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A technique for fast conductivity-temperature-depth oceanographic surveys

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RESUMEN
Se presenta un nuevo método para efectuar mediciones oceanográficas usando un sensor CTD en un fuselaje especialmente construido para este efecto. En cada estación de medición, la nave describe un círculo sin cambiar de velocidad mientras el dispositivo se hunde a razón de hasta 5 m/s. La profundidad de muestreo depende de la longitud del cable. Para un micropolígono de prueba frente a Barra de Navidad, México se obtuvieron 27 registros en algo más de 5 horas, hasta una profundidad de 120 m y con perfiles de más de 52 km de largo. La rapidez del método lo hace adecuado para medir ondas internas cortas.

PALABRAS CLAVE: Método de medición, rápido levantamiento oceanográfico.

ABSTRACT
A method for making a fast oceanographic survey using a CTD profiler is described. The CTD is provided with a special case and is towed at maximum speed by the research ship. At each station the ship describes one or two smooth circles without slowing down, while the instrument sinks at a rate of up to 5 m/s (depending on the weight of the case). Sampling depth is determined by the length of the towing cable. An example of a fast survey of a micropolygon on the continental platform of the west coast of Mexico is provided. In 5 hours and 21 minutes, 27 vertical records were obtained up to a depth of 120 m, along transects totalling more than 52 km. The possibility of using the fast-survey method for determining the parameters of short internal gravitational waves is also discussed.

KEY WORDS: Measurement method, fast oceanographic survey.

INTRODUCTION

In the study of the processes related to the upper oceanic layer, the need to make a fast oceanographic survey of the region often arises. Traditionally, such a survey is made with the aid of a conductivity-temperature-depth (CTD) profiler from a drifting research ship. The measurement at each station requires a large investment of time in stopping the ship, lowering and recovering the CTD, and picking up speed to proceed to the next station. During the measurement, the ship is displaced by winds and currents, and the sampling does not correspond to the desired location. The horizontal error can reach hundreds of meters or even kilometers depending on drift speed and measuring depth; and the path of the ship is difficult to determine.

We describe a method which permits sampling to take place while the ship is moving. This speeds up work at sea and increases the accuracy of location of the oceanographic station, which may be important when studying the dynamics of rapidly changing processes in the thermocline, such as internal gravitational waves.

DESCRIPTION OF THE METHOD

The method consists essentially of the following. The CTD recorder is enclosed in a special metal case of hydrodynamical shape, with a switch which is activated by the flow of water (Figure 1a, 1b). The fish containing the CTD is towed at maximum speed by the research vessel using a cable (a signal cable unless the instrument is autonomous), whose length equals the maximum depth of measurements. While towing the fish remains just below the surface. Upon arriving at the station, without slowing down, the ship describes one or two circles around the location to be measured. The apparatus rapidly loses horizontal velocity and begins to sink under its own weight; at the same time, the switch is activated and the instrument begins to record or to transmit data by means of the cable to the recorder on board the ship.

The sinking velocity is regulated by the weight of the apparatus plus an additional weight; it may vary from 0.2 m/s to 5 m/s. Thus the time spent at a station depends on the sinking speed of the apparatus, the speed of the ship, and the depth of the profile. The rotation of the ship around the target point and the short time required to complete a profile ensures that the data will not be affected by drifting.

Care must be taken to prevent the apparatus from bumping against the ocean floor and become lost when working at maximum depth. It is important to keep the recorder at a reasonable distance above the ocean floor. The cable length should be regulated between stations when the ocean floor relief is variable.

TECHNICAL IMPLEMENTATION

The method described was used to measure the thermohaline structure of the waters of the continental shelf of the Mexican Pacific coast, in a polygon off Barra de Navidad (Figure 2a).

