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Methane Emission from High-Intensity Marine Gas Seeps into the Atmosphere. Case Study from the Black Sea

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High-intensity marine gas seeps are defined as seep locations which almost continuously release high amounts of free gas from the seabed into the water column. The effect of these high intensity bubble seeps on the atmosphere is more significant compared to fluid seeps which transport only dissolved methane. Dissolved methane is prone to oxidation due to the microbial filter of anaerobic oxidation of methane (AOM) in the sediment and later on in the anoxic lower water column of the Black Sea. High intensity seeps are of major interest because methane transport by bubbles provides a very efficient way for fast vertical transport through the water column into the atmosphere. The release of free gases from these sites can bypass the anaerobic methane consumption in the anoxic water, the strongly stratified upper water column as well as the microbial oxidation of methane in the oxic water, which act together as highly efficient barrier between the large methane reservoir of the lower water column and the atmosphere.

Our research cruise in summer 2003 with *RV Professor Vodyanitsky* was part of the EU-funded CRIMEA project (http://www.crimea-info.org/). Main study areas have been the paleo delta area of the Dnepr river and the Sorokin Trough south of Crimea where active seep sites from the shelf down to 2050m water depth were studied.

To estimate the sea-air methane flux above these high-intensity marine gas seeps the methane concentration of the surface water and the overlying air was continuously measured during the cruises using a fully automated, semi-continuous seawater-air equilibrator system based on gas chromatography. A total of 711 water samples and 915 air samples were taken during the cruise.

Surface water methane measurements in the Sorokin Trough mud volcano area in around 2080m water depth show average methane saturation ratios (SR) of 143%. The average sea-air methane flux can be determined as 0.2–0.57 nmol m^{-2} s^{-1},using two different sea-air gas exchange models. The investigations in the Paleo Dnepr Area (60 to 800m water depth) reflects a more diverse pattern. Spots of high methane concentrations in the surface water have been recorded above a seep location in around 90m water depth (SR up to 294%). The air-sea methane flux above this seep site (0.96–2.32 nmol m^{-2} s^{-1}) is 3 times higher than calculated for the surrounding shelf (0.32–0.77 nmol m^{-2} s^{-1}) and 5 times higher than assessed for open Black Sea waters (water depth $>$ 200m, 0.19–0.47 nmol m^{-2} s^{-1}).

Our findings suggest that only shallow seeps, in water depth shallower than 100m, affect the surface water methane concentration and the direct local emission into the atmosphere. High intensity seep sites below this boundary show no direct influence on the surface concentration. The different redox regimes in connection with the hydrographic structure in the Black Sea provide an effective mechanism to hamper evasion from this reservoir into the atmosphere. Thus, gas bubble transport, providing a rapid pathway through the water column and mostly unaffected by oxidative consumption, might be a major contribution to the methane flux to the atmosphere from the sea floor.