CENTRAL FORECASTING MONITORING NOTE NO. 11

MONITORING STATISTICS FOR ERS-1 RADAR ALTIMETER DATA

16 October - 22 October 1992

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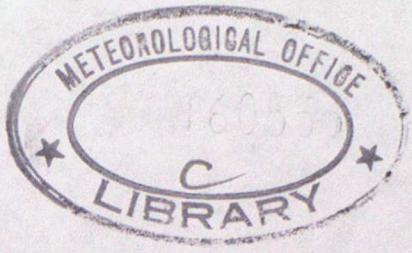

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Contents

1. Introduction

The aim of this note is to identify useful radar altimeter data from the ERS-1 satellite, and report on its quality and quantity. In order to do this one weeks data was compared against appropriate background values from the UK Met Office operational atmospheric and wave models.

The radar altimeter on ERS-1 uses a microwave radar to determine the height of the satellite. The signal is processed in order to identify the 'roughness' of the surface. From this it is possible to derive surface type, and over sea, significant wave height (SWH) and wind speed (WS), but not wind direction.

The SWH, if correct, is of use in wave modelling, and more directly to the routeing of ships. The ship routeing group in CFO receive a global chart every 12 hours of averaged observations, as well as wave model output. Ship routeing have commented favourably on the SWH observations in spite of the coarse time window and resolution of the charts.

The WS may be of use to both atmospheric and wave modellers, particularly in separating the wind and swell components of the collocated radar altimeter wave height observations.

2. Description of Data

The radar altimeter observations lie along the sub-satellite track of ERS-1. ESA supply data which over sea, when instruments are functioning correctly, give a SWH and WS observation every second, resulting in approximately a 7 km spacing of observations.

These observations are themselves an average of (usually) 20 observations, or looks, along the satellite track. Only 17 looks are used when a second instrument requiring the microwave radar is in use. The main problem with the observed SWH and WS is identifying when the data have been corrupted, eg by small amounts of land, or sea ice, or where the instrument is swapping between its different operating modes.

Only observations where both SWH, WS, and forecast values of these elements are available are used in this analysis. The model background SWH heights used are from the wave model, and include T+0,T+6 and T+12 (No interpolation in time was performed). Wind fields are from the atmospheric model and are T+3 to T+8 (by hour)

The operational wave model had a known problem with losing swell as the wind speed drops (Holt 1992). An improved model has been implemented, but for these figures one might expect SWH greater than forecast. The wave model forcing is derived from the 10 m wind field, and is sensitive to any problems with this field.

For this study data from 00Z 16 October 1992 till 00Z 23 October 1992, was extracted from the Meteorological Database. For this period 436,821 observations of both wind speed and wave height, were extracted, of these 36,960 had no associated forecast wind speed data, and 190,457 no associated model wave height data. An observation was omitted when either of the model values were missing. Exclusion of this data will have some impact on the statistics produced, chiefly removing observations over continental areas.

No data were available for use on the 20 October. Interruptions to the supply of data have been a recurring problem with ERS-1, including wind scatterometer observations (Smith and Waters 1992), and should be borne in mind when considering using the data operationally.

3. Analysis

Statistics on raw data were produced, broken down by factors such as ESA product confidence flags, number in average and standard deviation of wave height. Results of this are presented in Appendix A. These statistics were then used to set criteria for selecting the better quality observations. Similar statistics were then produced for the selected subset of the data, again broken down by similar factors.

The criteria used in selecting the subset of data were:

The number in average should be 17 or 20.
The Product confidence should be non-zero.
The bad altitude flag should not be set.
The bad peakiness flag should not be set.
The bad checksum flag should not be set.

4. Results

The occurrence of different observed wind speeds is represented in figure 1. Whilst the selected data is relatively free of the problems at 0 and 25 m/s (That is the large number of zero and large wind speeds, the zeros are a feature of the data storage, the 25m/s winds are caused by saturation of the signal as the satellite passes over land), it still has problems at 7 and 11 m/s.

Further investigation of the distribution of wind speed was made examining the distribution of wind speeds to the nearest 0.1 m/s. A smooth trough shape at about 7 m/s reflects the problem noted. The tails of the distribution were corrupted by outliers, particularly the observations with product confidence values of 32. Though the trough at 7 m/s may be due to the differences between the northern and southern hemisphere flows, it was considered worthy of further investigation.

Broken down by latitude (figure 4) the lack of 7 m/s observations is less obvious, but still apparent. It seems unlikely to the author that this peculiarity of the data is due to synoptic features. Although it may be a peculiarity of the selection process, it seems more likely that the extraction of wind speeds from radar returns is in error.

