Icelandic Met Office

ACF
Arctic Climate Forum

WORLD METEOROLOGICAL ORGANIZATION

ARCTIC REGIONAL CLIMATE CENTRE (ArcRCC) Network

13th Arctic Climate Forum (ACF-13)

22 – 23 May 2024, from 16:00 to 19:00 UTC

ACF
Arctic Climate Forum

Agenda DAY 2

WORLD METEOROLOGICAL ORGANIZATION

Icelandic Met Office

Thursday May 23 - Day 2 Video conference link		
TIME (UTC)	**ITEM**	**DETAILS**
16:00 (10')	**Day 1 Sum Up and Day 2 Intro**	Halldór Björnsson - IMO
16:10 (30')	**Arctic winter 2023/2024 Seasonal Summary:** • Atmospheric patterns • Temperature, precipitation, sea-ice, polar ocean and land hydrology based on observations and reanalysis data	Session Chair: Jelmer Jeuring - MET Norway Vasily Smolyanitsky - AARI
16:40 (15')	**Climate Conditions and Socio-Ecological Impacts at the (Sub)Seasonal Timescale:** • Summary of bioclimatic indexes in the Arctic for winter 2023/2024 and verification of the previous forecast	Anastasiia Revina - AARI Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva - Hydrometcenter of Russia
	• Forecast for summer 2024	
16:55 (10')	**Q&As on Seasonal Summary of Observations**	Moderator: Jelmer Jeuring - MET Norway

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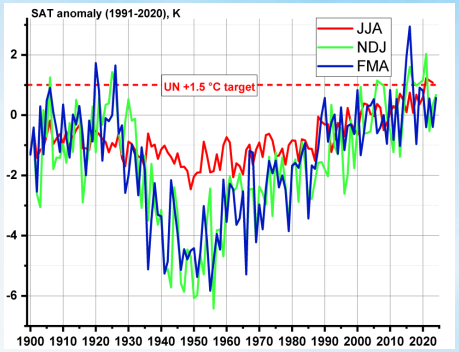
17:05 (15')	**BREAK**	
17:20 (25')	**Temperature, Precipitation, Sea Surface Temperature and Snow/Water Equivalent** • Validation of the outlook for winter 2023/2024 • Outlook for summer 2024 and model confidence	Session Chair: Kristín Björg Ólafsdóttir, IMO Marko Markovic - ECCC
17:45 (25')	**Sea Ice Outlook for summer 2024** • Validation of the winter 2023/2024 outlook • Outlook for summer 2024 and model confidence	Adrienne Tivy - ECCC
18:10 (10')	**Q&As on Validation and Confidence and Sea-Ice Outlooks**	Moderator: Kristín Björg Ólafsdóttir - IMO
18:20 (20')	**Use of long term forecasts**	Andri Gunnarsson - Landsvirkjun
18:40 (10')	**Final Thoughts and Wrap-Up**	Halldór Björnsson - IMO

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

AARI

October 2023 – April 2024 Arctic Seasonal Review



Vasily Smolyanitsky (coordination, sea ice)

vms@aari.aq/vsmolyanitsky@gmail.com

Anastasia Revina (surface reanalysis),

Anna Danshina (marine reanalysis)

Arctic and Antarctic Research Institute (AARI)

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

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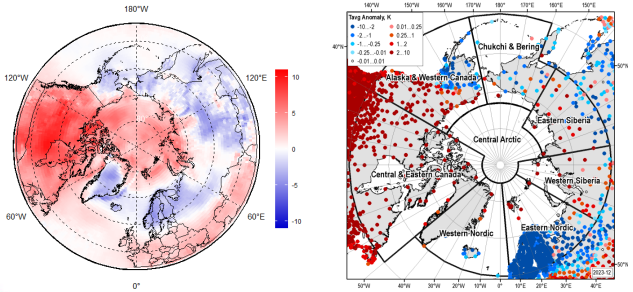
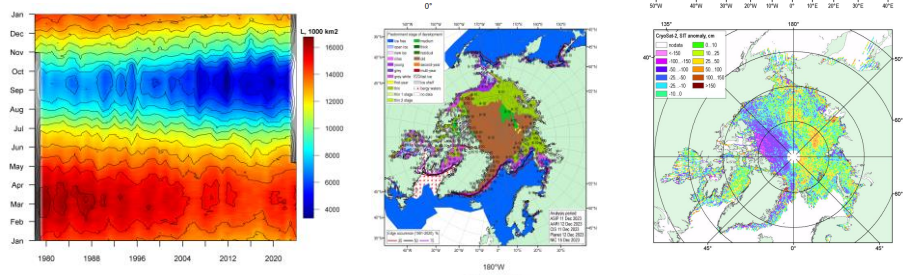
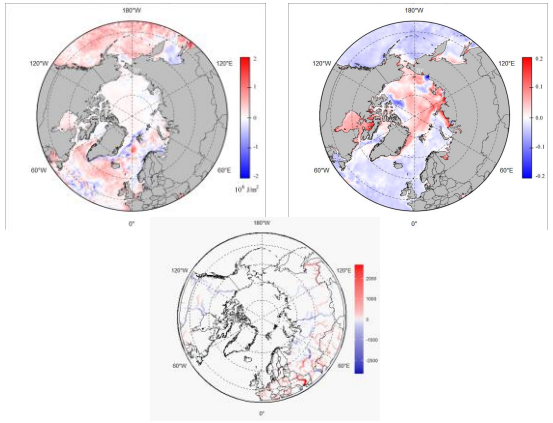
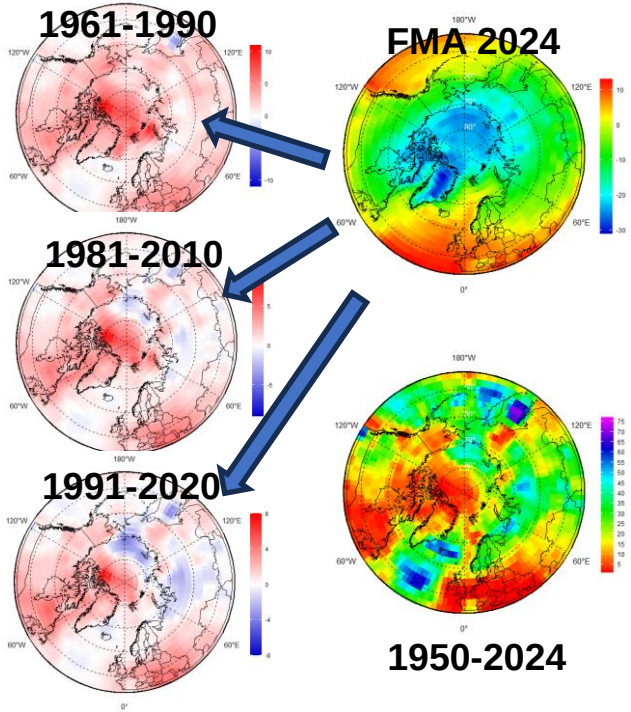
Content of seasonal review for October 2023… April 2024

- **Atmosphere:**
  - Precursors in atmospheric circulation
  - Surface air temperature and precipitation– statistics by ArcRCC-N region
- **Sea ice:**
  - Precursors in atmosphere and polar ocean
  - Sea ice extent, conditions, including March'23 maximum
  - Sea ice thickness, and volume
- **Polar Ocean:**
  - Heat content
  - pH (acidification/alkalization)
- **Land hydrology:**
  - river discharge
  - snow extent









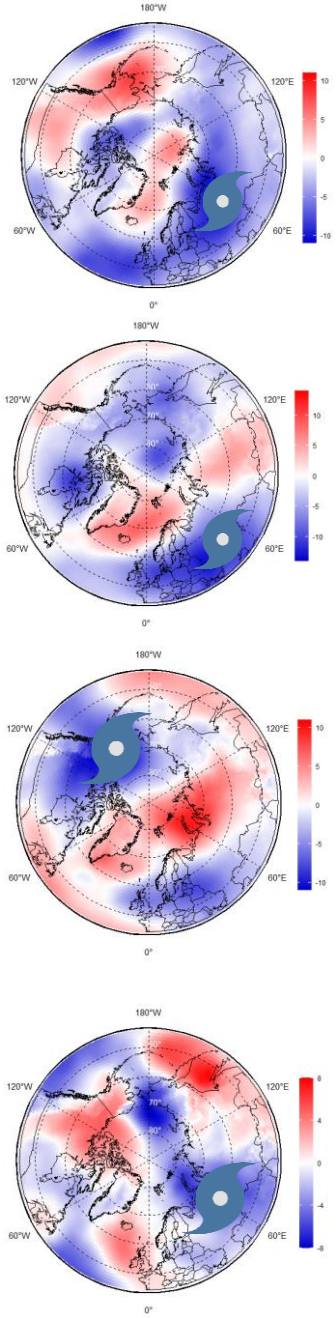
Majority of the described parameters are the **WMO Essential Climate Variables (ECV)**.
Information is based on reanalysis and surface observations and is provided:

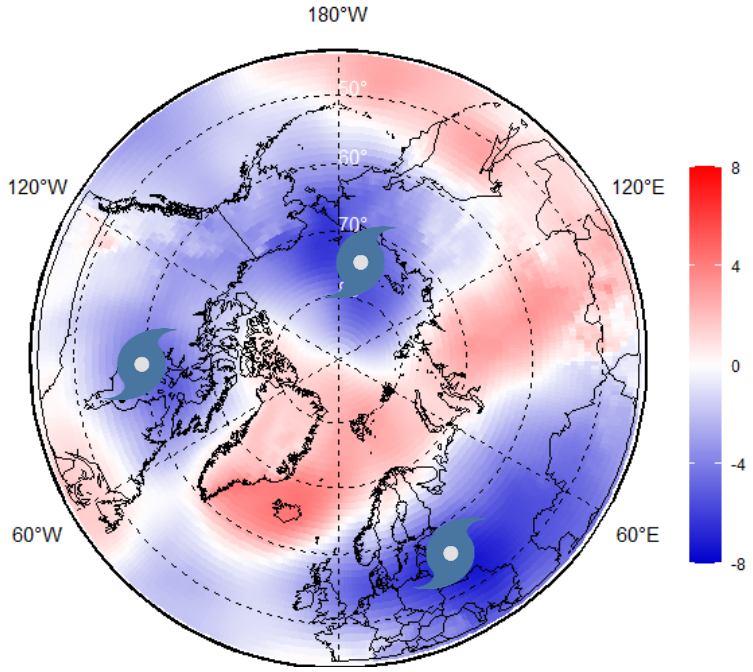
- for anomalies relative to the latest **3rd WMO period 1991-2020**
- for ranks to period of observation or reanalysis **1950-2023/2024** or **1979…2024**)

Atmosphere

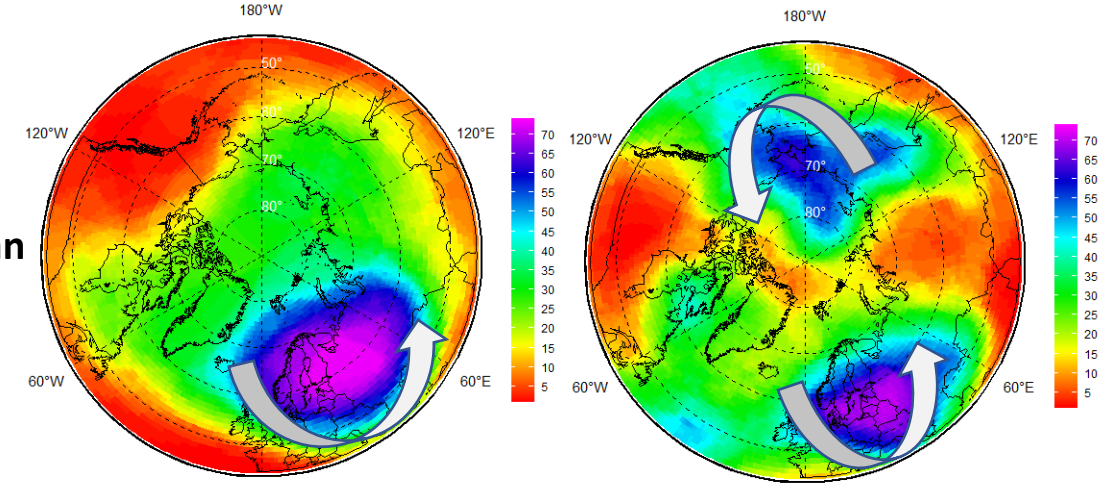
- Atmospheric circulation
- Surface air temperature
- Precipitation

Atmospheric circulation: ONDJ 2023/2024





NDJ 2023/2024 MSLP hPa anomalies (1991-2020)

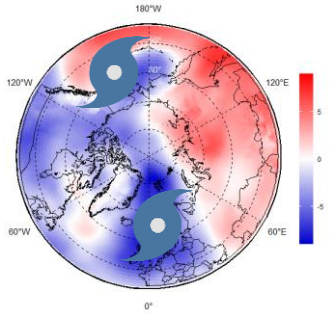


NDJ 2023/2024 H50 (left) and H500 (right) ranks (1950-2023/2024)

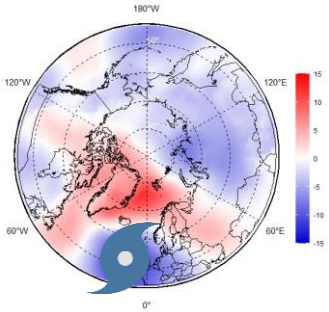
- **During November 2023 – January 2024 (NDJ) an intense single-center polar vortex** (dark violet, 50hPa and 500hPa geopotential height patterns) was observed centered **over the Eastern Nordic/Western Siberia**. That led to prevalence of meridian circulation (transfer south/north) in the troposphere over Siberian and Canadian regions and zonal one over other parts of the Arctic in Oct – Dec 2023 with exception for the next two months - Jan and Feb 2024.
- **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 southern Nordic, E Siberian regions.
- Opposite situation (higher pressure, marked in red) was observed over Greenland and Central Siberia regions

[AARI / CCCS ERA5]

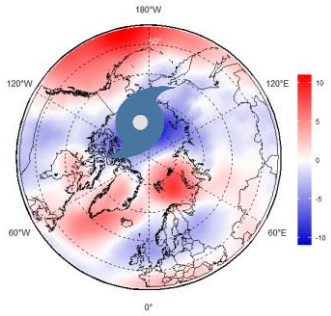
Atmospheric circulation: FMA 2024



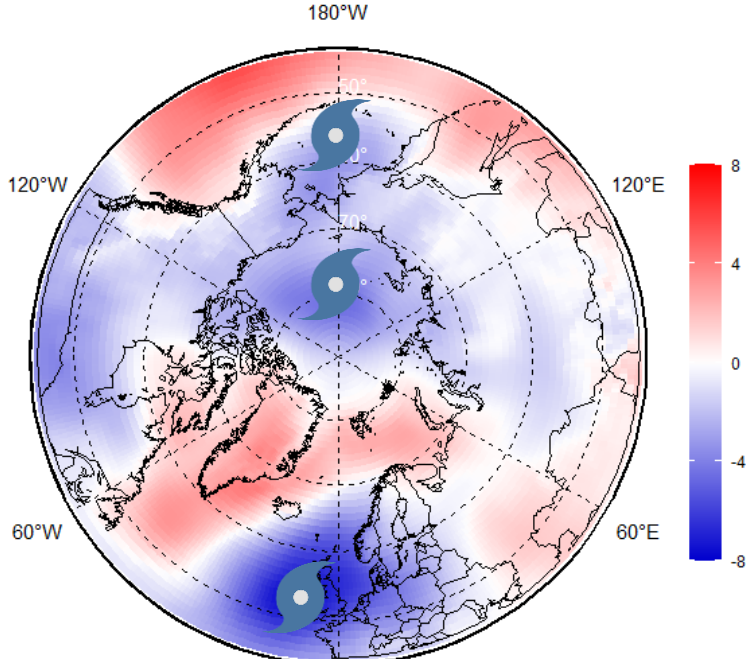
Feb



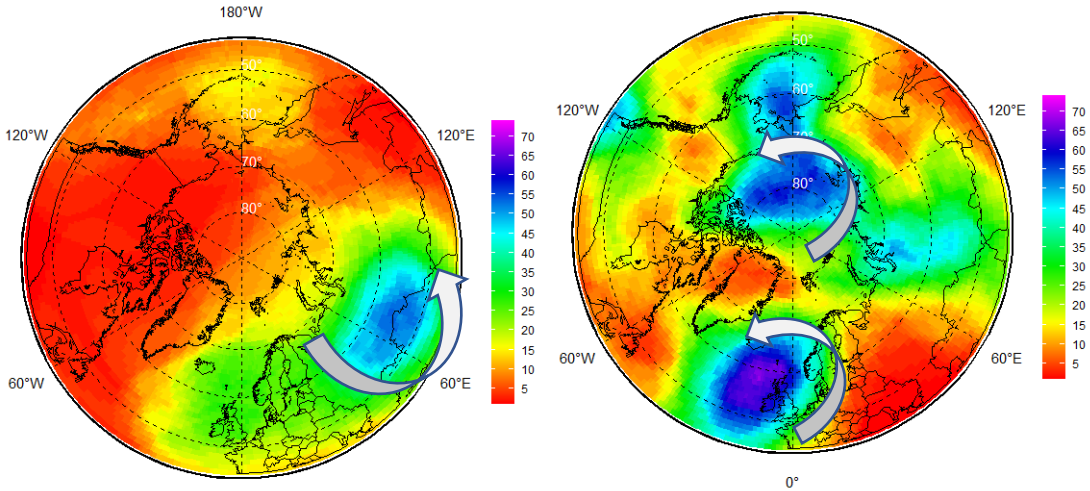
Mar



Apr



FMA 2024 MSLP hPa anomalies (1991-2020)

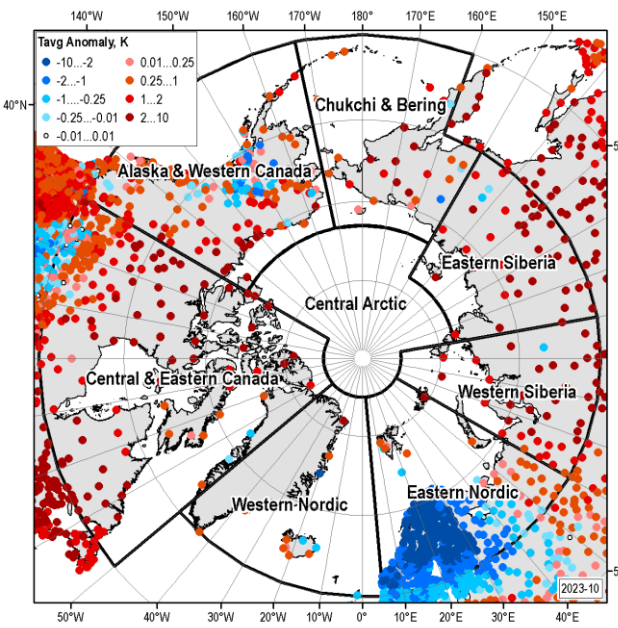


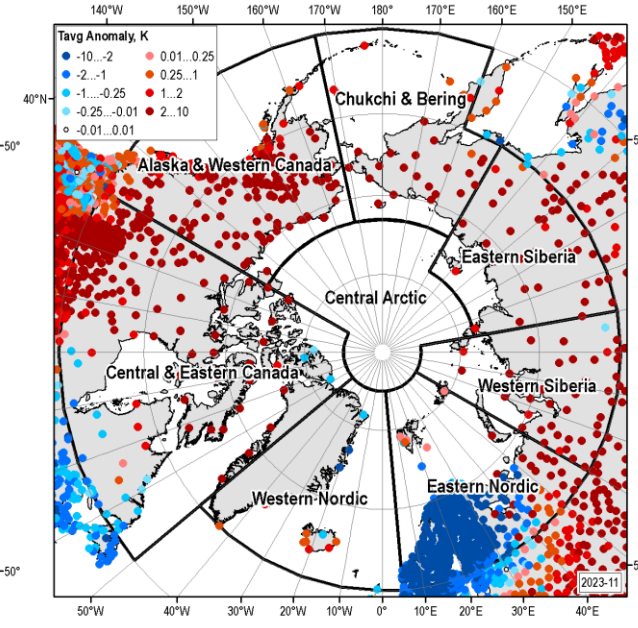
FMA 2024 H50 (left) and H500 ranks (1950-2024)

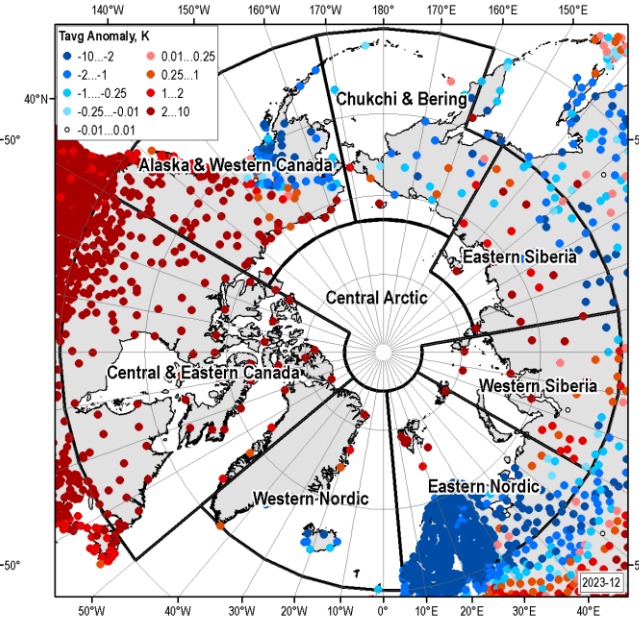
- **Further in season during February-April (FMA) 2024** bi-center polar vortex with centers over the North Atlantic and Central Arctic was observed causing in general zonal circulation in southern Nordic and Eastern Canada regions.
- Monthly patterns of the surface atmosphere circulation were fully different in Jan - February and Mar-Apr 2024 with negative MSLP anomalies - cyclonic activity over North Atlantic, Central Arctic, Central and Eastern Siberia and Canada, Bering Sea.
- Blocking positive MSLP anomalies were observed in Northern Nordic and Greenland regions.

