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**Corrections to the Seven Stones wave data
for 1978-1981**

by

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ABSTRACT

There appears to have been an error in estimates of significant wave height (H_s) and zero-up-cross period (T_z) from the Mk 1 Shipborne Wave Recorder fitted in the Seven Stones Light Vessel from May 1978 to July 1981. This document reports on a comparison of H_s and T_z values obtained simultaneously at Seven Stones and from a Waverider moored West of the Isles of Scilly which confirms the error. It concludes that estimates of T_z at Seven Stones from 1978 to 1981 should be increased by 18% and gives an expression for correcting the estimates of H_s .

1. INTRODUCTION

A study of significant wave heights and zero-up-cross periods (H_s and T_z) obtained from the Shipborne Wave Recorder (SBWR) fitted in the Seven Stones Light Vessel indicated a probable error in the values obtained between May 1978 and July 1981. The problem is well illustrated by Figs. 1 and 2 showing the scatterplots for 1979 and 1982. The former shows very steep waves, some with a significant steepness of 1/7, and only one value with $T_z > 11$ s. These figures suggest an error in values of T_z in the 1979 data sets. Any such error would also produce an error in the estimate of H_s because the correction which allows for the depth of the pressure sensors is dependent upon T_z (see section 2).

In this note we compare Seven Stones SBWR values with values, obtained at the same time, from a Waverider off the Isles of Scilly. This comparison confirms the error in the Seven Stones data for 1978-81, and suggests a correction factor to be applied.

2. SBWR RESPONSE

The wave heights measured by the SBWR have to be corrected for the response of the instrument's filters and for the depth of the pressure sensors below the sea surface. For the Mk 1 SBWR, fitted in the Seven Stones L.V. until it was replaced by the Mk 2 in July 1981, the correction factor F is given by Page (1973) as:

$$F = 0.83[1 + (8.8\omega)^{-2}]^{3/2} \text{ Exp}(2.5D\omega^2/g) \quad (1)$$

where $\omega = 2\pi/T_z$

and D = depth of the pressure measurements.

For the Seven Stones L.V. the value of D was 2.44m (8ft) prior to its 1981 refit and 2.6m afterwards. Because of these large values for D , F is very large for short period waves. For example, if $T_z = 4$ s then, with $D = 2.44$ m, $F = 3.9$.

Note that T_z is the value estimated by the SBWR. It would seem more appropriate to base the pressure depth correction upon T_p , the period corresponding to the spectral peak frequency; but the SBWR tends to overestimate T_z (giving a value closer to T_p) which Crisp (1987) finds is a reasonable period to use in (1).

The SBWR values also have to be corrected for any errors revealed by calibrations. A check of the Mk 1 system when it was removed in July 1981

indicated no change in the sensitivity of the pressure sensors, but revealed a change in response of the port and starboard accelerometers since May 1978 of -16.3% and -6.4% respectively with the accelerometers recording low (Wave Recorder Event Sheet dated 24 July 1981). An investigation by Gleason (pers. comm. 1984) failed to resolve when this calibration error was introduced. We shall assume that it was present from the time the instrument was installed. It is not possible to allow precisely for this error, which results in a component of the ship's motion in the recorded trace, but usually the mean of the accelerometer errors is applied as an approximate correction. Thus wave heights to July 1981 should be increased by a factor C given by

$$C = \frac{1}{2} \left(\frac{100}{83.7} + \frac{100}{93.6} \right) \approx 1.13 \quad (2)$$

3. THE DATA SETS

The Seven Stones L.V. is between the Isles of Scilly and Cornwall in about 60m water depth. The Waverider was moored west of the Isles of Scilly in a depth approaching 100m; the site was moved by about 2 miles in 1982. The locations are shown in Fig. 3. Thus the SBWR and the Waverider were about 25n. miles apart.

