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Annual layering in the NGRIP ice core during the Eemian

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The Greenland NGRIP ice core continuously covers the period from present day back to 123 ka before present, which includes several thousand years of ice from the previous interglacial period, MIS 5e or the Eemian. In the glacial part of the core annual layers can be identified from impurity records and visual stratigraphy, and stratigraphic layer counting has been performed back to 60 ka. In the deepest part of the core, however, the ice is close to the pressure melting point, the visual stratigraphy is dominated by ice crystal boundaries, and annual layering is not visible to the naked eye. In this study, we apply a newly developed setup for high-resolution ice core impurity analysis to produce continuous records of dust, sodium and ammonium concentrations as well as conductivity of melt water. We analyzed three 2.2 m sections of ice from the Eemian and the glacial inception. In all of the analyzed ice, annual layers can clearly be recognized, most prominently in the dust and conductivity profiles. Part of the samples is, however, contaminated in dust, most likely from drill liquid that entered the core through grain boundaries. It is interesting that the annual layering is preserved despite a very active crystal growth and grain boundary migration in the deep and warm NGRIP ice. Based on annual layer counting of the new records, we determine a mean annual layer thickness close to 10 mm for all three sections, which, to first order, confirms the modelled NGRIP time scale (ss09sea). The counting does, however, suggest a longer duration of the climatically warmest part of the NGRIP record (MIS5e) of up to 1 ka as compared to the model estimate. Our results suggest that stratigraphic layer counting is possible basically throughout the entire NGRIP ice core provided sufficiently highly-resolved profiles become available. A 120 ka independent Greenland time scale would provide an important tool for climate reconstruction of the late Quaternary and we hope to make such a chronology available in the coming years.