WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

AARI

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

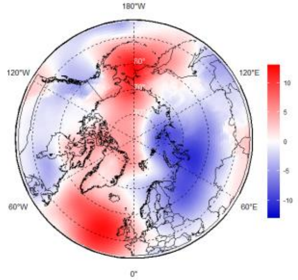
- **Review for NDJFMA (November 2021… April 2022)**
  - Atmosphere:
    - Atmospheric circulation
    - Surface air temperature – anomalies, ranks and trends by Arctic regions
    - Precipitation – anomalies, ranks and trends by Arctic regions
  - Sea ice:
    - Precursors in atmosphere and polar ocean
    - 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 for the latest **3rd WMO period 1991-2020** with ranks given for **1950…2021/2022** period. Years corresponding to extreme SAT anomalies based on surface observations are given for 1900…2021/2022 period.

Atmosphere

- Precursors: atmospheric circulation
- Surface air temperature
- Precipitation

NDJ 2021/2022 atmospheric circulation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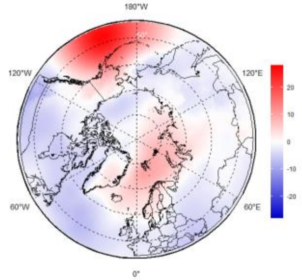
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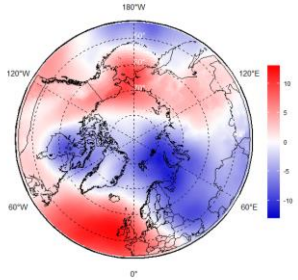
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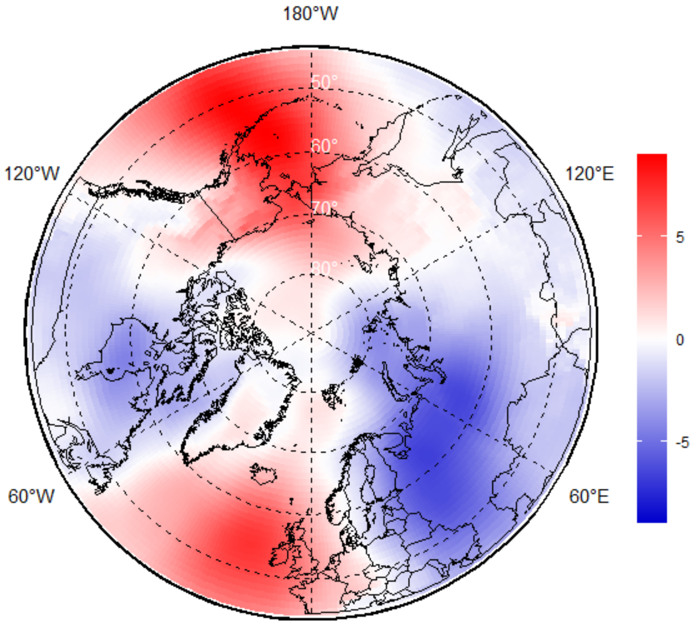
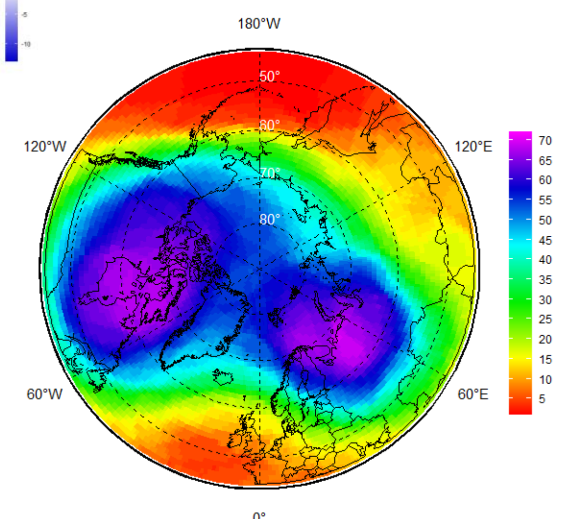
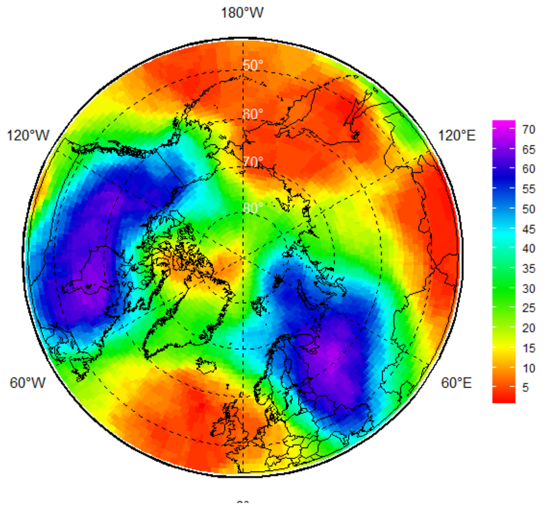


NDJ MSLP hPa anomalies (1991-2020)



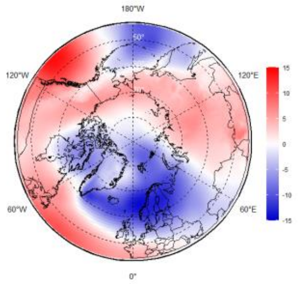


NDJ H50 (left) and H500 (right) ranks (1950-2021/2022)

- 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

[AARI / CCCS ERA5]

FMA 2022 atmospheric circulation



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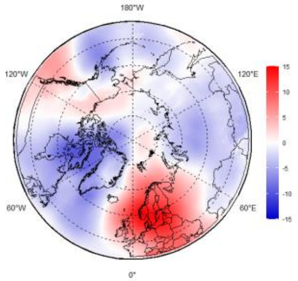

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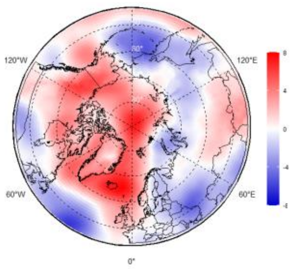

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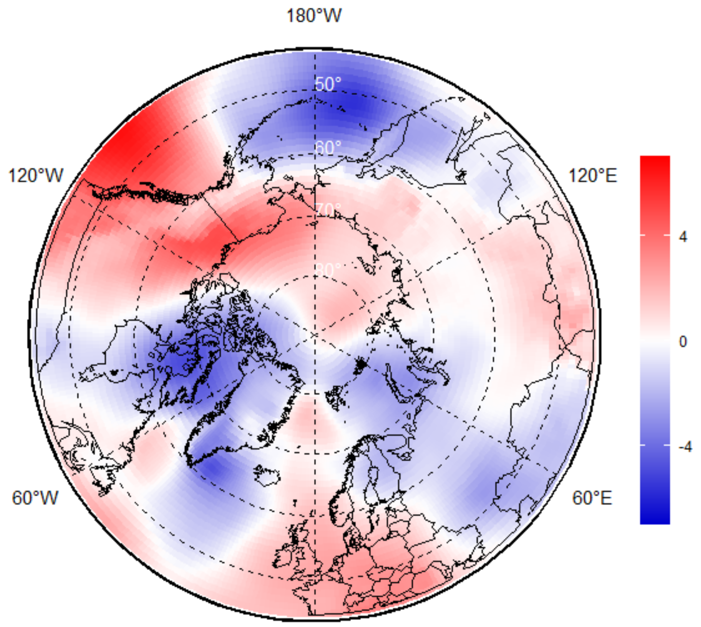
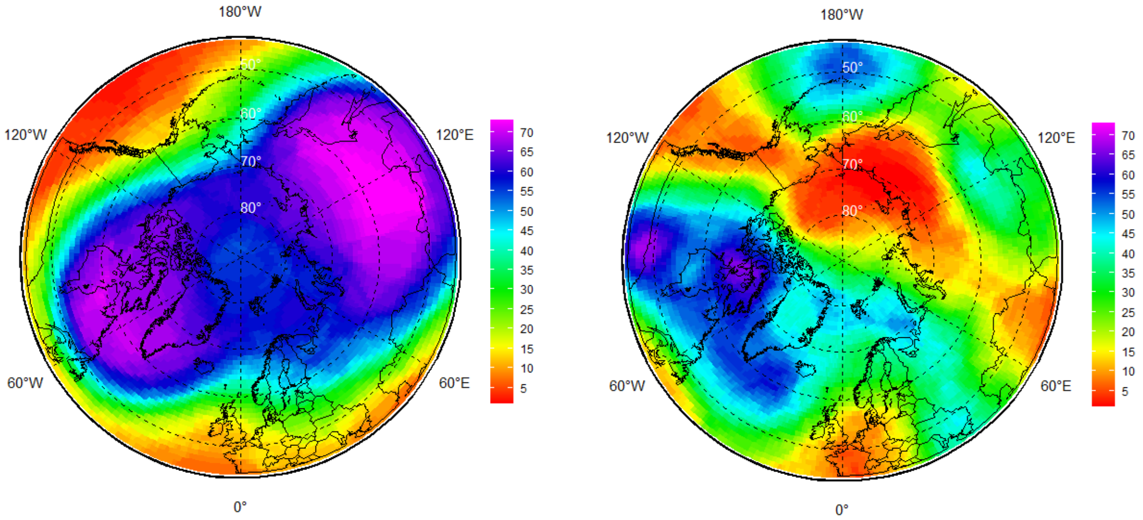


FMA MSLP hPa anomalies (1991-2020)

