Computation of Wind Drift Currents in the Southern Waters of Korea

by

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한국 남해안의 취송류 계산

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한국 남해 연안 해역의 바람 자료를 사용하여 Palmén 식에 의해 순별 취송류를 계산하였다. 한국 남해안의 바람의 특성에 관하여도 간단히 언급하였다.

바람의 응력과 취송류를 정확하게 계산하기 위하여는 아직도 해결되어야 할 여러 가지 문제점이 있다. 이 계산 결과는 한국 남해안의 개략적인 취송류 자료로 사용될 수 있을 것이라 생각된다.

Abstract

By use of wind data, the wind drift currents in the southern waters of Korea were computed applying Palmén's formula. The characteristics of winds in the region were described in brief.

Introduction

A Norwegian scientist Fridtjop Nansen was the first man to cross the Greenland ice cap. While he was testing his theory of surface currents in the Arctic Sea with a specially reinforced ship "Fram", he found out that the drifting route of the ice didn't coincide with the wind direction, deviating 20-40 degrees to the right according to the rotation of the earth (Nansen, 1902). After mathematical investigations on the subject, Ekman (1902, 1905) represented the first model of, what we call, the wind drift current.

Although it is considered one of the most remarkable theoretical developments in oceanography, it is difficult to apply Ekman's theory practically to the real ocean, since we can't find a current which satisfies the assumption that the ocean is horizontally unbounded and infinitely deep. The wind speed and direction are not uniform over the sea surface. The knowledge of the effective eddy viscosity coefficients seems to be insufficient for permitting a complete comparison of theoretical results with direct observations. Moreover, the problem of wind stresses still remains unsettled. Munk (1947) stated that there is a jump of wind stress at a critical wind velocity of 6.6 m/sec. Neuman (1951), however, declared that the jump of wind stress which Munk had mentioned did not exist. The Scripps Institution of Oceanography, University of California (1948), published a series of tables of the field of mean monthly wind stress over the North

Pacific. Hidaka(1958) extended the computation of the wind stress field to the South Pacific, Indian and Atlantic Oceans for four seasons and their annual mean values. To keep pace with the Scripps computation, he employed the Munk's formula:

$$\tau=0.008\rho_a W^2 \qquad W<6.6\ \text{m/sec}$$
$$\tau=0.026\rho_a W^2 \qquad W>6.6\ \text{m/sec} \tag{1}$$

where W denotes the wind speed and ρ_a the density of the air (Munk, 1947). Palmén and Laurila(1938) found similar results with the factor 2.4×10^{-3}, while Hela(1948) suggested the formula:

$$\tau=1.9\times10^{-3}W^2 \tag{2}$$

and Neuman(1948) the formula:

$$\tau=0.9\times10^{-3}\ \rho_a W^{\frac{3}{2}} \tag{3}$$

Trying to study empirically the relation between the wind speed and the surface wind drift currents, Thorade(1914) found the following formulae which shows the dependence of the surface velocity of a wind drift current on geographical latitude:

$$V_o=\frac{2.59\sqrt{W}}{\sqrt{\sin\phi}} \qquad W\leq 6\text{m/sec approx.}$$
$$V_o=\frac{1.26W}{\sqrt{\sin\phi}} \qquad W>6\text{m/sec} \tag{4}$$

where V_o denotes the velocity of the surface drift current in centimeters per second when the wind speed, W, is measured in metres per second, and ϕ the geographic latitude. Palmén(1931) suggested a relationship shown by the formula:

$$V_o=1.4W \tag{5}$$

while Durst(1924) obtained

$$V_o=\frac{0.79W}{\sqrt{\sin\phi}} \tag{6}$$

Chang(1970) calculated the wind drift current at 35° N Lat (Fig. 1) and compared it with the drift bottle observation data recorded in the southern coastal waters of Korea. Calculated velocities obtained by applying Palmén's formula were found to be in better consistance with the observed ones than when obtained by applying the other formulae(Chang, 1970).

