Our Ocean Backyard — *Santa Cruz Sentinel* columns by Gary Griggs, Director, Institute of Marine Sciences, UC Santa Cruz.

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Changing Climates and Migrating Shorelines

The rise and fall of global sea level is intimately connected to the climate history of the planet. When the Earth gets warm, two processes take place that conspire to raise the level of the oceans. One is the expansion of seawater as the ocean temperature rises. Warm water takes up more space than cold water, so as the ocean heats up, it expands and raises sea level. Your home water heater was designed with this thermal expansion in mind. When you fill your water heater, you need to leave some extra room at the top, so when the water is heated it has room to expand and doesn't blow up your house. Actually, there is also a high pressure release valve or overflow to keep that from happening. The ocean also has space for that extra water to go; it's called the continental shelf.

The other 800-pound gorilla in the climate room is ice, and there is quite a lot of it scattered around the planet, most of it in the Arctic and Antarctic. And there was a whole lot more during past Ice Ages. The warmer the Earth's climate, the more of that ice melts, which is happening today. And all ice melts at 32 degrees Fahrenheit, it doesn't matter if you are a Republican or a Democrat.

Climate change has taken place ever since we've had an Earth and a Sun, or for about 4.5 billion years. In response, sea level is always changing. Climate gets warm, ice sheets and glaciers melt, ocean water expands and sea level rises. But why does climate change?

It all really boils down to how much heat we get from the Sun. Even though the sun is about 93 million miles away, it's the heat from the fusion of hydrogen into helium that provides nearly all the Earth's heat.

But the distance from the Earth to the Sun changes over time due to three irregularities in the Earth's rotation and orbit. Our yearly trip around the sun isn't circular, but elliptical. Over a period of about 100,000 years we move a little closer to the sun, which makes the Earth a little warmer, and then we get a little farther away, which makes things cooler.

The Earth also tilts slightly on its axis of rotation, producing the seasons. But over a period of about 41,000 years, the tilt changes slightly (from 22 to 24.5 degrees). This also affects the amount of sunlight reaching different parts of the Earth. The third piece of the puzzle is a wobble in the Earth's rotation, which changes over a cycle of about 26,000 years.

These three irregularities in the Earth's orbit have been taking place throughout virtually the entire 4.5 billion year history of the Earth, and in concert, determine how much heat we receive from that burning mass 93 million miles away. When combined with a few other global changes, like how the continents and oceans are distributed around the planet, the Earth's overall temperature can change by as much as 8 degrees C. This is enough to help initiate or end an Ice Age and change sea level by hundreds of feet.

The records of the climate changes that the Earth has experienced are diverse, widespread and well documented. These include: 1) the fossil record from deep-sea sediment cores extending back 65 million years; 2) the chemical signatures from long Antarctic ice cores that extend back 850,000 years; 3) 10,000 year old climate records extracted from deep-sea corals; and 4) dendrochronology, or the study of tree rings from California's bristlecone pines that can be 5000 years old.

Tide gauges have recorded sea level changes for over 150 years and satellites have provided precise values for the past 23 years. Sampling the offshore continental shelf has allowed us to determine where ancient shorelines were from the fossils that have been recovered.

Whether from the floor of the North Sea, or the shallow ocean bottom off Florida or southern California, the presence of intertidal organisms, ancient beach sands, peat or marsh deposits, now well below present sea level, have allowed us to determine where the shoreline was over the past 20,000 years since the last great ice age ended, and its moved around a lot.