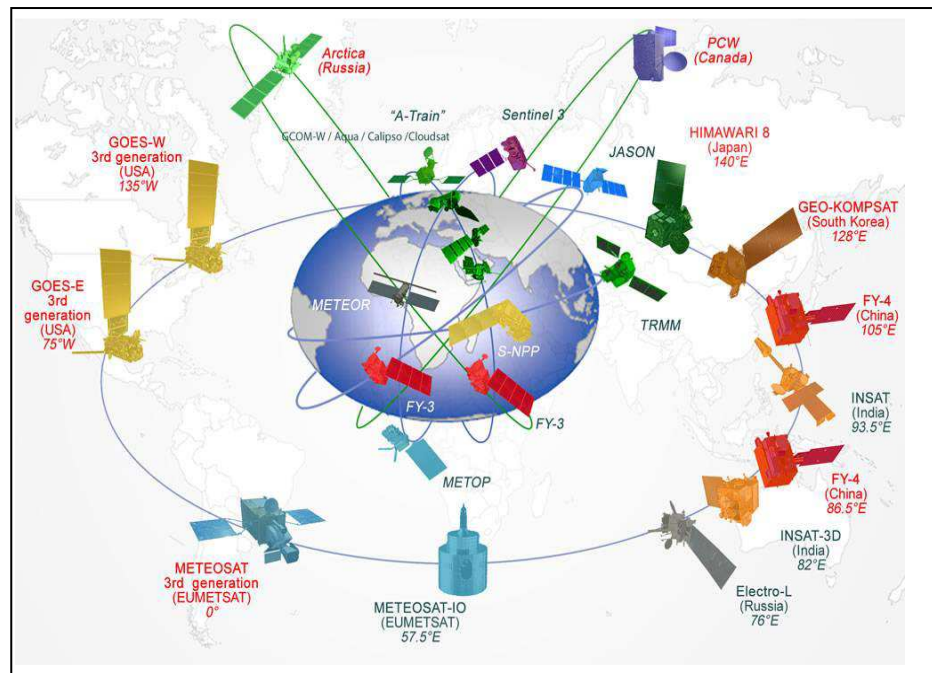


FUTURE SPACE-BASED OBSERVING SYSTEM

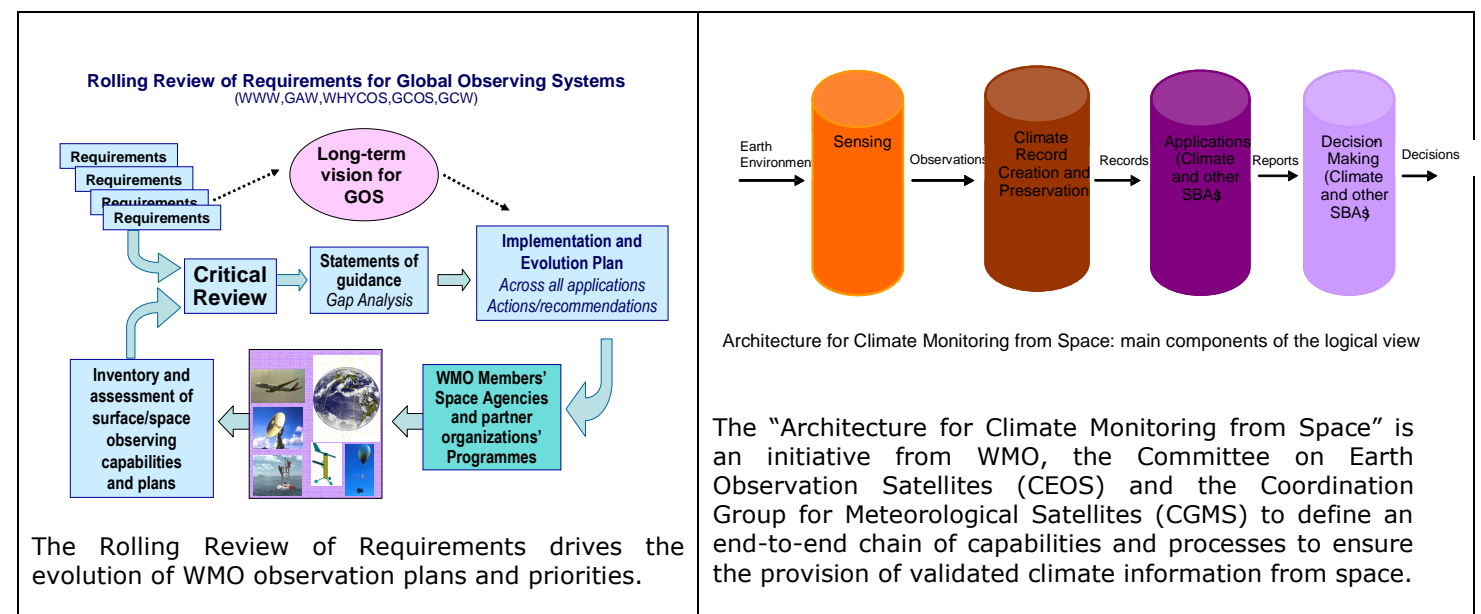
Jérôme Lafeuille (WMO, Space Programme Office)
International TOVS Study Conference XIX, Jeju, Republic of Korea, 26 March - 1 April 2014

