The EUMETSAT Polar System

Taking meteorology to a new level

EUMETSAT

Monitoring

WEATHER, CLIMATE AND THE ENVIRONMENT

Extreme weather conditions are being observed with greater frequency worldwide, posing major challenges for modern society.

Katrina, Rita and Wilma were just three of the destructive storms that hit the Gulf of Mexico region during the exceptional 2005 hurricane season, bringing death and devastation to hundreds of thousands of citizens living in that area. In recent years, severe storms and excessive rainfall have brought regular, widespread flooding to northern Europe, China, South America and India. In southern Europe, the trend towards drier, hotter conditions has led to failing crops and extensive wildfires. Whatever form it takes, severe weather usually has serious economic and human consequences for the communities it affects.

The increased incidence of severe weather events is being linked to changes in the global climate - to what extent continues to be a matter of debate. Achieving a greater understanding of the factors involved in climate change and how they interact with the environment requires international cooperation between environmental scientists and meteorologists. It also requires the analysis of detailed atmospheric observations collected continuously over many decades: ozone concentrations and moisture and temperature profiles, for example, are crucial factors in forecasting models such as in Numerical Weather Prediction and in the understanding of climatic change.

AVHRR colour composite image of Hurricane Katrina as observed by NOAA-15, 28 August 2005 (image courtesy of NOAA)

A SPACE-EYE VIEW OF THE EARTH

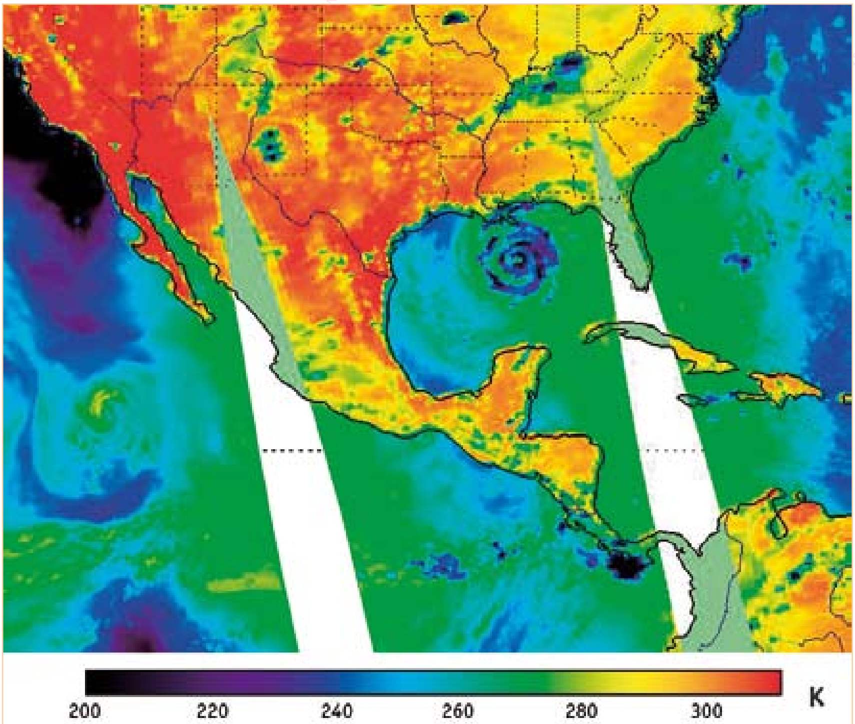
Satellites have been collecting atmospheric observations for decades and have contributed significantly to weather forecasting and to the long-term monitoring of the planet's well-being.

> *"Possibly the single biggest step to improving numerical weather prediction in the future will be the IASI instrument, which offers the exciting potential for much finer sounding capabilities than ever before."*
>
> **Bryan Conway, Manager, NWP SAF**

EUMETSAT's Meteosat Second Generation (MSG) satellites, the first of which was launched in 2002 and the second in December 2005, also provide important data for weather forecasting and climate monitoring. However, owing to their geostationary positions high above the Earth, Meteosat satellites cannot deliver the highly detailed observations of atmospheric conditions required by meteorologists and climatologists. Additionally, the more remote areas of northern Europe are on the periphery of Meteosat's field of vision. A second system is therefore required to complement the data from geostationary orbit.

