So in the last section we raised a question of why so much CO_2 is going into the ocean. We also saw that the CO_2 reservoir in the ocean is much, much larger than that in the atmosphere. It's helpful to compare the behavior of CO_2 to that of argon, which has a similar mass. There's something like 40 times more argon in the atmosphere than in the ocean. But for CO_2 the opposite is the case. There's over 60 times more carbon in the ocean than in the atmosphere. So why might this be?

Well for both gases the flux of either argon or carbon dioxide between the air and the surface ocean is proportional to the difference in partial pressures of the two gases in the air and in the sea. So if the partial pressure of argon is higher in the surface ocean than it is in the air above it, argon will move from the ocean into the atmosphere, and vice versa. The same is true for CO_2. If the partial pressure of CO_2 is higher in the atmosphere, CO_2 will move into the surface ocean.

But for argon the story pretty much stops there. For CO_2 it's just the beginning. If CO_2 in the air rises, CO_2 moves into the surface ocean. It's then equilibrates with a very large reservoir of other species of carbon that exist in the world's oceans. It first combines with water to form carbonic acid. It then partially dissociates to form the bicarbonate ion, which has a negative charge.

And after further dissociation it becomes the carbonate ion, which has a negative 2 charge. Looking at the full equations, we see CO_2 combines with water to form carbonic acid, carbonic acid can dissociate partially, losing a hydrogen ion and forming the bicarbonate ion, and the bicarbonate ion can also dissociate, losing a hydrogen ion and forming the carbonate ion. Summing all these together, we get what's known as dissolved inorganic carbon, or DIC. It's also sometimes known as total CO_2. And here we combine carbonic acid with CO_2 gas dissolved in the water, because these two are hard to distinguish analytically.

One consequence of these equations is that as CO_2 moves from CO_2 gas to carbonate ion, hydrogen ions are released. This increases the acidity of the oceans and reduces pH. We'll explore this more in just a minute. A further implication is that the distribution of carbon between aqueous CO_2, or carbonic acid, and bicarbonate ion, and carbonate ion is in equilibrium with the pH of seawater. Shown here is the distribution of carbon between these different species as a function of pH. Seawater pH is around 8.2, and so you can see that at this pH most of the carbon is in the form of bicarbonate ion, about 10%

is the carbonate ion, and a very small proportion is as dissolved CO2, or carbonic acid.

Let's get back to this point, that as you add carbon to the ocean, its combination with water leads to dissociations that increase the acidity of seawater. We're able to observe this in stable open ocean sites such as what's known as Station Aloha, north of Hawaii. Shown in red is rising atmospheric pCO2, measured at the Mauna Loa Station. Shown in blue is surface water pCO2, measured at Station Aloha. It's rising along with the atmosphere, has large interannual and seasonal variability, and it's not quite in equilibrium with the atmosphere.

In parallel, with this rise in surface ocean pCO2 is a decline in surface ocean pH, consistent with the equations that we've just looked at. As pH declines two things happen. First of all, the proportion of carbon that is in the form of dissolved CO2 rises because surface ocean dissolved CO2 seeks equilibrium with atmospheric pCO2. This exerts an increasing back pressure on the atmosphere, and makes it harder for more CO2 in the atmosphere to move into the ocean.

The other thing that happens is that the proportion of dissolved inorganic carbon that's in the form of the carbonate ion decreases. This is important because the carbonate ion is what is easiest for organisms to use to combine with calcium to form calcium carbonate shells. As carbonate ion concentrations decrease, the saturation state of calcium carbonate in the world's ocean decreases. That is, the world's oceans become more corrosive to calcium carbonate. This means that organisms have to expend increasing amounts of energy to secrete calcium carbonate shells and to preserve them from dissolution. It also means that seafloor calcium carbonate starts to dissolve, which acts to partially buffer the decrease in ocean pH.

This decline in saturation state is already observable at places like Station Aloha. Shown in purple is the saturation state for one form of calcium carbonate, that of calcite. And shown in blue is the saturation state of the second form of calcium carbonate, known as aragonite, which is what most corals build their skeletons out of. We see that both saturation states are declining with time, which effectively means that the oceans are becoming more corrosive.