

01 Climate system

Ladislava Řezníčková, MSc, PhD

Content

1. What is the climate system?

- Components of the climate system
- Positive and negative climate feedbacks

2. Natural causes of climate change

- fluctuations in solar radiation, orbital changes
- distribution of continents and oceans, volcanic eruptions, vegetation
- atmosphere and ocean relationship
- changes in the composition of the Earth's atmosphere

Weather vs Climate

Weather

- **short-term** changes in the atmosphere
- the state of the atmosphere at a particular place and time as regards heat, cloudiness, dryness, sunshine, wind, rain, etc.
- most weather happens in the troposphere

Climate

- the weather conditions prevailing in a specific area over a long period
- **long-term** characteristic weather regime (long-term average state of the atmosphere in a certain place), conditioned by the energy balance, atmospheric circulation, the character of the surface and human interventions

How does the climate change?



Time scale!

Climate system

HYDROSPHERE

(the Earth's liquid water in oceans, rivers, lakes and underground)

CRYOSPHERE

(the frozen water in ice and snow – sea ice, ice sheets, snow cover, permafrost)

ATMOSPHERE

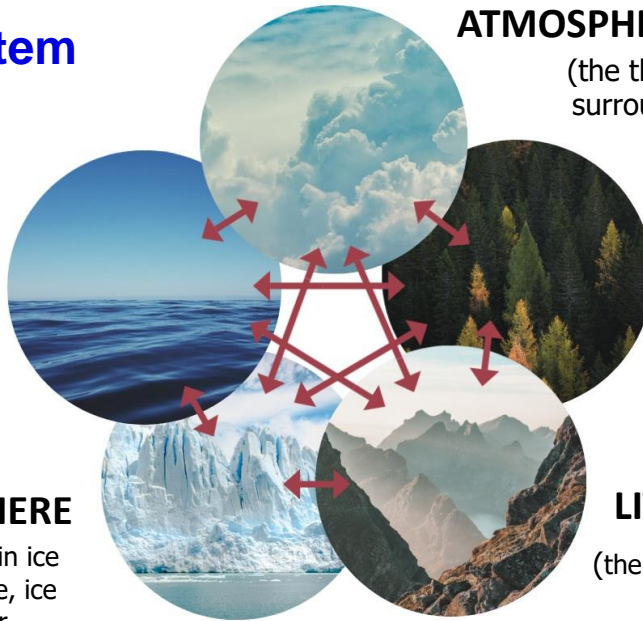
(the thin layer of gases surrounding the Earth)

BIOSPHERE

(the living things such as plants and animals including humans)

LITHOSPHERE

(the land surfaces such as soil and rocks)



By Femkemilene - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=79629050>

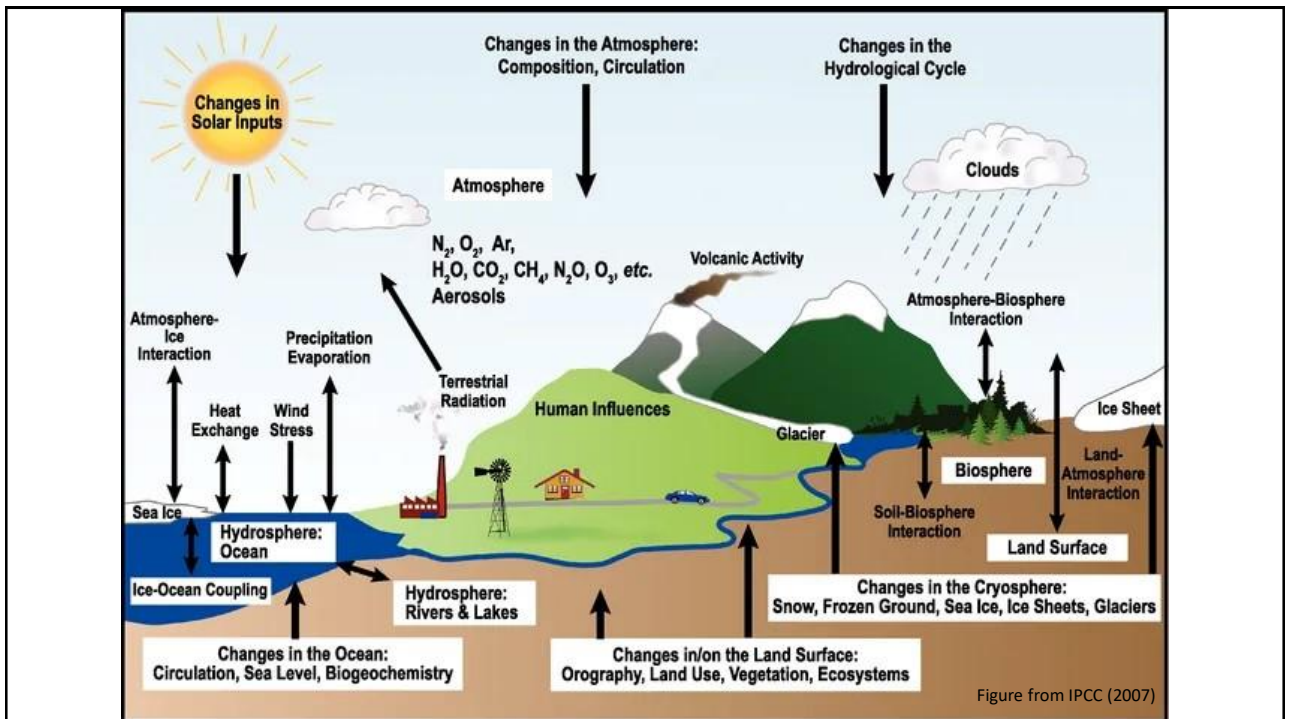


Figure from IPCC (2007)



