Carbon in the Atmosphere

Overview of Carbon Reservoirs

Carbon is present in each of the Earth's spheres and in all known life forms. On Earth, carbon is a fundamental building block of life. The places and forms in which we find carbon are called ***reservoirs***.

Carbon combined with oxygen is carbon dioxide (CO_2) which is found:

…in the atmosphere

…dissolved in all bodies of water

Carbon combined with hydrogen creates a hydrocarbon, a historically important source of energy as fossil fuels. Fossil fuels are found in our environment:

…as coal

…as oil

…as natural gas

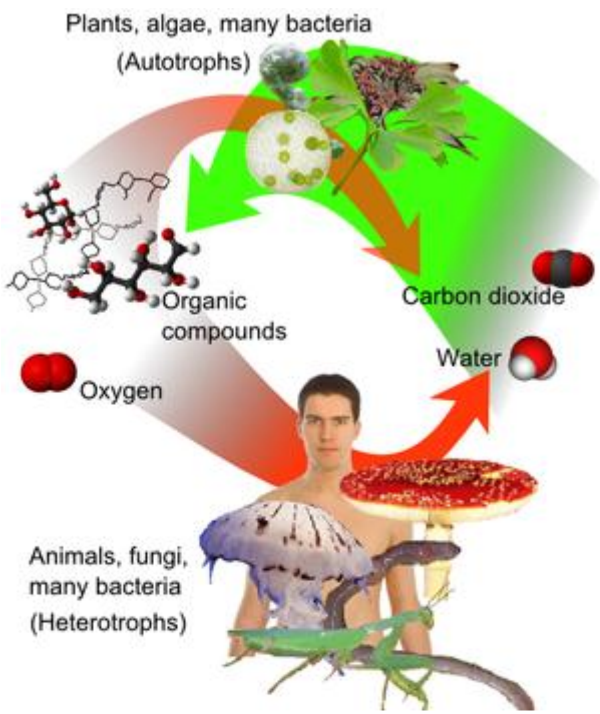
Carbon forms minerals and is found in the earth:

…as carbonate rock

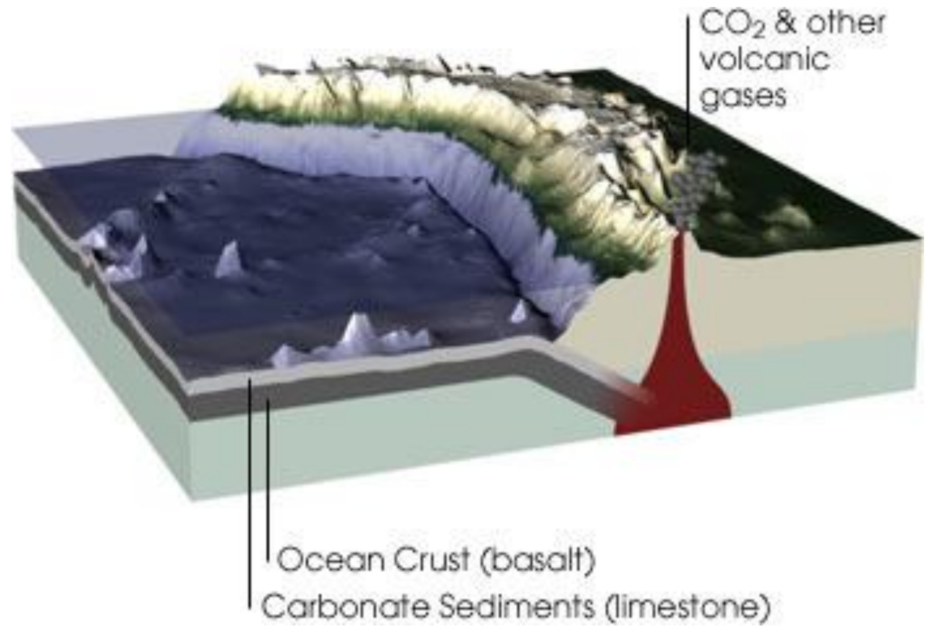
…as diamonds

Carbon Flux

The movement of carbon between reservoirs is carbon flux. Various processes—including chemical, physical, geological, and biological—enable the movement of carbon. Carbon moves between reservoirs at varying rates ranging from minutes to millions of years.



Flux between carbon in the food and water we ingest and the air we breathe is small. Flux between carbon in vegetation and soils and the atmosphere and between the ocean and the atmosphere is large.

