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An Introduction to EUMETSAT Polar System

Produced by the COMET® Program

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Learning Objectives

After completing this module learners will be able to:

- Identify the three major disciplines to which EPS contributes.
- Describe the role of EPS within the Global Operational Satellite Observation System (GOSOS) and the Initial Joint Polar-Orbiting Operational Satellite System (IJPS).
- Describe the main differences between polar and geostationary satellites.
- Describe the EPS programme elements and how they contribute to the flow of data products.
- Identify the instruments on the Metop satellite and their primary applications.
- Describe the capabilities and anticipated benefits of the IASI hyperspectral sounder.
- Describe the main services provided by EPS.

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1.0 Introduction

I am Dieter Klaes, the Programme Scientist of the EUMETSAT Polar System, known as EPS. My background is in meteorology and physics. I worked as a forecast meteorologist in aviation meteorology and general forecasting, so I know the user side and their needs very well. I have 17 years of experience in satellite meteorology and in building systems and software to exploit satellite data. I created the Satellite Data Processing System for the German Armed Forces and coordinated the development of the direct readout software package AAPP (ATOVS and AVHRR Processing Package) for NOAA satellites. I have worked on the EPS Programme at EUMETSAT for the past twelve years, the last seven of them as Programme Scientist.

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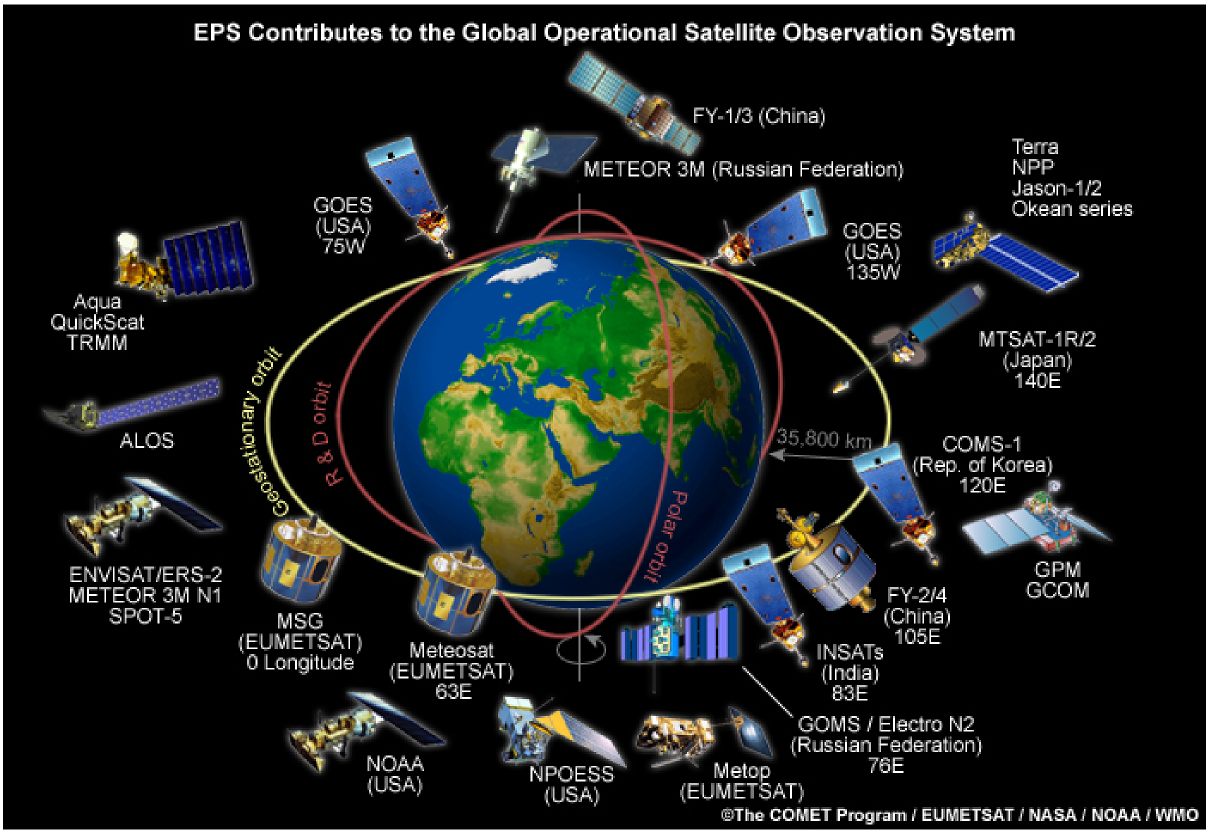
1.1 EPS as Part of the Global Operational Satellite Observing System

EPS (the EUMETSAT Polar System) is part of the Global Operational Satellite Observation System (GOSOS), which is under the auspices of the World Meteorological Organisation (WMO). GOSOS consists of operational and research satellites in both polar and geostationary orbits that provide a wealth of information to the global user community for operational meteorology and climate monitoring.



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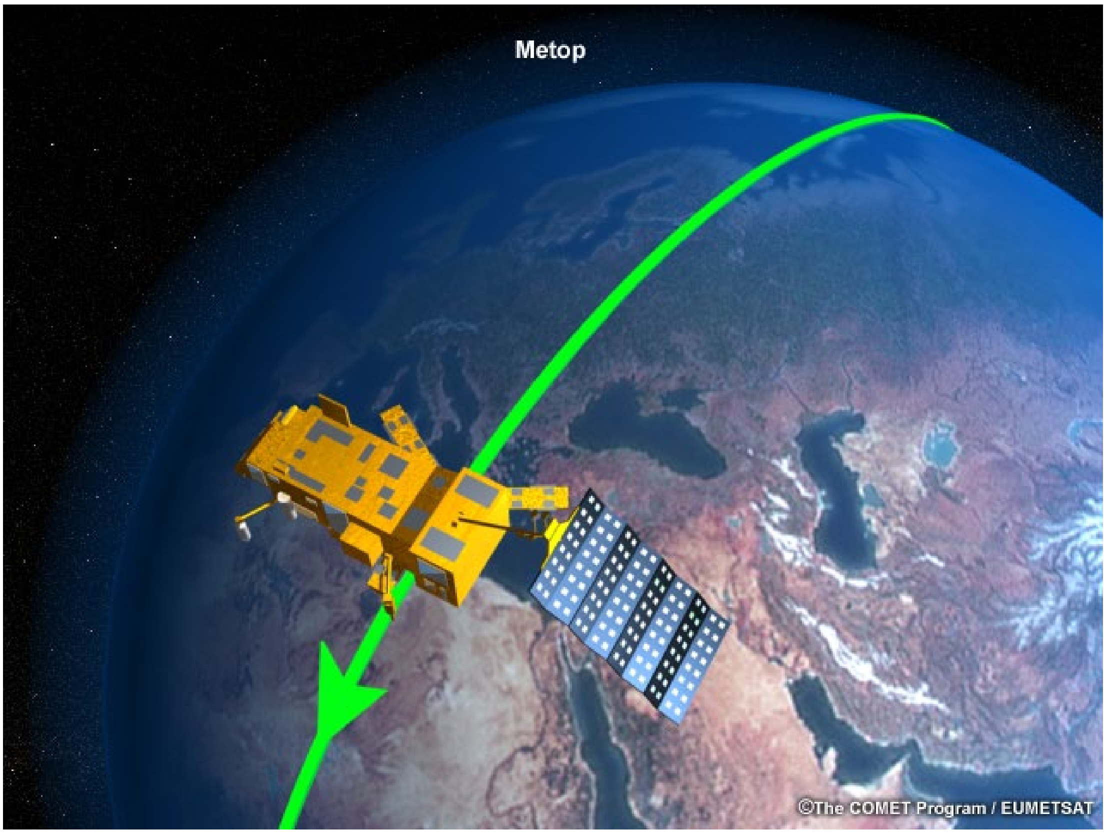
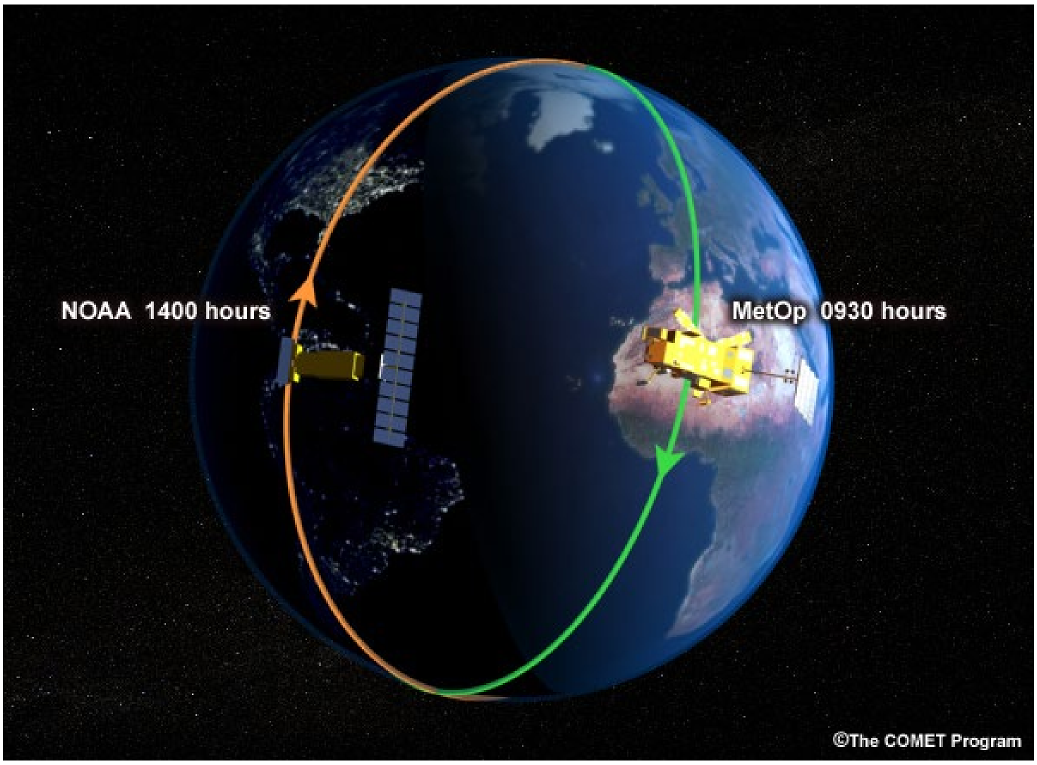
1.2 EUMETSAT's Role in IJPS

The EPS Programme is EUMETSAT's first polar-orbiting weather satellite programme. It contributes to the Initial Joint Polar System (IJPS) under a cooperation agreement between EUMETSAT and NOAA to provide and improve operational meteorological and environmental forecasting and global climate monitoring services worldwide.

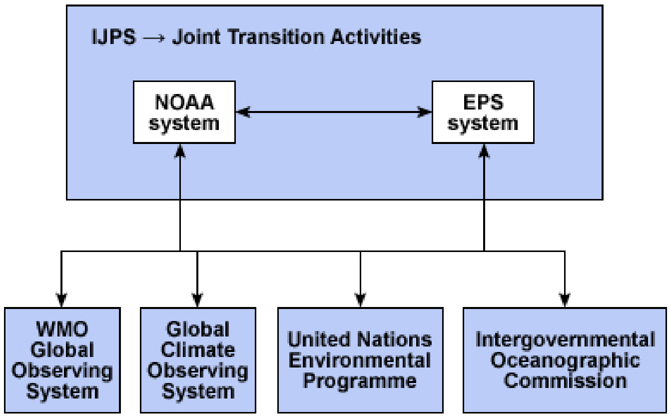




The IJPS program also contributes to and supports the following systems and programs:

- The World Meteorological Organization (or WMO) Global Observing System
- The Global Climate Observing System
- The United Nations Environmental Programme (UNEP)
- The Intergovernmental Oceanographic Commission (IOC)
- And other related programs

Through the Joint Transition Activities agreement signed in 2003, EUMETSAT and NOAA have agreed to provide an operational polar-orbiting service until at least 2019.



EUMETSAT

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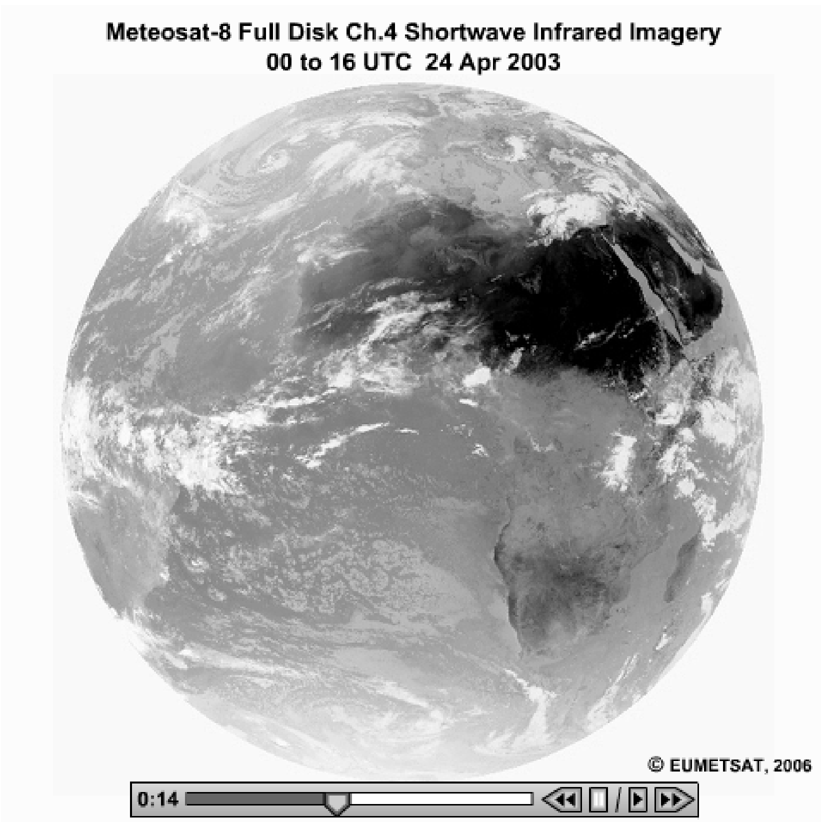
1.3 EUMETSAT's Geostationary Satellites

EUMETSAT has operated the geostationary Meteosat satellites for over a decade. These images are from the SEVIRI (the Spinning Enhanced Visible and Infrared Imaging Radiometer) instrument on the Meteosat Second Generation geostationary satellite (MSG-1, now known as Meteosat-8).



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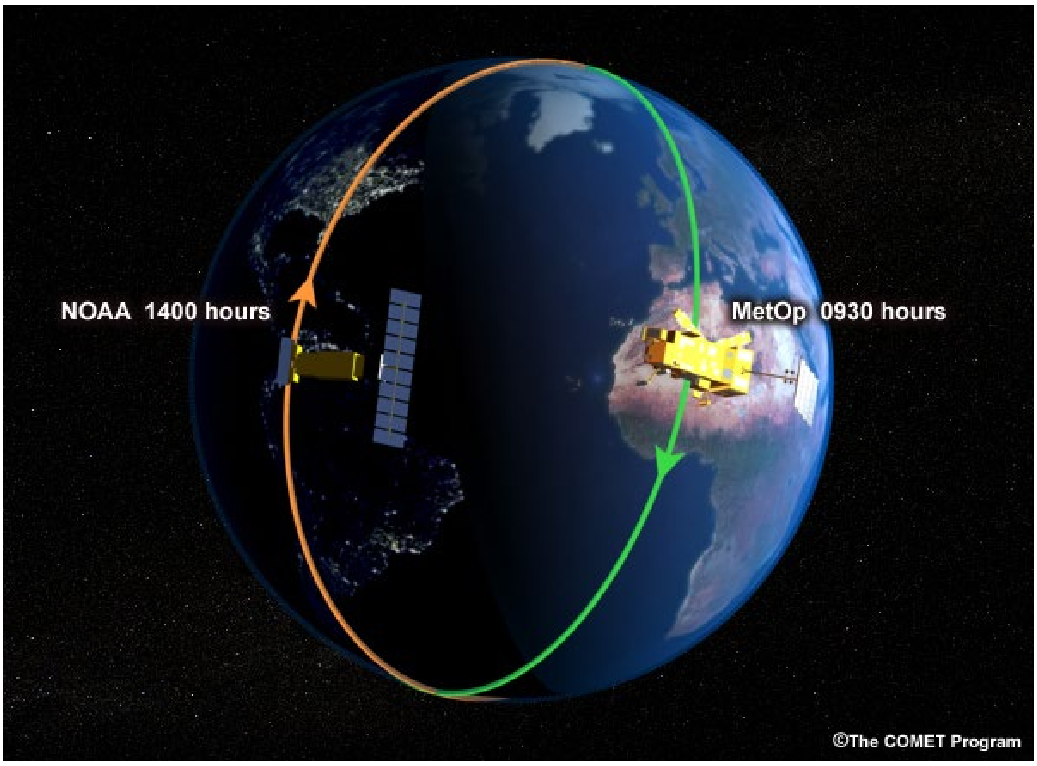
1.4 EUMETSAT Enters the Polar Satellite Era

With Metop and EPS, EUMETSAT has entered the polar satellite era. EUMETSAT is responsible for the mid-morning orbit of the operational polar satellite observation system, whereas NOAA continues to serve the afternoon orbit with NOAA-18 and NOAA-N'.



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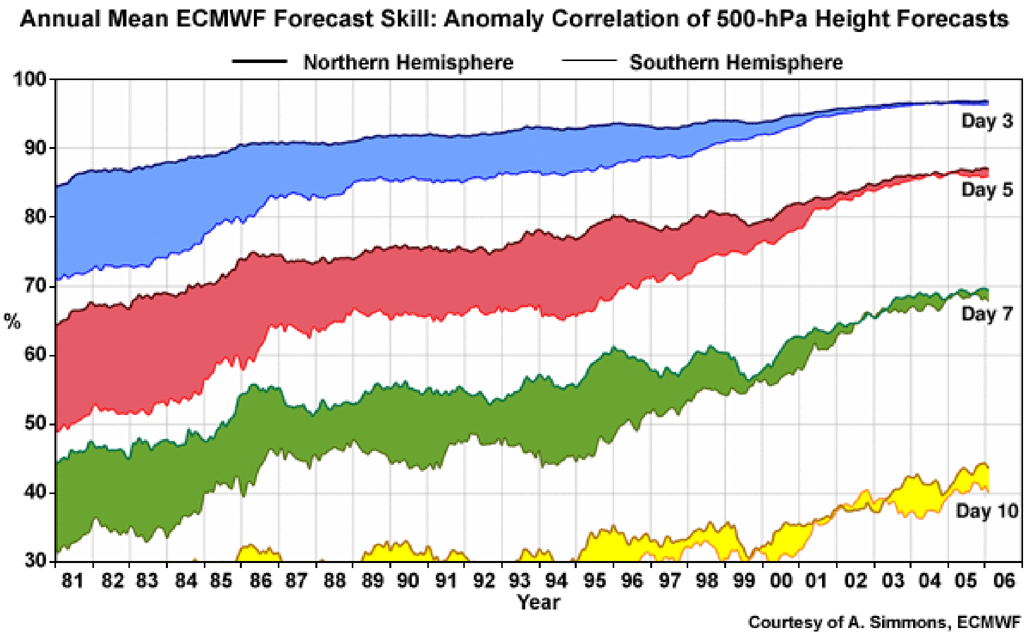
1.5 Why Meteorological Satellites?

Satellite data have considerably improved weather prediction, in part because of the information they provide over data-sparse areas. This includes the oceans, which cover almost three-quarters of the earth's surface and most of the Southern Hemisphere.

This graph shows the increase in forecast quality over time, with the quality of forecasts in the Southern Hemisphere now close to that of the Northern Hemisphere.



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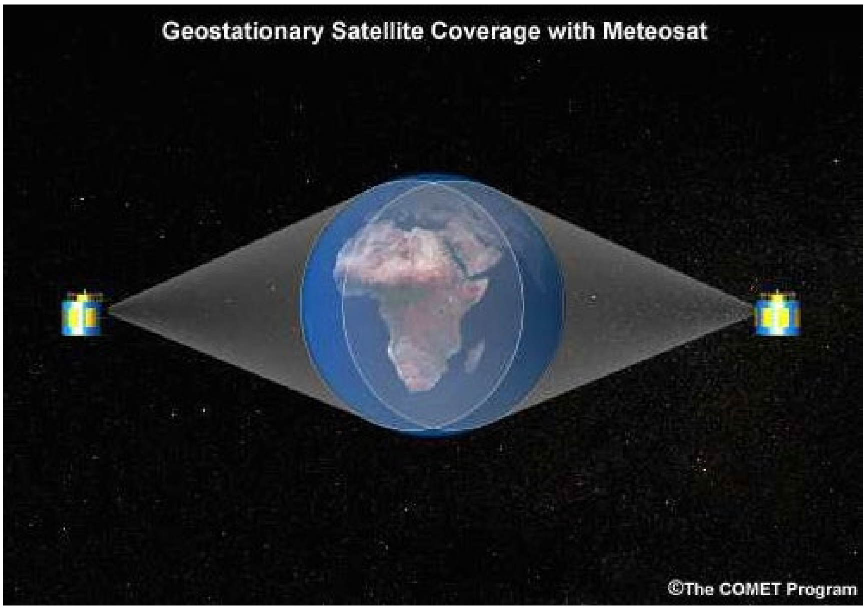
1.6 Polar Versus Geosynchronous Orbits

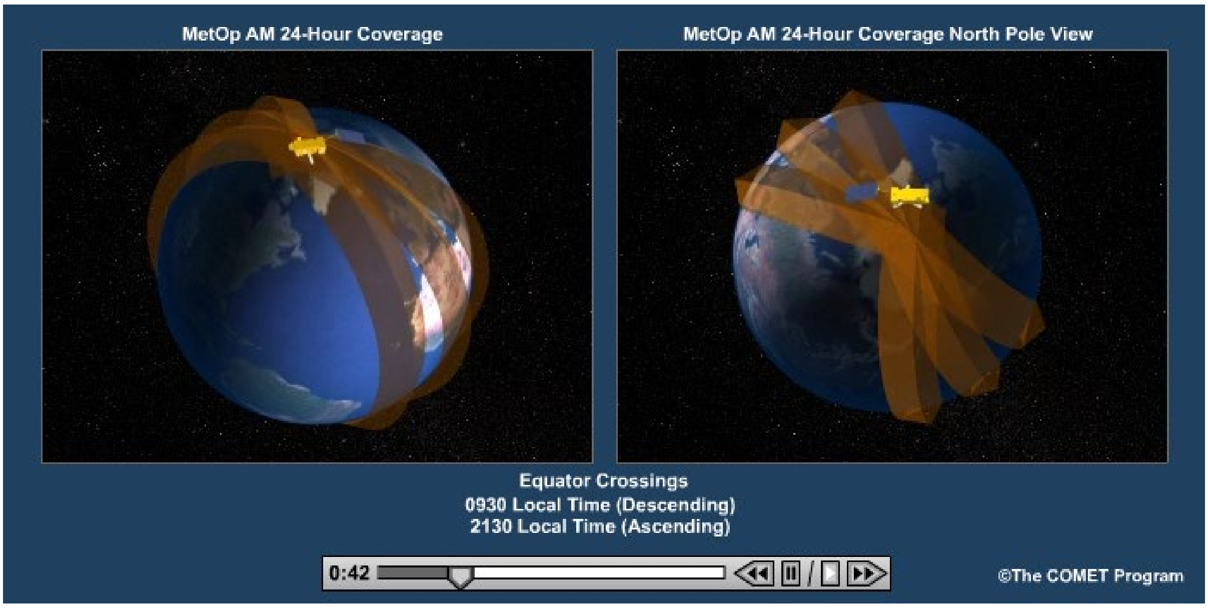
What is a polar orbit compared to a geosynchronous orbit? And what are the advantages and benefits of polar satellites? In a geosynchronous orbit, the satellites are positioned over the equator at an altitude of about 36000 km. They orbit at exactly the angular speed of the earth's surface, making them appear to stand still over the equator at a given longitude.



A polar orbit is quite different. The satellites fly at lower altitudes (typically about 820 km) and pass close to the poles.

A single polar-orbiting satellite observes the entire globe in 12 hours. Most locations are viewed a minimum of twice daily. Coverage at high latitudes is more frequent due to the overlap by consecutive orbits. The global coverage provided by polar-orbiting satellites makes the data extremely useful for applications such as numerical weather prediction and climate monitoring.

To allow for the routine viewing of a fixed point at about the same local solar time each day, meteorological polar orbiters are placed into sun-synchronous near-polar orbits. Sun-synchronous means that the satellite orbit remains fixed with respect to the sun with the earth rotating under the satellite. A specific satellite will pass overhead at a specific time of day or night, for example, at 9:30 and 21:30 local time at the equator for Metop. A network of polar satellites, such as IJPS, is usually coordinated to cover a specific location at various times of day.



