

MONITORING THE WEATHER
FROM POLAR ORBIT

METOP



ESA'S EARTH OBSERVATION MISSIONS

METEOSAT - In 1977 the first of seven Meteosat meteorological satellites was launched to monitor the weather over Europe and Africa. Operational services from these satellites still continue to this very day.



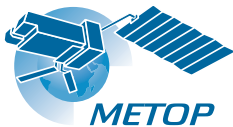
ERS-1 and 2 - ERS-1, launched in 1991, was ESA's first remote-sensing satellite in polar orbit and carried a comprehensive payload to measure ocean-surface temperature, waves and winds at sea. ERS-2, which overlapped with ERS-1, was launched in 1995 and added the Global Ozone Monitoring Experiment (GOME) for atmospheric ozone research.



ENVISAT - Launched in 2002, Envisat is the largest Earth Observation satellite ever built. It carries 10 sophisticated optical and radar instruments to provide continuous observation of the Earth's oceans, land, ice caps and atmosphere for the study of natural and man-made contributors to climate change and for the study of natural resources.



MSG (Meteosat Second Generation) - Following the success of Meteosat, the procurement of four much-improved geostationary MSG satellites guarantees operational services until 2018. The first MSG was launched in 2002 and the second in 2005. MSG is a joint venture between ESA and EUMETSAT.



METOP (Meteorological Operational) - MetOp is a series of three polar-orbiting satellites dedicated to providing data for operational meteorology until at least 2020. MetOp forms the space segment of EUMETSAT's Polar System (EPS). MetOp-A, the first in the series, is to be launched in 2006.



GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) - Due for launch in 2007, GOCE will provide the data set required to accurately determine global and regional models of the Earth's gravity field and geoid. It will advance research in the areas of ocean circulation, physics of the Earth's interior, geodesy and surveying, and sea-level change.



SMOS (Soil Moisture and Ocean Salinity) - Due for launch in 2007, SMOS will provide global maps of soil moisture and ocean salinity to further our understanding of the Earth's water cycle and contribute to climate, weather and extreme-event forecasting.



ADM-AEOLUS (Atmospheric Dynamics Mission) - Due for launch in 2008, ADM-Aeolus will make novel advances in global wind-profile observation and provide much-needed information to improve weather forecasting.



CRYOSAT-2 - Due for launch in 2009, CryoSat-2 will determine variations in the thickness of the Earth's continental ice sheets and marine ice cover to further our understanding of the relationship between ice and global warming. CryoSat-2 replaces CryoSat, which was lost at launch in 2005.



SWARM - Due for launch early 2010, Swarm is a constellation of three satellites to study the dynamics of the magnetic field to gain new insights into the Earth system by improving our understanding of the Earth's interior and climate.



EARTHCARE (Earth Clouds, Aerosols and Radiation Explorer) - Due for launch in 2012, EarthCARE is a joint European-Japanese mission addressing the need for a better understanding of the interactions between cloud, radiative and aerosol processes that play a role in climate regulation.

SENTINELS - Within the framework of the Global Monitoring for Environment and Security (GMES) programme, ESA is currently undertaking the development of five new mission families called Sentinels.

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MONITORING THE WEATHER FROM POLAR ORBIT

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MetOp launches a new meteorological era

The weather governs many aspects of the way we live. As well as having an influence on public health and our general well-being, weather conditions have a direct impact on numerous sectors of the economy such as agriculture, business, industry, transport and tourism. Take, for example, how heavy snow can bring the transport system to a standstill, how a heat wave increases the demand for water, or how an extreme event such as a hurricane can bring about widespread devastation.

The economic and social benefits of accurate weather forecasts are huge; they allow us the time to prepare and make decisions, whether it be harvesting a crop before it rains, gritting the roads to prevent accidents, routing air traffic to avoid adverse conditions or simply planning day-to-day activities. In the extreme, knowing that hazardous weather conditions are on the way can save human life and property.

In fact, severe weather poses one of today's biggest challenges as the damage caused by weather-related natural disasters is becoming increasingly significant. Since the apparent increase in the incidence of severe weather events is thought to be linked to a changing climate, it is crucial that we continue to further our understanding of the Earth system and its processes, enabling us to better predict the effects a changing climate may bring.

The advent of observing the Earth from space with satellites has, without question, resulted in enormous improvements in the accuracy of weather prediction and our understanding of climate over the last 40 years or so. Nevertheless, in order to improve numerical weather prediction so that we can benefit from better weather and climate forecasting, there is a growing demand for fast and more precise observations made from space. To this end,



28 May 2004, Nebraska, USA



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the field of satellite meteorology is about to enter a new era with the launch of the first in a series of three brand new MetOp (Meteorological Operational) satellites.

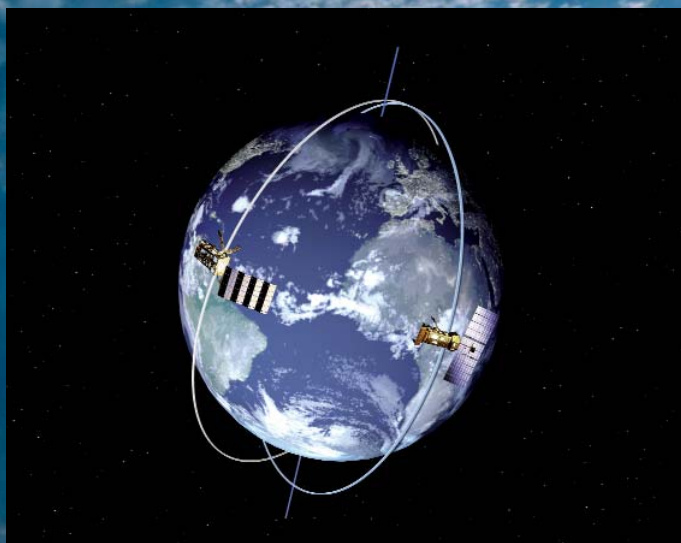
To be launched in 2006, MetOp-A will be Europe's first polar-orbiting satellite dedicated to operational meteorology. With its array of sophisticated instruments, this weather satellite promises to provide data of unprecedented accuracy and resolution on a host of different variables such as temperature and humidity, wind speed and direction over the ocean, ozone and other trace gases, thus making a huge contribution to global weather forecasting and climate monitoring capabilities. In addition, MetOp-A carries instruments to observe land and ocean surfaces as well as search-and-rescue instruments to aid ships and aircraft in distress.

The MetOp series of satellites has been developed as part of a joint undertaking between the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), whereby MetOp forms the space segment of EUMETSAT's Polar System (EPS). Moreover, MetOp is the European contribution to a new cooperative venture with the American National Oceanic and Atmospheric Administration (NOAA) through the Initial Joint Polar Satellite System.

The three MetOp satellites will be launched sequentially, about 4.5 years apart, ensuring the delivery of continuous, high-quality global meteorological data to improve medium- to long-term weather forecasting and climate monitoring until at least 2020.



Monitoring the weather from space - a global approach



The European MetOp satellite and the American NOAA satellite both fly in Sun-synchronous, low-Earth, polar orbits. MetOp is responsible for the morning orbit by passing over the Equator (descending node) at 09.30 local time each orbit, whilst the NOAA satellite occupies the afternoon orbit by passing over the Equator (ascending node) at 14.30 local time each orbit. Together, these two orbits maximise the coverage area over which the observations are made.

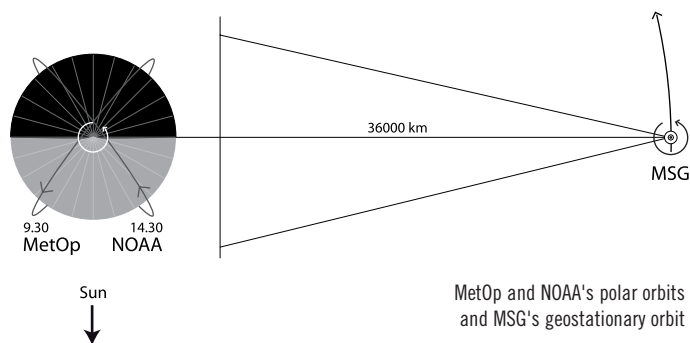
Until MetOp is launched in 2006, Europe's weather satellites have all been placed in geostationary orbit. The first of these Meteosat missions was launched back in 1977 to monitor the weather over Europe and Africa. The success of the initial series of seven satellites has led to the development of a new improved series of four Meteosat Second Generation (MSG) satellites to provide high-quality images of about one quarter of the Earth's disc. So far, two MSG satellites have launched - MSG-1 in 2002 and MSG-2 in 2005.