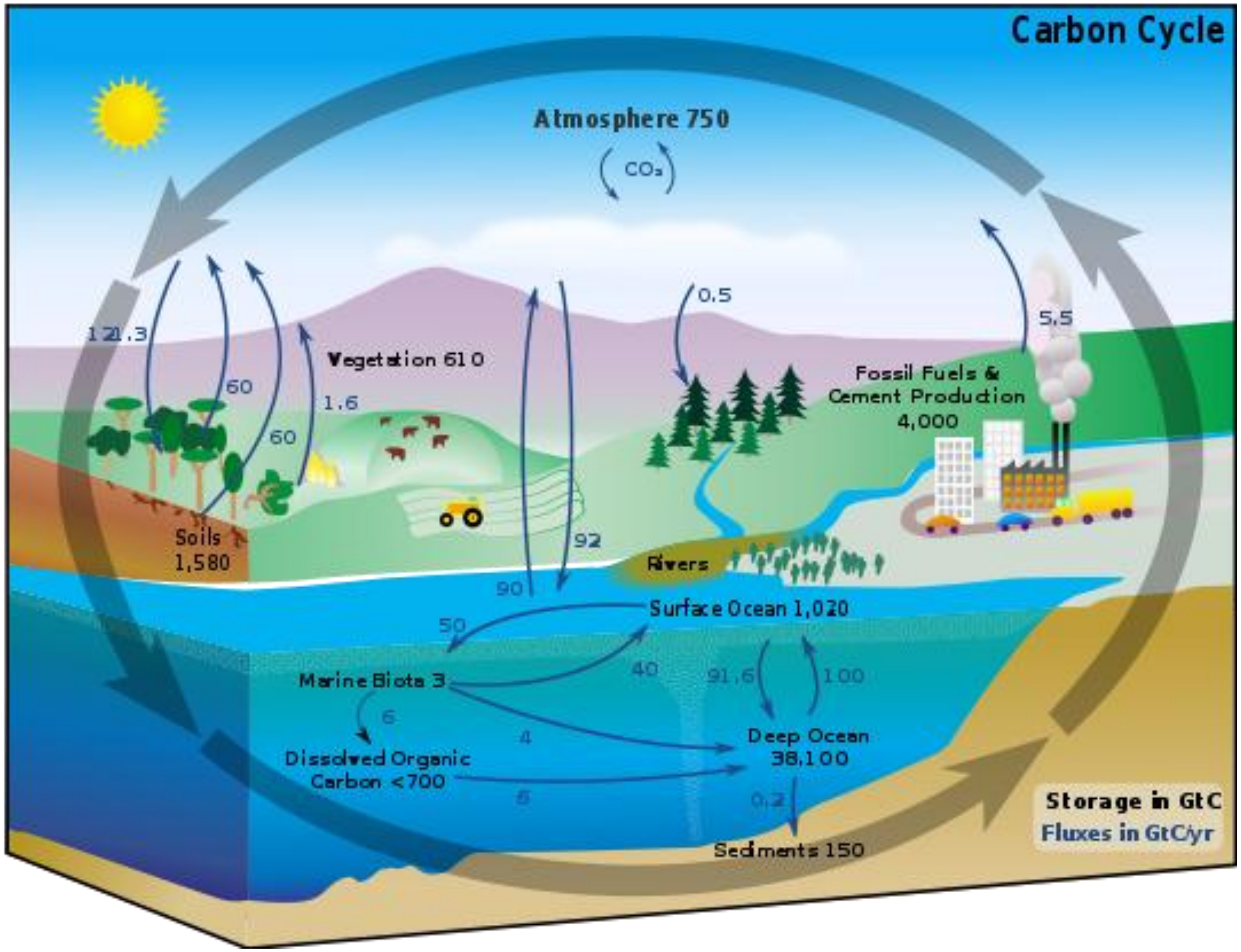


On longer time scales, carbon moves from the atmosphere, through the ocean and into sediments, which are subducted into the mantle, along with the ocean lithosphere, which melts so that the carbon returns to the atmosphere through volcanoes.

The concepts of carbon *reservoirs* and *fluxes* are very important to understand the carbon cycle.

Carbon Cycle

The flux of carbon from one area to another is the basis for the carbon cycle.

