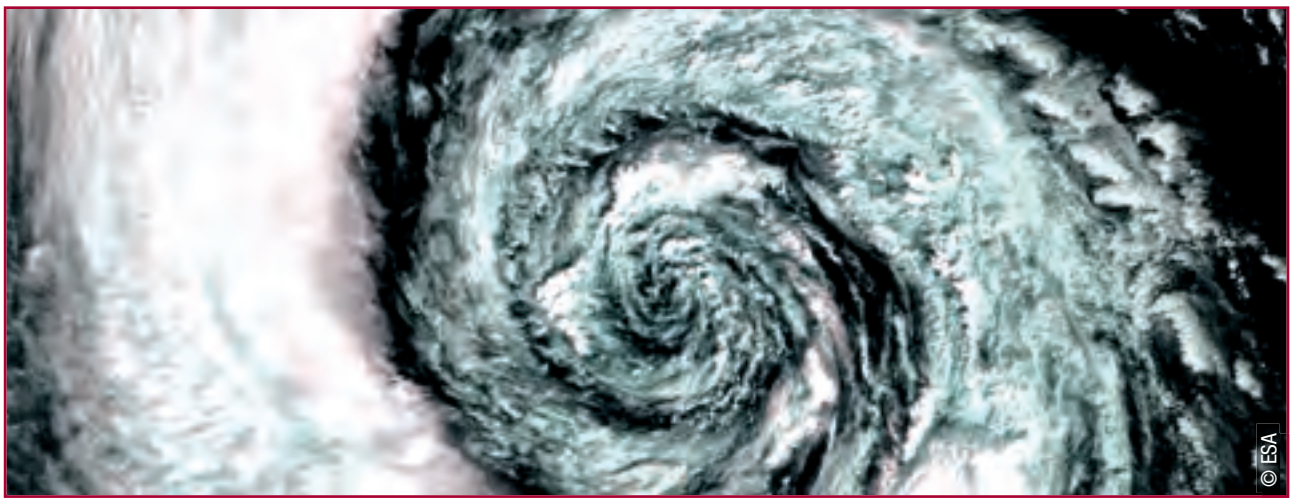
esa

8- Water on Earth

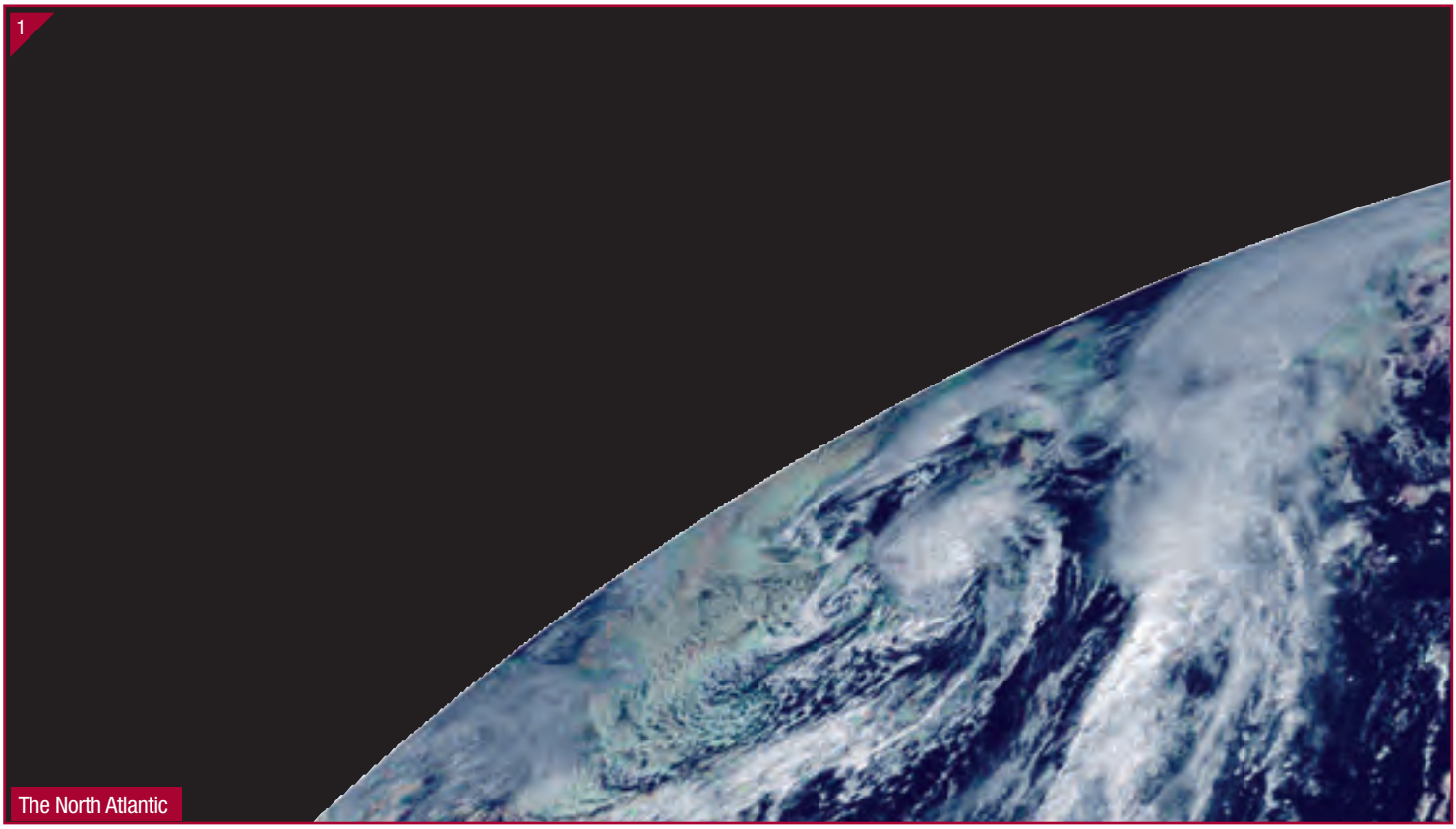


Watching over the Earth

European Space Agency
Agence spatiale européenne

the Living Planet

The movement of water in the atmosphere

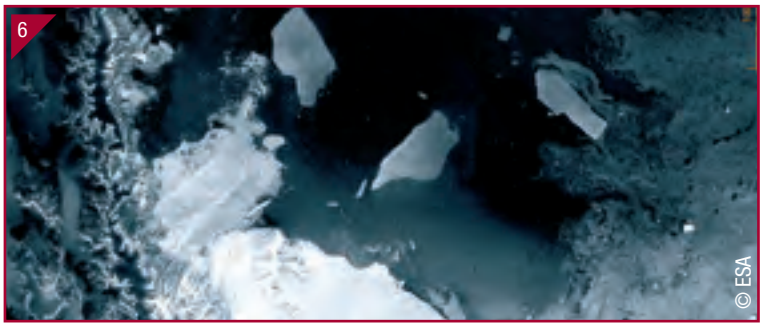


The Atlantic Ocean as seen by the Meteosat satellite. A depression is forming off the coast of North America and will soon arrive over Europe. 97.1% of all the world's water is in the form of sea water: in other words, almost all the water on the planet is in liquid form and is salty.

Water reserves on Earth

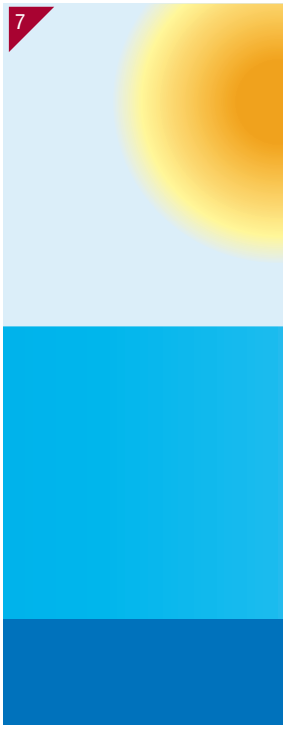
The volume of water in the seas amounts to 1,350 million km^3. It was in this environment that life first emerged on Earth some several billion years ago.

