Diedrich Fritzsche[1)], Luisa von Albedyll[1),2)], Silke Merchel[3)], Thomas Opel[1),4)], Georg Rugel[3)], Andreas Scharf[3)]
[1)] Alfred Wegener Institute, Potsdam [2)] University of Bremen [3)] Helmholtz-Zentrum Dresden-Rossendorf [4)] University of Sussex

The Akademii Nauk ice core and solar activity

Fig.1: Map of the Arctic.

Inset: Severnaya Zemlya with Akademii Nauk ice cap and drilling site at 80°31'N 94°49'E (altitude about 750 m a.s.l.).

Knowledge of the natural climate variability is essential for the understanding and assessment of the recent climate change and reliable predictions of future climate. In the Arctic, a key region for the global climate system and more affected by the ongoing warming than other regions, meteorological records are relatively short, with only a few time series starting before the 20th century. Hence, climate archives, especially high-resolution ones like ice cores, are of particular importance for the assessment of past and recent climate changes.

To gain new high-resolution proxy data for the reconstruction of climate and environmental changes, in 1999-2001 a 724 m long ice core was drilled near the summit of Akademii Nauk (AN) ice cap, the largest glacier on Severnaya Zemlya (Fig. 1) within a joined German - Russian project (*Fritzsche et al., 2002*). The first core chronology was based on annual layer counting using $\delta^{18}O$, δD and d-excess data, cross-checked by radioactive (^{137}Cs) horizons and non-sea-salt (nss) SO_4 peaks interpreted as volcanic signals. The Akademii Nauk ice cap has a relatively low altitude compared to Greenland and is affected by melting and infiltration processes in summertime. Percolating waters cause alterations of original isotopic and chemical signals, which makes the interpretation more difficult. This requires an additional climate-independent approach to validate the age model.

The concentration of cosmogenic radionuclides in ice cores reflects the solar activity in the past and, thus, can be used as a dating tool for ice cores. Accelerator mass spectrometry (AMS) allows the determination of nuclides in high resolution. Using a core-sampling strategy for ^{10}Be developed by *von Albedyll et al. (2017)* more than 500 AN ice-core samples were taken, chemically treated and analysed at the DREAMS (DREsden Accelerator Mass Spectrometry) facility of the Helmholtz-Zentrum Dresden-Rossendorf (*Akhmadaliev et al., 2013; Rugel et al., 2016*) using the 6 MV accelerator of the Ion Beam Center (Fig. 5). For the time period 430 to 2000 AD - corresponding to core depth of 0 m to 452 m - the temporal variations of ^{10}Be reflect the centennial variations of solar activity known from Greenlandic and Antarctic ice cores and from reconstructions of ^{14}C production (Fig. 2).

In the AN core the strongest ^{10}Be peak was found at a depth of 402.22 m (Fig. 3) corresponding to the strongest known solar energetic particle storm in 774/775 AD (*Sigl et al., 2015; Sukhodolov et al., 2017*). It was used as an additional tie point for the AN core chronology. Additionally, slight indications for the 1859 solar storm (Carrington event) were found in AN core but much weaker than the 774/775 AD event.

A high-resolution record of environmental data at AN was reconstructed for the last millennium by *Opel et al. (2013)*. Here, we present the extended $\delta^{18}O$ record (temperature proxy) for 430 to 2000 AD using the updated chronology (Fig. 4).

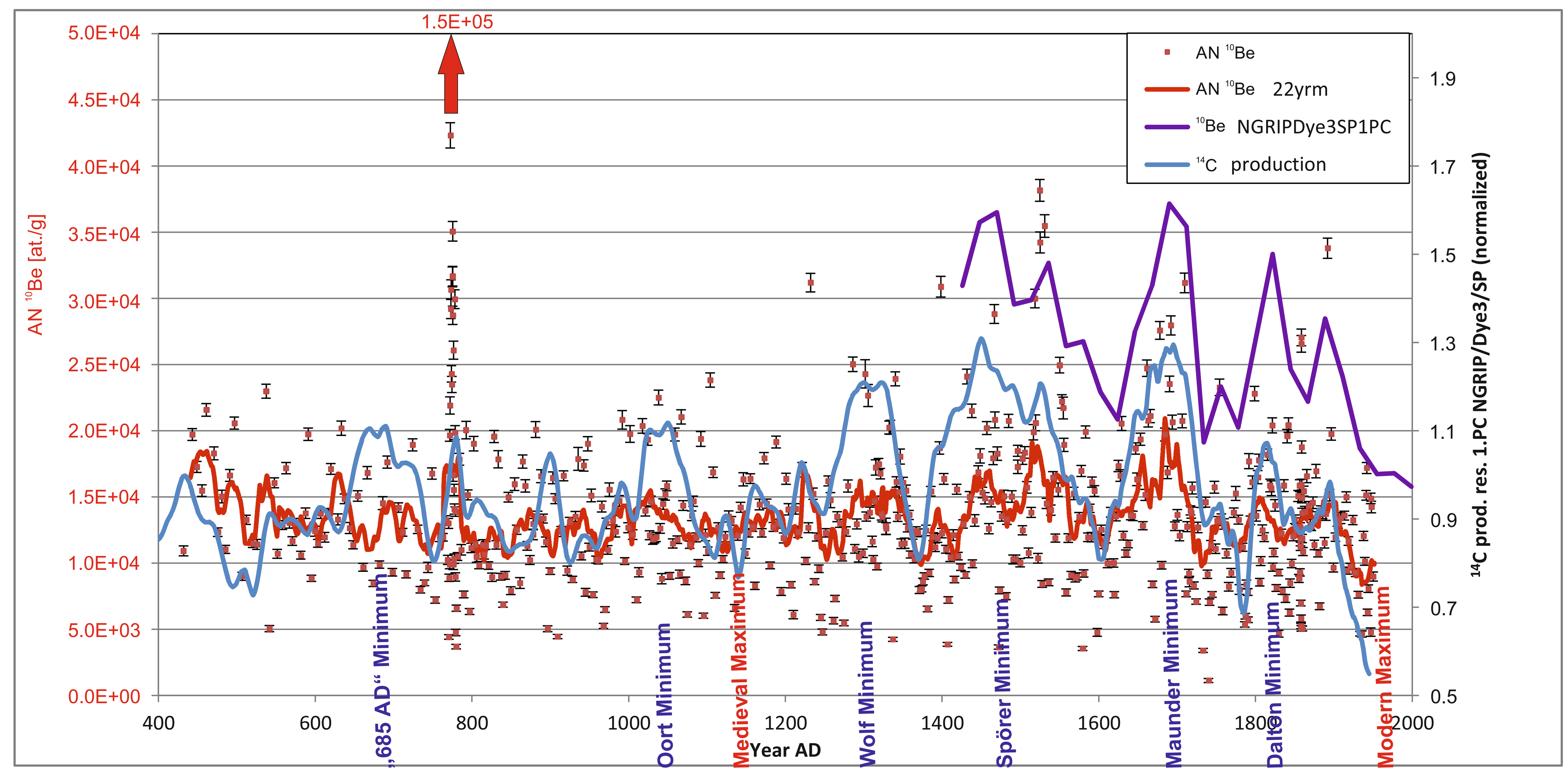

Fig.2: Concentration of ^{10}Be in the AN ice core compared with ^{14}C production after *Muscheler et al., 2005* and the first principal component of ^{10}Be records from ice cores drilled at NGRIP, Dye3 (both Greenland) and at South Pole after *Steinhilber et al., 2012.*