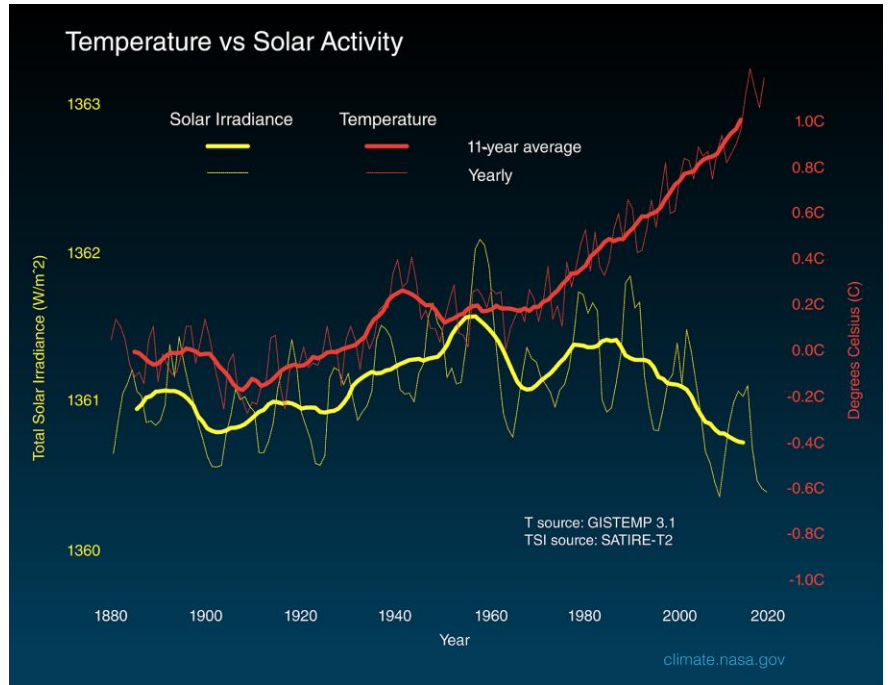
Climate Change – natural causes

- fluctuations in solar radiation, orbital changes
- distribution of continents and oceans, volcanic eruptions, vegetation
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The Sun

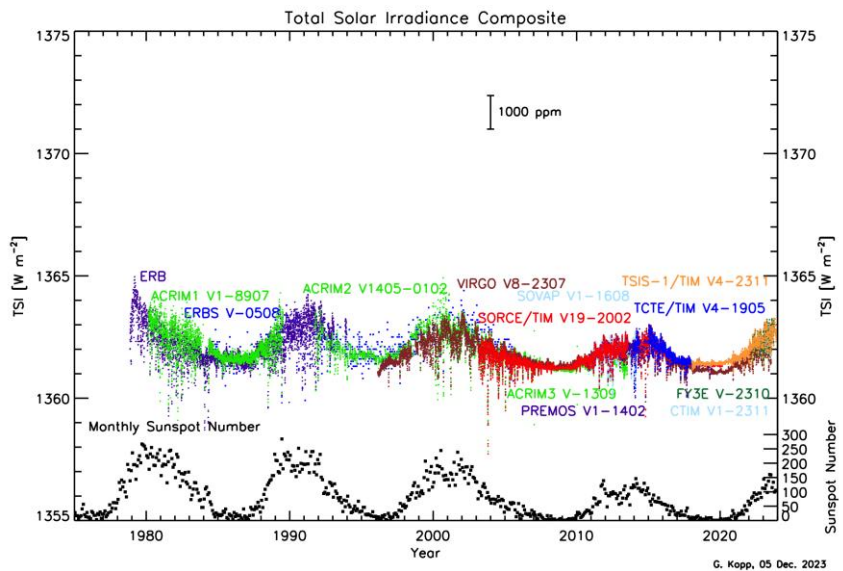


- 73% hydrogen, 25% helium, 2% the other elements
- thermonuclear reactions: $4 \text{ H}(1,1) \rightarrow 1 \text{ He}(4,2) + \text{energy production (solar radiation)}$

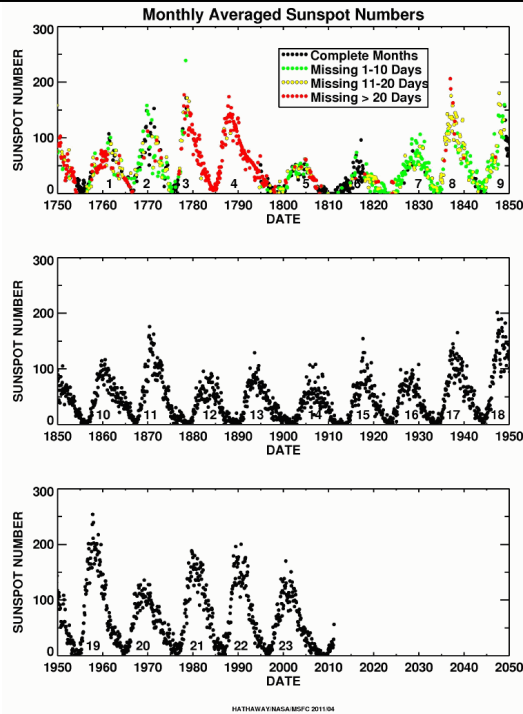


The Sun

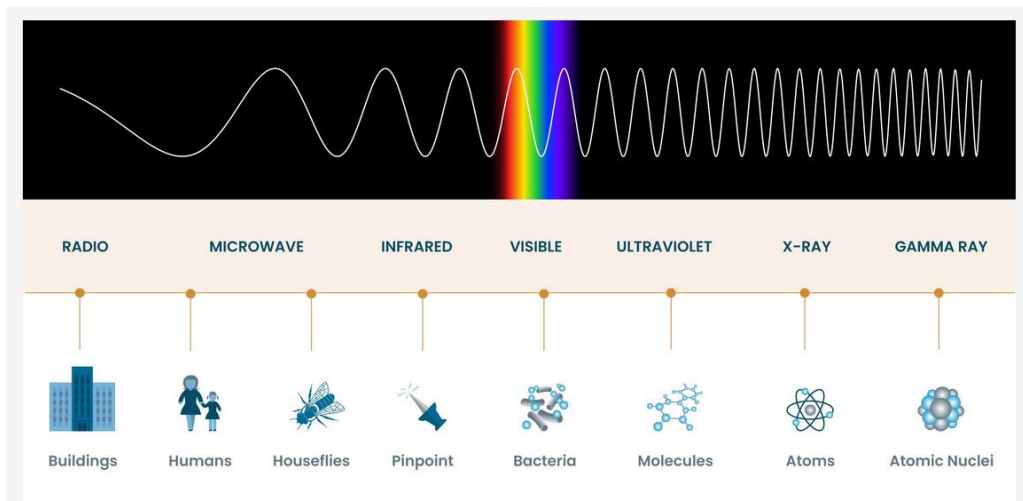
- solar activity – sunspot cycle – **Wolf number** (relative sunspot number)