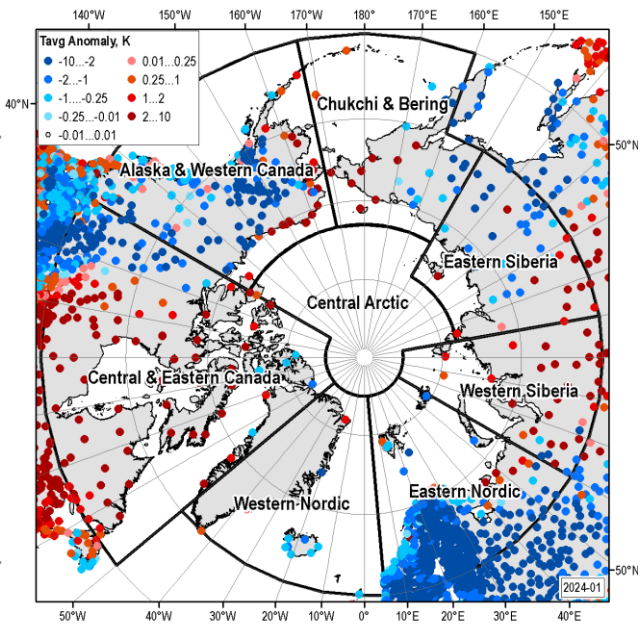
[AARI / CCCS ERA5]

Surface air temperature: Oct 2023 – Jan 2024 anomalies (1991-2020)

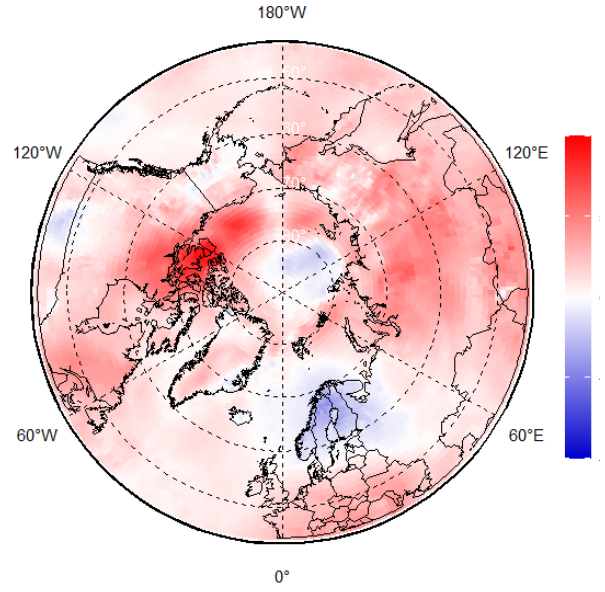




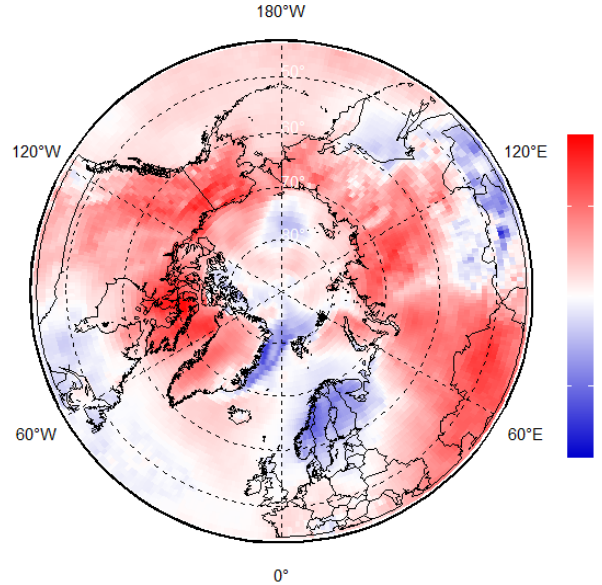




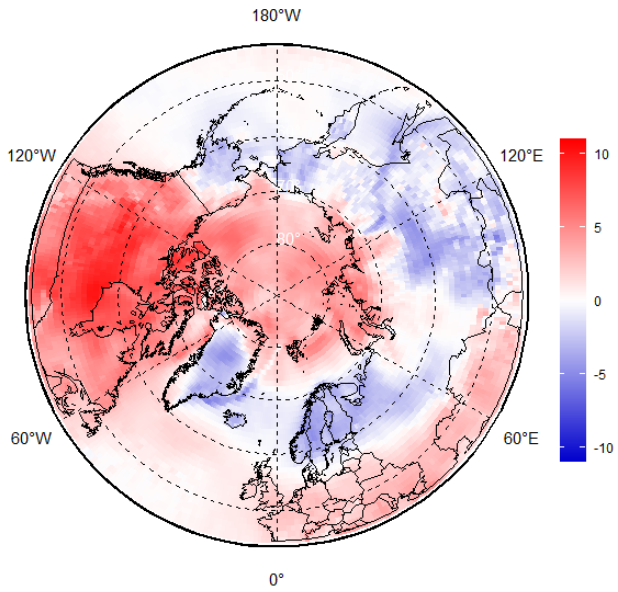
Oct 2023



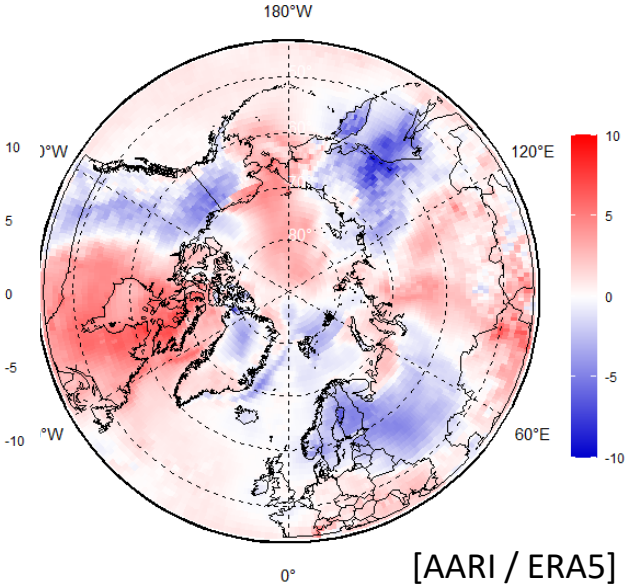
Nov 2023



Dec 2023

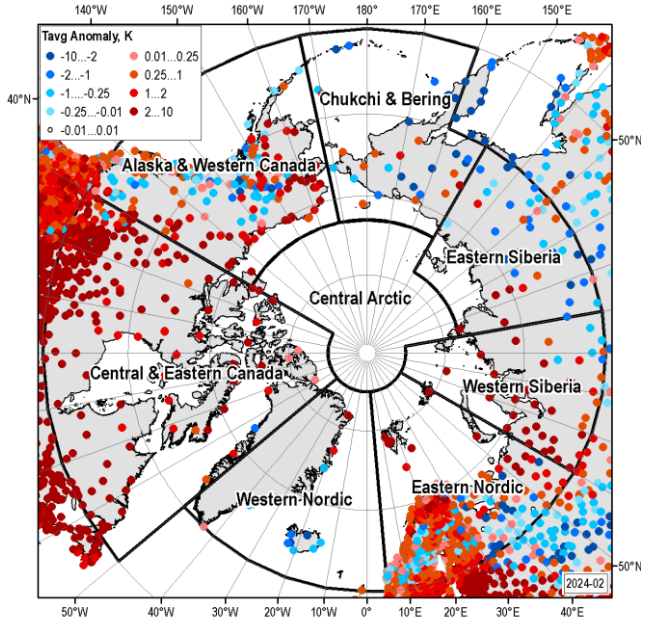


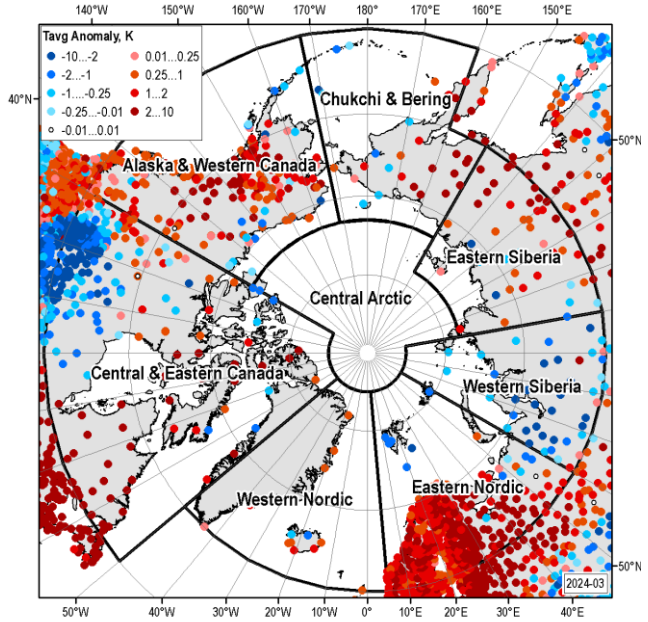
Jan 2024

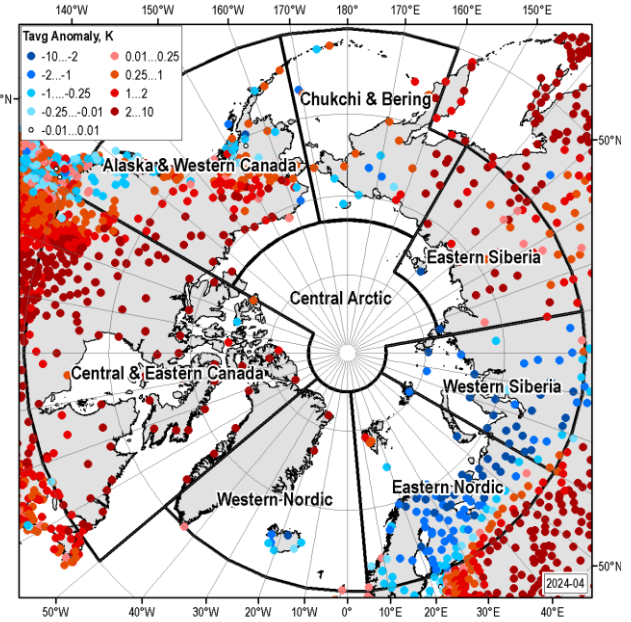


[AARI / ERA5]

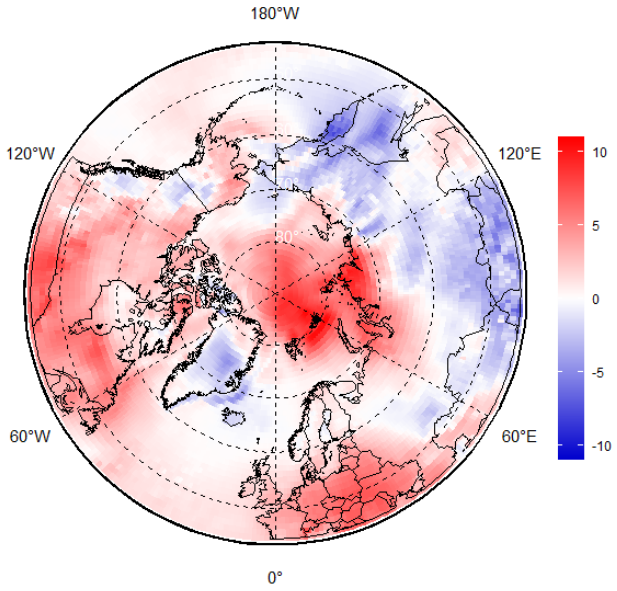
Surface air temperature: Feb - Apr 2024 anomalies (1991-2020)



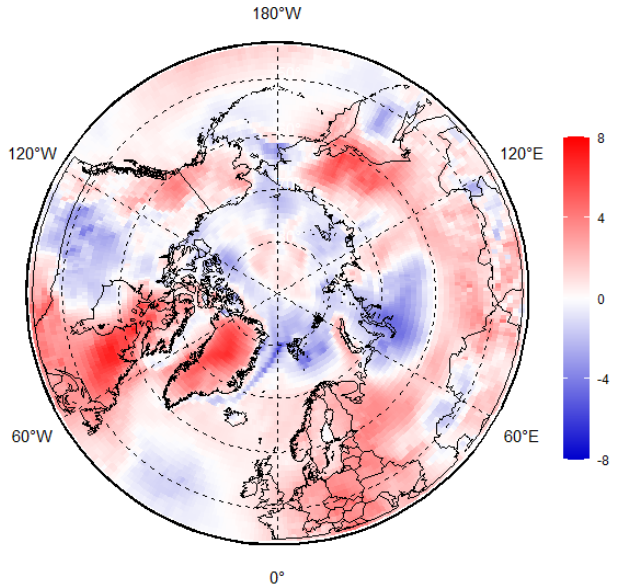




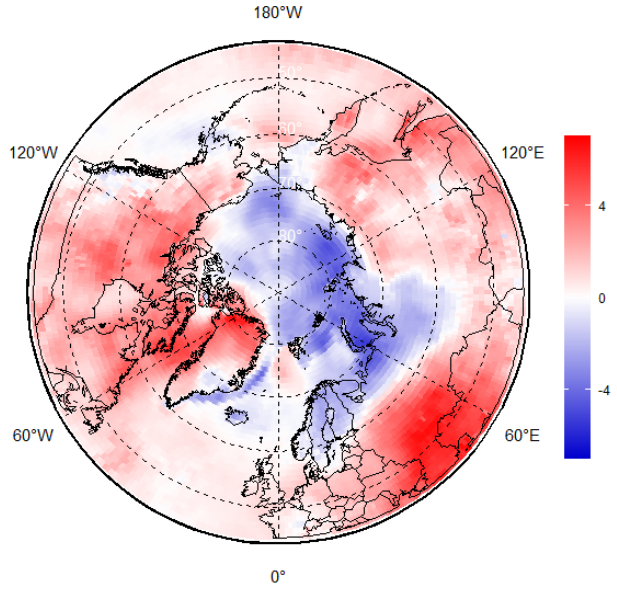
Feb 2024



Mar 2024



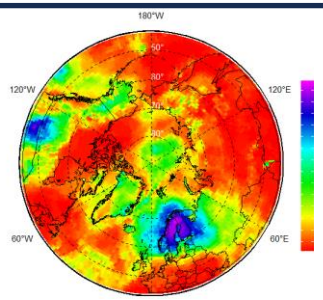
Apr 2024



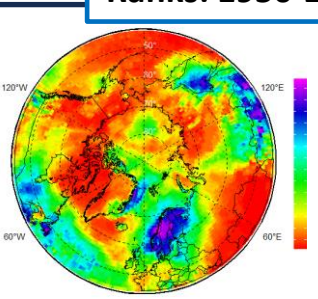
[AARI / ERA5]

Surface air temperature: October 2023 – April 2024

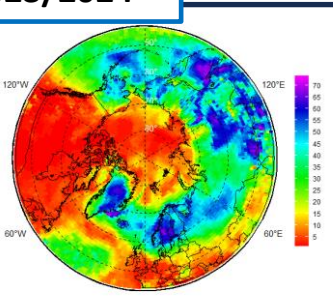
Ranks: 1950-2023/2024



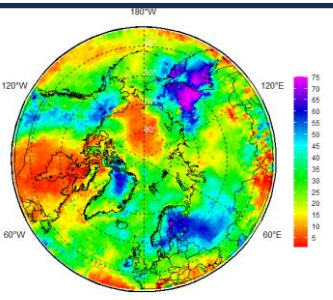
Oct 2023



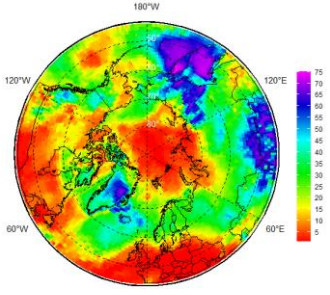
Nov 2023



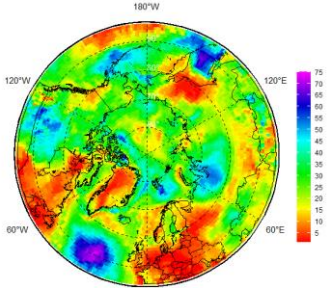
Dec 2023



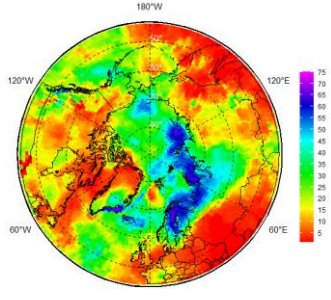
Jan 2024



Feb 2024

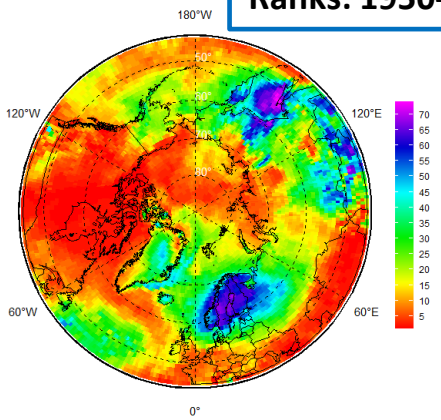


Mar 2024

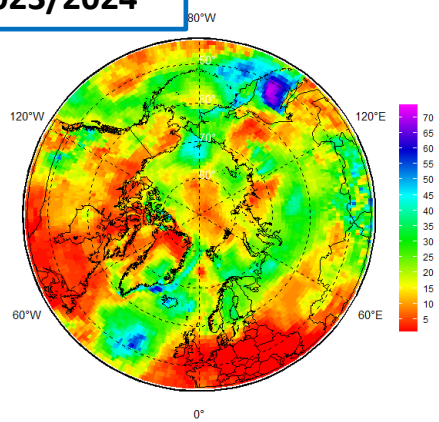


Apr 2024

Ranks: 1950-2023/2024



NDJ 2023-2024



FMA 2024

[AARI / WMO GTS]

Month/Season		Alaska and Western Canada				Central and Eastern Canada			
2023	Oct	0.73	28	1996	1914	1.80	7	1959	1938
2023	Nov	3.50	7	2006	1979	3.75	3	1985	1917
2023	Dec	1.18	22	1933	1986	6.18	1	1933	1930
2024	Jan	-1.48	47	1909	1981	0.00	26	1950	1931
2024	Feb	0.14	32	1904	1977	4.30	1	1979	1931
2024	Mar	1.14	30	2007	1915	0.24	20	1964	2010
2024	Apr	0.94	15	1972	1940	3.15	2	1954	1915
2023-24	NDJ	1.02	25	1946	1913	3.83	1	1949	1930
2024	FMA	0.45	24	1972	1906	2.28	4	1948	1915

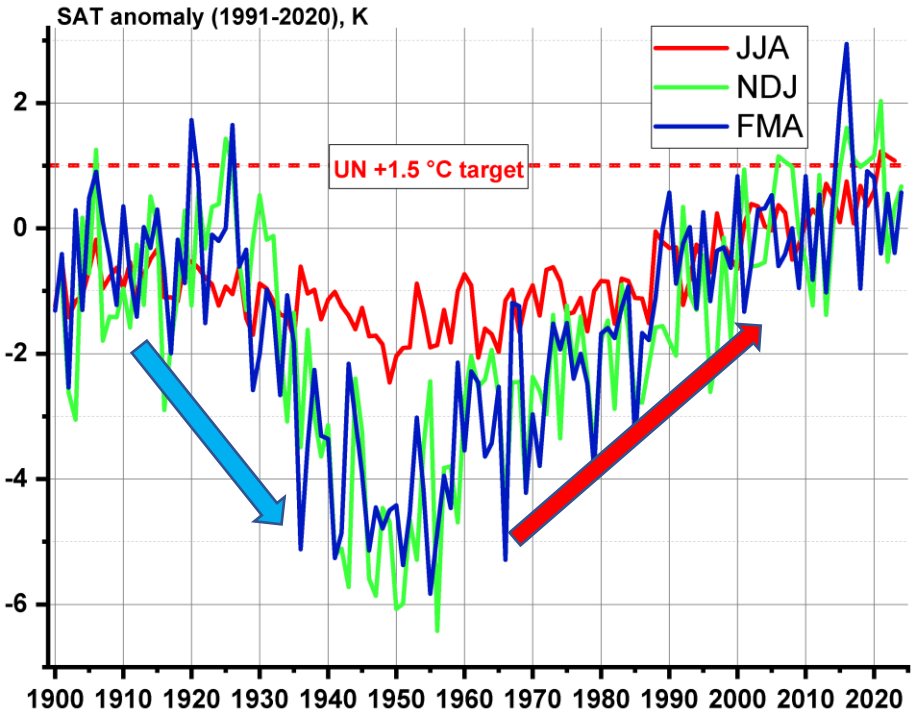
Month/Season		Western Nordic				Eastern Nordic			
2023	Oct	-0.47	41	1968	1915	-1.83	63	1992	1961
2023	Nov	-0.72	46	1971	1941	-2.70	57	1902	2020
2023	Dec	-2.02	60	1965	1933	-2.85	50	1915	2006
2024	Jan	-0.31	37	1971	1933	-2.72	54	1987	2020
2024	Feb	-2.02	62	1969	1932	0.77	25	1966	1990
2024	Mar	-0.72	41	1967	1929	1.93	13	1942	2007
2024	Apr	0.03	27	1983	1926	-1.52	55	1929	2011
2023-24	NDJ	-1.00	49	1965	1933	-2.70	61	1915	2011
2024	FMA	-1.00	48	1969	1929	-0.52	35	1917	2014

Month/Season		Western Siberia				Eastern Siberia				Chukchi and Bering			
2023	Oct	2.76	6	1976	1947	3.30	3	1977	1947	1.79	6	1902	1910
2023	Nov	3.72	10	1968	2020	4.09	3	1982	2020	3.70	6	1905	1919
2023	Dec	1.02	28	1968	1913	0.00	35	1907	2013	-0.02	30	1993	1924
2024	Jan	2.38	14	1969	2007	-0.97	33	1900	2007	1.03	32	1910	1926
2024	Feb	3.36	7	1966	2020	-0.18	33	1900	1934	-0.17	27	1902	1926
2024	Mar	-1.58	41	1960	2017	0.95	19	1942	2017	3.11	8	1901	1926
2024	Apr	-1.76	43	1984	1995	1.46	11	1956	1920	1.38	10	1976	1926
2023-24	NDJ	2.79	8	1968	1936	0.91	17	1907	1924	1.72	10	1994	1925
2024	FMA	0.07	20	1966	2020	1.06	13	1966	1920	1.36	11	1902	1926

Anomalies relative to: 1991-2020 (stations, ERA5)
Ranks: based on 1950-2023/2024 (stations, ERA5)
Year min/max: based on 1900-2023/2024 (stations)

Anom(Rank|Year$_{min}$|Year$_{max}$)

Surface air temperature

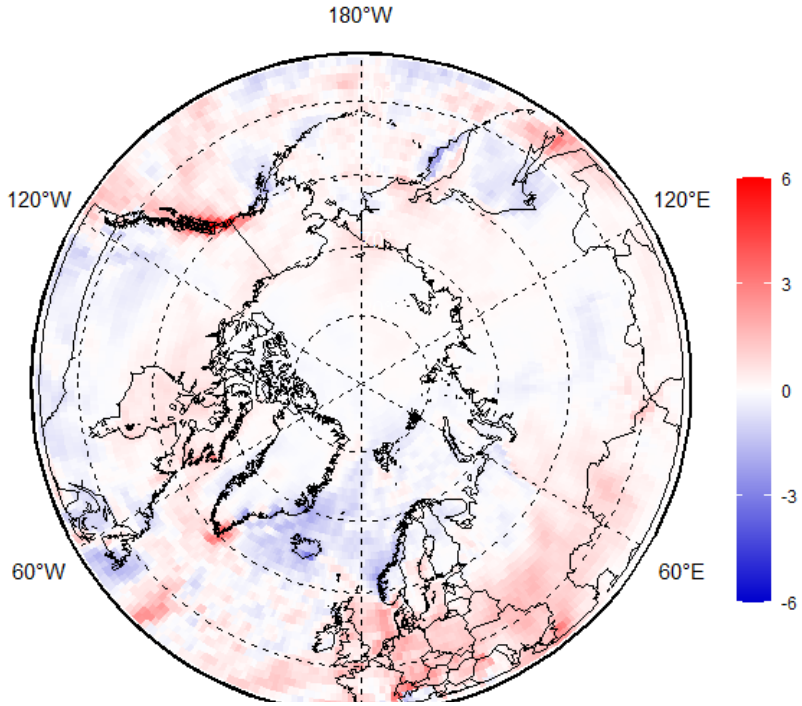


Month/Season		Arctic			
2023	Oct	0.44	16	1956	2022
2023	Nov	**1.56**	**5**	1955	1924
2023	Dec	1.07	11	1955	2006
2024	Jan	-0.98	30	1950	1926
2024	Feb	**1.83**	**2**	1936	2016
2024	Mar	**1.20**	**6**	1942	1926
2024	Apr	**0.67**	**7**	1956	2016
2023-24	NDJ	0.67	13	1955	2020
2024	FMA	**0.57**	**9**	1955	2016

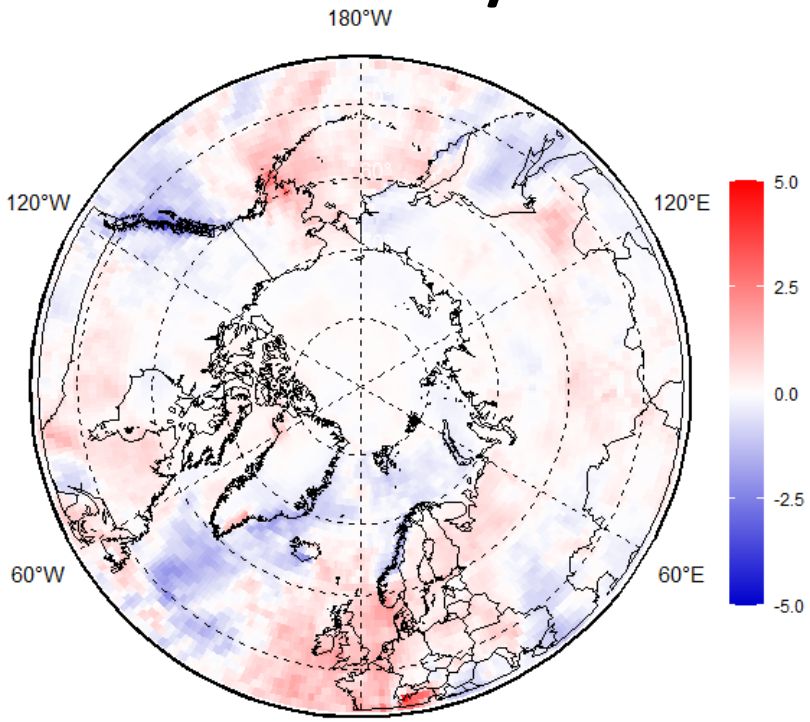
Anom(Rank|Yearmin|Yearmax)

- The start of winter 2023 (November-December) surface air temperature showed prominent positive anomalies in Eastern Siberia (3rd in row), Chukchi&Bering (6th in row), Alaska (7th in row) in particular in Central&Eastern Canada (1st – 3rd in row), though negative in Western Nordic (60th in row) and Eastern Nordic (57-63rd in row) (to 3rd WMO reference period 1991-2020, ranks for 1950-2023 observation period).
- During mid-winter (January-February 2024) strong positive anomalies were observed over Western Siberia (7th in row) and again over Central and Eastern Canada (1st in row) with negative anomalies observed over Western Nordic region (62nd in row) and E Siberia (70th in row).
- Further by the end of winter in March – April 2024 strong positive anomalies were observed again over Central & Eastern Canada (2nd in row) and Chukchi&Bering (8th in row) with smaller negative over Eastern Nordic (55th in row).
- Due to lack of surface marine observations conclusions for the Central Arctic, done on reanalysis, include partly strongly warmer conditions in November-January and warmer to colder during February – April 2024.
- For the whole land Arctic extremely warmer conditions were observed in November 2023 and February – April 2024 though lesser or even colder in February 2024 with preliminary ranks 2nd (from 1950) and 5-6th in row, though large regional and inner season variations and changes in anomaly sign did occur.
- Centennial long analysis show that extreme negative anomalies (to 1991-2020 period) in general occurred in mid 20th century with comparable to current decade positive anomalies occurred in 1910-1920s but that is again NOT the SAME for all of the Artic subregions. Though positive trends from 1940s-1950s are obvious, the quantitive estimates depend on the WMO reference period chosen, density and subset of the stations chosen for the analyzed subregion, in particular for the marine Arctic.

