Earth as a planet

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Outline

1) Earth's interior structure: magnetic activity, volcanic activity, and seismic activity.

2) Earth's atmosphere: structure, weather, and the effect of pollution and other emissions.

3) Earth's magnetosphere, space weather and solar storms on Earth, and radiation from space.

4) Earth's surface: meteor impacts, temperature.

Blue Marble

Credit: NASA images "The Blue Marble" taken by the crew of Apollo 17 (1972).

- Earth is sometimes called the "Blue Marble."
- The original "Blue Marble" photo was taken by the crew of Apollo 17 on December 7, 1972, from a distance of about 29,000 kilometers (18,000 miles) from the planet's surface.
- Over 20 years, astronauts on the International Space Station have shot millions of photographs of the full Earth.
- NASA has applied the name to a 2012 series of images which cover the entire globe at relatively high resolution.
- The "blue" refers to the fact that Earth's surface is largely covered by ocean (71%).

Interior Structure of Earth

Earth's interior is divided into four layers: the dense, hot inner core (yellow), the molten outer core (orange), the mantle (tan), and the crust (blue).

- Inner Core: (5100-6370 km deep) is solid, and made up of iron & nickel.
- Outer Core: (2900-5100 km deep) is liquid, and made up of molten iron & nickel.
- Mantle: (100 to 2900 km deep) is made of soft rock, mostly silicates.
- Crust: (0 - 100 km deep) is a thin layer made up of different kinds of rock, depending on whether it is covered by ocean or land.

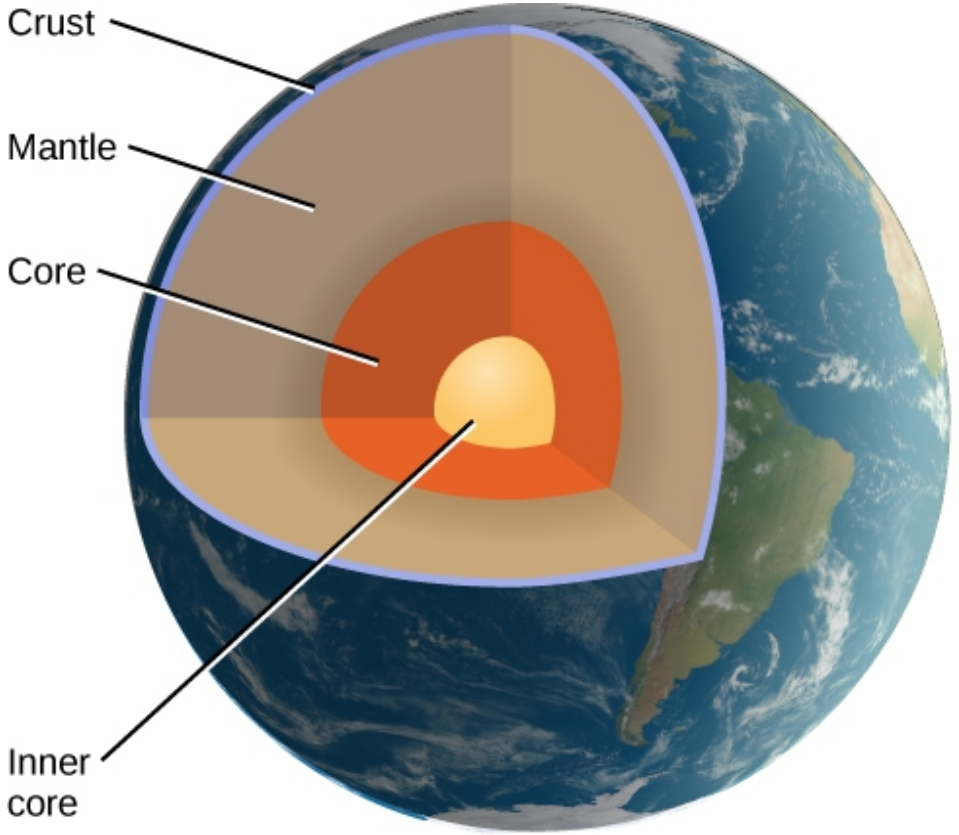


Image from OpenStax Astronomy

Liquid metal dynamics in Earth's core

- Metals carry electric currents (think of the wires that we use to charge devices, including your smart phone!)
- When metals get very hot, they melt, but melted metal can still carry electric currents, and interact with magnetic fields.
- The complicated motions of liquid iron in the outer core layer generate and maintain a magnetic field that surrounds the Earth.
- This creates a pattern of magnetic field lines in the shape shown (the Sun is to the left in this cartoon).

