

Measuring detailed vertical density profiles in cohesive sediment layers

- A comparison of techniques -

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Introduction

Between 2013 and 2018 several hydrological and morphological changes have been observed in the Tidal Elbe, particularly an unusually high increase in tidal range, turbidity and sedimentation rates. [1]

The joint project ELMOD is conducted to improve the ability of numerical models to represent the complex underlying processes and deepen the understanding of estuarine sediment transport in general. Two **goals** of the first ship-based measurement campaign in June 2023 in the Port of Hamburg were **i)** to utilize and compare different techniques to capture detailed and continuous vertical density/SSC profiles and **ii)** to examine the representation of the natural density profile by the extracted sediment cores.

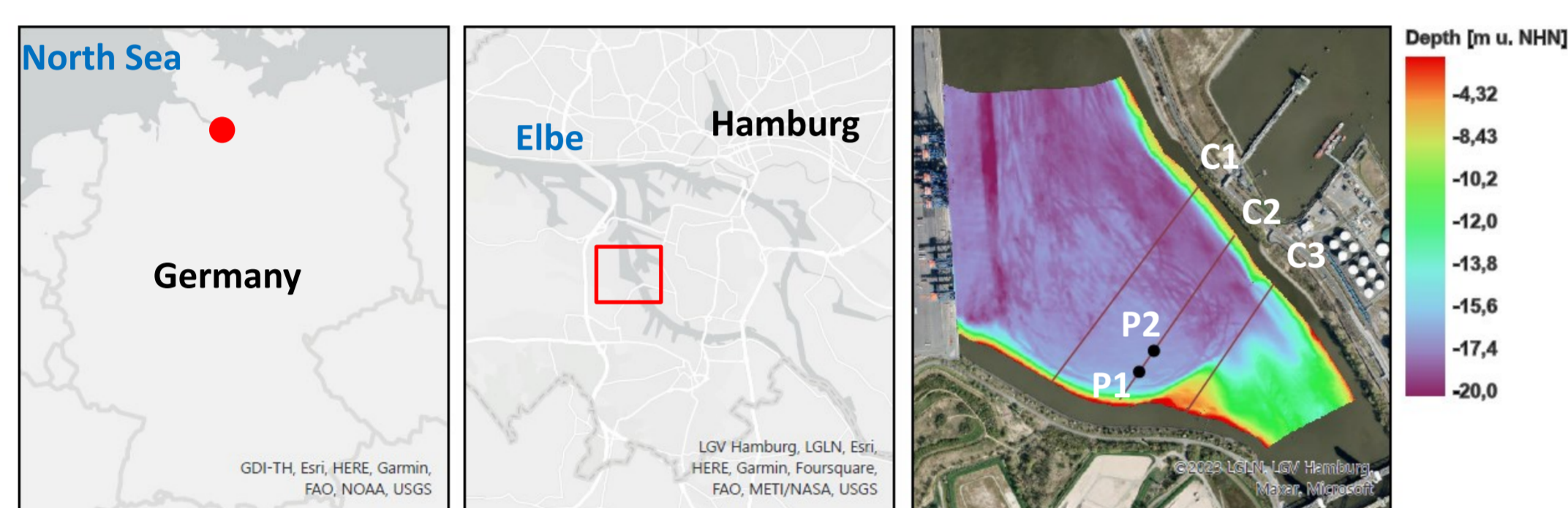


Figure 1: Location of first measurement campaign in the Port of Hamburg. Bed elevation data collected three days before campaign.

Methodology

The measurements were carried out around flood slack water. Two ships were employed for the campaign. Ship 1 recorded the cross sections C1-C3 (see Fig.1) with ADCP and sediment echo sounder at three points of time, collected sediment cores from position P1 and P2 and measured density profiles with a Rheotune. Ship 2 stayed in the vicinity of Ship 1 (distance ~30 m) and was equipped with a Solitax suspended matter probe, Admodus density probe and a peristaltic pump.

