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Seasonal methane accumulation and release from a gas emission site in the central North Sea

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Hydroacoustic data document the occurrence of 5 flare clusters and several single flares from which bubbles rise through the entire water column from an active seep site at 40 m water depth in the central North Sea. We investigated the difference in dissolved methane distributions along a 6 km transect crossing this seep site during a period of seasonal summer stratification (July 2013) and a period of well mixed winter water column (January 2014). Dissolved methane accumulated below the seasonal thermocline in summer with a median concentration of 390 nM, whereas during winter, methane concentrations were much lower (median concentration of 22 nM) and punctually elevated due to bubble transport. High resolution methane analysis by an underwater mass-spectrometer confirmed our summer results and were used to document prevailing stratification over the tidal cycle. Although sufficient methane was available, microbial methane oxidation was limited during both seasons. Measured and averaged rate constants (k') using Michaelis Menten kinetics were on the order of 0.01 d-1, equivalent to a turnover time of 100 d. Time series measurements indicated an uptake of only 5-6% of the gas after 4 d, and no known methanotrophs and pmoA-genes were detected. Estimated methane fluxes indicate that horizontal eddy transport rapidly disperses dissolved methane, vertical transport becomes dominant during phases of high wind speeds, and relative to these processes, microbial methane oxidation appears to be comparably low. To bridge the discrete field data we developed a 1D seasonal model using available year-long records of wind speed, surface temperatures and thermocline depth. The model simulations show a peak release of methane at the beginning of fall when the water column becomes mixed. Consistent with our field data, inclusion of microbial methane oxidation does not change the model results significantly, thus microbial oxidation appears to be not sufficient to notably reduce methane during summer stratification before the peak release in fall.