Central Forecasting's work in monitoring wave height observations, has previously been limited chiefly to the development of the wave model verification scheme, using buoys. Some of the techniques applicable to buoy data can not be applied to radar altimeter data, as it involves analysis of wave spectrum from one point. The distribution of the selected data appears natural (Figure 7). Table 12, observed SWH mean and standard deviation broken down in bands on of the observed and background wave height, show that a few (less than 0.1%) spuriously large wave heights survived the selection criteria. Otherwise there are no obvious problems with the observed wave heights.

5. Summary and Conclusions

The radar altimeter wind speeds and wave heights available from ERS-1, which are available for use in the operational wave model, contain useful information as well as many corrupted observations. It is possible to eliminate the vast majority of corrupted observations, and unusable reports using the flags, and instrument mode information supplied by ESA. Using suggested criteria approximately 15,000 usable observations of wind speed and wave height a day are available.

Given the availability of scatterometer winds from ERS-1, the observed wind speeds from the radar altimeter, whilst of good quality, are of limited value to the atmospheric model.

6. References

Holt, M.W. 1992 'A re-calibration of the Wave Model', Short-range Forecasting Research Note, Meteorological Office (Bracknell)

Smith S.G. & Waters S.R. 1992 'Statistics of ERS-1 Scatterometer Winds for March 1992 (Including a comparison with ship Observations)', Central Forecasting Monitoring Note 8, Meteorological Office.

7. Appendix A

In this monitoring it was attempted to find which ESA supplied flags identified useful data. ESA set flags based on various conditions under which the instrument is not fully reliable (Table 1)

Table 1. Product Confidence (MDB Flag table 021198)

#	Value	Description
1	1	Bad Wind
2	2	Bad SWH
3	4	Bad Altitude (ESA Report Satellite Altitude in meters)
4	8	Bad Peakiness (Refers to radar return)
5	16	Checksum error (Refers to communication checks)
6	32	No HTL correction
7	64	<10 values (Refers to number of looks used)

Where no flags are raised the data elements normally contain zeros.

Flags 1 is set depending on the standard deviation of wind speed. See section in appendix headed 'Standard Deviation of Wind Speed'.

Flag 2, is difficult to judge, except for the 14 observations with a product confidence of 34, it is not seen to occur without other significant flags.

Where flags 3, or 4, are set the data are generally of poor quality.

No experience of data with flag 5 set.

Flag 6 refers to the 'Height Tracking Loop correction', when this correction is applied the data is of poorer quality. Note the flag is set when no correction is applied.

Product Confidence (PC)

Tables 2, and 3, show wind speed, and wave height, statistics against the product confidence. Use table 1 to interpret the product confidence. EG a PC value of 38 = 32 + 4 + 2, indicating ESA flags for 'No HTL correction', 'Bad Altitude' and 'Bad significant wave height'.

Observed values of wind speed are silly for product confidence values of 0, 4, 5, 12, 13, 46, 64. Similarly for wave heights of 0, 4 to 7, 12 to 15, 36 to 39, 44 to 47, and 64. Product confidence of 0 and 64 are normally associated with zero values for all observed quantities. By inspection it is seen that the 'Bad Altitude' flag is also a significant indicator of bad data. For many of these observations the altitude reported is zero, where as the satellite has a nominal height of 780,000 m. Data with checksum errors are not stored by the Meteorological Office.

Data with peakiness errors were excluded from the second set of statistics produced, this exclusion means data with a product confidence of 41 was not used, though these preliminary statistics do not show any obvious problems with this particular subset of data.

Instrument Mode

The radar altimeter has several different modes. All observations passing the selection criteria were from mode 'Track over Sea'.

Number in Average

As mentioned the two normal operating modes of the instrument give 17 or 20 looks over which an observation is averaged. There is little value in data with missing looks. We received no data with less than 10 looks (Excluding zero looks).

Standard Deviation of Wind Speed

The standard deviation of wind speeds represents the standard deviation over the number of looks, of the derived wind speed. Large values are associated with observations contaminated with looks over land or sea ice. As one might expect the standard deviation of the observed wind speed increases with the mean wind speed (Table 8). ESA appear to set the 'Bad Wind Speed' flag, based on a low threshold value of the standard deviation of wind speed. This excludes large amounts of data, as well as biasing the observations towards low wind speed situations. The standard deviation of forecast wind speed is of course lower in low wind speed situations.