The Seven Stones data are at 3 hourly intervals throughout the period 1979-85, with H_s and T_z estimated from chart records ('Tucker/Draper' analysis). The Scillies Waverider data also covers 1979-85; in later years measurements were made at $1\frac{1}{2}$ hour intervals, but only those within $\frac{1}{2}$ hour of the synoptic hours (i.e. 3 hourly) have been used in this comparison. H_s and T_z were calculated from spectral estimates.

4. COMPARISON BETWEEN SBWR AND WAVERIDER MEASUREMENTS

4.1 Analysis

Because of the effect of an error in the SBWR estimate of T_z upon the estimate of H_s , it was decided to compare the simultaneous measurements from the two instruments by value of the SBWR T_z . Table 1 gives the means of the ratios of H_s at Seven Stones to that at Scillies for 1 second bands of T_z , and the similar means of the ratios of T_z . The calibration correction (equation 2) has not been applied to the 1979-81 Seven Stones wave heights. Note

TABLE 1

The ratios of H_s and T_z measured by a SBWR
 in the Seven Stones L.V. and by a Waverider off the Isles of Scilly
 for specified bands of T_z measured by the SBWR

SBWR T_z (s)	H_s S. Stones/ H_s Scillies				T_z S. Stones/ T_z Scillies			
	1979-July 1981 Nb	1979-July 1981 Mean	Aug 1981-1985 Nb	Aug 1981-1985 Mean	1979-July 1981 %	1979-July 1981 Mean	Aug 1981-1985 %	Aug 1981-1985 Mean
<5	283	1.62	120	1.85	10.3	1.07	1.7	1.12
5-6	911	1.34	471	1.47	33.3	1.09	6.7	1.22
6-7	834	1.20	1368	1.26	30.5	1.08	19.4	1.27
7-8	450	1.10	1862	1.15	16.4	1.08	26.4	1.30
8-9	187	1.03	1647	1.09	6.8	1.06	23.3	1.29
9-10	64	0.97	954	1.05	2.3	1.05	13.5	1.28
>10	9	0.95	638	1.02	0.3	1.03	9.0	1.27
All	2738	1.26	7060	1.17	100.0	1.08	100.0	1.28

TABLE 2

As for Table 1 but with corrected values of Seven Stones data

SBWR T_z (corrected)	H_s S. Stones/ H_s Scillies			T_z S. Stones/ T_z Scillies		
	1979-July 1981 Nb	1979-July 1981 Mean	1979-July 1981 %	1979-July 1981 Mean	1979-July 1981 %	1979-July 1981 Mean
<5	23	1.51			0.8	1.27
5-6	314	1.30			11.5	1.27
6-7	767	1.23			28.0	1.29
7-8	783	1.17			28.6	1.29
8-9	456	1.13			16.6	1.28
9-10	251	1.07			9.2	1.24
>10	148	1.05			5.4	1.24
All	2742	1.18			100.0	1.28

that a few questionable values in the data sets were revealed by examining those for which the ratio of the wave heights or the periods were greater than 3.0. Consequently, all such 'outliers' were omitted from the analysis. The total number and percentage of data in each SBWR T_z band are also given.

The table shows that over all T_z the ratio of H_s was about 8% higher in 1979-81 than in 1981-85; while the ratio of T_z was about 15% lower. For the long period waves, with SBWR T_z greater than about 8s, the estimates of H_s from the SBWR and the Waverider would seem on average to be in quite good agreement. The ratio of T_z appear not to vary with the T_z band.

4.2 Results

The SBWR T_z prior to 1981 - which Fig. 1 suggests are in error - are considerably closer to the Waverider values than the post '81 values. In fact such good agreement, particularly of the short period waves would not be expected because of the different responses of the instruments. Table 1 in Carter and Tucker (1986) shows that for a Pierson-Moskowitz spectrum with $T_z = 5.19s$, the effect of high-frequency cut-off leads to a SBWR T_z of 6.39s compared to a value from an instrument with a sharp cut-off at 0.5Hz (more severe than the Waverider) of 5.43s, a ratio of 1.18.

The analysis supports the contention that there was an error in the SBWR T_z for 1979-81. The method of estimating wave period with the instrument in use until August 1981 was based upon a time scale provided by the frequency of the ship's AC supply. This frequency was dependent upon the voltage of the ship's generated DC, and Trinity House now admits that the nominal voltage in the L.V. was probably not achieved (J. Driver, personal comm.). A reduction in voltage could explain the apparent under-estimation of T_z . (The new instrument fitted in August 1981 has its own inbuilt timing device.)

4.3 Correcting the 1978-81 Data

If the voltage of the L.V.'s power supply varied significantly then no correction for errors in individual periods is possible, but assuming an approximately constant voltage throughout the commission (May 1978-July 1981) then T_z during this time should be 'corrected' by $1.280/1.082 = 1.18$ (so that the mean ratio with the W/R measurements is the same as post 1981).

The value of H_s then has to be recorrected to adjust for the change in T_z in equation 1 and for the accelerometer correction, equation 2, by multiplying by a factor R given by

$$R = C \left\{ \frac{1 + (8.8\omega^1)^{-2}}{1 + (8.8\omega)^{-2}} \right\}^{3/2} \cdot \frac{\exp(2.5D(\omega^1)^2/g)}{\exp(2.5D\omega^2/g)}$$

where $\omega = 2\pi/T_z$

$$\omega^1 = 2\pi/1.18T_z$$

This reduces, with $D = 2.44m$, to

$$R \approx 1.13 \{1 + 0.000193T_z^2\} \exp(-6.9181/T_z^2) \quad (3)$$

where T_z is the uncorrected value.

The results of applying these corrections to the 1979-81 data set are given in Table 2. Note that the slight change in the total number of observations is a result of omitting outliers with ratios greater than 3 from the analysis.

The ratio of H_s are now closer to the values for 1981-85, except for $T_z < 6s$, with the overall ratio within 1%. The ratios of H_s for the larger period waves, which will include the high waves, are on average close to unity; the small variations (with the SBWR giving on average higher values of H_s) may be due to refraction and to differences in tidal streams at the two instruments, sited 25 miles apart. The larger ratios in H_s from the two instruments for shorter period waves is puzzling; it could be due in part to differences in tidal streams but probably result mainly from inaccuracies in the correction for the depth of the SBWR pressure sensors.

5. CONCLUSIONS

A comparison of H_s and T_z values from the Shipborne Wave Recorder (SBWR) in the Seven Stones Light Vessel and from a Waverider moored off the Isles of Scilly made between 1979 and 1985 confirm an error in the SBWR T_z values for the Mk 1 instrument in the Seven Stones L.V. from March 1978 to July 1981. This error could have arisen from a deviation in the Light Vessel's DC voltage.

Assuming a constant error, then comparison of the SBWR and Waverider measurements between 1979 and 1985 suggests that values of T_z during the 1978-81 commission should be increased by a factor of 1.18, to bring them into line with SBWR values from 1981 to '85.

The consequent correction to the SBWR values of H_s including an increase of 13% to allow roughly for a change in the accelerometer's response is given by equation 3. The application of this correction give values of H_s from the SBWR during 1978-81 which are consistent, when compared with Waverider values, with those from later years.

The comparison shows a considerable discrepancy between estimates of H_s from the SBWR and from the Waverider for short period waves (as measured by the SBWR). This is probably largely due to the crude correction that has to be made to the analogue data to allow for the depth of the pressure sensors, this correction is particularly large for short period waves measured by the Seven Stones L.V. in which these sensor are especially deep. However the estimates of H_s from the two instruments for the longer period waves, which would include very high waves, are in considerably better agreement.

