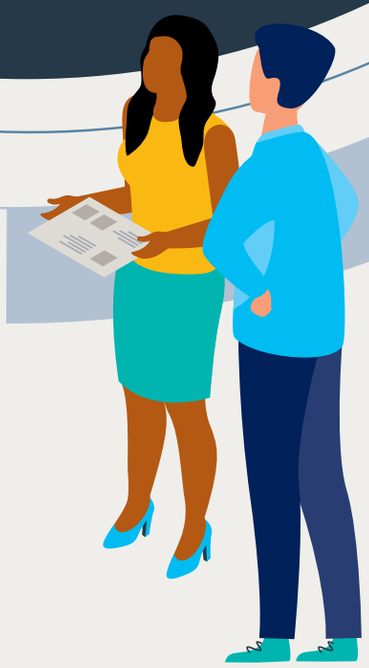


EUMETSAT

ANNUAL REPORT 2021

TABLE OF CONTENTS

> “The aim is the successful deployment of the next-generation satellite systems, Meteosat Third Generation and EUMETSAT Polar System - Second Generation. The citizens of our member states will feel the benefits from these more technologically advanced satellite systems over the next decade.”

As Europe again faced the consequences of extreme weather events in 2021, the social and economic importance of EUMETSAT's work, the need for continual innovation and the expertise of its staff was clear. Despite the impact of the covid pandemic on working conditions, EUMETSAT continued to deliver its high-quality service to member states without interruption. This was particularly rewarding for me in my first year as Director-General of EUMETSAT. I am immensely proud of what was achieved by the organisation, as a team, in 2021.

The maintaining of reliable operations was, therefore, an achievement not to be underestimated in a difficult year.

Although the number of EUMETSAT staff and contractors who caught the covid virus was, thankfully, comparatively low, working conditions at headquarters and beyond remained impacted. Onsite staff presence was limited for much of the year. Despite this, considerable progress was made on EUMETSAT's organisational objectives.

Additionally, EUMETSAT successfully de-orbited Metop-A, the first of its polar-orbiting meteorological satellites. This was carried out in accordance with UN-agreed debris mitigation guidelines and demonstrates the organisation's commitment to preserving a sustainable space environment.

DIRECTOR-GENERAL'S FOREWORD

EUMETSAT published its new, 10-year strategy, *Destination 2030*, in September. The strategy details how EUMETSAT will fulfil its objective of providing member states with the data and services they need to meet the challenges posed by extreme weather in a changing climate.

Central to this aim is the successful deployment of the next-generation satellite systems, Meteosat Third Generation (MTG) and EUMETSAT Polar System - Second Generation. The citizens of our member states will feel the benefits from these more technologically advanced satellite systems over the next decade, and from EUMETSAT's continued investment in the translation of satellite data into products and services for improved weather forecasting.

Destination 2030 also makes clear the importance of strengthening our cooperation efforts with the European Union and space agencies around the world. Through this cooperation, EUMETSAT will make even more data available for weather forecasting and climate analysis. The global challenges we face from extreme weather events in a changing climate require global responses.

EUMETSAT will seek opportunities from new approaches to satellite development in the decade ahead, including exploring the potential benefits of new space innovations. In addition, EUMETSAT will capitalise on advances in digital technologies to improve delivery of services. To this end, significant progress was made in 2021 in preparing a roadmap for the use of artificial intelligence and machine learning.

Finally, *Destination 2030* will ensure EUMETSAT strengthens its flexibility, efficiency, and innovative spirit to be ready to embrace the challenges ahead, while remaining an attractive employer.

That flexibility, efficiency and innovation was evident in 2021 across all divisions of the organisation. Staff and contractors maintained the high level of service that our member states and the users of our data expect, despite the changed working environment.

Two critical objectives for 2021 were the completion of the commissioning phase of Copernicus Sentinel-6 Michael Freilich and the continued progress toward the launch of MTG-I1 at the end of 2022. Both of these goals were met.

Further, our determination to make EUMETSAT data more quickly and easily available also was realised. EUMETSAT's new data services, EUMETView, Data Store and Data Tailor transitioned from pilot to operational status in 2021.

Another critical milestone for the organisation in 2021 was the signing of the "Copernicus 2.0" agreement with the European Commission. This agreement solidifies EUMETSAT's key role in the European Union's Copernicus Earth observation programme. Our role will expand, with EUMETSAT taking responsibility for the future anthropogenic carbon emissions-monitoring mission, CO2M. In addition, EUMETSAT has taken responsibility for a key aspect of the EC's Destination Earth initiative, an ambitious project to build digital twins of the Earth. The signing of both agreements is evidence of the EC's trust in EUMETSAT's expertise and efficiency.

In conclusion, none of these achievements would have been possible without the talent and dedication of EUMETSAT's people. I pay tribute to EUMETSAT staff members for their contributions to the organisation's successes in 2021 in challenging conditions and thank the EUMETSAT Council for its guidance and support.

Phil Evans
Director-General

> “Apart from the day-to-day operations and the preparation and development work for future missions and services, one of the most significant developments in 2021 was the launch of EUMETSAT’s new long-term strategy, *Destination 2030.*”

On behalf of the EUMETSAT member states, I would like to congratulate the EUMETSAT staff and leadership for their excellent performance in challenging times. The uninterrupted delivery of satellite data is key to the successful weather forecasts continuously provided by national meteorological and hydrological services every day of the year. These forecasts, and climate analyses based on satellite data, are of growing importance now that our societies are ever more frequently hit by extreme weather events.

In 2021, this became very visible when the border area shared by Germany, Belgium and the Netherlands was exposed to a very large amount of precipitation in less than two days, causing more than 240 casualties and an incredible amount of material damage. This event, which can be associated with climate change, illustrates the importance of improved satellite observations that will contribute to more precise weather forecasts.

And this is the core mission of EUMETSAT: developing novel meteorological satellites while at the same time operating existing satellites to provide 24/7 data to all users.

As the coronavirus pandemic dragged through its second full year in Europe, EUMETSAT staff and leadership continued to

COUNCIL CHAIRMAN'S FOREWORD

rise to this challenge by delivering on the organisation's core mission. There is no doubt the restrictions and limitations that the virus imposed caused difficulties, professional and personal. However, significant achievements were recorded in 2021 and important milestones were reached.

Phil Evans took the reins as EUMETSAT's new Director-General on 1 January. His experience and leadership qualities were critical at an important time in the organisation's history and when the value of its work has come sharply into focus.

Apart from the day-to-day operations and the preparation and development work for future missions and services, one of the most significant developments in 2021 was the launch of EUMETSAT's new long-term strategy, *Destination 2030*. This document maps out how EUMETSAT will deliver on its core mission, that is, to provide high quality, accurate data about our weather and climate to member states to enable them to protect human life and property. The fundamental value of that mission to member states and their peoples comes into increasingly sharp relief as extreme weather events occur more often due to climate change.

The first priority of the strategy is the successful deployment of the Meteosat Third Generation (MTG) and EUMETSAT Polar System - Second Generation (EPS-SG) systems. The council was pleased to see progress towards this objective was maintained in 2021, despite the impact of the pandemic.

The MTG system will revolutionise nowcasting, that is, very short-range forecasting, of severe weather events. This system will, undoubtedly, save lives. EPS-SG will improve the accuracy of weather forecasts from 12 hours to 10 or more days in advance. Its value to member states and their economies, particularly weather-dependent sectors such as agriculture, transport and tourism, will be significant. Both systems will aid our understanding of the climate.

The EUMETSAT Council also was pleased to approve the transition of the organisation's new data services from pilot to operational status in 2021. The MTG and EPS-SG systems will provide a vastly increased amount of higher resolution data. EUMETSAT's new, cloud-based data services will allow for faster, easier access to its data.

The Satellite Application Facilities (SAFs) will play a central role in translating data from the next-generation satellites into services and products. The council approved the next phase of the SAFs' work, Continuous Development and Operations Phase 4, in 2021. It also approved the allocation of €58 million over five years for the SAFs to continue and to expand their work. The SAFs have been assigned responsibility for "day one" products from the next-generation satellites. This is a first for the SAFs and recognition of the important role they play for EUMETSAT's member states.

The EUMETSAT Council met an unusual six times in 2021, the reason being two additional, very special developments: the approval of two third-party programes supported by the European Commission. The programes - "Copernicus 2.0" and DestinE - will substantially increase the number of satellite instruments under EUMETSAT's responsibility and services the organisation will provide in the near future. It is recognition of quality and reliability that the EC has asked EUMETSAT, in collaboration with the ECMWF and ESA, to run these programes. Moreover, these additional data and services are of great relevance to member states as more information on the atmosphere (CO_2 levels) will be provided.

Reaching all these milestones in 2021, while ensuring the uninterrupted continuation of services to member states, was a noteworthy feat during the pandemic. I thank Phil Evans and the whole EUMETSAT staff body, once more, for their commitment during those difficult times and wish them well for the challenging, but equally exciting, times ahead in 2022.

Gerard van der Steenhoven
Council Chairman

2021 HIGHLIGHTS

Phil Evans becomes EUMETSAT Director-General

Phil Evans became EUMETSAT's Director-General on 1 January 2021. "Being appointed by EUMETSAT at this crucial moment is both an immense honour and a huge responsibility because I could not think of a more socially relevant institution to work for at the moment," Evans said. By providing precise satellite data and products when and how they can be best used, EUMETSAT plays a central role in enabling national meteorological and hydrological services to deliver accurate weather forecasts to their communities. The importance of this mission cannot be overstated as the frequency of severe weather events increases as the Earth's climate changes.

Launcher agreement signed with Arianespace

Agreement was reached with Arianespace to launch two of EUMETSAT's Meteosat Third Generation (MTG) satellites on the next generation of Ariane launcher. The sounder satellite MTG-S1 and the imager satellite MTG-I2 will be launched on Ariane 6 rockets from Kourou in French Guiana.

EUMETSAT Director-General Phil Evans (top right) and Arianespace CEO Stéphane Israël sign an updated launch services agreement

€58 million for innovative satellite data and software products

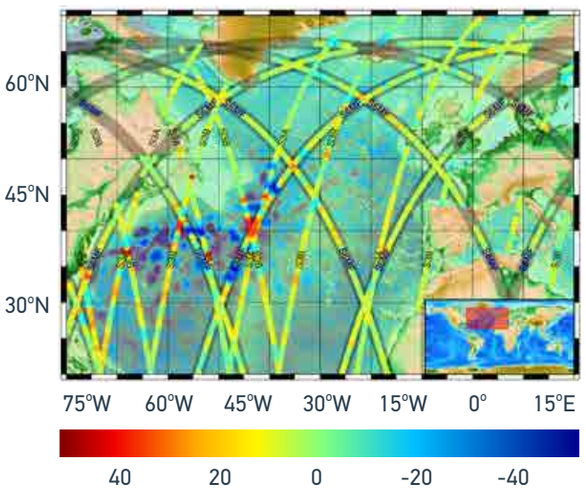
EUMETSAT's Satellite Application Facilities (SAFs) received an allocation of €58 million over five years to keep developing innovative approaches to translating satellite data into services that will provide significant benefits to society.

EUMETSAT at the centre of global data sharing network

The EUMETSAT Council approved the renewal of a series of cooperation agreements with international agencies, strengthening the organisation's place at the centre of a global network sharing weather and climate data. The agreements, with Chinese, Japanese, South Korean and African agencies, reflect the global nature of the challenge of improving weather forecasting and climate change monitoring.

Copernicus Sentinel-6 data released

The first data and products from instruments on board Copernicus Sentinel-6 Michael Freilich were released to data users in June, after intensive calibration and validation activities. High-resolution data were released to users in November, at the end of the satellite's commissioning phase.



Sea level variations across the northern Atlantic Ocean as measured from satellite altimetry on 13 June 2021. Strong negative (blue) and positive (red) anomalies are associated with the Gulf Stream. Along-track data from current altimetry missions is laid over an image of modelled sea level variations from a long-term mean, as produced by the Copernicus Marine Service for the same day. The overlaid tracks reflect the measurements by the Copernicus altimeter constellation, where the data from Sentinel-6 Michael Freilich is highlighted in yellow.

Pilot programme to buy satellite data approved

EUMETSAT signed a contract with Spire Global Luxembourg S.a.r.l. for a three-year pilot programme to purchase radio occultation data, process it and disseminate it for use in weather forecast modelling. It is the first time EUMETSAT has agreed to purchase data from a commercial satellite fleet operator.

2021 HIGHLIGHTS

Artist's impression of the Spire satellite network (credit: Spire)

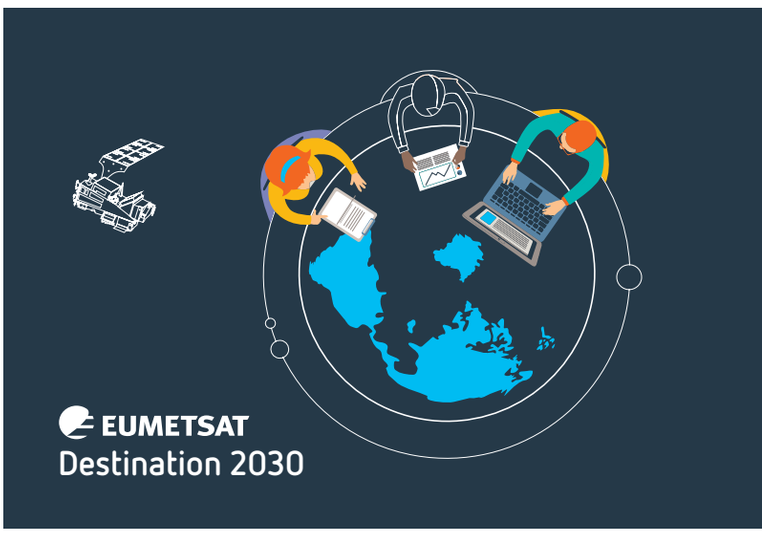
European Earth observation missions assured

EUMETSAT signed an agreement with the European Commission that will result in the organisation taking responsibility for the operations of the largest number of Sentinel satellites in the Copernicus Earth observation programme fleet. The agreement is worth €755 million until the end of 2027 and provides continuity of support to the Copernicus programme.

EUMETSAT's Low-Earth Orbit Mission Control Centre

EUMETSAT releases long-term strategy, *Destination 2030*

EUMETSAT released its long-term strategy, *Destination 2030*, which focuses on the challenge of providing more precise information, faster, about the weather and climate. Director-General Phil Evans said the returns will be felt over the next decade from soon-to-be-launched, more technologically advanced, satellite systems, as well as continued investment in the translation of satellite data into products and services for weather forecasting, and improved data access.



Scientists virtually discuss advances in Earth observation

About 600 scientists from around the world took part in the virtual 2021 EUMETSAT Meteorological Satellite Conference, focusing on the benefits for weather and climate prediction flowing from the renewal of Europe's meteorological satellite fleet. The conference was jointly organised and hosted by EUMETSAT and Romania's national meteorological service.

2021 HIGHLIGHTS

EUMETSAT's Africa User Forum takes place online in September-October 2021

Africa User Forum focuses on next-generation systems

The 2021 Africa User forum focused on African nations' capacity to significantly improve weather and climate forecasting through access to data from Europe's next-generation meteorological satellites. The forum attracted more than 200 participants, despite pandemic restrictions forcing the change to an online format.

EUMETSAT takes key role in digital twins project

EUMETSAT has taken responsibility for a key part of the European Union's Destination Earth (DestinE) initiative to create digital twins of the entire Earth system. EUMETSAT will have end-to-end responsibility for the multi-cloud data lake underpinning DestinE, including its design, establishment, testing and operations, and provision of an online inventory. ESA and the ECMWF are the other partners in the DestinE project.

Metop-A successfully deorbited

EUMETSAT's first polar-orbiting satellite, Metop-A, was successfully deorbited at the end of November after more than 15 years' service, more than three times as long as planned. A series of experiments was held before the satellite's deorbiting, with the aim of providing information to benefit operations of the remaining polar-orbiting satellites, Metop-B and -C.

Artist's impression of Metop-A in orbit

Staff survey

About 91 percent of EUMETSAT's staff members completed the latest staff survey, conducted online in September. The high level of engagement will assist the organisation to respond to issues highlighted by the survey's results. Detailed responses to the survey's findings will be implemented in 2022.

African Space Art Project

Artists Michel Ekeba and Géraldine Tobé from the Democratic Republic of Congo and Jean David Nkot of Cameroon were selected to produce a piece of contemporary art to adorn the launcher taking the first MTG satellite into space. The African Space Art Project is a joint initiative of African Artists for Development, EUMETSAT and Arianespace and highlights the importance of the MTG system for Africa.

2021 HIGHLIGHTS

Jean David Nkot, Géraldine Tobé, EUMETSAT Head of Strategy, Communication and International Relations Paul Counet and Michel Ekeba at the unveiling of artwork to grace the Arianespace rocket taking the first MTG satellite into space

Energy-efficient EUMETSAT

EUMETSAT's Technical Infrastructure Building received the highest level award from the independently evaluated global certification programme for energy efficiency best practices for data centres (CEEDA). The Technical Infrastructure Building is the largest consumer of energy at EUMETSAT, accounting for 62% of the campus's entire energy use. Ensuring it is run as efficiently as possible provides value for our member states.

The energy-efficient Technical Infrastructure Building at EUMETSAT headquarters

EUMETSAT AND THE COPERNICUS PROGRAMME

The Copernicus programme is the European Union's Earth observation programme. Its information services draw on vast amounts of satellite observations and *in-situ* data to help service providers, public authorities and other organisations improve the quality of life of citizens in Europe and beyond. The information services are free and open to everybody.

The European Commission manages the Copernicus programme, which is implemented in partnership with EU member states, the European Space Agency, EUMETSAT, the European Centre for Medium-Range Weather Forecasts (ECMWF), EU agencies and Mercator Ocean International.

EUMETSAT's involvement in the Copernicus programme extends beyond operating satellites and processing, disseminating and archiving their data. EUMETSAT's expertise and long-term data records are important inputs for the Copernicus programme's climate services. EUMETSAT, the ECMWF, Mercator Ocean International and the European Environment Agency jointly operate the WEkEO Copernicus data and information access platform.

From its headquarters in Darmstadt, Germany, EUMETSAT operates the ocean-monitoring Sentinel-3 and Sentinel-6 missions. The atmosphere-monitoring Sentinel-4 and Sentinel-5 instruments will be flown aboard EUMETSAT's Meteosat Third Generation and EUMETSAT Polar System - Second Generation satellites. EUMETSAT also will play a key role in the future Copernicus carbon-monitoring and polar-monitoring missions.

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

CASE STUDY

Using satellite data to benefit Romania

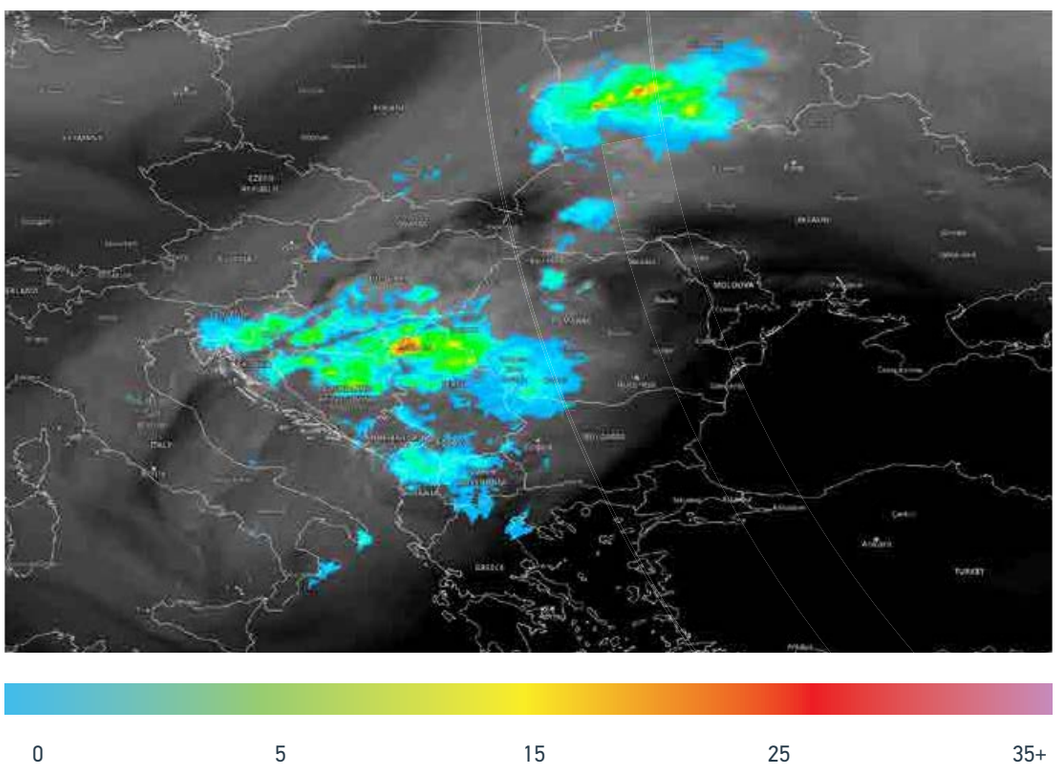
The 2021 EUMETSAT Meteorological Satellite Conference was jointly hosted with the National Meteorological Administration of Romania. A highlight of the online conference was a panel discussion on how EUMETSAT's satellite data are used to benefit Romania's people. Here, we focus on the importance of satellite data for helping to forecast flooding in Romania.

Riverine floods are one of the most destructive natural disasters worldwide and climate change is widely expected to make them more frequent and extreme in the coming decades. Yet floods can be very difficult to predict.

Dr Marius Matreata, Director of Romania's National Hydrological Forecasts Centre (NHFC), a department within the National Institute of Hydrology and Water Management, explained how the centre is using satellite data to support the delivery of short-, medium-, and long-term flood forecasting and warnings across Romania.

Romania's landscapes, culture, and economy are intertwined with rivers - the country is located almost entirely within the Danube river basin. Heavy rainfall can result in major flood events. The NHFC uses forecasting and modelling systems that integrate satellite and ground-based data to simulate and forecast hydrological processes in Romania in real time. Specialised hydrological modelling components support real-time simulation and forecasting of hydrological processes at different spatial and temporal scales, Matreata said.

The centre is also a partner in regional cooperation projects, like the European Flood Awareness System, which makes use of EUMETSAT Satellite Application Facilities, and the South-East Europe Flash Flood Guidance System, which is using the US National Oceanic and Atmospheric Administration's HydroEstimator satellite-based precipitation estimates.



This image using the Operational Hydrology and Water Management Satellite Application Facility's precipitation product over a Meteosat water vapour image shows a heavy rain event over Eastern Europe at 12:00 UTC on 18 July 2021, with eastern Romania particularly affected (credit: H SAF)

> “Over the next five to 10 years, we will use more and more satellite products for real-time operations, as well as for the calibration and validation of hydrological forecasting models.”

Dr Marius Matreata, *Director of Romania’s National Hydrological Forecasts Centre*

Next-generation satellites such as EUMETSAT’s forthcoming Meteosat Third Generation imager series will provide tremendous opportunities to further improve flood predictions, Matreata said. For instance, data collected by MTG-I satellites will significantly boost both numerical weather prediction and nowcasting capabilities across Europe.

Matreata said that the development of hydrological forecast products to take advantage of the increasing volumes of data is both a huge challenge and opportunity.

“These could be crucial, especially for flooding events,” he said. “The new generations of satellite sensors and products could help us to detect initiation of intense surface runoff formation.

“Over the next five to 10 years, we will use more and more satellite products for real-time operations, as well as for the calibration and validation of hydrological forecasting models.

“We will be able to significantly improve our hydrological forecasting and modelling products and their spatial and temporal resolution.”

Main image: An aerial image of a flooded neighbourhood in Tecuci, 220km north-east of Bucharest, 6 September 2007 (credit: Reuters/Intact Images/Victor Stroe (Romania))

CASE STUDY

Nowcasting without doubt

A once-in-four-hundred-years catastrophe. Flooding like Germany had not witnessed in the entire 20th Century… Storm Bernd, which swept through north-western Europe on 12-15 July 2021, left desolation behind it. Satellite data and advanced modelling capacities had provided advanced warnings, but disbelief at the enormity of the rainfall figures predicted diminished their impact.

Flooding associated with Storm Bernd affected Austria, Belgium, Croatia, Germany, Italy, Luxembourg and the Netherlands, causing an estimated minimum of €10 billion in damage. At least 243 people in Germany, Belgium, Romania, Italy and Austria were killed.

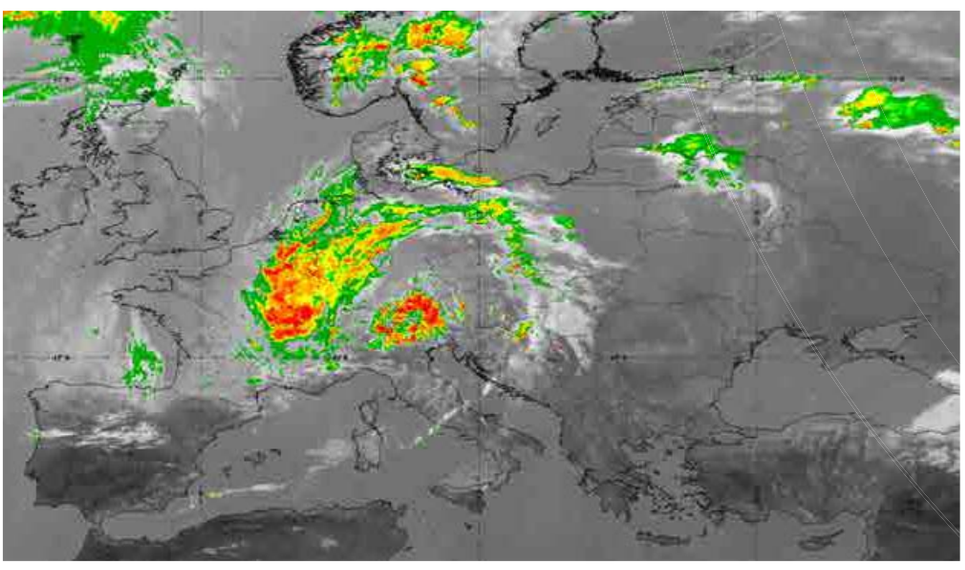
Prof Dr Roland Potthast, Head of Numerical Weather Prediction at the Deutscher Wetterdienst (DWD), looks back with us on the performance of the global and regional predictive models used by the German national meteorological and hydrological service and explains how they will evolve.

"Because we have so little time to warn people and launch alerts, the accuracy of our predictive models and the realism of our short-range forecasts of extreme weather events should raise no doubts," explains Potthast. "Our models are already very accurate, but it is important to keep assimilating new data that can make forecasts even more precise. Improvement is needed and it should be possible!"

Current models of DWD forecasting with 2km resolution deliver 48 hours' advance notice; models that provide more advance notice have a resolution of 6.5km (European Union) or 13km (global). The range and the resolution of the data provided by satellites are paramount to ensure that forecasting models become even more realistic. Geostationary satellites, in particular, that enable forecasters to follow extreme weather events from their onset to their end, provide crucial data for reaching that goal.

"The models used to forecast the precipitation in July 2021 assimilated data from different sources, not only satellite data. However, microwave and infrared sounders were very important to ensure accuracy in predicting the massive rainfalls," explains Potthast. "In the future, we want to assimilate data from sensors scanning the entire spectrum up to the visible range, to increase resolution, and be able to issue earlier warnings with high precision."

