ON THE DISTRIBUTION OF SOUND VELOCITY IN A SECTION OF VIZAG IN THE BAY OF BENGAL

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ABSTRACT

The vertical sound velocity distribution in a section of Visakhapatnam in the Bay of Bengal has been computed making use of Kuwahara's tables. In an attempt to find out the corrections to the echo-sounder readings the average sound velocity distribution is computed together with the sound velocity profiles taking the spot values only. The physical oceanography of the area in relation to the sound velocity distribution is discussed.

Introduction

Sound waves travel more rapidly and with much less attenuation through water than through air. The transmission of sound pulses had become important in physical oceanography and one of the several uses is to determine the depth of the ocean floor. Generally the time that is noted in the echo-sounder when an impulse is set to travel to the bottom and back is a measure of the depth on the assumption of a uniform velocity for the sound wave throughout the depth. But, when critically examined, the temperature and salinity distribution in the column under study will influence the velocity of sound and hence an error in the evaluation of depth. The first computations of sound velocity were made by Heck and Service (1924) of the U. S. Coast and Geodetic Survey and thereafter improved by the British admiralty tables prepared by Mathews (1927). S. Kuwahara[1] (1939) had computed sound velocities and had prepared tables for computing sound velocity. In the present investigation the vertical sound velocity distribution has been computed based on Kuwahara's tables from temperature and salinity data at various depths and at eight stations taken during March 1935, by I. N. S. Bengal. As the purpose of the cruise was to take a vertical section of temperature and salinity off Visakhapatnam and to have a knowledge of upwelling and to measure surface and subsurface currents in the top layers of the bay, these observations were not quite sufficient to compute the sound velocity upto the bottom of the sea. However as first attempt, the average sound velocity distribution upto the depths reached is presented in the following pages. To a first approximation the vertical column is divided into layers whose thickness depends upon the depths at which samples are collected by Nansen bottles. The mean temperatures and salinities are evaluated and these are applied for obtaining average corrections for the sound velocity.

For the discussion on the physical Oceanography, only the values for sound velocity at the particular positions defined by positions of Nansen bottles are calculated in which average values are not taken. These are obtained by merely applying corrections due to temperature, pressure and salinity to the normal velocity of 1445·5 m/sec. at temperature of 0°C, salinity 35°/₀₀ and at the surface.

Vertical Distribution of Sound Velocity

Figure 1 shows the oceanographic stations of the cruise No. 12 taken during March 1953 by I.N.S. Bengal[2]. At each station water samples are taken by means of Nansen bottles and temperatures were measured by reversing thermometers. The depths were obtained from the readings of the protected and unprotected types of reversing thermometers taking care that all the necessary corrections are applied. In addition bathythermograms were taken up to a depth of 200 ft. The maximum depth that was reached by Nansen casts was only up to about 500 m.