Table 1: Utilized techniques for the collection of density/SSC-profiles

Ship 1	
Sediment echosounder	<ul style="list-style-type: none"> - Stema EBPI0 System [2] - Transducer: Teledyne OTSSB200/24KHz [3] - Calibrated by Rheotune measurements
Subsamples of sediment core	<ul style="list-style-type: none"> - Coring device developed at TUHH [4] - Sediment core (1,2m x 0,2m) divided into layers of ~ 4cm thickness - Density of subsamples measured with Anton Paar DMA 35 and suspension balance
Stema Systems Rheotune	<ul style="list-style-type: none"> - Working on tuning fork principle - Output rate: 20 Hz - Accuracy: <1% of density (Newtonian Fluid) [5] - Additional output of Bingham yield stress and viscosity
Ship 2	
Admodus USP pro	<ul style="list-style-type: none"> - Working on ultrasonic principle - Output rate: 50 Hz - Accuracy: $\pm 0.005 \text{ g/cm}^3$ [6]
Hach Solitax sc	<ul style="list-style-type: none"> - Turbidity/SSC probe - Working on combined infrared absorption scattered light technique [7] - Output rate 0.2 Hz - Probe was held in Position for ~90 seconds in depth-intervals of 1-2.5 m - Average SSC-values for depth-intervals of 0.1 m have been calculated
Peristaltic pump	<ul style="list-style-type: none"> - SSC of water samples derived via vacuum filtration - Samples taken in depth-intervals of 1-2.5 m

Results

Figure 2 shows the center cross-section C2 recorded by the sediment echosounder and gives a general spatial impression of the encountered conditions. In the sample area the density of the bed increases to $\sim 1200 \text{ kg/m}^3$ over the top layer of $\sim 40\text{cm}$. The results of all employed techniques are shown in Figure 3 for the sample site P2. The SSC-values derived by Solitax and peristaltic pump (and vacuum filtration) have been converted to densities therefore.

The measured SSC-values for the latter techniques are shown in Figure 4 over the whole water column.

