A PRELIMINARY STUDY ON THE RELATIONS BETWEEN THE SURFACE CURRENTS AND THE WINDS ALONG CHINA COAST

KWAN PING-HSIEN
(Institute of Marine Biology, Academia Sinica)

Taking the problem of the character of the surface currents along China Coast into consideration, we must, first of all, consider the effects of the monsoon along China Coast and the current system of the Taiwan Warm Current—the Kuroshio on the surface currents along China Coast.

Up to date, no specific works dealing with the relations between the currents and the winds along China Coast are available, С. О. Макаров [8], however, pointed out that the current direction in the South China Sea coincides with that of the monsoon. Moreover, as shown in the explanation in "Ocean Currents in the Vicinity of the Japanese Islands and China Coast" [12], the currents within the areas are partly seasonal in character, being affected by two principal forces, namely the monsoon and the Kuroshio.

In this paper it is attempted to offer some opinions about the character of the surface currents along China Coast first by analysing the relations between the surface currents and the winds along China Coast, and then, by considering the feature of the Taiwan Warm Current and the coastal configuration of China, some preliminary explanations on these analytical results are given.

Materials used for this work are "the Current and Meteorology Charts of the

Seas near Japan"[3], (material No. 1) for the wind, and "Current Charts North Western Pacific Ocean"[11], (material No. 2) for the current.

In both charts, the wind velocities and the current velocities will be represented by the wind roses and current roses. Since the subregions subdivided in these two charts do not perfectly agree, the subregions in these two charts do not correspond to each other exactly.

The evaluated results show that the wind velocities off China Coast vary little with longtitudes while variations with latitudes are much larger, and therefore, in the following analysis, data of wind and current are selected as closely located on the same latitudes as possible.

According to the material No. 2, we may subdivide the region under consideration into five subregions (referred as subregion 1, subregion 2 etc.) when considering the distribution of the surface currents along China Coast. Locations of these subregions are shown in the fig. 1. Subregions numbered by 2′, 3′, 4′, 5′ and 5″ are located nearly on the same latitudes respectively with the subregions numbered by 2, 3, 4 and 5 but far from the coast.

We take the runs[14]—the products of the mean velocity and the frequency from the wind roses and current roses—as the components to evaluate the resultant wind velocity and wind direction, the resultant current velocity and current direction for each month and for each subregion respectively, and then annual variation curves of the resultant wind velocity and resultant current velocity are drawn (fig. 3).

The evaluated results of wind show that the wind direction off China Coast is predominately northwestern and northeastern during winter, and predominately southeastern and southwestern during summer; and the wind velocity off China Coast is much stronger in winter than in summer, the highest values being found in November and December. Moreover, the wind in winter is much stronger in southern part than in northern part of the China Seas, and in either the southern or the northern part the wind is generally weakened during summer. Winds in subregions 4 and 5′ are stronger than those in all of the other subregions. All these evaluated results agree quite well with the actual state of the prevailing winds off China Coast.

The computed results of current show that the current directions in subregions 3, 4 and 5 change twice within one year (deviate to south in winter, to north in summer) at the times nearly corresponding with ones during which wind changes its directions; while in subregions 1 and 2, the current changes directions more frequently. With the exception of the period at which wind changes its directions, current velocities in all subregions along China Coast are larger in southern part than in northern part, and they are especially strong in the Taiwan Strait during summer. Away from the coast, most of the current directions in subregions 3′, 4′, 5′ and 5″ are nearly in northeastern or northwestern directions throughout the year; moreover the current velocity in subregion 5″ is the strongest one, especially strong during summer. All these results agree satisfactorily with the actual state of the prevailing currents off China Coast.

According to the preliminary analysis, the relations between the surface currents and the winds along Ching Coast may be stated as following:

(1) Relation between the prevailing current directions and the prevailing wind directions.

The prevailing current directions and prevailing wind directions along China Coast and in the South China Sea were drawn in the same figure as shown in fig. 2. (data of the current are taken from "Ocean currents in the Vicinity of the Japanese Islands and China Coast" and "Quarterly Surface Current Charts of the Western North Pacific Ocean" [13], while data of the wind are taken from" Charts of Monthly Average Air Currents over the Ground" [1]. It can be readily seen from this figure that with the exception of the conditions in the Yellow Sea and Pohai region during summer (as shown in fig. 2b), the prevailing current directions along China Coast and in the South China Sea deflect some degrees cum sole from or coincide with the prevailing wind directions, this agreeing with the relation of the Ekman's wind-driven current theory.

