Sediments and Sea Levels Effects on Climate Change

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Abstract

In the last two hundred years human's burning of fossil fuels have caused excess carbon dioxide to be released into the atmosphere. In 1880, the atmospheric carbon increased from 280 to 300 ppm in just one year due to the burning of fossil fuels. The increasing amount of carbon dioxide in the atmosphere transfers into the ocean, negatively affecting marine life. This carbon dioxide has contributed to ocean acidification and rising sea levels. Ocean acidification has affected the largest producers of organic carbon in the world, phytoplankton. In the past, the ocean has been more acidic than today, and the ancestors of today's phytoplankton adapted by calcifying smaller calcium carbonate shells. This trend of decreasing calcification in the shells of the phytoplankton is progressing in organisms of today in the last century. Methods of dumping excess carbon dioxide into the deep waters of the ocean may affect phytoplankton even more. Sea levels are rising from thermal expansion and melting glaciers, and human's groundwater mining is playing a role. Rising sea levels are flooding coastal marshes and causing salt intrusions that could have a devastating effect on marine organisms. Preventions humans have engineered so far have been temporary and inconsistent, and structures have been built to withstand the changes instead of trying to delay them.

Scientists are growing increasingly concerned regarding the impacts of climate change. As fossil fuels are burned, more carbon dioxide is released into the atmosphere and complications arise in response to the unnatural rise in atmospheric carbon. In 1880, the atmospheric carbon increased from 280 to 300 ppm in just one year due to the burning of fossil fuels. Humans are unquestionably the cause of this sudden jump in carbon dioxide in the atmosphere. This excess carbon dioxide in the atmosphere is causing complications to marine organisms and is raising the temperature of the ocean and atmosphere, causing the sea levels to rise.

The carbon dioxide in the atmosphere transfers into the ocean, causing negative effects to calcium-carbonate producing phytoplankton. The ocean is the largest of the rapidly exchanging carbon reservoirs on the globe.

Increased carbon dioxide dissolution in surface ocean waters causes a decrease in seawater pH. Increases of carbon dioxide dissolution causes a decrease in carbonate ion concentration, called ocean acidification. Ocean acidification can harm biological carbon pumps in the oceans and decrease the ocean’s ability to hold carbon.

Throughout the ocean, carbon dioxide is produced as the organisms respire, just as oxygen is respired as carbon dioxide on land. In the shallow waters this excess carbon dioxide escapes into the atmosphere, but in the deeper waters the carbon dioxide is trapped. This built up carbon dioxide dissolves the calcium carbonate in the water.

When the added carbon dioxide mixes with water in the ocean, carbonic acid is formed, making the ocean’s water more acidic. If there is more carbon dioxide in the atmosphere, there are less carbonate ions for phytoplankton. Without as much carbonate to produce their shells, phytoplankton must adapt to survive.

During the Aptian age about 120 million years ago, the ocean was extremely acidic. Levels of acidity in today’s oceans are about 400 ppm, but during this time, levels of acidity rose to 800 ppm. The high levels of acidity were cause by volcanic eruptions in the ocean.

In this geologic past, organisms were able to cope with higher levels of carbon dioxide than is present in oceans today. The ancestors of today’s phytoplankton coped with the changing pH level by building smaller calcium carbonate shells. The species themselves reduced in size but increased in variety. Species of phytoplankton with larger shells reduced largely in number until the ocean returned to a less acidic state. A process taking 160,000 years was necessary for the ocean to return to a more neutral acidity, with a 25,000 year gap before the deeper waters were affected at all.

This trend of decreasing calcification in the shells of the phytoplankton is progressing in organisms of today in the last century. Different species of phytoplankton are expected to adapt in varying ways to the lack of calcium carbonate.

Changes in calcification also affect oceanic carbon storage. The oceans have sequestered about 30 to 40 percent of carbon dioxide in the last two hundred years. If the calcium carbonate production is changed, the ocean's capacity to absorb carbon dioxide could change. Henry's Law states that the concentration of a dissolved gas in a solution is directly proportional to the partial pressure of the gas above the liquid. If the amount of carbon dioxide in the atmosphere increases, the amount of carbon dioxide the ocean absorbs increases.

A recent study on rapid climate change and ocean acidification appearing in *Science* concluded that when atmospheric carbon dioxide concentrations reach 450-550ppm-- a possible occurrence by the middle of this century-- the rates of calcification by coral will be overcome by reef erosion. Coupled with the rising temperatures, this climate may "reduce coral reef ecosystems to crumbling frameworks with few calcareous corals."

