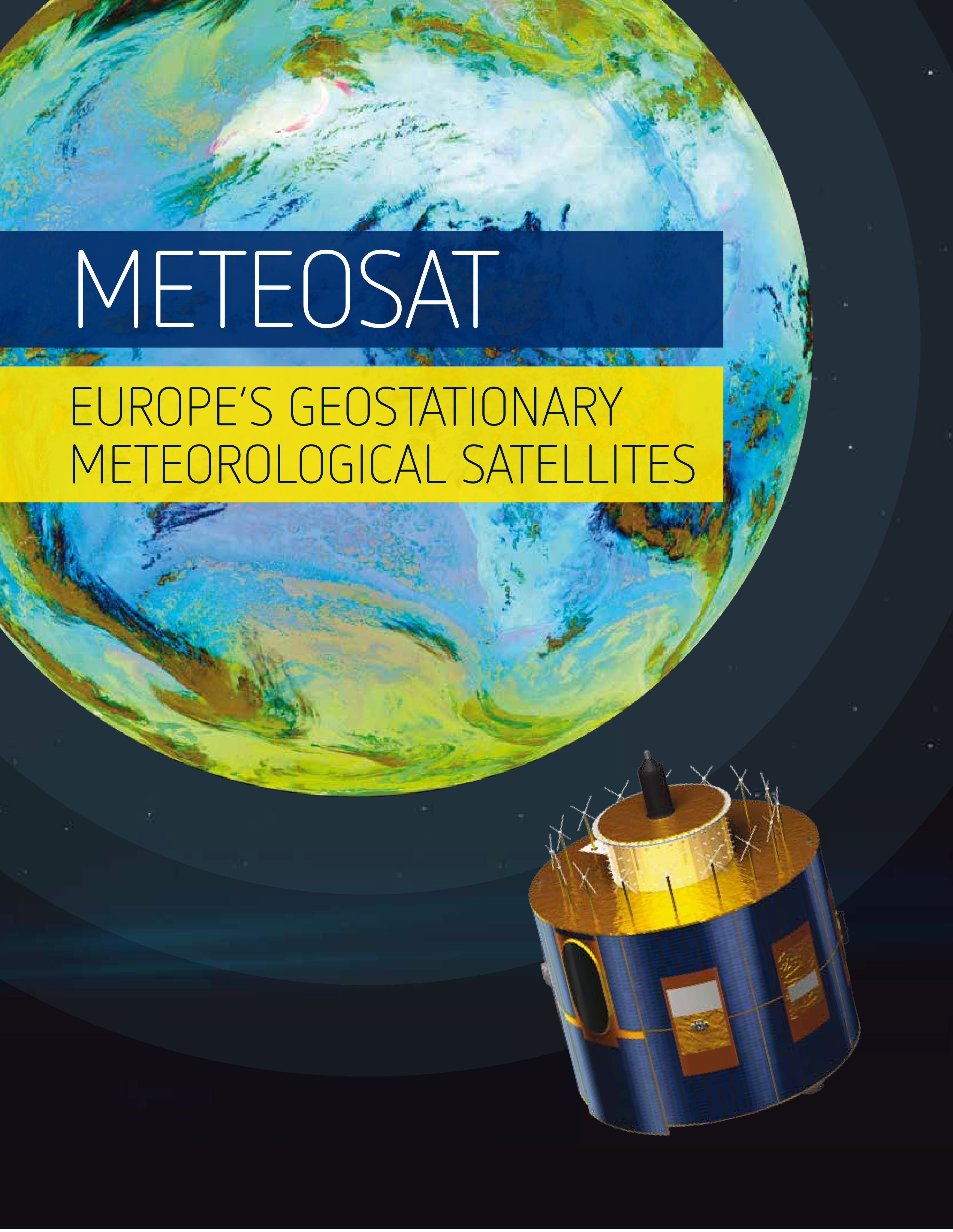
METEOSAT

EUROPE'S GEOSTATIONARY METEOROLOGICAL SATELLITES



MONITORING WEATHER AND CLIMATE FROM SPACE

EUMETSAT

OBSERVATIONS FROM GEOSTATIONARY ORBIT SAVE LIVES ON EARTH

Changes in weather and climate significantly impact not only our economy and infrastructure - but actually our very lives

Paul de Valk
Koninklijk Nederlands
Meteorologisch Instituut (KNMI)

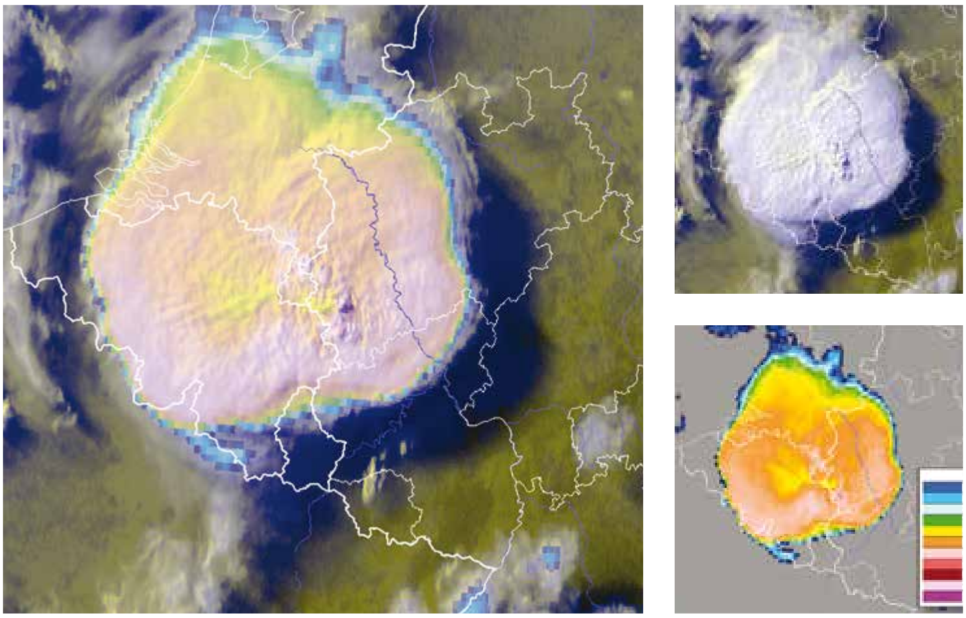
"You need satellites these days, without them you are actually blind to the weather coming towards you. It is too expensive for a country to have its own satellites so it is very beneficial to share costs in Europe, as we do through EUMETSAT."

Between 1970 and 2012, weather and water-related natural disasters in Europe claimed 149,959 lives and caused over 340 billion EUR in economic damage, according to a study by the World Meteorological Organization. Thunderstorms and fog are examples of high-impact weather that can pose a severe threat to safety and businesses and are difficult to forecast more than a few hours in advance.

