality Monitoring**

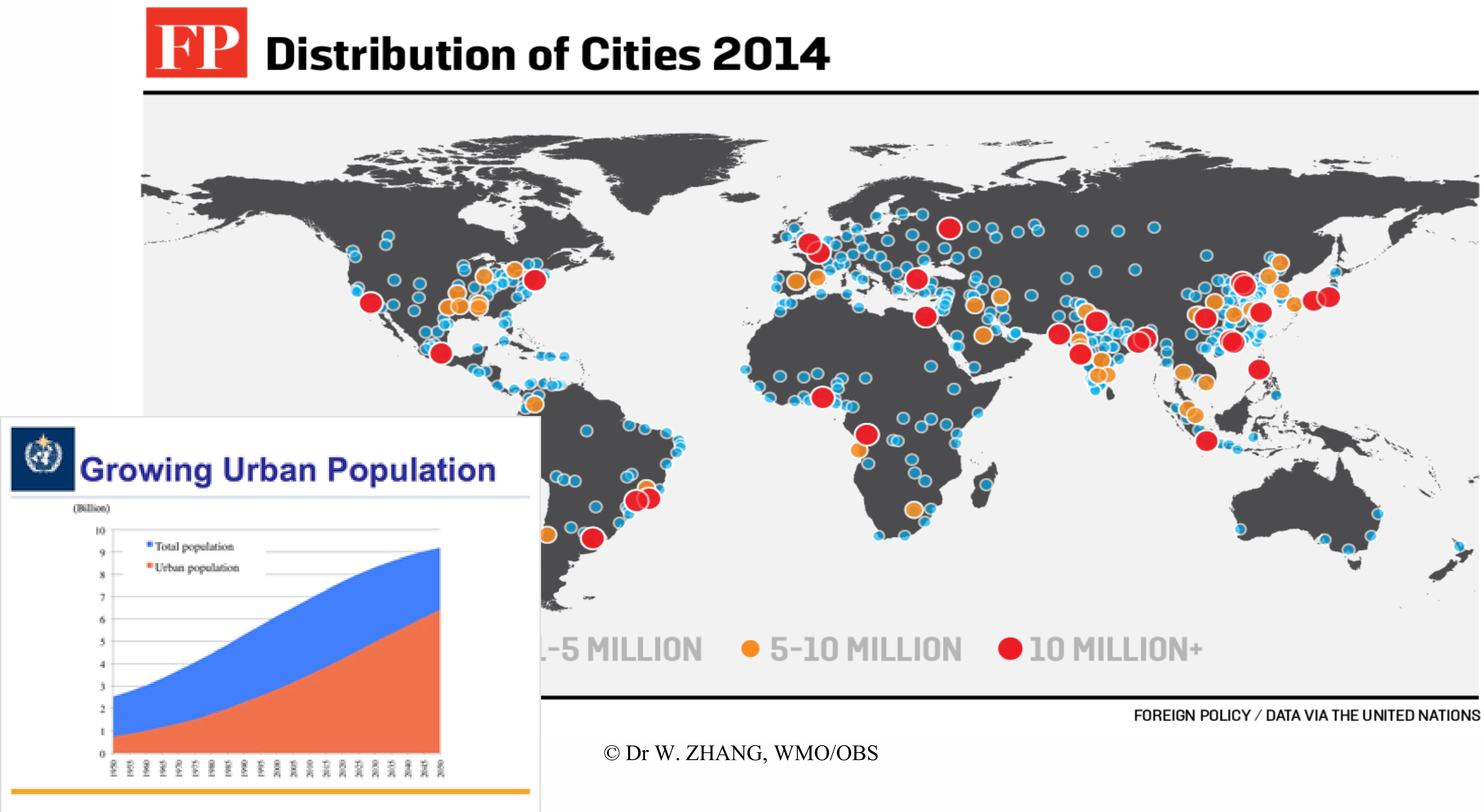
But there is more….

2021 Global Risks Outlook



Global Risk Landscape 2021

Climate & climate change –extreme weather and climate events impact to costal Megacities !!!!