Wind drift current information plays an important role in the estimation of transport and recruitment of larvae, fish eggs and plankton, the diffusion of oils and other contaminants, the drift of fishing gears, nets and vessels, and in the solving of other problems connected with ccean developments. This paper presents the results of the wind drift current computations made in the southern coastal waters of Korea, including some comments on wind characteristics.

Table 1. Locations and Heights of Anemometer in Meter

Name of Observatory	N Lat	E Long	Ho*	Ha**	Ho+Ha
Pusan	35°06′	129°02′	69.2	17.8	87.0
Yosu	34°44′	127°44′	67.0	10.5	77.5
Mokpo	34°47′	126°23′	53.4	15.8	69.2

* Height of observation field above mean sea level.
** Height of Robinson's anemometer above ground.

Materials and Methods

Wind data observed at Mokpo, Yosu and Pusan Meteorological Observatory from January 1967 to December 1969 were adopted from the Monthly Reports of the Central Meteorolcgical Office (1967–1969), Korea. Anemometer locations and heights are listed in Table 1.

The mean values of the daily 24 hour averages were computed for a 10 day pericd. The most prominant directions of the wind were recorded. The x- and y-components of the wind were computed and are shown in Fig. 2. For the computation of the wind drift currents, Palmén's formula was employed for the reason mentioned earlier. A clockwise deflection of 45 degrees was applied to the direction of the wind drift currents.

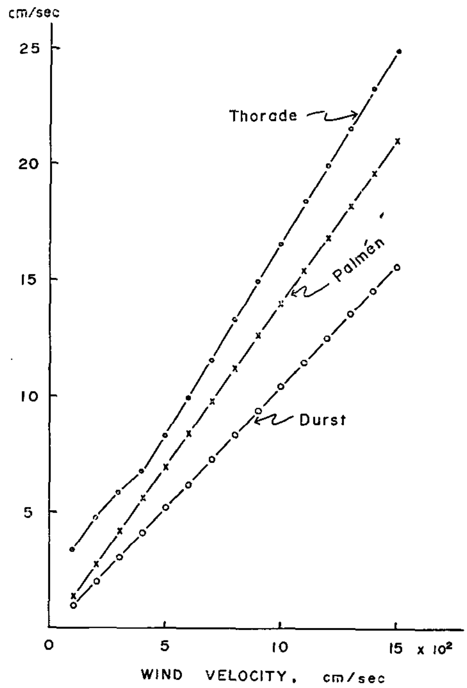

Fig. 1. Velocities of wind drift current in relation to the wind speed.

Results and Discussion

It is seen from Fig. 2 that in winter from October to March, a northwest monsoon prevails in the central and eastern portion of the southern coastal waters of Korea with an occasional northeast wind. At Mokpo in the western portion of the southern waters of Korea, however, a northwest monsoon blows steadily from September to April revealing its maximum speed in February. In summer, a southerly wind prevails from June to August in the western and central part, and from April to August in the eastern part. The predominant winds in autumn are those from the northeast in September and October.

Tabulated are the computed results of the wind drift current at Mokpo, Yosu and Pusan. Assuming that the coefficient of the eddy viscosity is constant, the velocity components of a pure wind drift current, as a function of depth, can be expressed by the formulae

$$U=V_o \exp\left(-\frac{\pi z}{D}\right) \cos\left(45^\circ-\frac{\pi z}{D}\right)$$
$$V=V_o \exp\left(-\frac{\pi z}{D}\right) \sin\left(45^\circ-\frac{\pi z}{D}\right) \tag{7}$$

