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Worldwide Ship Drift Distributions Identify Missing Data

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The geographical and temporal distributions of worldwide ship drift velocities were plotted in order to see where and when the observations were made and to identify what appear to be major gaps in the data. Curiously, large areas of the North Atlantic, North Pacific, and South Pacific were found to be devoid of observations in some months during the years 1920–1934 when the number of yearly observations is large. An estimated 700,000 observations are missing. These would significantly enhance the usefulness of the data set if they could be found and added to it, especially in the Pacific where the data density is low.

INTRODUCTION

Historical ship drifts have provided most of what we know about the worldwide near-surface velocity in the oceans, including the mean ocean circulation, eddy kinetic energy, and seasonal variations. In mapping and describing historical ship drifts, we discovered that some months of some years are mysteriously devoid of observations. In order to clearly identify the data gaps, we plotted maps and histograms of the worldwide distribution of ship drifts. With these we estimate that about 700,000 observations have disappeared.

To successfully use ship drift data and to help interpret the resulting velocity fields, we need to know their geographical and temporal distributions. This paper discusses the time and space distributions of ship drifts and the implied missing observations in the hope that missing observations can be searched for and added to the data set, making it much more useful.

Under the direction of M. F. Maury, the U.S. Naval Oceanographic Office began compiling wind and current measurements in the mid 1800s from logs of U.S. Naval Ships as well as domestic and foreign merchant ships. The data were used to develop the first pilot charts and sailing directions. The pilot charts that are issued today are based on the entire suite of data collected since the time of Maury; the accumulated current measurements have been very useful in identifying characteristics of major ocean currents [*Fuglister*, 1951; *Meehl*, 1982; *Hager*, 1977; *Arnault*, 1987], in discovering where energetic eddies are found [*Wyrtki et al.*, 1976], in planning field experiments and interpreting results [*Richardson and McKee*, 1984], and in evaluating model simulations [*Richardson and Philander*, 1987].

SHIP DRIFT DATA

We obtained the worldwide ship drift data set, consisting of 4,175,414 surface current observations, from the National Oceanographic Data Center (NODC). About 64% of the total observations are from United States ships and 32% are from Netherlands ships. A more complete description of the data and documentation can be obtained from NODC.

Each ship drift measurement of surface current velocity consists of the vector difference between the velocity of a ship determined from two position fixes and the average estimated velocity of the ship through the water during the same time interval, usually 12–24 hours. The vector difference is considered to be a surface current. Since each measurement is an average along the ship's path between fixes, usually a few hundred kilometers, only large-scale features can be resolved using this technique. Many possible random and systematic errors can occur, and it is difficult to evaluate them very accurately. The question of windage has been discussed by *Stidd* [1975] and *Richardson and Walsh* [1986] and random measurement errors have been discussed by *Richardson* [1983].

RESULTS

We calculated and plotted annual and monthly mean velocities for each 2° latitude by 5° longitude box in the world ocean (Figure 1). The large-scale patterns are clearly apparent. Adjacent vectors generally agree except near the southern part of the South Pacific, where few observations are available in each box. Identifiable are the ocean gyres centered near 30°N and 30°S, the swift western boundary currents (Gulf Stream, Kuroshio, Agulhas), and the swift equatorial currents and countercurrents.

We then plotted a geographical map of the total number of observations in each 1° box and histograms of the number of observations in each year and in each month. Most observations were made along sailing routes which appear as dark lines in Figure 2, along which the number of observations is greater than 1000 per 1° box. The North Atlantic has the highest data density, mostly >100 observations per 1° box. The South Pacific, by contrast, has typically 10 observations per 1° square, and the southern ocean and Arctic Ocean are virtually devoid of observations. Most observations, 66% of the total, were made from 1920 to 1941, with the largest number in 1937 (Figure 3). At the end of 1941 the number of yearly observations dropped precipitously, from about 100,000 to around 10,000, never again rising to pre–World

