Quantitative Marine Science

Thesis Abstract

A heat balance of the Great Barrier Reef with particular emphasis on recent sea surface temperature trends

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The waters off the coast of Tasmania have become gradually warmer and saltier over the past 60 years according to a coast station time series, with sea surface temperatures rising at a rate more than double the global average. I demonstrate that this is related to a strengthening and more southerly reach of the East Australian Current (EAC) extension. The station also shows a strong decadal timescale signal in temperature and salinity. In this thesis, I use a combination of the Maria Island time series and Tasman Box XBT sections, 50 year atmosphere and ocean state estimates, and idealised forcing experiments with a global ocean model to build a picture of how the EAC system is changing, and what is driving it. I find that changes at Maria Island are closely related to changes in the wind stress curl in the South Pacific, with Maria Island lagging the winds by 3 years. This propagation speed is too fast for 1st Mode baroclinic Rossby wave adjustment which would take 10-15 years, so a faster mechanism is needed.

The observed variability at Maria Island is part of a bigger picture of decadal variability in the Southwest Pacific region. The EAC takes one of two paths at the point of separation at 32°S; it either continues down the coast as the EAC Extension, or separates and flows across the Tasman Sea to New Zealand as the Tasman Front.
On decadal timescales either the Tasman Front or the EAC Extension is favoured, which form part of two gyre scale states. When the Tasman Front is favoured, a single gyre structure is seen, which mainly sits to the north of New Zealand; whereas when the EAC extension is favoured, a double gyre structure exists, with a second gyre centre east of New Zealand. Analysis of ocean reanalyses suggests that an enhanced wind stress curl maximum in the South Pacific appears to favour the EAC extension over the Tasman Front.

From model forcing experiments, where the wind stress curl maximum is enhanced in a 20°S longitude region for a period of a year, I am able to demonstrate a rapid mechanism by which the EAC can respond to changes in the South Pacific winds.

Ocean ridges and islands provide a mechanism for conversion between fast barotropic and slow baroclinic Rossby waves. Due to the position of New Zealand, barotropic Rossby waves can travel across to New Zealand, travel around New Zealand as a coastal Kelvin wave, and then take 3 years to cross to interact with the EAC as a baroclinic Rossby wave. This shows that islands and bathymetry, as well as basin size, can dictate the rate at which oceans respond to changes in wind forcing. In addition intrinsic ocean variability exists, so that decadal variability in the ocean can be set up by a single pulse of wind forcing, due to the multiple ways in which the ocean responds to wind forcing. The model was also able to recreate the anticorrelation between the EAC Extension and the Tasman Front.

This thesis illustrates a very close relationship between the variability in the EAC western boundary current system and basin scale wind stress variability. In addition I identify a rapid mechanism by which the ocean can adjust in the presence of islands and ridges to explain the observed 3 year time lag. This suggests that both barotropic and baroclinic physics are needed to explain the timescales of observed low frequency variability in the ocean.