Increase in high frequency variability (2-14 years) in sea level records

S. Jevrejeva (1), A. Grinsted (2), and J.C. Moore (2)

Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

(1) Proudman Oceanographic Laboratory, Liverpool, UK, sveta@pol.ac.uk
(2) Arctic Centre, University of Lapland, Rovaniemi, Finland

Abstract

We analyze 1000 sea level records from the Permanent Service for Mean Sea Level (PSMSL) database. Using advanced statistical methods we separate nonlinear trends and statistically significance oscillations for 12 large ocean basins. We demonstrate that signals in the 2.2-13.9 year band contribute from 5 to 20 % of variability in time series. We also show that variability in sea level records over periods 2-14 years has increased during the past 50 years in most ocean basins. We provide evidence that this increase in 2-13.9 year variability is associated with the greater influence of the large scale atmospheric circulation represented by the Southern Oscillation, North Atlantic Oscillation, Arctic Oscillation and Pacific Decadal Oscillation indices.

Objectives

- To separate statistically significant components (signals) from noise and examine their development over the past 150 years using Monte- Carlo Singular Spectrum Analysis;
- To investigate the role of signals with periods 2-13.9 years in variability of sea level records using wavelet method;
- To analyze the link of 2-13.9 year signals to the large scale atmospheric circulation (amplitude and phase difference relationships).

Data

We use all relative sea level (RSL) monthly mean time series in the Permanent Service for Mean Sea Level (PSMSL) database [*Woodworth and Player*, 2003]. However, data from Japan were excluded from the analysis due to uncertainty in earthquake-related land movement of bench marks and tide gauge stations.

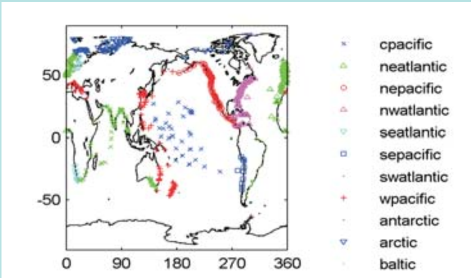

Figure 1. Location of tide gauges included in this study (12 regions)

Detailed descriptions of the RSL time series are available from www.pol.ac.uk/psmsl. No inverted barometer correction was applied. RSL data sets were corrected for local datum changes and glacial isostatic adjustment (GIA) of the solid Earth [*Peltier*, 2001]. This procedure results in data from 1023 stations containing 385324 individual monthly records. The maximum number of stations in any year is 585, with only 70 stations in 1900, and 5 in 1850. Due to the time lag between data collection and supply to the PSMSL recent decades have also seen reductions in station numbers with only 390 stations in 2000.

We have developed a new 'virtual station' method to overcome geographical bias and which can quantify the uncertainties due to representativity issues of the used stations. We assign each station to one of 12 regions (Figure 1).

Results from Monte-Carlo Singular Spectrum Analysis (MC-SSA)

Using MC-SSA we extract statistically significant components from time series of regional sea level. Signals in the 2.2-13.9 year band contribute from 5 to 20 % of variability in time series. Our results are in good agreement with oscillations detected at 3.5, 5.2- 5.7, 7-8.5 and 10-13.9 years for individual sea level station time series by *Unal and Ghil* [1995]. It is notable that 3.5-13.9 year oscillations demonstrate an increase in amplitude since the 1940s in several regions; Northeastern Atlantic, Eastern Pacific, presented in Figure 2.

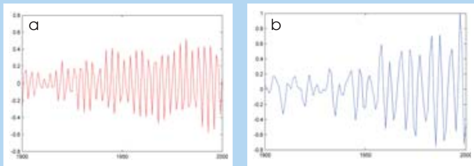

Figure 2. (a) Standardized sum of the statistically significant (at the 95% confidence level against red noise model) SSA components for the 3.5- and 2.4- year oscillations in time series of mean sea level in Northeastern Atlantic region; (b) for 5.2 year oscillations in Eastern Pacific. Both showing increased amplitude since 1950.

Results from wavelet transform method

To isolate the different timescales of variability, and analyze the changes of variance in the time series of sea level we examine their behaviour in time-frequency space using the Morlet wavelet. Figure 3 shows the wavelet power spectrum of two regional sea level time series, displayed as a function of cycle period and time. The left axis is the Fourier period; the bottom axis shows the time in years. The strong non-stationary behaviour of the spectra is clearly seen. Most of the time series show an increase of power in the wavelet power spectrum at 2-30 year periods since 1940s.

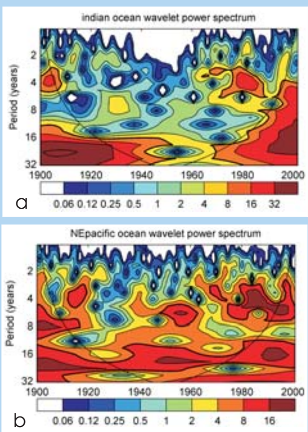

Figure 3. Wavelet power spectrum (Morlet) of mean monthly mean sea level for the Indian Ocean (a); Northeast Pacific (b).Contours are in variance units. In all panels the black thick line is the 5 % significance level using the red noise model, solid line indicates the cone of influence. The colour bar represents normalized variances. All of the time series show an increase of power in the wavelet power spectrum at 2-30 year periods since 1940s as can be seen by the spread of the red and yellow shading to the upper rights of the panels.

What is the possible source for the changes in 2-14 year variability?

To identify the frequency bands within which time series of sea level and the large scale atmospheric circulation are co-varying, we use the wavelet coherency method [Grinsted et al., 2004; Jevrejeva et al., 2005]. Indian and Pacific oceans sea level variability is mainly associated with Southern Oscillation Index (SOI) [Ropelewski and Jones, 1987] signals at 2.2, 3.5, 5.7 year periods. Figure 4 demonstrate that the relationship is not stationary and the influence of SOI has generally increased over the last 60 years over a broadening spectrum of periods. The SOI influence since 1940, shows an increase in the low frequency power in the 13.9 year band, and large changes in the 3.5-7.8 year band.

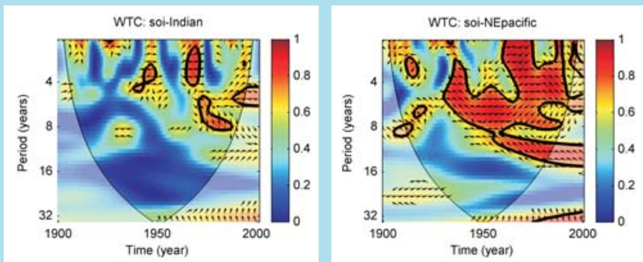

Figure 4. The wavelet coherency between SOI/ Indian ocean sea level and SOI/ Northeast Pacific sea level. Contours are wavelet squared coherencies. The vectors indicate the phase difference (a horizontal arrow pointing from left to right signifies in-phase and an arrow pointing vertically upward means the second series lags the first by 90 degrees (i.e. the phase angle is 270º). In all panels the black thick line is the 5 % significance level using the red noise model.