MUNI
SCI

01 Climate system

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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 it the troposphere

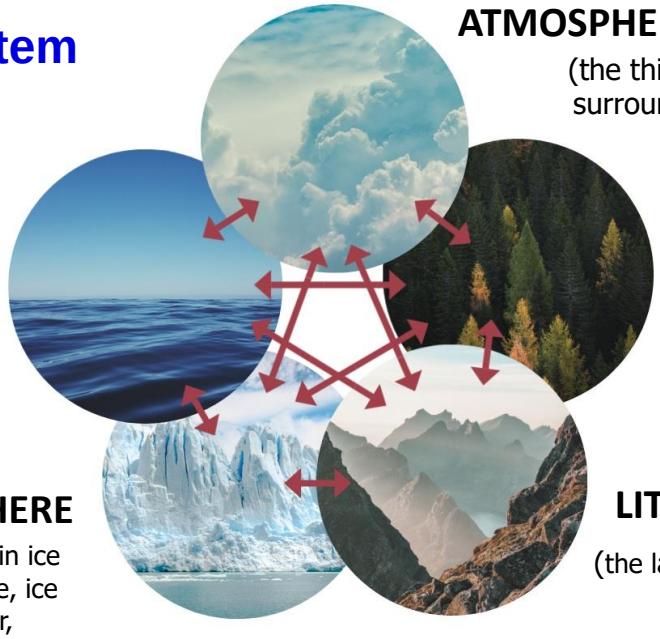
Climate

- 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



ATMOSPHERE

(the thin layer of gases surrounding the Earth)

HYDROSPHERE

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

BIOSPHERE

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

CRYOSPHERE

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

LITHOSPHERE

(the land surfaces such as soil and rocks)

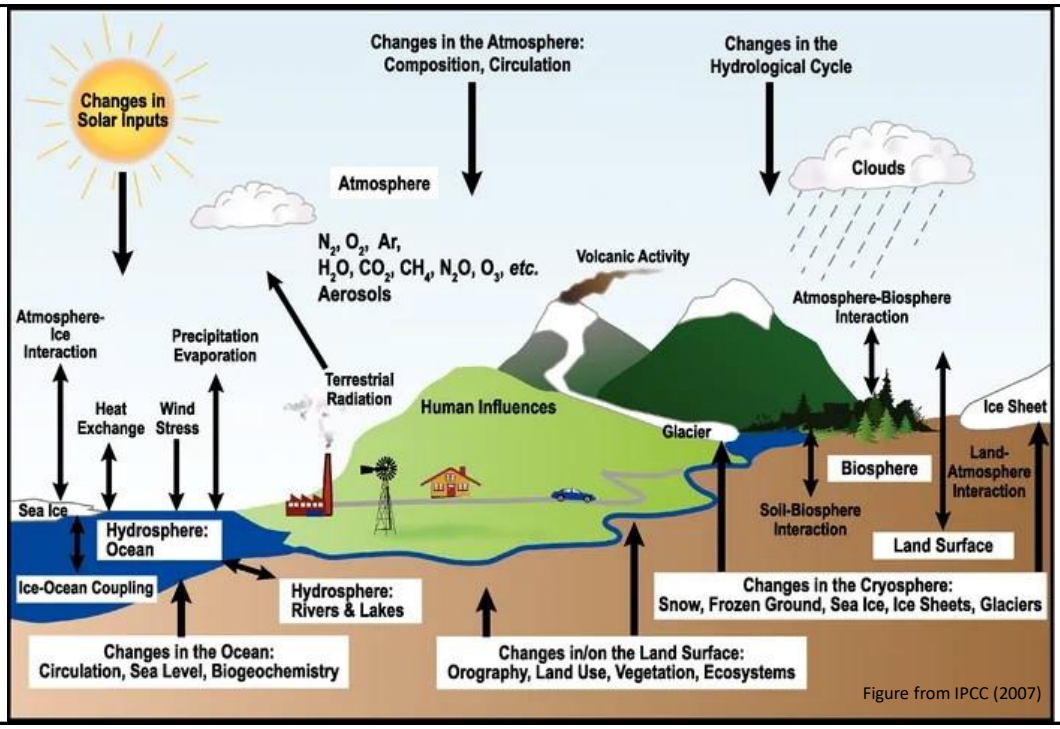


Figure from IPCC (2007)

