A NEW CONCEPT OF SURFACE OCEAN CURRENTS

SUMMARY OF REMARKS ON GERMAN WEATHER CHARTS OF THE SOUTH ATLANTIC.

1. *GENERAL.*

Since the surface currents of the ocean are largely wind-produced currents which vary with the force and direction of the wind, it might be argued that charts of such currents are of doubtful value to mariners. Therefore the simple mapping of such currents by roses (similar to wind roses) indicating the set and drift in each five-degree field based on ship observations (difference between true and D. R. positions) might be considered ample for practical purposes ; the more so, since such data represent statistical observations uninfluenced by preconceived ideas or theories.

However, aside from the fact that such current roses frequently contain data properly belonging to two or more currents, when plotted in a five-degree or even smaller field, the eye of the navigator demands a better physical representation of the set of the current than is given by such means. In mapping the average wind-produced currents by lines — (method employed by the German Naval Observatory for the wind charts of the South Atlantic) two difficulties are encountered. First, the observations are relatively few and little data is available ; secondly — the displacement of the ship's position (attributed to current) is based on observations over a 24 hour interval, during which time several different currents may have been encountered.

An entirely new chart of surface currents in the Atlantic has been prepared by Dr Hans F. MEYER (for the month of February only). Plotting the observed current data in each field of one degree, he computed the average set and drift by traverse calculation. Naturally, this method frequently involved adding the influence of two different currents. This led Dr MEYER to investigate the so-called condition of "permanence" or constancy of the current. He concluded that in a unit field 18 observations sufficed to establish the average set and drift in areas having a definite trend of current while in other areas, with no definite set of current, at least 35 observations were necessary. Under such conditions many areas were left with fragmentary data which the compiler of the chart was forced to fill in according to his own conception of surface currents.

To illustrate, in certain places the observed currents make an angle with each other, or leave the coast at a more or less sharp angle. Under the older concept it was assumed that one or the other current would be effective or that an average value might be used. According to the modern hydrodynamic theory of V. BJERKNES, however, the types of current flow illustrated in fig. 1-3 are admissible.

