A vertical strip of satellite imagery showing a coastline with a mix of orange, yellow, and blue colors.

ANNUAL REPORT 2016

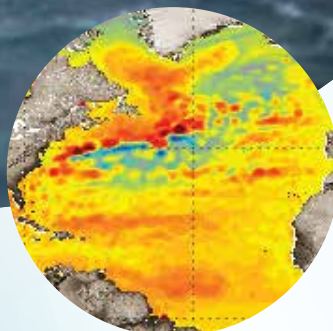
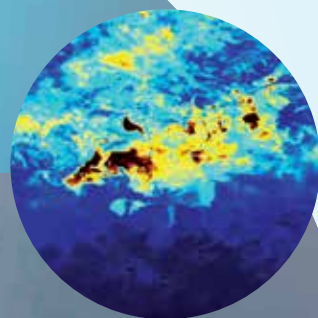




Table of contents

The word of the Director-General 2

Member and Cooperating States 5

2016 highlights 6

Operating complex satellite systems around the clock 8

Evolution of ground infrastructure 12

Further improvements to capacity, resilience and efficiency 12

The EUMETSAT response to the “big data” challenge takes shape 12

EUMETSAT satellites track climate features in a record warm year 13

El Nino declines and turns to La Nina 13

A tropical cyclone near the Azores in January 13

A Mediterranean hurricane (Medicane) in the Ionian Sea 14

High temperatures and fires in Portugal and Russia 14

Delivering services and benefits to real-time users 15

Meteosat imagery helps manage a series of devastating thunderstorms in Germany 15

Metop data support forecasts of a long, large-scale precipitation episode over Italy and Switzerland, and Meteosat imagery points to local foehn effects 16

Metop observations help forecast large winter storms, spring and summer cold fronts 17

Data access and real-time delivery 18

Support to climate services 20

Developing enhanced and new products in partnership with Member States 23

New and improved products and user software 24

New products available from international partners 26

Scientific developments target future products 26

Supporting and expanding the user base 28

User training 28

Fellowships and visiting scientists 30

User conferences 31

Outreach and local life 30

EUMETSAT celebrates its 30th Anniversary 31

Support to capacity-building initiatives 34

Optimum deployment of the recurrent satellites 35

Development of the Meteosat Third Generation (MTG) system. . . 36

EUMETSAT replans system and ground segment development activities. 36

Confidence grows in the space segment development schedule 36

The system and ground segment development pass key milestones 37

Development of the EUMETSAT Polar System-Second Generation. . 38

The ESA-led space segment development programme continues to progress rapidly 38

All contracts for the ground segment development are in place 39

Operational oceanography in the context of Copernicus. 40

After a long-awaited launch, Jason-3 becomes operational in five months 40

EUMETSAT takes over Sentinel-3A flight operations and releases first marine products 41

The cooperative development of the Jason-CS/Sentinel-6 system achieves first milestones 43

Space Strategy for Europe 44

EUMETSAT investments provide key assets for the Space Strategy for Europe 44

Preparing Europe for monitoring atmospheric CO₂ and the Arctic from space 44

Copernicus cooperation with the European Commission 45

Cooperation with other satellite operators 46

Global partnerships 48

Global Framework for Climate Services 48

Architecture for climate monitoring from space 48

CEOS and GEO 49

Management and administration 50

Key figures 55

Appendix 62

Organigramme 62

EUMETSAT Council and Delegate Body chairpersons 62

EUMETSAT Council Delegates and Advisors 64

Participation in major external events 66

Scientific and technical publications 67

Glossary 71

The word of the Director-General



As illustrated by the cover of this report, 2016 was the year of the ocean from an operations perspective, as two more ocean-monitoring satellites, Jason-3 and Sentinel-3A, began to be exploited and Meteosat-8 was moved over the Indian Ocean.

Jason-3 and Sentinel-3 are the first Copernicus-dedicated missions exploited by EUMETSAT on behalf of the European Union. Jason-3, a mission also shared with CNES, NOAA and NASA, became fully operational in October. Then a first set of Sentinel-3A products was released in the fourth quarter, adding ocean colour to the portfolio of marine products already comprising sea surface height, temperature and wind and air-sea flux products available from Jason, Metop and Meteosat satellites.

As a matter of fact, Jason-3 and Sentinel-3A start to build the backbone of the truly operational space-based observing system of the global ocean required for marine, ocean and seasonal forecasting and climate monitoring. To go further, EUMETSAT started to plan for the launch of Sentinel-3B with ESA and signed a Memorandum of Understanding with NASA, NOAA and ESA for the development of the Jason-CS/Sentinel-6 mission expected to take over from Jason-3 in 2020.

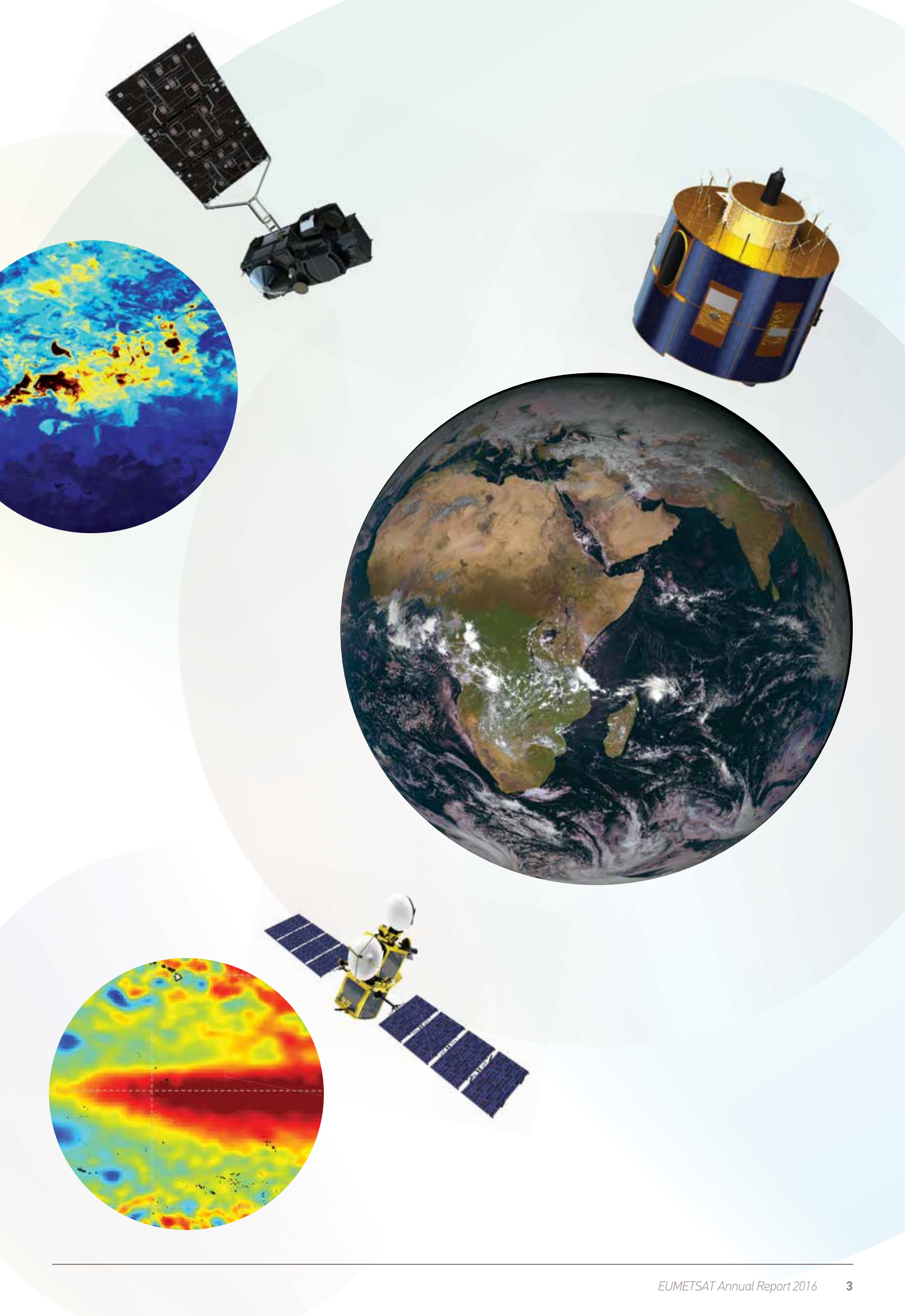
After the successful commissioning of the new Meteosat-11 satellite, Meteosat-8, the first Meteosat Second Generation satellite launched in 2002, could be moved over the Indian Ocean, to 41.5°E. This move brought geostationary imagery to a standard never achieved before over the Indian Ocean, with images taken every 15 minutes in 12 spectral channels, including a 1km high-resolution visible channel. This is EUMETSAT's best effort contribution to a multi-partner Indian Ocean Data Coverage mission also involving satellites from India, Russia and China, which aims to improve the quality and resilience of geostationary observations of a meteorologically fascinating region affected by monsoons and tropical cyclones.

2016 was also EUMETSAT's 30th anniversary. This was an ideal milestone for the Member States to adopt a new strategy that frames EUMETSAT's activities in the next decade.

Named "Challenge 2025", the new strategy builds on the legacy of the previous strategy adopted in 2011 ("EUMETSAT: a global operational satellite agency at the heart of Europe"). It will further develop EUMETSAT through the realisation of the ambitious programmes approved in the past five years, namely Meteosat Third Generation (MTG), EUMETSAT Polar System-Second Generation (EPS-SG), Jason-Continuity of Service (Jason-CS) and EUMETSAT's contribution to the EU Copernicus programme. These programmes will shape Europe's future in weather and climate monitoring from space.

The main objective of "Challenge 2025" is the full deployment of the new MTG, EPS-SG and Jason-CS satellite systems in 2025, in a safe transition from current generation systems built on the maximum extension of their lifetimes. It also targets the delivery of new products through the infusion of science, building on expertise available across EUMETSAT and its Member States. Further, "Challenge 2025" shapes EUMETSAT's response to the "big data" challenge through a roadmap of pathfinder projects for future data services.

"Challenge 2025" is also EUMETSAT's contribution to the Space Strategy for Europe published by the European Commission in October 2016. It confirms EUMETSAT's commitment to the full implementation of the Copernicus Sentinel -3, -4, -5 and -6 missions on behalf of the EU and its ambition to be the operator of the next generation of these Sentinels and possible additional Sentinels monitoring atmospheric CO₂ and the global ocean.



The word of the Director-General

Some achievements of 2016 should be seen as the first contributions to the implementation of "Challenge 2025".

The safest possible transition from the current to the second generation of the EUMETSAT Polar System has been assured. This was achieved by extending the lifetime of the ageing Metop-A satellite by two years, until 2021, through optimised operations and de-orbiting at end of life, and by further progress in preparations for the launch of Metop-C, which remains planned for October 2018 despite the need to repair two instruments. Meanwhile, the development of the EPS-SG satellite system in cooperation with ESA continued at a fast pace, with the finalisation of the cooperation framework across all development partners and the signing of all major ground segment development contracts.

Likewise, the lifetime of all Meteosat Second Generation spacecraft was confirmed or extended - Meteosat-8 by one year until mid-2020 - after reassessment of fuel reserves and lifetime implications of on-board anomalies. At the same time, confidence grew in the schedule of the ESA-led development of the Meteosat Third Generation satellites, while pre-integration of the ground segment started at EUMETSAT. This reinforced the reliability of the planning for the transition from MSG to MTG which was one of the main topics discussed by the 12th EUMETSAT User Forum in Africa in Kigali, Rwanda.

Finally, the EUMETSAT Jason-CS programme team was beefed up and fully mobilised to progress system and ground segment development activities as quickly as possible to catch up with the satellite development schedule and thus absorb the impact of the late start of this optional programme. This will secure continuity with Jason-3 at the end of this decade.

The scientific expertise and operational capacities for developing new products and user software were secured across the network of eight Satellite Application Facilities by the approval of their third Continuous Development and Operations Phase covering the period 2017-2021.



Finally, implementation of the roadmap of pathfinder projects for future "big data" services started with the procurement of industrial support for the architectural design and deployment of the cloud infrastructure and web applications required across all six projects.

In the context of the implementation of the Paris Agreement, climate monitoring from space was another focus of EUMETSAT's activities in 2016.

An agreement formalising EUMETSAT's support to the Copernicus Climate Change Service was signed with the European Centre for Medium-Range Weather Forecasts (ECMWF). Further, EUMETSAT led an international effort to establish a web-based inventory of existing and planned climate data records of essential climate variables observable from space and contributed more than 25 percent of the entries. The inventory will be used in 2017 for a gap analysis assessing not only the missing climate data records but also gaps in suitable observations from space.

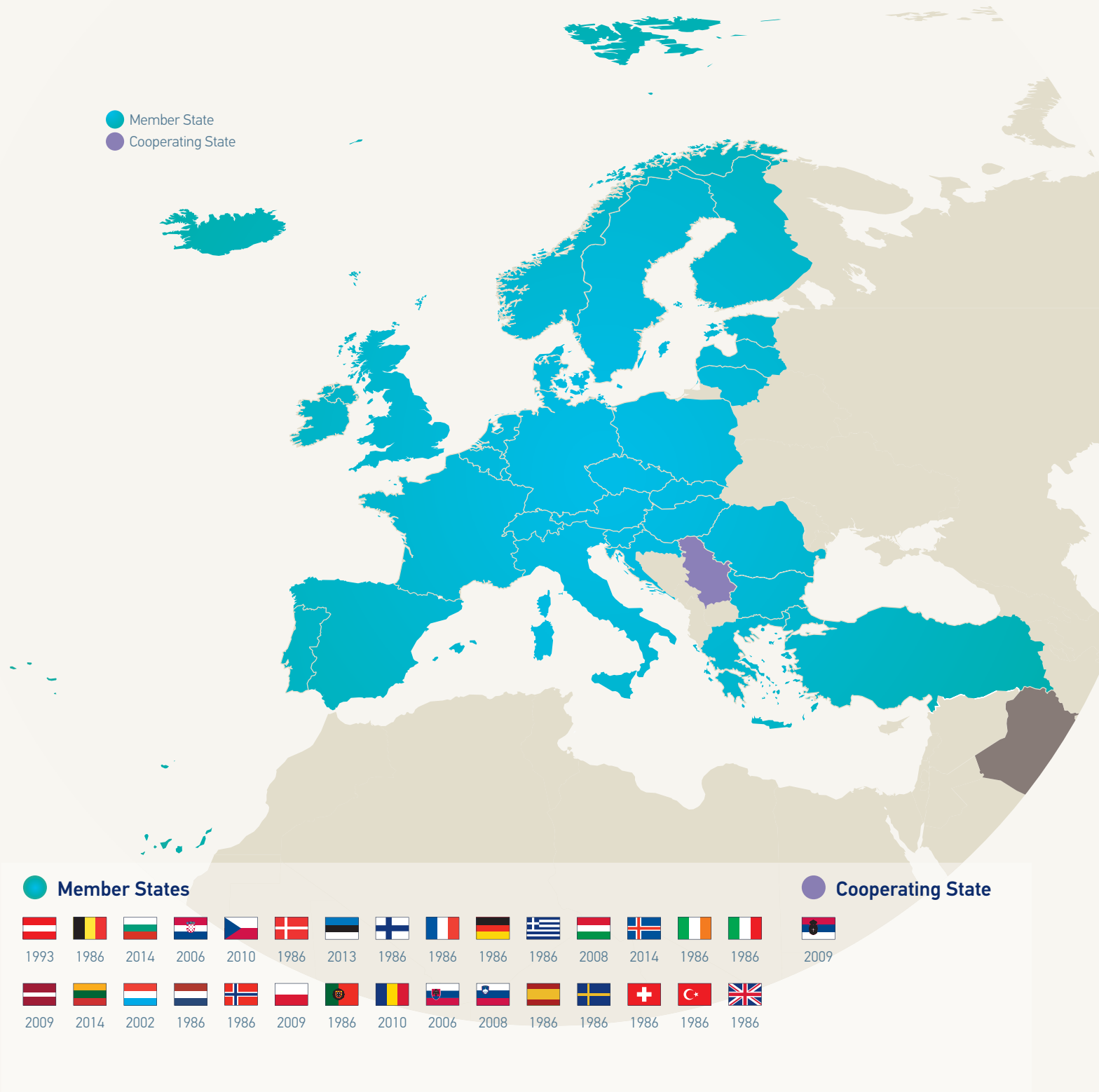
None of these achievements would have been possible without the commitment of all EUMETSAT personnel and I wish to express my sincere gratitude to all of them. I also extend a warm welcome to our new staff, in particular the young engineers and scientists recruited under the Early Career Programme launched in 2016.

My gratitude also goes to the EUMETSAT Council and its advisory bodies for their trust and guidance. This year, I wish to add my congratulations to Prof Anton Eliassen for his re-election as Chairman of the Council and Prof Gerard van der Steenhoven for his election as Vice-Chairman.

Alain Ratier
Director-General



Member and Cooperating States



After the general election in the Republic of Serbia, EUMETSAT proposed to the new Prime Minister to initiate the process for the country's accession as a full Member State, and started preparatory work with the national meteorological and hydrological service.

In line with its Membership Accession Policy, EUMETSAT has continued to monitor the EU accession process of the western Balkan countries and provided preliminary information to those considering joining EUMETSAT as Cooperating States.



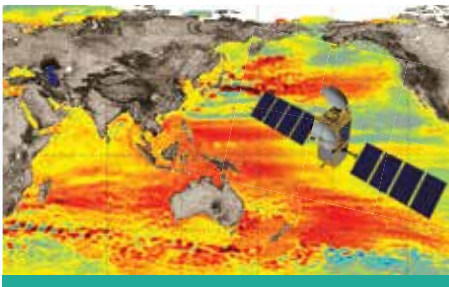
January

Signature of the service contract for the hosting of the EPS and EPS-SG ground stations in Svalbard

Launch and start of commissioning of the Jason-3 ocean surface topography mission

Workshop on pathfinder projects for future “big data” services

Launch of “Early Career Programme” with the publication of four vacancies targeting young talent



February

Jason-3 reaches its final orbit and delivers its first 10-day cycle of sea surface height measurements

Launch and start of commissioning of the Copernicus Sentinel-3A satellite

Validation of the Jason-CS/Sentinel-6 ground segment system requirements by a four-partner review



March

Release of first images of Sentinel-3A and start of calibration and validation activities with ESA

2016 highlights

In its 30th anniversary year, EUMETSAT started to exploit two new marine missions, Jason-3 and Sentinel-3A, and moved Meteosat-8 over the Indian Ocean. Implementation of the new “Challenge 2025” strategy started with further progress in the development of the MTG, EPS-SG and Jason-CS next generation satellite systems and the kick-off of pathfinder projects for big data services.



July

Completion of the detailed design of the mission control and data acquisition chain of the MTG ground segment

Release of Jason-3 near-real-time products as the first EUMETSAT data service for a Copernicus-dedicated mission

Start of relocation of Meteosat-8 over the Indian Ocean

Handover of Sentinel-3A flight operations from ESA space operations centre (ESOC)

Start of the development of the mission control and operations chain of the EPS-SG ground segment



August

EUMETSAT celebrates its 30th anniversary with its personnel

Agreement with the ECMWF formalising EUMETSAT’s support to the Copernicus Climate Change Service (C3S)

Validation of the virtualised configuration of the EPS core ground segment for use in the preparation of the Metop-C launch and for three-Metop operations



September

12th EUMETSAT User Forum in Africa, in Kigali, Rwanda

Jason-3 takes over the reference high-precision ocean altimetry mission from Jason-2

Start of pre-integration tests of the MTG ground segment at EUMETSAT premises

Agreement with DLR for the development of METImage instruments for Metop-SG satellites

Meteosat-8 arrives at 41.5°E and starts imaging over the Indian Ocean



April

- EUMETSAT sends its first command to the Sentinel-3A spacecraft
- EUMETSAT becomes a participant in the EU Code of Conduct for Data Centres
- Completion of the critical design of the Meteosat Third Generation mission control centre
- Successful in-orbit assessment of the Jason-3 system by a four-partner review



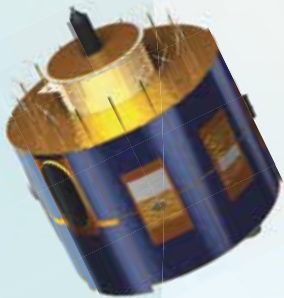
May

- Swap of operations of the fleet of Meteosat Second Generation satellites to the virtualised configuration of the ground segment
- The EUMETSAT Jason-2 and Jason-3 ground segments are merged



June

- Adoption of the “Challenge 2025” strategy and the roadmap for big data services
- Agreement with CNES for the continuation of the ARGOS mission on Metop-SG satellites
- Installation of a first version of the infrastructure for the processing of MTG imagery
- Approval of the third development and operations phase of SAFs for 2017-2021
- Completion of the critical design of the Svalbard site infrastructure hosting the EPS-SG ground stations
- Celebration of 30th anniversary with officials from Member States and international partners



October

- Start of dissemination of Meteosat-8 imagery of the Indian Ocean region
- The Jason-2 satellite is manoeuvred to an “interleaved” orbit
- Reintegration of the repaired IASI instrument on the payload module of Metop-C
- Decision to repair the GOME-2 instrument of Metop-C
- Handover of the Sentinel-3 payload data ground segment from ESA and release of the first near-real-time products



November

- Completion of the first part of the MTG System Implementation Review dedicated to the MTG-I imaging mission
- Release of the most accurate Jason-3 product (GDR) used for mean sea level monitoring



December

- Signature of the Jason-CS Memorandum of Understanding with NASA and NOAA
- Completion of the preliminary design of the level-2 processing facility of the MTG ground segment
- All Sentinel-3A near-real-time physical (level 1) products become available to users
- Signature of the Joint Polar System Programme Implementation Plan with NOAA

Operating complex satellite systems around the clock

Meteosat satellites

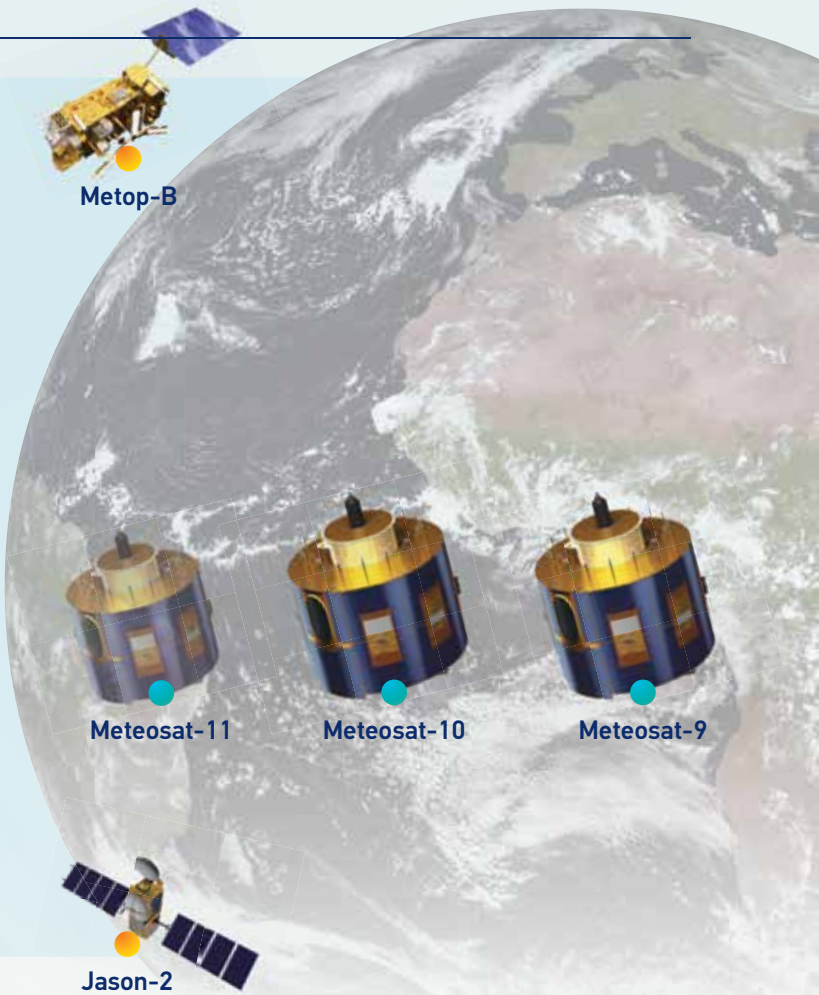
Meteosat-11
In-orbit storage

Meteosat-10
0°E *Full Disc Imagery*
Provides the prime Meteosat full disc imagery service over the European continent, Africa and parts of the Atlantic and Indian oceans

Meteosat-9
9.5°E *Rapid Scan Service (RSS)*
Delivers the RSS over Europe and adjacent seas

Meteosat-8
3.5°E (until end of June) *Meteosat Backup Services*
Provided a hot backup for both the full disc and rapid scan services, and was then moved to 41.5°E over the Indian Ocean

Meteosat-7
57.5°E *Indian Ocean Data Coverage (IODC)*
Supports the IODC mission, bridging an observational gap in this region



The availability of a healthy Meteosat capacity around 0° allows moving Meteosat-8 to the Indian Ocean

Meteosat-7, the last first-generation Meteosat satellite, continued to be exploited from 57.5°E over the Indian Ocean, but preparations started for the end of its mission and move to a graveyard orbit planned for 2017, after almost 20 years of service.

Meteosat-8, the first second-generation satellite, served as a backup to Meteosat-9 and -10 at 3.5°E until the end of June. It was then moved to 41.5°E to replace Meteosat-7, as part of EUMETSAT's best effort contribution to an Indian Ocean Data Coverage mission also involving satellites from India, Russia and China.

The spacecraft started to drift on 4 July and reached 41.5°E on 21 September, after performing moon imaging on the way for calibration purposes and Geostationary Earth Radiation Budget (GERB) imaging for comparison with radiant flux measurements from the NASA CERES instrument.

Dissemination of Meteosat-8 imagery and meteorological products started in trial mode over Europe in October and over Africa in November, in parallel to operational Meteosat-7 services.

In February 2017, when it becomes fully operational at 41.5°E, Meteosat-8 will provide optimum coverage of the Indian Ocean in combination with Meteosat-10 at 0° and the Indian INSAT-3D satellite at 82°E. From 41.5°E it will also improve observation over the Eastern part of Europe.

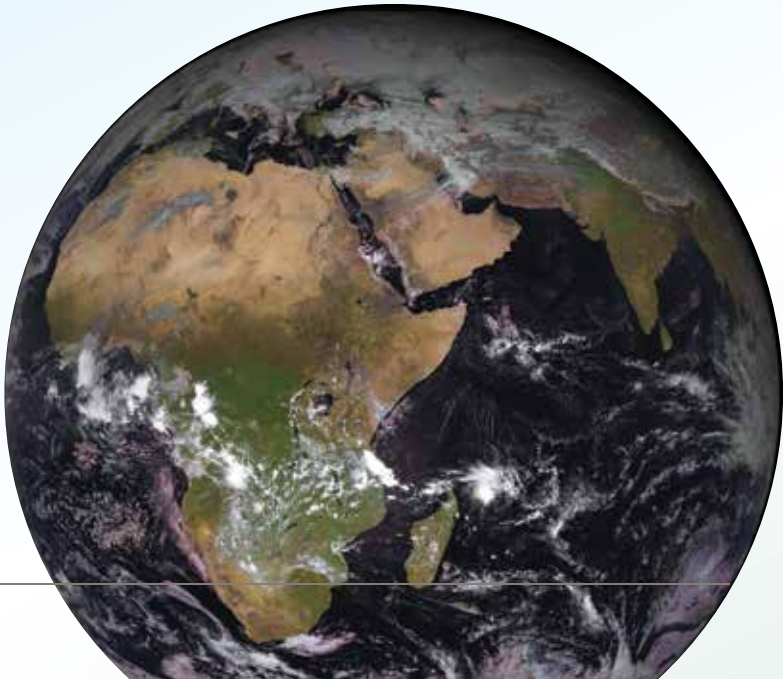
The three other Meteosat Second Generation (MSG) satellites remained in their nominal orbital positions.

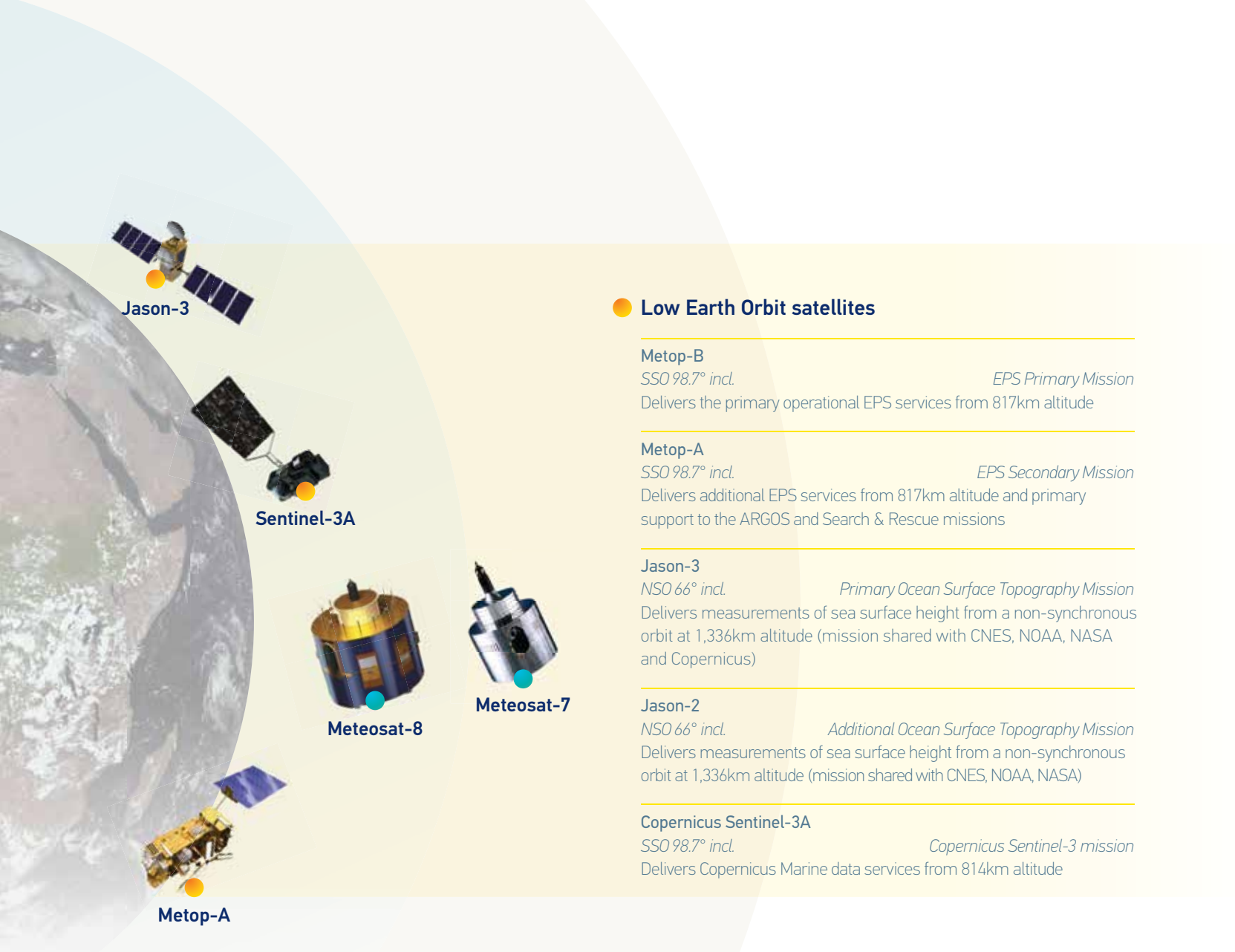
Meteosat-10 delivered the primary full Earth scan service covering Europe and Africa from 0° and the GERB mission, while Meteosat-9 was exploited from 9.5°E for the Rapid Scan Service (RSS) over Europe and adjacent seas.

Meteosat-11 remained stored in orbit with its instruments activated twice, in February and July, for maintenance purposes.

A north-south inclination manoeuvre of Meteosat-10 was executed on 21 June.

Meteosat-8 first operational image from 41.5°E





● **Low Earth Orbit satellites**

Metop-B
SSO 98.7° incl. *EPS Primary Mission*
Delivers the primary operational EPS services from 817km altitude

Metop-A
SSO 98.7° incl. *EPS Secondary Mission*
Delivers additional EPS services from 817km altitude and primary support to the ARGOS and Search & Rescue missions

Jason-3
NSO 66° incl. *Primary Ocean Surface Topography Mission*
Delivers measurements of sea surface height from a non-synchronous orbit at 1,336km altitude (mission shared with CNES, NOAA, NASA and Copernicus)

Jason-2
NSO 66° incl. *Additional Ocean Surface Topography Mission*
Delivers measurements of sea surface height from a non-synchronous orbit at 1,336km altitude (mission shared with CNES, NOAA, NASA)

Copernicus Sentinel-3A
SSO 98.7° incl. *Copernicus Sentinel-3 mission*
Delivers Copernicus Marine data services from 814km altitude

Optimum manoeuvres mitigate risk of collision, extend the lifetime of Metop-A

The EUMETSAT Polar System (EPS) continued to be exploited as a dual Metop satellite system.

Metop-B served as the primary satellite, dumping its data twice per orbit, at Svalbard and at McMurdo – the latter through the Antarctic Data Service provided through NOAA - to deliver global data to users with the shortest possible latency.

As the secondary satellite, the ageing Metop-A dumped its data only once per orbit at Svalbard, but continued to provide primary support to the ARGOS localisation and data collection mission.

The annual Metop-B out-of-plane manoeuvre was executed in two burns, on 16 March and 27 April.

Fuel margins restored by the optimisation of manoeuvres and of the planned re-entry orbit enabled the performance of an additional and final Metop-A out-of-plane manoeuvre on 31 August, prolonging operations on nominal orbit by six months, until June 2017.

