Presenter: Stephen Lougheed

Article: Hörhold, M., T. Münch, S. Weißbach et al. 2022. Modern temperatures in central–north Greenland warmest in past millennium. *Nature* 613: 503–507.

Context: Human-induced climate change is irrevocably altering ecosystems and species distributions with potentially profound consequences for human well-being. The Greenland Ice Sheet plays a pivotal role in global climate because of its size, radiative effects, and freshwater storage. The average annual global temperature has increased to 1 °C above pre-industrial levels in the second decade of the 21st century, with the Arctic disproportionately affected.

Knowledge deficit: Instrument-based temperature records extend back only about 200 years, but imply a lag in warming compared to other regions. Previous ice-core data from central and north Greenland are inconclusive regarding anthropogenic forcing on the surface temperature in Greenland and we thus know little about recent trends in this large and important ice sheet. Climate models are insufficient for quantifying local or regional patterns. Robust temperature reconstructions from palaeoclimate proxies are essential for estimating pre-industrial natural climate variability to quantify true recent warming trends

Research objectives: To use ice cores and isotopic data to create a high-quality reconstruction of central and north Greenland temperatures from AD 1000 until 2011

Hypothesis: Temperatures in the decade spanning 2001-2011 shows a significant departure in inferred temperatures compared to pre-industrial temperatures with elevated run-off.

Methods: The authors sought to augment a previous dataset that extended only to the mid 1990s that was based on 13 ice cores from 12 distinct sites (from a sampling campaign called the North Greenland Traverse or NGT) and 3 additional cores from the North Greenland Ice Core Project (NGRIP) deep ice core project. They redrilled shallow ice cores from 5 of these sites to capture time between 1995 and 2011 and to quantify the most recent temporal trends. The authors used electrical profiling of different segments of these ice cores to derive dating tie points (calibrations) by matching against known volcanic eruptions. They estimated $\delta^{18}O$ (deviation of the ratio of oxygen-18 to oxygen-16 isotopes from the global mean ratio in the ocean) for dated sections of the cores – and then estimated the annual mean $\delta^{18}O$ time series from the raw $\delta^{18}O$ data to quantify the depth and the depth–age relationship. The authors then converted the $\delta^{18}O$ values to temperatures using known linear calibrations (for Greenland 1/0.67 °C per ‰). Greenland meltwater run-off was inferred from the surface mass balance outputs of the regional climate model called MAR3.5.2.

Results: Warming in the recent reconstructed decade (2001-2011) exceeds the range of pre-industrial temperature variability in the past millennium ($P < 0.001$) and is, on average, 1.5 ± 0.4°C warmer than the twentieth century. The NGT-2012 stack (the new combined dataset) showed a strong correlation ($R \geq 0.75$, $P < 0.01$) with the decadal annual mean air temperatures from weather stations along the Greenlandic coast for the period that these different data sources overlapped. Together with other evidence, these new data comprise a robust temperature record for central and north Greenland over the past millennium.

Overarching conclusions: Recent temperatures and meltwater run-off in central and north Greenland are higher now than at any time in the last millennium. Thus, global warming is now detectable in one of the most remote regions on earth. An increasing loss of the Greenland ice sheet is predicted with potentially global impacts on climate and sea levels worldwide.