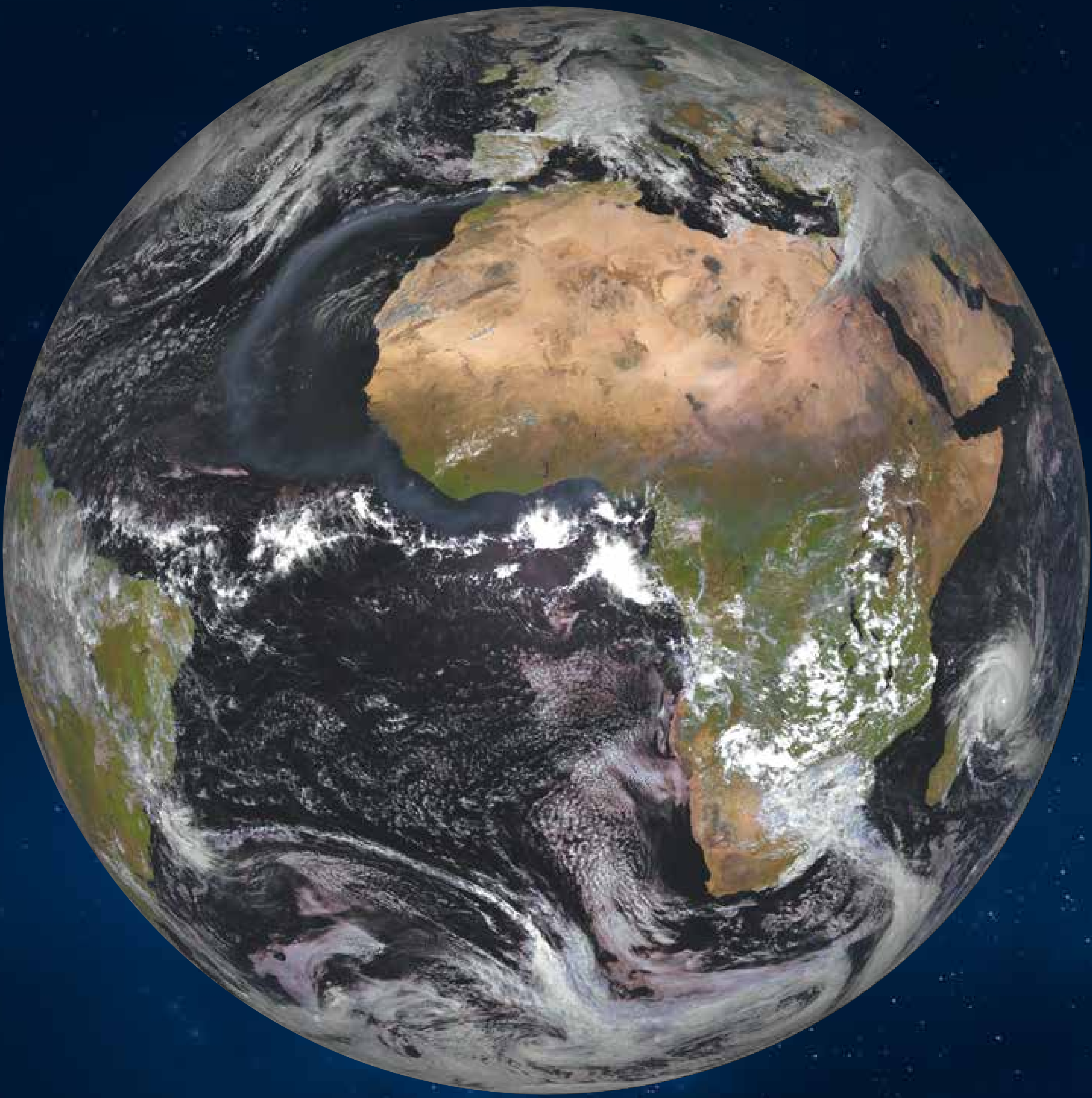
To issue the earliest possible warnings and support decision makers in the minimisation of the consequences, weather forecasters have to perform one of their most challenging tasks - called 'nowcasting'. This is about detecting, in real time, rapidly developing situations of high-impact weather and predicting their evolution a few hours ahead. For nowcasting to be successful very frequent, high-quality images of the atmosphere are required in real time – images that only advanced geostationary weather satellites like Meteosat can deliver continuously from their fixed position 36,000 km above the equator.

Geostationary satellites are also unique in their ability to deliver information on winds by observing the displacement of cloud tops as well as water vapour patterns, thus providing valuable inputs to Numerical Weather Prediction models that complement observations made by polar-orbiting satellites like Metop, which are the primary source.

The contribution of geostationary satellites to climate monitoring is also significant, considering the more than 35 years of Meteosat observations already accumulated.



Nowcasting a "super cell" in Germany: Meteosat visible information (top right) on the texture of clouds and infrared information on cloud top temperature (bottom right) are combined into a "sandwich" product (left) to characterise the intensity and development of the cell



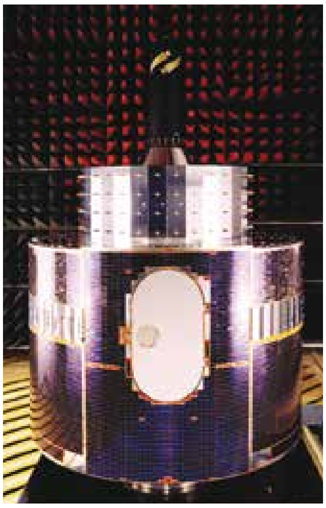
WHAT IS GEOSTATIONARY ORBIT?

A satellite in geostationary orbit 36,000 km above the equator remains above the same point on the Earth's surface at all times. This means that the satellite can continuously observe those parts of the globe in its field of view.

EUMETSAT

METEOSAT: PROVIDING A CONSTANT VIEW OF OUR RAPIDLY CHANGING WEATHER

Meteosat weather satellites of the first and second generations have been delivering weather and climate data for Europe and beyond, from geostationary orbit 36,000 kilometres above the Earth's surface, since 1977



Meteosat-1, Europe's first meteorological satellite (source: ESA)

MSG-4 in the cleanroom, ready for shipment (source: Thales Alenia Space)

The data provided by Meteosat satellites make a vital contribution to daily weather forecasting, in particular for nowcasting and very short range forecasting of high impact weather.

The operational imagery services over Europe and Africa, are now exclusively provided by Meteosat Second Generation (MSG) satellites, and are based on their optimum use as a two-satellite system: one satellite provides full disc imagery of the European and African continents and parts of the Atlantic and Indian oceans every fifteen minutes, while the second delivers more frequent images every five minutes (Rapid Scan Service) over Europe only, to further support warnings of localised high-impact weather such as thunderstorms and fog.

The last satellite of the first generation, Meteosat-7, is still functional and has been moved to 57.5° East, over the Indian Ocean, where it is filling an observational gap until 2017 when it will be de-orbited.

From 2020 onwards, Meteosat Third Generation (MTG) will gradually replace MSG, to continue providing support to nowcasting and very short range forecasting. The requirements of the new MTG system have been developed in dialogue with users and in consultation with remote sensing and forecast experts. To meet these requirements, the MTG spacecraft will deliver major enhancements to the MSG imagery mission, including lightning imagery, but also, for the first time ever from the geostationary orbit, observations every thirty minutes of vertical profiles of temperature and humidity in the atmosphere. These "soundings" will bring critical input to high resolution regional numerical models expected to be used for nowcasting purposes in the 2022 timeframe.