Four collision avoidance manoeuvres – the first since 2014 – had to be performed, two for each Metop satellite.

Jason-2, Jason-3 and Sentinel-3A: a constellation of ocean-monitoring satellites

Flying on a different, non-synchronous orbit inclined at 66°, the Jason-2 satellite was the reference high-precision ocean altimetry (HPOA) mission until Jason-3 took over on 19 September, after completion of in-orbit commissioning. The Jason-2 satellite was then manoeuvred towards an “interleaved” orbit to double the sampling of measurements delivered by both satellites

After the formal handover from the European Space Agency (ESA) on 13 July, EUMETSAT performed Sentinel-3A flight operations including out-of-plane manoeuvres and a sequence of eight successive yaw manoeuvres over the South Pole to support calibration of the Ocean and Land Colour Instrument (OLCI).

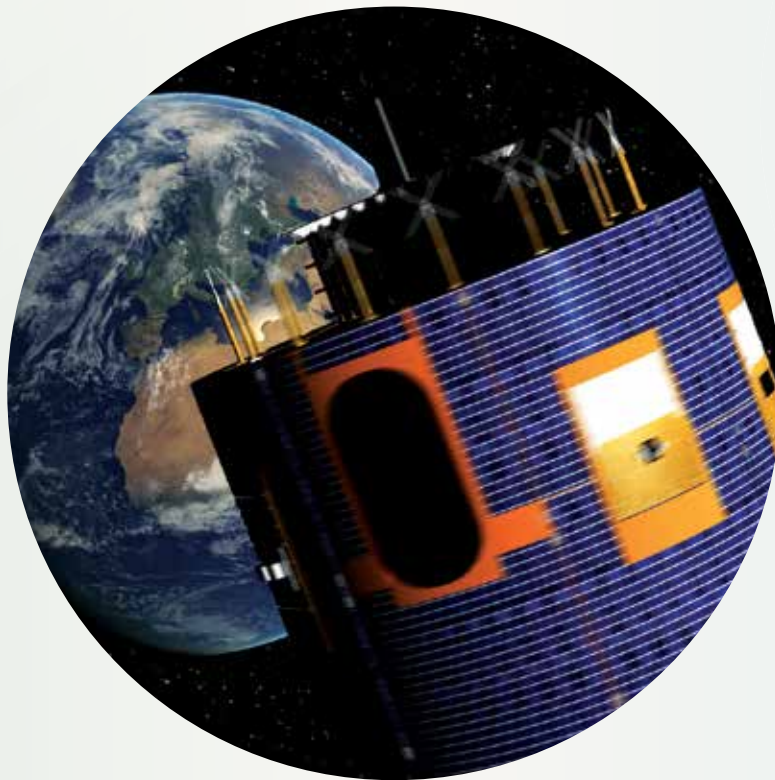
Operating complex satellite systems around the clock

Meteosat services available from three orbital slots, extended until 2020 over the Indian Ocean

The availability of the Indian Ocean Data Coverage (IODC) services delivered by Meteosat-7 from 57.5°E remained high, as the satellite performed well even across the critical eclipse seasons, where the battery voltage remained above the minimum level required to exploit the full payload.

The limited number of rapid scan cycles that remained possible with the ageing Meteosat-8 scan mechanism was agreed to be used until June to back up the secondary Rapid Scan Service during the monthly 48-hour reconfigurations of Meteosat-9 to full scan mode that are necessary to preserve the lifetime of its own scan mechanism. Therefore, the one-month interruption of Meteosat-9 rapid scan operations that is imposed by the same lifetime considerations could not be backed up in January-February.

From July onwards, when Meteosat-8 could no longer support rapid scan operations and was moved to the Indian Ocean, the monthly availability of the secondary rapid scan service dropped mechanically by 7 percent. At the same time, Meteosat-9 replaced Meteosat-8 as the hot backup for the primary full Earth scan service, having to stop rapid scan operations if Meteosat-10 could not deliver this service from 0°.



This happened on 15 October when Meteosat-10 went to safe mode due to space weather. The fast reconfiguration of Meteosat-9 to full scan mode limited the interruption of the 0° service to 75 minutes but caused a 25-hour interruption of the Rapid Scan Service. However, the monthly availability of the latter was not affected as the monthly 48-hour interruption planned on 18-20 October could be cancelled.

Thus, the availability of the 0° service remained very high throughout the year, also as a result of the excellent performance of Meteosat-10, and the availability of the secondary Rapid Scan Service was kept at the highest level achievable with no backup satellite.

The availability of the Geostationary Earth Radiation Budget (GERB) mission performed by Meteosat-10 was also high, but the GERB-1 instrument of Meteosat-9 stopped imaging in the autumn after 10 years of operations, probably due to the wearing out of the dry lubricant in the bearings of its de-spin mirror.

The reconciliation of the discrepancies between fuel consumption rates estimated by different methods on board Meteosat-8, -9 and -10, narrowed down uncertainties in the estimation of the fuel reserves, and analyses showed that image quality should remain adequate at inclination up to 10 degrees. On that basis, the predicted Meteosat-8 lifetime was extended from April 2019 to June 2020.





The Metop dual-satellite capacity remains robust, with Metop-A lifetime extended to 2022

The primary Metop-B satellite continued to perform well, with only a couple of anomalies affecting legacy sounders.

The most significant one was the loss of one window channel of the AMSU-A1 microwave temperature sounder on 17 October due to the failure of its local oscillator. The increasing frequency of temporary noise spikes observed on another channel also triggered a formal investigation.

The high noise with erratic variations continued to affect long wave channels of the HIRS infrared sounder, probably caused by a filter wheel bonding issue for which no mitigation could be identified.

The ageing, secondary Metop-A satellite continued to deliver useful observations despite further degradations of its legacy infrared and microwave sounders exploited well beyond their design lifetime.

Due to exponentially increasing noise, the channels 3 and 8 of the AMSU-A1 microwave temperature sounder could no longer be used for extracting temperature profiles.

The noise of the long wave infrared channels of the HIRS legacy sounder continued to evolve erratically with alarming noise jumps, due to missing lubricant in the bearings of the filter-wheel mechanism. Building on the experience of NOAA satellites, the temperature of the instrument and the current of its filter-wheel motor were increased in an attempt to migrate lubricant back into the bearings and mitigate the risk of stalling.

By contrast, the noise on channels 3 and 4 of the MHS microwave humidity sounder continued to decrease, which may be due to a power drift of the local oscillator of these channels, and the increasing noise of channel 2 could be brought back to nominal level after a swap to the redundant local oscillator.

Studies showed that Metop-A could be exploited up to 2021/2022 on a drifting orbit with a local time at ascending node evolving from 21:30 to 20:00, before being moved to a lower perigee orbit for uncontrolled reentry into the atmosphere within 25 years. This will enable three-Metop operations for a couple of years after the commissioning of Metop-C, whilst maintaining the agreed level of voluntary compliance with debris mitigation regulation established long after the design of the Metop satellites.



Jason-2 operations extended until the end of 2019

The availability of the Jason mission performed by Jason-2 and Jason-3 remained very high, extending to 24 years the mean sea level climate record started in 1992 with Topex/Poseidon.

In view of the healthy status of the Jason-2 spacecraft and the possibility to eliminate the single point of failure of on-board processors by a software patch developed by CNES, the four programme partners agreed to extend operations until 2019, and EUMETSAT Member States opened the voting process needed to enforce this decision.



Evolution of ground infrastructure



Further improvements to capacity, resilience and efficiency

The “power usage effectiveness” measuring the ratio of the power consumed to the “useful” power delivered to IT systems was further reduced from 1.57 to 1.45, and EUMETSAT obtained the status of “Participant” in the EU Code of Conduct for Data Centre Energy Efficiency for the energy efficient design and exploitation of its Technical Infrastructure Building.

Following a reassessment of bandwidth requirements for data dissemination in the period 2017-2020, the capacity of a full second transponder was acquired and the scalability of the service towards a multi-transponder capacity was tested.

Efficiency and IT security were improved by the migration of a number of operational data flows from legacy systems to the new multi-mission dissemination system and to the virtualised common processing facility developed for processing data acquired from third-parties.

Operations of the four Meteosat satellites were swapped from the legacy ground segment to a new, more resilient and energy-efficient, virtualised configuration.

As part of the adjustment of the capacities of Meteosat ground station services to a decreasing number of satellites in orbit, Fucino was selected as the only remaining site for hosting ground stations from 2018 onwards, and the relocation of one antenna from Usingen to Fucino was kicked off.

Upgrades to the EPS ground segment were completed to remove obsolescence and increase efficiency before the launch of Metop-C. The virtualised configuration of the EPS ground segment was validated for use for Metop-C and three-Metop operations. However, the swap of dual-Metop operations from the legacy system was postponed to January 2017, in view of the risk associated with the occurrence of a “leap second” on the night of 31 December.

In Svalbard, the antenna control systems of both command and data acquisition stations were upgraded as the last major milestone of their refurbishment.

The Jason-2 and Jason-3 ground segments were merged into one single, resilient system.

The EUMETSAT response to the “big data” challenge takes shape

After a workshop with Member States in January, six pathfinder projects for future big data services were defined, addressing online data access, Web Map services, multicasting of large data volumes via high bandwidth terrestrial networks, format conversion and processing as a service.

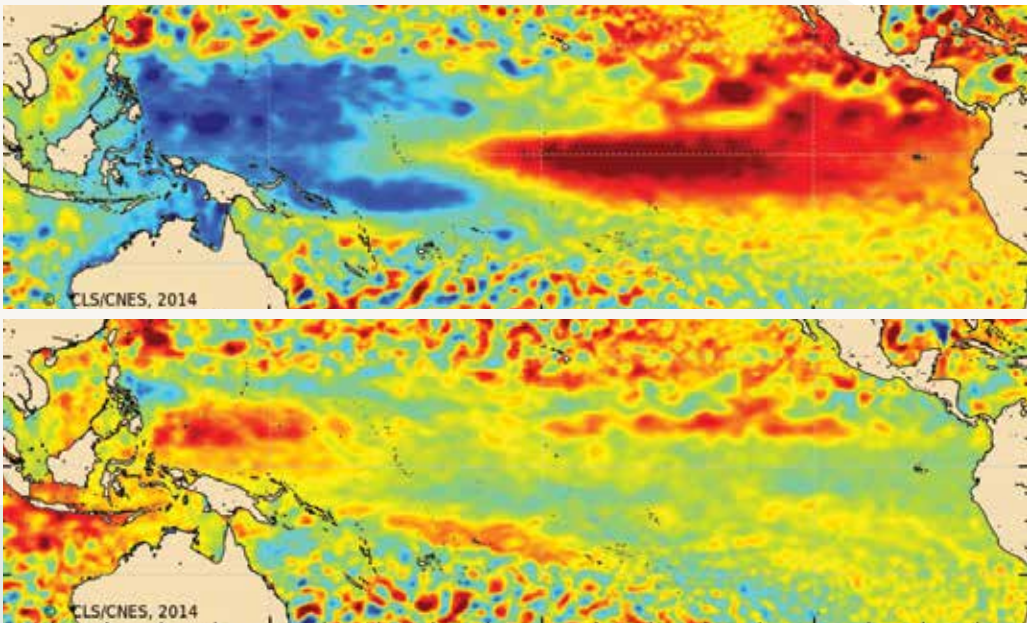
The procurement of industrial support and services required across all pathfinder projects was initiated with the release of two main invitations to tender addressing the IT cloud architecture, including middleware and deployment support, and web applications, and the preparation of a third one on dedicated software and formatting tools.

EUMETSAT satellites track climate features in a record warm year

In a year characterised by the World Meteorological Organization (WMO) as the warmest on record globally, the satellites exploited by EUMETSAT tracked a number of exceptional events in Europe and worldwide.

El Nino declines and turns to La Nina

Sea surface height observations from the Jason missions shared with American and European partners observed the decline of an exceptionally intense El Nino episode that had reached its peak in the Pacific Ocean at the end of 2015 and turned into La Nina in the second half of 2016.



Maps of sea surface height anomalies derived from Jason and other altimeter observations depict the transition from the El Nino peak present in January (top), characterised by warm waters in the central and eastern Pacific and cold waters in the Caribbean, to less contrasted La Nina conditions in December (bottom) (Source: CLS/CNES)

A tropical cyclone near the Azores in January

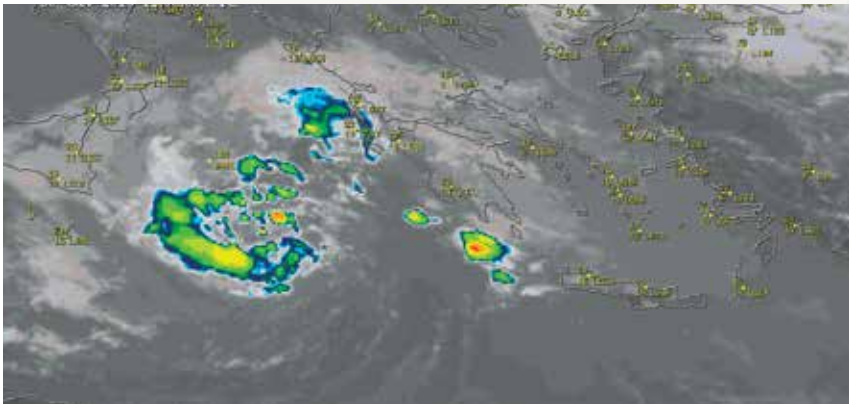
In the Atlantic, the Metop and Meteosat satellites observed tropical cyclone Alex, another exceptional climate feature which triggered a red warning from the Portuguese weather service for high wind, high waves and heavy rain in the Azores, before it hit the islands on 15 January. Not only did Alex develop in January, outside the June–November cyclone season, but it was the second cyclone on record to form north of 30°N and east of 30°W, probably due to warmer than usual ocean surface waters in this area at that time of the year.

On 14 January, Metop-B imagery tracks the movement of tropical cyclone Alex towards the Azores, in a very unusual period and area for the development of cyclones

EUMETSAT satellites track climate features in a record warm year

A Mediterranean hurricane (Medicane) in the Ionian Sea

Though less exceptional, the compact tropical-like cyclone - known as a Medicane (MEDiterranean hurriCANE) - moving across the Mediterranean from 28 to 31 October was also remarkable. Meteosat imagery followed its full life cycle from its initial development over the Ionian Sea to the end of its course in Crete on 31 October, and the gusty winds and heavy rain it brought along its path.



On 30 October, Meteosat infrared imagery tracks the development of a Medicane and its movement from the Ionian Sea towards Crete



On 10 August, Meteosat-10 imagery tracks smoke plumes (natural colour, top) originating from wildfires in northern Portugal and Madeira. A general view of Sitio de Curral dos Romeiros during the wildfires at Funchal, Madeira island, Portugal, August 9, 2016 (bottom, source: Reuters)

High temperatures and fires in Portugal and Russia

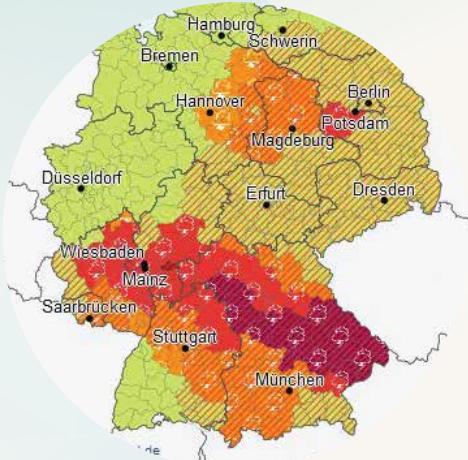
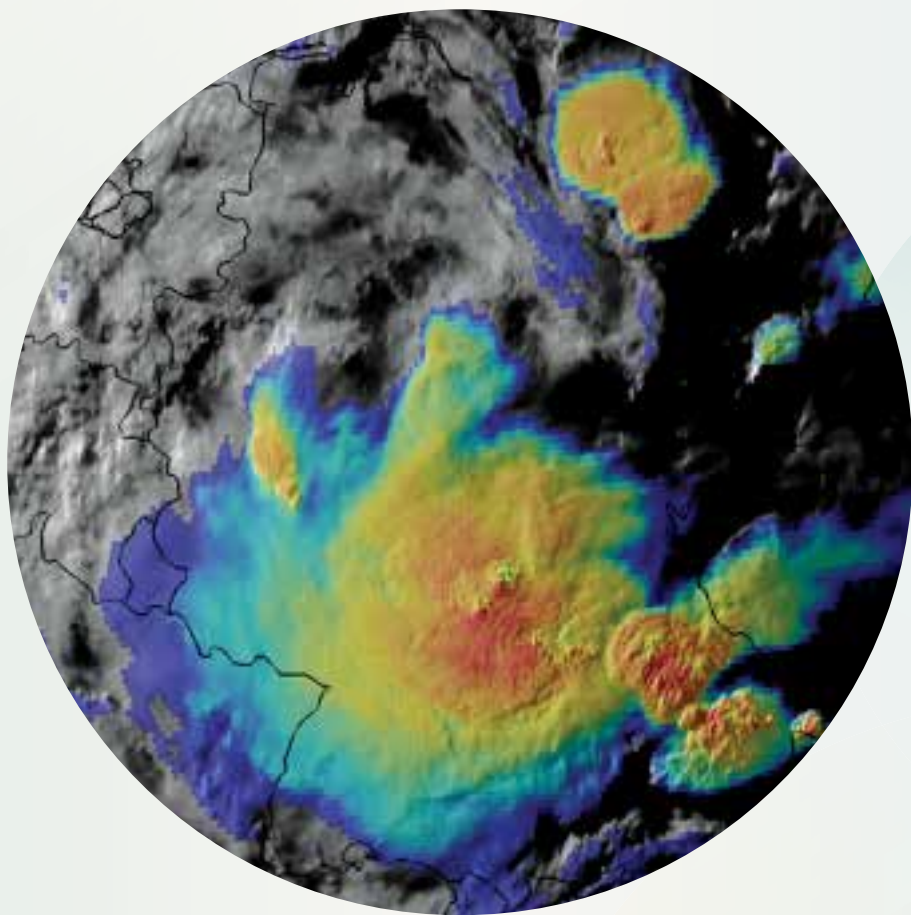
Temperatures remained high until very late in the summer over parts of Europe, reaching a record maximum of 45.4°C in Cordoba, Spain on 6 September. This created favourable conditions for widespread wildfires in Portugal in August. A state of emergency was declared in the northern part of the country and thousands of people had to be evacuated in Madeira.

Earlier in the summer, smoke plumes originating from wildfires in eastern Russia propagated to the Black Sea and the Mediterranean regions.



On 26 July, Meteosat-10 also monitored the propagation of widespread smoke (bluish-cyan colour) from eastern Russia to the Black Sea and ultimately to Greece and Turkey on 28 July (not shown).

Delivering services and benefits to real-time users



Meteosat imagery helps manage a series of devastating thunderstorms in Germany

In late spring, parts of Europe were hit by severe thunderstorms, and Meteosat imagery helped identify “supercells” likely to produce hail, damaging winds and deadly tornadoes, heavy rain and flooding and dangerous cloud-to-ground lightning.

In Germany at the end of May and in early June, heavy rain associated with an unusual series of convective storms triggered flash floods of unprecedented intensity leading to 11 casualties and billions of euros worth of damage in Braunsbach (Baden-Württemberg) and Simbach am Inn (Bavaria).

During these events, Deutscher Wetterdienst (DWD) forecasters used Meteosat imagery as one input to diagnose the fast development of extreme phenomena and issued authoritative red warnings, enabling local authorities to protect life and property and avoid a higher death toll. This was the case on 29 May, when Meteosat imagery depicted a fast-developing convective system of circular shape covering large parts of Baden-Württemberg and Bavaria, with cloud top temperatures well below $-60\text{ }^{\circ}\text{C}$, pointing to the presence of supercells.



On 29 May, as the DWD issues red warnings (top right), Meteosat imagery depicts a fast-developing, circular-shaped thunderstorm with very cold cloud tops (in red, top left). Catastrophic floods washed away trees and cars and caused severe damage in Braunsbach and Simbach am Inn (bottom, source: Reuters).

Delivering services and benefits to real-time users



“The combined use of EUMETSAT observations and hydrological products derived by the H SAF was essential for the tight nowcasting of the long precipitation event of 21-24 November.”

Lt Colonel Di Diodato,
Head of Forecasting
Italian Air Force Operational Centre for Meteorology

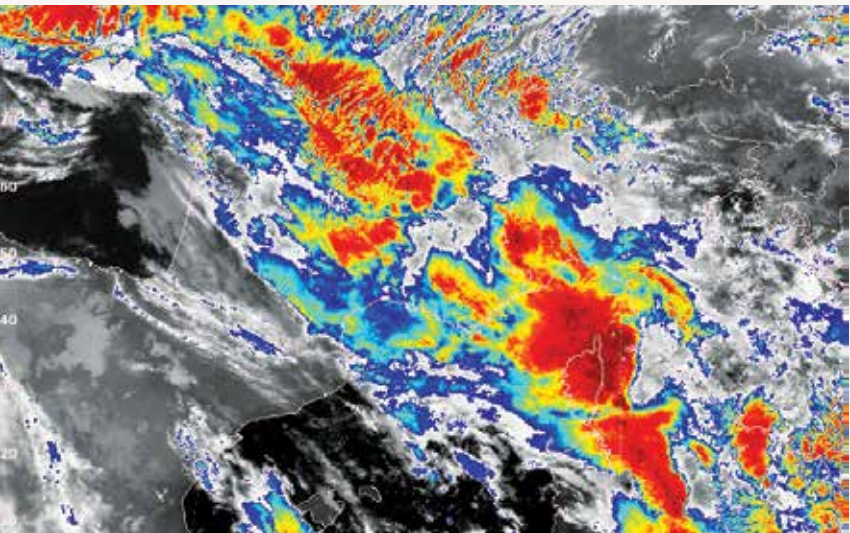


High waters at Turin, Italy, during the precipitation episode of 22-25 November (Source: Reuters)

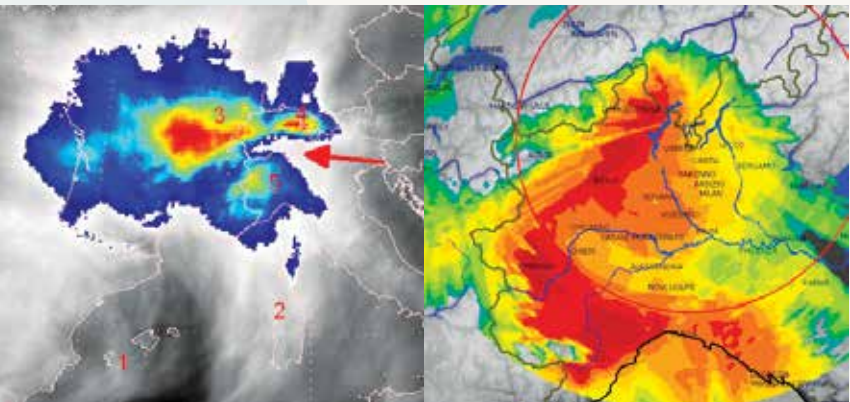
Metop data support forecasts of a long, large-scale precipitation episode over Italy and Switzerland, and Meteosat imagery points to local foehn effects

At the end of November, the circulation around a deep stationary depression over Portugal pushed unstable Mediterranean air against the Alpine south side and created a long, intense precipitation period associated with floods in the Italian Piedmont and Switzerland.

Meteosat infrared imagery available every five to fifteen minutes was used to monitor the cumulative effects of the episode at local scale, including the relatively dry conditions that prevailed along the north side of the Alpine crests due to a foehn effect, i.e. downdraught under southerly winds.



On 24 November, Metop-B imagery shows an elongated perturbation causing sustained heavy rain over north-eastern Italy and Switzerland

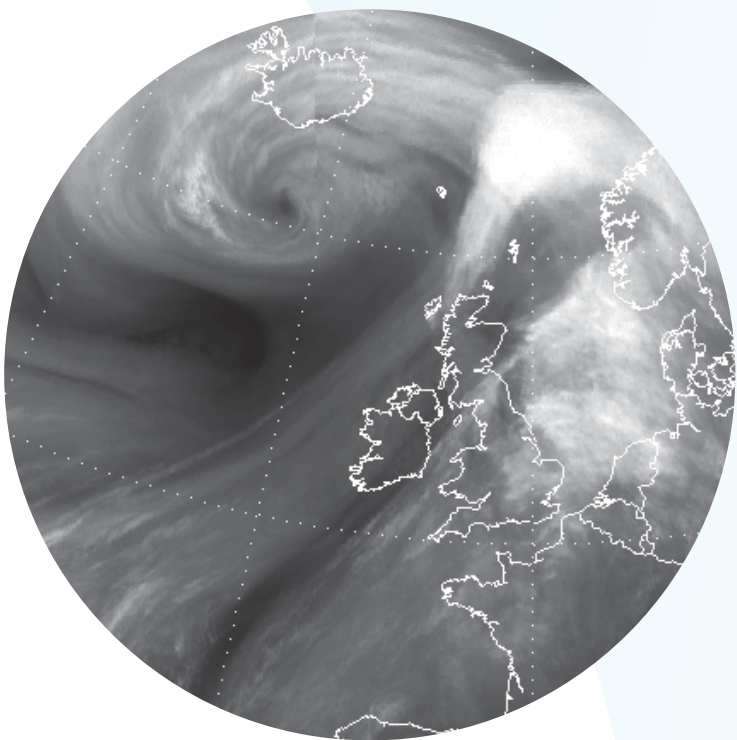


Meteosat-10 infrared imagery averaged over 22-24 November (left) depicts areas where precipitating clouds persisted (in red) and dryer foehn conditions north of the Alpine crests (arrow). The foehn effect was confirmed by the map of cumulated precipitation produced by the weather radar of Monte Lema (right, source: MeteoSwiss)

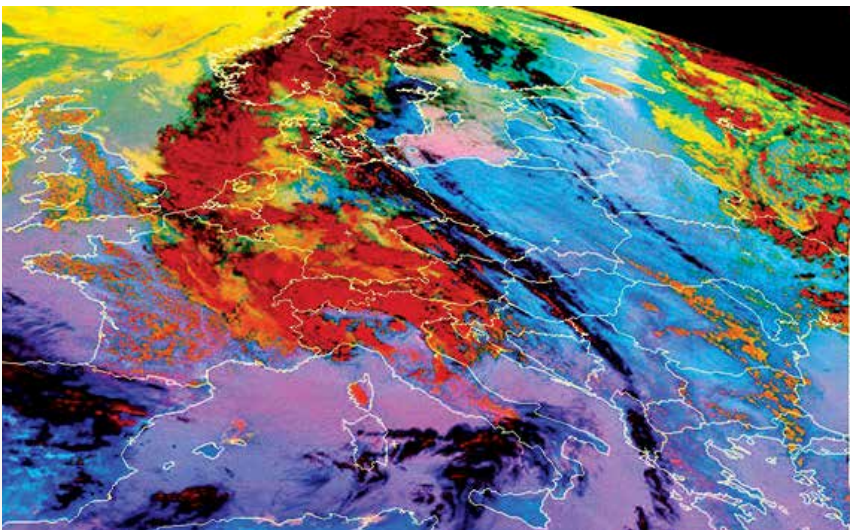
Metop observations help forecast large winter storms, spring and summer cold fronts

At both ends of the year, the winter brought a series of large-scale storms which could be forecast several days in advance using numerical prediction models ingesting Metop observations and monitored in real time by Meteosat imagery.

This included Storm Henry which brought high winds and seas on 1 and 2 February when it moved east between Iceland and Scotland.



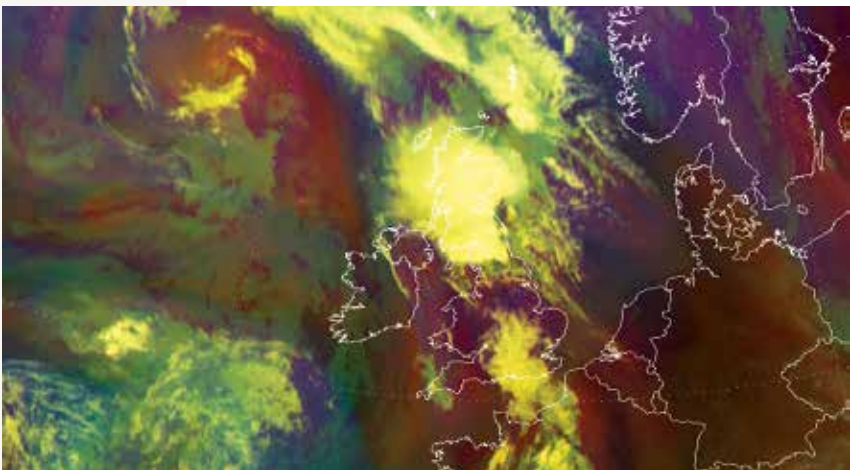
On 1 February, Meteosat water vapour imagery shows the cyclonic structure of storm Henry off the coast of Iceland



Meteosat-10 imagery of the severe thunderstorm episodes over northern Italy, Austria and the Czech Republic on 23 May

The spring and summer were also marked by large-scale perturbations associated with active cold fronts.

This was the case on 23 May, when a cold front swept over northern Italy, Austria, and the Czech Republic, creating severe episodes of hail, before propagating further to the north, bringing intense thunderstorms to eastern Germany.



On 20 July, Meteosat-10 imagery (airmass product) shows a cold front moving north-east across the UK

Another cold front moved north-east across the UK on 20 July, one day after the hottest day of 2016, bringing heavy rain and thunderstorms over the north-west of England, Wales and Scotland.

Data access and real-time delivery

EUMETSAT delivers time-critical data safely to a widely distributed population of operational users in push mode and online

EUMETSAT must deliver observational products safely to a widely distributed population of operational users as quickly as possible after sensing because the value of observations for forecasting diminishes with increasing latency. In particular, geostationary imagery must be disseminated within minutes from sensing for nowcasting applications.

Time-critical products are therefore broadcast to operational users by EUMETCast services using commercial telecommunication satellites and the same reliable, flexible and cost-effective technology as used for digital TV broadcasting. These “push mode” services are supplemented by online internet services, including an increasing range of Web Map services.

The availability of the EUMETCast data broadcast services remains at the highest level at 99.9 percent

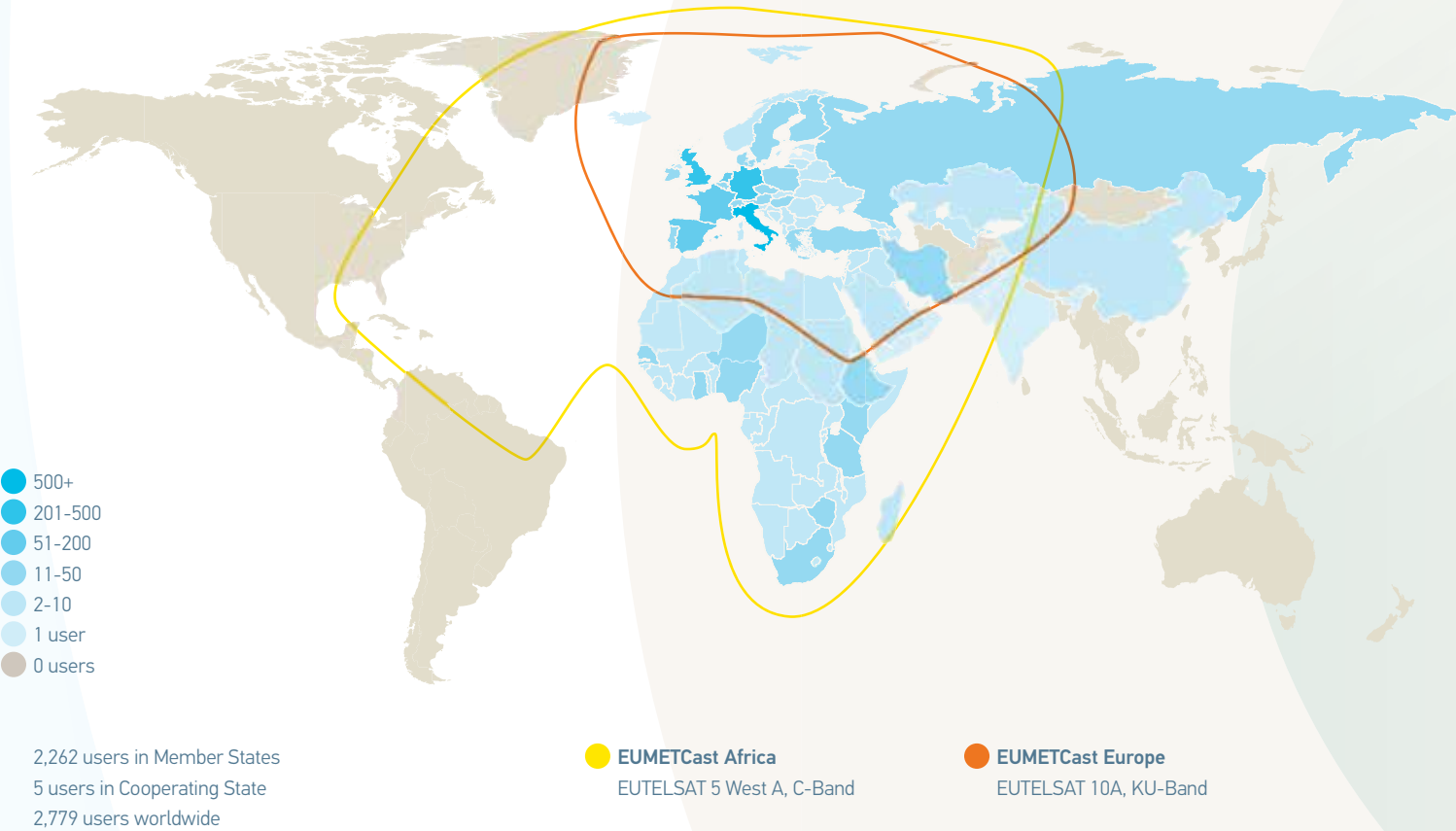
The availability of the EUMETCast-Europe, -Africa and -Americas services remained extremely high throughout 2016, above 99.9 percent for EUMETCast-Europe.

