A SOUTH AFRICAN WAVE CLIMATE STUDY

by

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ABSTRACT

A study was made, using all the available sources of deep-sea wave data around the South African coast, to establish a statistical representation of the wave climate in this region. Data obtained from clinometer observations, the Datawell Waverider and voluntary observing ships were found to be the most useful.

The most accurate source of height, period and spectral information came from the Waverider which has been in extensive use in the region since 1969. To optimise the information value of these data a sophisticated data qualification technique was developed for digitised Waverider data in order to exclude poor data. This technique was also found to be useful in optimising the operational efficiency of a Waverider station.

A clear pattern was obtained for the general wave climate around the South African coast; this is in accordance with the pattern that may be expected from the weather climate affecting this region. Of interest are the SE'ly winds generating increased wave heights in proportion to the distance offshore from the west coast as well as the effect of the Agulhas current, opposing the SW'ly waves along the east coast, also creating high-wave conditions.

1. INTRODUCTION

Instrumental recording of waves has been done in South African coastal waters since 1961. Initially a wide variety of instruments were used including clinometers, NIO ship-borne wave recorders, inverted echosounders and pressure recorders. The first Datawell accelerometer buoy

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(Waverider) was installed off Mossel Bay in 1969 and the Waverider has since become the main recording instrument to be used in South African coastal waters. The number of Waverider stations varied over the years, but data representative of the open coast were obtained from 11 stations covering the entire South African and South West African coastline.

The main purpose of this study was to investigate all the possible sources of wave data that might be of use to the design engineer, to analyse the data and to publish the data in a form useful to all possible users. The data were also to be stored in a computer data bank to enable fast retrieval for further analysis by interested researchers and engineers.

This paper presents a summary of the main aspects of the study. It describes the development and application of a standard wave analysis and data qualification computer program for digital Waverider data, the system of data handling and storage, the comparison of the Waverider data with information from other sources and the present knowledge of the wave climate around South Africa.

2. WAVE ANALYSIS AND DATA QUALIFICATION

2.1 Data Collection

Waverider data are usually obtained for periods of 20 minutes every six hours from the various wave recording stations around the South African coastline. A sampling interval of 0,5 s is normally used for digital data and the resolution of the water elevation measured is 10 mm.

2.2 Computer Program

The detailed description of the program WAVES can be found elsewhere (Visser *et al.*, 1980; Visser *et al.*, not yet published). WAVES reads digitized wave records, applies qualification criteria to the data, performs spectral analysis, labels records as good, suspect or bad, and stores the processed records in a data bank. An example of a printout with a brief description is shown in Appendix A.

The procedures for spectral analysis are well documented and numerous computer routines for the fast Fourier transform (FFT) can be found in the literature. Writing a program to perform the basic computations is therefore relatively easy. However, the real problem lies in identifying invalid wave records which can result when, for example, noise due to equipment malfunction is superimposed on the data. Some bad records are easily identified, while in others, deficiencies are elusively masked. The influence of unidentified invalid results in a data bank needs no elaboration.

2.3 Conventional Data Qualification

Examples of methods being used for the identification of invalid wave records are visual inspection and identification of outliers according to the number of standard deviations they are removed from the mean water level. The first method is deemed unpractical because of the dependence on a trained observer and the large amounts of data involved. The second method is based on the assumption of normality of the instantaneous water elevation $x(t_i)$ as a function of time t_i. Outliers change the shape and position of the distribution. The intensity of this depends on the number of outliers, their magnitude and their bias towards the peak or trough side of the record. In many cases this renders the method useless.

2.4 WAVES-program Data Qualification

A rather random approach was adopted in arriving at the present qualification procedure. As many tests as could be thought of were applied to a large number of wave records. The types of tests ranged from crude empirical models to standard statistical tests. The procedure was refined by comparing, for a large number of records of various localities, the outcome of the tests with the judgement of experienced observers. A wave record (usually consisting of 2 048 digitized $x(t_i)$-values) is split into two halves of 1 024 data points each. This facilitates investigating stationarity and provides results when one half of the record is bad or non-existent. Six tests on time-domain and frequency-domain parameters are performed on each half of the record to identify good ("GOOD"), suspect ("BAD?") or bad ("BAD") data. On the basis of the outcome of each test a severity code is assigned to the test. The severity codes are then used to determine a category ("GOOD", "BAD?" or "BAD") for each half. A further scheme is then used to determine a category for a whole record. For example, "GOOD2B" means that the second half is "GOOD" and the first half is "BAD").

The following tests are used to categorize records.

2.4.1 Flatheads ("P2", "P3", "P4" and ">P4" in Appendix A)

A flathead is identified when consecutive $x(t_i)$ have the same numerical value (to the nearest 10 mm, that is, the resolution of the digitizer). Thus the value of "P2" denotes the number of times two (and no more) consecutive $x(t_i)$ with the same value are detected. Similarly for the "P3", "P4" and ">P4" parameters. (For example, if

">P4" = 2, then two occurrences of flatheads with more than four $x(t_i)$ values occurred.)

2.4.2 Rate of change of wave profile ("ERR" in Appendix A)

If the slope of two consecutive data points is greater than the theoretical maximum slope that the water surface can attain, an erratic point is identified. The value of "ERR" denotes the number of erratic points in the record.