THREE GENERATIONS OF METEOSAT SATELLITES

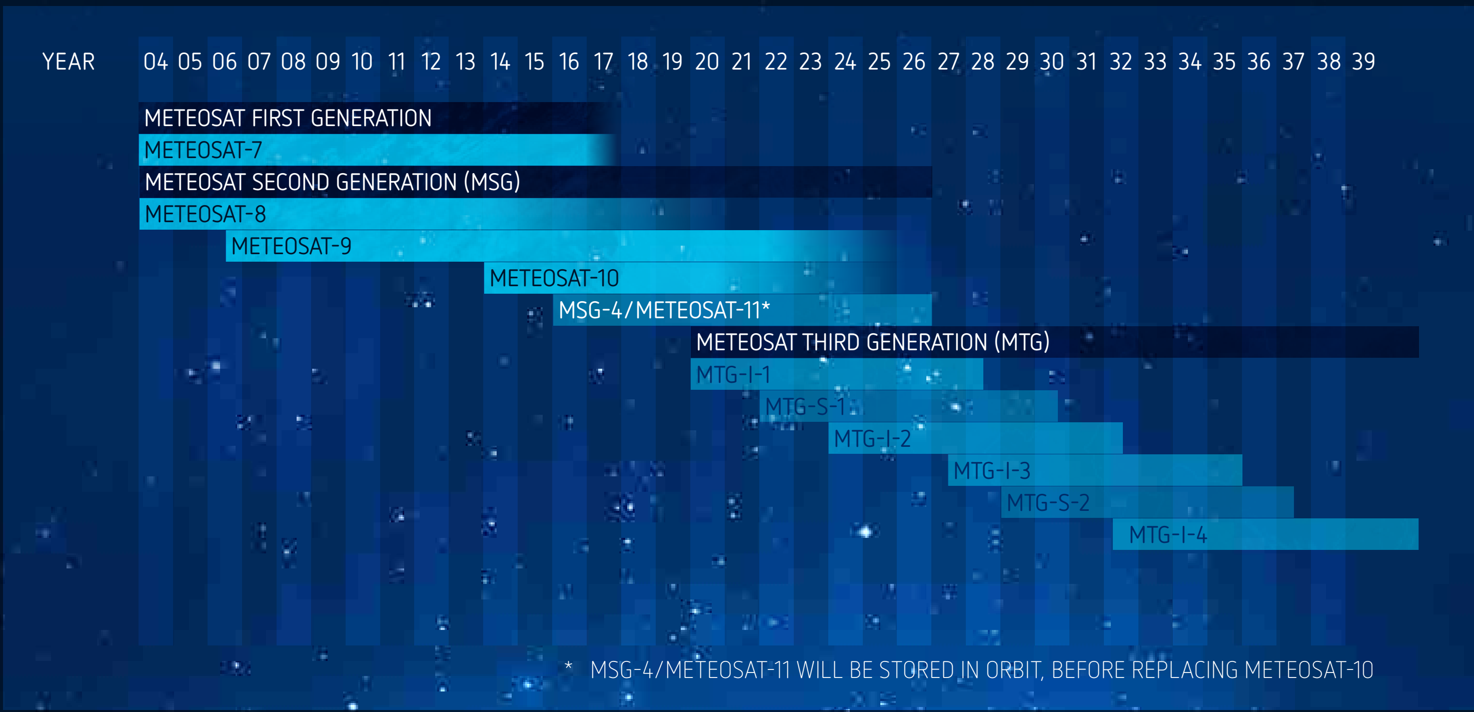
METEOSAT FIRST GENERATION

The first of the Meteosat First Generation (MFG) satellites, Meteosat-1, was launched in November 1977. Developed and operated by the European Space Agency it had a three-channel Meteosat Visible and InfraRed Imager (MVIRI), supplying imagery every thirty minutes. After nine years and five more satellites, EUMETSAT took over responsibility for the Meteosat system in 1995 and the last satellite, Meteosat-7, was launched in September 1997.

METEOSAT SECOND GENERATION

In August 2002, the first Meteosat Second Generation satellite, MSG-1 (renamed Meteosat-8), was launched. With its new imager, the Spinning Enhanced Visible and InfraRed Imager (SEVIRI), capable of observing the Earth in 12 channels covering the visible, near-infrared and thermal infrared part of the spectrum, MSG-1 was the beginning a new era in weather monitoring over Europe and Africa. The satellite also provided data much more frequently, as often as every five minutes for Europe in rapid scan mode, and it carried the Geostationary Earth Radiation Budget (GERB) instrument for climate studies.

MSG-1 was followed by MSG-2 (Meteosat-9) on 21 December 2005 and MSG-3 (Meteosat-10) in July 2012. Meteosat-9 and 10 now work in tandem, with Meteosat-10 providing the full disc operational service over Europe and Africa, and Meteosat-9 delivering the Rapid Scan Service over Europe and acting as a backup satellite. The final MSG satellite, MSG-4, will be stored in orbit after its launch (2015) until it is required as a replacement for Meteosat-9.



Planning for Meteosat Missions

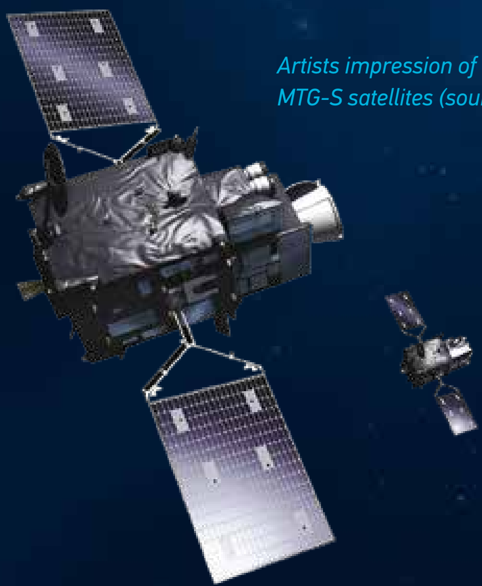
METEOSAT THIRD GENERATION

The Meteosat Third Generation satellites will revolutionise weather and environmental monitoring capabilities over Europe and Africa, with an enhanced imaging mission and for the first time, a new infrared sounding mission. The most complex and innovative geostationary system ever built, MTG will comprise six satellites: four imaging (MTG-I) and two sounding (MTG-S) satellites. Unlike the two previous generations of Meteosat spinning satellites, all MTG satellites will be three-axis stabilised.

The MTG-I imaging satellites will carry the advanced Flexible Combined Imager (FCI) and the Lightning Imager. The 16 channel FCI will provide increased support to nowcasting and very short-range forecasts of high-impact weather, with more capabilities for measuring cloud and aerosol properties. The new Lightning Imager, another first for Meteosat satellites, will continuously monitor lightning activity in near-real time, supporting nowcasting of severe storms and warnings of lightning strikes.

On the MTG-S satellites, there will be an infrared sounder (IRS) and the Copernicus Sentinel-4 Ultraviolet Visible Near-Infrared spectrometer (UVN). The IRS will provide detailed vertical profiles of atmospheric temperature and moisture - every thirty minutes over Europe – to support nowcasting and short range numerical weather prediction. The instrument will also work together with the Copernicus Sentinel-4 UVN sounder to provide a unique, integrated capability to observe ozone, carbon monoxide, sulphur dioxide and other trace gases in support of air quality monitoring and forecasting, and climate monitoring.

