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Characteristics of maximal energy component of waves in Terpeniya Bay (Sakhalin Island)

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Abstract. Analysis of natural sea surface oscillations was performed in order to determine maximal spectral energy components in sea waves in the area of Terpeniya Bay. It has been found out that maximal components appear at periods of 5 and 8 seconds and reach energy of $3{\cdot}10^6$ cm$^2{\cdot}$s during storms. During calm weather maximums can be observed in the range of swell waves, herewith maximums exist at periods of 12 and 15 seconds. Energy of these maximums doesn't go upper then $8{\cdot}10^5$ cm$^2{\cdot}$s and $3{\cdot}10^5$ cm$^2{\cdot}$s accordingly. Maximum components in the infragravity band of energy spectrum were estimated as well. Two steady energy peaks were determined at periods of 75 and 135 seconds, which are most probably relate to edge waves in considered water area.

1. Introduction

Significant wave heights, mean wave period and peak wave period are the basic parameters for description of sea waves due to its random nature. Knowing of these parameters is necessary for diverse spheres of human activity related to description of wave modes, shipping, coastal engineering [1, 2] and even to analysis of seismic oscillations [3]. Results of analysis of amplitude A_{max} and period T_p of maximum energy component in energy spectrum of waves in Terpeniya Bay are presented in this paper. Analysis was done on the base of observation of hydrostatic pressure performed from May 22 to October 6 in 2010. Record of hydrostatic pressure was captured at sample frequency 1Hz by pressure recorder mounted on the sea bottom at 17 m depth and 700 m distance from shoreline near Vzmor'e locality.

2. Experimental data and analysis

Relatively calm sea state with maximum wave height around 0.3 m as well as moderate and strong storms with maximum wave height up to 7 m were observed during all time of observation. Figure 1 is a record of sea level change. Estimations of T_p and A_{max} were performed by using power spectral density (PSD) of wave process. Sliding window with 100 minutes length and 95 % of window overlap were applied. Energy spectrum band from 2 to 600 s was analysed. Results are presented in the figure 2 as 2D distribution histogram. Most intensive and frequent were wind waves at the periods around 5 s. They prevailed upon others. Maximum components which appeared at the periods around 8 s reached the same energy, but were not so frequent.

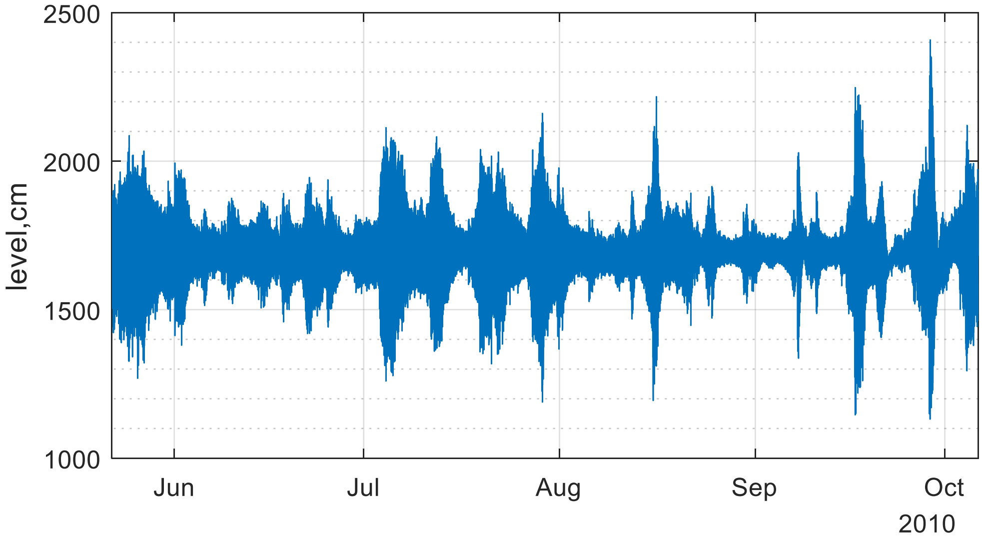

Figure 1. Water level changes during measurement time.