Climate Change – natural causes

- fluctuations in solar radiation, orbital changes
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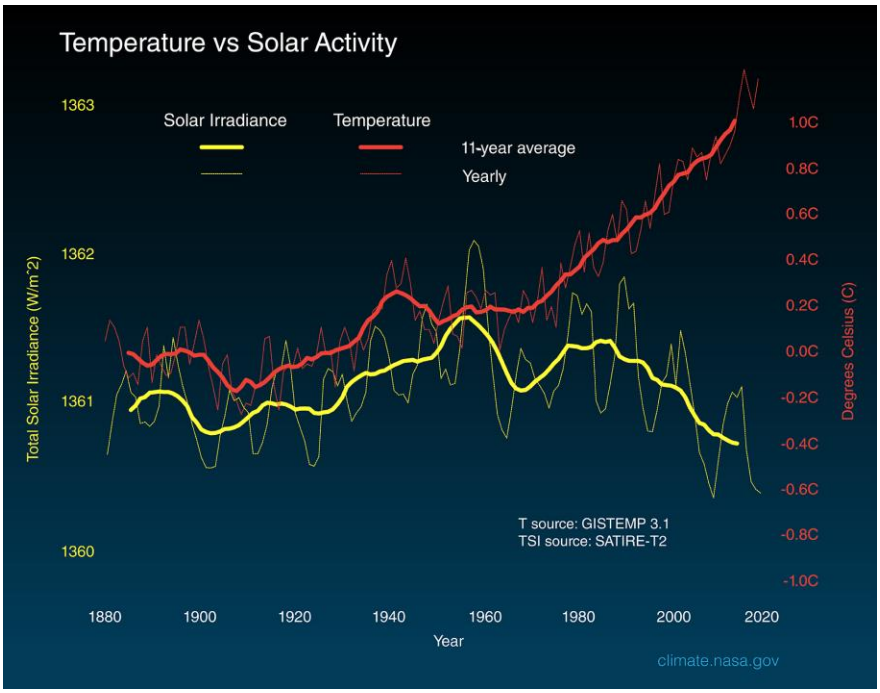
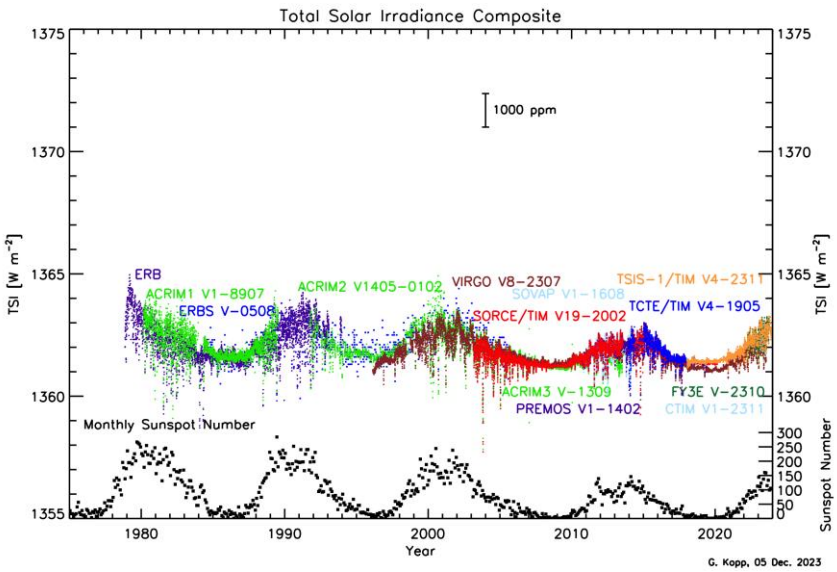
The Sun

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

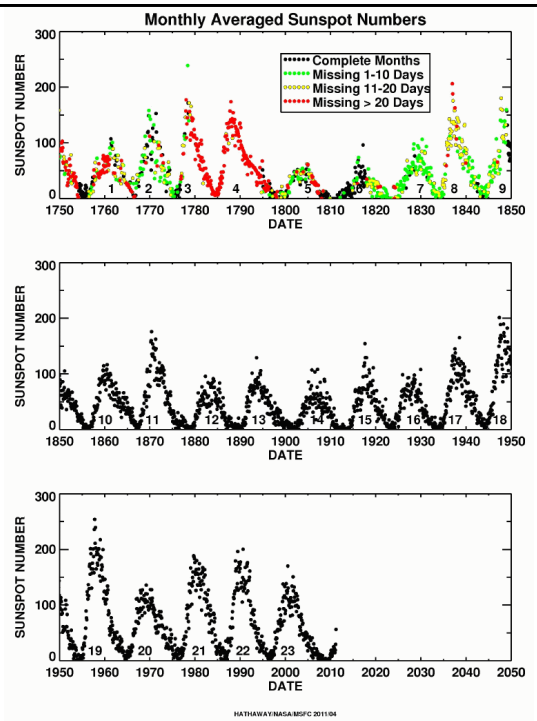


The Sun

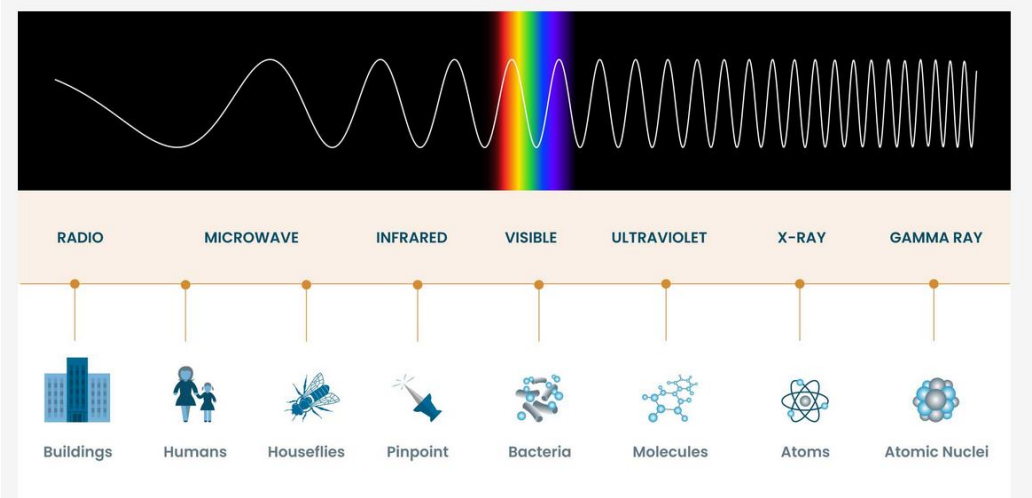
- solar activity – sunspot cycle – **Wolf number** (relative sunspot number)



