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THE CURRENTS

ON THE SOUTH-EASTERN COASTS OF

NEWFOUNDLAND

AND THE AMOUNT OF INDRAUGHT INTO

THE LARGER BAYS ON THE SOUTH COAST

FROM INVESTIGATIONS OF THE TIDAL AND CURRENT SURVEY
IN THE SEASON OF 1903

W. BELL DAWSON, M.A., D. Sc., F.R.S.C., M. CAN. SOC. C. E., ENGINEER IN CHARGE

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OTTAWA, January 25, 1904.

During the season of 1903, from May to September, the currents were examined off the southeastern coasts of Newfoundland, along the European steamship route. This route passes as close as convenient to the shore for 160 miles, from St. Pierre to Cape Race, and then turns northeastward on a great circle for points in Great Britain and Europe. The examination had special reference to the question of indraught of the current into the large bays on the south coast. The largest of these, Placentia bay, is 75 miles deep and 40 miles wide. Eastward of Cape Race, the Polar current, which flows very constantly in a southward direction past the eastern side of Newfoundland, is met.

The steamer used in this investigation was the D.G.S. *Gulnare*, of the Department of Marine and Fisheries. Its length is 137 feet, beam 20 feet 5 inches, draught 13 to 14 feet, gross tonnage 262. As the purpose in view was to ascertain what currents steamships might expect when passing this coast at a reasonable offing, no observations were taken closer than four or five miles to the shore. The in-shore currents of a merely local character were thus avoided.

The general method employed, was to anchor the steamer at carefully selected points or stations; and to make use of the steamer itself as a fixed point from which the direction and speed of the current could be taken or measured. This was the method already found most advantageous in my investigation of the currents in the Gulf of St. Lawrence in former years. It is not too much to say, that with adequate appliances, as much information can thus be obtained in 24 hours as in a week by running courses. This is the more emphasized in so foggy a region, where long sights to fix the ends of courses can rarely be had; but at anchor the fog did not interfere with the work.

To carry out this general plan it was necessary to provide appliances for deep anchorage, which were necessarily of a special character. Anchorages were made in all depths up to 90 fathoms. The observations were continuous day and night. During the day time, the direction and velocity of the current were taken every half hour; and at night the direction only was observed, with an estimate of the relative strength at different times. Captain Thos. G. Taylor gave valuable co-operation in facilitating the work. Mr. L. Keller acted as technical assistant; and the night observations were taken by the first and second officers, Mr. John Smith and Mr. Reginald Clarke.

Nature of the currents.—The currents were almost invariably less than one knot. As a rule, they veered widely and were irregular in direction; and with so low a speed they were readily influenced by the wind. There were three elements to distinguish:—(1) Any general tendency to set in one direction more than in others. (2) Any tidal influence, which might show itself either as a marked change in the direction of the set, or as a period in which a variation in velocity would recur. (3) The influence of the wind in disturbing the usual behaviour of the current. From our observation, the effect of any storms which occur during the summer season seldom extends to a greater depth than 5 or 10 fathoms; and it was therefore found that the behaviour of the under-current at 15 to 30 fathoms afforded a most valuable indication of the normal character of the current. In these currents, the tidal element is almost invariably present in some form, more or less distinct; and this is almost always combined with a tendency to make on the whole in some one direction. It is not therefore possible to maintain an arbitrary distinction between 'constant currents' and 'tidal streams'; but the only natural distinction is to use the term *current* for all horizontal movements of the water, and *tide* for the vertical movement from high to low water.

Current measurement.—The speed of the current was measured by a current-meter, registering electrically on board and read every half hour. For use at sea, the chief desideratum is to keep the meter as steady in the water as possible. To do so, the meter was supported by a line which was carried completely over the steamer, through pulleys fitted with patent sheaves, to a water-anchor on the opposite side. The steamer could thus roll under the whole apparatus without disturbing it too seriously. The meter was also placed amidships to avoid the pitching. Allowance was made by experiment for the increased record due to the movement remaining. Even when it was too rough for the absolute record to be relied on, the relative velocities obtained were of value, especially in detecting tidal influence. With a larger steamer, the motion would have been less serious; but with these arrangements the meter could still be used to advantage in waves of 6 feet to 8 feet high and 60 feet to 80 feet in length, which was the usual proportion. In all cases the measurement of velocity was made at a depth of 18 feet, which was well below the keel of the steamer, and below superficial disturbance.

Surface direction.—This was obtained by a float built of board, and weighted to bring its surface awash with the water. It was thus unaffected by the wind. The chief difficulty in obtaining the correct direction, was the sheer of the steamer while lying at anchor, which at times was very troublesome. At night, a small electric light was attached to the float, which eventually was made to work satisfactorily and proved very convenient.

Under-current.—The direction of the under-current was found by means of a fan, made of two sheets of galvanized iron passing through each other at right angles, and

attached to a length of patent sounding wire. The fan was 26 inches deep and 18 inches wide and weighed 16 pounds. In stronger currents, an additional weight was attached. The depth to which it was lowered was conveniently measured by a patent sounding machine. This simple appliance proved very serviceable to show the direction of the under-current at any depth. The inclination of the supporting wire also gave a close estimate of the speed, by means of a formula determined by experiment; the angle of inclination being measured with a clinometer.

Density and temperature of the water.—Extended observations of density and temperature were taken from the outset, on the courses after leaving Halifax, and during the season. This was done in the hope of tracing the movement of the water, as this method had proved so serviceable in the Gulf of St. Lawrence. The density of the water was taken at the surface only. The variation did not prove sufficient, however, to be relied upon as an indication of direction of movement. We do not publish the results therefore, though interesting in themselves.

The temperature was taken to a depth of thirty fathoms, by means of registering or inverting deep-sea thermometers. The thermometers used, either had Kew certificates, or were tested by comparison with standards. More was expected from the temperature than from the density, as it was hoped it would serve to trace the course of the Polar current. The nature of the results in this respect are given in describing the character of that current.

The depth of thirty fathoms was found sufficient, as the water was there at the freezing point throughout the region examined, both south and east of Newfoundland, during the whole season from May to September. All the change which took place during the progress of the season or from other causes, was between the surface and thirty fathoms. The change of the temperature of the water also afforded an interesting valuation for the amount of wind disturbance, and the depth to which it extended, under given conditions. This will be briefly referred to in its place. Some of the more important results of the temperature observations are given in the tables appended. (See pages 28 and 29.)

Wind and barometer.—The wind-velocity was measured by an anemometer on board, and the direction was taken every half hour with the other readings. A recording barograph gave a continuous barometer record. These observations were essential to ascertain the effect of the wind on the current; and they were also useful at the time, as a careful look-out for bad weather had to be kept, because of the persistence of the fog.

Tide.—Observations were taken during the previous season of 1902, and throughout the present season, on a self-registering tide-gauge at Trepassey harbour. This afforded the time of high and low water for comparison with the set of the current; and the tide at other harbours further west, was deduced from this by the difference of 'Establishment.'

Accessory observations.—There was necessarily some interruption during the season in obtaining coal and other supplies. The courses run on such occasions were carefully taken and laid down on the chart, to ascertain any current effect which could be

detected. The results were interesting and useful for comparison with the more consecutive observations. The drift of icebergs was also serviceable as an indication of the general movement of the water. Few of them were seen this season, but their movements were always observed by sextant angles, as ordinary bearings were not sufficiently close for the purpose. Some information was thus obtained, but it cannot be said that the results repaid the amount of trouble taken.

Fog.—No systematic observations of the fog were taken, to ascertain its prevalence with winds from various quarters, of which explanations are given in the Sailing Directions. It may be noted, however, that the fog is of all kinds, from a dry fog to a wet drizzle, and also that any kind of weather may come up during fog. It may vary from calm to a whole gale ; and it will also range from a clear sky overhead, with the sun breaking through at noon, to heavy rain ; but these changes were without marked effect. Rain made the most difference, and it was always welcome ; as it partially cleared the air, and extended the view. So far as we noticed therefore, the weather seemed to have very little influence upon the fog ; but with the progress of the season it became somewhat less persistent.

We also met with some curious examples of echo and deflection of sound ; but this question is being more systematically investigated than we had opportunity to do.

Subdivisions. Time. Bearings.—For convenience in reference, a division is made into two parts : (1) The currents in the south coast region, and (2) the Polar current to the eastward of Newfoundland. This division is the more permissible, as it could not be definitely ascertained that the Polar current had any influence upon the westward movement of the water along the south shore. Throughout the observations the time used is Atlantic standard for the 60th Meridian, or four hours slower than Greenwich mean time. It is reckoned on the twenty-four hour system from midnight to midnight. All bearings are magnetic, the variation being 26° to 28° west.

PART I.—THE SOUTH SHORE.

At the beginning of the season, as soon as general observations of the temperature and density of the water had been secured, for comparison with results at later dates, four stations were chosen for a general examination of the currents off the capes separating the bays on the south coast of Newfoundland, between Cape Race and Placentia bay. These stations were so located as to be outside the line of the headlands on the coast, and also within the general line of the shore on one side of the bay ; and thus to lie in the set of any current parallel to either of these directions. The positions chosen are marked A. B. C. D, on the map, Plate IX.

An anchorage was made for one or two days at each of these stations, to ascertain in a general way, the nature of the currents on this coast as a basis for the work. It was found in general that the current was tidal, flowing N. W. and S. E. (magnetic) with the flood and ebb respectively. There was a slight preponderance in the northwestward direction on the whole. This result is confirmed by observations secured at a

later date at the same points. This is of interest at the outset; and these stations will be referred to again in describing the character of the current in the offing of the several bays on this coast.

Placentia Bay.

If vessels when on an easterly course along the south coast of Newfoundland, are set to the northward because of an indraught into the bays which they pass, this effect must chiefly be due to Placentia bay, which is the largest one there is. If a vessel keeps to its true course as far as the longitude of Cape St. Mary, we cannot suppose that it would be set so far north, while crossing St. Marys bay, as to run ashore at Cape Pine. Any northward set must occur earlier, while crossing the mouth of Placentia bay. For these reasons more time and attention were given to this bay than to the others on this coast. It is generally supposed that the water makes to the northward, past Cape St. Mary, and that it circles around the bay and passes out on the western side. We may keep this view in mind as a fairly reasonable supposition, while we consider how far it is justified by the observations obtained and the facts arrived at. The observations in the region of this bay were taken at five stations; three of these were off the mouth on the eastern side, one was in the middle of the bay, and another at the mouth on the western side. In following the supposed movement of the water, we may begin with the stations at the mouth on the eastern side.

Station D.—Position 5½ miles west of Cape St. Mary, in 36 fathoms. This position was outside the line of the headlands to the eastward and it also opened up the east shore of Placentia bay. It was thus in the line of any set in either of these directions. Anchorages were made on three occasions; but it was poor holding ground, so that even a moderate sea made the vessel drag, notwithstanding every effort to keep hold. It is unfortunate that the observations were thus interrupted on each occasion, as this position is an important one in arriving at an understanding of the movement of the water in Placentia bay. To make up for this, a specially careful analysis of the observations has been made.

The observations secured were as follows:—June 2nd and 3rd, 15 hours; September 3rd to 5th, 40 hours; September 21st and 22nd, 18 hours. On all three occasions the set was to the eastward of a north and south line (magnetic) between N.N.E. and S. by E. as limiting directions. In veering between these limits, the set was at times directly east or on shore towards the cape. The wind at these dates was light or very moderate, between west and southwest.

The current here is distinctly tidal in its character, the direction being northeastward into the bay during flood tide and southeastward along the general line of the coast during ebb tide. The average set of the flood and ebb is shown on Plate II, based upon five complete tidal periods, making up a total of 62 hours on the three occasions. Their resultant directions are also shown relatively to the coast, as found from the ultimate reduction of these observations. The tidal regularity is unmistakably shown by the fluctuation in velocity; as it always rises to a maximum at half tide, when it amounts to nearly a knot, and it falls to half a knot at about the turn of the tide. The highest of the maxima was 0·91 knot, at the spring tides.