The EUMETCast-Americas service was terminated as planned on 31 December, after the transition of its users to the NOAA GEONETCast-America service. In parallel, the dissemination programme for Europe and Africa was extended to real-time Meteosat-8 imagery and Copernicus marine products from Jason-3 and Sentinel-3A.

The re-procurement of the EUMETCast-Africa service was initiated in November to increase capacity in the period 2018-2024 and make the service independent from EUMETCast-Europe, in view of increasingly different user requirements.

Online Web Map services are enhanced

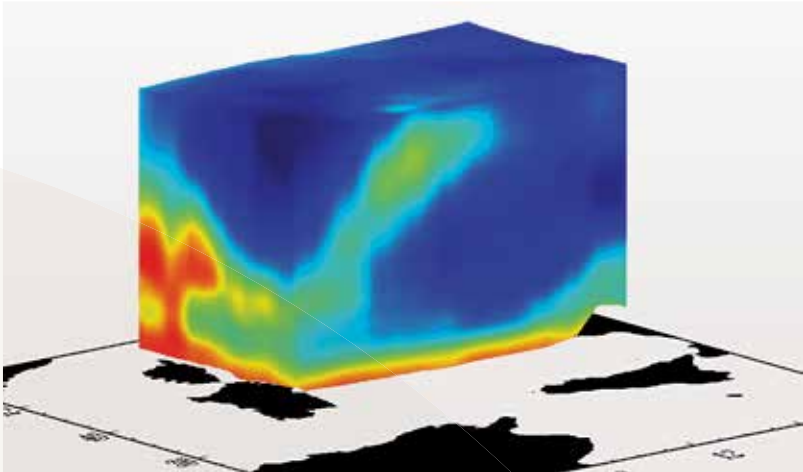
Following excellent uptake from internet users, the pilot EUMETView Open Web Map Service was improved to offer the possibility to visualise up to 30 days of data available online, including more Meteosat imagery and a first set of marine products from Sentinel-3, Jason and the SAF on Ocean and Sea Ice.



The EARS network gives fast access to regional data from polar-orbiting satellites

Because of less stringent latency requirements from users, global Metop data are recorded on board, dumped to high-latitude ground stations at each 100-minute orbit cycle, 14 times a day, and repatriated to EUMETSAT for fast “pipeline” processing and broadcasting of output products via EUMETCast. Within the Initial Joint Polar System (IJPS) shared with NOAA, Metop-B data are dumped twice per orbit at Svalbard and McMurdo, to halve latency to 50 minutes.

To fulfil the most stringent timeliness requirements for regional products used for very short-range forecasting across Europe and nowcasting at high altitudes, the EUMETSAT Advanced Retransmission Service (EARS) delivers regional data from a constellation of four EUMETSAT, US and Chinese polar-orbiting satellites within 15 to 30 minutes of sensing. This is achieved through local processing of sounding and imagery data directly broadcast by the satellites to a European network of ground stations and dissemination of output products via EUMETCast-Europe.



Three-dimensional field of humidity over the Mediterranean sea available within 30 minutes of sensing via the EARS-IASI level 2 service

EARS regional data services expand to the east and deliver new imagery and sounding products

Low light visible imagery available from the Visible Infrared Imaging Radiometer Suite (VIIRS) of the NOAA Suomi-NPP satellite and usable during night time was added to the EARS imagery service, and new software improved nowcasting products extracted from AVHRR imagery.

The EARS-ASCAT service was enhanced to deliver more and better quality ocean surface wind products near coastlines.

The coverage of EARS sounding services was extended to the east by the addition of Metop and NOAA products extracted at the Russian stations of Novosibirsk, Khabarovsk and Moscow.

In addition, a new EARS-IASI level 2 service started to deliver vertical profiles of temperature and humidity extracted from observations performed by the Metop infrared and microwave sounders that are easier to ingest in regional high-resolution models than level 1 radiances.

Improvements to online user support services

The new online ordering client was further upgraded to support ordering of Sentinel-3 data. A two-month user survey showed that more than 70 percent of users rated the usability and capability of the new client as “very good” or “good” and suggested improvements to both the client and the ordering service which will be addressed by future enhancements of the system.

The release of a new version of EUMETSAT’s Earth Observation Portal provided faster and more direct access to Sentinel-3 and EUMETSAT products to registered users and doubled the average monthly number of new users of archived data.

Support to climate services

In support of climate services, EUMETSAT rescues, recalibrates and reprocesses historical satellite data and contributes to research on how to quantify uncertainties attached to climate records

Mobilising expertise and infrastructure in Darmstadt and across its network of Satellite Application Facilities (SAFs), in particular at the SAF on Climate Monitoring (CM SAF), EUMETSAT's climate monitoring activities encompass recalibration of historical satellite data, production of homogeneous series of physical parameters (e.g. radiance, reflectance) called fundamental climate data records, downstream extraction of a series of geophysical parameters (e.g. temperature, wind) forming thematic climate data records (TCDR) and validation throughout the process.

EUMETSAT climate data records can then be used directly or ingested into the best numerical weather prediction models used in "reanalysis" (hindcast) mode to produce consistent records of a broader range of climate variables.

After improving climate records of infrared imagery, recalibration efforts target visible imagery

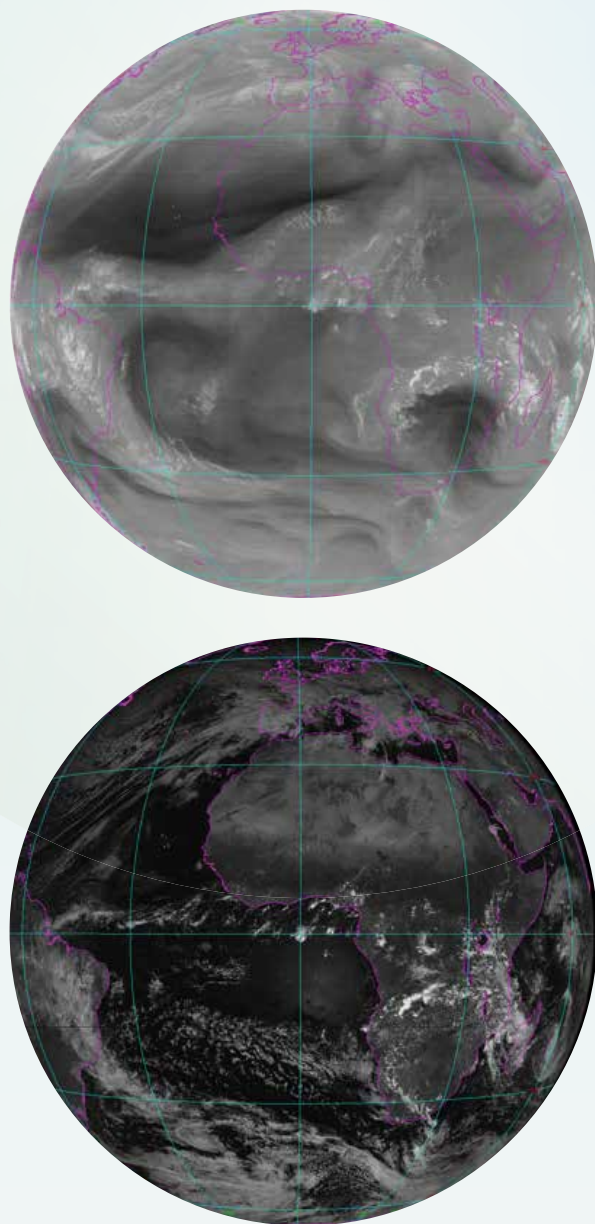
The recalibration of 27 years of infrared imagery from the first generation of Meteosat satellites (Meteosat-4 to -7) against infrared soundings from polar-orbiting satellites substantially improved the temporal stability of the climate record of land surface temperature produced by the CM SAF.

The quality of the CM SAF climate record of cloud properties also improved as a result of cross-calibration of MSG visible imagery against data from the Moderate Resolution Imaging Spectroradiometer (MODIS) NASA instrument, and its temporal resolution increased to 15 minutes over a 12-year period (2004-2015).

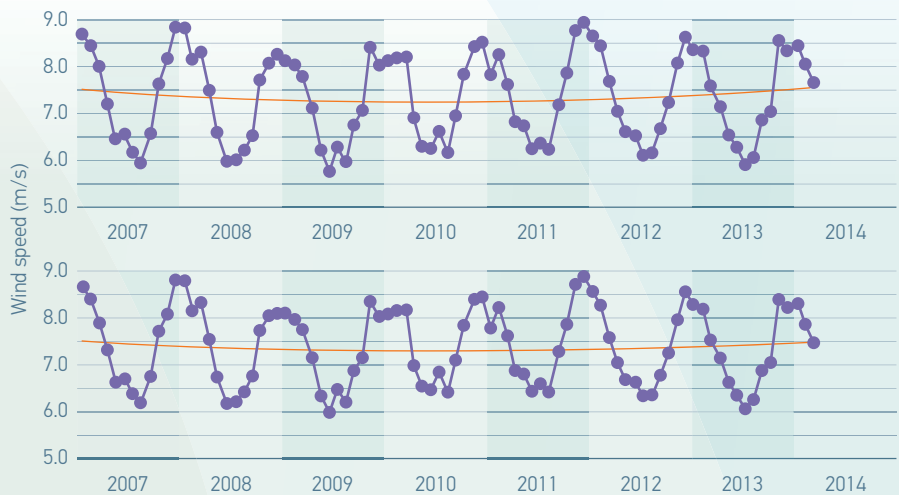
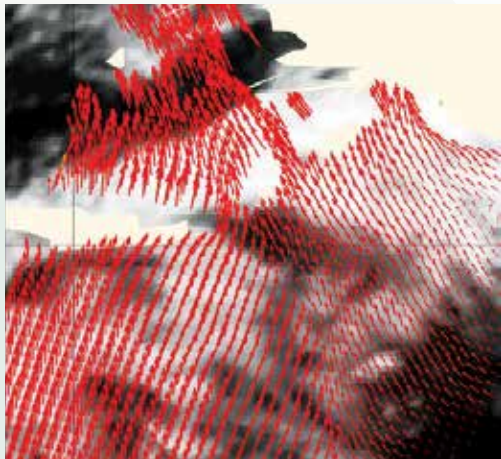
A more ambitious method was selected for cross-calibrating visible imagery of both generations of Meteosat using natural desert, ocean and convective clouds as reference targets to cover the full dynamic and spectral range of the signal, and a new database of characterisation of natural land targets (<http://savs.eumetsat.int/>) was deployed.

One year of Meteosat-1 imagery rescued in the United States!

Almost 21,000 images from Meteosat-1 for the period December 1978-November 1979 were discovered at the University of Wisconsin. The images require substantial work for quality control, improvement of geo-location and recalibration prior to any possible use for climate monitoring.



Samples of the 21,000 Meteosat-1 images discovered in the US: water vapour (top) and visible (bottom) channels

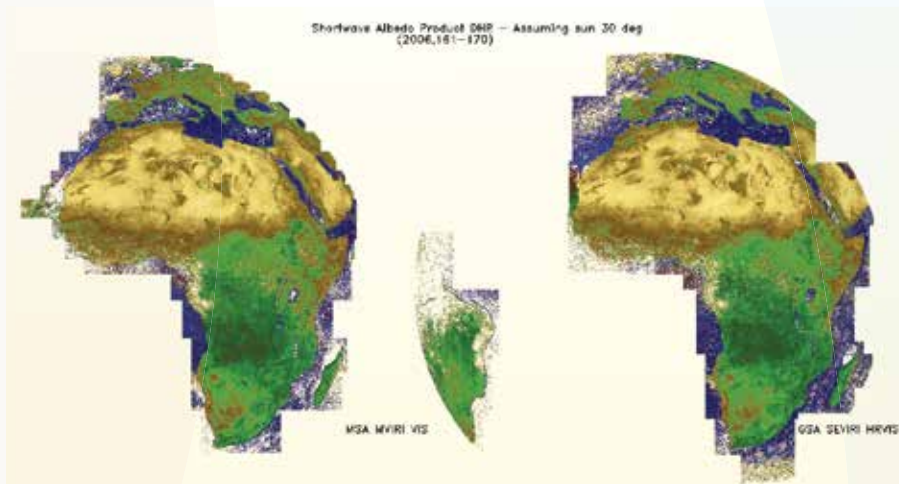


New climate records of essential climate variables: wind, cloud and surface parameters

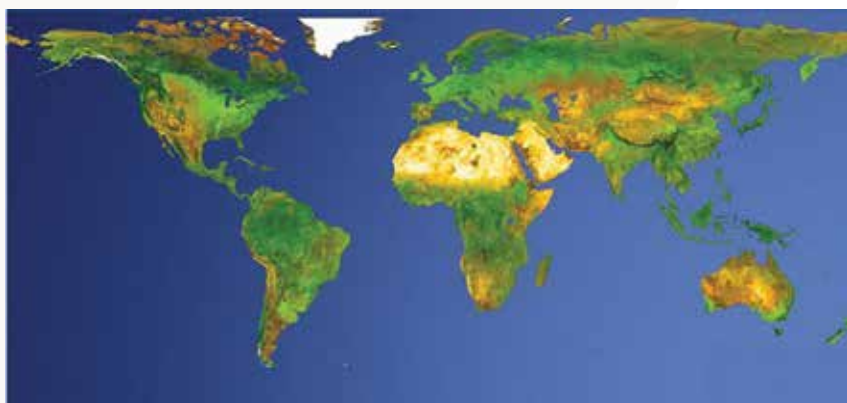
Climate records of ocean surface wind vectors at 25km and 12.5km resolution were released as a result of the reprocessing of radar backscatter measurements collected from January 2007 to March 2014 by the ASCAT scatterometers of both Metop satellites.

The MSG High Resolution Visible (HRVIS) channel was selected as the closest match to the only visible channel of Meteosat first generation to extend the existing climate record of surface albedo into the MSG era. The resulting time series has an outstanding homogeneity over the period 1982-2010, though it builds on data from eight Meteosat satellites of two generations.

Sample of ASCAT ocean surface wind field observed by the ASCAT scatterometer of Metop (left), climate record of monthly average wind speed at 25km resolution (top right plot) compared to a record of collocated buoy measurements (bottom)



The consistency of overlapping climate records of surface albedo derived from Meteosat-7 (first generation, left) and Meteosat-9 (second generation, right) visible imagery for the year 2006 illustrates the homogeneity of the time series across both generations of Meteosat



Composite map of vegetation index for the year 2009 extracted from a climate record derived from Metop AVHRR imagery

The Land Surface Analysis Satellite Application Facility (LSA SAF) released a climate record of Normalised Difference Vegetation Index from Metop imagery covering the period 2007-2016.

Wind vectors could be retrieved from the displacement of clouds observed in polar regions by successive overlapping AVHRR images at coarse (GAC) resolution. This confirmed the feasibility of producing a 30-year climate record of wind vectors from coarse resolution imagery available since 1982 from NOAA.

Support to climate services

Tracing uncertainties of climate records in collaborative research projects

The optimum use of climate data records in climate services requires knowledge and traceability of uncertainties attached to each record, which is a scientific challenge in itself. Through its involvement in the EU-funded FIDUCEO and GAIA-CLIM cooperative research projects, EUMETSAT contributes to the development of relevant methods and tools, using metrology (FIDUCEO) and ground-based observations (GAIA-CLIM) for reference.

In 2016, a traceability chain describing all steps of the production of a climate record and their individual contributions to the total uncertainty was developed in collaboration with FIDUCEO metrology experts. Then, traceability analyses concentrated on the three most important sources of uncertainty affecting visible imagery from first generation Meteosat satellites, namely the spectral response function, the instrument electronics and the geo-location and time of the measurements. The uncertainty on the spectral response function and its propagation into the production of climate records will be estimated through the comparison of results obtained using a reference set of calibration coefficients calculated from spectral response measured pre-launch and updated by a linear ageing model with those obtained using a time-varying spectral response reconstructed by modelling the physical properties of the sensor and their ageing.

The GAIA-CLIM project selected ozone, water vapour and aerosol optical depth measurements as the first to be included in the Virtual Observatory (VO) developed by EUMETSAT to enable comparison of satellite, *in-situ* measurements and

reanalyses, taking due account of estimated uncertainties for all sources and space time mismatches.

Radiosonde measurements from the Global Climate Observing System Reference Upper-Air Network (GRUAN) satellite observations and outputs of numerical weather prediction models were collocated within a single database that enables their comparison using a forward radiative transfer model to simulate satellite observations from radiosonde measurements and model outputs. A graphical user interface was then developed to support the demonstration of a first version of the VO to beta users at a GAIA-CLIM User Workshop.

EUMETSAT's support of the Copernicus Climate Change Service (C3S) was formalised in August by the signing of a dedicated agreement with the European Centre for Medium-Range Weather Forecasts (ECMWF). In the context of the C3S, a workshop held at the ECMWF confirmed that reanalysis, seasonal, decadal prediction and other climate services using modelling of the atmosphere, ocean, land and their coupling need satellite climate data records spanning 15 to 50 years that EUMETSAT can deliver now or in the future.

New IT infrastructure unleashes production of climate records

The first version of the "CDR" IT infrastructure required to provide more flexible access to large datasets and increased computer power for the production of climate records was deployed and validated using IASI spectra, Meteosat cloud mask and surface albedo reprocessing software as test cases. The system started to be used in December for the production of a number of pending climate records.



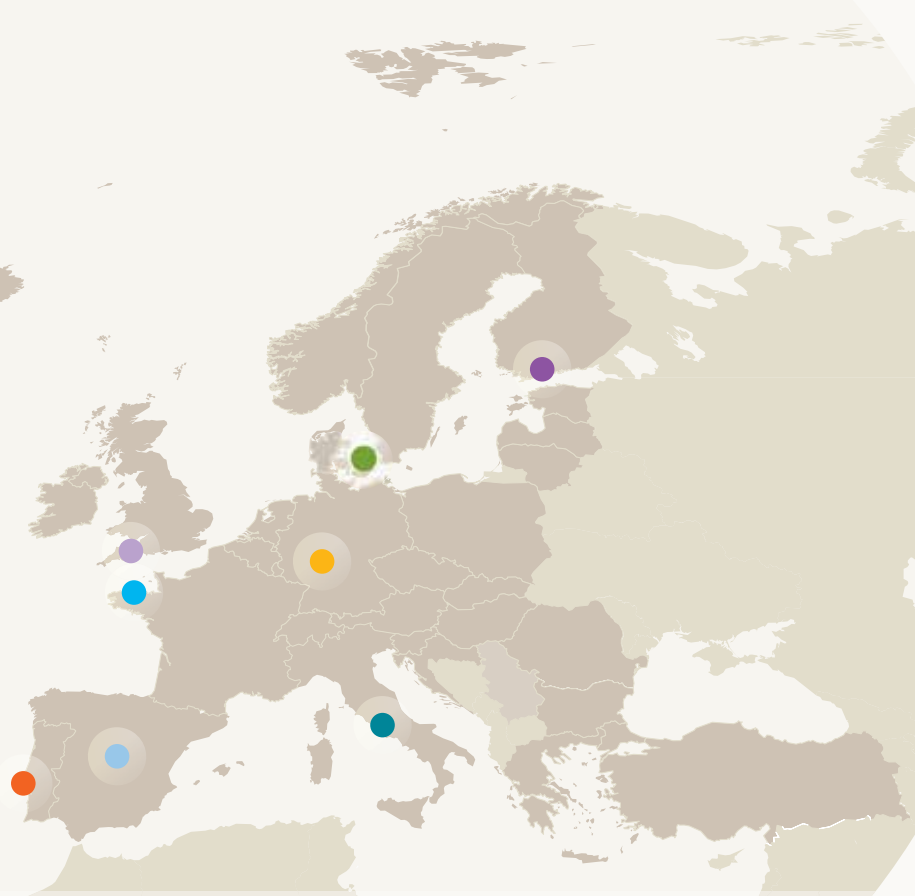
Workshop held at the ECMWF on climate services using numerical modelling (source: ECMWF)

Developing enhanced and new products in partnership with Member States

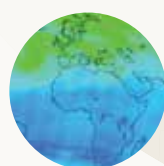
In order to exploit the full potential of its satellites in a broadening range of meteorological and environmental applications, EUMETSAT relies on its central facilities in Darmstadt and a network of eight Satellite Application Facility (SAF) consortia distributed across its Member States, each specialised in one application area and led by a National Meteorological Service (NMS).

This cooperative network allows the best use of distributed resources and scientific expertise for the development and delivery of innovative products, capitalising on close interactions with application experts.

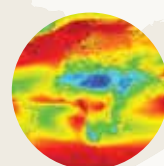
In 2016, agreements were signed with all Satellite Application Facilities for their third Continuous Development and Operations Phase (CDOP-3) covering the period 2017-2021 including contributions to the development of MTG and EPS-SG products. SAF Network Workshops were then organised to prepare the closure of the CDOP-2 and the kick-off of CDOP-3 activities.



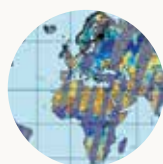
Atmospheric Composition Monitoring
Led by Ilmatieteen Laitos (FMI), Finland



Climate Monitoring
Led by Deutscher Wetterdienst (DWD), Germany



Support to Operational Hydrology and Water Management
Led by Ufficio Generale Spazio Aereo e Meteorologia, Italy



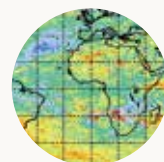
Land Surface Analysis
Led by Instituto Portugues do Mar e da Atmosfera (IPMA), Portugal



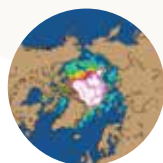
Support to Nowcasting and Very Short Range Forecasting
Led by Agencia Estatal de Meteorología (AEMET), Spain



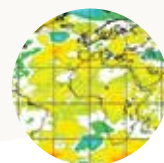
Numerical Weather Prediction
Led by Met Office, United Kingdom



Ocean and Sea Ice
Led by Météo-France (MF), France



Radio Occultation Meteorology
Led by Danish Meteorological Institute (DMI), Denmark



Developing enhanced and new products in partnership with Member States

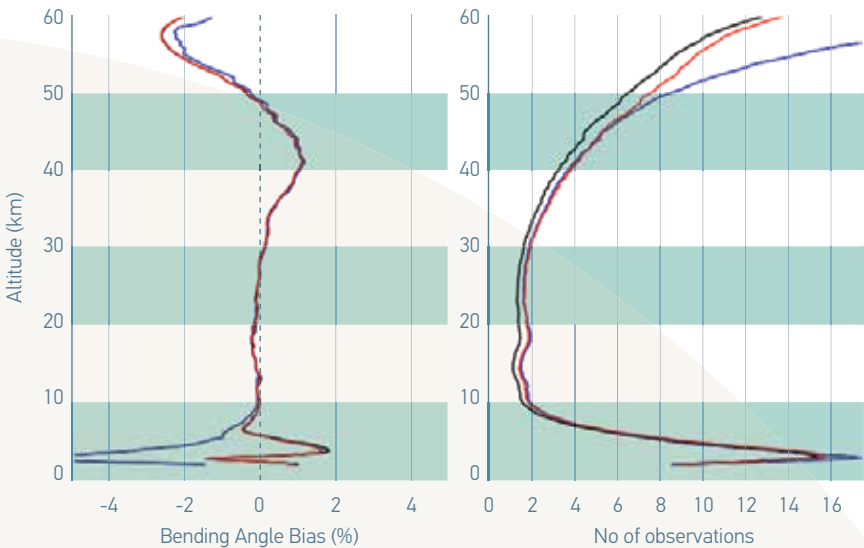
New and improved products and user software

Meteorology

The processing of Meteosat imagery was extended from 65 to 67.5 degrees around nadir, and the Optimal Cloud Analysis (OCA) product became available in real time at its full production frequency of 15 minutes for use in nowcasting applications.

The quality of wind vectors estimated from the displacement of clouds observed by successive overlapping images from geostationary and polar-orbiting satellites increased. For Meteosat, this was achieved by improving geometric processing and using the OCA for assigning a more accurate altitude to each wind vector. Wind vectors at high latitudes became more accurate using triplets of Metop images (i.e. Metop-A/ Metop-B/ Metop-A or Metop-B/ Metop-A/ Metop-B images) for retrieval instead of pairs.

The quality of vertical profiles of temperature and moisture extracted from IASI infrared spectra was improved through initialisation of the retrieval using co-located profiles available at low resolution but in all cloud conditions from the co-orbiting MHS and AMSU-A microwave sounders.



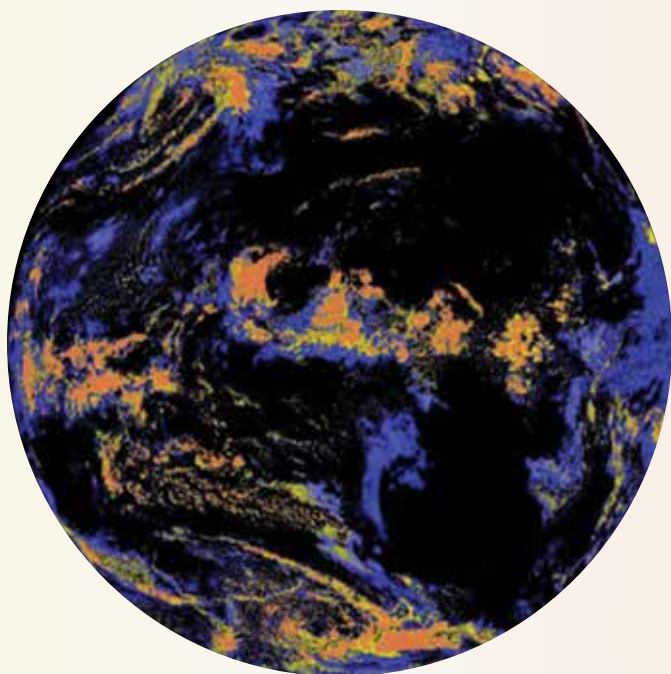
The new “wave optics” algorithm (red curve) used to extract vertical profiles of bending angles from GRAS radio-occultation measurements reduces the bias (left) and increases the number of retrievals in the lower troposphere (right) compared to the best geometric optics algorithms (blue and black lines)

A new algorithm implementing the wave optics theory increased significantly the number and accuracy of vertical profiles of bending angle retrieved from Metop radio occultation observations at altitudes below 8km. This paves the way for improving vertical profiles of refractivity index, temperature and moisture derived from bending angles.

A new version of the software extracting real-time nowcasting products from geostationary imagery enabled forecasters to combine products from Meteosat and NOAA’s geostationary GOES satellites over the Atlantic and to gain access to new experimental Meteosat products, like cloud microphysical properties.

New algorithms were introduced in the AAPP software to improve calibration, cloud detection and the retrieval of temperature and moisture profiles from polar satellite data.

Likewise, the new geophysical model function introduced in the processing of radar backscatter observations of fan beam C-band scatterometers improved the quality of ocean surface wind products at low wind speed and uniformity across the instrument swath.



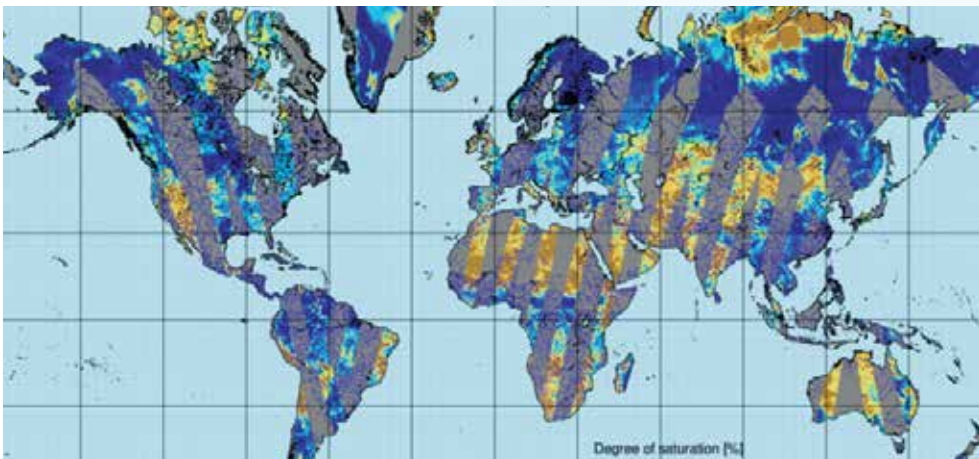
Example for cloud droplet effective radius information as derived from the CMIC Product Generation Element of the NWC SAF GEO Version 2016 software package.

Hydrology

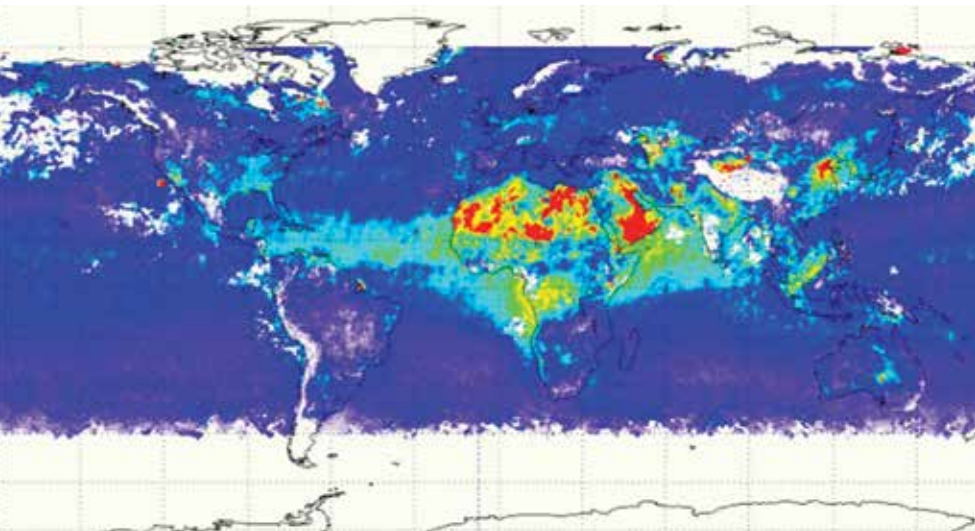
The resolution of the near-real-time soil moisture product retrieved from Metop ASCAT radar backscatter observations over land was increased from 25km to 12.5km.

Ocean

Near-real-time sea-ice concentration products were enhanced to achieve full algorithmic consistency with the corresponding climate record, and to include quality information.



Near-real-time soil moisture product retrieved from Metop ASCAT radar backscatter observations at 12.5km resolution



The Metop multi-sensor aerosol optical depth product is now available over land and sea

Atmospheric composition and greenhouse gases

Retrievals of aerosol optical depth over all land surfaces (except over snow/ice) became operational as part of the Metop Polar Multi-Sensor Aerosol Optical Properties (PMAp) product already mapping aerosol properties over the ocean.

New algorithms improved the quality of ozone, NO₂, BrO, SO₂, HCHO and H₂O column products extracted from Global Ozone Monitoring Experiment-2 (GOME-2) observations.

Land

Ten-day vegetation products derived from Metop AVHRR imagery and initially developed by the Joint Research Centre (JRC – European Commission) and the Flemish Institute for Technological Research (VITO) reached operational status at the LSA SAF, and daily and 10-day composite Fractional Vegetation Cover and Leaf Area Index products extracted from Meteosat imagery were improved by a more accurate classification of pixels covered with vegetation, bare soil and snow.



Ten-Day composite of Normalised Difference Vegetation Index (NDVI) derived from Metop AVHRR imagery

Developing enhanced and new products in partnership with Member States

New products available from international partners

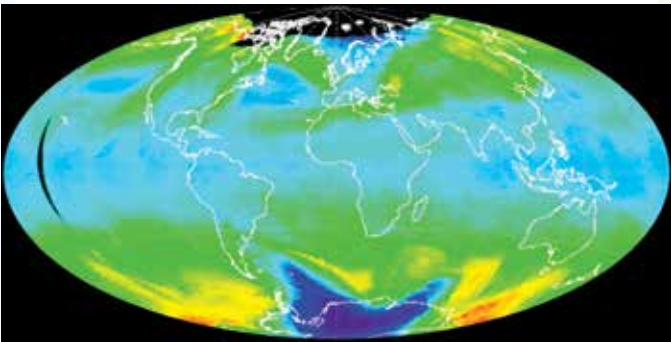
Additional all-weather temperature and moisture soundings became available from the MTVZA-GY microwave sounder of the new Russian Meteor-M N2 polar-orbiting satellite.

Two infrared channels (2.3 μ and 6.95 μ) were added to the Himawari-8 geostationary imagery data service established with the Japan Meteorological Agency, and a GOES-16 imagery data service was prepared to begin in 2017, upon completion of GOES-R commissioning by NOAA.

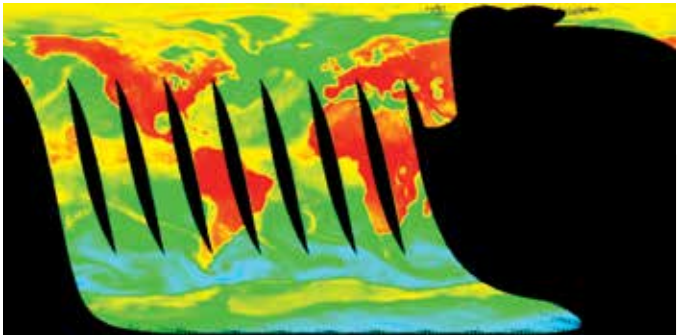
Thanks to a fast neural network retrieval method, a near-real-time soil moisture product from ESA's Earth Explorer Soil Moisture and Ocean Salinity (SMOS) mission was introduced, and preparations for the redistribution of similar products from the NASA Soil Moisture Active Passive (SMAP) mission were completed.

The near-real-time distribution of high-resolution vertical profiles of wind vectors to be produced by the ECMWF using Doppler lidar measurements of the ESA Earth Explorer Aeolus mission was prepared to enable assimilation by regional numerical weather prediction models as soon as possible after the Aeolus launch foreseen in 2018.