Like for MSG, the MTG imagery mission will be implemented by tandem operation of two MTG-I satellites, one delivering rapid imagery over Europe, in four channels and every 2.5 minutes, and the other full disc imagery every 10 minutes. The MTG-S will be operated in parallel, forming a three-satellite operational system.



Artists impression of MTG-I and MTG-S satellites (source: ESA)

EUMETSAT

THE CURRENT METEOSAT MISSIONS AND SERVICES

The Meteosat primary mission is to support nowcasting and short-range weather forecasting over Europe and Africa, but the system also delivers important observational inputs to numerical weather prediction and climate monitoring applications

Philip Watts
Remote Sensing Scientist
EUMETSAT

"As the Meteosat satellites are in geostationary orbit, they observe the Earth over the same location every fifteen minutes or even every five minutes, in rapid scan mode. So we see the weather in motion, which is critical for forecasting events that might take place in a few hours."

The images and data delivered are used to extract a wealth of meteorological and climate products, the number of which is steadily increasing as a result of scientific innovation. Data and products are distributed in real time to users in Europe, Africa and worldwide primarily via EUMETCast, EUMETSAT's satellite-based broadcast service for environmental data.
EUMETCast delivers data through inexpensive VSAT user terminals and is EUMETSAT's contribution to GEONETCast, a global network of satellite-based data dissemination systems, and also to the World Meteorological Organization's information service (WIS).

0° SEVIRI IMAGE DATA SERVICE

The full disc image service is MSG's main service and provides operational image data every 15 minutes from the satellite's field of view at 0 degree longitude, which includes the whole of Europe, all of Africa and parts of the Atlantic and Indian oceans. The image service is currently delivered in 12 spectral channels by the Meteosat-10 satellite through the SEVIRI instrument. Each of the visible, near-infrared and thermal infrared channels has its own spectral signature and can be used either alone, or in combination with other channels to detect and classify clouds and to observe other phenomena in the atmosphere, like fog, dust storms, or the features of tropical cyclones or mid-latitude storms approaching Europe.

RAPID SCAN SERVICE (RSS)

The underlying principle of this service is that the SEVIRI instrument can provide scans more frequently than every fifteen minutes if only a third of the Earth disc is scanned. In practice, the Rapid Scan Service scans Europe and adjacent seas every five minutes providing vital support for nowcasting of rapidly developing high impact weather events like thunderstorms.

DATA COLLECTION SERVICES (DCS)

The Meteosat DCS collects and relays in situ observations, transmitted to the satellite by Data Collection Platforms, to users in real time. It is particularly useful for the collection of data from remote and inhospitable locations where it may provide the only possibility for data relay.

The DCS has expanded on MSG, with a new high-rate DCP service, which enables the collection and retransmission of more data.

Field of view captured by the Rapid Scan Service every five minutes

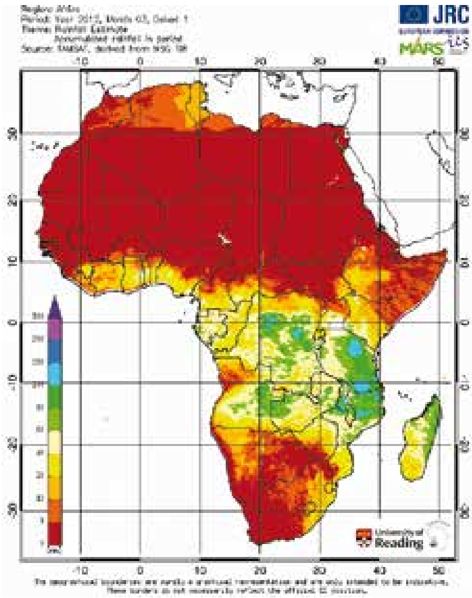
METEOSAT OVER AFRICA AND THE INDIAN OCEAN

A POWERFUL OBSERVING SYSTEM TO SUPPORT SUSTAINABLE DEVELOPMENT IN AFRICA

Meteosat is a key system to enhance weather forecasting capabilities across the African continent and to support climate and environmental monitoring applications.

For example, near-real time estimates of rainfall are essential over the African continent to forewarn of possible crop shortfalls in drought prone areas or for flood prediction. Satellite-based rainfall estimates are often the only feasible way of estimating rainfall over parts of the African continent, and the Meteosat satellites, with their constant view over Africa, are ideally placed to provide data for this role.

Meteosat data are made available to users, together with other information, through hundreds of EUMETCast user stations deployed across the African continent in the framework of projects (PUMA, AMESD, and now MESA) established in cooperation between the African Union Commission and the European Development Fund.



African accumulated rainfall estimate for March 2012 derived from data provided by MSG (source: TAMSAT, University of Reading, UK)

Joseph Kagenyi
Principal Meteorologist and Acting Assistant Director (Research and Development)
Institute for Meteorological Training and Research and Regional Training Centre, Nairobi, Kenya

"The main issue for forecasters in Africa is the lack of observation stations (data). Thanks to observations from space we can see what is happening, even in the areas with no other observation equipment."

THE INDIAN OCEAN DATA COVERAGE (IODC) MISSION

In order to make best use of the residual capacities of Meteosat-7, the last first generation satellite, the EUMETSAT Council decided to move it to 57.5°E, to bridge an important data gap over the Indian Ocean until the end of its lifetime. The satellite provides image data 24 hours a day in three spectral channels, every 30 minutes, delivering important information that is used, in particular, to monitor tropical cyclones and dust storms. In addition, the wind and water vapour products are used in global numerical weather prediction models, for instance as run by the European Centre for Medium-Range Weather Forecasts, the world leader in medium range numerical weather forecasts.

The Meteosat-7 Data Collection Services are an important element of the Indian Ocean Tsunami Warning System, relaying in real time to tsunami warning centres, measurements of sea bed pressure variations transmitted by some 50 moored buoys.

METEOSAT APPLICATIONS

The data provided by Meteosat satellites make an essential contribution to weather forecasting, and environment and climate monitoring

Nataša Strelec Mahovic
Meteorological and Hydrological Service Of Croatia (DHMZ)

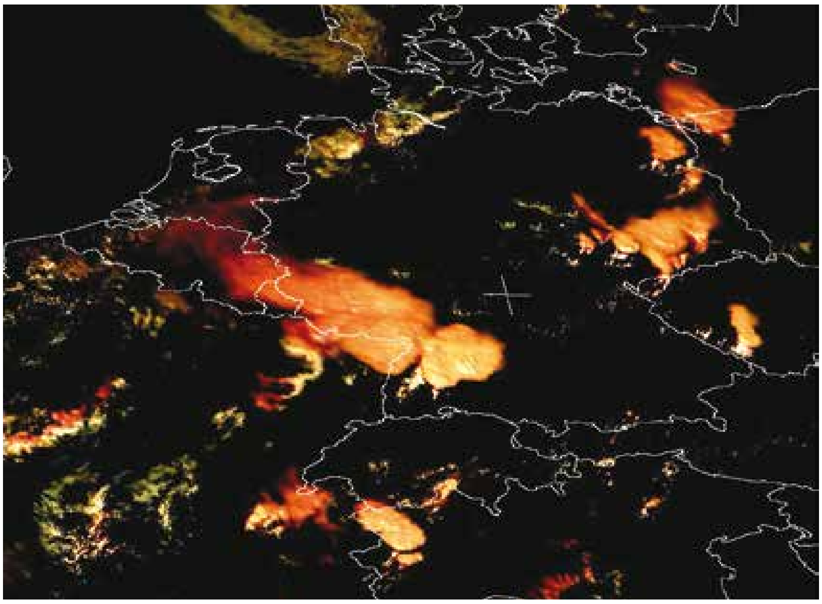
"MSG data are used in the operational weather room in the everyday forecast chain."