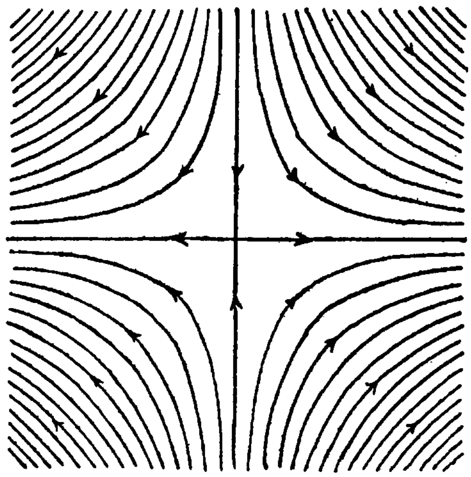

Fig. 1

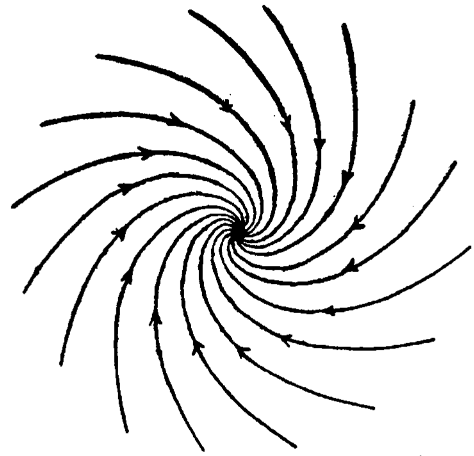

Fig. 2

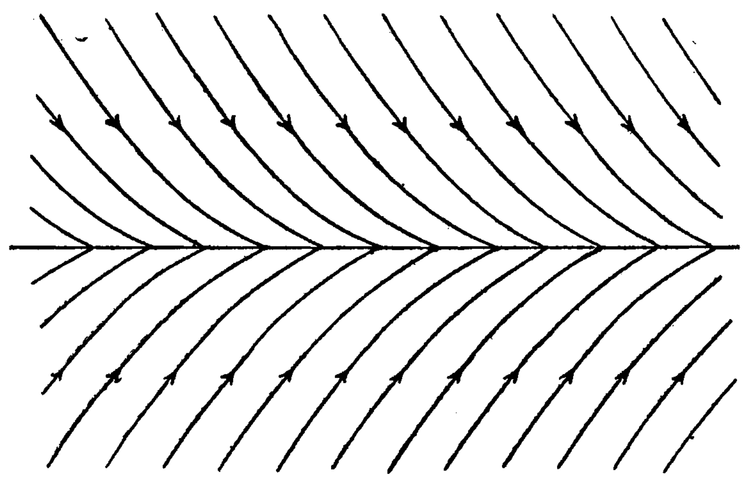

Fig. 3

The mass of water which piles up along such "convergence lines" or at such "convergence points" sinks to the bottom, giving rise to vertical currents. If the lines of flow shown in the figures are reversed we have "divergence lines" and "divergence points". In a warm stream such convergence lines are indicated by a massing of warm water while a "divergence line" is indicated by the presence of colder water drawn from depths. Thus streaks of foam on the surface as well as differences in temperature on the surface are valuable indications of such convergence or divergence lines.

2. *SURFACE CURRENTS IN THE NORTHERN WINTER SEASON.*

To illustrate these new concepts the surface currents chart of Dr Meyer (shown in fig. 4) has been chosen. This chart shows the set of the currents and their correlation. Data on the set and drift of such currents is given in the comprehensive work of Dr Meyer (*Die Oberflâchenstrômung des Atlantischen in Feb.*) and on the graphic chart of Prof. Schott.

Considering the chart reproduced in fig. 4, the symmetry in current flow between the northern and southern hemispheres as shown on the older current charts is seen to be lacking, thus, (as formerly represented) the Equatorial Stream, the Gulf Stream and Canary current in the North, — and the South Equatorial Stream, South Atlantic Connecting Current ("west wind drift") together with the Guinea current. Between these two main streams lay the large convergence areas — in the north the Sargasso Sea and the large area without current in the South Atlantic. These areas are replaced on this new chart by long extended "convergence lines", which may vary in position from year to year depending on the latitude in which the converging currents originate.

The greatest current, the Equatorial Current, is of great constancy, with a drift of 5-10 miles (per day) (greater near land) and extending over 3000 miles in breadth. Near the African coast this current is opposed by the Guinea current (30 mile drift) which flows between two branches of the Equatorial Current. The boundary of the currents is marked by a divergence line, which is characterized by colder surface water.

In the North Atlantic the contour of the North American continental shelf forces the mass of water passing along the West-Indies and flowing from the Caribbean into a northeasterly direction, producing the Florida Current and the Gulf Stream. In the South Atlantic the receding contour of the coast line gives rise to the divergence lines off the southern coast of Brazil. The stream divides equally to both sides, forming the weaker and less constant Brazil current. There does not appear, however, to be any close relation between this current and the Falkland Island or Cape Horn Current.

Even the Gulf Stream, in spite of its great strength and constancy and its great importance for the climate of Europe, is not so large as its counterpart in the South Atlantic, namely the South Atlantic Connecting Current ("west wind drift").

According to this conception of ocean currents, the Canary Current cannot be considered as an extension or continuation of the Gulf Stream, nor, for like reasons, can the South African current be considered a continuation of the South Atlantic Connecting Current, since in each case a well defined convergence line separates the currents. Both currents have their origin in the depths, drawing water from the deeper layers of the ocean, as shown by temperature observations. Under these conditions the adjacent coast may be considered as a one-sided "divergence line" with the other half of the divergence current lacking.

Also, the Agulhas Current, flowing from the Indian Ocean to the southward of Africa, comes between the South Atlantic Connecting Current and the South African Current giving rise to swirls bounded by convergence lines.