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 E



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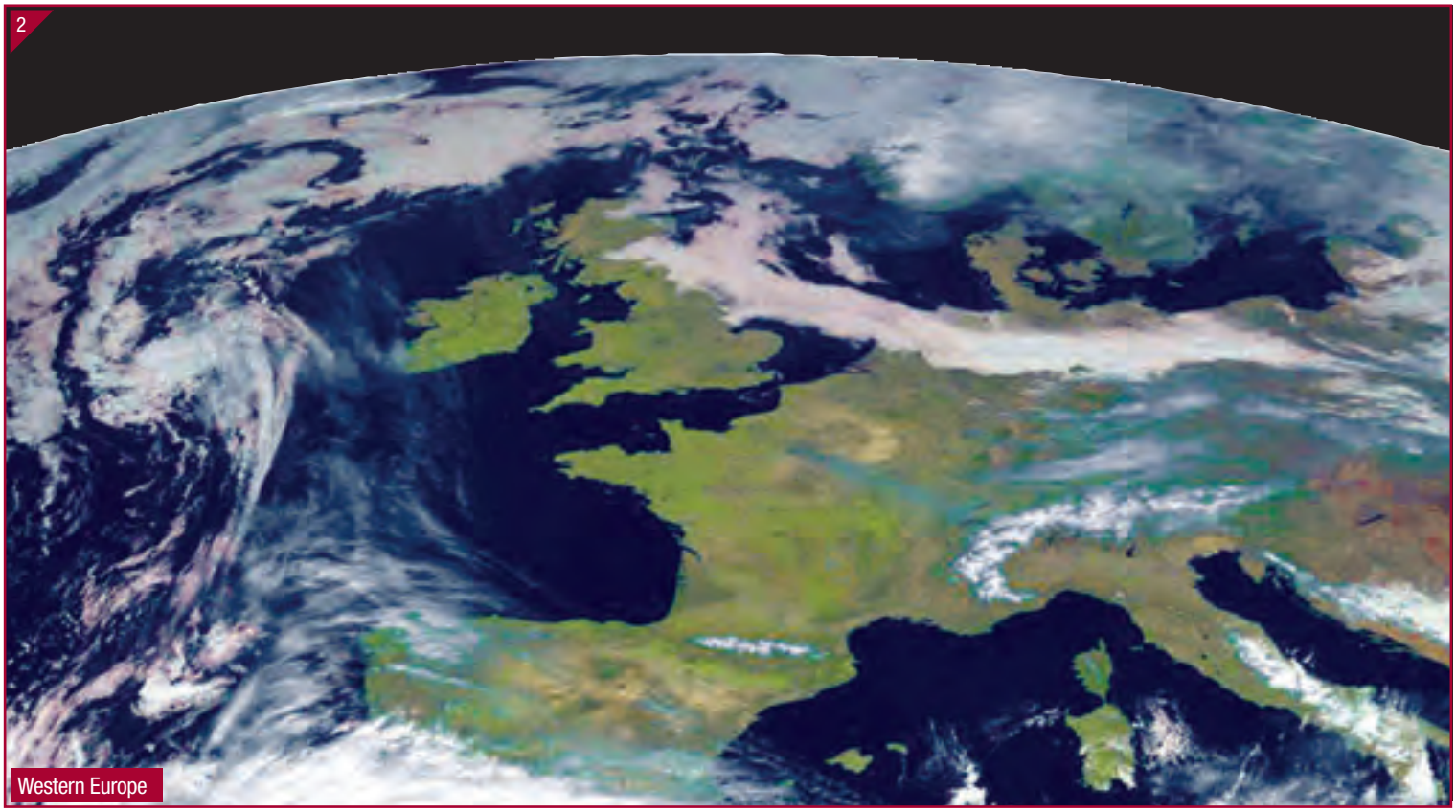
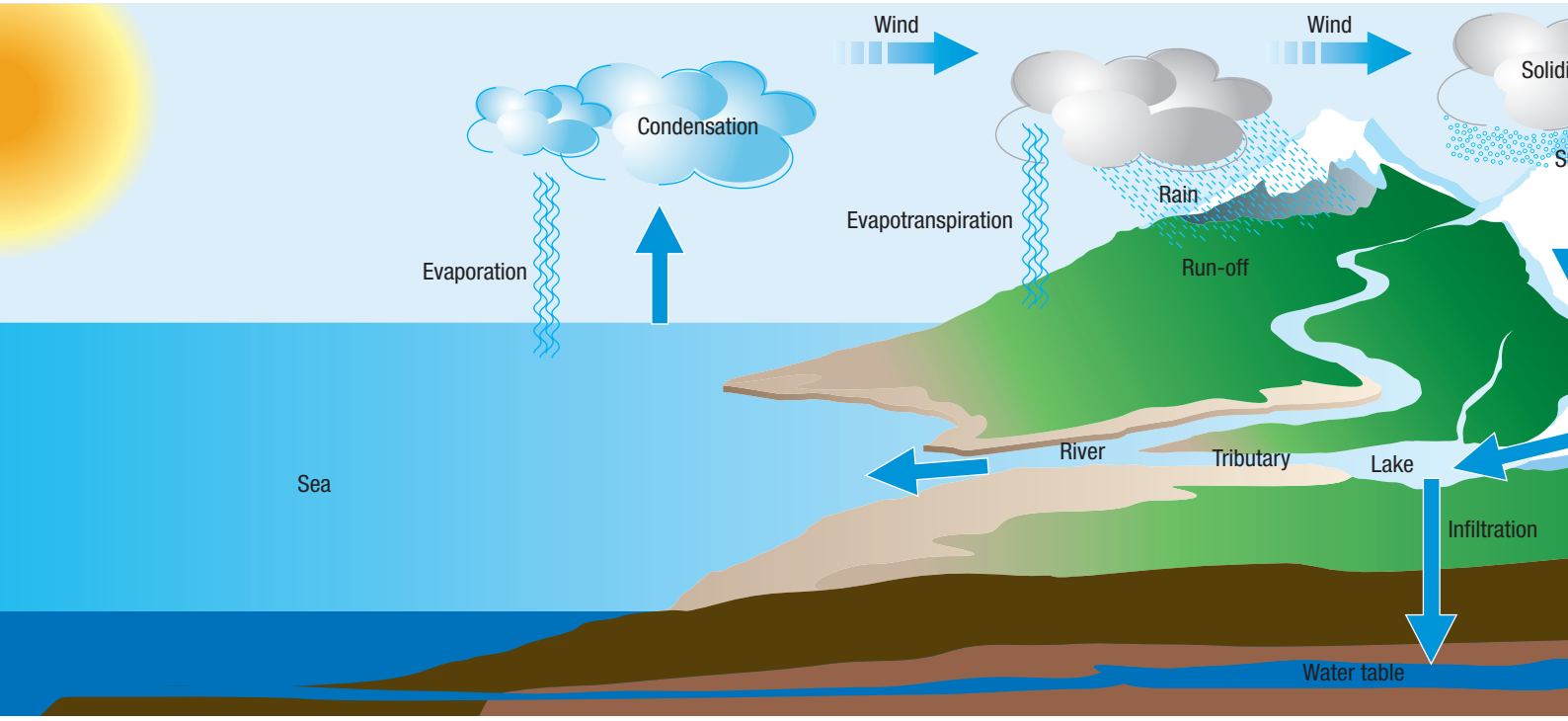


Water in the atmosphere in a gaseous, liquid or solid state represents only 0.001% of total water on the planet but that water is nonetheless vital to human beings: indeed, it is cloud which brings rain, crucial to vegetation and thus to human life.

arth 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 Ear



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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.

