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Space science for achieving the Sustainable Development Goals

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Space science for achieving the Sustainable Development Goals

By Houlin Zhao, ITU Secretary-General

ITU has contributed to the space endeavour since its inception. This edition of the ITU News Magazine focuses on ITU's role in space science and in particular in areas of critical importance for humanity and the planet in support of the Sustainable Development Goals (SDGs).

Since the SDGs were adopted at the United Nations Sustainable Development Summit in New York in September 2015, they have been guiding us in striving towards a better world for everyone.

Through ITU's efforts and global collaboration in space science, we have seen ground-breaking advances in communication technology, the unique capabilities of satellites brought to the fore in SDG initiatives, and its essential tool in monitoring the Earth and tackling climate change.

Space science services are the subject of the ITU's Radiocommunication Sector (ITU–R) Study Group 7. ITU–R Study Groups produce universally applied regulations, standards and best practices that enable the sustainable development of the wireless ecosystem.

With 10 years left to achieve the SDGs, you can read more about how ITU's work and its global partnerships are leveraging space science to make our world a better and more inclusive place.

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Houlin Zhao

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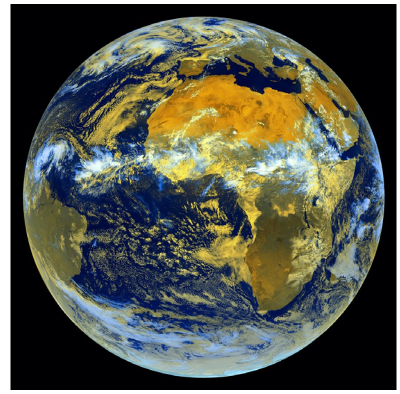
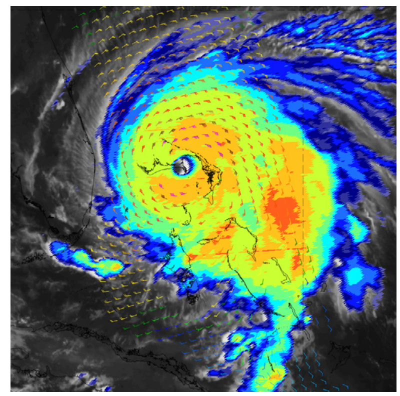
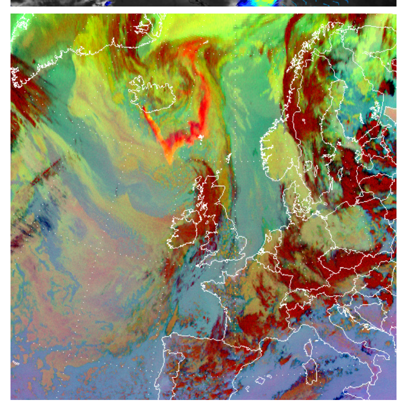
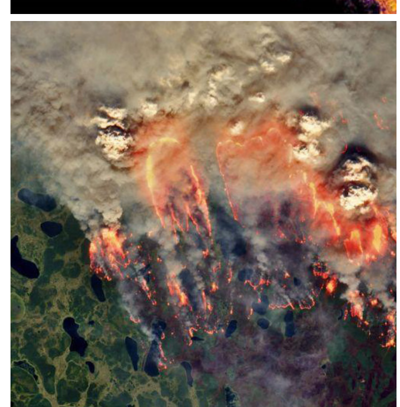








Foreword by the Director

By Mario Maniewicz, Director,
ITU Radiocommunication Bureau

I am delighted to present to you this ITU News Magazine edition, which contains articles and viewpoints on how space science and technologies can be harnessed to accelerate the attainment of the 2030 Agenda for Sustainable Development.

Space assets and technologies can be used to support most, if not all, the United Nations Sustainable Development Goals (SDGs). Data from Earth-observation satellites play a key role in most of the seventeen SDGs to help monitor targets, plan and track progress, and help countries and organizations make well-informed decisions as they work towards SDG objectives to improve daily life on our planet.

Satellite data, images and information provide useful insights into tackling some of the major global development challenges including providing food security, reducing the risk of disasters, preventing humanitarian crises, monitoring natural resources, and reducing poverty.

A recent report by the United Nations Office for Outer Space Affairs made the following observation, *"For the 2030 Agenda for Sustainable Development to be successful, the use of space services shall become the norm. A global partnership is needed to ensure that countries are fully aware of the potential of space to implement and monitor the SDGs, and to ensure that the needs of all countries are taken into account, reducing existing gaps, when designing and operating new space-based infrastructure."*

Learn more here.

"Satellite data, images and information provide useful insights into tackling some of the major global development challenges."

Mario Maniewicz

> *It is just over one year since we successfully concluded WRC-19 and paved the way for new, more innovative ways to connect the world through both terrestrial and space-based communication technologies.*
>
> Mario Maniewicz

Ground-breaking advances in communication technology

Since the launch of the first satellite in 1957, we have witnessed ground-breaking advances in satellite design, manufacturing and launch service capabilities providing immeasurable opportunities for Earth observation, weather forecasting, remote sensing, global positioning systems, satellite television, mobile communication systems and many others.

It is just over one year since we successfully concluded the World Radiocommunication Conference 2019 (WRC-19) and paved the way for new, more innovative ways to connect the world through both terrestrial and space-based communication technologies.

Regularly updating the ITU Radio Regulations at each WRC is key to enabling advancements in satellite imagery and Earth resource monitoring, space science and missions, meteorology, maritime and aeronautical transport and safety, civil protection, and defence systems.

The decisions reached at WRC-19 will enable the introduction of new technologies, as well as the protection of existing services, and will allow people and industries to benefit from the advances of radiocommunication technologies.

The unique capabilities of satellites

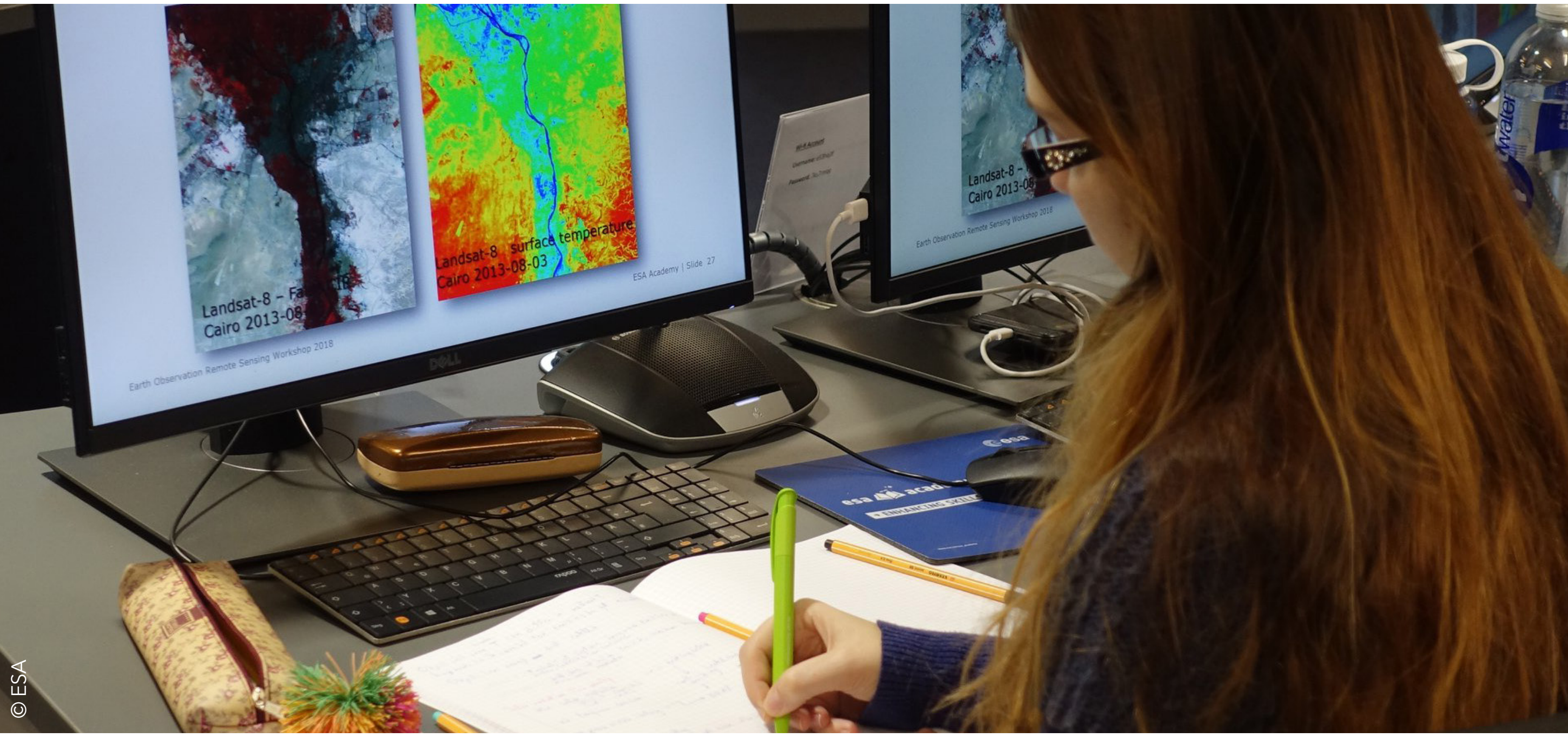
Satellites provide the only viable way to monitor the environment of the entire Earth, land, sea, and air. The unique capabilities of satellites include observing wide areas non intrusively and uniformly (by using the same instrument) with the ability to rapidly target any point on Earth, including remote and inhospitable places, and to continue with a series of observations over a long period of time.

Through these capabilities, the Earth exploration-satellite service brings many benefits to society in both the public and private sector.

The threat of climate change

The growing threat of climate change is all around us. The number of natural disasters has increased considerably in the last decades: hurricanes, earthquakes, storms, floods and fires. Robust and effective international action has never been more urgent.

Space-enabled technology applications have become an important element of local, regional and national disaster risk reduction strategies including the provision of emergency communications and tracking and tracing efforts during and after natural disasters and in complex humanitarian emergencies.



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As accurate weather predictions need to start from the best possible assessment of the current state of the atmosphere, it is crucial that meteorologists have real-time, accurate global observations about what is happening in the Earth's atmosphere over land and oceans. Many of the solutions will be informed by global monitoring of the environment, including the use of space assets.

Monitoring – essential for data

In addition, data obtained by using relevant radio systems are essential for monitoring the results of SDG initiatives. For example, around 30 of the 232 indicators developed for monitoring the progress towards the SDGs require data obtained from remote sensing satellites.

From the point of view of radio spectrum use, it is necessary not only to ensure access to appropriate resources for the relevant radio systems, but also to guarantee the protection from man-made emissions of the bands that are used globally for monitoring the various parameters of the Earth's atmosphere and surface by exploiting natural radio emissions.

It is my hope that you will enjoy reading the articles in this edition.

Spectrum management for science services after WRC-19

By John Zuzek, Chairman, ITU Radiocommunication Sector (ITU–R) Study Group 7

The ITU Radiocommunication Sector (ITU–R) Study Group 7 (SG 7) deals with radio services supporting scientific pursuits. Among space science services are the Earth exploration-satellite and meteorological-satellite services, including systems for passive and active remote sensing.

These radio services enable us to obtain important data about Earth and its atmosphere. The world's civil space agencies use the space research and space operation services to explore and work in space. These include robotic missions to other planets and objects in space along with the human exploration of space, the Moon, and beyond.

Currently, there is a focused effort by many nations to explore and further understand the Moon, demonstrate that humans can live beyond Earth's orbit, and eventually extend human exploration to other planetary bodies.

WRC-19 agenda items directly related to space science/meteorology

At the World Radiocommunication Conference 2019 (WRC-19), three agenda items (AIs) were directly related to space science and meteorology. Their outcomes are summarized in Table 1.

WRC-19 agenda item 1.2

AI 1.2 dealt with in-band power limits for earth stations operating in the mobile-satellite service, meteorological-satellite service and Earth exploration-satellite service in the 401–403 MHz and 399.9–400.05 MHz frequency bands.

Based on studies carried out in ITU–R Study Group 7, WRC-19 enacted in-band power limits accordingly.

"There were also several WRC-19 agenda items that were of concern to the space science and Earth-observation operators due to the possible negative impacts on their missions."

John Zuzek

Table 1 – WRC-19 outcomes for science service agenda items

WRC-19 agenda item		Outcomes
1.2	In-band power limits for the mobile-satellite service, meteorological-satellite service, and Earth exploration-satellite service earth stations around 400 MHz.	■ Power limits placed on mobile-satellite service earth stations (399.9–400.02 MHz). ■ No power limits on higher telecommand operations (400.02–400.05 MHz). ■ Power limits placed across 401–403 MHz.
1.3	Upgrade of the meteorological-satellite service (space-to-Earth) and Earth exploration-satellite service allocation (space-to-Earth) at 460–470 MHz.	■ No change.
1.7	Short-duration missions.	■ 137–138 MHz and 148–149.9 MHz for use by non-geostationary satellite orbit (non-GSO) satellites with short-duration missions.

WRC-19 agenda item 1.3

AI 1.3 considered the possible upgrade of the secondary allocation to the meteorological-satellite service (space-to-Earth) to primary status and a possible primary allocation to the Earth exploration-satellite service (space-to-Earth) in the frequency band 460–470 MHz. Unfortunately, WRC-19 could not come to agreement on a solution to this agenda item so there was no change to the Radio Regulations in this regard.

WRC-19 agenda item 1.7

AI 1.7 was developed to study the spectrum needs for telemetry, tracking, and control (TT&C) in the space operation service for non-GSO satellites with short duration missions, to assess the suitability of existing allocations to the space operation service and, if necessary, to consider new allocations in certain portions of the radio spectrum. WRC-19 decided to identify the frequency ranges 137–138 MHz and 148–149.9 MHz for use by non-GSO satellites with short-duration missions subject to several terms and conditions outlined in a Resolution.

WRC-19 agenda items with potential negative impact to space science and Earth observation

There were also several WRC-19 agenda items that were of concern to the space science and Earth-observation operators due to the possible negative impacts on their missions. The outcomes of these items are summarized in Table 2.

Table 2 – WRC-19 outcomes on agenda items of concern to science services

WRC-19 agenda item		Outcomes
1.6	A regulatory framework for non-GSO fixed-satellite service (FSS) at 37.5–39.5 GHz (↓) and 47.2–50.2 GHz (↑).	■ The outcome is significantly better than the existing Resolution-750 limits for the fixed-satellite service. ■ Limits provide full protection for nadir-scanning sensors operating in the 50.2–50.4 GHz passive band.
1.13	International Mobile Telecommunications (IMT) identification between 24.25–86 GHz.	■ 24.25–27.5 GHz: Satisfactory protection achieved. ■ 37.0–40.5 GHz: Satisfactory protection achieved. ■ 47.2–50.2 GHz, 50.4–52.6 GHz, 81.0–86.0 GHz: No change for these bands.
1.14	High-altitude platform station (HAPS) systems in the 22 and 26 GHz frequency bands.	■ Satisfactory outcomes for all science-service bands.
1.15	Identification of land mobile and fixed service use between 275–450 GHz.	■ Bands identified for land-mobile and fixed-service applications neither preclude use nor establish priority. ■ Protection of current and future Earth-observation applications is established.

