CHAPTER 53

Analysis of maximum sea levels in southern England

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Abstract

Along the south coast of England, series of observed annual maximum sea levels, ranging from 16 years to 125 years have been analysed for each of 10 ports. The Jenkinson[1] method of analysis was used to compute the frequency of recurrence of extreme levels. For a number of these ports the series of annual maxima are shown to have significant trends of the same order as those for mean sea level. The Jenkinson method can be simply adjusted to cope with maxima having a component linear trend, making it possible to allow for such trends in computing the frequency of recurrence of extreme levels. If a trend in the annual maxima varies throughout the sample of observations it is shown that difficulties arise in using the Jenkinson method to compute acceptable statistics. It is also shown that for certain ports having long series of observed annual maxima it may be necessary to restrict the sample size of observations in order to compute estimates of the recurrence of extreme levels within reasonable return periods.

Introduction

Around the coastline of England, particularly along the north west, east and south east the occurrence in recent years of abnormal flood levels has created a demand for the reassessment of flood defence levels and a need to revise measures of the frequency of recurrence of extreme levels. Subsequent to the disastrous east coast flooding of 1953, coastal defence levels were established to protect against a further recurrence of these levels. In the past decade, the levels of 1953, which were generally associated with return periods exceeding 100 years, have been overtopped on a number of occasions at certain north west and east coast ports suggesting that factors may have contributed to increase the frequency of occurrence of extreme levels. Lennon[2] and Suthons[3] published studies in 1963 on the analysis of occurrence of observed annual maxima for ports respectively on the west and south east coasts of England. For south east ports Suthons, using Jenkinsons method of analysis, included the effects of a linear trend of 1ft/century, representing an assumed secular trend in mean sea level. The series of observations studied by Lennon and Suthons extended to the average period 1957/60. In recent years the need to update the work of Suthons[3] for south east coast ports has led to a number of studies, notably Akers & Ruxton[4] (1974, Southend), Webber & Davies[5,6] (1976 Portsmouth, Southampton, Calshot) and Blackman & Graff[7] (1978). The study[7] by the authors, covering 10 ports along the south

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coast of England forms in part the basic framework of this paper. All the studies mentioned so far (viz. 2, 3, 4, 5, 6, 7) accept that the longest available and reliable series of observed annual maxima should be analysed by extreme level techniques. Although no strict information is available (moreso perhaps possible) to indicate how far one may extrapolate the analysis curves showing the frequency of occurrence of extreme levels it is accepted[10] that some reliability can be based on considering a period up to perhaps 4 times the original sample size. It is however not uncommon practice, in considering design criterea for coastal defences that the extrapolated extreme sea level likely to occur once in a period exceeding 15 times the original sample size, is in fact used.

For the coastline of east, south east and south England, secular trends of various order exist in the series of annual maxima. Suthons[3] and the authors[7] included the effects of mean linear trends occurring throughout the sample of observations to provide "more likely" estimates of the recurrence of extreme levels. More recently, in reviewing their work on south coast ports, and extending their studies to other U.K. ports the authors have shown that the use of an analysis method such as the Jenkinson technique can be highly dependent not only on the sample size of observations but also on thenature and linear measure of secular trends in the data. Whereas in the past it was thought acceptable to make an analysis of the full available sample of observed annual maxima, and perhaps adjust these for a mean linear trend, it would now seem that such results can cloud the presence of many anomalies and it may be necessary to make the analysis more detailed in order to provide information of practical use. In this paper the authors present a summary of their already published study[7] and an account of the more recent work[8] in the analysis of observed annual sea level maxima.

The form of sea level maxima

An observed sea level can be simply expressed as

$$h_o = h_p + h_w + h_r \qquad 1.$$

where h_p is the astronomically generated (predictable) tide.

h_w is the wave height induced by wind or otherwise.

h_r is a residual due to non tidal or weather effects.

Tide gauges are generally so designed to filter out the wave height and record only the level h_o^*

$$h_o^* = h_p + h_r \qquad 2.$$

In reality however a more explicit form of the recorded level h_o^* should be expressed as

$$h_o^* = h_p + h_R \qquad 3.$$

where $h_R = h_r + \epsilon$, ϵ being a small (or sometimes large) error due to effects in the recording mechanism which should be accounted for in the reduction of records.