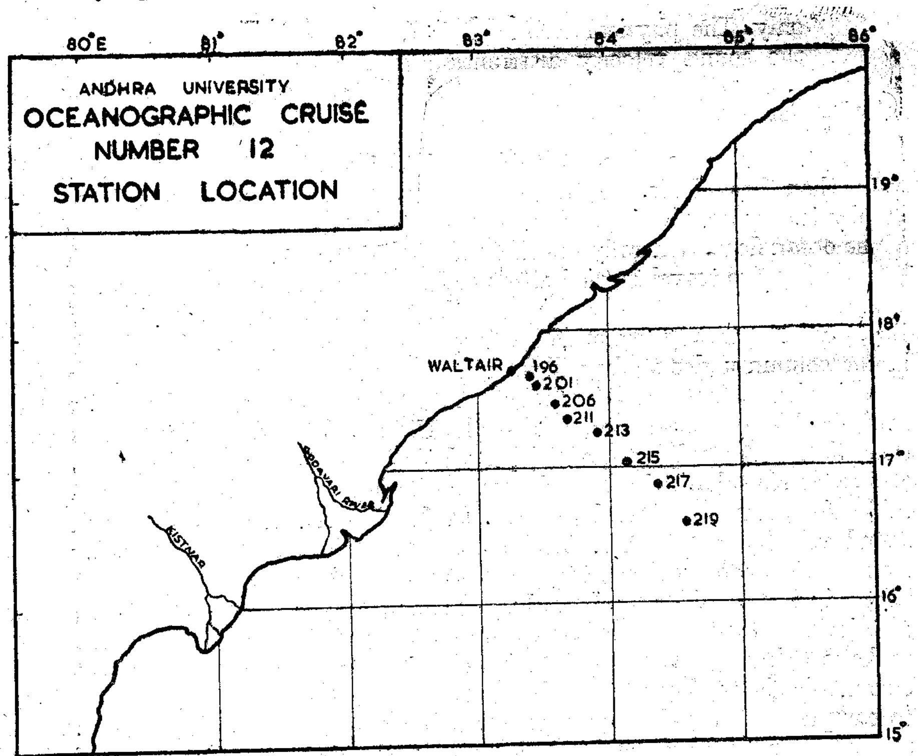

FIG.-1.
STATION LOCATION MAP

The samples were analysed by standard methods for obtaining salinity and temperature. The salinity has been calculated from chlorinity which in turn is determined by titrating a given sample of sea water with silver nitrate. The accuracy of measurement of salinity is—0·1°/₀₀ while that of temperature is—0·1°F. The gravity correction given in Kuwahara's tables has been neglected as it is practically zero at depths indicated herein and for the latitude in which the section appears. The error in the sound velocity does not exceed—0·2 m/sec.

Table 1 gives the depth, temperature and salinity data and the average sound velocity upto the depths indicated in column (1) together with the computed velocities of sound for each depth of sampling. The resulting section of the average sound velocity distribution is given in Fig. 2. These values have been computed from the surface upto a depth of about 500 m. Each contour represents the average velocity upto that depth, and reflects the character of whole water mass above that depth and not the actual velocity at that depth. The method of computation is given as an Appendix.

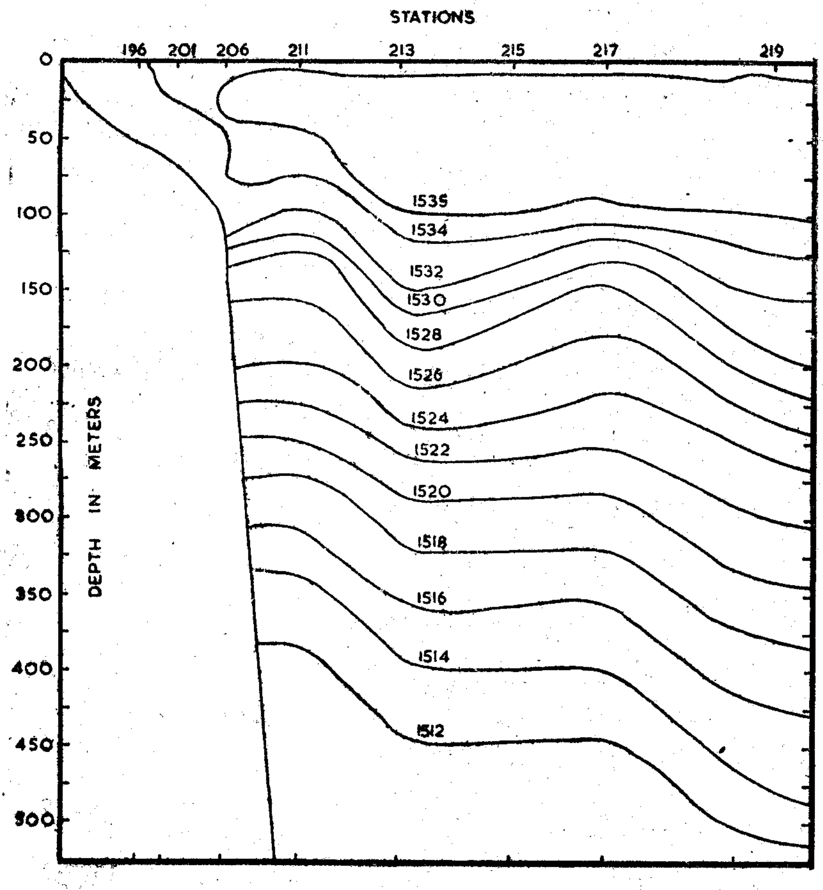

FIG. 2.

VERTICAL SECTION OF VERTICAL SOUND VELOCITY DISTRIBUTION

TABLE 1

D Meters	t °C	S °/oo	Average Velocity	Actual Velocity
		Station 196		
0·0	26·61	33·66		1533·8
			1533·9	
7·9	26·59	33·84		1534·2
			1533·8	
16·5	26·28	33·84		1533·6
			1533·6	
24·4	25·44	34·20		1532·3
			1532·9	
40·2	24·62	34·99		1531·5
		Station 201		
0·0	27·17	33·31		1534·7
			1534·7	
8·2	27·08	33·49		1534·2
			1534·8	
16·8	26·91	33·84		1533·6
			1532·2	
33·2	26·72	34·29		1532·3
			1532·8	
49·7	24·94	34·90		1531·5
		Station 206		
0·0	27·31	33·22		1534·7
			1535·0	
16·6	27·36	33·40		1535·5
			1535·1	
32·9	26·89	33·75		1535·2
			1534·0	
49·4	26·53	34·20		1535·2
			1534·0	
74·1	24·86	34·72		1532·3
			1532·9	
98·7	22·71	35·26		1528·1