The instruments on board the next-generation, geostationary, Meteosat Third Generation satellites, that will start to be launched in 2022, have the potential to do just that: bring the data variety and resolution that nowcasters are currently missing to maximise the impact of their models. The MTG-Imager (MTG-I) satellites will carry the Lightning Imager instrument. The Lightning Imager will continuously map lightning flashes, from cloud to cloud and from clouds to the ground.



The slow-moving nature of the storm in the image, left, led to significant accumulations of rainfall and devastating flooding. The areas of most intense rainfall are shown in red. The image uses the Nowcasting Satellite Application Facility's precipitating clouds product overlaid on a Meteosat infrared 10.8 micron image and was taken on 14 July 2021.

> “Because we have so little time to warn people and launch alerts, the accuracy of our predictive models and the realism of our short-range forecasts of extreme weather events should raise no doubts. Our models are already very accurate, but it is important to keep assimilating new data that can make forecasts even more precise. Improvement is needed and it should be possible!”

Prof Dr Roland Potthast, *Head of Numerical Weather Prediction at Deutscher Wetterdienst*

Aviation safety is just one area expected to benefit from this instrument. The Infrared Sounder instrument on MTG-Sounder satellites will add an important new element to EUMETSAT's geostationary fleet. This instrument will enable forecasters to detect initial instability in the atmosphere, before clouds even form, through to the formation of a convective storm.

So the MTG system will provide continuous information allowing forecasters to track the full lifecycle of a storm, from initial instability through to lightning strikes. The first MTG-I satellite is due to be launched at the end of 2022 and the first MTG-S satellite in 2024. This highly complex satellite system will revolutionise the nowcasting of severe weather events in Europe.

Main image: The aerial image above shows the high water levels and flooded banks where the Mosel River joins the Rhine at the so-called "Deutsches Eck" in Koblenz, Germany, 3 February 2021 (credit: Reuters/Wolfgang Rattay)

CASE STUDY

Unprecedented wildfires in Siberia spread smoke over the Arctic

Smoke from wildfires in parts of Siberia set undesirable new records in 2021, with meteorologists recording large plumes reaching the geographic North Pole.

Wildfires in Siberia, North America, Africa, and southern Europe contributed to the largest global total of wildfire emissions for July since comprehensive satellite records began in 2003.

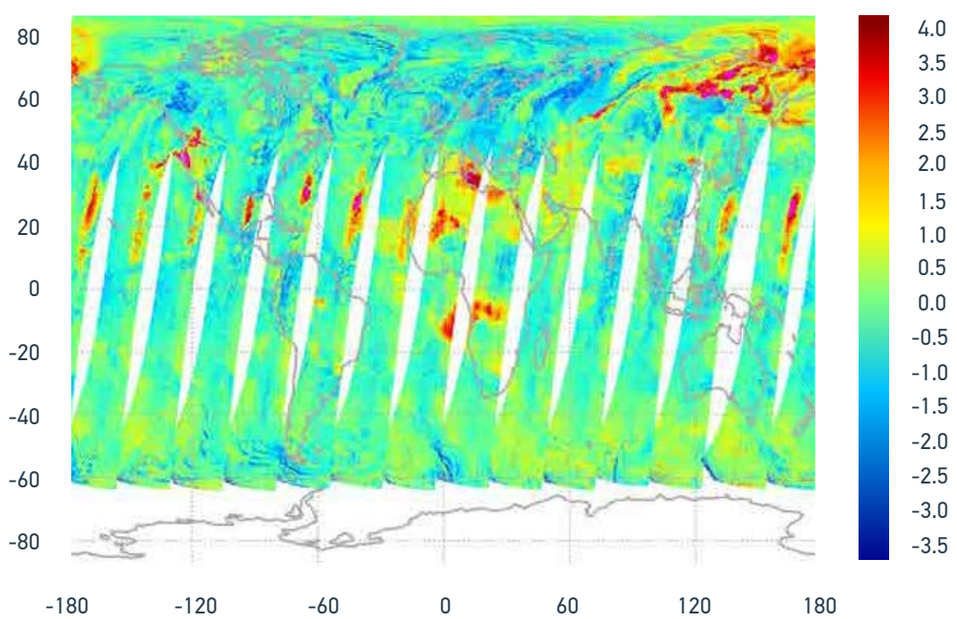
"Satellites are crucial for monitoring wildfires and their impact on the atmosphere and on land," Dr Federico Fierli, an atmospheric composition expert at EUMETSAT, said. "This is even more important in regions where control and monitoring from the ground is particularly difficult."

Satellite data and products from EUMETSAT-operated missions and international partners helped researchers and authorities track wildfires, the pollution and particles they produced, and the scorched lands they created, in near-real time. This information can aid understanding of the potential impacts and inform communities about potential public health risks. The long-term data show worrying trends, with average fire seasons in Siberia and many other parts of the world increasing in intensity and duration.

By mid-August, fires had burned more than 150,000km^2 of forest and tundra in Siberia, an area larger than the Netherlands, Belgium, and Denmark combined. Studies have pinpointed human-driven climate change as playing a key role in this change. The average annual temperature in the Sakha region has risen by about 3°C since the beginning of the 20th Century and fires in the region are starting, on average, earlier and farther north than before. Images taken by the EUMETSAT-operated Copernicus Sentinel-3 satellites in August showed brown-coloured smoke from the fires sprawling across Siberia and up towards the North Pole.

"Fires in Siberia, like in many other places across the globe, are increasing in size and intensity," Fierli said.

"Although wildfires are regularly seen in Siberia at this time of year, it is becoming clear that their increasing scale is now the norm, rather than the exception. The trend is deeply concerning."



Absorbing aerosol index using polarisation measurement devices data collected using Metop-C's Global Ozone Monitoring Experiment-2 on 12 August 2021

> “The increase in the total estimated fire emissions in the Sakha region has been almost double the total from last year, which itself was a record annual total in our fire emissions dataset, going back to 2003.”

Mark Parrington, *Copernicus Atmosphere Monitoring Service senior scientist*

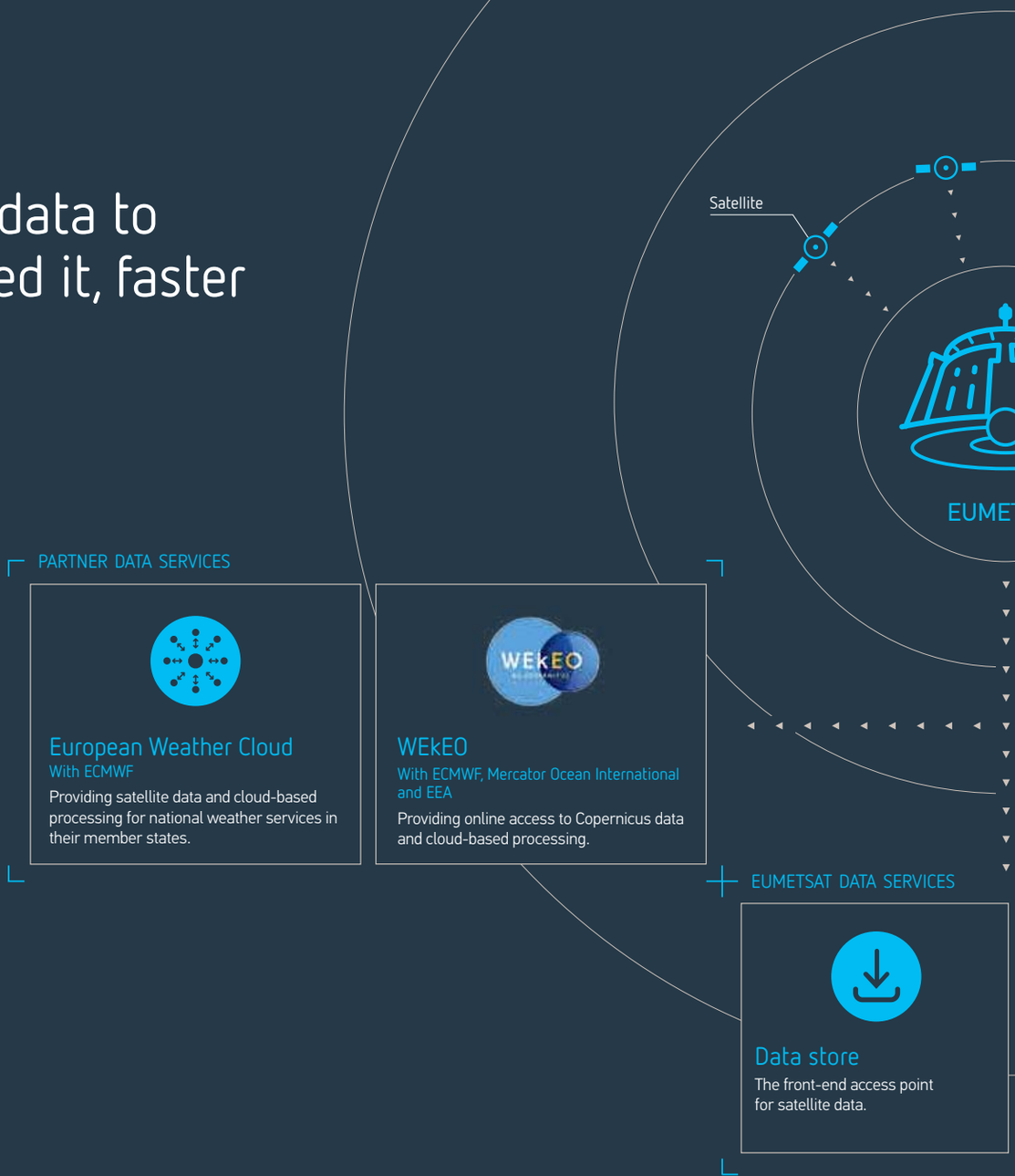
Other measures also revealed a deeply disturbing picture. For instance, the Absorbing Aerosol Index, which indicates the presence of elevated absorbing aerosols in the Earth's atmosphere - such as soot particles in smoke which absorb and scatter incoming sunlight - clearly showed the scale and extent of fires across Siberia. By monitoring aerosol particles suspended in the air, researchers are able to learn their global distribution and understand their long-range transport. EUMETSAT is responsible for generating and ensuring the quality of near-real-time aerosol observations, as well as long-term validation and improvements, helping researchers and organisations track the intensity and emissions of wildfires the world over.

The European Union's Copernicus Atmosphere Monitoring Service (CAMS) estimates that emissions between 1 June and 15 August from the Sakha Republic totalled approximately 800 megatons of carbon dioxide equivalent. This compares to 450 megatons from the same region for the whole of 2020.

Main image: Smoke from Siberian wildfires is shown in this composite image taken by the Copernicus Sentinel-3 Ocean and Land Colour Instrument, 00:30 and 01:32 UTC over the Dzhigda region and Sea of Okhotsk on 12 August 2021

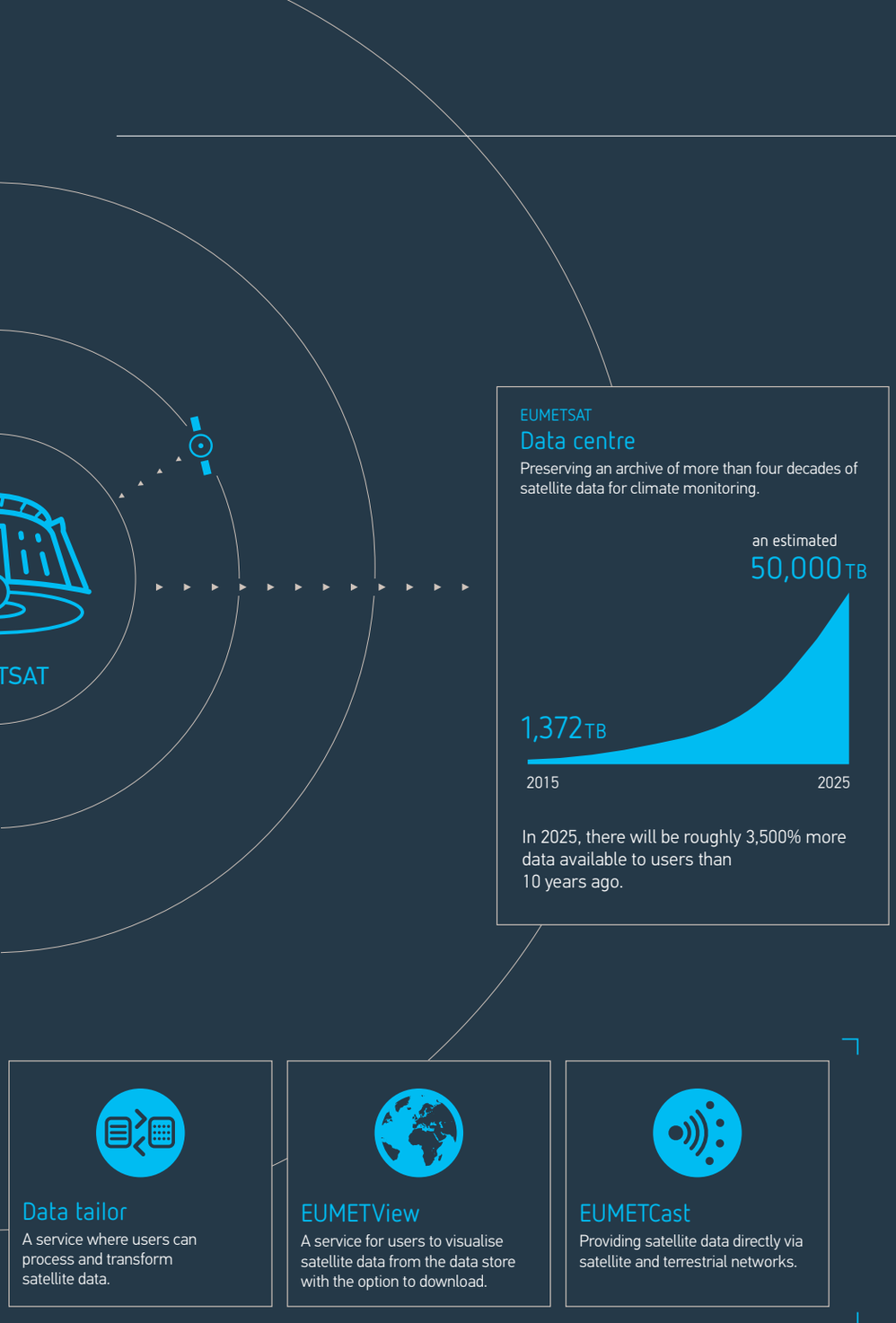
SATELLITE OPERATIONS

Getting more data to those who need it, faster



Our data services provide quick and easy access to all of EUMETSAT's satellite data. And now, users can work directly with this data through new cloud platforms.

Central to EUMETSAT's ability to provide its member states, and others, with precise, timely data for weather forecasting and climate monitoring is the responsible and efficient operation of its satellite fleets. A highlight in this area in 2021 was the end of the commissioning phase of Copernicus Sentinel-6 Michael Freilich, which began routine operations at the end of the year. Metop-A reached the end of its very long lifetime of service and was de-orbited in line with UN-agreed debris mitigation standards.



EUMETSAT

Data centre

Preserving an archive of more than four decades of satellite data for climate monitoring.

In 2025, there will be roughly 3,500% more data available to users than 10 years ago.

Data tailor

A service where users can process and transform satellite data.

EUMETView

A service for users to visualise satellite data from the data store with the option to download.

EUMETCast

Providing satellite data directly via satellite and terrestrial networks.

Across EUMETSAT's fleets, a direct operational response was required in 56 instances when radiation or heavy particle impacts from the space environment triggered a disruption (single event transient, or SET) to a satellite's platform systems or instruments. Also in 2021, while several predicted conjunctions with space debris indicated a high risk to one of our operational satellites, only one event - between Metop-A and an operational ISRO satellite - ultimately required a collision avoidance manoeuvre.

Very significant milestones were achieved during the year for EUMETSAT's data services. New "big data" services transitioned from pilot programmes to fully operational status. EUMETSAT's Satellite Application Facilities (SAFs) were allocated funding for their next phase of development and operations and the climate services team's contributions to understanding of the Earth's climate were reflected in a major international report.

SATELLITE OPERATIONS

SATELLITES IN OPERATION IN 2021

GEOSTATIONARY SATELLITES

Meteosat-11

0° Longitude - Full Earth Scan imagery

Provides the Meteosat primary full-disc imagery service over the European continent, Africa, and parts of the Atlantic and Indian oceans.

Meteosat-10

9.5°E - Rapid Scan Service (RSS)

Delivers the Meteosat secondary RSS service over Europe and adjacent seas.

Meteosat-9

3.5°E - Backup spacecraft

Hot backup satellite for the Full Earth and Rapid Scan services. To be relocated to the Indian Ocean in early 2022.

Meteosat-8

41.5°E - Indian Ocean data coverage (IODC)

Delivers the EUMETSAT best-effort contribution to multi-partner IODC services. To be decommissioned in late 2022.

METEOSAT

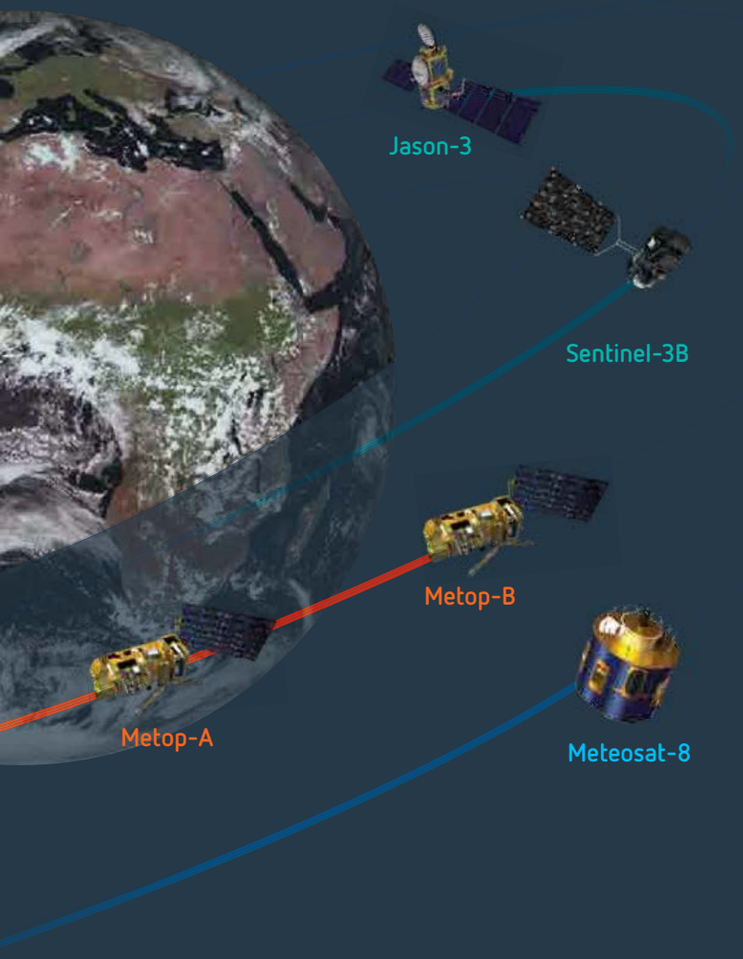
Routine operations of all four Meteosat satellites were the focus in 2021, along with preparation for relocation and decommissioning activities for Meteosat-8 and -9 planned for 2022. The satellites' health remains good with characterisation of thermal effects and mitigation strategies ongoing. An unprecedented concurrent satellite safe mode event occurred in December 2021 but resulted in minimal interruption to services.

METOP

Three-Metop routine operations continued throughout 2021 until October, when Metop-A was removed from operational service. After a period of technology testing, Metop-A was decommissioned and disposed of in line with UN-agreed debris mitigation guidelines. Metop operations ended the year in a dual-satellite configuration.

JASON

Jason-3 continued as the reference mission for high precision ocean altimetry. In 2021, Jason-3 continued to operate in formation with Copernicus Sentinel-6 Michael Freilich to allow for cross-calibration of its instrument suite.



LOW-EARTH ORBIT SATELLITES

Metop-B
SSO 98.7° inclination - EPS primary mission
Delivers the primary operational EPS services from 817km altitude.

Metop-C
SSO 98.7° inclination - EPS secondary mission
Delivers additional EPS services from 817km altitude.

Metop-A
SSO 98.7° inclination - EPS secondary mission
Delivered additional EPS services from 817km altitude and primary support to the ARGOS and search and rescue missions. Was decommissioned in November 2021.

Jason-3
NSO 66° inclination - Primary ocean surface topography mission
Delivers measurements of ocean surface topography and sea state from a non-synchronous, 10-day repeat orbit at 1,336km altitude (mission shared with CNES, NOAA, NASA and the European Commission). Current reference altimetry mission in the high precision ocean altimetry orbit. Planned to depart ocean altimetry reference orbit in 2022, to be replaced by Sentinel-6 Michael Freilich.

Copernicus Sentinel-6 Michael Freilich
NSO 66° inclination - Next-generation ocean altimetry mission
Primarily delivers measurements of ocean surface topography and sea state from a non-synchronous, 10-day repeat orbit at 1,336km altitude (mission partners are EUMETSAT, the European Commission, ESA, NASA/JPL and NOAA with support from CNES). To assume primary responsibility for ocean altimetry (OSTM) in 2022 when Jason-3 departs reference orbit.

Copernicus Sentinel-3A and -3B
SSO 98.7° inclination - Copernicus dual-satellite Sentinel-3 mission
Delivers Copernicus marine data services from 814km altitude.

SENTINELS

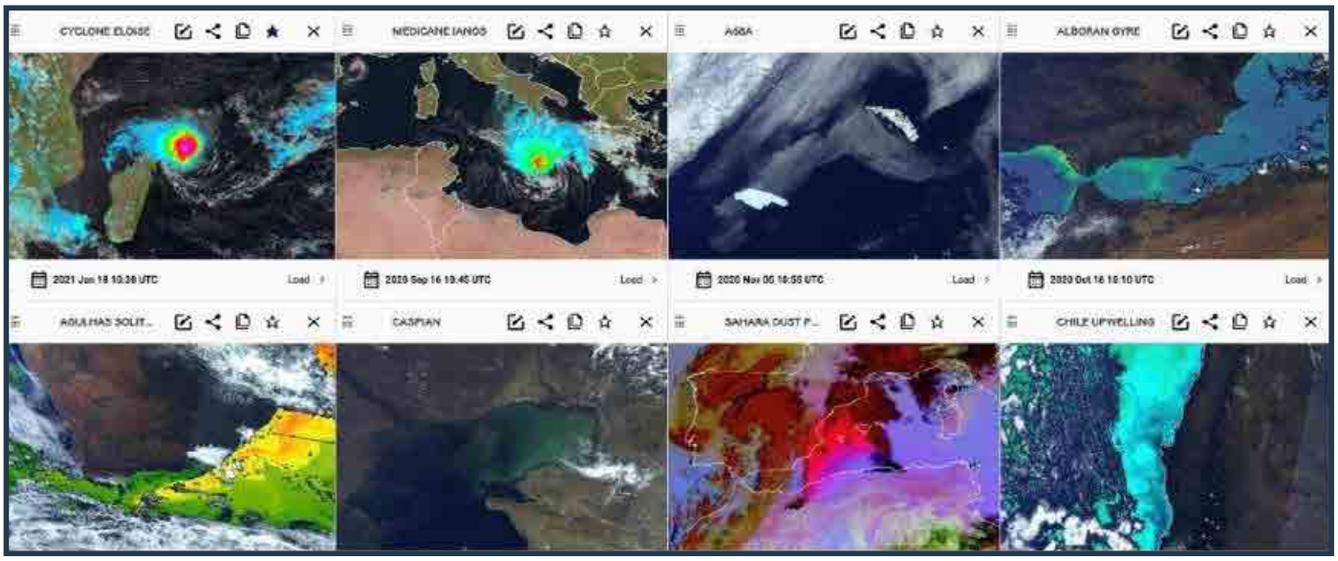
Copernicus Sentinel-3 satellite operations consisted of routine, dual-satellite operations. The Sea and Land Surface Temperature Radiometer decontamination process was optimised to reduce the duration of the process and minimise the resulting impact on service. The response to a known anomaly with the Ocean and Land Colour Instrument camera was optimised to minimise the impact on service during any outage.

The average yearly availability to users of Sentinel-3 marine and near-real-time atmospheric products exceeded all applicable targets.

Copernicus Sentinel-6 Michael Freilich completed its in-orbit verification and system commissioning activities following its 2020 launch and entered routine operations phase in November 2021.

The Poseidon-4 altimetry payload was reconfigured to the redundant electronics side to assess a degradation of gain seen on the nominal side, although similar performance was observed on the redundant. Mission products remain within specification and the risk to consistent calibration arising from a subsequent side swap later in the mission was mitigated.

SERVICES TO USERS



Users of EUMETSAT's EUMETView service can save their favourite satellite imagery, as shown in this screenshot

DATA SERVICES

To ensure member states reap the maximum benefit from EUMETSAT's satellite fleets, considerable effort is made to ensure data is provided to those who require it in a way that meets their needs, that is, quickly, reliably and efficiently. A key milestone in the modernisation of EUMETSAT's data services was reached in 2021, when a range of big data services became operationally available. After a successful pilot phase lasting more than a year, and the completion of operational readiness checks, the new EUMETView, Data Store and Data Tailor web services and EUMETCast Terrestrial became operational.

Activities began five years ago with the EUMETSAT Council's approval of the strategy, followed by a four-year pathfinder and pilot development phase. That phase culminated in the release of pilot services in 2020. Activities in 2021 focused on the transition of those services to operational status.

ACHIEVING OPERATIONAL STATUS

- August 2021: EUMETCast Terrestrial, a near-real-time feed of satellite and model output data disseminated via multicast-enabled national research networks to users equipped with EUMETCast receiving software and hardware.
- August 2021: Data Tailor standalone software, a data customisation toolbox which allows users to reformat, subset and aggregate Meteosat and Metop satellite data.
- October 2021: EUMETView, an interactive web service that allows data users to view, download and animate satellite imagery.
- October 2021: Data Store and Data Tailor web services, a data download service with data tailoring capabilities for near-real-time and historical Meteosat and Metop satellite data.

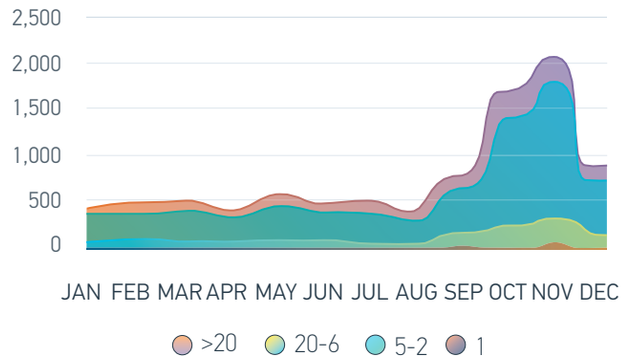
In 2022, new datasets will be added to Data Store and EUMETView, including datasets from the Sentinel-3 and Sentinel-6 missions and some data collections from EUMETSAT's Satellite Application Facilities.

SERVICES TO USERS

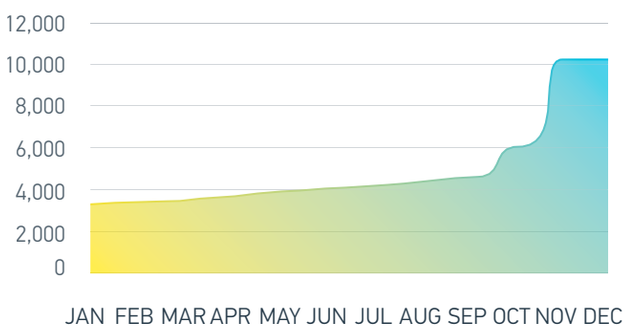
WEKEO

WEkEO is a Copernicus Data and Information Access Service in which EUMETSAT, the European Centre for Medium Range Weather Forecasts, Mercator Ocean International and the European Environment Agency are partners. It is a federated service, which allows the agencies to supply their Copernicus Earth observation data to users via the cloud, through one platform, without energy-intensive duplication of data streams and archives. The "Copernicus 2.0" agreement, signed by EUMETSAT and the European Commission in 2021, extends funding for the service for the next seven years.