The relative strength of the flood and ebb was quite unequal, however. The set into the bay to the northeastward continued for a longer time and was stronger than the set to the southeastward. As measured by the velocity, the difference is not large, but it is well marked. The mean velocities observed at half tide, flood and ebb, were as follows:—Northeastward, 0·86 knot; southeastward 0·63 knot; which gives 35 per cent. in favour of the northeastward direction. As measured on a time basis, the proportion is even greater; as the northeastward direction continued for 15½ hours and the southeastward for only 9½ hours during the tidal day.

The under-current observations give the same result with even greater emphasis. At a depth of 15 fathoms, the direction during flood is almost always to the north of northeast; or more directly into the bay than the surface current by 2½ points on the average. The strength of the current in this direction is more than double as great as to the southeastward.

It would thus appear that any westward tendency which the body of the water may have along the south coast from Cape Race to Placentia bay, does not continue to the westward of Cape St. Mary; as there is no set here to the westward of a north and south line (magnetic); but the water appears to turn at this cape, and to make inwards on the whole into the bay. There is no constant indraught however, but a fluctuation with the tide as described; and the velocity does not quite amount to one knot, even as near shore as this point of observation, which was only 5½ miles from the cape.

As it is thus evident that the water makes inward on the whole, into Placentia bay around Cape St. Mary, two other stations were selected in the middle of the bay and on the western side, to ascertain whether this movement could be further traced throughout the area of the bay.

Station E.—In the middle of Placentia bay, at the south end of Merasheen bank. Position, 19 miles W. by N. from Placentia light, in 66 fathoms. The anchorage made at this station was from Monday, June 8th to Thursday the 11th, and continuous observations were obtained during 70 hours. The weather was calm with a little swell, while the fog was persistent with occasional rain. The set of the current as observed at this station is shown on Plate III. and although at first sight it may appear irregular, there are two results of importance which throw light on the question which we have specially under consideration. The flood tide appears to have almost any direction, which may be due to its meeting the large body of water in the head of the bay; but the ebb tide sets very constantly in a southwestward direction, towards the mouth of the bay on the western side. Also, the current during flood tide was superficial, whereas the ebb was distinctly felt to a depth of 15 fathoms. Owing to this persistent set of the ebb, the water must work gradually in its direction; which corresponds with a general movement of the water from the eastern to the western side of the bay.

This general movement is also indicated by the total or resultant set throughout the tidal period. On Plate III. the direction of the centre line of Placentia bay is laid down; and it will be seen that much the larger part of the set is across this line to the left or westward side. When observations are taken in detail, it is only in such ways as these that the general movement of the water becomes apparent. The resultant

direction of the movement, as found from the ultimate reduction of the observations during 68 hours, is N.W. by W., or squarely across the bay.

STATION F.—At the mouth of Placentia bay on the west side. Position, 10 miles S. W. $\frac{1}{4}$ S. from Burin light, in 52 fathoms. The second anchorage was made at F_2 a little further to the eastward, on account of the heavy wind at the time, which made it impossible to hold on at anchor at the point first selected. For the purpose in hand, this makes little difference. The anchorages made were from Thursday, June 11th, to Saturday, the 13th, for 48 hours ; and Wednesday, July 29th, to Thursday, the 30th, for 25$\frac{1}{2}$ hours. The results at this station were of a somewhat similar character to those at Station E. The flood tide appears to strike somewhat squarely on this shore, giving rise to on-shore and irregular directions ; but the ebb tide has a fairly constant set to the westward. As the direction of the flood is irregular, the water will therefore gradually work to the westward under the influence of the ebb, as it does at Station E. The general movement of the water is thus outward, on this western side of the bay. The results are shown on Plate IV., where the ebb direction is indicated. These results are corroborated by the fishermen who anchor on the bank directly off Burin.

The under-current indicates more distinctly than the surface current that this is the general direction which the body of the water takes. During strong westerly winds which prevailed while at this station in July, the surface current was veered from its normal direction, while the under-current continued to the westward. This is indicated on Plate IV.

STATION G.—At the mouth of Placentia bay, on the eastern side. Position 17 miles W. $\frac{1}{4}$ S. from Cape St. Mary, in 56 fathoms. An anchorage was made at this station for nine days from Thursday, June 18th, to Friday, June 26th, when 158 hours of continuous observations were obtained. A second anchorage was made from Friday, July 31st, to Tuesday, August 4th, when an additional period of 71 hours observation was secured. In these periods the Sundays are omitted, as observations were not taken on them.

The behaviour of the current at this station is very variable, and during such long periods a variety of weather conditions obtained, although the wind did not ever exceed 21 miles an hour. To understand the nature of the current, careful comparisons with the tides and winds are undoubtedly required ; but the continuity of observations, taken every half hour day and night, affords a good basis for the comparison ; and with an anemometer on board, the wind observations are much better obtained than by comparison with an observatory on shore.

The most evident change in the behaviour of the current, is that sometimes the direction veers completely round the compass, and at other times it veers backwards and forwards between limiting directions. This change is evidently due to the variation in the amount of tidal influence, with the springs and neaps. See Plates V. and VI. The veer completely around the compass occurs at neap tides, this being well marked at the moon's quarters on two different occasions, namely, June 18th to 20th, and July 31st to August 1st. The veer is then continuously to the right, and the period in which a complete revolution occurs is just about 16 hours. This period is quite definite, as deduced

from six complete revolutions which were observed, four of which are given in detail in tabular form on page 12, compared with Station M. It appears to result from a combination of the tidal period with a general movement of the water to the westward. This appears to be the only possible explanation, in accordance with the principles of rotary movement. A more detailed discussion would involve technicalities which we cannot enter upon here. It will be sufficient to note that this 16-hour period has been met with at other stations during the season, as well as in other regions in former years.

At other times in the month, when the tidal influence is stronger, the current veers to the right and left through a range which varies from eight points to half a circumference. The complete period in which it veers and backs, is from ten to fourteen hours. It is not impossible that this veer would be found to correspond with the tidal period, if an average were taken which would be sufficiently long to eliminate other disturbing causes. On the other hand, at the neap tides, when the tidal element has the least influence, the 16-hour period throws the direction of the current entirely out of correspondence with the time of the tide.

Wind conditions.—As the anchorages at this station extended over so many days, the wind conditions were various; but the weather was moderate on the whole, and there was no marked disturbance of the current. A distinction in the effect of the wind must be made in accordance with the behaviour of the current itself.

During the period of sixty-two hours in June, while the current was veering continuously around the compass, the wind was N. and N.N.E., and for twenty-eight hours it had an average velocity of nineteen miles an hour. Again, in the second period of this character, during thirty-three hours at the end of July, the wind was W. and W. S. W. with an average velocity of eighteen miles an hour, throughout the time. These winds did not affect the total period in which the current veered completely around; but they strengthened the set to leeward, and made the rate of veer more rapid in passing the windward directions.

While the veer to the right and left took place, from June 22nd to 26th, there were only two occasions when the wind was at all heavy. From the evening of the 22nd to noon on the 23rd, the wind was E. to E. S. E. for twenty hours with a velocity of eighteen miles an hour. Again, from noon on the 25th for eight hours, the wind was W. with a velocity of twenty miles an hour. The current was little disturbed by these winds, however, until the evening of the 25th; and the disturbance then appeared to be quite as much due to the change from spring to neap conditions, as to the wind. The amount of influence which these winds had, in slightly veering the current, may be seen on Plate VI., where the direction of the wind is shown. It is to be noted also that during the spring tides on the 24th, there was no appreciable disturbance.

During the second anchorage, from July 31st to August 4th, the wind held steadily between W. S. W. and W. N. W. For six hours after anchoring, it attained twenty-one miles an hour, and again during the night of August 1st and 2nd it reached a velocity of twenty miles an hour for twelve hours; but at other times it was much more moderate. The wind keeping steadily in this direction however, appeared to cause the current to veer farther to the east of north and less to the west of north, than

during the anchorage in June ; but it does not definitely appear that the wind had any effect on the length of the period in which the veer took place.

It would be quite erroneous to suppose that the wind always causes a drift in its own direction. On the contrary, the set is primarily due to the nature of the current ; and if it has any definite direction of its own, owing to the tide or other causes, it takes a strong wind a considerable time to overcome this, even with currents such as these, which do not exceed one knot. For example, on anchoring on June 18th, the wind had been N.E. at 20 miles an hour for about 4 hours ; yet the current set strongly N.N.W. or into the windward quarter. Further examples of this will be given from the experience of fishermen while at anchor.

General results.—This station is eleven miles farther out from Cape St. Mary than Station D ; and on comparing the results at the two stations, we find the tidal influence here to be much weaker and more variable. But the indications of the tide which remain are in complete accord with the direction and relative strength of the well-marked tidal fluctuations at Station D. It is one of the features to be noted in the behaviour of the currents in this whole region, that the farther the point of observation is from shore, the less they are under the influence of the tide, and the greater the tendency is to veer completely around the compass.

In moderate weather at the springs, when the tidal influence is greatest, there is an indication that N.E. is the direction of the flood and S.E. the direction of the ebb. When the surface current is disturbed by the wind, and veered two or three points from the direction it would otherwise have, the under-current at ten fathoms usually continues to indicate these same directions for flood and ebb ; and once at the springs, this change of direction with the tide, was felt as far down as 30 fathoms. The N.E. set is directly into Placentia bay, and the S.E. set is along the general line of the coast.

In general, it is towards the N.E. quarter that the current is strongest on the whole ; and also the deeper under-current at 20 and 30 fathoms almost always sets into the bay, in directions between N. and N.E. This deep movement goes on very constantly without reference to the time of the tide ; and it indicates the general tendency of the body of the water to work in that direction.

As regards the question of indraught into the bay, we have the following indications from the observations at this station :—During flood tide, the more usual direction is northeastward, into the bay ; and also the general average of all the observations shows a distinct tendency in that direction. Also, the movement of the deeper water is inwards towards the bay ; and this may affect the surface water at times when other influences are less dominant. It must always be noted however, that the velocity of the current in no case exceeds one knot per hour ; the highest velocities observed being from 0·80 to 0·90 knot.

STATIONS G AND M, OFF PLACENTIA BAY, 1903.

SHOWING period of complete revolution in the direction of the current, while veering continuously to the right. Atlantic Standard time throughout.

Station.	Date and Hour of break in direction.	Directions at— High Water.	Directions at— Low Water.	Sudden change from—	Period of complete revolution.
G	June 18 at 10:00			(Setting NW)	
		ENE	S		15¾ hours.
	June 19 at 1:45			W to NW	
		NW WSW	ESE		16¼ hours.
	June 19 at 18:00			(Setting NW)	
		SE	NNE		15 hours.
	June 20 at 9:00			W to N	
		NE	N SSW		16 hours.
	June 21 about 1:00			Northwestward	
M	July 21 at 7:00			SE to N	
		E	NE		15½ hours.
	July 21 at 22:30			SW to W	
		NE	W ESE		15½ hours.
	July 22 at 14:00			SE to W	
		NNW	E		16½ hours.
	July 23 at 6:30			NE to SW	
	Aug. 4 at 22:30			SSW to W	
		ENE	SSE		16¾ hours.
	Aug. 5 at 15:15			WSW to WNW	
		NNW S	E		17½ hours.
	Aug. 6 at 8:45			SW to WNW	
		E	NE		15½ hours.
	Aug. 7 at 0:15			SSE to N	

STATION M.—At the mouth of Placentia bay on the east side, eight miles farther out than Station G. Position, 25 miles S.W. ¼ S. from Cape St. Mary, in 60 fathoms. Observations were taken here from July 20th to 23rd, and from August 4th to 7th, making two periods of 64 and 62 hours respectively, of continuous observations. Both of these periods were at similar parts of the lunar month, between the quarter and the change of the moon. The weather was moderate on both occasions, without sufficient wind to affect the current appreciably.

The current always veered round to the right in its direction, only once backing through eight points. The period in which a complete revolution took place was 16 hours, as at Station G. The current held longer in northeastward directions; and on coming round to the southward, would suddenly change to the westward direction. There was thus usually about a quarter of the circumference towards which it did not set at all, in making each revolution; and it was in general the southwest quarter which was thus omitted; which accords with a predominant set to the N.E.