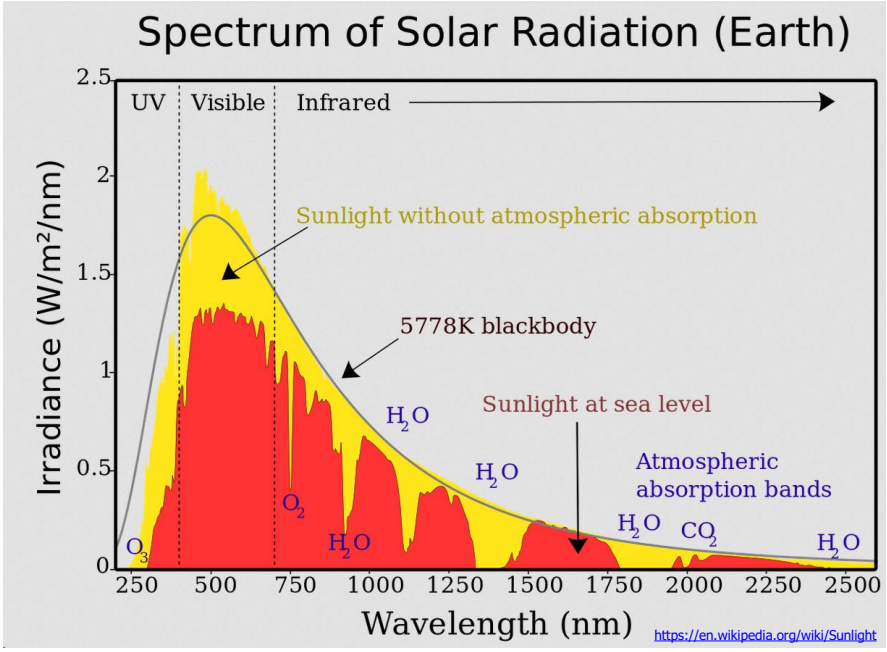
Wolf number since 1750

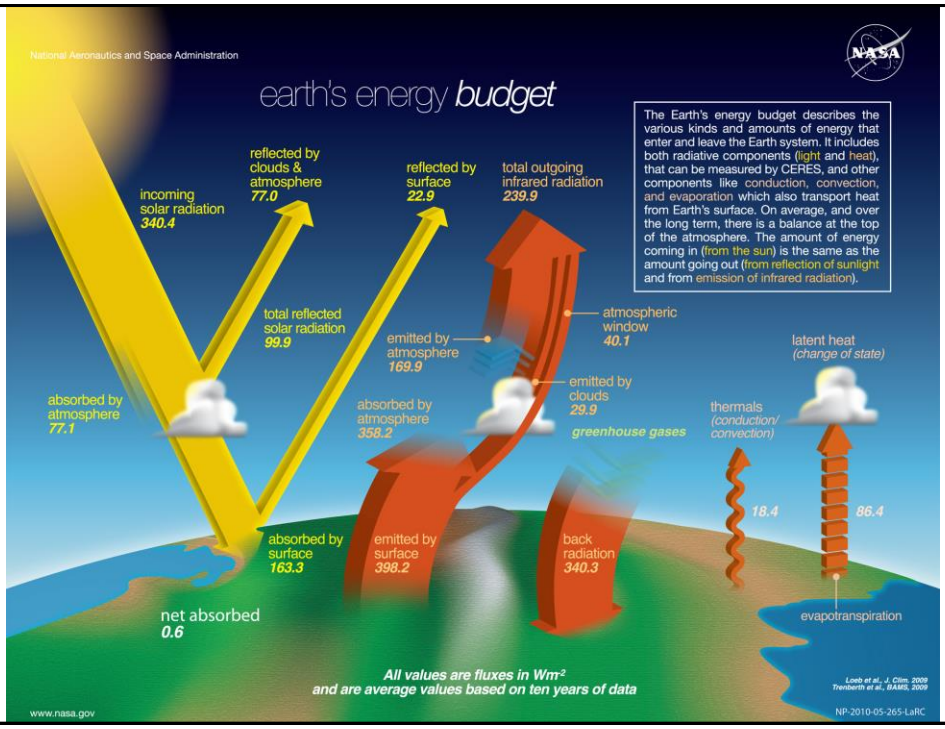


The electromagnetic spektrum



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

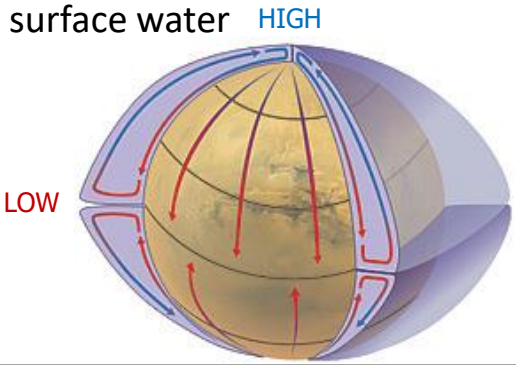

Spectrum of Solar Radiation (Earth)
UV
Visible
Infrared
Sunlight without atmospheric absorption
5778K blackbody
Sunlight at sea level
Atmospheric absorption bands
H_2O
O_2
O_3
CO_2
Irradiance (W/m²/nm)
Wavelength (nm)
2.5
2
1.5
1
0.5
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
https://en.wikipedia.org/wiki/Sunlight


National Aeronautics and Space Administration
NASA
earth's energy budget
The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (light and heat), that can be measured by CERES, and other components like conduction, convection, and evaporation which also transport heat from Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (from the sun) is the same as the amount going out (from reflection of sunlight and from emission of infrared radiation).
incoming solar radiation 340.4
reflected by clouds & atmosphere 77.0
reflected by surface 22.9
total outgoing infrared radiation 239.9
total reflected solar radiation 99.9
atmospheric window 40.1
