WILD WEATHER

Weather is the movement of the atmosphere in response to heating by the Sun. The Earth's atmosphere is essential to life but weather can have a powerful impact on people's lives and the most extreme events are devastating.

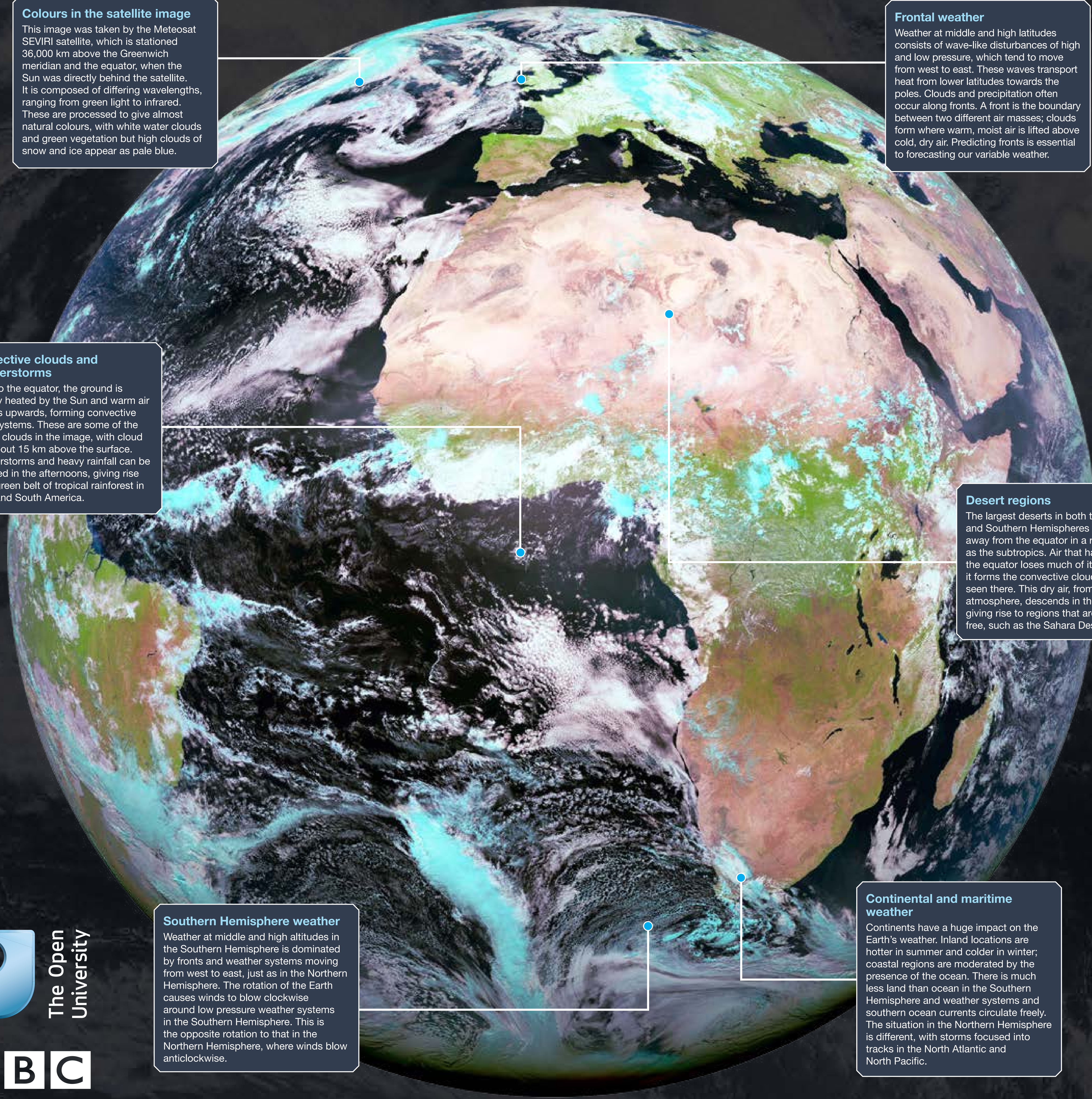
Find out more with The Open University visit **open.edu/openlearn/wildweather**

