Impact of Arctic Amplification variability on the chemical composition of the snowpack in Svalbard

Azzurra Spagnesi[a,b], Elena Barbaro[a,b] *, Matteo Feltracco[a,b], Federico Scoto[c,b], Marco Vecchiato[b], Massimiliano Vardè[a,], Mauro Mazzola[a], François Burgay[d,e], Federica Bruschi[f], Clara Jule Marie Hoppe[g], Allison Bailey[g], Andrea Gambaro[a,b], Carlo Barbante[a,b], Andrea Spolaor[a,b]

[a] Institute of Polar Sciences - National Research Council of Italy (ISP-CNR), Via Torino 155, 30172, Venice, Italy

[b] Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Via Torino 155, 30172, Venice, Italy

[c] Institute of Atmospheric Sciences and Climate - National Research Council of Italy (ISAC-CNR), Campus Ecotekne, Lecce, 73100, Italy

[d] Laboratory of Environmental Chemistry (LUC), Paul Scherrer Institut (PSI), Villigen, 5232, Switzerland

[e] Oeschger Centre for Climate Change Research, University of Bern, Bern, 3012, Switzerland

[f] Department of Chemistry, Biology and Biotechnology, University of Perugia, Via dell'Elce di Sotto 8, 06123, Perugia, Italy

[g] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, 27570 Bremerhaven, Germany

Corresponding: Elena Barbaro[a,b] (elena.barbaro@cnr.it)

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 (km²) 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.

Km²	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 (°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