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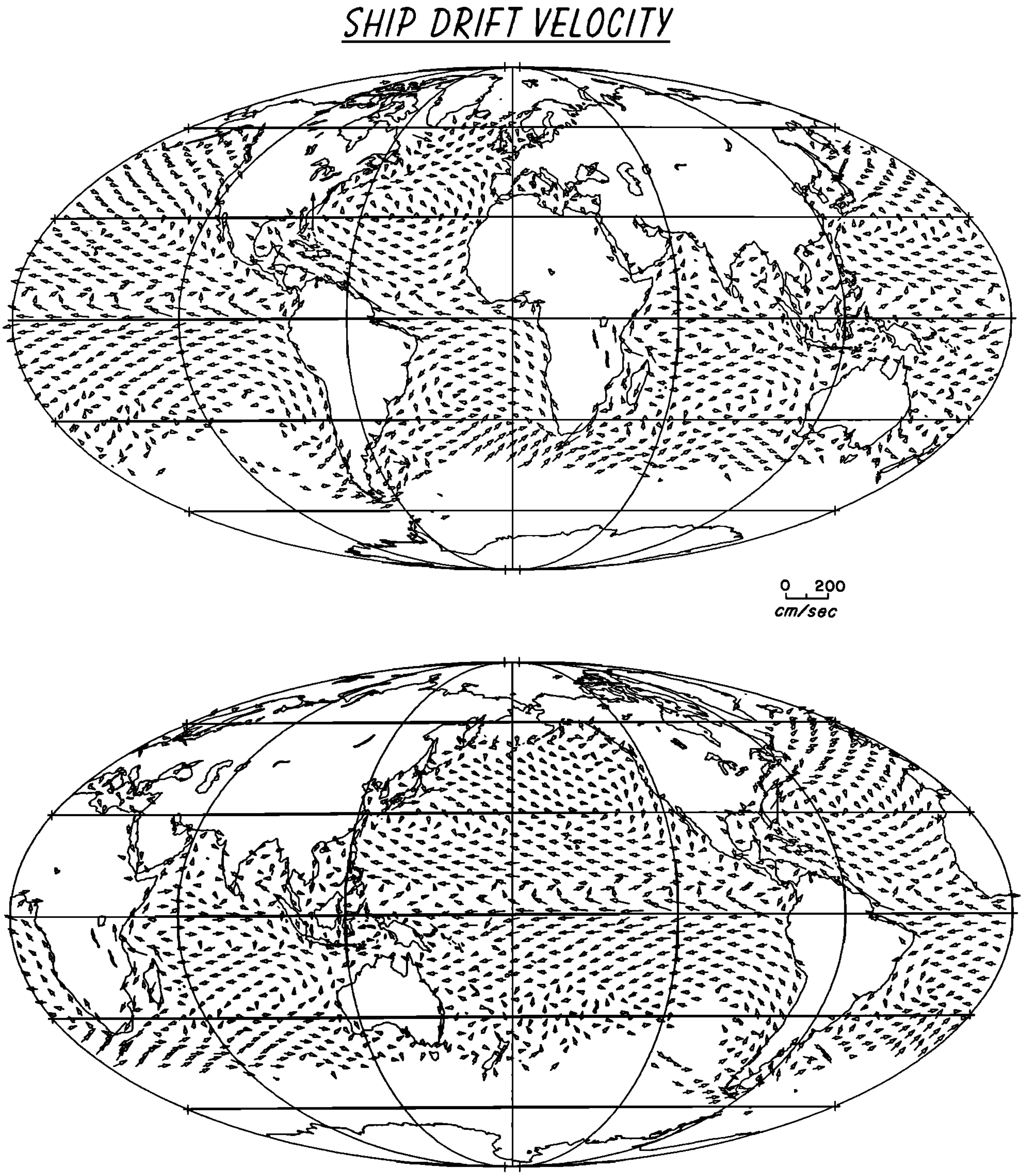

Fig. 1. Worldwide map of surface velocity vectors from historical ship drift measurements. Velocities are vector averages of all observations in 2° latitude by 5° longitude boxes. To reduce clutter, every other vector was omitted, as were vectors in boxes containing fewer than 20 observations. The lengths of the arrow tails are proportional to velocity.

War II levels. The very low data density after 1941 suggests that additional ship drifts from the last 47 years might have been measured but not included in the data set. Some of the 18% of observations without a known year could have been from after 1941.

