WMO Satellite Activities and Strategic Perspectives

World Meteorological Organization (WMO)
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NOAA Satellite Conference 2017

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

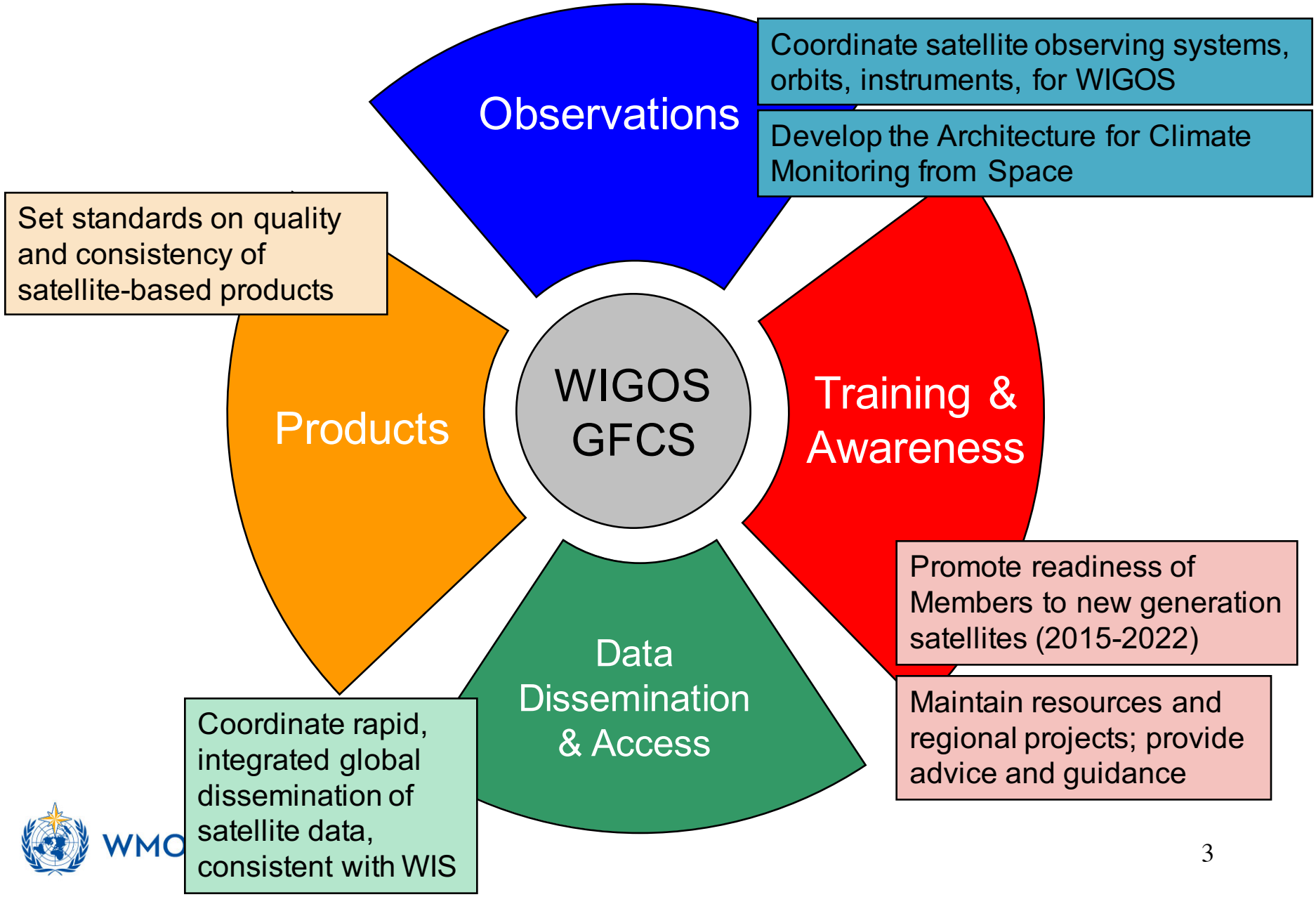
WMO OMM
World Meteorological Organization
Organisation météorologique mondiale

Outline

- WMO Satellite Activities
  - User readiness for new-generation satellites
  - Coordinated generation of satellite nowcasting products
  - Assessing impact of satellite data on NWP
  - Maintaining tools for users: OSCAR/Space
- WMO Strategic Perspectives – Vision 2040 WIGOS Space

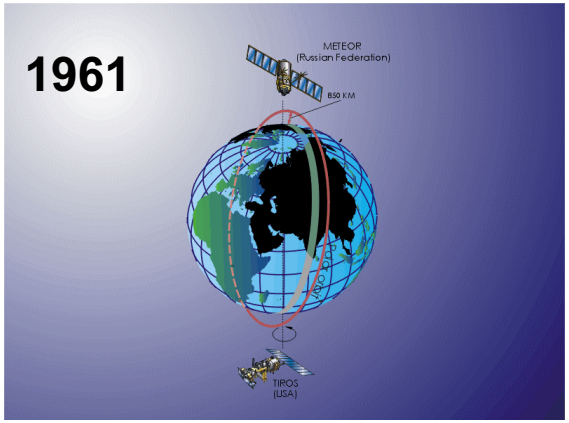
WMO Space Programme Activity Areas

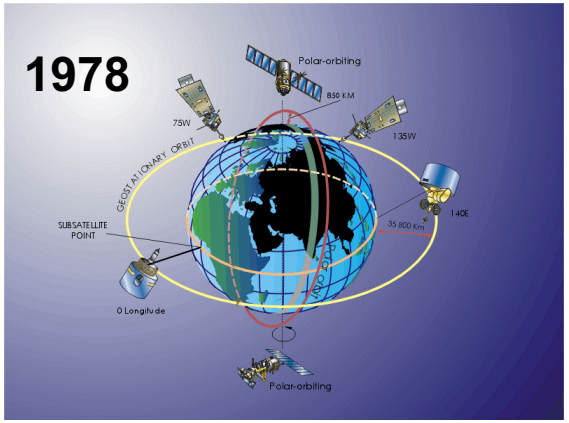
supporting weather, water, climate, and space weather

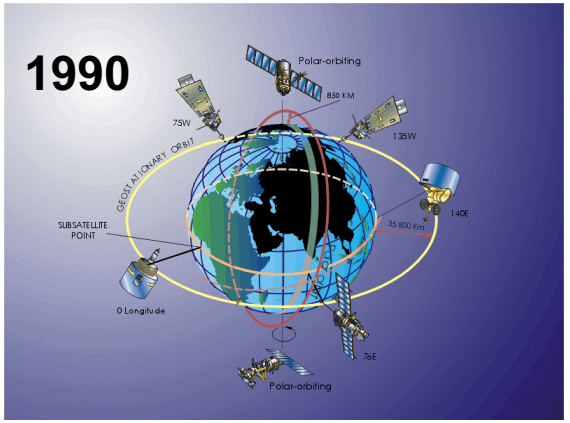


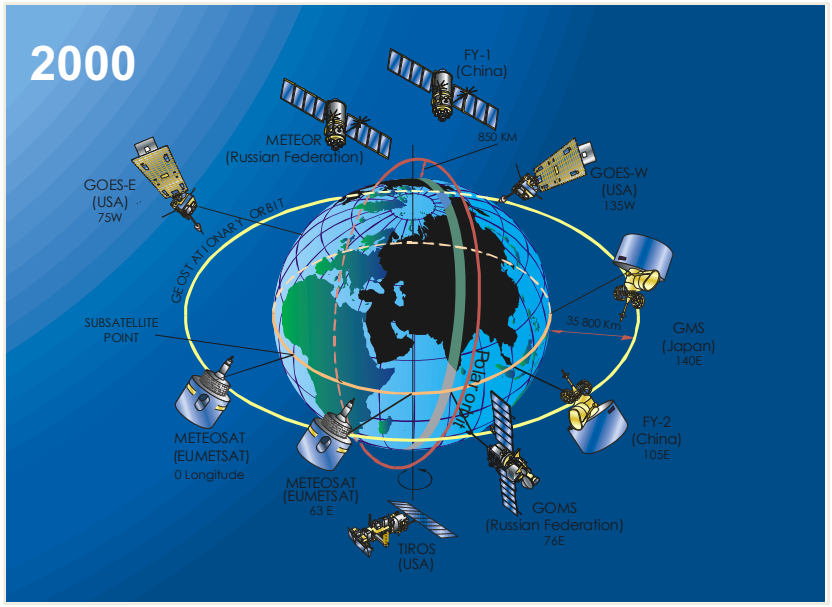
WMO

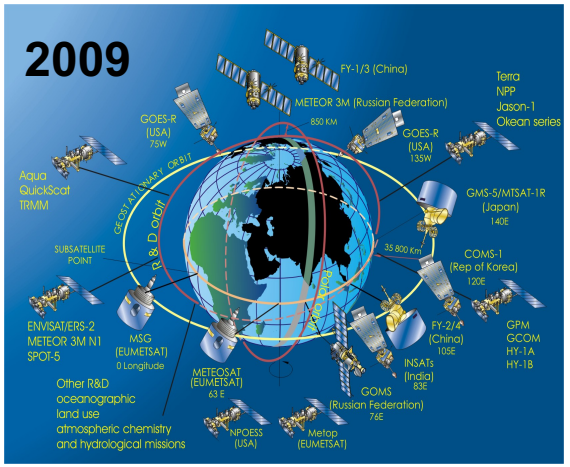
Evolution of the Space-based Global Observing System (GOS)