The details of the six complete revolutions are given in the table opposite, as well as four of the revolutions at Station G; and the directions omitted in each revolution are stated. The average result of the observations on each occasion, is given in Plate VI.

It thus appears that as far out as 25 miles from Cape St. Mary, the more usual direction of the set is northeastward, or inwards towards Placentia bay on its east side. The velocity however was not in any case as much as one knot, and did not actually exceed 0·77 knot.

It is also to be noted that the set of the current at this distance from shore is out of correspondence with the time of the tide; as a complete revolution in direction takes place in the 16-hour period. It is a general characteristic of these currents that they are less affected by the tide as the distance from the shore increases, as already mentioned.

The behaviour of the under-current is very irregular, and it is here difficult to draw any general conclusions when the observations are limited to the day time only. The surface direction of the current usually extends down to five fathoms without more than two points of change; but below this the direction usually becomes quite different. The under-current does not furnish any distinct indication of tidal influence; unless possibly there may be a tendency to a northeastward set during flood tide.

There is one important indication however, which corresponds with the behaviour of the surface current. It is quite exceptional for the under-current to set towards the southwest quarter, but in the other three quarters it is often strong and deep, being sometimes distinctly felt as far down as 30 fathoms.

STATION N.—This position was chosen on the centre line of Placentia bay opposite the line of the deep gulley of one hundred fathoms which runs up the middle of the bay. It was 28 miles outside the line of the headlands on the two sides of the bay. An anchorage was made here from July 23rd to 25th, when continuous observations were secured during 44 hours. The weather was quiet with the exception of a heavy rain squall during a few hours, but the fog was continuous.

The behaviour of the current was similar to Station M. It veered around to the right, the veer being more continuous than at M., as there was no omission of any special direction. The two complete revolutions observed were made in a period of 18 hours each, on the average. The direction of the set was thus entirely out of relation to the time of the tide. The speed was quite as great as elsewhere, as it ranged between a full knot and half a knot.

The current was sometimes felt as far down as 15 fathoms, but often it was limited quite definitely to a thickness which varied between 7 and 10 fathoms. On the average the thickness was about 10 fathoms. It was thus not nearly as deep a current as nearer the shore.

The current, as far out in the open as this, does not thus show any remnant of tidal influence, nor does it indicate any indraught into Placentia bay, nor any distinct tendency to the westward as a dominant direction. Speaking generally, the set here may be in any direction with a velocity not exceeding one knot.

St. Marys Bay.

Station H.—The position chosen for this station was midway between Cape Race and Cape St. Mary, and 16 miles off the nearest shore at Cape Pine. The object in view was to ascertain whether any movement of the water toward Placentia bay could be detected as far off as this (31 miles distant from Cape St. Mary), or any indraught towards St. Marys bay. It was at the neap tides that both the anchorages were made. The tidal influence was thus at its least, and any general movement could best be made out.

The first anchorage was made from Monday, June 29th, to Friday, July 3rd, when 87 hours of continuous observations were obtained. Only four complete tidal periods were observed, however, which were free from wind disturbance. During the first of these, the set of the ebb was between S.S.W. and S.S.E., and the flood to the N.W. During two other complete tidal periods, the current veered and backed four times between N.W. by W. and N.E. by E. as limiting directions. The disturbance of a heavy S.E. wind then began to be felt; and when quiet conditions were restored, a day and a half later, another complete tide was observed. The set of the ebb was then between S. and S.E., and the flood between W.N.W. and N.

To arrive at the general movement of the water, independently of the tide, it is evidently necessary to deal with complete tidal periods; as otherwise a greater preponderance of some one phase of the tide might be included in the average. At this station, when the set in these various directions is thus considered, it is found that on the whole, the strength is ten per cent. greater to the N.W. and W. than towards either N.E. or S.E., the average maximum velocities being 0·61 and 0·56 knot respectively. The total set in each direction during the four tidal periods combined, is shown on Plate VII.

The above observations comprised 49 hours of the time at this station. The remaining time was affected by wind disturbance; and the whole period of 24 hours during the second anchorage, at the end of August, was also more or less affected by the wind. It is noteworthy however, that while the wind disturbed the surface, the under-

current at 20 and 30 fathoms still continued to flow N.N.W. and S.S.E. as the average directions during flood and ebb respectively. The under-current also shows the north-westward direction to be much the stronger and more continuous of the two. The under-current was never found to set towards the N.E. quarter.

To sum up the results at this station, the influence of the tide is distinct ; and the directions of flood and ebb and the greater strength of the flood tide, are in accord with the observations at Station B, where the tidal influence is more accentuated, as it is nearer land. In general, the dominant direction in which the water makes, is between N.W. and N. as shown by the greater length of time and the greater strength and depth in that direction. This direction is nearly parallel with the general line of the coast and rather towards Placentia bay. The set in the N.E. quarter towards St. Marys bay, is infrequent; and as it is not indicated by the under-current, there can never be much indraught towards that bay at this offing. It is again to be noted that the velocity of the current in no case exceeded 0·73 knot in any direction ; and even this was exceptional, as it usually ranged between 0·50 and 0·60 knot.

Station B.—This station is off the headland on the eastern side of St. Marys bay, at 7 miles W. $\frac{1}{2}$ S. from Cape Pine light, in 26 fathoms. If there is any indraught into this bay, it must be on the eastern rather than on the western side, and the question of indraught may therefore be tested by the results at this station, more especially as the steamship route passes as close to the headland on this side of the bay as safety allows.

As this station is only $5\frac{1}{2}$ miles from the nearest shore, instead of 16 miles as at Station H, the tidal influence is much more distinct. Two anchorages were made here in May and September, for periods of 29 and 19 hours respectively ; the latter being cut short by the dragging of the anchor, as it is poor holding ground. On both occasions it was within three days of the full or change of the moon, or immediately after the spring tides.

The usual direction of the flood was between north and northwest, and of the ebb to the southeastward. See Plate I. The ultimate or resultant direction of the flood is N.W. by N. and of the ebb S.E. The tidal character was also distinctly marked by the fluctuation in velocity ; as it always strengthened at half tide and slacked at the turn of the tide. The maximum observed at half tide was 0·82 knot and at the slack it fell below 0·30 knot.

The under-current generally agreed with this, in both direction and velocity. The flood was also deeper than the ebb ; being quite strong to a depth of 15 fathoms, whereas the ebb was weak and sometimes not felt at all below 10 fathoms.

The directions of the flood and ebb are nearly parallel with the line of the extreme headlands westward and eastward ; and the observations, so far as they extend, show little appreciable indraught into the bay. As the current veered in direction, the set into the bay towards the northeast quarter, only took place during 13 per cent. of the total time. On the other hand, the current during flood is not only deeper but contin-ues longer than the ebb ; which indicates that the water makes on the whole to the northwestward across the mouth of St. Marys bay, rather than into the bay.

This is corroborated also by the observations at Station C, at the mouth of the bay on the west side. As an anchorage was made there only once for 24 hours, it will not

be necessary to detail the results, which are shown on Plate I. The limiting directions between which the current was found to veer were N.N.E. and W.N.W. The general movement of the water thus causes it to strike somewhat squarely on this shore as we found the flood to do at Station F, in a corresponding position on the west side of Placentia bay.

The general resultant of the directions at Station C, is N. by W. or across the end of the headland between St. Marys and Placentia bay; and not outward from St. Marys bay, as would be expected if there were any indraught on the east side.

Station Q.—In the middle of Placentia bay, ten miles inside the line of the headlands on each side. Position 9 miles W. ¼ S. from Lahaye point light, St. Marys harbour, in 75 fathoms. An anchorage was made here on September 7th, in the day time. The station was left for the night as the wind rose in the evening to 25 miles an hour. It was again occupied on September 8th and 9th, for 28 hours. The current here proved thin and weak. A set in the same direction as on the surface was seldom felt below ten fathoms, and it was usually less than five fathoms in thickness. It had no relation to the tide; and the velocity did not fall at the turn of the tide, but remained uniform at about half a knot.

This current may have been the thin edge of a general set across the mouth of the bay; but under the weather conditions prevailing at the time, it showed no definite character of its own, but appeared to be dominated by the wind. On September 7th with strong N.E. and E. wind, the set was between W.N.W. and W.S.W.; and on the 8th and 9th during moderate southwesterly wind, averaging 15 miles an hour, the set was between N.N.E. and S.S.E.

It may at least be said that these observations do not indicate any strong or dominant set to the westward across the middle of St. Marys bay; and this also accords with the results found at the mouth of the bay on the two sides, as already explained. Although the time spent at the four stations in the region of this bay was not long, the observations were at different parts of the season, and they all point to the same general result.

Off Trepassey Bay.

Stations A and L.—Position of Station A, 8 miles W.S.W. from Cape Race. Station L, 16 miles S.W. by W. from Cape Race, in 46 fathoms. The observations obtained at these stations were as follows:—

At A, May 27th to 28th; during 30 hours. Light S.W. wind.

At A, July 13th to 15th; during 48 hours. Light winds, W. and E.

At A, August 27th to 29th; during 44 hours. After heavy westerly winds.

At L, July 15th to 17th; during 45 hours. Light S.E. wind or calm.

At L, September 15th to 17th; during 54 hours. Calm after westerly gale.

These stations were so near the southeastern angle of Newfoundland that they came within the influence of the Polar current whenever its direction was deflected to the westward, around the angle of the land, by wind disturbance. This was made evident by the change of temperature of the water. See table of deep temperatures appended.

It was therefore only in the quietest weather that the normal movement of the water was apparent. Some very interesting observations were obtained here, which throw light upon the way that such a current as this, may be deflected from its usual course in heavy weather ; and also the length of time it takes to recover its normal position after disturbance, as indicated by the temperature of the water as well as by the set itself. These varying conditions are no doubt to be expected in such a position.

In the steadiest weather, in May and July, the tidal influence was dominant and in complete accord with the results already described further to the westward, as prevailing on this coast as a whole. At both stations considered together, the set of the flood tide was between N. by W. and S.W. as limiting directions, and the set of the ebb was to the eastward of a north and south line. This greater range in the ebb directions, was no doubt due to the proximity of these stations to the eastern angle of the land. The results which best show the undisturbed conditions at these stations, are given in Plates I and VII. The resultant directions of flood and ebb, as found by combining all the various directions on a time basis, are as follows :—At Station A, flood W.N.W., ebb E.S.E.; and at Station L, flood N.W., ebb E. by N. Also, as shown by these resultants, the westward set continues for 25 per cent. longer than the eastward, which again indicates the tendency of the water to make westward on the whole.

At the dates given in August and September, these stations were occupied immediately after times of disturbance of the current. There was then a greater tendency to a northwest or southwest set, due apparently to a reflow towards that quarter after the displacement of the Polar current by heavy westerly winds. At Station A, the northwestward set continued for 9 hours out of each tidal period of twelve and a half hours. Also at Station L, which was 8 miles farther from shore than Station A, the tidal influence was more easily overcome by the tendency to veer completely round. The period in which this veer took place, was much the same as further west ; as the current veered completely around the compass three times in 46 hours, or in a period of 15½ hours on the average. The current towards the southwest quarter was much the strongest and deepest, however, owing to the disturbance referred to. When the veer of the current brought it round to the S.W., it was strongly felt to a depth of 30 fathoms. This affords confirmation to the opinion already given, that the veer in this period is due to a dominant movement in one direction, combined with the tidal period.

INFORMATION FROM FISHERMEN.

Much information can be obtained from the shore fishermen on these coasts, as they usually keep to their own vicinity and thus have a long experience in one locality. In this respect, they are to be distinguished from the bankers who frequent Grand Bank. These shore fishermen use small schooners and dories ; and their information is chiefly valuable because they anchor their schooners and thus have a fixed point from which to note the set of the current. They anchor on the smaller banks which lie some distance out, and also anywhere along the shore where the depth does not exceed thirty fathoms. They call the 30-fathom line 'the edge of the ground' as this is as far out as they usually fish.

