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Two-dimensional mapping of fine structures in the Kuroshio Current using seismic reflection data

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[1] Multi-channel seismic reflection data acquired in the Pacific Ocean off the Muroto peninsula of Shikoku Island, Japan reveal the two-dimensional distribution of fine structures in the Kuroshio Current. Eighty-one seismic sections, each extending 80 km perpendicular to the current and separated by 100 m, were acquired from 20 June to 15 August 1999 (57 days). The seismic data clearly show that fine structures extend over 40 km perpendicular to the current in almost all of the profiles. A simulation study using acoustic model from CTD data demonstrates that fine structure of temperature and salinity identified in CTD data acquired from the Kuroshio Current off the Ashizuri peninsula yield a synthetic seismic profile with characteristics similar to the Muroto transect profiles.
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1. Introduction

[2] "Kuroshio" is a strong ocean current in the western Pacific Ocean that flows east of Taiwan and extends northeastward along the coast of southern Japan. It has a narrow rapid flow near the surface and in the upper thermocline. Although several studies on fine structures in the Kuroshio Current have been reported [e.g., *Worthington and Kawai*, 1972], the two-dimensional distribution of the fine structures in the Kuroshio Current has not yet been examined. Recently, *Holbrook et al.* [2003] reported that the seismic reflection method can image two-dimensional distributions of fine structures, and several authors have applied this method to investigate fine structures in various oceanographical settings [e.g., *Paramo et al.*, 2003; *Pearse et al.*, 2003]. Furthermore, a joint temperature and seismic reflection study [*Nandi et al.*, 2004] demonstrated that reflection seismology is capable of detecting even weaker fine structure (with temperature contrasts of 0.03°C) in the ocean. Here, we also use multi-channel seismic reflection data acquired in the Kuroshio Current off the Muroto peninsula, southwest Japan, to explore the characteristics of fine structures. Eighty-one seismic profiles acquired over 57 days provide unique information about common fine structures in the Kuroshio Current.

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2. Multi-Channel Seismic Reflection Data

[3] We analyzed multi-channel seismic reflection data acquired by R/V Ewing in 1999 [e.g., *Moore et al.*, 2001] to investigate fine structures within the water column across the axis of the Kuroshio Current (Figure 1). Because the seismic survey was designed for three-dimensional analysis, 81 individual lines with a cross-track spacing of 100 m were surveyed over an 80 km × 8 km area (see Figure 1). All of the lines strike 314°, which is nearly perpendicular to the Kuroshio Current flow direction. Each seismic line is 80 km long and took about 8 hours to shoot. The seismic source consisted of a tuned array of 14 airguns, with a total volume of ~70 liters. The volume of the airguns ranged from 1.3 to 10.5 liters. The receiver array was a 240 channel 6-km-long seismic streamer. Data processing included acoustic velocity analysis, stacking, and migration [*Yilmaz and Doherty*, 1987]. We conducted a post-stack time migration of the seismic traces, but in order to reduce migration artifacts within the section above the seafloor, we limited the migration to the interval from 0 to 2 s in two-way travel time.

3. Fine Structures on Seismic Profiles

[4] We regard the 81 two-dimensional seismic sections as a single transect and attribute differences between the lines as temporal rather than spatial variations. The Kuroshio Current travels the 100 m between adjacent survey lines in less than 2 minutes assuming a current speed of 1 m/s, and across the entire survey (8 km) in just over 2 hours, which is less than the acquisition time of each line. Figure 2 shows eight arbitrarily selected seismic reflection profiles obtained between 27 June and 17 July 1999. Figure 2a shows the seismic profile acquired on 27 June, and includes the interval from 0–6 s to show reflections at the seafloor and geologic structures below the seafloor [*Moore et al.*, 2001]. The reflections from oceanic fine structures, which are of principal concern here, are observed at two-way travel time of 0.4–1.6 s (300–1200 m below the sea surface) (Figure 2). Some fine structures have surprisingly consistent horizontal continuity of over 40 km. The reflections represent contrasts of acoustic impedance, which is the product of acoustic velocity and density. Since acoustic velocity and density are affected by temperature and salinity, rapid changes in temperature and salinity can be imaged as reflections on the seismic profiles. The horizontal straight lines with unusually strong contrast above two-way travel