

A Multi-frequency Look at Gas Seeps on the Eastern Siberian Margin

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Abstract

The Swedish-Russian-US Arctic Ocean Investigation of Climate-Cryosphere-Carbon Interactions (SWERUS-C3) is a multi-investigator, multi-disciplinary program aimed at increasing our understanding of the climate-cryosphere-carbon system of the Eastern Siberian Arctic Ocean. In 2014 SWERUS-C3 carried out a two-leg field program on the Swedish Icebreaker ODEN. A component of the SWERUS-C3 program focused on water column mapping of the spatial distribution and geologic context of gas seeps using the acoustic systems on board ODEN (12 kHz EM122 multibeam echo sounder, 2-8 kHz SBP120 subbottom profiler, and an 18 kHz EK60 split-beam sonar). On Leg 2 of the 2014 expedition, a new wideband transceiver (EK80) was added to the split-beam echosounder and calibrated, providing the ability to measure the acoustic response of the gas seeps over a much broader range of frequencies (15-30 kHz). While the broader bandwidth unquestionably provides higher target resolution a further objective of the broadband mapping was to determine whether information on bubble size distribution could be determined so as to help model the flux of gas coming from the seeps. On Leg 2, 53 seeps were identified in the vicinity of Herald Canyon. The wide-swath, high-resolution multibeam bathymetry (from the EM122) and high-resolution chirp subbottom profiling (from the SBP120 multibeam subbottom profiler) combined with water column imaging of seeps collected at both 12 kHz (from the EM122) and 15-30 kHz (from the EK80) offer an important opportunity to understand the spatial distribution of seeps and their relationship to local and regional processes as determined from seafloor and subsurface structure, as well as to explore the potential of extracting quantitative information about the magnitude of gas transport from the seeps.