Wolf number
since 1750

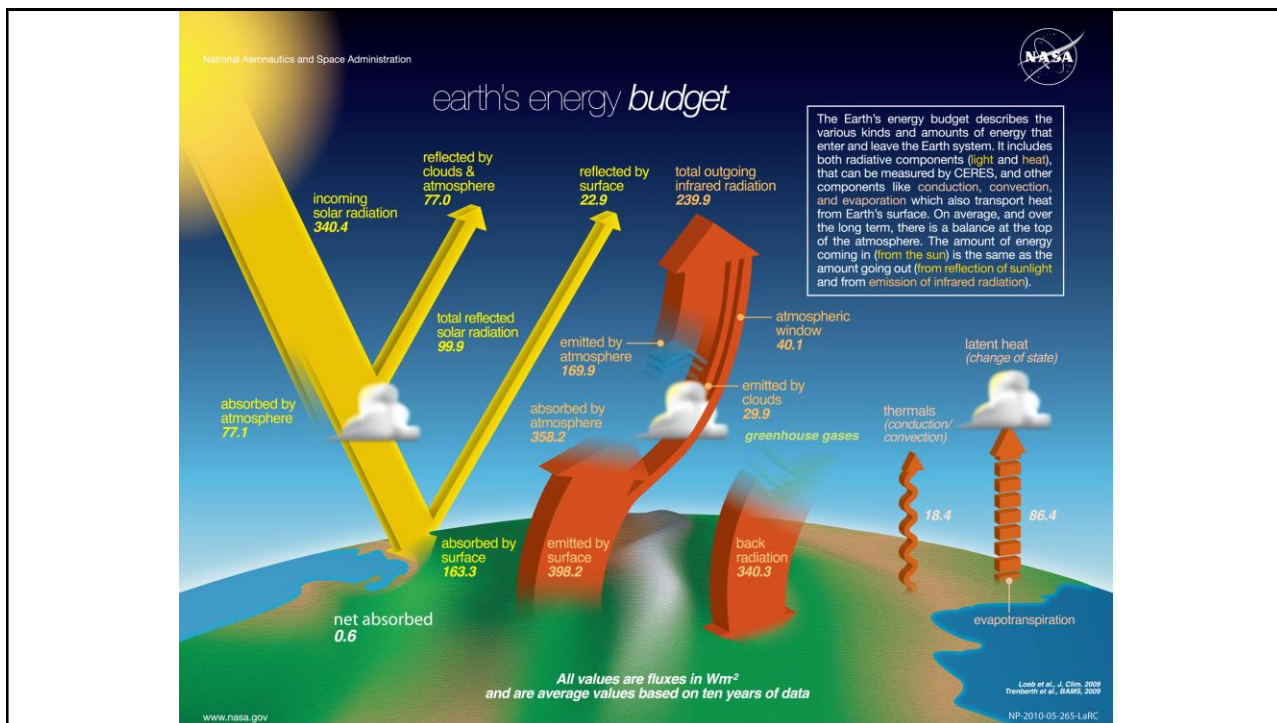
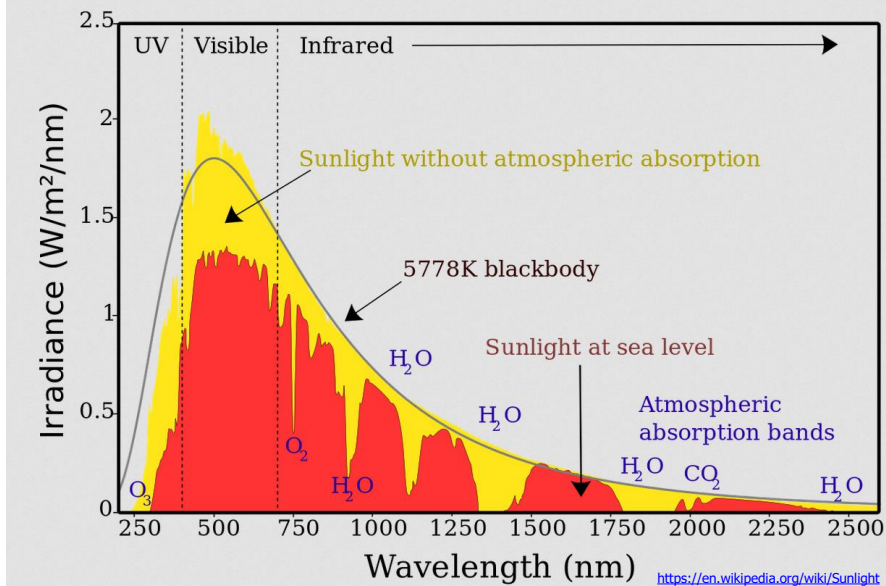


The electromagnetic spectrum



Comparison of different types of light, including wavelength size, and frequency.

