ANCHORING SHIPS ON THE HIGH SEAS (*)

by

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INTRODUCTION.

As a result of physical and chemical investigations of the sea conducted for more than half a century, the principal circulation features of the ocean basins are now believed to be generally known. Consequently, new methods for studying oceanic phenomena are being used which frequently require fundamental alterations in the customary field procedure of making observations at sea. For instance, to obtain continuous measurements of physical and chemical variations at fixed points in the sea, operations need to be carried out for periods of several days from a vessel anchored in the great depths of the ocean basins; and with modern precision instruments the data's value depends chiefly on maintaining the vessel in a relatively fixed position during observations. Measurements of oceanic phenomena from ships anchored on the high seas, although rare, are not new, and have been successfully carried out by at least six different research ships. Mooring ships in the great depths of the ocean basins, however, is still largely in an experimental stage. While actual demonstrations have solved the more general questions of technique, numerous specific problems for any individual vessel must be met under a variety of different, often difficult, conditions.

The two types of oceanographic measurements made from an anchored vessel differ in requirements of stability. Thus, observations on time variations of physical and chemical properties of the water (temperature, salinity, etc.) at a series of determined depths, measured from the physical sea surface along a fixed vertical, are not affected either by the usual pendular motions or by small amounts of drifting of the ship, and are more easily carried out. The procedure, as used on "Atlantis", is to make repeated successive samplings of the water column (between surface and 1,200 - 1,400 meters) at 18 different depths with a similar number of reversing Nansen type water bottles, to each of which are attached two reversing thermometers. Entanglements of the hydrographic (with samplers attached) and anchor wires, due to the ship overriding its anchor, can be avoided with judicious care.

The second method, direct measurements of ocean currents, is more uncertain since best results require the impossible situation of a completely immobile vessel. As a consequence, corrections based on analysis of the anchored ship's pendular movements and drift must be applied in analysing the observations. It is difficult to produce ideal conditions for the direct measurement of ocean currents from a ship anchored on the high seas as, for instance, through the use of triple moorings, two well-spaced anchors forward and one sternward. (1)

DEEP SEA ANCHORING AND EQUIPMENT OF OCEANOGRAPHIC RESEARCH SHIPS.

The first anchoring in deep water for scientific investigations of the ocean were made by PILLSBURY on the "Blake" in 1888 and 1889. Thirty-nine stations (up to 166 hours duration) were completed off the American coast in the Gulf Stream, the depths of mooring

(*) Contribution N° 237, *Woods Hole Oceanographic Institution.*

(1) SPIESS, F. "Mooring of Ships in Deep Water", "*Hydrographic Review*", Vol. IX, N° 1, May, 1932.

extending to approximately 4,000 meters. The method and technique employed (described by Pillsbury (2)) demonstrated the feasibility of anchoring a large ship in the ocean, and subsequent improvements are primarily the result of refined equipment. However, it was not until 20 years later that deep-sea anchoring was again attempted, when Helland-Hansen carried out a series of current measurements in the North Atlantic on board the "Michael Sars", and then later, between 1913 and 1924, successfully made a number of deep-sea anchorings (3), to depths of approximately 4,000 meters, from the "Armauer Hansen", a ship of only 57 gross tons. Further oceanographic measurements from ships moored on the high seas were undertaken by the German research ship "Meteor" (67 meters length, 1,180 tons displacement) during 1925-27 and 1937-38 in the North and South Atlantic; by the Dutch research ship "Willebrord Snellius" (62 meters length, 1,055 tons displacement) during 1929-30 in the waters of the Dutch East Indies; and by the American research ship "Atlantis" (43 meters length, 460 tons displacement) from 1936 to the present in the western North Atlantic and Caribbean Sea basins.