Background

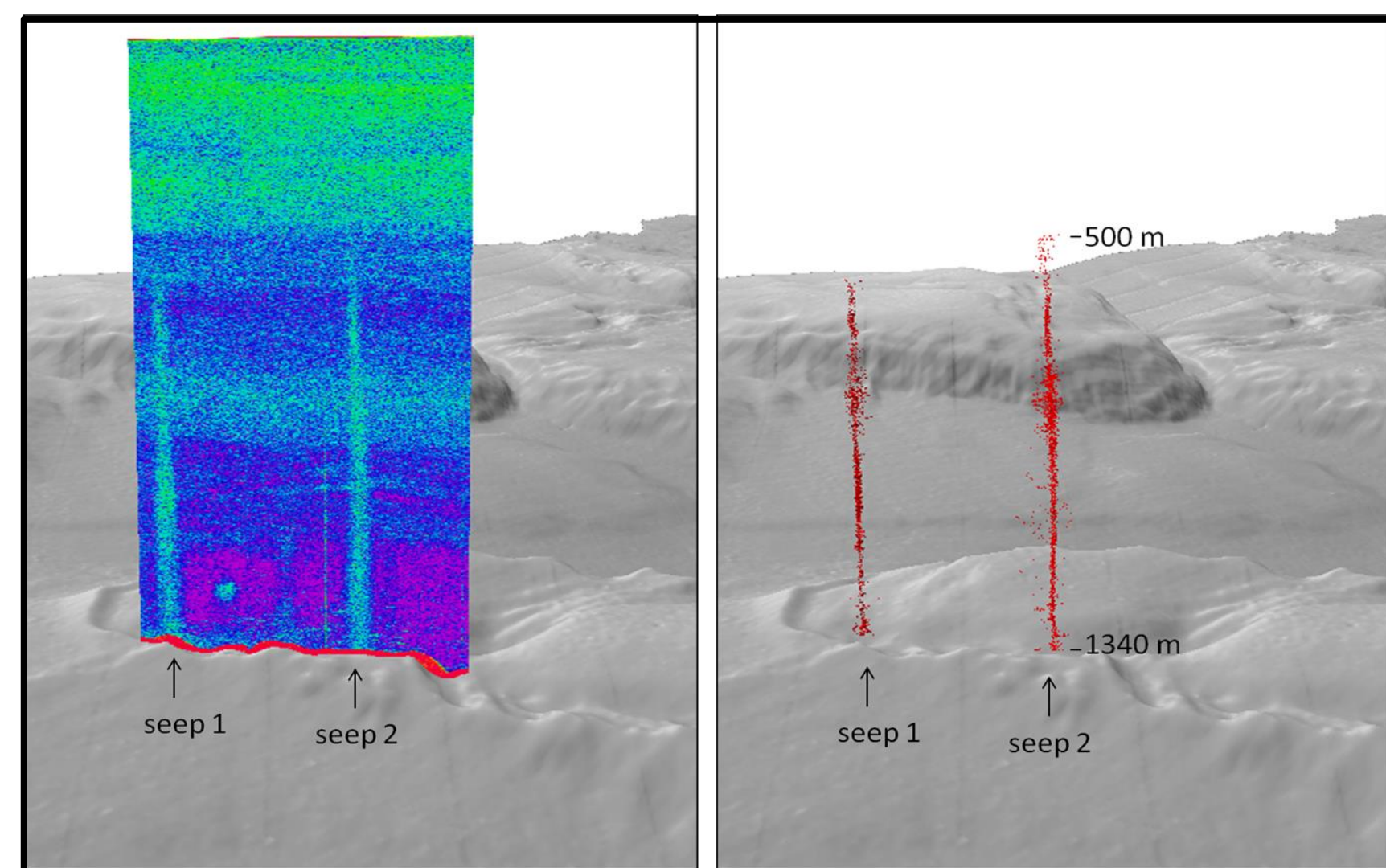


Figure 1: Spatial location of seeps via remote sensing survey.

We have demonstrated that seeps can be mapped and precisely located (e.g., Jerram et al. 2015), and that calibrated systems, we can measure the target strength of seeps (Weber et al. 2012), **but if we are to estimate seep flux we need to measure bubble size.**