A European polar-orbiting meteorological satellite system was first discussed in the late 1960s. At that time there was little need for Europe to develop a polar-orbiting system because the United States made available data from its civilian weather satellites flying in low earth orbit. By the early 1980s two things had become clear: forecasts were more accurate using data from two satellites with different equator crossing times; and the United States National Oceanic and Atmospheric Administration (NOAA) was looking for a partner to ensure the continuation of this service. It was time for Europe to share the responsibility for services from polar orbit. In 1998 the Councils of EUMETSAT and the European Space Agency (ESA) first approved a plan to design, develop, launch and operate a polar satellite system for Europe. Following this, EUMETSAT formally approved the EUMETSAT Polar System (EPS) programme in 1999.

In 1998 EUMETSAT and NOAA signed an agreement to collaborate in the Initial Joint Polar System (IJPS), comprising two polar-orbiting satellite systems and their respective ground segments. Through a further agreement, the Joint Transition Activities agreement signed in 2003, EUMETSAT and NOAA have agreed to provide an operational polar-orbiting service until at least 2019.



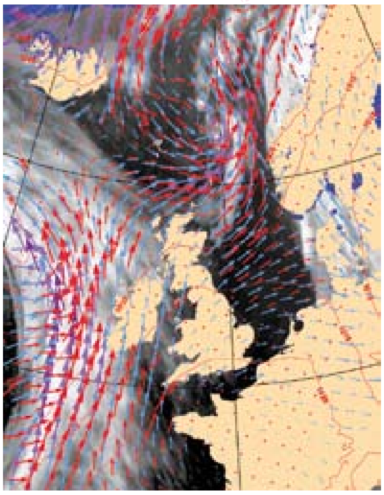
Hurricane Katrina as observed by the MHS instrument (channel H1) on NOAA-18, 28 and 29 August 2005

METOP: BENEFITS ON A GLOBAL SCALE

MetOp-2, the first satellite of the EPS system, will be launched in summer 2006 from Baikonur, Kazakhstan. The satellite orbits at an altitude of 837km (approximately 42 times closer to the Earth than a geostationary satellite), observing smaller areas in considerably finer detail. Data gathered by the MetOp satellites will revolutionise the way the Earth's weather, climate and environment are observed and will significantly improve operational meteorology, in particular Numerical Weather Prediction (NWP). MetOp will take meteorology and climatology to a new level!

EPS - THE MISSION

The MetOp satellites serve the operational requirements of the meteorological services of EUMETSAT's Member and Cooperating States and other users around the globe, as well as the World Meteorological Organization. In detail, the EPS mission will serve the following purposes:

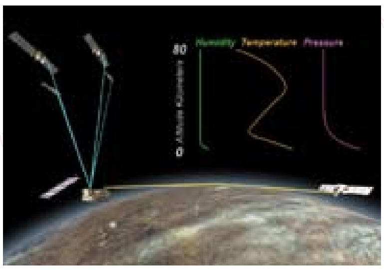


A product of the OSI SAF, showing wind vectors retrieved from QuikSCAT/SeaWinds (red) collocated with NWP winds (blue) (image courtesy of KNMI)

Operational meteorology

Numerical Weather Prediction (NWP) is the basis of all modern global and regional weather forecasting; the data generated by the instruments carried by MetOp can be assimilated directly into NWP models to compute forecasts ranging from a few hours to up to 10 days ahead.

Measurements from infrared and microwave radiometers and sounders on board MetOp provide NWP models with global information on the temperature and humidity of the atmosphere with a high vertical resolution. The Infrared Atmospheric Sounding Interferometer (IASI), for example, provides among other important data highly detailed global measurements of atmospheric temperature and water vapour, making it possible to ascertain temperature and humidity profi les with a vertical resolution of one kilometre, accurate to 1˚C and 10% respectively, at a horizontal sampling of 20 km.



Principle of radio-occultation with GRAS instrument (image courtesy of ESA)

The Global Navigation Satellite System Receiver for Atmospheric Sounding (GRAS) instrument will provide a new method for using satellite observations in NWP models for weather forecasting and climate monitoring. It uses the radio signals continuously broadcast by the GPS satellites of the Global Navigation Satellite System orbiting the Earth to measure the time delay of the refracted GPS radio signals as the ray signal path skirts the Earth's atmosphere on its way from the transmitting GPS satellite to the GRAS receiver on MetOp. This "delay" in the received signals is processed to obtain vertical profi les of atmospheric parameters, such as temperature and water vapour in the stratosphere and troposphere.

