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# WORLD SURFACE CURRENTS FROM SHIP'S DRIFT OBSERVATIONS (*)

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## ABSTRACT

Over 4 million observations of ship's drift are on file at the U.S. National Oceanographic Data Centre, in Washington, D.C., representing a vast amount of information on ocean surface currents. The observed drift speeds are dependent on the frequency of occurrence of the particular current speeds and the frequency of observation. By comparing frequency of observation with the drift speeds observed it is possible to confirm known current patterns and detect singularities in surface currents.

## INTRODUCTION

A very good estimate of the average surface current can be obtained at sea from the set and drift calculated from the difference between a ship's dead reckoning position and its true position. This method has only become common since Victorian times for the reasons given below, but it is the source of the data used in the compilation of Pilot Charts and the maps produced here.

The accurate determination of position at sea became possible in the middle of the 18th century with the invention of the chronometer (1735) and the sextant (1757) and the first publication of the *Nautical Almanac and Astronomical Ephemeris* which included lunar tables (1765). A measure of the accuracy available to

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mariners is given by KEMP (1976) who reports that Captain COOK, after circumnavigating the world, was only 8 miles in error in calculated longitude on returning to Plymouth in 1775. But in the 18th Century chronometers were too expensive for general purposes, and the method of lunar distances was seldom used because of the complexity of the calculations required.

The improvement of manufacturing techniques in the early 19th Century brought the cost of chronometers down to a level which enabled merchantmen to have them aboard as a matter of course. With the introduction of improved astronomical tables and methods, celestial navigation became so widespread that it was soon routine to calculate ship's drift as the difference between the course steered and the course made good. By 1853 so much progress had been made that, at the international conference on oceanography in Brussels, a uniform system of recording wind and current observations was adopted at the urging of Matthew Fontaine MAURY of the U.S. Navy (KEMP, 1976). The data subsequently obtained form the basis of the descriptions of ocean currents in the Pilot Charts and Sailing Directions put out by the seafaring nations, and are available in computer-usable form.

## SHIP'S DRIFT DATA

In the United States, the National Oceanographic Data Center (NODC) has developed a data storage and retrieval system referred to as the NODC Surface Current Data System (SCUDS). The SCUDS file consists of over 4 million ship's drift observations, taken mainly by U.S., Dutch, and Japanese ships, between 1854 and 1974. Drift data from U.S. ships alone account for 2.7 million of the observations and of these 38 % are in the North Atlantic and adjacent areas such as the Gulf of Mexico and the Mediterranean Sea. The Netherlands data comprises most of the remaining 1.3 million observations, and is similarly distributed. Such a distribution reflects historical shipping density, both merchant and naval, in these regions (U.S. Department of Commerce, 1979).

All U.S. ships' drift data were taken between 1909 and 1974. 92 % of these are from the period 1920 through 1959 and only 2 % since 1960. All Netherlands data were taken between 1854 and 1952 with 80 % from the period 1900 through 1939. Most observations were therefore obtained by celestial navigation and may be expected to have a velocity error of less than 0.2 knots between sightings at dawn and dusk.

Total ship's drift, as measured, is the sum of a surface current component and a wind component. Resolution of the effect of each component is difficult. STIDD (1975) indicates that the current effect is more dominant, and that it may lie within the range of 0.75 to 1.2 times the total measured ship's drift. In view of this result, and the fact that our prime concern is the relative difference between the number of observations and not the absolute velocities themselves, we have equated the ship's drift speed with the current speed and discounted the wind effect.

Figures 1 through 4 were produced from the SCUDS file and plotted on a modified Mercator projection. Figure 1 shows the frequency of ship's drift observations. These data were originally plotted by computer as the total number of observations per five-degree square, and then hand-contoured. The contouring of the observations into regions of less than 400, 400 to 1000, etc., was done in order to convey the significance of the frequencies visually.