For Copernicus, an additional total column ozone product from the Ozone Mapping and Profiler Suite of the US Suomi-NPP satellite was introduced in the dissemination programme to fulfil requirements of the Copernicus Atmosphere Monitoring Service (CAMS).



Global coverage of total column ozone achieved by the OMPS instrument of NOAA's Suomi-NPP satellite



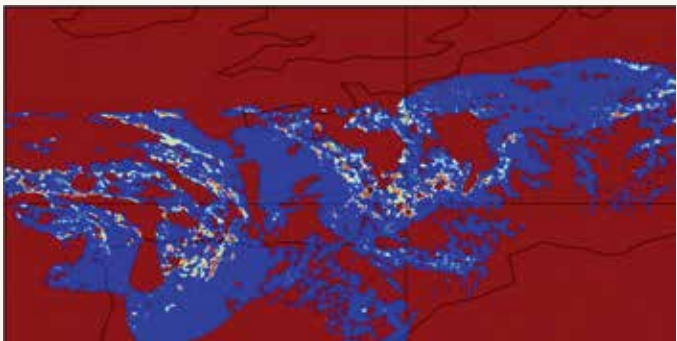
Observations from the MTVZA-GY microwave sounder of the new Russian Meteor-M N2 polar-orbiting satellite, at the frequency of 23.8GHz

Scientific developments target future products

Starting with aerosol products, scientific roadmaps started to be prepared to improve the consistency of the development of families of products using observations from different satellite systems and instruments, targeting a more modular, flexible and multi-mission approach to algorithms and processors.

Cross-calibration of visible imagery, using the moon and deep convective clouds as targets has progressed further with the deployment of a deep convective cloud calibration system to be first applied to improve the calibration of the Meteosat 0.6 μ channel.

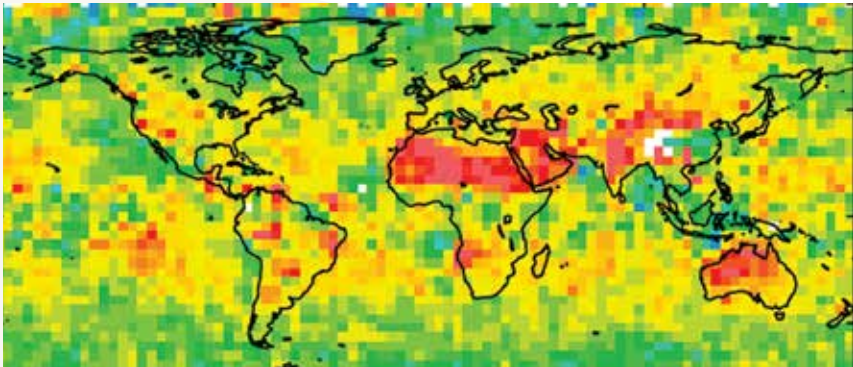
A new piece of nowcasting software is under development to tentatively estimate the probability of a thunderstorm developing within 30 minutes through the extrapolation of information on the initiation of convection contained in real-time Meteosat imagery.



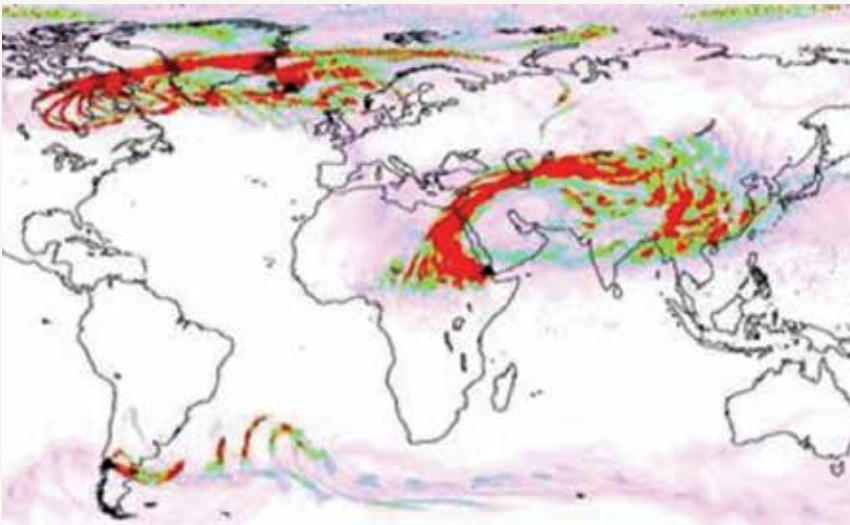
Experimental Meteosat product: probability of the development of a thunderstorm within 30 minutes. Colour codes ranges from 0 (blue) to 3 (75 percent probability, red)

Methods are being tested for mapping the large-scale variations of the height of the turbulent planetary boundary layer using vertical profiles of refractivity observed by the Metop Global Navigation Satellite System (GNSS) Receiver for Atmospheric Sounding (GRAS) radio occultation instruments.

An improved volcanic ash product based on optimum estimation methods will be embedded in the next version of the Optimum Cloud Analysis product.



Large-scale variations of the height of the planetary boundary layer in April 2013, derived from radio occultation observations

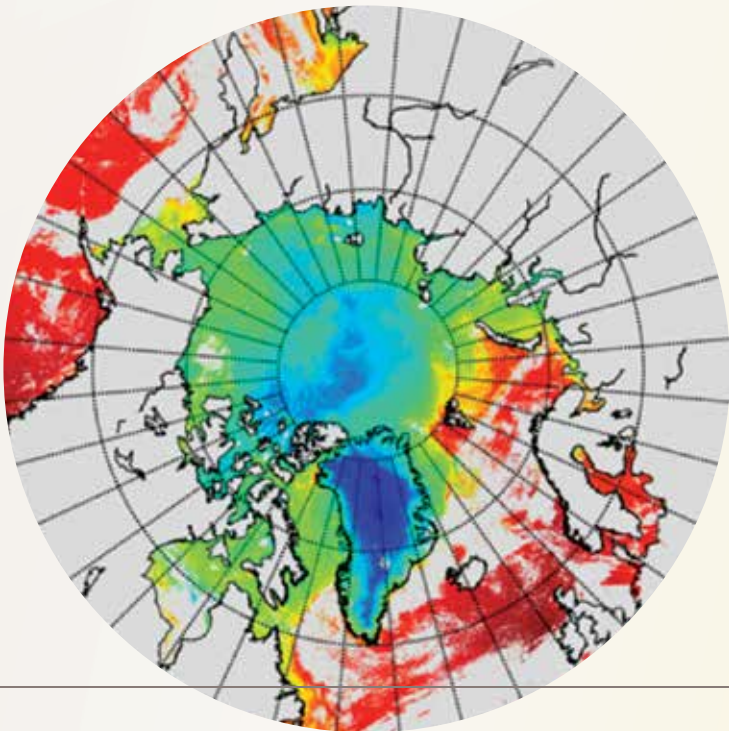


SO₂ plumes originating from several volcano eruptions, as retrieved from IASI infrared spectra

Near-real-time SO₂ total column and O₃ profile products extracted from IASI infrared spectra are under evaluation along with an aerosol scattering index retrieved from GOME-2 observations.

While additional microwave and infrared imagery from Japanese and US instruments are being used to improve the quality of sea surface temperature, sea ice concentration and sea ice emissivity products, new sea ice and land ice surface temperature (LIST) products are under development for the Greenland and Antarctic regions.

Likewise, albedo, snow cover vegetation parameters and land surface temperature products extracted from Metop AVHRR imagery are planned for release in 2017, and research is ongoing on the extraction of a snowfall intensity product from microwave observations.



Composite product for sea surface temperature (operational), and sea ice and ice cap surface temperature (experimental) at latitudes above 50°

Supporting and expanding the user base

EUMETSAT continuously invests in research fellowships, training, capacity building and sustained interactions with users to realise the full benefit of advanced satellite systems

The EUMETSAT cooperative training programme aims at expanding EUMETSAT’s user base and the use of satellite products in a growing range of applications and research areas.

The programme involves an international network of experts on satellite products, applications and techniques for using satellite data across the European Meteorological Infrastructure, the network of Satellite Application Facilities (SAFs), the World Meteorological Organization (WMO) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) and its regional Centres of Excellence.

The programme combines classroom and online events to attract more trainees and allow participants to bring cases from their work as an integral part of their on-the-job training.

Training prepares for the use of new mission data and is boosted in South-Eastern Europe and North Africa

EUMETSAT supported the first annual course of the South-Eastern Europe METeorological (SEEMET) regional training programme.

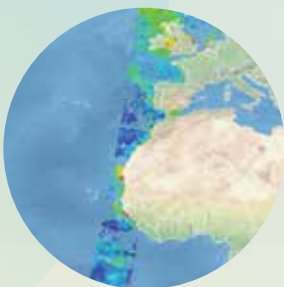
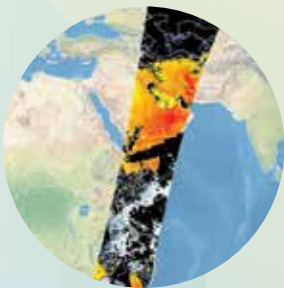
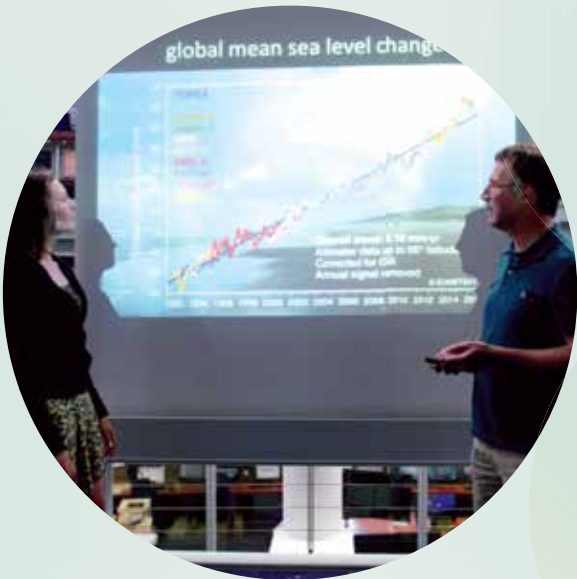
The visit of the Director of the Moroccan NMHS was also an opportunity to revitalise cooperation with the VLab Centre of Excellence in Casablanca.

Training coordination and planning meetings addressed user preparedness for Meteosat-8 over the Indian Ocean and Meteosat Third Generation, growing needs for training on climate applications and communication on impact-based warnings.

EUMETSAT hosted graduate trainees from Poland and Serbia.



EUMETSAT supports the first SEEMET training course in Ljubljana, Slovenia



EUMETSAT starts Copernicus training with a first Massive Open Online Course

As part of its Copernicus training programme on marine applications, EUMETSAT organised a first Massive Open Online Course (MOOC), “Monitoring the Oceans from Space”, with the Copernicus Marine Environment Monitoring Service.

The five-week MOOC presented the benefits and potential usage of EUMETSAT and Copernicus marine observations and CMEMS information and how to access them to 5,500 participants.

Pilot Web Map services (top and bottom right) were used during the Copernicus Marine MOOC to visualise Sentinel-3A marine products

Training and training coordination events

EUMETSAT supported 35 training events, of which 20 included an online phase, 150 instructors were involved and 350 trainees attended, including 330 from Member States.

January

5th Satellite Application Course for Southern Africa on the utilisation of satellite data for severe weather forecasting, online phase

February

Course on the use of EUMETSAT satellite data and numerical prediction for forecasters in Baltic countries for nowcasting and warnings, online phase

5th Satellite Application Course for Southern Africa on utilisation of satellite data for severe weather forecasting, classroom phase, WMO VLab Centre of Excellence, Pretoria, South Africa

March

3rd course on development and applications of weather event simulators for operational meteorologists, trainers and aviation forecasters, WMO VLab Centre of Excellence, Nairobi, Kenya

ECMWF/EUMETSAT/NWP SAF course on the assimilation of meteorological satellite observations in operational numerical weather prediction, Reading, United Kingdom

Course on the use of EUMETSAT satellite data and numerical prediction for forecasters in Baltic countries for nowcasting and warnings, classroom phase, Warsaw, Poland

April

Convection Working Group workshop on research and forecasting of convection and severe storms, Florence, Italy

South-Eastern European Meteorological course (SEEMET) on flash flood forecasting, Ljubljana, Slovenia

22nd Nordic Meteorological Post-Graduate Education (NOMEK) course on the use of satellite and radar data for forecasting high-impact weather, Riga, Latvia

May

Training of forecasters on satellite applications in Africa in English language (SAC-XIV-E), online phase

Training course on the use of satellite products for drought monitoring and agrometeorological applications, Tbilisi, Georgia

June

EUMeTrain core skills course for satellite applications in forecasting, online course

International summer school on applications with the newest multi-spectral environmental satellites, Bracciano, Italy

Training event on "Geospatial data in support of information systems for agroclimatology and crop monitoring", Managua, Nicaragua

Training course on operational marine surface analysis using Copernicus marine data in African waters, online phase

July

3rd International Ocean Colour Coordinating Group Summer Lecture Series on frontiers in ocean optics and ocean colour science, Villefranche-sur-Mer, France

Training course on operational marine surface analysis using Copernicus marine data in Mediterranean waters, online phase

August

Training of forecasters on satellite applications in Africa in English language (SAC-XIV-E), classroom phase, WMO VLab Centre of Excellence, Nairobi, Kenya

September

Training course for forecasters on satellite applications in Africa in French language, (SAC-XIV-F), online phase

Autumn school on the use of satellite data for nowcasting high impact weather, Thessaloniki, Greece

12th Ibero-American course on satellite meteorology, Antigua, Guatemala

October

Training course on the use of satellite products for drought monitoring and applications in agrometeorology, Harare, Zimbabwe

Satellite applications course for the Middle East region, online phase

XIth EUMETCAL Workshop on computer-assisted learning, Langen, Germany

Training course on operational marine surface analysis using Copernicus marine data in Mediterranean waters, classroom phase, Supetar, Croatia

November

Copernicus Massive Open Online Course (MOOC), "Monitoring the Oceans from Space"

5th WMO training course on Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) products, Teheran, Iran

Satellite Applications Course for the Middle East region, WMO-CGMS VLab Centre of Excellence Muscat, Oman

Training course for forecasters on satellite applications in Africa in French language, (SAC-XIV-F), classroom phase, Niamey, Niger

Workshop on applications of satellite climate data records in numerical modeling, Reading, United Kingdom

Expert Exchange on the Copernicus Marine Data Stream, Oostende, Belgium

December

Training course on operational marine surface analysis using Copernicus marine data in African waters, Pretoria, South Africa

Supporting and expanding the user base



“My goal, as a EUMETSAT fellow, is to demonstrate that cost efficient compression of data from the future MTG-IRS hyperspectral sounder will not reduce their positive impact on numerical weather prediction.”

Javier Andrey,
EUMETSAT Fellow
Météo France

Fellowships and visiting scientists

The EUMETSAT fellowship programme draws young, talented scientists into research on the use of satellite data, with the aim of consolidating the science base on the user side. It supports four fellowships at the ECMWF and six in EUMETSAT Member States.

Three new fellows were recruited and the recruitment of a fourth was opened for the following research topics:

- Treatment of radiance products from geostationary satellites in numerical weather prediction, at the ECMWF, UK
- Assimilation of geostationary water vapour radiance data to extract wind information with an Ensemble Kalman Filter, at the Deutscher Wetterdienst, Germany
- European High-Resolution Soil Moisture Analysis, at the Zentralanstalt für Meteorologie und Geodynamik, Austria
- Global Navigation Satellite System –R (GNSS-R) Observation Operator Development and Impact Evaluation, at Koninklijk Nederlands Meteorologisch Instituut, the Netherlands

A call for research topics for four fellowships becoming vacant in 2017-2018 was also prepared for release in 2017.

EUMETSAT hosted 30 visiting scientists from 11 countries to work on topics such as lunar calibration, validation of products and user preparedness for future satellites. Presentations and reports from visiting scientists are now available on the EUMETSAT website.

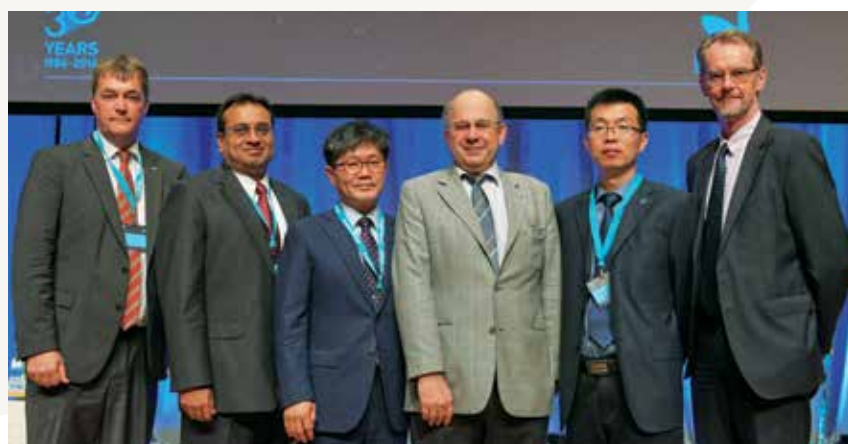
User conferences

The annual EUMETSAT Meteorological Satellite Conference held in Darmstadt attracted 440 participants from 40 countries. User preparedness for future geostationary satellites and the latest developments in the use of satellite data in very high-resolution regional models were among the main themes.

The 2017 and 2018 user conferences to be held in Rome and Tallinn started to be prepared in cooperation with the Italian and Estonian national meteorological services. A Memorandum of Understanding was signed with the American Meteorological Society to prepare the next joint conference planned for 2019 in Boston.

EUMETSAT and the ECMWF agreed to co-organise sessions at their respective user conferences on assimilation of satellite data in weather models and on the preparedness of the modelling community for future satellite data.

In the context of Copernicus, EUMETSAT and CNES co-organised the annual conference of the Ocean Surface Topography Science Team (OSTST) on “New era of altimetry, new challenges”, which was held in La Rochelle, France. Participants discussed the promising results of Sentinel-3A and Jason-3 commissioning and the new perspectives opened by synthetic aperture radar (SAR) altimetry (Sentinel-3, Jason-CS/Sentinel-6) and the SWOT wide swath altimeter mission.



Pictured at the 2016 EUMETSAT User Conference in Darmstadt are (left to right): EUMETSAT Director of Programme Preparation and Development Clemens Kaiser; NOAA/JPSS Deputy Director Ajay Mehta; NMSC/KMA Director-General Hoon Park; EUMETSAT Director-General Alain Ratier; NSMC/CMA Deputy Director-General Peng Zhang; EUMETSAT Chief Scientist Kenneth Holmlund

Outreach

Satellite imagery and animations were regularly posted on social media to raise EUMETSAT's profile with new audiences and were used in combination with microsites as the preferred way for live communication on the Jason-3 and Sentinel-3A launches. The Jason-3 microsite homepage was the third most viewed page of the main website and EUMETSAT's YouTube and Flickr channels reached more than 2 million views.

The ocean was the theme of a new Minecraft satellite-building competition inviting six to 16-year-old children to either build the best Minecraft model of the Sentinel-3 or Jason-3 satellites, or to design a new ocean-monitoring satellite or even an ocean-monitoring system with satellites, buoys, automatic robots etc.

Local life

The 30th anniversary was an opportunity to increase local visibility of EUMETSAT through events organised with the City of Darmstadt, i.e. guided tours of EUMETSAT premises attracting more 3,000 visitors, a summer exhibition in the most popular shopping centre and the decoration of a Darmstadt tram running on all city lines that was distinguished by a tram design award.

EUMETSAT hosted the 2016 Hessian Students' Award (Jugend Forscht), the regional division of one of Europe's longest-running creative competitions for school students. European organisations in Hessen take turns to host the annual competition.

The €4,370 raised by the 2016 Christmas Party was donated to the Darmstädter Tafel, a local German food bank supporting, in particular, children and adolescents.



On behalf of EUMETSAT employees, Alain Ratier, Director General (right) and Karim Hagouchi (centre), chairman of the Staff Association Committee, present a cheque to Gert Wentrup, from Darmstädter Tafel

EUMETSAT celebrates its 30th Anniversary

The 30th anniversary was celebrated with events throughout the year including a VIP event involving representatives from Member States, international partners and user organisations and a fun-filled event for all people working at EUMETSAT where renowned polar explorer, Dr Jean-Louis Etienne, gave an inspiring talk.



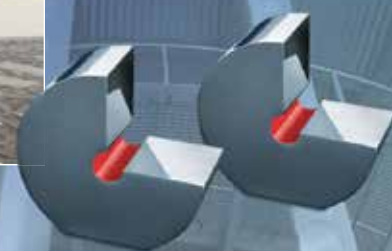
The views of different user communities on past EUMETSAT achievements and their expectations for the future were captured at the annual user conference, through several keynote speeches and round-table discussions.

For the public, an application for viewing, annotating and printing selected images from 30 years of Meteosat daily images was made available on the EUMETSAT website (<http://pics.eumetsat.int>).

Locals take the chance to learn more about EUMETSAT at an exhibition in a city-centre shopping centre and by visiting headquarters where a special timeline exhibit depicts 30 years of EUMETSAT history.



The design featured on a city tram won a local award and the 30 years logo and exhibition received two silver international awards from Graphis, New York.





"EUMETSAT has a very special relationship, not only with its Member States, but also with countries that have the most need. The best example of which is with the African meteorological community."

Dr David Grimes,
President
World Meteorological Organization (WMO)



VIP event and user conference

EUMETSAT's impact and contributions are discussed at a June VIP event with Member States and international partners. The annual User Conference, held in Darmstadt, celebrates the anniversary from an end-user perspective.

Staff event

An inspiring talk by renowned polar explorer Jean-Louis Etienne and light-hearted moments are enjoyed by all EUMETSAT's people while celebrating 30 years of working together in August.



Support to capacity-building initiatives

EUMETSAT delivers Meteosat-8 and Copernicus data to Africa and supports EU-funded capacity-building projects

The 12th EUMETSAT User Forum in Africa, held in Kigali, Rwanda, on 12-16 September discussed possible transition scenarios from Meteosat Second Generation (MSG) to Meteosat Third Generation (MTG) for African users. It was concluded that the priority for access to MTG data is for imagery at 10-minute frequency but for MSG channels only and at a spatial resolution equivalent to MSG, plus the accumulated flashes from the Lightning Imager. The matter will be further discussed with the WMO Regional Association 1 (RA-I) Dissemination Expert Group (RAIDEG) to arrive at a final transition scenario serving as a reference for future capacity-building initiatives and mobilisation of funds.

The forum also established the needs and priorities of the African user community for access to Sentinel-3 land products for consideration by the European Commission.

Under the Memorandum of Understanding with the African Union Commission (AUC), EUMETSAT continued to support the Monitoring of Environment and Security in Africa (MESA) project, focusing on the deployment of 178 upgraded EUMETCast receiving stations and associated training.

The deployment started in March at the WMO training centres and continued in all NMHS of sub-Saharan Africa, while training focused first on system administrators and the various WMO VLab training and education centres.

EUMETSAT also supported the 5th and 6th meetings of the MESA Steering Committee, held in Accra, Ghana, and in Brazzaville, Congo, where plans for the last phase of the project were agreed.

Through an exchange of letters with the African Development Bank (AfDB), EUMETSAT formalised its support to the Satellite and Weather Information for Disaster Resilience in Africa (SAWIDRA) programme funded by the EU. This support will concentrate on a continental sub-project led by ACMAD aimed at developing a regional numerical weather prediction (NWP) capability in Africa, including a "Regional Advanced Retransmission Service (RARS)-Africa" network of X/L band stations



The 12th EUMETSAT User Forum in Africa in Kigali, Rwanda, involves more than 160 participants from 51 African countries in a workshop atmosphere

acquiring and processing data from polar-orbiting satellites and disseminating products to the NWP centres.

EUMETSAT assisted the AfDB in the review of the terms of reference of the sub-project and the technical assistance team to be recruited by ACMAD and interacted with the African entities expected to host the X/L band stations.

In December, after the European Commission and the AUC signed an agreement on a Global Monitoring for Environment and Security & Africa project funded through the EU Pan-African programme, EUMETSAT initiated discussions of an arrangement with the AUC to formalise its support to the project on data access and training.

EUMETSAT disseminated a number of new products to the African community in support of capacity building, including maps of soil water indices, fire danger indices and burned areas, along with marine forecasts targeting fisheries in coastal areas and high-resolution weather forecasts for use by African NMHS.

The bandwidth of the EUMETCast-Africa data broadcasting service was increased in November to enable the dissemination of Copernicus Sentinel-3 marine products and Meteosat-8 imagery over the Indian Ocean.

New cooperation agreements were signed with ACMAD and the Agriculture, Hydrology, Meteorology centre (AGRHYMET).

Optimum deployment of recurrent satellites

Despite the need to repair two instruments, preparations remain on track for the launch of Metop-C in October 2018

The preparation of the Metop-C satellite passed major milestones with the reintegration of the repaired Microwave Humidity Sounder (MHS) and Infrared Atmospheric Sounding Interferometer (IASI) instruments on the payload module (PLM), followed by the de-storage of the service module (SVM) and PLM at the end of the year for testing prior to their integration.

The GOME-2 ozone monitoring instrument could not be integrated, as it had to be shipped back to industry for investigation of a critical anomaly of one focal plane assembly detected during recalibration.

The anomaly could not be reproduced but was localised in two subsystems for which spares were found for repair. After rehearsal of all critical repair operations at equipment level, ESA and EUMETSAT decided to proceed with the repair. The repaired instrument was delivered on 21 December in time for the PLM thermal vacuum test scheduled to start in January 2017. The satellite integration and testing sequence was replanned to allow dismounting of GOME-2 after that test and its final reintegration after the necessary repeat of the recalibration campaign, whilst preserving readiness for launch in October 2018.

In December, it was decided to dismount the MHS microwave sounder to investigate a significant noise degradation observed on two of its channels during instrument functional tests, but only in 2017, after completion of the PLM thermal vacuum test.

The Preliminary Mission Analysis Review for the launch service confirmed the full compatibility of launcher performance with the revised launch trajectory, and Arianespace agreed to introduce nitrogen purging in the fairing to protect the NOAA Space Environment Monitor (SEM) instrument from the moist environment prevailing in Kourou.

Preparations for flight operations and for the system verification and validation tests started at EUMETSAT after the decision to use the virtualised version of the EPS ground segment for three-Metop operations.



“Launching Metop-C in October 2018 is challenging, but this is critical for the continuity of our services from the mid-morning polar orbit and for the safe transition to EPS-SG.”

Manfred Lugert,
replacing Pierre Ranzoli, on 1 December,
as the EPS/Metop-C programme manager



The EPS Computer Infrastructure Upgrade Project team mark a significant milestone, when the new upgraded infrastructure for EPS, which will include all future Metop-C activities, was selected after a successful review



Dismounting of the GOME-2 instrument at Leonardo premises, for the repair of one focal plane assembly (marked FPA4)

Development of the Meteosat Third Generation (MTG) system

As confidence grows in the space segment development schedule, the MTG ground segment has completed the critical design of its mission control and data acquisition chain and started ground segment pre-integration

The massively improved and new observations expected from the Meteosat Third Generation (MTG) system will revolutionise nowcasting and very short-range forecasting of high-impact weather over Europe and Africa in the next decade.

MTG, the most complex and innovative meteorological geostationary system ever built, comprises two separate lines of satellites exploited simultaneously. The MTG-I (imaging) line will improve the current Meteosat imagery and add a new lightning imaging capability, while the MTG-S (sounding) line will establish a hyperspectral infrared sounding capability that delivers vertical profiles of temperature and moisture every 30 minutes over Europe. On board MTG-S, the synergy between the EUMETSAT Infrared Sounder and the Copernicus Sentinel-4 Ultraviolet, Visible and Near-Infrared Sounder will provide a unique, integrated capability to monitor the fast evolution of ozone, carbon monoxide, sulphur dioxide and other trace gases in support of air quality, pollution and climate monitoring.

EUMETSAT replans system and ground segment development activities

Programme management concentrated on replanning EUMETSAT system and ground segment development activities to cope with the one-year slippage of the space segment development announced at the end of 2015.

The development of the MTG-I instrument data processing chain was made more incremental to ingest deliveries of image quality software as they become available from the space segment, whilst providing the deliveries required for ground segment integration.

The development of the command, tracking and control station was slowed down and the level of service expected from the data acquisition stations was reduced in the short term to meet only requirements of system pre-integration.



Finally, the deadlines for deferring the launch dates of MTG-I1 and MTG-S1 were postponed by one year in agreement with Arianespace, and considering that Ariane-5 may no longer be available for launching MTG-I2, a first analysis of the new Ariane-6 User Manual was performed.

Confidence grows in the space segment development schedule

Meanwhile, the ESA-led development of the space segment progressed significantly, building on more efficient risk management and schedule control by industry.

The structural and thermal model of the platform common to both spacecraft was integrated and tested, two major subsystems of the Flexible Combined Imager (FCI) were removed from the critical path, the impact of micro-vibrations on the performances of the three instruments started to be mitigated, and performance issues on infrared detectors were resolved.

On the other hand, difficulties in the manufacturing of the most demanding mirror of the telescope optics, led ESA, EUMETSAT and industry to initiate an assessment of the flightworthiness of the first available models of that mirror, for flight on MTG-I1, as this appeared the only way to keep the launch in mid-2021. Moreover, the lower-than-required quantum efficiency of the prototype detectors of the Lightning Imager (LI) triggered detector redesign by ESA.



Optical bench of the Flexible Combined Imager (above) and MTG platform structural/thermal model at industry premises (right)



Overall, the advanced status of manufacturing of equipment and subsystems gives confidence that the schedule will stabilise when the remaining critical risks are mitigated, and the confirmation by the Intermediate Design Check Point that the design of the MTG-I satellite meets performance requirements is promising.

The system and ground segment development pass key milestones

The EUMETSAT-led ground segment development passed a major milestone in July, with the completion of the critical design of the full mission control and data acquisition chain composed of the command, tracking and control station, the mission data acquisition stations and the control centre.

The ground segment also became a tangible reality with first hardware and software installed and tested at EUMETSAT, and the two pairs of Ka-band antennas of the data acquisition stations were erected in Lario, Italy, and Leuk, Switzerland.

A first delivery of the mission control centre was installed and tested at EUMETSAT and integrated with the second version of the satellite simulator through the already established MTG network. This was an important achievement in the preparation for the first System Validation Test (SVT-I1-v0) with the satellite platform foreseen in October 2017 as the first milestone of the System Validation Test plan agreed with ESA.



The MTG ground segment becomes a tangible reality at EUMETSAT premises and at other sites in Italy and Switzerland



Likewise, the processing infrastructure hosting the software extracting physical (level 1) products from MTG-I instrument data was installed and tested, together with a preliminary version of the FCI instrument data processing software. It was then integrated with a first version of the satellite payload data simulator and the front ends of the multi-mission archive and data dissemination systems, which enabled the performing of dry runs of "data circulation" tests, as the first milestone in ground segment pre-integration testing.

All documentation and processing algorithms for the extraction of environmental products (level 2) from physical products (level 1) were delivered to the contractor tasked to develop the MTG-I level 2 processing chain, and the preliminary design phase of this development was concluded in December.

The EUMETSAT-developed prototype instrument data processor was used to generate FCI test data for use by Satellite Applications Facilities in their development of additional level 2 products.

These efforts were rewarded in November by the successful EUMETSAT System Implementation Review (SIR) part 1 confirming EUMETSAT's readiness to start the formal integration of the MTG-I ground segment and to support the first system validation test (SVT) with the satellite.

Development of the EUMETSAT Polar System-Second Generation (EPS-SG)

Apace with the fast development of the space segment, EUMETSAT establishes the system baseline and the contractual framework for the development of the EPS-SG ground segment

The EUMETSAT Polar System-Second Generation (EPS-SG) is Europe's contribution to the Joint Polar System to be shared with the US National Oceanic and Atmospheric Administration in the 2021-2042 timeframe.

The system is composed of two series of spacecraft, Metop-SG A and B, equipped with complementary instruments and flying simultaneously on the same mid-morning orbit like the current Metop satellites. Metop-SG A is an atmospheric sounding and imaging mission. It has a suite of infrared and microwave instruments for sounding temperature, moisture and trace gases in the atmosphere (IASI-NG, MWS), complemented by the Copernicus Sentinel-5 sounder and by two advanced imagers, METImage and 3MI. Metop-SG B is a microwave imaging mission, focused on radar observations of ocean-surface wind and soil moisture and all-weather microwave imagery of precipitation (MWI) and ice clouds (ICI). Both satellites are equipped with a Global Navigation Satellite System (GNSS) radio-occultation instrument (RO) for limb sounding of temperature and humidity at high vertical resolution.

The EPS-SG programme and its cooperation framework are firmly established

After the formal entry into force of the EPS-SG Programme on 1 January, cooperation agreements were signed with the Deutsche Zentrum für Luft- und Raumfahrt (DLR) for the procurement of the METImage instruments, and with the Centre National d'Études Spatiales (CNES) for the delivery of ARGOS receivers, and management arrangements were established with all development partners, putting a finishing touch to the EPS-SG cooperation framework.

The ESA-led space segment development programme continues to progress rapidly

The critical design of both Metop-SG satellites progressed towards the Critical Design Reviews which were postponed by only a few months as a knock-on effect of the slippage of Critical Design Reviews of some instruments. Launch dates were unaffected and remained June 2021 for Metop-SG A1 and December 2022 for Metop-SG B1.

However, the launch of Metop-SG A1 is likely to slip to September 2021, as a result of additional integration and test activities required to dismount the Enhanced –Engineering Model (E-EM) of the METImage instrument after the main tests and to replace it by the Flight Model for final testing, when the latter becomes available.

This followed from the decision of DLR, EUMETSAT, ESA and industry to introduce this E-EM model to avoid a more substantial schedule slippage, when it became evident that the METImage flight model could not be delivered in time to support the nominal satellite integration and test programme.