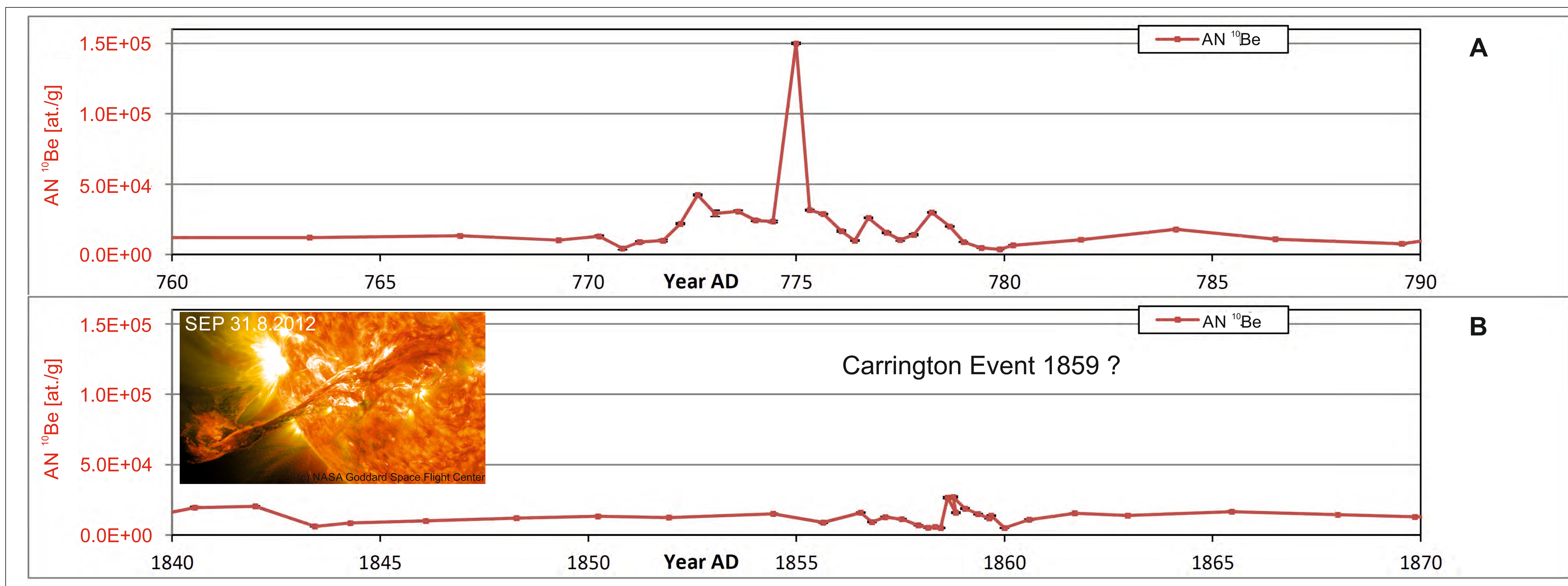

Fig.3: The distinct ^{10}Be peak in 774/775 AD (**A**) is related to the strongest solar energetic particle (SEP) event known. Slight indications of the first directely observed SEP, the so called "Carrington Event" in 1859 AD (**B**), were detected, but the signal might be about 30 times weaker than the event of 774/775 AD.