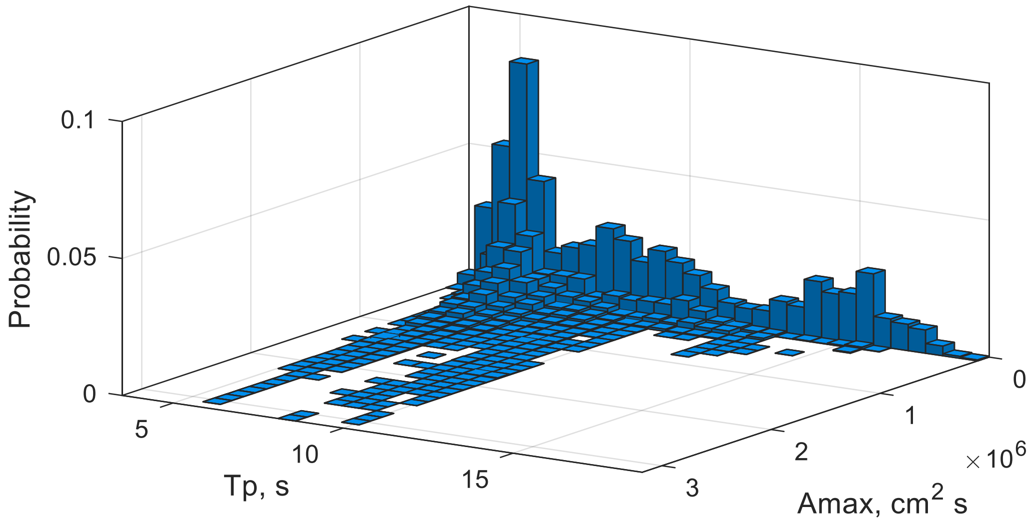

Figure 2. Bivariate histogram of maximum wave energy component distribution.

Two conditional maximums were detected in the range of swell wave periods. First one appeared in the vicinity of 12 s and another one – around 15 s. Spectral maximums at these periods were observed during calm weather. Herewith, components around 12 s had maximum amplitudes. But oscillations around 15 s were detected more frequent. It should be noted here, that energy spectrum in the range of swell waves has several steady peaks at periods of 13, 14, 15 and 17 s. This is visual in the figure 3. This fact is also mentioned in paper [4], where authors came across with separation of swell waves at close frequencies. Data for processing were taken by them from recorders mounted near Ostryi Cape in 2020.

Maximal energy of T_p component at wind wave periods reached value $A_{max} = 3\cdot10^6$ cm$^2\cdot$s, and at swell wave periods maximal amplitude of energy component didn't exceed value $A_{max} = 8\cdot10^5$ cm$^2\cdot$s for periods around 12 s and $A_{max} = 3\cdot10^5$ cm$^2\cdot$s for periods around 15 s.