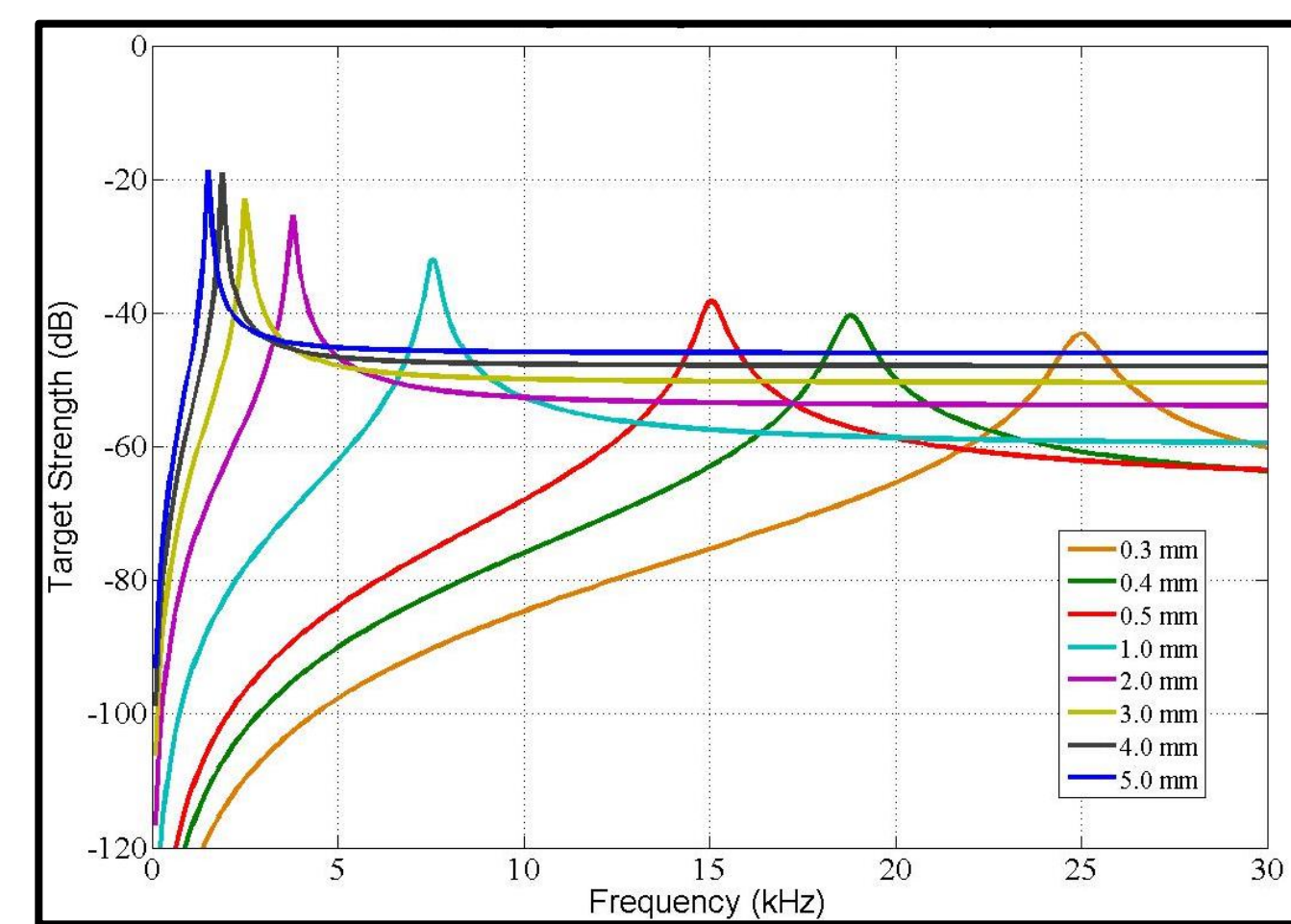


Figure 2: Modeled bubble target strength curves for 50m depth, from Clay and Medwin, 1977.

Bubble size distribution has been measured utilizing ROVs (e.g., Weber et al., 2014) but this is a time consuming and expensive process. **Can we use acoustics to remotely estimate bubble size distribution?** Fortunately there is a well-established theory relating bubble size to scattering strength (Fig 2). We can take advantage of this by collecting data over a wide frequency range, relating target strength to size for individual bubbles or measuring resonances peaks which indicate bubble size distribution.

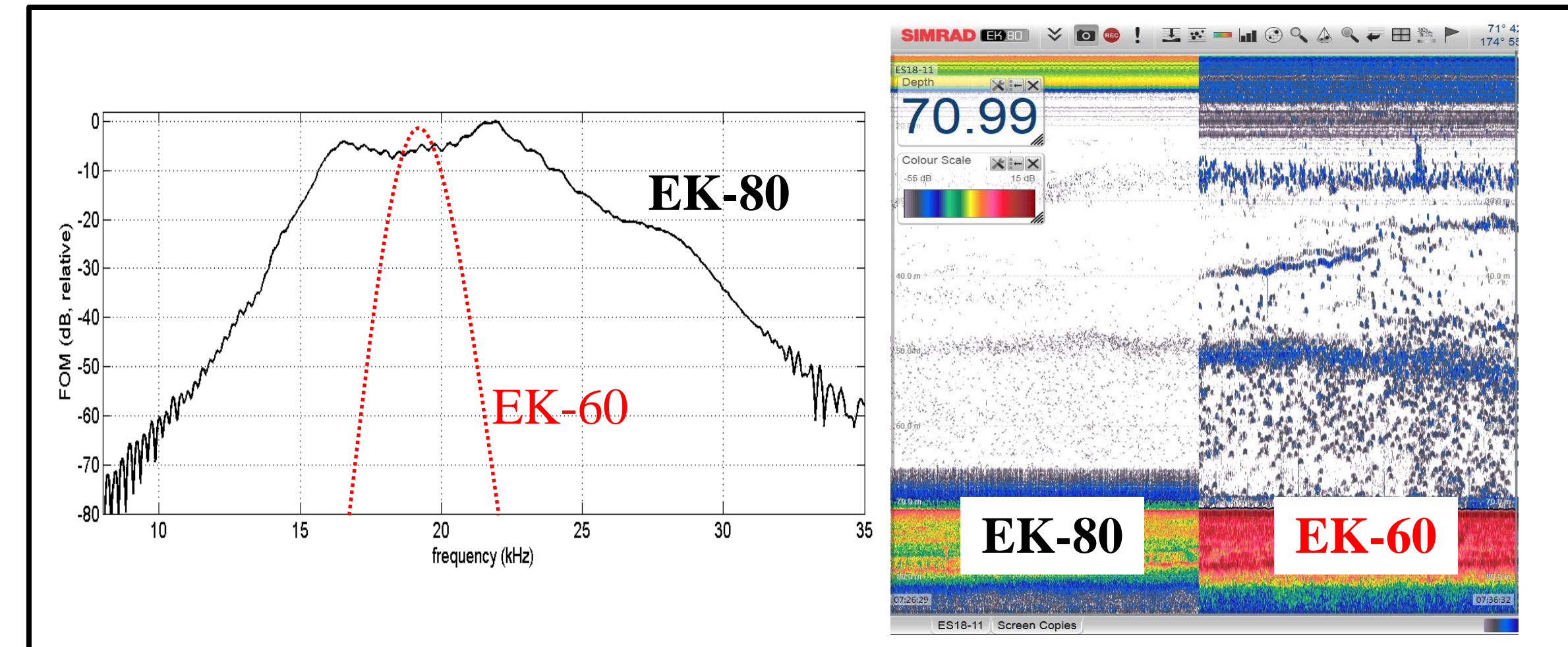


Figure 3: Bandwidth (left) and data resolution (right) comparison of the EK60 and EK80

In preparation for the SWERUS-C3 expedition, Kongsberg offered a newly developed wide-band receiver prototype, the EK80. The extended bandwidth of the EK80 relative to standardly used narrow-band EK60 offers a major improvement in target resolution and discrimination (Fig 3). The EK80 was tested in a region of known natural gas seeps during SWERUS-C3.

EK80 Calibration

Calibrating the EK80 allowed us to calculate absolute values of target strength for ensouffed targets. A copper sphere of known target strength was suspended in the echosounder field of view on the main response axis (Fig 4). Measured target strength was corrected for range and acoustic absorption. To provide target strength corrections for the entire echo sounder field of view a transducer model was applied to incorporate offsets from the main response axis.