Table 2

Wind Speed statistics broken down by product confidence for all observations.

	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
PRODUCT CONFIDENCE				
0	4315.00	0.06	-4.88	3.44
1	21.00	6.57	2.57	3.22
4	388.00	33.06	28.98	6.68
5	596.00	18.05	13.20	13.59
6	20.00	6.94	3.94	12.19
7	282.00	6.38	1.00	7.73
8	1.00	1.10	-2.40	.
9	6.00	4.93	1.15	1.75
12	82.00	30.04	26.14	11.23
13	700.00	15.51	10.86	14.29
14	41.00	5.07	0.38	12.70
15	232.00	9.17	4.32	12.16
32	8389.00	2.36	-1.28	1.78
33	109385.00	7.12	0.21	2.30
34	14.00	1.00	-2.63	1.77
35	34.00	4.21	-0.84	2.80
36	5161.00	5.65	2.21	10.82
37	47006.00	9.05	0.76	3.57
38	424.00	1.15	-2.00	5.12
39	1017.00	7.21	1.43	6.19
40	1888.00	2.01	-1.53	1.73
41	18010.00	6.57	0.15	2.20
42	6.00	0.23	-2.22	0.81
43	6.00	2.73	-1.45	2.09
44	1819.00	2.55	-1.04	7.69
45	7418.00	7.74	0.74	5.10
46	532.00	0.46	-4.94	5.51
47	811.00	4.46	-1.02	7.68
64	800.00	0.00	-4.57	2.86

For comparison, after removing gross errors:
Ships (March 1992) mean o-b WS = 1.4 m/s STD=3.2
ERS-1 Scat. Winds (October 1992) mean o-b WS = 0.1 m/s STD=2.1

Table 3

Wave height statistics broken down by product confidence for all observations.

	N	MEAN	MEAN	STD
	OBSERVED WAVE HEIGHT	OBSERVED WAVE HEIGHT	O-B WAVE HEIGHT	O-B WAVE HEIGHT
PRODUCT CONFIDENCE				
0	4315.00	0.04	-1.10	1.26
1	21.00	2.65	1.86	4.13
4	388.00	21.00	20.13	2.05
5	596.00	20.97	19.86	2.26
6	20.00	14.60	13.72	3.07
7	282.00	14.75	13.58	2.64
8	1.00	0.44	-0.04	.
9	6.00	2.07	1.15	0.68
12	82.00	20.72	19.79	3.03
13	700.00	21.12	20.12	1.49
14	41.00	16.74	15.67	3.14
15	232.00	17.30	16.13	3.52
32	8389.00	1.70	0.76	0.49
33	109385.00	2.32	0.65	0.72
34	14.00	2.12	1.46	1.30
35	34.00	3.35	2.17	2.54
36	5161.00	6.22	5.24	8.12
37	47006.00	3.83	1.43	3.81
38	424.00	8.51	7.71	6.18
39	1017.00	9.23	7.72	6.12
40	1888.00	1.64	0.75	0.47
41	18010.00	2.10	0.64	0.66
42	6.00	1.86	1.40	0.24
43	6.00	1.97	1.41	0.74
44	1819.00	7.83	6.86	8.98
45	7418.00	4.96	3.13	6.51
46	532.00	8.79	7.31	5.96
47	811.00	9.98	8.69	6.28
64	800.00	0.00	-1.00	0.90

Table 4

Wind speed statistics broken down by product confidence for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
PRODUCT CONFIDENCE				
1	1.00	4.10	0.80	.
32	8378.00	2.36	-1.28	1.77
33	109358.00	7.12	0.21	2.29
34	14.00	1.00	-2.63	1.77
35	34.00	4.21	-0.84	2.80

Table 5

Wave height statistics broken down by product confidence for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WAVE HEIGHT	OBSERVED WAVE HEIGHT	O-B WAVE HEIGHT	O-B WAVE HEIGHT
PRODUCT CONFIDENCE				
1	1.00	0.52	-0.19	.
32	8378.00	1.70	0.76	0.49
33	109358.00	2.32	0.65	0.72
34	14.00	2.12	1.46	1.30
35	34.00	3.35	2.17	2.54

Table 6

Wind speed statistics broken down by number in average for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
NUMBER IN AVERAGE				
17	3754.00	6.82	0.14	2.32
20	114031.00	6.78	0.10	2.29

