Is sea level rising? Do we have to worry about it? By how much?

Sea level is indeed rising. This determination is made when one averages changes in sea level over the entire globe for the past century. The Intergovernmental Panel on Climate Change (IPCC) has estimated that the global average sea level has risen 10 to 25 cm (4 to 10 inches) in the past century. However, sea level is affected by many factors, including local ones, so sea level change at any single location may be either a rise, a fall, or no change at all.

Furthermore, IPCC estimates that sea level will rise 20 to 86 cm (8 to 34 inches) by the year 2100. In other words, sea level rise will not only continue into the next century, but will continue at an accelerated rate.

Figure 1: Long sea level records from each continent: Takoradi, Ghana (Africa), Honolulu (Pacific), Sydney (Australia), Bombay (Asia), San Francisco (USA) and Brest (Europe). Each record has been offset vertically for presentation purposes. Observed trends for the twentieth century are 3.1, 1.5, 0.8, 0.9, 2.0 and 1.3 mm/year respectively. (Source: IPCC, 1995, Second Asssessment Report: The Science of Climate Change, Cambridge Univ. Press)

What causes sea level to rise?

Much of the rise in sea level has been due to the rise in global temperature associated with the global warming of the past century. This type of sea level rise is known as **eustatic sea level rise**. As the global temperature increases, the ocean water expands. This is also known as **thermal expansion** of the ocean water. The IPCC has estimated that thermal expansion has contributed 2 to 7 cm (1 to 3 inches) to the total sea-level rise over the past century.

In addition, as global temperatures rise, mountain glaciers melt. The IPCC estimates that 2 to 5 cm (1 to 2 inches) of the total sea-level rise over the last century has been due to the melting of glaciers. All over the world, scientists have documented the retreat of mountain glaciers, including the Rocky Mountains of North America, the Alps of Europe, and the Himalayas of Asia.

The effect of global temperature rise on the polar ice caps can be different at each of the two poles. Ice at the poles is of two types: **sea ice**, or frozen water floating on top of ocean water, and **ice sheets**, or large masses of frozen water on top of large land areas. The large continental ice sheets are those on Antarctica and Greenland. Whether these ice sheets are contributing to sea-level rise is largely unknown, but scientists are attempting to answer this question. It is hypothesized that Antarctica will not contribute to sea-level rise because it is just too cold there. In fact, if the rise in global temperature increases global precipitation rates, Antarctica is expected to store water as snow and ice, rather than contribute meltwater to the oceans. However, as ocean temperatures increase, the ice shelves around Antarctica may melt. While this may not contribute to sea-level rise (the ice shelves are already buoyant on the water's surface), the loss of the shelves may make the continental ice sheet unstable. Most scientists agree, however, that the Antarctic ice sheet will not pose a problem within the next century. On the other hand, it is hypothesized that the Greenland ice sheet will gradually melt and will contribute its water to the oceans, adding to the rate of sea-level rise.

Thus, eustatic sea level rise is a combination of thermal expansion of ocean water, melting of mountain glaciers, and the possible melting of continental ice sheets such as those of Greenland.

Another factor contributing to the rise in sea level is the movement of the land. Because the continents are dynamic and float on the Earth's mantle, the continents exhibit their own movements over long time periods. So, if a continent or portion of a continent is rising, the ocean water at the continent's coast will appear to fall with respect to the motion of the land. Likewise, if a continent or portion of a continent is sinking, the sea level at the coast will appear to rise. This effect is known as **relative sea level rise**.

A continent can be rising as a result of a retreating ice sheet from a previous ice age. As the Earth warms after an ice age and the weight of the ice is removed, the continent rebounds or rises higher in the mantel. This is currently occurring on the Norwegian Sea coast of Norway as a result of the retreat of the ice from the last ice age. On this coast, sea level is falling, not rising.