Descriptions of the anchoring equipment and technique on "Meteor" have been given by Spiess (4), Defant (5), and von Schubert (6). The anchor cable was one piece (without splice, the ends of each wire in every strand being welded together) galvanized cast steel, composed of 7 wire strands (24 wires each) wound over a hemp core, 7,500 meters long. The cable was tapered, the circumference of the end shackled to the anchor being 3.6 centimeters, and that fastened to the cable reel 5 centimeters. The deep-sea anchor was a normal or Admiralty type, long shank and iron stock ,weighing 100 kilograms; for mooring, this was backed by a second anchor, a "stockless bower" (Wasteneys Smith's patent) of the same weight, with a 50-meter wire pendant. The amount of cable reeled out, in general, amounted to about 1 1/3 times the depth of water. Between 1925 and 1927, 9 anchor stations (13 to 65 hours duration) were occupied by "Meteor", in the Atlantic between 24° N. and 28° S. The greatest depth of anchoring was 5,489 meters at Station 147 (14° —57.2' S., 0° —06.6' W.), where 6,500 meters of cable with two anchors were used; the ship lay at anchor for 49 hours dragging 2.4 miles. For this deep anchoring Spiess notes the mean wind velocity of force 4 to 5, increased to force 7 and the sea to 6, and that the anchor cable carried away while weighing, due to the vessel's pitching in a sea way.

The anchor gear on "Willebrord Snellius" was essentially identical with that of "Meteor": 7,500 meters of tapered, kinkless steel cable with two mushroom anchors weighing 100 and 200 kilograms, respectively. For mooring the 100 kilogram mushroom was shackled to the second heavier anchor by 30 meters of cable, and then followed by 15 fathoms of chain weighing 165 kilograms. Later, after loss of the lighter anchor, the 200 kilogram mushroom was successfully used alone (7). This vessel occupied seven deep-sea

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(2) Pillsbury, John Elliot — "The Gulf Stream", *Rept. U.S. Coast and Geodetic Survey*, Appendix 10, pp. 461-620, 1891.

(3) Helland-Hansen, Bjørn, "Neue Forschungen im nördlichen Atlantischen Ozean", Zeitschrift der. Ges. f. Erdkunde zu Berlin, 1911; and Helland-Hansen, Bjørn "Meeresforschung mit kleinen Forschungsschiffen", Zeitschrift der. Ges. f. Erdkunde zu Berlin, 1891.

(4) Helland-Hansen, Bjørn, "Neue Forschungen im nördlichen Atlantischen Ozean", Zeitschrift der. Ges. f. Erdkunde zu Berlin, 1911; and Helland-Hansen, Bjørn "Meeresforschung mit kleinen Forschungsschiffen", Zeitschrift der. Ges. f. Erdkunde zu Berlin, 1891.

(5) Defant, Albert, "Die Gezeiten und inneren Gezeitenwellen des Atlantischen Ozeans", Wiss. Ergeb. der Deutschen Atlantischen Expedition" "Meteor", 1925-1927. Vol. VIII, Part I; and Defant, A., "Bericht über den ersten Teil der Deutschen Nordatlantischen Expedition des Forschungs-und Vermessungsschiffes" "Meteor", Februar bis Mai 1937". Sitzungsberichten der Preussichen Akademie der Wissenschaften. Phys.-math. Klasse 1937. XIX.

(6) v. Schubert, O. — "Die ozeanographischen Arbeiten auf der Zweiten Teilfahrt der Deutschen Nordatlantischen Expedition Januar bis Juli, 1938". Annalen der Hydrographie und Maritimen Meteorologie, 1939, pp. 11-18.

(7) Perks, J.P.H., "The Deep Sea Anchorage Equipment", The *Snellius* Expedition, Vol. I Chap. II, Appendix 3, 1938.

anchor stations (24 to 89 hours duration) in the waters of the Netherlands East Indies, at depths between 1,150 and 4,850 meters; at the deepest (Station 308 a; 53 hours duration) 6,500 meters of anchor cable were lowered.

