Radius and Frequency of 15 m s^{-1} (30 kt) Winds around Tropical Cyclones

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ABSTRACT

Over 8500 rawinsonde soundings within 8° radius of tropical cyclones in the northwest Pacific and West Indies regions are statistically analyzed to determine occurrence frequencies of 15 m s^{-1} (30 kt) winds at the sea surface. At any radius the likelihood of encountering winds > 15 m s^{-1} is found to increase with increasing central wind speed and with increasing radius of the highest closed isobar. There are significant right-side wind maxima and left-side minima with respect to the direction of storm motion. This reflects the natural storm asymmetry. Much variability is found in the radius of 15 m s^{-1} winds between cyclones of similar inner core intensity.

1. Introduction

Sea traffic is greatly affected by the high seas generated by typhoon winds. To maximize safety and minimize the expense of rerouting ships, the horizontal extent of high winds must be forecast. The radius of 15 m s^{-1} (30 kt) surface winds is an important parameter for sea state. This study uses western North Pacific and western Atlantic rawinsonde data to estimate the probability of encountering surface winds ≥ 15 m s^{-1} (30 kt) at various points relative to the centers of typhoons and hurricanes. The dependence of the 15 m s^{-1} isotach on storm intensity and size are explored, and asymmetries relative to the storm's direction of motion are discussed.

2. Data and analysis procedure

Ten years (1961–70) of northwest Pacific rawinsonde data and 14 years (1961–74) of West Indies data from the networks of Figs. 1 and 2 were screened. Over 8500 soundings within 8° radius of the center of tropical cyclones make up the data set used in this analysis. All of the rawinsonde stations

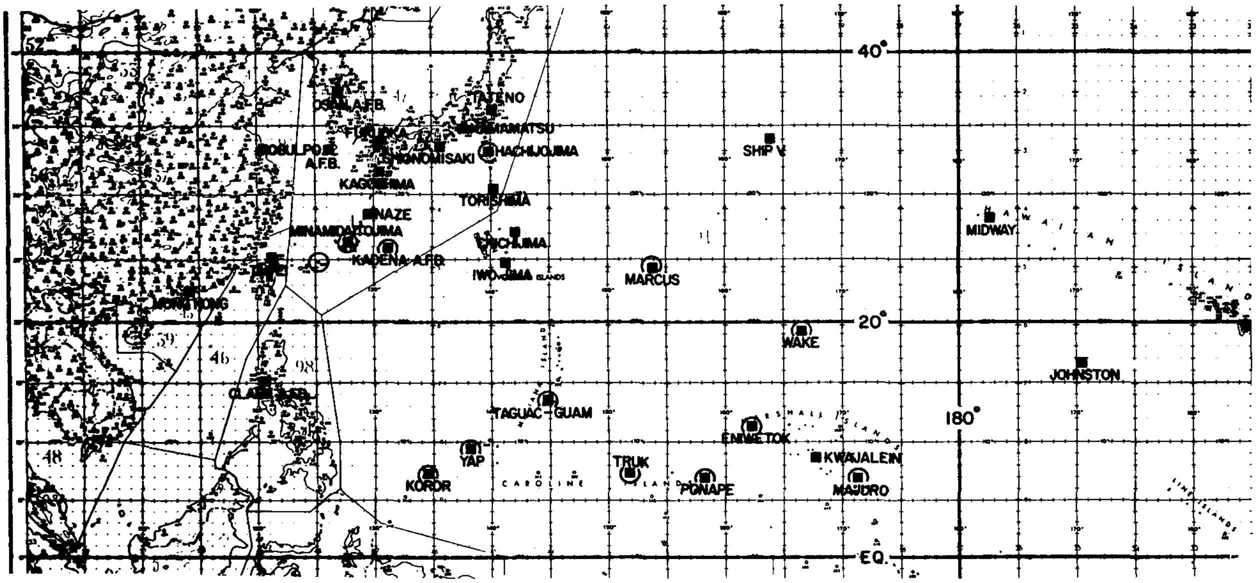

FIG. 1. Western North Pacific rawinsonde data network.

