Kinematics and Heat Budget of the Leeuwin Current

by

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Abstract

This study investigates the upper ocean circulation along the west Australian coast, based on recent observations (WOCE ICM6, 1994/96) and numerical output from the ⅙° Parallel Ocean Program model (POP11B 1993/97). Particularly, we identify the source regions of the Leeuwin Current, quantify its mean and seasonal variability in terms of volume, heat and salt transports, and examine its heat balance (cooling mechanism). This also leads to further understanding of the regional circulation associated with the Leeuwin Undercurrent, the Eastern Gyral Current and the southeast Indian Subtropical Gyre.

The tropical and subtropical sources of the Leeuwin Current are understood from an online numerical particle tracking. Some of the new findings are the Tropical Indian Ocean source of the Leeuwin Current (in addition to the Indonesian Throughflow/Pacific); the Eastern Gyral Current as a recirculation of the South Equatorial Current; the subtropical source of the Leeuwin Current fed by relatively narrow subsurface–intensified eastward jets in the Subtropical Gyre, which are also a major source for the Subtropical Water (salinity maximum) as observed in the Leeuwin Undercurrent along the ICM6 section at 22°S.

The ICM6 current meter array reveals a rich vertical current structure near North West Cape (22°S). The coastal part of the Leeuwin Current has dominant synoptic variability and occasionally contains large spikes in its transport time series arising from the passage of tropical cyclones. On the mean, it is weaker and shallower compared to further downstream, and it only transports Tropical Water, of a variable content. The Leeuwin Undercurrent carries Subtropical Water, South Indian Central Water and Antarctic Intermediate Water equatorward between 150/250 to 500/750 m. There is a poleward flow just below the undercurrent which advects a mixed Intermediate Water, partially associated with outflows from the Red Sea and Persian Gulf. Narrow bottom–intensified currents are also observed.

The 5–year mean model Leeuwin Current is a year–round poleward flow between 22°S and 34°S. It progressively deepens, from 150 to 300 m depth. Latitudinal variations in its volume transport are a response to lateral inflows/outflows. It has double the transport at 34°S (–2.2 Sv) compared to at 22°S (–1.2 Sv). These model estimates, however, may underestimate the transport of the Leeuwin Current by 50%. Along its path, the current becomes cooler (6°C), saltier (0.6 psu) and denser (2 kg m^{-3}). At seasonal scales, a stronger poleward flow in May–June advects the warmest and freshest waters along the west Australian coast. This advection is apparently spun up by the arrival of a poleward Kelvin wave in April, and reinforced by a minimum in the equatorward wind stress during July.

In the model heat balance, the Leeuwin Current is significantly cooled by the eddy heat flux divergence (4°C out of 6°C), associated with mechanisms operating at submonthly time scales. However, exactly which mechanisms it is not yet clear. Air–sea fluxes only account for ~30% of the cooling and seasonal rectification is negligible. The eddy heat divergence, originating over a narrow region along the outer edge of the Leeuwin Current, is responsible for a considerable warming of a vast area of the adjacent ocean interior, which is then associated with strong heat losses to the atmosphere. The model westward eddy heat flux estimates are considerably larger than those associated with long lived warm core eddies detaching from the Leeuwin Current and moving offshore. This suggests that these mesoscale features are not the main mechanism responsible for the cooling of the Leeuwin Current. We suspect instead that short lived warm core eddies might play an important role.

Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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List of supporting publications

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