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Application Note
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Knocked over by a sediment avalanche:
monitoring of earthquake-triggered turbidity currents in the Marmara Sea

Earthquake-triggered turbidity currents can generate tsunamis, as well as damage underwater infrastructure like submarine cables and pipelines. Such earthquake-triggered currents were recorded by a SeaGuard instrument mounted on a bottom lander that was deployed in the Marmara Sea off Istanbul, Turkey.

"SeaGuard measured currents and high loads of suspended sediments at 68 deg tilt"

Earthquakes are common in this seismically-active area, but the effects of them on the marine environment have seldom been recorded. In a French-Turkish research project, a bottom lander (Figure 1) was deployed at about 1200 m depth on the deep, flat seabed. A SeaGuard multiparameter instrument was attached to the lander, recording the down-slope effects of two consecutive earthquakes with moment magnitudes of 4.7 and 5.8 Mw.

Bottom currents in the area were slow in general, below 3 cm/s. The smaller seismic event caused a minor sediment resuspension but no strong currents. The larger event triggered a complex response involving an important mud flow and high currents with variable velocities and direction.

The mud flow knocked over the lander about 20 minutes after the earhquake and left it tilted for about 10 hours. Even at this unplanned tilt of 68 degrees the SeaGuard instrument on the frame was able to measure peak speed and direction of the arriving sediment clouds and the prevailing currents. In addition, acoustic backscatter delivered relative information about the particle concentrations (Figure 2).

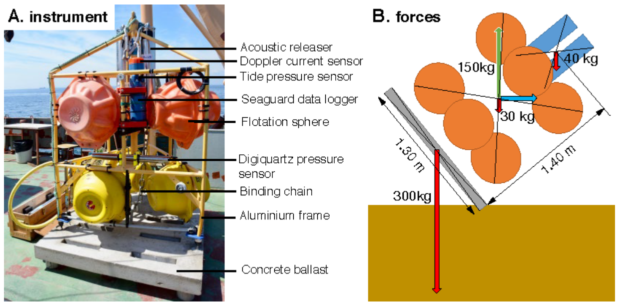

Figure 1. (A) photo of the instrumented frame before deployment. (B) Sketch showing forces applied to the lander after it was tilted over by a turbidity avalanche (figure from Henry et al 2022).

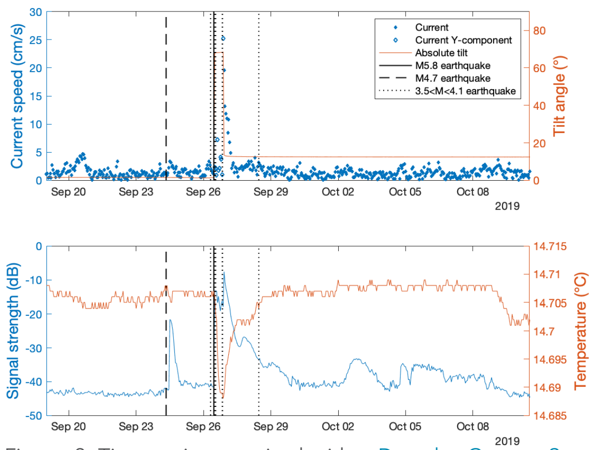

Figure 2. Time series acquired with a Doppler Current Sensor (DCS) on a SeaGuard during the September 2019 seismicity cluster; (top) current speed and tilt; (bottom) backscatter signal strength and temperature (figure from Henry et al 2022).

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The SeaGuard was also equipped with a Tide sensor that measured and averaged pressure over 300 seconds at the end of each one-hour time interval. This sensor is capable of measuring millimetre movements of the seafloor, it is rugged, has low drift and is not sensitive to vibrations nor how it is oriented. This sensor and a quartz-based pressure sensor simultaneously registered when the lander was hit by the turbidity current and when it rose up again. The drift of the tide sensor was checked against an atmospheric reference on-board the research ship before and after the deployment and was found to be less than 1 hPa (1 mbar).

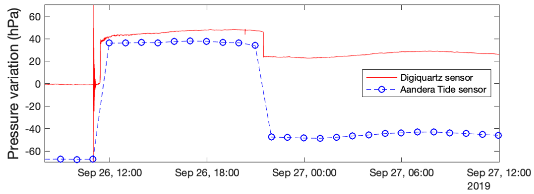

Figure 3: Pressure variations recorded by two instruments around the time of occurrence of a Mw 5.8 earthquake (figure from Henry et al 2022).

"Tide sensor runs correctly regardless of orientation; drift was less than 1 hPa over 7 months"

A series of trials were carried out after the deployment to verify the ability of the internal tilt sensor and the compass in the DCS to handle the levels of tilt that the instrument was subjected to in this deployment. The instrument was mounted to a cable drum and was rotated in different directions (figure 4). The conclusions were that tilt measurements are accurate within 3° up to 60° but saturate at about 80°. Uncertainty on heading increases with tilt but measured heading remains ±20° of true heading for a tilting of up to 60°. The compass and tilt sensors in this DCS were not calibrated for upside down operations which explains the decrease in accuracy with increasing tilt.

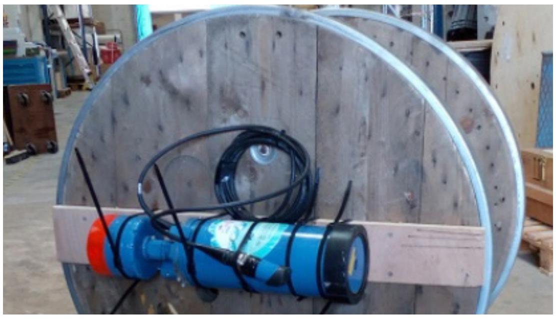
Figure 4: Set up for verifying functioning of inbuilt tilt sensor and compass at high tilt (figure from Henry et al 2022, additional material)

At Aanderaa all sensors that include tilt and compass components go through a thorough automatic calibration procedures by an Aluminum robot called CoTiCa that is placed in a sheltered room with minimal magnetic disturbances (figure 5). The doppler current profiling (DCPS) and accelerometer-based directional wave sensors (MOTUS) are calibrated for all tilts. This extended tilt calibration is also available for the DCS sensor upon request.


Figure 5: CoTiCa automatic tilt and compass calibration robot inside low magnetic room.

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