Natural seabed gas leakage from tidal activity

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I. EXTENDED ABSTRACT

The likely leakage from sub-seabed Carbon Capture and Storage (CCS) has been debated since geological storage was proposed as an effective option to reduce greenhouse gas emissions into the atmosphere. For determining such leakage, passive acoustics has been presented as a feasible way. However, it is vulnerable to dynamic environment, e.g., tidal activity, which may introduce influence. Panarea offshore area (Fig. 1), where exists natural CO₂-rich gas seeps, provides an excellent test bed and opportunity to investigate natural seabed CO₂ seepage over tidal cycles. In this study we address the following questions: (1) how much does the tide affect the power spectral density (PSD) and the PSD standard deviation (Std) of the bubble leakage sound; (2) how does the tidal cycle compare to estimated gas flux and bubble radius.

Fig. 1: Panarea island and surrounding islets. The seep site (marked as red X) is in the Bottaro Crater (38°38’25”N, 15°06’56”E) at water depth 12.5 m.

A calibrated hydrophone was deployed close (2 m) to the seep site at water depth 12.5 m dependent on the tidal level to record the acoustic signature of gas bubbles emitted from the seabed. CO₂ gas flux across the sediment-water interface and the bubble radius are quantified using a passive acoustic inversion technique [1] based on measured acoustic hydrophone data. The measurement started at 13:45 on May 14th 2018 and lasted for 17 hours until 06:53 on May 15th 2018. Tidal level was obtained at 10-min interval.

The data set is applied to identify dependencies between tide and bubble acoustic variables. Because the bubble sound was weak and the background noise (e.g., biological noise) has taken a large portion in the level of the acoustic recording, we first identify outliers and assign lower weight to these outliers by using a smoothing technique [2]. This is to ensure that even spread of small gas bubbles released into the sediment were measured. To compare and identify agreements between the time-varying tides and the estimated quantities, we set different span (e.g., a certain percent of the entire measured data) for the moving average filter in the regression.

Fig. 2 shows the acoustic spectrum, tidal level, sound PSD, PSD Std, estimated seabed gas flux and bubble radius. The tidal level shows 1.5 cycles. It can be observed that the differences were influenced by tides. Most of the tidally induced PSD peaks did concur, but not always due to the surrounding noise. The PSD and Std normally show low levels as the tide was at high level, while it is difficult to see tidal correlation to gas flux and bubble radius only from this figure.

To show the correlation between these variables, we use the Pearson correlation coefficient [3]. The correlation results are shown in Fig. 3, from which the strong tidal dependency is observed. In short period corresponding to small smooth span < 0.1%, the tidal level is modest positively correlated with the PSD Std, modest negatively correlated with the PSD, and weak correlated with the gas flux and bubble radius. While in the long period corresponding to large smooth span > 10%, the tidal level is strong positively correlated with the PSD Std, and strong negatively correlated with the PSD, the gas flux and bubble radius. The PSD is modest positively correlated with its Std in short period while strongly negatively correlated with its Std in long period. As the smooth span increases, the positive correlation between gas flux and bubble radius becomes stronger. The short period correlation shows instant changes, while the long period correlation shows the influence of tidal cycles on CO₂ gas seepage.

Fig. 4 shows the seabed gas seep related variables correlating with tidal circulation of ~12 hours. It is shown that in highly dynamic water areas like offshore Panarea, natural variability is comparable in its levels of gas seep variation with the effects of tidal variation. Natural forcing, such as tide, may be a strong factor in the gas seepage from the seabed. In general, the circulation offshore Panarea is tidally driven and the influence of tidal circulation was significant on all the measured seep variables.

We show that the tidal activity correlates significantly with the gas seep related sound PSD, the PSD Std, the seabed gas flux and bubble radius. Our results corroborate evidence that natural migration of CO₂ through the seabed is influenced by tidal activities with strong negative correlation. Tidal influences and moderate gas fluxes through a larger seabed
Fig. 2: Measured and estimated variables over 17 hours (~1.5 tidal cycles). Seabed gas flux and bubble radius correlate with tidal cycle, with low gas flux and small bubble size at high tide. Grey lines are measured data, and coloured lines are 10% span smoothed data. The gas flux and bubble radius are from the inversion of hydrophone data with 50th percentile of confidence interval. (a) spectrum; (b) tidal level; (c) PSD at 700 Hz; (d) Std at 700 Hz; (e) estimated gas flux; and (f) bubble radius.

Fig. 3: Correlation coefficient of multivariate analysis of the measurement data using smooth span. Positive values indicates positive correlation, vise versa.

Area on should expect more pronounced effects of CO₂ seeps in the form of an increased background CO₂ level and less pronounced gradients close to the leak. Results reported here advance the knowledge of the sensitivity of seabed greenhouse gas seepage to tidal circulations.

Fig. 4: Cross-correlation between the 10% span smoothed tidal level, the PSD, the Std, the gas flux and bubble radius.

REFERENCES