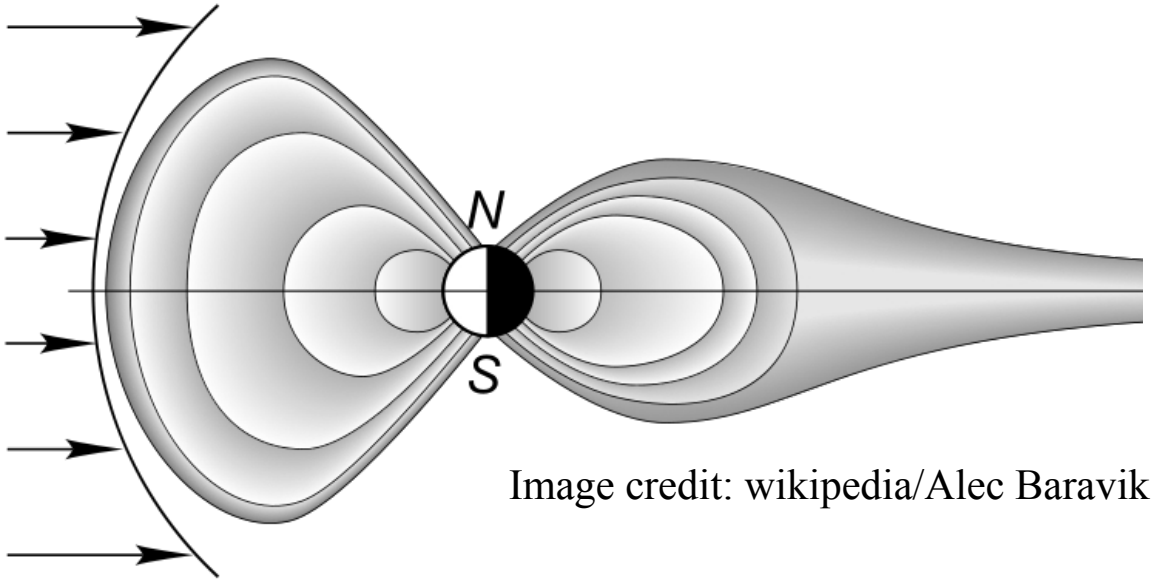
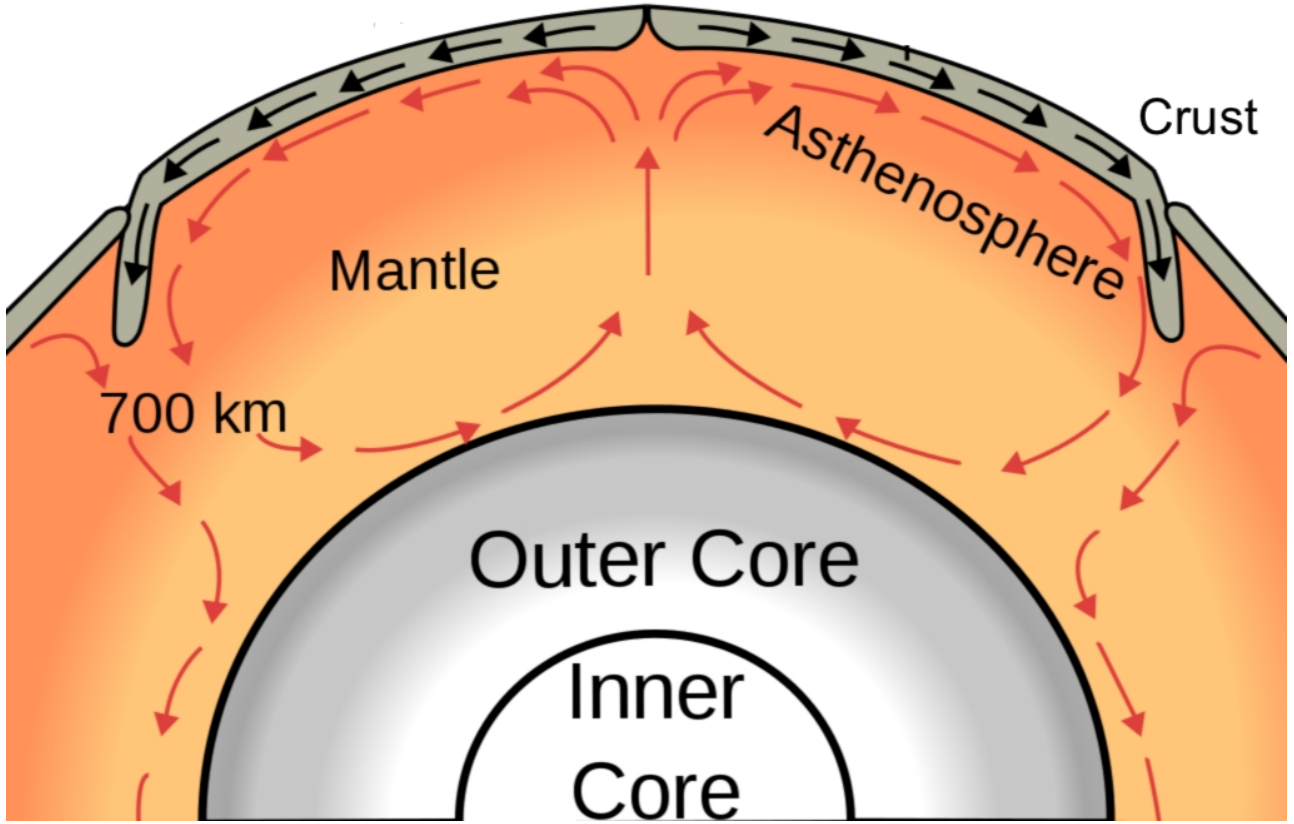


Image credit: wikipedia/Alec Baravik

Mantle convection

- Convection consists of large-scale motions of liquid metal carrying heat outward from the core.
- Earth's mantle has several sub-layers.
- The asthenosphere is the highly viscous region of the upper mantle.
- The Moho discontinuity is a point where the seismological waves change in velocity as they pass through different densities of rock.



Alfred Wegener (1880–1930)

Wegener (left) on his final expedition to Greenland (where he died). Image from the Archive of Alfred Wegener Institute (public domain in the US).

- Alfred Lothar Wegener was a German polar researcher.
- In 1912, he first proposed a scientific theory for the slow shifting of the continents.
- It was controversial and widely rejected by mainstream geology until the 1950s, when measurements of magnetic field lines in rocks were taken that supported his theory.