Surface precipitation: monthly ONDJFMA 2023/2024 anomalies (1991-2020)

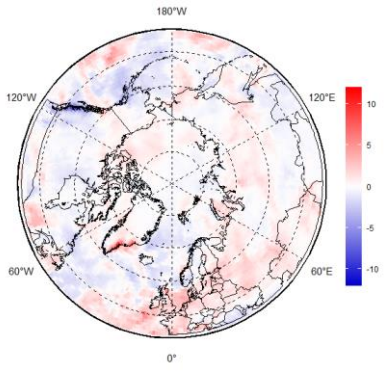


NDJ 2023/2024 precipitation anomaly

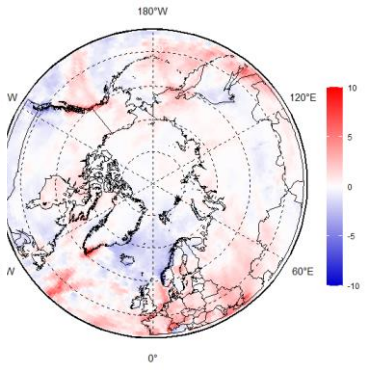


FMA 2024 precipitation anomaly

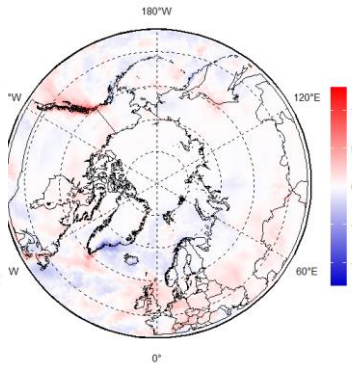
- In general, during the whole season **wetter** (snowy) conditions occurred in parts of Canadian, Alaska, Bering & Chukchi, Siberia and Eastern Nordic regions
- **Drier conditions** occurred in Nordic, parts of Canadian and Alaska regions



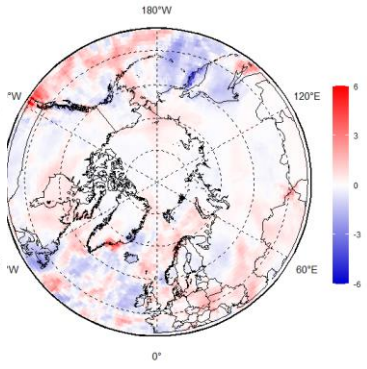
Oct



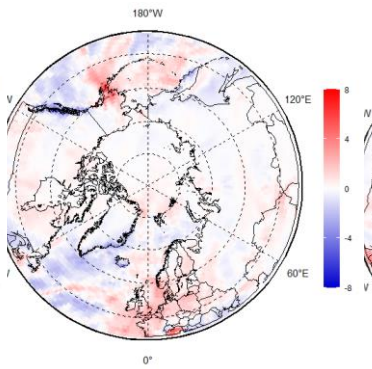
Nov



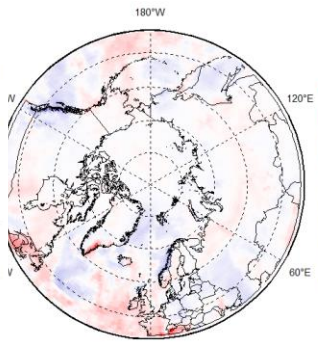
Dec



Jan



Feb



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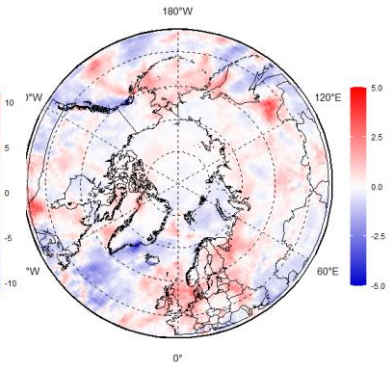


Apr

[AARI / CCCS ERA5]

Surface precipitation: seasonal NDJ 2023/2024 & FMA 2024 anomalies (reanalysis)

Region	NDJ 2023/2024	FMA 2024
Western Nordic	drier	drier to normal
Eastern Nordic	wetter to normal	wetter to drier
Western Siberia	normal	slightly drier
Eastern Siberia	normal	normal
Bering & Chukchi	slightly wetter	wetter to slightly drier
W Canada & Alaska	normal to wetter	drier, normal, wetter
Eastern Canada	slightly wetter	slightly wetter
Central Arctic	slightly wetter	normal

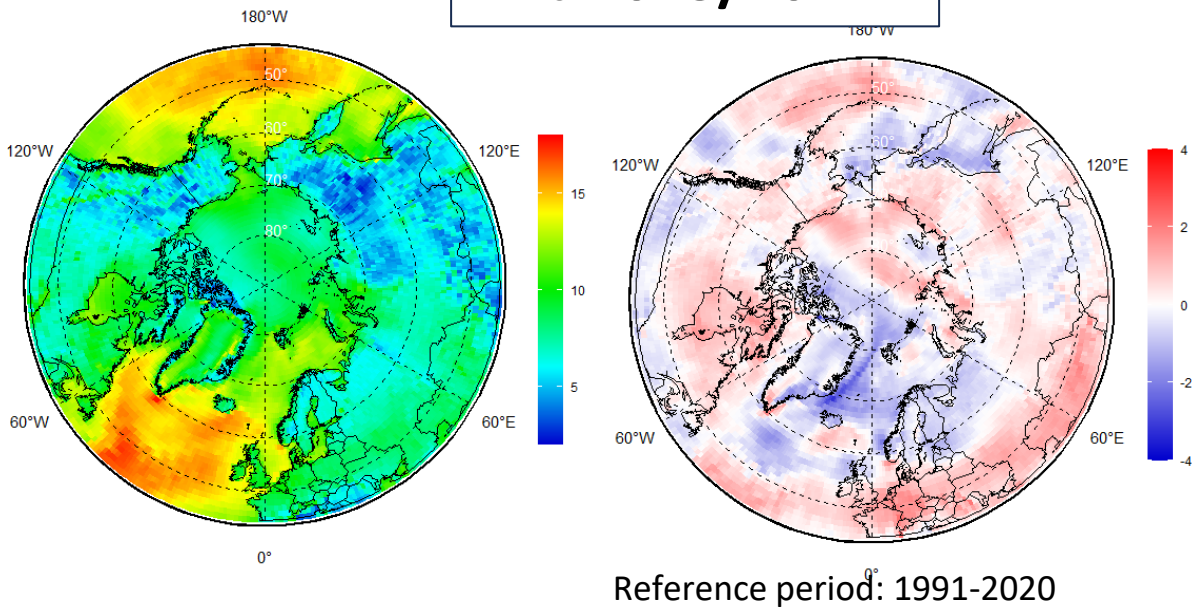
Reference period: 1991-2020

- **The least amount** of precipitation was for the **Western Nordic, parts of W Canada & Alaska regions** which is close to winter 2022/2023
- More abundant precipitation was observed in the **Eastern Nordic, parts of Alaska and Bering and Chukchi regions**.
- Somewhat close to normal conditions are estimated for the Central Arctic

[AARI / CCCS ERA5]

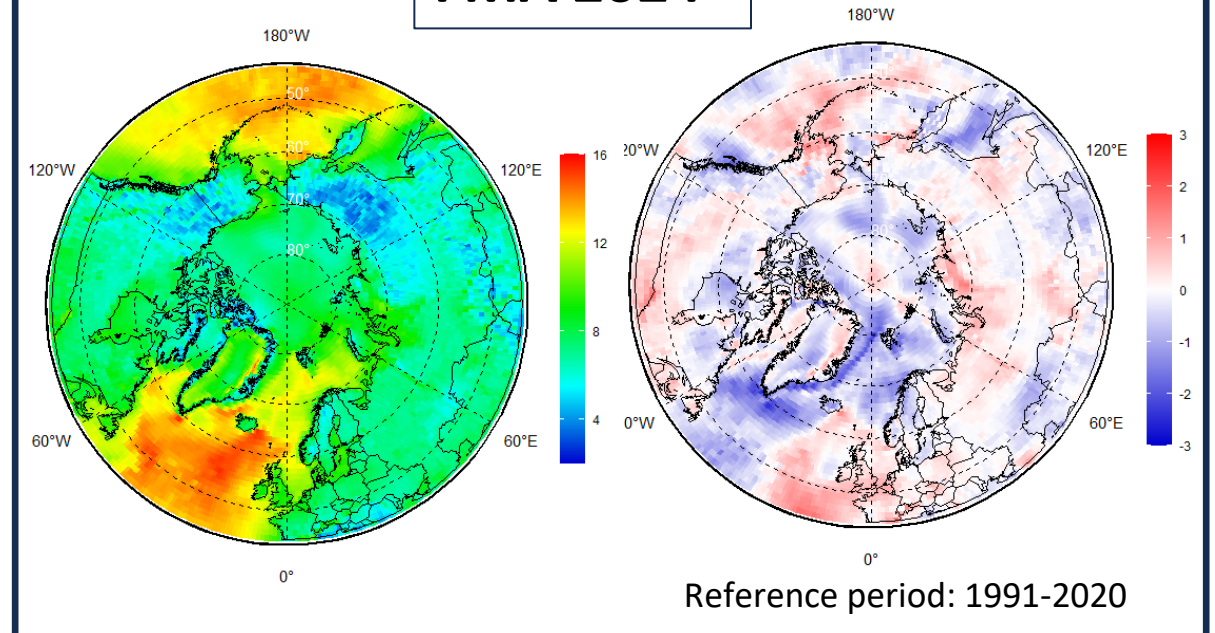
Surface wind (wind speed in gusts, 2 m): reanalysis

NDJ 2023/2024



Reference period: 1991-2020

FMA 2024



Reference period: 1991-2020

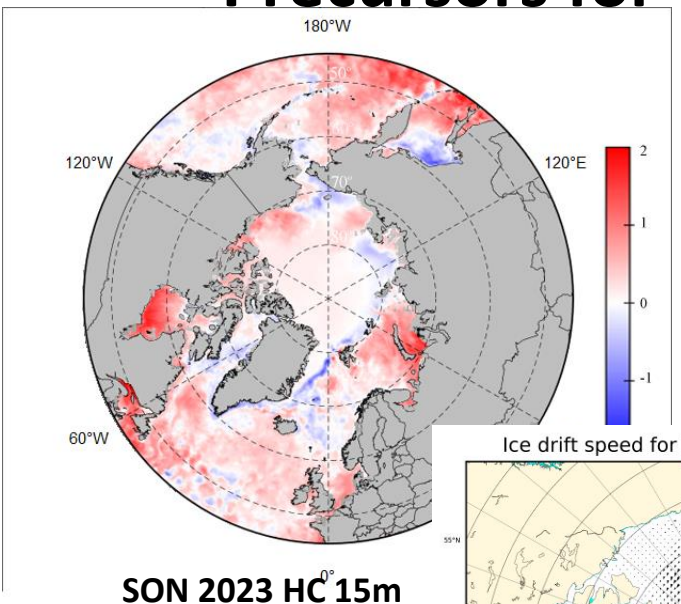
- **Calmer (less windy)** conditions (relative to the WMO period 1991-2020) were observed in the Nordic, Greenland, Sea of Okhotsk regions
- **More windy** conditions were observed in Central and Eastern Siberia, Central Canada, partly Alaska regions
- Wind speed along with surface temperature and humidity have direct impact on bioclimatic conditions which will be described in a separate presentation

[AARI / CCCS ERA5]

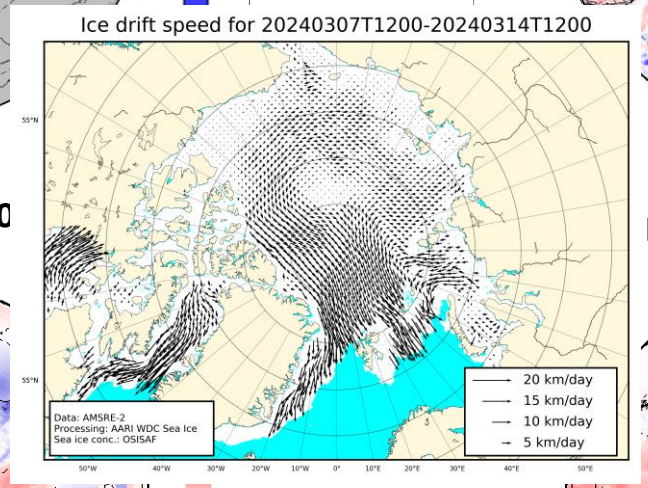
Sea ice

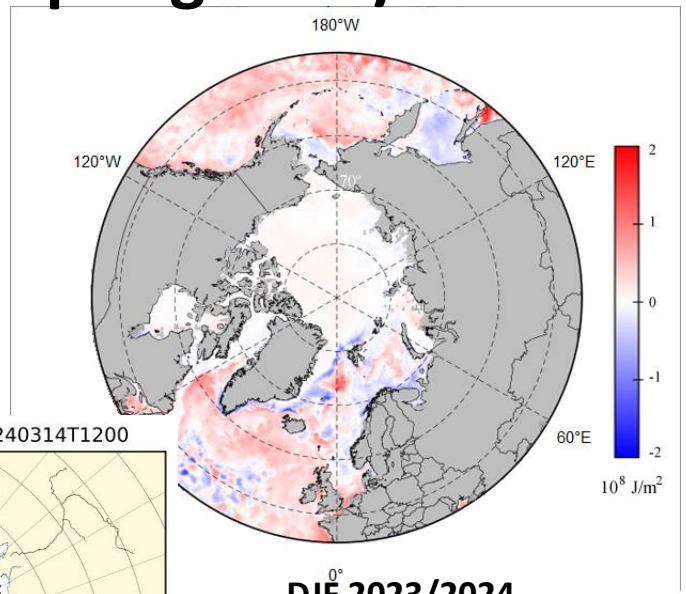
- Precursors in atmosphere and polar ocean
- Ice extent and ice conditions based on ice charting
- Sea ice thickness and volume based on reanalysis

Precursors for winter-spring 2023/2024 ice conditions: HC, SAT, drift

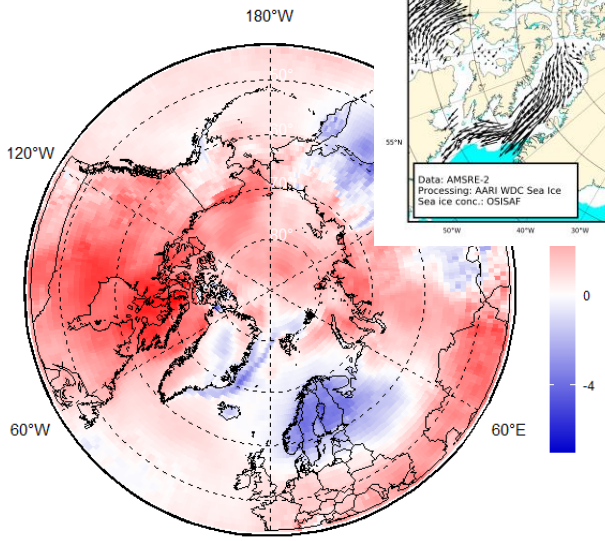


SON 2023 HC 15m anomaly, 1993-2020

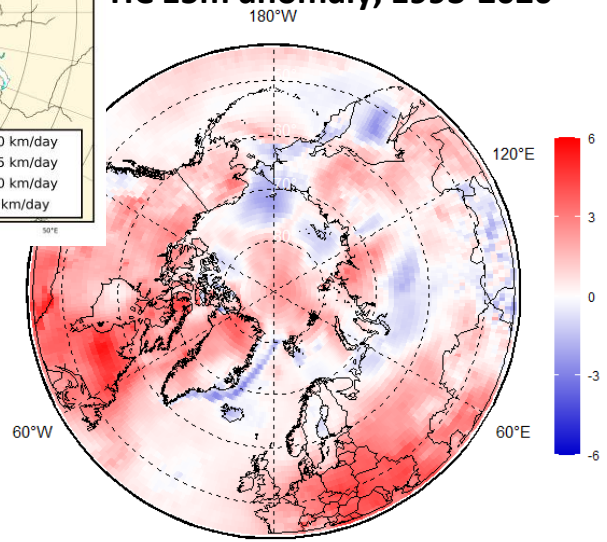




DJF 2023/2024 HC 15m anomaly, 1993-2020



NDJ 2023/2024 SAT anomaly (1991-2020)

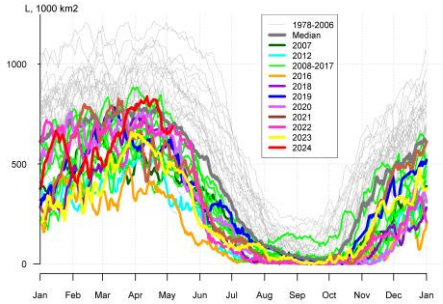


FMA 2024 SAT anomaly (1991-2020)

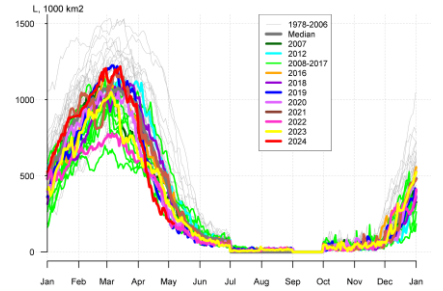
- Prevailing **positive** ocean heat content (HC) anomaly during Sep – Nov 2023 for the Barents, Kara, parts of Canadien Arctic slowed freezing processes in these regions
- Oppositely, zero or **negative** HC anomalies in Laptev, ESS, Chukchi, Bering, Okhotsk Seas provided background for closer to normal freeze-up
- Further in winter during FMA 2024 occurrence of general **positive** SAT anomalies over Central Arctic slowed the ice growth, with **negative** SAT anomalies stimulated ice growth in Eurasian Arctic, Bering and Okhotsk Seas. In addition to SAT general ice drift pattern stimulated ice extent in the Barents and Greenland Seas.

[AARI / CCCS MEMS & ERA5]

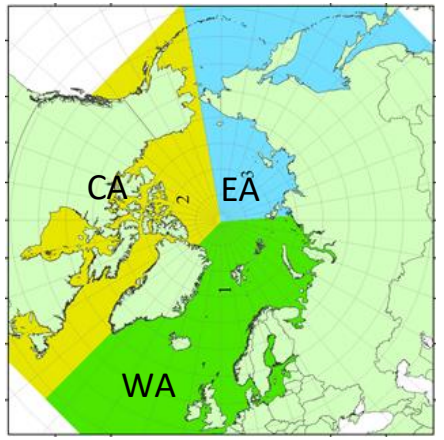
Arctic (NH) seasonal ice extent 1978…. 2024

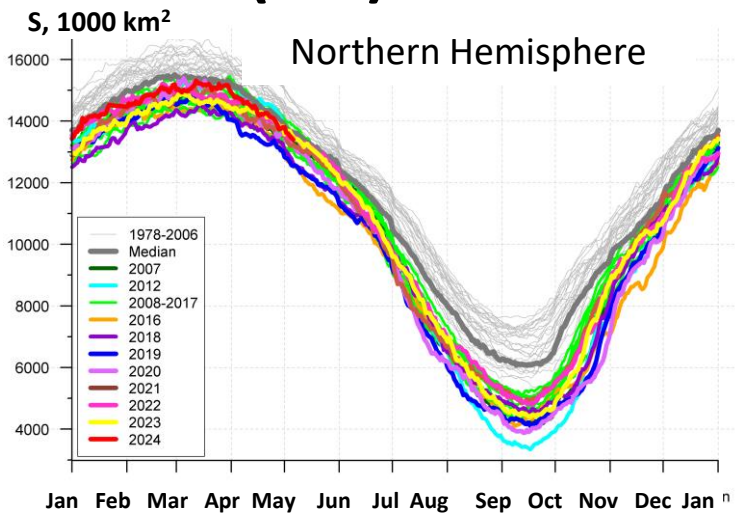


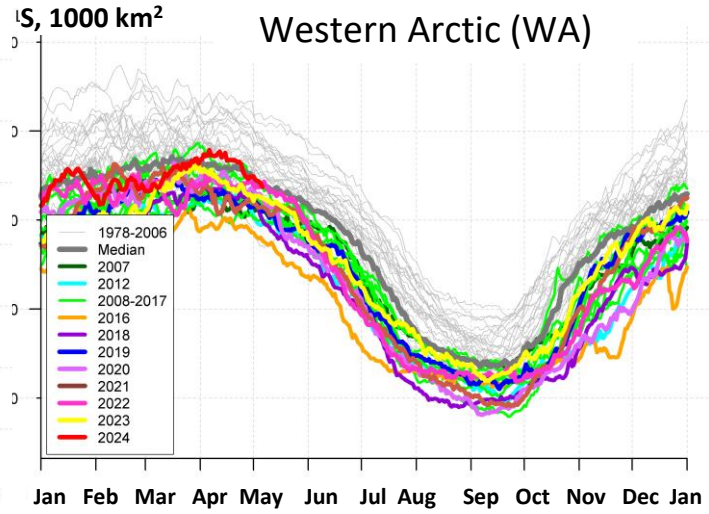
Barents Sea

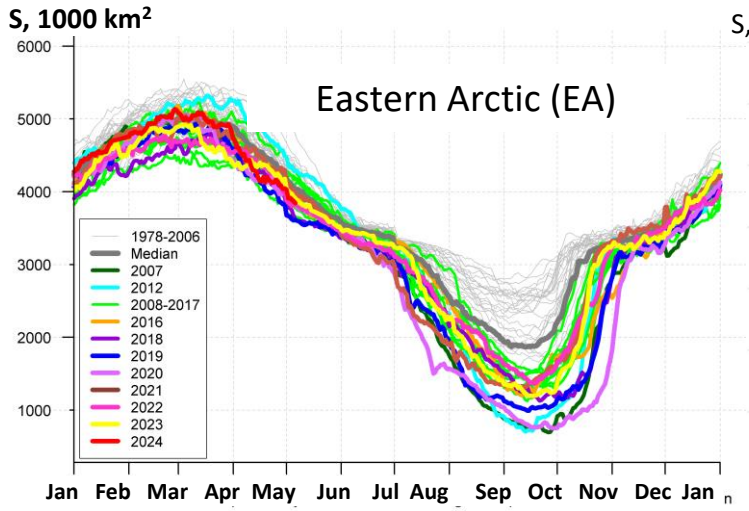


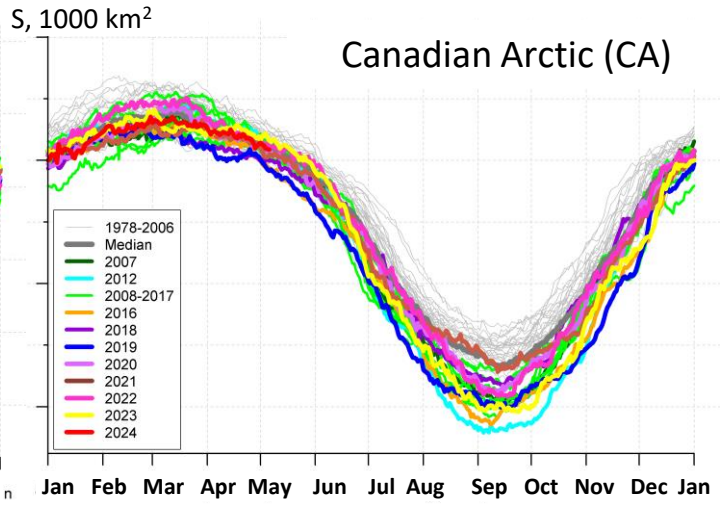
Sea of Okhotsk











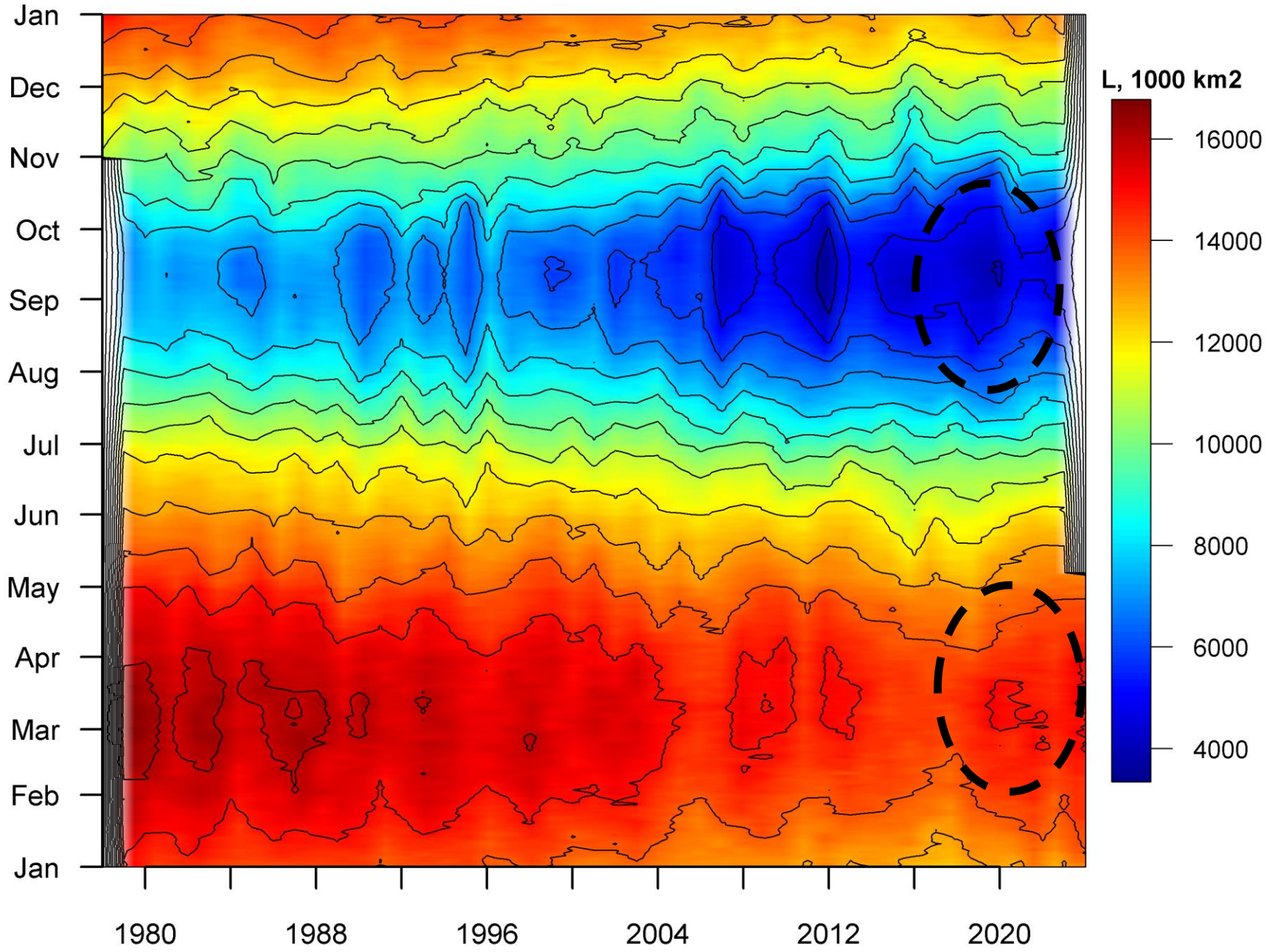
S, 1000 km²

Sep (Min)			Feb/Mar (Max)		
2012	3346	1	2017	14467	1
2020	3882	2	2018	14516	2
2016	4099	3	2015	14526	3
2019	4103	4	2016	14580	4
2007	4189	5	2011	14701	5
2011	4312	6	2006	14867	6
2015	4350	7	2023	14875	7
2023	4401	8	2019	14891	8
2018	4557	9	2007	14931	9
2008	4588	10	2014	14972	10
…	…	…	2021	15100	11
2022	4808	13	…	…	
2021	4848	14	2022	15210	14
…	…		2024	15317	15
1982	7246	43	…	…	
1983	7285	44	1983	16547	45
1980	7611	45	1979	16769	46

[AARI / NSIDC]

Maximum Arctic (NH) winter ice extent, 15th in row, ~15.3 mln km² (7th in row, ~14.9 mln km²) was reached 12-13 March 2024, which is close in time to climatic date and later by 1 weeks than previous year. Prominent area of residual ice in late summer led to decadal normal ice extent growth in the Eurasian Arctic. Similar to 2023 the Sea of Okhotsk and the Greenland Sea had ice extent close or higher than 46-years median and the Barents Sea ice extent close to normal in late winter 2024.