The case for the CTD was developed in the Physics Department workshop at the University of Guadalajara. It consists of an aluminum tube with 6 mm walls, 200 mm

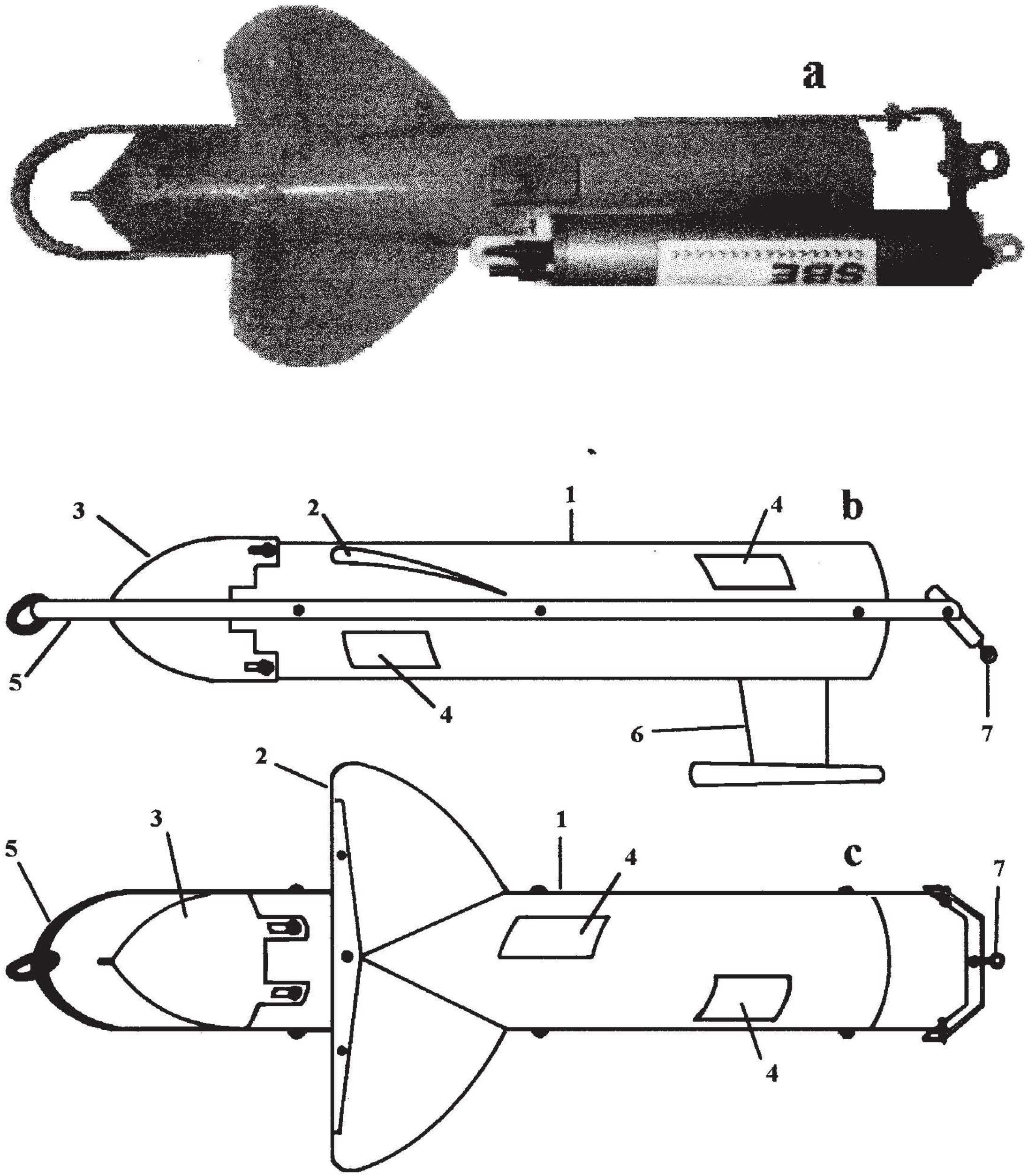

Fig. 1. (a) Towing case and CTD recorder. Figures (b) and (c) show lateral and top views. 1- Case. 2- Fins for sustentation, which provide a positive buoyancy while being towed. 3- Hydrodynamic removable lid. 4- Openings to allow flow of water through the case while it sinks. 5- Steel bar around the case for towing. 6- Directional keel to avoid rotation while towing. 7- Steel structure for attaching additional weights in order to regulate the speed of descent.

diameter and a length of 1000 mm. The CTD is secured by screws and rubber packing to eliminate vibration during towing, and for thermal insulation.

The bottom of the case is open to permit the flow of water, and the upper end has a removable lid with hydrodynamical shape which moves by means of a spring and by the force of the flowing water. The lid has a rod which transmits the stress to the switch on the recorder.