Earth's Crust: Rift Zones and Subduction Zones

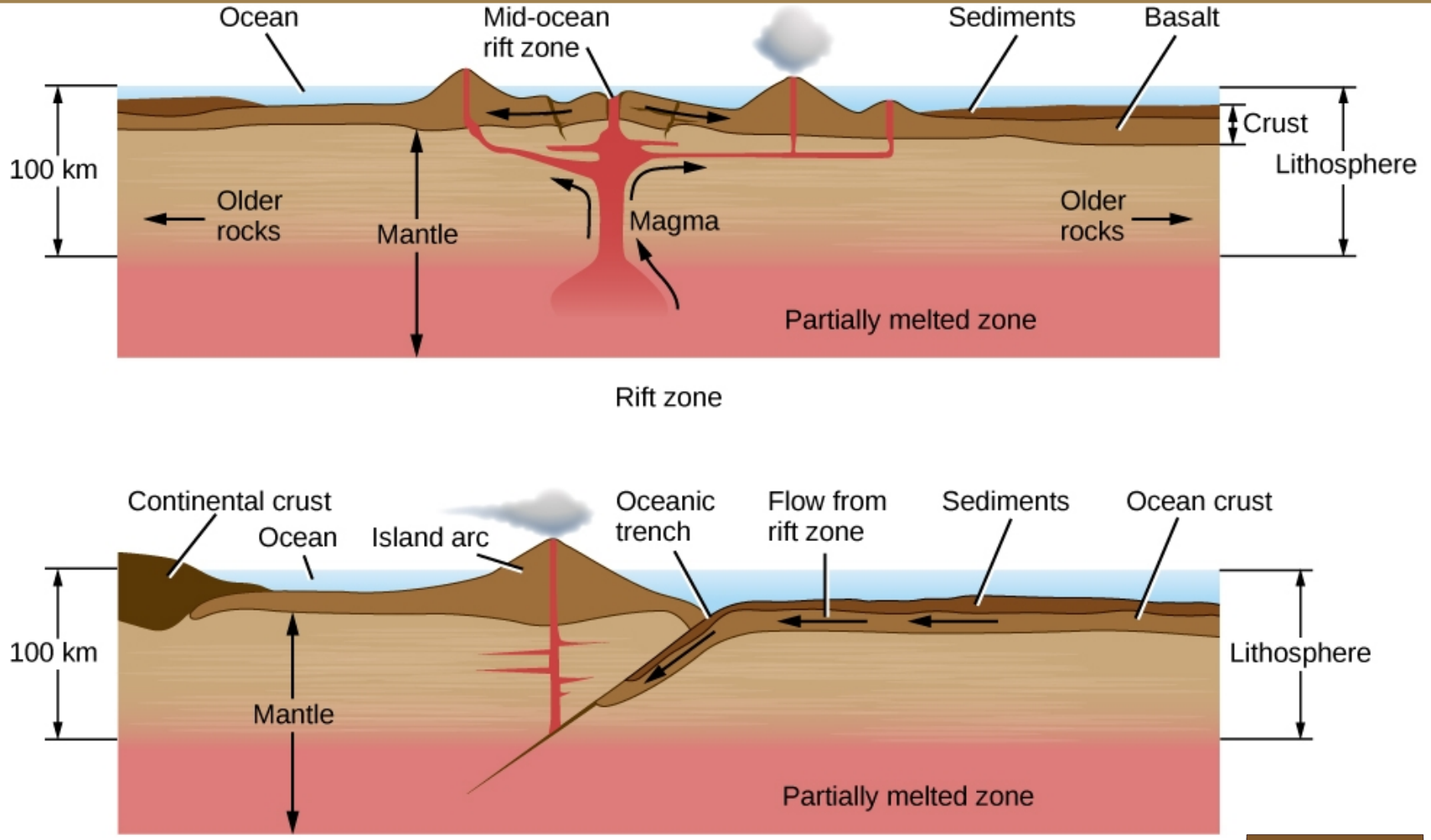


Image from OpenStax Astronomy

- Earth's crust is broken into 16 rigid plates that float on top of the mantle.
- Rift and subduction zones are the regions where new crust is formed and old crust is destroyed as part of the cycle of plate tectonics.
- On Earth these zones lie mostly beneath the oceans (remember 71% of the surface is ocean!).

Faults in the crust and earthquakes

The San Andres Fault, which runs lengthwise through California, is a place that produces large, destructive earthquakes. (Credit: John Wiley via OpenStax Astronomy)

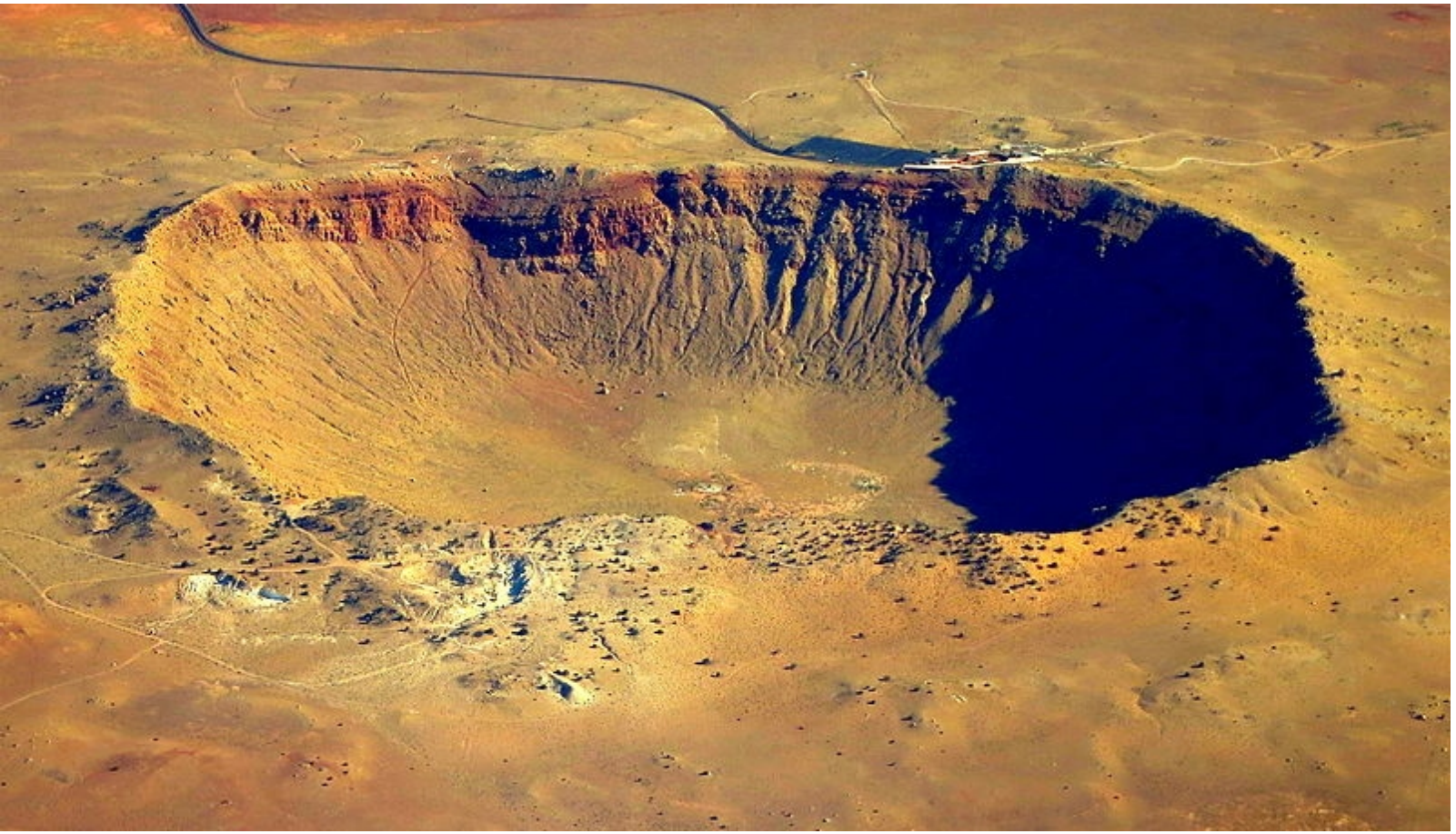
- Crustal plates slide around on top of the mantle.
- The motion of the plates is driven by convection currents in the mantle.
- Over millions of years, plate motions cause large-scale changes in the continents and oceans.
- Over short times, the convergence of plates or their slippage against each other can cause earthquakes.
- Plates can stick at their boundaries, building up strain.
- The strain releases, and the crust suddenly jumps several meters.
- Example: 1906 quake that leveled San Francisco.