Figures 2, 3, and 4 present actual data points where the ship's drift speed was greater than 2, 3 and 4 knots respectively. Each cross depicts an individual observation. The crosses represent the average position over a twelve-hour period, during which a ship would normally cover less than 300 miles. A ship steaming for 8 knots with a 4-knot current against it would only make 48 miles, and one steaming for 20-knots with a 4-knot current would make 288 miles, and these may be regarded as the outside limits for practical purposes. The size of the cross is printed for visibility at a scale equivalent to 100 miles at the equator. Any position errors in the fixes will therefore not be apparent in the figures. The number of observations that fall in the three categories are 207,097 for >2 knot currents, 63,538 for >3 knot currents, and 10,972 for >4 knot currents.

Because speeds up to 4 knots seem to occur everywhere in the ocean at some time or other, the density of crosses for a particular velocity category may be a function of either or both the frequency of occurrence of this velocity and the frequency of actual observations. Moreover, we assume here that a direct relationship exists between density of shipping and frequency of observations. By visual comparison of figure 1 with each of figures 2, 3, and 4, it is possible to differentiate those areas where the density of observation of a particular current velocity is 1) largely a result of high shipping density, 2) largely a result of persistently high occurrence of this velocity, and 3) a result of both these phenomena.

Using such an approach it is possible to discern known oceanographic features such as western boundary currents and equatorial currents. Assuming, therefore, that this confirms the validity of the approach taken, then further examination of figures 1 through 4 reveals a number of unexpected features.

## SHIPPING ROUTES

The major shipping routes show up clearly in figure 1, the most noticeable being the concentration around the Suez and Panama Canals, and the transatlantic traffic between the U.S. and Europe. Other routes that show up well are those from Brazil to Europe and the U.S., and the routes to eastern Australia from Panama and Honolulu. In the North Pacific, the Yokohama to California run is well-defined.

Some climatological features which affect shipping routes can also be detected. Examples are the southern ice limit at about 40° S between South America and Australia, and the northern one south of Iceland. The shipping lanes from New York to Europe have to avoid the icebergs which come south on the

