GLOBAL CLIMATE CHANGE

Syllabus

Unit-I	08 Hrs
Introduction to the climate change: Climate, climate change, temperature anomalies, radiation and energy balance	
Unit – II	**08 Hrs**
Simple Climate models: Source of energy, energy loss, greenhouse effect, carbon cycle, atmosphere–land-biosphere–ocean carbon exchange	
Unit –III	**08 Hrs**
Prediction and impacts of climate change: Factors that control emissions, emissions scenarios, physical impacts, abrupt climate changes	
Unit –IV	**08 Hrs**
Strategies to mitigate climate change: Adaptation: technology, politics personal actions, conventional regulations, market-based regulations, information and voluntary methods	
Unit –V	**08 Hrs**
Climate change conventions: Technical summary of IPCC reports, conference of parties and climate change protocols	

Introduction to the climate change

Introduction

- What is of Climate?
- Climate vs. Weather
- Components of the Climate System
- Factors Influencing Climate
  - Solar radiation
  - Greenhouse gases
  - Ocean currents
  - Land and water distribution
- Climate Classification Systems: Koppen and C.W. Thornthwaite
- Climate Variability and Change
- Impacts of Climate Change
- Climate Data and Observations
- Global Climate Governance: United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement, and the role of intergovernmental organizations, governments, and non-state actors in climate governance.
- Climate Communication and Education

UNIT-1

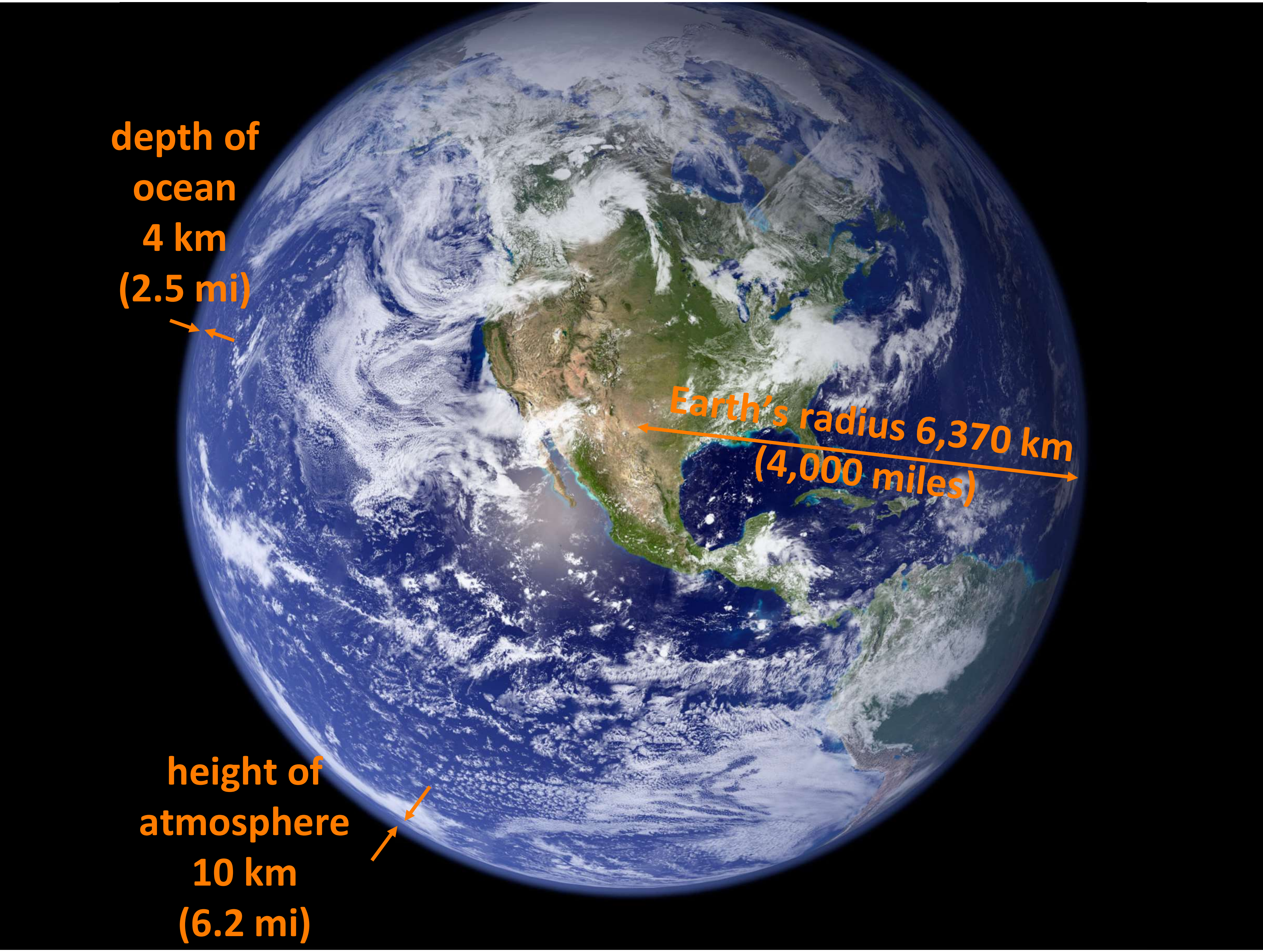
Introduction to the climate change

- Climate
- Climate change
- Temperature anomalies
- Radiation and energy balance

CLIMATE

What do you think?

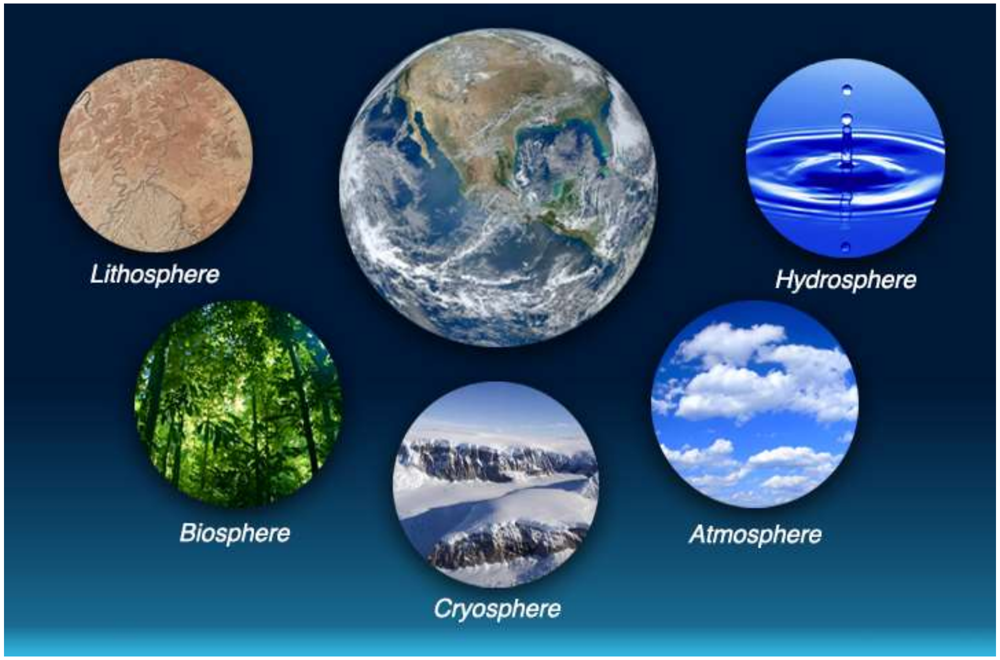
- How big is Earth?
- How high is the atmosphere?
- How deep is the ocean?

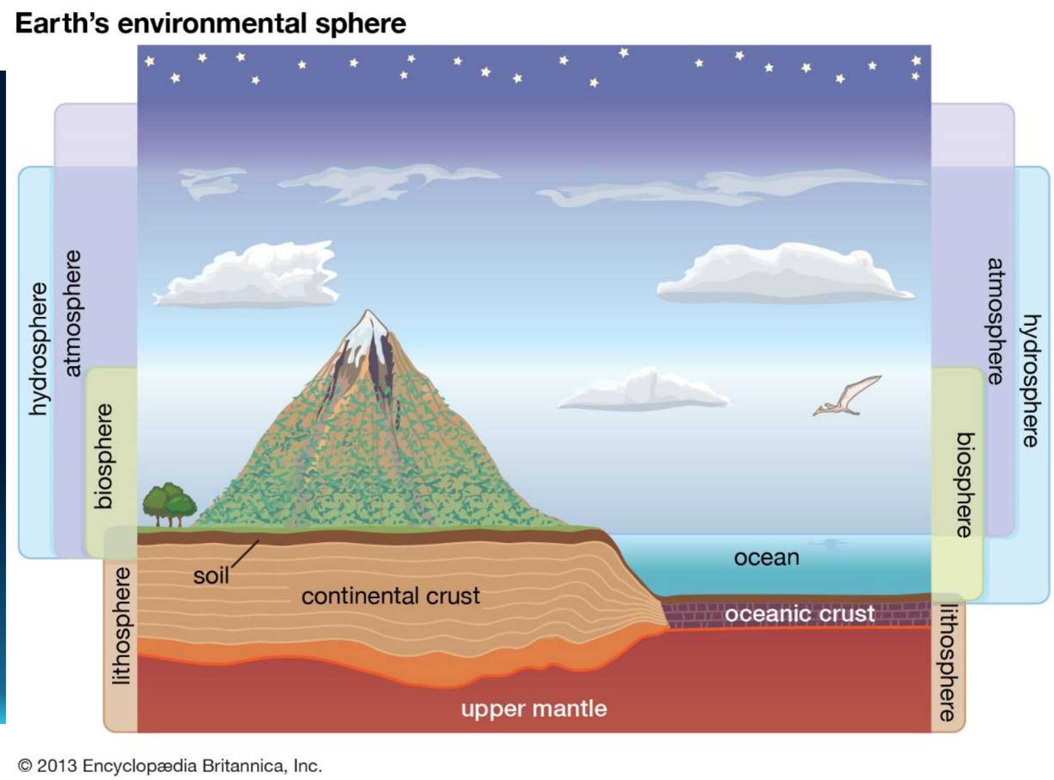

depth of
ocean
4 km
(2.5 mi)
Earth's radius 6,370 km
(4,000 miles)
height of
atmosphere
10 km
(6.2 mi)

What are the components of Earth's climate system?

Components of Earth's Climate System

- Atmosphere
- Ocean
- Cryosphere (ice & snow)
- Biosphere


Lithosphere
Hydrosphere
Biosphere
Atmosphere
Cryosphere


Earth's environmental sphere
hydrosphere
atmosphere
biosphere
lithosphere
soil
continental crust
ocean
oceanic crust
upper mantle
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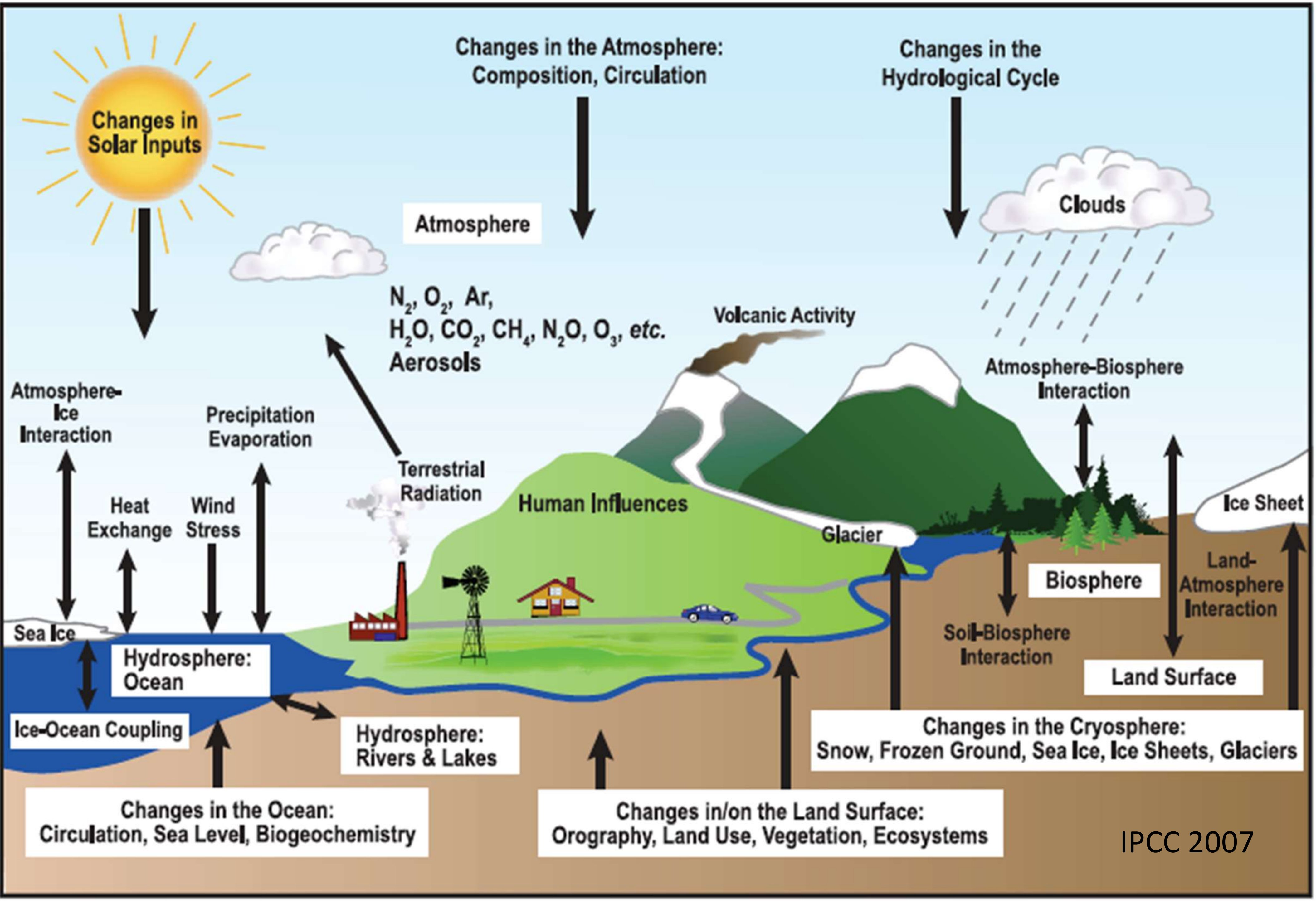
Components and Processes in the Climate System