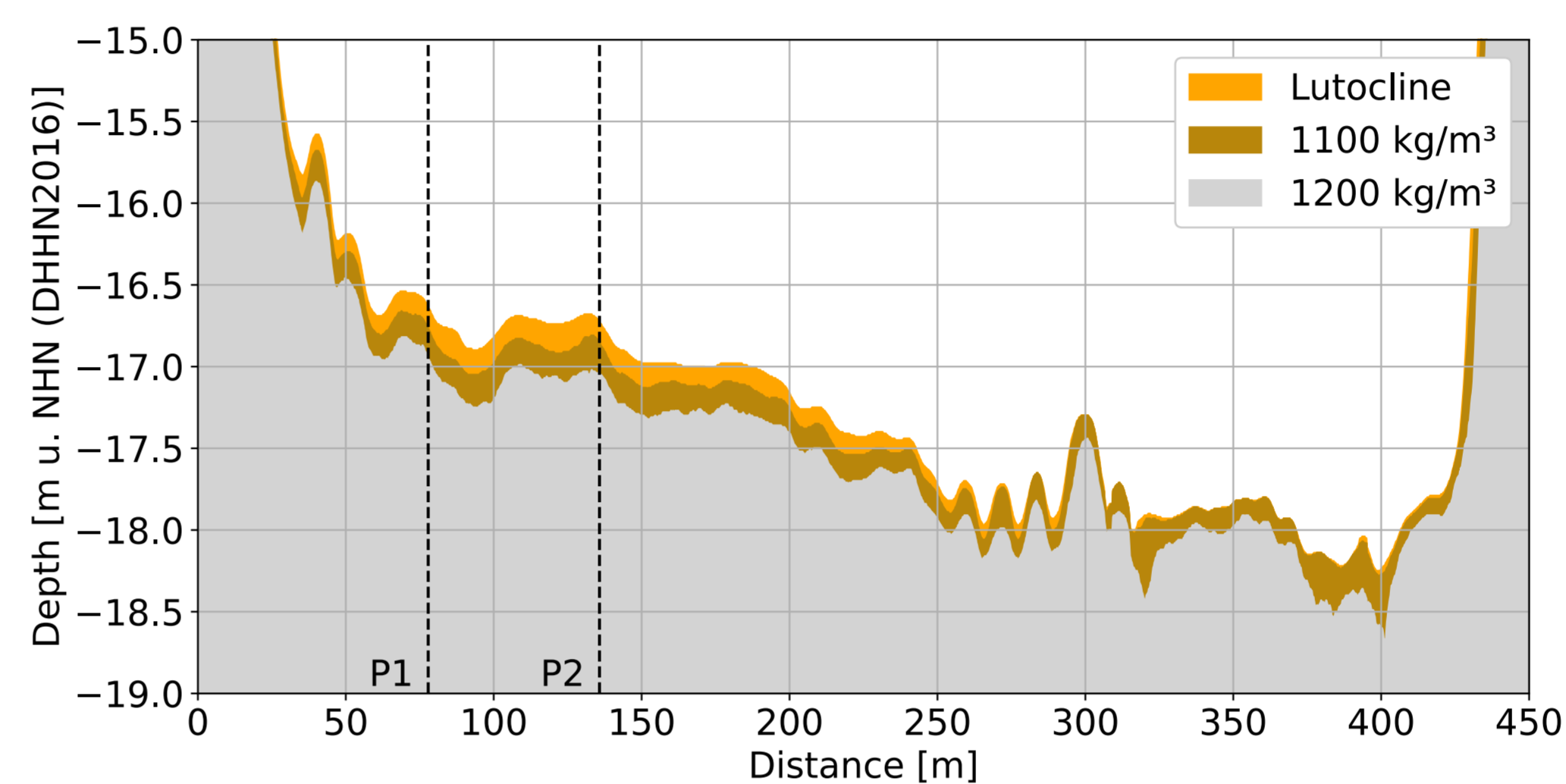


Figure 2: Density horizons of Cross-section C2 recorded by sediment echosounder. Sample sites P1 and P2 are marked. (Stacked lines plot)