Table 7

Wave height statistics broken down by number in average for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WAVE HEIGHT	OBSERVED WAVE HEIGHT	O-B WAVE HEIGHT	O-B WAVE HEIGHT
NUMBER IN AVERAGE				
17	3754.00	2.28	0.66	0.65
20	114031.00	2.27	0.66	0.71

Table 8

Wind speed statistics broken down by standard deviation of wind speed for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
STANDARD DEVIATION OF WIND SPEED				
0 TO .2 M/S	82651.00	6.14	-0.09	2.21
.2 TO 1 M/S	34908.00	8.30	0.55	2.42
>= 1 M/S	226.00	9.29	2.44	3.38

Table 9

Wind speed statistics broken down by 60 degree latitude bands for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
LATITUDE				
30S TO 90S	31859.00	9.00	0.44	2.93
30N TO 30S	59385.00	6.07	0.06	1.89
90N TO 30N	26541.00	5.71	-0.20	2.19

Table 10

Wave height statistics broken down by 60 degree latitude bands for selected observations.

	N	MEAN	MEAN	STD
	OBSERVED WAVE HEIGHT	OBSERVED WAVE HEIGHT	O-B WAVE HEIGHT	O-B WAVE HEIGHT
LATITUDE				
30S TO 90S	31859.00	3.11	0.57	0.93
30N TO 30S	59385.00	2.01	0.79	0.50
90N TO 30N	26541.00	1.85	0.46	0.75

Table 11

Wind speed statistics broken down by the mean of the observed and model wind speed for selected observations.

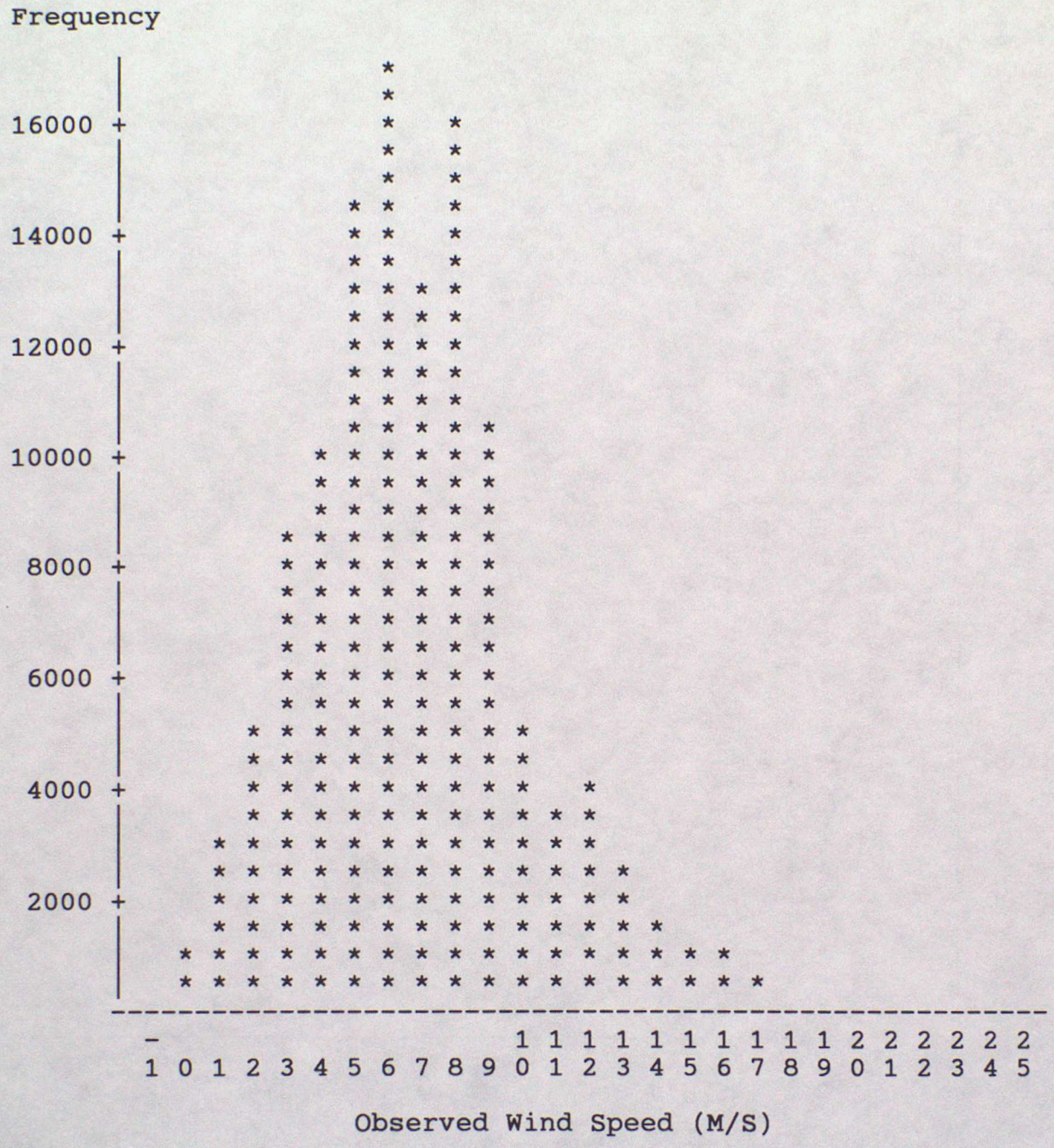
	N	MEAN	MEAN	STD
	OBSERVED WIND SPEED	OBSERVED WIND SPEED	O-B WIND SPEED	O-B WIND SPEED
MEAN OF O AND B WIND SPEED				
< 5 M/S	35042.00	3.57	0.11	2.36
5 TO 10 M/S	67481.00	7.18	0.06	2.15
10 TO 15 M/S	13782.00	11.96	0.27	2.72
15 TO 20 M/S	1480.00	16.41	0.60	2.42

