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An Inverse Modelling Approach to Constrain Be Cycling in the Subpolar North Atlantic

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Beryllium-7 is a short-lived cosmogenic radionuclide that has been used as a tracer of atmospheric deposition at the sea surface and of physical processes in the upper ocean. These applications generally assume that (i) the fraction of marine ^{7}Be in particulate form is negligible, and/or (ii) the interactions between the particulate and dissolved forms of ^{7}Be in seawater can be neglected. In this study, we test different steady-state models of upper ocean ^{7}Be cycling from measurements of total and particulate ^{7}Be activities collected at two stations of the GEOVIDE cruise in the subpolar North Atlantic (May-June 2014). The most complete model includes vertical advection, vertical diffusion, gravitational settling, radioactive decay, atmospheric deposition, and reversible exchange between dissolved ^{7}Be ($^{7}Be_{d}$) and particulate ^{7}Be ($^{7}Be_{p}$). Application of a generalized least-squares procedure shows that this model reproduces the measured ^{7}Be activities at both stations to within their uncertainties (± 1 standard deviation). At station 51/60, in the East Greenland-Irminger Current, models that neglect adsorption and/or desorption can still reproduce the measured activities, while at station 69, in the southern Labrador Sea, models that neglect reversible exchange or desorption poorly fit the data. Thus, $^{7}Be_{d}$ at station 51/60 could have been supplied entirely by surface deposition, whereas $^{7}Be_{d}$ at station 69 originated at least partly from $^{7}Be_{p}$ release into solution. The subsurface $^{7}Be_{p}$ maxima at both stations seem to require a flux of ^{7}Be between particles and solution at station 69 but not at station 51/60. We also find that total ^{7}Be deposited at the ocean surface is nearly balanced by radioactive decay, while radioactive decay can exceed surface $^{7}Be_{d}$ deposition by up to 40%. Hence, reversible exchange is important to consider in applications of $^{7}Be_{d}$ as a deposition tracer. The steady state assumption does not alter our results regarding the solid-solution exchange of ^{7}Be, but it does result in significant biases when deriving atmospheric $^{7}Be_{tot}$ deposition fluxes from water column $^{7}Be_{tot}$ inventories. Overall, our findings suggest that reversible exchange could significantly influence the oceanic cycling of ^{7}Be at some locations, and should not be systematically neglected when using $^{7}Be_{d}$ as an oceanic tracer.