Signature ceremonies for the METImage agreement with DLR (top) and the ARGOS agreement with CNES (bottom)

The CNES-led development of the IASI-NG instrument completed the preliminary design of most subsystems and passed a critical milestone in December, when potassium bromide (KBr) was confirmed as the optical material of the interferometer based on the results of pre-qualification tests, thus securing the radiometric performance that the zinc selenide (ZnSe) fall-back option could not meet.

After confirmation of the feasibility of launching Metop-SG spacecraft with Soyuz and Falcon-9 and assessment of the Arianespace and SpaceX replies to a Request for Information, distinct Requests for Quotation were released to both companies for initial Metop-SG launch services, and Arianespace was authorised to propose Ariane 62 for the optional launch service for the third Metop-SG satellite.

Likewise, EUMETSAT initiated the procurement of launch and early operations phase services for the first three Metop-SG satellites.



Metop-SG A satellite

Instrument/Mission	Predecessor on Metop	Applications Benefitting
1 IASI-NG (CNES) Infrared Atmospheric Sounding (IAS)	IASI (CNES)	<div><div></div><div></div><div></div><div></div><div></div></div>
2 MWS (ESA) Microwave Sounding (MWS)	AMSU-A (NOAA) MHS (EUMETSAT) AVHRR (NOAA)	<div><div></div><div></div><div></div></div>
3 METIMAGE (DLR) Visible-Infrared Imaging (VII)		<div><div></div><div></div><div></div><div></div><div></div><div></div></div>
4 RO (ESA) Visible-Infrared Imaging (VII)	GRAS (ESA)	<div><div></div><div></div></div>
5 SENTINEL-5 (Copernicus, ESA) UV/VIS/NIR/SWIR Sounding (UVNS)	GOME-2 (ESA)	<div><div></div><div></div><div></div></div>
6 3MI (ESA) Multi-viewing, -channel, -polarisation Imaging (3MI)		<div><div></div><div></div><div></div><div></div></div>



Metop-SG B satellite

Instrument/Mission	Predecessor on Metop	Applications Benefitting
1 SCA (ESA) Scatterometer	ASCAT (ESA)	<div><div></div><div></div><div></div><div></div><div></div><div></div></div>
2 RO#2 (ESA) Radio Occultation (RO)	GRAS (ESA)	<div><div></div><div></div></div>
3 MWI (ESA) Microwave Imaging for Precipitation (MWI)		<div><div></div><div></div><div></div><div></div><div></div></div>
4 ICI (ESA) Ice Cloud Imager (ICI)		<div><div></div><div></div><div></div><div></div></div>
5 ARGOS-4 (CNES) Advanced Data Collection System (ADCS)	A-DCS (CNES)	<div><div></div><div></div></div>

All contracts for the ground segment development are in place

EUMETSAT system development activities focused on consolidating the system design and preparing inputs to the ground segment procurements.

The consistency of the design of each instrument functional chain with the end-to-end performance requirements captured in the System Requirements Document was assessed, and the End User Requirement Document (EURD) was released.

The contractual framework for the ground segment development was established with the signature of industrial contracts for the mission control and operations (MCO) subsegment which monitors and controls the Metop-SG spacecraft and for the payload data acquisition and processing (PDAP) subsegment which acquires and processes mission data and delivers products for distribution to users.

Scientific documentation on processing algorithms and product generation specifications were prepared for all instrument chains for delivery to the PDAP contractor, along with existing processing software proposed for reuse in the EPS-SG data processing system.

Meanwhile, the suitability of the sites selected for hosting the ground stations developed by the MCO and PDAP contractors in Svalbard was confirmed as part of the multi-mission site service contract, together with the readiness to deploy the host infrastructure.

Finally, the upgrades required to all multi-mission elements e.g. for data dissemination, archiving, etc. for fulfilling EPS-SG needs were kicked off as internal projects.

Operational oceanography in the context of Copernicus

With the launch and commissioning of Jason-3 and Sentinel-3A, Europe established the backbone of an international operational observing system for monitoring the ocean and mean sea level

Only satellites can provide global observations of the physical and biological state of the ocean and the atmospheric parameters that drive its variability. The ingestion of their measurements of sea state, sea surface height, temperature and wind, ocean colour, sea ice, incoming solar radiation and precipitation by predictive numerical models of the ocean, along with equally indispensable *in-situ* observations from ships, buoys and profiling floats (ARGO) has opened the era of operational oceanography.

EUMETSAT provides ocean observations from its own Meteosat and Metop satellites and shares dedicated missions with CNES, ESA, the European Union, NASA and NOAA.

EUMETSAT's contribution to the development of Jason-3 and Sentinel-3A came to an end in 2016, with the launch and commissioning of both missions, and the exploitation phase started as part of the European Union Copernicus programme.

Flying on a non-synchronous orbit to avoid aliasing of sea level measurements by tidal signals, Jason-3 provides the most accurate altimeter measurements of sea level which are therefore used for cross-calibrating other altimeter missions.

The Sentinel-3 marine mission provides additional altimeter measurements to those of Jason-3 and restarts the series of highly accurate measurements of sea surface temperature and ocean colour interrupted after the loss of Envisat.



After a long-awaited launch, Jason-3 becomes operational within five months

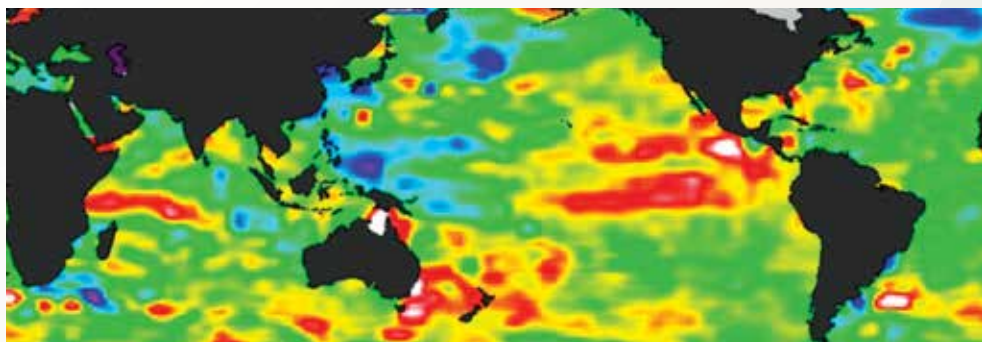
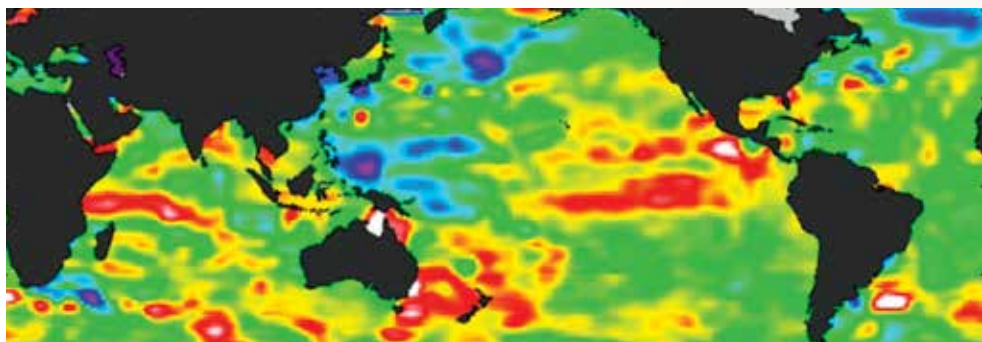
Jason-3 was the first launched, on 17 January, to the relief of the four programme partners – CNES, EUMETSAT, NASA and NOAA – and the satellite delivered its first data only four days later, upon completion of the CNES-led launch and early operations phase.

Commissioning activities had to be suspended for four days when the spacecraft went into safe hold mode but restarted on 29 January, when the inconsistency of on-board timing data causing the problem was overcome by manual commands, before its definitive elimination by an update of the on-board GPS software.

After a couple of days of trial processing of altimeter waveforms at CNES, the generation of the operational geophysical data record (OGDR) near-real-time products started at EUMETSAT and NOAA on 2 February, while the satellite was still on its way to its operational orbit.

The spacecraft reached its final orbit on 12 February, flying behind Jason-2 at a distance of 557km for a six-month tandem operations phase enabling cross-calibration of both systems and comparison of products.

The first Jason-3 sea level anomaly map extracted from the first 10-day repeat cycle, from 12 to 22 February, demonstrated that Jason-3 and Jason-2 measurements captured equally well the signature of the El Niño phenomena in the tropical Pacific.



Sea level anomaly maps for the period 12-22 February 2016 from Jason-3 (top) and Jason-2 (bottom) capture equally well the El Niño phenomena in the tropical Pacific Ocean

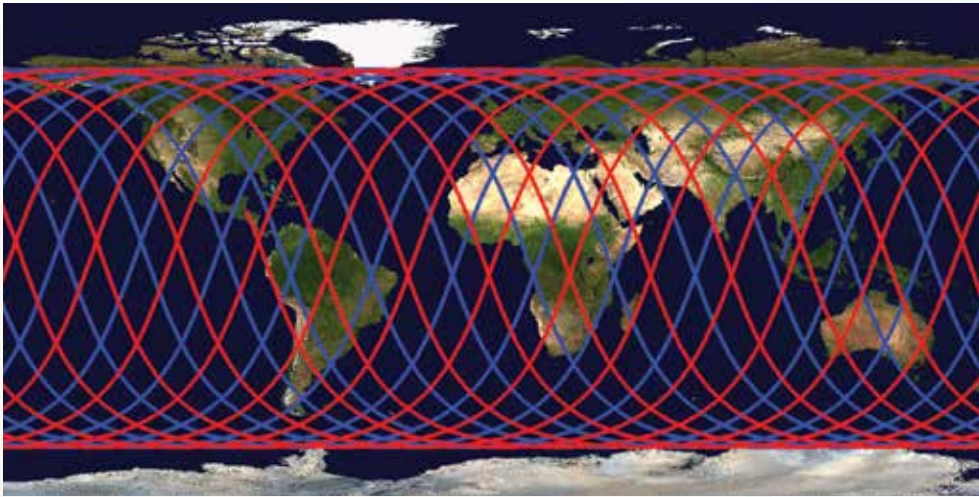
The four-partner In Flight Acceptance Review confirmed the excellent status of all satellite and ground systems and authorised the handover of flight operations from CNES to NOAA. This took place on 1 June and was followed on 13 June by the EUMETSAT internal handover from development to operations teams.

Following the recommendation of the first Jason-3 verification workshop, near-real-time (OGDR) products and the less time-critical interim geophysical data records (IGDRs) were released to all users on 1 July, as the first EUMETSAT operational data services for a Copernicus-dedicated mission.

With all criteria agreed in the Jason-3 calibration and validation plan being met, Jason-3 took over the high-precision ocean altimetry mission from the ageing Jason-2 spacecraft on 19 September, becoming the new reference for cross-calibrating all other altimeter missions, including Sentinel-3.

Jason-2 was then moved to an “interleaved” orbit to maximise the sampling of ocean variability by both missions.

The most accurate offline product, the so-called Geophysical Data Record, was released in November as recommended by the second Jason-3 verification workshop and the Ocean Surface Topography Science Team. The product is now used to expand the unique climate record of mean sea level initiated in 1992 by Topex-Poseidon.



The move of Jason-2 to an interleaved orbit (in red) maximises the sampling of sea surface height measurements by both Jason spacecraft (Jason-3 orbit is represented in blue)

EUMETSAT takes over Sentinel-3A flight operations and releases first marine products

The launch of Sentinel-3A followed one month later, on 16 February and the ESA-led satellite in-orbit verification started on 22 February, upon completion of the launch and early operations performed by the ESA space operations centre (ESOC).

After shadowing flight operations performed by ESOC, EUMETSAT took an increasing role in the control of the satellite, sending its first command on 29 April and performing its first manoeuvre on 2 June, and achieved readiness for taking over flight operations in early July. The actual handover from ESA took place on 13 July, one day after the In-Orbit Commissioning Review (IOCR).

The instrument data processing chains of the payload data ground segment (PDGS) deployed in the EUMETSAT marine centre were activated as soon as X-Band downlinks became available.

This enabled the delivery of level 0 real-time products to the ESA satellite commissioning team and the extraction of first images from the three instruments in cooperation with ESA for release to the public in March-April.

The high quality of images was decisive for the success of the IOC Review but the handover of the PDGS to EUMETSAT had to be postponed, pending acceptance of a new version of its software expected to fix most of the identified shortcomings. The handover finally took place on 10 October to give enough time to document remaining issues that prevented the fulfilment of specific requirements of the EUMETSAT marine centre and to establish a dedicated improvement plan with ESA.

The handover marked the start of the Sentinel-3A “ramp-up operations phase”, during which the capacity of the ground segment and the maturity of products are improved until the Routine Operations Readiness Review planned for spring 2017. The associated transfer of ownership of hardware and software enabled EUMETSAT to act on the system and address shortcomings affecting product timeliness, completeness and availability and stability of online data access.



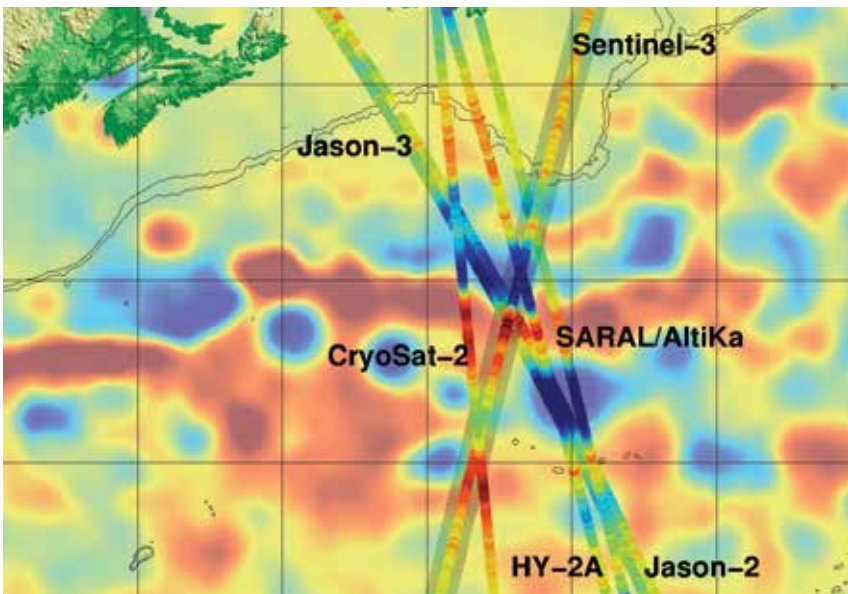
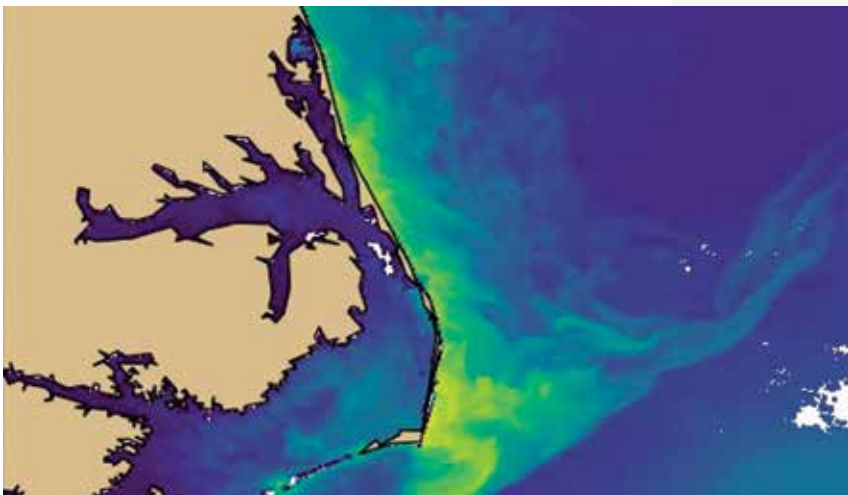
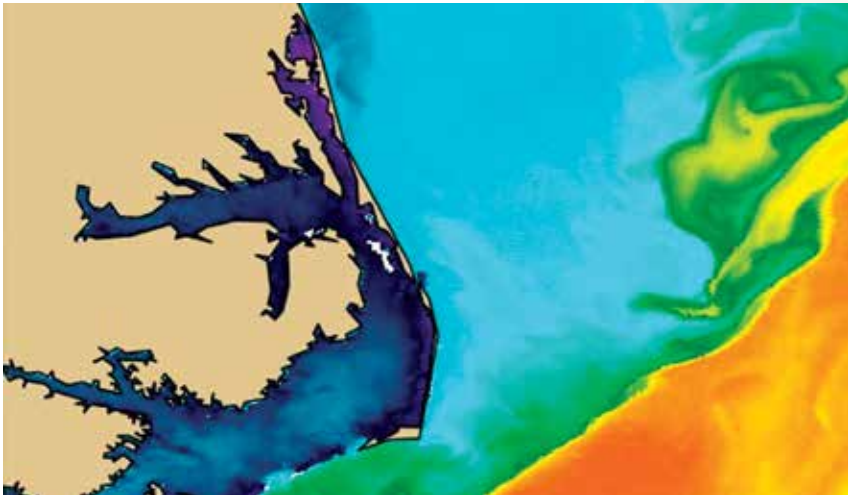
Operational oceanography in the context of Copernicus

The conditions for sustained operations were created through the fine tuning of the software and its migration from the test platform to the operational environment, and a data hub based on open-source software - called Copernicus Online Data Access (CODA) - was deployed to offload the unstable PDGS online data access system and replace it as the primary online data access service to all users.

The plan agreed with ESA for the progressive release of Sentinel-3 products was then implemented, using improved versions of instrument processing chains delivered by ESA, and the first near-real-time level 1 products from the Ocean and Land Colour Instrument (OLCI) were released to all users on 20 October. Near-real-time level 1 products from the Sea and Land Surface Temperature Radiometer (SLSTR) and from the altimeter suite (SRAL) followed in November and December, together with the more accurate non-time-critical level 1 SRAL products, and the first level 2 marine product from the SRAL suite containing information on sea state and ocean surface topography.

After extensive fine tuning and testing on the test platform, the offline production software was migrated to the operational environment on 24 November, enabling the release of the first non-time-critical level 1 product - from OLCI - on 14 December.

Thus, by mid-December all near-real-time level 1 products and altimeter near-real-time and short-time-critical marine products were available to all users in “push” mode via EUMETCast-Europe and online via the pilot CODA data hub system, as well as to NOAA and Geoscience Australia via the EUMETCast-Terrestrial multicasting system.



From top to bottom: sea surface temperature from SLSTR, water leaving radiance from OLCI over the Gulf Stream (11 November), and sea surface height anomalies measured by SRAL and five other altimeters (Jason-2, Jason-3, SARAL, HY-2A, and CryoSat) along their respective tracks superimposed with a Copernicus Marine Environmental Monitoring Service forecast.

The cooperative development of the Jason-CS/ Sentinel-6 system achieves first important milestones

With two successive satellites, the Sentinel-6/Jason-Continuity of Service (CS) cooperative programme will continue the high precision ocean altimetry mission after Jason-3, until at least 2030.

It involves Europe, through EUMETSAT, ESA, CNES and the EU Copernicus programme, and the United States, through NASA and NOAA.

Through its Jason-CS optional programme, EUMETSAT develops the ground segment, coordinates system activities, contributes a fixed financial contribution to the ESA development of the first satellite and co-funds the second with the EU. EUMETSAT will then exploit the Sentinel-6 mission on behalf of Copernicus.

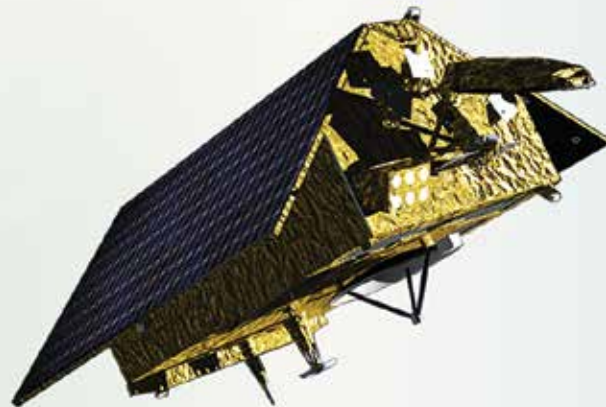
In December, Finland became the 15th Participating State in the Jason-CS optional programme, increasing the level of subscription to 96.29 percent, and the Memorandum of Understanding formalising the cooperation with NASA/NOAA and ESA was signed with the US partners.

The ESA-led detailed design of the spacecraft passed important milestones towards the Critical Design Review planned for spring 2017, including completion of the preliminary design of key subsystems and qualification of some equipment.

In parallel, NASA started the development of the US instruments and confirmed the addition of three frequencies (90, 130, 166GHz) to the Advanced Microwave Radiometer to better correct for the effect of atmospheric water vapour on sea surface height measurements.

At EUMETSAT, the Jason-CS project team was built up with the recruitment of key system and ground segment staff, and the support of CNES for system activities was secured through a dedicated agreement.

A system development schedule was developed with the partners, targeting November 2020 for the launch of the first satellite after its Flight Acceptance Review foreseen in April 2020.



The System Requirements Review was closed in September after consolidation of user and system requirements, and multi-partner groups were set up on system performances, engineering and operations preparation to prepare the System Preliminary Design Review planned for March 2017.

EUMETSAT and ESA started to define the scope and main objectives of the series of System Validation Tests involving the ground segment and the satellite, and planned the procurement of tools required to support these tests. These include a simulator of the data acquisition station and the satellite simulator which EUMETSAT will procure through ESA as an expansion of the simulator used by ESOC to support the launch and early operations phase.

The design of the ground segment progressed with the conclusion of the Overall Ground Segment Requirements Review (OGSRR) and the decision to hold a close-out meeting in early 2017 to confirm EUMETSAT's assessment of the possibility of reusing existing assets in the development of the ground segment.

The assumed reuse of the Sentinel-3 flight operations segment for the Jason-CS mission operations centre (MOC) and of the EPS product generation infrastructure for hosting the Jason-CS data processing chains was then validated by EUMETSAT prototyping.

On that basis, the schedule-critical procurement of the payload data acquisition and processing (PDAP) sub-segment started to be prepared.

Space Strategy for Europe

The final discussion of the Space Strategy for Europe published in October 2016 gave EUMETSAT opportunities for focused interventions at high-level meetings

EUMETSAT investments provide key assets for the Space Strategy for Europe

Addressing the Conference on European Space Policy in Brussels during a panel discussion on future European satellite systems, the Director-General recommended that the realisation of the high potential of the innovative Meteosat Third Generation (MTG) and EUMETSAT Polar System-Second Generation (EPS-SG) systems for non-meteorological applications be one objective of the next EU research and innovation programme.

In the same vein, he invited the European Commission and the Ministers of EU and European Space Agency (ESA) Member States who attended the Informal Space Ministerial Meeting in The Hague to consider MTG and EPS-SG as assets for the Space Strategy for Europe, considering that EUMETSAT Member States, of which 26 are EU members, have invested €7 billion in the programmes and that socio-economic benefits of €5 billion per year are already accrued in the EU from EUMETSAT satellites. The Director-General further recommended that the strategy should promote synergies between the public and private sectors to increase benefits to EU citizens and the economy. He reminded attendees of EUMETSAT's wish, as a public, business-neutral provider of satellite data, to offer opportunities to all through the combination of its own programmes and its contributions to Copernicus.

Addressing the dependencies between energy, weather and climate at a panel discussion of the conference "European Space Solutions", also organised by the Dutch EU Presidency, the Director-General recalled that temperature drives the demand for electricity while weather determines the supply of the renewable part of the energy mix. Therefore, weather forecasts fed by EUMETSAT satellite observations influence spot market prices and day-to-day decisions on production. On the other hand, climate projections are essential inputs for well-informed decisions on strategic investments in the energy sector, in particular for production capacity.

Finally, addressing the ESA Council meeting at ministerial level in Lucerne, Switzerland, the Director-General recalled the value of European meteorological satellites to the European economy and day-to-day lives of citizens and stressed that the combination of Copernicus and EUMETSAT programmes was broadening the operational leadership of Europe in Earth observation. He added that current success should not distract from the need for ESA, as a research and development agency, to invest more in innovative Earth Explorer missions and in development and in-orbit validation of advanced concepts and technology - including miniaturisation of instruments - that may shape a very different future for Earth observation in the next 10 years.

A letter to the European Commission from re-elected Council Chairman, Prof Eliassen, expressed EUMETSAT's support to the Space Strategy for Europe and its appreciation that Meteosat is acknowledged as a European success story and EUMETSAT as a key Copernicus partner.

Preparing Europe for monitoring atmospheric CO₂ and the Arctic from space

As part of discussions with the European Commission and ESA on possible additional Copernicus Sentinel missions, EUMETSAT contributed to task teams on the definition of an information system for monitoring anthropogenic CO₂ emissions and on a Sentinel mission providing observations of CO₂ and CH₄ in the lower troposphere as critical inputs to this system.

It also supported the assessment of user requirements for observations of the Arctic, hosting a workshop dedicated to a potential high-frequency imagery mission from a highly elliptical orbit (HEO) supporting environment situational awareness in the Arctic. The workshop confirmed that a Meteosat-class multispectral imager would fulfil user requirements subject to adjustments to the selection of spectral channels.

**EUROPEAN
SPACE
SOLUTIONS**
BRINGING SPACE TO EARTH

Copernicus cooperation with the European Commission

With Sentinel-3A and Jason-3 in orbit, cooperation with the European Commission on Copernicus focused on operations, data access and communication

In preparation for Sentinel-3 and Jason-3 operations, EUMETSAT released its Copernicus Service Level Specification to the Commission, which includes the definition of key performance indicators for data services.

The involvement of the Commission in the Jason-3 Joint Steering Group for decisions on operations matters was formalised by an exchange of letters, and the Joint Operations Management Plan (JOMP) with ESA was signed in July, before the handover of Sentinel-3A flight operations to EUMETSAT.

Management interactions focused on the processing of change requests from the Commission for improvements to Sentinel-3 operations and data access and the introduction of additional products, in response to requirements from the Copernicus Atmosphere Monitoring (CAMS) and Marine Environment Monitoring (CMEMS) services and user communities.

The EUMETSAT proposal to disseminate Sentinel-3 level 2 marine products to Africa via EUMETCast-Africa to fulfil user requirements conveyed by the African Union was approved by the Commission and implemented in November.

Technical Operations Arrangements were also implemented with NOAA and GeoScience Australia for the exchange of Copernicus-relevant data, as foreseen by Cooperation Arrangements signed by the Commission with the US and Australian governments.

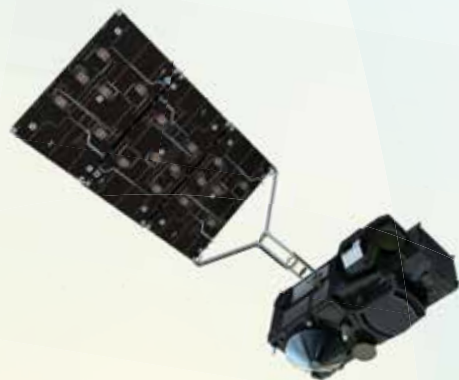
The Commission also agreed proposals from ESA and EUMETSAT to introduce new Sentinel-3 Aerosol Optical Depth (AOD) and Fire Radiative Power (FRP) products to fulfil CAMS requirements and to reduce from 180 to 140 degrees the separation between the Sentinel-3A and Sentinel-3B satellites to fulfil CMEMS requirements for improved sampling of ocean surface topography measurements.

In response to two more change requests from the Commission, ESA and EUMETSAT started to prepare joint proposals for the provision of access to Sentinel-3 land products to African users and for the real-time dissemination of Sentinel-5P atmospheric composition products via EUMETCast to fulfil requirements expressed by the Sentinel-4/-5 Mission Advisory Group.

Finally, in the context of the roadmap towards a more integrated Copernicus ground segment, EUMETSAT teamed up with the ECMWF and Mercator-Ocean to propose a concept for a data and information access service (DIAS) platform building on its "big data" pathfinder projects and the capacities available across the three partners. After endorsement of the concept by the Copernicus governance, the three partners started to prepare the formal proposal requested by the Commission and the detailed design of the platform to be deployed in 2018.

The Copernicus communication activities agreed with the Commission included the deployment of a microwebsite presenting the role of EUMETSAT in Copernicus, and culminated with an intervention by the Director-General in a presentation of the first Sentinel-3 images and their applications also involving the Director-General of ESA and Commissioner Bienkowska.

The first ex-post financial audit of the European Commission on the Copernicus tasks entrusted to EUMETSAT for the years 2014 and 2015 confirmed the eligibility of all costs, with some minor adjustments in favour of EUMETSAT.



Cooperation with other satellite operators

Through cooperation with other satellite operators, EUMETSAT supports the optimisation of the global observing system, delivers its data to a broader user community and gains access to additional data for the benefit of its own users



EUMETSAT hosts the 44th plenary session of the Coordination Group for Meteorological Satellites in Biot, France

CGMS improves geostationary observations over the Indian Ocean

The 44th Plenary Session of the Coordination Group for Meteorological Satellites (CGMS) welcomed the successful deployment of all Indian, Chinese and Russian geostationary satellites required to implement more resilient multi-partner Indian Ocean Data Coverage services after the de-orbiting of Meteosat-7, and the decision of EUMETSAT to relocate Meteosat-8 to 41.5°E as its best effort contribution. A multi-partner list of Indian Ocean meteorological products available without restriction to all users was agreed and the World Meteorological Organization (WMO) was notified.

WMO and CGMS shape the architecture of the future observing system

Discussion of the “Vision 2040” proposed by the WMO as the targeted architecture for the space-component of its integrated global observing system (WIGOS) started in January at the WMO High Level Consultative Meeting on Space Matters and continued at the 44th Plenary Session of the CGMS.

The WMO accepted the CGMS recommendations that architectures for data access, being unpredictable in the 2040 timeframe, should not be addressed by the Vision, and that the target architecture to be proposed to WMO Member States should not prescribe the possible contributions of the public and private sectors to its implementation. EUMETSAT suggested that observations of CO₂ and other greenhouse gases present in the atmosphere be addressed by the Vision in response to the Paris Agreement, at least in terms of sampling requirements and preferred orbits.

Bilateral cooperation brings mutual benefits and serves worldwide user communities

The US National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) and EUMETSAT prepared for the launch, commissioning and entry into operations of Jason-3 and signed a Memorandum of Understanding involving also ESA for the cooperative development of the follow-up Jason-Continuity of Service (CS)/Sentinel-6 mission.

With NOAA, the transition of the EUMETCast-Americas service to the GEONETCast-America service was completed with support from the Brazilian space agency (INPE). All registered users of EUMETCast-Americas were informed well ahead of the termination of the EUMETCast service on how to convert their reception station into a GEONETCast-America station and gain access to the broadcast service provided by NOAA.

In the area of joint operations, an exchange of letters formalised the exchange of regional sets of real-time products retrieved from data broadcast by Initial Joint Polar System (IJPS) polar-orbiting satellites to European and US networks of ground stations.

The rationalisation of transatlantic communication and data transfer systems also continued with the capacity upgrade of transatlantic links, their configuration to repatriate Metop data acquired at Fairbanks in case of the loss of the EUMETSAT Svalbard station and their use for multicasting Sentinel-3A and Meteosat-8 data from EUMETSAT to several NOAA sites.

At their annual bilateral meeting, the NOAA and EUMETSAT leadership agreed to go one step further and establish interface control documents for data exchange. The meeting was also the occasion to exchange information on respective science and big data roadmaps, and for the Director-General to attend a stakeholder meeting on NOAA’s future architecture plan for the 2030-2050 timeframe, setting the scene for the future of the Joint Polar System cooperation.

A Framework Agreement was negotiated with the Chinese National Space Administration (CNSA) as a policy framework for the further development of cooperation established with China's State Oceanic Administration (SOA) and the China Meteorology Administration (CMA). This enables cooperation with the CMA on climate missions it exploits on behalf of the CNSA and provides the missing long-term perspective for cooperating with the SOA on a series of ocean-monitoring satellites.

The CMA agreed to activate the direct broadcast system of its FY-3C satellite during longer periods over Europe to increase the geographical coverage of EUMETSAT's EARS-FY-3C regional data service. Both parties agreed to hold a bilateral workshop on next-generation polar-orbiting satellites to support the preparation of CMA's decadal plan and maximise synergy with the EUMETSAT Polar System - Second Generation (EPS-SG).

The Chairman of the Indian Space Research Organisation (ISRO) invited the Director-General to the opening session of the Asia Pacific Remote Sensing Symposium 2016 (APRS SPIE) hosted in Delhi and to present various models for international cooperation in weather and climate monitoring from space at a panel discussion involving other heads of space agencies.

The high-level bilateral meeting which followed brought excellent prospects for further cooperation with ISRO, including cross-calibration of INSAT-3D and Meteosat-8 imagery over the Indian Ocean and exchange and processing of data from scatterometer, microwave temperature and moisture sounding and radio-occultation missions. ISRO also expressed interest in using the EUMETCast-Terrestrial multicasting system to access EUMETSAT data, as well as Copernicus data when India has signed a Cooperation Arrangement with the European Commission.



Heads of space agencies open the 10th SPIE Asia-Pacific Remote Sensing Symposium, organised by NASA and ISRO in New Delhi, India

After an exchange of letters formalised an agreement on access to and processing of Scasat-1 ocean surface wind data and their distribution, as a continuation of the successful Oceansat-2 service, the equipment required on both sides to support data exchange was set up and tested.

The bilateral meeting held with Roshydromet/Roscosmos in June identified the increased contributions of the Moscow station to the EUMETSAT EARS regional data services, the successful joint training event organised in June 2015 and exchange of data, as the main recent achievements of the cooperation.

The inclusion of two more Russian stations (Novosibirsk in Siberia and Karashov in the far east) into the EARS network, the exchange of Meteosat-8 and Elektro L N2 data over the Indian Ocean and the delivery of sounding data from Meteor 3 M N2 to EUMETSAT, were identified as new objectives, which were all achieved in the second part of the year.