In considering recorded levels h^*_o of annual extremes it is not uncommon to find that stresses imposed on the tide gauge often contribute severe perturbations (ϵ) to the recorded tidal trace which can not always be resolved unambiguously from the true level being recorded ($h_p + h_r$).

Equally in instances where the tide gauge breaks down around the time of the extreme level occurring it is necessary to try and extrapolate the recorded trace to the time of the peak level.

In the case of extreme levels being recorded from a tide pole there is inherently a far greater uncertainty in accepting the level to be an accurate height as defined in (2). More likely than not, under associated severe weather conditions (often in the dark) a sea level read from a tide pole, even by an experienced observer, may reflect a significant measure of the superimposed wave effects (h_w).

It seems important to mention the above points here to highlight the form of data being considered in this type of analysis. These data are essentially a measure (often estimate) of the single annual maximum sea level as defined in (2), divorced of wave effects which on such occasions are often of a considerably pronounced form. These single annual maxima can be seen in the context of other peak tidal levels in Figure 1, which shows the distribution of observed monthly maxima over some 20 years for Newhaven, one of the ports studied. This bimodal form of distribution is typical of sea level maxima at many ports around the British Isles.

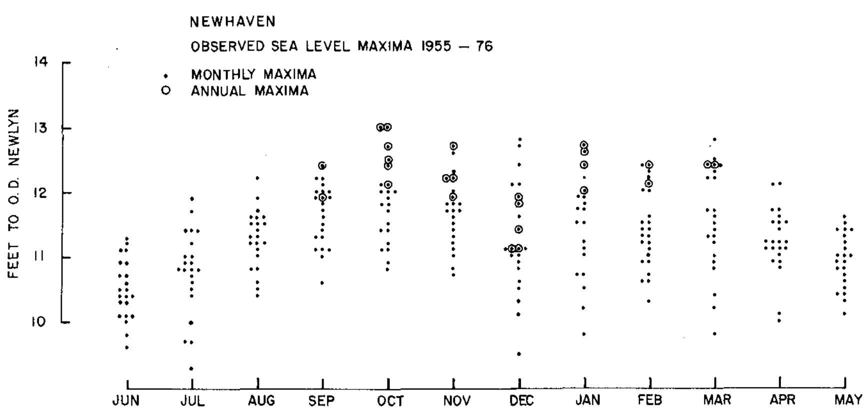

FIG. 1. Observed monthly sea level maxima at Newhaven.

To date only Akers & Ruxton[4] have endeavoured to analyse the interaction of the components h_p, h_w and h_r in relation to extreme levels, and the complexity of the problem and lack of suitable wave data have shown to present serious limitations. More recently Pugh & Vassie[9] have approached the problem of investigating the occurrence of maxima by studying the interactive effects of h_p and h_r at hourly intervals, a technique that is hopeful of finding suitable joint probability distributions (of h_p and h_r), based on reasonably short series of a few years, that can be combined to provide information concerning the recurrent frequencies of abnormal levels.

Referring back to the work presented in this paper it is useful again to be reminded that the observed annual maxima studied are principally as defined in (2) although where tide pole data have been used one must accept that some proportional influence of wave effects are included.

Observational data

For each of the 10 ports indicated in Figure 2 the best series of up-to-date annual maxima were obtained, in some cases extending the data studied by Suthons[3] by some 30%. Most of these data were based directly on tide gauge records, which for some ports covered a considerable period. All the sea level records were reduced to the national reference datum of Ordnance Datum Newlyn. Table 1 lists the coverage of data for each port.