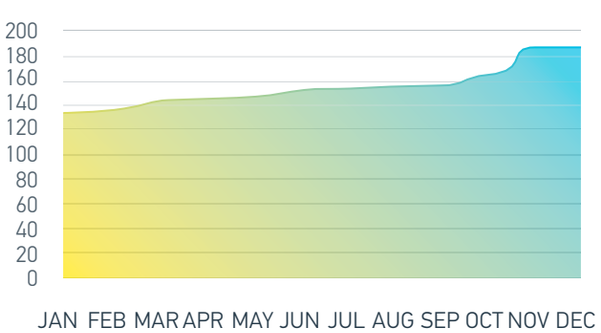
UNIQUE VISITORS TO THE WEB PORTAL



NUMBER OF REGISTERED USERS IN 2021

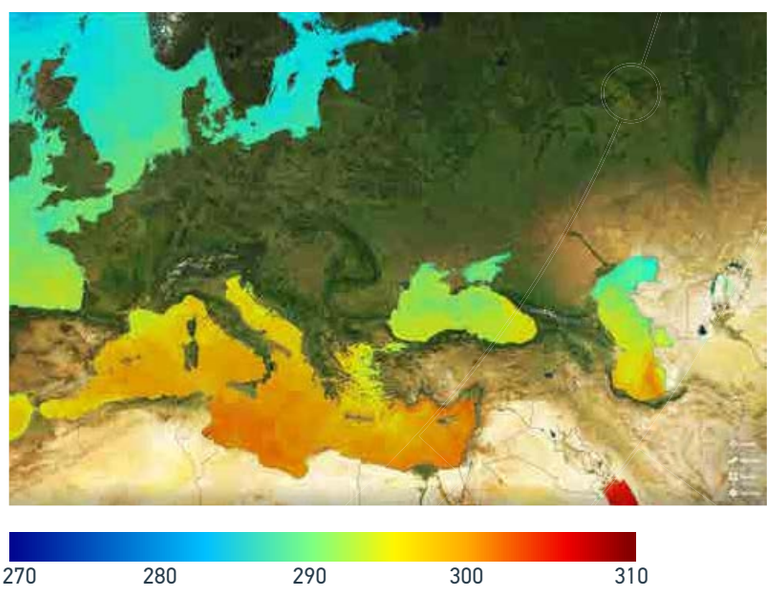


NUMBER OF HOSTED PROJECTS IN 2021:



WEkEO milestones achieved in 2021 were:

- WEkEO supported agencies in Bulgaria, Romania and Latvia taking part in the European Commission Joint Research Centre's new method, based on Earth observation, for monitoring agriculture and checking farm declarations.
- The web portal was relaunched and a survey of WEkEO users undertaken.
- The provision of the Copernicus Land Monitoring Service's High Resolution Vegetation Phenology and Productivity product from September triggered considerable interest from data users.
- Support was provided to Environment Canada for test runs on WEkEO as a precursor of its similar infrastructure.
- A massive open online course on artificial intelligence and Earth monitoring led to the registration of more than 5,000 new WEkEO users. The course will remain online for a year and also be put on the WEkEO and EUMETSAT websites.
- WEkEO provided cloud computing capabilities in November for the second CASSINI Hackathon addressing the challenges of the Arctic region and the sixth Ocean Hackathon addressing ocean challenges.
- The European Environment Agency became a partner in WEkEO with the finalisation of a four-party agreement in December. The EEA was already contributing actively throughout the year.
- EUMETSAT successfully used WEkEO for internal projects, such as the Sentinel-3 Sea and Land Surface Temperature Radiometer atmospheric motion vectors demonstrator.



Sea surface subskin temperature, in Kelvins, at 00:00 on 1 October 2021.

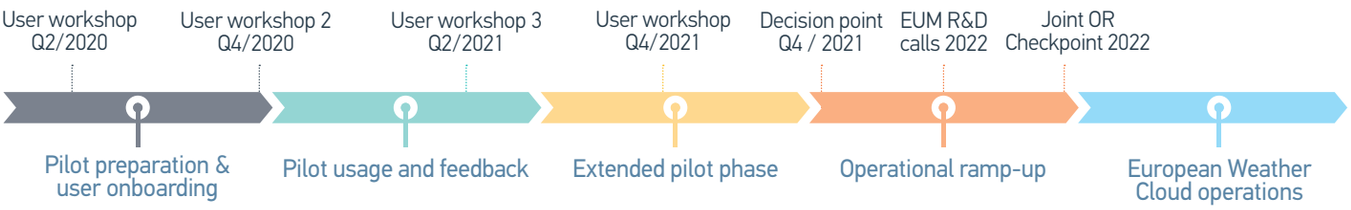
EUROPEAN WEATHER CLOUD

Advances in artificial intelligence, machine learning and cloud technology allow impactful developments in data management and processing. One of EUMETSAT's responses to this evolution was the development of the European Weather Cloud, a joint EUMETSAT and European Centre for Medium-Range Weather Forecasts (ECMWF) initiative. It provides access to both organisations' data, including expertise on the data, and computer resources to work with the data, on a shared cloud-based platform. The European Weather Cloud completed an intense pilot phase in 2021.

More than 40 different use cases assessed different aspects and usages of the cloud, ranging from mass data processing to platforms for international collaboration, all piloted by member states and supported by EUMETSAT and the ECMWF. Especially notable use cases included interactive training platforms that were essential tools during the period of reduced travel, demonstrations of cross-cloud working, support in providing a backup production facility to a member state's meteorological service, and the production by researchers from LEGOS in France of a novel Meteosat dataset, tracking mesoscale convective systems.

A series of user workshops showcased the most interesting use cases to encourage community innovation while gathering feedback and new ideas. The feedback identified strengths and weaknesses of the initial approach, and demonstrated strong demand for "bringing the computation to the data, rather than moving the data to the computing". A parallel process planned out a path to operational status, a joint framework for integrated working with the ECMWF, and looked forward to ways the European Weather Cloud could support the meteorological community's adoption of cloud computing and broaden access to EUMETSAT data. The latter is particularly important with the challenging increase in data volumes that MTG, EPS-SG and Copernicus missions will bring.

All of these activities culminated in joint EUMETSAT and ECMWF Council decisions commending the pilot and approving a coordinated transition to operational status in 2022. The European Weather Cloud will help the meteorological community maximise the usage of, and benefits from, EUMETSAT data.



SATELLITE APPLICATION FACILITIES

The EUMETSAT governing council approved a budget of €58 million over five years for the organisation's network of Satellite Application Facilities (SAFs) in 2021. The investment will be used to continue and to expand the eight SAFs' activities.

The SAFs are run by consortia headed by national meteorological services in EUMETSAT's member states, working with experts from other institutions, with each facility specialising in a specific field, or application area.

The SAFs develop innovative approaches to translating data from EUMETSAT's satellites into services that provide significant benefits to society, such as provision of software. The SAFs' outputs are used operationally, for example, for weather forecasting, disaster management, air traffic control and firefighting, which are areas that need this critical information on time, reliably and with high quality.

The funding spans the next phase of the SAFs' work, known as Continuous Development and Operations Phase 4. During this period, EUMETSAT will launch its next generation of meteorological satellites, Meteosat Third Generation (MTG) and EUMETSAT Polar System - Second Generation (EPS-SG).

When the current generation of satellites was designed and the programmes developed, the SAFs did not yet exist as operational entities. For MTG and EPS-SG, the SAFs have been considered throughout the whole process.

For the first time, the SAFs have been assigned responsibilities for "day one products": the products that will be available to users from the first day the system is declared operational. This is a very important milestone as the SAFs will be ready to disseminate products right away for the benefit of the users of EUMETSAT data. This ensures continuity between products from the Meteosat Second Generation (MSG) and EPS systems and those from MTG and EPS-SG.

Additionally, there is an opportunity for innovation as the new generation of satellites will bring improved and new types of data. The next-generation systems provide an immense increase in data volume requiring advances in capabilities and more agile approaches.

As an example, it is expected that software provided by the SAFs for numerical weather prediction and, in particular, for nowcasting, will have more frequent release cycles in order to provide users with the latest developments more quickly.

SERVICES TO USERS

EUMETSAT AC SAF
ATMOSPHERIC COMPOSITION MONITORING

EUMETSAT CM SAF
CLIMATE MONITORING

EUMETSAT LSA SAF
LAND SURFACE ANALYSIS

EUMETSAT OSI SAF
OCEAN AND SEA ICE

EUMETSAT NWP SAF
NUMERICAL WEATHER PREDICTION

EUMETSAT ROM SAF
RADIO OCCULTATION METEOROLOGY

EUMETSAT NWC SAF
SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

EUMETSAT H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

The eight SAFs are:

- **Atmospheric Composition Monitoring (AC SAF)**
  led by the Ilmatieteen laitos, Finland
- **Climate Monitoring (CM SAF)**
  let by Deutscher Wetterdienst, Germany
- **Land Surface Analysis (LSA SAF)**
  led by the Instituto Portugues do Mar e da Atmosfera, Portugal
- **Ocean and Sea Ice (OSI SAF)**
  led by Météo-France, France
- **Numerical Weather Prediction (NWP SAF)**
  led by the Met Office, United Kingdom
- **Radio Occultation Meteorology (ROM SAF)**
  led by the Danmarks Meteorologiske Institut, Denmark
- **Nowcasting and Very Short-Range Forecasting (NWC SAF)**
  led by the Agencia Estatal de Meteorología, Spain
- **Operational Hydrology and Water Management (H SAF)**
  led by Servizio Meteorologico Aeronautica Militare, Italy.

CONTINUOUS DEVELOPMENT AND OPERATIONS PHASE 4

MSG										EPS	MTG		EPS-SG	
Development / Initial Operations Phases										Continuous Development and Operations Phase CDOP 1	Continuous Development and Operations Phase CDOP 2	Continuous Development and Operations Phase CDOP 3	Continuous Development and Operations Phase CDOP 4	Continuous Development and Operations Phase CDOP 5
YEAR														
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007 - 2011	2012 - 2016	2017 - 2022	2023 - 2027	2028 - 2032
NWC SAF														
OSI SAF														
O3M SAF												AC SAF		
		NWP SAF												
		CM SAF												
		GRAS SAF									ROM SAF			
			LSA SAF											
									H SAF					

SERVICES TO USERS

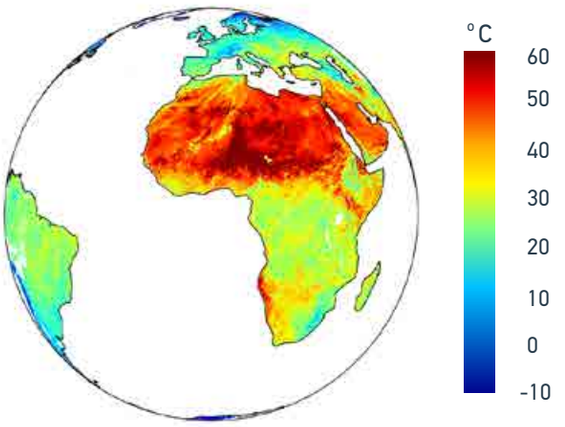
NEW PRODUCTS

In addition to new climate data records (see p67), seven new products were released by EUMETSAT's Satellite Application Facility (SAF) network in 2021. Another 13 SAF products were updated. Three of the new products are described below.

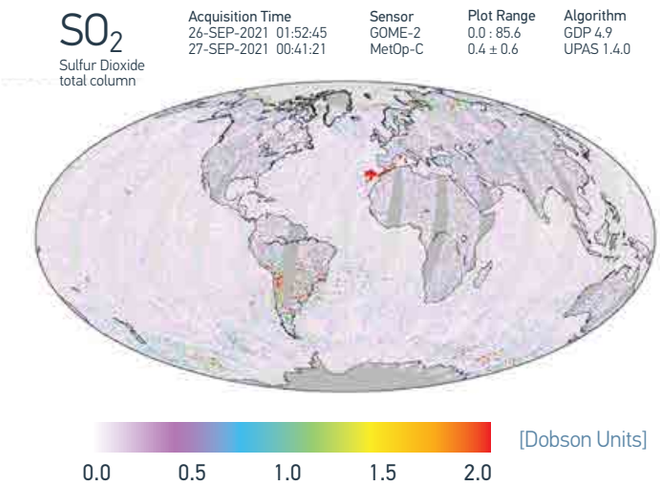
The Land Surface Analysis SAF released the All Sky Land Surface Temperature product on 16 March. The product provides radiative temperature over land surfaces with spatial completeness due to the combination of satellite and model data. It is derived from infrared observations (from the Meteosat SEVIRI instrument) in cloud-free situations and is obtained from the surface energy balance model in cloudy conditions. A full-disc image is produced every 30 minutes with a spatial resolution of 3-5km.

The Atmospheric Composition Monitoring SAF released a sulphur dioxide product on 15 April. The product provides vertical profiles of sulphur dioxide and is based on observations from the GOME-2 instrument on Metop-C. It complements operational products from Metop-B. This product includes new volcanic flags, allowing different source types of sulphur dioxide to be identified. The product is validated with reference data from satellites and ground stations.

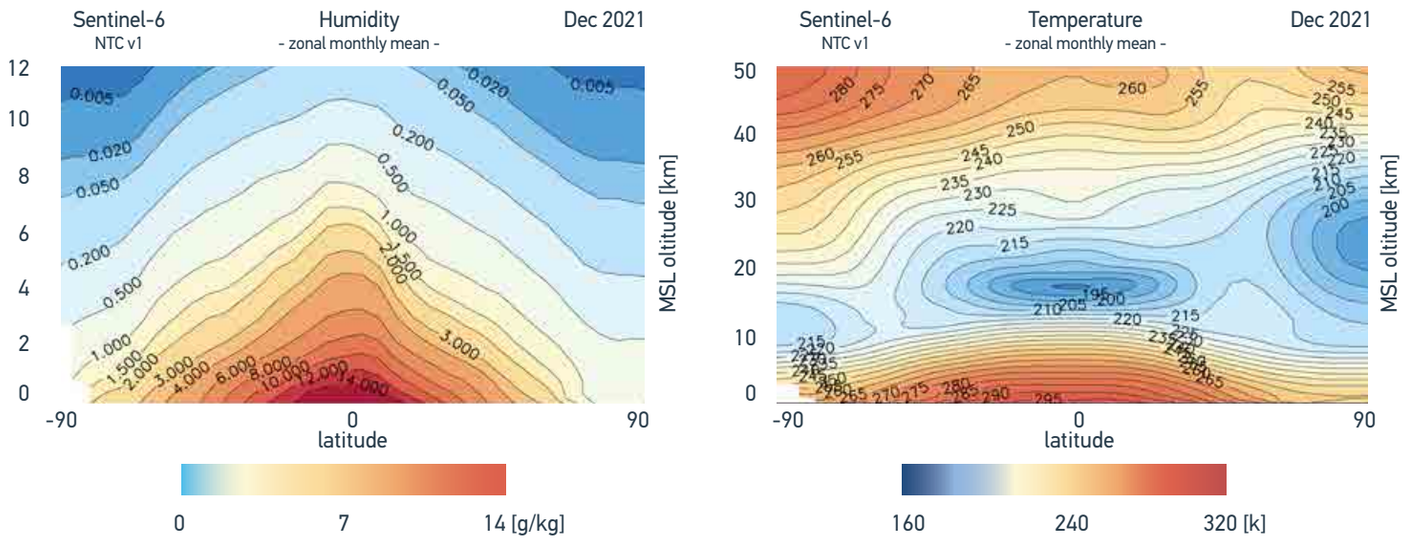
The Radio Occultation Meteorology SAF released radio occultation products from Copernicus Sentinel-6 Michael Freilich on 16 December. The product provides vertical profiles of atmospheric temperature, humidity, pressure and refractivity. It is based on data from the radio occultation sensor (GNSS-RO) on the satellite. It provides stable and controlled data for non-time-critical applications.



The Land Surface Analysis SAF's All Sky Land Surface Temperature product, 1 May 2021 at 12:00 UTC



The Atmospheric Composition Monitoring SAF's sulphur dioxide product, 26-27 September 2021



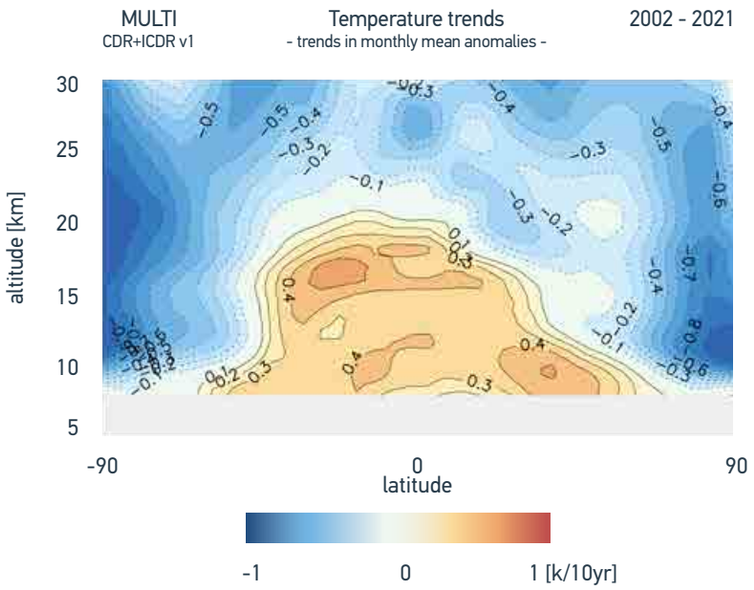
The Radio Occultation Meteorology SAF's Sentinel-6 products, December 2021

SERVICES TO USERS

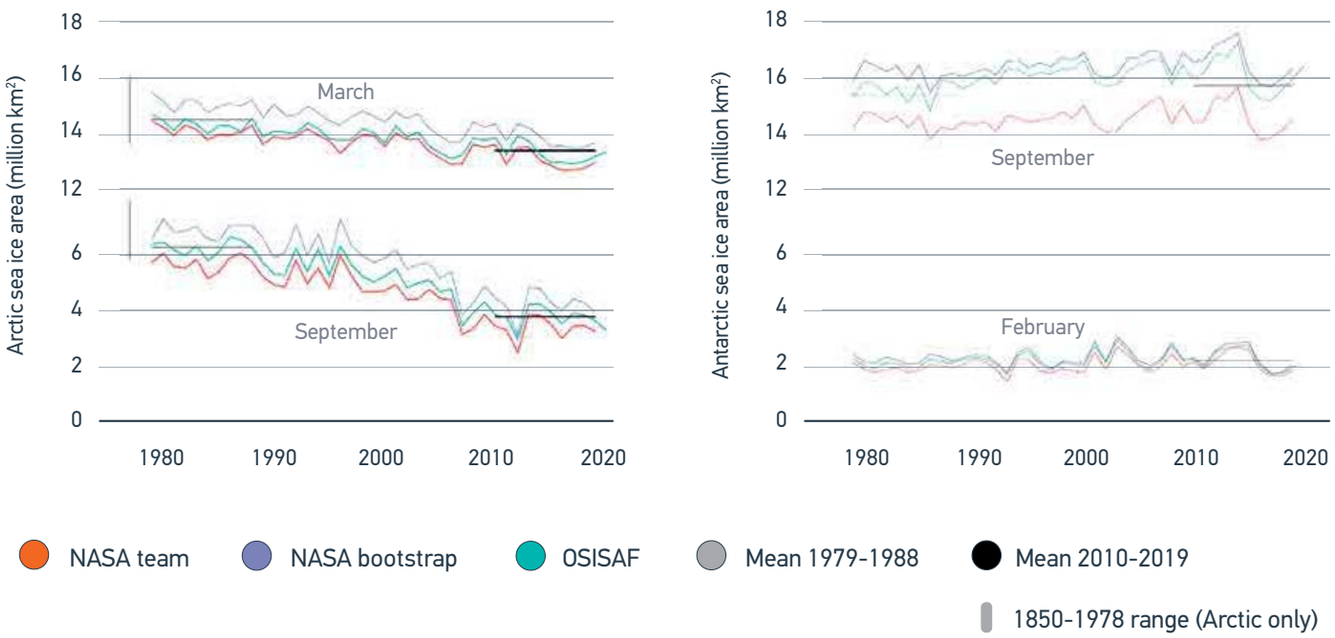
MONITORING THE CLIMATE

EUMETSAT's satellite observations, now stretching over more than 40 years, provide the long-term, homogeneous data required to detect changes in the climate. Climate data records are created at EUMETSAT headquarters and by the Satellite Application Facility (SAF) network.

The data records are used by climate services, such as EUMETSAT member states' national meteorological and hydrological services, the Copernicus Climate Change Service, and climate services in Africa. Climate scientists around the globe use the data as well to gain a deeper understanding of the Earth's changing climate. Results of that are essential inputs for the Intergovernmental Panel on Climate Change's (IPCC) assessment reports.



The image, left, is an example of upper atmospheric temperature trends, contributed by the ROM SAF to the IPCC's 6th assessment report



These Arctic and Antarctic sea ice area time series are an example of the OSI SAF's contribution to the IPCC's 6th assessment report (credit: IPCC)

SERVICES TO USERS

EUMETSAT CONTRIBUTIONS TO THE IPCC

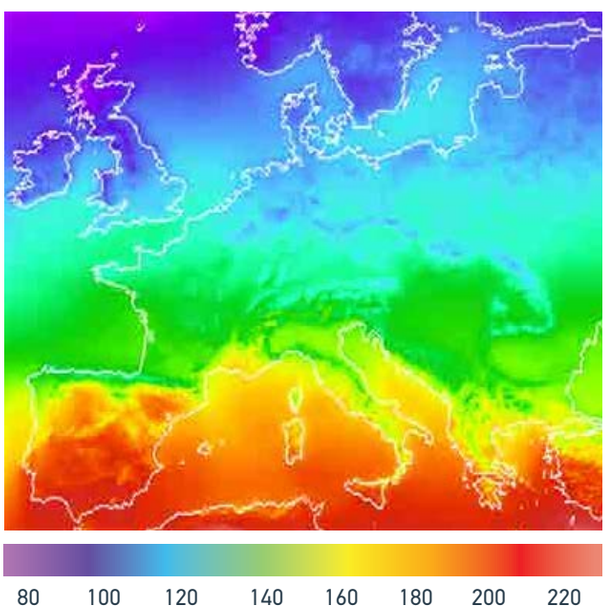
The IPCC provides policy makers with regular scientific assessments on climate change, its implications for the Earth system and societies, including future risks, and required adaptation and mitigation actions. With time, the use of satellite data in the IPCC assessments has increased, including EUMETSAT mission data and specific climate data records.

EUMETSAT contributed significantly to the IPCC's 6th assessment report: Climate Change 2021: The Physical Science Basis. Of the 283 observational data sets used in this report, about 45% were remote sensing data and weather model-based reanalyses using remote sensing data, while 55% were in-situ observations. There were 45 observation products with EUMETSAT contributions, representing about one-third of the non-in-situ data sets or 16% of the total number of data sets.

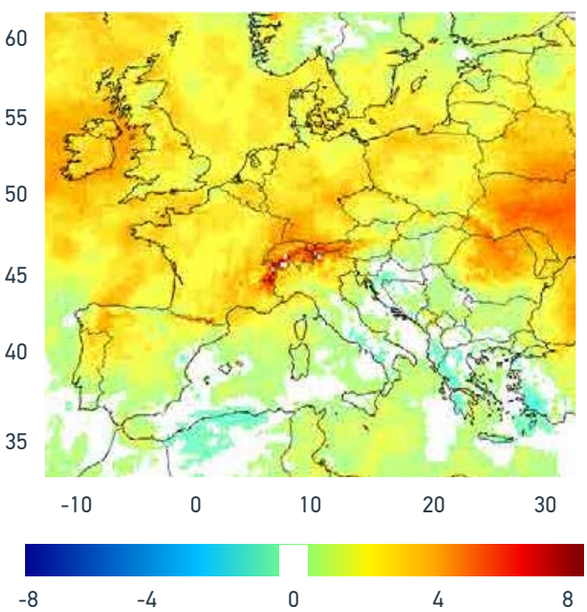
EUMETSAT's SAF network made important contributions with key data records:

- Global analysis of observed trends in atmospheric temperatures over the past two decades coming from data products provided by the Radio Occultation Meteorology SAF permit more robust quantification of temperature trends in the upper troposphere and lower stratosphere. Usage of the data confirms that the upper troposphere is warming faster than close to the surface. In addition, most climate simulations overestimate the observed warming in the upper troposphere because of an overestimation of the sea surface temperature increase.
- The IPCC report presents an analysis of sea ice area retreat during the satellite era (1980-2020). This features sea ice extent data records provided by the Ocean and Sea Ice SAF (OSI SAF) that are shown to be in good agreement with data sets provided by NASA in terms of trends in the sea ice extent. They show that the bulk of the changes occurred in the Arctic Ocean, where the sea ice area reduced up to 40% at the end of summer. Only a slight change in sea ice area was observed over the Antarctic as a whole, staying mostly within +/- 5%. OSI SAF data products are used to validate climate models and helped to confirm that the Arctic sea ice loss is captured by all models in the assessment, nonetheless, large inter-model differences in the Arctic sea ice decline remain.
- Trends in surface solar radiation, primarily changing due to aerosols in cloud-free atmospheres, are less spatially homogeneous since the beginning of the 21st Century. There is evidence of continued brightening in parts of Europe and the USA, some stabilisation in China and India, and dimming in other areas. Surface solar irradiance data from the Climate Monitoring SAF (CM SAF) are used to underpin the phenomenon of brightening observed over Europe in the IPCC's 6th assessment report. In fact, over Europe, the CM SAF found a significant increase in solar surface irradiance of more than 10% since the 1990s.

