Time series analyses of amplitude of the Earth’s background free oscillations

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The Earth’s background free oscillations (BFO) are slightly and continuously excited free oscillations of the solid Earth persistent even in seismically quiet periods [Nawa et al. 1998; Suda et al. 1998; Kobayashi and Nishida 1998; Tanimoto et al. 1998]. The observed modes are fundamental modes, suggesting that the excitation sources are atmospheric and oceanic disturbances [e.g. Nishida 2013]. Amplitude of BFO exhibits seasonal variations [Nishida et al. 2000]. Along with such a periodic variation, there may exist transient variations correlated with atmospheric/oceanic phenomena.

The target modes are fundamental modes ${}_0S_{22}$-${}_0S_{43}$ at frequencies between 3 and 5 mHz because they are most clearly observed in the frequency domain. We used vertical records of STS-1 broadband seismometers at 65 quite seismic stations downloaded from IRIS DMC. The data periods are from 2000 to 2017. The analysis method is mainly the same as used in Nishida et al. (2000). Continuous records were divided into 3-days records with a step of 1 day. After applying the Hanning taper, each record was converted into power spectral density (PSD) with the correction of system response. To reject noisy data, we used the data whose mean PSD values at 3-5 mHz are between 10^{-19} and 10^{-18} m^2/s^3. The remained PSDs were then stacked over all the stations to create monthly averaged PSDs. To avoid the influence of temporally changing PSD baseline due to the random background noise, we averaged the PSD values in the mode and the noise frequency bands, and then the averaged noise PSD is subtracted from the averaged signal PSD.

We used two methods of time series analysis for the statistical analysis of long-term variations in amplitude of BFO: one is based on the state-space model and the other is on the regression model. In the state-space analysis we adopted the local level model with seasonal variations, which divide time series into random noise, seasonal variations and a long-term trend. In the regression analysis we adopted the model that consist of random noise, seasonal variations and a long-term trend. We used the R packages dlm and prophet for the state-space and the regression analyses, respectively.

The result obtained in the space-state analysis shows the long-term variation with a time scale of 10 years from 2002 to 2012: the minimum is in 2002 and 2012 and the maximum is in 2008. The long-term trend obtained in the regression analysis shows almost the same characteristics: the minimums in 2000 and 2012 and the maximum in 2008. Thus, we for the first time robustly obtained the nearly 10-year variation in amplitude of BFO from the two different time-series analyses. We can utilize data of infragravity waves at frequencies between 3-30 mHz from WAVEWATCH III. We will show the result of comparison between BFO and infragravity waves in the presentation.

