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Real-time Acoustic Monitoring of Ocean Interiors Using Ocean Acoustic Tomography

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ABSTRACT

Ocean acoustic tomography is a unique and powerful oceanographic tool that can give time series of 3-dimensional snapshots of ocean interiors in nearly real-time. JAMSTEC has realized such an ideal ocean acoustic tomography system combined with the Global Telecommunication Network (INMARSAT-C). A demonstration experiment was carried out in the western Pacific Basin in the summer of 1997. During this experiment, the time series of 3-D tomographic maps of temperature was successfully reconstructed every 6 h. These maps showed the energetic meander of the Kuroshio Extension with high time resolution. Another tomographic observation experiment was conducted in the central equatorial Pacific Ocean from 1999 to 2000. The preliminary result showed that the temperature and current fields changed strongly in relation to ENSO (La Niña). In the latter experiment, the processing time of measured data was greatly reduced, and a tomographic snapshot was reconstructed in nearly real-time. Our goal of monitoring the ocean interiors in real-time is almost accomplished.

INTRODUCTION

It is becoming increasingly important to measure and understand the 3-dimensional structure and behavior of both the larger-scale and mesoscale features associated with the ocean's general circulation as regards the ocean's role during climate change. Because of the difficulty of direct, in situ observations of the large-scale structure of the ocean, it still remains to be measured through the use of new methods.

Ocean acoustic tomography is a powerful method for estimating large-scale ocean temperature and the current structures of ocean interiors. This method measures acoustic travel times along various acoustic ray paths through the ocean volume and reconstructs the distribution of oceanic parameters (sound speed, temperature and current velocity) by applying inverse methods to the travel times (Munk and Wunsch, 1979).

A conventional ocean acoustic tomography system is limited for research use because the system lacks the means to deliver observed data from the open sea to the land. However, some global satellite communication services—such as INMARSAT, ARGOS, ORBCOMM and IRIDIUM—have recently become available. They can support remote data telemetry for worldwide oceanographic observations. In addition, the full Global Positioning System (GPS) has been operational since the mid-1990s. A GPS receiver is routinely used to determine the position of any site on the earth. The clock of a GPS satellite is well calibrated by the Cesium atomic precision clock and is essential to synchronize all of the internal quartz clocks for the widely divergent ocean acoustic tomography system. Under these favorable circumstances, we proposed a new ocean acoustic tomography system equipped with such a global satellite communication device as INMARSAT-C in order to telemeter the measured data to the land station in real-time.

Ocean acoustic tomography can observe temperature and current fields and mean vorticity without any calibration and drift in principle by using reciprocal transmissions. In this paper, we describe the hardware of our new ocean acoustic tomography system and show the 3-D temperature field as one of the preliminary results of the acoustic tomographic demonstration experiment carried out in the summer of 1997. We also show time series of the zonal temperature field and mean vorticity as examples of the preliminary results of the central equatorial Pacific tomography experiment conducted from December 1999 to December 2000.

A TOMOGRAPHY SOURCE

The key component of our new ocean acoustic-tomography system is a tomography source. The sound pressure level and the optimum frequency of a tomography source are determined by the sonar equation in order to realize 1000-km propagation for ocean acoustic tomography. The results confirmed that the optimum frequency for the 1000-km propagation is around 200 Hz, and the source level is about 190 dB at 200 Hz. Our giant magnetostrictive source technology has produced a source that satisfies those requirements. It is a kind of octagonal transducer whose actuators are giant magnetostrictive rods of the rare earth metal $(Tb_{1-x}Dy_x)Fe_2$, called Terfenol_D.

Fig. 1 shows the schematic diagram of the source with a pulsating barrel shape. The source vibrates in the radial mode of octagonal radiating plates connecting to 8 driving units made of giant magnetostrictive rods. The source is 370 mm high; the diameters of the outer and inner boots are 940 mm and 560 mm, respectively. Inside the inner boot, a 50-mm-thick, cylindrical air cavity is mounted for reduction of the stiffness of the source. The air cavity can be maintained at a constant volume at any depth by adjusting the inflow and outflow of highly pressurized nitro-

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