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COMPARISON OF SURFACE WINDS ON THE GREAT LAKES AS REPORTED BY BUOYS AND SHIPS

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1. INTRODUCTION

The NOAA Data Buoy Office started its Great Lakes program in May of 1979 with the establishment of station 45001 in central Lake Superior (National Data Buoy Office, 1980a). In September of 1979 the second station (45002) was activated in northern Lake Michigan. In 1980 the Great Lakes buoy network was expanded from two to five stations, with stations being established in eastern Lake Superior, Lake Huron, and Lake Erie (National Data Buoy Office, 1980b).

The main purpose of the Data Buoy Program in the Great Lakes is to provide environmental information in data sparse areas. During 1981 the last three stations will be added to the network; they will be located in western Lake Superior, southern Lake Michigan, and central Lake Superior.

2. THE BUOYS

The buoy systems on the Great Lakes use 6-meter boat-shaped NOMAD buoys. Meteorological data recorded at the buoys include wind speed, wind direction, air temperature, and barometric pressure. Lake condition variables which are measured are surface water temperature, significant wave height, wave period, and wave spectra.

The information from the buoys is transmitted via the GOES satellite to Wallops Island, Va. and then to the National Meteorological Center from where it is disseminated over Weather Service circuits.

3. COMPARISON OF BUOY AND SHIP OBSERVATIONS

The buoy observations are used at Weather Service Forecast Offices (WSFO`s) to supplement the observations available from Great Lakes ships. A problem has been reported (WSFO, Cleveland) in using the buoy observations for this purpose because the wind speeds measured at the buoys are usually quite a bit less than wind speeds observed on ships. This is not surprising, as the buoys measure wind speed at a much lower level in the friction layer of the atmosphere than do the ships. The ship anemometers are about 20 meters (65 feet) above the water, whereas the buoys report the wind at the 5-meter (16-foot) level. Another factor is the different period of record between the ship and buoy observations. Ship wind speed observations are 1-minute averages and the buoy wind speeds are 8.5-minute averages.

Table 1. Stability ($T_a - T_w$) classification and number of cases in each class.

Class	($T_a - T_w$)	Cases
Stable	$> +2.8^oC$	3
Neutral	$\leq +2.8^oC$ to $\geq -2.8^oC$	67
Unstable	$< -2.8^oC$	55

The distribution of stable, neutral, and unstable cases in our sample of 125 is not consistent with the climatological distribution. Over 70% of the cases are for the months of October and November. Only two of the cases occurred before August which means the normally stable conditions of the spring months were not represented in the sample. However, in an attempt to look for a stability effect in these observations, the unstable cases are circled in Fig. 5. There is no distinction in the distribution of the unstable from the neutral and stable observations. Perhaps a clearer distinction will be evident when the 1980 observations become available to add to the 1979 observations.

B. Wind Direction

The direction of wind at the buoys was compared to the wind direction reported by the ships. This was done in an effort to determine the average shift in direction between the 5-meter wind observation of the buoys and the 20-meter observations of the ships. One would normally expect the wind to veer with increasing height. There are a couple of reasons why we might not expect to find a clear-cut variation of direction between the buoys and the ships. First, the buoys and ships are not at exactly the same locations, the two observations are for periods of different duration, and the ship observations may be affected by disruption of the air flow by the ship. Second, the wind directions are available only to tens of degrees. This relatively coarse measure of direction is not adequate to show small differences in direction between the buoy and ship observations.

The frequency distribution of the direction difference is shown in Fig. 6. The most prevalent direction difference is veering with height by 10°; this difference accounts for 21% of the cases. Another 19% of the cases have a direction difference of 0°, and 14% back with height by 10°. A total of about 55% of the cases show direction differences between the buoy and ship observations of -10° to $+10^o$. At this time with our limited data sample it might be best to consider no shift of direction between the buoys and ships for operational use of the buoy data.

