NOTES AND CORRESPONDENCE

Comments on the "Temperature and Salinity Structure in the Weddell Sea"

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The authors state that cabbeling instability is a distinct possibility in the central portion of the Weddell Sea gyre, between the Winter Water and the Warm Deep Water masses, the former of potential temperature −1.6°C or lower and the latter of salinity 34.64‰ or greater. In between surfaces of these values lies Modified Warm Deep Water, a product of vertical mixing of the two water masses. They have shown that the proper conditions for cabbeling instability to be operative occur in the "large step" portion of the Warm Deep Water, and suggest that a slight increase in salinity of the overlying Winter Water can precipitate the occurrence of cabbeling. It is also stated that upwelling of Warm Deep Water is a major feature in the center of the Weddell gyre and is responsible for the lensing, or doming, structure in the center of the gyre.

It is possible that the authors do not state a sufficiently strong case for cabbeling, and too strong a case for upwelling, as the mechanism responsible for the doming result. A study of their Figs. 2 and 3 show the following:

1) As pointed out by the authors, temperatures and salinities in the 20–50 m depth zone reflect summer heating and surface ice melting, coupled presumably with the general divergence of surface waters by the wind system.

2) Between stations 4 and 13, a distance of 700 km, the 0.0°C isotherm is level, more or less, and adjacent isotherms are uniformly spaced throughout this interval.

3) At the base of the Winter Water, the depth of the −1.2°C isotherm diminishes less rapidly toward the gyre center than does the 0.0°C isotherm.

4) Beginning at station 13 and continuing southward to station 16, the −0.4°C isotherm converges while the 0.4°C isotherm diverges with the 0.0°C isotherm.

5) Statements similar to 3 and 4 above apply also to the isohalines of salinity distribution, i.e., the 34.60‰ converges and the 34.68‰ diverges with the 34.64‰ isohaline, respectively.

6) Between stations 4 and 13 the depth of the 0.0°C isotherm fluctuates about the 200 m level. Consider the deviations of the depths of isothermal and isohaline surfaces from this level, from station 13 southward to the center of the gyre. Between stations 13 and 21, the elevations of the −0.4°C and 34.60‰ surfaces relative to 200 m are matched, more or less, by the depression of the 0.4°C and 34.68‰ surfaces, respectively. In Table 1 these vertical deviations are given in meters.

TABLE 1. Depth derivations and ratios.

Stations (Glacier-1973)	Depth deviation ΔZ (m) relative to 200 m of −0.04°C	+0.04°C	Ratio $\frac{\Delta Z_{-0.04°C}}{\Delta Z_{+0.04°C}}$ (a)	Depth deviation ΔZ (m) relative to 200 m of 34.60‰	34.68‰	Ratio $\frac{\Delta Z_{34.60‰}}{\Delta Z_{34.68‰}}$ (b)	$\frac{(a)}{(b)}$
12	16	37	0.43	32	53	0.60	0.72
13	42	26	1.6	53	64	0.83	1.9
14	69	117	0.59	74	206	0.36	1.6
15	74	270	0.27	85	318	0.27	1.0
16	106	297	0.36	106	291	0.36	1.0
17	85	228	0.37	96	249	0.38	1.0
18	48	85	0.56	48	233	0.20	2.8
19	85	53	0.16	90	159	0.56	6.0
20	117	238	0.48	106	291	0.36	1.3

Also given are the ratios $\Delta Z_{-0.4°C}/\Delta Z_{0.4°C}$ and $\Delta Z_{34.60‰}/\Delta Z_{34.68‰}$, as well as the ratio of these ratios.

Of most interest is that the ratio of ratios has values of unity throughout the center of the gyre, namely, stations 15, 16 and 17. This implies that the ratio of vertical turbulent diffusion coefficients, $K_{\text{salt}}/K_{\text{heat}}$, is unity. As pointed out by the authors, the stability factor for each of the large steps (station 16) in the depth interval 100 to 530 m is of order 1.03. Thus these steps are not easily attributed to double-diffusion mixing. Cabbeling, on the other hand, is mechanical mixing for which the ratio of turbulent diffusion coefficients is unity. It should also be noted that these steps may appear only in the summer as a result of highly unstable double diffusion acting upon a T, S distribution set up in wintertime by cabbeling.

7) All stations reported in this paper show clearly a mixing event at the level of the 34.64‰ isohaline, at depths of 270, 100 and 370 m for stations 3, 16, and 24, respectively. However, the profiles of the two outer stations differ from that in the center of the gyre in that stability immediately below the mixing event in the latter is essentially zero.

Discussion

The depth of the 34.64‰ isohaline is likely a shear zone and probably associated with the general upwelling of the region, i.e., upwelling related flow is confined to surface layers above the 34.64‰ isohaline. The dome structure seen in the central portion of the section is more likely a result of winter cabbeling and the formation of a lens of Modified Warm Deep Water. The upper limit of the lens is the 34.64‰ isohaline and the lower limit is inversely related to the relative height of the dome of the lens. Since, in winter, it is salt which is introduced into Winter Water, it follows that mixing by cabbeling must erode Winter Water and thereby create the dome structure.

Two questions remain. First, why is the dome structure where it is? The authors point out that the atmospheric conditions persist all year. If so, the surface waters diverge and consequently a regional ice pack cover will exhibit a concentration of leads over the gyre center. It follows that more salt flux is released in the central portion of the gyre than in the outer portions; hence, a doming characteristic in the center of the gyre.

It must be noted that the authors show summer data from which surface features cannot be projected to winter conditions. The existing lens of Modified Warm Deep Water is likely a residual from the previous winter. An application of the thermal wind equation to the area of highest horizontal gradients on the side of the central dome (stations 15 to 16, 120 m depth) yields a vertical shear of about 5×10^{-6} s^{-1} necessary to balance the horizontal density gradient. It follows then that a winter-formed lens will not dissipate in the following summer. The authors point out the existence of very low geostrophic velocities in all but the southern portion of the section.

The second question is: why two (or even three) domes? From the foregoing, one can speculate that the dome at station 16 represents the cabbeling in the 1972 austral winter while the dome at stations 20–21 is the residual of the 1971 winter. The displacement of the latter to the south is in consonance with the general southerly feeding of Modified Warm Deep Water toward the shelf and its eventual consumption in formation of Antarctic Deep and Bottom Water.

REFERENCE

Foster, Theodore D., and Eddy C. Carmack, 1976: Temperature and salinity structure in the Weddell Sea. *J. Phys. Oceanogr.*, **6**, 36–44.