

# GNSS Radio-occultation in the WMO Integrated Global Observing System (updated)



WORLD  
METEOROLOGICAL  
ORGANIZATION

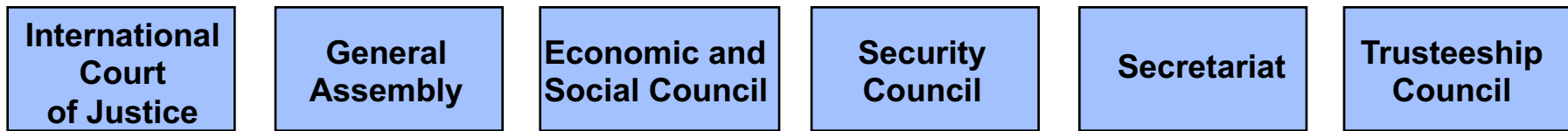
**COSMIC - IROWG 2017**

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# WMO in the United Nations



WMO is a specialized agency of the United Nations (UN) with 191 Member States and Territories.

WMO is dedicated to international cooperation and coordination on “Weather, Climate and Water”, namely the state and behavior of the Earth’s atmosphere, its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources.

- Main and other sessions
- Standing committees
- Other committees
- ◆ UN
- ◆ I
- ◆ II
- ◆ U
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- ◆ UN
- ◆ UNITAR
- ◆ UNU
- ◆ WFC

- COMMITTEES
- EXPERT, AD-HOC AND RELATED BODIES
- IFAD
- UNIDO
- WTO
- Specialized agencies and other autonomous organizations within the system
- Other commissions, committees and ad-hoc related bodies



# WMO Space Programme

The WMO Space Programme has 4 main components:

## The space-based Observing System



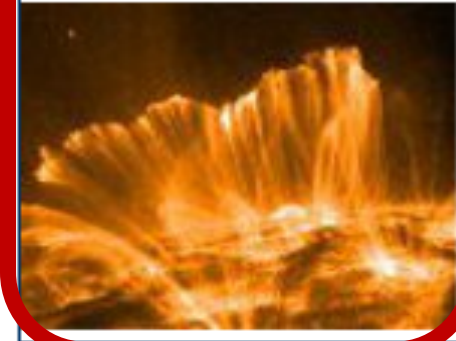
## Access to Satellite Data and Products



## Awareness and Training



## Space Weather Coordination



- [OSCAR/Requirements \(Observing Requirements Database\)](#)
- [OSCAR/Space \(Satellite & Instrument Database\)](#)
- [Satellite Status list](#)
- [Satellite User Readiness Navigator \(SATURN\)](#)
- [Product Access Guide \(PAG\)](#)
- [Virtual Laboratory for Education and Training in Satellite Meteorology \(VLAB\)](#)
- [Working Documents for Meetings](#)

[http://www.wmo.int/pages/prog/sat/index\\_en.php](http://www.wmo.int/pages/prog/sat/index_en.php)

# Coordination Group for Meteorological Satellites (CGMS)

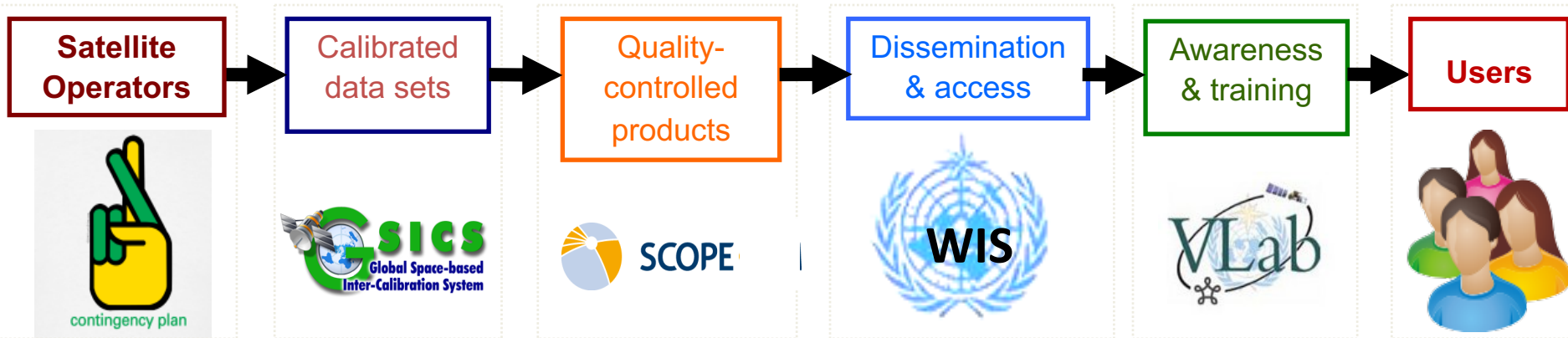
- WMO Space Programme's objectives are to be achieved through strong partnership with **CGMS**.
- CGMS is a **technical** coordination body of satellite operators including space agencies focusing primarily on weather and climate satellite programmes in response to WMO requirements.
- WMO and CGMS are co-sponsoring **international science working groups**: ITWG, IWWG, IPWG, **IROWG** and ICWG

The baseline for holding a CGMS Membership covers: ([http://www.cgms-info.org/index\\_.php/cgms/members\\_observers](http://www.cgms-info.org/index_.php/cgms/members_observers))

- Current and prospective developers and operators of meteorological satellites;
- WMO, because of its unique role as representative of the world meteorological data user community, and other programmes jointly supported by WMO and other international agencies;
- Space agencies operating R&D satellites contributing to WMO programmes.