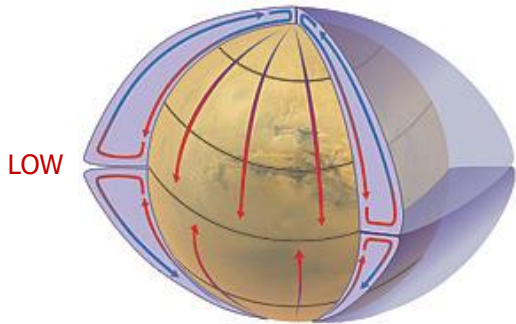
Spectrum of Solar Radiation (Earth)



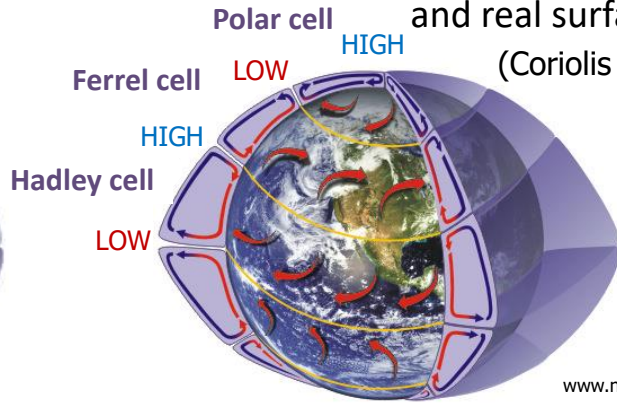
Energy distribution

Global Atmospheric Circulation

Without the Earth's rotation, tilt relative to the sun, and surface water

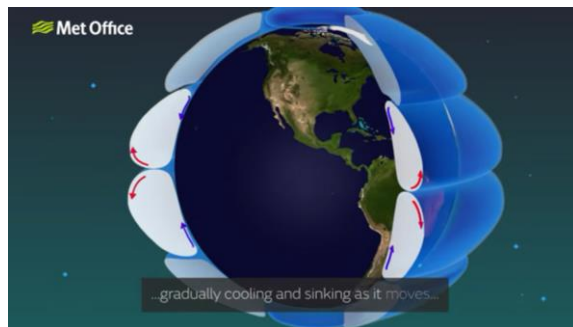


With the Earth's rotation, Earth's tilt and real surface effect (Coriolis effect)



Energy distribution

Global atmospheric circulation

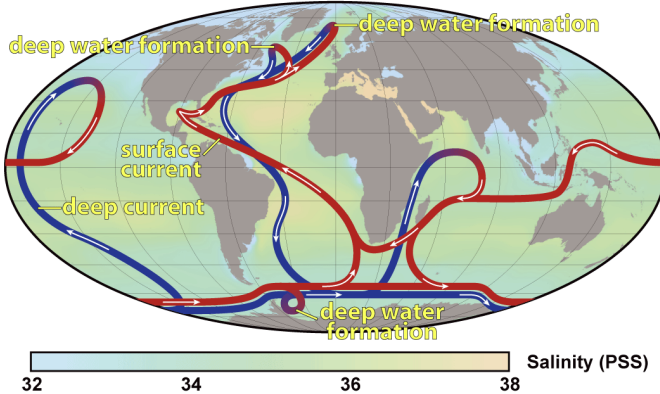


https://www.youtube.com/watch?v=xqM83_og1Fc

Energy distribution

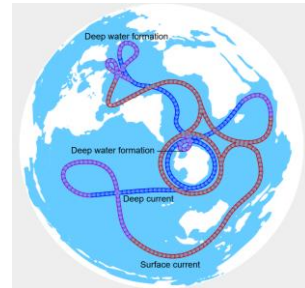
Thermohaline Circulation

- deep-ocean currents are driven by **differences in the water's density**, which is controlled by temperature (*thermo*) and **salinity** (*haline*).



A summary of the path of the thermohaline circulation. Blue paths represent deep-water currents, while red paths represent surface currents.

Animation:



https://upload.wikimedia.org/wikipedia/commons/a/ab/Thermohaline_circulation.svg

Climate Change – natural causes

- **fluctuations in solar radiation, orbital changes**
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The Sun – The Earth

Milankovitch Orbital Cycles

Changes in eccentricity

100.000 years cycles

Changes in obliquity (axial tilt)

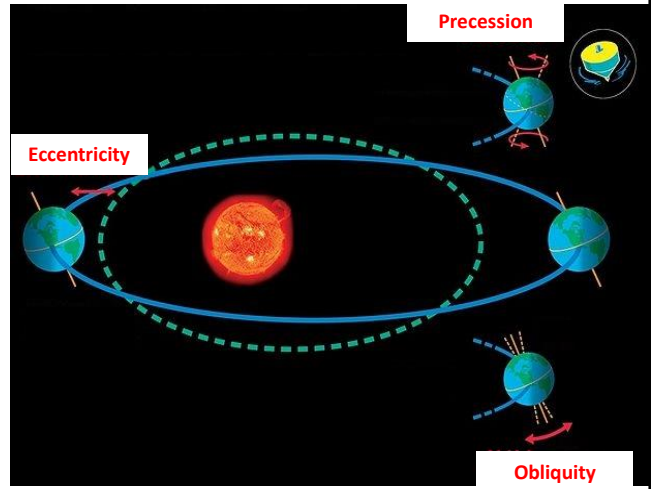
41.000 years cycles

Axial precession

21.000 years cycles

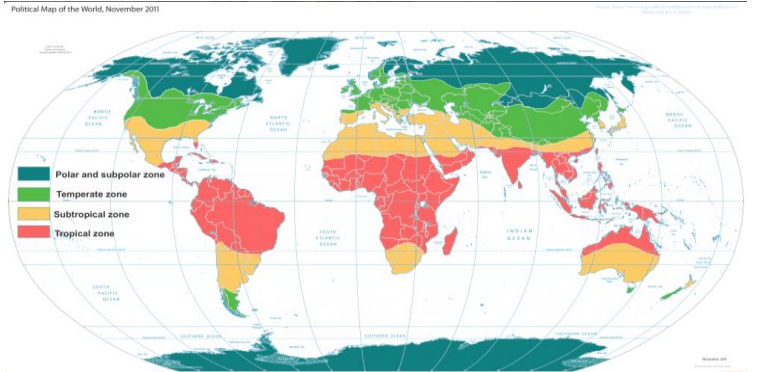
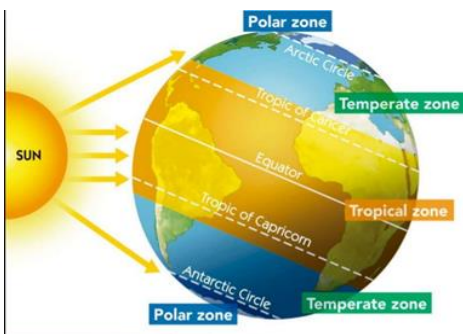
Theory with animations:

<https://climate.nasa.gov/news/2948/milankovitch-orbital-cycles-and-their-role-in-earths-climate/>



Climate Zones

- the areas with distinct climates
- east-west direction around the Earth



The consequence of the:

- orbit around the Sun
- angle of inclination of Earth's axis
- Earth's rotation



Climate Change – natural causes

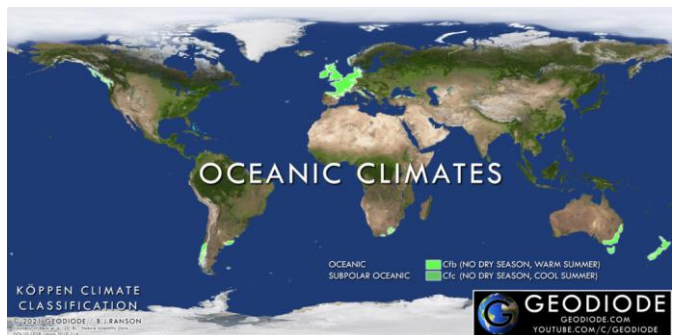
- fluctuations in solar radiation, orbital changes
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Oceanic (maritime) vs. continental climate

Oceanic climate

- can be found along the **west coasts at the middle latitudes** of all continents (NW Europe, the Pacific NW region of the USA and Canada, SE Australia)
- narrower range of annual **temperatures, precipitation** are usually higher and more dispersed throughout the year
- water has much **higher heat capacity** than soil and rock, it gain and lose heat slowly

Areas of the world with an oceanic climate (according to the Köppen climate classification)

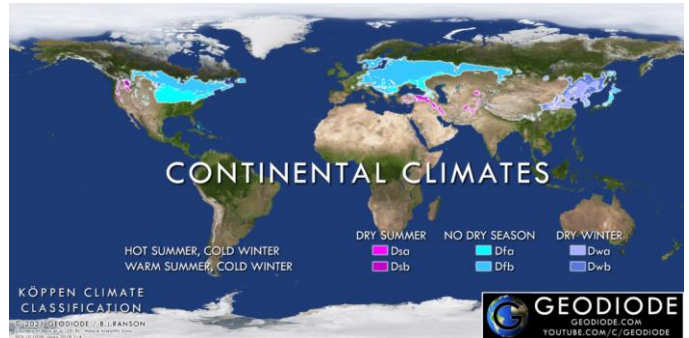


<https://geodiode.com/climate/continental/>

Oceanic (maritime) vs. continental climate

Continental Climate

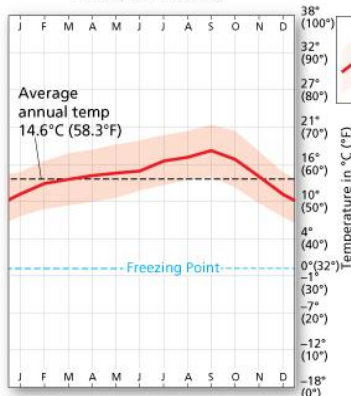
- usually found **in the interiors of continents** and are far away from the influence of the ocean or large water surfaces (Siberia and central Russia, much of North America)
- is often found to be relatively **dry** with **greater temperature variations** than oceanic climates (more extreme climate: hot summers, cold winters)



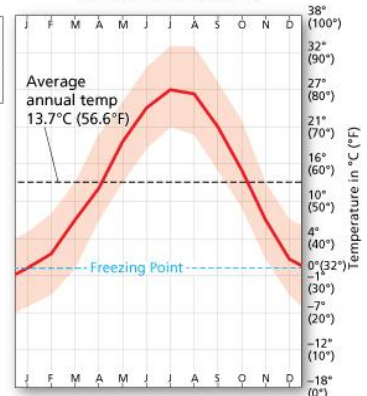
Areas of the world with an oceanic climate (according to the Köppen climate classification) <https://geodiode.com/climate/continental/>

Oceanic (maritime) vs. continental climate

MARINE CLIMATE: San Francisco, California
 Lat/long: 37° 46' N 122° 23' W
 Elevation: 5 m (16.4 ft)



CONTINENTAL CLIMATE: Wichita, Kansas
 Lat/long: 37° 39' N 97° 25' W
 Elevation: 402.6 m (1,321 ft)



Oceanic (maritime) climate in northwestern and northern Europe

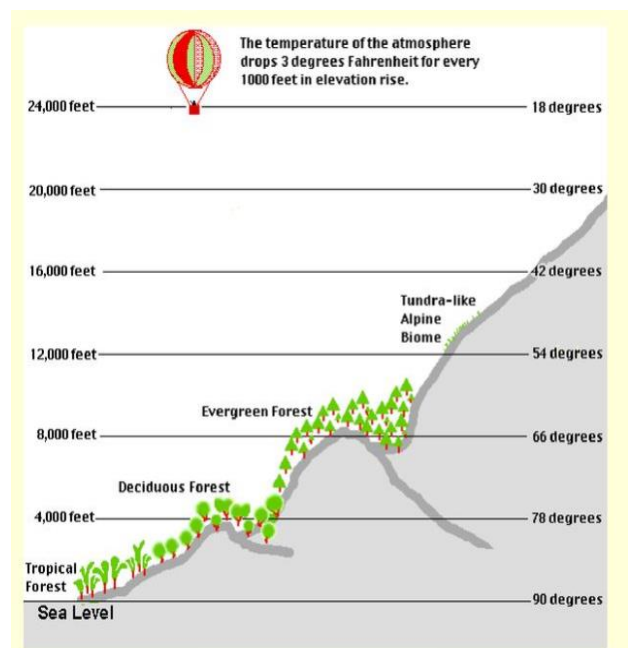


SOURCE: National Oceanic and Atmospheric Administration STAFF GRAPHIC | JAKE LAWS

