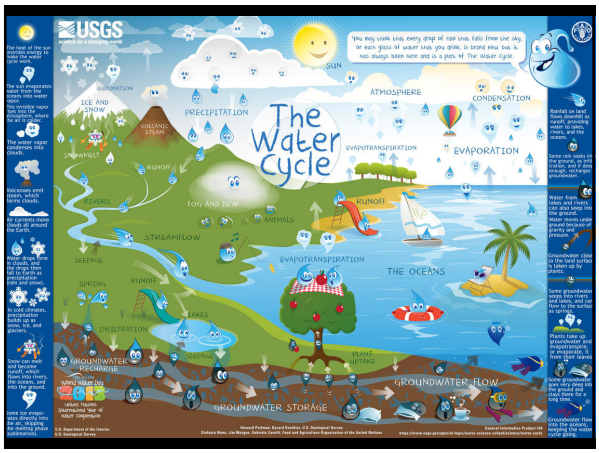
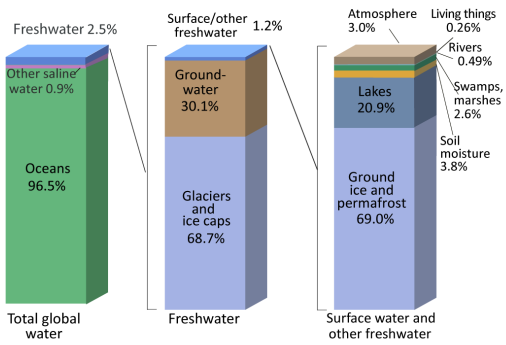
Thunderstorm – Kuster & Widhaber Photography (CC BY-ND 2.0)
Blizzard – Click Kodak (CC BY-NC-ND 2.0)
A Sunny Day Like This! – Iwt93 (CC BY 2.0)
Clouds – Edward stojakovic (CC BY 2.0)

Background Information

Clouds – Pattys photos (CC BY 2.0)
Glacier (Mt. Kilimanjaro) – Kevin Armstrong (CC BY-NC-ND 2.0)
Ocean – Wendy Harman (CC BY 2.0)
River – John Blower (CC BY-NC-ND 2.0)



Where is Earth's Water?

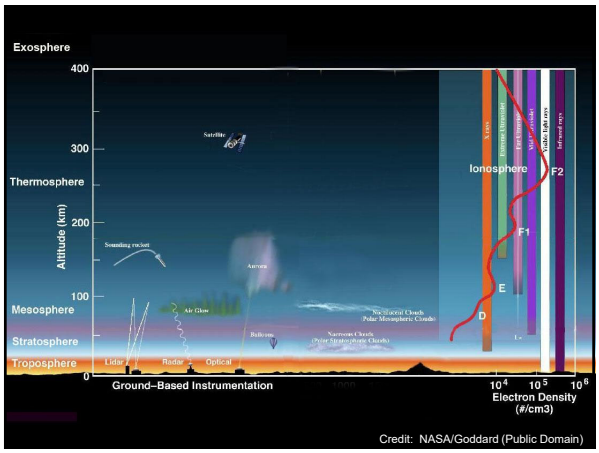


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

Atmosphere

- Layer of gases surrounding the earth
  - 78% nitrogen, 21% oxygen, 1% other gases
  - No definite boundary between atmosphere and outer space

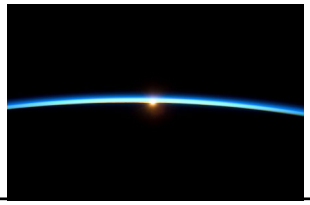
Top of Atmosphere – NASA Earth Observatory (Public Domain)



Credit: NASA/Goddard (Public Domain)

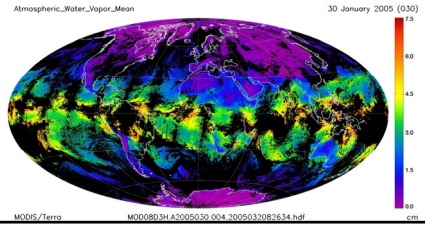
Troposphere

- Starts at the Earth's surface and extends 8 to 14.5 km high
- Most dense part of the atmosphere
  - Thickest at the equator and thinnest at the poles