emitted by atmosphere 169.9
emitted by clouds 29.9
greenhouse gases
absorbed by atmosphere 77.1
absorbed by atmosphere 358.2
latent heat (change of state)
thermals (conduction/ convection)
18.4
86.4
absorbed by surface 163.3
emitted by surface 398.2
back radiation 340.3
net absorbed 0.6
evapotranspiration
All values are fluxes in Wm-2 and are average values based on ten years of data
Loeb et al., J. Clim. 2009
Trenberth et al., BAMS, 2009
www.nasa.gov
NP-2010-05-265-LaRC

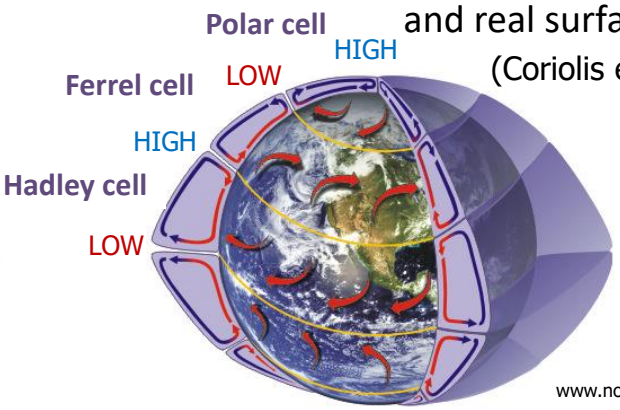
Energy distribution

Global Atmospheric Circulation

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



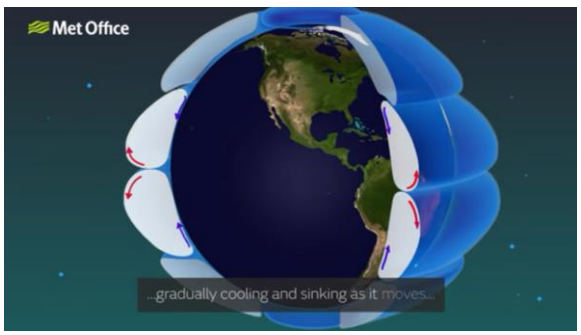
With the Earth's rotation, Earth's tilt and real surface (Coriolis effect)



www.noaa.gov

Energy distribution

Global atmospheric circulation

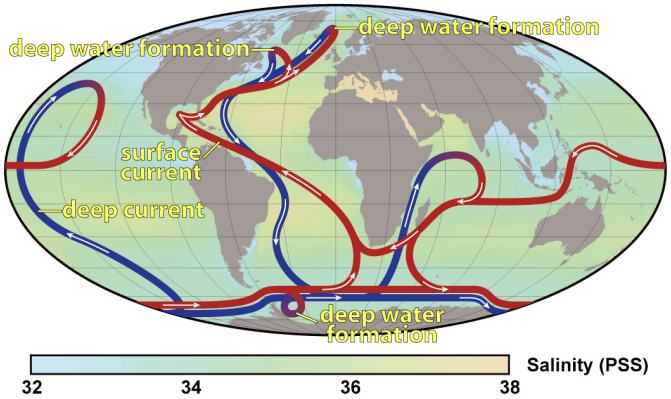


https://www.youtube.com/watch?v=xqM83_og1Fc

Energy distribution

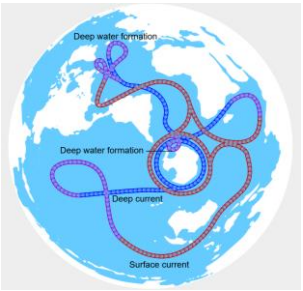
Thermohaline Circulation

- 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, <u>orbital changes</u>**
- distribution of continents and oceans, volcanic eruptions, vegetation
- atmosphere and ocean relationship
- changes in the composition of the Earth's atmosphere

