企画セッション：本論文掲載なし

Estimation of non-linear sea level rise and uncertainty and its projection in the Seto Inland Sea, Japan

OBJECTIVES

Coastal zone management and adaptation to sea-level rise (SLR) are largely based on SLR scenarios. In general, SLR scenarios are adapted using simple projections, for example, a 1 m rise by 2100, without plausible explanations, or using Intergovernmental Panel on Climate Change (IPCC) results, which are based on process-based dynamic modeling approaches with lack of information on ice-sheet dynamics and changes which make it difficult to predict reliable SLR. In the meantime, many coastal mega cities in Asia are experiencing more rapid subsidence rates of several centimeters because of soil compaction, groundwater withdrawal, rapid urbanization and poor water supplies compared with the global or regional SLR. Therefore, we illustrate a novel way to estimate a non-linear SLR trend in the case of Seto Inland Sea (SIS) by accounting for local effects such as the subsidence and future projections with uncertainty evaluation using ensemble empirical mode decomposition (EEMD).

DESCRIPTION OF THE STUDY

The observed sea level at 17 stations in and around the SIS was obtained from the Japan Meteorological Agency (JMA) and Japan Coastal Guard (JCG). The observation periods are different for each station. The longest hourly dataset comprises 64 years, from January 1, 1950, to December 31, 2013, at Tokuyama. There are 561,002 original raw data records at Tokuyama, with 10,939 (1.95%) missing data. The other stations are missing less than 8% of the data, except for the Kochi station (12.45%). The observed tidal levels at all stations are referenced to the Tokyo Peil (TP) of Japan. The predicted tides for the missing data are adjusted after reflecting the relationship between the datum and TP at each station. The Tokuyama station, which has the longest observations on sea-level change, is used for a detailed data analysis of future extreme sea-level changes. Figure 1(a) shows the data analysis procedure for projecting the regional relative SLR using EEMD.

First, because the observed records at Tokuyama contain intermittent missing data, a data reconstruction is performed by filling in the missing data with predicted tides of the NAO99 global tide model. The original raw data and the reconstructed source data with the predicted tides in red are shown in Fig. 1(b).

Second, EEMD is applied to the reconstructed source data with 30 ensembles. In other words, each ensemble is constructed by adding Gaussian white noise with a standard deviation of 0.2 to the reconstructed data. Then, EMD is applied 30 times to obtain 30 sets of IMFs. Finally, the 30 sets of IMFs are averaged to obtain the resulting IMFs for each IMF component from high to low frequencies and the residual. A statistically significant test was then performed to ensure the significance levels of all of the IMFs. The result shows that all of the IMFs are statistically significant at the 95% confidence interval. The selected IMFs and the Hilbert spectrum of all IMFs are shown in Fig. 2(a) and 2(b) to show how to interpret the IMFs.

Finally, to project future SLR, we use the previously mentioned residual from the EEMD results as the non-linear trend of the sea-level change. Then, the inter-decadal variations in the sea levels, IMFs 16, 17 and 18, and residual are summed to determine the inter-decadal trend. In the regional projection, both the non-linear trend and the inter-decadal trend are fitted to a quadratic polynomial and are then extended to predict the sea-level changes. The uncertainty in the SLR projection is evaluated by considering the inter-decadal variations, whereas the 95 % confidence interval for uncertainty of the fit is also estimated (Fig. 2(c)).

PRIMARY CONCLUSIONS

In addition to the volume and mass changes of the sea water, there are many local factors that contribute to the sea-level changes, such as river discharge, sediment, and land subsidence. In our approach, it is difficult to distinguish all factors and their contribution to the sea-level changes. However, we can interpret the residual as the sum of the local sea-level budget factors and predict the regional SLR for local and regional SLR scenarios.