The instrument is towed by a steel bar around it, fixed by screws. At the bottom a hydrodynamically shaped weight is attached to regulate the speed of descent during measurements.

The top of the fish has two small fins for sustentation, which allow it to remain just beneath the surface while being towed. To avoid rotation or vibration of the instrument in the water, the rear end has a directional keel with a weight at the end.

During the descent, water flows freely into and through the case through the rear (lower) opening, flowing over the CTD sensors and out again through the top openings in

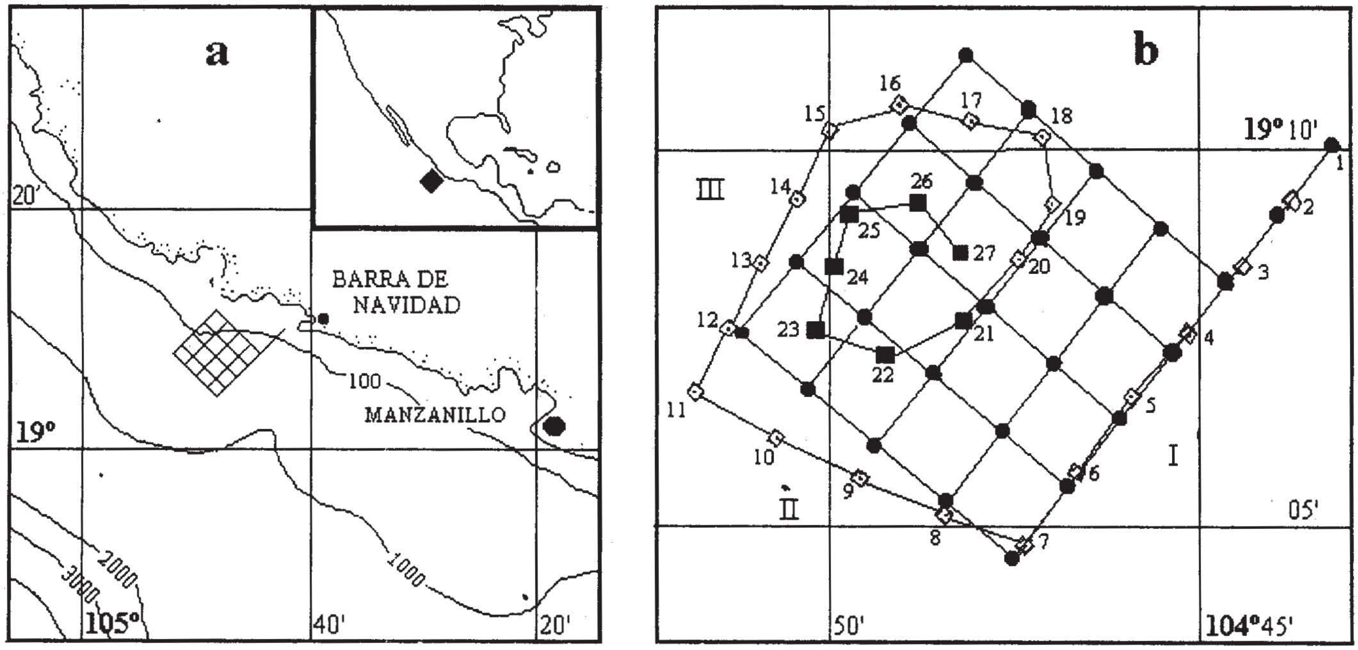

Fig. 2. (a) Micropolygon in which the fast-surveying method was tested. (b) Planned stations (solid dots) and actual positions of stations (squares) in the micropolygon. The transects are labeled with Roman numerals.

the case. The spring allows the lid to be pushed up. The total area of the openings exit is three times larger than the entrance area, which eliminates the influence of the thermal inertia of the case and any additional mass effects on the signal.

We used an SBE-19 CTD (Sea Bird Electronics, Inc., 1994) with a memory of 128 K, and a maximum inmersion depth of 2058 m.

The work at sea was done from a small BIP-V vessel, belonging to the University of Guadalajara Coast Ecology Center. Maximum cruising speed was close to 7 knots. The ship was equipped with a towing winch, satellite navigational system and video-probe as well as radar and radio.