The SEVIRI instrument which provides the imaging service on MSG is able to observe rapidly changing weather patterns and provide very detailed images, 24 hours a day. In particular, the instrument's wide range of spectral channels provide important information on many cloud properties, with channels sensitive to droplet size as well as the distinction between ice and water clouds, and also for example between clouds and snow cover. The channels are also used to derive information on a range of other variables including atmospheric instability, convection, winds, fog, precipitation, incoming solar radiation, snow cover, vegetation cover, surface albedo, volcanic ash, dust, land and sea surface temperature, and even fires.

NOWCASTING AND VERY SHORT RANGE FORECASTING

The primary role of the Meteosat satellites is to help detect and forecast rapidly developing high impact weather.

Thunderstorms over Germany, 6 August 2013, 13:00 UTC, captured by Meteosat-10 (High Resolution Visible Channel enhanced with VIS0.8, NIR1.6 and IR3.9)



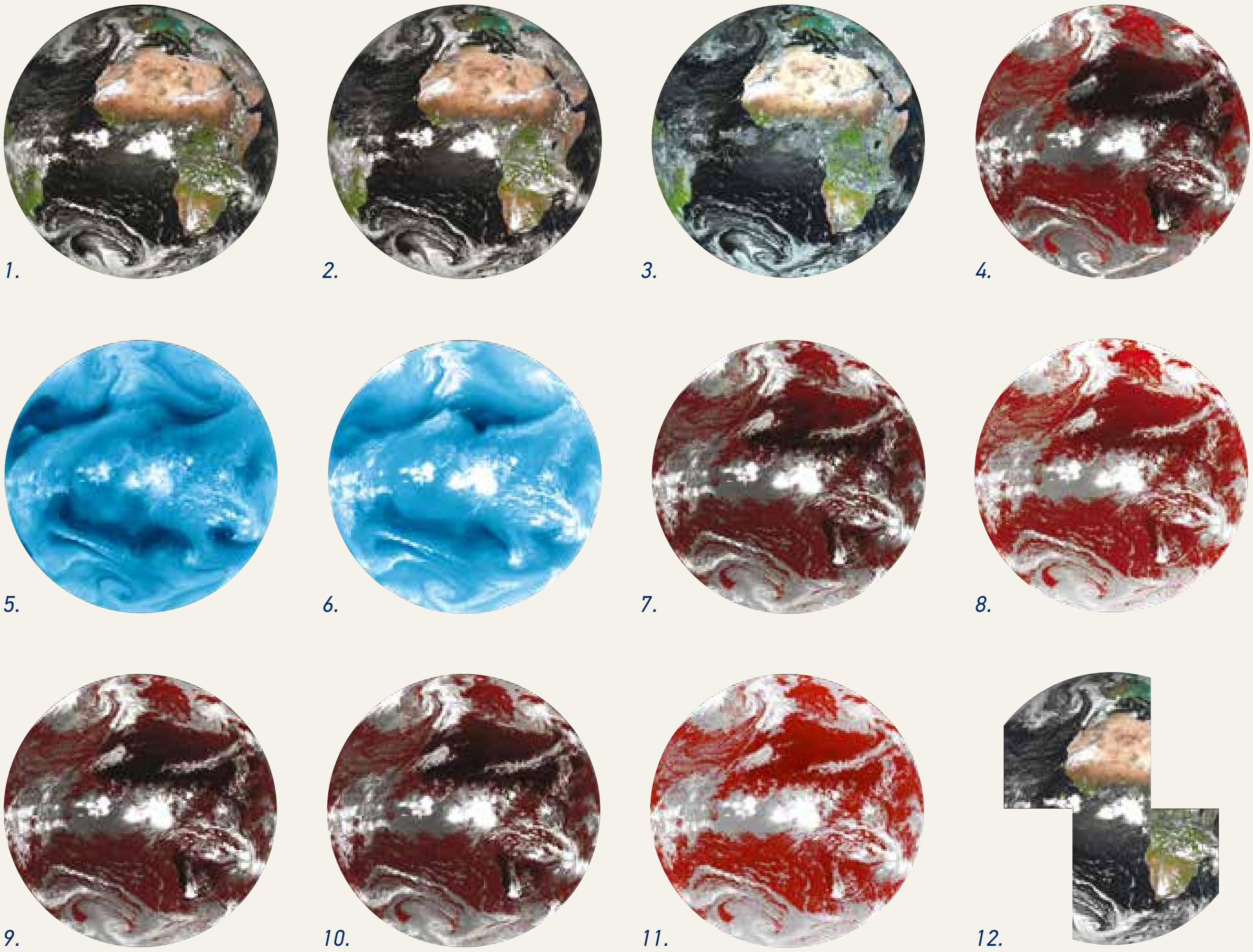
Nowcasting and very short range forecasts - up to six hours - are vital for the safety of life, property and infrastructure and rely on very frequent, detailed images of the atmosphere.

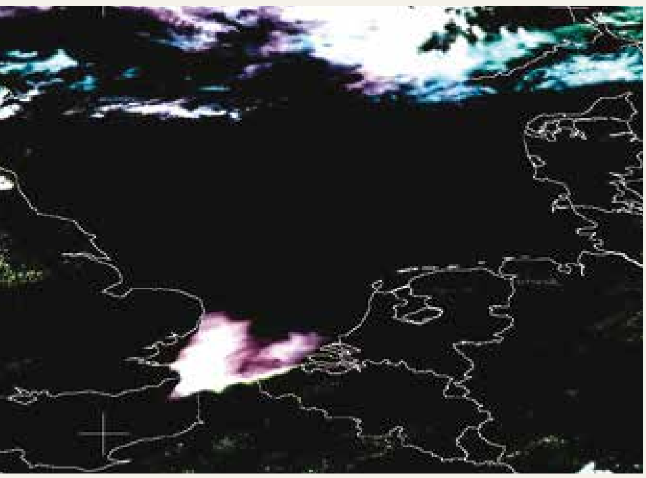
The data provided by MSG's SEVIRI instrument supports a large range of nowcasting applications such as detection and detailed monitoring of convection, which can lead to the development of severe thunderstorms, the detection of fog, dust storms or volcanic ash, and the assessment of air mass characteristics.

Meteosat imagery is also used by weather forecasters to cross check that weather prediction model output is in line with what is actually happening in the atmosphere, and to adjust their short range forecasts accordingly.