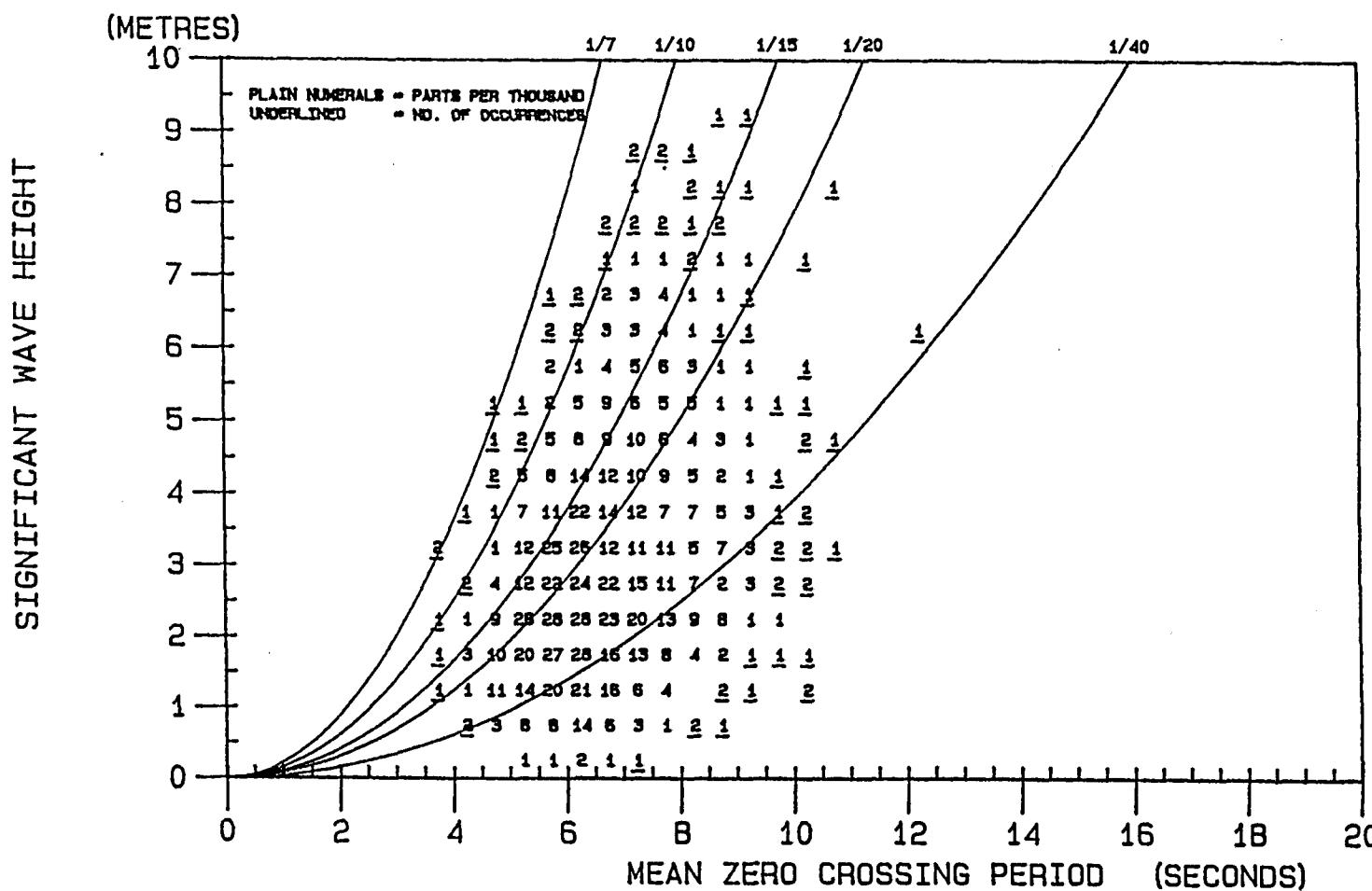
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M.I.A.S. DATABASE
MIAS/IN09/IST84071/SEV79