WRC-19 agenda item 1.6

WRC-19 AI 1.6 considered the development of a regulatory framework for non-GSO fixed-satellite service systems in certain bands between 37.5 and 51.4 GHz. Two of those frequency bands, 47.2–50.2 GHz and 50.4–51.4 GHz, for uplink transmissions, were immediately adjacent to either side of the 50.2–50.4 GHz passive Earth-observation band which is critical as a calibration window to measurements of atmospheric temperature. This item was studied extensively within Study Group 4 (SG 4 – Satellite Services) and WRC-19 enacted provisions that placed out-of-band emission limits on earth-station transmissions for both GSO and non-GSO satellite systems to help protect these atmospheric sensing systems.

WRC-19 agenda item 1.13

AI 1.13 considered the identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis for this purpose in various bands from 24.25 to 86 GHz.

For space science system operators, the main concern was the protection of existing earth stations operating in 25.5–27 GHz for both Earth observation and space research downlinks and ensuring the operation of future receiving earth stations in this band.

WRC-19 decided that such protection should be facilitated through bilateral agreements for cross-border coordination as necessary.

A second issue involved the protection of certain critical Earth-observation passive sensing bands, such as 23.6–24 GHz, 31.3–31.8 GHz, 50.2–50.4 GHz, 52.6–54.25 GHz, and 86–92 GHz. The protection of these bands from aggregate interference from out-of-band (OOB) emissions is critical as many of these bands are used to obtain measurements on a global basis that cannot be made in any other way.

For most of these bands, WRC-19 did not identify the adjacent bands for IMT use so no further action was required. For the 23.6–24 GHz band, WRC-19 enacted initial OOB emission limits on the IMT systems transitioning to stricter limits, as potential deployments of IMT systems are envisioned to increase over time.

WRC-19 agenda item 1.14

AI 1.14 considered appropriate regulatory actions for high-altitude platform station (HAPS) systems within existing fixed-service allocations. WRC-19 resolved this agenda item in ways that provide for the protection of the science-service uses in a satisfactory manner.

WRC-19 agenda item 1.15

Finally, AI 1.15 considered the identification of frequency bands for use by administrations for the land-mobile and fixed-services applications operating in the frequency range 275–450 GHz. There are several bands that are being used by Earth-observation systems in this frequency range. Based on ITU–R studies, except for the bands 296–306 GHz, 313–318 GHz and 333–356 GHz, the rest of this frequency range was identified for use by fixed and land mobile operations while allowing for future studies when additional information on such systems becomes more available.

WRC-23 agenda items for space science and Earth observation

WRC-19 established the agenda for the next World Radiocommunication Conference in 2023 (WRC-23). In doing so, WRC-19 decided to include four agenda items of direct interest to the space science community. These are shown in Table 3.

> *There are several WRC-23 agenda items that concern ITU–R Study Group 7 working parties because of their possible impact on the science services.*
>
> John Zuzek

WRC-23 agenda item 1.12

WRC-23 AI 1.12 concerns the possible secondary allocation to the Earth exploration-satellite service (active) for spaceborne radar sounders in the range of frequencies around 45 MHz. The reason that this allocation is being sought is to enable remote sensing from Earth orbit of the Earth's ice sheets in polar regions, and to locate and understand aquifers and underground water in desert regions.

Table 3 – WRC-23 agenda items related to science services

WRC-23 agenda item		Area of interest
1.12	Radar sounders around 45 MHz.	■ Space-based active sensing to detect water tables below ground level and ice thickness in polar regions.
1.13	Possible primary upgrade of the space research service in 14.8–15.35 GHz.	■ Current space research links to data relay satellites are on a secondary basis and future systems also require use of this band.
1.14	Adjustments to Earth exploration-satellite service (passive) allocations in 231.5–252 GHz.	■ Envisioned Earth remote sensing operations are not properly aligned with scientific needs.
9.1 a	Space weather.	■ Obtaining regulatory recognition of space weather sensors.

WRC-23 agenda item 1.13

WRC-23 AI 1.13 examines a possible upgrade to the primary status of the existing secondary allocation to the space research service in the frequency band 14.8–15.35 GHz. This frequency band is currently used by data relay satellites operating in the space research service which enables communications with non-GSO space research spacecraft. It is also used by existing high-speed data links from non-GSO space research spacecraft and is planned for use in future systems as well.

WRC-23 agenda item 1.14

WRC-23 AI 1.14 concerns the review of frequency allocations for passive Earth-observation sensors in the frequency range 231.5–252 GHz and possible adjustment according to the observation requirements of these passive microwave sensors. Such sensors are being planned to study ice clouds on the next generation of polar meteorological satellites. The purpose here is to ensure that the allocations to the Earth exploration-satellite (passive) service, within this frequency range considered, correspond to the observation requirements for these sensors.

WRC-23 agenda item 9.1 a)

WRC-23 AI 9.1 a) concerns the protection of space weather sensors that rely on radio-frequency systems for observations, global predictions and warnings. The ITU–R Study Group 7 will conduct studies on this, the results of which will be conveyed to WRC-23 by the Director of the Radiocommunication Bureau.

There is also an item on the tentative agenda for WRC-27 to consider possible regulatory provisions for the appropriate recognition of space weather sensors in the Radio Regulations, taking into account the results of the WRC-23 ITU–R studies.

Concerns about WRC-23's impact on the science services

Finally, there are several WRC-23 agenda items that concern ITU–R Study Group 7 working parties because of their possible impact on the science services. The study group will contribute to the studies on these items to ensure that the important work of the science services can continue into the future.

To continue the vital work of the science services in studying the environment and assisting in mitigating the environmental changes that threaten the entire planet, ITU–R Study Group 7 participants continue to perform the studies required to enable and protect the radio services supporting scientific pursuits. The protection of environmental, climate, and atmospheric Earth-observation systems and their sensors, including space weather sensors, is the very best way to continue studying our planet and furthering the understanding of our fragile home in the cosmos.

We also seek to reach for the stars, studying other planetary bodies, which ultimately assists humankind in understanding our own planet, and our place in the universe. ■

About ITU–R Study Group 7

The systems linked with Study Group 7 (SG 7) are used in activities that are a critical part of our everyday life, such as:

- Global environment monitoring – atmosphere (including greenhouse gases emissions), oceans, land surface, biomass, etc.
- Weather forecasting and climate change monitoring and prediction.
- Detection and tracking of many natural and man-made disasters (earthquakes, tsunamis, hurricanes, forest fires, oil leaks, etc.)
- Providing alert/warning information.
- Damage assessment and planning relief operations.

SG 7 also encompasses systems for the study of outer space:

- Satellites for studying the Sun, the magnetosphere and all the elements of our solar system.
- Spacecraft for human and robotic exploration of extraterrestrial bodies.
- Earth and satellite-based radio astronomy to study the universe and its phenomena.

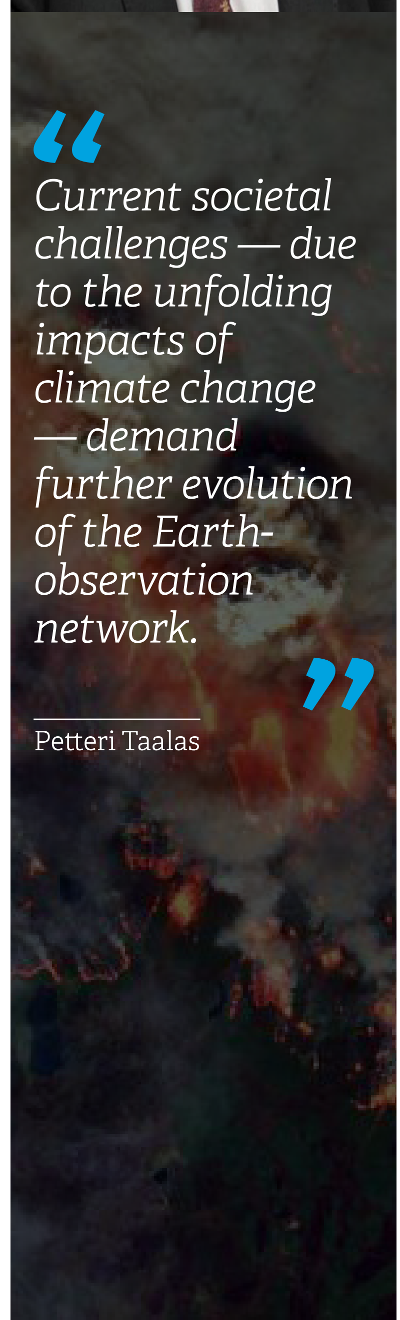
Learn more about SG 7 here.

The importance of progress in Earth observation from space to protect our planet

By Petteri Taalas, Secretary-General, World Meteorological Organization (WMO)

The World Meteorological Organization (WMO), the specialized agency of the United Nations for weather, climate, water and related environmental issues, is dedicated to international cooperation and coordination on the state and behaviour of the Earth's atmosphere. This includes its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources.

Meteorology has made enormous progress in the quality and diversity of weather-forecast services since the launch of the first meteorological satellites in 1957/1958 gave rise to the World Weather Watch (WWW) in 1963. But current societal challenges – due to the unfolding impacts of climate change – demand further evolution of the Earth-observation network: An upgrading of the global space- and surface-based observing systems and the adoption of a new and integrated approach that incorporates recent scientific and technical advances.



"Current societal challenges — due to the unfolding impacts of climate change — demand further evolution of the Earth-observation network."

Petteri Taalas

Enhancing the understanding of our Earth system

The WMO Integrated Global Observing System (WIGOS), encompassing both surface and space-based observations, is enhancing the understanding of our Earth system and facilitating the production of weather and climate services and products, through the provision of more and better observations. The observing networks provided by WMO Members form the backbone of WIGOS and the information gathered through these networks is vital for the global community.

WIGOS contributes to ensuring safety of life and property, and in the longer term to implementing global development agendas, such as the 2030 Agenda for Sustainable Development, the Paris Climate Agreement and the Sendai Framework for Disaster Risk Reduction.

The space-based observational capabilities have greatly improved since the launch of the first weather satellites in the early 60s. Today they provide high-precision observations of a wide range of parameters and are a key input for global numerical weather prediction models, underpinning the services of all WMO Members, enabling the protection of life and property. This allows us not only to monitor the weather, climate and water, but also to assess the health of the environment and the extent to which human activities are sustainable.

Recent impressive progress in analysis and forecasts

The impressive progress made in recent years in weather, water and climate analysis and forecasts, including warnings for dangerous weather phenomena (heavy rain, storms, cyclones) that affect all populations and economies, is to a great extent attributable to data provided by the spaceborne component of WIGOS and the assimilation of space-based observations in numerical models. Spaceborne sensing of the Earth's surface and atmosphere will continue to play an increasingly important role in operational and research meteorology, disaster monitoring, and in the scientific understanding, monitoring and prediction of climate change and its impacts as well as anthropogenic emissions, critical for the implementation of the Paris Agreement.

Studies have shown that Earth observation can contribute to the measurement of approximately 34 of the indicators linked to the 17 Sustainable Development Goals. (SDGs). The WMO Space Programme works closely with satellite operators in the Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observation Satellites (CEOS) to provide the necessary data and products at the spatial and temporal resolutions required by end users. It also provides guidance for the development of future space-based observing systems which is based on the Vision for the WMO Integrated Global Observing System in 2040, describing the desired space-based observing system capabilities we aim to operate by the year 2040 to fulfil observing and user requirements.

The WMO's space-based Observing System Capability Analysis and Review Tool (OSCAR/Space) as of October 2020 lists 288 operational satellite platforms contributing to this effort, which will be joined by ever more advanced next-generation satellites over the coming years. During the ongoing COVID-19 pandemic situation it has been found that the usually highly automated space-based observing systems have in general so far been more resilient than in-situ based ones (learn more here).

Radio-frequency bands — an important natural resource for spaceborne sensing

Spaceborne sensing for meteorological applications is performed in specific radio-frequency bands. These bands are determined by fixed physical properties (molecular resonance) that cannot be changed or ignored, nor can these physical properties be duplicated in other bands. Therefore, these frequency bands are an important natural resource.

Even low levels of interference may degrade the data and in most cases the sensors cannot discriminate between natural and man-made radiation.

In the more critical passive sensing frequency bands, the Table of Frequency Allocations in the international Radio Regulations states that "all emissions are prohibited", enabling in principle the deployment and operation of sensors with the highest reliability. However, experience has shown that in some cases the protection is jeopardized due to unregulated, and in some cases by mass-market short-range devices allowed nationally to operate in these bands or by unwanted emissions from improperly regulated adjacent bands, putting increasing pressure on the frequency bands used for meteorological purposes. This presents potential risks of limiting meteorological and other related applications.

Ground-based observations and their reliance on specific radio-frequency bands

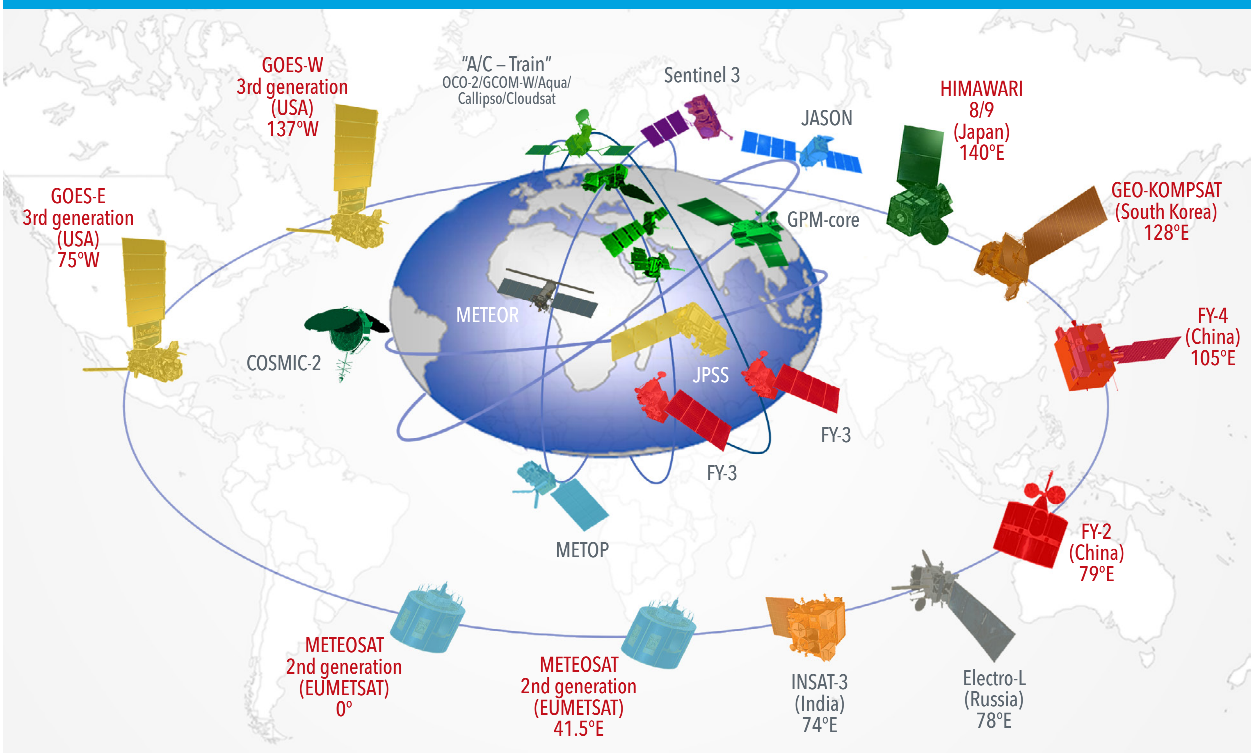
In addition to space-based observations, meteorological radars and wind profilers are important surface-based instruments in meteorological observation processes. Meteorological radar networks represent the main line of defence in a disaster-warning strategy against loss of life and property in flash flood or severe storm events, such as in several recent dramatic cases. In a similar fashion to space-based instruments these ground-based observations rely on specific radio-frequency bands.