The Sun – The Earth

Milankovitch Orbital Cycles

Theory with animations:

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

Changes in eccentricity

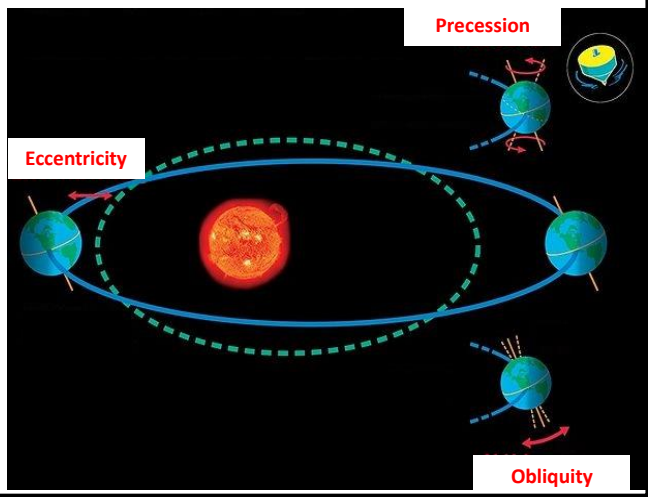
100.000 years cycles

Changes in obliquity (axial tilt)

41.000 years cycles

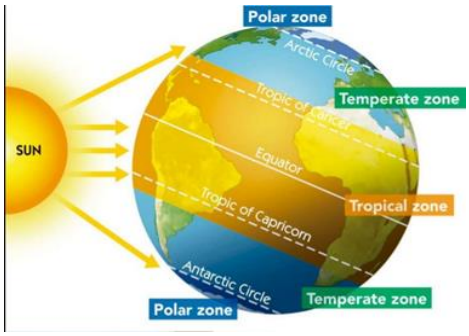
Axial precession

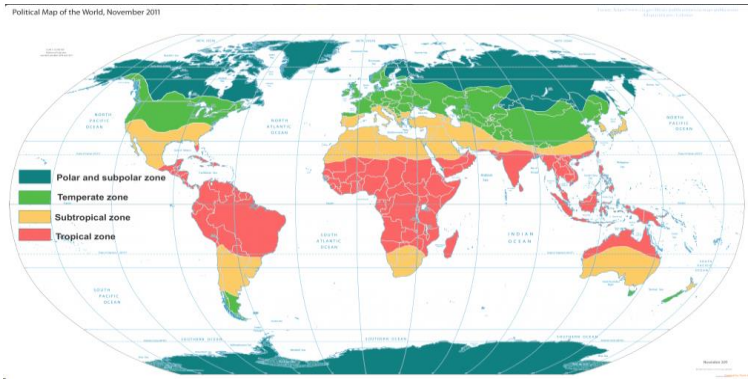
21.000 years cycles



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

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Oceanic (maritime) vs. continental climate

Continental Climate

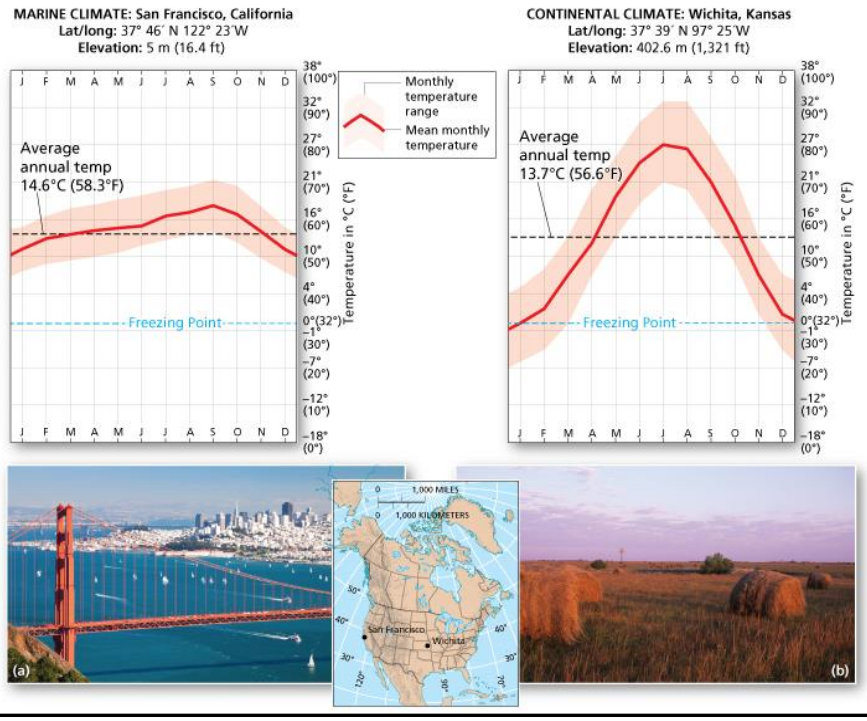
- Such regions are usually found in the interiors of continents and are far away from the influence of the ocean or large water surfaces
- as soil and rock have a much lower heat capacity than water, they gain and lose heat quickly.
- Continental climates are often found to be relatively dry and most of the water carried by air masses originating from ocean regions far away is lost as rainfall early in the journey.
- Regions of the Earth that: Siberia and central Russia, and much of North America.

