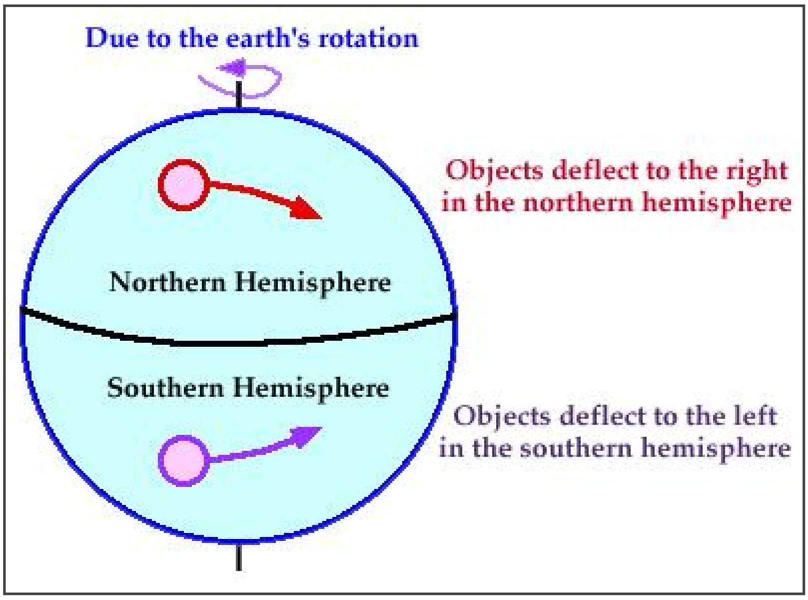
A. Coriolis force and Coriolis effect

Winds blow across the Earth from high-pressure systems to low-pressure systems. However, winds don't travel in a straight line. The actual paths of winds—and of ocean currents, which are pushed by wind—are partly a result of the Coriolis Effect. The Coriolis Effect is named after Gustave Coriolis, the 19th-century French mathematician who first explained it. *Once air has been set in motion by the pressure gradient force (The change in pressure measured across a given distance directed from high to low pressure), it undergoes an apparent deflection from its path, as seen by an observer on the earth. This apparent deflection is called the "Coriolis force" and is a result of the earth's rotation.*

The Earth rotates faster at the Equator than it does at the poles. This is because the Earth is wider at the Equator. A point on the Equator has farther to travel in a day. Let's pretend you're standing at the Equator and you want to throw a ball to your friend in the middle of North America. If you throw the ball in a straight line, it will appear to land to the right of your friend because he's moving slower and has not caught up. Now let's pretend you're standing at the North Pole. When you throw the ball to your friend, it will again appear to land to the right of him. But this time, it's because he's moving faster than you are and has moved ahead of the ball. This apparent deflection is the Coriolis effect. The wind is like the ball. It appears to bend to the right in the Northern Hemisphere. In the Southern Hemisphere, winds appear to bend to the left. The Coriolis force applies to movement on rotating objects. It is determined by the mass of the object and the object's rate of rotation. The Coriolis force is perpendicular to the object's axis. The Earth spins on its axis from west to east. The Coriolis force, therefore, acts in a north-south direction. The Coriolis force is zero at the Equator.

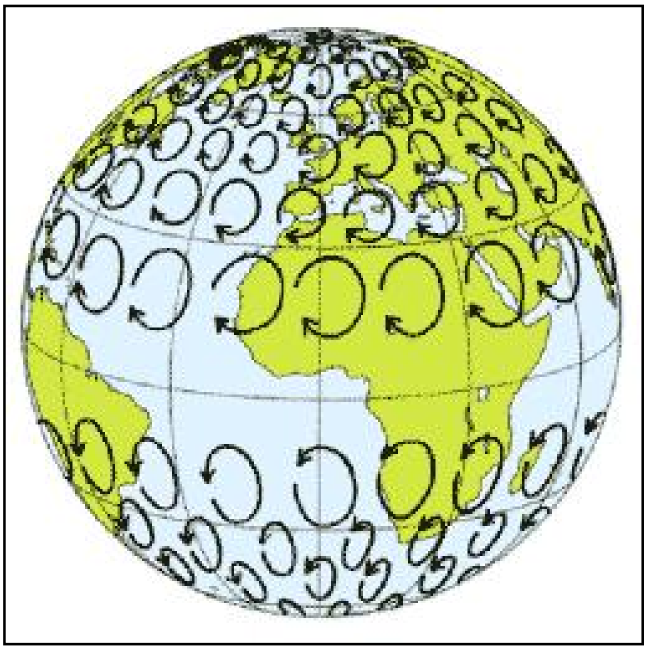


As air moves from high to low pressure in the northern hemisphere, it is deflected to the right by the Coriolis force. This causes the system to swirl counter-clockwise. Low-pressure systems usually bring storms. This means that hurricanes and other storms swirl counter-clockwise in the Northern Hemisphere. In the southern hemisphere, air moving from high to low pressure is deflected to the left by the Coriolis force. Therefore, in the Southern Hemisphere, storms swirl clockwise.

The amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected only a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator. The Coriolis force is zero right at the equator.

Fast-moving objects such as airplanes and rockets are influenced by the Coriolis effect. Pilots must take the Earth's rotation into account when charting flights over long distances. This means most planes are not flown in straight lines, even if the airports are directly across the continent from each other. Military aircraft and missile-control technology must calculate the Coriolis effect for similar reasons. The target of an air raid could be missed entirely, and innocent people and civilian structures could be damaged.

The Earth rotates fairly slowly, compared with other planets. The slow rotation of the Earth means the Coriolis Effect is not strong enough to be seen in small movements, such as the draining of water in a bathtub.



Schematic representation of inertial circles of air masses in the absence of other forces, calculated for a wind speed of approximately 50 to 70 m/s (110 to 160 mph).

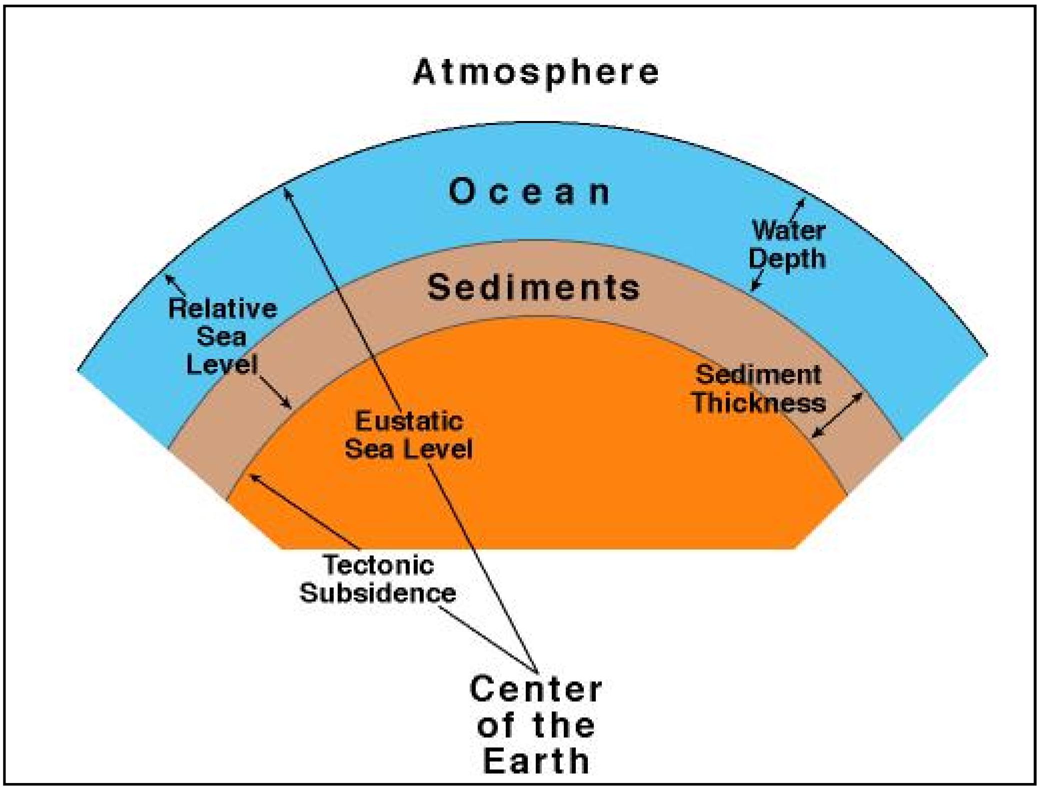
B. Eustasy

Eustasy is the world-wide sea-level regime and its fluctuations, caused by absolute changes in the quantity of seawater, e.g. by continental icecap fluctuations.

Eustasy is measured between the sea surface and a fixed datum, usually the centre of the Earth.

