How the oceans influence climate

The oceans influence climate over long and short time-scales. On the longest time-scale of geologic time, the shape and location of the continents helps to determine the oceans' circulation patterns. Since continental plates drift at about 5 cm per year and mountain ranges rise by about 1 mm, it usually takes millions of years for new land formations to change the oceans. Patterns of ocean circulation and up-welling can also change much more rapidly, resulting in climate variations and fluctuations on a human time-scale. Records of global and, in particular, regional climate show periods lasting from years to centuries during which the climate was systematically different from earlier and later periods. Scientists believe that this behavior is related to changes in the way the oceans store and transport heat, although the precise causes of these changes are not always clear.

The oceans and the atmosphere are tightly linked and together form the most dynamic component of the climate system. Changes in external factors such the sun's energy, the distribution of various plant species, or the emission of greenhouse gases into the atmosphere can alter the temperature and circulation patterns of the atmosphere-ocean system. Because the atmosphere and oceans are turbulent, they can also generate their own internal fluctuations. Short-term fluctuations in wind or temperature (that is, weather) can directly influence the currents and temperature of the underlying ocean, while oceanic fluctuations can magnify, diminish, or modify atmospheric fluctuations.

The oceans play a critical role in storing heat and carbon). When the earth's surface cools or is heated by the sun, the temperature change is greater - and faster - over the land than over the oceans. Because it is a fluid, the ocean diffuses the effects of a temperature change for great distances via vertical mixing and convective movements. The solid land cannot, so the sun's heat penetrates only the thin, upper crust. One consequence of the ocean's ability to absorb more heat is that when an area of ocean becomes warmer or cooler than usual, it takes much longer for that area to revert to "normal" than it would for a land area. This also explains why "maritime" climates tend to be less extreme than "continental" ones, with smaller day-night and winter-summer differences.

The ocean's waters are constantly being moved about by powerful currents. Surface currents are largely wind-driven, although the rotation of the earth, the presence of continents, and the oceans' internal dynamics also have a strong influence. Deep-ocean flow (and, to a lesser extent, surface flow) is driven by density differences produced by heating and cooling and by precipitation and evaporation (cool saline water is denser than warm fresh-water). The behavior of the atmosphere strongly affects these density differences. For example, clouds can cool the sea by blocking the warming rays of the sun or reduce surface salinity by bringing rain. The wind can influence evaporation rates by blowing more strongly or more weakly.

These currents influence the climate by transporting heat. Horizontal currents, particularly those moving north or south, can carry warmed or cooled water as far as several thousand kilometers. The displaced water can then warm or cool the air and, indirectly, the land over which this air blows. For example, water from the tropical and subtropical Atlantic (including some from the Gulf of Mexico) moves north through the Atlantic in a current popularly (if misleadingly) called the "Gulf Stream". There it bathes the shores of Western Europe, producing a climate that is surprisingly mild for that latitude. In addition to currents, up-wellings of cold water in places where the wind blows surface water away can also affect climate. Thus San Francisco, influenced by coastal up-welling, is hardly warmer than Dublin, which is influenced by the Gulf Stream, despite being over 1,600 km further south.

Currents involved in "deep-water formation" are particularly important for climate. In winter, surface cooling causes water to become more dense. (While fresh-water that is cooled starts to expand at temperatures below 4 C, salt-water continues to compress all the way down to its freezing point of -2 C.) In areas where evaporation exceeds precipitation, the resulting rise in salinity also increases density. When the surface water becomes denser than the underlying water, "convective overturning" occurs and the dense surface water mixes downwards. In certain places this downward mixing can occasionally extend all the way to the bottom, even in deep oceans. The dense, deep water thus formed spreads out over the whole ocean. As a result, when downward mixing takes place at high latitudes it creates a circulation pattern in which warm water from tropical and subtropical regions moves poleward, surrenders heat to the atmosphere, cools and sinks, and flows back towards the equator. The net result is a transport of heat poleward.

An apparently small change in just one aspect of the ocean's behavior can produce major climate variations over large areas of the earth. The areas of cold-water formation are one known example of this possibly wide-spread phenomenon. Although more research is needed, there is some agreement among oceanographers that, for the entire area north of 30 N latitude, the ocean's poleward transport of heat is the equivalent of about 15 watts per square meter of the earth's surface (W/m2). This can be compared with some 200 W/m2 from direct sunshine, and about 6 W/m2 for what climate change models predict will happen if the atmospheric concentration of carbon dioxide doubles. Recent observations, ocean core records, and some modelling results indicate that North Atlantic deep-water formation and its associated ocean heat flow fluctuate substantially over time-scales ranging from years to millennia. The system is vulnerable because even a relatively small decrease in surface salinity prevents water - no matter how cold it is - from sinking. This could occur if there is a flood of fresh-water run-off from the Arctic due to global warming.

Source: Climate Change Factsheets of Information Unit on Climate Change (IUCC)-UNEP, 1993