Seasonal Variations of Atmospheric and Ocean Bottom Pressure Data in the Milliherz Band

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Abstract. We have collected ocean bottom tide gauge data and microbarogram data in Japan for several years and estimated the monthly mean power spectrum density of pressure data. We have found clear annual variations in the 1-10 mHz band and the correlation the pressure power with the local wind speed. The power at the ocean bottom within this band is about one order of magnitude larger than that at the bottom of the atmosphere, suggesting ocean waves generated by wind can be a significant excitation source of the continuous free oscillations of the Earth.

1 Introduction

Since the discovery of continuous free oscillations of the Earth, the energy source of the osciilations has been sought. Atmospheric pressure fluctuations are often quoted as a probable source. Recently, annual or seasonal variations of the power spectrum of the continuous oscillation in the period between 100 to 1000 second are found by Tanimoto and Um (1999), Nishida *et al.* (2000). Therefore the source is likely to be limited in the ocean or in the atmosphere. The annual variation is attributed to the changes of intensity, distribution of the source, and/or the seasonal variation of the excitation mechanism. Long-term direct measurement of precise pressure will give a clue to distinguish the causes.

2 Data

We have collected ocean bottom tide gauge data and microbarographic data in Japan, spanning more than four years and two years, respectively (Table 1, Figure 1). The ocean bottom cable off the Boso Peninsula operated by JMA has one tide gauge sensor at about 4000 m and two at about 2000 m deep for the tsuami monitoring purpose. A microbarograph was installed at the Miyake Island in the Izu-Bonin ridge region by NIED for the volcano monitoring purpose. No eruptive activity was observed during the two years. The sensors are absolute pressure gauges using quartz oscillators and have sensitivity up to DC. Temperature dependency of the quarts oscillation frequency is calibrated by measuring temperature simultaneously. Both data are being telemetered to and recorded at each operating institute. Daily data traces are re-constructed by reading backup tapes or CD-ROMS.

Table. 1. Pressure Data

	Barogram	Tide Gauge
Operated by	NIED	JMA
Sampling	1 sec	10 sec
Resolution	0.2 Pa	5 Pa
Data used	1998, 1999	1995-1998
Height	214 m	-4011 m
		-2098 m
		-1992 m
Latitude	34.0972	34.6535
		34.7492
		34.7995
Longitude	139.555	140.9780
		140.7582
		140.5117

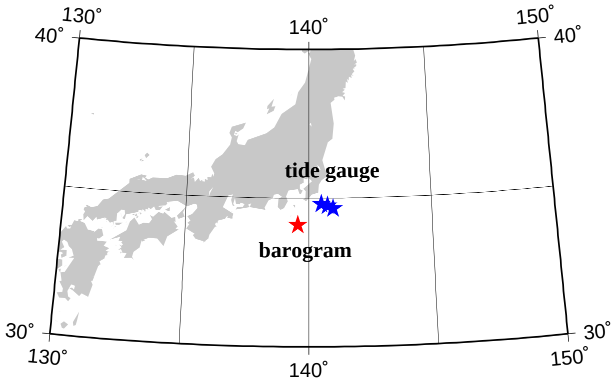

Fig. 1. Locations of microbarogram and tide gauge sensors.

3 Analyses

We removed any daily data containing jumps or gliches through the visual inspection. For example, the total number of days used in the analysis in 1998 are reduced to 332 days and 324 days for tide gauge data at -4011 m and barogram data, respectively. Daily mean power spectrum densities are computed by taking spectral average of sliding windowed data for 12 hours long with a time shift of 4 hours after the Hanning taper is applied. Annual mean power spectrum densities for 1998 are constructed by taking spectral mean of daily mean power spectrum densities (figure 2). Similarly, monthly mean power spectrum densities are computed.

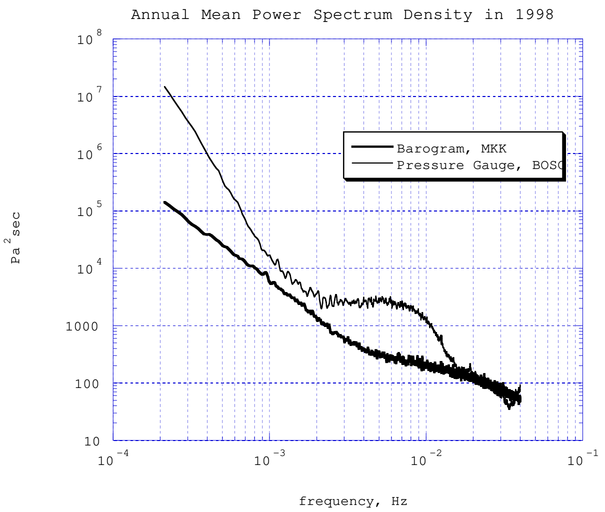

Fig. 2. Annual mean power spectrum of microbarogram and tide gauge at -4011 m data.