A TEST SURVEY

The following example illustrates the use of the method during an oceanographic survey. A micropolygon was measured on 14 May 1995, over an area of 4 x 4 nautical miles with a distance of one mile between stations. The sequence of measurements was done following a helix, starting from the perimeter of the square and circling toward the center (Figure 2b). The purpose was to measure the parameters of short internal gravitational waves on the continental shelf of the region. The pattern and the sequence of the profiles permitted the sampling of spectral spatial windows with a different resolution from that obtained from profiles done at close time intervals.

Figure 2b shows the location of the 27 stations in the micropolygon, which were measured on average at a depth of 120 m. The survey took 5 hours and 21 minutes. Sampling rate was 2 measurements per second and the speed of descent of the apparatus was 1.4 m/s. During the survey the ship covered more than 28 nautical miles, using less than two minutes for each profile. As is shown in Figure 2b, the actual location of the stations during the last phase of the survey differed substantially from the initial design. This was due to technical problems, including the lack of a drawing table and a navigation guard, and to the inexperience of the pilot in correcting the course every 10-12 minutes, which was the time delay between stations. However, such errors do not affect the quality of the data since the location of each station is known exactly from the satellite navigation system.

DISCUSSION

On the shelf and the continental slope, the barotropic tide is responsible for an intense generation of internal waves, which propagate towards the open sea and towards the coast. On the continental shelf, due to shallow water, they rapidly accumulate energy and in some cases they disintegrate into groups of short waves, eventually dissipating their energy near the coast (Graig, 1987, Howell *et al.*, 1985).

The groups of internal waves on the continental shelf cause significant spatial-temporal fluctuations of all the hydrophysical parameters and originate vertical and horizontal orbital currents which become evident on the surface in the form of long alternative strips of slicks and ripples (Apel and González, 1983). During our measurements smooth bands were found everywhere parallel to the coast. Their width was found to be up to 300-500 m and the distance between them was 1-8 km.

