

We are grateful for the comment by J. Savarino as it motivates to discuss in more detail the snow chemistry presented in this manuscript.

WAIS Divide and Summit have similar latitudes, surface temperature and snow accumulation rate (cf. Table 1 and Fig. 1a). Concentrations of nitrate in the top 0.5 cm of surface snow are also in the same range for both sites, between 24-206 ppbw for WAIS Divide and 61-207 ppbw for Summit (cf. Fig. 2a,b).

However, the median NO_3^- concentrations in the top 1 m of snow at WAIS Divide is lower than at Summit, 38 ± 4 vs. 138 ± 30 ppbw (median \pm standard deviation). At very dry and cold sites on the East Antarctic Plateau such as Dome C, mean nitrate concentrations are as low as 10-20 ppbw if one excludes the surface layer (Fig. 2c). Note that at Dome C most nitrate is concentrated in the top layer with levels 1-2 orders of magnitude larger than at depth (Erbland et al., 2012; Frey et al., 2009). Comparison of concentrations at the surface and at depth allows to estimate net preservation of nitrate in snow, which is $\sim 30\%$ at WAIS-Divide, 75-93% at Summit (Dibb et al., 2007; Burkhardt et al., 2004) and less than 10% at Dome C (Frey et al., 2009; Röthlisberger et al., 2002).

Differences in average nitrate concentrations in surface snow and preserved at depth between WAIS-Divide and Summit can be attributed to a) a lower background of atmospheric reactive nitrogen in Antarctica compared to the Arctic due to a larger distance from anthropogenic pollution sources and b) differences in processes occurring during and after deposition.

Regarding b) the nature of the processes involved is still under debate, i.e. both physical (evaporation and adsorption of nitric acid (HNO_3)) and photochemical (photolysis of nitrate) processes have been put forward to explain nitrate net preservation (sum of gain and loss) in polar snow (Frey et al., 2009; Röthlisberger et al., 2002). Both processes will be sensitive to accumulation rate and timing. For example, little snowfall in the sunlit season implies longer exposure of surface snow to UV radiation leading at some sites to significant loss of nitrate from photolysis (Erbland et al., 2012; Frey et al., 2009).

In general, nitrate concentration preserved in polar snow scale with mean annual temperature and accumulation rate (Röthlisberger et al., 2002; Fig.1). Comparison shows that nitrate concentrations at WAIS-Divide are not unusual at all as suggested in this comment, since they do fall into the range expected in Antarctica (Fig.1b,c). They are however still lower than those in pre-1940 snow at Greenlandic sites of similar accumulation rate and temperature (Fig.1). The slightly lower accumulation and thus slower burial rate of annual snow deposition at WAIS Divide vs. Summit may contribute to this difference in NO_3^- preservation.

But, as suggested by J. Savarino and the recent literature, variables linked to (post-)depositional processes other than accumulation rate may contribute as well to the observed difference and include micro physical properties and chemical composition of the snow matrix. Regarding the latter, observations of atmospheric and snow nitrate in coastal Antarctica showed that deposition of nitrate spikes is linked to sea salt aerosol, i.e. via conversion of gas-phase nitrate to nitrate aerosol and enhanced trapping of gas-phase nitrate on salty surfaces (Wolff et al., 2008). This enhanced deposition efficiency will be less important further inland. However, higher nitrate concentrations were also associated