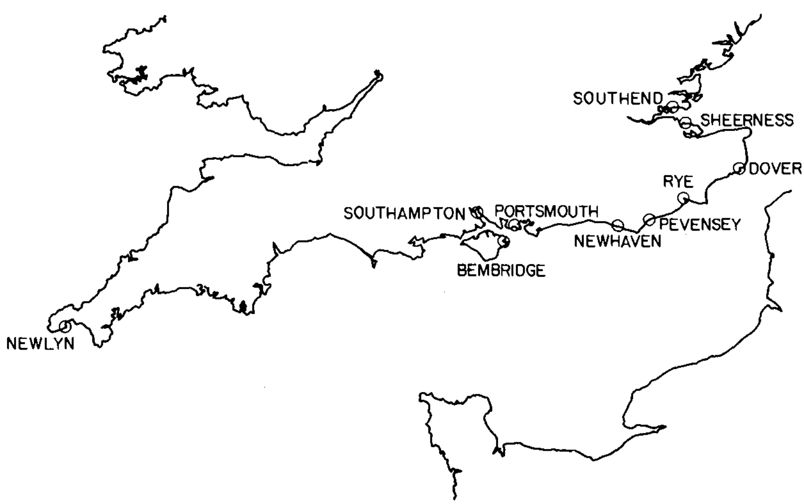

FIG. 2. Location of the 10 ports studied.

TABLE 1

Port	Years	Observed maxima
Newlyn	1916-76	61
Southampton	1924-75	47
Portsmouth	1813-75	105
Bembridge	1947-76	29
Newhaven	1913-76	60
Pevensey	1953-76	24
Rye	1949-74	16
Dover	1912-75	56
Sheerness	1819-70	125
Southend	1929-75	46

The Jenkinson method of analysis

If we assume that any observed annual maximum sea level h is a statistically random extreme event then these data can be analysed by a method such as that suggested by Jenkinson[1] in 1955. If T, the return period of height h is the average interval between occurrences of heights equal to or greater than h, it is easily shown that

$$T = -1/\ln.P \text{ or } \ln T = -\ln(-\ln P) = x$$

where P is the probability that the annual maxima is less than h. Jenkinson suggests that the most general form of curve between h and x is given by

$$x = {}^{1}/k \ln \left(1 - \frac{h-h_c}{a}\right)$$

where k, h_c and a are constants determined from observations. k is also a measure of the curve type of the data distribution such that if

$k < 0$, curve bends upwards; Fisher-Typpett Type I

$k = 0$, curve is a straight line; Fisher-Typpett Type II

$k > 0$, curve bends downwards; Fisher-Typpett Type III

Along the south coast of England the nature of the curve changes gradually eastwards, from Fisher-Typpett Type III through Type II to Type I, as seen in Figure 3.

Port diagram curves (Type A)

For the ports shown in Figure 2, the series of observed annual maxima indicated in Table 1 were analysed by the Jenkinson technique, and the results, showing the frequency of recurrence of maxima can be presented in a form as shown in Figure 3. These Port diagram curves are termed type A when related to analysis which do not account for the effect of linear trends.

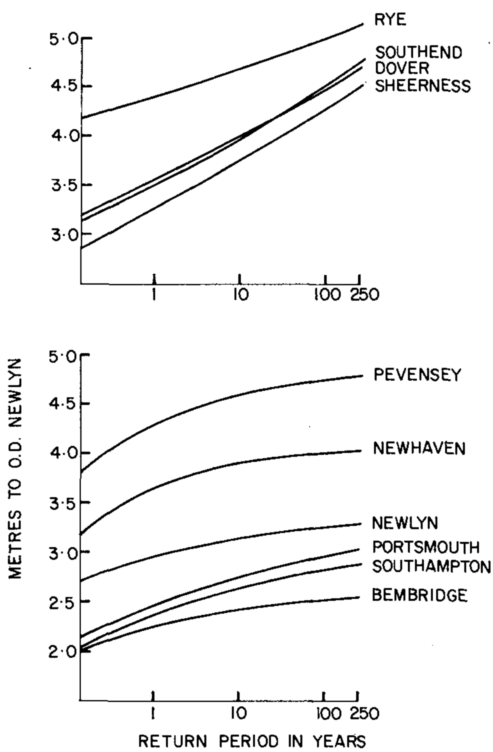

FIG. 3. Frequency of recurrence of observed annual maxima (excluding effects of trends).

Mean trends in observed annual maxima

The series of observed annual maxima for each port were examined for trends. No evidence was found to suggest that any secular fluctuation of data was correlated with long period tidal effects of astronomical origin. Mean linear trends were resolved by simple linear regression analysis, and for several ports where suitable hourly sea level data were available, it was possible to also obtain the linear trend of mean sea level. These trends are shown in Table 2 and it can be seen that in general, the trends in annual maxim are similar to those for mean sea level. For the ports Newhaven, Dover and Sheerness the linear trends in annual maxima are significant.

