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Infragravity waves at a dissipative coast; evidence upon multi-resolution analysis

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Abstract

Simultaneous records of water level and wave-driven longshore current by spatially co-located devices in close shoreline proximity have been analyzed with a multi-resolution technique and singular spectrum analysis to provide convincing evidence that infragravity waves can actually exist at a dissipative coast with multiple bars. The records represent a 6-h evolution of wave climate and longshore current in the conditions of the beginning of storm recession. The sampling rate of 3 Hz generated a series of nearly 60,000 elements each allowing for a very detailed description of their spectral behavior throughout the whole frequency domain. The multi-resolution analysis with a suitably chosen wavelet function was performed to extract spectrally disjoint slow-varying components of water level and longshore current. After having been fine-tuned by singular spectrum analysis these components were cross-examined to see whether slow variations of water level are imprinted in the variability of longshore current. High amplitude and phase coincidence of one pair representing the period of 120 s yields convincing evidence that progressive infragravity waves are indeed encountered at dissipative shores. Another pair with the period of 30 s delivers much less firm evidence, so for the time being it cannot be regarded as an infragravity wave. The study also produced guidelines for further research aimed at in-situ detection of the length and cross-shore decay of infragravity waves in a dissipative environment.

Keywords: Infragravity waves; Longshore current; Discrete wavelet transform; Nearshore hydrodynamics; Beach processes

1. Introduction

Beach processes involve complex, nonlinear phenomena characterized by a wide range of spatial and temporal scales, De Vriend (1991), Larson and Kraus (1995). Despite substantial progress in understanding of the flow-seabed response feedback mechanisms in marine environments, see e.g. Dronkers (2005), our present knowledge is still incomplete to properly describe and forecast the behavior of many coastal systems, Stive et al. (2002). Thus, one way to gain better understanding of the evolution of nearshore morphodynamics, is to focus on hydrodynamics as the major driver of changes in coastal morphology. However, the lack of hydrodynamic data fit for studies with data intensive statistical methods prevented state-of-the-art signal processing techniques from hydrodynamic studies. Instead, they were intensively exploited in the realm of coastal morphology, see e.g. Winant et al. (1975), Wijnberg and Terwindt (1995), Reeve et al. (2001). Notable exceptions are data from long-established national tide-gauge networks, see e.g. Aubrey and Emery (1983), Solow (1987), Ding et al. (2001) used for tidal harmonic decomposition and surge analysis. As a result, morphological patterns contained effects of all forcings, couplings and feedbacks and they were not able to single out the effects of changes in hydrodynamics.

The Coastal Research Station (CRS) at Lubiatowo, Poland, situated in the South Baltic Sea, see Fig. 1, is no exception to this rule. The morphology of this coastal segment is characterized by multiple longshore sandbars, Fig. 2. The system is highly dissipative and purely wave-driven, so it is shaped by wave-driven hydrodynamics, mostly during extreme events, when apart from wave action, storm surges and wave-generated nearshore currents largely contribute to morphological changes. These changes have been monitored for many years, providing data sets on nearshore bathymetry and shoreline evolution.