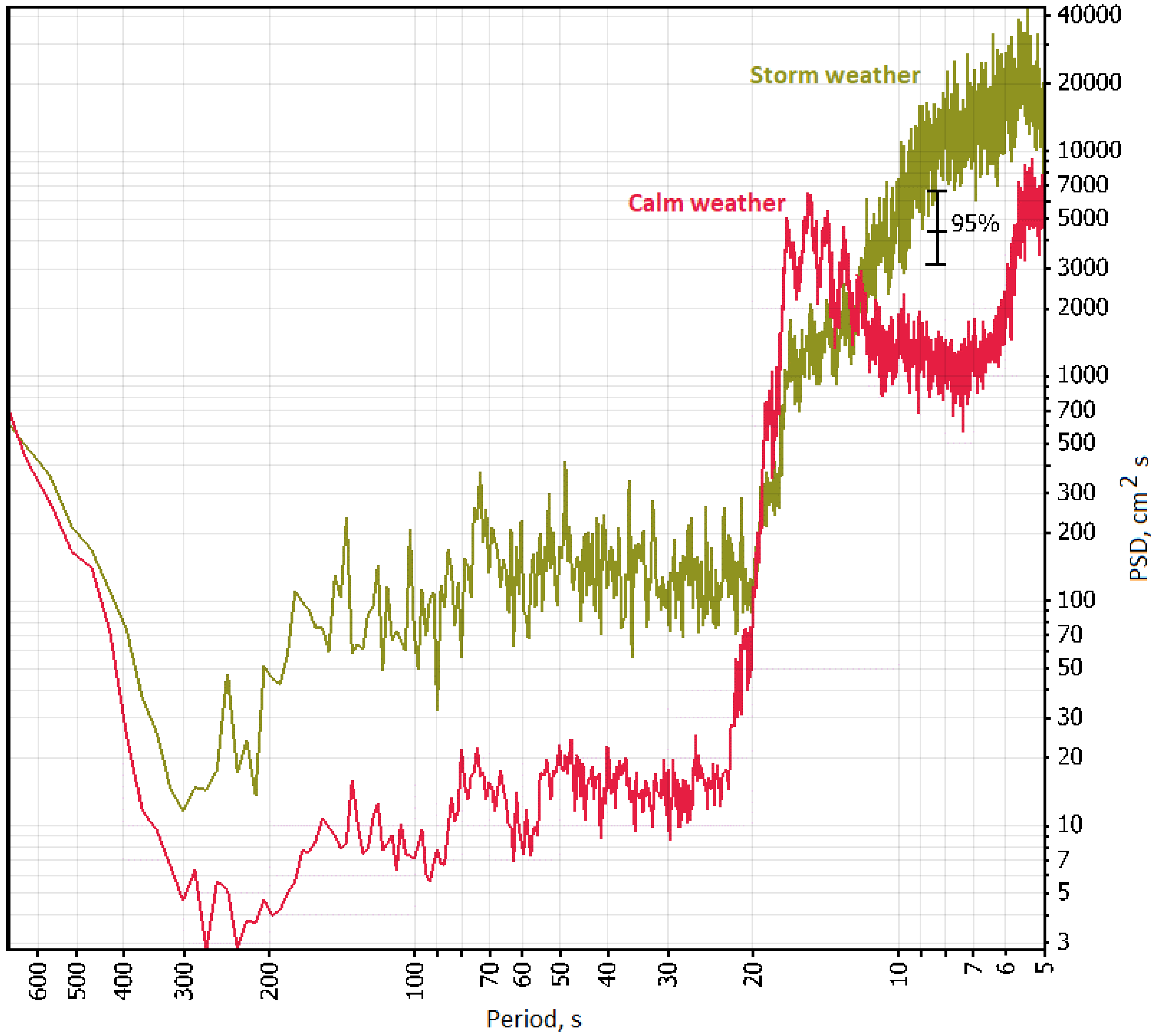

Figure 3. Power spectral density of wave during calm weather and during storm.

Investigation of parameters of infragravity (IG) waves has no less practical interest, especially in conditions of strong storms. According to research work [5], IG waves can appear as a result of nonlinear phenomena based on finiteness of amplitude of gravity sea waves. Frequency range of IG waves depends on frequencies of wind waves and occupies a range approximately from 0.005 to 0.05 Hz. Waves of this range differ from gravity waves with their effect on coastal constructions and sea medium. Degree of these differences depends on IG wave intensity relatively to wind waves. However, during IG waves propagation they can be considered as free waves having less steepness and therefore energy dissipation depending on it. That is why it is important to estimate relationships between IG and wind waves. Using only the characteristics of wind waves doesn't give an explanation of dynamic forces affecting transportation of sediments, deformation of bottom landform and seashore line, forming harmful process in port and etc.

Analysis of maximum energy components in frequency range of IG waves is considered below. One can see wave energy distribution versus time and period in the figure 4, where waveform and spectrogram of wave process during two weeks are presented. This chunk includes storm weather situation as well as situation with relatively calm water surface.

