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Acoustic impedance properties of seafloor sediments off the coast of Southeastern Hainan, South China Sea

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ABSTRACT

Geoacoustic parameters are essential inputs to sediment wave propagation theories and are vital to underwater acoustic environment and explorations of the sea bottom. In this study, 21 seafloor sediment samples were collected off the coast of southeastern Hainan in the South China Sea. The sound speed was measured using a portable WSD-3 digital sonic instrument and the coaxial differential distance measurement method. Based on the measured sound speed and physical properties, the acoustic impedance and the pore-water-independent index of impedance (IOI) were calculated in this study. Similar to the sound speed, the IOI values are closely related to the sediment physical properties and change gradually from the northwest to the southeast. The relations between IOI and physical properties were studied and compared to the relations between the sound speed and physical properties. IOI is better correlated to physical properties than sound speed. This study also uses an error norm method to analyze the sensitivity of IOI to the physical parameters in the double-parameter equations and finds that the most influential physical parameters are as follows: wet bulk density > porosity > clay content > mean particle size.

1. Introduction

The physical and geoacoustic properties of seafloor sediments are the basic data for the underwater acoustic environment. These data can provide important information for seafloor engineering, military oceanography and marine geotechnics. Many studies have been conducted to reveal the relationships among the physical and geoacoustic properties of seafloor sediments in different geographical units (Hamilton, 1971, 1980; Hamilton and Bachman, 1982; Briggs and Richardson, 1997; Richardson et al., 2002; Liu et al., 2013; Hou et al., 2015). However, these studies have mainly focused on the relationships between the compressional or shear wave speed and physical properties of sediments (Wang et al., 2014; Hou et al., 2015; Endler et al., 2016) and have rarely reported the acoustic impedance or sound speed ratio (Kan et al., 2014; Wang, et al., 2016). The acoustic impedance is an important parameter for calculating the reflection coefficient and transmission coefficient of the seafloor (Schock, 2004; Kan et al., 2014), and the ratio of compressional wave speed (here after called sound speed V) to pore-water speed in sediments is of interest and important in several scientific and engineering fields. Thus, the acoustic impedance and sound speed ratio must be carefully analyzed.

The objective of this study is to present the sound speed (V), the acoustic impedance (Z), and the index of impedance (IOI) of seafloor sediments from coastal southeastern Hainan, South China Sea. The seafloor sediments were collected from 21 stations using a box corer (shown in Fig. 1). The sound speed was measured by using a portable WSD-3 digital sonic instrument and the coaxial differential distance measurement method (Hou et al., 2015). The physical parameters were measured in the laboratory. Then, the acoustic impedance, sound speed ratio and IOI were calculated. This study investigates the relationships between IOI and physical properties of seafloor sediments and discusses the horizontal distributions of IOI and physical properties in the following sections.