Table 12

Wave height statistics broken down by mean of observed and model height for selected observations.

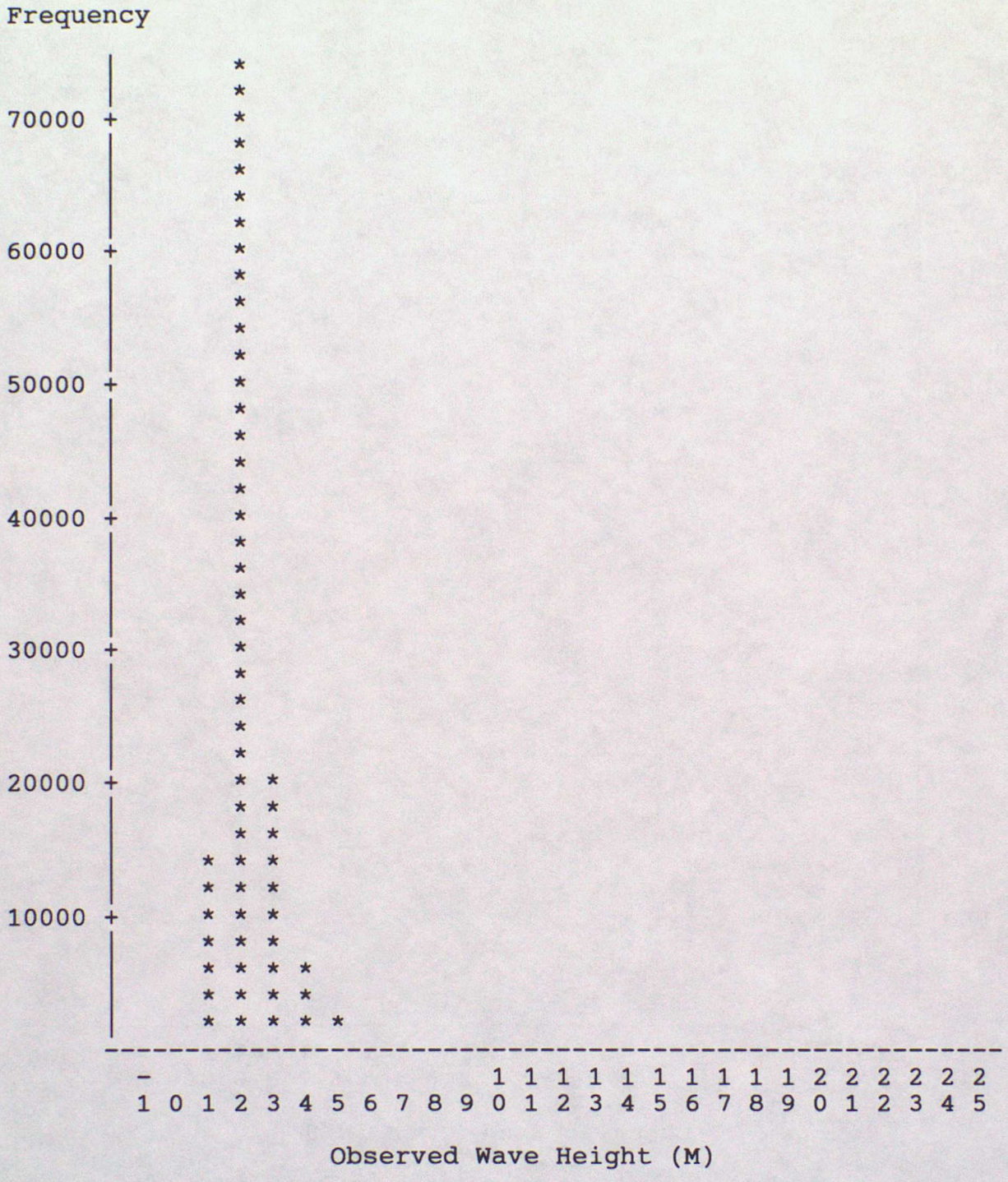
	N	MEAN	MEAN	STD
	OBSERVED WAVE HEIGHT	OBSERVED WAVE HEIGHT	O-B WAVE HEIGHT	O-B WAVE HEIGHT
MEAN OF O AND B WAVE HEIGHT				
0 TO 2 METERS	77912.00	1.83	0.77	0.43
2 TO 4 METERS	35070.00	2.88	0.48	0.85
4 TO 6 METERS	4372.00	4.71	-0.05	1.32
6 TO 8 METERS	407.00	6.55	0.09	1.74
8 TO 10 METERS	7.00	8.69	0.77	2.13
>= 10 METERS	17.00	21.20	20.45	0.42