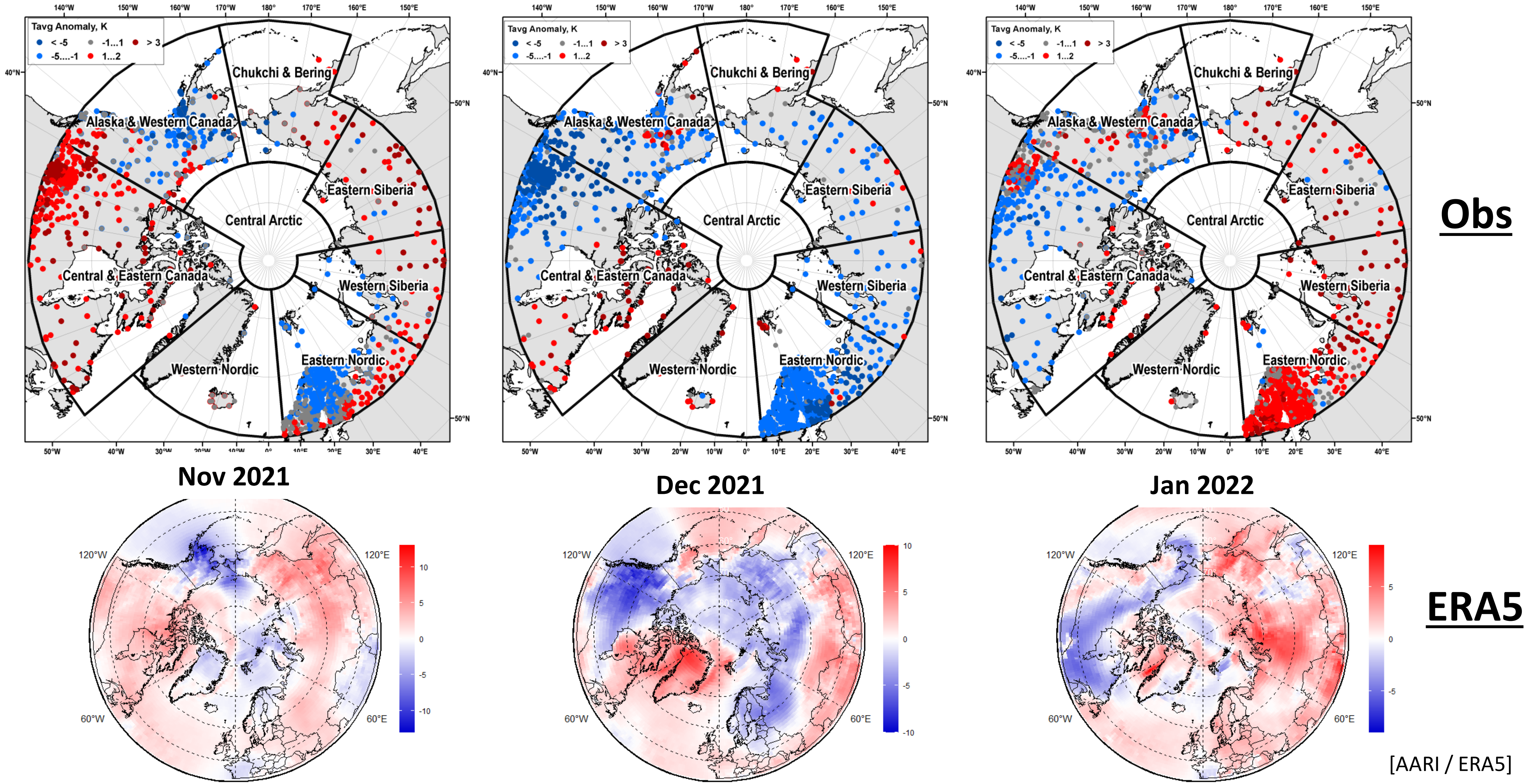


FMA H50 (left) and H500 ranks (1950-2022)

- ❖ 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 patters 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.

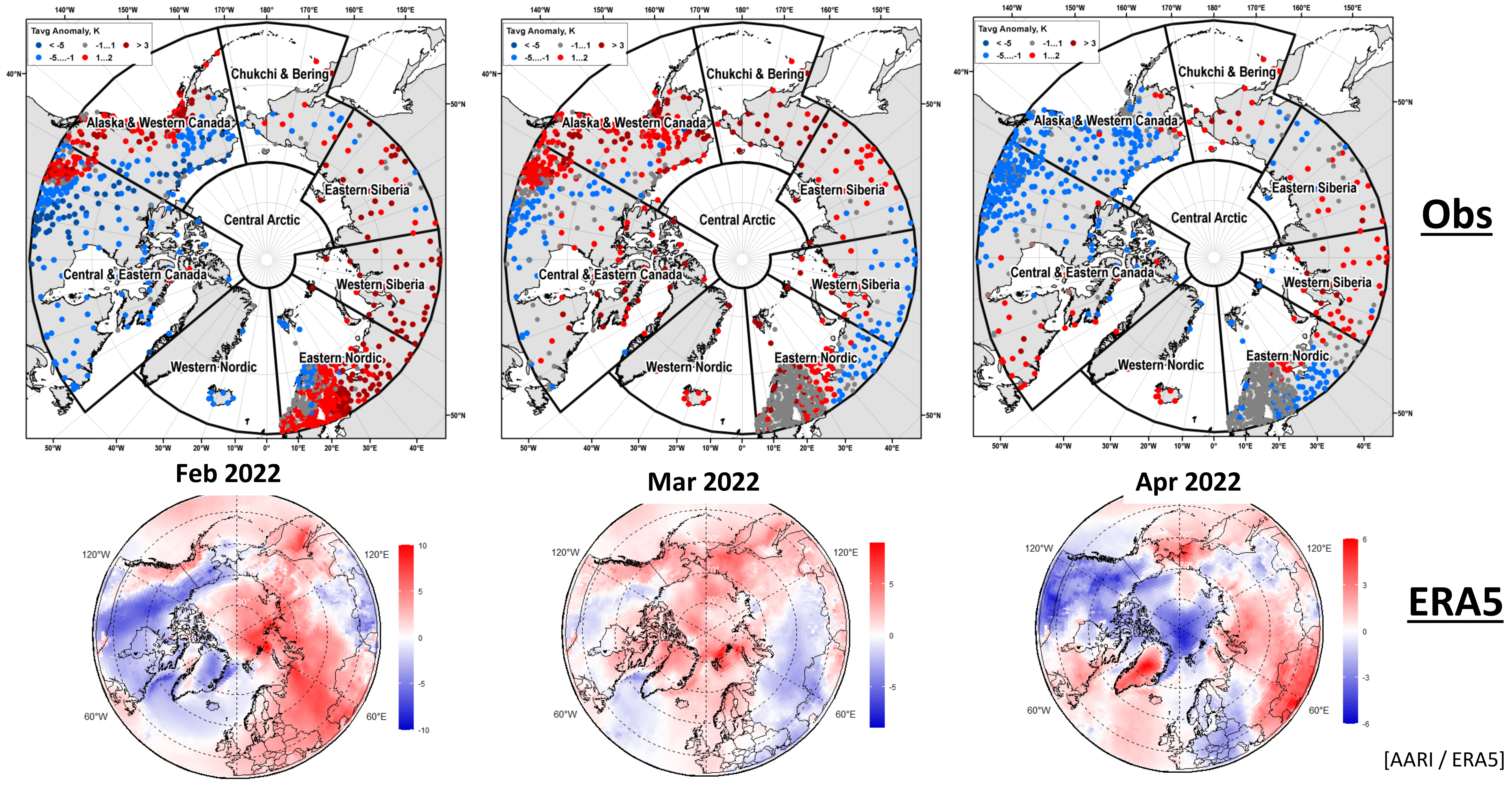
[AARI / CCCS ERA5]

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



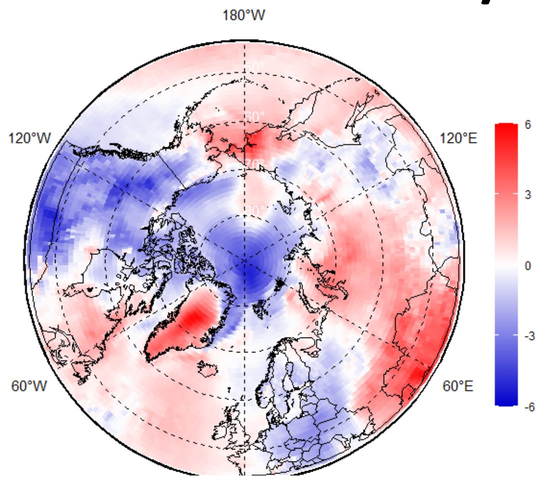
[AARI / ERA5]

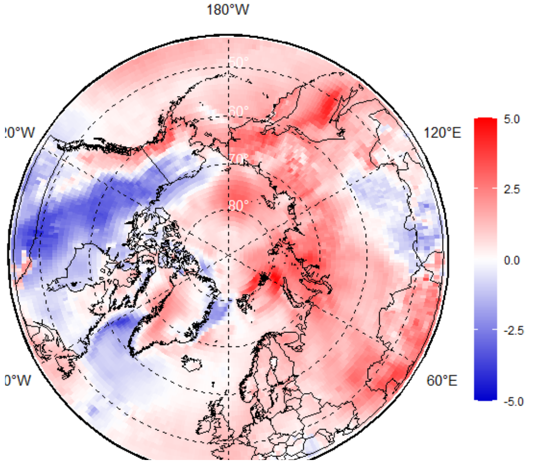
FMA 2022 Surface air temperature: anomalies (1991-2020)



[AARI / ERA5]

Surface air temperature
NDJ 2021-2022 anomalies and ranks (ERA5)
Nov 2021 - Apr 2022 anomalies and ranks (obs)
Anomalies: 1991-2020
Ranks: 1950-2021/2022

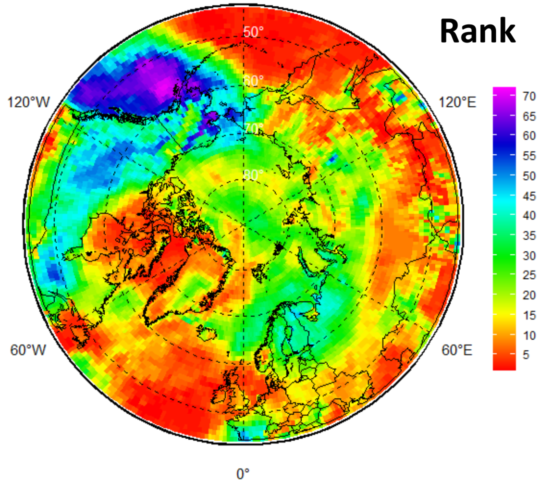


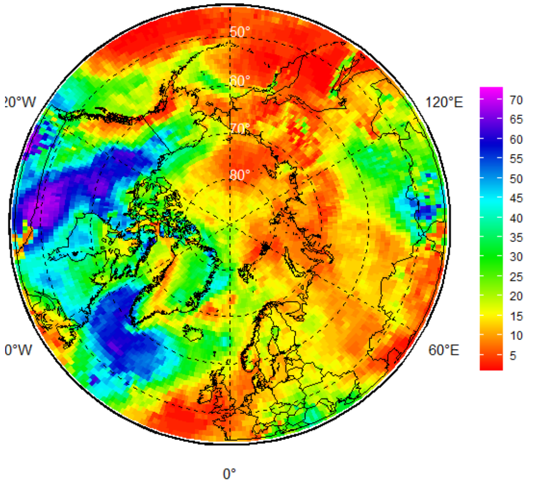


NDJ 2021-2022

FMA 2022

Rank





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)