- The observing system takes advantage of advances in remote sensing, satellite and information technology in response to evolving user requirements.
- The Rolling Review of Requirements compares needs and capabilities to support a gap analysis and to provide guidance for planning and implementation
- The Vision of Global Observing Systems, adopted by WMO Members, calls for an integrated approach of observation capabilities across applications, complementary use of surface and space-based capabilities, maximizing interoperability, quality assurance and observation traceability.



Schematic illustration of the future space segment of the global observing system. The drawing features the geostationary component, the core sun-synchronous meteorological component, examples of other missions in polar orbit, high-or or low-inclination orbit, and missions in high eccentricity orbit for Arctic area monitoring.

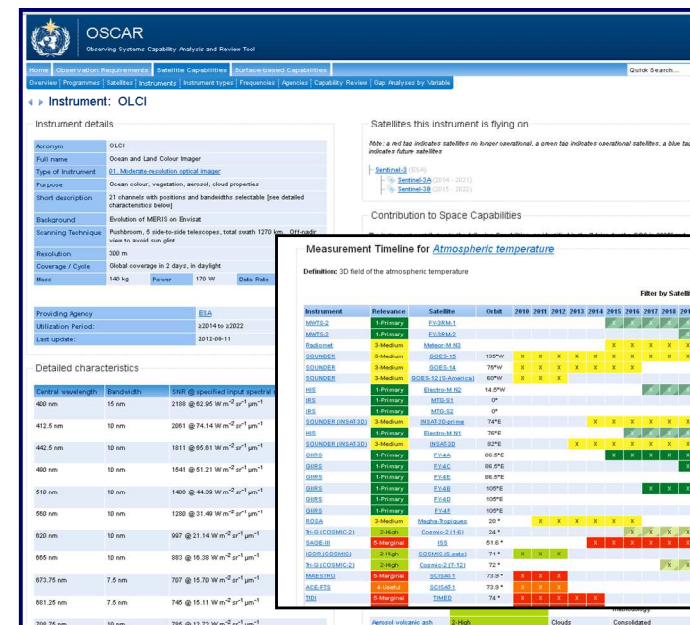
Evolution and assessment



General features of the WMO vision of space-based global observing systems

- Integration: the WMO Integrated Global Observing System (WIGOS) is a strategic priority for WMO members, which calls for a unified approach of observing needs of different applications, interoperability and integrated implementation and operation when appropriate. It involves both the surface-based and the space-based sub-systems.
- Standardization of observations and data formats. Global data exchange through the WMO Information System with standardized metadata, near-real time access to full resolution data
- Higher spatial, spectral and temporal resolution sensors, with improved timeliness.
- Calibration – traceable to SI standards - ensures data consistency over long time periods (decades) for climate monitoring in spite of possible lack of overlaps between successive sensor generations. Consistent inter-satellite calibration is also required for generating composite products merging data from different sources.
- Back-up and contingency arrangements ensuring continuity.

(http://www.wmo.int/pages/prog/www/OSY/WorkingStructure/documents/CBS-2009_Vision-GOS-2025.pdf)



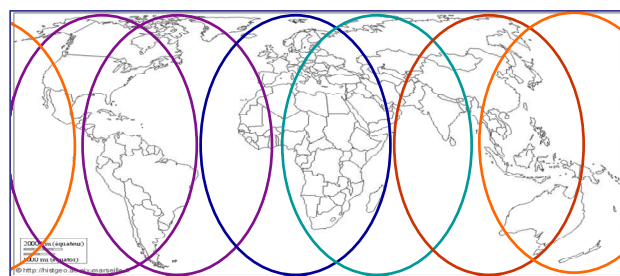
Status and plans of Earth Observation missions are summarized in:

www.wmo.int/pages/prog/sat/satellitestatus.php

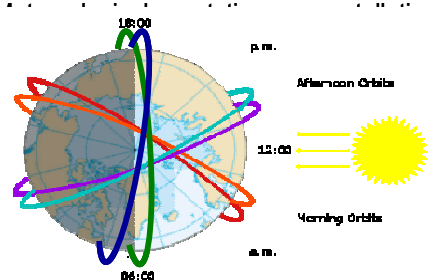
Technical details and high-level gap analyses are provided in the Observing System Capability Analysis and Review (OSCAR) on-line resource.

