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Science services

Earth observation at the World Radiocommunication Conference

ITUWRC DUBAI2023

ITU

Strengthening science services to safeguard our planet

Doreen Bogdan-Martin, ITU Secretary-General

“Radio networks are vital to make our world more sustainable, and WRC-23 can help us move forward together on all fronts.”

Doreen Bogdan-Martin

Nearly half of the United Nations Sustainable Development Goals (SDGs) hinge on Earth observation enabled by reliable radiocommunication networks. More broadly, we could meet over two-thirds of SDG targets faster through digital technologies and connectivity.

This makes the World Radiocommunication Conference, WRC-23, pivotal in tackling some of humanity's most pressing challenges, from education to health care to climate. Organized by the International Telecommunication Union (ITU), the conference will update the Radio Regulations, the global treaty governing radio spectrum and satellite orbits.

WRC-23 – taking place between 20 November and 15 December in Dubai, UAE – will see global participation, with countries striving together for agreements on the use of the radio spectrum for technologies that matter deeply to all of us. This is remarkable and increasingly rare.

Radio networks are vital to making our world more sustainable, and WRC-23 can help us move forward together on all fronts.

One of those fronts is climate monitoring, mitigation, and adaptation. ITU is a key partner in Early Warnings for All – the UN Secretary-General's groundbreaking initiative to ensure everyone on Earth is protected from climate hazards and disasters through life-saving alerts by the end of 2027.

At this critical juncture for action, *ITU News Magazine* explores space-based science services. Through keen observation and data, we can build a more resilient, inclusive, fair, and sustainable world.


WORLD RADIOCOMMUNICATION CONFERENCE
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DUBAI2023
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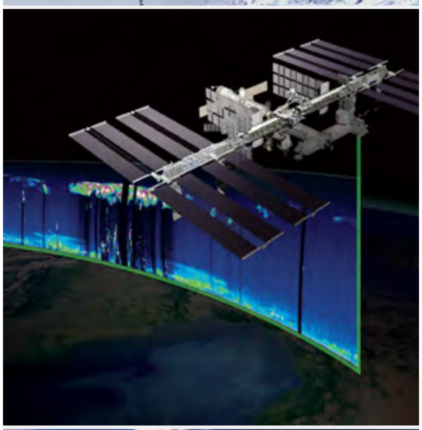
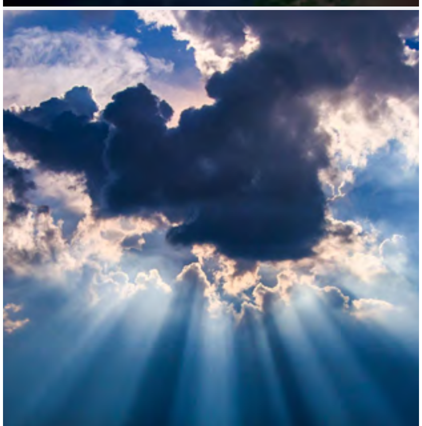




NASA

Science services: Observing our planet and understanding climate change

Mario Maniewicz, Director,
ITU Radiocommunication Bureau

Earth-observation systems have made remarkable advances in recent years, becoming critical for understanding our planet and addressing some of the most pressing challenges facing humanity.

The associated science services use radio technology to gather information about the Earth's atmosphere, land, and oceans, which is then analysed and interpreted to provide valuable insights into various natural and human-induced phenomena.

> *"Earth-observation systems have made remarkable advances in recent years, becoming critical for understanding our planet and addressing some of the most pressing challenges facing humanity."*
>
> Mario Maniewicz

Thanks to the advancements in satellite systems and high-speed Internet access, the volume and quality of data collected through Earth observation and remote sensing have increased significantly. Scientists, researchers, and policymakers can now obtain near real-time data on climate patterns, disasters, land-use changes, environmental degradation, and other indicators.

Such information has proven crucial in predicting and mitigating the impacts of hurricanes, floods, wildfires, and other disasters, as well as monitoring the health of ecosystems and informing land-use policies. Earth observation data is essential to assess the overall state of our planet, including progress towards achieving the Sustainable Development Goals (SDGs) set out by the United Nations.

Meteorological services, in parallel, can predict weather patterns and warn about extreme weather events. The changing climate makes accurate and timely weather information more important than ever before to protect human lives and property.

Meteorological services also provide aviation, marine, and agricultural information, enabling governments and companies to make informed decisions in those sectors.

Steady advances in Earth observation, remote sensing, and meteorological services have revolutionized our understanding of the Earth. These fields can help us better manage the planet's resources and our environment in the years to come.

Illuminating climate and development challenges

Integrating Earth-observation data into policymaking processes can strengthen sustainable development and help to create a more equitable and resilient world. For instance, data from satellite images can shed light on agricultural land use, crop health, and water availability, informing evidence-based policies aimed at promoting sustainable agriculture and achieving food security.

Similarly, remote sensing reveals water resources and helps to monitor water quality. Other satellite data can be used to ascertain the health of forests and other ecosystems.

Earth-observation systems are key for tracking climate change and its impacts. Data on temperature, sea-level rise, and greenhouse gas emissions can clarify long-term trends and shape emissions reduction and climate mitigation policies.

"Scientists, researchers, and policymakers can now obtain near real-time data on climate patterns, disasters, land-use changes, environmental degradation, and other indicators."

Yet it all hinges on protecting the necessary radio spectrum for Earth observation. Collecting, transmitting, and distributing data from satellites and other remote sensing platforms requires the uninterrupted availability of key radio frequencies.

This makes the upcoming World Radiocommunication Conference, WRC-23, a decisive milestone to ensure that Earth observation, remote sensing and meteorology services continue getting better and better.

As systems expand, interference from other radio sources can affect data quality, compromising the accuracy of analysis with potential implications for economic security, national defence, and the safety of life everywhere.

Safeguarding spectrum for science services

Previous World Radiocommunication Conferences have reinforced the mandate of the International Telecommunication Union (ITU) to promote sustainability, address climate change, and strengthen emergency communications. The decisions taken have continually secured the availability of spectrum and satellite orbits for monitoring the environment and modelling climate change.

ITU Member States will once again, at WRC-23, consider frequency allocations to safeguard and enhance science services, whether for Earth observation, exploring our solar system, or studying the universe.

Protecting sensitive science services in adjacent bands is paramount, particularly for the Earth exploration-satellite service (EESS) passive band used by weather prediction models. Harmful interference in this band could compromise the accuracy of weather predictions at a time when they need to be increasingly accurate.

WRC-23 will therefore consider new spectrum to facilitate the use of the Earth exploration-satellite services for climate monitoring, weather prediction, and other scientific missions.

“Previous World Radiocommunication Conferences have reinforced the mandate of ITU to promote sustainability, address climate change, and strengthen emergency communications.”

Key agenda items for the science services include:

- 1.12 – Earth exploration-satellite (active) service for spaceborne radar sounders: consider a possible new secondary allocation.
- 1.14 – EESS (passive): consider possible adjustments to ensure alignment with more up-to-date remote-sensing observation requirements.
- 9.1 (topic a) – review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services.

In April, ITU's Member States approved the Report of the Conference Preparatory Meeting to WRC-23, which summarizes and analyses the results of technical studies by the ITU Radiocommunication Sector (ITU–R) and outlines possible solutions for issues on the WRC-23 agenda. The report is available in the six ITU official languages.

The third and final Inter-regional Workshop on WRC-23 Preparation, which took place 27–29 September, provided another opportunity to consider proposed solutions for the issues identified.

Expert insights for WRC-23

This latest *ITU News Magazine* captures industry perspectives, along with the views of specialized international and regional organizations, on key issues related to science services for Earth observation ahead of WRC-23.

I would like to express my heartfelt gratitude to all the experts who have contributed their unique perspectives to the discussion. I am confident this edition offers a well-informed overview.

The outcomes of WRC-23 will be pivotal in shaping the future framework for radiocommunication services in all countries. I look forward to welcoming our delegates from around the world.

"The outcomes of WRC-23 will be pivotal in shaping the future framework for radiocommunication services in all countries."

WMO/ Edward Mitchell

Protecting Earth-observation systems at WRC-23

Petteri Taalas, Secretary-General, World Meteorological Organization

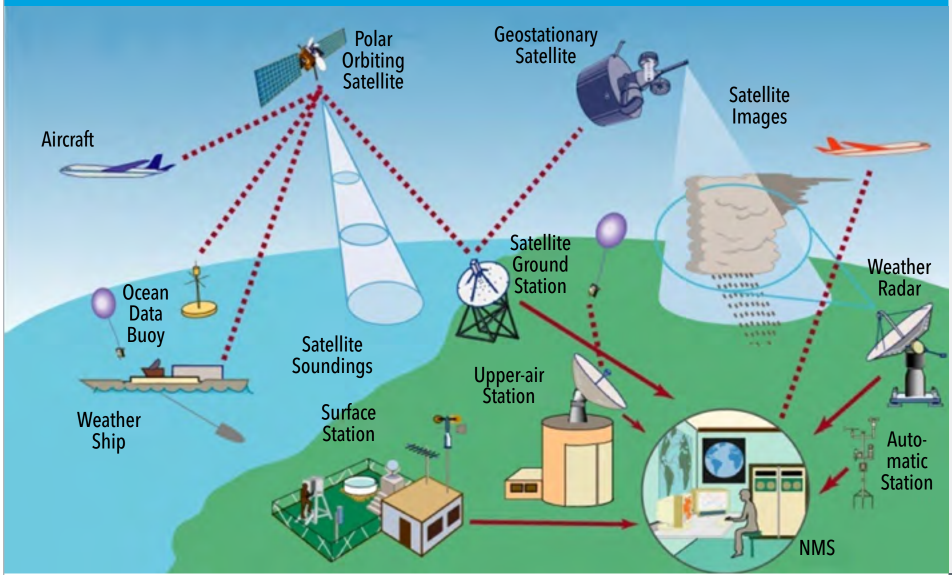
> *The safety of life and property depends on weather and environmental forecasts.*
>
> Petteri Taalas

Radio-frequency bands free from harmful interference are a key requirement for all Earth-observation systems. In fact, access to the radio-frequency spectrum is critical to the meteorological and hydrological infrastructure that underpins weather and related environmental services worldwide. Satellites, weather radar, radiosondes, hydrological observing systems, and drifting buoys all operate based on radio or microwave transmissions.

The safety of life and property depends on weather and environmental forecasts. Extended warning times for severe events enable citizens, civil authorities and first responders to act.

Longstanding collaboration between the World Meteorological Organization (WMO) and the ITU Radiocommunication Sector (ITU–R – one of three Sectors of the International Telecommunication Union) has cemented the growing synergies between meteorology, early warning systems, data and digital technologies.

WMO Integrated Global Observing System (WIGOS)



Source: World Meteorological Organization

WMO, through its Expert Team on Radio Frequency Coordination (ET-RFC), has produced a position statement on the agenda for ITU's upcoming World Radiocommunication Conference (WRC-23).

From a meteorological and climate-monitoring perspective, the most critical issues that require support from national administrations are concerned with the measurement of sea surface temperature and the observations of space weather.

Continuity of SST measurements: consequential to agenda item 1.2

Sea surface temperature (SST) is a vital component of the climate system, with a major influence on exchanges of energy, momentum and gases between oceans and the atmosphere. SST, as one of the main drivers of ocean circulation, is crucial for numerical weather and ocean prediction models.

The 6/7 gigahertz (GHz) frequency range – corresponding to peak SST sensitivity – is currently being utilized for passive ocean remote sensing. These are the only SST measurements that can "see" through clouds.

WMO's position statement

WMO Members, at the 19th World Meteorological Congress, adopted positions on 21 agenda items for the upcoming WRC-23.

Read the statement.

"Sea surface temperature is a vital component of the climate system..."

The Radio Regulations acknowledge the use of the 6425–7075 megahertz (MHz) and 7075–7250 MHz frequency bands by the Earth exploration-satellite service (EESS). Footnote 5.458 highlights that administrations should bear in mind the spectrum needs for EESS (passive) sensors in future planning for that frequency range. But this does not constitute a spectrum allocation and provides no protection to SST measurement operations.

WRC-23 agenda item 1.2 proposes the identification of frequency bands for International Mobile Telecommunications (IMT) within the 6/7 GHz range, even though ITU–R studies demonstrate that SST measurements could be severely hindered by such deployment. To mitigate this risk, WMO has identified other potential bands for SST measurement that could be used in combination with the 6/7 GHz range.

To ensure long-term continuity, WMO urges administrations to consider new primary EESS (passive) allocations in the 4.2–4.4 GHz and 8.4–8.5 GHz bands for SST measurement. Notably, these possible new primary EESS (passive) allocations would not claim protection from existing services in these bands.

Recognition of space weather: agenda item 9.1a

Space-weather observations from ground-based and space-based systems are essential for the detection of solar activity. Solar events can cause severe disruptions to critical infrastructure both on Earth and in space, resulting in radio blackouts, damage to satellites, perturbations in power grids, and increased radiation exposure on trans-polar aircraft routes.

Despite the need to anticipate hazardous space weather events, the current Radio Regulations contain no recognition or provisions related to space-weather observations. WRC-23 agenda item 9.1a considers appropriate recognition of space weather sensors in the Radio Regulations. Under WRC-23 agenda item 10, a new agenda item for WRC-27 will be discussed to ensure the protection of space weather sensors in some frequency bands, without placing constraints on incumbent services.

“Despite the need to anticipate hazardous space weather events, the current Radio Regulations contain no recognition or provisions related to space-weather observations.”

To protect space-weather sensor operations, WMO is advocating for a two-step approach at WRC-23:

Step 1

Define space weather in the context of the Radio Regulations and associate space weather with the appropriate "radiocommunication service" under which space-weather systems may operate – namely the meteorological aids *(space weather)* service, or in short: MetAids *(space weather)*.

Step 2

Develop a new WRC-27 agenda item proposing new MetAids *(space weather)* allocations in frequency bands used by operational space-weather sensors that require protection.

Safeguarding critical spectrum

The radio-frequency spectrum is a finite resource, with emerging technologies continually raising demand. Earlier this year, the 19th World Meteorological Congress (Cg-19) expressed serious concern over the threat to crucial radio-frequency bands, with Resolution 31 from the conference calling for safeguards.

The meteorological community appeals to ITU members to give due consideration to WMO's requirements for radio-frequency allocations and regulatory provisions at WRC-23.

ITU Radio Regulation No. 5.340 prohibits *all* radio emissions in specified frequency bands between 1400 MHz and 252 GHz. Weather, water and climate research and operations all depend on preserving these as emission-free bands.

At stake is the availability of spectrum for passive sensing of the Earth's atmosphere and other environmental variables. Only by working together can we – the global meteorological and radiocommunication communities – maintain and improve our future capacity for Earth observation and the vital services that depend on it.

"The meteorological community appeals to ITU members to give due consideration to WMO's requirements for radio-frequency allocations and regulatory provisions at WRC-23."

About the World Radiocommunication Conference (WRC-23)

Convened by the International Telecommunication Union (ITU) every 3–4 years, World Radiocommunication Conferences enable administrations worldwide to review, and, if necessary, revise the Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and geostationary and non-geostationary satellite orbits.

