Geophysical Research Abstracts
Vol. 19, EGU2017-7085, 2017
EGU General Assembly 2017

Temperature, productivity and sediment characteristics as drivers of seasonal and spatial variations of dissolved methane in the near-shore coastal areas (Belgian coastal zone, North Sea)

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The open ocean is a modest source of CH4 to the atmosphere compared to other natural and anthropogenic CH4 emissions. Coastal regions are more intense sources of CH4 to the atmosphere than open oceanic waters, in particular estuarine zones. The CH4 emission to the atmosphere from coastal areas is sustained by riverine inputs and methanogenesis in the sediments due to high organic matter (OM) deposition. Additionally, natural gas seeps are sources of CH4 to bottom waters leading to high dissolved CH4 concentrations in bottom waters (from tenths of nmol L-1 up to several μmol L-1).
We report a data set of dissolved CH4 concentrations obtained at nine fixed stations in the Belgian coastal zone (Southern North Sea), during one yearly cycle, with a bi-monthly frequency in spring, and a monthly frequency during the rest of the year. This is a coastal area with multiple possible sources of CH4 such as from rivers and gassy sediments, and where intense phytoplankton blooms are dominated by the high dimethylsulfoniopropionate (DMSP) producing micro-algae Phaeocystis globosa, leading to DMSP and dimethylsulfide (DMS) concentrations. Furthermore, the BCZ is a site of important OM sedimentation and accumulation unlike the rest of the North Sea. Spatial variations of dissolved CH4 concentrations were very marked with a minimum yearly average of 9 nmol L-1 in one of the most off-shore stations and maximum yearly average of 139 nmol L-1 at one of the most near-shore stations. The spatial variations of dissolved CH4 concentrations were related to the organic matter (OM) content of sediments, although the highest concentrations seemed to also be related to inputs of CH4 from gassy sediments associated to submerged peat. In the near-shore stations with fine sand or muddy sediments with a high OM content, the seasonal cycle of dissolved CH4 concentration closely followed the seasonal cycle of water temperature, suggesting the control of methanogenesis by temperature in these OM replete sediments. In the off-shore stations with permeable sediments with a low OM content, the seasonal cycle of dissolved CH4 concentration showed a yearly peak following the chlorophyll-a spring peak. This suggests that in these OM poor sediments, methanogenesis depended on the delivery to the sediments of freshly produced OM. In both types of sediments, the seasonal cycle of dissolved CH4 concentrations was unrelated the seasonal cycles of DMS, and DMSP, despite the fact that these quantities were very high during the spring Phaeocystis globosa bloom. This suggests that in this shallow coastal environment CH4 production is overwhelmingly related to benthic processes and unrelated to DMS(P) transformations in the water column as recently suggested in several open ocean regions. The annual average CH4 emission was 41 mmol m-2 yr-1 in the most near-shore stations ($\sim$4 km from the coast) and 10 mmol m-2 yr-1 in the most off-shore stations ($\sim$23 km from the coast), 410-100 times higher than the average value in the open ocean (0.1 mmol m-2 yr-1). The strong control of CH4 concentrations by sediment OM content and by temperature suggests that marine coastal CH4 emissions, in particular shallow coastal areas, should respond in future to eutrophication and warming of climate. This is confirmed by the comparison of CH4 concentrations at five stations obtained in March in years 1990 and 2016, showing a decreasing trend consistent with alleviation of eutrophication in the area.