Although the Meteosat satellites have been delivering wonderful imagery and greatly improving weather nowcasting for almost 30 years, there is a need for Europe to place meteorological satellites in polar orbit. Polar-orbiting satellites can achieve global coverage in a few days and their low orbital altitude can realise very accurate observations of numerous aspects of the atmosphere. Until MetOp is launched, data from polar-orbiting satellites have had to be obtained from the American satellites operated by NOAA.

However, Europe is now set to play a role in monitoring the weather from polar orbit through the Initial Joint Polar Satellite System (IJPS), which is a cooperative effort between NOAA and EUMETSAT. Through this venture, MetOp has been designed to work in conjunction with the NOAA satellite system, whereby MetOp occupies the 'morning' orbit and the NOAA satellite occupies the 'afternoon' shift. This means that the two satellites fly in complementary orbits, hence offering maximum coverage. This global observing system is able to provide invaluable meteorological data from polar orbit to users within 2 hours and 15 minutes of the measurements being taken, and global coverage within six hours.

So that the MetOp and NOAA satellites provide similar data they both carry a common set of well-proven instruments. In addition, MetOp carries a set of brand new European instruments, which will acquire data sets of atmospheric temperature and humidity of unprecedented accuracy along with profiles of atmospheric ozone and other trace gases. Wind speed and direction over the oceans will also be measured. It is envisaged that these new instruments will herald a significant contribution to the ever-growing need for fast and accurate global data to improve numerical weather prediction. This in turn will lead to more reliable weather forecasts and, in the longer-term, help us to monitor our changing climate more accurately.

The launch of the first MetOp satellite will also guarantee a contribution to the Global Monitoring for Environment and Security (GMES) initiative, which is a joint endeavour led by the European Commission and ESA to provide autonomous and independent access to information for policy makers, particularly in relation to the environment and security.



MetOp and NOAA's polar orbits and MSG's geostationary orbit



MetOp's polar orbit complements Meteosat's geostationary orbit

MetOp's polar orbit and MSG's geostationary orbit offer different advantages, making them complementary systems.

MSG orbits the Earth at the same rotational speed as the Earth itself, making it appear stationary from the point of view of the observer on the ground. This orbit is almost 36000 kilometres above the Equator, so at this distance a large portion of the Earth's surface is viewed all the time. This big picture is essential as the weather is driven by air mass exchange processes between the Equator and the poles. Therefore, MSG's vantage point enables rapidly evolving events to be continuously monitored for use in short-term weather prediction. However, being in geostationary orbit means that some parts of the Earth are never viewed and the high altitude of the orbit limits the resolution of the observations.

MetOp, on the other hand, orbits the Earth between 800 and 850 kilometres above the surface, and its orbit takes it over the poles 14 times every 24 hours. During the time it takes for MetOp to complete one orbit the Earth has rotated some 25°, so observations will be made over a different section of the Earth during each orbit. This means that the satellite passes over the Equator at essentially the same local time each orbit. MetOp achieves global coverage for all its instruments within five days. Moreover, the lower orbit allows observations to be made that are much more detailed than can be obtained from higher orbiting geostationary satellites.

Did you know?

In 1904, the Norwegian Vilhelm Bjerknes (1862-1951) paved the way towards modern meteorology by first proposing the procedure now known as numerical weather prediction.

The world's first weather satellite was launched in 1960. Named TIROS-1 (Television Infrared Observation Satellite), it demonstrated the advantage of mapping the Earth's cloud cover from space.

The amount of water held in the atmosphere at any time is sufficient to produce a layer of rain 1.25 cm deep over the entire surface of the Earth.

At any one time, there are approximately 1800 thunderstorms occurring in the Earth's atmosphere.

Sea-surface temperatures must be above 26.5°C for hurricanes to form. A hurricane is one of the most powerful weather systems and is powered by the thermal energy released by the condensation of water vapour.

The term 'weather forecast' was first used by British Admiral Robert Fitzroy in the 1850s. Fitzroy was captain of HMS Beagle and Britain's first chief meteorologist. He also pioneered the printing of a daily weather forecast in newspapers.

A molecule of water stays in the Earth's atmosphere for an average of 10-12 days.

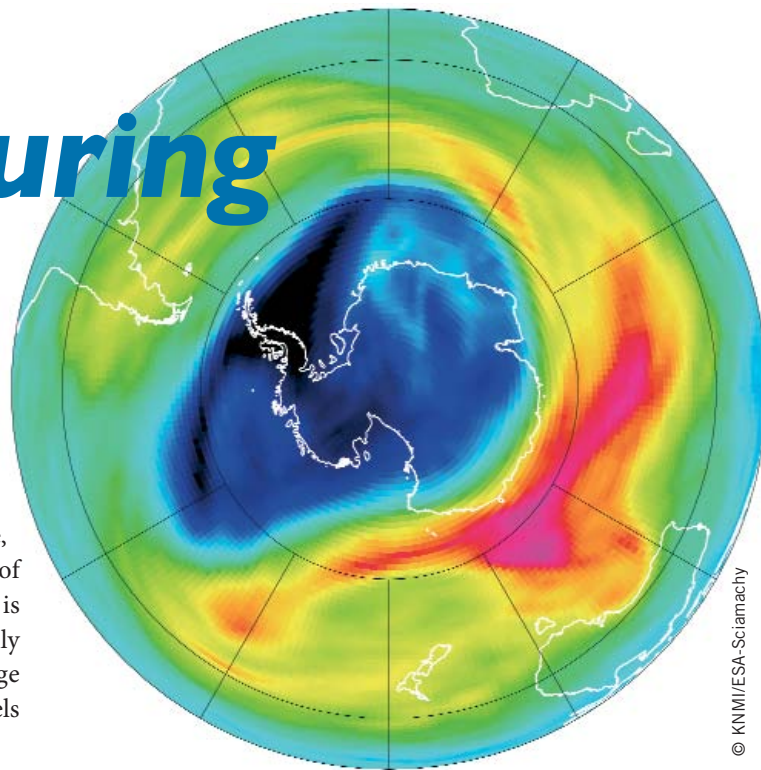
Differential heating of the Earth by the Sun drives all dynamic processes in the atmosphere, and is hence ultimately responsible for all of our weather.

Some measuring techniques

MetOp carries a range of different instruments, some of which are common to both it and the NOAA satellite. Several of the instruments measure similar aspects of the atmosphere, namely temperature and humidity, but use a variety of measuring techniques to acquire their data. This approach is crucial for numerical weather prediction, which not only requires high-quality observations, but also needs huge amounts of data from different sources to feed into the models to make them as accurate as possible.

In addition, since it is expected that temperature and humidity in the atmosphere are likely to vary as a result of a changing climate and this in turn will affect the atmosphere's radiation budget, multitudes of accurate data on atmospheric temperature and humidity are essential for monitoring the climate.

One of the most advanced instruments carried on MetOp is the new Infrared Atmospheric Sounding Interferometer (IASI), which measures infrared radiation emitted from the surface of the Earth to derive data of unprecedented accuracy and resolution on atmospheric temperature and humidity. The Microwave Humidity Sounder (MHS) also acquires measurements of atmospheric humidity and temperature, but measures microwave radiation emitted from the surface of the Earth to do so. The Global navigation satellite system Receiver for Atmospheric Sounding (GRAS), on the other hand, uses radio occultation to measure vertical profiles of atmospheric temperature and humidity by tracking signals received by a constellation of GPS navigation satellites while they are setting or rising behind the Earth's limb.



