SHORT-TERM SEA-LEVEL CHANGES AND COASTAL EROSION

PAUL D. KOMAR AND DAVID B. ENFIELD
College of Oceanography, Oregon State University, Corvallis, Oregon 97331

ABSTRACT: Investigations of the role of sea level in producing coastal erosion have focused mainly on the long-term rise due to melting of glaciers and thermal expansion of sea water. There are, however, additional shorter term changes in the local sea level produced by a variety of ocean processes. Variations in the coastal currents, for example, can alter the water level at the shoreline due to the geostrophic balance between the current and the offshore sea-surface slope. Other factors which may alter local sea level include changes in atmospheric pressure, winds blowing either in the longshore or cross-shore directions, and the occurrence of upwelling. Because the inclined continental shelf and slope act as a wave guide, the fluctuations often become trapped and propagate over longshore distances beyond where they are actually generated. In that many of these processes are typically seasonal, the responding sea level also has a pronounced seasonal cycle, but frequently there can be significant fluctuations at periodicities of several days to a few weeks. The magnitudes of such changes vary considerably with coastal location but are typically on the order of 10 to 30 cm, achieving a maximum of about 100 cm in the Bay of Bengal.

The occurrence of an El Niño in the equatorial Pacific is known to have considerable impact on the erosion of the coasts of California and Oregon. This occurs because associated with an El Niño are shifts in the storm paths and a temporary rise in sea level. An El Niño is a breakdown of the normal equatorial wind and current patterns. This breakdown releases water which is normally set up in the western Pacific by the trade winds. The release creates a "wave" of sea-level rise, which first propagates eastward along the equator and then poleward along the eastern ocean margin. Such "waves" have been measured in the tide records of the western United States, amounting to some 20 to 60 cm and lasting for several months. Such transient sea-level changes have likely played an important role in coastal erosion.

INTRODUCTION

The long-term and progressive rise in sea level has been cited justifiably as a major cause of erosion along our coastlines. Analyses of tide-gauge records from "stable" regions throughout the world place this eustatic rise at about 15 cm/century (Hicks, 1978) to 23 cm/century (Barnett, 1984). Any assessments of sea level determined from tide gauges show a great deal of variability, especially from week to week but even when yearly averages are being compared in attempts to determine such long-term trends. Thus, in the curves of annual sea-level changes (for example, those of Hicks, 1978, Gornitz and others, 1982 and Barnett, 1984), superimposed upon the long-term trend of generally rising sea levels are many irregularities and even some reversals. In those studies such fluctuations are considered to be unwanted "noise," but one person's "noise" is another's key to a better understanding of nature. In this case, physical oceanographers, in particular, have utilized short-term variations in coastal water levels as measured at tide gauges to advance our knowledge concerning the variability of major ocean currents and even to investigate global-scale responses of the ocean/atmosphere system.

Although the long-term sea-level rise of 15 to 23 cm/century undeniably plays an important role in causing coastal erosion, the shorter term sea-level changes might also contribute to erosion. The seasonal cycle typically accounts for water-level rises on the order of 10 to 30 cm and in unusual cases to as much as 100 cm, so that they equal or greatly exceed the long-term rise that has been the focus of most of our explanations for sea-level effects on coastal erosion. Unfortunately, in many cases little is known about the coastal response to these shorter term changes, although there are qualitative correlations which suggest their significance.

The principal objectives of this paper are to review what is known concerning the physical processes causing these shorter term sea-level fluctuations and to consider their possible role in producing coastal erosion.

SEASONAL CYCLES OF SEA LEVEL

The most obvious of the shorter term sea-level variations at nearly all coastal sites is the seasonal cycle. Examples are shown in Figure 1 for several locations around the coasts of the United States. A global summary of the month-by-month sea-level changes has been compiled by Pattullo and others (1955) and is discussed further by Pattullo (1966). She found that the seasonal variations range from only a few centimeters in the tropics to amounts on the order of 20 cm or more at higher latitudes. The largest change occurs in the Bay of Bengal, where the water-level variation regularly exceeds 100 cm within a year. Over most of the world the lowest sea level in the annual cycle occurs during the spring, the highest being in the fall (Fig. 1). This is true of both hemispheres, the Northern and Southern hemispheres oscillating in opposite directions according to the seasons. Although this is the average seasonal pattern of sea-level variability, there are many exceptions as to its exact timing which depends on local oceanic and atmospheric cycles.

Interpretations of the seasonal cycle of sea level are difficult because most of the driving mechanisms are seasonal and highly coherent, that is, exactly in phase with one another. Thus, at a specific coastal site, the sea level will be responding to the atmospheric pressure and its variability, local coastal winds, the currents they may generate (including coastal upwelling), and even rainfall. In that the atmospheric pressures, winds, rain and currents are all coupled, it is readily apparent that separating their comparative influences on the changing sea level will be difficult.

A significant portion of the annual change in sea level can be ascribed to variations in atmospheric pressure. Over the open ocean, sea level will respond as an inverse barometer to changes in the atmospheric pressure, that is, the sea surface is depressed 1 cm for each millibar of increased atmospheric pressure so that the net bottom pressure remains constant (Robinson, 1964). In the first detailed anal-