© Dr W. ZHANG, WMO/OBS

Supporting a holistic Earth-system monitoring and modelling approach

WMO Integrated Global Observing System Vision for 2040

HLG*

Data Exchange

RRR*

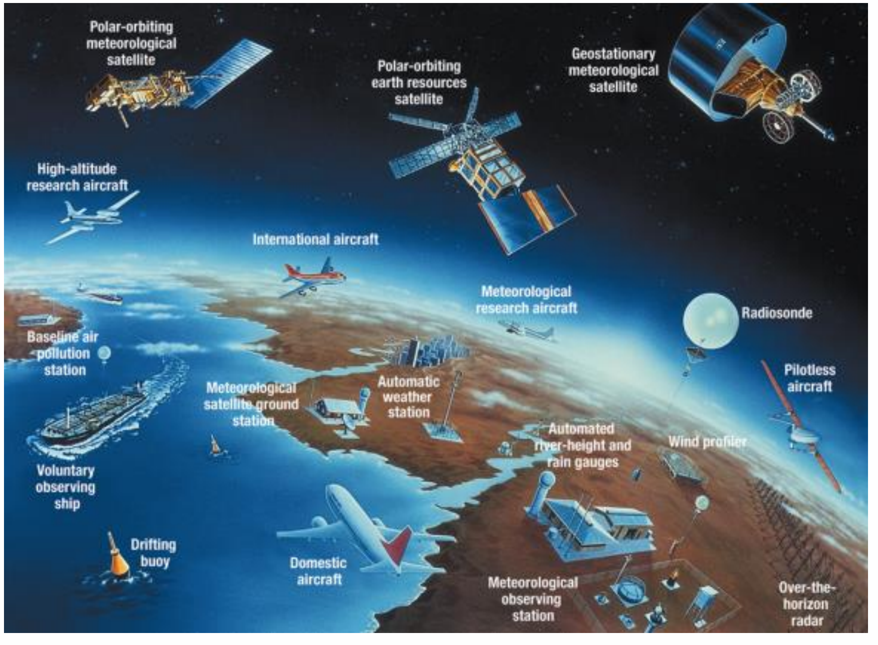
Gap Analysis

OSCAR

Data Policy Res 1 Ext C 21

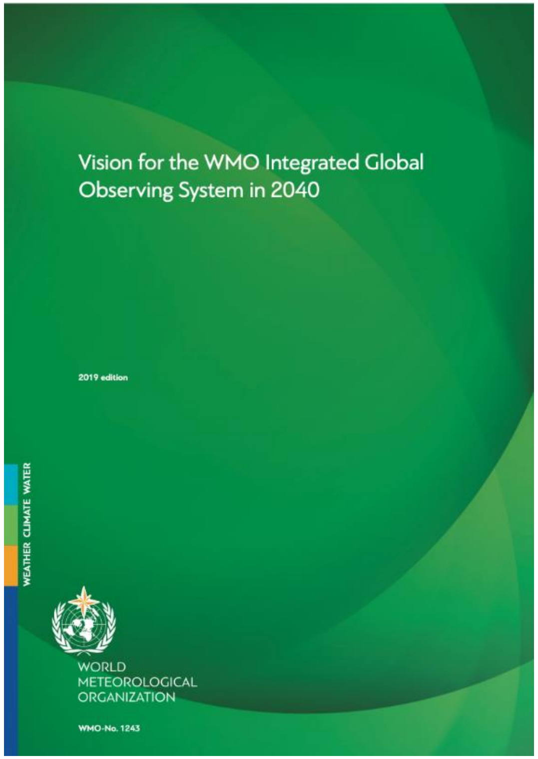
*Rolling Review of Requirements
**High Level Guidance
***Observing Systems Capability Analysis and Review Tool

WMO Integrated Global Observing System (WIGOS)



All surface- and space-based observing programs of WMO that are consolidated in a single integrated system, the WIGOS.

Vision for 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 2040 Vision anticipates a fully developed and implemented WIGOS framework within the general areas of weather, climate and water and related environmental services.
- 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.

- Which key user requirements remain unfulfilled if Vision for GOS in 2025 are fully achieved?
- Which new observing technologies will become available operationally during the period 2025 to 2040?

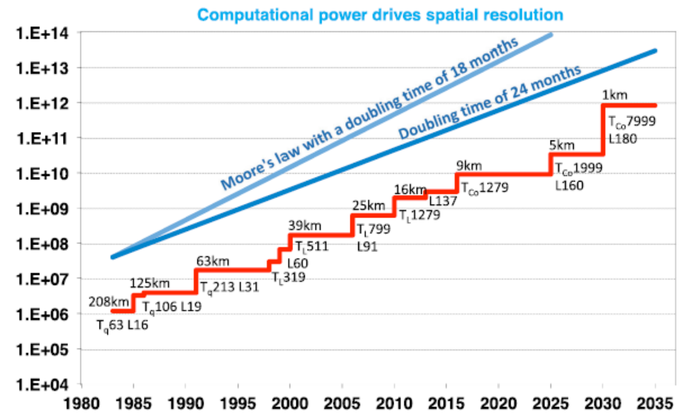
See https://community.wmo.int/vision2040