POWERFUL TROPICAL CYCLONE

Hurricanes are among the most devastating weather systems. This view of Hurricane Felix was taken on 3 September 2007 by a crew member on the International Space Station, when the centre of the storm was about 425 km south of Jamaica. Hurricane Felix was more than 1000 km in diameter and can be seen as a circular area of cloud with spiral cloud structures and a central, clear eye. The Earth's curvature can be seen along the horizon.

VIOLENT SPIRALLING VORTEX

Tornadoes are violent whirlwinds that form below a cumulonimbus storm cloud. The existence of the tornado is first revealed at ground level by a dust whirl. As the tornado develops, a funnel cloud forms in the centre of the vortex, although the strong winds circulate much further around it. The most extreme tornadoes can have wind speeds approaching 500 km/h, and cause extreme damage along their path. Tornadoes are seen almost everywhere, most famously in North America.



Colours in the satellite image

This image was taken by the Meteosat SEVIRI satellite, which is stationed 36,000 km above the Greenwich meridian and the equator, when the Sun was directly behind the satellite. It is composed of differing wavelengths, ranging from green light to infrared. These are processed to give almost natural colours, with white water clouds and green vegetation but high clouds of snow and ice appear as pale blue.

Frontal weather

Weather at middle and high latitudes consists of wave-like disturbances of high and low pressure, which tend to move from west to east. These waves transport heat from lower latitudes towards the poles. Clouds and precipitation often occur along fronts. A front is the boundary between two different air masses; clouds form where warm, moist air is lifted above cold, dry air. Predicting fronts is essential to forecasting our variable weather.

Convective clouds and thunderstorms

Close to the equator, the ground is strongly heated by the Sun and warm air bubbles upwards, forming convective cloud systems. These are some of the highest clouds in the image, with cloud tops about 15 km above the surface. Thunderstorms and heavy rainfall can be expected in the afternoons, giving rise to the green belt of tropical rainforest in Africa and South America.

Desert regions

The largest deserts in both the Northern and Southern Hemispheres are found away from the equator in a region known as the subtropics. Air that has risen near the equator loses much of its water as it forms the convective cloud systems seen there. This dry air, from high in the atmosphere, descends in the subtropics, giving rise to regions that are often cloud free, such as the Sahara Desert.

Southern Hemisphere weather

Weather at middle and high altitudes in the Southern Hemisphere is dominated by fronts and weather systems moving from west to east, just as in the Northern Hemisphere. The rotation of the Earth causes winds to blow clockwise around low pressure weather systems in the Southern Hemisphere. This is the opposite rotation to that in the Northern Hemisphere, where winds blow anticlockwise.

Continental and maritime weather

Continents have a huge impact on the Earth's weather. Inland locations are hotter in summer and colder in winter; coastal regions are moderated by the presence of the ocean. There is much less land than ocean in the Southern Hemisphere and weather systems and southern ocean currents circulate freely. The situation in the Northern Hemisphere is different, with storms focused into tracks in the North Atlantic and North Pacific.

The Open University

BBC

EXTREME SAND AND DUST STORMS

Dust can be lifted into the atmosphere by high winds. After large storms, small dust particles might remain airborne for weeks. Dust storms are more common in dry regions, but can occur in many parts of the world. The image of Khartoum, Sudan, shows a storm known as a 'haboob', initiated by the high winds associated with thunderstorms. Haboobs may reach altitudes of several kilometres and the wall of dust can be more than 100 km wide.

MASSIVE ELECTROSTATIC DISCHARGE

About 2,000 thunderstorms are active at any moment on Earth. Enormous voltages can develop within clouds as they become charged with static electricity. When the voltage becomes so high that air no longer acts as an insulator, a discharge happens as an electrical spark of lightning. Air in the centre of the lightning channel can briefly reach 30,000 °C, five times the temperature of the surface of the Sun. The thunder sound comes from the rapid expansion of the heated air.

