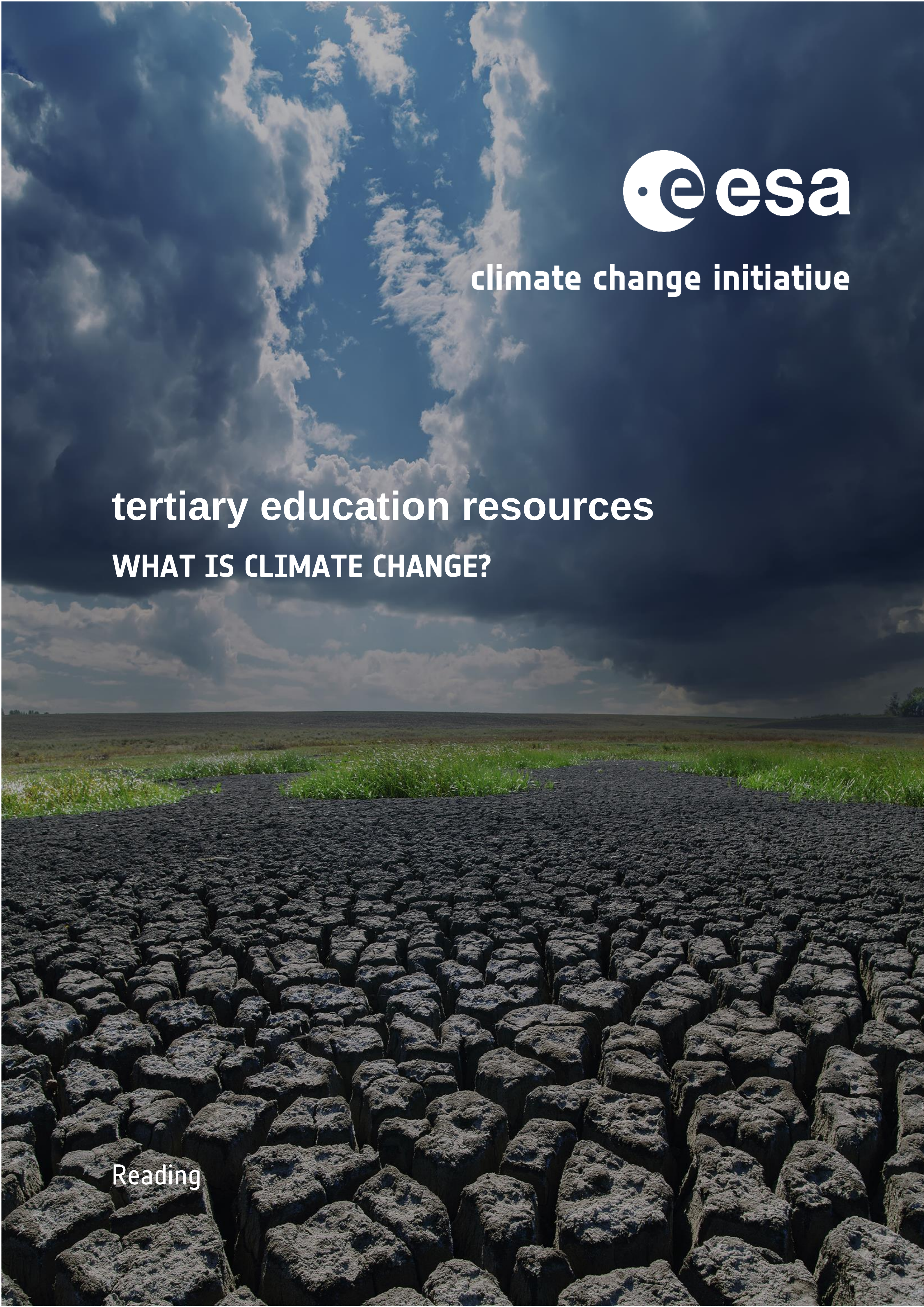

climate change initiative

tertiary education resources

WHAT IS CLIMATE CHANGE?

Reading

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climate change initiative– WHAT IS CLIMATE CHANGE?
https://climate.esa.int/educate/

Developed by University of Twente (NL)

The ESA Climate Office welcomes feedback and comments
https://climate.esa.int/helpdesk/

Produced by the ESA Climate Office

WHAT IS CLIMATE CHANGE?

