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ACCURATE REDUCTION OF SEA LEVEL RECORDS

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ABSTRACT

The established procedures for the reduction of tide gauge sea level records have been critically reviewed and adapted for systematic processing. Various new methods have been developed for screening and verification of digitised sea level data and a computer-based system has been developed to process and archive these data in a uniform fashion. The system, intended for the routine processing of the class A network of tide gauges around the British Isles, presents a new level of standards in the processing of coastal sea level records.

1. — INTRODUCTION

The Bidston Observatory Laboratory of the Institute of Oceanographic Sciences (IOS) has an established role within the U.K. to maintain high quality series of digital sea level records abstracted from analogue tide gauges at selected coastal sites around the British Isles. Such data provide not only the basis of researches and routine tidal information, but are also required to maintain a continuous historical record of mean sea level for certain sites around the coastline. IOS also undertake where necessary to process sea level records from many world-wide locations. In recent years there has been a growing demand for greater accuracy of such tidal data and an assessment of their quality. This demand is balanced with the advent of various new types of sea level recorders, particularly those which have an automatic digital mode of recording direct sea level measurements or their pressure equivalent.

Even in the past traditional format of tidal chart recorders, the accurate reduction of sea levels at hourly intervals, which is by necessity a very laborious process, has presented various problems. These problems mainly arise from irregularities in the performance of the recording system and encompass matters such as the accuracy of the clock drive, the stability of the tidal trace datum, and irregularities or discontinuities in the recorded tidal trace. The identification and adjustment of such irregularities at the digitizing stage has often been subjective, depending on the experience of the operator and on the levels of information available qualifying the tide gauge performance. It is not uncommon that errors can be overlooked in the course of reducing tidal charts, or indeed that anomalies are so great that extended periods of tidal records have to be discarded. Further, whereas such tidal chart records can be assessed in a visual manner, tide gauges with a purely digital mode of output to magnetic or paper tape pose considerably greater problems in seeking to detect and adjust errors.

To overcome many of these problems, a revised set of methods for processing sea level records has been devised. The scheme of processing leans heavily on the availability of extended computer facilities and enables data to be handled in a systematic fashion to provide reduced digital values to exacting standards. Data recorded at various time intervals can be handled. The influence of errors in the data has been highlighted, and these can be sought for in a systematic manner and adjusted automatically. Use is made of harmonic tidal predictions to compute residuals in schemes devised to monitor, more exactly, errors in timing and datum stability. The final smoothed set of reduced digital values is catalogued in parallel with the series of original raw (digital) data together with a direct reference list to any errors and the nature of their adjustment. For each twelve-month block of smoothed data, the quality of the record is summarised in statistical measures to maintain a comparison with succeeding years.

The overall scheme presents a new ordered approach to the problem of reducing sea level records and serves to highlight the careful measures necessary to convert coastal tide gauge records into a corrected smooth form of the true sea levels.

2. — THE MEASUREMENT OF SEA LEVELS

Continuous sea level measurements are recorded directly either in analogue or digital format. We are here mainly concerned with the processing of data from coastal tide gauges of the stilling-well type where the records are obtained as time series of sea levels in graphical or digital form. The same scheme is nevertheless applicable to data obtained from pressure recording gauges, subsequent to their intermediate translation into equivalent sea level measures.

2.1 Analogue tide gauges

Analogue tide gauges, which represent the traditional style of coastal sea level recorders, are designed to record a continuous measure of the sea level through the transmitted motion of a balanced float constrained to move vertically within a stilling well. The installation requires to be permanently sited and to be regularly monitored to ensure satisfactory levels of performance. The sea level is recorded either as a graphical trace or is coded directly in digital format onto paper tape. Whereas the graphical trace can be visually interpreted against both time and height scales set on the recording chart which allow regular monitoring checks to be easily made, the style of recording these same measurements in a code punched directly onto paper tape does not readily allow such simple monitoring procedures, and the recording of data is more critically dependent on the performance and stability of the tide gauge mechanism.

Of particular importance is the stability and accuracy of the clock drive mechanism which is designed to ensure a constant rate of transfer of the graphical charts or paper tape. Errors in the clock drive mechanism are not uncommon and although these can be monitored in the course of normal daily checks, the procedures for adjusting these in the subsequent reduction of records are not always straightforward. Poorly fitted tidal charts can introduce both timing and datum errors in any normal scheme of digitising the tidal trace, and although such errors can to an extent be assessed by visual examination of the charts a more exact level of check is required to assess the quality of digitally recorded data where, for instance, problems of a severe nature can arise in trying to adjust records that may have been corrupted in their continuity through slippage of the paper tape. Where the data are recorded in digital form, consideration must also be given to the time interval of the records to assess whether problems due to aliasing may arise.