TABLE 1—*contd.*

D Meters	t °C	S °/oo	Average Velocity	Actual Velocity
		Station 211		
0·0	27·22	33·31		1534·7
			1535·2	
18·0	27·36	33·49		1535·7
			1535·0	
33·8	26·53	33·66		1534·4
			1534·8	
62·8	26·40	34·20		1535·4
			1533·3	
89·6	23·76	34·90		1530·1
			1527·2	
131·7	18·58	34·99		1517·1
			1529·0	
148·7	18·08	34·99		1515·2
			1523·6	
206·4	13·67	35·17		1503·4
			1517·7	
277·1	11·62	35·26		1498·1
			1513·7	
344·1	10·42	35·35		1495·0
			1510·7	
416·1	9·87	35·17		1493·9
		Station 213		
0·0	27·22	33·49		1534·9
			1535·2	
17·7	27·33	33·31		1535·4
			1535·3	
35·7	26·89	33·84		1535·3
			1534·4	
62·2	26·53	34·72		1536·3
			1535·3	
88·7	25·51	34·91		1534·4
			1533·1	
133·2	20·36	35·52		1522·8
			1532·6	
139·6	20·05	35·35		1521·9
			1525·6	
221·0	14·18	35·26		1505·5
			1519·4	
298·1	11·94	35·26		1499·5
			1515·1	
373·1	10·75	35·35		1496·7
			1511·9	
451·1	10·10	35·26		1495·6

TABLE 1—*contd.*

D Meters	t °C	S ‰	Average Velocity	Normal Velocity
		Station 215		
0·0	27·1	32·95	1534·7	1534·0
16·5	27·43	33·33	1534·6	1534·3
33·0	26·87	33·57	1534·7	1535·0
58·7	26·62	33·66	1534·8	1534·8
83·4	26·07	34·63	1533·2	1535·1
119·7	21·88	35·17	1527·6	1525·7
189·9	15·55	35·26	1521·6	1509·2
258·9	12·77	35·08	1517·0	1501·2
326·7	11·19	35·26	1513·2	1497·4
403 5	10·44	35·26		1496·0
		Station 217		
0·0	27·50	32·95	1535·2	1534·9
18·0	27·28	33·49	1535·4	1535·5
36·0	27·09	33·75	1535·4	1535·7
62·8	26·60	33·84	1535·0	1535·4
88·9	25·28	34·54	1525·2	1533·4
135·0	20·42	35·08	1528·0	1522·3
143·3	18·88	34·72	1523·7	1520·8
226·2	14·60	35·44	1518·5	1507·2
306·0	12·18	35·44	1514·6	1500·7
383·1	10·90	35·06	1511·5	1487·0
465·1	10·25	35·26		1496·6

TABLE 1—*concld.*

D Meters	t °C	S °/∞	Average Velocity	Normal Velocity
		Station 219		
0·0	27·44	33·12		1535·0
			1535·2	
18·3	27·20	33·22		1534·9
			1535·4	
36·6	26·82	33·55		1534·8
			1535·4	
64·0	26·86	34·02		1536·2
			1535·0	
91·4	25·80	34·54		1534·7
			1525·2	
131·2	20·86	34·90		1523·5
			1528·0	
164·6	18·32	34·99		1516·9
			1523·7	
	13·45	34·72		1504·0
258·2			1518·5	
346·2	11·52	34·90		1497·6
			1514·6	
430·1	10·53	35·08		1496·6
			1511·5	
519·0	9·84	35·08		1495·7

Fig. 3 shows the sound velocity distribution in which the isopleths at 2 m. interval indicate the velocity of propogation of sound waves. These are obtained by using the values in column (5) of the table (1). The dotted line as shown in the figure represents the sound channel which may be defined after Ernest Anderson[3] (1950) as the region of minimum sound velocity with higher velocity above and below. The bottom sound channel which is supposed to exist at about a depth of 700 m could not be observed owing to lack of data below 500 m.

