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GEN150a

Earth observation and remote sensing

Secondary level teacher's pack

European Space Agency
Agence spatiale européenne

the Living Planet

Earth observation and remote sensing

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A joint project by the Directorate of Earth Observation and the Education Office
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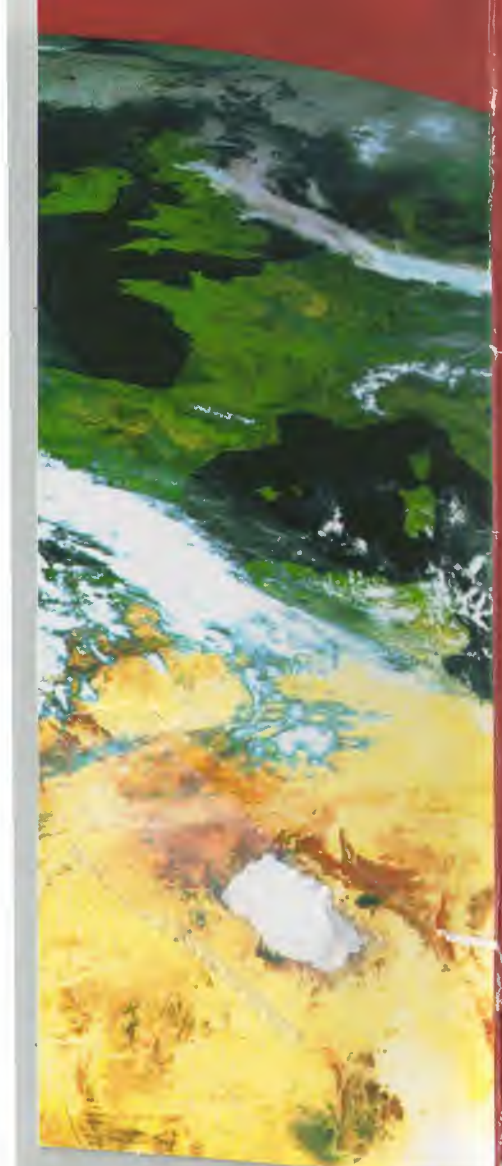

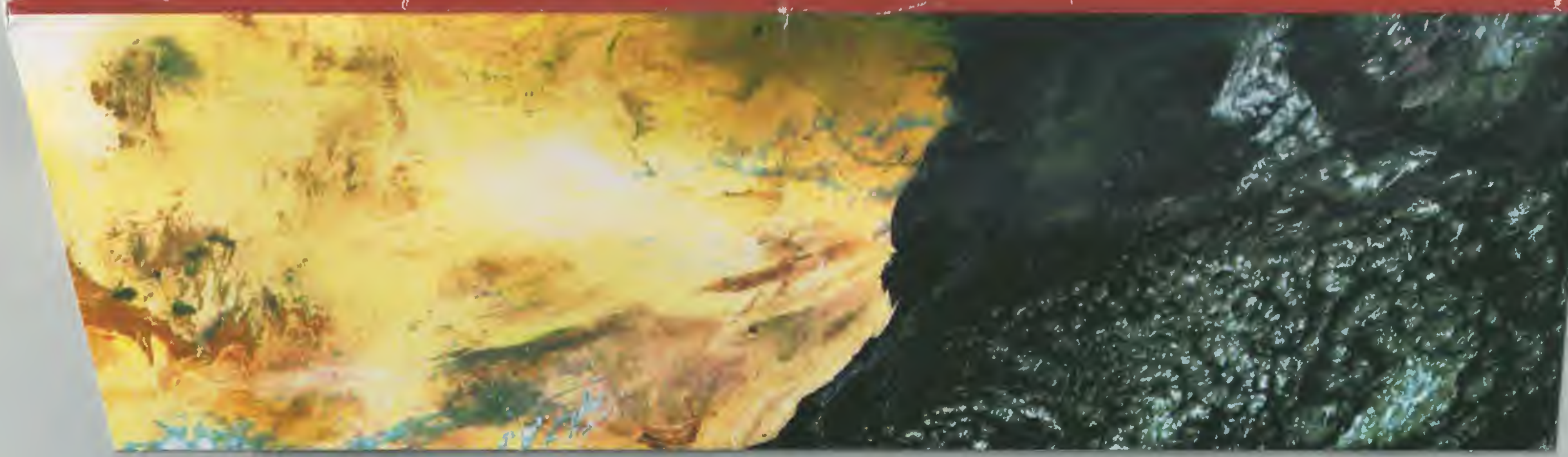

Earth Observation and Remote Sensing

Presentation of the teacher's pack

"Watching over the Earth"

The worksheets in this pack are intended to familiarise pupils between the ages of 11 and 14 with the subject of satellite imagery. Satellite images are of increasing importance in a great many domains and are dramatically changing the way we view the world and perceive physical phenomena. Both literally and figuratively, they add a new dimension to our knowledge, whether it be in the study of natural phenomena or in assisting humans in their various activities. Their use – and understanding – by pupils is one of the aims of this project.

The topics and examples in this pack were chosen to match the content of school curricula, especially in geography, life and Earth sciences and physics. Since this "teacher's pack" has been designed for use in European schools, it deals with topics common to the curricula of the various European countries, although some variations exist concerning the level or age of pupils to which these topics are taught.

The 11 topics combine satellite images, short texts, photographs and illustrations in an effort to provide information of different origins and on different scales.

The pack contains 15 copies of each worksheet so that they can be distributed to pupils in groups of two. Each worksheet comes with a sheet entitled "Information for teachers" that further develops the topic in question, providing additional information on each of the satellite images in the worksheet.

Also provided is a pupils' questionnaire (in black and white), which can be easily photocopied, reworded by the teacher and handed out to pupils. For those teachers who so wish, the questionnaire can be used as part of the lesson.

The worksheets are in colour, in a three panel fold-out (triptych) 63cm x 29.7 cm format. This format was chosen in order to retain the graphical quality (in terms of size, colour and definition) required to observe satellite images properly. These documents, when opened out, contain within their 3 inner pages (pages 2, 3 and 4) "core content" covering the main theme of the worksheet.

Page 5, on the back of the worksheet, examines a particular aspect of the topic in greater detail or provides an example.

The aim of page 6, always entitled "How do satellites work?", is to show how satellite images are obtained: knowledge of this subject is gradually accumulated by working through the 11 worksheets, allowing a general understanding to be gained of the techniques used, the physical phenomena involved and the processes behind the images. In fact, satellite images are not merely photographs taken from a great height which enable us to "see everything".

In reality, each image is designed to meet a precise need by deploying whatever observation methods and techniques are best suited to the objective in question. The specialised instruments on board satellites are thus designed, built and operated in such a way as to provide a suitable representation of the phenomena one wishes to study. Learning how the image was produced is often a first step on the way to clearly understanding certain aspects of the wider topic.

Teachers of physics and chemistry can concentrate primarily on these sections, which cover many of the themes in their curricula.

Certain worksheets, therefore, can be used in a cross-disciplinary approach involving two teachers.
Depending on the subject area and rate at which material is covered, a given class might be given lessons in year 5 or 6 using these worksheets, chosen from among the eleven topics: three or four would be presented by geography teachers and two others by teachers of life and Earth sciences, physics and chemistry. This would allow the same class to have an opportunity to discover all of the available topics over a period of two years.

GETTING TO KNOW ESA

What is ESA?

The European Space Agency is Europe's gateway to space. Since March 2006, ESA has had 17 Member States. By coordinating the financial and intellectual resources of its members, ESA can undertake programmes and activities far beyond the scope of any single European country.

What is ESA's role?

ESA's role is to draw up the European space programme and to see to its implementation. It is also responsible for developing Europe's space capacities and ensuring that the citizens of Europe benefit from investments in space.

The Agency's projects are designed to expand our knowledge of the Earth, its immediate environment in space, the solar system and the Universe, as well as to develop satellite technologies and services and promote European industry.

ESA coordinates its activities with those carried out at national level by the space agencies of its Member States. It also works closely with space organisations from outside Europe to ensure that the achievements of its space programmes are of benefit to mankind as a whole.

Who belongs to ESA?

ESA's 17 Member States are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State and takes part in certain Agency programmes. The Czech Republic, Hungary and Romania have the status of European Cooperating States (ECS).

ESA is an international organisation independent from the European Union, which nonetheless maintains close links with the EU through a framework agreement between the two organisations. ESA and the EU share a joint European strategy for space and together are developing the European Space Policy.

Where is ESA?

ESA has its headquarters in Paris and it is there that the ESA Council meets to take decisions on its policies and programmes. However, ESA also has centres in Europe, each with separate well-defined responsibilities.

* ESTEC, the European Space Research and Technology Centre, is where most ESA spacecraft are designed and tested. It is also where its space technology programmes are drawn up and developed. It is located in Noordwijk in the Netherlands.

* ESOC, the European Space Operations Centre, is responsible for the in-orbit command and control of ESA satellites. It is located in Darmstadt, Germany.

* EAC, the European Astronauts Centre, is responsible for the training of ESA astronauts for their future missions and is located in Cologne, Germany

* ESRIN, the European Space Research Institute, is based in Frascati, near Rome, Italy. Its responsibilities include gathering, storing and distributing satellite data to ESA's partners. It is also where the future European launcher, Vega, is undergoing development and is responsible for the Agency's information technology activities.

* ESAC, the European Space Astronomy Centre, is responsible for programming the astronomical observation instruments on board ESA scientific missions and archiving the corresponding data. It is located in Villafranca del Castillo, Spain.

In addition, ESA has liaison offices in Brussels, Washington and Moscow, while Kourou, French Guiana, is home to "Europe's spaceport", the CSG (Guiana Space Centre).
In various parts of the world ESA also has ground stations, satellite tracking stations and a number of offices dealing with European space activities in the fields of science and human spaceflight.

How many people work for ESA?

At the beginning of 2007, ESA employed 1900 specialists in space activities. Its highly qualified staff are drawn from all of the Member States and include scientists, engineers, IT specialists, administrative and legal personnel, and not forgetting the members of the "European Astronaut Corps".

How is ESA funded?

ESA's mandatory activities (Scientific Programme and General Budget) are funded by the contributions received from all the Member States. These are calculated on the basis of each country's gross national product. ESA also carries out optional programmes. Each country decides on those optional programmes in which it wants to take part and how much it wishes to contribute in each case.

How big is the ESA budget?

The budget for 2007 is 2975 million. The Agency operates on the basis of "geographical return". This means that in each Member State it invests, through contracts allocated to that country's firms to conduct space activities, an amount more or less equivalent to the country's contribution.

How much does each European spend on ESA?

Per capita, European investment in space activities is very low. To fund space programmes, every national of an ESA Member State pays in tax on average roughly the equivalent of the cost of a cinema ticket. In the United States, investment in civil space activities is almost four times as high.

How does ESA operate?

The European Space Agency has nine Directorates, five of which are Programme Directorates covering the following areas: Science; Launchers; Human Spaceflight, Microgravity and Exploration; Earth Observation; Telecommunications and Navigation.

The ESA Council is the Agency's governing body and provides the basic policy guidelines according to which the Agency develops the European space programme. Each Member State is represented on the Council and has one vote, regardless of its size or financial contribution.

Every four years, the Council elects a Director General to head the Agency. Jean-Jacques Dordain, ESA's current Director General, was appointed in 2003.

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Summary

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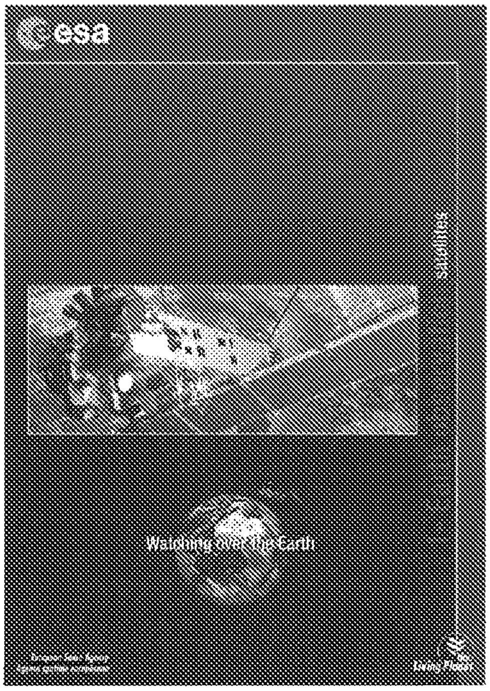
Production	Europimages - Aliette Cremer

Information for teachers

The "Information for teachers" sheets are designed to offer assistance with the preparation of classes and complement the worksheets handed out to pupils. They contain useful information for the presentation of the subject, additional information relating to the satellite images, and a list of websites dealing with the subjects concerned.

Worksheet 1: Earth observation satellites



Worksheet 1 is an introduction to the main types of Earth observation satellites and the two main types of orbits: geostationary and polar. This worksheet is the first in the series, and explains some key information regarding Earth observation by satellite. It can be used as a supplement to the part of your teaching programme dealing with the Solar System and learning about the Earth.

This worksheet can be used to:
- present the concept of Earth observation;
- help understand distances in space (illustration in the worksheet inner pages shows satellite positions true to distance scales);
- discuss the variety of uses and data provided by satellites.

Satellite orbits

The movement of satellites around the Earth is one of the consequences of gravitation. The process of putting a satellite into orbit is subject to the fundamental laws of physics. The flight trajectory depends on the initial speed of the satellite: if the speed is too slow, the satellite falls back to Earth following a parabolic path; if the speed is too high, reaching approximately 11 km per second (escape velocity), the vehicle (a space probe for example) leaves the Earth's orbit and continues indefinitely towards outer space. In order for it to travel in a circular trajectory at an altitude of 800 km, the initial speed needs to be approximately 7.5 km per second.

A satellite can stay in the same orbit for a long time, as long as the Earth's gravitational pull counteracts the centrifugal force. Since satellites travel in orbit outside the Earth's atmosphere, they are not affected by air resistance so their speed remains constant. This results in a stable orbit with the satellite circling the Earth for many years. The satellite travels around the Earth using solely the Earth's gravitational force. The propellant reserves on board are only used to make small adjustments to the trajectory or the altitude.

Gravitational pull decreases as the vehicle travels further away from the Earth, while the centrifugal force grows with orbital speed. A satellite in low orbit is under the influence of immensely powerful gravitational pull and must therefore travel at great speed in order to generate sufficient centrifugal force to counteract gravitation. As a result, there is a direct link between the distance to the Earth and the satellite's orbital speed.

At a distance of 36,000 km from the Earth, the satellite takes 24 hours to complete the orbit, which is the same amount of time the Earth takes to turn on its own axis. At this distance, a satellite positioned above the Equator will remain stationary with respect to the Earth. Telecommunication and weather satellites use "geostationary" orbits. Three geostationary satellites, spaced out at 120°, cover the entire surface of the Earth.
Satellites in "polar" orbits fly above the poles at an altitude of 700 and 800 km and are able to observe the entire surface of the Earth in just a few days.

The satellite images

Cover page

Cover image: Artist's impression of the Envisat satellite

On 1st March 2002, the European Space Agency launched Envisat. It is an Earth observation satellite placed in a polar orbit to provide measurements of the atmosphere, oceans, land mass and ice. Data from Envisat is used to conduct scientific research into the Earth and to monitor changes to the environment and climate.

Core content

View of the Earth showing the Americas. This shows Meteosat's true position in relation to the Earth. Thus, the European geostationary satellite Meteosat – positioned directly above the Gulf of Guinea – can be seen in this image to the right of the globe. An observer in space "seeing" Meteosat in that position would necessarily be above the American continent.

Image 1: The Earth

This image of the western hemisphere was produced by combining data from several Earth observation instruments. The data on cloud mass comes from GOES (Geostationary Operational Environmental Satellite), which belongs to NOAA (National Oceanic and Atmospheric Administration). The data on the oceans comes from NOAA's SeaWiFS (Sea-viewing Wide Field-of-view Sensor) satellite, while that on vegetation is from POES (Polar Orbiting Environmental Satellite). Shown here, near the west coast of the United States, is Tropical Cyclone Linda (9 September 1997).

Images 2, 3, 4: Argentina - Rio de la Plata estuary - Buenos Aires (Envisat, 2004)

The city of Buenos Aires (12 million inhabitants) is located on the Rio de la Plata estuary, which forms the border between Argentina and Uruguay. Montevideo (1.3 million inhabitants), the capital of Uruguay, is located at the northern mouth of the estuary. Each year the currents of the Rio de la Plata carry 57 million cubic metres of sediment, notably from its principal tributaries, the Paraná and Uruguay rivers. The mouth of the estuary is 219 km wide.

Images 5, 6, 7: The Earth as seen by Meteosat

Solar rays striking the Earth can be absorbed or reflected as well as being visible to the human eye or a satellite. The albedo value of a surface indicates the percentage of solar light reflected.

Thus Meteosat satellites measure, in the visible and near infrared, the different albedo values of the surfaces observed. Clouds, snow and ice, which reflect light strongly, appear light grey. Dry, barren surfaces are also shown in light colours, while vegetation-covered regions have a slightly lower albedo and appear darker. Water surfaces have a very low albedo and are represented in very dark tones.

From all of these measurements it is possible to create black and white images which can then be processed to produce colour images of the globe (see centre image). Depending on which channels are used, it is also possible to produce images which reveal variations in temperature on the Earth's surface (see right-hand image).

The Meteosat satellite spins rapidly around its axis, which is parallel to that of the Earth, and performs 100 revolutions per minute. With each rotation it scans a 5-km wide strip (or swath) from east to west. The scanograph mirror is adjusted so as to allow a new swath to be scanned with each rotation, thus providing a complete image.

MSG (Meteosat Second Generation) generates multispectral images of the Earth's surface and cloud systems every 15 minutes by covering 12 channels of the spectrum. MSG's spatial resolution has also been improved compared to previous Meteosat satellites (1 km for the visible high-resolution channel and 3 km for the others). Eight of these channels are located in the thermal infrared range and provide – in addition to other information – permanent data on cloud, land and sea surface temperatures. By using channels that absorb ozone, water vapour and carbon dioxide, MSG also enables meteorologists to analyse the characteristics of air masses, thus constituting 3D views of the atmosphere.

Page 5 - Views of Europe and Buenos Aires

Image 8: Europe as seen by the Envisat satellite

Dozens of images, taken during part of 2004, were required to produce this view of Europe without cloud cover. This image was produced by the MERIS (Medium Resolution Imaging Spectrometer) instrument on board Envisat.

Images 9, 10, 11: View of Buenos Aires taken by the SPOT 5 satellite

The new HRG (High Resolution Geometric) telescopes on SPOT 5 record high-resolution images of the Earth: 10 m in colour and 2.5-5 m in black and white (a single image with a resolution of 2.5 m covering 60 km^2 on the ground represents 576 MB). It has a 60-km wide field of view.

These images of Buenos Aires complement the images of the Rio de la Plata region produced by the Envisat satellite and presented in the worksheet core content.

Page 6 – "How do satellites work?"
Image 12: Artist's view of the Envisat satellite
Envisat performs a full cycle every 35 days, before going on to trace exactly the same course again and again. By the end of this 35-day period, the satellite has described a certain number of orbits, while in that same time, the Earth has performed the same number of revolutions. Envisat's orbit is also heliosynchronous (or sun-synchronous), meaning that it flies over a given point on the Earth's surface at the same local solar time. Since the conditions for capturing images are virtually identical (except for seasonal variations), the information thus provided can be rigorously compared.

Image 13: The satellite and its principal instruments
Its data is gathered by 10 complementary instruments:

MERIS stands for Medium Resolution Imaging Spectrometer (300 m). It records 15 spectral bands in the visible and near infrared. One of its main tasks is to measure the colour of the water in the oceans in order to calculate the chlorophyll concentration contained within. This data is essential to the study of the oceanic carbon cycle.

ASAR (Advanced Synthetic Aperture Radar) uses radar signals to map land surfaces, the profile of waves and ice at sea or on land, to monitor land use and vegetation types and to measure certain surface properties.

GOMOS stands for Global Ozone Monitoring by Occultation of Stars. It carries out very precise measurements of the ozone in the stratosphere as well as the profile of the trace gases in the upper troposphere and mesosphere.

GOME stands for Global Ozone Monitoring Experiment. This instrument explores the solar radiation emitted by reflection from the Earth's surface vertical to the Earth (nadir mode).

SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) is the principal atmospheric sensor onboard Envisat. It uses several measuring modes. Its data can teach us about the distribution of gases in three dimensions in the troposphere and lower stratosphere.

MIPAS (Michelson Interferometer for Passive Atmospheric Sounding). This interferometer is used to measure gas emissions in the mid infrared. Its data can notably be used to determine the composition of gas emissions from industry.

AATSR (Advanced Along Track Scanning Radiometer). This instrument scans the surface of the land and oceans to measure sea temperature. It detects the "hot-spots" in forest fires and maps the extent of vegetation in different regions.

DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) is a satellite radio system used to continuously calculate the satellite's position in orbit. This position is obtained to within a few centimetres using signals emitted by more than 50 ground beacons disseminated all around the globe.

RA-2 and **MWR** The RA-2 radar altimeter measures to within one nanosecond the time it takes for a signal to return and calculates its distance from the Earth accurate to within 4 centimetres. MWR is a microwave radiometer that measures the amount of water vapour in the atmosphere and is able to correct RA-2's signals to improve its accuracy.

LRR is a Laser Retro-Reflector system used to calibrate DORIS and RA-2.

Envisat is constantly scanning the Earth's surface and atmosphere. For two-thirds of its orbit it flies over the oceans. It is the moving mass of these oceans, the complexity of the thermal exchanges which bring them to life or which they conduct with the atmosphere that make them a major influence on the behaviour and evolution of the Earth's climate.

These three images demonstrate the variety of instruments carried on board Envisat:
Image 14: The English Channel to the north of Brittany (Envisat/MERIS)
Of particular interest in this image is the bloom (rapid development of phytoplankton) visible off the coast of Brittany and spread over a distance of 400 km.

Image 15: Image of an oil slick (Envisat/ASAR image, Nov. 2002)
The oil escaping from the tanks of the Prestige is close to the Galician coast. Radar images such as this show relief: the areas where the oil is concentrated are smoother than the sea surface and send back a weaker signal, which shows up as black in the image.

Image 16: NO_2 emissions in Europe (Envisat/SCIAMACHY)
This image, taken by the Heidelberg institute for environmental physics (IUP) was constructed from measurements taken by the SCIAMACHY instrument. This instrument records the spectrum of sunlight shining through the atmosphere. Very little data on such pollution is gathered by ground-based sensors; only sensors located in space are able to perform effective global monitoring.

About the kit and DVD

The worksheets, of which 15 copies are available, are to be distributed to pupils in pairs. The teacher, depending on the time available, can organise the lesson mainly around the worksheet's core content (inside 3-page spread) or, alternatively, make use of the information contained on the rear pages of the documents (page 5 and 6)

The DVD-ROM contains the principal satellite images shown in the worksheets. They can be projected onto a screen or displayed on a computer to complement the presentation of the subject by the teacher or to help with the correction of questionnaires.

The images corresponding to each subject can be accessed easily: it is possible to access the complete document and, with a simple mouse click, display the selected satellite image in full screen mode. Lastly, there are several screens which present, in word form, the main ideas contained in the document.

This DVD-ROM contains a form in PDF format entitled "Pupil questionnaire", which can be printed out and distributed to pupils. Lastly, there is a version of the questionnaire in Word format, which allows the teacher to adapt it to the needs of his/her lesson.

Online resources

www.esa.int	ESA (European Space Agency) website
www.esa.int/SPECIALS/ESRIN_SITE/index.html	ESRIN (European Space Research Institute) website ESRIN is ESA's centre for Earth observation
www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

ORBITOGRAPHY

www.eduspace.esa.int/subtopic/default.asp?document=297&language=en	EDUSPACE site principles of remote sensing/satellite orbits
www.bnsc.gov.uk/content.aspx?nid=5956	BNSC (British National Space Centre) website: different types of orbit
www.cnes.fr/web/5004-geostationary-orbit.php	Geostationary orbit and space debris issues
www.satcom.co.uk/article.asp?article=11	Geostationary, LEO, MEO and elliptical orbits
www.cnes.fr/web/1094-how-orbital-manoeuvres-work.php	Orbital manoeuvres
www.eoportal.org/orbits	Tracking the orbits of Earth observation satellites

ENVISAT

envisat.esa.int	Information on the Envisat satellite
www.esa.int/esaEO/SEMWYN2VQUD_index_0_m.html	Envisat overview
www.esa.int/esaEO/ESAXU0MBAMC_index_0.html	All about Envisat, including Envisat-related news
www.esa.int/envisat/instruments.html	Instruments onboard Envisat

METEOSAT

www.eumetsat.int	European organisation responsible for the exploitation of meteorological satellites
www.cnes.fr/web/1446-meteosatmsg.php	Europe's weather observation satellites
www.metoffice.gov.uk	Met Office website

Satellite images

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Worksheet N° 1 – Earth observation satellites

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – What are the main functions of remote sensing satellites? Give two examples of remote sensing satellites.

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....

2 – What is the altitude of a satellite in a polar orbit? Why do we call this type of orbit "polar"?

....

....

....

3 – What is the altitude of a satellite in a geostationary orbit? Why do we call this type of orbit "geostationary"?

....

....

....

4 – What can you see on the three images taken by the Envisat satellite?

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5 – Which continents or parts of continents can be seen from the 3 images taken by the Meteosat satellite?

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6 – What is the main purpose of satellites in geostationary orbit?

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....

7 – Describe the details you observe in the three images of Buenos Aires. Which satellite took these images?

....

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8 – Give three examples of the kind of missions that the instruments on-board the Envisat satellite would be able to carry out.

....

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Regardless of whether its field of view is broad or narrow, or whether it watches over a whole continent or focuses on the heart of a city, each satellite provides its own specific set of useful information.

VIEW OF EUROPE FROM THE ENVISAT SATELLITE

8

This image taken by Envisat shows the principal relief and variations in vegetation cover across continental Europe.

VIEW OF BUENOS AIRES FROM THE SPOT 5 SATELLITE

9

10

11

These images of Buenos Aires taken by the SPOT 5 satellite show precise details to within a few metres.

How do satellites work?

The example of Envisat

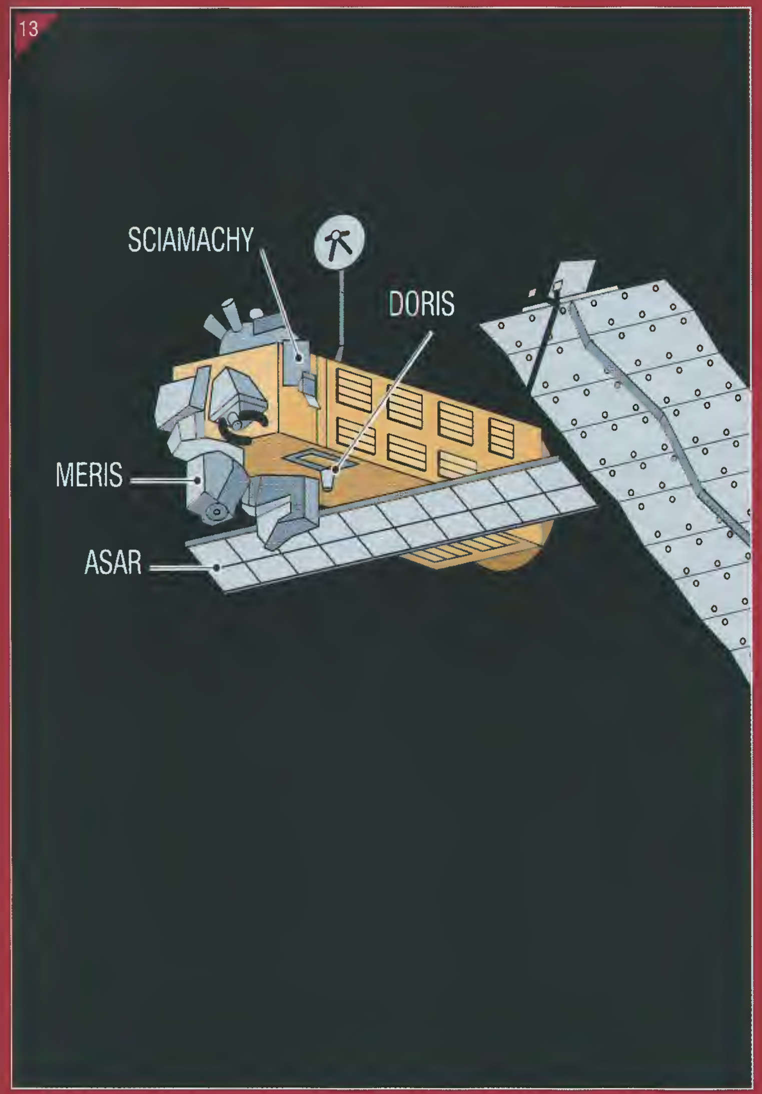
12

Envisat is a very large satellite. It has a mass of 8,200 kg, of which 2,050 kg is accounted for by its instruments, with dimensions – excluding solar panels – of 10m x 4m x 4m, making it roughly the size of a large truck.

It carries ten scientific instruments on board, all used to gather specific information and each with a specific name (for example MERIS, ASAR, SCIAMACHY). The measurements from these instruments are used to produce images or graphs in a form suited to whichever phenomena are being studied.

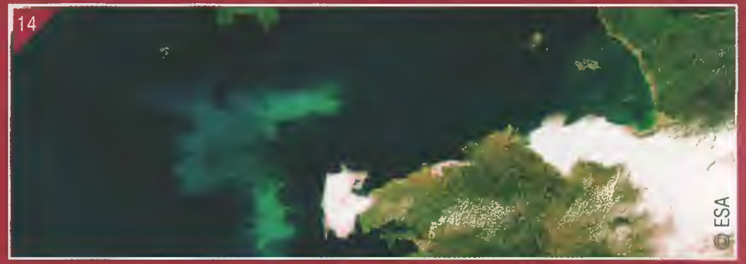
Some Envisat instruments

13



Envisat is made up of 10 instruments. Some capture images in the visible light range or using radar. Others, such as DORIS, are designed to produce altimetry measurements and control the satellite's positioning.

