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# South Pacific Surface Circulation during the Austral Summer

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This paper summarises the characteristics of surface circulation of the South Pacific during austral summer months when a surface albacore fishery is most likely to develop. The emphasis is on the southwestern region which has been more thoroughly studied and demonstrated the potential for supporting surface albacore fisheries. The information is summarised from several sources and unless cited can be found in Pickard (1963), Tchernia (1980) and Heath (1985a).

## General Features of Circulation

Surface circulation in the South Pacific is a wind driven gyre associated atmospherically with a permanent anticyclone centred near Easter Island. This anticyclone extends over most of the eastern Pacific and is continuous from about 10°S to 40°S. The intensity of this anticyclone weakens during the austral summer while in the Australia-New Guinea region a cyclonic system develops. The weakening anticyclone and its associated southeast Trade Winds result in a reduced flow in the westward flowing South Equatorial Current during the summer. The cyclonic system over Australia and New Guinea largely affect circulation in the Coral and Tasman Seas. Circulation is also influenced by a complex series of bathymetric features including ridges, rises, seamount chains as well as numerous island platforms.

The major features of the South Pacific gyre are the westward flowing South Equatorial Current, an eastward zonal flow north of the

West Wind Drift along the Subtropical Convergence, the southward flowing East Australian and East Auckland Currents and the northward flowing Peru Current. The isolation of the East Australian Current, a western boundary current, from the South Pacific gyre by the New Zealand shelf complicates the circulation of the Tasman Sea and New Zealand region. The currents which link the Tasman Sea to the South Pacific include the Tasman Front (an eastward flowing zonal intensification) and the near-shore currents on the east coasts of New Zealand. The flow of these currents is illustrated in figure 1, while Table 1 summarises the speed and volume transport where known. Each current, with the exception of the Peru Current, will be described separately.

## The South Equatorial Current

The South Equatorial Current extends from the coast of South America across the Pacific to New Guinea from about 10°S to 3-4°N latitude. The current is best developed in the eastern Pacific and as it flows westward divides into streams. East of 140°W the southern stream between 2°S and 20°S is deflected southwards by the island barriers of French Polynesia. In the mid-South Pacific between 140°W and 180° part of the South Equatorial Current turns southwest; between 20°S and 30°S this flow divides with one stream heading south and one due west. The south flowing stream returns eastwards north of and along the Subtropical Convergence to the east of New Zealand. The west flowing branch enters the Coral Sea. The remaining flow of the South Equatorial Current continues westward between the equator and the Tropical Convergence until reaching the coast of New Guinea. The waters of this northernmost branch recurve upon themselves to flow southeastwards along the New Guinea and Solomon Islands platforms.

Two additional currents embedded in the South Equatorial Current should be mentioned. One is the 200 m thick 300 km wide countercurrent between 2°N and 2°S known as the Cromwell Current. This current flows eastward from 160°E at a depth of 50-250 m rising to the surface east of the Galapagos Islands to rejoin the South Equatorial Current. The speed of the Cromwell Current at its core is about 125-150 cm/s, twice that of the South Equatorial Current. Volume transport in the Cromwell Current is about $40 \times 10^6$ $m^3/s$ which is comparable to that of the South Equatorial Current at its most intense (August). The second current is a weak eastward flowing surface current. This current, the South Equatorial Countercurrent, extends from 10°S to 12°S between 155°E and 180° dividing the South Equatorial Current.

## Coral Sea Circulation

Surface circulation has been reviewed by Rotschi and Lemasson (1967). During summer months the southwards displacement of the Trade Winds together with variable monsoon winds affects the surface currents, as well as convergence and divergence zones of the region. Surface circulation is variable with the dominant flow of equatorial water from the north and northeast entering the northern Coral Sea between Vanuatu and the Solomon Islands. This southwestward flow is joined in the western Coral Sea by a westward zonal flow south of New Caledonia. These waters combine along the Australian coast to form the southward flowing East Australian Current. In between these surface waters at 15°S to 17°S, lies the South Tropical Countercurrent studied by Donguy and Henin (1975). This countercurrent originates in the western Coral Sea and flows eastward between New Caledonia and Vanuatu.

