Hydraulics Research
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LONG TERM VARIATIONS IN SHORELINE WAVE CONDITIONS AROUND THE UNITED KINGDOM

- Interim Report

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ABSTRACT

An assessment is being made of long term changes in wave conditions around the UK coast, and how these changes may affect the management and planning of coastal defences. This interim report covers work done during the first year of a two year research programme which ends in March 1991. The first year's work involved a literature review, a review of long term wind and wave data, and establishment of research contacts. A longer final report on the project will be issued in about April 1991.

CONTENTS

1. INTRODUCTION

There is plenty of scientific evidence of very long term changes in the Earth's climate, occurring over tens of thousands of years. There is also some shorter term weather and wave data collected over periods of about twenty years from which to make a more objective study of changes during recent times. As to the future, there is much speculation, some of it well informed, about the effects and consequences of "greenhouse" warming. The majority of the published research concentrates on "global" effects, as opposed to specific local or national problems.

The present research programme was established specifically to look at changes in wave climate at the shoreline around the UK, and the consequences for coastal defences. The research was to include a review of changes during recent years (say from 1960 onwards), and, by extrapolation and numerical modelling, to estimate changes over the next fifty years or so.

The research is being carried out over a period of two years from April 1989 to March 1991. The present interim report covers work done during the first year of the project. Approximately 20% of the effort went into planning the project and carrying out a review of the existing literature. A further 20% went into establishing contacts with other organisations involved in similar work. Contact with the UK Meteorological Office at Bracknell turned out to be the most productive. Predicted global climate data was obtained from a simulation both of "present" conditions and of "future" conditions (represented by a doubled level of atmospheric carbon dioxide). Other contacts include the Institute of Oceanographic Sciences Deacon Laboratory, where MAFF sponsored research on wave climate change is also being carried out.

The remaining 60% of the effort was devoted to new mathematical modelling carried out at Hydraulics Research. About one third of this time was spent on developing and testing a method for simulating a long term sequence of wind records, based on short term or wind rose type data. The remaining two thirds of the time was spent on converting time series wind data into simulated coastal wave data, and analysing any resulting long term trends.

Chapters 2 and 3 of this report give a brief description of the results of the literature review, and of the numerical modelling, respectively. Chapter 4 looks forward to research to be carried out during the 1990-91 commission period. A longer report will be issued in about April 1991, covering the whole two year project in more detail.

2. LITERATURE REVIEW

The relevant literature falls neatly into two categories, namely that relating to well-documented past events, and that relating to expected changes in the future. Some is scientific, in other words an objective assessment of measured, or simulated or extrapolated data. Some is more speculative, fuelled in part by the apparent increase in the number of severe storms affecting the UK over the last few years.

There are many papers on climate change amongst the more general technical journals, and some journals and conferences specialising in information on global climate change. Also, since the subject is one of general public interest, there are regular newspaper, radio and television reports on the subject. The literature review has included a watching brief on all of these potential sources of information.

There are several sites around the UK where winds have been recorded over long periods. However, there are few where such records have been taken from a single site using a single type of instrument, and even fewer for long term wave records.

There is no real evidence of long term changes in average wind speeds around the UK over the last thirty years. However, there is some instrumentally recorded wind data suggesting that the west coast of Britain had slightly higher wind speeds fifty years ago than it does today.

The best set of long term instrumentally recorded wave data was collected at Seven Stones Light Vessel, starting in 1962. A tendency for the annually averaged wave heights to increase was first noted several years ago. However, a more recent report (S Bacon and D J T Carter, "Waves recorded at Seven Stones Light Vessel 1962-86", IOS Deacon Laboratory Report No 268) analysed the data more carefully, removing spurious trends due to changes in instrumentation, and looked separately at "average" and "extreme" waves. It appears that whilst increases in *average* wave height are quite noticeable, those in predicted *extremes* are less so. The explanation (first given by Dr N Hogben) is that wave activity in the Atlantic, which causes swell along the west coast of Britain, is increasing, leading to higher "background" wave heights along the coast. However, the most extreme wave heights and those causing damage to coastal defences, are usually associated with more locally occurring storms, and there is no particular evidence that these are increasing.

