Atmospheric krypton and xenon from ice cores suggest a two degree deep ocean warming from 18 ka to 16 ka, consistent with deep ocean ventilation cause of atmospheric carbon dioxide increase

J.P. Severinghaus, Scripps Institution of Oceanography

Despite four decades of intensive research, the underlying causes of glacial cycles remain incompletely understood. It is broadly agreed that the Earth's orbit is the ultimate cause and pacemaker of the fluctuations of the ice ages, but it is also clear that the orbital influence on climate (known as Milankovitch theory) can only explain part of the observed record. In particular, the role of atmospheric carbon dioxide as an amplifier of the orbital effects remains poorly quantified, and the detailed mechanistic sequence of events is still poorly understood. Part of the reason for this gap is that the proximate cause of the atmospheric CO_2 increase remains elusive despite an abundance of proposed mechanisms.

Here I show that ice core-based reconstructions of the time histories of atmospheric krypton and xenon burdens add a potential clue. Prior work has shown that these noble gases 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 GISP2 ice core show a roughly one per mil increase in the krypton/nitrogen ratio and a three per mil increase in the xenon/nitrogen ratio over the time interval 18 ka to 16 ka, equivalent to a two degree deep ocean warming. This time interval is the first half of 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 southern-shifted thermal equator and weak Atlantic Meridional Overturning Circulation (the "bipolar see-saw" in its warm-south mode). Taken together, these new data support previous suggestions 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 respiration-derived CO_2 to the atmosphere.