4. SUMMARY

It is desirable to supplement the regular ship observations on the Great Lakes with observations from NOAA data buoys. Problems have been encountered in using the buoy observations as the wind speeds reported by the buoys are usually considerably less than winds reported by nearby ships. This is probably because the buoy observations are at a lower level than the ship observations and the buoy observations are averaged over much longer time periods. Based on the small sample of data available for 1979, it appears a good way to adjust the buoy wind observations to represent ship observations is to multiply the buoy wind speeds by 1.54, or simply 1.5, and to use the directions reported by the buoys with no change.

It is planned to add the 1980 observations to the present data base. This should enable us to formulate more precise adjustment factors to use with the buoy observations.

REFERENCES

NOAA Data Buoy Office, 1980a: Great Lakes buoys complete first summer deployment. Ocean Engineering Technical Bulletin, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Vol. 6, No.1, p. 1.

NOAA Data Buoy Office, 1980b: NOAA Data Buoy Office Great Lakes buoy network. Ocean Engineering Technical Bulletin, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Vol. 6, No. 2, p. 3.

Strong, A. E., and F. R. Bellaire, 1965: The effect of air stability on wind and waves. Pub. No. 13, Great Lakes Research Division, University of Michigan, 283-289.

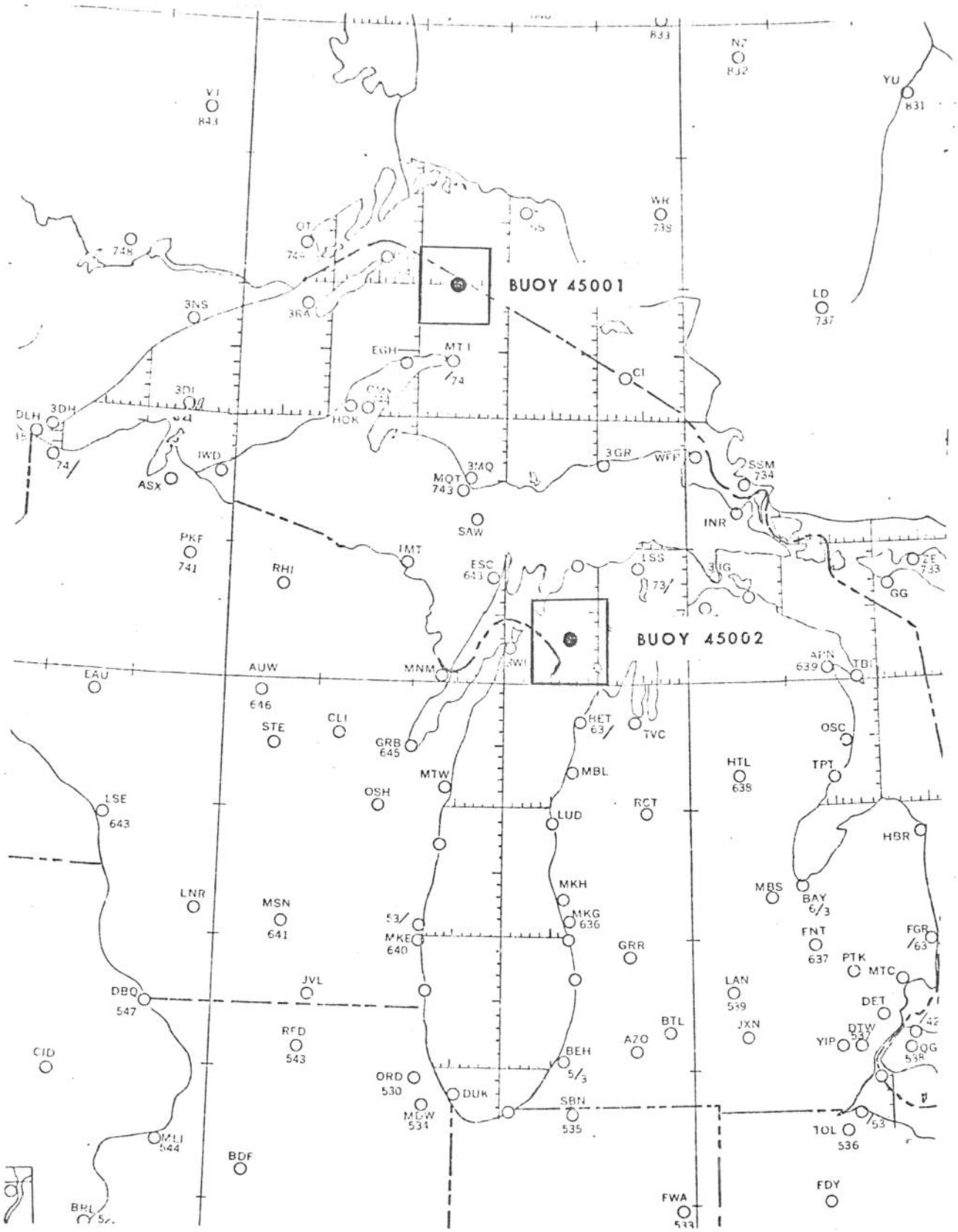

Figure 1. Locations of the two data buoys used on the Great Lakes during 1979. The boxes show the areas in which ship observations were considered for comparison to the buoy observations.

