Ocean circulation and the deep sound channel in the Subarctic Northeast Pacific

D.G. Browning, R.K. Chow and J.W. Powell

Defence Research Establishment Pacific,
FMO, Victoria, B.C. VOS 1B0 Canada

ABSTRACT

For most ocean areas, the depth of the deep sound channel (DSC) axis is inversely related to the amount of solar heating at the surface; hence the axis depth shallows toward higher latitudes. In the subarctic region of the North Pacific Ocean (Above 40° North Latitude) a net influx of fresh water creates a surface layer and a compressed halocline which tends to insulate the remainder of the water column from surface heating. This fresh water influx plus the dominant counterclockwise Alaskan Gyre and the intrusion of the warm California Undercurrent give rise to a well-behaved but atypical pattern for the depth of the DSC axis in the Subarctic Northeast Pacific. In this region we found that the axis depth contours are concentric about the Alaskan Gyre. This unique interrelation between ocean circulation and the DSC provides a link between the oceanographic and acoustic descriptions of this region.

Nature Browning, Chow and Powell

The deep sound channel (DSC)[1] is the primary means of long-range acoustic transmission in the ocean. Such transmissions can be used to scan large ocean areas to detect changes in oceanographic conditions.[2] A recent example has been the detection of mesoscale ocean eddys by the use of acoustic tomography.[3] Kibblewhite and Browning[4] have shown that long range transmission experiments can identify large scale changes in the sound speed profiles. These can be related to changes in water mass, and hence the circulation can be inferred.

In general, however, the sound speed profile and the DSC axis (axis is defined as the depth of minimum sound speed) are not directly related to the circulation pattern. For most ocean areas, the depth of the deep sound channel axis is inversely related to the solar heating at the ocean surface, hence the axis depth shallows at higher latitudes. Similarly, at constant latitudes there should be little change in axis depth.

The large subarctic region of the North Pacific Ocean, specifically the eastern half (Figure 1), has some unique properties[5] that suggest a direct link between circulation and the DSC. This region is isolated from the main part of the North Pacific circulation at the subarctic boundary, has abundant rainfall and freshwater runoff, but has a relatively low rate of evaporation. This gives rise to a surface layer of reduced salinity which deepens and compresses the normal halocline and results in a strong salinity gradient between 100 and 200 m of depth.[6] More importantly, this strong halocline insulates the "normal ocean" below 200 m depth from the effects of solar heating and storm mixing. This permits the DSC axis depth to be controlled by the subsurface circulation which, in this case, arises from the intermediate-depth flow of the Alaskan Gyre and the California Undercurrent (Figure 1).

In the Alaskan Gyre, relatively warm water from the Western Pacific flows eastward along the subarctic boundary and then counterclockwise around the Gyre. The divergence of this flow induces a cold upwelling in the centre of the gyre resulting in a relatively cold core. North of the Gyre the circulation is constricted by the Aleutian Island Chain producing an intense jet called the Alaskan Stream.[7] This circulation is usually intensified under winter conditions by the winds of the Alaskan Low which is centred near the Gyre.

To test the hypothesis of a direct correlation between the Alaskan Gyre and the DSC axis depth, we have analyzed two extensive oceanographic surveys[8,9] conducted in the Northeast Pacific (summer and winter). Additional data was obtained from the twenty-year record from Ocean Station PAPA (50°N, 145°W)[10,11] and the track between PAPA and the mouth of Juan de Fuca Strait (Swiftsure Bank).[12]

The smoothed results of the analysis for summer conditions (Figure 2) show that the contours of axis depth are concentric around the Alaskan Gyre. The depths range from less than 100 m in the centre to over 400 m along the North American Coast where it appears that the California

Undercurrent water follows the entire coastline around the Gyre. The contours also intensify in the Alaskan Stream. A transect north along 145°W, for example, demonstrates that although the axis depth shallows towards the centre of the Gyre, it then deepens again at higher latitudes.

The contours remain concentric about the Gyre under winter conditions (Figure 3). Two interesting changes are noted: the axis depth at the centre has shallowed and in fact has reached the surface, indicating an intensification of the cold core; at the same time, however, the entire pattern has contracted, resulting in greater axis depths near the edge. The seasonal change in the contour pattern can be related directly to the circulation of the Alaskan Gyre as illustrated in Figure 4. Under winter conditions the intensified upwelling at the core follows the increased circulation and leads to a shallowing of the axis depth. However, the increased flow around the Gyre includes the relatively warm California Undercurrent water with its deeper axis depth. The result is that the entire contour pattern contracts while the axis depth deepens around the edge, particularly to the north and east.