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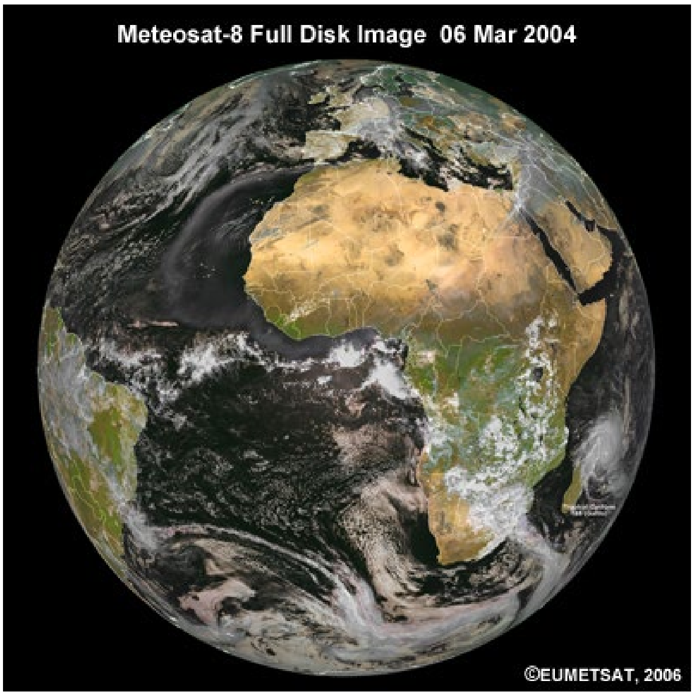
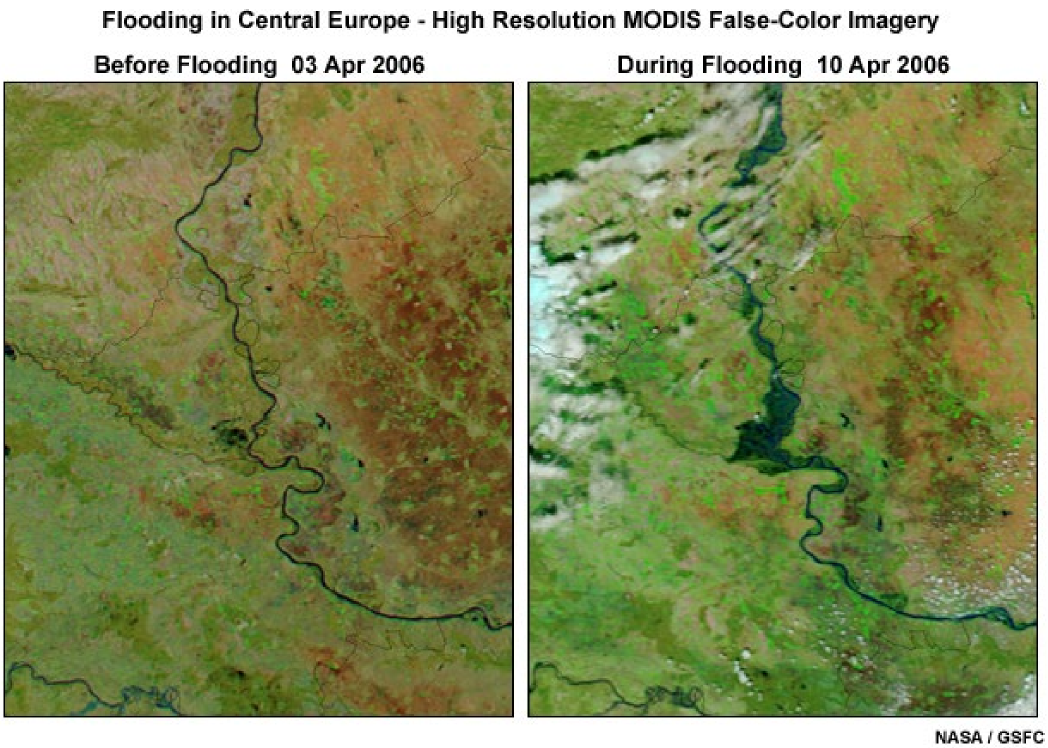
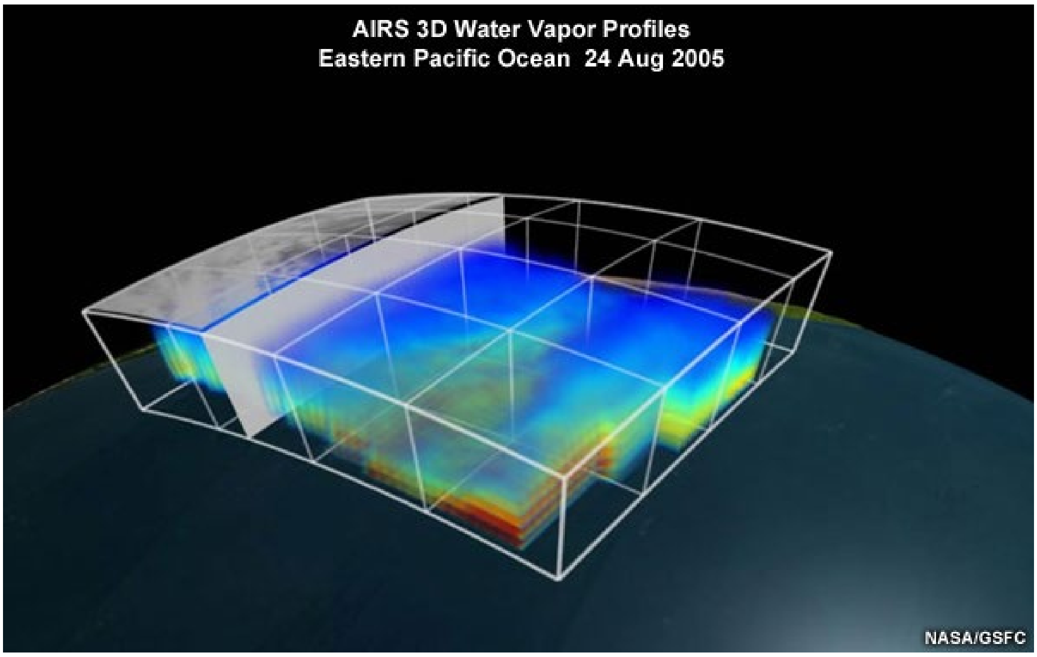
In contrast to polar-orbiting satellites, a single geostationary satellite observes about one-third of the surface of the earth and provides a higher refresh rate. Geostationary satellites, however, cannot observe polar latitudes.



Due to the low flight altitude, polar-orbiter instruments are capable of a higher ground resolution than geostationary satellites. This is especially true in the infrared, and results in higher-resolution imagery and derived products. In meteorological applications, the typical ground resolution of visible and infrared polar satellite imagery ranges from hundreds of meters to about one kilometre.



Polar satellites provide information on the vertical structure of the atmosphere from data-sparse areas, particularly oceans and polar regions. This is critical to NWP, where more than 90% of the data come from satellites.



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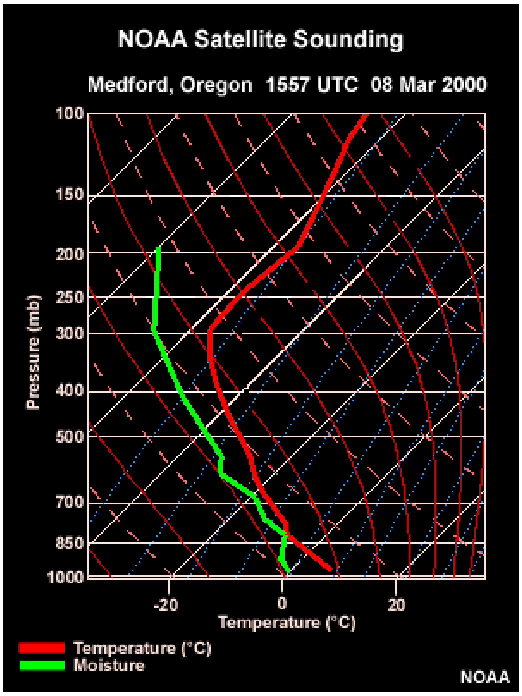
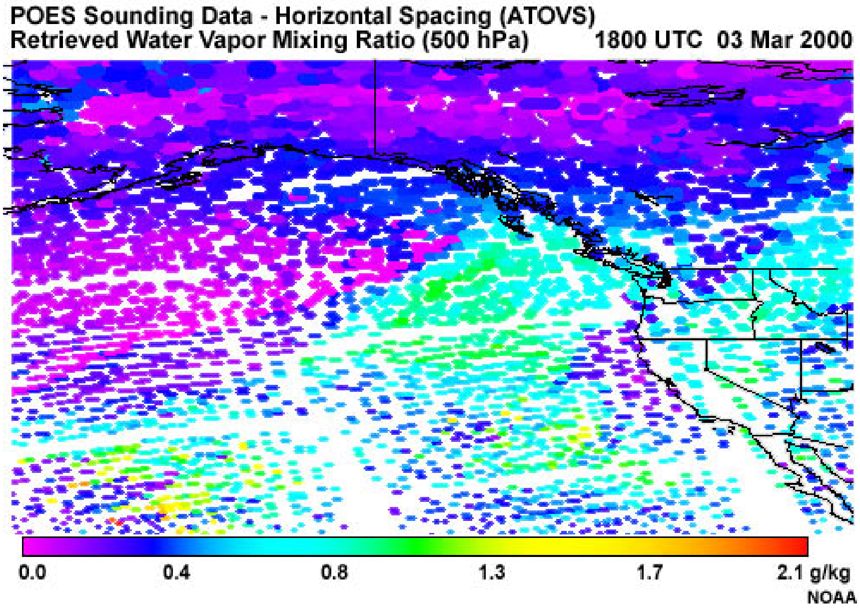
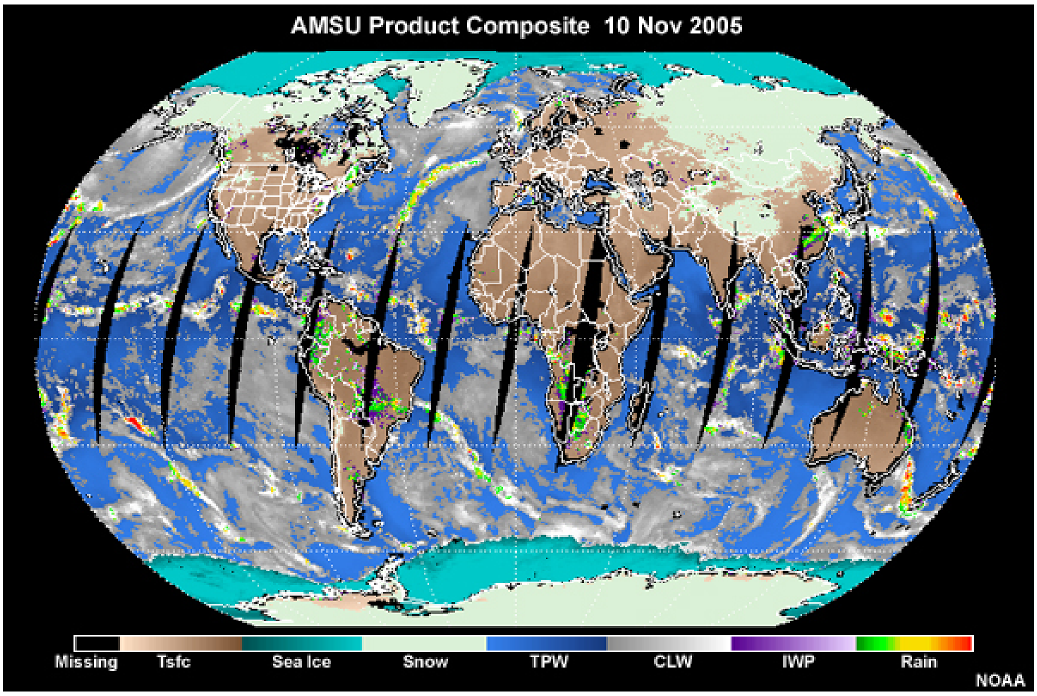
Because of their low orbit, polar satellites make it possible to provide atmospheric soundings at a ground resolution of some tens of kilometres in both the infrared and microwave regions of the electromagnetic spectrum.

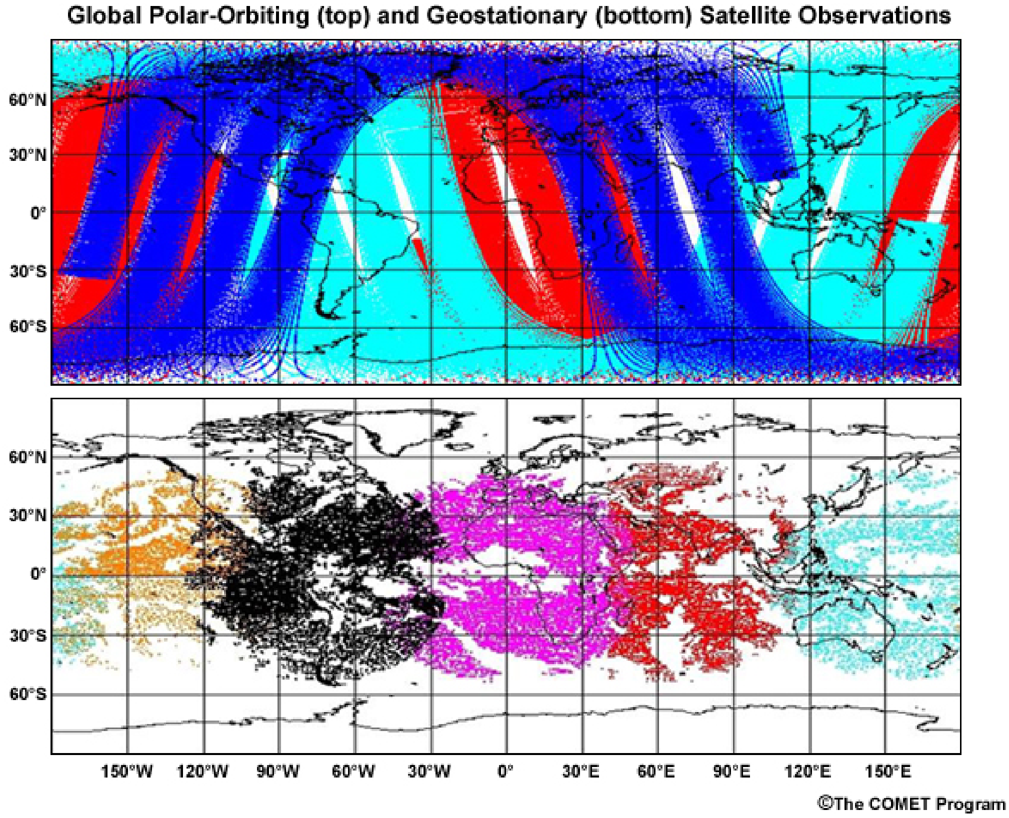




Polar-orbiting satellites offer another distinct advantage over geostationary satellites in that they are able to observe the earth-atmosphere system with microwave sensors. Microwaves penetrate clouds that would otherwise block the satellite's view of the atmosphere as occurs with visible and infrared observations. Microwave remote sensing allows us to probe the interior of clouds and see both the atmosphere and surface below. Microwave sensors operate day and night, as do infrared sensors, and in nearly all weather conditions. In addition, they provide improved coverage of the stratosphere.



While there are important differences between geostationary and polar systems, the two are complementary and together create a comprehensive observation system.



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1.7 The Rest of the Webcast

The rest of this Webcast will address the following topics:

- What EPS is and who the partners are
- The programme elements
- The novel technology that the Metop satellites provide and the applications and products that emerge from them

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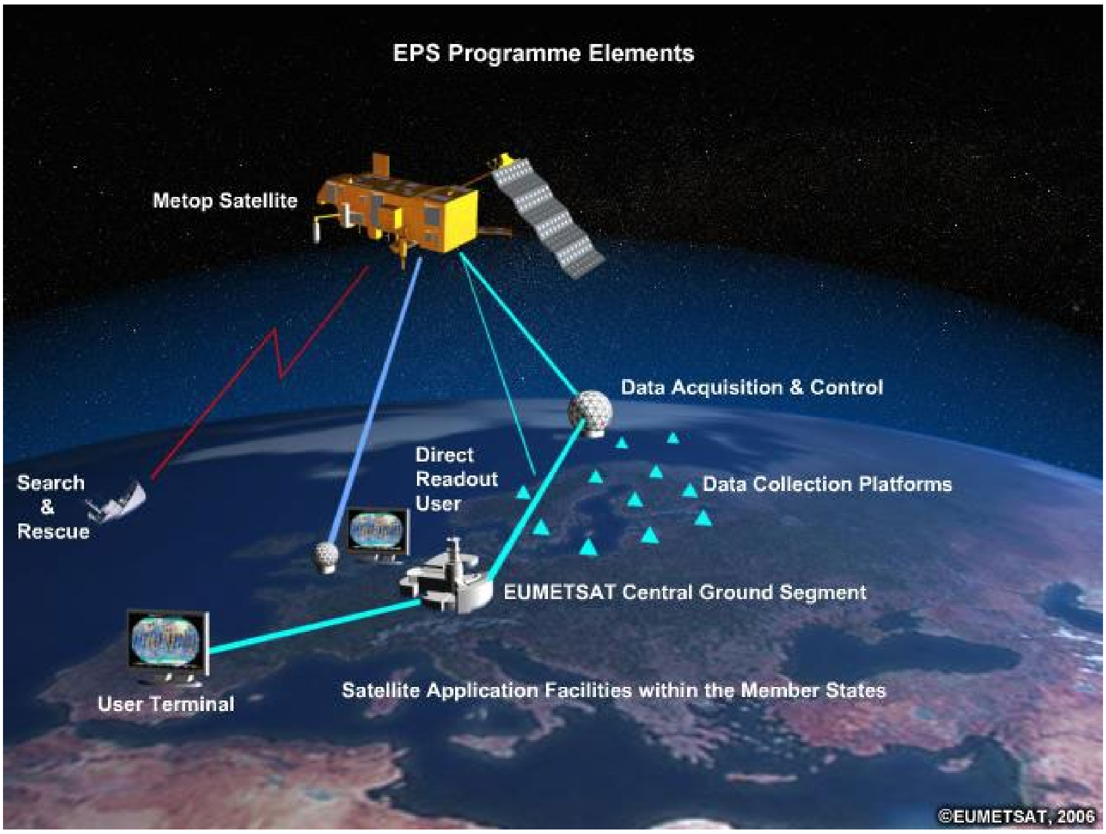
2.0 EPS Programme

2.1 EPS Programme Elements

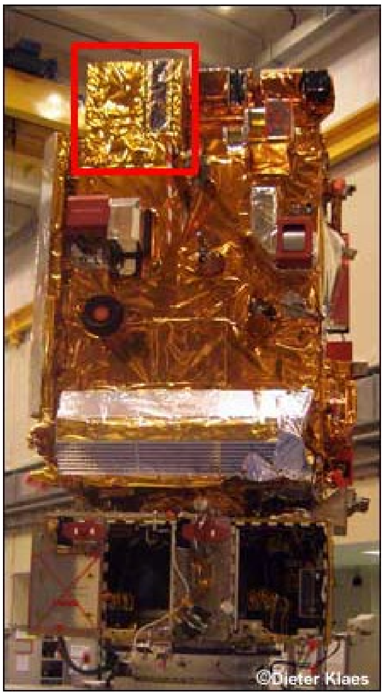
The EUMETSAT Polar System (EPS) is a complex programme with many international partners. EPS has both a ground component and a space component. The space component consists of the Metop satellites, which were jointly developed by EUMETSAT and ESA, the European Space Agency.

As mentioned earlier, EUMETSAT is working in partnership with NOAA to provide the Initial Joint Polar System.

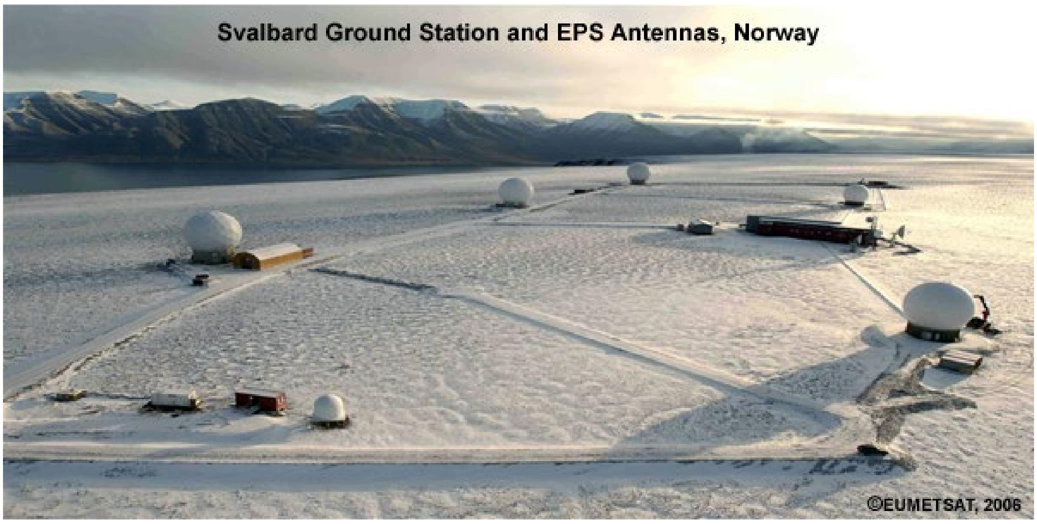


The key elements of IJPS are the coordination of polar-orbiting satellites, the exchange of common payload elements, and the processing and sharing of data. A separate agreement was signed in 2003 (the Joint Transition Activities agreement) that extends the cooperation beyond IJPS to provide an operational polar-orbiting service until at least 2019.

The partnership with the French Space Agency CNES (Centre National des Etudes Spatiales) has led to the development of IASI, the Infrared Atmospheric Sounding Interferometer. IASI is a key innovation in the Programme. CNES is also a partner for the Advanced Data Collection System (ADCS).



Another Programme element is the Northern Latitude Command and Data Acquisition Station located on Spitzbergen in the Svalbard Archipelago. Spitzbergen is far enough north (78° N) to receive all 14 orbits a day. The satellites store the measured global mission data of one orbit and then downlink the data when they are in view of the earth receiving station.



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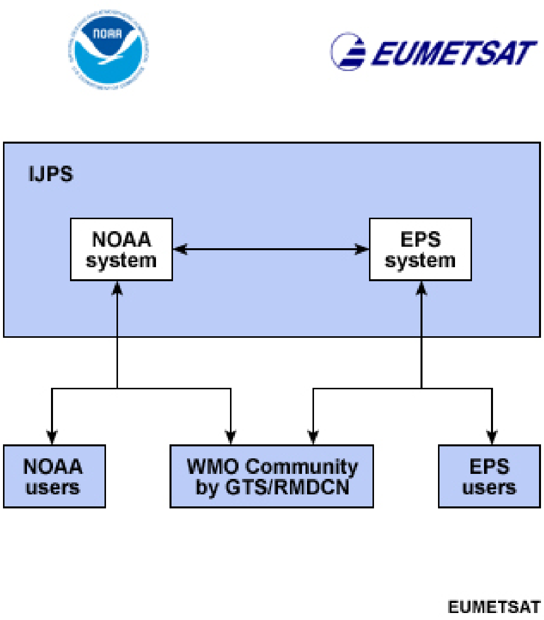
2.2 Data Exchange

EUMETSAT and NOAA exchange data as part of IJPS. NOAA receives all EPS data across a specific transatlantic link, and also gets so-called "blind orbit" data—that is, data from the orbits of NOAA satellites that cannot be seen from the NOAA station at Fairbanks, Alaska. EUMETSAT receives all data from the NOAA afternoon satellites and processes them in their ground segment. The ground segment performs command and control of the spacecraft and is responsible for the reception, processing, and exchange of data, as well as the generation of products.

The WMO community is served by both organisations through the Global Telecommunications System (GTS), a dedicated global network for the telecommunication of meteorological data and products.



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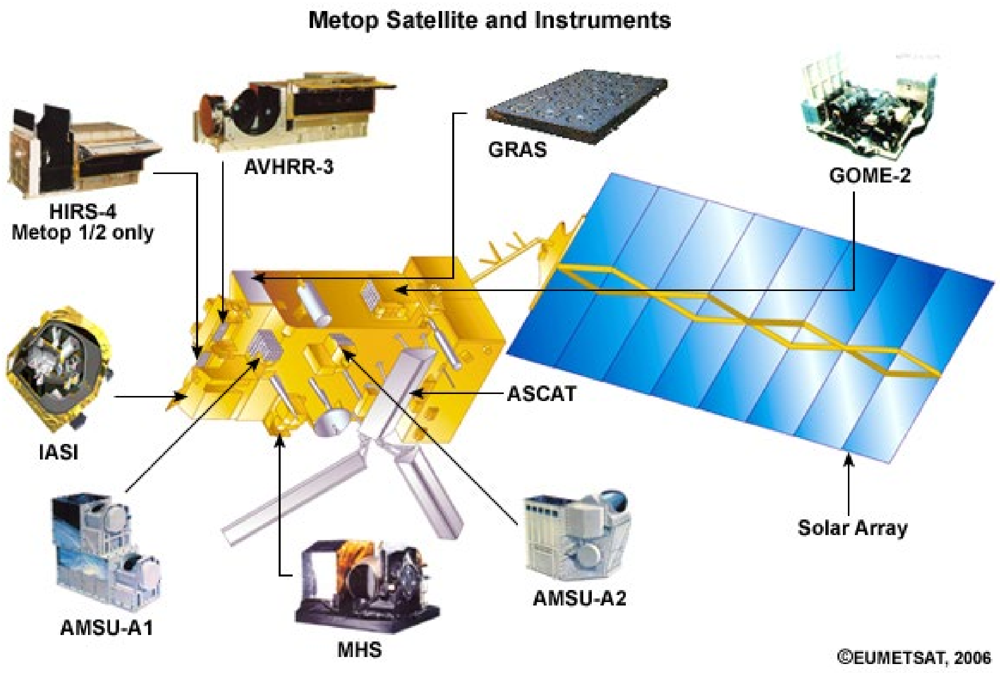
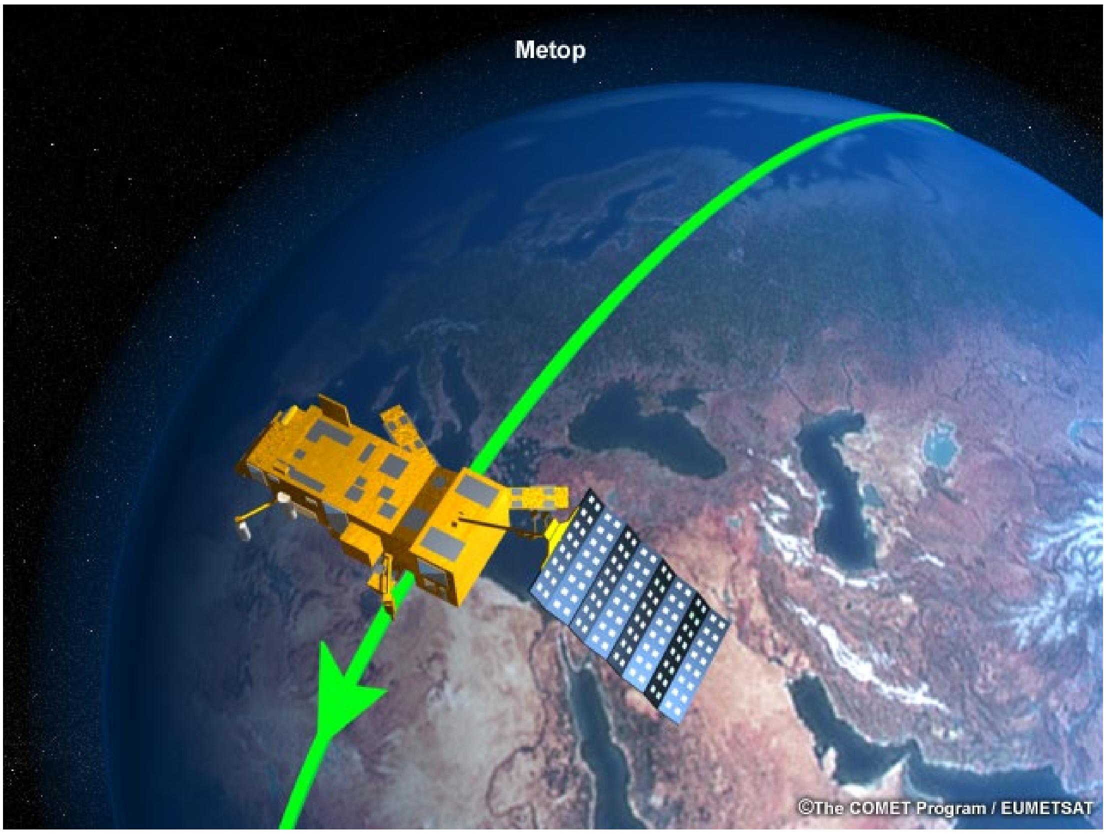
2.3 Space Segment Overview

As you've heard, the EPS space segment consists of the Metop satellites, which are composed of payload and service modules as well as a solar array. The payload module hosts twelve instruments, of which eight are meteorological.



The Metop satellites fly in a sun-synchronous orbit at an average altitude of about 820 km, crossing the equator at 9:30 Local Solar Time in the descending node. There will be three Metop satellites, providing uninterrupted service in the same orbit over at least a 14-year period.