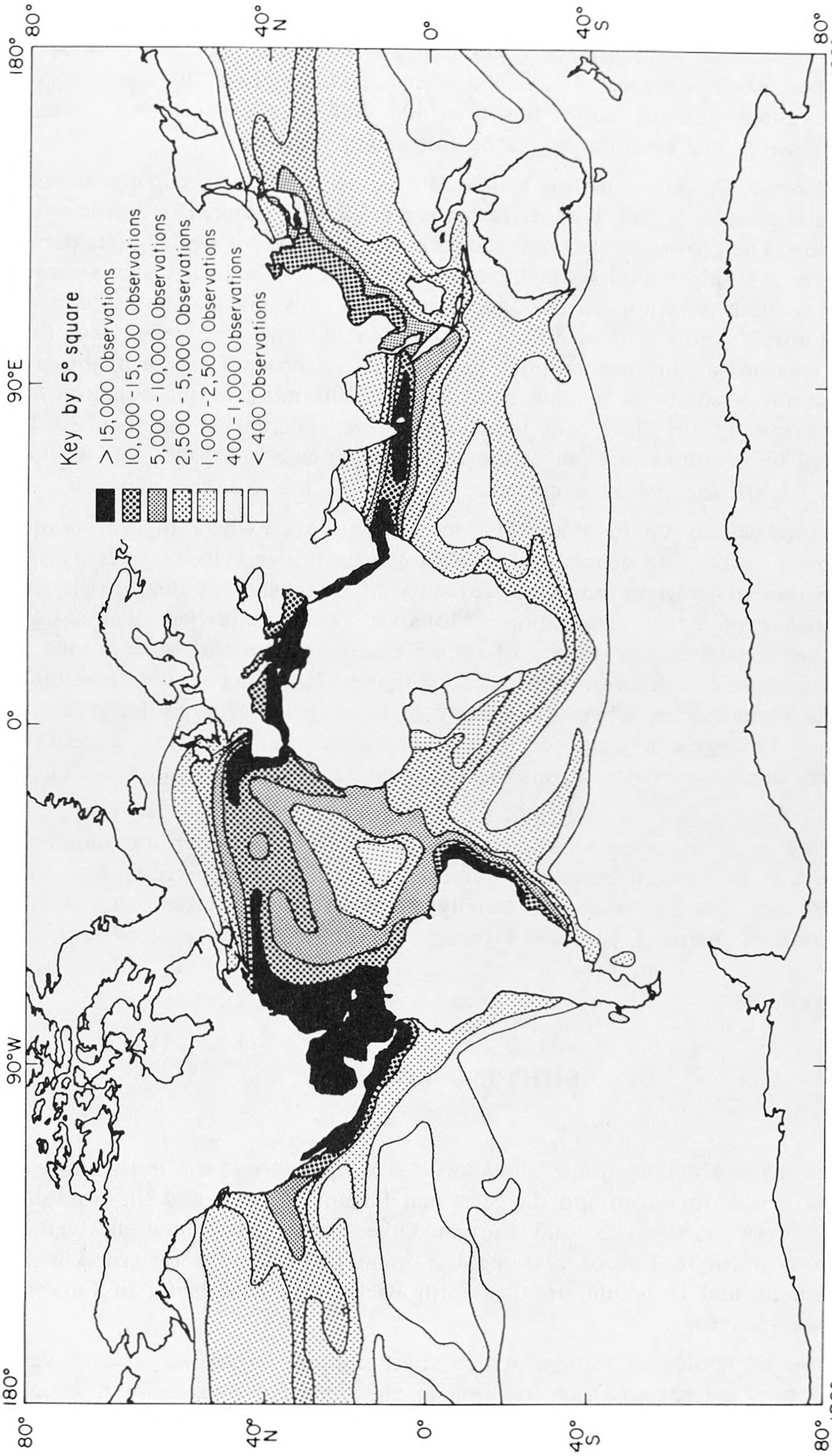


FIG. 1. – Frequency of ship's drift observations (total observations 4,175,325) (From : NODC SCUDS file).

