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WAVE POWER LEVELS TO THE WEST OF THE OUTER HEBRIDES

NATURAL ENVIRONMENT RESEARCH COUNCIL

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INTRODUCTION

Analysis of the 399 wave spectra selected from the South Uist data set has indicated a probable long term average power level of about 48 kw/m at this location. This figure is substantially less than the original estimates made after consideration of wave data measured at OWS India (Salter, 1974; Glendenning and Count, 1976; Leishman and Scobie, 1975).

The present paper seeks to examine the degree to which the power level predictions based on the data measured at South Uist are representative of the general area to the west of the Hebrides.

The study is divided into two sections.

Firstly, for a period of twenty four days when simultaneous wave recordings exist for the original South Uist buoy location and for the new waverider now installed close inshore, wave powers have been calculated at each of the two locations and compared.

Secondly, an attempt has been made to transfer the OWS India wave climate, using information about directions of travel derived from visual wave observations, to the location of the South Uist buoy. The transfer operation involves modifying the OWS India climate to take account of the more restricted exposure of the S Uist area. This procedure may be expected to give approximate estimates of the power availability in the area to the west of the Hebrides.

1. COMPARISON OF INSHORE AND OFFSHORE DATA

Data obtained for the period 3 December - 27 December 1978 (24 days) consisting of 145 simultaneous wave records taken at the inshore and offshore South Uist sites have been used to calculate simultaneous wave power levels at the two sites.

The inshore buoy is positioned at:

057° 19.8' N
007° 27.2' W

and moored in approximately fifteen metres of water.

The offshore buoy is positioned at:

057° 18.7' N
007° 38.3' W

and moored in approximately forty-four metres of water.

The two sites are separated by approximately eleven kilometres.

Wave power levels were calculated for each of the measured spectra by the method outlined in Crisp 1978:

$$P = \rho . g . \Delta f . \sum_i E(f_i) . Vg_i$$

ρ = density of sea water

g = acceleration due to gravity

P = power/unit wave front

$E(f_i)$ = spectral intensity estimate at frequency f_i

V_{gi} = group velocity of component with frequency f_i

Δf = freq interval between spectral components

The resulting power levels are plotted in Figure 1.

It may be seen that the average power at the offshore site is approximately 2.5 times greater than that at the inshore site.

Winds during this period blew mainly from the eastern sector and, in view of the limited fetches in these directions, it must be assumed that the majority of the power was due to westerly swell. Similar comparisons performed for a period of twenty seven days of predominantly westerly winds in August and September 1978 gave an average power ratio of 3.1:1

Although these comparisons show a marked difference between power levels at the two sites, there is no indication of anomalous conditions at either. Similar power reductions for swells propagating between roughly equivalent offshore and inshore sites were recorded during the JONSWAP experiment (Hasselmann et al 1973).

2. TRANSFER OF OWS INDIA WAVE CLIMATE

In outline, the procedure employed was to use visual observations to determine how wave power at OWS India is distributed with respect to direction, and then to exclude from the data those directions which are shielded by land at the South Uist waverider location. The proportional reduction as obtained was then applied to powers deduced from instrumental observations.

The average power level calculated for the reduced set was then compared with the average power level calculated for the South Uist buoy data, after certain corrections had been made to both figures to ensure that like quantities were being compared.

Data and Analysis

Visual wave observations made at OWS India during the period 1962-1975 were obtained from the Meteorological Office in the form of annual height and period scatter diagrams for each of twelve direction sectors. The diagrams were compiled separately for sea and swell waves.

The histograms supplied were divided into two direction categories as follows:

directions which would be exposed at S Uist $195^{\circ} - 15^{\circ}$

" " " shielded " $15^{\circ} - 195^{\circ}$

The resulting arc of exposure is a generous one for the present South Uist buoy location, where the actual exposed arc is approximately:

190° to 5° for wind waves

205° to 5° for swell waves

The grouping of the wave data into 30° sectors by the Met Office precluded any closer representation of the actual exposure. The direction categories chosen, however, serve to enhance the generality of the result, since they are more consistent with a location some five to ten miles further West from the current location.

