Supplementary material for "NEEM to EastGRIP Traverse - spatial variability, seasonality, extreme events and trends in common ice core proxies over the past decades."

The Copenhagen CFA set up for the analysis of the shallow firn cores

In Figure S1 a flow chart of the CFA setup used to analyse the firn cores is presented.

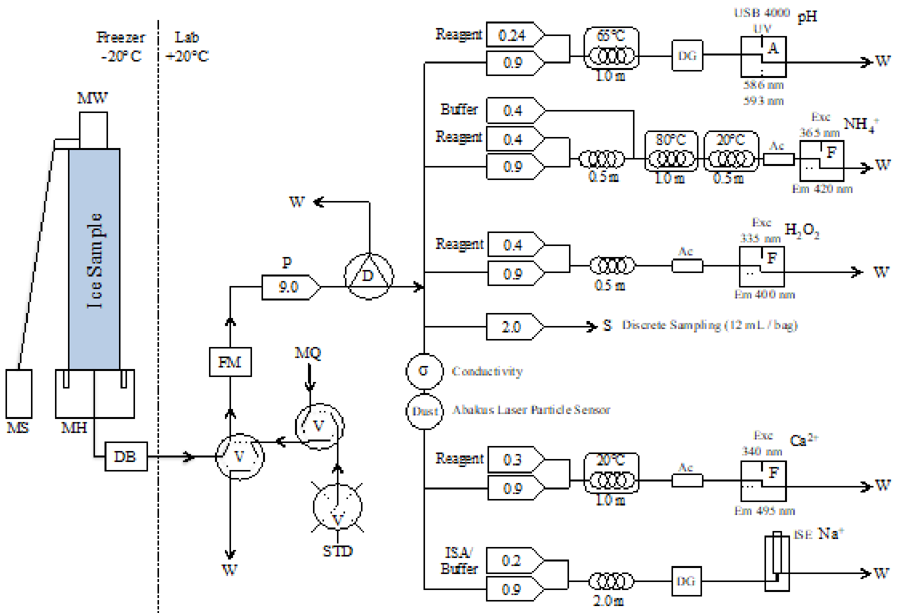


Figure S1: Copenhagen CFA (Bigler et al., 2011) set up used to measure the 6 firn cores. Flowchart of the Copenhagen continuous flow analysis system setup with a melt head (MH) melting the ice sample, melting speed encoder (MS), melting weight (MW), debubbler (DB) selection and injection valves (V) for standard solutions (STD) and blanks (MQ), waste (W), flow meter (FM), peristaltic pumps (P), triangular debubbler (D), buffer and reagents, reaction coils, Accurel membrane debubblers (Ac), absorption (A), fluorescence (F), discrete sampling line (S), conductivity detector (σ), particle sensor (Dust) and a vacuum degassing unit. Arrows indicate flow directions. Flow rates within the pump system (mL min^{-1}), temperatures, reaction coil lengths and detector light wavelengths are shown in the flowchart.

Insoluble dust was determined using an Abakus laser particle detector with a LDS-23/25bs sensor type (Klotz, (Simonsen et al., 2018)) and the conductivity using a bench-top conductivity meter (3082 with micro flow cell 829, Amber Science). The measurements of ammonium, hydrogen peroxide and calcium is based upon fluorescence methods (Kaufmann et al., 2008; Bigler et al., 2011) using photomultiplier detectors (PMT-FL, FIAlab instruments) and spectrofluorimeters set to specific (Sigg et al., 1994a). Acid was determined as described in Kjær et al. 2016a using a dye-based method. In Table S1 and S2 a full list of reagents and instrumentation used is presented.

Table S1. Overview of measurement instruments of the Copenhagen CFA system (Bigler et al., 2011).