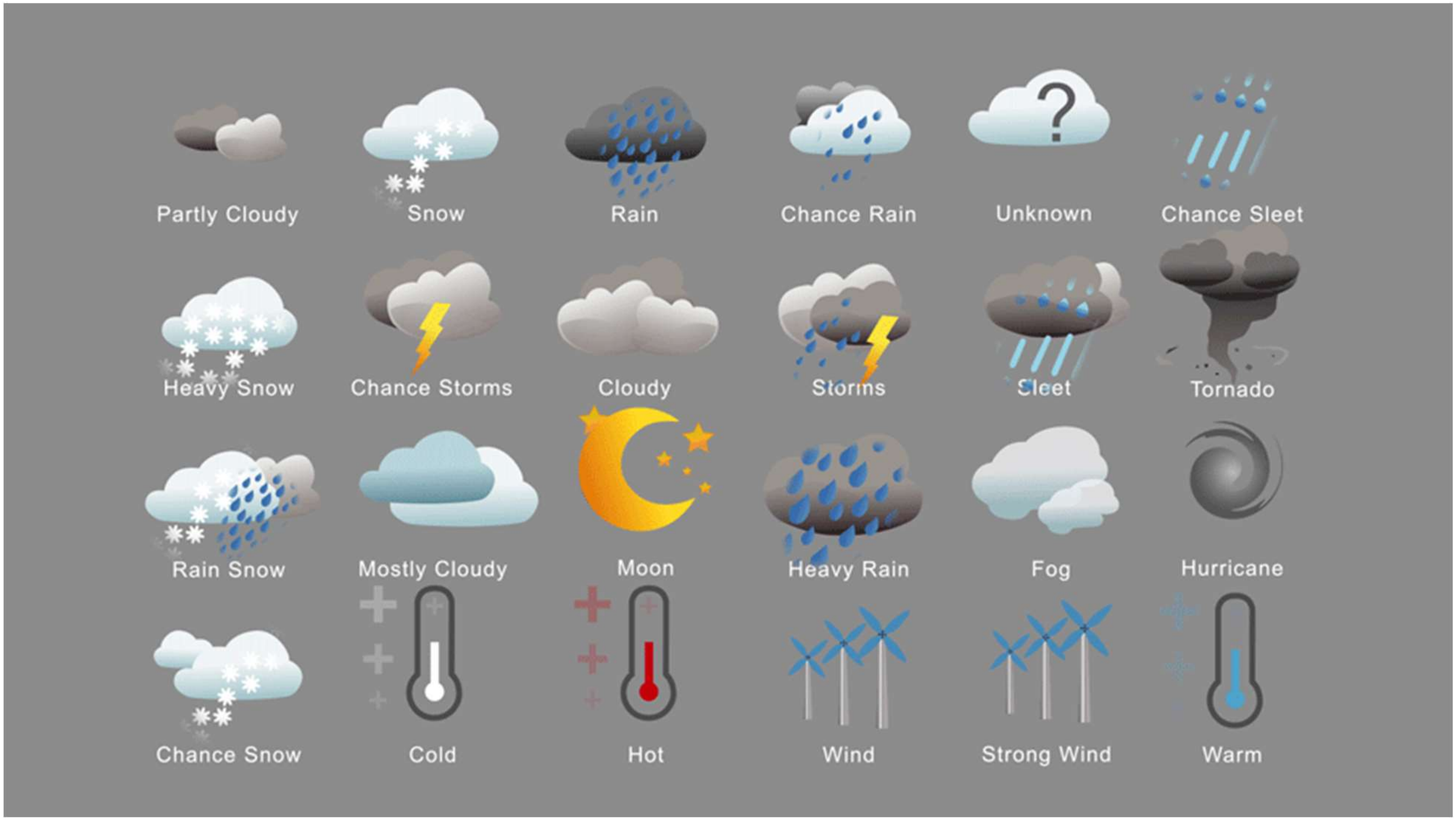
IPCC 2007

What is weather?

What is climate ?

What is weather?

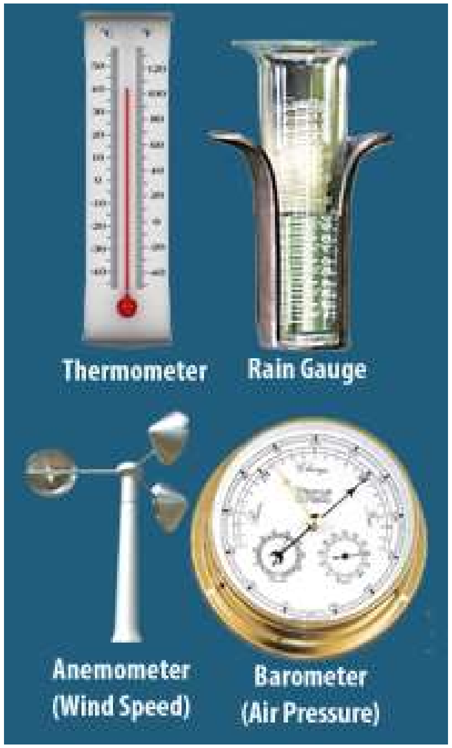
Weather is the state of the atmosphere at a particular place during a short period of time



Weather:

The **instantaneous** state of the atmosphere. Weather consists of the **short-term (minutes to days) variations** in the atmosphere of e.g. temperature, humidity, precipitation, cloudiness, visibility, wind.

Predictability limited to days due to the non-linear, chaotic nature of the governing equations.



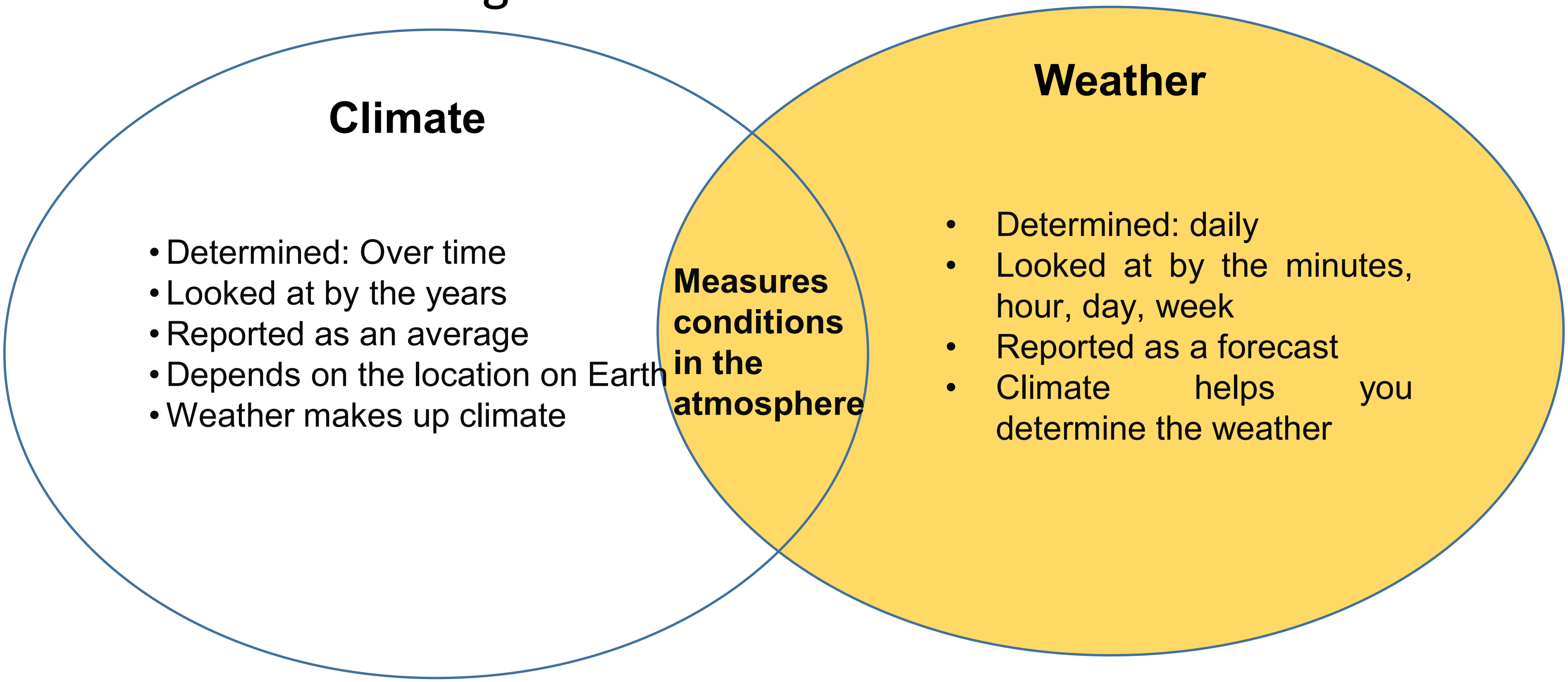
Climate:

The **average** of weather. Slowly varying aspects of the atmosphere-ocean-land surface system averaged over periods of **years, decades, or longer**, including the variability in time of these averaged quantities and other statistics such as the probability of extreme events. Potentially predictable on long time scales (decades-centuries) and large spatial scales if *forcing* is known.

Climate is defined as an area's long-term weather patterns. The simplest way to describe climate is to look at average temperature and precipitation over time.

Weather vs Climate

Weather refers to short term atmospheric conditions while climate is the weather of a specific region averaged over a long period of time. Climate change refers to long-term changes.



Climate Zones

Climate Zone	Description
Tropical	Hot and humid climates found near the equator, characterized by high temperatures year-round and abundant rainfall.
Subtropical	Warm to hot climates found between the tropical and temperate zones, with generally dry summers and mild winters.
Desert	Dry climates characterized by very low precipitation levels, often with extreme temperature variations between day and night.
Mediterranean	Warm to hot, dry summers and mild, wet winters, typically found along the coastlines of the Mediterranean Sea and similar regions.
Temperate	Moderate climates with distinct seasons, including warm summers and cool winters, found in the mid-latitudes.
Continental	Regions with large temperature variations between seasons, typically with hot summers and cold winters, found in the interior of continents.
Polar	Cold climates found near the Earth's poles, characterized by extremely low temperatures and minimal precipitation, with ice caps and glaciers.
Alpine	Cold climates found in mountainous regions at high altitudes, characterized by cold temperatures and heavy snowfall.
Equatorial	Near the equator, hot and humid, with consistently high temperatures and abundant rainfall throughout the year.
Tundra	Cold climates characterized by treeless landscapes, permafrost, and low temperatures, found primarily in the Arctic and subarctic regions.

Let’s explore!

- Follow the directions in the online textbook to explore some weather and climate data
- https://www.wunderground.com/history/
- http://www.wrcc.dri.edu/summary/climsmor.html
- https://www.ncdc.noaa.gov/cag


Climate change

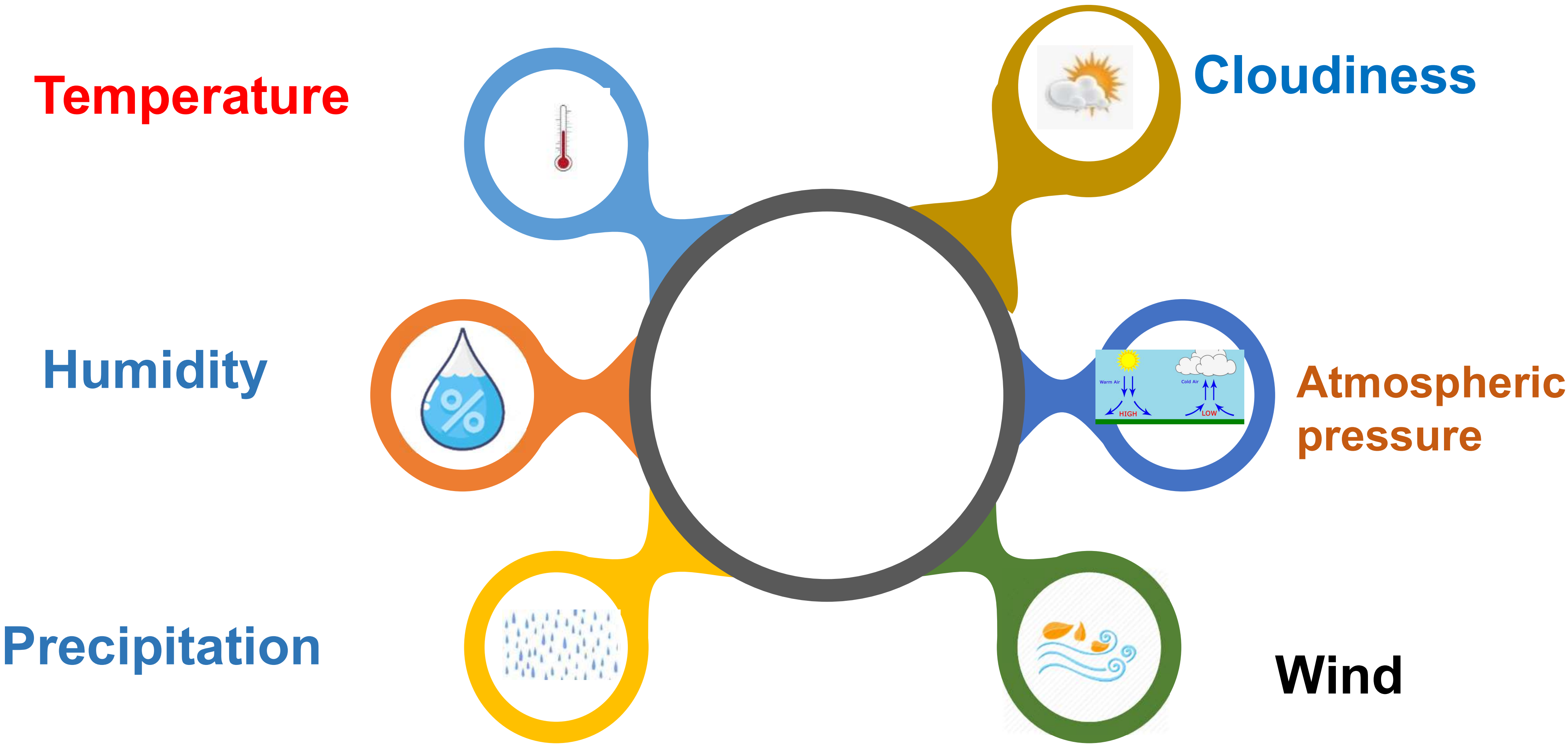
What is climate change?