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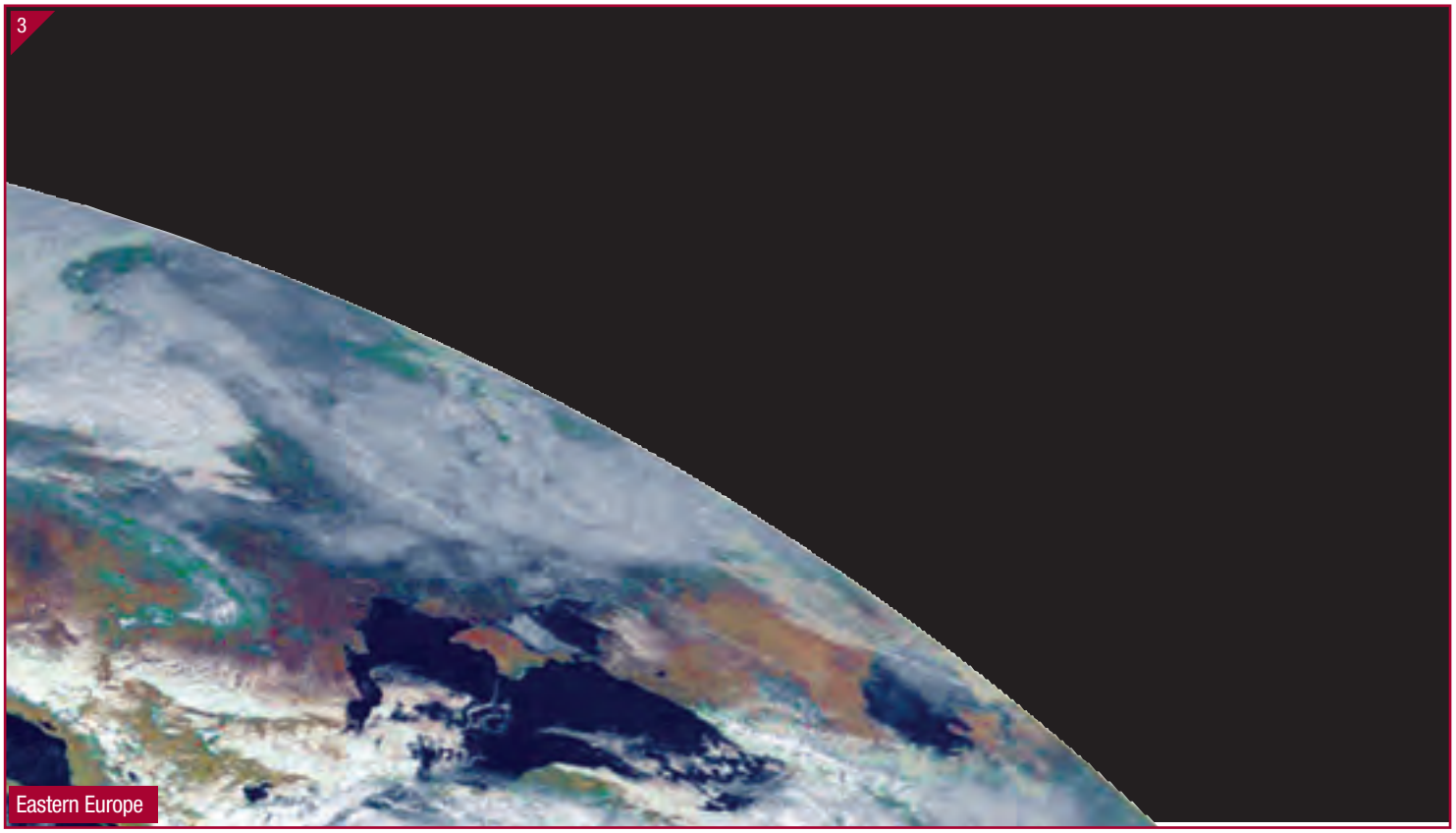

Water on land represents 2.9% of the total volume. Close to three quarters of this water is in the form of snow or ice (and therefore solid), while nearly a quarter is subterranean water, and less than 1% of this 2.9% is surface water in liquid form (lakes, rivers and so on).

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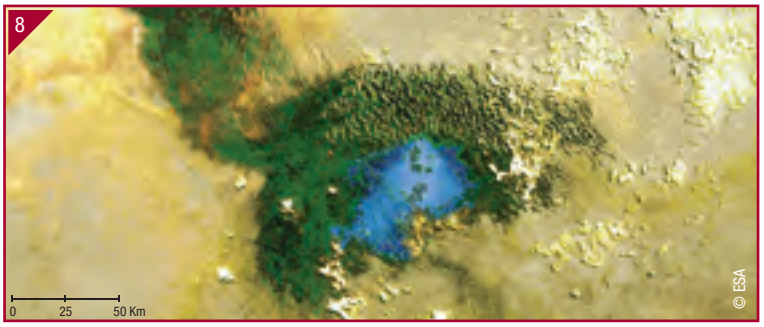
into the sea.

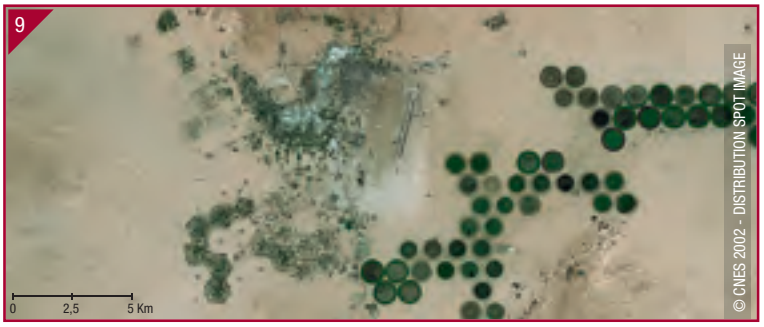
Lake Chad in Africa. Our water reserves are under threat from pollution and climate warming: satellites help improve monitoring and our understanding of such phenomena.

8



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.

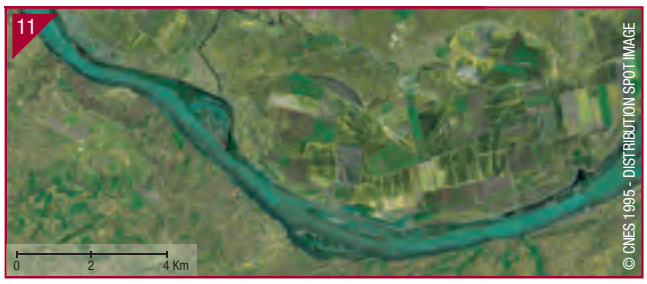
9



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.

10

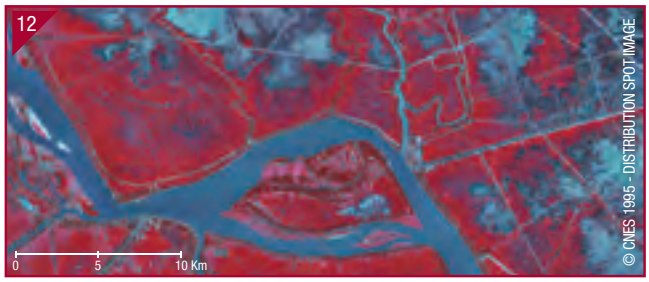
WATER AND HUMAN ACTIVITY



The Danube

River transportation

Rivers are used for navigation and transportation in general. It is for that reason that towns and villages first sprung up and developed on their banks.



Rice fields in the Mekong delta, Vietnam (the infrared channel is shown in red).

Irrigation

Agriculture is impossible without water. Through irrigation it is possible to increase the area on which crops are grown and lengthen the growing season. In Vietnam, rice fields produce several harvests each year.