Organisation	Website	Accession
Centre National d'Etudes Spatiales	<a href="#">CNES</a>	2004
China Meteorological Administration	<a href="#">CMA</a>	1989
China National Space Administration	<a href="#">CNSA</a>	2006
EUMETSAT	<a href="#">EUMETSAT</a>	1987
India Meteorological Department	<a href="#">IMD</a>	1979
Indian Space Research Organisation	<a href="#">ISRO</a>	2015
Intergovernmental Oceanographic Commission / UNESCO	<a href="#">IOC/Unesco</a>	2001
Japan Aerospace Exploration Agency	<a href="#">JAXA</a>	2003
Japan Meteorological Agency	<a href="#">JMA</a>	1972
Korea Meteorological Administration	<a href="#">KMA</a>	2005
National Aeronautics and Space Administration	<a href="#">NASA</a>	2003
National Oceanic and Atmospheric Administration	<a href="#">NOAA</a>	1972
Russian Federal Service for Hydrometeorology and Environmental Monitoring	<a href="#">ROSHYDROMET</a>	1973
Russian Federal Space Agency	<a href="#">ROSCOSMOS</a>	2003
The European Space Agency	<a href="#">ESA</a>	2003
World Meteorological Organization	<a href="#">WMO</a>	1973

# Value Chain for WMO Space Programme



# Importance of GNSS-RO from WMO's Perspective



## **NWP: NRT Temperature/Humidity information**

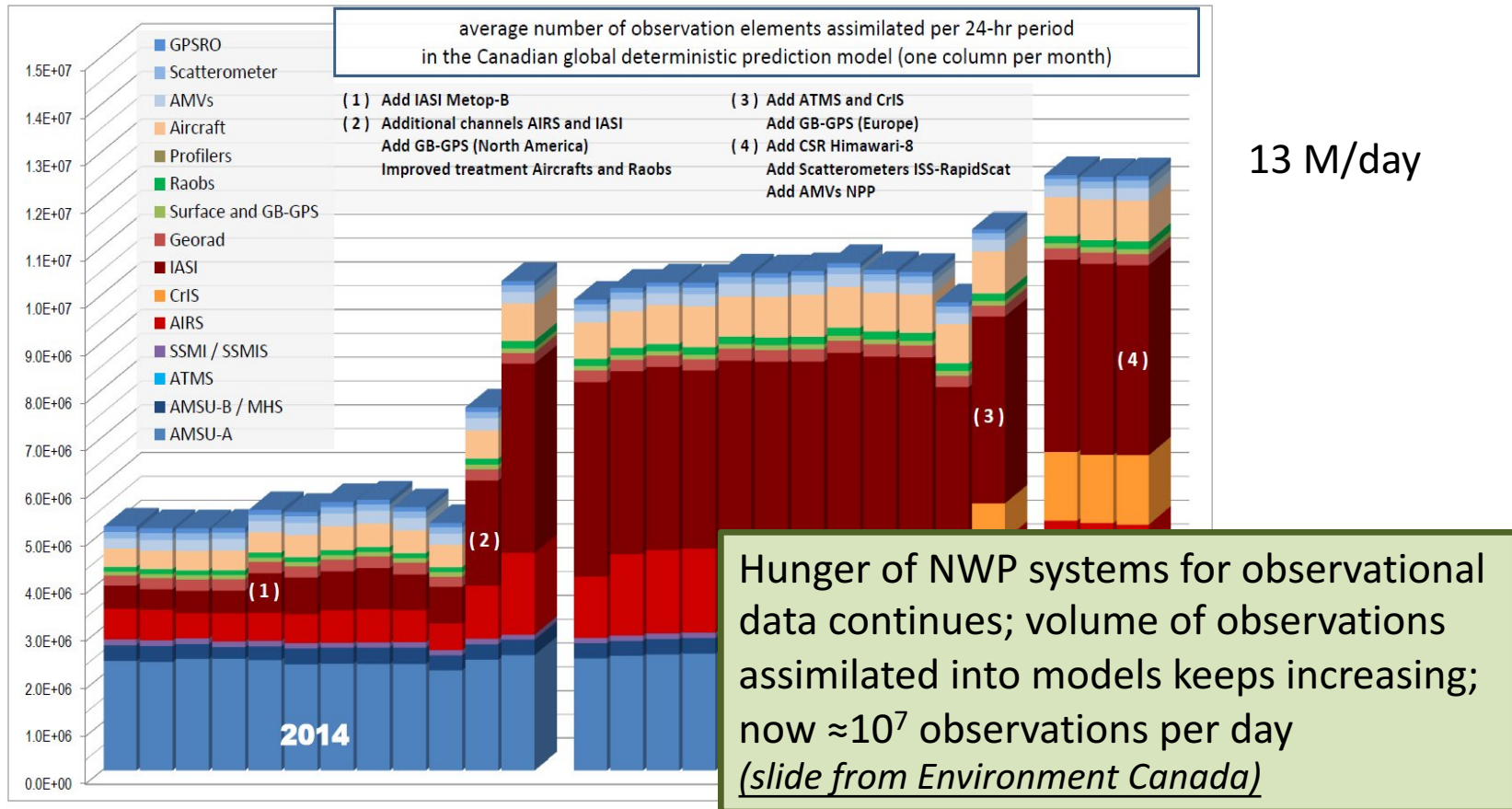
- Bending angles or refractivity profiles
  - Vertically resolved
  - High impact per observation
  - No significant instrumental bias
- **Climate : Climate Data Records**
    - Benchmark observations that can supplement the GCOS Reference Upper-Air Network (*GCOS Implementation Plan*) as a consequence of its calibration free nature
  - **Space Weather : Total Electron Content for Ionosphere Monitoring**
    - Stringent timeliness constraint
    - Need to scan up to > 100 km