The data collected by the GRAS instrument will be further processed into sounding products by the GRAS Satellite Application Facility (SAF), hosted by the Danish Meteorological Institute (DMI).

Furthermore, the NWP SAF hosted by the UK Met Offi ce will exploit MetOp's invaluable data to generate supporting data, software packages, validation products and a number of other services for use in NWP, climate studies and atmospheric research.

The importance of scatterometer wind measurements for weather forecasting and climate monitoring has been demonstrated during various research missions over the past decade. The data from the Advanced SCATterometer (ASCAT) will be further processed by the Ocean and Sea Ice (OSI) SAF, led by Météo-France, to provide global ocean surface wind vectors that are necessary for the defi nition of the atmospheric circulation on small scales and in the tropics. The main application will be the assimilation of these wind measurements into NWP models. The scatterometer measurements can also be used for the monitoring of sea ice, snow cover or land surface parameters such as soil moisture.

The Advanced TIROS Operational Vertical Sounder (ATOVS) suite in combination with the Advanced Very High Resolution Radiometer (AVHRR) is already fl own on the current NOAA satellites and will also be operated on board MetOp. Since ATOVS/AVHRR covers the visible, infrared and microwave spectral regions, this instrument package is useful for a variety of applications such as cloud and precipitation monitoring, determination of surface properties or humidity profi les. These data again play a key role for NWP.

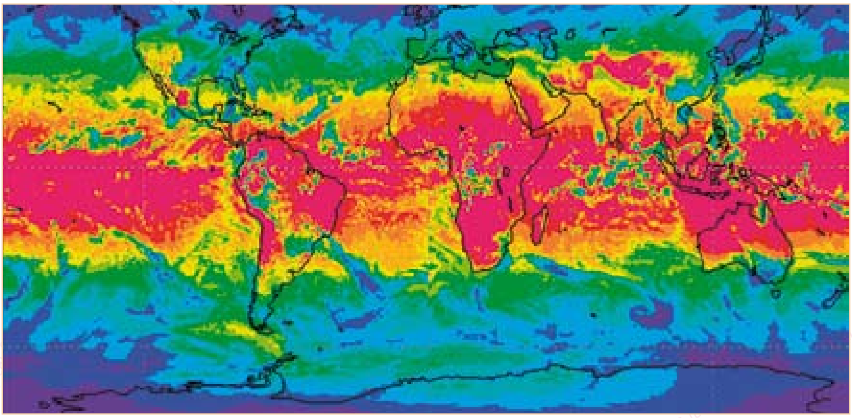
Monitoring climate and the environment

Computer models utilising satellite data collected continuously over many decades can be used to predict the likely impact of extreme weather events, climate change and human activities on the environment. The pressing environmental issues they reveal can be more effectively addressed, ensuring that national policies and activities are consistent with the goal of sustainable development.

All of the instruments on board MetOp contribute to global climate monitoring models and applications, helping scientists to understand the complex interactions between the various factors that influence the Earth's climate system.

In particular, IASI's ability to detect and accurately measure the levels and circulation patterns of gases known to influence the climate, such as carbon dioxide, will herald a breakthrough in the global monitoring of the climate. The data collected by IASI will feed into models, for the first time showing the variable global distribution of CO_2 as a function of seasons and circulation anomalies such as the Southern Oscillation (also known as El Niño) and the North Atlantic Oscillation.

Of particular current environmental concern is the depletion of the atmosphere's protective ozone layer, which is particularly noticeable over the Arctic and Antarctic regions. The resulting increased levels of ultra-violet radiation are having harmful effects on agriculture, forests and water ecosystems – and people.



A product of the O3M SAF, showing enhanced levels of UV radiation at the tip of South America due to the ozone hole on 7 October 2005 (image courtesy of FMI)

The Global Ozone Monitoring Experiment-2 (GOME-2) will measure ozone profiles, total columns of ozone and other atmospheric constituents like nitrogen- and sulphur dioxide. The observed trace gases are related not only to the depletion of ozone in the stratosphere, but also to other sources like volcanic eruptions and biomass burning. Additionally, the long-term monitoring of the observed trace gases will provide more insight into the impact of man-made sources of pollution on the environment (including air quality) and the climate on both regional and global scales.

Also very important is GOME-2's capacity to significantly extend the long time series of measurements already gathered by GOME-1, which will have a significant impact on our capability to model the climate system, leading to improved medium to long-term climate forecast capabilities.