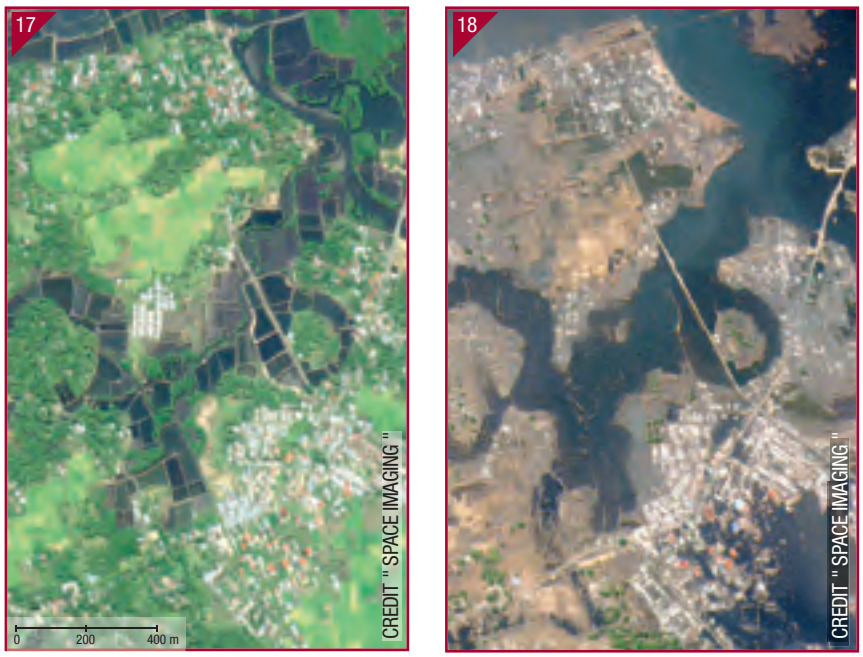
Dam near Gawadar, Pakistan

Electricity production

Man-made dams built along rivers can be used to produce electricity. Energy produced by such “hydraulic” means is renewable.

Humans depend on the Earth’s water reserves, and on their movement. It is such movement that makes possible the production of electricity, river navigation and agriculture. However, rising water levels, floods and tidal waves are just some examples of water movements which carry great dangers for human populations.

On 26 December 2004, a tsunami caused by an under-sea earthquake devastated the coasts of countries bordering the Indian Ocean. 300,000 people living in such coastal areas died.



Satellite image of the region around Banda Aceh before and after the tsunami struck: comparing the two, one can see previously cultivated areas which are totally submerged after the disaster, as well as the damage to axes of communication.

Examination of devastated areas by satellite is essential in evaluating what response is required to come to the aid of disaster-stricken communities.

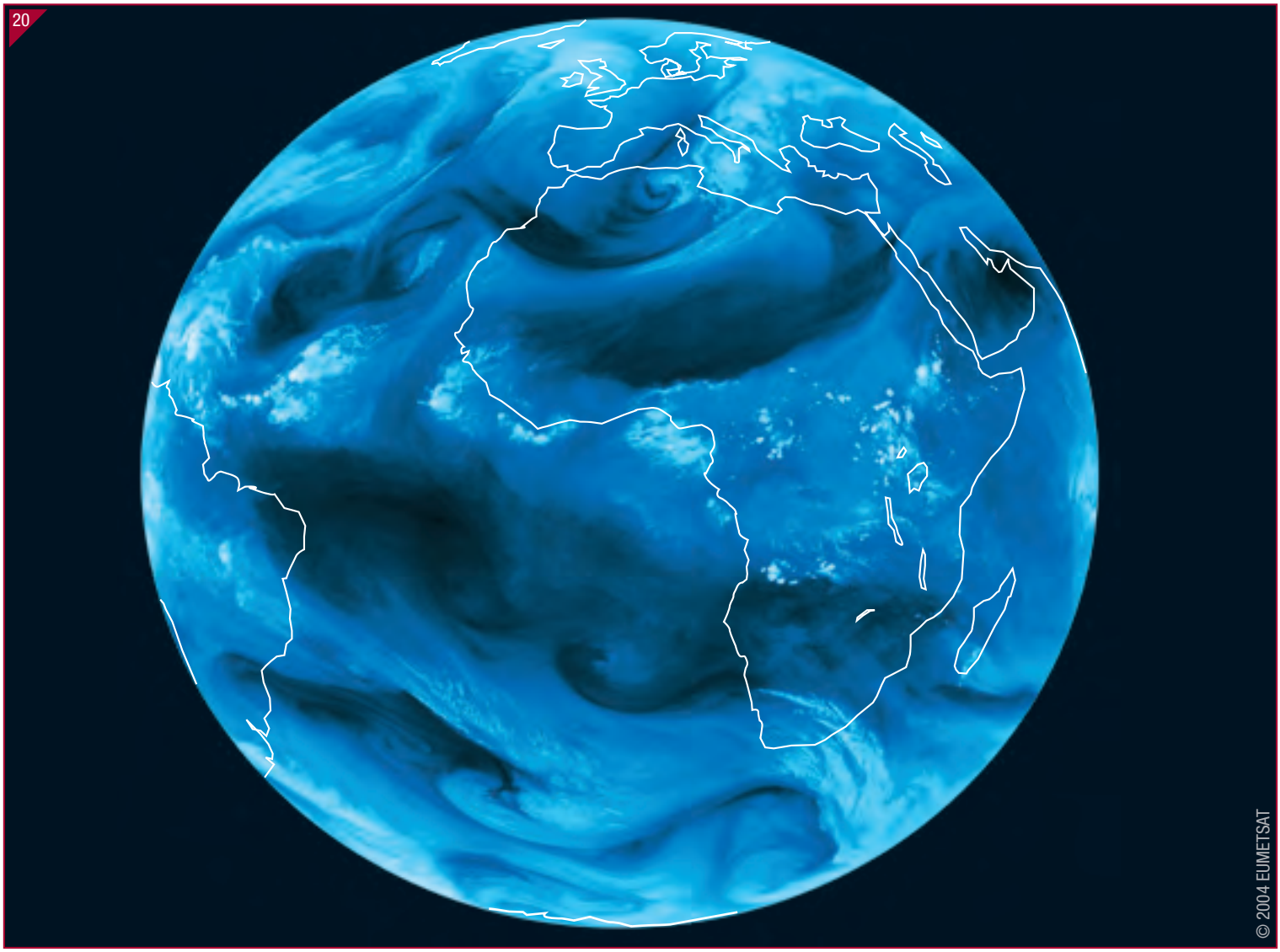
Satellite technology is one of the links in the chain which is gradually being put in place worldwide to identify such natural phenomena as they occur and alert the authorities in the countries concerned.

