

November 2021 – April 2022

Arctic Seasonal Review

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WMO OMM

World Meteorological Organization
Organisation météorologique mondiale



ACF

Arctic Climate Forum

Content of seasonal review

❖ Review for NDJFMA (November 2021... April 2022)

☐ Atmosphere:

- Atmospheric circulation
- Surface air temperature – anomalies, ranks by Arctic regions
- Precipitation – anomalies by Arctic regions

☐ Sea ice:

- Precursors in atmosphere and polar ocean
- Ice extent – anomalies by regions
- Ice conditions including February – March 2022 winter maximum
- Sea ice thickness and volume variability

☐ Polar Ocean:

- Heat content, waves and swell height (storminess) - anomalies
- pH (acidification/alkalization estimates) - anomalies

☐ Land hydrology:

- river discharge – anomalies (introduction to particular report by Alexandr Trunin)
- snow extent – anomalies and ranks

☐ Bioclimatic weather severity (introduction to particular report by Anastassiya Revina and Svetlana Emelina)

❖ Briefs for May 2022: SAT, winds, precipitation, sea ice, snow

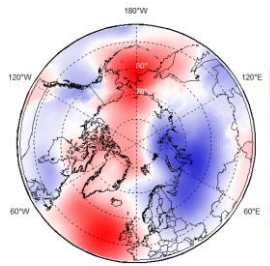
Majority of the described parameters are the WMO accepted Essential Climate Variables (ECV).

Anomalies based both on reanalysis and surface observations are given relative to the latest **3rd WMO period 1991-2020** while ranks are given for **1950...2021/2022** period.

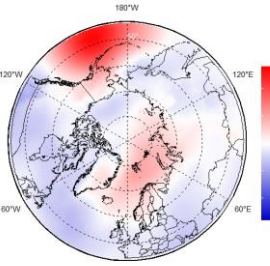
Atmosphere

- ❖ Precursors: atmospheric circulation
- ❖ Surface air temperature
- ❖ Precipitation

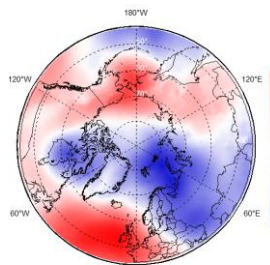
Atmospheric circulation: NDJ 2021/2022



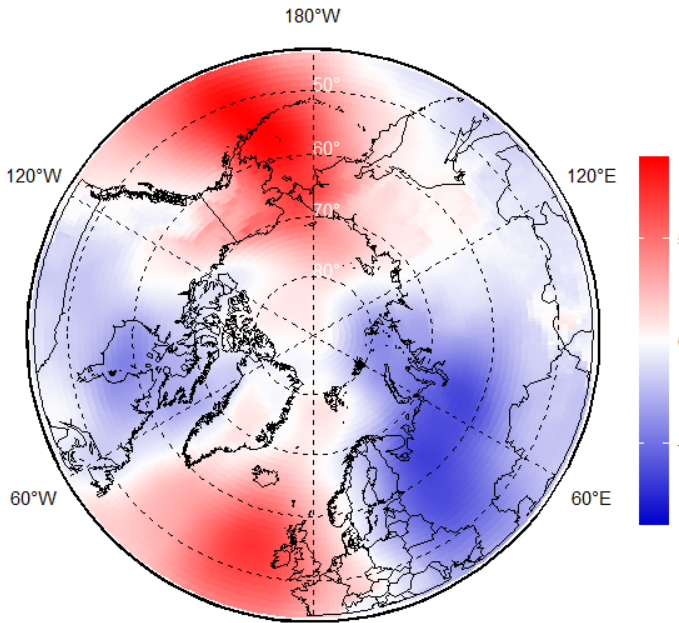
Nov



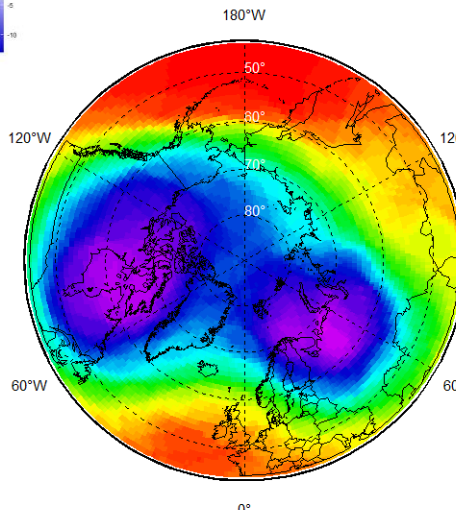
Dec



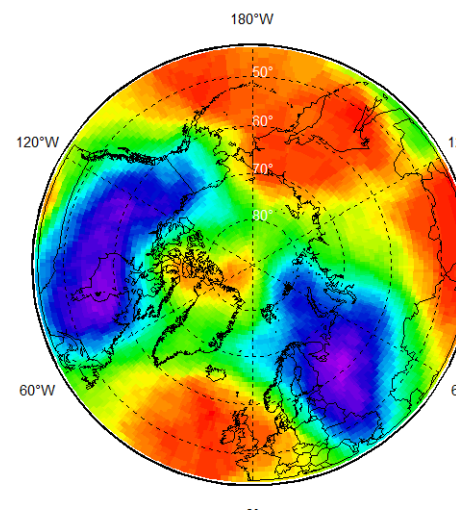
Jan



NDJ MSLP hPa anomalies (1991-2020)

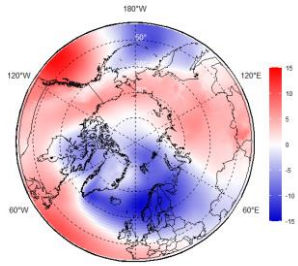


NDJ H50 (left) and H500 (right) ranks (1950-2021/2022)

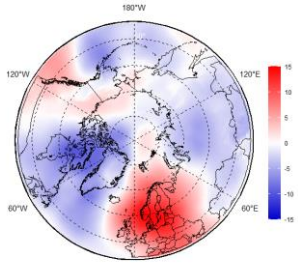


- ❖ During NDJ 2021/2022 an intense bi-center polar vortex (dark violet, 50hPa and 500hPa geopotential height patterns) was observed with centers over the Hudson Bay and the Barents Seas. That led to prevalence of meridian circulation (transfer south/north) in the troposphere over W Siberian and Canadian regions and zonal one over other parts of the Arctic
- ❖ For the surface atmosphere that meant predominance of negative mean sea level atmospheric pressure (MSLP) anomalies (lower pressure, marked in blue) and cyclonic activity over the E Nordic, W Siberian and Canadian regions
- ❖ Opposite situation (higher pressure, marked in red) was observed over Alaska, Bering and Chukchi and W Nordic regions

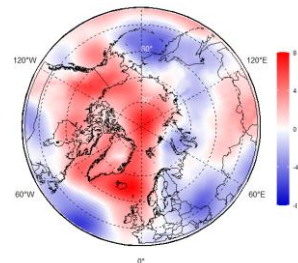
Atmospheric circulation: FMA 2022



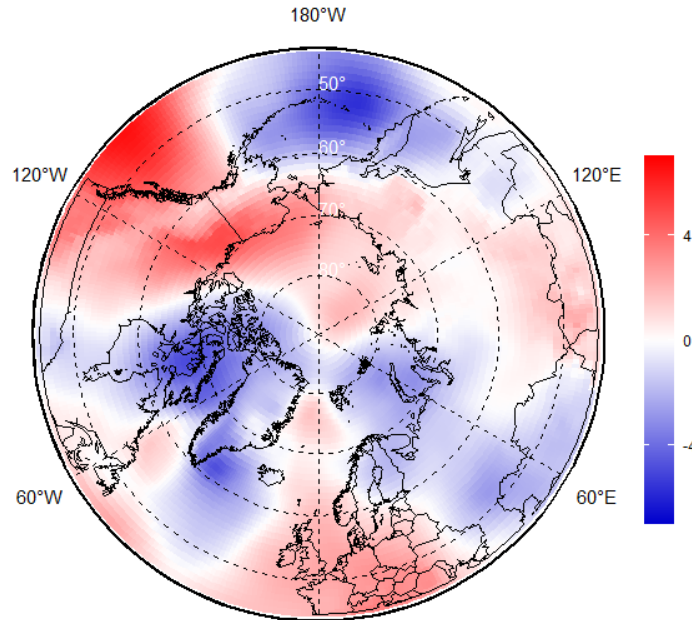
Feb



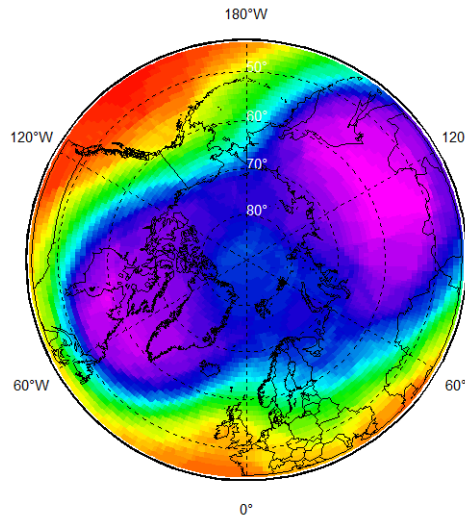
Mar



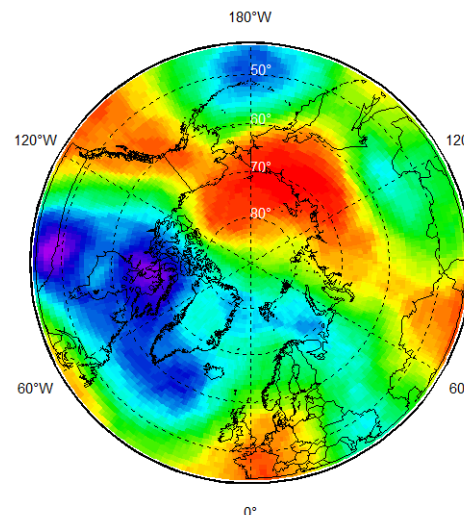
Apr



FMA MSLP hPa anomalies (1991-2020)

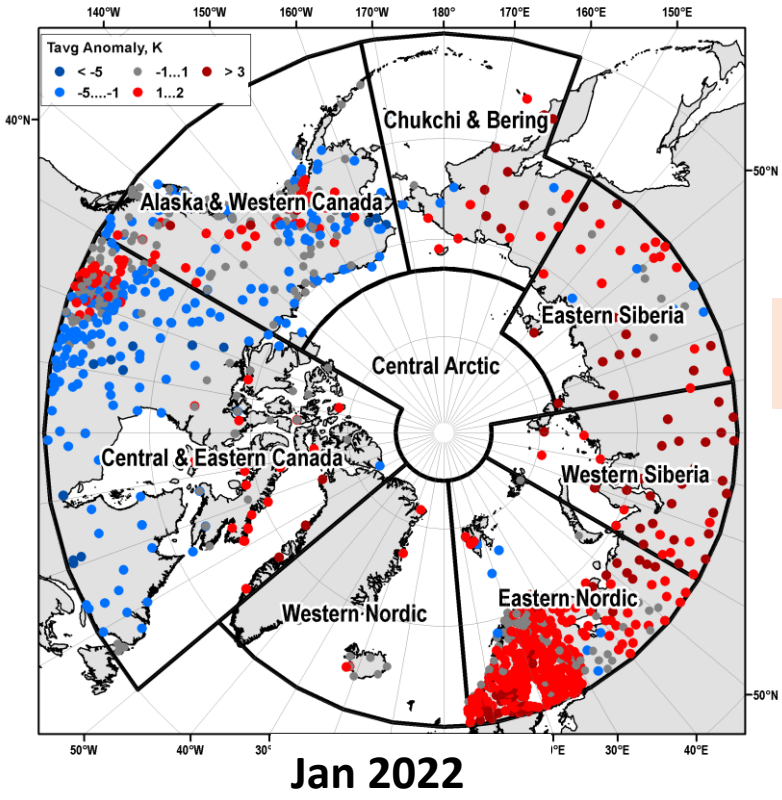
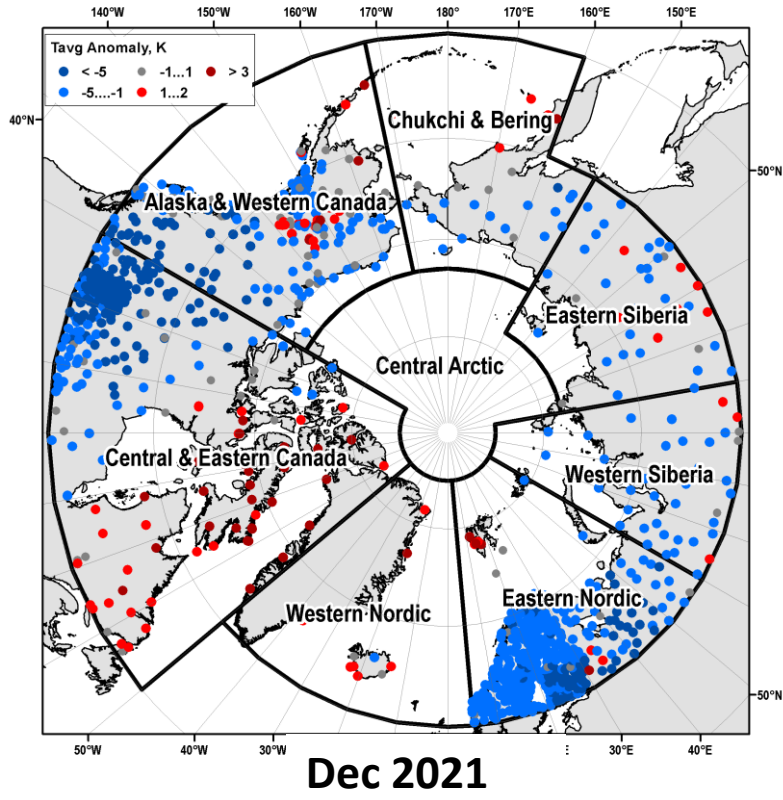
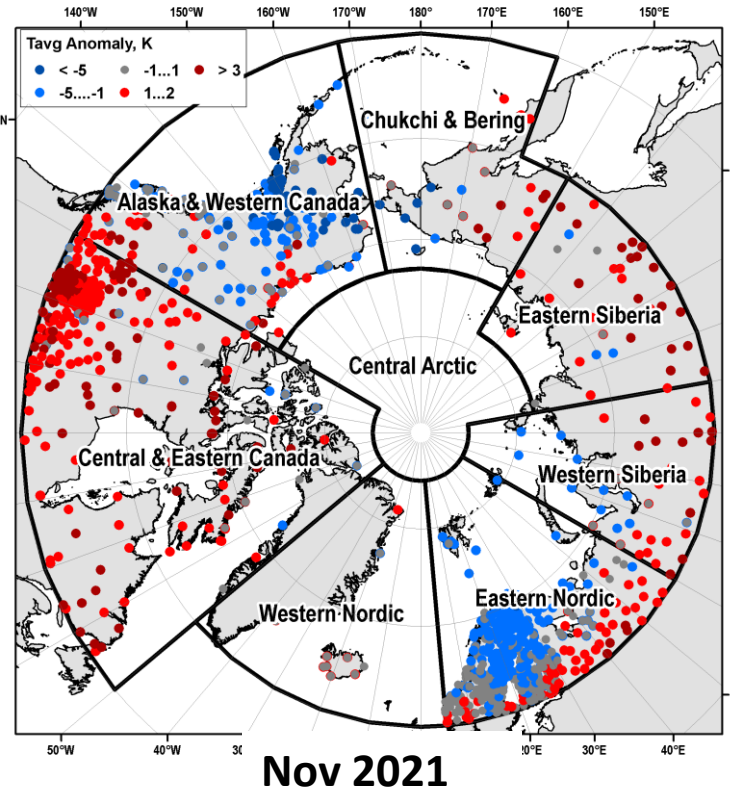