User Requirements – NWP

Trends: By 2040, global NWP resolution will reach 1km 10km at present), regional NWP 100m (1.5km at present), vertical resolution will be 200m (2km at present)

		At present	Future
Polar satellite resolution horizontal and vertical resolution	MWHS	Horizontal resolution:15km, 15 channels	Horizontal resolution: 0.5km, Vertical resolution: 0.2km
	MWTS	Horizontal resolution:50km, 13 channels	Horizontal resolution:0.5km Vertical resolution:0.2km
	MW imager	Horizontal resolution:10km , 10channels	Horizontal resolution:0.5km
	IR sounder	Horizontal resolution:17km, 26 channels	Horizontal resolution:0.5km Vertical resolution:0.2km
GNSS、Lidar & Radar(Precipitation, cloud aerosol temporal resolution	Profiler	16 days revisit	Higher (weekly?)
New Observation	Highly accurate satellite wind field observation		
	Highly accurate satellite atmospheric pressure observation(less than 1hPa at surface)		
	Highly accurate satellite hydrometeor size distribution and profiling		
Stability		5 yrs	15yrs

the NWP goal of reaching a 1-km horizontal resolution with 180 levels in the mid to late 2030s



Ambitious target configuration for global weather and climate simulations with km-scale horizontal resolution accounting for physical Earth system processes, and with today's computational throughput rate

Horizontal resolution	1 km (globally quasi-uniform)
Vertical resolution	180 levels (surface to ~100 km)
Time resolution	0.5 min
Coupled	Land-surface/ocean/ ocean-waves/sea-ice
Atmosphere	Non-hydrostatic
Precision	Single or mixed precision
Compute rate	1 SYPD (simulated years per wall-clock day)

Schulthess T C et al, 2018

Description of the space-based observing system components

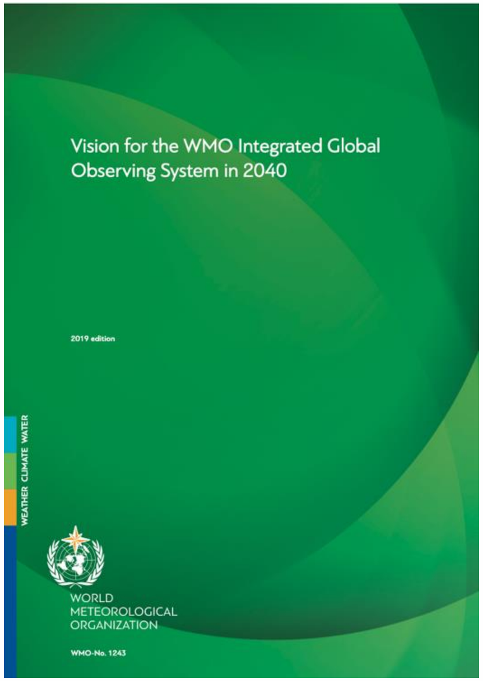
as given in the WIGOS Vision 2040 (WMO-No. 1243)

The proposed space-based component consists of **four main subcomponents.**

Rather than giving strict stipulations for each subcomponent, a balance has been struck between providing enough specificity to describe a **robust and resilient system** and accommodating potential **new capabilities** arising from unanticipated opportunities.

The division of the observing capabilities into four subcomponents does not imply sequential priorities, that is, it is not expected that all Subcomponent 1 systems will necessarily be realized before elements of other subcomponents are addressed.

The main distinction between the various subcomponents is the current level of consensus about the optimal measurement approach, especially the demonstrated maturity of that approach: there is stronger consensus for the capabilities included in Subcomponent 1 compared to those in Subcomponent 2, and so forth. It is likely that the boundaries between the groups will shift over time, for instance, some capabilities currently listed in Subcomponent 2 could transfer to Subcomponent 1.



WIGOS 2040 Space Component
Example microwave observations (1/2)

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)
- Sun-synchronous core constellation satellites in three orbital planes (morning, afternoon, early morning)
  - **MW sounding + Imagery:**
- Sun-synchronous satellites at three additional equatorial crossing times for improved robustness and improved time sampling, particularly for monitoring precipitation
  - **MW imagery for SST+MSU/SSU**
  - **MW sounding and imagery in inclined orbits**

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
- Backbone system with open orbit configuration and flexibility to optimize the implementation
  - **Constellation of high-temporal frequency MW sounding**

WIGOS 2040 Space Component
Example microwave observations (2/2)

Subcomponent 3: Operational pathfinders and technology and science demonstrators:

- This subcomponent shall respond to research and development needs
- **Hyperspectral MW**