The monthly summaries (Figure 4) revealed puzzling month-to-month discontinuities: March and May have approximately 450,000 observations; February, June, and December have around 250,000. To investigate these discontinuities, we plotted the number of observations for each

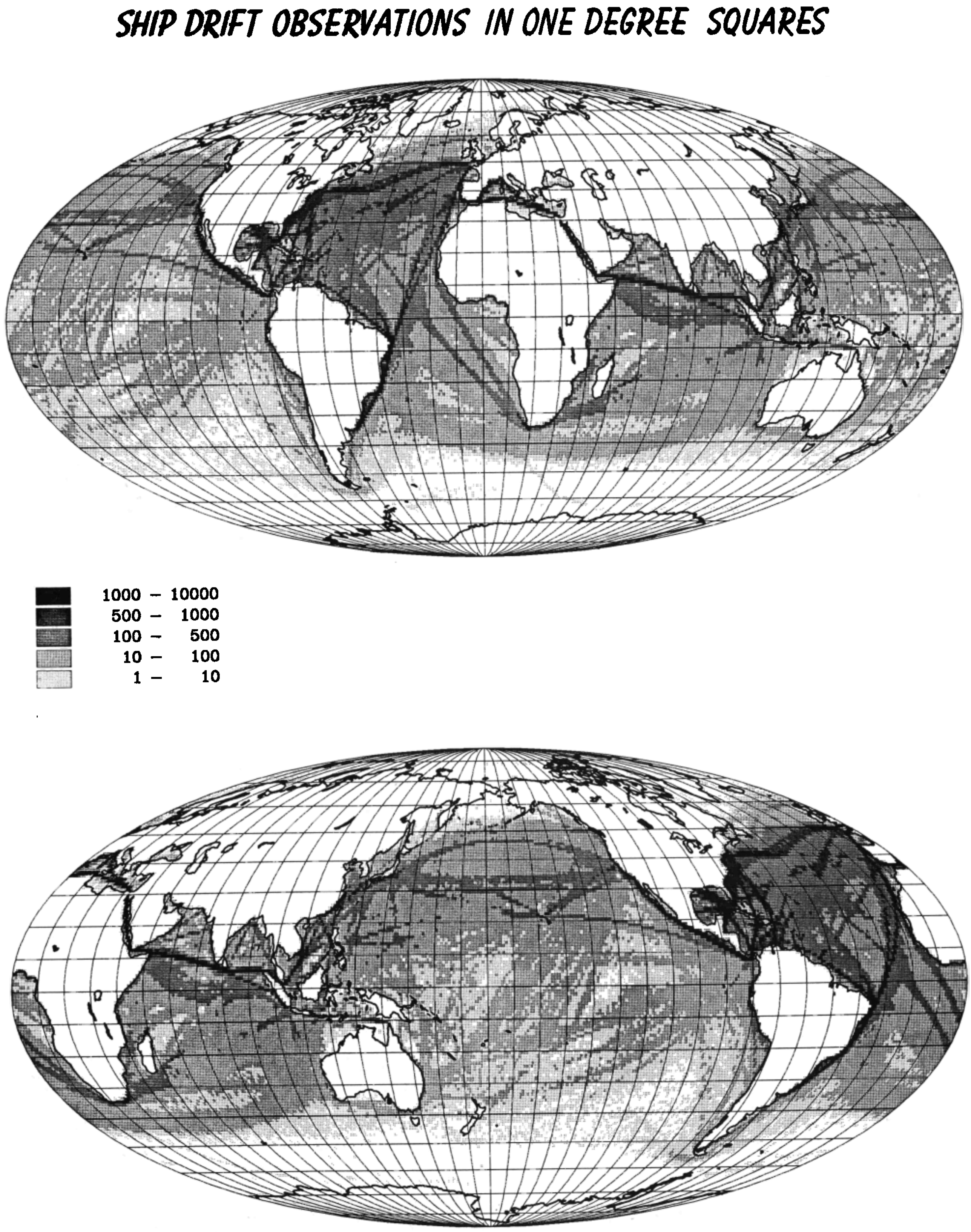

Fig. 2. Geographical distribution in 1° squares of the 4,175,414 worldwide ship drift velocity observations. The main ship routes appear as dark bands. A somewhat similar map of the number of observations in 5° boxes has been given by *Duncan and Schladow* [1981].

