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Measurement of marine snow abundance using the submersible

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Abstract: Marine snow photographs were taken every 50 m depth interval from 50 m to 1950 m in Suruga Bay (water depth, 1972m) on 29th April 1990, using a camera and a strobe and a clear-sight (a cylinder, 20 cm in diameter and 60 cm in length, with the clear water inside and the light-shielded body except the transparent parallel planes), on the submersible SHINKAI 2000 descending at about 10 m/min. We analyzed a total of 5710 marine snow particles using an image analyzer and made marine snow abundance profiles (number and density). Both profiles increase with depth below 1500 m except at depths of 1700 m and of 1950 m (20 m above bottom); density has a maximum in the midwater. The causes of the increases and the maximum are suggested as being due to advection.

1. Introduction

Marine snow are aggregated particles with a length of more than 0.5 mm and have significance as transport agents which fluxes much of surface-derived matter to the ocean interior and the sea floor. Advances in our understanding of the characteristics and abundance of marine snow have been hidered by problems associated with sampling and quantifying these fragile aggregate in nature (ALLDREDGE and SILVER, 1988). We found frequently disaggregation of marine snow in eddies produced by sharp edges of instruments on the submersible, even diving at a slow speed of 10 m/min.

The sampling problems have needed *in situ* observations using SCUBA (ALLDREDGE and GOTSCHALK, 1988 ; 1989) and the submersible (INOUE *et al.*, 1955; ALLDREDGE and YOUNGBLUTH, 1985), and recently HON-JO *et al.* (1984) developed a system to assess particle spectra directly in the water columun. The system uses a well-collimated beam which is produced by a sophisticated light source such as a combination of stroboscopic light and a Fresnel lens, and the system installed in a frame is lowered using a wire from a surface ship.

The submersible is a stable free-fall platform in the sea and free from rapid movement; usually it dives without propulsion. If we pay careful attentions to the layout of a system for marine snow observation, the submersible can get rid of those disturbing of fragile marine snow which might occur when the system is lowered using a wire from a ship and the ship tosses by waves. We used the submersible SHINKAI 2000 and equipped it with a simple system which was consisted of an ordinary strobe and a transparent cylinder in front of a camera, to take a clear marine snow photographs.

Suruga Bay was chosen for the survey station because pilots of the submersible have observed abundant marine snow almost all the diving times in the Bay.

2. Methods

Fig.1 shows the concept of the clear-sight method. The clear-sight we used is an acryl cylinder with the clear water inside and the light-shielded body the except the transparent parallel planes; it is after "clear-site", a plastic bag filled with clear water, which is used by divers to take clear photographs in the turbid seawater. A clear-sight excludes less sharp and relatively larger images which exist closer than the focused subject and hide sharp images at the focused distrance. Each