The information they give is very reliable on the whole, if proper precautions are taken in obtaining it. It is necessary to know the local topography thoroughly, to

have some knowledge of the behaviour of the currents from observation, and to avoid asking leading questions. The bent of their mind also, is to notice chiefly the unusual features of the current, which they take as storm warnings. It is thus difficult to get them to speak of usual or normal conditions, which they pay less attention to; and they will begin at once with a description of what took place just before or after some storm. Every care must be taken to ascertain exactly where they are speaking of, and how far it was from shore; as the behaviour of these currents is chiefly affected by the distance from shore, as we have seen. They may not always give their offing correctly, but it can be checked by the depth of water in which they were at the time.

With regard to the speed of the current they undoubtedly exaggerate. They will speak of a strength of 2, 3, or even 4 knots; but on investigation, this proves to be a mere estimate while rounding a point of land under sail, or some local circumstance close to shore. Also, when at anchor, they choose the shallowest point on a bank, where the current is thrown up by the rise of the bottom and locally increased. Under these conditions they aver that small kegs of three or four gallons, used as mark-buoys, are sometimes carried under by the strength of the current and crushed in by the water pressure. When they give some measurement however, such as the length of line needed to reach bottom with a given weight, their estimate of speed can be checked. The best instances to serve as test cases were as follows :—

An experienced fisherman stated that on one occasion, when three miles off a headland, it took 30 fathoms of cod line, with a jig attached, to reach a depth of 8 or 9 fathoms; and such a current he estimated at 2½ knots. This represents an angle of 74° from the vertical, and the jig he used weighed 15 ounces. By experiment with one of his own jigs, when the current at the surface measured 0.86 knot, we found an average inclination of 65° with 30 fathoms of line out. From the formula we have arrived at, the velocity corresponding to the higher inclination of 74° would be 1.20 knot. In obtaining this value the droop of the line at the outer end is allowed for, which was determined by letting out shorter lengths of the line in a current of measured strength. This amount of exaggeration shows that such statements of speed may be reduced to about one-half to be right. Again, on the shallowest part of Ballard bank, one of the fishermen found that in the strongest current he met with, it required 30 fathoms of line with jig attached, to reach a depth of 12 or 13 fathoms. The angle in this case is 67° from the vertical, representing a velocity of 0.91 knot, which as before is quite possible in itself, apart from his own estimate of the strength.

On the other hand, their description of the effect of storms in disturbing the current may be relied upon, as this is a matter which they watch with care. Indeed, they trust to the altered behaviour of the current before a gale, as the best storm-warning they are acquainted with. It is also noteworthy that it is only the least observant men who speak in a vague way of the current 'running with the wind.' The more intelligent men attribute less to the direct action of the wind, and distinguish its varying effects more carefully.

South shore from Cape Race to Cape St. Mary.—Within a few miles of this coast, the usual set of the current in fine weather is N.W. and S.E., and the northwestward set is the stronger of the two. It has been known to run northwestward for three days continuously, only slacking at the turn of the tide. Any decided or strong set southeastward is an indication of bad weather. There is a general agreement that this

is the usual behaviour of the current; but how far it sweeps inside the line of the headlands in passing Trepassey and St. Marys bays is very variously stated. The reason of this is no doubt owing to the difficulty of distinguishing the tidal streams, which run close to the shore on the sides of the bay, from the more unconfined movement of the water in the offing. This distinction will be more clearly explained in describing Placentia bay, whose greater size makes such differences more noticeable. There are two points, however, which are generally admitted: (1) The current is stronger outside the line of the headlands than within the bays, and (2) any inward set towards the bay will occur during the rise of the tide, while the general set in the offing is northwestward. There may thus be a northward set past the headlands on the east side of these bays, during the flood tide.

Farther out, as far as Lamb rock for example, which is 22 miles S. by W. from Cape St. Mary, the current veers completely around the compass. These descriptions are entirely in accord with our own observations.

Placentia bay.—In the region of Placentia bay, most of the fishing is done on the extensive bank lying off Cape St. Mary, and along the shore of the bay from that cape to Placentia, and on the banks in the vicinity of Burin. From a comparison of the information thus available at the mouth of the bay on the east side and on the west shore, good conclusions can be formed.

Off Cape St. Mary and around the Cays, the set is more frequent and stronger to the northward than in other directions; and the current often runs north against the wind. Also during flood tide, the normal set is northward; and in slacking it veers to the eastward and sets southeastward during the ebb for a short time. The inward current is felt some miles out, off the mouth of the bay; and its preponderance indicates the general inward tendency of the water.

Along the shore from Cape St. Mary to Placentia, there are tidal streams with the flood and ebb in the two directions. This is close to the shore, and is strictly a local feature within the bay; and has little to do with the general inward trend of the water from Cape St. Mary toward the middle of the bay.

On the west shore, the Burin fishermen anchor on the banks in that vicinity, in 25 and 30 fathoms. Within two or three miles of the land the current runs along the shore to the N.E. and S.W. It turns with the tide, but in moderate weather it runs longer and stronger to the S.W. It is also stronger on the surface than below. It is thus evident that the water on the whole makes inwards on the east side of Placentia bay, and outwards on the west side.

Drift of ice.—This general movement of the water is confirmed by the drift of icebergs. On the south shore the icebergs which come around Cape Race, make westward on the whole; though they do occasionally move eastward, as we have ourselves observed. In passing St. Marys bay, they do not drift into it, but pass its mouth. Many of them ground in 30 fathoms near St. Marys Cays, which shows that they must have passed outside St. Marys bank. But if they pass Cape St. Mary they turn into Placentia bay and are likely to ground on the banks in the head of the bay. They rarely reach the Burin side. One small berg grounded off Burin this year (July, 1903) but it is rare for them to come as far as this.

Wind disturbance.—In the summer, bad weather usually comes from the S.E. and 'blows itself out' from that direction; but later on, in the autumn, the wind chops round to the N.W. before the storm is over.

Off Cape St. Mary and along the south shore to Cape Race, it is only during ebb tide that there is a weak set to the S.E. Any strong set to the S.E. or S. is a sign of bad weather. The fishermen regard this as an unfailing indication, and at once run for shelter. The set of the current is thus towards the point from which a wind is about to come. To show how universally this opinion is held, we may cite the following statements from fishermen in different localities :—

Off Cape St. Mary the set is so much more northward than southward, that it will often continue northward against a strong N.E. wind. This set against the wind is commonly observed by the fishermen, and attracts their attention. But if there is any strong set to the S.E. or S., a gale from that quarter will follow. Off St. Shots on the east side of St. Marys bay, it runs strongly to the S.E. before east wind comes up. Also, during twenty four hours before a N. or N.E. wind begins, it runs strongly to the N.W. or N. for six or seven hours at a time, instead of five hours during the flood tide, which is there usual. Outside the line of the capes also, the current sets southeastward before bad weather, which comes from that direction in the summer. If the current continues to run into the wind after it begins to blow, it indicates that the gale will be heavy.

The only apparent contradiction to this, is from the Burin fishermen on the west side of Placentia bay. They state that the winds have no effect on the current, except the N.E. wind which strengthens it. But to understand this, the general conditions throughout the bay must be considered. It appears that during N.E. wind, although it is directly out of the bay, the current on both sides of the bay is strengthened. It then runs strongly northward into the bay on the east side, and on the west side it runs steadily southwestward and scarcely slacks at all with the tide as at other times. On the west side of the bay, the reversed set to the N.E. is a sign of bad weather.

These descriptions of the effect of the weather could readily be amplified; but this condensed abstract will suffice, in which every statement is based on long experience, or is confirmed by several men.

The main feature is the fact of the current setting 'into the weather' as they express it; and it is difficult to give a satisfactory explanation for this. It is possible to suppose that it is only a coincidence; that is to say, the ordinary conditions are upset in broken weather, and the set of the current is then contrary to its usual direction, and this merely happens to be the direction from which bad weather generally comes. But this explanation is not satisfactory. The actual direction of the current is necessarily modified by local conditions and guided by the trend of the shore; but the greater scope and freedom the current has, the more directly it appears to set towards the coming wind. And further, it will set in either direction in accord with the expected wind. On the other hand, if this behaviour is due to difference of barometer, it is not easy to understand why the water should be the first to feel a change, before the wind itself begins to blow. To offer a satisfactory explanation, it would be advisable to study the conditions over a wide area, including a part of the ocean adjoining; and also to compare unusual directions of the current with the disturbance of the tide as recorded on registering gauges in neighbouring harbours. An extended basis of fact would thus be obtained, sufficient to corroborate the explanation offered.

PART II—THE POLAR CURRENT.

On the extreme eastern side of Newfoundland, in the offing of the straight shore which runs from Cape Spear to Cape Race, there is a current which sets very constantly to the southwestward. It occupies the 'gully' between this coast and the western edge of Grand Bank. It is not unusual however for this current to be so disturbed as to set across its ordinary direction, or to be reversed on the surface.

On this coast, close in-shore, the flood stream sets S.W. and the ebb stream N.E.; and the Polar current is affected by a corresponding fluctuation in velocity, strengthening during the flood tide and slackening during the ebb.

Two stations 16 miles apart, were chosen in the line of this current; one to the eastward of the Bantam banks, and the other off the eastern side of Ballard bank. The more continuous observations were obtained at the latter of these, which is directly on the steamship route as it turns at Cape Race. The general character of the current is the same at both stations; and it is therefore only necessary to make a distinction between normal and disturbed conditions. It is remarked on this coast that there is usually a heavy swell running at the spring tides, which unfortunately makes it difficult to obtain good observations at that time.

STATION J.—Off the east side of Ballard bank, in 85 fathoms. Position, 12 miles S.E. by E. $\frac{1}{2}$ E. from Cape Race light. The first anchorage was made here on July 6th to 8th, just before the spring tides. It was nearly calm throughout the time, the wind being less than 10 miles an hour. Observations were obtained during a continuous period of 55 hours. This included nine half-tides, or five flood and four ebb tides; but during the whole time the set was very constantly to the S.W. and S.S.W., the extreme limits being S.W. by W. and S. by E.

STATION K.—To the eastward of the Bantam banks, in 86 fathoms. Position, 7 miles S. by E. from Ferryland light. Anchorages were made five times at this station, the longest which was free from wind disturbance being on July 9th to 11th, when 34 hours of observations were obtained. During both flood and ebb, the set was constantly southwestward, the extreme limits being W.S.W. and S W. by S.

A second anchorage at Station J, was made on August 25th to 27th, just after the spring tides. There was still some disturbance remaining from previous heavy winds, but the general characteristics of the current were maintained. It veered to the eastward of south during the ebb, while slack, but during the flood it recovered its normal direction, owing to the influence of the flood stream. During flood tides, the limiting directions were from S.W. to S.S.E., and during ebb tides from S. to S.E., and although the surface current thus veered from three to six points to the eastward of its normal direction, the under-current maintained a constant southwestward direction throughout the whole tidal period.

During all the anchorages made at this station, the greatest velocity observed at any time occurred at half-flood on July 7th, when it attained 1.15 knots. Frequently during flood tide, the velocity was nearly a full knot.

Tidal influence.—As these stations were within ten miles of the shore, the influence of the tide was distinctly marked by a fluctuation in velocity; the current being 24 per cent. stronger during flood tide on the average. The actual and relative strength during flood and ebb, is shown in the following table. The fluctuations are also shown graphically in Plate VIII.

POLAR CURRENT.—Tidal fluctuation in Velocity.

Locality and Date.		Mean Velocity during FLOOD.	Mean Velocity during EBB.	Current Stronger during Flood.
Station J	1903—July 6.	0·86 knot.	0·73 knot.	18 per cent.
" J	" July 7.	1·07 "	0·80 "	34 "
" J	" July 8.	0·88 "	0·75 "	17 "
" K	" July 10.	0·87 "	0·71 "	23 "
" J	" August 25.	0·80 "	0·63 "	27 "
" J	" August 26.	0·77 "	0·62 "	24 "
	Mean ratio.			24 per cent.

