Tide and Sea Level Fluctuations from Days to Decades

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Abstract: This presentation will review factors contributing to the water level along the coast of southern California on time scales of days to decades and compare their amplitudes to that of "mean" sea level (MSL) rise. The tide is the largest influence on coastal water levels in California on these time scales, and the only component that is predictable in detail. Other factors include storm surges, large-scale changes in water temperature, wind-driven circulation, and climate-related El Nino events. All of these raise or lower sea level for characteristic lengths of time from hours to years, and with amplitudes ranging from 10 cm to several m. On time scales shorter than about 100 yrs, they are all comparable to MSL rise, and in some cases much larger.

Tides are the regular changes of ocean water levels caused by the gravitational forces among the moon, sun, and earth, and the response of the water in the ocean to these forces. Because of the astronomical motions, tidal oscillations appear in bands around 1 and 2 cycles per day. Along the California coast, tides are mixed with a mean range of about 1.5 m, and an extreme range of up to 3 m. The nearly equal measures of diurnal and semidiurnal components gives rise to characteristic patterns of timing and height of high tide, low tide, and tide range with periods ranging from a day to 18.6 yrs, and including important variations twice per month, twice per year, and every 4.4 yrs. Further, tides along most of California's open coast show a secular increase in range, meaning that mean high water is actually rising faster than MSL.

Compared with the East and Gulf coasts of the United States, storm surges in southern California are small, ranging up to at most 30 cm. This is firstly because hurricanes are rare or nonexistent on this coast, and secondly because the continental shelf is relatively narrow, dropping off to deep-ocean depths close to shore. Nevertheless, storm surge magnitudes are comparable to 100 yrs of sea level rise.

As a consequence of seasonal heating and cooling, and the effects of changing large-scale wind and barometric pressure patterns over the eastern Pacific Ocean, the average water levels in southern California fluctuate by about 15 cm during an average year. The lowest levels occur during spring, when the surface waters are coldest and therefore occupy less volume, while the highest levels occur in autumn, when temperatures peak.

El Nino is a state of the ocean and atmosphere in the tropical Pacific Ocean appearing every 2 to 7 years with various strengths, and lasting 6 to 18 months. El Nino is characterized by higher than normal sea surface temperatures and sea levels along the west coast of South America, weaker or reversed trade winds over the tropical Pacific, and a shift of the intense convection and associated rainfall away from Australia and Indonesia toward the eastern tropical Pacific. El Nino is a tropical phenomenon with strong effects in mid-latitudes, including southern California. Severe El Nino events seem to occur several times per century. The intense transfer of heat from the ocean into the atmosphere during strong events

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produces more and more intense storm systems across the North Pacific Ocean. The ocean warming that appears off the South American coast spreads 1000's of kms north and south in a matter of months, warming the waters off southern California by up to 5 deg C above normal.

Aside from increased storminess, conspicuous effects of El Nino along the California coast are an exaggeration of the normal seasonal sea level pattern, as well as a net rise of sea level for about a year. For example, during the 1982-83 El Nino, the seasonal change reached about 25 cm with a mean value about 10 cm higher than the 1960-78 average. The net effect is an increase in MSL comparable to a century of sea level rise, but lasting for only about one year.

Rising MSL may become increasingly important in the future, especially if there is an acceleration of the modest rate of rise of about 20 cm per century observed over the past 100 yrs. Annual MSL records from San Francisco available since 1854 suggest that the rate of MSL rise on the California coast may be greater after about 1920 than it was before. No mechanism for this apparent acceleration has been defined, let alone determined if it has any relation to global warming. It may even be confined to the San Francisco Bay region, although Seattle shows a similar pattern.