Subcomponent 4: Additional capabilities:

- This subcomponent shall include additional contributions by WMO Members, as well as from the academic and private sectors.
- **Emerging!**

GEO Microwave:

- Note: Today there is no GEO MW instruments flying but it is being pursued by CMA
  - Open issues are wrt to optimization of integration time, resolution, NeDT
  - Benefit trade-off wrt to constellations

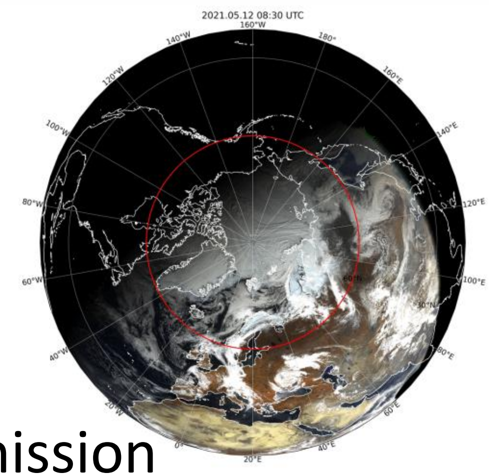
Future Challenges
Advancing the WIGOS 2040 Vision
Cannot do everything – Need to define priorities

- Current capabilities +
  - Aeolus (wind profiling) FO (possibly with swath e.g. push broom)
  - MW sounder, MW imager, HSIR LEO, Scat constellations (towards hourly data?)
  - GEO HSIR complete ring
  - HEO HSIR + imager
  - Increase to 20,000 RO per day constellations (of COSMIC-2 quality)
  - Radar constellation (rain and cloud, with wide swath)
  - Limb sounding (IR + MW, CAIRT/PREMIER type concept), including high freq RO concept (ATOMMS like)
  - High spatial resolution L-band (CIMR will only deliver low resolution L-band of limited value to hydrology)
  - Carbon mission
  - GEO + 10 LEO and at least one active instrument
  - Snow and ice active imaging (Cryosat, RA, CRISTAL, SAR, ISAR, CoreH2O-like)
  - GEO+HEO microwave?
  - Demo missions for new technologies e.g. photonic filtering

Future Challenges
Advancing the WIGOS 2040 Vision
Cannot do everything – Need to define priorities

Current Capabilities +

- Wind Lidar (Aeolus) FO
- MW sounding and imaging (hourly data?)
- GEO HSIR complete ring
- Advancing the HEO component
  - Roscosmos and Roshydromet launch first mission Arctica in Feb 21
- Increase number of daily radio-occultation measurements
- **Carbon monitoring**
  - Three GEO + 10 LEO and at least one active instrument
- Additional requirements
  - limb sounding, precipitation radars, snow and ice



MSU-GS/A
12 May 2021 08:30 – 13:30 UTC
Western pass

Future Challenges
Advancing the WIGOS 2040 Vision
Can we be more efficient

Optimizing the Space-based Architecture:

- E.g. More studies like Meier et al, 2021: Architecting the Future of Weather Satellites
- Is the concept of long-term big satellite programmes with rigid satellite and instrument complement outdated?
- Do we need more agile constellations?
- Concept of "calibration/reference" satellites/platforms supporting a fragmented observing system and short lifetime instruments
- The role of commercial satellite data providers in delivering the WIGOS2040 Vision

Future Challenges
Advancing the WIGOS 2040 Vision
Sustainability and Capacity Development

Ensuring continued access to spectrum:

- Protecting the 'fingerprints of nature' and working towards sustainable co-habitation
- Protecting downlink frequencies

Protecting the space environment:

- Limiting debris and space junk

Capacity Development:

- Building capability to use data and products
- Ensuring data accessibility and discoverability

The WMO Unified Data Policy Resolution (Res. 1) Ext Congress October 2021

Resolution 1; 2021

1. Covers all WMO Earth system data: weather, climate, hydrology, ...
2. Two main categories of data:
   - *Core* (*shall* be exchanged);
   - *Recommended*; (*should* be exchanged);
3. Specifics on *core* and *recommended* data referred to Technical Regulations, primarily Manuals on WIGOS, GDPFS;
4. "*Free and unrestricted*" exchange (term defined directly in the Resolution, literal interpretation);
5. Addressed to Members, but covers exchange of data between all partners, inclucing private sector, academia, etc.