ITUWRC DUBAI2023

20 November – 15 December 2023
Dubai, United Arab Emirates

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Countdown to WRC-23

The future of Coordinated Universal Time

Land, sea and airwaves

Satellite connectivity

Conference website: WRC-23

EUMETSAT

Topics on the agenda for WRC-23 include vital regulatory updates to maintain and upgrade humanity's Earth-observation capabilities.

John Zuzek

Science services and Earth-observation issues at WRC-23

John Zuzek, Chairman, ITU-R Study Group 7, and National Spectrum Program Manager, NASA

Research and exploration in space, including Earth observation and climate monitoring, rely on the International Telecommunication Union (ITU) and the highly specialized work of its ITU Radiocommunication Sector (ITU–R).

ITU-R Study Group 7, for example, deals with radio services supporting scientific pursuits. These include time signals and frequency standard emissions, space radiocommunication applications, remote sensing systems, and radio astronomy.

The working parties under Study Group 7 are currently completing the supporting documentation to assist in the decision-making process on these issues at the World Radiocommunication Conference (WRC-23) beginning mid-November.

Earth observation and remote sensing

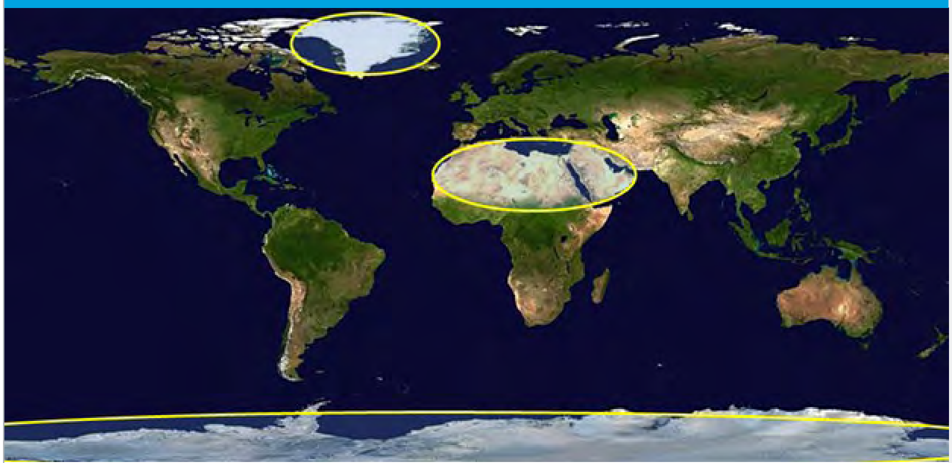
Topics on the agenda for WRC-23 include vital regulatory updates to maintain and upgrade humanity's Earth-observation capabilities.

Agenda item 1.12 considers a possible secondary allocation to the Earth exploration-satellite service, or EESS (active), for use by radar sounders that would operate around 45 megahertz (MHz).

These radar sounders enable space-based active remote sensing of the Earth's surface to detect subsurface water deposits in desertic environments such as Northern Africa and the Arabian Peninsula. They also measure ice thickness in polar regions.

An allocation to the EESS (active) is needed around 45 MHz to enable new satellites to collect this important data from the Earth's orbit.

Possible coverage areas for radar sounders



Source: Recommendation ITU-R RS 2042-1

Agenda item 1.14 calls for reviewing and adjusting existing allocations and possibly adding new primary frequency allocations to the EESS (passive) in the frequency range 231.5–252 gigahertz (GHz). Currently, use of this frequency range has been limited to microwave limb-sounding instruments, which point towards the Earth's limb to measure various atmospheric gases.

In recent years, new observation requirements have been identified for the study of ice clouds. Covering more than 33 per cent of the Earth's surface, ice clouds affect precipitation, atmospheric structure, and cloud processes, with important effects on the Earth's climate.

"Global measurements of ice-cloud properties are critically needed."

Enabling ice-cloud measurements

Global measurements of ice-cloud properties are critically needed. One way to enable this would be to rearrange the allocations in the 231.5–252 GHz frequency range. This would protect current microwave limb-sounding usage and allow for ice-cloud measurements by future meteorological satellites. It would also enable the unconstrained future use of terrestrial services in the same range.

Agenda item 9.1, topic d), considers the protection of passive remote sensing systems operating in the EESS (passive) in the frequency band 36–37 GHz from emissions of non-geostationary orbit (GSO) fixed-satellite service (FSS) systems. This continues from earlier studies, begun under WRC-19 agenda item 1.6 but not fully resolved. Now that those studies have been completed, WRC-23 could decide to act on this topic.

Agenda item 1.2 considers identifying 6425–7025 MHz, 7025–7125 MHz and 10.0–10.5 GHz and other bands for International Mobile Telecommunications (IMT). While this is not a science issue *per se*, IMT deployments in 6425–7125 MHz could have a negative impact on sea surface temperature (SST) measurements occurring in the overlapping 6425–7250 MHz band.

Similarly, IMT deployments in the 10.0–10.5 GHz band could have a negative impact on active sensing measurements in 10.0–10.4 GHz. Out-of-band emissions of IMT systems could also adversely affect passive measurements in the nearby 10.6–10.7 GHz band. Solutions to this agenda item should consider these factors.

EUMETSAT

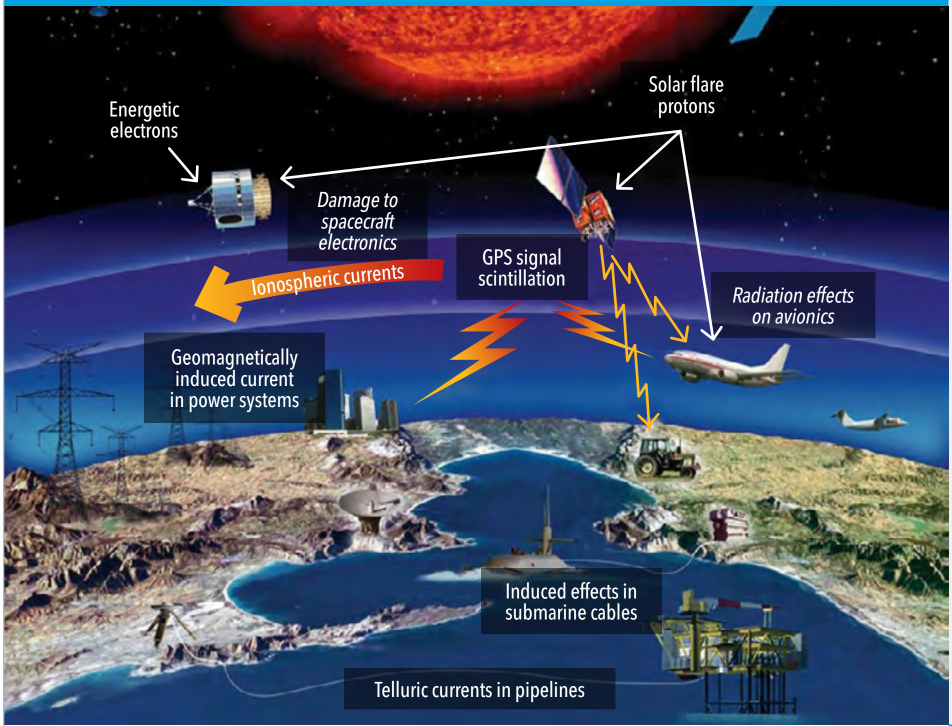
Other science issues

Agenda item 1.13 considers a possible upgrade of the allocation to the space research service in the frequency band 14.8–15.35 GHz, where that service currently has a global secondary allocation. Such spectrum could be used for direct data downlinks from spacecraft to earth stations, Earth-to-space links to data relay satellites, and space-to-space links from spacecraft to data relay satellites. This would support such things as lunar exploration missions.

Agenda item 9.1, topic a), considers the protection and possible recognition of radio spectrum-reliant space weather sensors used for global prediction and warning. Space weather systems let us observe various phenomena in space that affect our activities around the Earth. These include solar activity, such as coronal mass ejections (CME), geomagnetic storms, solar radiation, and solar winds.

The preliminary agenda for the next World Radiocommunication Conference (WRC-27) includes a possible agenda item to deal with this topic.

Possible effects of space weather



Source: NASA

Future considerations

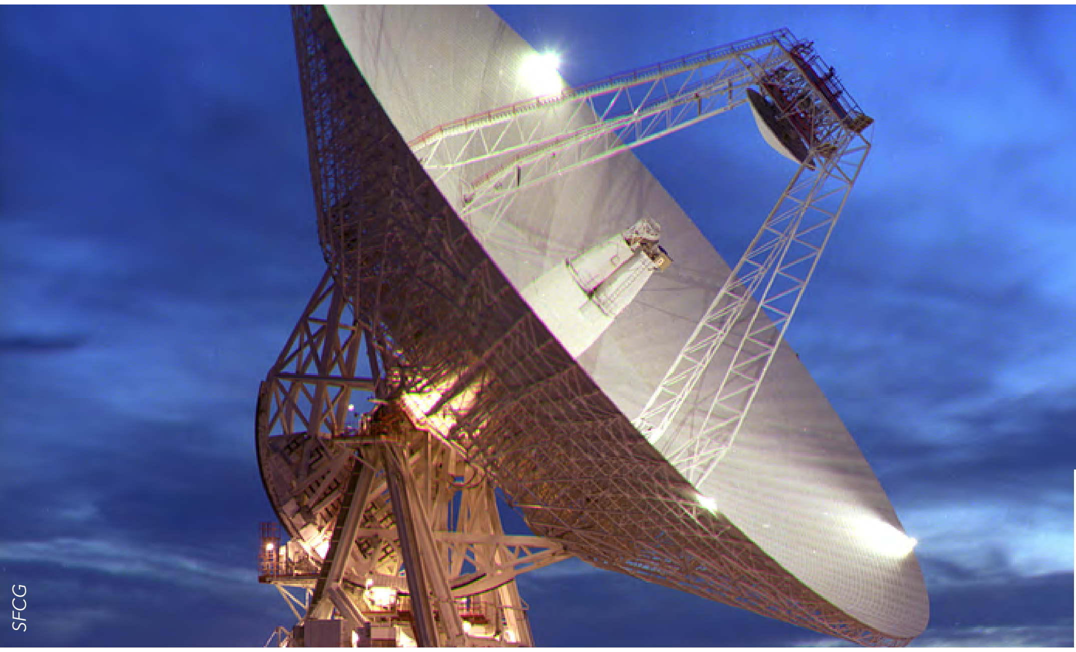
Several issues concerning the science services are already on the preliminary agenda for WRC-27. Several of these deal with allocations around the 86–92 GHz band, in which no emissions are permitted. This is a critical band for Earth-observation systems and must be protected.

Another potential agenda item deals with a possible Earth-to-space allocation in 22.55–23.15 GHz that would support future Earth-observation systems.

One more possible agenda item deals with the protection of space weather sensors for global prediction and warnings.

Part of WRC-23's job this November and December is to decide the final topics for WRC-27. That conference in 2027 is the next occasion to update the Radio Regulations and ensure undisrupted, equitable, global access to radio spectrum and orbital resources.

> *“Space weather systems let us observe various phenomena in space that affect our activities around the Earth.”*


SFCG


Maite Arza


Bruno Espinosa

Space Frequency Coordination Group: Objectives for WRC-23

Maite Arza, Head, Frequency Management Office, and Bruno Espinosa, Frequency Management Officer, European Space Agency (ESA) – Executive Secretariat for the Space Frequency Coordination Group (SFCG)

For some decades, the member space agencies of the Space Frequency Coordination Group (SFCG), have been developing common objectives for each World Radiocommunication Conference, recognizing the crucial importance of this quadrennial global sector meeting organized by the International Telecommunication Union (ITU).

The group promotes spectrum efficiency and the sharing of frequency bands between more than one radio service based on mutually agreed sharing and protection criteria, established in line with the results of ITU Radiocommunication Sector (ITU-R) studies.

As the next of these conferences approaches, the SFCG has outlined objectives for WRC-23 in reference to specific agenda items and topics of interest.

Opportunities for Earth observation and science services

Under WRC-23 agenda item 1.12, the SFCG supports a new secondary allocation to the Earth exploration-satellite service (EESS) (active) in the 40–50-megahertz (MHz) radio-frequency band, with associated provisions to balance the protection of existing services with opportunities for spaceborne radar sounder operations in this range. Sounder measurements in the 40–50 MHz range would provide an unprecedented view into the planet's subsurface, as well as a better understanding of ice sheets in polar regions and aquifers in arid regions.

If required, the SFCG might act as a focal organization in relation to any follow-up consultation and action, such as in developing guidelines for the implementation of WRC-23 decisions.

Another opportunity for Earth observation will be discussed at WRC-23 under agenda item 1.14, addressing EESS (passive) requirements in the 231.5–252 gigahertz (GHz) frequency range. Based on the outcome of ITU–R studies and the operational requirements for EESS (passive), the SFCG supports a new primary allocation to EESS (passive) in the frequency bands 239.2–242.2 GHz and 244.2–247.2 GHz. This would help accommodate ice cloud measurements, together with a rearrangement of allocations for fixed and mobile services.

The SFCG also welcomes the development of technical and regulatory provisions for satellite-to-satellite operations in the frequency bands 18.1–18.6 GHz, 18.8–20.2 GHz and 27.5–30 GHz (agenda item 1.17). As Earth observation and scientific missions generate increasing volumes of data, future space science missions would benefit from satellite communications services operated as data relays.

Two items would respond to general scientific requirements:

- Upgrading the space research service (SRS) allocation from secondary to primary status in the band 14.8–15.35 GHz to support existing and future applications and increasing data transport for science missions (agenda item 1.13), for which the SFCG recognizes the need for provisions to ensure compatibility between SRS and incumbent primary services.

- Considering inclusion in the Radio Regulations of provisions to address the appropriate recognition of space weather sensors (agenda item 9.1, topic a) under the MetAids service.

> *"Under WRC-23 agenda item 1.12, the SFCG supports a new secondary allocation to the Earth exploration-satellite service ..."*
>
> Maite Arza and Bruno Espinosa

SFCG objectives for WRC-23

The SFCG has outlined its key objectives in reference to specific WRC-23 agenda items and topics of interest.

Download SFCG objectives.

Protecting space remote sensors

The SFCG attaches particular importance to protecting the frequency bands used by space-based remote sensors for climate science and meteorology data, often unobtainable by any other means. Successful operation of these sensors depends on the use of specific frequency bands that are defined by physical laws.

The SFCG does not support an identification for International Mobile Telecommunications (IMT) in the band 10–10.5 GHz in Region 2 (the Americas) under agenda item 1.2, since the feasibility of spectrum sharing between IMT and the EESS (active) in the band 10–10.4 GHz has not been demonstrated.

The SFCG is also concerned by potential interference from active services for EESS (passive) sensors in adjacent frequency bands. Therefore, the SFCG supports the inclusion in the Radio Regulations of limits on active services, as summarized in the table, to protect the operation of EESS (passive) sensors.

Additionally, in relation to the discussions on the 6–7 GHz range under agenda item 1.2, the SFCG would welcome options to ensure the continuity of sea surface temperature (SST) measurements in other spectrum ranges, such as through new primary allocations to EESS (passive) in the 4200–4400 MHz and 8400–8500 MHz bands.