14

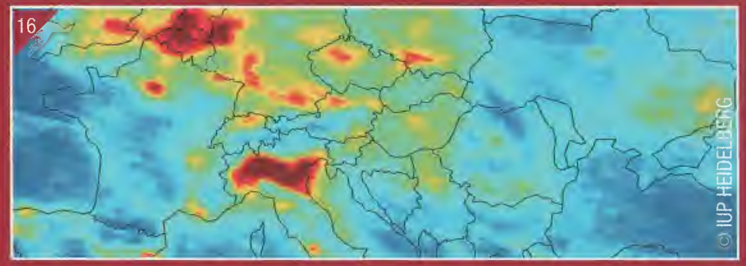


MERIS takes pictures by day of oceans and land mass. It also measures chlorophyll concentration in the sea or water vapour in the atmosphere.
Bloom off the coast of Brittany (15.06.03).

15

ASAR is a radar instrument that maps the surface of the land, ice and oceans and measures certain variations in them. It provides invaluable data on land use and land characteristics.
Spill from the tanker "Prestige" off the Spanish coast (17.10.02).

16



SCIAMACHY measures traces of gas, clouds and dust particles. It helps provide a better understanding of the consequences of industrial pollution, volcanic eruptions and forest fires.
NO_2 concentration in the atmosphere in Europe (2003 / 2004).

esa

1- Earth observation satellites

Watching over the Earth

European Space Agency
Agence spatiale européenne

the Living Planet

There are several types of satellite: remote-sensing satellites such as Envisat and Meteosat, used to observe our planet's surface and atmosphere, while other types are used for telecommunications or navigation (GPS, Galileo). Not all remote-sensing satellites occupy the same kinds of position in space. Their trajectories and distance from the Earth can vary. The picture below shows the positions and orbits of two different satellites – Envisat and Meteosat – in relation to the Earth.

POLAR ORBITS

These are circular orbits performed at low altitude. For example, the European Space Agency's Envisat satellite orbits the Earth at an altitude of about 800 km. With each pass, such observation satellites fly over a narrow zone (in the tens or hundreds of kilometres), thus allowing them, depending on the instruments on board, to obtain very detailed images.

In a 24-hour period, such satellites orbit the Earth several times, passing over the poles as they do so. The plane of their orbit has a set direction in space but because the Earth turns around its own axis, with each pass they fly over a different area.

Among their many applications they are used to produce very accurate geographical maps or to monitor variations in vegetation cover according to the season. They also help to locate and analyse clouds of atmospheric pollution or pollutant spills at sea.

Example of a polar orbit: the Envisat satellite

Images from a satellite like Envisat can provide very detailed information. Here for example, zooming in on Argentina's Atlantic coast, we can clearly see the Rio de la Plata estuary, with Buenos Aires also visible in grey.

Example of a geostationary orbit: the Meteosat satellite

Geostationary satellites are very far from the Earth compared to satellites in low-Earth orbit. They therefore provide images with a very wide field of view but relatively lacking in detail. While the images obtained are in black and white, subsequent conversion into colour brings out different kinds of information such as variations in temperature or the location of cloud masses.

GEOSTATIONARY ORBITS

These are circular orbits located precisely in the equatorial plane and performed at altitudes of around 36,000 km. Such satellites' movements mimic the rotation of the Earth so that they can remain constantly above the same region. This "geostationary" positioning is vital if they are to observe changes in meteorological phenomena and monitor the movement of cloud masses.
In addition, they remain in constant direct contact with receiving stations on the ground so as to be able to transmit their data.

It is Europe's Meteosat satellites that supply the images we are used to seeing in TV weather forecasts. Most of the Meteosat satellites are stationed at 0° longitude (above the Gulf of Guinea) and thus are able to cover both Europe and Africa.

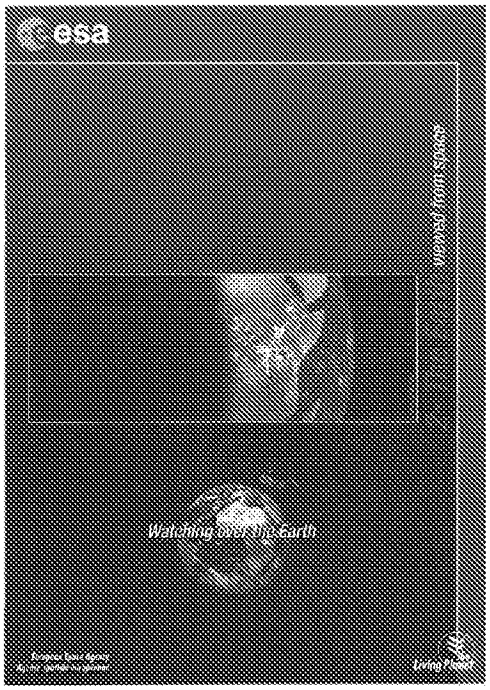
?!

Remote sensing refers to the observation of an object from a distance without coming into physical contact with it. This is what satellites which observe the Earth from a distance do. Remote sensing has become a science in its own right, the main aim of which is to discover and observe what is happening on the Earth's surface.

Information for teachers

The "Information for teachers" sheets are designed to offer assistance with the preparation of classes and complement the worksheets handed out to pupils. They contain useful information for the presentation of the subject, additional information relating to the satellite images, and a list of websites dealing with the subjects concerned.

Worksheet 2: The Earth viewed from space



Worksheet 2 focuses on the geographical aspects of the globe.

This worksheet can be used to:
- locate and identify the planet's continental masses and ocean basins;
- familiarise pupils with vocabulary specific to fundamental concepts in geography (poles, tropics, Equator, atmosphere, etc.);
- discuss the effects of the Earth's rotation and revolution;
- apply concepts such as longitude, latitude, radiation, etc.

The Earth

The Earth is one of nine planets in the solar system. It is not perfectly round: its diameter at the poles is slightly less than its diameter at the Equator (the imaginary line separating the Earth into two identical hemispheres). The Earth differs from the other planets in that it has surface water, life, and human societies. The surface of the Earth, nicknamed the "blue planet", is 71% seas and oceans, and 29% continents.

The Earth is constantly going through two types of motion: rotation and revolution. The term rotation refers to the Earth's spinning from west to east around an axis that goes through the two poles. This axis is inclined at 23°27′ with respect to the vertical axis. The term revolution refers to the Earth's orbit around the Sun, which it completes in 365.25 days. As a result of these two simultaneous motions we have the alternation of day and night and of the seasons (more or less distinctive depending on how close one is to the poles), respectively.

The Earth's surface is divided by lines of latitude (imaginary lines drawn parallel to the Equator, also known as "parallels") and lines of longitude (imaginary lines drawn from the North to the South Pole, also known as "meridians"). Latitude describes the angular distance of a point on the Earth's surface from the Equator. Longitude is used to describe the angular distance of a point on the Earth's surface from the Prime Meridian—at Greenwich in London. Every point on Earth is at the intersection of these two measurements, so maps use latitude and longitude as cartographic coordinates on the Earth's surface. The Tropic of Cancer in the northern hemisphere and the Tropic of Capricorn in the southern hemisphere delimitate the zone between the tropics—the only part of the globe where solar rays can be perpendicular to the Earth's surface. The planet's bioclimatic zones also change as one moves away from the Equator and towards the poles.

People around the world do not have the same time of day on their watches. Instead the planet's surface has been divided into 24 time zones.

Gaseous masses which envelop the Earth make up the atmosphere. Processes in the atmosphere contribute to the different climates present on Earth and the way these are distributed. They have had major implications for human societies.

The satellite images

Cover page

Cover image: Crescent Earth (image by Meteosat)
With respect to satellite images, it is useful to point out those characteristics specific to geostationary satellites.
Geostationary satellites, located almost 36,000 km from the Earth in the equatorial plane, are able to produce complete views of the planet. This is because, at that altitude, they revolve at the same speed as the Earth and thus remain stationary relative to locations on the Earth's surface.

Other observation satellites, typically at an average altitude of about 800 km, and in polar orbit, provide only partial views which have to be reassembled (as with a mosaic) to reconstitute a complete view of the globe.

Core content

Image 1: Two geostationary views of the Earth
The left-hand page shows two geostationary views, one by US satellite GOES 8 (Geostationary Operational Environmental Satellite 8), located 75° west and the other by Japan's GMS (Geostationary Meteorological Satellite), located 140° east. With these two views, the whole surface of the Earth can be kept under constant observation. They show the true extent of the oceanic masses and are essential to the monitoring of meteorological phenomena. In total, there are 9 meteorological satellites in geostationary orbit around the Earth: GOES W and GOES E (USA), Meteosat-7 and Meteosat-8 (Europe), GOMS (Russia), Insat (India), FY-1 and FY-2 (China) and GMS (Japan).

Image 3: The globe
This image was produced by the Meteosat satellite, located at 0° longitude above the Gulf of Guinea. Due to this location, this satellite always observes the same side of the globe and in particular the European and African continents. This image was taken early in the morning when it was still night-time over the Atlantic. A few hours later, as the Earth continues its rotation, it turns the Greenwich meridian to face the Sun. At midday, therefore, the geostationary satellite will be able to show a view of the Earth entirely bathed in sunlight.

Images 4 and 6: The northern hemisphere in winter and in summer
On the right-hand panel of the worksheet core content are two partial views of the northern hemisphere (one in winter and one in summer). One can notably see Canada and Greenland in the first and Siberia in the second. This serves to highlight seasonal differences in the lighting of the Pole by the Sun.

Page 5 - The Earth's Poles

Image 7: Radar image of the Antarctic
The Poles are usually covered in cloud and remain in darkness for 6 months of the year, so it is mainly radar instruments which are used to record this data. They accurately reproduce relief and ice cover, as can be seen in this image of the Antarctic from the Canadian satellite, Radarsat.

Images 8 and 9: The northern and southern hemispheres seen from vertically above the poles
Geostationary satellites cannot provide satisfactory observation of the Earth's Poles. Satellites in polar orbit, on the other hand, which provide a large number of partial images of the Earth's surface, bridge that gap. Thus, by assembling several images it is possible to reconstitute views of the Earth as it appears from above the North or South Pole.

These unusual views provide another perspective on the Earth, highlighting for example the extent of the oceanic mass in the southern hemisphere, the relatively size of the Antarctic or the geographical proximity of Siberia and Alaska.

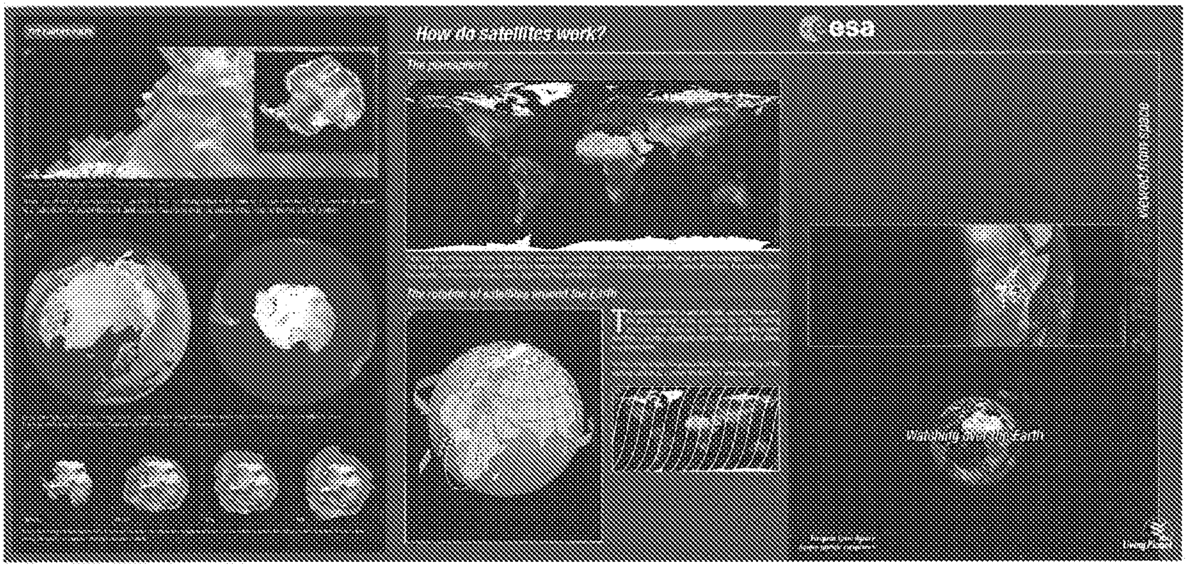
Image 10: Annual evolution of ice cover in the Antarctic
Likewise, the data gathered by the European satellites ERS and Envisat are used to reconstitute changes to sea ice around the Antarctic. Such precise and regular observations provide essential information, notably for the study of long-term climate change.

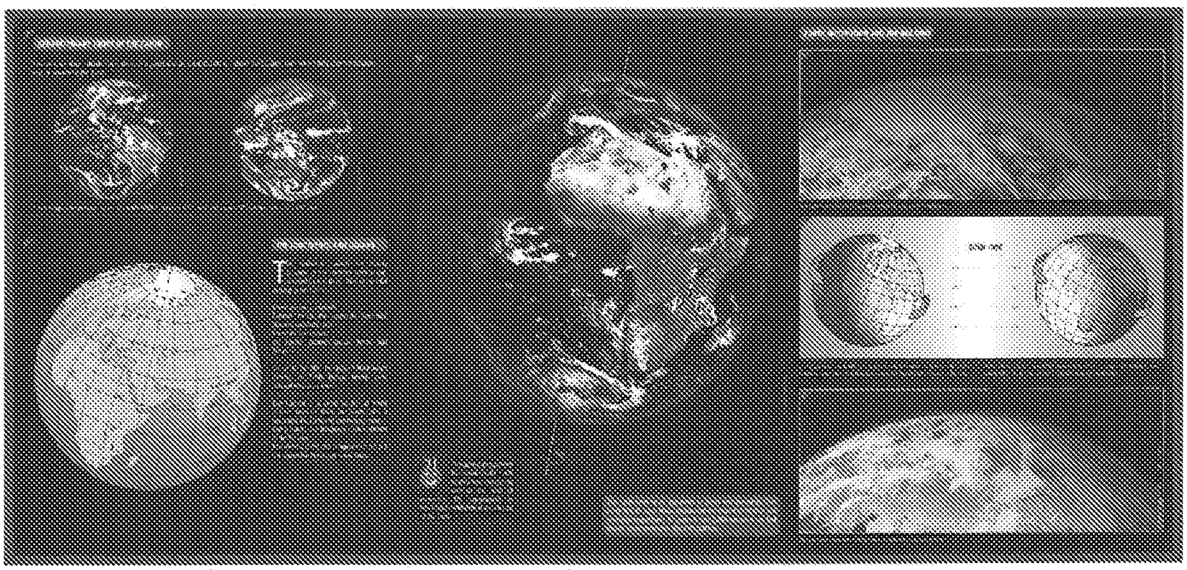
Page 6 – "How do satellites work?"

Images 11 and 13: Earth planisphere (Envisat - MERIS)

Satellites in polar orbit are able to produce views of the Earth as a planisphere. These satellites perform 14 rotations of the Earth each day, recording a continuous swath as they go. Taking advantage of the Earth's rotation, they can thus map the entire planet in 2 or 3 days.

The Envisat image shown here is reconstituted from images selected to eliminate cloudy periods. This view is a composite made up of partial images taken over a 1-month period. Oceans, which are covered by substantial masses of cloud, were not taken into account, and are thus shown here in black.





About the kit and DVD

The worksheets, of which 15 copies are available, are to be distributed to pupils in pairs. The teacher, depending on the time available, can organise the lesson mainly around the worksheet's core content (inside 3-page spread) or, alternatively, make use of the information contained on the rear pages of the documents (page 5 and 6).

The DVD-ROM contains the principal satellite images shown in the worksheets. They can be projected onto a screen or displayed on a computer to complement the presentation of the subject by the teacher or to help with the correction of questionnaires.

The images corresponding to each subject can be accessed easily: it is possible to access the complete document and, with a simple mouse click, display the selected satellite image in full screen mode. Lastly, there are several screens which present, in word form, the main ideas contained in the document.

This DVD-ROM contains a form in PDF format entitled Pupil questionnaire, which can be printed out and distributed to pupils. Lastly, there is a version of the questionnaire in Word format, which allows the teacher to adapt it to the needs of his/her lesson.

Online resources

www.esa.int	ESA (European Space Agency) website
www.esa.int/SPECIALS/ESRIN_SITE/index.html	ESRIN (European Space Research Institute) website ESRIN is ESA's centre for Earth observation
www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

GEODESIC SYSTEMS AND THE SEASONS

www.eduspace.esa.int/Background/default.asp?document=504&language=en	Climate and the seasons

PRESENTATION OF THE EARTH

www.cnes.fr/web/1116-earth.php	CNES "pocket guide" to the Earth
www.edumedia-sciences.com/m132_l2-the-earth.html	eduMedia resources – the Earth pedagogical resources / Presentation of the Earth

THE ANTARCTIC

www.space.gc.ca/asc/eng/default.asp	Website of the Canadian Space Agency
www.space.gc.ca/asc/eng/satellites/radarsat1/antarctic.asp	Antarctic Mapping Mission (AMM)
www.space.gc.ca/asc/eng/satellites/radarsat1/antarctic_csa.asp	The Antarctic as seen by Radarsat

Satellite images

esa SPOT IMAGE NASA EUMETSAT

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Editorial concept	Frédéric Létang / Patrice Desenne
Original text/project oversight	Frédéric Létang
Scientific advisors (ESA)	Isabelle Duvaux Béchon / Laurence Ghaye
Pedagogical advisors	Éric Janin / Jean Jandaly
Documentation	Valérie Massignon - XYZèbre
Graphics	Boris Uzan
Illustrations	Philippe Bouillon - Illustratek
Translations (ESA)	Colin McKinney / Anthony Blend
Production	Europimages - Aliette Cremer

Worksheet N° 2 – The Earth viewed from space

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – Name the continents and oceans covering the surface of the Earth? What proportion of the surface of the Earth is covered by the oceans?

....

....

....

2 – Name the different imaginary lines used by humans to orient themselves on the Earth's surface.

....

....

....

3 – Which continent is fully visible on the large satellite image in the middle of the worksheet? Which European countries can you identify?

....

....

....

4 – The left side of the Earth is in the dark; it is night time. Is it morning or afternoon on the part of the globe being illuminated by the Sun?

....

....

....

5 – What pole stays in the sunlight throughout the winter? Why?

....

....

....

6 – On the page entitled "The Earth's Poles", what is being shown in the two images in the centre? What difference do you see between the satellite image on the right and the image on the left?

....

....

....

....

7 – What do you call a map showing the entire surface of the globe on a single plane?

....

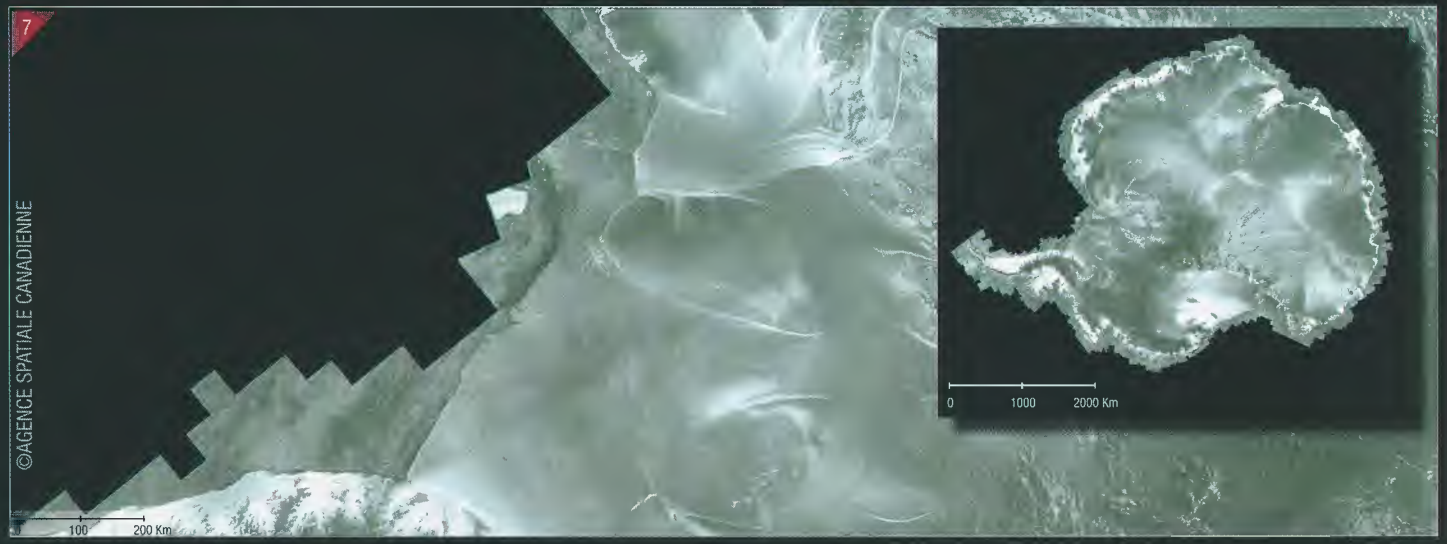
....

8 – How many times does a low orbit satellite circle the Earth in a day?

....

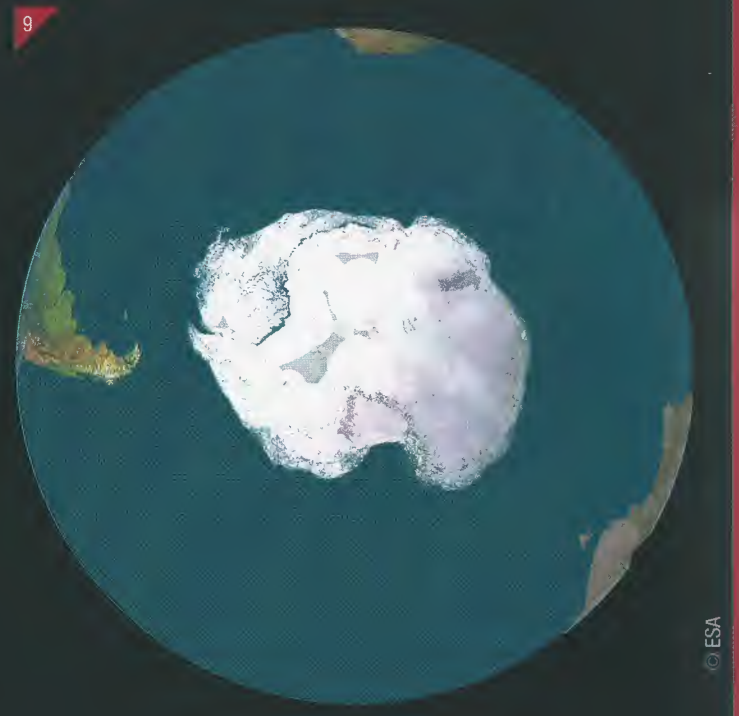
....

THE EARTH'S POLES



Radar image of the Antarctic taken by the Canadian satellite, Radarsat

Radar can be used to distinguish relief. However, it does not display colour in the same way as we perceive it. The framed image above is a "composite" of several thousand small images. Combining them has produced this image of the Antarctic as a whole.



Views of the northern and southern hemispheres reconstituted from an image mosaic taken by the Envisat satellite. Colour has been artificially added. This is an unusual representation of the Earth since we normally see it from the equatorial plane.

These four images taken by the ERS-1 satellite show the formation and evolution of sea ice in the Antarctic during the austral (southern) winter. Sea ice takes nearly six months to form and reach its maximum extent.

How do satellites work?

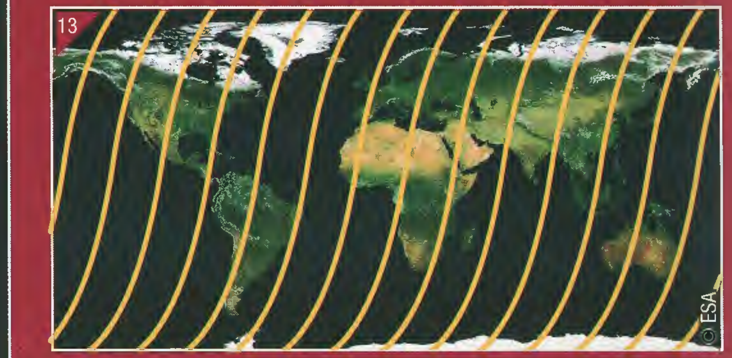
The planisphere

Planet Earth is not always shown in the form of a sphere. It can also be represented as a flattened image as in this planisphere. That way it is possible to see both of the Earth's hemispheres on just one map. This technique leads to certain distortions. For example, here the Antarctic and Greenland appear much larger than they actually are.

The rotation of satellites around the Earth

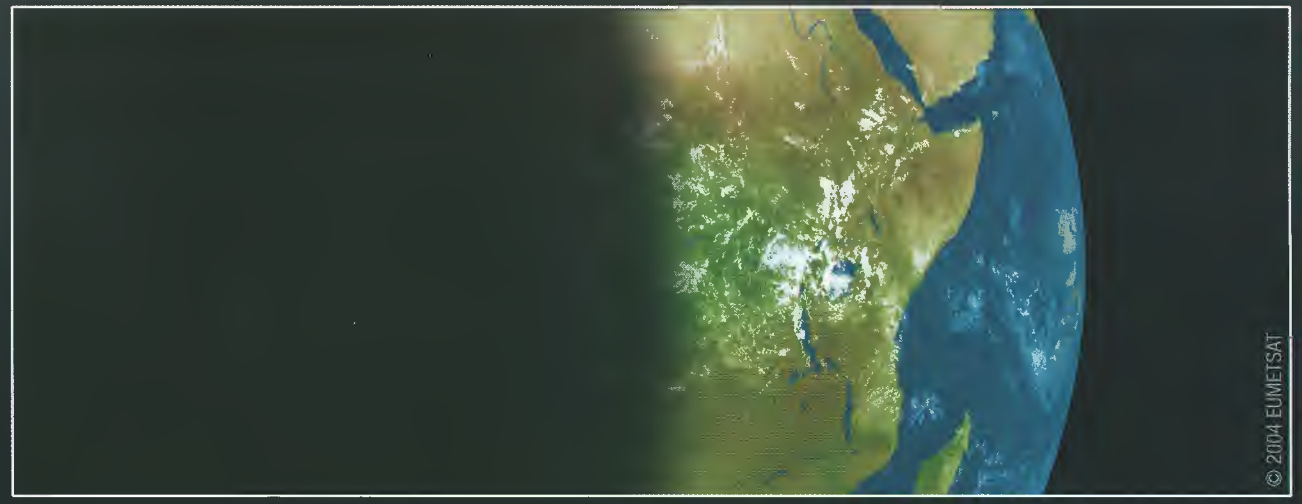
The satellite revolves around the Earth, passing almost over the poles. However, at the same time the Earth is turning around its axis. Therefore, the areas the satellite passes over form a slightly curved path over the Earth when it is shown as a planisphere.

On the image below, the yellow lines show the trajectory of the orbiting satellite as it circles the Earth 14 times a day.



esa

2- The Earth viewed from space



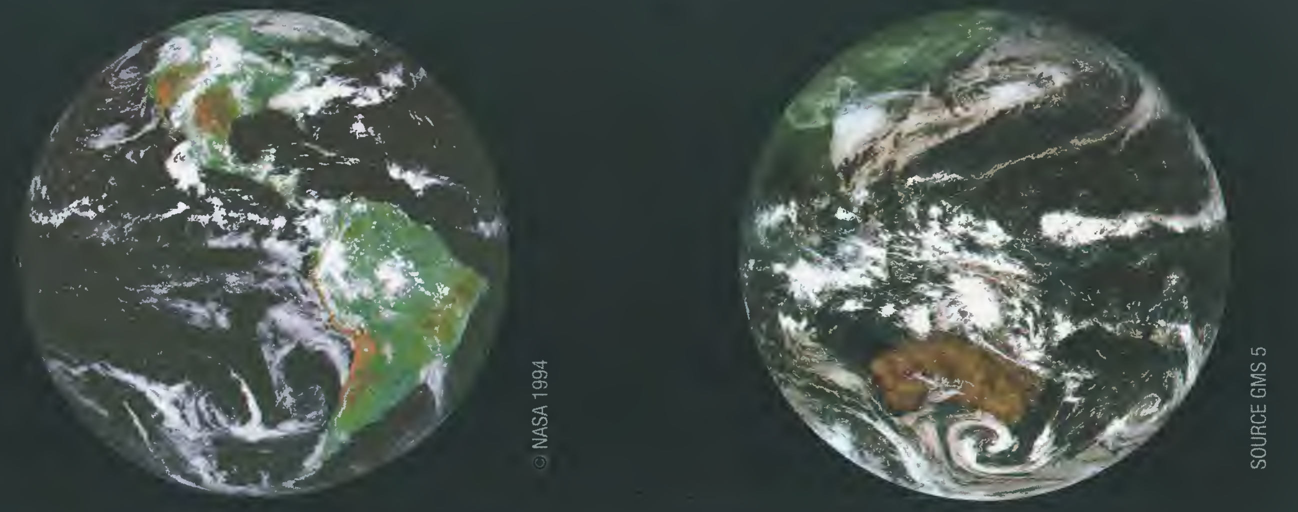
European Space Agency
Agence spatiale européenne

the Living Planet

1

GEOSTATIONARY VIEWS OF THE EARTH

Typically, weather satellites operate from a geostationary orbit 36,000 km above the Equator, from where they observe meteorological activity on the Earth.



These images were produced by the US satellite GOES 8, stationed at 75° west, and Japan's GMS satellite, stationed at 140° east.

2

THE CONTINENTS AND OCEANS

The continents, which are mainly situated in the northern hemisphere, account for less than a third of the total surface of the Earth.

There are five continents:
Eurasia, Africa, the Americas, Australia/Oceania and Antarctica.
There are five oceans:
the Pacific, Atlantic, Indian, Arctic and Antarctic.

