Frequently Asked Questions

FAQ 3.1 | Is the Ocean Warming?

Yes, the ocean is warming over many regions, depth ranges and time periods, although neither everywhere nor constantly. The signature of warming emerges most clearly when considering global, or even ocean basin, averages over time spans of a decade or more.

Ocean temperature at any given location can vary greatly with the seasons. It can also fluctuate substantially from year to year—or even decade to decade—because of variations in ocean currents and the exchange of heat between ocean and atmosphere.

Ocean temperatures have been recorded for centuries, but it was not until around 1971 that measurements were sufficiently comprehensive to estimate the average global temperature of the upper several hundred meters of the ocean confidently for any given year. In fact, before the international Argo temperature/salinity profiling float array first achieved worldwide coverage in 2005, the global average upper ocean temperature for any given year was sensitive to the methodology used to estimate it.

Global mean upper ocean temperatures have increased over decadal time scales from 1971 to 2010. Despite large uncertainty in most yearly means, this warming is a robust result. In the upper 75 m of the ocean, the global average warming trend has been 0.11 [0.09 to 0.13]°C per decade over this time. That trend generally lessens from the surface to mid-depth, reducing to about 0.04°C per decade by 200 m, and to less than 0.02°C per decade by 500 m.

Temperature anomalies enter the subsurface ocean by paths in addition to mixing from above (FAQ3.1, Figure 1). Colder—hence denser—waters from high latitudes can sink from the surface, then spread toward the equator beneath warmer, lighter, waters at lower latitudes. At a few locations—the northern North Atlantic Ocean and the Southern Ocean around Antarctica—ocean water is cooled so much that it sinks to great depths, even to the sea floor. This water then spreads out to fill much of the rest of the deep ocean. As ocean surface waters warm, these sinking waters also warm with time, increasing temperatures in the ocean interior much more quickly than would downward mixing of surface heating alone.

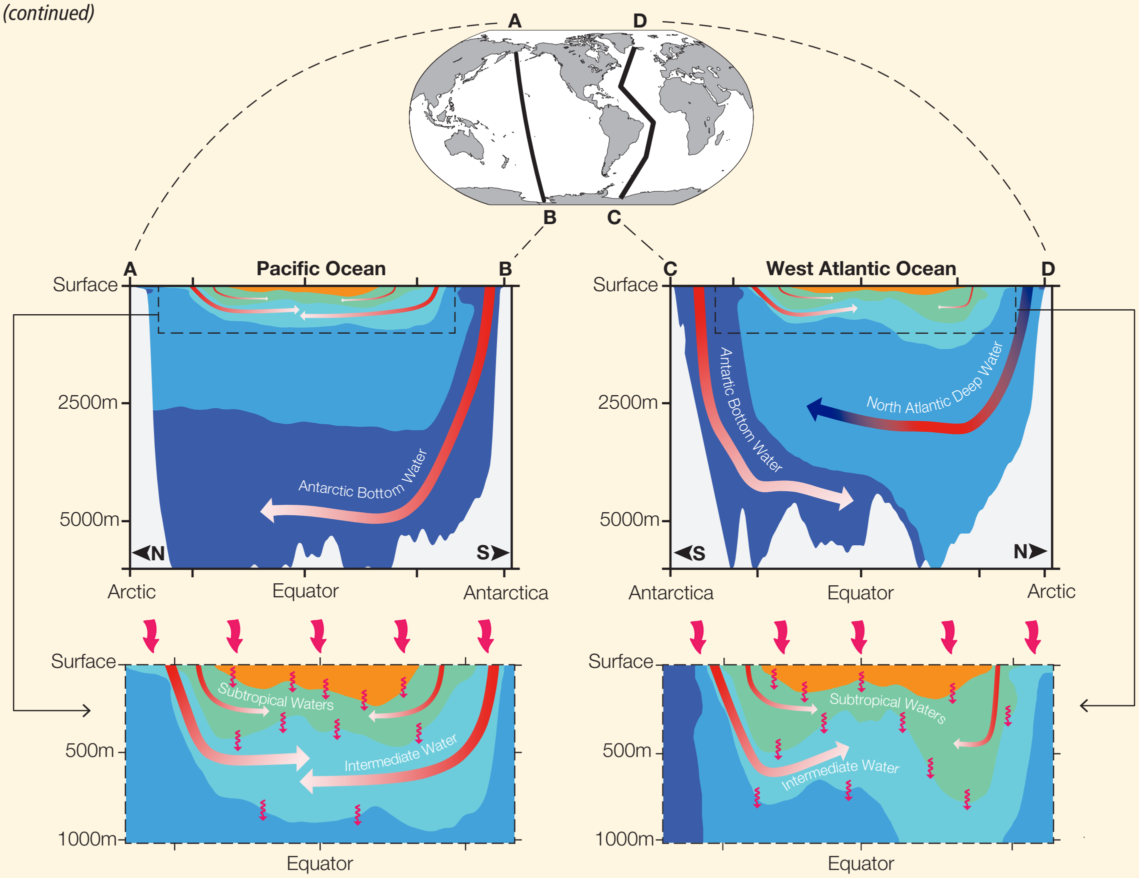
In the North Atlantic, the temperature of these deep waters varies from decade to decade—sometimes warming, sometimes cooling—depending on prevailing winter atmospheric patterns. Around Antarctica, bottom waters have warmed detectably from about 1992–2005, perhaps due to the strengthening and southward shift of westerly winds around the Southern Ocean over the last several decades. This warming signal in the deepest coldest bottom waters of the world ocean is detectable, although it weakens northward in the Indian, Atlantic and Pacific Oceans. Deep warming rates are generally less pronounced than ocean surface rates (around 0.03°C per decade since the 1990s in the deep and bottom waters around Antarctica, and smaller in many other locations). However, they occur over a large volume, so deep ocean warming contributes significantly to the total increase in ocean heat.