"The SFCG attaches particular importance to protecting the frequency bands used by space-based remote sensors for climate science and meteorology data."

Looking forward to WRC-27

Another key topic at WRC-23 will be the agenda for the subsequent conference, WRC-27.

The SFCG is of the view that the adoption of any new WRC agenda item should meet certain conditions, including a clear justification of spectrum requirements, a well-defined scope for studies, and specific frequency bands to be considered.

The SFCG has identified several topics related to space-science services for possible inclusion as WRC-27 agenda items and has invited its member agencies to promote these in their national and regional preparatory activities for WRC-23. The proposed topics include a possible new allocation for EESS communication links, the protection of EESS (passive) sensors in certain bands above 86 GHz, the protection of space weather observations in specific bands, and opportunities to develop wireless communications on the Moon.

"The SFCG has identified several topics related to space science services for possible inclusion as WRC-27 agenda items."

Limits supported by SFCG to address the protection of EESS (passive) sensors at WRC-23

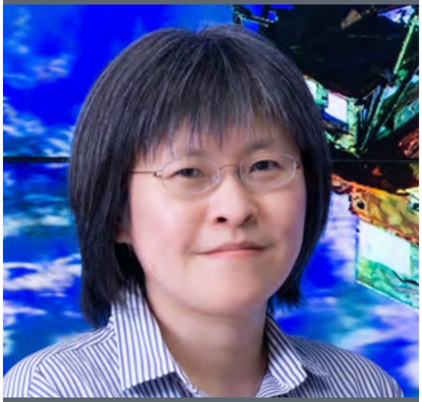
WRC-23 agenda item	EESS (passive) band	Active service operation	Proposed limit
1.2	10.6–10.7 GHz	IMT in 10–10.5 GHz	Unwanted emission limits
1.10	22.21–22.5 GHz	Aeronautical mobile service for non-safety applications in 22–22.21 GHz	Unwanted emission limit
1.16	18.6–18.8 GHz	Non-GSO FSS space station communicating with earth stations in motion (ESIM) in 18.3–18.6 GHz and 18.8–19.1 GHz	Set of power flux-density limits
1.17		Non-GSO FSS space station communicating with a non-GSO space station of lower altitude in 18.3–18.6 GHz and 18.8–19.1 GHz	
9.1, topic D	36–37 GHz	Non-GSO FSS space stations operating with an apogee altitude above 407 km and below 2000 km in the frequency band 37.5–38 GHz	Unwanted emission limit

The SFCG annual meeting in Toulouse, France, in June 2023

SFCG

JAXA

Yasunori Iwana



Misako Kachi

Sea surface temperature measurements using passive microwave sensors

Yasunori Iwana, Staff, Spectrum Management Office, and Misako Kachi, Manager for GCOM-W and AMSR3 Research, Earth Observation Research Center, Japan Aerospace Exploration Agency (JAXA)

The ocean covers more than 70 per cent of the Earth's surface and plays an important role in supplying water vapor to the atmosphere. Satellites, given their global observation capabilities, are useful for observing the ocean, which includes measuring sea surface temperature (SST).

This key parameter for air-sea interactions is widely used in weather and climate prediction, coastal disaster prevention, fisheries management, and ecosystem conservation.

Weekly SST maps are made with either traditional infrared (IR) or microwave imagers. The latter, which can observe day and night in all weather conditions, have become critical in the production of "daily" SST maps. To date, however, only a few types of microwave imagers are designed for sea surface temperature observation.

Opportunities for measuring with passive sensors

The Advanced Microwave Scanning Radiometer (AMSR) series developed by the Japan Aerospace Exploration Agency (JAXA) uses passive sensors to measure weak microwaves. These microwaves are radiated at varying frequencies from water particles in different states on land, on the sea surface, and in the atmosphere.

AMSR systems can observe various water-related parameters, including sea surface temperature, supporting such practical applications as numerical weather prediction, reports on sea conditions for fishing crews, and safe ship navigation, as well as water-cycle variations and climate change indicators.

First- and second-generation advanced microwave scanning radiometers

The first examples, AMSR-E and AMSR, were installed, respectively, on the Aqua satellite launched by the US National Aeronautics and Space Administration (NASA) in May 2002 and on the Advanced Earth Observation Satellite-II (ADEOS-II) launched later the same year by the National Space Development Agency of Japan (NASDA).

The second-generation AMSR2, launched in May 2012, remains in operation with Japan's Global Change Observation Mission – Water (GCOM-W).

With an antenna rotating every 1.5 seconds, AMSR2 obtains data across a 1450-kilometre (nominal) and 1620-kilometre (effective) swath. A conical scanning mechanism enables it to acquire new sets of daytime and night-time data, with over 99 per cent coverage of the Earth, every two days.

Advanced satellite imaging technologies represent a huge asset for weather forecasting and climate monitoring. Breakthroughs achieved with the first two generations of the AMSR series were possible because of close international coordination efficient radio spectrum management.

> *"Satellites, given their global observation capabilities, are useful for observing the ocean, which includes measuring sea surface temperature."*
>
> Yasunori Iwana and Misako Kachi

Updates initiated by the ITU Radiocommunication Sector (ITU-R – one of three Sectors of the International Telecommunication Union) prior to 2012 ensured that the Radio Regulations treaty maintained by ITU would support rapidly evolving satellite services to meet the world's changing needs.

Increasing sensitivity unaffected by the atmosphere

Compared to other passive microwave sensors, the AMSR series features a uniquely large antenna, about 2 metres in diameter, and can host channels in the 6–10 gigahertz (GHz) frequency. Since spatial resolution increases as centre frequency decreases, a large antenna is needed to obtain the best spatial resolution in 6–10 GHz channels *(see table)*.

Those 6–10 GHz frequency bands constitute an "atmospheric window" in which microwaves emitted from the sea or land surface can penetrate thick clouds. Channels in those bands are less affected by atmospheric conditions, enabling sensitivity to subtle variations in surface temperatures at sea and even sub-soil moisture on land.

The 6–7 GHz channels offer good SST sensitivity in almost all temperature ranges, while sensitivity in the 10 GHz band becomes degraded at temperatures below about 12 degrees Celsius.

As shown in the table, the 6.925 GHz, 7.3 GHz and 10.65 GHz channels in AMSR2's multichannel receiver of are mainly used for SST and soil moisture-content measurements.

Higher frequency channels are also commonly available in older passive microwave sensors, such as the US Department of Defence's Special Sensor Microwave/Imager (SSM/I), used to retrieve water vapor, rainfall, snow depth, sea-surface wind speed, and sea ice concentration.

> *"AMSR systems can observe various water-related parameters."*

AMSR2 receiving channel set					
Centre frequency (GHz)	Bandwidth (MHz)	Polarization	Beamwidth (degree)	Spatial resolution: cross-track x along-track (km)	Sampling interval (km)
6.925/7.3	350	Vertical and Horizontal	1.8	35 x 62	10
10.65	100		1.2	24 x 42	
18.7	200		0.65	14 x 22	
23.8	400		0.75	15 x 26	
36.5	1000		0.35	7 x 12	
89.0	3000		0.15	3 x 5	5

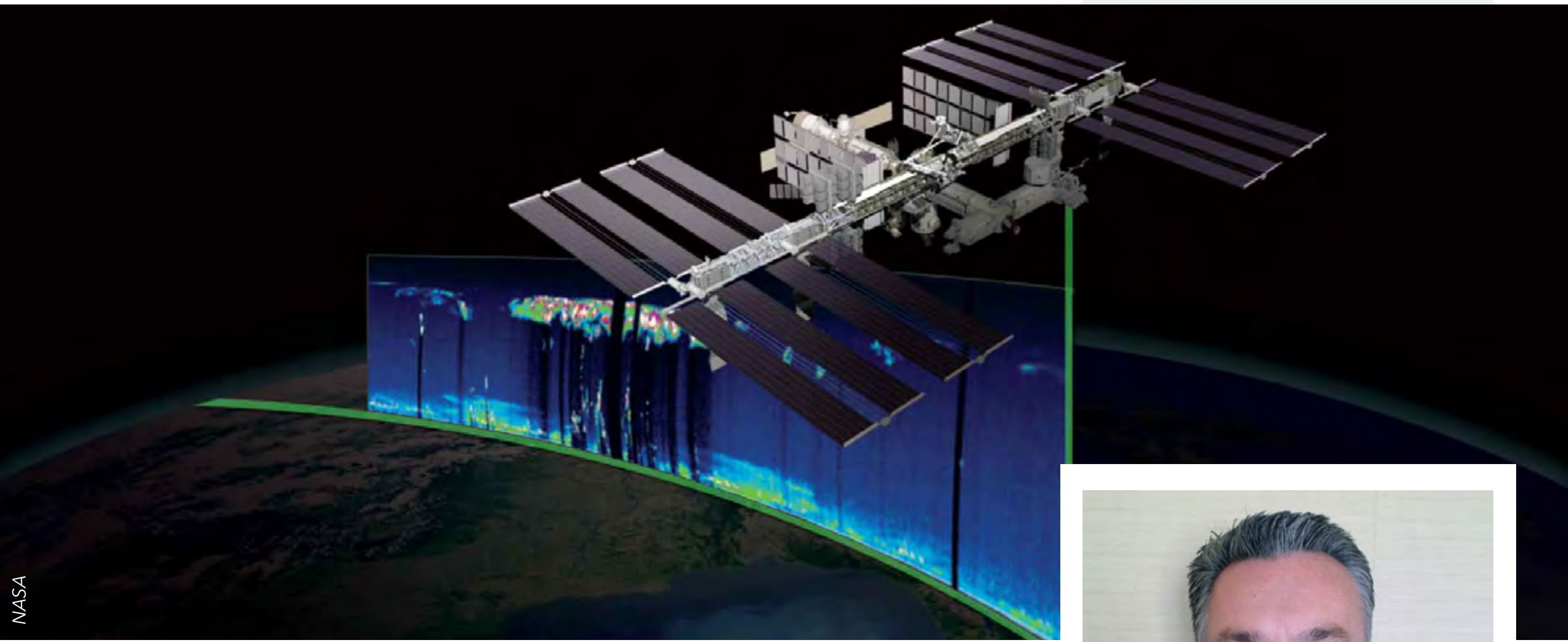
The 7.3 GHz channel is dedicated to the mitigation of radio-frequency interference in the C-band.

"Advanced satellite imaging technologies represent a huge asset for weather forecasting and climate monitoring."

Next-generation microwave scanning

JAXA's next-generation AMSR instrument, the Advanced Microwave Scanning Radiometer 3 (AMSR3), is intended for launch as a hosted payload on Japan's forthcoming Global Observing Satellite for Greenhouse-gases and Water-cycle (GOSAT-GW) mission in the Japanese fiscal year of 2024 (April 2024–March 2025).

AMSR3 – as a deliberate upgrade from AMSR2 – will include several new channels, contributing to the retrieval of solid precipitation data, water vapor analysis for numerical weather predictions, and robust SST retrievals in higher resolution.



The advent of ground-penetrating radar systems has sparked an interest in using such instruments, called sounders, for spaceborne active sensing.

Andre Tkacenko

Active sensing and potential use of frequencies around 45 MHz

Andre Tkacenko, Signal Analysis Engineer, Spectrum Engineering Group (332G), Jet Propulsion Laboratory (JPL), National Aeronautics and Space Administration (NASA)

Spaceborne active sensing for the Earth exploration-satellite service (EESS) consists of the following types (see Recommendation ITU-R RS.1166-4):

- **Scatterometers** – for measuring wind speed and direction: 5.25–5.57 gigahertz (GHz), 8.55–8.65 GHz, 9.5–9.8 GHz, 13.25–13.75 GHz, 17.2–17.3 GHz, and 35.5–36.0 GHz;
- **Altimeters** – for estimating altitude over land and ocean surface: 3.1–3.3 GHz, 5.25–5.57 GHz, 8.55–8.65 GHz, 9.5–9.8 GHz, 13.25–13.75 GHz, and 35.5–35.6 GHz;
- **Synthetic aperture radar (SAR) imagers** – for producing radar images or topographical maps: 432–438 megahertz (MHz), 1215–1300 MHz, 3100–3300 MHz, 5250–5570 MHz, 8550–8650 MHz, and 9200–10400 MHz;

- **Precipitation radars** – for determining rainfall rate: 13.25–13.75 GHz, 24.05–24.25 GHz, and 35.5–36.0 GHz;
- **Cloud profile radars** – for ascertaining cloud reflectivity profile: 94.0–94.1 GHz, 133.5–134.0 GHz, and 237.9–238 GHz.

The advent of ground-penetrating radar (GPR) systems has sparked an interest in using such instruments, called sounders, for spaceborne active sensing. Space agencies, including the US National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA), are interested in using sounders to explore the signatures of climate change on Earth.

The mission concept for the Orbiting Arid Subsurface and Ice Sheet Sounder (OASIS), a joint venture between the NASA Jet Propulsion Laboratory (JPL) and the Qatar Environment and Energy Research Institute (QEERI), involves studying subsurface climate change in areas like polar ice sheets and hyper-arid deserts. Such exploration requires lower frequencies than those from above, typically in the high-frequency (HF) or very high-frequency (VHF) bands. Centre frequencies around 50 MHz are required to meet the mission's science objectives.

“To provide adequate coverage, spaceborne sounders can typically be expected to operate on satellites in Sun-synchronous orbit.”

Exploring subsurface signatures of climate change

Concepts like OASIS involve several key scientific objectives.

Ice sheets

- Measure thickness to deduce topography, roughness, and geological time scale of strata;
- Identify and characterize regions of past ice flow reorganization;
- Reassess current state and discharge rates of ice;
- Integrate scientific observations with ice flow models to determine impact on sea-level rise.

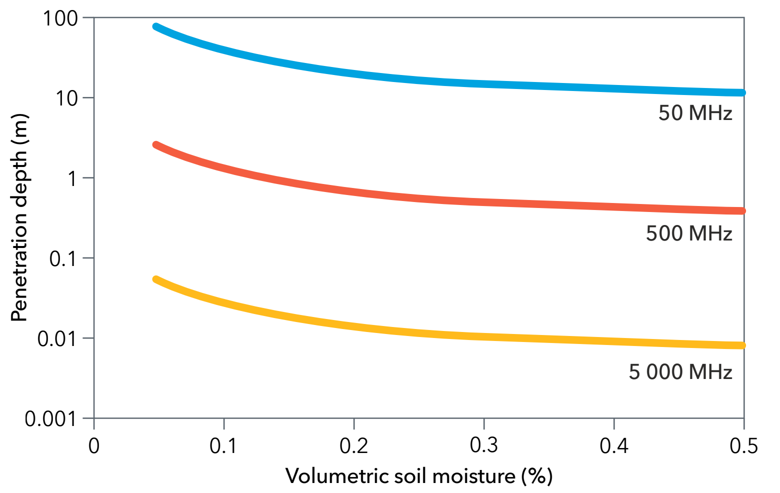
Deserts

- Measure depth and spatial distribution of water tables in shallow aquifers on a large scale at high resolution;
- Characterize geologic structures according to recharge, flow, and discharge of groundwater;
- Combine observations with available data to provide insights into evolution of aquifers.