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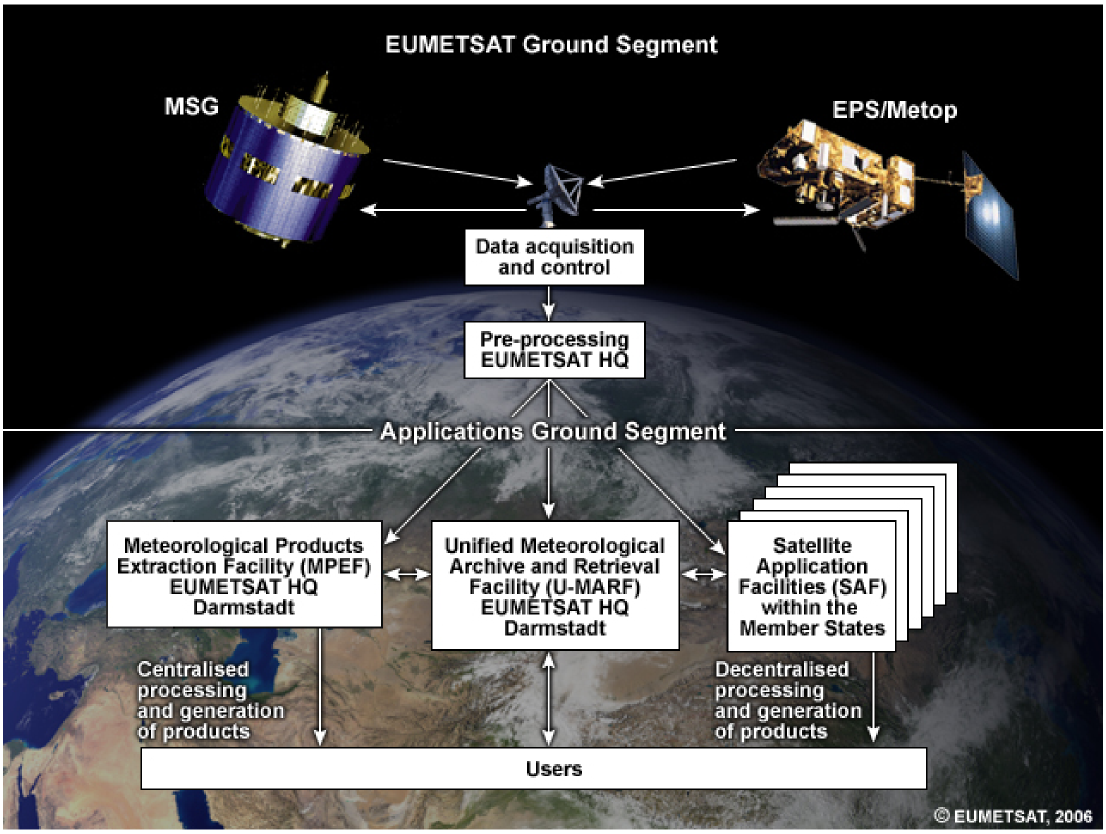
2.4 Ground Segment Overview

The EPS Ground Segment consists of the following:

- The Command and Data Acquisition stations at Svalbard and a backup control center in Madrid



- The Central Component at EUMETSAT headquarters in Darmstadt, Germany, where mission control and planning are done, as well as global data pre-processing and selected product processing

- The Satellite Application Facilities (SAF) hosted at the National Meteorological Services from the EUMETSAT Member States, which form centers of expertise along themes of meteorological applications
- The Unified Meteorological Archive and Retrieval Facility (known as U-MARF), which contains all meteorological products from EPS and the other EUMETSAT Programmes. Note that U-MARF is not a formal part of the EPS Programme.

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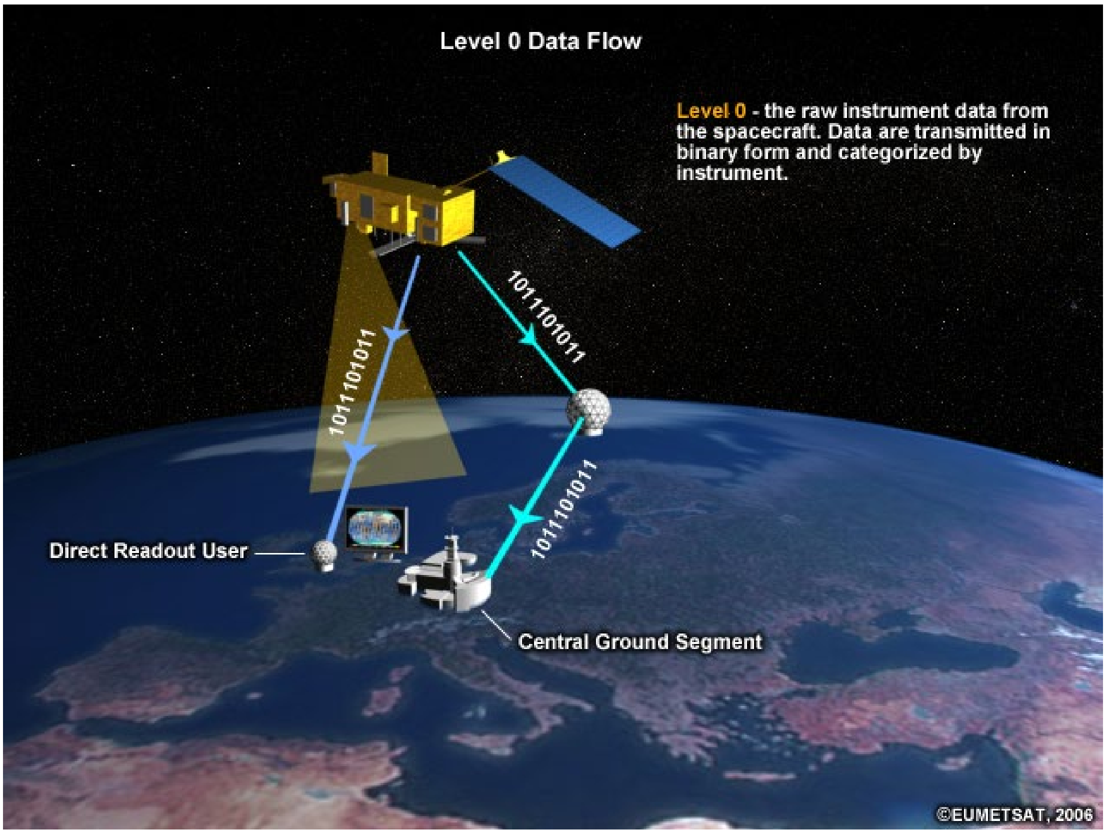
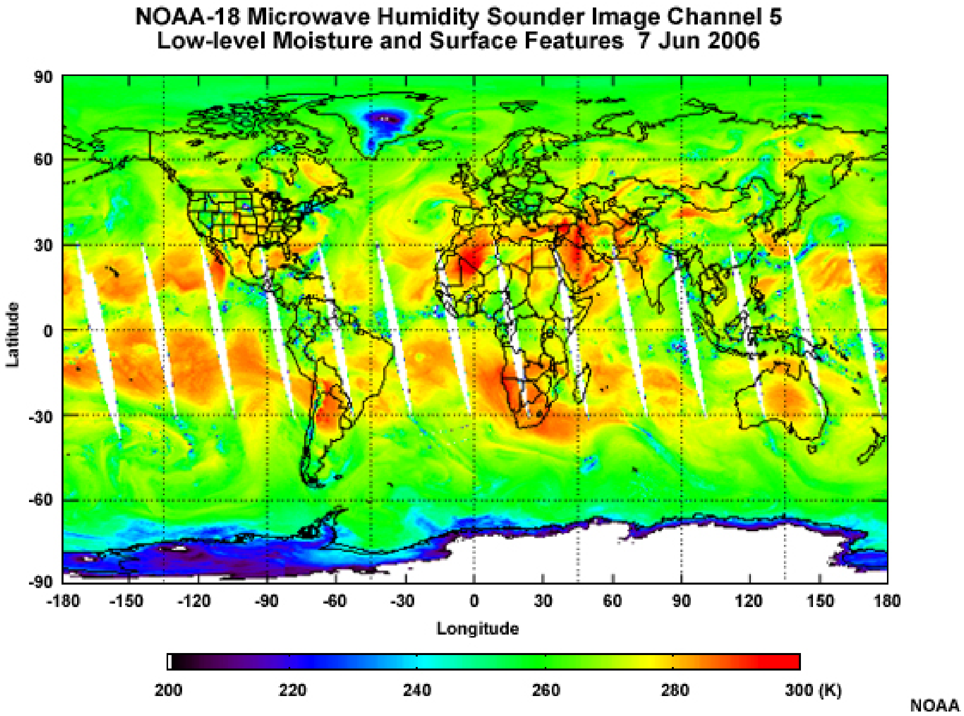
2.5 Processing and Data Flow

The EPS/Metop satellites generate products at three levels:

- Level 0 — The raw instrument data from the spacecraft. Data are transmitted in binary form and categorized by instrument.

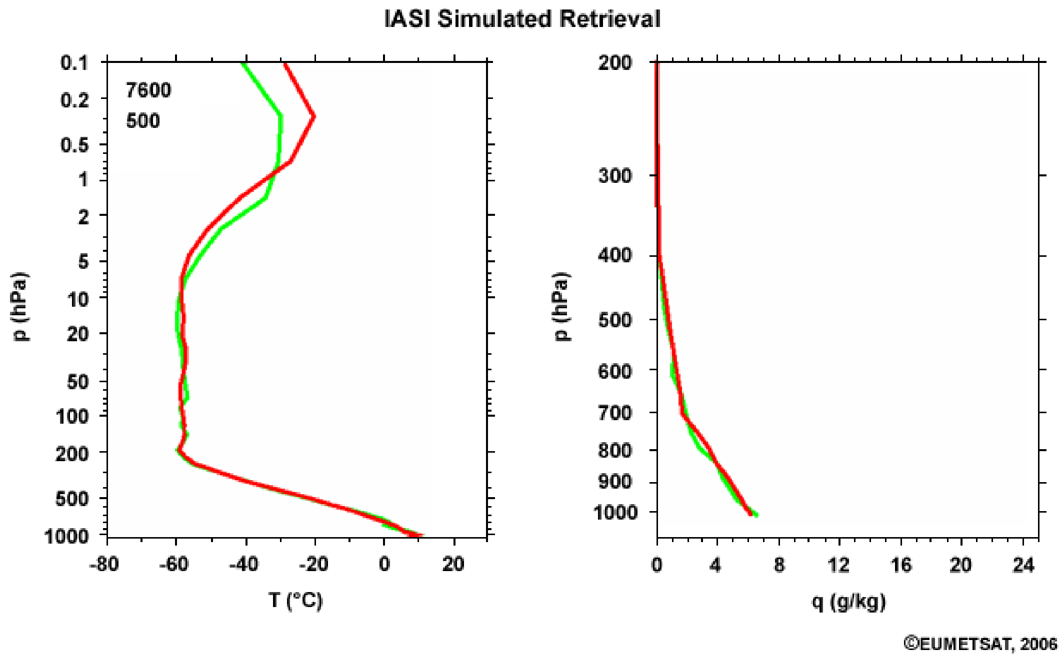


- Level 1 — The calibrated and navigated physical quantities (observed electromagnetic energy in most cases) for each instrument, such as radiances, brightness temperatures, reflectances, and bending angles.



Product examples include reflectances and brightness temperatures from AVHRR, IASI, and ATOVS radiance data with cloud information, ASCAT backscatter data, and GOME radiances.

- Level 2 — The geophysical quantities that most users are familiar with. Examples include IASI and ATOVS vertical profiles of temperature and humidity, ozone and trace gas amounts, ocean surface wind vectors, and total precipitable water.

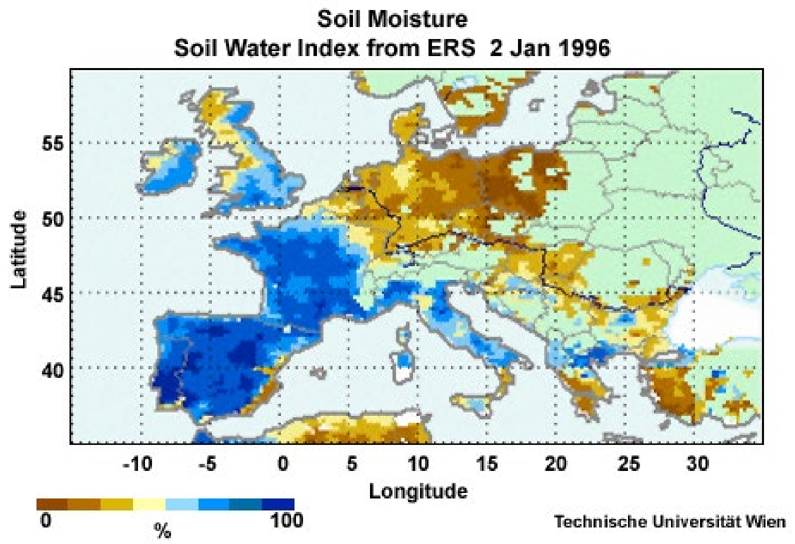


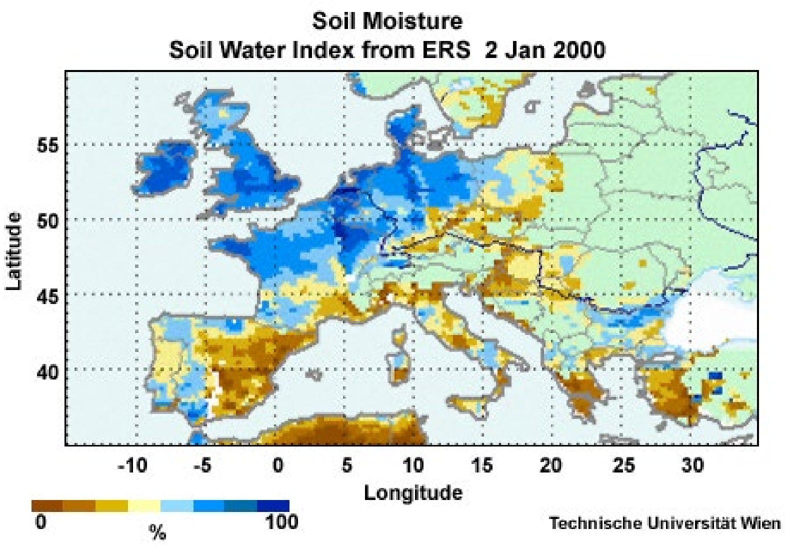
You may hear products referenced as day 1 or day 2. Day 1 products are those that form the baseline of the EPS development, i.e., they have been specified as mandatory in the EPS System Requirements, and the System is committed to providing them.

Day 1 products consist of the central processing Level 0 and Level 1 global products from each instrument and selected Level 2 products, including:

- IASI and ATOVS/AVHRR derived temperature and moisture vertical profiles
- IASI total columnar amounts of 0_3, CO_2, CH_4, and N_2O, as well as vertical profile components of ozone

Day 2 products are those that have been added since the system was successfully commissioned. Examples include soil moisture products from ASCAT data for use in NWP, global Normalized Difference Vegetation Index or NDVI, and polar cap winds. All of these products are based on EPS End User Requirements. Note that the decentralised Satellite Application Facilities produce a wealth of Level 2 products and those at higher levels.





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3.0 Innovations and Benefits

3.1 Metop Instruments

Here are the instruments on the Metop satellite. There are two major sounding systems:

- The infrared sounders (IASI and the High-Resolution Infrared Radiation Sounder or HIRS)
- The microwave sounders (AMSU-A and the Microwave Humidity Sounder (MHS))

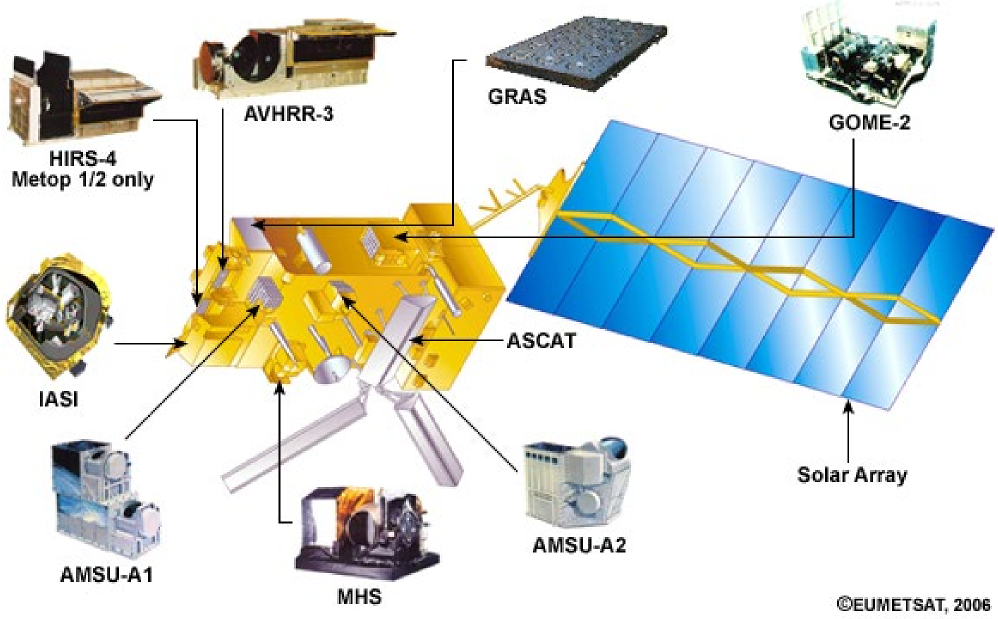
The AVHRR imager provides support to both.

Here is the front end of Metop with the six folded antennas of the Advanced Scatterometer (ASCAT). ASCAT's primary mission is to measure ocean surface wind vectors.

The Global Ozone Monitoring Instrument (GOME-2) is used to monitor total ozone, ozone profiles, and other trace gases.

Finally, here's one of the three antennas of the GNSS Receiver for Atmospheric Sounding (GRAS). (GNSS stands for Global Navigation Satellite System.) GRAS provides profiles of temperature and humidity at high vertical resolution.

Metop Satellite and Instruments



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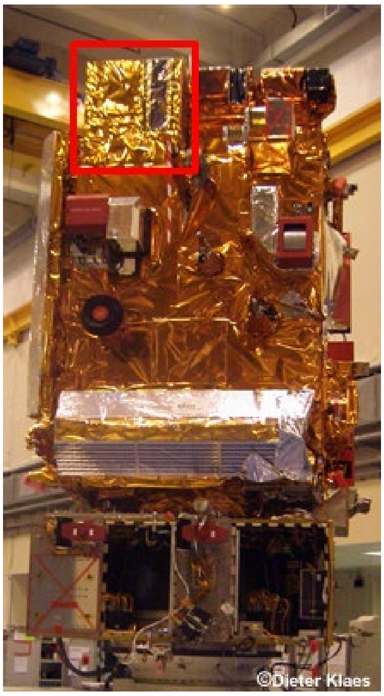
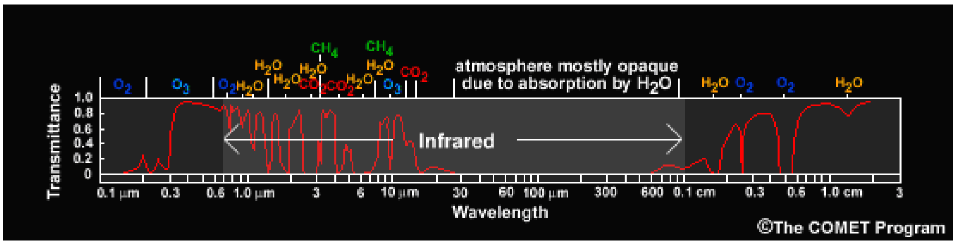
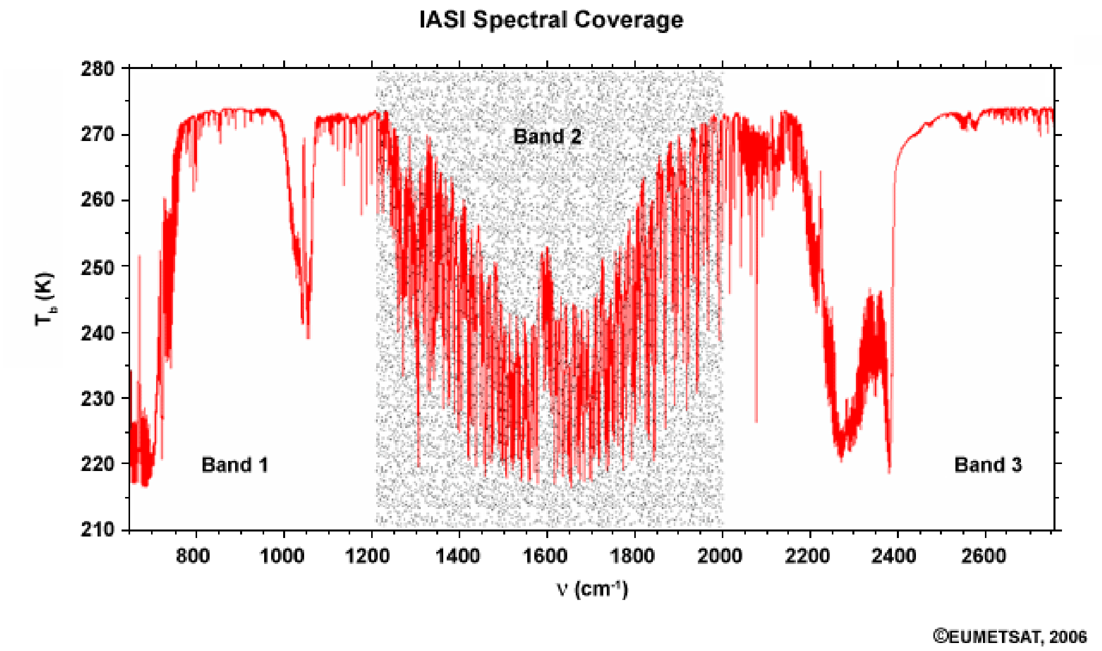
3.2 IASI as Groundbreaking New Technology

Now we're getting to the major technical innovation of the Metop/EPS system and basically the main reason for the Metop satellites, that is, the Infrared Atmospheric Sounding Interferometer, known as IASI . IASI is a spectrometer—a so-called Fourier Transform Spectrometer (FTS) or, to be more precise, a Michelson Interferometer.

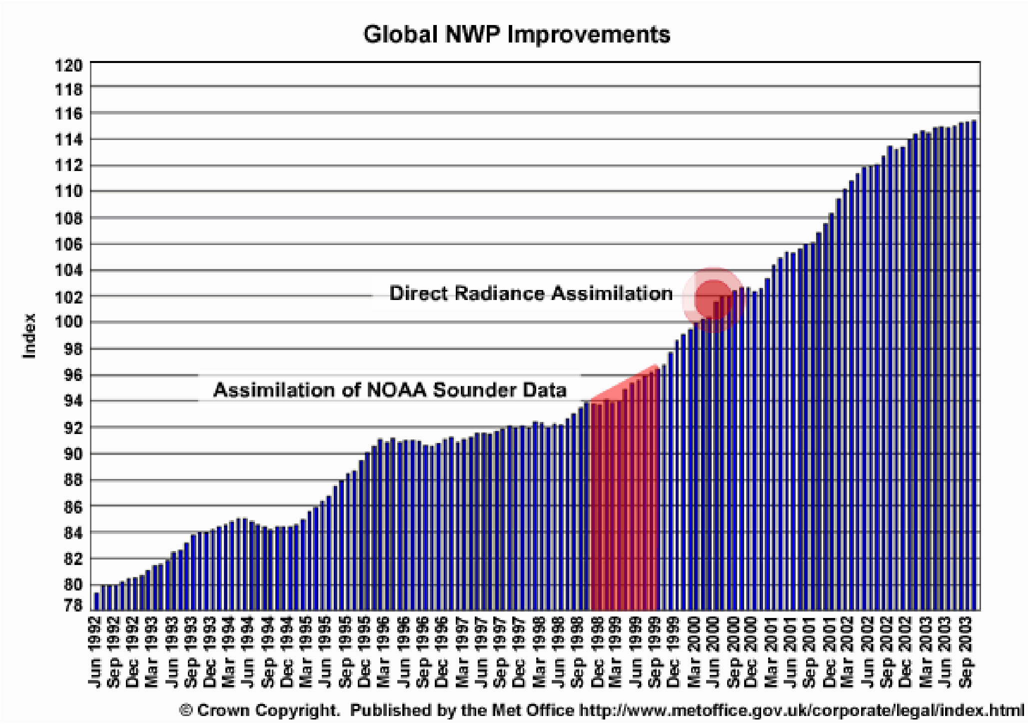


IASI measures energy emitted by the earth-atmosphere system in the infrared portion of the electromagnetic spectrum at high spectral resolution (8461 "channels") to provide improved profiles of atmospheric temperature and moisture and to monitor trace gases.

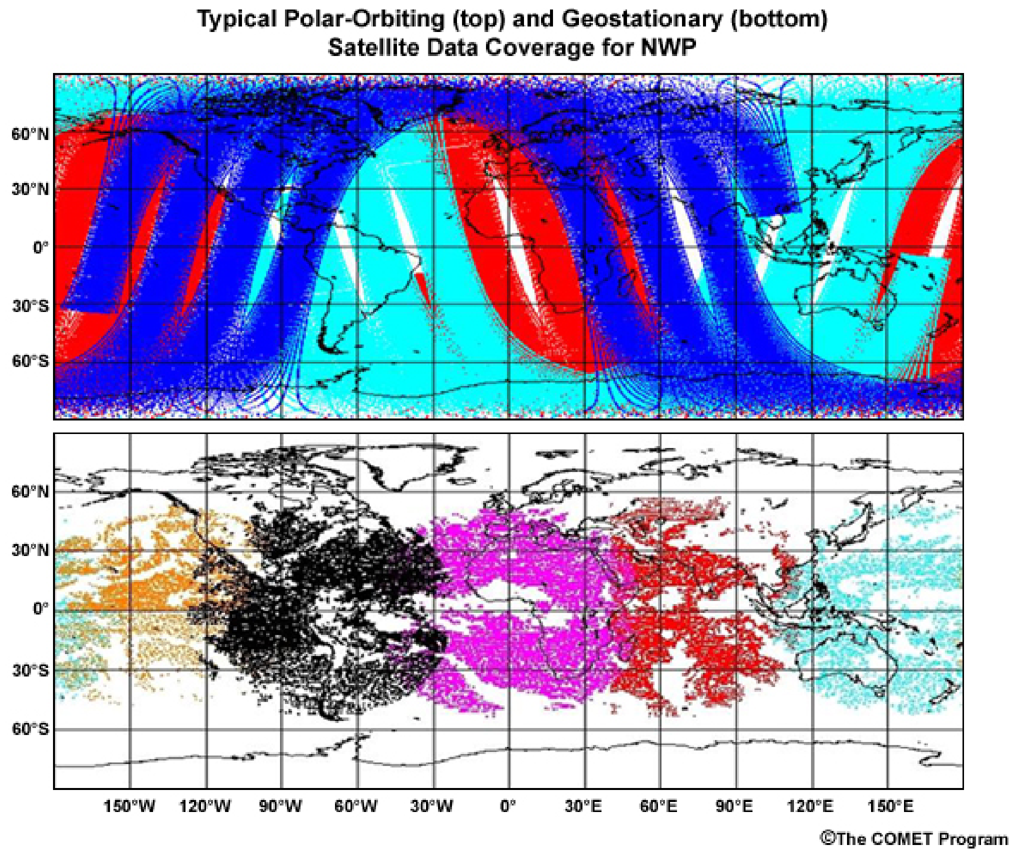




IASI provides a quantum leap in infrared sounding capabilities from space, which will have a significant impact on numerical weather prediction. The considerable progress in NWP over the last two decades has been due, in part, to the use of satellite sounding information in the data assimilation step.



As you've heard, more than 90% of the data entering NWP come from satellites. One of the primary motivations for developing IASI was to provide increased accuracy that would help improve the input for NWP models.



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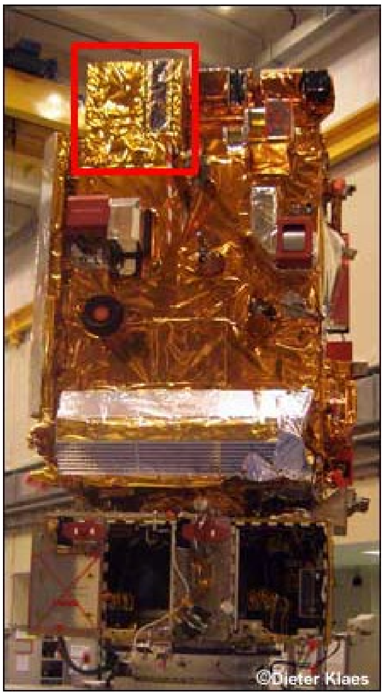
4.0 Infrared Atmospheric Sounding Interferometer (IASI)

4.1 IASI Instrument

IASI is the largest and heaviest instrument on the Metop satellite and is provided by the French Space Agency CNES. CNES also provides the operational Level 1 processing software for the Core Ground Segment and has a technical expertise center (known as IASI TEC) in Toulouse that analyzes instrument performance.