Faults in the crust and earthquakes

A plume of ash, and spurt of lava coming from the Eyjafjallajökull volcano in Iceland in 2010. (Credit: David Karnå via Wikimedia, CC-BY-1.0).

- Volcanic activity is evidence of the dynamic nature of Earth's crust.
- Volcanos often occur at subduction zones, where one tectonic plate moves under another.
- Subduction zones also lead to mountain building, as part of the crust is deformed and thrust upward.

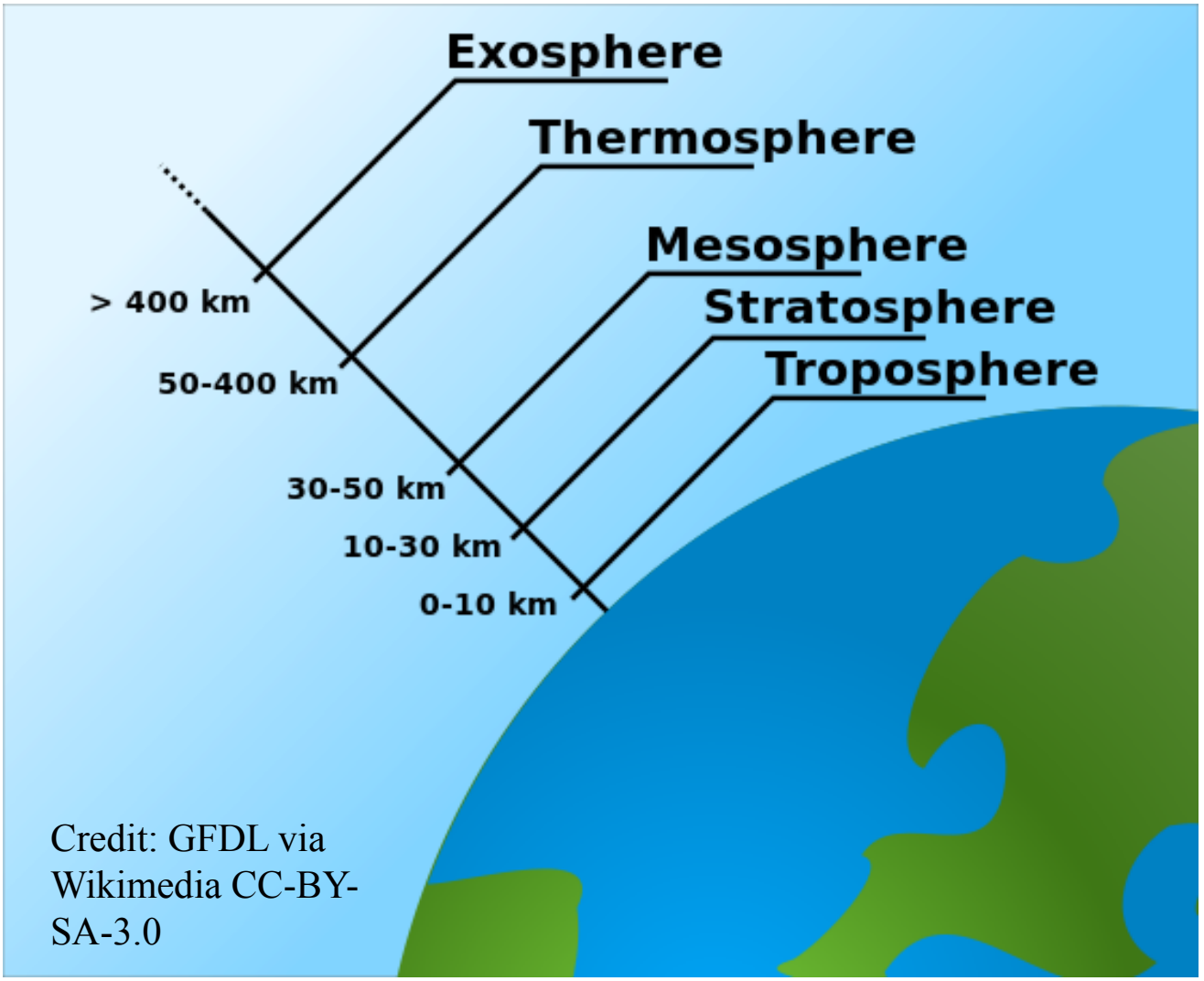
Meteor Impacts on Earth



- Earth's atmosphere burns up small pieces of rock that would otherwise hit the crust.
- Large meteor impacts on Earth do happen. They are less evident on Earth than on the moon because they are eroded by wind and rain, or destroyed over time because of our active crust (earthquakes, volcanoes, etc).

Barringer Crater in Arizona (Credit: Steve Jurvetson via Wikimedia, CC-BY-2.0).

Structure of Earth's Atmosphere



Credit: GFDL via Wikimedia CC-BY-SA-3.0

Exosphere: contains few particles that move into and from space.