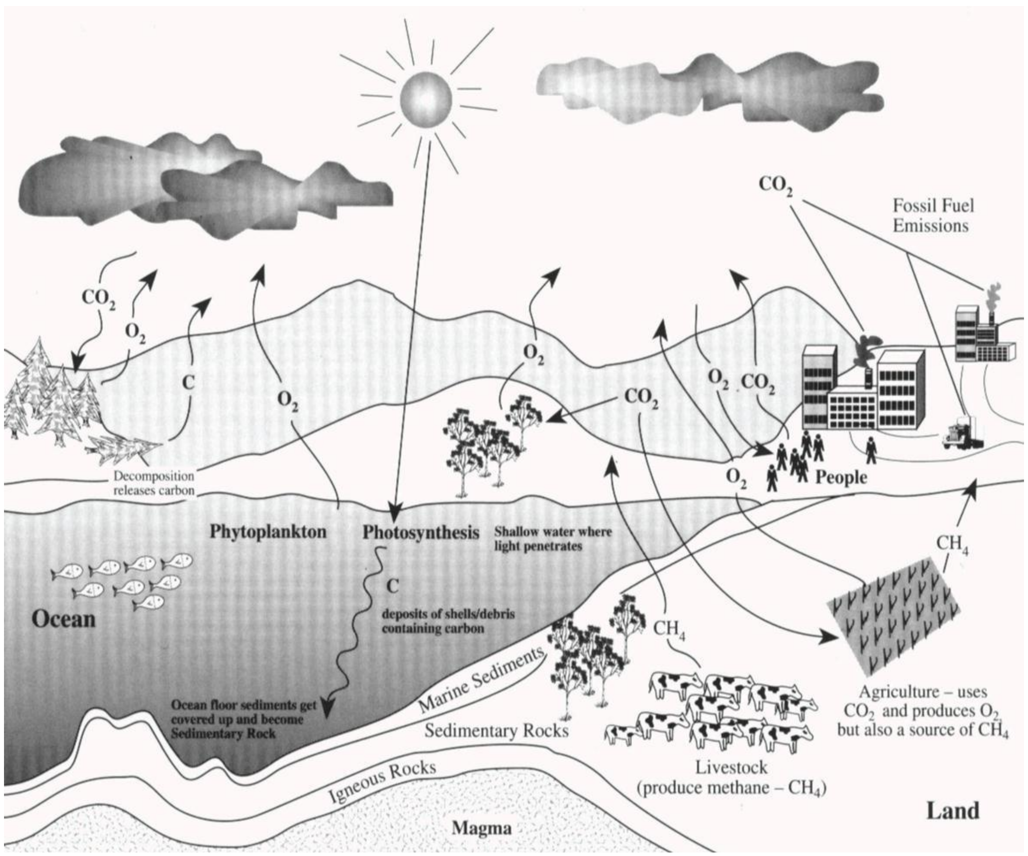


The black text highlights various carbon reservoirs and the numbers indicate how many GigaTons (GtC) of carbon is stored there. The dark blue text shows carbon flux. The arrows show which way the carbon moves and the numbers detail how many GigaTons of carbon move annually.

Carbon Cycle – Historical Context

Human civilization developed under natural levels of greenhouse warming.
But human activities are now causing extra carbon to go into the atmosphere.

Carbon Cyle ***Before*** Industrial Revolution	The carbon cycle functioned in relative balance before impacted by human activity. Carbon dioxide was emitted to the atmosphere by volcanoes and exchanged between the atmosphere, geosphere (vegetation and soils) and the hydrosphere (oceans).

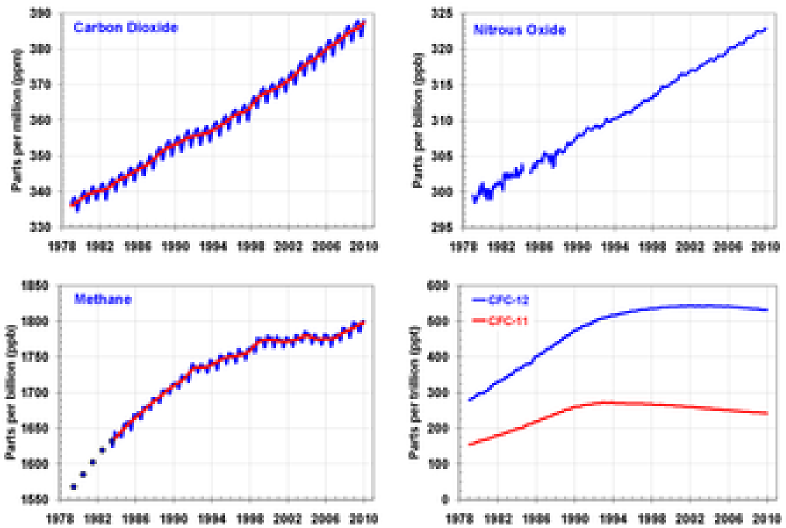


Carbon Cycle ***After*** Industrial Revolution

All these exchanges continue but human emissions from fossil fuels use has perturbed the cycle. As humans add carbon dioxide to the atmosphere between half and two thirds of it is currently absorbed by the oceans and land plants in carbon 'sinks' so that the atmospheric increase in carbon dioxide is greatly mitigated by nature. This process acidifies the oceans and causes some plants to grow faster. The fluxes into these carbon sinks may become reduced as they become saturated. Land plants are growing back from centuries of deforestation (which will end soon), and the oceans are becoming more acidic, which will reduce the ability of microrganizsms to make carbonate shells. As the oceans increase in temperature, the solubility of CO2 will decline. Thus the 'discount' we get from thee sinks will disappear in the future.