CONVECTIVE STORMS

Severe convective storms, or thunderstorms, are usually accompanied by strong winds, heavy rainfall and hail, and can be a serious threat to life and property in Europe and Africa. MSG allows the continuous monitoring of all stages of convection, ranging from the initial instability in the atmosphere indicating the possibility of convection, through to the formation of cumulonimbus clouds, and on to the development and properties of mature thunderstorms. The rapid fifteen-minute or even five-minute image updates from Meteosat satellites are an important tool for meteorologists to monitor the often rapid development of convective storms and help in issuing timely warnings.





Fog over the English Channel as seen by Meteosat-10, 18 July 2013 12:00 UTC (High Resolution Visible Channel enhanced with VIS0.8, NIR1.6 and VIS0.6), showing that the London airports are not affected

FOG

Meteosat imagery allows 24-hour monitoring of the distribution and behaviour of fog and is used, in combination with other techniques, to help detect and monitor fog formation and nowcast its dissipation. This information is particularly important in sensitive localised areas such as around airports, major road networks, and shipping routes and ports.

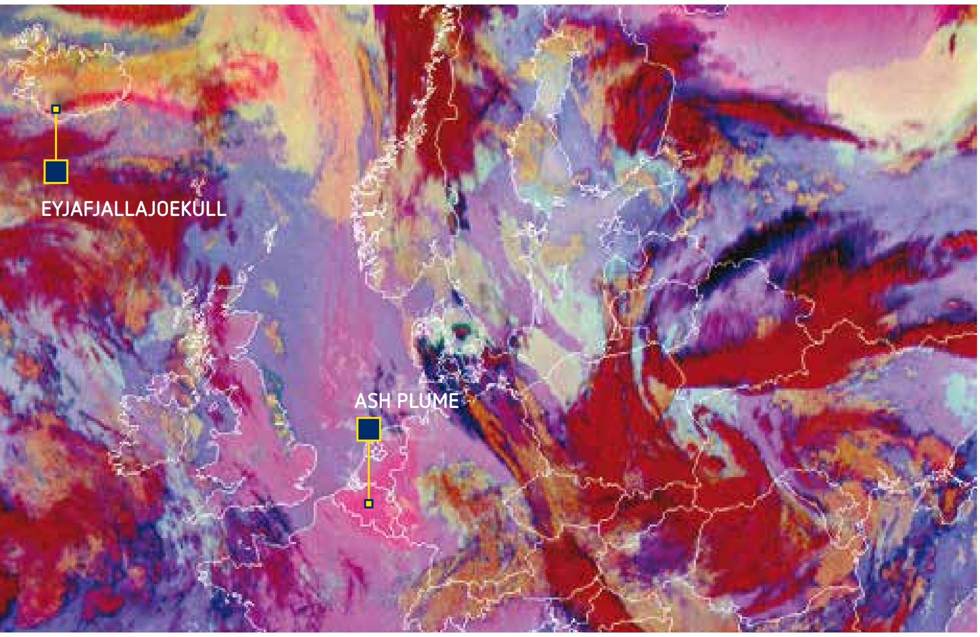
In particular, poor visibility due to fog and low cloud is a safety hazard and causes major disruption to aviation. As an example, four days of dense fog over the UK in the pre-Christmas period of 2006 led to hundreds of flight cancellations from Heathrow Airport and is estimated to have cost the airport operator millions of pounds.

The 12 spectral channels of the SEVIRI instrument aboard MSG satellites:

1. *Visible (0.6μm)*
2. *Visible (0.8μm)*
3. *Near-infrared (1.6μm)*
4. *Infrared (3.9μm)*
5. *Water vapour (6.2μm)*
6. *Water vapour (7.3μm)*
7. *Infrared (8.7μm)*
8. *Ozone (9.7μm)*
9. *Infrared (10.8μm)*
10. *Infrared (12.0μm)*
11. *Carbon dioxide (13.4μm)*
12. *Broadband high-resolution visible*

METEOSAT APPLICATIONS

The Eyjafjallajoekull ash plume seen in the Night Microphysics RGB product as it reaches Belgium, the Netherlands and Germany, 18 May 2010

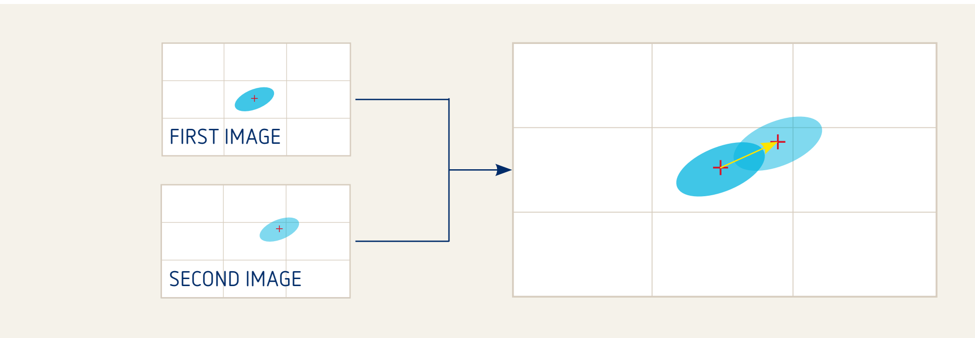


VOLCANIC ASH

Meteosat satellites can detect volcanic ash in the atmosphere and provide invaluable imagery to follow in near-real time the movement and dispersion of volcanic ash plumes in the European airspace, such as from the Eyjafjallajökull (2010) and Grímsvötn (May 2011) volcanoes. As volcanic ash can damage aircraft engines, knowledge of the presence of ash plumes is extremely important for air traffic management and flight restrictions can have severe economic impacts. As an example, the ash plumes from the eruption of Iceland's Eyjafjallajökull Volcano in April 2010 grounded hundreds of flights across Europe and cost the airline industry over 1.3 billion (EUR), according to IATA.

Using innovative algorithms and Meteosat imagery it is possible to discriminate ash from clouds and other aerosols, to enable the retrieval of mass loading, height and effective radius of ash. These capabilities make Meteosat imagery one of the primary sources of observations used by the London and Toulouse Volcanic Ash Advisory Centres, operated by the Met Office and Météo-France for monitoring volcanic ash plumes and their transport and dispersion in real time. These organisations are responsible for advisory warnings of volcanic ash in different parts of Europe's air space.

An overview of how wind speeds are measured by tracking the movement of clouds over time between each image interval



INPUTS TO NUMERICAL WEATHER PREDICTION MODELS

The fast image repeat cycles of Meteosat imagery allow the derivation of "atmospheric motion vectors", or winds, by tracking clouds and humidity structures between subsequent images. These wind products and also clear sky radiances (water vapour columns) products are ingested in numerical weather forecasting models and provide important information to improve the initial state.