Figure S1. Sampling sites of Ny-Ålesund and Gruvebadet, located in the Brøgger peninsula (Svalbard Islands).
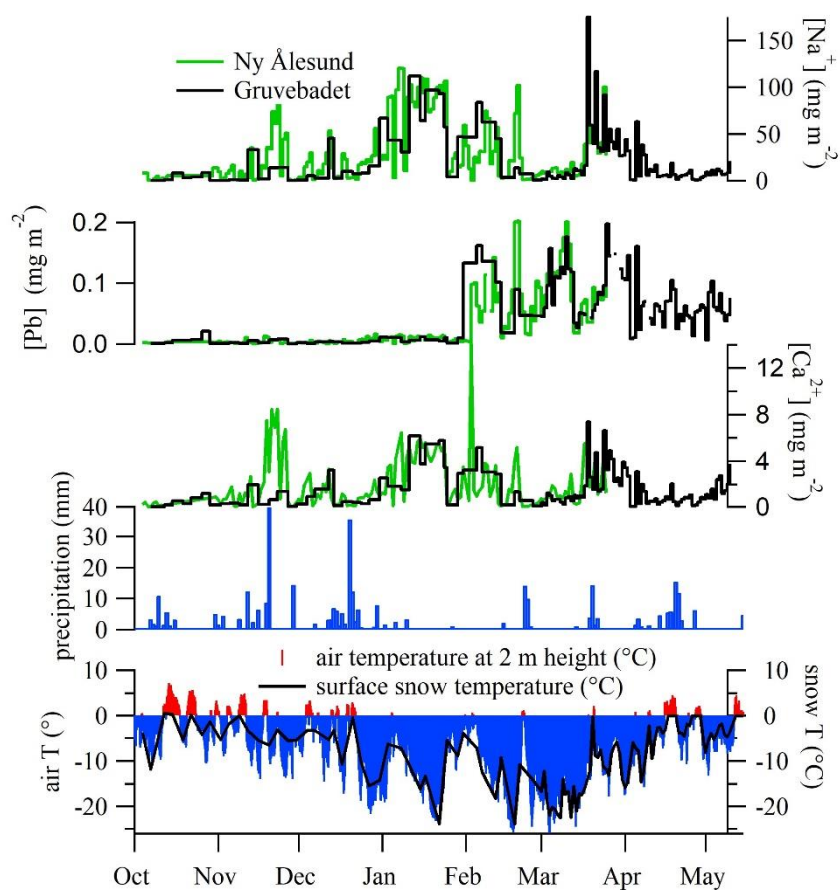
Figure S2. Concentration trends of sodium (Na^+), lead (Pb) and calcium (Ca^{2+}) in the surface snow collected at Gruvebadet and Ny-Ålesund during 2018-2019 sampling campaign. The precipitation (in mm), the air and snow temperatures (°C) are reported in the graphs below.
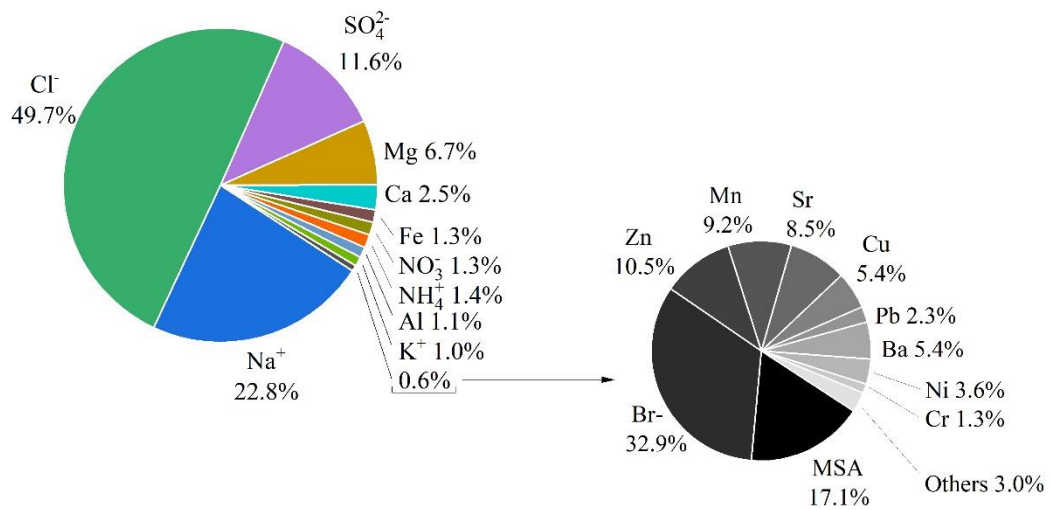
Figure S3. Pie diagram of average concentration of major ions and trace elements during three sampling campaigns at Gruvebadet (Svalbard Islands).