TROPICAL CYCLONES

Tropical cyclones are among the most costly weather disasters. These violent storms are given different names, such as 'hurricanes' in the Americas and 'typhoons' in the Far East, but they are all low pressure systems driven by energy from water vapour, which condenses to form the high storm clouds. Tropical cyclones occur when the seas are at their warmest, in summer and autumn.

Damage comes not only from the high winds around the centre of the storm, but also from flooding caused by the surge in sea surface height and intense rainfall. The equivalent of the average UK annual rainfall may fall in less than two hours from the clouds around the centre of the tropical cyclone.

TROPICAL DEPRESSIONS

Tropical cyclones begin as low pressure disturbances, often close to the equator, which develop into tropical depressions (wind speeds of between 40–60 km/h) as they grow stronger. North Atlantic hurricanes begin as storms close to west Africa and cross the ocean, growing in strength. This image shows Tropical Storm Isaac (left) in the eastern Caribbean Sea, Tropical Depression Joyce (centre) in the central Atlantic Ocean and System 97L (far right) near the African coast.

TROPICAL STORM BARRY

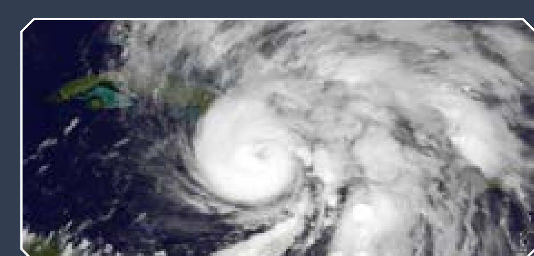
When wind speeds exceed 60 km/h a tropical depression becomes a tropical storm. This image of Tropical Storm Barry was taken on 20 June 2013. Tropical storms are named using an alphabetical list agreed by the World Meteorological Organization. Male and female names alternate and the lists follow a six-year cycle. Names rather than numbered systems make communication easier in hazardous and stressful situations.

CATEGORY 1 HURRICANE INGRID

Hurricane Ingrid on 14 September 2014 when it had just reached full hurricane status. The eye can hardly be seen. When the wind speed (sustained over one minute, brief gusts will be much faster) exceeds 118 km/h then the storm is classified as a category 1 hurricane; Hurricane Ingrid peaked at 140 km/h. The category system for hurricanes is called the Saffir-Simpson scale but other similar scales are used to rate tropical cyclones in the Pacific.

CATEGORY 2 HURRICANE JUAN

When the sustained winds reach above 153 km/h, the cyclone becomes a category 2 (or moderate) hurricane, like Hurricane Juan above, photographed on 27 September 2013 over the warm Gulf Stream. Hurricanes can rise and fall in intensity, growing when over warm seas and becoming weaker when over land. This was the peak intensity for Hurricane Juan, which made landfall two days later in Nova Scotia, Canada.



CATEGORY 3 HURRICANE SANDY

Hurricane Sandy was a strong, category 3 hurricane, here shown close to Cuba in the Caribbean Sea on 25 October 2012. For a hurricane to be category 3, the sustained winds must exceed 177 km/h. Hurricane Sandy was the deadliest and most destructive hurricane of 2012 and although it later fell to category 2 off the North-east coast of the USA, it became the largest North Atlantic hurricane with a diameter of 1800 km.

CATEGORY 4 HURRICANE DENNIS

A category 4 (very strong) hurricane has sustained winds of more than 208 km/h. Hurricane Dennis was the second hurricane of 2005, shown here on 9 July. Hurricane Dennis hit Cuba twice as a category 4 hurricane. It later made landfall on Florida as a category 3 cyclone, before moving north across the USA and weakening. Dennis caused more than one hundred deaths and billions of dollars in damage to Cuba and to the USA.