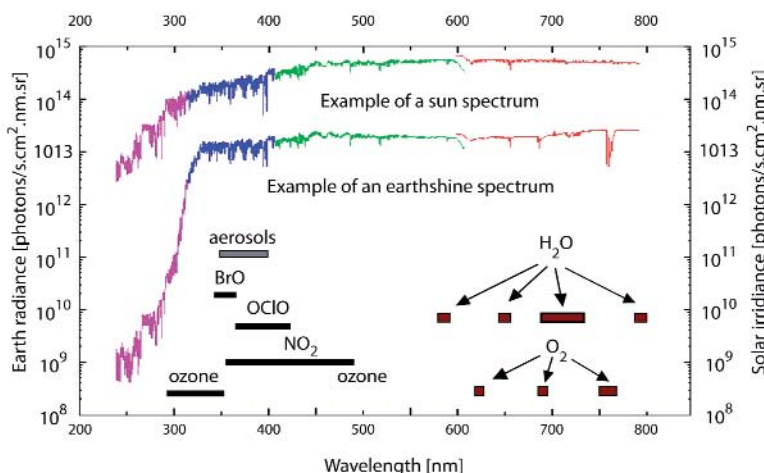
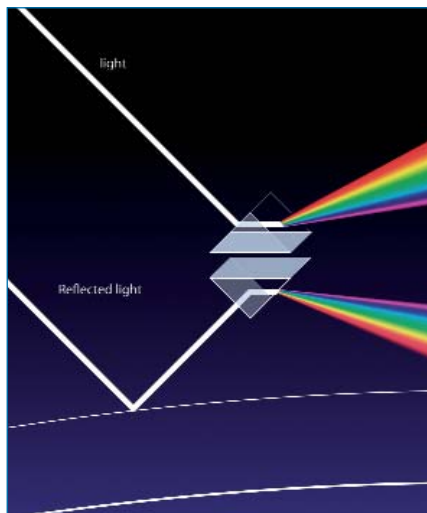
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Assimilated total ozone, 9 September 2005
 Dobson Units [DU]
 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Ultraviolet-visible spectroscopy

Absorption spectroscopy is widely used to detect and measure concentrations of atmospheric constituents. Molecules such as ozone only absorb light at very well defined energy levels. If light that has passed through ozone is split by a prism into a wavelength spectrum, missing energy is identified as a dip in the spectrum. Since each gas has a characteristic fingerprint, its concentration can be measured by the depth of the dip in the spectrum. For reference purposes, a clear signal is measured. The Sun is usually used as a reference source for atmospheric measurements.

The GOME-2 (Global Ozone Monitoring Experiment-2) uses the principles of spectroscopy to determine concentrations of atmospheric ozone and other trace gases present in the atmosphere.



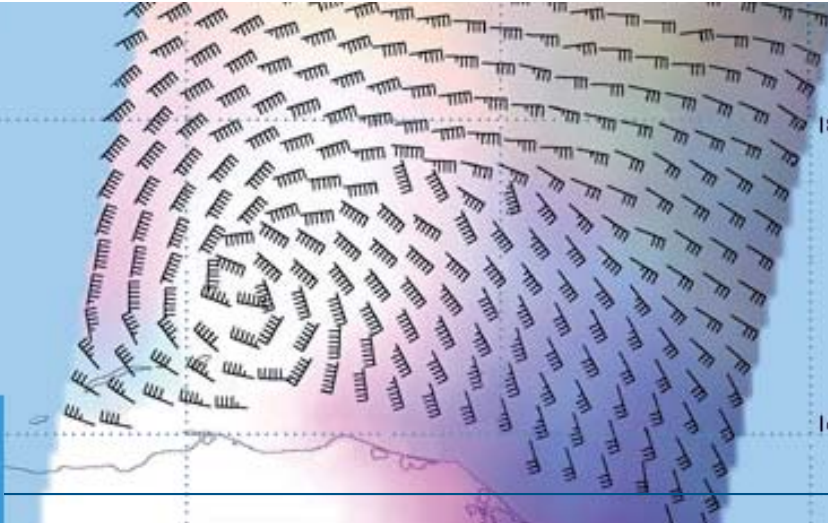


ERS-2 Scatterometer image showing Hurricane Mitch near the coast of Honduras, 27 October 1998.

Other meteorological instruments on board operate using radar to detect winds over the oceans, and spectroscopy to capture light reflected from the Earth's surface and atmosphere to derive profiles of atmospheric ozone, other trace gases and ultraviolet radiation.

Not all of the instruments on board work independently; some work in conjunction with each other. The new European MHS instrument, for example, works together with the four American meteorological instruments provided by NOAA.

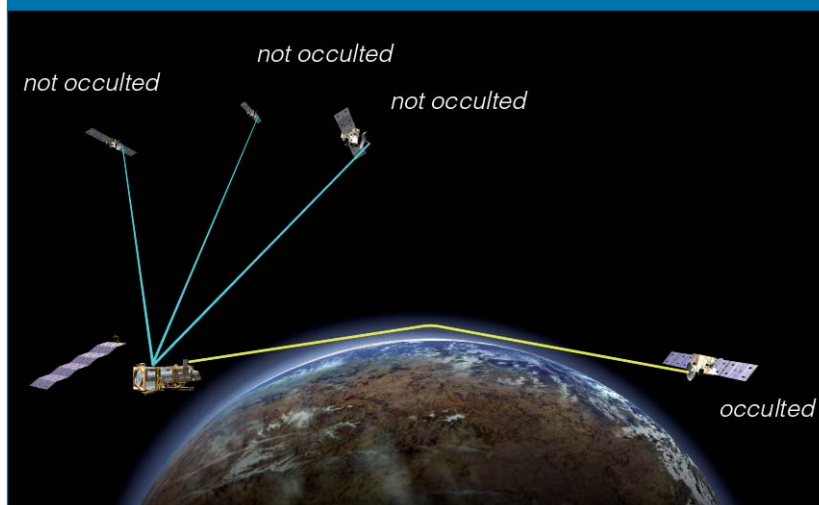
With its sophisticated array of instruments and diverse measuring techniques, MetOp promises to provide outstanding data sets to advance the field of meteorology, which will ultimately improve the accuracy of weather forecasting and our understanding of climate change.



Radio occultation

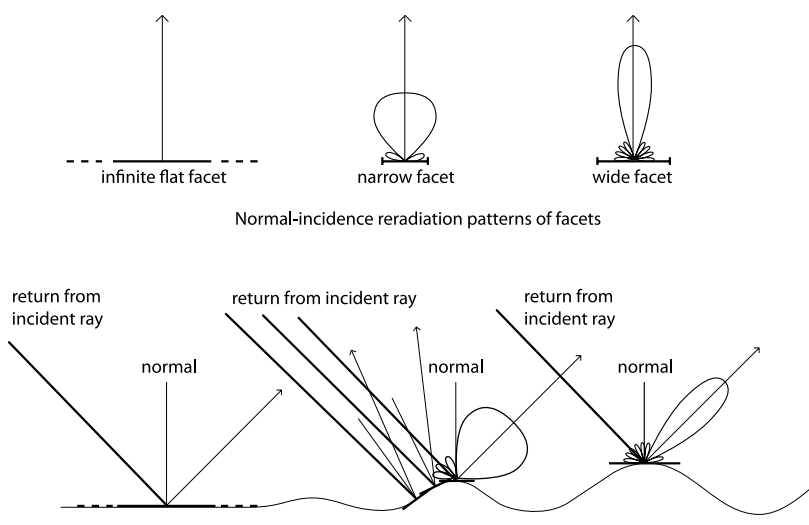
The new European GRAS (Global navigation satellite system Receiver for Atmospheric Sounding) instrument uses radio occultation to measure vertical profiles of atmospheric temperature and humidity by tracking signals received from a constellation of GPS navigation satellites while they are setting or rising behind the Earth's atmosphere. Radio occultation is based on the fact that when radio waves pass through the atmosphere, either during a rising or setting event as seen by the receiver, they are refracted along the atmospheric path. The degree of refraction depends on gradients of air density, which in turn depends on temperature and water vapour. Therefore, measurement of the refracted angle contains information about these atmospheric variables.

The yellow line between the MetOp satellite and a GPS navigation satellite in the image shows an occultation. The straight blue lines tracking the other GPS satellites are not occulted.