Credit: NASA (Public Domain)

- Temperatures decrease with altitude
- Most of the water vapor in the atmosphere, along with dust and ash particles, are found here
  - Most clouds are in this layer
  - Almost all weather occurs in this layer



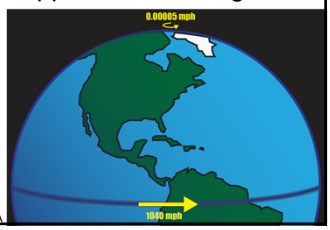
Credit: NASA/MODIS (Public Domain)

Stratosphere

- Starts just above the troposphere and extends to 50 kilometers high
- Temperatures increase with altitude
- A high concentration of ozone, a molecule composed of three atoms of oxygen, makes up the ozone layer of the stratosphere
  - Ozone absorbs some of the incoming solar radiation, shielding life on Earth from potentially harmful ultraviolet (UV)light, and is responsible for the temperature increase in altitude.

Coriolis Effect

- The Coriolis Effect makes things (like planes or currents of air) traveling long distances around the Earth appear to move at a curve as opposed to a straight line.
- This occurs because different parts of the Earth move at different speeds.

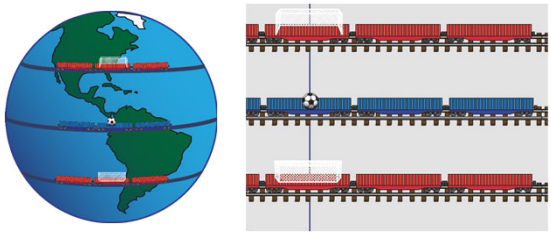


Credit: NOAA

https://youtu.be/mPsLanVS1Q8

https://youtu.be/dt_XJp77-mk

- The path appears to bend to the right in the Northern Hemisphere.



- The path appears to bend to the left in the Southern Hemisphere.

Images Credit: NOAA

Heat Transfer

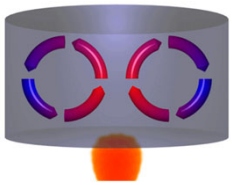
- Conduction
  - Molecules colliding with each other transferring energy
- Convection
  - Heat flows by the mass movement of molecules from one place to another
- Radiation
  - Heat transfer that occurs without any medium

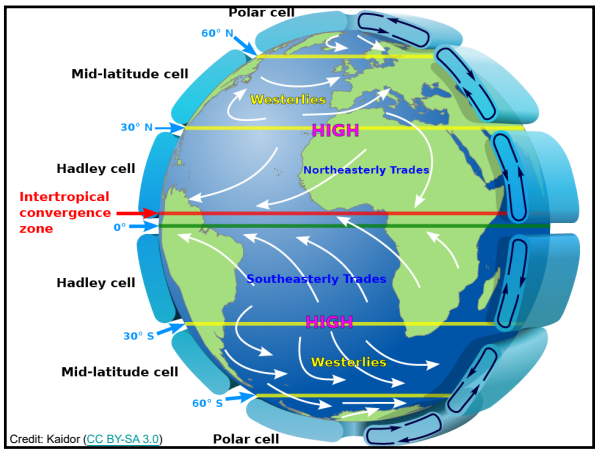
Phenomena that Contribute to Weather

Atmospheric Convection

- Convection drives the circulation of air in the earth's atmosphere.
- The sun heats the air near the earth's equator, which becomes less dense and rises upward.
- As it rises, it cools and becomes less dense than the air around it, spreading out and descending toward the equator again.

- These constantly moving cells of warm and cold air, known as Hadley Cells, drive the continual circulation of air at the earth's surface that we call wind.
- Atmospheric convection currents are also what keep clouds aloft.





Prevailing Winds

- Because of the rotation of the earth and the coriolis force, air is deflected to the right in the Northern Hemisphere.
- As a result, the movement of air in the different regions tends to move (blow) in one particular direction
  - In our part of the world it is from the west

Jet Streams

- Jet streams are fast flowing, relatively narrow air currents found in the atmosphere around 10 km above the surface of the Earth.
- They form at the boundaries of adjacent air masses with significant differences in temperature such as the polar region and the warmer air to the south.

