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Autonomous-hydrophone arrays: a powerful tool for long-term monitoring of geological processes, biological activity and iceberg tremors over large and remote areas of the ocean

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Following the initiative of the Acoustic Monitoring Project of the VENTS Program at PMEL/NOAA, the Domaines Océaniques Laboratory (LDO) has conducted a series of experiments using arrays of autonomous hydrophones, in the Atlantic and Indian oceans. We hold about 5.5 years of sound recordings for continuous periods ranging from 14 months to 3 years. With the objective to monitor the low-magnitude seismic background activity along active spreading ridges, our arrays were deployed on ridge flanks, covering areas ranging from 600x600km to 1500x1500km. Due to the efficiency of sound propagation in the oceans, hydroacoustic data can provide for significant improvements in the location and detection capability afforded by land-based seismic stations, improving the completeness level of detection by 1.5-2.0 orders of magnitude for the remote areas of the ridge crest. On average, an hydrophone array (3 to 6 receivers) detects and localizes 30 to 50 times more earthquakes (M > 2.5) than global networks of land-based stations do for the same period of time. Our catalog, from the five experiments conducted by LDO since 2002, includes more than 22000 events.

The spatial and temporal distributions of earthquakes derived from these catalogs can be fruitfully used to characterize, at various spatial scales, processes occurring along spreading ridges. Overall, events seem evenly distributed between FZs and ridge segments for slow spreading ridges (1.6-4.5 cm/yr) and concentrate on FZ transforms for faster spreading ridge (6-7 cm/yr). Within clusters, acoustic source level (SL) vs. time distribution can discriminate sequences occurring in a tectonic context from those related to volcanic processes. In some instances, swarms could be associated with bathymetric features along the ridge axes (within the 2-3 km uncertainties in the location of acoustic events inside the array). Spatial distribution of these low-magnitude events also provide insights on the thermal state of the lithosphere, for instance on the dissymmetrical effect of the Azores plume on the MAR. In the Indian Ocean, where our array encompasses three spreading ridges with contrasted rates, the immediate vicinity of the triple junction where they meet shows periods of quiescence and of intense activity. Some large earthquakes (M>5) near the triple junction (SEIR and CIR) seem to be preceded by several small acoustic events that may be precursors. Off-ridge seismicity is also detected in the southern part of the Central Indian Basin as a result of intraplate deformation.

In addition to seismicity, many other sounds are detected. In the Indian Ocean, a 6-week long series of broadband (1-125 Hz) explosive signals was recorded at a receiver between the Kerguelen and Amsterdam islands. Also, many cryogenic tremors are easily recognizable from their varying tones and harmonics. In combination with data from the CTBTO permanent hydroacoustic station in Cape Leeuwin, we located more than 4000 icequakes, most of which along the Antarctic margin. Acoustic monitoring may thus provide insights on the effects of global change on the Antarctic ice discharge in the Southern Ocean. Finally all our instruments detected numerous whale calls attributed to four different whale species, for which little information is known about their presence, abundance, and migration pattern. Their vocal activity is found to be highly seasonal, occurring mainly from April to October with subspecies and latitudinal variations.

Thus, hydrophone arrays prove a very powerful tool for monitoring geological, biological and other activities in the ocean at a scale appropriate to its immensity. In remote areas, they provide, so far, the only long-time series on seafloor spreading processes at a ridge scale. For these reasons, LDO has invested in the development of autonomous hydrophones with adjustable sampling rates and long autonomy (18m), and is currently maintaining two arrays in the MOMAR area, south of the Azores, and in the Southern Indian Ocean. Underway developments for a longer autonomy and simpler data recovery may broaden the user community.