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)

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)

Anom(Rank|Year$_{min}$|Year$_{max}$)
0.6 (012 | 1955 |1924)

[AARI / ERA5]

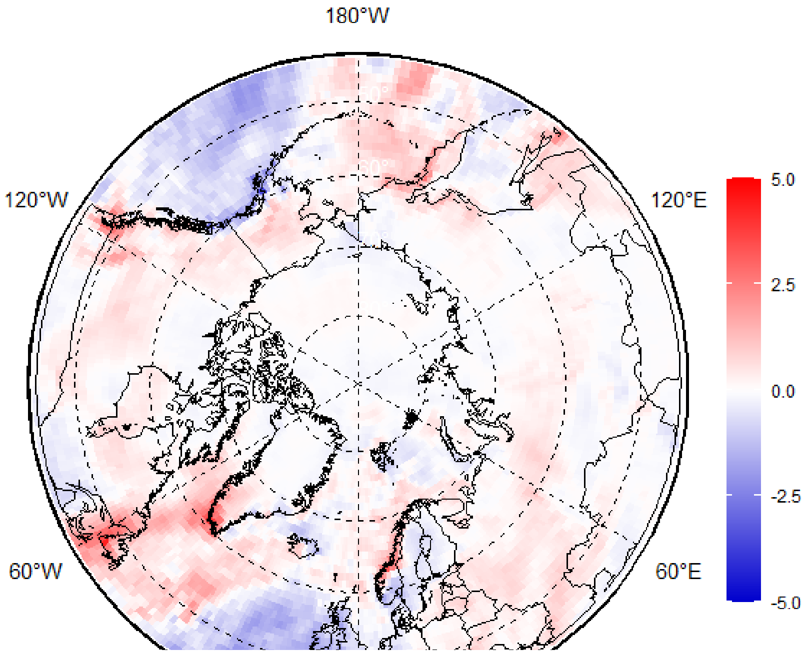
Surface air temperature

	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)

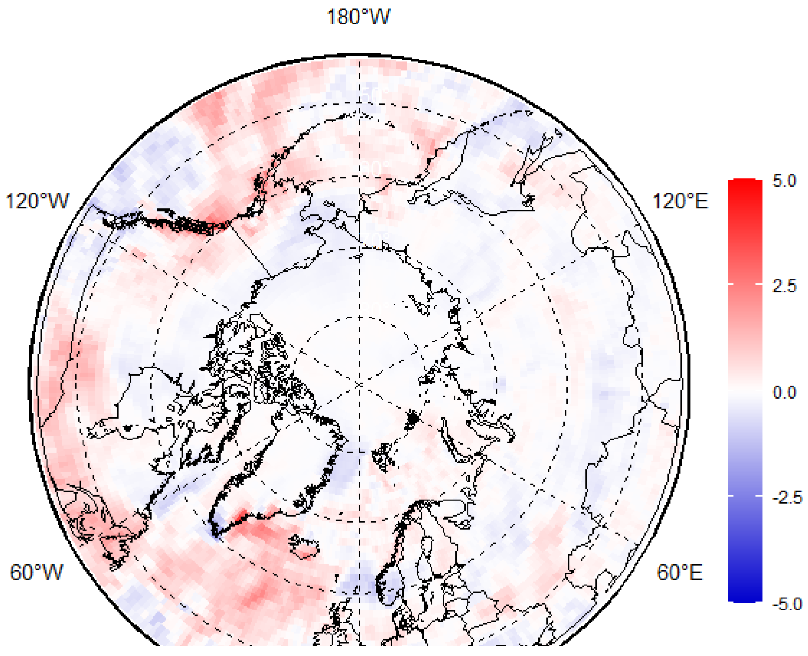
Anom(Rank|Year$_{min}$|Year$_{max}$)
0.6 (012 | 1955 |1924)

- 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 negative anomalies occurred with a very few exceptions in the beginning – mid 20th century, that is 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 are obvious, the quantitive estimates depend on the WMO reference period chosen and density of the stations, in particular for the marine Arctic.

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

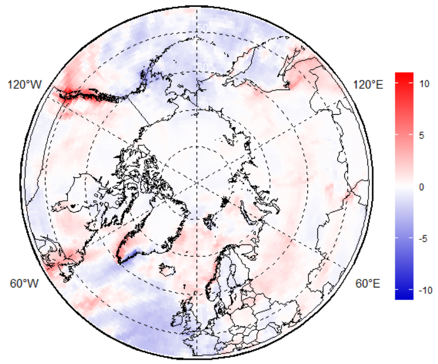


NDJ 2021/2022 precipitation anomaly

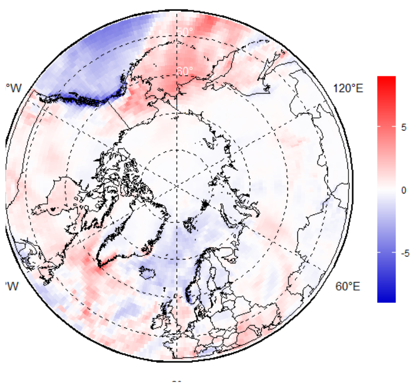


FMA 2022 precipitation anomaly

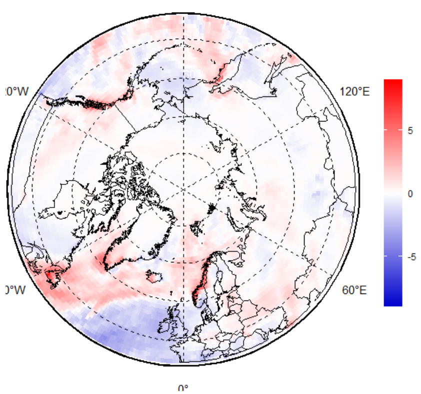
- In general, during the whole season **wetter** (snowy) conditions occurred in most parts of Canadian, Alaska, Bering & Chukchi and W Nordic regions
- **Drier conditions** occurred in parts of E Nordic, Siberia and Central Arctic regions



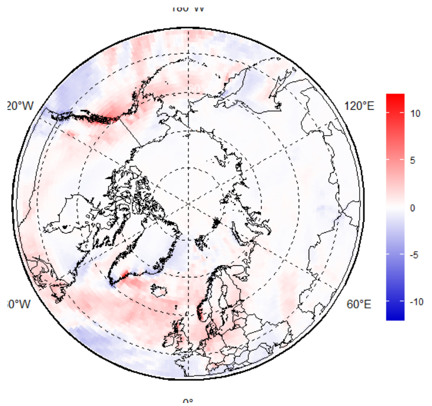
Nov



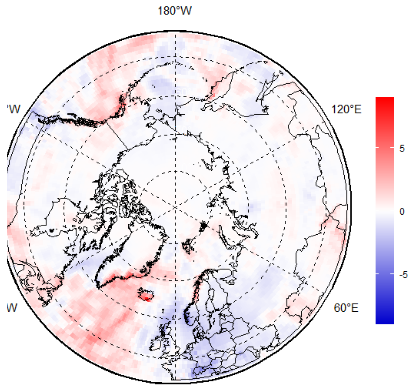
Dec



Jan



Feb



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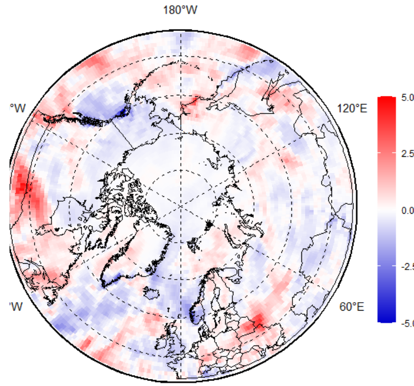


Apr

[AARI / CCCS ERA5]

JJA 2021 surface precipitation by regions: 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

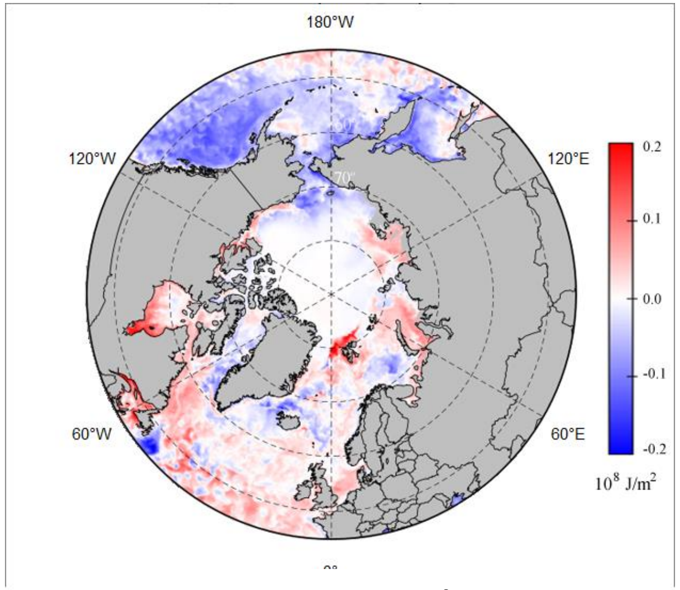
- **The least amount** of precipitation was for the **Eastern Nordic and Siberia regions**
- More abundant precipitation was observed in the **Western Nordic, Bering and Chukchi and Canada and Alaska regions**.
- Somewhat **drier** or close to normal conditions are estimated for the Central Arctic

[AARI / CCCS ERA5]