CM SAF annual mean solar surface irradiance climatology
[Wm $^{-2}$ day $^{-1}$]

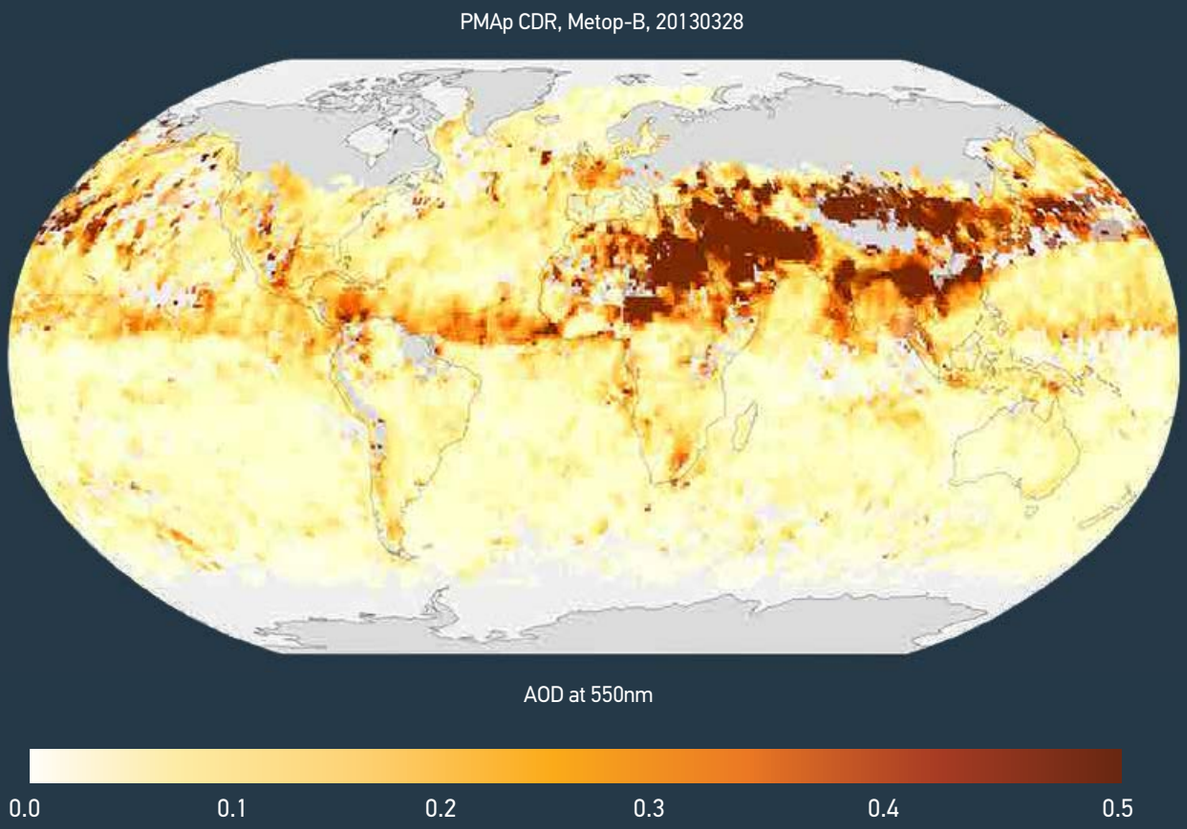


CM SAF surface solar irradiance trend 1992-2015
[W.m $^{-2}$ .dec $^{-1}$]



Surface solar irradiance climatology (left panel, unpublished figure provided by DWD) and trend (right panel), is an example of the CM SAF's contribution to 2021 IPCC report

SERVICES TO USERS



A global map of aerosol optical depth using the Polar Multi-Sensor Aerosol product for 3 March 2013

EUMETSAT indirectly contributed to the 6th assessment report as a key provider of input data for global numerical weather prediction model-based reanalyses. Through its support to the Copernicus Climate Change Service, operated by the ECMWF, EUMETSAT delivered a significant number of data records to the fifth generation of the ECMWF's atmospheric reanalysis, ERA5. This reanalysis is widely used in the IPCC 6th assessment report.

MORE TO COME

Major evolutions in 2021 were the finalisation of a best calibrated version of the Metop GOME-2 instrument data that enabled the production of an aerosol data record utilising the latest algorithm for the Polar Multi-Sensor Aerosol Product. Covering the lifespan of Metop-A, and Metop-B until the end of 2019, it will be released in 2022. The data record is useful to analyse temporal changes in desert dust plumes, biomass burnings, anthropogenic pollution, and volcanic emissions worldwide. In addition, a cloud property data record has been derived from the Meteosat SEVIRI instrument's observations.

EUMETSAT provides examples of how its data are used in climate applications. In 2021, the climate use cases centred around themes of interest to the IPCC, such as long-term changes in sea ice area, the effect of increased melt from the Greenland glacier on temperatures in the North Atlantic, and using atmospheric wind data to better understand changes in the North Atlantic Oscillation. All climate use cases can be found on EUMETSAT's website.

CASE STUDY

US-European cooperation on a global challenge

Leaders of small island states gave impassioned pleas for urgent action to halt global warming at the UN's COP26 conference in Glasgow in November.

The citizens of those island states are experiencing first hand one of the catastrophic impacts of global warming, an inexorably rising sea level that puts the very existence of their homes at risk.

The Copernicus Sentinel-6 Michael Freilich satellite was launched in November 2020. It is the latest in a series of high-precision satellite altimetry missions that began in 1992 with TOPEX/ Poseidon, a French-American initiative, and was followed by the Jason series of satellites.

All of these have been the "reference missions" for satellite ocean altimetry, meaning all other satellite altimetry missions calibrate their measurements against these to ensure accuracy. Copernicus Sentinel-6 Michael Freilich completed its "commissioning phase" of intensive testing and the validation of its instruments' data in November 2021, making it ready to take over as the reference mission.

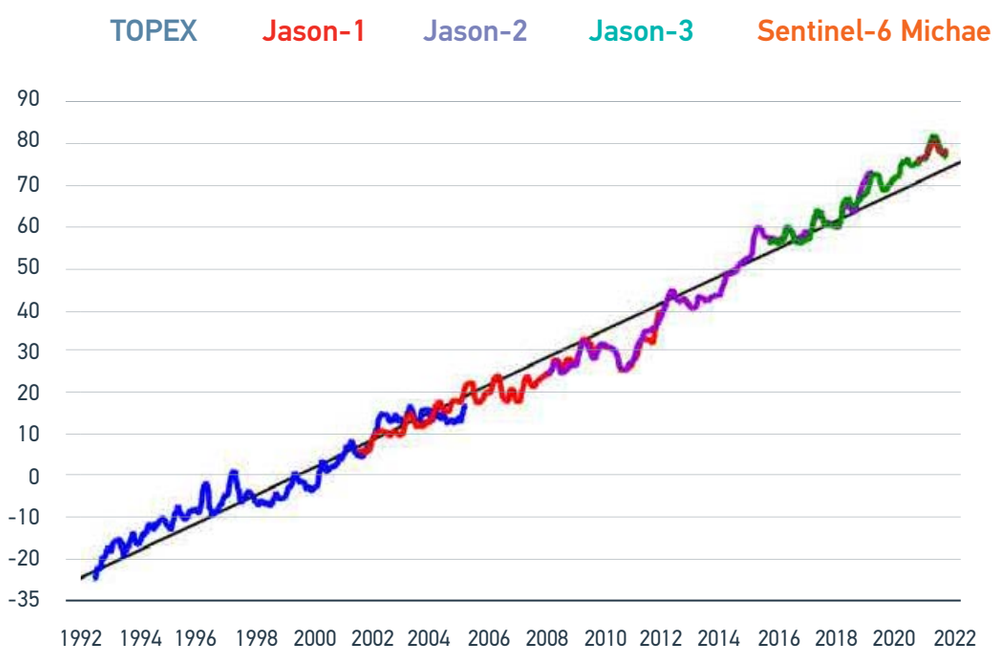
The mission is a unique, US-European project involving EUMETSAT, NASA, the US National Oceanic and Atmospheric Administration, the European Union through the Copernicus programme, and the European Space Agency.

"The data from Copernicus Sentinel-6 is critical for monitoring the impact of climate change on Earth's oceans," EUMETSAT Ocean Altimetry Programme Manager Julia Figa Saldana said.

"As the satellite ocean altimetry reference mission, it will continue the unbroken high-precision data record of sea level rise first started in 1992.

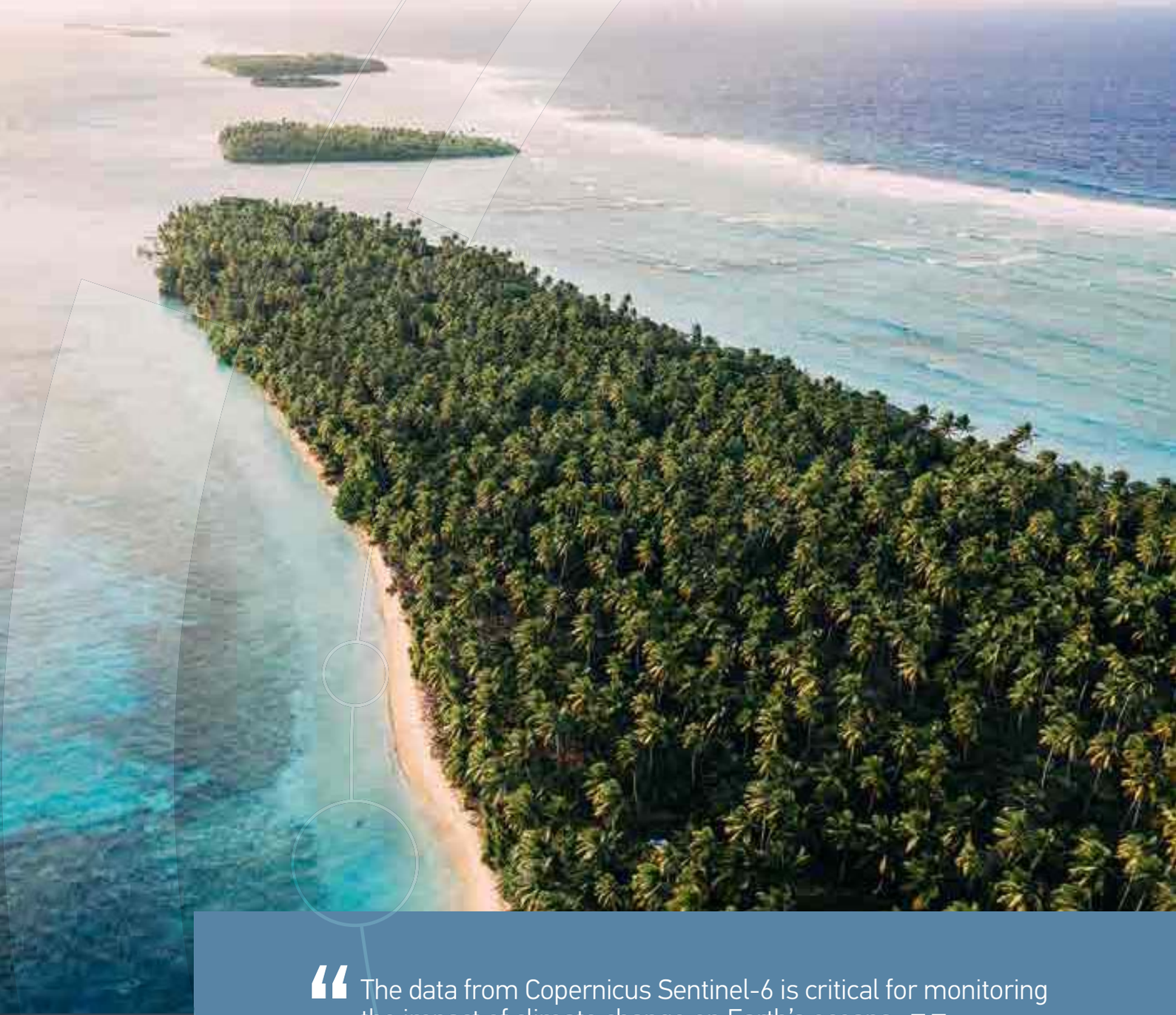
"By cross-calibrating Sentinel-6 against its predecessor Jason-3 to within 1mm, we ensure that the 30-year-long record of global mean sea level, as captured by satellite radar altimeters, continues uninterrupted."

Copernicus Sentinel-6 Michael Freilich is controlled from EUMETSAT's Darmstadt headquarters, where its altimetry data is processed then disseminated to users of the data.



Overall trend: 3.29 mm/yr
Core altimeters up to 66^0 latitude
Corrected for GIA
Annual signal removed

This image charts the global mean sea level rise (in milimetres), as measured by the reference high-precision ocean altimetry satellite missions. Copernicus Sentinel-6 Michael Freilich (Sentinel-6A) became fully operational at the end of 2021.



> “The data from Copernicus Sentinel-6 is critical for monitoring the impact of climate change on Earth’s oceans.”

Julia Figa Saldana, *EUMETSAT ocean altimetry programme manager*

The satellite is the first of the next-generation high-precision altimetry ocean-monitoring satellites. Unlike the previous reference missions, which provided low-resolution altimetry data, this satellite’s altimeter provides both low-resolution and high-resolution data.

The high-resolution-mode data, which provide accurate information about atmospheric corrections and sea level in coastal areas - which has not been possible before - are tremendously important for people living and working in coastal areas that are impacted by climate change. While the data from Copernicus Sentinel-6 are used for a variety of very important applications - from safety at sea to predicting the track and strength of hurricanes to seasonal weather forecasts - the importance of their role in monitoring climate change cannot be overstated.

On the first day of the COP26 conference, the World Meteorological Organisation released its provisional report on the state of the global climate for 2021.

One of the report’s key findings was that the rate of sea level rise was twice as fast between 2013 and 2021 as it had been between 1993 and 2002.

The availability of more precise information than ever about the state of Earth’s oceans will be crucial for gaining additional insights into sea level rise, at a time its importance - and impacts - are sharply in focus.

Main image: The Marshall Islands, one of the Pacific Island states feeling the impact of rising sea levels (credit: Adobe Stock)

CASE STUDY

The storm seeker

As a child, EUMETSAT research fellow Dr Felix Erdmann recalls sitting for hours gazing at thunderstorms, mesmerised by their beauty, power, and unpredictability. This enchantment with the extreme ultimately inspired him to pursue a career as a lightning scientist, where his postdoctoral research at the Royal Meteorological Institute of Belgium (RMI) enables him to tackle questions he has long dreamed of answering.

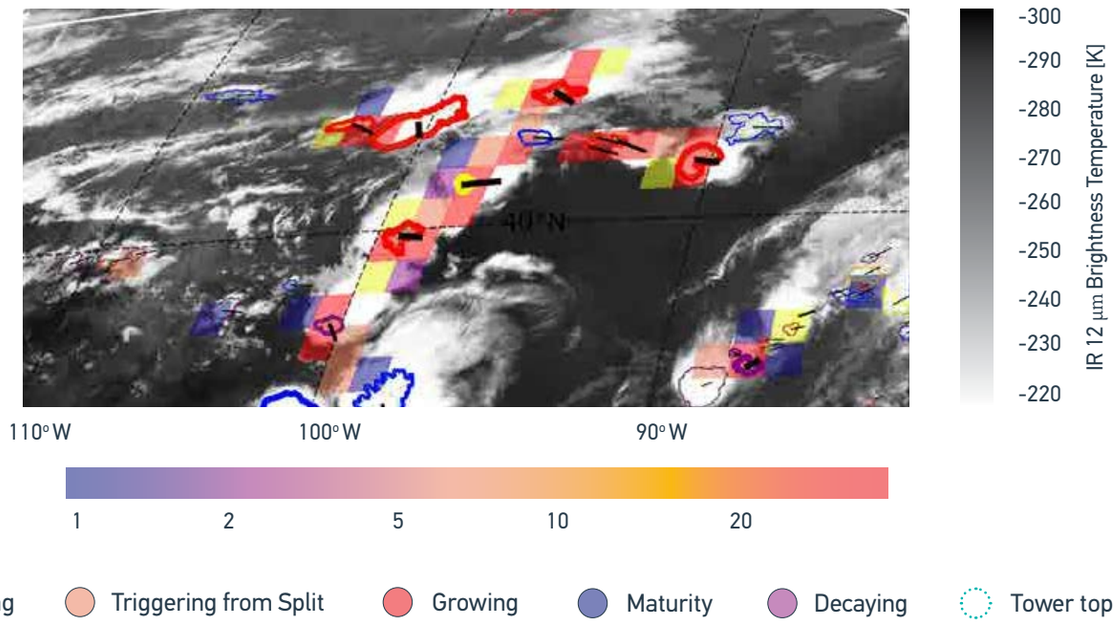
"Thunderstorms rank as the most destructive weather-related disaster in Europe, and despite advances in forecasting it's still very difficult to predict them," said Erdmann, whose fellowship is focused on developing an automated severe weather warning tool making use of data from EUMETSAT's forthcoming Meteosat Third Generation imaging satellite. The satellite will carry a lightning imager.

"There's no thunder without lightning, and we can use lightning observations to track thunderstorms and identify areas of deep convection - highly organised updrafts that twist, tilt, and create menacing-looking cumulonimbus clouds. Convection currents can, under certain circumstances, result in very severe storms lasting several hours, and my work aims to understand correlations between the evolution of these cells and lightning patterns."

Of particular interest to Erdmann are abrupt increases in lightning flash rates. These tell-tale signs of thunderstorm intensification, known as lightning jumps, manifest in the minutes leading up to severe weather events. They are valuable indicators that an ordinary thunderstorm is about to turn into something more sinister.

The first part of Erdmann's fellowship work involves matching severe weather reports in America to lightning data collected by the National Oceanic and Atmospheric Administration's GOES-16 and -17 satellites, which are among the few weather satellites in geostationary orbit featuring lightning imagers.

"I'm using EUMETSAT's nowcasting software and exploring how we can integrate lightning data from space in weather models to improve nowcasting," Erdmann said.



Nowcasting of significant convective cloud cells (coloured lines) superimposed on an infrared satellite image and the lightning flash density as observed by GEO sensor GLM (5 June 2020 03:10-03:20 UTC). Storm cell motion shown as black lines (data from the Nowcasting SAF RDT-CW) (copyright: felix.erdmann@meteo.be.)

> “The best case outcome from my project will be that we will be able to use the EUMETSAT nowcasting software to develop a product that can provide better lead times for potential severe weather warnings, and implement this here in Belgium and across Europe.”

***Dr Felix Erdmann,** post-doctoral researcher at the Royal Meteorological Institute of Belgium*

“I want to get a better understanding of how many severe weather events are preluded by lightning jumps, and develop algorithms that can automatically detect abrupt increases in lightning activity from satellite data. At the moment we are working with data covering the US, but as soon as MTG-I is up and running we will be able to use this for Europe as well.”

The MTG-I Lightning Imager will deliver continuous lightning observations over Europe, Africa, and parts of the Atlantic Ocean and South America from the end of 2022.

“These are optical sensors and provide data from all types of lightning across a wide geographical area - including remote mountain and marine areas that are particularly difficult to monitor from the ground,” Erdmann said. “We will be able to use this data to understand and track current thunderstorms, wherever they are on the continent, and then weather services will be able to use that information to make better predictions about their course."

Laying the foundations for making best use of these new data presents both the biggest challenges and greatest opportunities of his fellowship, Erdmann said.

“The best case outcome from my project will be that we will be able to use the EUMETSAT nowcasting software to develop a product that can provide better lead times for potential severe weather warnings, and implement this here in Belgium and across Europe.”

Main image: (credit: Patrick Wylleman)

PROGRAMME DEVELOPMENT

A view like never before

Over the next three years, EUMETSAT's new fleet of satellites will open our eyes to a whole new universe. They will provide more frequent and detailed data about the Earth systems that shape our lives.

The first strategic objective in *Destination 2030* is the deployment of the Meteosat Third Generation (MTG) and EUMETSAT Polar System - Second Generation (EPS-SG) systems. The systems will bring about a new era of monitoring the weather and climate from space and offer huge potential for developing new products and applications. The development of these new systems benefits from EUMETSAT's effective cooperation with the European Space Agency, ESA. After EUMETSAT defines its member states' requirements from its satellite systems, ESA procures the spacecraft on EUMETSAT's behalf.

The observations captured by the next-generation satellites will help increase the accuracy of essential services, such as:

- Weather forecasting & severe weather alerts
- Air pollution forecasting
- Fire detection & warnings
- Climate monitoring
- Ocean monitoring & forecasting
- Hydrology

3/4

of the world rely on these data

Industries like aviation, power, agriculture, and search and rescue rely on EUMETSAT data every day to understand the planet and make informed decisions, which benefit economies and protect lives and property.

This cooperation is central to the success of EUMETAT's meteorological satellite systems. EUMETSAT also works closely with European industrial partners responsible for building the satellites and instruments.

In 2021, EUMETSAT achieved significant milestones in these programmes: the MTG imager mission conducted a successful, long-duration data circulation test with the SAFs and confirmed the stability of the set-up for the launch and early operations phase with the provider of this service.

The ground segment and system critical design review for the sounder mission was accomplished. EPS-SG received an important version of its future data processing system that allowed a significant step forward in the system integration and verification. Finally, the Sentinel-6 mission entered routine operations, while the CO2M mission ground segment development was launched in cooperation with ESA. Altogether, EUMETSAT made significant steps towards providing major new satellite observation systems to the member states and the users of EUMETSAT data worldwide.

After completion of the first flight model of the Flexible Combined Imager in July 2021, the instrument is successfully mounted on to the MTG-I protoflight platform (credit: Thales Alenia Space)

METEOSAT THIRD GENERATION

Covid mitigation measures were implemented across all Meteosat Third Generation (MTG) programme segments in 2021. Maintaining the December 2022 launch date for MTG-I1 was the clear priority for the test facilities and the main focus of management.

The space segment demonstrated clear evidence of progress. The Flexible Combined Imager flight model instrument was delivered to the satellite project. This allowed for the start of the final assembly, integration and test activities for the MTG-I1 satellite in July. The first main test at satellite level, the thermal vacuum test, was successfully performed in November. Preparation for the mechanical test began in early December.

On the ground segment side, all ground stations were under maintenance and were used for system activities related to preparation for operations. The mission operations facility was received as the basis for the preliminary acceptance review, which was passed in October. A pre-delivery of the image data processing facility for the imager mission was received in early July to secure the start of the operational scenario validation campaign by the end of 2021.

In May, the system validation test was performed with the MTG-I satellite in the clean room and the EUMETSAT and launch and early operations control centres. The launch and early operation phase service provider and EUMETSAT conducted the test to verify their respective operational procedures.

PROGRAMME DEVELOPMENT

In July, an end-to-end test was performed with the Ocean and Sea Ice Satellite Application Facility (SAF), the Land Surface Analysis SAF, and the Hydrology and Water Management SAF, which were integrated into the Flexible Combined Imager production chain to generate their products.

These three SAFs integrated a version of their software package, which was delivered by the Nowcasting and Very-Short Range Forecasting SAF for the updates required by the Flexible Combined Imager on board the MTG-I1 satellite. The complete loop was an exercise giving confidence in the maturity of the data processing chain: from ground station transmission to level 1C product processing, distribution, archiving and dissemination, to level 2/level 3 production at the SAFs, with subsequent transmission, archiving and further dissemination.

After the dedicated check point related to the Sentinel-4 mission, the system critical design review for the MTG-S (sounding) mission was kicked off in July, showing the good shape of the system design and interfaces. For the MTG-I (imaging) mission, in November, the operational scenario validation readiness review gave the green light to start the system validation activities.

EUMETSAT POLAR SYSTEM - SECOND GENERATION

Further progress was achieved in the development of Metop-SG instruments in 2021, some being provided by partners, the French Space Agency. CNES, Deutsches Zentrum für Luft-und Raumfahrt (DLR) and the European Commission.

The integration of the IASI-NG instrument was completed and testing at instrument level started, before delivery planned for 2022. The METimage and Sentinel-5 instruments' intermediate integration models were delivered and integrated into the Metop-SGA proto flight model. The ARGOS instrument was delivered for integration on the Metop-SGB proto flight model.

At space segment level, the Metop-SGA proto flight model completed the integration phase of all platform units, except the solar array, and passed the qualification review in July 2021. The Metop-SGB proto flight model integration also progressed quickly, with most mechanical and electrical units already integrated.

Metop-SG compatibility with the Ariane 6 launcher was confirmed.

Cooperation with United States' National Oceanic and Atmospheric Administration reached an important milestone at the Joint Polar System integration, verification and validation key point. This confirmed the achievements reached with regard to verification activities at Svalbard in 2021 and endorsed the plan for the McMurdo ground station.

Integrating the Metop-SGA1 satellite platform at Airbus Defense and Space, Toulouse (credit: ESA/Airbus Defense and Space)

PROGRAMME DEVELOPMENT

SENTINEL-6

Copernicus Sentinel-6 Michael Freilich was successfully launched in November 2020 and began a 12-month commissioning phase. A series of reviews found that the spacecraft and system met requirements. In June 2021, responsibility for all the assets necessary for the operations and exploitation of the mission, space and ground segment elements, was handed to the Operations and Services to Users Department.

The low-resolution near-real-time and short-time-critical altimetry data service became operational in June 2021 and the radio occultation near-real-time data service became operational in August.

The in-orbit commissioning review held in November 2021 confirmed commissioning activities were complete and the satellite's readiness for routine operations. Low-resolution, non-time-critical and high-resolution altimetry data became operationally available in late November, as well as non-time-critical radio occultation products.

The level 2 non-time-critical products service from the Radio Occultation Meteorology Satellite Application Facility became operational in December 2021.

SENTINEL-3C AND -3D

Preparations for the launch of Sentinel-3C, which has a launch window of Q4 2024 to Q1 2025, and Sentinel-3D (2025 to 2028) continued throughout 2021. The main focus was on progressing the re-engineering of the Sentinel-3 ground segment to remove hardware and software obsolescence and to expand its capacity to process data from the third satellite.

The entry into operations of the re-engineered flight operations segment for Sentinel-3A and -3B is expected in Q3 2022 and the new payload data processing system is expected in Q4 2023. The Sentinel-3C ground segment acceptance review will take place shortly afterwards.

The main activity relating to the spacecraft has been the preparation and validation of the operations preparation test environment to support the pre-storage satellite verification tests and the preparation for and the execution of the tests themselves.

The first satellite verification test involving EUMETSAT was successfully performed in late September and early October. EUMETSAT commanded the virtual engineering model with no issues. The next test is planned for January 2022.

Artist's impression of the Copernicus CO2M satellite in orbit (credit: OHB)

The EUMETSAT Low-Earth Orbit Mission Control Centre, where Copernicus Sentinel-6 spacecraft operations take place

Finally, the ESA-led first Sentinel-3D pre-storage review was completed and the Sentinel-3C flight acceptance review is planned for 2022.

CO2M

EUMETSAT will develop the ground segment for, operate, and process and disseminate the data from, the future Copernicus anthropogenic carbon dioxide emissions-monitoring mission, CO2M.

In 2021, a series of milestones in the development of this mission were successfully passed. They include:

- The ESA space segment requirements review
- The joint ESA-EUMETSAT system requirements review
- The joint ESA-EUMETSAT overall ground segment requirements review.

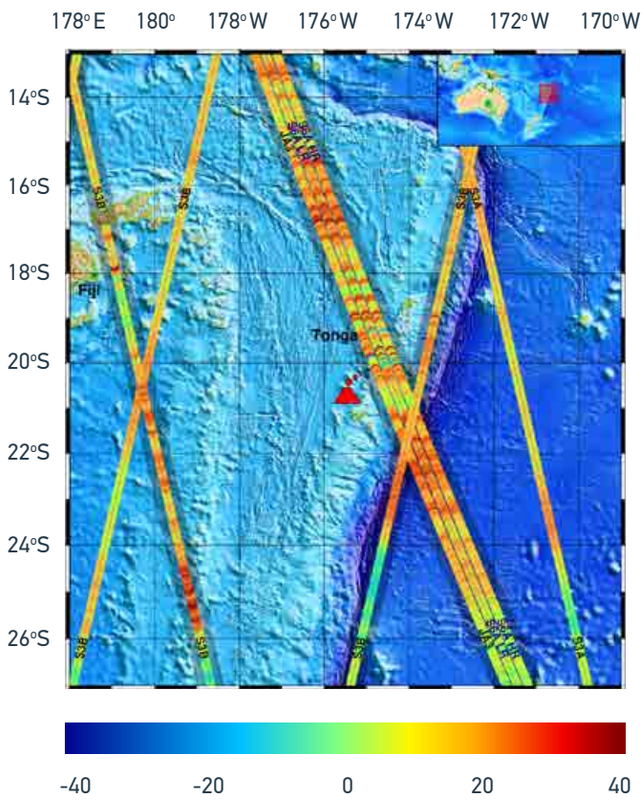
In December 2021, the implementing arrangement between ESA and EUMETSAT for CO2M was finalised and signed.