Under-current.—The under-current had the same general direction as the surface current. It set constantly to the southwestward, even at times when the current on the surface was most disturbed by the wind. Judging from numerous observations at 40 fathoms, or about one-half the total depth of the water, it rarely veered beyond the limits of S.W. and S.S.W. under any conditions. This shows the constancy of the movement of the Polar current as a whole, in this direction.

The fluctuation in velocity with the tide, was even more marked in the under-current than on the surface. During the flood tide, the strength from 15 to 40 fathoms was unusually constant; and at 40 fathoms it was always as strong and often stronger than on the surface. During the ebb tide, it slacked below, as it did on the surface; and was usually weaker at the greater depths. When slackest at about half-ebb, it fell below one-fourth of its greatest strength during flood tide; but even then, the movement was distinctly felt to a depth of 60 and 75 fathoms.

Temperature.—The temperature of this Polar current was taken repeatedly during the season, as far down as 30 fathoms. The observations were compared with other localities in the hope of tracing the movement of the water by its temperature. But two results were arrived at, which made the temperature observations of little value for this purpose, and which it will therefore be sufficient to mention briefly: (1) The temperature of the water at 30 fathoms is practically at the freezing point in all parts

of this region, from the mouth of Placentia bay to St. Johns. It varied only from 30½° to 34° Fahr. and there was no change from one month to another, from May to September. (2) The water of the Polar current warms up quite as much on the surface, as the surface water elsewhere in this region. The general increase of the surface temperature along the south shore, from St. Pierre to Trepassey, was from 36½° in May to 50° in September; and the surface temperature of the Polar current rose from an average of 34½° at the end of May to 50¼° at the middle of August. Whether this increase of the surface temperature takes place during the progress of the current southward, or whether this warmer surface water flows over it from elsewhere, we have not sufficiently extended observations to determine. But for the guidance of the mariner, it is evident that the lower temperature cannot be depended on, as an indication of the current-belt itself. The deep temperatures taken, are appended in a tabular form, on pages 28 and 29.

A very interesting result was met with, however, on account of the rapid fall in temperature from the surface downwards. The temperature proved to be a valuable indication of wind disturbance. During heavy winds, especially when off-shore, the surface water was driven out to the offing, and the cold under-water came up to the surface. A heavy fall in temperature would thus occur. For example, towards the end of August the surface temperature over the area from Cape Spear to Cape Race was 50°. There followed during three days, 1312 miles of westerly winds, ranging from N.W. to W.S.W., when the surface temperature within three miles of the shore fell to 36° and 34°; and in a belt ten miles wide along the windward shore, it was below 45°. Careful observations and some special runs were made, to ascertain the amount of lateral displacement of the current and the depth of disturbance due to a measured mileage of wind. This was done without loss of time, as the weather was then too heavy to carry on work at anchor. Later, when the weather moderated, the temperature again furnished a basis for a very fair estimate of the rate at which the current-belt moved back laterally to resume its usual course. The results of these investigations we need not here detail, as they might not be considered of immediate practical value.

Disturbed conditions.—It is possible for the Polar current to veer completely around the compass in broken weather, or times of disturbance. At Station K on August 12th to 13th, during 24 hours the current veered from S.W. through west and north to N.N.E. It then slacked at low water and set in to the south, and again veered to the right as far as N.N.W. up to the end of the time. This was between spring and neap tides, and the wind was moderate. During the 36 hours which included this period of observation, the wind veered from N. through east to S.E., and rose from 12 to 20 miles an hour.

Again in the night of August 20th to 21st, for 8 hours the current held in the eastward quarter, between S.E. and N.E.; and on the 22nd during 7 hours it veered from E. through south to S.W. This was just before the spring tides; and the wind conditions were as follows:—From noon on August 20th to 9:00 on the 22nd during 45 hours, there were 941 miles of wind from the westerly quarter, between N.W. and S.W.

These observations are given because of their importance as examples, obtained by some perseverance during those disturbed times. The above directions of the current were on the surface only; and from 5 or 10 fathoms downward, the under-current set southwestward as usual. This is important to note, as it explains statements made by fishermen and others, which would otherwise be contradictory.

The tide, so far as its effect could be distinguished, gave rise to the same tendencies during flood and ebb as already described. It was also during the ebb, when the current is always slacker, that it was veered farthest from its usual direction.

Information from other sources.—The Bantam and Ballard banks which lie off the extreme eastern coast of Newfoundland in the line of the Polar current, are frequented by fishermen who are well able to observe what takes place, because they anchor upon them in their small schooners. The information following, is condensed from the account given by a number of these men who live in the adjoining harbours. Unlike the bankers, they fish almost exclusively on these small banks in their own vicinity ; and many of them have had the experience of half a life time. Their accounts harmonize well with each other, when carefully sifted to distinguish the effects of tide and weather from the more constant conditions.

They state that in the vicinity of the Bantam banks, the current runs constantly southwestward in fine weather. The usual direction is between S.S.W. and S.W. It is strong during the flood tide ; and after high water it slacks as a rule, and goes on again ; or it may set weakly in the reverse direction, to the N.E., during part of the ebb tide. It is to be noted that these banks are within five miles of the shore ; and the tide has therefore more influence in slackening or reversing the current than farther out where our observations were taken.

On Ballard bank, which is twelve miles to the southwest and farther from shore, the behaviour of the current is very similar, but the tide has less influence. The current runs nearly all the time to the S.W. and strengthens during the flood tide ; but during two or three hours on the ebb tide, it may set weakly to the S.E. or even to the N.E. It is also stronger with northeast winds.

On either of these banks, any decided set to the E. or N.E. is a sign that bad weather is coming. The current may only veer as far as S.E. before an east wind comes up ; but a strong set to the E. or N.E. usually indicates a northeast wind ; and although it is possible that the wind may come from the E. or S.E., it will always be from the easterly side. Any set in these directions is more usual and will be more accentuated during the ebb tide ; but the current has been known to set N.E. for a whole day, previous to a northeast wind. After the northeast wind sets in, the wind sea and current all go together. In general, the more unsettled the weather the more set there will be toward the eastward quarter.

This set of the current towards the point from which a wind is about to come, is in accord with the universal testimony of the fishermen throughout these regions. Of all the signs of bad weather, it is the one which they appear to find the most trustworthy. In the present instance, the wind effect is no doubt complicated with tidal influence ; and even the wind itself is often known to set in strongly at the turn of the tide. But the above statement is the result of long experience ; and is as well-balanced and concise as it can be made, without describing individual storms.

With regard to the season of the year, there is said to be least current in July, and that the currents are stronger as the fall season advances. It is also stated by bankers, that the southwestward current is limited to the width of the deep gully between the east coast of Newfoundland and Grand Bank. The width referred to is from thirty to forty-five miles.

Ice as an indication of current.—To infer the behaviour of a current from the drift of ice with any certainty, the indications given by flat ice and by icebergs must be carefully distinguished. The flat or pan ice runs with the surface current, and is much influenced by the wind; whereas the icebergs indicate the average movement of the body of the water as a whole, and the wind has no appreciable effect upon them. This distinction is well known to sealers, and they habitually take advantage of it. When working against a gale of wind, they will moor their vessel to an iceberg, and lie in its lee while the small ice goes past with the drive of the wind; because as they express it, the wind takes no hold on an iceberg at all. They thus save a long drift to leeward.

For our present purpose, it is from the icebergs rather than from the flat ice that we can find indications of value. The field ice as seen from Cape Race, will pack into the bend of the shore; and the running ice will follow the straight line of its outside edge. It is usually packed close, and sets continuously to the S.W. Winds from the S.W. quarter, if at all off-shore, will scatter it and possibly set it back; but it never runs in a compact mass to the N.E. There has been less flat ice in recent years than formerly. Icebergs are most numerous in May and June, and become fewer as the season advances. During our observations a few were seen, and their movements checked by angles and bearings; but the information they afforded was not sufficiently definite to be of value.

The points of chief importance on which the icebergs throw light are:—(1) The general set of the Polar current, and (2) to what extent it sweeps round to the westward on passing Cape Race. The information on these points was obtained from fishermen who anchor on the Bantam and Ballard banks; and from the light-keepers at Cape Spear and Cape Race, who have been many years there, with a commanding view over the area of this current.

The icebergs always move to the southwestward. They may stand or turn about, as they ground in as much as 60 fathoms; but they set on again. They never move northeastward. This is stated most definitely by fishermen who know that the surface current sometimes sets in that direction; but they give it as a fact. It is also confirmed positively by both the light-keepers, one of whom has been at Cape Spear since 1852.

This drift of the icebergs is entirely in accord with the persistent set of the undercurrent to the southwestward, as found by the observations. It also shows that the surface current may set in quite a different direction to the one which they indicate. We have already had occasion to remark this, in Belle Isle strait. (See Report of Progress of Tidal Survey, 31st October, 1895, page 9.)

As to the second question, according to the light-keeper at Cape Race, the great majority of the icebergs after passing the cape, keep straight on to the southwestward till they disappear. Only one now and then, will turn westward along the south shore. The fishermen give exactly the same account of their drift, as seen from Ballard bank. If they pass inside the bank, however, they are more apt to turn around Cape Race. Also when seen from St. Marys bay, they are usually far out and making to the southwestward.

Concluding Note.—From these observations, taken at all points along the steamship route on these coasts, we may draw special attention to the following points which result: (1) When more than five miles from shore, there are no currents at any time

throughout the season which exceed one knot per hour in any direction. The only exception to this is the Polar current, in which a maximum speed of 1·15 knots was observed. (2) On the south coast, when within four or five miles of the shore, the current is chiefly governed by the tide, and sets in the two opposite directions alternately; but the farther out the point of observation, the greater the tendency for the direction of the current to veer completely around the compass. (3) The water makes northwestward on the whole along the south shore, from Cape Race towards Placentia bay; that is to say, when a long average is taken, the set is more frequently in that direction than in any other. (4) With regard to indraught towards the bays, the water makes inwards on the whole on the eastern side of Placentia bay, in the same sense that it makes northwestward along the south coast. A corresponding indraught is felt at certain times of the tide, on the east side of St. Marys bay. As already noted regarding the currents in general, these indraughts do not exceed one knot at an offing of five miles. (5) The Polar current sets very constantly to the southwest, for a width of 30 or 40 miles off the eastern coast. During times of disturbance, it may set southeastward, or even be reversed, on the surface. When such disturbance occurs, it is usually for part of a day immediately before a gale comes on.

The above note refers in general to the currents when undisturbed by the wind. The effect of heavy winds and the influence of the tide on the behaviour of the current in the various localities, have been explained in the body of the report.

MAGNETIC VARIATION FROM SOLAR AZIMUTHS.

These observations were taken at every available opportunity, whenever the fog cleared. They are nearly all at stations where anchorages were made, but two harbours are included. The binnacle compass on the steamer is in the pilot house, and roofed over; so that the sun's azimuth could only be observed at low altitudes.

The compass was adjusted by swinging the ship in Halifax harbour, in May, before beginning the season's work. This adjustment was made by Mr. D. H. Baker of Boston, and the outstanding deviation in his table of corrections amounted at the most to $1\frac{1}{2}°$. The deviation was also checked at sea during the season and was found to correspond with these corrections, except in one quadrant, where it appeared to be 1° greater; but after careful revision, Mr. Baker's determinations were adopted finally in working out the results. It is also to be noted, that his values make the results accord more nearly with the variation as given on the chart, than our check determinations at sea would have done.

The observations were made with a solar azimuth instrument of modern type, fitted with a lens and prism. The sun's bearings were read to the nearest half degree; and the ship's heading noted, to correct for deviation. It was found best to watch the sun until its bearing came to an even degree or half degree, and then to take the time which could always be had exactly. This was specially advisable when the rolling was considerable, and every care was taken to avoid accidental error from this cause. After correction for deviation, the observations were reduced by Commander Burdwood's azimuth tables, with full interpolations for intermédiate values in time, declination and latitude. The reduction is thus quite beyond the limit of accuracy in the observations themselves.

The only known source of error results from the ship's heading being taken only to the nearest point as a rule, in correcting for the deviation. The limit of error from this cause does not probably exceed $\frac{1}{4}°$ in individual observations. A part of the irregularity in the observations may be due to this; but in the average values, this should eliminate itself.