TABLE 2

Port	Trend in annual observed maxima, mm/year	Trend in mean sea levels, mm/year
Newlyn	1.31 ± 0.75 (61 years)	1.95 ± 0.12 (60 years)
Southampton	1.18 ± 1.62 (47 years)	1.06 ± 1.11 (15 years)
Portsmouth	0.68 ± 0.29 (105 years)	8.35 ± 0.80 (13 years)
Bembridge	-3.38 ± 2.06	
Newhaven	5.44 ± 0.94 (60 years)	4.11 ± 1.65 (18 years)
Pevensey	4.60 ± 5.39	
Rye	1.53 ± 5.54	
Dover	4.99 ± 1.68 (56 years)	4.52 ± 0.53 (39 years)
Sheerness	2.41 ± 0.53	2.37 ± 0.17*
Southend	0.39 ± 2.92 (46 years)	1.71 ± 0.29 (49 years)

* Values established by Rossiter,[11] based on 85 years.

One could perhaps suggest, in broad terms, that mean trends observed in series of extreme levels reflect the secular trends in mean sea levels, although one should bear in mind that the mean sea levels are based on continuous hourly observations throughout the years whereas the annual maxima represents a single level occurring generally within the "storm months" August-March (See Figure 1).

Port diagram curves (Type B, C)

The Jenkinson method of analysis can be also applied to data which have a component of linear trend, providing that the data are first reduced to some selected epoch. For instance if the epoch is 1900 and a linear trend of .001 m/yr exists in the annual maxima then an observed level of 10.0m in 1850 reduces to a level of 10.05m in 1900, and similarly an observed level of 10.0m in 1950 reduced to a level of 9.95m in 1900. The resulting port diagram curves, termed type B, accounting for a linear trend component, are similar to those noted as type A. The interpretation of type B curves is strict in the sense that a linear trend has been accounted for up to the base year of the selected epoch and no trend exists in the data beyond this year.

Suthons[3] suggested it is possible to make some allowance for including a trend beyond the epoch by adjusting type B curves (into curves termed type C) in the following manner.

If T is a return period of height h_B (type B curve) or h_C (type C curve) where a mean rate of annual rise S is being considered in the data, then

$$h_C = h_B + T.S/2$$

This gives some guidance to interpreting the additive effects of a continuing trend assumed to exist in the data.

Figure 4 illustrates all three Port diagram curve types (A, B, C) for Sheerness.

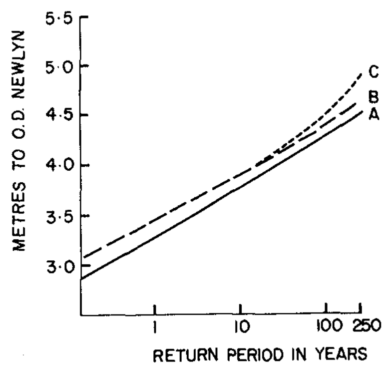

FIG. 4. Frequency of recurrence of observed annual maxima for Sheerness.

Curve A. unadjusted for any trend effects.

Curve B. adjusted to the epoch 1976 for a linear trend of 2mm/yr present only in the data analysed.

Curve C. adjusted to the epoch 1976 for a linear trend of 2mm/yr assumed to persist indefinitely.

As the return period T increases beyond a value equal to about twice the sample size of observations, the expected height h_c increases rapidly to unreal proportions. The format of computing the type C curve is subjective and gives guidance only as a broad illustration of including extrapolated trends. Appendix 1 lists for all 10 ports, data from port diagram curves type A, B, C, related to recurrence periods of 10, 20, 50, 100 and 250 years.

Some further considerations in the analysis of annual sea level maxima

Since in general, only a limited series of observed annual maxima, of the order of 10-20 years, are available for most ports, it is of interest to have some feeling for the response of the analysis method (Jenkinson) to different sample sizes. It is also of considerable interest to understand the nature of secular trends which may exist in the data series since they can have a pronounced effect on the analysis of such data. These considerations are particularly important for ports where a substantial investment is to be made in raising flood defences for protection against abnormal levels, subjectively assessed as being of the order of 1-in-100 years or more. At present the terms "return periods" and the associated "expected levels" are perhpas too freely used in the assessment of design criterea for coastal defences and it seems important to illustrate the drawbacks and limitations of interpreting what may seem to be "standard" port diagram curves.