with higher dust content (i.e. calcium Ca^{2+}), suggesting reduced post-depositional loss of nitrate via photolysis or evaporation (Röthlisberger et al., 2000). In comparison with Summit, the lower dust content in WAIS Divide snow – 5 times less alkaline, 4 times less Ca^{2+} (cf. Table 1) – may reduce the preservation of nitrate in snow and conversely enhance the NO_x emission flux in summer. Systematic differences of NO_x emissions from surface snow could indeed further support differences in the strength of the local nitrate sink in snow. However, Honrath et al. (2002) measured at Summit 24-h average NO_x fluxes of 2.5×10^8 molecule $\text{cm}^{-2} \text{s}^{-1}$, in the range of what we calculated for WAIS Divide. Based on a similar approach to our study, Zatzko et al. (2013) recently modeled NO_x flux at Summit 5-10 times that reported by Honrath ($13\text{-}28 \times 10^8$ molecule $\text{cm}^{-2} \text{s}^{-1}$). These results point to significant NO_x emissions from nitrate in the snowpack at both sites, but uncertainties in available measurements and model estimates prevent to conclude that emission rates are significantly higher at WAIS-Divide than at Summit.

Further, the stable isotopic composition of nitrate in snow can yield information on the amount of post-depositional nitrate loss (e.g. Erbland et al., 2012; Frey et al., 2009). At Summit the N and O isotopes of nitrate showed that most of the NO_x emitted from the surface snow is recycled back to the snow as NO_3^- explaining high NO_3^- preservation (Hastings et al., 2004). It can be speculated that if the nitrate loss rate was similar at WAIS-Divide, then some of the emitted gas phase species may be lost through lateral export implying a lower recycling efficiency and therefore lower NO_3^- preservation.

Thus NO_3^- post-depositional loss is a non-linear combination of both accumulation and temperature, but other parameters need also to be considered including snow chemistry to get a more complete process understanding.

Table 1: Surface snow concentrations, in $\mu\text{Eq L}^{-1}$, of major ions measured at Summit and WAIS Divide.

	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO_3^-	SO_4^{2-}	pH ^a	Alkalinity ^b
Summit:										
Mean annual temperature: -29.5°C										
Snow accumulation: $24\text{cm}_{\text{weq}} \text{yr}^{-1}$										
Dibb, 2007 ^c	0.176	0.529	0.066	0.131	0.972	0.641	3.14	1.49	5.30	1.64
Dibb, 2008 ^c	0.116	0.282	0.074	0.046	0.287	0.547	3.86	1.12	5.27	0.654
Mayewski, 1987 ^d	0.087	0.333	0.026	0.082	0.749	0.226	0.645	1.87	5.58	1.16
Geosummit, 2003-2009 ^e	0.355	1.16	0.250	0.153	0.903	1.18	3.77	2.24	5.17	2.36
								Average	5.33	1.45
WAIS-Divide:										
Mean annual temperature: -28.5°C										
Snow accumulation: $20\text{cm}_{\text{weq}} \text{yr}^{-1}$										
ITASE00-1, 2000 ^f	0.552	0.392	0.026	0.082	0.423	0.667	0.388	0.506	6.07	0.757
Cole-Dai, 2006 ^g	0.242	0.249	0.042	0.060	0.060	0.943	0.980	0.889	5.60	0.339
Cole-Dai, 2006 ^g	0.180	0.136	0.009	0.071	0.109	0.888	0.994	0.865	5.60	0.271
Cole-Dai, 2006 ^g	0.738	0.291	0.015	0.162	0.065	1.08	1.00	0.688	5.74	0.311
Kreutz, 2008 ^g	1.33	-	0.043	0.374	0.269	1.51	1.09	0.851	5.76	0.286
								Average	5.68	0.302

^a using $[\text{H}^+] = [\text{SO}_4^{2-}]^* + [\text{NO}_3^-] + [\text{Cl}^-]^*$ (Legrand and Delmas, 1988) with $[\text{SO}_4^{2-}]^* = [\text{SO}_4^{2-}] - 0.12 \times [\text{Na}^+]$ and $[\text{Cl}^-]^* = [\text{Cl}^-] - 1.17 \times [\text{Na}^+]$;

^b derived from the ionic balance and attributing the missing part of anions to dissolved carbonate;

^c Dibb et al. (2010);

^d Mayewski et al. (1990);

^e unpublished data from <http://www.geosummit.org>;

^f unpublished data, Mayewski et al. (2005);