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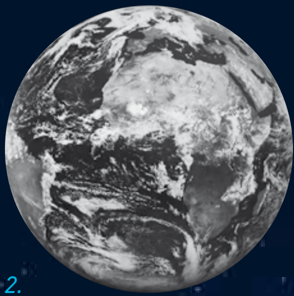

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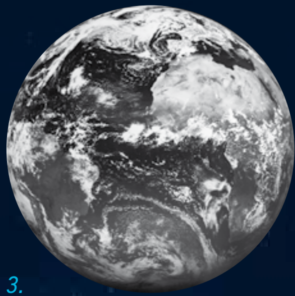

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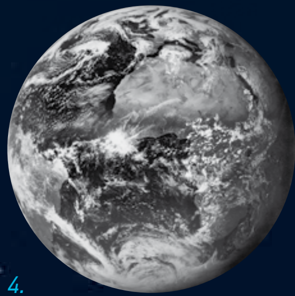

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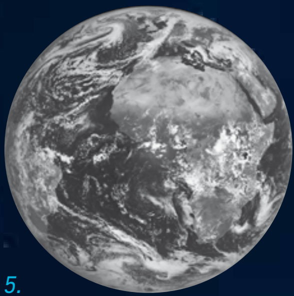

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CLIMATE AND ENVIRONMENTAL MONITORING

Meteosat satellites have been collecting observations relevant for climate and environmental monitoring since the late seventies, building up in the process one of the longest time-series of climate-relevant data collected by satellite in the world. These observations are primarily related to albedo, water vapour, cloud properties, precipitation associated to convective systems, and winds.

After the first Meteosat Second Generation satellite began operational service in 2004, the range of climate-relevant observations that are collected expanded to include sea surface temperature, snow cover, vegetation cover and occurrence of fires. Also, the MSG GERB measurements of the short wave and long wave components of the radiation budget at the top of the atmosphere became available to study the radiation budget, namely the balance between incoming energy from the Sun and outgoing thermal (long-wave) and reflected (short-wave) energy from the Earth, which is an important parameter for climate research.

The most valuable aspects of Meteosat data for climate monitoring are the continuity in spectral channels across the generations of satellites, and that they provide good observation capabilities of daily cycles throughout the seasons.

With the data collected from the existing first generation MVIRI and MSG's SEVIRI and the future MTG-I's Flexible Combined Imager, the duration of the Meteosat climate data record will reach 50 years in 2031 - longer than most other satellite records. In addition, with the new Infrared Sounder (IRS), observations of the three-dimensional structure of the temperature and moisture fields in the atmosphere will become available from the MTG-S satellites from 2020 onwards. Climate records of atmospheric chemical compounds (O3, etc.) will also start in the same timeframe, as a result of the combination of IRS and the Sentinel-4 Ultra Violet Sounder (UVN) on both MTG-S satellites.

9.

10.

The first images of Meteosats:

1. Meteosat-1, 9 December 1977
2. Meteosat-2, 28 July 1981
3. Meteosat-3, 29 June 1988
4. Meteosat-4, 19 April 1989
5. Meteosat-5, 3 April 1991
6. Meteosat-6, 29 November 1993
7. Meteosat-7, 18 September 1997
8. Meteosat-8, 28 November 2002
9. Meteosat-9, 24 January 2006
10. Meteosat-10, 7 August 2012

COOPERATION

The Meteosat programme is the result of a quarter of a century of successful cooperation between EUMETSAT, ESA and a competitive European space industry

Jean-Jaques Dordain
Director-General
European Space Agency

"Cooperation between ESA and EUMETSAT has evolved with dedicated people on both sides working closely towards a common goal and, moreover, achieving remarkable results."

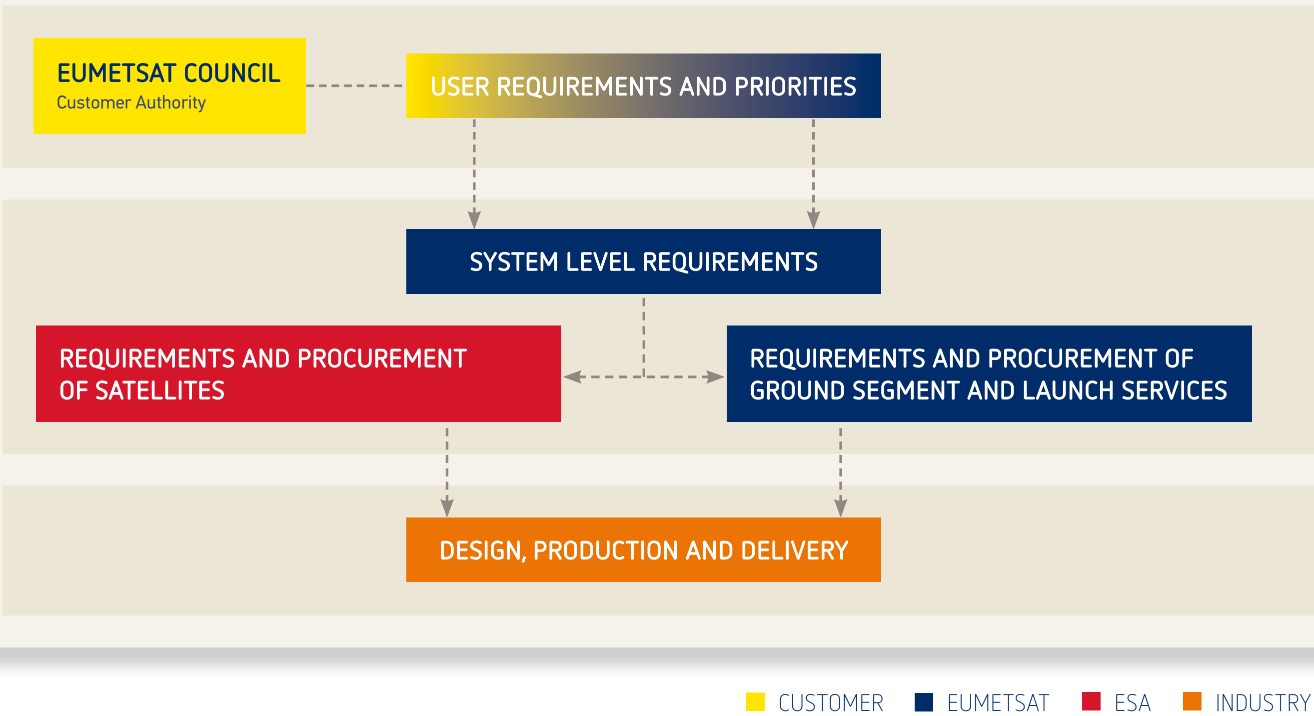
THE COOPERATION MODEL WITH THE EUROPEAN SPACE AGENCY

For more than 25 years, EUMETSAT has been successfully cooperating with the European Space Agency (ESA), which develops new satellites fulfilling the requirements of EUMETSAT and also procures recurring satellites on its behalf. EUMETSAT directly procures launch services and develops the ground infrastructure needed to control the satellites, acquire and process the data and disseminate the extracted information to users around the world. This sharing of responsibilities avoids duplication and gives EUMETSAT full control on the design and development of all elements required on ground to develop and enhance operational services to users in response to evolving requirements and capitalising on scientific innovation.

This cooperation model has made Europe the world leader in meteorological satellites and is the foundation of the Meteosat Third Generation programme currently in its development phase.