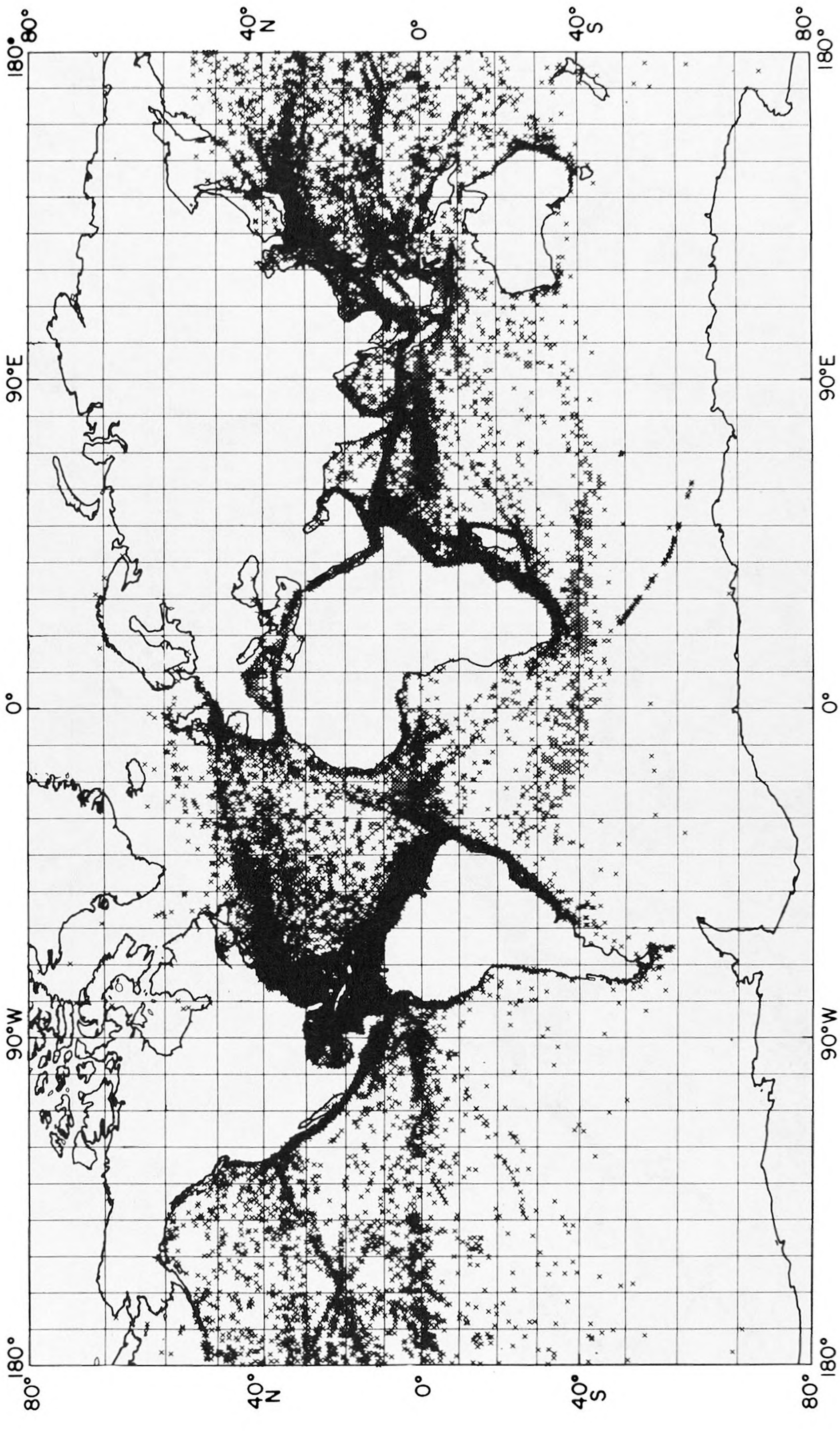


FIG. 2. – Ship's drift > 2 knots (207,097 observations) (From : NODC SCUDS file).