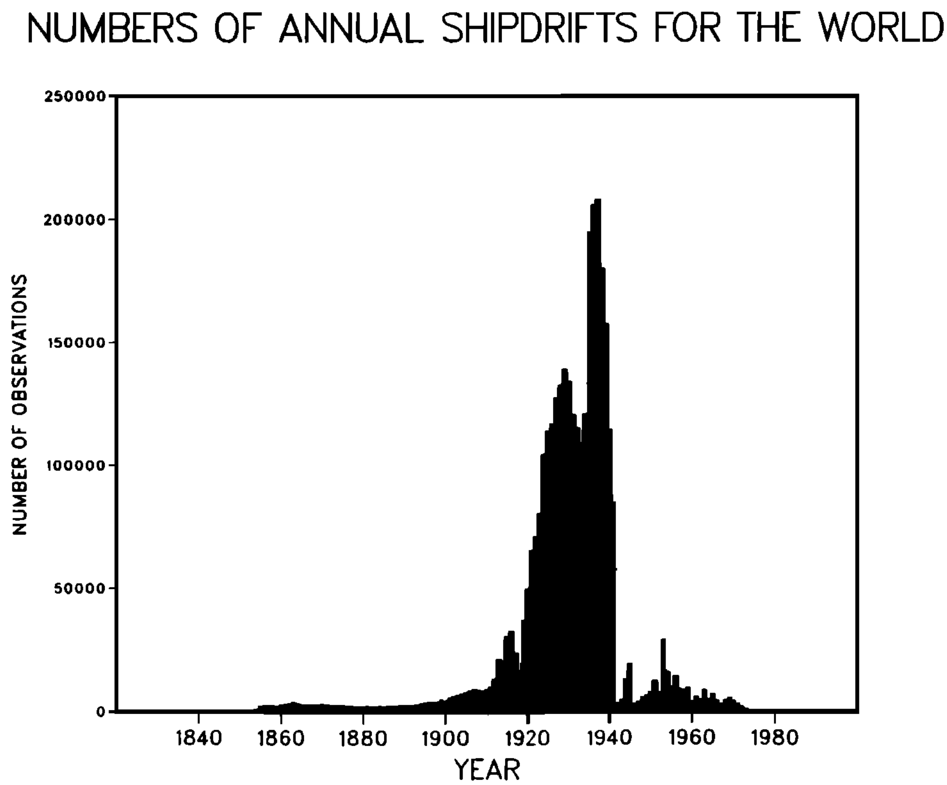

Fig. 3. Histogram of the number of yearly ship drift observations with a known year. No year was available for 771,258 observations, or 18% of the total.

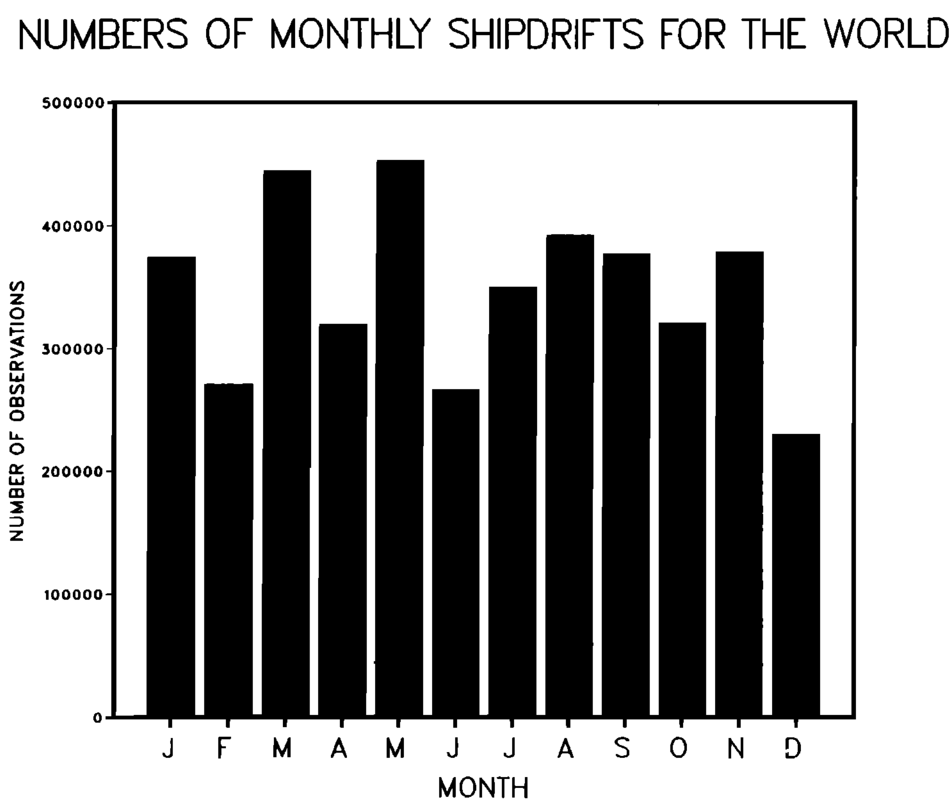

Fig. 4. Numbers of monthly ship drift observations for all years combined. Note the apparent discontinuities between low months, February, April, and June, and high months, March and May.