2.2 Pressure recording tide gauges

It is useful to mention here briefly the class of tide gauges where the measure of sea levels is determined by recording pressure at depth. The continuous variation of pressure due to the tidal motion of the water column can be accurately recorded either using electrical transducers or gas flow systems. In each case the system may be designed to record the pressure due to the water column, including or excluding the barometric pressure at the sea surface. The latter type of gauges are more normally used for inshore measurements and require a shore- or surface-based station to record the data in either digital or graphical format. The use of electrical transducers allows the design of highly sophisticated self-contained tide gauges for the offshore measurement of tides in deep water.

Pressure recording gauges have many advantages over the more inflexible permanently sited stilling-well type gauges, and are designed to record for extended periods with the minimum of regular maintenance. The reduction of the recorded data is dependent on the particular calibration parameters of the instrument, and their translation into equivalent sea levels requires measurement of parallel parameters of surface air pressure and sea water density. Whereas the translation of such data from deep sea recorders demands highly sophisticated procedures to resolve an accurate interpretation of the pressure record, the situation is generally far less exacting in the case of determining sea level pressures in shallow inshore waters.

2.3 Datum of sea level measurements

At this introductory stage it is also important to discuss briefly the significance of datum references associated with the measurement of sea levels. In order to provide a meaningful time series of sea level measurements, these must be related to a fixed reference datum which can be either defined in a local sense, or more generally, interconnected to a national geodetic reference plane. In Great Britain, the national reference plane is defined as Ordnance Datum Newlyn (O.D.N.), and over the years a systematic levelling network has been established to connect this level through intermediate bench marks to some datum measure (normally known as Tide Gauge Zero) associated with permanent coastal sea level recorders. In the case of permanently fixed tide staffs, this interconnection can provide a reasonably exact relationship to O.D.N. in view of the simple form of sea level recorder used. In the case of analogue stilling-well type tide gauges, considerably more levels of interconnections are necessary to relate the zero of a tide chart trace to O.D.N. Although the tide gauge structure itself may be connected exactly to O.D.N., the nature of the tidal trace recording mechanism and the variable levels of operator maintenance can introduce degrees of uncertainty in the continuous stability of the datum of such recorded levels. In this context it is necessary, if not essential, to maintain exact regular daily checks of the instrumentally recorded levels against independently mounted tide staffs sited locally. These checks, together with the less frequent (six monthly or yearly), but exacting datum monitoring exercises can provide the necessary information to establish a continuously stable reference datum for the recorded sea levels.

If we recognise that effects of siltation in the stilling well, imbalance of the float and related mechanism, or indeed poorly fitted tidal charts, can all contribute to errors in the continuity of a true datum reference, we may readily see the importance of procedures designed to detect and subsequently adjust such errors in the course of reducing such records. In the case of pressure recording gauges used to measure sea level variations, the instrumental conditions necessary to monitor a continuously stable datum reference are of equal importance but of substantially different nature to those discussed above.

A detailed and up-to-date description of sea level instrumentation can be found in the Hydrographic Society Special Publication No. 4 — Proceedings of the Symposium on Tide Recording held on 14th - 15th April 1976 at University of Southampton, U.K.

3. — DISCUSSION OF STANDARD ESTABLISHED PROCEDURE FOR THE REDUCTION OF SEA LEVEL DATA

Once a graphical or digital record of sea level (or its pressure equivalent) has been obtained, it is usual to reduce this record into an accurate time series of hourly values. At Bidston Observatory, the reduction of tidal records has been an established practice for over fifty years and on the basis of this experience it is possible to identify the main features related to the earlier programmes of processing analogue tidal records.

3.1 Analogue tidal charts

3.1.1 Each chart, which may generally contain from 2 to 14 days of records, is examined to assess the quality of the record. Particular attention is paid to any irregularities which may reflect a gauge malfunction and any notes made by the operator regarding the performance of the gauge throughout the processing period. Micronegative copies of the charts are made and catalogued.

3.1.2 Any time checks noted by the operator are carefully examined, since any discrepancy in these checks must be verified and incorporated in the eventual reduction of the data.

3.1.3 Where short gaps exist in the tidal trace, they may be traced in manually in cases where the tidal profile is naturally smooth and the adjoining data are free of any meteorological disturbances. However, even this practice is viewed with caution, since such gaps often suggest the likelihood of some form of malfunction in the tide gauge, which might have influenced the quality of the record prior to, or even beyond, the gap.