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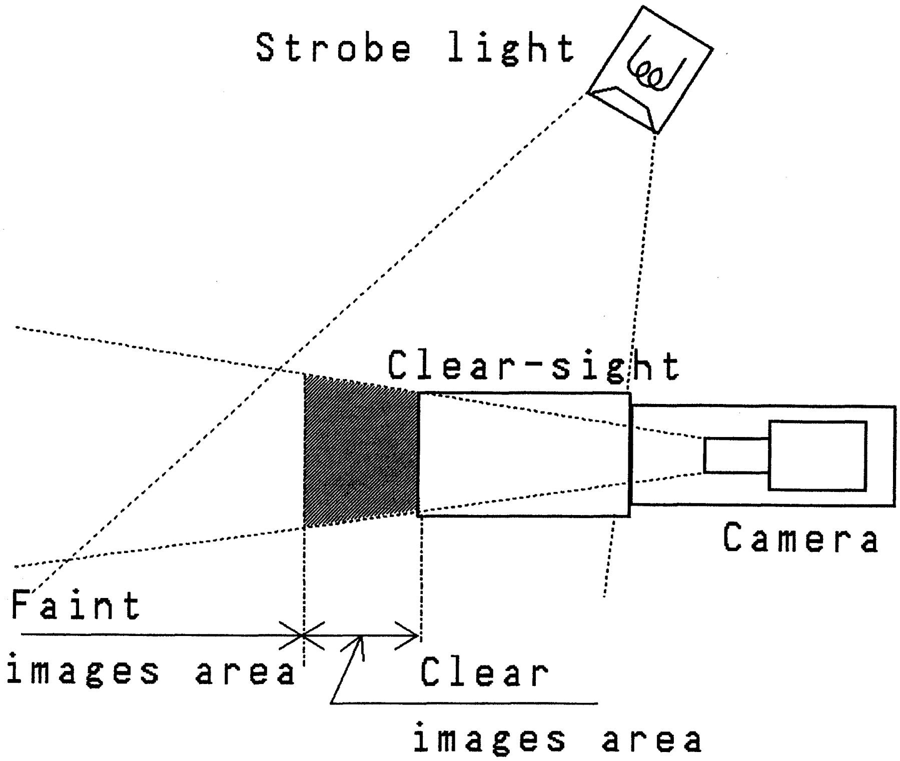

Fig.1. Concept of the clear-sight method. The clear-sight is an acryl cylinder with the clear water inside and the light-shielded body except the transparent parallel planes. A clear-sight placed in front of the camera excludes less sharp and relatively larger images which would exist closer than the focused subject.

photograph taken with a clear-sight contains both sharp and faint marine snow images; sharp and faint ones correspond to focused and farther objects, respectively. The faint ones are easily excluded using aimage analyzer.

We mounted a clear-sight (diameter, 20 cm; length, 60 cm) horizontally on the front side of the SHINKAI 2000; The front end of the clear-sight was placed far enough from the foremost of the SHINKAI 2000 to avoid the wake produced by it. The other end was placed just in front of a camera (f 28 mm ; F 3.5; object distance in water, 0.8m).

Three photographs were taken every 50 m depth interval (the depth difference between the first and the third photographs is less than 2 m) from 50 m to 1950 m in Suruga Bay (34° 43.00′ N, 138° 35.50′ E; water depth 1972 m), central Japan on 29th April 1990 ; the SHINKAI 2000 Started diving at 9:47 a.m. and descended about 10 m/min., half the regular speed. The submersible stopped diving to survey horizontally at about 1800 m for 17 minutes and resumed diving to bottom. We supposed that the disaggregation of marine snow by eddies produced at the edge of the front end of the clear-sight was negligible because of two reasons: the simple shape of the clear-sight with the lesser eddy production and the sparse existence of marine snow which reduces its chance to near eddies.

A image analyzer (NEXUS system) with a digitizer (768 × 493 pixels, the brightness unit ranges 0 - 255) gave area of each particle and a particle-number in a photograph, excluding faint images (less bright than 170 brightness). The size resolution and the sampling volume (a sum of three photographs) for this study were estimated to be 0.3 mm and 9.3 liter, respectively, according to an assumption: if a strobe gives equal brightness to all particles in front of a camera, the brightness of a particles decreases inversely with the square of the distance between the particle and the camera.

The volume of a particle was calculated from the diameter of the corresponding circle, assuming that the particle was sphere and the area of the image of the particle was equivalent to a circle. The details of clear-sight method can be seen elsewhere (TSUJI *et al.*, 1991).

3. Results and discussion

Fig. 2 shows photographs of marine snow taken at the depth of 450 m in Suruga Bay, with and without a clear-sight. Almost all the images in the photograph with a clear-sight are clear compared to the ones in the photograph without it. We analyzed a total of 5710 marine snow particles; Kruskal-Wallis analysis of variance of ranks (CAMPBELL, 1967) showed that the locations of the median of marine snow populations in three photographs of the same depth are the same ($p > 0.05$) through all depths except three depths (300 m, 700 m and 1150 m), particle data of which were not excluded from other depths' because of a little effect on the whole depth profiles.