Radio frequencies are therefore critical in terms of remote sensing from both ground-based and space-based observations. However, also of great importance is the availability of sufficient and well-protected radio-frequency spectrum for data relay of some ground-based observations, like radiosondes, and as well as telemetry/telecommand for satellite control and downlink of the collected data.

In this context, Resolution 673 of the International Telecommunication Union (ITU) World Radiocommunication Conference 2012 (WRC-12, held in Geneva, Switzerland) recognizes the value of Earth-observation data for the whole international community, and its dependency on radio frequencies. It further resolves to:

- continue to recognize that the use of spectrum by Earth-observation applications has a considerable societal and economic value;
- urge administrations to take into account Earth observation radio-frequency requirements and in particular protection of the Earth-observation systems in the related frequency bands;
- encourage administrations to consider the importance of the use and availability of spectrum for Earth-observation applications prior to taking decisions that would negatively impact the operation of these applications.

Figure 1 – Some of the current satellites providing observations to WMO Members in support of achieving the Sustainable Development Goals



It is therefore critical that the Earth-observation community works together with the ITU Radiocommunication Sector (ITU–R) with a forward-looking view on radio-frequency matters. WMO remains committed to ITU and through its Expert Team on Radio Frequency Coordination (ET-RFC) works closely with its members to support ITU in its work to help allocate global radio spectrum. WMO is also an active participant in the World Radiocommunication Conferences (WRCs), such as WRC-19 held in November 2019. The ET-RFC is also preparing WMO's position on the WRC-23 agenda, which will be further refined in the years leading up to the conference.

The protection of the radio frequency spectrum for Earth observation is of the highest priority to WMO and its members and WMO is looking forward to continuing close collaboration with ITU to ensure that we can provide the essential observations in support of sustainable development and in achieving the SDGs. (See Figure 1.)

How satellites contribute to environmental protection and mitigation

Here are just a few examples of how satellites contribute to environmental protection and mitigation in support of the SDGs:

Global Numerical Weather Prediction (NWP) underpins most application areas within an Earth-system modelling approach integrating all domains including atmosphere, ocean, cryosphere and land. The WMO Rolling Review of Requirements and the WMO Global Observing System (GOS) Vision for 2040 provide the guidance and requirements for essential ground-based, in-situ and satellite observations for a state-of-the-art NWP system. Today, satellite data from the WMO space-based part of the GOS provide 90 per cent of the data actively assimilated during the initialization of the NWP models with a significant impact on the quality of the NWP forecasts.

The Copernicus Atmosphere Monitoring Service (CAMS) implemented by the European Centre for Medium-Range Weather Forecasting (ECMWF) on behalf of the European Union provides air quality information using satellite and ground-based observations and advanced numerical models. The service also monitors ozone and UV radiation and observes smoke emanating from wildfires. It has also allowed for assessment of the impact of COVID-19 on air quality in Europe and globally.

The WMO Disaster Risk Reduction (DRR) Programme assists WMO Members in developing and delivering services that are directed at protecting lives, livelihoods and property from natural hazards in a cost-effective, systematic, and sustainable manner. For instance: It is well documented that high-impact weather events and climate extremes, e.g. rapid onset as flash floods have devastating effects throughout the world. The Global Space Based Observing System operated by CGMS and CEOS Space Agencies are providing data for global flood map products and information, allowing to detect floods and flood extent. In response to the need for flash flood early warnings, WMO together with its partners the United States National Weather Service, the Office of U.S. Foreign Disaster Assistance, and the Hydrologic Research Center have developed and implemented an early warning flash flood forecasting system (Flash Flood Guidance System – FFGS) for global application. This is especially important when climate pressures, resulting in more severe precipitation events and rising ocean levels, contribute to more frequent and pervasive flash floods and coastal flooding.

Satellites also provide information and tools to support wildfire management at varying geographic scales as well as assessing fire effects at global level (see Figure 2). Recently, exceptional and prolonged heat in Siberia has fuelled unprecedented Arctic fires, with high carbon emissions, contributing to the already complex climate situation. Again, it is CAMS that incorporates observations of wildfires from the MODIS instruments on NASA's Terra and Aqua satellites into its Global Fire Assimilation System (GFAS) to monitor fires and estimate the pollution that they emit. Another service addressing wildfires is the Global Observation of Forest Cover-Global Observation of Land Dynamics (GOFC-GOLD) Fire Implementation Team (GOFC Fire IT) contributes to the Global Wildfire Information System (GWIS).

Figure 2 – Satellite images from Europe's Sentinel 3 taken in July 2020 showed that the wildfires affecting Siberia inside and outside the Arctic Circle cover a width of about 800 kilometres.

Countries in the Asia-Pacific region are increasingly affected by tropical cyclones. The China Meteorological Administration (CMA) and the Japan Meteorological Agency (JMA) provide so-called request-based high frequency regional observation, which can also provide useful information for other extreme events as heavy rain, severe convection, forest or grassland fire and sand and dust storm. These observation services are frequently used by the WMO Regional Specialized Meteorological Centres with the activity specialization in tropical cyclones and WMO Tropical Cyclone Warning Centres, for example, to track the path of cyclones over the open water.

Satellites – a major role in tracking ocean climate change

Satellites also play a major role in tracking the impact of the changing climate on our oceans. Today, space-based climate data records cover 37 of the 54 Essential Climate Variables defined by the Global Climate Observing System (GCOS) – a programme co-sponsored by WMO, the Intergovernmental Oceanographic Commission of UNESCO, United Nations Environment Programme (UNEP) and International Science Council. For example, a range of satellite altimetry missions have helped us to track the mean sea level rise over the past decades.

The space-based observations cited in the above examples use active and passive instruments that rely on measuring minute changes in specific bands of the radio-frequency spectrum. It is therefore of paramount importance that these bands are protected and remain free from interference. ■

Space as an enabler to achieve the Sustainable Development Goals

By ISHII Yasuo, Vice President, Japan Aerospace Exploration Agency (JAXA)

The Japan Aerospace Exploration Agency (JAXA) is Japan's national research and development agency designated to support the Japanese government's overall aerospace activities. It engages in a wide range of undertakings, from basic aerospace research and development to space utilization.

Japan's new Basic Plan on Space Policy, adopted in June 2020, has set solving global issues, including contributing to achieving the Sustainable Development Goals (SDGs), as one of the core targets of Japan's space activities.

Space science, technologies and innovation have significant potential to contribute to the SDGs. With its diverse expertise and assets, JAXA is well-positioned to support these global and national efforts.

Earth-observation satellites or Earth-exploration satellites in particular are cutting-edge technologies that strongly contribute to the achievement of the SDGs. Satellites provide essential information on disaster-risk management and agricultural activities in our daily lives on Earth. Long-term observation and the accumulation of archived data can improve worldwide climate change projection. In this way, Earth observation by satellites can enhance the sustainability of our Earth, including human society.

A variety of JAXA's Earth-observation programmes have been contributing to relevant SDGs through its partnerships with various stakeholders around the world. Here are some examples of our efforts.

"Space science, technologies and innovation have significant potential to contribute to the SDGs."

ISHII Yasuo

Life on land and climate action

The first example concerns "Life on land" and "Climate action". Together with the Japan International Cooperation Agency (JICA), JAXA has been operating the JICA-JAXA Forest Early Warning System (JJ-FAST) to monitor forest data since 2016. It offers free and easy access to information on deforestation and changes in global rainforests via the Internet.

The data from JAXA's L-band Synthetic Aperture Radar satellite, ALOS-2, is used to observe the Earth's surface day and night, and in all weather conditions. It now monitors tropical forests in 77 countries and has detected more than 308 000 areas of forest cover changes since its launch.

JAXA satellites for SDG 15 – forest monitoring

JJ-FAST is a valuable tool for sustainable forest management, combatting global warming, and halting biodiversity loss.

Sustainable water management, resilient cities and climate action

Another example is a global rainfall watch system called GSMaP for "Sustainable water management", "Resilient cities," and "Climate action".

Every hour, JAXA provides an updated global precipitation map by integrating various satellite and sensor data from Japan's meteorological satellite (Himawari), precipitation radars (PR, DPR), and the Advanced Microwave Scanning Radiometer (AMSR-2), together with those of the United States and Europe. Currently, meteorological agencies and disaster-management organizations in 133 countries worldwide are using the data from GSMaP. It significantly helps countries in the Asia-Pacific region suffering from typhoons and hazardous rainfall by providing essential information that is difficult to observe with ground-based radars. We are pleased and honoured that GSMaP effectively supports the stability and resilience of the region.

> *"Through working together, we believe that space agencies can play a foundational role in enabling sound and well-informed decision-making for better 'Climate action'."*
>
> ISHII Yasuo

The COVID-19 Earth-observation dashboard

Another more recent example is the response to the COVID-19 pandemic. Three space agencies, JAXA, NASA and ESA have joined forces to create a satellite data dashboard that shows the environmental and economic effects of the COVID-19 pandemic. It demonstrates the strength of Earth-observation satellites that can provide synoptic and scientific views from space despite the global challenges caused by the coronavirus outbreak on Earth.

For example, the CO_2 and NO_2 emission reduction during lockdown can be seen based on the data from each respective organization's greenhouse gas observing satellite series, including the Greenhouse Gases Observing Satellite (GOSAT), the Orbiting Carbon Observatory 2 (OCO-2), and Sentinel.

Such satellite data is expected to contribute to the Global Stocktake under the Paris Agreement (see figure).

Through working together, we believe that space agencies can play a foundational role in enabling sound and well-informed decision-making for better "Climate action".

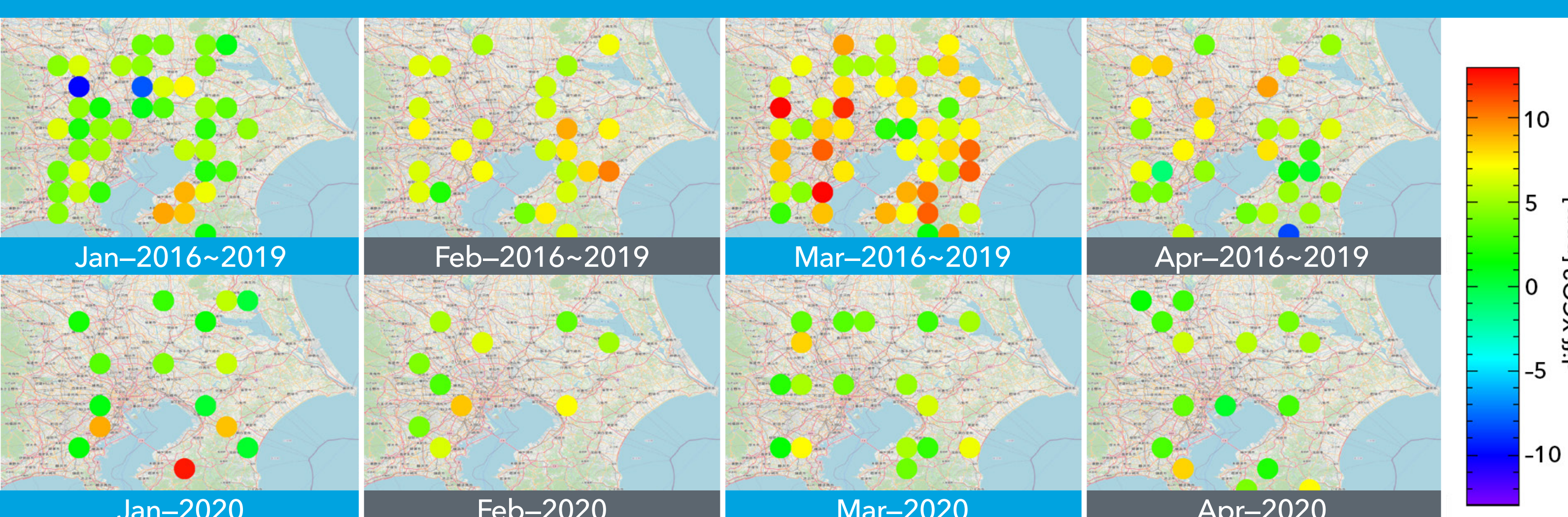
KiboCUBE: A partnership for education, industry, innovation and infrastructure

JAXA's contribution to the SDGs is not only in the field of Earth observation. Through a partnership initiative called KiboCUBE, implemented with the United Nations Office for Outer Space Affairs (UNOOSA), JAXA also supports the emerging and developing countries by providing opportunities to deploy CubeSats from the Japanese Experimental Module "Kibo" on the International Space Station, as well as providing the training and capacity building on satellite technologies.

KiboCUBE promotes "Resilient infrastructure, inclusive industrialization and innovation" in the participating countries by supporting "Quality education" in high technological skill sets. Kenya and Guatemala have already deployed their first satellites into orbit through KiboCUBE, building their space technology skills and gaining access to satellite data.

In parallel to the advancement of aerospace technologies that contribute to society, JAXA actively promotes international cooperation and partnerships to realize a society where "No one will be left behind."

Figure – Monthly lower tropospheric CO_2 enhancements map over Tokyo for January through April 2020 compared with the 2016–2019 monthly climatology.
(GOSAT target observations are shown in color-coded circles of 10 km diameter field of view.)
Analysed by JAXA/EORC.



JAXA's Earth-observation satellites and the Sustainable Development Goals

JAXA's ALOS-2

JAXA's GCOM-W, GPM/DPR and ALOS-2

JAXA's ALOS-2, GCOM-W, GPM/DPR, GOSAT and GCOM-C

JAXA's ALOS-2, GCOM-W, GPM/DPR and GOSAT

To maximize the benefits of space technologies, especially Earth observation for solving global issues and achieving the SDGs, space activities' sustainability towards the future is a prerequisite, and we plan to launch several new satellites and sensors such as ALOS-3/4, AMSR3 (GOSAT-GW), and Cloud Profiling Rader (EarthCARE).

It is essential to secure radio frequencies used by Earth-observation sensors and satellites, and to protect them from interference. The ITU World Radiocommunication Conference (WRC) can play a significant role in this regard.

