

# Deep echoes: an interdisciplinary approach to investigate the oceans

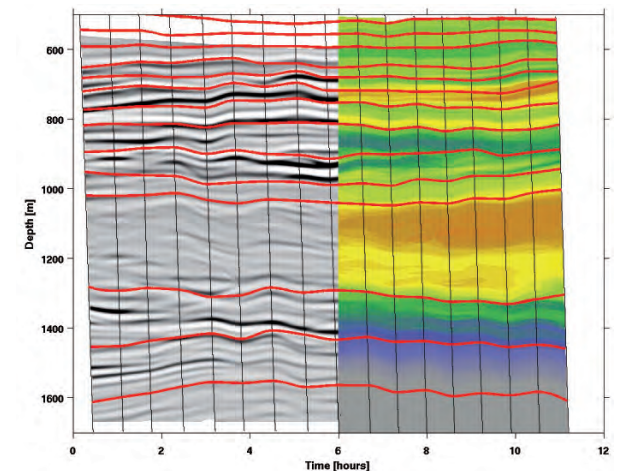
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*Seismic oceanography is a new field in marine research combining expertise of proven geophysical methods with classical physical oceanography to get more insight into physical processes in the water column. An interdisciplinary working group at IFM-GEOMAR has successfully used the in-house expertise for deep ocean investigations.*

**P**hysical Oceanography (PO) and Reflection Seismics are two fields that until recently had little to share. Although using the same platform, a research vessel, marine seismologists would gladly empty the world's oceans to gain direct access to their primary target, the interior of the earth, while oceanographers had no use for information below the ocean sea floor. This strong separation was shattered when in 2003 Holbrook et al. described structures within the water column seen by seismic methods. Why were oceanographers so interested in these observations? It was because of the extremely different horizontal resolutions typically sampled by the two communities. PO data is collected from research vessels at discrete locations distanced 10 km or more, while seismic multi-channel-streamer (MCS) data provides information at horizontal scales down to 5 m; four orders of magnitude better. Since Holbrook et al.'s publication the race has thus been on to extract meaningful PO information from MCS data. IFM-GEOMAR's interdisciplinary research group on Seismic Oceanography (SO) participated in the EU-project GO (Geophysical Oceanography) that had the evaluation and development of SO as its goals.

With the Gulf of Cadiz GO picked one of the world ocean's most promising spots to study the possibilities of SO. The outflow of the Mediterranean into the Atlantic Ocean creates a distinct regime in which the different water masses mix through interleaving and create a wealth of layers that can be imaged in seismic data. Additional funding from the DFG allowed in spring 2007 for the first time the use of two research vessels (RRS Discovery and FS Poseidon) to simultaneously collect PO and MCS data. The fruits of the combined measurements are now being collected.

PO yoyo measurements in which a CTD was lowered and raised repeatedly from FS Poseidon (see Figure 1) were converted into information comparable to that collected by the MCS system. The close similarity proved that MCS is indeed imaging oceanic structures. Further analyses of the CTD data showed that the depth variations of seismically reflecting layers closely follow the excursions of isopycnals (Krahmann et al., 2009), a finding that underpinned the calculation of internal wave spectra from MCS reflection sections (Krahmann et al., 2008).



*Figure 1: Reflectivity (grey) and temperature (color) of parts of the water column (colorscale is similar to Figure 2) derived from a Yoyo CTD in the Gulf of Cadiz. Also shown are isopycnals (red lines) for the same data. Depth variations of reflectivity and isopycnals go largely hand in hand and allow the use of reflectivities observed with seismic methods as a proxy for isopycnal depth variations.*

A major step forward for SO was the combination of MCS and lower accuracy PO data collected with expendable temperature probes (XBT). These two can be collected at the same time from a single ship. The key to the combination lies in the different parts of the variability spectra sampled by the two systems. MCS data is, depending on the configuration of the seismic sound source, restricted to vertical wavelengths between

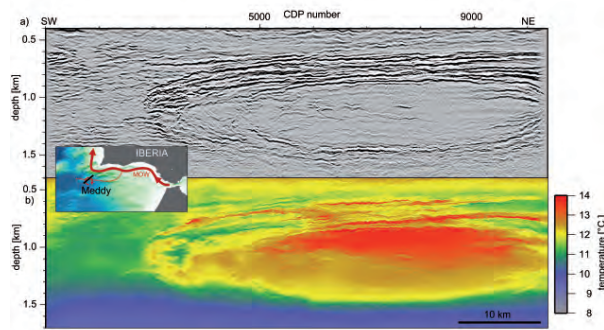


Figure 2: Seismic reflection image (a) and corresponding temperature field (b) derived from seismic-oceanographic data. The seismic section cuts a warm saline Meddy, detached from the main vein of Mediterranean Outflow Water and generating a clear acoustic contrast against the cold Atlantic Water. The data from Figure 1 compares to about CDP 4000.

about 10 and 200 m. It does, however, collect this data at a very high horizontal resolution. XBTs in contrast sample the ocean at a much lower horizontal resolution but collect temperature measurements every 2 m in the vertical with no limit at the long wavelength end of the spectrum. Using the horizontally coarse resolution XBT data to estimate the long wavelength part of the ocean temperature field and combining this with the horizontally high resolution but bandwidth limited MCS data, we arrived at a combined data set with high resolution in both the horizontal and vertical domain (Papenberg et al., 2010). The resulting images of the ocean's temperatures are truly stunning (see Figure 2). In particular intrusive features that occur when two water masses of different thermohaline properties but similar density mix, can with

this new type of data be closely followed over long horizontal distances. The details seen in these images might allow us to answer such open questions as what the horizontal aspect ratios of intrusions are or how intrusions radiating away from an eddy are wrapped by its rotation. Further analyses showed that the MCS data was even able to provide information on the dynamics (flow direction) of oceanic water layers (Klaeschen et al., 2009).

Seismic oceanography has made big steps over the past years and already yielded many valuable insights into e.g. the spatial patterns of oceanic fine structure. Some of the challenges even lead to new and unexpected results like e.g. the dynamic movement information that can now be extracted from seismic data. Further opportunities arise from the combination of SO data with that from other recent measurement tools such as microstructure probes and autonomous gliders. In spring 2010 we will conduct such a combined experiment in the Tyrrhenian Sea. We expect that the resulting data will lead to a more quantitative connection between seismic and ocean mixing data.

## References

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