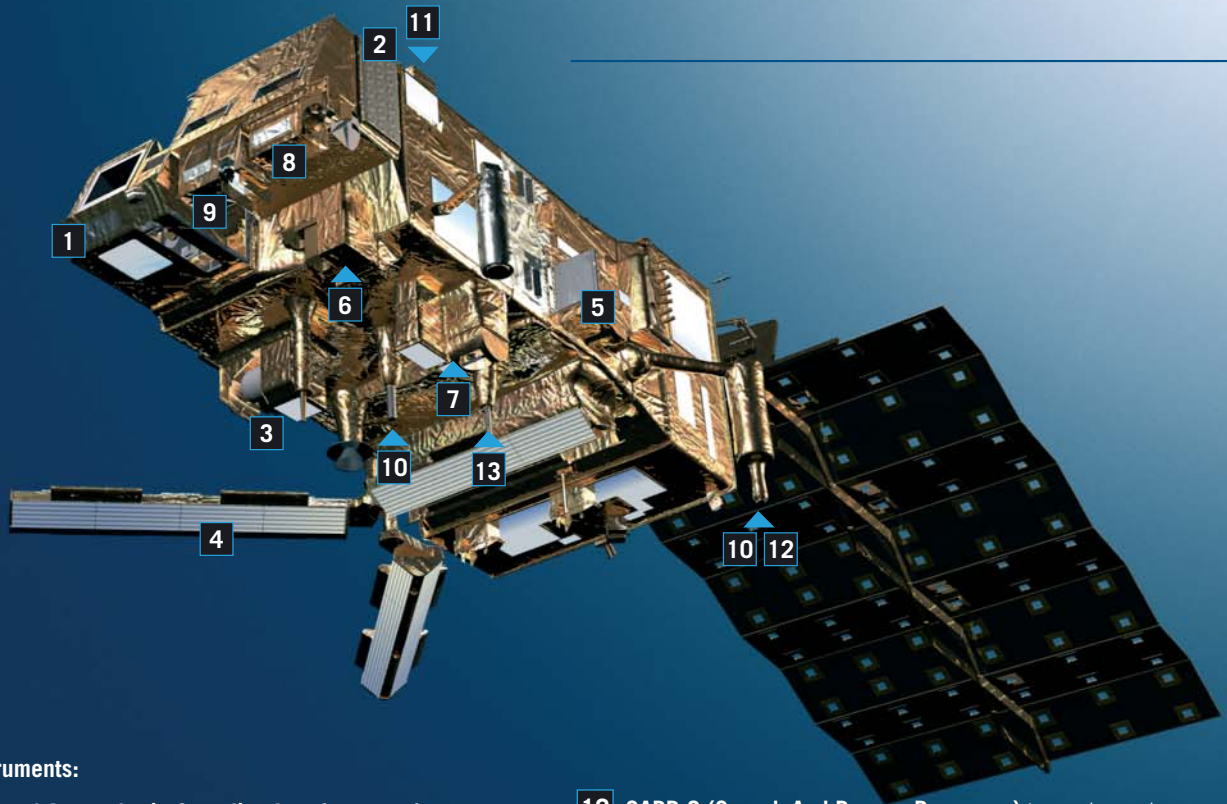


Scatterometry

A radar scatterometer is an active instrument, which emits radio-frequency pulses and detects the reflected microwave radiation. The Advanced Scatterometer (ASCAT) operates by transmitting linear frequency-modulated pulses through antenna beams down onto the ocean surface. The echo signal reflected back towards the satellite (backscatter) is recorded and then processed on the ground. Wind-driven ripples on the ocean surface modify the radar backscatter (Bragg scattering), and as the energy in these ripples increases with wind velocity, so the backscatter increases as well. Scatterometer results from multiple beams enable the wind speed and direction across the water surface to be derived.



MetOp's suite of instruments



European instruments:

- 1 IASI (Infrared Atmospheric Sounding Interferometer)** to measure atmospheric temperature and moisture, and trace gases such as carbon monoxide, nitrogen oxides, methane, ozone.
- 2 GRAS (Global navigation satellite system Receiver for Atmospheric Sounding)** to measure atmospheric temperature and humidity.
- 3 MHS (Microwave Humidity Sounder)** to measure atmospheric humidity and temperature.
- 4 ASCAT (Advanced SCATerometer)** to measure wind speed and direction over the ocean.
- 5 GOME-2 (Global Ozone Monitoring Experiment-2)** to measure concentrations of atmospheric ozone and other gases.

Heritage instruments:

- 6 AMSU-A1 (Advanced Microwave Sounding Unit)** to calculate atmospheric temperature and humidity profiles.
- 7 AMSU-A2 (Advanced Microwave Sounding Unit)** to calculate atmospheric temperature and humidity profiles.
- 8 AVHRR/3 (Advanced Very High Resolution Radiometer)** to provide day and night imaging of land, water and clouds.
- 9 HIRS/4 (High-resolution Infrared Sounder)** to calculate atmospheric temperature and pressure.
- 10 A-DCS (Advanced Data Collection System)** to provide in-situ environmental data collection and Doppler-derived location services.
- 11 SEM-2 (Space Environment Monitor)** to determine the intensity of the Earth's radiation belts and flux of charged particles at satellite altitude.

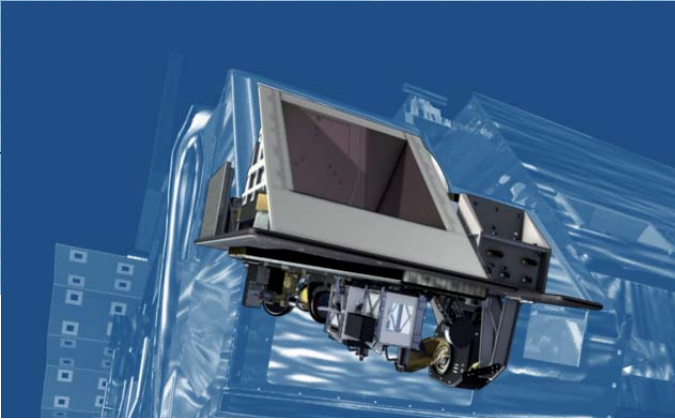
- 12 SARP-3 (Search And Rescue Processor)** to receive and process emergency signals from aircraft and ships in distress.
- 13 SARR (Search And Rescue Repeater)** to receive and downlink emergency signals from aircraft and ships in distress and provide a downlink for data received by the SARP-3.

Carrying an impressive suite of instruments, MetOp is the second largest Earth-observation satellite built in Europe. It offers enhanced remote-sensing capabilities to provide high-resolution images, detailed vertical temperature and humidity profiles, and temperatures of the land and ocean surface on a global basis. Also on board are instruments for monitoring ozone levels in the atmosphere and wind over the oceans. In addition, the payload includes an instrument for data collection, an instrument to observe the weather in space, as well as a tracking system to aid search-and-rescue operations.

Five are new European state-of-the-art instruments, whilst the others, which have been provided by the American National Oceanic and Atmospheric Administration (NOAA) and the French Centre National d'Etudes Spatiales (CNES), come with well-proven heritage, being flown on American satellites already delivering valuable data.

The following sections focus on the new European instruments.

IASI

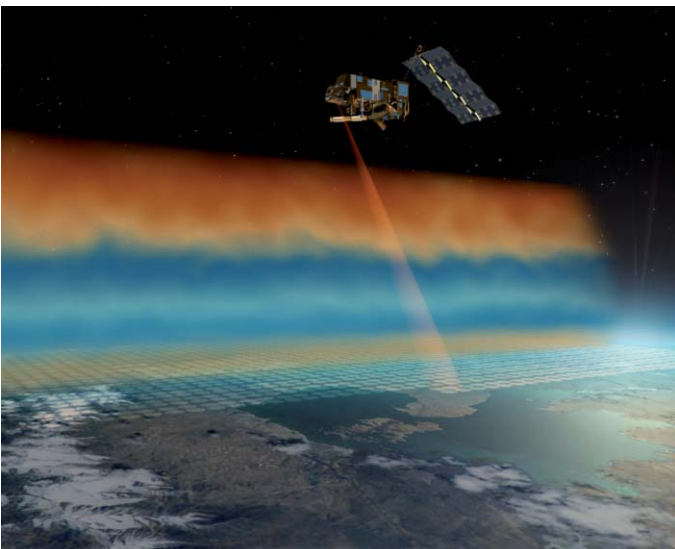


To measure atmospheric temperature and moisture, and trace gases such as carbon monoxide, nitrogen oxides, methane, ozone

Developed by the French Space Agency CNES, the Infrared Atmospheric Sounding Interferometer (IASI) is probably the most advanced instrument carried on the MetOp satellite. Marking a significant technological step forward, it will provide meteorologists with data of unprecedented accuracy and resolution on atmospheric temperature and humidity, with which to improve weather prediction.

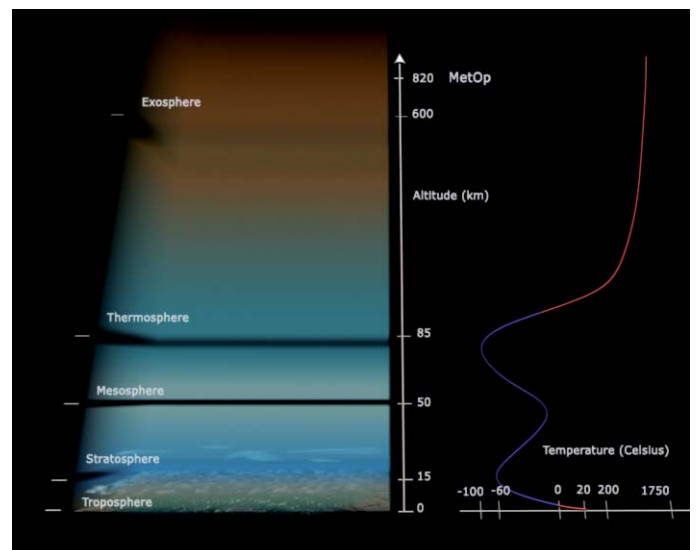
This European instrument is also destined to provide a wealth of data on various components of the atmosphere to further our understanding of atmospheric processes and the interactions between atmospheric chemistry, climate and pollution. In addition, the IASI will deliver data on land-surface emissivity and sea-surface temperature (in cloud-free conditions).