Parameter	Instrument
Conductivity	Amber Science 3082 Muli-Function Conductivity Meter
Dust	Abakus LDS 23/25bs sensor, Klotz; ASL-1600-20, Sensirion
Ca^{2+}, NH_4^+, H_2O_2	PMT-FL Fluorometer, FIAlab Instruments
H^+	Ocean Optics USB 4000 Spectrometer
Na^+	PerfectION^{TM} comb Na^+, S220 SevenCompact^{TM}, Mettler Toledo

Table S2. Reagent and buffer solutions for fluorescence methods (Röthlisberger et al., 2000; Sigg et al., 1994b; Bigler et al., 2011; Kjær et al., 2016)

NH_4^+ reagent	**Components**	Lifetime: 2 days
950 mL	Milli-Q	
1.43 g	Fluoraldehyde o-Phthaldialdehyde reagent solution (OPA)	
60 mL	Ethanol	
NH_4^+ buffer	**Components**	Lifetime: 2 days
1L	Milli Q	
35.8 g	Sodium phosphate dibasic dodecahydrate ($Na_2HPO_4 \cdot 12H_2O$)	
600 µg	Sodiumhydroxide (NaOH >32%)	
100 µg	Formaldehyde (HCHO >37%)	
0.8 g	Sodium sulfite (Na_2SO_3)	
H_2O_2 reagent	**Components**	Lifetime: 3 days
1 L	Milli-Q	
0.61 g	4-ethylphenol	
5 mg	Peroxidase type II	
6.18 g	Boric acid (H_3Bo_3)	
7.46 g	Potassium chloride (KCl)	
150 µg	Sodium hydroxide (NaOH)	
Ca^{2+} reagent	**Components**	Lifetime: 1 days
800 mL	Milli-Q	
20 mg	Quin-2 Potassium hydrate	
2.91 g	PIPES	
1 - 1.5 mL	Sodium hydroxide (NaOH) to buffer pH7	
pH reagent	**Components**	Lifetime: >1 week
900 mL	Milli-Q	
0.025 g	Bromophenol Blue	
0.025 g	Chlorophenol Red	
250 µg	Brij L23	

The NH_4^+ and Ca^{2+} was calibrated using 3 standards made from a multielement stock solution, acid was calibrated with a two-point calibration made from a 0.1M HCl (Fluka), and the H_2O_2 was calibrated based on a two-point calibration using a Peroxide stock solution (30% H2O2). The standards concentration preparation scheme is presented in table S3.

Table S3. Concentrations of CFA standard solutions used to calibrate the data

Ca^{2+}, NH_4^+, Na^+	**Multi-element standard**	**Milli-Q**	**Concentration**
	µL	mL	ppb
Stock solution			10^5
Std 1	20	200	10
Std 2	50	200	25
Std 3	200	200	100
H_2O_2	**Peroxide standard**	**Milli-Q**	**Concentration**
	µL	mL	ppb
Stock solution			3×10^8
1st dilution	30	100	9×10^4
Std 1 (2nd dilution)	50	75	60
Std 2 (2nd dilution)	100	75	120
pH (H^+)	**Acidity standard HCL**	**Milli-Q**	**Concentration**
	µL	mL	µM
Stock solution			3.65×10^6
1st dilution	600	60	991
Std 1 (2nd dilution)	1200	120	9.8
Std 2 (2nd dilution)	2400	120	19.6

Additional analysis of the data

Conductivity in the 6 shallow cores are presented in Figure S2.

Table S4 presents the correlation of the excess ammonium between the 5 sites for which ammonium was analyzed.

In Figure S3 the particle dust fluxes are presented with time for small particles 1.25-2.9 um, medium particles 2.9-8.13 um and large particles 8.13-10.5 um.