So as to be able to pinpoint their exact location on Earth, human beings have defined imaginary lines:

The Equator is a circle located at equal distance from the North and South Poles. It separates the Earth into two hemispheres.
The parallels are imaginary circles parallel to the Equator.
The meridians are also imaginary circles but cut across the North and South Poles.

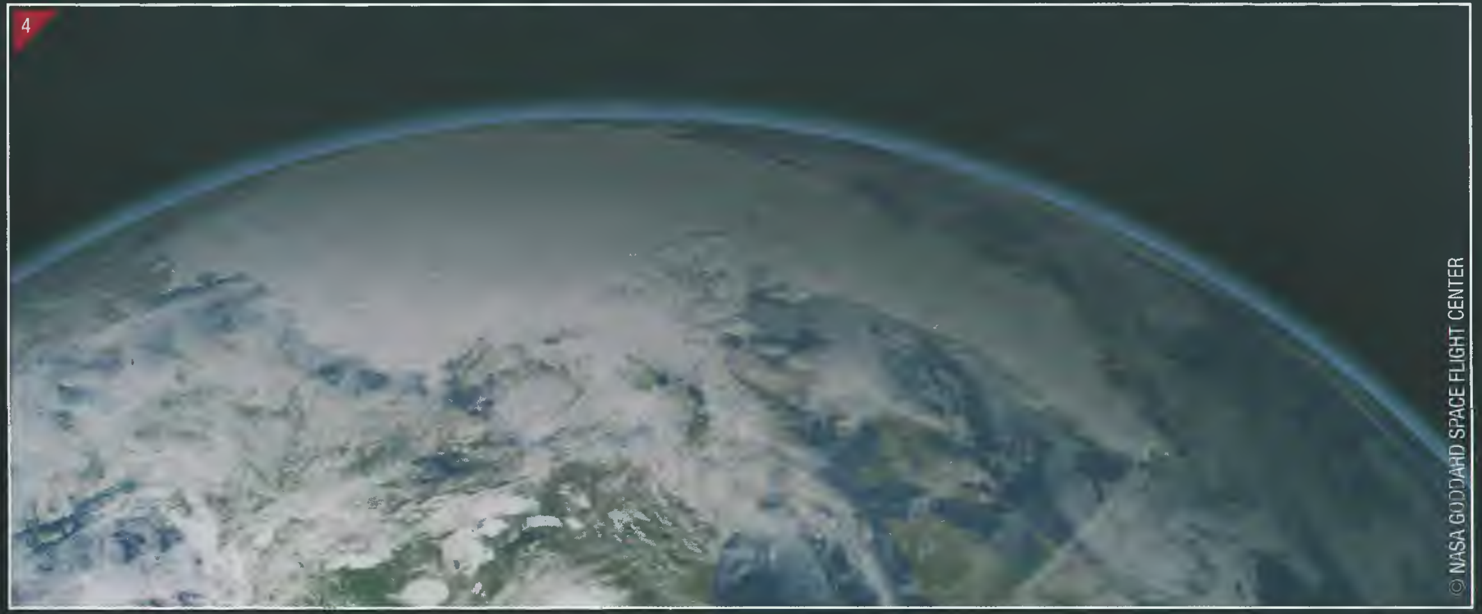
3

The layer of atmosphere that surrounds the Earth is very thin, measuring only in the tens of kilometres. This corresponds to less than a millimetre in this picture of the Earth.

The Earth turns on its axis every 24 hours and around the Sun every 365.25 days. These movements are known as rotation and revolution respectively. Its centre is over 6,000 km below our feet and its circumference is about 40,000 km.

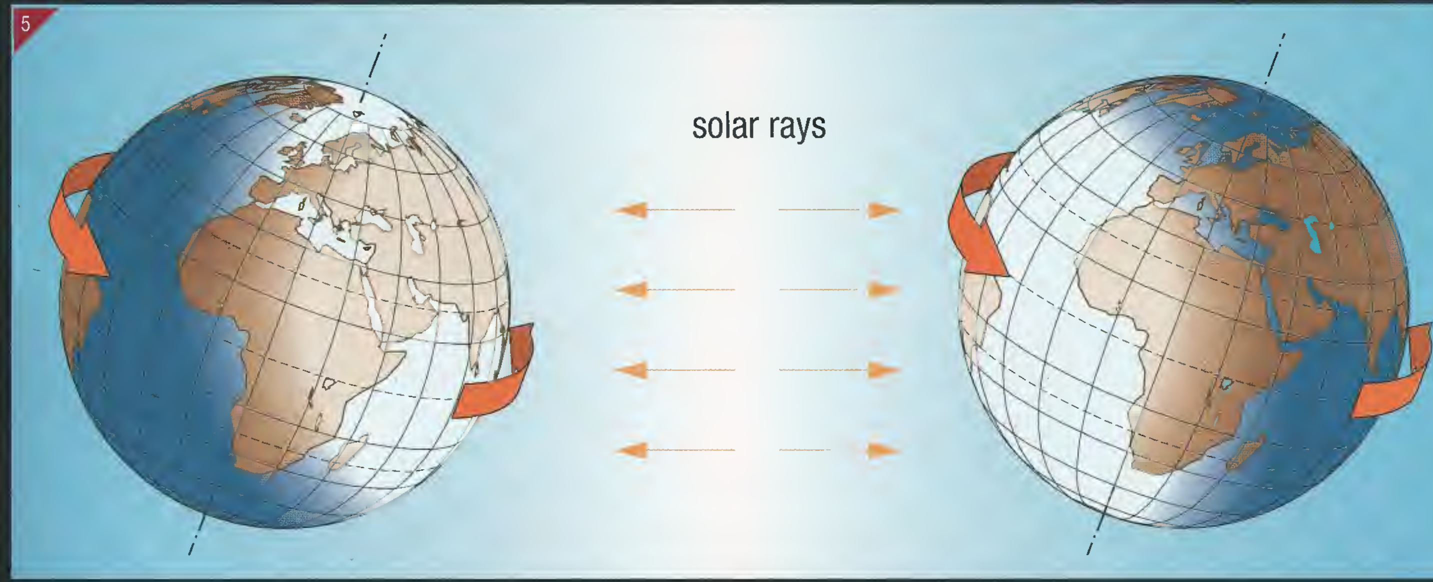
EARTH INCLINATION AND THE SEASONS

4



The northern hemisphere in winter when the icecaps are expanding.

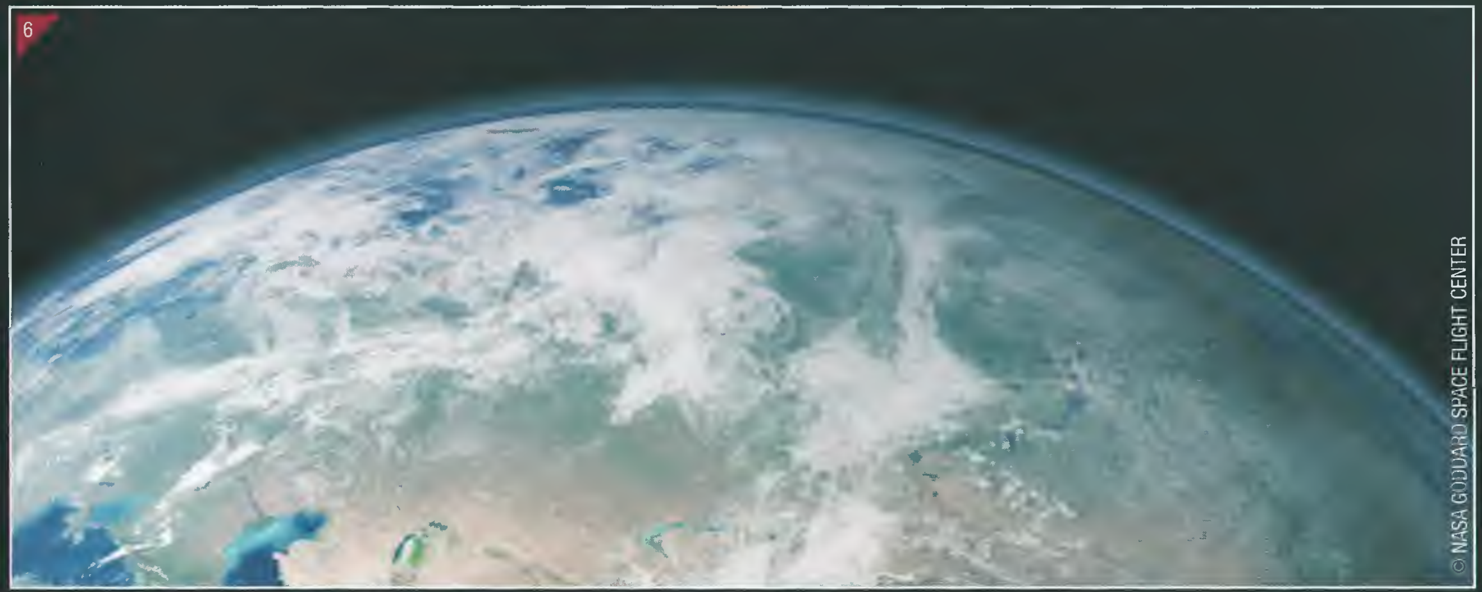
5



In the summer the North Pole is constantly bathed in sunshine, while in the northern hemisphere the days are longer. The South Pole remains in the dark.

In the winter it is the South Pole which is constantly sunny while sunlight never reaches the North Pole, where it remains dark for six months.

6

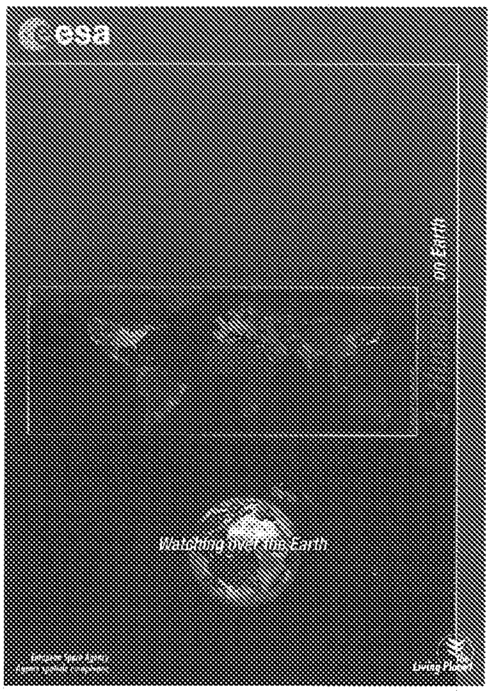


The northern hemisphere in the summer when the icecaps recede.

Information for teachers

The "Information for teachers" sheets are designed to offer assistance with the preparation of classes and complement the worksheets handed out to pupils. They contain useful information for the presentation of the subject, additional information relating to the satellite images, and a list of websites dealing with the subjects concerned.

Worksheet 3: Humans on Earth



Worksheet 3 discusses human population distribution around the world. If you take a global perspective (see central illustration), the documents provided also offer views at different scales: continental, regional, and local.

This worksheet can be used to:
- locate and identify areas with the largest population concentrations in the world;
- analyse the relationship between spaces and societies at different levels;
- determine the reasons for which different areas of the planet have high or low population density.
- apply concepts such as population concentration, polarisation, density, coastal concentration, the Earth's inhabited surface, etc.

Population distribution

The Earth's inhabited surface—that space where human societies settle, create their living space and territories—is in a constant state of flux. By this we mean all those spaces that have been adapted, transformed, or built on by humans. The relationship between space and societies is what determines population density, and leads to imbalances in the distribution of the world's population around the globe. There are five major points that can be made about the way the human population is distributed on Earth:
Despite its population of 6.5 billion in 2005, the Earth is nonetheless an under-populated planet, with a low overall population density (50 inhabitants per square km of total land mass area). Human societies only live on continental and insular zones. If one were to exclude seas and oceans, hostile environments and cultivated areas, the world's population is essentially concentrated in a total area of 300 million hectares (3 million square kilometres) —barely 1% of the total surface of the Earth!

Population concentration is irregular and reflects the effects of polarisation. There are four major areas where human populations are concentrated. All four are in the Eurasian continent, the largest continent on Earth. The Far East accounts for 23% of the world's population concentrated on 3% of the Earth's landmass; the Indian subcontinent accounts for 21% of the population on just 2% of the Earth's landmass; Europe (which geographically extends to the Urals), is home to 12% of the world's population, living on 7% of all landmass; and Southeast Asia accounts for 8.5% of the world's population on 3% of all landmass. There are other regions considered to be secondary in terms of population density, such as the Gulf of Guinea, the Atlantic coast of Brazil, and the northeastern region of North America. Other regions on Earth, such as cold or hot deserts, the tropical forest belts in South America and Africa, are either unpopulated or very lightly populated. Population polarisation is also visible in terms of increased urbanisation. Today, 50% of the world's population is concentrated in cities.
Furthermore, the world's population is mainly distributed throughout the temperate zone in the northern hemisphere (the southern hemisphere is 75% ocean). Human populations are also increasingly concentrated around continent edges, while the heart of those continents is deserted. Currently, almost 1 billion of the Earth's inhabitants live near seas and oceans, indicating increased concentration of the world's human population in coastal areas. Lastly, there is also an altitudinal inequality: 80% of the world's population lives at an altitude of less than 500m on 57% of all landmass area.

The satellite images

Cover page

Cover image: Night-time planisphere of the Earth (NASA/DLR)
This optical image reveals the consumption of electric light in cities and urban areas. It has been produced by combining partial captures obtained in cloudless, moonless periods. Adjustments to the contrast were made in digital processing to show the extent of urban centres. This image, from NASA, was processed by the German Remote Sensing Data Center.

Core content

A number of satellite images are presented showing very diverse regions, at different scales.
Image 1: Greenland ice field (MERIS/Envisat image, 17 May 2002)
This image shows the east coast of Greenland. The average thickness of the ice of the plateau of this island of almost 1.9 million km^2 is 2.3 km. While increases in snowfall at altitude are currently causing a slight increase in the ice layer, the ice surrounding Greenland and that forms the arctic icefield is receding rapidly.

With just over 55,000 inhabitants, the population density is very low at 0.029 inhabitants per km^2.

The near infrared channel used for this image makes it possible to differentiate between atmospheric elements (shaded red) and ice (shaded green).

Image 2: San Francisco (PROBA image)
This image of San Francisco was produced by the European Space Agency satellite PROBA from an altitude of 600 km. In it one can clearly see the geometrical layout that is characteristic of American cities.

Image 3: The Amazon Basin (MERIS/Envisat image)
The Rio Negro cuts right across this picture, while the Rio Solimões can be seen in the bottom right-hand corner. A narrow strip of cleared agricultural land is visible to the right of the picture.

The whole of Amazonia has barely 20 million inhabitants spread across close to 5 million km^2, representing an average density of about 4 inhabitants per km^2. Nearly half of that population is concentrated in very large towns, whose total area makes up less than 0.5 % of the overall territory.

Image 4: The Namib Desert (MERIS/Envisat image)
The Namib Desert is the oldest desert in the world. It extends along the Atlantic coastline for almost 2000 km. Namibia is one of the three countries with the lowest population densities in the world.

Image 5: New Delhi (SPOT 5 image. Distribution Spotimage)
New Delhi with its 14 million inhabitants is the capital of India. It extends over an area of 1,483 km^2.

Image 6: Asia by night (NASA/DLR)
The trailing urban conurbation formed by Japanese cities is particularly visible. The two highly developed regions of Taiwan and Hong Kong are also very easily recognised.

It is possible to make out thin strips of light emitted by the medium-sized cities located along China's main communication axes.

Image 7: Asia and the Indian subcontinent (MERIS/Envisat image)
In this image it is possible to see the geophysical characteristics of this vast region of the globe. For this image the Envisat satellite uses the MERIS (Medium Resolution Imaging Spectrometer) instrument , a wide field-of-view optical sensor which can notably be used to observe vegetation cover.

The "swath" of this instrument (width of the portion of land observed in its field of view) is 1,250 km and its resolution 300 m. MERIS provides full coverage of the Earth every 3 days.

Page 5 - Population zones in Italy

Image 8: Northern Italy and the Po Valley (MERIS/Envisat image)
This image shows the geophysical situation of the Po plain, Italy's most populated area. It is possible to make out Lake Maggiore, Lake Como and Lake Garda. The light green areas in the Venice lagoon and along the Adriatic coastline indicate the large quantities of sediment expelled into the sea.

Page 6 – "How do satellites work?"

Image 11: Map of nitrogen dioxide NO_2 emissions
This image is generated from measurements recorded by the SCIAMACHY instrument on-board the Envisat satellite. (Image by IUP, Heidelberg)

Based on 18 months of Envisat observations, this high-resolution global atmospheric map of nitrogen dioxide pollution makes clear the extent of the impact human activity has on air quality.

ESA's 10-instrument Envisat satellite was launched in February 2002 and is the world's biggest environmental monitoring satellite. Its Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument records the spectrum of sunlight shining through the atmosphere. These results are then carefully sifted to find spectral absorption "fingerprints" of trace gases in the air. Nitrogen dioxide (NO_2) is a mainly man-made gas, excess exposure to which causes lung damage and respiratory problems. It also plays an important role in atmospheric chemistry since it triggers ozone production in the troposhere, the lowermost layer of the atmosphere extending up to an altitude of eight to sixteen kilometres.

Nitrogen dioxide is produced by emissions from power stations, heavy industry, road transport and biomass combustion. Localised in-situ measurements of atmospheric nitrogen dioxide are carried out in many western industrial countries, but ground-based data sources are, generally speaking, very limited in number. Space-based sensors are the only way to carry out effective global monitoring.

The improved spatial resolution provided by SCIAMACHY means that it is able to identify many details, including towns which are sources of pollution. To give a sense of scale, the ratio of NO_2 particles above highly polluted large cities such as London can reach levels of one hundred parts per billion air particles.

Images 12 and 13: Illustrations showing the principles of atmospheric analysis by satellite
SCIAMACHY's average resolution is 60 x 30 km. It observes the atmosphere from two different angles – downwards or "nadir looking" as well as making "limb" observations in the direction of flight – hence its wide spectral range.

SCIAMACHY is a spectrometer which maps the air over a very wide wavelength range, thus allowing the detection of rare gases, ozone and related gases, as well as clouds and dust particles throughout the atmosphere. It works by measuring solar radiation transmitted, reflected and scattered by the atmosphere or the Earth's surface in the ultraviolet, visible and near infrared wavelength regions. With its 960 km swath, it covers the whole planet every six days.

About the kit and DVD

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www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

GLOBAL POPULATION

esa.un.org/unpp	Nations Population Division – World Population Prospects: 2006 Revision
www.unfpa.org/swp/2006/english/introduction.html	State of the world's population in 2006. United Nations Population Fund (UNFPA)

NO_2 POLLUTION

www.esa.int/esaEO/SEM340NKPZD_index_0.html	Global air pollution map produced by SCIAMACHY
www.bnsc.gov.uk/content.aspx?nid=5677	BNSC website: measuring and modelling the Earth's atmosphere

Satellite images

ESA project lead	Agostino de Agostini	Documentation	Valérie Massignon - XYZèbre
Editorial concept	Frédéric Létang / Patrice Desenne	Graphics	Boris Uzan
Original text/project oversight	Frédéric Létang	Illustrations	Philippe Bouillon - Illustratek
Scientific advisors (ESA)	Isabelle Duvaux Béchon / Laurence Ghaye	Translations (ESA)	Colin McKinney / Anthony Blend
Pedagogical advisors	Éric Janin / Jean Jandaly	Production	Europimages - Aliette Cremer

Worksheet N° 3 – Humans life on Earth

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – How is the Earth's population distributed? Look at the map and the satellite images and give two densely populated regions of the world and two regions with very low population density.

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2 – What is the average population density on Earth? What population density levels can be found in large agglomerations?

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3 – Look at the satellite image of China taken at night. What conclusions can you make regarding population density based on this image?

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4 – Look at the satellite image of Asia. What connection can you make between physical characteristics of this region, and its population density?

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5 – Carefully study the page entitled "Population Zones in Italy". What region is Italy is the most densely populated? Why?

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6 – Look at the satellite image of the north of Italy. Describe the main features of the landscape.

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7 – What do you see in the satellite image of Europe shown on the last page?
Compare this image with the population density maps included in this worksheet. What connections do you see?

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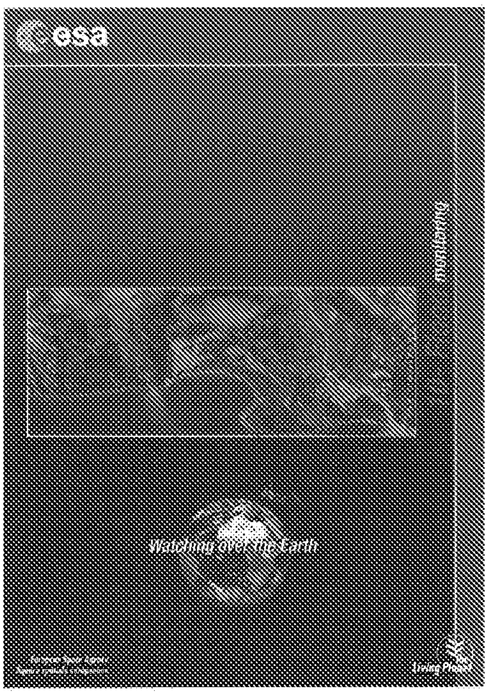
Information for teachers

The "Information for teachers" sheets are designed to offer assistance with the preparation of classes and complement the worksheets handed out to pupils. They contain useful information for the presentation of the subject, additional information relating to the satellite images, and a list of websites dealing with the subjects concerned.

Worksheet 10: Flood monitoring



Worksheet 10 discusses risks and natural disasters around the world, taking as an example the floods caused by the Rhône (2003) and Elbe (2002) rivers. The worksheet considers the fragility and vulnerability of human societies with respect to the forces of nature, brought more or less under control.

This worksheet can be used to:

- locate and identify certain at-risk regions in Western Europe;
- distinguish the different natural risks for human societies;
- evaluate the role humans play in the consequences of natural disasters;
- apply concepts such as variables, risks, disaster, vulnerability, etc.

Risks and natural disasters in the world

Each year nearly 250 million people are affected by one or more natural calamities. Although the most vulnerable are the populations in developing countries, which are located in the tropical belt and are subject to natural disasters, wealthy countries are not exempt. Over the past 35 years, 3 million people have died worldwide in a natural disaster. Of these, 97% lived in developing countries, in Asia and Africa in particular. Insufficient infrastructure, the absence of prevention systems, and inadequate emergency services are among the different factors that help underscore the strong correlation that exists between poverty and the impact of natural disasters.

Since the early 70s, the CRED (Center for Research on the Epidemiology of Disasters) has surveyed nearly 7,000 disasters, not counting epidemics. Natural disasters are much more common, more deadly, and most costly than technology-related catastrophes. Munich Re, a German reinsurance company, has estimated that in 2004, without including the costs of the tsunami in South and Southeast Asia, natural disasters had cost approximately 40 billion dollars, making it the most expensive year in insurance history. This cost could have been still higher had the value of the property destroyed during the catastrophes been greater in the developing countries. In fact, property in these countries is almost always valued very low and is under-insured. By contrast, the losses sustained as a result of these disasters always make up a major share of the GDP of the affected countries.

In Western Europe, such risks remain fairly moderate, though they are present all the same. Dramatic flooding took place recently in the fluvial plain and humid regions in Europe, notably in the Somme, Gard, and Bouches-du-Rhône regions of France and in the Elbe river valley in Eastern Germany. Seismic risks are also present, and several mini earthquakes have shaken the Vosges, Alps, and even Brittany. There is continuing volcanic activity in the south of Italy and the Chaîne des Puys region in Auvergne, France is not entirely risk-free. In 2004, 641 natural disasters were recorded around the world (Source: Munich Re 2004 report). The percentages by disaster type are as follows: storms (41%), floods (24%), earthquakes (13%) and other (16%). The geographical distribution is very uneven across continents: Africa (7.5%), Europe (19%), Americas (26%), Asia (39%) and Oceania (8.5%). The major disaster of the year was the tsunami in South and Southeast Asia on December 26, 2004 which caused an estimated 300,000 deaths.

The satellite images

Cover page

Cover image: The Rhône Delta in France (SPOT 5 image, 2003)
The flooded areas to the west of Lake Vaccarès appear in blue in this image taken using the near infrared band. As a result, vegetation is shown in red (see Worksheet N°11, "Colours in satellite imagery", for information on infrared images).
To the right of the picture, it is possible to distinguish the industrial facilities at Fos sur Mer.

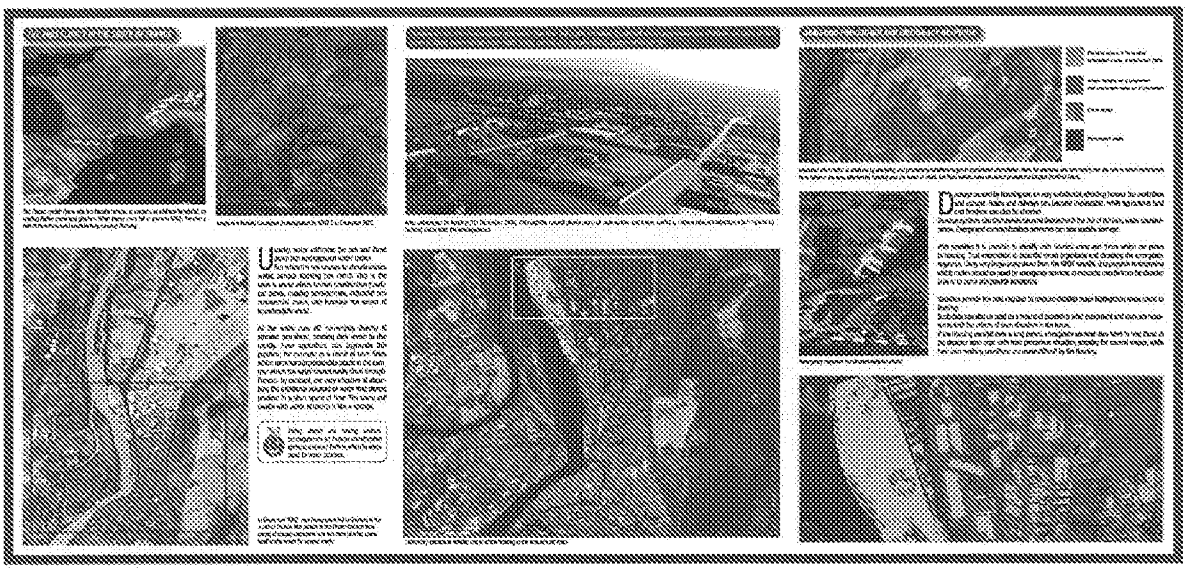
Core content

Image 1: France (Envisat/MERIS image, 2004)
This image shows the Camargue and Rhône delta, as well as the snow-capped mountainous regions of the Pyrenees and Alps, which constitute one of the water reserves that contribute to the risk of flooding.

Image 2: The Rhône Delta in France (SPOT 5 image, 2003)
This image is the same as the one on the front cover, except that it shows a wider expanse of the Camargue. The flooded areas to the south and east of Nîmes and north of Arles are particularly visible. Between Nîmes and Arles, the roads have been cut off.

Images 3, 5, 6 and 8: Flooding in the Arles region
These four satellite images of the Arles region were taken by the SPOT 5 satellite and were processed by SERTIT, France's remote sensing and data processing service. SERTIT has a rapid-response cartography department, which processes satellite data and images in order to rapidly produce maps and images for emergency rescue services.

These images highlight the extent and scale of the damage affecting the devastated area and can immediately be used by those whose job it is to respond. SERTIT also produces series of maps showing the evolution of a disaster over time. It also intervenes outside Europe, providing, for example, satellite images of the earthquakes that struck Boumerdes in Algeria and Bam in Iran and of the south-east Asian tsunami in December 2004.



Page 5 - Flooding of the Elbe in September 2002

Images 9 and 10 : Dresden and the surrounding area (DLR, 2002)
The two satellite images shown here were also processed by SERTIT.

Aerial photographs also have their uses but obviously to obtain each series of shots, a specific plane or helicopter flight has to be scheduled. Orbiting satellites, on the other hand, fly with great regularity over every region of the world and have differing fields of view and spatial resolutions, which makes them adapted to every situation. They are often equipped with radar instruments which can also supply information at night or in overcast conditions. This is also the case with satellites that can capture data in the infrared. Satellites are also a particularly useful tool for crisis monitoring and management.

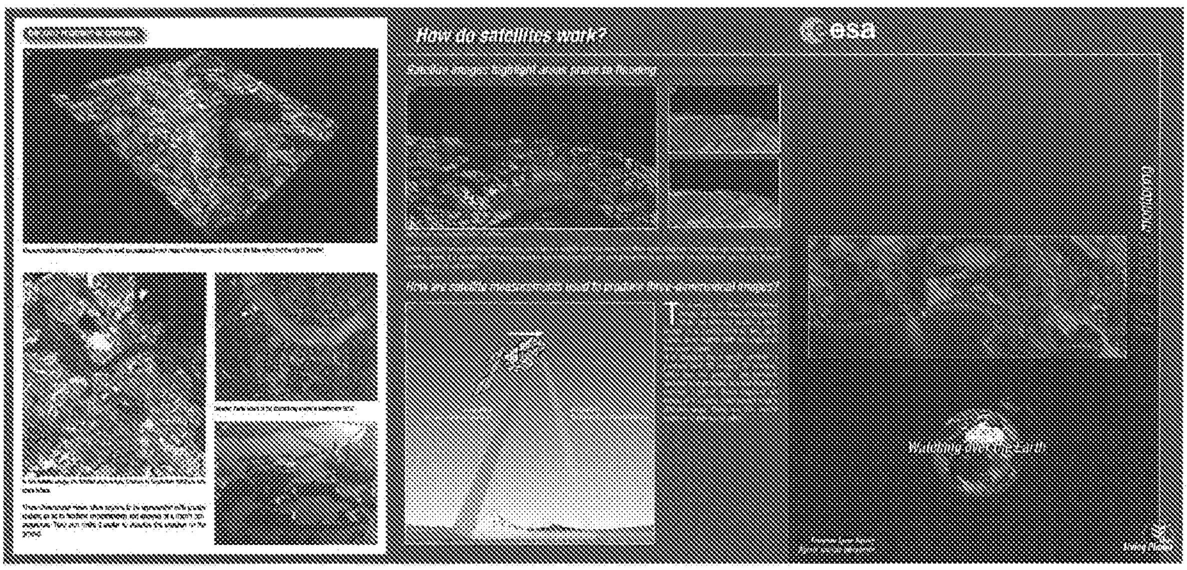
The flooding of the Elbe was particularly devastating: in places the level of the river rose by more than 9 metres. 9 people died and more than 20,000 inhabitants of Dresden were evacuated.
At the time, more than 740 kilometres of roads and 180 bridges were damaged or destroyed in the various countries affected by the floods.