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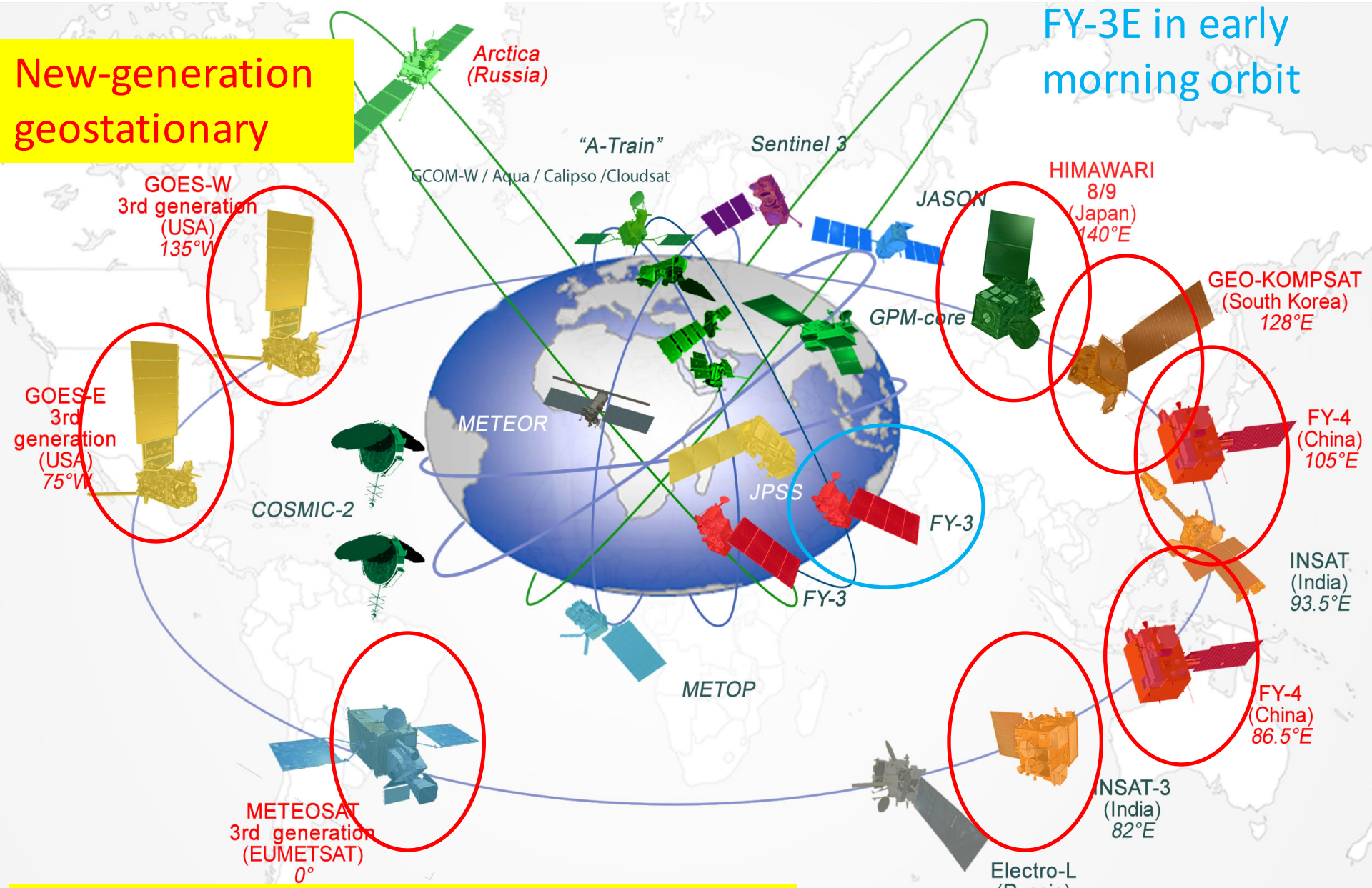
Space-based GOS 2015 ⟶ 2022

New-generation geostationary

FY-3E in early morning orbit



ALL WMO REGIONS CONCERNED!

1. Promoting User Readiness for New-Generation Satellites

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New-Generation Meteorological Satellites

Geostationary orbit:

Satellite	Operator	Launch date	Longitude	Imager	Number of spectral channels	Spatial resolution	Temporal resolution (full disk)	Sounder / Lightning Mapper
Himawari-8	JMA	7 Dec 2014	140E	AHI	16	0.5-2km	10min	- / -
Electro-L N2	ROSHYDRO-MET	11 Dec 2015	78E	MSU-GS	10	1-4km	15min	- / -
INSAT-3DR	ISRO	8 Sep 2016	74E	IMAGER	6	1-8km	30min	S / -
Himawari-9	JMA	2 Nov 2016	140E	AHI	16	0.5-2km	10min	- / -
GOES-16 (GOES-R)	NOAA	19 Nov 2016	89.5W (final TBD)	ABI	16	0.5-2km	15min	- / L
FY-4A	CMA	10 Dec 2016	86.5E	AGRI	14	1-4km	15min	S / L
Geo-KOMPSAT-2A	KMA	2018	128.2E	AMI	16	0.5-2km	10min	- / -
GOES-S	NOAA	2018	75W	ABI	16	0.5-2km	15min	- / L
FY-4B	CMA	2018	105E	AGRI	14	0.5-4km	15min	S / L
MTG-I/S	EUMETSAT	2020-22	9.5E	FCI	16	0.5-2km	10min	S / L
…								

Low-Earth orbit:

Satellite	Operator	Launch date	Orbit	Payload
JPSS-1	NOAA	2017	13:30 asc	ATMS, CrIS, CERES, OMPS-nadir, VIIRS, SEM (EPS, HES, SSJ5)
FY-3E	CMA	2018	06:00 desc	HIRAS, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-3, OMS (limb, nadir), SIM-2, WindRAD, SES (IPM, SEM, X-EUV)
…				

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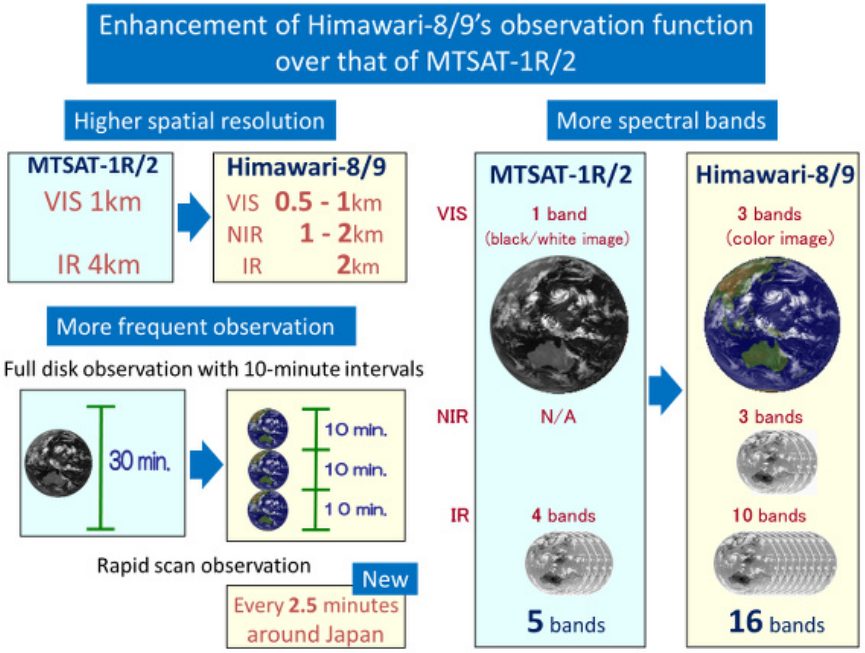
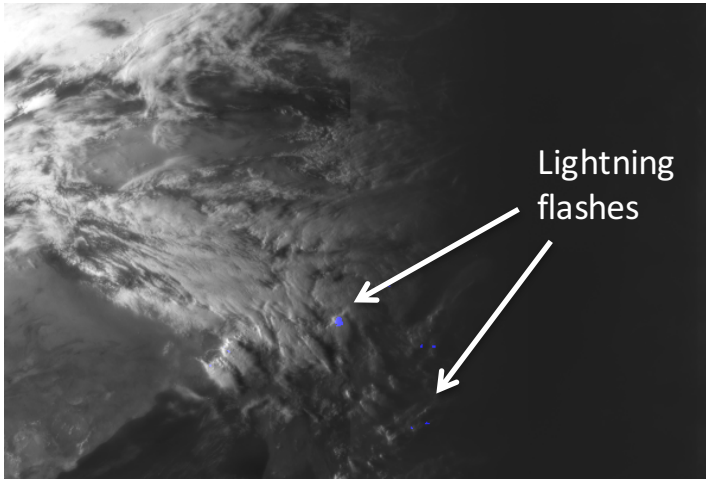
Status: May 2017; Source: OSCAR/Space