These results demonstrate, we believe, a direct relationship between ocean circulation and the DSC in the Subarctic Northeast Pacific. This implies that changes in the circulation pattern will have a significant impact on long-range sound transmission, which suggests the possibility of using long-range acoustic transmission to study changes in the large scale oceanographic features in this region.

REFERENCES

1. Ewing M. and Worzel J.L. Soc. Am. Mem 27, 1-15 (1948).
2. Browning D.G. et al. Nature 282, 820-822 (1979).
3. Behringer, D. et al. (The Ocean Tomography Group.) Nature 299, 121-125 (1982).
4. Kibblewhite A.C. and Browning D.G. Deep-Sea Res. 25, 1107-1118 (1978).
5. Dodimead A.J. et al. Int. N. Pac. Fish, Com., Bulletin 13 (1962).
6. Roden G.I. J. Geophys. Res. 69, 2899-2914 (1964).
7. Roden G.I. J. Geophys. Res. 74, 4523-4534 (1969).
8. Barber F.G. and Johnson R.L. Pac. Nav. Lab Tech Memo 59-10 (1959).
9. Barber F.G. and Johnson R.L. Pac. Nav. Lab Tech Memo 59-12 (1959).
10. Cox B.J. and DeJong C. Can. IOS Pac. Mar. Science Rpt. 75-4 (1975).
11. Robertson D.G. et al. Fish. Res. Board of Can. Rpt. 187 (1965).
12. Fofonoff N.P. and Tabata S. J. Fish. Res. Board of Can. 23, 825-868 (1966).

Nature Browning, Chow and Powell

FIGURE CAPTIONS

Figure 1. The 200-m circulation in the Subarctic Northeast Pacific Ocean showing the Alaskan Gyre and the California Undercurrent.

Figure 2. Depth contours of the deep sound channel axis in the summer.

Figure 3. Depth contours of the deep sound channel axis in the winter.

Figure 4. Comparison of summer (dotted) and winter (solid) DSC axis depths showing the contraction and intensification of the circulation pattern. (a) top view and (b) side view.