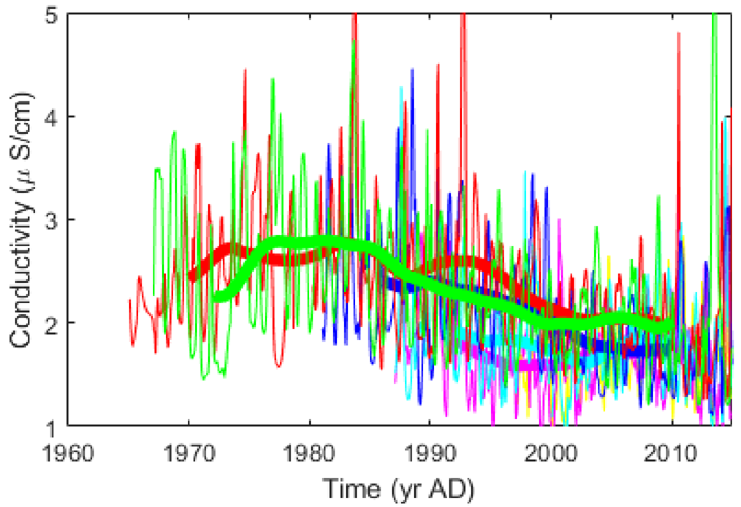
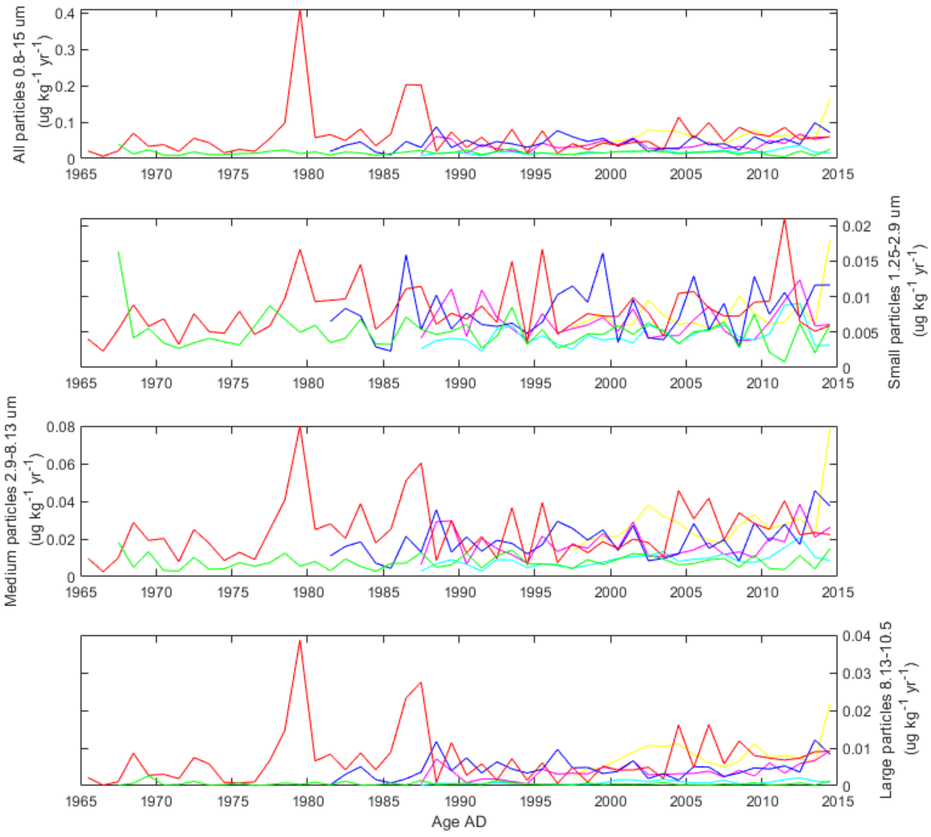


Figure S2: Conductivity of the T2015-A1 (yellow), T2015-A2 (purple), T2015-A3 (cyan), T2015-A4 (blue), T2015-A5 (red) and T2015-A6 (green) shown in monthly resolution (thin lines) and in a 5 year running average (thick lines).

Table S4: Correlation table for excess ammonium between the 5 shallow traverse cores. Excess ammonium is defined as excess compared to a 5 year running average. Italic shows the same allowing for a +- 1 year dating uncertainty of the entire record. In bold if p<0.1.

R^2	T2015-A1	T2015-A2	T2015-A3	T2015-A4	T2015-A6
T2015-A1	1.00	0.21, ***(0.70)***	**0.57**	-0.04 *(0.11)*	0.01 (0.53)
T2015-A2		1.00	-0.08 ***(0.67)***	0.04 *(0.17)*	-0.27 *(0.40)*
T2015-A3			1.00	0.29	**0.36**
T2015-A4				1.00	-0.14 *(0.18)*
T2015-A6					1.00



5 **Figure S3: Insoluble dust particle fluxes determined from the Abakus instrument by assumptions of perfect spherical particles and a weight of 2400 kg/m³. From the top total 0.8-15 um, Small particles 1.25-2.9 um, Medium particles 2.9-8.13 um and Large particles 8.13-10.5 as observed in the T2015-A1 (yellow), T2015-A2 (purple), T2015-A3 (cyan), T2015-A4 (blue), T2015-A5 (red) and T2015-A6 (green)**.