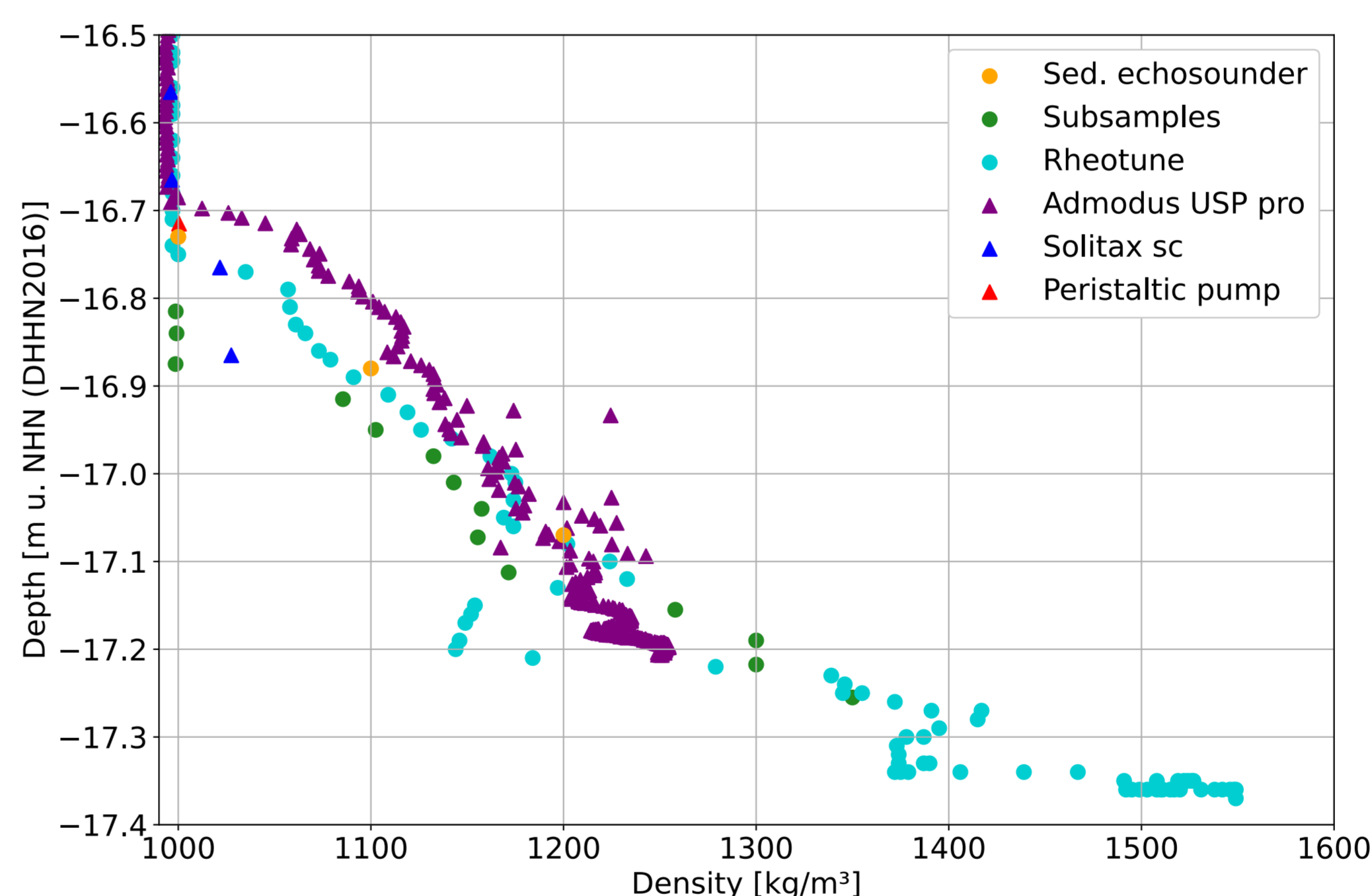


Figure 3: Comparison of the results of utilized methods for sample site P2 (Circle: Measured from Ship 1; Triangle Ship 2)

Discussion

The utilized devices and techniques deliver very consistent results. The bed-density profiles (Fig.3) and especially their gradient are in good agreement for the subsamples, Admodus, Rheotune (and sediment echosounder), which shows that the extracted sediment cores reflect the natural density profiles to a high degree. The slightly different elevations of the associated densities are seen to be due to small changes in Ship positions.

Solitax and peristaltic pump deliver comparable SSC-values in the water column (Fig.4). In the relatively thin bottom layer with rapidly rising sediment concentrations both techniques reach their limits. A further test in conditions with larger layers of fluid mud is desirable.

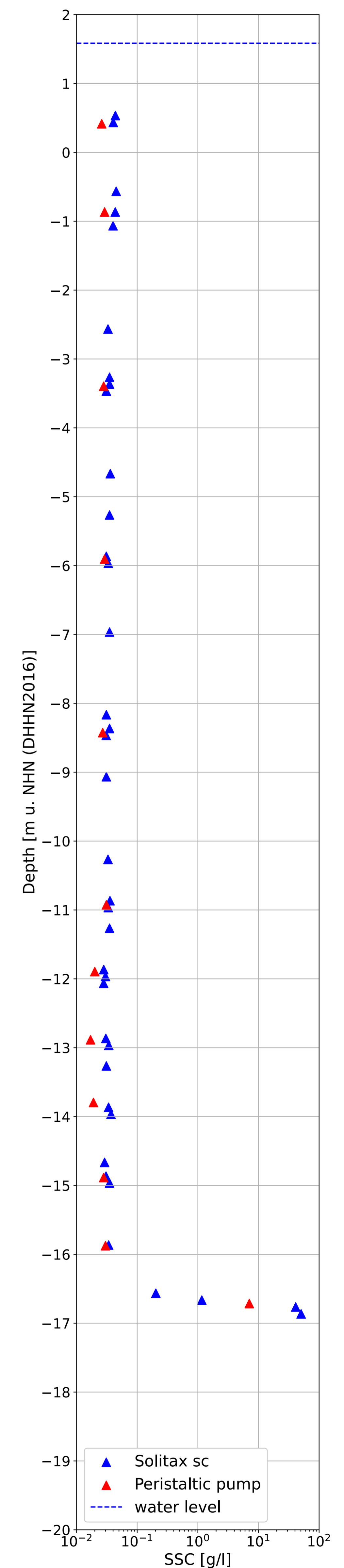


Figure 4: Comparison of measured SSC-profiles at sample site P2