The sophisticated IASI instrument measures infrared radiation emitted from the surface of the Earth to derive atmospheric temperature and humidity profiles of unprecedented accuracy and vertical resolution. The high resolution means that small concentrations of atmospheric gases can also be measured.

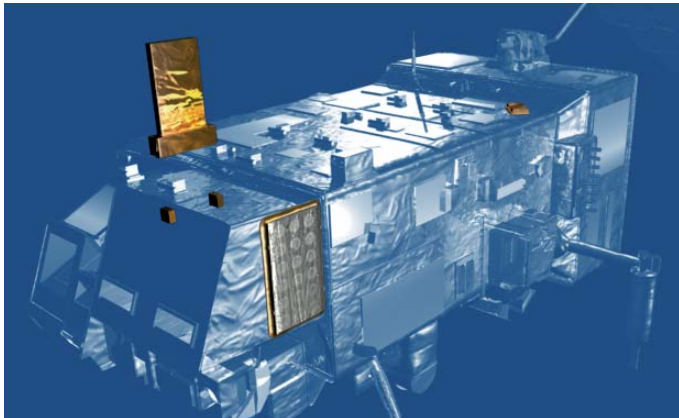


The sophisticated IASI instrument is a Fourier Transform Spectrometer based on a Michelson Interferometer coupled to an integrated imaging system that observes and measures infrared radiation emitted from the Earth. The optical interferometry process offers fine spectral samplings of the atmosphere in the infrared band between wavelengths of 3.4 and 15.5 microns. This enables the instrument to establish temperature and water-vapour profiles in the troposphere and the lower stratosphere, as well as measure the quantities of carbon monoxide, methane and other compounds, all of which play major roles in atmospheric processes such as the greenhouse effect.

The IASI instrument will deliver temperature profiles with an accuracy of 1 Kelvin and a vertical resolution of 1 kilometre. Profiles of atmospheric humidity will be realised with an accuracy of 10% and a vertical resolution of 1 kilometre. This degree of resolution also allows chemical components in small concentrations to be detected. With a swath width on the Earth's surface of about 2000 kilometres, global coverage will be achieved in 12 hours. For optimum operation, the IASI measurement cycle is synchronised with that of the American AMSU (Advanced Microwave Sounding Unit) instruments.



GRAS



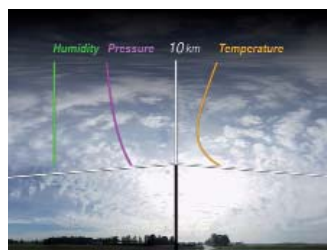
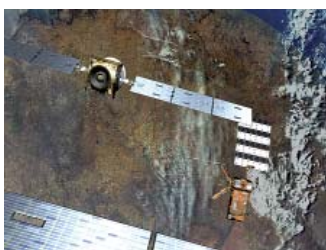
To measure atmospheric temperature and humidity

Developed by ESA, GRAS (Global navigation satellite system Receiver for Atmospheric Sounding) is a new European GNSS (Global Navigation Satellite System) receiver that operates as an atmospheric sounder.

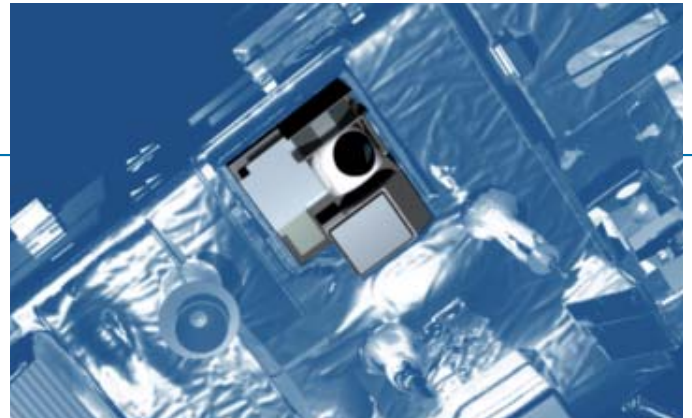
GRAS uses radio occultation to measure vertical profiles of atmospheric temperature and humidity by tracking signals received from a constellation of GPS navigation satellites while they are rising or setting behind the Earth's atmosphere. The Doppler shift of the received signals is directly affected by the refraction of the signal as a result of gradients of atmospheric temperature and humidity. Therefore, profiles of temperature, humidity and pressure can be derived from the refraction angles through the occultation process.

By processing the navigation signals received by GRAS, 500 very accurate profiles of atmospheric temperature, humidity and pressure can be derived every day. Assimilation of GRAS observations into Numerical Weather Prediction models is the most important operational application for data produced by the instrument. GRAS observations combine high vertical resolution and high accuracy with global coverage. Since coverage is global, much of the data will be sampled in the atmosphere over the oceans, which is currently poorly observed.

The GRAS instrument comprises three antenna-receivers positioned separately on the MetOp satellite. Two of the antennae are sited to look tangentially through the Earth's atmosphere and the smaller antenna is used to determine the precise position of MetOp by continuously tracking other GPS satellites.



MHS



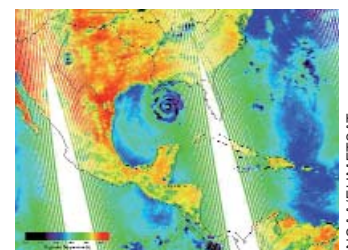
To measure atmospheric humidity and temperature

The Microwave Humidity Sounder (MHS) was developed by EUMETSAT and is a five-channel, total power, microwave radiometer designed to scan through the atmosphere to measure the apparent upwelling microwave radiation from the Earth in specific frequency bands.

Since humidity in the atmosphere (ice, cloud cover, rain and snow) attenuates microwave radiation emitted from the surface of the Earth, it is possible from the observations made by MHS to derive a detailed picture of atmospheric humidity, with the different channels relating to different altitudes in the atmosphere. Temperature at the surface of the Earth can also be determined.

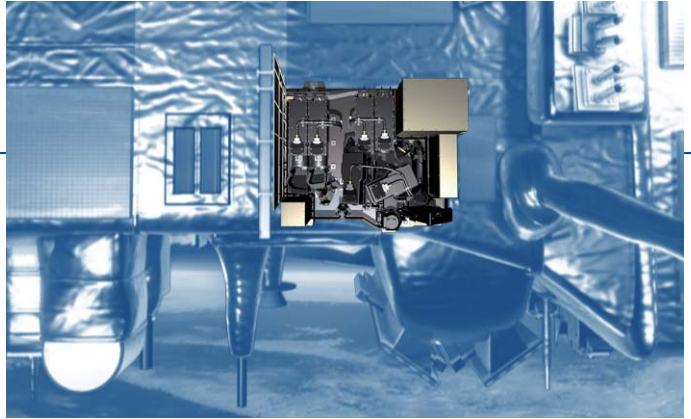
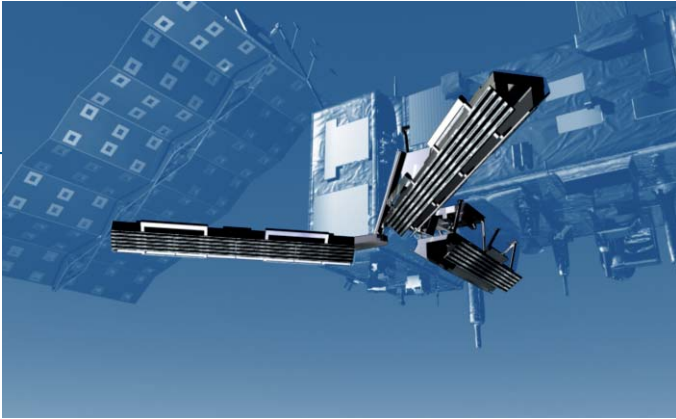
MHS works in conjunction with four of the American instruments provided by NOAA; namely, the Advanced Microwave Sounding Unit-A1 (AMSU-A1), the Advanced Microwave Sounding Unit-A2 (AMSU-2), the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Sounder (HIRS). Along with these instruments, MHS is already in operation on the NOAA-18 satellite, which was launched in May 2005.