Page 6 – "How do satellites work?"

Images N°13, 14 : Easily flooded zone around Wittenberg
These three-dimensional images of the Wittenberg region were created by the Germany space agency, the DLR .
Such 3D images give a more realistic representation of the true lie of the land. They allow more precise assessment and expert analysis, which is more tailored to the situation and thus helps with management of the response. They also help with the setting up of prevention programmes and with making changes designed to lessen the impact of such disasters.

The SPOT satellite carries on board the HRS (High Resolution Stereoscopic) instrument. Two cameras view at a fixed 20° angle, one pointing forwards and the other back, with a 90 second gap between the two shots of the same area, thus making it possible to obtain stereo views of the terrain.

Using these data, it is possible to generate 3D views and especially Digital Elevation Models (DEMs) of the terrain precise to within ten metres, which are used in many different areas including cartography, civil and military aeronautical databases or when setting up telephone networks. Each stereo view covers a wide area of up to 600 by 120 km.



About the kit and DVD

The worksheets, of which 15 copies are available, are to be distributed to pupils in pairs. The teacher, depending on the time available, can organise the lesson mainly around the worksheet's core content (inside 3-page spread) or, alternatively, make use of the information contained on the rear pages of the documents (page 5 and 6).
The DVD-ROM contains the principal satellite images shown in the worksheets. They can be projected onto a screen or displayed on a computer to complement the presentation of the subject by the teacher or to help with the correction of questionnaires.
The images corresponding to each subject can be accessed easily: It is possible to access the complete document and, with a simple mouse click, display the selected satellite image in full screen mode. Lastly, there are several screens which present, in word form, the main ideas contained in the document.
This DVD-ROM contains a form in PDF format entitled Pupil questionnaire, which can be printed out and distributed to pupils. Lastly, there is a version of the questionnaire in Word format, which allows the teacher to adapt it to the needs of his/her lesson.

Online resources

www.esa.int	ESA (European Space Agency) website
www.esa.int/SPECIALS/ESRIN_SITE/index.html	ESRIN (European Space Research Institute) website ESRIN is ESA's centre for Earth observation
www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

NATURAL DISASTERS

ec.europa.eu/research/leaflets/index_en.html	European Commission: research in action - disasters/Floods
ec.europa.eu/environment/water/flood_risk/index.htm	EU action aimed at combating and managing flooding
www.cred.be	Website of the Centre for Research on the Epidemiology of Disasters (CRED), Université Catholique de Louvain, Belgium
www.disasterscharter.org	Website of the International Charter "Space and Major Disasters"

IMAGE PROCESSING

sertit.u-strasbg.fr/english/en_welcome.htm	SERTIT website: France-based remote sensing and image processing service
www.dlr.de	German space agency, DLR (Deutsches Zentrum für Luft- und Raumfahrt) website

Satellite images

esa SPOT IMAGE DLR sertit

ESA project lead	Agostino de Agostini	Documentation	Valérie Massignon - XYZèbre
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Original text/project oversight	Frédéric Létang	Illustrations	Philippe Bouillon - Illustratek
Scientific advisors (ESA)	Isabelle Duvaux Béchon / Laurence Ghaye	Translations (ESA)	Colin McKinney / Anthony Blend
Pedagogical advisors	Éric Janin / Jean Jandaly	Production	Europimages - Aliette Cremer

Worksheet N° 10 – Flood Monitoring

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – What natural phenomena cause flooding?

2 – What human activities aggravate natural factors?

3 – Why are human-made structures particularly vulnerable to flooding?

4 – How are satellite images useful during floods?

5 – How can satellite images be used to prevent floods?

6 – Look at the page discussing flooding in Germany in 2002. What similarities do you see between the satellite images and the aerial photographs? What additional information can be found in the satellite images?

7 – What kind of satellite image is especially helpful for monitoring a valley or a region that may flood? Why?

8 – Give a rough description of how a satellite produces a three-dimensional image. What similarity is there with the way human vision works?

THE 2002 FLOODING IN GERMANY

9

Measurements carried out by satellites are used to reconstruct relief maps of whole regions, in this case the Elbe valley and the city of Dresden.

10

In this satellite image, the flooded areas around Dresden in September 2002 are indicated in blue.

11

Dresden. Aerial views of the flooded city centre in September 2002.

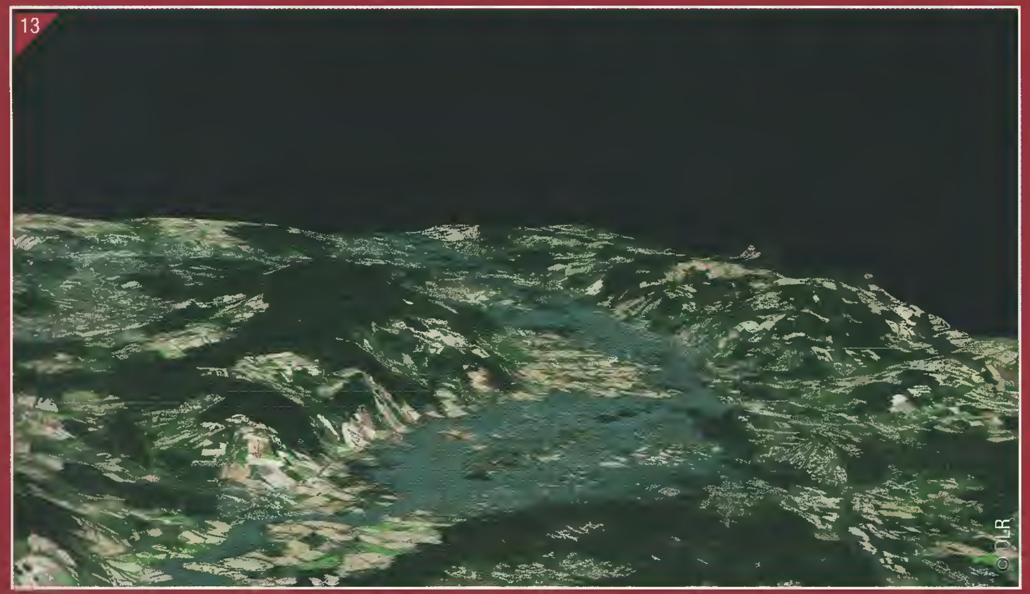
12

Three-dimensional views allow regions to be represented with greater realism so as to facilitate understanding and analysis of a flood's consequences. They also make it easier to visualise the situation on the ground.

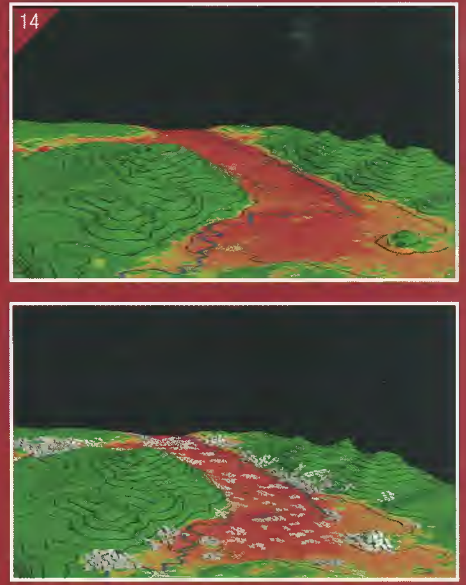
How do satellites work?

Satellite images highlight areas prone to flooding

13



14

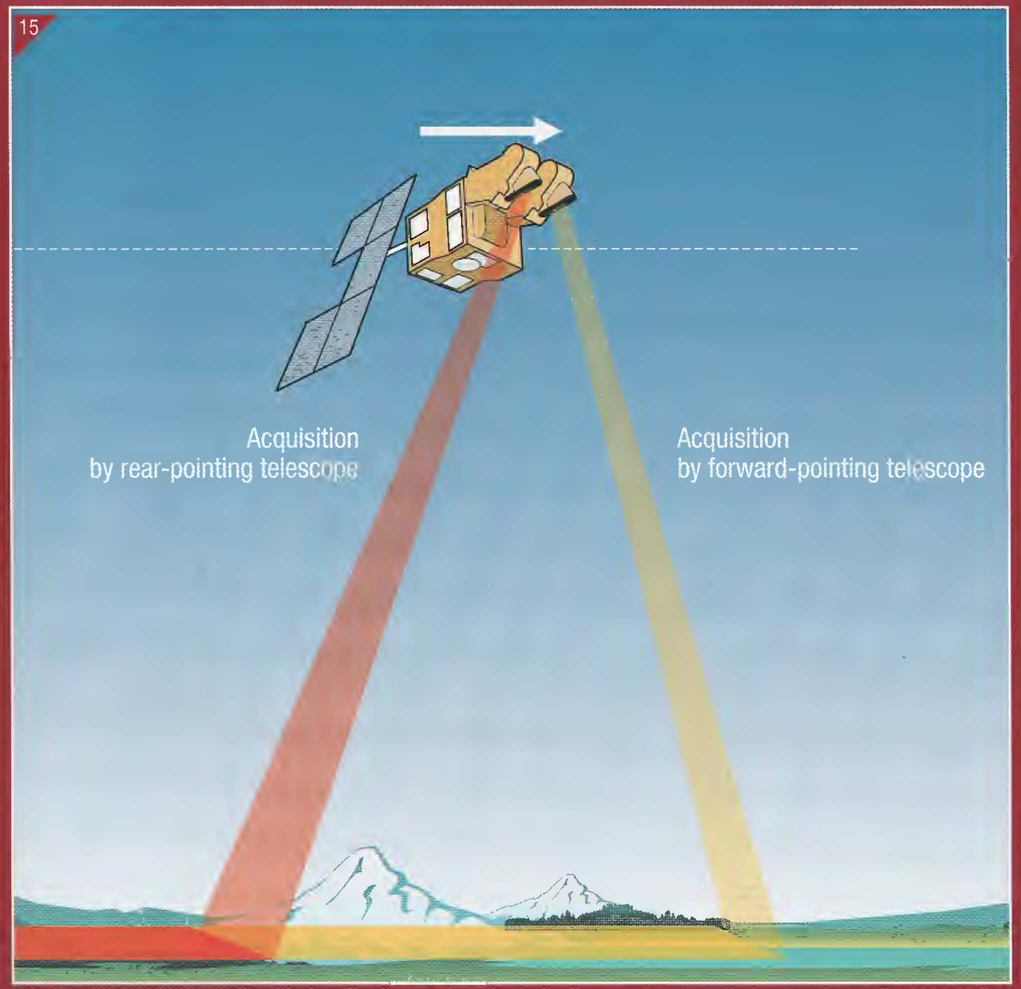


Flood-prone area around the town of Wittenberg.

Relief maps are produced using two images, each from a slightly different viewpoint, thus replicating how the human eye works. From these satellite views, it is possible to produce computer-generated images containing information on various infrastructures and thus to identify equipment in at-risk areas.

How are satellite measurements used to produce three-dimensional images?

15



To produce a three-dimensional image, an object must be observed from two different angles. A relief image is a combination of two such views, from slightly different angles, of the same object.
It is possible for a single satellite to produce such 3D images: for example, SPOT has two sensors, one forward- and one rear-pointing. At a few minutes' interval, each of these captures an image of the same zone viewed from a different angle. These are then pieced together to reproduce relief.

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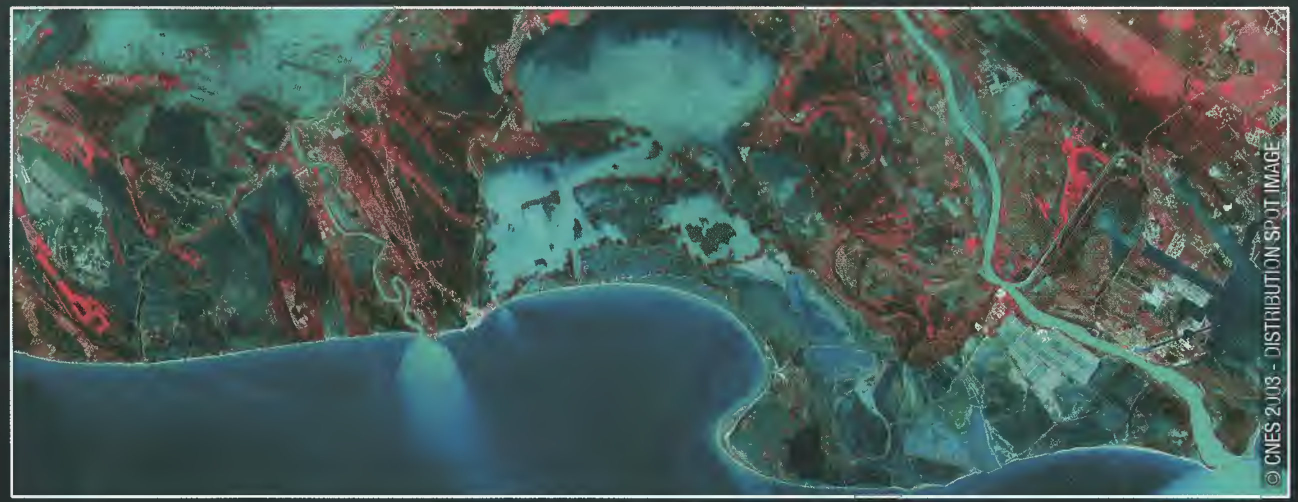
10- Flood monitoring



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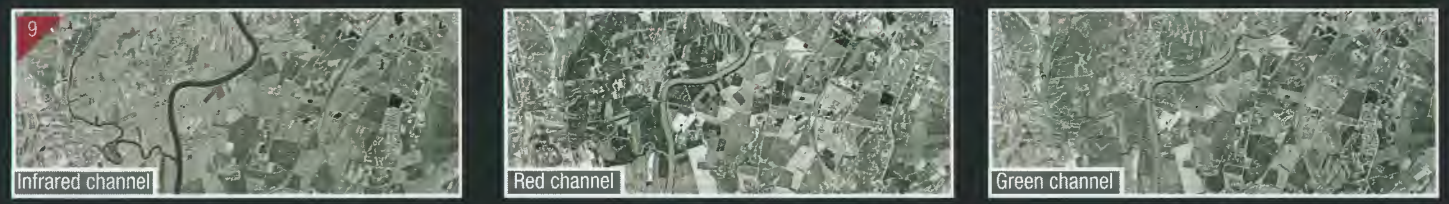
COMBINING CHANNELS TO FORM COLOUR IMAGES

Each colour channel is represented in black and white. Each indicates, in a scale ranging from black to white, that is from the weakest to the strongest, the intensity of reflection in each wavelength. It is by combining these three black and white images and giving each one its proper colour that the image can be reconstituted in natural colour.

Each channel is given its proper colour. The end result of combining the three images is an image in natural colour.

It is possible to artificially switch the colours chosen for each channel. When creating an image that includes information provided by the infrared channel (which is invisible to the human eye), by convention that channel is shown in red. The colour green is attributed to the red channel and blue to the green channel.



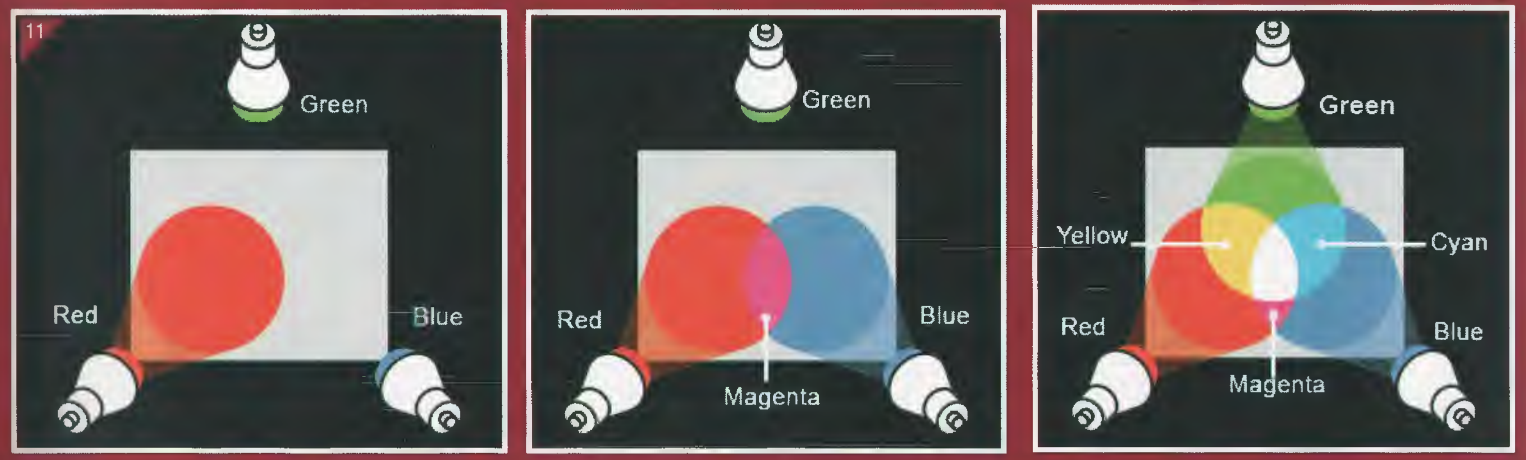
ir

The colour red is attributed to the infrared channel, green to the red channel and blue to the green channel.

Vegetation reflects more energy in the infrared than in the green channel. This channel is therefore useful for identifying and revealing certain variations in vegetation. That is why many satellite images show vegetation in red.

How do satellites work?

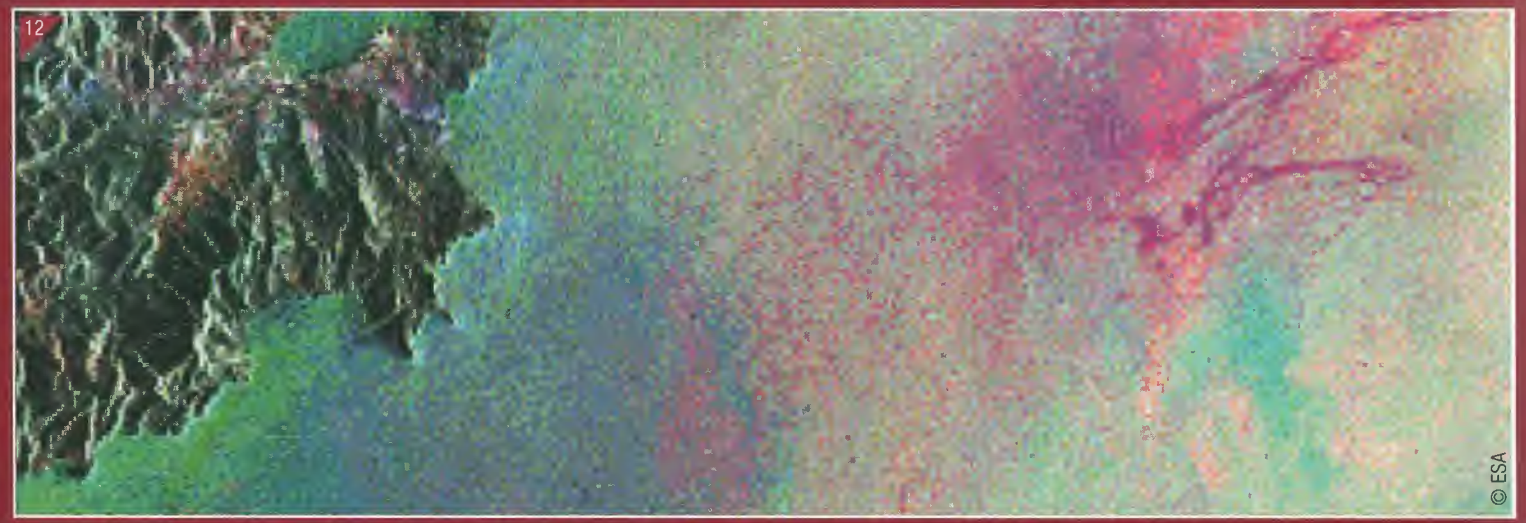
Additive colour synthesis



Images in photography, on television screens and computer monitors are all produced using 3 primary colours: red, green and blue. By combining these colours two at a time, one obtains either yellow, magenta or cyan. It is possible to obtain any shade by combinations of the three primary colours and adjusting the intensity of each.

Multitemporal radar images

By combining three radar images, taken on three different days and attributing a different primary colour to each, one can create a new image in colour revealing the changes which have occurred between the different days on which the images were taken.



Three superimposed coloured radar images.

Before the pollution occurred | Pollution off the coast | Pollution at the bottom near the coast

The oil slick has made the sea surface smooth so that the radar signal sent back to the satellite is very weak. Consequently, the area covered in oil appears black in these radar images.

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11- Colours in satellite imagery

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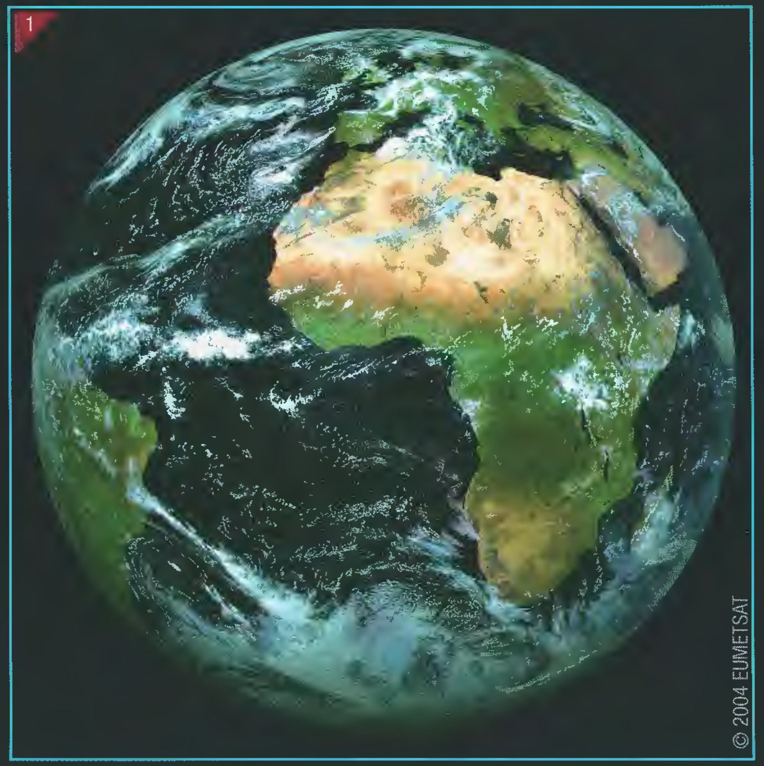
VISIBLE LIGHT

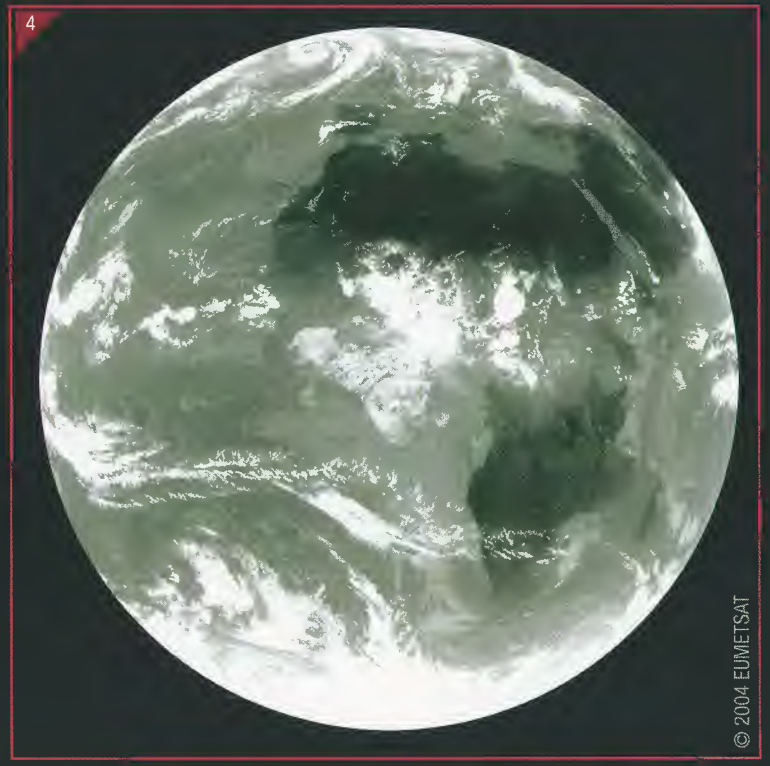
To our eyes, visible light emitted by the Sun appears white. It is in fact composed of a mixture of primary colours, as is clear when we look at a rainbow or light passing through a glass prism. Each of these colours (red, orange, yellow, green, blue and purple) has its own specific wavelength.

Earth observation satellites can use their sensors to record the various waves emitted or reflected by the Earth's surface.
There are many types of waves, all differing according to their wavelengths.
The human eye is only able to perceive visible light, which represents only a very small fraction of the spectrum.



INFRARED AND THERMAL IMAGING

Thermal infrared images are in fact no more than a map of temperatures on the Earth's surface. This is why images taken at night are not necessarily black as is the case for images in the visible channel. Hot surfaces such as deserts produce strong emissions, whereas cold surfaces such as clouds and ice produce very few. The source images obtained, therefore, show cold cloud as black and deserts as white. These are then displayed in negative form (see below) to make the clouds show up as white, just as the public is used to seeing them. It is satellites equipped with a thermal channel such as Meteosat which make such observations possible. They provide important information on cloud temperature and water vapour in the atmosphere.



Optical images

Temperature measurements

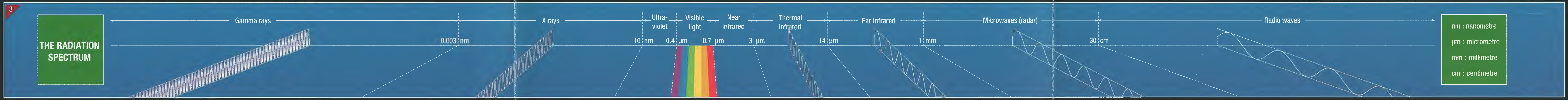
Radar waves

RADAR IMAGES

A radar image is one which is taken by a satellite equipped with a radar instrument, which sends a signal and detects its echo as it bounces back off objects and relief on the ground. Radar images do not reflect reality as we see it. They are in black and white because all that they show is the intensity of the signal received as an echo. In general, if a surface is smooth, the signal bounces, yet does not bounce back to the radar with the result that the area shows up as black on the image. In contrast, if a surface is uneven with substantial relief, many rays bounce back to be recorded by the radar, producing grey or white areas depending on the intensity of the relief.

Some animals such as bats are able to detect radar waves, which enables them to perceive the world around them in the form of a mental image of the relief and not just as a colour image like human beings. There are also other wavelengths such as X-rays or infrared rays for example. Specialised instruments measure and then reconstitute the corresponding images which we are unable to perceive. These images are every bit as relevant and real as those which we are accustomed to seeing.

Radar images can also be used to monitor sea conditions: the rougher the sea, the lighter the image produced. This image clearly shows the extent of an oil spill. Crude oil, like any oil for that matter, maintains a very smooth profile on the surface of the sea, making it difficult for waves to form. Consequently, the area covered by the oil spill appears somewhat black.



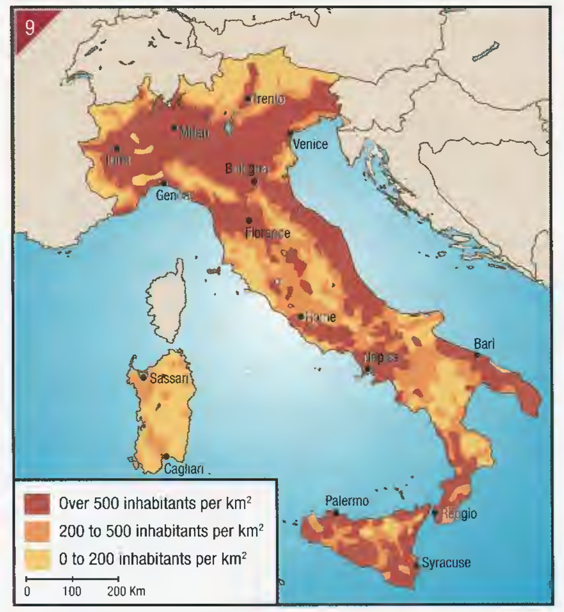
POPULATION ZONES IN ITALY

8

The Po plain as seen by Envisat.

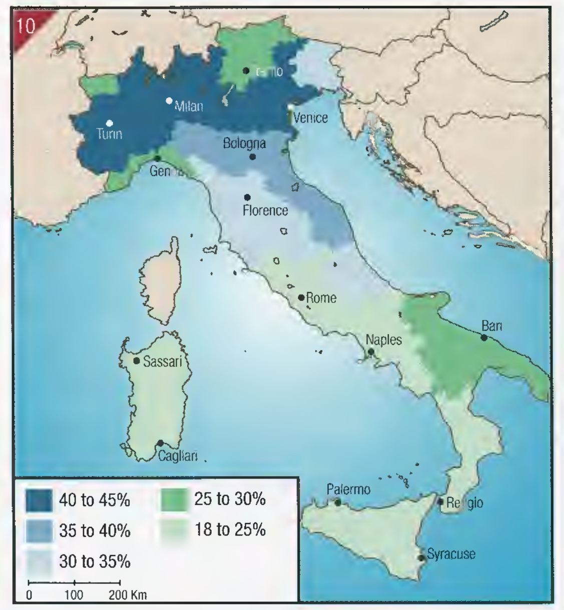
Population distribution in Europe is also very uneven. The Po plain at the foot of the Italian Alps is extremely fertile with a good climate, factors which have encouraged the development of agriculture. Urban centres have also sprung up there, as has a great deal of industrial activity. In the picture above, the white areas to the north indicate the presence of snow and glaciers. Further south are banks of cloud skirting the Apennine mountains.