- Climate change is a change in the pattern of weather, and related changes in oceans, land surfaces and ice sheets, that have come to define Earth’s local, regional and global climates and occurring over time scales of decades or longer.

- Human activities, especially emissions of heat-trapping greenhouse gases from fossil fuel combustion, deforestation, and land-use change, are the primary driver of the climate changes observed in the industrial era.

Climate variables

- Some meteorological variables that are commonly measured are as follows:



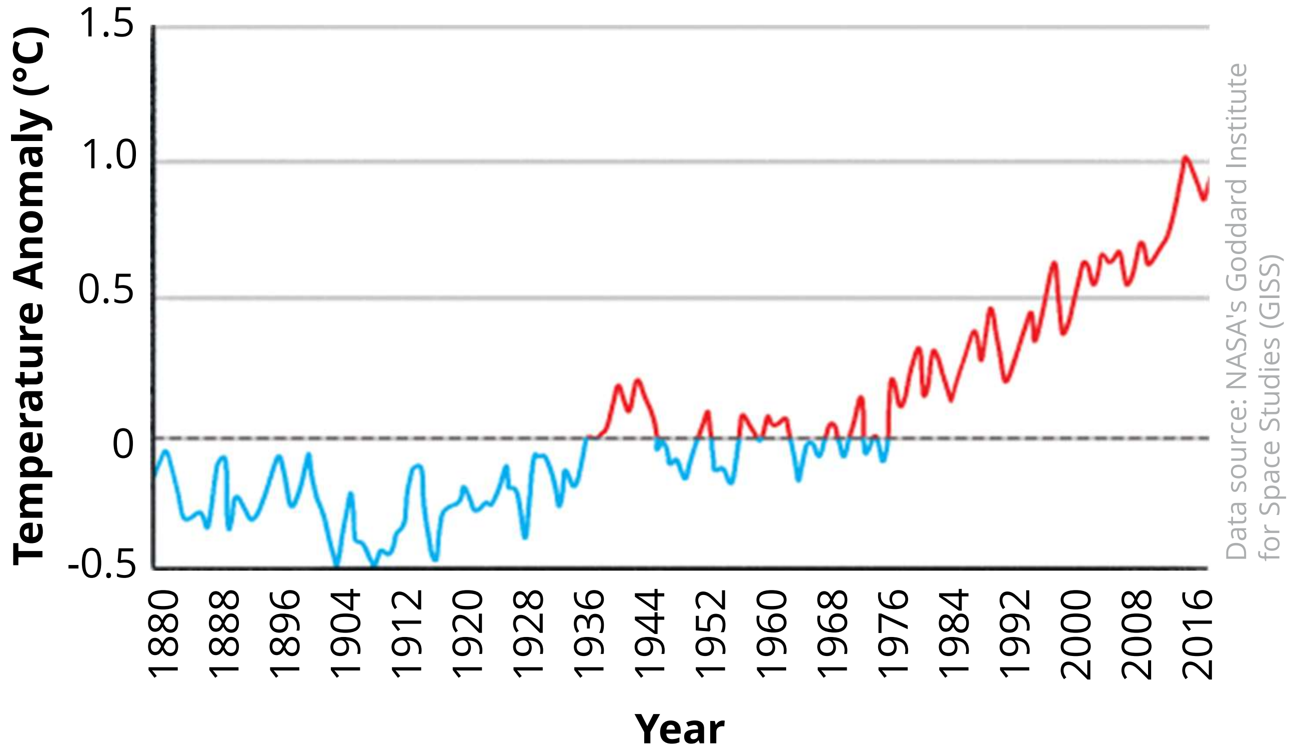
What Is Climate Change?

Climate change is a change in the average temperature and cycles of weather over a long period of time.

Since 1880, scientists have kept thermometer-based records of the global surface temperature.

What is happening to the global temperature?

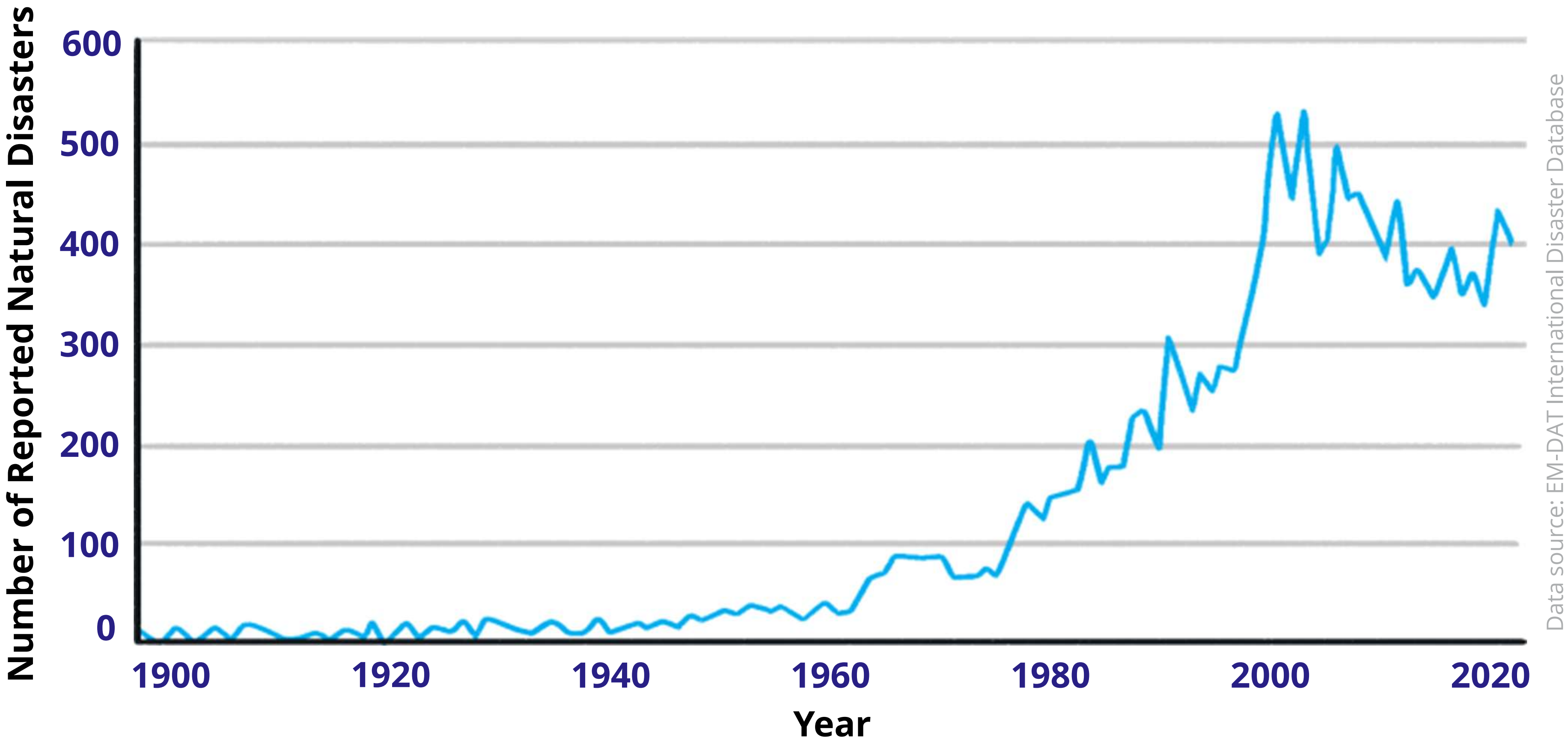
The planet is becoming warmer; the climate is changing.



Why Is Climate Change a Problem?

Climate change disrupts weather patterns and causes extreme weather events to become more common. These include hurricane activity, droughts and floods.

As the global temperature has increased, so has the number of reported natural disasters.



Why Is Climate Change a Problem?

Rising temperatures are causing sea levels to increase.

The rising water can cover coastal areas, destroying habitats and displacing whole populations from low-lying areas.

Rising sea levels are driven by two main processes:

1. **Ice Melt:** When the atmosphere and ocean get warmer, ice sheets and glaciers melt, resulting in the addition of fresh water to the ocean.
2. **Thermal Expansion:** As ocean water gets warmer, it expands, causing sea levels to rise.

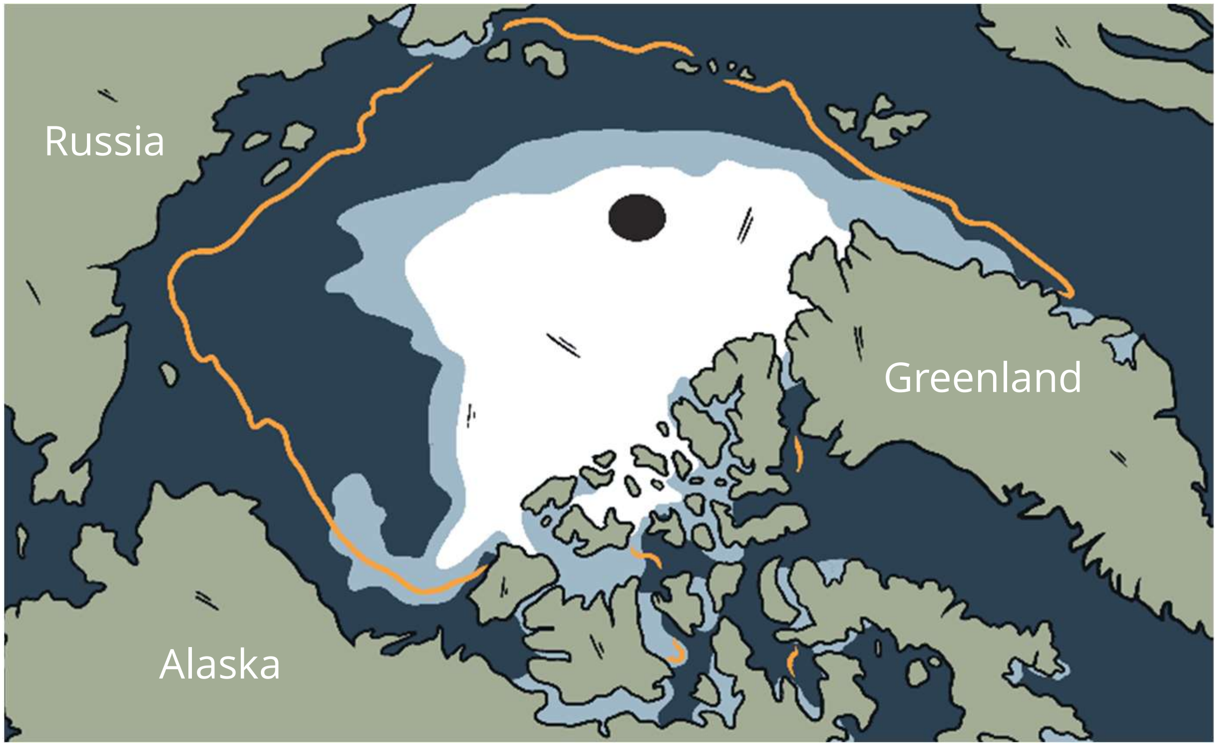
Why Is Climate Change a Problem?

The bright surface of the ice reflects 80% of the sunlight that hits it back into space. This keeps the polar regions cool and moderates the global climate.

When the area of sea ice is reduced, less sunlight is reflected back into space. This causes more ocean warming and reduces the sea ice even further.

This feedback drives faster climate change.

The orange line on the picture marks the average minimum sea ice coverage from 1981 to 2010. The white ice shows the minimum sea ice coverage in 2020.



Why Is Climate Change a Problem?

No matter how fast we act, the global temperature is set to continue rising as a result of greenhouse gases that are already in the atmosphere. The problems that we are already experiencing are going to worsen.

