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# Past atmospheric krypton and xenon over the last 24,000 years from trapped air in polar ice cores: A potential constraint on mean ocean temperature

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Prior work has shown that atmospheric concentrations of Kr and Xe respond mainly to mean ocean temperature variations, due to their strongly temperature-dependent solubility in liquid water and due to the fact that no significant sources or sinks exist in the ocean-atmosphere system (Headly and Severinghaus, 2007 JGR; Ritz et al., 2011 QSR). Because roughly 80% of the ocean's volume is colder than 4˚C, and cold water holds more gas than warm water, the atmospheric noble gases Kr and Xe mainly record changes in deep ocean temperature. Records from the WAIS Divide, GISP2 and Dome Fuji ice cores show a large increase in the $Kr/N_2$ and $Xe/N_2$ over the time interval 19 ka to 15 ka, equivalent to $\sim$1.5 ˚C deep ocean warming (from the WAIS data and a box model). This time interval is contemporaneous with Heinrich Stadial 1, a time of strong retreat of southern hemisphere mountain glaciers, rapid warming of southern mid-latitude surface waters, and weak northern hemisphere monsoons, all consistent with a south-shifted ITCZ and weak Atlantic Meridional Overturning Circulation (the "bipolar see-saw" in its warm-south mode). These new data are consistent with the idea that the initial rise in $CO_2$ at the last Termination was caused by a strong increase in the rate at which the deep ocean is exposed to the atmosphere around Antarctica (known as "ventilation") and the concomitant release of $CO_2$ to the atmosphere. The WAIS Divide data also suggest a slow-down of ocean warming between 15 ka and 13 ka, and then the second strong warming by about one degree until $\sim$11.5 ka, roughly coincident with Antarctic Cold Reversal and Younger Dryas, respectively.