Oceanic (maritime) vs. continental climate

Oceanic climate

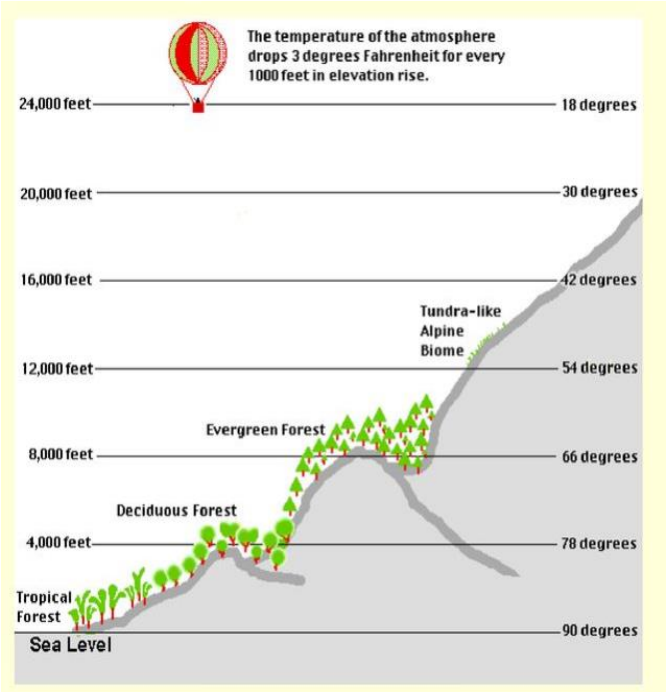
- found along the west coasts at the middle latitudes of all continents (NW Europe, the Pacific NW region of the USA and Canada, SE Australia
- narrower range of annual temperatures, precipitations are more dispersed throughout the year

Maritime (oceanic) vs. continental climate



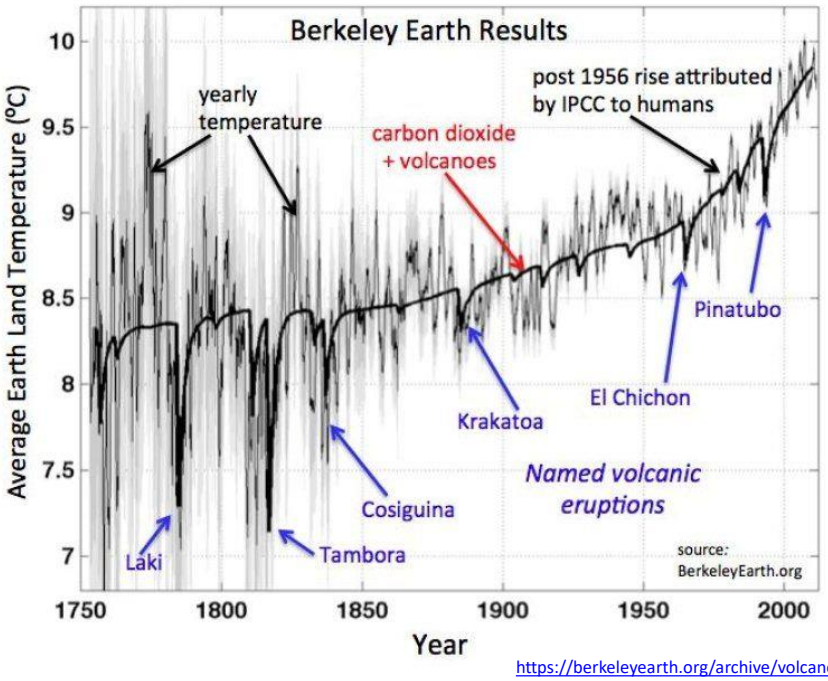
Maritime climate in northwestern and nothern Europe

Highland Climate



Vegetation altitude zones

Volcanic eruptions



https://berkeleyearth.org/archive/volcanoes/

Climate Change – natural causes

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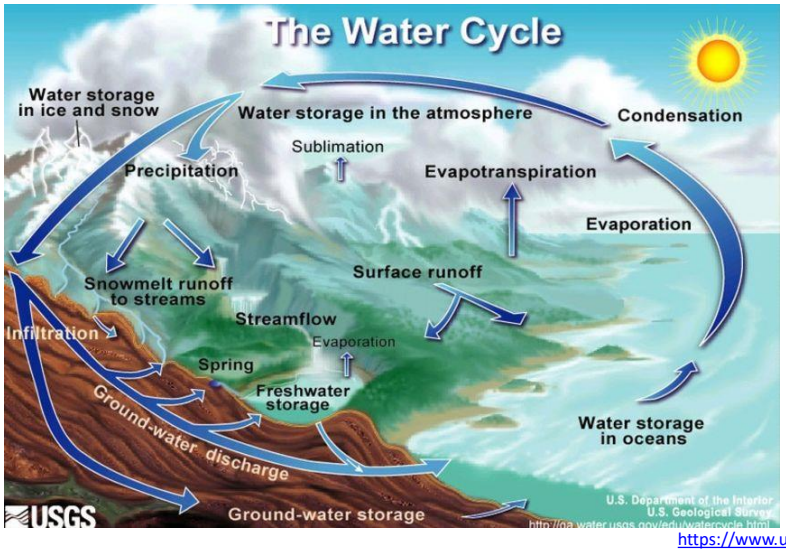
- **atmosphere and ocean relationship**
- changes in the composition of the Earth's atmosphere