These data will be further processed by the Ozone Monitoring (O3M) SAF, hosted by the Finnish Meteorological Institute (FMI), into invaluable products for monitoring the seasonal variations in the atmosphere's ozone levels over time, which in turn will assist atmospheric scientists and climatologists in identifying long-term climatic trends of major importance for the planet and its population.

MetOp data will also be processed by the Climate Monitoring (CM) SAF hosted by the Deutsche Wetterdienst (DWD). It will support the analysis and diagnosis of climate parameters to detect and understand climate change.

INTERNATIONAL COOPERATION IS IMPERATIVE

The growing apprehension posed by global warming, climate change and increasingly destructive weather events has woken governments, scientists and other interested parties to the strategic value, efficiency and cost-effectiveness of marshalling scientifi c resources on a global scale in the pursuit of operational meteorology and climatology.

> *"The data from the ATOVS group of instruments have been the single most important source of satellite data for our NWP models for some years. MetOp will provide vital continuity of this data source."*
>
> **Dick Francis, Head of Satellite Data Processing Systems, UK Met Offi ce**

As the European Organisation for the Exploitation of Meteorological Satellites, EUMETSAT is a major contributor to global programmes such as the World Meteorological Organization's Global Observing System (GOS).

The organisation's operational capabilities, now considerably enhanced by EPS, are set to make a signifi cant contribution to the operational services of the European Global Monitoring for Environment and Security (GMES) initiative. Led by the European Commission and ESA, the objective of GMES is to establish an operational European capacity for the timely provision of quality ground-, air- and space-based data, information and knowledge in support of a wide range of European policy areas for the benefi t of European citizens. GMES aims to achieve this by providing a portfolio of operational services based on Earth observation systems, to which EPS will make a crucial operational contribution.

The Initial Joint Polar System (IJPS)

PARTNERS OF THE EUMETSAT POLAR SYSTEM

www.esa.int

www.noaa.gov

CENTRE NATIONAL D'ÉTUDES SPATIALES
www.cnes.fr

www.space.eads.net

www.starsem.com

Launching and Operating EPS

On 17 April 2006, the MetOp-2 satellite was transferred from the prime contractor EADS Astrium in Toulouse, France, to the launch site at the Baikonur Space Cosmodrome in Kazakhstan. Starsem, a Russian/European joint venture, was procured by EUMETSAT to provide the Soyuz ST launch vehicle and all integration and launch services. Following three months of complex tests and integration activities, the satellite will take a slow six-hour train ride to the launch complex where it will be integrated into the Soyuz launcher, given a fi nal check and then rolled out on to the very same launch pad used to send the fi rst man, Yuri Gagarin, into space.