Estimates of historical changes in global average ocean temperature have become more accurate over the past several years, largely thanks to the recognition, and reduction, of systematic measurement errors. By carefully comparing less accurate measurements with sparser, more accurate ones at adjacent locations and similar times, scientists have reduced some spurious instrumental biases in the historical record. These improvements revealed that the global average ocean temperature has increased much more steadily from year to year than was reported prior to 2008. Nevertheless, the global average warming rate may not be uniform in time. In some years, the ocean appears to warm faster than average; in others, the warming rate seems to slow.

The ocean's large mass and high heat capacity allow it to store huge amounts of energy—more than 1000 times that in the atmosphere for an equivalent increase in temperature. The Earth is absorbing more heat than it is emitting back into space, and nearly all this excess heat is entering the oceans and being stored there. The ocean has absorbed about 93% of the combined heat stored by warmed air, sea, and land, and melted ice between 1971 and 2010.

The ocean's huge heat capacity and slow circulation lend it significant thermal inertia. It takes about a decade for near-surface ocean temperatures to adjust in response to climate forcing (Section 12.5), such as changes in greenhouse gas concentrations. Thus, if greenhouse gas concentrations could be held at present levels into the future, increases in the Earth's surface temperature would begin to slow within about a decade. However, deep ocean temperature would continue to warm for centuries to millennia (Section 12.5), and thus sea levels would continue to rise for centuries to millennia as well (Section 13.5). *(continued on next page)*

FAQ 3.1 (continued)



FAQ 3.1, Figure 1 | Ocean heat uptake pathways. The ocean is stratified, with the coldest, densest water in the deep ocean (upper panels: use map at top for orientation). Cold Antarctic Bottom Water (dark blue) sinks around Antarctica then spreads northward along the ocean floor into the central Pacific (upper left panel: red arrows fading to white indicate stronger warming of the bottom water most recently in contact with the ocean surface) and western Atlantic oceans (upper right panel), as well as the Indian Ocean (not shown). Less cold, hence lighter, North Atlantic Deep Water (lighter blue) sinks in the northern North Atlantic Ocean (upper right panel: red and blue arrow in the deep water indicates decadal warming and cooling), then spreads south above the Antarctic Bottom Water. Similarly, in the upper ocean (lower left panel shows Pacific Ocean detail, lower right panel the Atlantic), cool Intermediate Waters (cyan) sink in sub-polar regions (red arrows fading to white indicating warming with time), before spreading toward the equator under warmer Subtropical Waters (green), which in turn sink (red arrows fading to white indicate stronger warming of the intermediate and subtropical waters most recently in contact with the surface) and spread toward the equator under tropical waters, the warmest and lightest (orange) in all three oceans. Excess heat or cold entering at the ocean surface (top curvy red arrows) also mixes slowly downward (sub-surface wavy red arrows).

3.3.2 Global to Basin-Scale Trends

The salinity of near-surface waters is changing on global and basin scales, with an increase in the more evaporative regions and a decrease in the precipitation-dominant regions in almost all ocean basins.

3.3.2.1 Sea Surface Salinity

Multi-decadal trends in sea surface salinity have been documented in studies published since AR4 (Boyer et al., 2007; Hosoda et al., 2009; Roemmich and Gilson, 2009; Durack and Wijffels, 2010), confirming the trends reported in AR4 based mainly on Boyer et al. (2005). The spatial pattern of surface salinity change is similar to the distribution of surface salinity itself: salinity tends to increase in regions of high mean salinity, where evaporation exceeds precipitation, and tends to decrease in regions of low mean salinity, where precipitation dominates (Figure 3.4). For example, salinity generally increased in the surface salinity maxima formed in the evaporation-dominated subtropical gyres. The surface salinity minima at subpolar latitudes and the intertropical convergence zones have generally freshened. Interbasin salinity differences are also enhanced: the relatively salty Atlantic has become more saline on average, while the relatively fresh Pacific has become fresher (Figures 3.5 and 3.9). No well-defined trend is found in the subpolar North Atlantic , which is dominated by decadal variability from atmospheric modes like the North Atlantic Oscillation (NAO, Box 2.5). The 50-year salinity trends in Figure 3.4c, both positive and negative, are statistically significant at the 99% level over 43.8% of the global ocean surface (Durack and Wijffels, 2010); trends were less significant over the remainder of the surface. The patterns of salinity change in the complementary Hosoda et al. (2009) study of differences between the periods 1960–1989 and 2003–2007 (Figure 3.4d), using a different methodology, have a point-to-point correlation of 0.64 with