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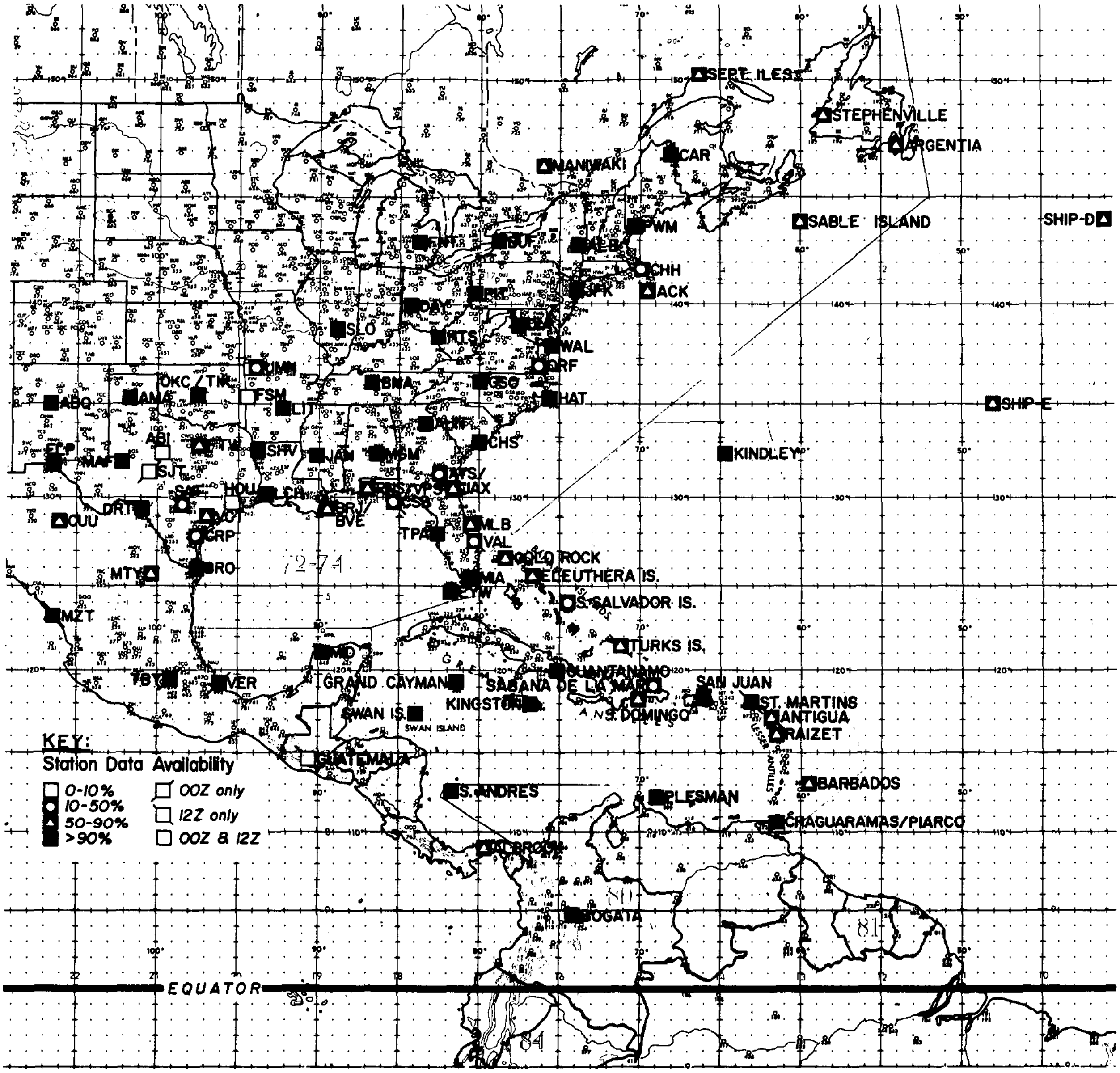

FIG. 2. North Atlantic rawinsonde data network.

are over land, and local topography influences are variable and difficult to estimate. Therefore, the best method of obtaining surface winds over the ocean is to estimate them from observations of winds at a level above the boundary layer. Winds at 850 mb are used. This is the approximate level of maximum winds in typhoons (Frank, 1977). Since winds at ship deck or 10 m height are significantly lower than those at 850 mb, a correction factor had to be applied to the 850 mb winds. Bates[2] found the 10 m winds over water in hurricanes to be about 72% of the winds at 1000 m. Here it is assumed that sustained 10 m winds are 75% of the 850 mb winds, i.e., a 20 m s^{-1} wind at 850 mb corresponds to a 15 m s^{-1} wind at the sea surface (defined as the 10 m ship deck level).

