ON THE TIDAL AND DRIFT CURRENTS AT URKT ROAD NORTH SAKHALIN.

by

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1. *INTRODUCTION.*

The currents in Urkt Road (53°34' N., 143°4' E.), on the east coast of North Sakhalin, were observed in 1924, by the Japanese Naval Special Service Ship *Sunosaki*, while anchored at a point about 1,500 metres (0.8 mile) from the coast, in a depth of 13 metres (7 fms.) at half tide. The float by means of which the observations were made consisted of a bamboo pole about 4 metres (13 ft.) long, with two planks each about 1 metre (1 ft. 3 ins) long and 0,3 metre (1 ft.) wide secured at their centres, across their longer sides one above the other and at right angles to each other, to the lower part of the pole, and a weight attached to the lower end of the pole so as to keep it upright, its upper part showing 0,5 metre (1 ft. 8 ins) above the surface of the water. The currents observed were therefore those at a depth of about 3 metres (10 ft.) below the surface of the sea. Such observations were repeated every 3 hours, day and night, from the 1st to the 31st of August, 1924, with a whole day's interruption beginning 21.00 of the 10th.

For a distance of more than 20 miles North and 20 miles South of Urkt Road, the coast is nearly straight extending in the direction N. 9° W. and S. 9° E. (magnetic variation being about 9° W.) and the land is very flat with a sandy beach. The bottom of the sea is generally very flat and the depth contours run nearly parallel to the coast line, the distance from the coast of the 5, 10, 20 and 100 metres (2 3/4, 5 1/2, 11 & 55 fms.) contours being about 600, 1,300, 2,500 and 35,000 metres (0.32, 0.70, 1.35 and 19.0 miles) respectively.

2. *TIDAL CURRENTS.*

The results of these observations show that there are only one north-going and one south-going current in a day, the maximum velocity of which coincides approximately with the time of high water and low water at Chai-vo, a station situated about 70 miles south of Urkt Road; that the currents are apparently affected by wind, a strong north wind giving rise to comparatively greater velocity and longer duration of the south-going current, the north-going current being slower and shorter, and a strong south wind acting contrary wise; that there is no perceptible regular oceanic current; and finally that the principal directions of the currents are to the north and the south, nearly parallel to the coast, with a slight tendency to turn to the right with time. The observed currents for 15 days from noon on 13th August, were plotted on paper with time and velocity as abcissa and ordinate respectively and a smoothed curve was drawn. From this curve the velocities were read for every one hour, taking the north-going current as positive, and they were submitted to harmonic analysis by G. H. DARWIN'S method. The harmonic constants of currents thus obtained are tabulated below together with the harmonic constants of tides at the neighbouring stations. The velocity of currents is expressed in nautical miles per hour or knots (1 knot is nearly equal to 0.51 metre per second).

	M_2		S_2		K_2		K_1		O		P	
	H	k	H	k	H	k	H	k	H	k	H	k
Currents	$N+$											
	kn.		kn.		kn.		kn.		kn.		kn.	
URKT ROAD	0,03	21°	0,05	265°	0,01	265°	0,86	262°	0,55	190°	0,29	262°
Tides												
KYAKR-VO....	0m10	269°	0m02	323°	0m01	323°	0m38	228°	0m28	182°	0m13	228°
CHAI-VO............	0m09	276°	0m03	1°	0m01	1°	0m38	257°	0m35	209°	0m13	257°

	M_2+S_2	K_1+O	$\frac{O}{K_1}$	$K_1° - O°$	Cotidal hour. M_2	Cotidal hour. K_1	Lat.	Long.
Currents								
	kn.	kn.			h.	h.		
URKT ROAD.......	0.08	1.41	0.64	72°	3.1	7.8	53°34'	143° 3'
Tides								
					h.	h.		
KYAKR-VO..........	0m12	0m66	0.74	46°	11.4	5.7	52°52'	143° 19'
CHAI-VO............	0m12	0m73	0.92	48°	11.6	7.6	52°22'	143° 12'

The mean value of the currents is − 0.17 knot, showing that the oceanic currents during the period of reduction run to the south with a mean velocity of 0.17 knot.