- strong ocean current that brings **warm water** from the Gulf of America into the Atlantic Ocean (NW and N Europe)
- this keeps **the climate warmer and milder** (the climate in Britain is warmer than other places at a similar latitude)

Highland Climate

- the climate is influenced by the **elevation**
- high insolation, low temperature, low air pressure, large diurnal ranges of temperature, larger amount of precipitation
- the Alps, the Himalayas, the Tibetan Plateau, the Rockies, the Andes

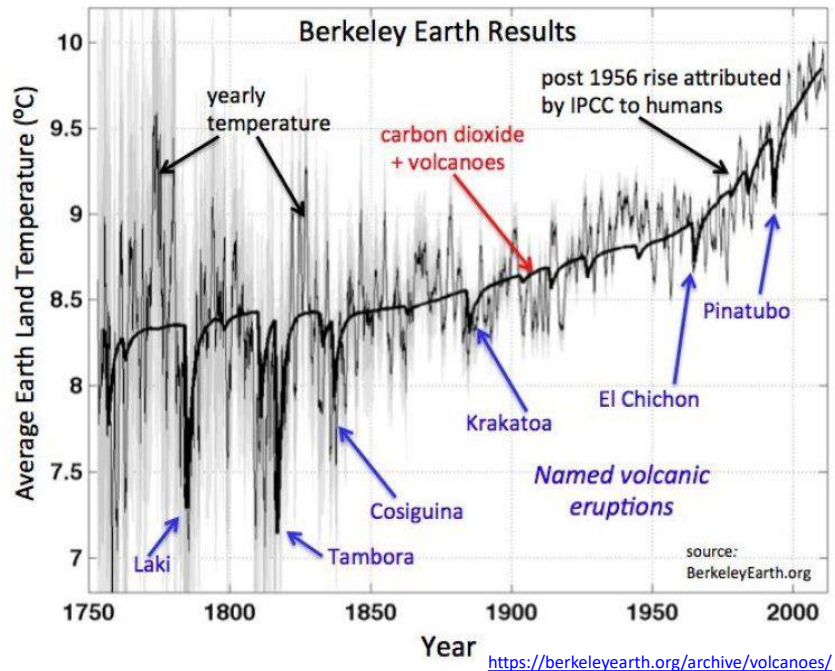


Vegetation altitude zones

Volcanic eruptions

Large volcanic eruptions

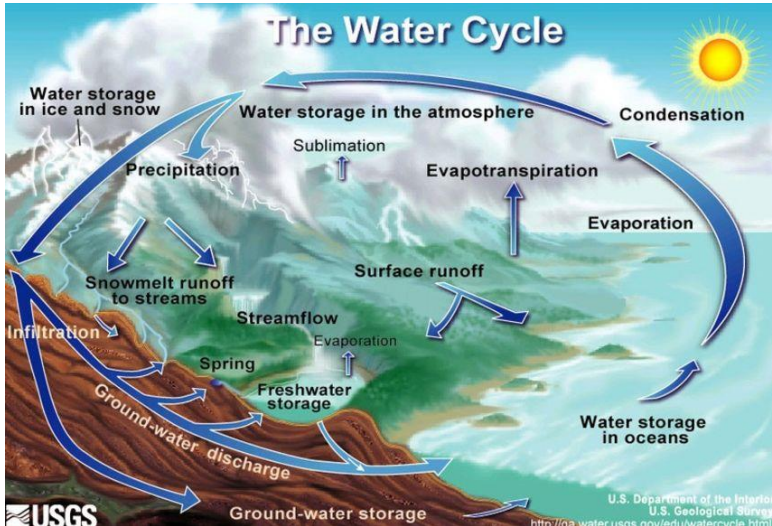
- release of emissions (particles) into the stratosphere where they form a layer
- particles reflect the sunlight and cool the Earth's surface for a few years



Climate Change – natural causes

- fluctuations in solar radiation, orbital changes
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- **atmosphere and ocean relationship**
- changes in the composition of the Earth's atmosphere

The Water Cycle



- continuous movement of moisture/water between the atmosphere and the ocean

The most important processes are:

- **evaporation**
- **transpiration**
- **condensation**
- **precipitation**
- **runoff**

<https://education.nationalgeographic.org/resource/800px-water-cycle/>

https://www.usgs.gov/special-topic/water-science-school/science/water-cycle?qt-science_center_objects=0#qt-science_center_objects

The Water Cycle

Evaporation

- change of water from a liquid to gas
- energy is required

Transpiration

- evaporation of water from plants through stomata
- plant prevents overheating

Condensation

- water vapour is changed into a liquid state
- formation of clouds and fog
- heat energy is released

Precipitation

- the water released from clouds in the form of rain, freezing rain, sleet, snow, or hail
- primary source of fresh water on Earth

Runoff

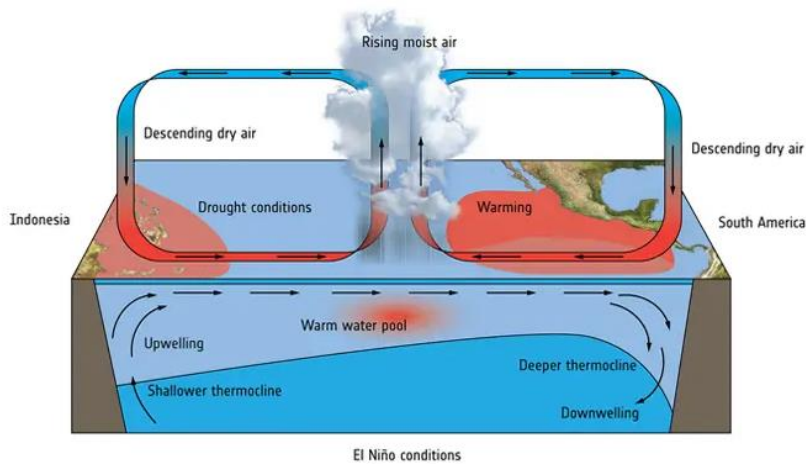
- intense precipitation and the ground is saturated
- the results are rivers and lakes