The original histograms were, then, condensed into four frequency of occurrence height and period diagrams, by grouping sea and swell waves into the two direction categories previously mentioned. (The distinction between sea and swell is not significant for the present application and need not have been preserved). These four diagrams describe the observed waves at OWS India in the following categories:

(a) Wind Sea waves which would be exposed at S Uist

(b) Swell waves " " " "

(c) Wind Sea waves which would be shielded at S Uist

(d) Swell waves " " " "

Mean annual power levels were calculated for each of these four categories, by applying the expression

$$P_{ij} = 0.49 \times 1.12 \times H_i^2 \times T_j$$

P_{ij} = power assoc with waves of significant height H_i, period T_j

to each of the height and period classes (H_i, T_j) of the histograms, whence

$$\bar{P} = \sum_{ij} P_{ij} . F_{ij}$$

$\bar{P}$ = mean power

F_{ij} = frequency of occurrence in class H_i, T_j

Results

The mean power levels for the four categories were as follows:

Power kw/m	As percentage of total	
(a) 30.06	39.3	Exposed at S Uist
(b) 22.87	29.9	
(c) 13.61	17.8	Shielded at S Uist
(d) 9.97	13.0	

Total: 76.51 kw/m

The resultant total of 76.51 kw/m is close enough to the reported range of annual mean power levels at OWS India to give some confidence in the form of the analysis. In assessing the implications for South Uist, however, only the percentage figures will be used in dividing the total annual wave power at India, as reported in other sources, into the various categories.

3. COMPARISON OF TRANSFERRED INDIA AND S UIST POWERS

India

Estimates of the long term average wave power at India vary from 77 kw/m (Salter, 1974; Glendenning and Count, 1976) to 91 kw/m (Mollison, Buneman and Salter, 1976). Both figures will be retained throughout the following comparisons.

Of the total annual power at India, 31% would be shielded by land at S Uist, the above figures then reduce to 53.3 kw/m and 63.0 kw/m. Before these figures can be compared with the measurements made at S Uist account must be taken of the fact that the India data were recorded using a shipborne wave recorder (SBWR) and the South Uist data a Datawell waverider (WR). A systematic discrepancy between the wave heights recorded by these two instruments has been reported (Graham and Verboom 1978). After comparison of data collected over 16 sensor-years they report that significant wave heights derived from SBWR measurements exceed those from WR measurements by an average of 8%.

The final annual power figures for direct comparison with South Uist data are therefore 45.7 kw/m and 54.0 kw/m.

South Uist

As with India, long term mean power estimates vary. Analysis of the 399 spectra, selected so that their associated wind records match the long term local wind distribution (Crabb 1978) yield a figure of 42.5 kw/m (reported by RPT). Mollison using a different bias correction technique reports 38 kw/m (reported by RPT).

Both of these figures have been calculated using the moment M-1 of the spectrum as a proportional indicator of power. This calculation incorporates a deep water assumption which is not justified, and a recalculation of the selected set power levels by the method reported in Crisp 1978 gives 47.8 kw/m; applying this increase of 12.5% to Mollison's figure gives 42.8 kw/m.

Summary

	Power kw/m Lowest estimate	Highest estimate
OWS India (transferred)	45.7	54.0
South Uist	42.8	47.8

Additional factors

At least four additional factors, not specifically taken into account so far, are also relevant.

(a) The wind climate at OWS India is more severe than at South Uist. This means that it is not sufficient, in transferring the India climate to South Uist, to simply exclude those wave directions shielded by land; but that the remaining power should also be reduced to reflect the less severe wind climate pertaining at South Uist. No estimate of the magnitude of this correction has been made.

(b) The transfer of the OWS India climate to South Uist involves not only excluding those directions to the east and south which would be shielded by land, but also an increase in the area of ocean to the west. Contributions of swell from these additional westerly regions may in part compensate for the loss of exposure in the other directions. The increase in the mean annual power level for the transferred climate which this implies has not been estimated.

(c) Selection of the 399 spectra has, of necessity, meant the exclusion of the most energetic but relatively infrequent sea states. If these could have been included, the estimated annual mean power level at South Uist would have been higher. RPT estimate that approximately 4 kw/m should be added to the present figure to allow for this fact.

(d) The effect of decreasing depth on moving from India to South Uist has not been considered, and water depths immediately to the west of the buoy site are such that no appreciable effect on power levels would be expected.

It would appear that the most likely combined effect of these factors would be to cause a relative increase in the South Uist power levels, and a decrease in the transferred India power. The overlap apparent in the range of estimates for the two locations could, in these circumstances, be increased.