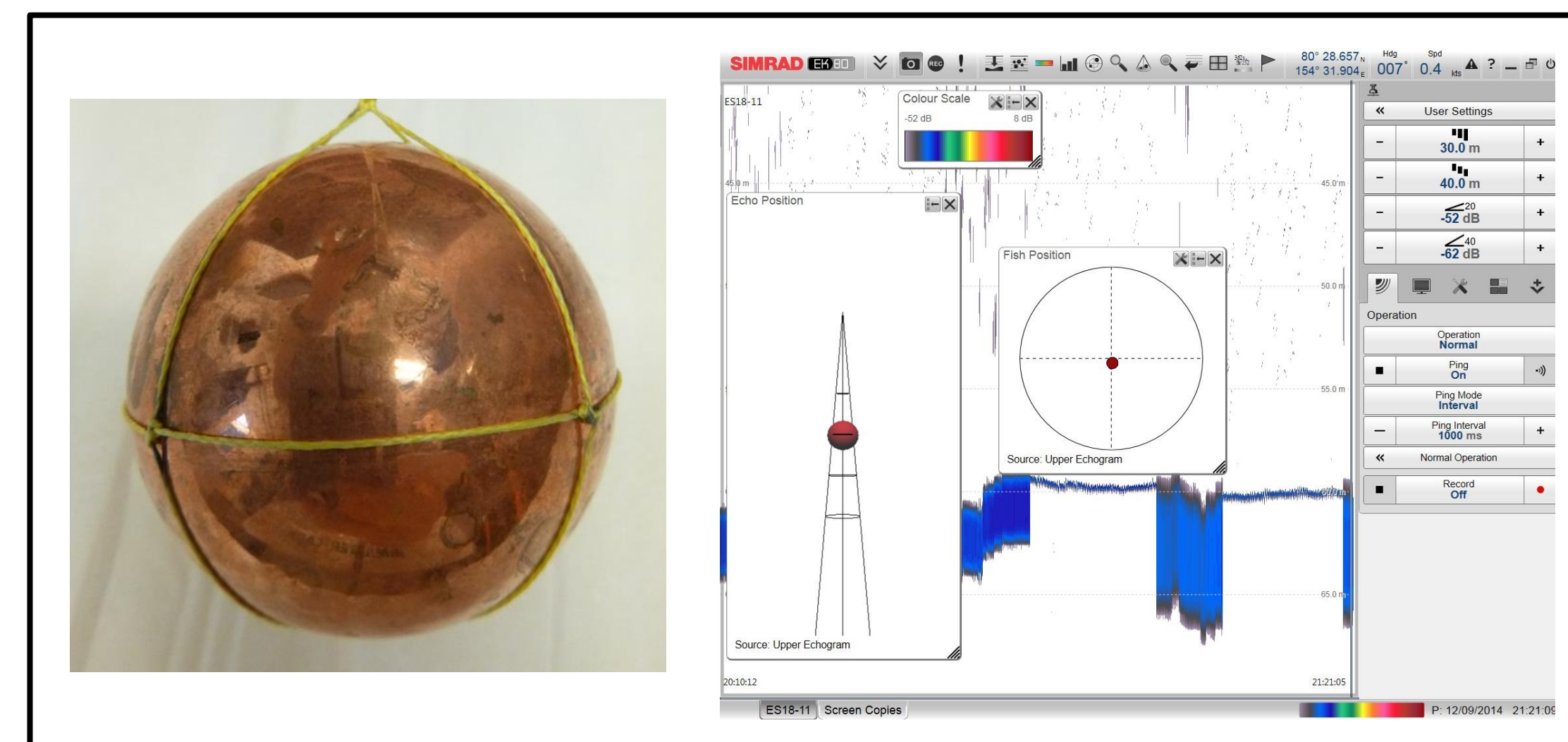


Figure 4: Calibration sphere (left) location in the EK80 maximum response axis onboard the Oden (right).

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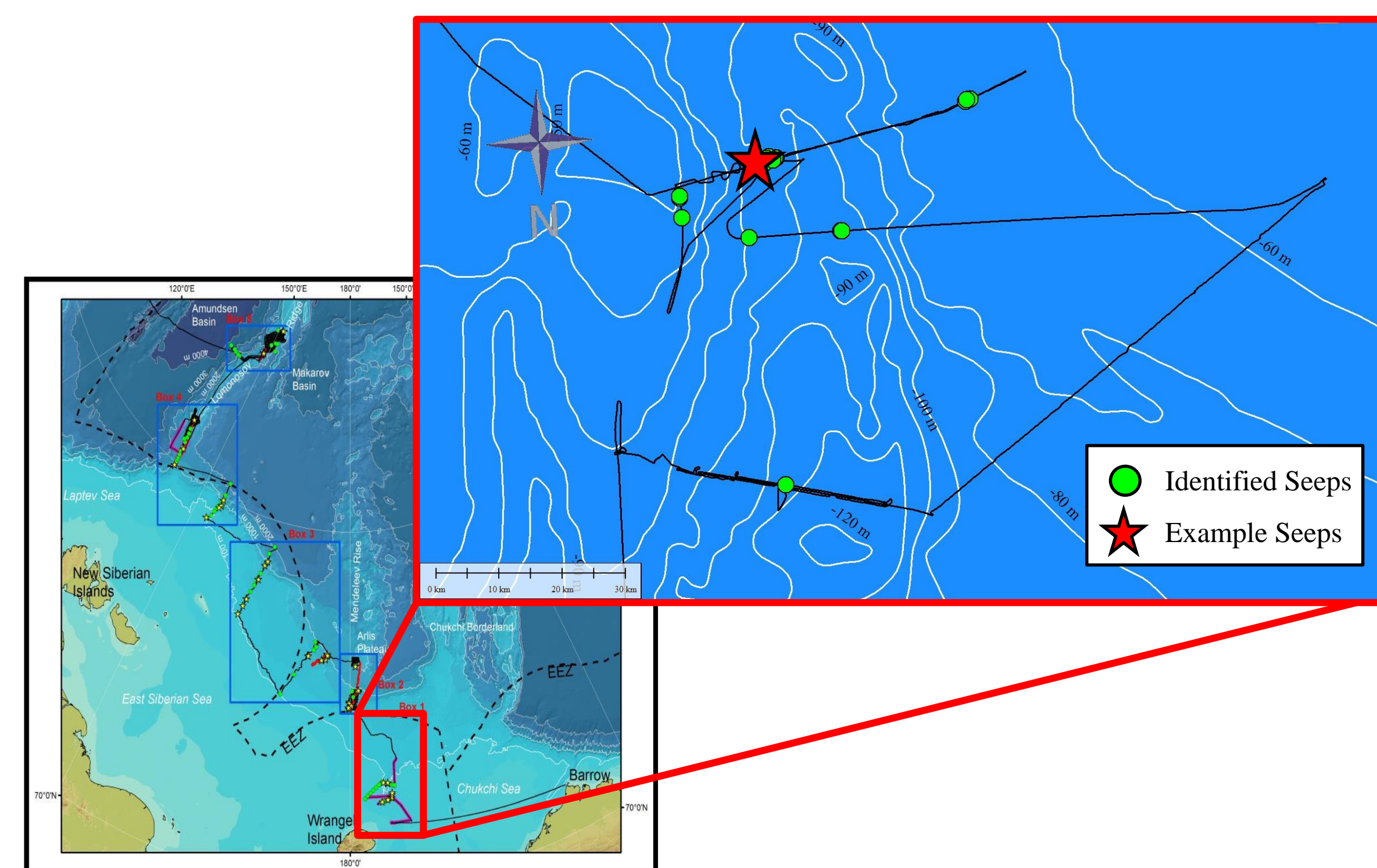


