National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

NATIONAL CENTRE FOR EARTH OBSERVATION

www.nceo.ac.uk

NATIONAL CENTRE FOR EARTH OBSERVATION

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The Earth at night. Daytime photographs of planet Earth show few signs of humanity. At night it's a different story. Areas of high economic prosperity and/or large populations shine the brightest. The main hubs and arteries of the industrialised nations are easy to follow and it is clear people like to live by the coast.
Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC.

Earth-orbiting satellites are revolutionising our understanding of our dynamic, constantly evolving planet. They provide stunning images with the power to inspire – such as images of powerful storms, complex ocean currents, majestic ice floes and delicate, interconnected ecosystems. But the value of satellites is much more than inspirational. Allied with ground-based observing systems and models, they provide essential quantitative information that enables us to comprehend, predict and thereby adapt to our changing environment and climate. Because satellites provide a global view of the interconnected forces that shape our planet, they are a key component of an 'Earth Management System', which will enable us to live on Earth in a sustainable manner.

The National Centre for Earth Observation (NCEO) was set up to make the scientific advances that space technology is now making possible. We bring together scientists with a wide range of skills, since the challenging questions we are tackling demand a multi-disciplinary approach. A high priority is to spread our expertise by training other scientists in the skills needed to exploit Earth observation, especially young scientists. We are also working to develop strong partnerships nationally and internationally to make faster progress, to spread the scientific benefits of our work, and to influence scientific and technological priorities.

Another key objective of NCEO is to build a parallel programme whereby advances in scientific knowledge are translated into benefits for government agencies, commerce and the general public. Exciting opportunities are being provided for example, by the UK's involvement in the European Global Monitoring for the Environment and Security (GMES) programme.

As director of the NCEO, I have the privilege of working with many dedicated and enthusiastic people. The science they do is as inspirational as it is challenging, diverse and important. It is fun to be involved in a scientific and technological revolution, which is where we are today in the world of Earth observation.

Professor Alan O'Neill
Director, National Centre for Earth Observation

Society is relying on science for answers to the most complex and daunting environmental challenges facing the planet. The National Centre for Earth Observation will channel and focus the UK's considerable expertise in this area.

Lord Paul Drayson *UK Science Minister*

Some of the most iconic images of mankind's journey into space have been of planet Earth. Since the first rockets left our atmosphere these images have inspired generations of scientists. NASA and the European Space Agency (ESA) have created a remarkable legacy and galvanised the international research community.

For many years UK researchers have worked closely with both agencies. They have helped develop missions, and stored, calibrated and used the information generated by those missions to increase knowledge of planet Earth and monitor rapid environmental change. A significant portion of this work has been managed by the Natural Environment Research Council.

The growing environmental challenges facing the planet have led the Natural Environment Research Council to launch the National Centre for Earth Observation.

WHAT IS EARTH OBSERVATION?

Earth observation is the use of satellites with aircraft and ground-based instruments to measure, monitor and understand our planet. It gives us a unique perspective of the Earth and has revolutionised how scientists work.

> It is critical that the research community provides governments with the most accurate and timely information on the global environment and how it is changing. The National Centre for Earth Observation will play a central role in this knowledge exchange.
>
> **Professor Alan Thorpe** *Chief Executive, Natural Environment Research Council*

Earthrise is one of the world's most reproduced photographs and was taken by NASA astronaut Bill Anders onboard Apollo 8 as it orbited the Moon on Christmas Eve 1968. NASA

NATIONAL CENTRE FOR EARTH OBSERVATION

Responding to the challenges of climate and environmental change

THE NEED FOR EARTH OBSERVATION

Governments, industry and the public are demanding knowledge to deal with environmental change and to protect Earth's life-support system. The scientific issues involved with climate and environmental changes are complex and interconnected. The crucial challenges have timescales ranging from minutes to millennia and spatial scales from local to global. Satellites have many advantages over traditional methods of data gathering:

- Real-time data from remote areas
- Global information with regional detail
- Repetitive, consistent measurements
- Near simultaneous measurements of many different factors – temperature, composition, colour, height, etc.

The National Centre for Earth Observation is the UK's dedicated centre to harness the full potential of space technology for environmental research. It brings together satellite data, other data and models of the Earth system to improve understanding and predictions of environmental change and its impacts on society and the planet.

Harnessing the power of the latest generation of high performance computers, the centre will analyse and process enormous quantities of data generated by Earth observation techniques to derive climatological datasets and to combine and compare data with Earth-system models. The work will reveal and help us to understand recent changes in environmental conditions and give increasing confidence about our ability to predict the future.

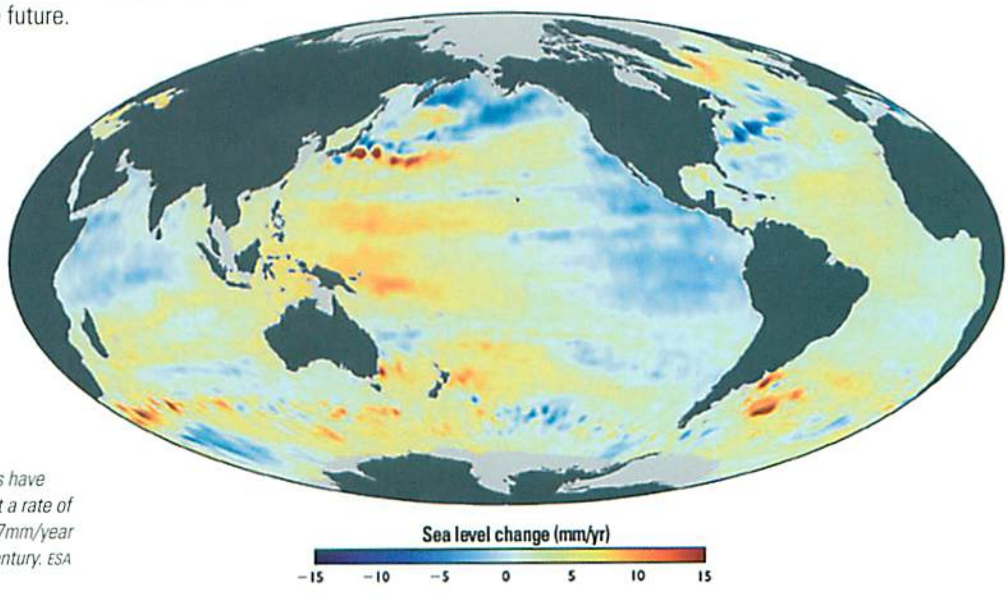
MISSION

The National Centre for Earth Observation's mission is to unlock the full potential of Earth observation to monitor, diagnose and predict climate and environmental changes.

The National Centre for Earth Observation is one of the Natural Environment Research Council's (NERC) family of centres. The NCEO collaborates closely with these centres, a range of NERC services and facilities, and with the wider academic community to deliver NERC's science strategy, *Next Generation Science for Planet Earth*. Our research and outreach programme is designed to respond to the needs of this strategy, focusing on areas where Earth observation provides opportunities for rapid progress (see pages 22 and 25).

FACTS AND FIGURES

The NCEO has a budget of £33 million for five years and involves more than 100 investigators from 26 UK universities and research centres. The centre is providing an unprecedented level of collaboration and integration. It builds on the strong heritage of NERC's previous seven Centres of Excellence in Earth Observation.



Sea-level rise 1993-2006
Since 1992, tide gauges and satellites have watched global mean sea level rise at a rate of 3.2mm/year, compared to a rate of 1.7mm/year from tide gauges over the previous century. ESA

THE KEY QUESTIONS

CLIMATE

The oceans and land absorb carbon from the atmosphere. How will the changing climate affect these carbon 'sinks'?

ATMOSPHERE

How can satellites improve flood forecasts?

CHANGING

CRYOSPHERE AND POLAR OCEANS

Where are stresses and strains in the Earth building up and can scientists predict earthquakes, volcanic eruptions and tsunamis more accurately?

DATA ASSIMILATION

THE SEVEN SCIENCE THEMES

How has the Atlantic Ocean circulation varied during the past decade and is there any sign of a slowdown?

CARBON CYCLE

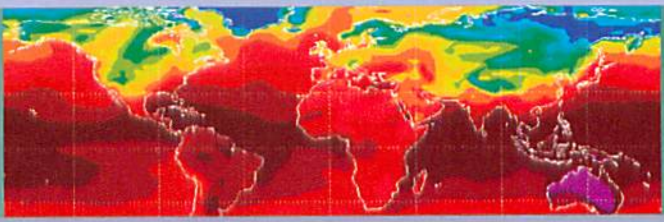
Where does air pollution come from and will climate change make its effects on health worse?

WATER CYCLE AND HAZARDOUS WEATHER

How fast is the Arctic's ice cover disappearing and how much are ice sheets contributing to sea-level rise?

DYNAMIC EARTH AND GEOHAZARDS

How can researchers use Earth observation data to improve climate models?



EUROPEAN SPACE AGENCY

The UK is the fourth largest investor in the European Space Agency (ESA) and the second largest funder of EUMETSAT – another European satellite agency that monitors weather, climate and the environment. ESA and EUMETSAT plan to launch 17 Earth observation satellites by 2016.

ESA's six approved Earth Explorer satellite missions will monitor ice, soil moisture, ocean salinity, gravity, ocean currents, wind, the Earth's magnetic field and radiation arriving from the Sun and leaving the Earth's atmosphere. UK scientists have been closely involved in their planning and preparation. The CryoSat-2 mission was proposed by researchers at University College London. The EarthCARE mission was proposed by researchers at University of Reading.

In 2008, ESA announced it is opening its first facility in the UK. The facility will focus on climate change research and robotics. A key reason for the choice of location is the UK's pre-eminent expertise in climate research, Earth observation and space engineering.

ENVISAT

The Envisat satellite, launched by the European Space Agency in 2002, is the largest Earth observation spacecraft ever built. It carries ten instruments to monitor the land, atmosphere, oceans and ice caps. The UK has been one of Europe's main contributors to Envisat.

THE SENTINELS – Global Monitoring for Environment and Security (GMES)

The Sentinel missions being developed by ESA include instruments for land, ice, ocean and atmospheric monitoring. The missions form the cornerstone of ESA and the European Commission's Global Monitoring for Environment and Security (GMES) programme. The data from these instruments are primarily targeted at government departments and operational agencies to help environmental and security policy. The long-term continuity of these missions also makes the data valuable for researchers investigating environmental changes.

Recognising the important contribution its missions are making to climate change research, Member States of ESA, including the UK, have recently endorsed a related initiative: Global Monitoring of Essential Climate Variables.

EARTH EXPLORERS

CryoSat-2

CryoSat-2 will determine variations in the thickness of the Earth's continental ice sheets and marine ice cover. **Launch date 2009.**

GOCE

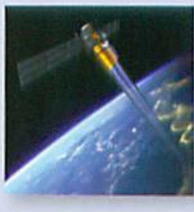
The Gravity field and steady-state Ocean Circulation Explorer will advance research in ocean circulation, the Earth's interior and sea-level rise. **Launch date 2009.**

SMOS

The global water cycle is changing. The Soil Moisture and Ocean Salinity (SMOS) mission will map soil moisture and ocean salinity to help monitor this change.
Launch date 2009.

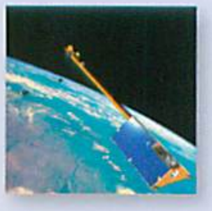
ADM – Aeolus

The Atmospheric Dynamics Mission (ADM) will pave the way for future operational meteorological satellites dedicated to measuring the Earth's wind fields. **Launch date 2011.**



Swarm

Swarm is a constellation of three satellites to study the dynamics of Earth's magnetic field.
Launch date 2010.



EarthCARE

A joint European-Japanese mission to improve how Earth's radiative balance is represented in climate models and weather forecasts.
Launch date 2013.

All above courtesy ESA.

EUMETSAT

EUMETSAT operates a fleet of meteorological satellites and their related ground systems to deliver data, images and products for weather and climate monitoring primarily for national meteorological services in the member and cooperating states. The Meteosat Second Generation satellites also include scientific instruments for measuring the incoming and outgoing radiation from the sun, designed and built in the UK. This provides scientists with information on Earth's energy balance.

NASA

The UK works closely with NASA and the US research community to develop instruments and use Earth observation data.

Aqua provides precise atmospheric and ocean measurements.

Aura monitors the ozone layer, air quality and climate. One of Aura's four instruments was funded by the UK.

Terra's sensors monitor the interactions between Earth's atmosphere, lands and oceans.

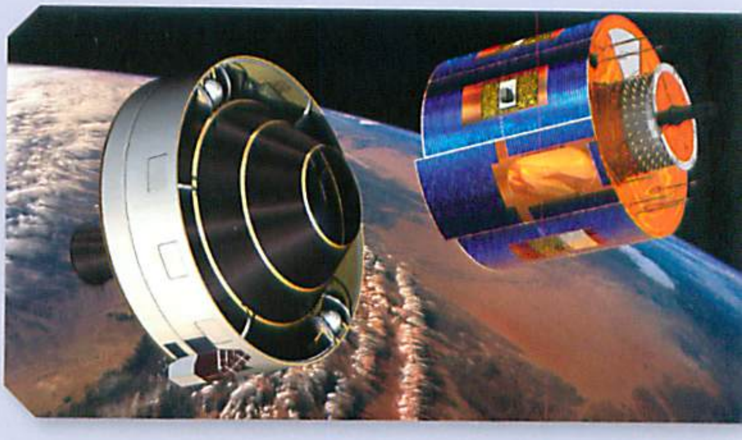
IceSat measures ice-sheet mass balance and cloud properties.

CloudSat's instruments slice through clouds to examine their composition and structure.

OCO provides space-based observations of atmospheric carbon dioxide.

Grace – twin satellites making detailed measurements of Earth's gravity field.

The National Centre for Earth Observation will work with other space agencies, including the Japanese space agency, JAXA, and it plans to work with Earth observation programmes in Argentina, Brazil, China and India.



Top to bottom:
Meteosat Second Generation (MSG), Europe's new weather satellite. ESA

A new European Space Agency facility will be built at Harwell in Oxfordshire. The hi-tech site already houses the Diamond Light Source and Rutherford Appleton Laboratory. UK Science and Technology Facilities Council

Jason-2, also known as the Ocean Surface Topography Mission, monitors global ocean circulation. NASA/JPL

The Envisat satellite is the largest Earth observation spacecraft ever built. ESA

CLIMATE

The UK science community is a world leader in climate research. The priority now is to increase knowledge of the climate system to improve predictions and develop effective mitigation and adaptation strategies.

THE ROLE OF EARTH OBSERVATION

Earth observation satellites and aircraft already play a crucial role in measuring ocean warming, sea-level rise, Arctic sea-ice loss and changes in vegetation cover. Data from major new missions such as Cloudsat, GOCE and Cryosat-2 will need to be combined with existing data to provide a comprehensive description of recent changes in the climate system.

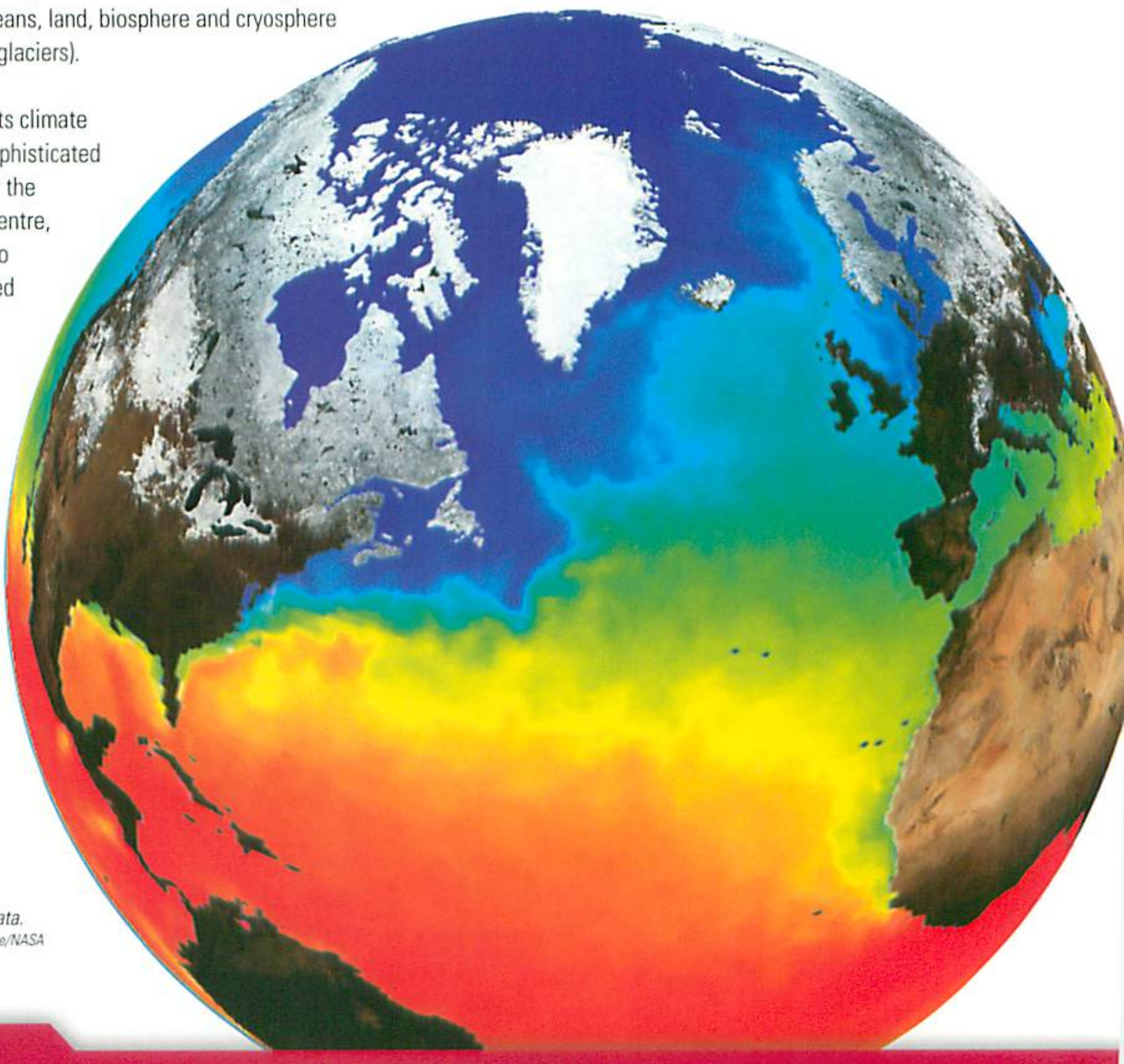
The exchanges of heat, water and carbon dioxide within the climate system are the key quantities we need to measure and understand. The strength of Earth observation is that it provides a global picture of the whole climate system and how it is changing that ground-based measurements cannot. It allows us to monitor both large- and small-scale interactions and provides key data for testing the performance of complex global climate models linking the atmosphere to the oceans, land, biosphere and cryosphere (ice sheets, floes and glaciers).

The centre will build its climate programme around sophisticated climate models run by the Met Office's Hadley Centre, allowing the models to be tested and improved to make better climate predictions. The programme will develop its already excellent relationships with the Met Office and the European Centre for Medium-Range Weather Forecasts.

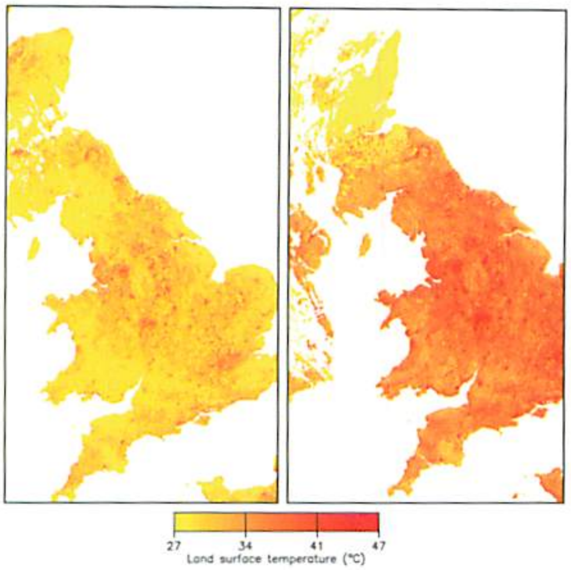
JOINING THE DOTS

Even with the large number of satellites orbiting the planet data are still incomplete, and data from older instruments need to be seamlessly joined with satellite measurements made today. This is crucial for creating longer time records necessary for understanding climate change.

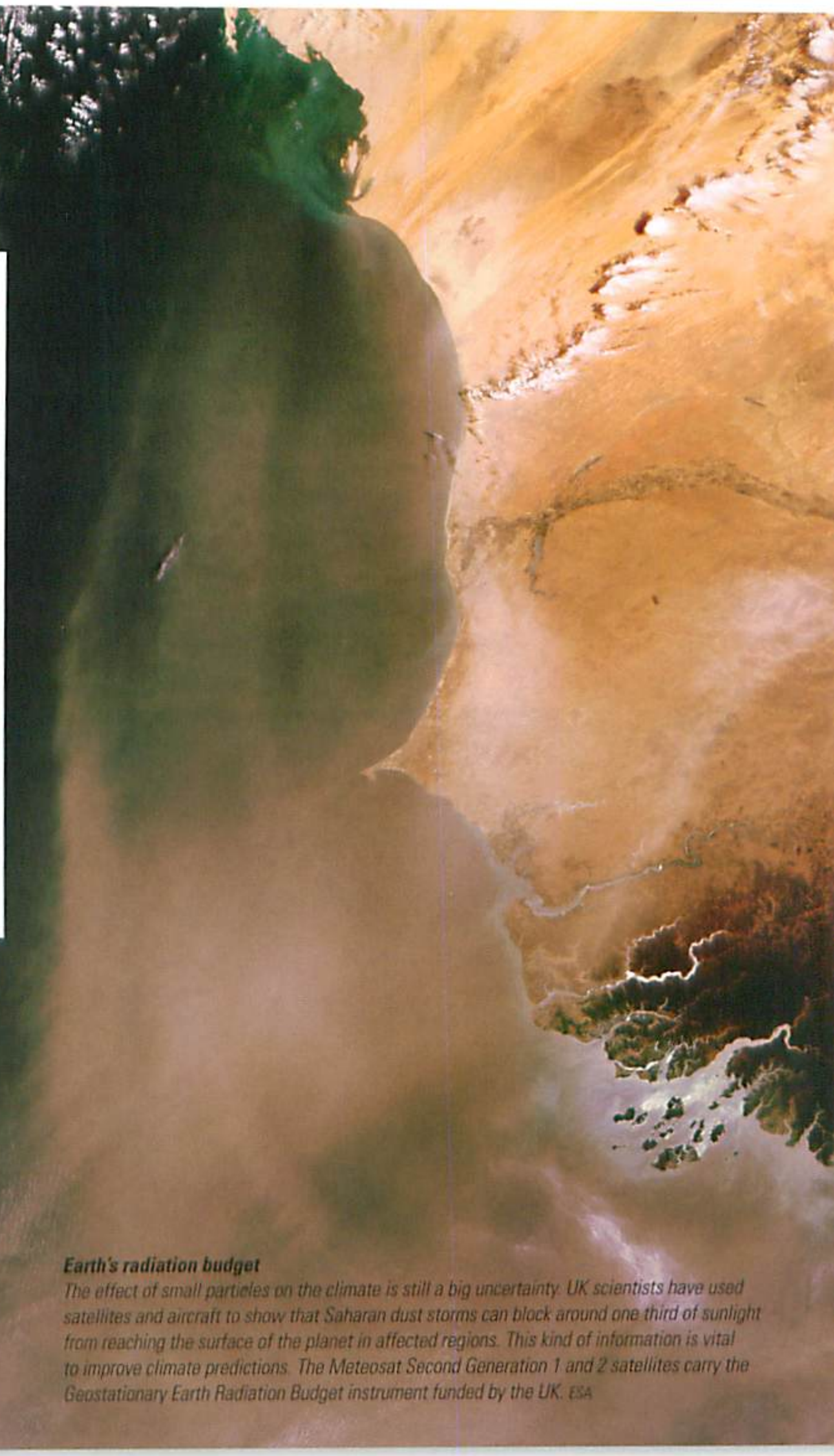
The UK has world-class data assimilation specialists to synthesise and reanalyse the global datasets, to fill the gaps in measurements to create a more complete picture. The work allows scientists to get more out of the Earth-observation data, it allows the climate models to be improved, and it will soon allow climate models to start from the best current global observations to make climate predictions from a season to decades ahead, in a similar way to how we make weather forecasts today.



Sea surface temperature data.



The 2006 heatwave: land-surface temperature retrieved from the UK-funded AATSR instrument on the European Space Agency satellite Envisat, on 15 July 2006. University of Leicester



Earth's radiation budget

The effect of small particles on the climate is still a big uncertainty. UK scientists have used satellites and aircraft to show that Saharan dust storms can block around one third of sunlight from reaching the surface of the planet in affected regions. This kind of information is vital to improve climate predictions. The Meteosat Second Generation 1 and 2 satellites carry the Geostationary Earth Radiation Budget instrument funded by the UK. ESA

PRIORITIES

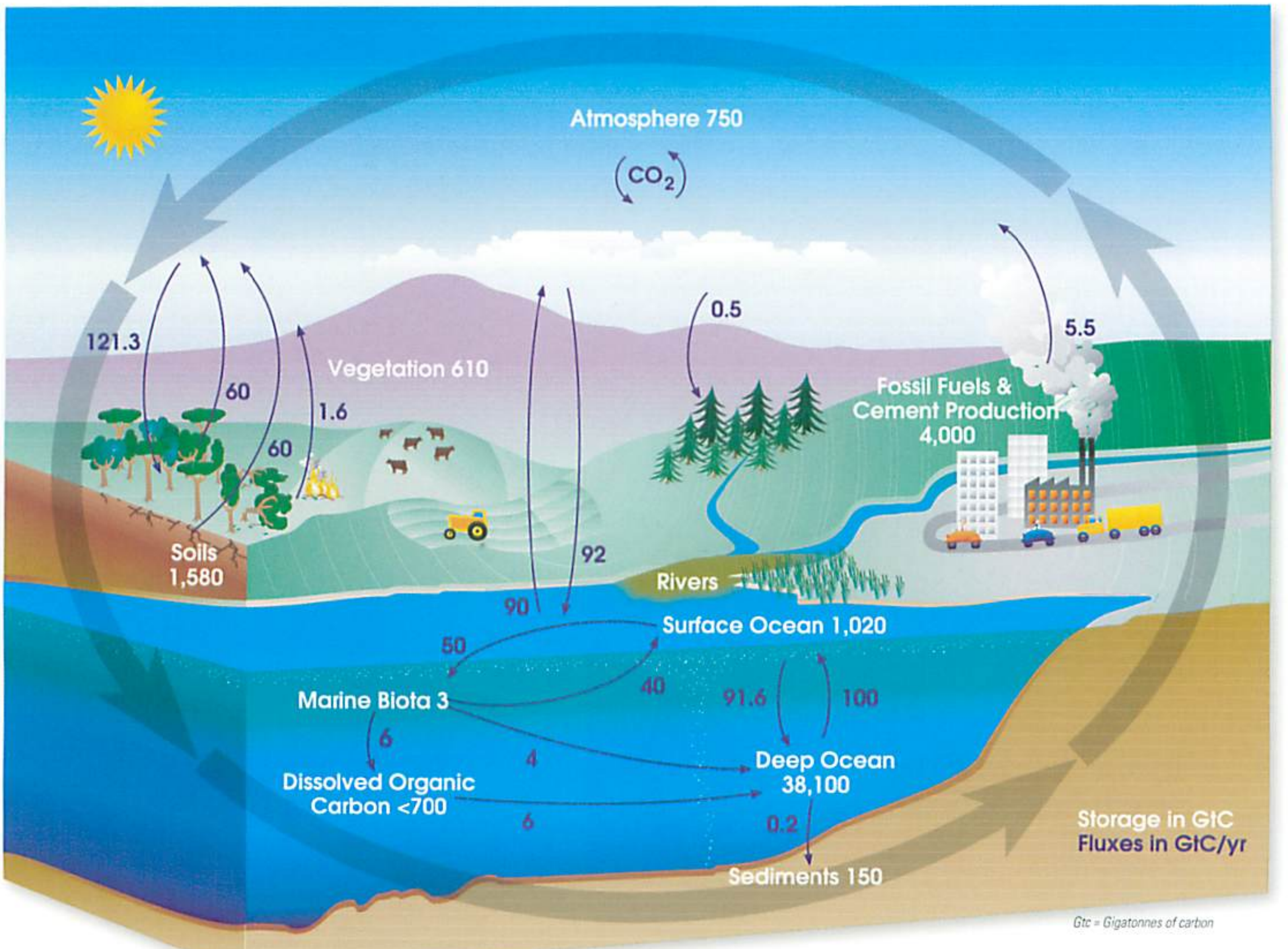
- Compare how computer models represent water vapour, clouds and the Earth's radiation budget with satellite data.
- Combine ocean-surface data from space with data taken from instruments on-board ships and subsurface ocean monitoring networks to understand changes in ocean circulation and ocean warming.
- Improve how climate models represent cryosphere interactions with the oceans and atmosphere.
- Improve how climate models represent the land surface, including life processes, and the resulting heat, water and gas exchanges with the atmosphere.

Carbon flows in huge quantities between the atmosphere, the oceans and the land. This natural cycle is driven by plant and marine algal growth, soil respiration and absorption, and gas exchange between the ocean and the atmosphere.

While emissions from fossil-fuel burning are much smaller than these natural flows, they are inexorably pushing up atmospheric carbon-dioxide levels. The land and oceans each remove about a quarter of the carbon dioxide put into the atmosphere by man-made emissions. Without these natural processes storing carbon away from the atmosphere, the climate would be warming faster than it is. New evidence suggests these carbon sinks may be slowing down.

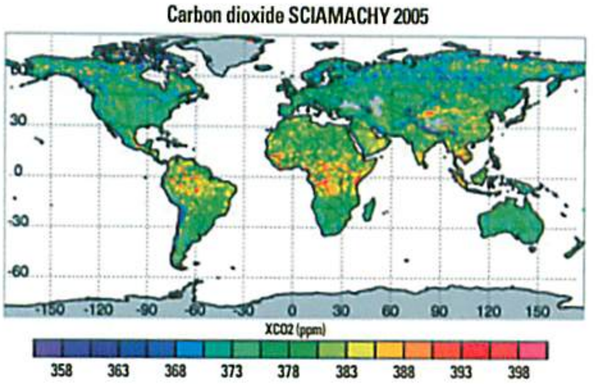
THE BASIS OF LIFE ON EARTH

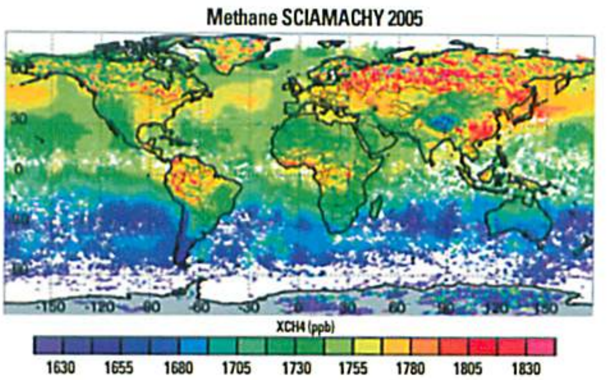
The carbon cycle is not just about greenhouse warming. Vegetation and marine algae (phytoplankton) fix carbon as they grow. This provides the whole basis of the food chain on which life on the planet depends. The carbon cycle tells us about the productivity of the planet – how much plant life there is – and how it is rapidly changing.



Earth's carbon cycle

The illustration shows total amounts of stored carbon in white, and annual carbon fluxes in purple. Precise information on the global carbon cycle is contained in the Intergovernmental Panel on Climate Change Fourth Assessment Report (www.ipcc.ch). NASA Earth Science Enterprise





Satellites provide global estimates of greenhouse gas concentrations in the atmosphere (carbon dioxide, methane, nitrous oxides).

Because greenhouse gas flows are global it is hard to build an overall picture of how they are behaving and what is driving them. Space is one place where researchers can get this global view. But satellites don't detect the flows directly. Instead, scientists measure quantities like absorbed radiation, fire scars or ocean colour, which shows carbon take-up by marine plants.

To convert these quantities into carbon flows to and from the atmosphere, scientists need to combine them with computer models of how biophysical systems work. Finding the best way to combine these two sorts of information is a major challenge. We need to bring together ecologists, oceanographers, statisticians and computer modellers to complete the picture.

CARBON FOOTPRINT

The latest satellites can measure the total amount of atmospheric carbon dioxide and methane between the satellite and the ground. This still doesn't tell us about the size of gas flows, so the measurements have to be combined with computer models of how the gases move in the atmosphere to find out where the surface is soaking them up and where they're being emitted.

The National Centre for Earth Observation brings together the best knowledge of ocean, land and atmospheric processes, from computers, satellite data and ground-based information to create an accurate picture of how the carbon cycle is behaving.

PRIORITIES

- Combine satellite measurements of the Earth's surface and atmosphere with sophisticated models of the land and ocean that mimic life in these ecosystems.
- Vastly increase knowledge of the role of fire in the carbon cycle.
- Accurately account for the carbon balance in the tropics to provide strong support for the negotiations on the post-Kyoto Protocol, particularly regarding deforestation.
- Provide complete tracking of carbon and water through land ecosystems into the atmosphere.
- Deliver a better quantification of carbon sources and sinks in the oceans.
- Understand shelf seas – the shallow seas surrounding the continents – which are rich in life and so draw down much carbon dioxide from the atmosphere. Other CO_2 'hot spots' include the high latitudes – the Arctic and Antarctic. Earth observation satellites can help establish the importance of these areas.
- Help build a high-resolution global, regional and UK carbon-monitoring system.

The atmosphere is made up of a delicate balance of many different chemicals. Climate change and pollution are causing this balance to shift. There are still many uncertainties as to how this shift will affect the atmosphere and the chemical reactions going on within it.

Changes in the composition of the atmosphere are important for three reasons. First, they are driving climate change. Second, air pollution affects human health and life on Earth. Third, the changing temperatures will affect the types of chemical reactions that happen in the atmosphere.

Because there are so many uncertainties in this field, the United Nations Intergovernmental Panel on Climate Change has identified this area as a high priority for research.

The National Centre for Earth Observation will focus on methane, gases that remain in the atmosphere briefly, and small particles (also known as particulates or aerosols). These affect the climate either directly by influencing incoming or outgoing radiation, or indirectly through chemical reactions.

The shorter-lived gases and particulates are also responsible for pollution and air quality at surface level.

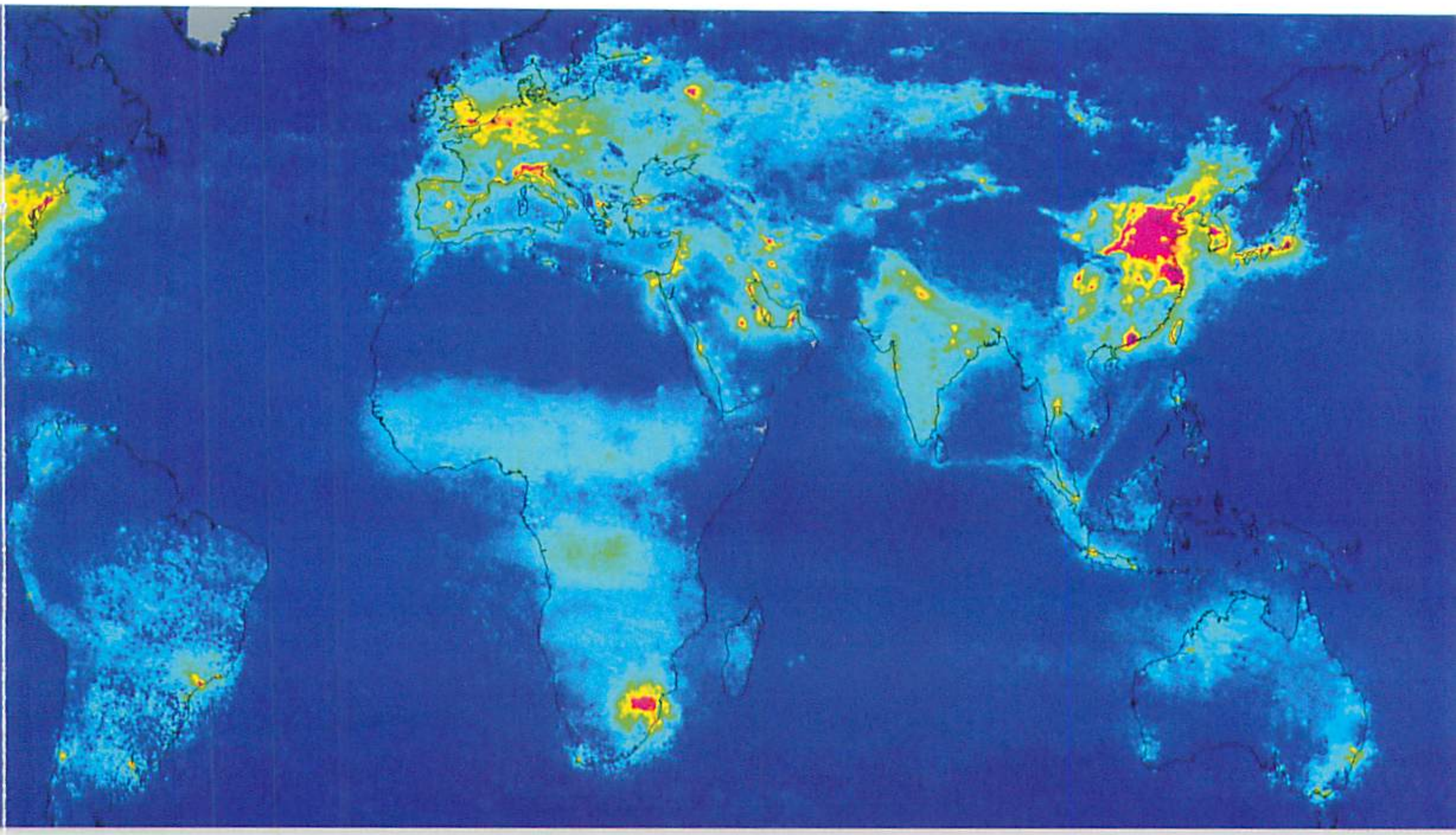
THE BIG PICTURE

Satellites, research aircraft and ground-based instruments can create a comprehensive picture of what is happening to the atmosphere in great detail.

Researchers can use satellites to identify chemicals in the atmosphere by analysing the different types of radiation – longwave and shortwave – emitted by the Earth or reflected from clouds.

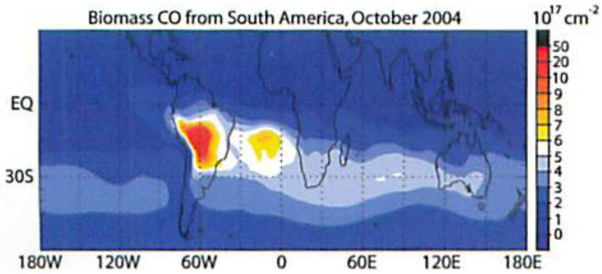
Computer models simulate the major processes governing the atmospheric distributions of trace gases and aerosols. By comparing these with satellite observations, scientists can improve how models represent the real atmosphere. From this, scientists will have more accurate projections of future climate. This is important for two reasons. First, changes to atmospheric composition are the root cause of global warming. Scientists expect atmospheric composition to change in response to future warming, giving rise to feedbacks. At the moment, researchers are still unsure whether this will fuel more warming or curb warming, nor how big these changes could be. Second, air pollution at ground-level, and its deleterious effects on our health and life on Earth, are likely to increase in a warmer climate.

Average nitrogen dioxide (NO_2) pollution map for 2006, measured by Envisat. NO_2 is mainly a man-made gas, which can cause lung damage and respiratory problems. It plays an important role in atmospheric chemistry because it leads to the production of ozone in the lowest part of the atmosphere. KNMI/IASB/ESA



PRIORITIES

- Generate data on trace gases and small particles, both natural and man-made – also known as aerosols – in the troposphere (0-11km) and the lower stratosphere (around the altitude commercial jets fly).
- Improve understanding of where these gases and particles come from and how they move in the atmosphere.
- Test the UK's chemistry-climate model.
- Work with governments across Europe to help monitor pollution and forecast air quality.



Above: Cyclist wearing a pollution mask in London. Photofusion Picture Library/Alamy

Left: A computer-based simulation of the movement of carbon monoxide (CO) released from South American wild fires. The CO is clearly visible moving across southern Africa to Australia, and confirmed by Envisat observations. SRON

CHANGING WATER CYCLE AND HAZARDOUS WEATHER

Society needs better forecasting of hazardous weather. In 2006, an estimated 130 million people worldwide were hit by storms, storm surges, floods and droughts. One consequence of climate change is that the frequency and strength of hazardous weather is likely to increase in the future.

Dust storm after a prolonged drought in Australia. *UK researchers have discovered that storms in the southern hemisphere could move farther south, leading to less rainfall in already-dry south-east Australia. This could have major economic effects on the region, particularly on wine production.*

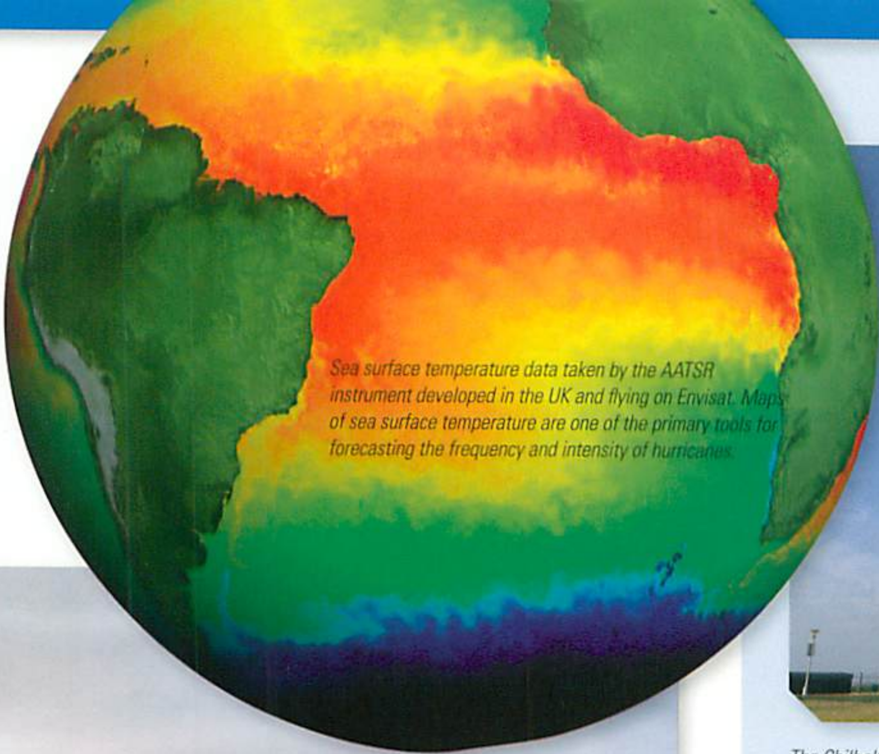
Jamie Alexander/AP/PA Photos

PA News

Satellites are already invaluable tools for monitoring and forecasting tropical storms and other types of severe weather. Scientists are now examining other natural processes that affect the weather such as soil moisture, snow, wind and rain to make weather predictions more accurate.

The UK is well placed to take a lead when it comes to making better predictions of the weather because it already has high-quality data and a wealth of research expertise in meteorology.

Researchers at the National Centre for Earth Observation plan to work with several space agencies launching satellites focusing on severe weather. Using Earth observation satellites and new data-assimilation techniques will help minimise both the risk and cost of severe weather in the future.



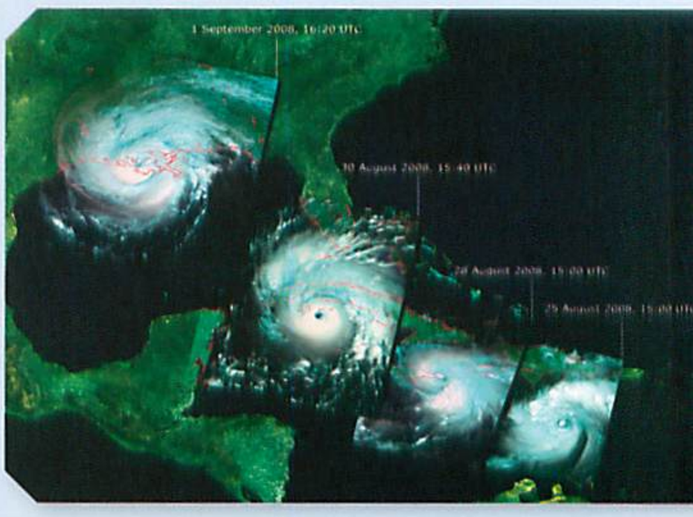
Sea surface temperature data taken by the AATSR instrument developed in the UK and flying on Envisat. Maps of sea surface temperature are one of the primary tools for forecasting the frequency and intensity of hurricanes.

The Chilbolton Observatory in Hampshire helps atmospheric scientists research how rain develops to improve estimates of rainfall. The radar can distinguish rain from snow and ice, as well as the size of individual raindrops. A new radar allows scientists to see how and where convective clouds form and develop into rain clouds.

A rescue worker wades through flood water at Calshot, near Southampton, as high winds and heavy rain batter the coast of England in March 2008.
Chris Ison/PA Archive/PA Photos

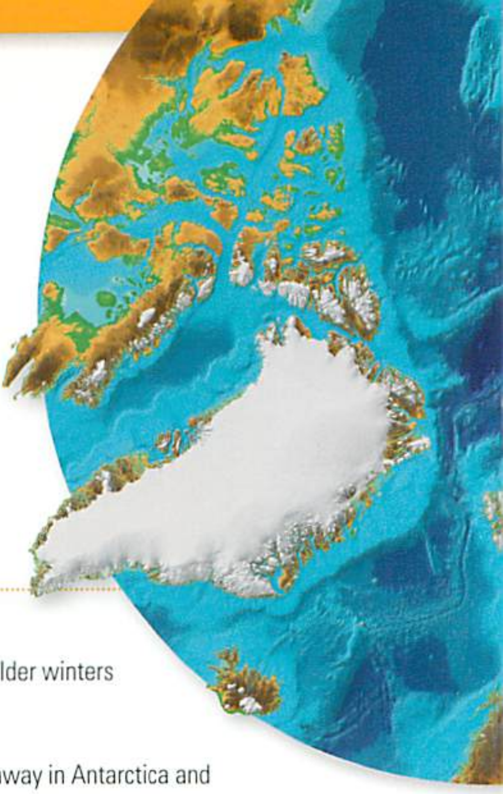
PRIORITIES

- Develop data-assimilation techniques that incorporate satellite and ground-based measurements into high-resolution models.
- Improve water and flooding models.
- Exploit data from upcoming missions such as Global Precipitation Measurement (GPM) and EarthCARE.



The path of Hurricane Gustav over six days in 2008. ESA

CRYOSPHERE AND POLAR OCEANS



The polar regions of the Arctic and Antarctic are alluring places. They're beautiful, wild and seemingly untouched. But over the past few decades, scientists using Earth observation satellites have witnessed major changes in both regions.

The greenhouse effect is turning the poles into the fastest warming regions on Earth. Arctic sea ice is retreating as well as thinning and Antarctic ice shelves have collapsed. Widespread melting of ice in both the Arctic and Antarctic is set to have global impacts.

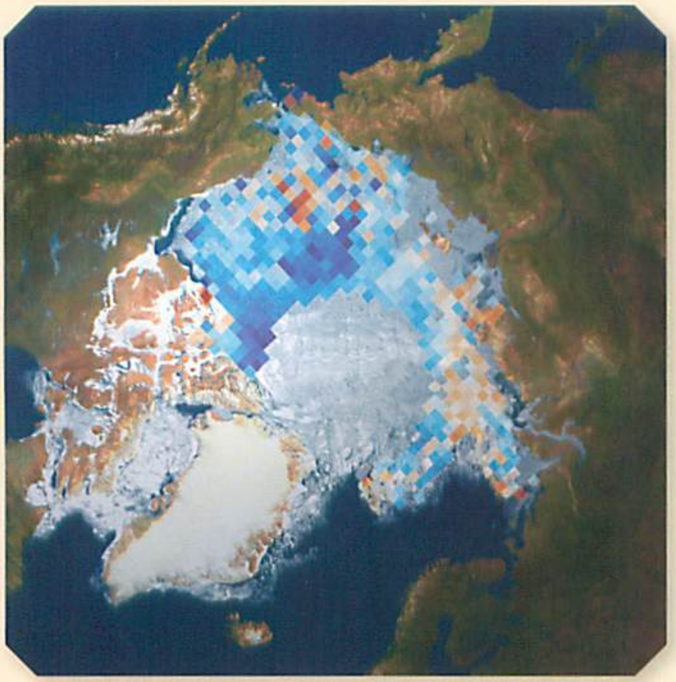
As Arctic sea ice retreats, winds act directly on the exposed ocean surface, changing ocean circulation patterns. Fresh water can move into the North Atlantic, changing the way a key ocean current – the Atlantic conveyor belt – behaves. It's this current that helps give Western Europe its mild winters. If the current changes too much, we may have much colder winters to look forward to.

As ancient ice that's locked away in Antarctica and Greenland melts, sea levels may rise faster than currently predicted. The Greenland ice sheet contains enough ice to raise sea levels by over six metres.

At the poles, ice acts like a mirror reflecting heat from the sun back out to space: the albedo effect. As ice melts, scientists are uncertain about exactly what effect this will have on the remaining ice.

Arctic on thin ice

UK scientists used satellites to show that the thickness of sea ice in large parts of the Arctic fell by nearly half a metre (19 per cent) during the 2007-08 Arctic winter compared with the average thickness of the previous five winters. This followed the dramatic 2007 summer low when Arctic ice extent dropped to its lowest level in 30 years. UCL/Planetary Visions Ltd



Europe's ice mission

UK researchers provide scientific leadership for a new satellite – CryoSat-2 – that will measure sea-ice thickness in the Arctic, as well as ice thickness at the edges of ice sheets in both Greenland and Antarctica, with greater resolution than any previous satellite. The European Space Agency is planning on launching CryoSat-2 in 2009. ESA

SATELLITE REVOLUTION

These are just some of the reasons it is vital that scientists keep track of exactly how the poles are changing. But the polar regions are huge, inhospitable and difficult places to get to and taking direct measurements isn't always practical or efficient. Satellites have revolutionised the way that scientists study the poles because they allow vast areas to be monitored continuously.

The National Centre for Earth Observation will improve knowledge of the cryosphere – the parts of the Earth that are frozen – and the polar oceans. Scientists at the centre will use new and existing satellites to plug gaps in our understanding of the poles.

Data from satellites allow researchers to find out how the poles contribute to sea-level rise and ocean freshening; understand the origins of Arctic freshwater; uncover how ice moves around polar regions; measure changes in sea ice thickness in the Arctic and understand how melting regions contribute to climate change.

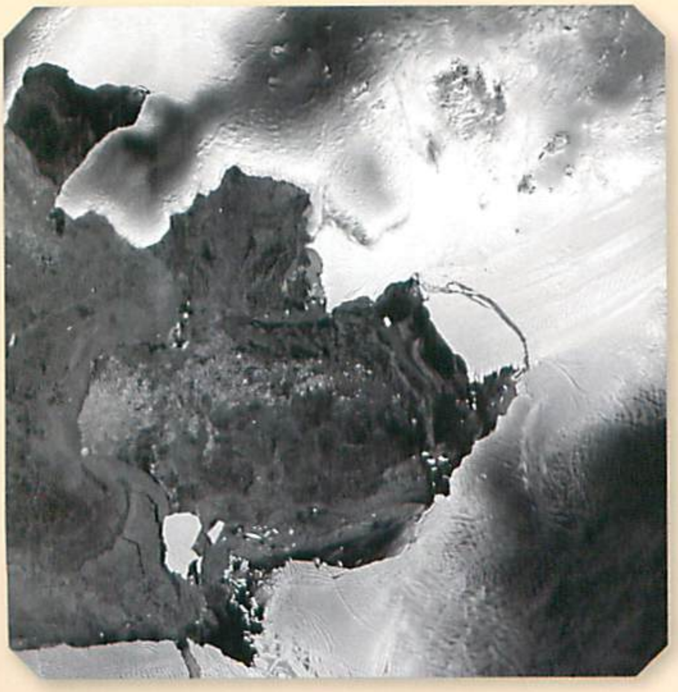
These observations will generate data for researchers to develop new models, which will feed into global climate models improving how these models represent the poles.

PRIORITIES

- Quantify and understand recent mass changes in the marine and land cryosphere.
- Exploit three satellites, the US-led gravity satellite GRACE, the European Space Agency's GOCE (Gravity and steady-state Ocean Circulation Explorer) satellite, and CryoSat-2, to provide constraints on models of Arctic Ocean circulation and global sea-level rise.
- Provide a historical and future perspective on data gathered during the International Polar Year initiative.
- Develop key models of processes involving ice in the climate system.

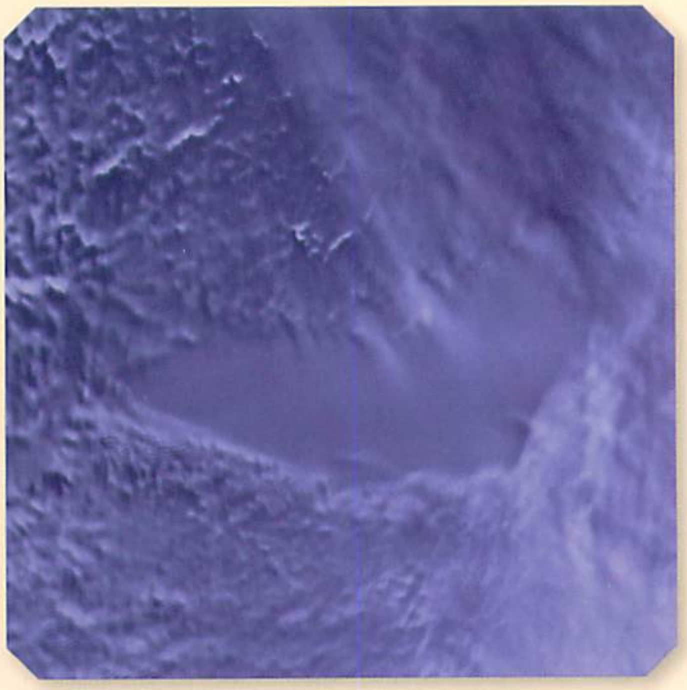
Freezer thaws

One of Antarctica's five largest glaciers – the Pine Island Glacier – is losing ice faster than all of the West Antarctic ice streams. What's more, satellite data in combination with models have shown that the ice is thinning inland. If the present rate of thinning continues, the currently grounded Pine Island Glacier will be afloat in 600 years. ESA

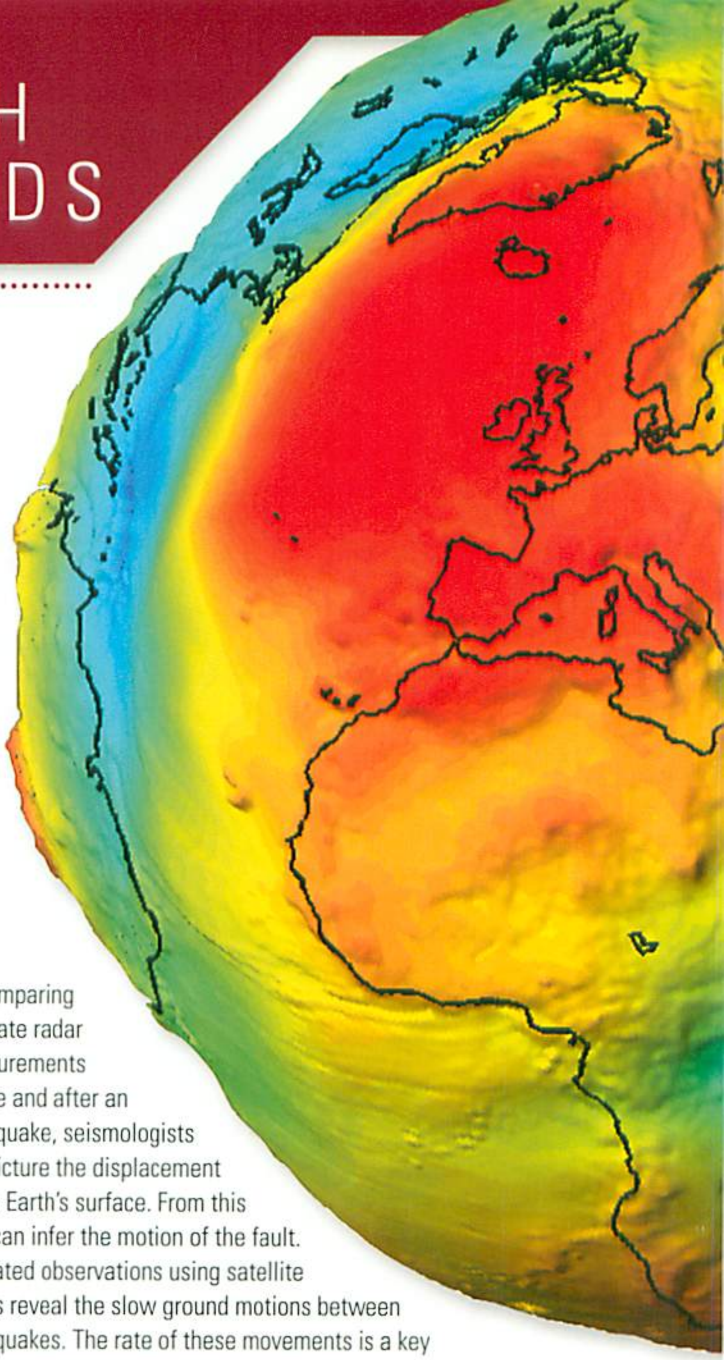


Subglacial lakes pop like champagne corks

Water from melting Antarctic ice could be forcing subglacial lakes that lie deep beneath the continent, such as Lake Vostok (pictured), to burst under pressure, challenging the idea that the lakes are isolated. Researchers originally thought that isolated lakes could harbour unique microbial ecosystems, but the discovery that the lakes are connected means that drilling down to them could lead to widespread contamination. NASA



DYNAMIC EARTH AND GEOHAZARDS



The public perception that there is a growing risk from natural hazards such as earthquakes, volcanic eruptions, tsunami and landslides is well founded. This is not due to any change in the behaviour of natural processes, but rather to large and growing populations living in areas prone to these hazards.

Better prediction will limit damage and save lives, but to do this researchers need to advance understanding of the natural processes at work. But how can satellites measure processes that begin deep beneath our feet?

The earthquake cycle of a particular fault may take hundreds to thousands of years, and individual volcanoes often erupt sporadically on timescales of centuries to tens of thousands of years. But globally, these events occur frequently. By accurately and comprehensively monitoring one, seismologists can apply what they've learned more generally.

EARTHQUAKES

Seismologists can combine observations from space and aircraft with surface measurements and mathematical models of the physical and chemical processes to gain insights into what causes earthquakes deep within the Earth. A major advantage of satellites is that measurements are global, regular and uniform.

Aftermath of the earthquake which hit Kashmir in 2005. Sipa Press/Rex Features

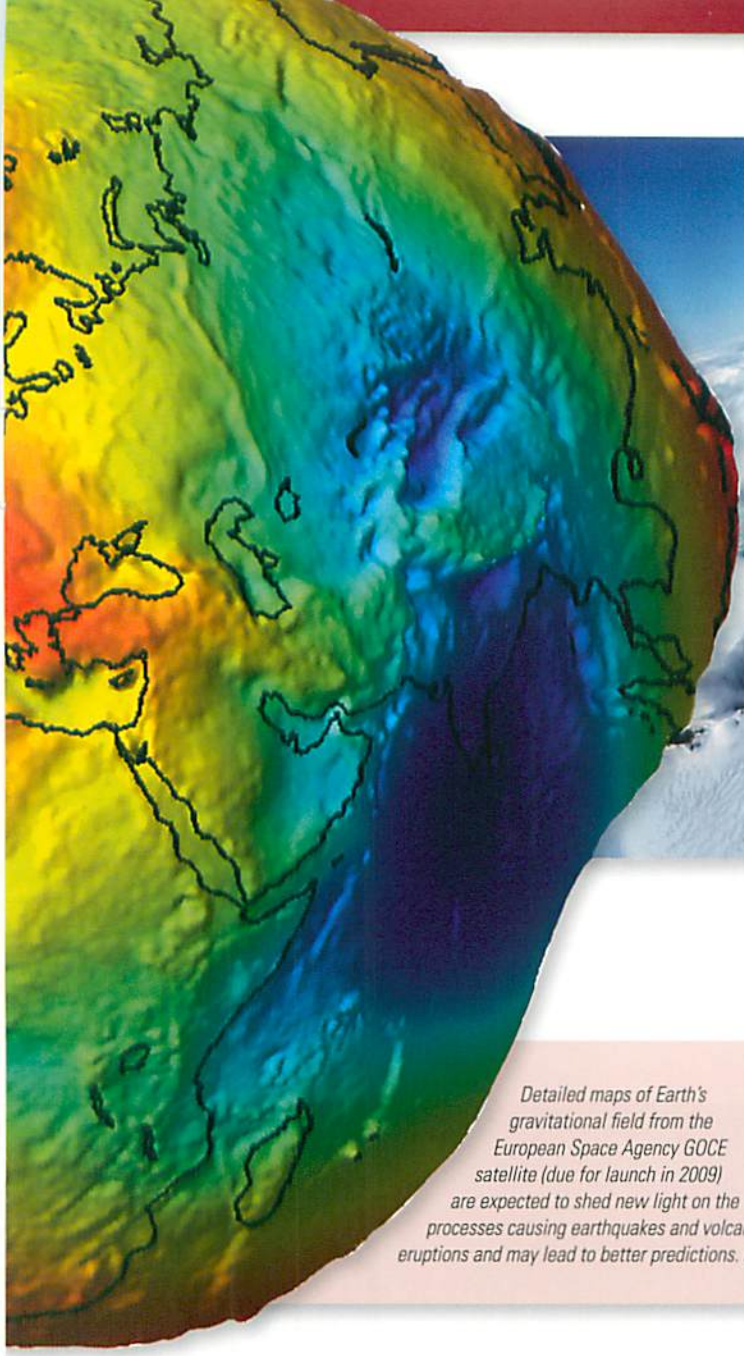
By comparing accurate radar measurements before and after an earthquake, seismologists can picture the displacement of the Earth's surface. From this they can infer the motion of the fault. Repeated observations using satellite radars reveal the slow ground motions between earthquakes. The rate of these movements is a key factor in the likelihood of future earthquakes.

VOLCANOES

Satellites can detect surface deformation around volcanoes which can indicate that things are stirring deep below. They can also monitor the gases emitted to the atmosphere which are linked to the depth of the magma and its composition.

The challenge is to combine these measurements with measurements of the small volcanic earthquakes between eruptions to work out how magma moves before finally erupting.

The National Centre for Earth Observation brings together researchers with expertise in areas such as seismology, geomorphology, geochronology, geochemistry and atmospheric chemistry to improve predictions and reduce uncertainty. A key UK partner will be the British Geological Survey.



Detailed maps of Earth's gravitational field from the European Space Agency GOCE satellite (due for launch in 2009) are expected to shed new light on the processes causing earthquakes and volcanic eruptions and may lead to better predictions. ESA

A damaged school in Sichuan province after the earthquake of 12 May 2008. Reuters/Nir Elias

PRIORITIES

- Create detailed descriptions of what happens at depth in earthquake zones and construct regional models of faulting and crust deformation.
- Assess the hazards from individual volcanoes by monitoring deformation, lava, thermal radiation and gas and particle emissions.
- Improve the accuracy of surface deformation measurements.
- Realise the potential of the global GPS system of instruments to provide an alternative source of seismological information. This work could also benefit tsunami warning systems.

Smoke spewing from Europe's largest active volcano, Mt Etna. Envisat ESA

DATA ASSIMILATION

Effective environmental prediction requires several elements including high-quality satellite measurements. This data is most valuable when combined with numerical models of the oceans, land and atmosphere, ground-based measurements and powerful computers running models rapidly. This is known as data assimilation.

Data assimilation takes raw data and transforms it into more useful high-level information, maximising the benefits to other researchers and governments and industry. The UK is already a world-leader in data assimilation.

Current assimilation techniques mainly look at large-scale atmospheric and ocean processes. They are based on simple assumptions, but scientists think they can be improved markedly.

The National Centre for Earth Observation will develop new techniques for assimilating data into different Earth-system models. By concentrating resources in this separate data-assimilation strand, the centre will provide expertise to other UK scientists and operational centres such as the Met Office.

PRIORITIES

- Create data-assimilation techniques for use in coupled, multi-scale Earth-system models.
- Construct techniques to represent uncertainty in observations and models.
- Determine surface movements of trace gases.
- Quantify the impact of observations.
- Develop observing-system simulation experiments.

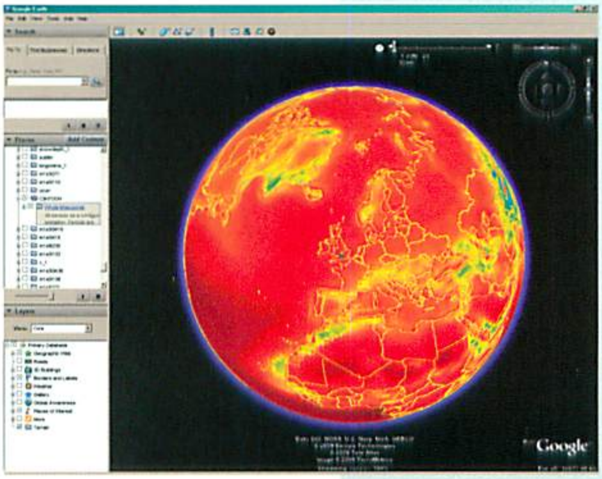
INFORMATICS

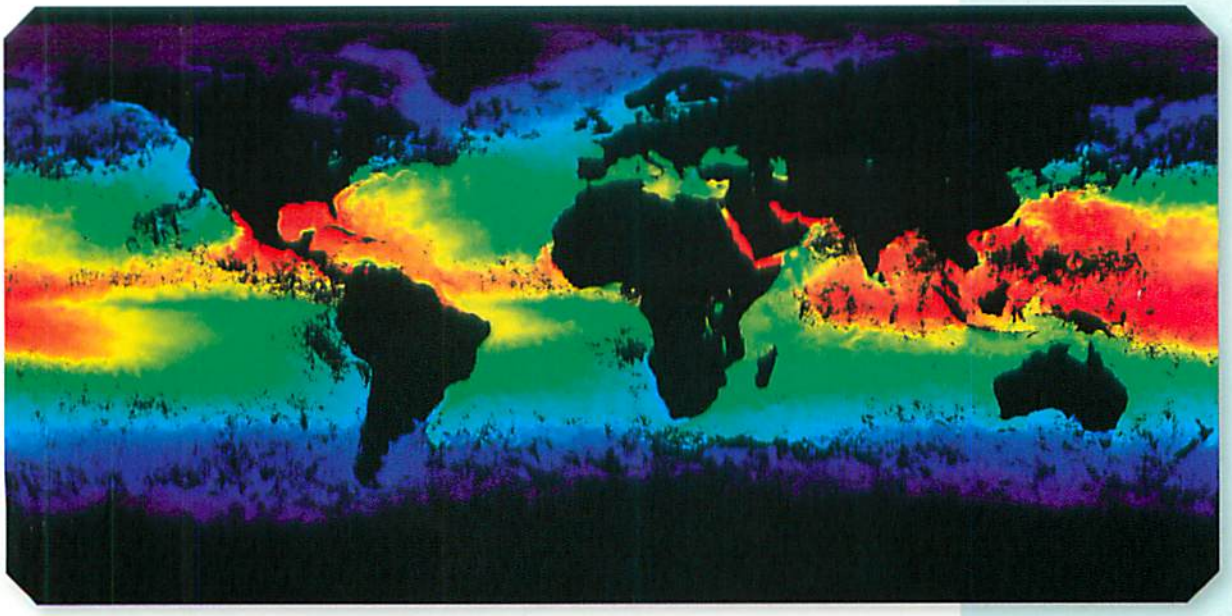
As part of the NCEO, the NERC Earth Observation Data Centre (NEODC) will provide data management and support for NCEO participants and the wider community of Earth observation users.

Remote-sensing from aircraft and satellite systems generates a vast amount of data. Storing, managing and disseminating this data is an enormous challenge. The NEODC based at Rutherford Appleton Laboratory in Oxfordshire, is a core partner within the National Centre for Earth Observation providing essential data management and services to the UK research community.

Data-management services incorporated into the NCEO programme include:

- Regular data acquisition to ensure that NCEO and the wider Earth observation community minimise duplication of effort in acquiring data, and improvement of access speeds for scientific data users.
- *Ad hoc* data acquisition to acquire specific Earth observation and correlative datasets as required by the NCEO and wider environmental community.
- Active management and curation of data and associated information to maintain the data, now and for posterity, and to develop and maintain the information needed to automate data access and management.
- Maintenance and development of tools and systems for cataloguing and delivering data to enable users to find, visualise and extract data using international and interoperable standards.
- General science support for data users and providing help for data providers on formatting and documenting data for archival, along with query management.
- Activities to publicise NCEO data, and participation in international programmes.





SERVICES AND FACILITIES

The UK has many facilities dedicated to acquiring and processing Earth observation data from satellite, airborne and ground-based systems. The National Centre for Earth Observation will provide scientific direction for these facilities to maximise use of their expertise, data and equipment.

AIRBORNE RESEARCH AND SURVEY FACILITY (ARSF)

ARSF operates a Dornier 228 aircraft that provides essential remote-sensing support to a range of scientific disciplines. The facility undertakes surveys and data-collection missions worldwide and is a member of the European Fleet for Airborne Research (EUFAR).

NERC EARTH OBSERVATION DATA ACQUISITION AND ANALYSIS SERVICE (NEODAAS)

Comprising the Dundee Satellite Receiving Station and the Plymouth Marine Laboratory Remote Sensing Group, NEODAAS provides a combination of 24-hour data reception, archiving and near-real-time processing services. The facility receives data from a wide range of missions operated by agencies including ESA and NASA.

FIELD SPECTROSCOPY FACILITY

The facility, based at the University of Edinburgh, provides equipment for measuring the reflectance properties of vegetation, soil, rocks and water. Such ground-based measurements are essential to the understanding and validation of remote observations.

SPACE GEODESY FACILITY

Precise information about a satellite orbit and height is essential to validate data on, for example, sea-surface height and ice thickness.

Based at Herstmonceux in Sussex, the facility tracks satellites in orbit and is one of ten key global reference stations.

BRITISH ISLES CONTINUOUS GLOBAL NAVIGATION SATELLITE SYSTEMS FACILITY

The facility continuously archives data from GPS stations throughout the UK. This data are increasingly valuable in fields such as atmospheric water-vapour studies, long-term regional land movements and numerical weather prediction.

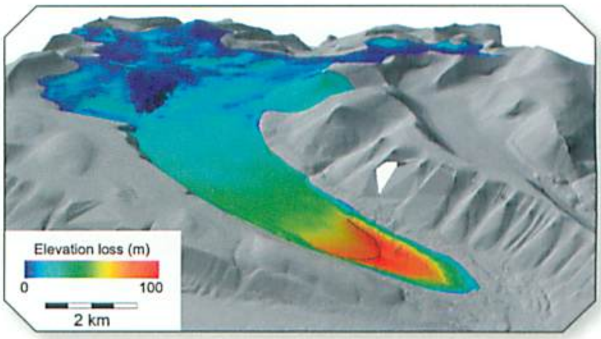
EARTH OBSERVATION WITHIN THE NERC RESEARCH CENTRES

The National Centre for Earth Observation will work closely with partners in all NERC's centres, many of which have established and world-leading Earth observation capability.

These include:

- British Antarctic Survey
- British Geological Survey
- Centre for Ecology & Hydrology
- National Oceanography Centre, Southampton
- National Centre for Atmospheric Science
- Plymouth Marine Laboratory
- Proudman Oceanographic Laboratory
- Scottish Association for Marine Science

Remote sensing has helped show that the Slakbreen glacier in Svalbard – a remote archipelago in the Arctic Circle – has thinned by up to 100m and retreated 1.4 kilometres since 1961.



KNOWLEDGE EXCHANGE

DELIVERING ECONOMIC IMPACT AND SOCIAL RELEVANCE

A major goal of NCEO is to ensure Earth observation data, systems and models benefit the economy and society. NCEO will work with stakeholders nationally and internationally to meet the environmental challenges facing society.

We plan an extensive programme of knowledge exchange with partners, users and customers across both public and private sectors.

Andy Shaw, Director of Knowledge Exchange

SCIENCE INTO POLICY

NCEO will play a proactive role assisting policy-makers at national, European and global levels to use Earth observation to achieve a range of outcomes.

- Evidence-based policy-making: creating and maintaining a strong evidence base for environmental decision-making.
- Policy delivery and evaluation: developing and validating systems to deliver policy goals through monitoring and surveillance capability.
- International engagement: supporting, representing and promoting UK policy interests within international Earth observation fora.

ECONOMIC IMPACT

Recent estimates suggest that Earth observation generates around $170 billion of economic activity globally. This figure is increasing dramatically with advances in availability and capability of Earth observation systems. The NCEO will work to exploit fully the value of Earth observation, socially and economically, to the UK economy.

TURNING ON TO SPACE TECHNOLOGY – PUBLIC ENGAGEMENT

Tools such as Google Earth and Microsoft Virtual Earth allow scientists, policy-makers and businesses to engage with people in new and exciting ways. There were, at the last count, approximately 400 million users of Google Earth offering an unprecedented opportunity to inform and influence public attitudes and behaviour. NCEO partners already exploit the power of such tools and will continue to develop new and innovative applications that communicate Earth observation information for public and business benefit.

KNOWLEDGE EXCHANGE MECHANISMS

We will develop a range of policy, business and public-focused mechanisms to ensure the optimum exploitation of NCEO knowledge assets by all stakeholders, partners and customers. These will include:

- Policy and industrial placements and exchanges.
- A programme of meetings, seminars and information events, including our annual science meeting.
- Active participation in relevant government and business fora.
- Development of tailored advisory and consulting services.
- Public-engagement tools to inform, educate and stimulate discussion on environmental topics.

THE ORGANISATION

NCEO MANAGEMENT STRUCTURE

The overall management structure of the NCEO, incorporating management, external advice and support functions, is shown below.

The NCEO Director has overall responsibility for setting the strategic direction of the NCEO and managing and delivering its programme. The Director chairs the NCEO Board, which is the senior management committee taking responsibility for the centre. It comprises NCEO Theme Leaders and Deputy Theme Leaders. The board agrees the science content of the programme and the implementation plan. The NCEO Director delegates day-to-day management tasks to an operational support team that assists with the running of the programme and drives essential tasks, such as knowledge exchange, which cut across the whole programme.

The NCEO Advisory Committee includes the leading users of the science programme and representatives of collaborating programmes and institutes. It supports knowledge exchange within NCEO by monitoring the progress and success of knowledge exchange activities and advises the Director on the implementation of the NCEO science programme in relation to the Natural Environment Research Council's strategy.

TRAINING

The NCEO will run a coordinated graduate training programme to help remedy the skills shortage limiting the exploitation of Earth observation. Training and continuing support will be offered both to students affiliated to NCEO (through tied studentships, or through the affiliation of their supervisors) and to unaffiliated students nationally and internationally.

NCEO will foster joint training activities with other national programmes as well as with international agencies such as ESA and NASA.

POST-LAUNCH SUPPORT

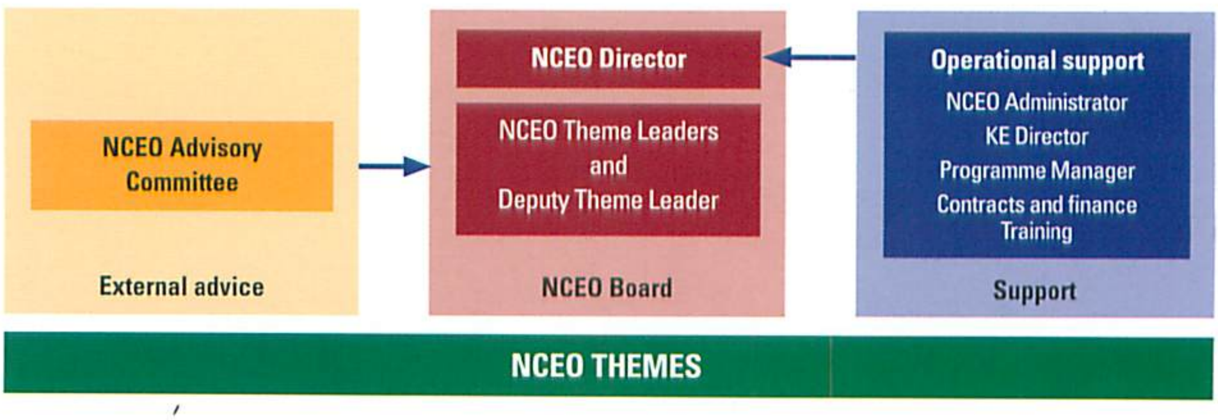
NCEO will provide post-launch support for the CryoSat-2 mission. This mission's lead principal investigator, Professor Duncan Wingham, is based in the UK at the Centre for Polar Observation and Modelling, which is part of NCEO.

MISSION SUPPORT

NCEO's focus on fusion of Earth observation data with models will provide a solid foundation to support the selection and definition of future Earth observation missions. Models developed at NCEO will contribute to observing-system simulation experiments, which will allow researchers to establish the benefits of different overall mission scenarios.

The theme on Data Assimilation will be at the forefront of promoting the use of these simulation experiments with ESA and other space agencies. Future observing needs established in NCEO will act as a catalyst for new sensor development at the Centre for Earth Observation Instrumentation and ESA.

NCEO will provide quantitative evidence to support UK mission priorities and to help industry prepare for future development programmes. NCEO scientists will continue their cooperation with UK industry in mission feasibility and Phase-A studies, and in providing science support for mission planning and development.
The mission support fund within NCEO will support strategic activities related to early concepts for new missions, encourage NCEO scientists to become members of mission science teams and provide funding for pre- and post-launch activities such as algorithm development.



NEXT GENERATION SCIENCE FOR PLANET EARTH

The Natural Environment Research Council (NERC) funds independent environmental research in the UK and manages the UK's Earth observation budget.

NERC'S STRATEGIC GOAL

To deliver world-leading environmental research at the frontiers of knowledge:

- enabling society to respond urgently to global climate change and the increasing pressures on natural resources,
- contributing to UK leadership in predicting the regional and local impacts of environmental change from days to decades, and
- creating and supporting vibrant, integrated research communities.

The NCEO strategy was designed to map on to NERC's strategy *Next Generation Science for Planet Earth*. Key correlations between NCEO and the strategy's themes are summarised below.

NCEO SCIENCE THEME	NERC STRATEGY THEME						
	Climate system	Biodiversity	Environment, pollution and human health	Sustainable use of natural resources	Natural hazards	Earth system science	Technologies
Climate	■					■	
Carbon cycle	■			■		■	
Atmosphere	■		■			■	
Changing water cycle & hazardous weather				■	■		
Cryosphere and polar oceans	■					■	
Dynamic Earth and geohazards					■		
Data assimilation	■		■		■	■	■
Informatics							■

NATIONAL CENTRE FOR EARTH OBSERVATION PARTICIPATING INSTITUTIONS

A cloudless UK showing forest and moorland fires taken by the MODIS satellite.
NERC Satellite Receiving Station/University of Dundee

1. Bangor University
2. University of Bristol
3. University of Cambridge
4. Centre for Ecology & Hydrology
5. University of Durham
6. University of Edinburgh
7. University of Exeter
8. Imperial College, London
9. King's College London
10. University of Leeds
11. University of Leicester
12. National Oceanography Centre, Southampton
13. University of Oxford
14. Plymouth Marine Laboratory
15. Proudman Oceanographic Laboratory
16. Rutherford Appleton Laboratory
17. University of Reading
18. University of Sheffield
19. University of Surrey
20. Swansea University
21. Environmental Research Institute, Thurso
22. University College London
23. University of East Anglia
24. University of Southampton
25. University of Warwick
26. University of York

NATURAL ENVIRONMENT RESEARCH COUNCIL

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