Acting quickly to keep the temperature rise to minimum is extremely important for humans and wildlife.

How much difference do you think a 0.5°C increase in global temperature can make?

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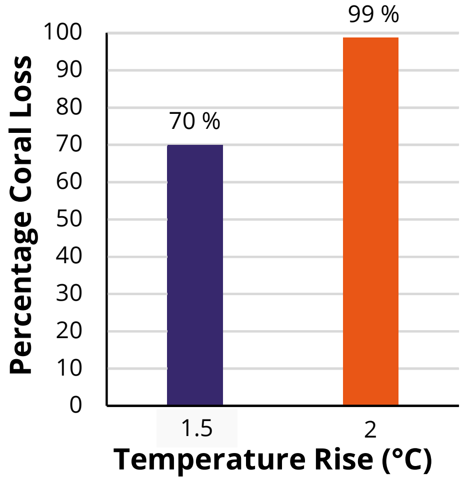
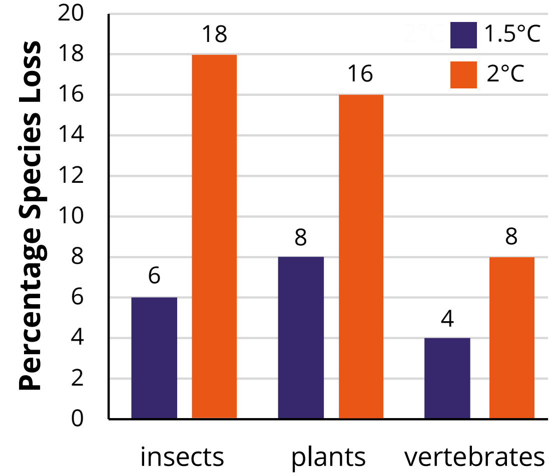
Why Is Climate Change a Problem?

Coral Bleaching



Bleached coral, Maldives by

Species Loss



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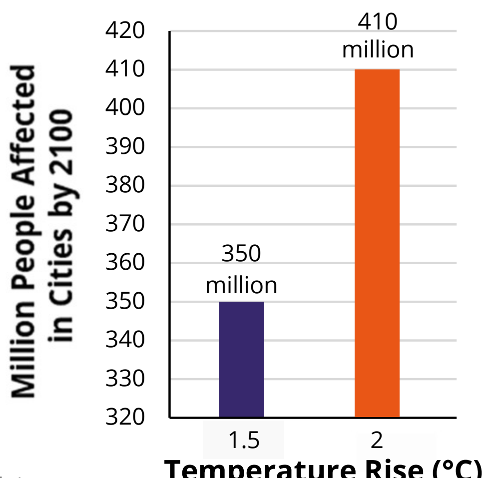
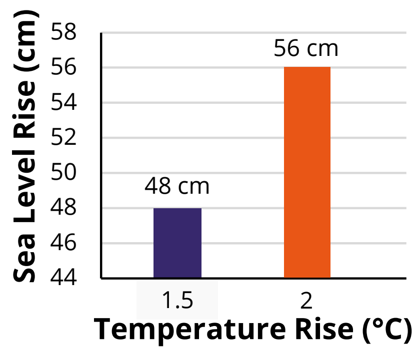
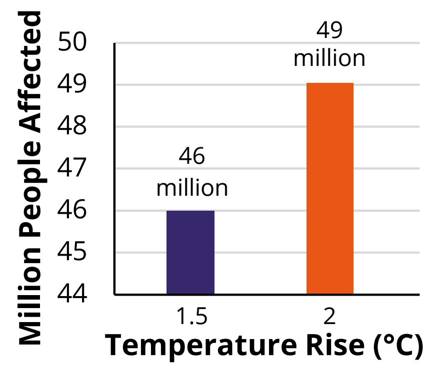
Drought



Dried up fishing pans in Liuwa plain National Park by

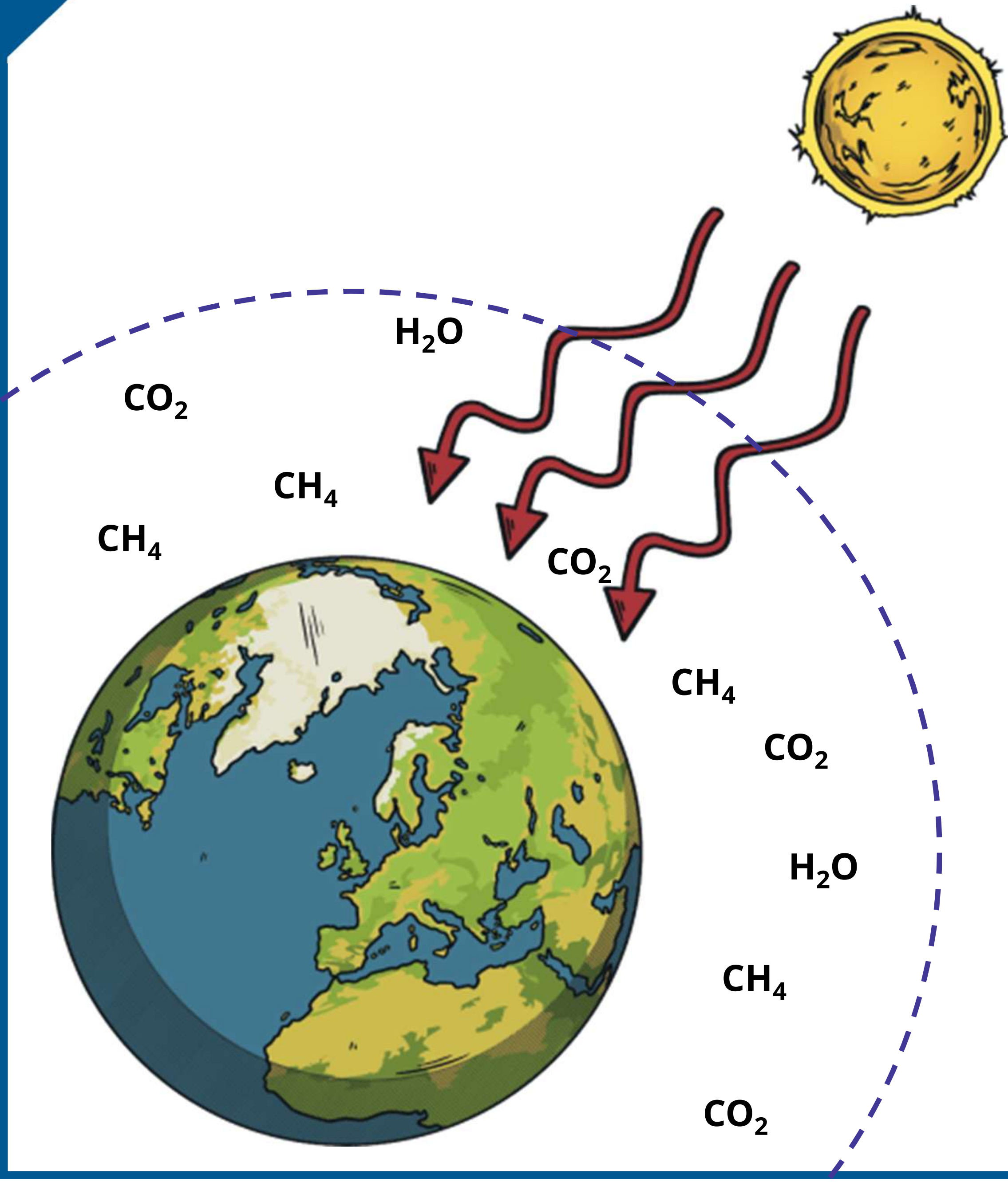
Rise in Sea Level





Climate change adaption Wadden sea by

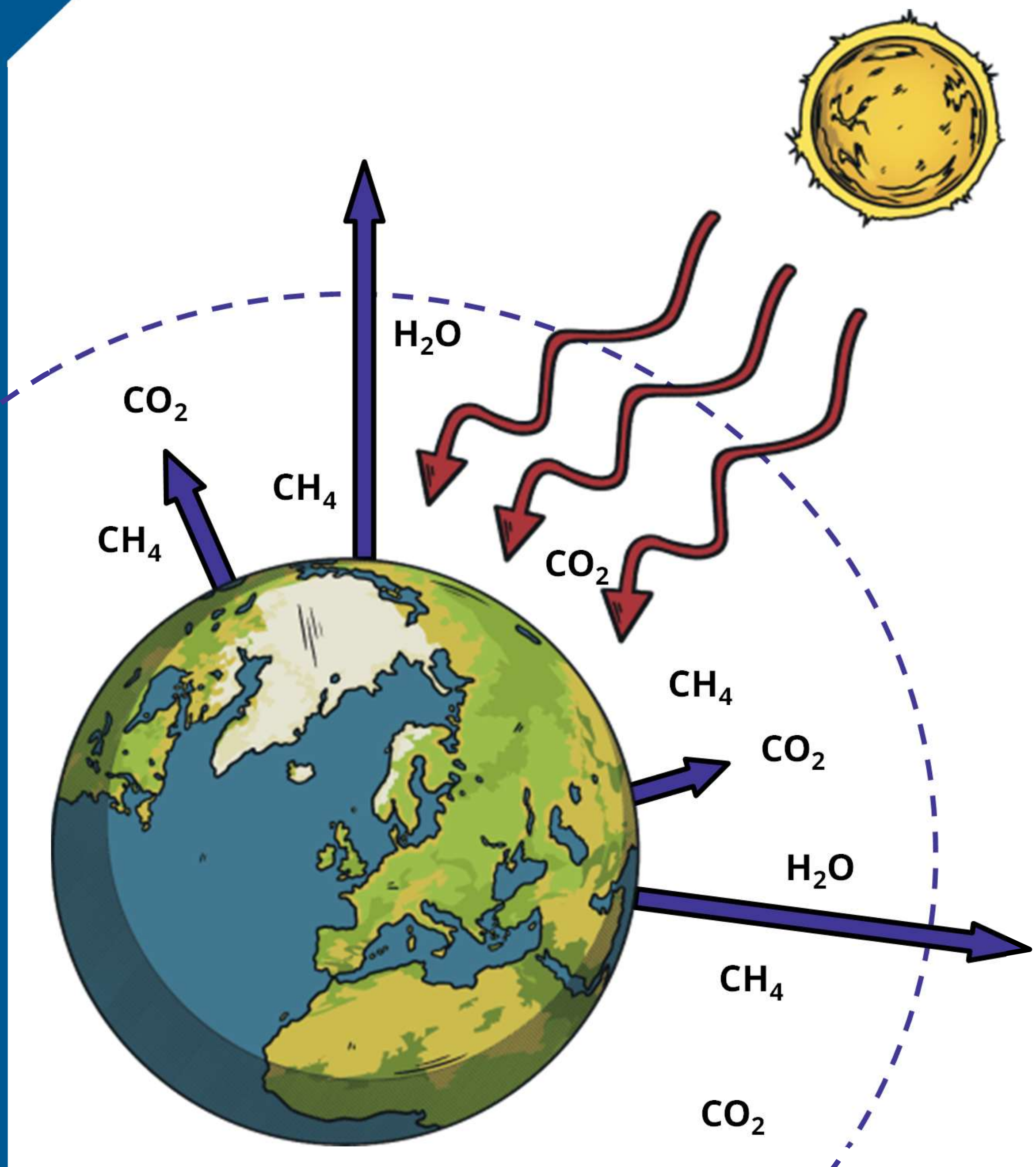
What Causes Climate Change?



Carbon dioxide (CO_2), methane (CH_4) and water vapour (H_2O) are greenhouse gases that are found in the atmosphere.

Energy travels from the Sun to the Earth as short wave radiation. It does not interact strongly with the greenhouse gas molecules so it reaches the Earth's surface.

What Causes Climate Change?



The Earth's surface emits long wavelength radiation. This does interact with the greenhouse gas molecules.

The greenhouse gas molecules absorb some of the energy, trapping it in the atmosphere.

This process keeps the Earth warm and is essential for life.