^g unpublished data from <http://www.waisdivide.unh.edu/>

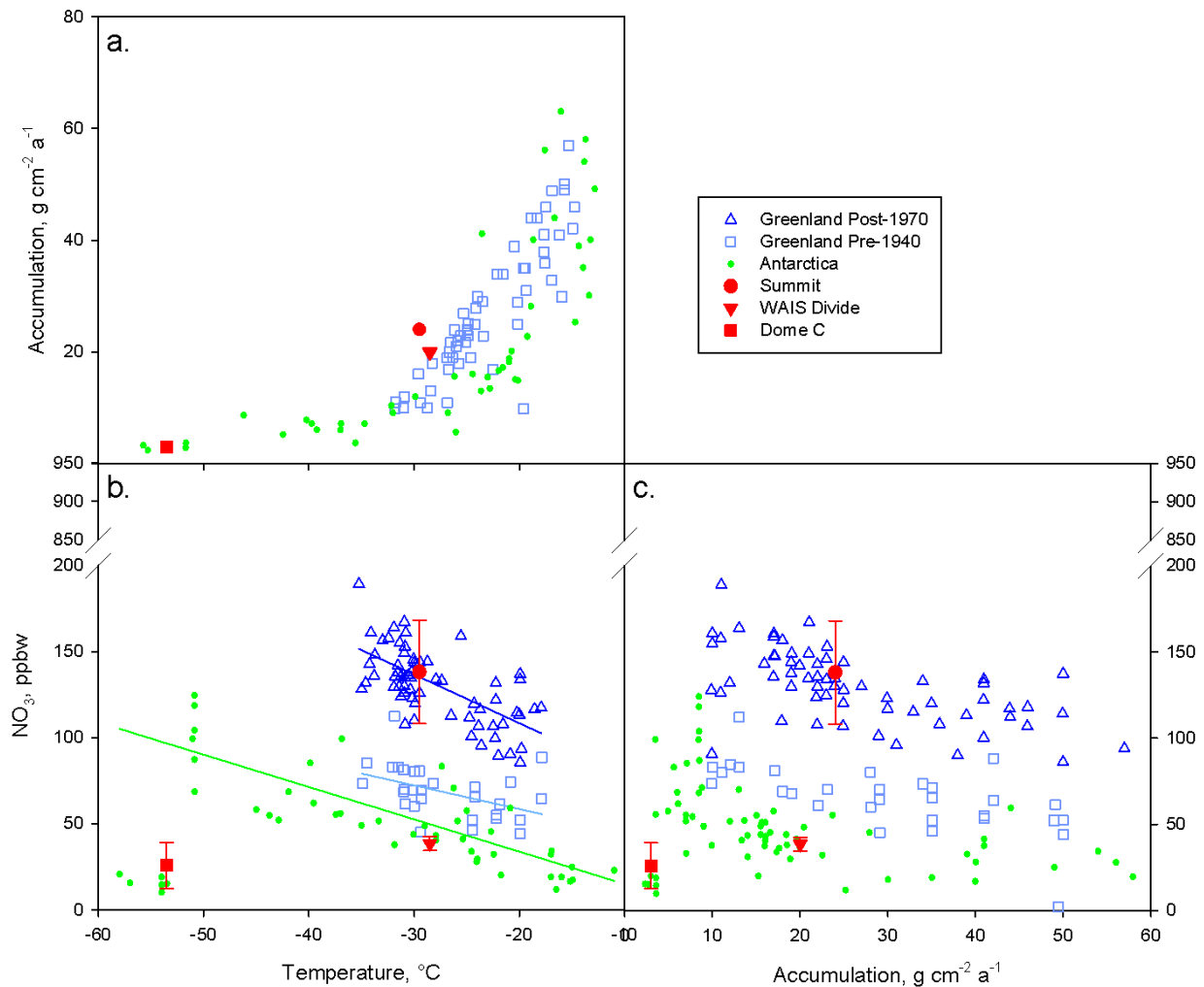


Figure 1: Updated figures 2, 3 and 4 from Röthlisberger et al. (2002) with additional measurements from WAIS Divide, Summit and Dome C (median \pm standard deviation). Data reported from Greenland are NO_3^- concentrations in snow deposited either before 1940 (squares) or after 1970 (triangles). The nitrate levels observed in the snow deposited after 1970 over Greenland are influenced by anthropogenic emissions that do not