9



Demographic map of Italy

10



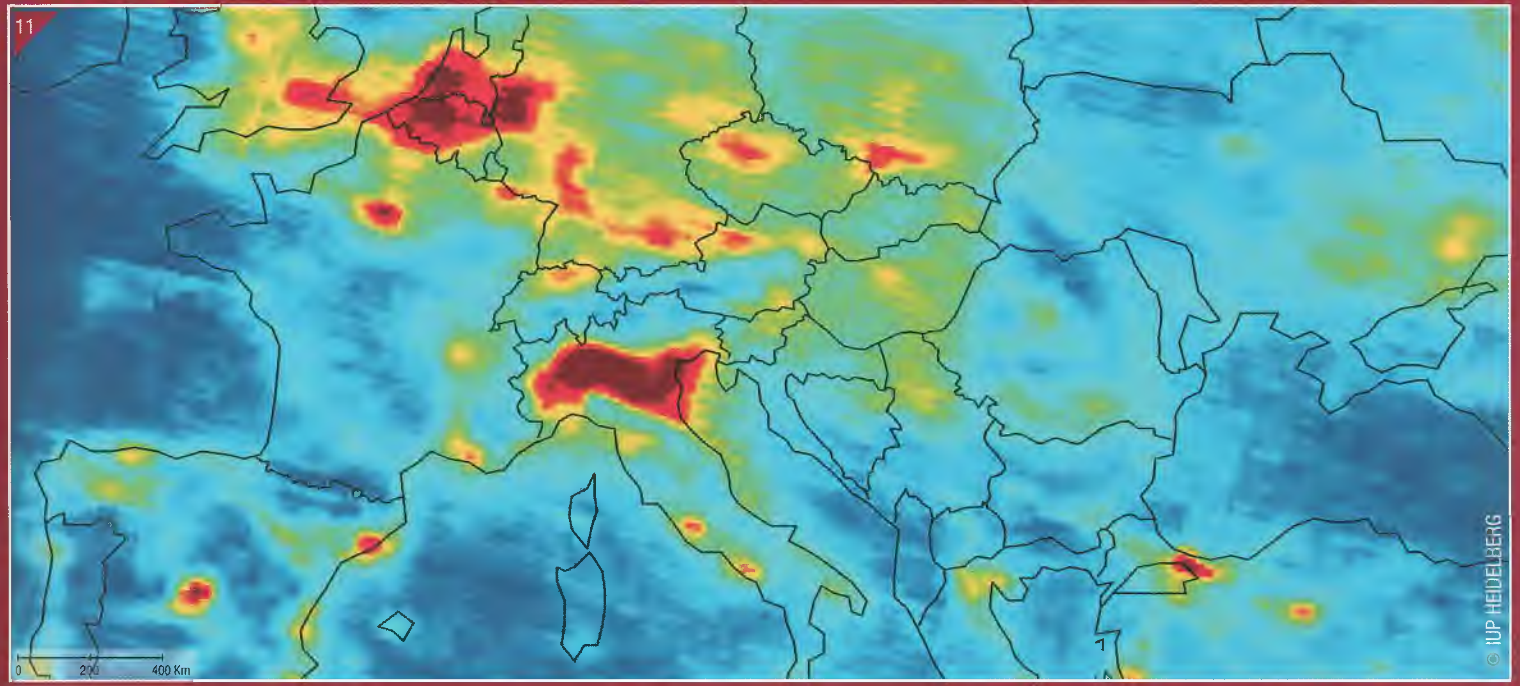
Italy's regions classified according to percentage employment in the industrial sector.

In Italy the most populated areas are in the north. This is also where most of the country's industrial activity is concentrated.

How do satellites work?

Satellites that measure pollution

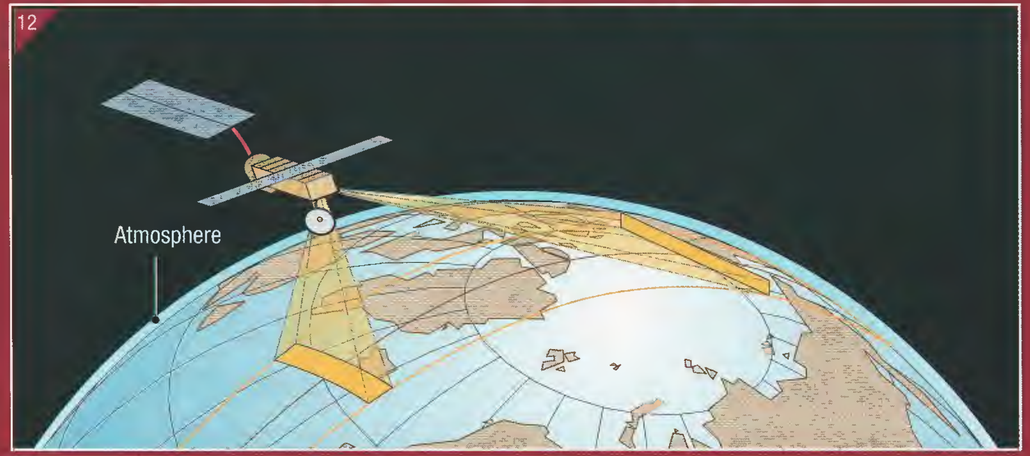
11



A map of nitrogen dioxide (NO_2) emissions above Europe, produced using measurements from special instruments on board Envisat. Regions where emissions of this pollutant gas are at their highest are shown in yellow and red. These also correspond to areas of high population density and major industrial activity (measured between July 2003 and July 2004).

How satellites analyse the atmosphere

12



13

Satellites can measure the composition of pollution clouds in the atmosphere in various ways.

In the first illustration to the left, the satellite analyses the chemical spectrum of the atmosphere of a given zone from two different angles and at a few minutes' interval, and is thus able to obtain more precise information on the different layers of pollution clouds.

Another technique, shown in the second illustration, involves aiming the satellite's sensor at a known star or the Sun on the horizon.
The light these objects emit is measured through the atmosphere, which acts as a kind of filter. Since the characteristics of light emitted by these stars are well known, any variations (for example, in colour or intensity) will provide clues as to the chemical composition of the upper atmosphere (ozone, aerosols and so on).

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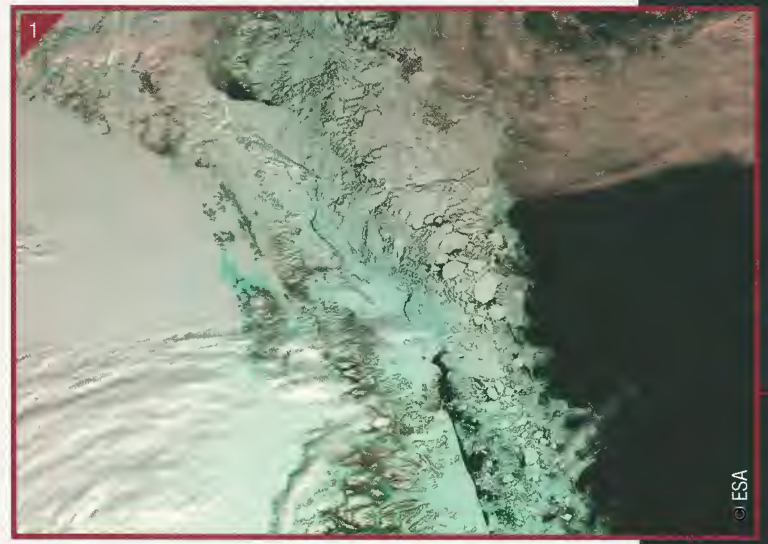
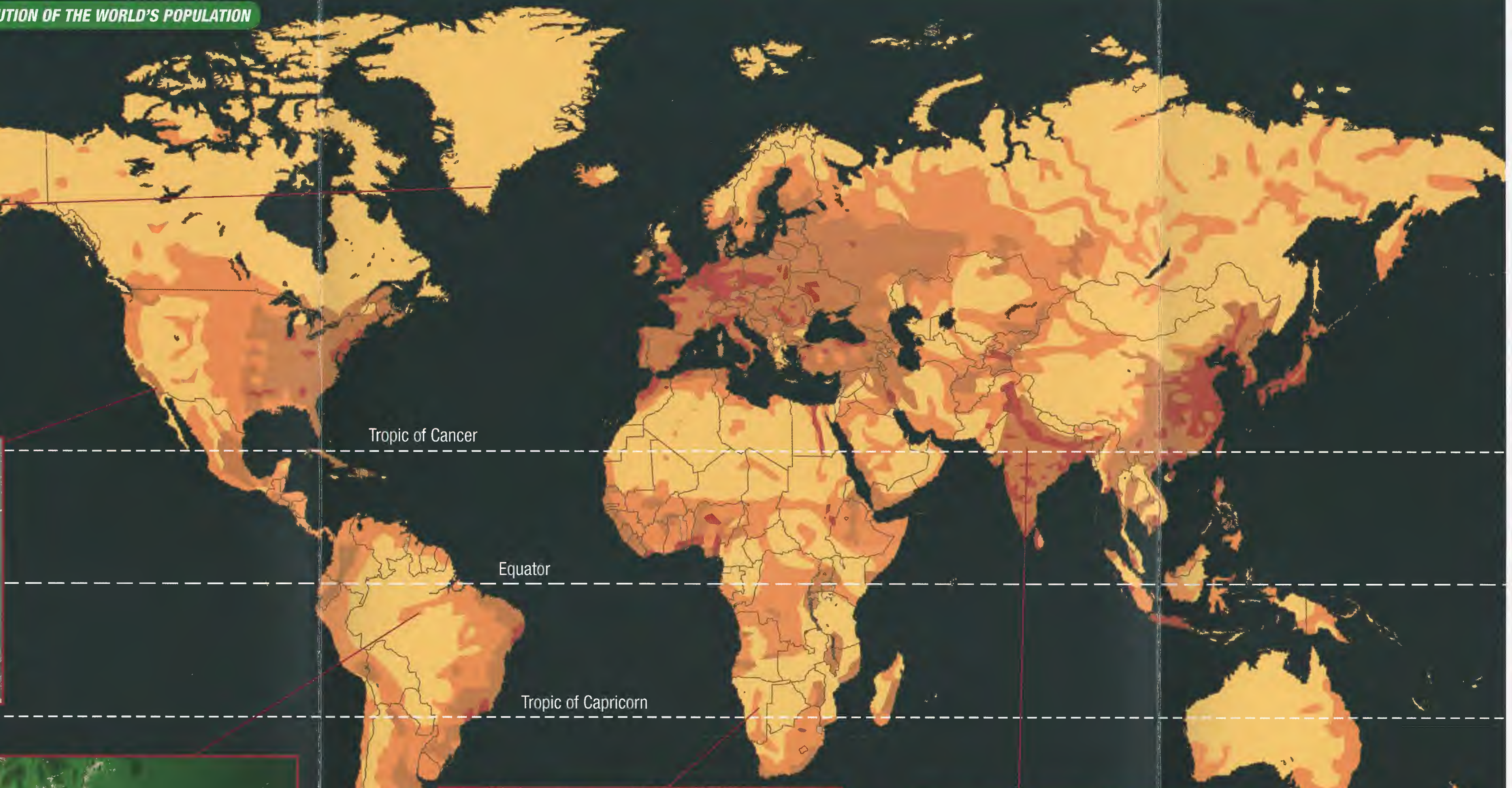


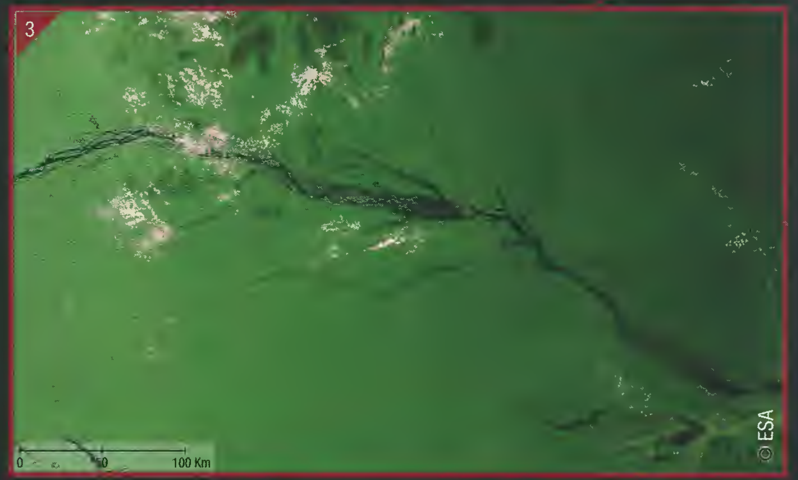
The Arctic region consists mainly of ice shelves and has little land mass. In the winter, when these ice shelves form, certain hunters such as the Inuit may temporarily inhabit the area.

The city of San Francisco has 7.5 million inhabitants. Some major cities have population densities in excess of 15,000 inhabitants per square kilometre.

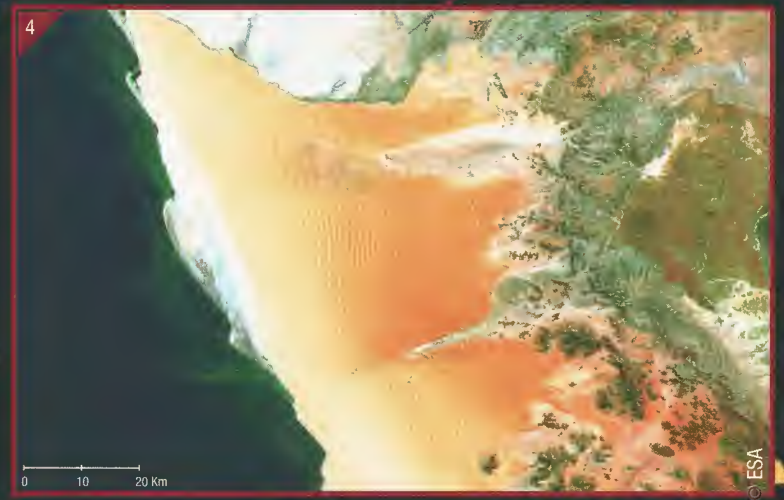
In 2005, the Earth's population stood at 6.5 billion. Population density was 50 inhabitants per square kilometre. However, the distribution of the human population on the Earth's surface is very uneven, with some areas deserted and others home to large concentrations of population.

DISTRIBUTION OF THE WORLD'S POPULATION

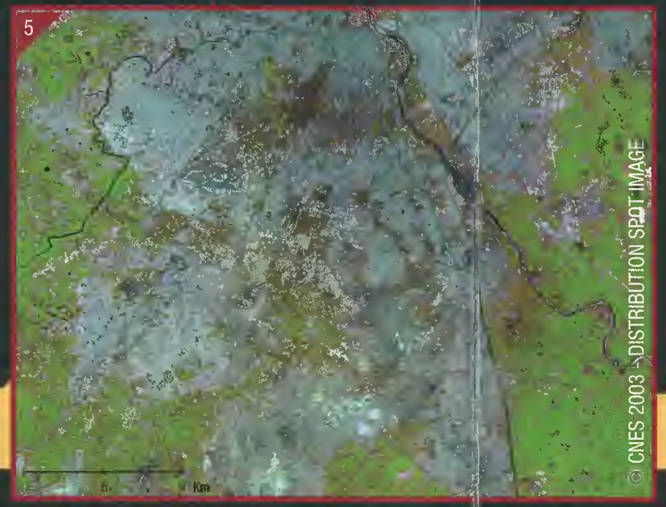




Many Indian communities live in the heart of the Amazon Forest. However, it can be reached only with great difficulty and is not an easy environment for outsiders to live in. In those areas which have not yet been colonised, the natural environment is well-preserved. Population density in Amazonia is 4 inhabitants per square kilometre.

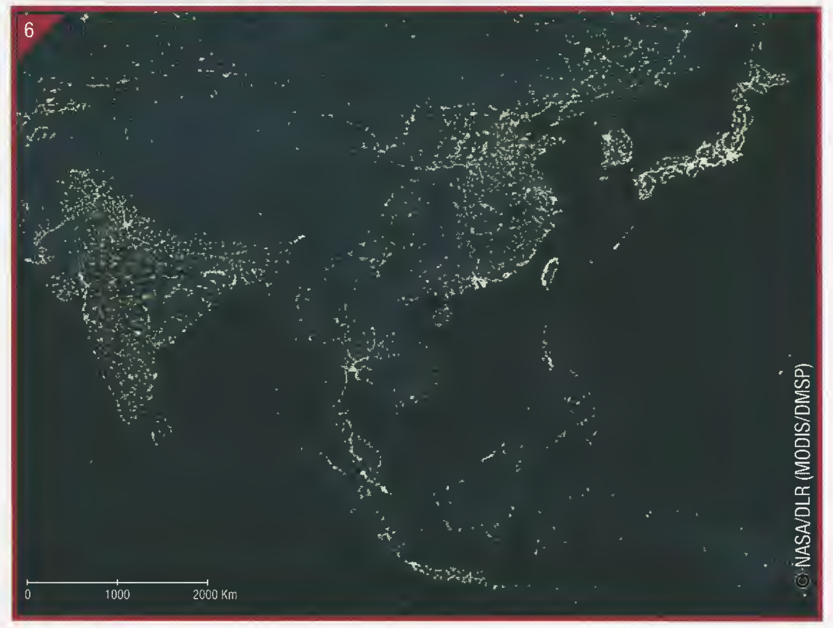


Certain regions of the Earth are very sparsely populated due to cold temperatures, drought or high altitude. The Namib Desert, shown here, is one of the hottest on the planet and is virtually devoid of all human habitation.

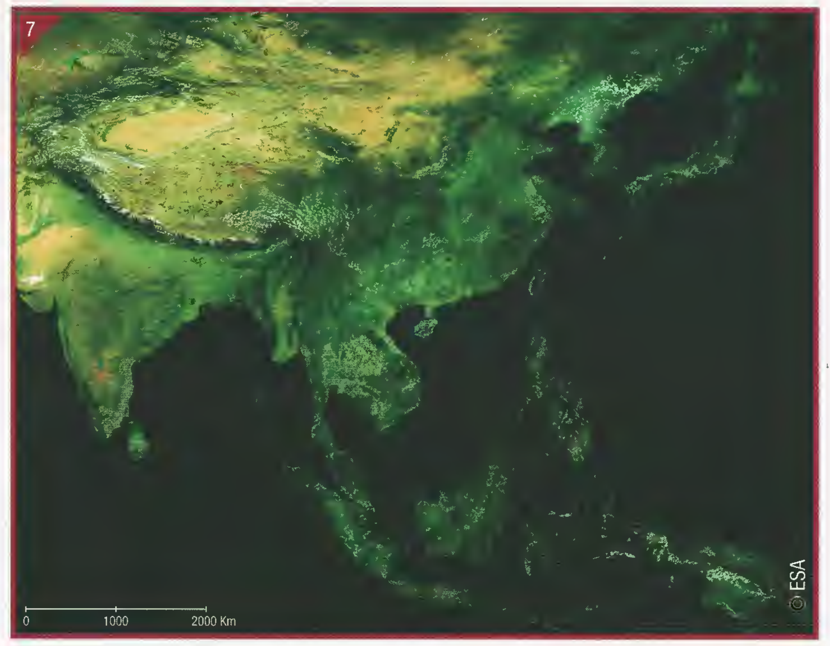


New Delhi, which has over 17 million inhabitants, is the capital of India. It is a new city, founded in 1931 and set up alongside the old capital Delhi.

ASIA: A MAJOR POPULATION CENTRE

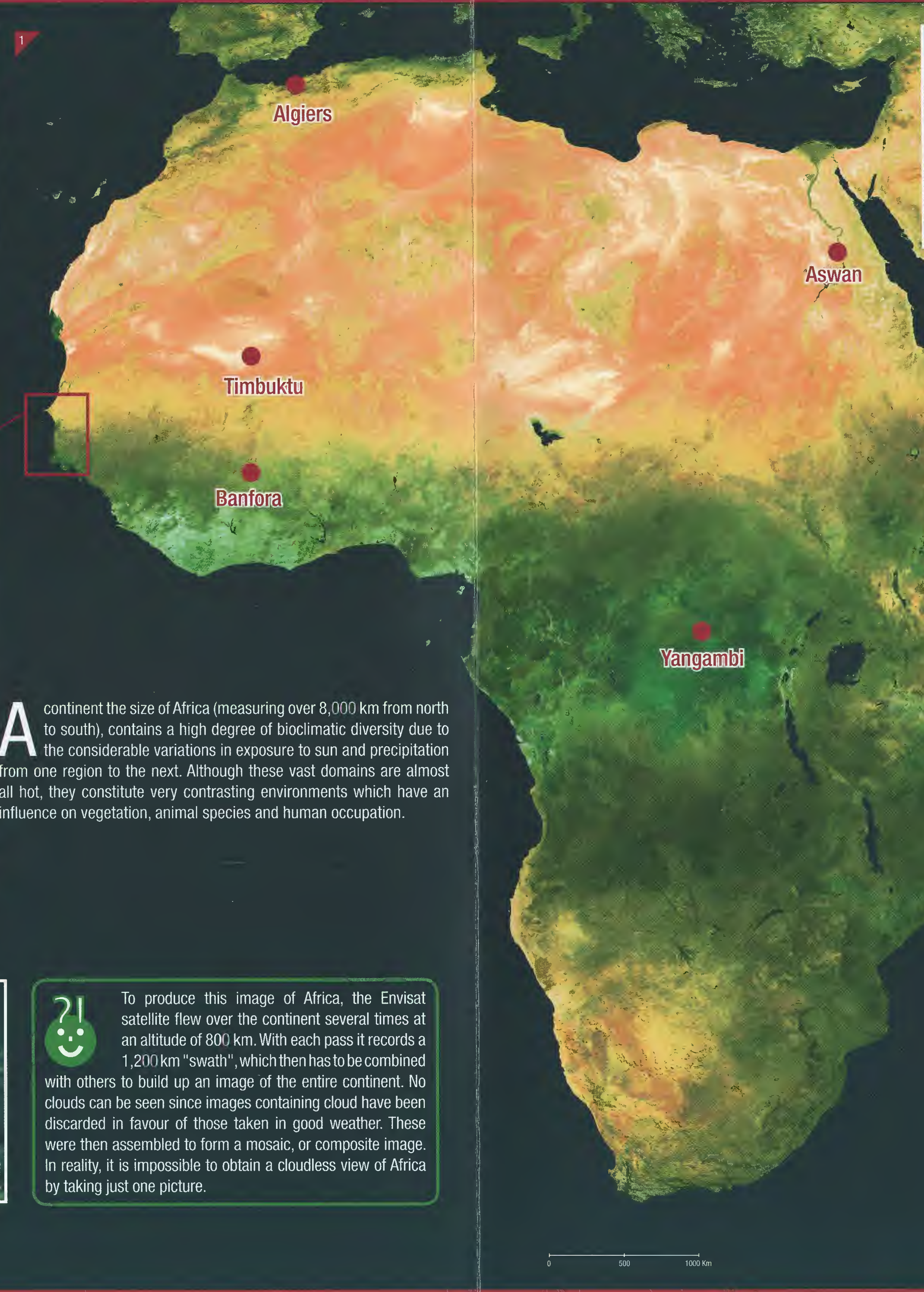


The points of light in this satellite view indicate urban electricity consumption (public lighting, communication routes, town centres, industrial areas and so on). These points are signs of high population density but above all indicate areas of high economic activity. Of course, certain regions may be poor as well as very densely populated and therefore consume very little energy and electricity.



The two largest population clusters are to be found in Asia. Very often, human communities gather in valleys or along coastlines. Clearly distinguishable at the foot of the Himalayas is the Ganges valley, whose waters eventually flow into the Indian Ocean. Such valleys are well suited to agriculture, a factor which in itself often promotes strong demographic growth.

Nowadays, increasing numbers of people are living in urban areas, and such urban living accounts for 50% of the world's population.
Moreover, half the world's population occupies less than 3% of the Earth's surface.



Satellite view of the coastal region of West Africa showing the difference between desert and tropical domains.

A continent the size of Africa (measuring over 8,000 km from north to south), contains a high degree of bioclimatic diversity due to the considerable variations in exposure to sun and precipitation from one region to the next. Although these vast domains are almost all hot, they constitute very contrasting environments which have an influence on vegetation, animal species and human occupation.

To produce this image of Africa, the Envisat satellite flew over the continent several times at an altitude of 800 km. With each pass it records a 1,200 km "swath", which then has to be combined with others to build up an image of the entire continent. No clouds can be seen since images containing cloud have been discarded in favour of those taken in good weather. These were then assembled to form a mosaic, or composite image. In reality, it is impossible to obtain a cloudless view of Africa by taking just one picture.

Bioclimatic domains are areas that share the same type of climate, soil and natural vegetation.

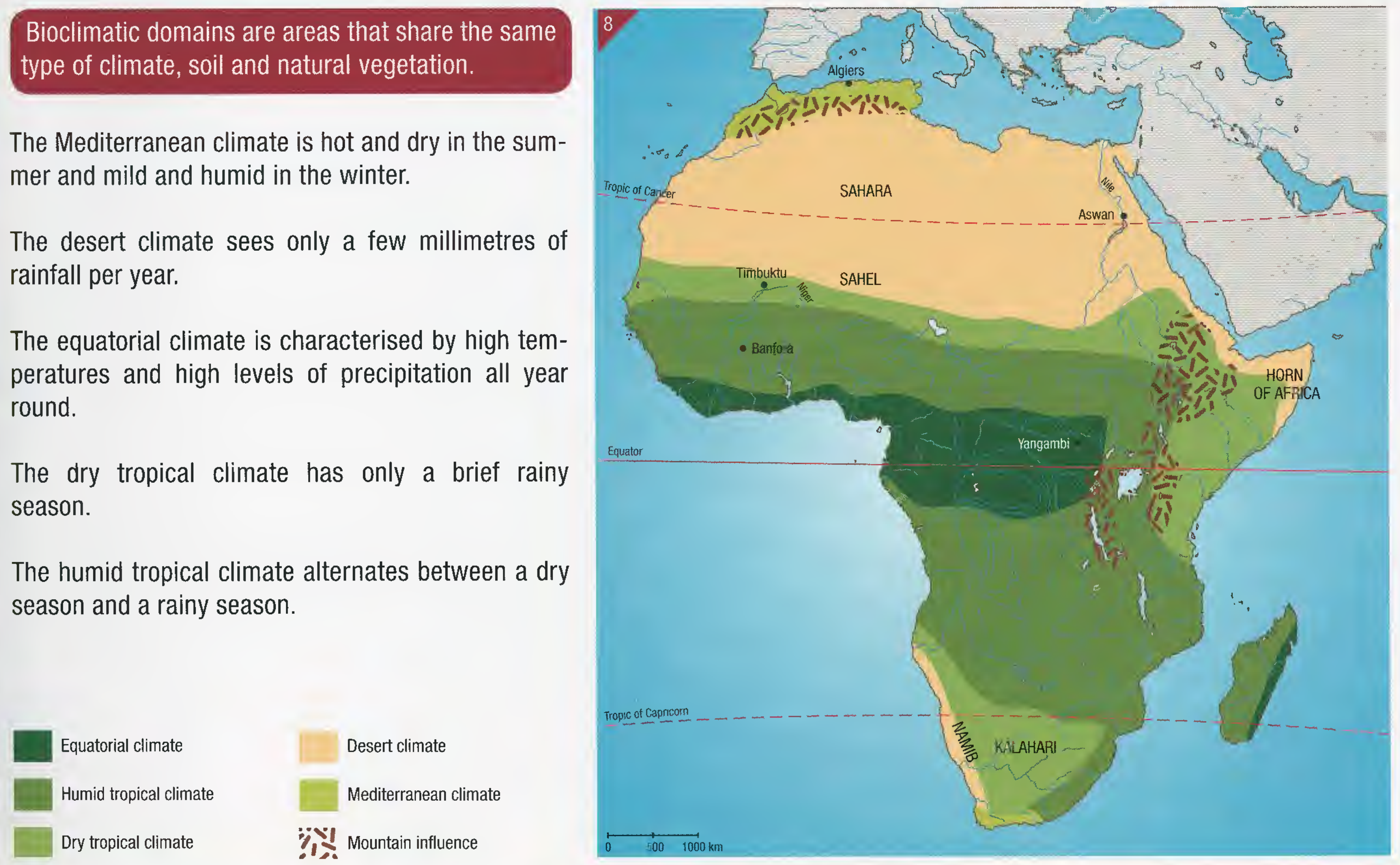
The Mediterranean climate is hot and dry in the summer and mild and humid in the winter.

The desert climate sees only a few millimetres of rainfall per year.

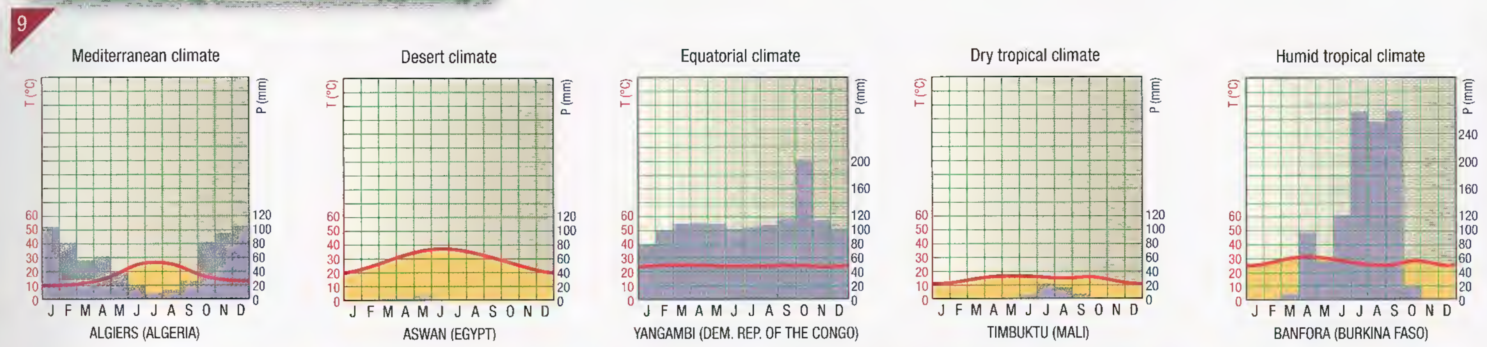
The equatorial climate is characterised by high temperatures and high levels of precipitation all year round.