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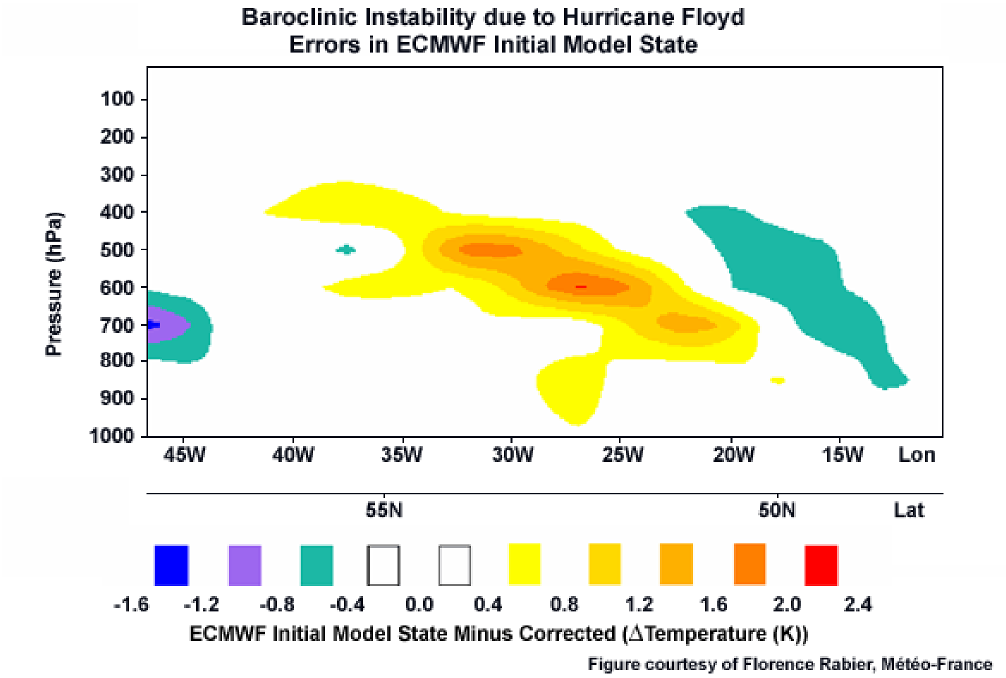
4.2 Motivation for IASI

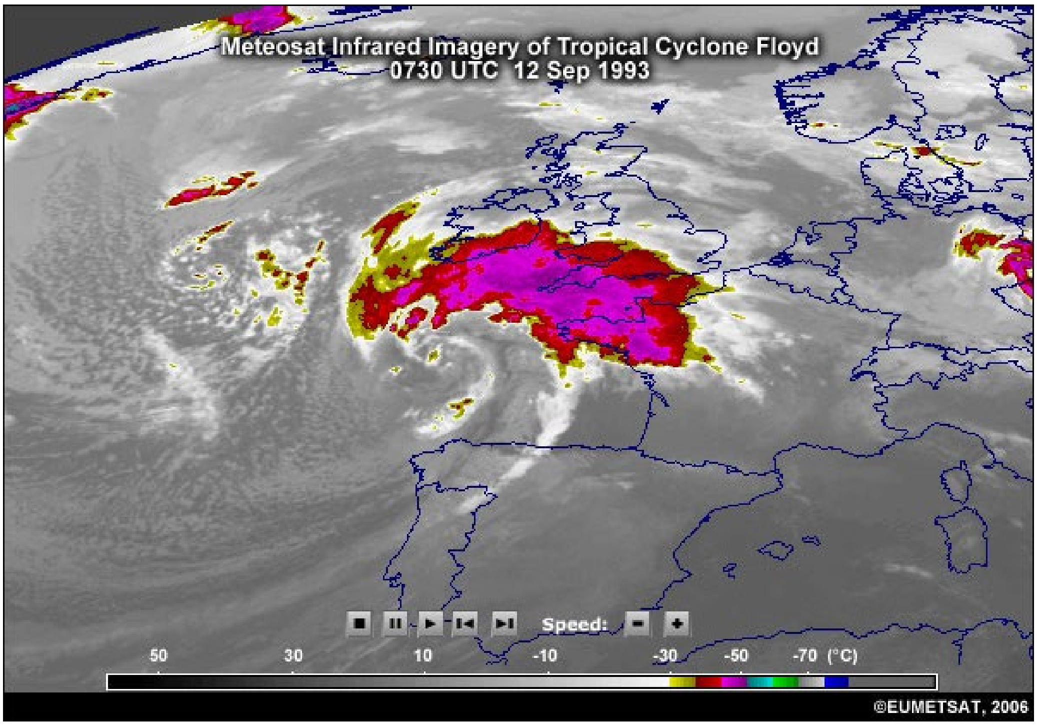
The cross section shows a baroclinic structure generated in the remnants of Hurricane Floyd. The hurricane was responsible for a major storm in the United Kingdom and Brittany, resulting in major damage and loss of lives. The feature was not analysed by the forecast model, and the storm was not correctly predicted.



This example illustrates what needs to be measured and input into NWP models. Vertical temperature information should be provided at 1 K/km resolution and about 25 km horizontal sampling. Relative humidity should be provided with an accuracy of about 10%.

Since meteorological features like tropical cyclones occur mostly over oceans, we must rely on satellite data to provide this information.

IASI was developed in response to the need to observe the atmosphere in greater detail, employing sensors that measure energy in a large number of narrow spectral channels. This approach to remote sensing is also commonly referred to as hyperspectral sounding.



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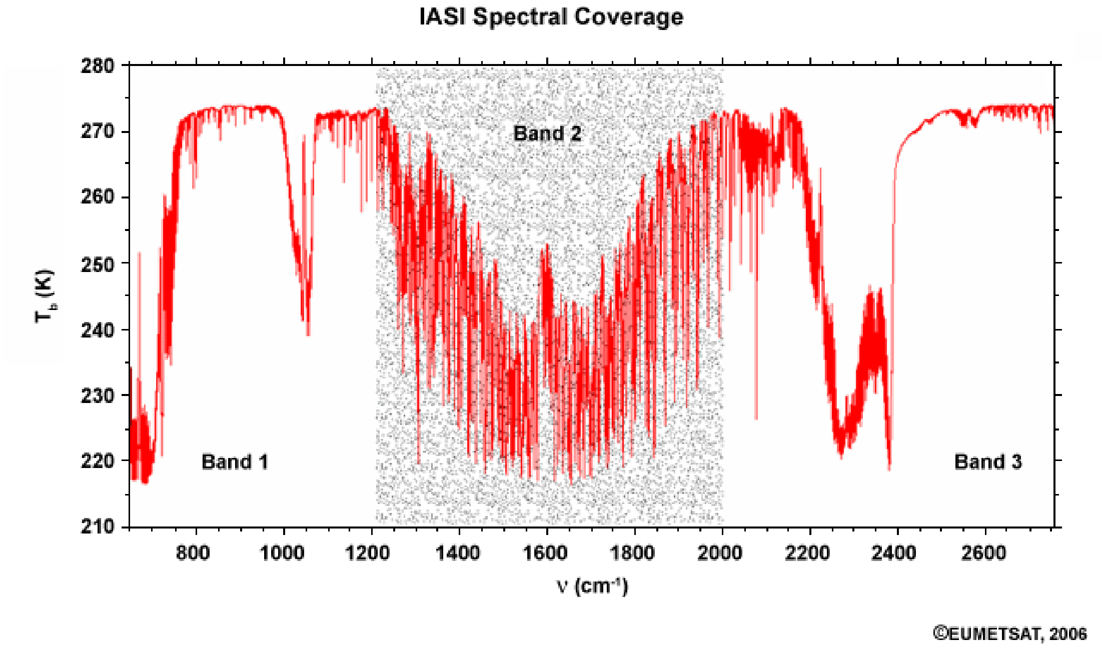
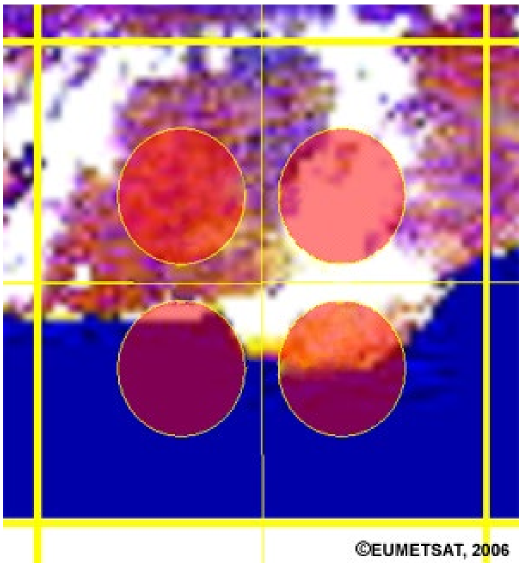
4.3 IASI: Going from Level 0 to 1 Data

IASI processes raw observations into calibrated spectra on board the Metop satellite, which are sent to the ground as Level 0 data.

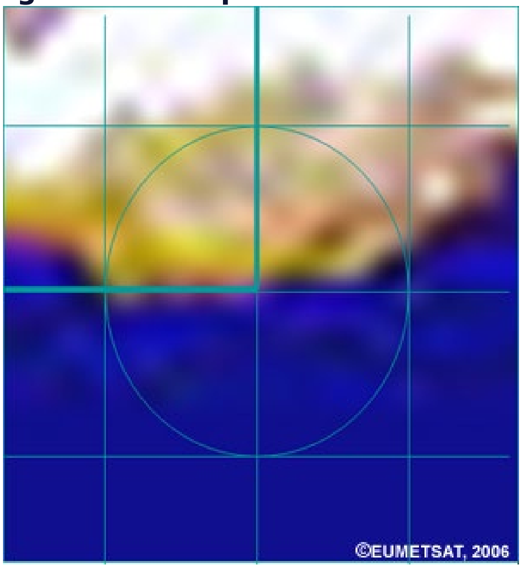


During Level 1 processing, AVHRR radiances are analysed within one IASI field of view (FOV) to obtain the location of clouds in the FOV.

IASI Samples and Integrated Imager Pixels



Single IASI Sample and AVHRR Pixels

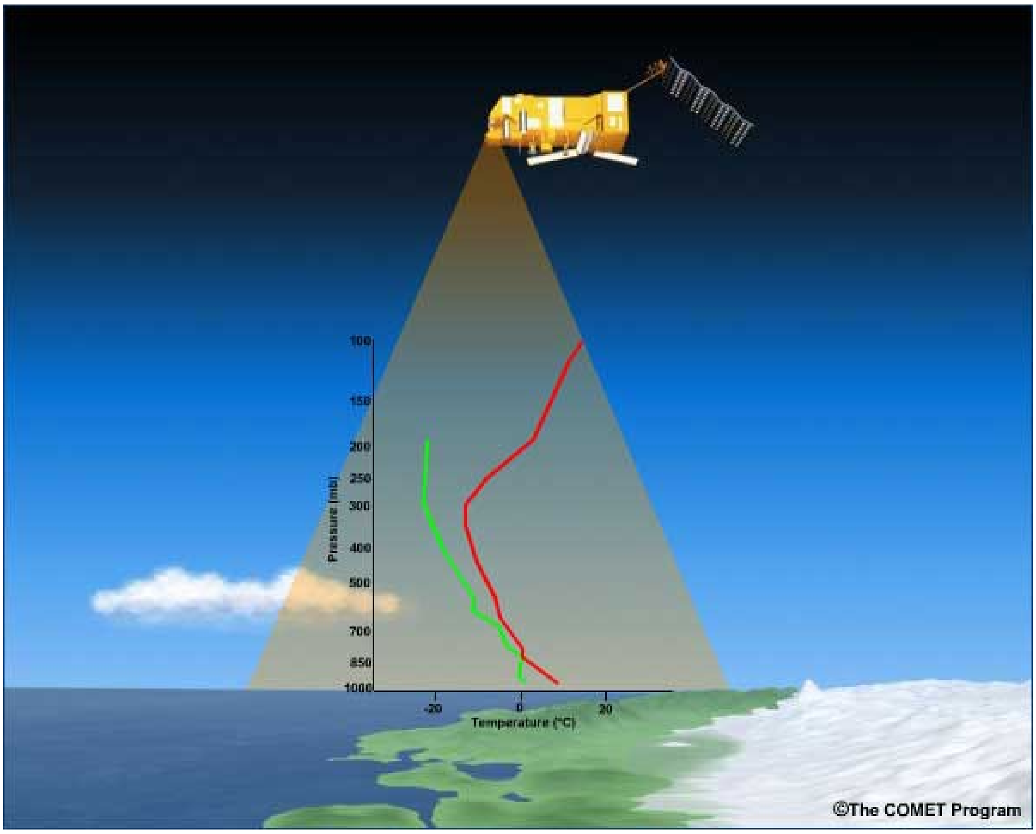


IASI has an integrated imaging radiometer, which provides 64 x 64 pixel images in the IR window region (10.5 – 12 μm) in the same focal plane as the sounding radiances.

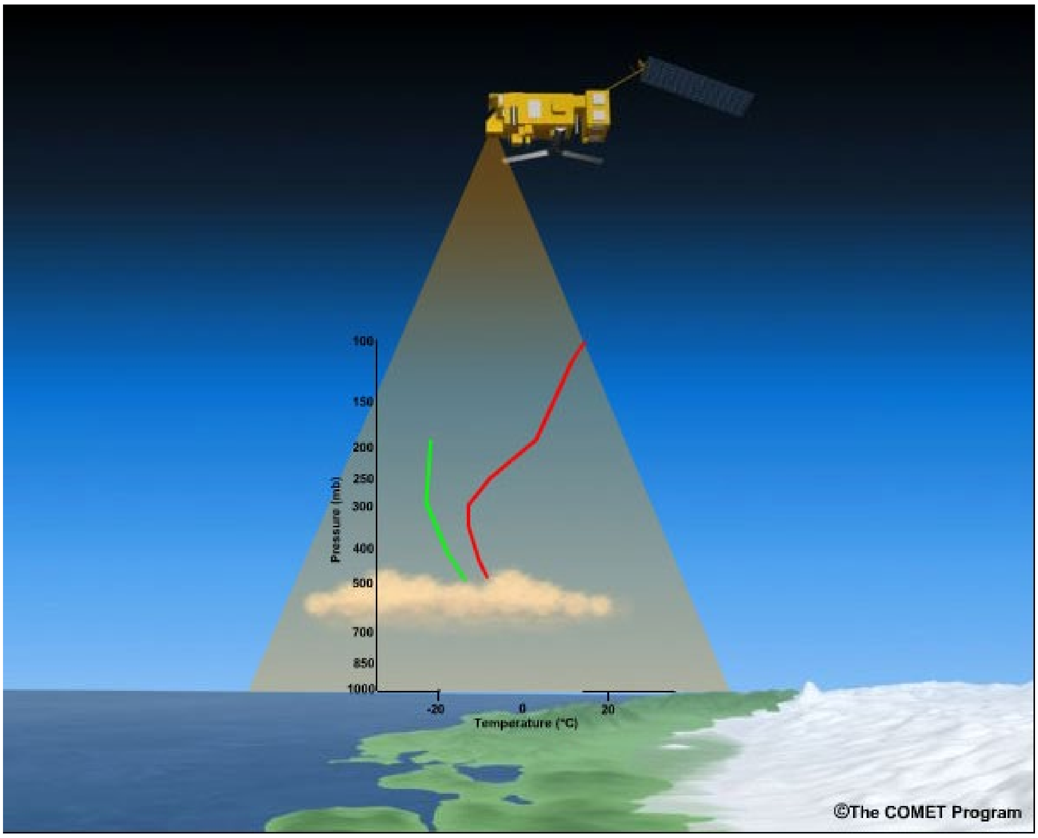
The imager serves to align the AVHRR information to the IASI FOV. AVHRR is also used to navigate the IASI pixels.

The integrated imager provides a sampling of better than 1 km for infrared scenes, which are collocated with the AVHRR images.

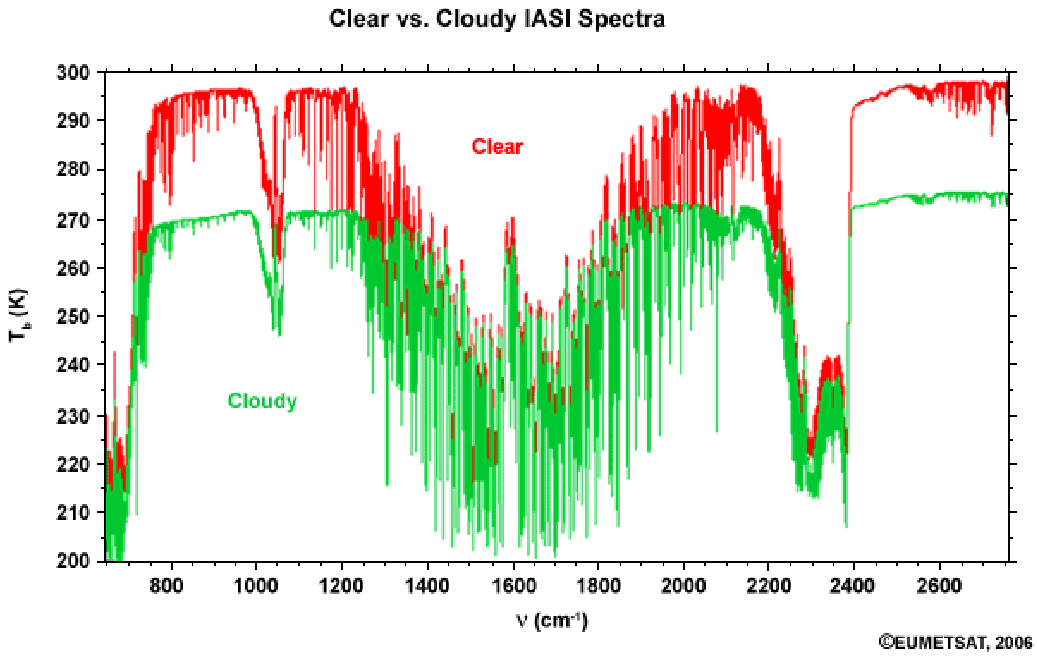
During Level 2 processing, a determination is made as to whether a cloud clearing or cloudy retrieval will be performed. Cloud clearing implies that you can get an atmospheric profile down to the ground even when the IASI scene/FOV is not totally "clear."

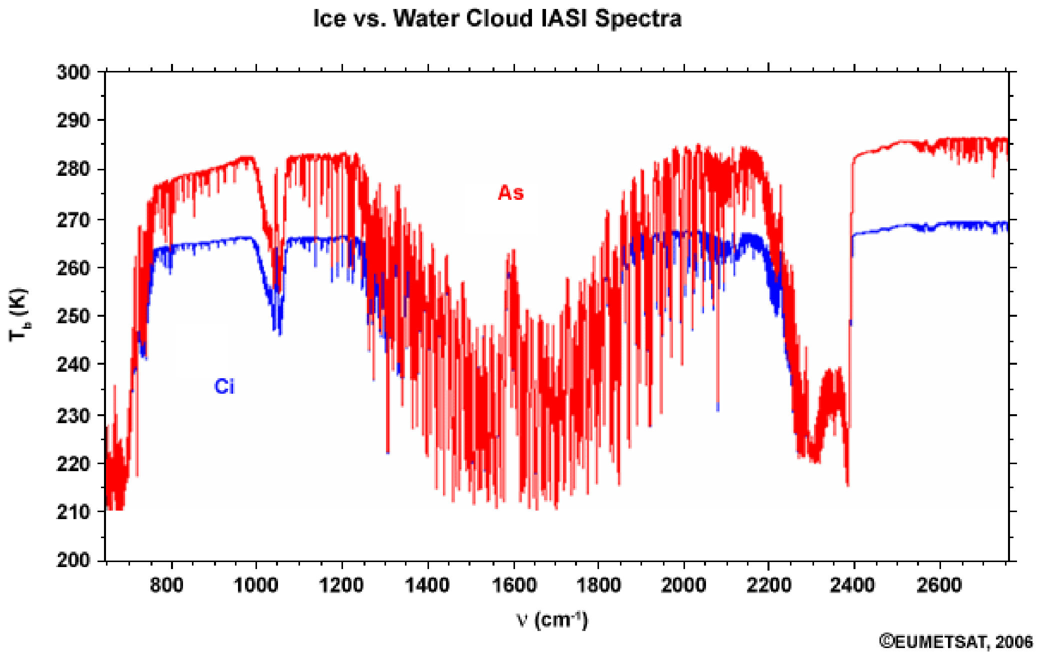


Cloudy retrieval means that you get a sounding from cloud top and up.



IASI Level 1 spectra for all 8461 channels are disseminated to users via the EUMETCast service. A subset of 300 channels is transmitted over the GTS system. Both datasets are made available in the standardized BUFR format.





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4.4 IASI: Going from Level 0 to 1 Data

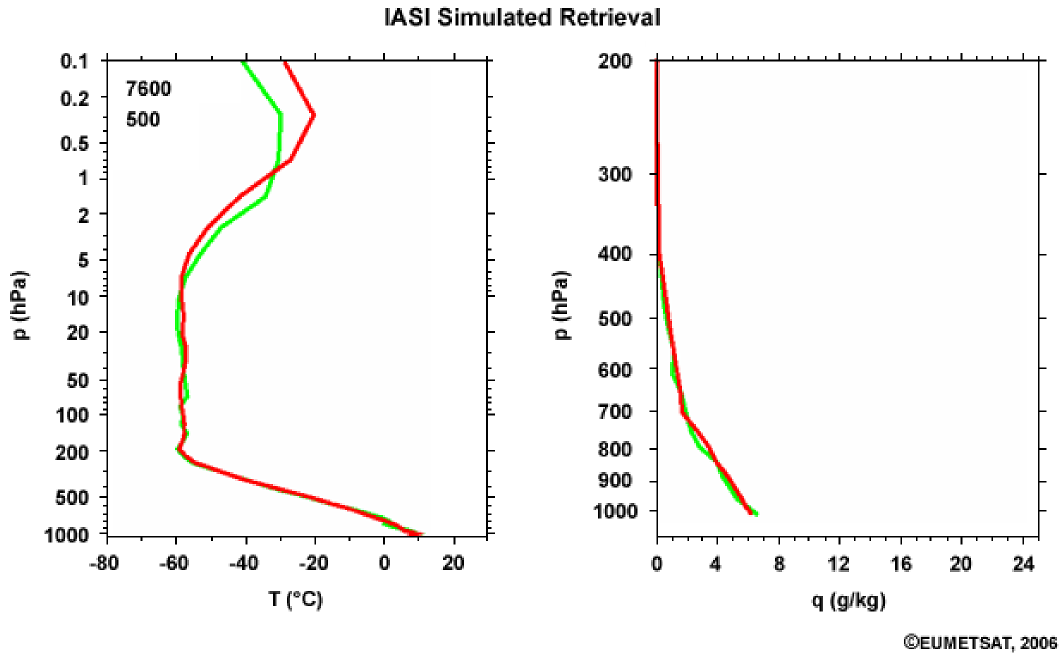
IASI Level 2 products are derived via a complex process that uses the full spectral information of the IASI instrument, supplementary information from the ATOVS and AVHRR instruments, and input from NWP data.

The Level 2 product suite typically used by the forecaster and climate communities includes:

- Temperature profile at a minimum of 40 levels
- Water vapour profile at a minimum of 20 levels
- Ozone columns in four deep layers (0-6 km, 0-12 km, 0-16 km, total column)
- Land or sea surface temperature
- Surface emissivity at 12 spectral positions
- Total column N_2O (nitrous oxide), CO (carbon monoxide), CO_2 (carbon dioxide), and CH_4 (methane)
- Cloud amount (up to three cloud formations)
- Cloud-top temperature (up to three cloud formations)
- Cloud phase

Keep in mind that the product suite is modified when there is cloud coverage, and that data quality information is delivered with the products.

This picture shows an example for a single retrieval at midlatitudes, derived with the IASI Level 2 algorithm from synthetic data. A temperature profile is shown on the left, a humidity profile on the right. The retrieved quantities (red) are displayed together with the true state (green).



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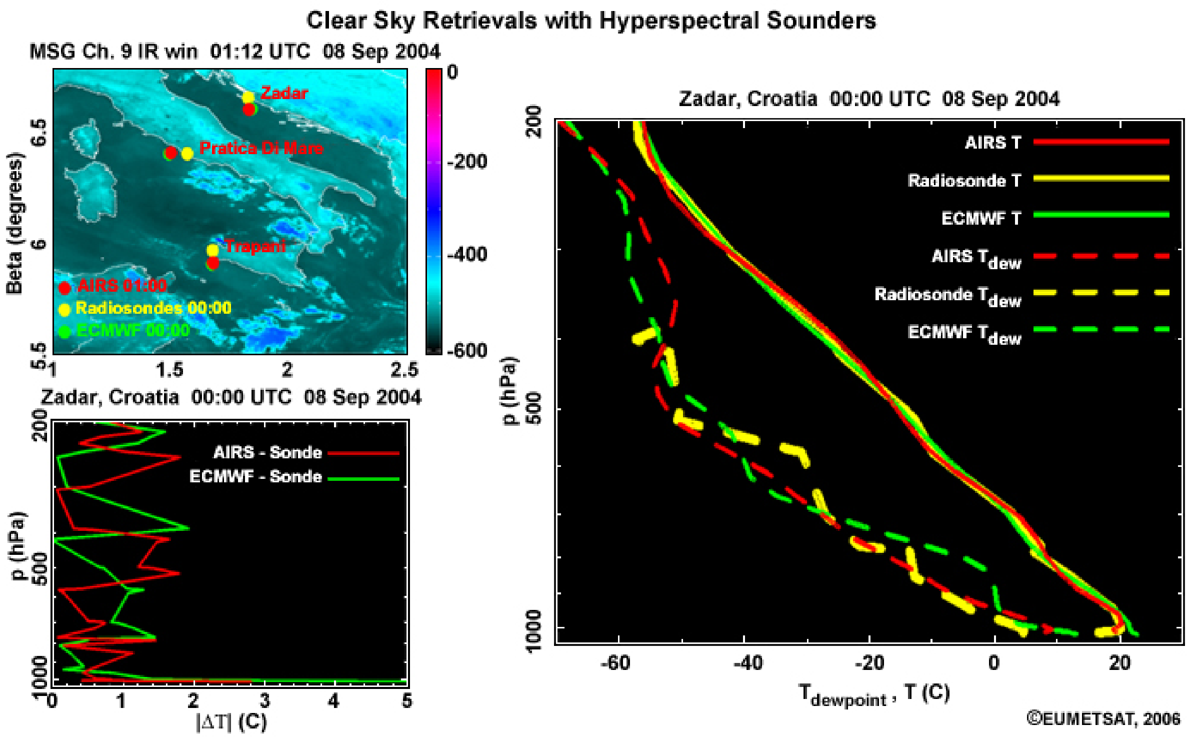
4.5 IASI Level 2 Validation with AIRS Data

Validation efforts involving measurements from NASA's hyperspectral sounder, AIRS, have demonstrated that IASI Level 2 processing is meeting user requirements. The graphics compare IASI temperature and dewpoint profiles with profiles obtained from an ECMWF analysis and collocated radiosonde observations. Good agreement is achieved.



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4.6 Potential IASI Chemistry Products

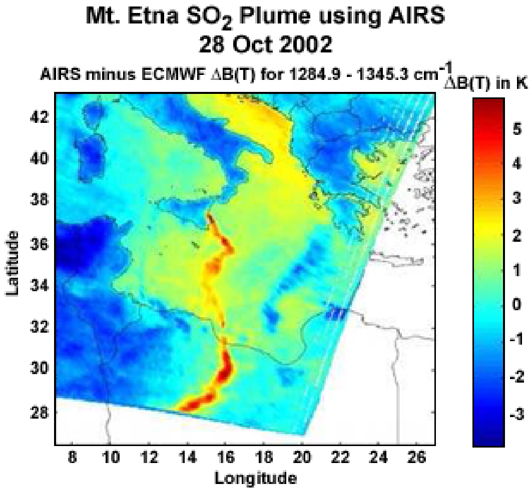
IASI is also expected to retrieve the following trace gases.