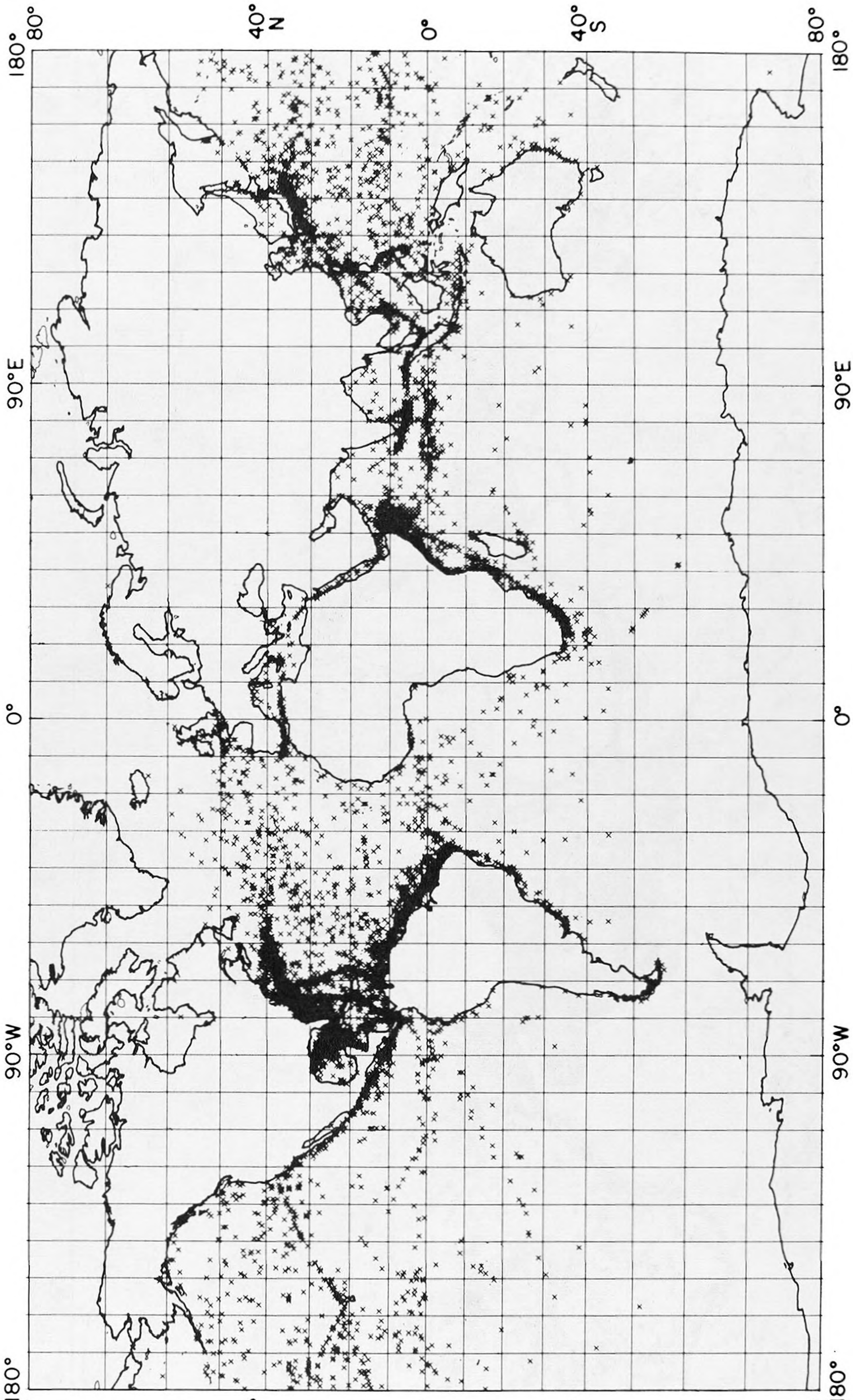


FIG. 3. – Ship's drift > 3 knots (63,538 observations) (From : NODC SCUDS file).

