A Method for Extracting Storm Surges from Tidal Records

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With 3 Plates including tables I.1-I.5, I.6-I.9 and tables A-G (Tafel 11, 12 und 13)

Summary. A method is described for extracting storm surge heights from hourly tabulations of tidal heights, which dispense with the use of a tide predicting machine. Within limits the method is adaptable according to the nature of the tidal regime encountered, and is particularly useful where shallow water effects are important. The computational work involved requires only slide rule, adding machine and graph paper. Two examples are given; one theoretical to justify the method, and one from nature.

Introduction. The reduction of tide gauge records to determine a surge is a purely tidal problem, involving as it does the elimination of the astronomical tide. This process gives residuals which can almost invariably be attributed to meteorological causes of one type or another, and it is perhaps as well to state that the definition of “storm surge” here adopted is “the oscillation(s) remaining after removing the astronomical tide from the observed levels.” It follows that although our prime interest lies in those residuals which, when combined with the astronomical tide, present a danger to sea defences, they will also contain relatively minor perturbations of level (such as free oscillations) which are not pertinent to the research.

The most obvious method of obtaining the astronomical tide is to use a tide-predicting machine, but the following objections are too important to be ignored:

a. Tide predicting machines are expensive to use, and a considerable amount of preparatory calculation is necessary to predict for the numerous scattered and short periods often required for each port. Furthermore, not all the national authorities possess a prediction machine.
b. An accurate knowledge of the harmonic tidal constants is essential for reliable machine predictions, but the results of harmonic analysis of the required accuracy exist for very few ports.

c. Many of the places for which storm surge research is important are situated in shallow water areas. In the harmonic theory of tides such areas are peculiar in that the third-, quarter- and sixth-diurnal and higher species of tide cannot be dismissed as of negligible amplitude. They exert a very marked influence upon the profile of the tide curve and no method has yet been devised, applicable to existing predicting machines, which will give satisfactory hourly height predictions for the majority of places, for example, on the coasts of Holland and southeast England.

The eighth-diurnal and higher species of tide may be graphically smoothed from the final residuals with efficiency, and thus do not present a serious objection to the use of a predicting machine. The major inadequacy of the machine lies in its inability to represent all the semi-, quarter- and sixth-diurnal constituents which are generated in shallow water by the interaction of the astronomically generated tide.

It is a common practice to overcome this difficulty by the use of reduction curves, that is to say, typical tide profiles classified in terms of the range and period of tide. Such curves are obtained by averaging observed curves, thus eliminating the diurnal tide, and are applied to predictions of high and low water. Although the shallow water tide may be thus adequately represented, the diurnal tide presents a complication. Standard predictions will include the diurnal tide, thus presenting a false range to which one of the reduction curves will be fitted, unless a special correction is made. Another objection to the reduction curve method for our purposes is that very infrequently do both the range and period of a curve fit given predictions. This had led to the use of ‘‘elastic’’ curves, but they cannot be considered wholly satisfactory devices.

Since there are difficulties in the direct computation of the astronomical tide hour by hour, the possibility of elimination of the tide by other methods needs to be explored. A. T. Doodson [1929] gave a method for determining surges from tidal observations which has since been freely used at the Tidal Institute; for example, R. H. Corkan [1948, 1950]. The principle used was that relative to mean sea level the absolute heights of a semidiurnal tide (i.e. taken without regard to sign) at intervals of six hours form a smooth series. For actual tidal observations no such precision is available because of the effects of diurnal and shallow-water tides, and also because daily values of mean sea level are not constant. Nevertheless, if the value of mean sea level is known approximately, and denoted by $A$, then the sequence of observations ($\zeta$) at intervals of 12 hours could form the elements of one graph, and the values of $2A - \zeta$ six hours later could form the elements of another graph. These would show perturbations from diurnal and quarter-diurnal tides, and also from meteorological causes, but the smooth curves would give extremely good values of the combined semidiurnal and sixth-diurnal tides. If $A$ is well chosen the two curves would be identical but if there is an error in $A$ the two curves would be parallel; in practice only one curve would be drawn and the departures of the observations from this curve would give the results of eliminating the semidiurnal and sixth-diurnal tides. When a surge occurs the departures are large, and so, in order to get accurate curves, it would be necessary to have observations for a number of ‘‘quiet days’’ on either side of the surge. Six series of curves would be required.

The departures or residues after the semidiurnal and sixth-diurnal tides are removed would need treatment for the removal of the diurnal and quarter-diurnal tides. The removal of the diurnal tide needs great care, because its period approaches the average period of surges. Also, it is especially susceptible to diurnal oscillations of air pressure. Therefore it is necessary to eliminate it by means of harmonic predictions, a method which is quite satisfactory for the diurnal tide. If no machine is available use may be made of a method adapted from one used by Doodson [1921] and which is explained later. This method is probably quicker even than the use of a machine, when the diurnal tide is small, and it is well adapted for use with observations from the North Sea. It would be a simple matter to extend the method for use with observations at places where the diurnal tide is comparable with the semidiurnal.