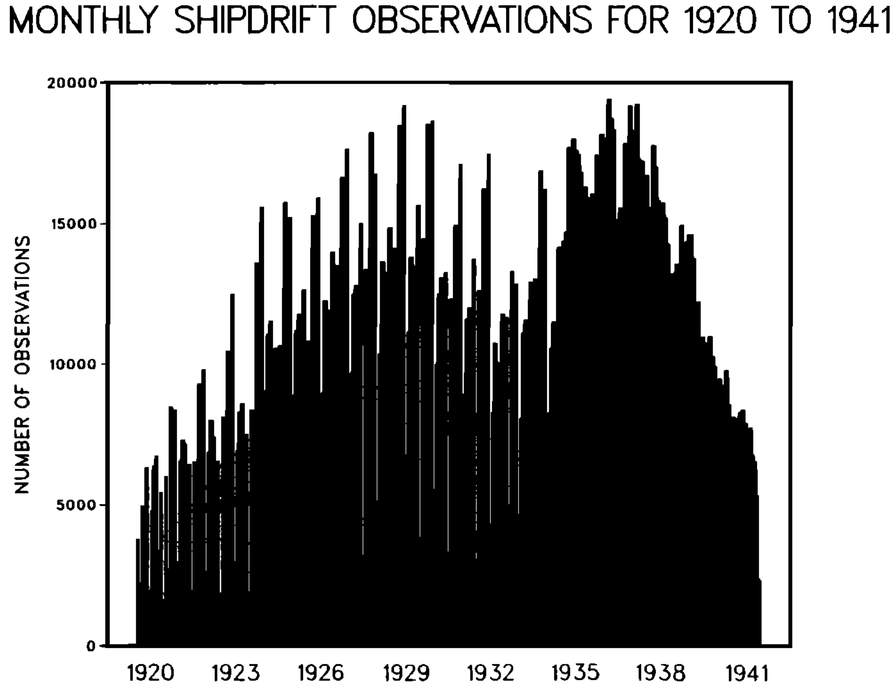

Fig. 5. Numbers of monthly ship drift observations made from 1920 to 1941. March and May have particularly large numbers of observations, and December, February, and June have very low numbers.

month of each year. These revealed that from 1920 to 1934 even larger variations between months occurred and that the pattern was similar for each year (Figure 5). It appeared that something had happened to some of the data.

This was particularly distressing because such a large amount of data came from these 15 years with very large monthly variations. Geographical maps of the monthly number of observations in each 10° square for the combined years 1920–1934 (Figure 6) showed that for some months large ocean areas were nearly devoid of observations, while other areas looked reasonable. The monthly maps of the Indian Ocean and also the South Atlantic Ocean were rather consistent, with similar numbers of observations in each month. Most of the North Pacific has reasonable distributions in 1920–1934, except for an area centered near 0°N–10°N, 90°W–180°W in which data are missing for all months except January, March, May, and November (Figure 7). In the South Pacific, 0°S–50°S, 70°W–170°E, data look reasonable for March, April, and June, but the remaining months are virtually devoid of observations (Figure 7). The North Atlantic has several troublesome areas and months: a nearly total absence of observations from 0°N to 40°N in June and December, a large data gap from 0°N to 20°N in July, and some partial data gaps from 30°N to 40°N in February and April. If we assume that March, the month with the most observations during 1920–1934, is typical of the possible number of monthly observations during these years, then we estimate that about 700,000 ship drift observations have mysteriously disappeared. This represents about 17% of the total present data set, but a much larger percentage, 63%, in the South Pacific, where the data density is low.

What happened to the missing observations? We think that the data were either omitted from the original file or were expunged during a computer transfer of files. The Naval Oceanographic Office file has about the same number of observations as NODC, indicating that the data were not lost in the transfer to NODC. Thus the problem lies in the Oceanographic Office file. The data could possibly have been listed under an incorrect month, year, or position, but the various maps and time series that we prepared suggest that this did not occur. Geographical maps of the number of monthly observations for observations without a known year look similar and reasonable, ruling out the possibility that the data had their year removed. Maps of data without a known year also show almost no observations in the North Pacific, possibly indicating more missing observations.