New and enhanced satellite data

Enhanced imaging

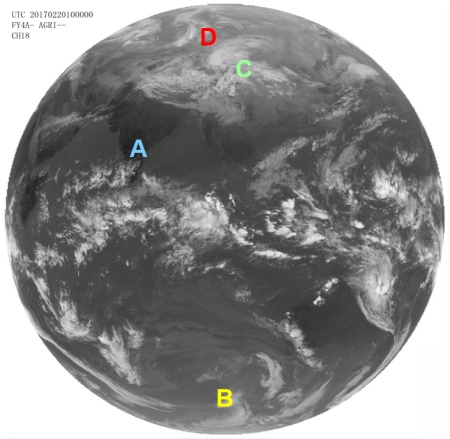


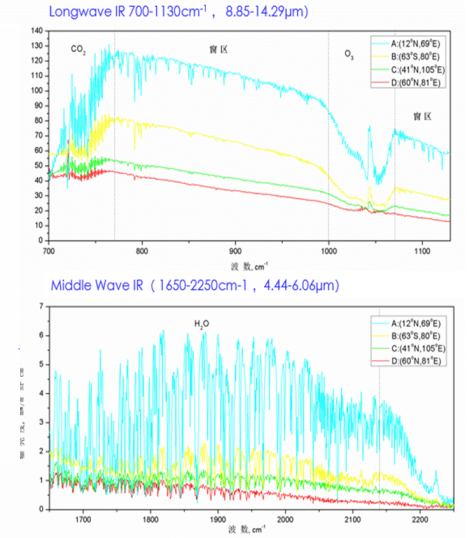
Lightning detection from GEO (NEW)



Source: FY-4A LMI Data; X. Fang, CMA, 2 May 2017

Hyperspectral sounding from GEO (NEW)





Source: FY-4A GIIRS Data; X. Fang, CMA, 2 May 2017

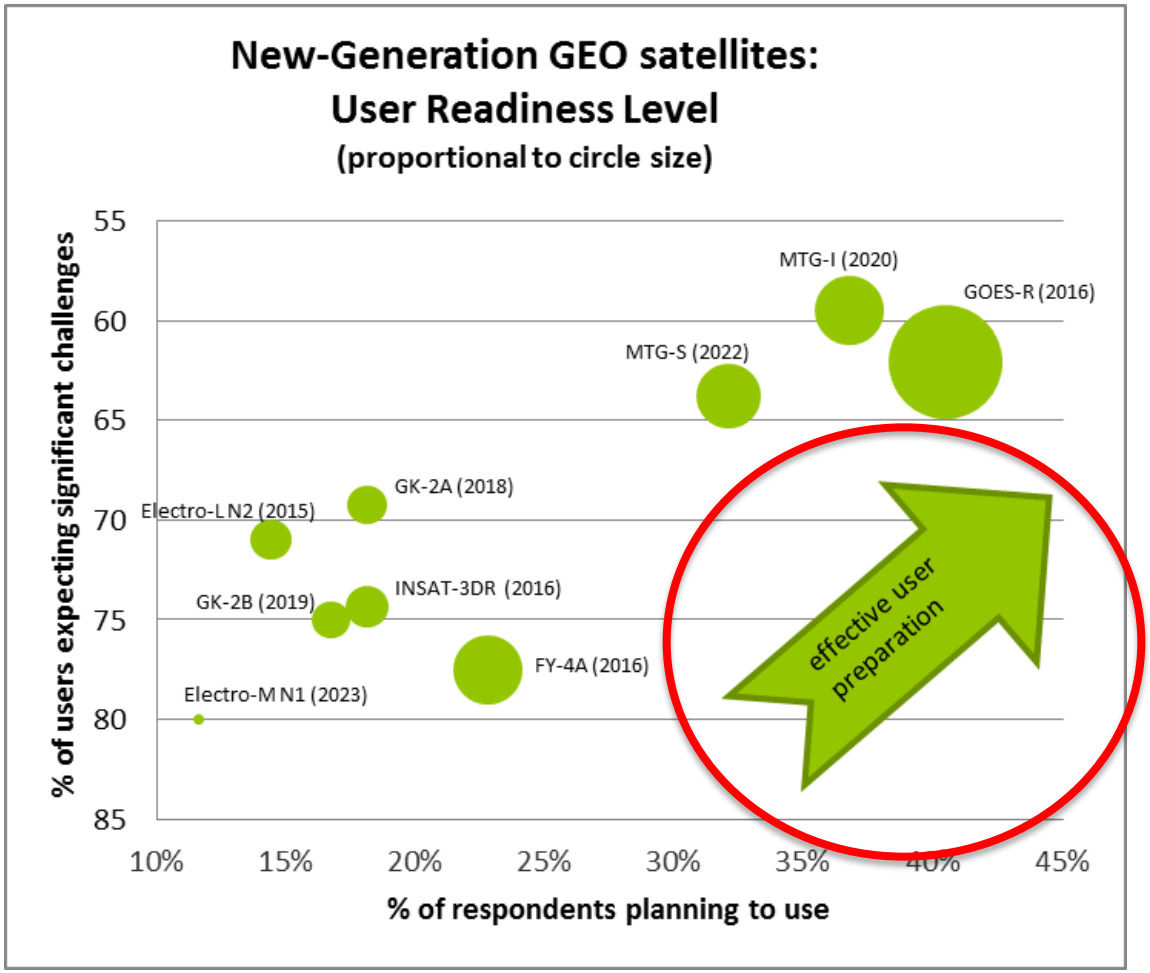
- Many opportunities for enhancing services
- Preparation by Members needed to achieve user readiness

WMO Satellite User Survey 2016

Higher readiness level

Lower readiness level

Higher challenge



Lower challenge

Less users

More users

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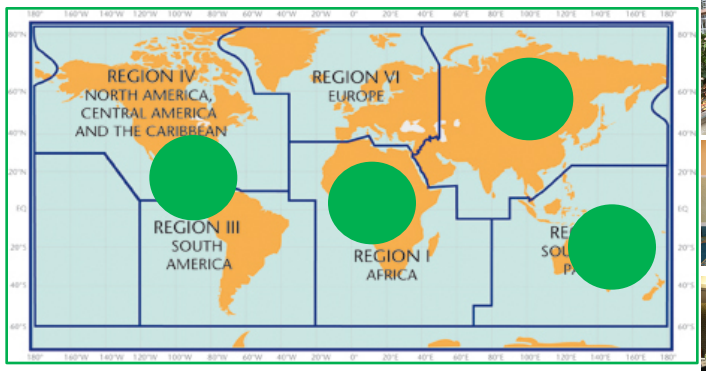
4 Areas of WMO Support to User Readiness