4 Discussions

The annual mean power spectrum density of pressure at a deep ocean bottom in the 2-10 mHz band, where continuous free oscillations of the Earth are clearly seen (Tanimoto and Um 1999, Nishida it et al. 2000), is about order of magnitude larger than those of the atmosphere. The atmospheric pressure power spectrum is very similar to the spectra at other globally distributed sites reported by Tanimoto and Um (1999) and Fukao *et al.* (2000). The ocean pressure power spectrum is also similar to the spectra at other deep ocean bottoms resported by Webb (1998). The local maximum in pressure spectra at the deep ocean bottom in the Pacific and the Atlantic between 2-10 mHz band are already reported by Webb (1998), probably ubiquitous feature of the pressure spectrum in the deep ocean. The sharp cutoff of the flat ocean bottom pressure spectrum near 10 mHz is well explained if we assume the the pressure fluctuation source is the surface gravity waves of the ocean. If fact, the power spectrum density computed from the tide gauge data at about -2000m off the Boso Peninsula shows a higher cutoff frequency than the one at about -4000m, supporting the ocean surface gravity waves origin hypothesis for the cause of the pressure fluctuation at the ocean bottom between 2-10mHz.

If the ocean surface gravity waves are responsible for the pressure fluctuations at the ocean bottom in 1-10 mHz band, we expect a correlation between wind speed and the power spectrum integrated the 1-10 mHz band. We used a global weather model derived from the NCEP global re-analysis project to compute the mean wind velocity above the tide gauge at altitude of 10 m. The model provides a wind vector field over the global mesh. The mean monthly wind speed and the pressure power at the ocean bottom correlate well, except for occasional large amplitude pressure power in summer and fall caused by super tyhoons (Figure 3).

The wind-wave interaction is an efficient mechanism to convert wind energy which has a maximum power in the zero frequency to the wave frequency. The cascadal energy transfer in the atmospheric turbulence towards high frequency from DC wind regime by the atmospheric process alone results in small amplitude of power in the frequency band of Earth's normal mode (Figure 2).

If we separately argue the total atmospheric motion in the north and southern hemisphere, the total wind speed of the northern hemisphere in winter is larger than the total wind speed of the southern hemisphere in winter, as evident from the seasonal change of Earth rotation rates. In the oceanic region, however, the largest surface wind speed or surface momentum flux occurs in the winter time of the southern hemisphere, especially over the circum Antarctic ocean. If ocean waves generated by the

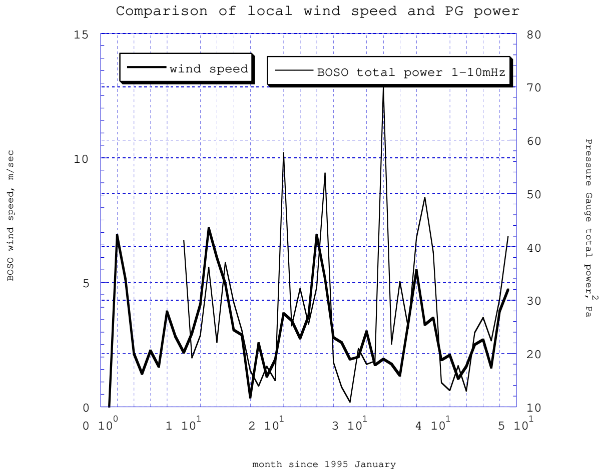

Fig. 3. Comparison of monthly mean wind speed over the location of the tide gauge and the power spectrum integrated between 1-10mHz band of tide gauge data at -4011 m. In August and September, we sometimes have large power of ocean bottom pressure caused by super typoons passed near Japan.

surface wind are responsible for the ocean bottom pressure fluctuation, and if the pressure variation in the deep ocean bottom is the main cause of excitation of the continuous free oscillation of the Earth, we expect larger amplitude of the continuous free oscillation of the Earth in the winter time of the southern hemisphere, or the summer time of the northern hemisphere. Annual variation of the amplitude of continuous free oscillations of the Earth reported by Nishida *et al.* (2000) has this feature.

A quantitative assessment whether the ocean bottom pressure can explain the observed amplitude of the continuous Earth's free oscillations or not is needed to identify the excitation source.

5 Conclusion

We have shown that the ocean bottom pressure spectrum and the atmospheric pressure spectrum have clear annual variation, correlating with the local wind speed. In the frequency band of the Earth's free oscillations, between 1 to 10 mHz, the power at the deep the ocean bottom is about one order of magnitude larger than that of atmosphere. Ocean waves generated by wind can be a significant energy source for the continuous free oscillations of the Earth. A quantitative free oscillation amplitude estimate by the ocean bottom pressure fluctuation is awaited.

6 Reference

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