Defining Core and Recommended satellite data for international data Exchange as per the new WMO Unified Data Policy

- **WMO has nominated a Data Policy Coordinator (Sue Barrell)**

- **Analysis of what data is needed by the users has been consolidated with WMO Expert Teams**

- **Analysis to be presented to and consolidated with Space Agencies**
  - Letters to Space Agencies (and/or Members) in May 2022
    - It may not be in the mandate for all Agencies to commit to everything (in the table)
    - They may need to consult stakeholders (which may take time)
  - Status presented to CGMS Plenary 15 – 17 June 2022

WMO OMM
World Meteorological Organization
Organisation météorologique mondiale
Organización Meteorológica Mundial
Всемирная метеорологическая организация
المنظمة العالمية للأرصاد الجوية
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wmo@wmo.

Our ref.: 10394/2022/I/SSU

Annexes: Current CGMS Members capabilities to deliver the Vision for WIGOS 2040

Dr Stephen Voltz
Assistant Administra
Information Service
National Oceanic an
Administration (NOA
1335 East-West High
20910 Silver Spring,
United States of Am

10 May 2022

Subject: Invitation to bilateral discussions on Core Satellite Data and W the International Exchange of Earth System Data

Dear Dr Voltz,

The 2021 Extraordinary Congress approved the WMO Unified Policy for th Exchange of Earth System Data, which defines Core and Recommended d Members shall exchange Core data on a free and unrestricted basis to un they provide for the protection of life and property and for the well-being

With the new WMO Unified Policy for the International Exchange of Earth approved, WMO wants to define the Core satellite data related to satellite order to define the Core data commitments of NOAA, we kindly invite you discussions on the Core satellite data content provided by your agency.

To support the discussions, we have prepared the document in Annex. Th that data from all the measurements identified in the tables will be freely users and for NWP/Nowcasting disseminated within near real time. The ta the relevant column the contributions expected from your Agency.

Please contact until the end of May 2022 WMO Director of Infrastructure (area@wmo.in t) and Director of WIGOS Lars Peter Riishojgaard (lriishojg Head of Space Systems and Utilization Division Kenneth Holmlund (kholm cc, for establishing the way forward for the upcoming bilateral discussion

- **Definition of core data does not imply commitments on:**
  - Technical implementation
  - Protocols
  - Quality

- **Information document to INFCOM 2, October 2022**

- **Consolidated commitments to be tabled in WMO regulatory material and reflected elsewhere as suitable (e.g. OSCAR)**

- **Decision is with WMO Members**

- **Will be reviewed and updated regularly (in consultation with the Space Agencies)**

Analysis of Geostationary Core Data 2022

Longitude	0E	41E	76E	82E	105E	123E	128E	141E	137W	100W	75W
Agency	EUMETSAT	EUMETSAT	Roshydromet Roscosmos	IMD ISRO	CMA	CMA	KMA KIOST	JMA	NOAA	NASA	NOAA
VIS/IR Imagery channels	12	12	10	6	15	15	16	16	16	N	16
Rapid scan (<5 mins)	12	N	N	6	15	15	16	16	16	N	16
Sounder channels	N	N	N	19	1680	1680	N	N	N	N	N
Lightning detection	N	N	N	N	Y	Y	N	N	Y	N	Y
Radiation Budget	Y	Y	N	N	N	N	N	N	N	N	N
Ocean Colour*	N	N	N	N	N	N	Y	N	N	N	N
UV/VIS Sounder	N	N	N	N	N	N	N	N	N	N	N

Analysis of Geostationary Core Data 2025

Longitude	0E	41E	76E	82E	105E	123E	128E	141E	137W	100W	75W
Agency	EUMETSAT	EUMETSAT	Roshydromet Roscosmos	IMD ISRO	CMA	CMA	KMA KIOST	JMA	NOAA	NASA	NOAA
VIS/IR Imagery channels	16	12	20	6	15	15	16	16	16	N	16
Rapid scan (<5 mins)	16	N	20	6	7	7	16	16	16	N	16
Sounder channels	1700	N	2528	19	1680	1680	N	N	N	N	N
Lightning detection	Y	N	Y	N	Y	Y	N	N	Y	N	Y
Radiation Budget	N	N	Y	N	N	N	N	N	N	N	N
Ocean Colour*	N	N	N	N	N	N	Y	N	N	N	N
UV/VIS Sounder	Y	N	N	N	N	N	N	N	N	Y	N