CATEGORY 5 HURRICANE KATRINA

Hurricane Katrina, which did huge damage to New Orleans in 2005, was rated at category 5 (or devastating), meaning that the sustained winds exceeded 250 km/h. The image shows Hurricane Katrina at peak intensity (wind speeds of about 280 km/h) in the Gulf of Mexico on 28 August 2005. Hurricane Katrina caused almost 2000 deaths and more than $100 billion-worth of damage in the USA.

SOUTHERN HEMISPHERE CYCLONES

A train of four tropical cyclones in the southern Indian Ocean, east of Madagascar, on 12 February 2003. The cyclones are named Gerry, Hape, 18S (a tropical storm that became Cyclone Isha) and Fiona. Gerry and Hape have clear eyes and spiral arms of thick clouds, just like a hurricane. The spirals imply that they rotate clockwise, in the opposite direction to the hurricanes, which betrays their Southern Hemisphere origin.

WILD WEATHER

Dramatic weather events are natural Earth processes and occur around the world every day. Since their impact on humans and the environment can be quite extreme, it is important to know what causes these events.

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Last presentation will be February 2016

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Environmental science (S206/SXF206)

This module spans biology, chemistry, Earth science and physics, drawing them together in a holistic approach to studying the environment. You'll investigate air, water, Earth, life and cycles and explore the processes, interactions and feedback mechanisms operating within different environments.

An example of a 100-hour flexible online topic in science intended for interest or as a trial of a new study area:

Learn about the weather (SG089)
From February 2015 check module availability

An introduction to weather patterns and events around the world, explaining the main drivers that determine the weather on a seasonal and daily basis. You'll explore how professional weather forecasts are made and develop your own skills in interpreting observations.

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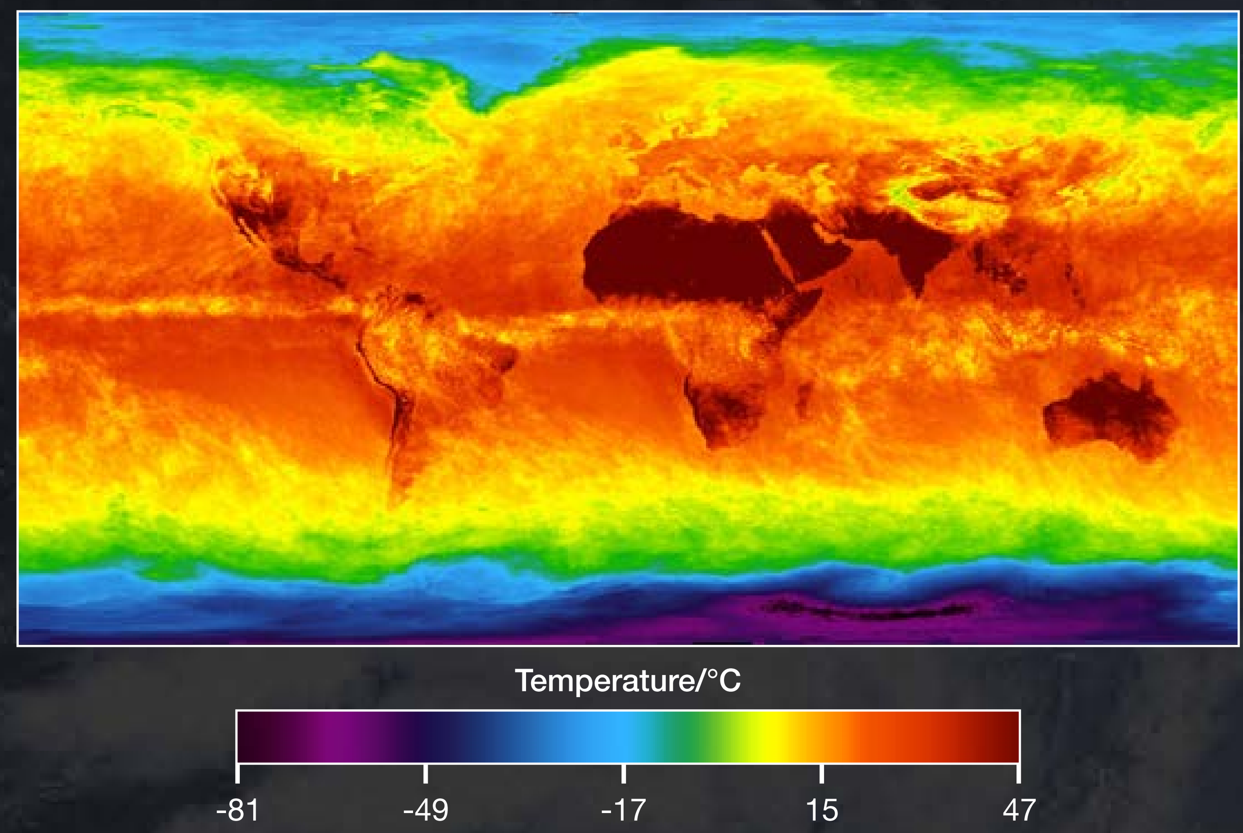
TAKING THE EARTH'S TEMPERATURE

