The role of anaerobic oxidation of methane on hydrate-related benthic carbon fluxes

De La Fuente Ruiz Maria[1], Arndt Sandra[1], Marín-moreno Héctor[2] and Minshull Tim A.[2]

[1] BGeosys, Department Geoscience, Environment & Society, Université Libre de Bruxelles, Brussels, Belgium, Av. Franklin Roosevelt 50, 1050 Bruxelles
E-mail: maria.de.la.fuente.ruiz@ulb.be

[2] School of Ocean and Earth Science, University of Southampton, European Way, Southampton SO14 3ZH, UK

Modern observations and geological records suggest that anthropogenic ocean warming may destabilise marine methane hydrate reservoirs, releasing methane from the seafloor to the ocean-atmosphere, and potentially triggering positive feedback on global temperature. On the decadal to millennial timescales over which hydrate-sourced methane release is hypothesized to occur, several processes consuming methane below and above the seafloor have the potential to slow, reduce or even prevent such release. Yet, their modulating effect on seafloor methane emissions remains poorly quantified, and their full impact on ocean carbon chemistry is still to be explored.

The microbially mediated anaerobic oxidation of methane (AOM) is the major biological sink of methane in marine sediments. Globally, the AOM bio-filter is hypothesized to convert most of the upward methane into inorganic and organic carbon pools, reducing seafloor methane escape and thus, preventing a direct impact of methane carbon on the climate system. However, the AOM efficiency may be highly variable (particularly at cold seeps and other gas-rich sediments) and is strongly controlled by the balance between multiphase methane transport and microbial dynamics. Past modelling efforts examining the evolution of hydrate reservoirs in response to climate perturbations have largely ignored the role of the AOM bio-filter and its variable efficiency when estimating benthic methane fluxes and potential ocean-carbon cycle feedbacks. Here, we present a new 1D thermo-hydro-biogeochemical hydrate model that couples the complex interplay between hydrate thermodynamics, benthic transport, and microbial dynamics, and accounts for the main redox and equilibrium reactions that drive methane, total alkalinity (TA), total sulfide, and dissolved inorganic carbon (DIC) production/consumption in oxic and anoxic marine settings. In particular, the model explicitly resolves the dynamics of the methane-oxidizing microbial community and describes the AOM rate as a biomass-explicit formulation that accounts for kinetic, as well as thermodynamic factors. The model is, thus, able to account for transient changes in the AOM bio-filter efficiency, can simulate potential windows of opportunity for seafloor methane escape, and assesses hydrate-related TA and DIC benthic fluxes.

Keywords
Methane Hydrate Destabilisation; Climate Change; Benthic Carbon Fluxes; Methane Emissions; Anaerobic Oxidation Of Methane; Carbon Cycle-Climate Feed-Backs; Modelling