Reservoir Times

The impact of greenhouse gases on the enhanced greenhouse effect is determined by their residence time in the atmosphere.



Atmospheric residence time represents the average amount of time the molecules of a greenhouse gas exist in air before it is removed or converted to something else. When atmospheric residence time is greater, the total impact of a greenhouse gas on global warming is larger.

The average residence time of atmospheric gases are:

1) water vapor (H_2O):

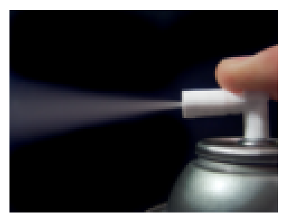
   9 days

2) carbon dioxide (CO_2):

   tens of thousands of years

3) methane (CH_4):

   12 ±3 years



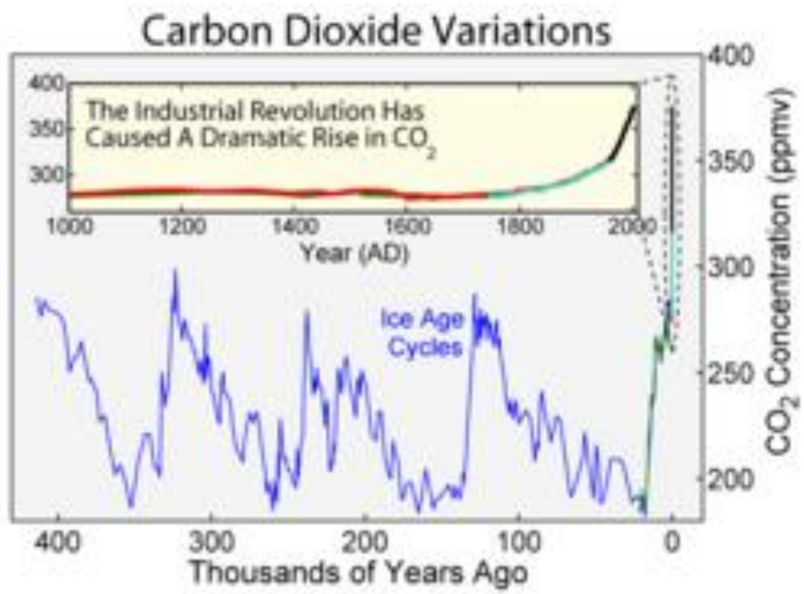
4) chlorofluorocarbons (CFC):

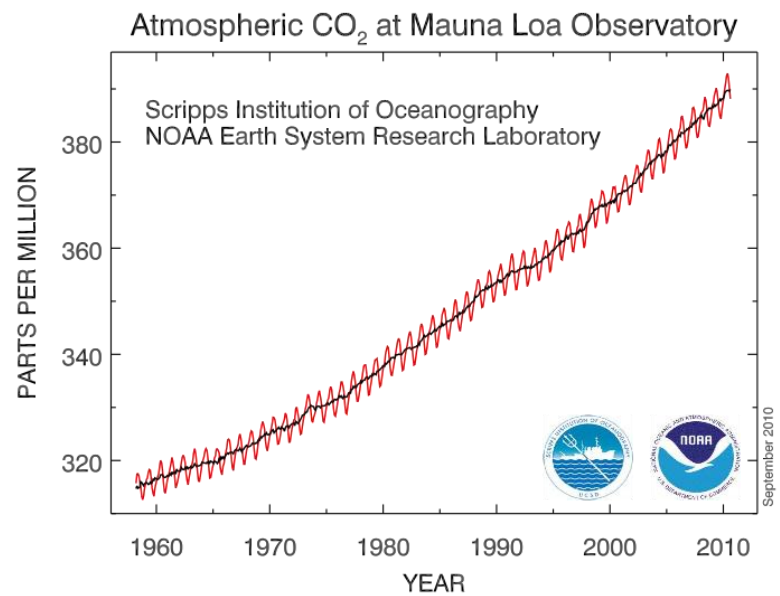
   decade to century

Consequently, anthropogenic greenhouse gases will impact global warming long after emission cut-backs are achieved.

Keeling Curve

Nature can no longer mitigate the extra carbon that human activities are emitting into the atmosphere.





In the past, the atmospheric carbon dioxide concentration has varied within a certain range. However, this graph clearly shows an increase in atmospheric carbon dioxide concentration since the beginning of the Industrial Revolution.

The Keeling curve documents the observed increase in atmospheric carbon dioxide concentration since 1958. The annual oscillation in the graph is explained by a decrease during the vegetative growing season in the Northern hemisphere and an increase in the winter months when plants are dormant and natural and anthropogenic carbon dioxide contributions to the atmosphere continue.