Figure 5: Overview map of Leg 2 and Herald Canyon study area. Green markers indicate the location of multiple seeps, red star indication location of seeps shown in figure 6 and 7.

SWERUS-C3 Leg 2 left Barrow, Alaska on August 21, 2014 and returned to Tromso, Norway on October 4, 2014. Of the 10747 km mapped during Leg 2, gas seeps were only found in the region of Herald Canyon northeast of Wrangel Island (Fig 5).

Seeps in Herald Canyon

A total of **53 seeps have been identified** thus far in the Leg 2 data from both the EK80 and the EM122. In addition, SBP120 subbottom profiles were collected over the seep sites. Combining data from the EK80, EM122, and SBP120 provides a geophysical context for the seeps. Seeps were found in a variety of geomorphological settings including associations with subsurface gas, pockmarks, and iceberg scours (Fig 6, left). Other seep locations showed no direct association with gas blanking or scouring (Fig 6, right).

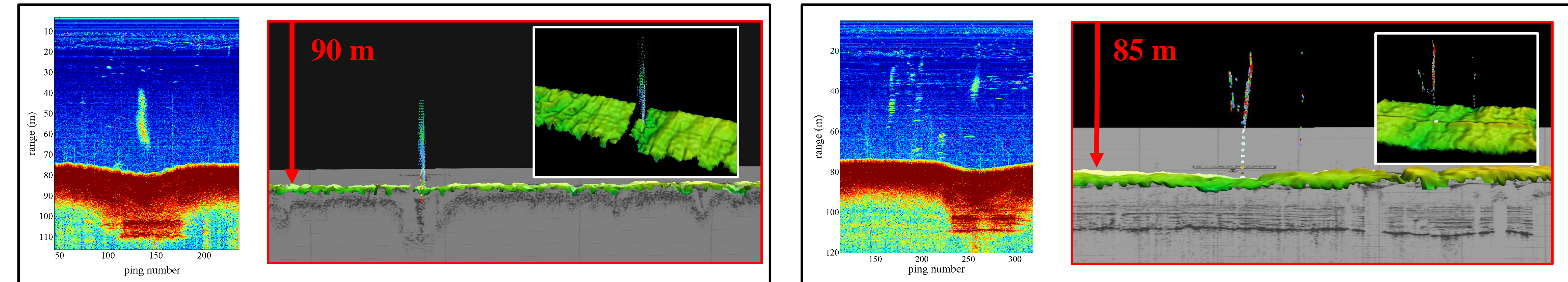


Figure 6: Two example seeps. Left image in boxes shows the EK80 datagram and right image shows the EM122 and SBP120 integrated data scene.