The Earth's surface is warmed by light from the Sun and this heats the air close to the surface. The heating is strongest in regions near the equator (where the Sun is almost directly overhead at midday when viewed from the ground), and where the surface absorbs more sunlight (bright ice scatters more sunlight back to space than darker surfaces). The surface also warms and cools at different rates: land responds much more quickly to changes in heating than does the ocean. This uneven pattern of heating is what powers the weather as warmer air moves to cooler regions.

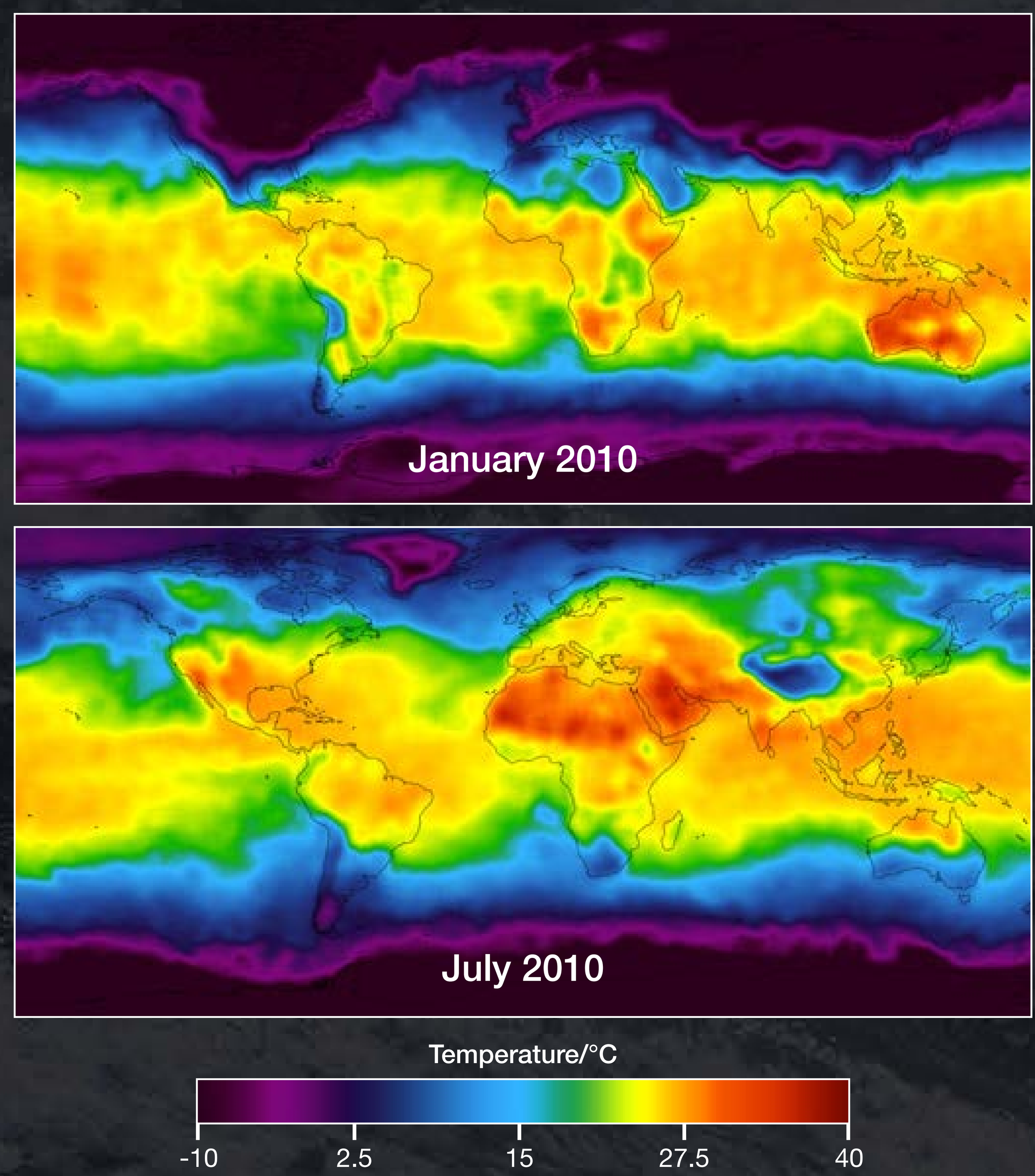


SURFACE TEMPERATURE IN APRIL 2003

The Earth's surface temperature as observed by the Atmospheric Infrared Sounder (AIRS) instrument aboard NASA's Aqua satellite. The main landmasses can be seen as the hottest objects at low latitudes. An irregular band of cooler temperatures (yellow) near the equator does not indicate cooler surface temperatures, instead it means the satellite can only see the tops of the thick clouds that form where warm, moist air rises.

A PATTERN OF SEASONS

The tilt of the Earth's rotation axis means that the latitude where the Sun is directly overhead at midday moves from the Tropic of Cancer (23.4° N) in late June to the Tropic of Capricorn (23.4° S) in late December (the solstices), passing over the equator twice a year in March and September (the equinoxes). This shifts the latitude where the heating is greatest from the Northern Hemisphere to the Southern Hemisphere and back. These changes in the Sun's heating cause changes in weather patterns to give us summer and winter weather.



AIR TEMPERATURES IN JANUARY AND JULY 2010

These images above show the average air temperatures near the Earth's surface in January and July 2010, the months immediately following the solstices. The warmest surface temperatures are seen in desert regions in the summer hemisphere (the Southern Hemisphere in January and the Northern Hemisphere in July). The coldest temperatures are seen in the high-altitude Antarctic Plateau in winter. The large landmasses show the greatest temperature difference between January and July, with the greatest winter to summer difference usually in Siberia. In comparison the ocean surface temperatures barely change with the seasons. Note that the colour scale is not the same as in the image above and that all temperatures colder than -10 °C are shaded dark.

RAINFALL OVER BERMUDA

Air is often lifted over land, both as a result of horizontal winds being deflected upwards by hills and mountains and as a result of convection, when the land warms faster than the nearby sea as it is heated by the Sun. As air rises and cools, clouds form if the air is moist enough for water to condense. In this example, rain is falling from convective clouds that have formed over an island.

RAIN, HAIL AND SNOW

Water plays a large role in the Earth's weather: as solid ice, liquid water or as a transparent vapour in the atmosphere. When water vapour condenses on small particles, known as nuclei, it forms clouds of water droplets or ice crystals according to the temperature. Only low clouds (below about 3 km altitude and above 0 °C) are purely liquid water droplets, and only high clouds (above about 7 km altitude and below -40 °C) are purely ice crystals. Within clouds, ice crystals tend to grow at the expense of water droplets as water molecules bind to them more readily. When ice crystals grow too large to be supported by air currents, they fall. Small crystals may stick together to form snowflakes. Larger crystals may continue to grow as water droplets stick to them to form hail, perhaps through several cycles in different upward and downward air currents within the cloud.