It can vary by:

- changing ocean-basin volume; (e.g. by varying ocean-ridge volume)
- by varying ocean-water volume (e.g. by glacio-eustasy)



Global sea level (eustasy) has undergone cyclical change throughout earth's history, at a wide range of rates and periods of change. Sea-level changes are often described in terms of their time scale, as follows: 1st order (100–1000 my), 2nd order (10–100 my), 3rd order (1–10 my), 4th order (0.1–1 my), and so on. Causes of eustatic change fall into two broad categories: changes due to variations in the volume of water in the oceans, and changes due to variation in the shape and volume of ocean basins.

Changes in volume of ocean water

The volume of ocean water is capable of changing on relatively short time-scales (< 10 ky) and for some mechanisms, capable of undergoing changes of large magnitude. Changes in continental glacier volume are capable of driving the largest and most rapid eustatic variations and is perhaps the best known mechanism of eustatic change. Glacial ice is produced from the precipitation of water that has been evaporated from the ocean, so any growth in ice volume must decrease the volume of ocean water, and any loss of ice volume must increase the volume of ocean water. Note that sea ice has no effect on eustasy, because the mass of sea ice is already displacing ocean water. However, the growth and melting of mountain glaciers and continental ice sheets both contribute to eustasy, with the much greater volume of continental ice sheets having a much greater effect. Continental ice sheets are present today in Antarctica and Greenland, but covered much of North America, northern Europe, and northern Asia during the Neogene. In the Paleozoic, large continental ice sheets were present on Gondwana, which was situated over the south pole.

Ocean water can also be stored on land in the form of lakes and groundwater. These sinks may grow and shrink with climate and therefore on geologically brief time scales. Because lakes and groundwater represent relatively little volume compared to the oceans, changes in freshwater storage drive only small amplitudes of eustatic variation.

Changes in the temperature of the ocean can also change the volume of ocean water, owing to the thermal expansion and contraction of water. As ocean water is heated, it expands, and as it cools, it contracts. The shallow ocean (0–500 m) can undergo more rapid changes than the deep ocean (500–4000 m), but changes in the deep ocean can generate up to ten times greater amplitudes of eustatic variation, owing to the greater volume of water in the deep ocean.

Changes in volume and shape of ocean basins

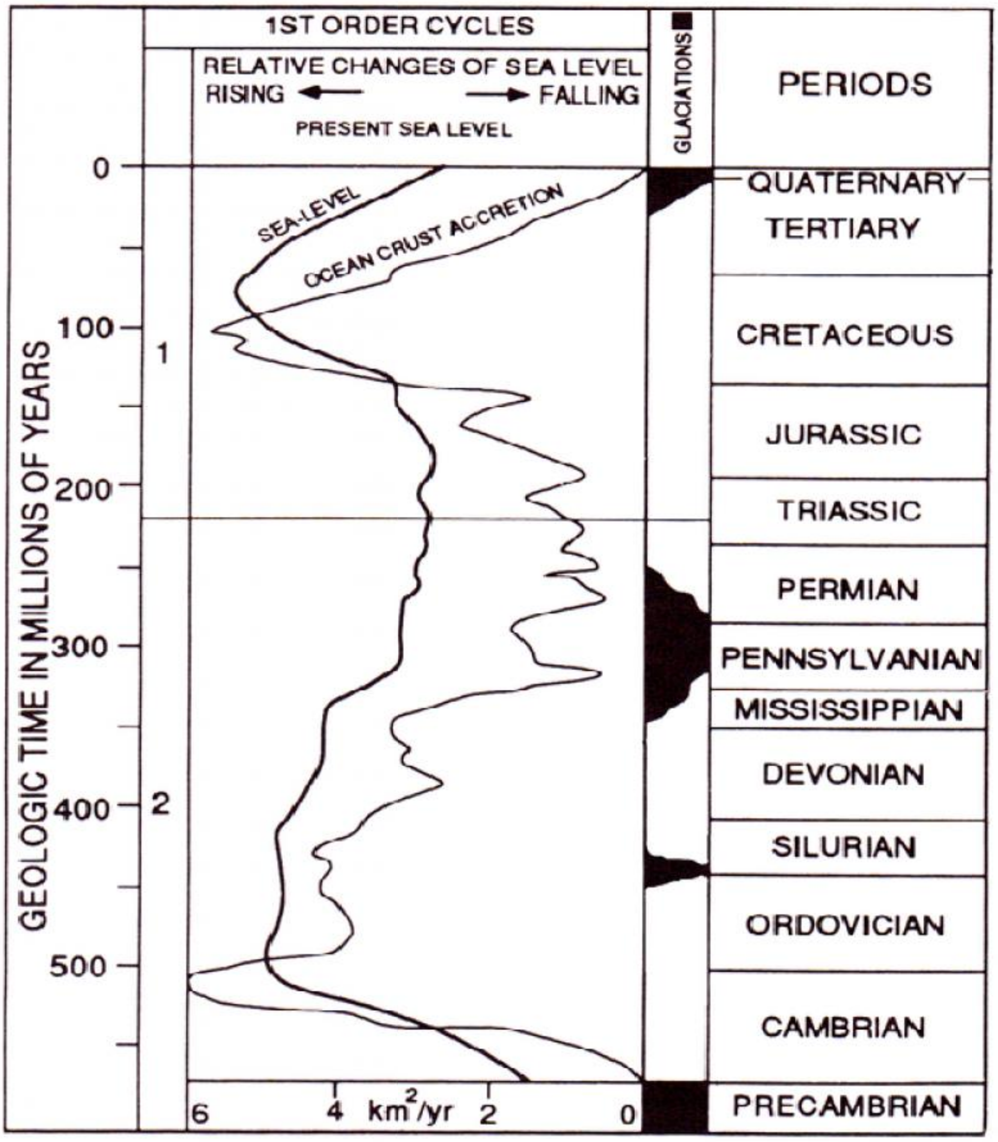
Changes in the rate of sea-floor spreading have the potential for driving geologically slow (>1 my) but large (on the order of 100 m) eustatic variations. Ocean lithosphere floats on the mantle and the elevation at which it floats is controlled by the density of the lithosphere. Where lithosphere is produced at mid-ocean ridges, it is hot and is topographically high as a result. As ocean lithosphere cools, it sits progressively lower topographically. These changes are an exponential function of sea-floor age.

