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# Fluid mud monitoring using optical fibers combined with DAS and DTS

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**Introduction:** Multi-beam echosounders have been routinely used to evaluate the bathymetry in navigational channels. These measurements, however, fail to capture the dynamic changes of the bathymetry caused by storm events or dredging activities. Thus, new continuous methods are required for monitoring dynamic bathymetry changes. We show that with Distributed Acoustic Sensing (DAS) [1] can use fiber optics (FO) as receivers for detecting the water/mud (w/m) interface up to centimeters accuracy. We also show how the same fiber can be used to also measure temperature and derive the w/m interface with active heating elements, by measuring a change in Brillion Frequency [2] using Distributed Temperature (Strain) Sensing, DT(S)S.

**Methods:** We use a standard communication fiber, with the iDAS system from Silixa, to capture seismic waveforms and a DITEST STA-R from Omnisens to measure temperature. We coil the fiber around a PVC pipe, covering 0.7 m in length of the pipe, which we mounted in a transparent column. This allows us to visually track the w/m interface. We use a signal generator in combination with an amplifier, a dual-frequency echosounder and a transducer for our DAS experiments. For our DTS experiments, we used two standard heating rods with a length equal to the whole column length, to ensure equal heat distribution. A schematic sketch of our setup is shown in Figure 1. For DAS, we record for 0.1 s, during which we send 10 burst with frequencies from 25 kHz up to 45 kHz. We stack 10 times, to suppress random noise and improve the signal-to-noise ratio.

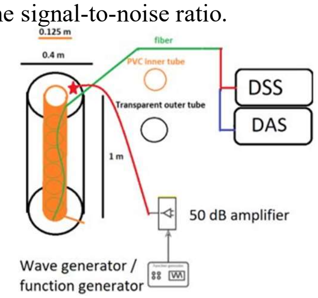


**Figure 1:** Schematic laboratory setup

**Results:** In the stacked result in Figure 2, obtained using a 38 kHz source with a mud sample that has settled for 9 days, we see reflected waves from the w/m interface. Furthermore, we can observe that due to the high attenuation in mud, the multiples exhibit gradual loss of amplitude. Using the multiples, we can estimate the w/m interface up to 1.2 cm accurate.

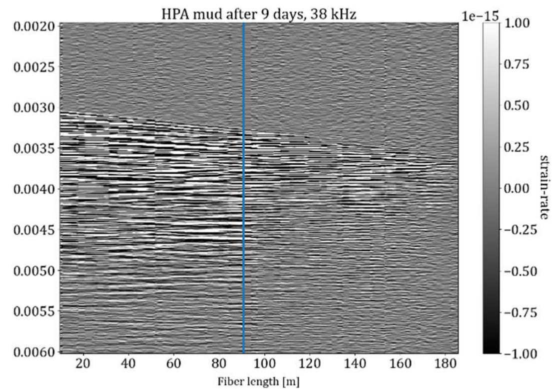


**Figure 2:** Reflections and attenuation can be observed before and after the blue line, respectively, which indicates the w/m boundary. By using the multiples, we can estimate the w/m interface down to 1.2 cm accuracy in depth.

In addition to using acoustic waves, we also use DTS to estimate the w/m boundary. Figure 3 shows a linear increase in the Brillion frequency in water, and a non-linear response in the mud, due to the difference in heat-capacity and conductivity between the fluids.

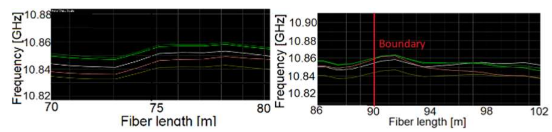


**Figure 3:** Brillion-frequency change along the fiber.

We estimate that one can derive the w/m boundary up to 4 cm accurate with this method. However, the accuracy will mainly depend on the difference in temperature between water and mud. Nevertheless, it still is more accurate than, for instance, multibeam echo-sounder, which could easily have a 15 cm inaccuracy.

**Discussion:** We show how the w/m interface can be estimated using FO in a non-intrusive manner. Our DAS results are more accurate and less ambiguous than the DTS results. With DAS, there are strong indications that transverse waves and a difference in attenuation can be captured and monitored, which in turn can be related to rheological properties (e.g., the yield stress) of fluid mud and used for nautical bottom applications [3].