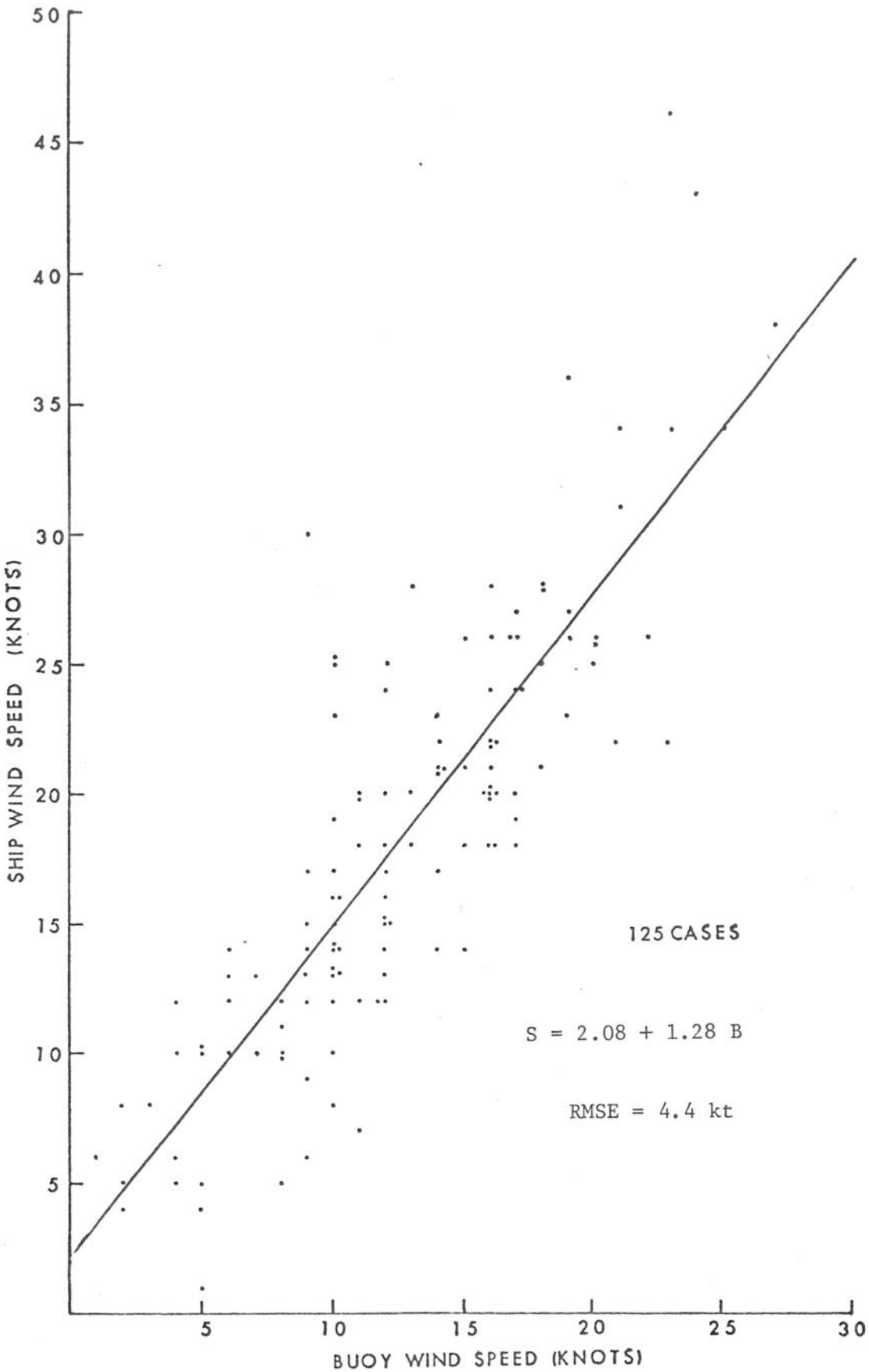

Figure 2. Plot of observed wind speeds at Great Lakes data buoys and the corresponding wind speeds observed on nearby ships. The regression line shown was determined by the method of least squares; it gives the ship wind speed (S) as a function of the buoy wind speed (B). The associated correlation coefficient is 0.84 and the root-mean-square error is 4.4 kt.

