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An ongoing shift in Pacific Ocean sea level

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Key Points:
- Sea level in the Pacific has undergone a shift in the past 5 years, with sea level in the eastern (western) Pacific rising (falling)
- Sea level variability in the Pacific Ocean has been separated into a biennial oscillation mode and a decadal mode
- This shift appears to result from a change of phase of a low-frequency climate signal, that could continue on for the next several years

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Abstract Based on the satellite altimeter data, sea level off the west coast of the United States has increased over the past 5 years, while sea level in the western tropical Pacific has declined. Understanding whether this is a short-term shift or the beginning of a longer-term change in sea level has important implications for coastal planning efforts in the coming decades. Here, we identify and quantify the recent shift in Pacific Ocean sea level, and also seek to describe the variability in a manner consistent with recent descriptions of El Nino-Southern Oscillation (ENSO) and particularly the Pacific Decadal Oscillation (PDO). More specifically, we extract two dominant modes of sea level variability, one related to the biennial oscillation associated with ENSO and the other representative of lower-frequency variability with a strong signal in the northern Pacific. We rely on cyclostationary empirical orthogonal function (CSEOF) analysis along with sea level reconstructions to describe these modes and provide historical context for the recent sea level changes observed in the Pacific. As a result, we find that a shift in sea level has occurred in the Pacific Ocean over the past few years that will likely persist in the coming years, leading to substantially higher sea level off the west coast of the United States and lower sea level in the western tropical Pacific.

1. Introduction

Since 1993, satellite altimeters have provided continuous, near-global (± 66°N) measurements of sea surface height. These measurements provide definitive estimates of global mean sea level (GMSL) rise during recent decades, indicating an increase at a rate of 3.3 ±0.4 mm/yr from 1993 to present [*Mitchum et al.*, 2010]. While the trend in GMSL has been positive and relatively linear, regional deviations from the global mean trend often reach 50-100% along the world's coastlines. This regional variability is particularly notable in the Pacific Ocean (Figure 1a) where trends in the western tropical Pacific have exceeded 1 cm/yr and trends along the United States west coast have been near zero over the past two decades. Much attention has been devoted to this trend pattern, with several studies examining the historical record provided by tide gauges and sea level reconstructions to understand this apparent dipole pattern in Pacific Ocean decadal sea level variability [e.g., *Enfield and Allen*, 1980; *Chelton and Davis*, 1982; *Merrifield et al.*, 2012; *Moon et al.*, 2013, 2015; *Bromirski et al.*, 2011; *Zhang and Church*, 2012; *Thompson et al.*, 2014; *Hamlington et al.*, 2014]. These studies have indicated an enhancement (suppression) in the western (eastern) Pacific Ocean sea level over the past two decades resulting from decadal-to-multidecadal shifts in wind patterns associated with the Pacific Decadal Oscillation (PDO). *Bromirski et al.* [2011] further suggested an imminent phase shift in the PDO indicated by recent changes in winds that would lead to a sharp increase in U.S. west coast sea level and a similar magnitude drop in sea level in the western tropical Pacific in the coming years.

Although a shift in Pacific Ocean sea level has been anticipated, detecting such a change in sea level is a challenge. The broad spectrum of variability in the ocean makes it difficult to separate and distinguish different climate signals. This problem is further exacerbated by the relatively short satellite altimeter record length, which has only recently extended beyond 20 years. Given this limitation, extracting decadal scale variability directly from the altimeter record is difficult. With specific regard to the Pacific Ocean, the recent occurrence of a strong La Niña (2010/2011) followed shortly after by a strong El Niño (2015/2016) has potentially obscured an underlying long-term (decadal) shift in sea level. Separating the PDO from the El Niño-Southern Oscillation (ENSO) would appear to be a necessary first step in assessing the impact of the PDO on sea level.