Range of frequencies needed for ground penetration

The graph plots surface penetration depth versus volumetric soil moisture. Exploring subsurface ice sheets and shallow aquifers – less than 100 metres deep – requires a centre frequency of around 50 MHz.

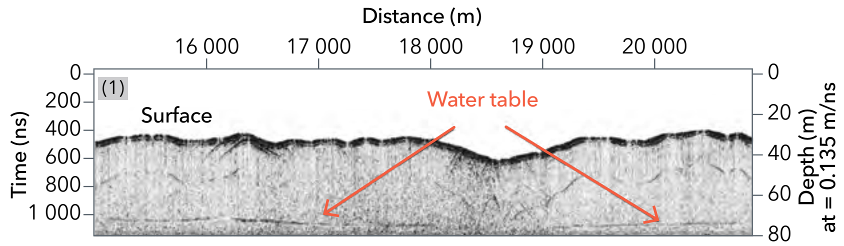
Surface penetration depth of an incident radar wave versus volumetric soil moisture, parameterized by centre frequency



Source: Figure 1 of Recommendation ITU-R RS.2042-1.

Airborne sounders have made measurements around 50 MHz in desertic areas of the Arabian Peninsula. The figure shows a sample radargram from such a campaign.

Radargram from airborne VHF radar over Kuwait in 2011



Source: Figure 2 of Recommendation ITU-R RS.2042-1.

> *Airborne sounders have made measurements around 50 MHz in desertic areas of the Arabian Peninsula.*

For OASIS, the designers considered a 45 MHz centre frequency, 10 MHz bandwidth emission (see Recommendation ITU-R RS.2042-1).

Several factors went into designing this radar waveform, including:

- Centre frequency: 45 MHz – as low as possible for subsurface penetration without suffering excessive ionospheric delay, dispersion, and loss;
- Spatial resolution: 10 MHz bandwidth – to achieve a vertical resolution of 10 metres in ice and dry sand.

"If WRC-23 were to grant a frequency allocation for EESS (active) at or around 45 MHz, then this would greatly enhance the likelihood of concepts like OASIS coming to fruition."

Intended operational usage

To meet scientific objectives, operations are intended to be implemented over uninhabited or sparsely populated areas, including the ice sheets of Antarctica and Greenland, along with desertic areas of the North African Sahara and Arabian Peninsula.

To provide adequate coverage, spaceborne sounders can typically be expected to operate on satellites in Sun-synchronous orbit (SSO). For OASIS, specifically, a 548-day exact repeat orbit at an altitude of 400 kilometres altitude was considered. To minimize impact on incumbent services, operations would take place in the early morning via an SSO with a local time of the ascending node (LTAN) of 4 am, within a 10-minute window in a 92.7-minute orbit.

Intended coverage areas for spaceborne 45 MHz radar sounder

Source: Figure 4 of Recommendation ITU-R RS.2042-1.

Raising possibilities

If the upcoming ITU World Radiocommunication Conference, WRC-23, were to grant a frequency allocation for EESS (active) at or around 45 MHz, then this would greatly enhance the likelihood of concepts like OASIS coming to fruition.

Adobe Stock

Passive microwave sensing of ice clouds: Key for nowcasting and climate modelling

Markus Dreis, Chairman, ITU-R Working Party 7C (Remote sensing systems), and Frequency Manager, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

> *Global measurements of ice-cloud properties are critical to understand the global effects of ice clouds.*
>
> Markus Dreis

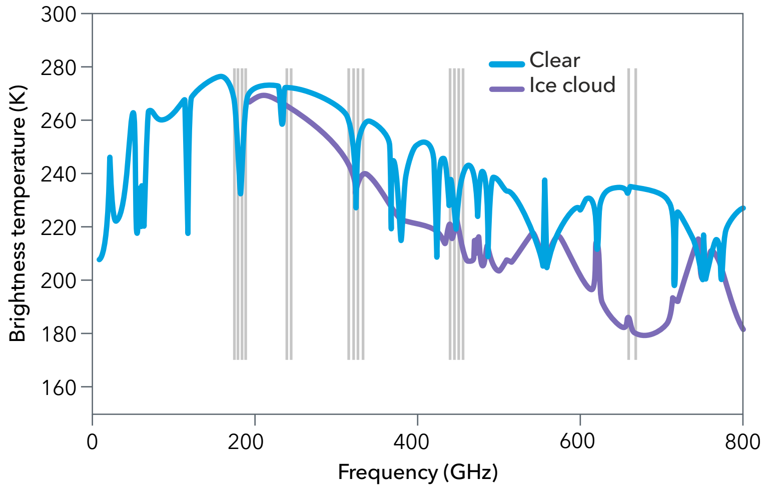
Ice clouds cover more than one third of the Earth's surface. They affect precipitation, atmospheric structure and cloud processes, with a great impact on the planet's climate and hydrological cycles.

Global measurements of their properties – including ice-water path and ice-particle size distribution – are critical to understand the global effects of ice clouds.

To obtain ice-cloud measurements, passive microwave remote-sensing instruments observe the atmosphere at microwave frequencies that are carefully selected to retrieve atmospheric components. Those measurements can best be observed in specific "channels" at frequencies around 183 gigahertz (GHz), 243 GHz, 325 GHz, 448 GHz, and 664 GHz *(see figure)*.

> *To obtain ice-cloud measurements, passive microwave remote-sensing instruments observe the atmosphere at microwave frequencies that are carefully selected to retrieve atmospheric components.*

Sensitivity of brightness temperature to clear sky and ice cloud



Source: ITU-R Document 7/91.

The figure compares brightness temperatures relative to a clear sky and an ice cloud. The bars indicate the ice-cloud channel positions.

These channels must be observed as a set, because observations from multiple microwave frequencies are needed to retrieve specific physical parameters. The resulting data is fed into regional and global weather and climate models to properly represent the radiative and thermodynamic effects of ice clouds.

New sensors optimized for ice clouds

Today's operational passive microwave sensors typically observe the atmosphere at frequencies below 200 GHz or use limb sounding to measure chemical processes and atmospheric composition. Unfortunately, these methods are inadequate for optimal ice-cloud observation.

Passive microwave sensors, specifically optimized to measure ice clouds, are now under development, set to become operational by 2026. A prime example is the Ice Cloud Imager (ICI) on the Polar System-Second Generation (EPS-SG) satellites operated by EUMETSAT – the European Organisation for the Operation of Meteorological Satellites.

Those newly designed sensors will perform observations at the set of microwave frequencies outlined in the figure, using 11 channels ranging from 183 GHz up to 664 GHz. A conical scanning mechanism will provide good cloud-penetration capability at different cloud heights, and sensitivity to ice particles at a large range of sizes.

The new ICI instruments will furnish missing information on ice clouds – especially about cirrus clouds, the water path and effective radius of cloud ice, and cloud altitude – for weather and climate models. They will also provide vertical profiles for humidity and hydrometeors (cloud ice, graupel and snowfall distribution), as well as water vapour, all in support of numerical weather prediction, "nowcasting" and climate monitoring.

Regulations lagging

The specific channels for passive microwave sensors to measure atmospheric components related to ice clouds are at frequencies centred around 183 GHz, 243 GHz, 325 GHz, 448 GHz, and 664 GHz.

One of those channels, around 243 GHz, involves a pair of symmetric spectral bands at 239.2–242.2 GHz and 244.2–247.2 GHz. However, these frequencies are not currently allocated to the Earth exploration-satellite service (passive) in the Radio Regulations maintained by the International Telecommunication Union (ITU).

"Passive microwave sensors, specifically optimized to measure ice clouds, are now under development, set to become operational by 2026."

ITU Radio Regulations

The Radio Regulations facilitate equitable access to and rational use of the natural resources of the radio-frequency spectrum and geostationary-satellite orbits. They will be updated this year at the World Radiocommunication Conference, WRC-23.

See the current Radio Regulations.

This channel around 243 GHz – centrally placed between the 183 GHz and 325 GHz water-vapour transitions – provides high sensitivity to ice particles around 700 micrometres in size. This makes it optimal for estimating cloud ice content, for measuring the hydrometeor properties of cirrus clouds, the heat convective at higher altitudes, and anvil clouds.

It is a very specific channel, a so-called (semi) window channel, at a high frequency range that allows measurements through the entire atmosphere, with minimum atmospheric absorption compared to neighbouring channels.

But the need for those bands for passive microwave sensors was not known or anticipated in 2000, when the frequency allocation table for this range in the Radio Regulations was last reviewed and updated. Therefore, the Earth exploration-satellite service (passive) received no allocation in the 239.2–242.2 GHz and 244.2–247.2 GHz bands at the time.

Update needed at WRC-23

WRC-23 agenda item 1.14 calls for review and adjustments to frequency allocations in the range 231.5–252 GHz. This is the golden opportunity to allocate frequencies in the 239.2–242.2 GHz and 244.2–247.2 GHz bands to the Earth exploration-satellite service (passive).

Doing so would align the Radio Regulations with current needs, enable thorough observation of ice clouds, and bring benefits for global society.

"WRC-23 agenda item 1.14 calls for review and adjustments to frequency allocations in the range 231.5-252 GHz."


CNES

Frequency coordination for satellite radio services in S, X and Ka bands

Jean Pla, Expert in frequency management,
Centre National d'Etudes Spatiales (CNES), France

Satellite coordination is an essential part of frequency management that all satellite operators, under the auspices of their respective administrations, should perform to ensure interference-free operations.

Scientific organizations such as space and meteorological agencies, as well as telecom operators and now new space operators, use the satellite scientific bands in the S, X and Ka radio-frequency ranges. They are used essentially for telemetry and telecommand purposes.

Satellite frequency coordination, particularly in these frequency bands, relies on a global regulatory and technical framework maintained by the International Telecommunication Union (ITU), the United Nations agency for information and communication technologies.

> *Satellite coordination is an essential part of frequency management that all satellite operators, under the auspices of their respective administrations, should perform to ensure interference-free operations.*
>
> Jean Pla

What is satellite coordination and when is it necessary?

Satellite coordination is a bilateral and multilateral process aimed at conducting interference-free operation of the existing and planned satellite systems of ITU Member State administrations. In addition, mandatory or non-mandatory coordination processes allow future recognition of new stations or systems.

Mandatory coordination is applicable for satellite networks using geostationary-satellite orbits, satellite systems in the fixed-satellite and the broadcasting-satellite service, and for stations for which the requirement to coordinate is included in a footnote to the Table of Frequency Allocations (Radio Regulations, Article 5).

Other non-geostationary-satellite networks – including all pertinent services and certain frequency bands – are subject to non-mandatory coordination and only require advance publication before notification and the recording of frequency assignments.

How coordination is conducted

Satellite coordination should be understood as a process to avoid potential harmful interference between new and existing wireless systems, stations, or applications.

It involves the following steps:

1 The exchange of technical and operational data on existing, previously submitted, or new frequency assignments for radio stations or systems.

2 Studies of potential interference effects between existing and new frequency assignments.

3 Correspondence between national or international spectrum management authorities and spectrum users.

4 Consideration, when technical works are conducted, of the appropriate ITU radiocommunication standards – known as ITU-R Recommendations – defining protection criteria.

“Satellite coordination should be understood as a process to avoid potential harmful interference between new and existing wireless systems, stations, or applications.”

WRC-23 agenda item 9.2

The *Report of the Conference Preparatory Meeting* of the upcoming World Radiocommunication Conference, WRC-23, gives important instructions for administrations when drafting an advanced publication information in the S band (in fact 2025–2110 megahertz (MHz) and 2200–2290 MHz). This will be an issue to be addressed at the next radiocommunication conference.

An increasing number of submissions for advance publication information in the *International Frequency Circular* (BR IFIC), as required under Radio Regulations Article 9, No. 9.1, contain generic information. In particular, an unhealthy tendency has arisen for submissions to book the whole space operation bands covering 2025–2110 MHz and 2200–2290 MHz, or major parts of the S band. Some submissions have even declared the whole Earth surface as a service area and mentioned no specific earth stations – only "typical" ones.

Such a lack of specific information makes the cooperation process under Article 9 (Nos. 9.3 and 9.4) longer and more complicated. Faced with such generic information, administrations can either make equally generic comments or request more detailed information from the notifying administration. The ITU Radiocommunication Bureau cannot reject filings with large frequency ranges, as long as the filing complies with the Radio Regulations.

"The S band requires specific care since it is widely used by many operators."

Practical approach in the S band

The S band requires specific care since it is widely used by many operators. The ITU Radiocommunication Sector (ITU–R) and the less formal Space Frequency Coordination Group (SFCG) have approved recommendations and resolutions to help operators and administrations with advance publication, in addition to the ITU–R Recommendations for performing calculations.

ITU Constitution and Radio Regulations

According to Article 1 of the ITU Constitution, one of the organization's responsibilities is to "*coordinate efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of the radio-frequency spectrum for radiocommunication services and of the geostationary-satellite and other satellite orbits*".

Article 44 of the Constitution adds: "*In using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and… must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations*".

ITU Member State administrations and satellite operators are bound by the ITU Radio Regulations, the sole globally-binding treaty governing the use of the radio-frequency spectrum and satellite orbits. Article 9 of the treaty contains the requirements and processes to obtain agreement, through satellite coordination between operators, prior to the notification process for a satellite network, while Article 11 outlines the conditions for which such notification is required.

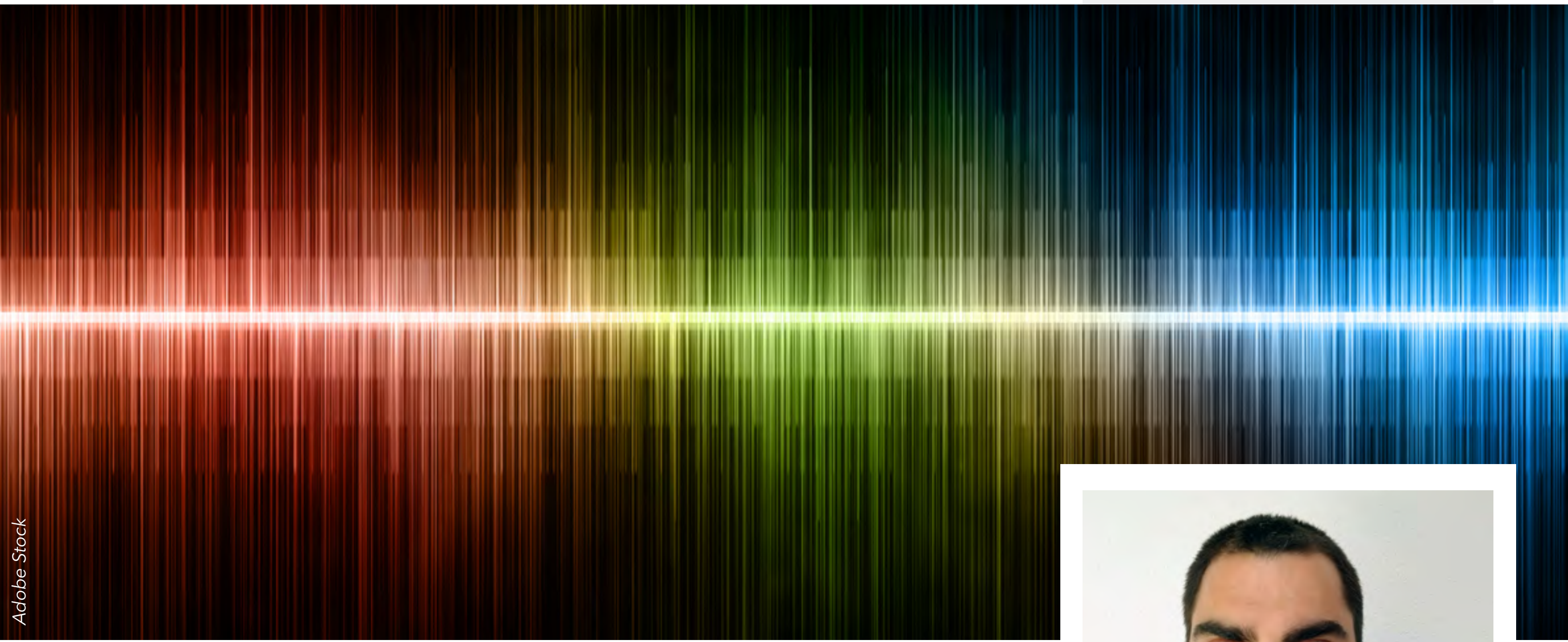
The outcome of a satellite coordination meeting is subject to approval by ITU Member State administrations, and any satellite coordination is framed by the regulatory and technical principles outlined above.