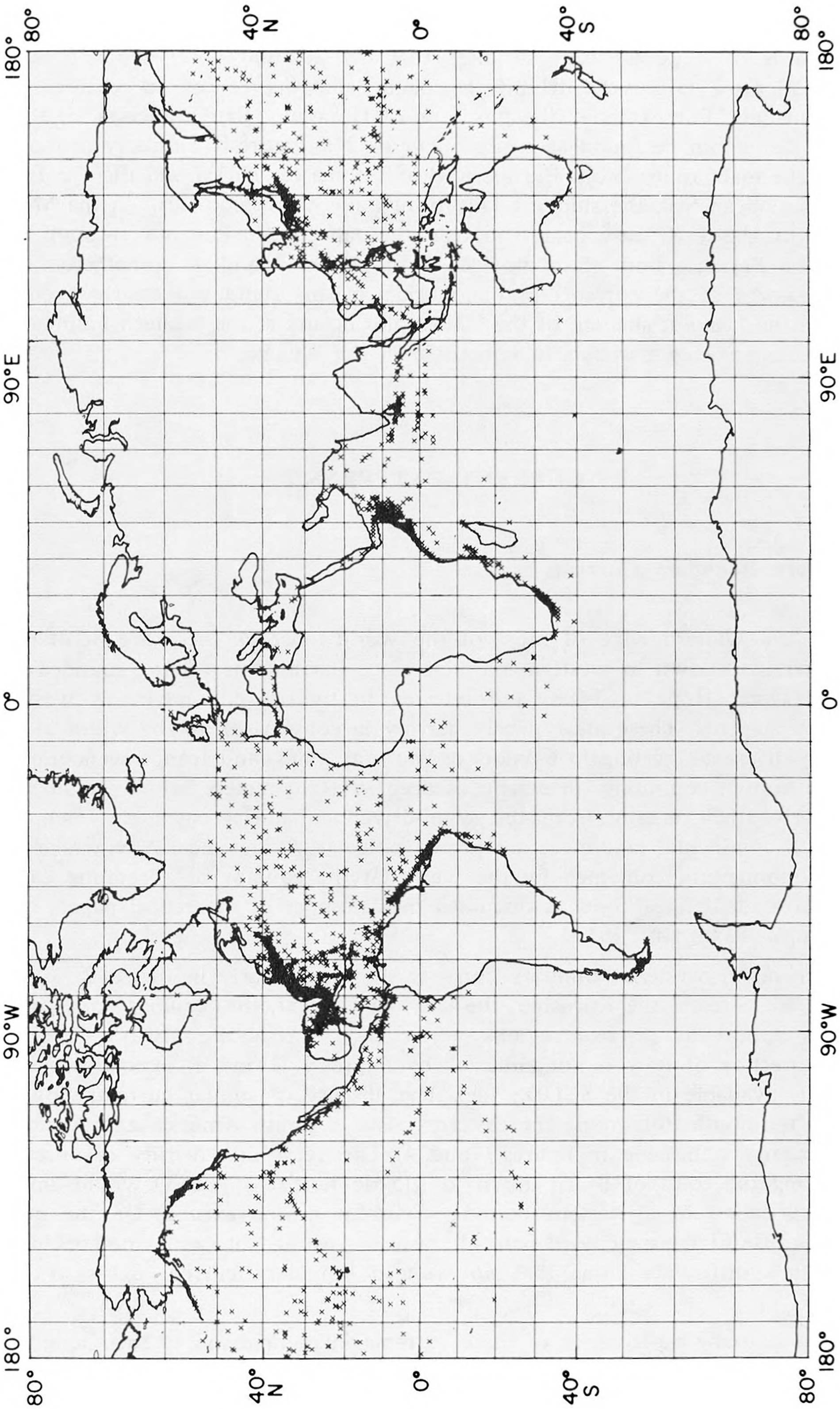


FIG. 4. – Ship's drift > 4 knots (10,972 observations) (From : NODC SCUDS file).

Labrador Current, so they lie south of 43° N until a safe great circle route can be laid, and the greatest density of observations naturally lie in the shipping lanes.

Speeds of 2 knots occur so often that the 207,000 observations used to produce figure 2 effectively delimit the major shipping routes, as well as the major currents. For example, the positions of Honolulu, San Francisco, and the Panama Canal can be found as easily on figure 2 as figure 1. Similarly pronounced are the main routes from Europe to South America, Africa and the Far East. In the Caribbean Sea, the shipping lane from Lake Maracaibo through the Mona Passage to the U.S. east coast parallels the lane from Panama through the Windward Passage; both show up clearly in figures 3 and 4. Nonetheless, the major features of the currents in the world's oceans stand out clearly even in figure 2 : the heaviest shading of the scatter plot occurs at the western boundaries of the oceans, being particularly noticeable in the Atlantic.

## CURRENT PATTERNS

### a) Western Boundary Currents

At the western edge of most of the world's oceans there are permanent rapid currents known to western mariners since Bartholomew DIAZ rounded the Cape of Good Hope in 1488, and referred to by oceanographers as western boundary currents. These are typically narrow in comparison to the width of the ocean, with speeds gusting to 6 knots or more at times, and from oceanographic data are known commonly to extend as deep as 1000 meters below the surface. They derive their energy from the wind-driven equatorial currents which, on meeting a continental landmass, are turned polewards. The means by which the angular momentum contained by the water (at the equator of a rotating earth) results in a rapid linear flow is discussed in a number of theoretical papers (see, for example, ROBINSON, 1963).

The major western boundary currents show up clearly in figures 2, 3, and 4. The Gulf Stream, the Kuroshio, the Guyana Current, the Agulhas and Somali Currents appear as discrete regions where high speeds are always expected. (While direction of flow is not indicated by figures 2, 3 and 4, directional information is available in the SCUDS file). The absence of similar currents flowing towards the South Pole along the eastern coasts of South America and Australia is particularly noticeable in figures 3 and 4. The very high density of observations along the coast of Brazil down to Rio de Janeiro (figure 1) would ensure the identification of a western boundary current if one existed. On the other hand, because of the paucity of data off eastern Australia, it cannot be concluded from ship's drift data alone that no western boundary current exists in that region.