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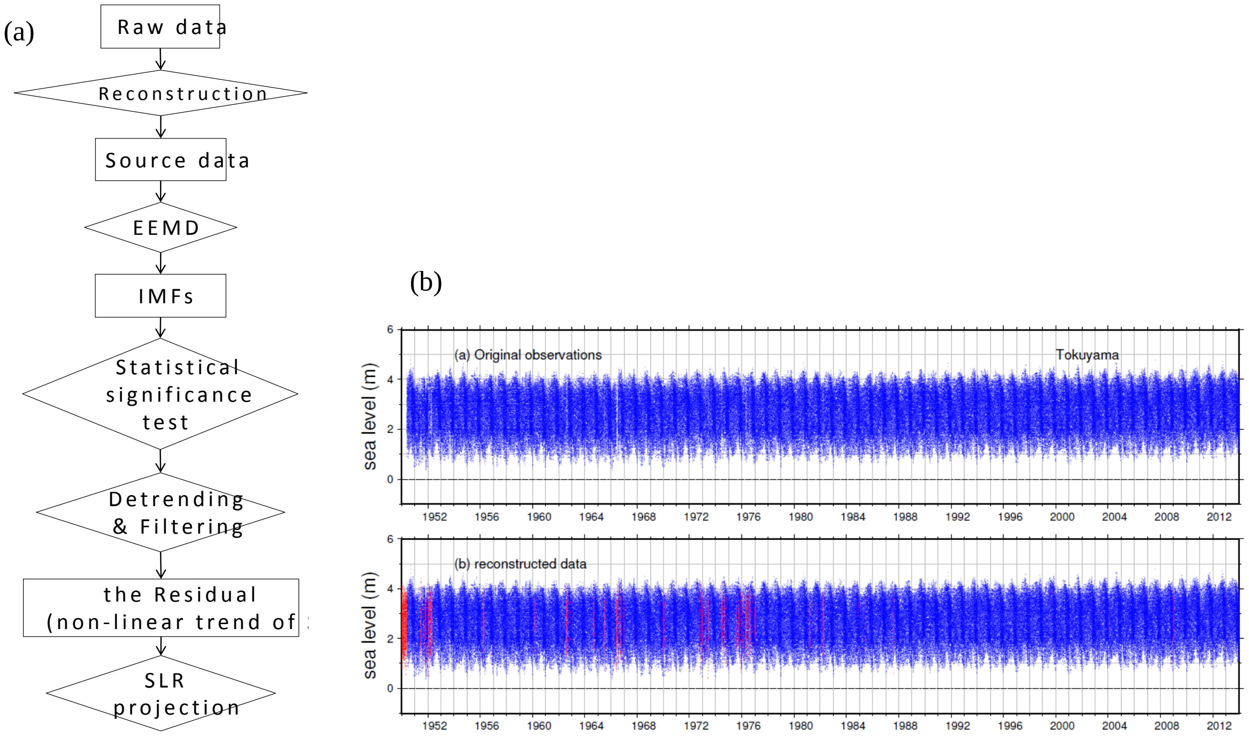
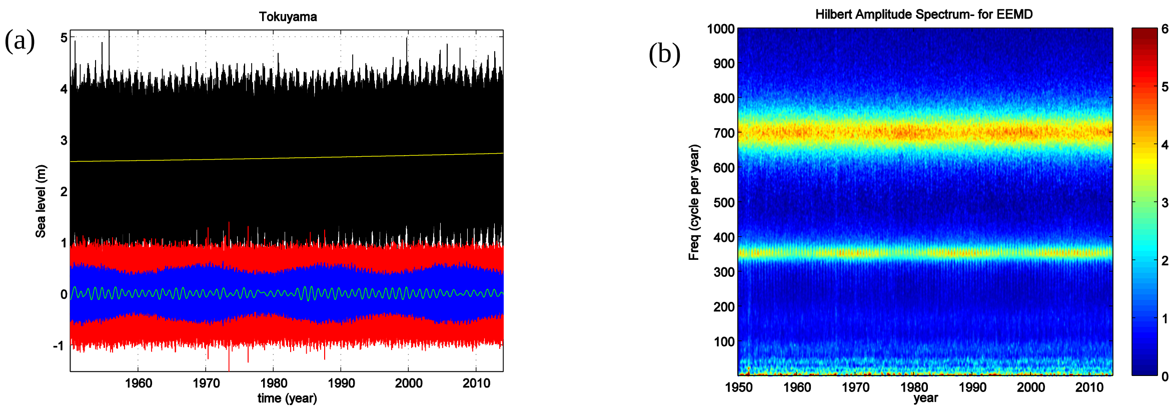


Figure 1 (a) Data analysis procedure to estimate the non-linear SLR trend and projection using EEMD, and (b) Original observed sea levels (upper) at Tokuyama and the reconstructed source data (lower) after filling in the missing gaps with supplementary predicted data using a high-resolution tide model.



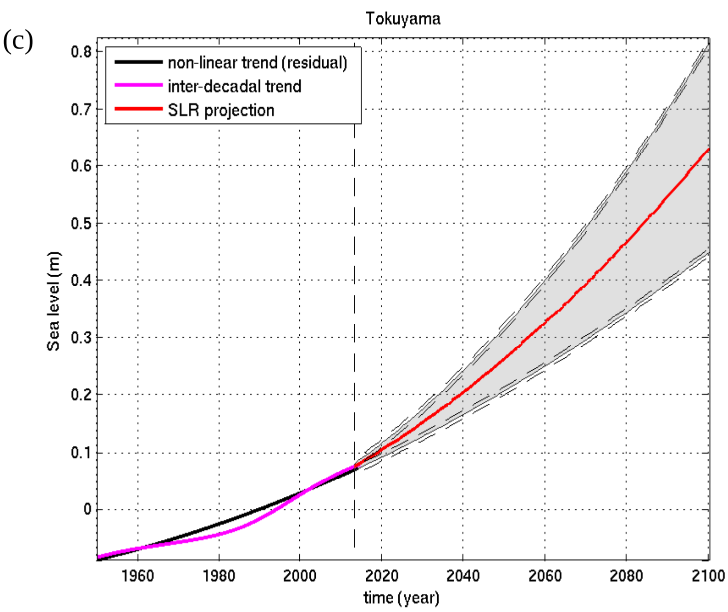


Figure 2 (a) Reconstructed source data (black), IMF2 (red), IMF3 (blue), IMF11 (green), and the residual (yellow); (b) the Hilbert spectrum for source data. Persistent high values are found at approximately 12 hr (730 cpy), 24 hr (370 cpy), and 1 yr in the Hilbert spectrum, and (c) the non-linear SLR trend (the residual, black) and the inter-decadal trend (sum of the residual and IMF16~18, purple) at Tokuyama from 1950 to 2013. The red curve indicates the mean of the upper and lower bounds. The shaded area is the uncertainty in the regional SLR projection by considering the inter-decadal variations in the sea levels. Dashed lines are the uncertainty in the fit (95% CI).