3.1.4 The continuity of the tidal traces throughout a chart, and between charts, is checked to assess the stability of the tide gauge datum (chart zero) and the regularity of the clock drive mechanism. Attention is specially paid to trace discontinuities that may be introduced due to charts being fitted poorly on the revolving drum of the tide gauge.

3.1.5 Once the preliminary assessments made in the above fashion are satisfactory, the data are digitised either by first tabulating the abstracted heights, or, directly with the aid of an automatic optical digitiser. Any time errors identified in the preliminary assessment are corrected manually at the digitising stage, by digitising over a revised time scale corresponding to the magnitude and the direction of the time error. When the time errors are identified as of linear form (i.e. when the clock drive is gaining or losing time), the revised time scale chosen is treated in a correspondingly linear fashion. This process of editing for time errors manually while digitising over a revised time scale is a tedious task and can be highly subjective, in that it depends on the degree of skill, judgement and experience of the personnel involved in the digitisation process. Problems in resolving a time error may often be disguised as the result of a datum trace discontinuity.

3.1.6 The digital values are then screened for any gross errors which may have been introduced in the digitisation process. A set of Lagrangian interpolation formulae are used to estimate each data value, the difference between the estimated and the real value being tested against some preset tolerance limit (LENNON 1964, 1965; CARTWRIGHT 1968). Any such flagged value is then re-checked with reference to the original tidal record.

3.1.7 The final digital time series is related to some measure of the tide chart zero. In ideal cases the explicit relationship between the tide chart zero and a national reference datum can be established through intermediate relationships between tide gauge zero and bench marks connected locally to the national reference plane.

3.2 Digital tidal records

3.2.1 Most digital records from coastal tide gauges are in the form of paper tape with the measure of sea level coded in a punched format. First these data, which are generally non-hourly time series of 30 - 35 days in length, are transferred onto a suitable computer compatible form and the original paper tapes are archived.

3.2.2 As for graphical chart records, any time checks made independently by the operator are noted and verified against the data to establish continuity of the time series. These time checks are of particular importance, since the punched data do not contain a time scale reference. Hence reliability is placed on the stability of the paper tape clock drive and the accuracy of the code punch mechanism set to transfer recorded measures at constant intervals. The interpolation of gaps in such data can pose serious difficulties in the absence of independent operator checks, and moreover, malfunction in the tape transport mechanism can result in multi-punched code that proves difficult to resolve.

3.2.3 Once this preliminary assessment is completed, the time series is plotted on a suitable scale to screen for anomalous values. Editing of these values and the assessment of other normal errors are again subjective, since unlike graphical tidal charts (which have exact time and height scales printed) no reference frame is available for verification. In screening of such data at IOS Bidston, there has been a growing use of harmonic predictions to provide a base line against which to assess the recorded data, since it is possible to identify features in residuals that directly reflect normal forms of data recording error. This method of data screening, based on residuals is discussed in detail later.

3.2.4 If the recorded data were not sampled at hourly intervals, the data series is converted into hourly values (after discarding any high frequency non-tidal components in the data by applying suitable filtering techniques), and any time errors identified are corrected in the hourly data series.

3.2.5 Once again, as described for graphical tidal charts, the final data series is related to some defined datum reference.

4. — DEVELOPMENT OF A STANDARD SYSTEMATIC PROCEDURE FOR THE ROUTINE REDUCTION OF SEA LEVEL DATA

4.1 Resume

Within the procedures established for the reduction of sea level data, it is readily seen that, due to the diversity of forms of tidal records and the nature of different forms of error that can be encountered, there is a need to introduce a more rigorous programme for reducing sea level records. Although established guidelines do exist in the processing of such data, there is no systematic set of procedures to aid the detailed screening of data in relation to resolving time errors and datum trace continuity, and the quality of reduced digital time series is often dependent on the level of experience and expertise of the operator. Even for limited spans of data, it has been shown that the established processing schemes can give rise to differences between the digitised sea level data reduced from independent analogue tide gauges at the same location, which respectively record either in digital or graphical format. (KARUNARATNE, 1977).

In order to establish a standard scheme for processing of sea level records, and to meet the growing need for accurately screened data series, the existing procedures were critically reviewed.

In the process of reviewing the existing procedures and the possible methods of improvement, the following points were highlighted.

4.1.1 Some of the established data screening and the associated editing methods were highly dependent upon the expertise and judgement of the personnel involved in the reduction process. The level of this dependence could be reduced by automating some of the well-behaved processes, such as the application of time and datum error corrections and the interpolation of limited gaps in the data series. However, it should be noted that in the case of interpolation of limited gaps, judgement and experience is still essential, since even specially developed interpolation schemes can be inadequate for data affected by strong meteorological disturbances (KARUNARATNE, 1980).