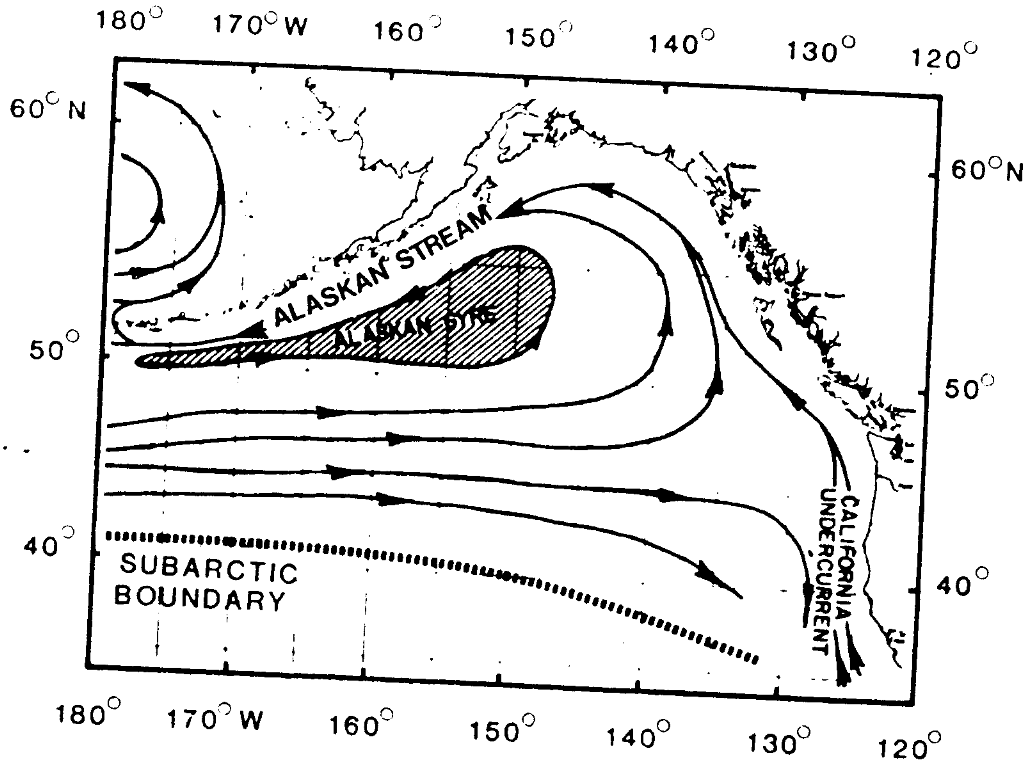

180°
170°W
160°
150°
140°
130°
120°
60°N
50°
40°
ALASKAN STREAM
ALASKAN GYRE
SUBARCTIC