2.4.3 Consecutive erratic points ("CON" in Appendix A)

The value of "CON" denotes the number of times two erratic points (see 2.4.2) next to each other are detected.

2.4.4 The sample correlation coefficient ("CORR" in Appendix A)

A linear trend in the data, which can be caused, for example, by zero-drift in recording instrumentation, is detected when the correlation between $x(t_i)$ and t is statistically significant.

2.4.5 Normality of the $x(t_i)$ ("SKEWNESS" and "KURTOSIS" in Appendix A

Experience shows that the instantaneous water elevation $x(t_i)$ of sea waves follows approximately the normal distribution. Tests for normality are done using slightly adjusted distributions for skewness and kurtosis. (Relaxing slightly on the theoretical distributions.)

2.4.6 Low-frequency detector ("LF.DET" in Appendix A)

Most Waverider buoys used in South Africa will respond only to waves with periods in the range 1 to 33 seconds (band width of 0,03 to 1,0 Hz). This covers the domain for most applications. The buoy is "blind" to waves with periods outside the mentioned range (for example, the tide). Therefore, if the power spectrum contains significant spectral information outside the mentioned band width, invalid data that could not be measured with the buoy are indicated. The sum of the first four power spectral density values 0,006 to 0,035 Hz is denoted by "LF.DET".

The test criteria used to assign severity counts to the six parameters are shown in Appendix B.

3. DATA HANDLING AND STORAGE

The main agency dealing with waves in the RSA is the National Research Institute for Oceanology (NRIO) of the

Council for Scientific and Industrial Research (CSIR) at Stellenbosch.

A Wave Study Group was established within NRIO during mid-1980 with one of its primary purposes to develop a system for the more efficient gathering and analysing of digitized wave data, thus providing more effective quality control and faster feedback of the analysed information. At present this group copes with the management of wave data gathered at seven Waverider stations.

System improvements include the following:

3.1 Waverider Data Logger

An improved micro-computer-based Waverider data logger was developed by the Electronic Systems Division within NRIO (Holroyd, 1982). This system features a real-time full calendar clock with built-in leap-year compensation. Recording times are fixed at 00h00, 06h00, 12h00 and 18h00 GMT with additional facilities to initiate recordings at other chosen intervals as well as single recordings. A stand-by battery will drive the clock for about six hours during a power failure. A Memodyne Model 200 cassette data logger is used together with Philips data cassettes. Storage capacity amounts to about 11 days of 4 × 20 minute recordings per day.

Each wave record contains unique station identification, time, calibration and self-test data. File lengths are recorded at exactly 2 100 words of data, sampled at 2 Hz rate and recorded as 12-bit words. A real-time Draper analysis option can be utilized by connecting an 80-column printer to the data logger. H_s, H_1, T_z and T_c are printed. The data logger is also supplied with an external Esterline Angus servo recorder providing an analogue trace of each wave record.

3.2 Process Control

The present system of gathering, analysing and storing wave data consists basically of the following steps:

- Waverider data are transmitted to nearby shore stations using the 27 MHz band.

- Cassette and analogue recordings are transported to NRIO using the most suitable means.

- Cassette data are transferred to 9-track magnetic tape using the NRIO in-house computer.

- The 9-track tape data are transmitted to the central CSIR computer in Pretoria using the available remote batch facilities.

- Final analysis and storage of the data are performed.

In order to obtain the maximum possible yield of good data from each recording station every effort is made to speed up and maintain a steady flow of data from the station to its final destination in Pretoria.

3.3 Quality Control

At NRIO several checks are done on the data prior to transferring it to the CSIR central computer. This includes a visual examination of the analogue records and also of suspect digital records on a graphics terminal. Time domain analysis is also done on the digital data and includes tests for normality. Useful fault reports are generated at this stage, although it was found that these tests are not critical enough to detect bad or suspect data in a large number of cases. Figure 1 shows digital records which were rejected by WAVES, although the records had passed the test for normality and were also not rejected during the visual test of the analogue record. At this preliminary check stage it is also difficult to decide whether the performance of a station is actually deteriorating, because a certain level of bad data appears to be inevitable, for example, where the station is exposed to heavy, sporadic R/T traffic.

Once the data have been transferred to the central computer, they are analysed by means of the program WAVES described earlier. At this stage information is obtained which forms the basis of a more critical quality control system.

Regarding each cassette as a "unit of wave data", the data are analysed and statistics plotted of the various tests obtained through WAVES. In order to determine whether a particular fault detected occurs consistently over a period of time, time series plots are made of the results of the data qualification tests.

Figure 2 shows the results of a study which was made of the bad performance at the Slangkop recording station during 1982. A backlog of data had inadvertently been allowed to build up at this station and action was therefore taken only when the problem was revealed during the pre-checks at NRIO. Analysis of 4 342 records collected at Slangkop showed that 12,8 per cent of the records had been rejected (Figure 3). This was due mainly to L.F. Detection and the occurrence of erratics. Further analysis showed that all but 1 per cent of the rejections through the detection of

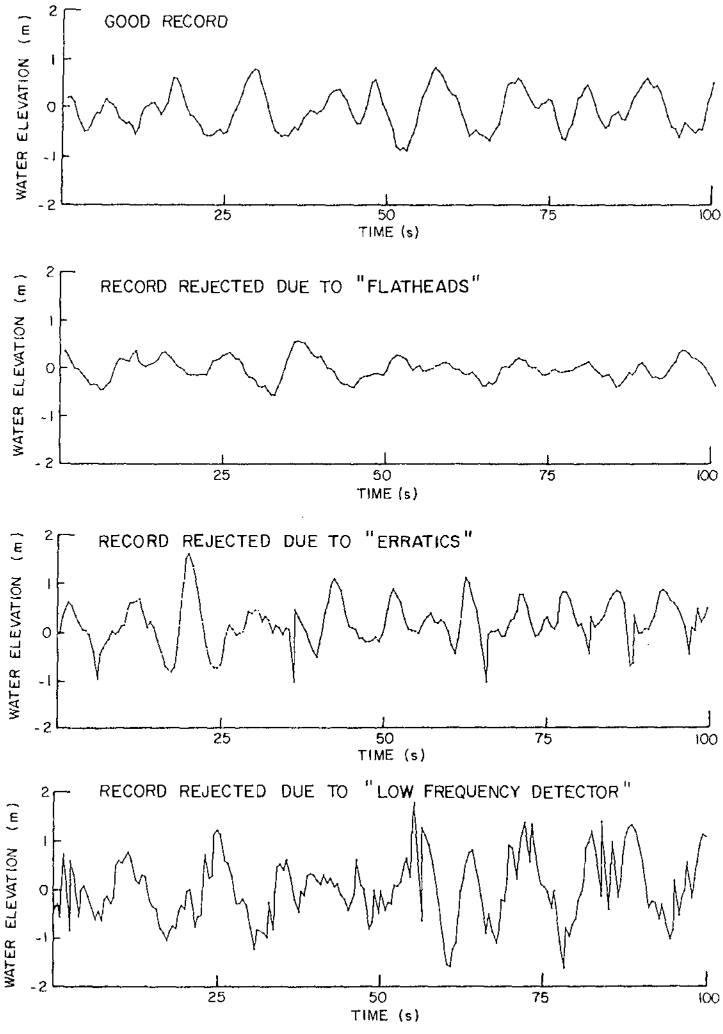


FIG. 1. EXAMPLES OF 100 SECOND PORTIONS OF GOOD AND BAD DIGITAL WAVE RECORDINGS

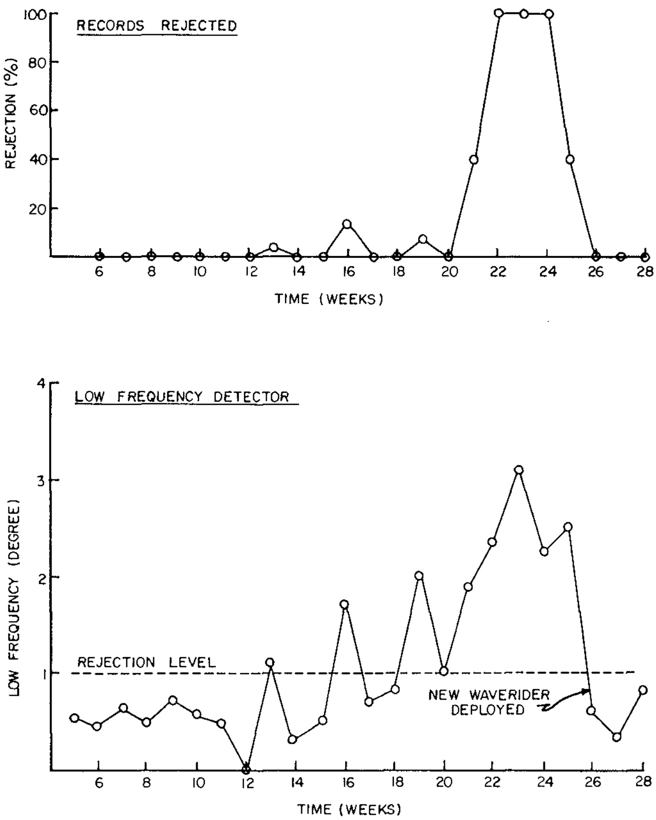
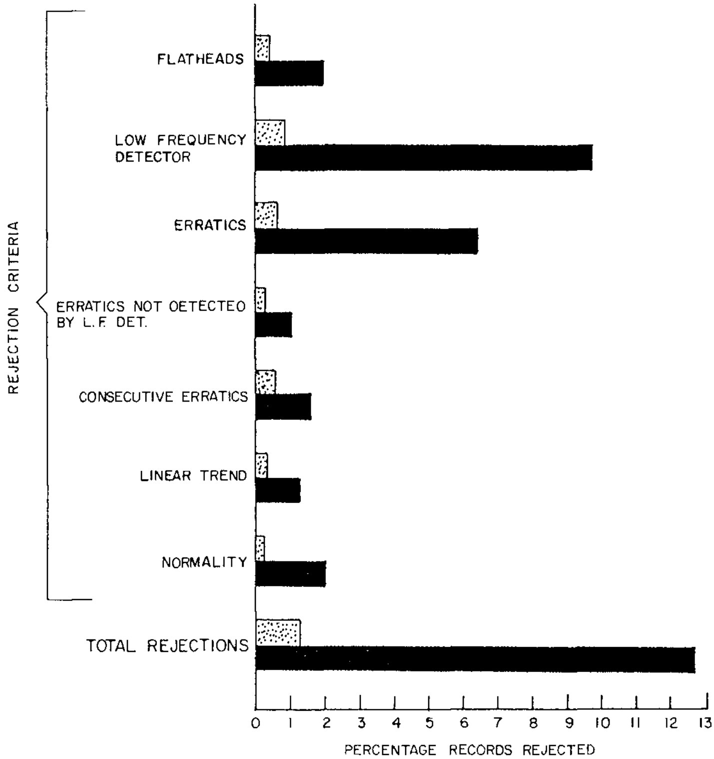


FIG. 2. TREND PLOTS OF LOW FREQUENCY DETECTED AND RECORDS REJECTED (STATION: SLANGKOP, PERIOD: 1982.2.5 TO 1982.7.16)



KEY	STATION	PERIOD	NO. OF RECORDS
■	SLANGKOP	OCT. 1978 - AUG. 1982	4352
▒	KOEBERG	NOV. 1977 - FEB. 1982	4386

FIG. 3. WAVE DATA QUALITY ANALYSIS FOR SLANGKOP AND KOEBERG

erratics had also been picked up by the L.F. Detector, thus leaving the main cause for rejection the detection of a low-frequency component. Figure 2 shows that the station performed well up to week 12 after which the L.F. Detector became very unstable. In addition, there is a clear trend indicating that the situation was worsening gradually. Subsequently the Waverider buoy could not be located and it is surmised that it had probably started to drift slowly, dragging its anchor, with a slowly weakening signal and thus became more prone to radio interference. A new buoy was deployed and good records obtained. A similar analysis was done for another station (Koeberg) and the results are included in Figure 3. This waverider is deployed closer inshore and completely away from any normal shipping routes as well as fishing areas, both hazards to which the Slangkop Waverider is exposed. A great improvement in data quality is evident under these improved conditions.

3.4 Data Storage

A prototype scheme for a computerized WAVES data base has been designed and installed on the CSIR central computer. Provision was made to store the entire output of the WAVES program and about three years' data have been stored. The data base is presently being "user-tested" prior to finalising its format.

4. WAVE CLIMATE

4.1 Introduction

In this section the wave climate as evident from all available data sources will be summarised. Wave height and wave period data are based mainly on the analysis of Waverider records since these are considered the most reliable source of such data. Wave direction data are based on clinometer observations that were refracted to deepsea as well as data from voluntary observing ships (VOS).

4.2 Weather Patterns

The major wave-generating system resulting in high waves along the RSA coastline is the regular cold fronts with their associated low pressure systems that pass west to east just to the south of the continent. These fronts together with two permanent high-pressure systems, that is, the South Atlantic high off the west coast and the Indian Ocean high off the east coast, totally dominate the wave-generating forces in the oceans surrounding the southern tip of the continent. A typical example of the passage of such a low-pressure system is shown in Figure 4 (Weather Bureau, 1979). These low-pressure systems normally shift towards the south in summer and towards the north in winter so that high waves occur more frequently in winter. They

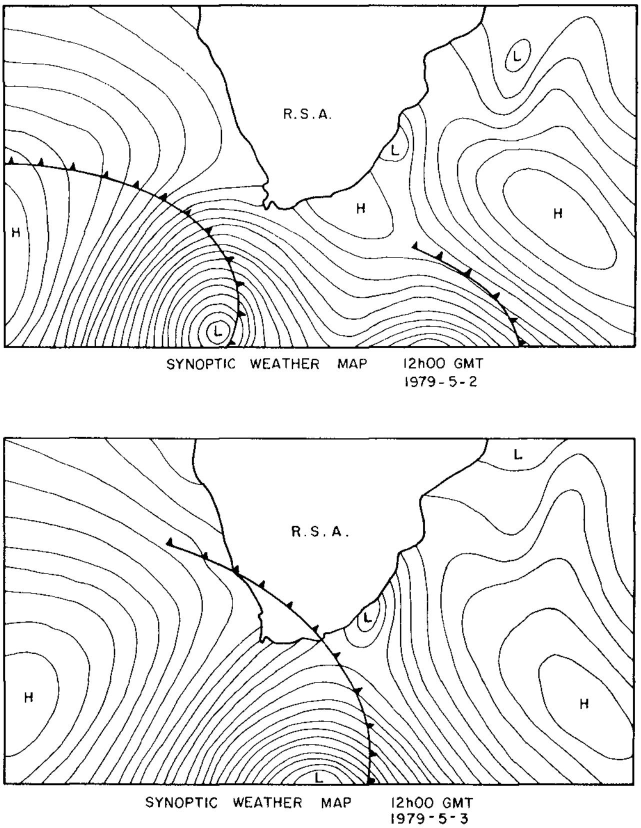


FIG. 4 PASSAGE OF A COLD FRONT CAUSING HIGH WAVES ALONG THE R.S.A. SOUTHERN COAST

do, however, on occasion move far enough north in summer to cause large waves but the occurrence of these high waves is less frequent in summer than in winter.

4.3 Wave Height Distribution

The 0,01 per cent wave height (H_s) obtained from the extrapolation of Waverider data for all the open-coast wave stations is shown in Figure 5. The 0,01 per cent wave height obtained from a shipborne wave recorder on a weathership stationed at 40°S, 10°E is also shown in this figure.

Comparing the wave heights along the west coast from Slangkop in the south to Walvis Bay in the north, it can be seen that a steady decrease in wave height occurs towards the north. This is very much in accordance with the weather patterns described earlier, that is, the wave height decrease with increase in distance from the storm centre.

From Figure 5 it can also be seen that the wave heights at Mossel Bay, Durban and Richards Bay along the east coast are very similar. The 0,01 per cent wave height at these stations vary from 5,5 to 6,0 m. At Gans Bay this wave height is 8,1 m which lies between the values at Mossel Bay and Slangkop.

An interesting wave station is the Waverider off SEDCO-K, a drill rig operating in the area offshore off Mossel Bay. As can be seen from Figure 5 the 0,01 per cent wave height at SEDCO-K is 9,7 m as compared with the 6,0 m at Mossel Bay closer inshore. The reason for this difference is thought to be the protection afforded by the land mass to the Mossel Bay station against the fronts approaching from the west. Another very interesting aspect of the SEDCO-K station is the similarity in wave conditions there with the station at Slangkop, 300 km to the west. Figure 6 illustrates this similarity.

In Figure 5 the 0,01 per cent wave heights obtained from VOS data are summarized for a few areas around the coast. Although these data are considered to be of lower quality with respect to wave height and period than the Waverider data, a few interesting points emerge. Firstly, the decrease in wave height towards the north up the west coast is also apparent from these data. The decrease in wave height is, however, much less pronounced than in the Waverider data and the wave heights are also considerably higher than those obtained from Waverider data. It is also interesting to note that the VOS data show the highest wave heights off East London. The reason for the higher wave heights by VOS in comparison to Waverider along the west coast is explained by wave directions and will be discussed

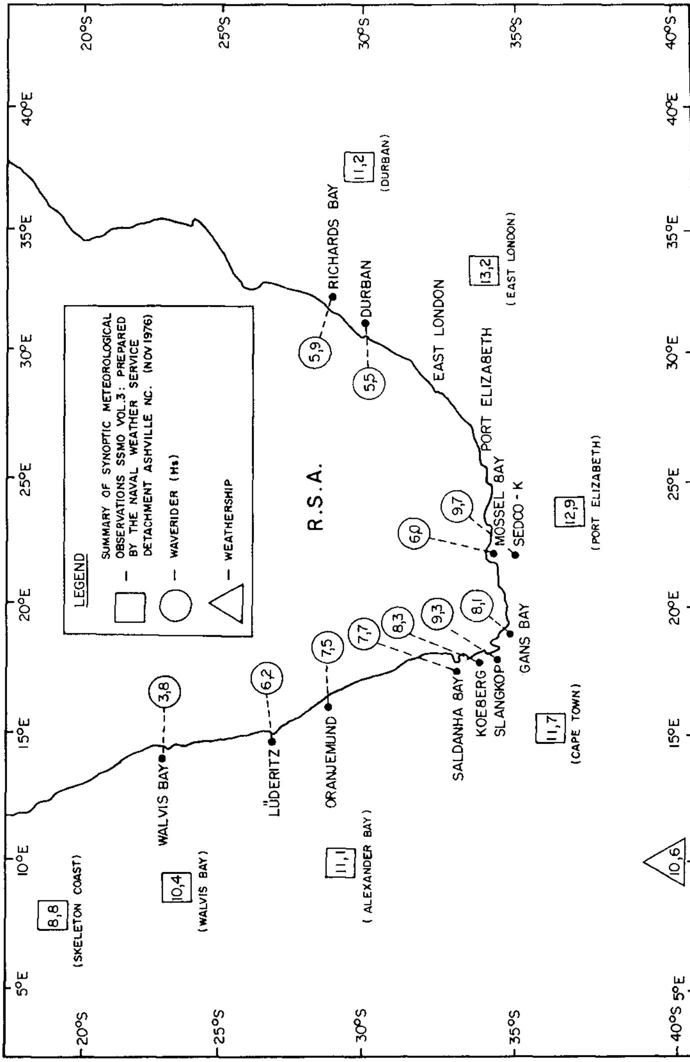


FIG. 5. DISTRIBUTION OF 0,01 PERCENT WAVE HEIGHT FROM WAVERIDERS, VOS AND WEATHERSHIP

in the next section. The reason for the higher waves off the east coast is explained by the presence of the very strong Agulhas current which flows from a NE'ly direction along this coast, directly opposing the dominant SW'ly waves. Energy transfer occurs from current to wave, resulting in so-called "freak" waves along this coast (Schumann, 1976).

4.4 Wave Direction Distribution

The wave direction distribution for four clinometer stations refracted to deepsea are shown in Figure 8 (Ashby, Harper and Van Schaik, 1973). Data from these four clinometer stations fully reflect the general wave direction pattern obtained for all the clinometer stations around the coast. The wave direction distribution for the weathership (Weather Ship Action Committee, 1973) as well as from VOS data (Hogben and Lumb, 1967) are also indicated on this figure.

The direction data obtained from clinometers show good agreement with the known weather patterns. It is clear that the main source of wave data are from the fronts to the south of the continent causing the waves along both the west and the east coast to have a resultant energy component towards the north. This is also in agreement with the known sediment transport pattern along the RSA coastline whereby sediment is transported towards the north on the west and east coasts and towards the east on the south coast.

A few interesting aspects also appear from the VOS data. Along the west coast the wave direction is very dominantly from the south-east, that is, either parallel to shore or in an offshore direction. These SE'ly waves, therefore, never reach the shore, which explains the large difference in wave height between the nearshore Waverider data and the VOS data recorded further offshore.

The wave direction at the weathership is very dominantly from the W'ly directions as can be expected in these latitudes.

Along the south and east coasts the agreement between the clinometer and VOS directional data is good.

4.5 Wave Period Distribution

Researchers normally find poor correlations between wave periods recorded by various means or analysed by different methods. The reason for this is that it is impossible to describe the periodicity of the waves by a single variable such as T_z, T_p, T_c, etc. For the purpose of this paper only the distribution of T_p as recorded at a number

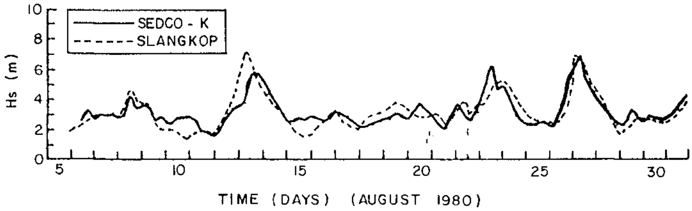


FIG. 6. COMPARISON OF WAVE HEIGHTS (Hs) RECORDED AT SEDCO-K AND SLANGKOP

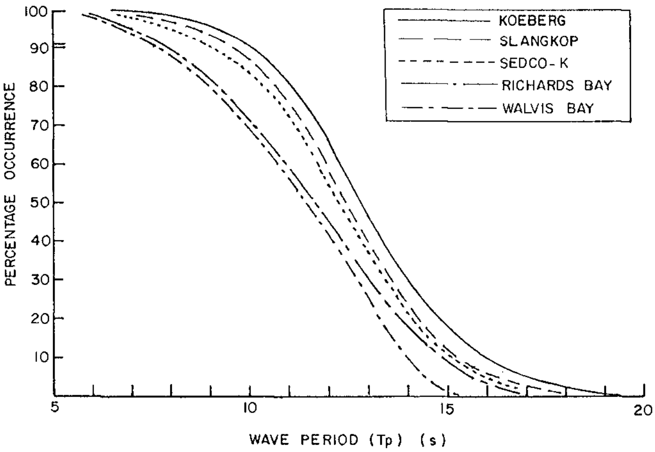


FIG. 7. DISTRIBUTION OF PEAK ENERGY PERIOD (Tp)

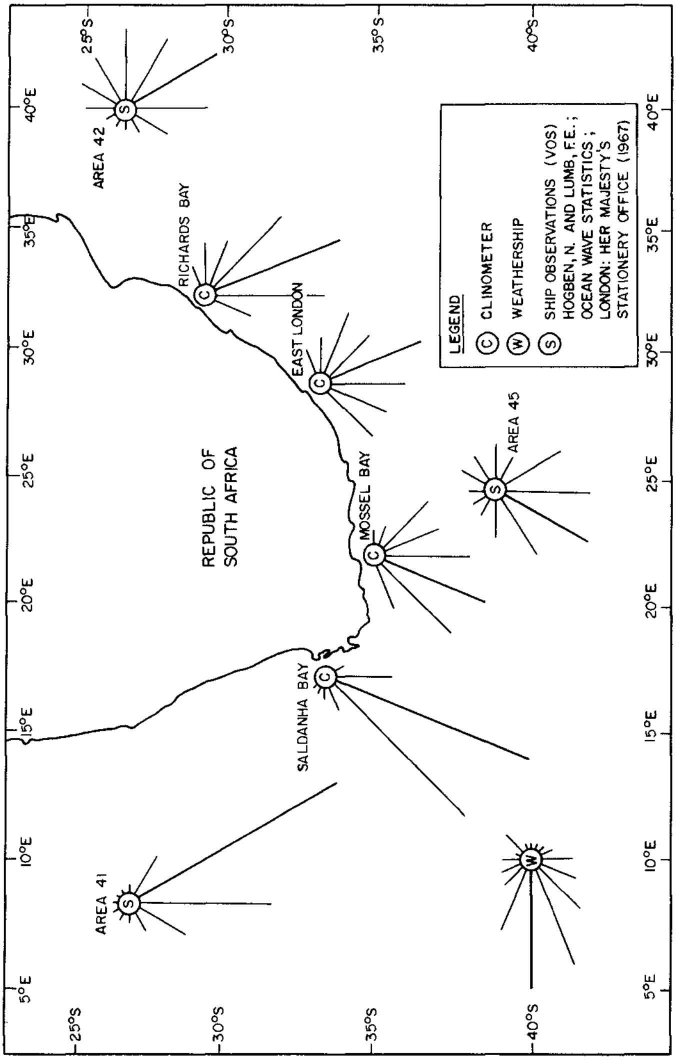


FIG. 8. WAVE DIRECTION DISTRIBUTIONS

of Waverider stations will be discussed, although it is fully realised that discussion and comparison of wave energy density spectra will be more satisfactory. A large quantity of spectral data is available but a lack of space prohibits it being discussed in this paper.

The peak energy period (T_p) distribution for a few Waverider stations is shown in Figure 7. From this figure it is obvious that the wave period distribution is very similar along the entire coastline with the wave periods along the southernmost parts of the country slightly longer than on the more northerly coasts. The period (T_p) exceeded for 50 per cent of the time varies from approximately 12,5 s in the south to 11,5 s in the north along both the east and west coasts.

Comparison between wave period data obtained from VOS and T_p obtained by Waverider shows very poor correlation with the VOS recording wave periods very much lower than the Waverider.

5. CONCLUSIONS

(i) A standard wave analysis program with special emphasis on data qualification routines has been developed for digital wave data.

(ii) The data qualification routines proved invaluable in the analysis of large quantities of data and help to detect hidden faults in the wave recording system.

(iii) A very clear wave pattern emerges from the available Waverider data and this is in accordance with the pattern to be expected from the known weather patterns around the coast.

(iv) Waverider data indicate considerable lower wave heights than those from VOS. The reason for this is thought to be that SE'ly winds generate waves parallel or offshore along the west coast which will lead to increasing wave height with increasing distance offshore. The difference in wave height along the east coast can be explained by energy transfer from the Agulhas current to the opposing SW'ly waves.

6. REFERENCES

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APPENDIX A

The "WAVES" Program Printout

The program is designed to print all the information of one record on a single printer page. From the top down, the page is divided into five areas. The areas are described, in order, in points 1 to 5:

1. The header area

   The first three lines of the printout contain the information necessary to identify the record (for example, degrees latitude and longitude) and information about how the sampling took place. The header area also gives the category assigned to the record.

2. Time domain parameter area

   The values of all the time domain parameters calculated are given in this area. As on the whole printout, the values are given separately for the two halves that the record is divided into.

3. Frequency domain parameter area

   The values of the frequency domain parametes calculated are given in this area.

4. Data qualification area

   The severity codes for the tests performed on the record are given in this area. A severity code of 0 means that all the requirements of the test were met. A code of 3 means that the record badly fails the test.

5. The spectral information area

   In this area, the last on the page, the power spectral density is given per frequency for each half of the record. The mean values for the two halves are also given. To facilitate interpreting the values, a small printer plot is provided.

APPENDIX A (continued)

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WAVE ANALYSIS OF : SLANGKOP            (1ST:GOOD 2ND:GOOD) CATEGORY: GOOD
DATE: 1978  1Ø   5. TIME: 12ØØ.                                                        PROGRAMME REVISION: 1
RECORDER:WAVE RIDER  ;DEPTN:    ØM; 34DEG  3.1MIN S 18DEG  3.5MIN E;WATER DEPTN: 197M;SAMPLING INTERVAL:Ø.5ØS;SAMPLES/HALF:1Ø24
..........................................................................................................................
TIME DOMAIN    HALF   P2  P3  P4 >P4 ERR CON   G(MAX)    CORR      MEAN   VARIANCE    NS       N1       TZ    SKEWNESS KURTOSIS
***********    ----   --- --- --- --- --- ---  -------- --------  -------- --------  -------- -------- -------- -------- --------
PARAMETERS:     1.    1Ø   Ø   Ø   Ø   Ø   Ø    2.Ø67    Ø.ØØ2    1Ø.199    Ø.524    2.896    4.26Ø    6.649   -Ø.Ø62    2.722
***********
                2.     8   Ø   Ø   Ø   Ø   Ø    2.Ø94   -Ø.Ø1Ø    1Ø.2Ø3    Ø.554    2.976    4.28Ø    5.333    Ø.Ø53    2.945
..........................................................................................................................
FREQ DOMAIN    NALF      TP       HMO      TMØ2      TM24     TMØ1       E        QP      LF.DET   NF.DET
***********    ----   -------- -------- -------- -------- -------- -------- -------- -------- --------
PARAMETERS:     1.     11.9Ø7    2.8Ø9    5.6Ø8    2.455    6.864    Ø.899    2.168    Ø.Ø23    Ø.ØØ4
***********
                2.     1Ø.667    2.91Ø    5.369    2.616    6.332    Ø.873    1.68Ø    Ø.Ø32    Ø.ØØ3
..........................................................................................................................
DATA QUALI-    NALF   FLATHEAD ERRATICS  CONSEC   MEAN#Ø    TREND  NON-NORM  LF.DET        CORR1#CORR2 MEAN1#MEAN2 VAR1#VAR2
***********    ----   -------- -------- -------- -------- -------- -------- --------      ----------- ----------- ---------
FICATION:       1.       Ø        Ø        Ø        1        Ø        Ø        Ø
*********                                                                                      Ø           Ø           Ø
                2.       Ø        Ø        Ø        1        Ø        Ø        Ø
..........................................................................................................................
SPECTRUM   NO   FREQUENCY  PERIOD     SPECTRAL DENSITY(M*M/NZ)                  MEAN SPECTRAL DENSITY (X OF  8.964)
---------          (HZ)      (S)      1ST HALF   2ND NALF    MEAN           Ø        2Ø        4Ø        6Ø        8Ø       1ØØ
                                                                            |---------|---------|---------|---------|---------|
            1     Ø.ØØ6   17Ø.667      Ø.ØØ3      Ø.ØØ3      Ø.ØØ3          |
            2     Ø.Ø16    64.ØØØ      Ø.ØØ8      Ø.ØØ5      Ø.ØØ7          |
            3     Ø.Ø25    39.385      Ø.ØØ5      Ø.ØØ7      Ø.ØØ6          |
            4     Ø.Ø35    28.444      Ø.ØØ7      Ø.Ø16      Ø.Ø12          |
            5     Ø.Ø45    22.261      Ø.ØØ5      Ø.ØØ8      Ø.ØØ7          |
            6     Ø.Ø55    18.286      Ø.Ø37      Ø.ØØ9      Ø.Ø23          |
            7     Ø.Ø64    15.515      Ø.283      Ø.254      Ø.269          |*
            8     Ø.Ø74    13.474      2.147      1.Ø97      1.622          |*********
            9     Ø.Ø84    11.9Ø7     13.536      4.391      8.964         F|**************************************************
           1Ø     Ø.Ø94    1Ø.667      7.Ø81      8.537      7.8Ø9         R|********************************************
           11     Ø.1Ø4     9.66Ø      4.11Ø      5.589      4.849         E|***************************
           12     Ø.113     8.828      2.46Ø      4.435      3.448         Q|*******************
           13     Ø.123     8.127      1.992      5.387      3.689         U|********************
           14     Ø.133     7.529      3.Ø32      4.22Ø      3.626         E|********************
           15     Ø.143     7.Ø14      1.549      1.783      1.666         N|*********
           16     Ø.152     6.564      1.353      2.411      1.882         C|**********
           17     Ø.162     6.169      Ø.826      Ø.538      Ø.682         Y|***
           18     Ø.172     5.818      1.346      Ø.929      1.137          |******
           19     Ø.182     5.5Ø5      Ø.559      Ø.9Ø3      Ø.731          |****
           2Ø     Ø.191     5.224      Ø.315      1.591      Ø.953          |*****
           21     Ø.2Ø1     4.971      Ø.547      1.468      1.ØØ8          |*****
           22     Ø.211     4.741      Ø.986      Ø.874      Ø.93Ø          |*****
           23     Ø.221     4.531      Ø.855      Ø.658      Ø.757          |****
           24     Ø.23Ø     4.339      Ø.87Ø      Ø.963      Ø.917          |*****
           25     Ø.24Ø     4.163      Ø.378      Ø.857      Ø.617          |***
           26     Ø.25Ø     4.ØØØ      Ø.518      Ø.711      Ø.615          |***
           27     Ø.26Ø     3.85Ø      1.Ø71      Ø.838      Ø.955          |*****
           28     Ø.27Ø     3.71Ø      Ø.335      Ø.284      Ø.3Ø9          |*
           29     Ø.279     3.58Ø      Ø.28Ø      1.ØØ7      Ø.643          |***
           3Ø     Ø.289     3.459      Ø.367      Ø.37Ø      Ø.368          |**
          RESOLUTION (DELTA F IN NZ): RAW =  Ø.ØØ195    SMOOTHED OVER  5 LINES =  Ø.ØØ977
..........................................................................................................................
FINAL SUMMARY (    MEAN ) :  HS=  2.936 M    HMO=  2.859 M    TZ=  5.991 S   TMØ2=  5.489 S    TP= 11.9Ø7 S
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APPENDIX B

Assigning severity counts to qualification parameters:

Parameter	Severity count	Test	Test values
FLATHEAD	0	"P2"≤T1 and "P3" + "P4" + ">P4" = 0 or "P2"<T2 and "P4"≤1	T1=86-7,5"Hs" T2=46,2-3,45"Hs" + 5,24"P3"- 0,803"P3""P4"
	2	All other cases	
	3	">P4" > T3	T3=16,56-3,18"Hs"
ERRATICS	0	"ERR" < 5	
	1	5 ≤ "ERR" ≤ 10	
	3	"ERR" > 10	
CONSEC	0	"CON" = 0	
	3	"CON" > 0	
TREND	0	$0{,}0 \le \lvert\text{"CORR"}\rvert < 0{,}062$	P = 0,01 and P=0,5 correlation test with 1 024 d.f.
	1	$0{,}062 \le \lvert\text{"CORR"}\rvert \le 0{,}081$	
	3	$\lvert\text{"CORR"}\rvert > 0{,}081$	
NON-NORM	0	$0{,}0 \le \lvert\text{"SKEWNESS"}\rvert \le 0{,}26$ $2{,}3 \le \lvert\text{"KURTOSIS"}\rvert \le 3{,}85$	
	1	$0{,}26 < \lvert\text{"SKEWNESS"}\rvert \le 0{,}3$ $2{,}0 \le \lvert\text{"KURTOSIS"}\rvert < 2{,}3$ or $3{,}85 < \lvert\text{"KURTOSIS"}\rvert \le 5{,}0$	
	2	$0{,}3 < \lvert\text{"SKEWNESS"}\rvert \le 0{,}4$	
	3	$\lvert\text{"SKEWNESS"}\rvert > 0{,}4$ $0{,}0 \le \lvert\text{"KURTOSIS"}\rvert < 2{,}0$ or $5{,}0 < \lvert\text{"KURTOSIS"}\rvert < \infty$	
LF.DET	0	"LF.DET"<T14	T14=0,2+0,17"Hs"
	2	T14≤"LF.DET"≤T15	
	3	"LF.DET">T15	T15=0,4+0,2"Hs"