Devastated zone near Banda Aceh following the passage of the tsunami.

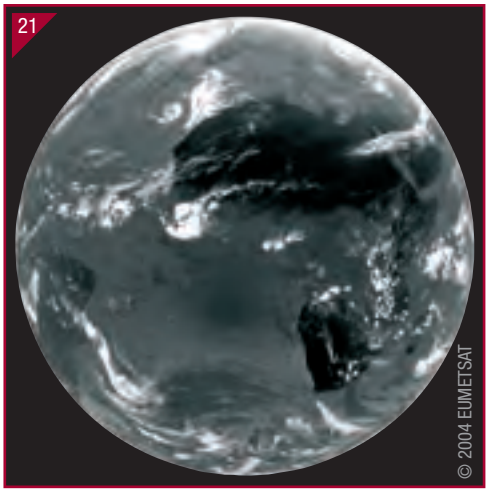
How do satellites work?

Water vapour in the atmosphere

In this image of the Earth the satellite has detected the presence of water vapour in the atmosphere. Although cloud has a tendency to form over certain regions of the globe, water vapour is present practically everywhere in the atmosphere. However, as it is a colourless gas, it is not something we are able to see.

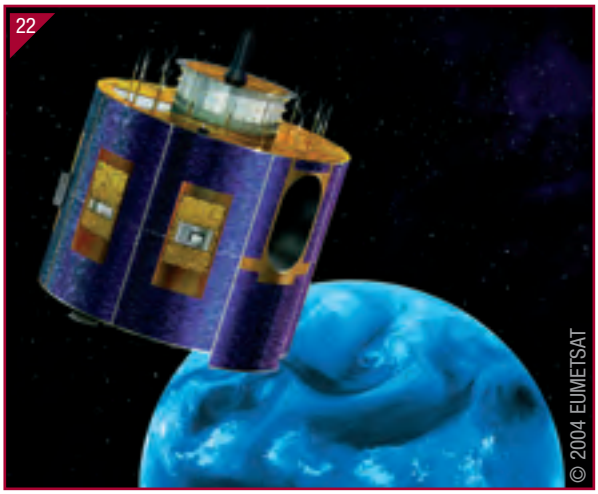


The satellite has recorded the specific wavelength absorbed by water vapour to create this unusual image of our planet. The infrared radiation emitted by the Earth is absorbed by water vapour in the atmosphere. The more vapour that is present, the less radiation is detected by the satellite. These measurements then undergo processing in order to produce the above image. The contours of the continents have been added to facilitate interpretation.

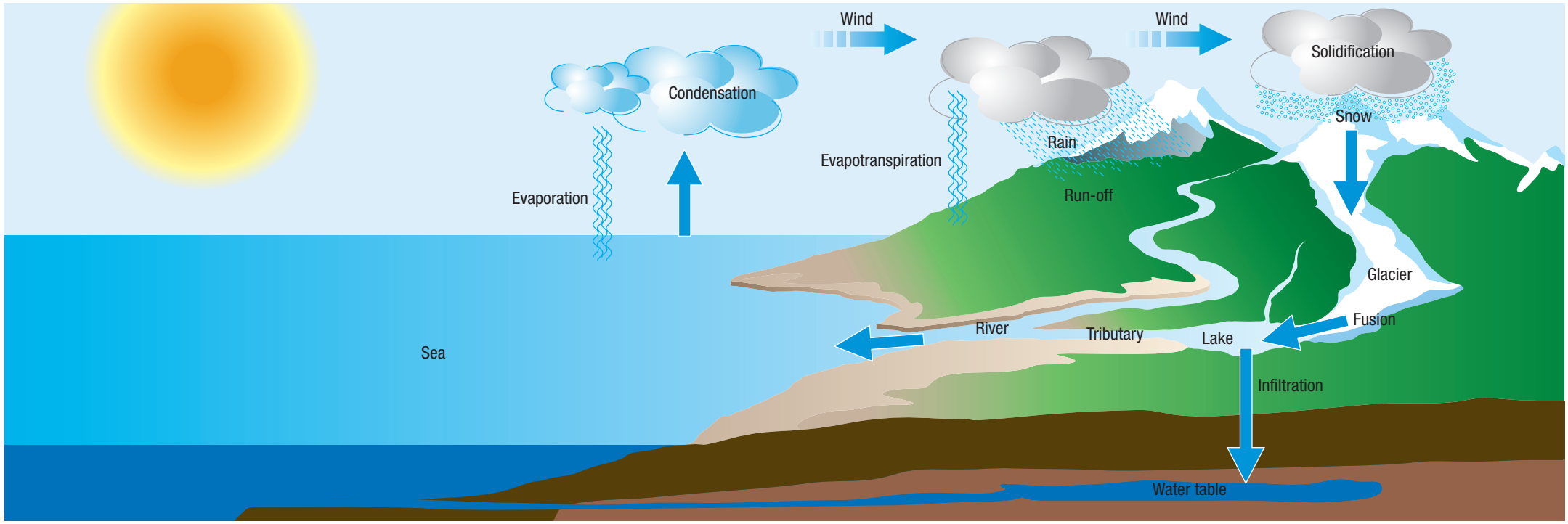


Satellites detect the infrared radiation emitted by the Earth's surface, thereby measuring the heat produced by the Earth, as can be seen in the black and white image to the left.