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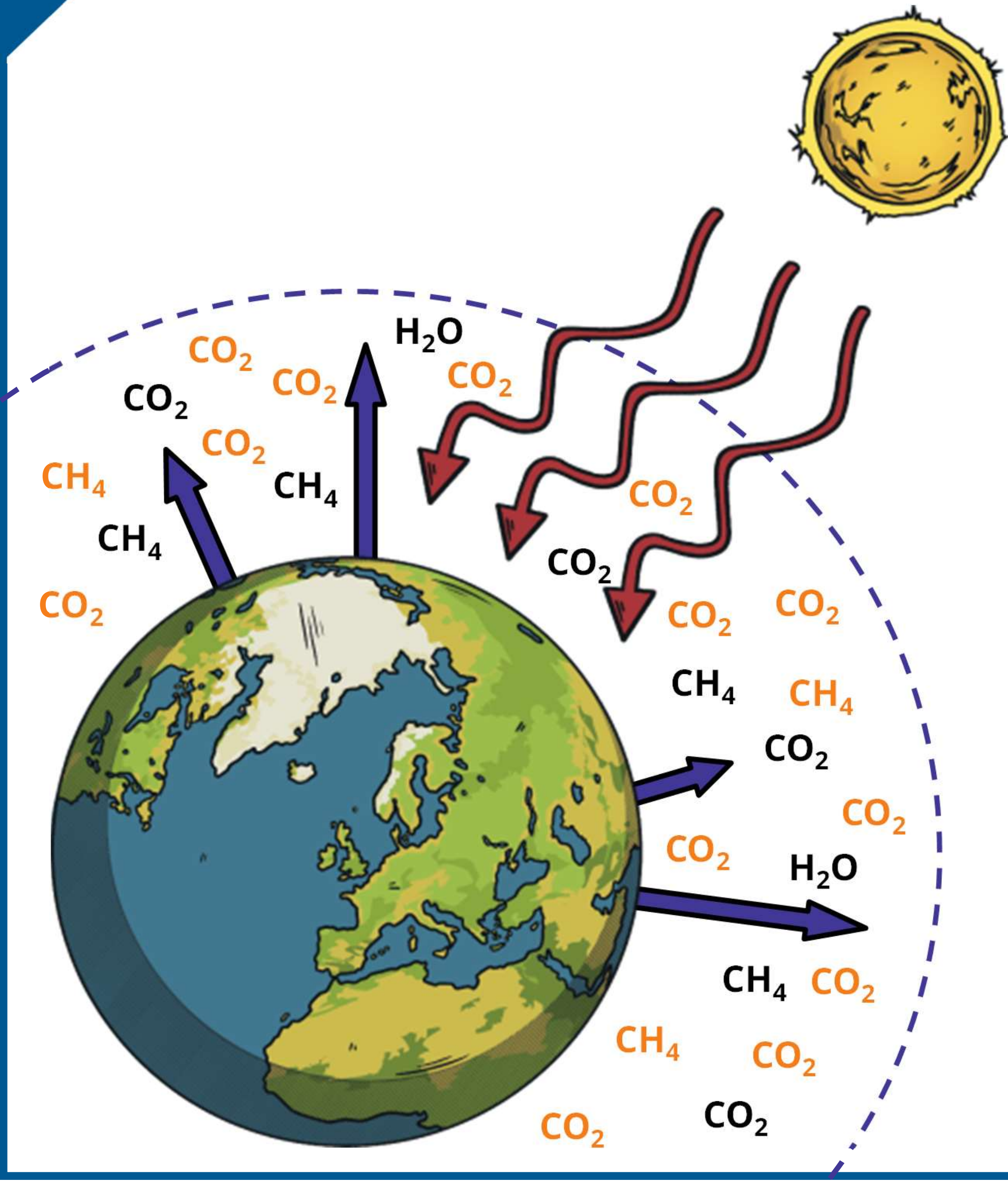
What Causes Climate Change?



The higher the proportion of greenhouse gases in the atmosphere, the more radiation is absorbed.

This causes a rise in the temperature of the Earth and is known as the greenhouse effect.

This increase in temperature drives climate change.

What Causes Climate Change?

Climate change can be caused gradually by natural processes or suddenly by large events, such as a massive meteorite strike or volcanic activity. However, the rapid climate change we are experiencing now is due to three main human activities:

- **Burning fossil fuels** for heating and cooking, generating electricity and powering vehicles releases carbon dioxide into the atmosphere.
- **Deforestation** (destruction of forests) releases carbon dioxide and reduces the number of trees able to capture carbon dioxide from the atmosphere.
- **Reduction of biodiversity** creates an unstable ecosystem. Nature loss leads to ecosystems that are less able to capture carbon from the atmosphere and less resilient to rising temperatures.

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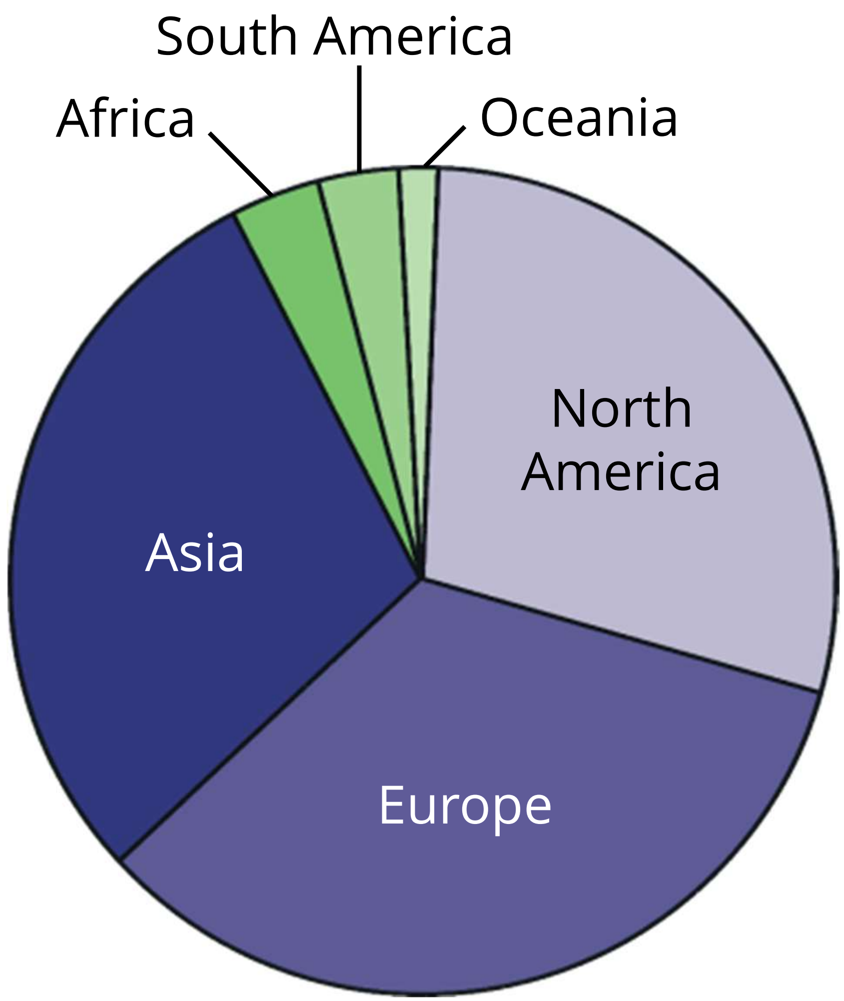
Deforestation for future agriculture plantation-Tahuamanu Province, heading to Centro Poblado de Alerta - Madre de Dios Region, Peru by © Nicolas Villaume / WWF-US licensed under CC BY

Who Causes Climate Change?

The 50 least developed countries are thought to have contributed 1% of the greenhouse gases that have caused global warming. The USA, the EU and China alone have contributed around 60%.



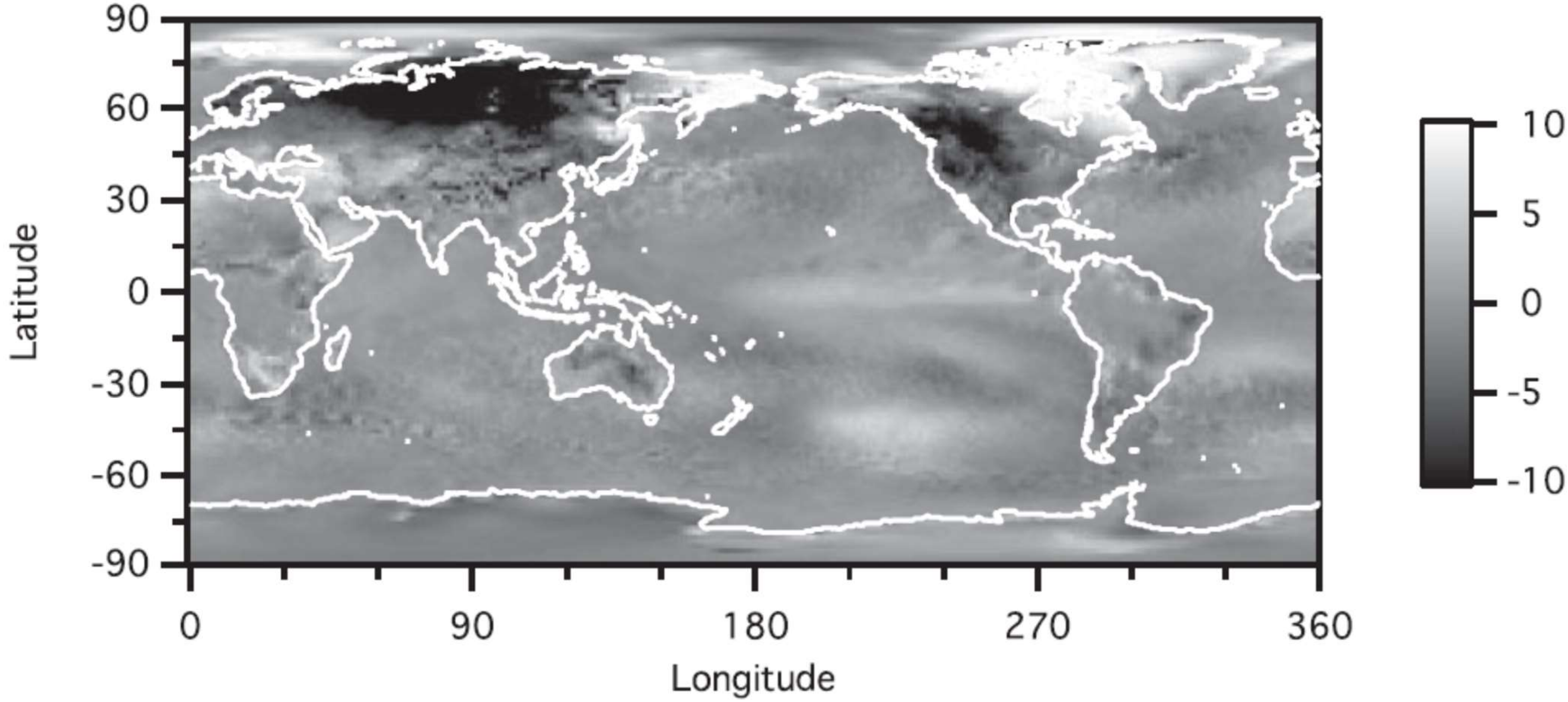
Temperature Anomalies

Temperature Anomaly

Why use anomalies rather than absolute temperature in these figures?

- Absolute temperature can vary sharply over short distances, such as between a city and a nearby rural area, or between two nearby sites at different altitudes.
- A temperature anomaly is the difference between the actual temperature and a reference temperature, usually an average over a previous multidecadal period.
- This makes the calculation of anomalies more accurate by requiring a less dense measurement network.
- Focus on the global annual average temperature

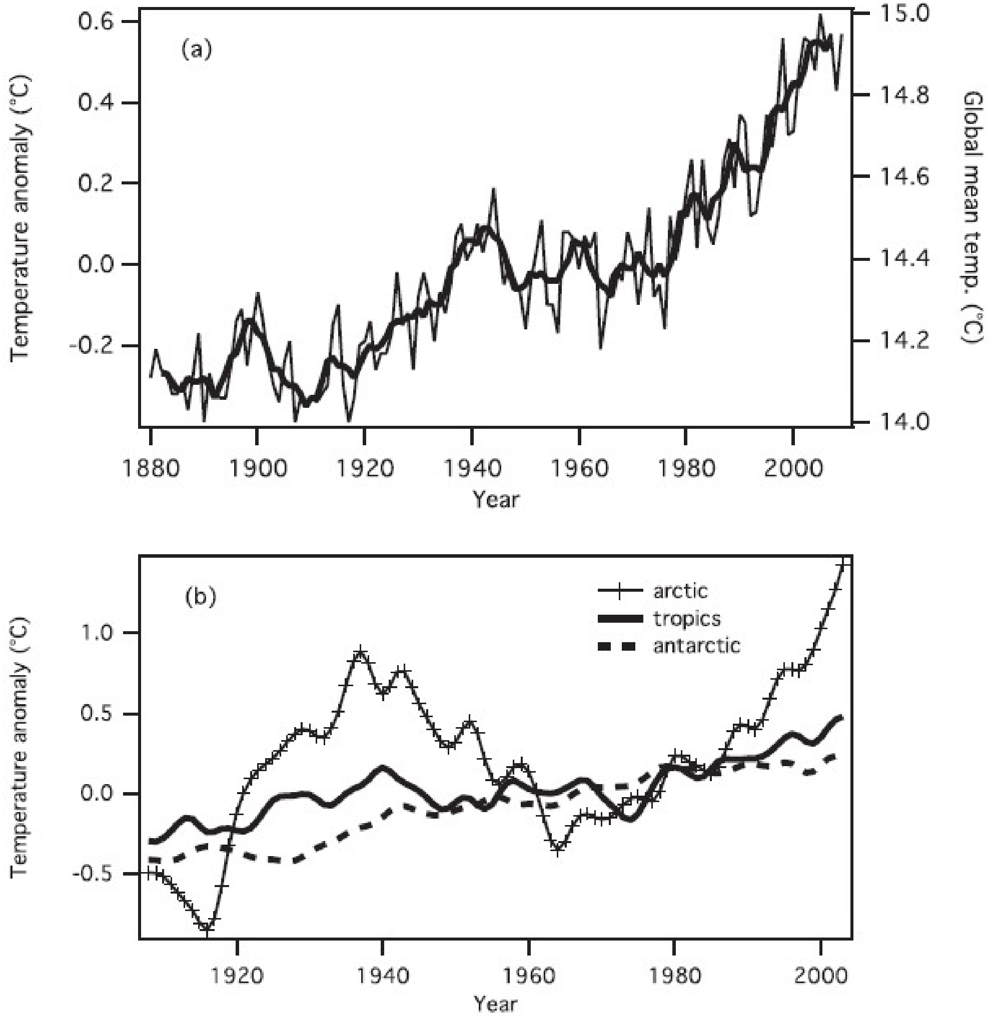
Temperature Anomaly



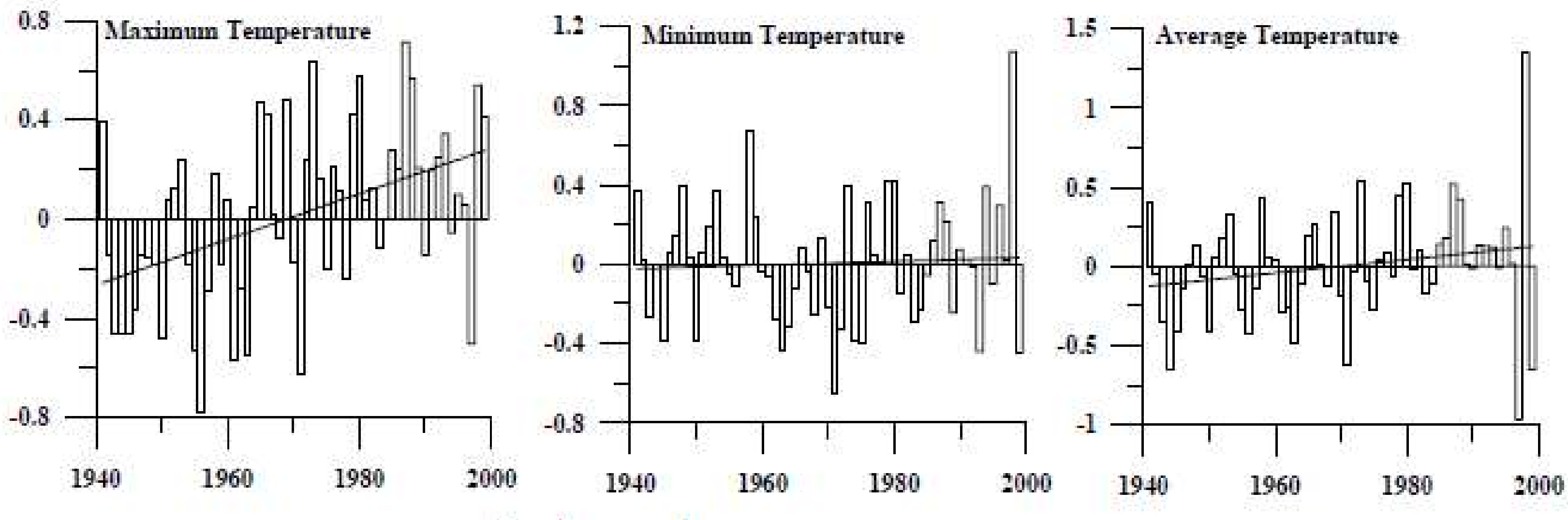
The monthly surface temperature anomaly in December 2009 in degrees Celsius. The reference temperature for the anomaly calculation is calculated at each location as the average of the December temperatures from 2000 to 2009 at that location (data obtained from the ECMWF-interim reanalysis)

Temperature Anomaly

Global annual average temperature anomalies: (a) The right-hand axis shows approximate global average temperature. The gray line is a smoothed time series. (b) Smoothed temperature time series for three different regions of the planet: the Arctic (64 ◦N–90 ◦N), the tropics (24 ◦N–24 ◦S), and the Antarctic (64 ◦S–90 ◦S). In both plots, the reference temperature used in calculating the anomalies is the 1951–1980 average (data are from the NASA GISS Surface Temperature Analysis, or GISTEMP, product – see http://data.giss.nasa.gov/gistemp/



Evaluation of temperature trends over India

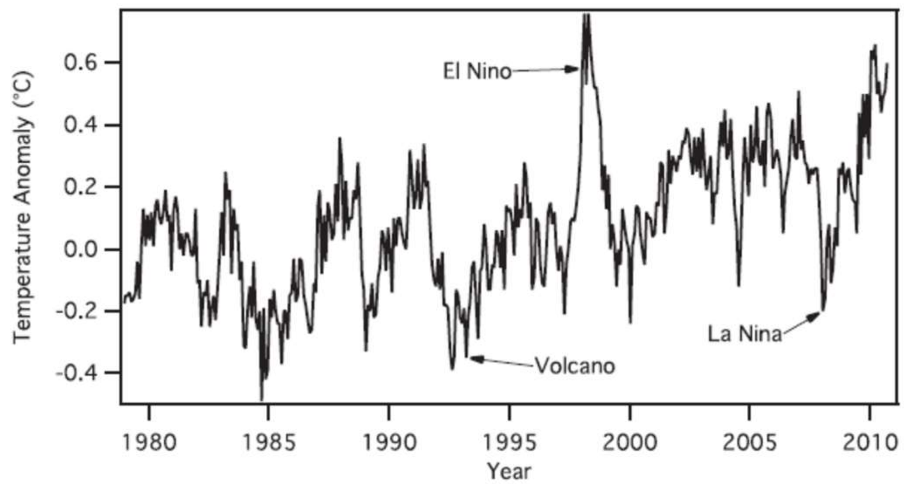


- The anomalies for maximum, minimum and mean temperatures for different regions and seasons with respect to their mean of 59 years (1941–1999) are shown
- The linear trend value, represented by the slope of a simple least-square regression line with time as the independent variable gives the magnitude of rise or fall in temperature.

Is Our Climate Changing???

Satellite measurements of temperature

- It is possible to measure global average temperature from orbit, and the United States has been flying satellites to make that measurement since 1978.
- These data show a general warming trend over this period of approximately 0.13◦C per decade (1.3◦C per century), which is similar to that seen in the surface thermometer record in the late 20th century
- Satellites do not measure the surface temperature; instead they measure the average temperature of the bottom 8 km of the atmosphere, from the surface to about the altitude where airliners fly.
- Issues: Orbit drift, calibration of the satellite instruments,



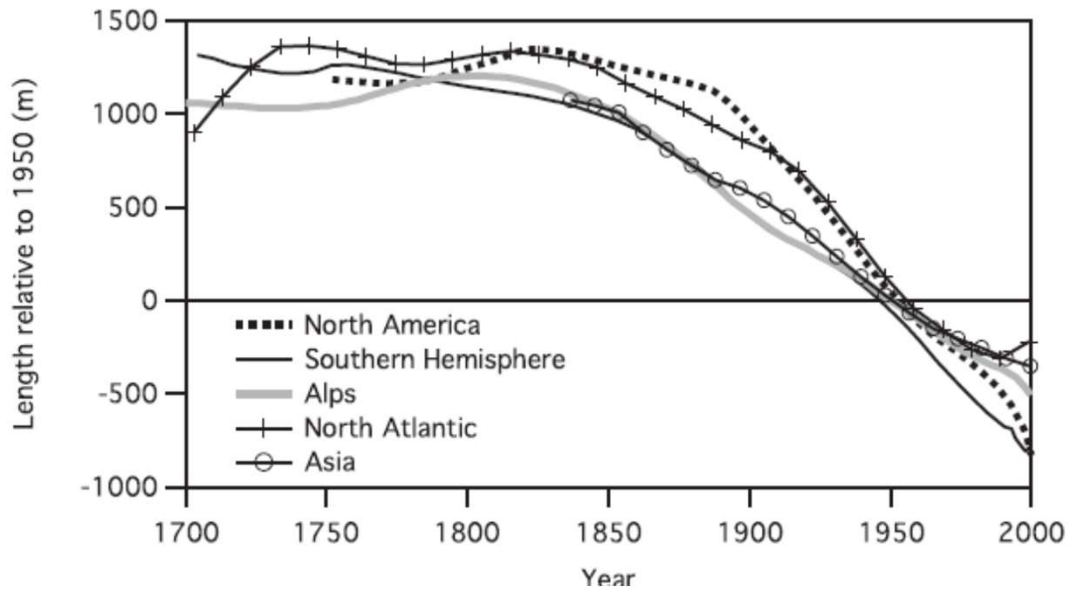
Satellite measurements of the global monthly average temperature. The satellite measures the average temperature of a layer of the atmosphere from the surface to an altitude of approximately 8 km, about the height that airliners fly

Ice

- Ice is a dependable indicator of temperature as it melts 0°C

Glaciers:

- Figure shows changes in average glacier length (relative to the length in 1950) for five world regions over the past few centuries.
- It shows that glaciers began retreating around 1800, with the shrinkage accelerating later in the 19th century.
- The pattern of glacier retreat is consistent worldwide; this shows that the warming we are now experiencing is truly global.



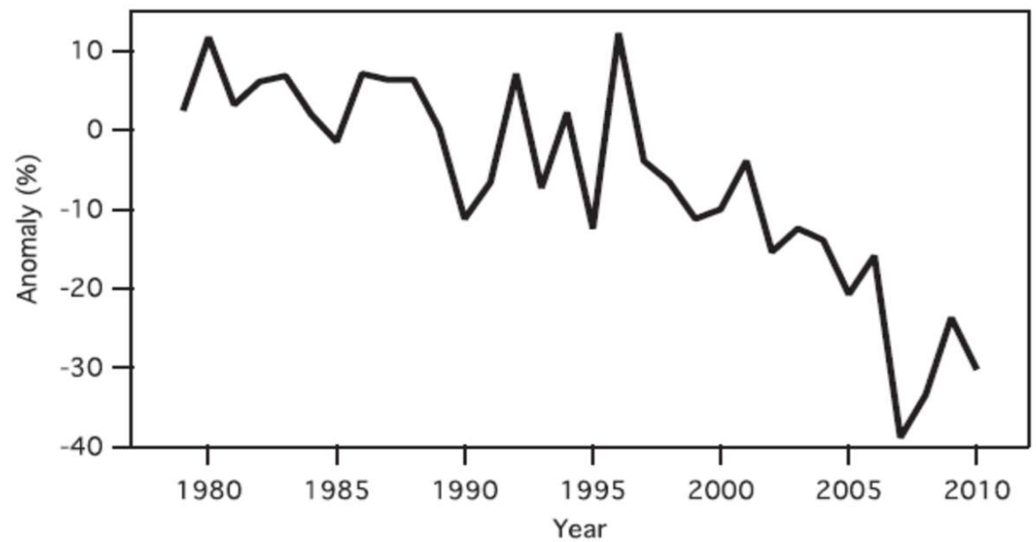
Change in mean glacier length over time, measured relative to length in 1950, for five world regions

The recession of glaciers provides confirmation of the global warming of the climate

Ice

Sea ice

- At the cold temperatures found in polar regions, seawater freezes to form a layer of ice floating on top of the ocean
- Figure confirms this by showing a clear downward trend in the area covered by Arctic sea ice during September.
- Measurements also show that, in addition to shrinking in area, sea ice has grown thinner.
- The sea-ice area around Antarctica has remained stable since the mid-1970s.
- Large losses of sea ice in the Arctic but little loss in the Antarctic – matches the regional temperature trends in these regions.

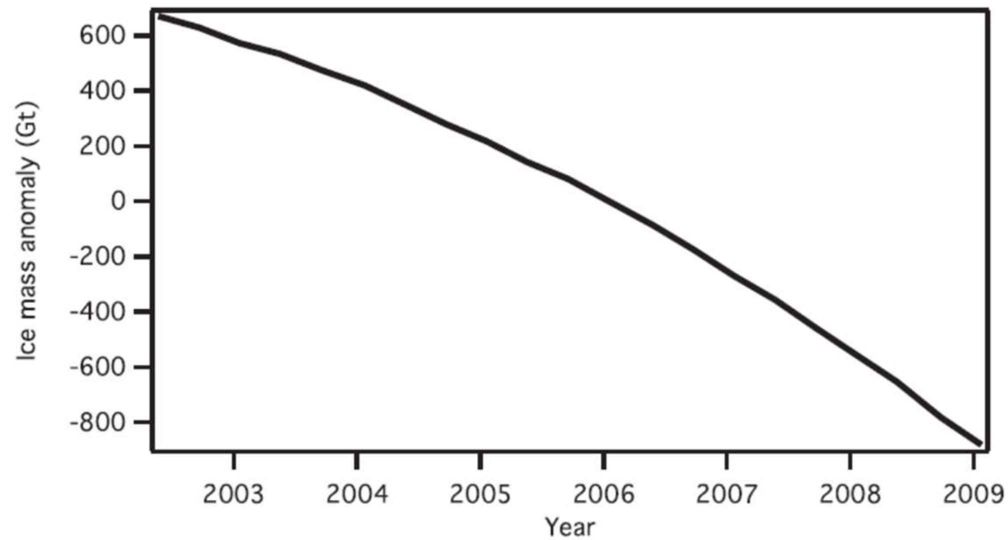


Arctic sea-ice area anomaly in September of each year. The anomaly is the percent deviation from the 1979–2000 mean area of 7 million km^2 (data obtained from the National Snow and Ice Data Center)

The sea-ice data strongly confirm not just the warming trend but also the global distribution of the warming.

Ice sheets

- Greenland in the northern hemisphere and the other on Antarctica in the southern hemisphere.
- These ice sheets cover millions of square kilometers of the Earth, and in places they are more than 3,000 m thick.
- If they melted completely, the sea level would rise approximately 100 m
- The measurements come from a satellite that measures the gravity of the Earth very precisely, and from that can determine changes in the mass of the ice sheets.
- Measurements from Antarctica show comparable losses for that ice sheet.

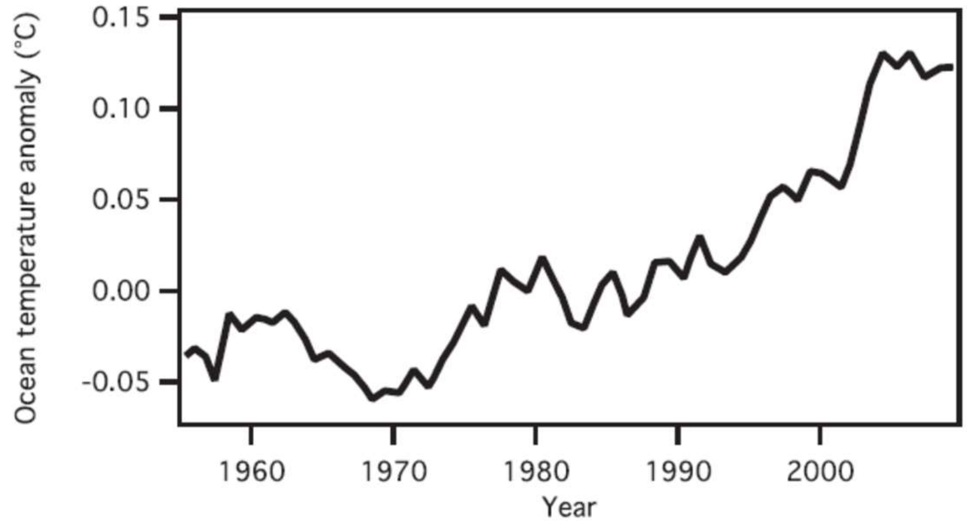


Change in Greenland's ice mass, in billions of tons (Gt) of ice, as measured by the GRACE satellite during the period from April 2002 to February 2009. The plotted curve is a best quadratic fit to the data (adapted from Fig. 1 of Velicogna, 2009).

Thus, the amount of ice on the planet (glaciers, sea ice, and ice sheets) is decreasing. This is consistent with measurements of rising temperatures from the surface thermometer network and from the satellites

Ocean temperatures

- Much of the heat trapped by greenhouse gases goes into heating the oceans, so we can also look to see if the temperatures of the oceans are increasing.
- Temperature of the bulk of the ocean – in other words, the water temperature averaged over a significant fraction of the ocean's average depth of 4 km.
- Scientists determine this temperature by lowering thermometers into the ocean and measuring the temperature at various depths, and then averaging these results to come up with a single average ocean temperature over that depth

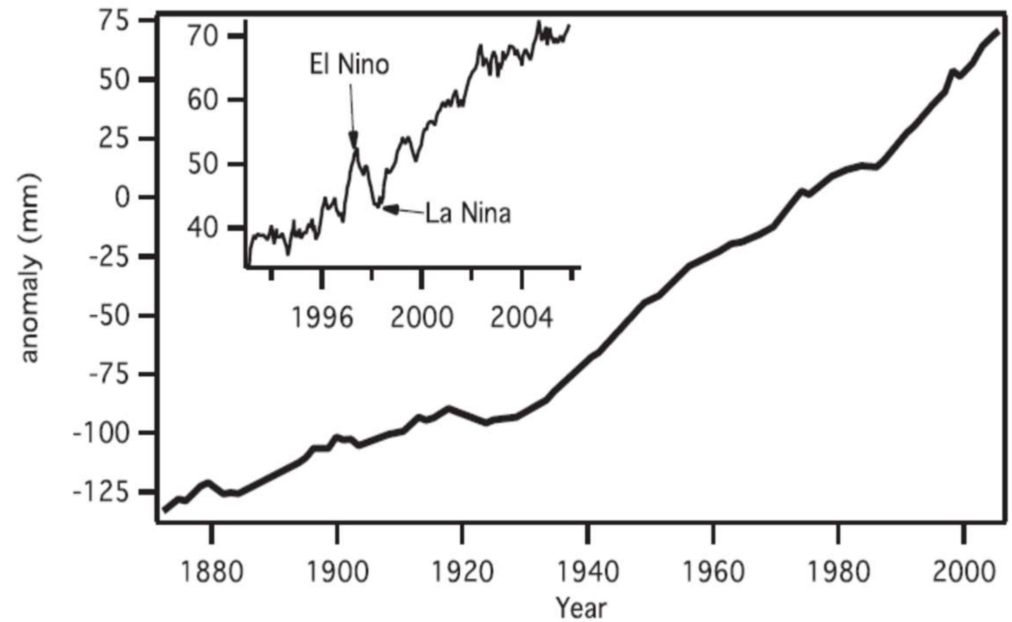


Ocean temperature anomaly in degrees Celsius for the top 700 m of the ocean. Anomalies are calculated relative to the 1957–1990 period (data obtained from http://www.nodc.noaa.gov/OC5/3M HEAT CONTENT/).

The ocean is indeed observed to be warming, and this provides another source of independent confirmation that the Earth is warming.

Sea level

- Sea-level change is connected to climate change in two ways: 1) Ice Melting and 2) Elevated Temperatures of sea water
- During the 20th century, the rate of increase in sea level was approximately 1.5 mm per year, for a total of 15 cm over the century
- In the past 40 years, the increase has been roughly 1.8 mm per year,
- Of which thermal expansion accounts for approximately one fourth (0.42 mm per year) and the melting of land ice the remainder
- From 1993 to 2003, the increase has been 3.1 mm per year, with more or less equal contributions from thermal expansion and melting glaciers.



Global annual average sea-level anomaly, measured relative to the 1961–1990 average and smoothed to show decadal variations.

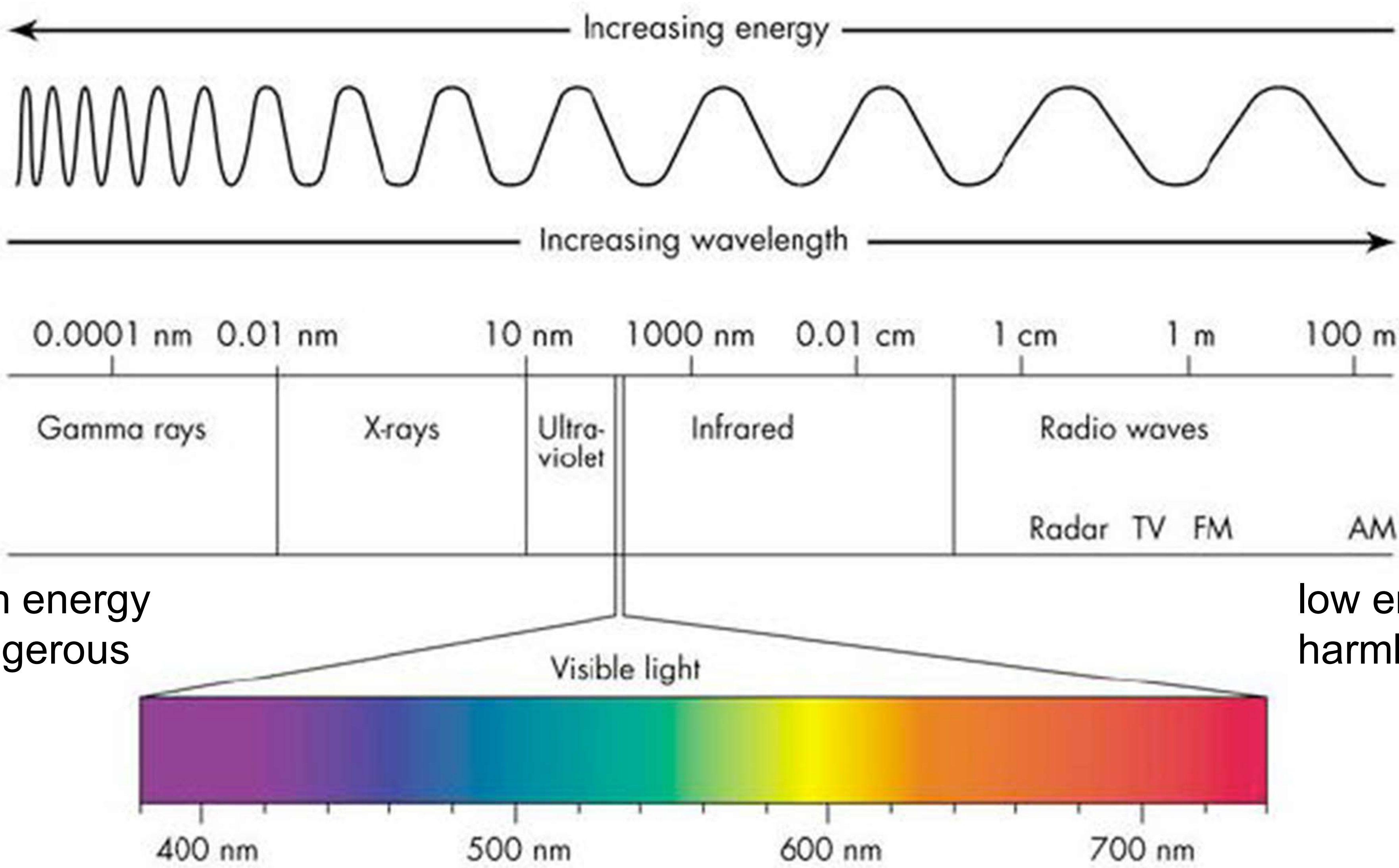
The observed change in sea level is consistent with the loss of ice as well as with the warming of the ocean.

Radiation and Energy Balance

Temperature and energy

- Energy is the capacity to do work – such as lifting a weight, turning a wheel, or compressing a spring.
- The unit of energy most frequently used in physics is the *joule*, abbreviated as the letter *J*. 1 cal = 4.18 J.
- The rate at which energy is moving is referred to as *power*. It is usually expressed in *watts,* abbreviated as the letter *W*.
- One watt is equal to one joule per second – that is, 1 W = 1 J/s.
- Flow of energy is expressed in units of watts (joules per second).
- How much power does it take to run a human body? Calculate.
- The *internal energy* of an object refers to how fast the atoms and molecules in the object are moving.
- Temperature is a measure of the internal energy of an object. *Units* Celsius and Kelvin. K = C + 273.15
- Physicists prefer the Kelvin scale because temperature expressed in degrees Kelvin is proportional to internal energy.

Electromagnetic Spectrum



high energy
dangerous

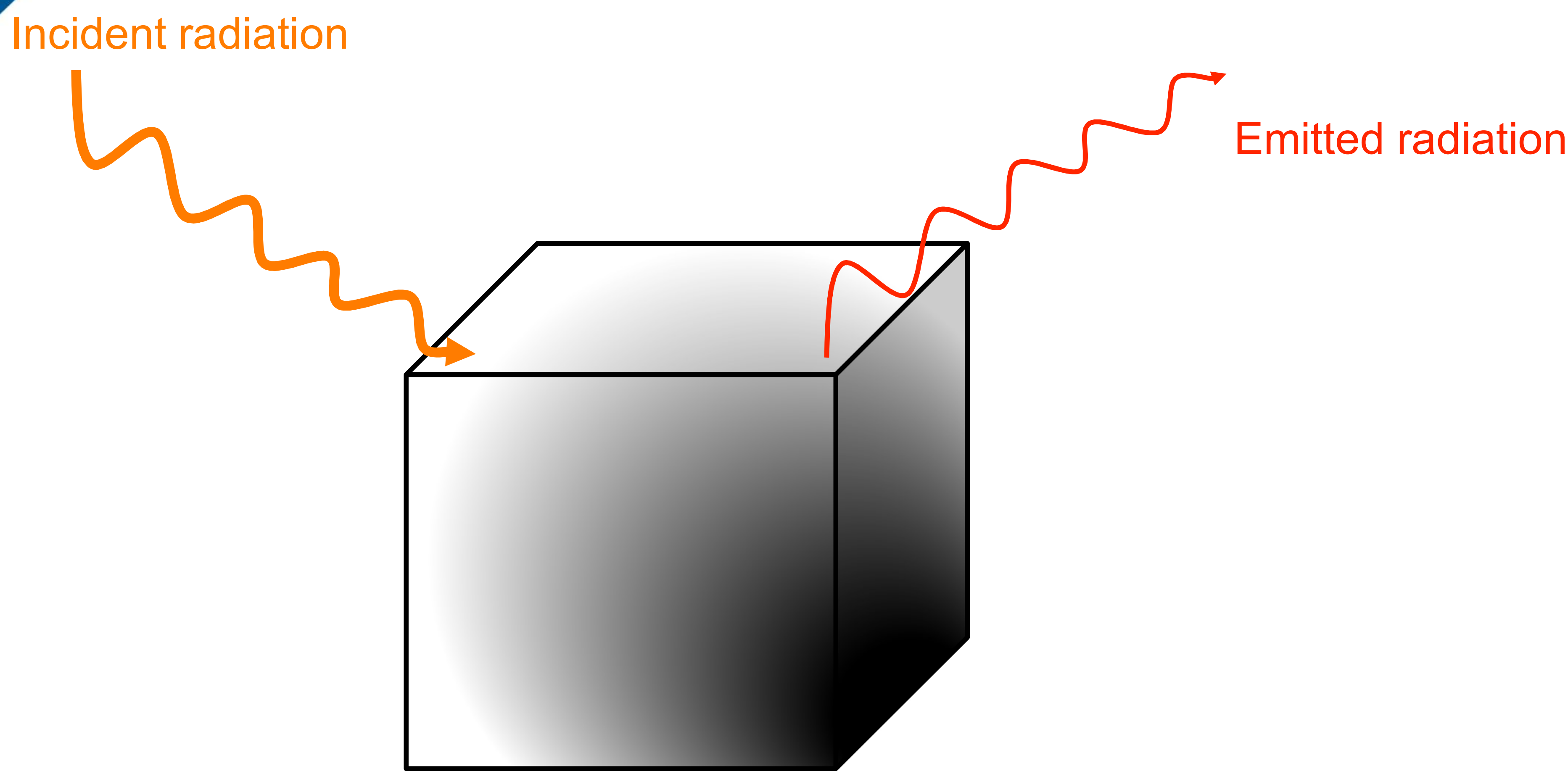
low energy
harmless

1 nm = 10^{-9}m = 0.000000001 m = 10^{-6} mm = 10^{-3} µm

Electromagnetic Spectrum

- Energy is transported from the Sun to the Earth by *electromagnetic radiation*
- Energy is transported from the Sun to the Earth through photons
- Photons have a characteristic size, referred to as the *wavelength*, which determines how the photons interact with the world
- Photons with wavelengths of between 0.3 and 0.8 micrometers, abbreviated as µm can be seen with the human eye –*visible light* (0.4 µm as blue, 0.6 µm as yellow, and 0.8 µm as red)
- Photons with longer wavelengths, from 0.8 to 1,000 µm, are termed *infrared.*
- Photons with wavelengths just below the human detection limit of 0.3 µm are called *ultraviolet.*
- Photons with wavelengths between 1,000 µm (1 mm) and 0.3 m are termed *microwaves*
- Wavelengths bigger than about 0.3 mare radio-frequency waves
- The atmosphere is transparent to visible photons but less transparent to infrared photons

