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Characterization of in situ cosmogenic ^{14}CO production, retention and loss in firn and shallow ice at Summit, Greenland

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Supplement for "Characterization of *in situ* cosmogenic ^{14}CO production, retention and loss in firn and shallow ice at Summit, Greenland" by Hmiel et al.

Table S1: Measurements and associated corrections for Summit 2013 firn air samples.

All uncertainties represent ± 1σ. Measured pMC values shown are after the empirical correction for ANSTO processing. The procedural blanks were not measured for $\delta^{13}CO$ and a value of -32.5 ± 7.5 ‰ is assumed instead; this large uncertainty does not make a significant impact on the uncertainty of the final [^{14}CO] values since the CO carbon from air in the blanks contributed only ~1-2% of total C in the diluted samples that were measured for ^{14}C. No corrections for firn gravitational or diffusive isotopic fractionation were applied, as these are also negligible compared to other sources of [^{14}CO] uncertainty.

Sample depth, m	Measured x_{CO} prior to dilution, nmol / mol	Measured $\delta^{13}CO$ prior to dilution, ‰ relative to VPDB	Fraction of CO carbon from sample after dilution with ^{14}C-depleted high-CO gas	Measured ^{14}C of CO in diluted samples, pMC	[^{14}CO] corrected for dilution, molecules / cm^3 STP air	[^{14}CO] further corrected for procedural blank, molecules / cm^3 STP air
0	151.7 ± 3.0	-24.85 ± 0.17	0.0909 ± 0.0035	47.99 ± 0.70	23.70 ± 0.88	20.55 ± 0.94
11.32	187.4 ± 3.0	-26.89 ± 0.19	0.0913 ± 0.0030	42.29 ± 0.54	25.50 ± 0.82	22.57 ± 0.86
20.99	153.7 ± 3.0	-26.88 ± 0.17	0.0906 ± 0.0034	48.49 ± 0.67	24.35 ± 0.89	21.52 ± 0.92
31.83	152.0 ± 3.0	-26.54 ± 0.20	0.0907 ± 0.0035	48.66 ± 0.89	24.13 ± 0.94	21.42 ± 0.96
44.69	149.5 ± 3.0	-25.89 ± 0.17	0.0915 ± 0.0036	52.42 ± 0.78	25.38 ± 0.96	22.77 ± 0.98
60.25	142.8 ± 3.0	-25.11 ± 0.19	0.0909 ± 0.0037	56.79 ± 1.03	26.50 ± 1.06	24.01 ± 1.08
68.02	145.3 ± 3.0	-24.87 ± 0.17	0.0911 ± 0.0045	56.48 ± 0.67	26.75 ± 1.29	24.37 ± 1.30
69.98	160.0 ± 3.0	-26.42 ± 0.25	0.0917 ± 0.0034	53.29 ± 0.87	27.59 ± 1.02	25.20 ± 1.03
72.21	156.6 ± 3.0	-24.81 ± 0.20	0.0912 ± 0.0034	56.83 ± 0.95	29.00 ± 1.08	26.72 ± 1.09
74.05	181.5 ± 3.0	-24.71 ± 0.17	0.0909 ± 0.0030	57.03 ± 0.63	33.81 ± 1.07	31.53 ± 1.08
76.04	173.0 ± 3.0	-25.02 ± 0.17	0.0911 ± 0.0031	61.90 ± 0.75	34.97 ± 1.16	32.80 ± 1.17
78.03	181.8 ± 3.0	-24.97 ± 0.17	0.0907 ± 0.0030	65.41 ± 0.73	39.05 ± 1.23	36.88 ± 1.24
80.06	175.0 ± 3.0	-26.08 ± 0.37	0.0912 ± 0.0031	74.14 ± 1.15	42.47 ± 1.45	40.41 ± 1.46
procedural blank 1	19.0 ± 3.0	*-32.50 ± 7.50*	0.0132 ± 0.0021	8.24 ± 0.41	3.04 ± 0.23	
procedural blank 2	30.2 ± 3.0	*-32.50 ± 7.50*	0.0211 ± 0.0023	5.49 ± 0.19	1.83 ± 0.13	
dilution gas	10290 ± 130	-40.07 ± 0.18		1.26 ± 0.06		

Table S2: Sampling details and some parameters relevant for ^{14}C calculations and corrections for 2014 and 2015 firn matrix (FM), LIZ and bubbly ice (BI) samples and accompanying procedural blanks. Note that to apply the solubility correction, the [^{14}CO] values are divided by the factor shown in the table.