The results are compared with the values shown on Admiralty chart, No. 2666, St. Johns to Halifax, on which the magnetic variation is given for 1895. The chart-variation at each station was found by interpolation between the lines of equal magnetic variation as laid down on this chart. A decrease of one minute per annum was allowed, during the eight years since elapsed. In the tables following, the observations themselves are given and the resulting comparisons with the chart, as well as a summary showing approximately the error found at each degree-line of variation on the chart.

Respectfully submitted,

W. BELL DAWSON,
Engineer in charge of Tidal and Current Survey.

Deep Temperatures—Nova Scotia to Newfoundland.

Depth.	Off SE coast of Nova Scotia. May 21, 1903.—Three points 27 miles apart, on the 50-fathom line.			Between Cape Breton and St. Pierre I. May 22, 1903.—Four points, at 19, 34, 79 and 99 miles from Scatari I.			
	°	°	°	°	°	°	°
Surface	42	40½	42½	36½	36½	37	36½
10 F	—	39½	39	36	37	36½	37
30 F	37	36	37	31½	33	33	--

Deep Temperatures—South Coast of Newfoundland—Season of 1903.

Depth.	Station E.		Station G.			Station H.	
	June 8.	June 9.	June 20.	June 22.	June 24.	June 30.	July 1.
	°	°	°	°	°	°	°
Surface	39½	39	42	43	43	43	44
10 F	36	37	41	40	41	40½	42
15 F	—	—	35½	37½	37	37	38
20 F	—	—	34½	36½	36	35	36
30 F	34	34	32	32½	33½	33½	34

Depth.	Station A.			Station N.	Station M.	Station G.	Station D.
	July 13. Ebb, ESE.	July 14. Flood, NW.	Aug. 29. (Disturbed.)	July 24.	Aug. 4.	Aug. 4. Set, NE.	Sept. 21.
	°	°	°	°	°	°	°
Surface	45	45	48	52	49	48½	51
5 F	43	44½	38½	51½	46	—	48
10 F	42½	42	34½	42	45½	45	37½
15 F	38	38½	33½	—	39½	40	32
20 F	37	37	33	35	35½	34½	—
30 F	—	—	—	34	32½	31	30½

Depth.	From Cape Pine, on a line SW by S. Aug. 10, 1903.—At the following distances :—					Station L.	
	½ Mile.	3½ Miles.	8 Miles.	13 Miles.	18 Miles.	July 15.	Sept. 16.
	°	°	°	°	°	°	°
Surface	47	48	51½	51	51	46	47½
5 F	44	43	43	46½	—	46	45
10 F	—	38½	36	38	—	43½	39
15 F	—	36	35	38	39	40½	38½
30 F	—	—	32	33	33	37 (?)	31½

Note.—Lower temperatures at A on Aug. 29, and L on Sept. 16, are due to veering of Polar Current to the westward of Cape Race, after heavy winds.

Deep Temperatures in the Polar Current.

Date.	Depth.	From Cape Race, on a line SE by S, to the edge of Grand Bank. At the following distances from Cape Race :—					
		2 Miles.	5 Miles.	10 Miles.	18 Miles.	26 Miles.	34 Miles.
1903.		°	°	°	°	°	°
May 26.....	Surface	33	33½	34	35½	36	36
" 26	10 F.....	33	32	33½	35	35	35½
" 26	30 F.. ...	—	32	32	35	35	35½
Aug. 11.....	Surface	50½	50	50½	50	50	—
" 11.....	5 F..	49	—	50½	—	50½	—
" 11.....	10 F.....	45	47	37	42½	45	—
" 11.....	15 F.....	39½	—	34	—	—	—
" 11.....	30 F.....	—	32	—	31½	31	—
	Total depth	28 F.	.....	76 F.	.....	....	45 F.

Station K.—Off Bantam Banks. Depth 86 fathoms.

Depth.	July 10.	July 11.	Aug. 13.
	°	°	°
Surface.....	43	43	51
5 F.....	—	42½	51
10 F	42	41	46
15 F	37½	36	35½
20 F	35	35	—
30 F	31	34	31

From Cape Spear, on an ESE line. At the following distances :—

Date.	3 Miles.	8 Miles.	13 Miles.
1903.	°	°	°
Aug. 14....	50	50	51
" 14	50	49½	49
" 14....	44½	46	37½
" 14....	34	36	38½
" 14....	—	—	—
" 14....	31½	31	30½

Station J.—East of Ballard Bank.—Depth 85 fathoms.

Depth.	July 7.	July 8.	Aug. 25.*	Aug. 26.*	Aug. 27.
	°	°	°	°	°
Surface	43	43	41	46	50
5 F	41	—	40½	43½	49
10 F	36	36½	38	40	39
15 F	35	36	36	37	33½
20 F.....	34	35	—	—	--
30 F.....	31½	34	30½	30½	31

* At J on Aug. 25 and 26, surface water exceptionally cold, after off-shore gales.

MAGNETIC VARIATION, from observations of the Sun's Azimuth, on the South-eastern Coast of Newfoundland, in the Season of 1903.

(NOTE.—The Sun's bearing, as given, is corrected for the Deviation of the binnacle compass on board.)

Station.	Date. — 1903.	Time of observation. G.M.T.	Apparent hour angle.	Sun's bearing. Corrected.	Sun's true azimuth.	Magnetic variation (West).	Variation from Chart.	Difference.
C	June 1..	(Long	bearings	on cape.	Mean).	28° 45′	29° 10′	0° 25′
		h. m.	h. m. s.					
D	June 2..	10 36	7 00 45	N 36° W	64° 08′	28° 08′	(At Sta. D, not corrected for deviation.)	
	" 2..	10 59	7 23 45	32	60 04	28 04		
	" 2..	11 14	7 38 45	29	57 22	28 22		
	" 2..	11 18	7 42 45	28	56 38	28 38		
Mean						28 18	29° 10′	0° 52′
Q	Sept. 8..	9 36	6 02 55	N 58½° W	85° 22′	26° 52′		
	" 8..	9 43	6 09 55	58	84 05	26 05		
	" 8..	9 45	6 11 55	56¾	83 43	26 58		
Mean						26 38	29° 28′	2° 50′
H	Aug. 31..	8 49	5 13 20	N 65° W	92° 12′	27° 12′		
	" 31..	8 51	5 15 20	64	91 49	27 49		
	" 31..	9 17	5 41 20	61	87 06	26 06		
	" 31..	9 20	5 44 20	60	86 34	26 34		
	" 31..	9 36	6 00 20	57	83 44	26 44		
Mean						26 53	28° 54′	2° 01′
L	Sept. 16..	9 07	5 38 55	N 65½° W	91° 44′	26° 29′		
	" 16..	9 14	5 45 55	63½	90 28	26 58		
	" 16..	9 16	5 47 55	63	90 06	27 06		
	" 16..	9 18	5 49 55	62¾	89 44	26 59		
	" 16..	9 25½	5 57 25	62	88 23	26 23		
	" 16..	9 27	5 58 55	61½	88 07	26 37		
Mean						26 45	29° 05′	2° 20′
J	July 7..	9 20	5 44 15	N 49° W	76° 32′	27° 32′		
	" 7..	9 46	6 10 15	45	72 10	27 10		
	" 7..	11 02	7 26 15	32	59 05	27 05		
	" 7..	11 05	7 29 15	31½	58 30	27 00		
	" 7..	11 09	7 33 15	31	57 50	26 50		
	" 7..	11 12	7 36 15	30½	57 17	26 47		
Mean						27 04	29° 35′	2° 31′
Trepassey	Sept. 20..	9 09½	5 42 20	N 65° W	92° 33′	27° 33′		
	" 20..	9 15	5 47 50	63½	91 31	28 01		
	" 20..	9 16½	5 49 20	63½	91 16	27 46		
Mean						27 47	29° 28′	1° 41′
G	June 24..	11 12	7 31 50	N 32° W	57° 41′	25° 41′		
	" 24..	11 16½	7 36 20	31¼	56 58	25 43		
	" 24..	11 29	7 48 50	29¼	54 44	25 29		
	Aug. 1..	9 55	6 10 40	50	75 35	25 35		
	" 1..	9 57	6 12 40	49½	75 15	25 45		
	" 1..	9 59	6 14 40	49½	74 54	25 24		
	" 1..	11 03	7 18 40	37	63 35	26 35		
	" 3..	9 53	6 08 45	50¾	75 57	25 12		
	" 3..	9 57	6 12 45	50¼	75 15	25 00		
	" 3..	10 00½	6 16 15	49¾	74 45	25 00		
	" 3..	10 02	6 17 45	49¼	74 23	25 08		
	" 3..	10 30½	6 46 15	44¼	69 27	25 12		
Mean						25 29	28° 57′	3° 28′

MAGNETIC VARIATION.—South-eastern Coast of Newfoundland.—*Continued.*

Station.	Date. — 1903.	Time of observation. G.M.T.	Apparent hour angle.	Sun's bearing. Corrected.	Sun's true azimuth.	Magnetic variation (West).	Variation from Chart.	Difference.
		h. m.	h. m. s.					
M	Aug. 4..	10 04	6 20 25	N 48½°W	74° 13′	25° 48′		
	" 4..	10 30	6 46 25	45	69 40	24 40		
	" 5..	9 20	5 36 35	56½	82 12	25 42		
	" 5..	9 27	5 43 35	55	80 58	25 58		
	" 5..	9 32	5 48 35	54½	80 06	25 36		
	" 5..	9 38	5 54 35	53	79 04	26 04		
	" 5..	9 42	5 58 35	52	78 22	26 22		
	" 5..	9 54	6 10 35	50½	76 17	25 47		
	" 6..	9 36	5 52 40	54	79 20	25 20		
	" 6..	9 42½	5 59 10	51½	78 17	26 47		
	" 6..	9 51	6 07 40	50½	76 43	26 13		
	" 6..	10 26	6 42 40	45½	70 36	25 06		
	" 6..	10 30	6 46 40	44	69 59	25 59		
Mean						25 47	28° 40′	2° 53′
Placentia	June 16..	9 34	5 57 50	N 45° W	73° 56′	28° 56′		
	" 16..	9 49	6 12 50	43	71 26	28 26		
	" 16..	10 01	6 24 50	41	69 26	28 26		
	July 17..	11 02	7 20 15	32½	61 13	28 43		
	" 19..	9 54	6 12 05	45	73 16	28 16		
	" 19..	10 06	6 24 05	42½	71 13	28 43		
	" 19..	10 08	6 26 05	42	70 52	28 52		
	" 19..	10 54½	7 12 35	35	62 46	27 46		
Mean						28 31	29° 57′	1° 26′
E	June 10	9 45	6 08 10	N 45° W	72° 30′	27° 30′		
	" 10.	9 49	6 12 10	44	71 50	27 50		
	" 10..	9 53	6 16 10	43	71 09	28 09		
	" 10..	10 49	7 12 10	33	61 33	28 33		
	" 10..	10 52	7 15 10	32	61 01	29 01		
Mean						28 13	29° 37′	1° 24′
F_1	June 11..	9 49	6 09 00	N 46° W	72° 20′	26° 20′		
	" 11..	9 55	6 15 00	45	71 20	26 20		
	" 11..	10 59	7 19 00	34½	60 20	25 50		
	" 11..	11 04	7 24 00	33½	59 26	25 56		
	" 12..	9 46	6 05 45	47	72 50	25 50		
	" 12..	9 52	6 11 45	45¾	71 50	26 05		
	" 12..	9 57	6 16 45	44½	70 59	26 29		
	" 12..	10 58	7 17 45	35	60 30	25 30		
	" 12..	11 03½	7 23 15	33½	59 36	26 06		
	" 12..	11 08½	7 28 15	31¾	58 43	26 58		
F_2	July 29..	9 46	5 59 05	51½	76 57	25 27		
	" 29..	11 01	7 14 05	38½	63 47	25 17		
	" 29..	11 03	7 16 05	38	63 26	25 26		
	" 29..	11 05	7 18 05	37½	63 05	25 35		
Mean						25 56	28° 57′	3° 01′

Magnetic Variation.—Summary of results.