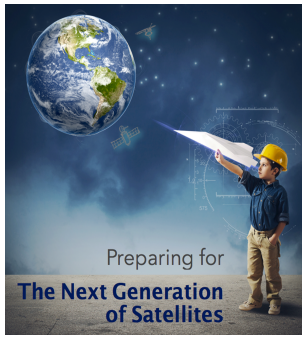
Region-based Satellite User Groups

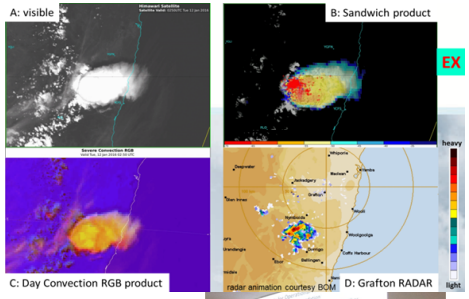


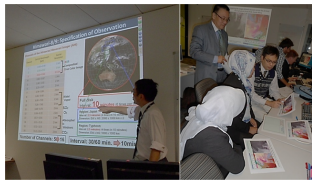
- Capture user requirements for data
- Identify training needs
- Foster dialogue with satellite operators
- Guide cap dev & infrastructure projects

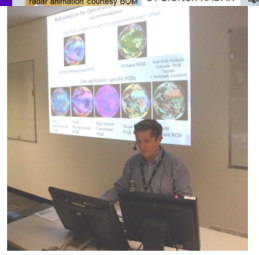
Photos: 2016 meetings of satellite user groups in RA I, III-IV, II-V

Training Events organized by VLab









Source: Vlab; Himawari-8 BOM training campaign

Satellite User Readiness Portal (SATURN)

- One-stop information resource
- Maintained by satellite operators in CGMS on behalf of WMO

Best Practices for Achieving User Readiness

- Recommended user readiness activities over 3-5 year period before launch ("reference user readiness project")
- Deliverables by satellite agencies and operators to the user community

(WMO Guideline; CGMS best practice)

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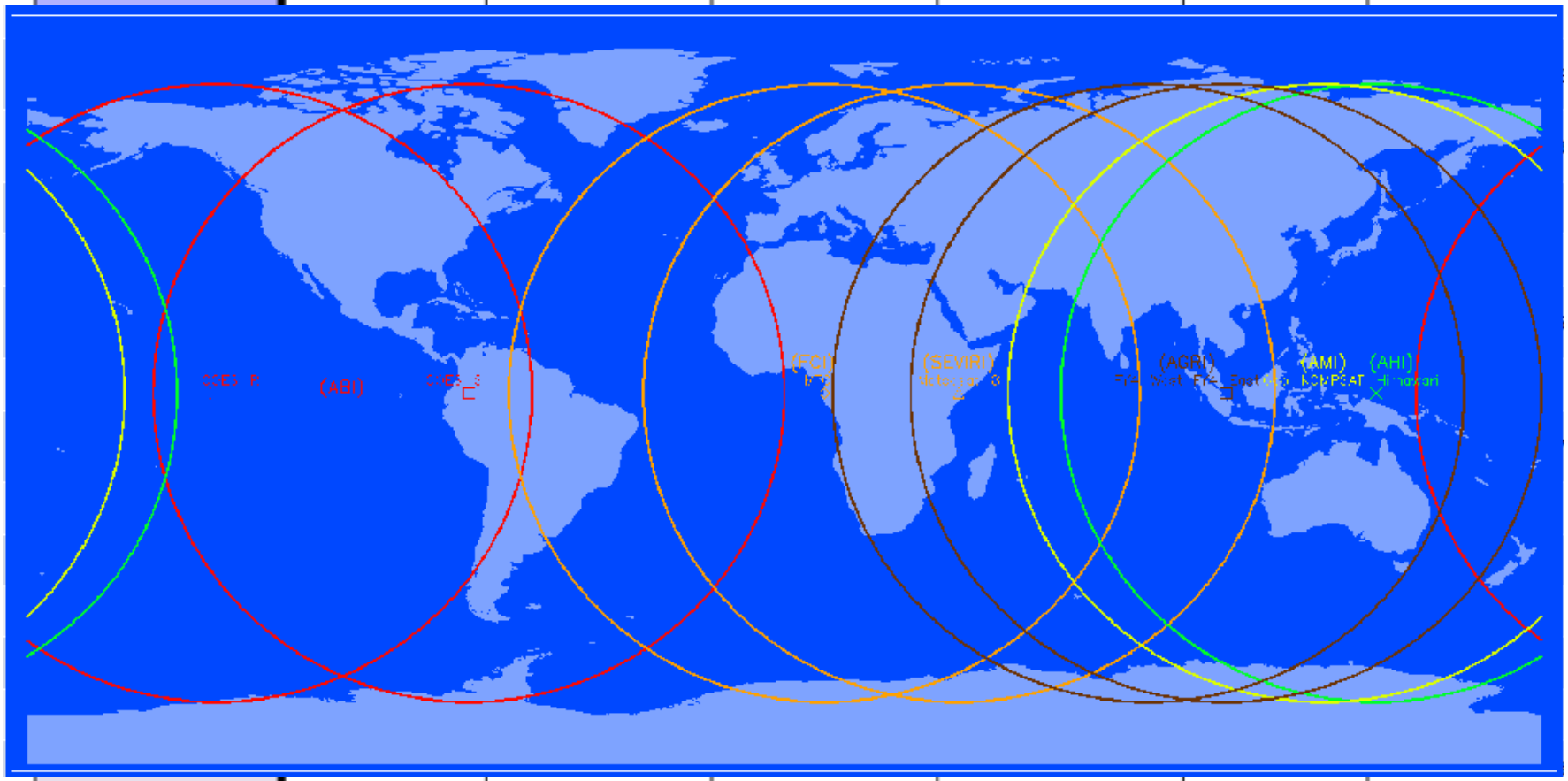
2. Fostering coordinated generation of satellite products for nowcasting

Overlap in Imaging Channels
Overlap in Geographical Footprint

Central Wavelength [µm]	H-8 AHI	GOES-R ABI	FY-4A AGRI	GEO-KOMPSAT-2A AMI	MTG-I1 FCI
11.0 - 11.2	•	•	•	•	
12.3	•	•		•	•
13.3 - 13.5	•	•	•	•	•



Overlap in Level 2 Products

Level 2 Product Category	Himawari AHI	GOES-R ABI	FY-4A AGRI	GEO-KOMPSAT-2A AMI	MTG-I1 FCI
Clear Sky / Cloud Mask and Radiances	•	•	•	•	•
At					
Clo					
C					
(					
Fi					
Volcanic Ash information (detection, height, mass loading)	•	•			•

Overlap in satellite footprint, imaging channels, and derived products

- offers opportunities for combined use, but
- poses challenges for users (data reception, data interpretation and potential redundancy)

The WMO SCOPE-Nowcasting initiative addresses some of these challenges for nowcasting applications

WMO SCOPE-Nowcasting - Pilot Projects

Category	Product	Region	Provider	User	Gaps
Basic nowcasting	RGB composites	WMO Region II (Asia) and Region V (SW Pacific)	JMA, CMA, KMA	NMSs in Region II and V	No standard products available; products limited
Advanced nowcasting	Volcanic Ash Products and Intercomparison	Global	CMA, JMA, KMA, EUMETSAT, NOAA	NMHSs, VAACs	No standard products available; products limited
Advanced nowcasting	Blended satellite global precipitation product (GEO+LEO)	Global coverage	Hydro Estimator, NASA TRMM (3B42), NOAA (real-time MW)	Civil authorities, NMHSs, Flash flood guidance systems, general users	Rapid, facilitated access to quantitative precipitation estimates
RT Atmospheric Composition products	Dust Monitoring and Prediction Products	WMO Region II (Asia) and V (South-West Pacific)	CMA, JMA, KMA	SDS-WDCs, NMSs (to issue results and warnings) in RA II and RA V	Regional diversity of aerosol-related products not harmonized

- Potential new activities on: flood mapping, aerosols, fires (following CEOS-CGMS "non-met applications" initiative)

