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Mean ocean temperature change over the last glacial transition based on heavy noble gases in the atmosphere

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On paleo-climatic timescales heavy noble gases (krypton and xenon) are conserved in the atmosphere-ocean system and are passively cycled through this system without interaction with any biogeochemical process. Due to the characteristic temperature dependency of the gas solubility factors in sea water, the atmospheric noble gas content is unambiguously linked to mean global ocean temperature (MOT). Here we use this proxy to reconstruct MOT over the course of the last glacial transition based on measurements of trapped air in the WAIS Divide ice core. We analyzed 78 ice samples with a recently developed method that yields the isotopic ratios of N2, Ar, Kr and the elemental ratios of Kr/N2, Xe/N2 and Xe/Kr in the trapped air with the required precision. Based on the isotopic ratios we correct the elemental ratios for the fractionation processes in the firn column to obtain the true atmospheric values. On the basis of a 4-box model that incorporates effects of sea-level change, different saturation states of the water and different temperature distributions in the global ocean, we infer MOT based on the three elemental ratio pairs and assess its uncertainty. On average, the uncertainty of our MOT record is +/- 0.27°C, which is a significant improvement to earlier studies that reached about +/- 1°C uncertainty. This allows an unprecedented assessment of the glacial-interglacial MOT difference, as well as a direct comparison between MOT and climate change for the first time. We find a LGM-Holocene difference of 2.6°C, which is on the lower end of what earlier studies have suggested (3 +/- 1°C) and provides a new constraint on ocean heat uptake over the last glacial transition. Furthermore, we find a very close relation between MOT and Antarctic temperatures which shows for the first time the effect of Atlantic overturning circulation changes on global ocean heat uptake. Finally, our record shows a MOT warming rate during the Younger Dryas that is almost double to that estimated for the current anthropogenic MOT warming. This represents the strongest MOT warming on record to our knowledge and challenges our current understanding of how the global ocean sets its temperature.