*Dedicated instruments for ocean colour monitoring

Analysis of LEO Core data 2022

Local Overpass Time	05:30	06:00	06:00	07:00	09:30	10:30	12:00	13:30	13:30	13:30	13:30	15:00
Agency	CMA	NOAA DOD	ESA	CNES CNSA	EUMETSAT ESA	CNES	IMD ISRO	NOAA NASA	CMA	ESA	JAXA	Roshydromet Roscosmos
VIS/IR Imagery channels	6+D/N	N	N	N	6	N	15	21+D/N	25	N	N	6
IR Sounder channels	1370	N	N	N	8461	N	N	2211/2378	1370	N	N	2670
MW Sounder channels	32	N	N	N	20	N	N	22	28	N	N	N
MW Imagers	N	24	N	N	N	N	N	N	10	N	16	29
Radar backscatter	Y	N	N	Y	Y	N	Y	N	N	N	N	N
GNSS Bending Angle	Y	N	N	N	Y	N	Y	N	Y	N	N	N
UV/VIS Sounder	N	N	N	N	Y	N	N	Y	N	Y	N	N
Radiation Budget	Solar Irrad	N	N	N	N	N	N	ERB	N	N	N	SW only
Doppler Winds	N	N	Y	N	N	N	N	N	N	N	N	N
Cloud Radar	N	N	N	N	N	N	N	N	N	N	N	N
Rain Radar	N	N	N	N	N	N	N	N	N	N	N	N
Ocean Colour	N	N	N	N	Y	N	N	Y	N	N	N	N
SST (Dual View)	N	N	N	N	Y	N	N	N	N	N	N	N
Radar Altimeter	N	N	N	N	Y	N	N	N	N	N	N	N
GHG monitoring	N	N	N	N	N	N	N	Y	Y	N	Y	N

Analysis of LEO Core data 2025

Local Overpass Time	05:30	06:00	06:00	07:00	09:30	10:30	12:00	13:30	13:30	13:30	13:30	15:00
Agency	CMA	NOAA DOD	ESA	CNES CNSA	EUMETSAT ESA	CNES	IMD ISRO	NOAA NASA	CMA	ESA	JAXA	Roshydromet Roscosmos
VIS/IR Imagery channels	6+D/N	N	N	N	20	N	15	21+D/N	25	N	N	6
IR Sounder channels	1370	N	N	N	16921	N	N	2211/2378	1370	N	N	2670
MW Sounder channels	32	N	N	N	20	N	N	22	28	N	N	N
MW Imagers	N	N	N	N	Y	N	N	N	10	N	16	29
Radar backscatter	Y	N	N	Y	Y	N	Y	N	N	N	N	N
GNSS Bending Angle	Y	N	N	N	Y	N	Y	N	Y	N	N	N
UV/VIS Sounder	N	N	N	N	Y	N	N	Y	N	Y	N	N
Radiation Budget	Solar Irrad	N	N	N	N	N	N	ERB	N	N	N	SW only
Doppler Winds	N	N	N	N	N	N	N	N	N	N	N	N
Cloud Radar	N	N	N	N	N	N	N	N	N	N	N	N
Rain Radar	N	N	N	N	N	N	N	N	N	N	N	N
Ocean Colour	N	N	N	N	Y	N	N	Y	N	N	N	N
SST (Dual View)	N	N	N	N	Y	N	N	N	N	N	N	N
Radar Altimeter	N	N	N	N	Y	N	N	N	N	N	N	N
GHG monitoring	N	N	N	N	N	Y	N	Y	Y	N	Y	N

Analysis of Drifter Core data 2022

Agency	CMA	NSOAS	ISRO	NOAA	ESA	CNES	EUMETSAT	NASA	JAXA	Satellites
MW Imagers	N	N	Y	N	N	N	N	Y	N	MeghaTropiques, TROPICS, GMI
Radar backscatter	N	Y	N	N	N	N	N	Y	N	COWVR,CYGNSS, HY-2
GNSS Bending Angle	N	N	N	Y	Y	N	N	Y	N	COSMIC-2, Sentinel-6, GRACE
UV/VIS Sounder	N	N	N	N	N	N	N	N	N	
Doppler Winds	N	N	N	N	Y	N	N	N	N	Aeolus
Cloud Radar	N	N	N	N	N	N	N	N	N	
Rain Radar	N	N	N	N	N	N	N	Y	N	GPM-Core
Radar Altimeter	N	Y	N	Y	Y	Y	Y	Y	N	JASON-3, Sentinel-6A, HY-2
GHG monitoring	N	N	N	N	N	N	N	Y	N	OCO-3

Analysis of Drifter Core data 2025

Agency	CMA	NSOAS	ISRO	NOAA	ESA	CNES	EUMETSAT	NASA	JAXA	
MW Imagers	Y	N	N	N	Y	N	Y	Y	N	AWS,TROPICS, FY-3G, GMI
Radar backscatter	N	Y	N	N	N	N	N	N	N	HY-2
GNSS Bending Angle	N	N	N	Y	Y	N	N	N	N	COSMIC-2, Sentinel-6
UV/VIS Sounder	N	N	N	N	N	N	N	N	N	
Doppler Winds	N	N	N	N	N	N	N	N	N	
Cloud Radar	N	N	N	N	N	N	N	N	N	
Rain Radar	Y	N	N	N	N	N	N	Y	N	FY-3G, GPM-Core
Radar Altimeter	N	Y	N	N	Y	Y	N	Y	Y	COMPIRA, Sentinel-6, HY-2, SWOT
GHG monitoring	N	N	N	N	N	N	N	N	N	

WMO Regional Satellite Data Groups play a key role in establishing the regional needs!