The cooperation agreement with the Korean Meteorological Agency (KMA) was renewed for the period 2017-2021. A high-level bilateral meeting was held during the EUMETSAT user conference to discuss data exchange and scientific cooperation and EUMETSAT encouraged the KMA to select an orbit that does not duplicate other operational missions for the first small meteorological polar-orbiting satellite which Korea may decide to develop for launch around 2022.

A first cooperation agreement with the Japan Aerospace Exploration Agency (JAXA) was signed for data exchange and scientific cooperation, starting with the exchange of Meteosat, Metop, Himawari-8 and GCOM-W products. Cross-calibration between IASI and the future GOSAT-2 mission was identified as a first topic for scientific cooperation.

A new Memorandum of Understanding on data exchange was signed with Canada's Department of Environment.

Global partnerships

EUMETSAT plays an active role in global partnerships, including GFCS, CEOS and GEO, with a focus on climate monitoring from space

Global Framework for Climate Services

EUMETSAT hosted a meeting of the Management and Partners Advisory committees of the Intergovernmental Board of the Global Framework for Climate Services (GFCS) on 17-19 October and showcased its strategy in support of climate services.

During the 12th EUMETSAT User Forum in Africa, a Kigali Declaration establishing the Climate Application and Prediction Centre for Central Africa was signed by the Minister for Natural Resources of Rwanda and a senior advisor to the African Union Commissioner for Rural Economy and Agriculture.

Within the GFCS Africa, Caribbean and Pacific (ACP) Task Team, involving the African Union Commission, the ACP Secretariat and the World Meteorological Organization (WMO), EUMETSAT supported the definition of a project aimed at expanding the existing MESA Climate Services in Africa and developing such services in the Caribbean and Pacific regions, as part of the implementation of the intra-ACP strategy adopted by the 11th European Development Fund (EDF).

The European Commission confirmed at the 12th EUMETSAT User Forum in Africa its intention to launch a project formulation study to prepare a funding decision by the 11th EDF. In preparation for the study, EUMETSAT hosted a workshop involving ACMAD, the lead of the MESA Continental Climate Service, and the EU Joint Research Centre to discuss requirements for products, climate data records, tools and capacity development.

Architecture for climate monitoring from space

EUMETSAT supported the organisation of the Global Climate Observation System (GCOS) Open Science Conference, "Climate observations: the road to the future", in Amsterdam, which launched the preparation of the new GCOS Implementation Plan. The plan captures updated requirements for observations of essential climate variables.

After the finalisation of the plan and its presentation to the 45th session of the Subsidiary Body for Scientific and Technological

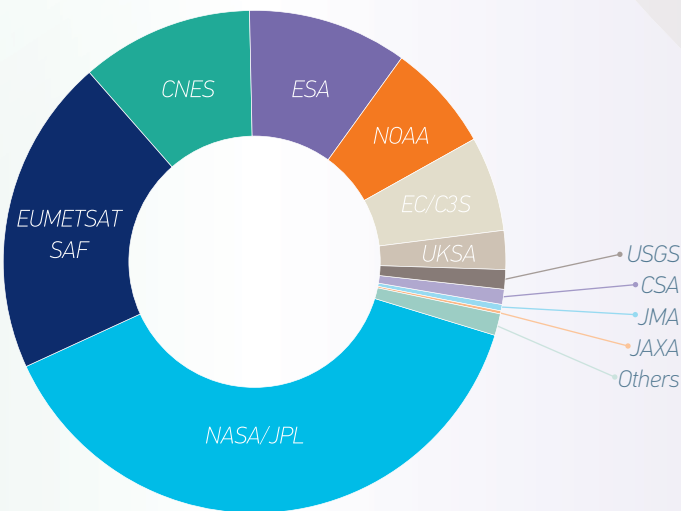
Advice (SBSTA) of the United Nations Framework Convention on Climate Change (UNFCCC), the Committee on Earth Observation Satellites (CEOS) and the CGMS tasked their Joint Working Group on Climate to coordinate their response.

This response will build on a gap analysis planned for 2017 using the web-based inventory of existing and planned climate data records of essential climate variables (ECVs) observable from space developed by EUMETSAT (<http://climatemonitoring.info/ecvinventory>). The inventory was populated with 924 entries collected from 11 CEOS and CGMS member agencies. Of the 924 entries, 25.7 percent originated from EUMETSAT and its SAF network. The inventory covers 30 of the 35 ECVs identified by the GCOS plan as observable from space.

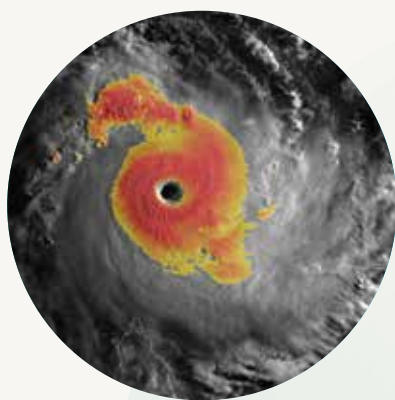
Plans for monitoring anthropogenic CO₂ emissions in response to the Paris Agreement were extensively discussed throughout the year, starting in April with a dedicated session of the 44th CGMS Plenary meeting hosted by EUMETSAT. Dr Philippe Ciais, the lead author of the "CO₂ report" published by the European Commission, presented the targeted information system for monitoring anthropogenic CO₂ emissions, and NASA, JAXA, CMA and ESA/EUMETSAT presented existing and planned atmospheric CO₂ monitoring missions contributing key observational inputs to the system.

CGMS proposed the establishment of a joint CGMS-CEOS virtual constellation for greenhouse gas monitoring missions and that the WMO Vision 2040 for the space-based component of the global observing system (WIGOS) should consider a target constellation for monitoring atmospheric CO₂ and other greenhouse gases.

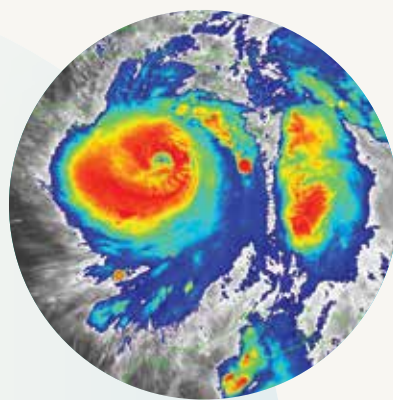
In November, the CEOS Plenary confirmed the need for an assessment of existing and planned CO₂-monitoring capabilities as an input to the detailed plan the European Commission wishes to establish in 2018 during its CEOS Chairmanship. The Virtual Constellation on Atmospheric Composition was tasked to prepare this assessment and propose a targeted architecture for observing greenhouse gases from space, against which individual agencies will map their contributions.



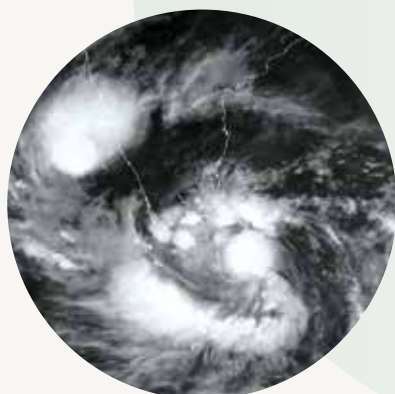
EUMETSAT provides 25.7% of the 924 entries from CEOS and CGMS member agencies to the inventory of existing and planned climate data records of essential climate variables observable from space



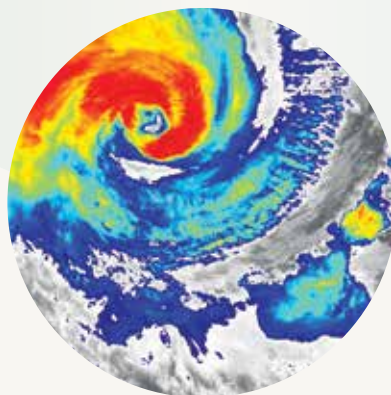
*Tropical Cyclone Fantala,
18 April 2016*



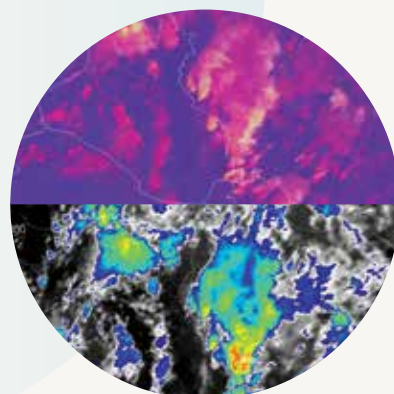
*Hurricane Matthew,
4 October 2016*



*Severe storms in Sri Lanka,
15 May 2016*



*Tropical Cyclone Winston,
21 February 2016*



*Flash flooding in Iran,
14 April 2016*

*EUMETSAT responded to five activations of the
Charter on Space and Major Disasters in 2016*

CEOS and GEO

Co-chairing one of the studies launched by CSIRO - the 2016 Chair of CEOS - on non-meteorological applications of the future geostationary meteorological satellites, EUMETSAT organised a dedicated session at the 44th CGMS plenary where the Satellite Application Facilities on Ocean and Sea Ice, Land Surface Analysis and Climate Monitoring presented their capabilities and know-how. The SAF representatives demonstrated that many of the "non-meteorological" applications were either part and parcel of modern meteorology or addressed by the meteorological community in partnership with others.

EUMETSAT participated in CEOS Strategy Implementation Team meetings and in the Plenary hosted by CSIRO in Brisbane, Australia.

Within the Group on Earth Observations (GEO), EUMETSAT supported the drafting of the first GEO Work Programme (2017-2019), implementing the strategic plan adopted in 2015 by the Ministerial Summit, focusing its contribution on the description of the GEONETCast task.

The Work Programme approved in November by the GEO XIII Plenary held in Saint-Petersburg, Russia, confirmed GEONETCast as one GEO Foundational Task contributing

to the implementation of the Global Earth Observation System of Systems (GEOSS) Common Infrastructure (GCI). Its implementation by the National Oceanic and Atmospheric Administration (NOAA), EUMETSAT and the China Meteorological Administration (CMA), with contributions from the Brazilian space agency (INPE) and the WMO, includes three lines of activity i.e. (i) operate the GEONETCast infrastructure; (ii) engage with GEO Flagships and initiatives to assess needs for data access and dissemination; and (iii) maintain and improve services to users.

EUMETSAT responded to five activations of the Charter on Space and Major Disasters. Metop-B infrared imagery was delivered in February to support Fiji in dealing with Tropical Cyclone Winston and in October to support Haiti's response to Hurricane Matthew. Meteosat imagery and animation were provided twice in April, to support the management of flash floods in Iran and of tropical cyclone Fantala in the Seychelles, and in May for the management of large, severe storms in Sri Lanka.

EUMETSAT is preparing to co-chair the Charter with the Deutsche Zentrum für Luft- und Raumfahrt (DLR) for a period of six months from April to October 2018.

Management and administration

As part of its commitment to continuous improvement, EUMETSAT adapted its organisation to the requirements of new programme phases, reinforced internal and external communication and started to recruit young talents under a new Early Career Programme

Organisational management

The organisational structure was adjusted for the sake of efficiency and to adapt to requirements of new phases of some programmes.

A Financial Control and Internal Audit Division (FIA) was established to regroup the Financial Control and the Internal Audit function under one roof.

The Strategy and International Relations and Communication and Information Services divisions were merged into one division to acknowledge the strategic relevance of communication and improve efficiency through the integration of the definition of messages and their delivery. At the same time, the role of head of cabinet supporting the Director-General was re-established and assigned to the head of the new division.

The MTG programme team was reorganised to be more responsive in the highly interactive system integration, verification and validation phase, based on more direct reporting lines and shorter loops for the management of critical system and ground segment development activities. This was prepared by an offsite team-building event addressing changes in roles and responsibilities.

As in previous programmes, key Sentinel-3 personnel were reassigned from the Programme Preparation and Development Department to the Operations and Services to Users and Technical and Scientific Support departments to transfer the knowledge required for Sentinel-3 mission operations.

In the context of the matrix organisation, the use of the resource management framework (RMF) web tool was generalised in the Technical and Scientific Support (TSS) Department to assist in the planning and assessment of human resources providing support to a portfolio of projects.

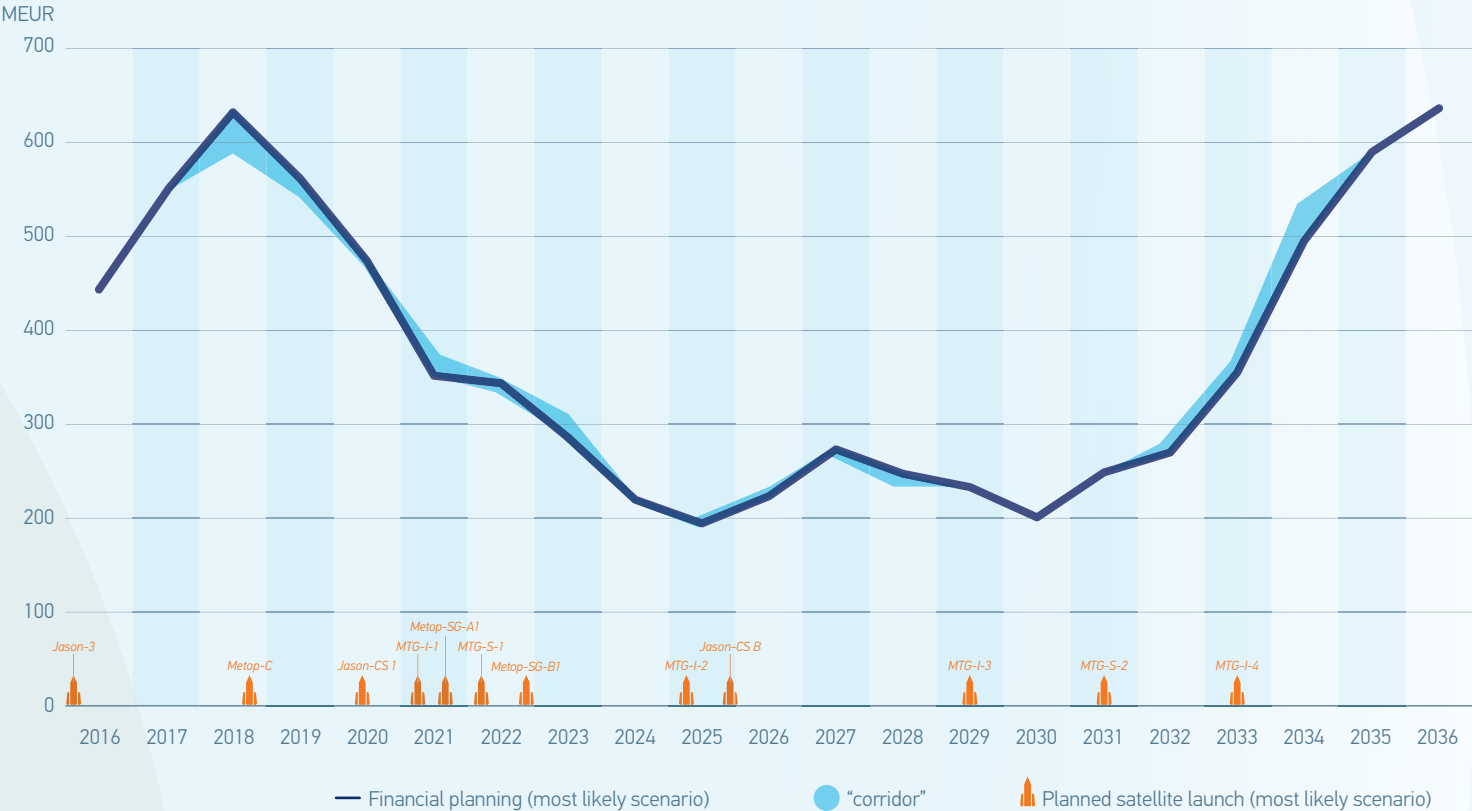
The Enterprise Resource Planning (ERP) Task Force implemented the agreed recommendations of the SAP security audit, introduced improvements to the SAP workflows for procurements and simplified the overly complex human resource planning process for SAP implementation in 2017.

Cloud services started to be used to support the management system. In particular, cloud-based tools were tested to support the transformation of the restructured management system documentation into a user-friendly information system available on the intranet that enables navigation starting from the visual representation of key business processes.

A cloud-based service was also opened for a trial period to support the submission and processing of staff proposals for changes to the management system.



Financial planning (contributions) 2016-2036



Internal communication

After a successful experiment involving two departments, internal communication was improved by the assignment of "Internal Communication Business Partners" providing advice and support to each department.

Blogs were established for communicating on long-lasting activities that evolve day by day, namely the move of Meteosat-8 over the Indian Ocean and the commissioning and operations ramp-up of Sentinel-3A.

Financial processes

The external audit of the EUMETSAT 2015 Annual Accounts was concluded with an unqualified opinion.

EUMETSAT used all market options to avoid being charged negative interest for funds under its direct responsibility and agreed changes of account with ESA to mitigate risks for ESA-managed funds.

As a result of the delays of the MTG development programme and the postponement of related expenditure, financial planning requires contributions of more than €500 million in the period 2017-2020, peaking above €600 million in 2018.

In order to give full visibility to Member States and staff on the capacity of the pension funds to cover projected liabilities, the scope of regular actuarial studies was expanded to address projections for the next 50 years in addition to the calculation of funding ratios used for accounting purposes. The results of the 2016 study will be used in 2017 to set objectives for pension funds and define appropriate asset management strategies.

Management and administration

Procurement process

Member States were familiarised with and consulted on procurement procedures through detailed presentations at meetings of the Administrative and Finance Group.

Industry days were held in Rome and Budapest to inform national industry on the procurement process and forthcoming opportunities.

An Industry Day held to present the procurements planned for the implementation of Pathfinder projects for big data services attracted 60 participants from 30 space and IT companies.

Main contracts and financial agreements approved by the Council

Capacity of a second transponder for the EUMETCast-Europe data broadcast system

Extension of EARS station support services in Maspalomas and Svalbard

Agreements with eight National Meteorological Services of Member States for the Third Continuous Development and Operations Phase of Satellite Application Facilities

Multi-vendor maintenance service for IT hardware used in operations

Extension of maintenance services for EPS ground systems

Extension of site infrastructure services for hosting ASCAT transponders

Risk reduction measures for the continuity of Meteosat Second Generation Primary Ground Station services beyond 2018

MTG integration, verification and validation support service

Extension of warranty of MTG mission data acquisition stations

Image navigation and registration software for the MTG-S instrument data processing facility

Agreement with DLR on the development of the Metop-SG METimage instruments

Mission control and operations subsegment of the EPS-SG ground segment

Payload data acquisition and processing subsegment of the EPS-SG ground segment

Agreement with CNES on support to the development of the 3MI processing chain of the EPS-SG payload data acquisition and processing subsegment.

Human resources management

The Staff Rules were amended to introduce temporary incapacity and partial invalidity and thus bridge gaps of the social security system. The re-procurement of social security services was initiated.

A health and wellness day was organised to help the full workforce learn how to deal with stress on the job.

The Early Career Programme had a successful start with the recruitment of four engineers under the age of 30 from 500 applicants, leading to the decision to open three more posts in 2017.

Other measures established in 2014 to counteract the observed ageing of the population of engineers achieved the recruitment of 51 staff under the age of 40 and increased the proportion of such recruitments to 68 percent.

On the other hand, an event organised to celebrate more than 20 years of service by more than 30 staff was the opportunity to exchange anecdotes about EUMETSAT history, and will be repeated in 2018 and 2020.

The staff training programme addressed inter alia project management in a multi-project environment and requirements and system engineering.



The Director-General and members of the Personnel Division welcome four young female engineers and scientists recruited under the Early Career Programme

General infrastructure and services

The unforeseen alignment of the MTG and EPS-SG development schedules increased pressure on office space for the accommodation of more staff and contractors working at EUMETSAT premises in the period 2017-2022.

Every possible way to optimise usage of available space was therefore explored, leading to the decision to build a dedicated onsite warehousing facility to free up space currently used for storage and use it for offices.

Nevertheless, it turned out that additional temporary building modules will be needed from 2018 onwards to host industrial teams during the overlapping tests of the MTG, EPS-SG and Jason-CS systems.

This was taken into account in a reassessment of the need for land for EUMETSAT premises, together with requirements arising from security regulations and EUMETSAT's foreseen involvement in additional Copernicus missions. The immediate need for one additional plot of land and for developing a strategy with the German authorities for the successive acquisition of other plots was unanimously confirmed by the Council and, on that basis, exploratory discussions were initiated with the Federal Republic of Germany and the Land of Hessen.

Internal ICT services evolved with the migration of the hosting of the SAP system to the platforms of a new contractor, the upgrades of the email system and the deployment of a new intranet platform to be rolled out in 2017. The latter offers blog and other innovative internal communication functionalities and will facilitate the generation of content and interoperability with tablets and smart phones.



Quality management

The ISO 9001:2008 certification was confirmed for another year, and the preparations for recertification against the new ISO 9001:2015 standard started with training of managers and quality engineers.

A new process and specific tools were developed and tested for assessing and controlling the quality of software. They will be used in 2017 to establish a full cartography of the quality of existing operations software and to attach quality metrics to new software.

Internal control

The threshold of transactions subject to independent *a priori* control by the financial control function was increased to €5,000, with the understanding that further increases will be considered for low-risk transactions in relation to downward delegation of the role of authorising officer.

A new Internal Audit Charter was published and the internal audit function was benchmarked against the Capability Model of the Institute of Internal Auditors. The benchmark concluded that the existing audit infrastructure and framework qualifies EUMETSAT for level 2 capability and provides a sound basis for reaching level 3, considered as the appropriate target for EUMETSAT within three years.

An "Anti-Fraud" e-learning system that enables the monitoring of training results and production of statistics was opened to all staff.

Management and administration

Risk management

Risk management focused on financial risks, cyber risks, continuity of operations in case of disaster and control of risks materialising at the end of development programmes that can no longer be mitigated by preventive measures.

In the exceptional circumstances of the unforeseeable realignment of the MTG and Metop-SG development schedules and expenditure profiles, a financing facility was proposed to Member States to mitigate the financial risk arising from the higher than anticipated, possibly unaffordable peak of contributions in the period 2017-2020.

In order to improve the management of cyber risks, the scope of the Information Security Management System was extended to all connected systems (internet of things) of the building infrastructure, two dedicated staff positions were opened, and a General Assembly was organised to raise awareness of all staff.

The isolation of operations systems from the open internet was reinforced, expert services were procured to monitor the continuous evolution of threats, and a security audit of the new SAP hosting service was performed.

An important cyber risk was removed by the activation of authentication of commands received on board the Metop spacecraft after making sure this would not hamper recoverability in case one satellite goes to safe mode.

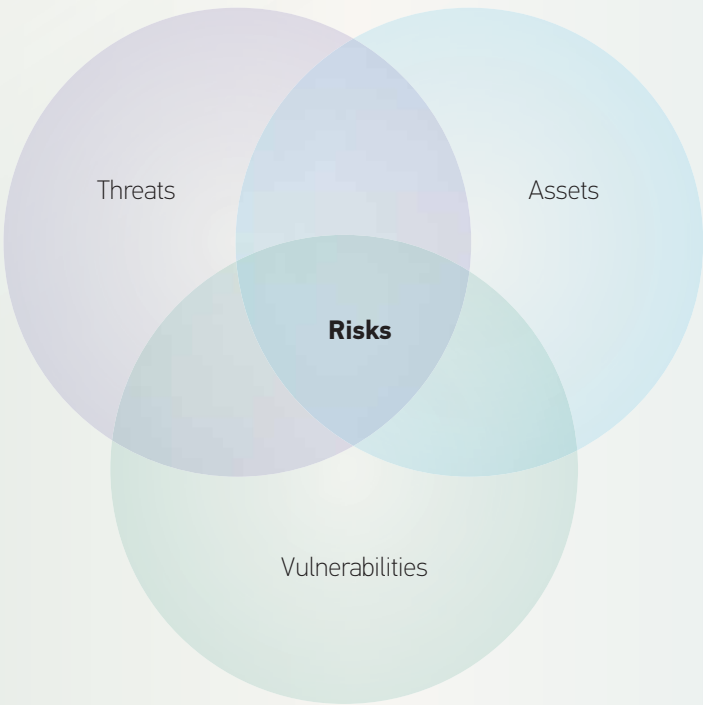
In the area of operations, anomalies affecting Metop sounding instruments and Meteosat satellites were investigated. One important outcome was the confirmation of a loose connection as the likely root cause of the anomaly of one telecommand receiver of Meteosat-10, in view of the observed temperature-related variations of its gain.

Operations continuity in case of disaster at headquarters was tested by a full mission control evacuation exercise and the activation of Meteosat and EPS-SG backup control centres from the Operations Evacuation Coordination Room hosted by the Deutscher Wetterdienst (DWD) in Offenbach. A sharp test also confirmed the performance of the automatic switch over to the emergency power supply systems.

In addition, requirements were established for the recovery of all generic infrastructure and services required to support continuity of core services to users and recovery measures started to be implemented.

In the area of development programmes, the focus was on the assessment of the feasibility and implications of repairing the GOME-2 instrument of Metop-C and on ensuring EUMETSAT's readiness to take over Sentinel-3A flight operations from ESA.

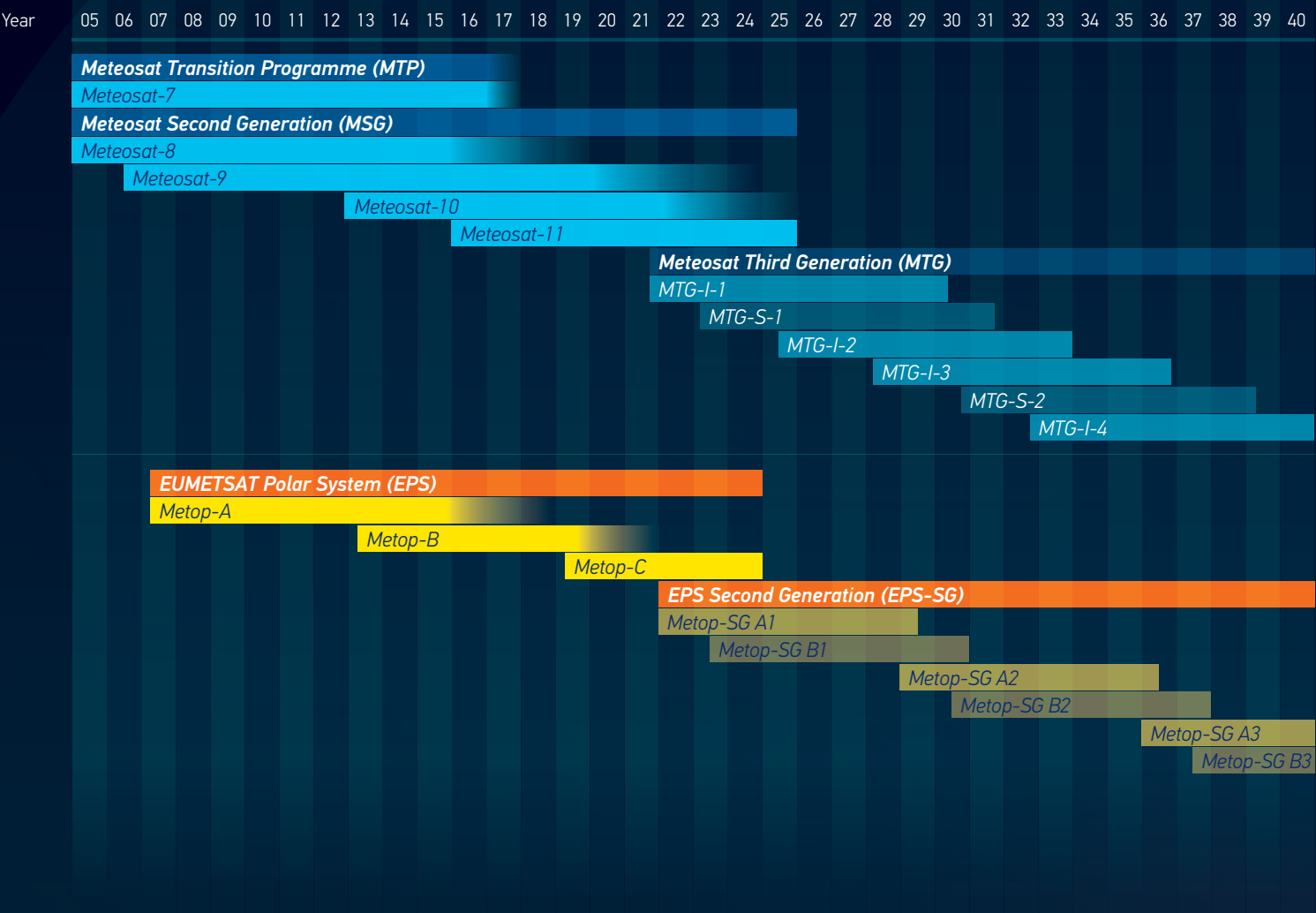
In the context of the early preparations for the International Telecommunication Union (ITU) World Radiocommunication Conference 2019, the Directors-General of ESA and EUMETSAT invited the European Commission to defer the selection of the 24.25-27.5GHz frequency band for the implementation of the "strategic roadmap towards 5G for Europe" until studies demonstrate compatibility with the indispensable use of this band by Earth stations for the acquisition of data from MTG and Metop-SG and other Earth observation satellites. A European 5G workshop involving industry, regulators and the Commission then acknowledged the need for appropriate provisions for protecting Earth stations.



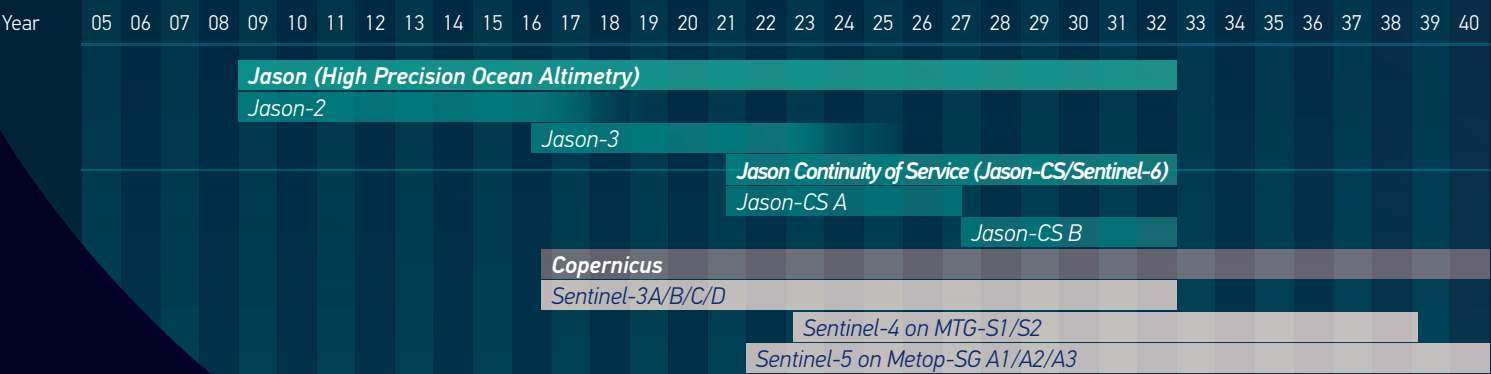
Key figures

EUMETSAT mission planning

Mandatory programmes



Optional and third-party programmes

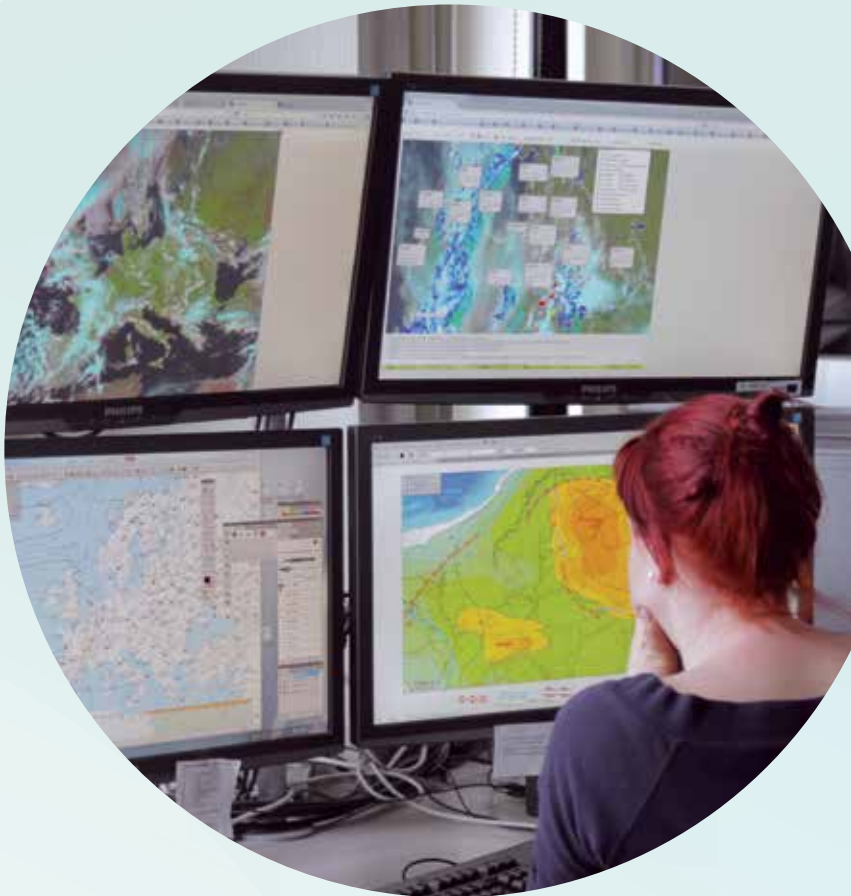


Key figures

The EUMETSAT user base

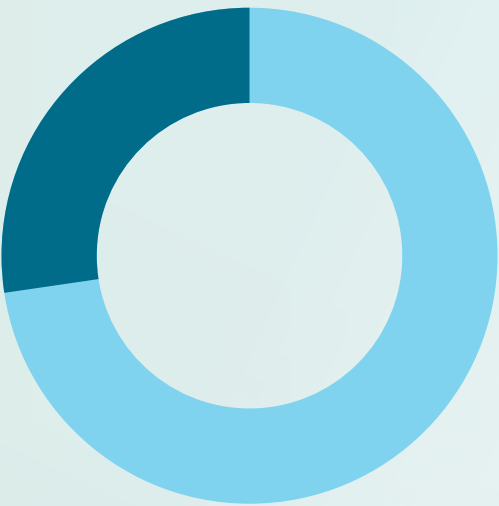
The EUMETSAT user base is comprised of users in the National Meteorological Services of its Member and Cooperating States, the ECMWF, international partners and a number of individual licensed users.