Due to continuous high usage, regulatory attention is increasingly focused on preserving the S band.

The case of the X band, which is used for high data-rate transmission, is specific since it usually requires technical calculations to facilitate coexistence between satellite networks using the same frequency bands.

In the future, the Ka band will be widely used for very high data-rate Earth-observation satellites.

"Due to continuous high usage, regulatory attention is increasingly focused on preserving the S band."



Adobe Stock

Radio-frequency interference in Earth-observation measurements

Yan Soldo, Frequency Management and Technology Engineer, European Space Agency (ESA)

Radio-frequency interference (RFI) poses several challenges for the Earth exploration-satellite service (EESS), which relies on precise sensors affected by radio waves. Typically, the presence of RFI will either completely prevent measurements, cause larger uncertainties (if the RFI is correctly identified), or introduce measurement errors. Measurement errors tend to happen at lower RFI levels, which are more difficult to identify [Oliva et al., 2016].

Strong RFI may also damage satellite receivers, resulting in permanent losses of science data. In addition, the need to account for RFI adds to design and operational costs for EESS sensors.

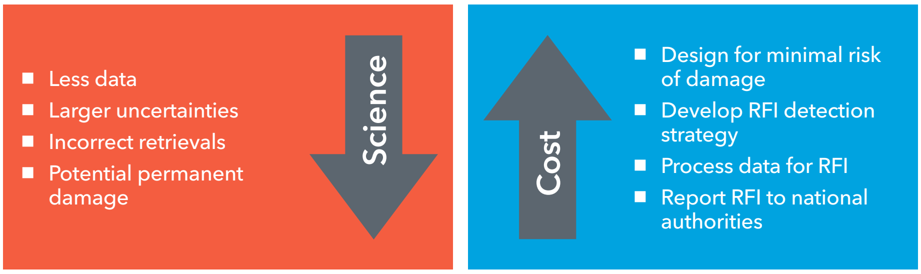
> *"Radio-frequency interference poses several challenges for the Earth exploration-satellite service."*
>
> Yan Soldo

Need for regulation protection and regulatory actions

Software or hardware improvements can reduce, but not eliminate, the impact of RFI on science data. Even a perfect RFI detection algorithm leaves Earth-observation satellite networks exposed to some data loss and measurement uncertainties. Therefore, regulatory protection and regulatory actions, including RFI reporting [Pedro et al., 2022], are needed to protect science measurements that are vital for environmental and climate studies, as well as for meteorology.

> *Software or hardware improvements can reduce, but not eliminate, the impact of RFI on science data.*

Science loss and rising cost: Impact of RFI on EESS sensors

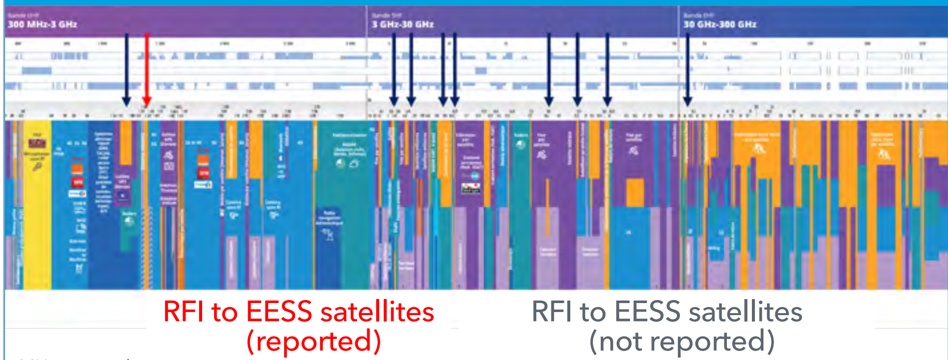


RFI contamination of EESS sensors

Today, many EESS sensors are affected by RFI. Some examples are provided in Draper, 2018, and in the dedicated webpage from the Space Frequency Coordination Group (SFCG). However, few operators can consistently detect and locate sources of interference, and even fewer have taken steps to report RFI to their appropriate national regulatory authorities.

The next figure shows a portion of France's national table of frequency allocations. The arrows indicate frequency bands with documented cases of EESS sensors being affected by RFI (although RFI may be present in even more bands), while the red arrow indicates the 1400–1427 MHz band, the only band where there have been systematic RFI reports.

Part of the French national table of frequency allocations
Arrows indicate frequency bands with known RFI cases.
Red indicates a frequency band where RFI reporting is done systematically.



MHz = megahertz
GHz = gigahertz

Source: anfr.fr

> *Space agencies, recognizing this as a powerful tool to protect and maintain science measurements, are striving to improve their RFI reporting capacity.*

As this figure shows, RFI affecting EESS sensors is largely under-reported. This is partly due to the complexity of detecting RFI, but mostly because the footprint of EESS sensors – meaning the area they observe at each instant – is tens of kilometres wide, which is too large for any practical action on the ground.

Algorithms developed in recent years, however, can locate RFI sources with accuracies finer than the size of the footprint, typically within a few kilometres, which is sufficient for national regulatory authorities to identify the source of the RFI reported by EESS sensors.

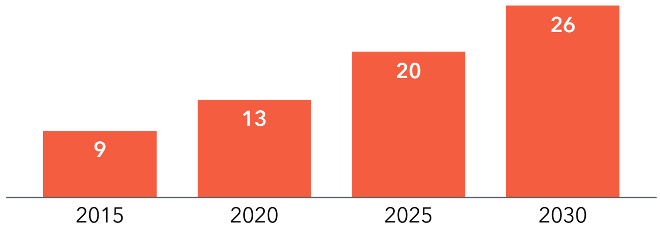
Expected trends

Looking ahead, RFI is likely to become an even bigger issue. Current plans are that Earth-observation satellites will become more present in the spectrum, both in terms of number of satellites and frequency bands observed.

At the same time, many other services are planning to expand their presence in the spectrum. For example, according to the American Institute of Aeronautics and Astronautics (AIAA), the private satellite sector is planning to deploy tens of thousands of satellites; and a report from global mobile telecom industry association GSMA forecasts 37.4 billion Internet-of-Things connections by 2030.

> *EESS sensors must be readied for the presence of radio-frequency interference.*

Number of frequency bands targeted by ESA satellites

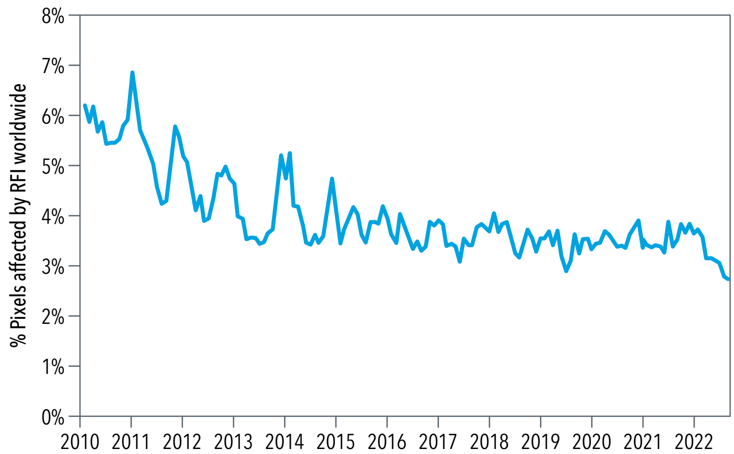


Impact of reporting RFI

The 1400–1427 MHz band is one case where the RFI environment has slightly improved rather than degraded in recent years. RFI was first noticed in this band in 2010 by the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) mission. This triggered concerted efforts to detect, locate and report the sources of interference.

The continuation of these endeavours over the years has led to a gradual reduction of RFI contamination *(see figure)*, demonstrating the effectiveness of RFI reporting.

Percentage of Earth's surface land pixels affected by RFI in SMOS products



Source: Uranga et al., 2022

Future of RFI reporting

Space agencies, recognizing this as a powerful tool to protect and maintain science measurements, are striving to improve their RFI reporting capacity.

Future ESA missions, such as Metop-SG and the Copernicus Imaging Microwave Radiometer (CIMR), will carry hardware dedicated to RFI processing, and work is currently ongoing to improve RFI detection and monitoring capabilities. This should lead, in the coming years, to more systematic reporting of RFI sources affecting EESS sensors.

Conclusions

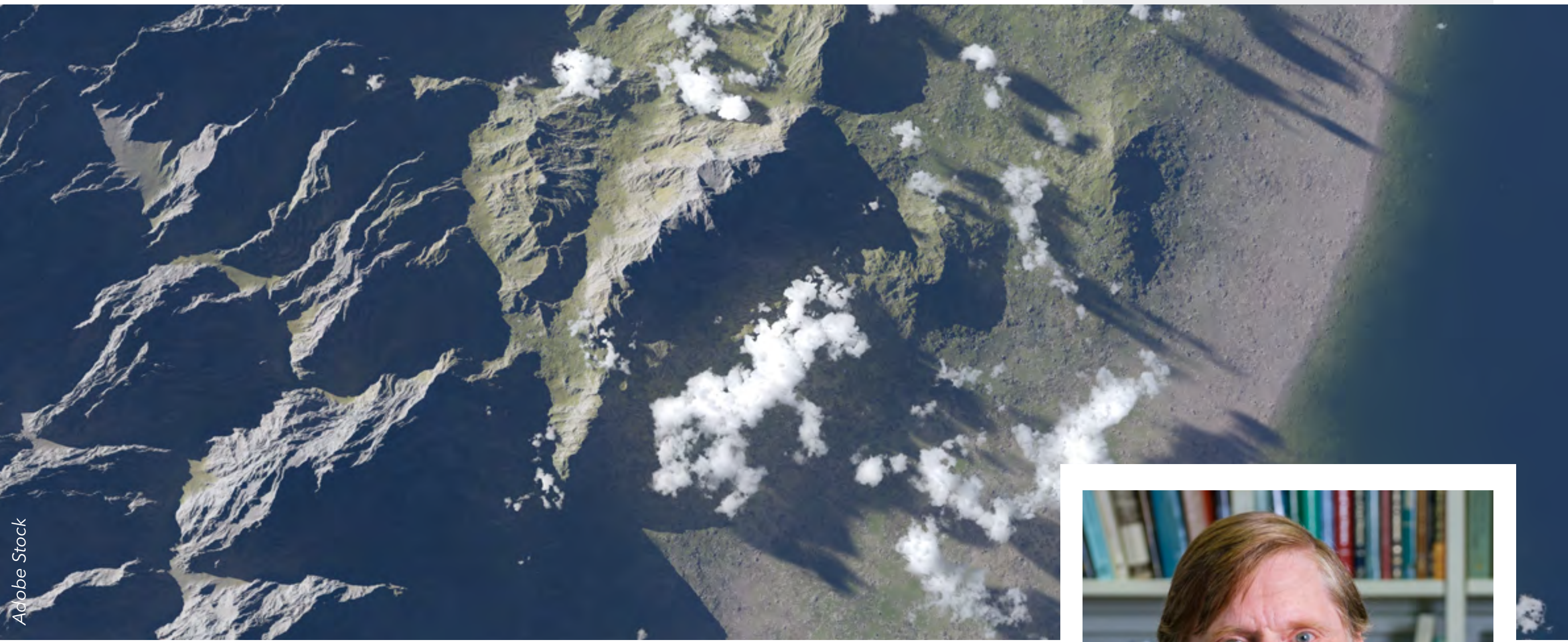
Cases of RFI have been documented in several bands, and RFI is deemed an increasing concern as many terrestrial and spaceborne services plan to rely more heavily on the spectrum.

Therefore, EESS sensors must be readied for the presence of RFI. A key part of this preparation is to set in place a strategy that allows systematic identification and reporting of RFI to national regulatory authorities. This has been implemented in one band – with positive results – and more work is currently underway to improve RFI reporting, including in additional bands.

Metop-SG

Metop – Second Generation will secure the continuation of meteorological observations from the polar orbit.

Watch video overview



Passive microwave remote sensing for numerical weather prediction

Stephen English, Deputy Director of Research,
European Centre for Medium-Range Weather Forecasts

Passive microwave observations are crucial for numerical weather prediction (NWP), climate modelling, and disaster preparedness. As the World Radiocommunication Conference, WRC-23, approaches, these and other vital services need regulatory protection.

NWP underpins key goals in the United Nations 2030 Agenda for Sustainable Development and the Sendai Framework for Disaster Risk Reduction. Its "quiet revolution" in meteorology has mitigated weather-related disaster risks, reducing losses in lives and livelihoods (Nature, vol. 525, 2015).

Combining observations with numerical models allows us to predict the future state of the Earth system, including weather, ocean, land surface, snow, sea ice, and atmospheric conditions.

> *"Passive microwave observations are crucial for numerical weather prediction, climate modelling, and disaster preparedness."*
>
> Stephen English

Why NWP models need protected frequency bands

Satellite instruments observe the Earth in many spectral frequency bands. Radio-spectrum observations, uniquely, can penetrate clouds, often where information is most needed.

Specified bands – some included in footnote 5.340 of the Radio Regulations – provide different kinds of weather-related information.