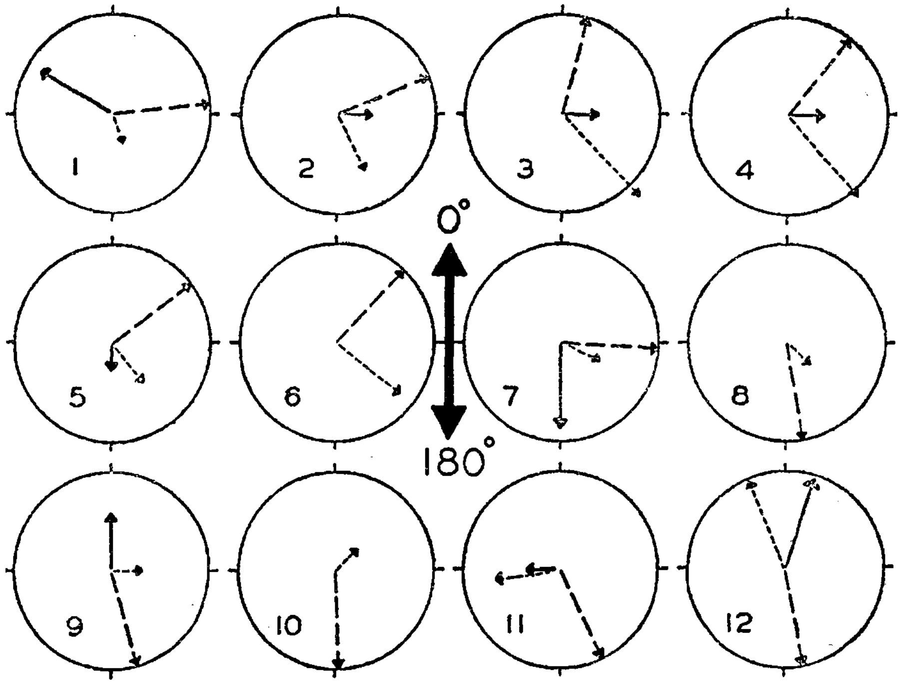

FIG. 1.

General relationships between average ship's heading, average wind current directions (dashed arrow; 1 cm. = 1 Beaufort unit), and average ship's drift or anchor drag (solid arrow; 1 cm. = 0.2 naut.), for 12 time intervals between position determinations, Oct. 9 to 14, 1939, "Atlantis" anchor Station 3703 (30° —56' N. 67° —09' W.). The 12 time intervals (+ 5 time zone) are :

1. Noon to 17 h. —30 m., Oct. 9
2. 17 h. —30 m. to 05 h., Oct. 10 —
3. 05 h. —05 m. to noon.
4. Noon to 17 h. —30 m.
5. 17 h. —30 m. to 05 h. —07 m. Oct. 11
6. 05 h. —07 m. to noon.
7. Noon to 17 h. —30 m.
8. 17 h. —30 m. to 05 h. —00 m., Oct. 12
9. 05 h. —00 m. to noon
10. Noon to noon, Oct. 13
11. Noon to 05 h. —00 m., Oct. 14
12. 05 h. —00 m. to noon.

DEEP-SEA ANCHORING BY "*ATLANTIS*".

The auxiliary steel ketch "Atlantis" (research vessel of the Woods Hole Oceanographic Institution), about 460 tons displacement, 142 feet length on deck and 29 foot beam, carries 7,200 square feet of canvas and is powered by a 280-horsepower Diesel engine. The latter also supplies power through a special dynamo to a heavy trawl winch in the lower hold that carries the anchoring cable. Specific arrangements were not made for deep-sea anchoring at the time of construction, 1930-31, but with the initiation of a deep-sea anchoring program several years later, available facilities were utilized to the extent that the only major acquisition was the construction of a steel gallows over the bow of the ship (see illustrations pages) from which is suspended a 16-inch shiver to lead the anchor cable overboard. The gallows is bolted to the ship's hull and to take up extra strains two jury preventer stays are fastened between its head and the fittings of the jib backstay.

TABLE I

SUMMARY: *Atlantis* DEEP SEA-ANCHOR STATIONS (MORE THAN 1,000 METERS DEPTH)

