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On the Ratio of the Mixing Coefficients of Heat and Salt of Antarctic Bottom Water in the North Atlantic

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Values of vertical eddy salt diffusivity and heat diffusivity for Antarctic Bottom Water were estimated by Whitehead and Worthington (1982) from both current meter results and geostrophic calculations. The ratios of the diffusivities have one impossible value of 0.858 for water colder than 1.1°C potential temperature for the geostrophic results. This could be evidence against the geostrophic results. However, a small interpolation error in their Tables 5 and 6 was uncovered. The corrected ratio is 1.01, which is possible, although very close to 1, and one other ratio is 0.98. Thus geostrophic calculations cannot be ruled out, but they lead to ratios very close to 1.

INTRODUCTION

Whitehead and Worthington [1982] estimated the volume flux of northward flow of Antarctic Bottom Water into the western North Atlantic basin through a passageway at about 4°N. Two different methods, one based on current meter results and one based on geostrophic calculations, gave surprisingly different results. For each result, residence times and mixing coefficients were calculated for each 0.1°C potential temperature interval for water in the North Atlantic from 1.0°C to 1.9°C.

One meaningful calculation which can be done using the resulting numbers is to take the ratio of the estimated salt diffusivity to thermal diffusivity. When this was recently done, the ratio based upon the geostrophic calculations for the 1.1°C isotherm was found to be 0.858, which is probably impossible. There is a salt inversion because the Antarctic Bottom Water is fresher than North Atlantic Deep Water, and in such a case, salt should be transported vertically more readily than heat. Therefore a transport ratio of less than 1 argues strongly against the validity of the numbers from the geostrophic calculations if they were to hold up.

In examining the data, a known error [*McDougall and Whitehead*, 1984, p. 10,480] in the interpolation of the mean salinity of the 1.05°C layer was found to be the cause of this low number. This leads to a tens of percent error in the final estimate for the salt mixing coefficients of the water colder than 1.2°C based upon the geostrophic calculations.

REVISED TABLES

Because of this error, all the calculations which went into the tables of *Whitehead and Worthington* [1982] have been redone. The only error found is that mentioned above. The corrected values of the eddy diffusivities and the ratio of the mixing coefficients R are shown in Table 1. They come from the corrected Tables 5 and 6 from *Whitehead and Worthington* [1982], which are given here as Tables 2 and 3. They are also improved slightly by interpolating the mean salinity of each layer to the nearest 0.0005‰, but in all cases this leads to a very small correction. All changes are in boldface.

The numbers from the current meter results in Table 1 are almost the same as would have been obtained from Whitehead and Worthington. For the geostrophic results, many values of the ratio are now very close to 1; one is slightly less at 0.98, and the value of the 1.1°C isotherm ratio is now 1.01. Both are probably indistinguishably close to 1. These numbers are low but are still possible. Thus the corrections presented here lead to the conclusion that the geostrophic calculations cannot be ruled out.

TABLE 1. Salt Diffusivity, Heat Diffusivity, and Their Ratio

Potential Temperature, °C	Current Meters			Geostrophic Calculations		
	K_s, cm² s⁻¹	K, cm² s⁻¹	R	K_s, cm² s⁻¹	K, cm² s⁻¹	R
1.9	1.703	1.144	1.49	5.365	4.616	1.16
1.8	1.242	0.890	1.40	4.116	3.851	1.07
1.7	0.902	0.698	1.29	3.223	3.285	0.98
1.6	1.006	0.722	1.39	4.059	3.944	1.03
1.5	0.634	0.406	1.56	3.120	2.833	1.10
1.4	0.251	0.153	1.64	1.588	1.447	1.10
1.3	0.358	0.211	1.69	3.171	2.914	1.09
1.2	0.341	0.186	1.83	4.183	4.010	1.04
1.1	0.212	0.095	2.23	3.349	3.327	1.01

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TABLE 2. Corrected Estimate of Salt Flux for Waters Colder Than 1.9° in the North Atlantic