COPERNICUS IMAGING MICROWAVE RADIOMETER AND POLAR ICE AND SNOW TOPOGRAPHY ALTIMETER MISSIONS

EUMETSAT will contribute to the Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL) mission with the deployment of data processing chains for global ocean altimetry products.

EUMETSAT will contribute to the Copernicus Imaging Microwave Radiometer (CIMR) mission by generating global ocean products, in order to support weather applications and by extracting the associated geophysical parameters, in synergy with other relevant missions operated by EUMETSAT.

In 2021, EUMETSAT participated in ESA space segment requirements reviews and mission advisory group meetings for both missions.

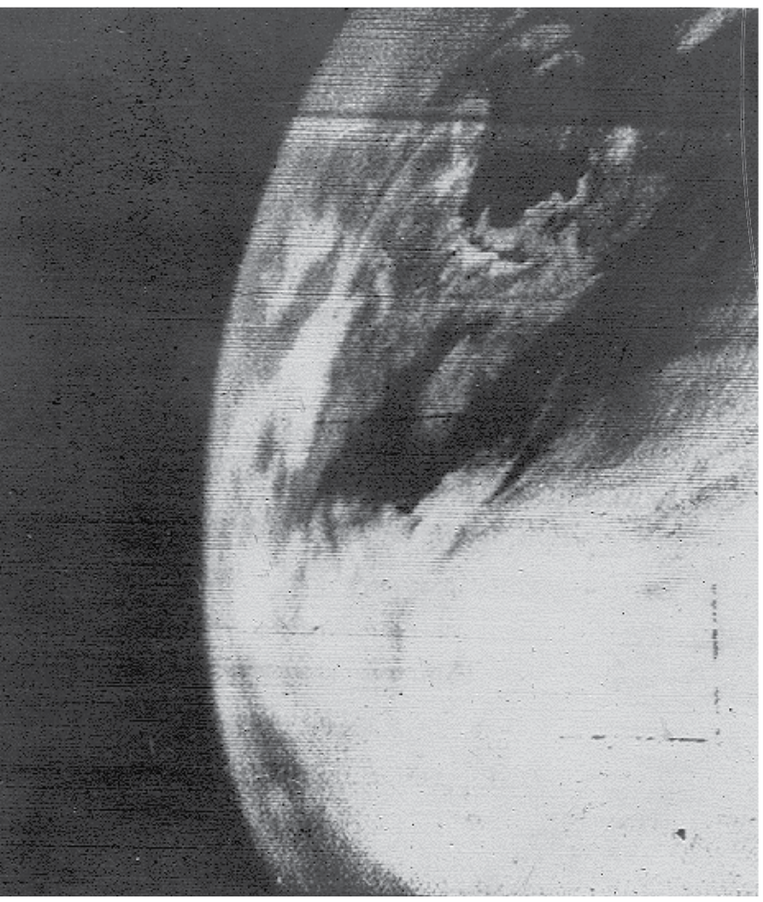


Sea level anomaly (height of the sea level compared to a long-term mean) as measured by Copernicus altimeter missions around the time of the Hunga Tonga-Hunga Ha'apai volcano eruption on 14 January 2022

CASE STUDY

Rescuing old satellite data aids understanding of climate

The launch of NASA's experimental weather satellite Television Infrared Observation Satellite-1 (TIROS-1) in 1960 created a forecasting revolution. For the first time in the Earth's 4.54 billion-year history, it was possible to observe weather patterns in detail from the perspective of a neighbour.



Planet Earth, as seen in the first TV image from TIROS-1, on 1 April 1960 (credit: TIROS Programme, NASA)

Footage from TIROS-1 and other early weather satellites provided spectacular new opportunities for weather forecasters. Cloud formations, for instance, showed up on recordings with astonishing clarity. Meteorologists could spot wind patterns, the formation of hurricanes, and better understand the lifecycles of storms.

As newer generations of satellites delivered data of better resolution, clarity, and detail, these early observations faded into oblivion. More than six decades later, they are again proving crucial, this time for understanding and reacting to the global climate crisis.

"The first weather satellites were experimental," Dr Jörg Schulz, leading climate scientist at EUMETSAT, said. "They may have provided data for a few months or up to two years if you were lucky. There were also significant gaps in time between missions. But these observations provide valuable insights into the global environment at that time.

"The value of historical data has increased dramatically: it extends the time series, filling in the details of the past as we move forward to the future," Schulz said. "With the forthcoming Meteosat Third Generation satellites, we will ultimately have 60 to 70 years of comparative observation. With these data, climate trends become much clearer."

Data from early satellites were stored on media such as magnetic tape which are now obsolete. Many of the observations were archived, but rescuing them proves more difficult the older they are. The quality of the data stored on magnetic tapes and floppy disks can deteriorate and physical media have been lost.

However, highly successful international initiatives led by EUMETSAT, the ECMWF, ESA, the Met Office (UK), NASA, NOAA, and the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies (CIMSS), have sought to recover old satellite data and make them available for climate analyses.

> “Rescuing and restoring these multitudes of data to make them useful for further analysis is hard work and time consuming. But done right, these data provide a powerful resource for understanding how the world is changing as climate change accelerates.”

Dr Jörg Schulz, *leading climate scientist at EUMETSAT*

“Rescuing and restoring these multitudes of data to make them useful for further analysis is hard work and time consuming,” Schulz said. “Steps include decoding, reformatting, debugging, removing errors, and recalibrating if possible. But done right, these data provide a powerful resource for understanding how the world is changing as climate change accelerates.”

The endeavour to reanalyse historic datasets is like an immense four-dimensional jigsaw puzzle across space and time. It extends from the surface of the Earth to the edge of the atmosphere. Some pieces are missing, while others are overlapping.

The Paris climate agreement was signed in 2015 and has since been ratified by 191 states and the European Union. It underscored the importance of accurate and continuous measurements of climate change.

“Satellite data are an essential resource for climate monitoring, including in its reanalysis,” Schulz said. “Unless we react decisively there will be huge implications for the natural world and for humankind. We need to continue to strengthen the use of satellite data for climate science and services to help guide this response.”

Main image: First image from the Meteosat-1 satelllite, which was launched in November 1977

CASE STUDY

In West Africa, monitoring droughts with satellites saves lives

When the rains are good in the Sahel, a region of Africa just south of the Sahara stretching from northern Senegal to Sudan, baobabs bloom, millet and sorghum flourish, and harvests are fruitful.

In 1968, the rain began to stop.

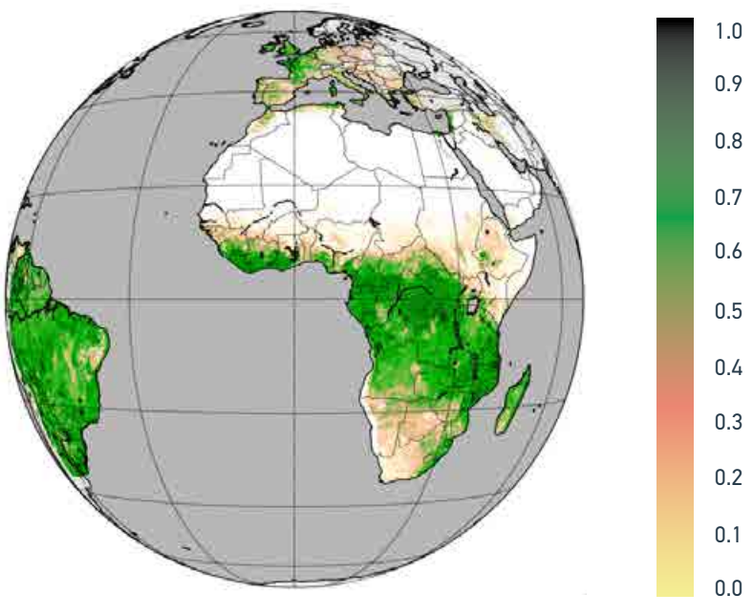
Over the next five years, droughts caused more than half the cattle population to perish, thousands of inhabitants to flee, and more than 100,000 people to die of starvation and disease. With no reliable way to predict rainfall, or how successful harvests would be, farmers relied on traditional indicators to decide when best to plant crops. Out of this need, AGRHYMET, an organisation for drought monitoring in the Sahel, was founded in 1974. AGRHYMET collects, processes, and disseminates to its 13 member states information on food security, water resource management, desertification control, and climate change impacts.

"The majority of food crises in the Sahel are still linked to drought, caused by a later start of the rainy season, shorter seasons, or dry spells," Issa Garba, a remote sensing specialist for AGRHYMET, said.

Actively monitoring for drought begins in May, when experts combine data from satellites, information from rain gauges, and hydrological and agrometeorological models to create seasonal rainfall and hydrological forecasts for July to September.

The data remote sensing experts at AGRHYMET obtain from EUMETSAT's Meteosat-11 satellite are crucial. Its Spinning Enhanced Visible and Infrared Imager provides near-real-time data that can be used to monitor how long vegetation takes to respond after rainfall. Experts at AGRHYMET combine this vegetation information with rainfall estimates to create forecasts, which they pair with practical advice for farmers in order to help them optimise their harvest.

"Our work is very important for the community because our maps are shown to the Food Crisis Prevention Network annually in September and October, during the rainy season," Garba said, referring to the international platform that communicates about food security issues and provides decision makers with the tools to better provide people with food assistance.



The Land Surface Analysis Satellite Application Facility's fractional vegetation product can be used to track the progress of growing seasons

> “The majority of food crises in the Sahel are still linked to drought, caused by a later start of the rainy season, shorter seasons, or dry spells.”

***Issa Garba,** remote sensing specialist for AGRHYMET in Niger*

“Also, the United Nations’ World Food Programme uses these maps to request funding for impacted regions.”

The ability to monitor drought will improve after the deployment of EUMETSAT’s Meteosat Third Generation system. The first imager in the system, MTG-I1, will be launched in late 2022 and will provide images of Africa every 10 minutes. The higher resolution images will enable experts to create even more accurate forecasts. To prepare for this new data, experts at AGRHYMET are building a new web portal that will make it possible for policy makers to better understand the needs of their constituents and enact lasting, life-saving changes.

EUMETSAT, too, is helping this transition.

“EUMETSAT is committed to making the data from this satellite system readily available to African weather and climate services, to providing training for forecasters and to participating in capacity building projects on the continent,” EUMETSAT Director-General Phil Evans said.

This is the heart of EUMETSAT’s mission in supporting AGRHYMET’s drought-monitoring work: to empower the Sahelian people with knowledge they can use to optimise their harvests.

Main image: the “Great Green Wall” of the Sahara (credit: Reuters)

EUROPEAN AND INTERNATIONAL COOPERATION

The need for accurate weather forecasts, early warnings of severe weather events and understanding of Earth's changing climate are global challenges that require global cooperation to address. Through a framework established by the World Meteorological Organization, EUMETSAT maintains global, multilateral and bilateral cooperation agreements focusing on data and scientific exchange. This was an area impacted heavily by covid restrictions. Restrictions caused a decrease in activity and interactions were not as efficient as in the past, except in relation to operations.

RELATIONSHIPS WITH PARTNERS IN EUROPE

EUROPEAN SPACE AGENCY

An ESA-EUMETSAT strategic workshop on future programmes took place on 24 September, in addition to twice-yearly bilateral meetings. EUMETSAT's Director-General also spoke with the ESA Director-General on his *Agenda 2025* and discussed possible contributions from EUMETSAT's regular attendance at meetings of the Programme Board for Earth Observation in a year that was crucial for the conclusion of the Copernicus agreement and to prepare for the ESA Ministerial meeting in 2022.

EUMETSAT's Director-General participated in an informal ESA Ministerial meeting in Porto on 19 November 2021. The meeting adopted the Matosinhos Manifesto, which defined three "accelerators" to bring Europe's space ambitions to the next level. They are: "space for a green future", "rapid and resilient crisis response" and "protection of space assets". EUMETSAT's Director-General underlined the importance of the relationship with ESA to plan future EUMETSAT programmes, including new opportunities.

EUROPEAN UNION

The European Space Programme was launched on 22 June with major contributions from EUMETSAT in relation to Copernicus and on space weather.

EUMETSAT continued discussions with the commission on the inclusion in the Horizon Europe research programme of a theme dealing with the use of Meteosat Third Generation and EUMETSAT Polar System - Second Generation data.

EUMETSAT was invited to participate in the European Commission-led Platform on Space Traffic Management. In addition, the Director-General participated in a roundtable on space launchers in Europe and future trends on 27 September.

EUROPEAN METEOROLOGICAL INFRASTRUCTURE

The European Weather Cloud (EWC), a joint EUMETSAT-ECMWF initiative, successfully completed its pilot phase in 2021 and will transition to operational status in 2022. The EWC provides meteorological services throughout Europe with the opportunity to process data from EUMETSAT and the ECMWF on one cloud-based platform.

PROGRAMMES WITH THE EUROPEAN UNION

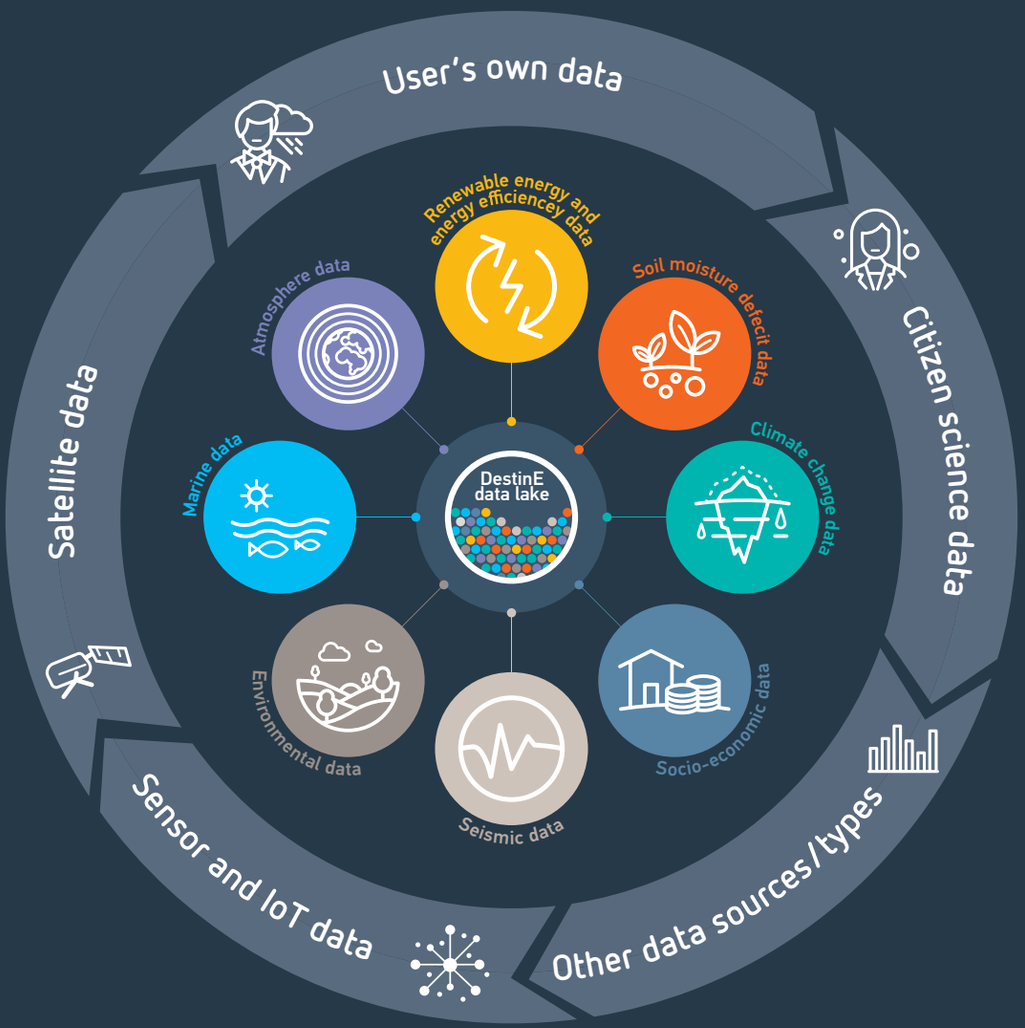
COPERNICUS

EUMETSAT's primary area of cooperation with the European Union is through the environmental Earth observation programme, Copernicus. In July 2021, EUMETSAT and the European Commission signed the Contribution Agreement on the Implementation of the Copernicus Component of the Space Programme of the European Union. This agreement, worth €735 million over seven years to EUMETSAT, will expand the organisation's role to become the operator of the most Sentinel satellites in the Copernicus programme.

Over the life of the agreement, the EUMETSAT-operated fleet of Sentinels will expand to include the follow-on Sentinel-3 and Sentinel-6 satellites and the launch of the MTG and EPS-SG satellites carrying the Sentinel-4 and Sentinel-5 instruments.

In addition, the Copernicus Sentinel mission monitoring anthropogenic carbon dioxide emissions, CO2M, will be launched. EUMETSAT will develop the ground segment and operate the CO2M satellites, and process, disseminate and archive their data.

EUMETSAT will also generate global atmospheric and ocean products from the future Copernicus Imaging Microwave Radiometer (CIMR) and CRISTAL polar-monitoring missions.



The "Copernicus 2.0" agreement signed by the commission and EUMETSAT also extended funding for the WEkEO Copernicus Data and Information Access Service for seven years. And the EUMETSAT Council approved a four-party arrangement between EUMETSAT, the European Centre for Medium-Range Weather Forecasts (ECMWF), Mercator Ocean International and the European Environment Agency to continue to cooperate on WEkEO from 2022 to 2027.

In December 2021, the EUMETSAT Council approved a multiannual agreement to provide the ECMWF with climate data records from EUMETSAT satellites for the Copernicus Climate Change Service (C3S), which it hosts. EUMETSAT's unique capability to generate the records in a traceable way, which is unprecedented in Europe, is invaluable to the C3S.

Also in December, EUMETSAT and ESA finalised and signed the implementing arrangement for the future Copernicus anthropogenic carbon dioxide emissions-monitoring mission, CO2M. EUMETSAT will develop the ground segment for and operate the CO2M satellites, as well as process and disseminate their data. The data will enable governments to measure their progress on commitments in the Paris climate accord.

EUMETSAT will provide the University of Chile with access to near-real-time Copernicus marine data under an agreement that will result in Chile providing Europe with access to geophysical, meteorological and other in-situ data collected by it and partner institutions.

DESTINATION EARTH

The European Commission has entrusted EUMETSAT with a major role in the European Union's Destination Earth (DestinE) initiative, a key plank it its digital and green agendas. DestinE involves building virtual replicas of Earth systems, ultimately allowing greater insight into weather and climate phenomena and their impacts on society. EUMETSAT will have end-to-end responsibility for the multi-cloud data lake underpinning DestinE, including its design, establishment and testing, as well as its operations and the provision of an online inventory. The ECMWF and ESA are the other two agencies selected by the EC for the first phase of DestinE. ESA is responsible for DestinE's core service platform and the ECMWF for the digital twins driving the weather and climate modelling.

EUROPEAN AND INTERNATIONAL COOPERATION

BILATERAL PARTNERSHIPS

US NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

EUMETSAT's Director-General maintained regular dialogue with NOAA's National Environmental Satellite, Data and Information Service Assistant Administrator even though they could not meet in person. In addition to that dialogue, discussions were held with NOAA on two main topics: coordination of commercial radio occultation data services and planning for future observation systems.

In relation to radio occultation, EUMETSAT and NOAA are planning licencing conditions to share the data they acquire from commercial services on similar licencing terms. This would increase the amount of radio occultation data available through both agencies.

NOAA has undertaken a study of future observing infrastructure and the future US weather and climate system. At a workshop on 30 September, NOAA gave a presentation on its study and EUMETSAT spoke of its plans and views on future Earth observation architecture, including in relation to Doppler Wind Lidar and the Arctic Weather Satellite constellation.

NASA

The Director-General of EUMETSAT held discussions with NASA's Director for Earth Science on areas for potential future cooperation. This includes potential future missions in line with NASA's decadal survey conducted in 2017 where cooperation might be of mutual benefit. Discussions were held about coordinating atmospheric composition monitoring missions and cooperation arrangements in which EUMETSAT could share data from the Copernicus Sentinel-4, Sentinel-5 and CO2M missions.

CHINA

On 18 November, the China National Space Administration (CNSA) and EUMETSAT held a virtual bilateral meeting to review their cooperation. The parties reconfirmed their intent to continue the framework cooperation.

In September, CNSA successfully launched the GF-5-2 land and atmospheric chemistry observation mission, which includes high-resolution aerosol observations. CNSA has agreed to consider granting EUMETSAT access to these data for European users. In return, EUMETSAT will share its future MTG and EPS-SG data, and offered to provide scientific support, particularly in the areas of calibration and cross-calibration

In mid-2021, the EUMETSAT Council has approved a global HY-2 service with China's National Satellite Ocean Application Service.

KOREA

The Korea Meteorological Administration (KMA) and EUMETSAT held their eighth bilateral meeting on 4 November. At the meeting, it was decided to hold a series of topical mini-workshops focusing on applications ranging from hyperspectral sensors, trace gas retrieval validation, forest fires, satellite data applications for carbon dioxide and greenhouse gas monitoring and artificial intelligence.

Once circumstances permit, the EUMETSAT visiting scientist scheme will be reactivated, with the likelihood of KMA colleagues visiting EUMETSAT for short periods.

The EUMETSAT Council approved a draft memorandum of understanding on data and science exchange with the KMA in mid-2021.

JAPAN

An updated data and science exchange agreement between EUMETSAT and the Japan Aerospace Exploration Agency (JAXA) and the associated scientific and technical project plan on monitoring greenhouse gases entered into force on 21 July and 6 September 2021 respectively.

EUMETSAT reiterated its willingness to support the Japan Meteorological Agency (JMA) as far as is possible in its plans for a hyperspectral infrared sounder instrument on the Himawari next-generation mission.

EUMETSAT and the JMA confirmed their intent to resume their long-term visiting scientist programme as soon as circumstances permit.

RUSSIA

Roshydromet's Arctica-M N1 satellite was successfully launched on 28 February 2021 and completed its commissioning phase. EUMETSAT agreed to enter into an arrangement to receive data from the mission, if consent can be received to redistribute the data without restriction.

MULTILATERAL PARTNERSHIPS

WORLD METEOROLOGICAL ORGANIZATION

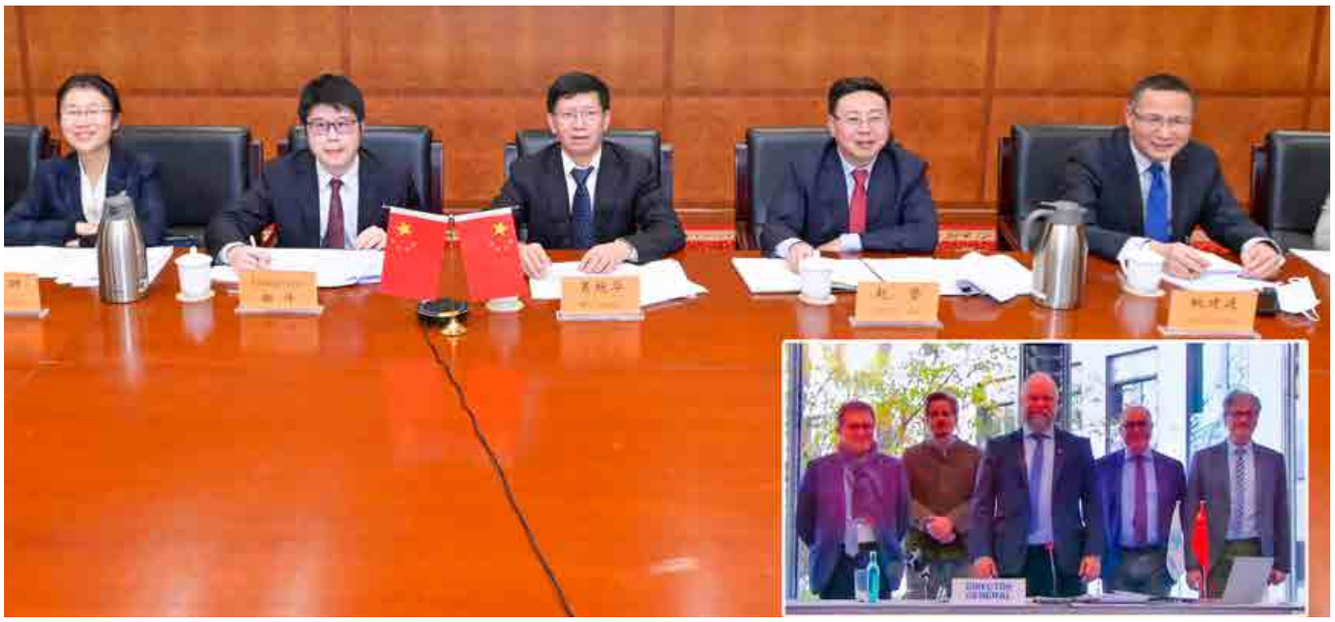
An extraordinary session of the World Meteorological Congress in October 2021 endorsed a new unified data policy on exchange of Earth system monitoring and prediction data.

The new data policy encompasses:

- all WMO-relevant Earth system data: weather, climate, hydrology, ocean, atmospheric composition, cryosphere, and space weather
- a clear commitment to free and unrestricted global data exchange
- the introduction of new terminology on data, replacing "essential" and "additional" data with "core" data (standard practice, will be exchanged) and "recommended" data (best practice, should be exchanged), and
- guidelines for national implementation and public-private engagement.

EUMETSAT will consider how to categorise its own data using the new WMO data terminology and propose this to its member states for approval in 2022.

EUROPEAN AND INTERNATIONAL COOPERATION



EUMETSAT's bilateral meeting with the China National Space Administration takes place online, due to pandemic restrictions, 18 November 2021

COORDINATION GROUP FOR METEOROLOGICAL SATELLITES

China, supported by EUMETSAT, hosted the 49th plenary session of the Coordination Group for Meteorological Satellites on 19-21 May 2021. For the second year in a row, the session was held online.

The WMO's data policy was discussed. A mechanism for satellite operators to reach agreement with the WMO on which data are categorised as "core" and which as "recommended" will be discussed in 2022.

The plenary focused on the long-term continuity risk for various observations. The speakers expressed strong support for long-term and operational continuity of atmospheric composition and air quality measurements in geostationary orbit, microwave and hyperspectral sounders and multipurpose imagers, radio occultation, broadband short and long wave radiometer in the early morning orbit, the continuity of precipitation radar observations, and space weather observations.

The thematic session focused on the impact of satellite data on global numerical weather prediction, the future Earth-observing satellite constellation and the evolution of the data assimilation system.

The plenary included the following recommendations in the annual update of the CGMS priority plan.

- Space agencies should continue pursuing wind profile measurements from space.
- Effort is encouraged to assess complementarities and synergies between different wind measurement systems and technologies.
- Special, concerted efforts should be considered to protect microwave frequencies given their critical importance for weather forecasting.
- The need for sustained impact assessment studies, including for satellite data, is recognised.

The standing session on climate and greenhouse gas observation addressed the essential climate variables (ECV) inventory gap analysis with respect to the carbon cycle ECVs, including global stocktake aspects. CGMS space agencies were requested to produce more climate data record use cases.

A general view of the UN climate change conference (COP26), in Glasgow, Scotland, 12 November 2021 (credit: Reuters/Yves Herman)

COMMITTEE ON EARTH OBSERVATION SATELLITES

The annual plenary session of the Committee on Earth Observation Satellites took place online in 2021, on 1-4 November. Discussion centred on space-based Earth observation data for open science and decision support. Other topics included contributions to the UN Decade of Ocean Science for Sustainable Development initiative, and the potential need for a dedicated CEOS ocean strategy.