Cotidal hour for M_2 is $\frac{M_2^\circ}{30^\circ}$ - Longitude in hour.

» » » K_1 is $\frac{K_1^\circ}{15^\circ}$ - » »

The harmonic constants of tidal currents determined as above must contain a great amount of errors ; for instance, for the values of H and k for K_1, O and P the error must be 0.1 to 0.2 knot and more than 10 degrees, while the constants for M_2, S_2 and K_2 are of no value. The constants for tides at Kyakr-vo and Chai-vo must have a higher order of accuracy, being deduced from the hourly heights for 1 and 2 month's observations respectively.

It will be noted from the above table that the diurnal components are far greater than the semi-diurnal, in both tides and currents, and give rise to the single-day tides and single-day currents for the majority throughout the year, that the time of the maximum north velocity of the diurnal currents nearly coincides with the time of high water of the diurnal tides. Figure 1 shows the cotidal chart for K_1 tide, being a slight modification of the chart formerly published by the author (1). As can be seen from this chart, the K_1 tidal wave, after entering into the Sea of Okhotsk from the Pacific Ocean,

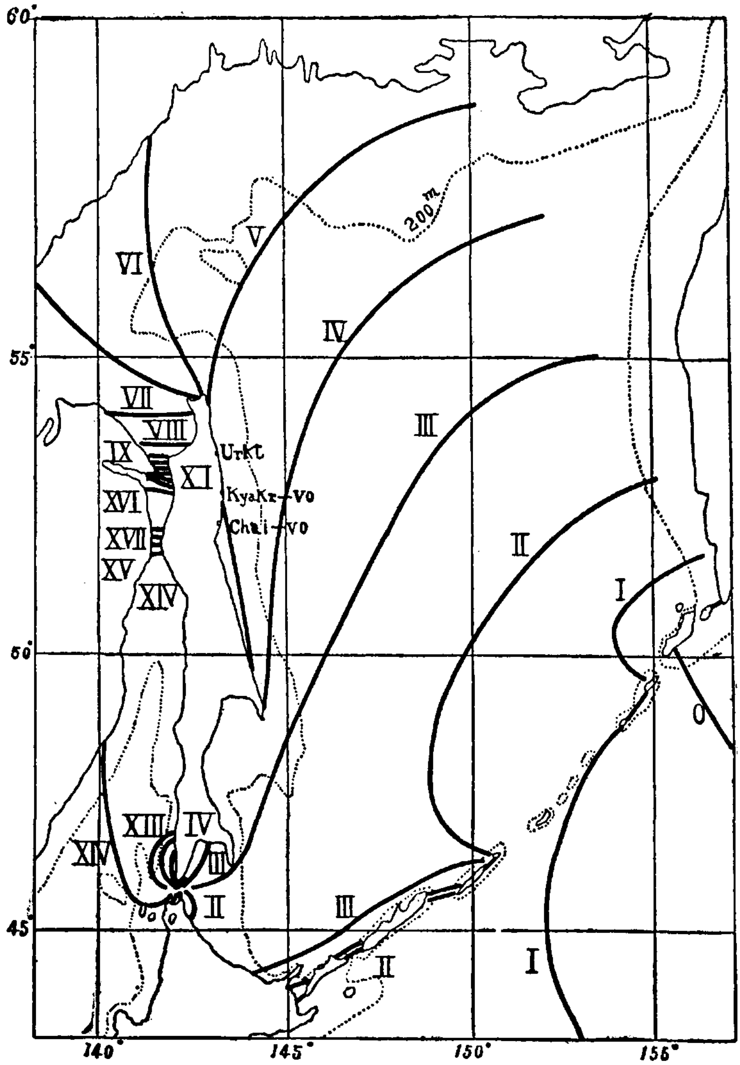

Fig. 1. — CO-TIDAL CHART FOR K_1

progresses as a free wave in a long canal towards the northwest at a velocity corresponding to the depth of the sea. According to the theory of long waves in an uniform long canal, the velocity of current is given by $\eta\sqrt{\frac{g}{h}}$ where η the height of the surface of the sea above the mean sea-level, g and h the acceleration due to gravity and the mean depth of the sea respectively. We have no data on tides at Urkt Road. Kyakr-vo and Chai-vo are situated each just inside the small mouth of a large lake communicating with the sea, and therefore the range may be a little reduced and the phase a little retarded as compared with those on the outer coast. If we assume that the tides at Urkt Road are equal to those at Chai-vo, we have

	H	$H\sqrt{\frac{g}{h}}$	*Observ. H of current.*	*Ratio*
	m	kn.	kn.	
K_1	0.38	0.64	0.86	0.74
O	0.35	0.59	0.55	1.07
			Mean	0.91

The ratio for K_1 differs considerably from that for O, but the mean of the two is not very far from unity. Thus, it may be fairly accurately concluded that the diurnal tides and currents at Urkt Road are caused by free diurnal tidal waves in a long canal, the discrepancy between the calculated and the observed velocities being considered to be due to the uncertainty of the constants of tides and currents.

