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Seasonal and interannual variability on the chemical composition of the Svalbard surface snowpack

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Table S1. Average ionic loads of major ions and trace elements present with percentage lower than 1% in the surface snow collected at GSRS during each season of the three consecutive sampling campaigns. In the brackets the standard deviation is reported.

μg m^{-2}	MSA	Ag	Al	As	Ba	Be	Bi	Cd	Cs	Cr	Co	Cu	Li	Mn	Ni	Pb	Rb	Se	Sr	Tl	U	V	Zn
autumn 2018	5 (4)	0.04 (0.08)	963 (1317)	1 (1)	12 (15)	0.1 (0.1)	0.7 (1.9)	0.1 (0.1)	0.3 (0.6)	11 (15)	1 (2)	10 (21)	2 (3)	39 (71)	20 (20)	4 (4)	3 (5)	0.5 (0.5)	18 (20)	0.03 (0.04)	0.1 (0.2)	4 (5)	27 (31)
winter 2018-19	8 (5)	0.06 (0.07)	345 (191)	2 (1)	64 (353)	0.02 (0.02)	0.2 (0.2)	0.4 (0.3)	0.1 (0.1)	5 (5)	0.3 (0.2)	17 (13)	2 (2)	14 (11)	13 (21)	60 (53)	2 (1)	2 (2)	57 (50)	0.03 (0.03)	0.1 (0)	2 (2)	56 (59)
spring 2019	106 (137)	0.06 (0.04)	742 (753)	1 (1)	17 (18)	0.05 (0.08)	0.7 (1.8)	0.4 (0.3)	0.2 (0.3)	19 (32)	1 (1)	133 (239)	2 (2)	53 (91)	31 (32)	70 (41)	2 (3)	1 (1)	45 (36)	0.03 (0.04)	0.2 (0.2)	5 (3)	118 (199)
autumn 2019	72 (46)	0.03 (0.01)	893 (1006)	1 (1)	28 (33)	0.22 (0.25)	0.3 (0.2)	0.1 (0.1)	0.2 (0.3)	18 (12)	2 (1)	44 (34)	15 (14)	156 (229)	44 (34)	3 (1)	3 (3)	5 (4)	117 (139)	0.21 (0.23)	0.1 (0.2)	7 (8)	101 (148)
winter 2019-20	36 (19)	0.06 (0.1)	2207 (3752)	3 (7)	32 (35)	0.41 (0.72)	0.4 (0.4)	0.3 (0.3)	0.5 (0.7)	23 (18)	3 (11)	32 (49)	9 (8)	170 (230)	32 (49)	8 (10)	5 (6)	9 (11)	163 (138)	0.15 (0.11)	0.2 (0.2)	12 (24)	81 (102)
spring 2020	847 (690)	0.08 (0.08)	6460 (8276)	3 (4)	59 (73)	0.92 (1.12)	0.6 (0.3)	0.3 (0.3)	1.5 (1.9)	25 (11)	5 (6)	131 (401)	16 (16)	261 (319)	131 (401)	13 (14)	14 (17)	18 (23)	180 (190)	0.24 (0.17)	0.7 (1)	20 (23)	182 (217)
autumn 2020	73 (129)	0.1 (0.2)	1439 (2820)	8 (7)	1043 (2654)	0.12 (0.12)	0.1 (0.1)	0.3 (0.7)	0.2 (0.3)	7 (11)	1 (3)	69 (167)	13 (25)	65 (92)	8 (18)	10 (17)	5 (6)	9 (9)	284 (445)	0.13 (0.11)	0 (0)	2 (2)	2160 (3028)
winter 2020-21	53 (59)	0.01 (0.01)	155 (201)	4 (3)	16 (36)	0.04 (0.04)	0.02 (0.02)	0.1 (0.1)	0.1 (0.1)	1 (1)	0.1 (0.1)	4 (5)	1 (1)	7 (10)	0.3 (0.4)	2 (3)	1 (1)	3 (2)	42 (35)	0.05 (0.06)	0 (0)	0.3 (0.1)	
spring 2021	114 (252)	0.1 (0.1)	2320 (3888)	8 (6)	41 (57)	0.2 (0.29)	0.1 (0.2)	0.7 (1.9)	0.6 (0.8)	9 (12)	2 (4)	24 (42)	4 (5)	113 (200)	9 (13)	5 (6)	9 (13)	5 (6)	75 (113)	0.14 (0.16)	0 (0)	8 (9)	816 (556)