Before any type of port diagram curve is to be interpreted seriously for practical purposes a number of questions would seem to be of prime importance.

1. How real is the sample of observed data in terms of their measured values.

2. Does a trend exist in the sample data set, and if so what is its form.

3. Will a trend persist in the future and can this trend, and that in a sample data set, be approximated by a constant linear term.

4. What is the confidence in extrapolating port diagram curves and how is this related to the size of the sample set.

Although we would not presume to suggest that any of these questions can be strictly answered we do suggest it is possible to illustrate their significance, hereby gaining a far greater awareness of the problem, thus enabling one to make a more objective interpretation of results.

Reliability of observed data

The uncertainty of measured data has already been discussed earlier and it is a simple fact that for good or bad, most early records of annual maxima proceeding the early fifties must be accepted as the "best measures" available. To review such data in terms of the performance and stability of the measuring instrument presents considerable problems and frustration in what is often a mass of conflicting historically documented heresay. The national reference level, Ordnance Datum Newlyn, was only introduced as a datum measure to most Ports in Great Britain, in various degrees of accuracy, during the period between the late thirties and early fifties. Diligent checking of the annual tidal records, tide gauge histories and datum levelling exercises is the only sure way of attempting to collate a continuous datum level for series of records dating back through the early part of this century. In a few instances, for portions of data, much of the relevant information has been lost to antiquity.

Trends in annual maxima

With a substantial series of annual maxima one can identify fluctuations that can be resolved as a linear estimate of a mean trend. Table 2 already presents such measures for the 10 south coast ports which leads one to assume it is a simple matter to proceed in computing port diagram curves of type B. If we examine the form of these fluctuations or trends, a little closer it becomes obvious that they are far from linear, and like mean sea level data they vary in an ill defined and unpredictable fashion. Figure 5 shows the annual maxima plotted as 5 year running means for Sheerness and Portsmouth which represent the longest data series available in the study.

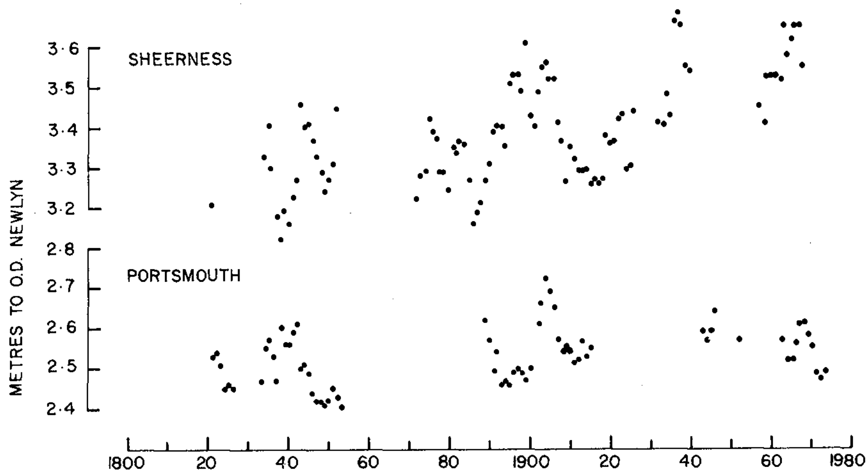

FIG. 5. Observed annual maxima plotted as 5 year running means for Sheerness and Portsmouth.

For some of the 10 ports a significant mean trend can be identified throughout the full data series but moreso in these cases (Sheerness) more pronounced secondary trends also can be identified within both long and short portions of the data set. Simple regression analysis of the annual maxima in cumulative sets to a 10 year base, both forward and backward (in a time wise fashion) readily show the extreme variability of the linear trend estimate and its generally poor fit to the observed data. These results are illustrated for all 10 ports in Appendix 2.

Since one can in fact adjust for linear trends in computing port diagram curves it is easy to see that the question of "what trend do we adjust for" is not a simple one to answer and indeed is a matter for some, if not considerable conjecture.