The results of a few day's observations made by the *Kôsyû* in Chai-vo Road at a point about 4,000 metres (2.16 miles) from the coast, show that the currents there are very weak and their directions variable, the principal direction of the currents being nearly parallel to the coast, and that the currents to the south and north attain maximum velocity approximately at the time of high and low waters respectively, contrary to those at Urkt Road. The calculated value of $\eta\sqrt{\frac{g}{h}}$ is about twice that of the corresponding observed velocity. Thus it is evident that the tides and currents there are not caused by free tidal waves in a long canal, as can be inferred from Fig. 1.

3. *DRIFT CURRENTS.*

As pointed out in the preceding paragraph, wind has perceptible effects on the currents, the north wind giving rise to the south-going drift and the south wind to the north. For a quantitative study of the wind effect on currents, the tidal currents were calculated for the whole period of current observations, a total of 30 days, by means of the harmonic constants obtained in the preceding paragraph with additional estimated constants for Q (H=0.12 kn., k=262), and by using the KELVIN'S Tide-predictor belonging to the Hydrographic Department, Tôkyô. Each of the observed 3-hourly velocities was decomposed into north and west components, and the residual Δv, north component velocity minus calculated velocity, was obtained. The west components of the observed currents and Δv were correlated with the wind observed on board the ship every 3 hours at the same time as the currents, the force of wind being estimated according to BEAUFORT'S scale and the direction observed to within two points (22.5°) by means of the ship's compass.

The values of Δv were grouped first into five groups corresponding to wind forces 0, 1–2, 3–4, 5–6, and 7 which were blowing at the same moment. In each group, except that for wind force *o*, the values of Δv were further divided into 8 groups corresponding to the direction of the wind, the first group with the wind direction E and ENE, the second NE and NNE, etc... Thus we have 33 groups of Δv characterised by the force and direction of the wind. The mean of Δv for each group was taken as the north component of the drift current caused by the wind of that group. For instance, the mean of sixteen Δv belonging to the group of wind directions S and SSE, and wind forces 1 and 2 being -0.15 knot, this value is regarded as the north component of the drift current caused by the wind of direction S by E (S 11° 1/4 E) and of force 1.5. As the drift currents thus obtained are distributed irregularly, the following process was employed to get the smoothed values as a whole:

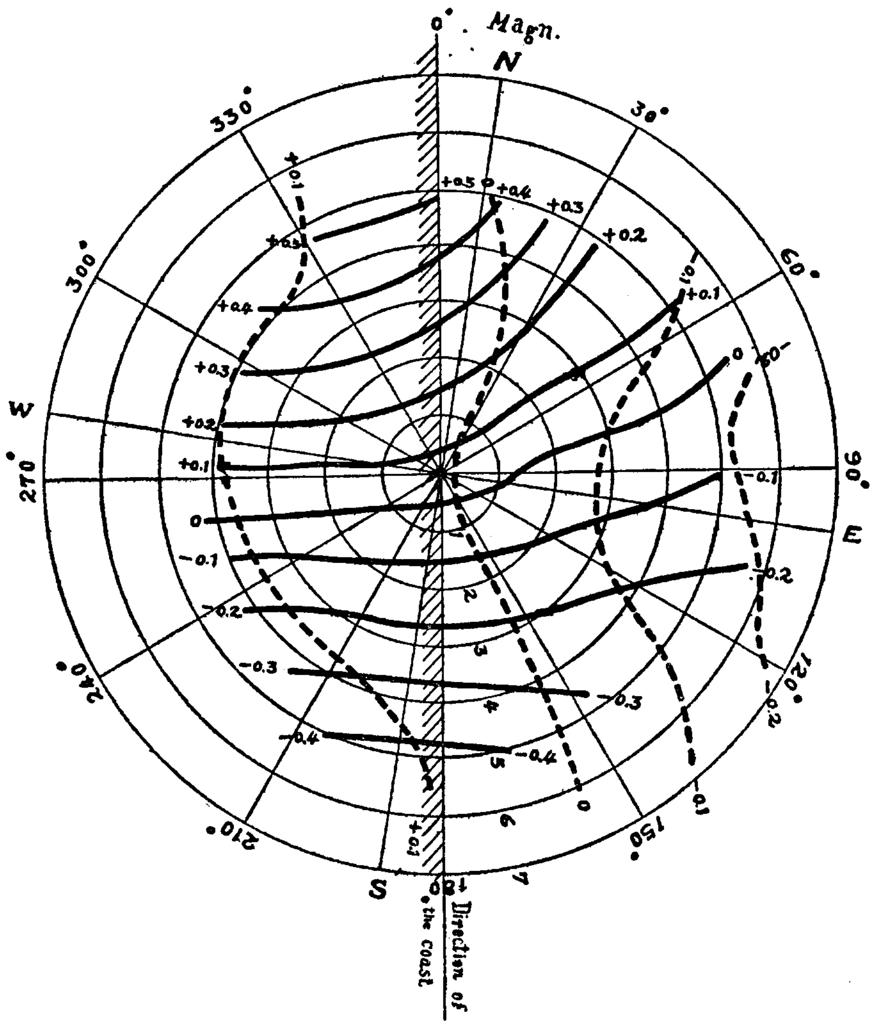

Fig. 2.

DIAGRAM SHOWING THE RELATION BETWEEN THE DRIFT CURRENT AND THE WIND BLOWING DURING THE 3 PRECEDING HOURS.

——————— North Component } of the drift current in knots.
.... West Component }

Wind direction is measured from the centre outwards. Concentric circles are equal wind-force circles (BEAUFORT scale).

Around a point were drawn concentric circles with radii proportional to the wind forces, and from this centre straight lines to the directions of the groups. At each point in this diagram, corresponding to the position of each group, the mean value of Δv for that group was marked. With these values the smoothed curves were drawn on the diagram, at intervals of 0.1 knot, showing the lines of the equal north component velocity of currents with respect to wind.

The west components of the observed currents were treated in the same way for obtaining the west components of the drift currents.

In the above treatment the drift currents are correlated with the wind blowing at the same moment. For discussing the time retardation of the effect of wind on drift currents, the drift currents were correlated with winds blowing 3 hours and 6 hours previously, in the same manner as described above. The results show that the correlation seems to be greatest, though not conspicuous, in the case of 3 hours, which is shown in Fig. 2. From that figure the north and west components of the drift currents were read for every 30 degrees of wind direction and for every wind force from 2 to 5, and the resultant drift currents were calculated with the result as shown in the following table :-

The drift current and the wind blowing during the 3 preceding hours.
The directions of wind and current are measured to the right of the coast (N. 9° W).