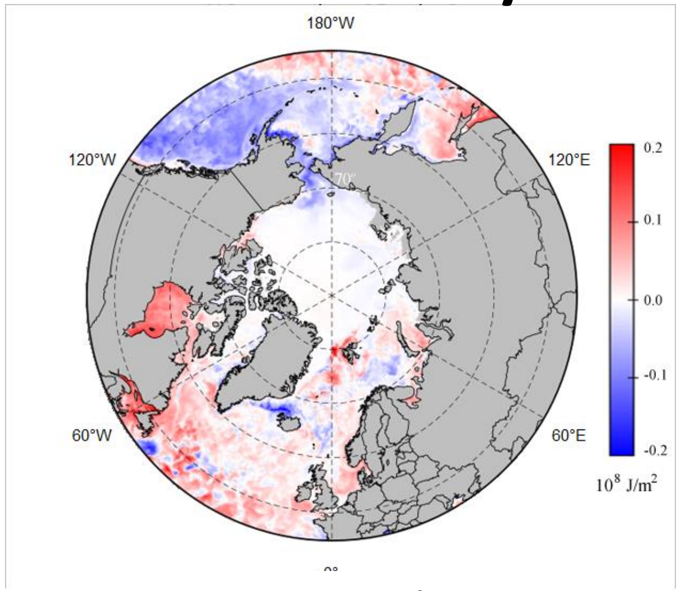
Sea ice

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

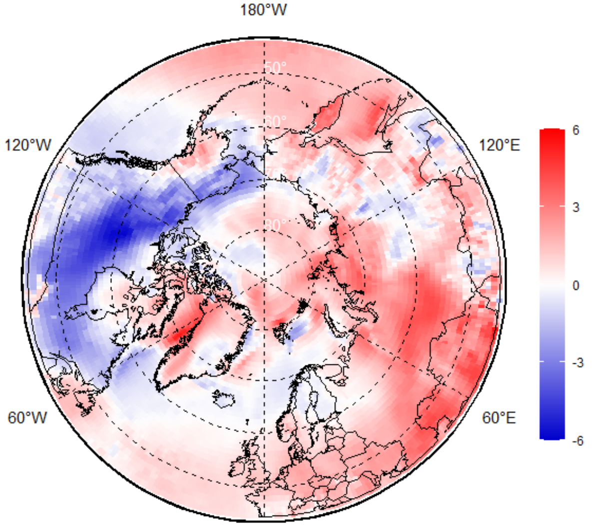
Precursors for winter 2021/2022 ice conditions



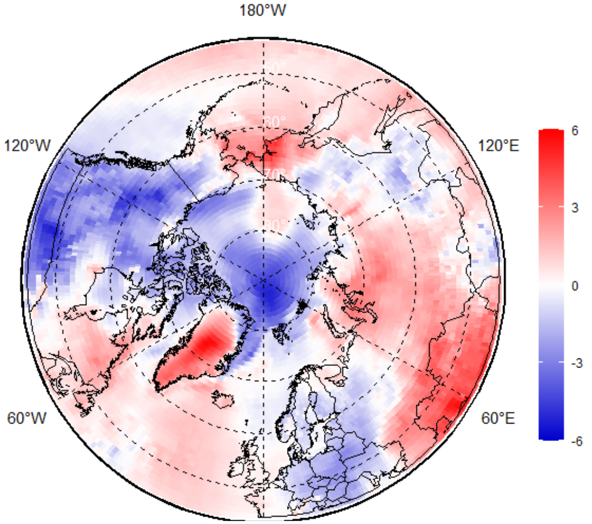
Oct 2021 Heat Capacity 15m anomaly, 1993-2020



Nov 2021 Heat Capacity 15m anomaly, 2020



DJF 2021/2022



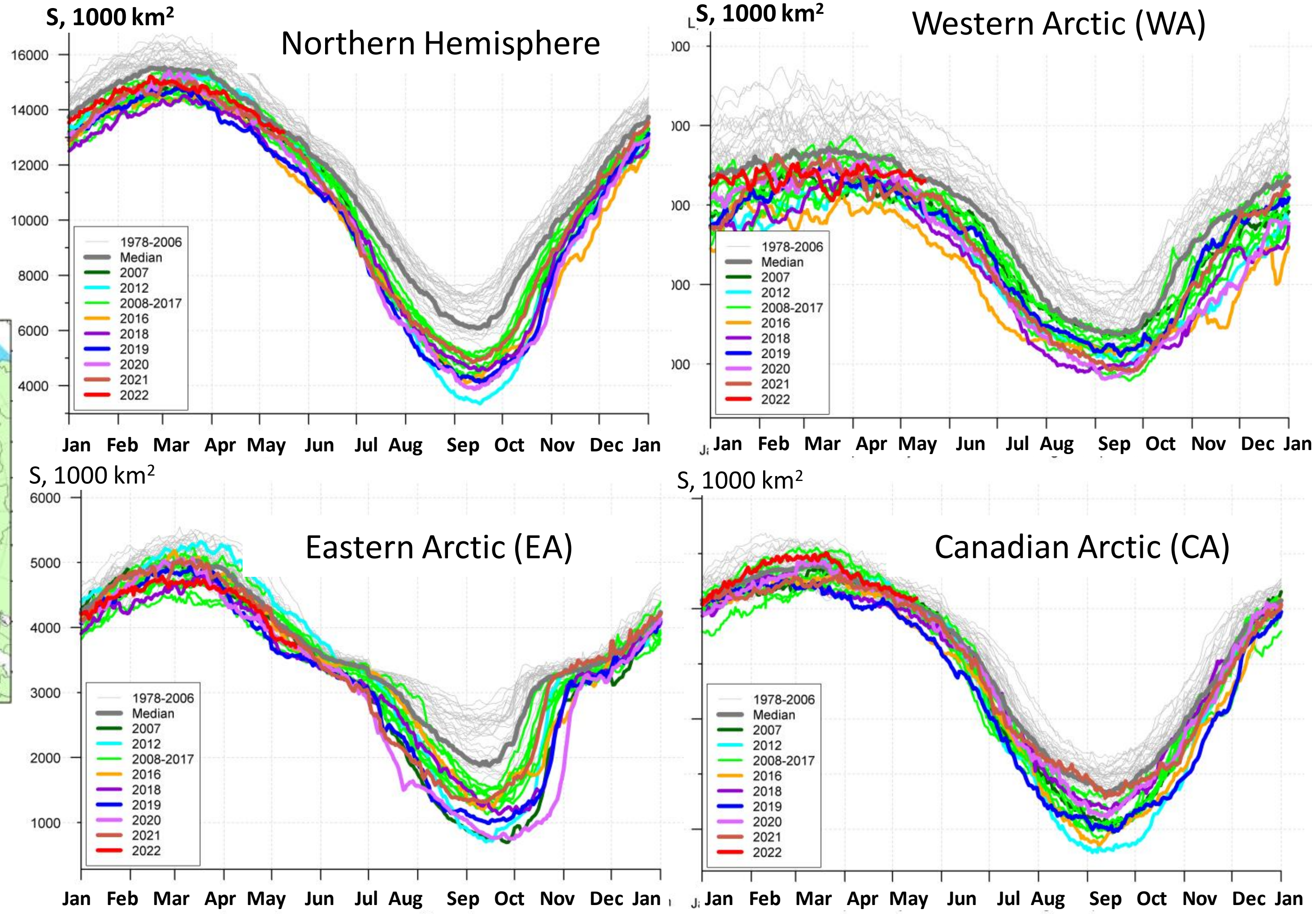
Apr 2022

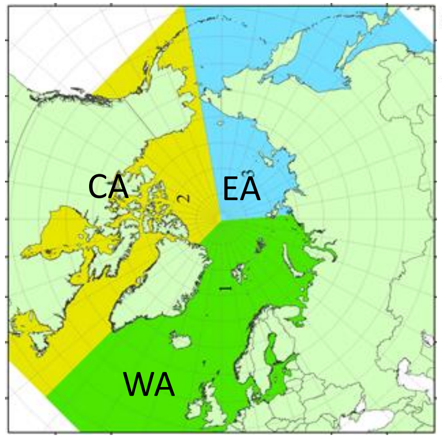
SAT anomaly, 1991-2020

- 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

[AARI / CCCS MEMS & ERA5]

Arctic (NH) seasonal ice extent 1978…. 2022





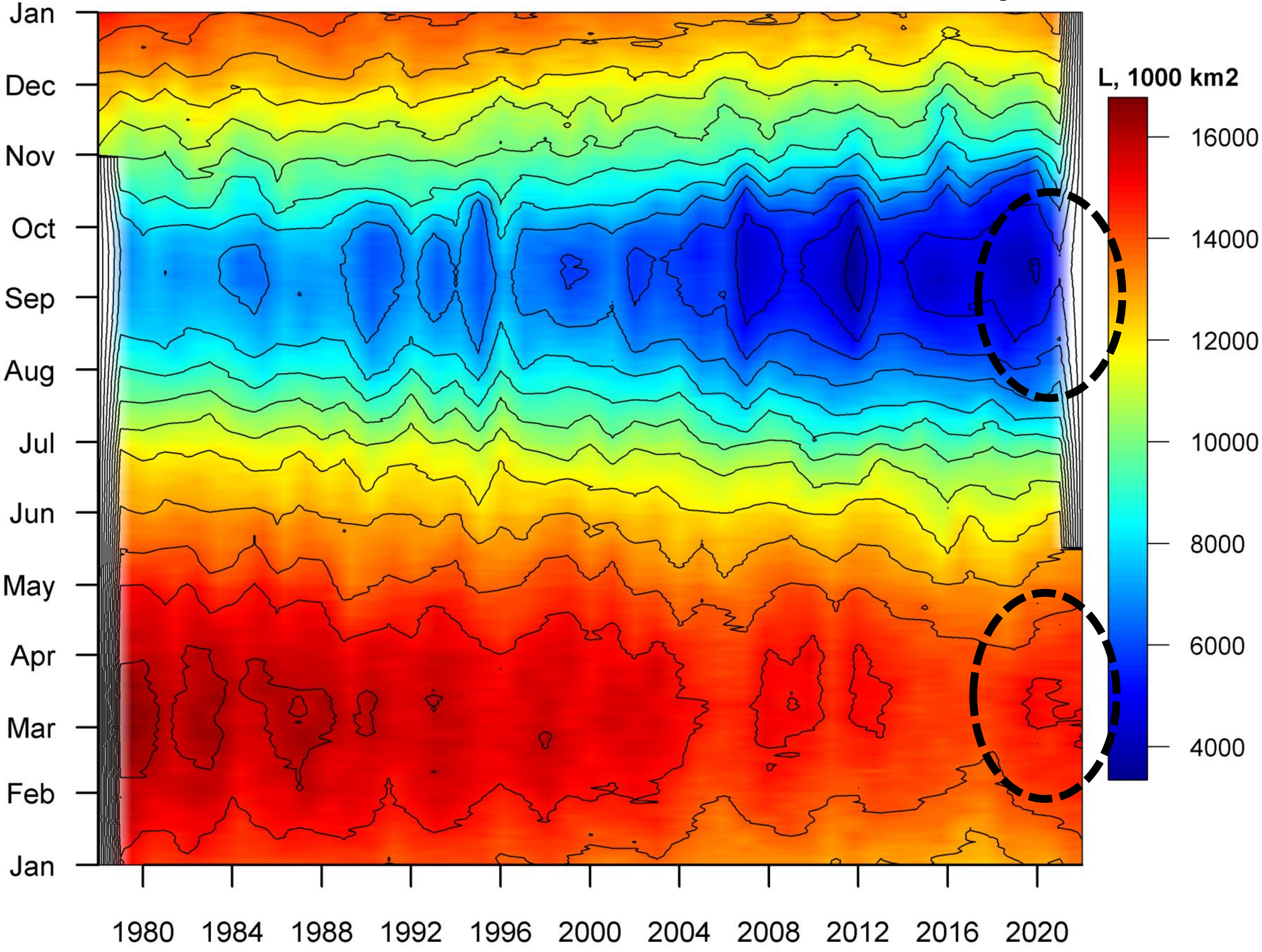
[AARI / NSIDC]

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

- 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.