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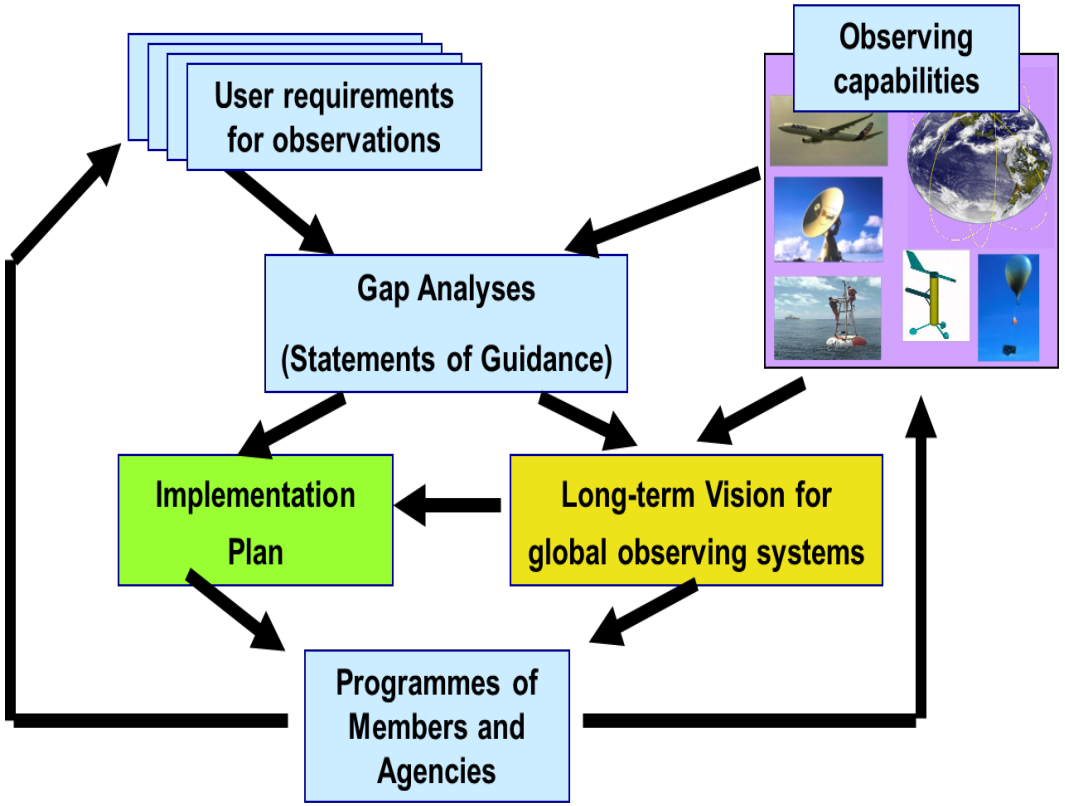
SCOPE•NWC

3. Assessing the impact of satellite observations on NWP

Rolling Review of Requirements (RRR)

- WMO Congress: All WMO and WMO co-sponsored observing systems shall use the RRR to design networks, plan evolution and assess performance.

- The RRR is the process used by WMO to collect, vet and record user requirements for all WMO application areas and match them against observational capabilities

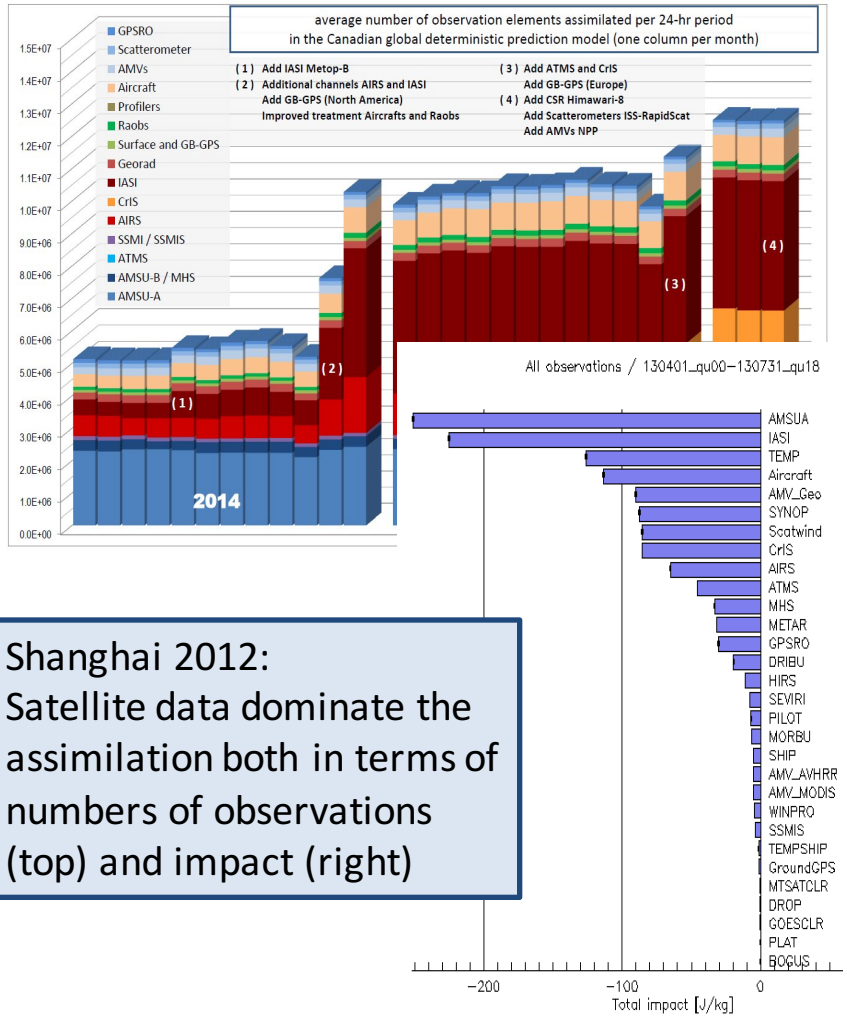


Rolling Review of Requirements

Key element of the RRR:

WMO Workshops on the Impact of Various Observing Systems on NWP

- *Held every four years, last events in **Sedona 2012, Shanghai 2016**, next Workshop planned for 2020*
- *Involving all major NWP centers, research community and other stakeholders*
- *Contribution to forecast skill of various WIGOS/GOS components assessed and evaluated*
- *Guidance (desired science questions to be investigated) provided to participants well in advance of Workshop*
- ***Satellite community is invited to formulate science questions to be investigated prior to the 2020 Workshop and address them to WMO***



Shanghai 2012:
Satellite data dominate the assimilation both in terms of numbers of observations (top) and impact (right)

Results from 6th WMO Impact Workshop in Shanghai, May 2016

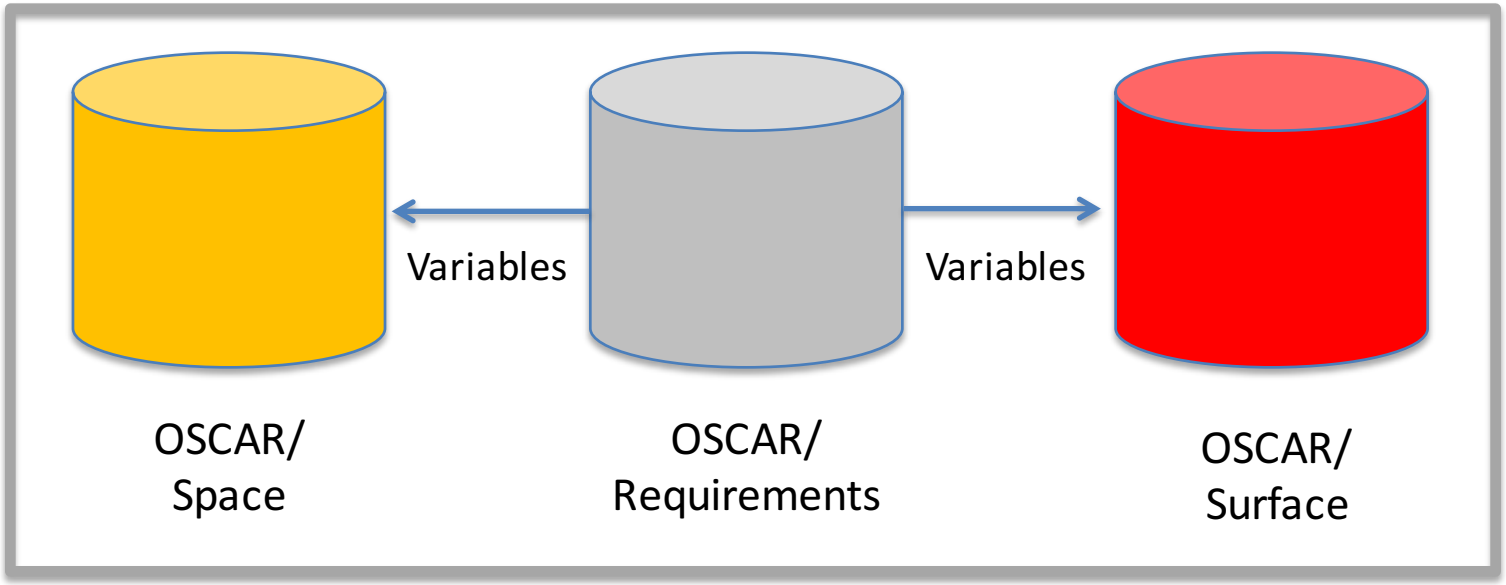
- Final Report from the Workshop available at:
  - Sixth WMO Impact Workshop; Report and Presentations