- SO_2 (sulphur dioxide)
- N_2O (nitrous oxide)
- CO (carbon monoxide)
- CO_2 (carbon dioxide)
- CH_4 (methane)
- O_3 (ozone)

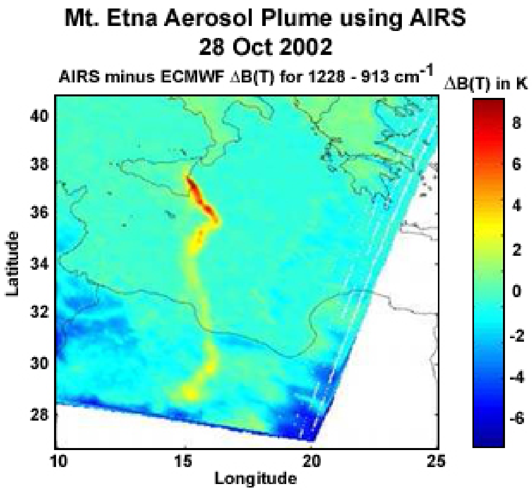
SO_2 (sulphur dioxide)

The infrared spectrum has absorption lines for trace gases that play a role in monitoring volcanic activity. This picture from an October 2002 eruption of the Mt. Etna volcano shows the aerosol and sulphur dioxide (SO_2) plumes in the wake of the eruption. The data were derived from the AIRS instrument.

Volcanoes can produce large SO_2 concentrations over limited regions and for relatively short time periods. The most common sources of SO_2 are fuel combustion for power generation for use in homes, industry, and transportation.



Carn, S. A. et al., Quantifying tropospheric volcanic emissions with AIRS: The 2002 eruption of Mt. Etna (Italy). Geophysical Research Letters, Vol. 32, L02301, 2005.



Carn, S. A. et al., Quantifying tropospheric volcanic emissions with AIRS: The 2002 eruption of Mt. Etna (Italy). Geophysical Research Letters, Vol. 32, L02301, 2005.

N_2O (nitrous oxide)

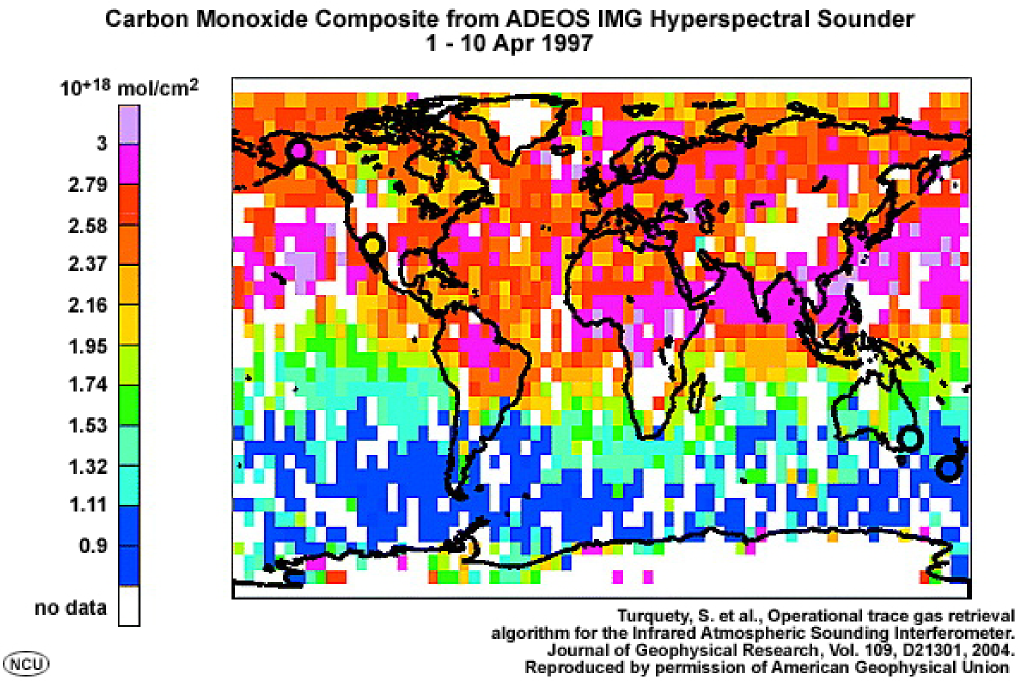
N_2O is a product of burning fossil fuels and other organic matter and is also naturally emitted from soils and oceans. It is the third most important greenhouse gas as well as a component in the ozone cycle.


©UCAR


©UCAR, Photo by Patrick Zimmerman

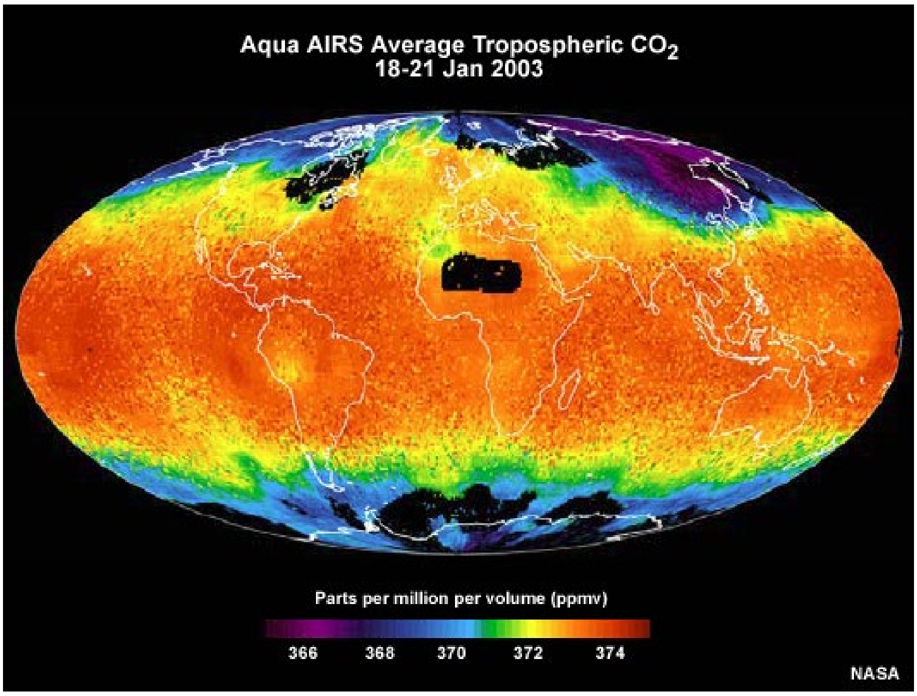
CO (carbon monoxide)

The most common sources of carbon monoxide include motor vehicles and various industrial processes. It contributes to the formation of ground-level ozone and smog in urban areas. Carbon monoxide harms our health by reducing the amount of oxygen available to body organs and tissues.



CO_2 (carbon dioxide)

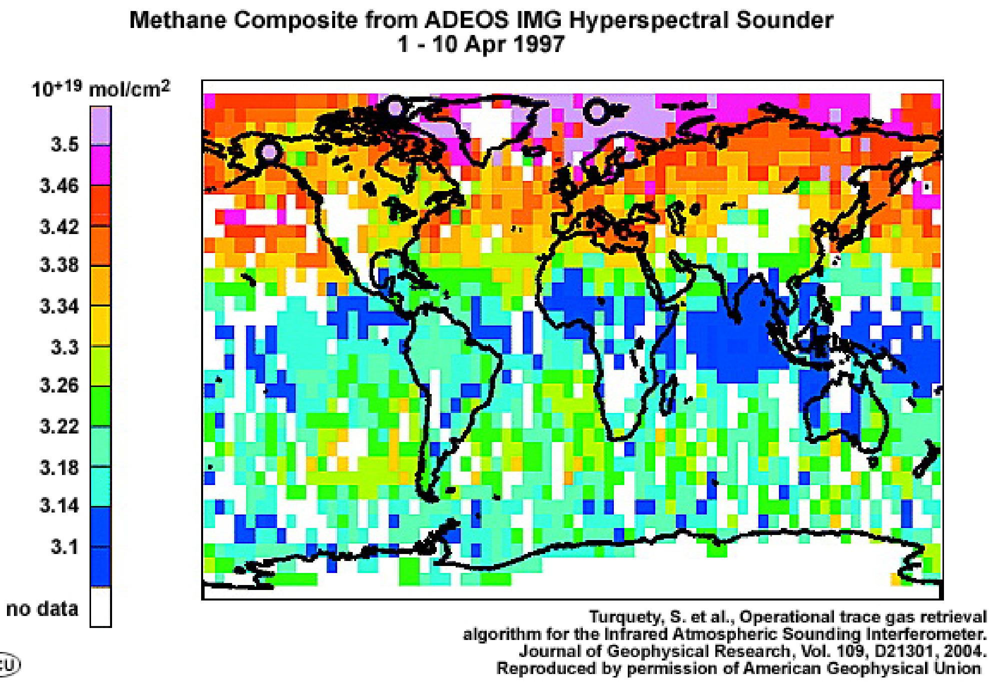
Carbon dioxide is a major component of the carbon cycle. Its most common sources include volcanic outgassing, the combustion of organic matter, and the respiration by living organisms (plants and animals). CO_2 plays a key role in the Earth's greenhouse effect and is a major focus of the debate on global warming and climate change.



CH_4 (methane)

IASI data will be used to produce a methane columnar amount. The product displayed was generated by a study within the IASI Sounding Science Working Group from IMG Interferometer data. (IMG stands for Interferometer Monitor for Greenhouse Gases.) The Interferometer flew on the Japanese ADEOS satellite.

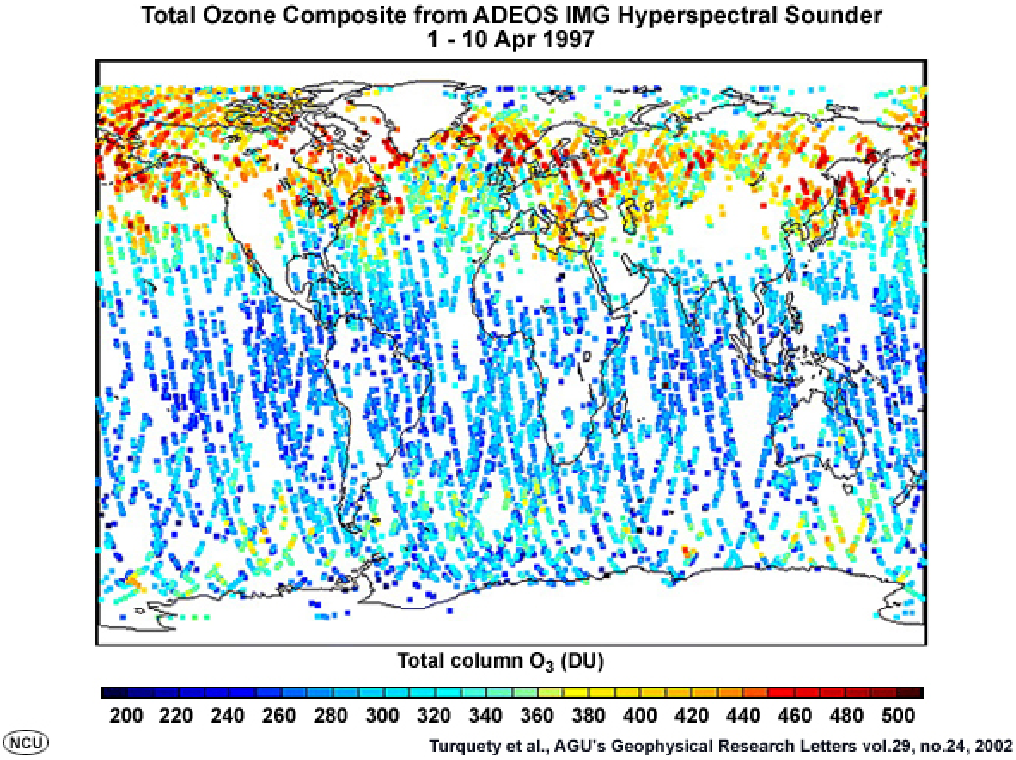
Methane is an important greenhouse gas and accounts for approximately 20% of the total warming effect of all greenhouse gases combined.



O_3 (ozone)

This image shows an example of the total column ozone from 1 to 10 April 1997. This is one of two ozone products, and was produced by the IASI Sounding Science Working Group (ISSWG) using IMG Interferometer data.

Ozone plays an important role in the Earth's stratosphere by absorbing harmful ultraviolet radiation from the Sun. At high concentrations near ground level, however, ozone is considered a pollutant that can cause respiratory health problems for humans and damage plants and ecosystems.



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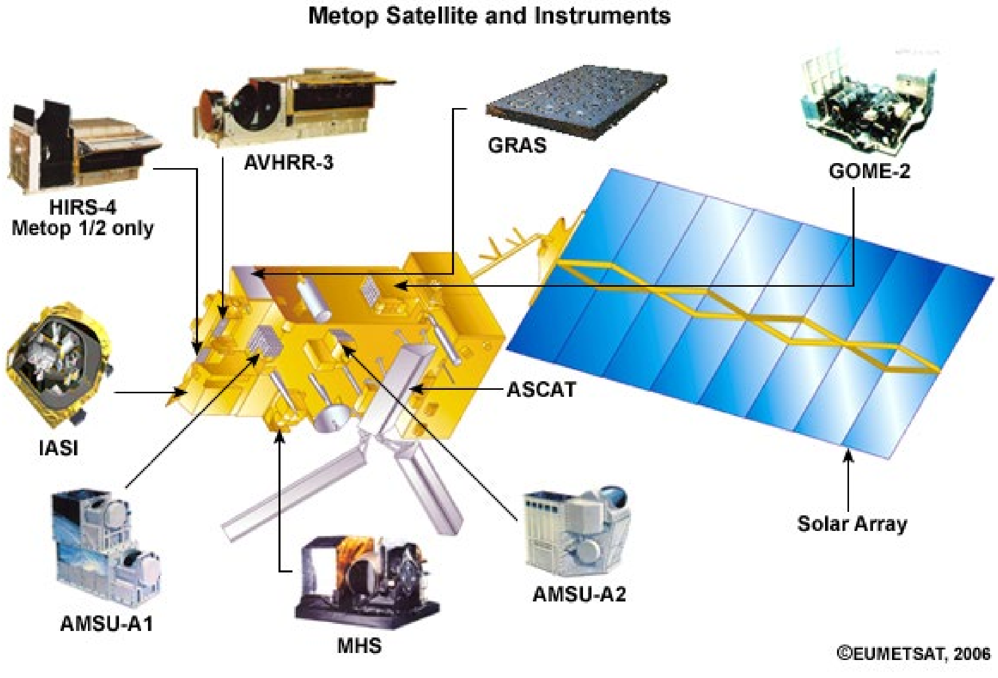
5.0 ATOVS, MHS, AVHRR Heritage Sounding Instruments

5.1 ATOVS and AVHRR Provide Continuity

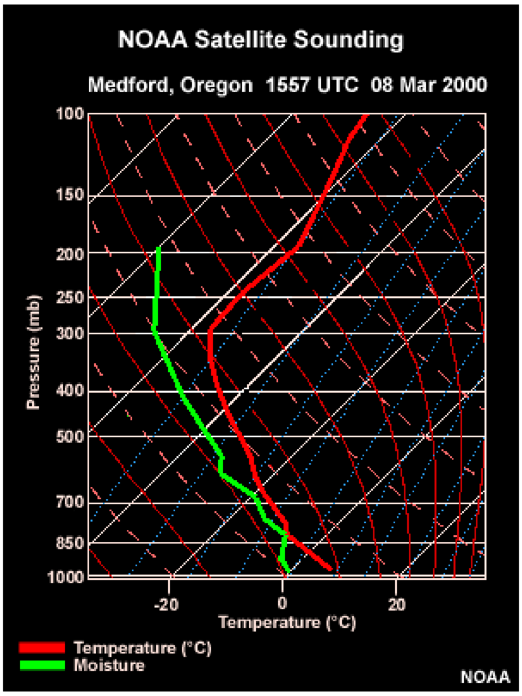
One aspect of running an operational satellite system is to provide continuity with previous systems and ensure coherence between the various components of the system. ATOVS and the AVHRR imager were originally developed for the sounding of temperature and moisture for the NOAA satellites using the TIROS-N system and the NOAA-KLM series.

The ATOVS suite includes the HIRS/4, AMSU-A, and Microwave Humidity Sounder (MHS) instruments. In addition to flying on the NOAA satellites, both ATOVS and AVHRR are on Metop as part of IJPS.

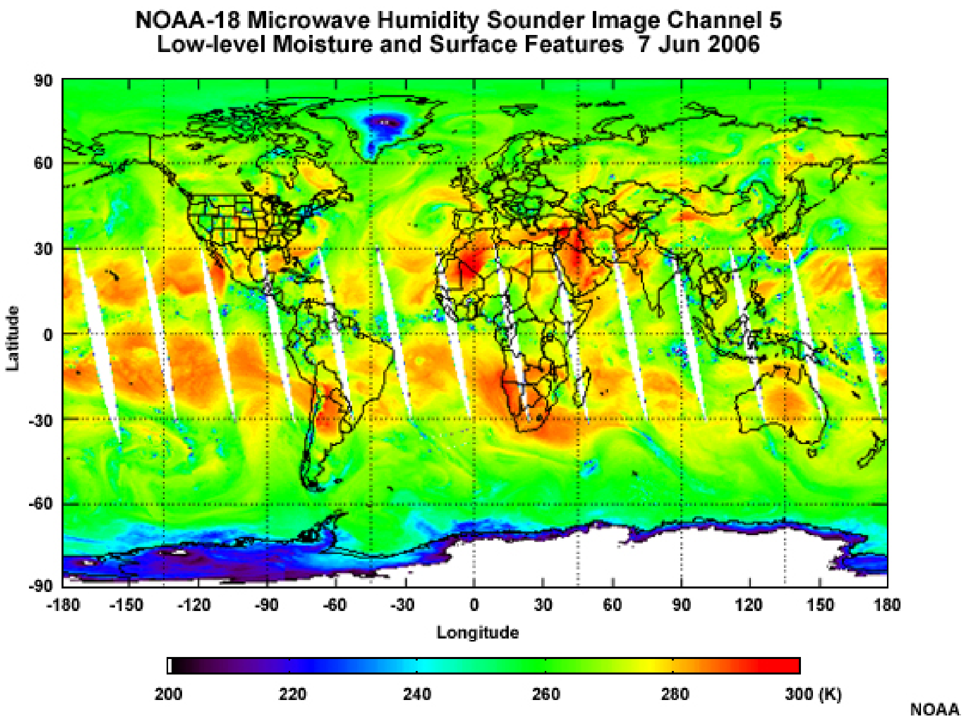
Bear in mind that microwave instruments provide near-all-weather sounding capability.



Global ATOVS and AVHRR Level 1 products are provided to users from the central facility.



A Level 2 product containing ATOVS-derived vertical profiles of temperature and humidity will be produced as well.



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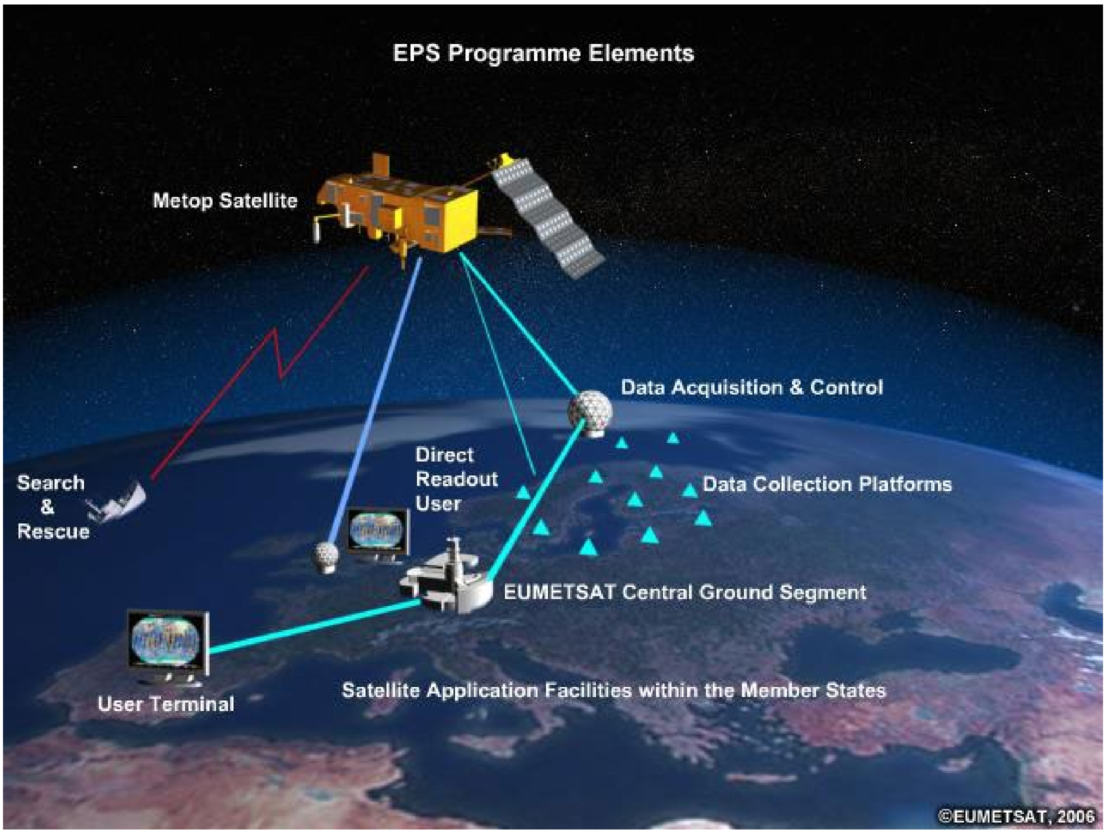
5.2 Potential ATOVS Level 2 Products

EUMETSAT may provide an expanded product suite in its central facility or within the Satellite Application Facilities.

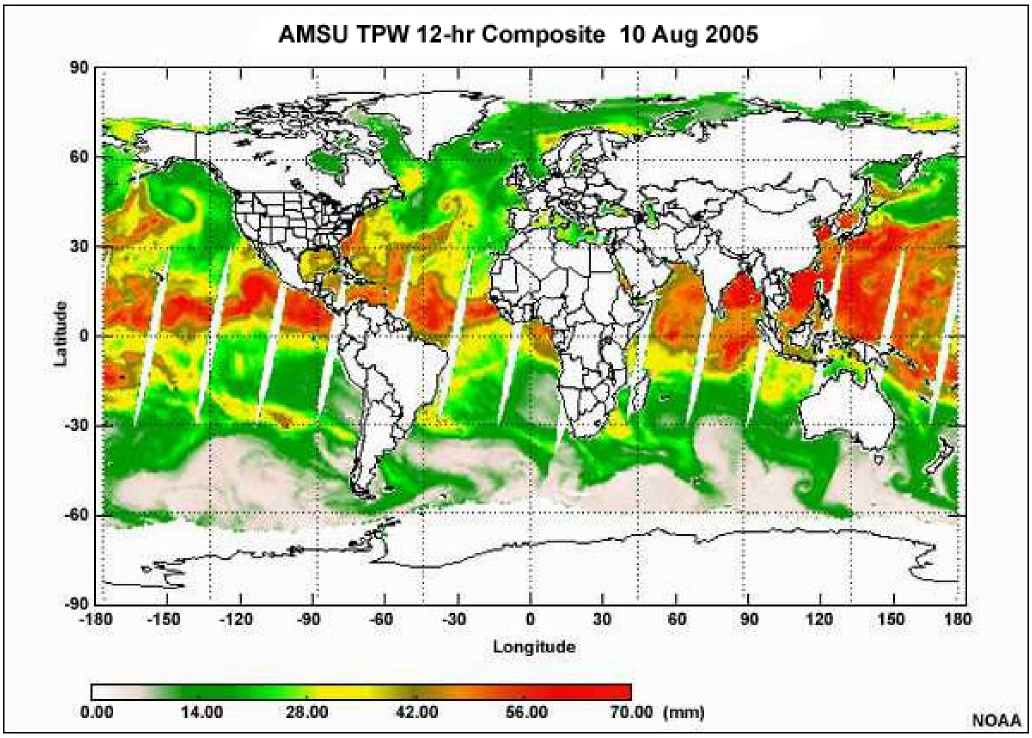


The following is a list of potential products. Note that sea ice and precipitation products are already provided by the SAF's.

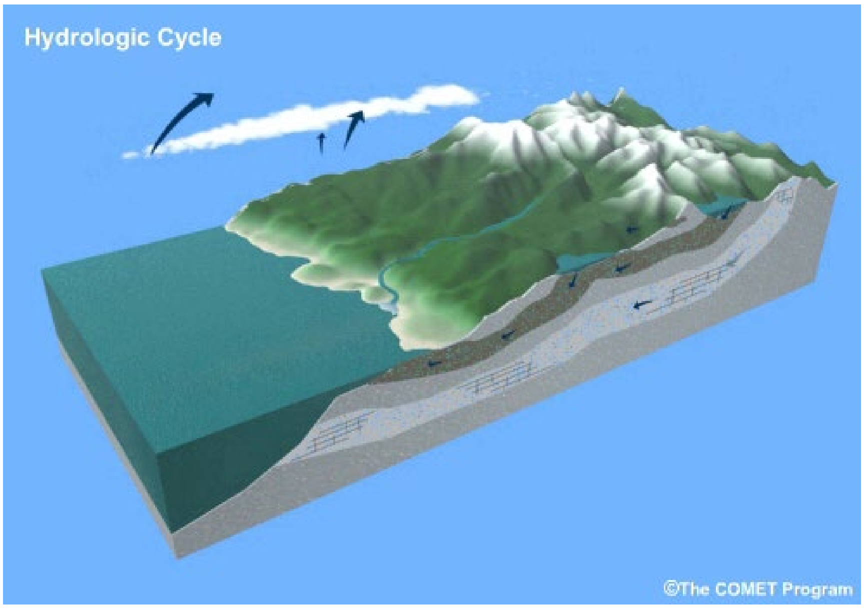
- Total precipitable water
- Cloud liquid water
- Sea ice detection
- Precipitation
- Snow and ice cover over land

Total Precipitable Water

Using microwave and infrared sounders in combination, we can derive column-integrated atmospheric water vapour, also known as total precipitable water (TPW), over land and ocean.