We hope that these critical issues are duly taken into consideration at the next WRC, in 2023, to strengthen our efforts to serve society.

Today's world brings us various challenges and opportunities, as crystalized in the SDGs. As we have seen, aerospace technologies are an enabler to achieve a better and more sustainable future for all. JAXA continues to endeavour to realize the SDGs through its innovative missions and global partnerships.

Let us act together and make a significant impact on society and Earth!

Météo-France's Space Meteorology Centre

By Sylvain Le Moal, Head of Satellite Data Development Division, Space Meteorology Centre, Météo-France

On 1 April 1960, barely three years after the launch of Sputnik, the United States sent the first weather satellite, TIROS-1, into orbit from Cape Canaveral in Florida. Although TIROS-1 stopped working after 78 days owing to an electrical fault, in the two and a half months in which it was operational, it sent 22 952 images to Earth.

"For the first time man had a complete look at the weather over a large segment of the Earth's surface," said Francis Reichelderfer, former chief of the United States Weather Bureau. "It would have taken a thousand or 10 000 ships in the Pacific to have given observations to fill in what we got by these few photographs from TIROS."

In 1963, the National Meteorological Office (*Direction de la Météorologie Nationale* – now *Météo-France*) established the Space Meteorology Centre in Lannion in Brittany. The first image of a segment of orbit No. 45 of TIROS-8 was received just in time for Christmas, at around 12.30 p.m. UTC on 24 December 1963.

The Space Meteorology Centre was the first in Europe to receive a satellite weather image. Satellite images are interpreted by specialists known as nephanalysts, who create representations of the cloud data on maps, including marking the outlines of cloudy areas, the level of cloud cover and the symbols used to classify types of clouds.

The Space Meteorology Centre's role

The Space Meteorology Centre plays a key role in the use of data from Earth-observation satellites, drawing on its 60 years of operational experience at the heart of weather reporting for Météo-France. The Centre oversees the entire production chain for satellite data, from the acquisition of raw data to their use in meteorology, oceanography and climate studies. It has an extensive range of technical tools for use in acquiring satellite data and tracking satellite movements, in addition to a large computing and data storage capacity so that the data can be accessed again in future.

The Centre plays a vital international role in various areas:

- It contributes to Copernicus, the European Union's Earth observation programme, as part of its marine environment monitoring and climate change services.
- It runs the Satellite Application Facility on Ocean and Sea Ice of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and coordinates satellite activity related to ocean surfaces for the Danish, Norwegian and the Netherlands' meteorological services and the French Research Institute for the Exploitation of the Sea (IFREMER).
- It is entrusted with new projects, such as remote sensing of sargassum seaweed in the Atlantic Ocean with a view to improving forecasts for such seaweed being washed up on beaches in the Caribbean and South America.
- It is developing a global tool for estimating rainfall using satellite data with the aim of preventing flooding, in particular in countries without their own radars, within the framework of the European Space Agency's spatial contribution to flood risk analysis (COSPARIN) project.

The Lannion site, which employs 65 staff, focuses primarily on research, in particular to develop and validate algorithms for restoring geophysical parameters based on meteorological satellite measurements in the following fields:

- Microphysical and macrophysical properties of clouds.
- Ocean surface parameters.
- Atmospheric sounding.

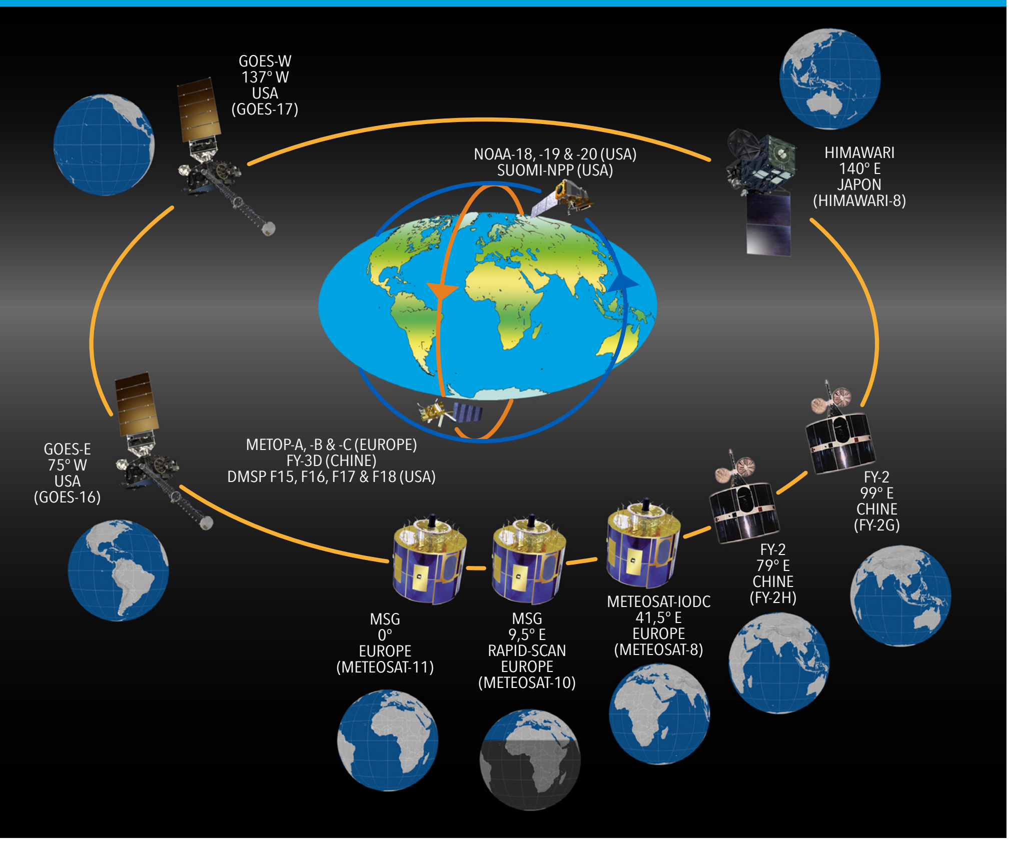
Meteorological satellites

EUMETSAT operates the Meteosat geostationary satellites and the MetOp orbiting satellites. The World Meteorological Organization (WMO) facilitates exchanges between space agencies, satellite operators and national meteorological services and provides real-time access to meteorological data from satellites owned by the United States, China and Japan, among others.

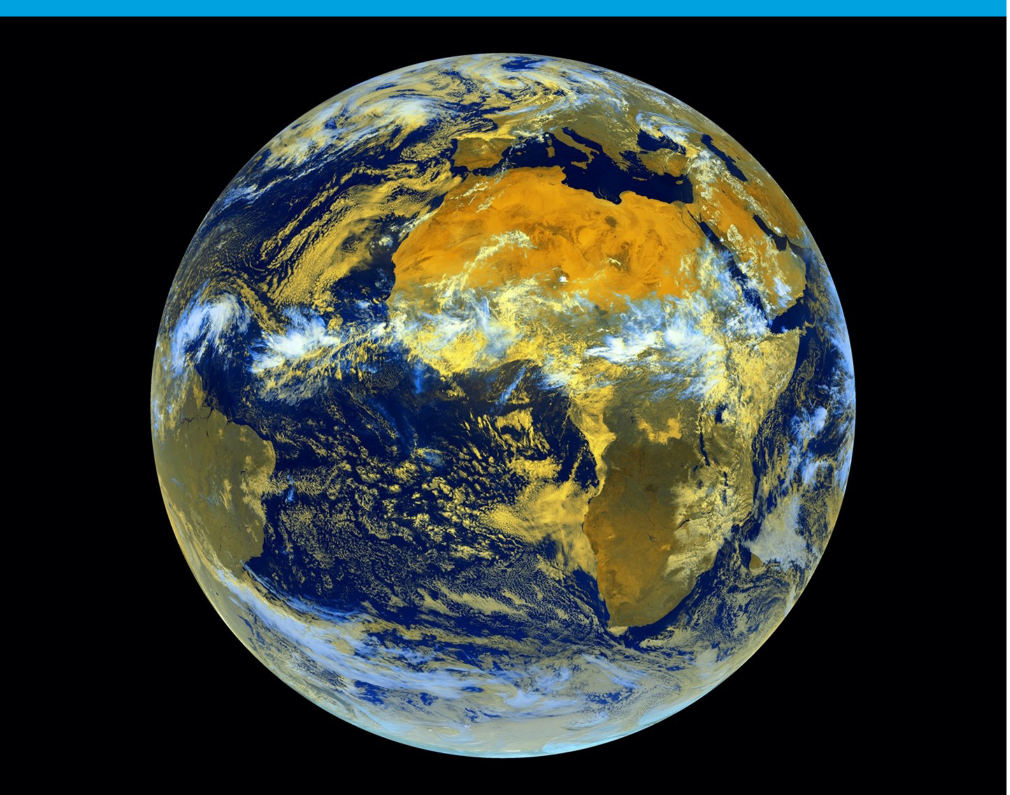
Providing universally useful information: From data for numerical weather prediction models – to images for weather forecasters

The Centre receives raw data from meteorological satellites and produces, in real time, images and data for use by weather forecasters and in numerical weather prediction models, among other things.

Meteorological satellites used by Météo-France
© Météo-France/Space Meteorology Centre



Meteosat-11, colour composite image from 28 July 2020 at 12 p.m. UTC
© Météo-France/Space Meteorology Centre



The majority (over 90 per cent) of observation data used in numerical weather prediction models come from satellites. Satellite data is used in particular to compensate for the lack of conventional measurements in "meteorological deserts" such as vast stretches of ocean, desert or mountains.

Images are created to meet the needs of various users, such as:

- Météo-France's own internal needs.
- External needs via Meteo France International.
- Research laboratories, universities and colleges.
- Businesses.
- The media and major users of satellite imagery in mainland France and its overseas territories.
- National defence, for which the use of satellite data is growing steadily.
- Sports events.
- Individuals.

> *Most data collected from global Earth-observation satellites come from suitable frequency bands with precise, unique physical properties that cannot be modified nor reproduced in other frequency bands.*
>
> Sylvain Le Moal

Most data collected from global Earth-observation satellites come from suitable frequency bands with precise, unique physical properties that cannot be modified nor reproduced in other frequency bands. WMO and the International Telecommunication Union (ITU) have therefore renewed their cooperation agreement on the protection and optimal use of frequencies of crucial importance for Earth and atmospheric observations.

Future of European satellites

The Meteosat Third Generation (MTG) programme and the MetOp Second Generation (MetOp-SG) programme will take over from current satellite missions, with the first satellites from each programme scheduled to be sent into orbit in 2022 and 2023, respectively.

The MTG programme has six geostationary satellites: four MTG-I imaging satellites and two MTG-S sounding satellites. In addition to new radiometers for advanced imaging, the MTG satellites will have infrared sounding and lightning detection capabilities.

The MetOp-SG satellites will also be higher performing than the current MetOp satellites in orbit and will carry more advanced instruments, in particular microwave imaging tools for use in the study of rainfall.

The launch of the first MTG and MetOp-SG satellites will be another major step forward for European meteorology, as witnessed every couple of decades.

Meteosat Third Generation (MTG) satellites
© European Space Agency (ESA)

EEA and Copernicus role in supporting the EU environment and climate change policy

By **Andrus Meiner,** Head of Group, Geospatial information services, and **Chris Steenmans**, Head of Data and Information Services, European Environment Agency (EEA)

Andrus Meiner

Chris Steenmans

The European Environment Agency (EEA) is an agency of the European Union established in 1990 and located in Copenhagen. EEA's main task is to provide sound, independent information on the environment and act as a major information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public. EEA is supported by the European Environment Information and Observation Network (Eionet), of around 350 organizations across Europe through which environmental-related data and information are collected and disseminated. The Agency has 32 member countries.

EEA's mandate is to help the European Community and member and cooperating countries make informed decisions on improving the environment, integrating environmental considerations into economic policies and moving towards sustainability. It also coordinates Eionet.

State and outlook of environment in Europe

EEA helps achieve significant and measurable improvements in Europe's environment and supports sustainable development, particularly by regularly producing the State and Outlook of Environment in Europe report.

In December 2019, the EEA presented its report The European environment – state and outlook 2020, (SOER) which detailed the unprecedented scale and urgency of Europe's current environmental, climate and sustainability challenges. Many persistent challenges rooted in the past are coupled and amplified by emerging and systemic issues, associated with uncertainty, ambiguity, and conflicts of interests (see the report and associated video).

> *“Many persistent challenges rooted in the past are coupled and amplified by emerging and systemic issues.”*
>
> Andrus Meiner and Chris Steenmans

The European environment – state and outlook 2020: Knowledge for transition to a sustainable Europe

Europe will not achieve its 2030 goals without urgent action during the next 10 years to address the alarming rate of biodiversity loss, increasing impacts of climate change and the overconsumption of natural resources. The European Environment Agency's (EEA) latest "State of the environment" report says that Europe faces environmental challenges of unprecedented scale and urgency.

See full Report.

The European Environment Agency presents an in-depth analysis on the state of the European environment

See video.

The European Green Deal

The European Green Deal (EGD) adopted by the new European Commission in December 2019, is the European response to these systemic challenges. It provides a framework for ambitious actions and measures to position Europe firmly onto a path towards sustainability, demonstrating that sustainability and prosperity could be achieved together. The EGD acknowledges EEA's work in highlighting the extent and urgency of the challenges and sets out a roadmap of around 50 key policies and measures needed to address them.

Amongst the measures proposed, the EGD also suggested the adoption of a General Union Environment Action Programme to 2030 (8th EAP) to help ensure the implementation, enforcement and effective delivery of environmental and climate policies and legislation and also introduced a new monitoring mechanism. EEA and Eionet will play a key role in supporting these actions under the EGD and in the implementation of the 8th EAP.

The new EEA-Eionet Strategy 2021–2030

To that end, a new EEA-Eionet Strategy 2021–2030 has been developed.

The strategy underlines the role of data and understanding data in the pivotal decade to come. It sets out how EEA and Eionet will work together with other knowledge providers at the European level and within Eionet countries in support of Europe's environment and climate ambitions.

The European Commission's proposal for an 8th EAP presents enabling conditions to achieve the programme's priority objectives. Among them there is a requirement for "harnessing the potential of digital and data technologies to support environment policy while minimizing their environmental footprint". Specifically, EEA is requested to support the Commission in improving the availability and relevance of data and knowledge, among others, by "integrating data on environmental, social and economic impacts, and exploiting fully other available data, such as those delivered by Copernicus".

> *While the implementation of Copernicus services has advanced enormously, it has become increasingly urgent to support the users and uptake of Copernicus services and their data sets.*
>
> Andrus Meiner and Chris Steenmans

The Copernicus Programme

The Copernicus Programme was established by a European Union (EU) regulation in 2014 and supports EU environment and climate policies by developing information services based on satellite and in situ data. This includes the Copernicus Marine Environment Monitoring Service (CMEMS), the Copernicus Land Monitoring Services (CLMS), the Copernicus Climate Change Service (C3S), the Copernicus Atmosphere monitoring service (CAMS), and for specific cases, the Copernicus Emergency Management service (CEMS).