Sample or Blank name	Depth range of sampled firn or ice, m	Number of melt or simulated extractions performed	Total mass of firn or ice melted (kg)	Effective total air content (cm^3 STP / g ice)	Fraction of air in sample from closed porosity (for LIZ and ice) or microbubbles (for firn matrix)	Solubility correction factor for x_{CO} and [^{14}CO]
Surface Sample (2014 FM)	0.24 – 1.0	7	1287.74 ± 25.77	0.106 ± 0.002	0.0062 ± 0.0003	0.9977 ± 0.0001
~4.5m sample (2014 FM)	3.63 – 5.39	8	1501.41 ± 29.96	0.090 ± 0.002	0.0095 ± 0.0005	0.9973 ± 0.0001
~10m sample (2014 FM)	9.02 – 10.9	6	1430.27 ± 28.68	0.086 ± 0.002	0.0089 ± 0.0002	0.9962 ± 0.0002
~20m sample (2014 FM)	19.12 – 20.92	6	1618.64 ± 32.26	0.080 ± 0.002	0.0103 ± 0.0002	0.9957 ± 0.0002
~36m sample (2015 FM)	31.2 – 42	5	1528.34 ± 5.04	0.082 ± 0.001	0.0082 ± 0.0004	0.9945 ± 0.0002
~53m sample (2015 FM)	47.9 – 58.9	5	1766.77 ± 5.04	0.073 ± 0.002	0.0146 ± 0.0003	0.9933 ± 0.0002
~70m sample (2015 LIZ)	63.5 – 74.7	2	718.88 ± 3.19	0.078 ± 0.001	0.251 ± 0.002	0.9928 ± 0.0007
~80m sample (2015 LIZ)	74.9 – 85.5	2	771.98 ± 3.19	0.087 ± 0.001	0.861 ± 0.008	0.9914 ± 0.0009
~90m sample (2015 BI)	85.5 – 96.7	2	771.98 ± 3.19	0.090 ± 0.002	1	0.9913 ± 0.0009
~100m sample (2015 BI)	96.7 – 107.5	2	789.69 ± 3.19	0.090 ± 0.002	1	0.9906 ± 0.0009
~130m sample (2015 BI)	124.7 – 135.9	3	1190.06 ± 3.91	0.090 ± 0.002	1	0.9906 ± 0.0009
2014 Water Blank #1		7				0.9974 ± 0.0001
2014 Water Blank #2		7				0.9958 ± 0.0001
2015 Water Blank #1		5				0.9940 ± 0.0002
2015 Water Blank #2		3				0.9901 ± 0.0035

Table S3: Further measurements and parameters relevant for ^{14}C calculations and corrections for firn matrix (FM), LIZ and bubbly ice (BI) samples. All uncertainties represent ± 1σ. The relatively large uncertainties for x_{CO} contribution from closed porosity and for extraneous x_{CO} derive from a combination of 1) uncertainties in trapped air age distributions in the LIZ, 2) uncertain *in situ* x_{CO} production in LIZ and ice and associated uncertainty in atmospheric x_{CO} history and 3) x_{CO} agreement for water blanks from the same season. *The 130 m sample had sufficient air to perform the CO carbon extraction and ^{14}C measurement in triplicate; the value and uncertainty shown here represent the mean and standard deviation of the 3 measurements.