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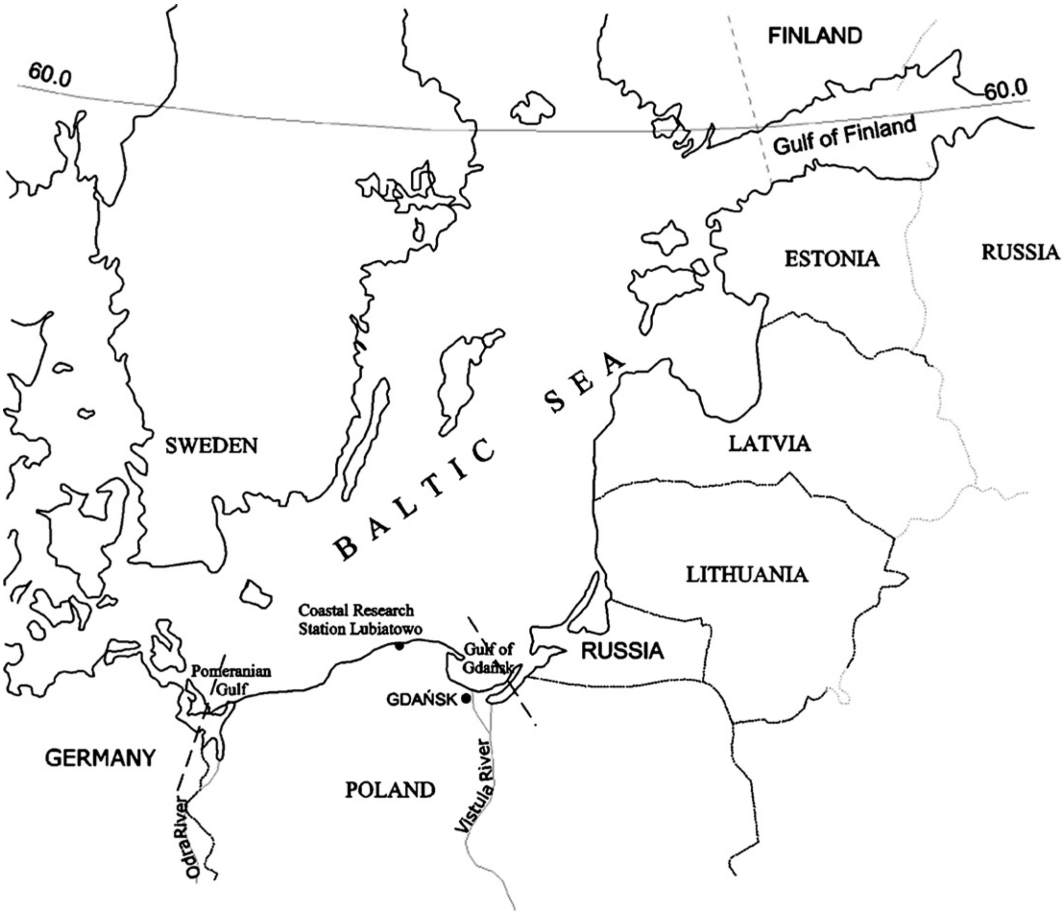

Fig. 1. Geographic location of Coastal Research Station at Lubiatowo.

Measurements of the former are usually executed twice a year: they gained geodetic compatibility in 1987. Records of the latter have been collected on a monthly basis since September 1983 and were geodetically referenced from the beginning. During recent years these data sets were extensively analyzed with modern statistical techniques. Ordinary and Multi-channel Singular Spectrum Analysis was employed to trace forced and self-organized components of shoreline change, see Różyński et al. (2001), Reeve (2002), and Różyński (2005). Principal Oscillation Patterns were used to derive a data-driven model of changes in nearshore bathymetry, Różyński and Jansen (2002). Empirical Orthogonal Functions and Canonical Correlation Analysis were combined to study interactions among inner and outer bars, Różyński (2003). Since morphological investigations have reached a limit now more in-depth insight into the evolution of the Lubiatowo beach requires the analysis of hydrodynamic data, in order to identify its major patterns and their time scales. They should establish grounds for better understanding of the nature of hydrodynamic forcings that drive changes in shoreline and seabed morphology. Such data were also collected at Lubiatowo during field experiments. The measurements included the records of deep and shallow water waves at different locations of the nearshore zone to grasp key elements of wave transformation and wave energy dissipation patterns along multi-bar cross-shore profiles. Wave-driven longshore and cross-shore currents were also recorded to study physical models of such currents in a system with multiple bars. In 2002 and 2003 field experiments were targeted towards identification and description of infragravity waves. Therefore, a co-located wave-gauge and current meters were fixed in close shoreline proximity, some 20–30 m offshore. The data sets they acquired allowed for in-depth studies of hydrodynamic processes in that part of the nearshore region with modern statistical tools. A 24-h record of water level and longshore current during a storm in 2002 was analyzed with discrete wavelet transform based multi-resolution analysis, Różyński and Reeve (2005). The major aim of that study was to check the performance of wavelet methodology when processing long time series of non-stationary nearshore hydrodynamic data. Non-stationarity is an inherent feature during storms, which can take the form of long term changes in mean values (such as changes in mean sea level), or intermittent changes in variance arising as a result of e.g. wave groupiness. The variations of significance of orthogonal, spectrally disjoint time series, into which the analyzed signal is resolved with multi-resolution analysis, can be easily seen in its output. This merit of wavelets in marine sciences was first highlighted by Liu (1994), who applied the wavelet transform to a study on ocean wind waves. Wavelets were then used by Massel (2001), who implemented them to the records of deepwater waves, breaking over tropical coral reefs and Huang (2004) who investigated the use of wavelets as a means of filtering time series to extract wave parameters. The study by Różyński and Reeve (2005) generally confirmed high potential of wavelets in hydrodynamic studies,