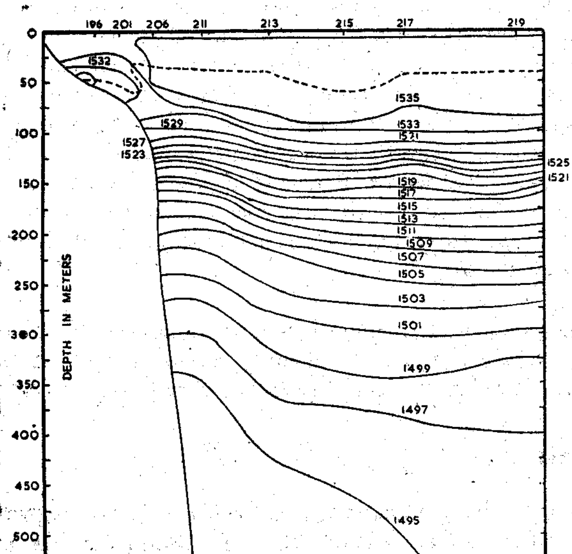

FIG. 3

VERTICAL SECTION OF NORMAL SOUND VELOCITY DISTRIBUTION

Distribution of Sound Velocity and the Physical Oceanography of the Area

Since any water mass is identified by its temperature salinity diagram and since the sound velocity is mainly dependent upon temperature and salinity, all features of the sound distribution may be related to the water masses that are present. Sound velocity distribution indicated the usual upwelling near shore as is also clear from BT observations i.e. upwelling was present especially near shore and a maximum occurred around five miles off shore. At this location, there was no distinct surface layer defined by homogeneous density and the thermocline came upto the surface. Away from the point where upwelling is maximum (from station 201 onwards) a surface layer developed and the depth progressively increased with the distance from shore. At the 100 mile station (station 219) it is about 65 m. in thickness.

Near the shore and upto about 8 miles away from the shore the sound velocity gradually increased from 1531 m/sec. to 1534 m/sec. as is seen from the tongue like distribution. Away from the station 201 (Fig. 3) the sound velocity is rather uniform in the top layers upto the station 219 as can be seen from the isopleth of 1535 m/sec. This indicates that there is a surface layer gradually increasing in depth as we go away from station 201. Between the coast and station 201, the tongue like distribution of the sound velocity may be attributed to the observed upwelling in this region. At the thermocline came up nearly to the surface at most of the stations, the sound velocity is maximum at and near the surface as is clearly seen from Fig. 3.

The Top Sound Channel

In fig. 3 the dotted line represents the surface sound channel. The depth of the sound channel gradually decreased between stations 196 and 201. Between stations 201 and 214 the depth of the sound channel is uniform and thereafter increased slightly at stations 215. From the station 215 onwards it has a uniform depth of 40 m. An observation of the structure of the isobaric surface (Rama Sastry[4] 1955), and the distribution of temperature and salinity indicate the intensity of upwelling. This sound channel may be attributed as a separating line (in between stations 196 and 201) between the source of upwelled water and the formation of the surface water. Water of higher density from below this line is drawn up to the surface. And here is the location for the formation of the surface layer. This is drawn away from the coast and gradually increases in thickness away from station 201.

Data is being collected during this year along the East coast and it is proposed to investigate the sound velocity distribution along the East coast of India with special reference to the seasonal variation of Visakhapatnam.

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APPENDIX

Computation of average velocity of sound upto any depth

The sound waves run vertically between the surface and the bottom of the sea in case of sonic sounding. Since the physical conditions change with depth (the pressure increases, even if we suppose that the temperature and salinity do not change) the velocity of sound varies with depth. Since we require the mean velocity, we have to take into consideration the average conditions and the method of averaging is explained with reference to the table below.

In the table II the first three columns contain the depths, temperatures and salinities. Columns (4) and (5) give the temperature and salinity corrections respectively, while the column (6) gives the correction for any simultaneous changes of temperature pressure and salinity. These corrections are added in column (7) and in column (8) the average corrections for the layer in between the two depths are noted. Column (9) gives the value of $X = (d \times \bar{c} \times 10^{-1})$ where d is the difference in depths where the successive samples are collected and $\bar{c}$ is the average correction obtained in the previous column. The cumulative values of X are given in column (10) while the actual corrections due to temperature and salinity are given in column (11). In this the effect of the factor d has been eliminated. The column (12) gives the normal velocity of sound in sea water for sounding at various depths when the salinity is 35°/₀₀ and temperature is 0°C. Addition of columns (11) and (12) gives the average vertical velocity v_s.

The value in columns 4, 5, 6 and 12 are taken from Kuwahara's tables.

TABLE II

Station 206

d_m (1)	$t°C$ (2)	S °/₀₀ (3)	c_t (4)	c_s (5)	c_{stp} (6)	c (7)	$\bar{c}$ (8)	X (9)	ΣX (10)	C (11)	V^n_s (12)	V_s (13)
0·0	27·31	33·22	91·6	−2·4	0·3	89·5						
							89·75	148·5				
16·6	27·36	33·40	91·8	−2·1	0·3	90·0			148·5	89·45	1445·5	1535·0
							89·65	145·6				
32·9	26·89	33·75	90·7	−1·7	0·3	89·3			294·1	89·54	1445·6	1535·1
							89·15	140·8				
49·4	26·35	34·20	89·9	−1·0	0·1	89·0			434·9	88·14	1445·9	1534·0
							87·25	215·4				
74·1	24·86	34·72	85·9	−0·4	0·0	85·5			650·3	87·88	1446·1	1534·0
							83·15	204·6				
98·7	22·71	35·26	0·4	0·4	0·0	80·8			854·9	86·64	1446·3	1532·9