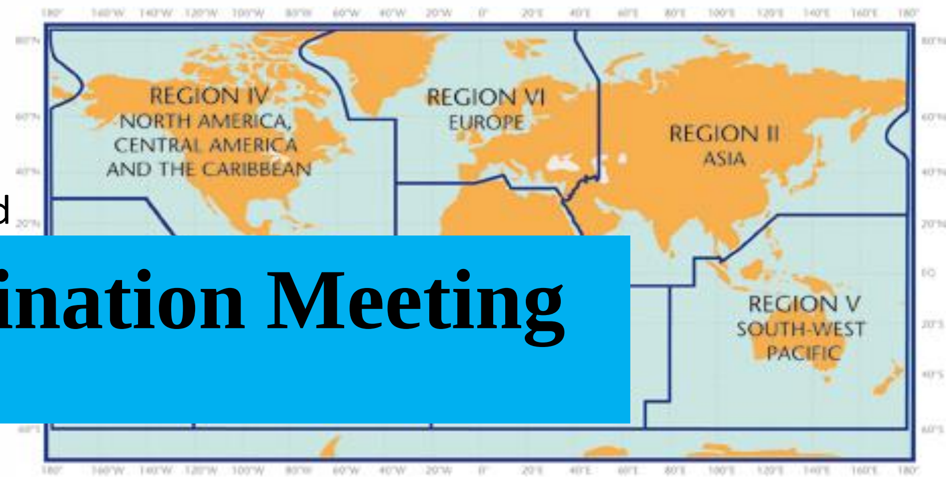
WMO gratefully acknowledges the support by the CGMS Members to regional activities:

- RA I (Africa) Dissemination Expert Group (RAIDEG)
- RA II (Asia): WIGOS Project Coordination Group
- RA III/IV (Americas): Coordination Group
- RA V (SW Pacific): Task Team on Satellite Utilization (TT-SU)

Continued support from the Space Agencies is needed

Vlab acti

- Increase
  monitor



RA II - RA V Coordination Meeting

Objectives:

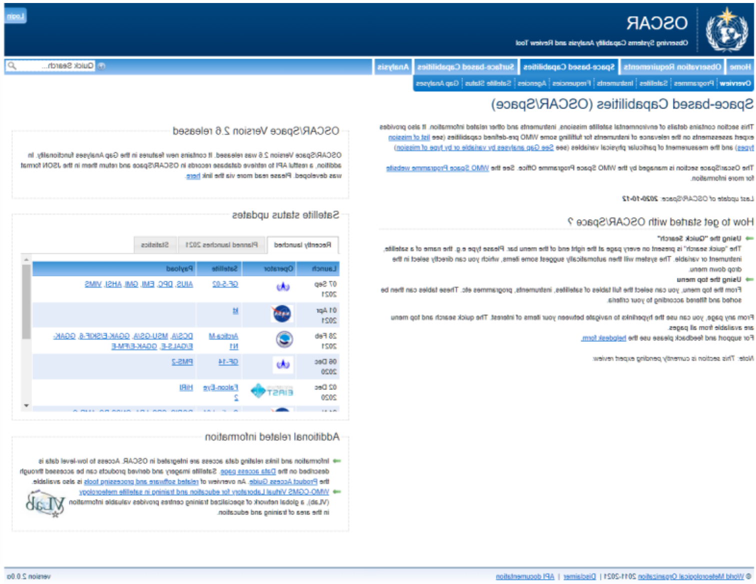
- User-provider dialogue
- Expressing user requirements
- Coordinating data distribution
- Identifying training needs
- Implementing WIGOS/WIS

See https://community.wmo.int/activity-areas/wmo-space-programme-wsp/wmo-regional-coordination-groups-satellite-data-requirements

OSCAR/Space

Observing Systems Capability Analysis and Review Tool

- OSCAR Space Captures
  - Over 800 satellites
  - Around 1000 instruments: 650 for Earth Observation and 350 for Space Weather.