Figure 1



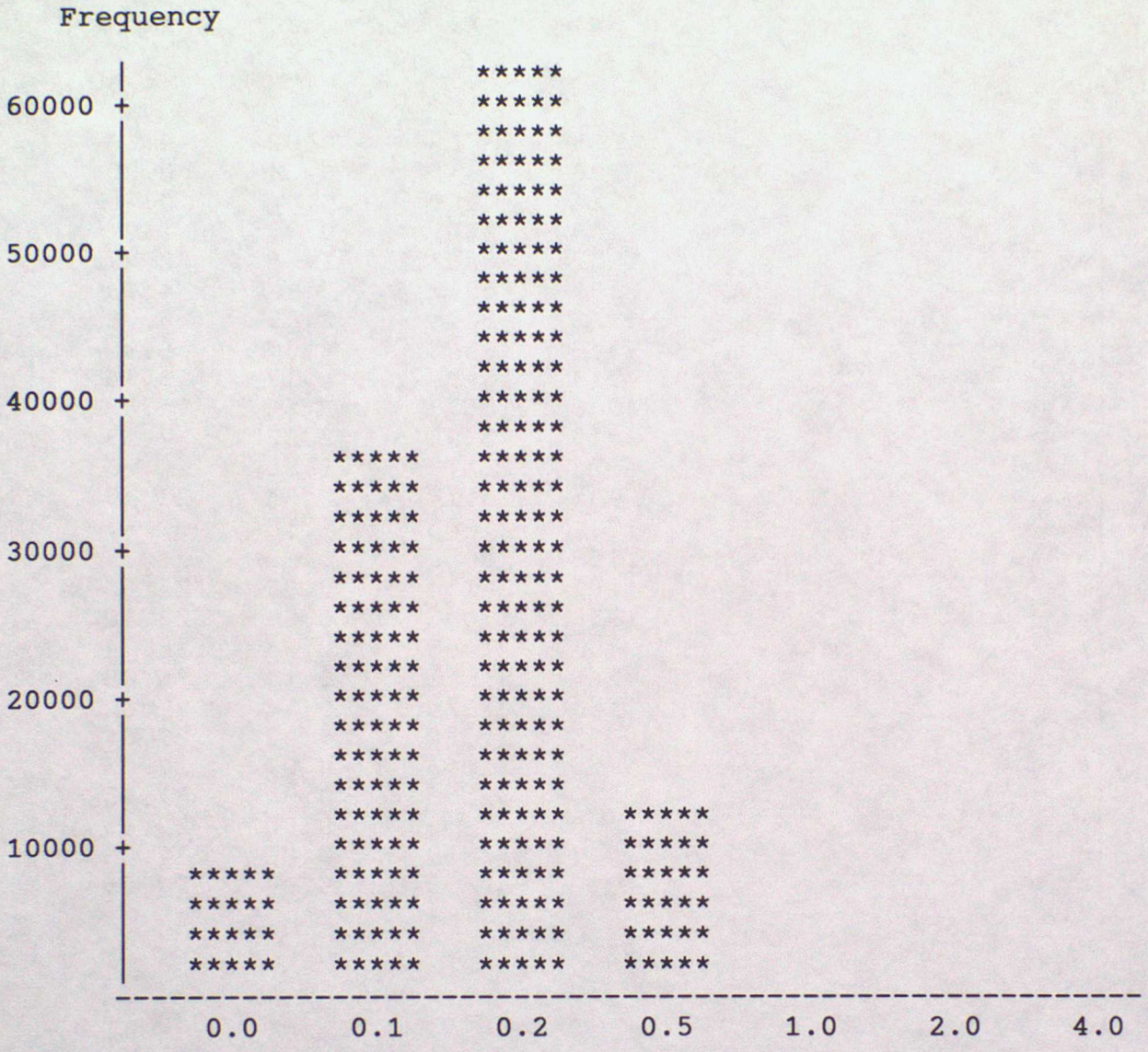
Distribution of observed wind speed for selected observations, to nearest whole M/S. Note the lack of 7 M/S observations.