It is evident, that amplification of IG waves occurs during storms and simultaneously with amplification of wind waves. But sometimes IG energy increases during calm weather when swell waves come. Such a situation happened on May 31 (figure 4). Maximum amplification of IG waves observed at presence of wind and swell waves together. This is visible at the beginning of May 27 in figure 4.

Maximum IG wave components have peaks at periods of approximately 75 and 135 s. Energy of these components increases during storms or long-lasting presence of swell waves. One can see these peaks in detail in figure 3. Existence of oscillations at 75 and 135 s is probably caused by edge IG waves. In paper [5] IG waves at the periods of 95 and 170 s were detected. Using Stokes dispersion relationship authors of [5] found that these waves correspond to modes of edge waves.

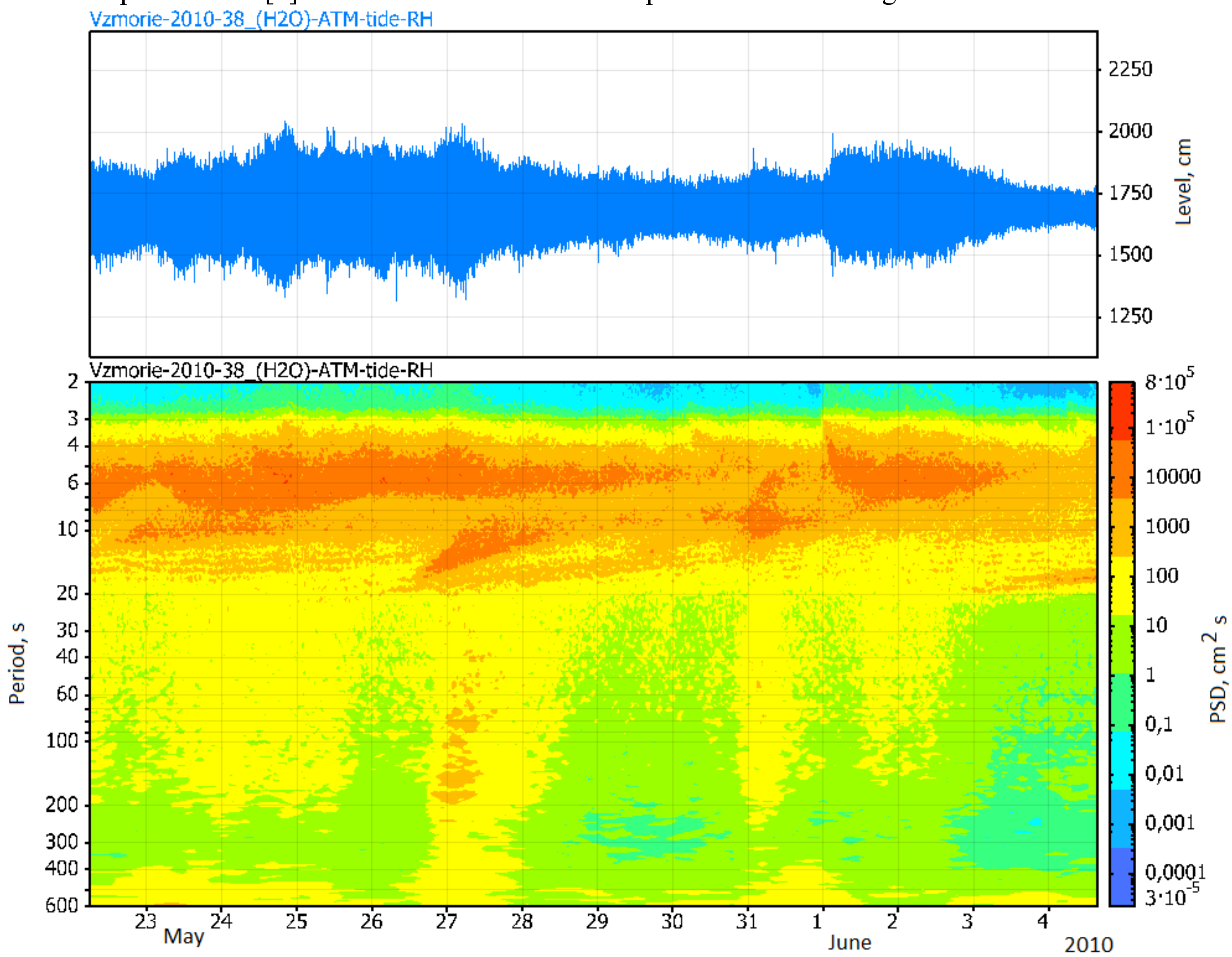

Figure 4. Waveform and spectrogram.