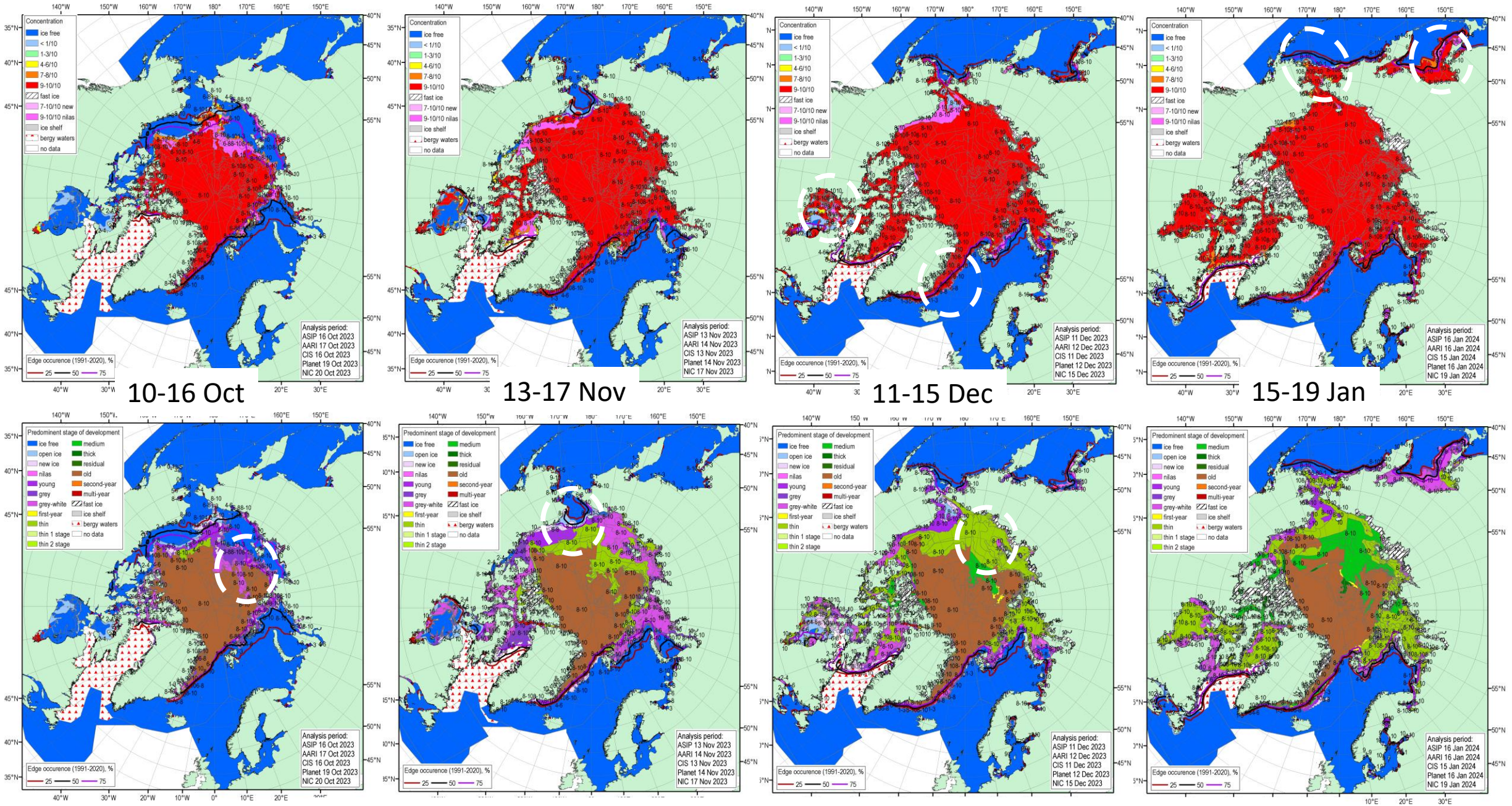
Seasonal NH ice extent variability: 1978 -2023



- 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 are certain hints to possibility for summer ice cover in 2024 be greater than in 2019-2020 and close to 2021-2023

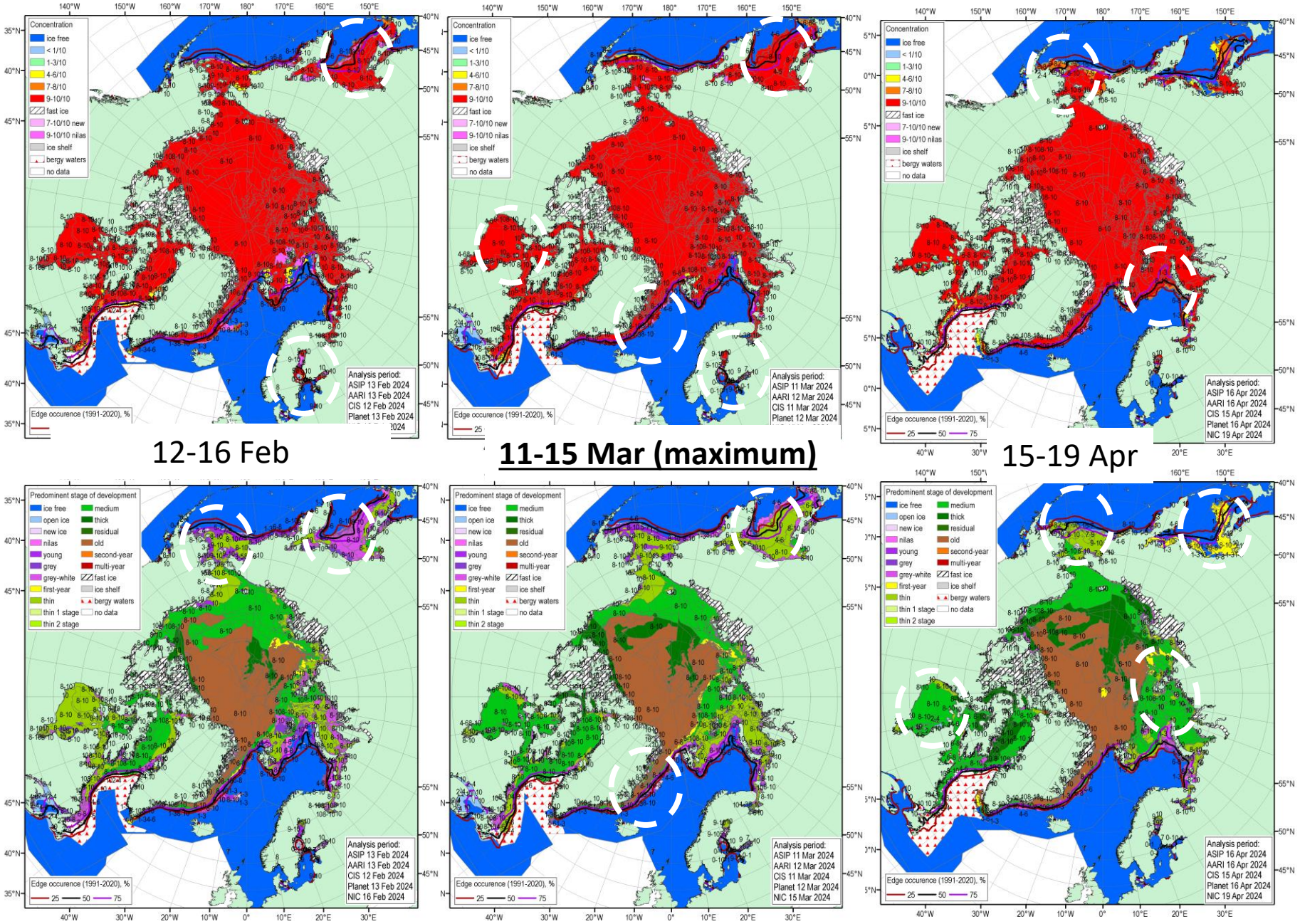
[AARI / NSIDC]

ONDJ 2023/2024 Arctic sea ice – concentration and stage of development



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

FMA 2024 Arctic sea ice – concentration and stage of development

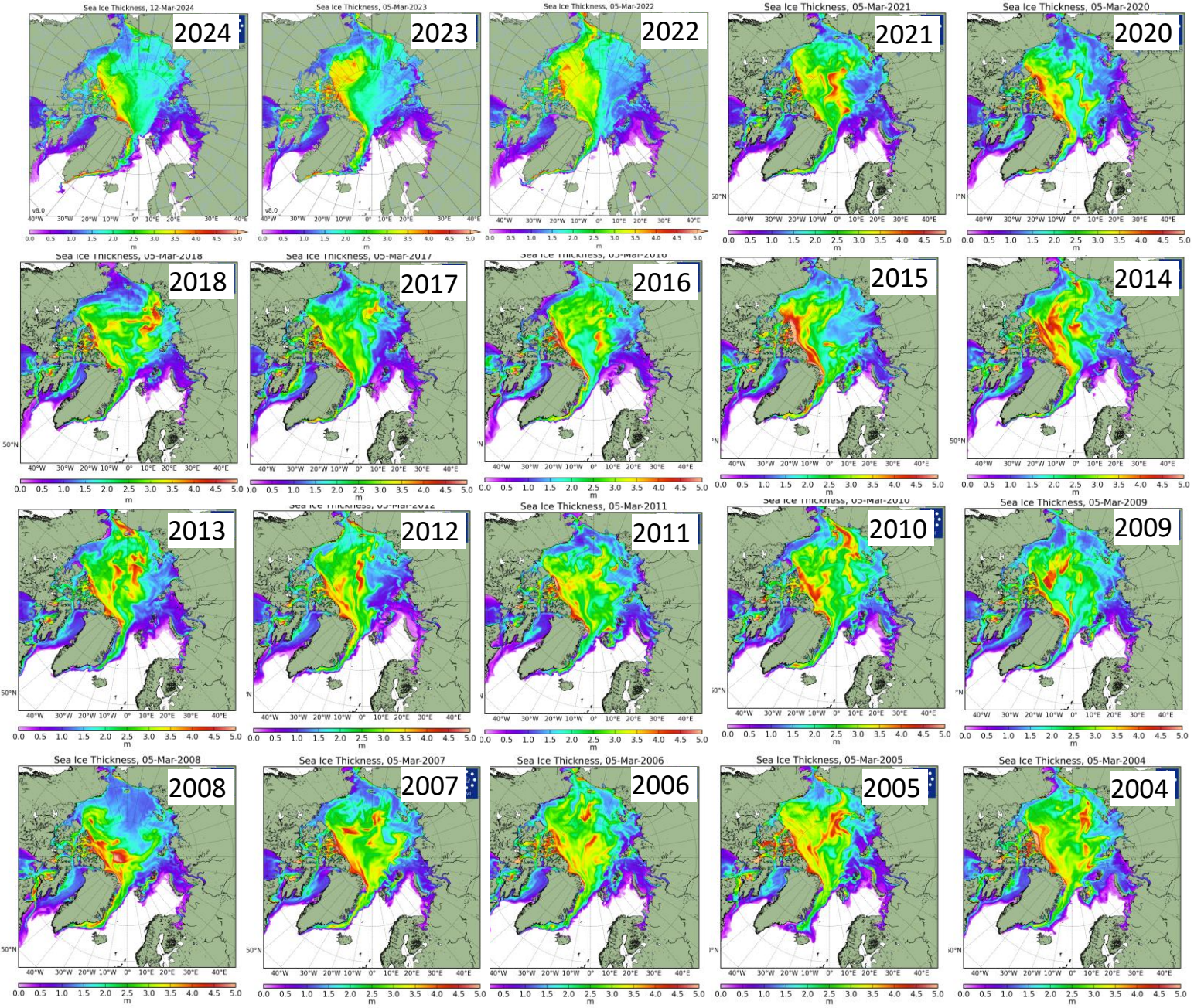


Special features of ice conditions in the Arctic during autumn – winter 2023/2024 included:

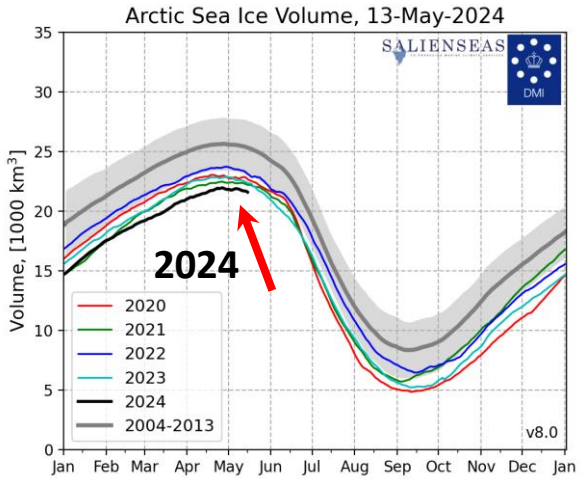
- occurrence of residual and further in season the second-year ice in the parts of the Laptev and East Siberian Sea and close to normal autumn ice growth within eastern lanes of the NSR,
- Close to decadal normal ice conditions in the Greenland and in late winter in the Barents Sea
- Close or higher than normal ice conditions in the Sea of Okhotsk which is same as in 2023

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

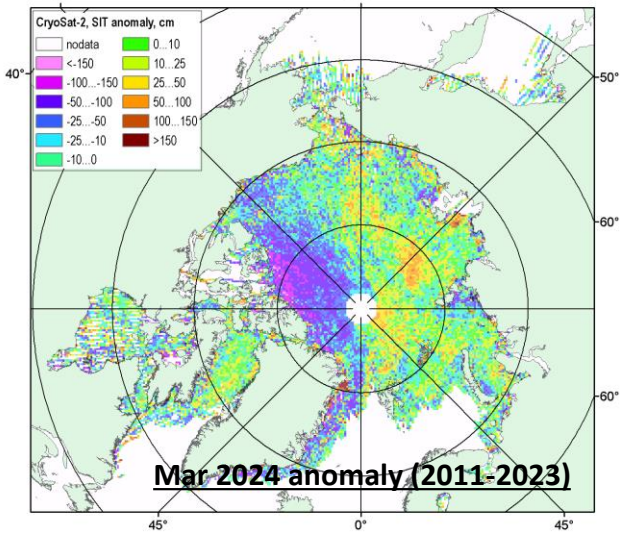
Sea ice thickness for Mar max 2004…2024, ice volume and CryoSAT-2 SIT



DMI HYCOM-CICE sea ice model



ESA CryoSAT-2 sea ice thickness (AWI v2p6)



Cryosat-2 measurements in March 2024 show general SIT growth in the Eurasian Arctic though prominent decline in the Canadian part to mean 2011-2024 which explains results of the Arctic sea ice volume modelling with the 1st lowest volume this March

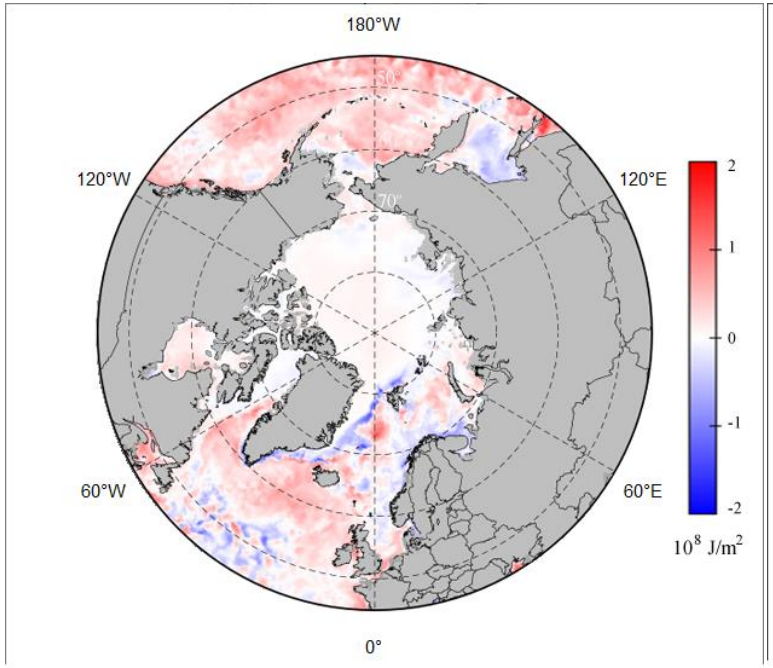
[DMI North Atlantic - Arctic Ocean model HYCOM-CICE - http://ocean.dmi.dk/models/hycom.uk.php]

Polar Ocean

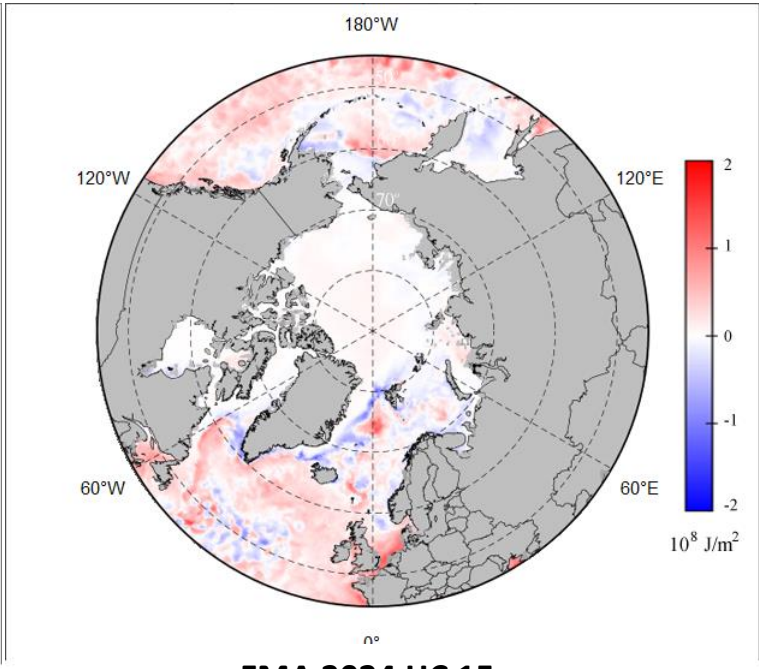
- Surface layer heat content
- pH (acidification and alkalization of the Arctic)

Heat content – NDJ 2023/2024 & FMA 2024

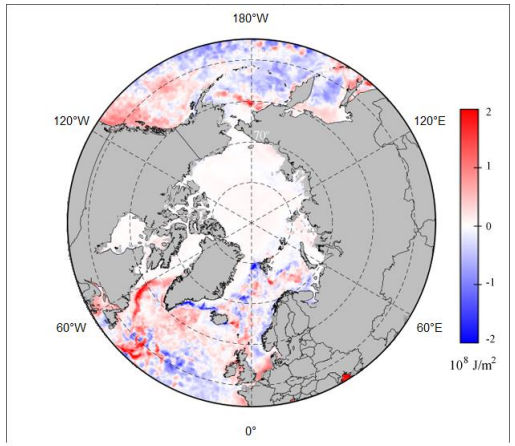
- During first part of the winter 2023/2024 **higher** 15 m upper ocean layer Heat Content (HC) was noticed in the southern Bering, Northern Barents, southern Greenland waters. **Lower** HC was noticed for northern Bering, Laptev, Okhotsk seas, northern Greenland waters with somewhat neutral over other parts of the Arctic.
- Later in winter the HC was mostly neutral to 1993-2020 average for most of the Arctic with the same **lower** exception for the Sea of Okhotsk, Laptev seas, parts of Greenland sea and **higher** for southern Bering, Greenland water. In general the Barents and Bering Seas in 2024 were colder than in 2022-2023.



