Vision for the space-based component of WIGOS in 2040

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Acknowledgments:
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Overview

1. Background and initial assumptions
2. Evolving user needs
3. Evolving capabilities
4. Evolving provider community
5. Elements of a Vision

Background

- The ***Vision of GOS in 2025*** developed in 2007-2008 needs updating
  - just as it replaced the Vision in 2015 adopted in 2002
- A ***long-term perspective*** is needed to inform satellite agency planning
  - Some agency plans are confirmed until the early 2030s
  - Based on anticipated user needs and expected technological capabilities
- WMO started developing the ***Vision of WIGOS component observing systems in 2040*** in 2015-2016, under CBS leadership, as requested by Executive Council, for submission to Cg-18 in 2019.
- The Vision is intended to provide a ***challenging but achievable***, ***high-level goal***

Initial Assumptions

- The current structure of the space-based observing system is a solid foundation underpinning the success story of the «World Weather Watch» and essential to WIGOS

  (Ref: Manual on WIGOS endorsed by Cg-17, and CGMS baseline)

  - Geostationary constellation
  - 3-orbit sun-synchronous constellation for sounding and imagery
  - Complementary missions on appropriate orbits
  - Near-real time data availability

- Questions were raised with reference to the current Vision
  - What should be added ?
  - What is at risk and should be reinforced ?
  - What should be improved (performance, coverage) ?
  - What could be performed differently in the future ?
  - What are the major challenges?

Main Drivers for the 2040 Vision

- Evolving and emerging user requirements
  - Future modelling requires increased resolution (spatial, temporal, spectral..)
  - Consistent, comprehensive data records (calibration & traceability)
  - Applications related to atmospheric composition (e.g. air quality), cryosphere, hydrology, space weather, are more mature and should be better addressed
- Recent/anticipated advances in technology enabling new capabilities
  - Sensor technology
  - Orbital concepts
  - Satellite programme concepts (small satellites, constellations)
  - Data system architecture
- Changes in the provision of satellite systems
  - More space faring nations – Vision should promote various cooperation models
  - Enhanced pressure to provide cost/benefit justification
  - Increased interest from private sector in providing data

Approach to developing a new vision (1)

- Rather than prescribing every component, strike a balance:
  - Specific enough to provide clear guidance on system to be achieved (including which constellations are needed for each application area)
  - Open to opportunities and encouraging initiatives

- Vision addresses specifically the space segment because of long-lead decisions needed by space programmes

- Some generic consideration however needed on :

  - how it will be supplemented by the surface-based component

  - and on the associated ground segment, application development, user support, capacity building

Approach to developing a new vision (2)

Vision consists of 4 components for national/international contributions, with data accessible in timely manner with metadata, sensor characteristics, etc.:

- **Component 1: backbone component, specified orbital configuration and measurement approach**
  - Basis for Members' commitments, should respond to the vital data needs
  - Similar to the current CGMS baseline with addition of newly mature capabilities
- **Component 2: backbone component, keeping open the orbital configuration and measurement approach,** leaving room for further system optimization
  - Basis for open contributions of WMO Members, responding to target data goals,
- **Component 3: Operational pathfinders and technology and science demonstrators**
  - Responding to R&D needs
- **Component 4: Other operators** (e.g. academic, commercial) exploiting technical/ business /programmatic opportunities are likely to provide additional data
  - WMO should recommend standards, best practices, guiding principles to maximize the chance that these additional data sources contribute to the community

Component 1. Backbone system - with specified orbital configuration and measurement approaches (1/2)

- **Geostationary** ring providing frequent multispectral VIS/IR imagery
  - with IR hyperspectral sounder, lightning mapper, UV/VIS/NIR sounder
- **LEO sun-sync. core constellation** in 3 orbit planes (am/pm/earlymorning)
  - with hyperspectral IR sounder, VIS/IR imager including Day/Night band
  - with MW imager, MW sounder, Scatterometer
- **LEO sun-sync. at 3 additional ECT** for improved robustness and improved time sampling particularly for monitoring precipitation
- Wide-swath radar altimeter, and high-altitude, inclined, high-precision orbit altimeter,
- IR dual-angle view imager (for SST)
- MW imagery at 6.7 GHz (for all-weather SST)
- Low-frequency MW (for soil moisture and ocean salinity)
- MW cross-track upper stratospheric and mesospheric temperature sounder
- UV/VIS/NIR sounder , nadir and limb (for atmospheric composition, incl H_2O)

Component 1. Backbone system - with specified orbital configuration and measurement approaches (2/2)

- Precipitation and cloud radars, and MW sounder and imager on inclined orbits
- Absolutely calibrated broadband radiometer, and TSI and SSI radiometer
- GNSS radio-occultation (basic constellation) for temperature, humidity and electron density
- Narrow-band or hyperspectral imagery (ocean colour, vegetation)
- High-resolution multispectral VIS/IR imagers (land use, vegetation, flood, landslide monitoring)
- SAR imagery (sea state, sea ice, ice sheets, soil moisture, floods)
- Gravimetry mission (ground water, oceanography)
- Solar wind in situ plasma and energetic particles, magnetic field, at L1
- Solar coronagraph and radio-spectrograph, at L1
- In situ plasma, energetic particles at GEO and LEO, and magnetic field at GEO
- On-orbit measurement reference standards for VIS/NIR, IR, MW absolute calibration