At the end of 2016 the number of licensed users was 2,049.



User enquiries

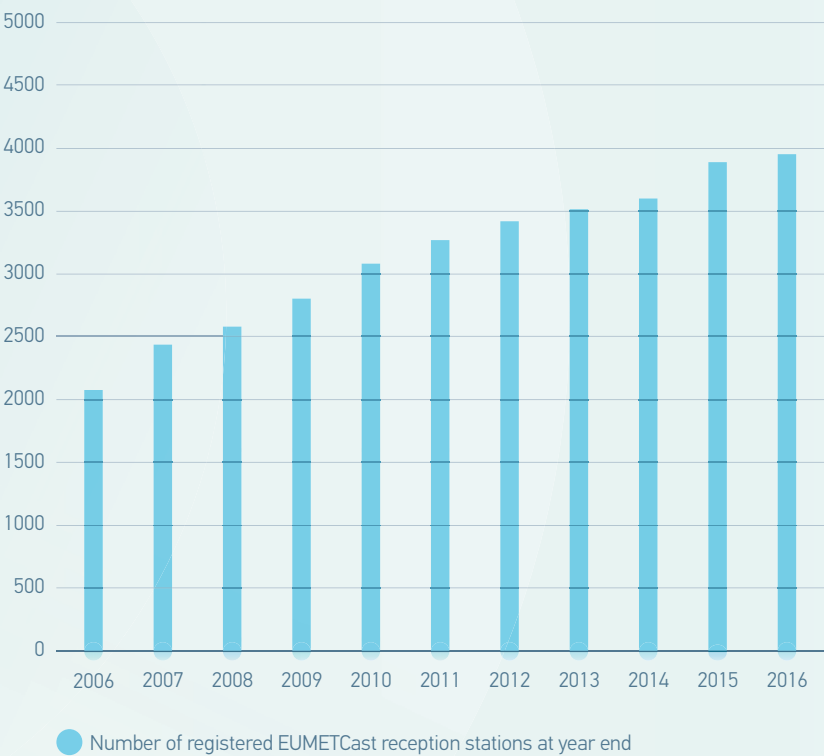
A total of 3,597 user enquiries was processed in 2016



Member and Cooperating States 71%
Other countries 29%

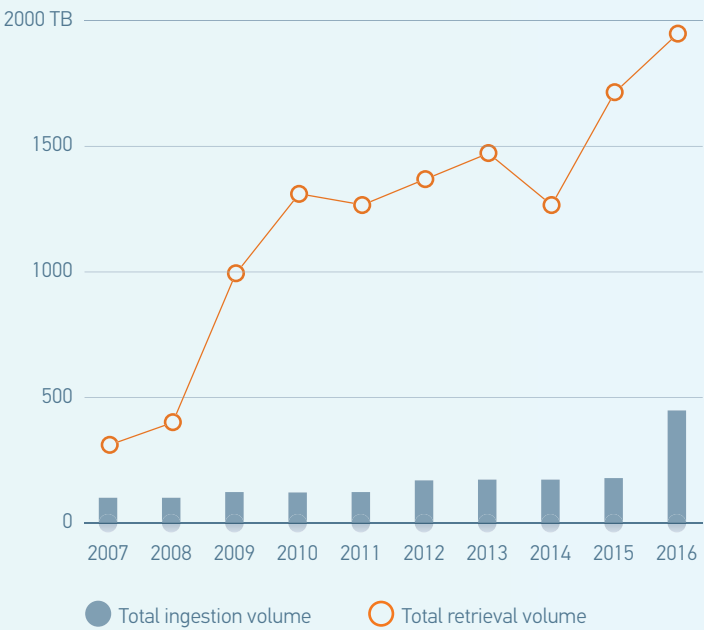
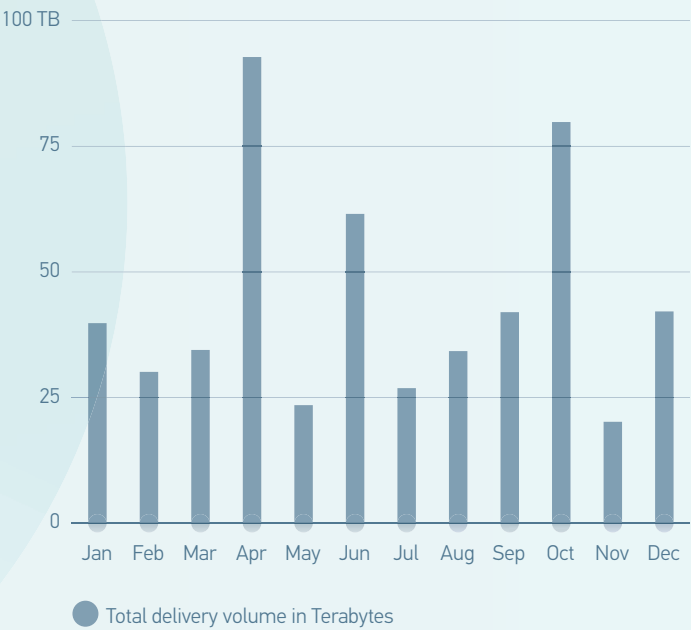
EUMETCast users

At the end of 2016 there were 2,876 registered users of EUMETCast, using a total of 3,972 reception stations, out of which 82 percent were located in Member States.



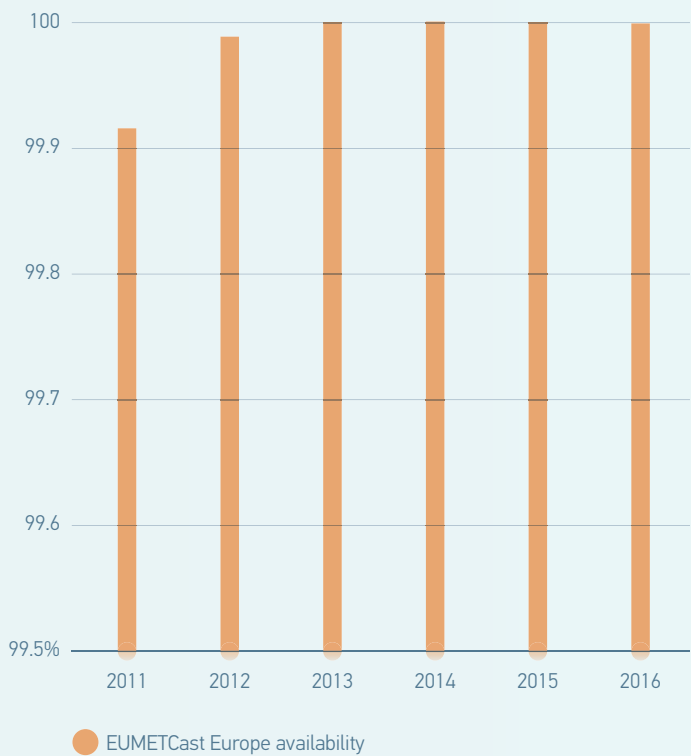
Data Centre users and orders

At the end of 2016 there were 6,180 registered users of archived data, as a result of an average 77 new registrations per month. On average, 261 users per month accessed the Data Centre Online Ordering Tool for search and ordering.

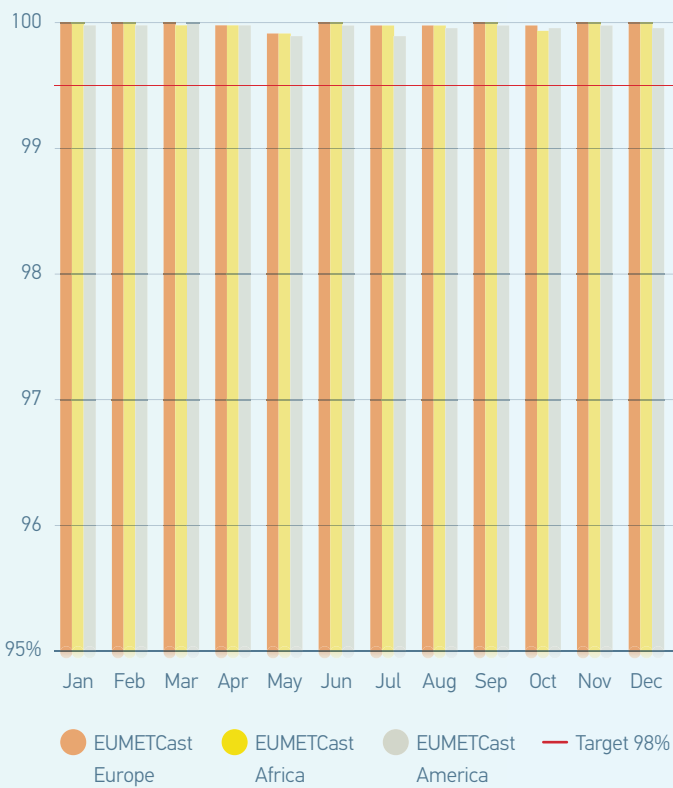


EUMETCast Europe availability 2011-2016

The availability of EUMETCast Europe remained at a record-breaking high level of 99.98 percent throughout 2016.



EUMETCast availability 2016

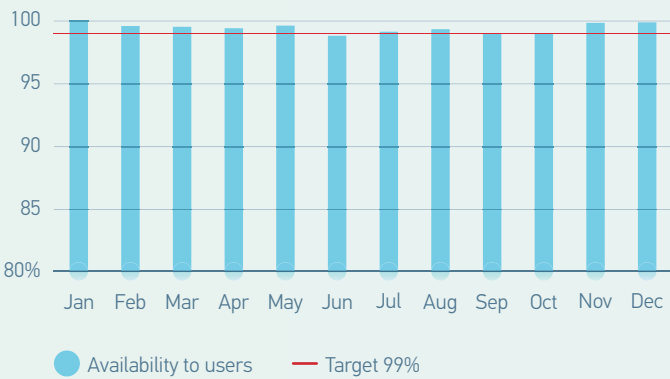


Key figures

Operational performance indicators

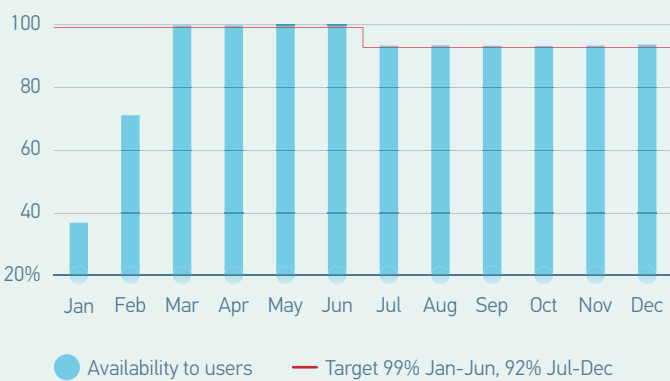
Availability of Meteosat SEVIRI Full Disc image data (0°)

The availability of the service was marginally below target in June, September and October due to a manoeuvre, a satellite safe mode, impacts of eclipse conditions and minor ground segment anomalies.



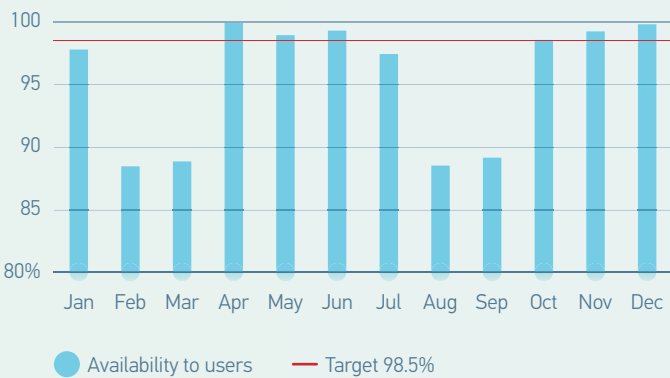
Availability of Meteosat SEVIRI Rapid Scan data (9.5°E)

The service was interrupted one month in January/February to preserve the life time of the Meteosat-9 scan mechanism, and its availability dropped mechanically by 7 percent after June, when monthly 48-hour interruptions could no longer be backed up by Meteosat-8 after the move of that satellite to the Indian Ocean.

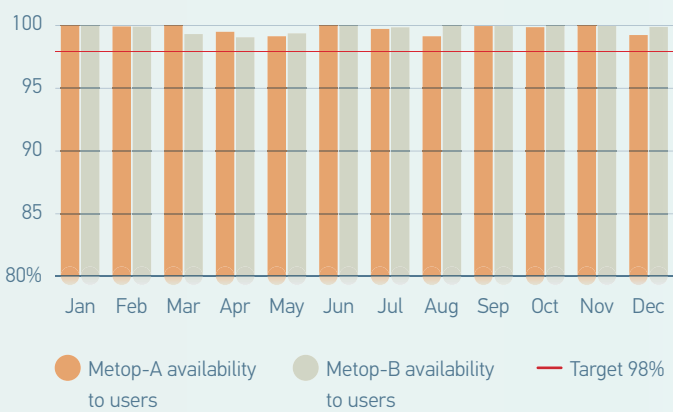


Availability of Meteosat IODC image data (57.5°E)

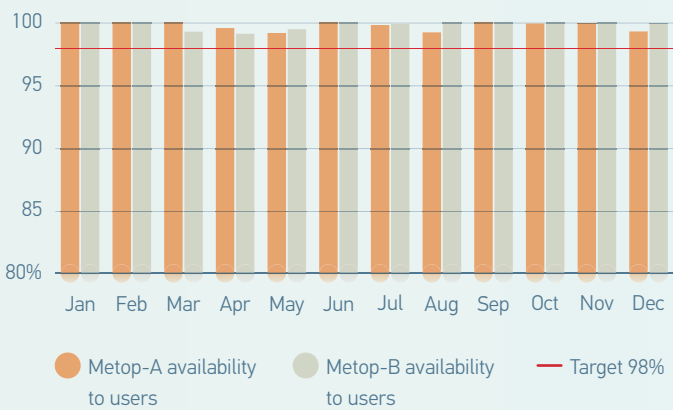
As usual, the availability of the service fell slightly below 90 percent during the demanding eclipse seasons, in February/March and August/September.



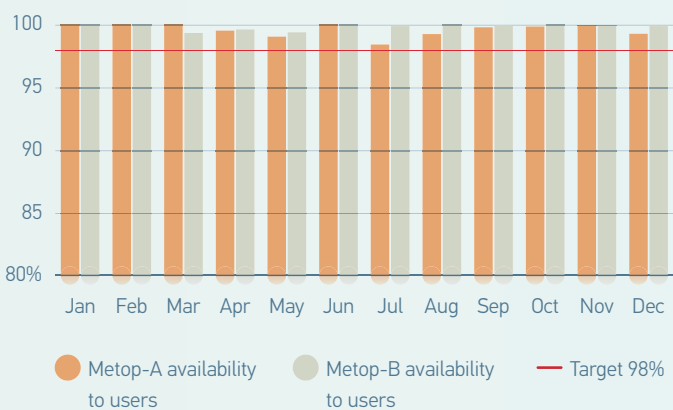
Availability of Metop AMSU level 1B BUFR data



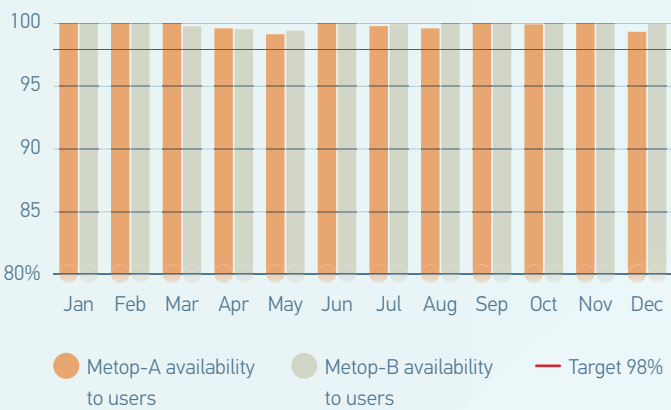
Availability of Metop MHS level 1B BUFR data



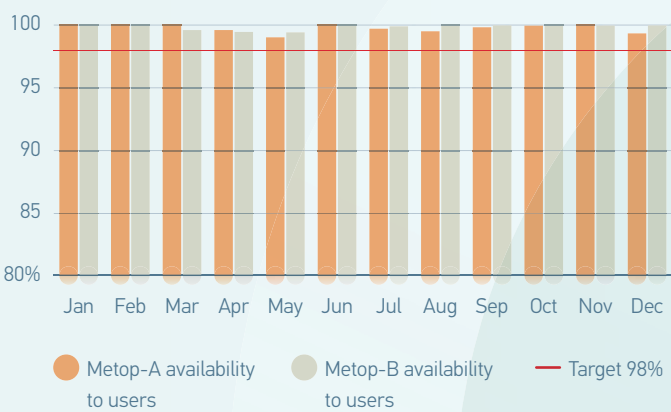
Availability of Metop ASCAT level 1B data



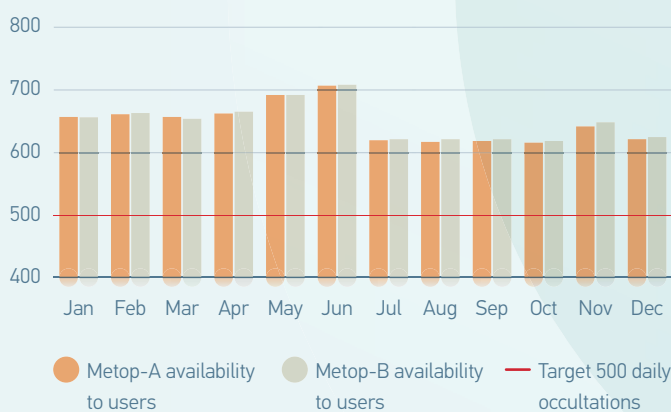
Availability of Metop AVHRR level 1B data



Availability of Metop GOME-2 level 1B data

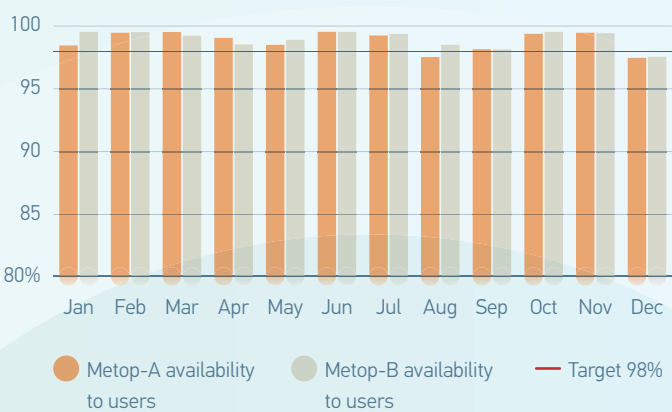


Availability of Metop GRAS level 1B data



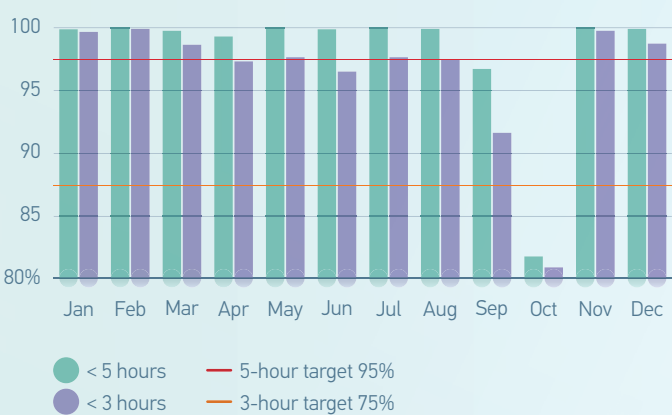
Availability of Metop IASI level 1C BUFR data

The availability of IASI data services was marginally below target for Metop-A in August, due to a satellite manoeuvre and in December due to exceptional external calibration operations using the moon as reference target.



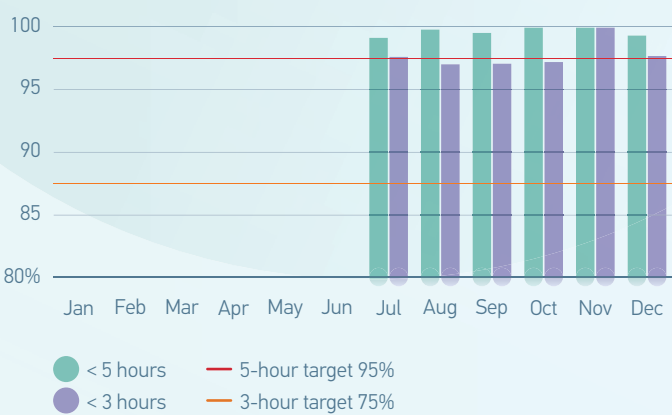
Availability of Jason-2 operational geophysical data records

The availability of the Jason-2 Near-Real-Time data services dropped below target in September due to an equipment problem at the data acquisition station and in October when the service was interrupted for manoeuvring the satellite towards the "interleaved" orbit.



Availability of Jason-3 operational geophysical data records

The Jason-3 operational Near-Real-Time data services started on 1 July 2016.

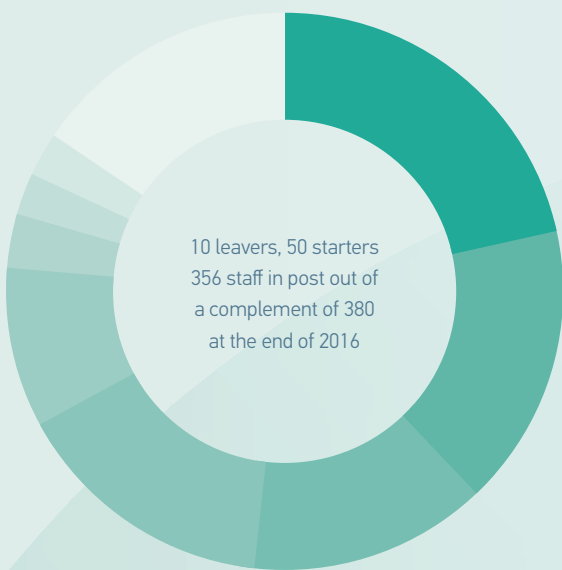


Key figures

Human resources

Staff in post

31 December 2016

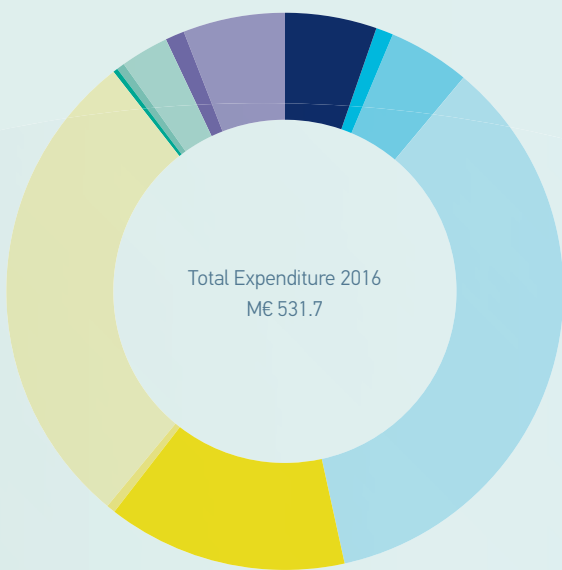


Germany	21.45%	Netherlands	3.09%
France	16.29%	Belgium	2.53%
United Kingdom	14.89%	Portugal	2.53%
Italy	14.33%	Other	15.45%
Spain	9.27%		

Financial information

Expenditure Budgets

Total Expenditure 2016



GB	M€	28.3	Jason-2	M€	0.5
MTP	M€	5.5	Jason-3	M€	2.5
MSG	M€	25.1	Jason-CS	M€	15.4
MTG	M€	188.5	Sentinel-3	M€	5.8
EPS	M€	74.8	Copernicus	M€	31.5
EPS-SG PP	M€	1.7			
EPS-SG	M€	152.1			



Financial information

EUMETSAT's 2016 Financial Statement has been audited by the Bundesrechnungshof. The following tables, in K€, are a summary of the information for 2016 included in those accounts.

Summary Revenue and Expenses

	KEUR
Revenue	
Member & Cooperating State Contributions	432,304
Other Contributions	30,500
Tax on Salary	7,354
Sales Revenue	2,017
Other Revenue	59,022
Asset Impairments	0
Total Revenue	531,196
Expenses	
Costs for Human Resources	135,006
Other Operating Expenses	10,509
Satellites related costs	31,735
SAF, Prospective Activities, Research Fellows	11,997
Depreciation	108,130
Asset Impairments	0
Total Expenses	297,377
Revenue from Financial Operations	126
Net surplus for the period	233,945
Surplus to be distributed to Member and Cooperating States	19,611
Result Allocated to Reserves	214,333

Summary Balance Sheet

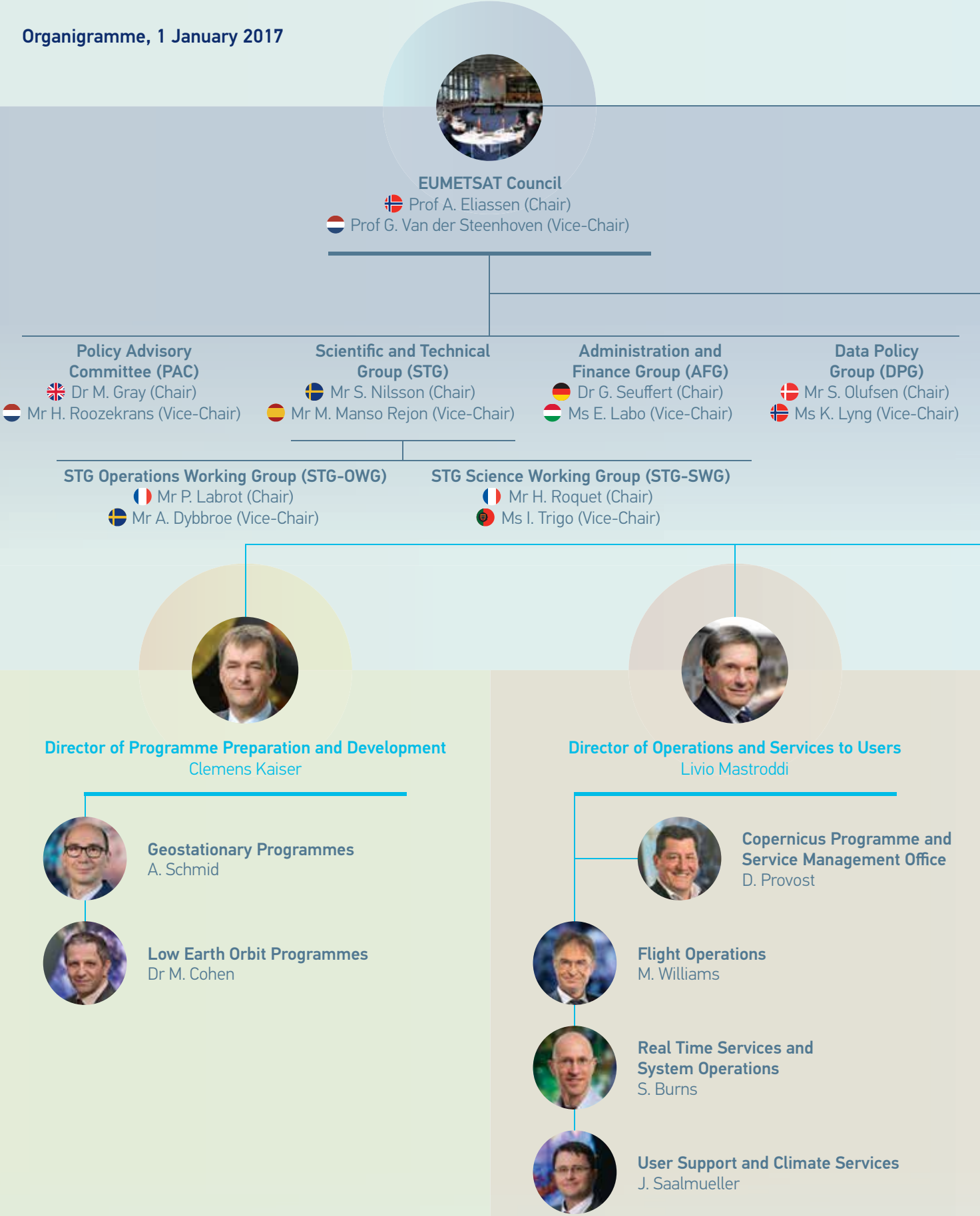
	KEUR
Assets	
Current Assets	904,436
Non-Current Assets	2,191,296
Total Assets	3,095,733
Liabilities	
Current Liabilities	702,392
Non-Current Liabilities	303,398
Total Liabilities	1,005,790
Total Net Assets/Equity	2,089,943
Total Liabilities & Net Assets/Equity	3,095,733

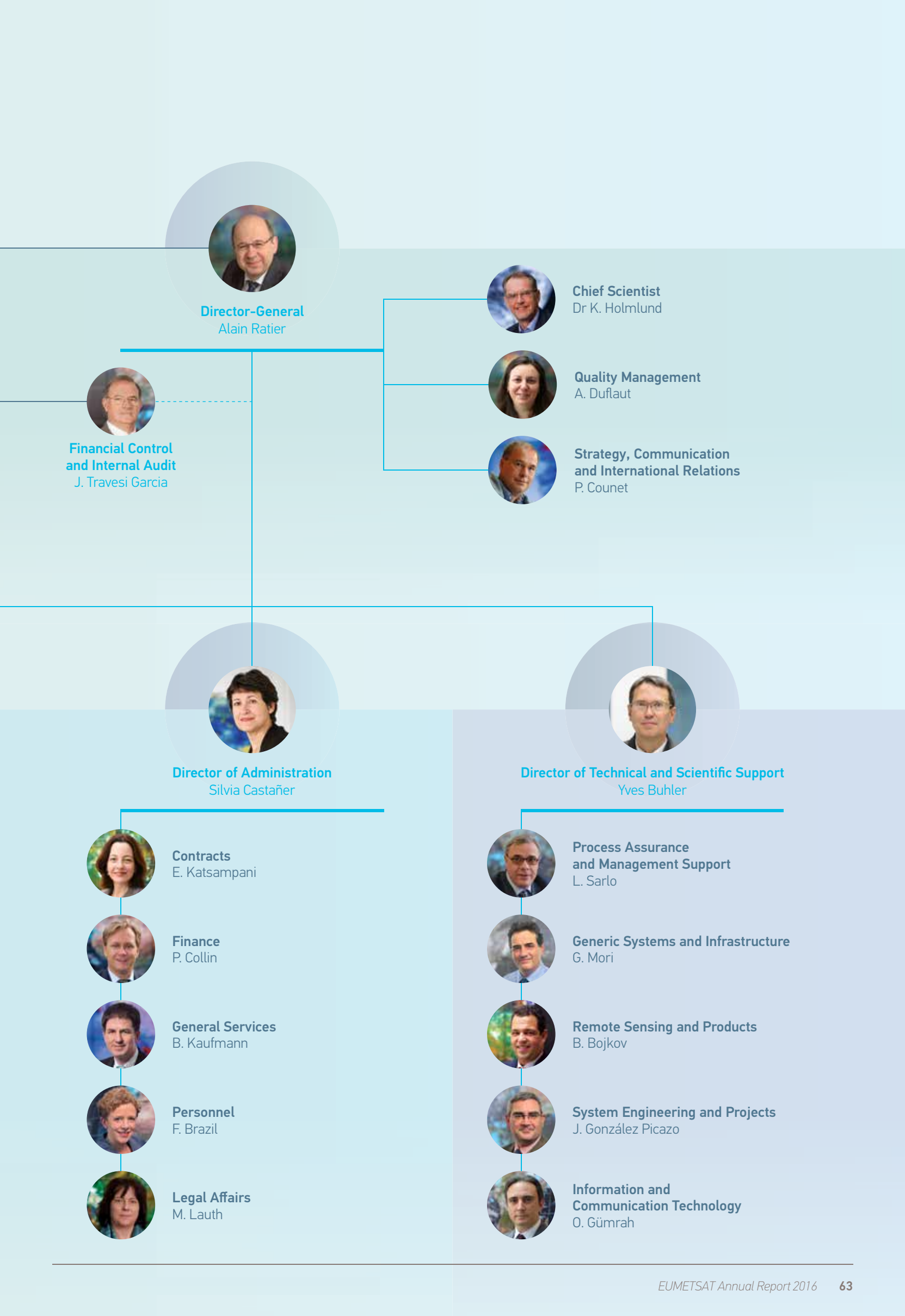
Member and Cooperating State Contributions

	KEUR
Member State Contributions	
Austria	9.036
Belgium	10.996
Bulgaria	1.104
Croatia	1.266
Czech Republic	4.167
Denmark	7.601
Estonia	449
Finland	5.800
France	63.137
Germany	81.990
Greece	6.042
Hungary	2.716
Iceland	272
Ireland	3.951
Italy	47.763
Latvia	598
Lithuania	917
Luxembourg	886
Netherlands	18.452
Norway	11.081
Poland	10.403
Portugal	5.070
Romania	3.764
Slovakia	1.970
Slovenia	1.045
Spain	30.422
Sweden	12.091
Switzerland	14.828
Turkey	17.641
United Kingdom	56.415
Total Member State Contributions	431,873
Cooperating State Contributions	
Serbia	431
Total Cooperating State Contributions	431
Total Member and Cooperating State Contributions	432,304

