Physical oceanography of New Zealand/Aotearoa shelf seas – a review

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The shelf seas surrounding New Zealand/Aotearoa, a region nominally extending out to the 250 m depth contour, are complex and varied as they sit above the submerged continent of Zealandia. These seas surround the two main islands that span 1,500 km in latitude from 34°S to 47°S and include a series of plateaus that extend far beyond.

New Zealand’s shelf seas encompass a diverse range of environments from shallow river-affected coastal waters through to essentially open-ocean.

Physical oceanographic understanding relates to currents, transport, mixing, dilution and fate and provenance of water masses. Near-shore temperatures and dissolved oxygen levels and other biophysical properties strongly affect coastal ecosystems and marine industries such as aquaculture and fishing.

At the regional scale, the Zealandia system is fed with Subtropical Water from the north by the East Australia Current and the Tasman Front, which becomes the East Auckland Current (EAUC, Figure 1). This merges with highly modified Subtropical Water from the south in flows associated with the Sub-tropical Front that forms the Southland Current. The Southland Current is the local name for the Subtropical Front as it runs up the New Zealand South Island east coast. The front separates modified Subtropical Water inshore and Subantarctic Water offshore (Sutton 2003). While the current is formed by Pacific Ocean regional processes, fluctuations are predominately wind-driven (Chiswell 1996). There is also a much smaller contribution directly from the Tasman Sea to the west, although this is relatively weak in terms of ener-getics (Chiswell et al. 2015). Exactly how these currents affect the shelf region varies in both space and time and depends on a confluence of drivers.

New Zealand’s marine wind field, a function of its latitudinal position and topography, is characterised by the land blocking the prevailing westerly winds (Sterl et al. 1998; Sturman and Tapper 2006). Despite this, the modest area of the land means that primarily maritime conditions prevail (see example wind roses in Figure 2). In the ocean, this wind field drives currents and generates mixing, both of which can contribute to upwelling of deeper, cooler, nutrient-rich waters. In addition, wind is often associated with rainfall, especially due to the orographic effects of the New Zealand landmass.

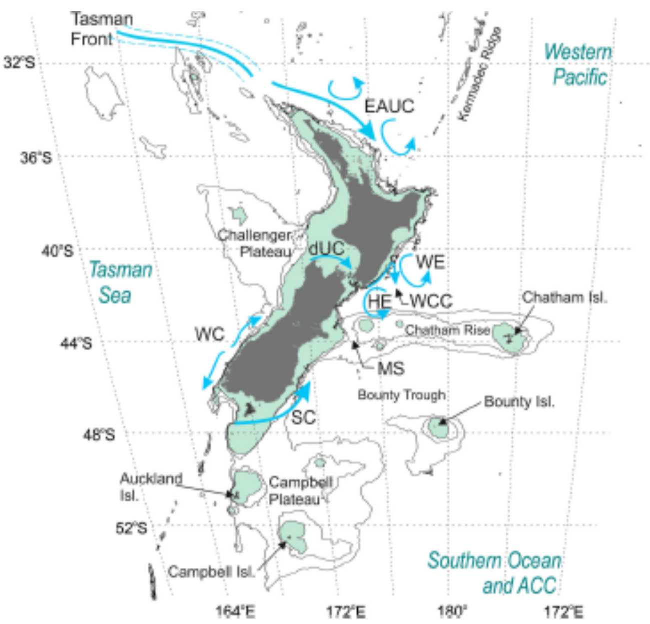
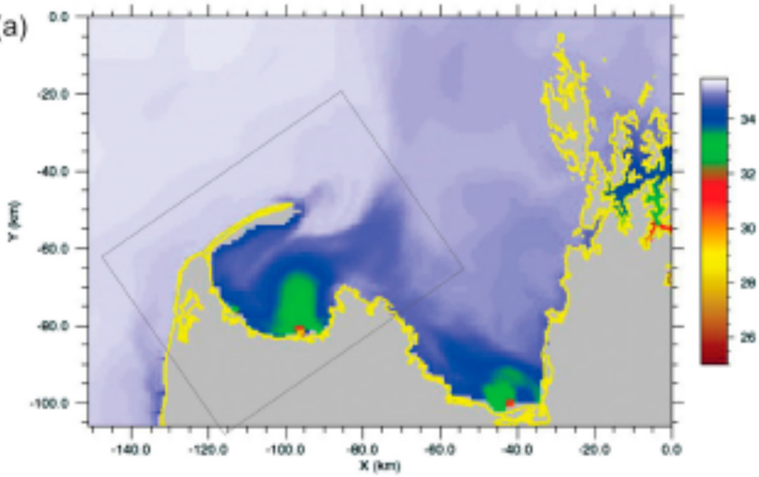


Figure 1. New Zealand/Aotearoa at the shelf seas scale showing coastal currents, plateaus and features including the Tasman Front, East Auckland Current (EAUC), Wairarapa Coastal Current (WCC) and Eddy (WE), Westland (WC) and Southland Currents (SC), Hikurangi Eddy (HE), Mernoo Saddle (MS) and the d’Urville Current (dUC). Regions less than 250 m are shaded and the 500 and 1000 m isobaths are shown.