The data product image shows Hurricane Katrina taken by MHS (channel 1) from NOAA-18 on 28-29 August 2005.



ASCAT

GOME-2



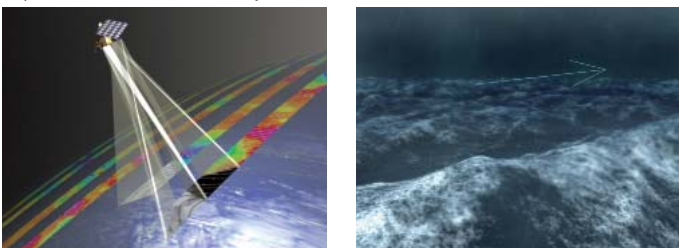
To measure wind speed and direction over the ocean

Developed by ESA, the Advanced Scatterometer, or ASCAT for short, is used to determine information about the wind for use primarily in weather forecasting and climate research. Data from ASCAT will also find applications in a number of other areas such as the monitoring of land- and sea-ice, snow cover and soil moisture.

Winds over the sea cause disturbances of its surface, which modify its radar backscattering characteristics in a particular way. These backscattering properties are well-known and are dependent on both the wind speed and direction with respect to the point from which the sea surface is observed. ASCAT exploits this fact by using radar to measure these backscatter coefficients, which can then be applied to deduce actual wind speed and direction for weather forecasting.

The instrument employs two sets of three antennae, which allow observations to be made from three directions in each of its two 550 km-wide swaths. This will achieve better resolution and over twice the coverage of its predecessors flying on ERS-1 and ERS-2.

ASCAT transmits pulses of microwave energy towards the surface of the Earth and then records the resulting echoes to derive wind speed and direction over the ocean. Since observations are made using radar, ASCAT provides day- and night-time imaging capabilities and is not affected by cloud cover.



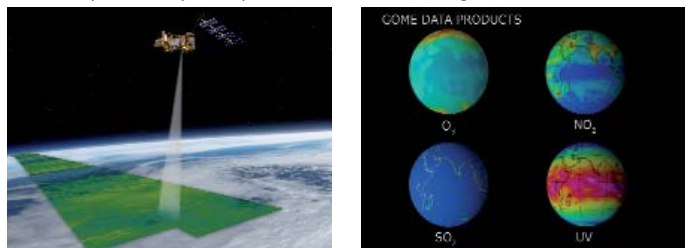
To measure concentrations of atmospheric ozone and other gases

Developed by ESA, the GOME-2 instrument will continue the long-term monitoring of atmospheric ozone started by GOME on ERS and SCIAMACHY on Envisat. The more advanced GOME-2 is set to make a significant contribution to climate and atmospheric research, whilst providing near-real-time data for use in air-quality forecasting.

As solar radiation reaches the Earth's atmosphere and surface, a certain percentage is reflected or backscattered into space. The degree to which incident light is backscattered depends on the albedo of the surface the light encounters; for example, clouds in the atmosphere have a high albedo so a large proportion of sunlight is reflected back. GOME-2 is able to determine amounts of certain gases present in the atmosphere through the principles of spectroscopy; whereby incoming light is split into its spectral components by a complex set of telescopes and prisms to reveal absorption lines, which correspond to the various gases present in the observed sample.

GOME-2 data will provide vertical profiles of atmospheric ozone, nitrogen dioxide and sulphur dioxide, as well as other trace gases and levels of harmful ultraviolet light penetrating the atmosphere.

GOME-2 is a scanning spectrometer that captures light reflected by the Earth's surface and atmosphere to map atmospheric ozone and other trace gases.



Heritage instruments



The instruments described here are common to both the MetOp and NOAA satellite payloads.

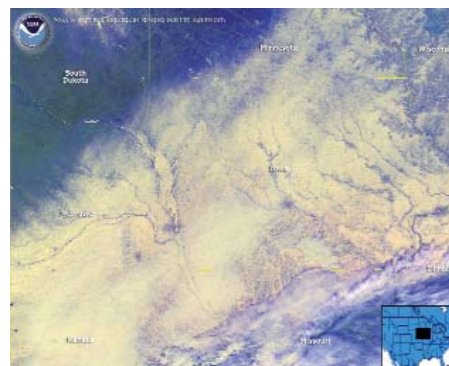
This image shows icebergs (C-18 and C-19) calved from the Ross Ice Shelf in Antarctica on 14 May 2002. It was generated from NOAA-16 AVHRR 1.1-km (0.7-mi) LAC data.

Meteorological instruments

These are part of the complement of instruments provided by NOAA to fly on MetOp-A and MetOp-B. Some instruments are also provided for MetOp-C. They have a well-proven heritage of already providing excellent meteorological data.

AMSU-A1 and A2: Advanced Microwave Sounding Units

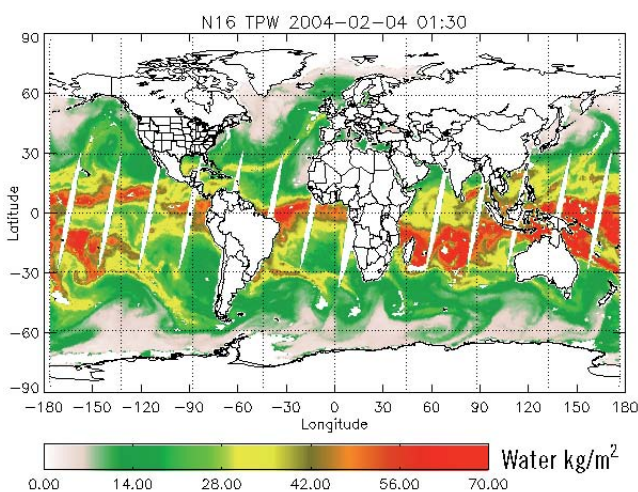
The AMSU instruments measure scene radiance in the microwave spectrum. The data from these instruments are used in conjunction with the High-resolution Infrared Sounder (HIRS) to calculate the global atmospheric temperature and humidity profiles between the Earth's surface and the upper stratosphere. The data are used to provide precipitation and surface measurements including snow cover, sea-ice concentration, and soil moisture.



Snow cover (off-white) is visible in this NOAA-16 image over parts of the Plains and Midwest States of the USA. It was generated from AVHRR High Resolution Picture Transmission (HRPT) 1.1-km (0.7-mi) data for 6 February 2002.

HIRS/4: High-resolution Infrared Sounder

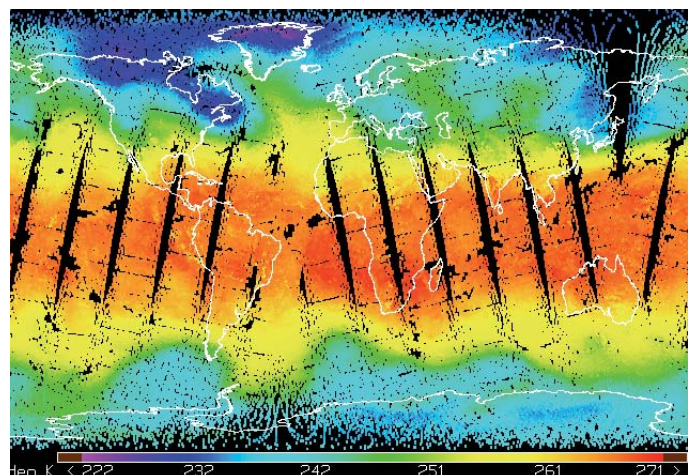
This is a 20 channel radiometric sounder that measures radiance mainly in the infrared spectrum. Data from HIRS/4 are used in conjunction with data from the AMSU instruments to calculate the atmosphere's vertical temperature profile and pressure from the Earth's surface to an altitude of about 40 km. HIRS/4 data is also to be used to determine ocean-surface temperatures, total atmospheric ozone levels, precipitable water, cloud height and coverage, and surface radiance (albedo).



This image produced on 4 February 2004 shows the total precipitable water derived from NOAA-16 AMSU-A data. Total precipitable water shows the amount of water vapour in a column extending from the surface of the Earth to the top of the atmosphere.

AVHRR/3: Advanced Very High Resolution Radiometer

The AVHRR/3 scans the Earth's surface in six spectral bands to provide day and night imaging of land, water and clouds. It also measures sea-surface temperature, ice, snow and vegetation cover.