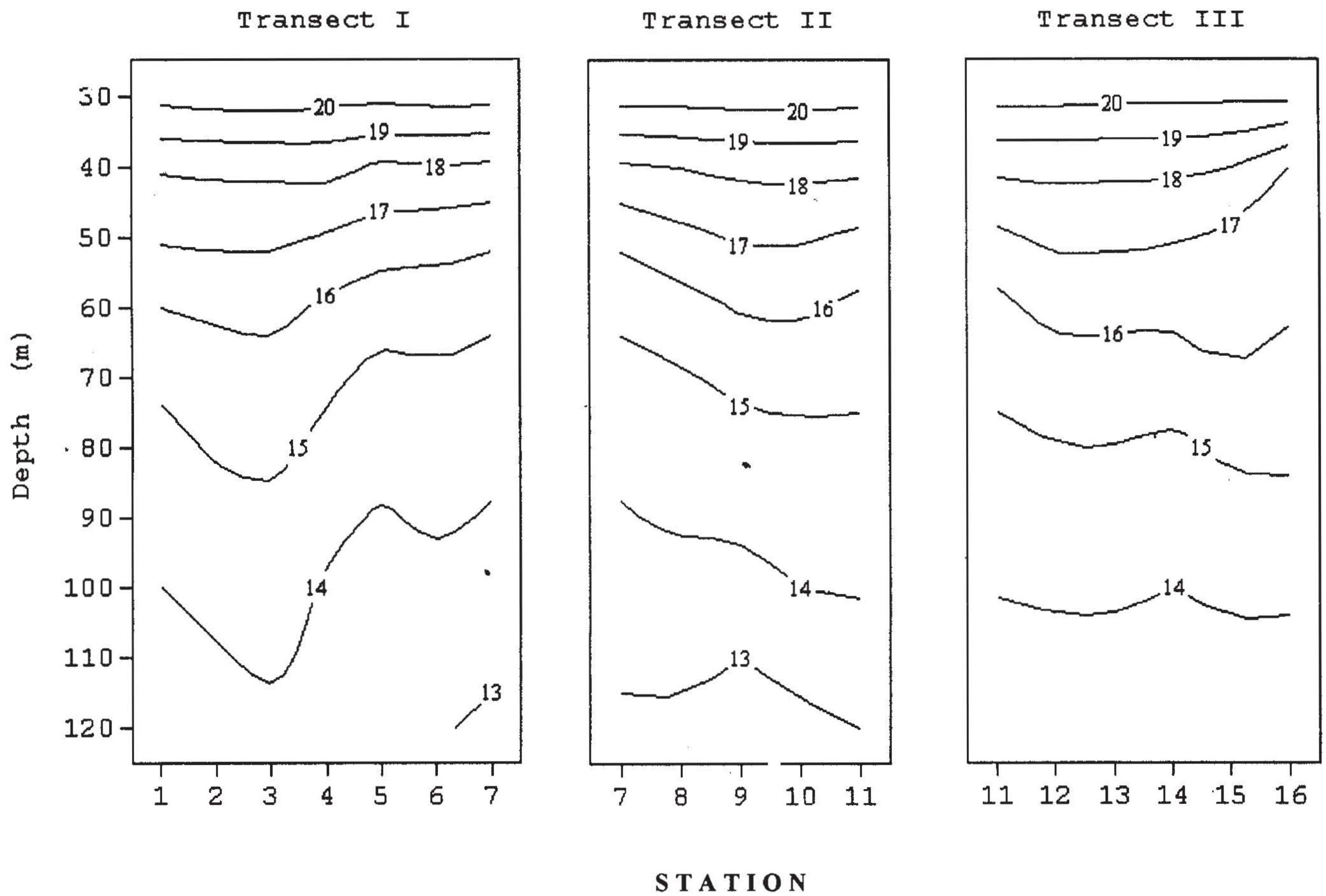

Fig. 3. Temperature sections based on data from the three transects.

The orbital currents, related to the internal waves in the subsuperficial layers of the ocean, form convergence and divergence zones which determine the biological productivity of the continental waters ("spots"). These move in space and are well known to biologists and fishermen (Gaiskiy *et al.*, 1987).

Figure 3 shows temperature data obtained in transects I, II and III. The temperature field suffered strong vertical oscillations with a maximum amplitude of up to 25 m and a horizontal perturbation length of up to 7-8 km. To determine the average parameters of the internal waves, a spatial spectral analysis of the oscillations of the isotherms 14°, 14.5°, 15°, 15.5°, 16°, 16.5°, 17° and 18 °C was made by the linear method, and by the non-linear methods of Maximum Entropy (ME) and Maximum Likelihood (ML). The spectral estimates were calculated as described, for example, in Filonov (1982) and Konyaev (1981).

No instrumental measurements of the parameters of internal waves had been made before in the region. Thus their length was estimated from theory (Filonov *et al.*, 1996). An antenna formed by the last seven survey stations was used for the spatial spectral calculations (Figure 2b, solid squares). These measurements were closest in time and formed a sufficiently compact spatial spectral window for a linear estimate.

Figure 4 shows the mean estimates of the spatial spectra calculated by the three methods. In all spectra there are two significant peaks situated on the borders of the wave number area limited by the Nyquist spatial frequency ($1/2\Delta x$, $1/2\Delta y$ cycles per km). One peak corresponds to an internal wave travelling close to 40-50 degrees (almost normal to the coast) with a wavelength of around 7.4-8 km. Another wave travels close to 330 degrees (nearly along the coast) and has a length of 7.2 km. The average estimates of the spatial spectra, obtained by different methods, give very similar results, which confirms their reliability.

The ocean-floor relief in the area of the survey is rugged, with many canyons and depth variations. One canyon is located southeast of the region and is well expressed on the continental shelf. Its slopes could be a source of internal waves propagating toward the northwest. The other set of waves are most probably emitted by the edge of the continental shelf, which is near the micropolygon. Their superposition forms a complex field of temperature fluctuations, which is detected by our measurements.