WIND FORCE.		2		3		4		5		
WIND VEL. (m./s.).		1.6 - 3.3		3.4 - 5.4		5.5 - 7.9		8.0 - 10.7		CURRENT-WIND.
		Vel. kn.	Dir.	Vel. kn.	Dir.	Vel. kn.	Dir.	Vel. kn.	Dir.	
DIRECTION OF WIND.	0°	0.19	354°	0.28	356°	0.36	357°	0.46	357°	- 3°
	30	0.11	10	0.15	11	0.17	13	0.20	15	-15
	60	0.06	81	0.08	83	0.10	84	0.13	86	26
	90	0.12	138	0.17	130	0.21	129	0.25	127	37
	120	0.16	158	0.23	155	0.30	154	0.32	154	34
	150	0.19	171	0.28	174	0.32	175	0.40	176	26
	180	0.20	186	0.29	188	0.39	187	0.50	188	8
	210	0.18	193	0.28	195	0.38	197	0.45	197	-13
	240	0.11	207	0.17	204	0.25	207	0.31	205	-35
	270	0.05	297	0.07	286	0.10	281	0.11	280	10
	300	0.15	344	0.21	343	0.28	341	0.32	340	40
	330	0.20	349	0.30	348	0.39	350	0.48	349	19

Figure 3 is the graphical representation of the drift currents caused by winds of force 5.

The following relations between wind and drift currents can be observed from the above table and Fig. 3.

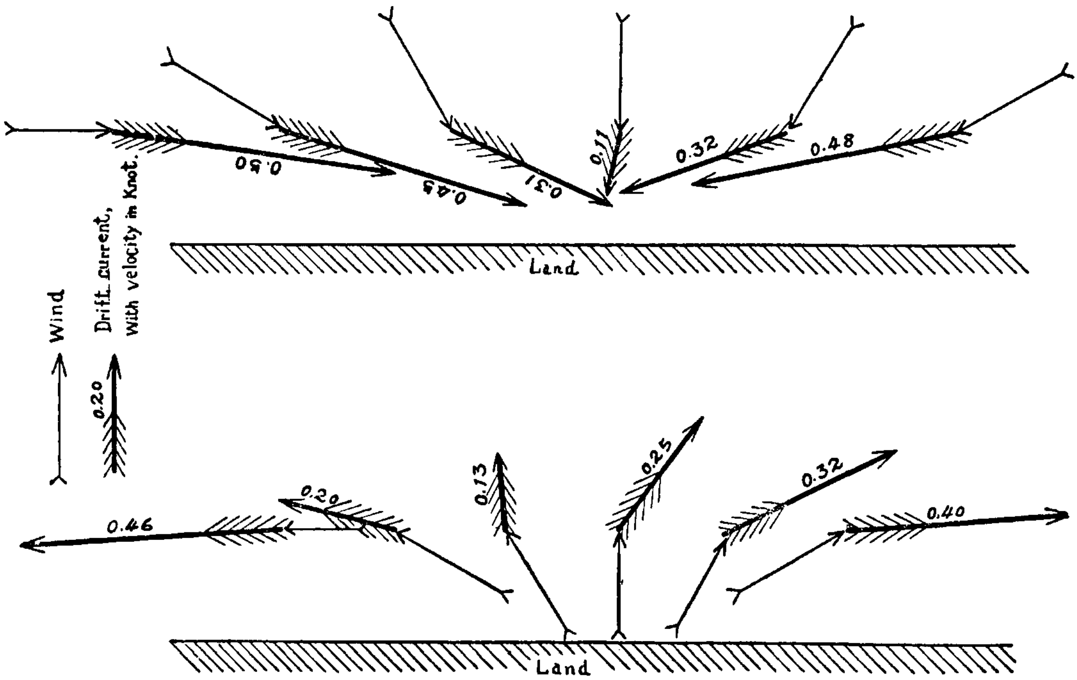

Fig. **3.**

Drift currents due to winds of force 5 at Urkt Road.
Depth of the sea, 13 metres (7 fathoms).
Distance from the coast, 1, 500 metres (0.8 miles).
Numerals denote velocity in knots.