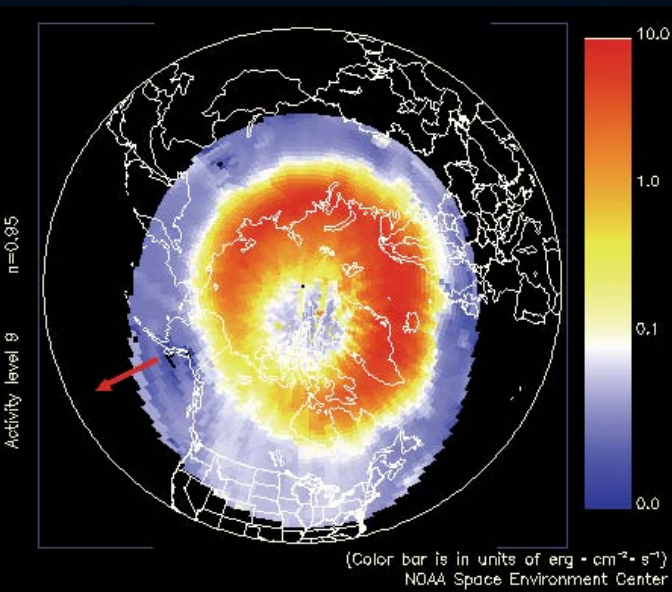
Global atmospheric temperature profiles are derived from the AMSU-A, HIRS, and AVHRR/3 instruments. This 500-millibar atmospheric temperature sounding was produced from NOAA-16 data for 25 January 2004.



Data-collection instrument

A-DCS: Advanced Data Collection System

Provided by CNES, the A-DCS furnishes a worldwide in-situ environmental data collection and Doppler-derived location service with the objective of studying and protecting the Earth's environment. The A-DCS is currently jointly operated by NOAA and CNES. However, with the instrument installed on the MetOp series, EUMETSAT will become the third agency to operate the system.



This image shows the extent and position of the auroral oval in the Northern Hemisphere extrapolated from measurements taken from a pass by the NOAA-17 satellite on 26 January 2004. The red arrow at the left of the image points toward the noon meridian. An estimate of the location, extent, and intensity of aurora is generated by NOAA's Space Environment Center on a global basis from the SEM-2 instrument.

Space weather instrument

SEM-2: Space Environment Monitor

Provided by NOAA, the SEM-2 is a charged-particle spectrometer that provides measurements to determine the intensity of the Earth's radiation belts and the flux of charged particles at the satellite altitude. It provides knowledge of solar-terrestrial phenomena and also provides warnings of solar-wind occurrences that may impair long-range communication, high-altitude operations, damage satellite circuits and solar panels, or cause changes in drag and magnetic torque on satellites.

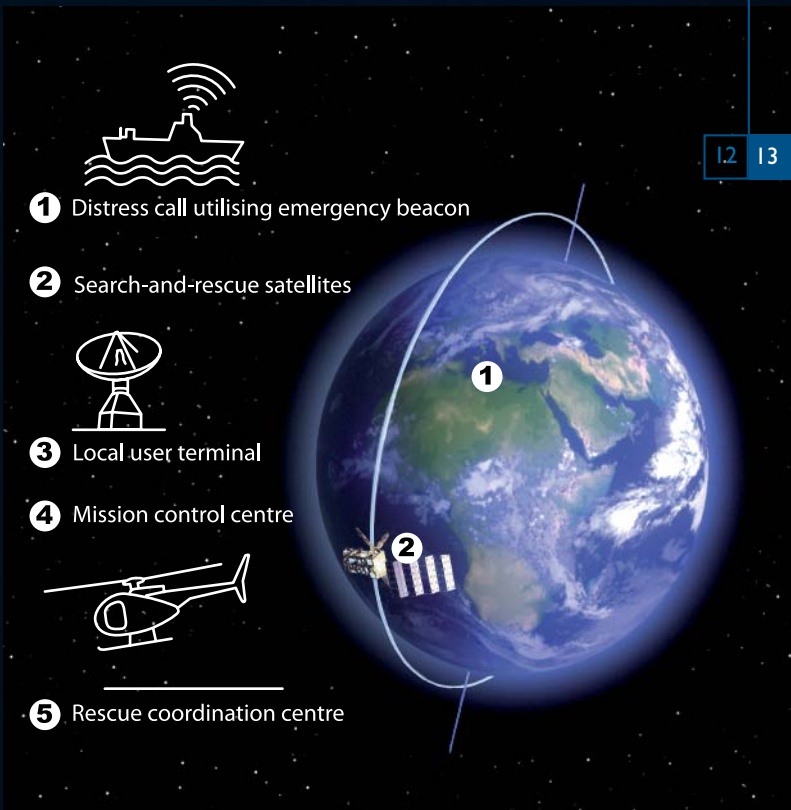
Search and Rescue instruments

SARP-3: Search And Rescue Processor

Provided by CNES, the SARP-3 receives and processes emergency signals from aircraft and ships in distress. It determines the name, frequency and time of the signal. These data are then fed into the SARR instrument for immediate transmission to Cospas-Sarsat (Search and Rescue Satellite) distress terminals on the ground.

SARR: Search And Rescue Repeater

Provided by the Canadian Department of Defence through NOAA, the SARR receives and downlinks emergency signals from aircraft and ships in distress. In addition, it provides a downlink for data received by the SARP-3. The SARR receives distress-beacon signals in three separate frequencies, translates and retransmits them to Local User Terminals on the ground. These terminals process the signals, determine the location of the beacons and then forward this information to a Rescue Mission Control Centre.



Search and Rescue instruments are carried on MetOp and the NOAA satellite to aid ships, aircraft and people in distress.

The satellite



Soyuz 2-1A before being erected on the launch pad (the fairing is wrapped in a thermal protective covering).

The MetOp satellite design builds on the heritage gained from a successful series of European satellites including SPOT, ERS and Envisat, and it will be the second largest European Earth Observation satellite ever launched. The MetOp satellite was developed by a consortium of European companies led by the main contractor EADS-Astrium, France.

It is made up of two main sections: the Payload Module and the Service Module. This modular approach allowed the development and testing of these elements to be carried out in parallel, minimising the need for satellite-integrated activities.

The Payload Module accommodates all of the instruments and associated payload-support equipment. The Service Module provides the main satellite support functions, such as command and control, communications with the ground, power, attitude and orbit control, and propulsion. It also interfaces with the launcher. Together with the instruments the satellite weighs just over 4000 kg and measures 17.6 m x 6.6 m x 5.0 m when in orbit.

The first satellite in the series, MetOp-A, will be launched in mid-2006 from the Baikonur Cosmodrome in Kazakhstan on a Soyuz-ST Fregat launcher operated by Starsem. However, compatibility with the Ariane-5 fairing has also been retained.

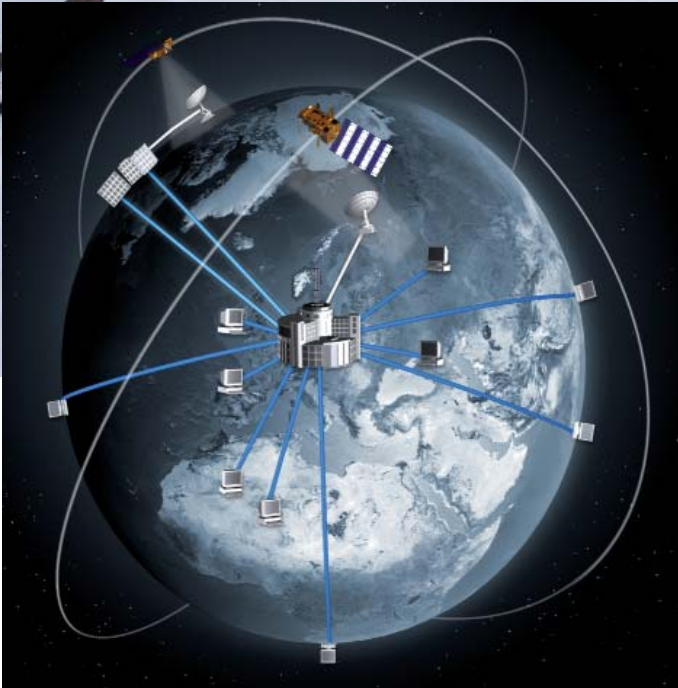
Although MetOp has a polar orbit, it does not pass exactly over the geographic poles but is slightly inclined at an angle of 98.7° to the Equator. At an altitude of between 800 and 850 km it takes about 100 minutes to complete one orbit. During the time it takes to complete one orbit, the Earth will have rotated some 25°, which means that observations will be made over a different section of the Earth with each orbit. Different instruments have different swath widths and hence take different times to observe the entire Earth. However, all the instruments will have achieved global coverage within five days.

