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Methane Fluxes from a High Intensity Seep Area west of Crimea, Black Sea

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Methane seepage is a wide-spread phenomenon in the Black Sea with an increase in density and intensity west of the Crimea in the Paleo Dnepr area between 70 and 250m water depth. Within the EU funded project CRIMEA we studied the impact of high intensity seeps on the methane distribution in the water column and its possible transport into the atmosphere. Here we present data which allow flux calculations of free methane from an area of 1 by 1.23 miles between 80 and 95m water depth. Our calculations are based on direct and hydroacoustic flux measurements of single seeps or small-scaled seep areas (several m^2); the spatial extrapolation of these fluxes use the very strong correlation between the bubble seep occurrence and a high backscattering seafloor; the temporal variability of bubble release was detected via the lander-based hydroacoustic system GasQuant.

More than 1000 bubbling seep sites were identified during two cruises in 2003 and 2004 by hydroacoustic water column surveys. The hydroacoustic detection of bubbles uses the strong backscattering of the free gas phase caused by the great impedance difference of bubbles in water (equivalent to the detection of fish and their swim blad-

der). In echograms, bubble streams or even single bubbles can be detected, traced and used for special analyses such as bubble rising speed, bubble size and shrinking rates. Because of the flare-like appearance of bubble streams in echograms we call these features 'flares'.

Parallel multi beam mapping allowed the detection of the seafloor morphology together with the spatial backscatter intensity of the seafloor. The combination of flare occurrences with high backscatter areas provided a very good correlation. Normalized, the backscatter ranged from -12.5 to 7.1 dB for an area of 4.23 km^2. All seep positions plott in areas with more than -2.7 dB, which is almost the entire area of investigation (95.8 %). However, 75% of the flares occur within only 20.1% of the area, half of the flares occur in only 9.2% and 25% even occur in only 3.8% of the area with backscattering values above 2.4 dB. This correlation allows to predict and extrapolate active bubble seeps even without direct or hydroacoustic observations.

One reason for the high backscattering seafloor are patches of carbonate cemented seafloor (formed via AOM) which typically occurs just below bright white *Beggiatoa* mats. In addition, high resolution seismic studies with a 5kHz sub-bottom profiler clearly show a shallow gas front in normally 3m sediment depth. In those areas where strong gas front reflectors dome up and reach the seafloor surface the backscatter values and flare density are the highest. This clearly shows that the bubbles released are fed from shallow gas which also might have an impact on the physical properties of the seafloor and its backscatter behaviour. Seeps in lower or even very low backscatter areas possibly indicate a rather young or weak activity which did not (so far) cause a remarkable carbonate cementation detectable during multi beam surveys.

However, the backscatter data are the base for our spatial flux calculations which use direct bubble trapping to distinguish the flux rate from one single seep hole and hydroacoustic methods for small seep areas of several m^2. Direct bubble flux measurements were performed with the submersible JAGO by trapping the bubbles with a funnel. Fluxes vary between 0.55 and 1.44 ml/s (or 1.98 to 5.18 l/h at in situ volume; or 0.24 to 0.64 mmol/s). Subsequent GC-based gas analyses onboard confirmed that the gas phase consists exclusively of methane. Visual observations by JAGO and towed camera systems showed bubble diameters between 1 and 15mm with typical sizes between 3 and 7mm. Together with bubble rising speeds of typically 25cm/s both attributes are in very good agreement with detailed hydroacoustic measurements using a dual frequency scientific echo sounder EK500 (120 and 38kHz). Flux estimates based on intense hydroacoustic data processing resulted in 7.8 ml/s (28.08 l/h at in situ pressure; or 3.45mmol/s) over an area of approx. 60 m^2 (the footprint of the echo sounder in 92m water depth is 9m). The approx. 8 time higher flux values analysed via hydroacoustic are in good agreement with visual observations at the seafloor which often show clusters of several bubbling sites. One of these clusters was analysed as integrated signal during the hydroacoustic measurements. As an average we calculated that $57.5\mu mol/s/m^2$ are released from the backscatter area which contains 50% of the seeps (9.2% of the entire area = 0.389 km^2). This results in a spatial flux of 22.36mol/s or $721.6m^2/d$. Assuming that only 3.8% of the area are really active (the area that still contains 25% of the seeps) the total flux would be reduced to 9.26mol/s or $298.8m^2/d$.

Both, direct and hydroacoustic measurements certainly give very accurate results for short-term and small-scaled flux quantifications. The accuracy of the spatial extrapolation base on the accuracy of the average flux per square meter and the real size of the active seep area. Within a certain range and specific assumptions the total fluxes of an area can be quantified, but did not include the temporal variability of the bubble release. To get an idea about this variability, we deployed a lander based hydroacoustic system for 2.5 days close to an active area. The system is able to detect bubbles in the water column within a range of 63° up to a distance of 55m ($1663m^2$) via a horizontally looking acoustic swath system. We detected that most of the smaller bubble sites are not active during most of the time. Quite often they show only short periods (1 to 10 minutes) of activity followed by one to several hours of silence. More constantly active are seep clusters of few square meter in size but even those have interruptions of several tens of minutes up to few hours. Thus, the spatial flux of an area over longer periods cannot be calculated by a simply multiplication of flux per square meter with the suggested active seep area as done above. A correction for the activity has to be applied as direct and hydroacoustic flux measurements do not take this into account. The final statistical analyses of the temporal variability in bubble activity and its application to our flux data are still in progress but first estimates show that long-term fluxes (assuming that the activity changes were accurate enough recorded during the 2.5 day deployment) have to be decreased by approx. one third to a half of the flux values calculated above.