Table S2. Average areas (km^2) occupied by Drift Ice (DI). Fast Ice (FI). and Open Water (OW) in March 2019. 2020. 2021 within the Kongsfjorden. Dataset: Gerland et al.. 2022.

km^2	**March 2019**	**March 2020**	**March 2021**
Drift Ice (DI)	6.08	16.53	8.67
Fast Ice (FI)	57.86	113.28	37.59
Open Water (OW)	86.71	23.80	106.68

Table S3. Seasonal mean air temperatures at Ny-Ålesund (°C). average precipitation (mm). average wind speed (m s^{-1}). moderate wind days (5-10 m s^{-1}). strong wind days (> 10 m s^{-1}) and mean snow height (cm) characterizing the three consecutive sampling campaigns. from 2018-19 to 2020-21. Dataset: Norwegian Centre for Climate Services (NCCS). The "moderate" and "strong" wind speed thresholds are those established in Pilguj et al.. 2019.

	Mean air temperature (°C)	Precipitation average (mm)	Average wind speed (m s^{-1})	Max wind speed (m s^{-1})	Days with moderate wind speed (5-10 m s^{-1})	Days with strong wind speed (> 10 m s^{-1})	Mean snow height (cm)
autumn 2018	-3.65	5.50	4.14	11.98	25	2	20.75
winter 2018-19	-11.37	2.56	3.79	15.41	19	3	57.56
spring 2019	-4.12	2.66	3.30	9.32	11	0	74.90
autumn 2019	-8.18	1.42	3.21	12.39	11	1	15.33
winter 2019-20	-14.74	2.09	3.73	17.69	17	6	62.18
spring 2020	-7.47	2.13	3.61	16.09	13	4	85.42
autumn 2020	-4.78	4.91	4.11	9.72	17	0	17.25
winter 2020-21	-7.92	3.25	3.91	13.85	23	5	57.77
spring 2021	-5.31	1.80	3.99	13.87	18	3	101.69

Table S4. Averages of seawater temperatures (°C) and salinity (psu) at Kb3 in Kongsfjorden (10 m depth) in the 2019, 2020, and 2021 spring seasons.

	Seawater temperature (°C)	**Salinity**
2019	2.42	34.99
2020	-0.55	34.64
2021	0.09	34.74

Table S5. Results of Dunn's post-hoc test. Light-blue rows (P.adj < 0.05) highlight seasonal pairs where significant differences in species concentrations were detected. The species included were selected based on significant results from the preceding Kruskal-Wallis test.