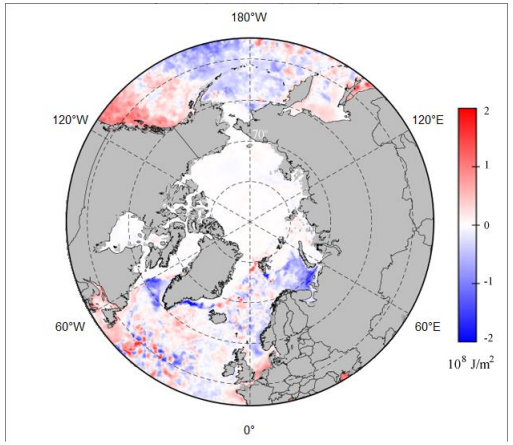
NDJ 2023/2024 HC 15m anomaly (1993-2020)



FMA 2024 HC 15m anomaly (1993-2020)



April HC 15m 2024 minus 2022

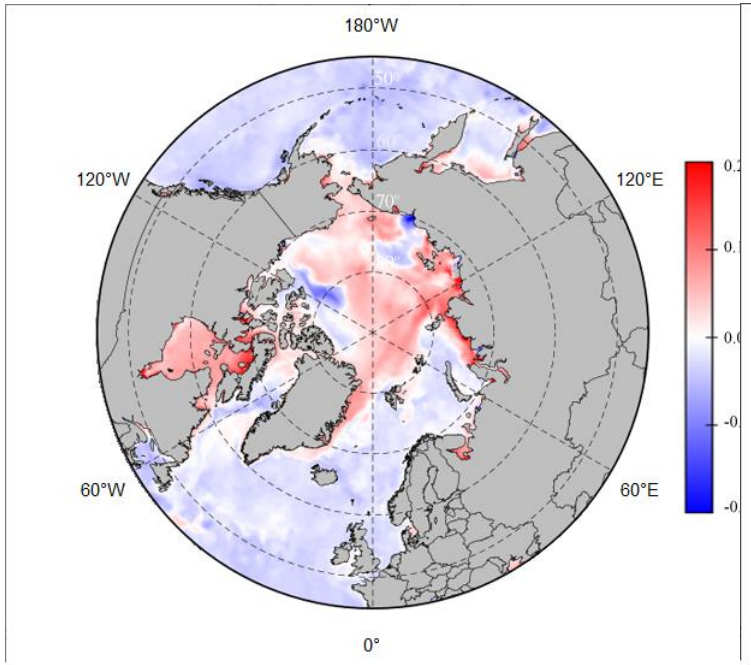


April HC 15m 2024 minus 2023

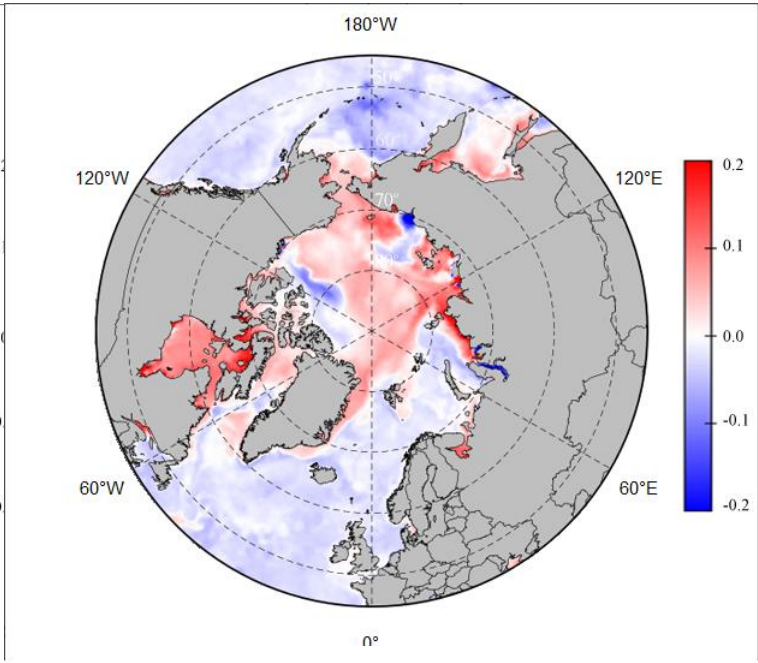
[AARI / CCCS MEMS & ERA5]

pH 2 meter layer – NDJ 2023/2024 & FMA 2024

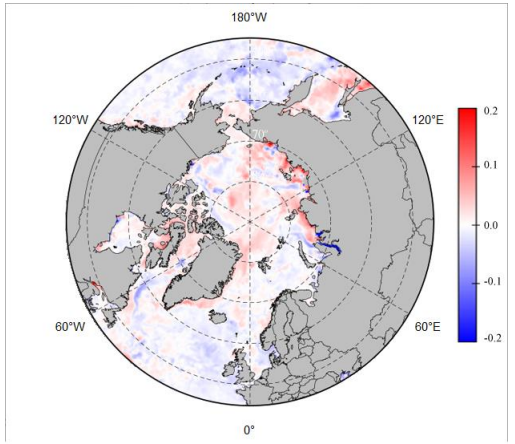
- Numerical models show for the current winter season both **positive pH 2m anomalies** (alkalization) for the Arctic Basin, Laptev, Chukchi Seas and **negative pH anomalies** (acidification) for the Barents, parts of the Kara, East Siberian, Greenland Seas to the 1993-2020 period, which is in general similar to 2022-2023, the latter may point to **alkalization** in most of the Arctic Ocean with **acidification** processes in the Barents, Greenland and Bering Seas though that need verification with ground-truth data.



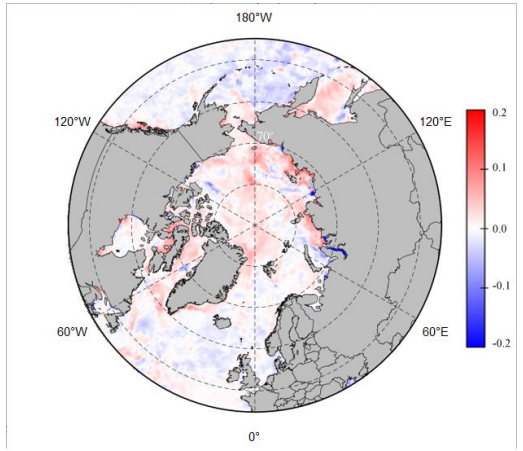
NDJ 2023/2024 pH 2m anomaly (1993-2020)



FMA 2024 pH 2m anomaly (1993-2020)



April pH 2m 2024 minus 2022



April pH 2m 2024 minus 2023

[AARI / CCCS MEMS & ERA5]

Hydrology and land Snow

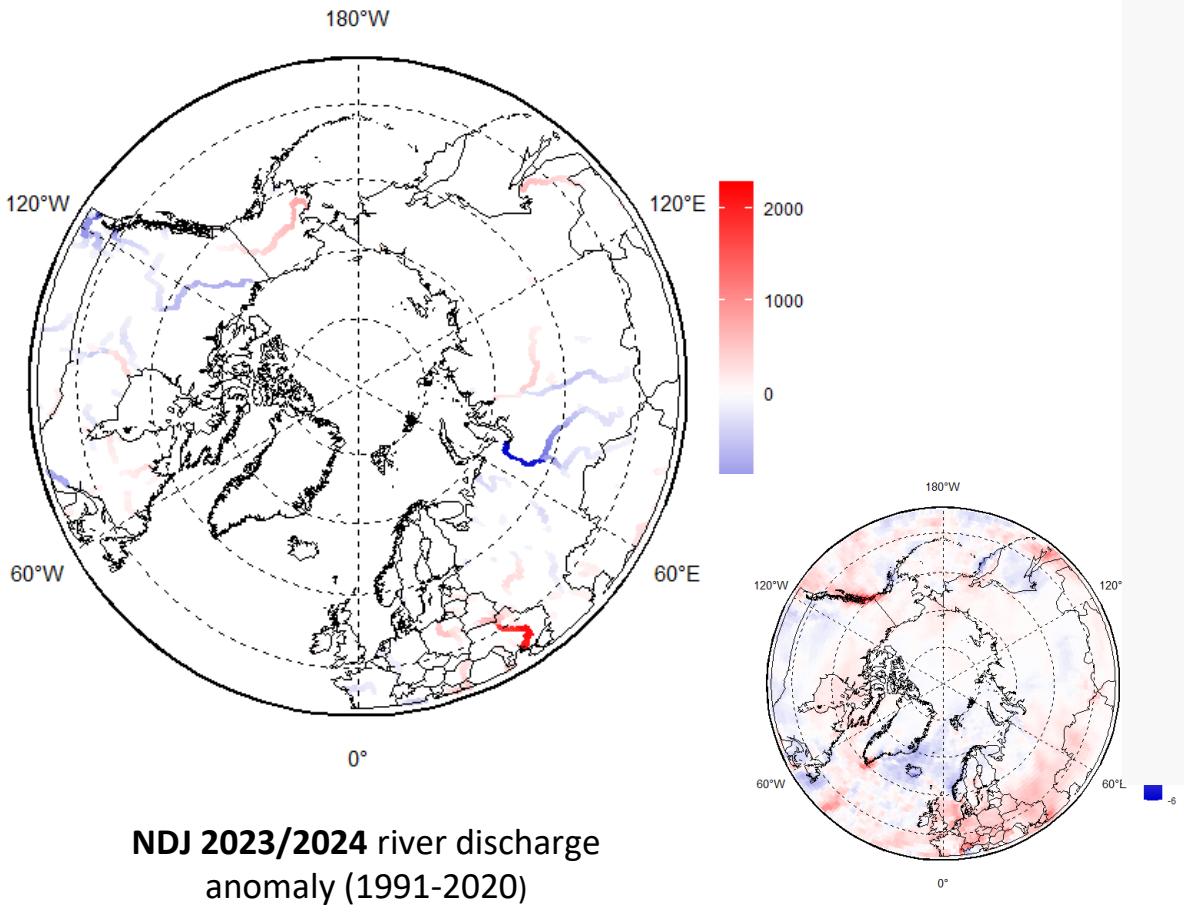
- River discharge
- Snow height and extent

Impacts of precipitation on river discharge

Impacts of wetter/drier and colder/warmer weather conditions were reflected in the winter/spring 2023-2024 Arctic rivers discharge though the frozen ground restricts direct effects

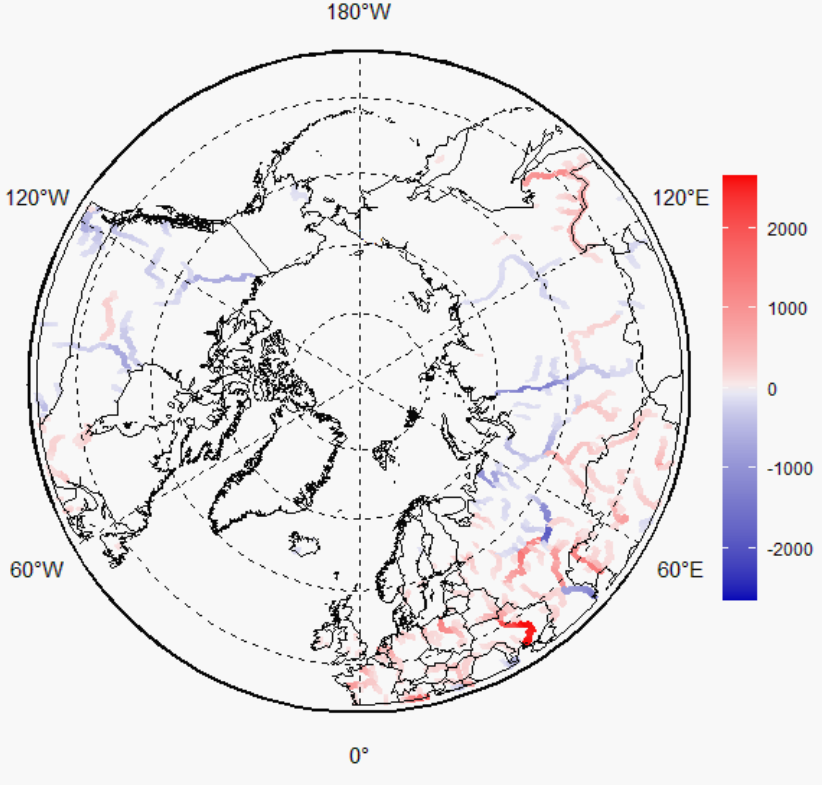
- **lesser** drainage than normal is seen for Pechora, Ob', partly Enisey, Mackenzie rivers through the whole season
- Yukon, partly Enisey rivers experienced **greater** discharge than normal
- Close to normal river discharge was estimated for Lena and further eastward Siberian rivers

[AARI / CCCS ERA5-GloFAS]

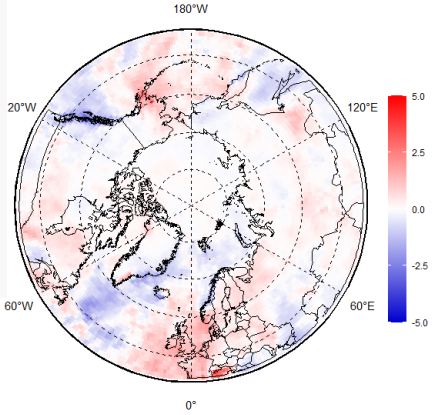


NDJ 2023/2024 river discharge anomaly (1991-2020)

NDJ 2023/2024 prec anomaly (1991-2020)



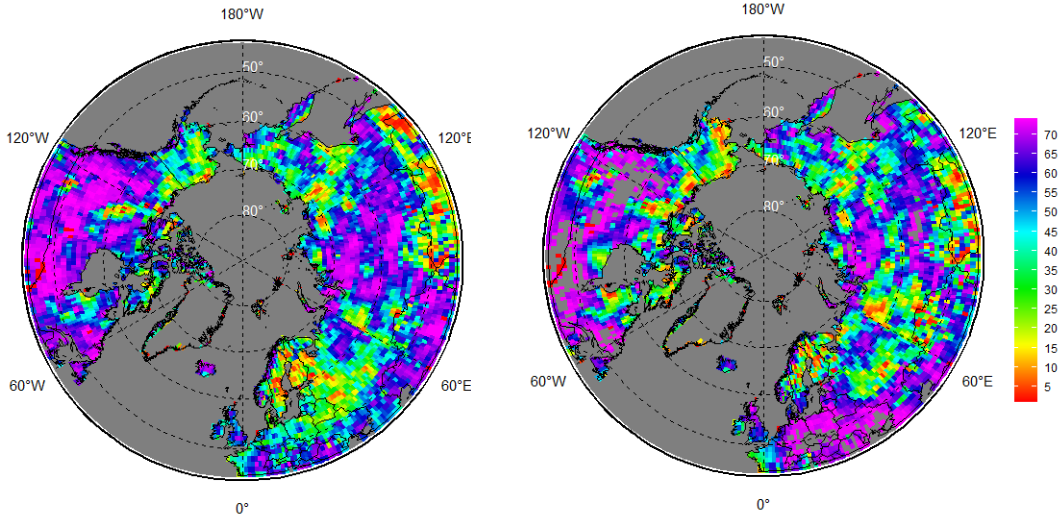
FMA 2024 river discharge anomaly (1991-2020)



FMA 2024 prec anomaly (1991-2020)

NDJFMA 2023-2024 land snow

- During NDJFMA 2023-2024 **lesser** snow height as well as snow water equivalent dominated over parts of central Siberia and E Canada
- Positive anomalies (**greater snow height**) were observed in parts of Alaska, Chuchi, Nordic and W Siberia regions
- The snow extent over Eurasia and Canada was mostly below 1991-2020 normal. Alaska in general experienced normal or somewhat greater snow extent



NDJ 2023/2024 **FMA 2024**

snow height ranks (1950-2023/2024)
from highest (1) to lowest (74)

[GCW / Rutgers Global SnowLab]

2023-2024		1991-2020 Normal		Period of Record from Nov 1966		
Month	Area, 1000 km^2	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
			Eurasia			
4	15,864	16,759	-895	49/58	20,687 (1981)	14,767 (2014)
3	23,249	24,091	-842	46/58	27,950 (1981)	20,183 (2002)
2	27,915	28,515	-600	39/58	32,285 (1978)	25,913 (2002)
1	28,930	29,647	-717	41/58	32,265 (2008)	25,823 (1981)
12	27,534	27,365	169	18/58	29,699 (2002)	22,882 (1980)
11	21,991	21,181	810	16/58	24,132 (1993)	16,796 (1979)
			Canada			
4	7,801	8,787	-986	55/58	9,860 (1979)	6,939 (2010)
3	9,744	10,074	-330	50/58	10,368 (1982)	9,486 (1981)
2	10,189	10,309	-120	50/58	10,424 (2013)	10,015 (1981)
1	10,299	10,319	-20	36/58	10,424 (1982)	10,060 (1981)
12	9,544	10,147	-603	58/58	10,403 (2016)	9,544 (2023)
11	9,018	8,948	70	22/58	9,978 (2018)	7,254 (1987)
			Alaska			
4	1,487	1,461	26	21/58	1,526 (2018)	1,360 (2016)
3	1,512	1,495	17	8/58	1,534 (2008)	1,293 (1968)
2	1,518	1,513	5	31/58	1,534 (tie)	1,417 (1968)
1	1,534	1,505	30	1-7/58	1,534 (tie)	1,423 (1986)
12	1,519	1,495	24	6/58	1,534 (tie)	1,330 (1967)
11	1,490	1,416	74	6/58	1,521 (2021)	950 (1979)

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

Data sources and useful links:

1. WMO Global Cryosphere Watch - https://globalcryospherewatch.org
2. AARI Review of Hydrometeorological Processes in the Northern Polar Region (http://old.aari.ru/misc/publicat/gmo.php)
3. Copernicus Climate Change Service (https://cds.climate.copernicus.eu)
   - ERA5 monthly averaged data on pressure and single levels (ERA5)
   - Marine environment monitoring service (CMEMS)
   - GloFAS operational global river discharge reanalysis (ERA5-GloFAS)
4. Blended ice charts from AARI, CIS, NIC, ASIP, Planet (http://wdc.aari.ru/prcc/datasets/icecharts/gallery.html, http://wdc.aari.ru)
5. NSIDC Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations
6. ESA CryoSAT-2 data (AWI, https://data.seaiceportal.de/data/cryosat2/)
7. DMI PolarPortal (http://polarportal.dk)
8. 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!

Questions: vms@aari.aq/vsmolyanitsky@gmail.com

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

- http://wdc.aari.ru/prcc/reanalysis/era5/png/monthly/arctic/0/
- http://wdc.aari.ru/prcc/reanalysis/era5/png/season/arctic/0/
- http://wdc.aari.ru/prcc/datasets/icecharts/gallery.html

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

Bioclimatic indexes in the Arctic: summary for October 2023– April 2024 and weather Comfort Outlook for summer 2024

Anastasiia Revina

Arctic and Antarctic Research Institute (AARI)

Svetlana Emelina, Maria Tarasevich, Vasilisa Bragina

Hydrometeocentre of Russia

ACF
Arctic Climate Forum

Summary
for October 2023– April 2024

Anastasiia Revina (AARI)
nfennni@gmail.com
Svetlana Emelina (Hydrometcenter Russia)

How to evaluate weather comfort on seasonal timescales?

Complex indicator that takes into account several weather factors

Bodman's weather severity index (S)

[Rusanov, 1981, Isaev, 2003]

This index was developed specifically for the Arctic region, for initially difficult climatic conditions. It is widely used in biometeorological practice to assess the possibility of working outdoors.

$$S = (1 - 0.04\,T)\,(1 + 0.272\,V)$$

V - wind speed (in m/ s) at 10 m above ground level, T - air temperature (in °C)

S	Severity of the weather	Working conditions
S<2	Slightly&less severe	Slightly uncomfortable
2 ≤ S <5	Severe & very severe	Uncomfortable
5≤ S	Extremely severe	Extremely discomfort

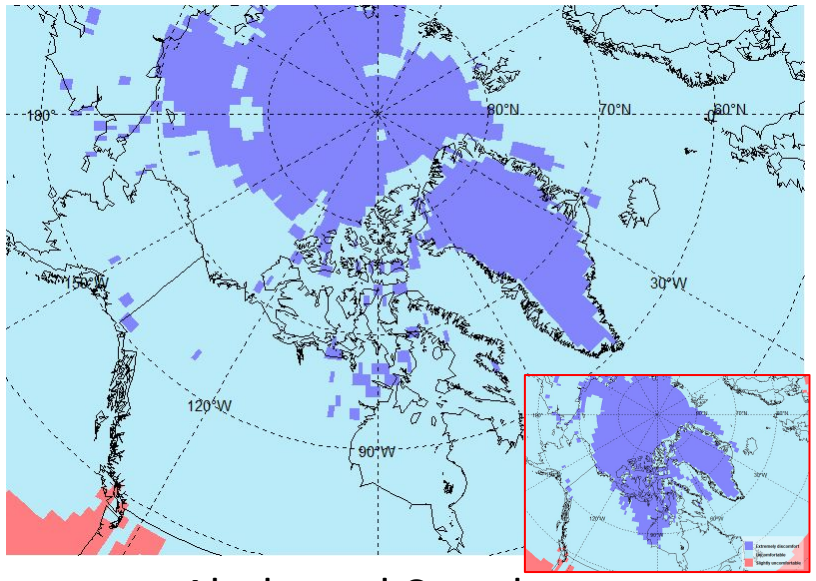
Effective temperature index
All year

$$ET = T - 0{,}4(T - 10)(1 - f/100)$$

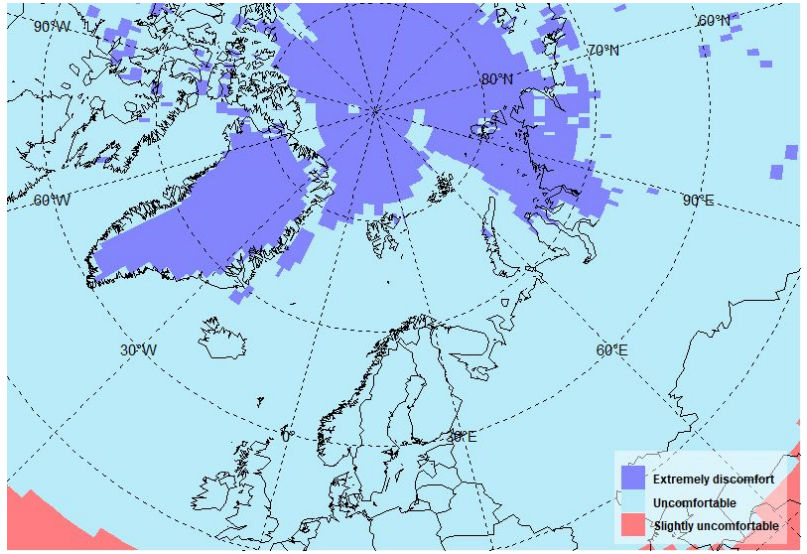
T - air temperature (in °C), f – relative humidity

	Thermal sensation	Physiological effect	Comfort sensation
≥+30	Very hot	Incomprensible heat	Discomfort
+24..+30	Hot	Slightly uncomfortable	Partial discomfort
+18..+24	Warm	Comfortable	Comfort
+12..+18	Slightly warm	Neutral	Partial comfort
+6..+12	Slightly cool	Slightly uncomfortable	Partial discomfort
0..+6	Cool	Slightly uncomfortable	Partial discomfort
-12..0	Cold	Uncomfortable	Partial discomfort
-24..-12	Very cold	Uncomfortable	Discomfort
-30..-24	Extremely cold	Incomprensible cold	Extremely discomfort
≥-30	Extremely cold	Incomprensible cold	Extremely discomfort

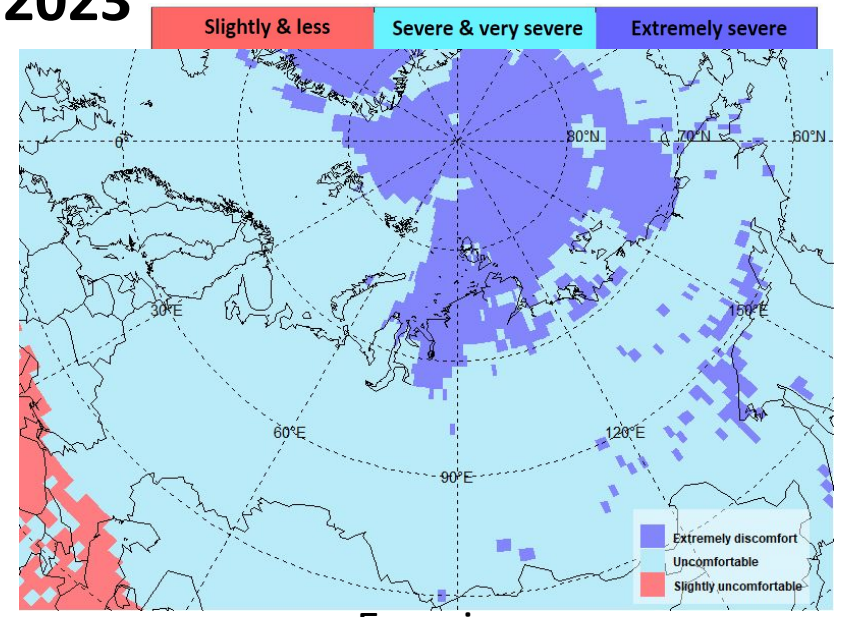
Bodman's index (S) of weather severity OND (Oct, Nov, Dec) 2023



Alaska and Canada

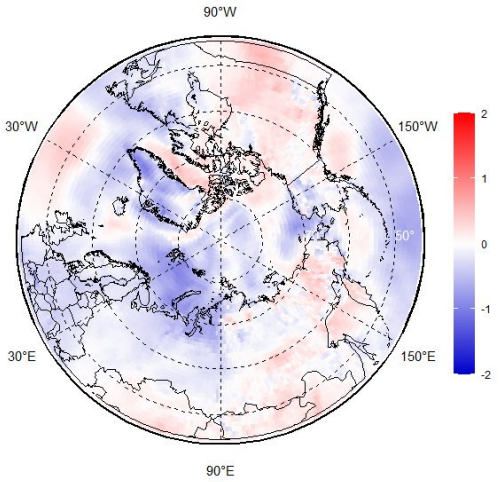


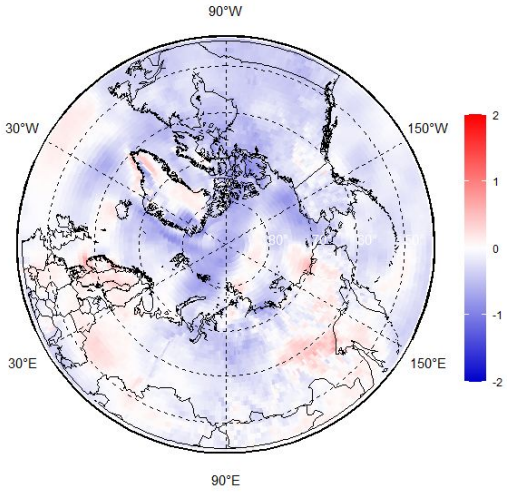
Nordic



Eurasia

2022





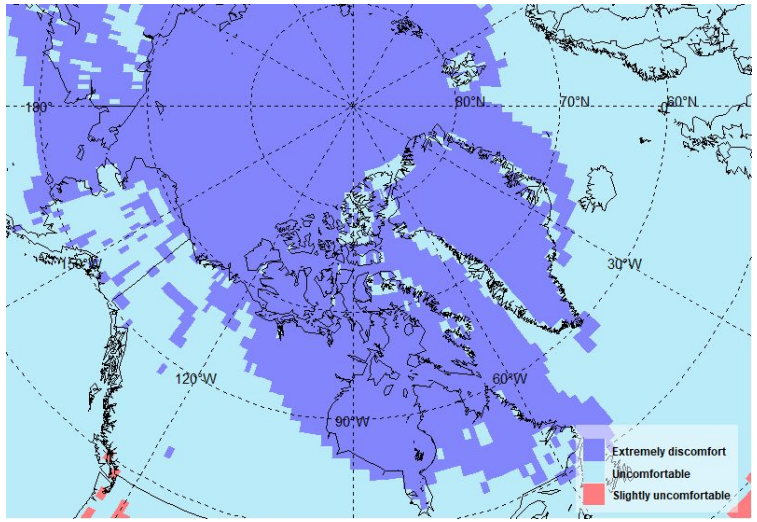
anomalies from (1991– 2020)

2022 **2023**

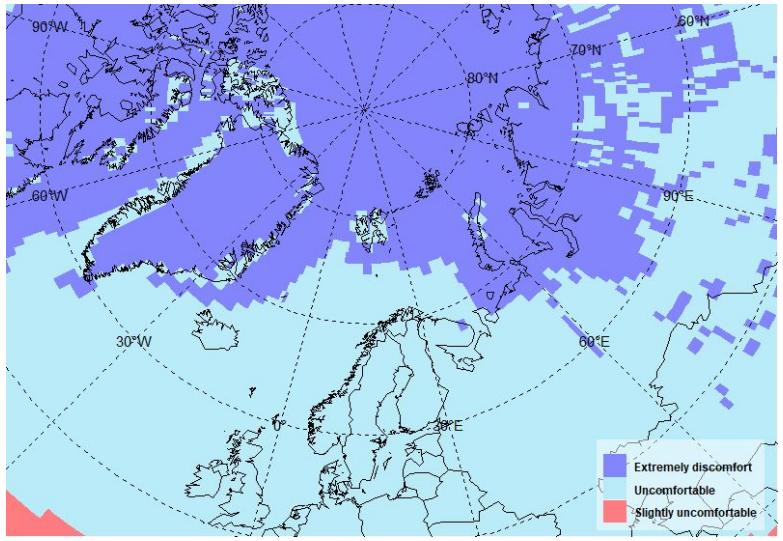
- **Extremely severe** conditions were observed in **OND** period over the Greenland, in Central Arctic, over east part of Kara Sea, nothern part of Laptev Sea, East Siberian Sea and northern part of Chuckchi Sea.
- The Canadian Arctic Archipelago in fall 2023 was in severe conditions, while in 2022 all this area belonged to **extremely severe** zone.
- Milder conditions (**blue color** on the anomalies map) where observed over the North America and adjoined seas, Central Arctic, in Western Siberia, Northern Barents, Kara, Laptevih and Chukchi Seas
- Colder than usual conditions (**red color**): over western Greenland, Europe, East Siberian Sea, Eastern Siberia and Okhotsk Sea.