Rawinsonde wind data around a hurricane always includes a low wind bias. Since the balloon can't be launched in very high wind conditions, the data sample tends to underestimate the true frequency of high wind occurrences. This phenomenon is most important at inner radii. Beyond a radius of 3° latitude or so this bias is probably insignificant, but it should be recognized that the mean winds and the frequency of 15 m s^{-1} wind occurrences is in-

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[2] Bates, J., 1977: Vertical shear of the horizontal wind speed in tropical cyclones. NOAA Tech. Memo. ERL WMPO-39, 19 pp.

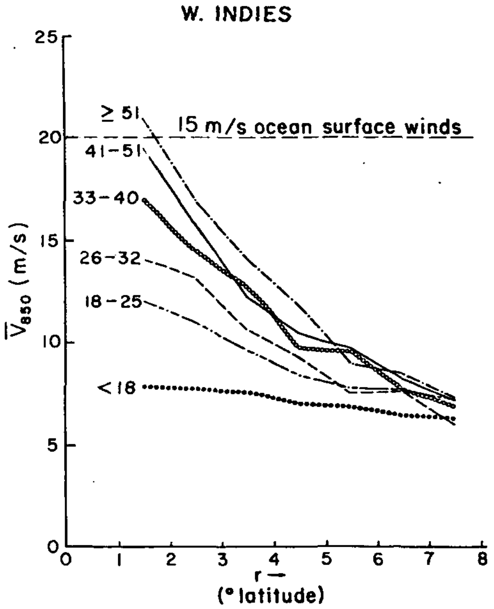

FIG. 3. Mean 850 mb winds around West Indies storms for cyclones with different maximum sustained wind velocities. The number at the left of each line is the maximum wind range (m s^{-1}) for that class of storms. The dashed line corresponds to estimated 15 m s^{-1} winds at the sea surface.

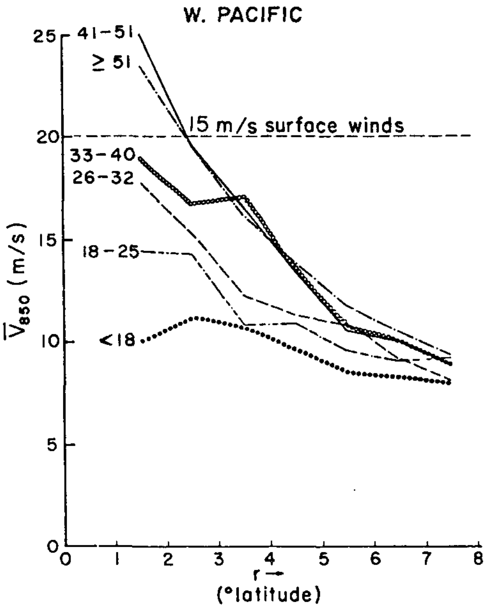

FIG. 4. As in Fig. 3 except for the west Pacific storms.

creasingly underestimated as one approaches the center.

The data sample is composed of all the soundings of the west Pacific and West Indies rawinsonde data networks. This includes numerous soundings common to each storm. Extremely long-lived storms or those which traverse the denser portions of the data networks are therefore weighted the most heavily. It is assumed that this type of bias has negligible effect on the results presented due to the very large number of storms studied.

3. Results

Figs. 3 and 4 show the average 850 mb winds for the two regions. A 20 m s^{-1} wind at 850 mb is assumed equal to a sustained 15 m s^{-1} wind at the sea surface and this line is dashed in. There is only a weak correlation between the mean wind speeds at 7–8° radius and the maximum winds near the center. Mean winds in excess of 20 m s^{-1} are found only inside 2° radius of the strongest storms, although the winds inside 3° radius or so are probably under-

TABLE 1. Percent of total west Pacific soundings with estimated sea surface winds ≥15 m s^{-1} (30 kt) for various storm intensities. Numbers in parentheses are the number of observations.

Maximum winds (m s^{-1})	Radius (deg latitude)						
	1–2°	2–3°	3–4°	4–5°	5–6°	6–7°	7–8°
<18	5 (41)	5 (42)	5 (77)	7 (99)	2 (105)	2 (105)	0 (129)
18–25	22 (36)	20 (60)	5 (93)	6 (114)	1 (145)	5 (149)	3 (179)
26–32	26 (35)	20 (49)	13 (64)	9 (94)	6 (126)	4 (145)	1 (141)
33–40	32 (19)	38 (42)	36 (75)	13 (87)	11 (109)	8 (125)	2 (155)
41–51	80 (20)	49 (35)	29 (65)	11 (71)	6 (99)	4 (130)	2 (129)
≥51	58 (55)	50 (84)	29 (134)	18 (182)	11 (223)	6 (251)	5 (292)

TABLE 2. As in Table 1 except for percent of total West Indies soundings.