# WMO Workshops on the Impact of Various Observing Systems on NWP

- 1<sup>st</sup> – Geneva, 1997
- 2<sup>nd</sup> – Toulouse, 2000
- 3<sup>rd</sup> – Alpbach, 2004
- 4<sup>th</sup> – Geneva, 2008
  - [http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-4\\_Geneva2008\\_index.html](http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-4_Geneva2008_index.html)
- 5<sup>th</sup> – Sedona 2012
  - [http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-5\\_Sedona2012.html](http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-5_Sedona2012.html)
- **6<sup>th</sup> – Shanghai, May 10-13 2016**
  - [http://www.wmo.int/pages/prog/www/WIGOS-WIS/reports/6NWP\\_Shanghai2016/WMO6-Impact-workshop\\_Shanghai-May2016.html](http://www.wmo.int/pages/prog/www/WIGOS-WIS/reports/6NWP_Shanghai2016/WMO6-Impact-workshop_Shanghai-May2016.html)

*Extremely important for WIGOS due to their role in the WMO Rolling Review of Requirements, WMO Impact Workshops bring together major NWP centers, research community and other stakeholders to discuss the contribution to forecast skill of various WIGOS/GOS elements; guidance to participants provided well in advance of Workshop*

# Daily data volumes (assimilated)



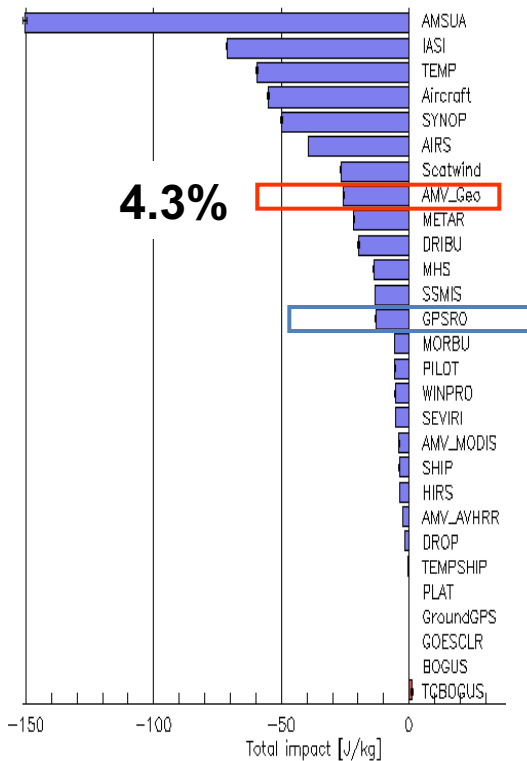
AMSU-A: NOAA 15-18-19, METOP A/B, AQUA; AIRS & IASI A/B: 142 channels each, CrIS: 103 channels.