Bodman's index (S) of weather severity DJF (Dec, Jan, Feb) 2023/24

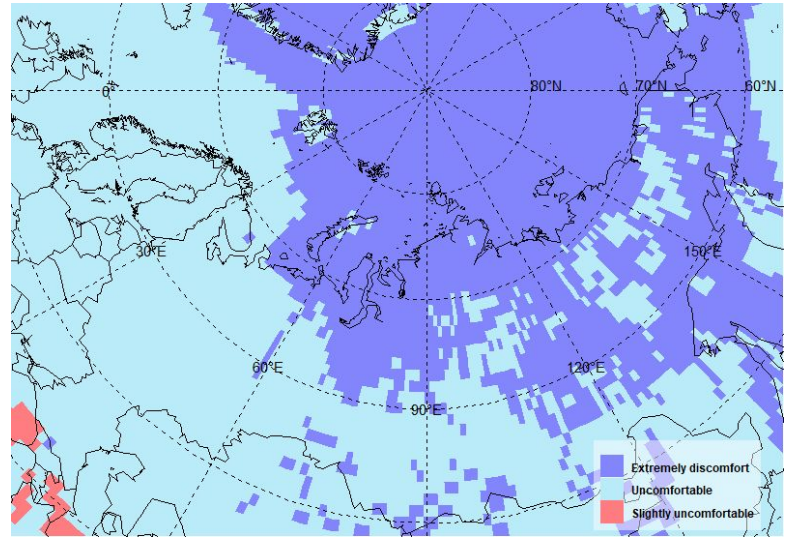
Slightly & less | Severe & very severe | Extremely severe



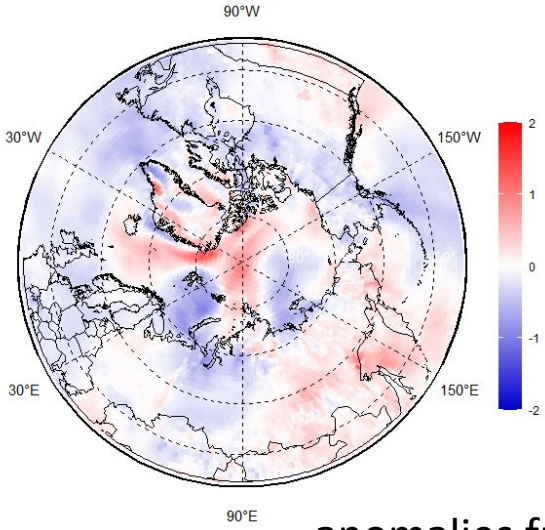
Alaska and Canada

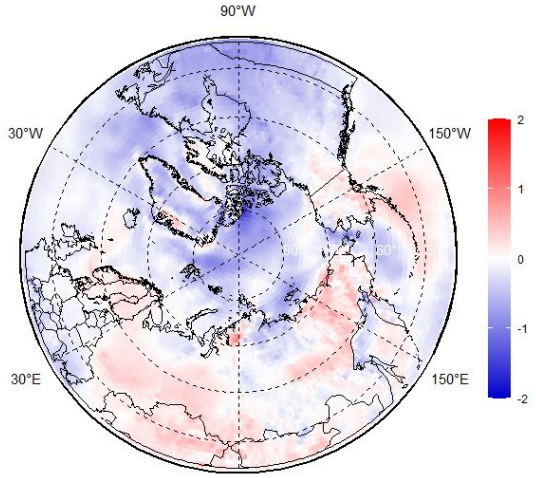


Nordic



Eurasia





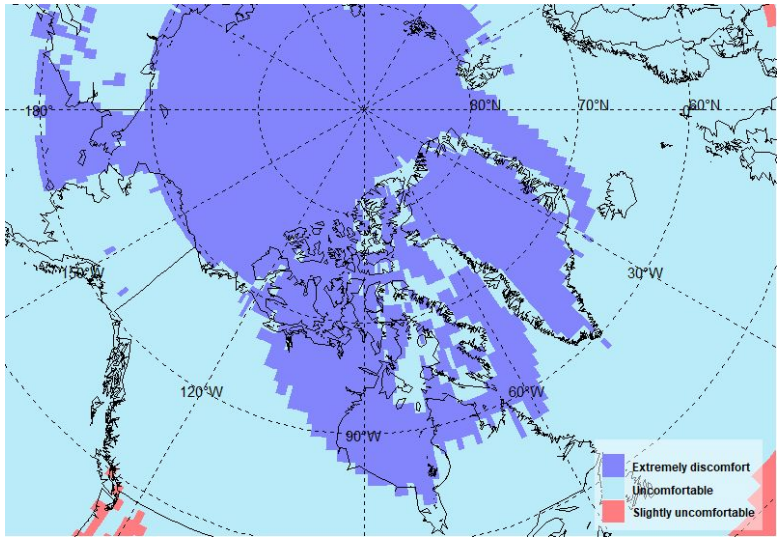
anomalies from (1991– 2020)

2022/23 **2023/24**

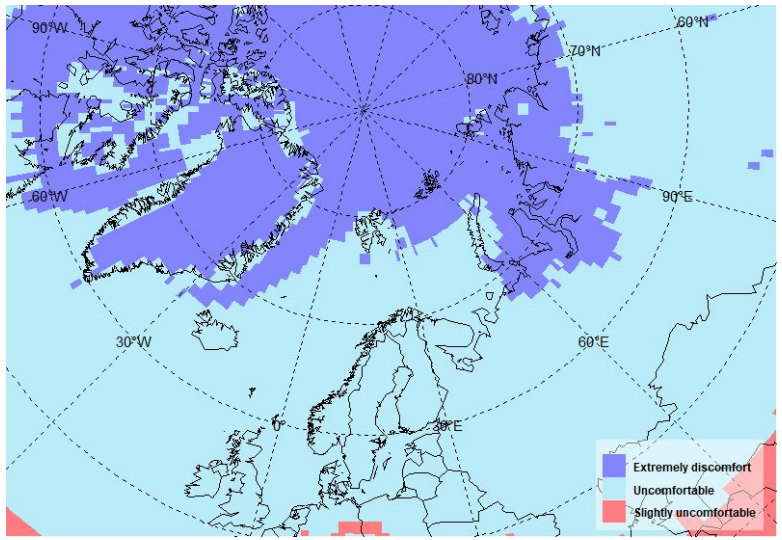
- Winter period (**DJF**) is characterized by increase of **extremely severe** zone over Beaufort Sea, the Canadian Arctic Archipelago and land areas south of it, Hudson Bay, Baffin Bay, Labrador Sea, Fram Strait. In Eurasian part **extremely severe** condition widened over all seas of the Northern Sea route, including eastern and northern parts of Barents Sea, over land in the Western and Eastern Siberia (with some gaps), Bering and Okhotsk Seas.
- The winter 2023/24 proceeded autumn situation of milder conditions (**blue color**) in North America and Central Arctic, also milder or close to normal conditions were over Central Europe.
- Colder conditions (**red color**) were observed over Scandinavia, European part of Russia, Ural, east of Eastern Siberia, Alaska and Aleutian Islands.

Bodman's index (S) of weather severity FMA (Feb, Mar, Apr) 2024

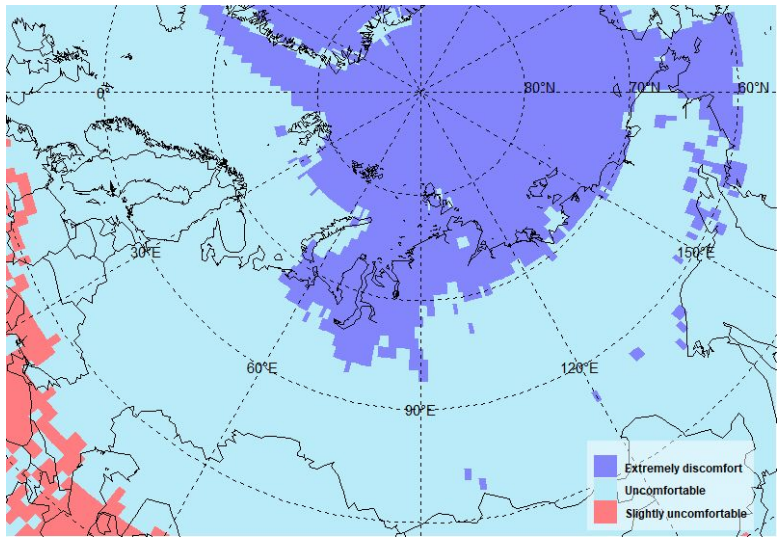
Slightly & less | Severe & very severe | Extremely severe



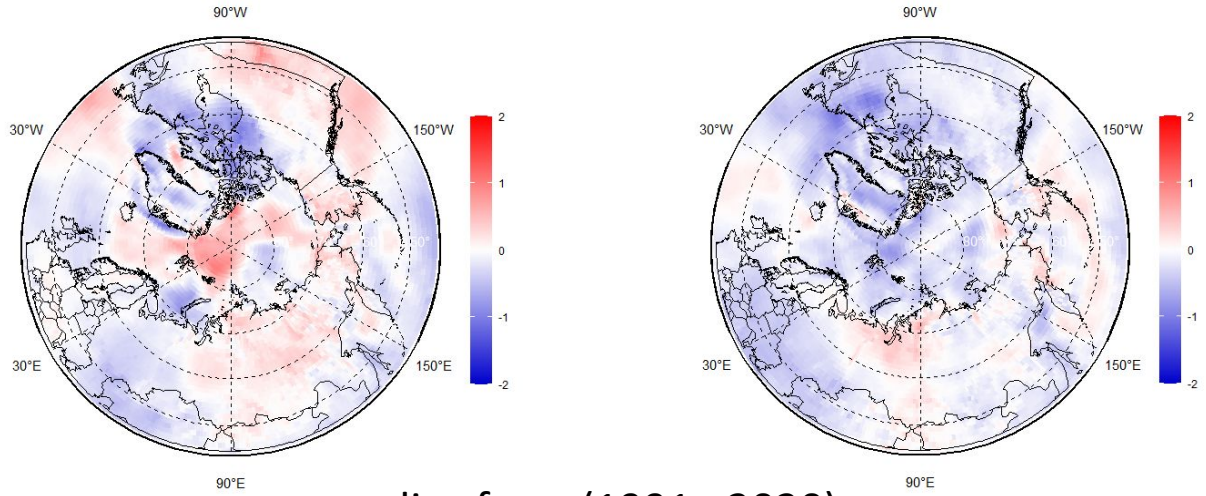
Alaska and Canada



Nordic



Eurasia



anomalies from (1991– 2020)

2023 **2024**

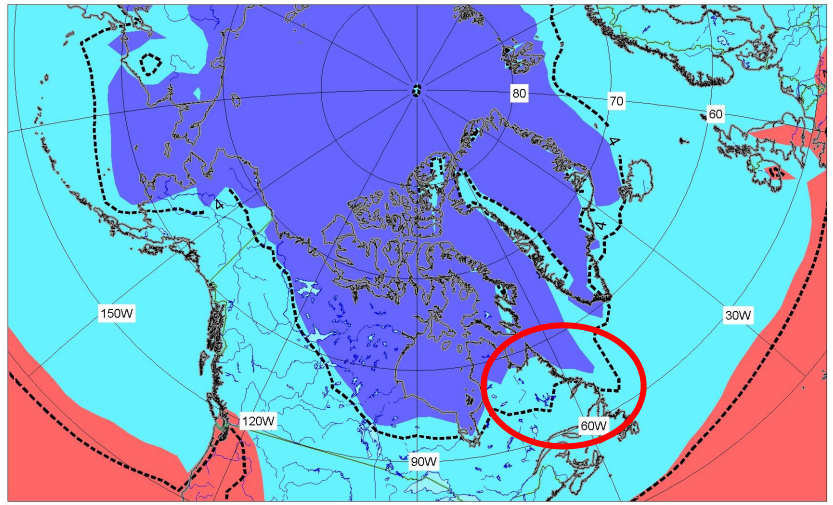
- In **FMA** period **extremely severe** conditions were decreased over eastern Canada, Labrador Sea, Okhotsk Sea, eastern Barents Sea and around Svalbard. In the inland parts of Siberia extremely severe conditions remained only over the shores and in Gulfs of Ob' and Enisey, over Taymyr Peninsula.
- The predominance of milder conditions (**blue color**) was observed in **FMA** period, but there were as well areas with colder conditions (**red color**): Western Siberia, especially Gulfs of Ob' and Yenisey, area to the north from Bering Strait, Koryak Highlands and area of Aleutian Islands, south of Alaska Peninsula, shore of eastern Greenland.
- The situation in central Arctic and especially in North European basin differs greatly from 2023, when there were rather cold conditions in winter and spring periods.

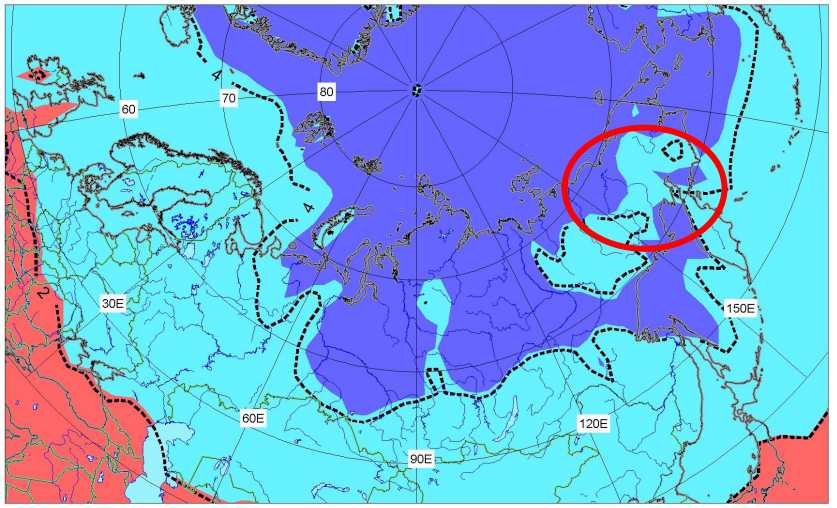
Bodman's index (S): Comparison with forecast for DJF 2023/24

Slightly & less | Severe & very severe | Extremely severe

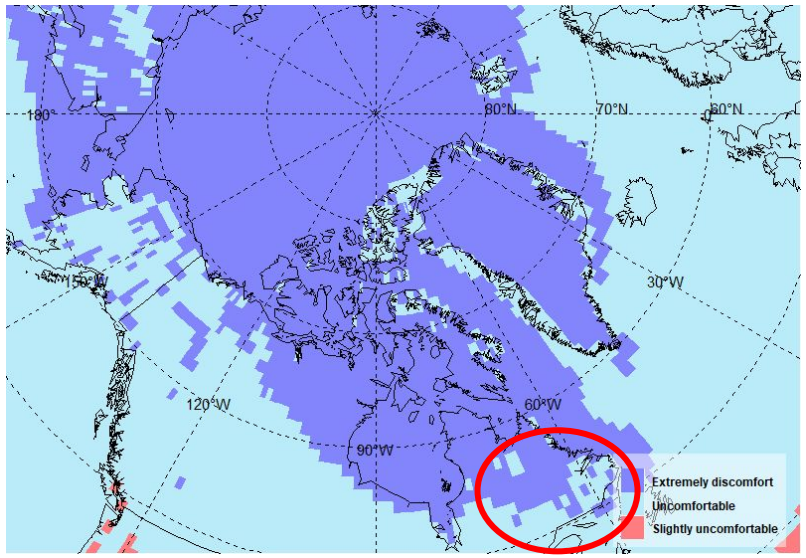
Alaska and Canada region

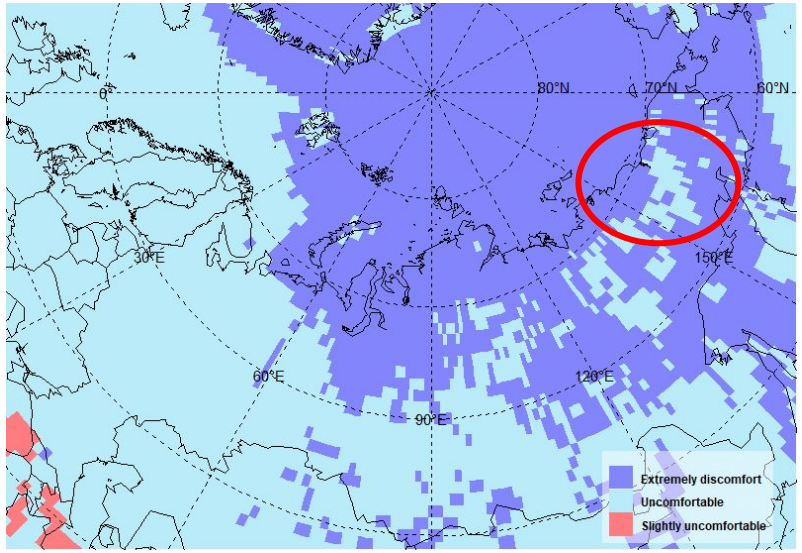
Eurasia region





Forecast





ERA5 data

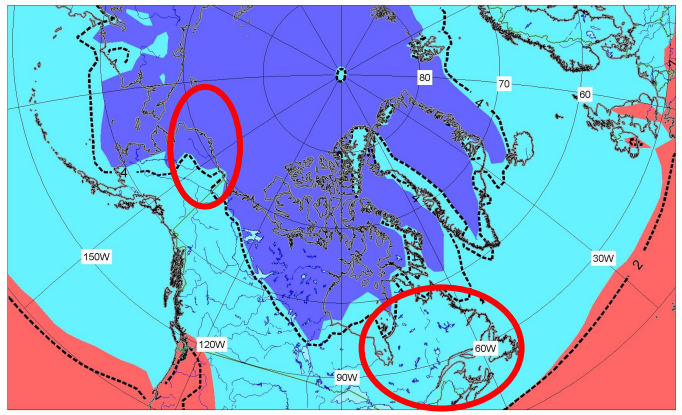
- For **Alaska and Canada region** the forecast identified **extremely severe conditions** quite accurate, it only underestimated the situation over southern part of Labrador Sea and Labrador province (there were **extremely severe** conditions according to ERA5 rather than severe conditions in forecast).

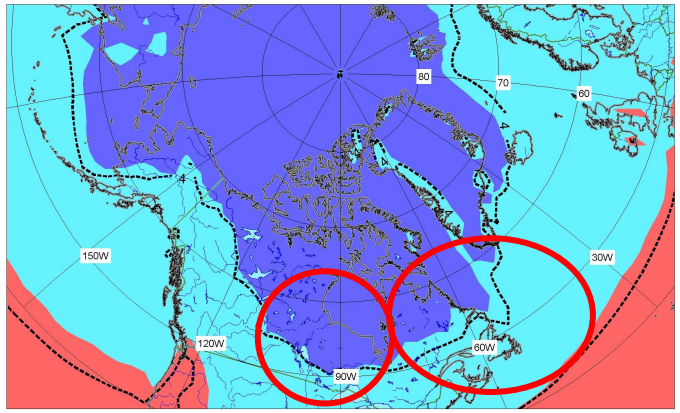
- For **Eurasia region** forecast was also quite accurate, except from some land areas in the far east of Eastern Siberia and adjacent western part of Bering Sea, where the severity was underestimated (there were **extremely severe** conditions according to ERA5 rather than severe conditions in forecast).