Artists impression of MTG-I and MTG-S satellites in orbit (source: ESA)

ESA-EUMETSAT COOPERATION MODEL



EUROPEAN SPACE INDUSTRY

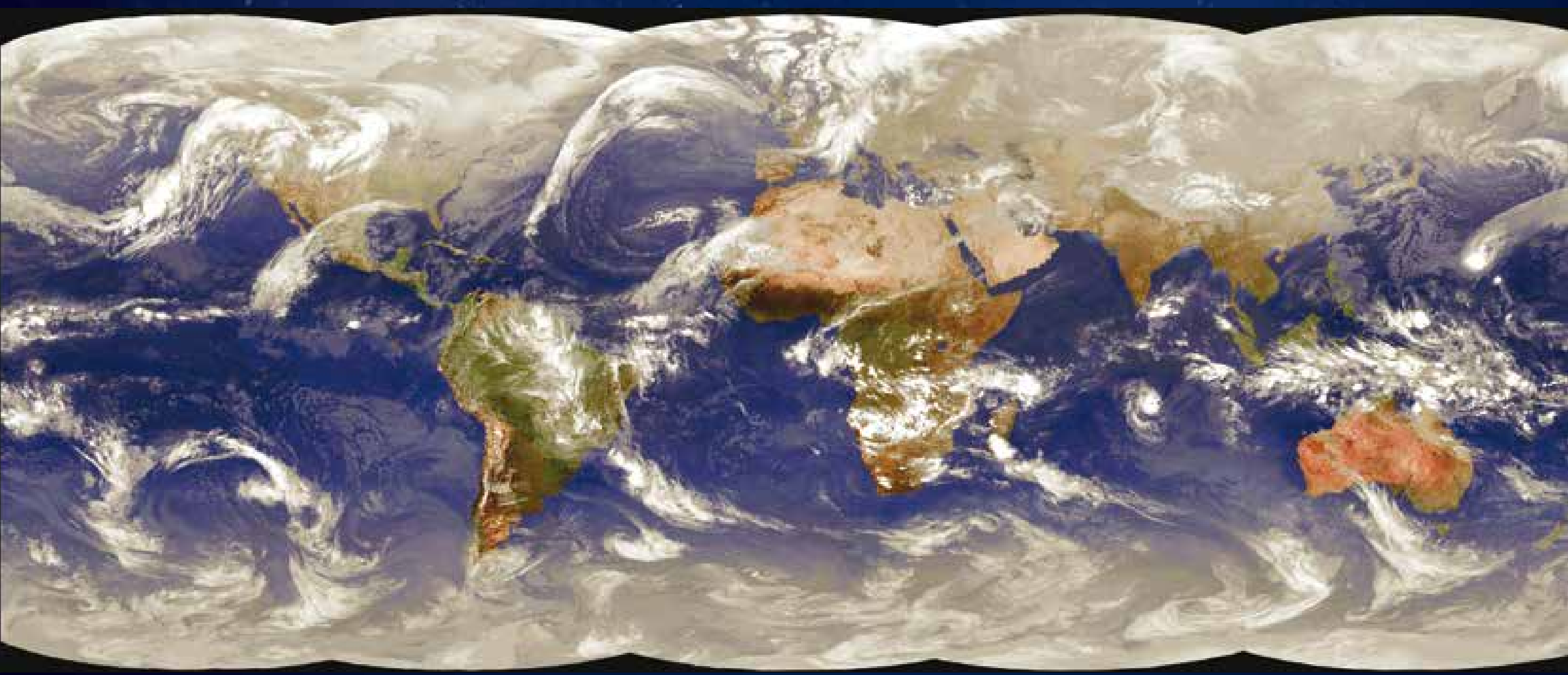
The MSG and future MTG satellites are procured from European industrial consortia led by Thales Alenia Space. Innovative technologies developed for Meteosat satellites contribute to maintaining their benefits over the long life span of each generation, whilst enhancing the competitiveness of the European space industry.

In addition, a European consortium, led by the Rutherford Appleton Laboratory (RAL) in the United Kingdom, provides the Geostationary Earth Radiation Budget (GERB) instruments on the MSG satellites and delivers the associated data services.

COOPERATION ACROSS THE GEOSTATIONARY "RING": WMO AND CGMS

The Meteosat programme is the well-established European contribution to the equatorial "ring" composed of all operational meteorological geostationary satellites, which are one key element of the permanent and global observing system coordinated by the World Meteorological Organisation to monitor the weather and climate. As Member and Permanent Secretary of the Coordination Group for Meteorological Satellites (CGMS), EUMETSAT cooperates with other operators to coordinate operations of geostationary satellites across the "ring", to harmonise processing and improve data quality, and to maximise the value of the full system to the WMO user community.

World cloud map generated from image data delivered by meteorological satellites of the geostationary ring



CURRENT METEOSAT SYSTEM ARCHITECTURE

METEOSAT SECOND GENERATION

SPINNING ENHANCED VISIBLE AND INFRARED IMAGER (SEVIRI)
12 spectral channels
Full disc image every fifteen minutes
Rapid scan every five minutes

GEOSTATIONARY EARTH RADIATION BUDGET (GERB)

METEOSAT FIRST GENERATION

METEOSAT VISIBLE AND INFRARED IMAGER (MVIRI)
3 spectral channels
Full disc image every thirty minutes

METEOSAT SECOND GENERATION GROUND SYSTEM

The primary ground station receiving data transmitted from the MSG satellites is in Usingen, Germany, where there are three fully steerable 13-metre diameter parabolic antennas. The two antennas supporting Meteosat-7, in Fucino, Italy, have been upgraded to receive also MSG data, when more than three satellites are in orbit, after the launch of MSG-4 in 2015. There are also backup and ranging ground stations located in Maspolomas, Gran Canaria, Spain and in Cheia, Romania.

EUMETSAT geostationary Mission Control Centre, Darmstadt, Germany

The ground stations are the main communication channel between the satellites and the EUMETSAT Control Centre in Darmstadt, Germany. The raw data are relayed via the ground station to the control centre and then used to generate data from which EUMETSAT's Application Ground Segment derives meteorological products. Data are processed, archived in the EUMETSAT Data Centre, and transmitted in near-real time to the user community, mainly via EUMETCast, EUMETSAT's broadcast system for environmental data.

A comprehensive range of meteorological and geophysical products is derived by EUMETSAT's Application Ground Segment at its headquarters in Darmstadt and its network of eight Satellite Application Facilities (SAFs), all specialised in a defined application area. The eight SAFs are geographically distributed across EUMETSAT Member States.

Meteosat ground stations in Usingen, Germany (left) and Fucino, Italy (right)

MSG-4321

WHAT A JOURNEY!

In 2015, the fourth and last of the Meteosat Second Generation satellites will be launched from Kourou, 13 years after the launch of MSG-1, and more than 20 years after the start of the development programme at ESA and EUMETSAT.

This is one generation of Meteosat satellites, but this is also the work of one generation of engineers, scientists and administrative staff in EUMETSAT, ESA, RAL, Industry, ECMWF and National Weather Services.

What a journey, what a human venture for improving forecasts and saving lives on Earth!

Congratulations to everybody involved! And let us continue this journey with Meteosat Third Generation!

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MEMBER STATES

COOPERATING STATES

EUMETSAT also has established cooperation agreements with organisations involved in meteorological satellite activities, including the National Meteorological Services of Canada, China, India, Japan, Russia, South Korea and USA

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