Fast facts

Subjects: supplementary materials for the introduction lecture

Type: reading

Complexity: medium

Lesson time required: 1 hour

Cost: none

Location: indoors

Includes the use of the internet

Keywords: climate change, essential climate variables, satellite

Brief description

An overview document supports the introductory lecture on climate change and essential climate variables.

Intended learning outcomes

Reading this document, students will be able to:

Understand the difference between weather and climate.

Become familiar with concepts of climate change.

Become familiar with the climate change causes.

Summary of activities

	Title	Description	Outcome	Requirements	Time
1	What is Climate Change?	An overview document that supports the introductory lecture on climate change and essential climate variables	understand the difference between weather and climate. Become familiar with concepts of climate change. Become familiar with the climate change causes.	Reader, or any device that can read files in PDF, Word, and PowerPoint format	1 hour

Times given are for the main reading activity. They include searching the web but not experimenting with the Climate from Space application or the CCI Toolbox (CATE).

What is climate?

How atmospheric circulations govern weather patterns and the climate?

The earth is governed by two main cycles, energy and water, that have their imprints on local weather and long-term climate variability. The main engine to these cycles is solar radiation.

The short and long waves of solar radiation entering the earth's atmosphere initiate the energy and water cycles. The energy cycle is initiated from the heat warming the atmosphere, land and ocean. This heat will be stored during the day and released during the night as longwave radiation. This heat also ignites the evapotranspiration process starting the water cycle. This movement of energy, in the form of heat, and water mass, in the form of water vapour and precipitation, will initiate the global atmospheric circulation, Figure 1.

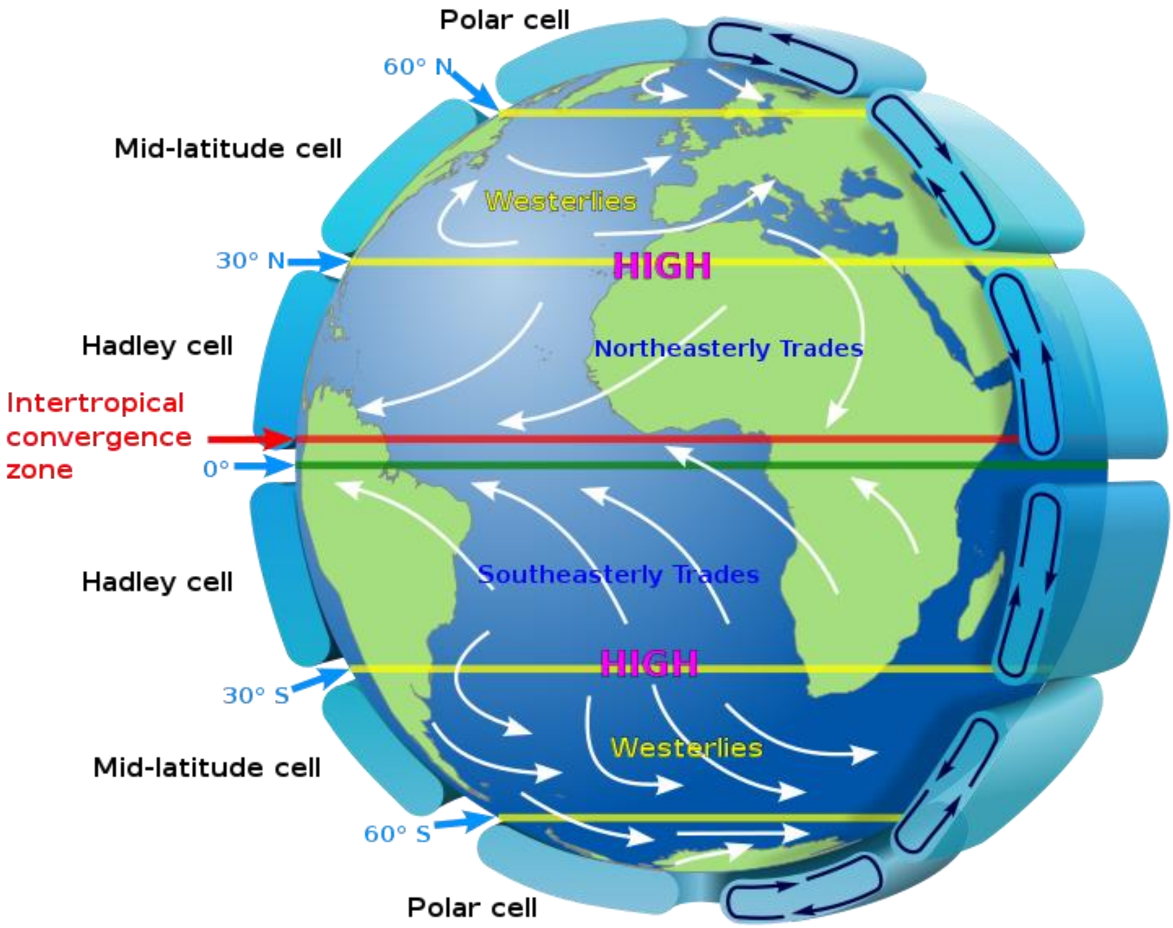

Figure 1: Atmospheric Global Circulation, by [Kaidor] is licensed under [CC BY-SA 3.0.]

Trade winds in the Northern Hemisphere blow from East to West carrying the air to the intertropical Convergence Zone. There the air mass will become warmer. As the air rises, it will travel towards the North and South subtropics. Then the air cools down and descends to the surface of the Earth. This global circulation affects the weather of the planet. It creates warm-rising and cool-descending winds leading to areas of high rainfall normally in the tropics and areas of dryness where air does not contain much moisture like the deserts. A graphical representation is to the right side of the Globe in Figure 1.

However, due to the inclination of the Earth leading to seasons, the system displaces South in December to March and North in June to September.

What is weather?

Weather[1] refers to the condition of the atmosphere, indicating how wet or dry it is and to what extent it is either hot or cold, clear or cloudy, as well as stormy or calm*. In other words, the term weather relates to the daily temperature and precipitation activities. Weather events occur in the lowest level of the Earth's atmosphere which troposphere. Weather is determined by variations in air pressure, temperature, and moisture content between locations. These variations arise for several reasons, including temperature gradients, and orography (mountains). However, the main driver of weather is the unequal distribution of solar irradiation on Earth.

The movement of warm and cold air around the globe is described as weather systems. In other words, weather systems are weather patterns (Bluestein, 1993). These movements are referred to as low and high-pressure systems.

A high-pressure system contains a whirling mass of cool, dry air and is often associated with light surface winds and subsidence through the lower troposphere. Clear skies and dry weather are usually associated with high-pressure systems. A low-pressure system happens when the atmospheric pressure at sea level is lower than in the surrounding regions —a low-pressure system develops in the areas of wind divergence in the troposphere's upper levels. In addition, the low-pressure system is linked with precipitation and clouds, which keeps the temperature variations at a minimum during the day.

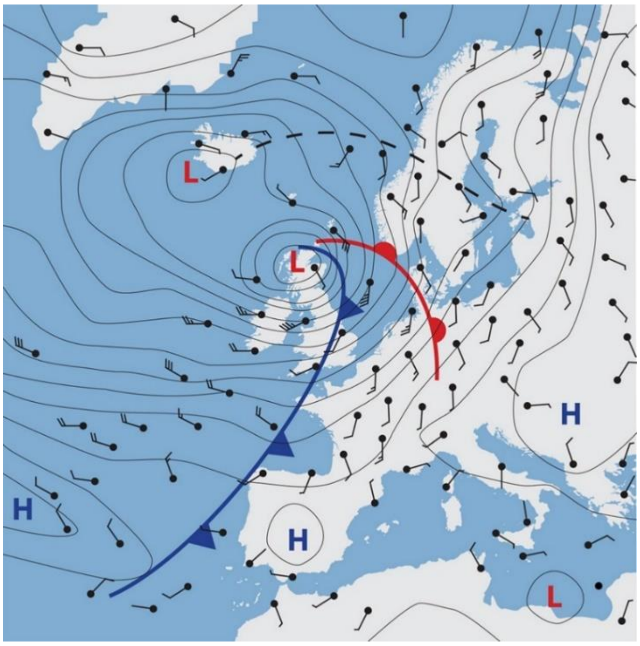

Figure 2: High and low- pressure system. A high-pressure system is represented as a big, blue H, and A low-pressure system is represented as a big, red L. Source: https://www.esa.int/ESA_Multimedia/Images/2018/06/Weather_map#.YJPMM-tccb4.link

[1] When used without qualification, the term "weather" is widely understood to refer to Earth's weather.

What is climate?

To understand what type of weather prevails in a specific area, scientists usually take the long-term average (over 30 years or more) of weather patterns in this area, to describe its climate, in this respect climate can be defined as the long-term weather patterns of a region. In summary, the weather varies from day to day and from place to place, and it affects our everyday routine no matter what we do and where we live in the world. On the other hand, the climate represents the prevailing weather conditions in a location for an extended time, typically over 30 years. Hence, it is a matter of time when it comes to distinguishing between weather and climate.

Some weather events can be better forecasted than others: for example, synoptic-scale cyclones- a horizontal length scale of 1000 km, are predictable over several days to a week, whereas mesoscale (i.e., an the intermediate scale between those of weather systems and microclimates, on which storms and other phenomena occur) convective systems are only predictable over hours. On the other hand, climate change happens at a much slower rate than weather change, which can be drastic daily.

Precipitation, temperature, wind speed and direction, incident solar radiation, cloud, and other variables determine the weather conditions (Leroux, 2006). In this respect, the climate is also characterised by the long-term average of these variables. Scientists refer to these variables as essential climate variables (ECVs). Some types of weather can be better forecasted than others: whereas synoptic-scale[2] cyclones are predictable over several days to a week, mesoscale[3] convective systems are only predictable over hours. On the other hand, climate change happens at a much slower rate than weather change, which can be drastic on a daily basis.

Table 1: Climate versus weather

Weather	**Climate**
Over a short period of minutes	Typically 30 years
Weather is what you get	Climate is what you expect
Always include time and the location	Average weather over many years in a specific location
Affected by the weather systems	Affected by latitude, elevation, nearby water, etc
Examples: sunny, windy weather	Examples: continental climate, arid climate

[2] A horizontal length scale of 1000 km or more is known as synoptic scale.
[3] Mesoscale is an intermediate scale between those of weather systems and of microclimates, on which storms and other phenomena occur.

What is climate change?

Are human activities tipping the climate balance?

CO_2 concentration in the atmosphere has never exceeded 300 parts per million (ppm) in the last 800,000 years. Despite this, CO_2 concentrations in 2018 reached 407.4 ppm Ades et al., 2020, which is significantly higher than those observed during warmer interglacial periods.

Figure (3) shows the *global atmospheric carbon dioxide concentrations (CO_2) in parts per million (ppm) for the past 800,000 years. The peaks and valleys track ice ages (low CO_2) and warmer interglacials (higher CO_2). During these cycles, CO_2 was never higher than 300 ppm*, (Lindsey, 2020)

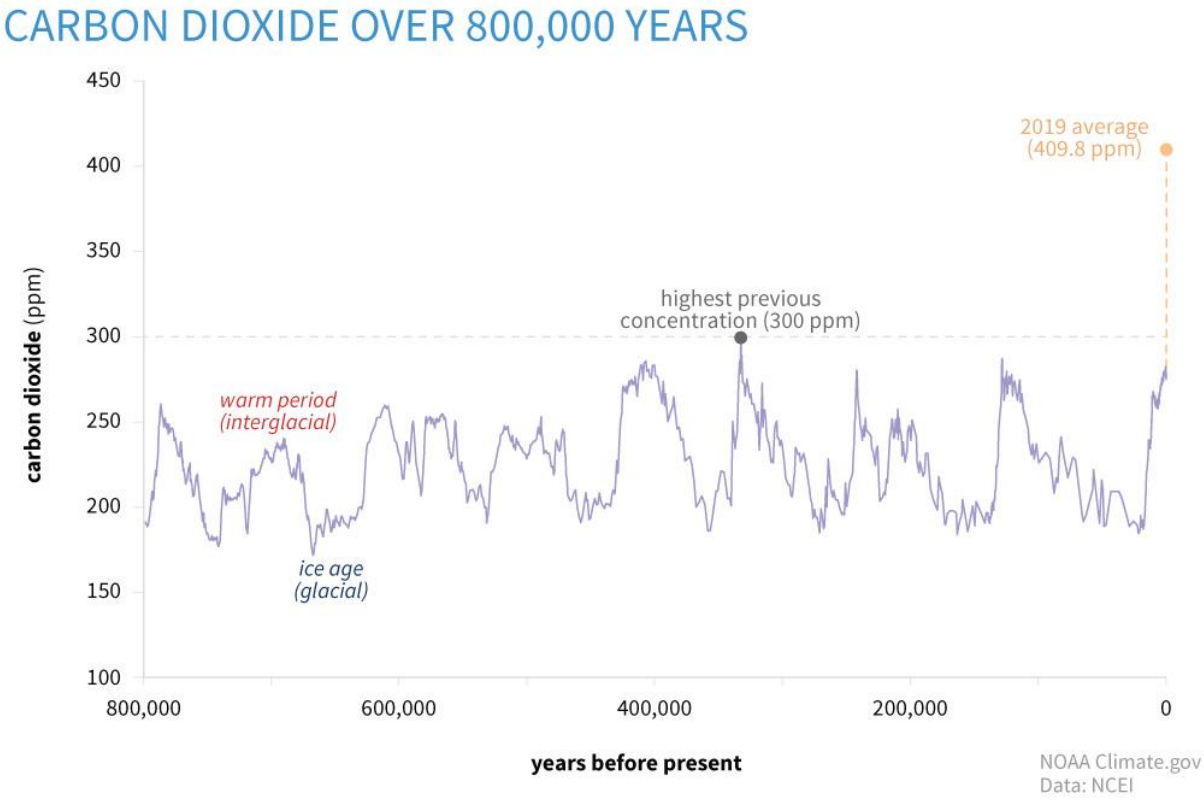

Figure 3: Global atmospheric carbon dioxide concentrations (CO_2) in parts per million (ppm) for the past 800,000 years. From NOAA Climate.gov based on data from Lüthi, et al., (2008)).

Research findings proved that human activities are the leading cause of increased concentrations levels of carbon dioxide in the atmosphere climate change. Since the industrial revolution, anthropogenic activities have disrupted the climate for centuries by altering land use and, more recently, by deforestation, extracting and consuming fossil fuel on a large scale.

Most fossil carbon (e.g., oil and gas) has been extracted in the last 50 years, and extraction rates are rising exponentially (Heede, 2014 and Ritchie and Roser, 2017).

As a result, CO_2 concentration in the atmosphere has risen roughly 50% since pre-industrial times by 2020, while approximately 30% and 25% of the anthropogenic CO_2 is absorbed by terrestrial ecosystems and the ocean, respectively (Ballantyne et al., 2012), and 45% remains in the atmosphere. Each year, 5.5 TgC (billions of metric tons of carbon) is released into the atmosphere by burning fossil fuels, while only 3.3 TgC/yr accumulates in the atmosphere. Consequently, the CO_2 being a greenhouse gas *one that absorbs heat energy* drastically increased in the atmosphere and caused significant global warming and imbalance in the energy, water and carbon cycles.

In addition, deforestation and clearing natural vegetation cover for urbanisation and agriculture alter the biomass component and affect the carbon exchange between soil and atmosphere. Burning vegetation releases a large amount of stored carbon swiftly into the atmosphere. As CO_2 level increases in the atmosphere, the temperature rises, and so does the atmosphere's water content.

Climate change

Climate change refers to a change in the weather pattern, as well as changes in oceans, land surfaces, and ice sheets that describe Earth's local, regional, and global climates, which occur over time scales of decades or longer (Houghton et al., 1990). According to IPCC, climate change is defined as an alteration in the climate condition, which can be discovered employing statistical analysis through changes in the climate properties over time (e.g., usually 30 years), regardless of whether it is caused by natural variability or anthropogenic activity. It is worth mentioning that the IPCC's definition of climate change differs from that of the United Nations Framework Convention on Climate Change UNFCCC. UNFCCC describes climate change as a change in climate caused by anthropogenic activity that alters the global atmospheric composition. In this respect, the main factor of anthropogenic activity changing the climate is the increased greenhouse emission due to fossil fuel combustion and industrial processes (Fischedick et al., 2014).

Effects of greenhouse gasses and global warming

The Earth's surface receives radiation from the Sun. Part of this radiation is reflected and part of it is absorbed, then re-emitted at the wavelength corresponding to the temperature of the surface. Without an atmosphere, the radiation leaving the Earth's surface would be lost to space and the temperature on Earth would be far below the freezing point. Greenhouse gases absorb the long-wave radiation emitted by the Earth and re-emit it in all directions, so only some of it escapes to space. The natural effect of greenhouse gases is shown schematically in Figure 4-a. Water vapour contributes most to the total greenhouse effect, as it absorbs radiation in a wide range of frequencies. The anthropogenic (human-caused) enhancement of the greenhouse effect (Figure 4-b) is, however, mainly due to carbon dioxide, owing to the sheer amount of CO_2 emitted into the atmosphere (Buchwitz et al., 2017). Methane and Nitrous oxide (N_2O) are also enhanced by anthropogenic activities, although present in smaller amounts, they are much more potent than CO_2.

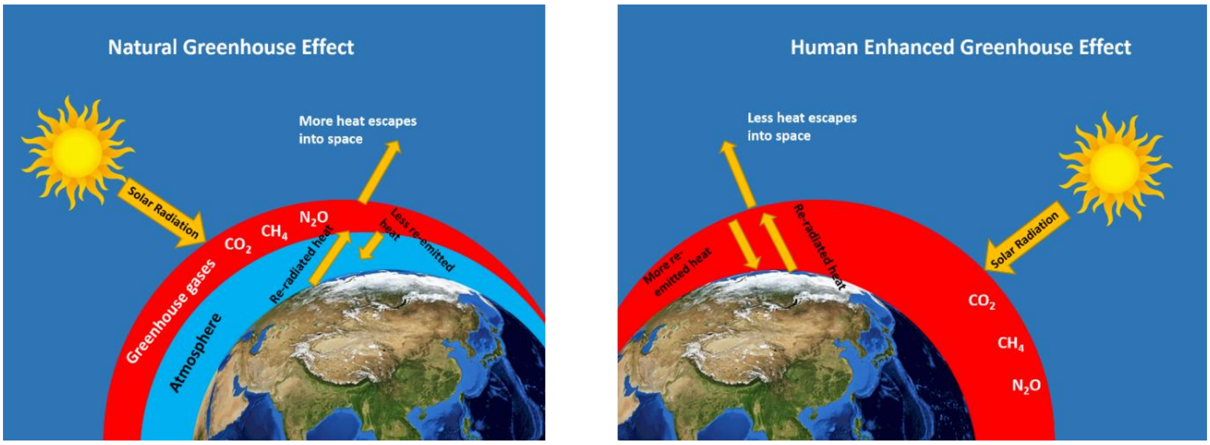

Figure 4: Schematic of the greenhouse effect: natural (a) and human-enhanced (b) effects of greenhouse gases.

Currently, CO_2 levels in the atmosphere are 40% greater than they were prior to the Industrial Revolution, and since 2007, the concentration of CH4in the atmosphere has constantly been rising. Burning fossil fuels, waste management, and deterioration of wetlands are considered dominant anthropogenic sources of Methane CH4 in the atmosphere (Turner et al., 2019). The energy added to the Earth system by enhanced effects of greenhouse gases is called radiative forcing. Positive radiative forcing causes global warming, and negative forcing causes cooling (Change, 2001) which influence other aspects of the Earth's climate system due to interconnected physics (Piontek et al., 2014).

In addition, to fossil fuel combustion and industrial activities, the emission of greenhouse gasses is enhanced due to deforestation, contributing up to 20% of carbon emissions (Myhre et al., 2013, Turner et al., 2019) and coal mining, contributing to 60% of Methane global emission (Kholod et al., 2020)

The CCI greenhouse project merged different satellite missions and provided empirical evidence of the global increase of carbon dioxide and methane emissions on a global scale, as shown in Figure 5, (from Reuter et al., 2020)

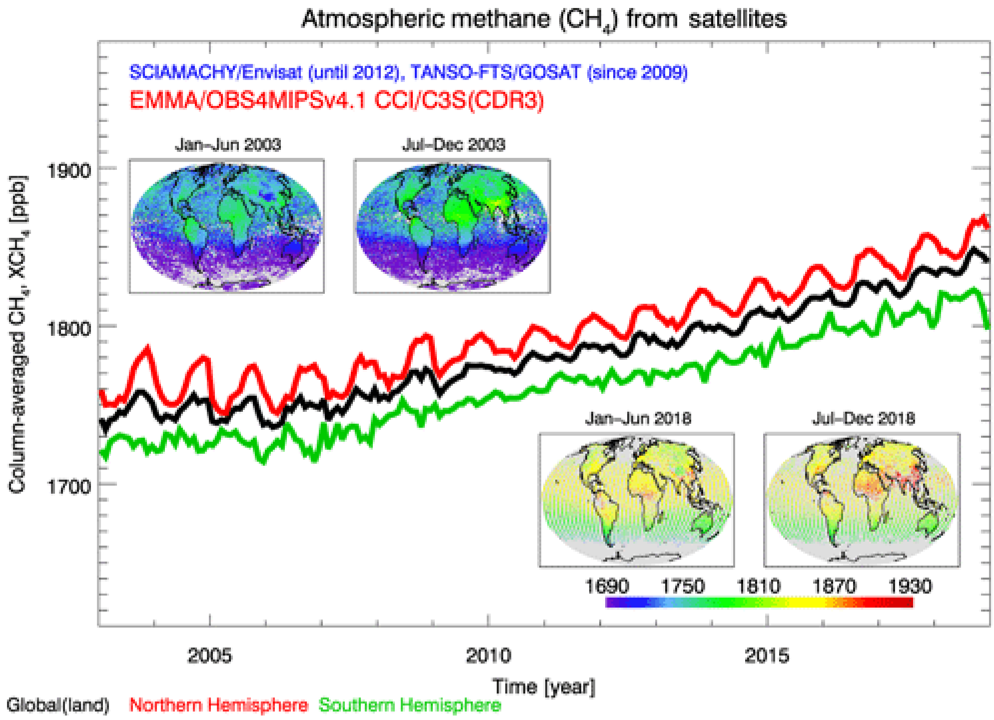

Figure 5: Time series over land for three latitude bands (global , black line, Northern hemisphere, red; Southern hemisphere, green) and global map (half yearly average). From Reuter et al., 2020.

Links

Climate from Space online resource
https://cfs.climate.esa.int

Climate for schools
https://climate.esa.int/en/educate/climate-for-schools/

Teach with space
http://www.esa.int/Education/Teachers_Corner/Teach_with_space3

ESA climate change initiative projects

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

ESA Climate Office
https://climate.esa.int/en/

Space for our climate
http://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate

ESA's Earth Observation missions
www.esa.int/Our_Activities/Observing_the_Earth/ESA_for_Earth

Earth Explorers
http://www.esa.int/Applications/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers

Copernicus Sentinels
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Overview4

Envisat
esa.int/Applications/Observing_the_Earth/Envisat

Appendix: 1

List of climate essential variables (ECVs)

ATMOSPHERE	OCEAN	LAND
SURFACE	**PHYSICAL**	**HYDROSPHERE**
Precipitation	Ocean Surface Heat Flux	River Discharge
Pressure	Sea Ice	Groundwater
Surface Radiation Budget	Sea Level	Lakes
Surface Wind Speed and Direction	Sea State	Soil Moisture
Temperature	Sea Surface Salinity	**CRYOSPHERE**
Water Vapour	Sea Surface Temperature	Snow
UPPER-ATMOSPHERE	Subsurface Currents	Glaciers
Earth Radiation Budget	Subsurface Salinity	Ice Sheets and Ice Shelves
Lightning	Subsurface Temperature	Permafrost
Temperature	Surface Currents	**BIOSPHERE**
Water Vapour	Surface Stress	Albedo
Wind Speed and Direction	**BIOGEOCHEMISTRY**	Land Cover
ATMOSPHERE COMPOSITION	Inorganic Carbon	FAPAR
Aerosols Properties	Nitrous Oxide	Leaf Area Index
Carbon Dioxide, Methane and other Greenhouse Gases	Nutrients	Above-Ground Biomass
	Ocean Colour	Soil Carbon
Cloud Properties	Oxygen	Land Surface Temperature
Ozone	Transient Tracers	Fire
Precursors	**BIOLOGY/ECOSYSTEMS**	Evaporation from land
	Marine Habitat Properties	**ANTHROPOSPHERE**
	Plankton	Anthropogenic Greenhouse Gas Fluxes
		Anthropogenic Water Use