Figure 2



Distribution of observed wave heights for selected observations, to nearest meter. On this scale the small number of spuriously high wave heights (~21M) are not represented.

Figure 3



Distribution of the standard deviation of wind speed for selected observations. Values on X axis are midpoints, hence 0.1 refers to values from 0.05 to 0.15.

Figure 4

LATITUDE Midpoint	Observed Wind Speed	Freq	Cum. Freq	Percent	Cum. Percent
30S TO 90S					
0	|	65	65	0.06	0.06
1	*	280	345	0.24	0.29
2	*	524	869	0.44	0.74
3	**	1140	2009	0.97	1.71
4	***	1252	3261	1.06	2.77
5	*****	2501	5762	2.12	4.89
6	*****	2463	8225	2.09	6.98
7	*****	2358	10583	2.00	8.99
8	**********	4914	15497	4.17	13.16
9	******	3080	18577	2.61	15.77
10	*****	2419	20996	2.05	17.83
11	****	2123	23119	1.80	19.63
12	******	2995	26114	2.54	22.17
13	****	1771	27885	1.50	23.67
14	**	1168	29053	0.99	24.67
15	**	1101	30154	0.93	25.60
16	**	938	31092	0.80	26.40
17	*	401	31493	0.34	26.74
18	|	168	31661	0.14	26.88
19	|	163	31824	0.14	27.02
20	|	25	31849	0.02	27.04
21	|	9	31858	0.01	27.05
22	|	0	31858	0.00	27.05
23	|	0	31858	0.00	27.05
24	|	1	31859	0.00	27.05
25	|	0	31859	0.00	27.05

....cntd

30N TO 30S

0	*	410	32269	0.35	27.40
1	***	1361	33630	1.16	28.55
2	*****	2476	36106	2.10	30.65
3	*********	4603	40709	3.91	34.56
4	**********	6009	46718	5.10	39.66
5	**********	8307	55025	7.05	46.72
6	**********	10866	65891	9.23	55.94
7	**********	8033	73924	6.82	62.76
8	**********	7930	81854	6.73	69.49
9	**********	5814	87668	4.94	74.43
10	***	1678	89346	1.42	75.86
11	**	761	90107	0.65	76.50
12	*	580	90687	0.49	76.99
13	*	360	91047	0.31	77.30
14		97	91144	0.08	77.38
15		54	91198	0.05	77.43
16		29	91227	0.02	77.45
17		7	91234	0.01	77.46
18		5	91239	0.00	77.46
19		4	91243	0.00	77.47
20		1	91244	0.00	77.47
21		0	91244	0.00	77.47
22		0	91244	0.00	77.47
23		0	91244	0.00	77.47
24		0	91244	0.00	77.47
25		0	91244	0.00	77.47

....cntd

90N TO 30N

0	*	344	91588	0.29	77.76
1	***	1271	92859	1.08	78.84
2	****	1965	94824	1.67	80.51
3	******	2943	97767	2.50	83.00
4	*****	2666	100433	2.26	85.27
5	*******	3723	104156	3.16	88.43
6	*******	3640	107796	3.09	91.52
7	*****	2687	110483	2.28	93.80
8	******	3024	113507	2.57	96.37
9	****	1839	115346	1.56	97.93
10	**	953	116299	0.81	98.74
11	*	531	116830	0.45	99.19
12	*	419	117249	0.36	99.54
13		219	117468	0.19	99.73
14		118	117586	0.10	99.83
15		60	117646	0.05	99.88
16		101	117747	0.09	99.97
17		26	117773	0.02	99.99
18		4	117777	0.00	99.99
19		4	117781	0.00	100.00
20		1	117782	0.00	100.00
21		1	117783	0.00	100.00
22		1	117784	0.00	100.00
23		1	117785	0.00	100.00
24		0	117785	0.00	100.00
25		0	117785	0.00	100.00