The same regulation established a formal EEA commitment, that is re-confirmed by the EU space programme and a new regulation for 2021–2027. It defines a new EEA contribution agreement with the European Commission to implement a land monitoring service and coordinate the Copernicus in situ component. EEA also continues to build on the other above-mentioned services for developing e.g. an air quality index, indicators for monitoring terrestrial and marine ecosystems, an operating climate adapt platform and many other use cases.

While the implementation of Copernicus services has advanced enormously, it has become increasingly urgent to support the users and uptake of Copernicus services and their data sets. User uptake of Copernicus services by EEA and Eionet is as explicitly mentioned in the EEA-Eionet Strategy 2021–2030. The new EU space regulation also calls for a combined use of different Copernicus services which will require cooperation and coordination among EEA-Eionet actors that relate to Copernicus.

New policy initiatives set up via EGD include new requests for land-related information in the domains of biodiversity and ecosystems, climate change mitigation and adaptation, as well as zero-pollution ambition and relevant aspects of the circular economy (e.g. a sustainably built environment). At a global level, land degradation is a part of the Sustainable Development goals (SDGs). SDG target 15.3 on land use information underpins several other goals, such as SDG goal 11 on sustainable cities.

The link between EGD priorities and CLMS outputs is explicitly stated in the 8th EAP. Therefore, EEA is currently setting up a policy relevant information platform that provides user friendly and transparent access tools for retrieving data and information based on CLMS products.

The new EEA-Eionet Strategy 2021–2030 highlights knowledge backed by data comprised of assessments, indicators, and progress to target assessments, built on the largest regular collection of data in Europe on environment and climate topics. One of the strategic objectives foresees making full use of the potential of data, technology and digitalization to embrace new technologies, big data, artificial intelligence and Earth observation (Copernicus) to support decision making. ■

Earth microwave remote sensing and the electromagnetic spectrum

By Paolo de Matthaeis, Chair, IEEE Geoscience and Remote Sensing Society (GRSS) Frequency Allocations in Remote Sensing (FARS) Technical Committee

"The specific frequencies for these observations are driven by the immutable physical characteristics of the object and other frequencies cannot be used in their place."

Paolo de Matthaeis

Remote sensing is the collection of information on an object or phenomenon from a distance without any physical contact. In the context of Earth science, space- or airborne sensors are used for data acquisition and the subject of these observations are the atmosphere or the surface of land and the ocean. For microwave remote sensing, measurements are made of electromagnetic radiation ranging from below 45 MHz up to a Terahertz or more.

Microwave remote sensing can be either passive or active. Passive sensors gather radiation originating from the particular objects under observation. This radiation can either be emission by the objects themselves or energy coming from the Sun and reflected by these objects. In the case of microwave remote sensing, the signal of interest is predominantly the former and the emitted radiation is collected by instruments called radiometers. Active instruments transmit signals and measure the radiation that is reflected or scattered from an illuminated area.

Operating at specific radio frequencies

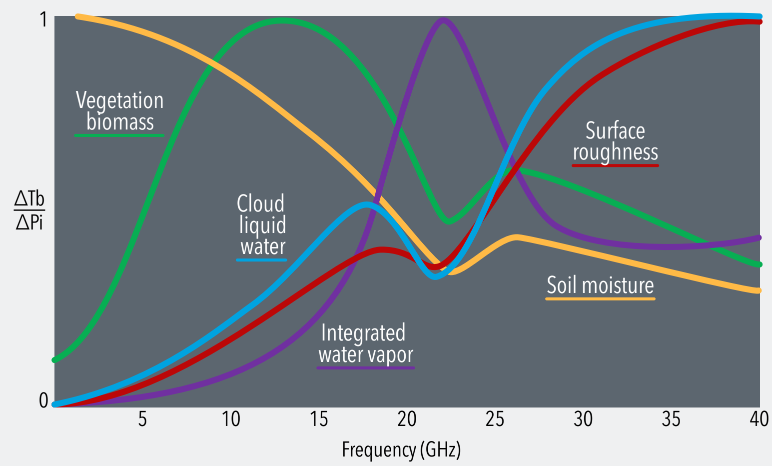
The microwave sensors used for Earth science operate at specific radio frequencies chosen according to the electromagnetic radiation emission, reflection, or absorption characteristics of the object under observation. The specific frequencies for these observations are driven by the immutable physical characteristics of the object and other frequencies cannot be used in their place.

In addition to the need for a specific frequency, it should be noted that, in general, the use of a wider bandwidth during the measurement allows for a higher degree of resolution of the desired characteristic. A narrower bandwidth can be used but this approach then requires a more sensitive receiver to obtain the same desired resolution.

Figures 1 and 2 show, over the range of 0–40 GHz, the sensitivity of the electromagnetic emission characteristics of the main subjects of interest to Earth science for ocean and land remote sensing, respectively. For example, soil moisture estimates are most accurate when using measurements at low frequencies, where the sensitivity is very high (Figure 1), and, consequently, 1.4 GHz is the operational frequency of current sensors designed for this purpose.

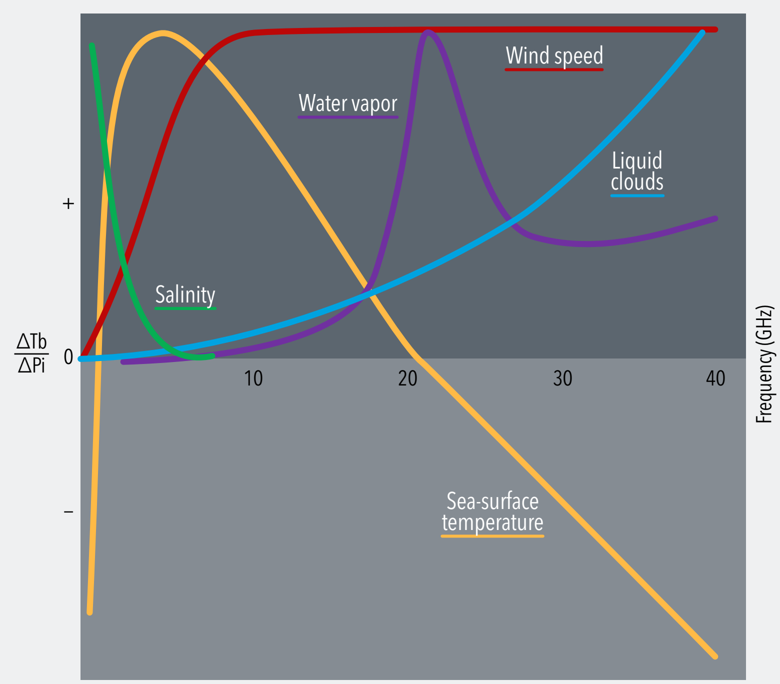
The emission dependence on any one physical parameter is entangled with the dependence on other parameters, thus in order to correctly estimate a physical parameter, it is also often necessary to collect measurements over multiple frequencies to allow for the correction of the undesired emissions.

Figure 1 – Relative sensitivity of brightness temperature to geophysical parameters over land surfaces as a function of frequency.



Source: National Academies of Sciences, Engineering, and Medicine, Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses, Second Edition. Washington, DC, 2015.

Figure 2 – Relative sensitivity of brightness temperature to geophysical parameters over the ocean as a function of frequency.



Source: National Academies of Sciences, Engineering, and Medicine, Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses, Second Edition. Washington, DC, 2015.

For example, observations at two frequencies surrounding the water vapor absorption peak, usually around 18 GHz and 23 GHz, are needed to assess the amount of water vapor in the atmosphere (Figure 2).

Value for society

Space-based remote sensing makes it possible to collect data on a global basis including otherwise dangerous or inaccessible areas. Remote-sensing applications include monitoring deforestation in areas such as the Amazon Basin, glacial features in the Arctic and Antarctic regions, and depth sounding of coastal and ocean depths.

Remote sensing also supplements, or even replaces costly and slow ground-based data collection, ensuring in the process that areas or objects are not disturbed.

Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, which in conjunction with larger scale aerial or ground-based sensing and analysis, provides researchers with enough information to monitor trends such as El Niño and other natural long- and short-term phenomena.

Earth science uses include, among others, natural resource management, agricultural fields such as land usage and conservation, oil spill detection and monitoring, and national security and overhead, as well as ground-based and stand-off collection on border areas.

The economic value of these Earth-science observations has been estimated to be easily in the hundreds of billions of dollars, which is far in excess of the cost of the programmes which operate these Earth science data collection systems.

> *"Growing demand for electromagnetic spectrum, particularly from commercial applications, has created a situation in which many services have to share or use contiguous frequency bands."*
>
> Paolo de Matthaeis

Frequency bands and interference

Growing demand for electromagnetic spectrum, particularly from commercial applications, has created a situation in which many services have to share or use contiguous frequency bands.

As a result, many radio systems are being affected by unwanted man-made signals, known as radio-frequency interference (RFI), that disrupts and degrades performance. Microwave remote sensing is not immune from this problem, with passive remote sensing being particularly harmed due to its reliance on very weak natural electromagnetic emissions, narrow observation bands, and sensitive instruments. Remote-sensing operations in frequency bands below 20 GHz have experienced interference for decades from the operation of other services.

However, RFI in remote sensing operations is expected to occur in bands above 20 GHz and, in addition, to become ubiquitous and more severe due to the utilization of these higher frequencies by services such as those supporting 5G and broadband Internet on airplanes and ships or in remote locations.

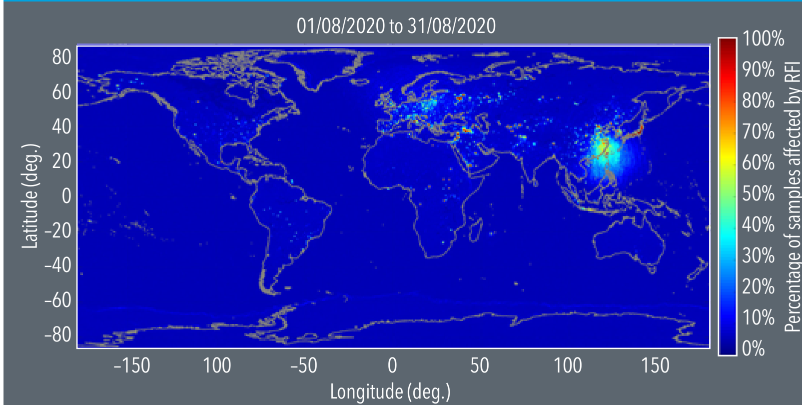
Examples of interference observed by passive sensors operating at 1.4 GHz and 18.7 GHz are given in Figures 3 and 4, respectively, while Figure 5 shows RFI detected by an active instrument at 5.405 GHz.

The IEEE GRSS Frequency Allocations in Remote Sensing Technical Committee

The Frequency Allocations in Remote Sensing (FARS) Technical Committee of the IEEE Geoscience and Remote Sensing Society (GRSS) was formed in 2000 to serve as an interface between the remote-sensing community and the radio-frequency regulatory world.

The technical committee strives to educate all involved parties by providing the remote-sensing perspective and technical input to frequency regulators and also by assisting remote-sensing scientists and engineers on spectrum management matters.

Figure 3 – RFI observed by the Soil Moisture Active Passive (SMAP) radiometer in the 1400–1427 MHz band during August 2020.



Source: NASA Goddard Space Flight Center.

Figure 4 – Maximum RFI levels observed by the Global Precipitation Measurement (GPM) Microwave Imager in the 18.6–18.8 GHz band over the United States during 2019.

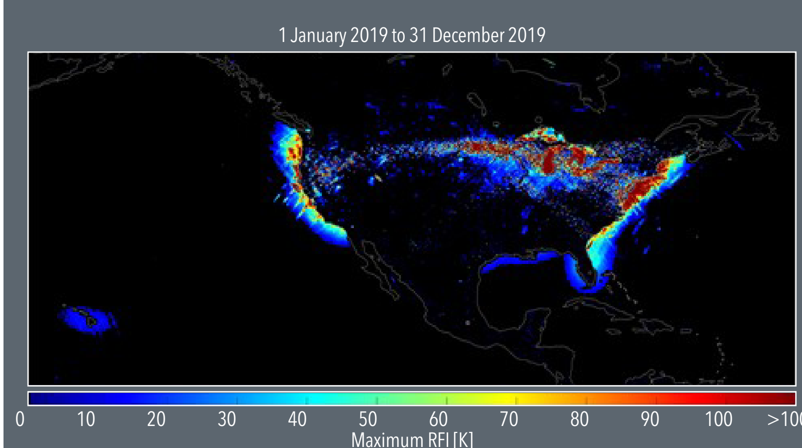
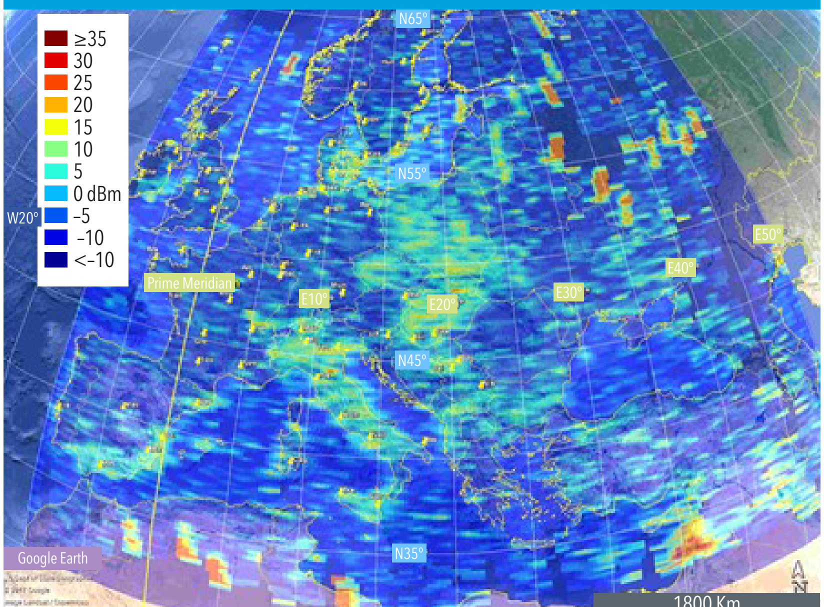


Figure 5 – Map of RFI power at C-band in Sentinel-1 Synthetic Aperture Radar measurements, with locations of weather radars superimposed.