reach the Antarctic continent; whereas the difference between the pre-1940s records and the Antarctic data is likely due to a difference in alkalinity.

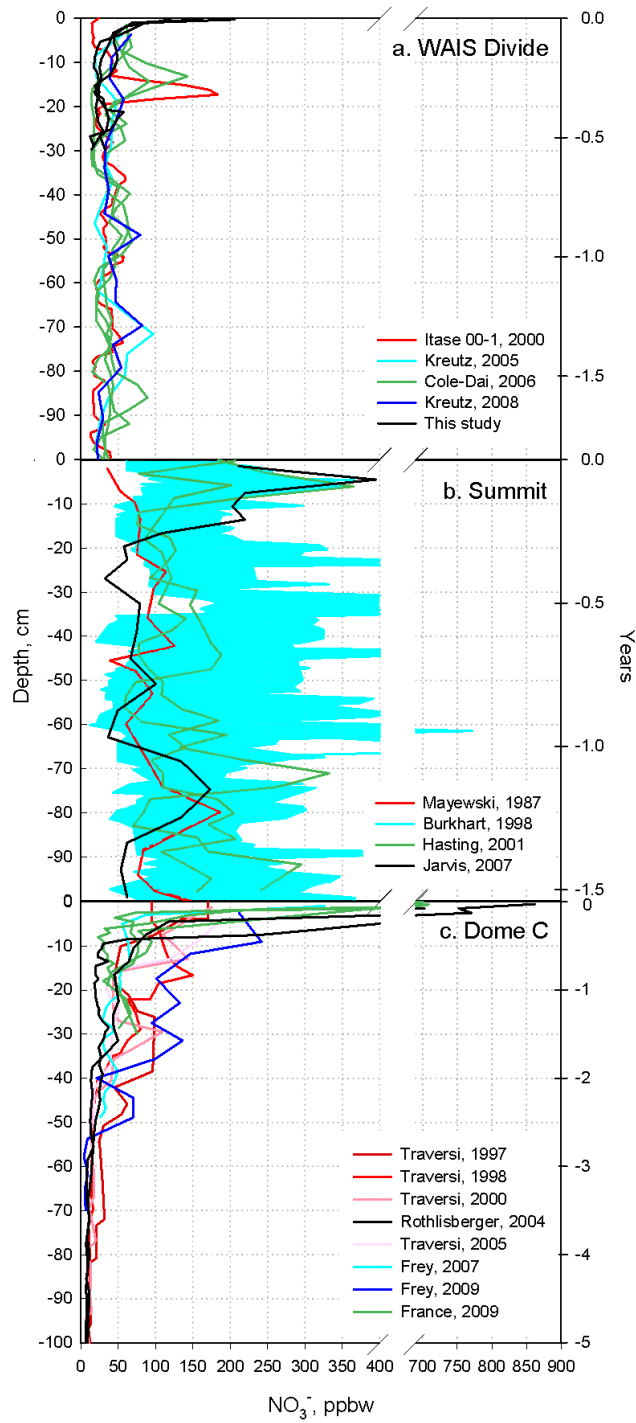


Figure 2: 1-m NO_3^- profiles from snowpits reported from WAIS Divide, Summit and Dome C (data from Frey et al., 2012; France et al., 2011; Traversi et al., 2009; Jarvis (unpublished data); Burkhart et al., 2004; Hastings, 2004; Röthlisberger et al., 2000; Mayewski et al., 1990).

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