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On the estimation of deglacial changes in ocean ventilation from a global compilation of deep-sea radiocarbon records

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The deep ocean is renewed, or “ventilated”, when surface waters present at high latitudes become sufficiently cold and dense to sink. These waters subsequently spread laterally, filling the various deep oceanic basins, and eventually return to the sea surface through mixing and upwelling. Ventilation is therefore the process by which the deep ocean communicates with the atmosphere and, as such, is thought to play an important role in the exchange of climatically-relevant constituents, such as carbon dioxide, between these two media. Inferences about deep ocean ventilation both today and in the past are typically drawn from measurements of the radiocarbon age or concentration (Δ^{14}C) of deep-water samples and fossil carbonates found on the seafloor or in sediment cores. In our presentation, we will describe an ongoing effort to compile deep-sea Δ^{14}C records from the world oceans as generated over the past three decades, and to extract from these records information about deep-ocean ventilation over the last deglaciation. Our current compilation includes about 1,600 Δ^{14}C data with estimated uncertainties. It is based primarily on measurements on benthic foraminifera and deep-sea corals originating from all major oceanic basins, ranging from 250-5000 m water depths, and spanning the past 40 kyrs. A preliminary effort to extract from the compiled data quantitative information about ventilation changes in the deep Atlantic from 20 to 10 kyr BP will be presented. In this analysis, a numerical model of Δ^{14}C transport is combined with Δ^{14}C data using recursive least-squares techniques of optimal estimation theory (a Kalman filter and a related smoother). This approach leads to an estimate of the time-dependent discrete velocity field that is consistent with the data and the model, given estimates of their respective error statistics. The formidable computational challenge posed by the application of recursive techniques to ocean state estimation is addressed by using a model with coarse resolution (3 degrees horizontally and 4 layers) and an approximate filter and smoother. In our presentation, an estimate of the deglacial history of ventilation rates of deep Atlantic basins and of their errors as obtained through this approach will be described and discussed.