Because the carbon dioxide found in the deepest waters of the ocean is essentially cut off from the surrounding atmosphere, it is possible to inject carbon dioxide into the deepest waters of the ocean in hopes of clearing excess carbon dioxide the atmosphere. Small studies have been conducted entertaining the idea of carbon dioxide intentionally being stored in the depths of the ocean. Twenty-five years of theoretical study and models have been conducted on the subject, but the idea has not been thoroughly tested. Scientists have hypothesized water-proof pipe-lines to the storage area or air-tight ships as transport.

The world is covered by seventy percent water; there is little limit to the amount of carbon dioxide that could be stored in these hypothetical carbon dioxide dumps. Over time, the carbon dioxide dumped in the oceans would reach equilibrium amongst the calcium carbonate and silica coming in from freshwater rivers and phytoplankton.

The carbon dioxide deep in the ocean would be retained from the atmosphere only for a few hundred years. Studies are being conducted to engineer ways to slow the carbon dioxide's reentrance into the atmosphere. Scientist have considered forming solid carbon dioxide hydrates and dissolving mineral carbonates to increase the carbon dioxide's solubility. Dissolving mineral carbonates may keep the carbon dioxide in the water's depths for up to ten thousand years.

If the study was to be gone through with, the ocean life around this carbon dioxide would have to be unaffected by the huge increase of carbon dioxide into their waters.

Experiments have shown that this added carbon dioxide could harm marine organisms. Effects of the excess carbon dioxide have only been studied on surface level organisms for duration of several months. Carbon dioxide has caused negative effects on calcification, reproduction, growth, circulatory oxygen supply, and mobility of phytoplankton. Long-term effects must be studied on deep sea organisms to go through with this proposal.

The calcium carbonate these organisms create balances the input of carbon dioxide into the ocean. The rivers that feed into the ocean hold solutions of calcium bicarbonate and silica, which, if not countered, would cause chemical imbalance in the ocean's waters. Almost all of the calcium carbonate in the ocean is produced by calcareous ooze.

Calcium carbonate is a necessary chemical for a healthy ocean; this chemical is intertwined with many marine processes of organic carbon. Phytoplankton's photosynthesis is the biggest producer of organic carbon. Calcareous organisms thrive in the surface waters where they are able to absorb light necessary for photosynthesis. These phytoplankton require the inorganic nutrients abundant in surface waters, such as aragonite and calcite.

Because surface waters are supersaturated with calcium carbonate, the excess carbon dioxide that absorbs into the water from the atmosphere would not cause the calcium carbonate to dissolve immediately. As the super saturation of calcium carbonate decreases, though, the calcareous organisms produce calcium carbonate more slowly. These organisms make their shells out of calcium carbonate in a process called biogenic calcifying. The rate of this calcification is dependent on the amount of calcium carbonate in the ocean.

Much of the organic matter that lives in the surface waters sinks down to the deeper waters when it perishes. It is not until their skeletons sink to the ocean floor that the organisms build up as ocean sediment. Once the calcareous organisms' skeletons have built up to a concentration of at least thirty percent, they are formed into calcareous ooze.

In the depths of the ocean, the temperature is lower and the pressure is higher. This is a more suitable environment for carbon dioxide to be held in a solution. When there is more carbon dioxide in a solution, more calcium carbonate can dissolve. Calcium carbonate solution is affected by the temperature of the surrounding water, the pressure, and the partial pressure of the carbon dioxide. An increase of Pco2 causes a lack of the inorganic nutrients found in the surface waters. This increase in Pco2 is caused by the oxidation of the organic matter that has fallen from the surface waters into the deeper waters.

The shells of calcareous organisms are much heavier than the water. This causes which them to sink toward deeper waters. Many aspects of these tiny organisms, including their size itself, are created to combat this downward pull and increase their buoyancy. Because of this, most of their remains never reach the sea floor.

Calcareous ooze does not form deeper than 4500 meters simply because the shells do not make it to the ocean floor. The carbon dioxide in the deeper waters dissolves the carbonate shells. Those that do are too delicate to be preserved intact in the sediments.

$$CaCO_3 + H_20 + CO_2 <====> Ca^{++} + 2HCO_3^-$$

Though a tentative solution has been introduced to store the excess carbon dioxide in the atmosphere, excess carbon dioxide is not the only cause of the temperature's rise. Sea levels are rising. Scientists predict a 31mm sea level rise by 2050 since 1900. (groundwater)

As water gets warmer, it takes up more space. When you multiply the expansion of each miniscule drop over the entire depth of the ocean, it adds up, causing sea level to rise. This is called thermal expansion. Sea level is also rising because melting glaciers and ice sheets are adding more water to the oceans.