- Supported by CGMS Members and hence also by a significant sector of CEOS with the agencies outside CGMS

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

WMO OMM

EC-75: Development of a WMO-coordinated Global Greenhouse Gas Monitoring Infrastructure

Many of the required elements do exist or are being developed

Several countries and international organizations investing in carbon monitoring capabilities:

- Surface-based observations
- Space-based observations
- Modeling
- Data assimilation

Missing element:

- Integrated, internationally coordinated global approach allowing these capabilities to complement and leverage each other for optimal overall impact!

Building on the existing such as the Global Atmospheric Watch (GAW) and the Integrated Global Greenhouse Gas Information System (IG3IS). (Res 4, EC -75, June 2022)

Toward a coordinated Global Greenhouse Gas (GHG) Monitoring Infrastructure

Greenhouse gas monitoring provides critical input to scientific research and support for the implementation of the Paris agreement; however, GHG monitoring currently relies primarily on individual research activities and research funding,

- Important natural sources and sinks terms for GHG still not sufficiently well understood;
- Multiple coordination mechanisms for GHG monitoring exist, but are typically discipline-specific or regional in scope;
- No integration of space-based and surface-based observations; no universal access to observational data;

Conjecture: GHG monitoring would benefit from coordinated, global, operational approach similar to the one taken for weather prediction and climate monitoring

Required infrastructure:

- Integrated carbon observing system (surface- and space-based);
- Earth System modeling with data assimilation tracking CO_2, CH_4 and N_2O;
- Timely international exchange of all observations and relevant model data;
- Framework for intercomparison of output, possibly also for collaboration on algorithms, model components;
- Coupling with ocean and/or land biosphere models;

The WMO World Weather Watch as a paradigm

Such an approach would help

- Leverage all existing GHG monitoring capabilities for common goals
- Maximize return on investments
- Avoid fragmentation of effort, both scientifically and politically
- Lead to a consolidated design

Could facilitate access to funding for the required observing systems in developing countries

WMO OMM

WMO International Greenhouse Gas Monitoring Symposium
30 January-1 February 2023

The Symposium is targeted primarily at entities involved in greenhouse gas observations, modeling, data assimilation and related research in all domains of the Earth System. It is open to other interested parties as well.

Engagement from an Earth-system Monitoring approach, ie integrations with oceans, land, permafrost, cryosphere, biosphere is key

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

How to engage with WMO

WMO Commissions Expert Teams e.g.

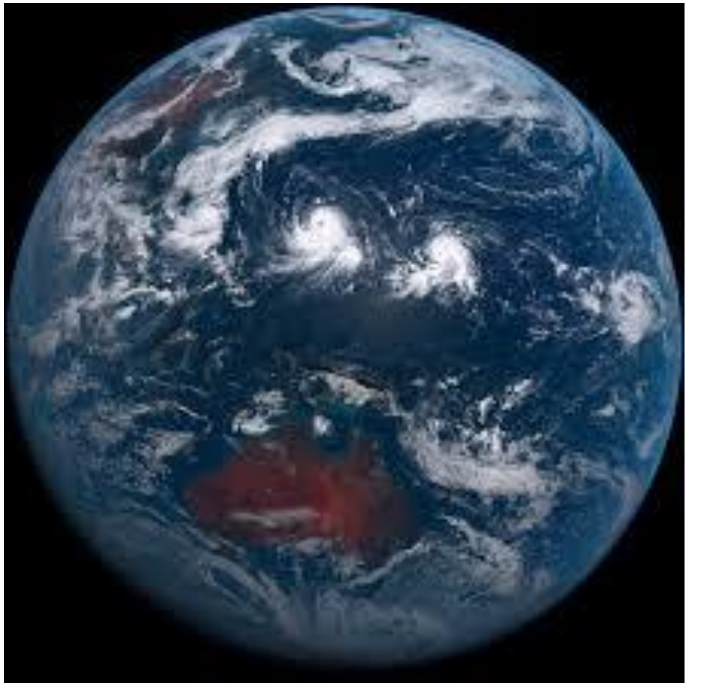
- Expert Team on **Space Systems and Utilization** (ET-SSU)
- Joint Expert Team On **Earth Observing Systems Design And Evolution** (JET-EOSDE)
- Expert Team on **Radio Frequency Coordination** (ET-RFC)
- Expert Team on **Space Weather** (ET-SWx)
- Joint Expert Team on **Operational Weather Radar**

WMO Regional Association Expert Teams

WMO Secondments

WMO Junior Professional Officers

Talk to you local Weather Service!



Thank you!
Merci!

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale