

Underwater acoustic propagation experiments during ARMEX

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सार – आरमेक्स – I चरण के दौरान आई. एन. एस. सागरध्वनि और ओ. आर. वी. सागरकन्या नामक पोत पर 22–25 जुलाई के मध्य और 7–8 अगस्त 2002 को अरब सागर के गहरे समुद्र में दो पोत ध्वनि प्रसारण संबंधी प्रयोग किए गए। इस जाँच का उद्देश्य धरातलीय प्रणाली की सीमा में ध्वनि संबंधी तीव्रताओं के स्थानिक (30 कि. मी. तक) और कालिक (24 घंटे तक) उतार – चढ़ावों का पता लगाना था। एक पोत से 15 मीटर की गहराई से 2.4 किलोहर्ट्ज और 620 हर्ट्ज की आवृत्तियों के ध्वनि संबंधी प्रेषण लिए गए तथा दूसरे पोत से 15 मी. और 40 मी. की गहराईयों से सिगनल प्राप्त किए गए। इन आँकड़ों का रिकार्ड प्रत्येक प्रेषण के दौरान 10 मिनट की अवधि के लिए किया गया और ध्वनि संबंधी तीव्रताओं के आकलन के लिए 30 से. के औसत लिए गए। इस दौरान तापमान (सी. टी. डी. और एक्स. बी. टी.), धाराओं (ए. डी. सी. पी.) और तरंगों (एस. बी. डब्ल्यू. आर.) पर समकालिक समुद्र वैज्ञानिक आँकड़ें भी रिकार्ड किए गए। स्थिर और 50–60 मी. की समरूपी मिश्रित स्तर की गहराईयों धरातलीय प्रणाली प्रसारण के लिए एक सही पर्यावरणीय अवस्था को प्रस्तुत करता है। 1.5 से लेकर 2.3 मी. तक की उल्लेखनीय तरंग की उँचाई के साथ समुद्र की स्थिति सामान्य थी। जल स्तंभ के ऊपरी 125 मी. पर धरातल और उप धरातल धाराओं से 6 घंटे के अंतरालों पर धारा की दिशा के परिवर्तन सहित ज्वारों की पूर्वप्रभाविता का पता चला है। इस दौरान धारा की गति ~ 50 से.मी./सें. थी। ध्वनि संबंधी आँकड़ों के विश्लेषण से स्थानिक भिन्नताओं की तुलना में कालिक भिन्नताओं के महत्व का पता चला है। कालिक भिन्नताओं के लिए ध्वनि संबंधी तीव्रता में लगभग 20 डी. बी. के उतार चढ़ाव देखे गए जबकि स्थानिक भिन्नताओं के लिए मात्र 7 डी. बी. के उतार चढ़ाव देखे गए

ABSTRACT. Two-ship acoustic propagation experiments were conducted in deep waters of the Arabian Sea between 22-25 July and 7-8 August 2002 from onboard INS Sagardhwani and ORV Sagarkanya during ARMEX-I phase. The aim of this experiment was to understand the spatial (up to 30 km) and temporal (up to 24 hr) fluctuations of acoustic intensities within the surface duct. The acoustic transmissions were made from 15m depth at 2.4 KHz and 620 Hz frequencies from one ship and the signals were received at 15m and 40m depths on the second ship. The data were recorded for 10 min duration during each transmission and 30 sec averages were taken for computing acoustic intensities. Simultaneous oceanographic data on temperature (CTD and XBT), currents (ADCP) and waves (SBWR) were also recorded. Steady and homogeneous mixed layer depths of 50-60m offered an ideal environmental condition for surface duct propagation. The sea-state was moderate with significant wave height ranging from 1.5 to 2.3m. The surface and sub-surface currents in the upper 125m water column revealed the predominance of tides with change of current direction at 6 hr intervals. The current speeds were ~ 50 cm/s. The analysis of acoustic data highlighted the importance of temporal variations compared to spatial variations. Around 20 dB fluctuations in acoustic intensity were noticed for temporal variability where as only 7 dB fluctuation was observed for spatial variability.

Key words – ARMEX, Acoustic experiment, Surface duct, Acoustic intensities, Temporal, Spatial, Currents, Waves.

1. Introduction

The Indian monsoon experiments like the Bay of Bengal Monsoon Experiment (BOBMEX) and the Arabian Sea Monsoon Experiment (ARMEX) were conducted under a major umbrella of the science plan, which is known as the Indian Climate Research Programme (ICRP). The objectives and details of this programme can be seen in DST reports (1996, 2002).

BOBMEX pilot experiment was conducted during 23 October - 12 November, 1998 in the central and southern Bay of Bengal and the BOBMEX main experiment during 15 July - 31 August 1999 in the northern Bay. The ARMEX consists of Off Shore Trough Experiment (OST) and Warm Pool Experiment (WP) in the eastern Arabian Sea. The ARMEX-I (OST) was conducted during 20 June - 16 August 2002. The intensive field measurements were carried out during ARMEX-II between March and

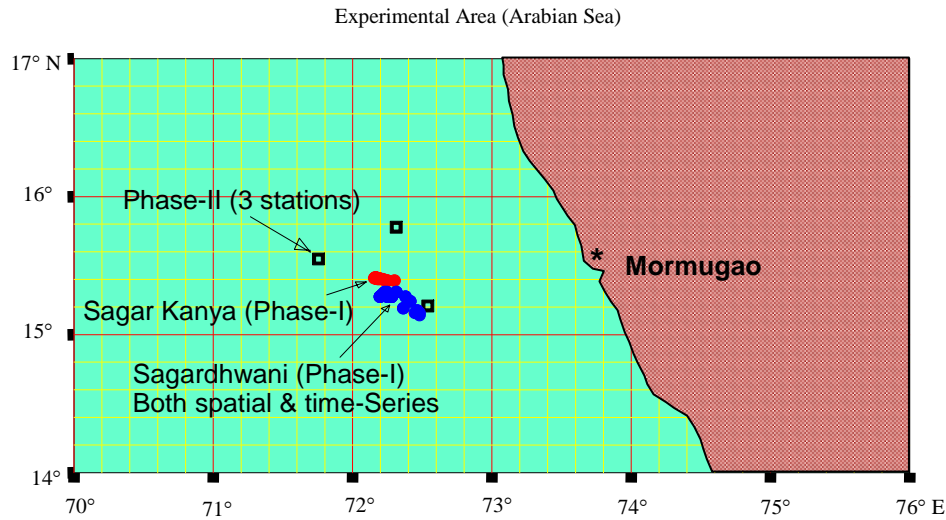


Fig. 1. Location of acoustic propagation experiments

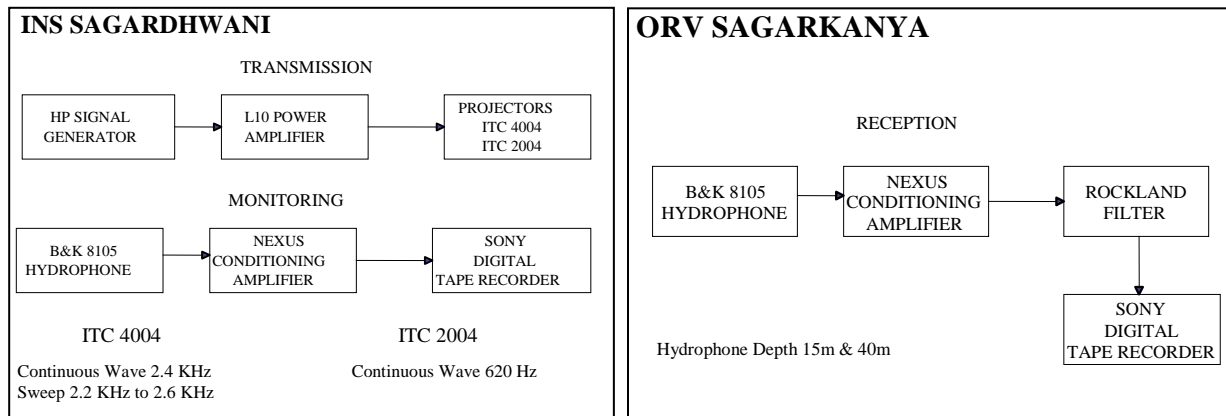


Fig. 2. Instrumentation used for acoustic Transmission and Reception

June 2003, primarily to capture the warm pool dynamics, its build up, maintenance and collapse with the onset of monsoon.

INS Sagardhwani, the research vessel of Defence Research and Development Organisation (DRDO) has taken active part during BOBMEX and ARMEX-I. This vessel is specially equipped to carryout underwater acoustics experiments along with oceanographic observations. However, for conducting underwater acoustic propagation experiments two vessels are required for transmission and reception of acoustic signals. During ARMEX-I, ORV Sagarkanya (SK) and INS Sagardhwani (SD) were positioned in the northern Arabian Sea which enabled us to conduct acoustic propagation experiments (Fig. 1) between 22-25 July 2002 (Phase-I) and 7-8 August 2002 (Phase-II). The aim of these experiments were to study the fluctuations of acoustic intensity levels

in the surface duct (50-60 m) with time (10 min to 24 hr) and with range (5-30 km) under southwest monsoon conditions. Results of the preliminary analysis of these data are presented in this paper.

2. Materials and methods

In order to carryout the acoustic experiment, Sagardhwani (SD) and Sagarkanya (SK) were used as transmitting-ship and a receiving-ship respectively. For transmission of sound in the sea one can use either underwater explosives (1 lb TNT scare charges) or an acoustic projector (transducer). The explosives are basically impulsive in nature but they serve as wide-band (frequency) acoustic sources. On the other hand, a fixed-frequency type of acoustic projector can offer continuous transmission of sound for certain duration at a given

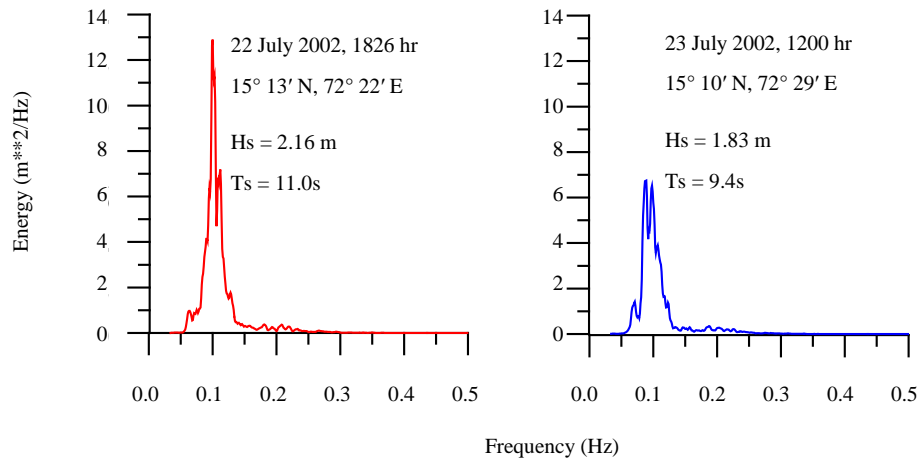


Fig. 3. Typical examples of observed surface wave spectra

frequency. Such projectors also have a sweep facility that enables a marginal variation of frequency around the central-frequency of transmission. For reception of sound, either an array of hydrophones lowered from a ship or deployed along with a bottom-moored acoustic buoy can be utilised. A buoy moored with hydrophones is the most ideal one for reception, but it is difficult to configure such an array for deepwater conditions. Hence, we have adopted the two-ship approach for our experiment. Instead of explosives, we lowered an acoustic projector for transmission of sound.

In this experiment, acoustic transmissions were made using two acoustic projectors of frequencies 2.4 KHz and 620 Hz from SD and these signals were received onboard SK. The transmissions were made by lowering the projector to depth of 15m while the acoustic signals were received by a vertical array comprising of two hydrophones attached at depth of 15m and 40m. These two hydrophones were situated well within the surface duct, one close to the surface and the other for bottom boundary of the duct propagation. Particulars of experimental set up used for conducting the above mentioned acoustic experiments from SD and SK are shown in the block diagram (Fig. 2).

Both temporal (over a tidal cycle) and spatial (up to 30 km) fluctuations of acoustic intensity were studied. The duration of each transmission/reception was restricted for 10 min. and transmitted/received signals were averaged for 30 sec duration to estimate the acoustic intensities. During spatial experiments (along range), SD remained stationary while SK opened out to different distances up to a maximum of 30 km. For the time-series experiment, both the research vessels were separated by 5 km in drift mode. Mention must be made here about the constraints and limitations of the experimental setup. As both ships

are adrift and subjected to oscillations due to the prevailing sea-state conditions some errors in the estimated range as well as depth of the sensors can be expected. To minimize these errors, corrections are applied for range estimation (due to ship-drift) by using GPS data recorded at 5 min intervals onboard both the ships during the experiment.

Apart from acoustic measurements, marine met, CTD (Conductivity Temperature Depth), ADCP (Acoustic Doppler Current Profiler) and SBWR (Ship Borne Wave Recorder) data were also obtained during these experiments.

3. Results and discussions

Underwater acoustic experiments can be conducted in shallow as well as deep waters. A well-known Shallow Water Internal Wave Acoustic Scattering Experiment (SWARM) was conducted in the Atlantic Ocean during summer of 1995 (Apel *et al.*, 1997) which highlights the importance of internal waves in the ocean for acoustic propagation. Similarly in the late summer of 1996 a joint acoustics and physical oceanography experiment was conducted in the Yellow Sea and the results on internal waves and their effects on sound transmission were reported by Yani *et al.* (1999). Hareesh Kumar *et al.* (2002) have also given acoustic intensity fluctuations due to internal waves in shallow water in the Arabian Sea and Andaman Sea. They reported internal waves of 15-20 m height from time-series high-resolution oceanographic measurements and the associated acoustic intensity fluctuations of more than 10 dB. It is interesting to note that many oceanographic features appear off the Indian coasts seasonally due to reversal of monsoon winds and currents. Sanilkumar *et al.* (2002) have studied the influence of such oceanographic features like mixed

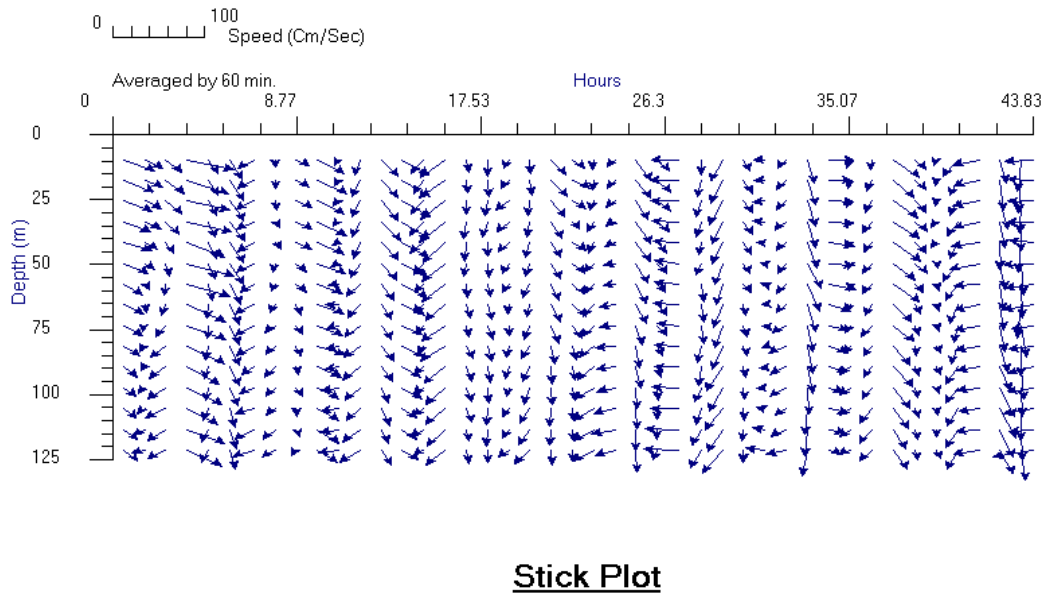


Fig. 4. Time-series of ocean currents observed using ADCP

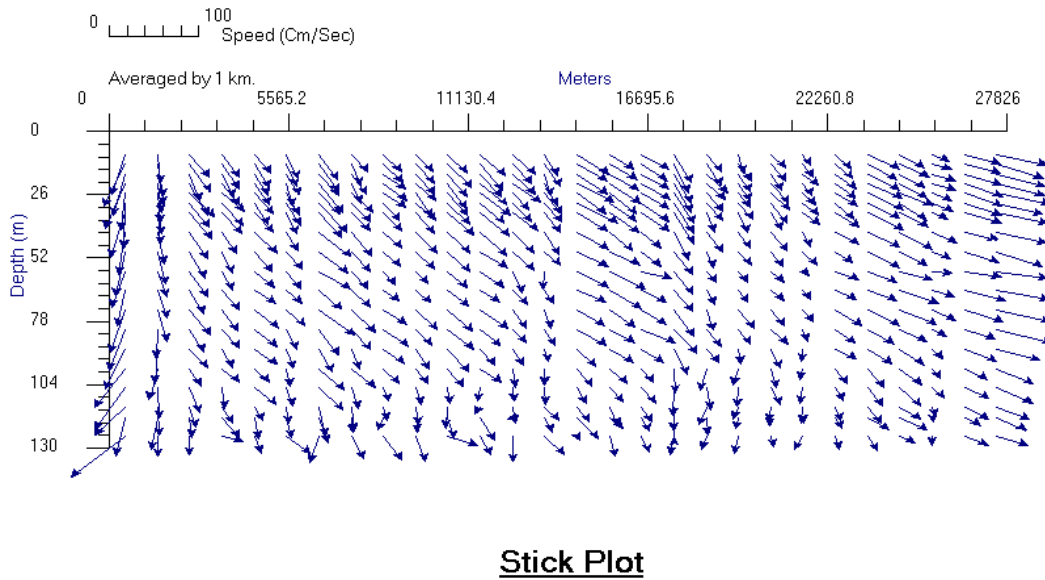


Fig. 5. Spatial variation of ocean currents observed using ADCP

layer, eddies, fronts and upwelling/sinking on the acoustic propagation using a parabolic equation (PE) acoustic propagation model. The purpose of these studies is to quantify the acoustic behaviour of the ocean by characterizing the oceanic environment.

When experiments are done in shallow water, the acoustic rays might get scattered or attenuated by the sea

surface and bottom due to limitation of water column depth. Thus it leads to multi-path propagation situations. In deep waters, longer ranges can be obtained and attenuation of sound due to sea bottom can be avoided. In this study, we carried out the experiments in deep water to estimate acoustic intensity fluctuations, both temporal (one tidal cycle *i.e.* 24 hr) and spatial (ranges up to 30 km) variations in surface duct (upper mixed layer)

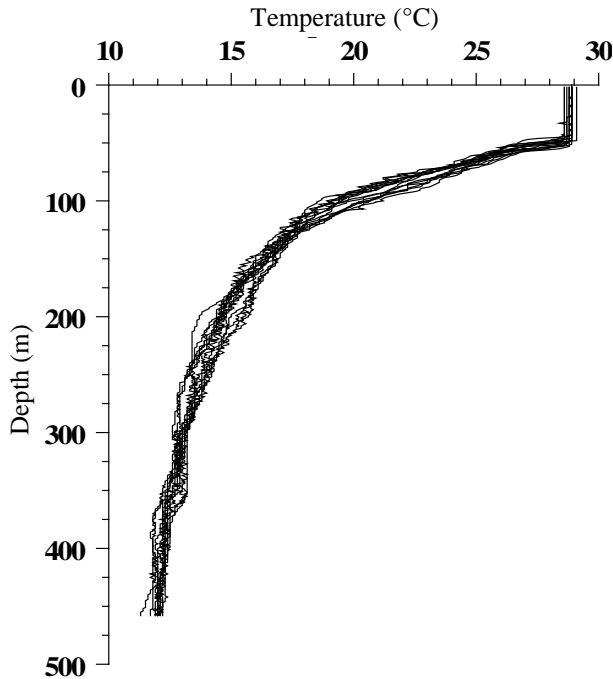


Fig. 6. Vertical profiles of observed ocean temperature

propagation. During the experiment period, westerly/southwesterly winds with an average speed of 8.5 m/s (ranging from 5.5 to 13.0 m/s) prevailed. The continuous time-series of wind data (2hr interval) obtained onboard SK shows that the wind speeds are mostly below 10m/s indicating weak (lull) monsoon period. Analysis of wave data (SBWR) revealed variation of significant wave heights (H_s) from 1.5 to 2.3 m and significant wave period (T_s) from 8 to 12 sec. The observed wave spectra (Fig. 3) were predominantly single peaked indicating a developed sea-state.

During the time-series acoustics experiment, the ship remained stationary/adrift for nearly 45 hr in the deep water. Depending on the drift, for every 2-hr the ship was moved to the original time-series position. The time-series of currents were measured using a hull mounted ADCP system at 5 min sampling interval. These data were averaged for 60 min and current vectors are presented in Fig. 4 for the upper 125 m water column. The sub-surface currents were generally weaker and the maximum current speed was ~ 30 -50 cm/s. It is also observed that the direction of current changed from southeasterly to southwesterly alternatively at intervals of ~ 6 hrs. These changes in current direction appear to have occurred due to tidal influence and thus interesting to see the effect of tides on currents in deep water also.

Similarly the spatial variation of currents along the track of the range experiment (about 30 km distance) was

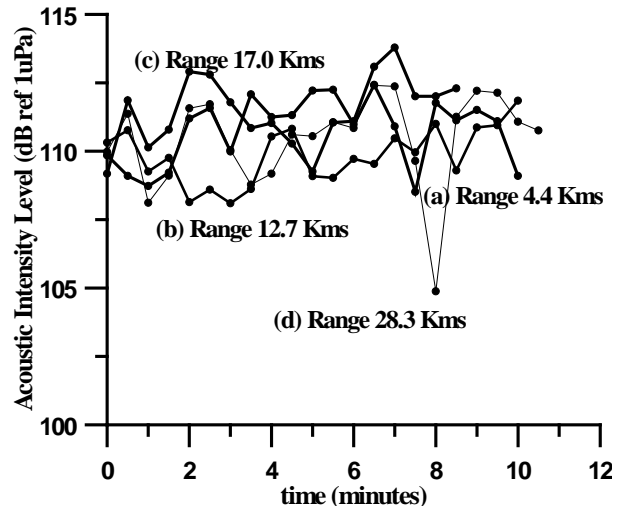


Fig. 7. Spatial acoustic intensity variations

also recorded. The current vectors were averaged for every 1 km and shown in Fig. 5. The currents were mostly with speeds of 50 cm/s and above. On a closer examination, it can be seen that the observational period falls within the transitional phase of tide. Therefore, initially the currents were mostly southwesterly with speeds less than 30 cm/s. At a distance of 1 km, the direction changed to southerly with a marked reduction in the speed and became southeasterly afterwards (*i.e.*, after ~ 3 km away). The change of direction in association with tide, which could be seen from the time series data also. This suggests that the tides are very important even in the deep waters.

The vertical profiles of temperature (Fig. 6) revealed a homogeneous upper layer of 50-60 m throughout the observation period. Apparently the diurnal fluctuations of mixed layer were minimal due to monsoon wind and wave mixing. The estimated vertical sound speed profiles normally follow the observed vertical temperature structure (especially in deep ocean) and hence they are not shown here. Thus the sonic layer depth (SLD) remained more or less steady around 50-60 m. The deep and steady SLD enabled effective surface duct propagation during the both time-series and spatial acoustics experiments.

The observed temporal and spatial acoustic intensity fluctuations can be attributed to scattering and attenuation of sound from the sea surface and the environmental inhomogeneities like currents and micro scale turbulence prevailing in the upper mixed layer. Since internal waves occur in the thermocline region *i.e.*, below the mixed layer, the effect of these waves are negligible for surface duct propagation. The acoustic intensity values (30 sec averages) along range are shown in Fig. 7. The overall

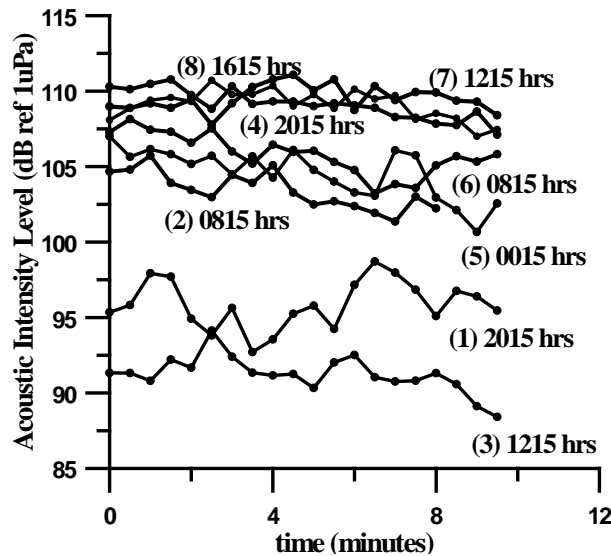


Fig. 8. Temporal acoustic intensity variations

variation for different ranges (up to 30 km) is only 5-7 dB. It is also seen that the received acoustic intensities in some cases increased when range increased. Interestingly, time-series of acoustic intensity fluctuations (Fig. 8) were of the order of 20 dB for different times of the day. By viewing the spatial and temporal fluctuations together one can infer that the increase in acoustic intensity with the increase of range could be due to the domination of temporal variation over the spatial variation. Hence this is an important conclusion that, the acoustic intensity fluctuations with time (temporal) are more predominant than the changes observed with range (spatial). Further studies are planned to correlate fluctuations of acoustic intensities with surface waves and vertical current structures observed during the experiment.

4. Conclusions

Results of a two-ship acoustic propagation experiment conducted in deep waters (>200m) during ARMEX-I are presented. The objective of these studies is to understand the temporal (up to 24hr) and spatial (up to 30 km) fluctuations of acoustic intensities for surface duct propagation. The important findings are: (i) The mixed layer depths were 50-60 m and remained steady due to monsoon mixing. It provided an ideal situation for surface duct propagation. (ii) The monsoon winds were relatively weak (mostly <10 m/s) and moderate sea-state (H_s : 1.5-2.3 m) conditions prevailed. (iii) The spatial as well as temporal variations of sub-surface (up to 125 m) currents were 30-50 cm/s. The reversal of current direction at 6 hr

intervals was also observed due to the influence of tides. (iv) The spatial variability of acoustic intensities was 5-7 dB where as the temporal variations were about 20 dB. (v) The study brings out the significance of temporal variability of acoustic intensities in the surface duct due to environmental variations. The variations of acoustic intensities need to be studied further by correlating with waves and currents.

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