The confidence in port diagram curves

Bearing in mind that available series of annual maxima may be short or long, some thought should be given to interpreting resulting port diagram curves against the criterea of sample size. Again we split the series of observed data for each port into cumulative 10 year sets as noted earlier and made a systematic analysis to compute port diagram curves of both type A and type B for each block of data, in the same forward and backward fashion as for the regression analysis. To compute the type B curves the appropriate cumulative data sets were adjusted for the associated mean linear trend, to a common epoch. It would be impractical to try and present here even a summary of such results for all 10 ports, a form of analysis [8] which is now being systematically applied to data from many other ports around the British Isles. However, it is of some considerable interest to present typical results, for Sheerness, a port of major importance in the Thames estuary. The series of annual maxima for Sheerness show fluctuations in trend as seen in Figure 5 and Appendix 2, these having a significant positive mean linear trend throughout the full series of 125 annual observed maxima.

In Figure 6, the height with a period of recurrence of 100 years, based on type A curve analysis, has been plotted directly against the cumulative size of sample (number of annual maxima) used for the analysis. The cumulative sample sets relate, as shown, to the base year 1819 and 1970, respectively the start and end of the full observed series. It has also been possible to show these estimates based on analysis of 6 independent sets of 20 maxima taken throughout the period of data available. Similarly on the same diagram the results related to a type B curve analysis are shown, each cumulative data set being adjusted for the associated mean linear trend (Appendix 2) to the epoch 1980.

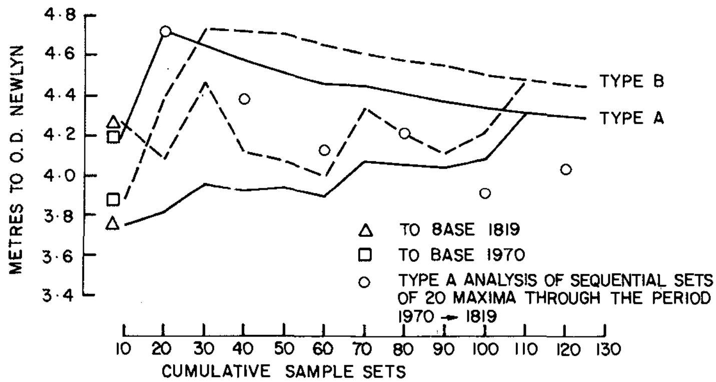

FIG. 6. Frequency of recurrence of observed annual maxima for Sheerness showing the 1-in-100 year event, based on analysis of different subsets of the data.

We would point out that the results shown in Figure 6 are not untypical[8] of other ports in Great Britain where a far shorter series of annual maxima (up to 60 years) are available. Figure 6 (for Sheerness) highlights two points of particular interest

1. Depending on the sample set of maxima analysed (some multiple of 10) the 1-in-100 yr level can vary within a range of up to 1 metre. This range diminishes only as the sample size approaches its maximum length.

2. There is a pronounced increase in the estimated height of the 1-in-100 yr level throughout the period 1819 to 1970, e.g. there seems to be a general increase in the recurrence of abnormal levels.

This readily illustrates the considerable uncertainty in trying to interpret such results for practical purposes. In the past, and currently, it is often accepted that results based on analysis of a maximum available data series would provide a confident "best estimate" or a recurrence level for basic design level estimates. However this is clearly not the case, and the above results suggest that the assessment of a frequency of recurrence of an abnormal level (design level perhaps) is much more subjective than hitherto suspected, especially if sea level maxima are subject to some form of secular trends. If the data were truly devoid of significant trend components (as is the case for other ports) then we would expect considerably less divergence in the plots as shown in Figure 6 above, and consequently would have a greater confidence in making an interpretation of such results. Portsmouth is seen to be a case-in-point where the absence of any significant trends produces a relatively stable set of recurrence levels, as illustrated in Figure 7 in the same fashion as for Sheerness. The high anomalous value associated analysis of the 10 earliest maxima reflects in fact the presence of dubious recorded levels.