The extreme narrowness of these currents in comparison to their length is more noticeable in the Atlantic, where the Guyana Current is about 150 nautical miles wide, but over 2500 nautical miles long, and the Gulf Stream, although wider at 240 nautical miles, is nonetheless of similar length. The Somali Current is atypical in that it is almost as wide as it is long. A peculiarity of the Gulf Stream and the Kuroshio is the seaward extension of the core of the currents after leaving the coast. For the Gulf Stream this departure point lies between 35° and 37° N, whence the high-velocity core extends seawards for 1200 nautical miles (figures 3 and 4). The density of shipping within this tongue is very high, exceeding 5000 observations per 5° square, but the phenomenon is not observed north-east of Somalia, where shipping density is of a comparable magnitude, so that some physical reason should be sought by theoreticians. Another peculiarity is that the Mozambique-Agulhas Current appears as a unit in figure 2, but in figures 3 and 4 gives the appearance of two discrete regions of high speeds; one between 10° S and 20° S, and another south of 30° S.

In addition to the major currents at the western boundaries of the oceans, a number of minor currents with the same characteristics of high speed in a polewards flow next to a landmass can be discerned. The Kuroshio has a precursor in the patch of high speeds found north of Luzon and along the east coast of Taiwan in figure 2, and it even appears in figure 3. In the South China Sea, at about 12° N along the coast of Vietnam, there is a similar phenomenon (which however is monsoonal). A permanent southward flow along the southeast coast of Madagascar appears in the Pilot Charts of the British Admiralty, and has been shown to have the characteristics of a western boundary current by GRUNDLING, BANG and DUNCAN (1980), being narrow, fast and deep. The second patch of high speeds at 50° E at the Tropic of Capricorn could be the eastward edge of the recirculation eddy postulated by DUNCAN (1970), but it should be noted that the apparent bifurcation of the Somali Current at the Equator in figure 3 results from diverging shipping routes.

North of the Yucatan Peninsula and Cuba lies the Gulf Loop Current, a region of permanent high speeds which is the connection between the Caribbean Current and the Florida Current. It is anomalous in that it has the appearance and characteristics of a western boundary current, with no western boundary. It is a region of high speeds which shows up clearly in figure 4 as the triangular patch west of Florida.

Another anomalous region is found in the band of high speeds in the Guyana Current, south of the equator. This current actually extends over both hemispheres, commencing at about 7° S (figure 4) and flowing rapidly northwest towards the Carribean Sea. Consequently, the direction of flow between 7° S and the equator is directly opposite the poleward flow characteristic of western boundary currents. A similar phenomenon occurs in the Philippine Islands off the east coast of Mindanao. Here a permanent, rapid, southward flow is found, displaying the characteristics of a western boundary current, with the exception that the flow direction is equatorwards, not polewards. Both regions are well defined in figures 3 and 4.

**b) Equatorial Currents**

The north and south equatorial currents of the world's oceans are usually envisaged as broad and slow-moving currents under the trade winds as they blow from the subtropical high pressure belts to the equatorial low pressure belt of the Intertropical Convergence Zone.

The South Equatorial Current of the Pacific Ocean extends westward (in figure 2) from South America to about 170° E. There is a large drop in the number of observations between 2 knots and 3 knots, indicating that the current is indeed a slow-moving one. From the Philippines to about 170° W, between 10° and 20° N, the North Equatorial Current can be distinguished in figures 2, 3 and 4, but it is not well evidenced beyond this point. The Equatorial Counter-Current between these two is not well defined.

Because of the ubiquity of current speeds greater than 2 knots, in regions of high shipping density the current patterns are obscured by the shipping lanes. This is particularly true in the tropical Atlantic. However, as in the Pacific, speeds greater than 3 knots are rare, displaying the slow nature of these currents. The Guinea Current, in contrast, shows up well in figure 2 along the coast of Africa between 2° W and 14° W. A few observations greater than 3 knots can be seen in figure 3, centered at 5° W.

The equatorial currents of the Indian Ocean appear to be distinctly different from those in the other two oceans. There is a well-defined current straddling the Equator, which frequently exceeds 3 knots and often even 4 knots (figures 2, 3 and 4). This equatorial current is distributed asymmetrically about the equator from 5° S to 2° N in a manner which is not related to shipping density as can be seen by a comparison of figures 1 and 2. For example, along 70° E the large number of observations of currents greater than 2 knots at 9° N can be related directly to the large number of observations at the same latitude. The asymmetrical peak of observations greater than 2 knots at the equator, however, clearly owes neither its existence nor its distribution to a large shipping density.