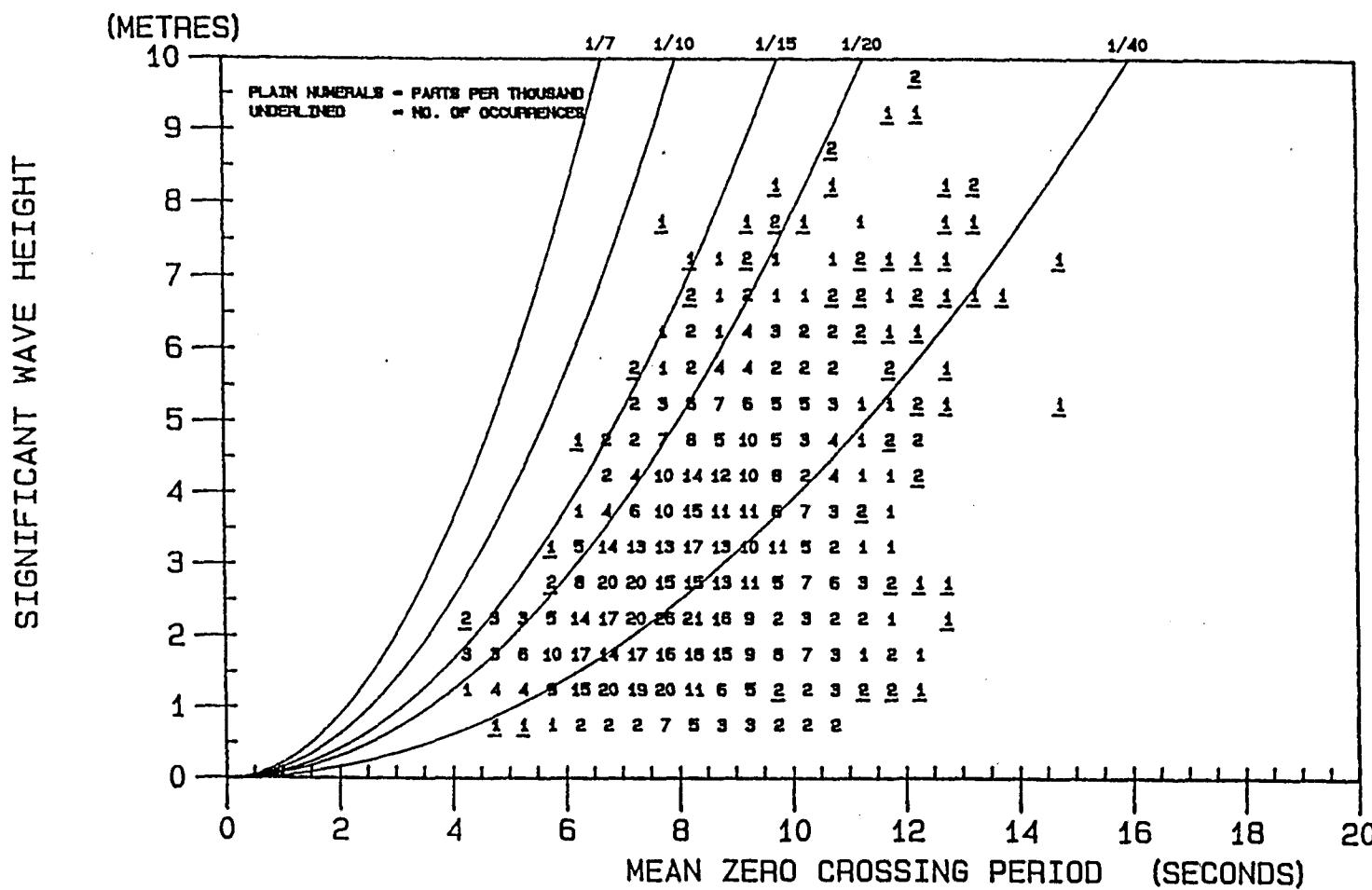


SEVEN STONES L.V. 1979
FROM 01 JAN 1979 TO 31 DEC 1979
NUMBER OF RECORDS = 2742
CALMS = 0. %
6 VALUES WERE OUTSIDE RANGE
PLOTTED ON 27 NOV. 1986