Fig. 3 shows profiles of particle-number (particles / liter), density (a sum of the volume of particles in three photographs taken at the same depth to sampling volume; cubic mm/liter) and salinity and temperature measured by a STD on the submersible. Particle-number is almost the same (about 12 particles/liter) from 100 m to 1450 m and increases with depth below 1450 m except two declines at 1700 m and at 1950 m; the decrease at 50 m seems to be due to the effect of the strong ambient lights on the photographing in the shallow waters. Density has a midwater maximum at 600 m and local maxima in the deeper depths, slightly increasing with depth below 1500 m except the declines at the same depths as particle-number. Salinity has a large variation in the depths shallower than about 500

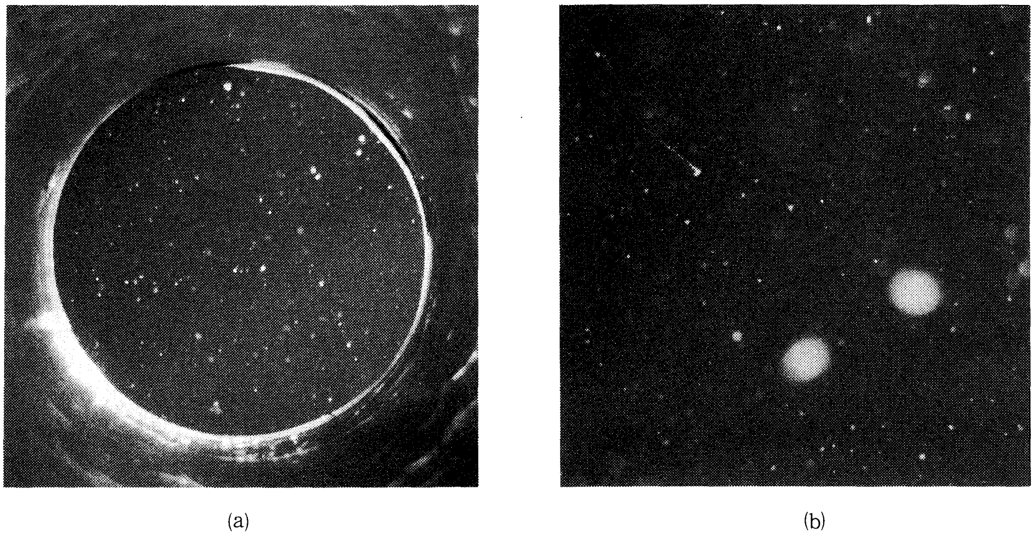

Fig. 2. Photographs of marine snow taken simultaneously at the depth of 450 m in Suruga Bay, (a) with and (b) without a clear-sight. (a) shows clear images of particles with the inside of the clear-sight sean on the outer part of the photograph. (b) contains some faint and enlarged images of particles. (From TSUJI *et al.*, 1991)