The zones of convergence and divergence associated with the surface circulation in the Coral Sea change position and intensity seasonally. During the austral summer they are weak. The Tropical Convergence is an area of downwelling located south of New Caledonia at 26°S to 30°S. This zone, unlike that of the Subtropical Convergence, is caused by the wind field of the Trade Winds. There is also a zone of divergence, sometimes referred to as the Solomons Divergence, northwest of New Caledonia between 10°S and 15°S and about 160°E. This feature is locally enriched due to subsurface upwelling. Another divergence zone, the Tasman Front, separates the surface waters of the Coral and Tasman Seas from Australia to the north of New Zealand. The Tasman Front will be discussed below.

## Tasman Sea Circulation

Circulation in the Tasman Sea is well known north of 35°S. The major components of circulation include a western boundary current flowing southwards out of the Coral Sea (the East Australian Current), an eastward flowing zonal intersification (the Tasman Front), the mesoscale cyclonic and anticyclonic eddies formed by these currents and an eastward zonal flow across the Tasman Basin. The general features of Tasman Sea circulation and its connection to that of the South Pacific gyre are summarised from the reviews of Denham and Crook (1976), Andrews et al. (1980), Heath (1980, 1985a) and Stanton (1981). Circulation is geostrophic but seasonally variable. The variability in flow of both the East Australian Current and the Tasman Front have been attributed to the complex series of north-south trending bathymetric highs which act as partial meridional barriers (see figure 2). The most important barrier to the eastern zonal flow is the New Zealand platform. Other features which are reported to influence Tasman Sea circulation are the bend in the Australian coastline at Sugarloaf Point (32°25'S), the seamount chain between 155°E and 156°E north of 34°S, Lord Howe Rise and the Norfolk Ridge.

The East Australian Current flows southward along the Australian continental shelf between 20°S and 35°25'S. Current speeds vary both with latitude and season with a long term average of 30 cm/s. The current varies from 35-110 km in width with the axis of strongest flow along the 183 m isobath (Anon, 1973). The southward flow of the East Australian Current separates from the coast at about 32°25'S. Associated with the change in flow to the east, there appears to be some recirculation of water to the north through the formation of ellipsoidal eddies. In addition, a reduced southward flow is maintained through the propagation of eddies south of 34°S. The dominant flow south of 34°S, however, is zonal. The presence of anticyclonic eddies north and south of the point of eastwards deflection of the current was noted by Andrews et al. (1980) and Stanton (1981). The latter author suggests the point of current separation is a long term feature of the East Australian Current.

After leaving the Australian continental shelf, circulation occurs as a permanent eastward zonal flow about 600 km wide centred between 33°S and 34°S (Andrews et al. 1980). Within the broad zonal flow the Tasman Front can be recognized as a coherent meandering feature of locally intense flow between the coast of Australia and northern New Zealand. Heath (1980) attributes the intensification to shoaling of the geostrophic flow over the bathymetric highs and the meandering to changes in volume transport. As noted by Andrews *et al.* (1980) the Tasman Front represents the thermal interface between warm south Coral Sea water and cooler Tasman Sea water. They and other authors note that the Tasman Front is evident as an abrupt thermal front at all depths. Temperature gradients across the front vary along its length and with season being greater to the west and in winter months. Maximum gradients of 3°C over 6 km have been reported (Andrews *et al.* 1980). The associated pressure fields are known to generate locally intense currents along the front especially over Lord Howe Rise and the Norfolk Ridge. Stanton (1981) has estimated geostrophic surface currents (relative to 1300 m) of up to 65 cm/s and suggests that these may be underestimates for the Tasman Front. The importance of the Tasman Front to Tasman Sea circulation is also evident from volume transport calculations. Andrews *et al.* (1981) and Stanton (1981) suggest that about half of the volume transport of the East Australian Current is released to the Tasman Front. Stanton (1981) attributes the residual flow to recirculation by eddies within the East Australia Current system, while Andrews *et al.* (1980) suggest that residual transport is by as yet unestimated flows along meridional barriers like the Lord Howe Rise, Norfolk Ridge and Kermadec Ridge.