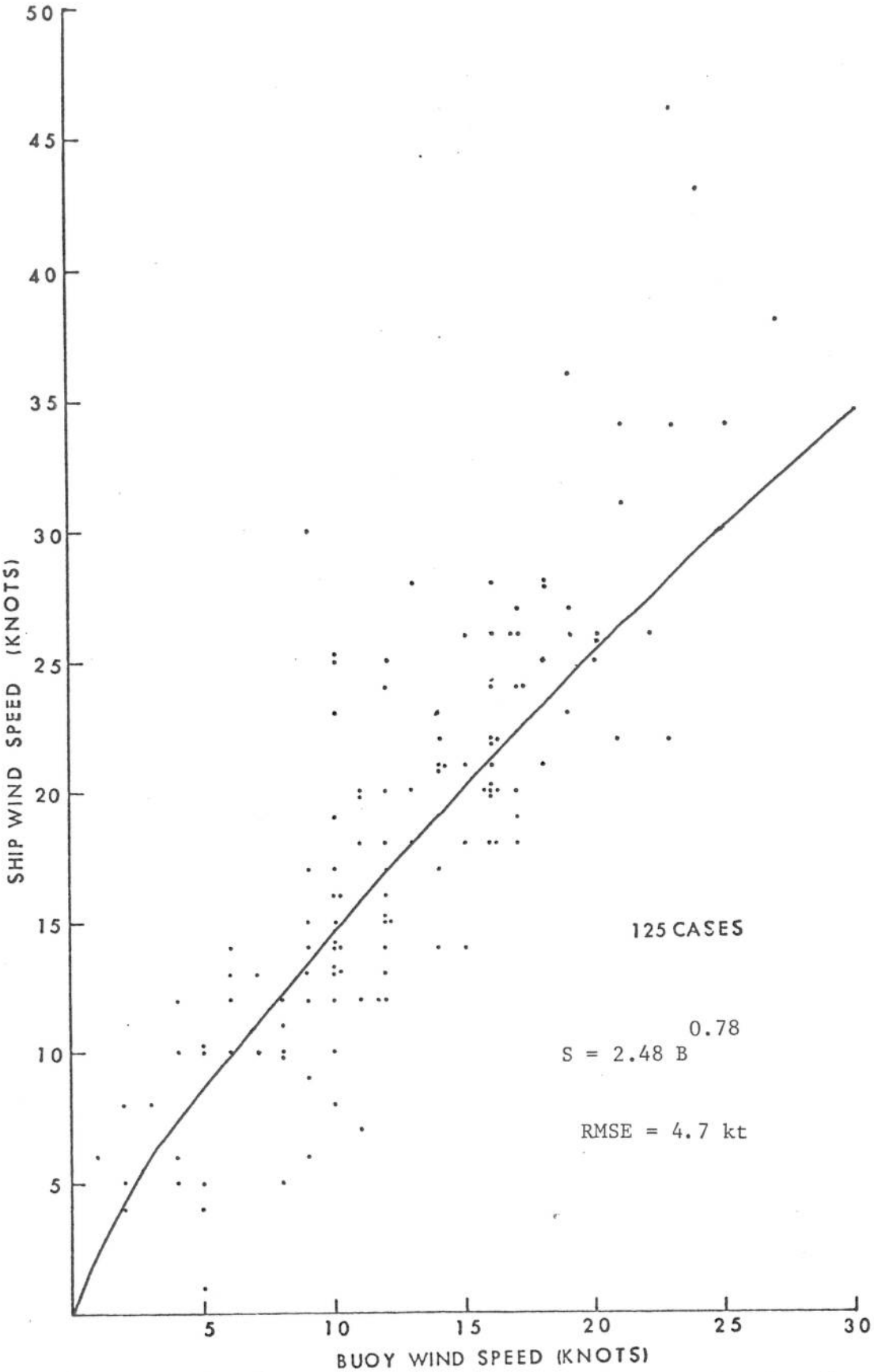

Figure 3. Plot of observed wind speeds at Great Lakes data buoys and the corresponding wind speeds observed on nearby ships. The exponential curve shown was determined by the method of least squares and logarithmic transformation of the buoy and ship wind speeds. The curve gives the ship wind speed (S) as a function of the buoy wind speed (B). The associated root-mean-square error is 4.7 kt.