Station	Mean Position	G.M.T.[1]	Depth (meters)	(a) Cable length (b) % scope	(a) Anchoring[2] (b) Weighing	(a) Wind range (b) Mean	(a) Sea range (b) Mean	Drag	Remarks	Observation Time	No. Samplings	No. Temperature Samples[3]	Hydrographic Range	Wire Angle Mean[4]
3183	32°-08′N 64°-10′W	Oct. 14 (05^h-33′)-15 (15^h-34′) 1938	4,550	(a) 6222 (b) 36.75%	(a) 3^h-08′ (b) 2^h-10′	(a) 3-4 (b) 3-4	(a) 3-4 (b) 3-4	14th: 5^h-55′-12^h-00′=2.6 mi. 270°; 0.43 nauts		34^h-01′	24	360		
3245	25°-32′N 53°-46′W	Jan. 23 (02^h-54′)-24 (04^h-45′) 1939	4,865- 5,000	(a) 6500 (b) 32.8%	(a) 2^h-30′ (b) 2^h-14′	(a) 1-2 (b) 1-2	(a) 1-2 (b) 1-2	05^h-50′-12^h-00′-4.4 mi. 155°; 0.71 nauts 12^h-00′-17^h-42′=3.5 mi. 210°; 0.31 nauts		25^h-51′	28	504	9°-23′-15°-36′	12°-47′
3296	14°-55′N 60°-18′W	Feb. 16 (01^h-06′)-17 (02^h-54′) 1939	3,266- 3,380	(a) 5000 (b) 50.3%	(a) 2^h-05′ (b) 1^h-25′*	(a) 2-4 (b) 3	(a) 3-4 (b) 3	0	Anchor and 50-ft. Manila hemp lost; wire parted at shackle	25^h-48′	30	540	0°-16°-15′	12°-30′
3297	15°-38′N 66°-26′W	Feb. 27 (00^h-44′)-28 (02^h-02′) 1939	4,740- 4,831	(a) 6400 (b) 33.7%	(a) 2^h-41′ (b) 2^h-15′	(a) 4-5 (b) 4	(a) 4-5 (b) 4	06^h-20′-12^h-00′=5.8 mi. 300°; 1.02 nauts 12^h-00′-19^h-00′=5.3 mi. 250°; 0.76 nauts		25^h-18′	29	522	13°-15′-20°-20′	16°-12′
3298	18°-10′N 75°-07′W	Mar. 3 (03^h-15′)-4 (07^h-13′) 1939	2,270- 2,330	(a) 3500 (b) 52.2%	(a) 1^h-10′ (b) 0^h-30′*	(a) 0-3 (b) 1-2	(a) 0-3 (b) 1-2	0	Anchor and 1100 meters wire lost	27^h-58′	32	576	12°-35′-19°-14′	15°-03′
3300	19°-31′N 73°-26′W	Mar. 12 (15^h-41′)-13 (17^h-10′) 1939	1,190- 1,400	(a) 1400 (b) 0.8%	(a) 0^h-39′ (b) 0^h-40′*	(a) 0-2 (b) 1-2	(a) 0-2 (b) 1-2	0	Anchor and 1200 meters wire lost	25^h-29′	31	558	11°-30′-17°50′-	15°-03′
3703	34°-56′N 67°-09′W	Oct. 9 (17^h-49′)-14 (21^h-37′) 1939	5,325	(a) 5948 (b) 11.7%	(a) 3^h-20′ (b) 1^h-36′*	(a) 0-4 (b) 1-2	(a) 0-3 (b) 1-2	Max: Oct. 14th, 05^h-00′-12^h-00′=4.1 mi.; 17° Rate=0.17-0.59 nauts Average=0.24 nauts	Anchor, weight, and 975 meters wire lost	123^h-48′	123	2213	0°-15°-00′	8°-52′

[1] Time interval between closing of first and final series of water samplers.

[2] *Gear lost while weighing.

[3] Approximately 15% of samples titrated for salinity.

[4] Based on computed depth of samplings; usually to depths of 250-300 meters

For deep-sea anchoring 29,500 feet (9,678 meters) of preformed, galvanized 1/2 inch steel rope, in one continuous length, is available. This cable, also used for deep-sea trawling, has its outer end of 500 feet composed of 6 strands (37 wires each) with hemp center, the next 10,000 feet is of 6 strands (19 wires each) with hemp center, and the final 19,000 feet identical except for a wire rope center. The extra pliability of the outer 500 meters has not withstood kinking, with subsequent breaking and loss of gear. From the winch control on deck, anchoring operations are conducted in full sight of all running gear. Ordinary iron stock kedge anchors weighing between 400 and 250 pounds have generally been used; at Station 3703 the lighter anchor was backed by a 300-pound block of cement to which it was shackled by a 50-foot, 3 1/2 inch Manila hemp pendant.