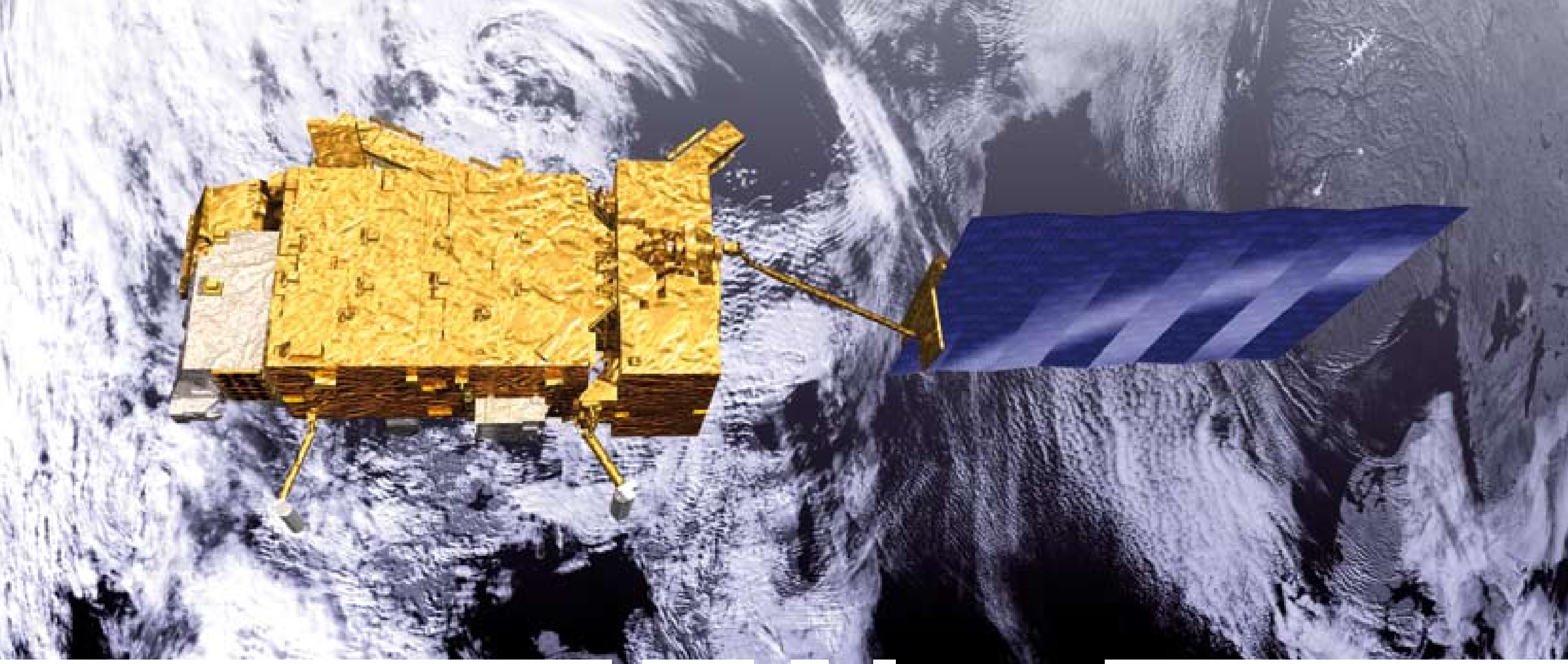
MetOp-2 will be launched into a sun-synchronous polar orbit and, once in orbit, renamed METOP-A. Following the satellite's successful injection into orbit, a team at the European Space Operations Centre (ESOC) will take over control of the satellite and manoeuvre it into its fi nal orbit around 837km above the Earth, deploy the various MetOp antennas and over the next three days perform the early orbit phase operations.

On completion, ESOC will hand control of the satellite over to EUMETSAT for the six-month commissioning phase comprising the satellite in-orbit verification phase and the subsequent scientifi c validation of the products generated by the instruments and the ground segment.

With the commissioning phase completed, Europe's first polar-orbiting satellite will be formally declared operational, taking over the morning service which had formerly been provided by the US NOAA-17 satellite.

EPS METOP

Image courtesy of Starsem



THE INFRASTRUCTURE OF EPS

The EPS infrastructure comprises a space segment of three MetOp satellites and the EPS ground segment.

THE EUMETSAT POLAR SYSTEM IS OPERATED BY EUMETSAT AND HAS BEEN DEVELOPED, PROCURED AND IMPLEMENTED IN PARTNERSHIP WITH THE EUROPEAN SPACE AGENCY (ESA), THE CENTRE NATIONAL D'ETUDES SPATIALES (CNES) AND THE US NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA).

THE SPACE SEGMENT

Each MetOp satellite has a design lifetime of five years. The satellites will fly consecutively, providing an operational service until at least 2019. There will be an operational overlap of about six months between two successive MetOp satellites.

They will provide continuity of accurate, high resolution observations from a low Earth, sun-synchronous orbit at an altitude of 837km, circling the planet 14 times a day and covering every point of the Earth twice a day. MetOp flies in a complementary orbit with the NOAA satellite, with EUMETSAT taking operational responsibility for the "morning orbit" and NOAA for the "afternoon orbit".

The satellite broadcasts high resolution real-time data from all instruments to local user stations around the world. In addition, data is continuously recorded on board the satellite as it circles the Earth using solid-state storage technology. The datastream is downloaded once per orbit as the satellite passes over the northern latitude ground station on Spitsbergen, one of the Svalbard islands.