Estimation of interaction between IG and wind and swell waves was performed by the calculation of standard deviation in appropriate frequency ranges. Results are presented in figure 5. Analysis shows that amplification of IG waves occurs when total energy level in range from 2 to 22 s increases. But the best correlation is observed between IG and wind waves.

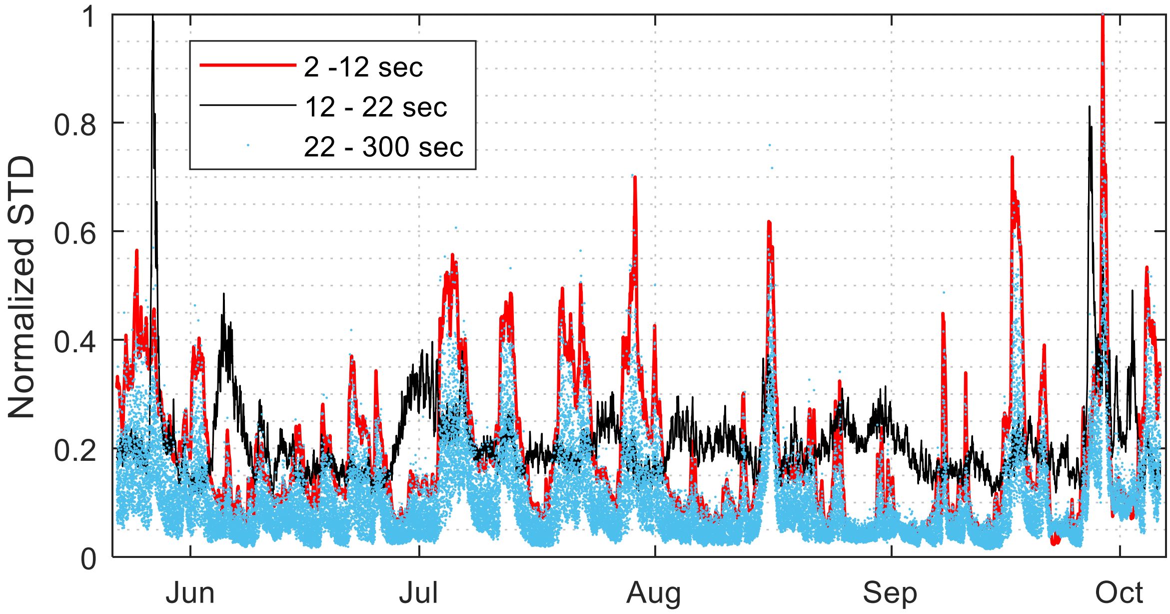

Figure 5. Standard deviation of wave process in three frequency ranges.

3. Conclusion

Periods of sea waves with maximum energy components were considered in the paper. Maximum energy in sea wave spectrum appears in wind wave band mostly at periods of 5 and 8 s and reaches value of $3\cdot10^6$ $cm^2\cdot s$. During calm weather maximum components can appear in swell waves range around 12 or 15 s. Energy in this range don't get upper then $8\cdot10^5$ $cm^2\cdot s$ and $3\cdot10^5$ $cm^2\cdot s$ relatively. Two steady peaks were detected in IG wave range. One at 75 s and another one at 135 s. These two periods correspond to periods of edge waves in considered water area.

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