The plenary accepted the ECMWF's application to become an associate member of CEOS, with its contribution expected to focus on the CEOS/CGMS Working Group on Climate.

The monitoring of carbon and biomass were extensively discussed, including:

- the CEOS strategy to support the global stocktakes identified in the Paris agreement
- contributions to COP26 and the first global stocktake in 2023
- the way forward for the CEOS agriculture, forestry and other land use roadmap.

The French Space Agency, CNES, took over as CEOS chair from NASA at the end of the plenary, and ESA took over as Strategic Implementation Team chair from Geosciences Australia/CSIRO.

GROUP ON EARTH OBSERVATIONS

EUMETSAT participated in the Group on Earth Observations' (GEO) plenary meeting and "GEO Week 2021", which was held virtually in November 2021. GEO gave an update on its activities and priorities which include the United Nations 2030 Agenda for Sustainable Development, the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction. The speakers also discussed the GEO mid-term evaluation report.

Based on the mid-term evaluation, GEO will encourage outreach to small and medium enterprises, and assess how the GEO system of systems concept could evolve considering the global landscape related to big data, Earth information delivery and knowledge infrastructure. EUMETSAT supported the implementation of the GEO system of systems through the joint operation of GEONETCast with NOAA and the China Meteorological Agency.

A key GEO engagement priority is the Paris Agreement. The GEO Climate Change Working Group has focused its efforts on creating awareness of the role for Earth observation in implementing the Paris Agreement, and engaging with the broader "climate community". GEO held a workshop on climate policy and finance in September 2021, involving development banks, the Green Climate Fund and the finance and insurance sector, to assess the relevance of Earth observation data and information for their own analyses and decision making. The workshop was an important milestone for GEO participation in the COP26 conference in Glasgow.

EUROPEAN AND INTERNATIONAL COOPERATION

RELATIONSHIPS WITH AFRICA

Although Africa is the continent producing the lowest proportion of greenhouse gases, it is deeply impacted by climate change. EUMETSAT has been working with African agencies for more than 20 years, providing meteorological and climate data, training and technical assistance to enhance access to, and use of, satellite data for weather and climate forecasting. EUMETSAT's Meteosat Third Generation system, with its satellites having a constant view of Africa and Europe, will provide imagery and data of unprecedented precision and resolution to meteorologists and climate experts on the African continent.

African nations' capacity to improve weather and climate forecasting through access to data from EUMETSAT's next-generation meteorological satellites was the key focus of the Africa User Forum in September-October. The event was held online, due to covid travel restrictions. However, this created opportunities for more people to attend and for the plenary session to be preceded by three days of technical workshops for weather forecasters.

The first Meteosat Third Generation (MTG) imaging satellite will be launched at the end of 2022. The satellite will provide significantly more and better weather and climate information for Africa. EUMETSAT is committed to making the data from the MTG system readily available to African weather and climate services, to providing training for forecasters and to participating in capacity-building projects on the continent.

To mark the special significance of the MTG-I satellites to Africa, EUMETSAT has teamed up with the French organisation, African Artists for Development, and Arianespace in a unique initiative. The jury of the African Space Art Project in November selected three artists to produce a work of art for replication on the rocket launching MTG-I into orbit. Michel Ekeba and Géraldine Tobé from the Democratic Republic of Congo and Jean David Nkot of Cameroon will produce a unique joint artwork for the faring of the Ariane rocket.

To complement the Africa User Forum, EUMETSAT held three webinars for African users of weather, marine and climate data. The first, Meteosat Third Generation in Africa, was held on 31 March. The second African climate monitoring from space, took place on 7-8 June and the third, Earth observation for marine applications in Africa, on 2 December.

In June, the Portuguese Presidency of the Council of the European Union organised the Europe-Africa Space Earth Observation High-Level Forum. EUMETSAT and some of its key partners in Africa participated actively, and welcomed the "Lisbon Manifesto on Earth Observation for Africa and Europe", which calls for collective action throughout Africa and Europe to strengthen advanced Earth observation systems and their integration with advanced, user-driven, citizen-based information systems. This would include increased use of artificial intelligence, together with massive data sets about our living pathways and their ecological impacts.

Participants taking part in the online 14th Africa User Forum, 6 October 2021

CASE STUDY

Effects of the pandemic lockdown on air pollution

The first lockdown due to the coronavirus in 2020 led to striking absences in public spaces across the globe. But what were the environmental effects of this? Dr Federico Fierli, an atmospheric composition expert at EUMETSAT, examined satellite and ground-based data to clarify which pollutants in the air and ocean changed as a result of the first coronavirus lockdown.

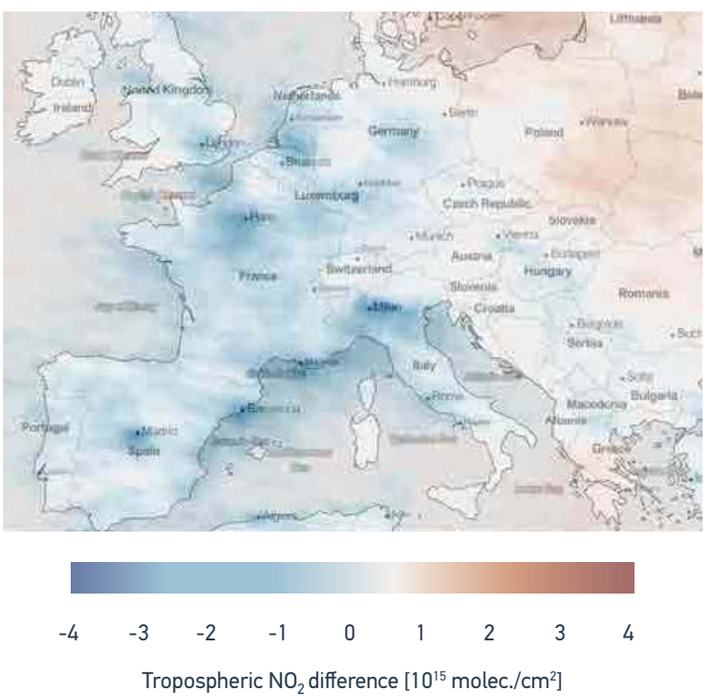
One way to keep tabs on the environment is by monitoring nitrogen dioxide in the atmosphere. Since nitrogen dioxide mainly comes from burning fuel, the decrease in traffic during the March and April 2020 lockdown in Europe meant that one could expect a decrease in nitrogen dioxide in the atmosphere. This is exactly what the Global Ozone Monitoring Experiment-2, an instrument aboard EUMETSAT's Metop satellites, observed.

"In 2020, we had less pollution than in previous years, despite the variability of the weather," Fierli said. "The decrease in nitrogen dioxide was clearly an effect of lockdown."

Ammonia is a gas that is produced primarily through agriculture. Observations of the atmospheric concentration of ammonia in China, by the Infrared Atmospheric Sounding Interferometer aboard Metop satellites between February and March 2017, 2018, and 2019, showed no significant difference to those during lockdown.

"The production of ammonia did not change during lockdown because the production of food didn't change during that time," Fierli said. "This same lack of change can be seen during Europe's lockdown as well."

Carbon dioxide is the main greenhouse gas produced through human activity. Carbon dioxide levels fluctuate seasonally. When plant materials decompose in autumn and winter, the gas builds up in the atmosphere, peaking in spring. This process reverses when new leaves grow and draw carbon dioxide out of the atmosphere, leading to low concentrations in autumn.



This image from the Atmospheric Composition Monitoring Satellite Application Facility shows the average difference of tropospheric nitrogen dioxide levels over Europe from 15 March - 30 April 2020 compared to the same period in 2019

> “In 2020, we had less pollution than in previous years, despite the variability of the weather. The decrease in nitrogen dioxide was clearly an effect of lockdown.”

***Dr Federico Fierli,** EUMETSAT atmospheric composition expert*

Should we expect lasting environmental benefits from the lockdown? Fierli doesn’t think so.

“Lockdown can be seen as a temporary period during which emissions from several sectors, including transport, were drastically cut,” Fierli said. “Now, emissions are expected to bounce back. The control of pollution has been a work in progress since before the covid crisis. In the last decade, emissions have been reduced in most countries in Europe and it is important to keep going in this direction.”

Monitoring atmospheric pollutants is essential. Three upcoming satellite missions will make it possible to measure them with greater accuracy.

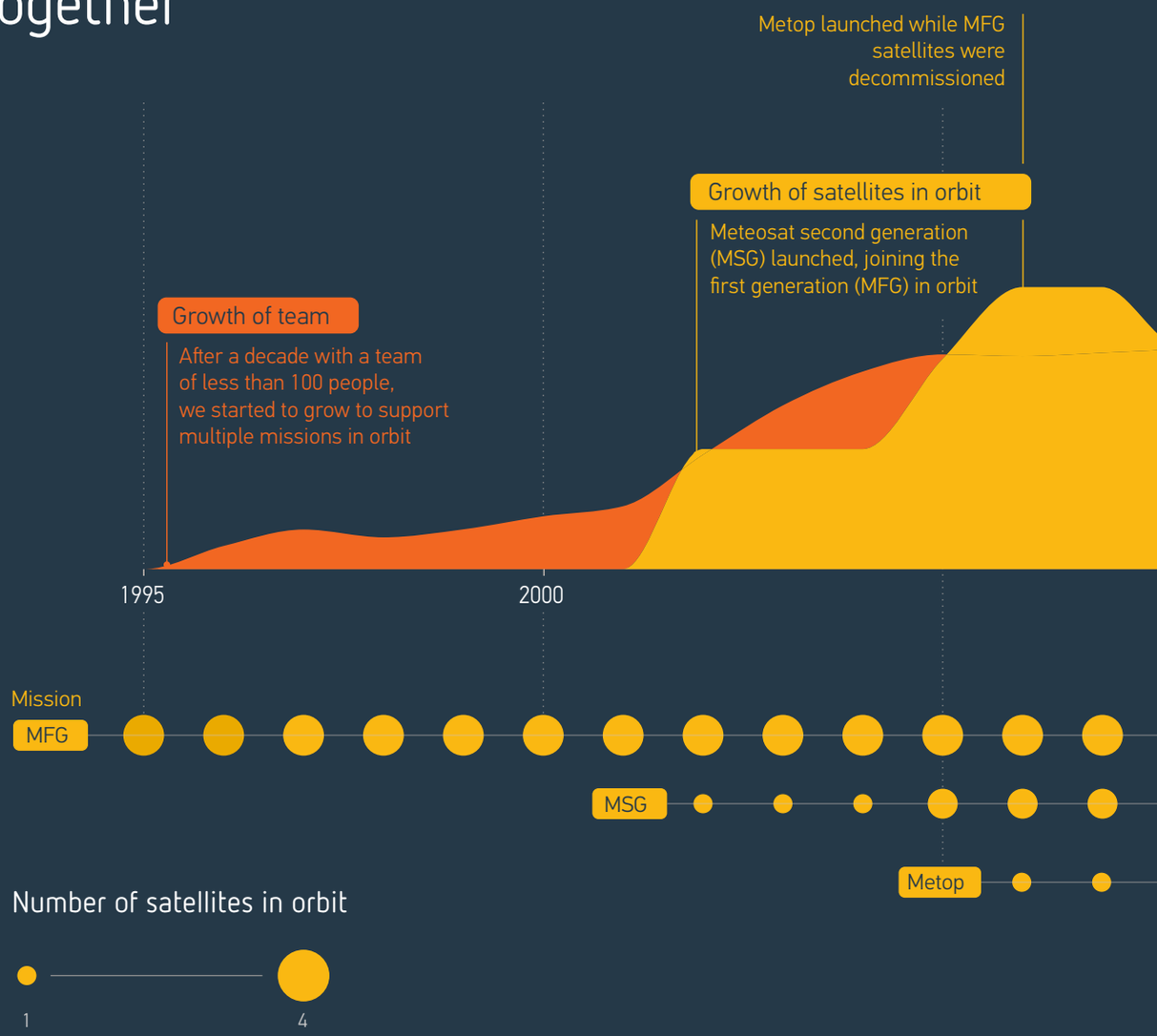
The Copernicus programme’s Sentinel-4 and Sentinel-5 missions, replacing or complementing the Global Ozone Monitoring Experiment and Infrared Atmospheric Sounding Interferometer on Metop-Second Generation satellites, will enable EUMETSAT to collect more frequent, higher resolution data on atmospheric gases.

The Copernicus Anthropogenic Carbon Dioxide Monitoring mission, to be launched in late 2025, will measure carbon dioxide emitted through human activity. Observations of specific emissions hotspots and keeping track of emissions on a national level can assist policy makers to design targeted and efficient counter measures.

Main image: Air pollution temporarily decreased during the pandemic (credit: Adobe Stock)

MANAGEMENT AND ADMINISTRATION

Growing together

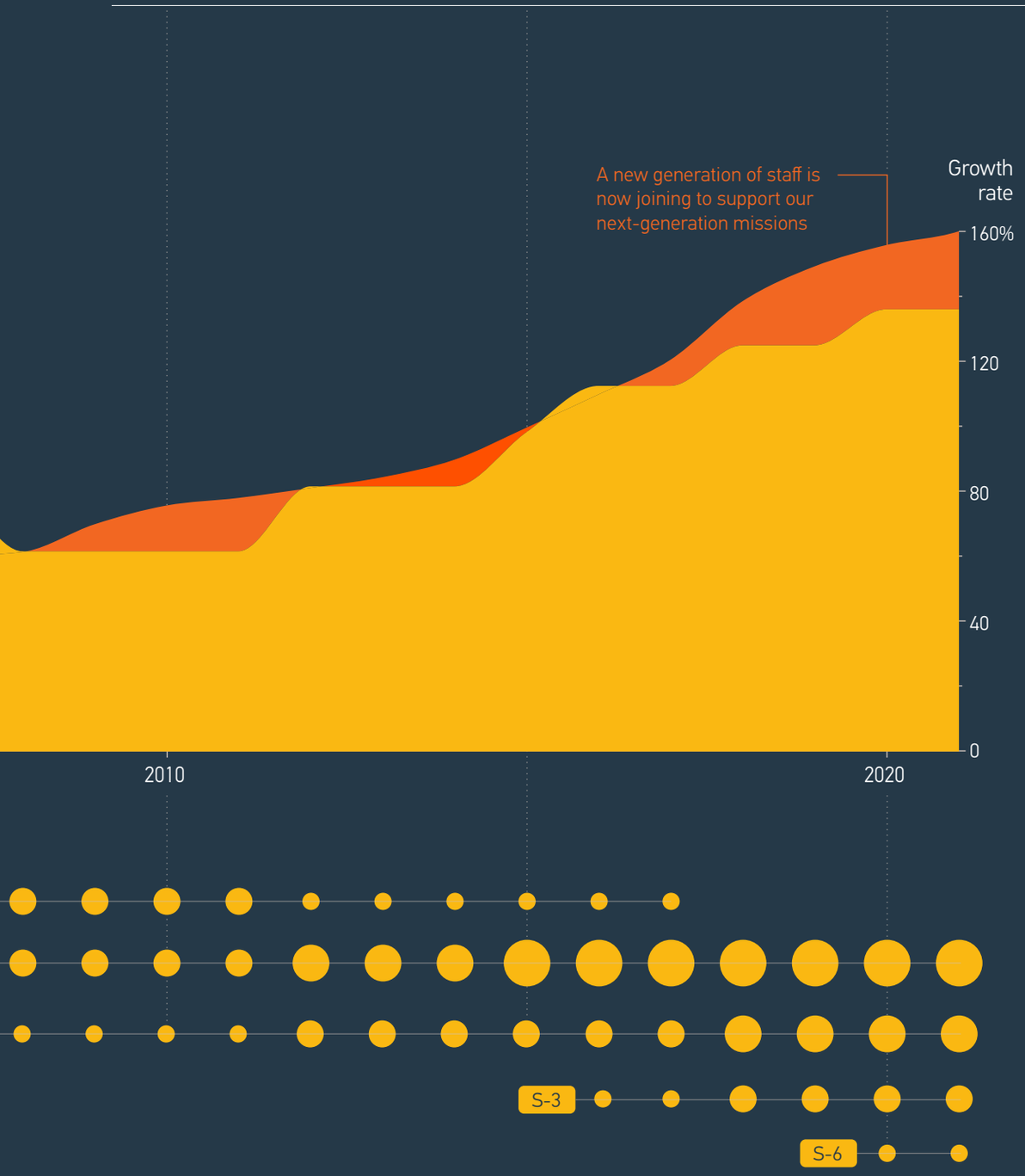


Launching satellites into space is only possible with the right people on the ground. EUMETSAT's team has been steadily growing to support our satellites in orbit.

EUMETSAT staff members continued to show their ability to adapt to the impact of the covid pandemic on working conditions throughout 2021. Large-scale events and outreach efforts continued but shifted to online platforms. EUMETSAT's commitment to energy efficiency and sustainability also was maintained and recognised. New human resources technology and processes were adopted. The staff survey was conducted in September and the first steps were taken to address the issues it highlighted.

COVID SITUATION

The covid crisis coordination group at management board level met on a weekly basis throughout 2021. This allowed infection levels in Germany and elsewhere and local authorities' regulations



and measures to be monitored so that measures taken at EUMETSAT could be adapted as flexibly as required.

As infection rates in Germany and elsewhere in Europe rose towards the later part of 2020, more severe restrictions on presence at EUMETSAT headquarters were required during the first several months of 2021. Onsite presence was reduced to the minimum level required to ensure business-critical activities continued and for the maintenance of infrastructure and onsite services.

Fortunately, only a very low number of EUMETSAT staff and onsite contractors contracted covid, and none severely.

Due to the long duration of the social confinement measures in place, management paid greater attention to minimising the impact on the mental health of staff members. Workshops and coaching for reporting officers were organised to support managers in detecting mental health issues, improving team cohesion and maintaining the required high level of staff motivation and engagement. The frequency of burnout detection workshops was increased. EUMETSAT's social advisor regularly broadcast podcasts about relevant topics and offered individual counselling to staff members.

Frédéric Pradeilles, Director of Technical and Scientific Support

Frédéric Pradeilles became Director of Technical and Scientific Support at EUMETSAT on 1 October 2021.

> "When I think of EUMETSAT, one concept sums it up, operational and financial efficiency serving the European meteorological and climate sciences community of 30 countries and about 650 million people.
>
> "This is something we have to take into account but I think that EUMETSAT has all the means and the expertise, together with its member states, to be able to face this challenge. I am optimistic about the exciting future EUMETSAT faces."

Pradeilles joined EUMETSAT from the French Space Agency (CNES), where he was Director of Digital, Exploitation and Operations and Site Director of the Toulouse Space Centre. He worked at CNES for more than five years, after joining the Directorate of Innovation, Applications and Science. In this key role, Pradeilles aims to ensure cost-efficient technical, scientific, project control and costing support is provided for the development and operations of EUMETSAT's satellite systems.

"I am honoured to join EUMETSAT and very excited to face the organisation's forthcoming challenges over the next decade and continue the work done by (former Director of TSS) Yves Buhler and the TSS teams," Pradeilles said after his appointment.

"In some sense, this means that you have to be cleverer and more innovative in fulfilling the needs of the member states while being able to justify every euro spent. So I think it is really exciting from this point of view.

"Another aspect I like is working at the crossroads of space and digital industries: it is obviously very high-tech and future-oriented, with teams working on projects for several years or even decades in advance.

"Our industry and economic environment is changing rapidly, mainly due to the challenges from the 'new space' area - private companies triggering EUMETSAT to do its job in a different way."

Before joining EUMETSAT, Pradeilles had a long career in the space, digital technology and defence fields, as an armament engineer. He also spent 15 years as a teaching fellow in mathematics at the French National Higher Institute of Aeronautics and Space (ISAE/Supaero) and running research in these fields, as well as in signal and image processing. Pradeilles holds a post-doctoral internship in applied mathematics from the University of Maryland in the US, a PhD in applied mathematics from the University of Aix-Marseille, France, and a degree in engineering from the Ecole Polytechnique (X88) in Palaiseau, France. In addition, he graduated as an auditor of the 66th national session of the French Institute for Higher National Defence Studies.

MANAGEMENT AND ADMINISTRATION

NEW POLICIES AND WORK PRACTICES

EUMETSAT's Ethics Officer, a newly established post, began on 1 August 2021. Shortly afterward, the policy on reporting of wrongdoing was communicated to employees.

The EUMETSAT core values continued to be communicated throughout EUMETSAT with a dedicated e-learning training programme and workshops. More than 130 reporting officers have undertaken training on the core values through full-day workshops with a focus on empowerment. Training for the remaining staff population began later in the year.

A new post-pandemic teleworking policy was adopted but its introduction was delayed due to the covid onsite presence restrictions.

A new service was implemented to support EUMETSAT's direct recruitment efforts. This new service has enabled EUMETSAT to apply a more targeted candidate-sourcing strategy to recruitment, rather than relying on passive advertising, and will enable a more proactive approach in attracting specific skills whilst actively addressing our gender and nationality imbalances.

EUMETSAT provides covid self-testing kits to those working onsite

> "As well as supporting and guiding people through the process of reporting wrongdoing, a key part of my role is to assist and provide advice to the organisation and employees on ethics and standards of conduct. Helping people examine their options and provide guidance to assist them in identifying and managing ethical issues is hugely rewarding."

***Denise Griffey,** EUMETSAT Ethics Officer and Learning and Development Officer*

The implementation of a digital personnel filing system continued. The software system was successfully deployed to the Human Resources (HR) division and conversion of existing paper-based archives began. In addition, the digitalisation and automation of certain basic HR processes began, such as the contract renewal process and staff claims for the education allowance. This was a first step in a broader multi-year plan to digitalise and automate all HR processes.

STAFF SURVEY

The 2021 Staff Survey was conducted online on 6-24 September. A record participation rate of more than 90% was achieved. Results showed solid improvement on the 2018 results, albeit from a rather low level and with still significant room for improvement. The results of the survey were communicated and action planning at various levels within the organisation began.

MANAGEMENT AND ADMINISTRATION

Charging stations for electric vehicles are available on EUMETSAT premises

SUSTAINABLE EUMETSAT

EUMETSAT is committed to sustainability and to taking measures to limit its carbon footprint, for example, by installing energy efficient lighting, scrapping the use of non-recyclable coffee cups and providing chargers for electric vehicles.

The Technical Infrastructure Building again received the highest level Certified Energy Efficiency Data Centre Award (CEEDA) in 2021. The certification recognises the building's energy efficiency. EUMETSAT already receives 100% of its electricity supply from renewable sources. The Technical Infrastructure Building is the largest consumer of energy at EUMETSAT, accounting for 62% of the campus's entire energy use. Ensuring it is run as efficiently as possible provides value for our member states.

COMMUNICATION AND OUTREACH

Due to pandemic restrictions, large events in 2021 could not take place fully in person.

EUMETSAT, the World Meteorological Organization and the European Centre for Medium-Range Weather Forecasts (ECMWF) held an online workshop in February for member state weather services' communication teams. The workshop was a useful platform for sharing experiences and ideas for communicating about weather and climate issues in Europe.

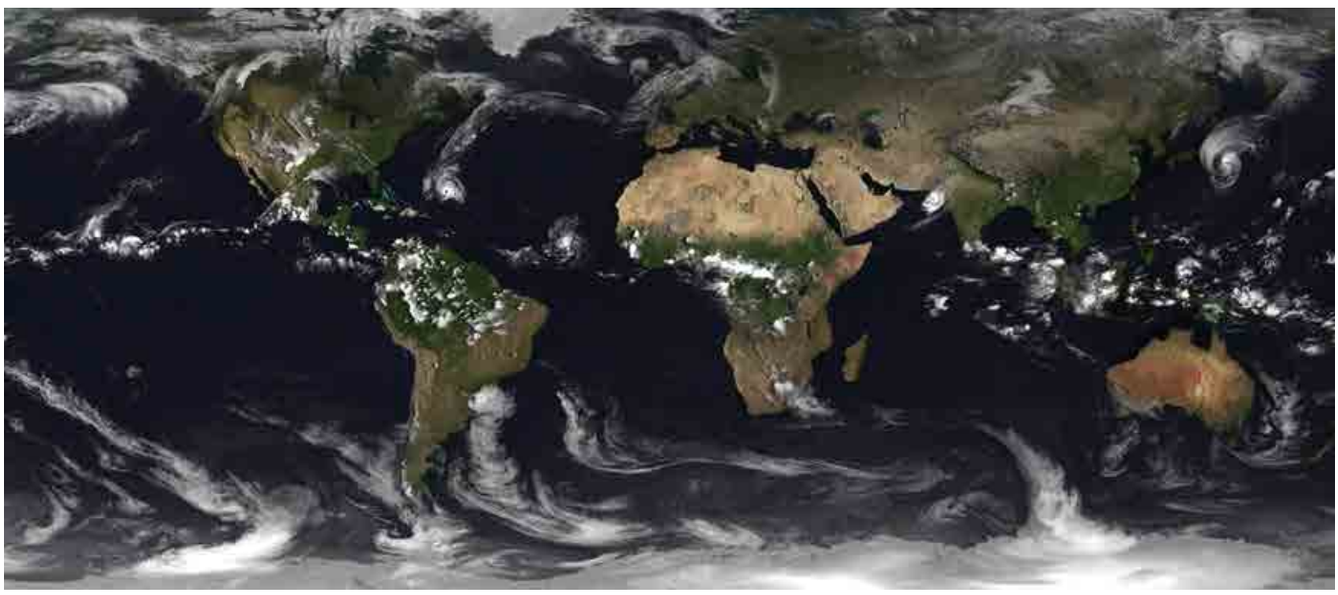
In a first, the annual EUMETSAT Meteorological Satellite Conference, which took place on 20-24 September, was held fully online. This posed challenges for the organising team, as this type of conference required a different type of programme and technology to be effective. The conference attracted 700 participants, about 40% more than usual.

As part of activities to promote the Copernicus Programme and WEkEO, EUMETSAT launched a new massive open online course (MOOC) on the theme of artificial intelligence and Earth monitoring in October. The course was hosted on the FutureLearn MOOC platform. It included video interviews with more than 40 experts, text, animations, and a series of Jupyter notebooks to show people how to work with Copernicus data and machine learning techniques on the WEkEO platform. The course attracted nearly 10,000 participants and has led to an increase of more than 5,000 new users for WEkEO. The MOOC was a joint project involving EUMETSAT, the ECMWF, Mercator Ocean International and the European Environment Agency.

The IASI conference, named after the Infrared Atmospheric Sounding Interferometer instrument, took place in Evian-les-Bains, France

At the end of the year, the IASI conference, named after the Infrared Atmospheric Sounding Interferometer instrument, took place in Evian-les-Bains, France. The conference was held in a hybrid format, with 32 virtual participants and 85 people on site. This format worked very well technically. Nevertheless, networking is important at any conference and participants on site were pleased to make new contacts and to catch up with developments and new research projects.