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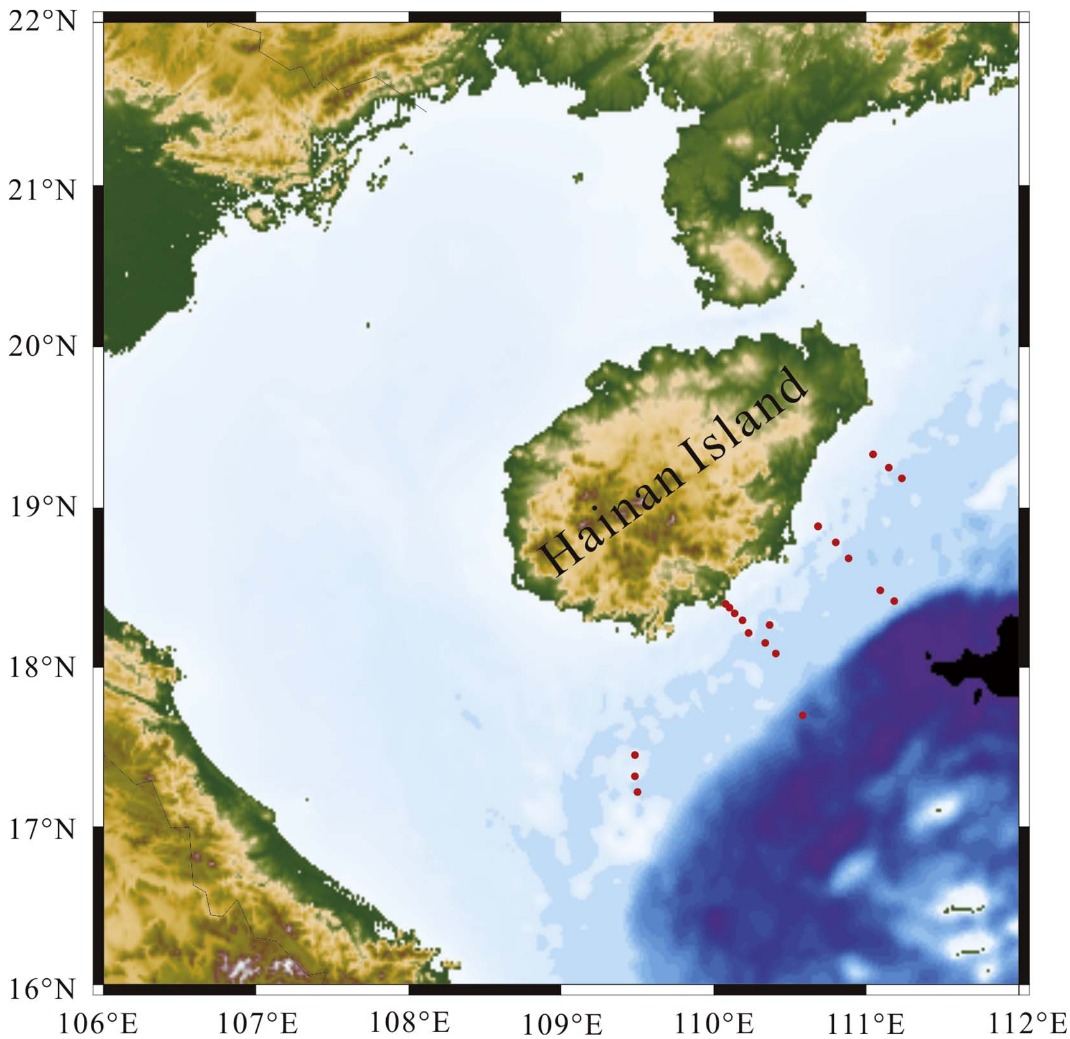

Fig. 1. Coring stations in the study area.

2. Materials and Methods

2.1. Study area

The study area (see Fig. 1) sits in lies off the coast of southeastern Hainan, which is mainly composed of the Beibu Gulf, continental shelf and continental slope. The submarine topography off the coast of Hainan is relatively flat, and the water depth of the study area is 0–200 m (except for one station at a water depth of 917 m). The sediment source is relatively uniform, and the sediment is dominated by offshore deposits; the sediment type can be divided into sand, silty sand, clayey silt, silty clay, etc. The particle sizes of the seafloor sediments in the southern and southeastern coastal areas are relatively coarse because of strong hydrodynamic erosion and abundant river sediment sources (Wan Quan river) (Ge et al., 2003). The sediment particles are coarser in the near-shore areas and finer in more distal areas (Li et al., 2014).

2.2. Methods

A box corer was used to collect 21 sediment samples during the western South China Sea open cruises in 2014. After the seafloor sediments were collected, we inserted PVC tubes into the box corer to collect short cylindrical samples, each of which was approximately 0.2–0.6 m long. The acoustic properties were measured in the laboratory at a constant temperature and pressure (23 °C, atmospheric pressure). The sound speed was measured using a portable WSD-3 digital sonic instrument and the coaxial differential distance measurement method. The center frequency of the pulse signal was 100 kHz, the sound wave sampling length was 1024 points, the length measurement accuracy of the sediment cylindrical sample was 0.5 mm, the transducer calibrated time t_0 was 3.7 μs, the sound wave sampling interval was 1 μs, and the uncertainty of the sound speed measurements was approximately ± 5 m/s. The detailed measurements are described in Hou et al. (2015), and the sound speed (V) was calculated as follows:

$$v = \frac{D}{t - t_0}$$

D is the length of the sediment cylindrical sample, t is the acoustic wave propagation time, and t_0 is the transducer calibrated time. The acoustic wave and spectrum analysis are shown in Fig. 2.

The pore-water speed was reported for the standard laboratory conditions favored by Hamilton (23 °C, 35 ppt, and atmospheric pressure). These conditions correspond to a water sound speed of 1529.4 m/s and a water density of 1024 kg/m^3. The sound speed ratio is the ratio of the measured sediment sound speed to the pore-water sound speed at an identical temperature, salinity and pressure. The physical properties of each sample were measured in the laboratory. The sand, silt, and clay components and the mean grain size were measured using a Mastersizer 2000 particle size analyzer at the South China Sea Institute of Oceanology Chinese Academy of Sciences. The measurement error of the particle size analysis was less than 2%. The sorting coefficient was