1. If the directions of the wind are the same, that of the drift current is nearly independent of wind force.

2. The direction of the drift current makes a smallei angle with the coast than the wind. The deviation of the direction of the drift current from that of the wind is at a minimum when the wind blows nearly parallel to the coast and at a maximum when it makes an angle of 45° to the coast. Deviation to the right is more frequent than to the left.

3. If the directions of the wind are the same, the velocity of the drift current is nearly proportional to the force or velocity of wind up to force 5.

4. The maximum drift current is caused by the wind blowing nearly parallel to the coast, a wind of force 5 (mean velocity 9.4 metres (30.9 feet) per second) producing a drift current of about 0.50 knot or about 2.7 % of the wind velocity.

5. As the angle between the directions of wind and coast increases, the ratio of the velocities of the drift current and of the wind gradually decreases, the minimum ratio 0.6 % being arrived at an angle of about 90°.

The relation between the wind and the current caused by it was treated theoretically by Ekman in 1905-06 (2) and in 1923 (3), by taking account of the effects of wind acting on the surface of the sea, internal friction of the sea water, rotation of the earth, and the slope of the surface of the sea caused by the current. His theory establishes, among other things:

a) In a very large and deep sea the direction of the surface current caused by a wind deviates 45° (to the right in the northern hemisphere and to the left in the southern) from the wind direction; and from the surface downwards the velocity gradually decreases and the direction gradually turns to the right (northern hemisphere), the direction at the "Reibungstiefe" (clashing-depth) being opposite to that at the surface with a velocity about 4.3 % of that at the surface.

b) In a large and shallow sea, shallower than the "Reibungstiefe", the deviation of the direction of current and the velocity of current relative to those of the wind gradually decrease as the sea becomes shallower.

c) In an uniformly deep sea, deeper than twice the depth of the "Reibungstiefe", near a straight coast, the currents caused by wind give rise to three different layers of currents, *viz.* the drift current layer from the surface down to the "Reibungstiefe", the bottom current layer from the bottom upwards to a distance equal to the "Reibungstiefe", and the deep current layer between the former two, the current running parallel to the coast.

d) In an uniformly shallow sea near a straight coast the deviation of the direction and the velocity of current relative to those of the wind gradually decrease as the sea becomes shallower.

The drift currents at Urkt Road correspond approximately to case (*d*), except that the bed of the sea is slightly sloped, and they nearly coincide with the theoretical results arrived at by EKMAN, noting that the depth of the sea (13 metres, 7 fathoms) is nearly equal to 0,21 times the "Reibungstiefe", and that the currents were observed at about 3 metres (10 ft.) below the surface.

The results of researches hitherto made by many investigators from observed data on the relation of wind and drift currents, such as DINKLAGE'S investigation (4) on the observations made at the light-vessel Adler-Grund in the Baltic Sea for 294 days, R. WITTING'S study (5) based on from 109 to 1,461 observations made at 11 light-vessels in the Baltic Sea, and MARMER'S study (6) on the observations from 1915 to 1920 at the five light-vessels along the Pacific coast, of the United States of America, are similar in their general character to those obtained at Urkt Road. Urkt Road is open to the high sea, the configuration of the coast and sea-bed is simple, and the station is near to the coast as compared with the other cases, consequently, the effects of wind on the drift currents are more marked and the effects of land very conspicuous, the current perpendicular to the coast being considerably smaller than that parallel to the coast.

An extended report on the present investigations is contained in the *Suiro Yôhô* (Hydrographic Bulletin) (7), a monthly journal published by the Hydrographic Department of the Imperial Japanese Navy.

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