- Some key satellite-related points from the report:
  - *"In terms of the most important observing systems contributing to forecast skill of global NWP models, the top five system were, in no particular order,* ***microwave sounders (AMSU-A, ATMS), hyperspectral infrared sounders (AIRS, IASI, CrIS), radiosondes, aircraft data and atmospheric motion vectors (AMVs)****."*
  - ***"So-called secondary (or back-up) satellites within a given orbital plane have a substantial impact on skill*** *– their data are thus not redundant with those provided by the primary satellites;"*
  - ***"One area showing very significant improvement was the use of microwave radiances affected by cloud and precipitation, i.e. all-sky radiance assimilation****. This has been made possible by much improved modelling of radiative transfer in these situations, especially in the water vapor absorption band at 183 GHz."*
  - ***"Several new satellite data types have entered operational assimilation during the past four years, all with positive impacts.*** *Among them are: MetOp-B (in addition to MetOp-A); CrIS and ATMS on Suomi-NPP; Megha-Tropiques/SAPHIR (microwave sounder in low-inclination orbit); ISS Rapidscat (scatterometer in low-inclination orbit); FY-3C/MWHS-2 183 and 118 GHz channels; GCOM-W/AMSR-2; GPM-core/GMI; LEO-GEO AMVs."*

4. Maintaining tools for users: WMO OSCAR/Space

WMO Observing System Capability Analysis and Review tool (OSCAR)

- WMO-maintained online resource with 3 components:
  - satellite programmes, instruments, and the variables they can observe (OSCAR/Space)
  - surface-based stations/platforms under WIGOS (OSCAR/Surface)
  - observation requirements for 14 “application areas” and for all relevant variables (OSCAR/Requirements)



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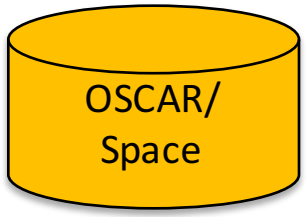
- WIGOS Information Resource
- Basis for WMO Rolling Review of Requirements

WMO OSCAR/Space



Two Components:

1. **Factual information on satellites and instruments** ("*capabilities*")

   – From 81 satellite operators, 673 satellites, 927 instruments
   – Weather and climate
   – Environmental monitoring
   – Space weather

2. **Assessment of instruments, and gap analyses** ("*analysis and review*")

   - Mapping instruments to measured variables
   - "Gap analysis" by measured variable, or by type of mission

✓ **1100 page visits / day and growing**

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

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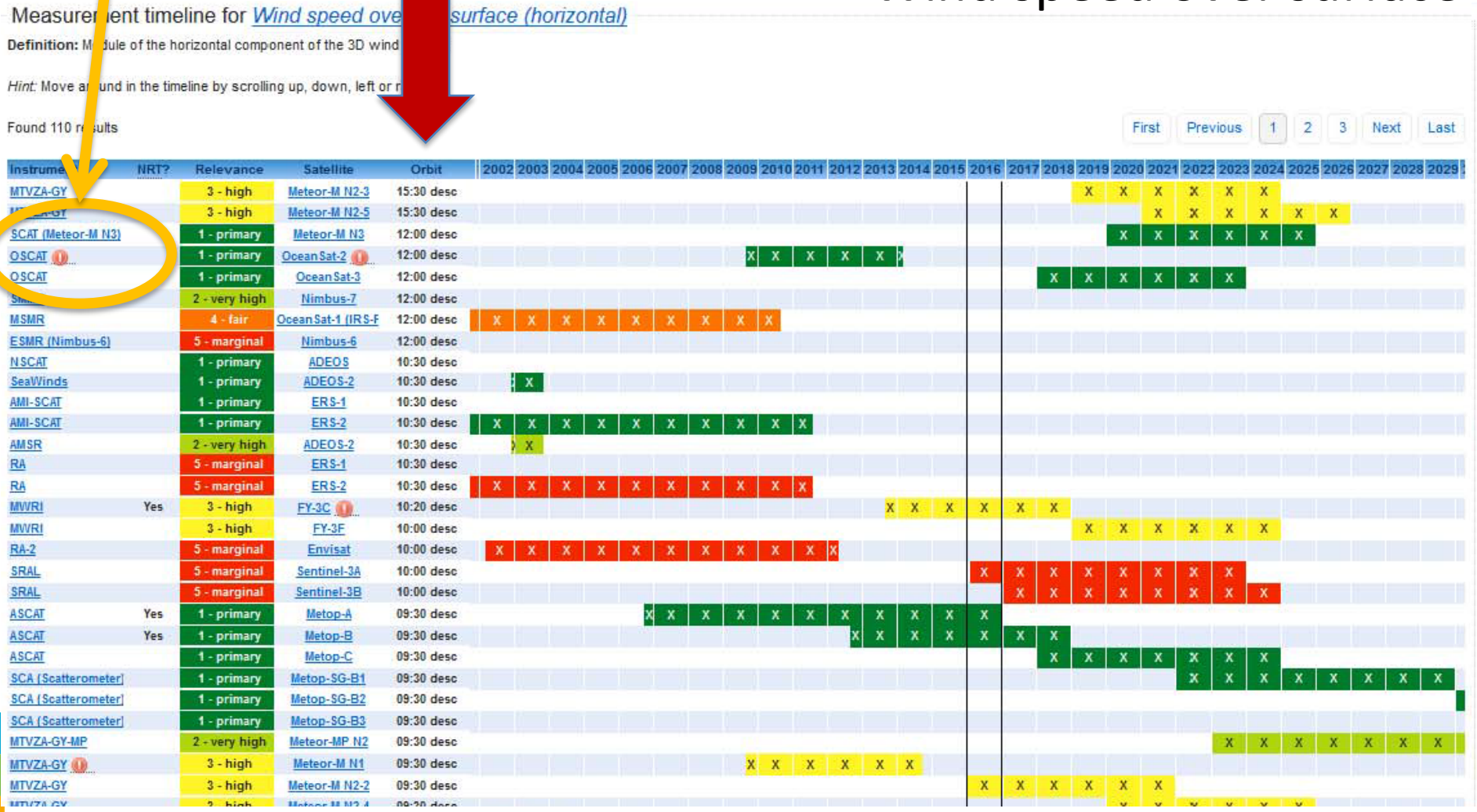
Gap analysis: Wind speed over surface

Flag instrument issue

Orbit



Measurement timeline for *Wind speed over surface (horizontal)*

Definition: Module of the horizontal component of the 3D wind

Hint: Move around in the timeline by scrolling up, down, left or r

Found 110 results

First | Previous | 1 | 2 | 3 | Next | Last

Instrume	NRT?	Relevance	Satellite	Orbit
MTVZA-GY		3 - high	Meteor-M N2-3	15:30 desc
MTVZA-GY		3 - high	Meteor-M N2-5	15:30 desc
SCAT (Meteor-M N3)		1 - primary	Meteor-M N3	12:00 desc
OSCAT		1 - primary	OceanSat-2	12:00 desc
OSCAT		1 - primary	OceanSat-3	12:00 desc
Sl...		2 - very high	Nimbus-7	12:00 desc
MSMR		4 - fair	OceanSat-1 (IRS-F	12:00 desc
ESMR (Nimbus-6)		5 - marginal	Nimbus-6	12:00 desc
NSCAT		1 - primary	ADEOS	10:30 desc
SeaWinds		1 - primary	ADEOS-2	10:30 desc
AMI-SCAT		1 - primary	ERS-1	10:30 desc
AMI-SCAT		1 - primary	ERS-2	10:30 desc
AMSR		2 - very high	ADEOS-2	10:30 desc
RA		5 - marginal	ERS-1	10:30 desc
RA		5 - marginal	ERS-2	10:30 desc
MWRI	Yes	3 - high	FY-3C	10:20 desc
MWRI		3 - high	FY-3F	10:00 desc
RA-2		5 - marginal	Envisat	10:00 desc
SRAL		5 - marginal	Sentinel-3A	10:00 desc
SRAL		5 - marginal	Sentinel-3B	10:00 desc
ASCAT	Yes	1 - primary	Metop-A	09:30 desc
ASCAT	Yes	1 - primary	Metop-B	09:30 desc
ASCAT		1 - primary	Metop-C	09:30 desc
SCA (Scatterometer)		1 - primary	Metop-SG-B1	09:30 desc
SCA (Scatterometer)		1 - primary	Metop-SG-B2	09:30 desc
SCA (Scatterometer)		1 - primary	Metop-SG-B3	09:30 desc
MTVZA-GY-MP		2 - very high	Meteor-MP N2	09:30 desc
MTVZA-GY		3 - high	Meteor-M N1	09:30 desc
MTVZA-GY		3 - high	Meteor-M N2-2	09:30 desc
MTVZA-GY		3 - high	Meteor-M N2-4	09:30 desc

WMO Strategic Perspectives

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WMO "Vision for WIGOS in 2040"

Why do we we need such a document?