Little is known of the Polar Currents to the northward of the Gulf Stream and to the southward of the South Atlantic Connecting Current. The Cabot Current flowing along the coast of Labrador and from the Gulf of St. Lawrence meets the Gulf Stream at an angle, producing swirls and convergence lines. The same phenomenon occurs somewhat further to the eastward where the Gulf Stream meets the Polar Current flowing to the southward.

Similar conditions obtain in the South Atlantic where the South Atlantic Connecting Current meets the South Polar current, causing the swirls and the long extended convergence line assumed by MEMARDUS and SCHOTT. This convergence line runs N. E. between lat. 60-47 S. and is determined on the basis of temperature measurements.

To avoid misconception it should be noted that according to this concept of ocean currents there exist practically no large areas free from currents, — such as the older concept of the Sargasso Sea.

The convergence of the Gulf Stream and Equatorial Current produces a series of swirls in which the direction of the current varies with the position of the observer relative to the centre of the swirl. It is also reasonable to assume that these swirls shift their position constantly, similar to the areas of high and low barometric pressure. Thus, in the mass of confused data in these regions, the records of opposing currents cancel each other and would seem to indicate an area without current. Definite data may therefore only be otained in such areas by simultaneous observations at different points, similar to observations on the wind.

3. *CAUSES OF OCEAN CURRENTS.*

Within the past decade, the concept of the origin of ocean currents has been considerably modified by the theories of BJERKNES and EKMAN. According to the older view of seamen, surface currents are produced by the wind, while scientists held to the view that such currents are produced by differences in density, due to variations in salinity and temperature.