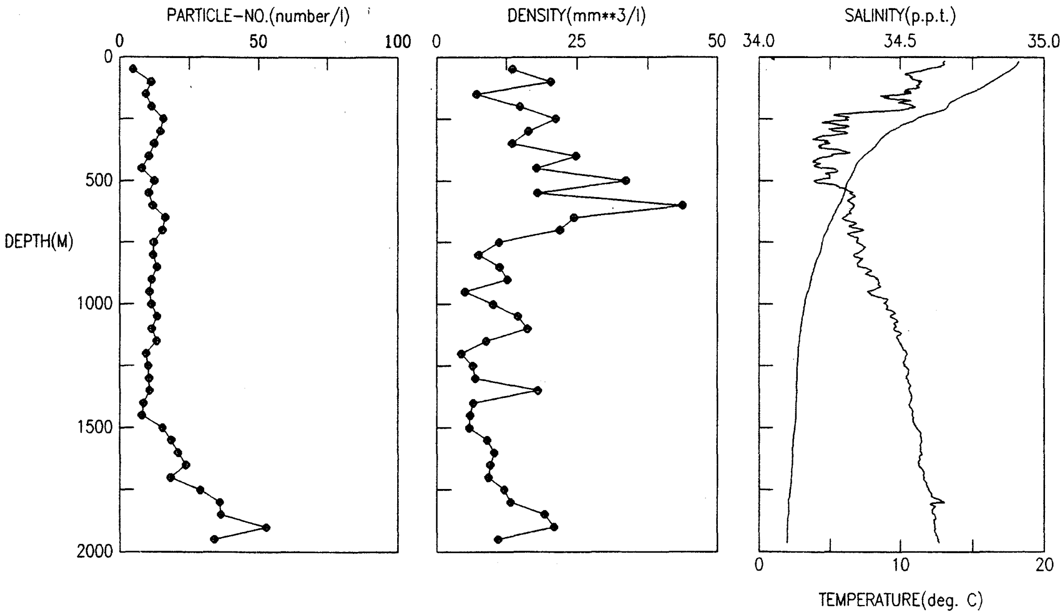

Fig. 3. Profiles of particle-number (particles/liter), density a (sum of the volume of particles in three photographs taken at the same depth to the sampling volume; cubic mm/liter) and salinity and temperature measured by a STD on the submersible. Note that salinity peaks at about 1800 m show the effect of the horizontal movement of the submersible at that depth. Density has a mid-water maximum at 600 m and local maxima in the deeper depths; both ponticle-number and density have general increases with depth below 1450 m. It is noticeable that the depths of large salinity intrusions are located shallower than that of the density maximum.

m with intrusions of high salinity waters. It is noticeable that the depths of large intrusions are located shallower than that of the density maximum.

The observations of midwater maximum of marine snow density agreed with previous reports (ASPER, 1986, 1987; GARDNER and WALSH, 1990); the cause of the maximum was suggested as advection of sediments which were resuspended on the shallow bottom (ASPER, 1986; GARDNER and WALSH, 1990) by the strong bottom current (LAMPITT, 1985). The station of this observation is located only 5 km off Senoumi Seamount with the summit depth of 32 m and it is probable that sediments on the shallow Seamount were resuspended and transported horizontally to this station by the currents. That the midwater maximum of marine snow density observed in this study appeared at the deeper depth than those of strong salinity intrusions, is sugges-ted as the sedimentation of the transported particles in the water column.

It is noticeable that although the general increase of particle-number below 1450m may correspond to the near-bottom nepheloid layer over rough topography as VANGRIESHEIM and KHRIPOUNOFF (1990) suggested, it has two declines instead of homogeneity as they indicated.

Fig. 4 shows enlarged profiles of particle-number, temperature and salinity below 1000 m. Features of profiles of temperature and salinity change significantly at 1450m. Trends of profiles above 1450 m are extrapolated to the deeper depths so that the differences (hatched area in Figure 4) between the profiles and the corresponding extrapolated trends can be seen clearly. All the diffrence