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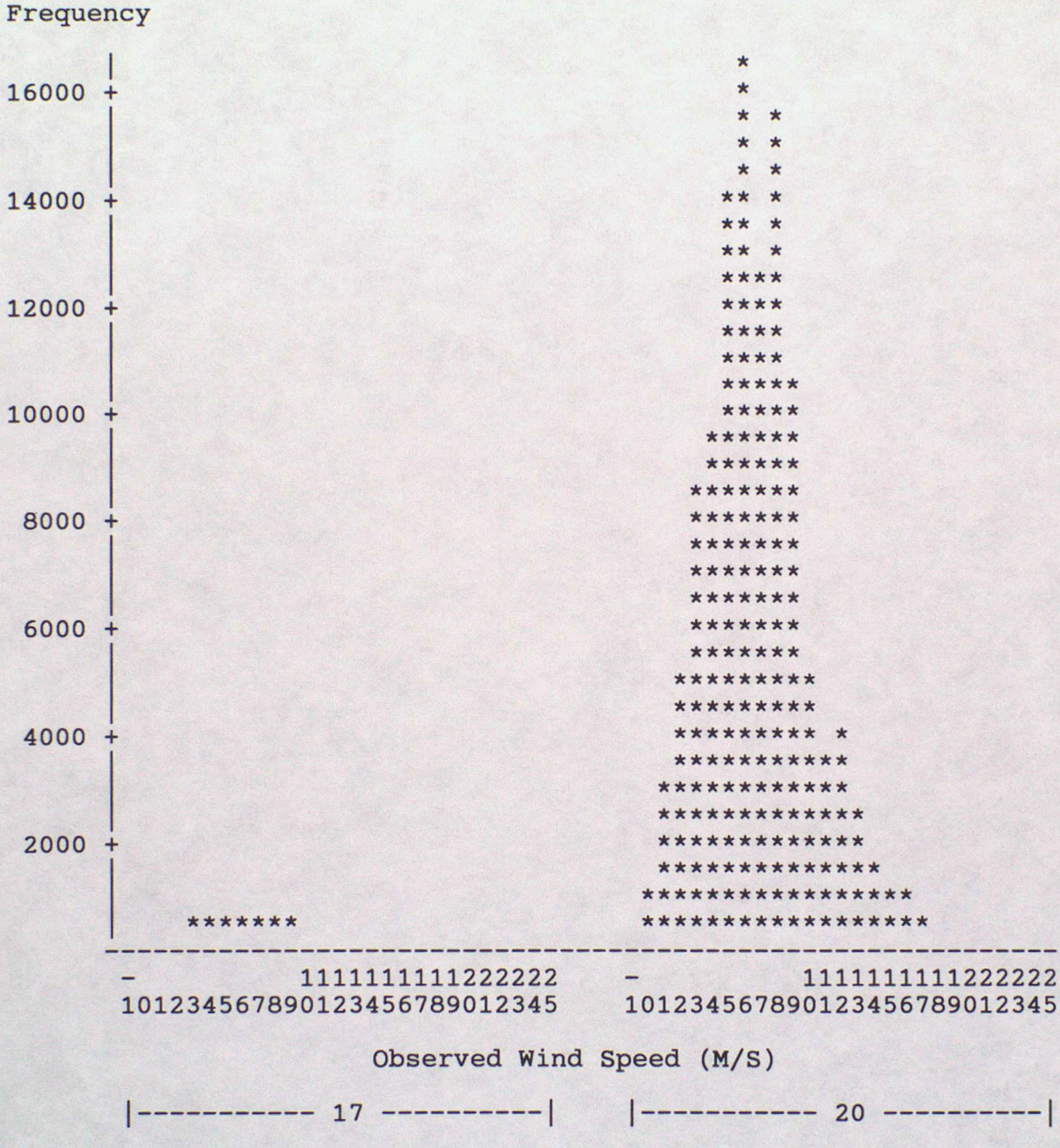
4000 8000

Frequency

Wind speed distribution for selected observations, broken down by latitude.

Figure 5



Distribution of observed wind speed for selected observations, broken down by number in average.