> *"If we did not have the satellite data we would lose 24-36 hours in forecasting capabilities. Without satellite data, our 24-hour forecast would only be as accurate as a 48-hour forecast with it included."*
>
> **Richard Dumelow, Observation Impact Scientist, UK Met Office**

CHARACTERISTICS OF THE METOP SATELLITE

Satellite Design	Three-axis stabilised, consisting of a service module and a payload module
Dimensions	6.5m x 3.4m x 3.4m (stowed launch configuration) 17.7m x 6.6m x 3.4m (deployed in-orbit configuration)
Launch Mass	4093kg
Power	1812W
Data Rate	3.5Mbps
Orbit	837km circular, sun-synchronous, 98.7° inclination, 09:30 local time descending node, 29-day/412-revolutions repeat cycle
Lifetime	5 years

The ground segment

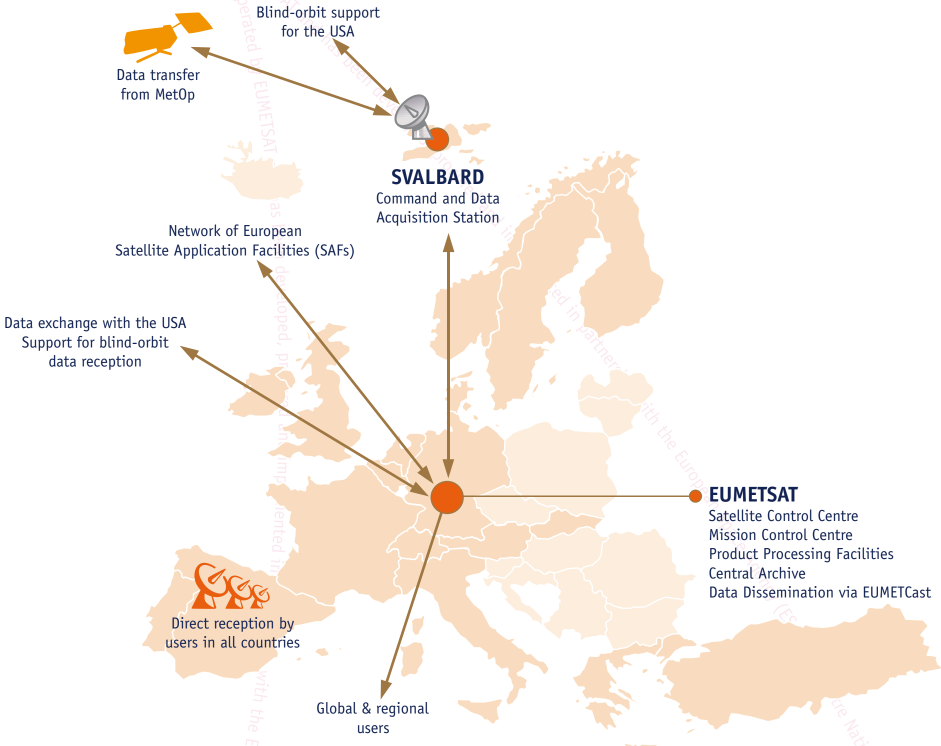
The EPS ground segment comprises the ground station for receiving data transmitted from the satellite and the core ground segment consisting of: the satellite and mission control centre; a full backup control centre in Spain; and facilities for the reception, processing and exchange of data and generation of products, including a network of Satellite Application Facilities for providing specialised, application-specific products, involving National Meteorological Services all over Europe.

The ground station

The purpose-built EPS ground station on Svalbard lies within the Arctic Circle at 78˚N, 15˚E. The ground station comprises two Command and Data Acquisition (CDA) stations, each providing the capabilities for monitoring and controlling the MetOp satellite.

At the end of each orbit, the data and images stored on board MetOp are transmitted to the ground station, which forwards them to the core ground segment at the EUMETSAT headquarters.

The ground station also receives data from the NOAA satellites when they are in a “blind orbit”, i.e. too far north to communicate with the NOAA ground station in Fairbanks.



The EPS ground segment

The core ground segment

The Core Ground Segment (CGS), located at EUMETSAT’s headquarters in Darmstadt, Germany, is responsible for operating the EPS satellites and for coordinating ground segment operations. It includes the functions of commanding and acquisition of data from MetOp and NOAA satellites, mission control, data processing and product generation, product quality control, online calibration, as well as dissemination of data and products generated within the CGS. In an emergency, its monitoring and control role can be taken over by a backup control centre located close to Madrid, Spain.

The data is disseminated to EUMETSAT Member States’ National Meteorological Services and other users all over the world via the Global Telecommunication System (GTS) and EUMETCast, the organisation’s unique data distribution system. The CGS also receives and processes data from the NOAA satellite and forwards data collected by MetOp to NOAA.

The data gathered consecutively by the three MetOp satellites over at least 14 years will be archived in EUMETSAT’s Unified Meteorological Archive and Retrieval Facility to ensure availability of long-term data series, which are necessary, for example, for climate research.