Comparison	Z	P.unadj	P.adj	Element
Autumn - Spring	-2.7319425	0.00629621	0.01888864	Br^-
Autumn - Winter	-4.1107436	3.9439E-05	0.00011832	Br^-
Spring - Winter	-1.8927718	0.05838822	0.17516467	Br^-
Autumn - Spring	-6.5042295	7.8093E-11	2.3428E-10	MSA
Autumn - Winter	-0.1358512	0.89193894	1	MSA
Spring - Winter	8.17375926	2.9893E-16	8.9678E-16	MSA
Autumn - Spring	-1.6644548	0.09602158	0.28806475	SO_4^{2-}
Autumn - Winter	-4.2381365	2.2538E-05	6.7615E-05	SO_4^{2-}
Spring - Winter	-3.4368483	0.00058853	0.00176558	SO_4^{2-}
Autumn - Spring	-2.4716422	0.01344941	0.04034822	nss- SO_4^{2-}
Autumn - Winter	-4.7044976	2.5449E-06	7.6348E-06	nss- SO_4^{2-}
Spring - Winter	-2.9786187	0.00289551	0.00868653	nss- SO_4^{2-}
Autumn - Spring	-2.783303	0.00538085	0.01614256	Bi
Autumn - Winter	0.36554538	0.71470434	1	Bi
Spring - Winter	4.1225077	3.7477E-05	0.00011243	Bi
Autumn - Spring	-5.3072913	1.1127E-07	3.338E-07	Cd
Autumn - Winter	-5.0874504	3.6291E-07	1.0887E-06	Cd
Spring - Winter	0.11199019	0.91083119	1	Cd
Autumn - Spring	-5.1157793	3.1245E-07	9.3734E-07	Cu
Autumn - Winter	-0.4611268	0.64470766	1	Cu
Spring - Winter	5.85357093	4.8113E-09	1.4434E-08	Cu
Autumn - Spring	-3.2170868	0.00129499	0.00388498	Fe
Autumn - Winter	0.2248829	0.82207037	1	Fe
Spring - Winter	4.33481055	1.4589E-05	4.3766E-05	Fe
Autumn - Spring	-6.7151699	1.8785E-11	5.6354E-11	Pb
Autumn - Winter	-4.7634258	1.9033E-06	5.71E-06	Pb
Spring - Winter	2.32321423	0.02016765	0.06050294	Pb
Autumn - Spring	-1.1938078	0.23255317	0.69765952	Ni
Autumn - Winter	2.33081804	0.01976296	0.05928887	Ni
Spring - Winter	4.51207231	6.4197E-06	1.9259E-05	Ni
Autumn - Spring	-4.5852907	4.5336E-06	1.3601E-05	Ag
Autumn - Winter	-1.8377451	0.06609998	0.19829993	Ag
Spring - Winter	3.4182193	0.00063032	0.00189097	Ag
Autumn - Spring	-3.8098063	0.00013908	0.00041723	U
Autumn - Winter	-0.7151166	0.47453701	1	U
Spring - Winter	3.92697057	8.6023E-05	0.00025807	U
Autumn - Spring	-3.5630348	0.00036659	0.00109978	V
Autumn - Winter	1.2507275	0.21103391	0.63310174	V
Spring - Winter	6.19555275	5.8081E-10	1.7424E-09	V
Autumn - Spring	-5.001315	5.6941E-07	1.7082E-06	Zn
Autumn - Winter	-1.8613235	0.06269851	0.18809552	Zn
Spring - Winter	3.8708804	0.00010844	0.00032533	Zn

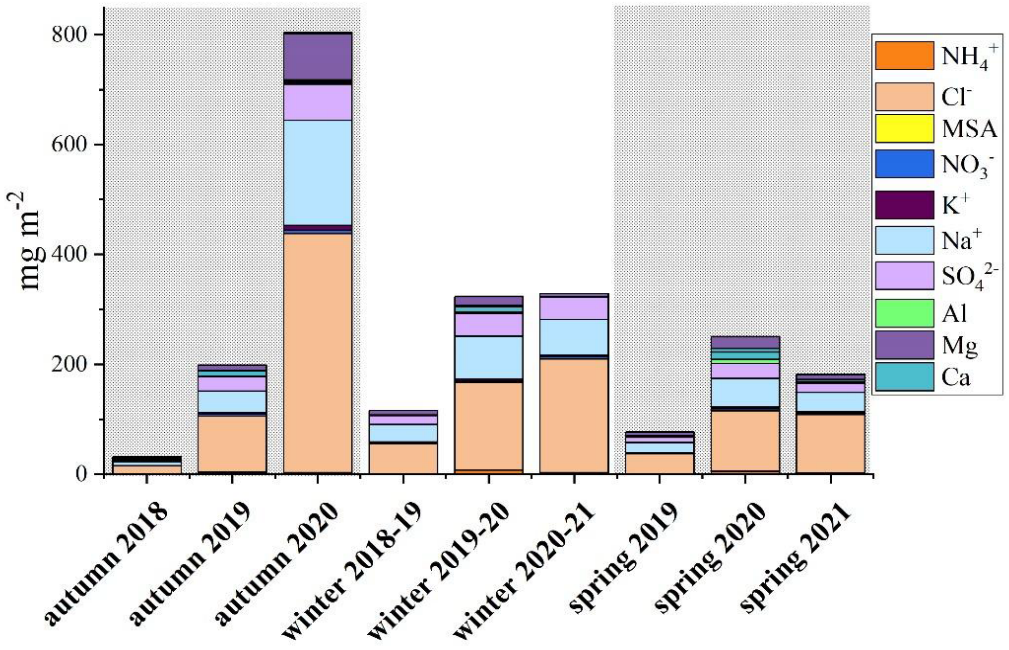

Fig. S1. Ionic load average of major ions and trace elements in the surface snow collected at Gruvebadet during each season of the three consecutive sampling campaigns. The grey areas correspond to the distinct snow seasons.