4.1.2 The existing method for the automatic verification of the smoothness of the data series, based on estimating the sea level using a set of Lagrangian interpolation formulae, has been shown to be unsatisfactory, frequently resulting in either a large volume of pseudo-errors, or, ignoring some genuine errors, or both (GREIG, 1977). This is particularly evident in tidal regimes where the basic sinusoidal character of the tide is overshadowed by the influence of other harmonics. As a result, in a recent study carried out by one of the authors, the methods were critically reviewed and a new interpolation scheme, based on representing a few principal tidal components to reproduce the tidal form, was developed (KARUNARATNE, 1980). This new approach, named the 'Harmonic Component Fit' method, has produced considerable improvement over the conventional Lagrangian and other numerical methods.

4.1.3. The data screening requirements necessary in order to attain the high levels of accuracy demanded by present day standards were inadequate. This becomes very evident when we examine residuals (defined here as being the difference between the reduced observed data and the harmonically predicted levels) derived from conventionally reduced tidal records. Ideally one should expect such residuals to represent a low level random signal or to display features of non-tidal origin which can be closely correlated with related meteorological phenomena. However, on examination of residuals produced from data reduced using the past screening methods, various systematic features can be identified.

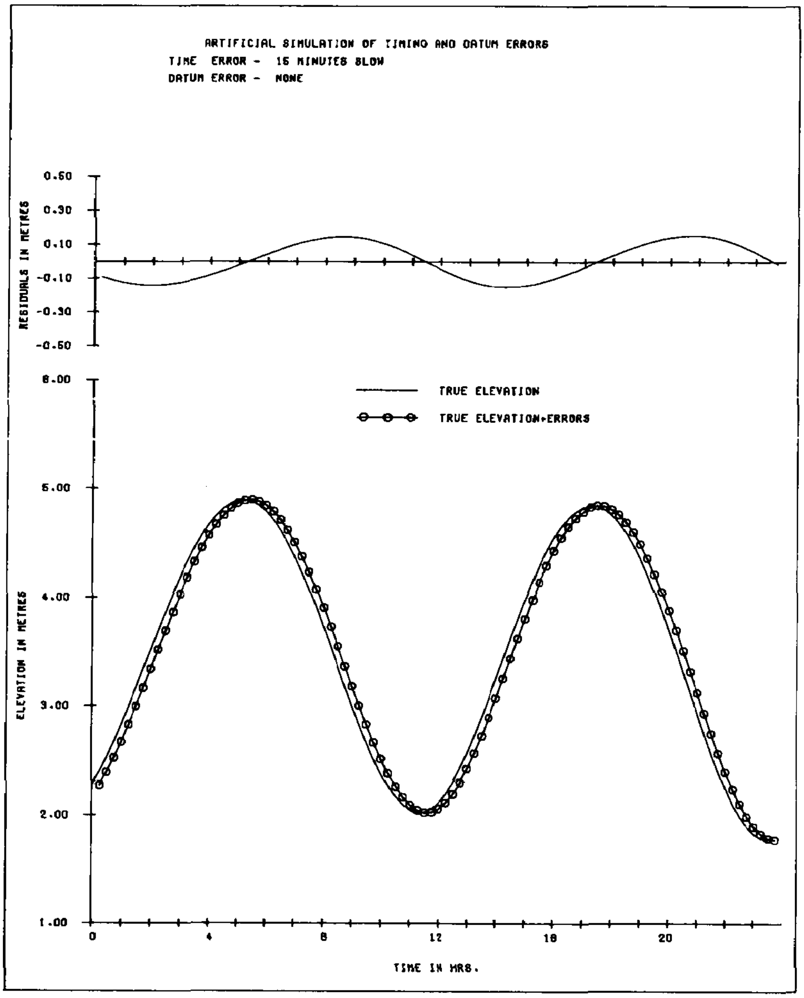

FIG. 1(a). — Oscillations in residuals generated by existence of a pure timing error. The residuals show the difference between the true sea levels and those containing the influence of an uncorrected timing error.

Often a dominant feature is an oscillation of semi-diurnal nature. The possible cause of this particular feature can be attributed to a time error that has been overlooked in the data reduction process. A phase shift, corresponding to the time error, in the dominant tidal frequency component (semi-diurnal) can result in the residuals displaying an oscillation having identical dominant frequency (see figure 1(a)). If we examine such a situation in detail, it is found that residuals with very similar features to those produced by the presence of a time error alone can also be produced by a datum error coupled with a time error. However, if the reduced data series and the harmonically predicted data series are closely compared, the two forms of error can be resolved individually. This can be easily illustrated by simulating time and datum errors in a smooth data series and examining the resulting residual series (see figure 1(b)).

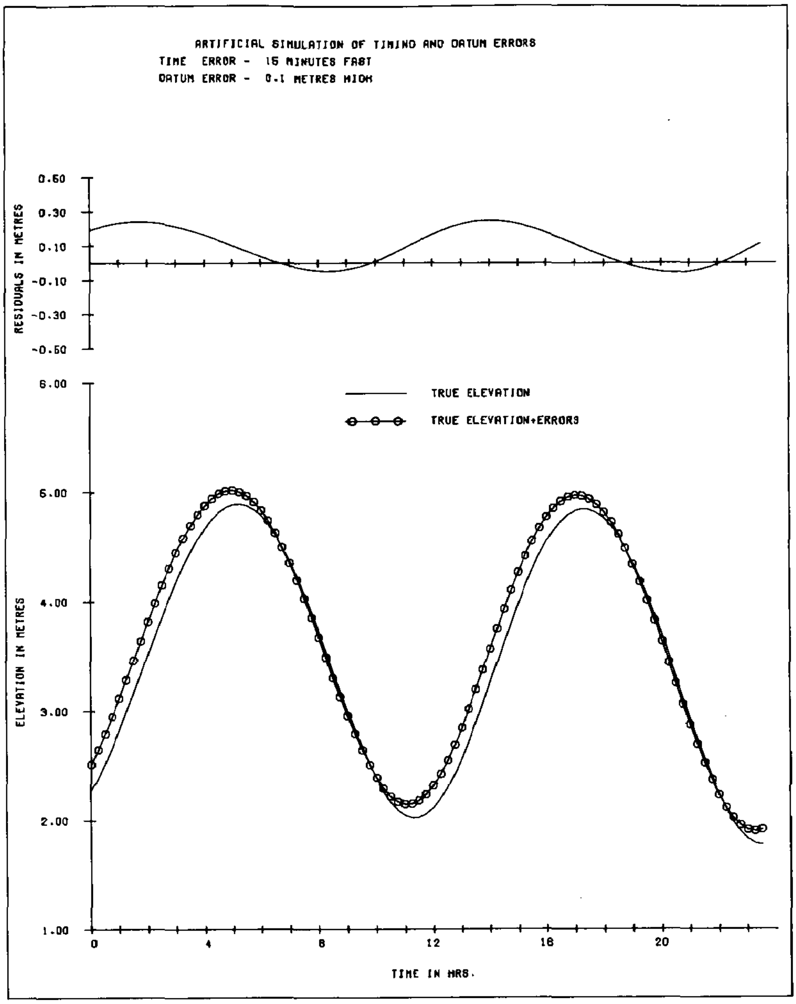

FIG. 1(b). — Oscillations in residuals generated by existence of both a timing error and a datum error unaccounted for in the reduced data.

It is important to note that great care is needed when resolving such time errors in data affected by strong meteorological disturbances, since such conditions themselves can also give rise to periodicity in the residuals. These transient oscillations arise due to the inadequacy of existing harmonic tidal prediction models in reproducing the non-linear features of the surge tide interaction processes.

The approach of visual examination of the graphical representation of the three data series (reduced observed, predicted and residual) can be adopted as an additional data screening procedure, thus helping to resolve data errors that may have been overlooked in the preliminary screening procedures. Figure 2 shows an example where residuals display various features which can be used to identify the influence of particular types of error in the reduced time series of sea levels.

This approach has been implemented successfully at IOS Bidston recently as a method of high level data screening, and has been increasingly adopted as a critical means of aiding the assessment of quality of the data series. Experience has shown that such monitoring of the residuals also helps to identify long-term malfunctions of the recording instruments such as siltation in the tide gauge stilling well (GRAFF, 1978).

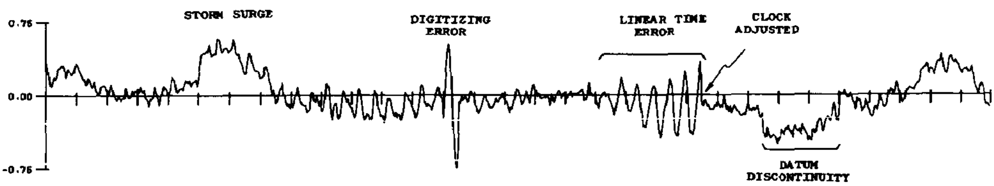

FIG. 2. — Typical features, due to various error effects or other influences, which can be identified in a residual time series.

4.1.4 Different processing stages in the programme of reducing the data were discontinuous, and hence the efficiency of the overall processing procedure was hindered. Again we can refer to programmes of data reduction where different personnel of differing levels of experience are involved in the stages of digitising sea level records for the same port. This could be remedied somewhat by re-organising the various processing stages into a more regular fashion within a high level of supervisory control, and implementing the transfer of data between different processing stages via easy access computer disc files, thus overcoming problems arising from continuous handling of computer cards with remote terminal access.

This situation can be usefully illustrated by considering the digital filtering process that may be associated with deriving a continuous data series. When the data are filtered, as is often required prior to converting records at non-hourly intervals (digital sea level recorders) into hourly values, a data loss corresponding to the half-length of the numerical filter, occurs at both ends of the data series. By overlapping sufficient lengths of data from the adjoining records one readily establishes a means of obtaining a continuously smooth series. With the aid of catalogued computer disc files, this operation of overlapping and matching the respective data sets can be automated, and becomes very efficient both in terms of time and accuracy, relative to the equivalent operation carried out manually using computer punched cards.

4.1.5 The degree of documentation regarding the processing history associated with the data series was inadequate. One of the major shortcomings was the lack of systematic documentation on data series which may have been adjusted or edited for various forms of original errors. This is of considerable importance, since it is often desirable at some stage to reproduce the original raw data series from an edited series to examine the edited portions in detail.

4.2 Design objectives

Having discussed the major criteria for a computer based standard scheme for processing sea level data, let us now consider in detail what might be the necessary objectives of such a system.

4.2.1 Input of the raw digital data series and the associated information necessary for processing from analogue recorders into a suitable computer storage medium (we have used the word 'raw' to denote the straightforward digitised data series without any subjective adjustments). In the case of tidal charts, we assume that the raw data consist of the abstracted heights in digital form.

4.2.2 Establishment of a system working data file, by organising the raw data series and the associated information within the storage medium to give maximum flexibility in processing.

4.2.3 Flagging of data values affected by the initial identified errors.

4.2.4 Archiving of a copy of the organised working data file in a full catalogued archiving system.

4.2.5 Application of standard screening and processing procedures, such as the verification of smoothness of data and the associated editing of error-affected data values, and conversion of non-hourly data into hourly data.

4.2.6 Optional high level processing, such as the automatic interpolation of limited gaps in the data series and further screening of quality of data with the aid of residuals.

4.2.7 Establishing continuous compatibility of data series for each sea level recording location.

4.2.8 Establishing exact cross-match between raw and edited data series.

4.2.9 Archiving of the final edited data series in a fully catalogued archiving system.

4.2.10 Optional scheme for the presentation of the final edited data series in terms of various plots and print-outs of data, residuals and their statistics, mean sea levels, extreme elevations etc, with full reference to the modes of processing undergone by the raw data series in establishing the final edited data series.

4.2.11 Organisation of all the above mentioned activities (4.2.1 to 4.2.10) into separate processing modules to give added flexibility to the complete system, as well as to provide necessary interaction to the user between different modules.

Having identified the design objectives, we will now describe briefly the outlines of an associated computer based system now being developed and implemented at IOS Bidston.

5. — BASIC OUTLINES OF THE SYSTEM — TERP

The system, named Tidal Elevation Reduction Package (TERP), is a comprehensive computer software package developed to provide a facility for the systematic reduction and presentation of sea level data, from analogue tide gauges providing a record in either graphical or digital format. It is hoped that the system will standardise the methods for reducing sea level data and furthermore will help to provide valuable information and guidance to personnel responsible for designing and maintaining accurate sea level recorders. The system is also designed to provide rapid access to statistical information regarding the data, increasingly sought by users.

TERP is capable of handling data lengths (at any one time) of up to 8,784 values (equivalent to one year of hourly values) sampled at every 5, 10, 15, 30 or 60 minute intervals. An optional facility exists to handle data digitised on an optical digitiser, at random sampling intervals. Input raw data in digital form are archived and catalogued on magnetic tape media, together with full reference to operator monitoring checks, to retain the original observed data set. The final edited data set is also archived and catalogued, together with cross-reference information identifying all modes of translation from the raw data set.

The complete system is implemented on a Honeywell 66/20 computer at IOS Bidston and all routines are coded in FORTRAN and compiled in ASCII mode. The entire system can be visualised as comprising of three independent modules.

(a) DATA REDUCTION MODULE

This module carries out the complete reduction process required to obtain an edited data set.

(b) FILE HANDLING UTILITY MODULE

This is a facility available for the maintenance (i.e. merging, reformatting and archiving) of the system working data file.

(c) DATA PRESENTATION UTILITY MODULE

Facility for the presentation of the processed (by the DATA REDUCTION MODULE) data and their associated properties, such as the mean sea levels, extreme elevations etc.

Figure 3 shows the modular layout of the complete TERP system.

Each of these modules is further divided into sub-packages in terms of software, to add maximum flexibility to the system as well as to provide necessary interaction to the user between different processing functions.

(a) Data Reduction Module

(i) INITIALISATION

— Read the input data file and load the working data file.

— Plot the raw non-hourly data for visual verification of smoothness of data.
— Copy the working data file into the system archiving catalogue for subsequent archiving.

(ii) Data Reduction I

— Verify the smoothness of hourly data.

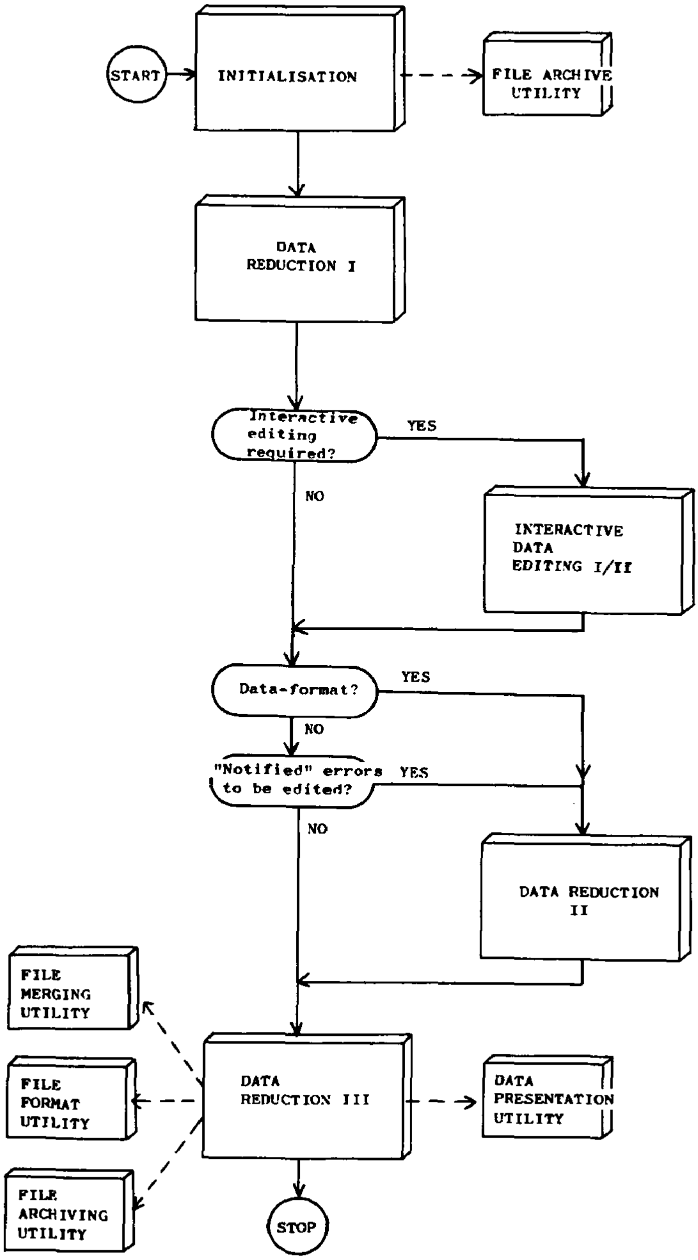

Fig. 3. — Modular layout of the computer system TERP indicating flow of operations.

(iii) DATA REDUCTION II

— Convert non-hourly data into hourly data.
— Edit for any 'user notified' time/datum errors.

(iv) DATA REDUCTION III

— Interpolate gaps (of < 13 hours) in the data on user request.
— Compute and plot residuals.
— Copy the working data file into the system archiving catalogue for subsequent archiving.

(v) INTERACTIVE DATA EDITING I

— Facility to edit the working data in interactive mode.

(vi) INTERACTIVE DATA EDITING II

— Facility to edit the graphical form of the working data in interactive mode.

(b) File Handling Utility Module

(i) FILE MERGING

— Facility to merge two working data files on calendar year basis. This is applicable to working data files of less than one calendar year in length to form complete calendar year data files, prior to archiving.

(ii) FILE REFORMATTING

— Facility to reformat data in the working data file into standard conventional card image (METRES/FEET) format with the appropriate identification field on the right hand side of each card image.

(iii) FILE ARCHIVING

— Facility to archive the working data file (in the system archiving catalogue) along with an automatically generated comment header.

(c) Data Presentation Utility Module

(i) DATA PRESENTATION

— Facility for the presentation of the processed (by the DATA REDUCTION MODULE) data, and their associated properties such as the mean sea levels, extreme elevations etc.

Initial raw sea level data and the associated input parameters are input at the INITIALISATION stage and are stored in the system working data file. All subsequent data manipulation between the sub-packages are carried out automatically via the system working data file. The complete layout of the TERP system, in terms of the individual sub-packages within the three processing modules, is shown in figure 4.

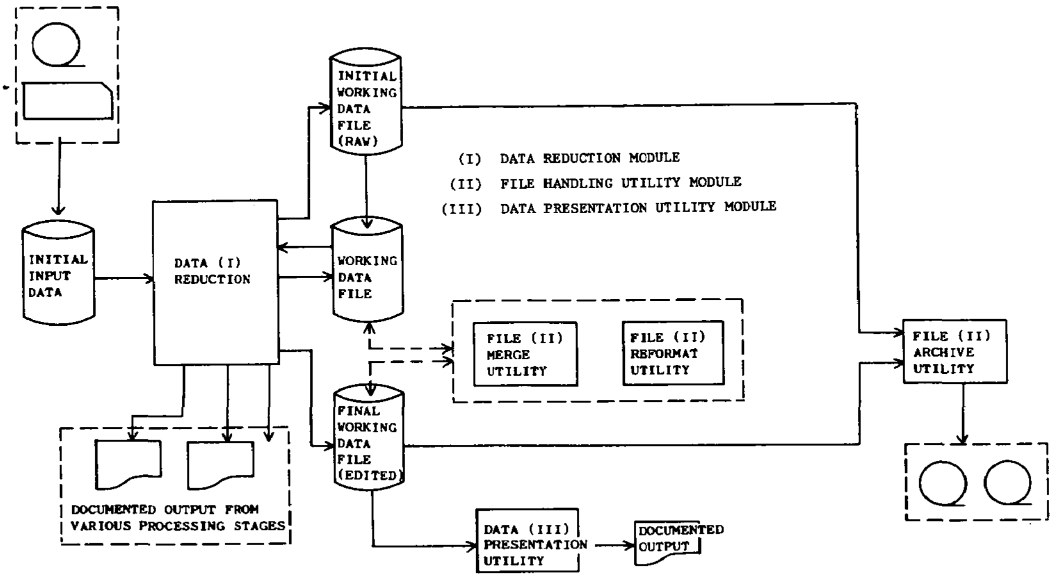

FIG. 4. — Layout of the computer system TERP showing sub-package structure and its interface with the three basic modules.

6. — CONCLUDING REMARKS

The computer orientated sea level data processing system TERP described here has been developed as a necessary requirement to introduce standardised procedures for the reduction and handling of tide gauge records. The system has been designed to process systematically digital sea level data series which may be obtained from a large variety of tide gauge recorders. The organisation of TERP is such that it may be directly interfaced to handle digital data series transmitted automatically from distant sea level recording stations which introduces a powerful flexibility for accepting, for processing centrally, data recorded from a wide range of new generation tidal recorders. The computer-based design introduces a new level of efficiency and management in the handling of sea level data series from many different locations and allows fast and easy access to these data and their interface with other established computer based tidal data handling systems at IOS Bidston, such as the oceanographic data bank of the Marine Information and Advisory Service (MIAS), and the network of tidal prediction programs used for annual preparation of tide tables (GRAFF, 1978).

Above all, the TERP system has been developed to establish sound and systematic procedures for the accurate reduction of sea level records. Both the raw digital data series and the subsequent smooth data series are fully monitored, together with the exact editing processes which are referenced in parallel to allow a two-way regeneration of either time series. Once fully established, TERP can offer a rapid data processing capability, thus avoiding the major problems of backlog that are typical of some establishments engaged in handling tidal records from a national network of gauges. Finally, as well as offering ready access to the archived smooth tidal time series, the nature of the many intermediate monitoring and screening checks allows access to the level of information necessary for the accurate maintenance of tide gauges. In this context it is useful to note the collaboration that has evolved at IOS Bidston between the Tidal Data Processing group and the Tide Gauge Inspectorate, a body responsible for the maintenance, monitoring and development of the class A network of tide gauges around Great Britain.

ACKNOWLEDGEMENTS

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