Near line of 30° Variation, Magnetic Chart.			Near line of 29½° Variation, Magnetic Chart.			Near line of 29° Variation, Magnetic Chart.		
Station.	Variation as found.	Chart error.	Station.	Variation as found.	Chart error.	Station.	Variation as found.	Chart error.
	° ′	° ′		° ′	° ′		° ′	° ′
Trepassey				27-47	1-41	H	26-53	2-01
Placentia	28-31	1-26	J	27-04	2-31	G	25-29	3-28
Station E	28-13	1-24	L	26-45	2-20	M	25-47	2-53
			Q	26-38	2-50	F	25-56	3-01
Average	28-22	1-25	Average	27-04	2-20	Average	26-01	2-51

Positions of Stations at which the Magnetic Variation was determined.

Station.	Latitude.	Longitude.	Station.	Latitude.	Longitude.
	° ′	° ′		° ′	° ′
A	46-33 N.	53-12 W.	H	46-24 N.	53-48 W.
C	46-42 "	54-03 "	J	46-40 "	52-48 "
D	46-47 "	54-19 "	L	46-25 "	53-16 "
E	47-09 "	54-28 "	M	46-26 "	54-23 "
F_1	46-51 "	55-12 "	Q	46-50 "	53-48 "
F_2	46-54 "	55-09 "	Placentia	47-15 "	53-58 "
G	46-41 "	54-33 "	Trepassey	46-44 "	53-23 "

Deviation of Compass.—Corrections applied.

Point.	(Nil.)	Point.	W'ly.	Point.	E'ly.	Point.	W'ly.
	°		°		°		°
North		East		South		West	
N. by E		E. by S		S. by W	¼	W. by N	
N.N.E		E.S.E	½	S.S.W	½	W.N.W	
N.E. by N		S.E. by E	1	S.W. by S	1	N.W. by W	½
N.E		S.E	1	S.W	1½	N.W	1
N.E. by E		S.E. by S	1	S.W. by W	1	N.W. by N	½
E.N.E		S.S.E	½	W.S.W	½	N.N.W	
E. by N		S. by E		W. by S	¼	N. by W	
East		South		West		North	

NOTE ON THE PLATES.

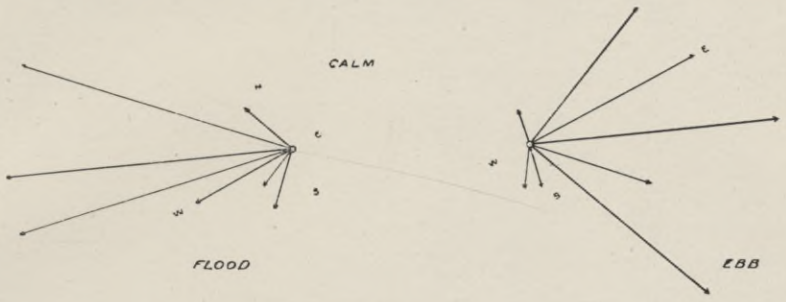
While examining the various plates, it will be found convenient for reference to open out the map, Plate IX., which shows all the stations in their relative positions.

The plates are set in the true meridian, with the north to the top, the same as a chart. The bearings marked are magnetic. The variation is 26° to 28° west.

The lengths of the lines, showing the direction of the current, are in proportion to the TIME during which the current sets in the various directions indicated.

The direction and strength of the wind is noted wherever it was sufficiently strong to affect the current.

STATION A. OFF HEADLAND BETWEEN CAPE RACE AND TREPASSEY BAY

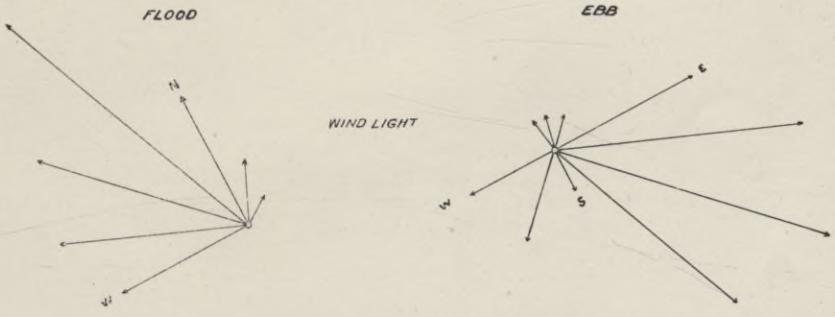


July 13-14. 1903.

Mean of three flood tides. *Mean of three ebb tides.*

STATION B.

MOUTH OF ST. MARYS BAY_ EAST SIDE



May 29-30 and Sept 8-10 1903.

Mean of three flood tides. *Mean of three ebb tides.*

STATION C.

MOUTH OF ST. MARYS BAY

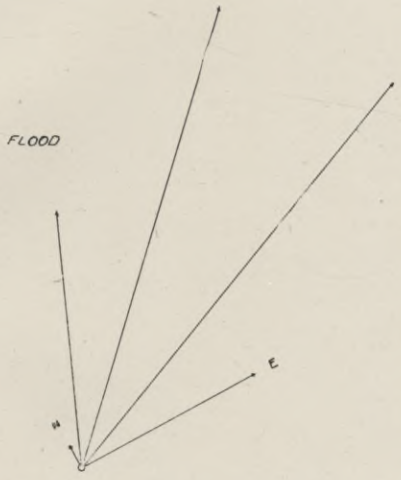
WEST SIDE

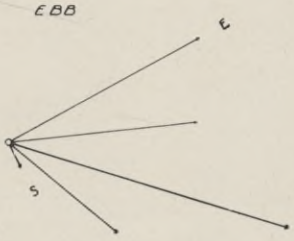
June 1-2. 1903.

Period 24 hours - two complete tides.

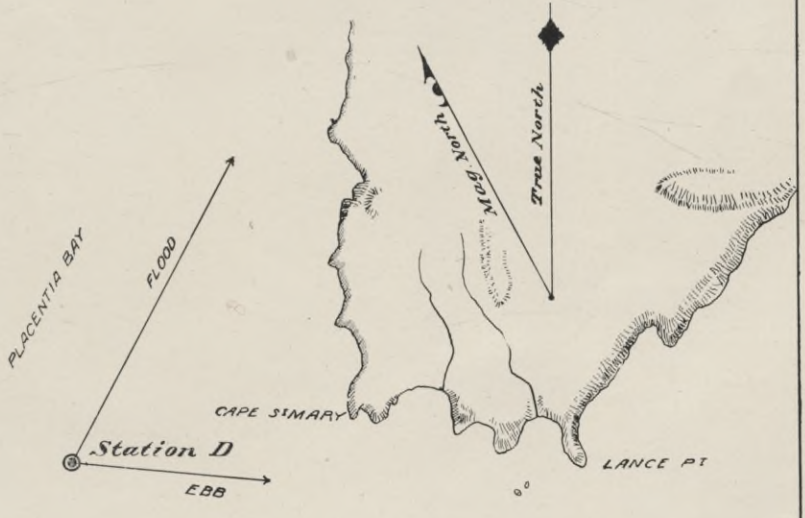
SCALE, ONE-HALF OF STATIONS ABOVE.

STATION D.
AT 5½ MILES OFF CAPE St. MARY





June 2 to 3, September 3 to 4 and 21, 1903.
Mean of five flood tides and five ebb tides.

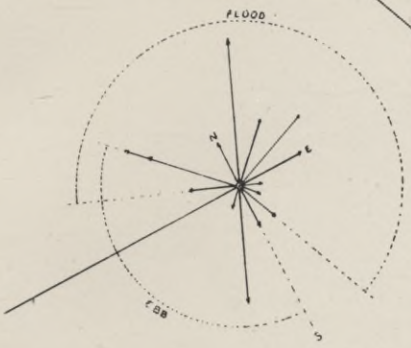


RESULTANT DIRECTIONS

STATION E.

MIDDLE OF PLACENTIA BAY

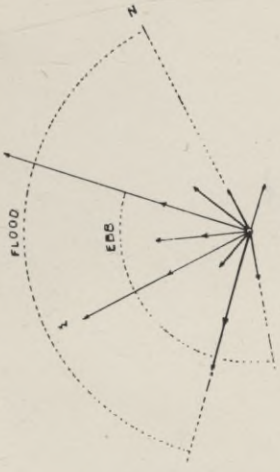
WEATHER CALM THROUGHOUT



June 8-9 1903.
Period 19 hours - two floods, one ebb.

June 9 1903.
Period 12 hours.

CENTRE LINE OF PLACENTIA BAY



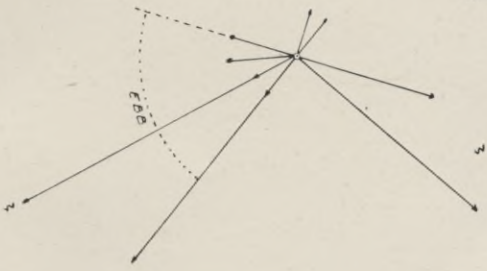
June 9-10 1903
Period 12 hours.

June 10-11 1903.
Period 24 hours - two tides.

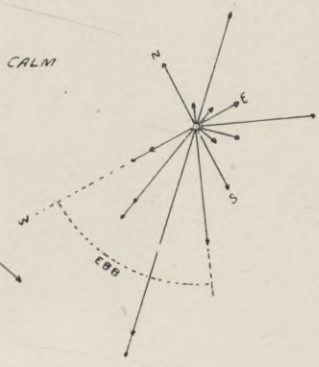
STATIONS F_1 AND F_2

MOUTH OF PLACENTIA BAY - WEST SIDE

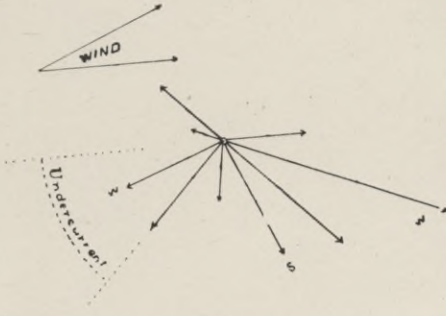
Prevailing Ebb in southwestward direction
Flood in all directions.



June 11-12 1903.
Period 12 hours = one tide.



June 12 1903
Period 18 hours



June 12-13, 1903.
Period 18 hours,
two ebb, one flood.

Wind 22 miles per hour during 7 hours.

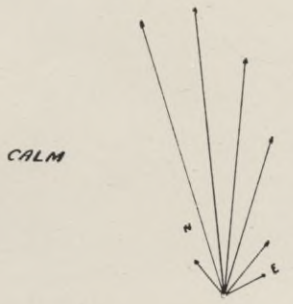
July 29-30 1903.
Period 25 hours - two tides.

After Easterly gale on the 27th
Wind 21 miles per hour during
28 hours on the 28th and 29th

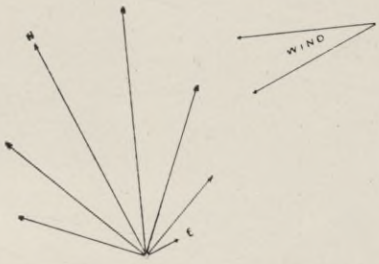
STATION G.

MOUTH OF PLACENTIA BAY - EAST SIDE

Direction of Current veering alternately to the right and left in 10 to 14 hours

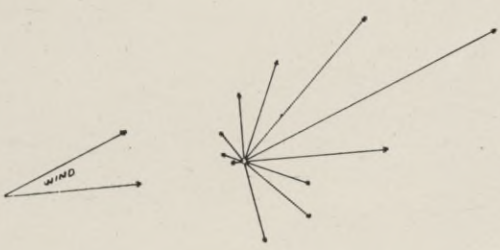


June 22 1903.
Period 12 hours.



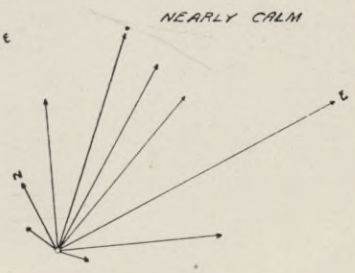
June 22-23 1903.
Period 23 hours.