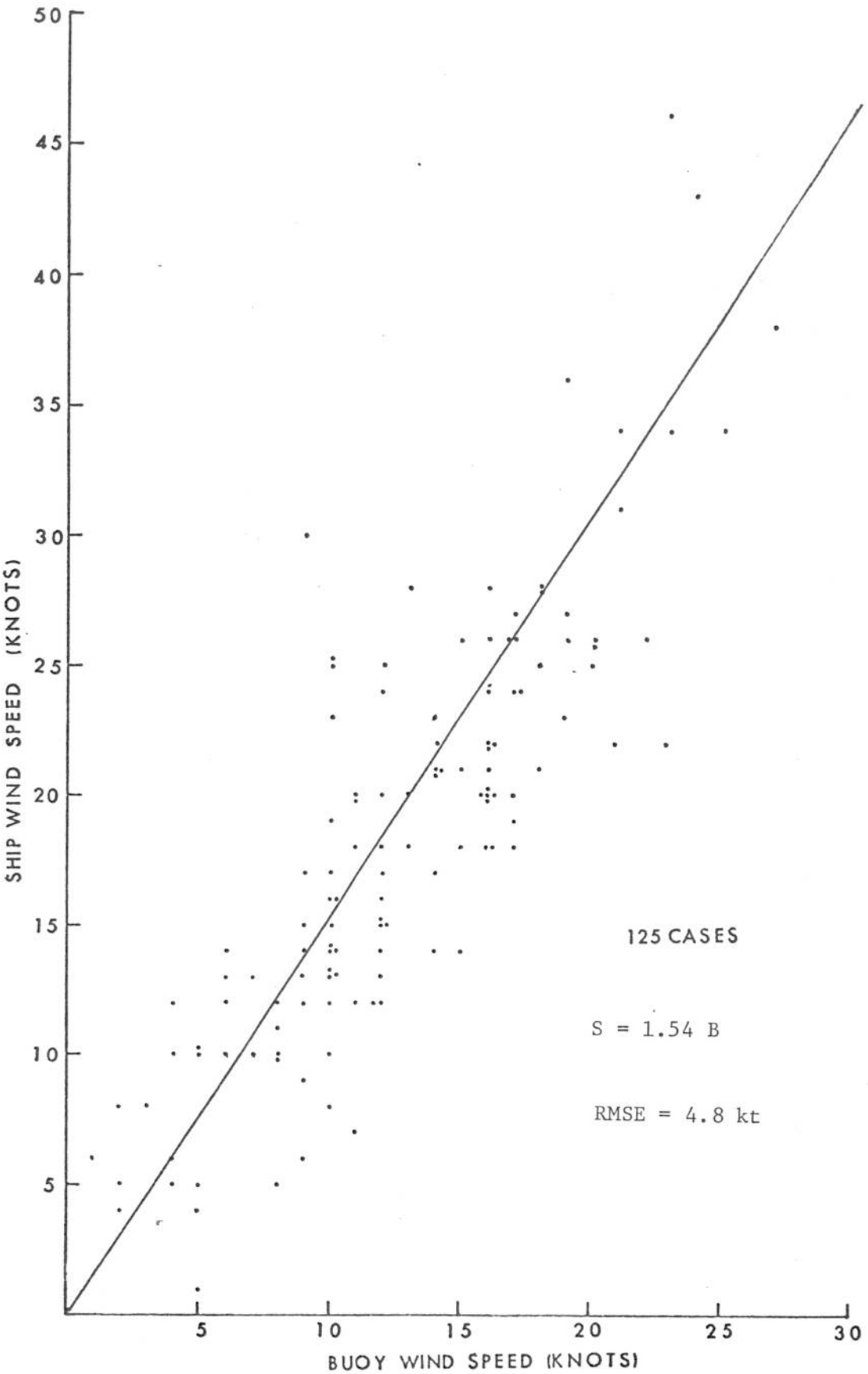

Figure 4. Plot of observed wind speeds at Great Lakes data buoys and the corresponding wind speeds observed on nearby ships. The line shown has a slope of 1.54, which is the mean ratio of ship wind speed to buoy wind speed. The line gives the ship wind speed (S) as a function of the buoy wind speed (B). The associated root-mean-square error is 4.8 kt.