BOUNDARY
CALIFORNIA
UNDERCURRENT

Figure 1

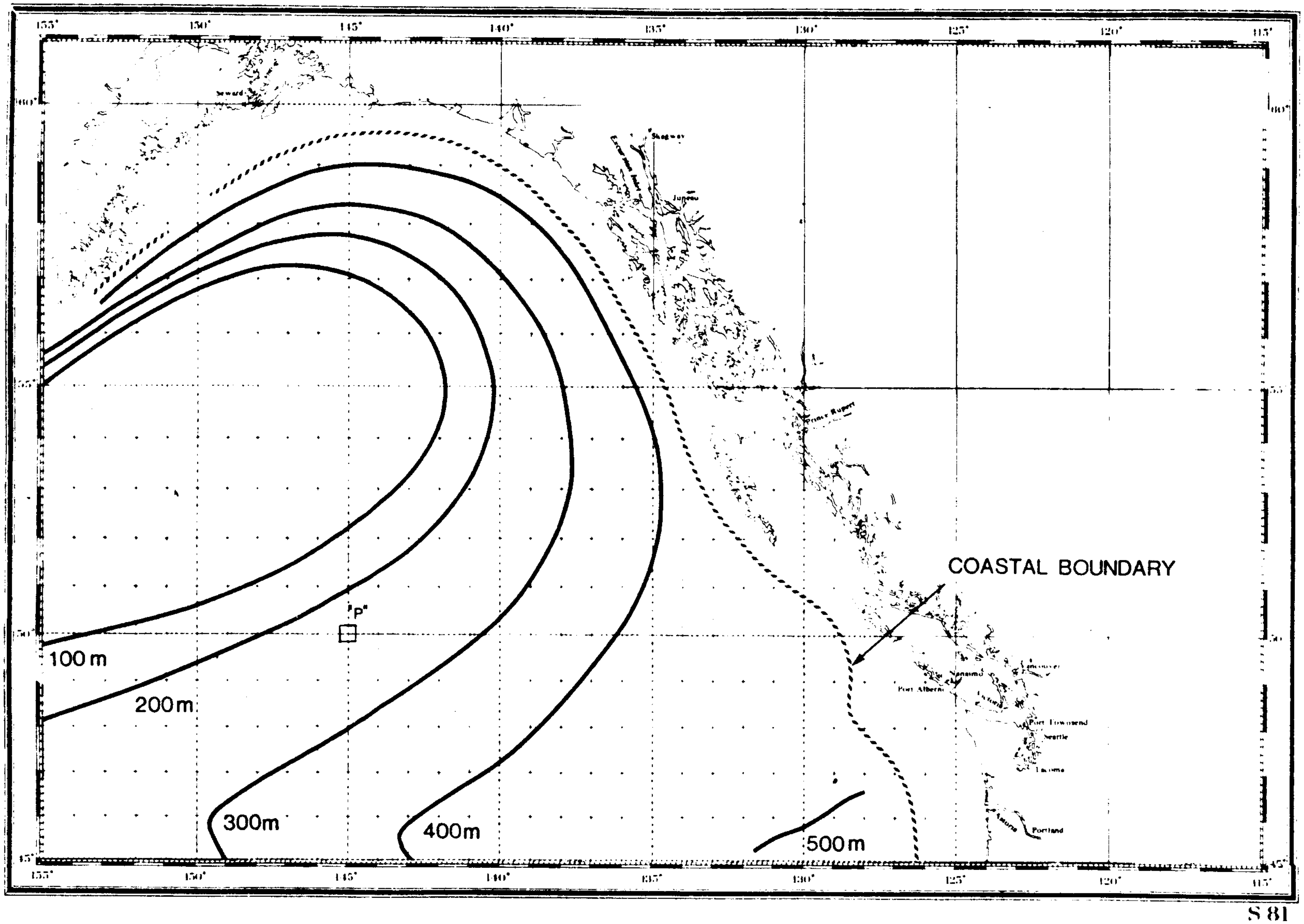
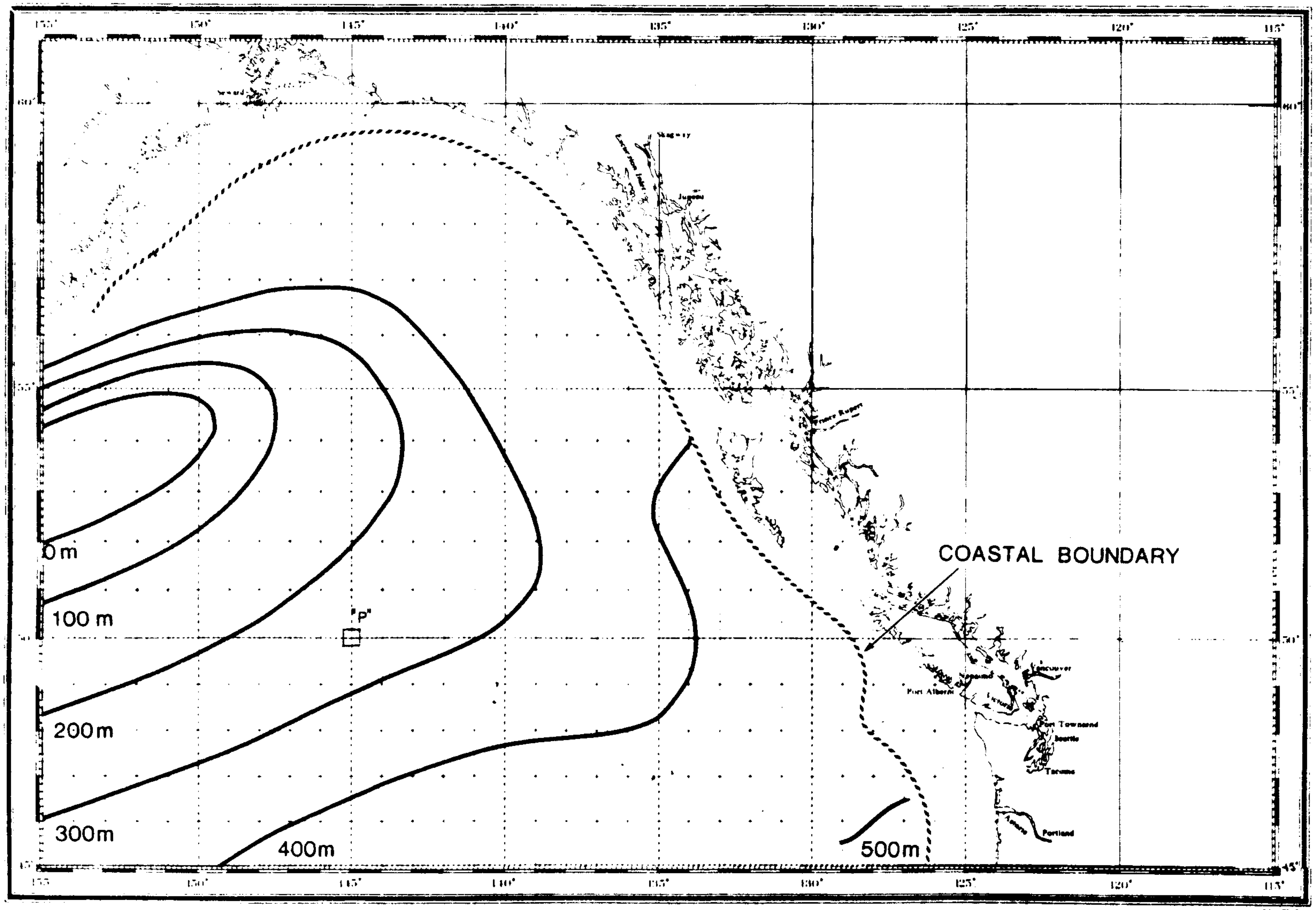