A continent can also be sinking as a result of retreat of ice sheets after an ice age. During an ice age, as the ice sheet presses down on the land, the land around the edge of the ice is forced up. When the ice sheets retreat, this land subsides. This is currently occurring in the Mid-Atlantic portion of the United States east coast. For example, in the Chesapeake Bay, the combined effects of sinking land (with its associated relative sea level rise) and eustatic sea level rise are resulting in a rate of sea level rise that is twice the world average.

Land can also subside as the result of groundwater extraction. Humans use groundwater for household and industrial purposes and obtain this water from aquifers deep within the ground. As the water is removed over long time periods, the land sinks. This is occuring in northern Italy where humans have extracted groundwater for many decades. As a result, the city of Venice is threatened by rising sea level due to land subsidence as well as the eustatic rise in sea level.

How does rising sea level affect us?

Rising sea level has such consequences coastal erosion, increased flood risk, and salt-water intrusion. Both human development and natural habitats are at risk when sea level rises.

Erosion is the main process that occurs to land as sea level rises. As a result, structures built by humans will be destroyed by the sea as the shoreline retreats. Entire properties can be eroded away. In some areas, a 30 cm (1 foot) rise in sea level can result in 4500 cm (150 feet) of landward erosion.

Natural landforms such as dunes, beaches and wetlands are also at risk. Ordinarily, as sea level rises, these features migrate inland. However, human development often prevents this natural migration. Structures such as dikes keep new beaches or wetlands from forming behind them. As a result, the existing beaches and wetlands erode or become inundated with water. Organisms that depend on the habitat for such resources as food or breeding grounds will lose their habitat and be faced with fewer and fewer resources.

Often, the very engineering efforts built by humans to protect against sea-level rise cause even more erosion. For example, the wave action at a bulkhead may prevent beach sediment from settling, so the sediment is deposited offshore rather than at the beach. Thus, the bulkhead works to enhance beach erosion rather than protecting against it.

Furthermore, human engineering of rivers have interrupted the supply of sediment to coasts. For example, dams and reservoirs on rivers trap sediment and prevent the sediment from being transported to the coast. Wetlands on the coast, for example, grow vertically because the marsh grasses trap the sediment brought there by rivers. Under ordinary circumstances, many marshes would thereby maintain their elevation in the face of rising sea level. With the sediment supply from rivers cut off due to trapping of sediment in reservoirs, the marshes can only erode or become inundated because there is not enough sediment to build new marsh.

Sea level rise also increases the risk of coastal areas to flooding. The higher the sea level, the higher the flood level of a storm. The Federal Emergency Management Agency (FEMA) has estimated that a rise in sea level of one foot would increase the size of the 100-year floodplain in the US from 19,500 square miles in 1990 to 23,000 square miles.

Water supplies for human or agricultural consumption are also affected by sea level rise. A higher sea level can mean that salty water intrudes into underground coastal aquifers more often than if the sea level were lower. Also, salty water can intrude higher upstream in estuaries, where the salty water may enter industrial or agricultural water intakes.

Do we have to worry about it?

Given the above effects of sea level rise on human property, state and local governments have implemented certain policies to mitigate against the risk. **Setbacks** are zones along the coast which are at high risk of erosion. Property owners may not build or may have restrictions on building within these zones. These zones are typically established for a certain time period into the future based on the current rate of erosion. For example, the 30-year setback is the zone of coast that is expected to erode within the next thirty years (i.e., 30 times the current annual rate of erosion). The purpose of setbacks is to allow the natural features of coast such as dunes, beaches and wetlands to migrate landward as sea level rises.

Setbacks, however, are unpopular with property owners because they impose restrictions. Therefore, some states have implemented a policy of **rolling easements** where owners may build but are required to remove a structure when it becomes threatened by an eroding shoreline.

Flood insurance costs will also rise. According to FEMA, a 30 cm (1 foot) rise in sea level is expected to increase flood damages by 36-58 percent. As a result, insurance companies will have to increase flood insurance rates for coasts prone to flooding.

http://gcmd.gsfc.nasa.gov/Resources/Learning/sealevel.html