Valérie V.M. Raas

Investigating Solar Storms from over 14,000 years ago

Solar storms occur when the Sun releases bursts of highly energetic particles, known as Solar Energetic Particles (SEPs), into space. Occasionally, these storms are strong enough that the SEPs reach Earth, where they interact with particles in our atmosphere and cause a sudden spike in the production of radioactive isotopes like beryllium-10 (^{10}Be), carbon-14 (^{14}C), and chlorine-36 (^{36}Cl). These isotopes are eventually deposited on Earth, where they are stored in natural archives such as ice cores or tree rings. Because these archives are precisely dated, stretching back tens of thousands of years, they allow us to measure past levels of these isotopes and thereby reconstruct past solar activity. Understanding when and how often these events happened, and how powerful they were, is important as they pose serious risks to astronauts, satellites, and electrical systems on Earth.

This study investigates two possible ancient solar storms around 14,300 and 14,700 BP ('Before Present', where 'Present' refers to the year 1950 CE), as this time interval has not been researched before and we can see from lower-resolution isotope records that there seems to be a spike there. This was done by extracting ^{10}Be and ^{36}Cl from a Greenland ice core. Their respective concentrations were measured using highly sensitive instruments. From this data, a timeline was created showing how the levels of these isotopes varied over the researched timespan.

Before interpreting the records, it was important to check the record for potential climate influences, as changes in snowfall can affect isotope concentrations in ice cores: increased snowfall dilutes the signal, while less snowfall amplifies it. This means a concentration spike could reflect either a solar storm or simply reduced snowfall. This effect was evaluated by assessing whether there was a correlation between the isotope concentrations and past temperature data from the same ice core. In polar regions like Greenland, higher temperatures generally lead to increased snowfall. No link was found between concentrations and climate during the interval surrounding the 14,300 BP interval, while there was a clear connection around 14,700 BP. This means that climate effects have to be considered for the latter. After doing so, it was confirmed that a major solar storm occurred around 14,300 BP. According to the new data, this storm appears to have been exceptionally intense and marked by very high-energy SEPs. It was far more powerful than any event recorded since instrumental measurements on Earth began, and ranks among the strongest ever detected in ice records. Aside from solar storms, ^{10}Be and ^{36}Cl are normally produced in our atmosphere by particles from outside our solar system. The Sun's magnetic field acts as a shield blocking these particles, so during high solar activity, fewer reach Earth, but during quiet solar periods, more get through and generate isotopes. The data shows the 14,300 BP solar storm happened during a time of high solar activity, which agrees with modern observations that solar storms usually occur during these active periods.

In contrast, no conclusive evidence was found for a similar event at 14,700 BP. This appears to be a time where climate had a large influence on ^{10}Be and ^{36}Cl concentrations. This means that the data from this time period is too difficult to interpret, which makes it hard to see any clear signs of a solar storm. If a solar storm did happen, its effects are hidden by the natural climate changes that were also happening then.

Master's Degree Project in Geology 45 credits 2025
Department of Geology, Lund University

Supervisor: **Raimund Muscheler**