www.wmo.int/oscar/space

The backbone meteorological space-based observing system: geostationary and core meteorological polar-



- Geostationary component**
- at least 6 evenly distributed locations, with back-up
 - Advanced Visible/Infrared imagers
 - Hyperspectral Infrared sounder
 - Lightning mappers



- Core sun-synchronous component**
- 3 evenly distributed orbital planes
 - Advanced Visible/Infrared imagers
 - Hyperspectral Infrared sounder
 - Microwave sounders
 - Contribution to other missions

- Geostationary constellation for permanent monitoring of rapidly evolving weather patterns at low and mid latitudes with high temporal resolution, an essential requirement for severe weather monitoring and forecasting, including tropical cyclones, convective situations and nowcasting in general, and for proper sampling of the diurnal cycle for climate monitoring and other applications
- A constellation of sun-synchronous spacecraft with infrared and microwave sounding package, implemented on at least three distributed orbital planes providing global sampling of atmospheric temperature and humidity profiles for Numerical Weather Prediction

Other missions called upon by the WMO Vision for the GOS

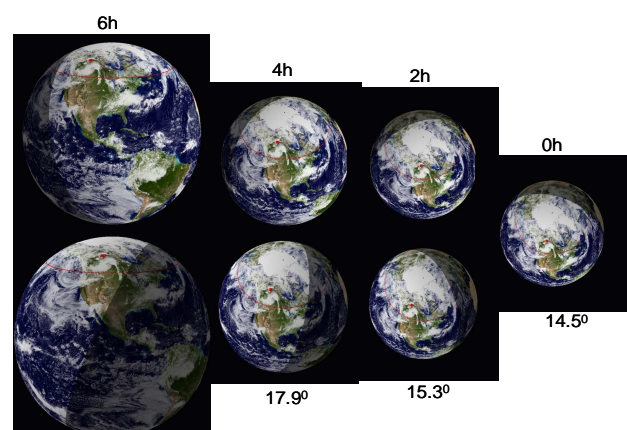
- MW imagery
 - Some polarimetric sensors
- Altimetry constellation
 - Reference mission + SSO
- Scatterometry
 - At least 2 separated orbits
- Radio-occultation
 - Dedicated constellation + SSO
- Global Precipitation (GPM)
 - Radar in low-incl. Orbit + MW imagery
- Atmospheric composition
 - UV sounder + to be refined
- Earth Radiation Budget
 - TSI + broadband (to be refined)
- Multi-directional viewing IR imager

- Space weather :**
- Solar activity monitoring
 - Energetic particles
 - Electron density

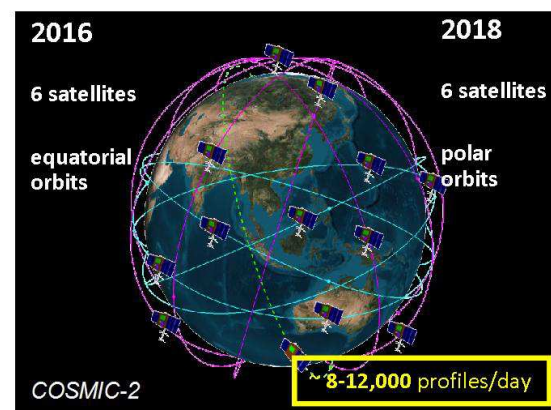
- Listed, but not specified :**
- Narrow-band VIS/NIR imager
 - High Resolution VIS/IR imagery constellation
 - SAR imagery

- Demonstration:**
- Highly Elliptical Orbit imaging
 - Doppler wind lidar
 - Low frequency MW
 - GEO MW

These missions are not necessarily all implemented on the same spacecraft as the core imagery and sounding missions above. Some of them may complement the core payload on these spacecraft, other will fly on other sun-synchronous spacecraft, and other will preferably fly on other orbit types.



Two spacecraft in Highly Elliptical Orbit can provide continuous monitoring of the Arctic region (Courtesy of Canadian Space Agency).