Wind - 18 miles per hour during 20 hours.



June 24-26 1903.
Period 47 hours.

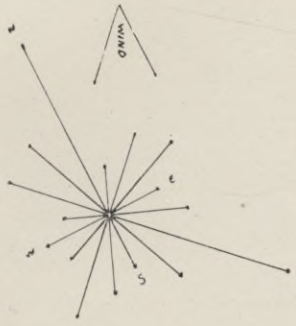
Wind 18 miles per hour during 12 hours.



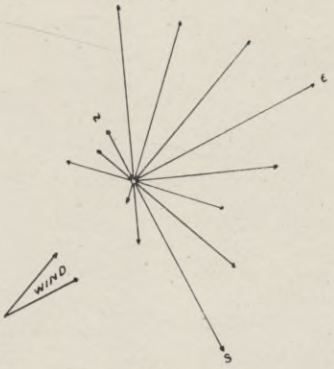
August 3-4 1903
Period 37 hours

STATION G, CONTINUED.

Direction of Current veering completely around to the right in a period of 16 hours, at neap tides.



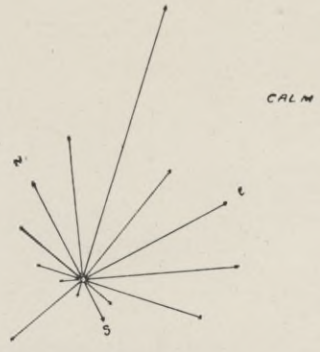
June 18–20, 1903.
Mean of 4 complete revolutions during 62 hours.



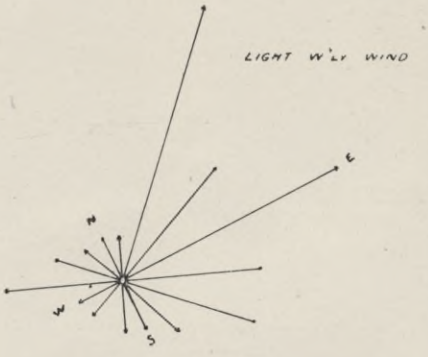
July 31 to August 1, 1903.
Mean of 2 complete revolutions during 33 hours.

STATION M.

Direction of Current veering completely around in a period of 16 hours.



July 21–23, 1903.
Mean of 3 complete revolutions during 47½ hours.



August 4–6, 1903.
Mean of 3 complete revolutions during 49½ hours.

STATION H.

17 MILES W.S.W. FROM CAPE PINE.

June 29 to July 3, 1903.
Period 48 hours in all.
Four complete tides.

Wind very light
(A day and a half of
wind disturbance omitted.)

SCALE, ONE HALF OF STATION L. BELOW.

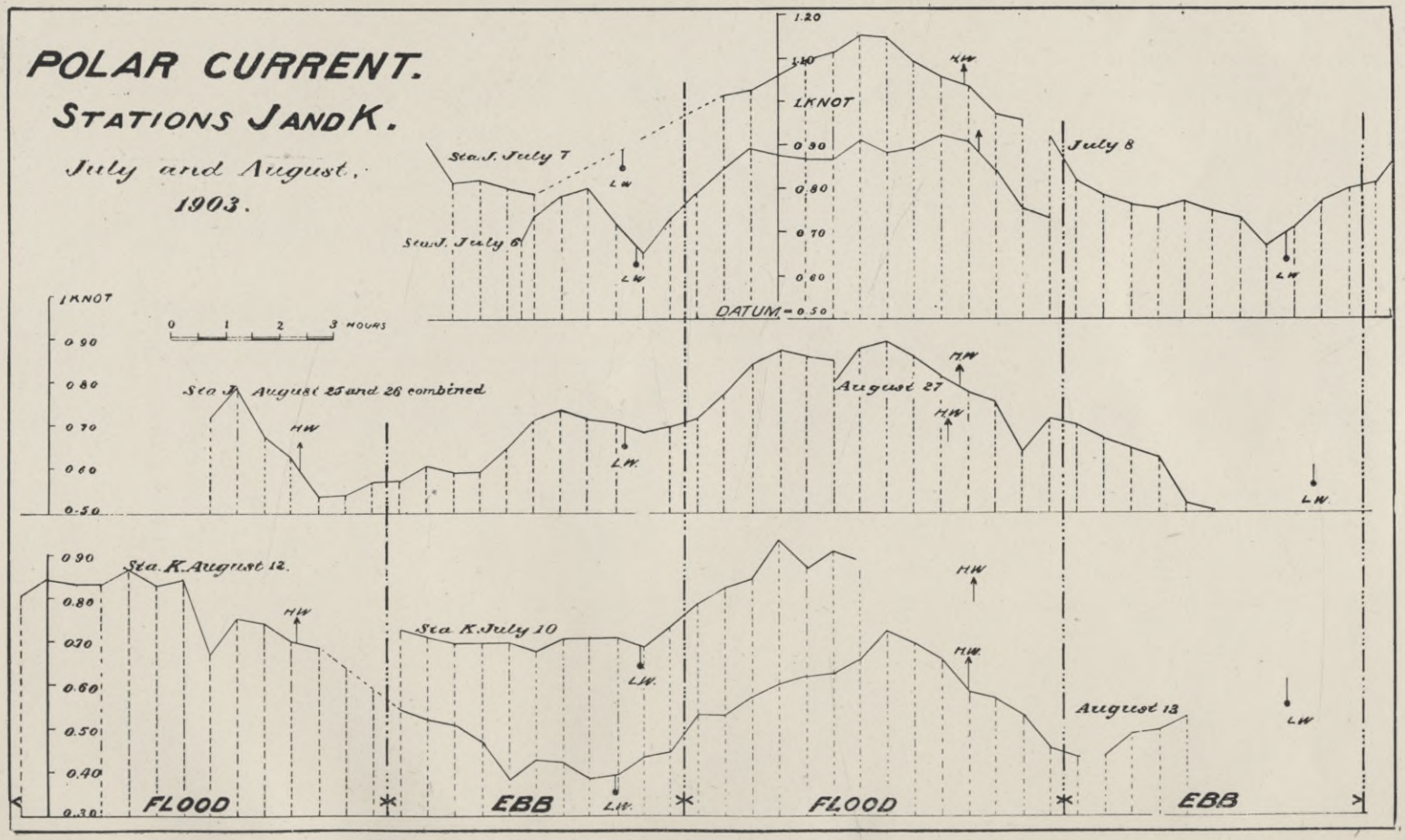
STATION L.

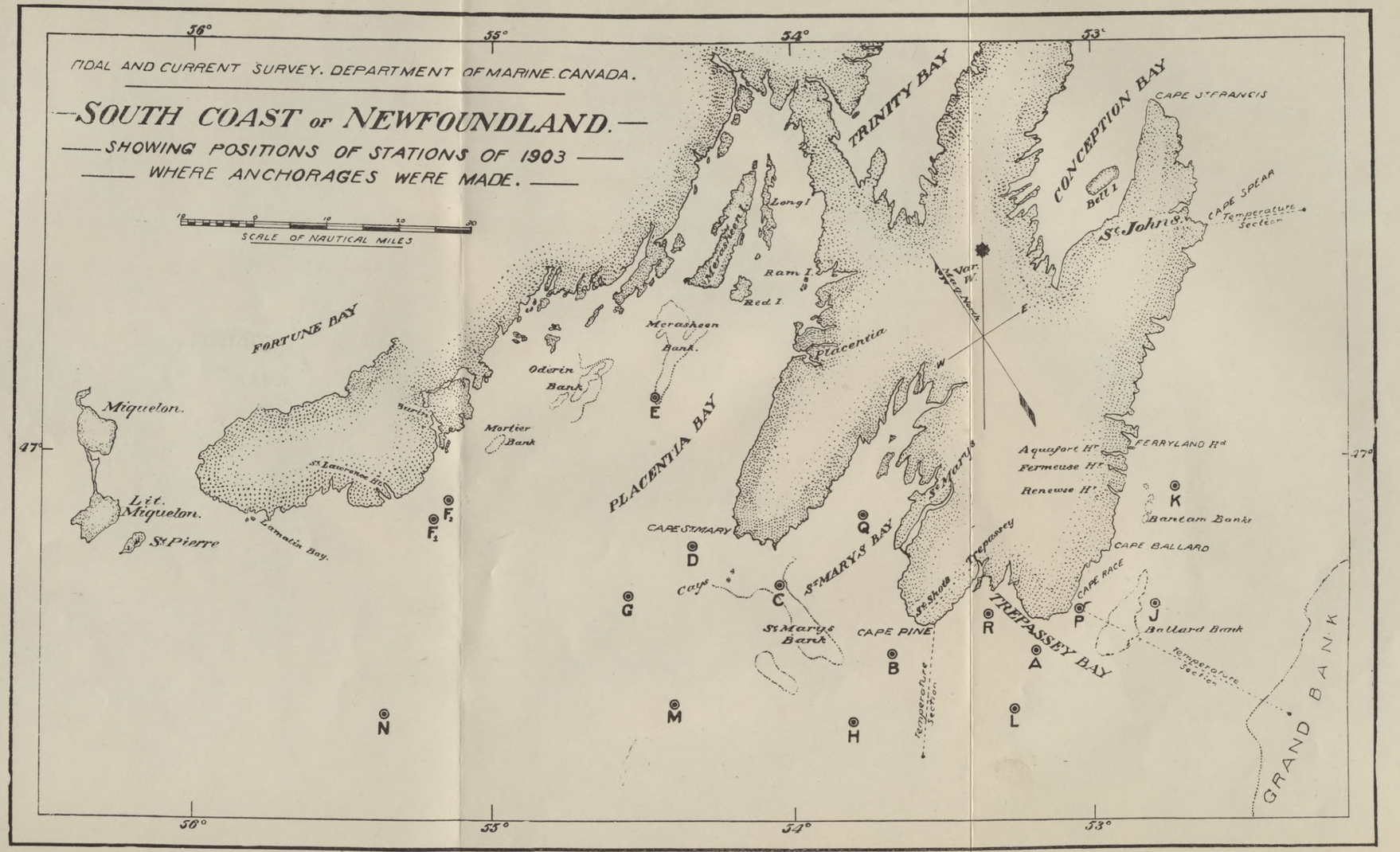
16 MILES S.W. BY W. FROM CAPE RACE

Light SE wind or calm

July 15 to 17, 1903.
Period 36 hours.
Three flood, three ebb
tides.

PLATE VIII.


POLAR CURRENT.
STATIONS J AND K.
July and August, 1903.
1 KNOT
0 1 2 3 HOURS
Sta. J. July 7
Sta. J. July 6
July 8
Sta. J. August 25 and 26 combined
August 27
Sta. K. August 12.
Sta. K. July 10
August 13
HW
LW
DATUM = 0.50
FLOOD
EBB
FLOOD
EBB


TIDAL AND CURRENT SURVEY. DEPARTMENT OF MARINE. CANADA.
SOUTH COAST OF NEWFOUNDLAND.
SHOWING POSITIONS OF STATIONS OF 1903
WHERE ANCHORAGES WERE MADE.
SCALE OF NAUTICAL MILES
56°
55°
54°
53°
47°
FORTUNE BAY
Miquelon.
Lit. Miquelon.
St Pierre
St Lawrence Hr.
Lamaline Bay.
Burin
Mortier Bank
Oderin Bank
Merasheen Bank.
PLACENTIA BAY
Placentia
Ram I.
Red I.
Long I.
Western I.
TRINITY BAY
CONCEPTION BAY
CAPE ST FRANCIS
Bell I.
St John's
CAPE SPEAR
Temperature Section
Aquafort Hr.
Fermeuse Hr.
Renewse Hr.
FERRYLAND Hr.
K
Bantam Banks
CAPE BALLARD
CAPE RACE
J
Ballard Bank
Temperature Section
St Mary's
St MARYS BAY
Trepassey
St Shotts
TREPASSEY BAY
CAPE PINE
St Marys Bank
CAPE ST MARY
Caps
GRAND BANK
E
F
F1
D
C
G
Q
R
P
A
B
N
M
H
L