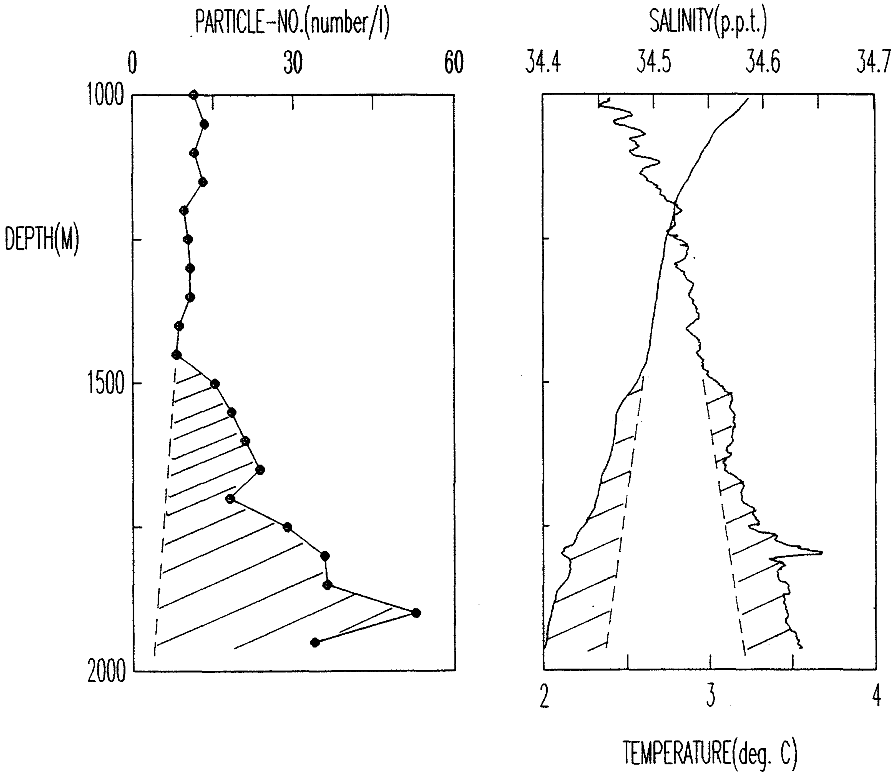

Fig.4. Enlarged profiles of particle-number, temperature and salinity below 1000 m. Hatched area show the differences between profiles below 1450 m and corresponding extrapolated lines (dashed line) of the trends above 1450 m toward the deeper. Peaks of salinity and temperature at about 1800 m, see the caption of Fig. 3. Trends of temperature and salinity change significantly at 1450 m; below that depth particle-number increases.

area are similar in general shape; a decline of particle number at 1700 m corresponds to a sharp decline of salinity and a decline of slope of temperature, but at a shallower depth by 50 m (one interval for the measurement in this study). The decline of particle number at 1950 m corresponds declines of slopes of temperature and salinity near that depth. Considering the shape similarities, we suggested that the increase of particle number is not due to resuspension of bottom sediment just below this survey station, but bue to horizontal transport of particles with intrusions as indicated for near-bottom nepheloid layers (MCCAVE, 1983; RICHARDSON, 1987).

The intrusions seem to have two layers. They have colder and higher-salinity waters than the near-bottom waters previously existed. The main waters of the lower layer exist presumably more than 20 m above bottom and transported from the seaward, the northward current (0.2 knots, 290 degree; inward direction for the Bay) was measured by a current meter on the submersible.

In this study, we showed clearly a midwater maximum and near-bottom increases of marine snow abundance, using the submersible with a simple photographing method. The causes of both are suggested as horizontal transport of particles. The slow sinking submersible showed significant advantages to measure the size distribution of fragile marine snow (TSUJI and SUKIZAKI, in preparation). Therefore, we suggest that using the submersible is effective to measure the large-size particle distributions precisely and that analysis of dynamics or modeling for large particles such as marine snow must account for horizontal transport, in particular, in the marginal sea.

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潜水調査船を使用したマリンスノーの鉛直分布観測

辻　義人・鋤崎俊二

1990年の4月29日，駿河湾（水深1972mの場所）において10m/分で沈降している「しんかい2000」に取り付けたスチールカメラ，ストロボ及びクリアサイト（直径20cm，長さ60cmの両端が透明な円筒で，内部に清水を満たしたもの）を使用して50mから1950mまでのマリンスノーの写真を撮影した。画像処理装置によって全部で5710ヶのマリンスノー粒を解析し，マリンスノーの数と総体積の鉛直分布を求めた。マリンスノーの鉛直分布は1500m以深で深度とともに数が増加し，中深度層で総体積が最大を示した。これらの増大の原因が移流によることが示唆された。