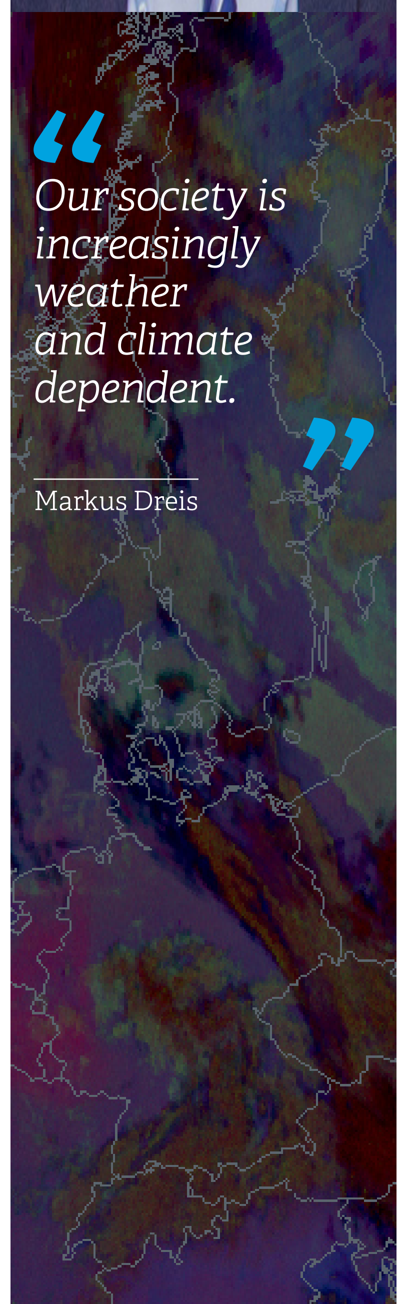
Source: A. Monti-Guarnieri, D. Giudici, and A. Recchia, "Identification of C-Band Radio Frequency Interferences from Sentinel-1 Data," Remote Sensing, vol. 9, no. 11, p. 1183, Nov. 2017.

FARS promotes the development of radio-frequency interference detection and mitigation technology by organizing technical sessions at conferences, workshops, and other relevant venues on the above processes, issues and technologies.

The FARS Technical Committee is also developing an online database of RFI observed by remote sensing sensors. In all these activities, FARS fosters the exchange of information between researchers in different fields, such as remote sensing, radio astronomy, telecommunications, with the unifying goal of minimizing harmful interference between systems.

Monitoring the atmosphere, ocean and climate from space for transforming our world

By Markus Dreis, Head, Frequency Management Office, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)



> *"Our society is increasingly weather and climate dependent."*
>
> Markus Dreis

In September 2015, the United Nations General Assembly adopted "Transforming our World: The 2030 Agenda for Sustainable Development". The agenda is a plan of action with 17 Sustainable Development Goals aimed at eradicating poverty as an indispensable requirement for sustainable development.

The ambitious goals contain 169 targets and stimulate action over 15 years in areas of critical importance for humanity and the planet. They recognize the interconnectedness of striving for peace and prosperity with promoting the health and dignity of people, the sustainable use of our planet's resources and the need for urgent action on climate change, and the importance of forging effective partnerships to make this a reality.

Global Earth observation from space – key role in achieving the Sustainable Development Goals

Our society is increasingly weather and climate dependent. Data from Earth observation and meteorological satellites have become vital for forecasting the weather at all ranges, monitoring the climate, and producing timely warnings and other information that support public and private decision making for our social and economic well-being and sustained development.

Thus, operating Earth observation and meteorological satellites is contributing directly to the implementation of the 2030 Agenda through the provision of global, accurate, consistent and timely observations of the weather, environment and climate from space.

The use of the data from such activities saves lives, prevents economic loss and supports sustainable development and innovation. The fulfilment of these objectives de facto contributes practically and tangibly to the achievement of many of the Sustainable Development Goals.

To be up to the challenge of sustainable development in the next decade and beyond, and to meet expectations from governments, citizens and industries on forecasts and early warnings of high-impact weather events, the availability of a global network of Earth observation and meteorological satellites has to be ensured.

> *Weather forecasts also support economic growth, as our highly-developed economies and many areas of our modern lives are very weather sensitive.*
>
> Markus Dreis

The role of EUMESTAT and other space agencies

Meteorological and Earth-observation satellites are equipped with visible and infrared imagers and sounders. The data provided by these instruments are used to derive many meteorological and environmental parameters. The polar-orbiting satellites are additionally equipped with active and passive microwave sensing instruments that provide, for example, vertical profiles of temperature and humidity of the atmosphere, information on the distribution of clouds, snow and ice cover, and ocean surface temperatures and winds, on a global basis. These atmospheric variables are all known to play an important role in weather forecasting and long-term climate-change monitoring.

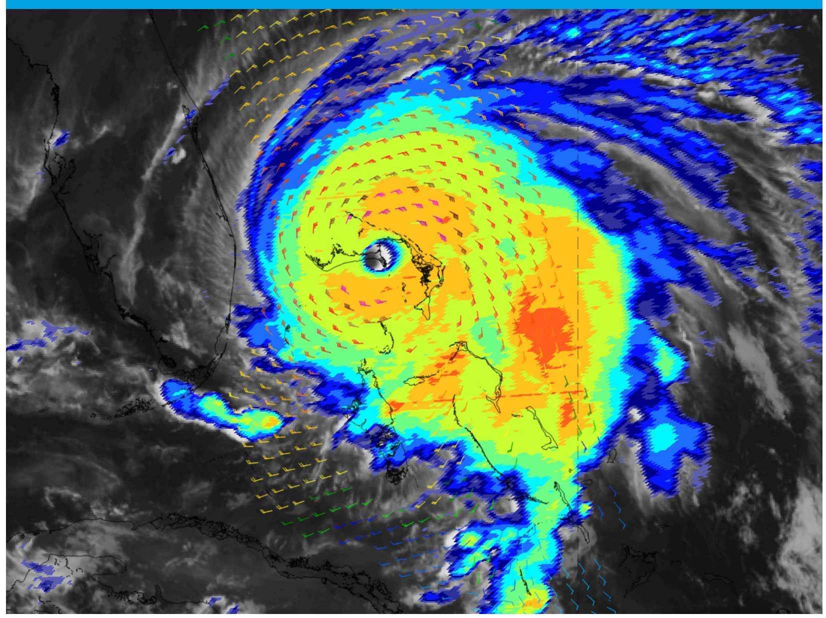
The primary objective of EUMETSAT, an intergovernmental organization, is to establish, maintain and exploit meteorological satellites, taking into account, as far as possible, the recommendations of the World Meteorological Organization (WMO). This is done in close cooperation with all other space agencies that operate meteorological satellites, with the shared objective of maintaining a global network of meteorological satellites, in the framework of the Coordination Group of Meteorological Satellites (CGMS).

In response to the global climate action agenda, a further objective is to contribute to the operational monitoring of the climate and detection of climatic changes through this global network of Earth-observation and meteorological satellite systems. The implementation of the Global Architecture for Climate Monitoring from Space is coordinated by the Joint Working Group on Climate established by CGMS and the Committee on Earth Observation Satellites (CEOS).

High-impact weather

Observations from geostationary and non-geostationary meteorological satellites are used by National Meteorological and Hydrological Services (NMHS) across the world in their endeavours to protect life and prevent economic loss from meteorological and hydrological hazards. Real-time satellite data are either used directly for nowcasting high-impact weather or ingested in numerical prediction models supporting forecasts for ranges from days to seasons.

Record-breaking Hurricane Dorian during September 2019 making landfall at Elbow Cay, Bahamas, with wind speeds of 295 km/h, observed by a number of instruments on different satellites (Metop-A, Sentinel-3B, GOES-17).
The different satellite-based instruments can be used to investigate different characteristics of hurricanes and their impacts as in this example.



Additionally, there is a global network of data collection systems on meteorological satellites to collect and relay, in real-time, in-situ observations from automated platforms deployed over continents and oceans; for example, over the Indian Ocean, as part of the global tsunami early warning system.

Building on these forecasts, NMHS release early warnings that help reduce the number of people affected by disasters and the related economic loss. Through their use in weather forecasts, weather observations from space also contribute to transport safety and capacity, sustainable development and agriculture, water and land resource management and protection of public health, e.g. in case of heat waves amplified by heat islands in megacities.

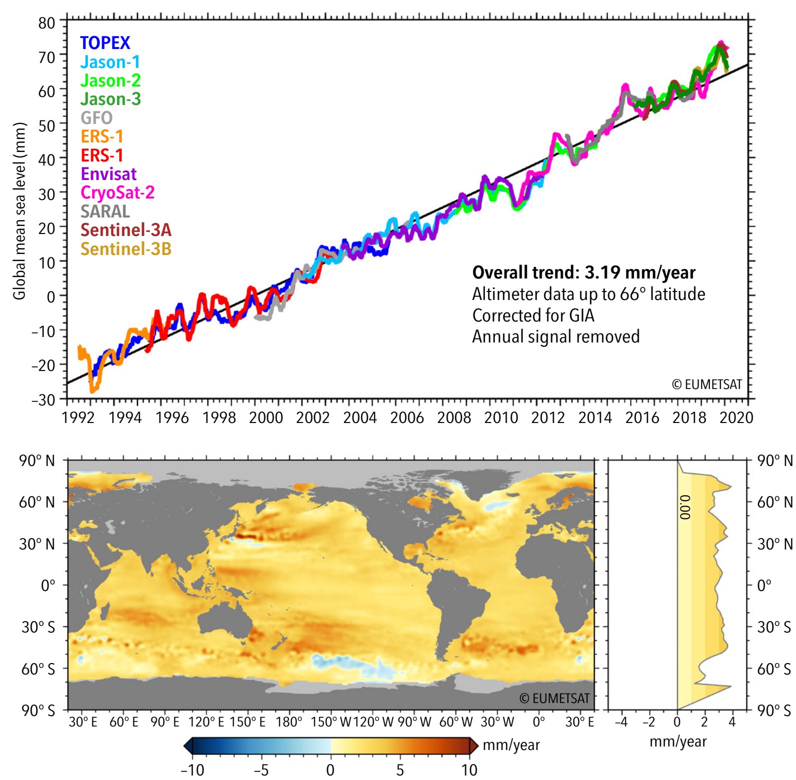
Weather forecasts also support economic growth, as our highly-developed economies and many areas of our modern lives are very weather sensitive. This is the case in the transport, energy, agriculture, tourism, food, and construction industries, for example. Consequently, the socio-economic benefits of forecasts and their constant improvement are proportional to the Gross Domestic Product (GDP) of a country or a region.

Our oceans

One essential component is the monitoring of the oceans. The resulting integrated marine data stream provides information about ocean currents, ocean surface winds, sea state, sea ice, sea surface temperature and ocean colour. These data are used directly and ingested in weather and ocean prediction models to provide crucial information for safety at sea, operations of marine infrastructure, fisheries, sustainable use of marine resources and the protection of vital marine and coastal ecosystems.

Mean sea level rise is both an impact and sensitive indicator of climate change with particular repercussions for coastal areas and small island States. Therefore, the availability of reliable, highly accurate mean sea level measurements (see the two related figures) will be crucial for achieving the central aims of the 2015 Paris Agreement. Those aims are to strengthen the global response to the threat of climate change, as well as countries' ability to deal with its impacts.

Sea level rise observed by 12 satellites over a period of 28 years (top) and a map of regional sea level trends (bottom)



Atmospheric composition

Another important element is the monitoring of the atmospheric composition from space using geostationary and polar-orbiting satellites, in future also with additional dedicated Sentinel instruments provided by the EU Copernicus programme.

These satellite observations provide key inputs to forecasts of air quality over large urban areas, the ozone layer and harmful ultraviolet radiation, as well as sand and dust storms, in particular in Africa. Public health benefits from the use of this information for regulating traffic or other economic activities and for warning of potential respiratory problems. The data and imagery are also used for forecasting the dispersion and transport of accidental pollution and to monitor wildfires and the plumes of aerosols and the gases they generate. (See images showing NO_2 anomalies.)

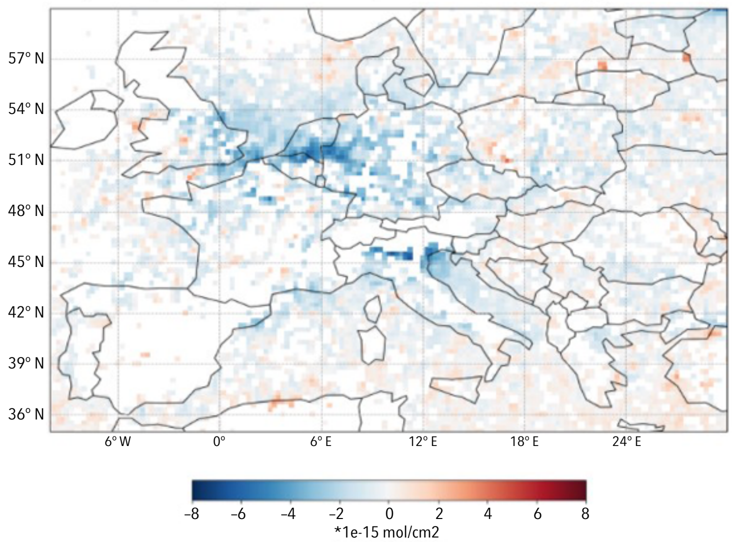
Observations of volcanic ash and SO2 plumes are also crucial for ensuring safety of aviation and optimization of air traffic management capacity in case of eruptions (see ash plume images).

The changing climate

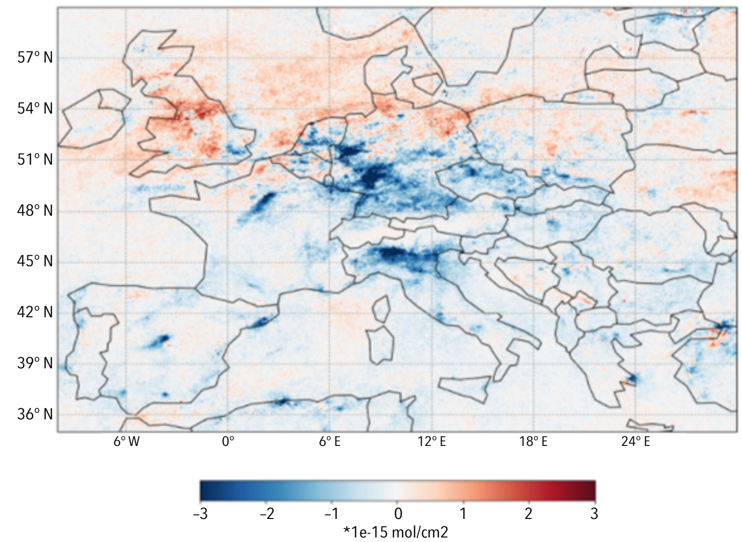
Satellites have unique potential for observing systematically and globally 31 of the 50 Essential Climate Variables (ECVs) identified by the WMO's Global Climate Observing System (GCOS).

With almost 40 years of meteorological satellite data (e.g. from Meteosat satellites), and commitments for collecting another 30 years' of observations from its current and next-generation satellites, EUMETSAT, like its international partner space agencies, is one key contributor to the Architecture for Climate Monitoring from Space, jointly coordinated by the Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observation Satellites (CEOS).