During the 7 " Atlantis " deep-sea anchorings, in depths of more than 1,000 meters (Table 1), 4 anchors and 3,100 meters of steel cable have been lost. In all cases except one (Stations 3300), loss of gear resulted from the kinked steel cable breaking on weighing. At Station 3300 (in Gonave Gulf) the 500-pound anchor resisted all attempts to break free of the bottom and the steel cable broke at the dynamometer on deck; the wire would probably have been saved by use of a lighter anchor or by a weakened pendant shackled between anchor and steel cable. It is obvious that the use of "kinkless" cable, at least in part is highly desirable, although this, in itself, is no guarantee against loss of gear. Since it appears that kinking occurs in that part of the cable which at some time or other during anchoring lies on the bottom, it is desirable to lower as little cable in excess of depth as is needed to prevent excessive drift of the ship. In general, an amount of cable about 15 per cent in excess of the depth appears to be adequate, although somewhat more may be required to reduce drag when anchored in strong currents or in winds above force 5. Thus, judging from " Atlantis " experience, for wind velocities up to force 5 variations in scope of the anchor cable of between 12 and 34 per cent appear to have little effect on the amount of drag. For instance, at Station 3297 (4,831 meters), with anchor cable lowered 33.7 per cent in excess of depth, and maximum wind velocity of force 5, the vessel's drag averaged 1.02 nautical miles per hour for nearly 6 hours; whereas at Station 3703 (5,325 meters), with the anchor cable only 11,7 per cent in excess of depth, and a maximum wind force 4, the maximum computed drag averaged 0.59 nautical miles per hour. Drag at this latter station was even less than that at Station 3245 (0.71 nautical miles per hour) where cable length was 32.8 per cent in excess of depth and where surface wind velocities were only force 2. Effects of surface layer currents at these stations are unknown, but were not at any time much in excess of 1/2 naut.

Accurate knowledge of the ship's drift and of its pendular movements is significant for reduction of the scientific observations, particularly when current measurements are undertaken. Computation of the ship's drift because of the anchor dragging (Table 1) is dependent on astronomical observations; in general, three satisfactory positions are available each day. The morning and evening position polygons are based on 3 to 5 position lines determined from altitudes of fixed stars or planets, and the noon position is based on several hour angle measurements of the sun during forenoon and afternoon combined with the meridian altitude. Accuracy of astronomically determined position to $\pm$ 1 mile, using the usual instruments, tables, and methods, was generally accepted, and, in computations of drag, position differences of one minute of arc or less were not considered significant. The maximum drag computed for any station was at an average rate of 1.02 nautical miles per hour. In general, anchor drag is greatest at the beginning, diminishing as the anchor apparently obtains a better grip in the bottom; at the three shallowest (1,190-3,386 meters) " Atlantis " anchoring ,in spite of wind velocities up to force 4, the drag was practically nil.

Detailed consideration of the ship's drift (drag of anchor) for the 5 days it lay at anchor at Station 3703, during intervals between morning, noon, and evening positions, brings out that apparently, except for three periods (05 h. —07 m. to noon, Oct. 11; 17 h. —30 m., Oct. 11 to 05 h. —00 m., Oct. 12; and noon, Oct. 12 to noon, Oct. 13) the vessel dragged its anchor on an average between 0.17 and 0.59 nautical miles per hour (Table 1); the maximum being at the beginning (0.53 naut) with wind force 1, and, at the end (0.59 naut) with wind force 3. Variations in ship's drift while at anchor, besides resulting from combined effects of wind and water currents, are apparently caused by the anchor's alternate gripping and breaking from the bottom. The general relationship between wind current directions, ship's heading, and drift is brought out for the 12 intervals (between position determinations) in Fig. 1 (page). The drift of the ship was not any time in the same direction as the wind current; for instance, between noon October 9 and 05 h. October 12 while the air current moved in a relatively steady direction (between average values of 113° and 158°) the ship drifted between 46° and 60° to the left and between 40° and 143° to the right. Still later, as the wind direction became more variable, the ship drifted between 90° to the left and 40° to the right of the average direction of air flow.