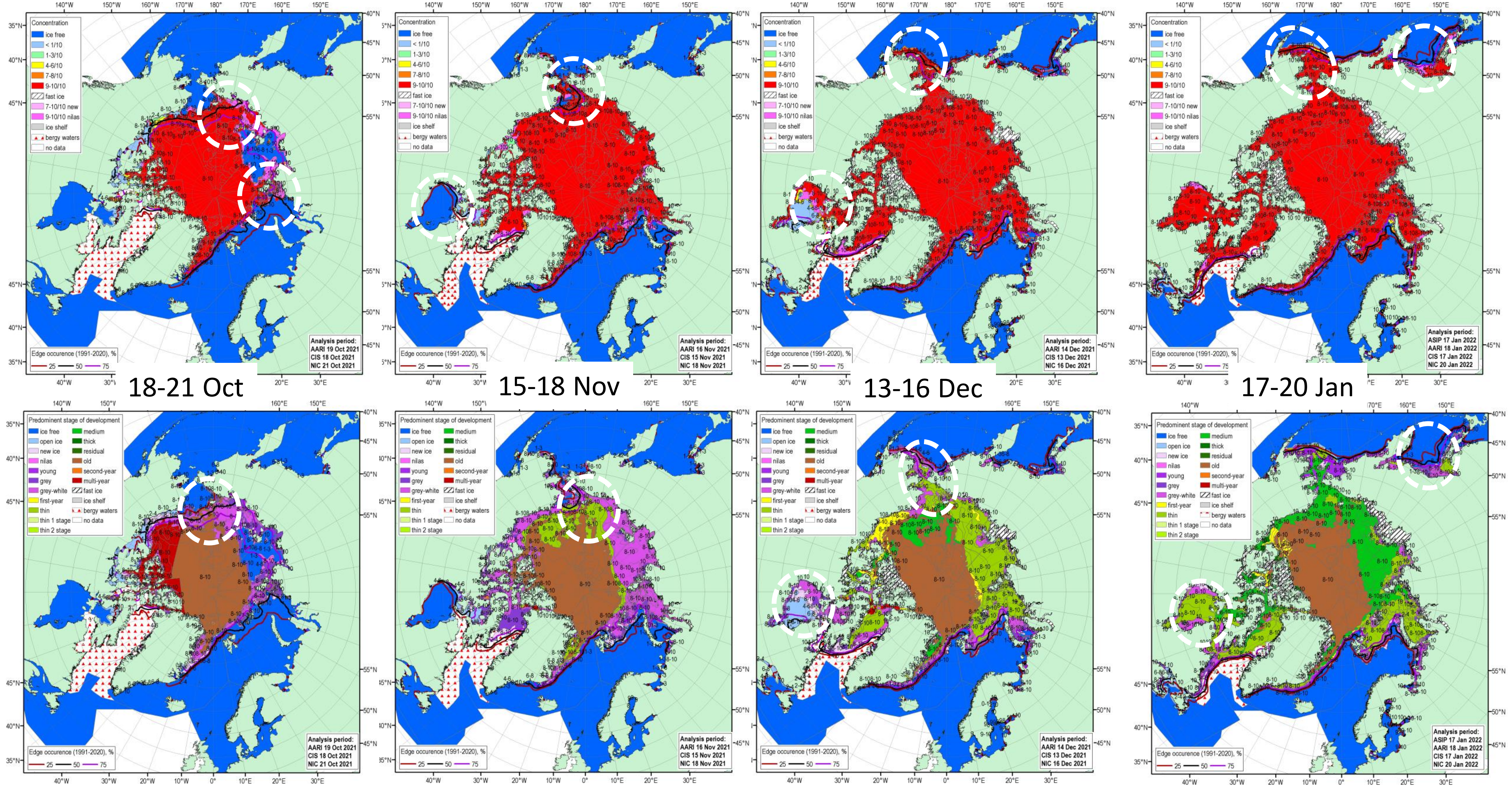
Seasonal NH ice extent variability: 1978 -2022



- ❖ 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

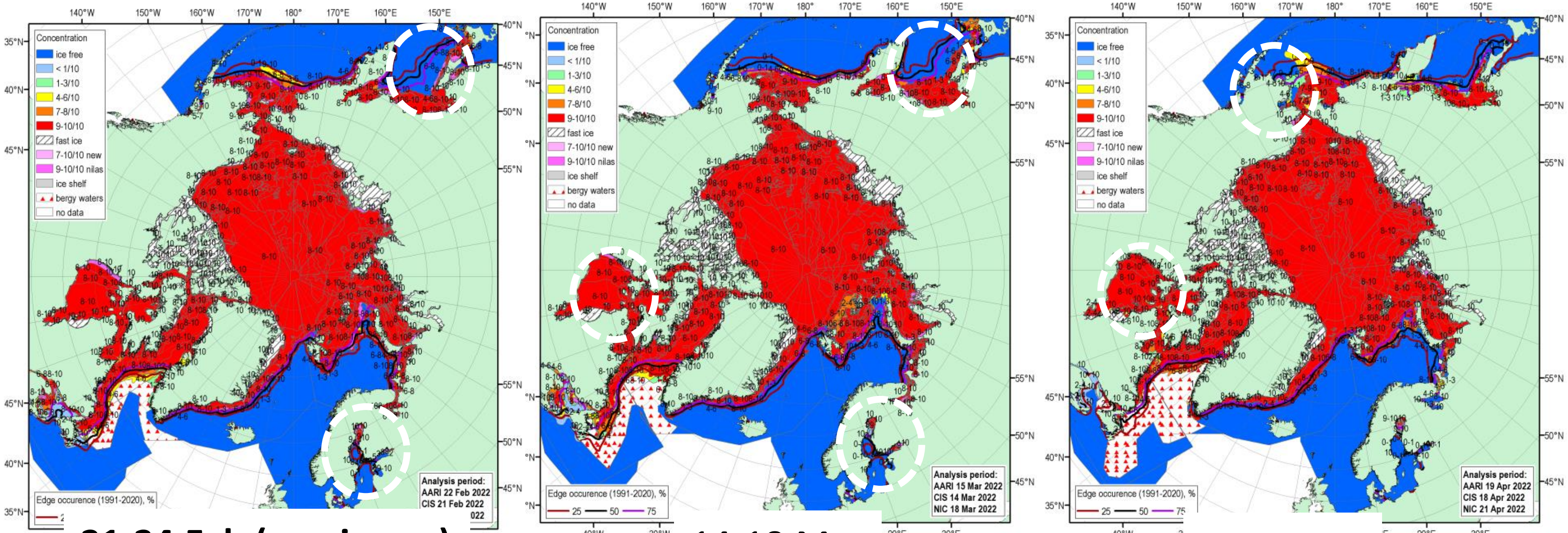
[AARI / NSIDC]

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

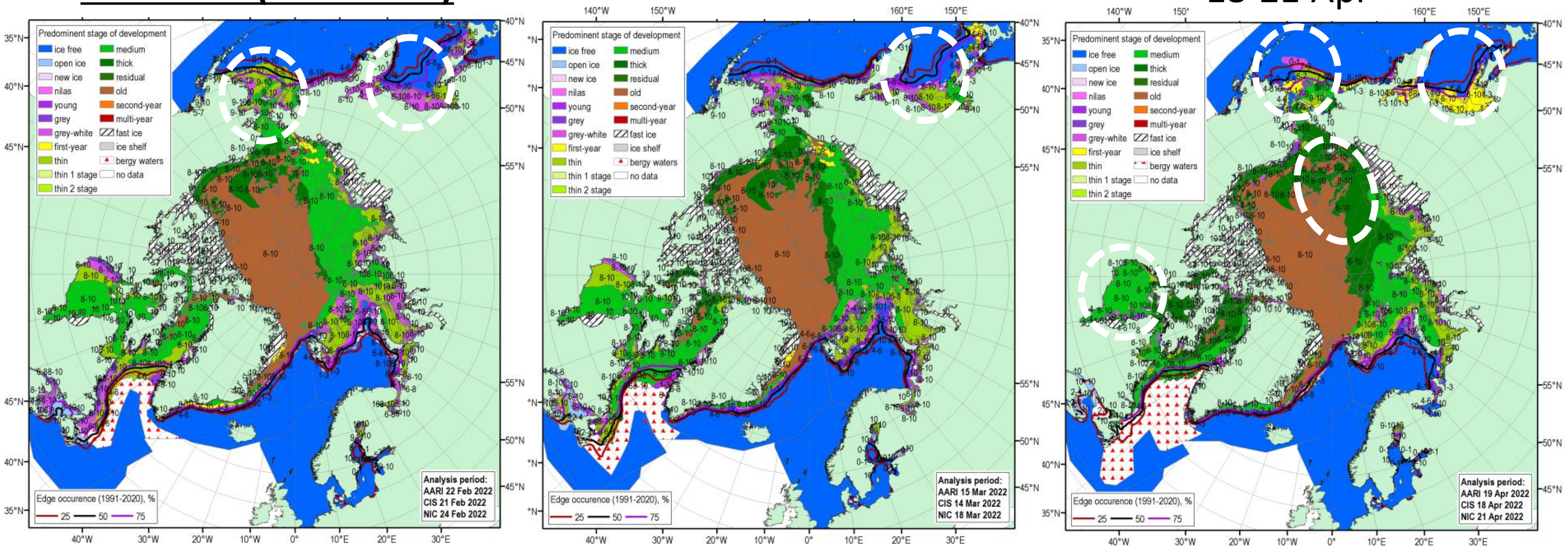


[sea ice analysis - AARI/CIS/NIC; ice edge – AARI/NSIDC, nearest 5days, reference period: 1991-2020]