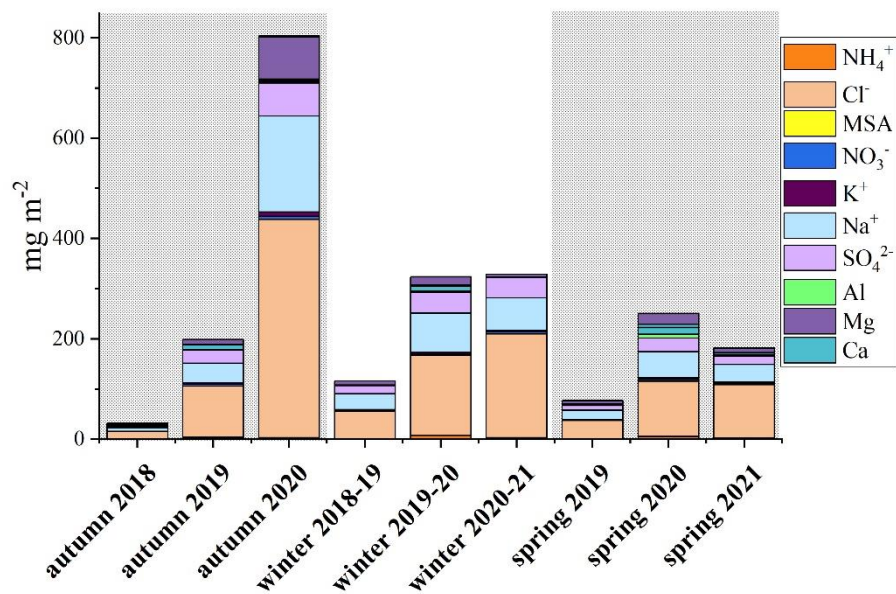
Figure S4. Ionic load average of major ions and trace elements in the surface snow collected at Gruvebadet during each season of the three consecutive sampling campaigns.
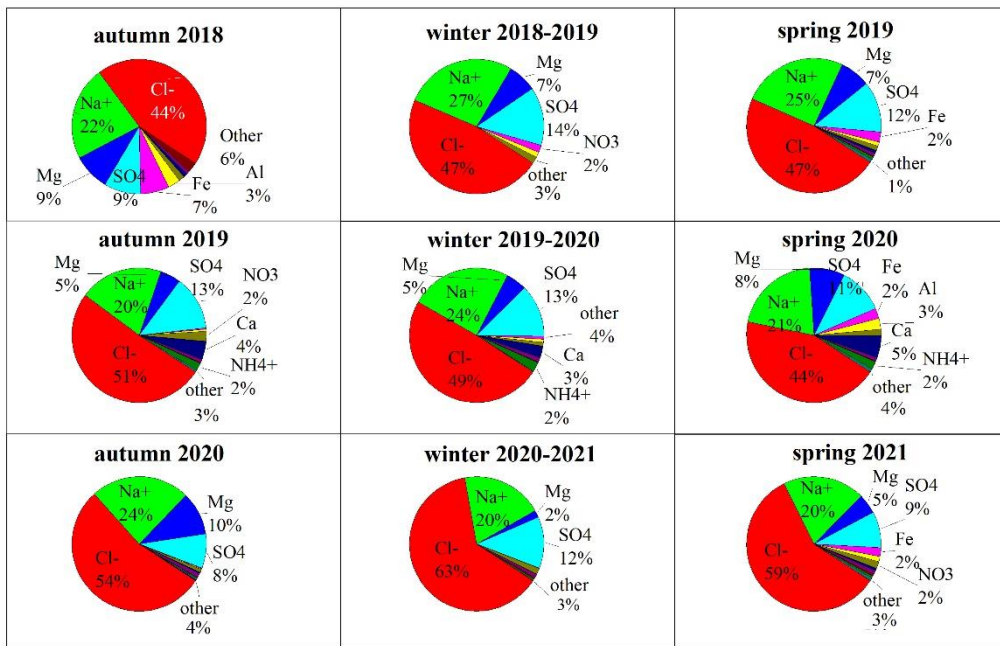
Figure S5. Pie diagrams of average concentrations of major ions and trace elements in the surface snow collected at Gruvebadet during each season of the three consecutive sampling campaigns.
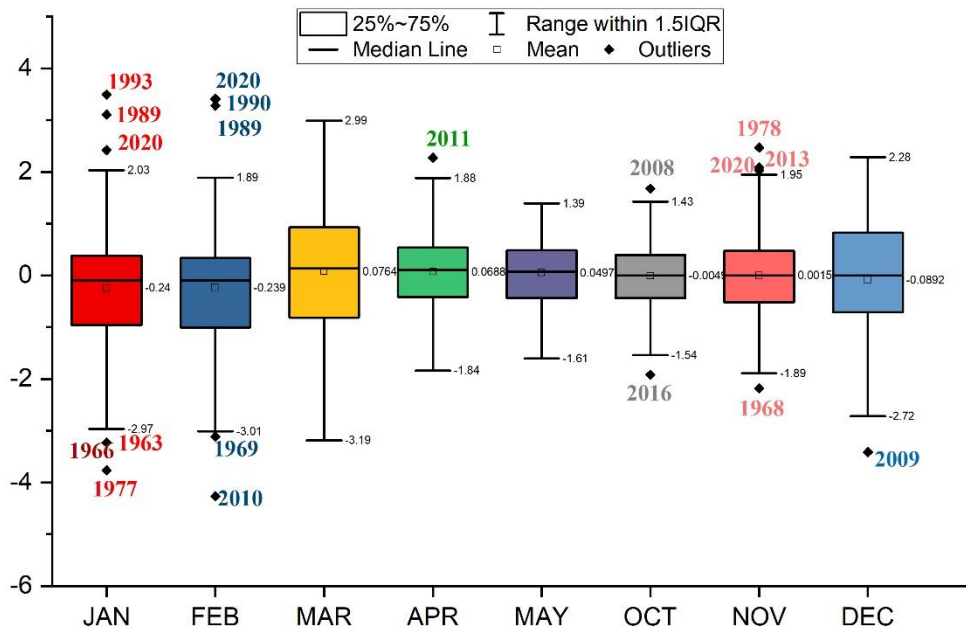
Figure S6. AO index boxplots on 1950 to 2021 timeframe (NOAA). January and February 2020 clearly appear as positive outliers on the reference historical timeseries.
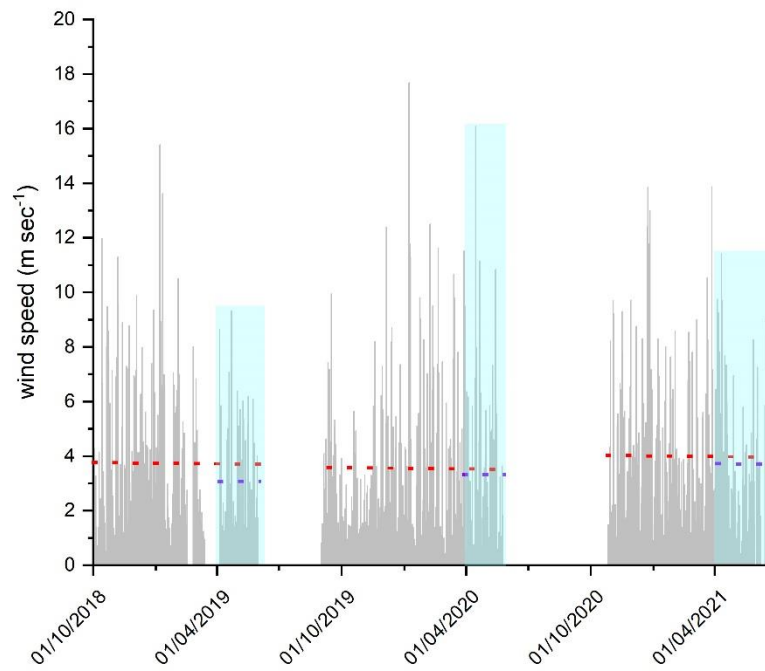
Figure S7. Wind speed (m sec^{-1}) at Kongsfjorden during the three sampling campaigns (2018-19, 2019-20, 2020-21). Red dashed lines represent average wind speeds for each campaign, while blue dashed lines show the average wind speed in spring seasons. Data provided by the Norwegian Centre for Climate Services (NCCS).
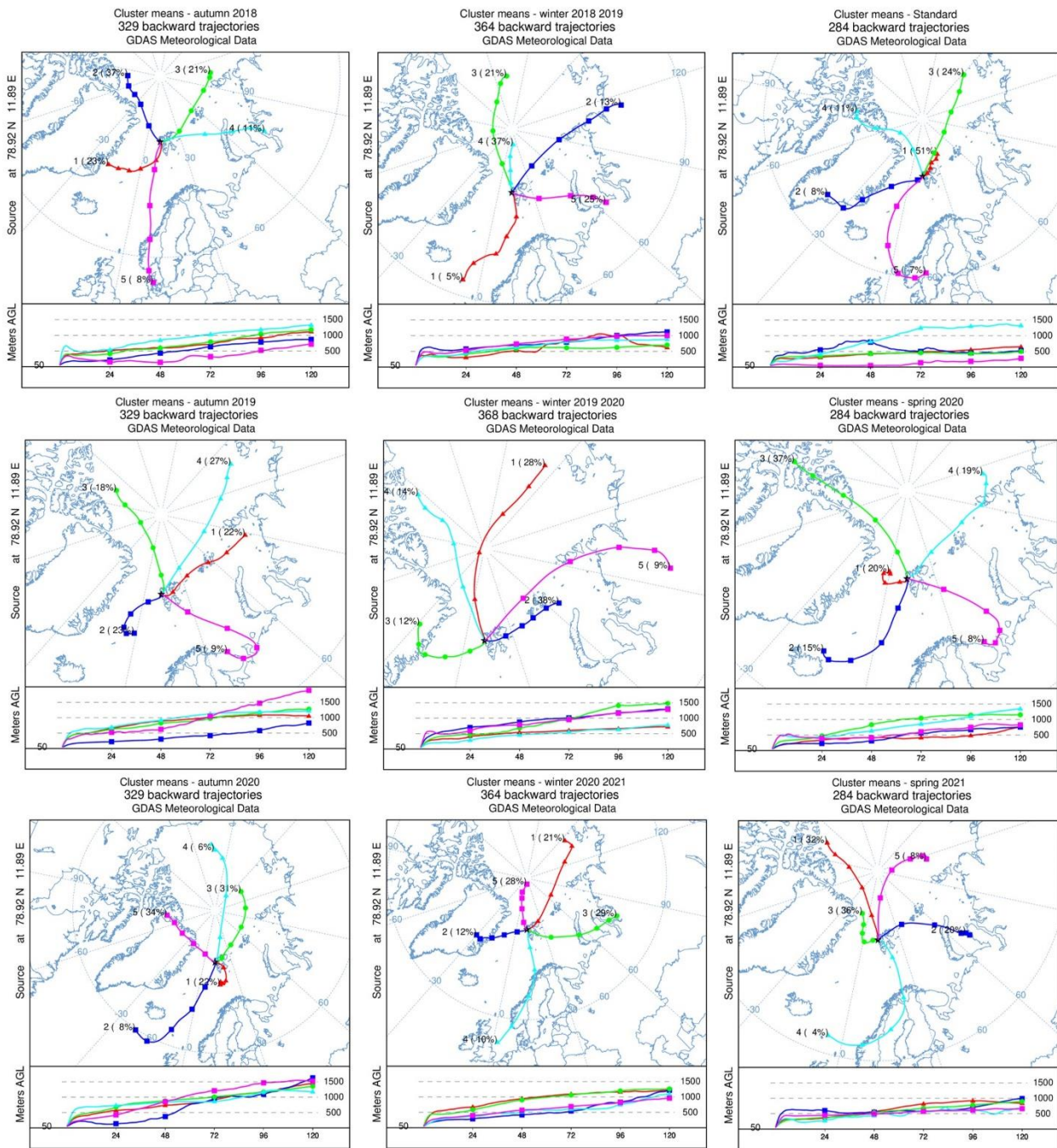
Figure S8. Back-trajectories computed with the HYSPLIT particle dispersion model over Ny-Ålesund, distinguished by season during the Arctic Haze period for the 2018-19, 2019-20, 2020-21 campaigns.
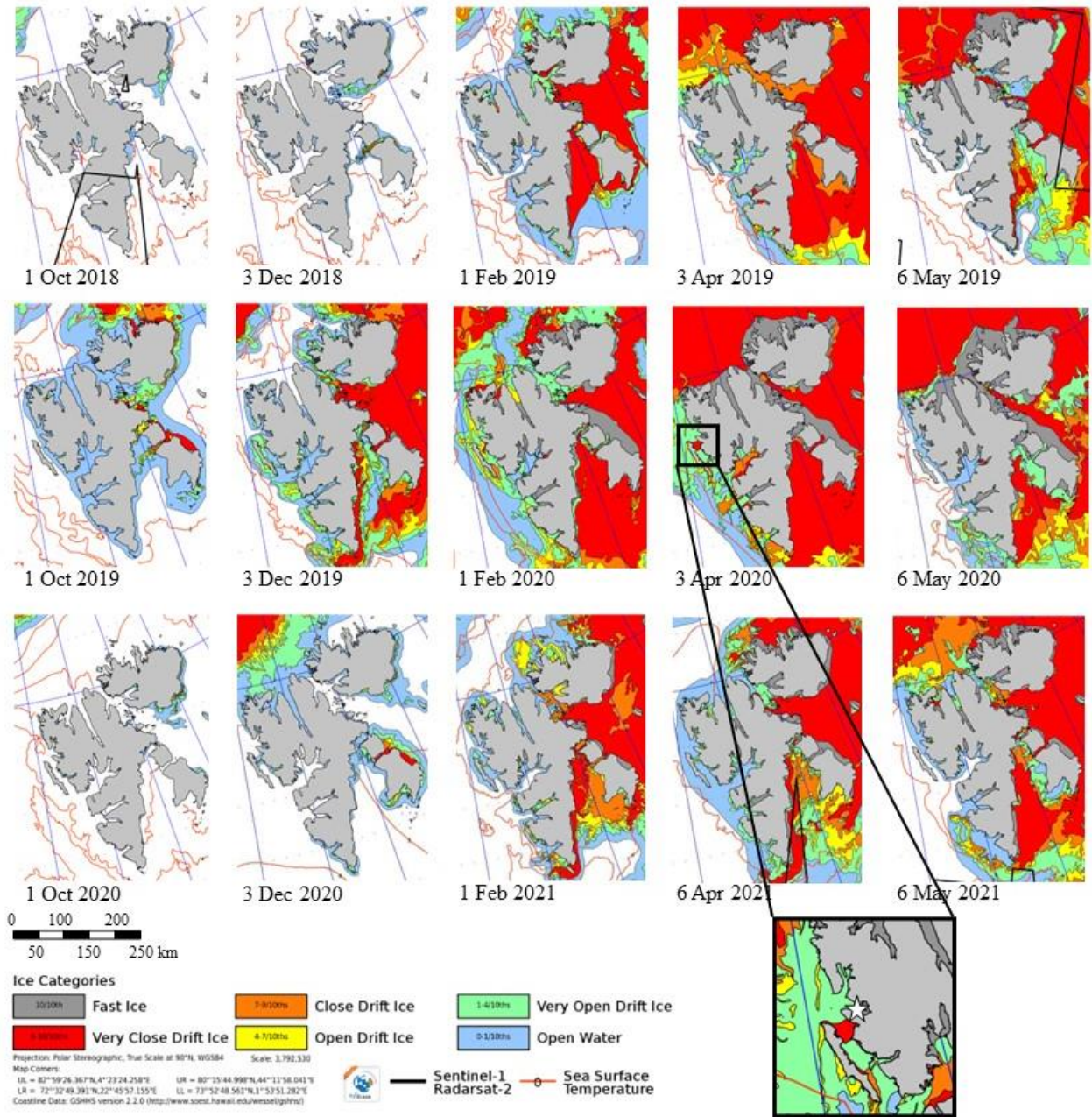
Figure S9. Norwegian Meteorological Institute ice charts show the seasonal sea ice expansion and contraction during the considered time-window (2018-19, 2019-20, 2020-21). A very close drift ice with respect to the coastal area of sampling (Ny-Ålesund) appears evident in the snapshot of the 3rd of April.