Black body radiation



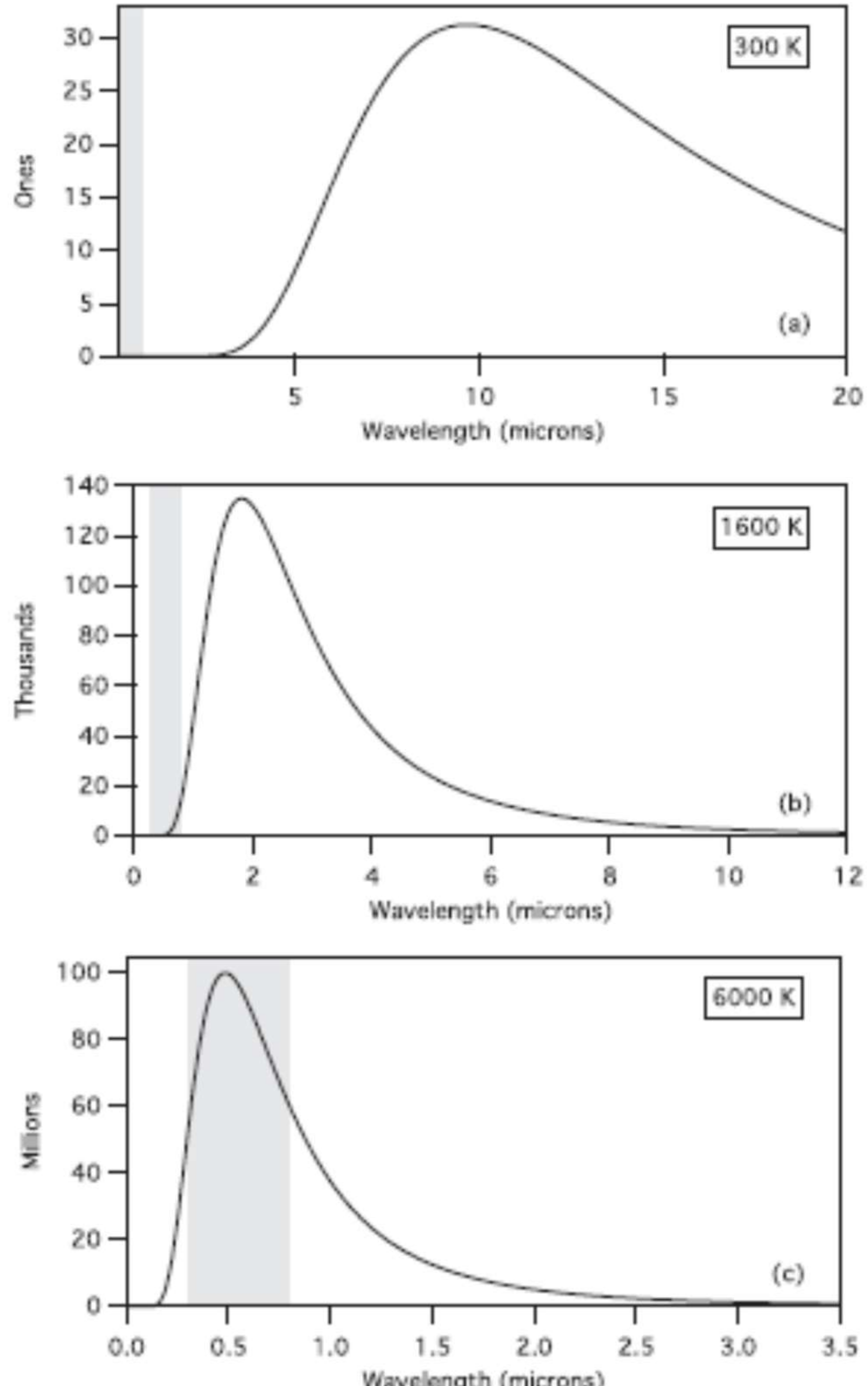
- A '**black body**' is an object completely absorbing all incident electromagnetic radiation no matter what its wavelength (frequency). It emits thermal radiation according to Planck's law.
- Many natural objects emit thermal radiation like a black body (*even fresh snow or the sun*). But we'll discuss some exceptions later.

Black body radiation

- An emissions spectrum is the amount of power carried away from an object by the photons at each wavelength
- All room-temperature objects are emitting photons, but you cannot see the photons because they fall outside the visible range
- Simple relation between the temperature of an object and the peak of the object's emission spectrum known as Wien's displacement law:

$$\lambda_{max} = \frac{3000}{T}$$

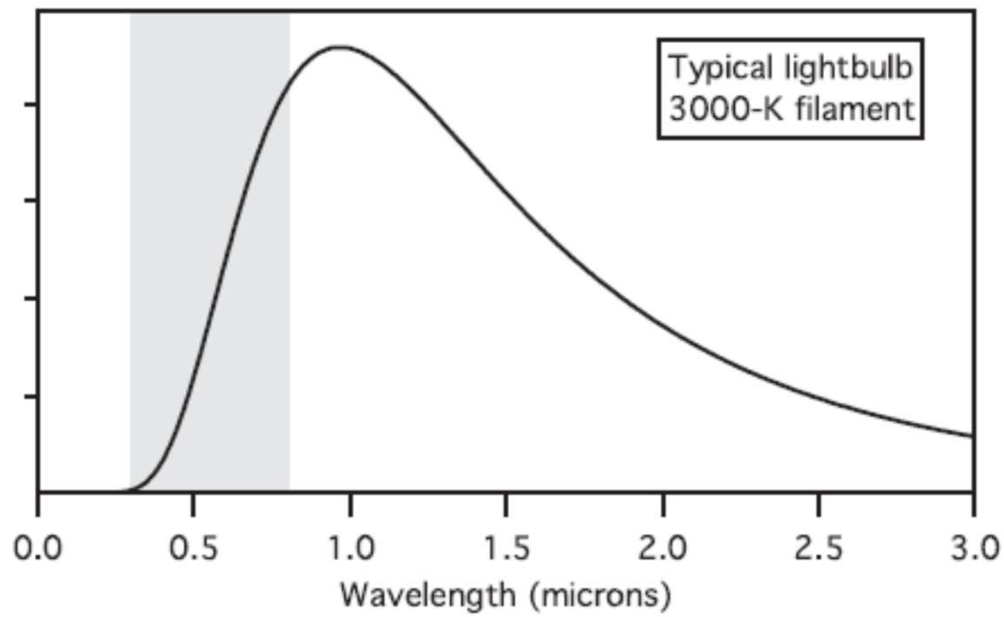
- Here λ_{max} is the wavelength of the peak of the emission spectrum and T is the temperature of the object in Kelvin
- Wien's displacement law also tells us that, as an object heats up, the peak of its emission spectrum moves to shorter wavelengths; in other words, λ_{max} becomes smaller.



Emissions spectra for idealized objects called *blackbodies* at three temperatures.

Black body radiation

- Figure shows the wavelength distribution of photons emitted by a 3000-K blackbody.
- The filament is hot enough that some of the photons emitted are visible
- However, nearly 85% of the photons emitted have wavelengths too long for the human eye to detect.
- The compact fluorescent light bulb, or CFL, uses a different technology to emit most of the bulb's photons in the visible wavelength range



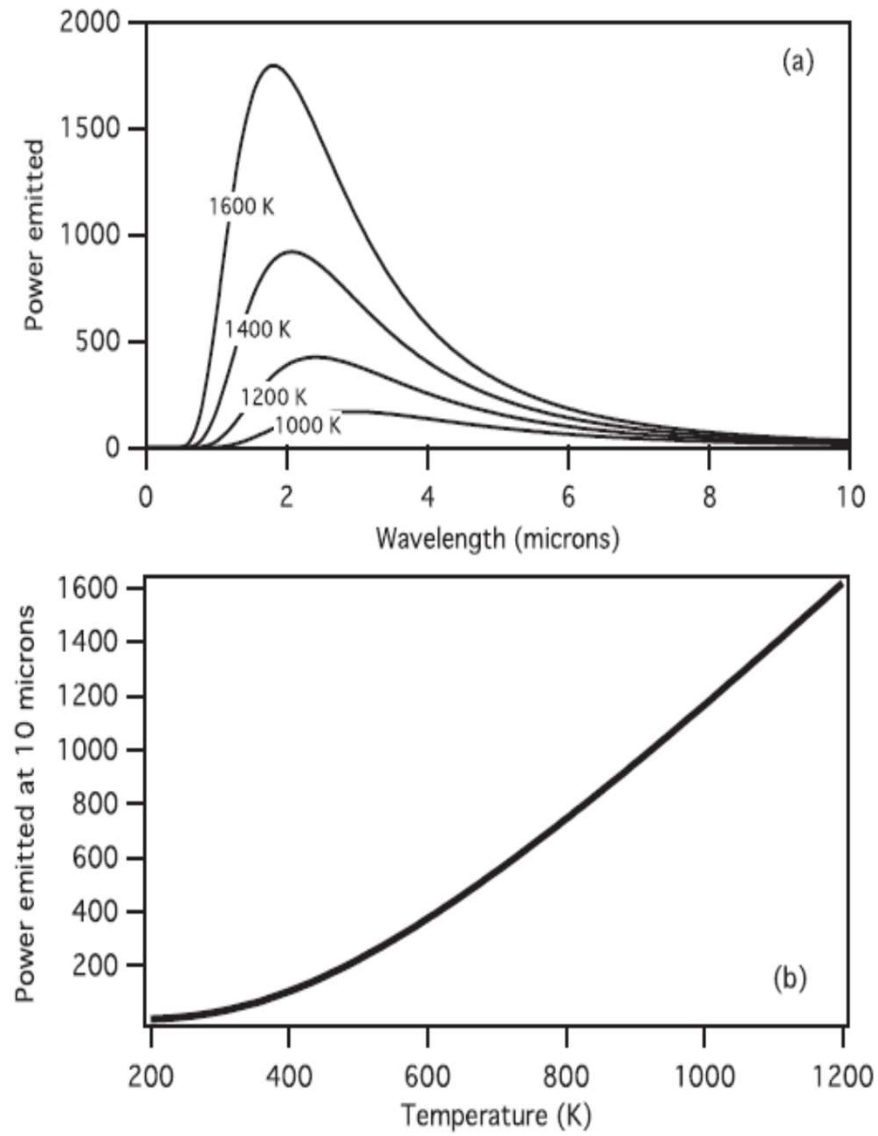
Emissions spectrum for a 3000-K blackbody, a typical filament temperature for an incandescent light bulb. The numbers on the y-axis are omitted.

Black body radiation

- Warmer objects emit more power than cooler objects at all wavelengths.
- The temperature of the object increases, so does the power emitted at this wavelength.
- The total power emitted by a blackbody increases with temperature. There is, in fact, a simple relation, known as the Stefan–Boltzmann equation, between the total power radiated by a blackbody and temperature:

$$P/a = \sigma T^4$$

- Note that P/a is the power emitted by a blackbody per unit of surface area, with units of watts per square meter; σ is the Stefan–Boltzmann constant, with σ = 5.67 ×10−8 (W/m2)/K^4; and T is the temperature of the object in degrees Kelvin.
- If you multiply P/a by the surface area a of the object (in square meters), then you get the total power emitted by a blackbody, in watts.



Plots of (a) the distribution of power emitted by a blackbody at four different temperatures (1600, 1400, 1200, and 1000 K) and (b) energy emitted by a blackbody at 10 μm as a function of temperature. Plotted quantities are in (W/m2)/μm.

Energy Balance

Energy balance

- First law of thermodynamics, which basically says that *energy is conserved*.
- If some object loses some energy, then some other object must gain that same amount of energy.
- The emission of a photon therefore causes the temperature of an object to decrease.
- If a photon hits an object and is absorbed, then the energy of the photon is transferred to the object's internal energy and the object's temperature will increase.
- Change in temperature $\propto$ Change in internal energy = energy in − energy out

- Https://www.youtube.com/watch?v=p-6DusnZ1pQ

Thank you

Sustainable Development Goals

1.No poverty
2.Zero hunger
3.Good health and well-being
4.Quality Education
5.Gender equality
6.Clean water and sanitation
7.Affordable and clean energy
8.Decent work and economic growth
9.Industry, innovation and infrastructure
10.Reduced inequalities
11.Sustainable cities and economies
12.Responsible consumption and production
13.Climate action
14.Life below water
15.Life on land
16.Peace, justice and strong institutions
17.Partnership for the goals