FMA 2022 Arctic sea ice – concentration and stage of development



21-24 Feb (maximum) 14-18 Mar 18-21 Apr

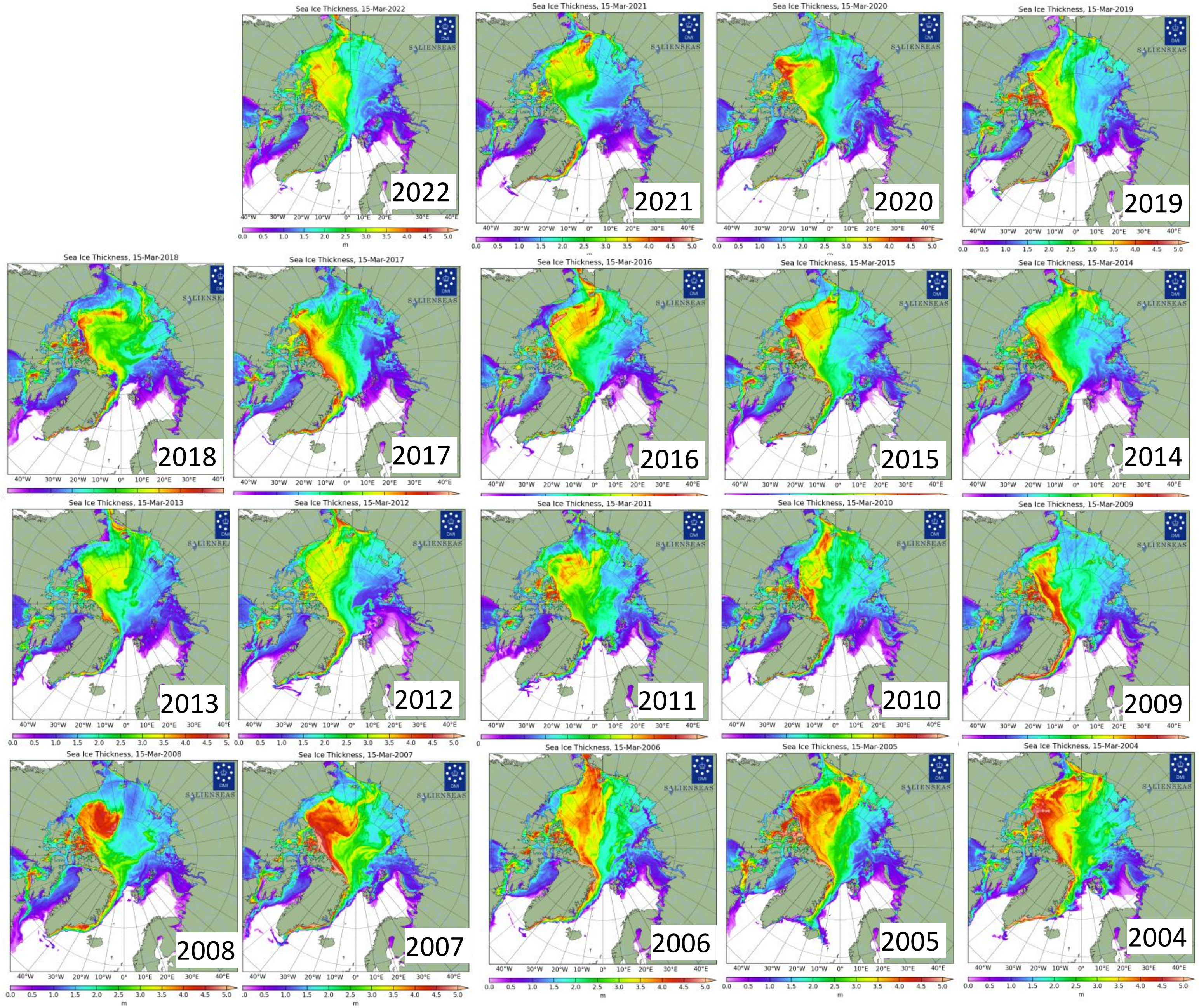


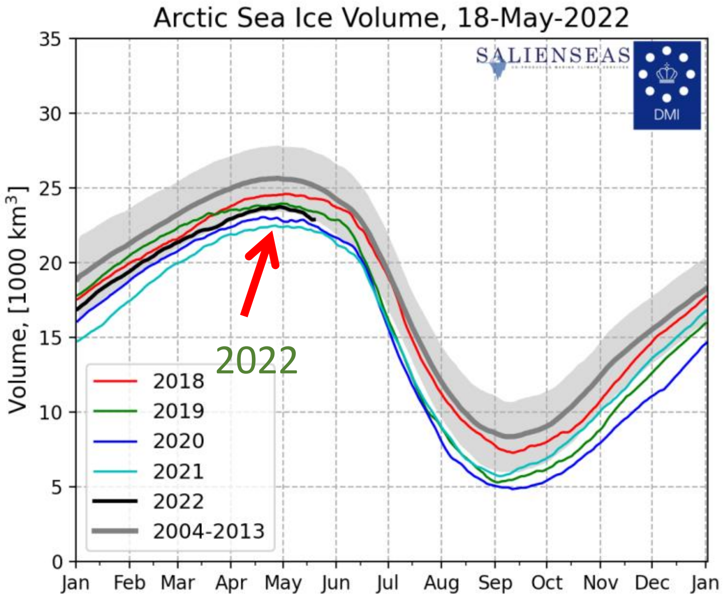
Special features of ice conditions in the Arctic during autumn – winter 2021/2022 included:

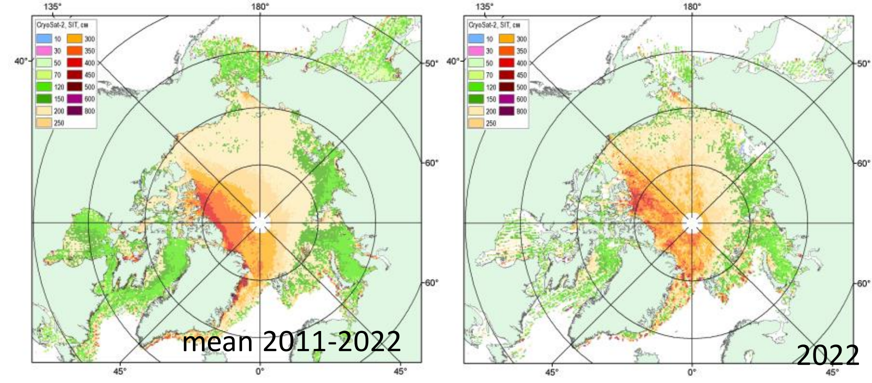
- occurrence of residual and further in season the second-year ice in the NE Kara and N parts of the East Siberian Sea or within eastern lanes of the NSR,
- lighter than median ice conditions in the Eastern Canadian Arctic during first part of the winter but opposite greater than median during late winter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







ESA CryoSAT-2 sea ice thickness

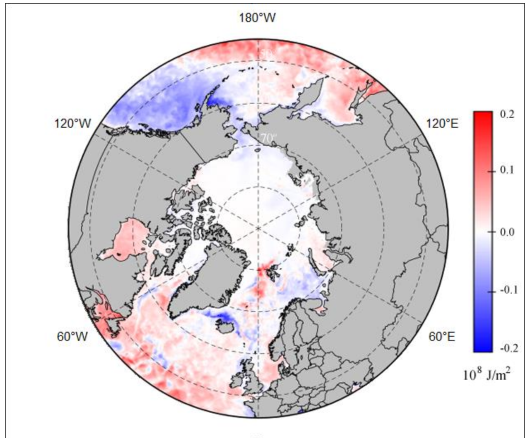
Cryosat-2 measurements show the general Arctic Basin SIT distribution in March 2022 similar to mean 2011-2022 pattern with estimate of the total Arctic ice volume, based on modelling as somewhat ~3rd lowest for 2004-2022 after 2020 and 2021

[DMI North Atlantic - Arctic Ocean model HYCOM-CICE - http://ocean.dmi.dk/models/hycom.uk.php]

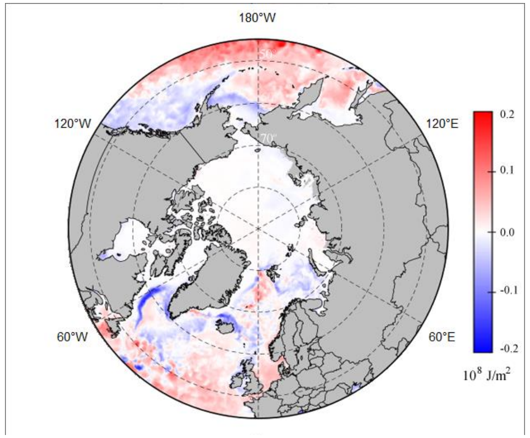
Polar Ocean:

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

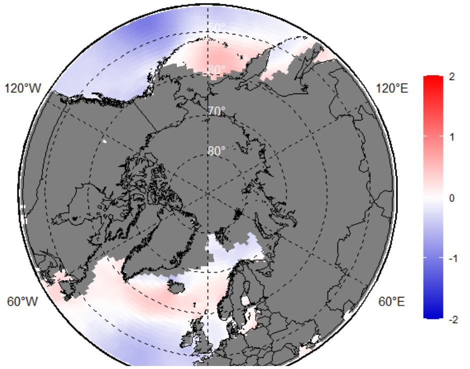
Heat content, waves and pH – NDJ 2020/2021 & FMA 2021



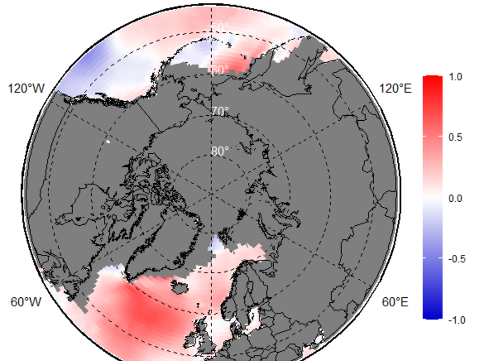
NDJ Heat Content anomaly (1993-2020)



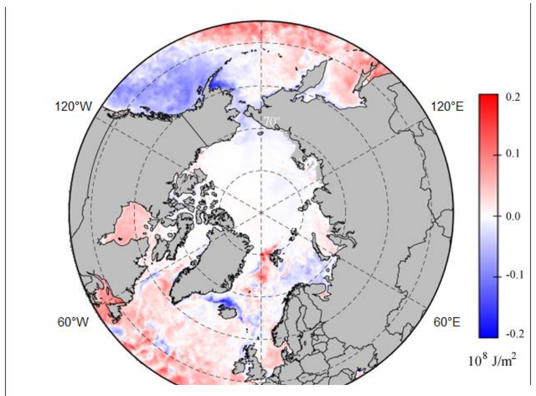
FMA Heat Content anomaly (1993-2020)



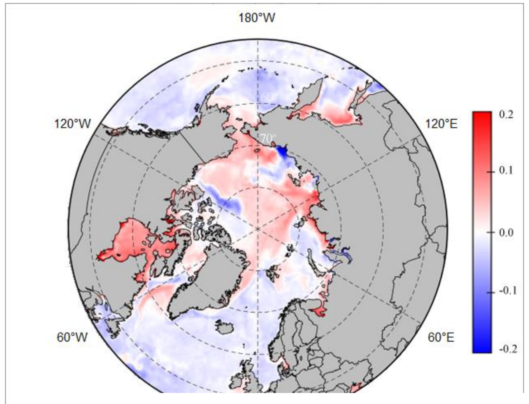
NDJ WW&S height anom (1991-2020)



FMA WW&S height anom (1991-2020)



NDJ pH anomaly 2m (1993-2020)



FMA pH anomaly 2m (1993-2020)

- 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.

