TIDAL DISTORTION IN SHALLOW ESTUARIES

by

PAUL EDWARD SPEER

Submitted to the Massachusetts Institute of Technology -
Woods Hole Oceanographic Institution
Joint Program In Oceanography
on March, 1984 in partial fulfillment of the
requirements for the Degree of Doctor of Philosophy

ABSTRACT

The offshore tide becomes distorted as it propagates into shallow inlet/estuarine systems. Time asymmetries develop in the rise and fall of sea surface with consequent time and magnitude asymmetries in tidal currents. Flood-dominant estuaries are characterized by longer falling tides and stronger flood currents while ebb-dominant estuaries have longer rising tides and stronger ebb currents. The asymmetries are reflected in the non-linear growth of harmonics and compound tides of the principal equilibrium tidal constituents. This dissertation consists of three papers which examine the development of tidal asymmetries in shallow estuarine systems: a study of the recent migration history of Nauset Inlet (MA), a shallow estuarine system located on Cape Cod; an analysis of the results of a series of field experiments conducted at Nauset; a numerical model study of the types of estuarine characteristics controlling tidal asymmetry. The analysis of field results focuses on sea surface measurements. Non-linear distortion of the tide at Nauset is characterized by the strong growth of harmonics and compound constituents particularly in the quarter-diurnal band. Phase relationships between the forced constituents and their parents produce a flood-dominant estuary. Numerical modeling of M_2 tidal propagation in shallow estuarine channels utilizes the one-dimensional equations of motion. Shallow, frictionally dominated channels with moderate tidal flat area develop a flood-dominant asymmetry while deeper channels with extensive tidal flats develop an ebb-dominant asymmetry. Model results are supported by observations of tidal asymmetry in natural estuaries. Implications of non-linear tidal distortion on bedload and suspended material transport are profound. Flood-dominant estuaries tend to import sediment if the supply is adequate whereas ebb-dominant estuaries can flush entering sediment effectively. Over long time periods, flood-dominant estuaries may eventually fill. Ebb-dominant estuaries may represent more stable long-term configurations.

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