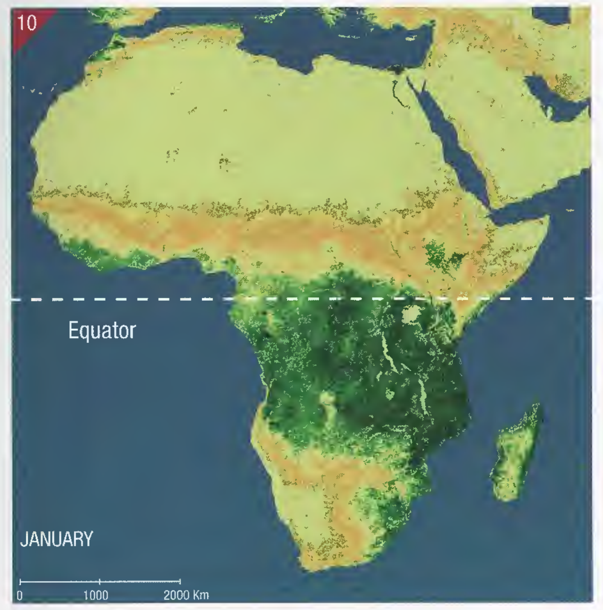
The dry tropical climate has only a brief rainy season.

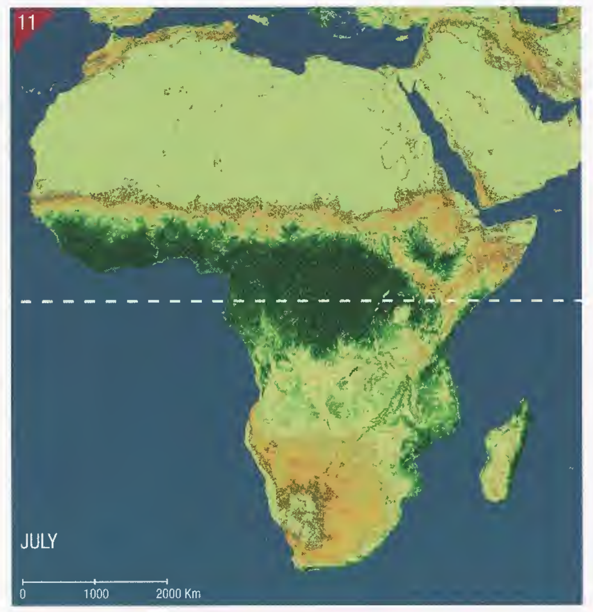
The humid tropical climate alternates between a dry season and a rainy season.



TEMPERATURE AND PRECIPATION







A typical feature of tropical regions is the alternation between rainy and dry seasons. Rainfall patterns are reversed depending on whether one is located north or south of the Equator. These two satellite images, taken six months apart, show vegetation growth and how it reaches its peak during the rainy season.

During its growth phase, vegetation undergoes strong photosynthesis activity, absorbing large amounts of visible light, while at the same time reflecting infrared rays. By processing satellite data obtained in these two wavelengths, it is possible to obtain images that clearly show those areas where strong vegetation growth is occurring. This index (NDVI) is often used to estimate the density of vegetation cover and how it evolves.

Information for teachers

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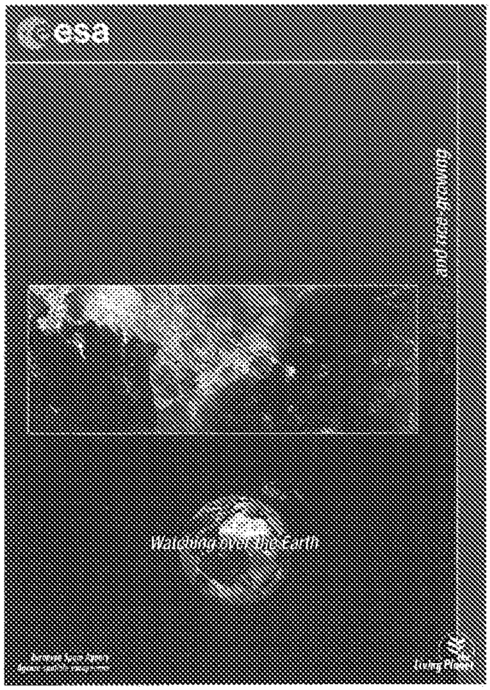
Worksheet 5: Asia and rice-growing



Worksheet 5 examines rice-growing in Asia. Geographically it focuses on rice-growing in the Mekong delta in Vietnam. As a crop, rice has extensively contributed to the high population density on this continent, which accounts for 3 of the 4 global regions with the highest population density (East Asia ~ 1.5 billion inhabitants, Southeast Asia - 580 million inhabitants, South Asia - 1.3 billion inhabitants).

This worksheet can be used to:

- observe and identify, with the help of different types of documents, the shapes and landscapes inherent to rice-growing;
- draw connections between the foundations of an agrarian civilisation, a "natural" phenomenon (the monsoon season), and high population density;
- identify the major rice-growing deltas and work with different scales using various documents provided;
- apply concepts such as agrarian civilisation, monsoon, density, nourishing river, rice-growing, etc.

Rice-growing in Asia's monsoon areas

Rice is more than "just another grain". Throughout Asia, it has played a role in the region's civilisations. Rice is the leading cereal produced for human consumption. It is the staple food for all the societies living on the vast Asian continent. It is grown in tropical regions, in particular in the deltas of major rivers which flow down from the Himalayas, such as the Mekong, Song Ho, Chao Phraya, and Irrawaddy rivers. Rice is also grown in mountainous regions with abundant rainfall. Rice is special not only because of its nutritional qualities----the straw from the rice plant is used as fuel, manure, to make ropes, bags, hats, etc. For a long time, rice was used in place of currency. It has had both economic and social implications: the need to control water and irrigation systems brought about a very complex pyramidal social structure.

Rice is also considered to contribute to population growth as it is extremely labour intensive and determines which regions will have high population density. Lastly, rice-growing creates orderly landscapes designed to accommodate dikes, canals, gates, etc.

Rice is a demanding plant, which needs to grow in temperatures of at least 20°C over three months, uses 30,000 m^3 of water per hectare, and requires special seedling planting techniques following 50 days in nurseries. The monsoon climate is perfectly suited to growing rice.

In 2003, 9 out of 10 leading rice-growing countries in the world were in Asia: China (166 MT), India (115 MT), Indonesia (52 MT), Bangladesh (38 MT), Vietnam (35 MT), Thailand (27 MT), Myanmar (22 MT), the Philippines (13 MT) and Japan (10 MT), together accounting for 90% of global rice production. Paradoxically, rice is the least traded grain in the world (barely 3% of all rice produced is exported), which shows its role in making Asian countries with monsoon climates self-sufficient in terms of food production. Thanks to improved crop yields, Thailand has become the world's leading exporter of rice (30% of total volume at nearly 6 MT).

The satellite images

Cover page

Cover image: Mekong Delta

In this satellite image, one can easily see where the silt has been deposited by the river. The formation of the Delta is continuing apace and it is progressing into the South China Sea at a rate of approximately 75 metres per year. Meanwhile, the eastern coastline of the southern part of the Delta is subject to severe erosion, which may be connected to a recent reduction in deposits on the coast or to marine encroachment (see also image 2).

Core content

Image 1: South-East Asia (ESA/Envisat, 2004)

This image shows the Himalayan mountain range, which constitutes a vast reservoir of water feeding the rivers of the region. In this image oceans and seas are in black because the data acquired from these marine territories have not been taken into account. There are no clouds because the image is a composite of multiple partial views taken at different periods when the sky was clear.

Image 2: The Mekong Delta (ESA/Envisat image)

In this close-up of the Delta, it is possible to make out the arms of the river and the cloud cover present at the time of capture. One can also see the silt which has been expelled into the sea. The green area in the centre is a more humid zone where vegetation is more highly developed.

Image 5: Rice fields in the Mekong Delta (Spot 5 image)

Vegetation reflects not only in the green band but also in the near infrared, notably when photosynthesis is very active. The use of this band is therefore a highly effective means of spotting vegetation and highlighting variations in it.

By convention, the near infrared channel is represented in red in these satellite images. To obtain an image in natural colours requires digital processing, which restores the green colour to these areas. (Worksheet N° 6, "Humans on Earth" and Worksheet N° 11, "Satellite images and their colours" also deal with these questions)

Abundant vegetation can be seen in the humid areas close to the river as can the irrigation canals taking water to areas further away. Certain fields, in blue, indicate rice fields in which the rice has not grown to a significant size, and thus shows variations in the speed of rice growth.

Image 8: Effects of the monsoon (Image by MODIS/NASA GSFC)

These two pictures taken in October 2002 (during rainy season) and in January 2003 (in the dry season) show the size of the Tonle Sap great lake, which declines from more than 12,000 km^2 to just a few hundred square kilometres, and in depth from 10 to 2 metres (Image from the "Rapid Response Team", based on MODIS data).

Page 5 - Crop management

It is important to emphasise the role played by radar instruments, which enable the production of images in a region where there is frequent and substantial cloud cover. It is mainly this type of image that is used by scientists to conduct detailed observation of the state of rice fields.

Image 10: Mekong Delta coastal area (ERS-2 – SAR)

This "multitemporal" image is formed from a series of images acquired by the European Space Agency's ERS-2 satellite's radar instrument. It makes it possible to differentiate between the various rice-growing areas in the western part of the Delta.

The image was created by combining radar captures performed at different times, each of which is attributed a different colour, according to an agreed code: (5 May = red / 9 June = green / 14 July = blue). Each colour indicates a time and place at which the rice plants reached maturity. A single image of this type is therefore able to provide specialists with comprehensive information, zone by zone, on the various rice varieties planted, but also on productivity and irrigation quality.

Image 11: Series of radar images of the Mekong Delta coastal area (ERS-2 – SAR)

These six black and white thumbnails were combined to form colour image10. Each thumbnail shows the increase and decrease in the intensity of the radar signal over a given time. Such images require that several acquisitions of data are performed at precise dates.

Page 6 – "How do satellites work?"

The aim of this page is to explain the principle of radar instruments on satellites.

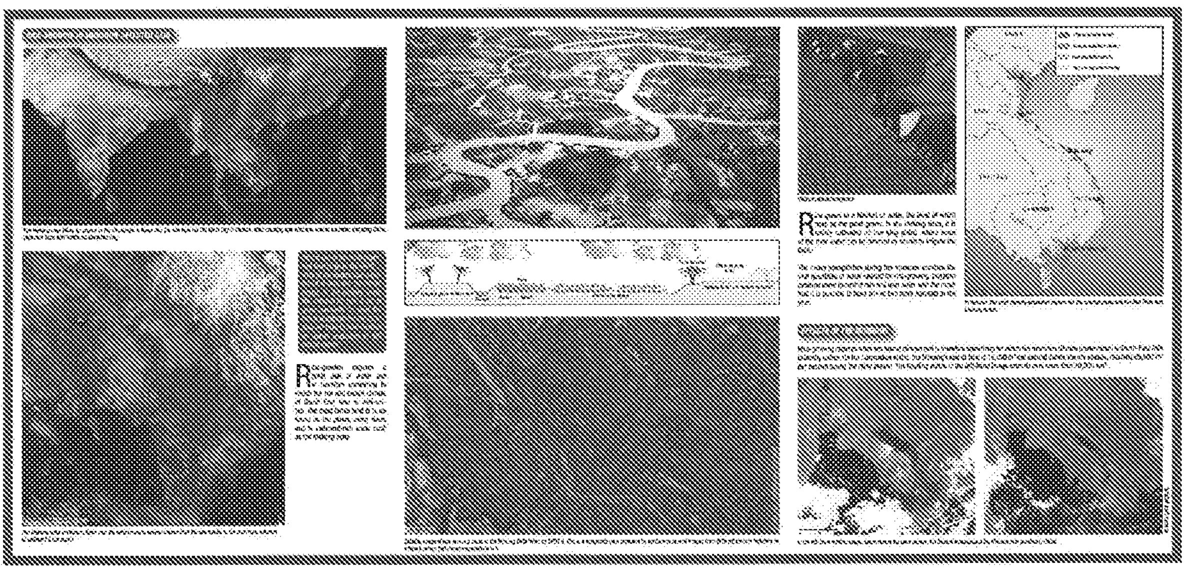
Image 12: The principles of radar imaging

There are two main sensor types used in remote sensing satellites: passive and active sensors. Passive sensors detect rays emitted directly by the Earth, such as thermal infrared rays or waves reflected by the Earth's surface (sunlight). Active sensors detect the echo from a signal (in the form of microwaves) which they themselves have sent. This is how radar instruments operate.

Thus, for each target that receives the wave emitted by the radar there is a corresponding "echo", which is of varying intensity and which returns more or less quickly. The amplitude of the reflected signal is measured to discern different targets, and the delay between the transmission and reception of the signal is used to determine the target distance.

Images 13, 14, 15 and 16: Radar signals to measure rice growth

Radar waves are just as sensitive to relief as to the ruggedness of terrain and its humidity. Radar is therefore as effective at detecting a mountain or vegetation cover as it is an expanse of water owing to their distinct echoes.



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This DVD-ROM contains a form in PDF format entitled Pupil questionnaire, which can be printed out and distributed to pupils. Lastly, there is a version of the questionnaire in Word format, which allows the teacher to adapt it to the needs of his/her lesson.

Online resources

www.esa.int	ESA (European Space Agency) website
www.esa.int/SPECIALS/ESRIN_SITE/index.html	ESRIN (European Space Research Institute) website ESRIN is ESA's centre for Earth observation
www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

RICE-GROWING

www.unctad.org/infocomm/anglais/rice/crop.htm	Information on rice farming. UNCTAD website. (United Nations Conference on Trade and Development)
www.fao.org/rice2004/en/aboutrice.htm	FAO (UN Food & Agriculture Organization) website. Information on rice growing
www.eomd.esa.int/booklets/booklet185.asp	ESA information on rice growing and remote sensing

MONSOONS

www.metoffice.gov.uk/education/secondary/students/monsoons.html	Met Office information on monsoons

Satellite images

esa · SPOT IMAGE · NASA

ESA project lead	Agostino de Agostini	Documentation	Valérie Massignon - XYZèbre
Editorial concept	Frédéric Létang / Patrice Deserne	Graphics	Boris Uzan
Original text/project oversight	Frédéric Létang	Illustrations	Philippe Bouillon - Illustratek
Scientific advisors (ESA)	Isabelle Duvaux Béchon / Laurence Ghaye	Translations (ESA)	Colin McKinney / Anthony Blend
Pedagogical advisors	Éric Janin / Jean Jandaly	Production	Europimages - Aliette Cremer

Worksheet N° 5 – Asia and rice-growing

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – In what part of the world is rice-growing most widespread? For what purpose is the rice grown?

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2 – What is special about this grain? What does it need in large quantity?

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3 – What is the name of the unusual climatic event that happens in this part of the world? What does it bring?

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4 – Look at and describe the landscapes shown in the two photographs. How can you tell that rice-growing requires a lot of hard work?

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5 – Look carefully at the map of Vietnam. Where are the most densely-populated regions? Why?

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6 – How can satellite images be useful for rice growers?

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7 – What is the name of the instrument placed on-board satellites which helps observe the relief and the different growth stages of the rice plants in the rice fields? What exactly does this instrument detect?

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Information for teachers

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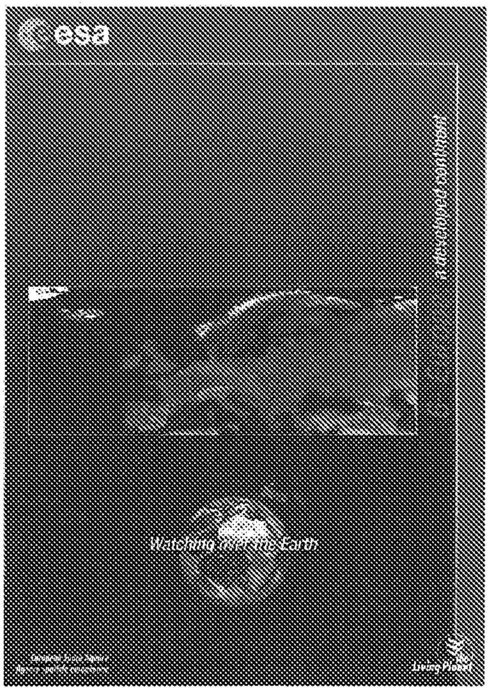
Worksheet 6: Europe, a developed continent



Worksheet 6 is centred on the study of Europe. Its aim is to focus on the major urban concentrations which make this part of the world the prosperous and dynamic continent it is. In terms of scale, the main focus is on western Europe, although some large urban areas such as London and Rotterdam are also examined in more detail.

This worksheet can be used to:
- locate and identify the continent's major urban centres and economic hubs;
- analyse urban landscapes;
- apply concepts such as city, landscape, pollution, etc.

The major areas of economic activity in Europe

Europe is home to 12% of the planet's inhabitants concentrated on 7% of the Earth's landmass. It has the third largest population concentration after East Asia and South Asia. The smallest of the Earth's continents (which is actually a part of the Eurasian continent), it is also the one whose urban and trade legacy reaches furthest into the past. It is one of the most densely populated regions in the world with estimated average density of 100 inhabitants per square km (not taking into account that part of Russia which is in Europe, which, along with Russia, has a density of 80 inhabitants per square km) which is double that of the global average density. Nonetheless, population distribution is uneven. This can be explained by both geographical factors (mountainous regions and large parts of Scandinavia's interior are less populated than the plains, river valleys, and coastal regions) and by historical factors (large valleys have always formed the communication axes which are key to major trade flows and which determined the siting of market towns).

The core of this population centre is made up of the major cities in the centre of Europe which links the system of vast agglomerations between London in the North and Genoa in Italy in the South. This core area constitutes the essence of the economic, financial, and demographic power of Western Europe and the European Union. Its cities, commercial activity, democracy, and now economic liberalism make up the essential pillars of a strong European identity. Europe (including Russia) produces a third of the planet's wealth and is one of the three major centres of the world economy (along with the United States and East Asia). It is a wealthy and developed continent. In addition, of the 20 countries with the highest HDI (Human Development Index) rating, 15 are in Europe. Of the 20 best health care systems (according to the WHO), 17 are to be found in European countries.

It is the product of a long social history, and despite persistent differences in development between West and East European countries, the region still serves as a model for development for the rest of the world. The European project and its successes—enlargement, establishment of a single currency, thriving intra-community trade—contribute to the idea of a continent where, despite certain internal difficulties, economic prosperity, social progress, and peace between neighbouring nations has succeeded in flourishing.

The satellite images

Cover page

Cover image : The European continent (Envisat/MERIS image)
This image, taken at the end of spring, shows northern and mountainous areas still covered in snow.

Core content

Image 1: Map of economic activity in Europe
This map of the European continent is shown at approximately the same scale as the two neighbouring images showing Europe by night and the zones severely polluted by nitrogen dioxide. This layout is designed to permit instant correlation of the information in the different images.

Images 2 and 3: London (Spot 5 images, 2003)
Greater London has a population of 7.4 million and is one of the most densely populated areas in Europe. One in eight inhabitants of the United Kingdom lives in Greater London.
The images here show only central London.

Image 4: Europe by night (NASA/DLR)
This optical image shows the use of electric light in major cities and other urban areas. It was created using partial views acquired during cloudless and moonless periods. The contrast has been adjusted through digital processing, thus highlighting the extent of urban areas. The contrast with the Sahara Desert is particularly pronounced. It can be interesting to view this image alongside the map showing the major areas of economic activity in Europe and the image showing the distribution of NO_2 pollution in Europe.
The image, from NASA (MODIS), was processed by the German Remote Sensing Data Center, operated by the German space agency, the DLR.
In 2004, electricity production in the European Union stood at 2950 TWh (terawatt hours). By comparison, the worldwide figure is 17450 TWh (NB: TWh = a thousand billion watts/hour or 1 billion KWh).

In Europe, in 2004, consumption per habitant per year stood at 6565 KWh, as opposed to 546 KWh in Africa. According to UN estimates, close to two billion humans had no access to electricity in 2004 (source: AIE).

Image 6: NO_2 emissions in Europe (Envisat/SCIAMACHY)
This image is produced from readings taken over 18 months by the SCIAMACHY instrument. (Image by IUP, Heidelberg). This instrument records the spectrum of sunlight shining through the atmosphere. Different gases present in the atmosphere influence the visible spectrum in various ways, thus allowing some of them to be identified.

This map reveals the impact of human activity on air quality. Nitrogen dioxide (NO_2) mainly produced by human activity and excessive exposure to this gas causes serious health problems. Over highly polluted large cities such as London, the ratio of NO_2 particles can reach levels of one hundred parts per billion air particles. There is little data on this pollution taken from sensors on the ground; only space-based sensors are able to carry out effective global monitoring. (Additional information on this map is to be found in Worksheet N° 3, "Humans on Earth").

Image 7: The port of Rotterdam (SPOT 5 image, 1999)
The vegetation surrounding inhabited areas and industrial facilities is shown in red. Satellite observation tools do not see in colour. They record in various spectral bands the amount of light reflected by the ground. Through processing the data in laboratories a different colour can be allocated to each spectral band in order to produce an image.

Satellite instruments such as SPOT are sensitive to the near infrared. (It is an important wavelength for observation from space, especially because vegetation reflects very strongly in this spectral band). However, SPOT does not record blue.
When producing an image, laboratories processing the data allocate - by convention - the colour red to that which is seen in infrared. However, this means they have to "shift" the other colours. Thus, the colour green is allocated to red-shaded areas and the colour blue to green-shaded ones. A coloured composition is thus created with false colours, in which vegetation is shown in red and water is black or dark blue. All these colours combine with each other, depending on the amount of light recorded, to reproduce the full range of shades.
This is the convention, and various choices can be made: the colours the general public is accustomed to are restored in the images produced, with green vegetation and blue water. These choices and representations are equally valid: landscapes as seen by the human eye are not actually any more true or real than when they are represented in infrared or by radar. (See Worksheet N° 11, "Colours in satellite imagery")

Page 5 - Europe contains vast tracts of agricultural land

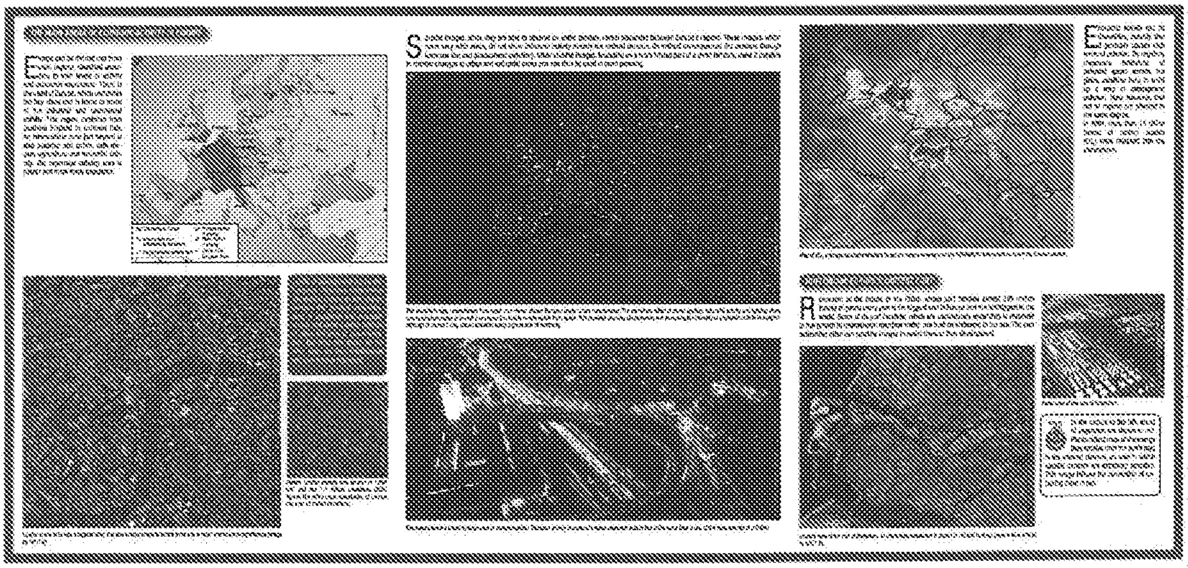
Images 10 and 11: Agricultural area north of Seville (two SPOT 5 images, 2003)
These two images of an agricultural region near Seville show the various possible processing methods. The first image reproduces the colours according to standard human vision (the colours match those in aerial photography) whereas in the second, the colour red has been allocated to the infrared channel.

Page 6 – "How do satellites work?"

Images 13 and 14: Urbanisation in Erfurt (ESA)
Satellites provide precise data for land classification and land use. The example provided here is that of an ESA study carried out on behalf of the town of Erfurt in Germany.

This type of sensing requires observations on the ground and by satellite to work in conjunction with one another. Satellites do not themselves "see" the characteristics of different land use types. However, the measurements and data they provide can be used to highlight with a very high degree of reliability any variation in terrain: scattered settlements do not send back the same signal as more densely inhabited areas, while pasture land does not send back the same signal as forest or cultivated fields. This makes it possible to create precise maps showing the land in all its variety and where the different land types are to be found. It is by conducting parallel studies on the ground that it is possible to determine the land use and characteristics of each area. This data is then correlated with data returned by the satellite. Armed with this information, which requires numerous studies and checks, it is then possible to interpret maps produced by satellite without having to carry out exhaustive investigations on the ground.

Regular satellite observations also provide the opportunity to study variations in land use over time. Thus, with space-based resources one can obtain up-to-date information on all the changes in a given region.



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earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

EUROPE

europa.eu/index_en.htm	European Union portal
www.fco.gov.uk/servlet/Front?pagename=OpenMarket/Xcelerate/ShowPage&c=Page&cid=1007029391674	Information on the European Union and Britain's place in it

URBAN SPRAWL IN EUROPE

reports.eea.europa.eu/eea_report_2006_10/en	The challenge of urban sprawl in Europe. Includes link to downloadable PDF

ATMOSPHERIC POLLUTION

www.esa.int/esaEO/SEM340NKPZD_index_0.html	Global air pollution map
www.esrin.esa.it/export/esaCP/SEM2AS1DU8E_index_2.html	Air pollution in London

Satellite images

esa · SPOT IMAGE · DLR · NASA

ESA project lead	Agostino de Agostini	Documentation	Valérie Massignon - XYZèbre
Editorial concept	Frédéric Létang / Patrice Desenne	Graphics	Boris Uzan
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Pedagogical advisors	Éric Janin / Jean Jandaly	Production	Europimages - Aliette Cremer

Worksheet N° 6 – Europe: a developed continent

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – What is the difference between the centre of Europe and its outlying regions?

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2 – Compare the map of Europe and the satellite image of Europe by night. What observations can you make?

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3 – Based on the satellite image of Europe by night, what conclusions can you make regarding urbanisation levels on the Iberian Peninsula?

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4 – How is nitrogen dioxide pollution distributed across Europe? Why?
What are the main reasons behind this pollution?

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5 – Compare the satellite image of Rotterdam and the aerial photograph of the port of Rotterdam. What industrial structures can you identify on both images?

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6 – Andalusia is an important agricultural region. Which regions of Europe import its agricultural production?

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7 – What do you think is the purpose of having detailed maps of urban areas and of their different features?

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EUROPE CONTAINS VAST TRACTS OF AGRICULTURAL LAND

9

Aerial view of Andalusia.

The great diversity of Europe's soil and climate means that conditions for agriculture are good. Consequently, Europe has a rich variety of rural and agricultural areas covering most of its landmass.
Farming has become a minority activity but is nonetheless essential to the economic balance of the continent.
Andalusia in Spain has a climate which provides high yields and allows precocious crop development (crops can be grown early). It is one of Europe's most important agricultural areas, and much of its production goes to the north of the continent.

When accurate observation of vegetation cover is required, images are often captured by satellites in the near infrared. It is this wavelength which is used to detect vegetation since it reflects more energy in the infrared than in the green channel. Such images thus show traces of vegetation and variations in the type of vegetation in more detail and with greater accuracy.

10

11

Agricultural area north of Seville in "true" colour, left, and "false" colour, right (images by SPOT 5).

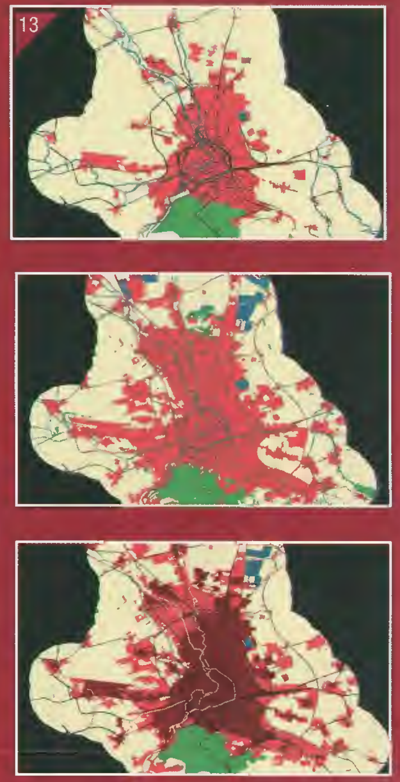
How do satellites work?

Urban expansion in Europe

12

Aerial view of Erfurt city centre.

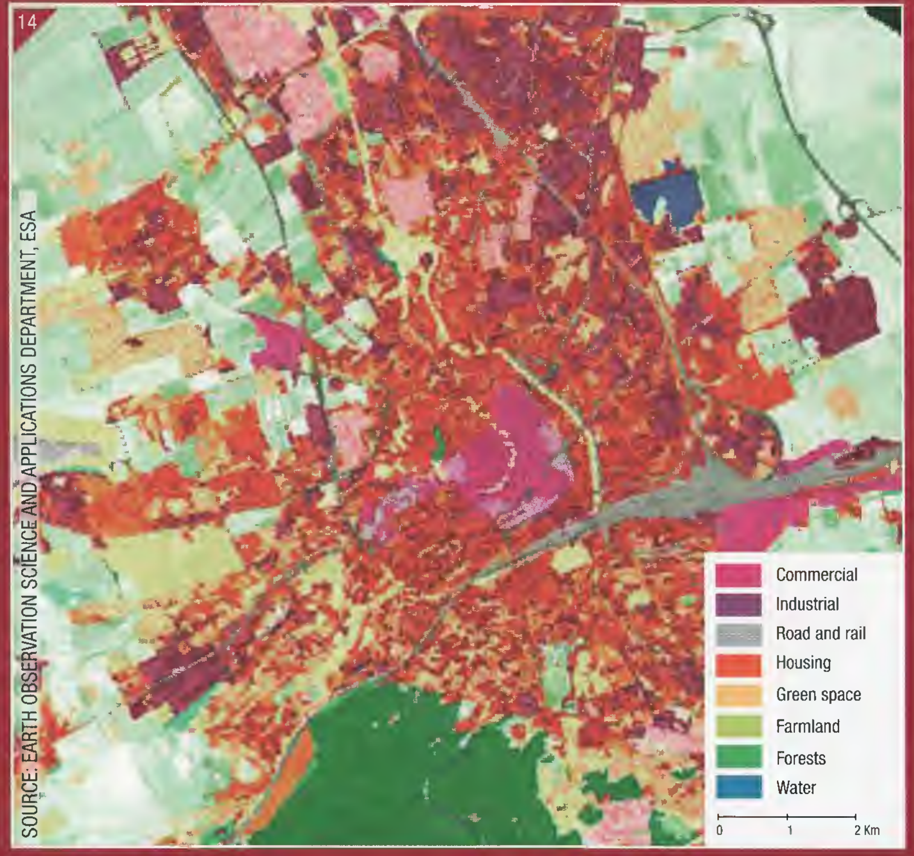
13



Expansion of the city over a 30-year period.

Using satellites to analyse the characteristics of urban areas

14



A satellite image laboratory-processed to highlight different types of urban areas.

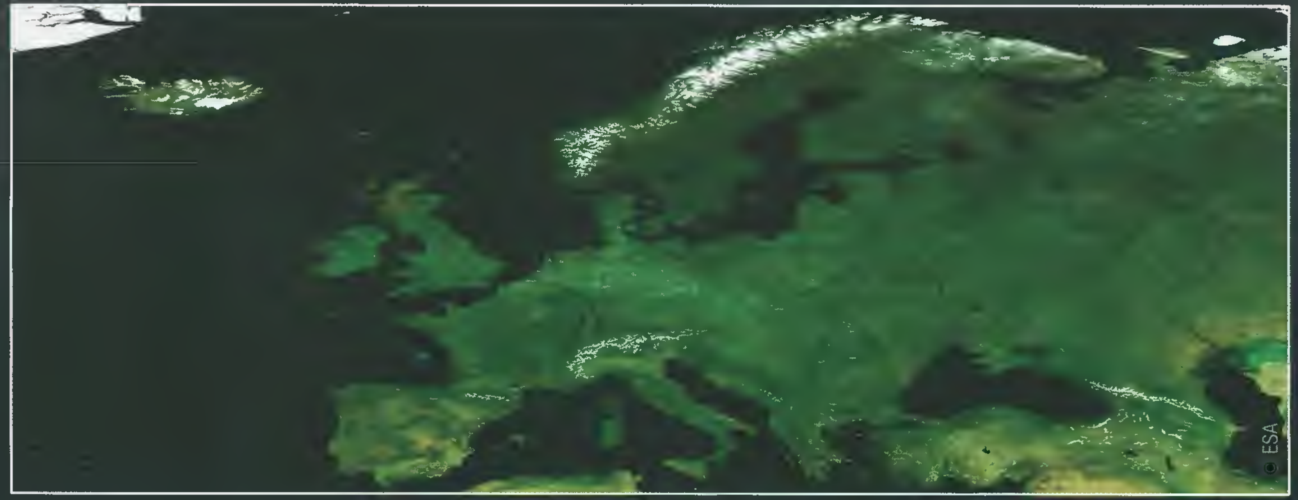
Light and the signals reflected by the Earth's surface display different characteristics depending on their nature. In built-up areas, a zone containing detached houses will not send back the same signal as one containing apartment buildings. Likewise, forests do not send back the same signals as meadows or fields.

Armed with a good knowledge of land use (acquired from ground-based observation), specialists correlate this knowledge with measurements from satellite images. They observe how the satellite reacts to certain land characteristics in a small area designated as a test zone. Then, knowing that when they obtain the same results these correspond to the same land types, they can draw up precise land use maps of other regions.

Satellites are used in the production of accurate and regularly updated maps. They can be of assistance in all types of development projects, notably in urban areas.

esa

6- Europe: a developed continent



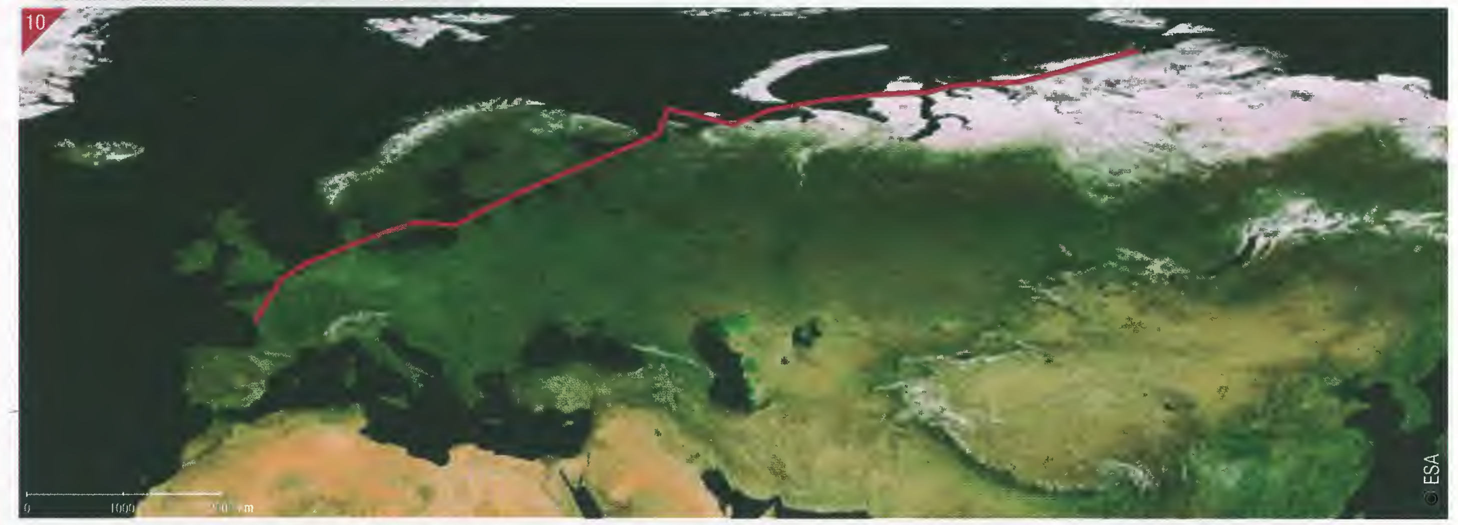
Watching over the Earth

European Space Agency
Agence spatiale européenne

the Living Planet

THE MIGRATION OF BRENT GEESE

10



This satellite image, taken at the end of autumn, shows Europe and the north of the Asian continent. Siberia is already covered in snow. Soon ice will engulf the entire coastline. There will be insufficient vegetation and food, especially for young birds fledged in the course of the year. Brent geese therefore leave this northern region behind to winter on the coast of Europe, where they will find all the necessary food. The red line indicates the route they will take.

11

Migrating geese have been known to gather in the tens of thousands.

12

Brent geese wintering on the coast of Poitou-Charentes, France.

Their diet includes seeds, buds, grass, worms and insects, but also small fish, shellfish, and green algae. In the daytime Brent geese feed on sea grass in shallow waters. By night they gather in groups out at sea.

13

The Atlantic coast close to the Garonne estuary, France. Brent geese often gather on the islands on the Atlantic coast, where they can enjoy relative tranquillity (image by Envisat).

How do satellites work?

Satellite positioning systems

14

15

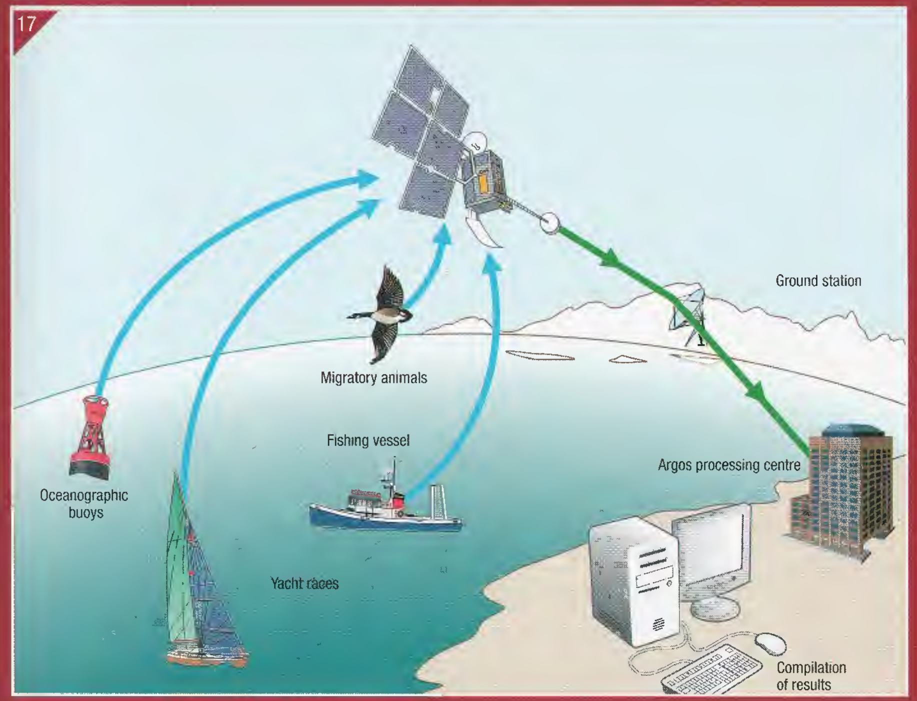
The geese leave Europe at the end of May to return to Siberia. It takes them about 3 weeks to cover the 5,000 km that separate Europe from western Siberia, but they often stop off for a few days on the White Sea (near Arkhangelsk) where they find eelgrass (*zostera marina*), which is only just beginning to emerge as the sea ice starts to melt.

16

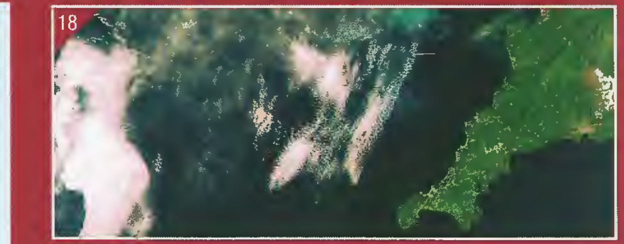
This scientific study monitored 8 birds fitted with tracking devices during their migration from the coasts of Europe to the Taymir Peninsula in northern Siberia, which provides a suitable environment for mating and where they return to nest each year.

One can see by the route taken, indicated by the coloured line, that the geese always stop off on the coast in areas where they can find food.

17



18



This small tracking device weighing only 30 grams is the one most commonly used to monitor the migrations of many bird species. It contains a transmitter linked to the Argos satellite system with which it is possible to monitor the routes the birds take.

Different types of device exist for tracking other animals such as sea turtles and penguins.

Applying the same principle, it is also possible to track the movements of shipping, land convoys and weather probes which are carried along by wind and by sea currents.

esa

7- Living species and their environments

Watching over the Earth

European Space Agency
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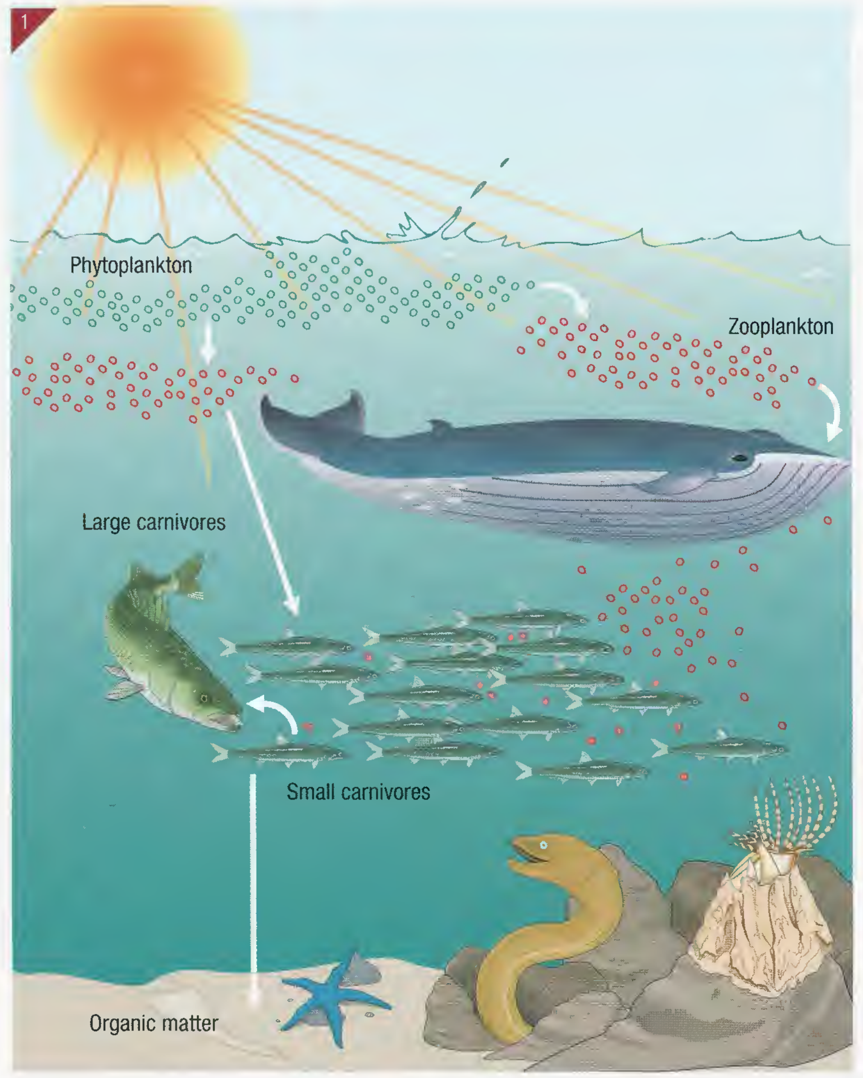
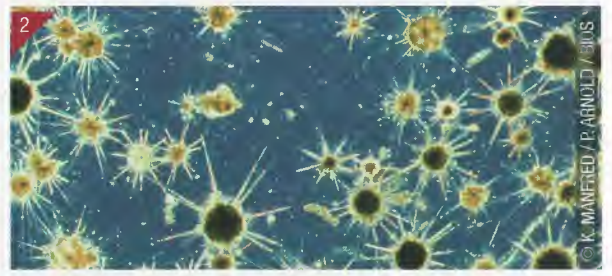
the Living Planet

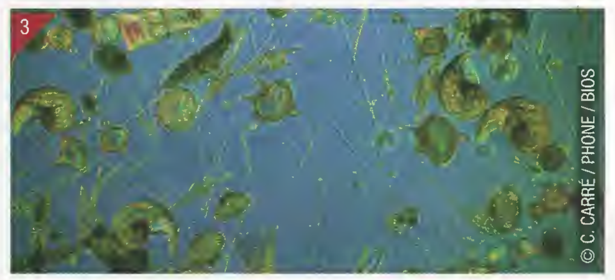
MARINE FOOD CHAINS



At the bottom of marine food chains are tiny algae suspended in sea water called phytoplankton. In the spring they increase rapidly in number due to the sun's rays, sometimes producing a "bloom". This form of marine vegetation can develop at sea over an area of several hundred square kilometres.
These algae provide the small pelagic shrimps known as zooplankton with food 300 to 400 times richer than their usual diet, thus allowing them to develop rapidly. They in turn form the basis of the whales' diet, along with fish.

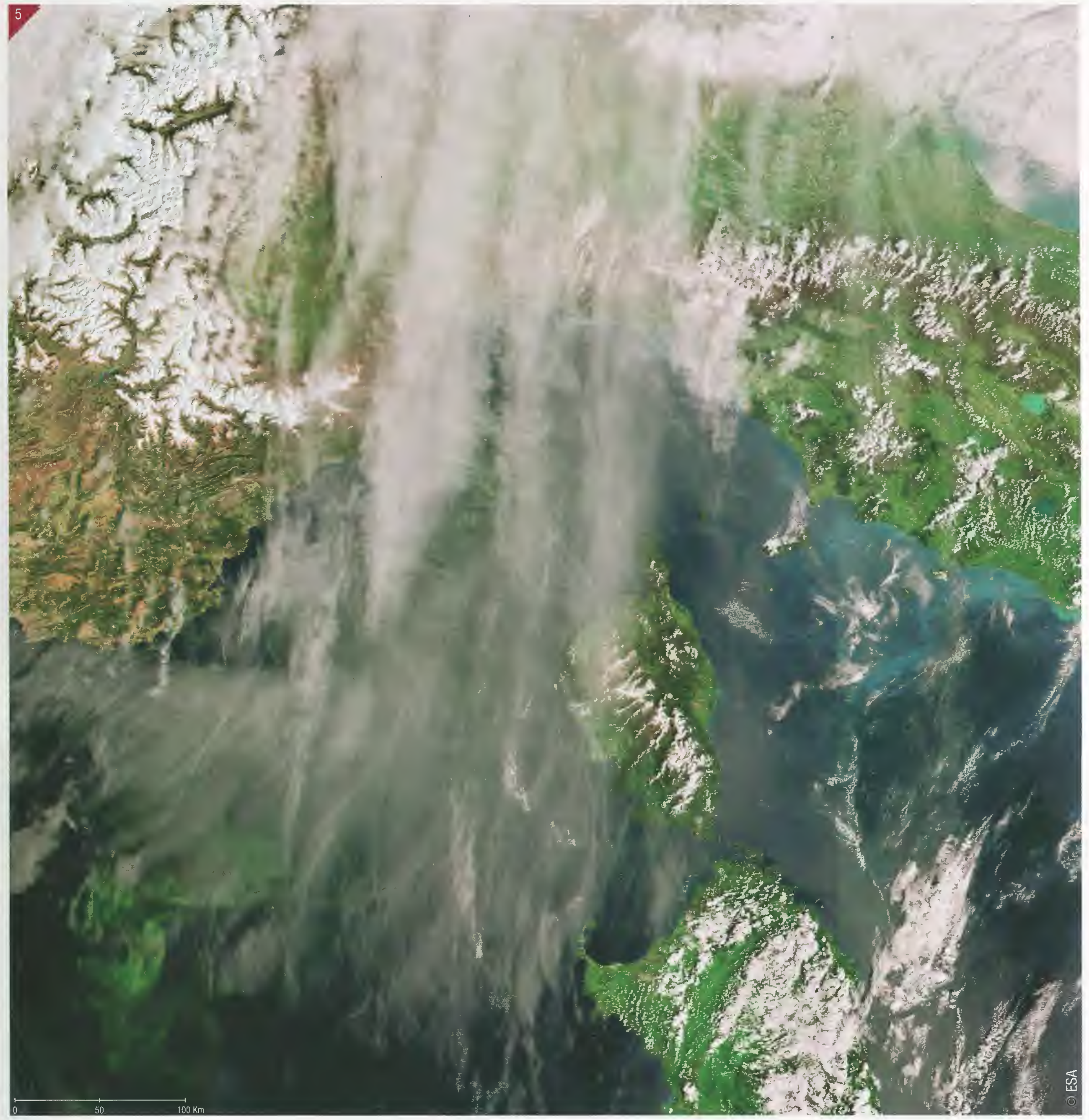


Phytoplankton

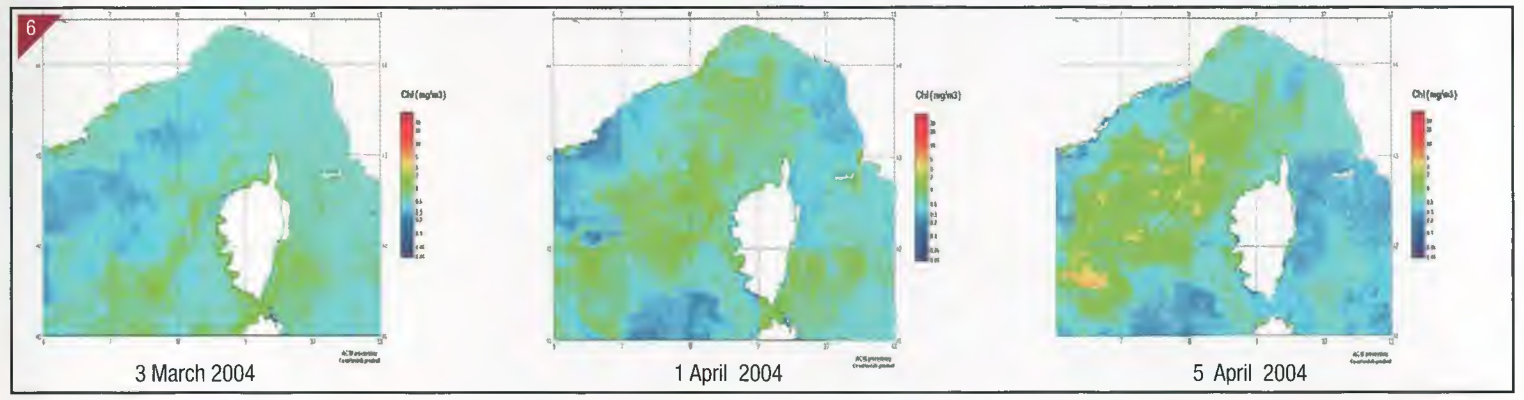


Zooplankton

The fin whale (Balaenoptera physalus), at 22 metres and over 50 tonnes, is the second largest animal after the blue whale. These mammals are estimated to number 3,000 to 4,000 in the western Mediterranean. During the summer, the largest numbers of fin whales are to be found in the Ligurian Sea north of Corsica, since it is there that they find large quantities of their favourite food, pelagic shrimps (or krill), swimming in tightly packed schools.



Bloom observed in the Ligurian Sea between Corsica and the French coast (bottom left in the image above) in April 2004. In this picture the bloom is recognisable due to the green colour of the water.



Graphs showing chlorophyll concentration levels recorded by the Envisat satellite's MERIS instrument between March and April 2004.

WHALES IN THE MEDITERRANEAN

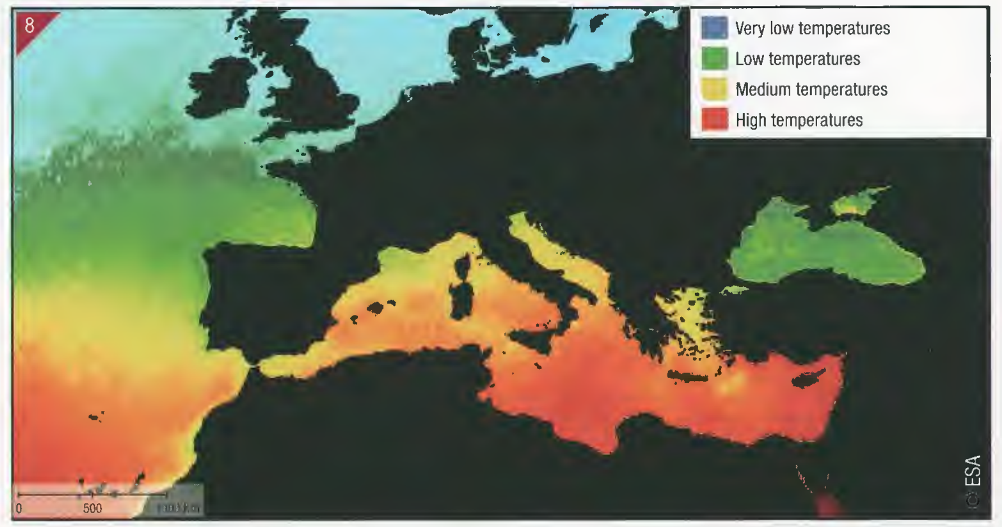
The western Mediterranean is a veritable marine sanctuary for cetaceans but is also subject to heavy maritime traffic. Knowledge of the area and when these mammals are present—and especially when they reproduce—is very important in limiting the causes and risks of disturbances to them.

As a result of observation carried out at sea by specialists and scientists, it has been possible to verify the connection between the appearance of food (biomass and consequently zooplankton) as observed by satellite, and the presence of large schools of whales. These studies have shown that whales naturally adapt their movements to the quantity of food available.

REGULAR SATELLITE MONITORING

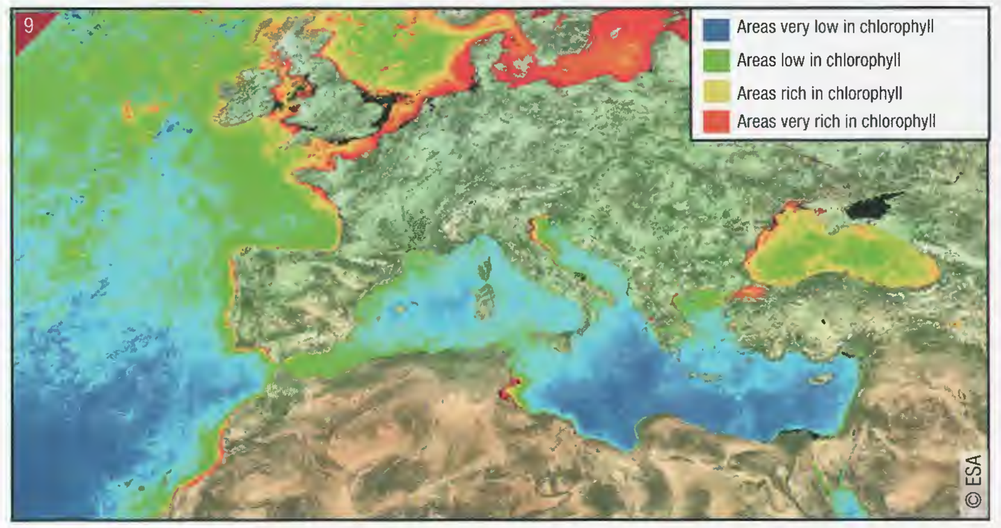
Nutritional resources in the Mediterranean are subject to significant seasonal and annual variations.
With the use of satellite images it is possible to evaluate the quantity of biomass (phytoplankton and zooplankton) over a large area and over long periods. This is done by measuring chlorophyll concentrations and sea surface temperature variations from space.

A certain amount of time elapses between chlorophyll peaks and the development of zooplankton. Therefore, by analysing satellite images it is possible to predict the areas in which whales are likely to gather.



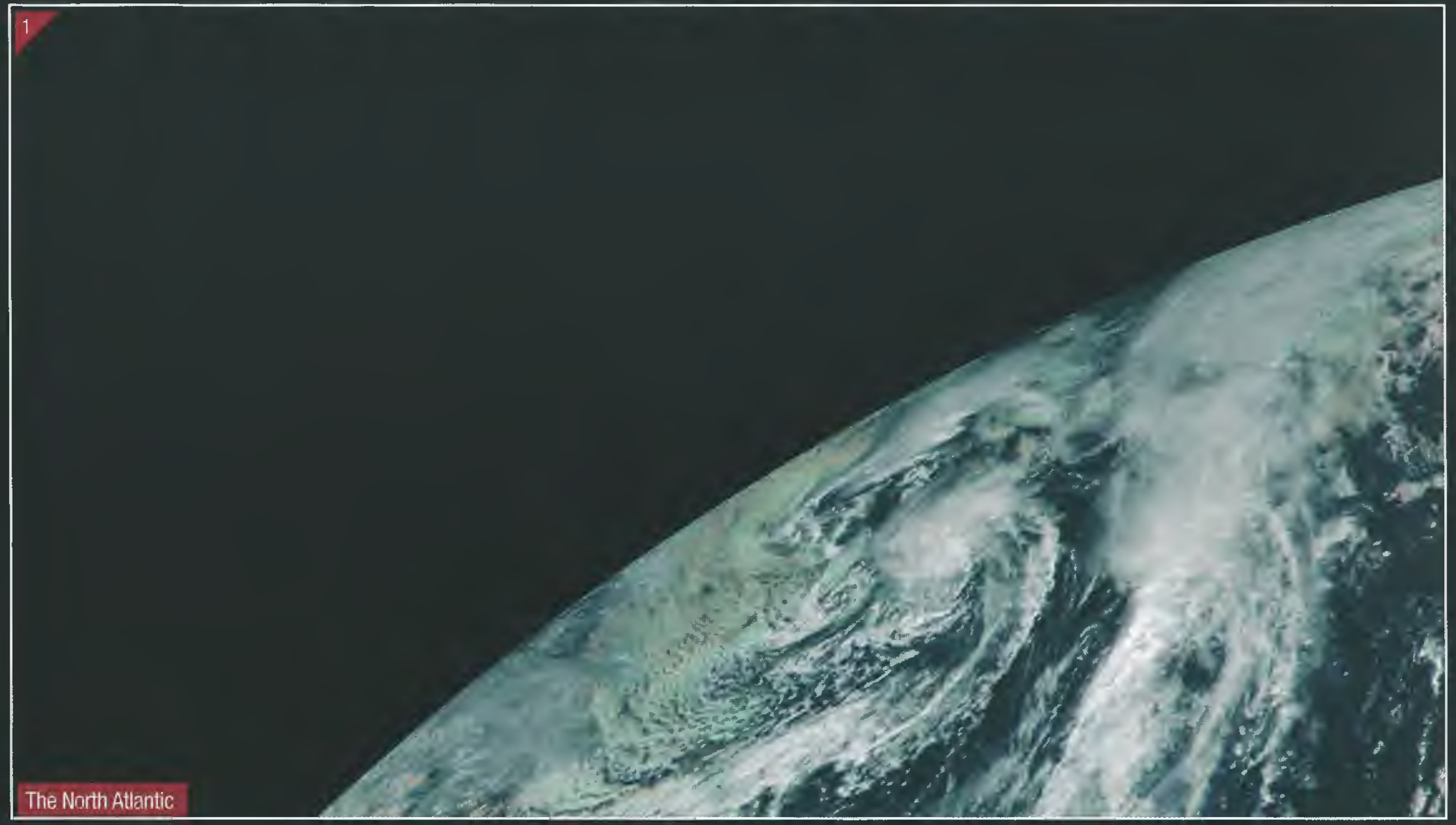
Sea surface temperatures

The colour of the sea is determined by the interaction of the sun's rays with the substances and particles present in the water. Suspended matter is largely composed of phytoplankton, a photosynthetic organism containing chlorophyll. Chlorophyll is a pigment which absorbs light in the red and blue wavelengths and transmits it in green, which explains its colour.

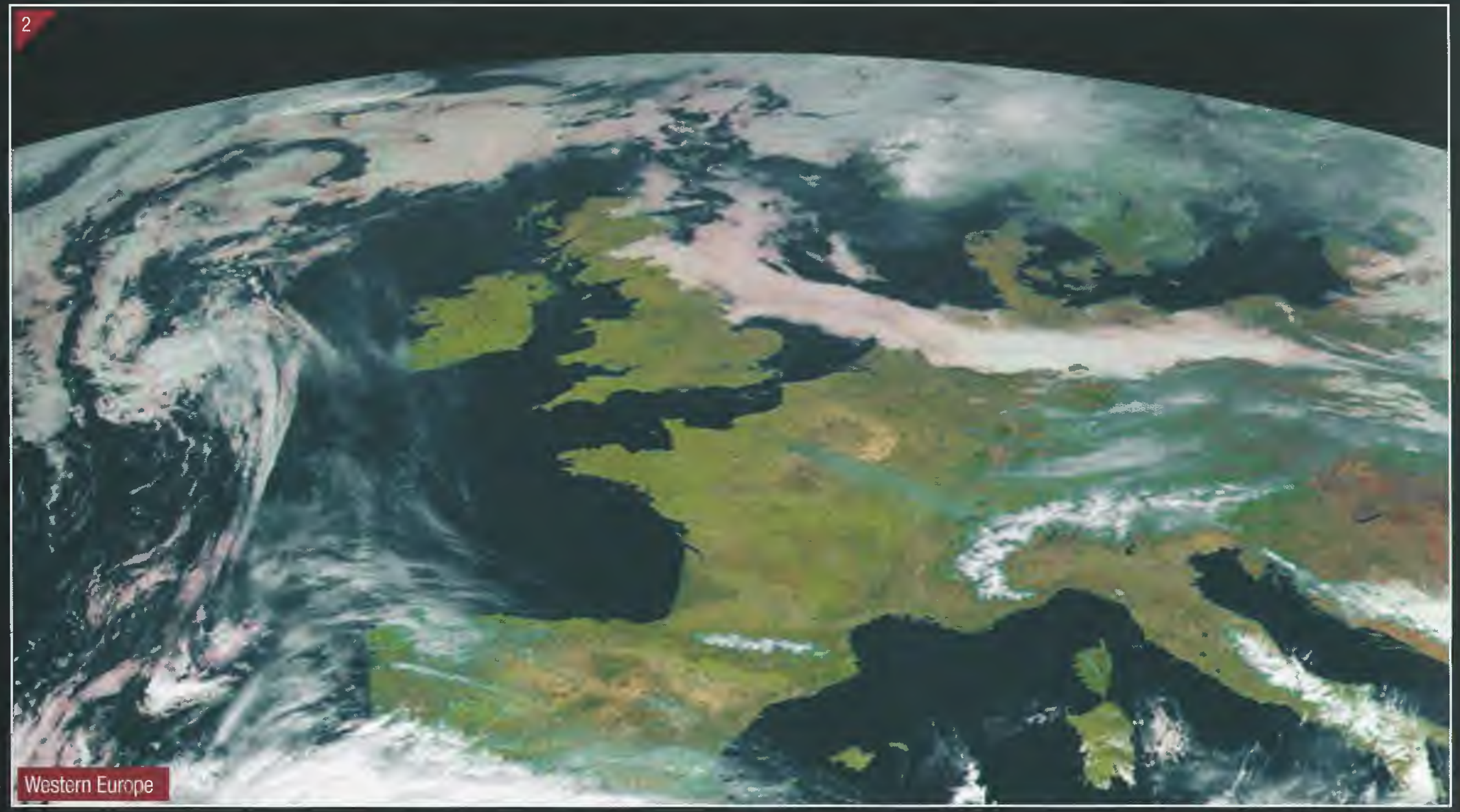


The phytoplankton present in the sea is highly dependent on sea surface temperatures, but also on nutrients from rivers, which gradually come to contain more and more suspended matter as they flow towards the sea.

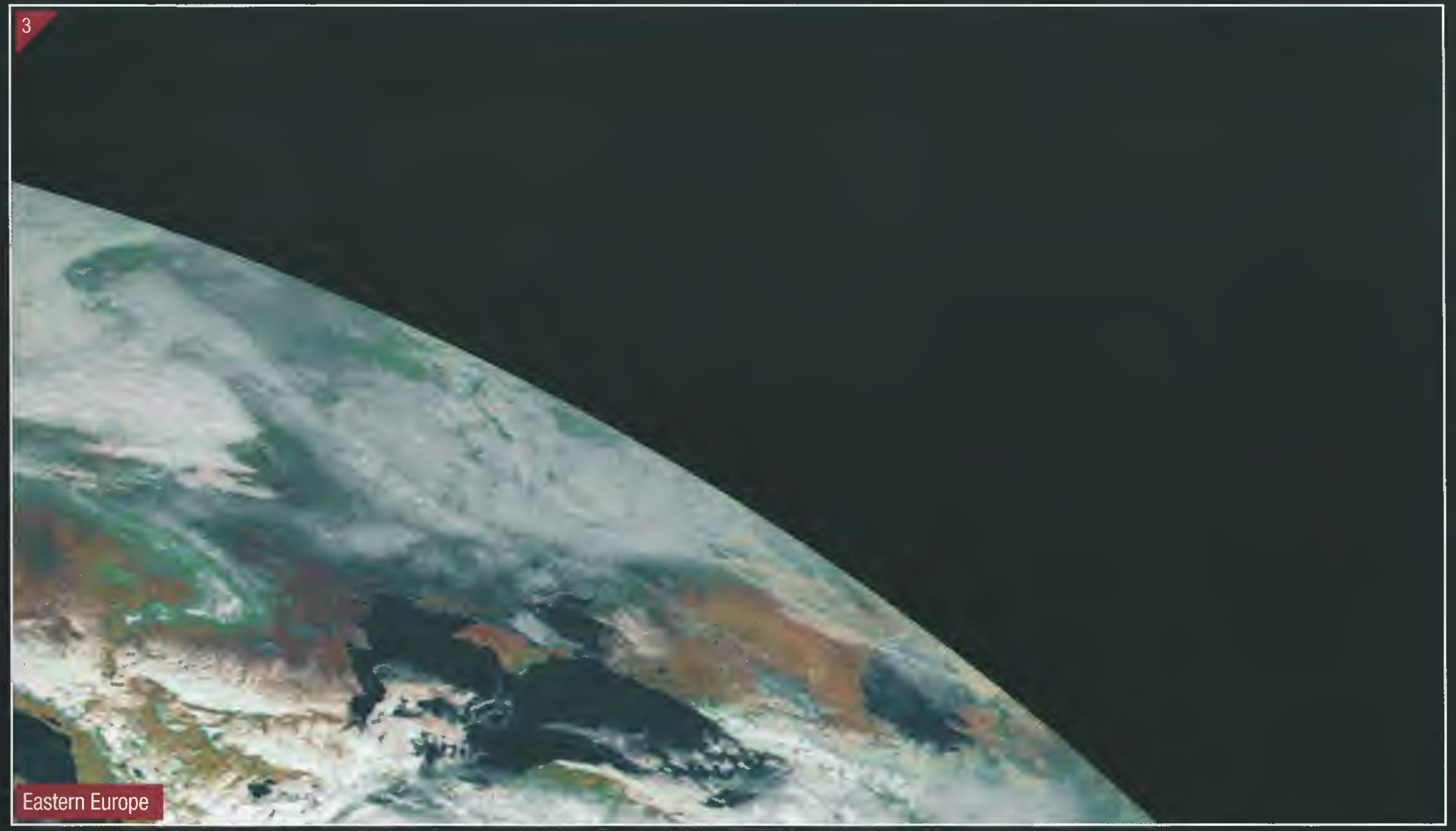
The movement of water in the atmosphere



The Atlantic Ocean as seen by the Meteosat satellite. A depression is forming off the coast of North America and will soon arrive over Europe. 97.1% of all the world's water is in the form of sea water: in other words, almost all the water on the planet is in liquid form and is salty.



Water in the atmosphere in a gaseous, liquid or solid state represents only 0.001% of total water on the planet but that water is nonetheless vital to human beings: indeed, it is cloud which brings rain, crucial to vegetation and thus to human life.



Water on land represents 2.9% of the total volume. Close to three quarters of this water is in the form of snow or ice (and therefore solid), while nearly a quarter is subterranean water, and less than 1% of this 2.9% is surface water in liquid form (lakes, rivers and so on).

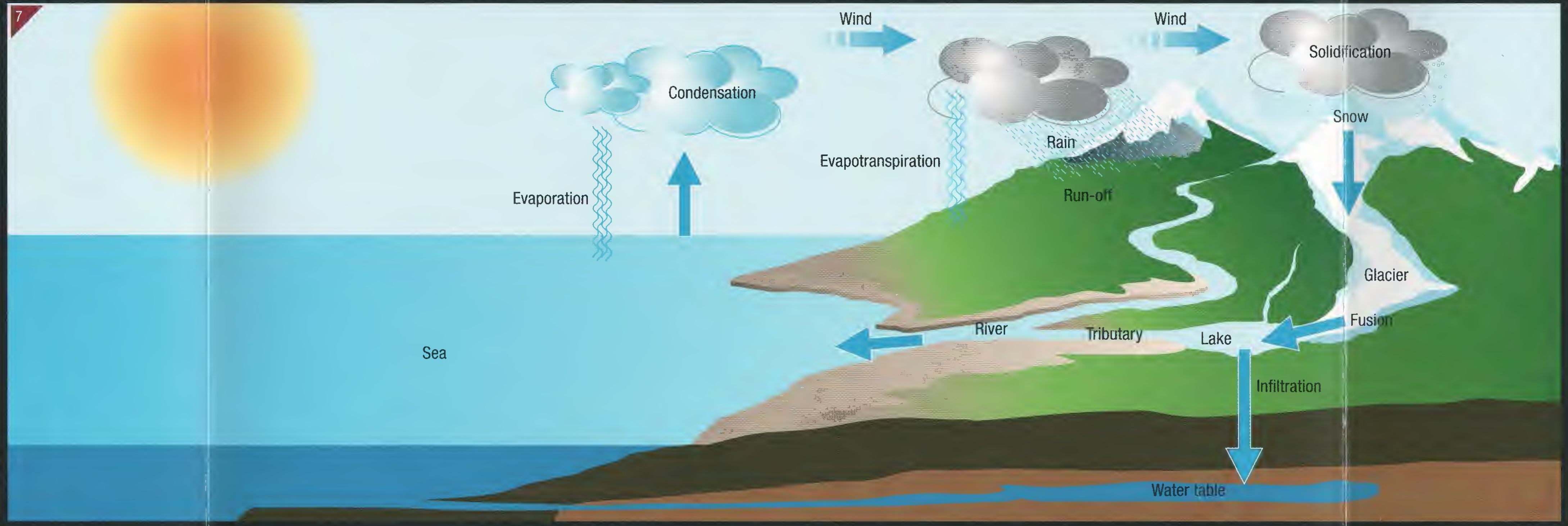
Water reserves on Earth

The volume of water in the seas amounts to 1,350 million km^3. It was in this environment that life first emerged on Earth some several billion years ago.

When water evaporates it is purified, since most impurities are too heavy to evaporate at the same time. That is why rainwater is good for plants.

Ice fields and the polar ice caps are under threat from climate warming. Consequently, their extent and thickness are permanently monitored by satellite.

The amount of water on Earth remains constant. The water available to us now in the 21st century is exactly the same as that which existed billions of years ago when the Earth was formed.



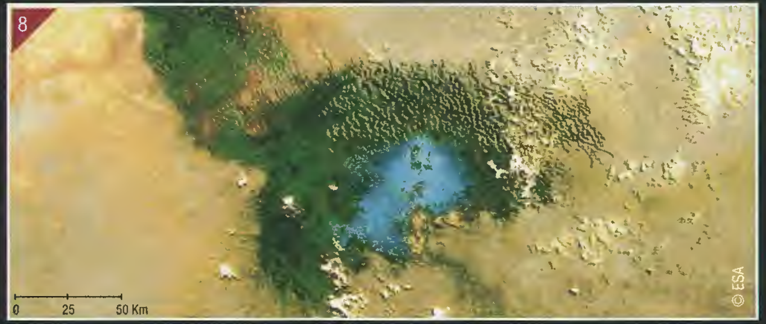
The main factor influencing the movement of water on Earth is the Sun: its rays cause lakes, oceans and rivers to evaporate and indeed have that effect on all liquid water.

Water vapour resulting from evaporation rises into the sky, is cooled and condenses into cloud. The cloud is then moved along by the action of the wind, carrying the water with it.

When the correct conditions arise, this water falls to earth again, notably in the form of rain, snow or hail. This is what is known as precipitation.

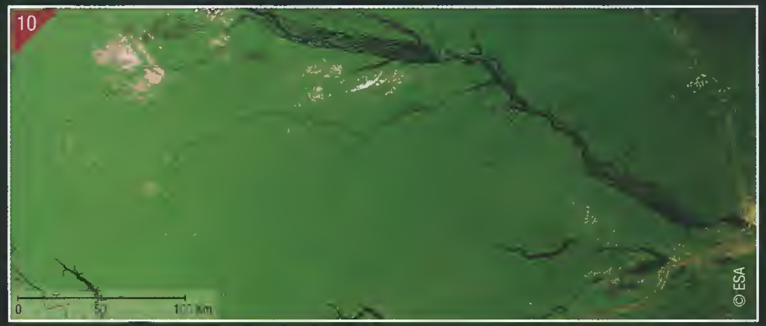
After falling on the ground, water can collect on the surface (in lakes, ice fields or glaciers), or infiltrate the ground to form ground water before finally flowing into the sea.

Lake Chad in Africa. Our water reserves are under threat from pollution and climate warming: satellites help improve monitoring and our understanding of such phenomena.



Thanks to water pumped from a depth of several hundred metres, crops can be grown in the middle of the desert (in this case close to Kufra in Libya). However, subterranean water sources are replenished very slowly.

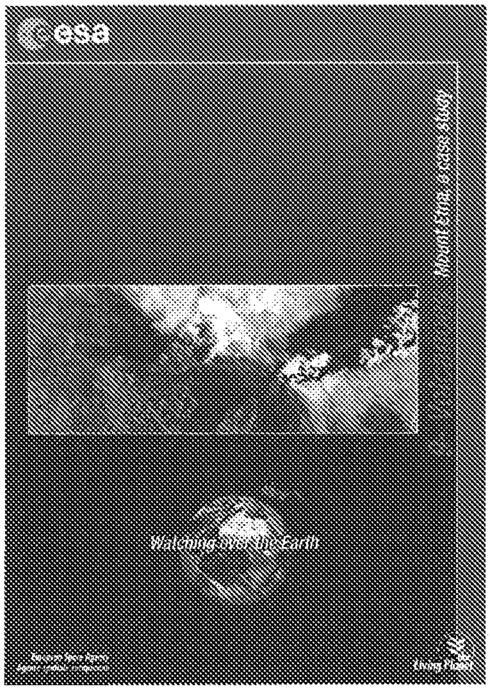
Fresh water is also contained in plants and living creatures. The human organism is made up of 65% water and that proportion reaches more than 80% for plants. The Amazon Forest, which at 4 million km^2 is the biggest forest in the world, also contains a vast quantity of water.



Information for teachers

The "Information for teachers" sheets are designed to offer assistance with the preparation of classes and complement the worksheets handed out to pupils. They contain useful information for the presentation of the subject, additional information relating to the satellite images, and a list of websites dealing with the subjects concerned.

Worksheet 9: Volcanoes: Mount Etna, a case study



Worksheet 9 is about volcanoes.

This worksheet can be used to:
- locate and identify the main volcanic phenomena, in Europe in particular;
- identify the different forms associated with these volcanic phenomena;
- analyse the relationships between human societies and volcanism.

Volcanism

Understanding and localising volcanic phenomena in the world is inseparable from the concept of tectonic plate movement. The top part of the Earth's crust, the lithosphere, is approximately 100 kilometres thick. It includes the continents and the ocean floors. It consists of the Earth's crust and the uppermost layer of the mantle, and is divided into six main tectonic plates and six secondary plates. These plates glide over the underlying viscous layer, the asthenosphere, under the influence of the convection movements resulting from the rise to the top of magmatic rock. This causes major fractures in the crust. There is a clear connection between volcanic activity and seismic instability (visible, for example, in the "Ring of Fire" in the Pacific) and so regions with active volcanism also have seismic activity.

Eruptions differ depending on the nature and form of the materials present in the magma chamber. The different types of volcanic eruptions include: Hawaiian (low lava dome, no explosions, few ejections, large lava flows), Strombolian (alternating lava flows and ejections deposited in layers on the sides of the domes), Vulcanian (copious ejections, impressive eruptions), and Pelean (explosions, glowing avalanches, formation of acidic lava needles). The eruptions are not always the same for a given volcano, and can change with the centuries. Volcanic activity is not always continuous.

The consequences of volcanism for human societies can vary. First and foremost, volcanoes represent a major natural risk for local populations. The dramatic examples of Vesuvius 2,000 years ago, and eruptions closer to our time, at Mount Pinatubo (Philippines), and Nevado del Ruiz (Colombia), and on the Island of Montserrat, remind us that volcanism constitutes a threat that is beyond our ability to control. But volcanism can also have positive economic consequences. Ash deposits on the slopes or at the base of the volcano can form fertile soil for use in agriculture. Spa treatments, tourism (as in the Chaîne des Puys province in Auvergne), and the mining of volcanic materials (pozzolan, andesite, basalt, etc.) are among the different ways human societies have learned to adapt to this natural phenomenon.

The satellite images

Cover page

Cover image: Mount Etna's crater (Proba/CHRIS)
Proba is a small experimental satellite launched by ESA in 2002. This platform, weighing only 94kg, can be used to test new automatic functionalities. In addition, it is equipped with a high-performance instrument (CHRIS), a multispectral high-resolution imaging device. The image was taken on the 30th October 2002.

Core content

Image 1: Digital Elevation Model of Europe and the Mediterranean
This Digital Elevation Model (DEM) image of Europe and the Mediterranean has been used to represent underwater relief.
The space sensors actually record small localised increases in sea levels. The accuracy and number of measurements taken enables us to recreate a map of the underwater landscape, having first incorporated this data into a digital model taking into account other sources (sonar measurements etc.) and other parameters (such as geoid knowledge and tidal effects). This one shows the continuity of the geological structures to be found on the continents.
Several laboratories collaborated in producing this map, using data from various satellites, notably ERS-1 and ERS-2.

Image 2: Sicily and an erupting Mount Etna (Envisat/MERIS image)
The aerosols and carbon particles ejected by the volcano will have a lasting impact in the atmosphere on both a local and global level, particularly sulphuric acid produced by sulphur dioxide, which can remain present for several years. Satellites enable us to monitor and analyse the evolution of such aerosols and their action in the atmosphere and cloud cover. Image taken on 28th October 2002.

Image 3: The eruption of Mount Etna (SPOT 5 image)
Mount Etna, which rises to 3370m, is the most active volcano in Europe.
The speed with which matter is thrown into the atmosphere can reach 450 meters per second: faster than the speed of sound. This image shows a lava flow from a secondary crater.

Image 7: Radar interferometry image of Mount Etna (Envisat)
Interferometry is a technique that enables us to accurately measure and detect ground movements to within millimetres.
This technique involves combining two radar signals from the same area taken at different times or from two different positions. If the signals are identical, the wave pattern of the combined signal will remain the same. On the other hand, changes (of geometric or temporal origin) produce wave patterns which are slightly different from one another and thus produce interference when they are combined. A precise measurement is made of the phase difference of the path of the outgoing and incoming signal of the two different recordings.

Analysis of these interference fringes is equivalent to a very precise measurement of the variation in distance (a fraction of the wavelength, i.e. measured in millimetres), but which is only known to within a whole multiple of the nearest wavelength. This image of the phase differences, composed of fringes, is what we call an interferogram.
If the ground changes in shape, this will directly affect the radar signals. The interferogram can therefore be understood as a map of earth movements to within millimetres, in which the fringes are lines of isodisplacement.
This complex technique is mostly used to detect ground movements—especially the expansion of volcanoes due to magma pressure— or signs of landslides or earthquakes. Also, it can complement recordings by seismographs on the ground.

Page 5 - The eruption of Mount Etna in 2002

Image 9: The lava flow from Mount Etna (SPOT 5 image)
This image is an enlarged version of the SPOT image in the worksheet core content. In this view it is possible to see a twisting road cut in half by the lava flow.

Image 11: Thermal flows on the slopes of Mount Etna
On 26th July 2001, the International Charter "Space and Major Disasters" was activated in the wake of the eruption of Mount Etna. The volcano was threatening Nicolosi, a village of 5,000 inhabitants situated in the path of the lava flow.
This map is an example of information Charter partners are able to provide with great speed: here the red and blue areas show the evolution in the thermal flows on 29th July compared to those on 21st July 2001. The map was created using Landsat imagery.

Page 6 – "How do satellites work?"

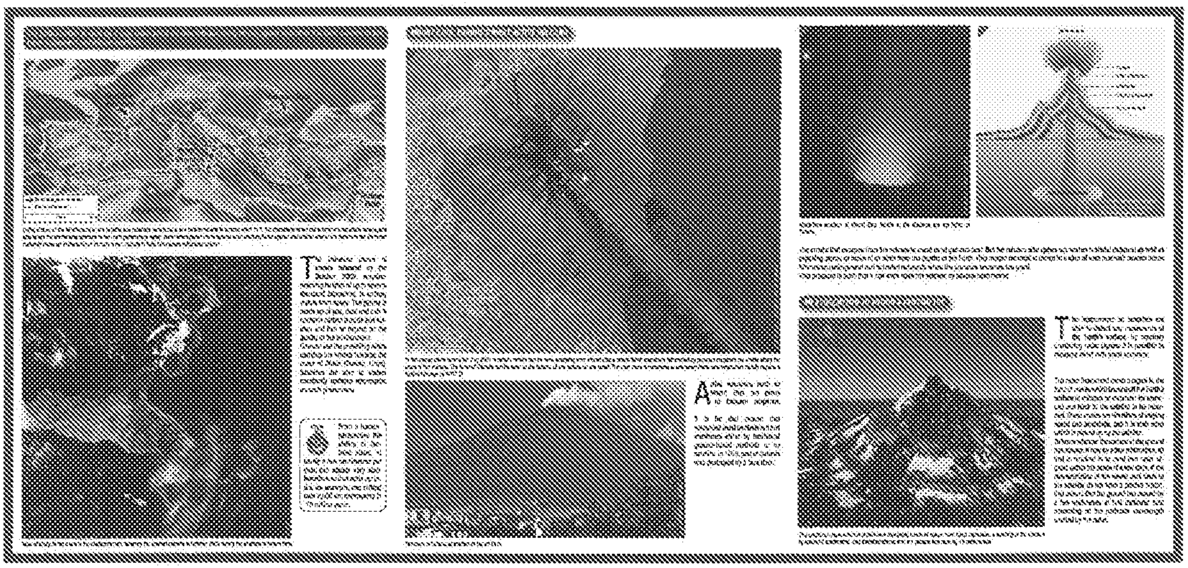
Image 18: The International Charter Space and Major Disasters
In July 1999, the French space agency, CNES and the European Space Agency decided to make their satellite systems available for the prevention and management of natural or industrial disasters. The International Charter officially entered into force on 1st November 2000 and, in January 2007, counted ten space agencies among its members.
Coordination and pooling of the space capability of several agencies is essential to guarantee monitoring and observation of a crisis-hit area.

By mobilising a large number of satellites, it is possible to guarantee that the moment a disaster happens, the nearest and most suitable satellites will immediately be able to take pictures of the disaster area. Other satellites in a low Earth orbit, which fly around the entire globe every two or three days on average, will in turn be able to provide the necessary images to understand the scale of the disaster and its evolution, and provide accurate maps to help emergency units and deliver aid to victims.

Annex - The following are extracts from Article II of the Charter citing its objectives:

1- "...supply during periods of crisis, to States or communities whose population, activities or property are exposed to an imminent risk, or are already victims, of natural or technological disasters, data providing a basis for critical information for the anticipation and management of potential crises."

2- "participation, by means of this data and of the information and services resulting from the exploitation of space facilities, in the organisation of emergency assistance or reconstruction and subsequent operations."



About the kit and DVD

The worksheets, of which 15 copies are available, are to be distributed to pupils in pairs. The teacher, depending on the time available, can organise the lesson mainly around the worksheet's core content (inside 3-page spread) or, alternatively, make use of the information contained on the rear pages of the documents (page 5 and 6).
The DVD-ROM contains the principal satellite images shown in the worksheets. They can be projected onto a screen or displayed on a computer to complement the presentation of the subject by the teacher or to help with the correction of questionnaires.
The images corresponding to each subject can be accessed easily: it is possible to access the complete document and, with a simple mouse click, display the selected satellite image in full screen mode. Lastly, there are several screens which present, in word form, the main ideas contained in the document.
This DVD-ROM contains a form in PDF format entitled Pupil questionnaire, which can be printed out and distributed to pupils. Lastly, there is a version of the questionnaire in Word format, which allows the teacher to adapt it to the needs of his/her lesson.

Online resources

www.esa.int	ESA (European Space Agency) website
www.esa.int/SPECIALS/ESRIN_SITE/index.html	ESRIN (European Space Research Institute) website ESRIN is ESA's centre for Earth observation
www.esa.int/eo	ESA Earth observation website
earth.esa.int/earthimages	Gallery of ESA satellite imagery
www.esa.int/education	ESA educational website
www.eduspace.esa.int	Earth observation educational website (EDUSPACE)
www.cnes.fr	CNES (Centre National d'Etudes Spatiales) website Presentation of the French national space agency's missions and activities
www.cnes-edu.org	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

VOLCANOES AND PLATE TECTONICS

www.eduspace.esa.int/subtopic/default.asp?document=277&language=en	EDUSPACE website: disaster monitoring-volcanoes
www.volcanoes.com	Website covering world volcanic activity, how volcanoes work
www.ucmp.berkeley.edu/geology/tectonics.html	History behind and mechanisms of plate tectonics
www.seismo.unr.edu/ftp/pub/louie/class/100/plate-tectonics.html	Plate tectonics: the cause of earthquakes
earth.esa.int/ew/volcanoes	ESA's "Earth Watching" website: includes case studies (Etna, Mt St Helens, Piton de la Fournaise etc.)

INTERFEROMETRY

www.space.com/scienceastronomy/astronomy/interferometry_101.html	Explaining interferometry

INTERNATIONAL CHARTER SPACE AND MAJOR DISASTERS

www.disasterscharter.org	Website of the International Charter "Space and Major Disasters"
www.bnsc.gov.uk/content.aspx?nid=5674	BNSC website: disaster monitoring and humanitarian relief

Satellite images

ESA project lead	Agostino de Agostini	Documentation	Valérie Massignon - XYZèbre
Editorial concept	Frédéric Létang / Patrice Decenne	Graphics	Boris Uzan
Original text/project oversight	Frédéric Létang	Illustrations	Philippe Bouillon - Illustratek
Scientific advisors (ESA)	Isabelle Duvaux Béchon / Laurence Ghaye	Translations (ESA)	Colin McKinney / Anthony Blend
Pedagogical advisors	Éric Janin / Jean Jandaly	Production	Europimages - Aliette Cremer

Worksheet N° 9 – Volcanoes: Mount Etna, a case study

Once you have read and carefully examined the worksheet, please answer the following questions :

1 – What natural phenomenon causes earthquakes and volcanic eruptions?

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2 – How fast can a tectonic plate move?

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3 – What are some of the elements released into the atmosphere during a volcanic eruption?

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4 – What kind of damage can be caused by volcanic eruptions?

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5 – What similarities do you see between the satellite image taken of Mount Etna by the SPOT satellite and the photograph of Mount Etna below? What kind of information does the satellite image provide?

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6 – What are the main functions of remote sensing satellites which monitor volcano activity?

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7 – How accurate can satellite instruments used to observe ground movement be?

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8 – What agreement did the space agencies conclude in case of a natural catastrophe? What is the purpose of this agreement?

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Topic N° 1 **Earth observation** *satellites*

Topic N° 2 **The Earth** *viewed from space*

Topic N° 3 **Humans** *on Earth*

Topic N° 4 **Africa** *and environmental diversity*

Topic N° 5 **Asia** *and rice-growing*

Topic N° 6 **Europe:** *a developed continent*

Topic N° 7 **Living species** *and their environments*

Topic N° 8 **Water** *on Earth*

Topic N° 9 **Volcanoes:** *Mount Etna, a case study*

Topic N° 10 **Flood** *monitoring*

Topic N° 11 **Colours** *in satellite imagery*