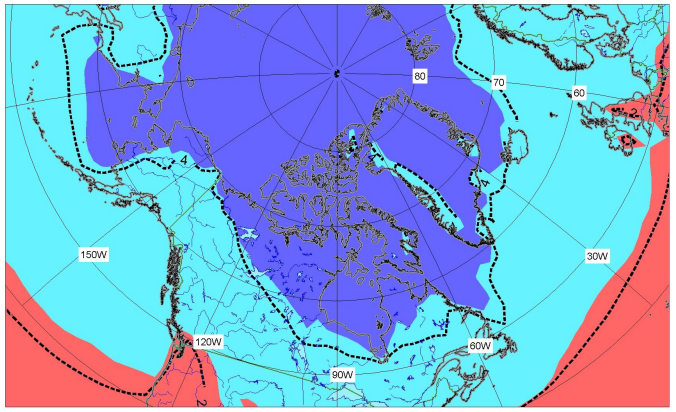
Bodman's index (S): Comparison with forecast for Alaska and Canada region

Dec 2023 | **Jan 2024** | **Feb 2024**

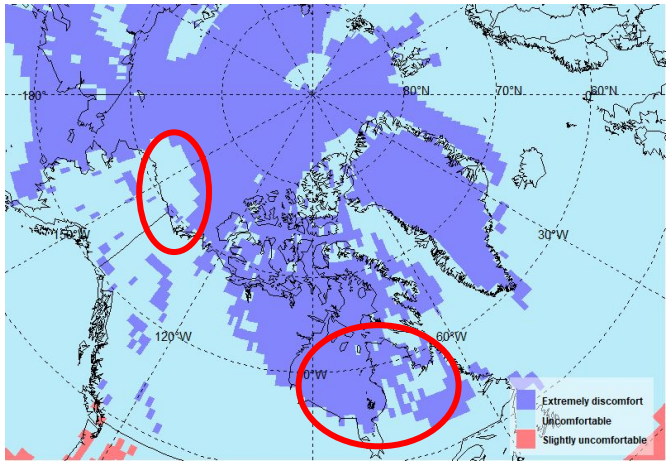
Forecast

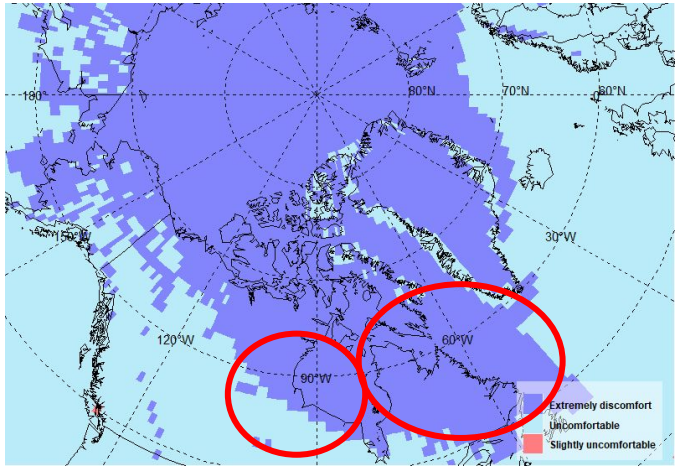


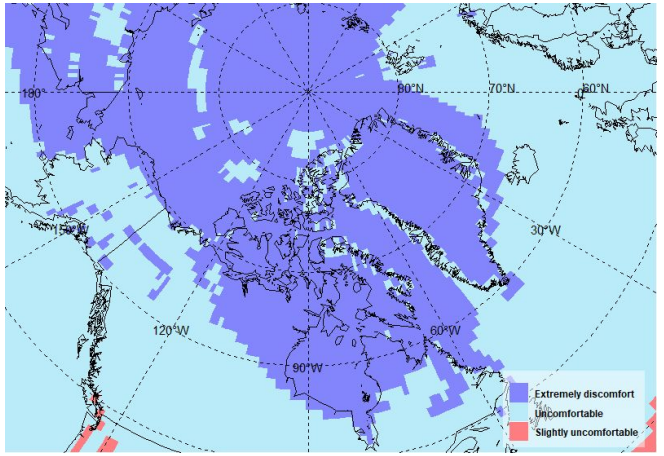




ERA5 data

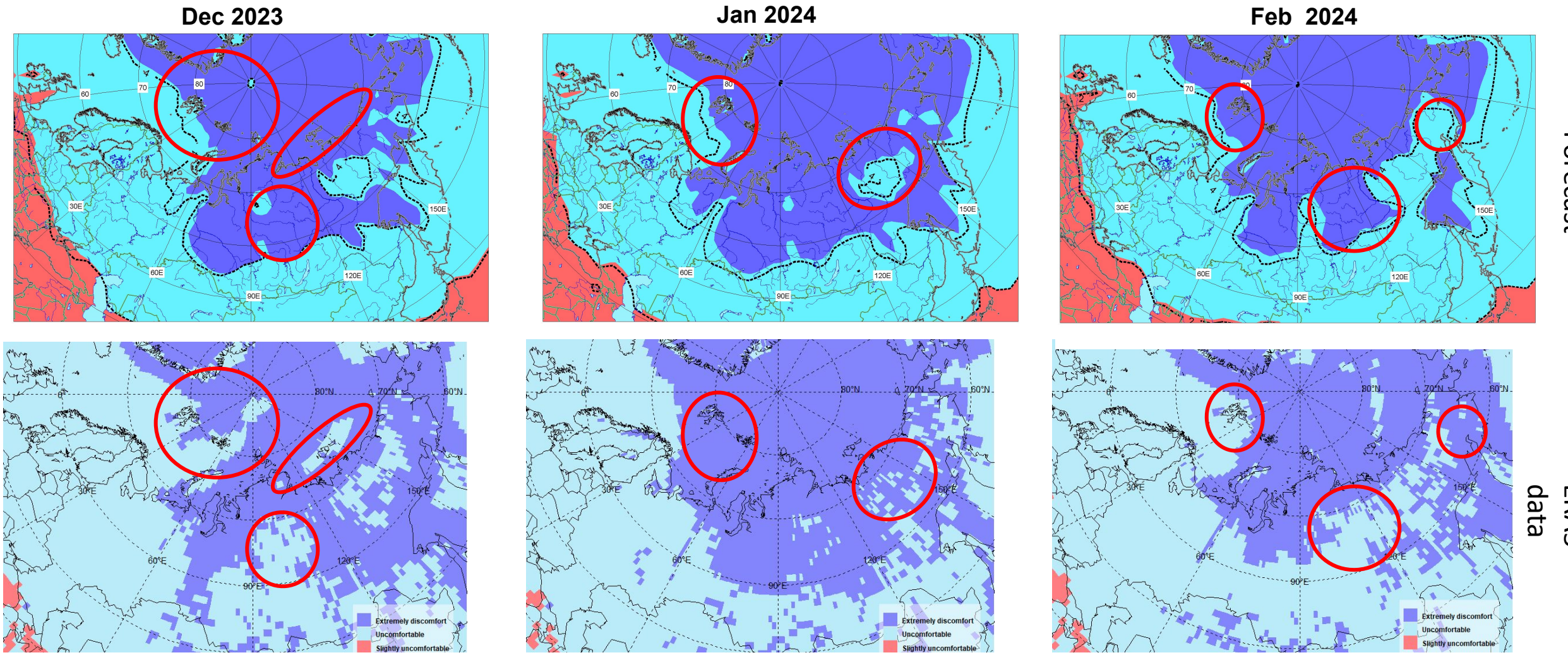






- In **December** forecast underestimated the severity of conditions over southern part of Hudson Bay, Labrador province and overestimated over western part of Beaufort Sea
- In **January** forecast underestimated severity over central Canada, Labrador, Newfoundland and Labrador Sea
- In **February** forecast was quite precise

Bodman's index (S): Comparison with forecast for Eurasia region



- In **December** forecast did not foreseen local zones of less severe conditions: near the North Pole, Svalbard and Franz Josef Land, around New Siberian Islands and area south of Taymyr Peninsula.
- In **January** forecast underestimated severity over Barents and Greenland Seas. Less severe conditions over eastern Siberia were not so pronounced as forecast showed it.
- In **February** forecast overestimated the severity around Svalbard and over Central Siberian Plateau and underestimated over Koryak Highlands .

Weather Comfort Outlook*
SUMMER-2024

Svetlana Emelina, Maria Tarasevich, Vasilisa Bragina
Hydrometeocentre of Russia
tkachukzn@gmail.com

experimental

Weather comfort indicator for summer: effective temperature index

	Thermal sensation	Physiological effect	Comfort sensation
≥+30	Very hot	Incomprensible heat	Discomfort
+24..+30	Hot	Slightly uncomfortable	Partial discomfort
+18..+24	Warm	Comfortable	Comfort
+12..+18	Slightly warm	Neutral	Partial comfort
+6..+12	Slightly cool	Slightly uncomfortable	Partial discomfort
0..+6	Cool	Slightly uncomfortable	Partial discomfort
-12..0	Cold	Uncomfortable	Partial discomfort
-24..-12	Very cold	Uncomfortable	Discomfort
-30..-24	Extremely cold	Incomprensible cold	Extremely discomfort
≥-30	Extremely cold	Incomprensible cold	Extremely discomfort

Forecast data

Operational subseasonal/seasonal forecasts (JJA 2024)
(collaborative model of the Institute of Numerical Mathematics RAS and Hydrometcentre of Russia)* were used to calculate the effective temperature values for Summer 2024 and hindcasts 1991-2020 for the norms.

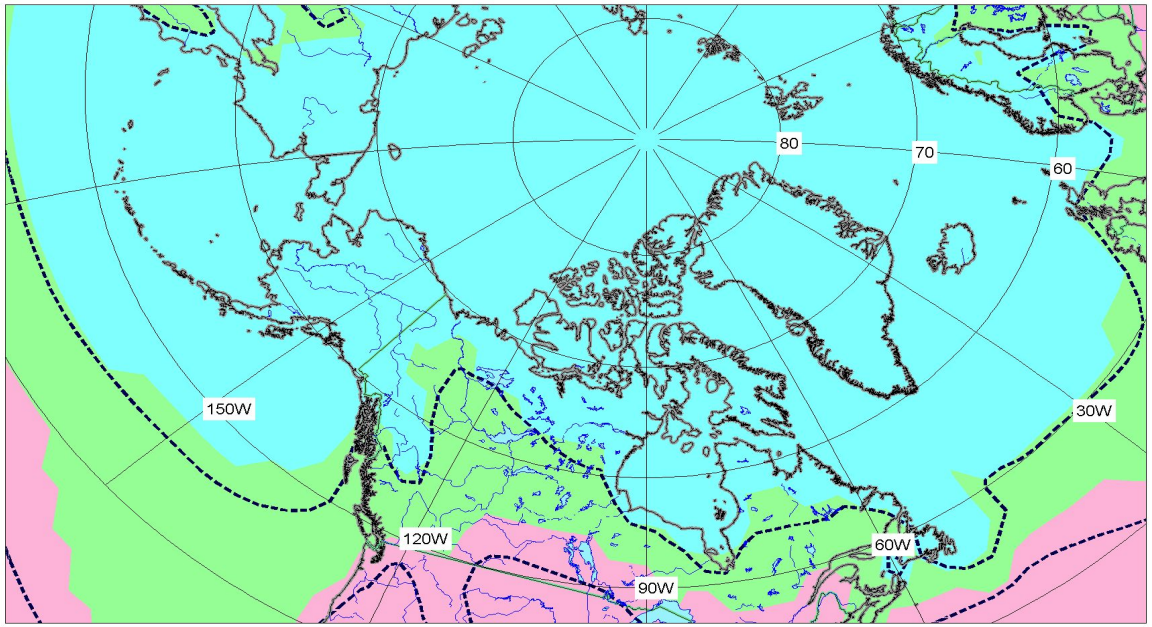
- Resolution 2,5°×2,5°

*Vorobyeva, V., Volodin, E.: Evaluation of the INM RAS climate model skill in climate indicesand stratospheric anomalies on seasonal timescale. Tellus A: Dynamic Meteorology andOceanography 73(1), 1–12(2021).https://doi.org/10.1080/16000870.2021.189243535

Vorobyeva, V.V., Volodin, E.M.: Experimental Studies of Seasonal Weather PredictabilityBased on the INM RAS Climate Model. Mathematical Models and Computer Simulations13(4), 571–578 (2021)

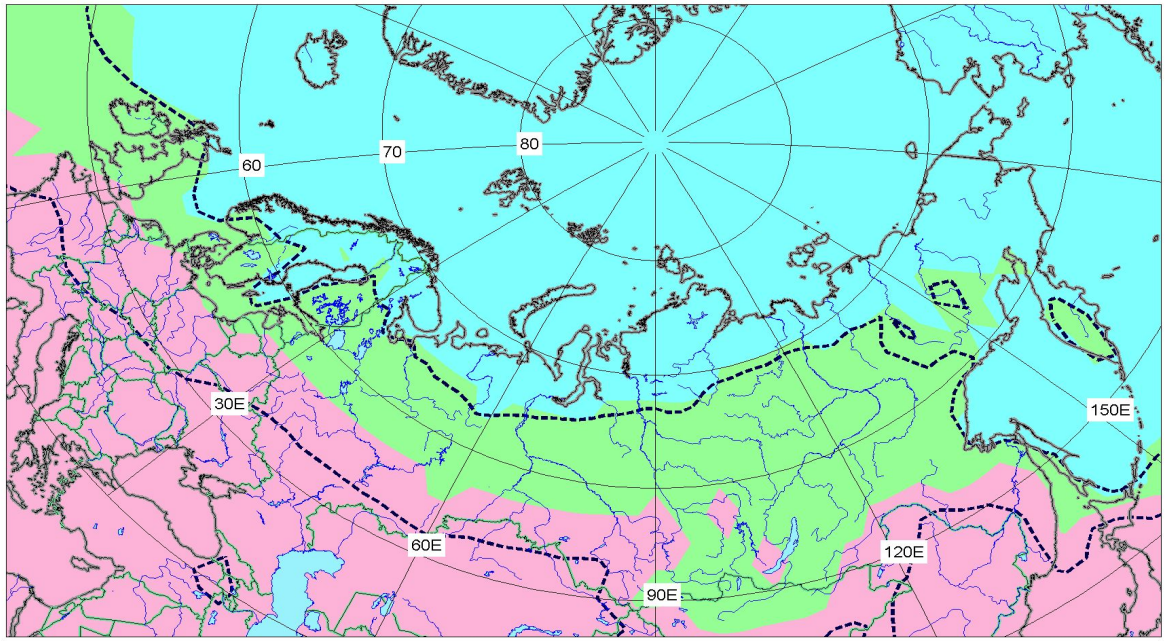
The forecast is issued in May 2024

Forecast of Weather comfort level. Summer-2024



- In the Western Hemisphere in the summer of 2024 **cold discomfort** conditions are expected in Alaska, in the western Yukon, in the north of the Northwest Territories, Nunavut and Quebec, in Greenland;
- **comfortable conditions**: in the center and south of the Northwest Territories, in the south of Nunavut and Quebec;
- **No hot discomfort** conditions expected in Arctic Zone

- In the Eastern Hemisphere in the summer of 2024 **cold discomfort conditions** are expected in Iceland, most of Norway and Sweden, in the north of Finland (this is consistent with long-term averages 1991-2020);
- On most of the Arctic coast of Russia, bioclimatic conditions will also generally be relatively cold and **uncomfortable**, but the **comfort zone** will shift slightly northward relative to the norm in Western Siberia, Eastern Siberia and Chukotka.



-------- **norm (1991-2020)**

The forecast is issued in May 2024

Regional Comparison of Forecasted Degree of Comfort
JJA 2024

Relative to the normal

Regions	Summer	June	July	August
Alaska and Western Canada				
Central and Eastern Canada				
Western Nordic				
Eastern Nordic				
Western Siberia				
Eastern Siberia				
Chukchi and Bering				

Less comfortable than 1991-2020	More comfortable than 1991-2020

Absolute index values

Regions	Summer	June	July	August
Alaska and Western Canada				
Central and Eastern Canada				
Western Nordic				
Eastern Nordic				
Western Siberia			!	
Eastern Siberia			!	
Chukchi and Bering				

In the summer of 2024, weather conditions are expected to be more comfortable than normal everywhere, with the exception of the **Western Nordic**.
It will be less comfortable in June in the **Western Nordic and Chukchi Bering** Nodes

According to forecasts, in July in the **Western and Eastern Siberia** nodes it is expected not just more comfortable weather, but a transition in the gradation of heat sensation from discomfort to comfort

The forecast is issued in May 2024

Thank you!

The work was carried out at the “Hydrometeorological Center of Russia” with the support of the most important innovative project of national importance “Unified National System for Monitoring Climate-Active Substances”

Icelandic Met Office

ACF
Arctic Climate Forum

WORLD METEOROLOGICAL ORGANIZATION

Break for 15 min

17:05 (15')	**BREAK**	
17:20 (25')	**Temperature, Precipitation, Sea Surface Temperature and Snow/Water Equivalent** • Validation of the outlook for winter 2023/2024 • Outlook for summer 2024 and model confidence	Session Chair: Kristín Björg Ólafsdóttir, IMO Marko Markovic - ECCC
17:45 (25')	**Sea Ice Outlook for summer 2024** • Validation of the winter 2023/2024 outlook • Outlook for summer 2024 and model confidence	Adrienne Tivy - ECCC
18:10 (10')	**Q&As on Validation and Confidence and Sea-Ice Outlooks**	Moderator: Kristín Björg Ólafsdóttir - IMO
18:20 (20')	**Use of long term forecasts**	Andri Gunnarsson - Landsvirkjun
18:40 (10')	**Final Thoughts and Wrap-Up**	Halldór Björnsson - IMO

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

ACF - 13: Verification of the FMA 2024 season
ACF - 13: Seasonal forecast for the JJA 2024 season

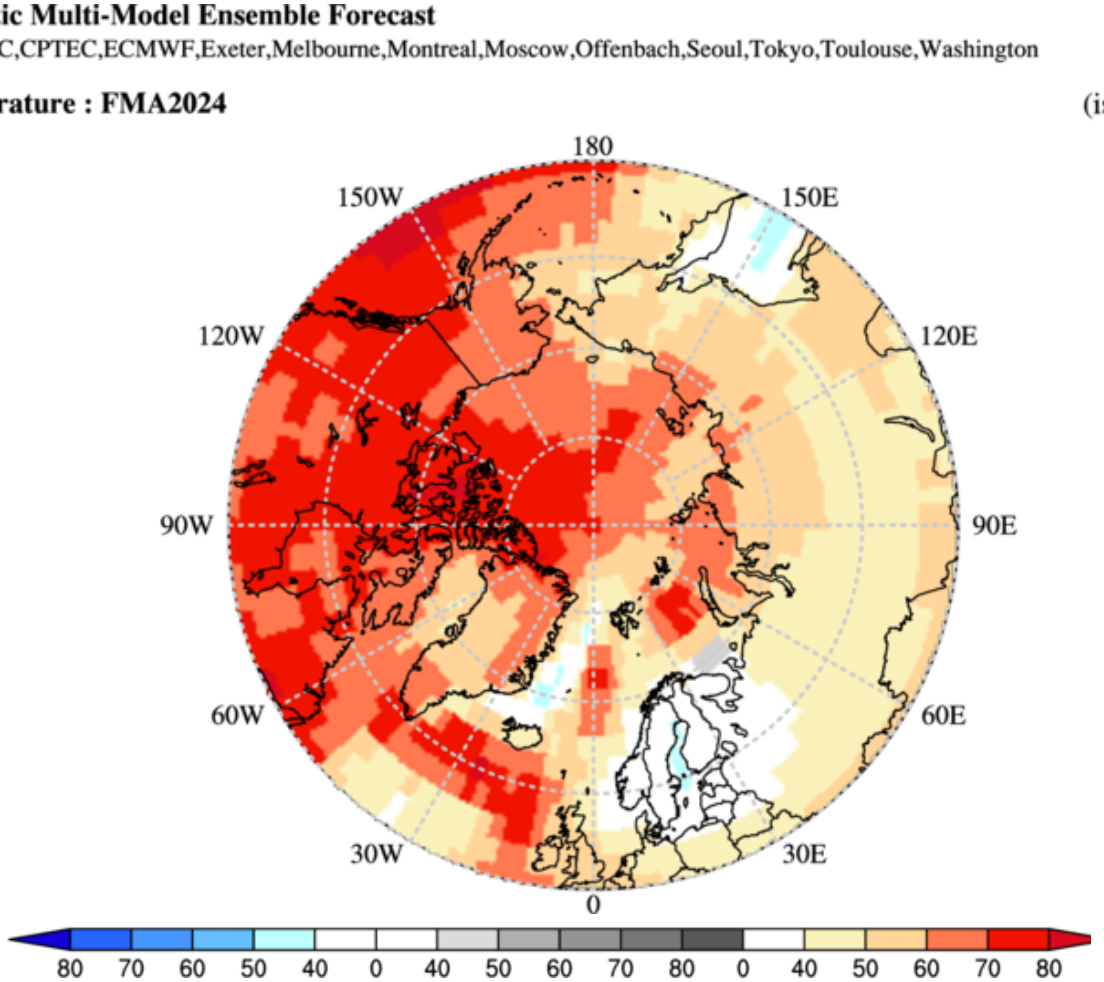
Marko Markovic
Meteorological Service of Canada
Environment and Climate Change Canada

WMO

ACF
Arctic Climate Forum

Seasonal forecast over the Arctic, FMA 2024

reminder

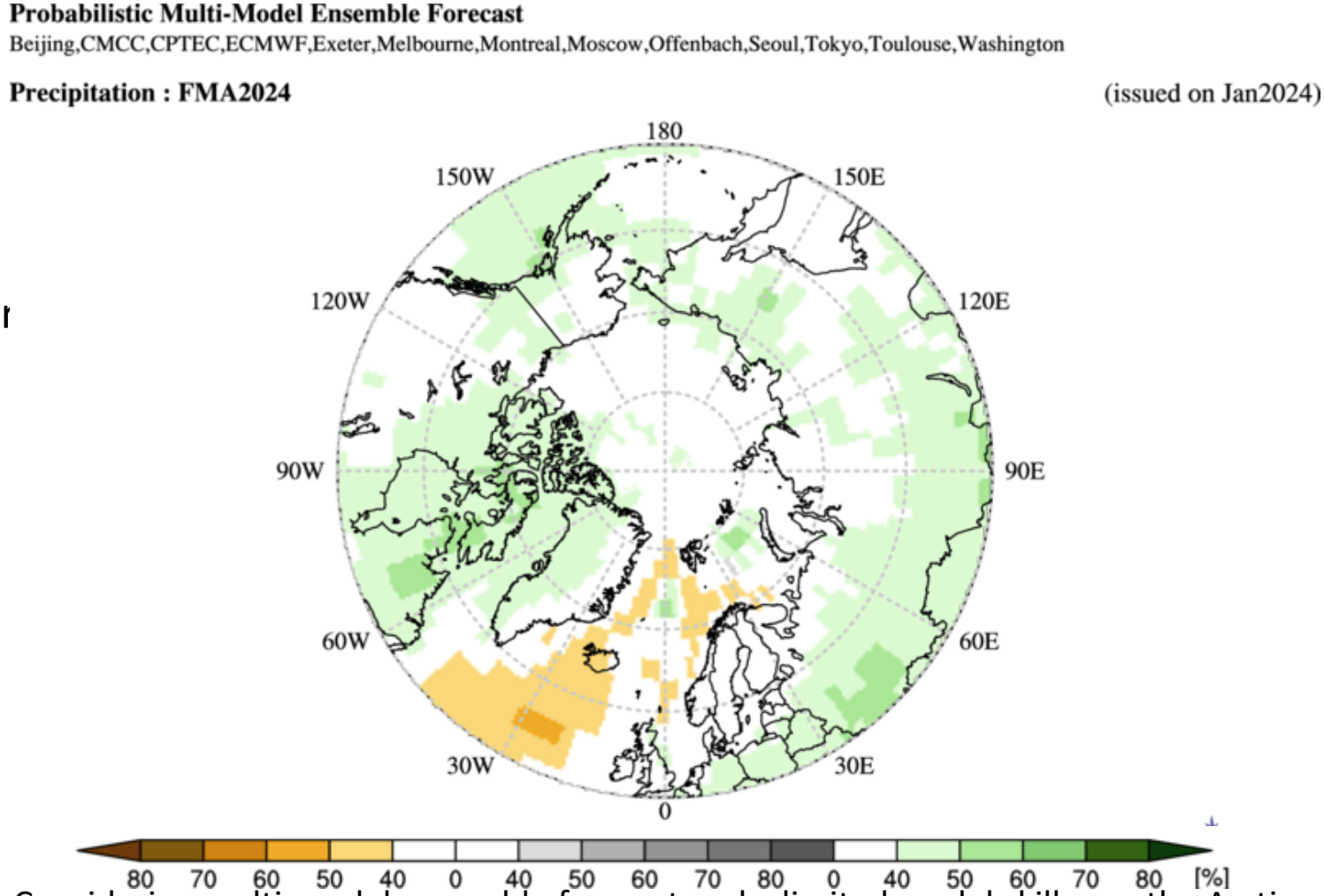


Considering multi-model ensemble forecast and a limited model skill over the Arctic:

Temperature: For February-March-April 2024 (FMA24), there was a probability of 40% or more that temperatures will be above normal in almost all regions across the Arctic with an exception of the easten Nordic regions where equal probability chances were expected. The highest probabilities were over the North America.

Seasonal forecast over the Arctic, FMA 2024

reminder



Considering multi-model ensemble forecast and a limited model skill over the Arctic:

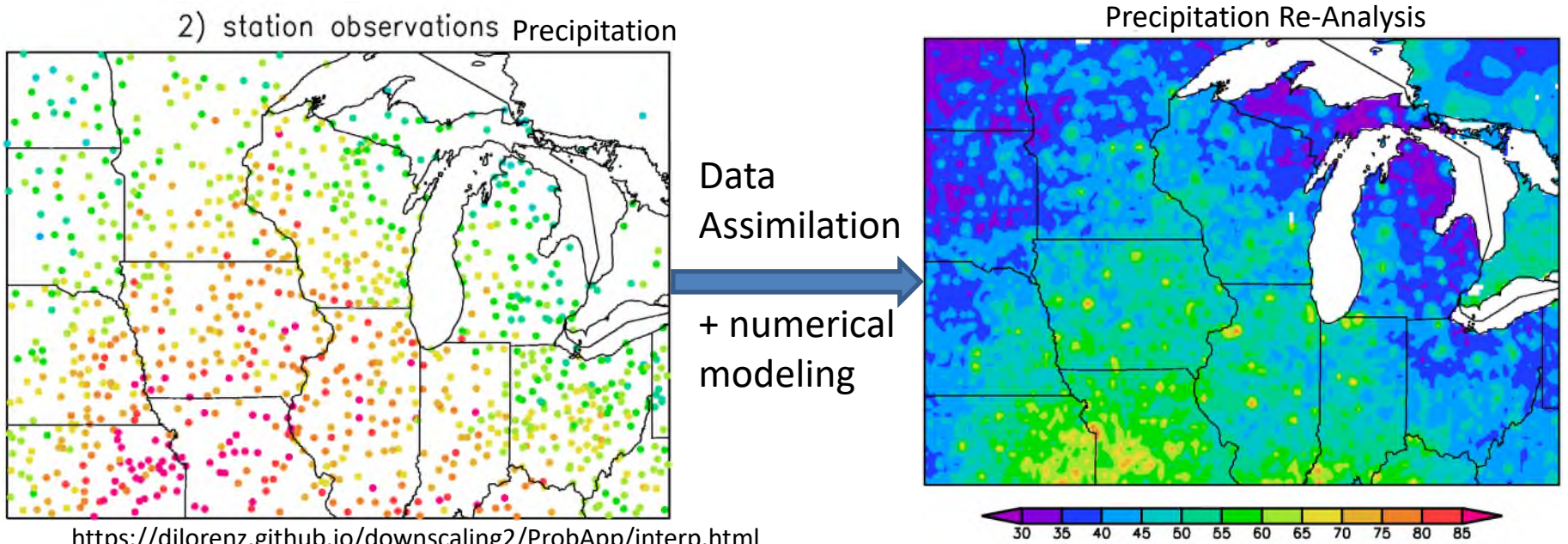
Precipitation: Over most of the Arctic region above normal precipitation expectancy was forecast. MME was not decisive over the eastern Nordic region, northern and central parts of the Sibierian regions and central parts of the Chukchi Bering region (white color on the map)

How do we verify seasonal forecasts?