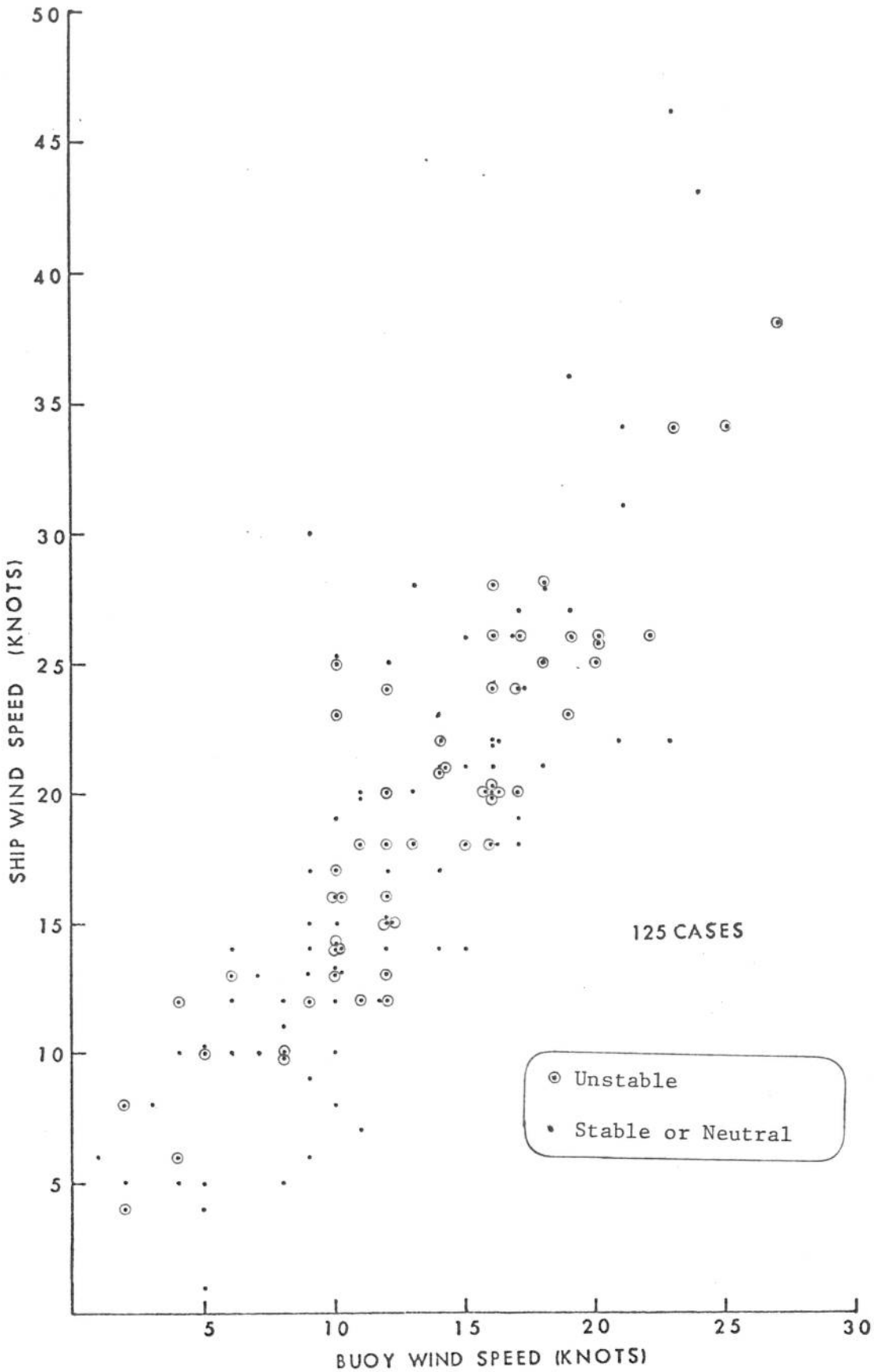

Figure 5. Plot of observed wind speeds at Great Lakes data buoys and the corresponding wind speeds observed on nearby ships. Unstable cases, where the air-water temperature difference is less than -2.8°C, are circled.