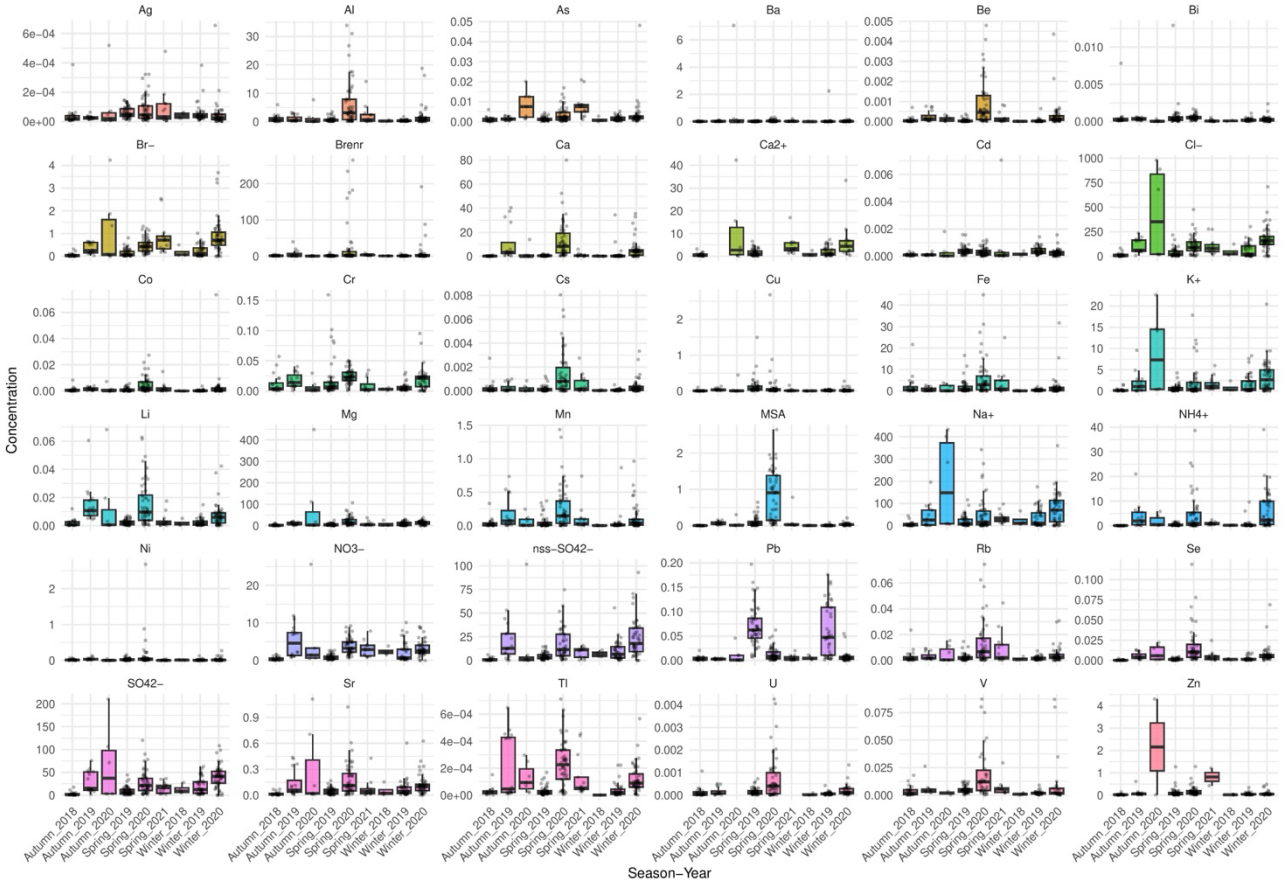

Fig. S2. Boxplot of element and ion concentrations by season – year. Concentrations are expressed in ng g^{-1}.