FMA H50 (left) and H500 ranks (1950-2022)

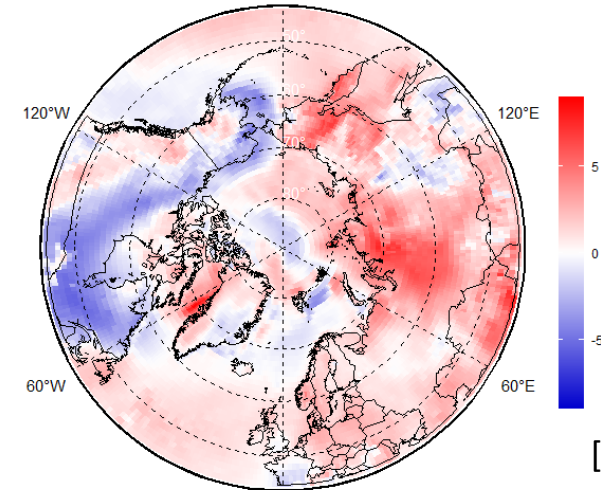
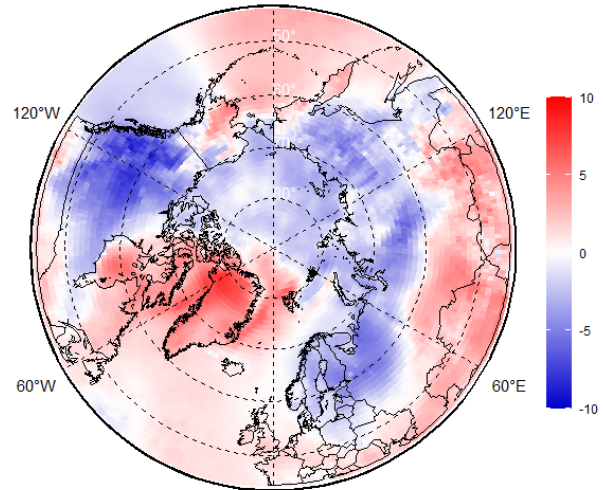
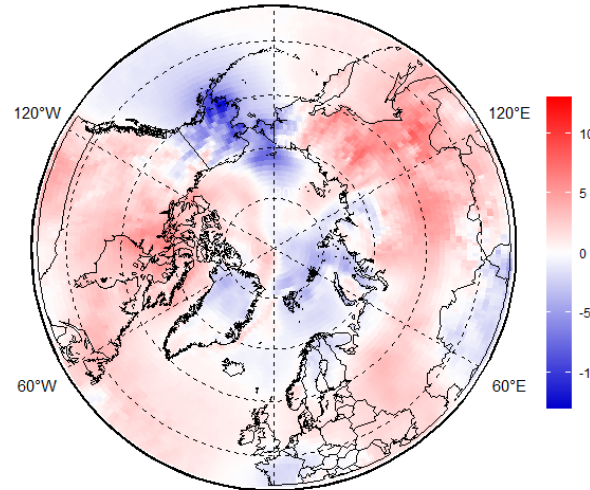


- ❖ Further in season during FMA 2022 bi-center polar vortex shifted counter-clockwise with centers over the Hudson Bay and central Siberia and in general caused meridian type of circulation in Siberia and eastern Canada regions.
- ❖ However, monthly patterns of the surface atmosphere circulation were fully different in February, March and April with negative MSLP anomalies - cyclonic activity over the Hudson Bay, Canadian Archipelago, Greenland and Nordic regions in February and April.
- ❖ Blocking positive MSLP anomalies were observed in February from Central Siberia through Alaska to Central Canada and in April as a vast area of high pressure over Arctic Ocean, N Canada and Alaska.

Surface air temperature: NDJ 2021-2022 anomalies (1991-2020)



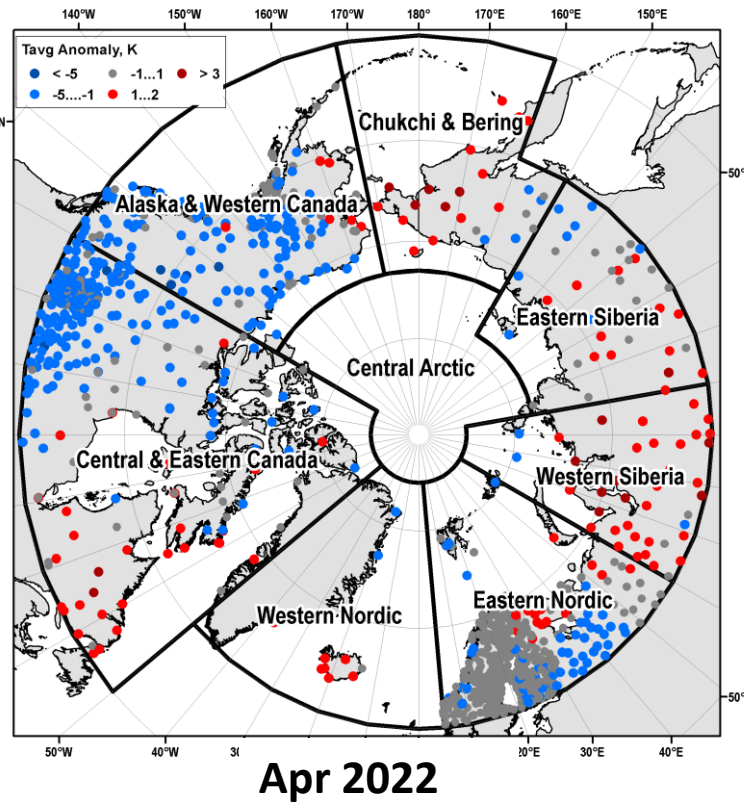
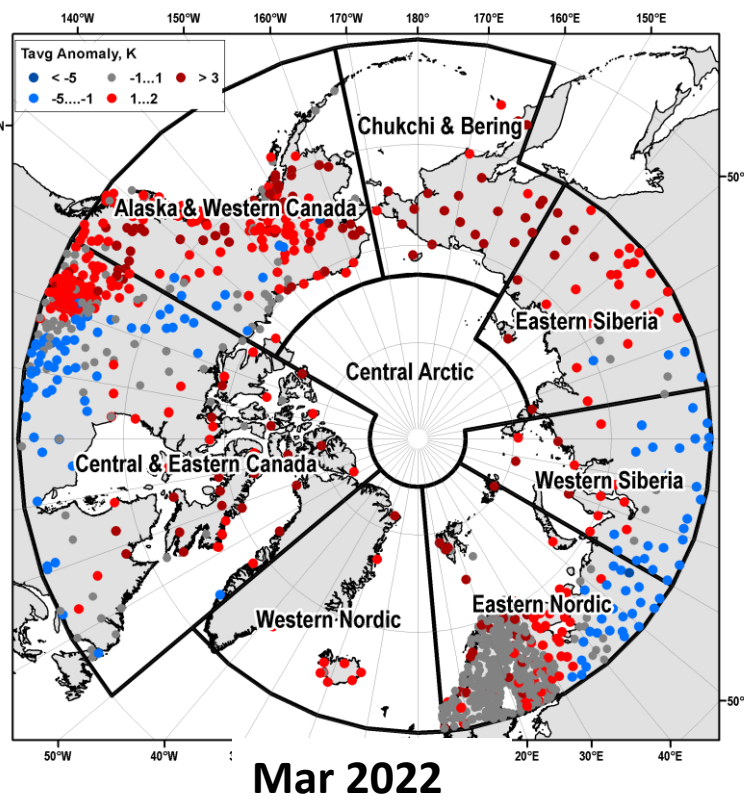
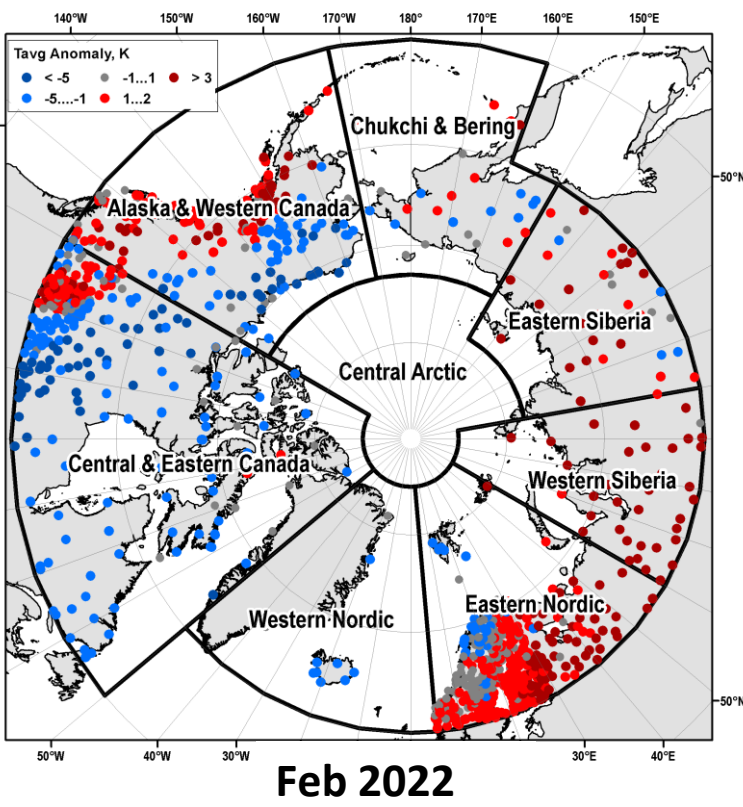
Obs



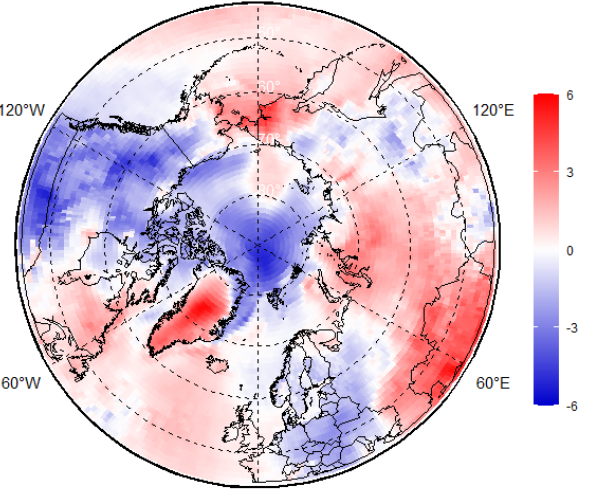
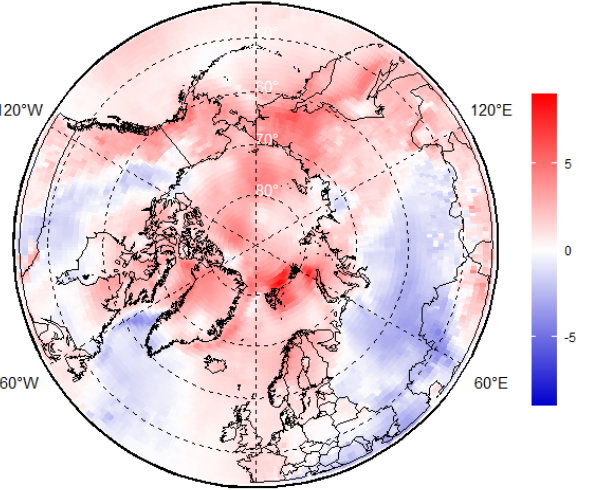
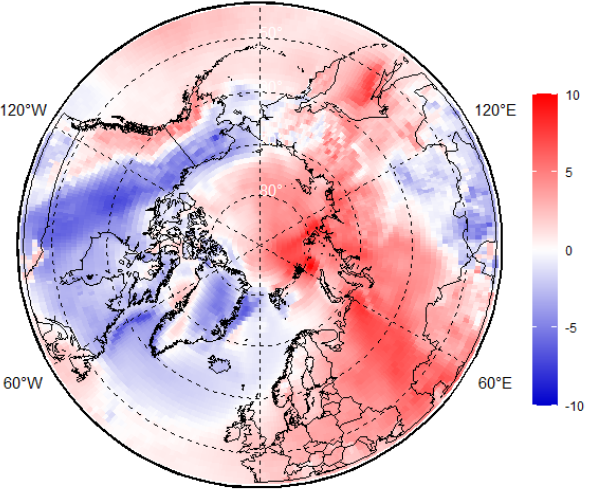
ERA5

[AARI / ERA5]

Surface air temperature: FMA 2022 anomalies (1991-2020)

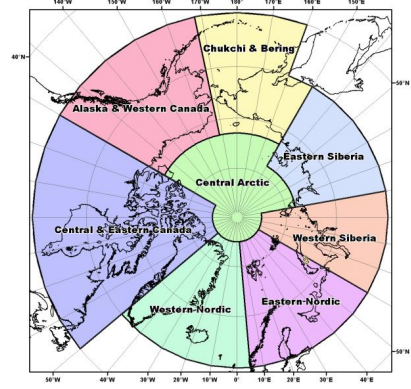
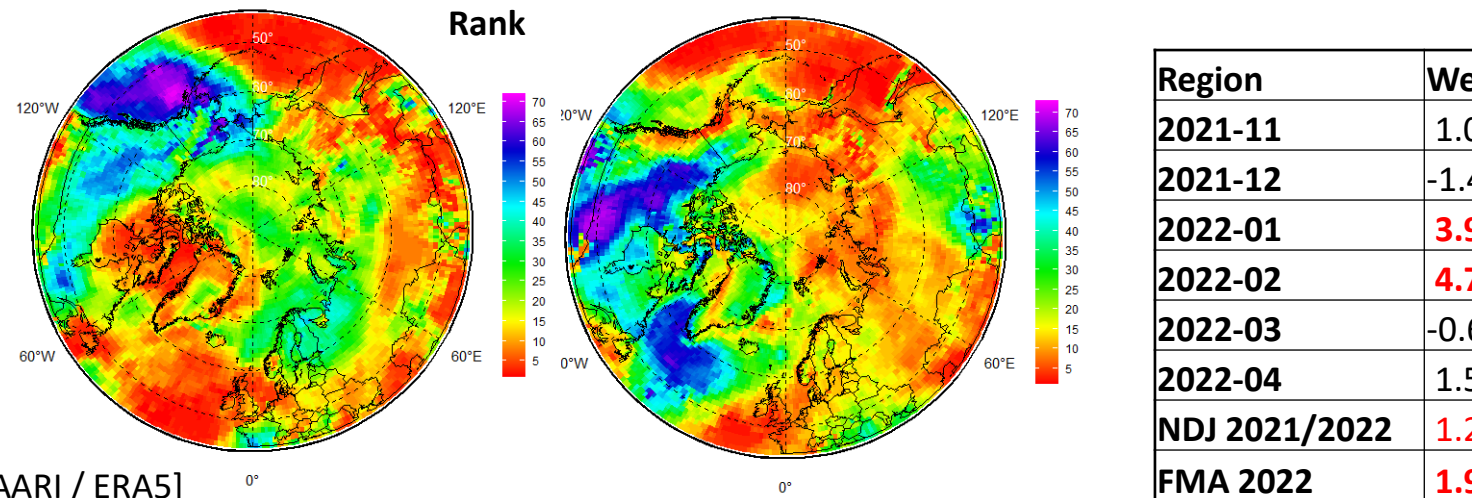
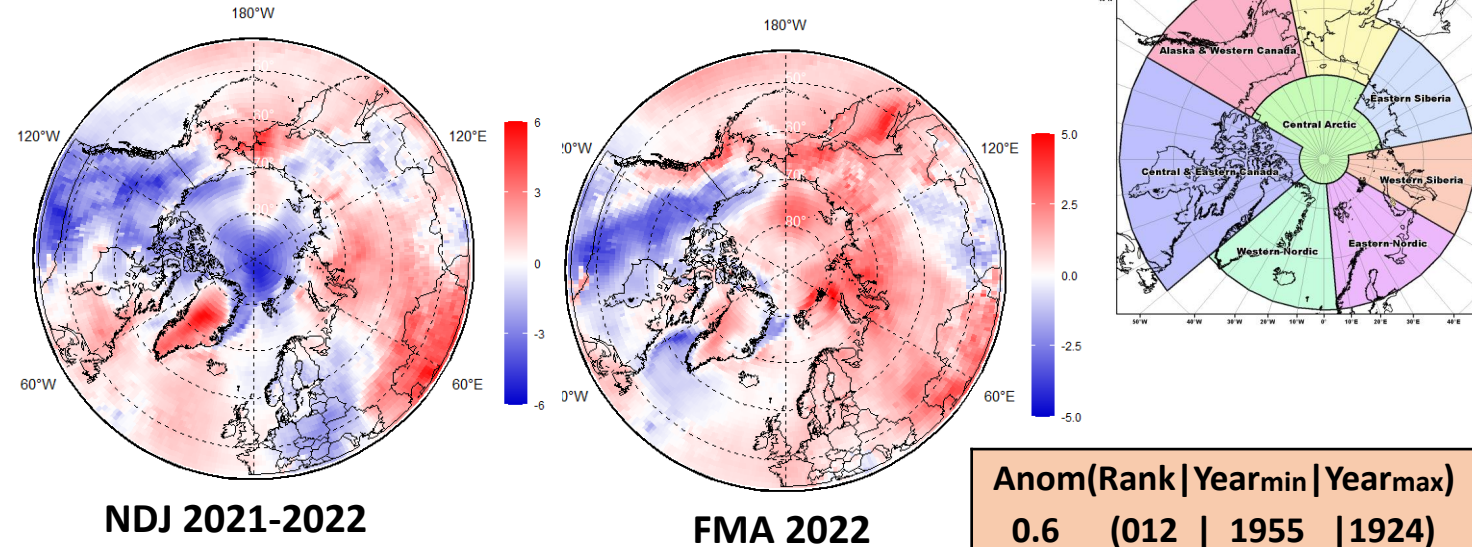


Obs



ERA5

Surface air temperature: NDJ 2021-2022 anomalies and ranks (ERA5) Nov 2021 - Apr 2022 anomalies and ranks (1093 st.) Anomalies relative to: 1991-2020 Ranks: based on 1950-2021/2022

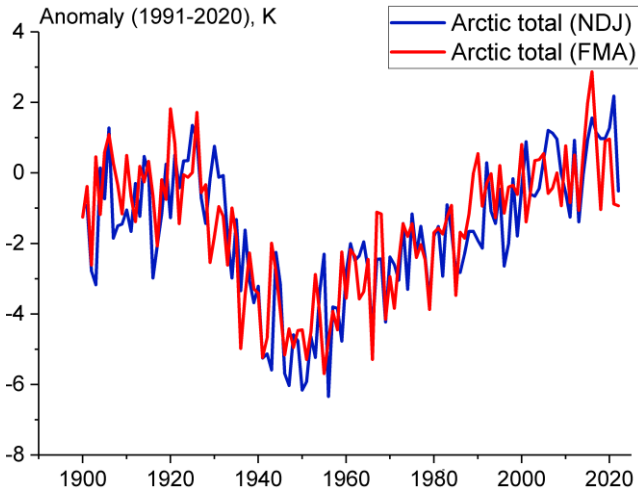


Region	Alaska & W Canada	Central & E Canada
2021-11	-2.3(061 2006 1979)	2.8(003 1985 1917)
2021-12	-3.2(062 1933 1904)	-3.2(052 1933 1930)
2022-01	-1.3(044 1909 1981)	0.2(023 1950 1919)
2022-02	-0.5(038 1904 1920)	-0.9(028 1979 1931)
2022-03	1.2(029 2007 1926)	1.3(011 1964 2010)
2022-04	-1.7(055 1972 1940)	-1.0(029 1954 1915)
NDJ 2021/2022	-2.2(063 1946 1926)	-0.2(020 1949 1930)
FMA 2022	-0.6(043 1972 1906)	-0.3(020 1948 1915)

Region	Western Nordic	Eastern Nordic
2021-11	0.2(030 1971 1941)	-0.2(033 1902 2020)
2021-12	1.4(013 1985 1933)	-3.0(051 1915 2006)
2022-01	0.6(023 1988 1950)	1.2(015 1987 2020)
2022-02	-1.4(056 1969 1932)	1.6(020 1966 1990)
2022-03	1.6(017 1990 1929)	0.2(028 1942 2007)
2022-04	0.3(027 1983 1926)	-0.9(042 1929 2011)
NDJ 2021/2022	0.7(018 1985 1933)	-0.6(029 1915 2020)
FMA 2022	0.2(027 1969 1929)	-1.0(037 1917 1990)

Region	Western Siberia	Eastern Siberia	Chukchi & Bering
2021-11	1.0(022 1968 2020)	3.0(007 1982 2020)	-0.7(026 1969 1919)
2021-12	-1.4(044 1968 1913)	-1.8(049 1907 2013)	-1.7(043 1993 1933)
2022-01	3.9(009 1969 2007)	1.6(012 1900 2007)	1.4(027 1910 1926)
2022-02	4.7(004 1966 2020)	2.4(009 1900 1934)	-0.5(030 1902 1926)
2022-03	-0.6(030 1960 2017)	1.3(016 1942 2017)	3.7(006 1901 1926)
2022-04	1.5(016 1984 1995)	0.2(017 1956 1920)	1.2(010 1976 1926)
NDJ 2021/2022	1.2(014 1968 1936)	1.1(013 1900 2020)	-0.4(031 1994 1927)
FMA 2022	1.9(009 1966 2020)	1.2(012 1966 1920)	1.6(009 1902 1926)

Surface air temperature

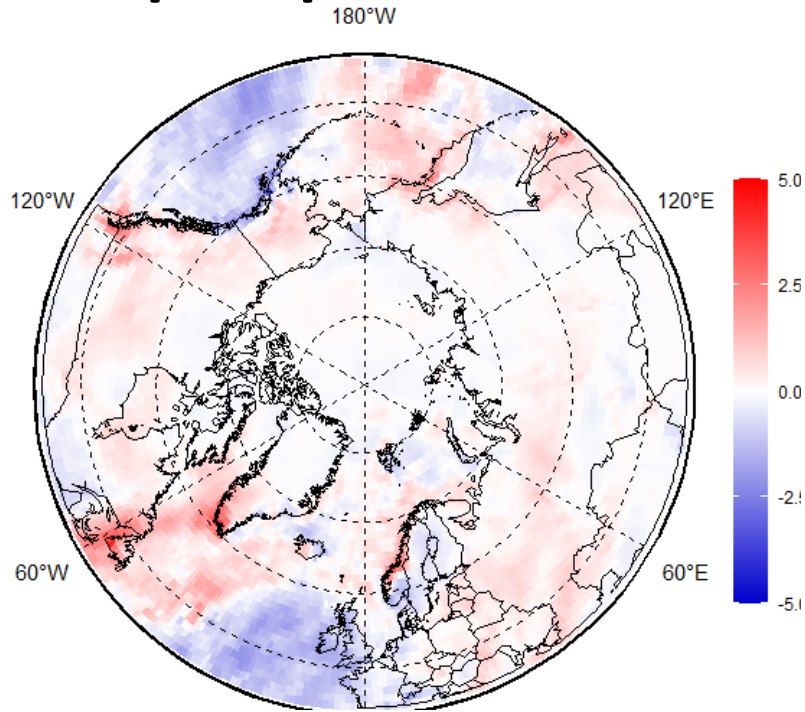


Region	Arctic total
2021-11	0.6(012 1955 1924)
2021-12	-2.6(047 1955 2006)
2022-01	0.6(014 1950 1926)
2022-02	0.6(016 1936 2016)
2022-03	-0.1(024 1942 1926)
2022-04	-1.5(038 1956 2010)
NDJ 2021/2022	-0.5(021 1955 2020)
FMA 2022	-0.9(028 1955 2016)

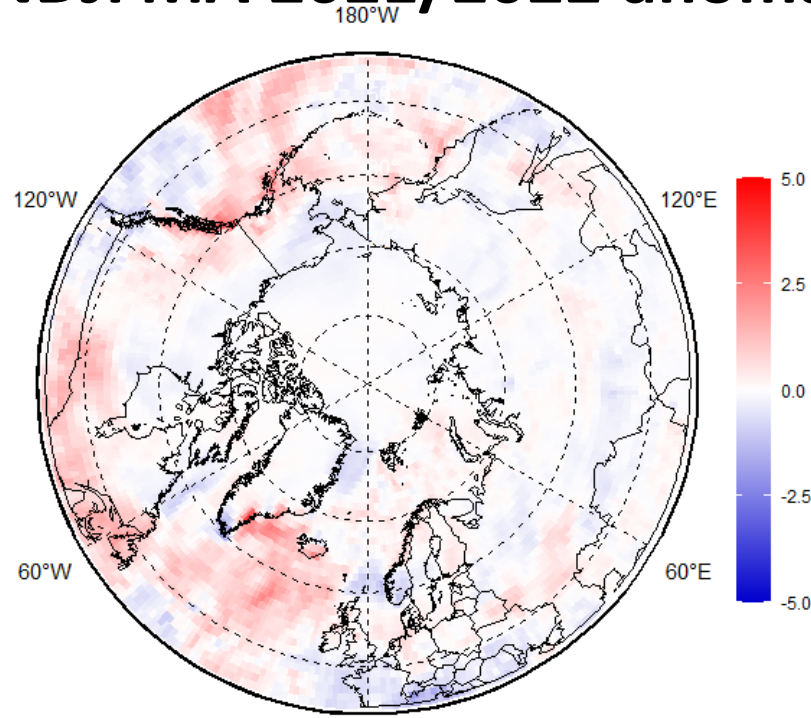
Anom(Rank | Year_{min} | Year_{max})
 0.6 (012 | 1955 | 1924)

- ❖ The start of winter 2021/2022 (November-December) surface air temperature experienced **prominent positive** – in Central and E.Canada (3rd in row), Eastern Siberia (7th in row) and **negative** – Alaska (62nd in row), Eastern Nordic (51st in row) anomalies (to 3rd WMO reference period 1991-2020 and 1950-2021 observation period).
- ❖ During mid-winter (January-February) strong **positive** anomalies were observed over the Eastern Nordic (15th in row), W and E Siberia (4th – 12th in row) with **negative** anomalies observed over W Nordic region (56th in row).
- ❖ Further by the end of winter in March – April 2022 both **positive** and **negative** anomalies were observed over Alaska (29th and 55th in row), Canadian (11th and 29th) and Nordic regions and mostly **positive** over Siberia (16th – 30th in row) and Chukchi (6th – 10th in row) regions.
- ❖ Due to lack of surface marine observations conclusions for the Central Arctic done on reanalysis, include partly colder conditions in November 2021, predominantly warmer in February – March 2021, and colder in December 2021 and April 2022.
- ❖ For the whole land Arctic prominent warmer conditions were observed in November 2021 (12th in row) with prominent colder in December 2021 (47th in row) and April 2022 (38th in row).
- ❖ It should be mentioned that though extreme monthly negative anomalies occurred with a very few exceptions in the beginning – mid 20th century, that could be not the case for extreme positive anomalies which could occur (for different months and regions) as early as 1920s. Simultaneously, it should be kept in mind that though positive trends from 1940s-1950s are obvious, the quantitative estimates depend on the WMO reference period chosen and density of the stations, in particular for the marine Arctic.

Surface precipitation: monthly NDJFMA 2021/2022 anomalies (1991-2020)



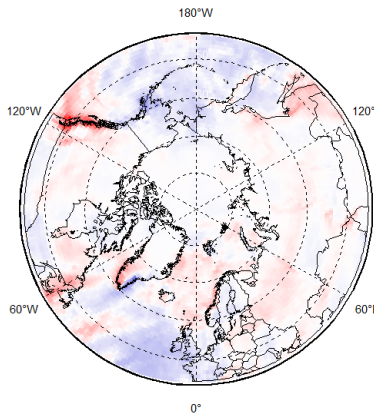
NDJ 2021/2022 precipitation anomaly



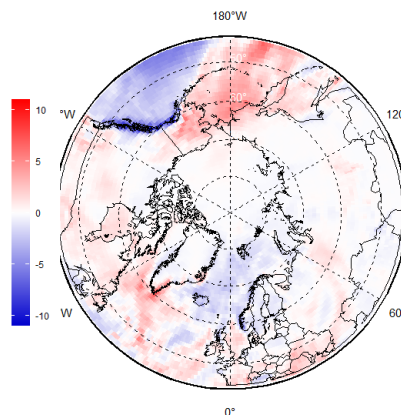
FMA 2022 precipitation anomaly

❖ In general, during the whole season **wetter** (snowy) conditions occurred in most parts of Canadian, Alaska, Bering & Chukchi and W Nordic regions

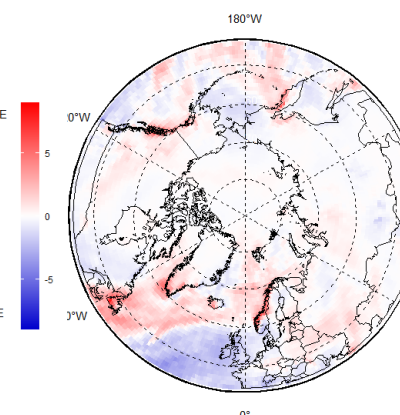
❖ **Drier** conditions occurred in parts of E Nordic, Siberia and Central Arctic regions



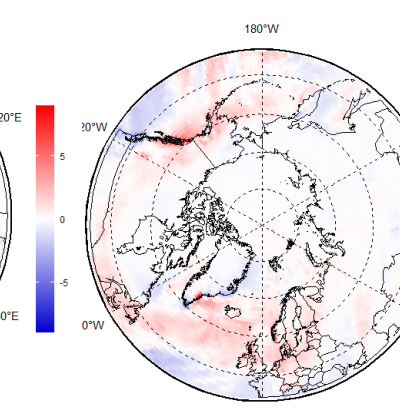
Nov



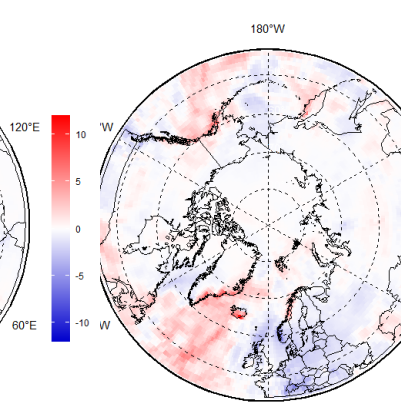
Dec



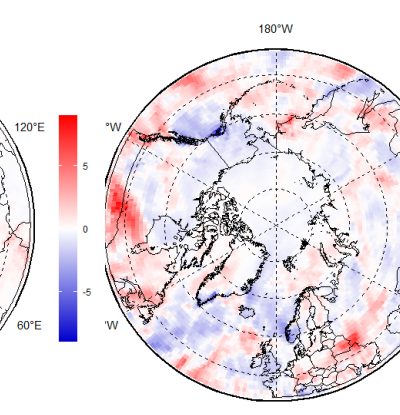
Jan



Feb



Mar



Apr

Surface precipitation: seasonal NDJ 2021/2022 & FMA 2022 anomalies (reanalysis)



Region	NDJ 2021/2022	FMA 2022
Western Nordic	wetter	wetter
Eastern Nordic	drier	slightly drier
Western Siberia	slightly wetter	slightly drier
Eastern Siberia	normal	slightly drier
Bering & Chukchi	wetter	wetter
W Canada & Alaska	wetter	wetter
Eastern Canada	wetter	normal
Central Arctic	slightly drier	slightly drier

Reference period: 1991-2020

- ❖ **The least amount** of precipitation was for the **Eastern Nordic and Siberia regions**
- ❖ More abundant precipitation was observed in the **Western Nordic, Bering and Chukchi and Canada and Alaska regions**.
- ❖ Somewhat **drier** or **close to normal** conditions are estimated for the Central Arctic

Bioclimatic weather severity

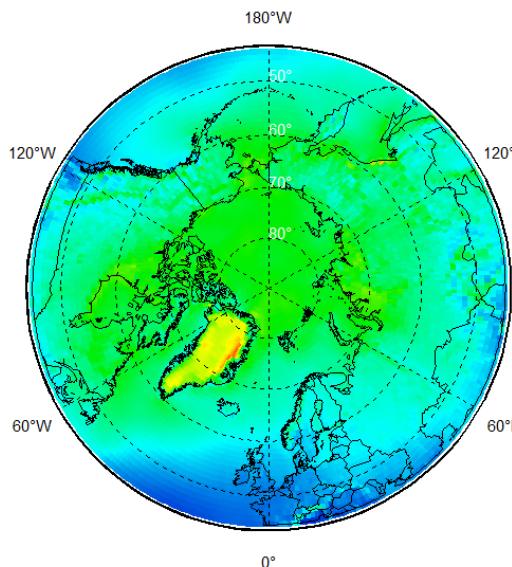
- ❖ During winter 2021/2022 milder than for the last 30 years weather severity can be attributed on a basis of Bodman's index to the most of Siberia, Central Arctic, Svalbard, parts of Canadian Archipelago areas.
- ❖ Opposite situation – harsher more severe weather can be attributed to most of Canada and Alaska and to parts of Nordic region.
- ❖ Particular report on bioclimatic indexes synopsis and forecast will follow.

Bodman's weather severity index (S) (dimensionless) is used for bioclimatic evaluation of weather conditions for winter half year and is calculated according to Bodman's formula as

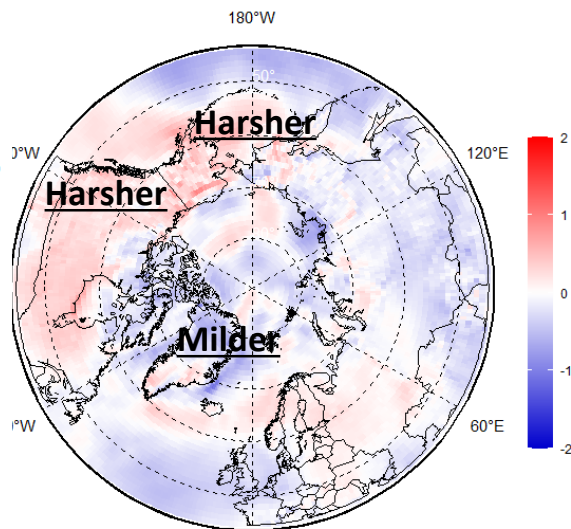
follows: $S = (1 - 0.04 T) (1 + 0.272 v)$ where: v is wind speed (in m/s) at 10 m above ground level and T is air temperature (in $^{\circ}C$)

The scale in use to assess using S is:

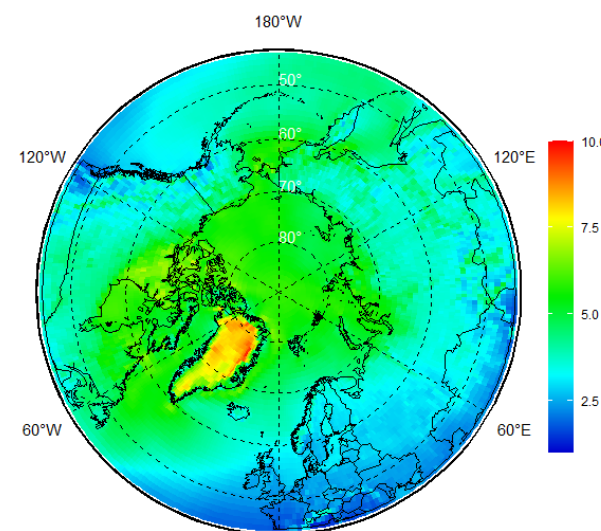
> 6 **extraordinary severe** 5– 6 **extremely severe**
 3– 5 **severe & very severe** 1– 3 **slightly&less severe**
 < 1– **mild**



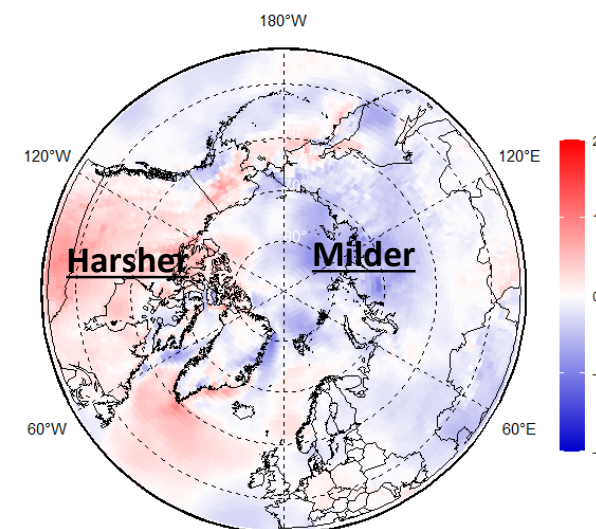
NDJ 2021/2022
Bodman's index



NDJ 2021/2022 Bodman's
index anomaly (1991-2020)



FMA 2022
Bodman's index

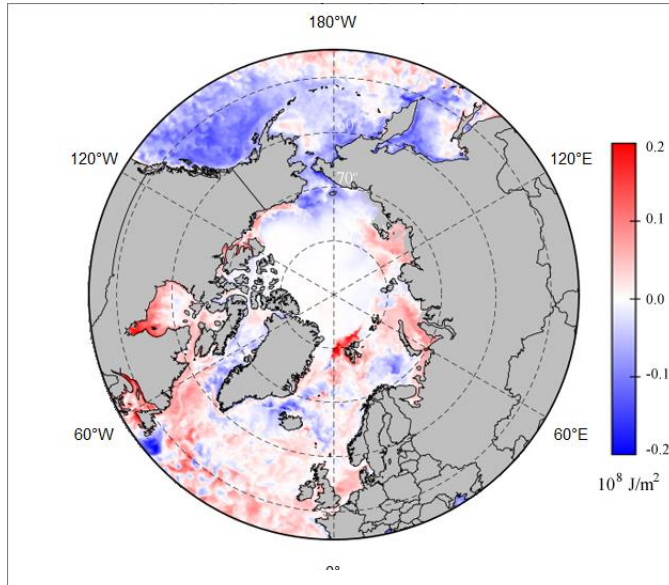


FMA 2022 Bodman's index
anomaly (1991-2020)

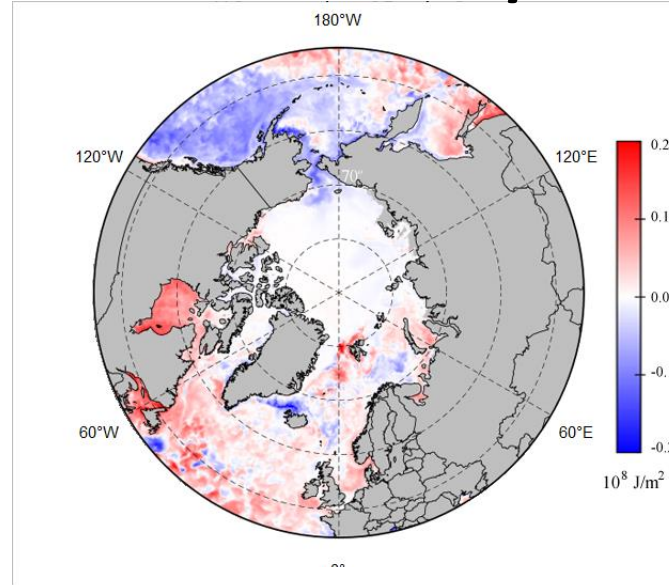
Sea ice

- ❖ Precursors in atmosphere and polar ocean
- ❖ Ice extent and ice conditions based on ice charting
- ❖ Sea ice thickness and volume based on reanalysis

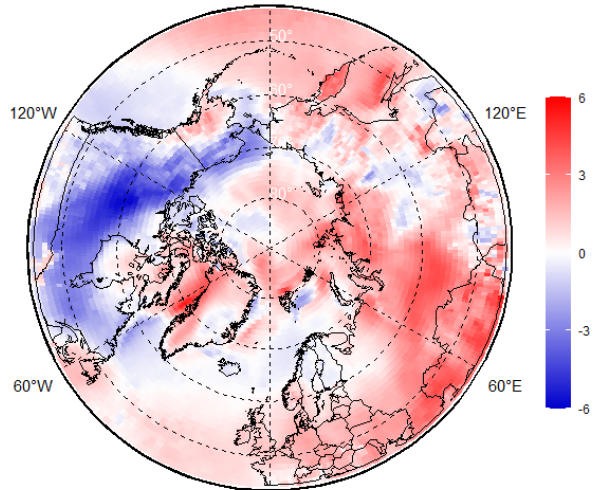
Precursors for winter 2021/2022 ice conditions



Oct 2021 Heat Capacity 15m anomaly, 1993-2020

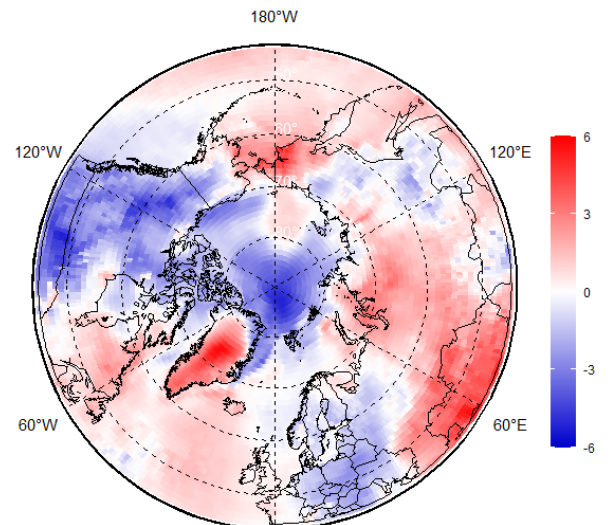


Nov 2021 Heat Capacity 15m anomaly, 2020



DJF 2021/2022

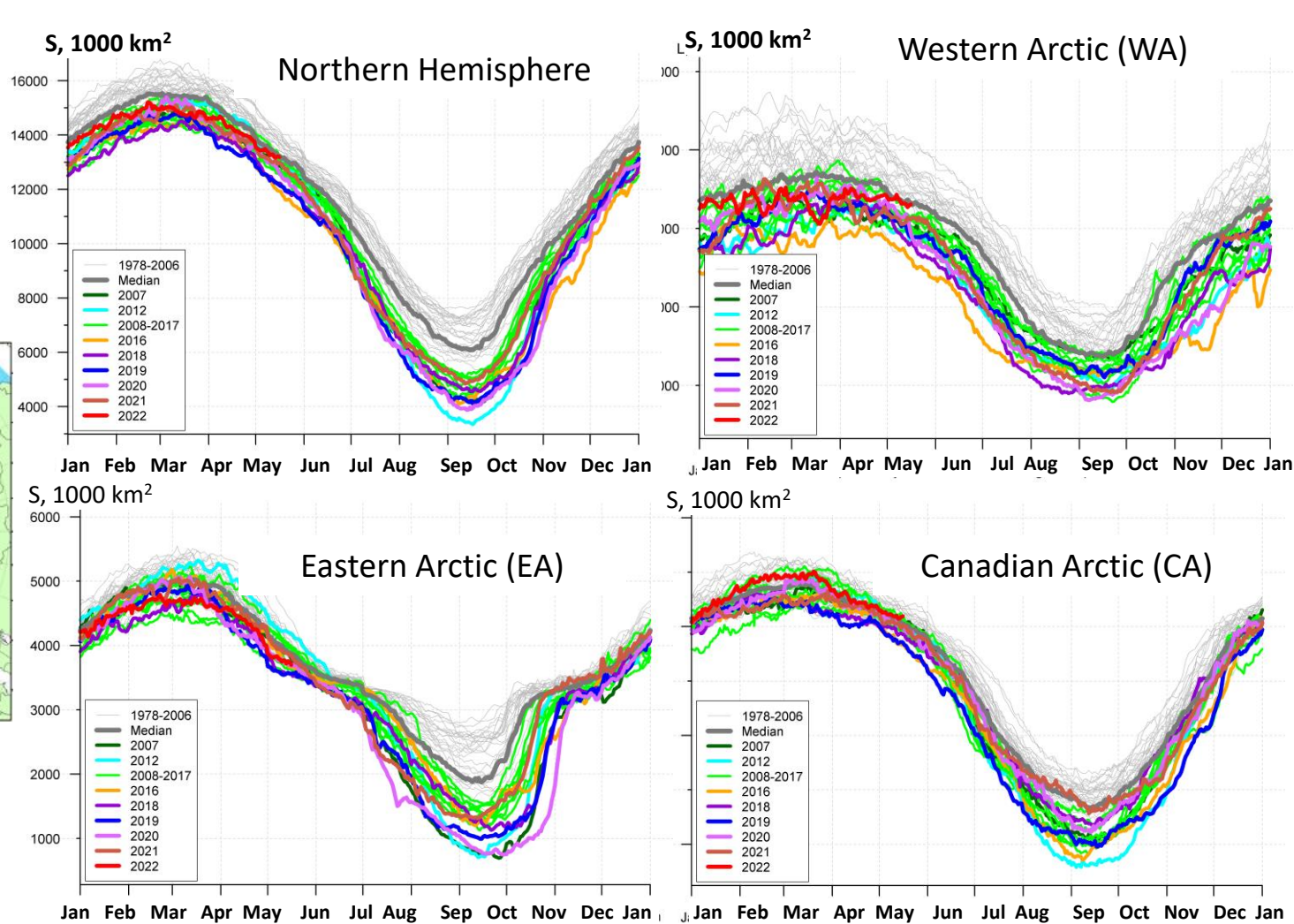
SAT anomaly, 1991-2020



Apr 2022

- ❖ Prevailing **positive** ocean heat capacity (HC) anomaly during Oct – Nov 2021 for the Svalbard, Kara, Laptev, Okhotsk Seas and Hudson Bay slowed freezing processes in these regions
- ❖ Oppositely, zero or **negative** HC anomalies in Oct-Nov 2021 in ESS, Chukchi, Bering, Baffin Seas provided background for close to normal freeze-up
- ❖ Further in winter occurrence of significant **positive** SAT anomalies over Arctic Basin in January-February 2022 slowed the ice growth, however **negative** SAT anomalies in April 2022 stimulated ice growth again

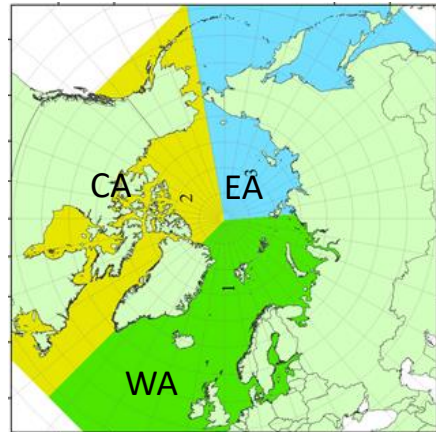
Arctic (NH) seasonal ice extent 1978... 2022



S, 1000 km²

	Sep (Min)	Feb/Mar (Max)
	2012 3346	2017 14467
	2020 3882	2018 14516
	2016 4099	2015 14526
	2019 4103	2016 14580
	2007 4189	2011 14701
	2011 4312	2006 14867
	2015 4350	2019 14891
	2018 4557	2007 14931
	2008 4588	2014 14972
	2017 4622	2021 15100
	2010 4641	...
	2021 4848	2022 15210

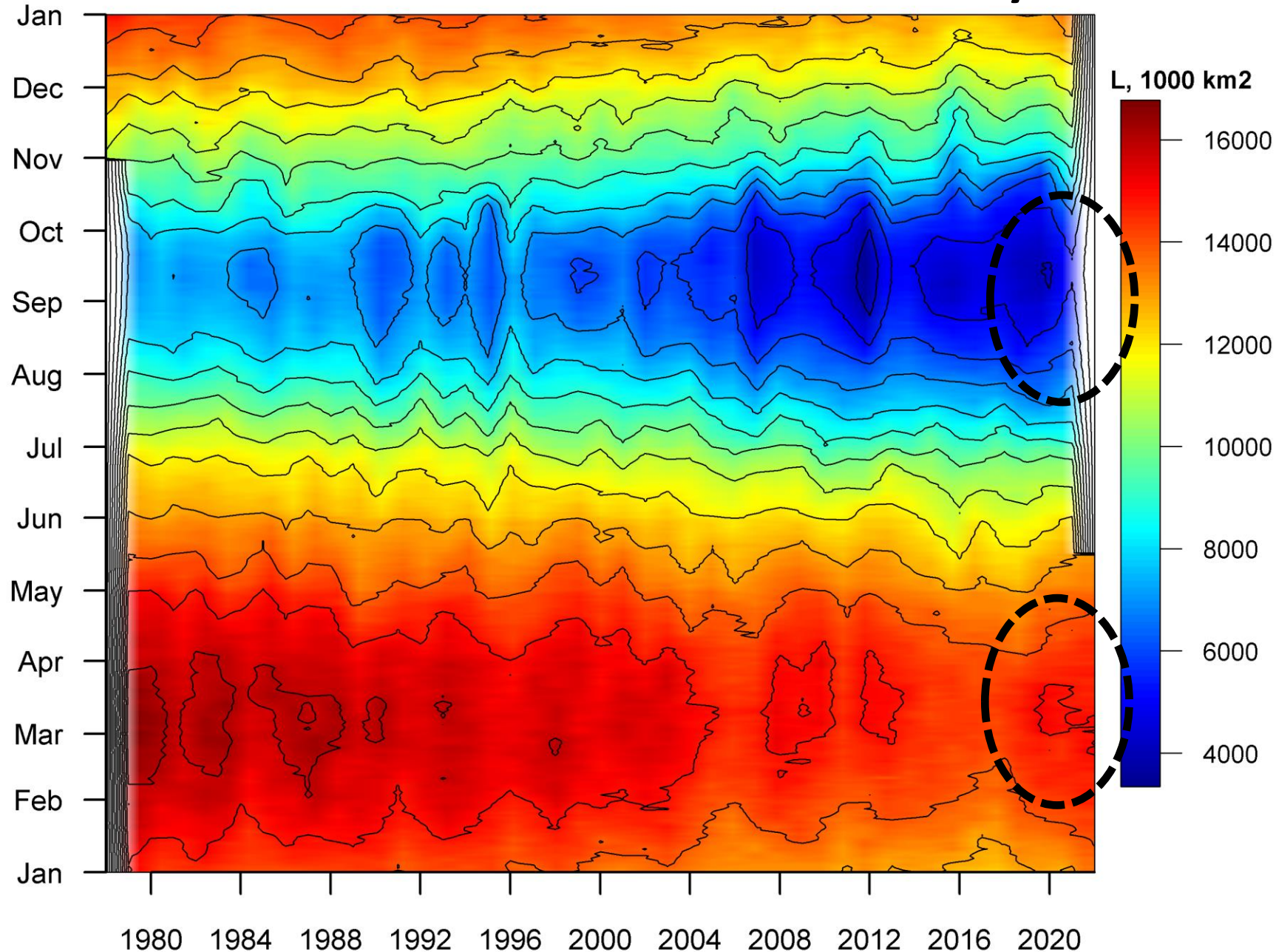
	1982 7246	1988 16461
	1983 7285	1983 16547
	1980 7611	1979 16769



[AARI / NSIDC]

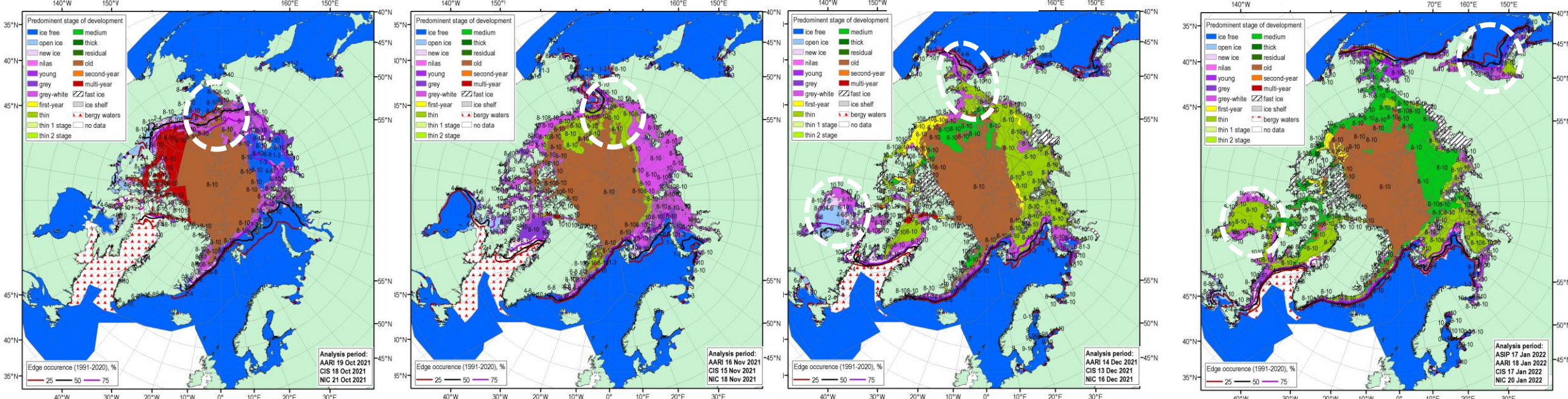
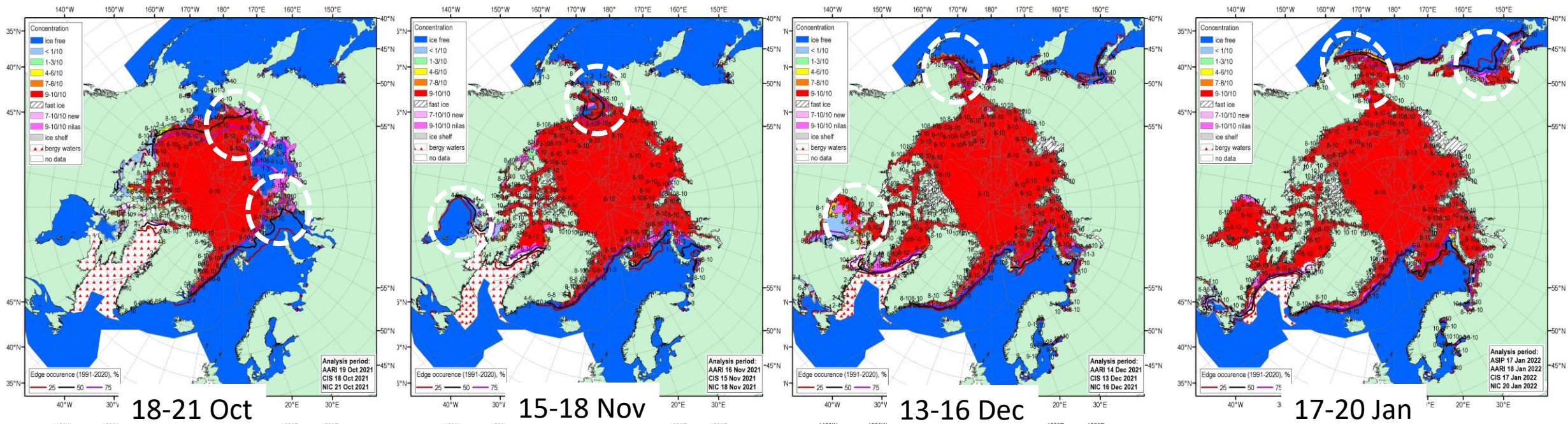
- ❖ Maximum winter ice extent, 13th in row, ~15.2 mln km² (~15,1 in 2021, 10th in row) reached 21-22 Feb 2022 (11 March in 2021). Winter 13th in row maximum in 2022 correlates with summer 12th in row minimum reached 12 Sep 2021.
- ❖ Earlier by 1-2 weeks than normal date of maximum ice extent was mostly due to lower ice extent in the Sea of Okhotsk though prevalence of negative surface air temperature anomalies over the Arctic Ocean at the end of winter 2022 stimulated general ice growth till the end of April 2022 as well as led to greater than 45y median ice extent in Canadian Arctic.

Seasonal NH ice extent variability: 1978 -2022



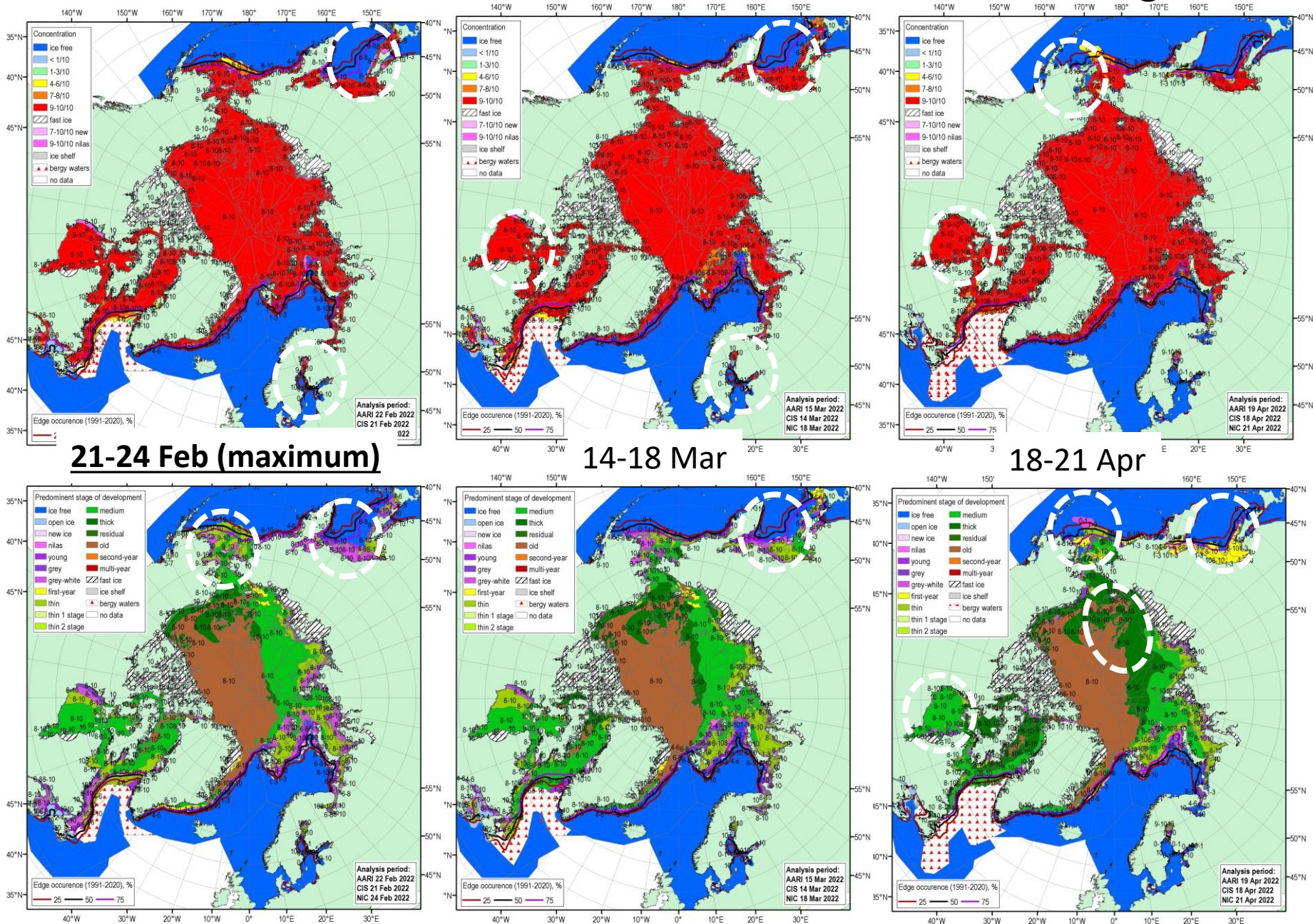
- ❖ Seasonal patterns of daily ice extent allow to retrieve additional information on interseasonal variability of ice extent
- ❖ Though both winter maximums and summer minimums continue to diminish there is certain hint to possibility for summer ice cover in 2022 be greater than in 2019-2021

ONDJ 2021/2022 Arctic sea ice – concentration and stage of development



[sea ice analysis - AARI/CIS/NIC; ice edge - AARI/NSIDC, nearest 5days, reference period: 1991-2020]

FMA 2022 Arctic sea ice – concentration and stage of development

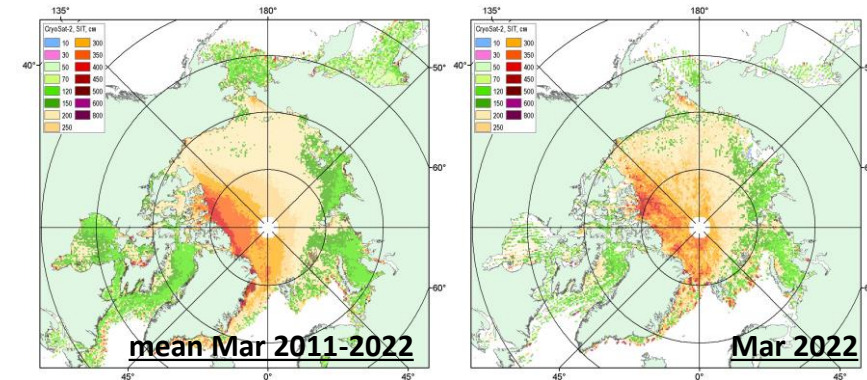
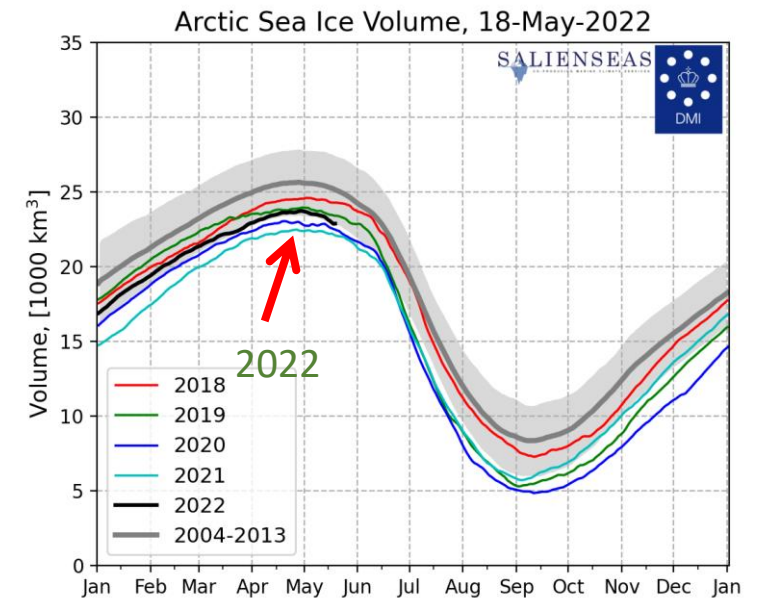
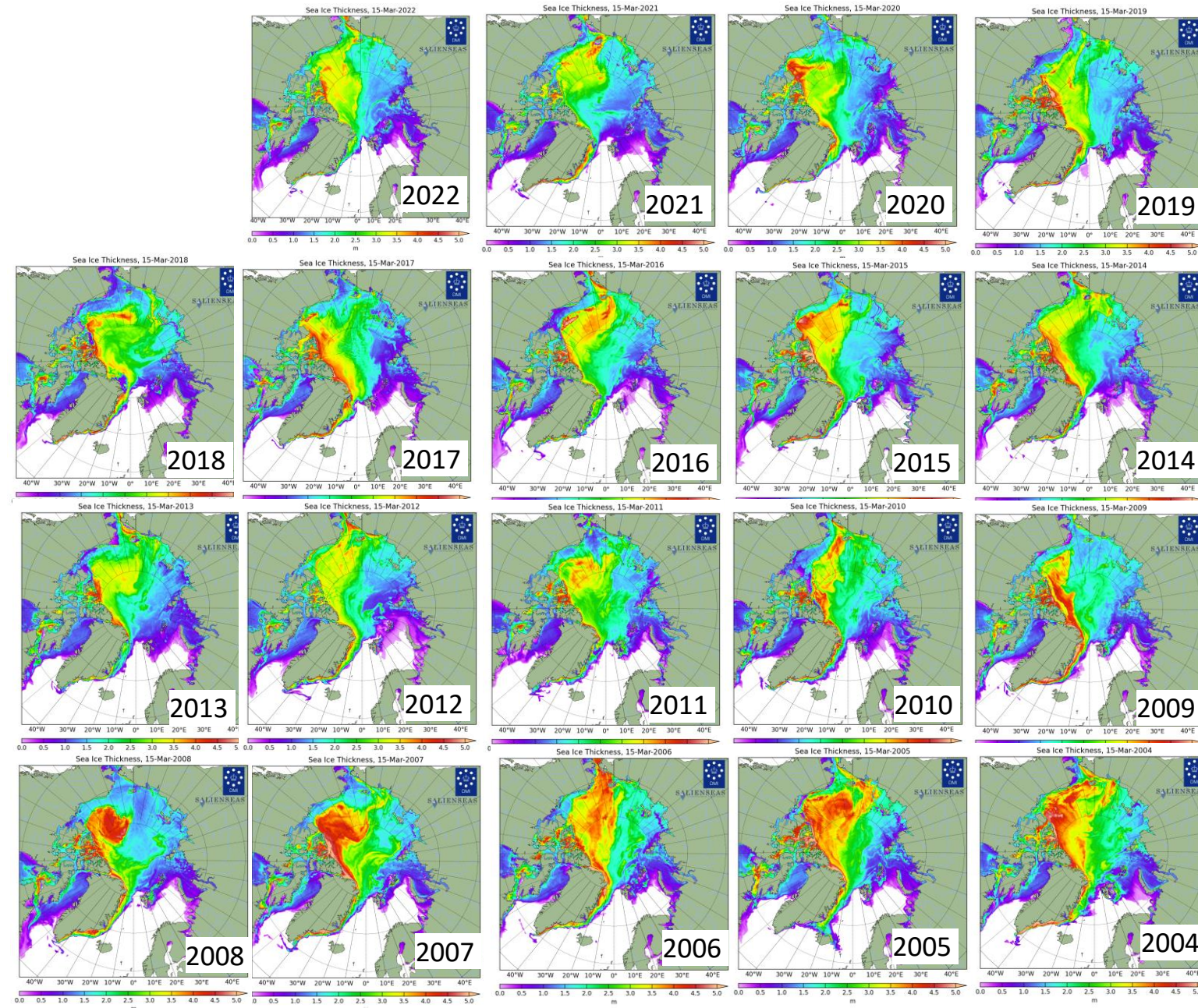


Special features of ice conditions in the Arctic during autumn – winter 2021/2022 included:

- ❖ occurrence of residual and further in season the second-year ice in the NE Kara and N parts of the East Siberian Sea or within eastern lanes of the NSR,
- ❖ lighter than median ice conditions in the Eastern Canadian Arctic during first part of the winter but opposite greater than median during late winter
- ❖ light ice conditions in the Sea of Okhotsk during the whole winter period which is opposite to 2021

[sea ice analysis - AARI/CIS/NIC; ice edge – AARI/NSIDC, nearest 5days, reference period: 1991-2020]

Sea ice thickness for 15 Mar 2004...2022 and ice volume



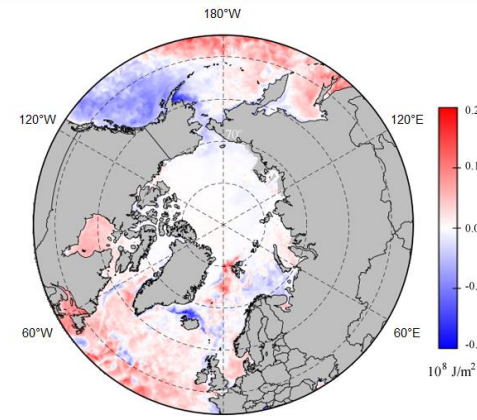
Cryosat-2 measurements show the general Arctic Basin SIT distribution in March 2022 similar to mean 2011-2022 pattern with estimate of the total Arctic ice volume, based on modelling as somewhat $\sim 3^{\text{rd}}$ lowest for 2004-2022 after 2020 and 2021

Polar Ocean:

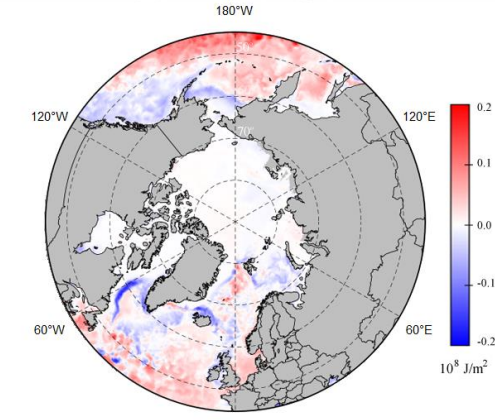
- ❖ Sea surface temperature
- ❖ Storms - Wave and swell height
- ❖ pH and acidification or alkalization of the Arctic ?

Heat content, waves and pH – NDJ 2020/2021 & FMA 2021

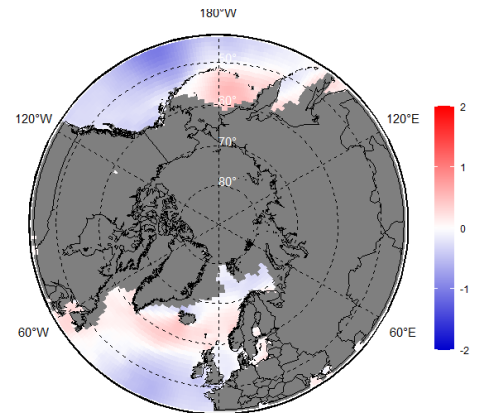
- ❖ During first part of the winter 2021/2022 **higher** 15 m upper ocean layer Heat Content (HC) was noticed in the Eastern Canadian Arctic, W Bering and Okhotsk seas and in Svalbard waters. Somewhat neutral or **calmer** sea surface conditions were observed in the Barents and Okhotsk Seas with **higher** stormier conditions near Iceland and in the Bering Sea.
- ❖ Later in winter the HC was mostly **lower** or neutral to 1993-2020 average for most of the Arctic with the same exception for the sub-arctic Sea of Okhotsk and parts of Svalbard waters. Prominent **higher** stormier sea surface conditions were observed for the open-water Atlantic sector of the Arctic, W Bering and Okhotsk seas.
- ❖ Numerical models show for the current winter season both neutral and **positive pH anomalies** (alkalization) for the Arctic Basin, Laptev Sea and Okhotsk Seas and **negative pH** for the Barents, parts of the Kara, East Siberian, Greenland Seas) anomalies to the 1993-2020 period, the latter may point to **acidification** processes though need further verification with ground-truth data.



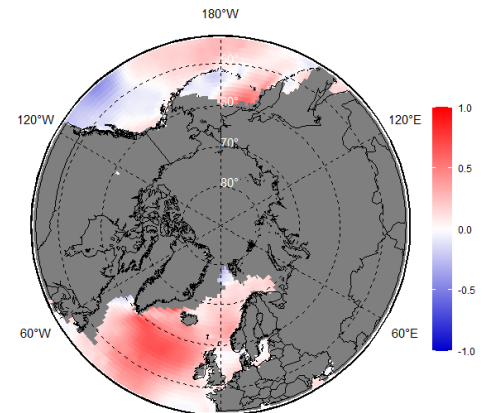
NDJ Heat Content anomaly (1993-2020)



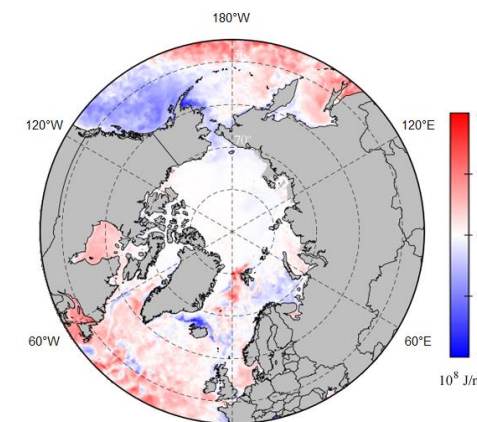
FMA Heat Content anomaly (1993-2020)



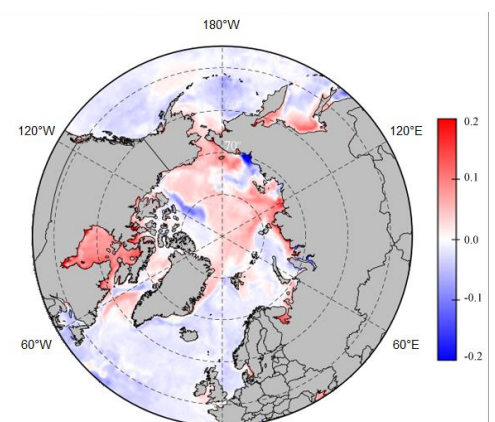
NDJ WW&S height anom (1991-2020)



FMA WW&S height anom (1991-2020)



NDJ pH anomaly 2m (1993-2020)



FMA pH anomaly 2m (1993-2020)

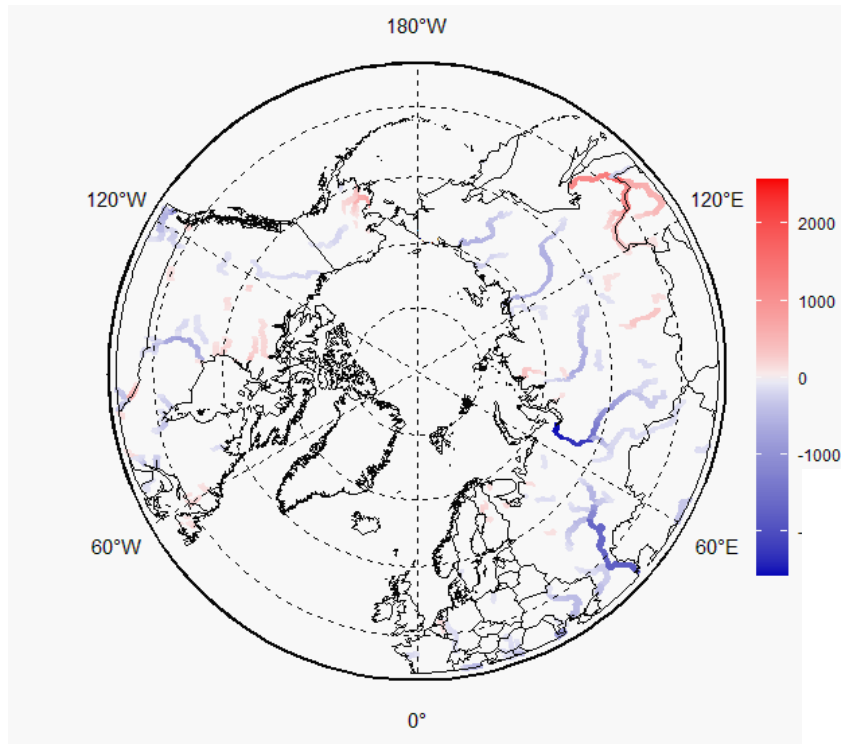
Hydrology and land Snow:

- ❖ River discharge
- ❖ Snow water equivalent
- ❖ Snow extent

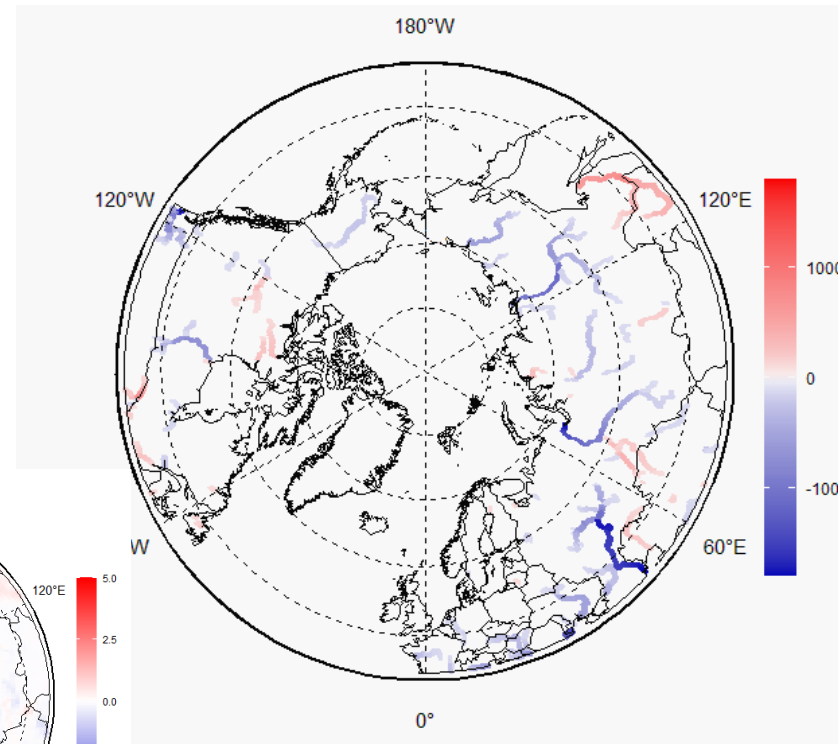
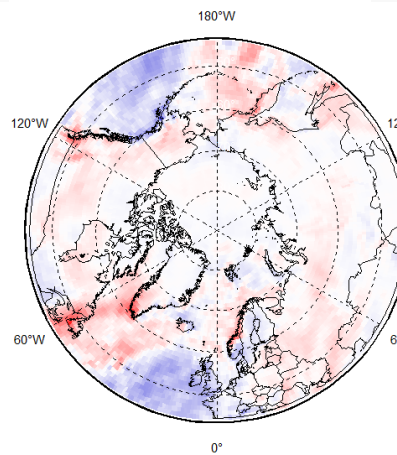
Impacts of precipitation on river discharge

Impacts of wetter/drier colder/warmer weather conditions were to certain extent reflected in the winter/spring 2021-2022 Arctic rivers discharge though the frozen ground restricts direct effects

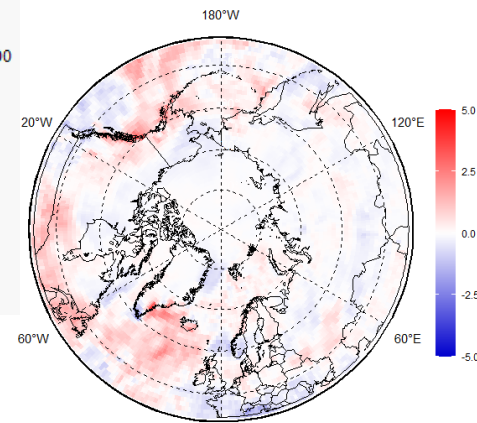
- ❖ **lesser** drainage than normal is seen for Ob', most of Enisey and Lena rivers, and further eastward through the whole season
- ❖ Partly Mackenzie, Yukon and Enisey rivers experienced **greater** discharge than normal
- ❖ Particular report on river discharge and precipitation for the Arctic Great rivers will follow.



NDJ 2021/2022 river discharge anomaly (1991-2020)



FMA 2022 river discharge anomaly (1991-2020)

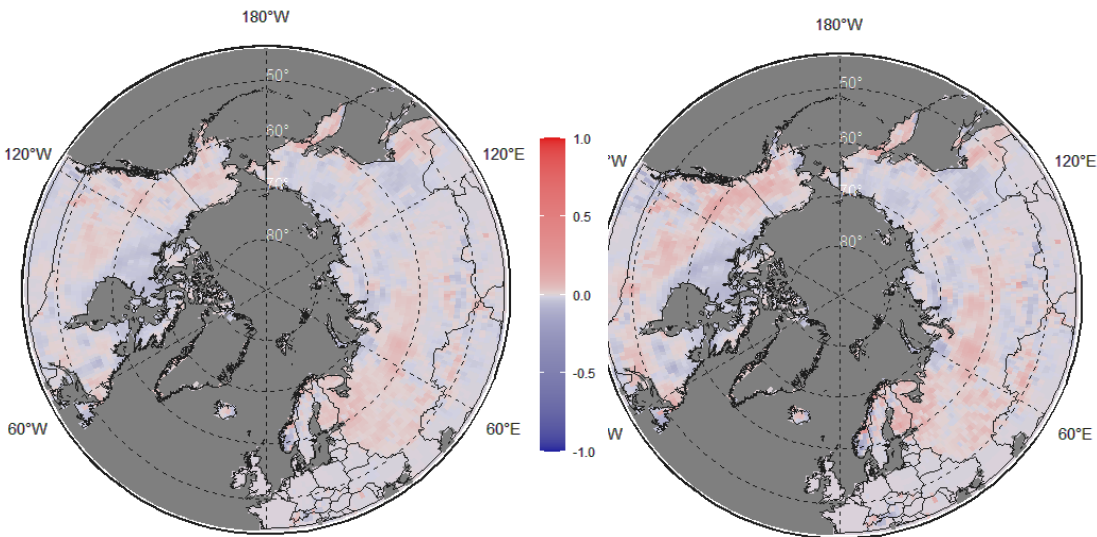


NDJFMA 2021-2022 land snow

- ❖ During NDJFMA 2021-2022 **lesser** snow height as well as snow water equivalent dominated over parts of E Siberia, Chukchi and N Canada
- ❖ Positive anomalies (**greater snow height**) were observed in parts of Alaska, C Canada, Nordic and W Siberia
- ❖ With exception of Alaska, the snow extent over Eurasia and Canada was close to 1991-2020 normal. Alaska experienced somewhat greater snow extent

[GCW / Rutgers Global SnowLab]

2021-2022		1991-2020 Normal		Period of Record from 11-1966		
Month	Area, 1000 km ²	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
Eurasia						
4	16,864	16,759	105	32/56	20,687 (1981)	14,767 (2014)
3	24,387	24,091	296	33/56	27,950 (1981)	20,183 (2002)
2	28,997	28,515	482	22/56	32,285 (1978)	25,913 (2002)
1	29,687	29,647	40	24/56	32,265 (2008)	25,823 (1981)
12	27,693	27,365	329	13/56	29,699 (2002)	22,882 (1980)
11	22,521	21,181	1,340	9/56	24,132 (1993)	16,796 (1979)
Canada						
4	9,409	8,787	622	16/56	9,860 (1979)	6,939 (2010)
3	10,130	10,074	56	27/56	10,368 (1982)	9,486 (1981)
2	10,303	10,309	-6	28/56	10,424 (2013)	10,015 (1981)
1	10,348	10,319	29	16/56	10,424 (1982)	10,060 (1981)
12	10,255	10,147	108	14/56	10,403 (2016)	9,691 (1980)
11	8,713	8,948	-235	32/56	9,978 (2018)	7,254 (1987)
Alaska						
4	1,487	1,461	26	20/56	1,526 (2018)	1,360 (2016)
3	1,523	1,495	28	5/56	1,534 (2008)	1,293 (1968)
2	1,534	1,513	21	1-8/56	1,534 (tie)	1,417 (1968)
1	1,534	1,505	30	1-6/56	1,534 (tie)	1,423 (1986)
12	1,534	1,495	39	1-3/56	1,534 (tie)	1,330 (1967)
11	1,521	1,416	105	1/56	1,521 (2021)	950 (1979)

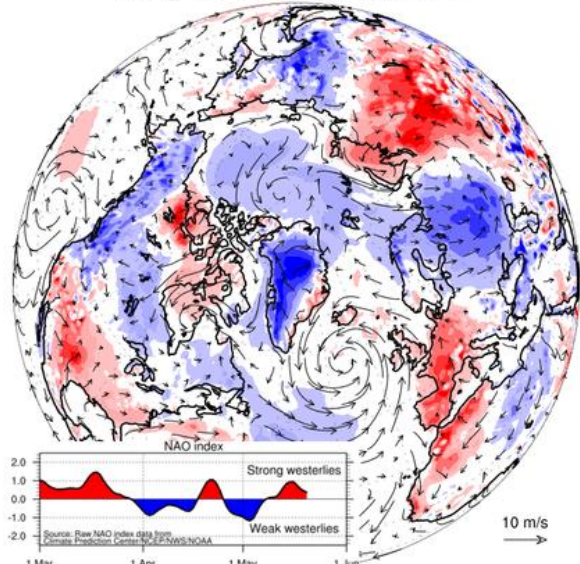


**NDJ 2021/2022
snow height anomaly
(1991-2020)**

**FMA 2021
snow height anomaly
(1991-2020)**

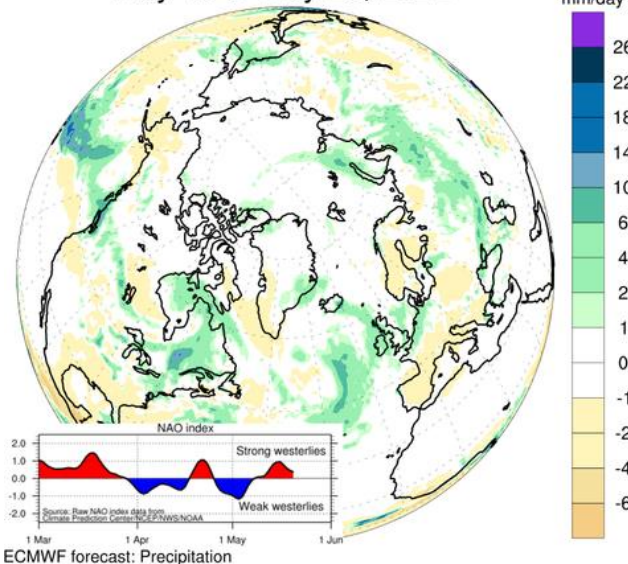
Current Conditions (16-20 May 2022)

May 16 to May 20, 2022



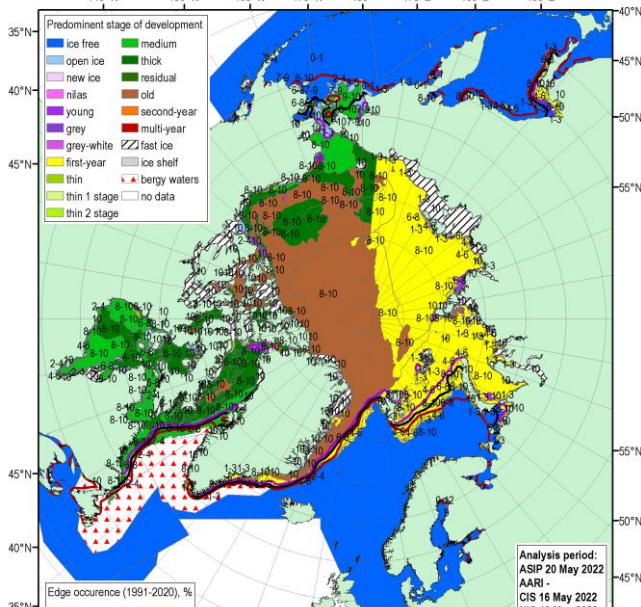
ECMWF fore T2m anomaly

May 16 to May 20, 2022



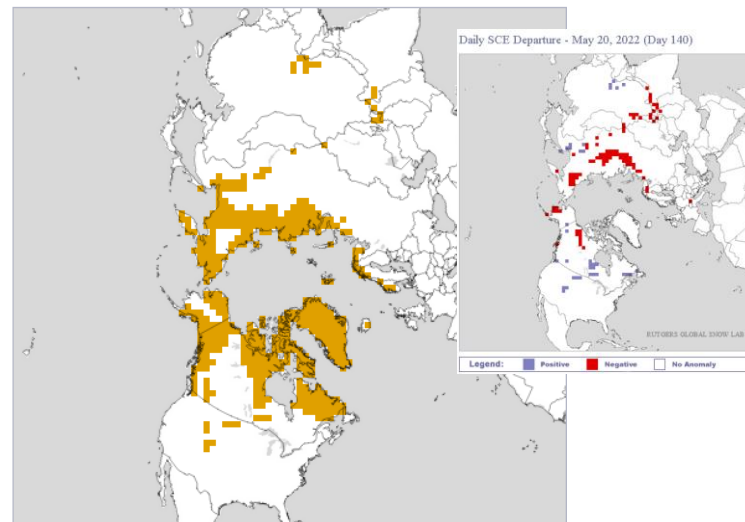
ECMWF forecast: Precipitation

SAT, precipitation, mean wind vectors, NAO for 16-20 May 2022 (<http://polarportal.dk>)



CIS/NIC/ASIP ice chart for 16-20 May 2022

Daily Snow Extent - May 20, 2022 (Day 140)



Snow extent and anomaly for 20 May 2022, Rutgers Global snow lab

- ❖ Since second week of May westerly, NW winds dominated in European sector with somewhat opposite patterns over Siberia and Canada
- ❖ Lower SAT observed over European, Alaska and W Canadian regions
- ❖ Higher SAT observed over E Siberia, partly Chukchi and Canadian Archipelago regions
- ❖ N Scandinavia, Arctic coasts, E Siberia, Chukchi, Alaska, N Canada are under snow (normal) with somewhat negative anomalies in Siberia
- ❖ SE Barents, Bering and in particular the Sea of Okhotsk are under intense melting, but not for other parts of the Arctic where fast ice zones in Siberia and Canadian Arctic are still well preserved, which is similar to 2021 but somewhat opposite to spring 2020 season

Data sources:

1. AARI Review of Hydrometeorological Processes in the Northern Polar Region (<http://old.aari.ru/misc/publicat/gmo.php>)
2. Copernicus Climate Change Service
 - ❖ ERA5 monthly averaged data on pressure and single levels (ERA5)
 - ❖ Marine environment monitoring service (CMEMS)
 - ❖ GloFAS operational global river discharge reanalysis (ERA5-GloFAS)
3. Weekly ice charts from AARI, CIS, NIC, ASIP / WMO GDSIDB project (<http://wdc.aari.ru>)
4. NSIDC Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations
5. ESA CryoSAT-2 data (AWI)
6. DMI PolarPortal (<http://polarportal.dk>)
7. WMO GCW SnowWatch (FMI, ECCO, Rutgers Glob Snow Lab, <http://climate.rutgers.edu/snowcover/>)

Thank you! Merci! Takk! Спасибо!
Tak! Tack! Kiitos! þakka þér fyrir!
Naqurmiik ! Qaġaasakuq !
Giitu! Vielen Dank!
Dhanyavaad !



WMO OMM

World Meteorological Organization

Organisation météorologique mondiale

Monthly and seasonal graphs at full resolution and for all ECVs are available at:

- ❑ <http://wdc.aari.ru/prcc/reanalysis/>
- ❑ <http://wdc.aari.ru/datasets/d0040/arctic/png/>