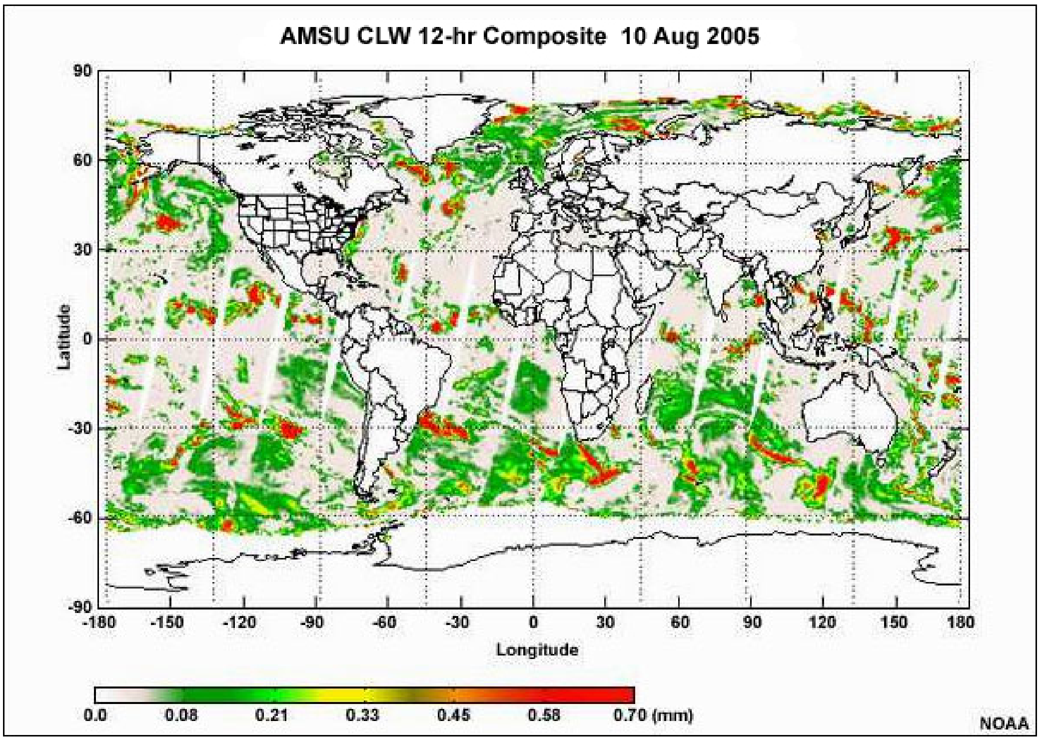
These measurements are vital for understanding the global hydrologic cycle. TPW is an important parameter in short-term weather prediction, including the analysis of tropical cyclone intensity trends, identification of atmospheric frontal boundaries, forecasting heavy precipitation, and data assimilation for numerical models. Water vapour also impacts atmospheric chemistry and pollution, transport, and climate trend monitoring. It also plays a key role in the ongoing debate over future climate change.



Click to view animation

Cloud Liquid Water

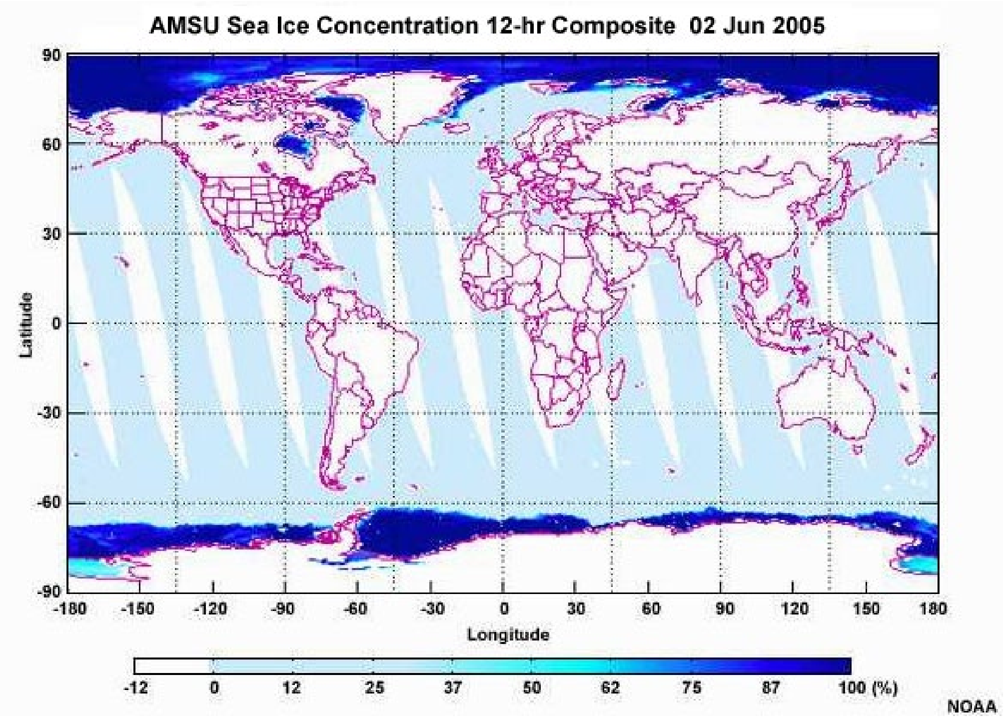
Research scientists use cloud liquid water (CLW) estimates to assess the properties of stratiform clouds. Forecasters can use cloud liquid water to help assess the potential for aircraft icing.



Sea Ice

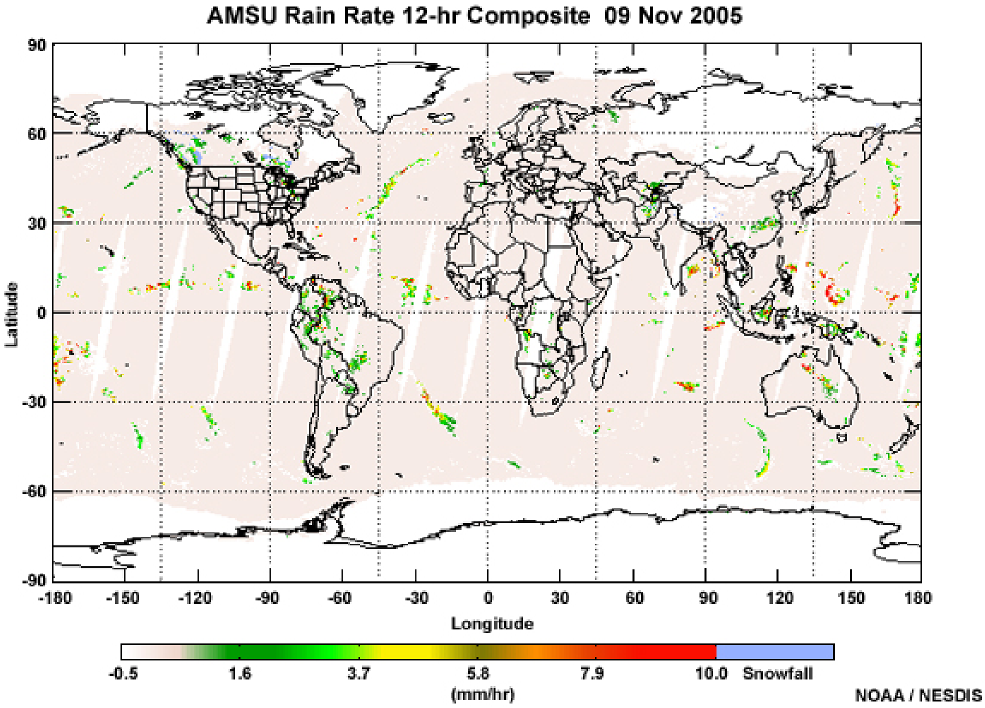
Using microwave imagery to monitor the concentration, extent, age, and thickness of sea ice is important for:

- Shipping and navigation
- Fishing
- Oceanography
- Climate monitoring and prediction
- Monitoring changes in atmospheric circulation patterns and storm potential
- Monitoring ecosystems, coastal conditions, and habitat



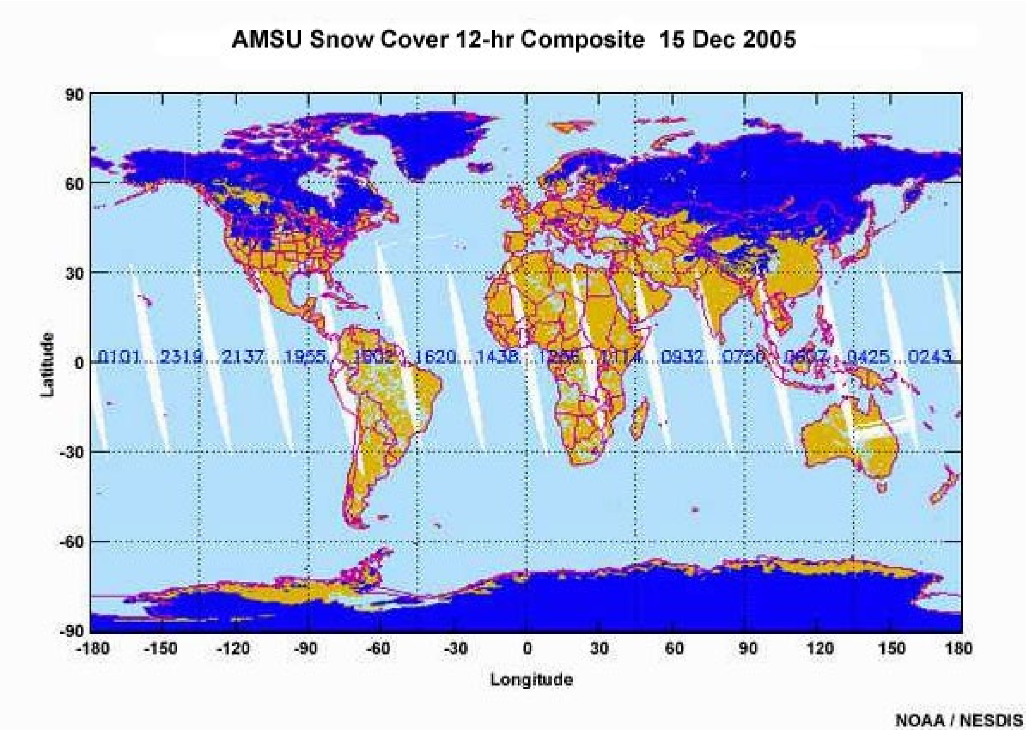
Precipitation

Microwave rain rate is a derived product useful for monitoring precipitation worldwide. Space-based precipitation estimates supplement land-based rain gauge and radar observations across Earth's vast, data-sparse oceanic regions and remote land areas. Knowledge of the spatial and temporal aspects of precipitation is important to our understanding and monitoring of the global hydrologic cycle. Space-based precipitation estimates in near-real-time also benefit short-term weather forecasting by providing critical information on potentially hazardous precipitation events beyond the range of land-based observing systems.



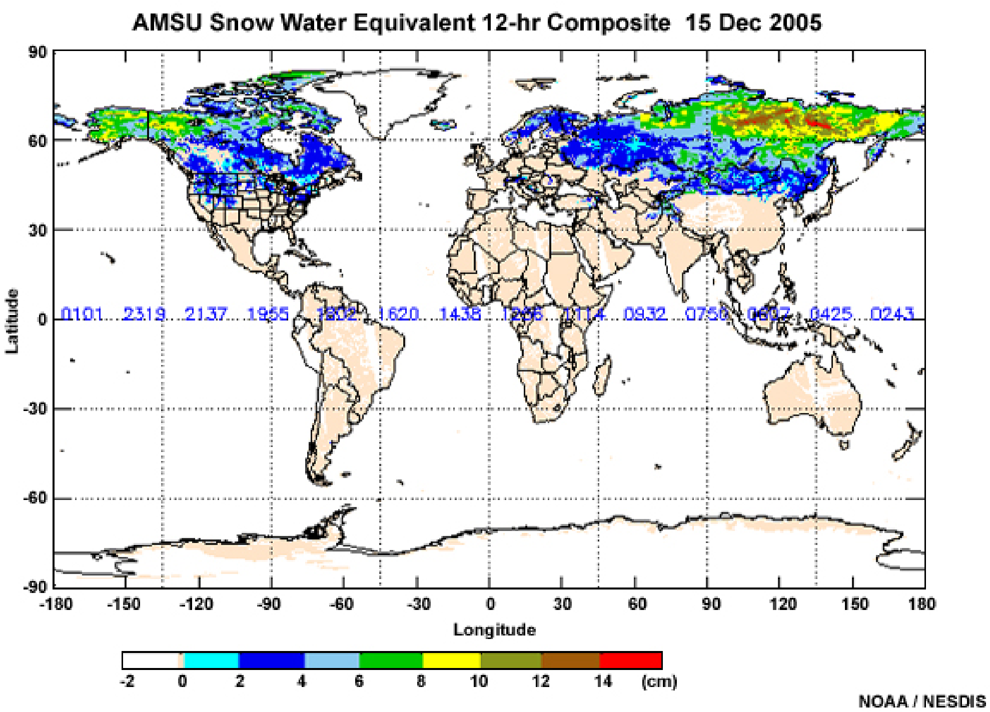
Snow and Ice Cover over Land

Products that monitor global snow and ice cover can be derived from microwave radiometers. Microwave observation is especially important at higher latitudes, including polar regions, where visible and infrared sensing can be limited due to cloud cover and long periods of darkness.



Another strength of microwave observations is the ability to probe beneath the surface of snow and ice, and reveal properties such as snow water equivalent and ice age. Characterizing snowpack and ice is important for:

- Climate monitoring and prediction
- Hydrology
- Short-range weather forecasting
- Monitoring changes in atmospheric circulation patterns
- Monitoring ecosystems and habitat
- Data assimilation for NWP models



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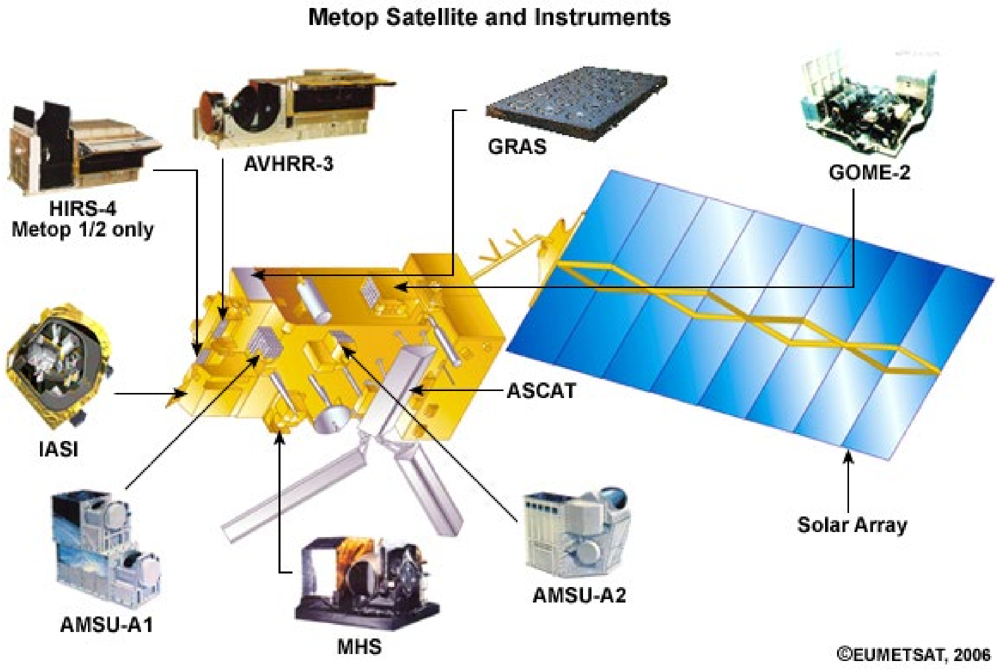
5.3 MHS: First European Contribution to IJPS

The Microwave Humidity Sounder (MHS) was developed by EUMETSAT as a replacement for the AMSU-B instrument in the ATOVS suite. MHS was the first instrument in polar orbit developed by EUMETSAT and became part of the payload of the first IJPS satellite in orbit, NOAA-18, launched 20 May 2005. This provided EUMETSAT with valuable experience, which was applied to the new instruments flying on Metop.



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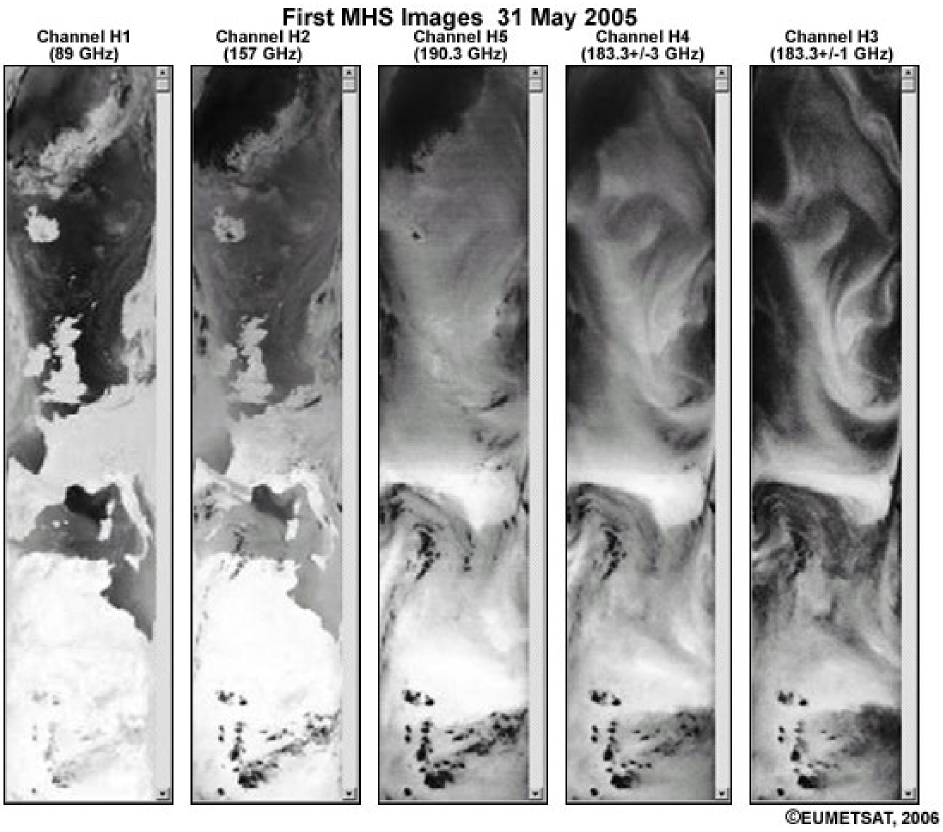
5.4 First MHS Images over Europe

The images show a scene acquired 31 May 2005 covering the North Atlantic down through portions of Europe and North Africa.



We see the surface and clouds in the two images taken with channels 1 and 2. Notice the Vatna glacier on Iceland.

The next three images show an increased sensitivity to water vapour, cloud ice, and precipitation-sized hydrometeors. Channels with increasing sensitivity to water vapour see energy emitted from layers higher in the atmosphere. Notice that the Vatna glacier, which extends to 2199 meters above sea level, is still visible in channel 5.

Measurements taken with the MHS are critical in deriving profiles of atmospheric moisture and for quantifying precipitation.

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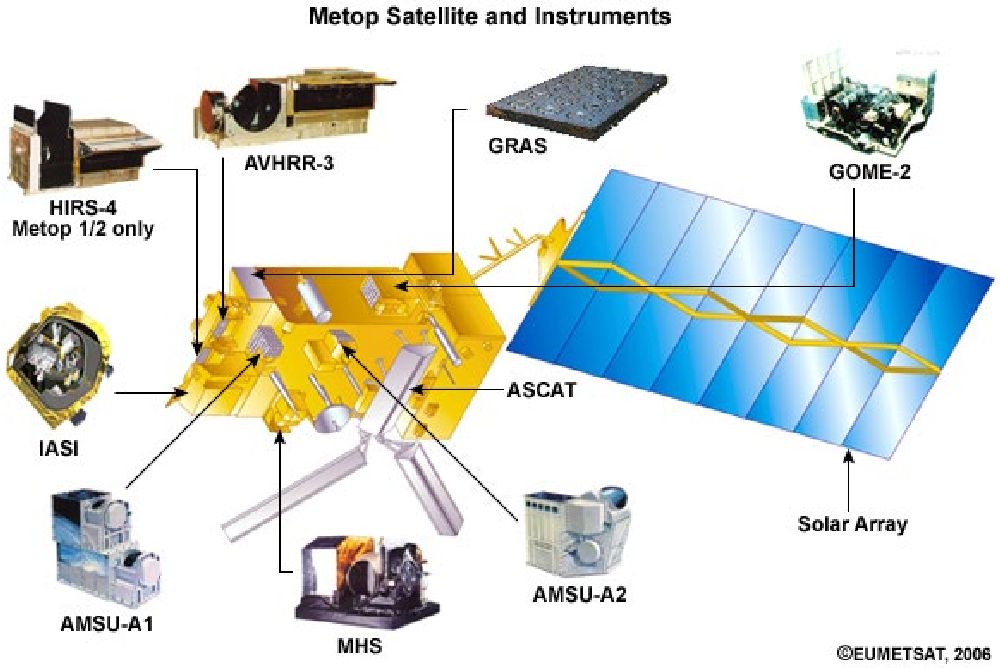
6.0 ASCAT Ocean Winds

6.1 ASCAT

Metop has two heritage instruments from the European Remote-Sensing Satellite (ERS), which form part of the ESA research missions, ASCAT and GOME-2. ASCAT provides observations of surface wind over the oceans, whereas GOME monitors ozone and trace gases.



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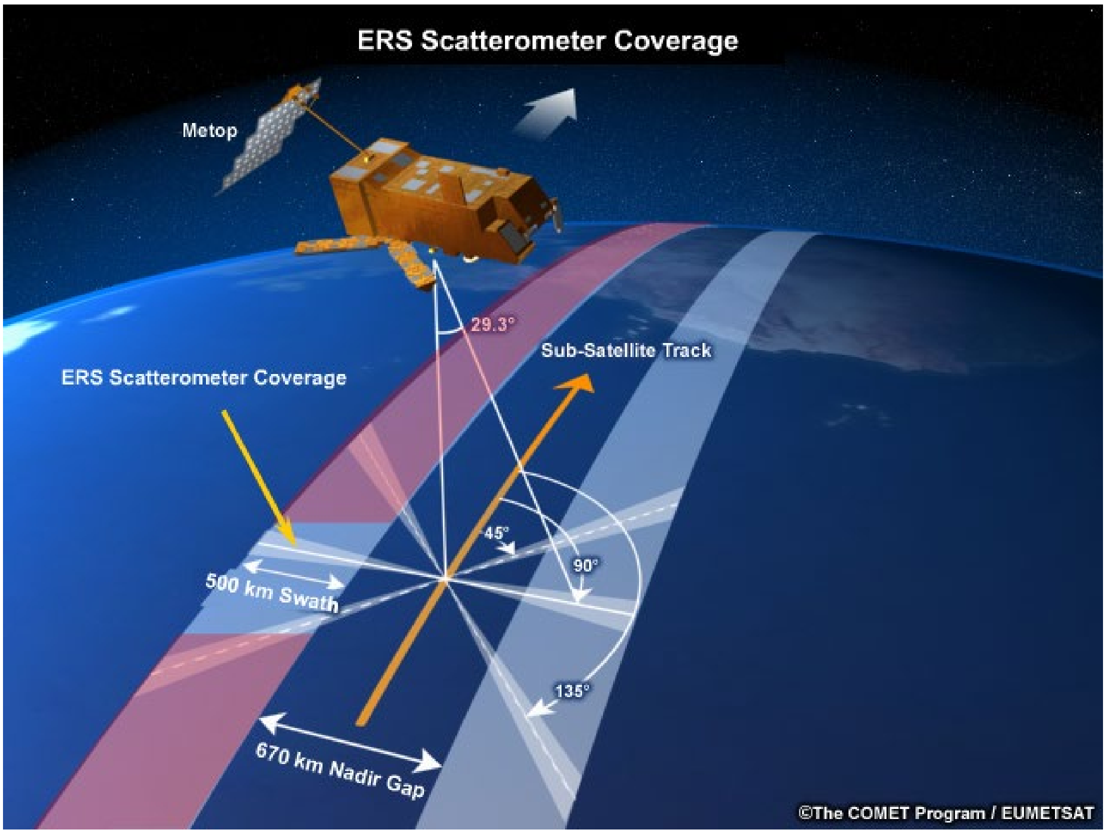
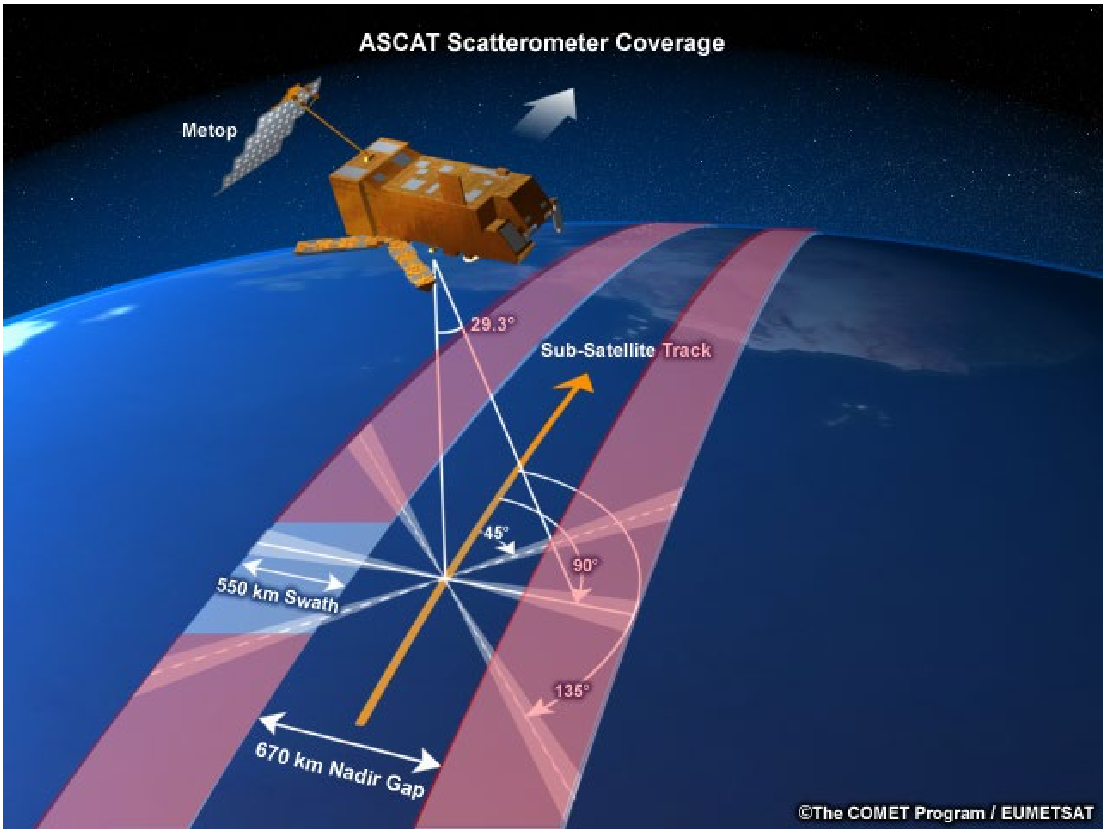
6.2 ASCAT, an Advanced Scatterometer

ASCAT is the only active remote sensing instrument on Metop. An active sensor transmits and then listens to the return energy as opposed to a passive sensor, which only listens to emitted energy. ASCAT is a C-band radar in the heritage of the Active Microwave Instruments (AMI) successfully flown on the ESA ERS satellites. The main mission objective is to derive wind vectors over the ocean surface.

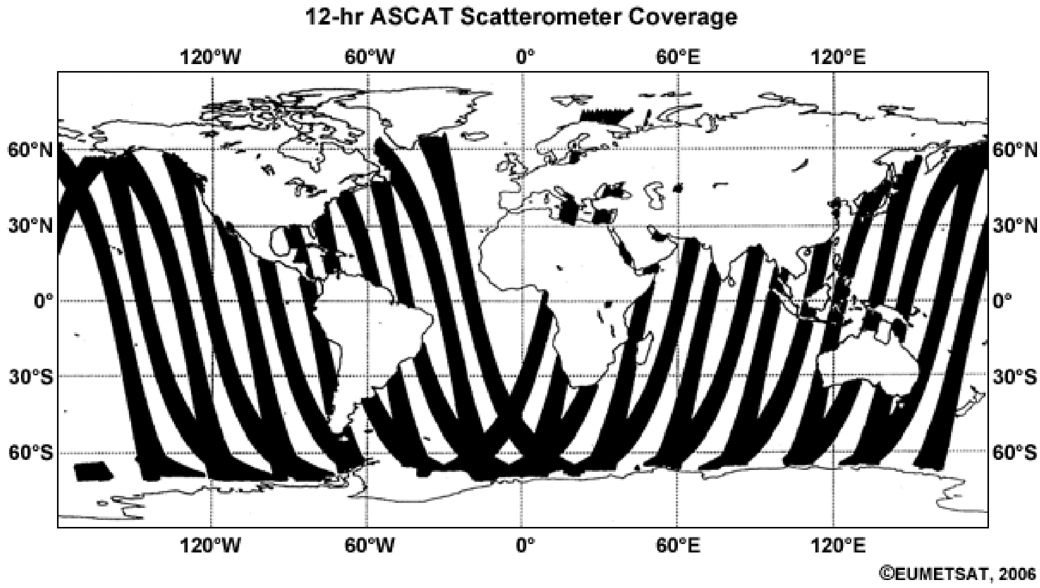
This first view shows swath coverage available with the heritage ERS scatterometer.



With the newer ASCAT instrument, we observe data over two swaths instead of one, with each swath being wider than with ERS. Note that ASCAT wind products will be available at both 25-km and 12.5-km resolution.

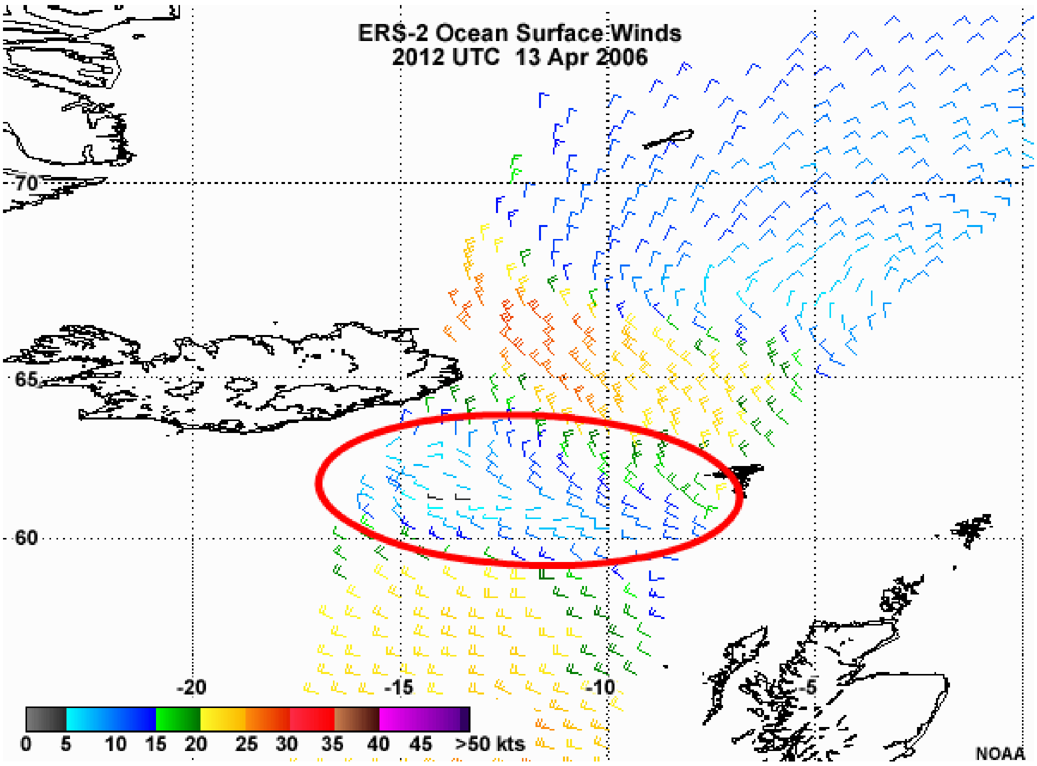


This plot shows ocean observation coverage for 12 hours, which is much improved with the addition of a second swath.

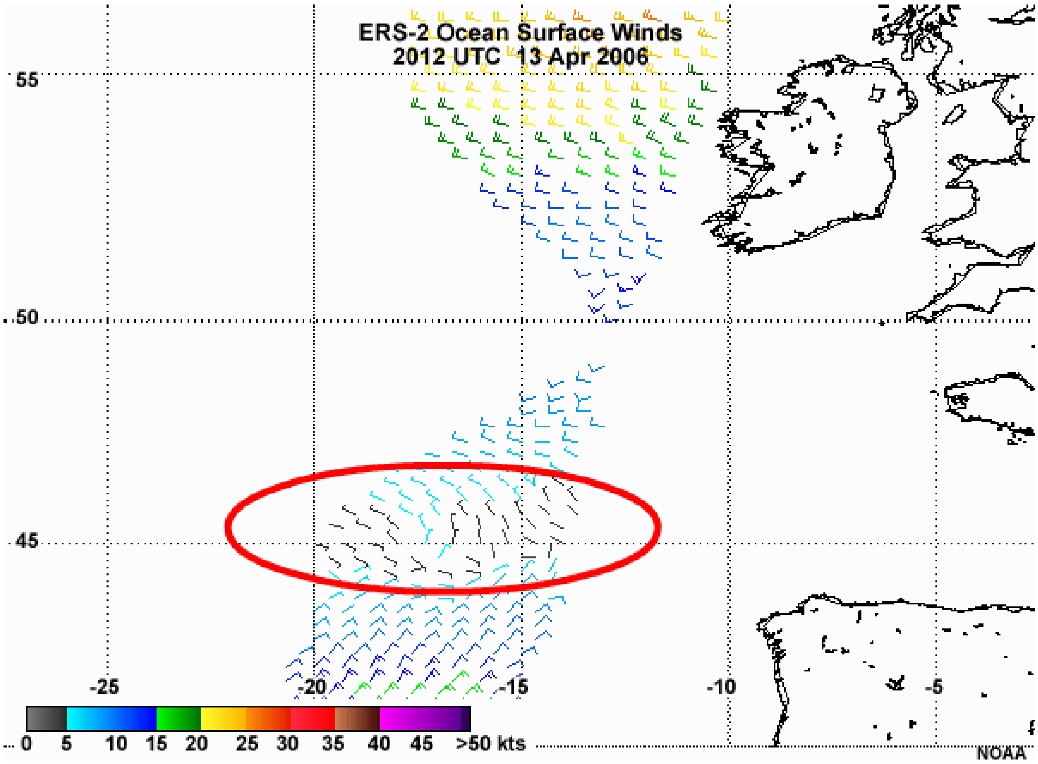


Ocean surface wind vectors have already demonstrated their value in the meteorological analysis of important weather features. The two examples show wind vectors over the North Atlantic from 13 April 2006.

In the first plot, we can see diminished wind speeds downwind of Iceland.



The second plot highlights a confluence pattern and indicates the presence of a frontal zone.



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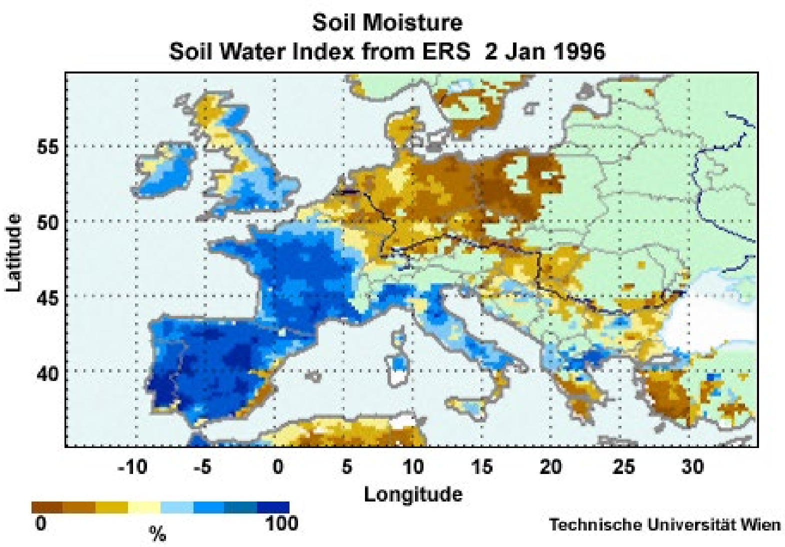
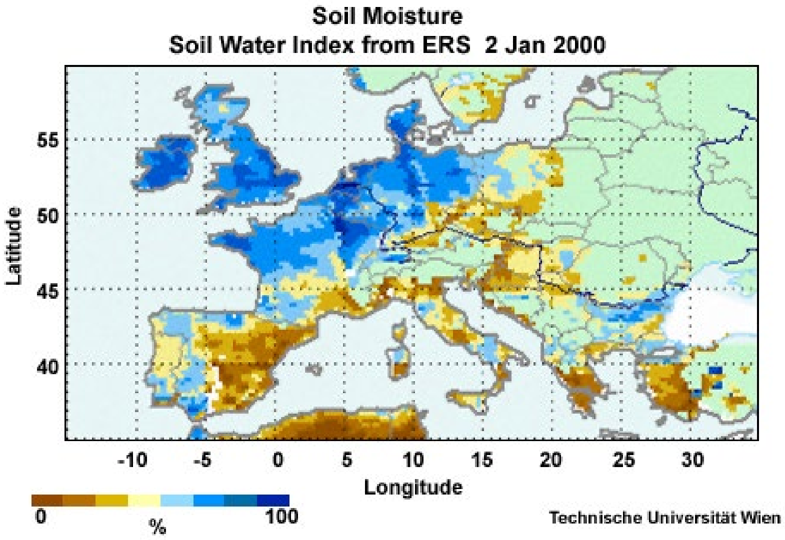
6.3 ASCAT Soil Moisture Product

Research activities have revealed a number of emerging applications based on scatterometer data that go beyond the "classical" derivation of wind vectors. One is the estimation of soil moisture, which is needed for NWP and is of interest to ground transportation. Satellites provide high-resolution coverage that could not be provided by the sparse ground measurement networks. The scatterometer makes it possible to map soil moisture, and will be available as a day 2 product for EPS.





Shown here is a typical soil moisture product derived from ERS data for January of two different years. Notice both the dramatic differences in soil moisture content across Europe for a given month, and the dramatic changes between 1996 and 2000.

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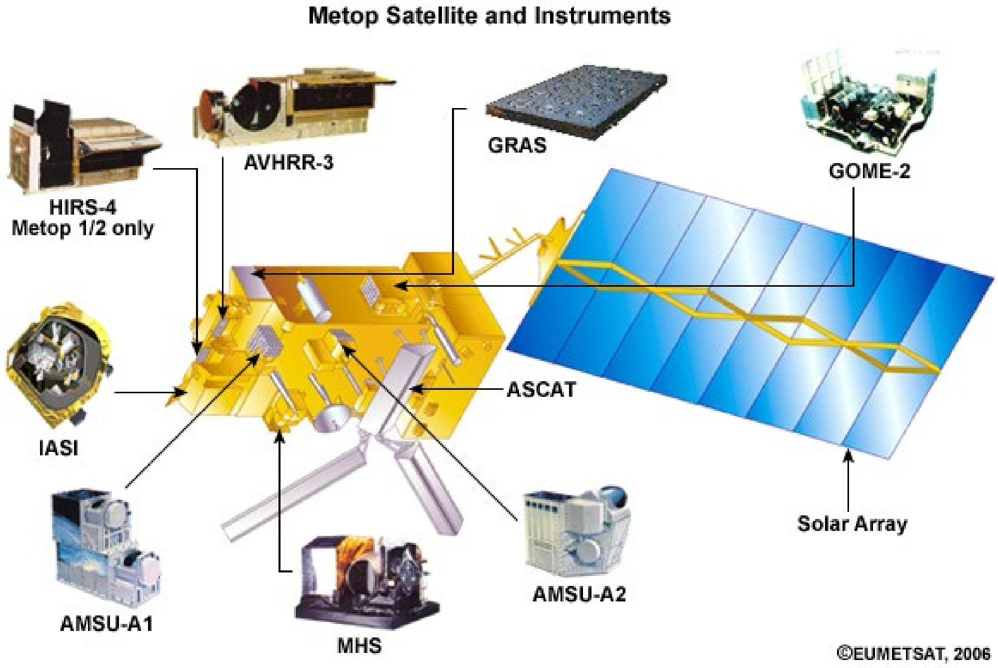
7.0 GOME-2 Atmospheric Chemistry Products

7.1 Global Ozone Monitoring Experiment (GOME-2)

Now let's look at the second heritage instrument on Metop, the GOME-2. Together with IASI, the GOME-2 provides the capability to monitor the total column ozone, ozone profiles, and trace gases. The information is useful for climate monitoring, atmospheric chemistry, the ozone cycle, and the radiation budget. The data will also aid in the monitoring and prediction of damaging UV radiation and the forecasting of volcanic cloud displacement. Ozone patterns can be used in NWP as tracers to derive stratospheric winds.



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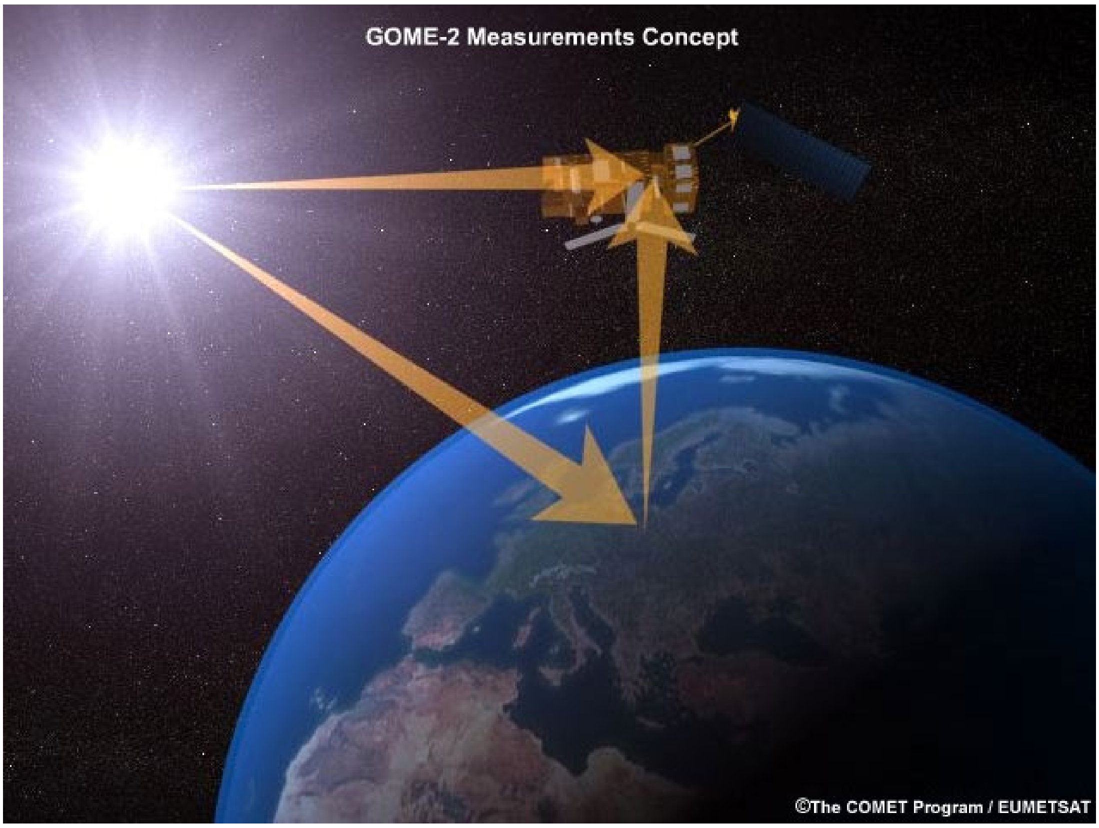
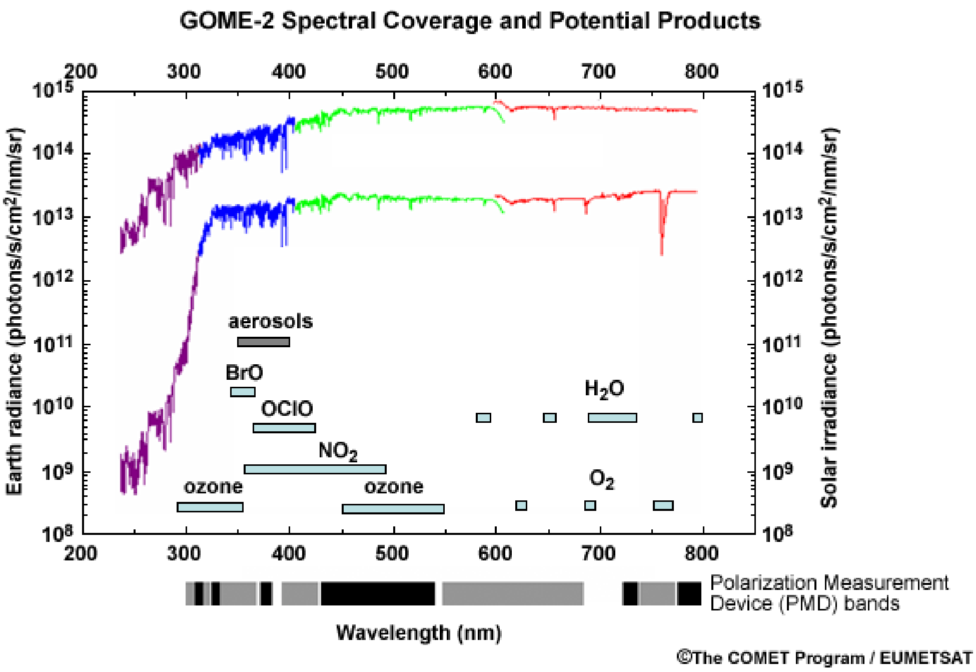
7.2 GOME-2 Level 1 Products — Measurement Spectra

GOME is a spectrometer that measures the backscattered ultraviolet and visible radiation from the earth/atmosphere system.



A reference spectrum is taken from the incoming solar radiation. Measurements are made in four spectral bands to retrieve amounts of both ozone and other trace gases. The four bands are indicated in different colours.

The figure summarizes the GOME-2 measurements and shows the potential trace gases that may be detected. This example shows spectra for both the incoming solar radiation and the backscattered UV and visible radiation (sometimes known as the Earthshine spectrum).



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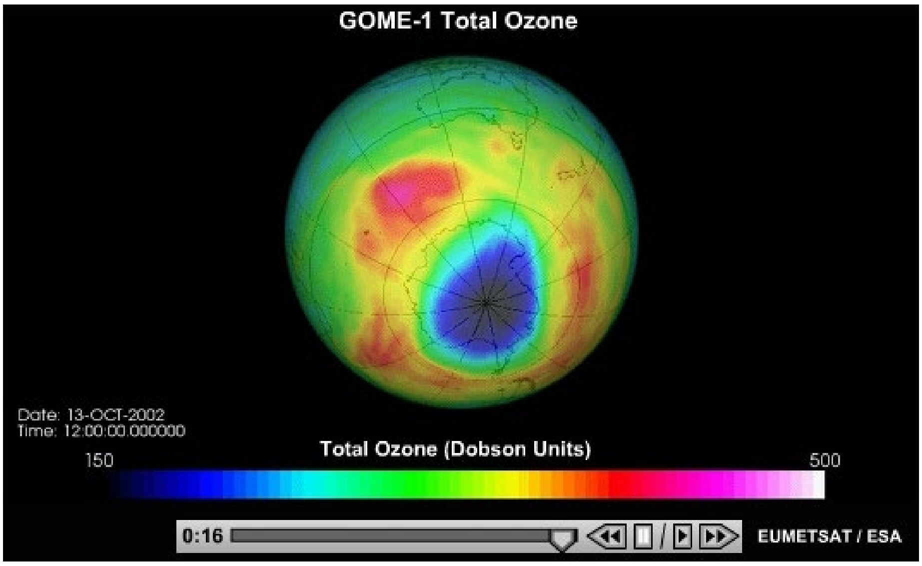
7.3 GOME Level 2 Products (Part 1)

The total ozone column amount is generated by the Ozone Monitoring Satellite Application Facility. The animation shows the Southern Hemisphere ozone hole and its development during October 2002, illustrated by the total ozone amount.



Click to view animation

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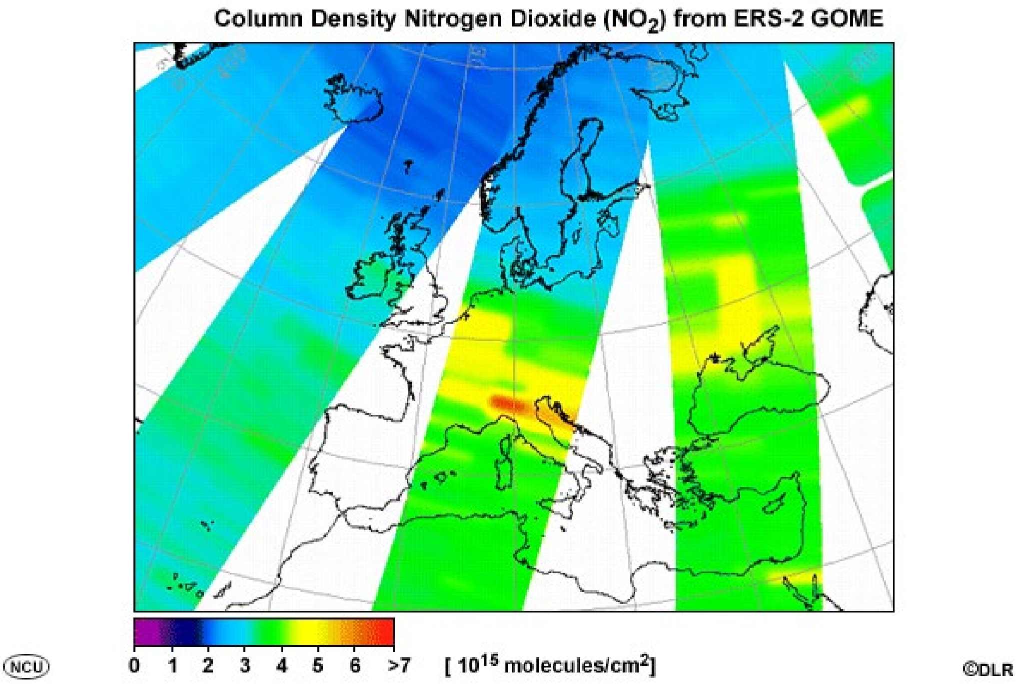
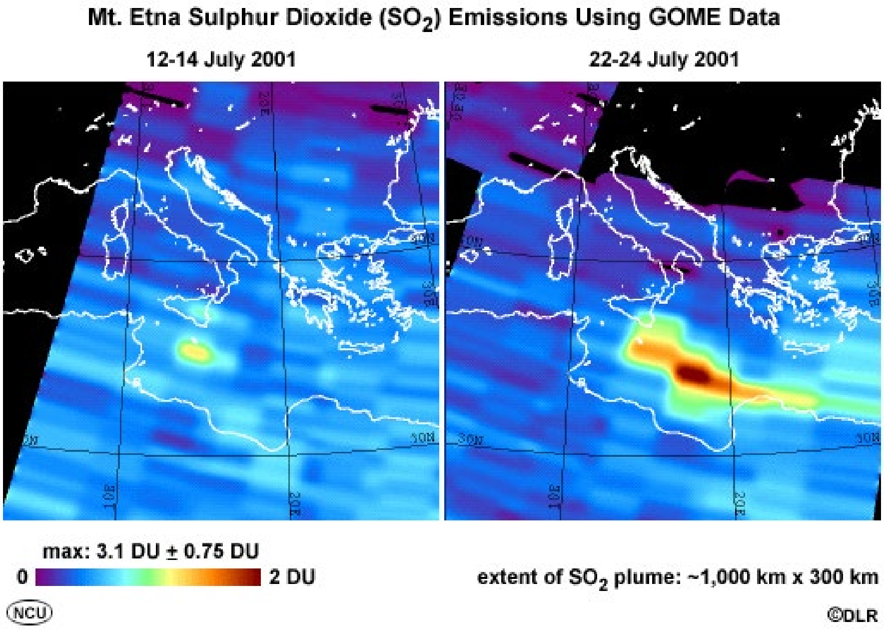
7.4 GOME Level 2 Products (Part 2)

Other trace gas products are expected to be derived from the GOME-2 data. The example shows high concentrations of nitrogen dioxide (NO_2) over densely populated and industrialised areas. NO_2 is a greenhouse gas, an important pollutant, and a contributor to the ozone cycle. It can cause respiratory problems from high concentrations or long exposure and contributes to the formation of acid rain, nutrient overload that diminishes water quality, reductions in visibility, and production of other toxic chemicals.



As mentioned earlier, sulphur dioxide is another important trace gas often associated with volcanic eruptions. Exposure to high levels of SO_2 can aggravate respiratory problems. Sulphate particles also result in haze and are a major cause of reduced visibility. SO_2 reacts with other substances to form acids that fall to earth as acid rain, fog, snow, and even dust. Acid rain damages buildings, painted surfaces, forests, crops, rivers and lakes, and can have long-term impacts on plant and animal ecosystems.

The images show eruptions of Mount Etna in Sicily on two dates in July 2001. Notice the extent of SO_2 plumes emitted from the volcano. Data like these can be used as a basis for predicting the displacement of volcanic clouds, if they are used in dispersion models with a forecast model.



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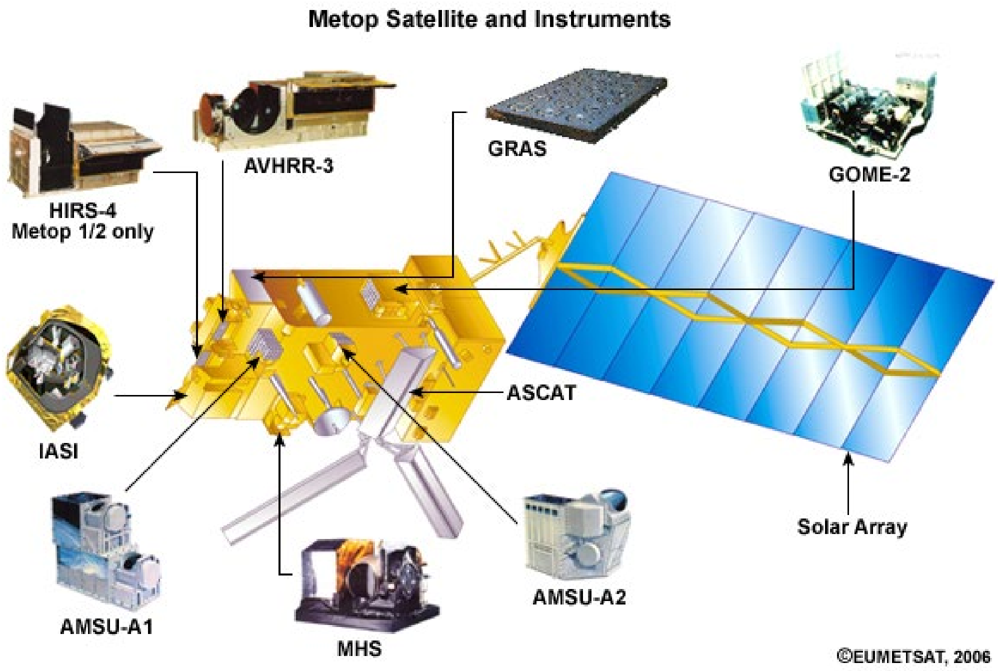
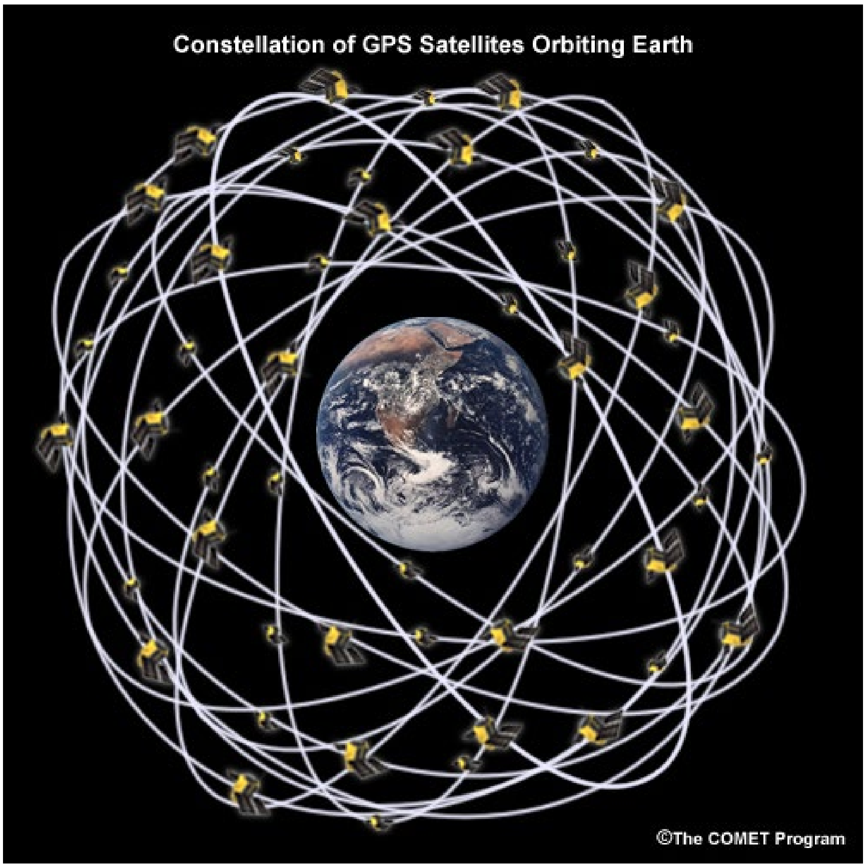
8.0 GRAS — Using Satellites for Atmospheric Sounding

8.1 GNSS Receiver for Atmospheric Sounding (GRAS)

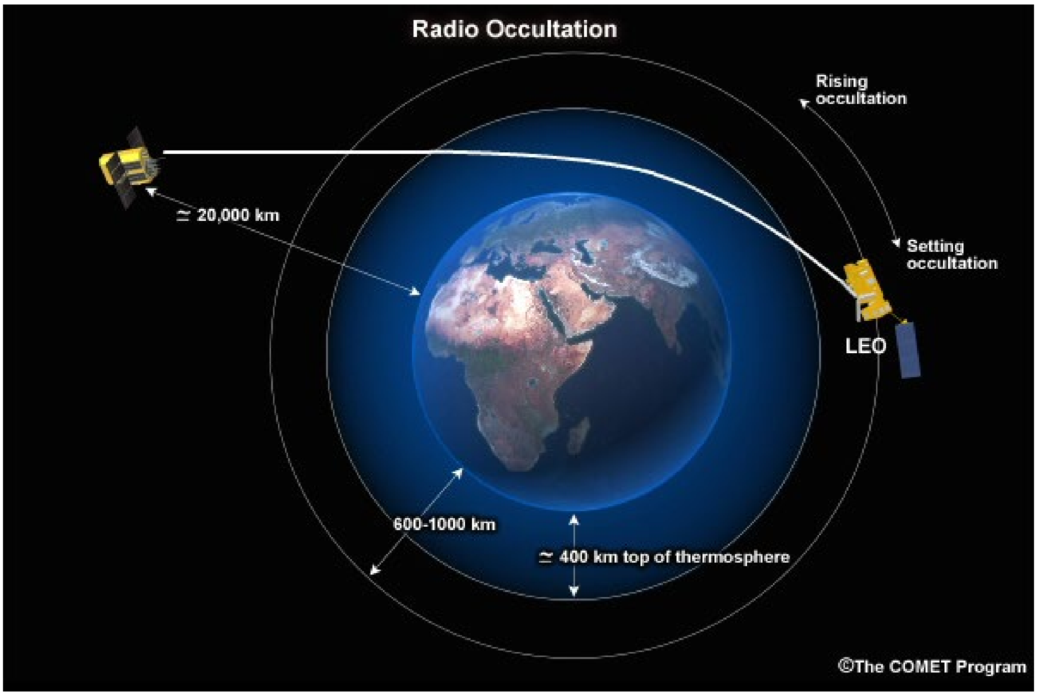
There is another innovative sounding system on the Metop Satellite (the GRAS instrument), which provides the first operational use of Global Positioning System (GPS) satellites for atmospheric sounding. GRAS uses GPS signals to provide profile information of temperature and humidity at high vertical resolution (potentially better than 1 km). This will be particularly beneficial for NWP and climate monitoring.



There are about 24 GPS satellites orbiting around the Earth, all in high-altitude orbits (about 20200 km).



An occultation occurs for GRAS whenever a GPS satellite rises or sets and is no longer in direct line of sight of the GRAS instrument. Despite this, the signal from the GPS transmitter still reaches the GRAS instrument as it passes through the limb of the atmosphere and is refracted. A single GRAS instrument in near-polar orbit at 824 km will observe over 500 occultations per day, distributed quite uniformly over the globe.



Click to view animation

When GRAS was first introduced as a payload, it was clear that a complete system beyond the GPS and Metop satellites was needed. Since several spacecraft are involved, each with a set of onboard clocks, time-based errors can contribute to errors in the measurements. With a ground-based set of reference stations, the satellites used for an occultation measurement can be seen from the stations simultaneously, eliminating clock errors through differencing. With approximately 24 stations world-wide, redundancy is about 200%, which ensures operational availability. In addition, the precise orbits for each spacecraft need to be known in real time.

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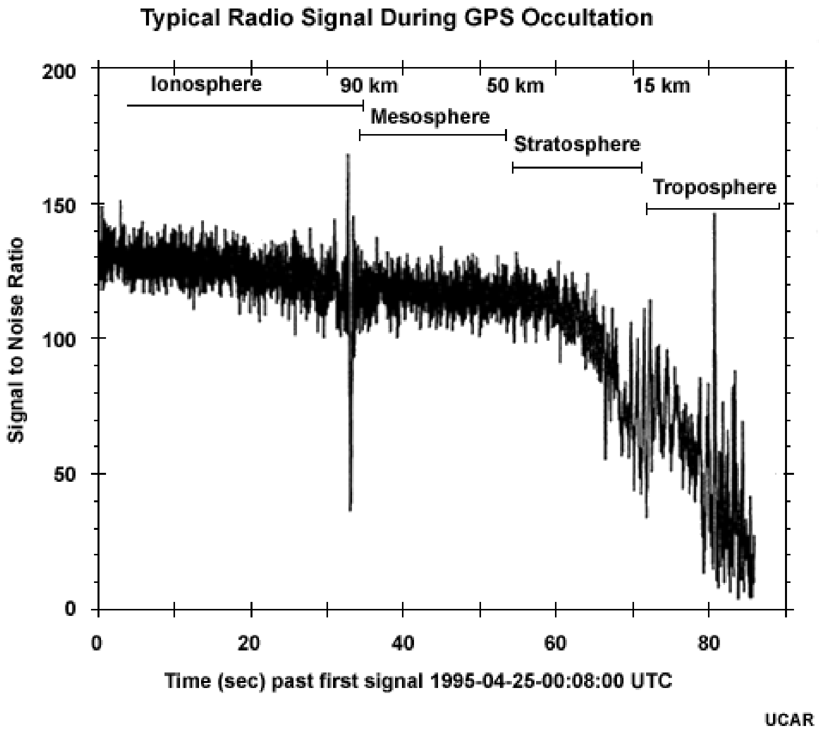
8.2 GRAS — First Operational Use of Radio-Occultation Technique

We're looking at the signal of a GPS satellite as it is received by the research system GPS-MET. Note the change of the signal-to-noise ratio, which decreases as the signal descends deeper into the troposphere. GRAS is expected to have a better signal-to-noise ratio and provide reliable profiles that extend deeper into the troposphere.



For more information on radio occultation, see the COSMIC Webcast (http://meted.ucar.edu/COSMIC/).

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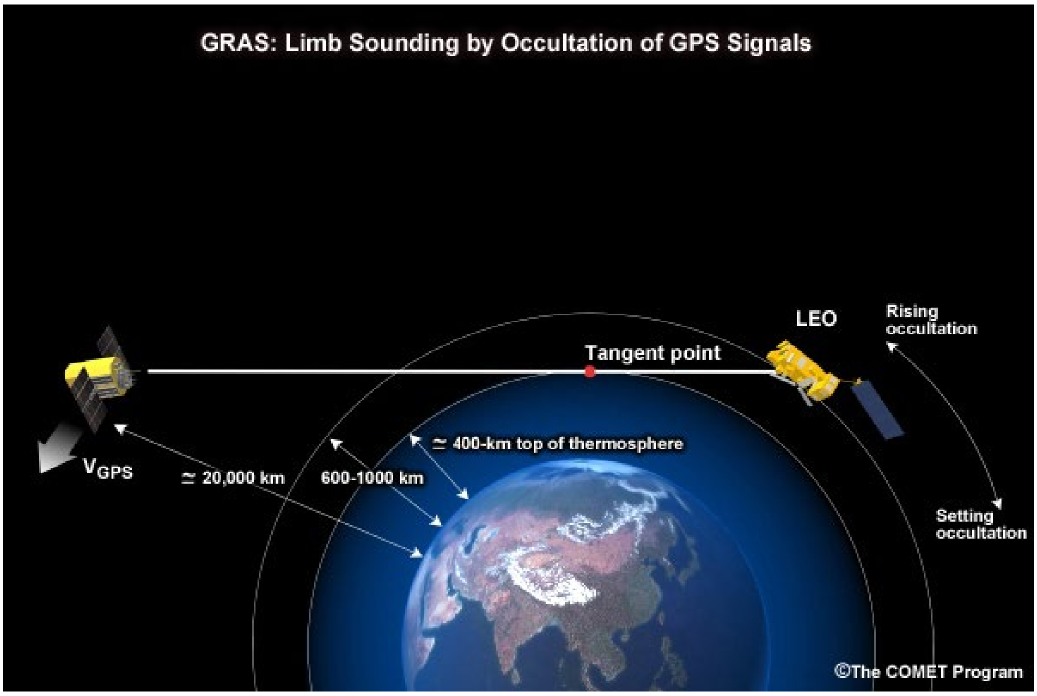
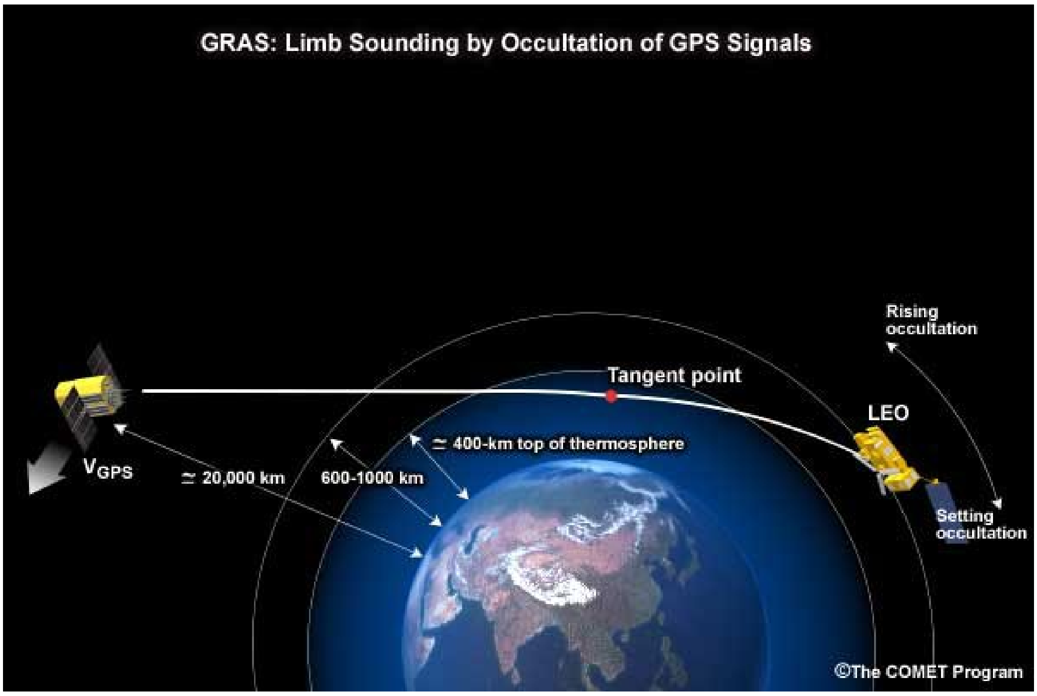
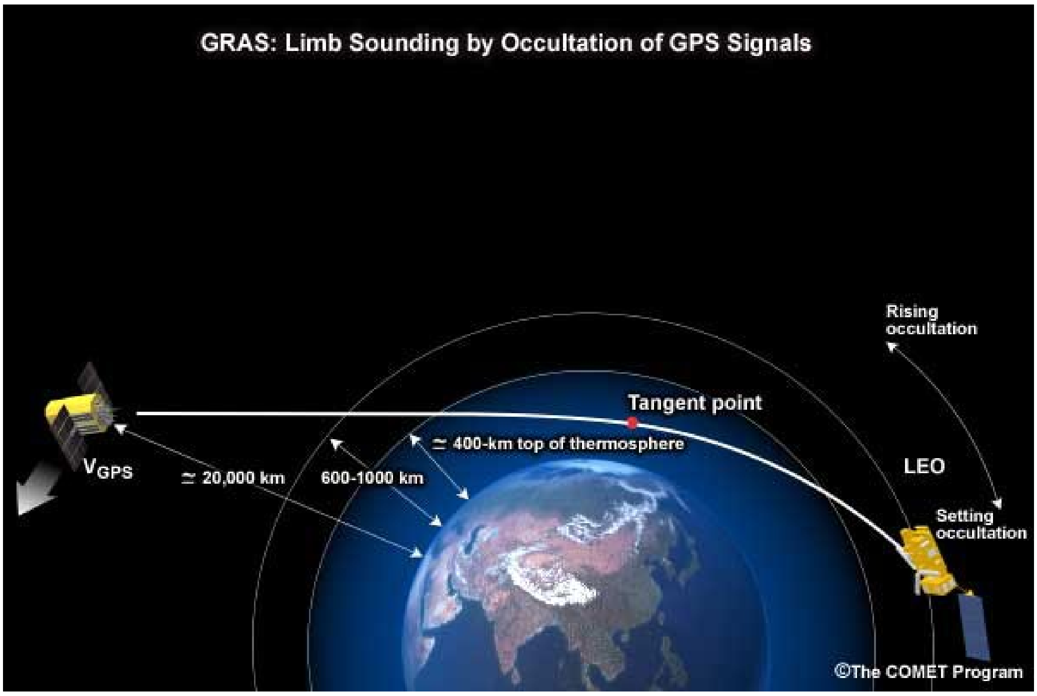
8.3 GRAS Level 1 Product — Bending Angle

As they travel through the atmosphere, GPS signals are bent due to the change in density, which is, in turn, a function of temperature and moisture. This relationship is described by the refractive index.

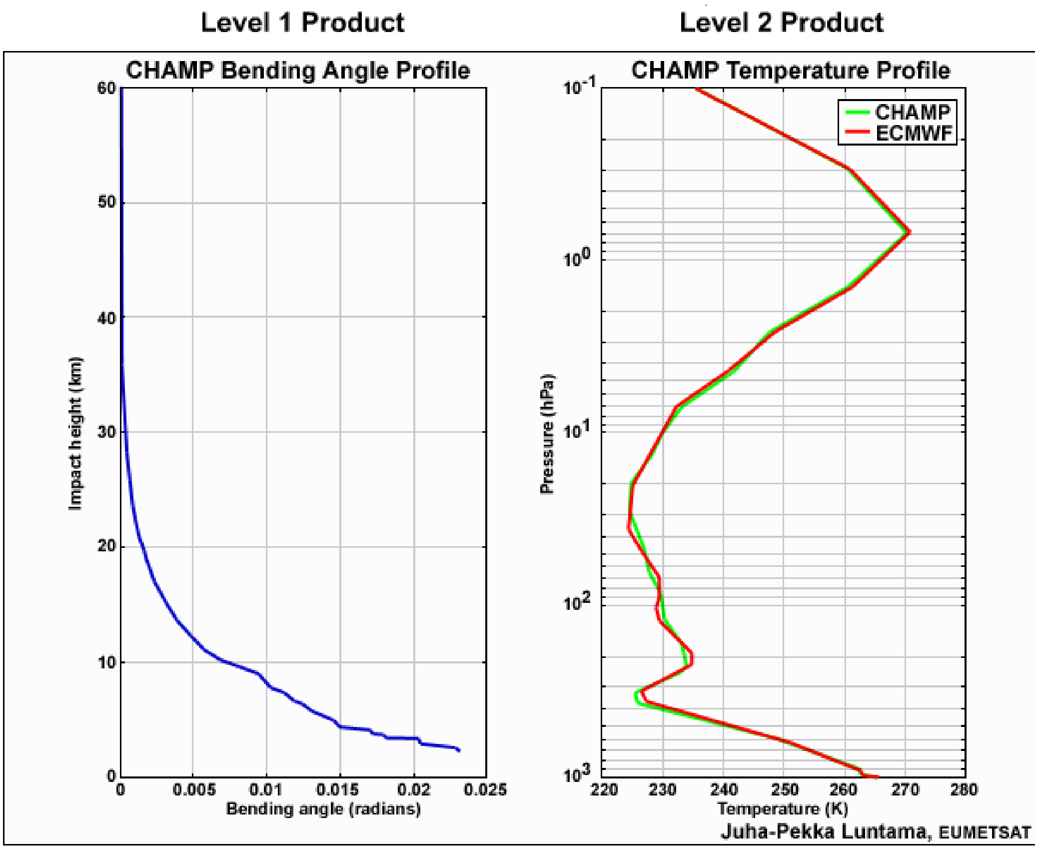
GRAS measures the phase delay of the signal caused by the bending of the signal ray.







The amount of bending, known as the bending angle, is then derived from the phase data, resulting in the Level 1 bending angle product. By integrating this information with an a priori knowledge of either temperature or moisture, the combined temperature moisture profile can be extracted. The GRAS Level 1 product is the vertical profile of the bending angle. The product also contains total electron content.



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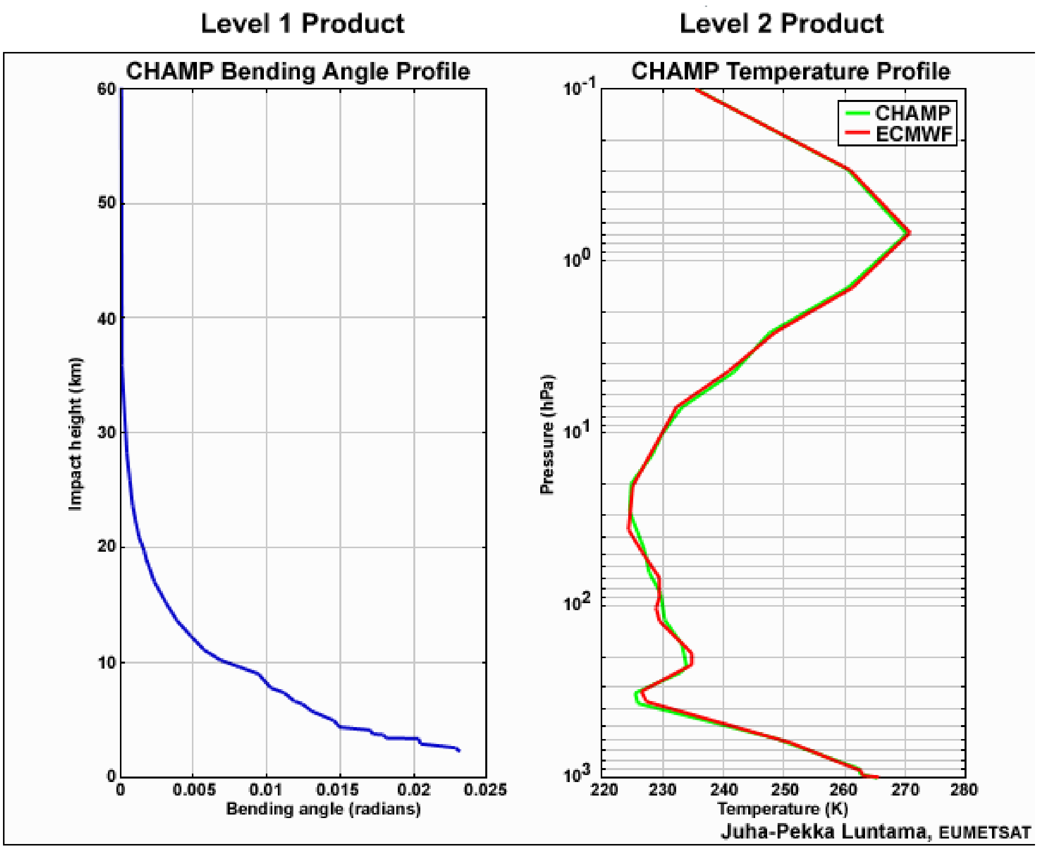
8.4 GRAS Level 2 Product

The Level 1 product is transmitted to both users and the GRAS Meteorology SAF, where the Level 2 vertical profiles are retrieved. The figure shows an example of bending angles and the retrieved temperature profile derived during the development phase of the operational GRAS processing system using Champ occultation data.



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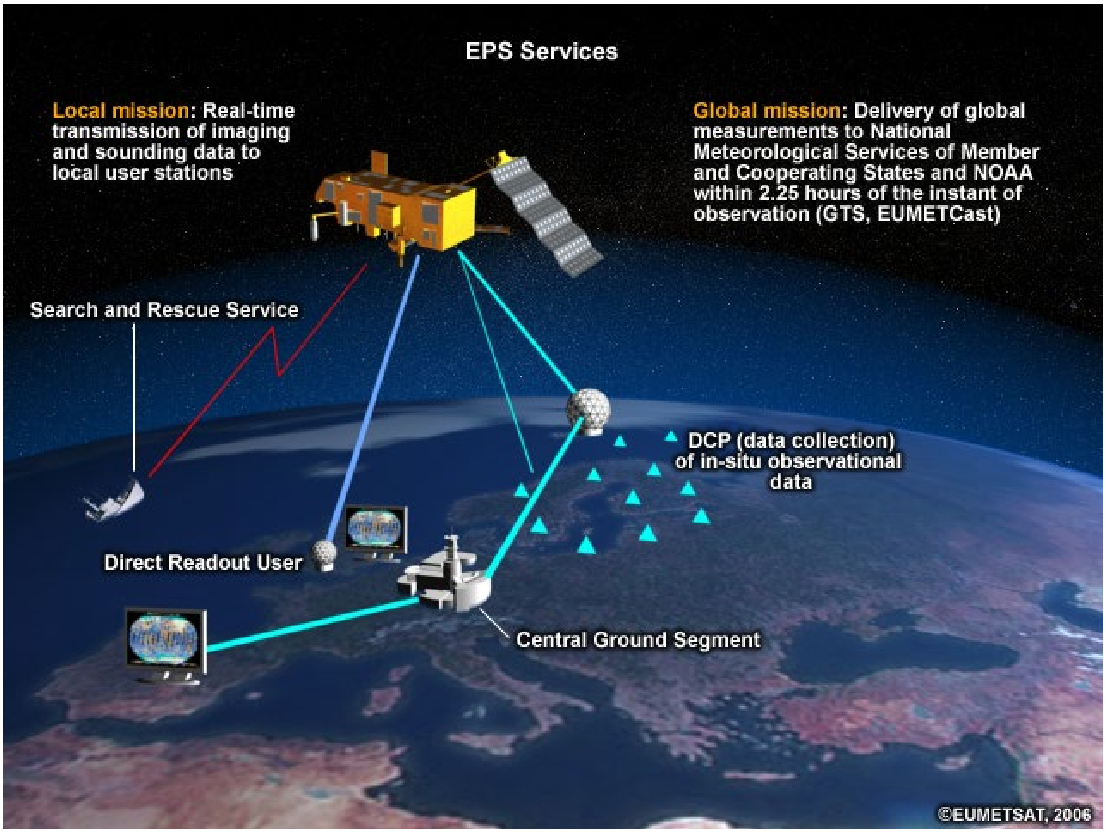
9.0 EPS Services

9.1 EPS Services Overview

EPS provides a number of services, ranging from the provision of global products to the support of humanitarian search and rescue missions.



The products and services provided by EPS include:

- Global Level 1 data in near-real-time with an average latency of 2 hours 15 minutes. Data, primarily in BUFR format, is provided through EUMETSAT's EUMETCast service.
- Selected global Level 2 products with an average latency of 3 hours. Data, in BUFR format, consist of ATOVS and IASI vertical sounding products as well as ozone and trace gas information.
- Advanced High-Resolution Picture Transmission (AHRPT) service. AHRPT delivers all the real-time raw instrument (Level 0) data at full spectral and spatial resolution to direct readout users when the satellite is in view of their receiving station.
- Low Resolution Picture Transmission (LRPT) service, the digital replacement for the former analogue APT (Automatic Picture Transmission) service. LRPT provides a subset of the full set of data, namely the complete ATOVS sounding data and a set of 3 JPEG compressed AVHRR image channels.
- ATOVS (radiances) and AVHRR (imagery) Level 1 data, and ASCAT Level 2 (ocean surface wind vector) products with an average latency of 30 minutes. Coverage is for most of the Northern Hemisphere. Products come to EUMETSAT from dedicated local stations and are reassembled and retransmitted via EUMETSAT's Advanced Retransmission Service (EARS).
- EPS products from the Central Facility are provided mostly in BUFR (Binary Universal Format Representation) format, which is widely used in the meteorological community. In fact, it is a WMO-supported format. Global products are disseminated via EUMETCast, with some subsets disseminated via the Global Telecommunications Service.
- The Argos Data Collection System (DCS) continues in an improved form. Argos is a satellite-based system that collects, processes, and disseminates environmental data from fixed and mobile platforms worldwide. Argos is also able to geographically locate the source of the data anywhere on Earth, making it ideally suited for tracking ships, floating buoys, balloons, and wildlife. Many remote automatic weather stations report via Argos. EPS supports the DCS as a service to the Argos data center and does not actually process and disseminate the data in the ground segment.
- The Search and Rescue Service on the NOAA satellites is continued on the Metop satellites. S&R has contributed to the rescue of many people in hazardous situations, both on land and at sea.
- U-MARF archives all products generated by EUMETSAT, including products from EPS and the Meteosat satellites. U-MARF also catalogues information from the SAF archives for user access through the U-MARF interface.

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10.0 Webcast Summary

10.1 Webcast Summary

EPS assures continuity to the current global observing system through the continuation of the proven ATOVS instrument suite and the AVHRR imager. In addition, highly innovative features have been implemented with EPS:

- High-level sounding performance (IASI) and enhanced data streams are available to further improve the capabilities of advanced NWP systems.
- Multi-instrument capabilities ensure a service that goes beyond operational meteorology and enables EUMETSAT to fulfill its commitments vis-à-vis climate monitoring, atmospheric chemistry, and support to climate research.
- ASCAT and GOME-2 ensure continuity of earth observation missions. For the first time, these instruments provide data for operational users and represent EUMETSAT's commitment to provide near-real-time products for a period of at least 14 years.
- GRAS is a non-traditional approach to retrieving temperature as well as moisture and electron density. GRAS has potential for contributing to climate monitoring. The radio occultation principle is introduced for the first time in a meteorological operational environment and demonstrates the capability to provide high-quality vertical soundings in near-real-time.
- The Metop satellite series ensure that users have long-term support for meteorological and climate applications.

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References

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