# Impact on 24h forecast error in Forecast Sensitivity - Observation Impact (FSOI) Diagnostics

Increasing FSOI as more AMV data assimilated

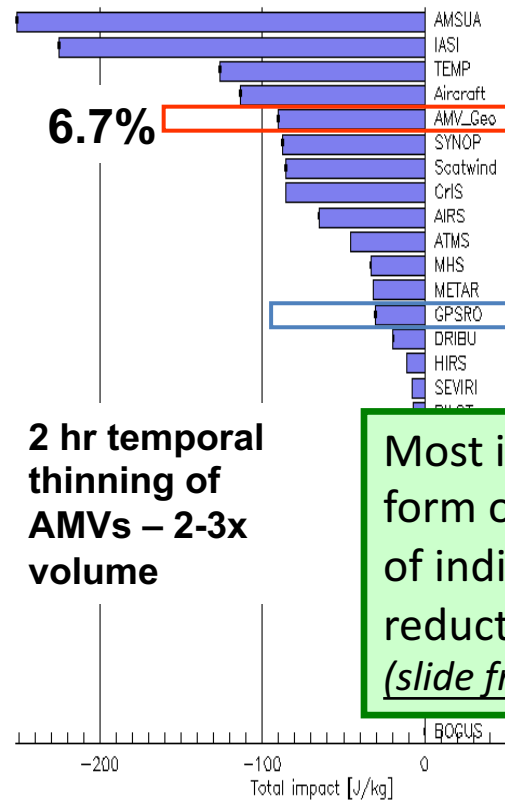
Jan-Mar 2012

All observations / 120130\_qu18-120318\_qu00



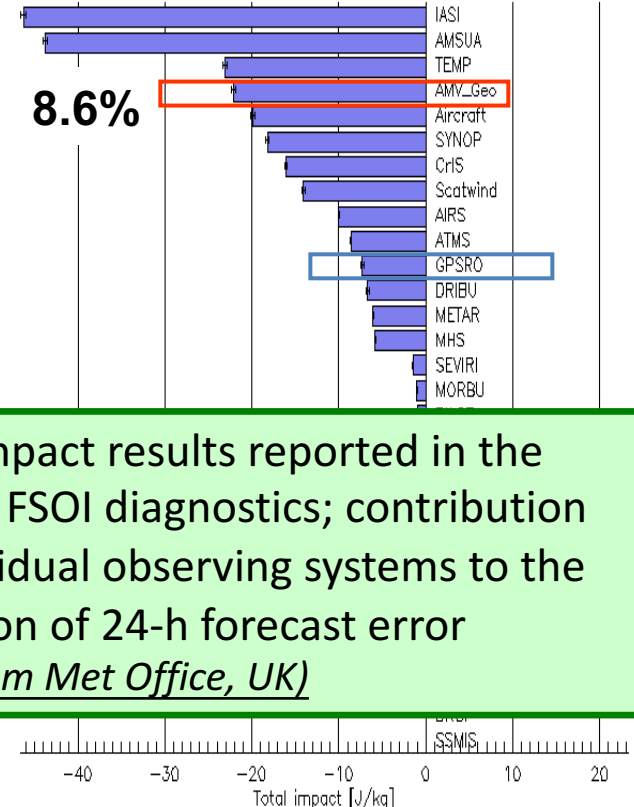
Apr-July 2013

All observations / 130401\_qu00-130731\_qu18



May 2014

All observations / 2014050100-2014052812



2 hr temporal thinning of AMVs – 2-3x volume

Most impact results reported in the form of FSOI diagnostics; contribution of individual observing systems to the reduction of 24-h forecast error (slide from Met Office, UK)

Contributions to the total observation impact on a moist 24-hour forecast-error energy-norm, surface-150 hPa (Richard Marriott and James Cotton)

# Key points from the report for GNSS

- *“The positive direct impact of GNSS-RO data on global NWP skill was confirmed, as well as the indirect impact of these data through their contribution to bias correction of radiance data from other satellite sensors.”*
- *“The Workshop took note of the current development in the space sector regarding commercial data providers proposing to put privately funded GNSS-RO constellations in space with an aim to sell these observations to national governments, and it was emphasized that unless the data are procured with a clear aim to continue respecting existing principles on international data sharing, these data will not be fully utilized,”*

# Key recommendation

- **Recommendation 5**; *(first proposed by the IROWG and supported by this Workshop in slightly modified form); The deployment of an operational constellation of GNSS-RO satellites capable of providing at least 20,000 high quality soundings per day, at near-uniform global coverage and extending well into the lower troposphere is strongly recommended.*
- **Recommendation 10**; *All data providers are encouraged to continue to share all observations internationally, especially those observations that are essential for numerical weather prediction, e.g. all GNSS-RO soundings.*

# **WMO Policy Framework for Public-Private Sector Engagement**

# Background

- Respective roles of private versus public sectors in meteorology are undergoing very rapid change, due to (among other factors):
  - Increasing demands for weather and climate information and increasing private sector appreciation for the value of such information
  - Commoditization of key observing, telecommunications and computing technologies
  - Limited public funds available for maintaining and improving basic capabilities and service delivery in meteorology
  - Political drive toward commercialization of government functions in many countries
- As a result the national weather services in many WMO Members are under pressure, in terms of budget, mandate and responsibility, visibility, or – in some cases - even regarding their very existence



# Role of WMO

- Members are looking to WMO for guidance on Public-Private Sector Engagement (PPE)
- As an organization, WMO is concerned about
  - Preserving the existing framework of international collaboration in meteorology, in particular as concerns the free and open exchange of data (observations and products)
  - Potential erosion in the mandates and roles of the NMHSs of its Members
- Discussion at the recent WMO Executive Council meeting resulted in
  - Draft Decision 12.2/1 (EC-69) “Public-Private Engagement: A Road Map to the Eighteenth World Meteorological Congress”

# WMO Executive Council 69 (May 2017)

*(from Draft Decision 12.2/1)*

{...}

**Recognizes** that growth of private sector involvement in all facets of meteorological and hydrological services are substantially expanding, making public-private engagement an urgent and important issue that will impact the future policies and strategies of WMO and its Members;

**Notes the potential risks to NMHSs in the evolving relationship between public and private sectors**, as well as the potential opportunities to better meet the needs of Members;

**Acknowledges the important leadership role of WMO**, through its Convention and through the authority of its Technical Regulations in helping to build a strong and strategic alliance between all of the parties contributing to a sustainable global weather enterprise for the benefit of society;

{...}

## EC-69 (*Draft Decision 12.2/1, II*)

{...}

### **Agrees:**

- (1) That there is some urgency to better equipping NMHSs, through WMO, to engage actively and positively with private sector organizations, not least to ensure that essential national mandates, including the importance of a single authoritative voice in relation to safety of life and property are sustained;
- (2) That in accordance with the aims and purposes of the Convention of WMO, a policy framework on public-private engagement would be beneficial to the Organization and should be prepared for consideration and approval at the next World Meteorological Congress (Cg-18);