- To serve a reference for WMO Members and other observing system operators, providing context and expected boundary conditions relevant for planning their future system developments
- To act as a (weak) forcing function for satellite agencies
  - Operational meteorological satellite programs tend to have very long life cycles, which means that the existing WMO "Vision for the GOS in 2025" is too near-sighted to be useful
- Sets a frame of reference also development of science algorithms, data processing, dissemination and archiving systems

17th World Meteorological Congress (2015): Commission for Basic System to develop a *"Vision for WIGOS in 2040",* to be submitted to Congress-18 in 2019

WMO "Vision for WIGOS in 2040"

What will be delivered to CG-18?

A document structured in three components:

- Over-arching "Vision" providing, purpose, context and scope
  - Societal drivers, e.g. increased vulnerability to and awareness of weather and climate risks, population growth, increased urbanization
- Annex I: Vision for the space-based component of WIGOS
  - Long-term satellite programs developed by a relatively small number of space agencies makes this (somewhat) manageable
  - Current draft developed in extensive consultation with user groups, WMO technical commission experts and space agencies.
- Annex II: Vision for the surface-based component of WIGOS
  - Developed with NMHSs, experts, user groups, funding agencies,…
  - This is by far the most difficult component!
  - Rapidly changing role of private sector, lack of central planning, commoditization of sensor, computing and telecommunication technologies makes it very difficult to predict the future

Vision 2040 WIGOS Space – 4 Components

Component 1 – Backbone system with specified orbits and approaches

Instruments:	Geophysical variables and phenomena:
Geostationary ring	
Multi-spectral VIS/IR imagery with rapid repeat cycles	Cloud amount, type, top height/temperature; wind (through tracking cloud and water vapour features); sea/land surface temperature; precipitation; aerosols; snow cover; vegetation cover; albedo; atmospheric stability; fires; volcanic ash
IR hyperspectral sounders	Atmospheric temperature, humidity, wind (through tracking cloud and water vapour features); rapidly evolving mesoscale features; sea/land surface temperature; cloud amount and top height/temperature; atmospheric composition (aerosols, ozone, greenhouse gases, trace gases)
Lightning mappers	Lightning (in particular cloud to cloud), location of intense convection, life cycle of convective systems
UV/VIS/NIR sounders	Ozone , trace gases, aerosol, humidity, cloud top height
Low-Earth orbiting sun-synchronous core constellation in 3 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; realisation of a Day/Night band	Cloud amount, type, top height/temperature; wind (high latitudes, through tracking cloud and water vapour features); sea/land surface temperature; precipitation; aerosols; snow and ice cover; vegetation cover; albedo; atmospheric stability
MW imagery	Sea ice parameters; total column water vapour; precipitation; sea surface wind speed [and direction]; cloud liquid water; sea/land surface temperature; soil moisture
Scatterometers	Sea surface wind speed and direction; surface stress; sea ice; soil moisture
Low-Earth orbit sun-synchronous satellites at 3 additional Equatorial Crossing Times, *for improved robustness and improved time sampling particularly for monitoring precipitation*	
Other Low-Earth orbit satellites	
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 topography
IR dual-angle view imagers	Sea surface temperature (of climate monitoring quality); aerosols; cloud properties
MW imagery with 6.7 GHz	Sea surface temperature (all-weather)
Low-frequency MW imagery	Soil moisture, ocean salinity, sea surface wind, sea-ice thickness
MW cross-track upper stratospheric and mesospheric sounders	Atmospheric temperature profiles in stratosphere and mesosphere
UV/VIS/NIR sounders, nadir and limb	Atmospheric composition and aerosol
Precipitation radars and cloud radars	Precipitation (liquid and solid), cloud phase/ top height/ particle distribution/ amount, 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 TSI and SSI radiometers	Broadband radiative flux; Earth radiation budget; total solar irradiance; spectral solar irradiance
GNSS radio occultation (basic constellation)	Atmospheric temperature and humidity; ionospheric electron density
Narrow-band or hyperspectral imagers	Ocean colour; vegetation (including burnt areas); aerosols; cloud properties; albedo
High-resolution multi-spectral VIS/IR imagers	Land use, vegetation; flood, landslide monitoring; snow and ice parameters; permafrost
SAR imagery and altimeters	Sea state, sea ice parameters, ice sheets, soil moisture, floods, permafrost
Gravimetry missions	Ground water, oceanography
Other missions	
Solar wind in situ plasma and energetic particles, magnetic field, at L1	Energetic particle flux and energy spectrum (Radiation storms, geomagnetic storms)
Solar coronagraph and radio-spectrograph, at L1	Solar imagery (detection of coronal mass ejections and solar activity monitoring)
In-situ plasma probes and energetic particle spectrometers at GEO and LEO, and magnetic field at GEO	Energetic particle flux and energy spectrum (Radiation storms, geomagnetic storms)
Magnetometers on GEO orbit	Geomagnetic field at GEO altitude (geomagnetic storms)
On-orbit measurement reference standards for VIS/NIR, IR, MW absolute calibration	

Component 2 – Backbone system with open orbit configuration, flexibility to optimize system

Instruments:	Geophysical variables and phenomena:
GNSS reflectrometry missions, passive MW, SAR	Surface wind and sea state, permafrost changes/melting
Lidar (Doppler and dual/triple-frequency backscatter)	Wind and aerosol profiling
Lidar (single wavelength) (in addition to radar missions mentioned in Component 1)	Sea ice thickness
Interferometric radar altimetry	Sea ice parameters, freeboard/sea ice thickness
Sub-mm imagery	Cloud microphysical parameters, e.g. cloud phase
NIR imagery	CO2, CH4
Multi-angle, multi-polarization radiometers	Aerosols, radiation budget
Multi-polarization SAR, hyperspectral VIS	High-resolution land and ocean observation
GEO or LEO 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, greenhouse gases, trace gases)
UV/VIS/NIR/IR/MW limb sounders	Ozone , trace gases, aerosol, humidity, cloud top height
HEO VIS/IR mission for continuous polar coverage (Arctic and Antarctica)	Sea ice parameters; cloud amount, cloud top height/temperature; cloud microphysics, wind (through tracking cloud and water vapour features); 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 the Earth-Sun line (e.g. L1, GEO) and off the Earth-Sun line (e.g. L5, L4)	Solar activity (Detection of solar flares, Coronal Mass Ejections and precursor events)
Solar wind in situ plasma and energetic particles and magnetic field off the Earth-Sun line (e.g. L5)	Solar wind; energetic particles; interplanetary magnetic field
Solar coronagraph and heliospheric imagery off the Earth-Sun line (e.g. L4, L5)	Solar heliospheric imagery (Detection and monitoring of coronal mass ejections travelling to the Earth)
Magnetospheric energetic particles	Energetic particle flux and energy spectrum (geomagnetic storms)

Component 3 – Operational pathfinders, technology and science demonstrators

Instruments:	Geophysical variables and phenomena:
GNSS RO additional constellation for enhanced atmospheric/ionospheric soundings, including additional frequencies optimized for atmospheric sounding	Atmospheric temperature and humidity; ionospheric electron density
NIR spectrometer	Surface pressure
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, greenhouse gases, trace gases)
Solar coronal magnetic field imagery, solar wind beyond L1	Solar wind, geomagnetic activity
Ionosphere/ thermosphere spectral imagery (e.g. GEO, HEO, MEO, LEO)	
Ionospheric electron and major ion density	
Thermospheric neutral density and constituents	

Component 4 – Additional capacities and capabilities

Contributed by WMO Members and third parties including governmental, academic or commercial initiatives that could augment the backbone elements and thus enhance the global observing system and its robustness. Complementarity to what already exists as well as enhancing resilience should be the guiding principles.

