Linear and nonlinear dynamical features of long-term tide gauge records: Spatial and temporal patterns in the Baltic Sea area

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Recent work on sea-level change has almost exclusively focused on long-term variations in the mean. In contrast, changes in the nonlinear dynamics of sea-level variability have hardly been studied so far, even though they can be expected to provide important information on long-term changes in atmospheric driving factors and the ocean's response to them.

In this work, we study a set of long-term daily tide gauge records from the Baltic Sea area by means of various methods of linear and nonlinear time series analysis, including statistical tests for nonstationarity and the presence of deterministic and stochastic trends, time-frequency decomposition, time- and scale-dependent detrended fluctuation analysis, and measures of complexity based on recurrence quantification analysis and recurrence networks. Our results clearly demonstrate a marked latitudinal gradient in most of the studied properties.

In general, linear and nonlinear features obtained for different sites show consistent long-term variations, which are determined by changes in both local hydrological factors and the regional climatology. Time- and scale-resolved analyses reveal that temporal changes of nonlinear dynamic characteristics affect different temporal scales in different ways and are thus reflected differently by the individual measures evaluated at distinct scales. The corresponding analysis allows identifying and distinguishing long-term changes in sub-annual as well as annual to decadal-scale variability, which can be related to triggering factors acting at different temporal scales.