Diurnal vertical motions over a seamount of the southern Gulf of California

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Abstract

A 6-month time series of velocity and scattered sound intensity profiles is used to document diurnal vertical motions over a seamount, El Bajo Espíritu Santo, in the southern Gulf of California, Mexico. The vertical motions persisted throughout the period of measurements and is a noteworthy finding in this study. Data were collected with a 153.6-kHz acoustic Doppler current profiler (ADCP) deployed in water ~ 300 m deep between June 19 and December 8, 1999. Vertical velocities and scattered sound intensity anomalies recorded by the ADCP showed a well-defined diurnal periodicity throughout the period of observation. Peaks of both variables coincided with the timing of sunrises and sunsets and featured phase shifts consistent with upward or downward motions. It was likely that the diurnal peaks in vertical velocities and scattered sound intensity anomalies were associated with motions of the deep scattering layer that depicted vertical migrations of euphausiids and other zooplanktonic groups. This was suggested by plankton samples collected over the seamount early in the deployment and also given the frequency of the emitted sound and the documented dominant taxa of El Bajo Espíritu Santo. Typical upward velocities, at sunset, were 3 cm/s while downward velocities, at sunrise, were 4 cm/s over vertical spans of 100–150 m. The persistence of diurnal vertical motions throughout the 6 months of measurements was attributed to injections of zooplankton swarms from other parts of the Gulf of California by means of near-surface advective fluxes. Once in the area of the seamount, continued vertical migrations effected by the zooplankton groups probably reduced their chances of being swept away from this area as subtidal flows at depth were considerably weaker (< 5 cm/s) than those near the surface (> 10 cm/s) and frequently in opposite direction.

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1. Introduction

Vertical motions of zooplankton and other organisms in the ocean and in lakes have been widely documented with acoustic methods (e.g. Plueddemann and Pinkel, 1989; Robinson and Gomez-Gutiérrez, 1998; Luo et al., 2000). The rate of these motions is usually inferred by estimating slopes of the acoustic signal strength during the periods of rapid changes in depth and time. Fewer studies have been able to document directly measured values of these vertical migration rates (e.g. Rippeth and Simpson, 1998; Winant et al., 1994; Thomson and Allen, 2000; Pinot and Jansa, 2001; Liljebladh and Thomasson, 2001). The availability of acoustic Doppler current profilers with four transducer heads distributed in a Janus configuration (two orthogonal pairs) has allowed redundant measurements of vertical velocities. In addition to measuring each component of the horizontal velocity, each pair of transducer heads records a value of vertical velocity that allows for quality control of the data. The purpose of this study is to document diurnal vertical motions over a seamount in the southern Gulf of California throughout a 6-month period that extends over the latter half of 1999. This is the first time that such migrations are recorded in the Gulf of California with such temporal resolution and over such an extended period, and also constitutes one of the few extended records of diurnal vertical migrations anywhere in the ocean. This purpose was achieved with data of vertical velocities and acoustic strength anomalies recorded by an acoustic Doppler current profiler deployed in the ‘El Bajo Espíritu Santo’ seamount.

1.1. Study area

The El Bajo Espíritu Santo seamount is recognized by fishermen and oceanographers alike as an area where large quantities of fish congregate. Fishermen and divers are attracted to the area by tuna, dolphin fish, marlin, manta ray, whale shark and the large schools of hammerhead shark that assemble here (Klimley and Butler, 1988; Muhlia-Melo et al., 2003). In the vicinity of the seamount, high concentrations of zooplankton and fish larvae are also found. Fish larvae diversity is high, 104 different species have been identified here. This represents nearly 30% of all species present in the Gulf of California (González-Armas, 2002) concentrated in an area that is only ~ 0.05% of the entire gulf.

Seasonal temperature changes are large in the southern Gulf of California. Tropical conditions occur during the months of May to November, sea surface temperatures (SSTs) vary between 25 and 29 °C. During the rest of the year, SSTs are more typical of subtropical latitudes, ranging from 19 to 24 °C (unpublished data from the authors). The main tidal components in the gulf are the M2 (semidiurnal) and K1 (diurnal). In this context the seamount is a subtropical, shallow seamount. The frequency of the tidal forcing (K1 + M2) is superinertial since the local inertial period is 28.6 h.

A number of physical processes should contribute to the local enhancement of biological productivity at different time scales (Trasvina et al., 2003). Increased vertical shear of the currents generates mixing over the seamount’s summit that promotes efficient redistribution of nutrients to the photic zone as reflected by high chlorophyll-a concentrations (Santamaría-del-Angel et al., 1994; Klimley and Butler, 1988). Three-dimensional tidal advection is important during spring tides. Surface hydrographic fields change quickly due to frequent, short-lived wind bursts that force current jets out of the neighboring Bay of La Paz. Impinging large-scale flows perturb the vertical structure along the flanks of the seamount. Low frequency (1–3 weeks) cool and warm filaments, consequence of the mesoscale structure in the Gulf of California, also reach the seamount (Soto-Mardones et al., 1999).

In addition to biomass, planktonic diversity is also high in the Bajo Espíritu Santo region, as 104 different species of fish larvae have been identified. This is thought to be due to the specific geographical location...
of the seamount. Outflows from the Bay of La Paz promote higher diversity of species by carrying zooplankton from a region that is biologically distinct from the seamount. Also, complex mesoscale structures (edds, jets) in the southern Gulf of California are likely to transport eggs and fish larvae across the gulf (Hamman et al., 1988, 1998; Green-Ruiz and Hinojosa-Corona, 1997). Amador-Buenrostro et al. (2003) report a mesoscale eddy just east of the seamount that affects local hydrographic fields. Their infrared imagery is consistent with the circulation around the eddy being capable of transporting properties from an upwelling region off the eastern coast of the gulf to the area around the seamount.

The reason for the documented aggregation of fish and larvae around the seamount area, however, is not completely clear. In higher latitude seamounts, the interaction between bathymetry and energetic
subinertial components of the tide produces resonance, resulting in closed circulations on the seamount or trapped baroclinic waves around it (Chapman, 1989; Rhines, 1969; Huthnance, 1974). In particular, the El Bajo Espíritu Santo seamount is located below the critical latitude (30° N) and therefore the main tidal components are superinertial. This study presents observational evidence of the presence of vertical migrating particles, believed to be zooplankton, around the seamount for a period of at least 6 months.

2. Data collection and processing

A 6-month time series of velocity and sound intensity profiles is used to document diurnal vertical motions in the water column over a seamount of the southern Gulf of California, Mexico. The profiles were obtained with a RD Instruments 153.6 kHz Broad Band acoustic Doppler current profiler (ADCP) during the period between 23:00 (local time) on June 19, 1999 and 09:00 on December 8, 1999 (days 170–342). The instrument was deployed at 24°42.656’ N, 110°17.727’ W on a taut-wire buoy over a depth of ~300 m. The instrument’s transducers faced upward at ~50 m from the sea bed and were oriented at 20° from the vertical. The mooring was located at a distance of ~1 km to the northeast of the crest of El Bajo Espíritu Santo (Fig. 1). The ADCP recorded 30 pings distributed over 40-min intervals and 40 bins with a length of 6 m. The first bin was centered at around 63.5 m from the sea bed, or 13.5 m from the transducers, and the last usable bin was bin 37, at ~279 m from the bottom. Additionally, a thermistor chain was deployed near the ADCP to examine the temporal changes in the vertical structure of the thermal field. Unfortunately, the thermistor chain was not successfully recovered. The variables recorded by the ADCP that receive most attention here are the vertical component of the flow $w$ (in cm/s) and the intensity of sound scattering in the water column $I$ (in arbitrary units).

The vertical component of the flow was slightly trimmed from values where the error velocity, the difference between the redundant vertical velocities measured independently by each pair of ADCP transducers, fell outside ±3 cm/s. This threshold was determined empirically through examination of the time series of error velocity that showed randomly distributed (in time) sporadic values that exceeded such threshold throughout the water column.

The intensity of the sound scattered $I$ was normalized as in Plueddeman and Pinkel (1989) and Rippeth and Simpson (1998). The aim of this normalization is to derive a measure of the scattering strength in order to describe temporal changes (i.e., the normalization consisted in determination of intensity anomalies $I'$ relative to a mean intensity $\langle I \rangle$). Following Rippeth and Simpson (1998):

$$I'(z,t) = I(z,t) - \langle I \rangle(z) \quad (1)$$

where $I(z,t) = 10 \log_{10} [\text{RSSI}(z,t)]$, and RSSI is the received signal strength indicator as recorded directly by the ADCP. The mean intensity $\langle I \rangle(z)$ is depth-dependent and calculated over an arbitrary period.

3. Data description

Both $w$ and $I'(z,t)$ showed clear diurnal periodicities throughout a large portion of the water column. This is first observed in the $w$ contours for each full month of deployment (Fig. 2). Pulses of negative $w$ appeared in the early part of each day, while positive $w$ developed in the late portion of each day. The regularity of these pulses throughout the 6 months of observation is remarkable and a first indication of vertical migrations throughout the period. The timing and extent of these pulses are better illustrated in Fig. 3, where shorter periods, selected arbitrarily, have been portrayed. The vertical extent of the pulses reached between 120 and 150 m, occasionally even exceeding 150 m. It is clear that negative $w$ (descending motions) appeared toward the first third of the day and positive $w$ (ascending) occurred at the beginning of the second third of the day. A slight shift in these motions is noticeable at times in Fig. 3 in such a way that descending motions occurred initially near the surface and later at depth, whereas ascending motions appeared initially at depth. The sampling interval (40 min) hindered a better elucidation of these phase shifts.

Closer examination of all $w$ velocities as a function of the hour of the day indicated that descents occur at
Fig. 2. Color contours of vertical velocity $w$ versus depth (distance from ADCP transducers in meters) and time for the months covered completely by the deployment. Positive (yellow and red) values represent ascending velocities. Note the persistent alternation between descending velocities early in the day and ascending velocities late in the day.
Fig. 3. Same as Fig. 2 but for three 10-day periods, selected arbitrarily.
sunrise, between 05:30 and 07:00, and ascents develop at sunset, between 18:00 and 20:00 (Fig. 4). Also, the phase shift from surface to bottom on descents and vice versa on ascents is more noticeable in this representation. The average descent velocity for the entire 6 months of observations is a little more than 2 cm/s, while the average ascent velocity is a little less than 1 cm/s. These $w$ velocities were uncorrelated to the horizontal velocities, which represents, together with the timing of the $w$ peaks, another indication of

![Fig. 4. Vertical velocities $w$ at selected distances from the ADCP transducers, for the entire deployment, as a function of the hour of the day. The continuous, thick line denotes the average $w$ of all observations (asterisks) at each time. Dark shaded regions indicate periods of darkness while light shaded regions denote times of sunrises and sunsets throughout the 6-month deployment. Vertical velocity averages at different depths are compared in the lowermost panel with the darkest line being the closest to the transducers.](image-url)
migrating particles or organisms. At speeds of 2 cm/s, the particles would descend 48 m in the 40 min sampling interval. Likewise, at 1 cm/s, particles would ascend 24 m in 40 min. Figs. 2 and 3 show that the \( w \) pulses span only two 40-min intervals. Therefore, in order to traverse 100–150 m as observed, the particles would need to move at larger \( w \) than the average 2 cm/s on descent and 1 cm/s on ascent.

Indeed, it was not surprising to note that the \( w \) velocities appeared larger upon examination of their distribution as a function of the hour of the day for each month, separately (Fig. 5). Average descent velocities for June, August, September and December were \( \sim 4 \) cm/s, while average ascent velocities were close to 3 cm/s. These are likely underestimates of the actual vertical velocities because of the 40 min sampling interval. In July, October and November, monthly \( w \) averages were smaller than in the other months. This may be the result of having fewer (or different types of) scatterers in the study area during

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Fig. 5. Vertical velocities \( w \) at 127 m from the ADCP transducers, for the entire deployment, as a function of the hour of the day. Each month is shown separately. Thick lines and shaded regions are the same as in Fig. 4.
those months. Another noteworthy feature is the time progression in the occurrence of the descent peak, from June to December, in agreement with the delay in sunrise, and also the advancement of the ascent peak in conjunction with earlier and earlier sunsets. Thus, the $w$ velocities portrayed in Figs. 2–5 strongly suggest that vertical motions observed over El Bajo Espíritu Santo are related to diurnal motions of the deep scattering layer and represent vertical migrations of zooplanktonic organisms. It is inferred that the migrations are carried out by zooplankton because the frequency of the ADCP (153 kHz) detects relatively large (1–4 cm long) organisms and because similarly long and fast vertical excursions have previously been documented for such organisms (Youngbluth, 1976; Lavaniegos, 1996; Robinson and Gomez-Gutiérrez, 1998; Pinot and Jansa, 2001). These suggestions are further supported by the logarithm of the intensity anomaly $I'$.

In the determination of $I'$, according to Eq. (1), the average interval has been taken as each month, separately. Therefore, we refer to anomalies relative to the monthly means. The monthly means of the log of the intensity (Fig. 6) indicated that there were less scatterers (or organisms) at the study site in June and July and that the monthly mean abundance changed little from August to December. The distributions of the anomalies for five full months of observation illustrated clearly the diurnal vertical excursions of the organisms (Fig. 7). Marked anomalies were appreciable as vertical streaks that appeared at the same times as $w$ peaks. These streaks occasionally were very thin because they portrayed rapid migrations. Other times, the streaks were well defined and joined to patches of high anomalies centered around midnight, like those around day 200 or 250 where the diurnal cycle was nicely illustrated. The thickness of the patches reached 60–70 m, in agreement to those observed by Robinson et al. (1995). The periods of highest anomalies, from the monthly mean profile, were related to energetic near-surface flows, not necessarily to monthly tidal or moon phase, as presented in the discussion.

The synchronization between $w$ peaks and large $I'$ can be confirmed in the distributions of $I'$ as a function of hour of the day for different depths in the water column (Fig. 8). This representation shows that peaks of $I'$, denoting increased organism concentrations, occurred at sunrise and sunset. In addition, at sufficiently large distances away from the transducers (e.g. >50 m), daytime $I'$ were lower than nighttime $I'$. In contrast, close to the transducers daytime $I'$ were larger than nighttime $I'$. These shifts of $I'$ from day to night reinforce the concept of vertical migrations of organisms consisting of daytime descents and nighttime ascents.

4. Discussion

Diurnal vertical migrations of organisms responding to day/night cycles have been documented in many other studies (e.g. Longhurst and Williams, 1979; Roe, 1984; Hays, 1995, 1996; Robinson and Gomez-Gutiérrez, 1998). The studies have shown that copepods and euphausiids are capable of carrying out migrations of hundreds of meters. Copepods and euphausiids are also the most likely to be detected by a 150-kHz ADCP (Rippeth and Simpson, 1998; Pinot and Jansa, 2001). Even though there was no frequent biological sampling in the El Bajo Espíritu...
Santo during the 6-month ADCP deployment, it is highly likely that the ADCP sampled euphausiids, copepods, pteropods and/or mesopelagic fish larvae (Aceves-Medina et al., submitted for publication). In fact, net sampling during the first few days of ADCP deployment in June of 1999 (González-Armas 2002; González-Armas et al., 2002) and in previous years has shown that the zooplankton communities in the area are dominated by juveniles and adults of euphausiids of transitional and equatorial affinity (Brinton et al., submitted).
al., 1986; De Silva Dávila and Palomares García, 2002). The species that are most likely found in the El Bajo Espíritu Santo during the second half of the year (June–December) are *Nyctiphanes simplex*, *Nematoscelis difficilis* and *Euphausia distinguenda*, the first one being the most abundant (Elorduy and Caraveo, 1994; Robinson et al., 1995; De Silva Dávila and Palomares García, 2002). Even though all the above aspects of the present study have been addressed to a certain extent in previous investigations, this is the first time that diurnal vertical migrations of zooplankton, as well as their migration speeds, are described with an ADCP in the Gulf of California. Most importantly, the unique and innovative aspect of this study is the documentation of an extended period, almost 6 months long, of vertical excursions of zooplankton at one point. In an attempt to explain the persistence of vertical excursions during such a long period, this study also discusses the probable circumstances that allow retention of zooplankton in El Bajo Espíritu Santo, a seamount that provides food and shelter to a great number of species in the Gulf of California.

The pulses of vertical motion illustrated in this investigation were observable throughout the 6 months of observation (Figs. 2 and 3). This is in contrast to events lasting a few days, as described in the Hebridean Shelf (Rippeth and Simpson, 1998) or the Bullmarsfjord (Liljebladh and Thomasson, 2001), where advection seemed to transport the zooplankton patch away from the measuring location. Even though the vertical motions in El Bajo Espíritu Santo appeared similar throughout the period, the anomalies of the sound scatter intensity $I'$ suggested that the zooplankton composition and concentrations fluctuated. Different zooplanktonic composition was conjectured from the extent of the excursions portrayed in Fig. 7. Some upward excursions reached near the surface (e.g. days 186–188, or 263–265, or 305–325), while others extended to ~ 150 m from the transducers (e.g. days 198–202, or 290–291, or 328–334), still some 100 m from the surface. Such variations in the extent of the excursions have been attributed to sun irradiance (or cloudiness) and moon phases (brightness of the moon) (e.g. Pinot and Jansa, 2001), which were not clearly influential in this data set (Fig. 7). However, the suggestion that variability in species composition was responsible for variations in excursion lengths observed here still requires field validation. Fluctuations in zooplankton concentrations were seen in monthly averages of $I'$ (Fig. 6), which indicated an increase from July to August and relatively small changes from June to July and from August to December. Shorter term fluctuations in zooplankton concentrations were also inferred from variations in $I'$ that were related to hydrodynamic agents.

The periods of most intense $I'$ were indeed related to energetic surface flows (Fig. 9). A total of nine episodes of large positive anomalies with different duration were identified and centered on days 200, 210, 219, 232, 247, 260, 271, 290 and 330 (see also Fig. 7). These episodes coincided with periods of subtidal (passed through a Lanczos filter with half-power of 40 h) surface currents that typically exceeded 10 cm/s. Most (six out of nine episodes) were associated with southeastward flow and seem to have produced a longer lasting effect than the northwestward episodes. The most energetic part of these pulses was concentrated near the surface, which leads to the speculation that during these nine episodes zooplankton patches were transported near the surface toward El Bajo Espíritu Santo. It is further hypothesized that once in the area of the seamount, organisms benefited by migrating vertically not only to find plentiful food toward surface waters at night and to avoid predation during the day, but also to avoid being advected away and increase their chances to stay in the area of the seamount where there was abundant food for them. In doing so, they in turn represent an ample food source to upper trophic levels in areas where their daytime descents were limited by shallow seabed (< 200 m). This easy availability (shallow, in daylight, and with prolonged residence times) of food to upper trophic levels could have caused zooplankton patchiness through daily gap formations over rugged bathymetry (Genin et al., 1988, 1994). The restricted vertical migrations by zooplankton over the seamount and consequent vulnerability to predators may help explain the congregation of large fish and mammals in this area.

The issue of longer residence time in the seamount area by zooplankton may be explored further through examination of passive particle and vertically migrating particle displacements at different depths as derived from progressive vector diagrams.
An easier visualization of various progressive vectors diagrams, corresponding to different depths, is achieved through representation of the separate displacement contributed by each of the two components, i.e., eastward and northward displacements of a passive particle. This allows identification of the most advective episodes during the observation period (Fig. 10). Periods of greatest $I'$ (shaded bars in Fig. 10a) corresponded to rapid displacements in the E–W direction, but only in near-surface regions. This correspondence reiterates the idea that zooplankton patches were advected near the surface to El Bajo Espíritu Santo. Displacements in both E–W and N–S directions were large near the surface but short near the bottom. Water temperature recorded at the ADCP transducer head (i.e., at a depth of 250 m) showed that few of the energetic episodes were also related to advection of different water properties even near the bottom.

Comparatively, water temperature from a nearby location at a depth of 30 m showed temperature changes corresponding to near-surface advective forcing. Therefore, migrations toward the bottom would generally minimize transport of organisms away from the seamount but migrations toward the surface would increase the chances for them to be swept away. Perhaps, this is why during most energetic events, maximum values of $I'$ are observed at 150 m from the transducers, rather than further up in the water column. The reduction of horizontal advection can be illustrated with the horizontal displacements of a vertically migrating particle.

The diurnal vertical migration pattern used to simulate horizontal displacements is a simplification of the observed behavior: a particle stays near the surface (20 m) at night; descends at dawn at speeds similar to those found in the ADCP record.
(4 cm/s), stays at depth (250 m) during daylight and ascends again at dusk. Progressive vector diagrams shown in Fig. 11 result from computing the horizontal displacements of such a vertically migrating particle, using observed horizontal currents from the ADCP record. Near-surface and bottom passive displacements are also included in these figures to provide additional information on the horizontal flow. Fig. 11 shows near-surface and near-bottom displacements for two periods: between days 274 and 278 and between days 335 and 339. These periods follow large $I'$ events in the last week of September and November, respectively (see also Fig 7). Large differences in horizontal displacements between near-surface and near-bottom locations arise from the vertical shear of the flow. Relatively strong surface currents produce the long displacement observed in the surface particle. In contrast, the horizontal path of a vertically migrating particle shows the tendency to remain close to its original position in a vertically sheared flow. Despite the strong surface flows the displacement is
significantly smaller, during the 5-day periods illustrated, than the one experienced by a particle remaining near the surface. These simple experiments illustrate two instances in which a particle migrating vertically can remain closer to its original position than one that remains at a fixed depth, in

Fig. 11. Five-day progressive vector diagrams of a surface (20 m) passive particle (dark gray line), a bottom (250 m) passive particle (light gray line) and a particle migrating vertically in a sheared flow (dark line). (a) Period from October 1 to 5 (days 274–278), and (b) from December 1 to 5 (days 335–339).
agreement with those of Rippeth and Simpson (1998).

The energetic surface flows during the period of study were likely caused by wind forcing. Even though there were no nearby wind velocity measurements available, this was inferred from the near-surface manifestation of the events and the frequent bidirectional character of the response with increasing depth. They could have also been caused by baroclinic cyclonic eddies that can be observed in the Gulf of California (Amador-Buenrostro et al., 2003). Distinct forcing was associated with the pulse around day 330, which was produced by a cyclonic gyre that covered most of the entrance to the Gulf of California as observed in sea surface temperature imagery. In this case, although the subtidal flows were most intense near the surface, the flows at depth were in the same direction as those at the surface. The irregular periodicity of the pulses indicated that fortnightly forcing by the tides had little influence on the flow modulation and on the anomalous zooplankton concentrations. Although the data presented here do not show that the seamount area is particularly different from its surroundings, the work of Amador-Buenrostro et al. (in press) suggests that the flow structure is greatly modified by it, and the study by González-Armas et al. (2002) show significant congregations of zooplankton over the seamount. The details on how the flow is modified and why zooplankton is aggregated in this area remain to be elucidated.

5. Conclusion

A 6-month deployment of a 153.6-kHz ADCP illustrated vertical diurnal migrations of zooplankton organisms over a seamount in the southwestern Gulf of California throughout nearly 6 months from June to December of 1999. The persistence of zooplankton migrations over such an extended period is a novel aspect of this study and is attributed to near-surface advective episodes that inject organisms into the seamount region. Diel vertical migrations carried out by these organisms reduce their chances of being swept away from the food-rich seamount area. In turn, their permanence and/or their seabed-limited vertical descents in the seamount region should constitute a sizable food source for the ecologically rich and diverse El Bajo Espíritu Santo.

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References