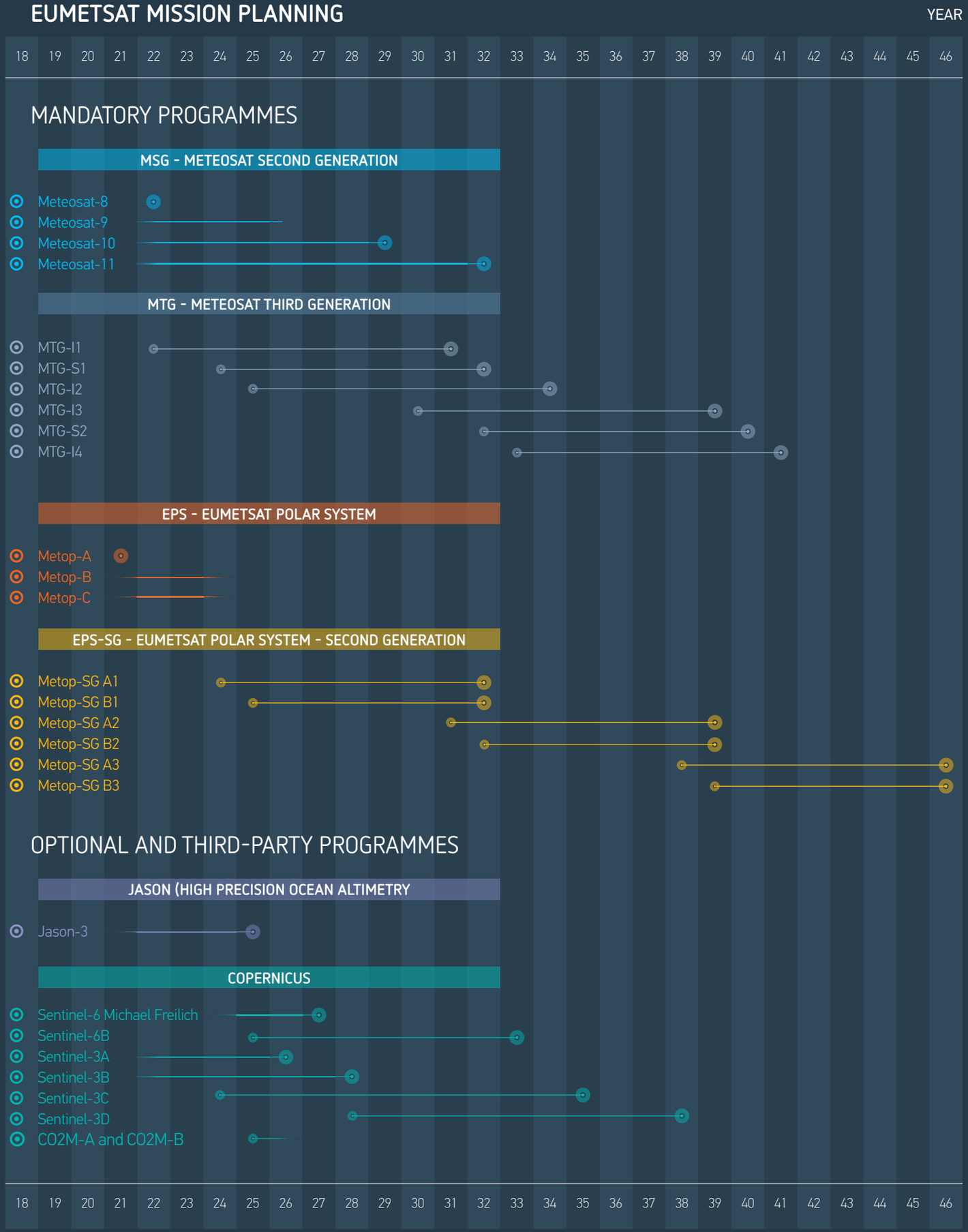
Video and animation productions in 2021 included the Year of Weather movie and a series of new satellite visualisations explaining how the Metosat Third Generation and EUMETSAT Polar System – Second Generation satellites will operate. All content was promoted to EUMETSAT's ever-increasing social media audience (Twitter, Facebook, Instagram and LinkedIn).



The Year of Weather animation illustrates different weather patterns across the globe as captured by satellites in the geostationary orbit operated by EUMETSAT, the US National Oceanic and Atmopsheric Administration, the China Meteorological Administration and the Japan Meteorological Agency, combined with data from EUMETSAT's polar-orbiting satellites

KEY FIGURES

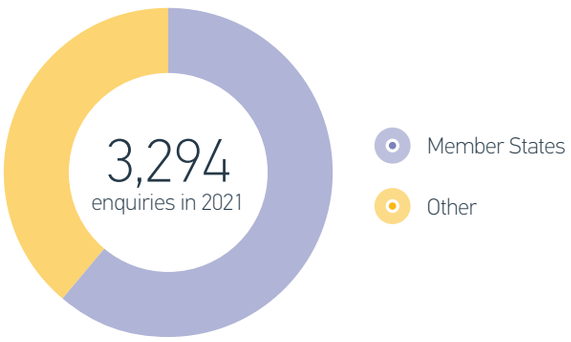
EUMETSAT MISSION PLANNING



KEY FIGURES

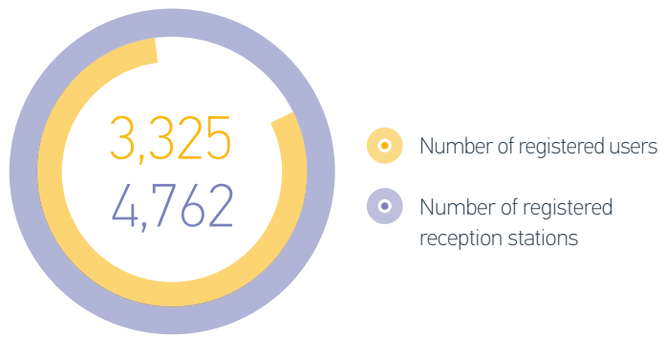
NUMBER OF USER ENQUIRIES IN 2021

- Total number of enquiries: 3,294
- % from member states: 63%



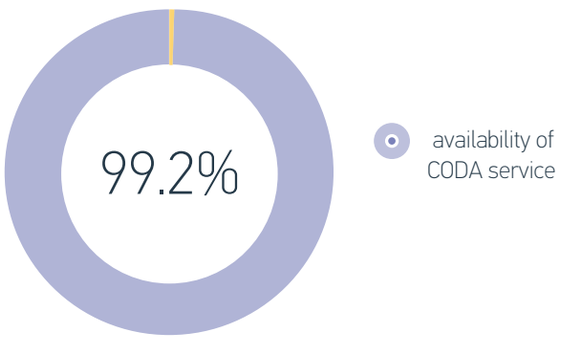
NUMBER OF EUMETCAST STATIONS/USERS ON 31 DECEMBER 2021

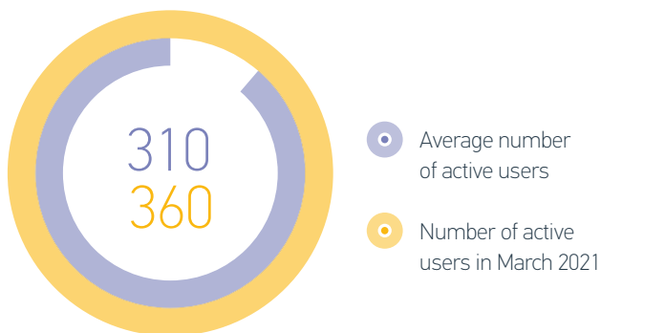
- Number of registered users: 3,325
- Number of registered reception stations: 4,762



COPERNICUS ONLINE DATA ACCESS (CODA) USERS IN 2021

- Number of active users downloading Sentinel-3 products via CODA: 310 users, with a peak in March of 360 users
- % availability of CODA service: 99.2%

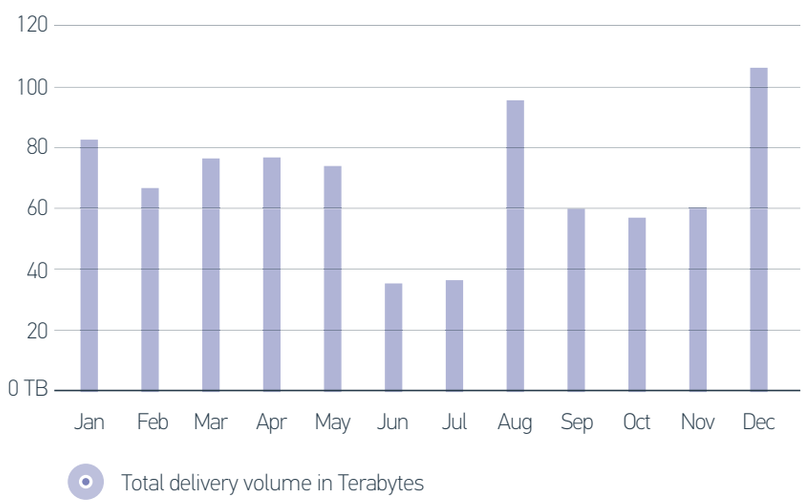




DATA CENTRE USERS AND ORDERS IN 2021

The cumulative number of EUMETSAT Data Centre users had reached 8,858 by the end of 2021, with an average of 101 new users per month.

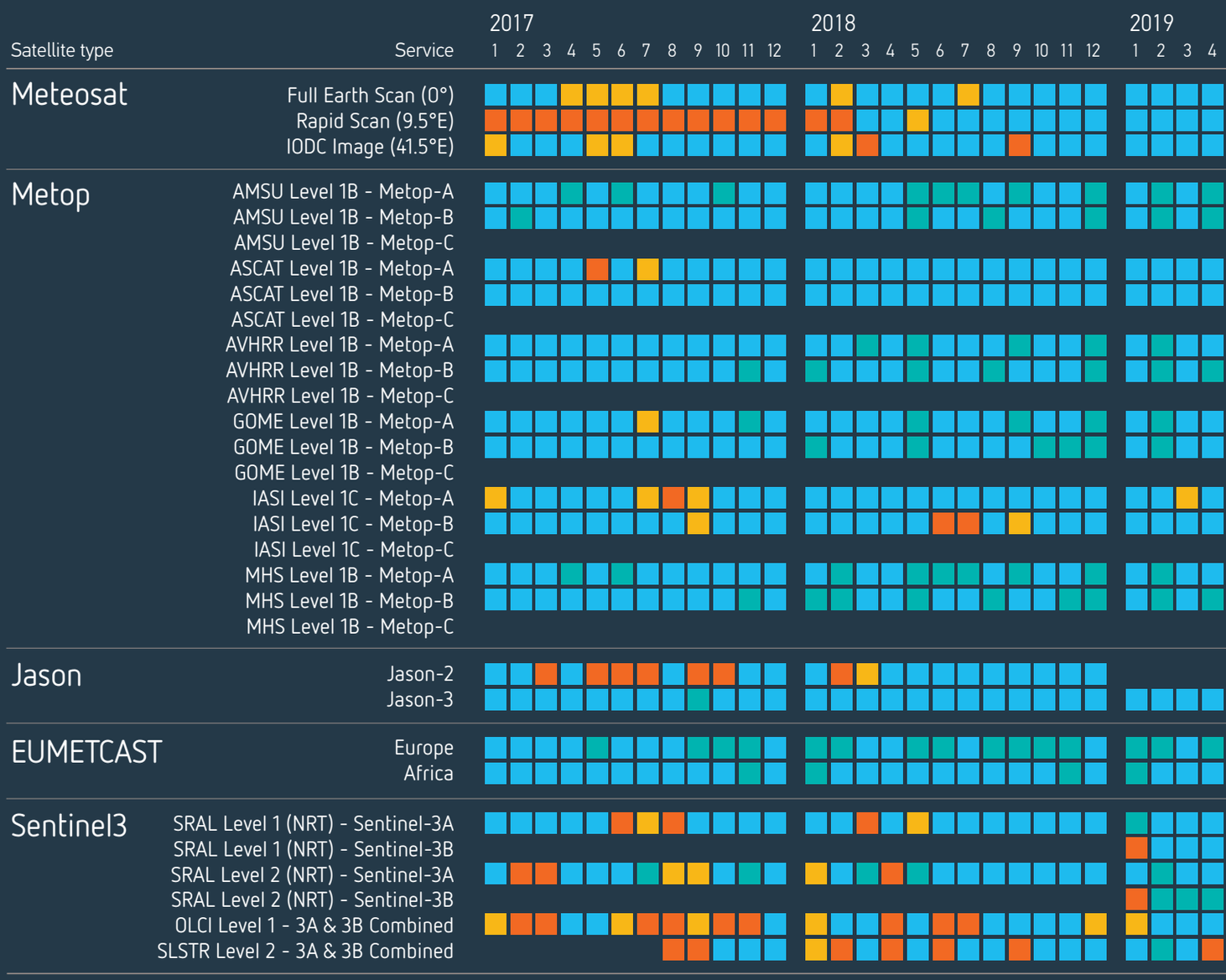
The centre delivered 9.71 million files, with a volume of 823 million terabytes. The volume of files retrieved was 2,359 terabytes.



KEY FIGURES

High performance

For the past five years, more than 90% of our satellites have exceeded their monthly operational performance targets. Many operate at maximum availability.

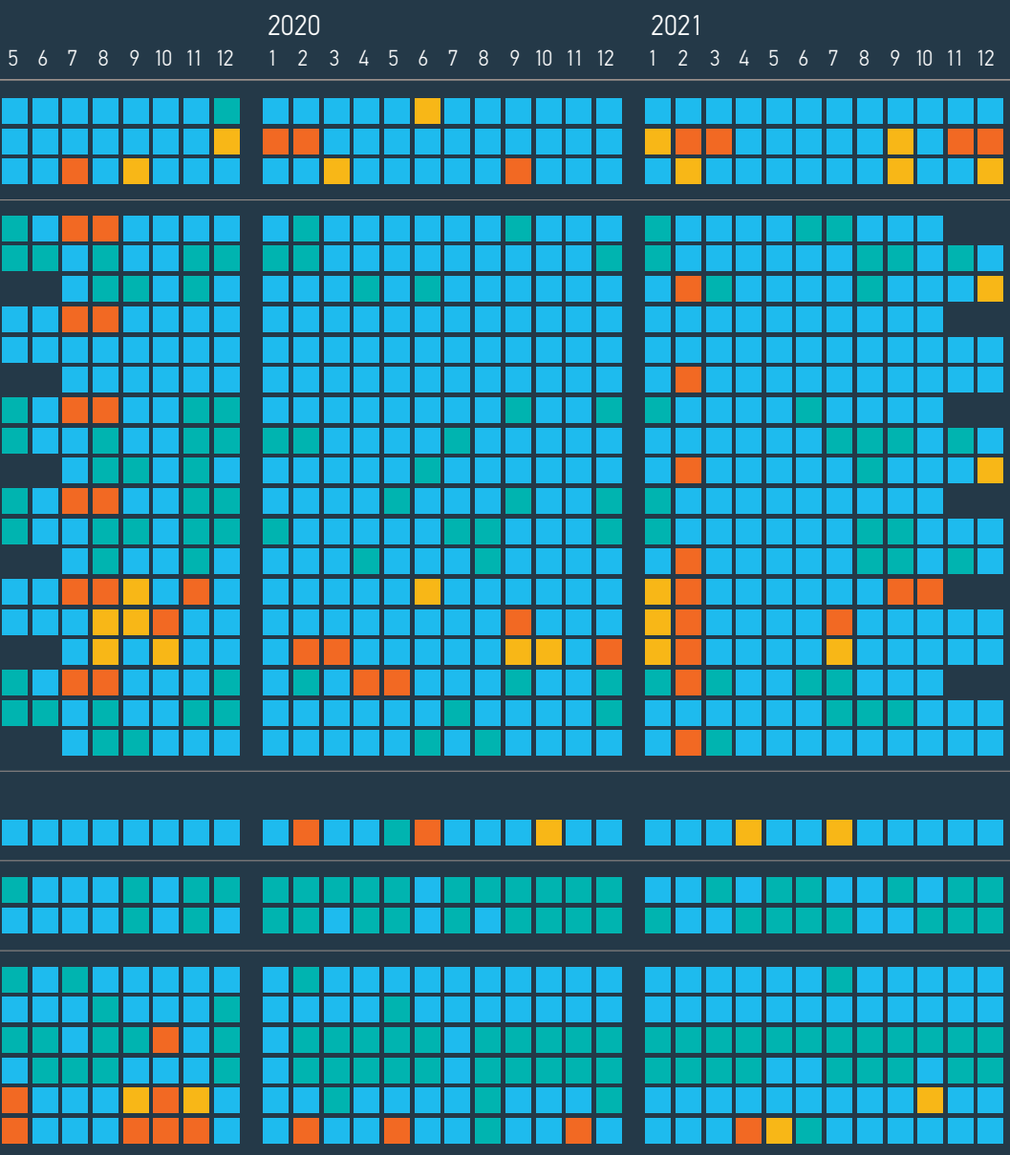


KEY FIGURES

Service availability to users

▲ Above target
- 100% availability
- Exceeded target

▼ Below target
- Within 1% of meeting target
- More than 1% below target



Why were some services below target?

Rapid Scan | Jan 2017 to Feb 2018, Jan to Feb 2020, Feb to Mar 2021 and Nov to Dec 2021: Planned routine instrument maintenance.

All Metop-A services | Jul to Aug 2019: Service module anomaly and subsequent payload switch off event on 30 Jul 2019.

ISAI Metop-A, -B, -C services | Jan 2021: External calibration and separate issues for each satellite (Metop-A: Moon intrusion, Metop-B: Heater refuse mode and Metop-C: Solid state recorder anomaly). One lost ground station pass reduced availability to 97-98%. | Feb 2021: External calibration and a ground segment anomaly affecting the EPS dissemination facility reduced availability to 96-97%.

KEY FIGURES

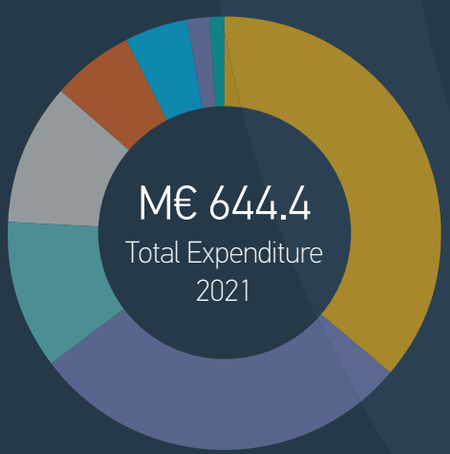
FINANCIAL INFORMATION

The 2021 EUMETSAT Financial Statement has been audited by the Tribunal De Contas. The following tables, in K€, are a summary of the information for 2021 included in those accounts.

SUMMARY REVENUE & EXPENSES 2021

	KEUR
REVENUE	
Member State Contributions	487,627
Other Contributions	76,568
Sales Revenue	1,303
Other Revenue	66,499
TOTAL REVENUE	**631,997**
EXPENSES	
Costs for Human Resources	163,224
Services and Works Contracts	80,897
Other Operating Expenses	13,070
Satellites related costs	63,116
SAF, Prospective Activities, Research Fellows	13,866
Depreciation	166,473
TOTAL EXPENDITURES	**500,646**
Expenses from Financial Operations	903
NET SURPLUS FOR THE PERIOD	**130,448**
Surplus to be distributed to Member States	30,415
Result Allocated to Reserves	100,033

EXPENDITURE BUDGETS 2021



	MEUR
General Budget (GB)	67.9
Meteosat Second Generation (MSG)	30.8
Meteosat Third Generation (MTG)	185.1
EUMETSAT Polar System (EPS)	38.9
EPS - Second Generation (EPS-SG)	233.4
Jason-CS	10.8
Copernicus	71.6
Copernicus-2	5.9

SUMMARY BALANCE SHEET 2021

	KEUR
ASSETS	
Current Assets	1,120,743
Non-Current Assets	3,271,262
TOTAL ASSETS	**4,392,005**
LIABILITIES	
Current Liabilities	760,485
Non-Current Liabilities	927,071
TOTAL LIABILITIES	**1,687,556**
TOTAL NET ASSETS/EQUITY	**2,704,449**
TOTAL LIABILITIES & NET ASSETS/EQUITY	**4,392,005**

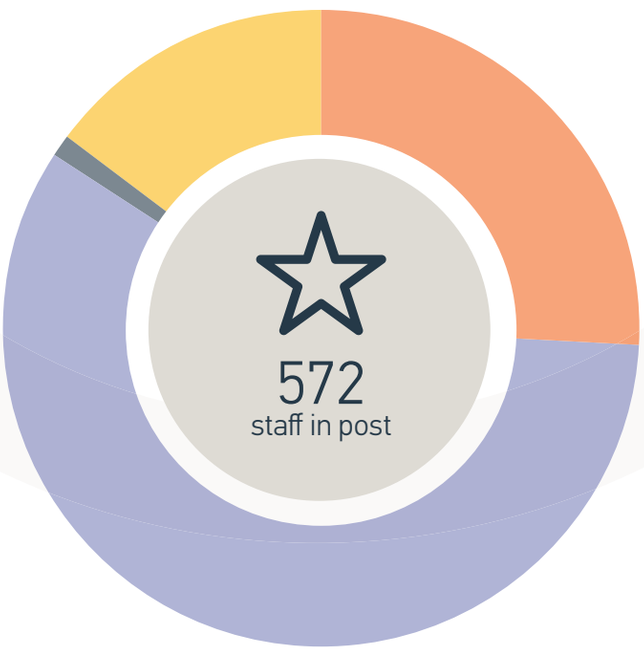
MEMBER STATE CONTRIBUTIONS 2021

MEMBER STATE	KEUR
Austria	10,529
Belgium	12,535
Bulgaria	1,426
Croatia	1,356
Czechia	5,091
Denmark	8,519
Estonia	650
Finland	6,457
France	67,198
Germany	95,073
Greece	5,028
Hungary	3,359
Iceland	525
Ireland	6,709
Italy	49,605
Latvia	747
Lithuania	1,134
Luxembourg	1,049
Netherlands	21,200
Norway	10,550
Poland	12,393
Portugal	5,451
Romania	5,115
Slovakia	2,323
Slovenia	1,177
Spain	32,652
Sweden	13,693
Switzerland	17,193
Turkey	21,312
United Kingdom	67,578
TOTAL CONTRIBUTIONS	**487,627**

KEY FIGURES

HUMAN RESOURCES

At the end of December 2021, there were 572 staff in post out of a complement of 599. There were 43 starters and 20 leavers in 2021.



Administration	148
Engineering	334
Science	84
Senior Management	6

Germany	21.2%
Italy	16.8%
United Kingdom	14.3%
Spain	13.3%
France	13.1%
Portugal	3.1%
Turkey	2.6%
Belgium	1.7%
The Netherlands	1.7%
Other	12.1%

APPENDIX

ORGANISATION CHART, 1 JANUARY 2021

Director-General
Phil Evans

EUMETSAT Council

Financial Control and Internal Audit
Jose Travesi Garcia

Policy Advisory Committee (PAC)

Scientific and Technical Group (STG)

Administration and Finance Group (AFG)

Data Policy Group (DPG)

STG Operations Working Group (STG-OWG)

STG Science Working Group (STG-SWG)

Chief Scientist
Paolo Ruti

Quality Management
Carmelo Aveni Cirino

Strategy, Communication and International Relations
Paul Counet

Programme Preparation and Development
Cristian Bank

Mandatory LEO Programmes
Gökan Kayal

Mandatory GEO Programmes
Alexander Schmid

Copernicus Missions Development
Vincenzo Santacesaria

Operations and Services to Users
Livio Mastroddi

Flight Operations
Gareth Williams

Real Time Services and System Operations
Sean Burns

User Support and Climate Services
Joachim Saalmueller

Copernicus Programme and Service Management Office
Lieven Bydekerke

Administration
Silvia Castañer

Contracts
Eleni Katsampani

Finance
Per Collin

General Services
Bernd Kaufmann

Human Resources
Raffael Clerici

Legal Affairs
Mechtild Lauth

Technical and Scientific Support
Frédéric Pradeilles

Process Assurance and Management Support
Andrea Duflaut

Generic Systems and Infrastructure
Graziano Mori

Remote Sensing and Products
Bojan Bojkov

System Engineering and Projects
Joaquin González Picazo

Information and Communication Technology
Okan Gümrah

APPENDIX

EUMETSAT DELEGATE BODY CHAIRS 2021

C EUMETSAT COUNCIL

Chair	Vice-Chair
Prof G. Van der Steenhoven Koninklijk Nederlands Meteorologisch Instituut	**Mr E. Moran** Met Éireann

PAC POLICY ADVISORY COMMITTEE

Chair	Vice-Chair
Mr F. Fontana MeteoSwiss	**Mr P. Rottiers** Belgian Science Policy Office (BELSPO)

STG SCIENTIFIC AND TECHNICAL GROUP

Chair	Vice-Chair
Mr M. Manso Rejón Agencia Estatal de Meteorología (AEMet)	**Dr I. Trigo** Instituto Português do Mar e da Atmosfera, IP

AFG ADMINISTRATION AND FINANCE GROUP

Chair	Vice-Chair
Mr S. Rasmussen Norwegian Meteorological Institute	**Mr S. Green** Met Office

STG OWG STG OPERATIONS WORKING GROUP

Chair	Vice-Chair
Dr S. J. Keogh Met Office	**Mr A. Dybbroe** Swedish Meteorological and Hydrological Institute

DPG DATA POLICY GROUP

Chair	Vice-Chair
Mr V. Rak Slovak Hydrometeorological Institute	**Ms M. Vignes** Météo France **Mr S. Olufsen** Danish Meteorological Institute

STG SWG STG SCIENCE WORKING GROUP

Chair	Vice-Chair
Dr D. Biron COMet, Italian Air Force	**Dr R. Hollmann** Deutscher Wetterdienst

APPENDIX

EUMETSAT COUNCIL DELEGATES AND ADVISORS

Austria

Dr A. Schaffhauser	Zentralanstalt für Meteorologie und Geodynamik
Mr Luc-Antoine Berset	Austrian Research Promotion Agency Aeronautics and Space Agency
Dr M. Staudinger	Zentralanstalt für Meteorologie und Geodynamik

Belgium

Dr D. Gellens	Royal Meteorological Institute of Belgium
Mr P. Rottiers	Belgian Science Policy Office, Space Department
Dr S. Dewitte	Royal Meteorological Institute of Belgium

Bulgaria

Prof Dr H. Branzov	National Institute of Meteorology and Hydrology (NIMH)
Ms L. Yosifova	National Institute of Meteorology and Hydrology (NIMH)

Croatia

Dr B. Ivancan-Picek	Croatian Meteorological and Hydrological Service

Czechia

Mr M. Rieder	Czech Hydrometeorological Institute (CHMI)
Mr M. Setvák	Czech Hydrometeorological Institute (CHMI)
Ms D. Bachmanová	Ministry of the Environment

Denmark

Ms M. Thyrring	Danish Meteorological Institute
Mr T. Kjellberg Christensen	Danish Meteorological Institute
Mr A, Højby Müller	Danish Meteorological Institute

Estonia

Mr T. Ala	Estonian Environment Agency
Ms K. Rosin	Estonian Environment Agency

Finland

Prof J. Kaurola	Finnish Meteorological Institute (FMI)
Mr J. Pulliainen	Finnish Meteorological Institute (FMI)

France

Ms V. Schwarz	Météo France
Mr M. Abdelkrim	Météo France
Mr A. Debar	Météo France
Ms L. Frachon	Météo France
Ms A. Magnouloux	Météo France
Ms D. De Sentenac	Météo France
Ms M. Vignes	Météo France
Ms M. Domergue	Ministère de la Transition Ecologique

Germany

Prof G. Adrian	Deutscher Wetterdienst (DWD)
Dr G. Seuffert	Bundesministerium für Verkehr und digitale Infrastruktur
Dr M. Uphoff	Bundesministerium für Verkehr und digitale Infrastruktur
Mr M. Rohn	Deutscher Wetterdienst (DWD)
Mr T. Ruwwe	Deutsches Zentrum für Luft-und Raumfahrt (DLR)

Greece

Brig. Gen. A. Gatopoulos	Hellenic National Meteorological Service (HNMS)
Col. K. Kasapas	Hellenic National Meteorological Service (HNMS)
Lt. Col I. Matsangouras	Hellenic National Meteorological Service (HNMS)