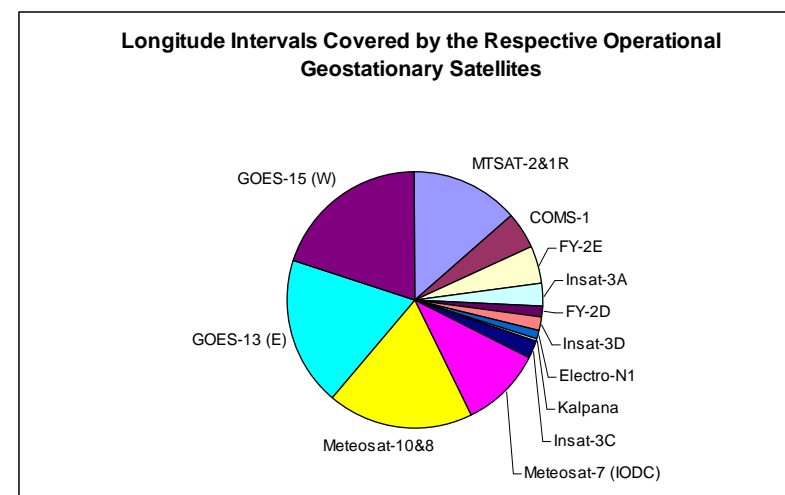
The COSMIC-2/Formosat-7 constellation is expected to provide around 10,000 globally distributed radio-occultation profiles per day (Courtesy: UCAR)

Implementation: CGMS baseline and actual status

The Coordination Group for Meteorological Satellites (CGMS) has adopted a "CGMS baseline for contribution to the GOS" to formalize its commitments to respond to the WMO Vision. The baseline describes the missions to be implemented on an operational or "sustained" basis.

- **Advanced geostationary imagers:** with Himawari-8 and 9 (first launch in late 2014), GOES-R, S, T, U (first launch in 2015/2016), the FY-4 series (first launch in 2017), the Electro-M series (2017), GEOKOMPSAT-2A (2018) and Meteosat Third Generation-Imager series (2019), most of the geostationary constellation will transition to a new generation of advanced imaging Visible/Infrared radiometers, capable of scanning the full disc in 10 to 15 minutes in at least 14 and in most cases 16 channels. The WMO Space Programme will open the SATURN website (SATellite User Readiness Navigator) to provide a common entry point to technical updates for user preparation.
- **Geostationary infrared hyperspectral sounding:** an hyperspectral Infrared sounder is planned on the Feng-Yun-4 series (as of 2017) and the Meteosat Third Generation Sounding (MTG-S) series (~2021). Currently, a 19-channel sounder is operated aboard the GOES series and the new INSAT-3D.
- **Lightning detectors** are now planned aboard the GOES-R, Meteor-M and MTG-I series.

The CGMS agreed baseline foresees at least six geostationary satellites with evenly distributed locations and in orbit redundancy. Thanks to the strong development of space capabilities in Asian countries, up to 8 satellites are being operated between 66°E and 134°E. This provides an opportunity for mutual back-up, rapid scan operations over targeted areas, and operation of complementary payloads. The other 5 satellite locations are covering 80% of the globe.



- **Towards a three-orbit polar constellation:** Hyperspectral infrared sounders are available with IASI on METOP-A and B, and CrIS on Suomi NPP. The vision of a polar-orbiting constellation with three orbits (mid-morning, afternoon, and dawn-dusk or early morning) is about to be realized if the plan to fly some spacecraft of the FY-3 series in an early morning orbit is confirmed by China. The core meteorological constellation in sun-synchronous orbits will then rely on three pillars: Europe (EUMETSAT) for the mid-morning (9:30 d), the United States (NOAA) for the afternoon orbit (13:30), and China (CMA) for the early morning (6:00 d).
- **Radio-occultation constellation:** with the aim to produce 10,000 to 20,000 occultations per day, the future radio-occultation system should rely on (i) radio-occultation sensors included in the payload of the meteorological sun-synchronous satellites (METOP/GRAS and FY-3/GNOS), and (ii) a constellation of small satellites on various high and low inclination orbits for adequate coverage of all latitudes. This is expected to be fully implemented with COSMIC-2/Formosat-7, hopefully by 2018.
- **Global precipitation measurement by radar and passive microwave imagery:** although not yet part of an "operational programme", a precipitation radar has been operated for 17 years on TRMM. The recently launched NASA/JAXA GPM-core mission will greatly enhance this capability. A Rain Monitoring mission is also considered by CMA within the FY-3 programme.
- **Scatterometers for ocean surface wind:** Scatterometers are currently operated on the METOP (EUMETSAT), HY-2 (NSOAS) and OCEANSAT (ISRO) series, and planned on FY-3 (CMA) as of 2016. A critical issue is the open accessibility of this data in near-real time.
- **Radar altimetry:** The reference mission pursued by the Jason-1, 2, 3, (funding TBC) and Jason-CS series will be supplemented by Sentinel-3/SRAL and HY-2/Alt series in sun-synchronous orbit.
- **Earth radiation, atmospheric composition, other missions:** plans are being consolidated.

More Information: <http://www.wmo.int/sat>

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