March anomaly of troposhperic column density of NO_2 – based on long-term mean (2007–2018)



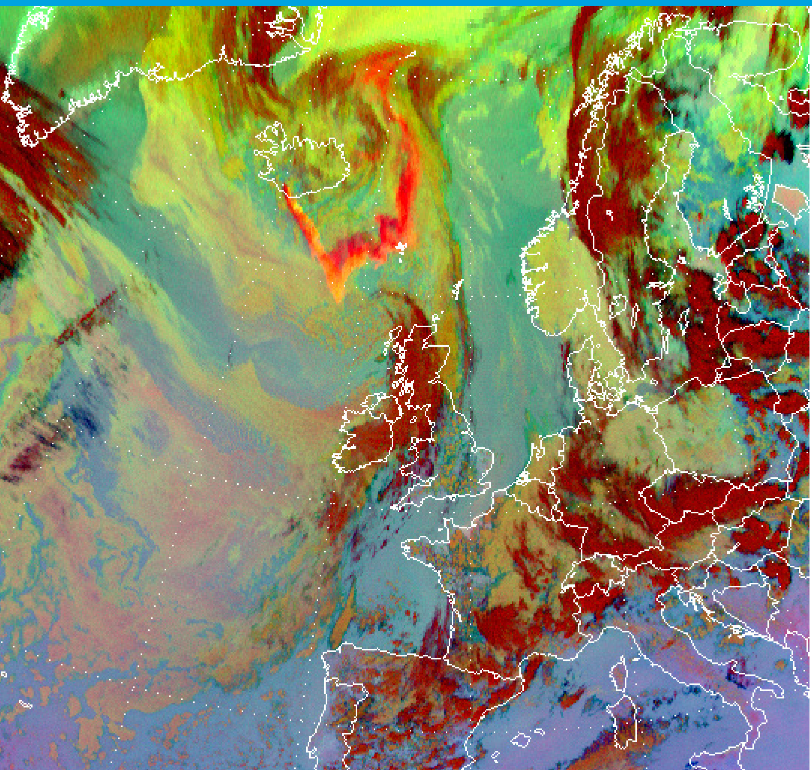
March anomaly of total column of NO_2 from Metop-A and B GOME-2. Reference period is 2007–2018.

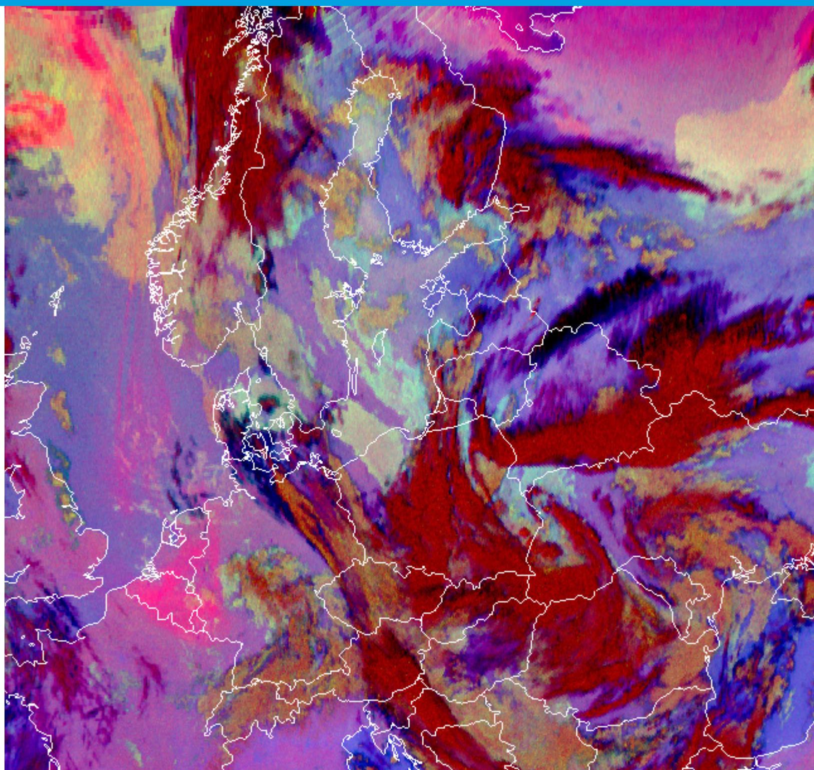


Sentinel 5p TROPOMI NO_2 anomaly for March 2020. Reference period is 2019, due to the limited time coverage of the instrument.

During the March 2020 lockdown in Europe, although there were different levels of restrictions in different countries, there was a visible decrease of NO_2 emissions This was more pronounced in the most polluted areas – Po Valley, Ruhr-Rhine, Benelux, London and Paris.

The ash plume from the eruption of Eyjafjallajökull as seen from Meteosat-9 on 13 May 2010 revisiting the British Isles and the Benelux countries (left), reaching Belgium, The Netherlands and Germany on 18 May 2010 (right). This ash plume seriously impacted civil aviation globally.





Through data rescue, the systematic recalibration of historical data and the reprocessing of long series of data using the latest algorithms, for example, EUMETSAT alone has already delivered many climate records addressing 15 ECVs. It has further plans to deliver more and improved data records to address additional ECVs from the atmosphere, ocean and terrestrial domains.

Weather forecasts and energy production

The interdependencies between energy, the weather and the climate are increasing. As the demand for energy remains temperature-dependent, the weather now determines the supply of the renewable part of the energy mix. Therefore, weather forecasts influence day-to-day decisions on energy production, while climate data are essential inputs for well-informed decisions on strategic investments in the energy sector, in particular on preferred energy sources and production capacity.

Observations from meteorological satellites have a twofold contribution as they increase the performance of weather forecasts and are used to produce climate records of solar radiation parameters that can aid decision making in relation to solar-energy installations.

Availability of the relevant frequency spectrum resources as a prerequisite

The exploitation of these meteorological and Earth-observation satellites relies on the interference-free availability of the necessary frequency resources (ensured by the appropriate provisions in the Radio Regulations). This is important for the control of satellites, the operation of a number of microwave instruments for active and passive sensing, and the timely distribution of the data directly from the satellites, or through alternative means of data distribution using other radiocommunication services.

This large portfolio of radio-frequency usage requires that the radio-frequency resources allocated to the corresponding radiocommunication services in the Radio Regulations are kept available and protected from interference in the long term. This is particularly important for passive microwave sensing instruments, which due to their sensitivity, require particular recognition in the Radio Regulations.

Since weather and climate monitoring are global challenges requiring strategic investments in the necessary global infrastructure, in space and on the ground, for the benefit of human society, the support of radiocommunication administrations from around the world for the protection of these indispensable frequency resources is necessary. ■

What do space science radiocommunications have to do with me?

By Catherine Sham, Spectrum Manager for Human Spaceflight Programs and Lunar Programs, NASA, and Chairman, ITU–R Working Party 7B

A remote satellite collects radio signatures while its antennas stare passively at Earth. A space probe's active radar scans for changes in soil temperature and moisture.

Safe to say, neither scenario was a usual topic of everyday, pre-pandemic conversation.

But, worth talking about now is how these same radiocommunication satellites are emblematic of the contributions science has and will continue to make to my benefit and yours, and how they may even help mitigate the effects of the pandemic itself.

Despite COVID-19, carefully allocated radio frequency spectrum and the ITU Radiocommunication Sector (ITU–R) World Radio Conference (WRC) treaty agreements have kept space science radiocommunication activities operating uninterrupted.

These radio-frequency spectra enable active and passive remote sensing technologies and meteorology missions to return continuous and incremental data on changes in Earth systems.

> *"Worth talking about now is how these same radiocommunication satellites are emblematic of the contributions science has and will continue to make to my benefit and yours."*
>
> Catherine Sham


NASA

"Nightlights" from the NASA-NOAA Suomi NPP satellite, like this one of San Francisco Bay, is just one of many types of Earth observations assembled by NASA, ESA, and JAXA to track global and local changes brought on by the world's response to the COVID-19 pandemic.

Adjusting to a new work environment

NASA and its partner agencies were quick to adjust their work environments and mission pace to the new normal. Aboard the International Space Station, travel restrictions and stay-at-home orders have been a way of life for scores of astronauts and cosmonauts who've lived and worked there since the Expedition 1 crew launched on 31 October 2000. Not to mention those of us back on the ground, who continue to work remotely over radio frequencies to command/control the spacecraft, monitor equipment, manage flight experiments, and communicate with and maintain the safety of our space-faring colleagues.

Accessible data for tracking climate change and mitigating threats

These radio-frequency spectra enable active and passive remote-sensing technologies and meteorology missions to return continuous and incremental data on changes in Earth systems. In light of the pandemic, NASA, ESA (European Space Agency) and JAXA (Japan Aerospace Exploration Agency) have used their collective, Earth-observing satellite power to create a publicly accessible COVID-19 Earth Observation Dashboard. Here, selective satellite data has tracked changes in air and water quality, climate change, economic activity and agriculture since the start of the pandemic.

Among recent observations: reductions in agricultural production from disrupted supply chains, and improved air and water quality due to reduced human activities (industry and stay-at-home orders).

All of these data can help worldwide business and government leaders rejuvenate the global economy.

Additional data for understanding and mitigating threats to our safety continue to be available at NASA's Earth Observing System Data and Information System (EOSDIS). EOSDIS provides global users with direct access to all science captured by NASA satellites.

These data can warn of dynamic, potentially deadly weather patterns, precipitation, flood and fire risks, as well as, among others, monitor long-term crop growth and health.

Improving lives with space asset spinoffs

Of course, our space assets continue to spawn so-called spinoffs: items developed for use by astronauts in space that now improve lives here on terra firma (e.g. memory foam, scratch-resistant sunglasses, cordless vacuums, etc.). One recent spinoff that made deadlines was rolled out in the midst of COVID-19's first wave last spring. A ventilator specifically for coronavirus patients was designed and demonstrated in just 37 days by engineers at NASA's Jet Propulsion Laboratory (JPL).

After securing an emergency use authorization from the Food and Drug Administration (FDA), the JPL team made its design available to select manufacturers at zero cost.

Scientific and technological advancement – a ray of hope for humankind's future

Our minds tell us that, in the long term, ingenuity and committed investment in research and development will continue to fuel advancements in science and technology. In turn, the knowledge that these advancements will improve daily life on Earth, as well as further pave the way for human space exploration, give us hope and inspiration for humankind's future.

However, through the lens of this pandemic, near-term hope and inspiration may seem in short supply.

> *“In the long term, ingenuity and committed investment in research and development will continue to fuel advancements in science and technology.”*
>
> Catherine Sham

Let's remember that our continued space-science activities and satellite capabilities are working to maintain and restore everyday necessities that we all likely have taken for granted until now. In and of itself, this recognition should provide us with enough hope and inspiration as a bright light at the end of this longer-than-expected tunnel.

Copernicus – Earth observation to achieving the Sustainable Development Goals

By Dominic Hayes, Spectrum Manager, European Union Space Programme, European Commission

From the earliest times, humans have dreamed of flying like birds – looking down from high above, to the ground below. Prehistoric civilizations are unlikely to have even imagined powered flight, or cameras that can record the world around us. Even 100 years ago, with flight and photography relatively common, the idea of "taking pictures" of the Earth from space was unheard of.

How we view the Earth today with satellites

Today, if you ask the average person about satellites looking at the Earth, the majority will tell you about spy satellites taking pictures of secret bases. While this is still done by dedicated satellites, and was indeed the precursor of modern Earth-observation (EO) satellites, now scientists prefer to view the Earth with a much wider spectrum of radio colours, far beyond the senses of any living thing.

Traditional optical images provide limited information about the world; most of the useful characteristics can only be seen through radio frequencies – things like soil moisture, CO_2 densities, water levels, atmospheric particulate concentrations and more.

A variety of different sensors are fitted to EO satellites, often taking advantage of particular natural phenomena, such as the absorption frequency of water vapour just below 24 GHz. This is a particularly useful frequency to monitor as it tells us the moisture content of the atmosphere, which helps to model and predict the build-up of storms and tropical cyclones. Water vapour is also a key greenhouse gas.

> *"When disaster strikes, the Copernicus Emergency Management Service can be activated by countries responding to natural disasters, human-made emergency situations or humanitarian crises."*
>
> Dominic Hayes

You can learn more about Copernicus here.

Measurements are done passively, looking at the infinitesimal interactions of those little water molecules as they do their rain dance around 24 GHz. This makes it imperative to keep that frequency free from interference, or the measurements will become degraded, or impossible to make. To help achieve this, the frequency range is listed as a passive band in the Radio Regulations; no emissions are allowed and out-of-band interference has to be minimized.

The World Radiocommunication Conference 2023 (WRC-23) agenda includes several items that could affect EO satellite measurements and so regulators will need to weigh up the benefits and implications of any proposed regulatory changes, especially where International Mobile Telecommunications (IMT) is considered for operation next to an Earth exploration-satellite service (EESS) allocation, and even more so when it is passive.

The European Union's Copernicus system

The European Union's Copernicus system is an Earth-observation system that looks at 24 GHz – but that is just one of the many instruments fitted to its satellites. As of January 2021, Copernicus has eight Sentinel satellites in orbit and each type is fitted with a different range of sensors to monitor different aspects of the Earth (using active and passive Earth exploration-satellite service allocations from 5 GHz through to 37 GHz, with future plans to use frequencies in the L-band). And yes, some satellites do include optical imaging, at around 10–20 m and 300 m resolutions.

The eighth Copernicus satellite was launched in November 2020. Named in honour of trailblazing former Director of the United States National Aeronautics and Space Administration (NASA) Earth Science Division, who passed away in August 2020, "Sentinel-6 Michael Freilich" measures sea-level changes with high accuracy.

Copernicus is not just composed of the European Union's Sentinel satellites; it is a system of systems, collecting data from a variety of other contributing Earth-observation space missions from around the world, as well as ground infrastructure. Through arrangements these systems get direct, full, free and open access to Copernicus data (16 TB per day) that adds to their own data. Copernicus in turn benefits from having access to their sensor data, thereby expanding its service coverage and reliability. The various data sets are then woven into a portfolio of six services that are offered to the world free of charge. Yes, for free; as in *gratis*, *zilch*, *nada*.

Six thematic service areas

The services address six thematic areas: land, marine, atmosphere, climate change, emergency management, and security. They support a wide range of applications, including environment protection, management of urban areas, regional and local planning,

agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection, and tourism.

When disaster strikes, the Copernicus Emergency Management Service (EMS) can be activated by countries responding to natural disasters, human-made emergency situations or humanitarian crises. This triggers a whole host of extra data that can be provided to help responding organizations get the best possible picture of the events as they unfold. Today, more than 400 activations have occurred across the globe, in developing and developed nations.

Data – a crucial tool to achieving the SDGs

Copernicus data are also integrated by third parties into many things we see and take for granted, such as TV and Internet weather forecasts, and are also a crucial tool in helping to achieve the Sustainable Development Goals (SDGs). Data from Earth-observation satellites play a key role in most of the seventeen SDGs to help monitor targets, plan and track progress, and help countries and organizations make well-informed decisions as they work towards SDG objectives.

Various international bodies such as the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS) have been set up to promote and coordinate the uptake of Earth-observation techniques that support environmental policies and improve daily life on our planet.