Potential Temperature, °C	Salinity at Each Isotherm, ‰	Mean Salinity of Each Layer, ‰	Volume Advected Into Each Layer at 4°N, 10^6 m^{-3} s^{-1}	Volume Advected Across Each Isotherm, 10^6 m^3 s^{-1}	Salt Advected Into Each Layer at 4°N, 10^9 g s^{-1}	Salt Advected Upward Across Each Isotherm, 10^9 g s^{-1}	Total Salt Advected Into Each Layer, 10^9 g s^{-1}	Downward Diffusion of Salt Across Each Isotherm, 10^9 g s^{-1}	Area of Each Isotherm, 10^{13} cm^3
Current Meter Transport									
1.9	34.892			0.8103		28.2730		0.0464	8205
		34.8865	0.0235		0.8198		28.2642		
1.8	34.881			0.7868		27.4444		0.0376	6504
		34.8750	0.0428		1.4927		27.4352		
1.7	34.869			0.7440		25.9425		0.0284	4784
		34.8625	0.0725		2.5275		25.9333		
1.6	34.856			0.6715		23.4058		**0.0192**	3500
		34.8500	0.1077		3.7533		23.3983		
1.5	34.844			0.5638		19.6450		0.0117	2382
		34.8385	0.1636		**5.6996**		**19.6396**		
1.4	34.833			0.4002		13.9402		0.0065	1296
		34.8275	0.1648		**5.7396**		13.9367		
1.3	34.822			0.2354		8.1971		**0.0030**	509
		34.8165	0.1204		**4.1919**		**8.1952**		
1.2	34.811			0.1150		4.0033		**0.00112**	191
		34.8050	0.0791		2.7531		4.0024		
1.1	34.799			0.0359		1.2493		**0.0002154**	55
		34.7930	0.0359		1.2491		1.2491		
1.0	34.787								0
Geostrophic Transport Referenced to 1.9°C									
1.9	34.892			1.982		69.1559		0.1463	8205
		34.8865	0.013		0.4535		69.1342		
1.8	34.881			1.969		68.6807		**0.1246**	6504
		34.8750	0.085		**2.9644**		68.6576		
1.7	34.869			1.884		65.6932		**0.1015**	4784
		34.8625	0.125		4.3578		65.6695		
1.6	34.856			1.759		61.3117		**0.0778**	3500
		34.8500	0.139		4.8442		61.2915		
1.5	34.844			1.620		56.4473		0.0576	2382
		34.8385	0.230		**8.0129**		**56.4308**		
1.4	34.833			1.390		48.4179		0.0411	1296
		34.8275	0.130		4.5276		48.4033		
1.3	34.822			1.260		43.8757		**0.0265**	509
		34.8165	0.153		**5.3269**		43.8627		
1.2	34.811			1.107		38.5358		**0.0135**	191
		34.8050	0.531		18.4815		38.5257		
1.1	34.799			0.576		20.0442		**0.0034**	55
		34.7930	0.576		**20.0408**		**20.0408**		
1.0	34.787					0			0

Boldface type indicates a change from Table 5 of *Whitehead and Worthington* [1982]. Columns referring to bodies between isotherms are staggered.

TABLE 3. Corrected Estimate of Salt Mixing Coefficients

Potential Temperature, °C	Downward Diffusion of Salt Q_s, 10^{-10} g cm^2 s^{-1}	4°–10°N		10°–15°N		15°–20°N		20°–25°N		25°–30°N		30°–35°N		35°–40°N		40°–43°N		K_s
		dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	dS/dz, 10^{-10} g cm^{-4}	K_s, cm^2 s^{-1}	
								$\langle \bar{K}_s \rangle = 1.061$										
1.9	5.66	7.38	0.767	5.26	1.076	4.58	1.236	3.89	1.455	3.58	1.581	3.06	1.850	2.00	2.830	2.00	2.830	1.703
1.8	5.78	10.34	0.559	6.94	0.833	5.29	1.093	4.86	1.189	3.90	1.482	4.01	1.441	2.76	2.094			1.242
1.7	5.94	19.70	0.302	12.04	0.493	6.67	0.891	6.47	0.918	4.06	1.463	4.41	1.347					0.902
1.6	5.51	25.53	0.216	12.24	0.450	6.45	0.854	3.83	1.439	2.66	2.071							1.006
1.5	4.91	33.33	0.147	9.48	0.518	3.97	1.237											0.634
1.4	5.02	28.95	0.173	15.28	0.329													0.251
1.3	5.89	16.42	0.358															0.358
1.2	5.76	16.90	0.341															0.341
1.1	3.92	18.46	0.212															0.212
								$\langle \bar{K}_s \rangle = 3.959$										
1.9	17.83	7.38	2.416	5.26	3.390	4.58	3.893	3.89	4.584	3.58	4.980	3.06	5.827	2.00	8.915	2.00	8.915	5.365
1.8	19.16	10.34	1.853	6.94	2.761	5.29	3.622	4.86	3.942	3.90	4.913	4.01	4.778	2.76	6.942			4.116
1.7	21.22	19.70	1.077	12.04	1.762	6.67	3.181	6.47	3.280	4.06	5.227	4.41	4.812					3.223
1.6	22.23	25.53	0.871	12.24	1.816	6.45	3.447	3.83	5.804	2.66	8.357							4.059
1.5	24.18	33.33	0.725	9.48	2.550	3.97	6.090											3.120
1.4	31.77	28.95	1.097	15.28	2.079													1.588
1.3	52.06	16.42	3.171															3.171
1.2	70.68	16.90	4.183															4.183
1.1	61.82	18.46	3.349															3.349

Boldface type indicates a change from Table 6 of *Whitehead and Worthington* [1982].

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