(2) Relation between the resultant currents and the resultant winds, both in velocity and direction.

From fig. 3, it is seen that with the exception of the period during which wind changes directions, most of the resultant current directions in subregions along China Coast deflect within 45° cum sole from the resultant wind directions, and it is especially so in subregions 3, 4 and 5. The results of evaluation also show that the angles of deflection in subregion 4 in most cases are smaller than those in other subregions.

In subregion 2, most of the angles of deflection are found to be within 45° cum sole during winter, but all fail during summer. Except in particular month, relations of the angle of deflection in subregion 1 agree quite bad with Ekman's theory.

For each subregion, the theoretical values of C/W [15] and the average observed values of C/W in winter and summer (only considering the months in which the angles of deflection obey Ekman's theory) are given in tab. 5.

As cited in tab. 5, the average observed values of C/W in winter lie between

0. 02 and 0. 04, which are, quite close, but a little higher than theoretically accepted values; while the average observed values of C/W in summer, except in subregion 3, are all much higher than the theoretical values; the highest one is found in subregion 4, exceeding about ten times the theoretical value.

The best relation is found in subregion 3, where not only the average observed values of C/W, either in winter or in summer, agree with the theoretical one, but also individual observed values of C/W in winter deviate less from the average winter value of C/W.

(3) Relation between the directions of the maximum current run and those of the maximum wind run.

For the sake of comparison, the directions of the maximum current runs θc and the directions of the maximum wind runs θw (denoting the direction to which wind blows) in each subregion are also taken monthly. As shown in tab. 4, except in the period during which wind changes directions, most of the directions of the maximum current runs in each subregion deflect 45° (since the data are taken from the roses consisting of eight directions) cum sole from the directions of the maximum wind runs or coincide with the latter. It is especially so in subregions 3, 4 and 5 and there is nearly no exception if the data in the periods during which wind changes directions are excluded. In subregion 4, which locates in the Taiwan Strait, the directions of the maximum current runs are all coincident with those of the maximum wind runs except in the periods during which wind changes directions. In subregions 1 and 2, agreement holds for six months.

(4) Relation between the "polygons" of the current frequency and those of the wind frequency.

Again we draw the current frequencies and wind frequencies in eight directions in subregions along China Coast into polygons of current frequency and polygons of wind frequency as shown in fig. 4. In this figure, frequencies are measured as the length from the origin of coordinates to the vertexes of the polygon. It shows that in subregions 3, 4 and 5, if we take the direction of maximum frequency as the direction of the polygon, then except in the periods during which wind changes directions, the polygons of the current frequency deflect 45° cum sole from or coincide with the polygons of the wind frequency; moreover, forms of these two kinds of polygons are quite similar in most cases.

(5) Relation between the annual ranges of the current velocity and those of the wind velocity.

Finally, the ranges (the difference between the maximum and the minimum of the velocity) of the annual variations of the resultant current velocity and of the resultant wind velocity in subregions along China Coast are taken for comparison. As shown in fig. 5, both of them are apparently larger in southern part than in northern part, the largest one is found in subregion 4.

The annual range of the current velocity is nearly proportional to that of of the wind velocity,

According to the above analysis from (1) to (5) we may therefore suggest that the surface currents along China Coast are nearly of wind-driven currents in character, and it is more evident in subregions 3, 4 and 5, especially so in subregion 3; but less evident in subregions 1 and 2, while the worst one is found in subregion 1.

It may be worth while to investigate why in the southeastern subregions which are located near the Taiwan Warm Current the character of wind-driven currents is more prominent than that in the northern subregions which are located far from the Taiwan Warm Current but in the Yellow Sea and Pohai.

For replying this question, we must first of all take the coastal configuration of China into consideration.