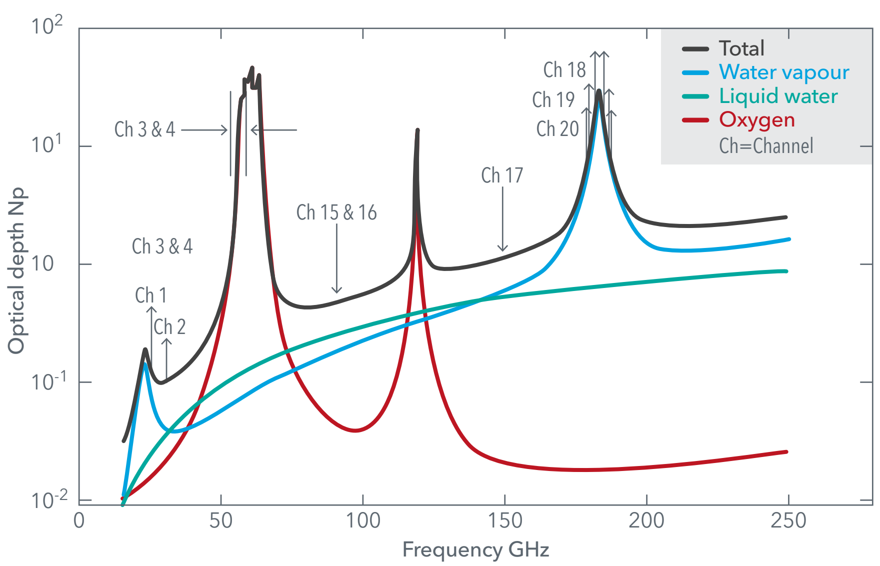
For example:

- 1.400–1.427, 6.9–7.0, 10.6–10.7, 18.6–18.8, 23.6–24, 31.3–31.5 and 36–37 gigahertz (GHz) – Earth's surface and near-surface atmosphere;
- 50.2–57.3 GHz, 87–91, 115–122, 165–166, 176–191, 228–230 GHz – 3-D atmospheric temperature, water vapour and liquid phase clouds;
- 241–245, 314–336, 439–457 and 657–671 GHz – ice-phase clouds; and
- 486–504 and 540–580 GHz – atmospheric trace gases.

Spectral features between 1 GHz and 250 GHz *(see Figure 1)* show:

- two water vapour spectral absorption lines close to 22 GHz and 183 GHz;
- oxygen lines close to 118 GHz; and
- a group of oxygen lines between 50.2 and 57.3 GHz.

Figure 1 – Microwave spectrum: showing attenuation due to liquid water (green), water vapour (blue), oxygen (red) and total (black) for 200 gm^{-2} cloud liquid water and a US Standard Atmosphere.



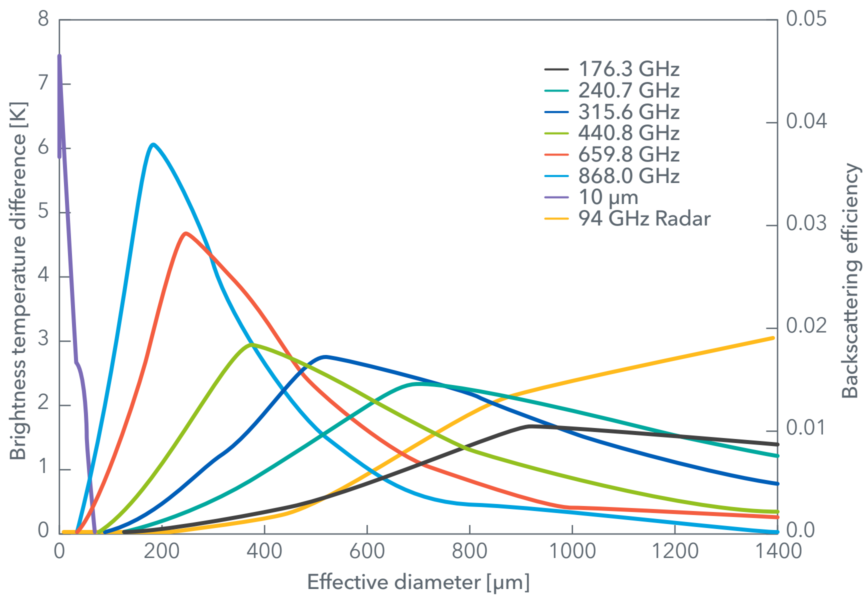
Source: *Met Office, UK*

> *Combining observations with numerical models allows us to predict the future state of the Earth system, including weather, ocean, land surface, snow, sea ice, and atmospheric conditions.*

Passive sensors observing such natural emissions, however, are sensitive even to very low levels of radio-frequency interference.

Ice-cloud information from bands above 200 GHz will soon be available via the Ice Cloud Imager and Arctic Weather Satellite. Several bands are needed in the range 176–868 GHz to capture various ice-cloud hydrometeor sizes *(see Figure 2)*.

Figure 2 – Sensitivity of bands to ice hydrometeors: 176–868 GHz.



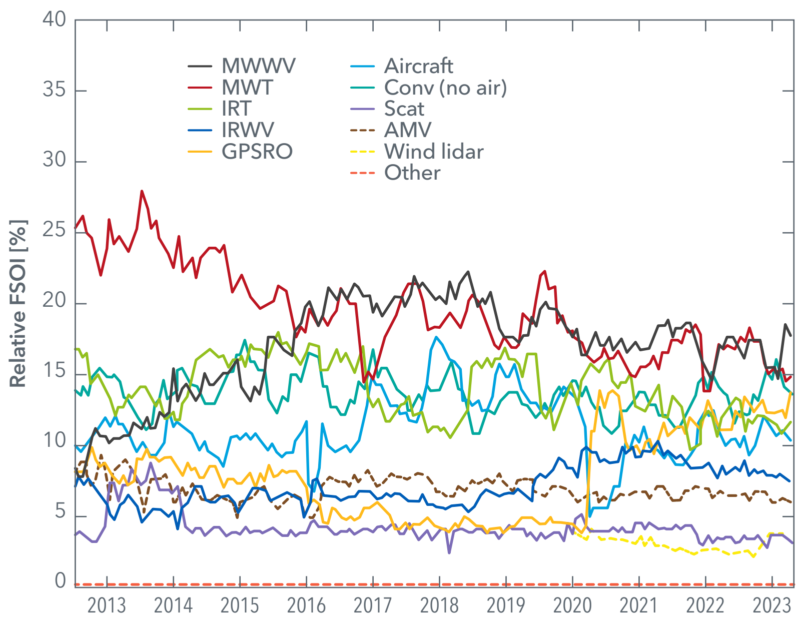
Source: Buelher et al. (2007) Copyright © 2007 Royal Meteorological Society.

Why radio-frequency observation matters in forecasting

Radio frequency-observations used by the European Centre for Medium-Range Weather Forecasts (ECMWF) provide the largest error reduction of any weather observation type *(see Figure 3)*.

The value of Earth-exploration satellites for weather forecasts has been reported widely, including at ECMWF in 2018 and Radio Frequency Interference (RFI) workshops in 2019 and 2022, and in literature, such as Bormann *et al.* (2019) and Randriamampianina *et al.* (2021).

Figure 3 – Forecast sensitivity-based observation impact (FSOI) for 2012-2023.



MWWV = Microwave humidity sounders at 174-192 GHz

MWT= Microwave temperature sounders 50-58 GHz

IRT = Infrared temperature sounders

IRWV = Infrared humidity sounders

GPSRO = GNSS radio occultation

Aircraft = *In situ* observations on aircraft

Conv (no air) = Other *in situ* observations

Scat = Scatterometers (currently all C-band)

AMV = Atmospheric motion vectors (from satellite image sequences)

Wind lidar = UV doppler wind lidar (only Aeolus in this period)

Other = All other observation types

Source: Alan Geer

Satellite data records for essential climate variables, going back over four decades, enable climate monitoring both through instrument-based climate data records (CDRs) and integration into "re-analysis" in a modified NWP system.

European databases, such as EUMETSAT's Satellite Application Facilities and the ESA Climate Change Initiative, have further enriched global climate knowledge.

The resulting "maps without gaps" – like ERA-5, produced by the Copernicus Climate Change Service, operated by ECMWF on behalf of the European Commission – increasingly inform climate change mitigation and adaptation. Long-term space-based observation is needed to monitor future changes.

Protecting EESS bands from interference

Several WRC-23 discussion topics relate to weather and climate services, and the World Meteorological Organization (WMO) has published a position statement on these. Earth observations around 7 GHz, used to monitor ocean temperatures (agenda item 1.2), are a particular concern.

The Radio Regulations provision on passive microwave sensor measurements (footnote 5.458) stops short of allocating spectrum to the Earth-observation satellite service (EESS), which could therefore be adversely affected by International Mobile Telecommunications (IMT-2020/5G) using the same frequency.

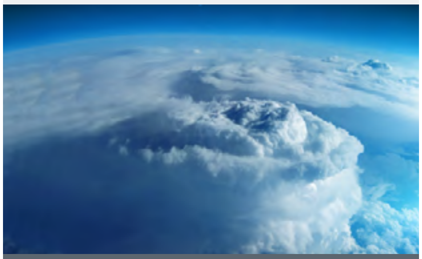
The WRC-23 agenda also affects 10.65 GHz (agenda item 1.2), 18.7 GHz (1.16 and 1.17) and 36.5 GHz (9.1d) – relevant for liquid clouds and terrestrial surfaces – and several other EESS bands (9.1c).

Decisions are needed to preserve global measurements in these unique passive-sensing bands.

European Scientists on Spectrum for Earth Observation (ESSEO) – an initiative led by the European Space Agency – will provide further scientific support for WMO's positions, both at WRC-23 and in another four years at WRC-27.

Weather forecasting is of tremendous socio-economic importance. Appropriate protection for it, therefore, needs to be maintained in the Radio Regulations.

"Weather forecasting is of tremendous socio-economic importance."



Monitoring our changing planet – ITU News Magazine

An ITU News Magazine article in 2019 explained the role passive microwave observations play in numerical weather predictions.

Read the article on page 54.

Adobe Stock

Flávio Jorge

Luis Pedro

Sandro Mendonça

Emerging prospects for Earth observation in addressing sustainable development goals

Flávio Jorge, National Chair and International Early Career Representative, Commission E (Electromagnetic Environment and Interference), International Union of Radio Science; Luis Pedro, Director, ANACOM, Portugal; and Sandro Mendonça, Professor, Iscte Business School/ University Institute of Lisbon, Portugal, and Advisor, Anatel, Brazil

Climate change, observed in the form of heatwaves, wildfires, draughts, and floods, often in the same territory within the same year, has dramatic social and economic impacts. It is threatening public safety and undermining food and water security, as well as changing disease patterns and forcing mass displacements of people.

ANACOM (Autoridade Nacional de Comunicações), Portugal
Anatel (Agência Nacional de Telecomunicações), Brazil

The 17 Sustainable Development Goals (SDGs) set out by the United Nations in 2015 provide the essential pathway to solve the grand societal challenges of our time. With the next UN climate conference, COP28, taking place in Dubai in late November, in parallel with the upcoming World Radiocommunication Conference (WRC-23), the time is ripe to acknowledge the intersection of the climate and radiocommunications agendas.

How Earth-observation satellites serve sustainable development

Earth-observation satellites are an indispensable piece of infrastructure, taking the pulse of our planet with the capability to contribute to most, if not all, SDGs. The resulting data on climate, land use and other factors is a source of strategic intelligence for the design and evaluation of anticipatory and corrective policies.

The Earth Exploration-satellite Service (EESS) – as operated by Earth-observation missions within the Radio Regulations framework maintained by the International Telecommunication Union (ITU) – amounts to a global public good that ensures unique benefits. But its continued delivery depends on the increasingly scarce availability of satellite orbits, along with the radio spectrum resources required for microwave remote sensing, as well as for communications.

Governance is key to ensure resilience and adaptability.

Fast-growing orbit and spectrum usage

Radio spectrum is essential for Earth-observation sensors.

OSCAR – the Observing Systems Capability Analysis and Review tool from the World Meteorological Organization (WMO) – makes available a database of satellite frequencies used for Earth observation, including for microwave remote sensing. The distribution of spectrum-uses *(see Figure 1)* shows the importance of radio spectrum for Earth-observation sensors: all the frequency ranges are used, in use, or planned for future use.

Furthermore, the number of Earth-observation satellites has been increasing quadratically, as has the number of spectrum uses by Earth-observation sensors *(see Figure 2)*.

> *“Earth-observation satellites are an indispensable piece of infrastructure, taking the pulse of our planet with the capability to contribute to most, if not all, SDGs.”*
>
> Flávio Jorge, Luis Pedro, and Sandro Mendonça

Figure 1 – Distribution of radio spectrum uses by Earth-observation sensors

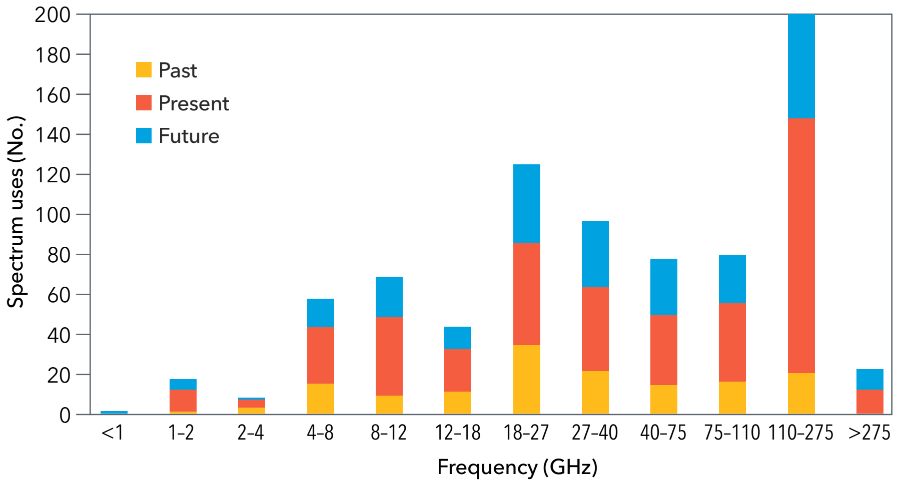
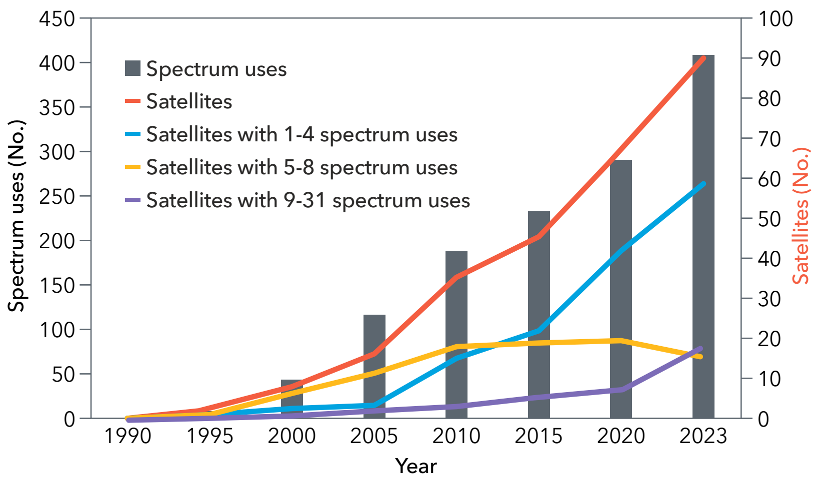


Figure 2 – Evolution of spectrum uses by Earth-observation sensors and of operational Earth-observation satellites (including per category of spectrum-use)



Increasingly timely Earth monitoring

Both the average and median numbers of spectrum uses, per satellite, by Earth-observation sensors have decreased in recent years, after peaking around 2005 *(see table)*.

