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A NECESSARY CONSTRAINT ON THE USE OF EXTENDED HARMONIC ANALYSIS FOR TIDE PREDICTIONS

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Abstract

When American and British tide researchers, in an effort to improve tide predictions for large-range shallow-water tides, greatly expanded the number of tide constituents (extended harmonic analysis), they chose the added frequencies by selecting peaks of energy greatly exceeding the continuum (noise level) in a high-resolution FOURIER analysis of tide residuals (observed minus predicted). Unfortunately, some tide agencies are now routinely analyzing for a greatly expanded number of constituents without checking as to whether the amplitudes of these added constituents are significantly larger than the continuum. They do this believing that more is necessarily better; actually, in some cases, a future prediction may be worse unless this check is done routinely.

About thirty years ago, Walter MUNK upset the international tides community with the comment 'Noise is found everywhere except in text books on tides'. He was referring to the practice of analyzing for a particular act of frequencies and disregarding all other frequencies in the spectrum.

In the following few years, MUNK and his associates made an intensive analysis of the entire spectrum, ending up with a description of a noise continuum which peaks near zero frequency and then declines monotonically toward the high frequency end of the spectrum except for cusps around important tidal lines (MUNK and BULLARD, 1963; GROVES and ZETLER, 1964; and MUNK et al, 1965). MUNK and CARTWRIGHT (1966) showed comparable results by response analysis.

As he worked with MUNK and GROVES on the continuum study, the author remembered thinking that he was the first in the Coast and Geodetic Survey to be aware of the continuum phenomenon. He then recalled that Paul SCHUREMAN had been aware of it many years earlier. He had analyzed many continuous individual years of hourly heights at one station and had noticed that, for very small amplitudes, the corresponding phases varied so much that they were essentially

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random. Accordingly, he issued an internal memo in the Tides and Currents Division instructing tidal mathematicians to substitute '<0.03 ft' for all amplitudes in that range and to omit the corresponding phases. This was to insure that these very small constituents were not used in future predictions.

He intuitively realized that including these small constituents was more apt to diminish the accuracy of future predictions rather than improve them. If the amplitude of a small constituent is 'a', and if the phase in a prediction happens to exactly match the analyzed phase, the residual variance in the prediction is *reduced* $a^2/2$. However, if the phase is exactly opposite (differs by 180°), the residual variance will be *increased* by $2a^2$ (four times as much). Comparable changes will be obtained for all other phases and, on the average, use of these small constituents will deteriorate rather than improve future predictions.

SCHUREMAN's limit of 0.03 foot was applied as a white noise limit, constant across the entire spectrum. Had he known that the continuum peaks sharply at low frequencies, many published harmonic constants for monthly and fortnightly tides would not have been accepted.

A few years after the continuum studies, ZETLER and CUMMINGS (1967) and ROSSITER and LENNON (1968) made use of this research by identifying and analyzing numerous additional frequencies in extended harmonic analysis of large, shallow-water tides at Anchorage and London respectively. After analyzing a set of tidal data for the harmonic constants of the routinely used constituents, they used these constants to predict for the entire period. They then obtained residuals by subtracting the predictions from the observations and did a high-resolution FOURIER analysis of the residuals. This showed a relatively smooth continuum except for occasional peaks significantly above the continuum. When it was possible to identify at such a peak, the frequency of a compound tide (the sums and/or differences of the frequencies of large tide constituents), each such compound tide was added to the set of tide constituents to be included in a subsequent harmonic analysis. By chance, both studies evolved with 114 frequencies but the sets of frequencies were not identical.

Some tidal agencies now routinely analyze for over 100 frequencies and the author suspects that they do not include a high resolution FOURIER analysis to check whether or not the analyzed amplitudes are significantly higher than the continuum. It cannot be emphasized strongly enough — more is not necessarily better and, indeed, quite possibly is worse.

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