Sample, blank or standard gas name	Measured x_{CO} in undiluted samples, nmol / mol	Fraction of CO carbon from sample after dilution	Estimated x_{CO} contribution from closed porosity (air bubbles), nmol / mol	Extraneous x_{CO} not accounted for by water blanks or closed porosity x_{CO}, nmol / mol	Measured $\delta^{13}CO$ in undiluted samples, ‰ relative to VPDB	^{14}C activity measured in diluted samples, after ANSTO empirical correction, pMC
Surface Sample (2014 FM)	477.0 ± 3.0	0.241 ± 0.007		275 ± 8	-35.74 ± 0.17	34.38 ± 0.50
~4.5m sample (2014 FM)	342.6 ± 3.0	0.153 ± 0.004		141 ± 8	-37.18 ± 0.17	52.11 ± 0.61
~10m sample (2014 FM)	333.4 ± 3.0	0.106 ± 0.002		131 ± 8	-37.20 ± 0.17	40.52 ± 0.55
~20m sample (2014 FM)	333.5 ± 3.0	0.140 ± 0.004		132 ± 8	-37.14 ± 0.17	64.38 ± 0.65
~36m sample (2015 FM)	198.5 ± 2.0	0.075 ± 0.002		121 ± 30	-32.42 ± 0.50	49.86 ± 0.57
~53m sample (2015 FM)	189.0 ± 2.0	0.097 ± 0.003		111 ± 30	-31.56 ± 0.50	59.68 ± 0.52
~70m sample (2015 LIZ)	246.1 ± 2.0	0.054 ± 0.001	36 ± 10	133 ± 32	-30.54 ± 0.50	26.04 ± 0.32
~80m sample (2015 LIZ)	290.3 ± 2.0	0.118 ± 0.003	129 ± 10	84 ± 32	-27.98 ± 0.50	77.91 ± 0.68
~90m sample (2015 BI)	304.2 ± 2.0	0.072 ± 0.001	120 ± 20	106 ± 36	-27.16 ± 0.50	52.87 ± 0.63
~100m sample (2015 BI)	284.0 ± 2.0	0.045 ± 0.001	98 ± 20	109 ± 36	-27.70 ± 0.50	41.35 ± 0.65
~130m sample (2015 BI)	279.2 ± 2.0	0.066 ± 0.001	90 ± 20	111 ± 36	-26.47 ± 0.50	68.17 ± 0.54*
2014 Water Blank #1	196.7 ± 3.0	0.071 ± 0.002			-38.65 ± 0.16	12.39 ± 0.37
2014 Water Blank #2	207.3 ± 3.0	0.110 ± 0.003			-38.05 ± 0.17	17.03 ± 0.29
2015 Water Blank #1	56.6 ± 2.0	0.023 ± 0.001			-31.94 ± 0.50	22.66 ± 0.29
2015 Water Blank #2	98.9 ± 2.0	0.019 ± 0.001			-34.55 ± 0.50	10.61 ± 0.31
dilution gas	10290 ± 130				-40.07 ± 0.18	1.39 ± 0.03 (2014) 1.66 ± 0.02 (2015)
2014 standard gas	131.6 ± 2.0					

Table S4: Firn matrix, LIZ and bubbly ice sample [^{14}CO] after each correction step

Sample, blank or standard gas name	[^{14}CO] corrected for dilution, molecules / cm^3 STP air	[^{14}CO] further corrected for dissolution, molecules / cm^3 STP air	[^{14}CO] further corrected for water blanks, molecules / cm^3 STP air	[^{14}CO] further corrected for extraneous x_{CO}, molecules / cm^3 STP air	[^{14}CO] further corrected for microbubble air (FM only), molecules / cm^3 STP air	[^{14}CO] in sample after all corrections, molecules / g ice
Surface Sample (2014 FM)	20.0 ± 0.6	20.0 ± 0.6	10.9 ± 0.7	6.6 ± 2.3	6.4 ± 2.3	0.68 ± 0.24
~4.5m sample (2014 FM)	34.6 ± 1.0	34.7 ± 1.0	25.5 ± 1.0	23.3 ± 1.5	23.1 ± 1.5	2.07 ± 0.14
~10m sample (2014 FM)	37.5 ± 1.0	37.6 ± 1.0	28.4 ± 1.0	26.4 ± 1.4	26.2 ± 1.4	2.25 ± 0.14
~20m sample (2014 FM)	45.5 ± 1.2	45.7 ± 1.2	36.5 ± 1.3	34.4 ± 1.6	34.2 ± 1.6	2.74 ± 0.15
~36m sample (2015 FM)	38.5 ± 1.1	38.8 ± 1.1	24.1 ± 1.2	22.2 ± 1.6	22.0 ± 1.6	1.80 ± 0.14
~53m sample (2015 FM)	34.3 ± 1.0	34.5 ± 1.1	20.0 ± 1.2	18.3 ± 1.6	18.0 ± 1.6	1.31 ± 0.12
~70m sample (2015 LIZ)	33.5 ± 0.8	33.7 ± 0.8	19.1 ± 1.0	17.1 ± 1.5		1.33 ± 0.12
~80m sample (2015 LIZ)	57.2 ± 1.5	57.7 ± 1.5	43.3 ± 1.6	42.0 ± 1.8		3.66 ± 0.17
~90m sample (2015 BI)	65.7 ± 1.5	66.3 ± 1.6	51.8 ± 1.7	50.2 ± 1.9		4.54 ± 0.20
~100m sample (2015 BI)	75.5 ± 1.8	76.2 ± 1.9	61.7 ± 2.0	60.0 ± 2.2		5.43 ± 0.23
~130m sample (2015 BI)	85.7 ± 1.7	86.5 ± 1.7	72.2 ± 1.8	70.5 ± 2.1		6.37 ± 0.23
2014 Water Blank #1	9.3 ± 0.4	9.3 ± 0.4				
2014 Water Blank #2	9.0 ± 0.3	9.0 ± 0.3				
2015 Water Blank #1	15.4 ± 0.5	15.5 ± 0.5				
2015 Water Blank #2	14.1 ± 0.6	14.2 ± 0.6				