WMO OMM

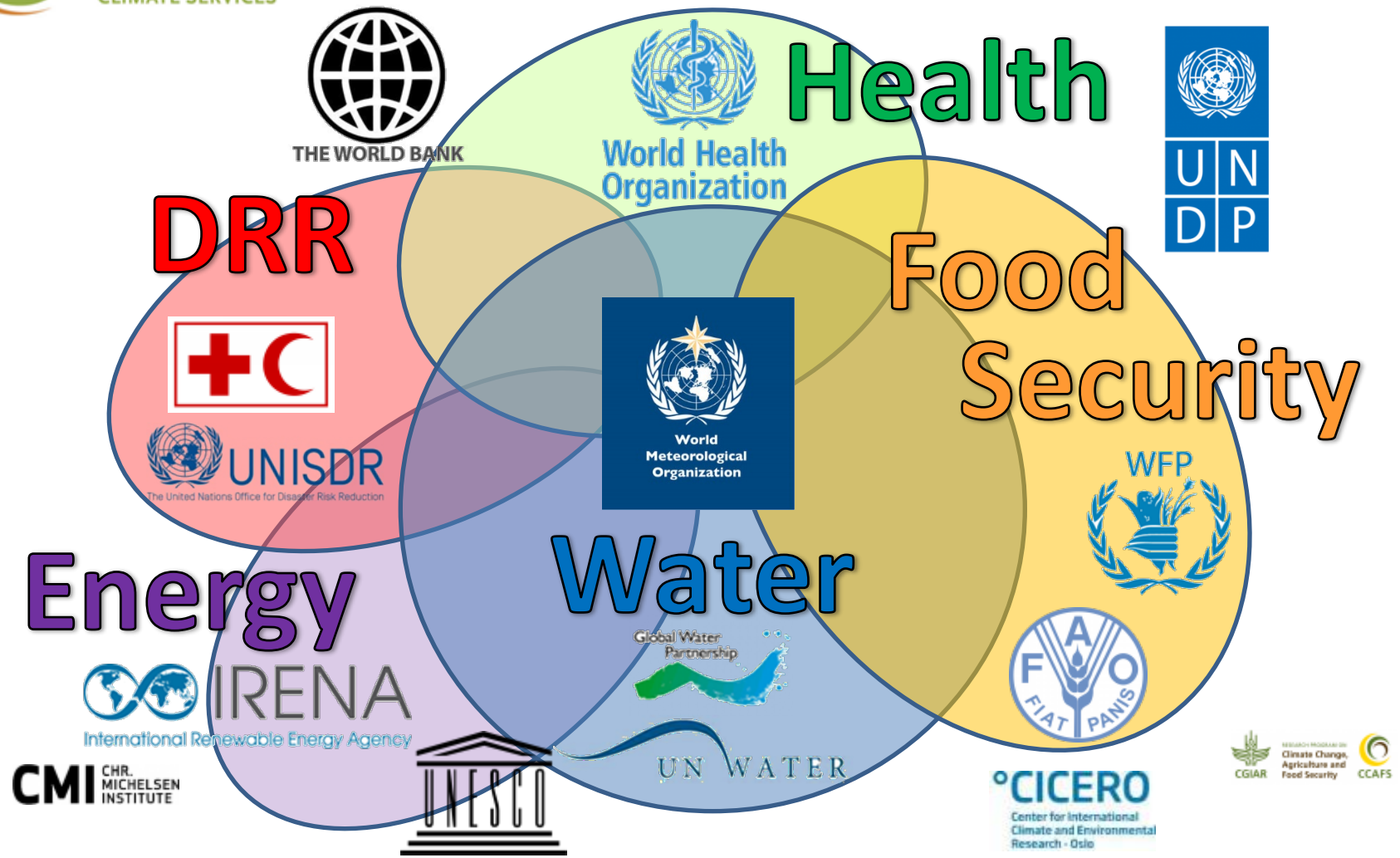
WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Thank you

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

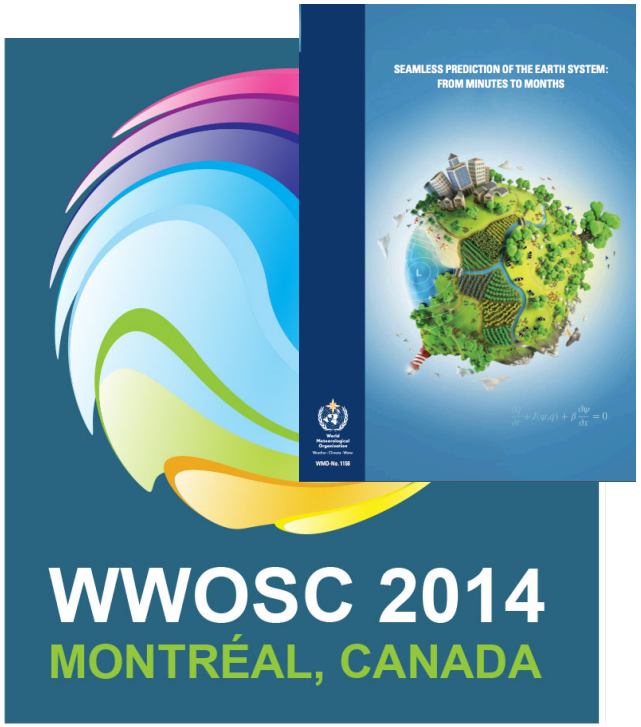
The Global Framework for Climate Services
A partnership



Successful adaptation will require substantially increased investment in climate services

WMO OMM

Weather and climate science



World Weather Open Science Conference (16-21 August 2014)

The Conference focused on the research NMHSs need for:

- **Developing a seamless predictive capability to advance environmental prediction on the weekly to monthly time scale, dramatically improving the capacity to deliver new services.**
- **Building community resilience in the face of increasing vulnerability to extreme weather events, through a better understanding of communication and decision-making processes.**

Seamless prediction of the Earth system: from minutes to months

Promoting gender equality

Socioeconomic benefits

- Conference "Secure and Sustainable Living: Social and economic benefits of weather, climate and water" (Madrid, 2007)
- Conference Madrid +10 (2018 TBC):
  - Economic value of weather and climate services
  - Investments in National Meteorological and Hydrological Services
  - Methodologies for the analysis of socio-economic benefits

Support to SIDS and Member Island Territories

- **New WMO programme dedicated to SIDS and Member Island Territories to increase their resilience to extreme weather and climate events:**
  - **To carry out initiatives that contribute to the implementation of the S.A.M.O.A. Pathway in WMO areas of competence**
  - **To strengthen the capacities of National Meteorological and Hydrological Services of WMO SIDS and Island Territories to strengthen community resilience and contribute to sustainable development**
- **GFCS partnership initiative for SIDS**

Disaster Risk Reduction

- **WMO contribution to the Sendai Framework (2015-2030)**
  - **International network of multi-hazard early warning systems**
    - **Multi-stakeholder partnership that will foster cooperation, collaboration, and networking in strengthening MHEWS**
    - **Sharing information about best practices and scientific, technical and social information to disseminate early warnings and enhance climate resilience**
  - **Impact-oriented warnings**
    - **Analysis of physical impacts of forecasted phenomena**
    - **Specific precautionary measures**

WMO OMM

UN World Conference on Disaster Risk Reduction
2015 Sendai Japan

SUSTAINABLE DEVELOPMENT GOALS/WMO

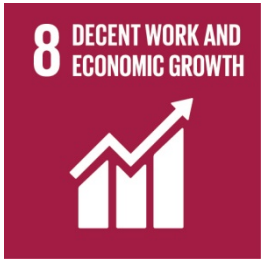
Weather resilience

Climate change & -services

Gender-sensitive services

Water resource management

Solar, wind & hydro use



Climate resilience

Big data, innovations

Air quality, heat waves, flooding

DRR, Adaptation, carbon & climate monitoring

Sea level rise, climate<->oceans

Climate change <->ecosystems

Climate driven conflicts

Resources for climate adaptation & DRR

Sustainable urban development

WMO integrated approach to urban issues

- Atmospheric research
- Satellite observations
- Weather and climate services
- Disaster risk reduction

- World urban population
  - 1950: 30%
  - 2014: 54%
  - 2050: 66% (projection)
- Cities occupy less than 2% of the Earth's land surface but represent:
  - 70% GDP
  - 60 energy consumption
  - 70% GHG emissions
  - 70% wastes
  - 28 megacities (> 10 million)

WMO strategic priorities for 2016-2019

1. Disaster Risk Reduction
2. Global Framework for Climate Services
3. WMO Integrated Global Observing System
4. Aviation meteorological services
5. Polar and high mountains regions
6. Capacity Development
7. Governance