CLIMATE CHANGE FROM SPACE

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CLIMATE KIT

A GLOBAL CHALLENGE

Climate change is a reality. Greenhouse gas emissions from human activity are responsible for rising temperatures, altering the Earth system's delicate balance. The effects of which are widespread, threatening lives, well-being and prosperity. If unaddressed, the consequences of a changing climate will become more pronounced.

The international community can still stabilise the future course of our climate.

Measurements from space are fundamental to the solution, enabling **governments, economies and societies** to understand the changes taking place so that effective action can be put in place to curb emissions and support a resilient global society.

How to navigate this brochure

An INTERNET CONNECTION is required to access the external webpages



Contents page



link to web page



link to video



DOWNLOAD images, videos or animations



Web link to satellite page



POSSIBLE FUTURE TEMPERATURE RISE

It is unequivocal that human influence has warmed the atmosphere, ocean and land IPCC AR6 2021

1

+1.1°C WHERE WE ARE NOW

Global warming due to emissions of greenhouse gases from human activities since the Industrial Revolution

+1.4°C TAKING THE GREEN ROAD

If net zero emissions are achieved by 2050 (SSP1-1.9)

+1.5°C PARIS AGREEMENT GOAL

+1.8°C LIMITING GLOBAL WARMING

If net zero emissions are achieved in second half of 21st century (SSP1-2.6)

+2.7°C NO EXTRA CLIMATE POLICIES

If current greenhouse gas emissions persist until mid-21st century (SSP2-4.5)

+4.4°C FOSSIL-FUELLED DEVELOPMENT

An energy and resource intensive scenario for the 21st century (SSP5-8.5)

GLOBAL MEAN TEMPERATURE INCREASE BY 2100 (RELATIVE TO 1850-1900) Source: IPCC Assessment report Working Group 1, Table SPM.1





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SPACE FOR OUR CLIMATE

Satellites observing Earth from space provide the crucial lines of evidence to understand our changing climate. They measure and monitor our vast oceans, land, atmosphere, and inhospitable difficult to reach areas such as the polar regions.

Satellite observations provide early warnings of change, improve climate predictions and deliver the hard facts needed for effective international climate action.

To produce data suitable for climate research, information from multiple satellite missions need to be combined to produce datasets that span decades.

Glasgow, UK, host city of the COP26 UN Climate Change Conference 2021



Developed by ESA and its Member States, the Climate Change Initiative generates robust, long-term global satellite datasets for over 21 key components of the Earth system.

Observations from ESA's 40-year satellite archive as well as current ESA missions, the Copernicus Sentinels and ESA third-party missions all contribute to these datasets, known as Essential Climate Variables. This body of evidence offers an accurate and impartial yardstick to study climate drivers, feedbacks, Earth system cycles, and provides the scientific basis for robust climate modelling. These state-of-the-art records directly support the United Nations Framework Convention on Climate Change and contribute to the scientific knowledge underpinning Intergovernmental Panel on Climate Change Assessment Reports.

Society is already benefiting. Climate Change Initiative research and data are used by major climate services to support policy-makers, scientists, consultants and planners.





Satellites measure several aspects of Earth's weather as well as provide essential data over decades to monitor how our climate is changing



Weather

refers to short-term changes in the atmosphere. It can change minute-to-minute, hour-to-hour and day-to-day







Climate

describes the average weather conditions in a specific area over a long period of time, of 30 years or more



WEATHER **VERSUS CLIMATE**

Weather shows how the atmosphere changes over short periods of time. There are many components to weather, which include temperature, rain, wind, hail, snow, humidity, flooding, thunderstorms, heatwaves, and more. When you look outside what you see is weather.

Climate, on the other hand, is the weather in a specific area over a long period of time – usually 30 years or more. When scientists talk about climate, they look for trends or cycles of variability, such as changes in temperature, humidity, precipitation, ocean-surface temperature and other weather phenomena that occur over longer periods of time in a specific location.









TAKING THE PULSE OF THE PLANET

Essential Climate Variables are key indicators that describe Earth's changing climate. Scientists use these variables to study climate drivers, interactions and feedbacks, as well as reservoirs, tipping points, and fluxes of energy, water and carbon.

The climate-quality datasets produced by the Climate Change Initiative are a major contribution to the evidence base used to understand climate change.

Satellite products provide a valuable complement to in-situ measurements. These observations are valuable (high confidence) for regional applications since they provide multi-channel images at very high spatiotemporal resolutions

IPCC AR6 2021



From space, the evidence for climate change is compelling

FND

NUM

AMOSPHERE

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GENERATING SATELLITE CLIMATE DATA RECORDS



Scientists and stakeholders help define the variables needed to monitor climate.

GATHER

Satellites are crucial for gathering global data for many Essential Climate Variables.

SHAPE

Scientists computationally stitch together data from many satellites to create decades-long time series. Data are calibrated and validated to correct for biases and confirm precision.



OPEN

Climate Change Initiative data products are free and open.

ENABLE

Over 1000 publications and 21 Essential Climate Variables contribute to the science literature and Intergovernmental Panel on Climate Change assessment reports to support decision-making.

SCALE UP

14 Essential Climate Variables are already being used by climate services.



GREENHOUSE GASES

The amount of carbon dioxide and methane in the atmosphere is unprecedented, and levels are rising.

Tracking these gases and the dynamics of natural and human-made sources and sinks is enabling scientists to improve the models that predict future global warming.

The Climate Change Initiative generates time series data to map the global distribution of carbon dioxide and methane using data from multiple satellite missions.

The growing ability of satellites to detect emission sources is set to help track the effectiveness of carbon reduction measures.



Atmospheric Carbon Dioxide (Co₂) from satellites Copernicus Climate Change Service dataset 2003–2021 (September) using algorithms and brokered products from CCI with data from Copernicus Atmosphere Monitoring Service

The upcoming **Copernicus Anthropogenic Carbon Dioxide Monitoring** mission will provide Europe with a unique and independent source of information to assess the effectiveness of policy measures, and to track their impact towards meeting national emission reduction targets.

While carbon dioxide is more abundant in the atmosphere and therefore more commonly associated with global warming, methane is around 30 times more potent as a heat-trapping gas.



eric carbon dioxide (XCO2) - ESA CCI

400

Atmospheric methane (XCH4) - ESA CCI

1825 p



OZONE

The ozone layer shields life on Earth from ultraviolet solar radiation. Ozone is also strongly linked to climate as it influences atmospheric temperature.

Atmospheric conditions of ozone vary naturally depending on temperature, weather, latitude and altitude, while substances ejected by natural events such as volcanic eruptions can also affect ozone levels.

By mapping the vertical distribution of global atmospheric ozone, the Climate Change Initiative helps to monitor the ozone layer and support the prediction of ozone depletion and recovery. September 1979

1.1 million sq km

Altius, ESA's ozone mission, will be a valuable complement to missions such as Copernicus Sentinel-5P, Sentinel-4 and Sentinel-5. The recovery of the ozone hole over Antarctica is a perfect example of scientific evidence leading to global policy, the Montreal Protocol, and subsequent changes in human behaviour.







SEA ICE

The decline in the coverage of Arctic sea ice in late summer is one of the biggest signs of climate change.

Satellite records since 1979 reveal that the area of the Arctic Ocean covered by ice has reduced by more than 10% every decade. Moreover, current estimates put sea ice at its lowest in 1000 years.

A shift towards thinner ice, which is more vulnerable to warmer summers and winter storms, is also observed from space.

The impacts are profound, be it for the climate system, the ecosystem or indigenous communities in the Arctic. This loss of ice is linked to a rise in local air temperatures of twice the global average.

Observations from satellites such as ESA's **CryoSat** have revolutionised our knowledge of the world's frozen areas, particularly in the polar regions where conditions make in-situ observations difficult. Climate projections, informed by satellite data, show that the Arctic Ocean is likely to experience 'ice free' summers before 2050.



 1979

Sea Ice Concentration - ESA CCI collaboration with Eumetsat OSISAF]



PERMAFROST

Thawing Arctic soils could release vast amounts of greenhouse gases to the atmosphere in the coming decades. Despite concerns this will fuel future global warming, the scale and speed of the processes involved are uncertain.

The Climate Change Initiative is addressing this knowledge gap using satellite measurements of land cover, snow cover and surface temperature to develop time series that will help assess permafrost in the northern hemisphere and predict future change.



Missions carrying thermal sensors such as **Copernicus Sentinel-3** can provide information about the changes in the temperature of Earth's surface. The amount of carbon stored in permafrost regions of the northern hemisphere is estimated to be almost twice that of carbon currently contained in Earth's atmosphere.

100%









LAND ICE

The loss of ice from the giant ice sheets of Antarctica and Greenland and from glaciers around the world is the main contributor to global sea-level rise, with consequences for society, the economy and the environment.

Satellites are vital for monitoring how ice on land changes. Surveys show that the rate of ice loss from the Greenland and Antarctic ice sheets increased fourfold in 1992–99 and in 2010–19. The rate at which ice is being lost has been accelerating since the 1990s.

Observations and modelling help to understand the processes driving ice loss, improve projections of future sea level and support climate resilience.



The Copernicus Sentinel Expansion missions, **CRISTAL**, **CIMR** and **ROSE-L** will expand the current capabilities of monitoring changes in global ice cover.





GLACIERS



Global total -9625 Gt

Alaska

-3019

GLACIER MASS LOSS 1961–2016

Ice loss isn't just restricted to the polar regions. According to recent research, glaciers around the world have lost well over 9000 gigatonnes (nine trillion tonnes) of ice since 1961, raising sea level by 27 mm.

ACN

-1069

ACS

WNA

-428



SEA-SURFACE TEMPERATURE

Sea-surface temperature measurements improve weather prediction and the study of marine ecosystems but also provide fundamental information on the global climate, helping to understand how the oceans exchange heat and gases with the atmosphere.

Heat and moisture released from the sea are the dominant drivers of atmospheric circulation and weather patterns. Sea-surface temperature influences the rate of this energy transfer to the atmosphere, as evaporation increases in line with temperature. Longterm, accurate measurements that are stable over time are fundamental for climate-change research.

Copernicus Sentinel-3 maintains and extends the high-quality sea-surface temperature measurements required for climate change research. The average temperature of the sea surface across ice-free oceans has increased by 0.6°C in the 40-year record of satellite observations. Marine heatwaves are increasingly common, with negative consequences such as mass coral bleaching events.

Sea-Surface Temperature - ESA CCI

-5 0 5 10 15 20 25 30 35 °C



SEA-SURFACE SALINITY

The saltiness of ocean surface waters is a key variable in the climate system. As well as wind driving ocean surface currents, temperature and salinity are key variables affecting ocean circulation.

Global maps of sea-surface salinity are used to study the water, ocean-atmosphere exchanges and ocean circulation, which are all vital components of the climate system transporting heat, momentum, carbon and nutrients around the globe.

The Climate Change Initiative has made a global record available spanning 2010-2020 using data from ESA's SMOS, and the US Aquarius and SMAP missions.



Ocean circulation conveyor belt The blue arrows indicate cool deeper currents and the red indicate warmer surface currents

SMOS is helping to improve our knowledge of the conditions that influence ocean circulation patterns and related changes in climate.

Unusual salinity levels may indicate the onset of extreme climate events, such as El Niño.



Sea-Sur	face Salinity -	ESA CCI	1
			-
30	35	4	





SEA LEVEL

Sea-level rise is placing coastal communities around the world at an increasing risk of flooding.

Satellite altimeters have monitored sea-surface height over the past three decades and reveal an upward trend in global mean sea level of 3.2 mm per year. Worryingly, this has accelerated to 4.8 mm per year in recent years (2013–18).

The impacts of global mean sea-level rise are not the same everywhere. Along coastlines, sea-level rise can exceed the global mean because of complex ocean dynamics nearer land, while land subsidence caused by human activity is compounding the problem in many of the world's coastal cities.



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Global Mean Sea Level

The **Copernicus Sentinel-6** mission's high-resolution data will advance the long-term sea-level record and improve the mapping of sea-surface height close to the coast. The Special Report on the Ocean and Cryosphere in a Changing Climate on sea-level rise states that the global mean sea level is likely to rise between 0.29 m and 1.1 m by the end of this century, with devastating consequences for many small island nations.

Contraction of the second s



-ESA Climate Change Initiative (SL_cci) data

Near Real Time Jason-3 Average trend: **3.33** +/- 0.3 mm/yr

CMEMS

10 <u>1993 1995</u> 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023





contains modified Copernicus Sentinel data (2020), processed by ESA



OCEAN COLOUR

The green hue of phytoplankton - free-floating marine plants - that occurs across the world's ocean surface can be observed from space. Acting as the marine equivalent of the world's forests, these organisms pump carbon through the ocean ecosystem, influencing Earth's climate system.

Satellite measurements help to track change in chlorophyll-a concentration and distribution as these organisms photosynthesise, allowing scientists to study their biology and response to environmental change.

Using data from multiple satellites, the Climate Change Initiative has produced a 23-year time-series (1997-2020) to support climate studies.



Chlorophyll-a in the Pacific Southern Ocean (in mg/m³)

Smoke and ash from the Australian 2019-2020 bushfires triggered phytoplankton blooms in the Pacific Southern Ocean, thousands of kilometres away. This graph shows chlorophyll-a concentration from 1997 to 2020 in the Pacific Southern Ocean, based on data from ESA's Ocean Colour Climate Change Initiative.



Chlorophyll-a concentration in seawater - ESA CCI 0.03 1.0 30 mg/m³



BIOMASS AND LAND COVER

Biomass

Fluctuations in the carbon-rich biomass held within the world's forests can contribute to, or slow, climate change.

Global satellite maps produced by the Climate Change Initiative, provide insights into the global carbon cycle, while supporting forest management, emissions reduction and sustainable development policy goals.

Land Cover

Annual land-cover maps provide information of the changes taking place across Earth's land in a consistent way, over decades at global scale.

The **Biomass** mission will further our knowledge of the role forests play in the carbon cycle. The future Copernicus Sentinel **CHIME** and **LSTM** mission will provide critical information for sustainable agricultural and biodiversity management.



According to the United Nations, the world is losing 10 million hectares of forest each year, which accounts for 12–20% of the global greenhouse gas emissions that contribute to climate change.



GLOBAL CARBON BUDGET

The Paris Agreement adopted a target for global warming not to exceed 1.5°C. This sets a limit on the additional carbon we can add to the atmosphere - the carbon budget. Only around 17% of the carbon budget is now left. That is about 10 years at current emission rates.

But there is sufficient uncertainty (indicated by the +- signs in the graphic on the right) across all the components of the carbon cycle that there is a small probability we have no remaining carbon budget. This means that even if emissions were to go to zero today, warming would still exceed 1.5°C.

As well as tracking atmospheric carbon, ESA's Climate Change Initiative uses satellite observations to track carbon stocks on land and sea and help reduce uncertainty.

FOSSIL FUEL EMISSIONS

VEGETATION 450-650

Global Carbon Budget - estimates for 2019

RMAFRO

STOCKS GtC



ATMOSPHERE YEARLY ACCUMULATION $+5.4 \pm 0.2$

ATMOSPHERE 860

 9.9 ± 0.5



FLUXES GtC PER YEAR

FIRES

As Earth warms, so does the risk of wildfires. In turn, fires release greenhouse gases and aerosols into the atmosphere – further adding to the greenhouse effect.

Observations from space help to quantify and understand interactions between fire, vegetation, carbon and emissions from regional to global scales.

The Climate Change Initiative's burned area products stretch back to 1982, providing decadal trends to support climate modelling and fire prediction and national emissions reporting. Cumulative burned area for one year (km

Fires not only decimate the land, but they also have a serious effect on air quality. **Copernicus Sentinel-2, Sentinel-3** and **Sentinel-5P** missions provide a wealth of complementary information, needed to monitor the blazes.





High resolution capabilities of Sentinel-2 detect small fires that contribute significantly to burned area and fire carbon emissions.

Fire Burned Area - ESA CCI



ontains modified Copernicus Sentinel data (2017), processed by ESA





LAKES

Lakes respond rapidly to environmental change and play a role in climate regulation. Understanding these inland water bodies is essential for future water resource and community resilience.

The Climate Change Initiative has released a timeseries covering physical, biogeochemical and hydrological variables for 2000 lakes around the world, helping to assess change.

In combination with climate models, these data provide early warnings of rising lake temperatures, heatwaves and threats to freshwater species.

Observations of lake water and ice extent are only feasible using satellites, while lakewater level and surface-water temperature measurements complement in-situ monitoring to provide a global view.













SPACE FOR A GREEN FUTURE

Over the last few decades, space has been instrumental in monitoring climate change. Today, new technology and advances in data collection are unlocking the full potential of space to support the transition to a sustainable, low-carbon economy.

Space technologies and data are unique in that they allow the entire planet to be monitored and modelled, and predictions made about its future. Crucially, this gives decision-makers the information they need to act on the many aspects of the climate crises.

esa

ESA is the **European Space Agency** and Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. Space offers a vast untapped potential to ramp up the fight for a green future and tackle global climate change

ESA Director General Josef Aschbacher



CLIMATE IN YOUR HANDS

ACCESS CLIMATE DATA

Researchers can access a suite of research-ready Essential Climate Variable datasets developed by the Climate Change Initiative.

All data products are free and open and can be accessed via direct download FTP, HTTP and OPeNDAP.

TEACH CLIMATE CHANGE

Climate Change Initiative classroom resources explore Earth's changing climate.

Activities support the teaching of science, technology, engineering and mathematics across ESA's Member States.

Visit the Climate Change Initiative Open Data Portal climate.esa.int/data

Free and Open Access

Global Coverage

30–40-year Time Series



https://climate.esa.int/en/educate

Primary

Secondary (lower)

Secondary (upper)





DISCOVER CLIMATE CHANGE

Discover how our climate is changing with ESA's new interactive Climate from Space web app.

Features include interactive 3D globes, maps, animations and self-guided climate stories that explain how and why the climate is changing.

The Climate from Space site can be used at home, in the classroom and at exhibitions.

Visit the Climate Change Initiative's learning resources

Discover ESA's Climate from Space web app https://cfs.climate.esa.int/index.html#/



Over 40 years of satellite data

Available in English, German, Dutch, French, **Italian and Spanish**

Desktop, tablet or phone



MEDIA RESOURCES

Smoke and flames Mediterranean Amazon Permafrost rainforest in Australia continues to bake thaw MEASURING SEA-LEVEL CHANGE

Phytoplankton bloom off the coast of Scotland

DISCOVER MORE

ESA Images https://www.esa.int/ESA_Multimedia/Images

ESA - photo library for professionals https://www.esa-photolibrary.com

Measuring sea-level change

Tarawa, Kiribati Baltic blooms



MEDIA RESOURCES

Counting carbon







How is ESA helping to curb climate change?











Change in the Arctic



Carbon dioxide oceanatmosphere exchange



in ocean salinity

DISCOVER MORE

Climate Change Collection https://www.esa.int/ESA_Multimedia/Keywords/Description/Climate_Change/(result_type)/videos ESA Videos www.esa.int/ESA_Multimedia/Videos

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