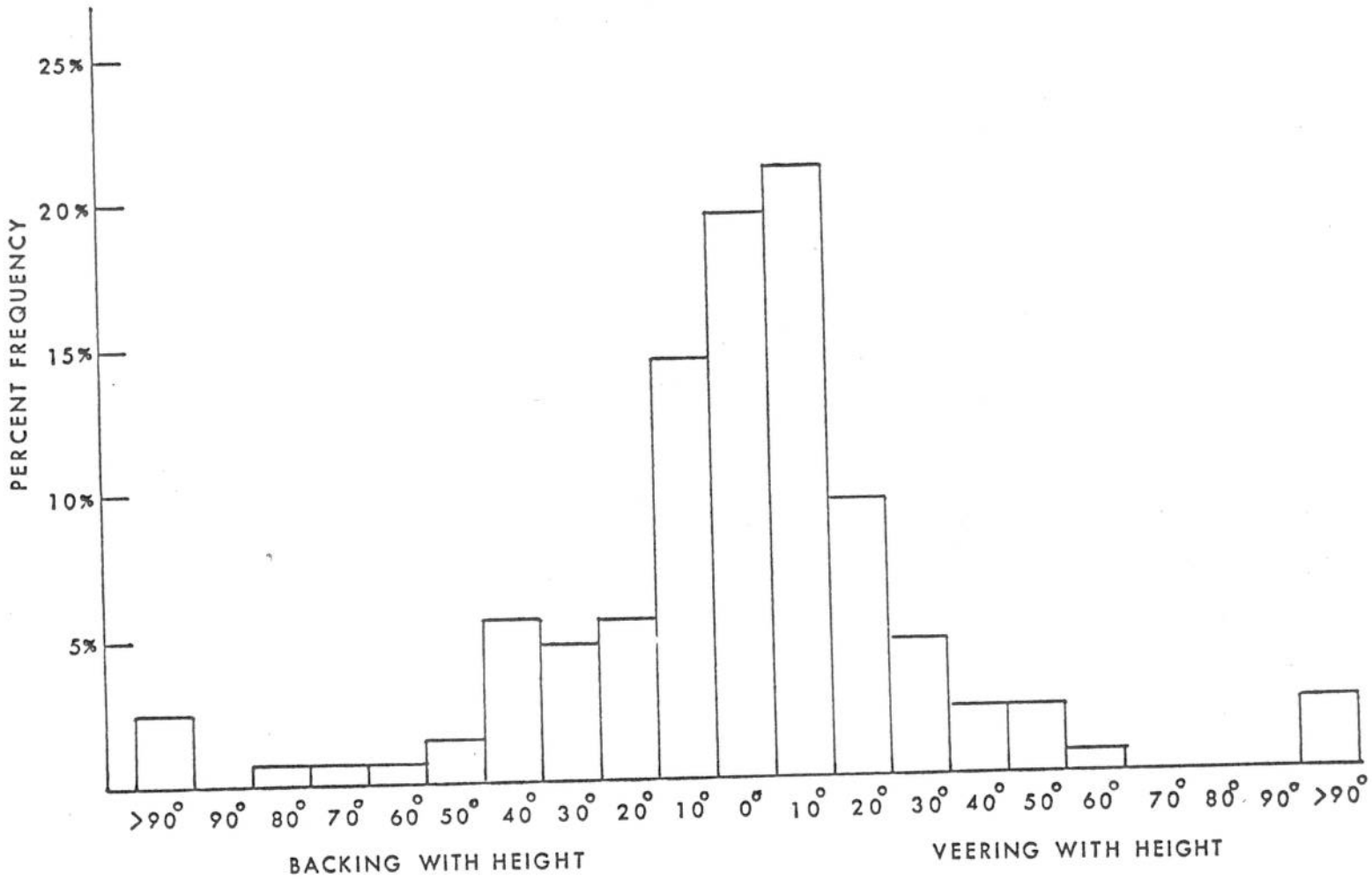

Figure 6. Frequency distribution of direction difference between wind observed on Great Lakes ships and buoys.

One approach to the problem of adjusting wind speeds from one level to another is to use a relationship of a logarithmic wind profile with height. Such a relationship can be used to determine the wind speed at various levels when the wind speed is known at one level. One problem with this approach is that the drag coefficient of the logarithmic profile relationship is not known. Many forms of the drag coefficient have been proposed and they result in many different wind profiles with height. It therefore does not seem appropriate to use this approach to determine the ship level wind speed from the buoy observations on the Great Lakes. An alternate approach was taken by comparing the ship and buoy observations and determining relationships between the two types. The locations of the two buoys used in 1979 are shown in Fig. 1. Station 45001 in central Lake Superior was established on May 3 and station 45002 began operations on September 6. The buoy wind observations were compared to observations from ships which passed relatively close to the buoys. The ship observations were used if the ship was within the rectangular areas shown in Fig. 1. These rectangular areas are centered over the buoy locations and have the dimensions of 0.6° latitude by 0.8° longtitude or about 36 by 33 nautical miles.

The buoy observations were considered for the regular 6-hourly observation times 0000, 0600, 1200, and 1800 GMT. If a ship observation was available for the same times within the rectangular areas, a comparison was made. If more than one ship observation was available within the rectangular area, the observation of the ship closest to the buoy was used. There were 125 cases during 1979 in which buoy and ship observations could be compared.