SUMMARY AND RECOMMENDATIONS

In summary, the worldwide ship drift data was investigated by plotting various geographical maps and summary histograms of monthly and yearly data; some were shown here. The study identified some large gaps in the data. We hypothesize that data were either accidentally omitted or deleted during a file transfer. It is recommended that a careful review of the original Naval Oceanographic Office ship drift data be made with the aim of finding and adding the missing observations. This would create a much more useful data set, especially for studies of seasonal and interannual variations in velocity. It is also recommended that available ship drift observations from other countries and from years after the outbreak of World War II be reviewed to make sure that all possible data have been included.

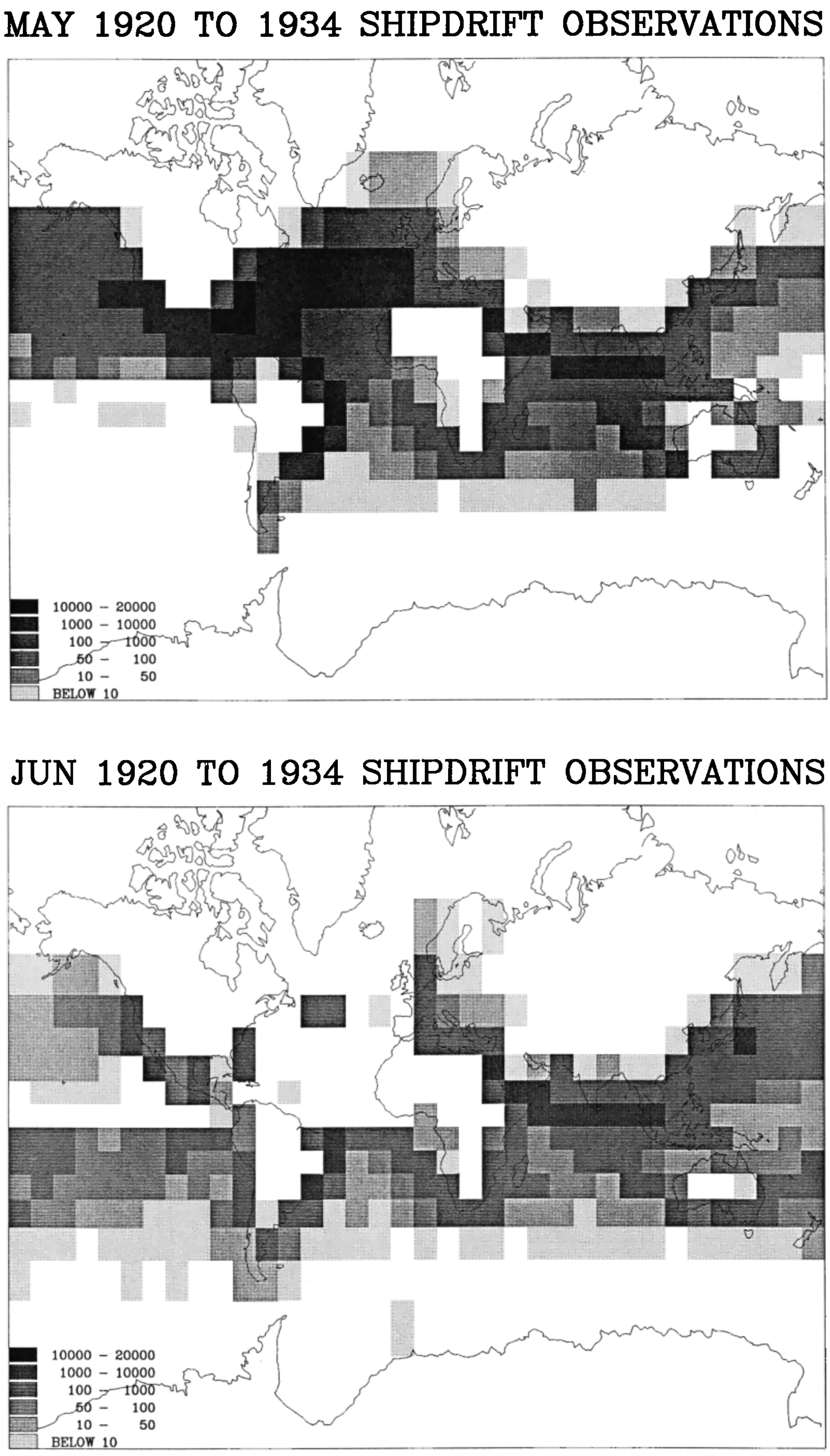

Fig. 6. Geographical distribution of ship drifts from 1920 to 1934, summed in 10° boxes. Note the low number of observations in the South Pacific in May and the low number in the North Pacific and North Atlantic in June.