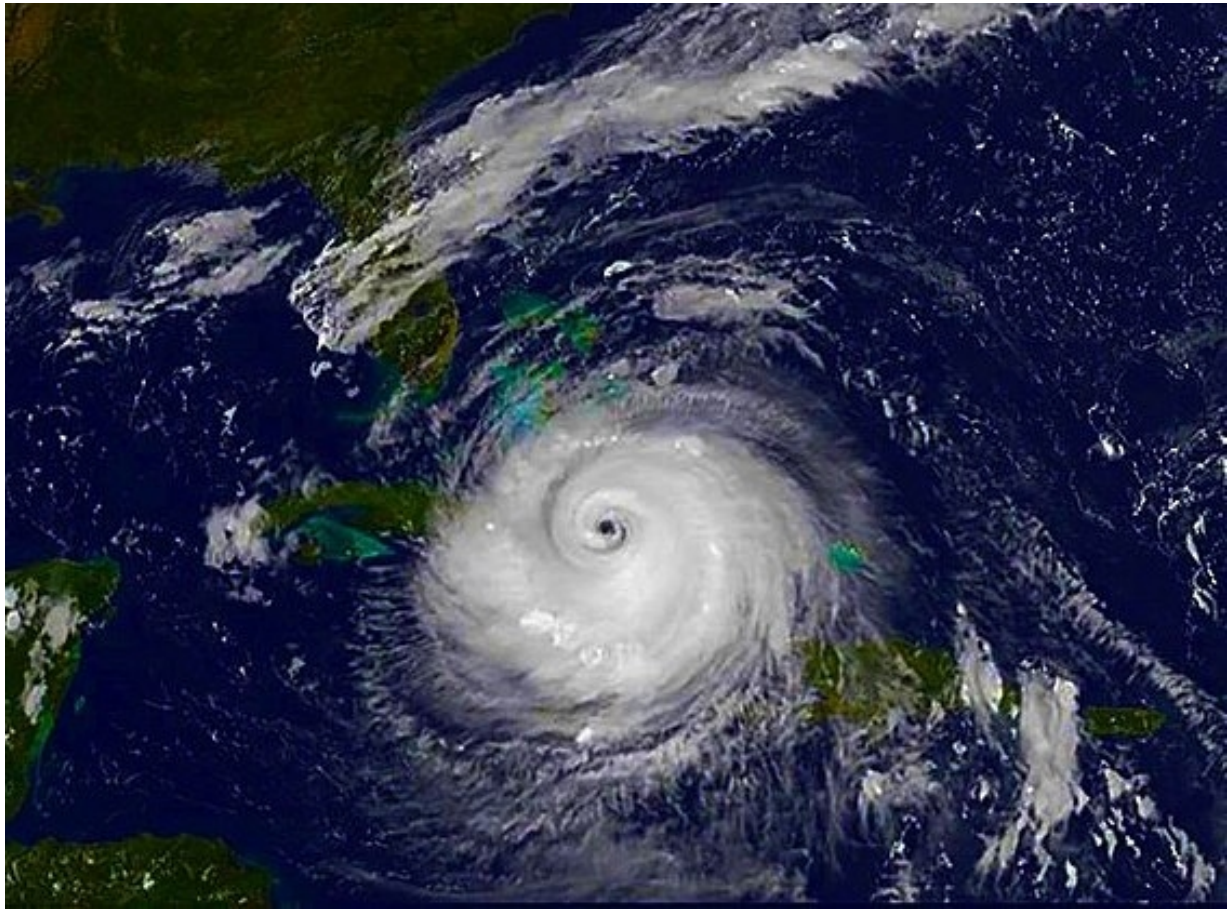
Thermosphere: temperature increases with height. The International Space Station orbits Earth in this layer.

Mesosphere: the layer in which most meteors burn up.

Stratosphere: contains the ozone layer; the layer where volcanic gases can affect the climate.

Troposphere: the layer closest to Earth's surface in which all weather occurs.

Atmospheric dynamics: Earth's weather viewed from space



Hurricane Irma over Cuba in 2017. Credit: NOAA.

- Earth's rotation causes a force called the Coriolis force.
- The Coriolis force appears when Newton's laws are transformed to a rotating frame of reference.
- The result of the Coriolis force is that when a wind blows north, it also moves a little bit east, because of the rotation of the Earth.
- Because of the Coriolis force, hurricanes always spin counter-clockwise in the Northern Hemisphere, and spin in the opposite direction in the Southern Hemisphere.

The Atmosphere and the "Greenhouse Effect"