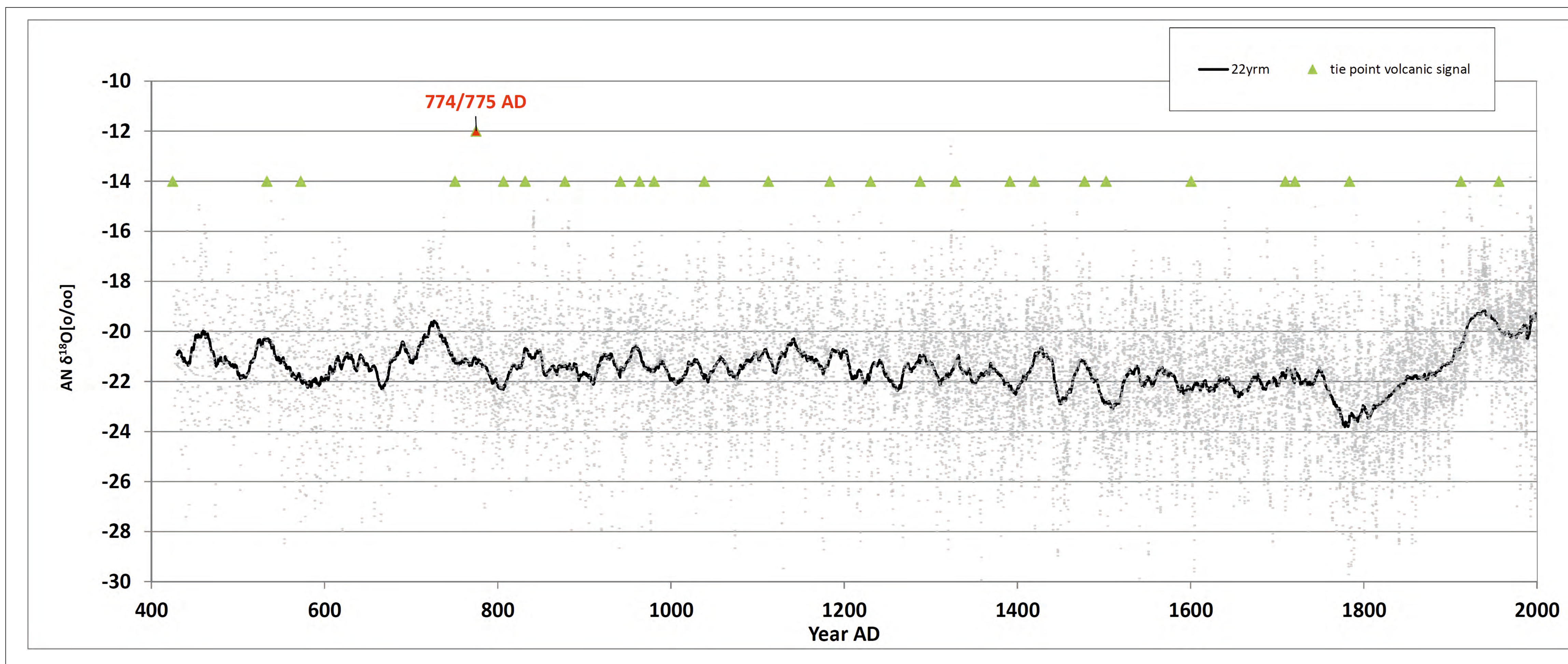

Fig.4: $\delta^{18}O$ record of the upper 452 m of AN ice core, using an updated core chronology considering the tie point of 774/775 AD.

Fig.5: DREAMS (DREsden Accelerator Mass Spectrometry) facility: Machine layout E.S.A. = electrostatic analyser).

References
Akhmadaliev, S. et al., *Nucl. Instrum. Meth. Res.* B, **294** (2013), 5-10
Albedyll, L. von et al., *J. Glaciol.*, **63** (2017), 514-522
Fritzsche, D. et al., *Ann. Glaciol.*, **35** (2002), 25-28
Muscheler, R. et al., *Quat. Sci. Rev.*, **24** (2005), 1849-1860
Opel, T. et al., *Clim. Past.*, **9** (2013), 2379-2389
Rugel, G. et al., *Nucl. Instrum. Meth. Res.* B, **370** (2016), 94-100
Sigl, M. et al., *Nature*, **523** (2015), 543-549
Steinhilber, F. et al., *PNAS*, **109** (2012), 5967-5971

Acknowledgements

Parts of this research were carried out at the Ion Beam Centre (IBC) at the Helmholtz-Zentrum Dresden-Rossendorf e. V., a member of the Helmholtz Association. Insightful discussions with D. Wagenbach (Heidelberg University, deceased) and his generous support are highly appreciated and valued. We thank Andreas Scharf, Shavkat Akhmadaliev and Santiago M. Enamorado Baez for their support to AMS measurements. The chemical sample preparation has been supported by Loic le Bras (France), Tina Köhler, Vicki Kühn, Malin Lüdicke, Katharina Stock, Collin Tiessen (Canada), Stephanie Uhlig, Hannes Wenzel and René Ziegenrücker.

Research Unit Potsdam
Telegrafenberg A45
14473 Potsdam
www.awi.de