{...}

## EC-69 (*Draft Decision 12.2/1, III*)

{...}

**Emphasizes the fundamental importance of free and open data and products exchange**, support to public good infrastructure, including the global observing networks, and the value of reinforcing the regulatory environment afforded by the WMO Convention as priority areas within the policy framework that require early attention to ensure security, sustained performance and growth of the global weather enterprise, including opportunities for public-private dialogue, noting in particular the overarching strategic priority of safety of life and property;

{...}

## EC-69 (*Draft Decision 12.2/1, IV*)

{...}

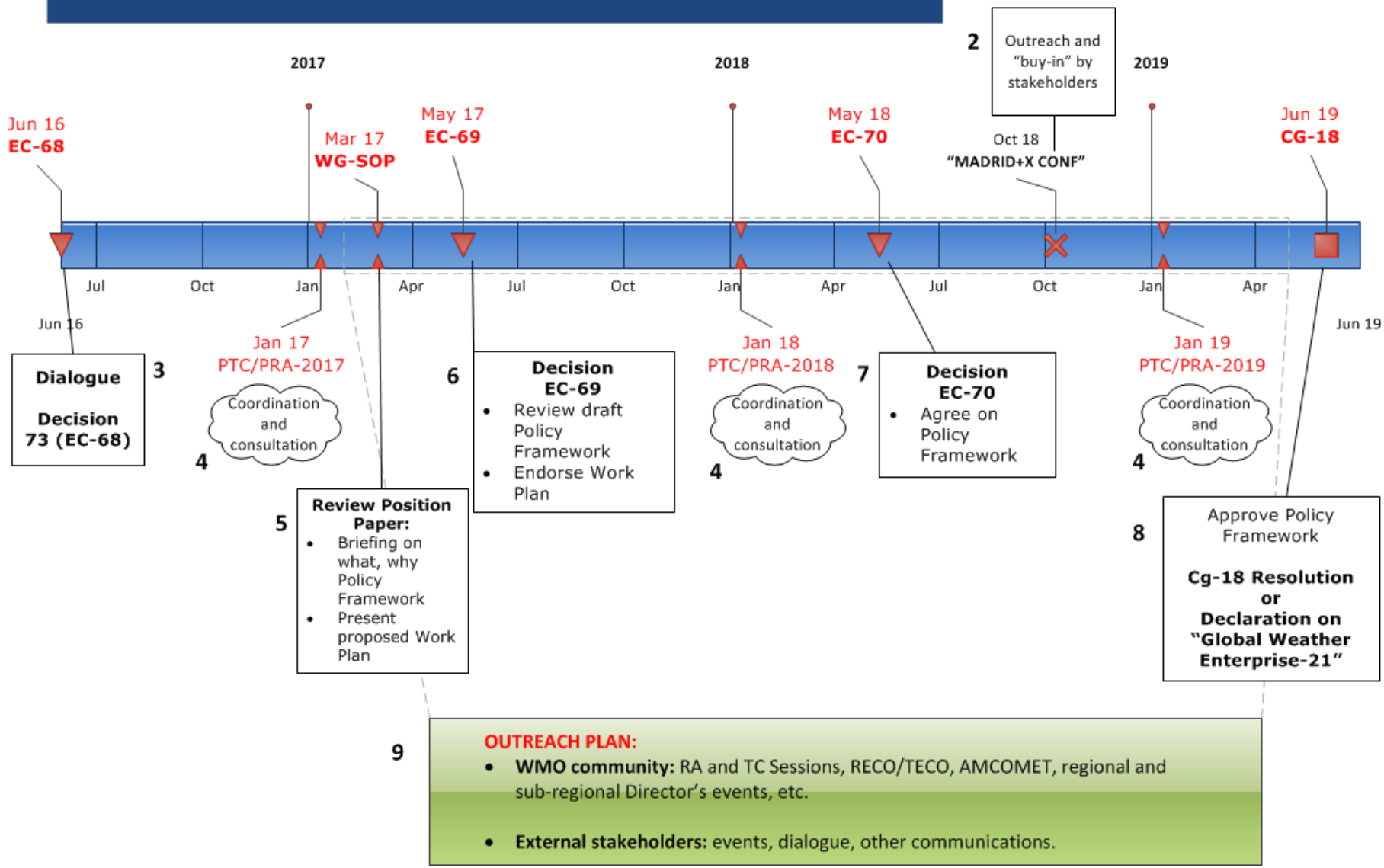
**Endorses** the Work Plan on Public-Private Engagement (thereafter referred to as “PPE Work Plan”) as provided in [Annex 2](#);

{...}

## EC-69 (*Draft Decision 12.2/1, Annex 2*)

*Annex 2 contains a roadmap for the two years leading up to the 18<sup>th</sup> World Meteorological Congress in 2019; while relatively light on detail, it does reflect the intention of EC to further develop and submit to CG-18 a Policy Framework on PPE*

# 1 Work Plan - Public-Private Engagement (PPE) activities by Cg-18



# Summary

- Respective roles of private versus public sectors in meteorology changing rapidly
- WMO Members are asking WMO for guidance on how to react to this
  - WMO is responding by developing a Policy Framework on Public-Private Sector Engagement
  - WMO course of action constrained by the fact that different Members have very different perspectives on this
  - Preserving existing international agreements on data exchange is likely to become a central part of discussion



# **Development of a WMO Position on Critical Satellite Data**

# WMO Critical Satellite Data Position Paper

- The prospect of private-sector operators of basic satellite systems has triggered attention to the issue of data access and availability for global WMO applications
- WMO is developing a position on what types of satellite data users consider critical for the protection of life and property, and which principles should apply to these data (lead: WMO Inter-Programme Expert Team on Satellite Utilization and Products (IPET-SUP) chaired by S. English, ECMWF)
- Purposes of the paper:
  1. Guide governments / NMHS on the terms under which to receive / purchase satellite data from private operators
  2. Guide data providers on the principles to apply to satellite data critical for WMO applications

# WMO Critical Satellite Data Position Paper

- Definition of “critical satellite data” for the purpose of the paper:

Any satellite data that is required to underpin **the 14 WMO Programme application areas** [Ref] where a critical demand in terms of timeliness, spatial and temporal resolution to fulfil these objectives exists.