MIAS

Fig. 1

M.I.A.S. DATABASE
MIAS/IN09/IST84071/SEV82



MIAS

SEVEN STONES L.V. 1982
FROM 01 JAN 1982 TO 31 DEC 1982
NUMBER OF RECORDS = 2870
CALMS = 2.06%
1 VALUES WERE OUTSIDE RANGE
PLOTTED ON 27 NOV. 1986

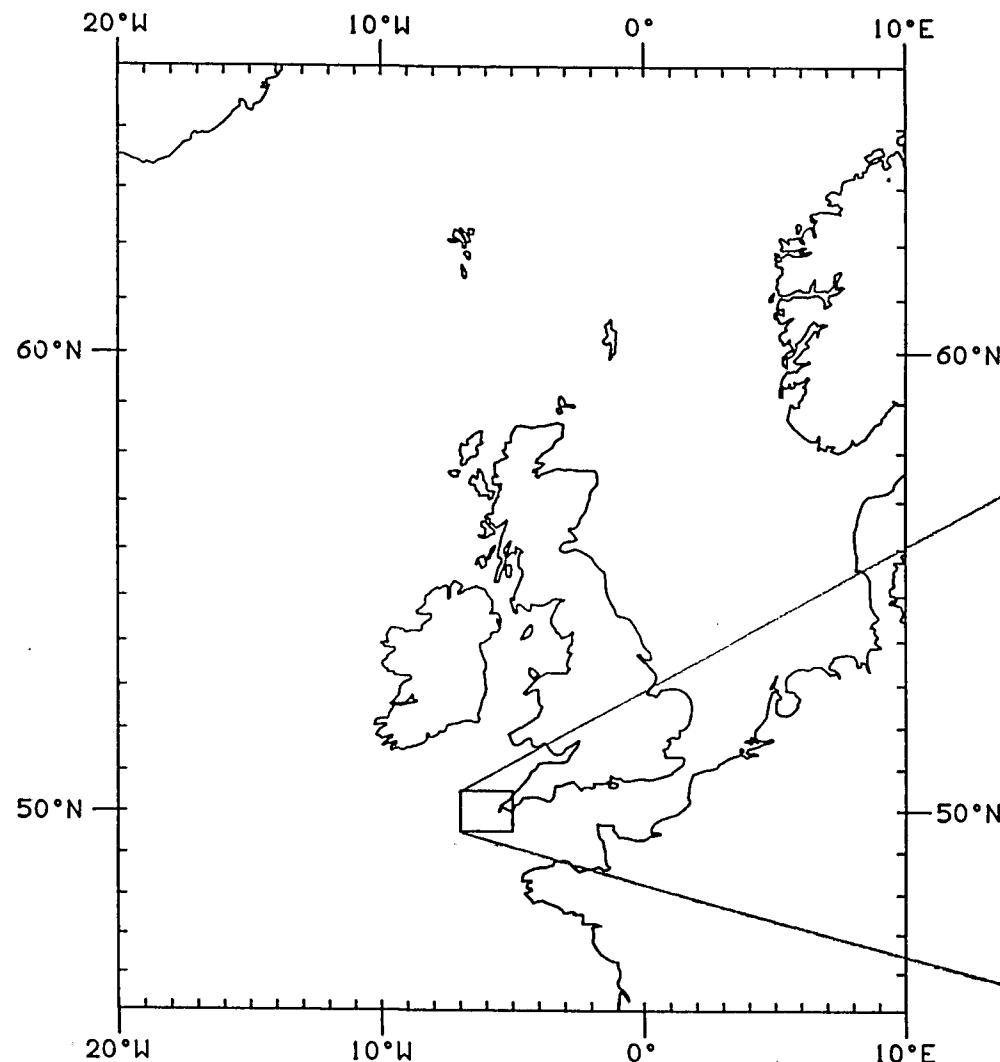


Fig. 3. Location of the Shipborne Wave Recorder (SBWR) in the Seven Stones Light Vessel and locations of the Waverider buoys (W/R) off the Isles of Scilly.