Maximum winds (m s^{-1})	Radius (deg latitude)						
	1–2°	2–3°	3–4°	4–5°	5–6°	6–7°	7–8°
<18	1 (75)	0 (138)	0 (182)	0 (205)	0 (258)	0 (314)	0 (350)
18–25	8 (38)	9 (45)	3 (63)	0 (85)	2 (112)	0 (97)	2 (125)
26–32	26 (19)	9 (55)	2 (63)	3 (96)	1 (82)	1 (85)	0 (112)
33–40	36 (28)	22 (45)	9 (87)	3 (90)	2 (99)	1 (105)	0 (117)
41–51	50 (14)	16 (32)	7 (41)	5 (57)	3 (79)	00 (88)	0 (100)
≥51	46 (33)	38 (56)	20 (69)	10 (94)	2 (135)	1 (157)	0 (163)

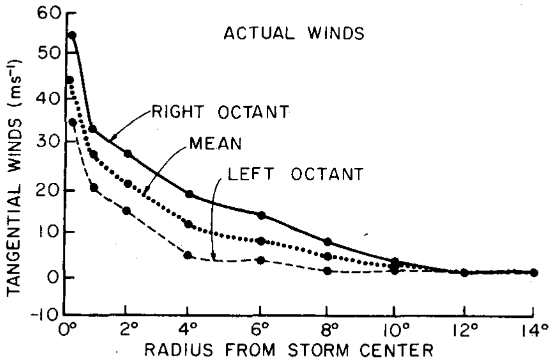

FIG. 5. 700 mb tangential wind profiles depicting the asymmetry between the right and left octants of west Pacific tropical cyclones for latitudes > 20°N (George and Gray, 1976).

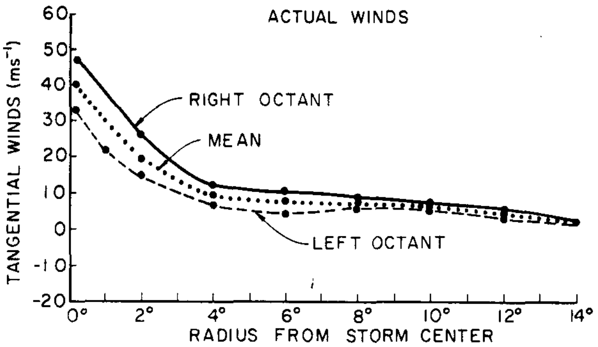

FIG. 6. As in Fig. 5 except for latitudes ≤ 20°N.

estimated as previously mentioned. Table 1 shows the frequency of occurrence of winds ≥ 15 m s^{-1} as a function of radius around west Pacific storms of various intensity. Table 2 shows the same information for West Indies storms. Beyond 6° radius in the Pacific (4° in the West Indies) 15 m s^{-1} winds are encountered no more than 10% of the time. Inside those radii there is a clear trend toward more high winds with increasing central core intensity. The greater size and intensity of the typhoon is evident from a comparison of Tables 1 and 2.

TABLE 3. Northwest Pacific radius of highest closed isobar (HCI) as related to percent of sea surface winds exceeding 15 m s^{-1}. Upper numbers are percent of soundings with estimated surface winds ≥ 15 m s^{-1}. Numbers in parentheses are the number of observations.

Radius of HCI	Radius (deg latitude) 1–2°	2–3°	3–4°	4–5°	5–6°	6–7°	7–8°
A. Maximum winds 18–33 m s^{-1}							
0–3	7 (27)	17 (42)	7 (82)	3 (86)	3 (120)	3 (129)	0 (139)
4–6	38 (39)	23 (61)	9 (64)	12 (104)	4 (129)	4 (143)	5 (147)
≥7	0 (2)	25 (4)	11 (9)	0 (10)	11 (9)	33 (12)	0 (24)
B. Maximum winds 33–46 m s^{-1}							
0–3	22 (9)	28 (25)	14 (35)	3 (31)	2 (54)	5 (55)	0 (84)
4–6	56 (18)	38 (21)	31 (52)	13 (69)	13 (89)	6 (93)	3 (96)
≥7	100 (3)	67 (3)	57 (14)	12 (17)	14 (14)	11 (27)	7 (8)
C. Maximum winds > 46 m s^{-1}							
0–3	64 (11)	27 (15)	17 (30)	23 (30)	7 (43)	0 (53)	7 (55)
4–6	74 (19)	50 (38)	37 (71)	13 (100)	9 (112)	7 (122)	1 (149)
≥7	100 (12)	91 (23)	52 (29)	48 (31)	21 (58)	13 (71)	9 (78)

The extent of 15 m s^{-1} winds is quite variable for a given central intensity class of storms. One measure of the size of a storm is the mean radius of the highest closed isobar (HCI) on the surface analysis. Table 3 shows the frequency of 15 m s^{-1} surface wind occurrences for three storm intensity classes which have been further stratified according to the HCI radius. These data are for west Pacific storms only.