**References:** [1] Lindsey, N. J., Rademacher, H., & Ajo-Franklin, J. B. (2020). On the broadband instrument response of fiber-optic DAS arrays. *Journal of Geophysical Research: Solid Earth*, *125*(2).
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# Monitoring fluid mud using optical fibres

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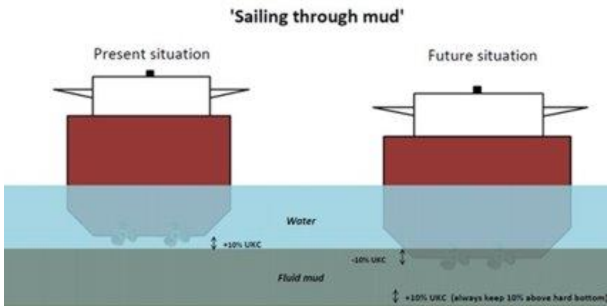


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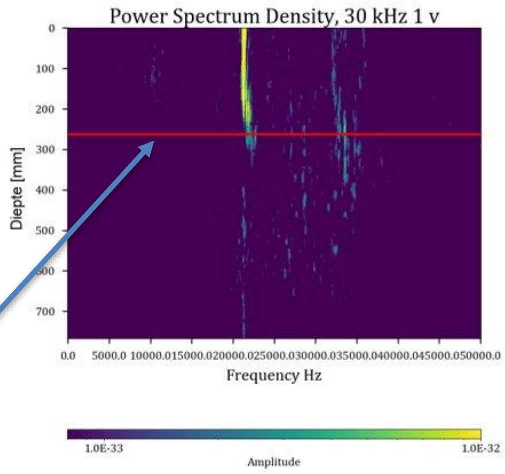
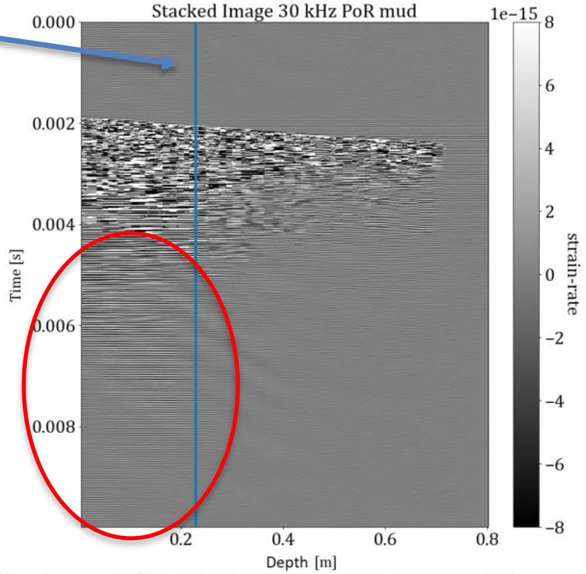
# We have the most accurate non-intrusive measuring system due to the sound conducting properties in water, and the sound insolating properties of mud

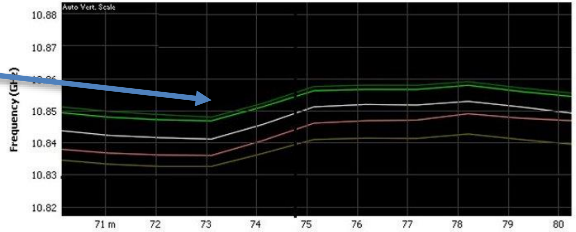
Water mud interface



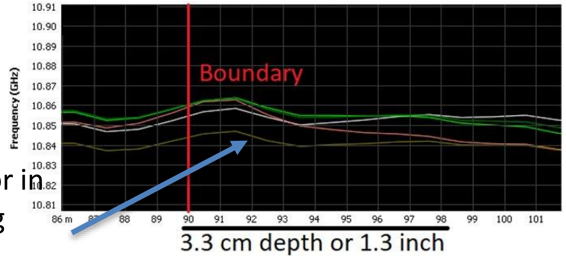




Water mud interface

**Linear** behavior in water during heating




**Non-linear** behavior in mud during heating

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