The existence of this current was first documented by WYRTKI (1973); however, at the time, he postulated that the flow was symmetrical about the equator. Such a conclusion is not confirmed by the ship's drift data.

South of India and Sri Lanka lies a small region of high speed currents. This is a shipping lane in which the frequency of ship's drift observations exceeds 15,000 per five-degree square, which is reflected in figure 2 by the band of observations extending from the Gulf of Aden to the Malacca Straits. But in the Red Sea, where the frequency of observations is equally high, and observations greater than 2 knots are common, there are only four observations greater than four knots. The conclusion is that the narrow belt of high speeds south of Sri Lanka is a real observation, not a spurious artifact resulting from the high density of observations.

### c) Tidal and Continuity Currents

The major energy sources for the currents mentioned above are the trade winds and the westerlies. A few currents, large enough to be identifiable on these maps, are driven by the tides, and a few result from evaporation or rainfall in an enclosed sea. The Gulf of St. Lawrence is an example of noticeable tidal currents over a large region, with speeds over 2 knots being common, but very seldom exceeding 3 knots. Around the British Isles the shipping density is so great that chance could possibly account for the distribution in figure 2, but there are two patches of speeds greater than 3 knots at the constrictions in the English Channel near Cherbourg and Calais, suggesting a tidal cause.

The most famous example of a current caused by evaporation is that at the Straits of Gibraltar, where the surface water always runs eastwards, and continues as the North Africa Coast Current to the Strait of Sicily (BOISVERT, 1967). In the Mediterranean Sea the high evaporation exceeds the ability of rainfall or rivers to replace it, and there is a perennial surface flow eastwards from the Atlantic to make up the difference. The current lies along the heavily-travelled shipping lane from Gibraltar to the Suez Canal, but is nonetheless discernible in figure 3. A similar condition exists in the Red Sea, resulting in a northwesterly flow at Bab-el-Mandeb.

A very localised current can be noticed at the northern tip of Madagascar where the south equatorial current, having been diverted by the island, resumes its flow towards Africa. This is presumably a continuity current of a kind, but its localized nature with an open sea to the north is a singularity in these charts.

## CONCLUSION

Ship's drift data is directly applicable to the study of the currents of the ocean's surface. Visual comparison, as employed above, readily lends itself to identifying both previously known and hitherto unnoticed current patterns.

Once areas of interest are detected in this way, it is possible to retrieve the particular data from the SCUDS file and subject them to a more rigorous statistical analysis, thereby imposing a more quantitative base on the conclusions. Comparisons between this method and the sparse oceanographic data can then be made. In view of the scarcity of other direct current measurements over most of the ocean's surface, such an approach would be a great step forward in our knowledge and understanding of surface currents. As a preliminary step in this direction, the area south of Sri Lanka is being studied.

## ACKNOWLEDGEMENTS

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Experts in many fields of chemistry, ship construction, hydrography, waves and currents, who have studied their subjects and practised them in the field, are ignored by legislators. Ministers who could use such depth of knowledge are ignorant of its existence and thus legislation complicates the chaos rather than achieving any clarification. Successive Administrations produce Ministers backed by permanent civil servants with no knowledge of the usages of ocean-going ships, and traffic lanes in congested waters become so complicated as to be ignored by even the best-managed ships. Much legislation is incomprehensible to shipowners and operators alike and ships' officers spend valuable time sifting forms that give employment to remote civil servants to give placebo answers to angry Members of Parliament.

Nothing has changed in the past ten years to halt the steady increase of lost lives and lost cargoes, the contamination of the oceans and the threat to the most endangered species, sanity. Until those put in power in democratic countries understand that dedicated oceanographers and hydrographers should be consulted before voters, the waste of the earth's dwindling treasures will increase. We are not the sufferers, but we sentence those who come after us to a bleak and ugly world for want of ordinary foresight. A news-hungry public is quickly indifferent to yesterday's disasters and the human psyche survives by wiping out a superfluity of painful memories. We must find quick means to reduce disasters at sea before we are in the midst of a bankrupt world.

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