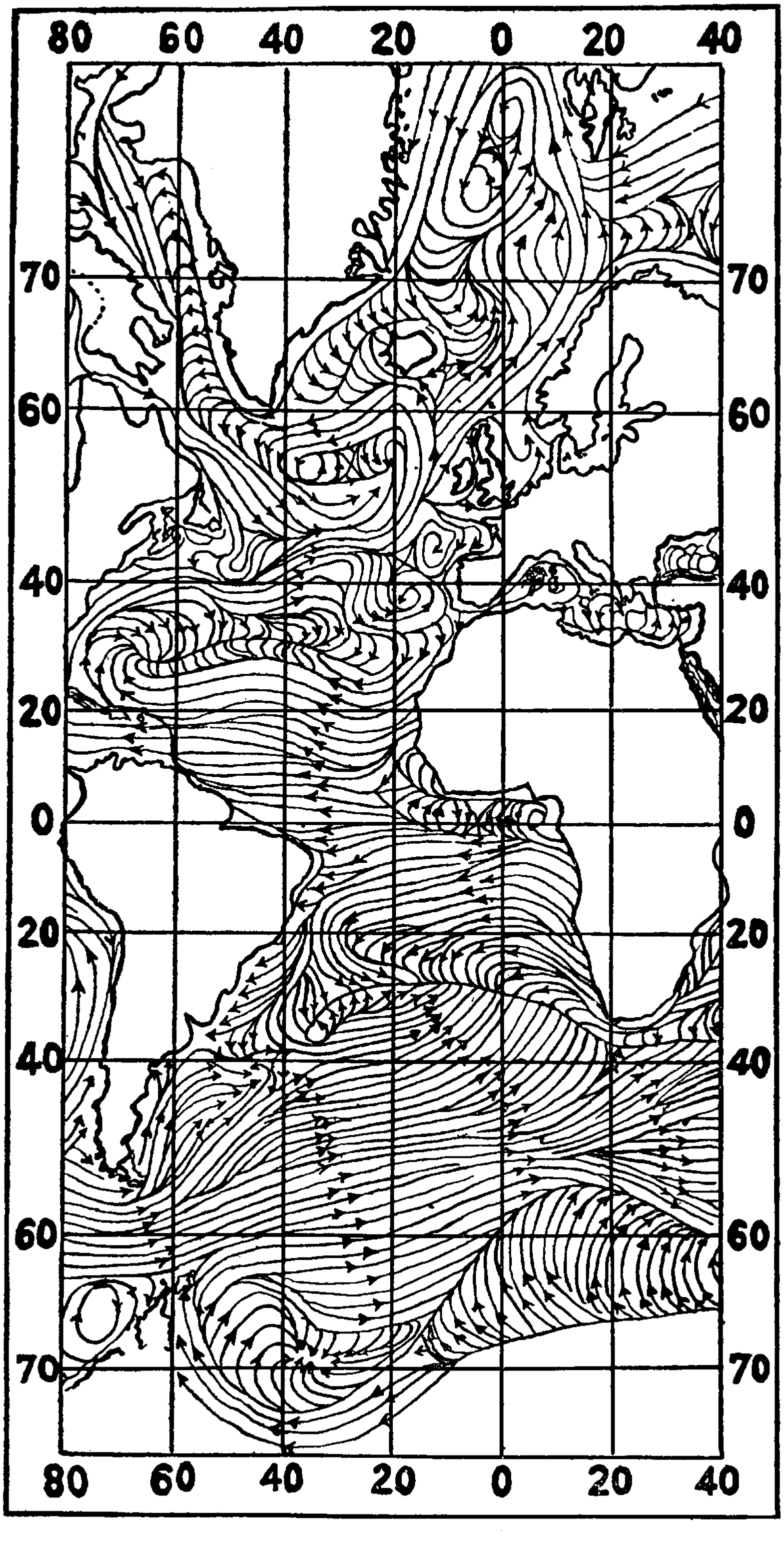

Fig. 4

According to the conclusions of EKMAN, the wind is capable of producing surface currents which movement is transmitted to the underlying layers of water by friction (turbulence). Further, the rotation of the earth deflects such wind-produced currents — (to the right in the northern hemisphere and to the left in the southern hemisphere). Theoretically, such wind-produced currents should have a set at 45° to the direction of the prevailing wind in deep water. If the depth is less than the turbulence depth the deflection due to the earth's rotation will be less than 45°.

This theory, however, cannot be directly applied without taking into consideration the movements of the mass of water at greater depths, caused by differences in density, the contour of the coast and the configuration of the ocean bottom.

According to BJERKNES the deep-seated ocean currents are produced solely by density differences. In these areas where sufficient data and observations were available on temperature and salinity at various depths, this theory has been confirmed. These areas however are rather few, and H. F. MEYER has approached the problem of determining the origin of ocean currents from another angle.

On a chart showing the average winds, he plotted lines at 45° to the direction of the wind in each unit area. Where these lines coincided with the set of the current observed, the current was designated as a wind-produced drift current. In these areas where such coincidence was lacking, the origin of the current was sought elsewhere.

Regarded from this standpoint, the Equatorial Current would appear to be a wind-produced current, unless subsequent observations show a deep-seated current having the same set. However the cause of the deflection of the North Equatorial Current to the northward and of its southern component to the southward, must be sought elsewhere. This may be due to the configuration of the ocean bottom or to differences in density.

In addition, the Gulf Stream cannot be explained on the basis of prevailing winds. Actual measurements of density at various depths have shown appreciable differences in density between the Gulf Stream and the North Polar Currents. The two currents do not mix with each other except within very narrow limits. According to recent investigations of EKMAN, the deep-seated currents are greatly influenced by the configuration of the ocean bottom and tend to follow the contour of the deeps. This tendency becomes appreciable even in the surface layers, where such flow is not obscured by drift currents. For example, the peculiar set of the current to the southeast of Newfoundland can only be explained by the influence of the Grand Banks. Similarly EKMAN points out that the Gulf Stream divides into two branches after passing the Mid-Atlantic shelf,— Long. 20°-30° W. It might be argued that the Equatorial Current should divide in a similar manner. However, EKMAN points out that the earth deflection force is proportional to the sine of the latitude and that in the case of the Equatorial Current this force tends to maintain the current flow parallel to the equator.

Possibly the fact that the equatorial counter-flow in the Pacific (which is not a wind-produced current) has an easterly set), may be considered as additional support for the theory.

(SUMMARY OF AN ARTICLE BY Dr H. THORADE, HAMBURG, by W. P. B.).