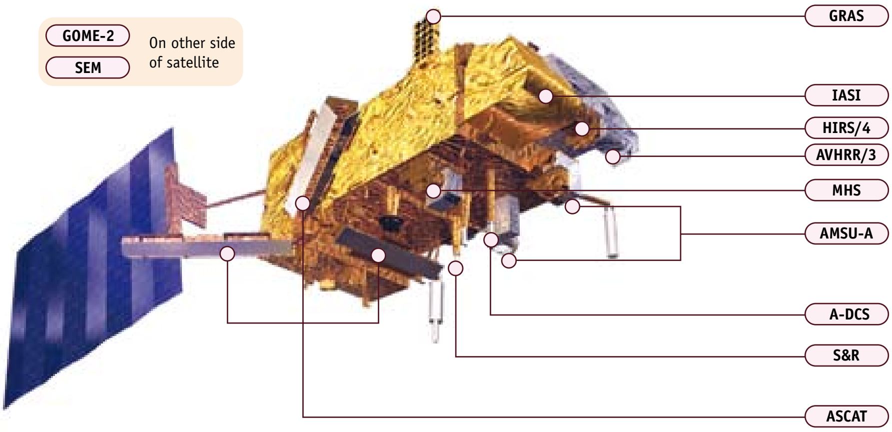
INSTRUMENTS

ON BOARD METOP

MetOp carries a payload of state-of-the-art sounding and imaging instruments - a new generation of operational meteorological European instruments developed by EUMETSAT, ESA and CNES - which offer enhanced remote sensing capabilities. The payload also contains a set of core instruments already fl own on the NOAA satellites: the AVHRR instrument and the Advanced TIROS Operational Vertical Sounder (ATOVS) suite consisting of the MHS, HIRS/4 and AMSU-A instruments.

Additionally, MetOp is equipped with a search and rescue receiver and transmitter for use by emergency services and a data collection and location system (ARGOS) for receiving and re-transmitting signals from transmitters on ground-based systems.

The main instruments and the antenna for transmitting data to ground stations are accommodated on the satellite's Earth-facing side. Instruments requiring low temperature for infrared detectors are mounted on a balcony at the longitudinal end of the satellite in the opposite direction of the sun.



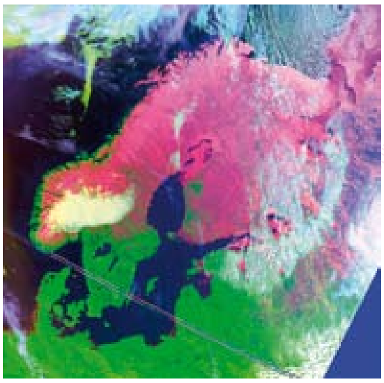
INSTRUMENT PAYLOAD OF METOP

Instrument	Primary Partner	Full Name	Primary Function
A-DCS	CNES	Advanced Data Collection System (ARGOS)	Receives signals from transmitters on buoys, ships and land sites
AMSU-A	NOAA	Advanced Microwave Sounding Unit-A	Measures sea ice and the temperature and humidity of the atmosphere in all weather conditions
ASCAT	EUMETSAT/ESA	Advanced SCATterometer	Measures near-surface wind speed and direction over the global oceans
AVHRR/3	NOAA	Advanced Very High Resolution Radiometer	Takes global visible, near-infrared and infrared imagery of clouds, oceans and land surfaces
GOME-2	EUMETSAT/ESA	Global Ozone Monitoring Experiment	Provides profi les of ozone and other atmospheric constituents
GRAS	EUMETSAT/ESA	GPS Receiver for Atmospheric Sounding	Measures the temperature of the upper troposphere and in the stratosphere with high vertical resolution
HIRS/4	NOAA	High-resolution Infrared Radiation Sounder	Measures the temperature and humidity of the global atmosphere in cloud-free and partly cloudy conditions
IASI	EUMETSAT/CNES	Infrared Atmospheric Sounding Interferometer	Provides enhanced atmospheric soundings of temperature, humidity, ozone and other trace gases, as well as sea surface temperature and cloud characteristics
MHS	EUMETSAT	Microwave Humidity Sounder	Measures the humidity of the global atmosphere
S&R	CNES/NOAA	Search and Rescue Terminal	Transmits the location of emergency beacons from ships, aircraft and people in distress to the ground stations
SEM	NOAA	Space Environment Monitor	Monitors the local space plasma and radiation environment

Taking METEOROLOGY to a NEW LEVEL

Monitoring Finland's spring melting season

Finnish meteorologists have long used AVHRR data from NOAA satellites to monitor ice cover on the Baltic sea to guide sea traffic and advise icebreakers where to find suitable routes for ships. Another important application is the monitoring of snow covered areas. Having daily, accurate input on these areas brings significant benefits to forecast models during spring, because as snow melts the albedo of the whole area changes rapidly, which is an important parameter for numerical models. It is also important to forecast and estimate spring flooding, and to provide power plants using water with the information they need to estimate and balance their power production.