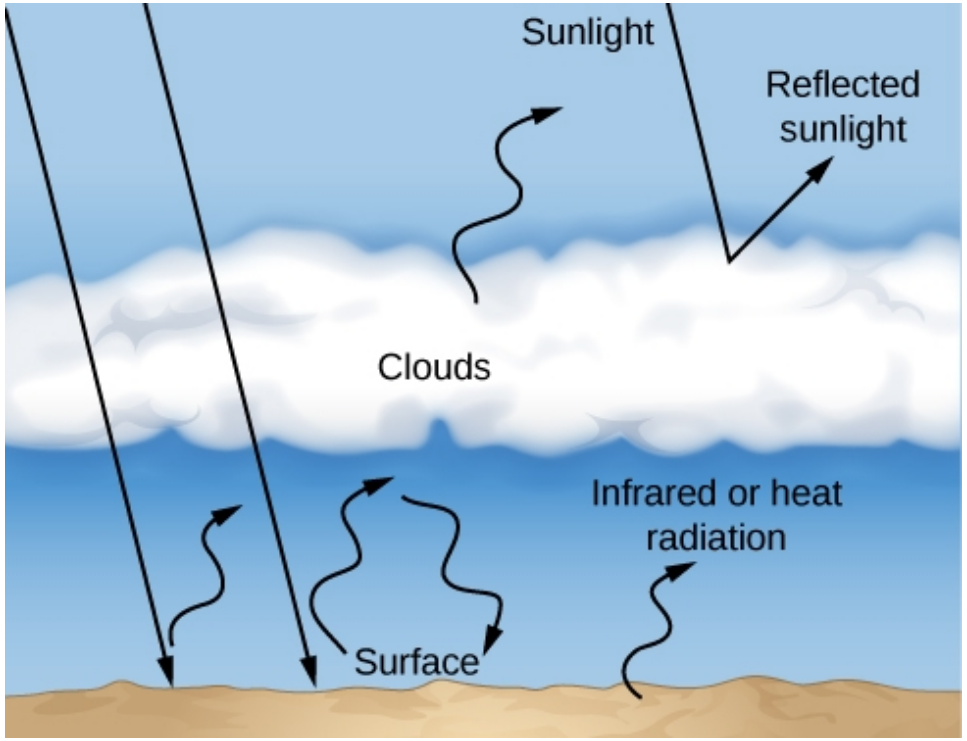
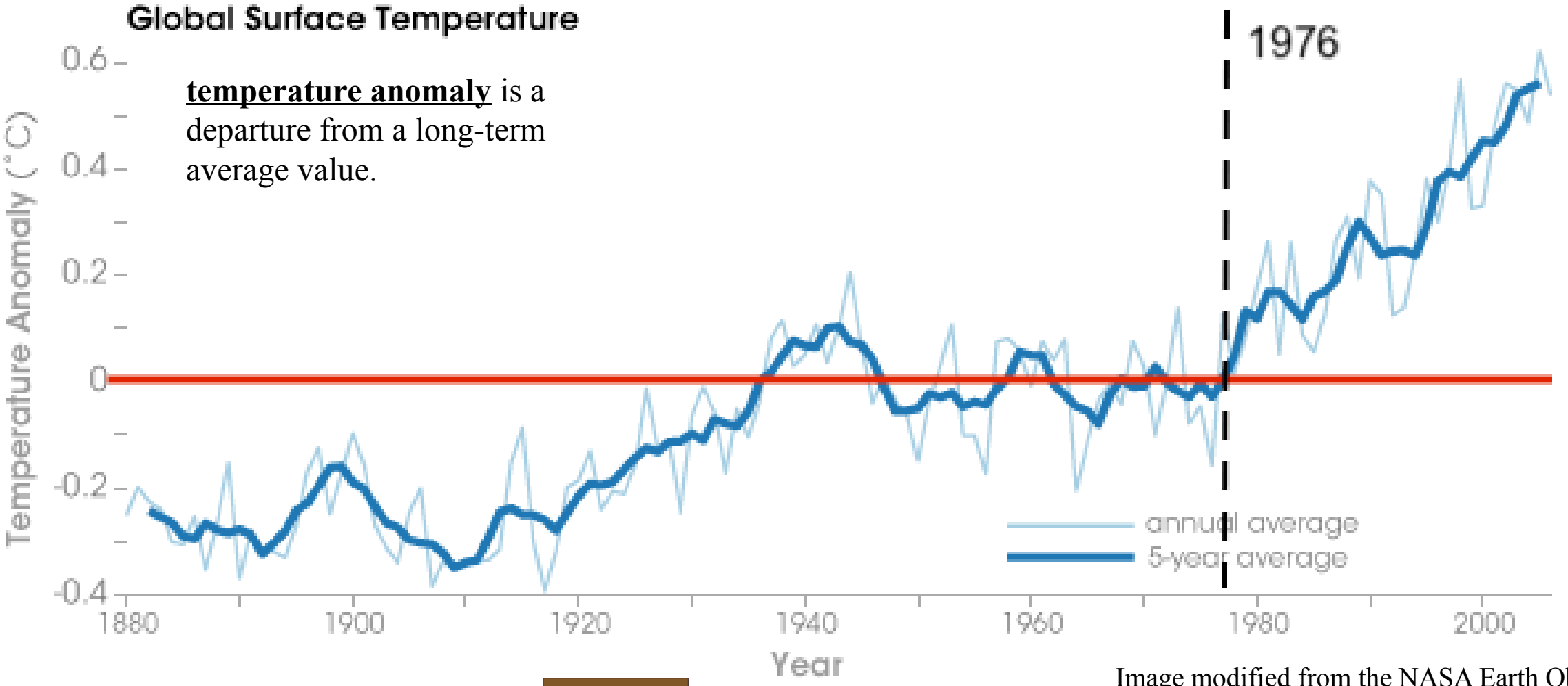


Image from OpenStax Astronomy

- Sunlight that penetrates to Earth's lower atmosphere and surface is reradiated as infrared or heat radiation.
- This heat can be trapped in the atmosphere by gases such as water vapor, methane, and CO_2.
- The result is a higher surface temperature for our planet.

Temperatures on Earth (measured by instruments)



temperature anomaly is a departure from a long-term average value.

Image modified from the NASA Earth Observatory.

Temperatures on Earth (estimated from tree rings, ice cores, corals, and ocean and lake sediments)

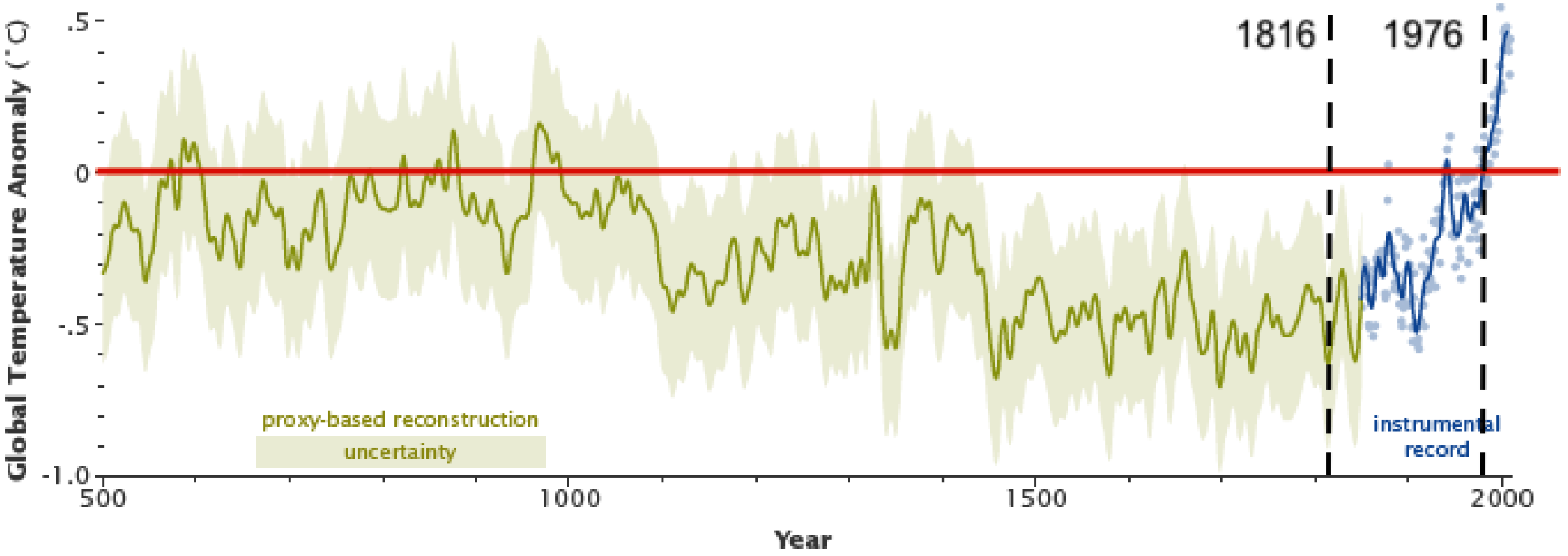


Image modified from NASA Earth Observatory, adapted from Mann et al., 2008.