Figure 2



S 81

Figure 3

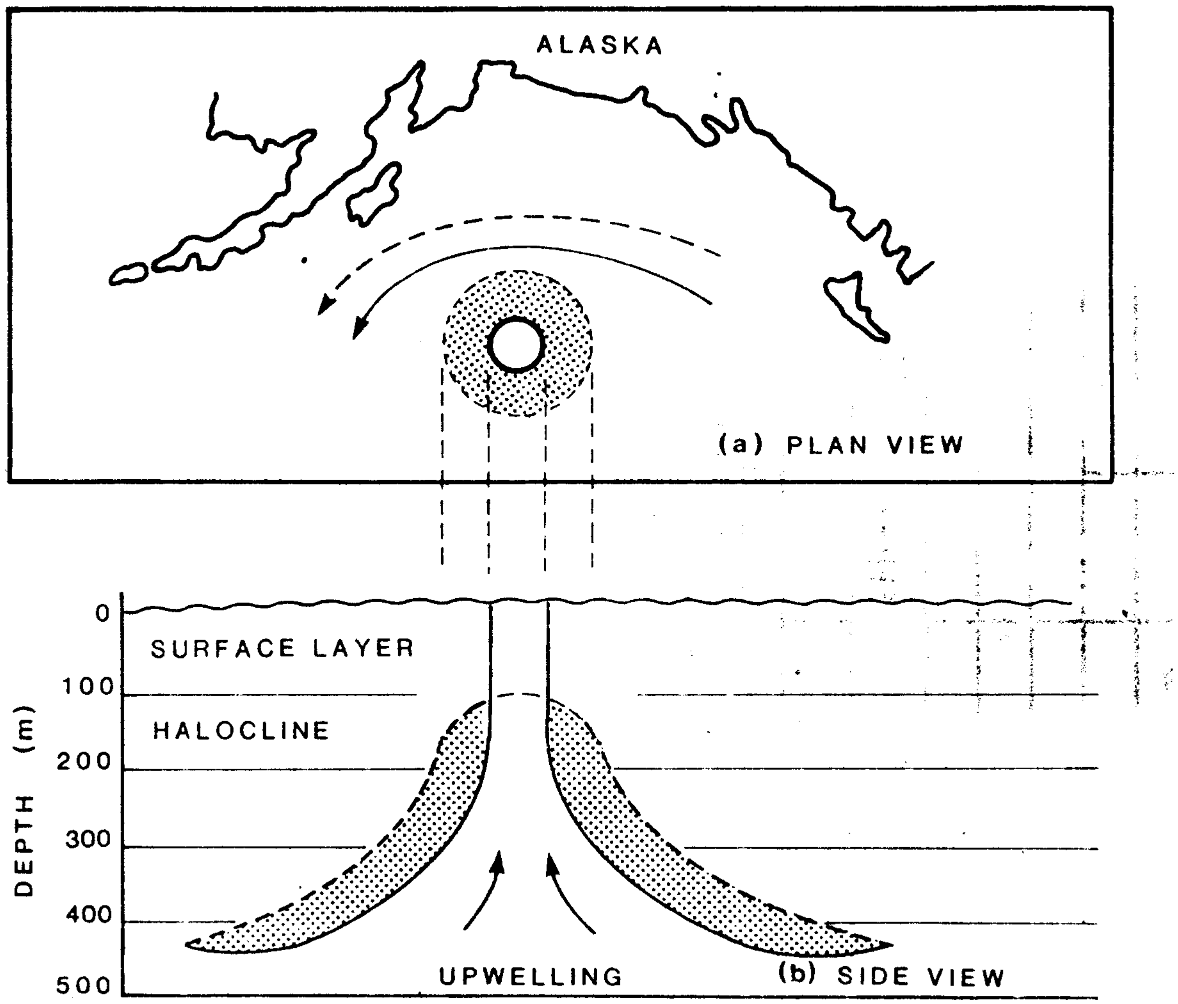

ALASKA
(a) PLAN VIEW
0
SURFACE LAYER
100
HALOCLINE
200
DEPTH (m)
300
400
500
UPWELLING
(b) SIDE VIEW

Figure 4