The Water Cycle



The most important 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

Climate Change – natural causes

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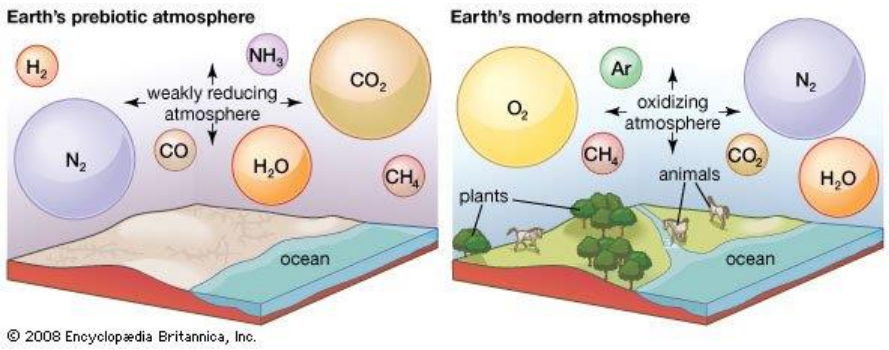
- atmosphere and ocean relationship
- **changes in the composition of the Earth's atmosphere**

Changes in the composition of the Earth's atmosphere

Evolution of the atmosphere



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

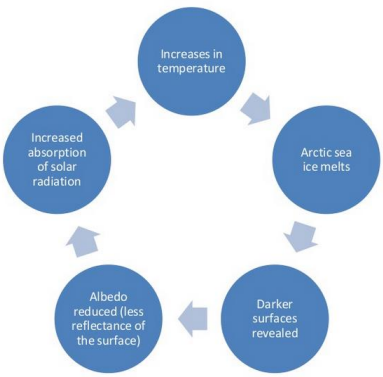
https://www.youtube.com/watch?v=l0h_-3M0Pso

Climate feedbacks

+ Positive climate feedback = increasing effect of climatic factors

- Negative climate feedback = reducing effect of climatic factors

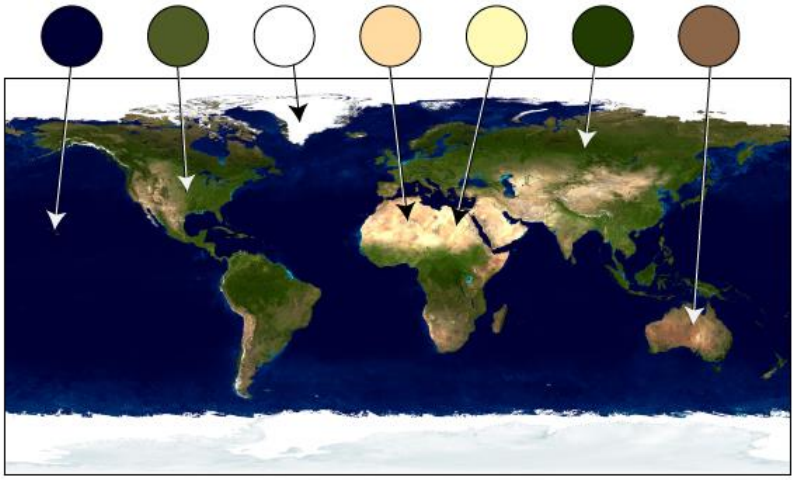
+ Ice-Albedo Feedback



Albedo

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

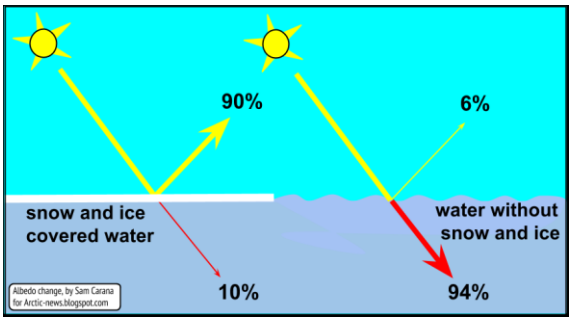
A sampling of Earth's colors
Credit: UCAR SciEd with NASA image
https://scied.ucar.edu