Countering the COVID-19 crisis

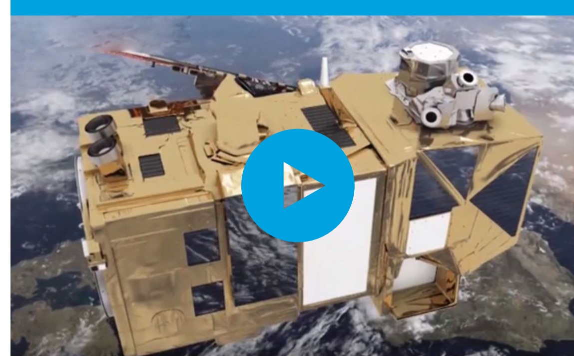
To help counter the ongoing COVID-19 crisis, Copernicus has provided data to assist GEO and CEOS efforts to better understand and react to the situation, and the European Commission and the European Space Agency (ESA) have also jointly developed "Rapid Action on COVID-19".

The COVID-19 Earth Observing Dashboard is an effort between ESA, Japan Aerospace Exploration Agency (JAXA) and NASA.

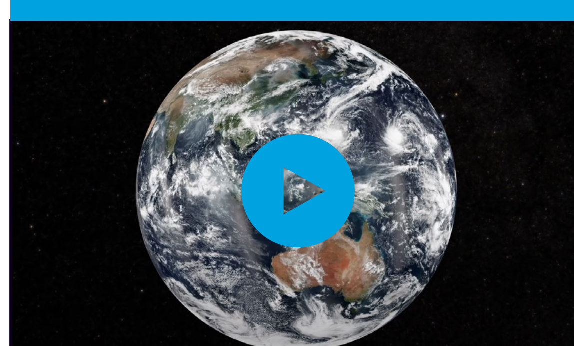
In addition, the European Commission, its partners and members of the Copernicus ecosystem have established a dedicated EU Space webpage that gathers their various initiatives.

Copernicus is coordinated and managed by the European Commission, working in partnership with the European Union (EU) Member States, ESA, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU agencies and Mercator Ocean. ■

Watch the Rapid Action on COVID-19 video



Watch the COVID-19 Earth-observation dashboard tutorial video



The German Earth observation programme in support of sustainable development

By Helmut Staudenrausch, Team Leader Operational Programmes, **Jens Danzeglocke**, Project Officer Earth Observation Applications, Earth Observation Department, and **Ralf Ewald**, Project Officer Frequency Management, Satellite Communications Department, German Aerospace Center (DLR) Space Administration

Helmut Staudenrausch

Jens Danzeglocke

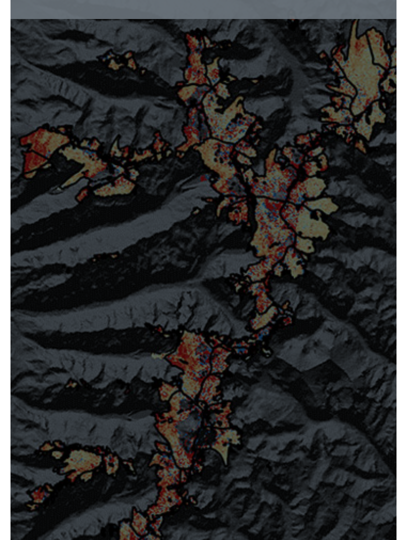
Ralf Ewald

Today we know a great deal more about our planet than we did a generation ago. Global change, the sustainable development of our habitat, careful use of resources, ensuring our mobility and our position amid international competition for cutting-edge technology, coping with crisis situations, and minimizing the risks that arise from technological and criminal threats – all pose major challenges.

Satellite-based Earth observation helps to address these issues. Today, it is strategically important for governments, the economy and citizens. Indeed, the German Space Strategy, implemented by German Aerospace Center (DLR) Space Administration, uses sustainability as one of its guiding principles, and Earth observation plays a major role in it.

Today's satellite technology capabilities

Present-day satellite technology enables objects under one metre across to be identified from an altitude of 800 kilometres. In addition, parameters such as the composition of the atmosphere, water bodies, and the condition of agricultural crops and forests can be observed. Even ground movements, such as subsiding areas or buildings and bulging volcanoes, can be determined with precisions down to the millimetre range.



> *Even ground movements, such as subsiding areas or buildings and bulging volcanoes, can be determined with precisions down to the millimetre range.*
>
> Helmut Staudenrausch, Jens Danzeglocke and Ralf Ewald

Germany's Earth observation programme covers the entire spectrum of these capabilities. The TerraSAR-X and TanDEM-X satellites are world leaders in the field of spaceborne X-band radar technology and, through their unique formation flight, could generate a global 3D dataset of the Earth's surface with unprecedented quality.

The X-band will also play a vital role in the new High Resolution Wide Swath (HRWS) mission – providing continuity in high resolution radar imaging and even finer resolution with larger coverage. Important pioneering optical remote sensing technologies are also part of our portfolio: The EnMAP mission carries an imaging spectrometer instrument (UV–SWIR) capable of measuring vegetation, soil and surface water properties from space with unprecedented accuracy. The MERLIN mission with its lidar instrument – a cooperation with the French space agency CNES – will measure atmospheric methane and contribute to the global monitoring of greenhouse gases.

Our national Earth observation programme (see Figure 1) operates in cooperation with our European partners. We are partners within the European Space Agency, where we collaborate to develop cutting-edge Earth and climate research satellites and related technology. Our project METimage is a direct contribution to the next generation polar-orbiting weather satellites of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

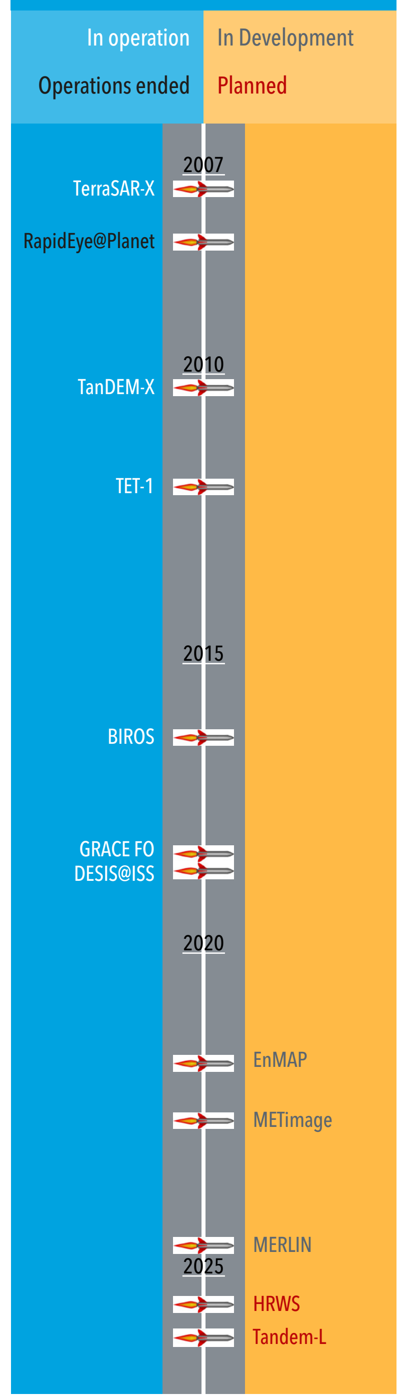


Figure 1 – German Earth observation programme missions

Implementing reliable and long-term Earth observation

In the Copernicus programme, we are working with our European Union partners to implement reliable and long-term Earth observation. Various satellites are deployed in series for this purpose, allowing every point on Earth to be surveyed repeatedly and frequently enough to detect changes or threats to forests, farmland, air and water across Germany, Europe and the rest of the world.

Germany is also involved in international networks and initiatives, through which coordinated data collections are made available worldwide to assist in the event of major natural disasters (International Charter Space and Major Disasters), to support the Global Stocktake process foreseen within the framework of the Paris Agreement, and to support the protection of tropical rainforests (Global Forest Observation Initiative, GFOI) and global food security (GEO Global Agricultural Monitoring, GEOGLAM).

Earth observation and the SDGs

The development of innovative applications is being supported by our Earth observation programme. One important field is the implementation of the United Nations (UN) 2030 Agenda for Sustainable Development: The 17 Sustainable Development Goals (SDGs) generate monitoring needs which require huge amounts of spatial information, many of which can be derived from satellite imagery; e.g. projects funded within our national programme have measured extent and volume changes of mountain glaciers at a continental scale (see Figure 2), analysed conditions and use intensities of tropical wetlands, and modelled wildfire risk in northern latitudes based on Earth-observation data.

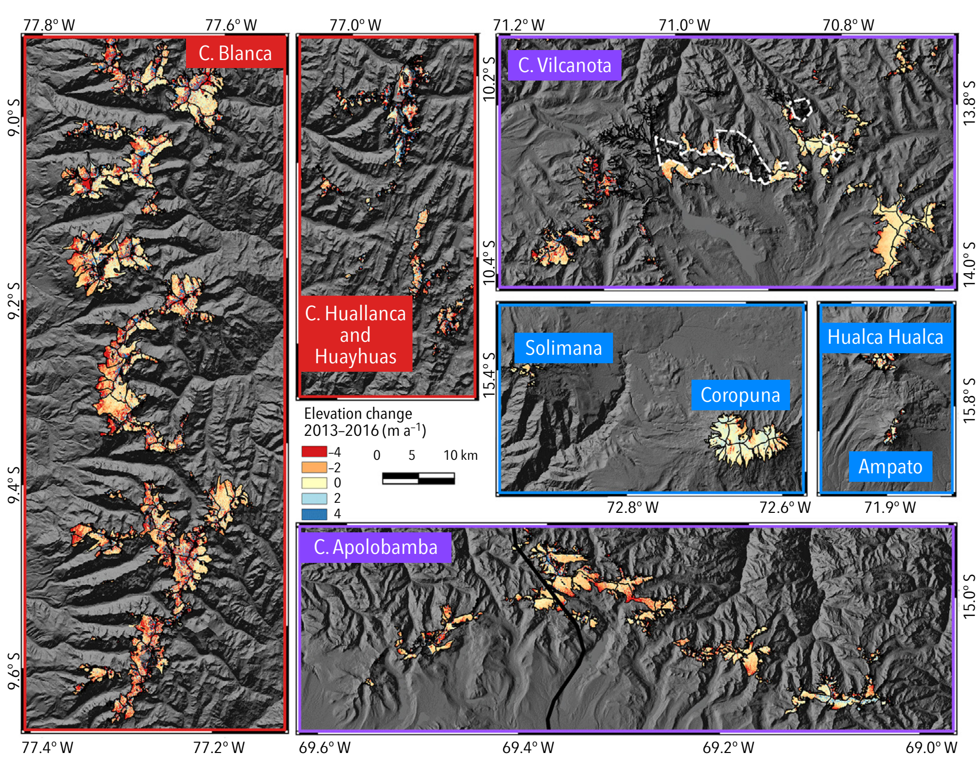


Figure 2 – Elevation change rates derived from TerraSAR-X and TanDEM-X data show a massive decrease of glacier surfaces in the tropical Andes (Peru, Bolivia) between 2013 and 2016.

These results from the project "GEKKO" not only form important input to a better understanding of regional and global climate change, but also provide a basis for future water management in affected regions and societies that receive water from the mountains (Seehaus et al. 2019).

> *To be able to better understand and manage such risks, governments and UN organizations need objective information from space.*
>
> Helmut Staudenrausch, Jens Danzeglocke and Ralf Ewald

The Co-Exist project in sub-Saharan Africa

The ongoing project "CoExist" deals with environmental determinants of transhumance patterns in sub-Saharan Africa. The changing migration routes of nomadic herders along with population increase and environmental factors such as water scarcity, can result in conflicts between farmers and nomads. This can lead to forced population displacement and substantial migration flows (see Figure 3).

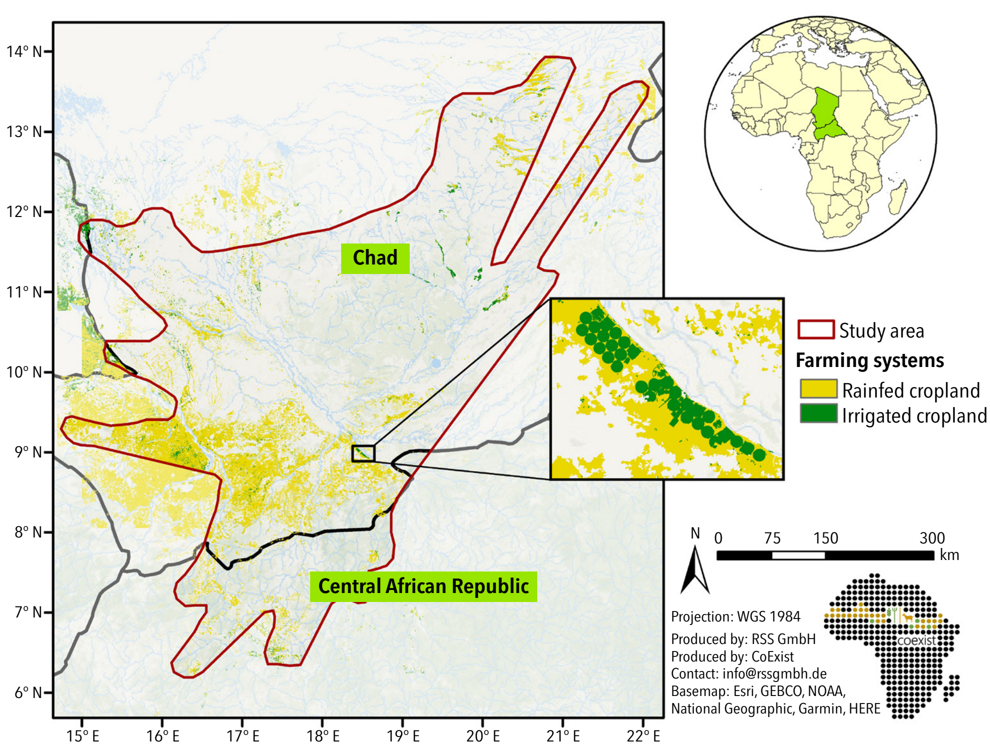
To be able to better understand and manage such risks, governments and UN organizations need objective information from space.

The importance of geospatial data and information

The aforementioned examples illustrate that geospatial data and information is of great importance for understanding processes and risks on Earth. The view from satellites has become an indispensable source of such information.

The German Earth observation programme has been designed to make a substantial contribution and to create societal benefit not only in Germany, but worldwide. ■

Figure 3 – A satellite-based map of rain-fed and irrigated agriculture in the south of Chad and an area in the north of the Central African Republic.
The study area is defined by the roughly known migration zones of nomads in that region (© Remote Sensing Solutions 2020).



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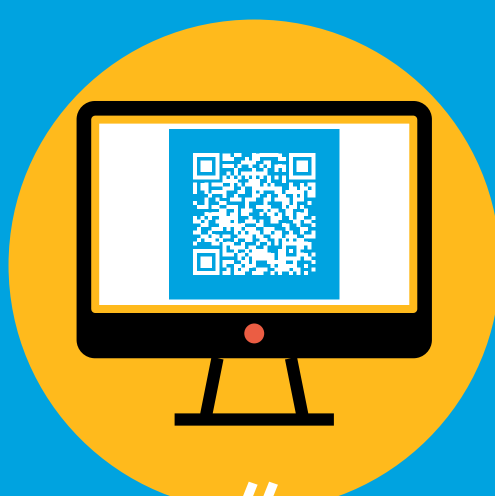

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