- The main jet streams are located near the top of the troposphere and are westerly winds (flowing west to east).

Credit: NASA/Goddard Space Flight Center (Public Domain)

Credit: NASA/JPL

Oceanic Convection

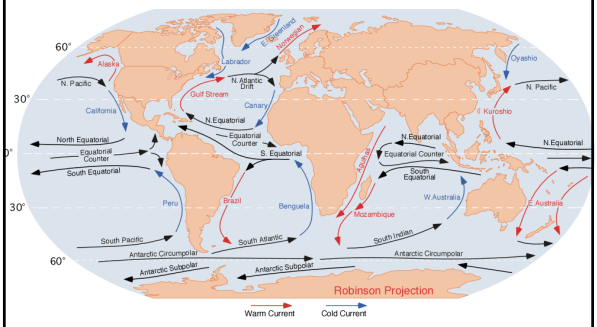
- Convection drives the Gulf Stream and other currents that turn over and mix up the waters in the world's oceans.
- Cold polar water is drawn down from higher latitudes and sinks to the ocean bottom, pulled down toward the equator as lighter, warmer water rises to the ocean's surface.

- The warmer water is pulled northward to replace the cold water that's been pulled southward.
- This process distributes heat and soluble nutrients around the world.

Oceanic Currents

- Describe the movement of water from one location to another
- Driven by three main factors:
  - Rise and fall of tides
  - Wind
  - Thermohaline circulation
    - Process driven by density differences due to temperature and salinity

- Large rotating currents that start near the equator are called subtropical **gyres**
- Currents affect the Earth's climate by driving warm water from the Equator and cold water from the poles around the Earth.



Public Domain

El Niño

- Refers to the extensive warming of the central and eastern Pacific that leads to a major shift in weather patterns across the Pacific
- In North America, temperatures in the winter are warmer than normal in the North and cooler than normal in the South

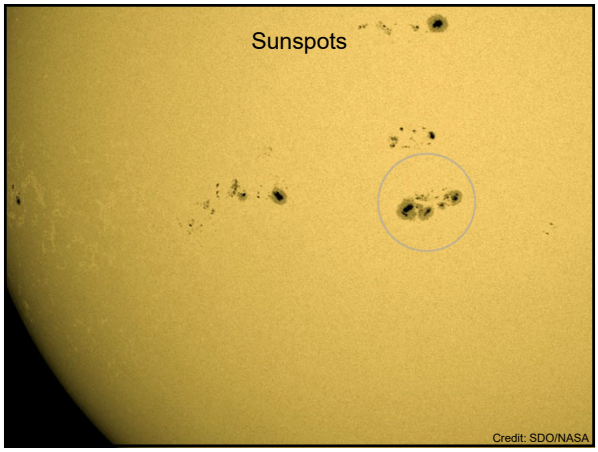
La Niña

- Characterized by unusually cold ocean temperatures in the Equatorial Pacific
- In North America winter temperatures are warmer than normal in the South and cooler than normal in the North