Component 2. Backbone system – Open measurement approaches (flexibility to optimize the implementation) 1/2

- Surface wind and sea state, e.g. by GNSS reflectometry missions, passive MW, SAR
- Stratosphere/mesosphere monitoring by UV–VIS–NIR–IR-MW limb sounders
- Wind and aerosol profiling by lidar (Doppler and dual/triple-frequency backscatter)
- Atmospheric moisture profiling by lidar (DIAL)
- Sea-ice thickness by lidar (in addition to radars mentioned in Component 1)
- Cloud phase detection, e.g. by sub-mm imagery
- Carbon Dioxide and Methane by NIR imagery
- Aerosol and radiation budget by multi-angle, multi-polarization radiometers
- High-resolution land or ocean observation (multi-polarization SAR, hyperspectral VIS)
- High temporal frequency MW sounding (GEO or LEO constellation)

Component 2. Backbone system – Open measurement approaches (flexibility to optimize the implementation) 2/2

- Surface pressure by NIR spectrometry
- HEO VIS/IR mission for continuous polar coverage (Arctic & Antarctica)
- Solar magnetograph , solar EUV/X-ray imager, 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 wind in situ plasma and energetic particles and magnetic field off the Earth-Sun line (e.g. L5)
- Solar coronagraph and heliospheric imager off the Earth-Sun line (e.g. L4, L5)
- Magnetospheric energetic particles (e.g. GEO, HEO, MEO, LEO)

Component 3. Operational pathfinders and technology and science demonstrators

- RO constellation for enhanced atmospheric/ionospheric soundings
  - Including additional frequencies optimized for atmospheric sounding
- Radar and Lidar for vegetation
- Hyperspectral MW sensors
- Solar coronal magnetic field imager, solar wind beyond L1
- Ionosphere/thermosphere spectral imager (e.g. GEO, HEO, MEO, LEO)
- Ionospheric electron and major ion density,
- Thermospheric neutral density and constituents
- Process study missions (content and duration TBD depending on process cycles)
- Use of nanosatellites for demonstration or science missions, and for contigency planning as gap fillers (notwithstanding their possible use in Component 2)
- Use of orbiting platforms (like the International Space Station) for demonstration or science missions

Component 4. Other contributions from WMO Members and third parties

- Governmental or academic EO projects
- Private sector initiatives
- Often using individual or constellations of small satellites (cubesats, nanosats)
- Exploiting technical or market opportunities
- Augmenting the backbone

- WMO would not pretend to coordinate these contributions, but
- WMO should recommend standards and best practices that the operators may consider to comply with, to facilitate data uptake and to maximize the chances that the data are interoperable with the backbone system