The purpose of the Meteosat satellite is to monitor meteorological phenomena. It can produce images of cloud masses in the atmosphere but also images representing temperatures on the Earth's surface.



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.

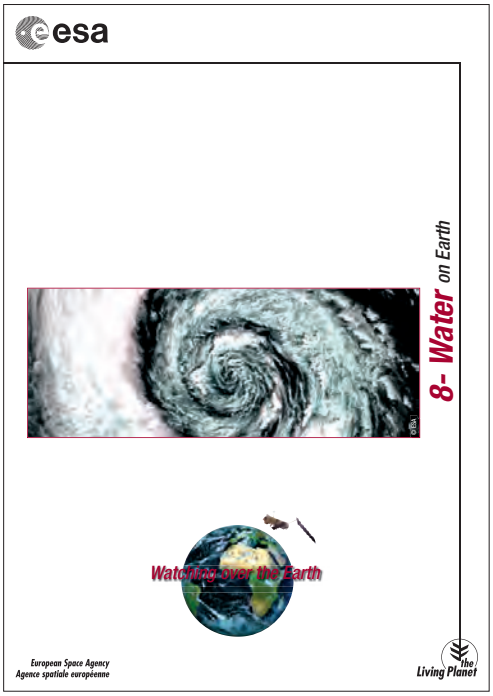
After falling on the ground, water can collect on the surface (in lakes, ice fields or glaciers), or infiltrate the ground to form ground water before finally flowing into the sea.

This image belongs to the 'Watching over the Earth' teaching pack from the European Space Agency (ESA).
The Living Planet programme.

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 8: Water on Earth



Worksheet 8 deals with the water cycle discussed both in life and earth sciences curricula, and in physics, chemistry and geography courses.

This worksheet can be used to:
- describe the different water reserves on the planet, where they are located (oceans, seas, rivers, lakes, polar ice caps, pack ice, subsoil, atmosphere, living species, etc.);
- discuss the different ways water is transferred from one form to the other;
- illustrate the importance of water and its movements for human activity (transportation, agriculture, industry, etc.)

The cycle of water

A first essential idea is that the water cycle is generated by solar radiation causing evaporation. However, the Earth receives substantially different amounts of solar radiation depending on the latitude (greatest at the equator where the solar rays arrive perpendicular to the ground, and least at the poles). This difference accentuates the exchanges between continents, oceans and the atmosphere. The sun is not the only source of energy responsible for water movement; gravity also contributes to this process.

A second essential idea is that of the "conservation of water" throughout its cycle: the total quantity of water present on Earth does not vary, and has not done so for at least 2 billion years. At a time-scale relevant to the climate (several thousand years), water masses remain stable from one reserve to another (oceanic, continental and atmospheric volumes remain at constant levels). Over a longer time scale, this can no longer be said with any degree of certainty: the last time glaciation occurred, reaching its peak 18,000 years ago, the volume of the oceans was lower. The total cumulative volume exchanged between the different types of water reserves over the course of the year is 920,000 km^3, which is very little in comparison with the total volume of water on Earth (about 1,390,000,000 km^3). Another way to look at this difference is that the volume of water exchanged represents a layer 1.8 m deep compared with a total depth of 2.7 km.

The third important idea is the following: a diagram of the water cycle hides some very important disparities. Certain regions receive very little water (barely a single instance of rainfall in a given century in the Atacama Desert in Chile), while others receive an enormous amount of rainfall (nearly 12 metres of precipitation per year in the Shillong region in the East of India). Another example of disparity: the Atlantic Ocean and the Indian Ocean carry water to the continents, while the Pacific Ocean carries it away, since precipitation there exceeds evaporation.
Providing a detailed explanation of atmospheric circulation, and consequently of the water it conveys, is a complex task being studied by meteorologists, taking into account numerous factors. Because solar radiation is stronger at the Equator than at the poles, this results in the rise of air masses at the Equator, and their change in altitude as they move towards the poles. The Earth's rotation is another factor: it explains the large circulating air masses operating at planetary level (Hadley, Ferrel, and Polar cells), and thereby the existence of tropical trade winds, west winds at middle latitudes, jet currents, and anticyclonic zones (in the tropics, where most of the large deserts are located, and at the poles) and depression zones (Equator, temperate zones).

Fourth key idea: the average time water stays in the different reserves differs greatly depending on the form it takes: 10 days on average in the atmosphere, several weeks in rivers and streams, several decades in lakes, and centuries or even millions of years in the subsoil.

Lastly, the water cycle is not invariable. First, it changes naturally over the course of major climatic eras (glaciation/climate warming). Second, between the beginning of the 19th century and today we have witnessed the appearance of a new phenomenon: human industrial activity is changing the atmosphere. Carbon dioxide levels have gone from 0.028% in 1800 to 0.037% in 2000, as a side-effect of burning fossil fuels. Carbon dioxide (a greenhouse gas) causes an increase in the average temperature on the planet's surface, which accelerates the water cycle and increases the quantity of water in the atmosphere. This in turn contributes to the greenhouse effect. The water cycle is locally affected by the building of large dams. It is also affected by massive ongoing deforestation, which diminishes evapotranspiration by substituting surface runoff in its place. Lastly, in certain regions (the western United States, Saudi Arabia), groundwater is being pumped out at a rate that outstrips the rate at which groundwater is replaced through infiltration.

Although all these changes to the water cycle can have significant consequences, the most important and immediate water problems of concern today have to do with the uneven distribution of water on the surface of our planet, on one hand, and the significant increase of its overall level of pollution, on the other.

The satellite images

Cover page

Cover image: Low-pressure area to the south of Iceland (Envisat/MERIS)
Using the infrared and near infrared band brings out details of the structure of clouds. This cloud formation measures about 600 km.