The suggestion that wave activity around the UK is increasing is supported by other wave measurements in the area. A Dutch reference (F M J Hoozemans and J Wiersma, "Is mean wave height in the North Sea increasing?", Rijswaterstaat Report GWAO - 89.004) shows the same trends over the period 1960-85, ie little change in wind speeds, but a steady increase in mean wave heights. However, it shows the highest waves of all occurring in the 1950's.

The apparent increase in the number of severe storms affecting southern England over the last few years has not yet been shown to be statistically significant.

There is general agreement that "greenhouse effects" will cause warming and an increase in mean sea levels (of the order of quarter to half a metre, globally averaged, over the next sixty years), and some evidence that such changes have already begun. However, the expected changes in winds, and consequently in waves, seem to be harder to predict. Tentative conclusions from models of future climate run at the UK Meteorological Office and in the USA suggest that wind speeds will not increase, and that they may even reduce slightly in some areas. However, such models are not yet good enough to make this a firm conclusion.

3. WAVE CLIMATE MODELLING

There are few continuous long spells of wave records around the UK or elsewhere, from which to determine long term variations in wave conditions. The present numerical modelling work was aimed at simulating several long time series of nearshore wave data for this purpose. These simulations were based on time series wind records, of 9 to 29 years duration, from several coastal weather stations around the UK.

It would be possible to study changes in wind climate (and by inference wave climate) simply by looking at changes in mean wind speed from year to year. However, this would neglect the importance of wind direction and of wind persistence in determining shoreline wave conditions. Instead the wind records were converted to equivalent sequential wave records using the Hydraulics Research HINDWAVE model, after which trends in wave height could be examined. However, this approach can only detect changes in the locally generated waves. It does not address the problem of long term changes in the intensity of distantly generated swell.

The longest UK coastal wind record, without change of site or instrument, and available in computer file format, is that measured at Rhoose (Cardiff Airport), from January 1960 onwards. This was used to simulate sequential wave data just offshore from Barry for a 29 year period 1960 - 1988. Figure 1 shows the significant wave heights expected to have been exceeded 1% and 10% of the time, and the mean values, during each calendar year. Although there are fluctuations, there is very little long term increase or decrease in wave height.

Figure 2 shows annually averaged significant wave heights from measurements at Seven Stones Light Vessel, for a roughly similar period of time. This plot shows an increase in average wave heights from 1962 to 1985. This leads towards the same conclusion as expressed in Chapter 2, ie that Atlantic swell may be increasing, but that locally generated waves are not.

Figure 3 shows previously unpublished data from Perranporth in Cornwall, held at HR. The graph shows significant wave heights exceeded 1% and 10% of the time, and mean values, for each calendar year from 1976 to 1985. There is a significant increase in wave heights between 1976 and 1984, at the 1% level. However, the rate of increase is reduced by the wave heights for 1985, which are the lowest of all (at the 1% and 10% levels) during the ten year period. The trend lines shown in Figure 3 suggest very little change in the commonly occurring wave conditions (10%> and mean values), but an apparent increase in the highest wave heights (represented by the 1%> trend line in Figure 3), from 1976 to 1985. It is interesting to note that this is the opposite conclusion to that to be drawn from the Seven Stones data, in which average wave heights were increasing more than extremes. However, there is insufficient length of data to draw any firm conclusion from the Perranporth data.

HINDWAVE was used to simulate coastal wave data for several further locations around the UK (in addition to Barry mentioned earlier), using wind data records already held at Hydraulics Research. The locations and dates are listed below:

Location	Source of wind data	Dates
Sunderland	South Shields	1976 - 89
Dowsing	Spurn Point	1978 - 86
Great Yarmouth	Gorleston	1974 - 87
Kentish Knock	Shoeburyness	1970 - 83
Littlehampton	Portland	1974 - 88
St Helier	Jersey Airport	1970 - 88
Barry	Rhoose	1960 - 88

Simulated significant wave heights were again assessed in terms of values exceeded 1% and 10% of the time, and mean values for each calendar year. Those at Sunderland decreased slightly during the period examined, by of the order of one per cent per year. Conversely, those at Dowsing, Great Yarmouth and Kentish Knock increased slightly, by of the order of one per cent per year. There was no upward or downward trend in results in Littlehampton, St Helier or Barry.

It is intended that future changes in shoreline wave climate will be handled in the way described above, except of course that there will be no measured wind records available for the purpose. General conclusions about changes in wind frequencies following global warming can be drawn from numerical weather models. It is hoped that such changes can be summarised in a simple form, for example that there will be 10% less winds from certain directions, but that the remaining winds will be 5% stronger. (Such changes could most easily be presented in the form of a pair of wind roses, for "present" and "future" conditions).

In preparation for this, a method of simulating time series data from wind rose data was developed. The method takes an existing time series of wind records (for example the 29 years of data from Rhoose), and the present and future wind roses. The differences between the two wind roses are broken down into a series of small component changes, which are then each applied in turn to individual hourly wind records. This method retains the sequencing of the original measured data (important for correct storm persistence data), whilst imposing the revised distribution of speeds and directions (the wind rose data).

The method is being validated against the long term records at Rhoose, (treating 1960-75 as "present", and then generating 1976-88 as "future", for comparison with actual 1976-88 records, etc). More details of this procedure, and some validation plots, will appear in the April 1991 report.

4. FUTURE WORK

The literature review and shoreline wave hindcasting described above will continue during the coming year. However, it will be done on an opportunistic basis, ie when it can be combined with other work, rather than as the main thrust of the research. From now on, the mathematical modelling (about 60% of the remaining resources) will switch to the use of weather data from models of future climate. The other 40% of resources will go towards assessing the effects of any expected changes on UK coastal defences, and on producing a final report.

The UK Meteorological Office at Bracknell run the only future global weather model outside the USA. The model has eleven levels of vertical resolution, a 5° North - South grid spacing, and a 7½° East - West grid spacing. (This means that the UK is represented by only two or three grid points in the model). This is far too coarse for the type of shoreline wave hindcasting described in Chapter 3. However, it should be adequate to describe changes in average wind conditions over the period covered by the model.

Hydraulics Research has already purchased data from the Bracknell model. This information comprises average daily surface pressures and wind velocities for a one year period for "present" and for "future" conditions (defined by doubled carbon dioxide levels), for each grid point covered by the model.

During the coming year, this data will be analysed with the following objectives:-

(1) Determine how average wind conditions may be expected to change around the UK. Simulate a future time series of hourly wind velocities and of coastal wave conditions, as described in Chapter 3. Assess any changes in wave heights.

(2) Determine how average wind conditions may be expected to change over the Atlantic. Assess whether or not the trend of increasing Atlantic swell will continue into the future (possibly repeat for the North Sea).

(3) Determine how average pressures may be expected to vary around the UK. This may have an influence on average water levels around the UK.

The Meteorological Office is currently developing a future global climate model with better resolution than the one described above. Hydraulics Research will maintain contact, and if appropriate and available by about the end of 1990, will request data from the new model.

Satellite ocean wave data is available for the sea area around the UK, going back to about 1985. This is probably not sufficient to be able to draw any long term conclusions about wave climate change. However, contact will be maintained with the Deacon Laboratory, where trends in the satellite wave data are being studied.

The assessment of the effect of the changes upon coastal defences will address the problem of increasing water levels, as well as that of changing wave conditions.

5. ACKNOWLEDGEMENTS

The numerical work was carried out by Miss Carol Jelliman. Advice and enthusiasm was contributed throughout the project by Dr Alan Brampton and Mr John Ewing.

Thanks are due to Dr Howard Cattle and Mrs E M Taylor of the Meteorological Office at Bracknell, for their co-operation and for supply of data from the Global Climate Model.

Figures

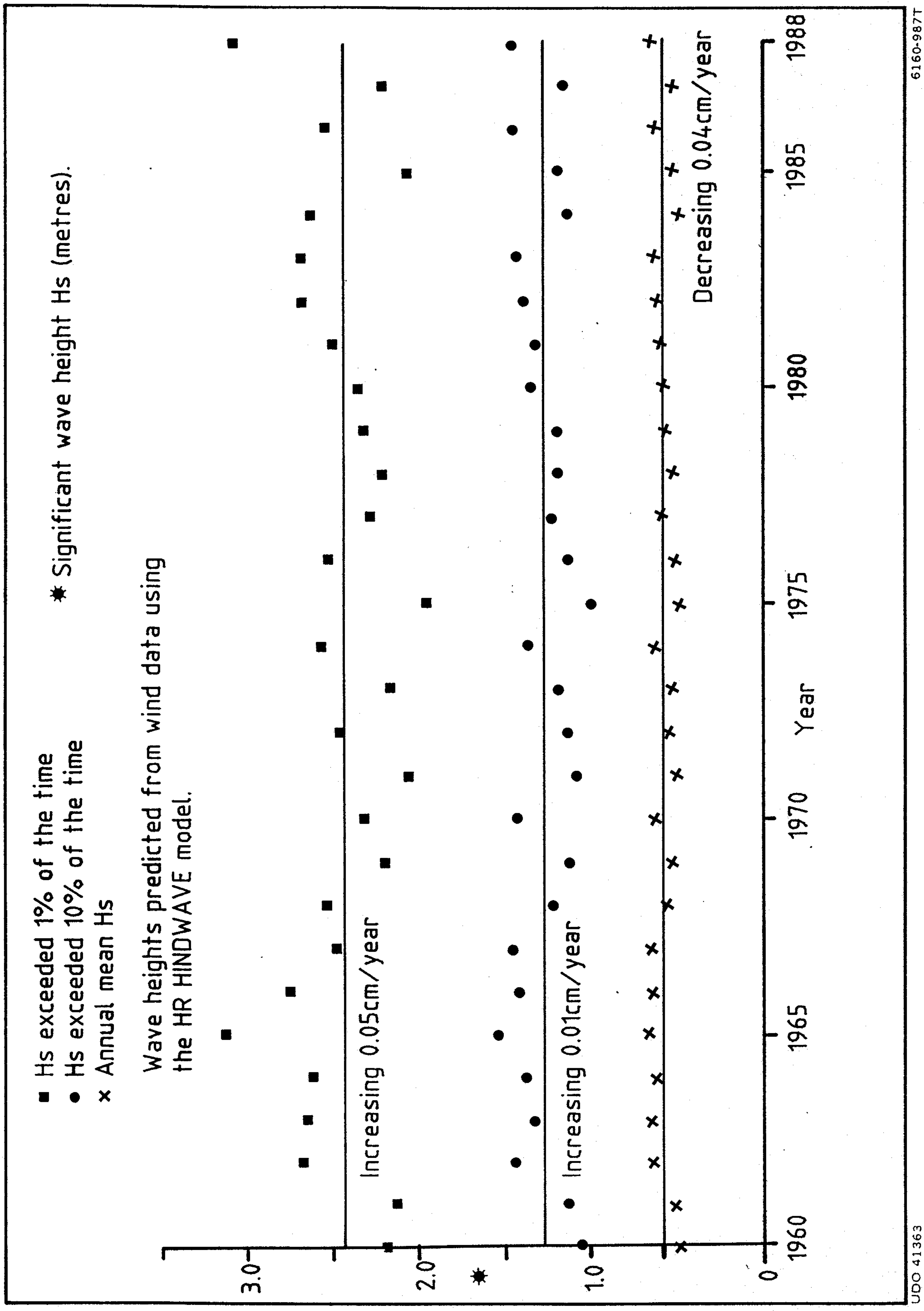

Fig 1 Variation in annually averaged Hs - Barry 1960 - 88.

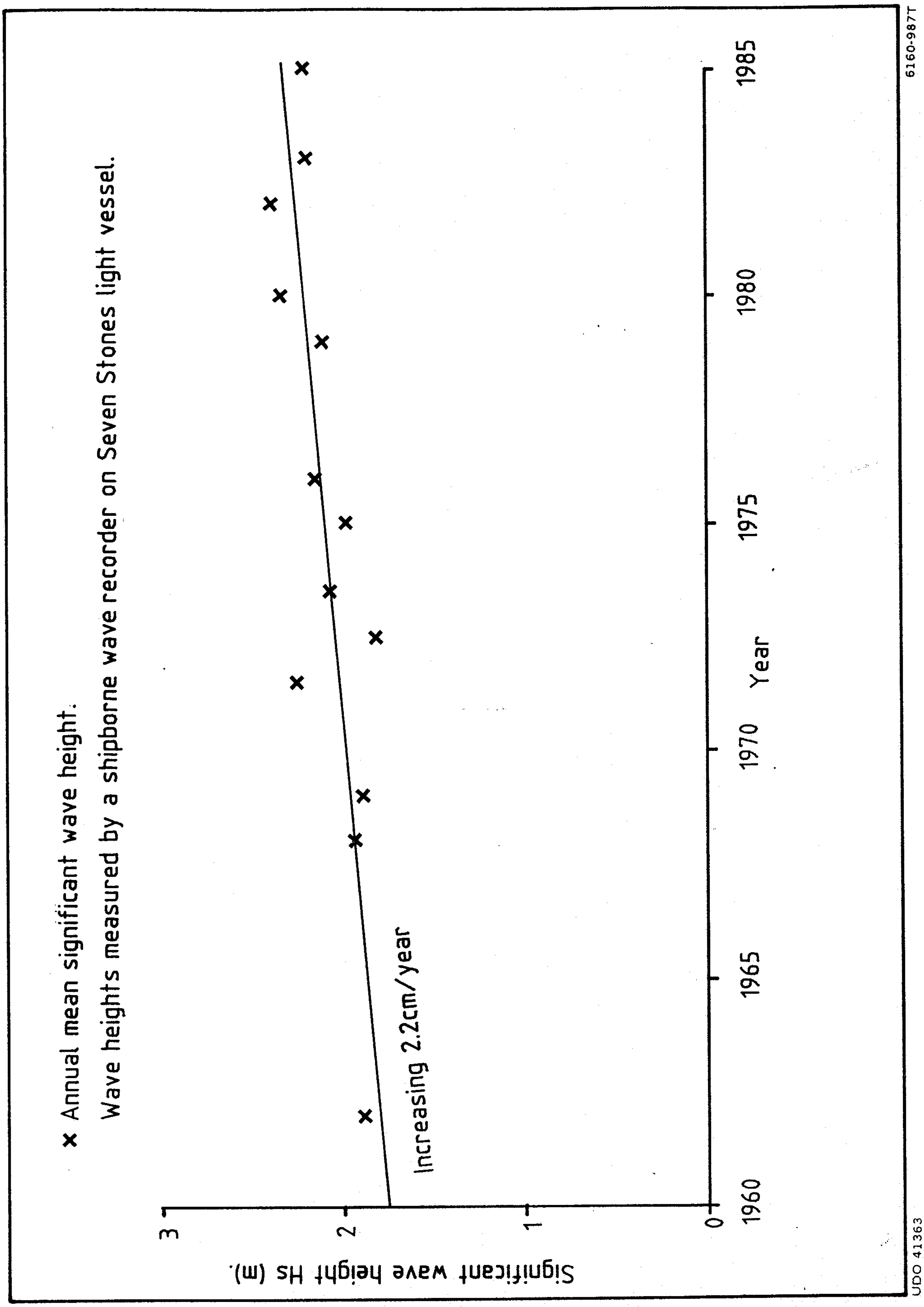

Fig 2 Variation in annually averaged Hs -Seven Stones 1962-85.

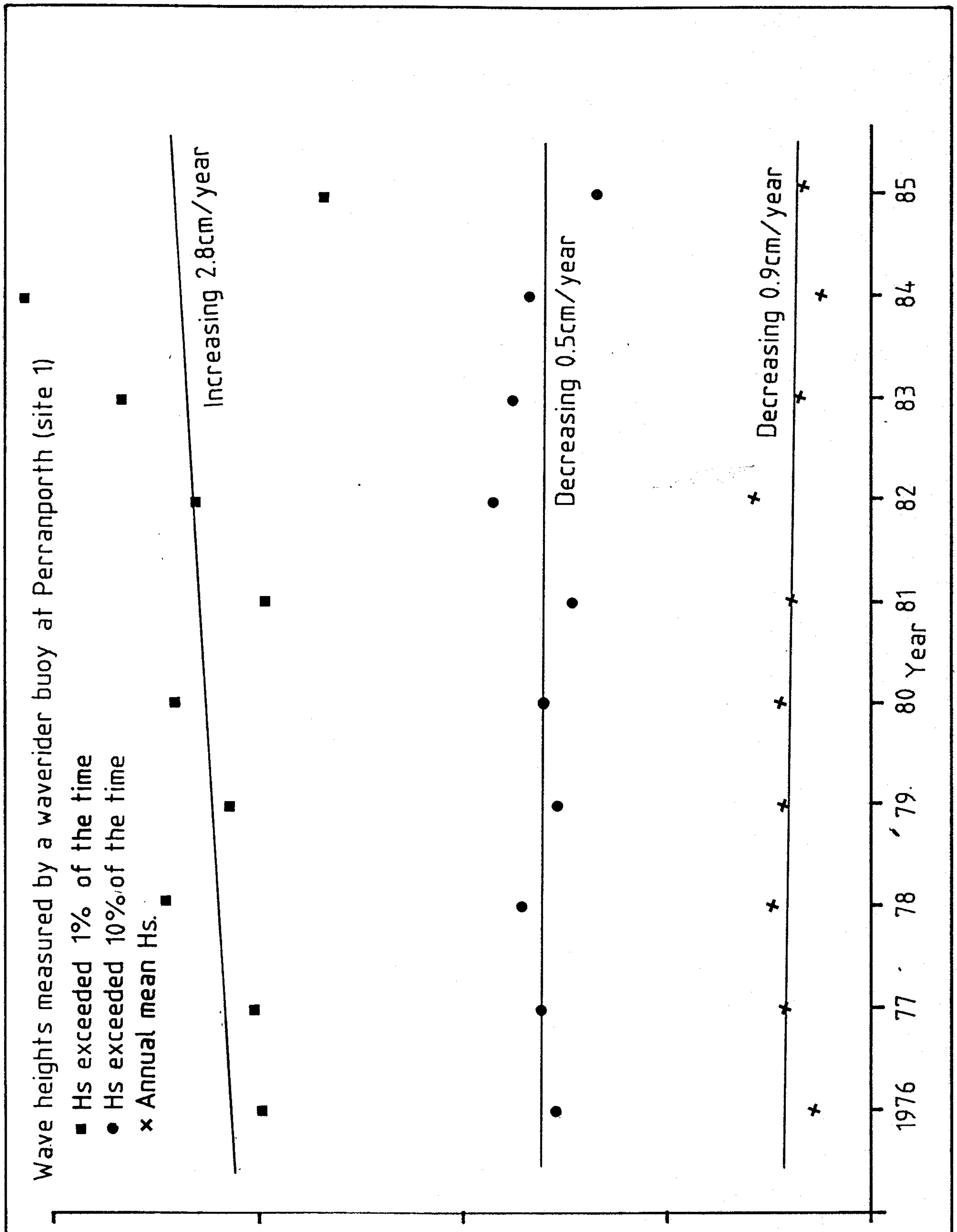

Fig 3 Variation in annually averaged Hs - Perranporth 1976 - 85.