Frequency Response

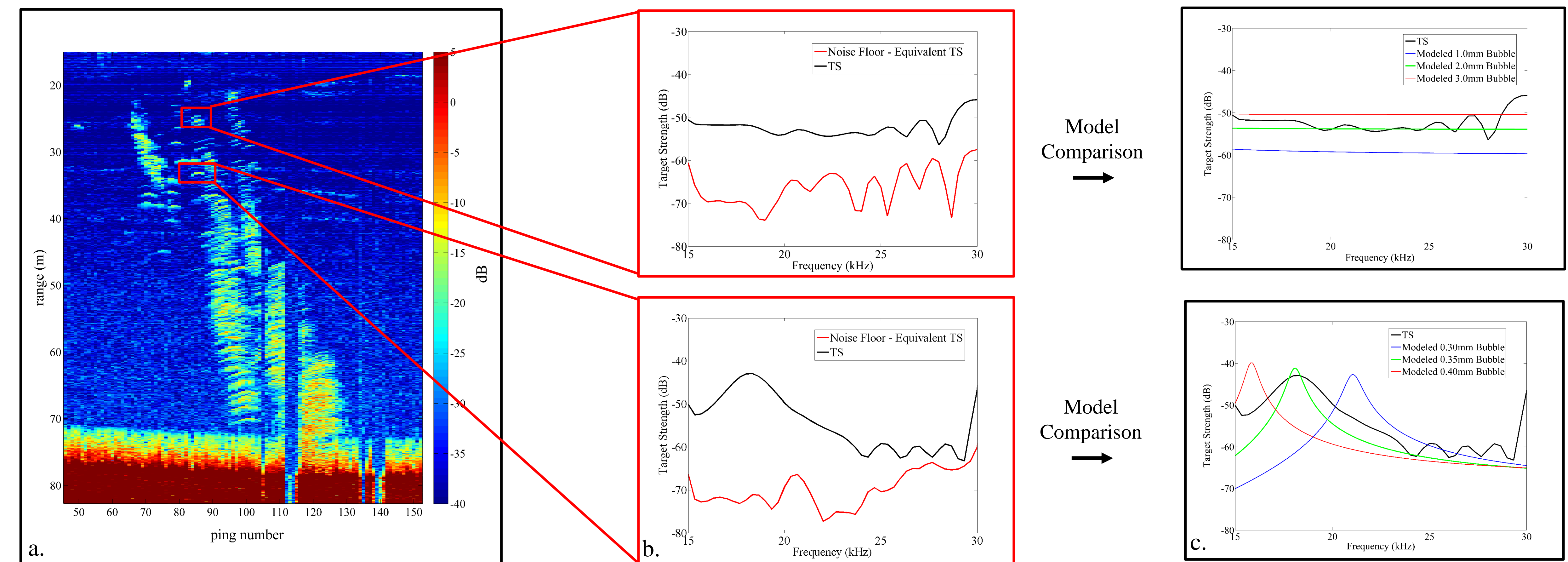


Figure 7: Calibrated target strength curves (middle) from single bubble targets of a seafloor seep (left). Target strength curves are fitted to the Clay and Medwin (1977) model to approximate bubble size (right).

The broad bandwidth of the EK80 allows for the identification of individual in the water column (Fig 7a). Wideband target strength curves are shown for individual bubbles and compared to a target strength model (Clay and Medwin, 1977). The first example displays a flat frequency response which is consistent with a bubble of radius 2.0 mm (Fig 7b&c, top). The second example is suggestive of a smaller bubble, between 0.3 and 0.4 mm, with a resonance peak between 17 and 20 kHz (Fig 7b&c, bottom).

Conclusions

- The combination of a calibrated wideband (15-30kHz) echosounder, a multibeam sonar (12kHz), and subbottom profiler (2-8kHz) offers the opportunity to explore gas seeps within their full geographical context.
- The calibrated broadband echosounder has provided the ability to identify individual bubbles in the water column and to measure their target strength. Comparison to models allows for the determination of bubble size from acoustic data.
- Coupling bubble size estimates with measured rise speed of bubbles sets the stage for acoustic calculation of seep flux and a better understanding of bubble evolution during ascent.

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