“Space Weather” is referred in #14

Ref: <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>

(Rolling Review of Requirements and Statements of Guidance)

# WMO Critical Satellite Data Position Paper

- Seven principles have been drafted that providers of satellite data should fulfil to meet the critical data needs of the meteorological community
- This is work in progress

# Principles that should apply to critical satellite data from the users' perspective

- **Principle 1:** International exchange of critical satellite data in near real-time with the WMO community
- **Principle 2:** Transparency in instrument characteristics and processing steps
- **Principle 3:** Documented algorithms and validation information available
- **Principle 4:** Information on data latency, data format, and processing tools available
- **Principle 5:** Timely provision of preliminary data to users (prior to full operation of new systems)
- **Principle 6:** Demonstrated utility of data in applications (“impact”)
- **Principle 7:** Free and unrestricted access to archived data

# **WMO's Involvement in Space Weather**

**Emphasizing synergy with  
core WMO operational frameworks to  
Space Weather**

# WMO's Involvement in Space Weather (1/5)

- In **June 2008**, the **WMO Executive Council (EC-60)** noted the considerable impact of Space Weather on meteorological infrastructure and important human activities. It acknowledged the potential synergy between meteorological and Space Weather services to operational users. The Council agreed that WMO should support international coordination of Space Weather activities and urged WMO Members to provide corresponding resources through Secondments and Trust Fund donations.

# WMO's Involvement in Space Weather (2/5)

• In **May 2010**, WMO established the **Interprogramme Coordination Team on Space Weather (ICTSW)** with a mandate to support Space Weather observation, data exchange, product and services delivery, and operational applications. As of May 2016, ICTSW involved experts from 26 WMO Member countries and 7 International organizations.



# WMO's Involvement in Space Weather (2/5)

- In **May 2011**, the **World Meteorological Congress (Cg-16)** acknowledged the need for a coordinated effort by WMO Members to address the **observing and service requirements to protect the society against the global hazards of Space Weather.**
- In **July 2014** the potential **space weather services to international air traffic navigation** were discussed at the conjoint session of the WMO Commission for Aeronautical Meteorology (CAeM) and the Meteorological Division of the International Civil Aviation Organization (ICAO).

# WMO's Involvement in Space Weather (4/5)

- In May 2015, the World Meteorological Congress (Cg-17) agreed that WMO should undertake international coordination of operational space weather monitoring and forecasting with a view to support the protection of life, property and critical infrastructures and the impacted economic activities in an optimized overall effort.

# WMO's Involvement in Space Weather (5/5)

- In **June 2016**, the **Executive Council (EC-68)** approved the **Four-year Plan** for WMO activities related to Space Weather in 2016-2019, and requested CAeM and CBS **to establish Inter-Programme Team on Space Weather Information, System and Services (IPT-SWeISS)** who will pursue the work and achievement of **ICTSW**

# CGMS's Involvement in Space Weather

- In 2014, CGMS decided to include objectives related to Space Weather monitoring into its multi-year High-Level Priority Plan (HLPP) and agreed on Terms of Reference for CGMS Space Weather Activities.
- It is anticipated that CGMS will soon extend the scope of its activity towards space-based observation of Space Weather variables.
- Space Weather Task Team (SWTT) was organized to define the methodology for the implementation of Space Weather into CGMS

# WMO Space Weather Services (Four-year Plan: 2016 - 2019)

to be implemented to improve capabilities of WMO Members to deliver Space Weather services;

As a result of this planned effort, space-based and ground-based Space Weather observing systems will be better coordinated;

-Consistent, quality-assured Space Weather products will be available to all WMO Members through WMO Information System (WIS);

-Space Weather services, in particular, for civil aviation will be addressed as required by the International Civil Aviation Organization (ICAO)

-IPT-SWeISS is expected to facilitate the effective coordination with initiatives external to WMO and to enable the long-term improvement of Space Weather service capabilities.