Average and median values for spectrum uses by Earth-observation sensors per satellite

	1995	2000	2005	2010	2015	2020	2023
Average	3.7	5.4	7.4	5.3	5.2	4.3	4.5
Median	5.0	5.5	6.5	5.0	5.0	1.0	1.0

Such findings are consistent with the trend of deploying smaller, simpler, and cheaper satellites in constellations of bigger numbers. This small-satellite, large-constellation approach reduces revisit time and provides near-real-time monitoring of the Earth.

"Radio spectrum is essential for Earth-observation sensors."

Lighter missions on the up

From the spectrum-use intensity standpoint *(see Figure 2)*, the number of "lighter" missions – with fewer than five distinct uses of radio spectrum, per satellite, by Earth-observation sensors – is on the rise. "Heavier" missions, with more than eight such uses per satellite, continue being deployed, but at a slower rate, possibly involving larger, more complex, costlier applications.

The "middle" missions, however, which dominated the Earth-observation sector in its early days, reached a plateau around a decade ago and have now begun to decrease, consistent with decommissioned missions modal lifetimes available at the moment.

Sustained, effective and efficient use of Earth-observation assets

With the ever-increasing demand for satellite orbits and radio spectrum, the rational use of Earth-observation assets has never been more important. Yet the complex value chain of the space economy requires continuous orchestration.

Distinct roles and responsibilities include:

- **Researchers** – expanding technology feasibility and resource-use efficiency.
- **Regulators** – shaping practical and enforceable rules, including realistic protection requirements.
- **Manufacturers** – engineering robust, affordable technologies, following circular-economy principles, duly observing both in-force and forthcoming regulations and recommendations.
- **Operators** – operating within established frameworks and claiming radio protection whenever needed (methods and procedures in this respect are addressed here).
- **Monitoring and enforcement authorities** – ensuring a safe electromagnetic environment for operations, keeping the radio spectrum free from harmful interference, providing effective radio protection where needed, and supporting efficient spectrum sharing.

ITU fulfils a crucial role in coordinating all these functions. As the UN agency for digital connectivity technologies, it fosters consensus while respecting sovereignty and diversity, builds bridges between communities, and maximizes benefits for societies worldwide.

Earth observation forms an integral part of the information and communication technologies (ICTs) ecosystem – a key element in the world's ongoing digital transformation. It is key in addressing our current planetary crisis.

The time, therefore, has come to rally around the SDGs, act together for our common future, and make the most of WRC-23 to ensure the continued availability of spectrum and space resources for all.

"The time has come to rally around the SDGs, act together for our common future, and make the most of WRC-23 to ensure the continued availability of spectrum and space resources for all."

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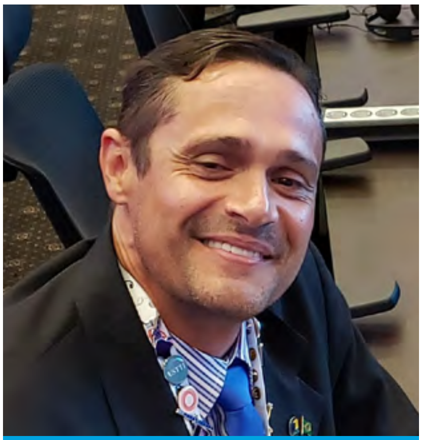


Earth exploration-satellite services in Latin America and the Caribbean

Tarcísio Bakaus, Vice-Chairman, ITU-R Working Party 7C (Remote sensing systems), and Coordinator of International Spectrum and Orbit Management (Spectrum, Orbit and Broadcasting Division), Brazilian National Telecommunications Agency (Anatel)

"Latin American and Caribbean countries have made significant progress in Earth observation using EESS."

Tarcísio Bakaus

The Earth exploration-satellite service (EESS) is a radiocommunication service between ground and space stations that obtains data from sensors on Earth-observation satellites and other platforms.

This service enables the provision of information about the Earth's characteristics, environment, and natural phenomena. It also supports environmental and climate monitoring, disaster management, agriculture, water management, natural resource exploration and various other purposes.

Latin American and Caribbean countries have made significant progress in Earth observation using EESS, thanks in part to international partnerships and specific programmes tailored to the needs of developing countries.

Argentina

The Satellite for Scientific Applications-D (SAC-D) was launched in 2011 in cooperation with the US National Aeronautics and Space Administration (NASA). The SAOCOM (Argentine Microwave On Observation Satellite) series saw launches in 2018 and 2020. Both programmes have provided extensive insights into oceanic processes, in addition to monitoring agriculture, soil moisture, and floods.

An upcoming dual-satellite joint Earth-observation project between Argentina and Brazil known as SABIA-Mar (Argentine-Brazilian Satellites for Environmental Information of the Sea) aims to combine oceanic data to gain a better understanding of the regional seas.

Brazil

The region's largest country currently operates multiple Earth-observation satellites. The China-Brazil Earth Resources Satellite (CBERS) series and the SCD (Data Collection Satellite) constellation, with launches initiated in 1999, and the Amazonia-1 satellite launched in 2021 under the International Disasters Charter, collect data on deforestation, urbanization, and agricultural activities. These satellites play a crucial role in understanding and preserving Brazil's natural resources, as well as in monitoring natural disasters and supporting regional monitoring activities.

Mexico

The Mexican Climate and Atmospheric Composition Observatory (OMECCA) satellite launched in 2022 and AzTechSat-1, launched in 2019 in cooperation with NASA, have created new possibilities in the realm of Earth observation for the country. These projects offer immense potential to enhance agriculture, disaster management, and security and surveillance capacity, along with supporting climate change studies, urban intelligence, and mapping.

Other Latin American initiatives

Prominent initiatives from Chile (FASat-Charlie Satellite, 2011), Bolivia (Túpac Katari-1, or TKSat-1, jointly with China, 2013), Uruguay (AntelSat, 2014), Peru (PerúSAT-1, 2016), and Colombia (FACSAT-1, 2018), among others, offer incomparable data acquisition capabilities that strengthen environmental monitoring and management.

"The region's largest country currently operates multiple Earth-observation satellites."

Caribbean projects

The Caribbean regional track of the Pilot Programme for Climate Resilience (PPCR), the Caribbean Disaster Emergency Management Agency (CDEMA), and the Caribbean Institute for Meteorology and Hydrology (CIMH) all actively contribute to research and development in Earth-observation systems.

Furthermore, collaborations with NASA, the European Space Agency (ESA), the China National Space Administration (CNSA) and other international space organizations have resulted in notable projects in the island region and remain instrumental in driving wider Latin American and Caribbean progress and innovation.

> *Supporting Latin American and Caribbean space and EESS development programmes is crucial.*

WRC-23 and next steps

Collaborative solutions, proactive engagement, and technical advancements are key for future Earth observation. Supporting Latin American and Caribbean space and EESS development programmes is, therefore, crucial.

The World Radiocommunication Conference, WRC-23, in November and December holds the opportunity to shape the future of EESS and ensure progress in various aspects of Earth observation that could support regional development goals.

What to expect for EESS

Approval at WRC-23 of a new secondary EESS allocation for the 40–50-megahertz (MHz) radio-frequency band would allow significant advances in subsoil measurement using sound radars, thereby facilitating the detection of water and ice in remote, sparsely-populated regions.

Another goal is to adjust existing or potential new primary frequency allocations to EESS (passive) in the 231.5–252 gigahertz (GHz) range, enabling advancements in climate models that accurately capture the impact of ice clouds on the Earth's climate and hydrological cycle.

The upcoming conference will also address the critical topic of safeguarding space weather sensors, which are vital in preventing detrimental effects on radiocommunication systems, including radionavigation and aeronautical services. Studies on the topic may be continued, with the aim of completion by WRC-27 in four years' time.

Additionally, WRC-23 will focus on the protection of passive systems in the range of 36–37 GHz for surface measurements, weather forecasting, and research.

Lastly, measures must be established for studying and updating technical and regulatory provisions to ensure the long-term sustainability of space operations.

Cooperation to strengthen space services

The involvement of international bodies is vital to guarantee ongoing satellite services and EESS capabilities and to facilitate their further development. Furthermore, the International Telecommunication Union (ITU) and its Radiocommunication Sector (ITU-R) must be strengthened to ensure continuity in the provision of new allocations and protection for existing operations, as well as to enhance the space sustainability framework.

These actions need to be implemented with the full participation of ITU Member State administrations, ITU Sector Member companies and organizations, and all relevant international and regional bodies. This needs to happen at both the region and global levels.

Developing and maintaining a safe and secure satellite environment requires vigorous cooperation, whether in the Latin American and Caribbean region or globally. The Earth exploration-satellite service and, indeed, the entire telecommunications industry will benefit.

"The involvement of international bodies is vital to guarantee ongoing satellite services and EESS capabilities and to facilitate their further development."

"Developing and maintaining a safe and secure satellite environment requires vigorous cooperation, whether in the Latin American and Caribbean region or globally."

Sentinel-2 European Union

Satellite image of sediment flow from the Fitzroy River to the Great Barrier Reef.

CSIRO

A satellite view to improve life on Earth

Amy Parker, Director, Centre for Earth Observation (CSIRO), Australia

Did you know that satellites can detect a volcano inflating before it erupts? Or that satellite imagery is being used to understand the impact of the war in Ukraine on global food supply?

At CSIRO, Australia's national science agency, we are using Earth observation to address the biggest challenges facing society and our planet. For example, we've analysed satellite imagery of Ukrainian cropland and shipping activity since February 2022 to help measure the impact of war on global food supply.

Closer to home, we're using Earth observation to generate national-scale mineral maps, measure environmental recovery after bushfires, and track the impact of flood sediment on the Great Barrier Reef.

"At CSIRO, Australia's national science agency, we are using Earth observation to address the biggest challenges facing society and our planet."

Amy Parker

The data challenge

The recent proliferation of open-access Earth-observation imagery is providing unprecedented opportunities and value. The economic benefits attributable to Earth-observation data during 2020 were in the order of AUD 2.5 billion (about USD 1.6 billion) in Australia alone, according to Deloitte. However, exponential increases in the volume and variety of data pose increasing challenges to users, requiring us to change the way that we approach data management and analysis.

To tackle this problem, CSIRO is using cloud computing to provide next-generation Earth observation processing capabilities to our researchers and partners. With Geoscience Australia, Australia's National Computational Infrastructure, and the Committee on Earth Observation Satellites, we created the "Open Data Cube" – an open-source software for geospatial data management and analysis.

Combining the Open Data Cube with the advantages and innovations of commercial cloud computing, we developed our Earth Analytics Science and Innovation (EASI) platform. This high-performance, scalable data analytics platform benefits from – and contributes back to – the Open Data Cube community, whilst also providing access to CSIRO's diverse scientific expertise. The technology improves the scale and speed of calculations by large orders of magnitude, promoting a fail-fast (and learn-fast) approach and enabling innovative science.

Sharing the benefits of Earth observation

With EASI, we are striving not only to push the boundaries of science, but to ensure more equal access to the benefits of Earth observation across different regions, tackling issues that span geographic borders. Our proximity to Southeast Asia means we are well placed to work together with our neighbours there, using science to solve problems and sharing computing infrastructure, data, knowledge, expertise, and ideas to address our shared challenges.

"The recent proliferation of open-access Earth-observation imagery is providing unprecedented opportunities and value."

For example, we deployed EASI on in-region cloud computing infrastructure in Southeast Asia in 2021 and have since then worked with academics, innovators and scientists from across the region to provide technical training and develop use cases based on climate resilience and adaptation. Early adopters from Hasanuddin University in Indonesia have used the technology to investigate the impacts of climate change on the water quality of Lake Tempe, South Sulawesi.

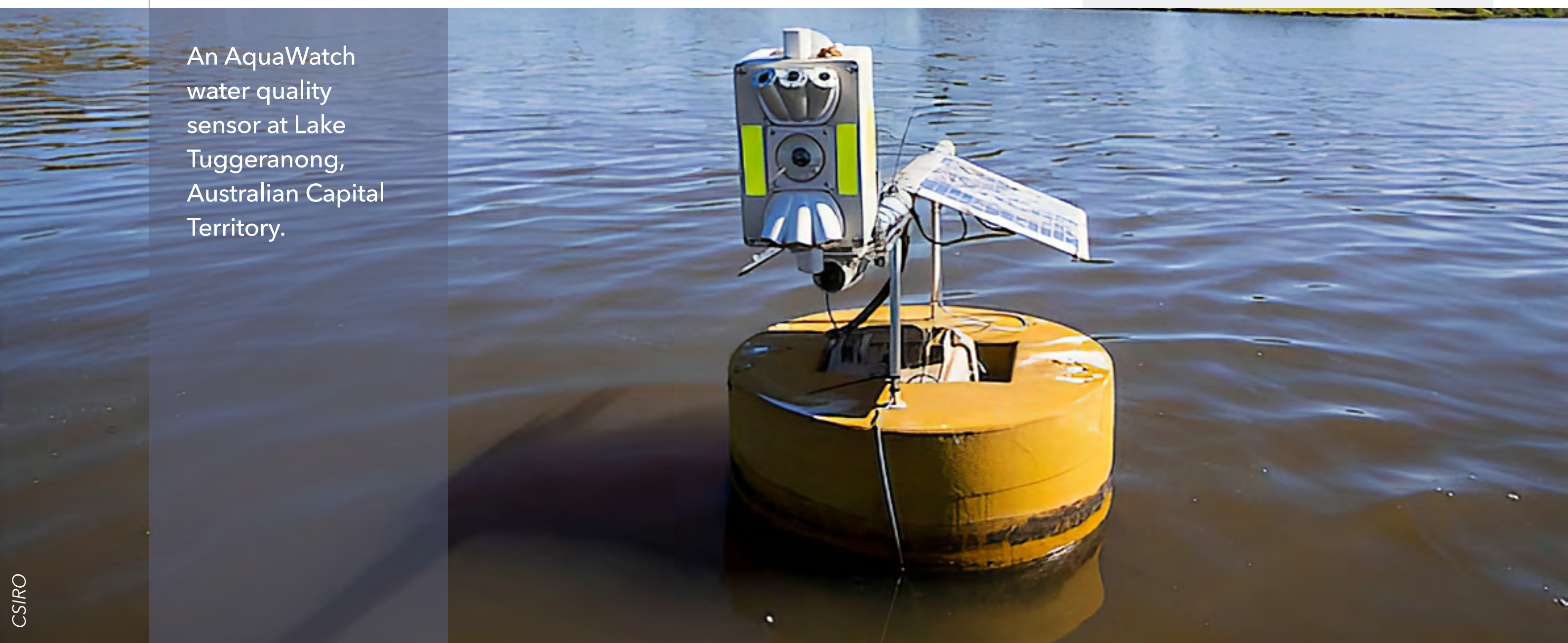
During a week-long hackathon, over 80 participants from Australia and Southeast Asia tackled applications related to carbon accounting, conservation, water security, and sustainable infrastructure.

"Back in Australia, we're now developing an EASI solution to inform us about our most vital resource – water."

Monitoring water quality from space

Back in Australia, we're now developing an EASI solution to inform us about our most vital resource – water. We are working with collaborators to co-design and deliver the AquaWatch Australia Mission – "a weather service for water quality" – to help safeguard freshwater and coastal resources in Australia and around the world.

The health and quality of inland and coastal waterways are under threat from increasing human activity and the effects of climate change. This is evident in the growing impacts from drought, bush fire sediment, storm events, toxic algal blooms and contamination.