Circulation in the Tasman Sea is certain to be more complicated than is presently known. The lifespan of East Australian Current eddies propagating south of 35°25'S is known to be at least one year (Cresswell, 1983) and could be two years if comparisons with cold core Gulf Stream eddies is valid. The fate of these mesoscale features is unknown but it seems possible that they may propagate eastwards either along or north of the Subtropical Convergence. If so they would contribute to the flow along the west coast of the South Island of New Zealand. Heath (1980) also suggests that part of the flow of the East Australian Current separates near the junction of Lord Howe Rise to flow southeastwards to contribute to the southwards flow along the New Zealand coast. Heath (1985b) estimates this flow along the Challenger Plateau to be about 7.6 x $10^6$ $m^3/s$.

Flow along the west coast is southwards south of 44°S and northwards north of this point. The generally northward flow along the west coast of New Zealand and the eastward flow along the Tasman Front join to form the eastwards flow north of New Zealand near 34°S. This flow feeds the southeast directed East Auckland Current along the east coast of the North Island while the southern flow along the southwest coast feeds the northward flowing Southland Current on the east coast of the South Island.

## Circulation East of New Zealand

The connection of Tasman Sea circulation around New Zealand with the South Pacific gyre is strongly influenced by bathymetry. Heath (1985b) has reviewed this influence on surface and deep western boundary currents in the region.

The main feature of the flow around the North Island is the southeastwards flowing East Auckland Current between 173°E and 178°E. At about 179°E this current splits with most of the flow deflected northwards by the Kermadec and Colville Ridge systems. The residual flow continues around East Cape where the current flows south to about 43°S. At this latitude the influence of the Chatham Rise deflects the

East Cape Current eastwards. Permanent eddies north and south of this deflection point result. In this region the East Cape Current is joined by water from the Southland Current.

After leaving the New Zealand shelf the circulation of the South Pacific gyre is continued by a zonal eastward flow along the Subtropical Convergence. The Subtropical Convergence Zone separates subtropical from subantarctic surface water and serves as the hydrographic boundary for the Southern Ocean. The position of this boundary varies seasonally. In the Australasian region during summer, Edwards and Emery (1982) report the Subtropical Convergence Zone occurs between 44°S and 48°S.

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Table 1. Speed and volume transport characteristics of the major currents of the South Pacific gyre

| Current | Speed (cm/s) | Source | Transport ($10^6 m^3/s$) | Source |
|---|---|---|---|---|
| Cromwell | 125-150 | Tchernia (1980) | 40 | Tchernia (1980) |
| E. Auckland | 18-30 | Heath (1980) | 1.2-8.5 | Heath (1975) |
| E. Australian | 30 | Anon (1973) | 20-40 | Andrews *et al.* (1980) |
| E. Cape | | | 3.5-13 | Heath (1975) |
| Peru | 10-15 | Tchernia (1980) | 15 | Tchernia (1980) |
| S. Equatorial | 50-60 | Tchernia (1980) | 50 | Tchernia (1980) |
| S. Equatorial Countercurrent | 4-11 | Donguy & Henin (1975) | 2 | Donguy & Henin (1975) |
| Tasman Front | 65 | Stanton (1979) | 9-15 | Andrews *et al.* (1980), Heath (1985b) |
| S. Tasman Sea (zonal flow) | | | 7.6 | Heath (1985b) |

