Quantifying gas bubble seepage using multibeam echosounders: a scalable workflow for monitoring

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Marine gas bubble seepage is a widespread phenomenon with implications for ecosystems, carbon cycling, and greenhouse gas inventories. Recent European regulation emphasizes the need for reliable monitoring at scales relevant for management and reporting. Multibeam echosounders (MBESs) could serve this purpose: they detect bubble plumes across wide areas (Figure 1 A), and capable systems are available on many scientific and commercial vessels.

Despite this potential, MBESs have rarely been used for quantification. Main barriers have been the absence of suitable processing methods, the large data volumes involved, and missing acoustic calibration. Here we show how recent advances can be combined into a feasible workflow for estimating bubble gas flow with commercial MBESs (Figure 1):

- [A] **Collect water-column images:** Acquire plume data with commercially available bathymetric MBESs.
- [B] **Geo-reference and pre-process:** Filter artifacts, geo-reference data to a 3D dataset and identify seeps (Urban et al., 2016).
- [C] **Generate acoustic maps:** Project plume signals to source locations, grid in 3D, and extract vertical averages to create 2D maps (Urban et al., 2016),
- [D] **Derive plume backscattering:** Apply Echo Grid Integration to aggregate plume backscatter values from identified seeps. (Urban et al., 2023)
- [E] **Calibrate to gas flow:** Convert plume backscatter values to absolute gas flow rates using inversion models or in situ reference measurements. (e.g. Veloso et al., 2015; Urban et al., in press)

We illustrate this workflow with two examples: (1) a Black Sea campaign on R/V Meteor, where a multibeam system was cross-calibrated against a scientific single-beam echosounder to estimate gas flow without in-situ reference, and (2) ongoing work at TNO & NIOZ comparing and verifying different methods for quantifying leakage from North Sea wells.

Transforming MBES from a detection tool into a calibrated monitoring instrument opens new possibilities for assessing methane seepage at scales relevant to both science and regulation, supporting emission reporting and leakage impact assessments in offshore energy contexts.

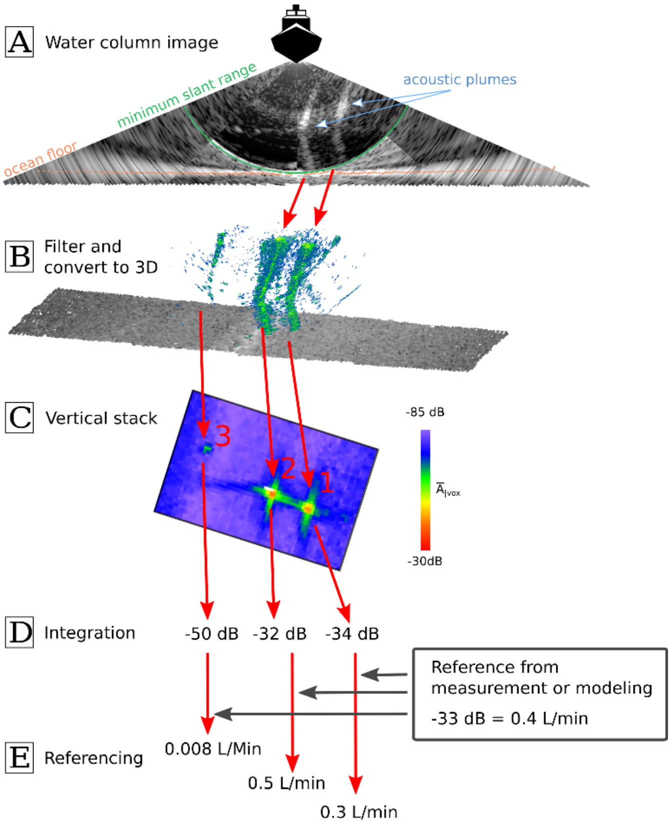

Figure 1: **Basic workflow for multibeam-based gas flow quantification.** Single water column images [A] are combined into a 3D volume [B], from which vertical slices create acoustic maps [C]. Integration of plume backscatter values enables relative comparison [D]; e.g., a 2 dB difference (Plume 1 and 2) means ~60% more bubbles, while 16 dB (Plume 1 and 3) corresponds to ~40× more. Absolute gas flow estimates require calibration [E], achievable with a single in-situ reference or with inversion modeling, though the latter carries higher uncertainty.

References

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