We cannot easily measure how much the sea level has risen because of regional differences and minor fluctuations over time. These minor fluctuations are either global or regional.

Global fluctuations make transgressions and regressions the shelves of all the continents. For example, Louisiana is losing over one hundred square kilometers of land per year, while emergence of land has caused difficulty for Finnish port authorities facing shallow harbors. () These are called eustatic changes, and they come from changes in the volume of ocean water or the average depth of the ocean basin.

Regional fluctuations are on one tectonic shelf, cause by sinking or uplifting of the shelf. These fluctuations are called tectonic changes. At the continental shelves, processes that are physical, chemical, and biological, are at a high intensity. This speeds up the waves, tides, and currents.

Where areas of the sea are exposed, the areas erode. Where the areas are submerged, they build up. The submerged areas absorb more sunlight than exposed ones, so the climate is not as warm when the sea levels are high and the submerged areas are absorbing the sunlight. When the ocean has retreated and the sea levels are lower, less sunlight is absorbed by the water and the climate is warmer.

The waves and the tides play a role in sea level as well. Some beaches seem to dip drastically where the land ends and the sea begins. This dip is called a sea cliff, and is a direct result of the force of the waves and the resistance of the material the land is made of. One may also recognize this eating away of the land as erosion. Places where sea cliffs grow rapidly have lost coastal development to the ocean.

Waves also move the ocean's floor, sorting through each grain of sediment and creating ripple marks on the ocean floor. Coquina, a type of rock built entirely from the skeletons of

Table 1-1. Worldwide Sea Level Rise Scenarios, 1980–2100 (in cm and ft above 1980 levels)

Scenario	*2000*	*2025*	*2050*	*2075*	*2100*
Conservative	4.8 (0.16)	13.0 (0.43)	23.8 (0.78)	38.0 (1.2)	56.2 (1.8)
Mid-range Low	8.8 (0.29)	26.2 (0.86)	52.3 (1.7)	91.2 (3.0)	144.4 (4.7)
Mid-range High	13.2 (0.43)	39.3 (1.3)	78.6 (2.6)	136.8 (4.5)	216.6 (7.1)
High	17.1 (0.56)	54.9 (1.8)	116.7 (3.8)	212.7 (7.0)	345.0 (11.3)

Table 1-2. Sea Level Rise Scenarios for Charleston, 1980-2075 (in cm, with ft in parentheses)

		Year	
Scenario[a]	*1980*	*2025*	*2075*
Baseline	0	11.2 (0.4)	23.8 (0.8)
Low	0	28.2 (0.9)	87.6 (2.9)
Medium	0	46 (1.5)	159.2 (5.2)
High	0	63.8 (2.1)	231.6 (7.6)

Source: Global sea level rise scenarios are from Chapter 3, modified to reflect local conditions based on the historical trend for Charleston. (S. D. Hicks et al., 1983, *Sea Level Variations for the United States, 1855-1980,* technical report, Rockville, Md., NOAA, Tides and Water Levels Branch)

[a]Baseline scenarios for each year reflect present trends. Other scenarios reflect accelerated sea level rises at various rates.

Table 1-3. Sea Level Rise Scenarios for Galveston, 1980-2075 (in cm, with ft in parentheses)

		Year	
Scenario	*1980*	*2025*	*2075*
Baseline	0	13.7 (0.45)	30.0 (0.98)
Low	0	30.7 (1.0)	92.4 (3.0)
Medium	0	48.4 (1.6)	164.5 (5.4)
High	0	66.2 (2.2)	236.9 (7.8)

Source: See Chapter 5.

marine organisms, is also a result of the waves sorting through the shells and skeletons. The waves only affect the sediment down ten to twenty meters, though, and even massive storms can only affect up to thirty meters of sediment.

In places particularly ravaged by waves and tides, sediments can be produced. Examples of sediment chemically produced by waves are calcareous oozes or polished beach shingles. Tides affect the sea's level daily with their rise and fall, from a few centimeters to many meters.