where

$$V_o=\frac{\tau}{\sqrt{\rho A\cdot 2\omega \sin\phi}} \tag{8}$$

$$D=\pi\sqrt{\frac{A}{\rho\omega \sin\phi}} \tag{9}$$

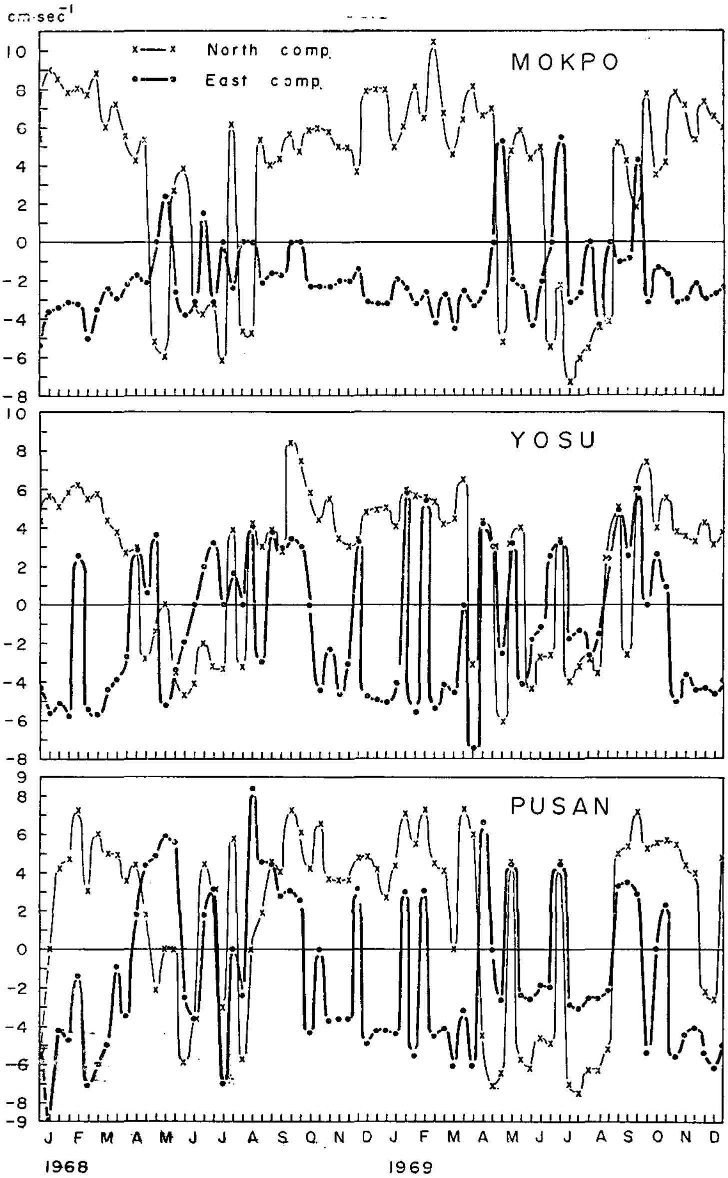

Fig. 2. North and East components of the winds in the southern coastal regions of Korea.

and τ denotes the wind stress, A the coefficient of eddy viscosity, ω the angular velocity of the Earth and ρ the density of sea water. It is apparent from the equations that surface current vector V_0 points in a direction 45° *cum sole* to the direction of the current, or right to the direction of the flow in the Northern Hemisphere, and that the current velocity decreases exponentially with an increasing depth. It seems reasonable, therefore, that the directions of the wind drift current in the tables are deflected 45 degrees to the right of the direction of flow, if the real ocean satisfies the Ekman's assumptions.