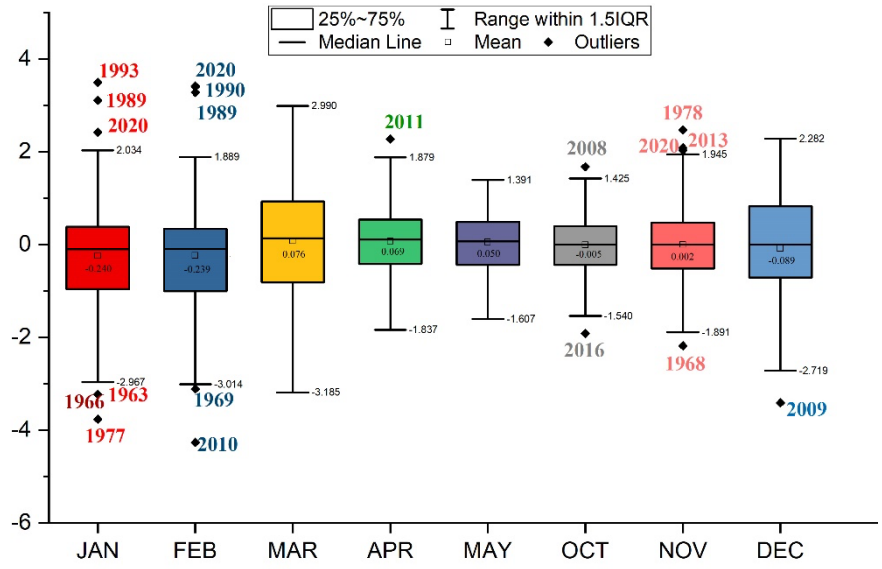

Fig. S3. AO index boxplots on 1950 to 2021 timeframe (NOAA. https://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/monthly.ao.index.b50.current.ascii.table). January and February 2020 clearly appear as positive outliers on the reference historical timeseries. Median values are reported within the box plots. below the median bar.

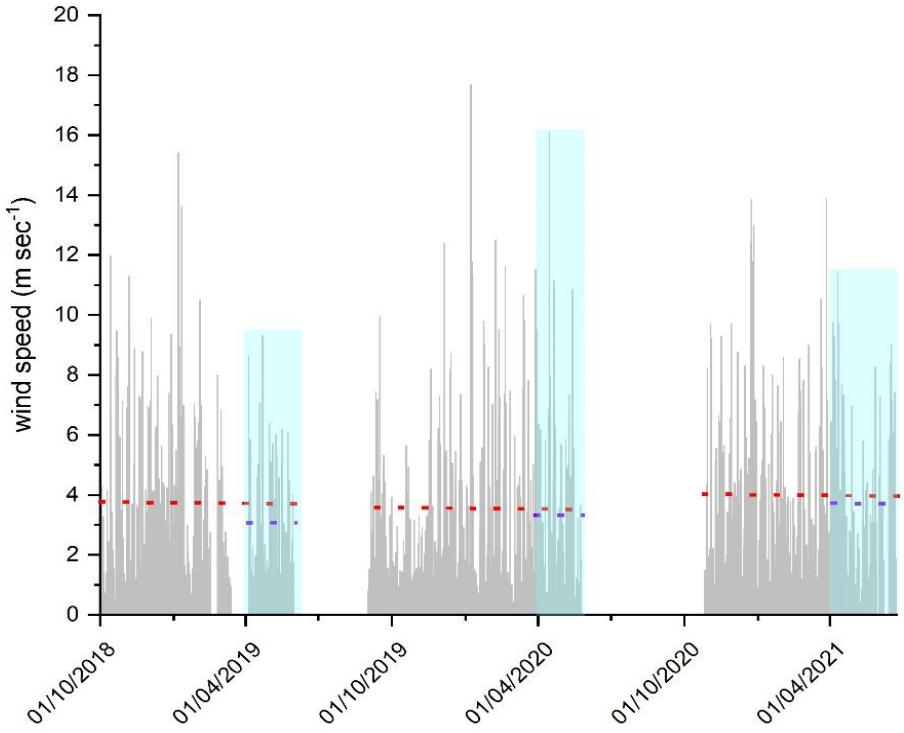

Fig. S4. Wind speed (m sec^{-1}) at Kongsfjorden during the three sampling campaigns (2018-19. 2019-20. 2020-21). Red dashed lines represent average wind speeds for each campaign. while blue dashed lines show the average wind speed in

spring seasons. Blue rectangles highlight the recorded wind speed values during the observed spring seasons. Data provided by the Norwegian Centre for Climate Services (NCCS).