Core content

Image 1, 2 and 3: The Earth (Meteosat image)
This triple-sequenced image of the Earth serves to highlight 3 essential stages in the circulation of water in the atmosphere: evaporation over the Atlantic Ocean, movement of a depression from west to east and precipitation over Eurasia. Of course, precipitation occurs over oceans and evaporation over continents, but this sequence indicates a general trend as further illustrated in the graph below.

The six photographs or satellite images shown here concern examples of water reserves on Earth including ice floes, Lake Chad, the Libyan desert and the Amazon Basin.

Image 6: The Antarctic Peninsula (image by Envisat)
The effects of climate warming are particularly noticeable in the Antarctic. This image taken in March 2002, shows part of the Larsen ice shelf having broken into a multitude of icebergs which then began drifting in the Wedell Sea.

Image 8: Lake Chad (image by Envisat)
This image also shows how climate warming is impacting the planet's water reserves. The area of vegetation around the lake indicates how far the lake extended roughly three decades earlier.

Image 9: The Kufra desert in Libya (SPOT 5 image)
Subsoil water reserves deep underground are replenished very slowly (about 1% per year). In some cases it has taken hundreds of thousands of years for deep water tables to form. The pumping of water from these sources is often carried out without any thought to their replenishment.

Image 10: The Amazon basin (MERIS/Envisat image)
The Amazon is one of the longest rivers in the world and that which carries the largest quantities of fresh water to the sea. The Rio Negro, shown in this image, owes its black colour to the fact that it carries little or no sediment, unlike the Rio Solimões (to the bottom right of the picture), which contains a great deal of it. On the right of the image, it is possible to make out a road and the cleared areas surrounding it.

Page 5 – Water and human activity

The three satellite images in this section illustrate some of the ways in which water is crucial to human activity: transport, energy production and irrigation.
The second part, meanwhile, dealing with the tsunami that occurred in December 2004 in the Indian Ocean, emphasises the risks associated with such natural phenomena.

Image 11: The Danube (SPOT 5 image)

This is Europe's longest river (at 2,850 km) and its hydrographic basin serves 17 countries.

Image 12: Rice fields in the Mekong Delta (Spot 5 image)

The monsoon climate of South-East Asia is ideally suited to the growing of rice. It is a demanding plant, requiring 30,000 m^3 of water per hectare. In 2003, rice production in Vietnam reached almost 35 million tonnes. See Worksheet N°5 "Asia and rice-growing" for more details.

Image 13: Dam in the region of Gwadar, Pakistan (Spot 5 image)

This dam supplies water to the town of Gwadar, a strategic deep-water port located in Pakistan, close to the Iranian border.

Images 17 and 18: The December 2004 Tsunami

These two images of the tsunami were taken by US satellite Ikonos, which has a resolution of 1 metre and orbits at an altitude of 600 km.
The first image was taken on 10 January 2003 and shows the northern coastline of Bandah Aceh province on the island of Sumatra in Indonesia. The second was taken on 29 December 2004 and clearly shows the extent of the damage.

Page 6 – "How do satellites work?"

Image 20: Water vapour in the Earth's atmosphere (Eumetsat)

Satellite images showing the presence of water vapour in the atmosphere are captured in the infrared. The reasons for this are as follows. The Earth receives light from the Sun, some of which it absorbs. This causes its temperature to rise and it to become an infrared transmitter in the wavelengths situated between 4 and 40 micrometres (µm).

This radiation emitted by the Earth is detected by the satellite but on its journey it passes through water vapour in the atmosphere, which absorbs infrared rays at certain very characteristic frequencies. The Meteosat and GOES satellites, for example, detect waves emitted by the Earth at frequencies of around 6 µm, corresponding to absorption by water vapour. Thus, the intensity of the signal recorded is a signature for the presence of varying amounts of water vapour in the atmosphere, and makes it possible to produce images such as those shown in this worksheet.

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.fr	CNES educational website
www.spotimage.fr	SPOT IMAGE gallery

THE WATER CYCLE

www.edumedia-sciences.com/m233-12-resources-and-environment.html	eduMedia resources – Resources and environment
www.ifpri.org/media/water2025.htm	Global water outlook to 2025
www.environment-agency.gov.uk/subjects/waterres/?lang=_e	Environment Agency - water resources in England and Wales
www.worldwater.org	The World's Water, website of the Pacific Institute

THE ATMOSPHERE

www.metoffice.gov.uk/education/secondary/teachers/atmosphere.html	Met Office. The atmosphere
www.bnsc.gov.uk/lzcontent.aspx?nid=4801	BNSC website: a wide range of information on the Earth's atmosphere
www.bnsc.gov.uk/content.aspx?nid=5677	BNSC website: measuring and modelling the Earth's atmosphere

TSUNAMIS

www.disasterscharter.org	Site of the International Charter "Space and Major Disasters"
earth.esa.int/applications/dm	Disaster management

Satellite images

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Pedagogical advisors	Éric Janin / Jean Jandaly
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Graphics	Boris Uzan
Illustrations	Philippe Bouillon - Illustratek
Translations (ESA)	Colin McKinney / Anthony Blend
Production	Europimages - Aliette Cremer

Worksheet N° 8 – Water on Earth

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

1 – What causes water movement on Earth? Briefly describe the water cycle.

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2 – The satellite image in the top left corner shows a depression forming above the Atlantic Ocean. In what direction will this mass of clouds continue to develop? Which satellite took this image?

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3 – Where is most of the water on Earth stored? What can be said about the total quantity of water? What proportion of all water on Earth is found in the atmosphere?

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4 – What types of phenomena change water quality and availability on Earth?

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5 – Give three examples of how satellites can be used to evaluate the state of water reserves on Earth.

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6 – Why is water movement, both in the atmosphere and on land, of vital importance for life and human activity on Earth?

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7 – Why is it that coastal regions, which are at the greatest risk from flooding and tsunamis, are nonetheless densely populated?

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8 – What different forms can water take in the atmosphere?

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