In principle, if the average global age of the seafloor changed over geologic time, the average elevation of the seafloor would also change, causing global sea-level to vary. Again in principle, the average global age of the seafloor would change over time if the average global spreading rate at mid-ocean ridges changed through time or if subduction preferentially affected lithosphere of a given age.

Geologists have argued that spreading rates should be slow as supercontinents such as Pangaea are assembled and that spreading rates should reach a maximum shortly after the breakup of a supercontinent. In fact, sea level was low in the Late Proterozic at the time of the supercontinent Rodinia, reached a peak in the Ordovician after breakup of Rodinia, reached a low in the Permian as the supercontinent Pangaea formed, reached a peak in the Cretaceous as Pangaea broke up, and has been falling since as a new supercontinent (Asia, Europe, and Africa) begins to assemble. This 1st-order curve is often called the M-curve, because of its similarity to the capital letter M. More recent work by Dave Rowley has called into question the origin of the M-curve, because his measurements indicate that the rate of production of ocean crust has not varied since the Jurassic.

Erosion of continents and deposition of sediment in ocean basins raises the bottom of the ocean basin and therefore raises global sea level. This is a slow process, typically causing sea-level change on the order of 10–100 my, with only a few tens of meters of eustatic variation.

Continental collision is also capable of changing global sea level. On short-time scales the volume of continental crust is fixed. But because continental collision causes the thickening of continental crust, the total area of continental crust must decrease. This causes the total area of oceans to increase, thereby lowering their average depth, that is, causing a eustatic fall. Rifting, which stretches and thins continental crust, must have the opposite effect. Rifting would increase the area of continental crust, decreasing the area of oceanic crust, and raising eustatic sea level. Note that this may well contribute to the shape of the M-curve.



Plint et al., 1992

C. Relative sea-level

Relative sea-level is measured between the sea surface and a local moving datum, such as basement or a surface within the sediment pile.

Tectonic subsidence or uplift of a basement datum, sediment compaction involving subsidence of a datum within the sediment pile, subsidence of a datum within the sediment pile, and vertical eustatic movements of the sea surface all contribute to relative sea-level changes.

⇑ ***Relative sea-level "rises"*** are due to:
• Subsidence
• Eustatic sea-level rise

⇓ ***Relative sea-level "falls"*** are due to:
• Tectonic uplift
• Eustatic sea-level fall

Accommodation

- Eustasy and subsidence rate together control the amount of space available for sediment accumulation, termed as accommodation space.
- It is defined as the space available for sediment to accumulate at any point in time.
- Accommodation is controlled by base level because for sediments to accumulate there must be space available below base level.