AVHRR image taken by a NOAA satellite on 1 April 2004 shows ice and snow in cyan colour (image courtesy of FMI)

"Polar-orbiting satellites reveal a wealth of fine detail in the snapshots they provide of weather features – given the increasing demand for accurate predictions of local variations in weather, they are invaluable to forecasters"

Eddy Carroll, Chief Forecaster, UK Met Office

Superior air safety

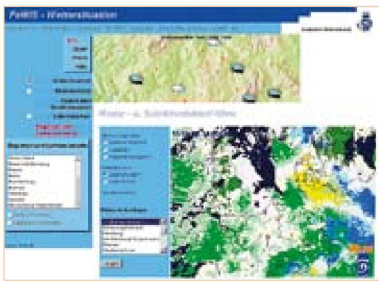
Søren Brodersen, Chief Meteorologist at the Danish Meteorological Institute, states the importance of the detail delivered by the AVHRR instruments, in particular for nowcasting forecasts in the northern regions: "I remember the old days in Sondrestrom, Greenland, back in the early 90s, waiting at dawn for the first glimpse of a NOAA satellite pass. We had to catch the signal from the satellite with portable equipment using a remote control. We waited for the satellite to rise on the horizon, caught the signal and more or less manually held its track as it passed over. It was just like a computer game. This first image of the day formed the basis of all aviation weather forecasting over Greenland. Losing it would set you back and make your voice tremble slightly when briefing VFR helicopter pilots."

ASCAT and marine meteorology

Wind measurements are also key ingredients in NWP models and for weather monitoring. Measurements of sea surface winds taken by MetOp's ASCAT instrument will be especially helpful to Marine Meteorological Services to improve ship-routing services, and also navigation and the monitoring of storms as they develop over oceans.

Managing severe weather situations

Disaster management will be a direct beneficiary of improved weather forecasting, courtesy of MetOp data. DWD makes data and products available on the internet via the Fire Brigade Weather Information System (FeWIS) to fire brigades, the federal states' emergency control centres, the Federal Agency for Population Protection and Disaster Assistance and the Technical Relief Organisation. This system will also include data products derived from MetOp data.



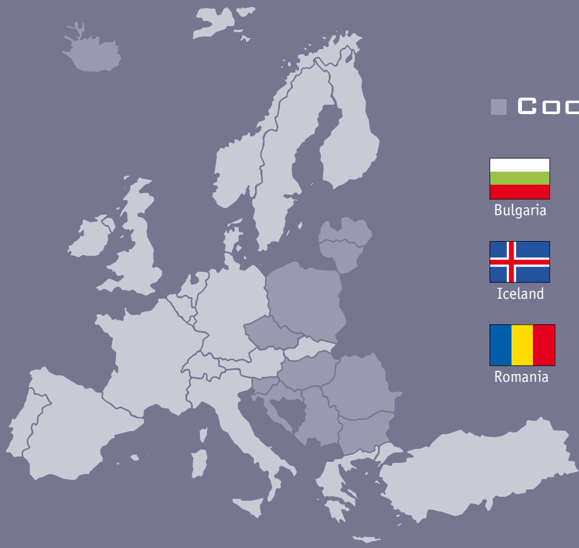
FeWIS internet browser (image courtesy of DWD)

"Detailed nowcasting is dependent on highly detailed satellite images. Aviation weather forecasts and briefings are significantly improved when the meteorologist has accurate information about low cloud distribution and fog. The data which we shall receive from a polar orbit by MetOp's AVHRR instrument will be essential for such forecasts."

Søren Brodersen, Chief Meteorologist, Danish Meteorological Institute

Member States

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom



Cooperating States

Bulgaria, Croatia, Czech Republic, Hungary, Iceland, Latvia, Lithuania, Poland, Romania, *Serbia & Montenegro, Slovenia

* Pending Ratification

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