The relation between ship's heading and its direction of drift while at anchor was likewise variable; average values for the 12 intervals (see Fig. 1) show that two thirds of the time the drift was between 22° and 127° to the right (clockwise) of the heading and one third of the time between 84° and 164° to the left (counterclockwise) of the heading. Data on the ship's swing are obtained by frequent observations of the ship's heading (taken every 2 hours at Station 3703); the average angular range between ship's heading and direction of the wind current was between 20° and 169° with ship heading to the left (wind blowing on port side) and between 39° and 133° with ship heading to the right (wind blowing on starboard side) of the wind current direction. The average angular swing of the ship per 2-hour intervals for the 5 days was 20°, varying between 0° and a maximum of 125°; for wind velocities less than force 3 the average angular swing per 2-hour intervals was 21° and for winds of force 3 it was 15°.

From the standpoint of obtaining measurements on time variations of the properties of sea water (temperature, etc.) along a fixed vertical in the ocean space, the anchoring arrangements on "Atlantis" are adequate. The swing of the vessel does not interfere with this type of observation, and the small amount of drift (anchor drag) and the apparently almost complete absence of anchor overriding, permit, even in regions of strongest horizontal gradients, satisfactory results while lying at anchor on the high seas for a week or more. On the other hand, while motions of the above magnitudes would invalidate results of direct current measurements, a recent mooring in the Gulf Stream has shown that pendular motions and drift are reduced to a minimum in a strong gradient current. Thus, during February 12 to 14, while "Atlantis" was moored with mushroom anchor at approximately 800 meters depth in the axis of the Gulf Stream, off Cape Cañaveral (not entered in Table 1), current measurements undertaken between surface and 100 meters depth were satisfactory. Not only was there an apparently complete absence of drift, but also the swing of the ship was only 2° to 5° per hour.

RESULTS OF OBSERVATIONS FROM AN ANCHORED SHIP.

(a) *Time variations of physical properties.* — The desirability of obtaining measurements from a ship lying at anchor on the high sea arises from the relatively recent discovery of internal waves — a phenomenon of vertical oscillations of the water particles which causes time variations of chemical and physical properties at fixed depths in the sea. These investigations have not only theoretical significance, but also supply critical information for the interpretation of practical oceanographical questions, as, for instance, in estimating significance of circulation patterns derived from distributions of the basic properties of temperature and salinity. Because vertical oscillations of the water will usually prevent representing average conditions in the sea based on single samplings along isolated verticals, the distributions of mass and pressure as usually computed for an oceanic area, and in turn used for derivation of horizontal circulation patterns, may be of doubtful significance, particularly in regions of not too strongly developed horizontal gradients (as in the Western Sargasso Sea). Hence, to control the significance of computed dynamic patterns, such as may be accomplished by knowledge of ratios of time changes at fixed points to computed horizontal changes of the properties involved, repeated observations for 25 hours or more are undertaken along selected fixed verticals in the area, simultaneously with its survey.

As an example of the time change in physical properties at fixed points in the sea, we briefly consider certain results observed during a 26-hour period of repeated sampling at Station 3245 (Table 2), and from a 14-day period at Station 3091 (Table 3). Both stations are located in the western basin of the North Atlantic (Table 1). At the former station (3245) the amount of temperature variation at fixed depths during the 26-hour period ranged from 0.32° in the nearly homogeneous part of the water column to 2.25° in the most strongly stratified part; a result of vertical displacements of the water particles of 15 to 56 meters. This demonstrates that single samplings of the water column will not represent average conditions in the region concerned. Moreover, a region cannot be characterized for extended periods on the basis of a single day's repeated observations, since data show that magnitude of vertical displacements of the water particles, and consequently the accompanying time variations of temperature at fixed depths, change from day to day. In this respect the effects of both quiet and disturbed days are brought out by comparison

TABLE 2.

