How our sea temperature has changed

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Climate Note 3/05 (August) in a series outlining observed climate changes or variations over recent decades in south-west Western Australia.

Summary

Sea surface temperature changes in the Indian Ocean since 1960 have resulted in a warming of 0.6°C averaged over the basin (Figure 1). The areas of largest warming are off Somalia, north-west WA and south of Madagascar. Over the same period, the heat content in the upper 300 m increased by 2 x 10^{22} Joules (Figure 2). The warming of the Indian Ocean is likely the result of the greenhouse effect combined with natural variation of the ocean-atmosphere system. Ongoing studies will address the mechanism of warming using improved ocean data sets and climate models. The changes in ocean temperature and heat content already have impacts on sea level rise, coral reefs heat stress, and global atmospheric circulation.

Sea surface temperatures in the Indian Ocean

Sea surface temperature (SST) in the Indian Ocean is higher than 28°C in the equatorial region and lower than 16°C in the southern Indian Ocean (Figure 1). On average the south-east trade winds and south-west monsoon blow toward the warmer water over the North Indian Ocean, a so-called direct response in the atmosphere.

The southward flowing Leeuwin Current off WA brings warm waters from the tropics and increases the surface temperature by about 3°C compared to farther offshore. The existence of the Leeuwin Current and its warm signature has a profound impact on the rock lobster and other industries and also affects the regional climate of south-west WA.

Changes at the sea surface

In the decade of 1991–2000, the average SST in the Indian Ocean was 0.6°C above the 1900–1960 base and continued to warm in 2001–2004. The largest increase is located in the Southern Ocean south of Madagascar, with secondary maxima off Somalia and north-west WA (Figure 1). In the Leeuwin Current, the temperature change is less than farther offshore and closer to the global average SST increase. This is due to the influence of El Niño/Southern Oscillation (ENSO) on the coast of WA. Since the mid-1970s, the Leeuwin Current is weaker, and its SST warming is damped by a shallow inshore thermocline. The impact of these changes in the SST gradients is not yet known.

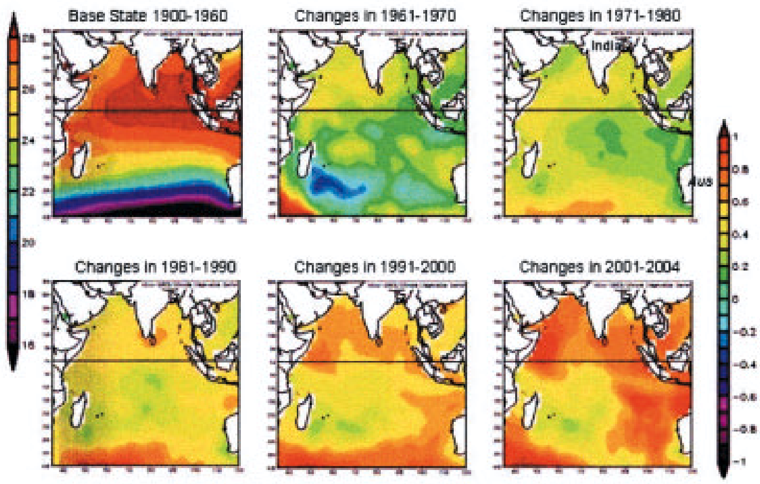

Figure 1: Decadal changes in mean sea surface temperatures. Mean sea surface temperature during 1900–1960 in the Indian Ocean and the relative temperature changes from the 1900–1960 mean over subsequent decades. The key on the left-hand-side is for mean temperature and that on the right-hand-side is for temperature change.

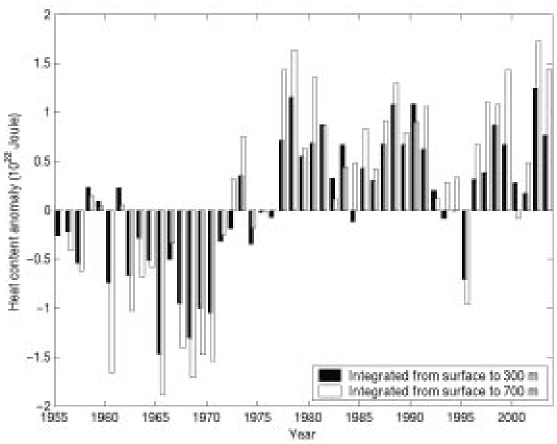

Figure 2: Heat content changes in the Indian Ocean.

Subsurface changes

Due to three-dimensional ocean circulation and mixing, change is also expected below the surface. A crude indicator of subsurface change is the heat content in the upper 300 m averaged over the whole basin (Figure 2). It is estimated to have increased by 2 x 10^{22} Joules. However, the increase has not been continuous, with a sharp change in the mid-1970s. The detailed subsurface temperature map of the Indian Ocean is not yet available; however, a high quality data set has been prepared and is being analysed.

What caused the changes?

From climate model simulations and radiative forcing analyses, the global warming during the second half of the 20th century is attributed to the greenhouse effect. The warming of SST can be transmitted down to deeper levels through vertical mixing and three-dimensional ocean circulation. However, the rapid change in heat content in the mid-1970s took place despite regional cooling within the depth range of the thermocline. A careful analysis of the subsurface temperature maps will be required to understand what caused the changes.

What are the implications?

The warming of the ocean has contributed significantly to the observed sea level rise, through thermal expansion of sea water.

Potentially, the atmospheric circulation pattern near WA may change as a result of the changed SST pattern. The impacts of Indian Ocean warming have been tracked to remote responses in the global climate system as far away as Sahel Africa and the North Atlantic.

The reduced precipitation in south-west WA in recent decades is a result of the changes in the atmospheric circulation patterns, which may have connections to ocean sea surface temperature variations.

Have there been impacts on WA coastal waters?

The coastal waters of north-west WA followed a similar warming trend to that of the Indian Ocean. The seasonal cycle of sea surface temperature off Ningaloo Reef, WA, is shown as an example (Figure 3).

Temperatures off Ningaloo increased by about 0.6°C in the recent decades, and there was a change of seasonal cycle. The highest temperature is now observed in April instead of March as in previous decades. A similar trend could be observed in other coastal areas and inferred from isotope measurements at coral reefs.

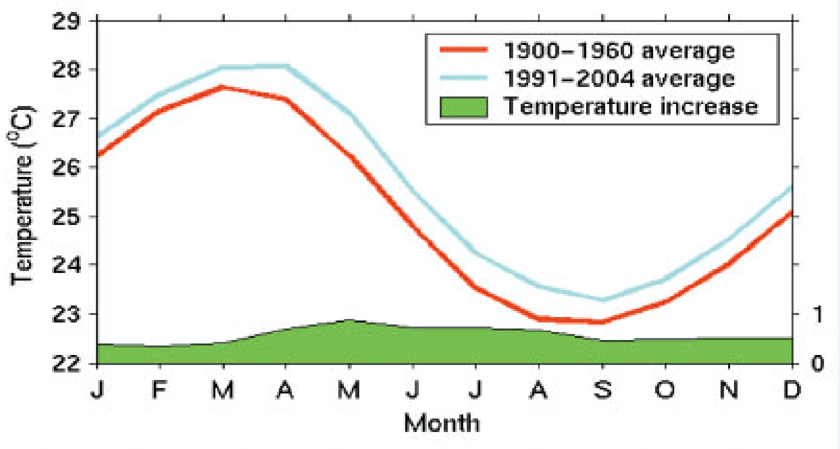

Figure 3: Averaged monthly sea surface temperatures at Ningaloo Reef during 1900–1960 and 1991–2004, and their differences. The axis on the right denotes the temperature increase.

The increase in sea surface temperature in the coastal region, superimposed on the annual and interannual variations, has increased the heat stress of the coral reefs.

What can we say about the future?

Human influences will continue to change atmospheric composition throughout the 21st century. It is predicted that the carbon dioxide level will increase by 90-250% of pre-industrial level in 2100, which will continue to affect the radiation balance of the earth. This mechanism is likely to continue to drive Indian Ocean SST upward. On the other hand, the genesis of the rapid change in the mid-1970s and its connection to ENSO is not yet understood and the possibility that the rapid change is a natural, decadal variation needs to be investigated.

With rising SST, the heat content of the ocean will continue to increase. The thermal expansion due to the heat content increase will cause further sea level rise.

The increase of heat content in the ocean may continue to affect the atmospheric circulation and rainfall patterns. Climate models suggest that the ocean thermohaline circulation, the density driven ocean conveyor belt that distributes heat energy from equatorial oceans to polar regions, may be weakened in a climate change scenario, though a complete shut-down and a dramatic irreversible change of the Earth's climate may not be foreseen by 2100.

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