Next steps

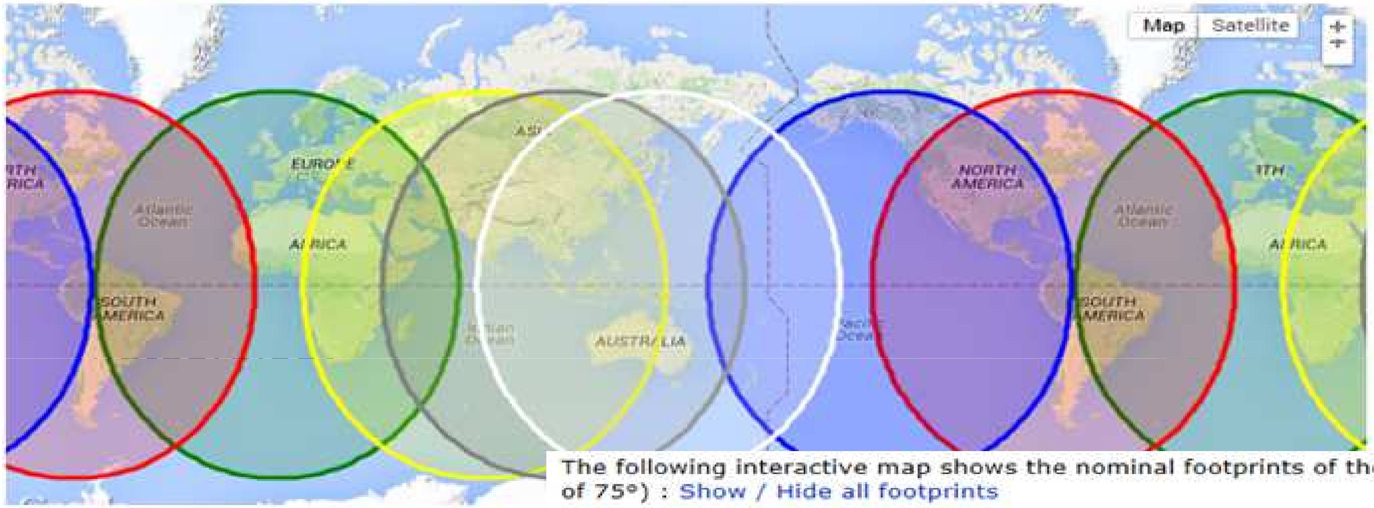
WMO Consultation Process

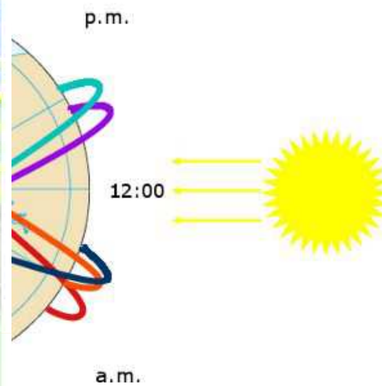
The role of Visions and the status

- **The role of WMO Visions**
  - Consolidating WMO Requirements supporting the justification of space agencies long-term plans
  - Provide high-level challenging but achievable goals to guide the evolution of the WMO Observing Systems in the coming decades.
- **The Global Observing System Vision in 2015 was adopted in 2002**
  - **The Implementation Plan for Evolution of Global Observing System (2015 EGOS-IP)** was approved in 2005
- **The Global Observing System Vision in 2025 was adopted in 2009**
  - **The Implementation Plan (2025 EGOS-IP) was** approved in 2012 (A 120 pages document and with 115 actions)
- **The WIGOS Vision 2040, targeted to be approved by Cg-18 (2019)**
  - Then WMO will follow up working together with space agencies for drafting the WIGOS Implementation Plan 2040 (with the hope be approved by 2021)

WMO Appreciates greatly the space agency response to the GOS Vision 2025

The following interactive map shows the nominal footprints of these satellites (Assuming a zenith angle of 75°) : Show / Hide all footprints





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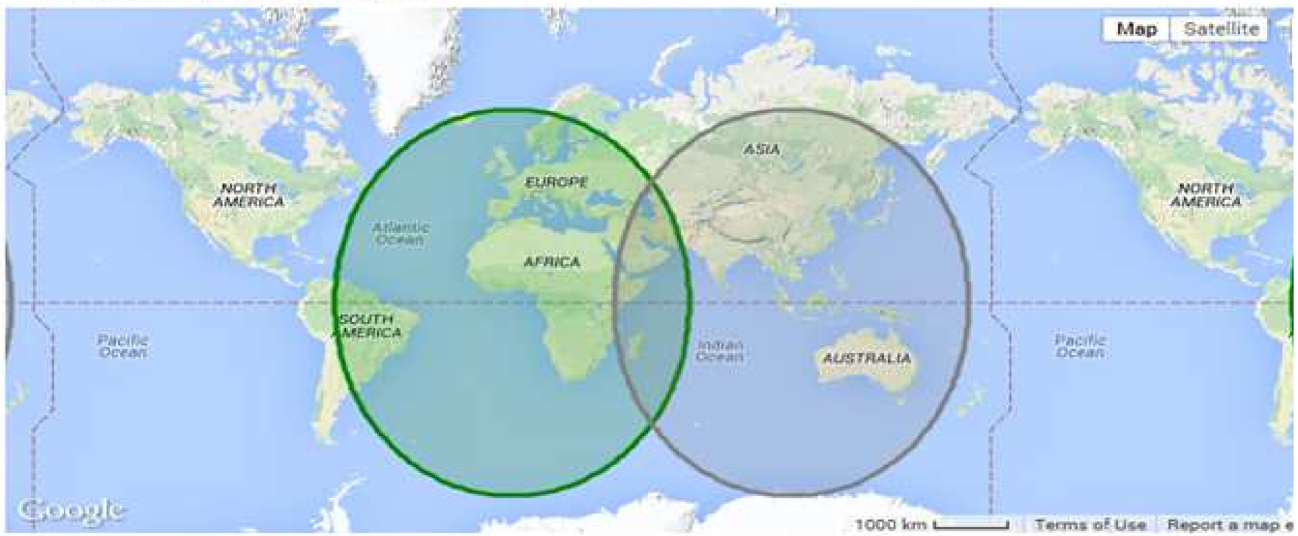

- -- LEO Doppler W
freq. MW, GPS/RO
- -- more gaps for (
monitoring and oth

- System vulnerabilities

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Key Consultations through WMO Constituent Body Sessions and CGMS, CEOS and Agencies

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC
2016						CGMS44 EC-68			RA II-16		CBS-16 China	CHy-15 Italy
2017				RA IV-17		CGMS 45 EC-69	CAS-17 Indonesia		RA VI-17	JCOMM-5 Indonesia		RA V-17
2018			CCl-17 Morocco / Chile	CAgM-17 Korea		CGMS 46 EC-70	CAeM-16 Geneva		CIMO-17 Turkey	RA I-17		RA III-17
2019					Cg-18 CICG	EC-71						

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The Vision is planned for finalization by the end of 2018, for endorsement by WMO 18th Congress in 2019

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Thank you
Merci

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