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DIRECTIONAL WAVE RECORDING

Report to Wave Energy Steering Committee
TAG II
on
A survey of available techniques and
recommendations for action

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(042-879-4141)

(Director: Professor H. Charnock)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051-652-2396)
(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823-86211)
(Assistant Director: M.J. Tucker)

Marine Scientific Equipment Service
Research Vessel Base,
No. 1 Dock,
Barry,
South Glamorgan, CF6 6UZ.
(04462-77451)
(Officer-in-Charge: Dr. L.M. Skinner)

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M J Tucker and J S Driver
Institute of Oceanographic Sciences
Crossway
Taunton
Somerset

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by

M J Tucker and J S Driver
Institute of Oceanographic Sciences

1. Introduction

TAG II has identified the need for directional wave spectra measured on a routine basis, and its Chairman (R C H Russell) wrote to IOS on 9 June 1978 requesting "an assessment of the two pitch-roll buoys that were available, a French toroidal buoy and the DABS-3M buoy, on the assumption that TAG 2 would wish to see one deployed fairly soon". In the event neither seemed immediately suitable for TAG II use, so that the assessment was widened to cover the whole situation and to include recommendations for action by TAG II.

2. General

2.1 Sensor system

For routine recording in the open sea within the next two years or so, it is impracticable to think in terms of anything other than a pitch-roll-heave buoy system, and this study is therefore confined to such. However, the authors feel that TAG II should lend at least its moral support to the development of improved systems for the more distant future.

The only suitable proved sensor available at present is that developed by Datawell in the Netherlands. All buoys of which the authors are aware use this sensor. It uses the Waverider passive inertia-stabilised platform together with sensors which measure the angular displacement relative to the case on two horizontal perpendicular axes. The heave accelerometer has to be mounted on a separate platform and, of course, a remote reading compass must be used to measure the position of the sensor axes relative to North/South.

This leads to a fundamental conflict in hull design. On the one hand, in order to respond to high frequency waves, the buoy hull must respond rapidly to changes in wave slope. On the other, a buoy which does this is easily turned over by breaking waves. It is by no means certain that a satisfactory compromise is available for TAG II work, but some amelioration can be achieved by more sophisticated data processing techniques (see below).

There are possible ways round this problem, but they involve the development of new sensors, which cannot be achieved and proven on the time scale considered in this study.

2.2 Data-processing and recording: general considerations

For practical reasons, all routine wave recording systems so far have used a sampled regime, typically leading to spectra with the following characteristics:

Sampling interval: 3 hours (10,800 s)

Sampling period: 1000 s

Separation of energy density estimates: 0.01 Hz

Standard deviation of sampling error of estimates: approx 30%

Many people feel that wave conditions change significantly within a 3 hour period, that the frequency resolution at the long period end of the spectrum is grossly inadequate, and that a 30% sampling error can hardly be regarded as satisfactory. In principle, ten times more information is available, but the amount of primary data involved is so great that it is impracticable to handle it on a routine basis if it all has to be recorded and then subsequently analysed by present techniques. However, microprocessors have just about reached the stage where it seems to be practicable to do the first stage of data reduction on board the buoy, and this should enable a much higher proportion of the available data (possibly all of it) to be used.

It is probably still not practicable to telemeter the primary data ashore and use microprocessors to handle it there, because in our experience most of the data corruption takes place in the telemeter system. This type of error is almost impossible to deal with using a 100% automatic system. On the other hand a system which reduces data and then records it on board is bound to be more or less unreliable. We consider it therefore essential that if an on-board processing system is developed, it should be backed up by telemetry of the primary sensor output with sampled recording on shore. Such records would also be extremely useful for diagnostic work.

2.3 Primary processing

Slopes must first be converted to N-S and E-W components.

Compution of directional spectra then requires initially the computation of auto and cross power spectra of the two slopes and heave. This is usually achieved via segmented FFT techniques. Even if we ask for hourly computations to a frequency resolution of 0.005 Hz, this reduces the total amount of data by a factor about 40 (depending on whether we can, for example, allow coarser frequency resolution at the higher frequencies). It seems likely that it will be just feasible to record the data reduced to this stage for 1 month aboard the buoy.

If the buoy/sensor system were perfect, some of these auto and cross spectra are either redundant or zero. However, useful checks on sensor performance can be obtained from the "redundant" auto spectra, and a real buoy produces phase and amplitude errors in the roll/wave slope response which can be both detected and partially corrected if all the spectra are available. Such techniques should enable one to extend the useful upper limit of high frequency response very significantly.

2.4 Final processing and presentation

Even if the first stage of processing is done automatically aboard the buoy, the amount of data which has to be processed and presented is still formidable. This problem is being tackled by W S Atkins and Partners in cooperation with IOS for the data from DB1. This buoy is being operated by the Seatek consortium under contract to UKOOA, and clearance will have to be obtained if TAG II wishes to have access to this work.

2.5 Quality Control

IOS experience in the field of routine environmental recording has underlined the necessity for a good system to control the quality of data. As much as half of the data which would have been generated and passed by the commercial standards of a few years ago has been shown to be badly in error. Of course, this work has led to improved standards of calibration, deployment and maintenance, but a reliable quality-checking procedure is still essential.

In the present case four routine checks are desirable.

(a) The ratio of the spectral estimate at .03 Hz to the total energy present. There is never appreciable wave energy in the sea at this frequency, but a whole class of instrumental faults produce spurious low frequency energy.

(b) The ratio of the highest frequency estimates to the total energy. High frequency energy in the sea is low, and indeed, the input frequency component at half the digitising frequency must be arranged to be negligible if aliasing is to be avoided. However, corruption of the data after digitising produces high frequency energy, which is detected by this check parameter.

(c) The sum of the slope auto-spectra should bear a known relationship to the heave spectrum.

(d) The phase between the slopes and heave is calculable from the cross spectra. Together with the (c) parameter above, this enables a check to be kept on the frequency response characteristics of the buoy hull (and sensors, if relevant).

3. Buoys available or under active development

3.1 Nereïdes/Technimer Oceanometeorological Toroidal Buoy XM 25
This was advertised at Oceanology International 78. At the request of one of the authors, Nereides subsequently sent us further information. The buoy appears to be manufactured by a firm called Technimer and marketed by Nereides, but the precise position is not clear: they may even be the same firm.

The wording of the brochure led us to suspect that the buoy was only partly developed, and we wrote on 22 June asking (amongst other things) as to how much operational experience they have had. At the time of writing (16 August) we have received no reply. We have also since learned by a roundabout route that they have ordered a pitch/roll/heave sensor from Datawell of a type which has only started production in the last few weeks, and this seems to be the first directional sensor ordered.

The buoy hull is toroidal with an overall diameter of 2.5m. The recording and processing system records only wave parameters, including the frequency spectrum. They claim that they can telemeter on HF, VHF, UHF or via satellites.

The only information we have about the directional calculations are that it calculates "wave direction average", which we take to mean the direction of the major axis of the slope vector scatter ellipse.

We do not consider this buoy suitable for TAG II use for the following reasons:

(a) It seems clear that it is not fully developed

(b) Toroidal buoys have become notorious for turning over in severe seas (see 2.1 above).

(c) The full directional spectrum is not calculated

(d) No raw data is either recorded or transmitted.

It is possible that the last three snags could be overcome, but it would be a major development programme.

3.2 Datawell are developing a wave-direction buoy but full details seem to be a commercial secret at the present time. They hope to have a prototype in operation in the first half of 1979.

Knowing Datawell, the system will probably be well designed and reliable, but will not be available as a tested system until 1980 at the earliest. We also suspect that it will telemeter raw data only, but this is not clear.

3.3 Hagenuk. UK agents, Hurst Equipment Ltd.

While Hagenuk manufacture buoys which record wave height, so far as we can discover they make no buoys which measure wave direction.

3.4 Marex

Marex disclaim interest in extending the capability of their buoy system to measure wave direction.

3.5 Offshore Environmental Systems Ltd (a member of the Decca Survey Group)

This firm is very keen to develop the CNEXO BP77 buoy system into a commercially available product, including a wave direction measurement capability. However we do not know how they propose to do this since the BP77 is a spar buoy which seems to us to be entirely unsuitable for this purpose.

3.6 Seatek

We have left this consortium to last since it seems to us to offer the most promising approach. In DB1 they have, so far as we are aware, the only operational routine wave direction measuring buoy in the world. Of course, this buoy is too expensive for TAG II to use because of its specification (TAG II requires less endurance, shorter-range telemetry, and fewer parameters). Also, mainly because of its size, its high-frequency response is inadequate for TAG II. However, it means that Seatek have unmatched experience of operating a directional wave measuring system, including analysis and presentation of the data. They are also extremely keen to produce just the sort of buoy that TAG II requires.

The buoy hull they propose to use is the semi-discus DABS-3M (this code means Data Acquisition Buoy System - 3 metres diameter).

It has been used for some time by Trinity House as a navigation buoy, and its survivability is therefore to some extent proven.

This hull highlights the conflict described in section 2.1 between speed of response and survivability. It has been tank tested with a three-point mooring system which ensures survival, but gives it a poor high-frequency pitch response. Following discussion with one of the authors, we understand that they will be trying a modified mooring system which should greatly improve the pitch response without prejudicing survivability. However, as we said in section 2.1, it is unlikely that a wholly satisfactory compromise can be achieved.

In this hull they propose to mount the Datawell sensors, and are keen to develop an on-board data processing system. However, this has not yet been done.

Seatek do not propose to sell their buoys, but to operate a data gathering service using the buoys. In such an arrangement the customer pays according to the amount of reliable data produced. In our experience, if the contract is properly drawn up, this can be a satisfactory system.

4. Our suggestion for action by TAG II

4.1 It is clear that no suitable buoy exists or is in a sufficiently advanced state of development to allow deployment by TAG II in the near future. However, all is not lost since it seems to us that a reasonably satisfactory interim system can be assembled from existing tested components. This would take a buoy hull such as DABS-3M, fit it with Datawell pitch/roll and heave sensors, a digital or analogue transmitting compass such as the one used in DB1,,and telemeter these 4 channels continuously over a 27 MHz link using the Waverider type of modulation with a slightly more powerful transmitter to give about the same signal/noise ratio. The standard receivers used with Waveriders can easily be adapted to receive these 4-channels, and the IOS standard data-loggers were designed with recording such signals in mind. This can be done on the usual 1024 s every 3 hours sample basis, when a tape on the Rapco loggers will carry 7 days of data with a margin of safety, and one on the Microdata loggers can carry 3 days of data. Continuous recording can be carried out for special periods if required.

While this is going on, the development of the on-board data processing system can be got under way and fitted into the buoy when it is ready. The original telemetry system then fulfils the back-up and monitoring function mentioned in section 2.2.

We have discussed this proposal with Seatek, who are very keen to proceed in just this way. We did not, of course, imply any commitment by TAG II to the Seatek consortium at this stage in the proceedings.

If this proposal is accepted in principle, the situation becomes one in which TAG II is no longer proposing to use existing buoy systems, but to specify the development of a system which it will guarantee to use if satisfactory. Thus, we need to produce a specification of requirements, and our proposal is as follows.

4.2 Proposed specification

This must be given as a Target Specification, since it is not clear at the present time that all of it is technically feasible using available components.

4.2.1. The buoy should be suitable for use up to 20 miles from the coast anywhere round the coasts of Britain.

4.2.2. It should measure pitch, roll, heave or equivalent variables with a usable frequency response from 0.04 Hz to 0.3 Hz. The definition of "usable" is complex but in general terms can be taken as being 5% accuracy after corrections have been applied.

4.2.3. The raw time series must be available, though computed N-S and E-W components of slope will be acceptable. They should preferably be telemetered continuously to a shore station, but sampled recording (minimum of 1024 s every 3 hours) aboard would be acceptable as a second best so long as the directional wave parameters are telemetered (see 4.2.6. below).

4.2.4. If telemetered ashore, the shore station should routinely record digitally (after suitable filtering) the signals for 1024 s every 3 hours with a 1 s sample rate. It must be possible to attach additional recording equipment for special investigations if required.

If the raw series are not telemetered ashore, then directional parameters must be telemetered as specified in 4.2.6. below.

4.2.5. Wind and other meteorological parameters are desirable but not of high priority.

4.2.6. If an on-board processor is used to reduce the data, it should do the following:

(a) Compute segmented FFT's with a frequency resolution of 0.005 Hz.
(b) Compute all possible auto, co and quad spectra.
(c) Average as many as possible of these within an hour and transmit or record the result once an hour.

All the low-frequency estimates from 0.02 Hz up are required. Some widening of the band may be permissible at higher frequencies (above say 0.1 Hz) by averaging adjacent frequency components.

4.2.7. In order to have a buoy available quickly, a buoy telemetering the raw data ashore with no on-board processing or recording would be acceptable initially.

4.2.8. The buoy would need to be able to operate without servicing visits for a minimum of 3 months, preferably longer.