Within a given intensity class the 15 m s^{-1} wind occurrences at each radius, as expected, become more frequent with increasing storm size. The effect is more pronounced in the stronger storms. There is also a tendency for the mean storm size to increase as the maximum winds become stronger, but the radius of the HCI is quite variable within each intensity grouping.

4. Asymmetrics

The winds at large radius in tropical cyclones are in approximate gradient balance, and the storms' motion is closely specified by the 500–700 mb large-scale geostrophic wind component (George and Gray, 1976). Therefore, a symmetrical storm pressure perturbation imposed upon a large-scale gradient results in increased winds on the right side and diminished winds on the left (looking downstream). One would expect the occurrences of 15 m s^{-1} winds to reflect this asymmetry.

Tables 4 and 5 show the left versus right percent of frequencies of 15 m s^{-1} winds for west Pacific and West Indies storms, respectively. The right-side maximum is observed at all radii studied (0–8°) and appears to increase with storm intensity. George and Gray (1976) found that the wind asymmetry occurred only inside of 10° radius in west Pacific typhoons (Figs. 5 and 6), and this radius would probably be less for the smaller west Atlantic

TABLE 4. Percent of estimated sea surface winds $\geq 15\ \mathrm{m\ s^{-1}}$ on left and right sides of storms in the west Pacific. Numbers in parentheses are total observations.

Maximum winds ($\mathrm{m\ s^{-1}}$)	Radius (deg latitude)													
	1–2°		2–3°		3–4°		4–5°		5–6°		6–7°		7–8°	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
18–32	30 (30)	33 (12)	10 (40)	38 (34)	6 (02)	5 (38)	5 (74)	13 (67)	2 (88)	5 (96)	5 (95)	7 (103)	2 (106)	3 (113)
33–51	36 (11)	75 (16)	21 (29)	64 (25)	20 (51)	45 (53)	4 (55)	22 (64)	6 (84)	14 (73)	4 (97)	10 (91)	1 (106)	2 (98)
≥51	71 (14)	55 (22)	42 (33)	65 (31)	26 (53)	39 (41)	16 (61)	25 (71)	9 (77)	14 (80)	3 (70)	9 (89)	2 (86)	9 (118)

TABLE 5. As in Table 4 except for the West Indies.

Maximum winds ($\mathrm{m\ s^{-1}}$)	Radius (deg latitude)													
	1–2°		2–3°		3–4°		4–5°		5–6°		6–7°		7–8°	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
18–32	11 (19)	18 (22)	6 (35)	11 (44)	0 (45)	6 (48)	0 (75)	2 (63)	1 (76)	0 (62)	0 (76)	2 (62)	0 (87)	2 (81)
33–51	17 (12)	60 (20)	0 (25)	27 (26)	0 (43)	20 (55)	4 (29)	7 (58)	3 (64)	2 (64)	0 (69)	1 (71)	0 (83)	0 (77)
≥51	25 (8)	58 (19)	29 (21)	35 (20)	5 (19)	32 (37)	0 (27)	16 (45)	0 (55)	4 (53)	0 (51)	1 (69)	0 (51)	0 (77)

cyclones. The degree of asymmetry depends upon the magnitude of the large-scale pressure gradient. Since the speed of the storm motion is also proportional to this environmental gradient, the left-right wind asymmetry is proportional to the speed of storm motion.

5. Conclusions

At any radius the probability of encountering surface winds $\geq 15\ \mathrm{m\ s^{-1}}$ increases with storm size and central intensity. The influence of storm size (as measured by the radius of the highest closed isobar) is greater for the more intense storms. Mean frequencies around northwest Pacific storms are higher than corresponding West Indies values due to the greater average storm size and intensity in the former region. The normal left-right intensity asymmetry of moving tropical cyclones results in a corresponding right-side maximum in frequency of $15\ \mathrm{m\ s^{-1}}$ wind occurrence. The variability of $15\ \mathrm{m\ s^{-1}}$ wind radius between storms of similar maximum wind speed is large.

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