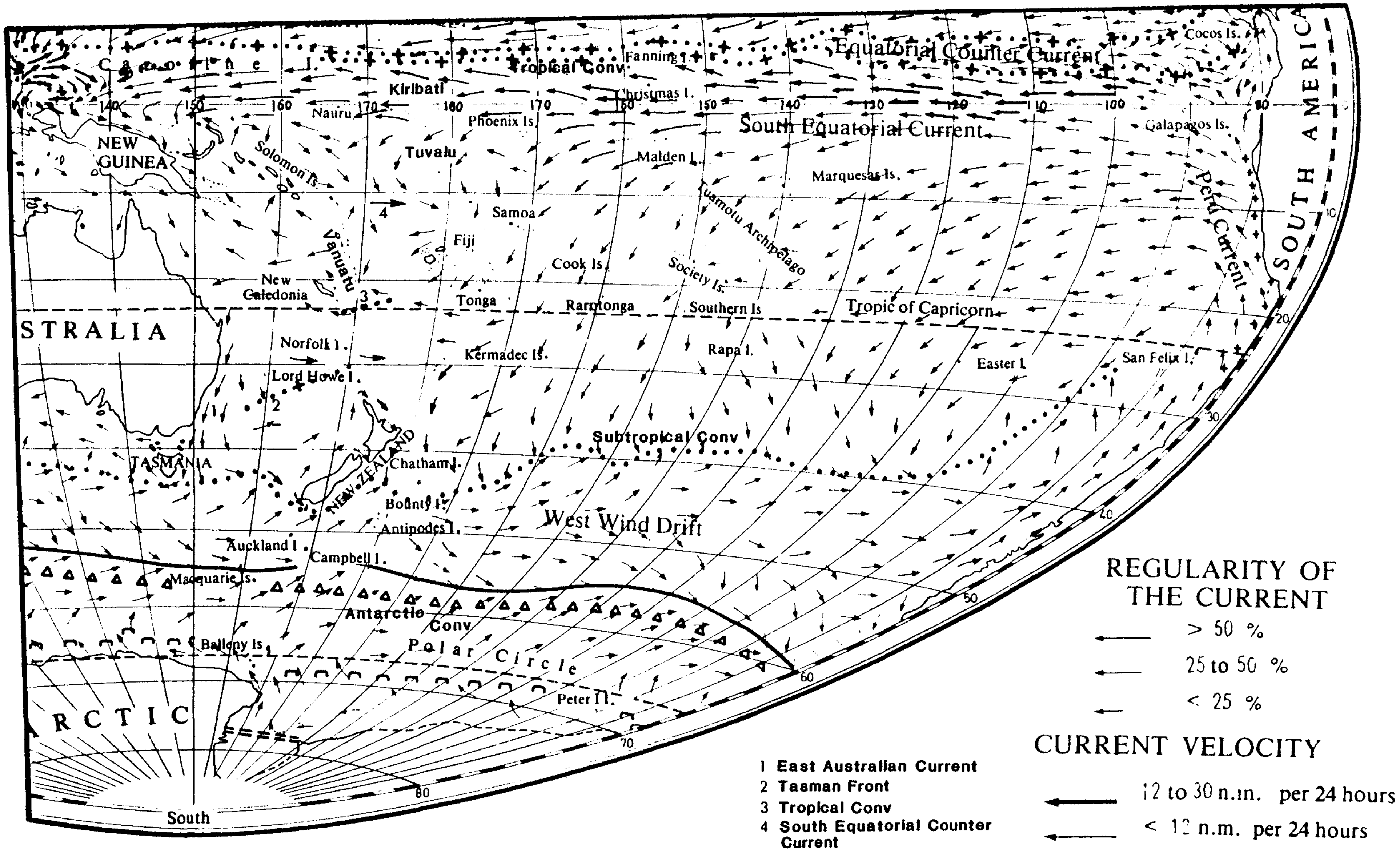


**Figure 1: Generalised surface circulation in the South Pacific, February (after Tchernia, 1980)**


Figure 2: The southwestern Pacific Ocean
(Depth contours are 1000 and 2000m.Scale 1:15 000 000)