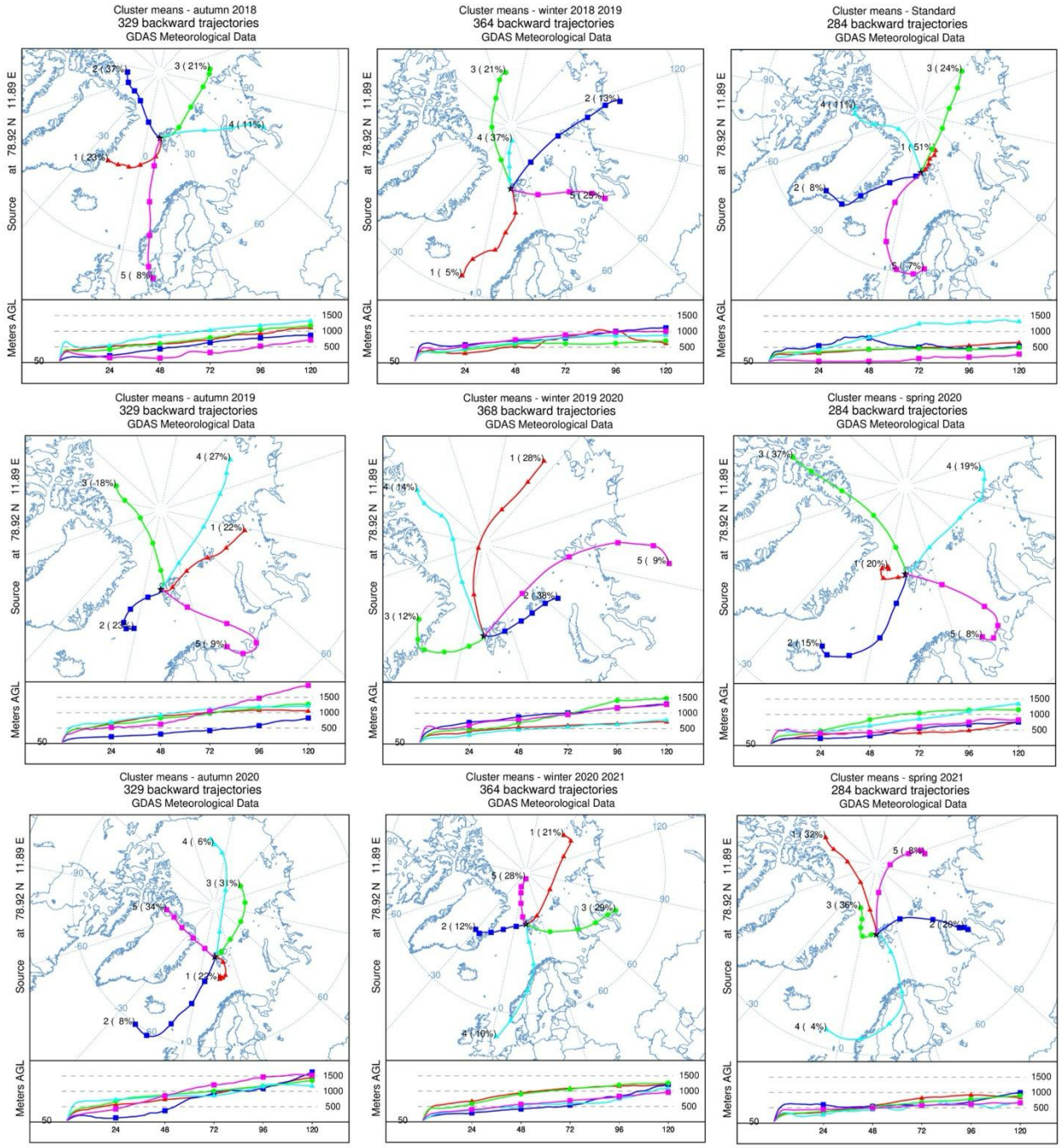

Fig. S5. Back-trajectories computed with the HYSPLIT particle dispersion model over Ny-Ålesund. distinguished by season during the Arctic Haze period for the 2018-19. 2019-20. 2020-21 campaigns.