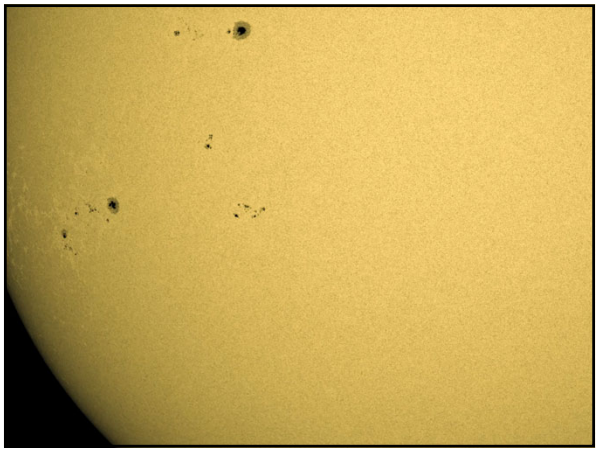
The Sun

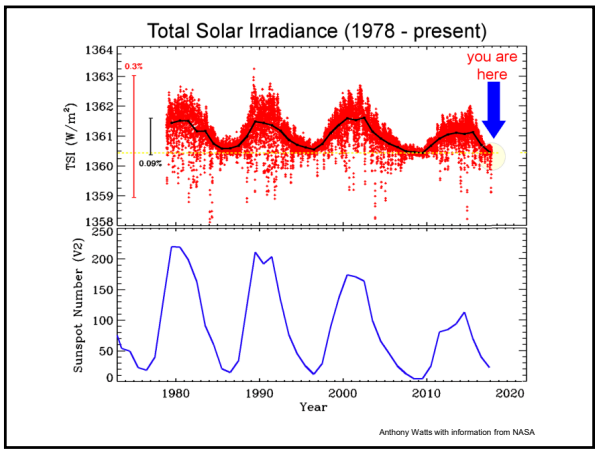
- Energy from the Sun is transferred to Earth
  - The total amount of energy reaching the Earth's atmosphere is referred to as the total solar irradiance (TSI).
  - The TSI varies due to changes in the Sun's magnetic field.
    - These changes correlate with the number of sunspots.

Sunspots



Credit: SDO/NASA





Reflection

- Part of the solar energy that comes to Earth is reflected back out to space
- The percentage of solar energy that is reflected back to space is called the ***albedo***
- Different surfaces have different albedos
  - Deserts have a higher albedo than oceans
- Over the whole surface of the Earth, about 30 percent of incoming solar energy is reflected back to space

Absorption/Emission

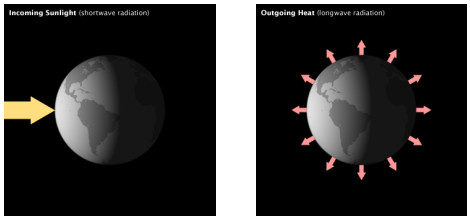
- Part of the energy from the Sun is absorbed by the atmosphere and the ground.
- This energy is emitted again after a period of time.
- This process increases the Earth's temperature

Clouds

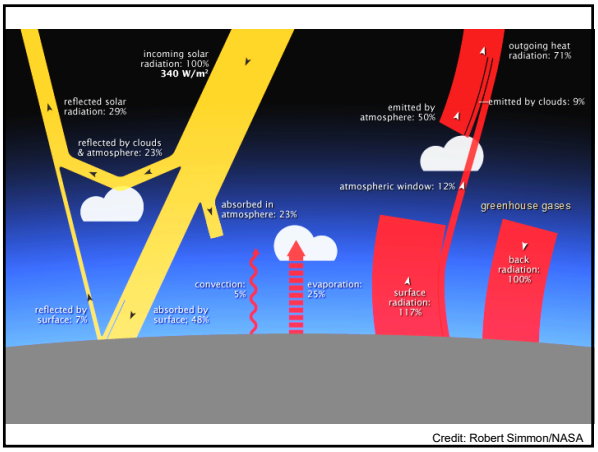
- Clouds have a higher albedo than the ground beneath them
  - More heat is reflected and therefore less heat makes it to the ground
- Clouds can absorb heat radiating from the surface of the earth and radiate it in all directions
  - Heat is radiated to the earth, heating it up

Energy Budget

- This net flow of energy into and out of the Earth system is Earth's energy budget.



Credit: Robert Simmon/NASA

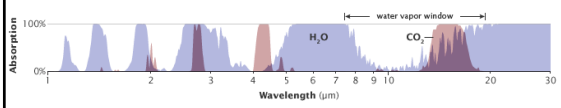


Credit: Robert Simmon/NASA

“Greenhouse” Effect

- Energy emitted from the surface of the Earth is absorbed by certain gases in the atmosphere resulting in an increase in the ambient temperature.
- This absorbed energy is then emitted both to space and back towards the Earth's surface.
- These gases are referred to as “greenhouse” gases.

- The main greenhouse gas is water



Credit: Robert Rohde, NASA