Hungary

Dr K. Radics	Hungarian Meteorological Service (OMSZ)
Dr M. Diószeghy	Hungarian Meteorological Service (OMSZ)
Dr E. Lábó-Szappanos	Hungarian Meteorological Service (OMSZ)

Iceland

Dr A. Snorrason	Icelandic Meteorological Office (IMO)

Ireland

Mr E. Moran	Met Éireann
Ms S. O'Reilly	Met Éireann
Mr J. Prendergast	Met Éireann

Italy

Mr L. Baione	Italian Air Force
Mr A. Raspanti	Italian Air Force
Dr A. Bartolini	Ministero dell'Economia e delle Finanze
Dr F. Battazza	Agenzia Spaziale Italiana
Mr L. Fasano	Agenzia Spaziale Italiana
Lt Col P. Capizzi	REMET - CSA-SM Reparto per la Meteorologia

Latvia

Mr E. Zarins	Latvian Environment, Geology and Meteorology Centre
Mr Andris Viksna	Latvian Environment, Geology and Meteorology Centre

APPENDIX

Lithuania

Mr K. Šetkus	Lithuanian Hydrometeorological Service under the Ministry of Environment
Ms V. Raliene	Lithuanian Hydrometeorological Service under the Ministry of Environment
Ms O. Snieškaitė	Lithuanian Hydrometeorological Service under the Ministry of Environment

Luxembourg

Ms M. Reckwerth	MeteoLux, Administration de la navigation aérienne
Dr J. Bareiss	MeteoLux, Administration de la navigation aérienne

Netherlands

Mr H. Roozekrans	Koninklijk Nederlands Meteorologisch Instituut (KNMI)

Norway

Mr R. Skålin	Norwegian Meteorological Institute (Met.no)
Mr L. A. Breivik	Norwegian Meteorological Institute (Met.no)
Mr S. Rasmussen	Norwegian Meteorological Institute (Met.no)
Mr H. Schyberg	Norwegian Meteorological Institute (Met.no)

Poland

Mr P. Ligenza	Institute of Meteorology and Water Management (IMGW)
Mr A. Arsen	Institute of Meteorology and Water Management (IMGW)
Dr A. Rutkowski	Institute of Meteorology and Water Management (IMGW)
Dr Ing P. Struzik	Institute of Meteorology and Water Management (IMGW)
Mr J. Trzosowski	Institute of Meteorology and Water Management (IMGW)

Portugal

Prof M. de Miranda	Instituto Português do Mar e da Atmosfera, IP
Ms I. M. Martins	Instituto Português do Mar e da Atmosfera, IP
Dr I. Trigo	Instituto Português do Mar e da Atmosfera, IP

Romania

Ms E. Mateescu	National Meteorological Administration (RNMA)
Dr G. Stancalie	National Meteorological Administration (RNMA)

Slovakia

Dr M. Benko	Slovak Hydrometeorological Institute (SHMU)
Mr V. Rak	Slovak Hydrometeorological Institute (SHMU)

Slovenia

Mr J. Knez	Slovenian Environment Agency
Mr J. Jerman	Slovenian Environment Agency
Mr G. Sluga	Slovenian Environment Agency

Spain

Mr M.-Á. López González	Agencia Estatal de Meteorologia (AEMET)
Mr J. González-Breña	Agencia Estatal de Meteorologia (AEMET)
Mr J. Manuel Montero Garrido	Agencia Estatal de Meteorologia (AEMET)
Mr M. Manso Rejón	Agencia Estatal de Meteorologia (AEMET)
Mr J. P. Ortiz-de-Galisteo Marin	Agencia Estatal de Meteorologia (AEMET)
Mr M. Palomares	Agencia Estatal de Meteorologia (AEMET)
Mr R. Squella	Agencia Estatal de Meteorologia (AEMET)
Mr E. Vez	Agencia Estatal de Meteorologia (AEMET)
Mr S. Lourenso Prieto	Centre for the Development of Industrial Technology

Sweden

Mr H. Wirtén	Swedish Meteorological and Hydrological Institute (SMHI)
Ms B. Aarhus Andrae	Swedish Meteorological and Hydrological Institute (SMHI)
Mr S. Nilsson	Swedish Meteorological and Hydrological Institute (SMHI)

Switzerland

Mr P. Binder	Federal Office of Meteorology and Climatology MeteoSwiss
Mr B. Calpini	Federal Office of Meteorology and Climatology MeteoSwiss
Mr F. Fontana	Federal Office of Meteorology and Climatology MeteoSwiss

Turkey

Mr V. Mutlu Coskun	Turkish State Meteorological Service (TSMS)
Mr M. Altinyollar	Turkish State Meteorological Service (TSMS)
Mr S. Karayusufoglu Uysal	Turkish State Meteorological Service (TSMS)
Dr K. Öztürk	Turkish State Meteorological Service (TSMS)

United Kingdom

Mr S. Brown	Met Office
Ms I. Cox	Met Office
Mr S. Green	Met Office
Ms I. Harrison-Roberts	Met Office
Ms S. Hewitt	Met Office
Ms S. Jackson	Met Office
Mr S. Turner	Met Office

Observers

European Centre for Medium-Range Weather Forecasts (ECMWF)

European Space Agency (ESA)

EUMETNET

European Commission

National Oceanic and Atmospheric Administration (NOAA)

World Meteorological Organization (WMO)

APPENDIX

EUMETSAT PARTICIPATION IN MAJOR EVENTS

13th Space Policy Conference	Hybrid - Brussels	12-13 January 2021
The Optimal Use Of Operational Satellite Microwave Products For High Latitudes And Polar Area Models	Virtual	23-24 February 2021
21st session of the African Centre Of Meteorological Applications For Development Board of Governors	Virtual	9-10 March 2021
5th session of the African Ministerial Conference on Meteorology	Virtual	16-17 March 2021
18th session of the World Meteorological Organization Regional Association I	Virtual	19 March 2021
EUMETSAT Information Days for Western Balkans National Meteorological and Hydrological Services	Virtual	13-14 April 2021
EUMETSAT Information Days for Eastern European, Caucasian and Central Asian National Meteorological and Hydrological Services	Virtual	21-22 April 2021
European Geosciences Union general assembly	Vienna	25-30 April 2021
26th EUMETNET Assembly meeting	Virtual	17-18 May 2021
Coordination Group for Meteorological Satellites-49 plenary session	Virtual	19-21 May 2021
Forum Météo et Climat	Virtual	17-19 June 2021
EUMETSAT Meteorological Satellite Conference, co-hosted with the Romanian National Meteorological Administration	Virtual	20-24 September 2021
Plenary session of the 14th African User Forum	Virtual	6-7 October 2021
World Meteorological Organization 74th Executive Congress	Virtual	25-29 October 2021
Committee on Earth Observation Satellites 35th plenary meeting	Virtual	1-4 November 2021
Joint 11th Asia/Oceania Meteorological Satellite Users' Conference (AOMSUC-11) and Second Fengyun Satellite Users Conference	Virtual	1-4 November 2021
Korea Meteorological Administration-EUMETSAT bilateral meeting	Virtual	4 November 2021
European Space Forum	Virtual	8-9 November 2021
Intra-Africa, Caribbean, Pacific Climate Services and Related Application Programme (ClimSA) Forum	Virtual	16-18 November 2021
China National Space Administration-EUMETSAT bilateral meeting	Virtual	18 November 2021
European Space Agency Ministerial Meeting	Porto	19 November 2021
GEO Week, including GEO-17 plenary	Virtual	23-26 November 2021
African Space Art Project selection of artists	Paris	27 November 2021
Infrared Atmospheric Sounding Interferometer Conference	Evian	2-6 December 2021
Global Monitoring for Environment and Security and Africa Forum	Abidjan	6-10 December 2021

APPENDIX

DATA RECORDS RELEASED IN 2021

In 2021 EUMETSAT released several new, extended, or improved data records, of (re)calibrated and quality-controlled sensor data and of validated and quality-controlled geophysical variables.

A major achievement was the delivery of a set of fundamental data records for atmospheric humidity in the upper atmosphere utilising microwave humidity sounder instruments aboard EUMETSAT, NOAA and CMA operated satellites. Further work is underway to harmonise the individual instrument data records into one climate data record.

The ROM SAF provided new versions of temperature profiles for the Earth's atmosphere and ionosphere with high vertical resolution and global coverage over the period 2001-2020 utilising data from the Metop satellites as well as from the third party CHAMP, COSMIC, and GRACE satellites.

A highlight was the delivery of atmospheric motion vector data records from our first and second generation geostationary Meteosat satellites covering data since 1981.

Even longer is the data record of atmospheric motion vectors for polar areas derived from infrared imagery covering more than 40 years (1979-2020).

Enhancing land monitoring the LSA SAF released a global data record on the state of vegetation based starting with Metop-A data in 2007 and being continued as an interim record since 2020.

Finally, the set of atmospheric composition data records was made more complete by the AC SAF with the release of a data record that enables a long-term consideration of the height where absorbing aerosol is present in the atmosphere and by a data record of total column Glyoxal from Metop GOME-2 observations. Glyoxal is an indicator of volatile organic compounds that are key precursors of very small particles in the atmosphere being harmful for human beings and ozone.

APPENDIX

SCIENTIFIC AND TECHNICAL PUBLICATIONS 2021

Names in **bold** indicate EUMETSAT authors

Abdalla, S., [...], C. **Nogueira Loddo**, and [...] (International Altimetry Team). 'Altimetry for the Future: Building on 25 Years of Progress'. *Adv. Space Res.* 68, no. 2 (2021): 319–63.

Abt, I., [...], **J. Onderwaate**r [...]. 'Azimuthal Correlations in Photoproduction and Deep Inelastic Ep Scattering at HERA'. *J. High Energy Phys.* 2021, no. 12: 102.

Albert, P., M. Dillmann, J. Miguens, L. Wolf, M. Schick, B. Saulyak, G. Mori, A. Arnaud, R. Correa, and H. Dufourmont. 'WEKEO - Distributed and Federated Access to Copernicus Data and Information'. In *Proc. of the 2021 Conf. on Big Data from Space*. online, 2021.

Barbieux, K., O. Hautecoeur, M. De Bartolomei, M. Carranza, and R. Borde. 'The Sentinel-3 SLSTR Atmospheric Motion Vectors Product at EUMETSAT'. *Remote Sens.* 13, no. 9 (2021): article No. 1702.

Bas, S., **V. Debaecker**, S. Kocaman, S. Saunier, and **D. Just.** 'Investigations on the Geometric Quality of AVHRR Level 1B Imagery Aboard MetOp-A'. *PFG, 2021*.

Bojinski, S., and **S. Thonipparambil**. 'Next-Generation EUMETSAT Satellite Missions: Key Features, Improvement to Meteorological Forecasting, and User Preparation'. *2021 EMS Annual Meeting*, virtual.

Bonelli, A., V. Vantrepotte, D. Jorge, J. Demaria, C. Jamet, **D. Dessailly,** A. Mangin, O. Fanton d'Andon, **E. Kwiatkowska**, and H. Loisel. 'Colored Dissolved Organic Matter Absorption at Global Scale from Ocean Color Radiometry Observation: Spatio-Temporal Variability and Contribution to the Absorption Budget'. *Remote Sens. Environ.* 265 (2021): article no. 112637.

Brenot, H., [...], **M. Vázquez-Navarro**, [...]. 'EUNADICS-AV Early Warning System Dedicated to Supporting Aviation in the Case of a Crisis from Natural Airborne Hazards and Radionuclide Clouds'. *Nat. Hazards Earth Syst. Sci.* 21, no. 11 (2021): 3367–3405.

Carrer, D., F. Pinault, G. Lellouch, I. Trigo, I. Benhadj, F. Camacho, X. Ceamanos, S. Moparthy, J. Munoz-Sabater, **L. Schüller**, J. Sanchez-Zapero. 'Surface Albedo Retrieval from 40-Years of Earth Observations through the EUMETSAT/LSA SAF and EU/C3S Programmes: The Versatile Algorithm of PYALUS'. *Remote Sens.* 13, no. 3 (2021): article no. 372.

Cazzaniga, I., G. Zibordi, F. Melin, **E. Kwiatkowska,** M. Talone, **D. Dessailly, J. Gossn**, and D. Muller. 'Evaluation of OLCI Neural Network Radiometric Water Products'. *IEEE Geosci. Remote Sensing Lett.* 19 (2021).

Cimini, D., F. Marzano, M. Biscarini, **R. Martinez Gil, P. Schlüssel**, F. Concaro, M. Marchetti, M. Pasian, and F. Romano. 'Applicability of the Langley Method for Non-Geostationary In-Orbit Satellite Effective Isotropic Radiated Power Estimation'. *IEEE Trans. Antennas Propag.* 69, no. 8 (2021): 4935-43.

Crewell, S., K. Ebell, P. Konjari, M. Mech, T. Nomokonova, A. Radovan, D. Strack, A. Triana-Gomez, S. Noel, R. Scarlat, G. Spreen, M. Maturilli, A. Rinke, I. Gorodetskaya, C. Viceto, **T. August**, M. Schröder. 'A Systematic Assessment of Water Vapor Products in the Arctic: From Instantaneous Measurements to Monthly Means'. *Atmos. Meas. Tech.* 14, no. 7 (2021): 4829–56.

Debaecker, V., S. Kocaman, S. Saunier, K. Garcia, S. Bas, and **D. Just**. 'On the Geometric Accuracy and Stability of MSG SEVIRI Images'. *Atmos. Environ.* 262 (2021): article no. 118645.

Dinardo, S., L. Fenoglio-Marc, M. Becker, **R. Scharroo**, M. Fernandes, J. Staneva, S. Grayek, and J. Benveniste. 'A RIP-Based SAR Retracker and Its Application in North East Atlantic with Sentinel-3'. *Adv. Space Res.* 68, no. 2 (2021): 892–929.

Donlon, C., [...], **R. Scharroo, C. Martin-Puig**, [...]. 'The Copernicus Sentinel-6 Mission: Enhanced Continuity of Satellite Sea Level Measurements from Space'. *Remote Sens. Environ.* 258 (2021): article no. 112395.

Dussarrat, P., B. Theodore, D. Coppens, C. Standfuss, and B. Tournier. 'Introduction to the Calibration Ringing Effect in Satellite Hyperspectral Atmospheric Spectrometry'. *ArXiv*, 2021, 2111.08574.

Ebel, P., **A. Meraner**, M. Schmitt, and X. Zhu. 'Multisensor Data Fusion for Cloud Removal in Global and All-Season Sentinel-2 Imagery'. *IEEE Trans. Geosc. Remote Sens.* 59, no. 7 (2021): 5866–78.

APPENDIX

SCIENTIFIC AND TECHNICAL PUBLICATIONS 2021

Names in **bold** indicate EUMETSAT authors

Holmlund, K., J. Grandell, J. Schmetz, **R. Stuhlmann, B. Bojkov, R. Munro, M. Lekouara, D. Coppens, B. Vittichie, T. August, B. Theodore, P. Watts, M. Dobber, G. Fowler, S. Bojinski, A. Schmid,** K. Salonen, S. Tjemkes, D. Aminou, P. Blythe. 'Meteosat Third Generation (MTG) Continuation and Innovation of Observations from Geostationary Orbit'. *Bull. Amer. Meteor. Soc.* 102, no. 5 (2021): E990–1015.

Jafariserajehlou, S., V. Rozanov, M. Vountas, C. Gatebe, and J. Burrows. 'Simulated Reflectance above Snow Constrained by Airborne Measurements of Solar Radiation: Implications for the Snow Grain Morphology in the Arctic'. *Atmos. Meas. Tech.* 14, no. 1 (2021): 369–89.

Jorge, D., H. Loisel, C. Jamet, **D. Dessailly,** J. Demaria, A. Bricaud, S. Maritorena, X. Zhang, D. Antoine, T. Kutser, S. Belanger, V. Brando, J. Werdell, **E. Kwiatkowska**, A. Mangin, O. d'Andon. 'A Three-Step Semi Analytical Algorithm (3SAA) for Estimating Inherent Optical Properties over Oceanic, Coastal, and Inland Waters from Remote Sensing Reflectance'. *Remote Sens. Environ.* 263 (2021): article no. 112537.

Klaes, D., J. Ackermann, C. Anderson, Y. Andres, T. August, R. Borde, B. Bojkov, L. Butenko, A. Cacciari, D. Coppens, M. Crapeau, S. Guedj, O. Hautecoeur, T. Hultberg, R. Lang, S. Linow, C. Marquardt, R. Munro, C. Pettirossi, G. Poli, F. Ticconi, O. Vandermarcq, **M. Vazquez, M. Vazquez-Navarro**. 'The EUMETSAT Polar System - 13+ Successful Years of Global Observations for Operational Weather Prediction and Climate Monitoring'. *Bull. Amer. Meteor.* Soc., 2021.

Kottayil, A., K. Satheesan, **V. John**, and R. Antony. 'Diurnal Variation of Deep Convective Clouds over Indian Monsoon Region and Its Association with Rainfall'. *Atmos. Res.* 255 (2021): article no. 105540.

Lam, K., [...], S. Padovan, [...]. 'GJ 367b: A Dense, Ultrashort-Period Sub-Earth Planet Transiting a Nearby Red Dwarf Star'. *Science* 374, no. 6572 (2021): 1271–75.

Landier, L., J. Nosavan, A. Rolland, **T. Marbach, B. Fougnie**, and **M. Vazquez-Navarro**. 'Radiometric and Geometric Calibration/ Validation of EPS-SG 3MI Using Natural Targets'. *Proc. SPIE* 11858 (2021): article no. 118580U.

Lattanzio, A., M. Grant, M. Doutriaux-Boucher, R. Roebeling, and **J. Schulz**. 'Assessment of the EUMETSAT Multi Decadal Land Surface Albedo Data Record from Meteosat Observations'. *Remote Sens.* 13, no. 10 (2021): article no. 1992.

Lompa, T., K. Wünnemann, D. Wahl, **S. Padovan**, and K. Miljkovic. 'Numerical Investigation of Lunar Basin Formation Constrained by Gravity Signature'. *Journal of Geophysical Research: Planets* 126, no. 11 (2021): article No. e2021JE006908.

Manninen, T., E. Jääskeläinen, A. Riihela, J. Peltoniemi, P. Lahtinen, N. Siljamo, L. Thölix, O. Meinander, A. Kontu, H. Suokanerva, R. Pirazzini, J. Suomalainen, T. Hakala, S. Kaasalainen, H. Kaartinen, A. Kukko, **O. Hautecoeur**, J. Roujean. 'Effect of Small-Scale Snow Surface Roughness on Snow Albedo and Reflectance'. *Cryosphere* 15, no. 2 (2021): 793–820.

Mastro, P., G. Masiello, D. Cimini, F. Romano, E. Ricciardelli, F. Di Paola, **T. Hultberg, T. August**, and C. Serio. 'Cloud Liquid and Ice Water Content Estimation from Satellite: A Regression Approach Based on Neural Networks'. *Proc. SPIE* 11859 (2021): article no. 118590H.

Miltiadou, M., N. Cambell, D. Cosker, and **M. Grant**. 'A Comparative Study about Data Structures Used for Efficient Management of Voxelised Full-Waveform Airborne LiDAR Data during 3D Polygonal Model Creation'. *Remote Sens.* 13, no. 4 (2021): article no. 559.

Montmory, A., and **F. Roveda**. 'Use of Modern Containerised Deployment Tool to Reach the 99,8 % Availability Requirement for the Meteosat Third Generation Level-2 Processing Facility'. In *Proc. of the 2021 Conf. on Big Data from Space*. online, 2021.

Nair, A., K. Sai Srujan, S. Kulkarni, K. Alwadhi, N. Jain, H. Kodamana, S. Sandeep, and **V. John**. 'A Deep Learning Framework for the Detection of Tropical Cyclones from Satellite Images'. *IEEE Geosc. Remote Sens. Lett.* 19 (2021): article no. 1004405.

Papa, M., **V. Mattioli**, M. Montopoli, D. Casella, B. Rydberg, and F. Marzano. 'Investigating Spaceborne Millimeter-Wave Ice Cloud Imager Geolocation Using Landmark Targets and Frequency-Scaling Approach'. *IEEE Trans. Geosc. Remote Sens.* 60 (2021): article no. 5301117.

Papa, M., **V. Mattioli, J. Avbelj**, and F. Marzano. 'Assessing the Spaceborne 183.31-GHz Radiometric Channel Geolocation Using High-Altitude Lakes, Ice Shelves, and SAR Imagery'. *IEEE Transactions on Geoscience and Remote Sensing* 59, no. 5 (May 2021): 4044–61.

APPENDIX

SCIENTIFIC AND TECHNICAL PUBLICATIONS 2021

Names in **bold** indicate EUMETSAT authors

Peng, G., [...], **J. Schulz**, [...] . 'Call to Action for Global Access to and Harmonization of Quality Information of Individual Earth Science Datasets'. *Data Sci. J.* 20, no. 1 (2021): article no. 19.

Posyniak, M., K. Markowicz, **D. Czyzewska**, M. Chilinski, P. Makuch, O. Zawadzka-Manko, K. Kucieba, K. Kachniarz, K. Mijal, and K. Borek. 'Experimental Study of Smog Microphysical and Optical Vertical Structure in the Silesian Beskids, Poland'. *Atmos. Pollut. Res.* 12, no. 9 (2021): article no. 101171.

Samuel, H., M. Ballmer, **S. Padovan**, N. Tosi, A. Rivoldini, and A. Plesa. 'The Thermo□chemical Evolution of Mars with a Strongly Stratified Mantle'. *JGR Planets*, 2021, e2020JE006613.

Saunders, R., T. Blackmore, B. Candy, P. Francis, and **T. Hewison**. 'Ten Years of Satellite Infrared Radiance Monitoring with the Met Office NWP Model'. *IEEE Trans. Geosc. Remote Sens.* 59, no. 6 (2021): 4561–69.

Siebert, H., [...], **D. Czyzewska,** [...]. 'Observations of Aerosol, Cloud, Turbulence, and Radiation Properties at the Top of the Marine Boundary Layer over the Eastern North Atlantic Ocean: The ACORES Campaign'. *Bull. Amer. Meteor. Soc.* 102, no. 1 (2021): E123–47.

Sist, M., G. Schiavon, and F. Del Frate. 'A New Data Fusion Neural Network Scheme for Rainfall Retrieval Using Passive Microwave and Visible/Infrared Satellite Data'. *Appl. Sci.* 11, no. 10 (2021): article no. 4686.

Tian, X., **Y. Wang**, S. Beirle, P. Xie, T. Wagner, J. Xu, A. Li, S. Dörner, B. Ren, and X. Li. 'Technical Note: Evaluation of Profile Retrievals of Aerosols and Trace Gases for MAX-DOAS Measurements under Different Aerosol Scenarios Based on Radiative Transfer Simulations'. *Atmos. Chem. Phys.* 21, no. 17 (2021): 12867–94.

Tilstone, G., S. Pardo, G. Dall'Olmo, R. Brewin, F. Nencioli, **D. Dessailly, E. Kwiatkowska**, T. Casal, and C. Donlon. 'Performance of Ocean Colour Chlorophyll a Algorithms for Sentinel-3 OLCI, MODIS-Aqua and Suomi-VIIRS in Open-Ocean Waters of the Atlantic'. *Remote Sens. Environ.* 260 (2021): article no. 112444.

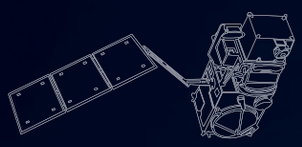
Tosi, N. and **S. Padovan**. 'Mercury, Moon, Mars: Surface Expressions of Mantle Convection and Interior Evolution of Stagnant-Lid Bodies'. In *Geophysical Monograph Series*, edited by H. Marquardt, M. Ballmer, S. Cottaar, and J. Konter, 1st ed., 455–89. Wiley, 2021.

Traeger Chatterjee, C., D. Lee, and **M. Grant**. 'EUMETSAT's Prototype Data Cube for Drought and Vegetation Monitoring'. *Int. Conf. Climate Services*. Odesa, Ukraine, 2021.

Vimic, A., B. Cvetkovic, T. Giannaros, R. Shahbazi, S. Kashani, **J. Prieto**, V. Kotroni, K. Lagouvardos, G. Pejanovic, S. Petkovic, S. Nickovic, M. Mandic. 'Numerical Simulation of Tehran Dust Storm on 2 June 2014: A Case Study of Agricultural Abandoned Lands as Emission Sources'. *Atmosphere* 12, no. 8 (2021): article no. 1054.

EUMETSAT

Destination 2030



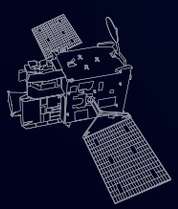
VISION

Be the leading user-driven operational agency in Europe, and a trusted global partner, for weather and Earth system monitoring from space.

PRIORITIES

1. To fulfil in the most efficient manner, through its own satellite programmes, the essential requirements of its member states for observations, data and support services for operational weather and Earth system monitoring and forecasting, and for climate services.

2. To establish additional, or shared, capabilities in partnership with the European Union and other satellite operators for the common benefit of EUMETSAT's member states and partners.



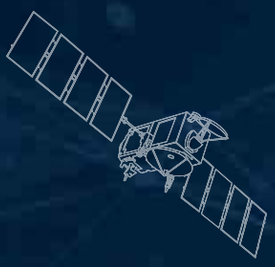
EUMETSAT Core Values

INTEGRITY

We all act ethically in every professional activity and in accordance with corporate policies

EXCELLENCE

We all strive to ensure excellent and efficient services



Read Destination 2030

STRATEGIC OBJECTIVES

1. Deploy the new Meteosat Third Generation and EUMETSAT Polar System - Second Generation satellite systems and maximise their benefits to member states and users
2. Deliver operational services responding to evolving user requirements, based on the continuous infusion of science and cost-effective infrastructures and operations
3. Establish and exploit a federative European Weather Cloud infrastructure in partnership with the ECMWF and European national meteorological and hydrological services
4. Consolidate EUMETSAT's contribution to the realisation of the Vision 2040 of the WMO Integrated Global Observing System and plan future satellite systems
5. As a partner of the Space Strategy for Europe, deliver Copernicus ocean and atmospheric composition monitoring missions and contribute to collaborative research and innovation projects for the common benefit of EUMETSAT and EU member states
6. Cooperate with other satellite operators and contribute to global partnerships for monitoring weather, the climate and greenhouse gases from space to meet additional needs of member states
7. Expand the user base for EUMETSAT-provided data, products and services
8. Continuously improve management and risk management processes
9. Remain an attractive employer for diverse, skilled, talented and engaged people

OPEN-MINDEDNESS

Our openness allows us to anticipate challenges and actively support change

COLLABORATION

We all collaborate openly in an environment of mutual respect

EMPOWERMENT

We hire diverse and talented people, empower them and foster their professional growth

Published by EUMETSAT - Europe's meteorological satellite organisation
Produced by the Strategy, Communication and International Relations Division

For further information about EUMETSAT,
its programmes and activities, please contact:

EUMETSAT
Eumetsat-Allee 1
64295 Darmstadt
Germany

Tel: +49 6151 807 3660/3770
Email: press@eumetsat.int
Web: www.eumetsat.int

EUM.AR.34
ISSN 1013-3410
ISBN 978-92-9110-110-8

EUMETSAT

Eumetsat-Allee 1
64295 Darmstadt,
Germany

Tel: +49 6151 807 3660/3770
Email: press@eumetsat.int
www.eumetsat.int

EUM AR.34, © EUMETSAT, 2022
ISSN 1013-3410
ISBN 978-92-9110-110-8