Tasman Bay

(a)



(b)

The wind fields are very complex due to the mountainous terrain surrounding the Sounds. Contrastingly, the high sediment loading means that in many places the bathyme-try is flat-bottomed, being filled with mud. Currents in the main channels are strongly tidal, but this degenerates in the embayments where headland eddies create complex eddy fields. Such eddy fields are a ubiquitous feature of these drowned river valleys with strong tidal flows along a central channel having many embayments on each side.

The wide shelf of Pegasus Bay north of Banks Peninsula (Figure 11B) supports a sub-marine canyon running away to the east. The southward flow events of the Southland Current, lasting 10–12 days, reported by Greig and Gilmour (1992) coincide with the influx of warm water at the surface within 5 km of the coast near Kaikoura, and they suggest that this influx of warm water is due to eddies arriving from the south of the Wair-arapa Eddy. As above, the nature of the partitioning of Subantarctic and Subtropical waters is important for biological productivity. Shaw and Vennell (2000) suggest that Sub-antarctic waters extends north through the western edge of the 580 m deep Mernoo Saddle (Figure 1) for most of the year, however in winter and early spring a southward extension of subtropical front appears in the region.

Moving north along the South Island coast, the combined Kaikoura Peninsula and Canyon create a key demarcation point. The canyon starts within a km of shore before running 60 km offshore to a depth of over 1 km (Lewis and Barnes 1999). This provides a pathway for productivity-enhancing nutrients in the Kaikoura region (Reid et al. 2011). There is at least one documented case of northerly winds inducing upwelling off Kaikoura (Heath 1972), and such upwelling is often associated with high productivity in the region (e.g. Childerhouse et al. 1995). However, not all instances of cooler inshore temperatures in the region are due to upwelling. Heath (1970) attributed one instance of a rapid decrease in SST to an increase in the strength of the downwelling-favourable Southland Current. Along this coast, wind-driven advection of the coastal current and upwelling have opposite effects on temperature, and Chiswell and Schiel (2001) used this to demonstrate that SST temperature variability is determined by along-shore advection, whereas deeper tempera-ture variability is determined principally by upwelling.

The 2016 M7.8 Kaikoura earthquake had a dramatic effect on the intertidal region along a substantial portion of the coast with uplift of 1–3 m in places (Bai et al. 2017). As well as the resulting tsunami and destruction of intertidal populations, it modified the sea floor topography. The vertical displacement, while devastating in the short term, is modest compared to overall water depths in the region and comparable to the tidal elevation. It became apparent however, that there were substantial sedimentary changes, with large turbidity currents draining offshore. Typically, the mechanics of such events can only be studied well after the fact, and so any depositional signature is heavily modified. However, the immediacy of the 2016 Kaikoura event provides greater knowl-edge of the drivers and more immediate access to the impact of these landslides (Mountjoy and Micallef 2018).

Changing climate – This is impacting New Zealand in a number of ways (Stevens and O'Callaghan 2015). Being maritime, several of these pathways are via ocean impacts like:

- sea level rise,
- marine heat waves
- and modifications to ocean ecosystems driven by changing temperature, currents and acidification (Law et al. 2017; Coleman et al. 2017).
- Tropical cyclone activity is another impact with strong oceanic drivers that will change with climate (Godoi et al. 2018).

Notably however, changing climate was not a focus of the bio-physical work conducted in Phase I of the Sustainable Seas National Science Challenge, a government initiative (2014–2025) described as driving marine science and how it affects New Zealanders. This is despite it playing a lead role in social science elements of the initiative (e.g. Davies et al. 2018).

- Shears and Bowen (2017) indicate that ocean warming in New Zealand will not be a straight-forward 'tropicalisation', but instead it will be regional and complicated as winds evolve also.
- Bell and Goring (1998) investigated seasonal variations in sea level and sea surface temperature (SST) for the north-east coast of the North Island and found a significant relationship between sea level and the Southern Oscillation Index. However, the relationship is highly variable, both in magnitude and in the range of time scales over which it occurs.
- An interdecadal response in sea level around northern New Zealand appears to coincide with shifts in the Pacific Decadal Oscillation. This slow increase in sea level will interact with higher frequency effects leading to the conclusion that to a large extent variation in sea level is caused by waves propagating into the area. At slightly longer periods, co…….

Craig L. Stevens, Joanne M. O'Callaghan, Stephen M. Chiswell & Mark G. Hadfield (2021) Physical oceanography of New Zealand/Aotearoa shelf seas – a review, New Zealand Journal of Marine and Freshwater Research, 55:1, 6-45,DOI: 10.1080/00288330.2019.1588746