THE SHAPE OF RAINDROPS

Small water droplets in clouds tend to be spherical. When larger raindrops fall some distance through air they form slightly flattened shapes, which are wider than they are high, as a result of air resistance. This is in direct contrast to the popular 'raindrop' shape, which is often seen when raindrops run down a pane of glass or when a water drip forms slowly, perhaps from a leaking tap. Many raindrops begin their descent as hail and melt on the way down as they fall through warmer air.

CROSS-SECTION THROUGH A HAILSTONE

If large hailstones are cut into slices they often show a pattern of rings, rather like growth rings in a tree. These layers reveal the history of the hailstone as it grew. The more opaque regions are formed when the hailstone is high in the cloud and ice particles stick together. The clear regions are formed lower in the cloud when liquid water droplets freeze onto the surface. Large hailstones can cycle several times through a cloud, moving through regions of different temperature and humidity.

SIX-FOLD SYMMETRY IN A SNOWFLAKE

Snowflakes form from many tiny ice crystals that stick together in a process called aggregation. This can result in many beautiful shapes, but all have six-fold, or hexagonal, symmetry. This pattern is actually a result of the shape of the water molecule, in which two hydrogen atoms are bonded to the oxygen atom at an angle of 104.5°. This in turn means that when water freezes into ice the water molecules are held in a hexagonal lattice. The hexagonal structure is reflected in the angles between the faces of the small ice crystals, which stick together preserving six-fold symmetry.

DEADLY HAILSTONES

Hailstones can grow either as water droplets freeze onto their surface or by colliding with other growing hailstones and sticking together. When there are strong updrafts of air, often associated with the development of thunderstorms, hailstones can reach very large sizes. The largest hailstone recorded in the USA in 2010 was about 20 cm in diameter and weighed 0.9 kg. In many subtropical and tropical regions hail storms can be deadly and there are records of hundreds of deaths in India and Bangladesh. Fatalities have even been recorded in Britain as far back as the 15th century.

FLOODS AND DROUGHT

Precipitation is vital to life on Earth and either too much or too little rainfall can have devastating impacts on both the environment and on human life. Both floods and droughts are normal aspects of the Earth's climate, but human activity modifying drainage or irrigation can have a strong influence locally. The frequency and severity of droughts and floods in any one location are a result of weather patterns and how the atmosphere interacts with the Earth's surface, both land and sea. If the climate changes, either naturally or as a result of human activity, the frequency of flooding and drought is one immediate impact on the environment.

TEWKESBURY BEFORE AND DURING FLOOD

The image shows Tewkesbury Cathedral and the surrounding area as it normally appears and during the summer floods of 2007. Similar flooding occurred in the winter of 2012. These floods occurred when the River Severn was unable to drain all the water from its catchment area and burst its banks. Excess rainfall in a river catchment area is one common cause of flooding. Rivers have always flooded, but increased development in the catchment area can exacerbate the problem. Rainfall on concrete or tarmac will reach the river much more quickly than it would in a less developed landscape, where more water would be absorbed into the soil and plants and would filter through to the river more slowly.

A DRIED-UP RESERVOIR IN DERBYSHIRE, ENGLAND

A prolonged dry period is classed as a drought. There is no universal definition of drought because the water requirements of different parts of the world vary, so a drought must always be understood in local context. In the developed world a drought may require restrictions on water usage as reservoirs dry up and will lead to a rise in the cost of food and possible shortages. In other parts of the world a drought can be devastating. For example, in East Africa there have been serious, but not continuous, droughts for decades. Short, rainy periods are connected to changes in the prevailing wind direction (monsoons) and occur between longer dry periods. Changes in weather patterns may lead to shorter rainy periods or to no rain at all.

The Open University has a wealth of free online information and resources about science. Watch specially created video experiments exploring the science behind avalanches, dust storms, floods and tornadoes. Try the experiments yourself and share your results online.

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