Depth (Meters)	*Temperature*		*26-Hour Temperature Range*
	Maximum	Minimum	
100	22.47°	21.16°	1.31°
150	21.08°	18.33°	2.25°
200	18.30°	17.98°	0.32°
500	15.31°	14.74°	0.57°
800	9.30°	8.64°	0.66°
1000	6.79°	6.29°	0.50°

TABLE 3.

Depth	*Temperature Range June 22*	*Temperature Range June 27*
50	1.55°	0.90°
200	0.10°	0.08°
500	1.09°	0.34°
800	2.50°	1.12°
1000	1.43°	0.39°
1200	0.40°	0.23°

of 24-hour temperature ranges at selected depths on two different days, taken from the 14-days series of continuous sampling at Station 3091, tabulated in Table 3. The vertical displacements of the water column bringing about these 24-hourly temperature variations at fixed depths were on the average three times as great on June 22 as on June 27 (8), five days later.

TABLE 4.

Date	*G. C. Time*	*Velocity-Nauts*
2/12/40	11:00 — 12:00	3.70
	14:00 — 15:00	3.28
	17:00 — 18:00	3.02
	20:00 — 21:00	2.97
	23:00 — 24:00	2.97
2/13/40	02:00 — 03:00	2.72
	05:00 — 06:00	2.47
	08:00 — 09:00	2.45
	11:00 — 12:00	2.48
	14:00 — 15:00	2.83
	17:00 — 18:00	3.30
	20:00 — 21:00	1.52
	23:00 — 24:00	1.35
2/14/40	02:00 — 03:00	1.50

(8) See also : H.R. SEIWELL — " Short Period Vertical Oscillations in the Western Basin of the North Atlantic ", Papers in Physical Oceanography and Meteorology, Vol. V, N° 2. " The Effect of Short Period Variations of Temperature and Salinity on Calculations in Dynamic Oceanography ", Papers in Physical Oceanography and Meteorology, Vol. VII, N° 3. " Daily Temperature Variations in the Western North Atlantic ", Journal du Conseil, Vol. XIV, N° 3.

(b) *Short time variations in surface layer velocity of the Gulf Stream.* — As a result of surface current observations with a small taffrail log, read approximately every 15 minutes, between 10 h. February 12 and 04 h. February 14, 1940 (G.C.T.), while "Atlantis" was anchored during a period of light winds (0-2 Beaufort in the Gulf Stream axis off Cape Canaveral (Station 3777, 28° —55' N., 79° —36' W.), average surface velocities as computed for one-hour intervals (Table 4) ranged between 3.70 and 1.35 nautical miles per hour. The average surface velocity for the entire 42 hours was 2.60 nautical miles per hour (134 cms/sec) and the two velocity maximums were separated by a 30-hour and the two minimums by a 12.5-hour interval. These observations are significant in that they show large variability in surface velocity at fixed points in the Gulf Stream, and questions concerning the depth and extent to which the main body of the Gulf Stream is affected are of added importance. Comparisons of simultaneous surface and subsurface readings at depths of 25 and 50 meters (taken with an Ekman current meter) indicate that although velocity variations are to some extent reflected downward they appear to be rapidly damped. Thus, simultaneous surface and 25 meter readings (Table 5) show that while the former diminished in velocity from 166 to 63 cms/sec, the 25-meter velocity changed from 146 to 100 cms/sec; still deeper, as brought out by comparison of surface and 50-meter levels, the velocity of the former dropped from 172 to 65 cms/sec while the latter remained nearly constant, decreasing from 122 to 107 cms/sec. Hence, considering the great thickness of this current, it is unlikely that the total transport of water is significantly affected by short period variations of this type. Since the observations apparently

TABLE 5.

G. C. T.	*Velocity: cms./sec.*		
	0 m.	25 m.	50 m.
13th 16 h. 18 m.	161	146	
16 h. 52 m.	166	137	
18 h. 03 m.	172		122
20 h. 50 m.	71	110	
22 h. 07 m.	72	107	
23 h. 20 m.	65		112
14th 00 h. 20 m.	63	100	
03 h. 46 m.	94		107

reveal the usual state of the surface layer of the Gulf Stream they are of considerable interest and may serve to clarify some of the curious sailing phenomena attributed by navigators to the Gulf Stream.