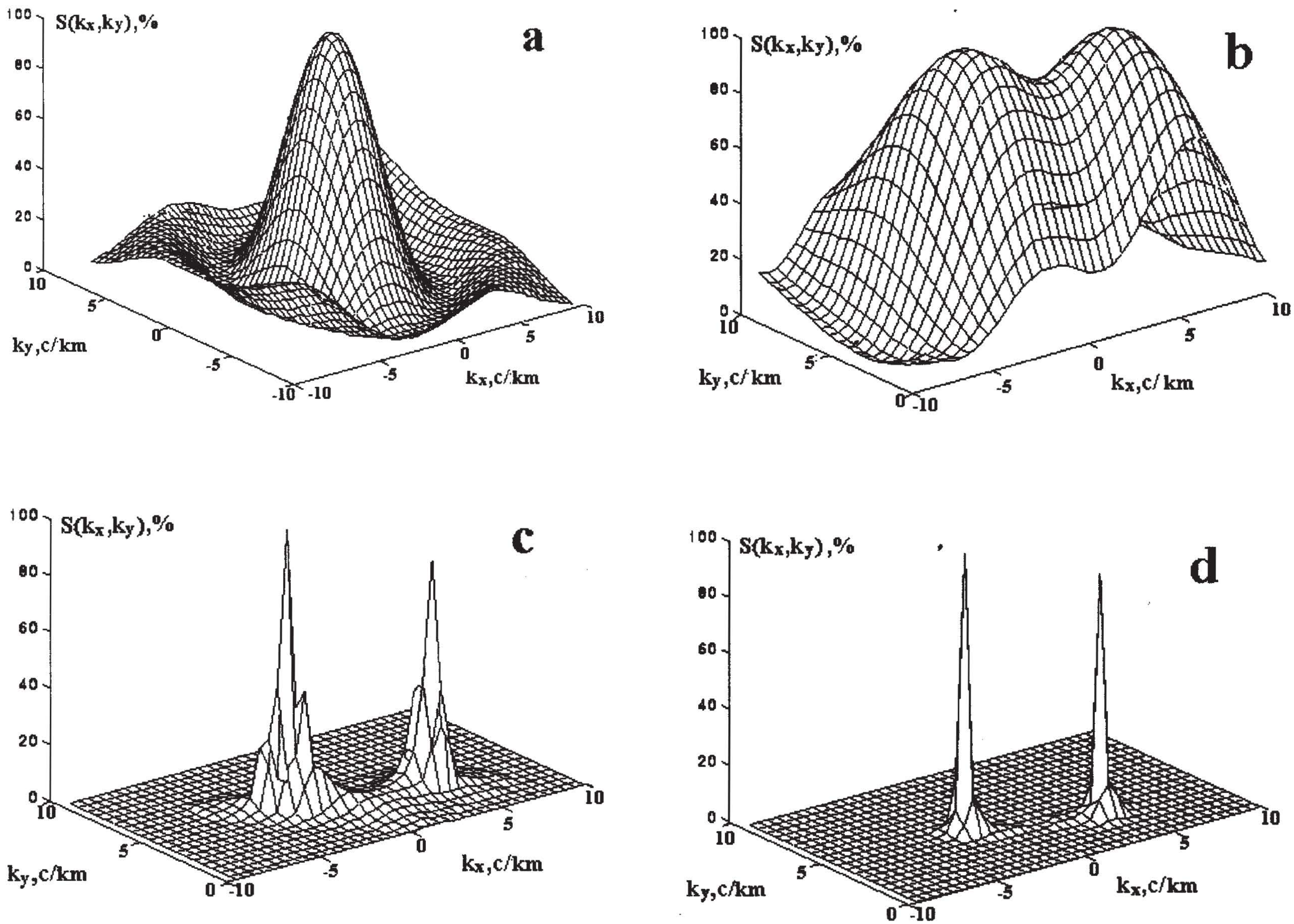

Fig. 4. (a) Spectral window based on the spatial position of the last seven stations of the micropolygon. Estimated average spatial spectra for temperature fluctuations at the stations, calculated using (b) the linear method, (c) the Maximum-Likelihood method, and (d) the Maximum-Entropy method. The spectral density profile is given as the ratio of the percentage to the maximum value.

It is difficult to estimate the error in the spatial spectra using the data from our measurements. The last seven stations in the micropolygon were surveyed in less than 58 minutes. In some of these stations the logs were in the direction of propagation of the waves, and in others against it. Thus the Doppler shifts are of different signs and should be averaged when calculating the spatial spectra. This should not significantly influence the total error in the internal wave lengths or the directions.

CONCLUSIONS

Estimation of spatial spectra of oscillations of hydrophysical fields in the ocean from fast oceanographic surveys is one of the possible uses of the method proposed. Another no less important use is the fast survey of ocean areas to determine the acoustic parameters of the environment.

The most important advantage of the method is in obtaining data on currents by the dynamical method in continental regions, where traditionally they should not be used due to the presence of internal waves. The proposed method permits oceanographic surveys to be completed more rapidly and as often as desired for any given set of stations. The parameters of the internal waves can be estimated and filtered from the observation data.

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