Table 2. Computed Wind Drift Currents in cm/sec at Pusan

Year and month	Date	Mean wind velocity	Wind drift current	Year and month	Date	Mean wind velocity	Wind drift current
'67 Jan.	1-10	NW 493	S 6.902	July	1-10	NE 324	W 4.536
	11-20	NW 504	S 7.056		11-20	SSW 550	NE 7.700
	21-31	NW 445	S 6.230		21-31	N 415	SW 5.810
Feb.	1-10	NW 521	S 7.294	Aug.	1-10	SSW 443	NE 6.202
	11-20	NW 537	S 7.518		11-20	E 600	W 8.400
	21-28	NW 550	S 7.700		21-31	ENE 364	WNW 5.096
Mar.	1-10	NW 502	S 7.028	Sept.	1-10	NE 457	W 6.398
	11-20	WSW 339	ESE 4.746		11-20	NE/N 359	W/S 5.026
	21-31	W 509	SE 7.126		21-30	NNE 573	WSW 8.022
Apr.	1-10	N 524	SW 7.336	Oct.	1-10	NNE 483	WSW 6.672
	11-20	NNE 673	WSW 9.422		11-20	NW 436	S 6.104
	21-30	SE/S 374	N/E 5.236		21-31	N 472	SW 6.608
May	1-10	NNE 401	WSW 5.614	Nov.	1-10	NW 380	S 5.320
	11-20	E 418	NW 5.852		11-20	NW 366	S 5.124
	21-31	W 343	SE 4.802		21-30	NW 369	S 5.166
June	1-10	ENE, W 467	SW/S 6.538	Dec.	1-10	NE/N 421	W/S 5.894
	11-20	SSW, S 339	NE/E 4.746		11-20	NW 495	S 6.930
	21-30	NNE 360	WSW 5.040		21-31	NW 429	S 6.006
July	1-10	NNE 480	WSW 6.720	'69. Jan.	1-10	NW/W 365	S/E 5.110
	11-20	SSW 407	ENE 5.898		11-20	NW 446	S 6.244
	21-31	NE 376	W 5.264		21-31	NNE 558	SW 7.812
Aug.	1-10	SW 361	E 5.054	Feb.	1-10	NW 558	S 7.812
	11-20	SSW 418	ENE 5.852		11-20	NNE 573	SW 8.022
	21-31	SW 401	E 5.614		21-28	NW 461	S 6.454
Sept.	1-10	NNE 373	WSW 5.222	Mar.	1-10	NW 421	S 5.894
	11-20	NNE 545	WSW 7.630		11-20	W 435	SE 6.090
	21-30	NE 437	W 6.118		21-31	NNE 572	WSW 8.008
Oct.	1-10	N/W 444	W/S 6.216	Apr.	1-10	NW 607	S 8.498
	11-20	NW 330	S 4.620		11-20	SE/E 585	N/E 8.190
	21-31	SE 515	N 7.210		21-30	S 509	NE 7.126
Nov.	1-10	NW 443	S 6.202	May.	1-10	SSW 498	NE 6.972
	11-20	NW 524	S 7.336		11-20	NE 461	W 6.454
	21-30	NW 452	S 6.328		21-30	SSW 444	NE 6.216
Dec.	1-10	NW 452	S 6.328	June	1-10	SSW 484	NE 6.776
	11-20	NW 402	S 5.628		11-20	SSW 355	NE 4.970
	21-31	NW 485	S 6.790		21-30	SSW 380	NE 5.320
'68. Jan.	1-10	SW 521	NE 7.294	July	1-10	NE 456	W 6.384
	11-20	W 653	E 9.142		11-20	SSW 545	ENE 7.630
	21-31	NW 426	SE 5.964		21-31	SSW 581	ENE 8.134
Feb.	1-10	NW 484	SE 6.776	Aug.	1-10	SSW 493	ENE 6.902
	11-20	NW 531	SE 7.434		11-20	SSW 493	ENE 6.902
	21-29	WNW 554	SSE 7.756		21-31	SSW 404	ENE 5.656
Mar.	1-10	NW 614	S 8.596	Sept.	1-10	NE/N 436	W/E 6.104
	11-20	NW 507	S 7.098		11-20	NE/N 470	W/S 6.580
	21-31	N/E 366	SW/W 5.124		21-30	NNE 565	WSW 7.910
Apr.	1-10	NW 362	S 5.068	Oct.	10-10	NW 537	S 7.518
	11-20	NNE 343	WSW 4.802		11-20	N 402	SW 5.628
	21-30	ENE 346	WNW 4.844		21-31	NNE 445	WSW 6.230
May	1-10	ESE 384	NNW 5.376	Nov.	1-10	NW 558	S 7.812
	11-20	E 424	NW 5.936		11-20	NW 445	S 6.230
	21-31	E 406	NW 5.656		21-30	NW 413	S 5.782
June	1-10	SSW 465	ENE 6.510	Dec.	1-10	WSW 412	ESE 5.768
	11-20	SW 373	E 5.222		11-20	WSW 476	ESE 6.664
	21-30	NNE 342	WSE 4.788		21-31	NW 503	S 7.042