A. Wind Speed

A plot of the ship wind speeds against the buoy wind speeds is shown in Fig. 2. Here it is evident that the wind speeds reported by the ships are significantly higher than those reported by the buoys. The correlation coefficient between the two types of wind speed observations is 0.84; the associated least squares regression line is shown in Fig. 2. The root-mean-square error (RMSE) of the regression line is 4.4 kt. This line does not very well fit the higher wind speeds.

A different type curve, of the exponential type, was then fit to the data. This curve, which was determined by least squares regression and logarithmic transformation of the buoy and ship wind speeds, is shown in Fig. 3; it still does not fit the high wind cases very well. The RMSE of this curve is 4.7 kt. The mean ratio of ship wind speed to buoy wind speed is 1.54. The line depicting this slope is shown in Fig. 4. It fits the data fairly well and certainly fits much better at the higher wind speeds. The RMSE of this relationship is 4.8 kt, which is only 0.4 kt greater than that of the least squares regression line of Fig. 2. This relationship may be practical for operational use when considering the buoy reports.

In order to look into the effect of atmospheric stability, the 125 cases were put into classes depending upon the air-water temperature difference. The water temperatures reported by the buoys are essentially for the upper 1 meter of water and the air temperature is measured at 5 meters. We have used an arbitrary stability classification similar to that of Strong and Bellaire (1965). The classification and number of cases in each class is shown in Table 1.