An AquaWatch water quality sensor at Lake Tuggeranong, Australian Capital Territory.

CSIRO

EASI incorporates Earth-observation data from satellites with *in-situ* sensors and artificial intelligence (AI), thus creating an integrated system that can deliver accurate monitoring and forecasting across Australia and beyond.

The development, design, build and roll-out of the AquaWatch system infrastructure will benefit diverse end users and directly stimulate growth in Australia's domestic space capability. It will also drive expertise in remote sensing, advanced manufacturing, and engineering.

> *"Protecting the radio frequencies used by Earth-observation sensors and satellites is critical."*

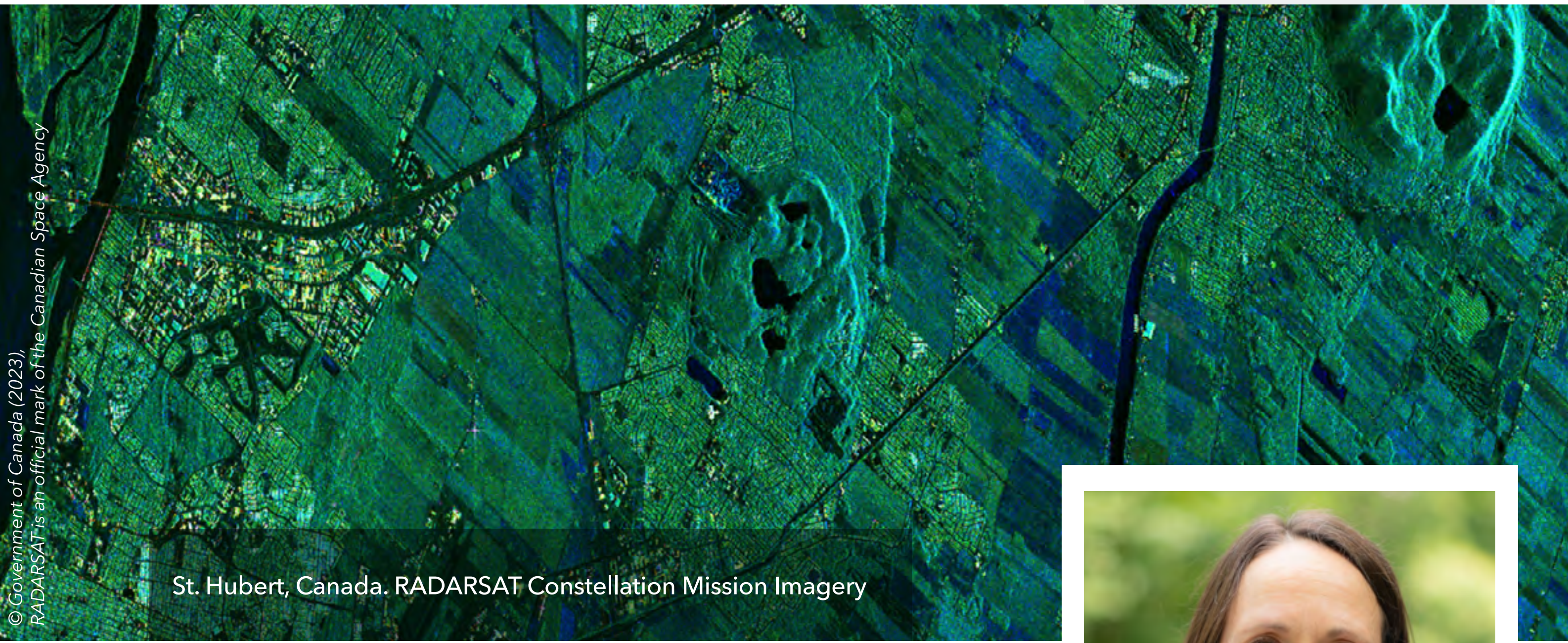
Protecting future access

Space presents significant opportunities to improve life on Earth. Taking a satellite view of our planet enables us to manage natural resources, address food-security challenges, respond effectively to disasters, adapt to and mitigate climate change, and optimize transport and urban development.

Protecting the radio frequencies used by Earth-observation sensors and satellites, therefore, is critical. We need to maintain our satellite view, through unhindered access to this valuable data, now and into the future.

CSIRO accesses imagery from NovaSAR-1, pictured here in a computer-generated image.

SSTL



St. Hubert, Canada. RADARSAT Constellation Mission Imagery

Earth exploration-satellite services in disaster response management

Joanne Frolek, Engineer, Space Utilization,
Canadian Space Agency

Not a day goes by without some disaster affecting people or ecosystems. Tornados, floods, landsides, forest fires, and even oil spills – are disasters that often cause extensive damage.

Satellites operating in the Earth exploration-satellite service (EESS) provide invaluable and immeasurable assistance to disaster-response organizations, helping them respond effectively and efficiently to save lives, assist in restoration, and protect critical infrastructure, ecosystems and property.

“Satellites operating in the Earth exploration-satellite service provide invaluable and immeasurable assistance to disaster-response organizations.”

Joanne Frolek

The International Charter "Space and Major Disasters"

Over 20 years ago, space agencies around the world created the International Charter 'Space and Major Disasters'. A collaboration between various space agencies and commercial satellite operators, the Charter allows national disaster management authorities in any country to request free satellite imaging to aid in disaster response.

Charter activation (by distribution)

Source: International Charter 'Space and Major Disasters', 2023.

Satellite sensors – different images for different purposes

The operators of the Charter determine the best satellites and sensor solutions to provide the most useful data based on a given disaster. Sensors operating at low frequencies provide better penetration into vegetation and are useful when a disaster occurs within vegetated areas. Sensors operating at high frequencies benefit from a larger available bandwidth and can provide better resolution images, like identifying damage to infrastructure.

Unlike optical sensors, synthetic aperture radar (SAR) sensors, with reduced latency, are unaffected by nighttime or clouds. This makes them highly effective in addressing key hazards like floods, oil spills, and landslides.

Hurricane Fiona

Last year, Hurricane Fiona passed over the Caribbean before hitting Canada's East Coast. The Category 4 storm was Canada's costliest ever. In response, the Canadian authorities activated the International Charter 'Space and Major Disasters' to obtain satellite data to facilitate rapid damage assessment and timely crisis management.

Different allocations for different types of EESS applications

Optical sensors do not currently require radio-spectrum allocations to operate, and infrared sensors are not allocated in the Table of Frequency Allocations maintained by the International Telecommunication Union (ITU). However, SAR sensors do require radio-spectrum allocations.

The table lists some SAR applications operating in different frequency bands along with some Charter satellites that operate in those bands.

Applications of SAR satellites in EESS (active) allocations

Frequency bands allocated to the EESS in the Radio Regulations	SAR applications	Operational Charter satellites
1215–1300 MHz	Biomass and vegetation mapping, forest monitoring, Earth deformation, soil moisture, and disaster management (best resolution: 3 m)	SAOCOM 1A, -1B ALOS-2
3100–3300 MHz	Agriculture (best resolution: 1.5 m)	None
5250–5570 MHz	Agriculture, land cover mapping, maritime applications (sea surface, ice, winds, oil pollution, maritime security), and disaster management. (Best resolution: <1 m)	Envisat Gaofen-3 RCM-1, -2, -3 RADARSAT-2 Sentinel 1A
9200–10 400 MHz	Infrastructure monitoring, object/change detection, topographic mapping, and ship detection and disaster management (dams, bridges, urban buildings). (Best resolution: < 0.25 m)	*COSMO-SkyMed2* *ICEYE-X2, X3, X4, X5, X6, X7* KOMPSAT-5 TerraSAR-X TanDem-X
13.25–13.75 GHz, 17.2–17.3 GHz	Snow water equivalent monitoring to improve prediction of flood events	None
35.5–36 GHz	New SAR altimeter application for ocean and surface water topography	None

Italics denote that the satellite's SAR operates in the 10–10.4 GHz EESS allocation.

> *Unlike optical sensors, synthetic aperture radar sensors, with reduced latency, are unaffected by nighttime or clouds.*

St. Hubert, Canada

Ensure spectrum availability

A potential new mobile service allocation and International Mobile Telecommunications (IMT) identification in 10–10.5 GHz in the Americas (Region2) is an agenda item for the upcoming World Radiocommunication Conference, WRC-23. This is of high importance to the disaster-management community, given the potential for harmful interference into the EESS systems providing important imaging to the global community.

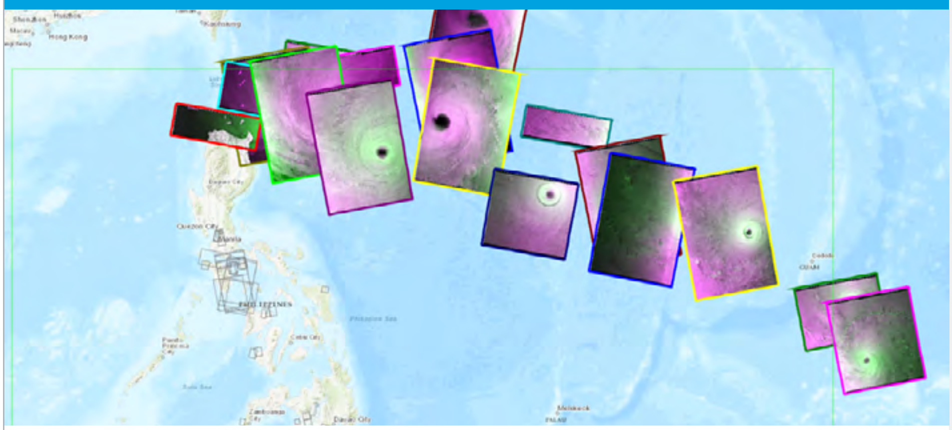
A previous WRC, in 2015, expanded the original EESS (active) allocation, recognizing the need for higher resolution data that the extension of the band allows. The allocation is valuable in situations where high-resolution data is needed over a localized area and weather conditions and the time of day prevent the use of optical sensors.

The high resolution offered by the 10 GHz band is advantageous in determining infrastructure damage in cities. At the same time, images and data from those urban areas would be most at risk from IMT deployments. Compromise on the existing use of the 10 GHz band could lead to erroneous and misinterpreted data, resulting in the loss of crucial information required for timely decision-making in disaster response.

To avoid major impacts to the EESS user community, all Earth-observation stakeholders need to ensure that satellite sensors can operate in this frequency band and other bands without interference. Failure to protect the EESS allocations would lower the quality of satellite images for disaster response efforts, undermining the International Charter and the EESS user community.

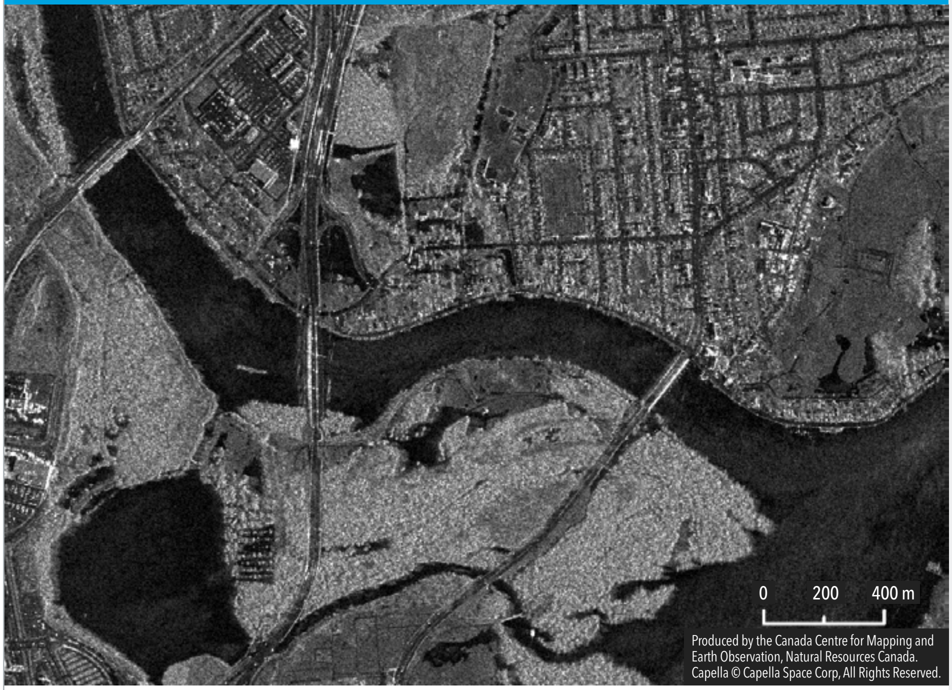
“Compromise on the existing use of the 10 GHz band could lead to erroneous and misinterpreted data, resulting in the loss of crucial information required.”

CSA Hurricane Watch, Typhoon Mawar, aka Super Typhoon Betty, from 22 May to 10 June 2023. RADARSAT Constellation Mission Imagery



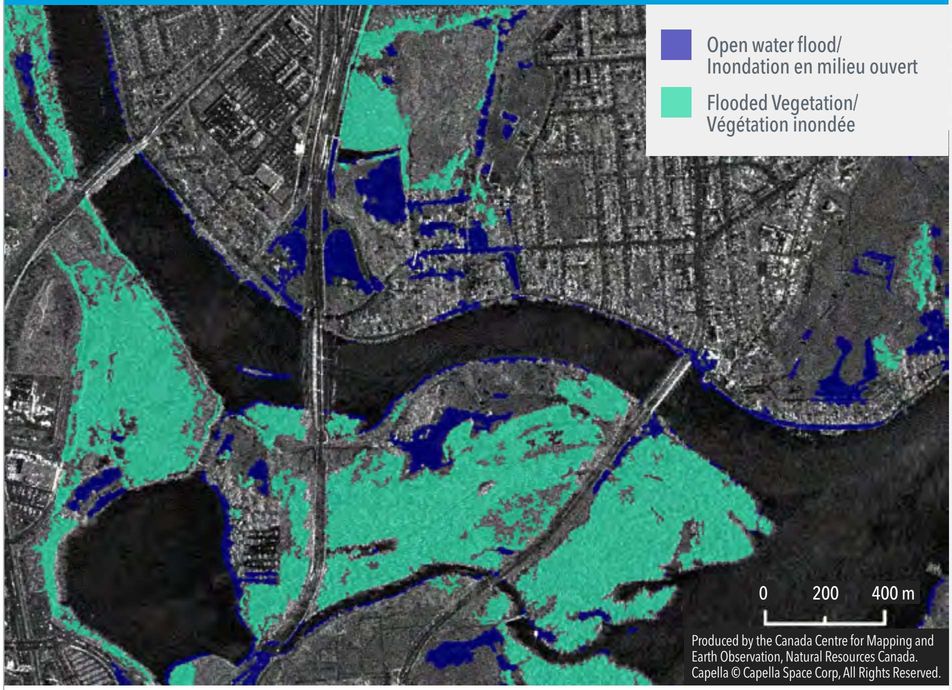
Government of Canada (2023). RADARSAT is an official mark of the Canadian Space Agency

Gatineau, Canada; Capella X-band SAR image before processing



Source: Capella, CCMEO.

Capella X-band SAR image, with flood mapping overlap



Source: Capella, CCMEO

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