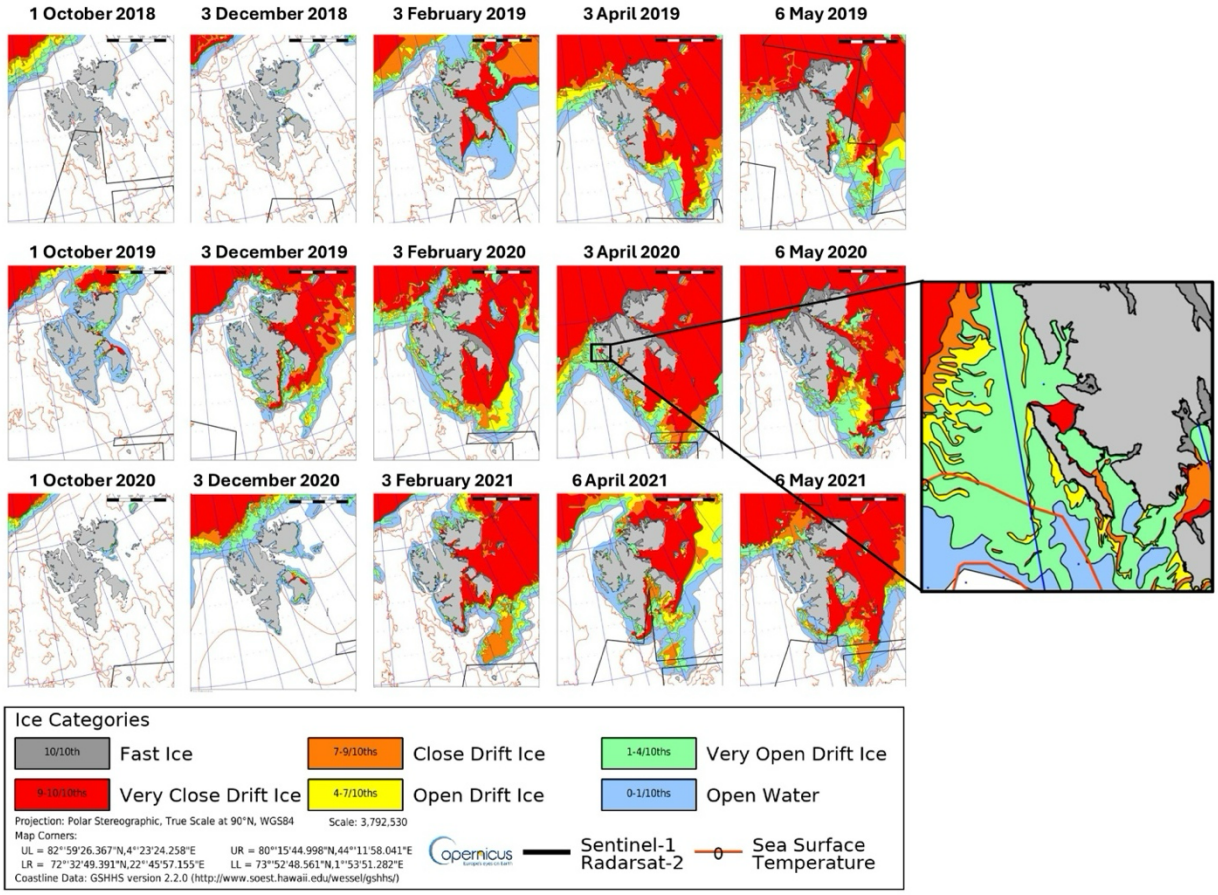

Fig. S6. Norwegian Meteorological Institute ice charts show the seasonal sea ice expansion and contraction during the considered time-window (2018-19. 2019-20. 2020-21). A very close drift ice with respect to the coastal area of sampling (Ny-Ålesund) appears evident in the snapshot of the 3rd of April.