4. CONCLUSIONS

The results of the comparison between inshore and offshore power levels are consistent with results obtained under similar conditions elsewhere, and show no evidence of anomalous conditions at either site.

A consideration of the OWS India data further suggests that no significant difference exists between the mean annual power level calculated for the measured data at South Uist and that which, within the accuracy of the present investigation, would be expected in the general area to the west of the Outer Hebrides.

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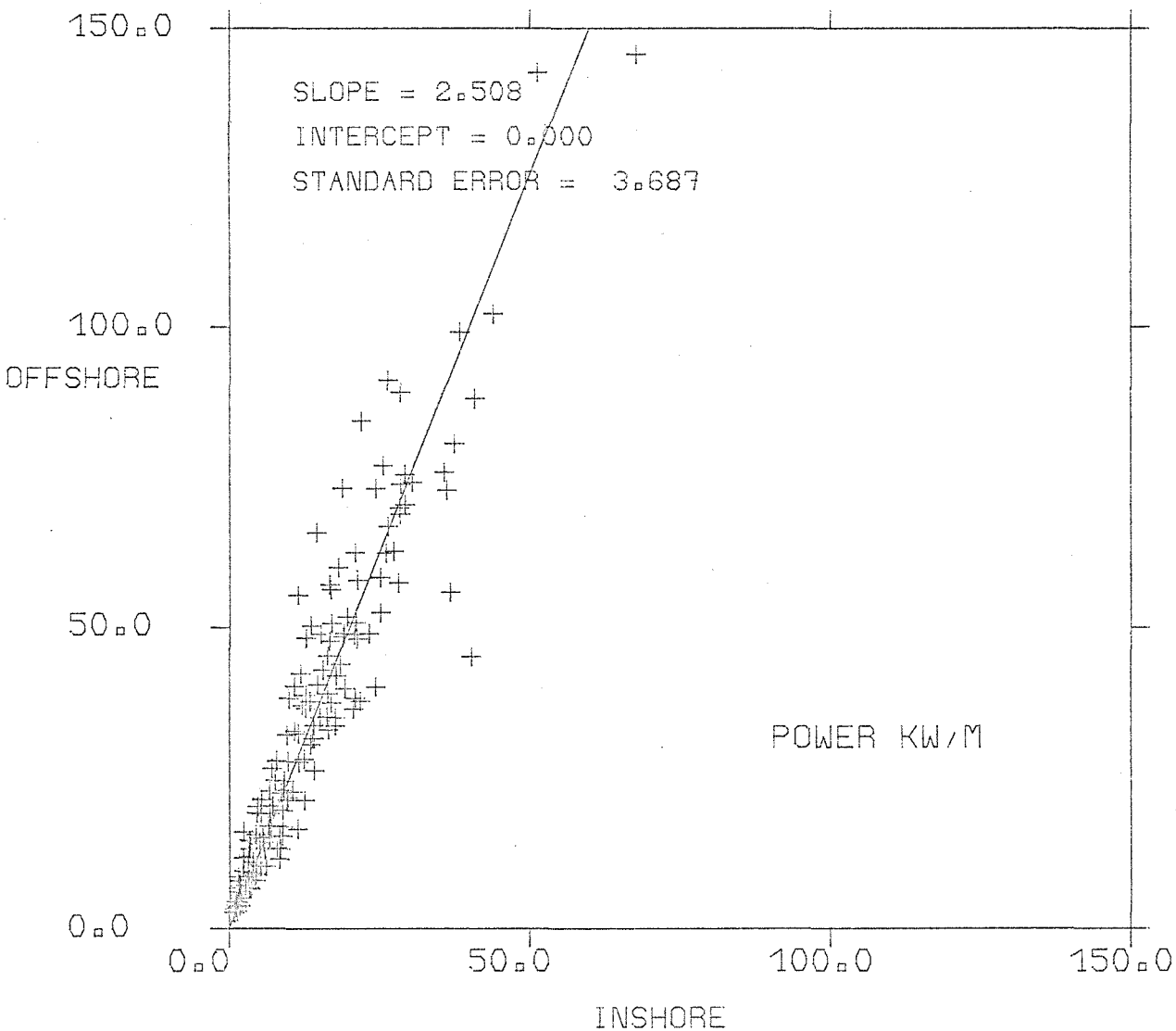

S.UIST INSHORE/OFFSHORE COMPARISON (BEST FIT)

FIG. 1