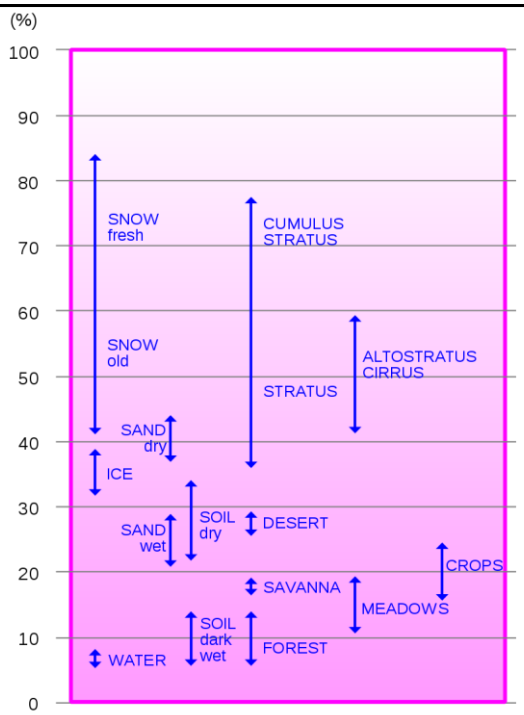
Albedo

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

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



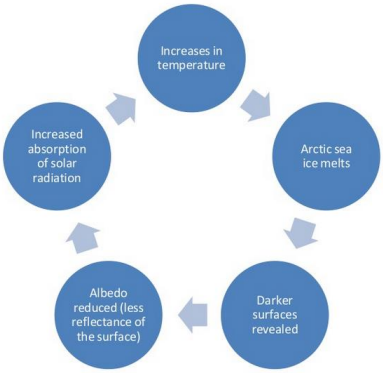
The percentage of reflected solar radiation relative to various surface conditions



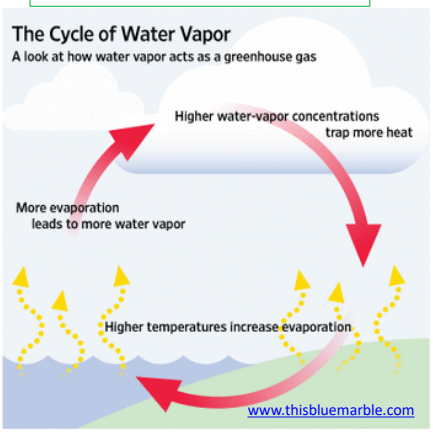
Climate feedbacks

+ Positive climate feedback = increasing effect of climatic factors
- Negative climate feedback = reducing effect of climatic factors

+ Ice-Albedo Feedback

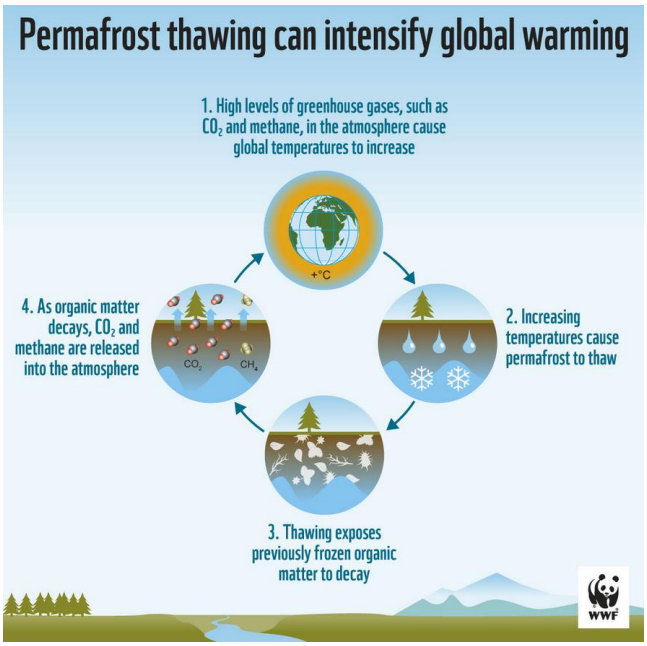


+ Water Vapour Release



Climate feedbacks

+ Carbon Release



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

Climate feedbacks

- Evaporation and Clouds

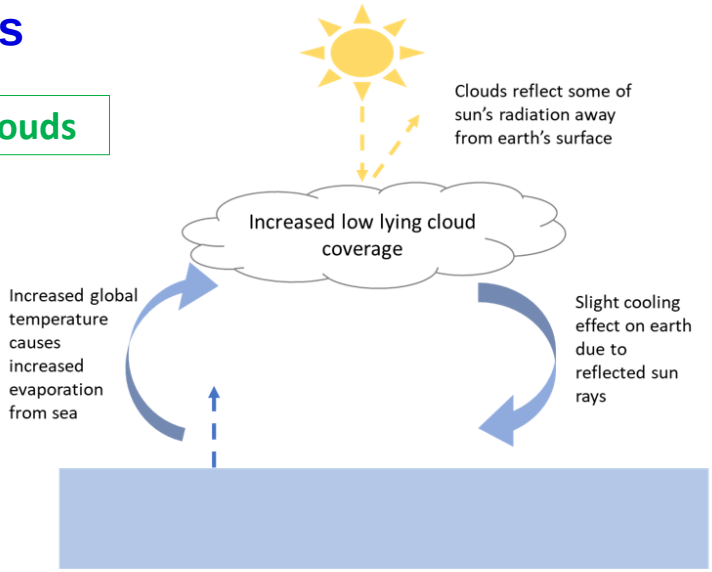


Figure 3 – *Diagram showing an example of negative feedback.*

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

Thank you for your attention

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….