Table 3. Computed Wind Drift Currents in cm/sec at Yosu

Year and month	Date	Mean wind Velocity		Wind drift current		Year and month	Date	Mean wind velocity		Wind drift current	
'67. Jan.	1-10	NW	608	S	8.512	July	1-10	NE	323	W	4.552
	11-20	NW	489	S	6.846		11-20	S	241	NE	3.374
	21-31	NW	514	S	7.196		21-31	NNE	304.5	WSW	4.263
Feb.	1-10	NW	497	S	6.958	Aug.	1-10	SE,SW	234	NE	3.276
	11-20	NW	587	S	8.218		11-20	NE	421	W	5.894
	21-28	NW	701	S	9.814		21-31	NW	299	S	4.186
Mar.	1-10	NW	462	S	6.468	Sept.	1-10	NE	383	W	5.362
	11-20	WNW	321	SSE	4.494		11-20	NE	302	W	4.228
	21-31	WNW	478	SSE	6.692		21-30	NNE	648	WSW	9.072
Apr.	1-10	NNE	437	WSW	6.118	Oct.	1-10	NNE	573	WSW	8.022
	11-20	NE	620	W	8.680		11-20	NNE,NW	414	SW	5.796
	21-30	SSW	236	ENE	3.304		21-31	NW	444.5	S	6.223
May	1-10	NE/N	320	W/S	4.480	Nov.	1-10	NE,W	430	NNE	6.020
	11-20	SE	316	N	4.424		11-20	NNW	411	SSW	5.754
	21-31	SSW	275	ENE	3.850		21-30	NW	312	S	4.368
June	1-10	SE	353	N	4.942	Dec.	1-10	NE	334	W	4.676
	11-20	ESE	234	NNW	3.276		11-20	NW	482	S	6.748
	21-30	S	288	NE	4.032		21-31	NW	495	S	6.930
July	1-10	WNW	432	SSE	6.048	'69 Jan.	1-10	NW	506	S	7.084
	11-20	SSW	231	ENE	3.234		11-20	NW	406	S	5.684
	21-31	ENE	289	WNW	4.046		21-31	NE	590	W	8.260
Aug.	1-10	SSW	240	ENE	3.360	Feb.	1-10	NW	572	S	8.008
	11-20	SSW	241	ENE	3.374		11-20	NE	548	W	7.672
	21-31	SSW	259	ENE	3.626		21-28	NW	527.5	S	7.525
Sept.	1-10	SE	198	N	2.772	Mar.	1-10	NW	414	S	5.796
	11-20	NNE	572	WSW	8.008		11-20	NW	456	S	6.384
	21-30	NNE	393	WSW	5.502		21-31	N	466	SW	6.524
Oct.	1-10	NE	435	W	6.090	Apr.	1-10	WSW	577	ESE	8.078
	11-20	NE	401	W	5.614		11-20	NE	427	W	5.978
	21-31	SW	483	E	6.762		21-30	NE	308	W	4.312
Nov.	1-10	NW/E	412	S/W	5.768	May	1-10	SSW	470	ENE	6.580
	11-20	NE	586	W	8.204		11-20	NE	324	W	4.536
	21-30	NE	484	W	6.776		21-31	NW	410	S	5.740
Dec.	1-10	NW	389	S	5.446	June	1-10	SSW	343	ENE	4.802
	11-20	NW	400	S	5.600		11-20	SSW	211	ENE	2.954
	21-31	NW	448	S	6.272		21-30	SE	272	N	3.808
'68. Jan.	1-10	NW	439	S	6.146	July	1-10	NE	340	W	4.760
	11-20	NW	572	S	8.008		11-20	SSW	312	ENE	4.368
	21-31	NW	517.2	S	7.240		21-31	SSW	253	ENE	3.542
Feb.	1-10	NW	587	S	8.218	Aug.	1-10	SW	265	E	3.710
	11-20	NNE	483	WSW	6.762		11-20	SSW	281	ENE	3.934
	21-29	NW	548.8	S	7.683		21-31	NE	258	W	3.612
Mar.	1-10	NW	581	S	8.143	Sept.	1-10	NE	255	W	3.570
	11-20	NW	446	S	6.244		11-20	SE	272	N	3.808
	21-31	NW	388.1	S	5.433		21-30	NE	620	W	8.680
Apr.	1-10	NW	274	S	3.836	Oct.	1-10	N	531	SW	7.434
	11-20	NE	284	W	3.976		11-20	NE/N	347	W/S	4.858
	21-30	SSW,SE	206	NE/N	2.884		21-31	N/E	406	SW/W	5.684
May	1-10	ESE	279	NNW	3.906	Nov.	1-10	NNW	455	SSW	6.370
	11-20	W	374	SE	5.236		11-20	NW	373	S	5.222
	21-31	SW	340.9	E	4.773		21-30	NNW	401	SSW	5.614
June	1-10	SSW	363	ENE	5.082	Dec.	1-10	NW	444	S	6.216
	11-20	SE,SW	290	NE	4.060		11-20	NW/W	398	S/E	5.572
	21-30	SE	201	N	2.814		21-31	NW	394	S	5.516

Table 4. Computed Wind Drift Currents in cm/sec at Mokpo

Year and month	Date	Mean wind velocity	Wind drift current	Year and month	Date	Mean wind velocity	Wind drift current
'67. Jan.	1-10	NW/N 493	S/W 6.902	July	1-10	SW 319	E 4.466
	11-20	NNW 504	SSW 7.056		11-20	S 443	NE 6.202
	21-31	NNW 445	SSW 6.230		21-31	NNW 474	SSW 6.636
Feb.	1-10	N/W 485	SW/S 6.790	Aug.	1-10	S 342	NE 4.788
	11-20	N/W 510	SW/S 7.140		11-20	S 346	NE 4.844
	21-28	N/W 680	SW/S 9.520		21-31	NNW 412	SSW 5.768
Mar.	1-10	NNW 624	SSW 8.736	Sept.	1-10	NNW 315	SSW 4.410
	11-20	NNW 420	SSW 5.880		11-20	NNW 334	SSW 4.676
	21-31	NNW 543	SSW 7.602		21-30	N 405	SW 5.670
Apr.	1-10	NNW 362	SSW 5.068	Oct.	1-10	N 337	SW 4.718
	11-20	NNW 350	SSW 4.900		11-20	NNW 450	SSW 6.300
	21-30	S 376	NE 5.264		21-31	NNW 455	SSW 6.370
May	1-10	NW 395	S 5.530	Nov.	1-10	NNW 446	SSW 6.244
	11-20	NW 325	S 4.550		11-20	NNW 385	SSW 5.390
	21-31	S 393	NE 5.502		21-30	NNW 381	SSW 5.334
June	1-10	NW 334	S 4.676	Dec.	1-10	NNW 282	SSW 3.948
	11-20	SW 340	E 4.760		11-20	NNW 603	SSW 8.442
	21-30	NW 418	S 5.852		21-31	NNW 615	SSW 8.610
July	1-10	NW 480	S 6.720	'69 Jan.	1-10	NNW 611	SSW 8.554
	11-20	S 473	NE 6.622		11-20	NNW 379	SSW 5.306
	21-31	SE 468	N 6.552		21-31	NNW 465	SSW 6.510
Aug.	1-10	NW 296	S 4.144	Feb.	1-10	NNW 618	SSW 8.652
	11-20	S/W 383	NE/E 5.362		11-20	NNW 499	SSW 6.986
	21-31	SW 319	E 4.466		21-28	NNW 809	SSW 11.326
Sept.	1-10	W/N 322	SE/S 4.508	Mar.	1-10	NNW 521	SSW 7.294
	11-20	N 380	SW 5.320		11-20	NW 461	S 6.454
	21-30	NNW 334	SSW 4.676		21-31	NNW 491	SSW 6.874
Oct.	1-10	NNW 405	SSW 5.670	Apr.	1-10	NNW 631	SSW 8.834
	11-20	NNW 571	SSW 7.994		11-20	NNW 501	SSW 7.014
	21-31	NNW 404	SSW 5.654		21-30	S 497	NE 6.958
Nov.	1-10	N/W 510	SW/S 7.140	May	1-10	SE 536	N 7.504
	11-20	NNW 517	SSW 7.238		11-20	NNW 364	SSW 5.096
	21-31	NNW 505	SSW 7.070		21-31	NNW 448	SSW 6.272
Dec.	1-10	NNW 433	SSW 6.062	June	1-10	NW 435	S 6.090
	11-20	NNW 408	SSW 5.712		11-20	NNW 383	SSW 5.362
	21-31	NW/N 515	S/W 7.210		21-30	S 399	NE 5.586
'68 Jan.	1-10	NW 551	S 7.714	July	1-10	ESE 428	NNE 5.992
	11-20	NNW 699	SSW 9.786		11-20	SSW 581	ENE 8.134
	21-31	NNW 656	SSW 9.184		21-21	SSW 480	ENE 6.720
Feb.	1-10	NNW 608	SSW 8.512	Aug.	1-10	S 407	NE 5.698
	11-20	NNW 620	SSW 8.680		11-20	SW 444	E 6.216
	21-29	NW/N 662	S/W 9.268		21-31	S 301	NE 4.214
Mar.	1-10	NNW 680	SSW 9.520	Sept.	1-10	N/W 376	SW/S 5.264
	11-20	NNW 466	SSW 6.254		11-20	N/W 310	SW/S 4.340
	21-31	NNW 559	SSW 7.826		21-30	ENE 339	WNW 4.746
Apr.	1-10	NNW 427	SSW 5.978	Oct.	1-10	NNW 597	SSW 8.258
	11-20	NNW 330	SSW 4.620		11-20	NNW 263	SSW 3.682
	21-30	NNW 410	SSW 5.740		21-31	NNW 323	SSW 4.522
May	1-10	S 377	NE 5.278	Nov.	1-10	NNW 596	SSW 8.344
	11-20	SSE 465	NNE 6.510		11-20	NNW 554	SSW 7.756
	21-31	NW 268	S 3.752		21-30	NNW 416	SSW 5.824
June	1-10	NW 386	S 5.404	Dec.	1-10	NNW 570	SSW 7.980
	11-20	SW 321	E 4.494		11-20	NNW 502	SSW 7.028
	21-30	SSE 295	NNE 4.130		21-31	NNW 452	SSW 6.328

It is important to note that there are many difficulties and questions to be solved for the exact computation of wind drift current as well as wind stress over the sea surface. In this connection, we can hardly say that these data present the exact velocities of the wind drift current in the southern waters of Korea. However, the author will be pleased if these data provide researchers with a rough idea of the wind drift current in the coastal waters.

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