The Year Without a Summer

- Variations, sometimes even extreme ones, occur in global surface temperature.
- In 1816, global surface temperatures dipped by about 1 °F.
- This may have been caused by a large volcanic eruption of Mount Tambora (Dutch East Indies).
- This was so extreme that it triggered extreme weather, harvests failed, and people across Europe were starving (causing an estimated 90,000 deaths).
- In the past 40-odd years, global surface temperatures have risen by more than 1 °F.

Even further back (estimated from carbon dioxide trapped in glacial ice)

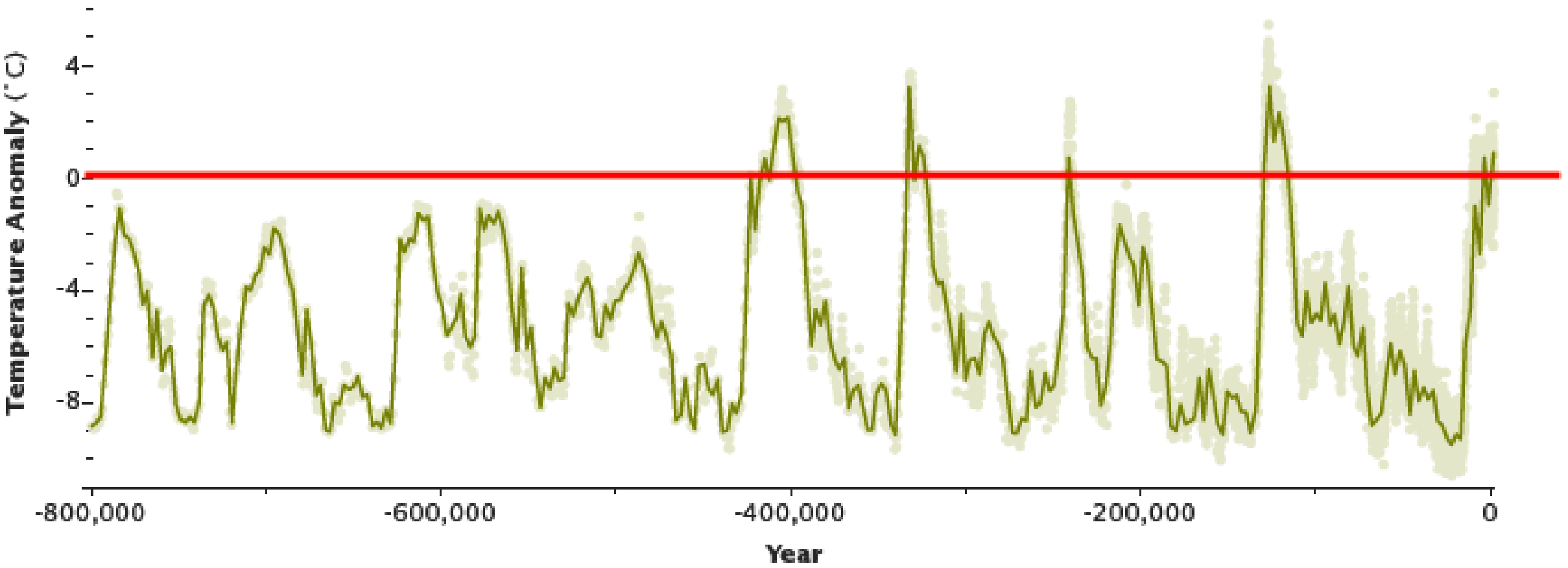


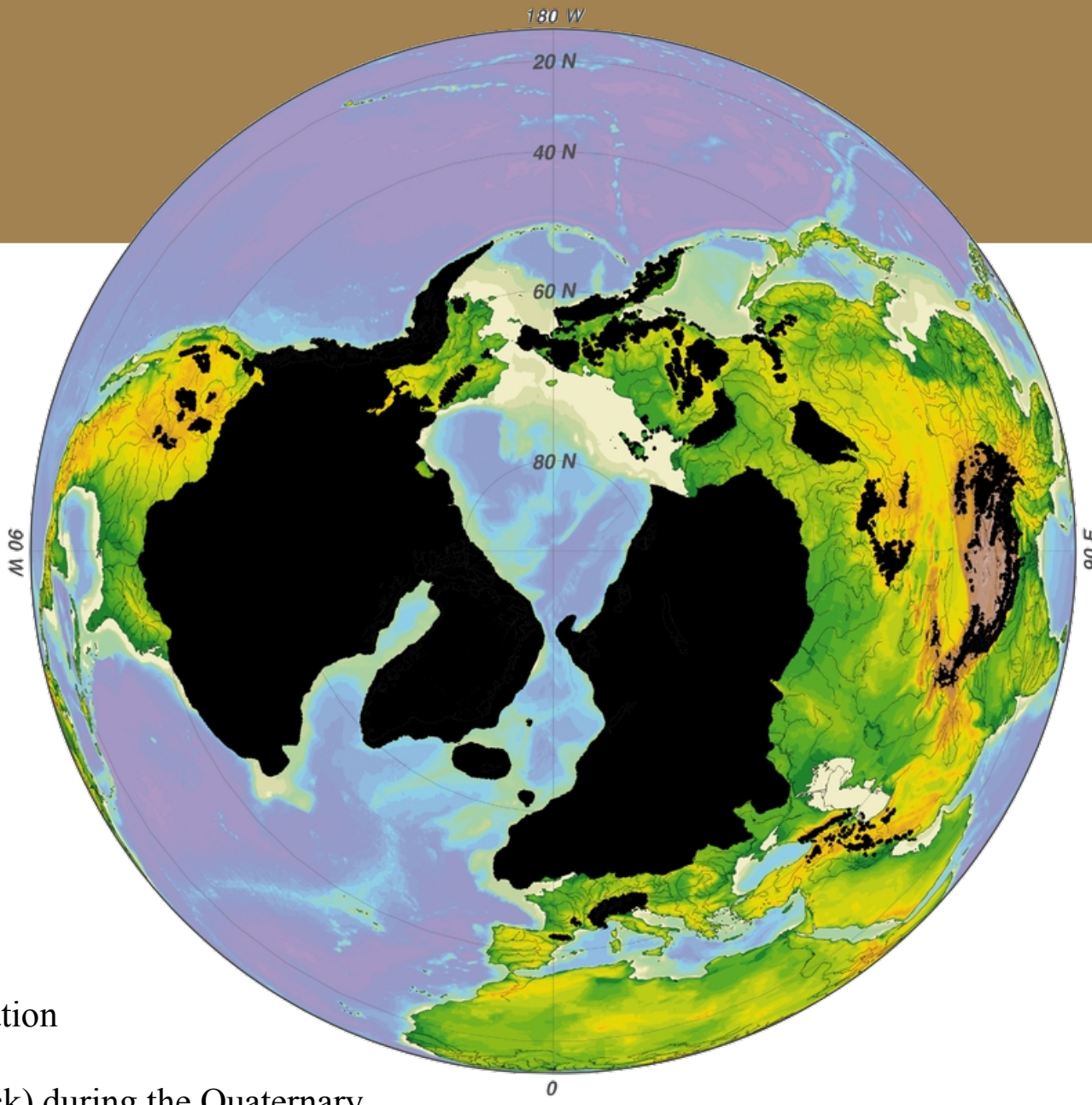
Image modified from NASA Earth Observatory graph by Robert Simmon, based on data from Jouzel et al., 2007.