Data will be transmitted once per orbit to a purpose-built ground station in Svalbard, Norway, inside the Arctic Circle. This station is situated close to MetOp's orbital track at the North Pole. From here the data are transferred to EUMETSAT in Darmstadt, Germany. There is also a data exchange with the National Oceanic and Atmospheric Administration (NOAA) in the USA. After processing, the data will be distributed to the users within 2 hours 15 minutes of the observations being made in space.



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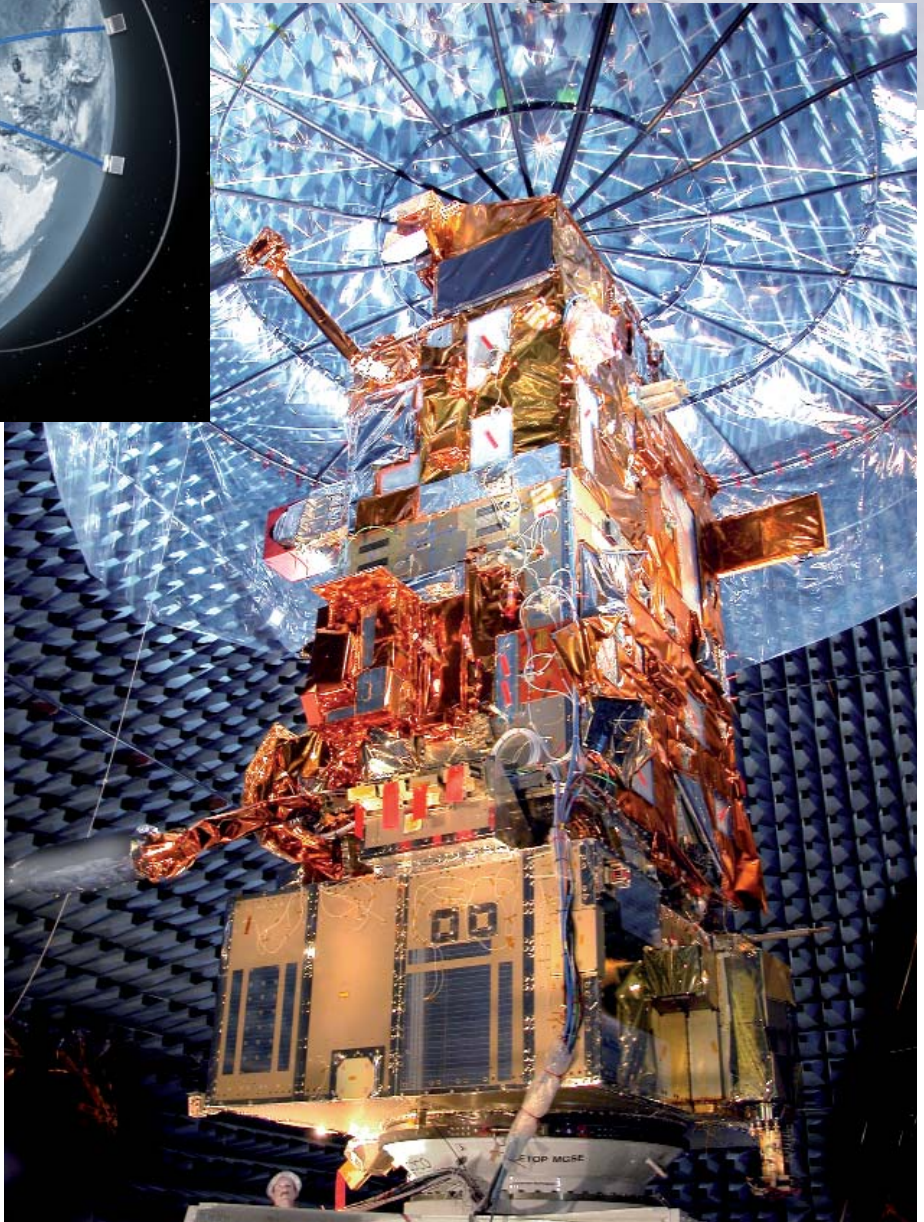
The data-receiving station in Svalbard, Norway.



Data from MetOp is delivered to meteorological offices every 2 hours 15 minutes and is available to local users as the satellite passes overhead.

MetOp-A undergoing final testing at the EADS-Astrium facilities in Toulouse, France.

In addition to the near-real-time data being delivered to meteorological offices, MetOp will also provide a service to local users. With the right tools it will be possible to receive data from the satellite as it passes overhead. Very little equipment is needed to receive data, which makes it a very useful service for small stations in remote areas throughout the World, or even at sea. This service will also be very useful for universities and other academic institutions.



MetOp overview

MetOp is Europe's first polar-orbiting satellite dedicated to operational meteorology. The series of three satellites, which have been developed in a joint undertaking between the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), will be flown sequentially to provide continuous data until at least 2020. MetOp forms the space segment of EUMETSAT's Polar System (EPS). To be launched in 2006, MetOp-A is the first in the series and will provide data of unprecedented accuracy on atmospheric temperature and moisture (for Numerical Weather Prediction models), wind speed and direction, atmospheric ozone and trace gases, as well as imagery of clouds, land and ocean surfaces.

MetOp represents the European contribution to a new cooperative venture between EUMETSAT and the American National Oceanic and Atmospheric Administration (NOAA).

Mission Objectives

To provide global meteorological observations from polar orbit to improve Numerical Weather Prediction (NWP), weather forecasting and climate monitoring.

Mission Details

Launch: MetOp-A in 2006 and MetOp-B and MetOp-C nominally 4.5 years after one another.

Duration: Nominally 5 years (including 6-month commissioning phase) for each mission.

Mission Orbit

Sun-synchronous polar orbit

Morning orbit 09.30 local time (descending node)

Inclination: 98.7° to the Equator

Altitude: 800-850 km

Costs

Total programme cost, including three satellites, launchers, ground segment and operations is 2.4 billion Euros (1.85 billion financed by EUMETSAT and 550 million by ESA for satellite development).

Configuration

Total mass: 4086 kg

Dimensions: height 17.6 m, length 6.7 m, width 5.4 m (in-orbit configuration)

Power

Solar Array with 3828 W EOL

Average power consumption per orbit: 1812 W

Average available power per orbit: 1835 W (EOL)

Energy storage: 5 VOS40 Ni-Cd batteries

Payload

European instruments

IASI (Infrared Atmospheric Sounding Interferometer)

GRAS (Global navigation satellite system Receiver for Atmospheric Sounding)

MHS (Microwave Humidity Sounder)

ASCAT (Advanced Scatterometer)

GOME-2 (Global Monitoring Experiment-2)

US meteorological instruments provided by NOAA

AMSU-A1 & A2 (Advanced Microwave Sounding Units)

AVHRR/3 (Advanced Very High Resolution Radiometer)

HIRS/4 (High-resolution Infrared Sounder)

Data-collection instrument

A-DCS (Advanced Data Collection System) (CNES)

Space weather instrument

SEM-2 (Space Environment Monitor) (NOAA)

Search and rescue instruments

SARP-3 (Search And Rescue Processor) (CNES)

SARR (Search And Rescue Repeater) (NOAA)

Telemetry and Command

- Telecommand uplink 2053 MHz (S-band), 2 kbps

- Telemetry downlink 2230 MHz (S-band), 4 kbps

- Global Data Stream downlink: X band 7800-7900 MHz 70 Mbps

- LRPT downlink: VHF 137.1 MHz 72 kbps

- HRPT downlink: L-band 1701.3 MHz 3.5 Mbps

Ground Infrastructure

- EUMETSAT Polar System (EPS) Command & Data Acquisition station, Svalbard (Norway)

- Command & Control Centre: EUMETSAT, Darmstadt (Germany)

- Data Processing: EUMETSAT, Darmstadt (Germany)

Launch

Soyuz-ST launcher (operated by Starsem) from Baikonur Space Centre in Kazakhstan

Main Contractors

EADS-Astrium, France

(Satellite and Service Module Prime Contractor)

EADS-Astrium, Germany

(Payload Module, ASCAT & GRAS instruments)

50 sub-contractors from 12 European countries



EPS
METOP

European Space Agency
Agence spatiale européenne

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