# **IPT-SWElSS Membership (as of July 2017)**

(20 WMO Members, and 6 UN and Intergovernmental Organizations)

## **WMO Members**

**Co-chairs: China and USA**

Argentina, Australia, Belgium, Brazil, Canada, France, Germany, Indonesia, Italy, Japan, Korea, Netherland, New Zealand, Poland, Russia, South Africa, Switzerland, UK

## **UN and Intergovernmental Organization**

CGMS, ESA, ICAO, ISES, ITU, UNOOSA



# An Urgent Need for Accelerated Action in Four-year Plan

- **Implementation of a Space Weather Basic System**, including issues related to observation techniques and networks, data management and exchange, data centers, and space climatology
- **Promoting of Space Weather Science**, including issues related to modelling, model evaluation and verification, interaction with climate, and transition from research to operations
- **Development of Space Weather Application**, including requirements evaluation, the delivery of services, capacity building and user interaction



# WMO's Initiative for Promoting Space Weather will be realized in collaboration with

- Service providers (**ISES**)
- Space-based observations providers (e.g., **CGMS**)
- Scientific organizations (e.g., **COSPAR**)
- UN and Intergovernmental organizations (e.g., **ICAO, ITU, ESA**)

**ICAO:** operational, global space weather information service for aviation

**ITU:** Radio Frequency Coordination

- Overall UN space policy framework (**COPUOS**)
- Emphasize synergy with core WMO operational frameworks; **WIGOS, WIS, GDPFS**



**CGMS**





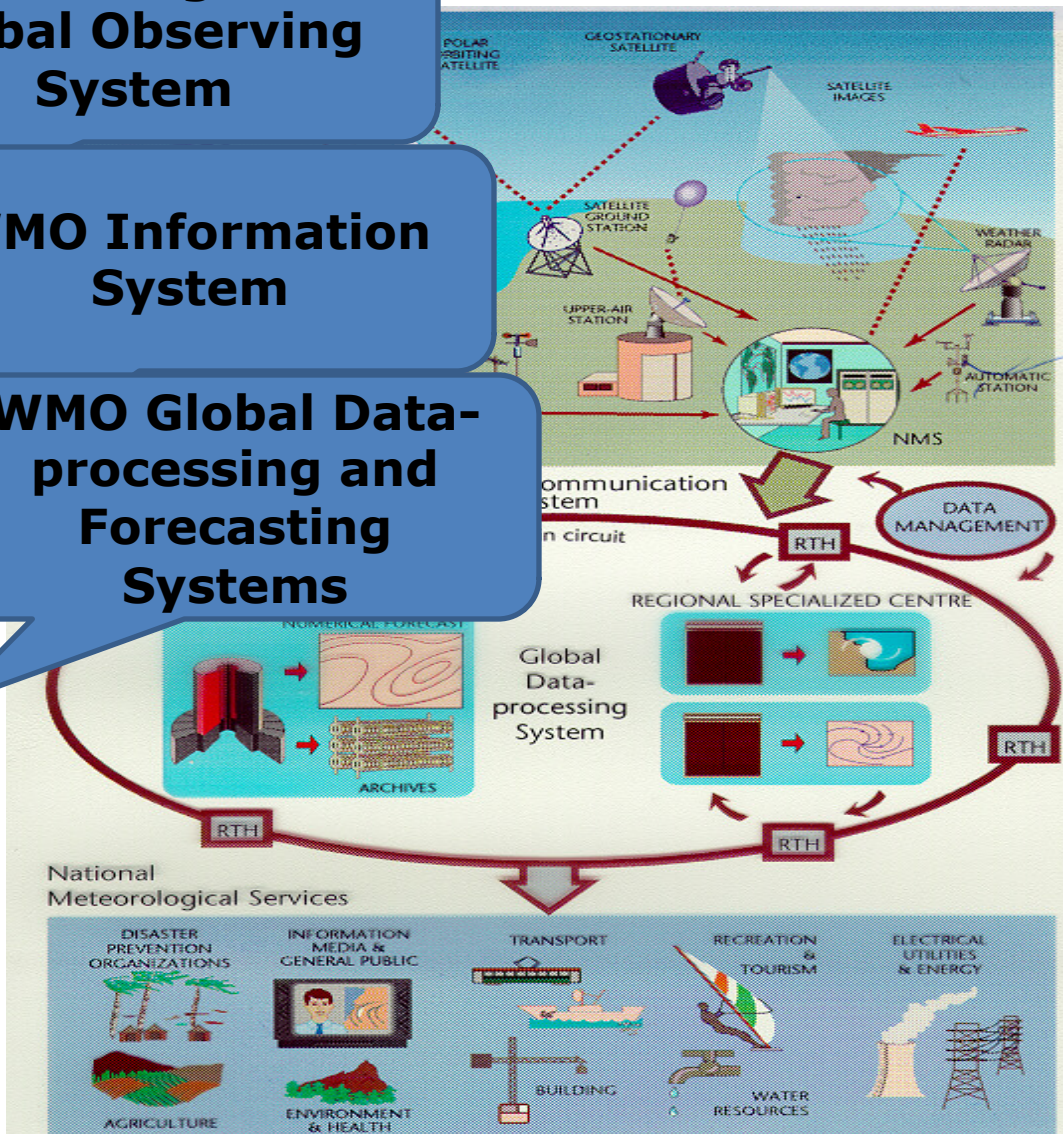
# WMO operational frameworks

**WMO Integrated Global Observing System**

**WMO Information System**

**WMO Global Data-processing and Forecasting Systems**

**GDPFS**



191 NMHSs: satellites, land, ships, buoys, and aircraft contribute to Global Observing every day

Global Telecom with Regional Hubs – becoming the WMO Information System

The GDPFS: Global, Regional Specialized Met. Centres (RSMC, RCC), and National Centres

NMHSs deliver analyses, forecast and early warning services

**Service delivery**



# Cooperation with International Civil Aviation Organization (ICAO)

As part of the long-established close working relationship between WMO and ICAO, e.g. World Area Forecast Centre (WAFC), Tropical Cyclone Advisory Centre (TCAC), and Volcanic Ash Advisory Centre (VAAC). These centres provide specialized warning services for the aviation community.