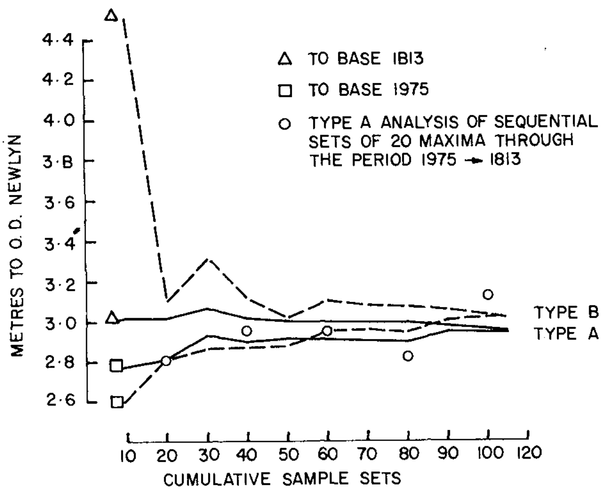

FIG. 7. Frequency of recurrence of observed annual maxima for Portsmouth, showing the 1-in-100 year event, based on analysis of different subsets of the data.

Appendix 3 lists heights associated with recurrence periods of 100 years based on type A curve analysis of 10 year cumulative data sets of the observed annual maxima for all the 10 south coast ports.

Conclusion

This paper has summarised results on the analysis of abnormal sea levels at south coast ports in England, and illustrated the revised level of information that is now necessary in order to provide a meaningful interpretation of the frequency statistics. Hitherto, estimates of recurrence levels have been based purely on analysis of the single full length sample of annual observed maxima. For certain ports this may be acceptable, but it is suggested that there is a need for a more detailed analysis of the data, as illustrated in this paper. Indeed it may be the case that for some ports, irrespective of the length of available annual observed maxima, one may be restricted to assessing levels with recurrence periods less than 50 years, and these based only on analysis of subsets of the full data series. The analysis procedures are highly sensitive to data which contains secular trends that are not of a strictly linear form. A component of such trends may indeed be due to some corrupting effect of errors in the raw observed data.

Although annual observed sea level maxima provide an attractive basis for analysis procedures, such as Jenkinsons, aimed at forecasting recurrence levels, it is proving more unlikely that such treatment of single annual tidal observations will provide a satisfactory standard level of reliable information for practical design purposes. The interactive effects of tide, wave and weather are complicated to such a degree, that coupled with the uncertainty of sea level measurements of maxima it may be necessary to approach such studies of frequency analysis in a more fundamental way.

Acknowledgements

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APPENDIX 1

PORT		RECURRENT SEA LEVELS associated with curve types A, B*, C* based on analysis of whole data sets of maxima				
		10 Yr	20 Yr	50 Yr	100 Yr	250 Yr
NEWLYN	A	3.15	3.19	3.24	3.27	3.30
	B	3.19	3.23	3.27	3.30	3.33
	C	3.20	3.24	3.31	3.37	3.49
SOUTHAMPTON	A	2.65	2.71	2.79	2.84	2.89
	B	2.68	2.74	2.82	2.87	2.93
	C	2.63	2.75	2.85	2.93	3.08
PORTSMOUTH	A	2.75	2.82	2.90	2.96	3.02
	B	2.79	2.87	2.96	3.03	3.12
	C	2.80	2.88	2.98	3.07	3.20
BEMBRIDGE	A	2.43	2.47	2.51	2.53	2.56
	B	2.36	2.38	2.40	2.41	2.42
	C	2.34	2.34	2.31	2.24	2.00
NEWHAVEN	A	3.89	3.94	3.98	4.01	4.04
	B	4.04	4.09	4.13	4.16	4.20
	C	4.07	4.14	4.27	4.44	4.88
PEVENSEY	A	4.60	4.66	4.72	4.76	4.80
	B	4.67	4.73	4.80	4.84	4.88
	C	4.69	4.78	4.91	5.07	5.45
RYE	A	4.72	4.81	4.94	5.03	5.17
	B	4.74	4.83	4.95	5.05	5.18
	C	4.75	4.85	4.99	5.13	5.38
DOVER	A	4.01	4.16	4.35	4.50	4.70
	B	4.16	4.30	4.49	4.65	4.87
	C	4.18	4.35	4.62	4.90	5.50
SHEERNESS	A	3.77	3.93	4.13	4.29	4.51
	B	3.94	4.09	4.29	4.45	4.66
	C	3.95	4.11	4.35	4.57	4.97
SOUTHEND	A	3.98	4.14	4.35	4.53	4.77
	B	3.99	4.15	4.36	4.54	4.77
	C	3.99	4.15	4.38	4.56	4.83

* curve types B, C adjusted to mean linear trend throughout whole data set (Table 2).
Curve type B related to epoch 1980.

