

Long-term variations of hydrogen peroxide in Greenland ice cores over the past 200 years

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Atmospheric oxidants including ozone (O_3), hydroxyl radicals (OH), and hydrogen peroxide (H_2O_2) play essential roles in atmospheric chemistry through removal of greenhouse gases such as methane (CH_4) as well as formation of aerosols. H_2O_2 is the only oxidant that can be preserved in ice cores and thus is expected to provide a constraint on the past oxidant chemistry. However, it has been pointed out that H_2O_2 records in ice cores may be altered by post-depositional loss, although H_2O_2 is more likely to be preserved at sites with greater snow accumulation [Frey et al., 2006]. In this study, we analyzed H_2O_2 records over the past 200 years based on the SE-Dome II (67.19°N, 36.47°W, 3160.7 m above sea level) ice core, where the snow accumulation rate is specifically high (> 1 m/year) within Greenland [Iizuka et al., 2021].

H_2O_2 in the SE-Dome II ice core ranged from 26.7 ppb to 143.1 ppb with a long-term trend characterized by increase from 1800s to 1860s, decrease until 1900s, and again increase from 1970s. The comparison of annual H_2O_2 concentration with the seasonal accumulation rate reconstructed for the SE-Dome II ice core showed no significant correlation ($r < 0.1$), suggesting that seasonality in snow accumulation rate is not a determining factor in preserved H_2O_2 . This result supports the hypothesis that H_2O_2 in the SE-Dome II ice core reflects atmospheric H_2O_2 variation. Our results were compared with H_2O_2 records in other Greenland ice cores from Dye2 [McConnell et al., 2013], Dye3 [Sigg and Neftel., 1991], Summit [Sigg and Neftel., 1991; McConnell et al., 2013], and Tunu [McConnell et al., 2016], which showed generally consistent long-term variations in H_2O_2 . Principal component analysis using the H_2O_2 data from all sites yielded the PC1 responsible for 35% variance, which was also generally consistent with the trend observed in the SE-Dome II ice core. This suggests that the trend in the PC1 is common over Greenland and reflects variations of atmospheric H_2O_2 . The decrease in H_2O_2 from 1860s to 1970s found in the PC1 coincides with the increases of black carbon (BC) and sulfate aerosols (SO_4^{2-}) recorded in Greenland ice cores, which is attributed to combustion of fossil fuels [McConnell et al., 2007]. This co-variation implies that H_2O_2 decreases in Greenland ice cores reflect the reduction of H_2O_2 production due to the accelerated uptake of precursor HO_2 by aerosols, of which importance for oxidant chemistry have been recognized in the recent studies [Mao et al., 2013; Ke Li et al., 2019].