Appendix

Organigramme, 1 January 2017





Appendix

EUMETSAT Council Delegates and Advisors, 1 January 2017



Austria

Dr M. Staudinger Zentralanstalt für
Meteorologie und
Geodynamik (ZAMG)

Mr L.A. Berset Österreichische
Forschungsförderungs-
gesellschaft



Belgium

Dr D. Gellens Insitut Royal
Météorologique (IRM)

Mr P. Rottiers Belgian Science
Policy Office



Bulgaria

Prof H. Branzov National Institute
of Meteorology
and Hydrology (NIMH)

Prof C. Georgiev NIMH



Croatia

Dr N. Strelec Mahovic Meteorological and
Hydrological Service
(DHMZ)



Czech Republic

Mr V. Dvořák Czech Hydrometeor-
ological Institute



Denmark

Ms M. Thyrring Danish Meteorological
Institute (DMI)



Estonia

Mr T. Ala Estonian Environment
Agency



Finland

Prof J. Damski Finish Meteorological
Institute (FMI)



France

Mr J.-M. Lacave Météo-France

Ms A. Debar Météo-France

Ms L. Desmaizieres Météo-France

Ms I. Bénézeth Ministère de L' Ecologie,
du Développement
durable et de l'Energie

Ms C. Carretta Centre National d'Etudes
Spatiales (CNES)



Germany

Prof Dr G. Adrian Deutscher Wetterdienst
(DWD)

Dr M. Rohn DWD

Dr G. Seuffert Bundesministerium für
Verkehr und digitale
Infrastruktur

Mr T. Ruwwe Deutsches Zentrum für
Luft-und Raumfahrt (DLR)



Greece

Mr I. Georgiou Hellenic National
Meteorological Service
(HNMS)

Mr C. Karvelis HNMS

Mr G. Alexakis HNMS

Mr A. Parallis HNMS



Hungary

Ms K. Radics Hungarian Meteorological
Service (OMSZ)

Ms E. Labo OMSZ

Dr F. Tari Hungarian Space Office



Iceland

Dr A. Snorrason Icelandic Meteorological
Office (IMO)



Ireland

Mr E. Moran Met Éireann



Italy

Col. S. Cau Aeronautica Militare

Dr A. Bartolini Ministero dell'Economia
e delle Finanze

Dr F. Battazza Agenzia Spaziale Italiana

EACCS Chairperson (Serbia), ECMWF, ESA, EUMETNET, European Commission, NOAA, WMO



Latvia

Mr A. Viksna


Latvian Environment,
Geology and Meteorology
Centre



Lithuania

Mr S. Balys

Lithuanian
Hydrometeorological
Service



Luxembourg

Ms M. Reckwerth

MeteoLux,
Administration de la
navigation aérienne



Netherlands

Mr G. Van der Steenhoven

Koninklijk Nederlands
Meteorologisch Instituut
(KNMI)



Norway

Prof A. Eliassen

Council Chairperson

Mr R. Skalin

Norwegian Meteorological
Institute (Met.no)

Mr J. Sunde

Met.no

Mr E. A. Herland

Norwegian Space Centre



Poland

Dr P. Lagodzki

Institute for Meteorology
and Water Management
(IMGW)

Dr P. Struzik

IMGW

Mr M. Sztobryn

Ministry of Environment

Ms A. Dlugosz

Polish Space Agency



Portugal

Prof M. Miranda

Istituto Portugues do Mar
e da Atmosfera (IPMA)

Dr P. Viterbo

IPMA



Romania

Ms E. Mateescu

National Meteorological
Administration (RNMA)

Dr G. Stancalie


RNMA



Slovak Republic

Dr M. Benko

Slovak Hydrometeorol-
ogical Institute



Slovenia

Dr K. Bergant

Slovenia Environmental
Agency



Spain

Mr M.A. LÓpez González

Agencia Estatal de
Meteorologia (AEMET)

Dr F. Belda

AEMET

Mr M. Palomares

AEMET

Mr J. Gonzalez

AEMET

Mr E. Vez-Rodriguez

Centro para el Desarrollo
Tecnologico Industrial



Sweden

Mr R. Brennerfelt

Swedish Meteorological
and Hydrological Institute


Mr S. Nilsson

(SMHI)

Ms B. Aarhus Andrae

SMHI

SMHI



Switzerland

Dr P. Binder

MeteoSwiss



Turkey

Mr I. Gunes

Turkish State
Meteorological Service

Mr E. Erdi

Turkish State
Meteorological Service

Mr E. Aydin

Turkish State
Meteorological Service



United Kingdom

Mr R. Varley

Met Office

Mr B. Truscott

Met Office

Mr S. Turner

Met Office

Mr M. Gray

Met Office

Appendix

Participation in major external events

96 th American Meteorological Society Annual Meeting	10-14 January
8 th Conference on European Space Policy	12-13 January
WMO Consultative Meeting on High-Level Policy on Satellite Matters	28-29 January
MESA 5 th PSC Meeting	7-12 February
GCOS Science Conference	2-4 March
EU-Japan Space Policy Dialogue	9 March
21 st session of the Atmospheric Observation Panel for Climate (AOPC-21)	5-8 April
Copernicus Value Chain Workshop	25-27 April
31 st meeting of the CEOS Strategy Implementation Team	18-20 April
EU-ESA Informal Space Ministerial Meeting	30 May
European Space Solutions conference	30 May -3 June
68 th meeting of the WMO Executive Council	15-24 June
ESA High Level Forum	20 June
44 th CGMS Plenary Session	5-10 June
2 ^{eme} Conseil Ministériel Afrique Centrale de la Météorologie	29 July
ESA Arctic and Space Workshop	6 September
18 th Plenary session of the European Interparliamentary Space Conference	3-4 October
24 th Session of the GCOS Steering Committee	6 October
Asia/Oceania Meteorological Satellite Users' Conference – AOMSUC-7	21-28 October
9 th Session of the Africa Working Group on Disaster Risk Reduction	25-26 October
30 th CEOS Plenary meeting	31 October -5 November
GEO-XIII Plenary meeting	7-10 November
Copernicus In Situ Coordination Workshop	09 November
Launch of the GMES & Africa project	25 November

Scientific and technical publications

Abdalla, S., **Bojkov, B.**, 2016. Assessment of Total Column Water Vapour Products from ERS and Envisat Missions. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Abdalla, S., **Dinardo, S.**, Benveniste, J., Janssen, P., 2016. Validation of CryoSat-2 SAR wind and wave products. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Ambrosini, M., 2016. GPS Precise Relative Positioning of Formation Flying Satellites: GPS Advanced Data Processing Methods using SW Tools for the Precise Relative Positioning of Formation Flying Satellites. *Lambert Academic Publishing.*

August, T., Hultberg, T., Crapeau, M., Goukenleuque, C., O'Carroll, A., Klaes, D., Munro, R., Clerbaux, C., Coheur, P., Hurtmans, D., 2016. The operational IASI L2 v6 products at EUMETSAT: Status, applications and evolutions. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES.*

Bonekamp, H., Montagner, F., Santasesaria, V., **Nogueira Loddo, C., Wannop, S., Tomažić, I., O'Carroll, A., Kwiatkowska, E., Scharroo, R., Wilson, H.**, 2016. Core operational Sentinel-3 marine data product services as part of the Copernicus Space Component. *Ocean Sci. 12, 787–795.*

Borde, R., Hautecoeur, O., Carranza, M., 2016. EUMETSAT Global AVHRR Wind Product. *J. Atmos. Ocean. Tech. 33, 429–438.*

Borde, R., Hautecoeur, O., Heas, P., 2016. Extraction of 3D Wind Profiles From IASI Level2 Products. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES.*

Borde, R., Carranza, M., Hautecoeur, O., 2016. Current status of EUMETSAT operational winds. *13th Int. Winds Workshop, Monterey, USA.*

Bouchez, E., Legendre, M., Murolo, F., Perin, R., 2016. Operational Validation of the MTG multi-satellite system. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Boylan, P., Wang, J., Cohn, S., **Hultberg, T., August, T.**, 2016. Identification and intercomparison of surface-based inversions over Antarctica from IASI, ERA-Interim, and Concordiasi dropsonde data. *J. Geophys. Res.: Atmos. 121, 9089–9104.*

Carranza, M., Borde, R., Hayashi, M., 2016. Generation of Himawari-8 AMVs using the future MTG AMV processor. *13th Int. Winds Workshop, Monterey, USA.*

Chung, E.-S., Soden, B.J., Huang, X., Shi, L., **John, V.**, 2016. An assessment of the consistency between satellite measurements of upper tropospheric water vapor. *J. Geophys. Res.: Atmos. 121, 2874–2887.*

Cocchiara, C., 2016. Mars Analogue Mission Crew 159 at MDRS: Christmas on Mars. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Coppens, D., Theodore, B., Gigli, S., Fowler, G., Stuhlmann, R., 2016. MTG-IRS instrument and level 1 processing overview. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES.*

Cotton, P., Andersen, O., Stenseng, L., Boy, F., Cancet, M., Cipolini, P., Gommenginger, C., **Dinardo, S.**, Egido, A., Fernandes, M., Garcia, P., Moreau, T., Naeije, M., **Scharroo, R., Lucas, B.**, Benveniste, J., 2016. Improved oceanographic measurements from SAR altimetry: Results and scientific roadmap from ESA cryosat plus for oceans project. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Crapeau, M., August, T., Hultberg, T., Goukenleuque, C., Klaes, D., 2016. Validation and monitoring of the IASI L2 products at EUMETSAT. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES.*

Dinardo, S., Fenoglio-Marc, L., Buchhaupt, C., **Scharroo, R.**, Fernandes, M., Benveniste, J., Becker, M., 2016. Coastal SAR and PLRM Altimetry in German Bight and West Baltic Sea. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Dinardo, S., Scharroo, R., Bonekamp, H., Lucas, B., Loddo, C., Benveniste, J., 2016. A preliminary assessment of the S-3A SRAL performances in SAR mode. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Doutriaux-Boucher, M., Zeder, J., **Lattanzio, A., Khlystova, I.**, 2016. Break and trend analysis of EUMETSAT Climate Data Records. *EGU General Assembly 2016, Vienna, Austria, Eur. Geophys. Union.*

Doutriaux-Boucher, M., Lattanzio, A., Borde, R., Hautecoeur, O., Schulz, J., 2016. Reprocessing of Atmospheric Motion Vectors at EUMETSAT. *13th Int. Winds Workshop, Monterey, USA.*

Dufour, E., Klonecki, A., Standfuss, C., Tournier, B., Serio, C., Masiello, G., **Tjemkes, S., Stuhlmann, R.**, 2016. Assessment of infrared sounder radiometric noise from analysis of spectral residuals. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Edwards, T., 2016. Multi-Mission Elements and their use in Enhanced Management Reporting at EUMETSAT. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Esdar, T., Martinez Fadrique, F., Reed, S., 2016. Today's ground segment software development challenges. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Fenoglio-Marc, L., Buchhaupt, C., **Dinardo, S., Scharroo, R.**, Benveniste, J., Becker, M., 2016. Retrieval of short scale geophysical signals and improved coastal data from SAR satellite altimetry. *EGU General Assembly 2016, Vienna, Austria, Eur. Geophys. Union.*

Appendix

Scientific and technical publications

Fowler, G., Gigli, S., Patterson, T., 2016. The MTG Infrared Sounder Level 1B Dataset. *EUMETSAT Meteorolog. Satellite Conf.*, Darmstadt, Germany, EUMETSAT.

Garcia, O., Sepulveda, E., Schneider, M., Hase, F., **August, T.**, Blumenstock, T., Kühl, S., **Munro, R.**, Gomez-Pelaez, A., **Hultberg, T.**, Redondas, A., Barthlott, S., Wiegele, A., Gonzalez, Y., Sanroma, E., 2016. Consistency and quality assessment of the Metop-A/IASI and Metop-B/IASI operational trace gas products (O₃, CO, N₂O, CH₄, and CO₂) in the subtropical North Atlantic. *Atmos. Meas. Tech.* 9, 2315–2333.

Grzegorski, M., Munro, R., Poli, G., Holdak, A., Lang, R., 2016. A new operational EUMETSAT product for the retrieval of aerosol optical properties over land (PMAp v2). *EGU General Assembly 2016*, Vienna, Austria, *Eur. Geophys. Union*.

Govaerts, Y., Quast, R., **Rüthrich, F.**, Giering, R., **Roebeling, R.**, 2016. Recovery of MVIRI/VIS Band Spectral Response. *EUMETSAT Meteorolog. Satellite Conf.*, Darmstadt, Germany.

Hadji-Lazaro, J., Boonne, C., Clerbaux, C., George, M., Clarisse, L., Van Damme, M., Whitburn, S., Hurtmans, D., Coheur, P., **August, T., Hultberg, T., Crapeau, M.**, 2016. Monitoring of atmospheric composition with IASI/MetOp Sounders : ULB/ LATMOS data in open access via Ether website. *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Hassinen, S., Balis, D., Bauer, H., Begoin, M., Delcloo, A., Eleftheratos, K., Gimeno Garcia, S., Granville, J., Grossi, M., Hao, N., Hedelt, P., Hendrick, F., Hess, M., Heue, K.-P., Hovila, J., Jønych-Sørensen, H., Kalakoski, N., Kauppi, A., Kiemle, S., Kins, L., Koukouli, M.E., Kujanpää, J., Lambert, J.-C., **Lang, R.**, Lerot, C., Loyola, D., Pedergrana, M., Pinardi, G., Romahn, F., Van Roozendael, M., Lutz, R., De Smedt, I., Stammes, P., Steinbrecht, W., Tamminen, J., Theys, N., Tilstra, L.G., Tuinder, O.N.E., Valks, P., Zerefos, C., Zimmer, W., Zyrichidou, I., 2016. Overview of the O3M SAF GOME-2 operational atmospheric composition and UV radiation data products and data availability. *Atmos. Meas. Tech.* 9, 383–407.

Hautecoeur, O., Borde, R., 2016. Derivation of wind vectors from Metop AVHRR at EUMETSAT. *13th Int. Winds Workshop*, Monterey, USA.

Hautecoeur, O., Heas, P., **Borde, R.**, 2016. Extraction of 3D wind profiles from IASI level 2 products. *13th Int. Winds Workshop*, Monterey, USA

Hewison, T., 2016. Prime GSICS Corrections, using double-differences of IASI-A and -B against the IR channels of Meteosat/SEVIRI. *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Hewison, T., Jouglet, D., Jacquette, E., Tobin, D., 2016. Defining IASI as the Primary Reference for the Global Space-based Inter-Calibration System (GSICS). *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Holmlund, K., Burns, S., Gonzalez, J., Mora, B., 2016. EUMETSAT — From Science to Operations. *96th AMS Annual Meeting*, New Orleans, United States, *Americ. Met. Soc.*

Holmlund, K., Klaes, D., Munro, R., Montagner, F., Grandell, J., Hanson, C., Rota, S., Cohen, M., Stuhlmann, R., Schlüssel, P., 2016. Providing Continuity into the Future: EUMETSAT Next Generation Meteorological Satellites. *96th AMS Annual Meeting*, New Orleans, United States, *Americ. Met. Soc.*

Holmlund, K., Schlüssel, P., Stuhlmann, R., Schüller, L., Schmetz, J., Cohen, M., Rota, S., Klaes, D., 2016. Status of EUMETSAT Satellite Programs: Towards the Next Generation Meteorological Satellites (Invited Presentation). *96th AMS Annual Meeting*, New Orleans, United States, *Americ. Met. Soc.*

Horny, M., Gonzalez, J., Mori, G., Burns, S., 2016. Multi-Mission Elements: Key Ground Systems Services for EUMETSAT Future Programmes. *96th AMS Annual Meeting*, New Orleans, United States, *Americ. Met. Soc.*

Hultberg, T., August, T., 2016a. IASI, CrIS, IASI-NG and MTG IRS PC compression - how to handle multiple detectors with different characteristics. *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Hultberg, T., August, T., 2016b. PWLR3 - exploiting horizontal correlation in PieceWise Linear Regression. *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Hultberg, T., August, T., 2016c. What is the error? *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Jacquette, E., Maraldi, C., Tournier, B., Standfuss, C., **Coppens, D.**, Delatte, B., Baque, C., Calvel, J., Buffet, L., Vandermarq, O., 2016. IASI performance assessment after permanent cube corner compensation device stop. *4th IASI Conf.*, Antibes Juan-Les-Pins, France, CNES.

Jia, Y., Savi, P., Canone, D., **Notarpietro, R.**, 2016. Estimation of Surface Characteristics Using GNSS LH-Reflected Signals: Land Versus Water. *IEEE J. Sel. Topics Appl. Earth Observ. in Remote Sens.*

Khanafseh, S., Pervan, S., **Von Engel, A.**, 2016. Tropospheric Duct Anomaly Threat Model for High Integrity and High Accuracy Navigation. *29th Int. Tech. Meeting of the Satellite Division of the Institute of Navigation*, 2016, Portland, United States.

Klaes, D., Holmlund, K., 2016. An update on EUMETSAT programmes and plans, in: SPIE Proceedings. *Earth Observing Systems Conf.*, San Diego, United States.

Kokhanovsky, A., 2016. Light Scattering Reviews, Vol.11: Light Scattering and Radiative Transfer. *Springer*.

Kokhanovsky, A., Munro, R., 2016. Cloud top height retrieval using the imaging polarimeter (3MI) top-of-atmosphere reflectance measurements in the oxygen absorption band. *EGU General Assembly 2016*, Vienna, Austria, *Eur. Geophys. Union*.

Koner, P., Harris, A., **Dash, P.**, 2016. A Deterministic Method for Profile Retrievals from Hyperspectral Satellite Measurements. *IEEE Trans. Geosci. Remote Sens.* 54, 5657–5670.

Kottayil, A., **John, V.**, Buehler, S., Mohanakumar, K., 2016. Evaluating the Diurnal Cycle of Upper Tropospheric Humidity in Two Different Climate Models Using Satellite Observations. *Remote Sens.* 8, 325.

Kwiatkowska, E., Ruddick, K., Ramon, D., Vanhellemont, Q., Brockmann, C., Lebreton, C., **Bonekamp, H.**, 2016. Ocean colour opportunities from Meteosat Second and Third Generation geostationary platforms. *Ocean Sci.* 12, 703–713.

Larsson, R., Milz, M., Rayer, P., Saunders, R., Bell, W., Booton, A., Buehler, S., Eriksson, P., **John, V.**, 2016. Modeling the Zeeman effect in high-altitude SSMIS channels for numerical weather prediction profiles: Comparing a fast model and a line-by-line model. *Atmos. Meas. Tech.* 9, 841–857.

Lelli, L., Gimeno Garcia, S., Sanders, A., Snee, M., Rozanov, V., **Kokhanovsky, A.**, Loyola, D., Burrows, J., 2016. Science verification of operational aerosol and cloud products for TROPOMI on Sentinel-5 precursor. *EGU General Assembly 2016, Vienna, Austria, Eur. Geophys. Union.*

Lindsley, R., **Anderson, C.**, **Figa Saldana, J.**, Long, D., 2016. A Parameterized ASCAT Measurement Spatial Response Function. *IEEE Trans. Geosci. Remote Sens.* 5, 4570–4579.

Loew, A., Bennartz, R., Fell, F., **Lattanzio, A.**, **Doutriaux-Boucher, M.**, **Schulz, J.**, 2016. A database of global reference sites to support validation of satellite surface albedo datasets (SAVS 1.0). *Earth Syst. Sci. Data* 8, 425–438.

Manninen, T., Riihelä, A., Schaaf, C., Key, J., **Lattanzio, A.**, 2016. Intercalibration of Two Polar Satellite Instruments without Simultaneous Nadir Observation. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Marbach, T., Fougnie, B., **Lacan, A.**, **Schlüssel, P.**, 2016. Vicarious calibration of the multiviewing channel polarisation imager (3MI) of the EUMETSAT Polar System-Second Generation (EPS-SG). *SPIE Proceed.*

Marston, K., 2016. Multi-Mission Elements: White Elephant or Essential Business Sense? *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Marzano, F., **Mattioli, V.**, Milani, L., Magde, K., Brost, G., 2016. Sun-tracking microwave radiometry: All-weather estimation of atmospheric path attenuation at Ka, V and W band. *IEEE Trans. Antennas Propag.* 64, 4815–4827.

Marzano, F., Milani, L., **Mattioli, V.**, Magde, K., Brost, G., 2016. Retrieval of precipitation extinction using ground-based sun-tracking millimeter-wave radiometry. *2016 IEEE Int. Geoscience and Remote Sensing Symposium (IGARSS), Beijing, China.*

Mattioli, V., Milani, L., Magde, K., Brost, G., Marzano, F., 2016. Retrieval of Sun Brightness Temperature and Precipitating Cloud Extinction Using Ground-Based Sun-Tracking Microwave Radiometry. *IEEE J. Sel. Topics Appl. Earth Observ. and Remote Sens.*

Mertikas, S., Donlon, C., Mavrokordatos, C., **Bojkov, B.**, Femenias, P., Paminello, T., Picot, N., Desjonqueres, J., Andersen, O., 2016. A fiducial reference site for satellite altimetry in Crete, Greece. *Living Planet Symposium 2016, Prague, Czech Republic, ESA.*

Munro, R., **Lang, R.**, **Klaes, D.**, **Poli, G.**, **Retscher, C.**, **Lindstrot, R.**, **Huckle, R.**, **Lacan, A.**, **Grzegorski, M.**, **Holdak, A.**, **Kokhanovsky, A.**, Livschitz, J., Eisinger, M., 2016. The GOME-2 instrument on the Metop series of satellites: instrument design, calibration, and level 1 data processing - an overview. *Atmos. Meas. Tech.* 9, 1279–1301.

Murolo, F., **Dammann, K.**, **Burns, S.**, 2016. Transition of EUMETSAT's Indian Ocean Data Coverage Service to the Meteosat Second Generation Satellites. *EUMETSAT Meteorolog. Satellite Conf., Darmstadt, Germany, EUMETSAT.*

O'Carroll, A., **Dash, P.**, **August, T.**, **Hultberg, T.**, Saux Picart, S., Fiedler, E., Marsouin, A., 2016. Sea Surface Temperature from IASI: OSI SAF L2P and analyses using SQUAM and OSTIA. *EUMETSAT Meteorolog. Satellite Conf., Darmstadt, Germany, EUMETSAT.*

O'Carroll, A., **Dash, P.**, **Tomazic, I.**, **Montagner, F.**, **Bonekamp, H.**, **Coto Cabaleiro, E.**, **Santecesaria, V.**, **Wilson, H.**, Donlon, C., Goryl, P., 2016. Sea Surface Temperature from Sentinel-3 SLSTR. *EUMETSAT Meteorolog. Satellite Conf., Darmstadt, Germany, EUMETSAT.*

Otto, J., Brown, C., Buontempo, C., Doblas-Reyes, F., Jacob, D., Juckes, M., Keup-Thiel, E., Kurnik, B., **Schulz, J.**, Taylor, A., Verhoelst, T., Walton, P., 2016. Uncertainty: Lessons Learned for Climate Services. *Bull. Amer. Meteor. Soc.* 97, ES265–ES269.

Perlik, F., **Garcia Monteiro, C.**, **Dyer, R.**, 2016. EPS-SG Operational Scenarios and System modelled in CORE. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Petersen, R., Cnonce, L., Line, W., **August, T.**, **Hultberg, T.**, 2016. Increasing the utility of real-time IASI moisture and temperature soundings In very-short-range forecasting. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES.*

Phillips, P., **Bonsignori, R.**, **Schlüssel, P.**, Schmölling, F., **Spezzi, L.**, **Watts, P.**, Zerkowski, I., 2016. Overview of calibration and validation activities for the EUMETSAT polar system: second generation (EPS-SG) visible/infrared imager (METImage). *SPIE Proceed.*

Pili, P., **Matheson, L.**, **Murolo, F.**, **Pessina, S.**, 2016. MSG-4 In-Orbit Storage: early experience. *14th Int. Conf. Space Operations (SpaceOps), Daejeon, Korea.*

Appendix

Scientific and technical publications

Pili, P., Matheson, L., Tranquilli, C., Müller, J., Hewison, T., Carlier, S., Bianchi, S., Coste, P., 2016, the In-orbit Performance of the Meteosat Second Generation SEVIRI Instruments. *EUMETSAT Meteorolog. Satellite Conf., Darmstadt, Germany, EUMETSAT*.

Quast, R., Govaerts, Y., **Rüthrich, F.**, Giering, R., **Roebeling, R.**, 2016. Creating fidelitious climate data records from Meteosat first generation observations. *Living Planet Symposium 2016, Prague, Czech Republic, ESA*.

Roman, J., Knuteson, R., **August, T., Hultberg, T.**, Ackerman, S., Revercomb, H., 2016. A Global Assessment of NASA AIRS v6 and EUMETSAT IASI v6 Precipitable Water Vapor using Ground-based GPS SuomiNet Stations. *J. Geophys. Res.: Atmos.* 121, 8925–8948.

Rüthrich, F., John, V., Roebeling, R., Wagner, S., Viticchie, B., Hewison, T., Govaerts, Y., Quast, R., Giering, R., **Schulz, J.**, 2016, Uncertainty Propagation in a Fundamental Climate Data Record derived from Meteosat Visible Band Data. *EGU General Assembly 2016, Vienna, Austria, Eur. Geophys. Union*.

Rüthrich, F., John, V., Roebeling, R., Wagner, S., Viticchie, B., Hewison, T., Govaerts, Y., Quast, R., Giering, R., **Schulz, J.**, 2016, A Fundamental Climate Data REcords that Accounts for Meteosat First Generation Visible Band Spectral Response Issues. *EUMETSAT Meteorolog. Satellite Conf., Darmstadt, Germany, EUMETSAT*.

Scharroo, R., Bonekamp, H., Ponsard, C., Parisot, F., Von Engeln, A., Tahtadjev, M., de Vriendt, K., Montagner, F., 2016. Jason continuity of services: Continuing the Jason altimeter data records as Copernicus Sentinel-6. *Ocean Sci.* 12, 471–479.

Scharroo, R., Leuliette, E., Naeije, M., **Martin-Puig, C.**, Pires, N., 2016. RADS version 4: An efficient way to analyse the multi-mission altimeter database. *Living Planet Symposium 2016, Prague, Czech Republic, ESA*.

Sepulveda, E., Garcia, O., Schneider, M., **August, T.**, Hase, F., Blumenstock, T., Sanroma, E., Gomez-Pelaez, A., **Hultberg, T.**, Redondas, A., Romero-Campos, P., Carreno, V., Gonzalez, Y., 2016. A Quasi Near-Real Time Operational Validation of IASI Level 2 Trace Gas Products. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Sepulveda, E., Garcia, O., Schneider, M., **August, T.**, Hase, F., Blumenstock, T., Sanroma, E., **Hultberg, T.**, Redondas, A., Cuevas, E., Peinado, N., Calbet, X., Lopez-Baeza, E., 2016. VALIASI: IASI Ozone Total Column Amounts and Vertical Profiles Validated at Subtropical, Mid-Latitude and Polar-Latitude. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Sonoyo, M., Sano, I., Yasumoto, M., Fujito, T., Nakata, M., **Kokhanovsky, A.**, 2016. Feasibility study for GCOM-C/SGLI: Retrieval algorithms for carbonaceous aerosols. *EGU General Assembly 2016, Vienna, Austria, Eur. Geophys. Union*.

Theodore, B., Coppens, D., 2016. IRMA: IASI Radiance Monitoring Assistant Operational Monitoring of IASI radiances at EUMETSAT. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Tranquilli, C., Viticchie, B., Pessina, S., Hewison, T., Müller, J., Wagner, S., 2016. Meteosat SEVIRI Performance Characterisation and Calibration with Dedicated Moon/Sun/Deep-space Scans. *14th Int. Conf.Space Operations (SpaceOps), Daejeon, Korea*.

Trent, T., **August, T.**, Moore, T., **Hultberg, T.**, Thomas, G., Poulsen, C., Clarisse, L., **O'Carroll, A.**, Remedios, J., 2016. Assessing The Impact of Aerosol on the Accuracy of IASI SST. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Trent, T., **August, T.**, Remedios, J., 2016. Defining Water Vapour Profiles from Nadir Sounders for the GEWEX Water Vapor Assessment. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Valente, A., Sathyendranath, S., Brotas, V., Groom, S., Grant, M., **Taberner, M.**, Antoine, D., Arnone, R., Balch, W., Barker, K., Barlow, R., Belanger, S., Berthon, J., Besiktepe, S., Brando, V., Canuti, E., Chavez, F., Claustre, H., Crout, R., Frouin, R., Garcia-Soto, C., Gibb, S., Gould, R., Hooker, S., Kahru, M., Klein, H., Kratzer, S., Loisel, H., McKee, D., Mitchell, B., Moisan, T., Muller-Karger, F., O'Dowd, L., Ondrusek, M., Poulton, A., Repecaud, M., Smyth, T., Sosik, H., Twardowski, M., Voss, K., Werdell, J., Wernand, M., Zibordi, G., 2016. A compilation of global bio-optical in-situ data for ocean-colour satellite applications. *Earth Syst. Sci. Data* 8, 235–252.

Valkonen, T., Schyberg, H., **Figa-Saldana, J.**, 2016. Assimilating Advanced Scatterometer Winds in a High-Resolution Limited Area Model Over Northern Europe. *IEEE J. Sel. Topics Appl. Earth Observ. and Remote Sens.*

Van Hoolst, R., Eerens, H., Haesen, D., Royer, A., **Bydekerke, L.**, Rojas, O., Li, Y., Racionzer, P., 2016. FAO's AVHRR-based Agricultural Stress Index System (ASIS) for global drought monitoring. *Int. J. Remote Sens.* 37, 418–439.

Vandermarcq, O., **Klaes, D.**, Buffet, L., Jacquette, E., **Coppens, D.**, 2016. IASI mission implementation and status. *4th IASI Conf., Antibes Juan-Les-Pins, France, CNES*.

Wanzong, S., Heidinger, A., Daniels, J., **Borde, R., Watts, P.**, Bresky, W., 2016. Comparison of the Optimal Cloud Analysis Product (OCA) and the GOES-R ABI Cloud Height Algorithm (ACHA) Cloud Top Pressures for AMVs. *13th Int. Winds Workshop, Monterey, USA*.

Yang, W., **John, V.**, Zhao, X., Lu, H., Knapp, K., 2016. Satellite Climate Data Records: Development, Applications, and Societal Benefits. *Remote Sens.* 8, 331.

Zhang, P., **Holmlund, K.**, Goldberg, M., Lafeuille, J., 2016. The Global Space-based Inter-Calibration System (GSICS). *2016 IEEE Int. Geoscience and Remote Sensing Symposium (IGARSS), Beijing, China*.

Glossary

ACMAD	African Centre of Meteorological Applications for Development
ACP	African, Caribbean and Pacific Group of States
AfDB	African Development Bank
AGRHYMET	Agriculture, Hydrology and Meteorology Centre
ARGOS	System for data collection and localisation via satellite from the polar orbit (France)
AUC	African Union Commission
CDOP-3	Third Continuous Development and Operations Phase (of SAFs)
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CMA	China Meteorological Administration
CNES	Centre National d'Etudes Spatiales (French space agency)
Copernicus	Earth Observation Programme of the European Union
CNSA	China National Space Administration
DIAS	Data and Information Access Service (platform)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential climate variable
EDF	European Development Fund
EMI	European Meteorological Infrastructure
EPS	EUMETSAT Polar System
EPS-SG	EPS Second Generation
ESA	European Space Agency
ESOC	European Space Operations Centre (ESA)
EU	European Union
EUMETCast	EUMETSAT's satellite data broadcast service
FIDUCEO	Fidelity and Uncertainty in Climate Data Records from Earth Observations (EU Horizon2020 project)
GAIA-CLIM	Gap Analysis for Integrated Atmospheric ECV CLimate Monitoring (EU Horizon2020 project)
GCOM	Global Change Observing Mission satellite (Japan)
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEONETCast	Global network of satellite data broadcast systems
GEOSS	Global Earth Observation System of Systems
GFCS	Global Framework for Climate Services
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite (NOAA)
Himawari	Japanese geostationary meteorological satellite
IJPS	Initial Joint Polar System
INPE	National Institute for Space Research (Brazil)
ISRO	Indian Space Research Organisation
Jason-2	Ocean altimeter satellite (NASA/CNES/NOAA/EUMETSAT)
Jason-3	Ocean altimeter satellite (NASA/CNES/NOAA/EUMETSAT/EU)
Jason-CS	Jason Continuity of Service, ocean altimeter satellite (NASA/ESA/NOAA/EUMETSAT/EU)
JAXA	Japan Aerospace Exploration Agency
JPS	Joint Polar System (shared with NOAA)
KMA	Korea Meteorological Agency

LEOP	Launch and early operations phase
MESA	Monitoring of Environment and Security in Africa
Meteosat	EUMETSAT geostationary meteorological satellite
Metop	EUMETSAT polar-orbiting meteorological satellite (EPS)
MOOC	Massive open online course
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
MTG-I	MTG imaging satellite
MTG-S	MTG sounding satellite
NASA	National Aeronautics and Space Administration (US)
NMHS	National Meteorological and Hydrological Service
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration (US)
NWP	Numerical weather prediction
RA-I	WMO Regional Association 1
RAIDEG	RA-I Dissemination Expert Group
Roshydromet	Russian Federal Service for Hydrometeorology and Environmental Monitoring
SAF	Satellite Application Facility
SAWIDRA	Satellite and Weather Information for Disaster Resilience in Africa
SBSTA	Subsidiary Body for Scientific and Technical Advice (UN)
Sentinel-3	Copernicus satellite
SOA	State Oceanic Administration (China)
SST	Sea surface temperature
Suomi-NPP	Suomi National Polar-orbiting Partnership (NASA/NOAA)
SVT	System validation test
TCDR	Thematic climate data record
VITO	Flemish Institute for Technological Research
Vlab	Virtual Laboratory for Training and Education in Satellite Meteorology (WMO)
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WMS	Web Map Service

