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Forecasting Shoreline Position: a Nonlinear Approach

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Analysis of historical shoreline positions on sandy coasts, in the geologic record, and study of sea-level rise curves reveals that the dynamics of the underlying processes produce temporal/spatial signals that exhibit power scaling and are therefore self-affine fractals. Self-affine time series signals can be quantified over many orders of magnitude in time and space in terms of persistence, a measure of the degree of internal correlation in the stochastic portion of a time series. Fractal statistics developed for self-affine time series are used to forecast a probability envelope bounding future shoreline positions. The envelope is the (+-) standard deviation as a function of three variables: persistence, a constant equal to the value of the power spectral density when 1/period equals 1, and the number of time increments. The persistence of a twenty-year time series of the mean-high-water (MHW) shoreline positions was measured for four profiles surveyed at Duck, NC at the Field Research Facility (FRF) by the U.S. Army Corps of Engineers. The four MHW shoreline time series signals are self-affine with persistence ranging between 0.8 and 0.9, which indicates that the shoreline position time series is weakly internally correlated (where zero is uncorrelated), slightly non-stationary (mean and standard deviation are not constant), and has highly varying trends for all time intervals sampled. Forecasts of a probability envelope for future MHW positions are made for the 20 years of record and beyond to 50 years from the start of the data records. The forecasts describe the twenty-year data sets well and indicate that within a 96% confidence envelope, future decadal MHW shoreline excursions should be within ñ 14.6 m of the position in 1981, i.e. this is a stable-oscillatory shoreline. The forecasting method developed here includes the stochastic portion of the time series while the traditional method reduces the time series to a linear trend line fit to historic shoreline positions and extrapolated linearly to forecast future posi-

tions with a linearly increasing mean that breaks the confidence envelope eight years into the future and continues to increase. The traditional method is a poor representation of the observed shoreline position time series and is a poor basis for extrapolating future shoreline positions.