Evaporation, percolation, transpiration ...are happening again

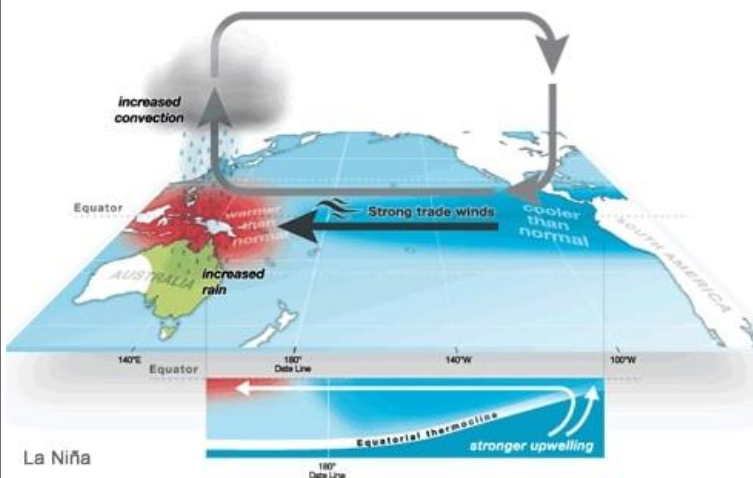
ENSO - El Niño-Southern Oscillation

El Niño conditions



ENSO - El Niño-Southern Oscillation

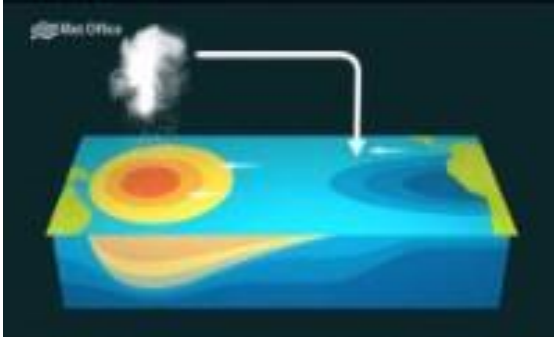
La Niña conditions



Remember:

- **El Niño:** the warming phase of the waters in the eastern Pacific, off the coast of South America
- **La Niña:** the cooling phase...

ENSO - El Niño-Southern Oscillation



<https://www.youtube.com/watch?v=WPA-KpldDVc>

El Niño:

- main weather impacts: heatwaves, floods, and droughts in the tropics, but also outside the tropics
- some of the effects worldwide:
 - floods - Peru
 - droughts - India, Indonesia, and Brazil

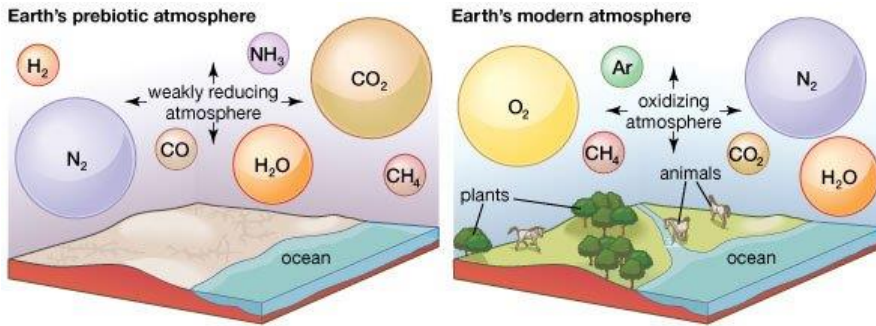
<https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml>

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Changes in the composition of the Earth's atmosphere

Evolution of the atmosphere



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<https://www.britannica.com/topic/evolution-of-the-atmosphere-1703862>



https://www.youtube.com/watch?v=I0h_-3M0Pso

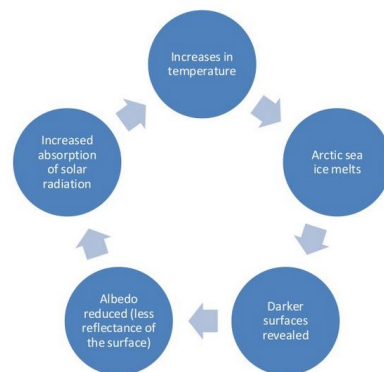
Climate feedbacks

- the response to the climate process that either intensifies or minimizes the initial effect of a climate forcing

+ Positive climate feedback =
increasing effect of climatic factors
(more imbalance in the system)

- Negative climate feedback =
reducing effect of climatic factor
(more stable state)

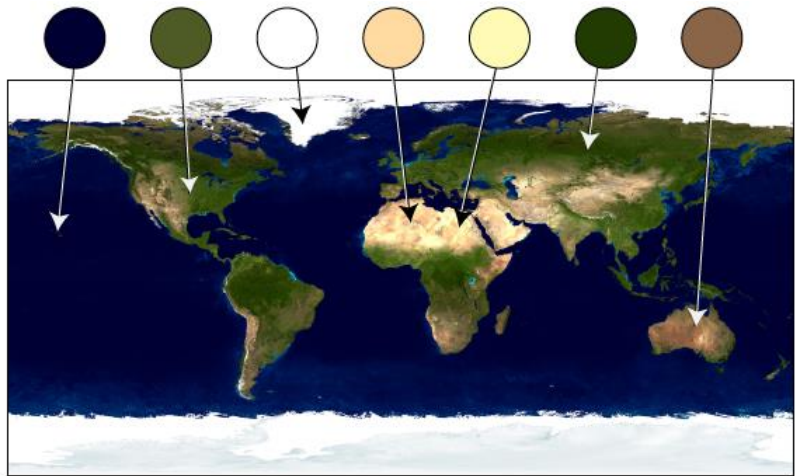
+ Ice-Albedo Feedback



Albedo

- the amount of solar radiation reflected by a surface (% or decimal value)

1.0 (100%) – perfect reflection
 0.0 – total absorption

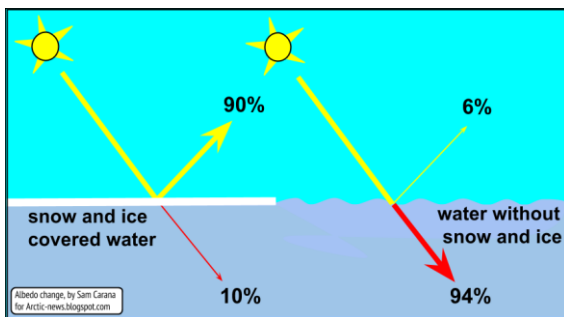


A sampling of Earth's colors Credit: UCAR SciEd with NASA image <https://scied.ucar.edu>

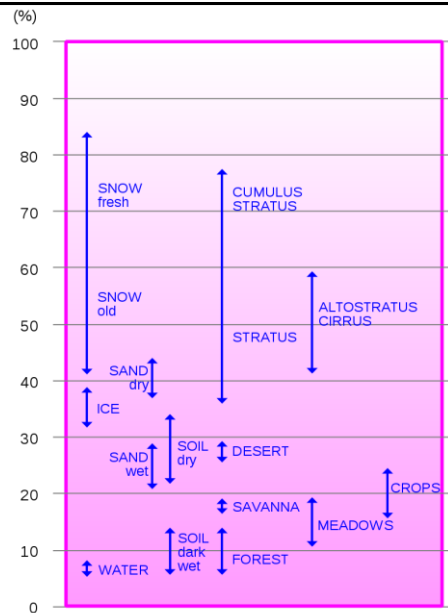
Albedo

White objects (e.g. fresh snow) – high albedo

Dark objects (e.g. dark soil, ocean) – low albedo



Earth's planetary albedo is about 31%.



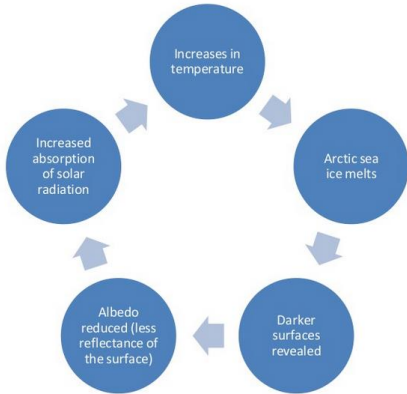
The percentage of reflected solar radiation relative to various surface conditions

Climate feedbacks

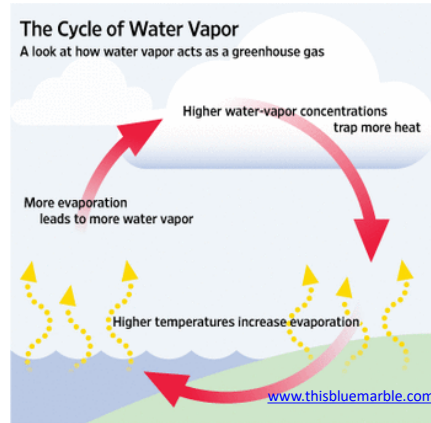
+ **Positive climate feedback** = increasing effect of climatic factors

- **Negative climate feedback** = reducing effect of climatic factors

+ Ice-Albedo Feedback



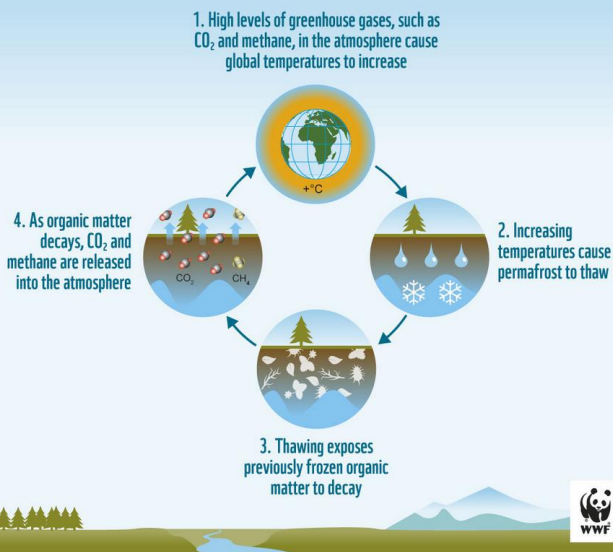
+ Water Vapour Release



Climate feedbacks

+ Carbon Release

Permafrost thawing can intensify global warming



<https://www.arcticwwf.org/newsroom/features/putting-a-lid-on-methane-emissions-before-its-too-late/>

Climate feedbacks

- Evaporation and Clouds

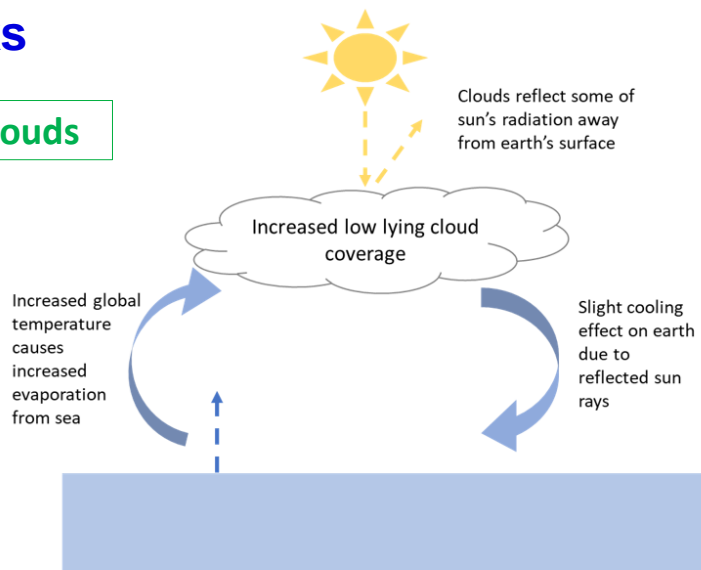


Figure 3 – Diagram showing an example of negative feedback.

<https://actionrenewables.co.uk/news/what-are-climate-feedbacks/>

References

- Hess, D. (2014): McKnight's physical geography: a landscape appreciation. 11th ed. Harlow: Pearson. Pearson new international edition. ISBN 978-1-292-02091-4
- <http://www....>