Though these minor fluctuations are the most common fluctuations of sea level, today's rising sea levels are not the first major fluctuation in sea level. The ocean's level and climate have fluctuated together in cycles of 100,000 years for the last two million years.

Ice ages are cause by changed in solar irradiance due to changes in the earth's axis. During ice ages, glaciers cover most portions of the continent. Around fifteen thousand years ago until seven thousand years ago after the last ice age, the Laurentian and Scandinavian Ice sheets melted and the sea level rose about one hundred and thirty meters as a whole. Seal level before these glaciers melted was about one hundred meters lower than today. Since the end of the last ice age, the sea level has risen approximately one meter per century. By putting back into carbon into the atmosphere that had been sequestered over the ages as fossil fuels, man is reversing millions of years of natural evolution. (an overview of) The concentration of carbon dioxide in the atmosphere should double by 2100.

Different areas of the world reacted in varying ways to this rise in sea level. Gently sloping shores without built up sea cliffs rose quickly. Coastal peat bogs would have been intruded by salt water that covered up the bog's ground with marine sediments. Dunes would have been eroded away unless it was cemented by lime that was created by shell material. This tough matter is called transgression conglomerate.

If the ocean's level was to rise like this today, similar reactions would occur. The rise of sea levels would flood the coastal wetlands and kill vegetation that are critical to the reproductive cycles of many marine species. Salt intrusion would be a threat to marine animals.

During past major fluctuations, humans have not been around to suffer the effect of rising sea levels. Today humans are densely populated in coastal regions. Nearly 75 percent of Americans, for example, live on or within 50 miles of the coast.

For humans today, rising seas will increase coastal erosion, pollution, storm damage, and flooding. The sea will harm coastal roads, bridges, jetties, breakwaters, docks, piers, and waterfront property. Sea level rise will cause shoreline retreat, temporary flooding, and salt intrusion. The most obvious consequence of a rise in sea level would be permanent inundation of low-lying areas. A sea level rise of a few meters would inundate major portions of Louisiana and Florida, as well as beach resorts along the coasts. Marshes and low-lying flood plains along rivers and bays would also be lost.

Methods to prevent this rise of sea level can be separated into two categories: eliminating or greatly reducing contribution to the problem, or using some kind of draining to reverse the damage.

The obvious solution to this dilemma is to build a wall. Examples of such barriers are the Maeslant Barrier, the Thames Barrier, the Venice Mose, and the Bay Arc. These projects can protect large areas consistently, but they are extremely expensive to build and may have damaging effects on the ecosystem.

Many businesses are dumping sand on to their beaches to protect coastal development, and consequently, their profits. This is a form of linear protection. Breakwaters have been built parallel to the shore to reduce waves, and sea walls have been built. These walls are short term solutions, though, as they eventually increase the vulnerability of beaches and make the area suspect to flooding.

Some businesses have stopped fighting the coast's deterioration and have begun to build structures to cope with the changing beaches. Structures built on stilts, floating structures, and even floodable development have been engineered to sustain flooding.

One effect humans are having on the sea levels rise is the pumping of groundwater. The water society pumps for drinking water and irrigation eventually evaporates into the atmosphere and rains down into the ocean. Groundwater pumping causes the water supply to be depleted faster than it can be replenished. This groundwater mining is becoming so excessive, Yoshide Wada of Utrecht University in the Netherlands states that "Other than the ice on land, the excessive groundwater extractions are fast becoming the most important terrestrial water contribution to sea level rise. If society is concerned about the melting of glaciers and ice caps' contribution to the ocean, should they not be concerned about their own equally devastating contribution to the problem?

When the United Nations Intergovernmental Panel on Climate change in 2007 reported the melting glacier's effect on sea level rise, they didn't address other water sources adding to the ocean, sources like groundwater, reservoirs, and wetlands. In 2000, groundwater pumping caused the sea levels to rise about 5.7 mm. Compared to 1900's rise of .035 mm, this is a big shift. (Groundwater pumping) Increased water needs have contributed to this huge rise in groundwater pumping. Government regulation of groundwater pumping could slow this process.

Though scientists have worked to engineer sea walls and adapted structures to prevent coastal development from being flooded, rising sea levels as a result of excess carbon dioxide in the atmosphere does not have a consistent and efficient solution. Ocean acidification affects the marine life in the ocean called phytoplankton, and these phytoplankton are adapting to the changing climate as well, reducing the size of their calcium carbonate shells.

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