[AARI / CCCS MEMS & ERA5]

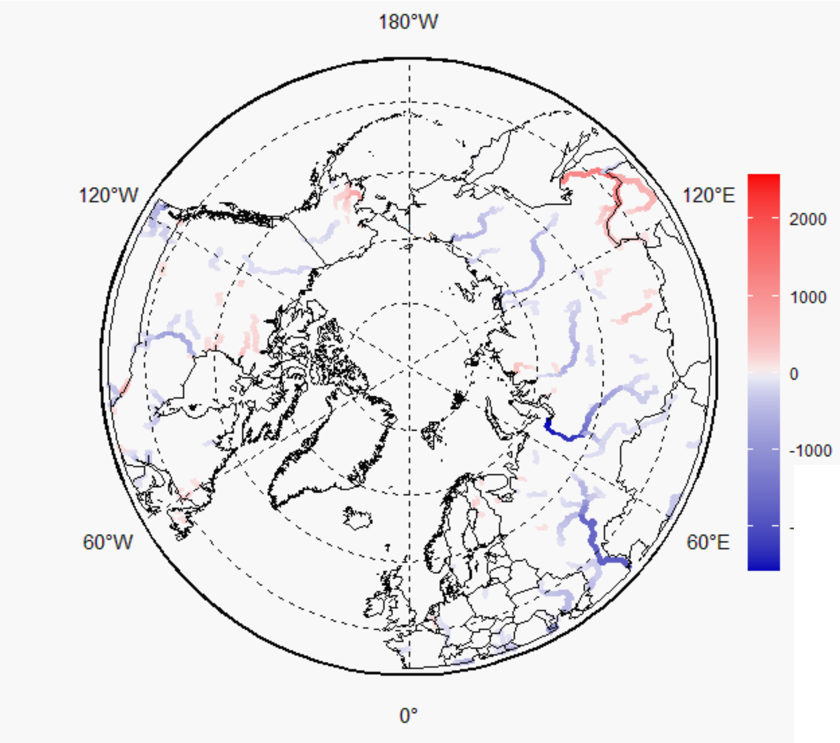
Hydrology and land Snow:

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

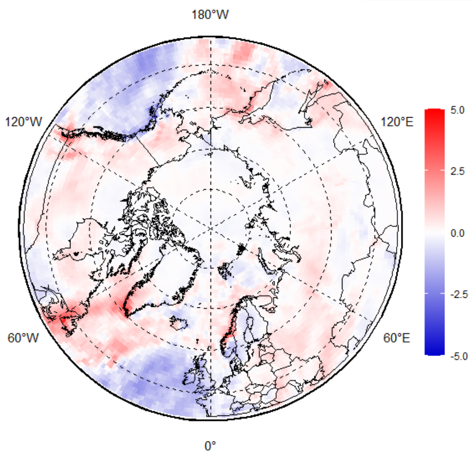
Impacts of precipitation on river discharge

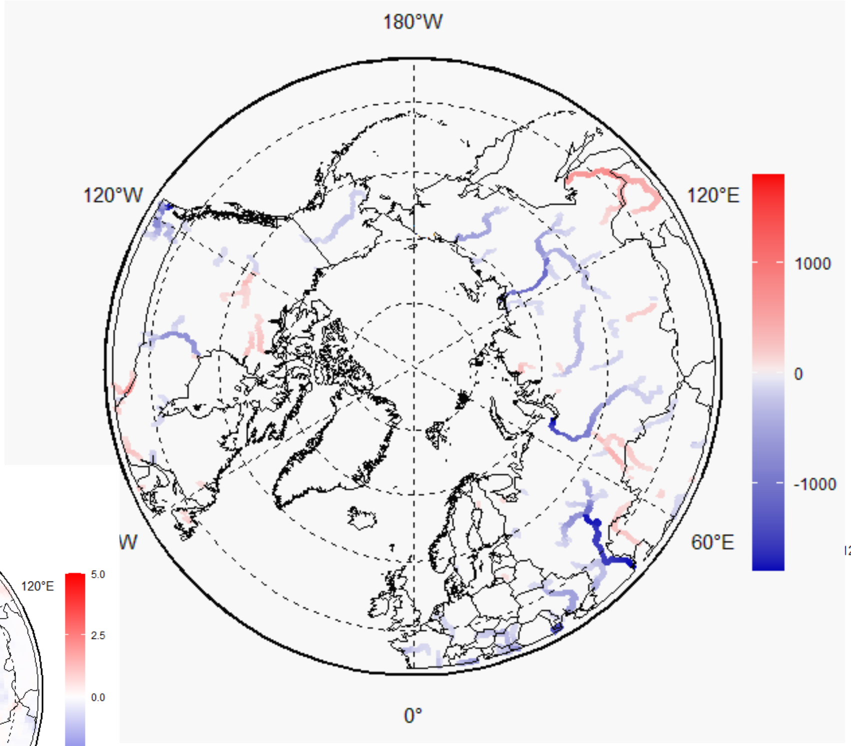
Impacts of wetter/drier colder/warmer weather conditions were to certain extent reflected in the winter/spring 2021-2022 Arctic rivers discharge though the frozen ground restricts direct effects

- ❖ **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.

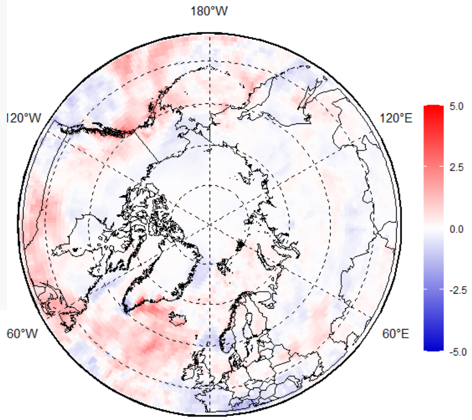


NDJ 2021/2022 river discharge anomaly (1991-2020)





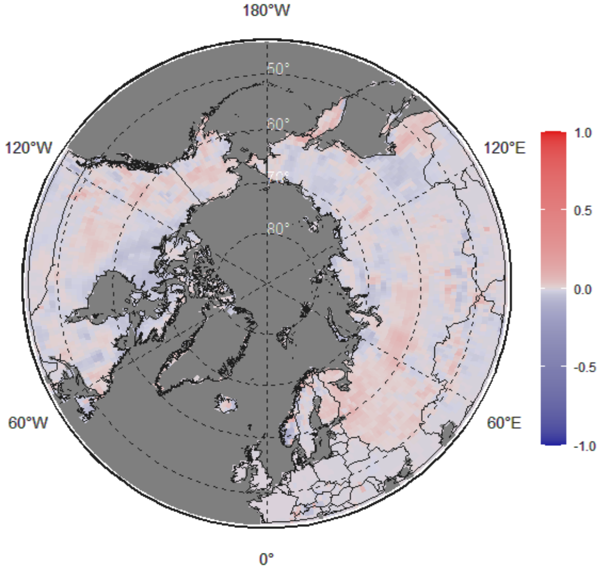
FMA 2022 river discharge anomaly (1991-2020)



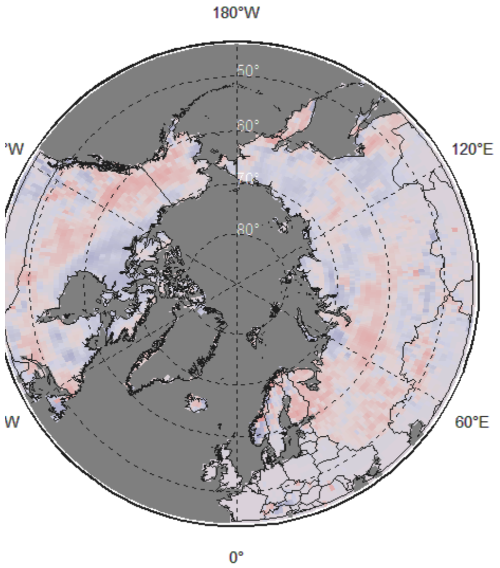
[AARI / CCCS ERA5-GloFAS]

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



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



FMA 2021 snow height anomaly (1991-2020)

[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)

[AARI / CCCS ERA5 / GCW / Rutgers Global SnowLab]

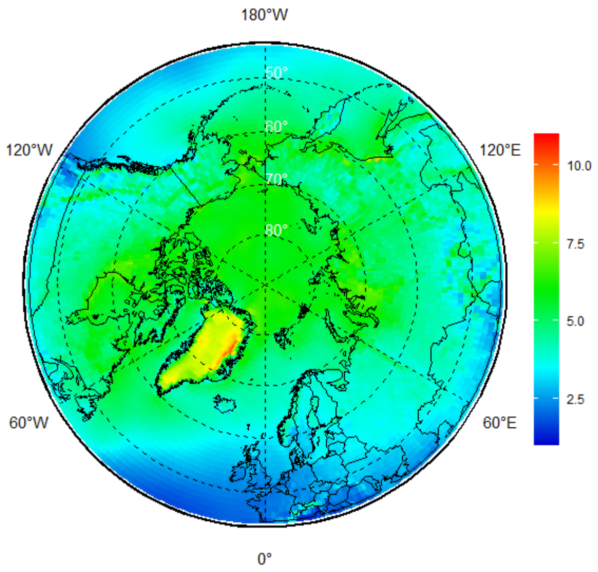
Bioclimatic weather severity

- 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.