In spite of the fact that the southeastern subregions are located nearer the Taiwan Warm Current (as shown in fig. 1), yet the main part of the Taiwan Warm Current flows northeastward along the eastern coast of Taiwan due to the present of Taiwan [4], thus, the Taiwan Warm Current is already far from the subregion 3, and its influence on the subregions 4 and 5 is only the influence of its branch which flows through the Bashi Strait. After passing through the Bashi Strait, the Taiwam Warm Current is weakened in strength, which could be confirmed by the comparison of the current velocities in outer and inter regions of the Bashi Strait (according to the evaluation: the highest resultant velocity in subregion 5″ is 1.16 knots, the lowest is 0.44 knot; while in subregion 5′, the highest is 0.77 knot, the lowest is 0.04 knot). Because of the "barrier effect" of Taiwan, the influence of the Taiwam Warm Current on the currents in the subregions along the southeastern coast decreases, and therefore the character of the wind-driven currents is still retained。

On the other hand, though the Taiwan Warm Current is far from the subregions located in the Yellow Sea and Pohai, yet in subregions 1 and 2, currents of other characters are present. For example, during summer, at the same time when the West Chosen Current flows northward into the Pohai by passing through the northern part of the Yellow Sea along the western coast of Chosen, and due to the semienclosed character of the Pohai, part of water flows out of the Pohai through the Pohai Strait, and flows southward along Shantung Peninsula and northern part of Kiangsu Province, and hence produces a longshore current [5] with direction contrary to that of the monsoon in summer. Moreover, subregion 2 is just located between Shantung Peninsula and the Estuary of Yangtze River, that is between two projected portions along China Coast, the seashore line between these two projected portions is concave westward, and hence an eddy [6] may be produced in this subregion during the northward current along the coast of Chekiang Province or southward current along Shantung Peninsula passes through this subregion. Two of these examples are illustrated in fig. 6. Here it might be led to suggest that these currents with peculiar characters owing to the effects of coastal configuration, could be part of the reason why the character of wind-driven currents in subregions 1 and 2 is less prominent.

Another question is why the character of wind-driven currents along the southeastern coast during winter, when the direction of the monsoon is just opposite to or different from that of the Taiwan Warm Current, is more evident than that during summer, when the direction of the monsoon is just coincident or near with that of the Taiwan Warm Current.

It might be suggested that this question is related to the seasonal variation of the monsoon off China Coast and that of the Taiwan Warm Current.

As far as we know that the strength of the monsoon off China Coast is stronger in winter than in summer, but contrary to this, the strength of the Taiwan Warm Current, as shown by the annual variation of current velocity in subregion 5″, is stronger in summer than in winter, and the velocity of the former is about twice that of the latter. Since the influence of the Taiwan Warm Current on the wind-driven currents along the southeastern coast during winter is less than that during summer, the character of the wind-driven currents is more prominent during winter than that during summer.

The area which being affected most by the Taiwan Warm Current is subregion 4, it is of course related to its location. As shown in fig. 1, the large portion of the Taiwan Warm Current coming from the Bashi Strait flows northeastward along the western coast of Taiwan [4], therefore, the subregion 4 is the area where the current enters so that the observed value of C/W in it could be attained to a value about ten times higher than the theoretical one in summer, when the strength of the Taiwan Warm Current is strongest and its direction is near with that of the monsoon.

Furthermore, owing to the "neck" shape of the Taiwan Strait, the relations between the surface currents and the winds in subregion 4 posses some peculiarities as stated before. First of all, the angles of deflection between the resultant current directions and the resultant wind directions, except in the periods during which wind changes directions, are smaller than those in other subregions, and at the same time, the directions of the maximum current run follow those of the maximum wind run. Secondly, both the resultant current velocities and the resultant wind velocities are larger, both the annual range of the current velocity and that of the wind velocity are larger than those in other subregions.

According to the previous analysis it is here, preliminarily suggested that the surface currents along China Coast from the Pohai to the South China Sea may be considered fundamentally as wind-driven currents, and the character of these wind-driven currents is more or less modified by the Taiwan Warm Current and the currents produced due to the coastal configuration.

For a more detailed study of this problem, simultaneous observations of surface currents and winds along China Coast are needed. It is also necessary to observe the currents and certain other hydrographic elements such as salinity and temperature of sea water in the layers below sea surface in order to study the character of the currents along China Coast from the point of view of subsurface currents and water masses. At the same time, in order to eliminate the tidal current components from the observational data, anchor stations lasting longer than 24 hours, if possible, up to 15 days are recommended.