The Ice Age

Scientists have predicted that the global average temperature during the ice age was around 46 degrees Fahrenheit.

There is evidence that greenhouse gas levels fell at the start of ice ages and rose during the retreat of the ice sheets, but it is difficult to establish cause and effect.

The ice ages have also been attributed to changes in Earth's rotational axis and orbit, and the position of the continents, and solar activity.



Maximum glaciation of the northern hemisphere (black) during the Quaternary climatic cycles. Credit: Hannes Grobe/AWI

Earth's Magnetosphere

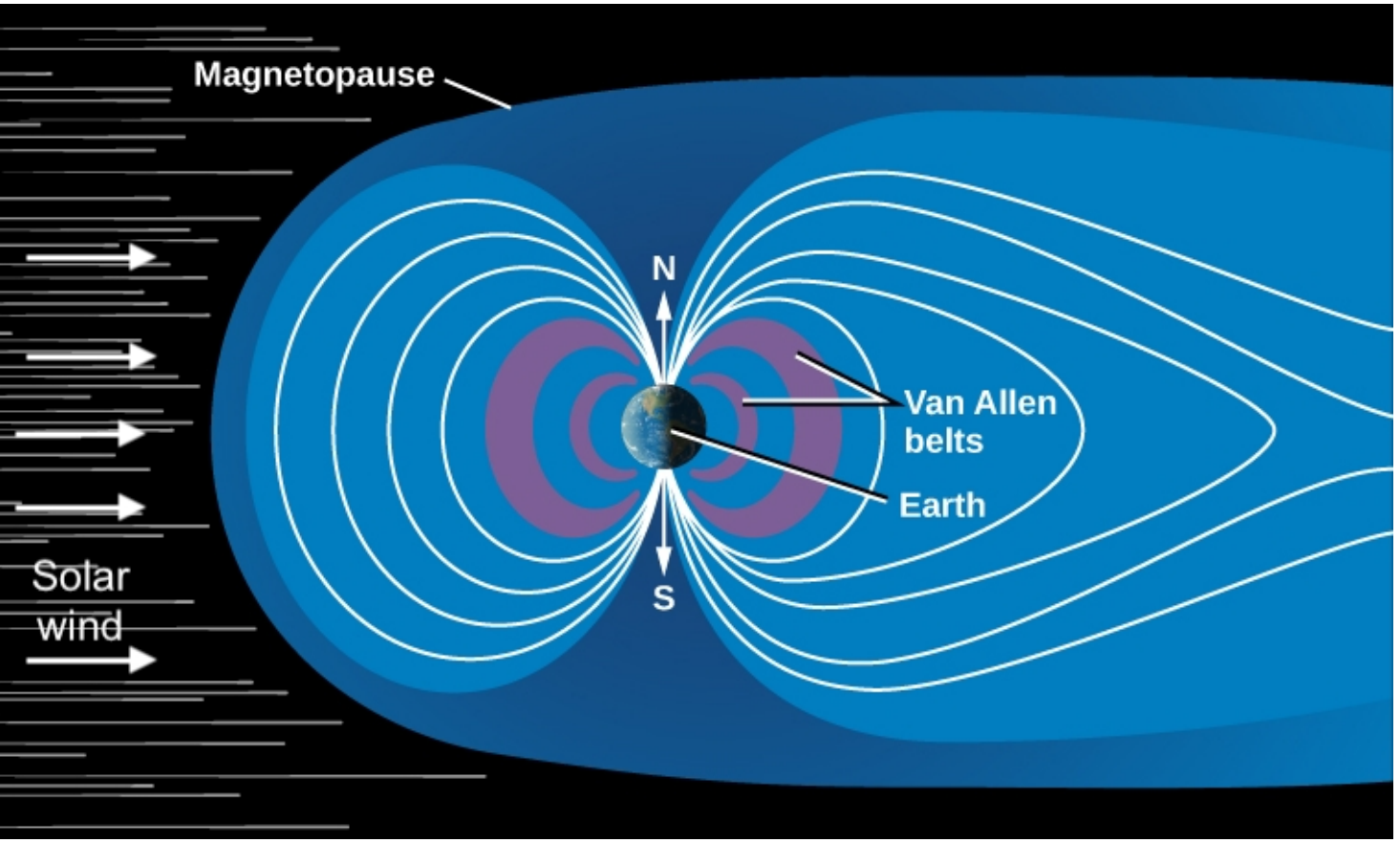


Image modified from OpenStax Astronomy

- Recall how the dynamo in the Earth's core creates a magnetic field around the Earth.
- This magnetic field defines the **magnetosphere**, a region of space surrounding the Earth in which charged particles are affected by Earth's magnetic field.
- Magnetic field lines guide charged particles so that they come down around the north and south poles, shielding the Earth to some extent from the radiation of the **solar wind**.
- **Solar storms** and more extreme **space weather** can still reach the Earth, and penetrate our magnetic field.

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Image modified from NASA.