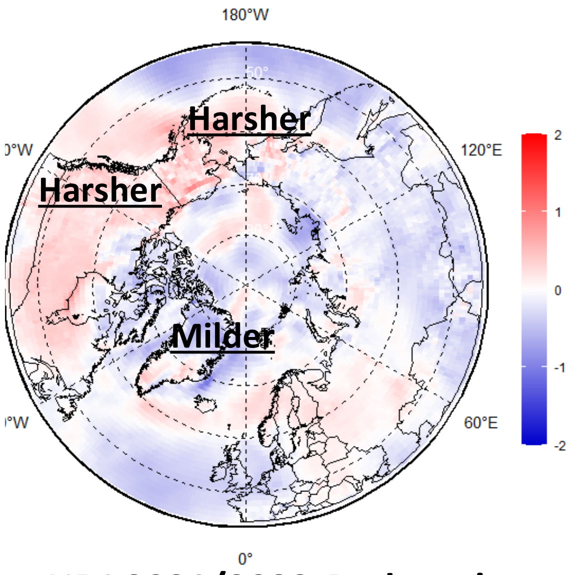
Bodman's weather severity index (S) (dimensionless) is used for bioclimatic evaluation of weather conditions for winter half year and is calculated according to Bodman's formula as follows: $S = (1 - 0.04\,T)\,(1 + 0.272\,v)$ where: v is wind speed (in m/s) at 10 m above ground level and T is air temperature (in °C)

The scale in use to assess using S is:

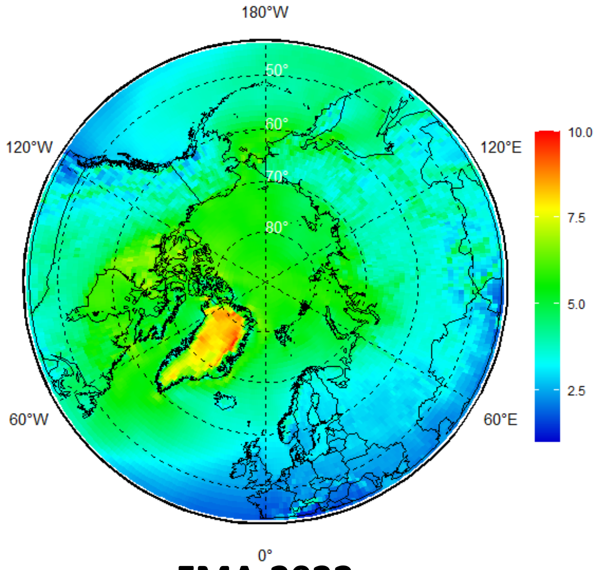
> 6 extraordinary severe 5– 6 extremely severe
3– 5 severe & very severe 1– 3 slightly&less severe
< 1– mild



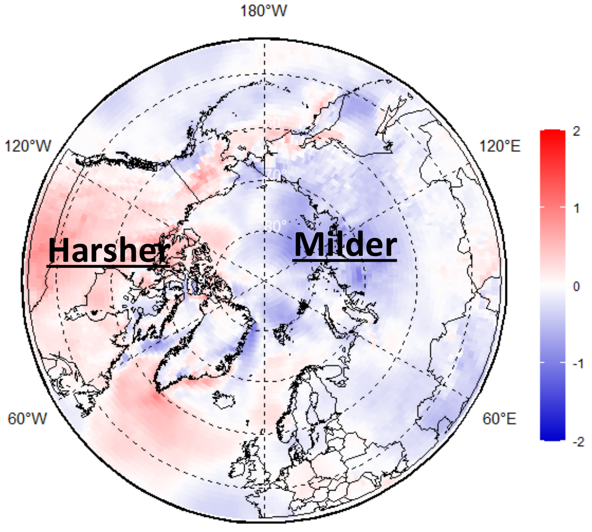
NDJ 2021/2022 Bodman's index



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



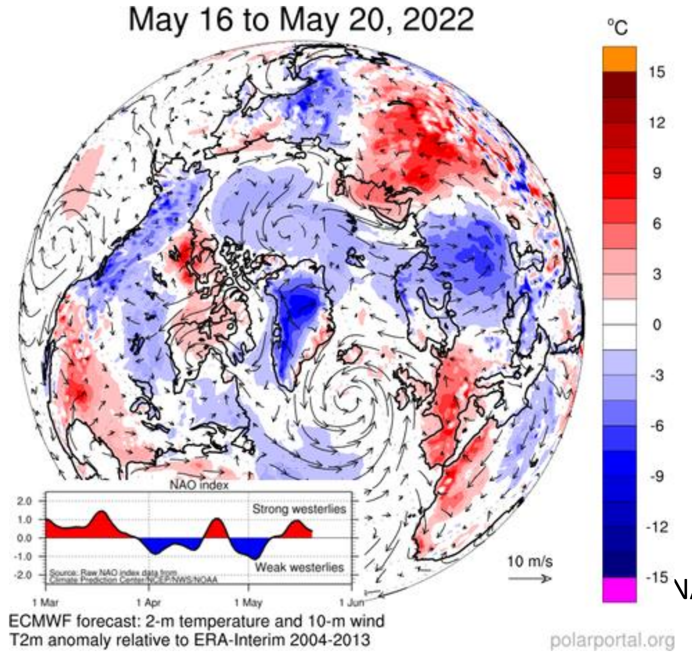
FMA 2022 Bodman's index

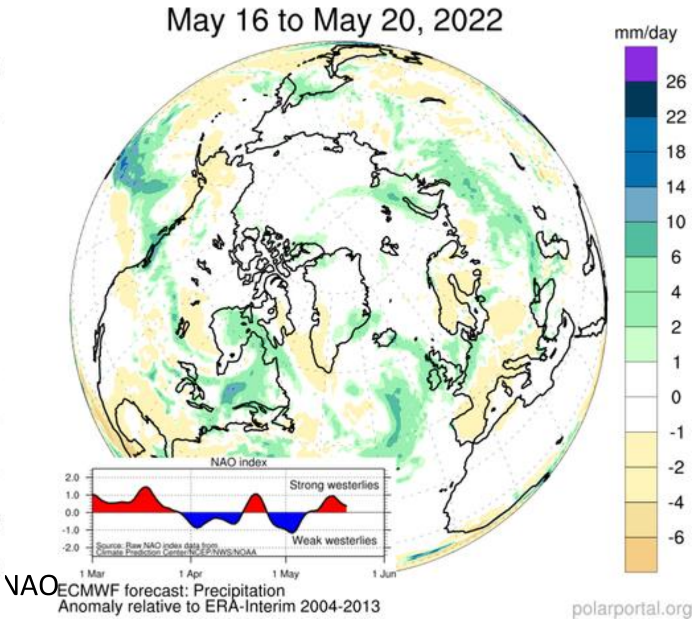


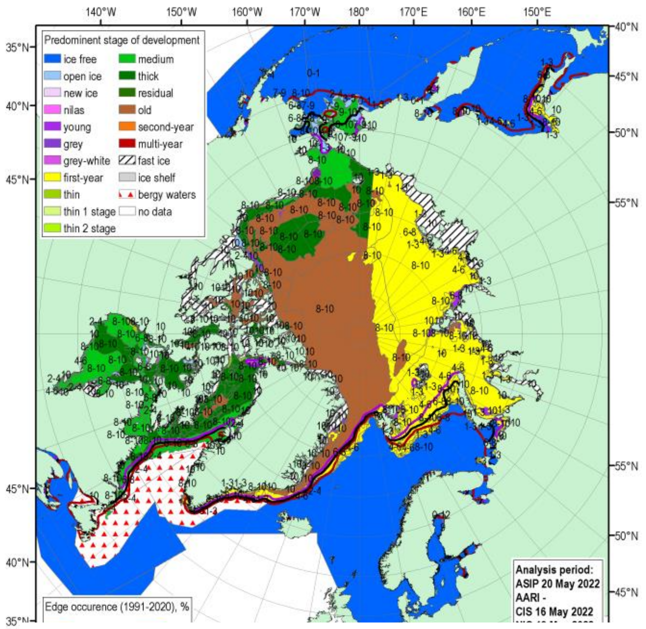
FMA 2022 Bodman's index anomaly (1991-2020)

[AARI / CCCS ERA5]

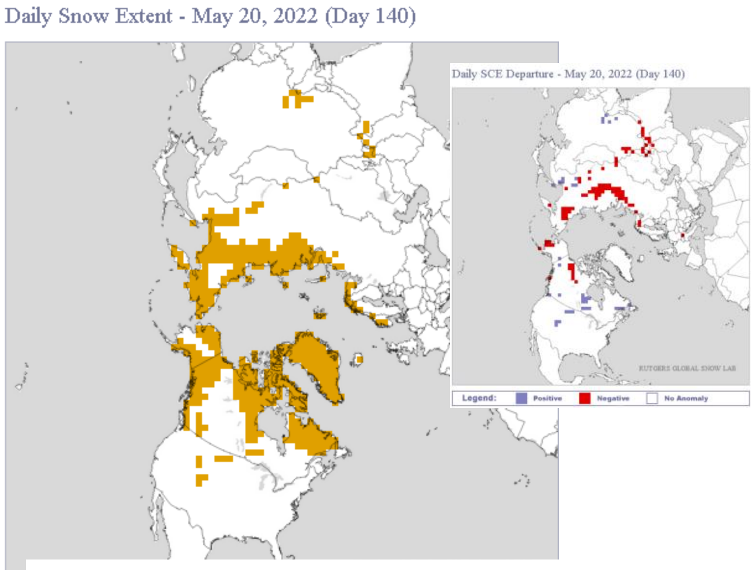
Current Conditions (16-20 May 2022)







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



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://www.aari.ru/misc/publicat/gmo.php)
2. Copernicus Climate Change Service
   - ERA5 monthly averaged data on pressure and single levels
   - Marine environment monitoring service
   - GloFAS operational global river discharge reanalysis
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, ECCC, Rutgers Glob Snow Lab, http://climate.rutgers.edu/snowcover/)

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

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

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/

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale