Indian Ocean Climate Initiative

Informed Adaptation

Variability in the Leeuwin Current

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Climate Note 10/05 (August) in a series outlining observed climate changes or variations over recent decades in south-west Western Australia.

Introduction

Within each of the main ocean basins, the surface water circulation consists of a gyre (circular movement of water) with poleward flow along the westward boundary of the basin and equatorward flow along the eastern margin. The surface circulation off the WA coast is anomalous in that the Leeuwin Current transports water poleward.

The Leeuwin Current system

The Leeuwin Current system consists of three major currents (Figure 1): the southward flowing Leeuwin Current at the surface; the northward flowing Leeuwin Undercurrent (LU) at the sub-surface; and, the northward flowing Capes and Ningaloo Currents on the continental shelf during the summer months.

The Leeuwin Current (LC) is a shallow (< 300 m), narrow band (< 100 km wide) of warm, lower salinity, nutrient-depleted water of tropical origin, which flows south from Exmouth to Cape Leeuwin and on to the Great Australian Bight (Figure 2). The warm water signature of the LC extends from North-West Cape to Tasmania and is the longest boundary current in the world. The amount of water transported by the LC, along the west coast, ranges between 1 Sv (Sverdrup = 1 million cubic metres per second) and 7 Sv with a mean of 5 Sv. The LC flows stronger during winter (May–September) and weaker during summer (October–March). These changes are mainly due to variation in the wind field – during the summer the current flows against the prevailing southerly winds.

Summary

The anomalous Leeuwin Current plays a dominant role in controlling the marine life and climate of Western Australia. The Leeuwin Current system consists of three major currents: the southward flowing Leeuwin Current at the surface; the northward flowing Leeuwin Undercurrent at the sub-surface; and, the northward flowing Capes and Ningaloo Currents on the continental shelf during the summer months. These current systems exhibit seasonal and inter-annual variability. The Leeuwin Current is stronger during winter and under La Nina conditions and weaker during the summer and El Nino conditions. Long-term climate models have predicted the strength of the Leeuwin Current may increase slightly by 2100. However, this change is considered to be small compared to the inter-annual variability.

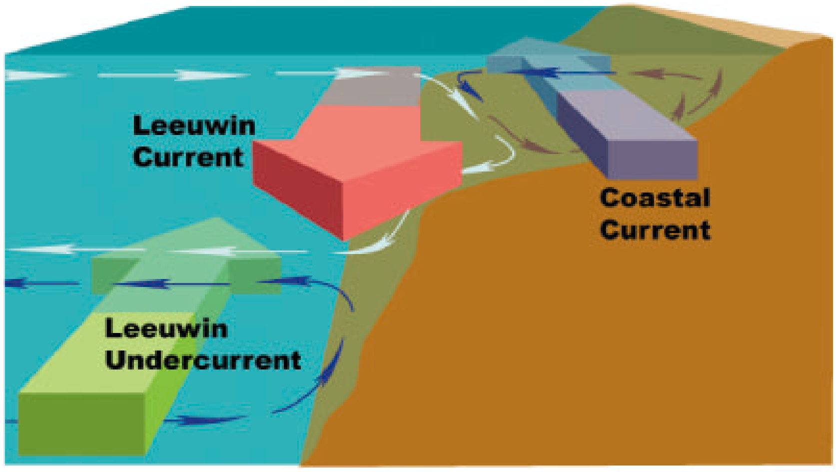

Figure 1: Schematic of the Leeuwin Current System. The coastal currents are the Capes and Ningaloo Currents, which flow during the summer months.

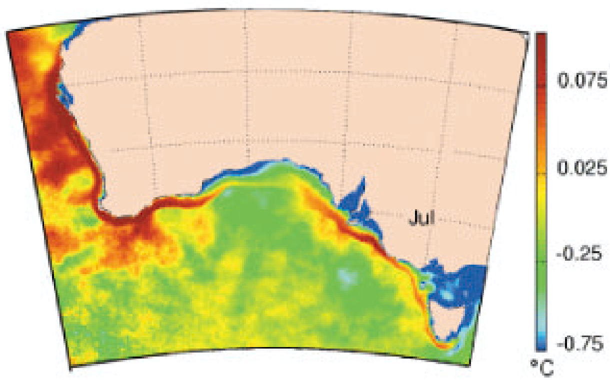

Figure 2: A composite satellite image of sea surface temperature anomalies in July. The Leeuwin Current can be identified as a narrow band of warmer water adjacent to the coast (image from CSIRO Marine Research).

The Leeuwin Undercurrent (LU) flows northwards beneath the LC at depths of 300–800 m transporting 5 Sv of higher salinity, oxygen-rich, nutrient-depleted water originating from the surface waters, south of Australia.

Inshore of the LC, cooler, higher salinity, wind-driven currents are present during the summer months. This includes the Capes Current flowing between Cape Leeuwin and Shark Bay. Similarly, north of Shark Bay, the Ningaloo Current flows inshore of the LC past North-West Cape.

Leeuwin Current variability

The LC exhibits seasonal and inter-annual variability. The LC is weakest in summer because it flows against strong southerly winds, whereas in winter it flows more strongly with a higher pressure gradient against weaker southerly winds. Because there is a correlation between the LC and the west coast sea levels; the mean monthly sea level at Fremantle is generally used as a proxy to determine the strength of the LC.

The Leeuwin Current also exhibits an inter-annual variability associated with the El Nino-Southern Oscillation (ENSO) phenomenon. During El Nino events weakening of the LC has been observed, while during La Nina events the LC is stronger. The Leeuwin Undercurrent also appears to respond to the ENSO events, but is stronger during El Nino events partially because of the decrease in the LC.

Impacts on WA

The Leeuwin Current plays a dominant role in controlling WA's marine life and climate. For example, the presence of tropical marine organisms off the west and southern coasts of Australia has been attributed to the Current. The Current also plays an important role in the life cycle of the western rock lobster; southern blue fin tuna; in the distribution of seagrass and algae; coral spawning and distribution; coastal scallop and fin fish stocks and the sea bird distribution. Similarly, the higher winter air temperatures and rainfall in the region, compared to similar latitudes elsewhere, can be attributed in part to the Current.

What causes the Leeuwin Current?

Warmer, lower salinity water flows through the Indonesian Archipelago from the Pacific to the Indian Ocean and results in lower density water being present between Australia and Indonesia compared to the cooler and more saline ocean waters off south-west WA. This density difference results in a change in sea level of about 0.5 m along the WA coast and is the driving force of the LC.

Due to the effect of the earth's rotation, water is entrained from the Indian Ocean into the LC as it flows southward; thus, the LC becomes stronger as it flows southward.

Interaction of the LC with changes in the bathymetry and offshore water of different densities results in the generation and subsequent offshore transport of eddies – in particular, off Shark Bay, Abrolhos Islands, Jurien Bay, Rottnest Island and Cape Leeuwin (Figure 3).

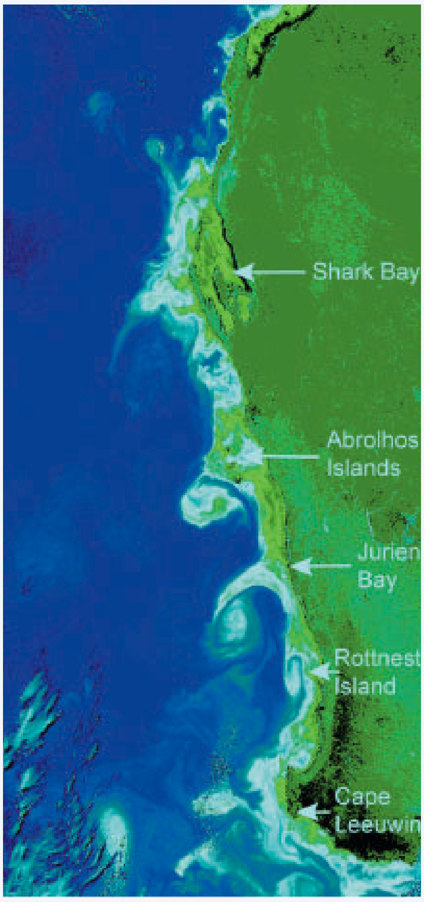

Figure 3: Ocean colour image of the WA coast showing eddies, generated by the Leeuwin Current, entraining chlorophyll rich water from the continental shelf.

What can we say about the future?

The Leeuwin Current system will continue to respond to the ENSO signal, where under El Nino (La Nina) conditions the current is weaker (stronger). Climate modelling results have indicated a slight increase in the alongshore pressure gradient, which is the driving force of the LC. This change is attributable to increased temperature and decreased salinity water in the Indonesian Throughflow. Thus, it is expected that the strength of the Leeuwin Current may increase slightly by 2100, although we cannot define this with any confidence. However, this change is considered to be small compared to the inter-annual variability.

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