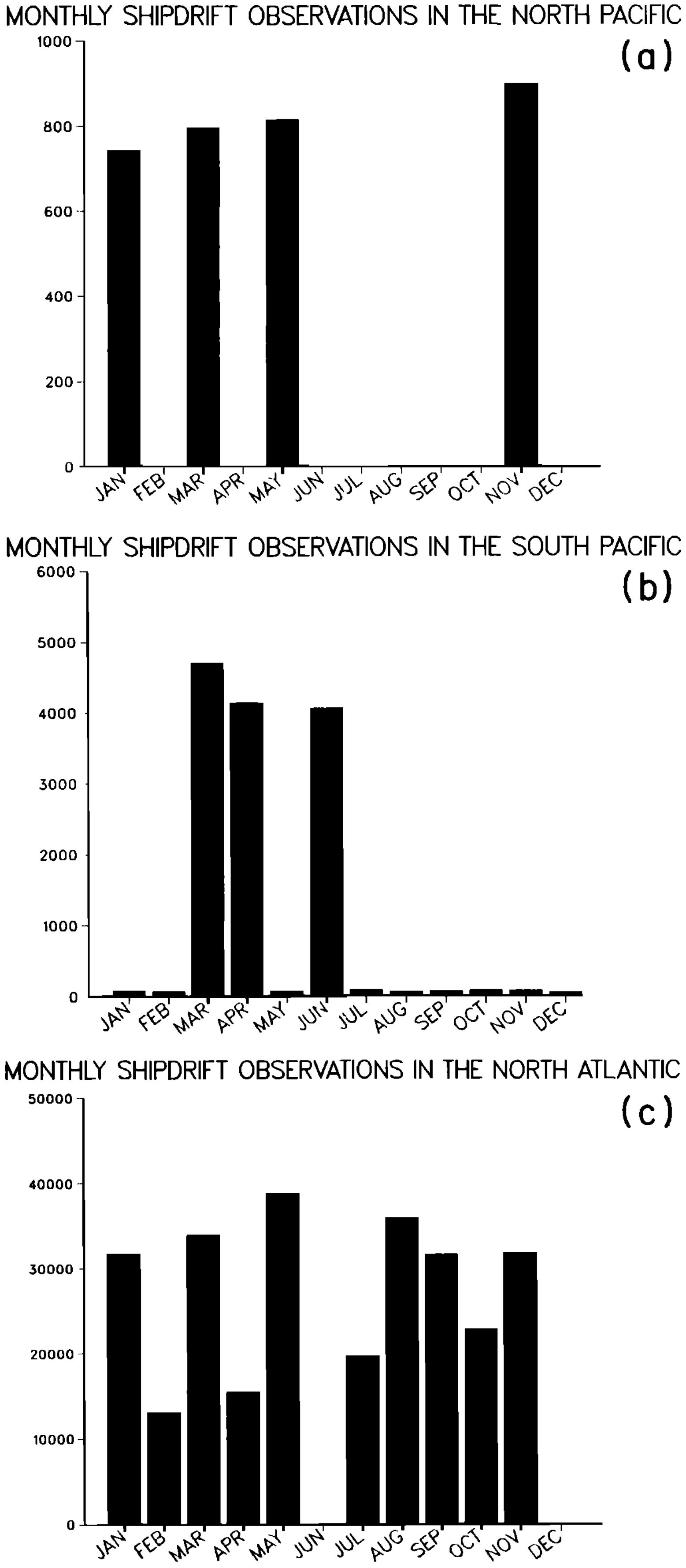

Fig. 7. Numbers of monthly ship drift observations from 1920 to 1934 in representative boxes of (*a*) the North Pacific (0°–10°N, 100°–180°W), (*b*) the South Pacific (0°–50°S, 80°–180°W), and (*c*) the North Atlantic (0°–40°N, 0°–70°W). Note the data gaps in certain months.

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