APPENDIX 2

LINEAR TREND ESTIMATES (mm/yr) IN CUMULATIVE SETS OF OBSERVED MAXIMA

		10	20	30	40	50	60	70	80	90	100	110	120	130
NEWLYN	Δ	-3.7	-3.6	2.5	1.4	2.0	1.3	1.3						
	□	-4.1	-4.1	0.2	0.3	1.2	1.2							
SOUTHAMPTON	Δ	-10.6	-7.1	-2.0	0.5	1.2								
	□	-14.4	9.0	3.6	1.9									
PORTSMOUTH	Δ	9.5	0.6	1.7	0.7	0.2	0.9	0.8	0.8	0.9	0.8	0.7		
	□	14.0	0.0	-1.5	-0.9	-0.9	0.7	1.0	1.0	0.6	0.6			
BEMBRIDGE	Δ	-10.1	-5.1	-3.4										
	□	-9.4*	3.3											
NEWHAVEN	Δ	18.2*	2.6	5.1	6.4*	7.4*	5.4*							
	□	-1.3	-5.2	1.6	3.9	5.9*								
PEVENSEY	Δ	50.6*	7.0	4.6										
	□	-22.6	-7.8											
RYE	Δ	5.3	1.5											
	□	-1.4												
DOVER	Δ	25.9	-3.3	1.5	4.3	5.8	5.0							
	□	-13.6	6.0	5.3	7.7	4.7								
SHEERNESS	Δ	4.9	2.0	3.6	1.5	1.1	0.8	2.6	1.5	1.2	1.6	2.6	2.5	2.4
	□	-18.6	-13.4	2.6	4.3	5.5	4.4	3.0	3.3	3.4	2.8	2.5	2.4	
SOUTHEND	Δ	26.5	5.3	2.6	2.3	0.4								
	□	-23.0	3.8	-0.7	-1.3									

circled value indicate trend estimate for full sample set of observed maxima (Table 2)

* observed maxima show high correlation with trend estimate

Δ cumulative data sets are to origin of observed maxima (Table 1)

□ " " " " " end " " "

APPENDIX 3

1-in-100 YEAR RECURRENT SEA LEVELS BASED ON TYPE A ANALYSIS OF CUMULATIVE SETS OF OBSERVED MAXIMA

		10	20	30	40	50	60	70	80	90	100	110	120	130
NEWLYN	△	3.10	3.17	3.21	3.26	3.28	3.27	3.27						
	□	3.21	3.27	3.31	3.28	3.27	3.26							
SOUTHAMPTON	△	2.99	2.88	2.86	2.84	2.84								
	□	2.74	2.79	2.78	2.78									
PORTSMOUTH	△	3.03	3.03	3.07	3.02	3.01	3.01	3.00	3.00	2.98	2.96	2.96		
	□	2.78	2.82	2.93	2.91	2.92	2.92	2.91	2.91	2.96	2.96			
BEMBRIDGE	△	2.57	2.54	2.53										
	□	2.43	2.39											
NEWHAVEN	△	3.84	3.79	3.87	4.01	4.02	4.01							
	□	4.03	4.01	4.04	4.03	4.02								
PEVENSEY	△	4.67	4.77	4.76										
	□	4.88	4.80											
RYE	△	5.13	5.03											
	□	5.09												
DOVER	△	4.01	4.04	4.26	4.53	4.53	4.50							
	□	4.29	4.34	4.62	4.61	4.53								
SHEERNESS	△	3.57	3.82	3.96	3.93	3.95	3.90	4.09	4.06	4.05	4.09	4.32	4.31	4.29
	□	4.22	4.73	4.66	4.58	4.52	4.47	4.46	4.42	4.38	4.35	4.33	4.30	
SOUTHEND	△	4.35	4.38	4.62	4.56	4.53								
	□	4.05	4.26	4.64	4.57									

circled value indicate result from analysis of full sample set of observed maxima (Table 2)

△ cumulative data sets are to origin of observed maxima (Table 1)
□ " " " " " end " " "

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