The ICAO Meteorology Panel (METP) noted an update to a concept of operations for space weather that would enable an operational **global space weather information service for aviation** in the 2018 timeframe, and guidance on the space weather information provider designation process.

One of the key components in the realization of an operational, global space weather information service for aviation before the end of 2018 is the conducting, by WMO at ICAO's request, of site assessments and audits of prospective space weather information providers.

# Global and Regional Centres Jointly Established by WMO and ICAO to Serve International Air Navigation

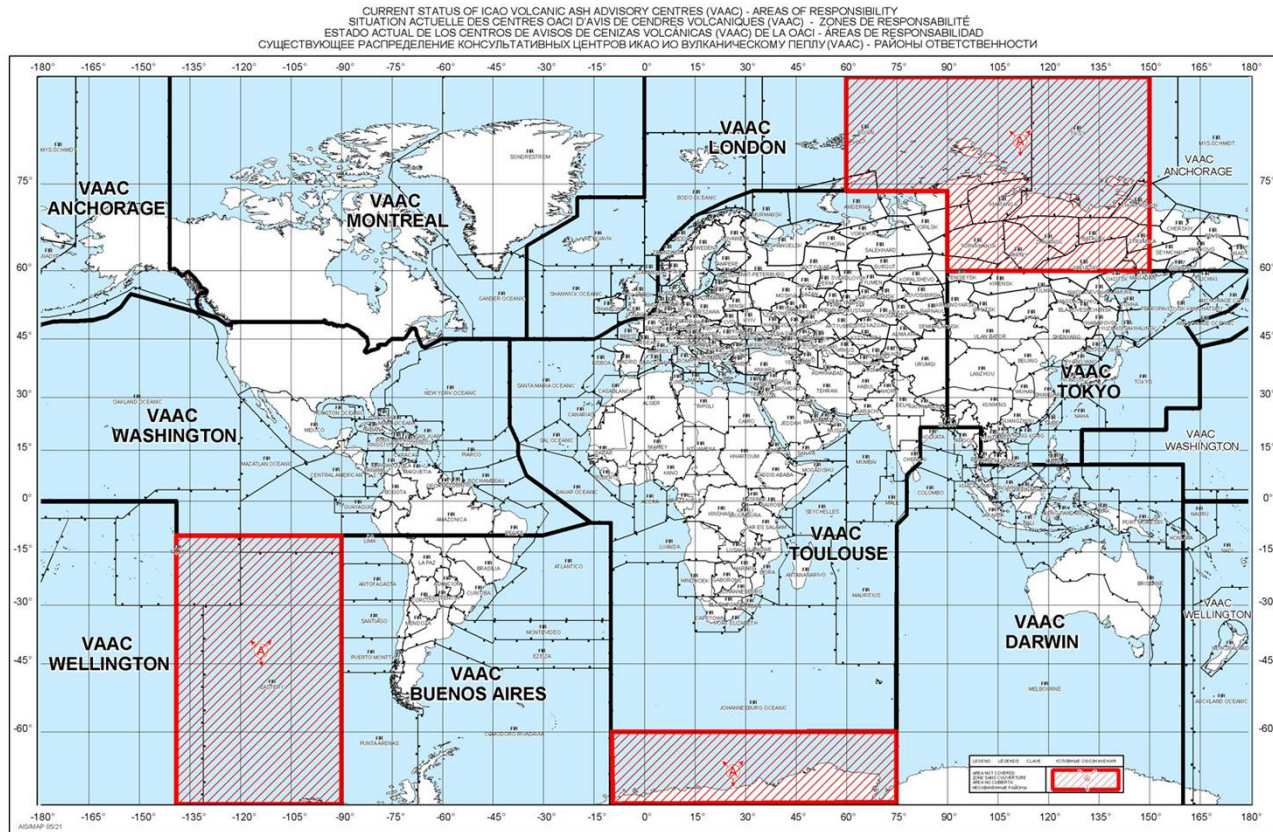


## Legend

- ▲ Volcanic Ash Advisory Centre (VAAC)
- Tropical Cyclone Advisory Centre (TCAC)
- World Area Forecast Centre (WAFC)

# Volcanic Ash Advisory Centers (VAACs)

ICAO in cooperation with WMO established a framework for the International Airways Volcano Watch (IAVW) in 1993. Within this framework, nine Volcanic Ash Advisory Centers (VAACs) monitor volcanic eruptions and **provide information on the locations and movement of volcanic ash in their areas of responsibility, as soon as volcanic ash is reported or detected** (volcano observatory, pilot report, satellite imagery, etc.)



# Summary for WMO's Space Weather Initiative

- Space Weather is still an area of emerging importance in WMO.
- As an emerging area, the level of maturity of space weather capabilities varies considerably among WMO Members.
- Whereas some Members have established operational service capabilities, others may have an interest only in exploring how or if they may initiate some activity.
- To date, one highly successful aspect of the current IPT-SWeISS is that it allows a forum for all WMO Members with any level of interest or maturity to participate in and contribute to space weather-related activities and discussions.
- It is important that WMO Members with an exploratory or emerging interest will continue to have a means to participate.





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# Thank you



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