ABSTRACT

[1] The downward export of organic material through the biological pump constitutes the critical process linking the surface to deep ocean and an important mechanism for carbon (C) sequestration. In simulation studies of the Southern Ocean's role in the global C cycle, resolving the issue of the controls on particle transport magnitude and efficiency in the upper 1000 m water column is of particular importance. Assessing C export and mineralization fluxes in the Southern Ocean (S.O.) via a multi-proxies approach represents indeed one of the major objectives of the BELCANTO II project (BELgian research on C uptake in the ANTarctic Ocean; Belspo). Among the different proxies used (i.e. Ba_{xs}-barite, ^{234}Th, biomarkers, $\delta^{15}N$, ^{13}C, $\delta^{29}Si$, bacterial activity and sediment traps data), specific focus in the present work was on the barium proxy.

[2] The great potential of the mesopelagic particulate biogenic Ba_{xs}-barite ($BaSO_4$) as a proxy of C mineralization processes in the S.O. was however shadowed by uncertainties related to the mechanism itself of Ba_{xs}-barite formation in the water column. This issue moreover constitutes the limiting keys for any application of the Ba proxies. In order to further improve the robustness of the Ba_{xs}-barite tool, two pathways were followed in this dissertation: the first one consisted in shedding light on the interaction between the dissolved and particulate Ba phases and the significance of this in the oceanic Ba dynamics. The second pathway consisted in better constraining and calibrating the mesopelagic Ba_{xs} proxy. Two major outcomes of this work are (1) the denial of the active biological mediation as the major factor setting both the dissolved Ba and Ba_{xs}-barite water column distributions and the clear decoupling between dissolved Ba, silicate and alkalinity, and (2) the significant link between mesopelagic particulate biogenic Ba_{xs}-barite and bacterial activity distributions. We demonstrated that the mesopelagic Ba_{xs} build-up reflects the intensity of exported biogenic material degradation by heterotrophic bacteria and that the release of biogenic Ba from acantharia celestite ($SrSO_4$) is only a minor contributor to barite formation. Moreover, the particulate biogenic Ba_{xs}-barite formation/dissolution dynamics overwhelmed by the general circulation appeared as the major mechanism shaping the water column dissolved Ba gradient. Findings allowed us to refine a potential scenario of open Ocean mesopelagic Ba_{xs}-barite formation process.

[3] The present work enabled a better evaluation of the processes controlling transport of sinking particles between surface and deep ocean. Various environments which significantly differed in terms of ecosystem functioning (intensity of the biological pump and subsequent fate of sinking biogenic materials with depth) were investigated. Mesopelagic Ba_{xs} fluxes were translated into C mineralization rates using a relationship relating Ba_{xs} to O_2 consumption as reported by Dehairs et al. [1997]. The Ba_{xs} residual content (Ba_{xs} signal at zero oxygen consumption, i.e. zero organic C demand) which depends on the saturation state of the water for barite was adjusted for each study area. We moreover showed that Ba_{xs}-based mesopelagic C mineralization fluxes compare well with results obtained with modes of C utilization assessment (i.e. bacterial carbon demand and POC flux decrease from Neutrally Buoyant Sediment Traps). From the different environments studied, the outcome of the C export, not only dependent on its magnitude, appears significantly modified by conditions at intermediate layers. The extent of mesopelagic C mineralization is closely linked to the combination of both the intensity and nature of the blooms, the grazing pressure, the distribution of bacterial activity and the type of biogenic material exported. It is actually difficult to define a single, global response in mineralization processes following bloom developments. Results seem however to indicate that systems where calcium carbonate producing plankton is significant are prone to more important deep export than systems dominated by diatoms. Moreover, in diatom dominated systems thriving in Fe replete conditions, it seems that blooms are less prone to mesopelagic C mineralization when surface productivity is particularly intense and the materials exported composed by larger diatoms and fast sinking pellets. On the contrary, mesopelagic processing of organic matter appears higher in HNLC's systems dominated by smaller diatoms, lower grazing pressure and deeper bacterial activity. Moreover, at the Southern Ocean's scale, the biological pump and undergoing C mineralization at intermediate depths appear more intense (in absolute values) in the subantarctic and polar front zones, coinciding with regions of atmospheric CO_2 sink. The intensity of mesopelagic C mineralization has moreover been shown to increase during the growth season in these areas. Frontal systems, where hydrodynamics and trophic gradients are well known to enhance productivity, seem also to be site of higher mesopelagic mineralization processes.