- We need observations!

- Unfortunately we can not measure temperature or precipitation on every single point over the globe.

- This is why we use statistical techniques to interpolate measured variables over the regions where we can measure. The results is called **the re-analysis**.

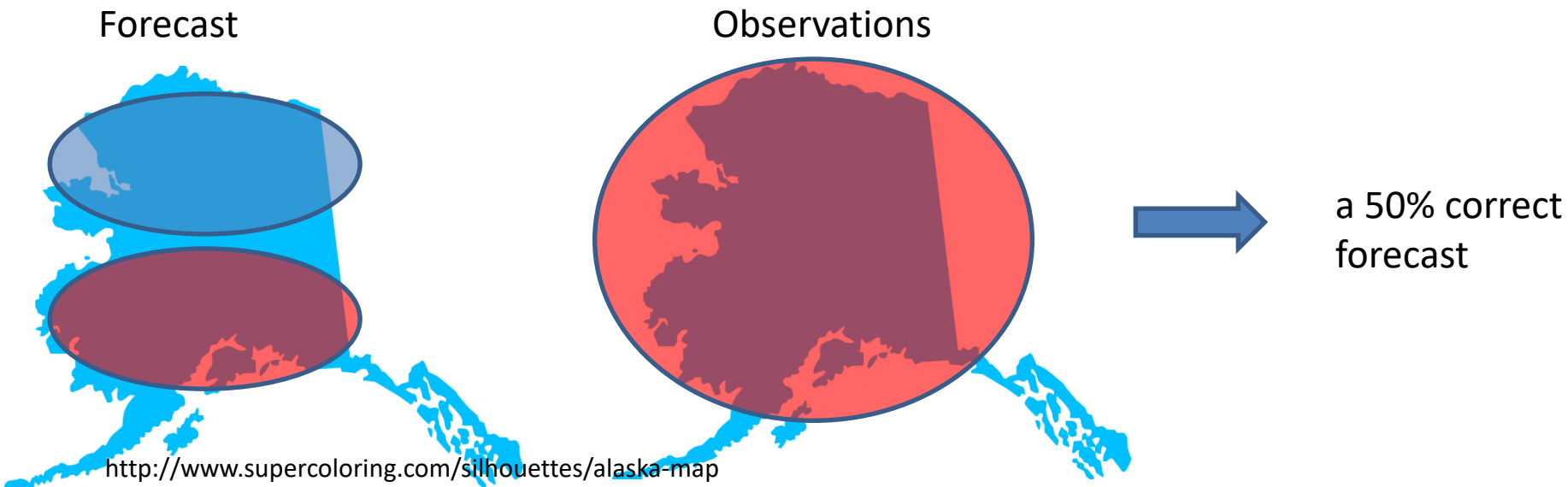


https://dilorenz.github.io/downscaling2/ProbApp/interp.html

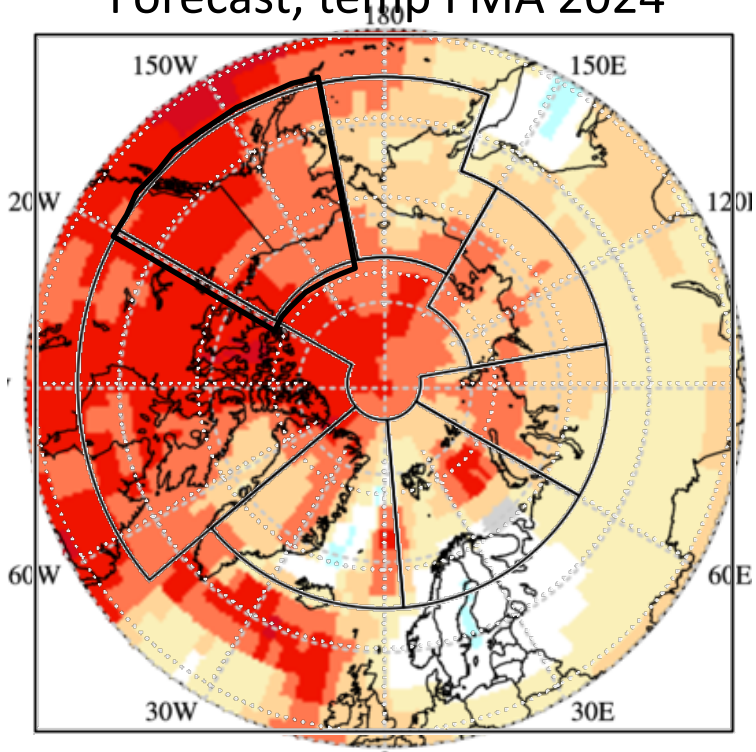
How do we verify seasonal forecasts?

- We need some metric, some number to quantify the verification result
- We call this metric a score

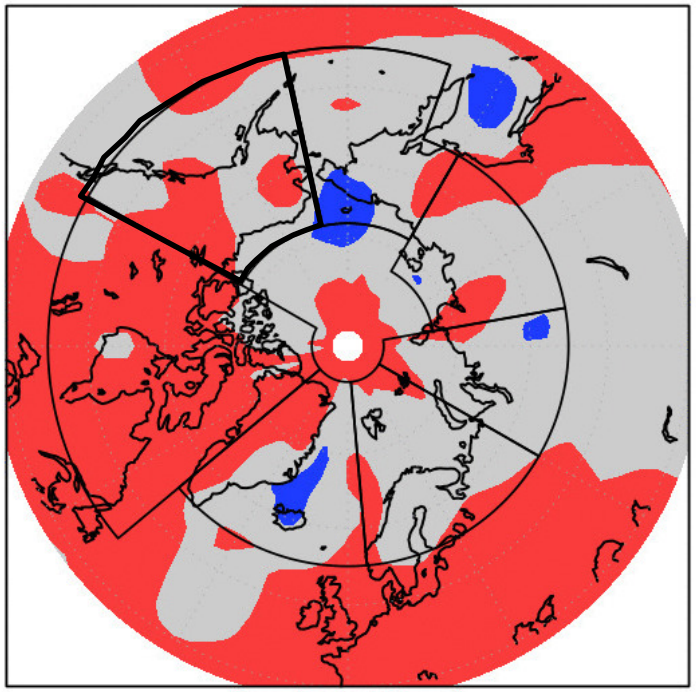
- For the verification over the Arctic we will use a subjective score: a percentage of the correct forecast over a selected region in the Arctic.



Forecast, temp FMA 2024



ERA5 Reanalysis, Temperature FMA2024



Verification Temperature

Above normal

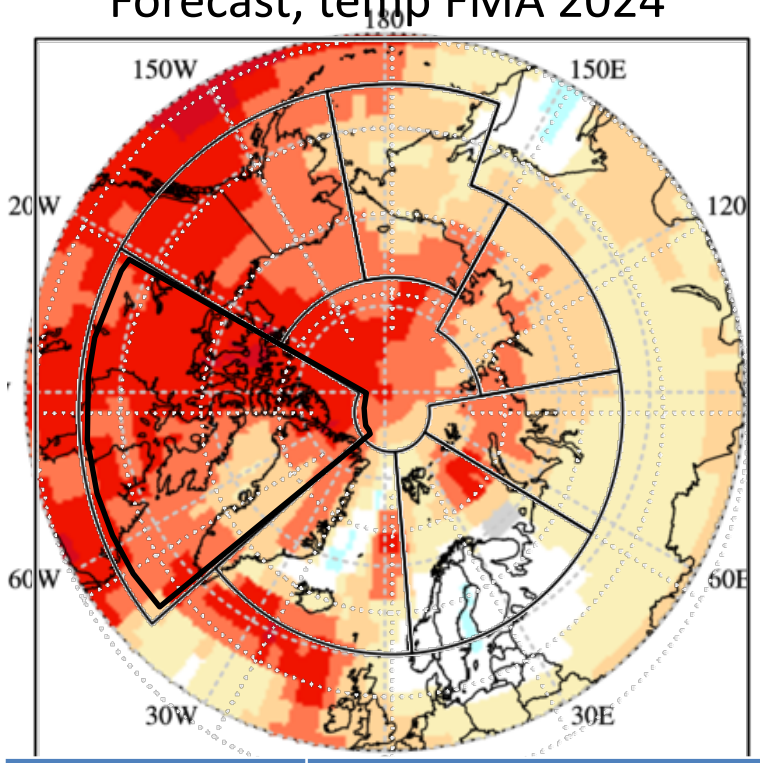
Near normal

Below normal

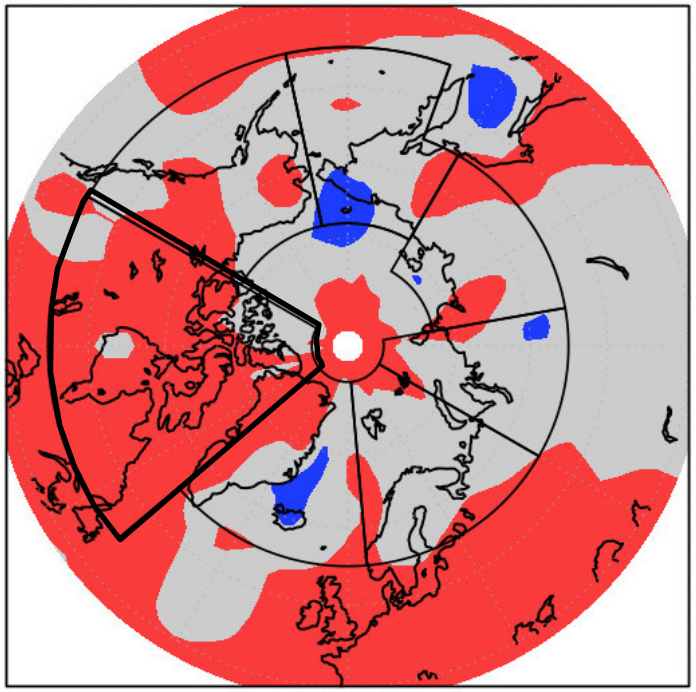
Environment and Environnement et

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	**Above normal**	**Above normal in the east near normal in the western parts**	**40%**
C. - E. Canada			
W. Nordic			
E. Nordic			
W. Siberia			
E. Siberia			
Chukchi-Bering			

Forecast, temp FMA 2024



ERA5 Reanalysis, Temperature FMA2024



Verification Temperature

Above normal

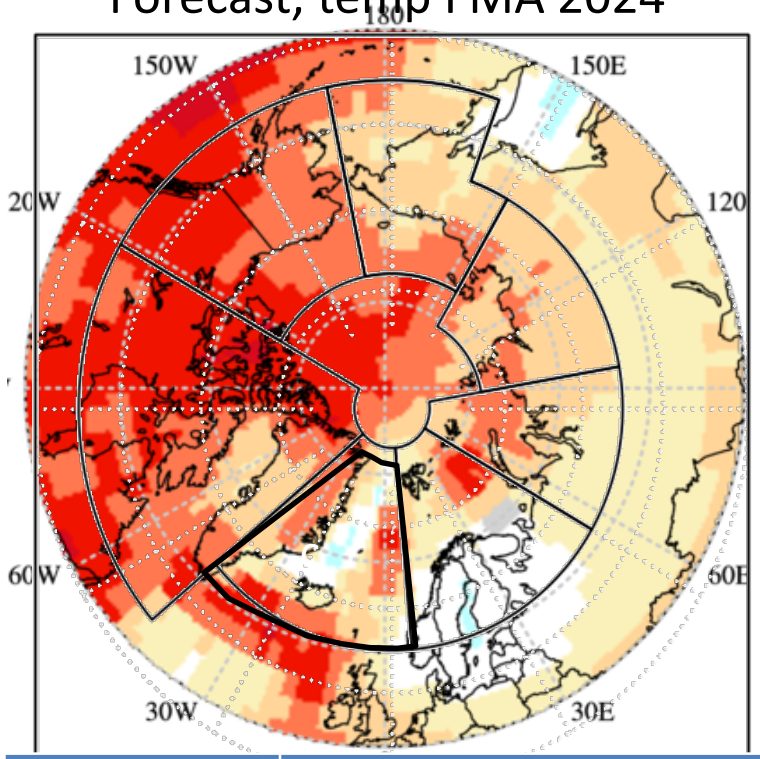
Near normal

Below normal

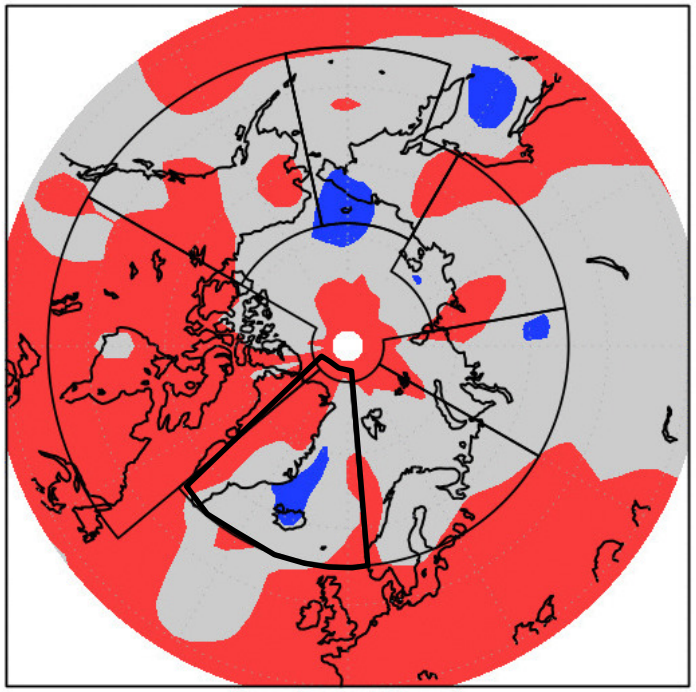
Environment and Environnement et

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	**Above normal**	**Mostly above normal**	**90%**
W. Nordic			
E. Nordic			
W. Siberia			
E. Siberia			
Chukchi-Bering			

Forecast, temp FMA 2024



ERA5 Reanalysis, Temperature FMA2024

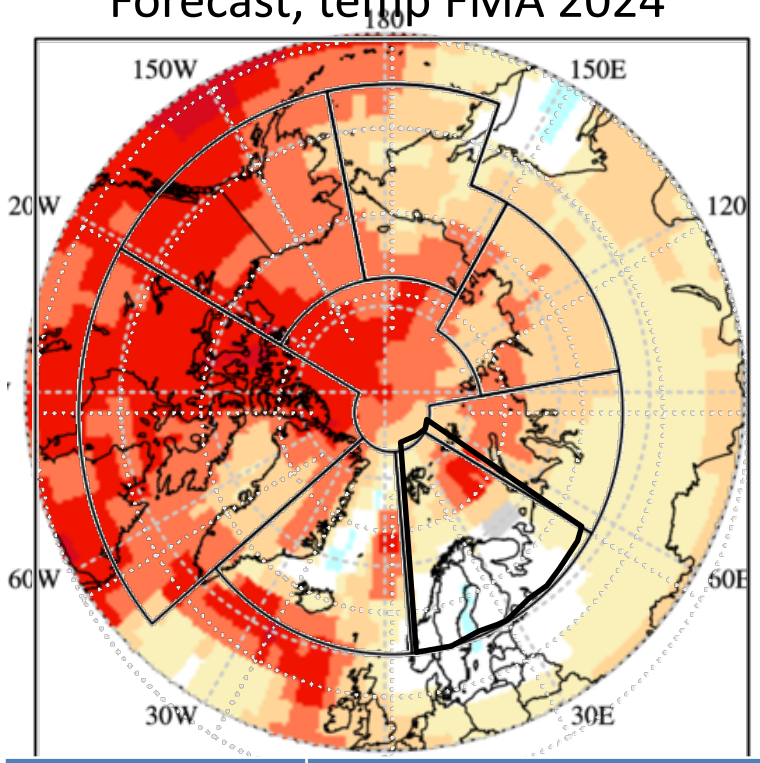


Verification Temperature

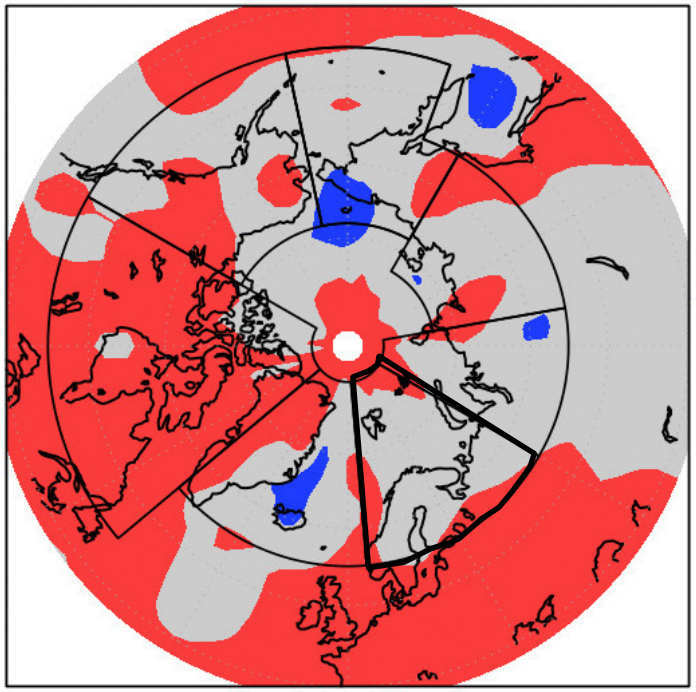
Environment and Environnement et

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	Above normal	Mostly above normal	90%
W. Nordic	**Below normal and non-decisive in the center, above normal outside**	**Below normal in the center, mostly near normal**	**40%**
E. Nordic			
W. Siberia			

Forecast, temp FMA 2024



ERA5 Reanalysis, Temperature FMA2024

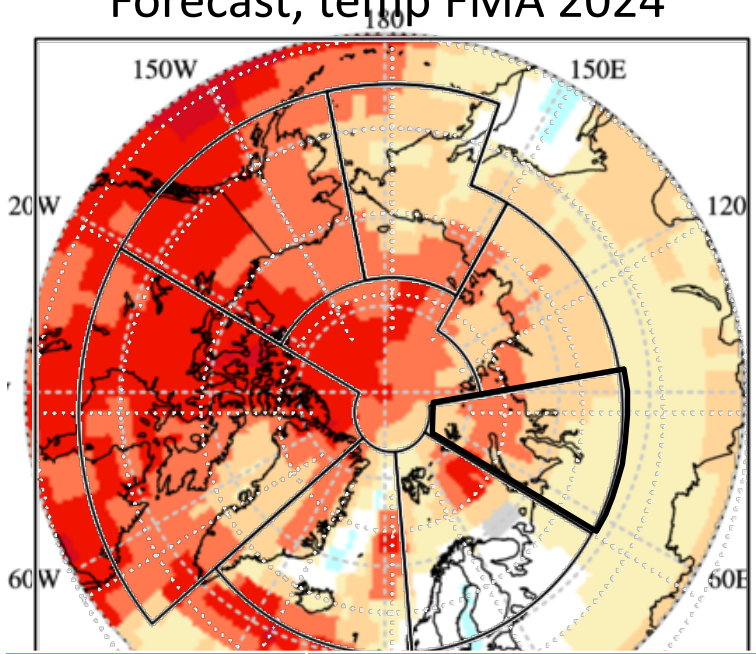


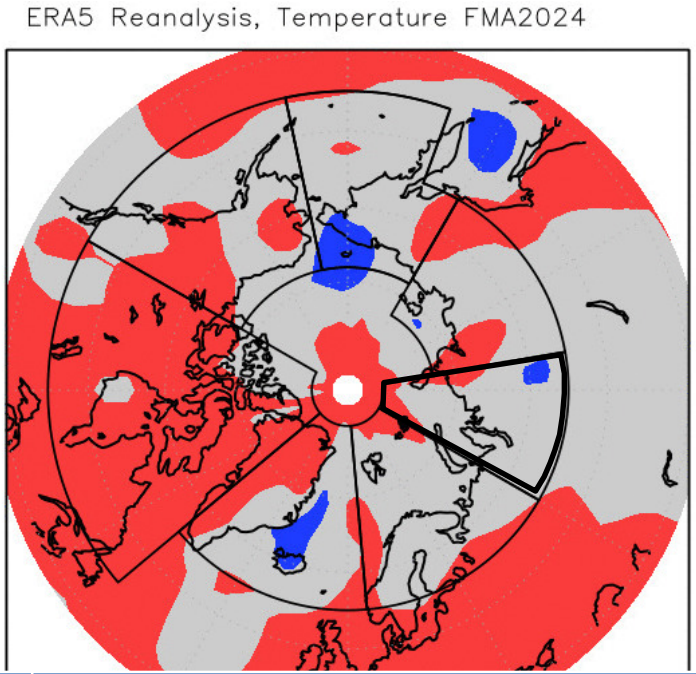
Verification Temperature

Environment and Environnement et

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	Above normal	Mostly above normal	90%
W. Nordic	Below normal and non-decisive in the center, above normal outside	Below normal in the center, mostly near normal	40%
E. Nordic	**Non decisive over the continent, above in the north**	**Mostly near normal**	**Miss where forecast**
W. Siberia			

Forecast, temp FMA 2024





Verification Temperature

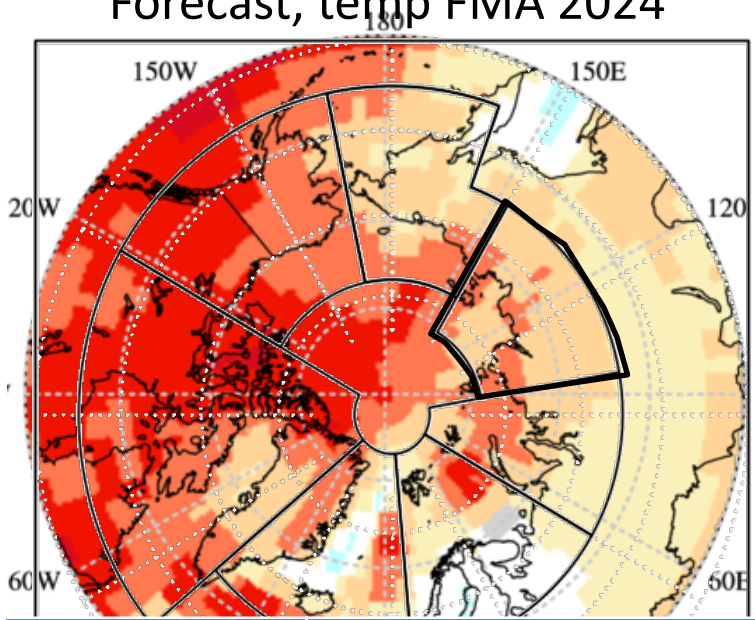
Above normal

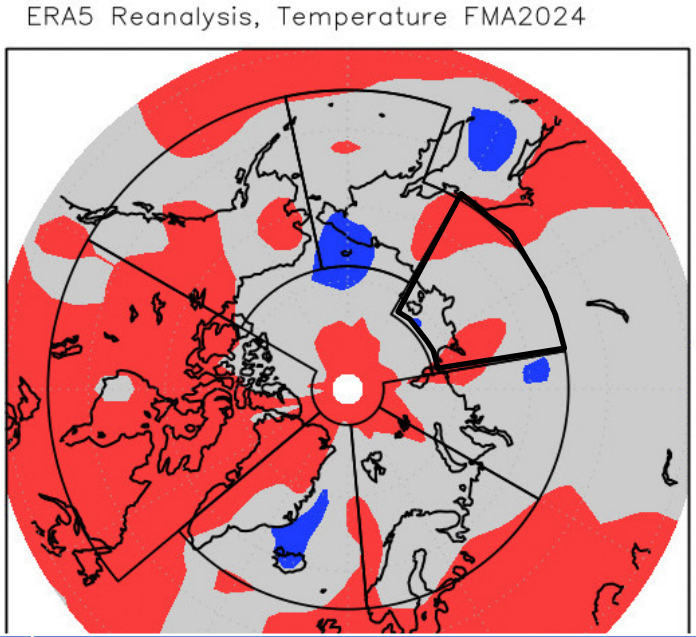
Near normal

Below normal

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	Above normal	Mostly above normal	90%
W. Nordic	Below normal and non-decisive in the center, above normal outside	Below normal in the center, mostly near normal	40%
E. Nordic	Non decisive over the continent, above in the north	Mostly near normal	Miss where forecast
W. Siberia	**Above normal**	**Near normal**	**miss**
E. Siberia			

Forecast, temp FMA 2024





Verification Temperature

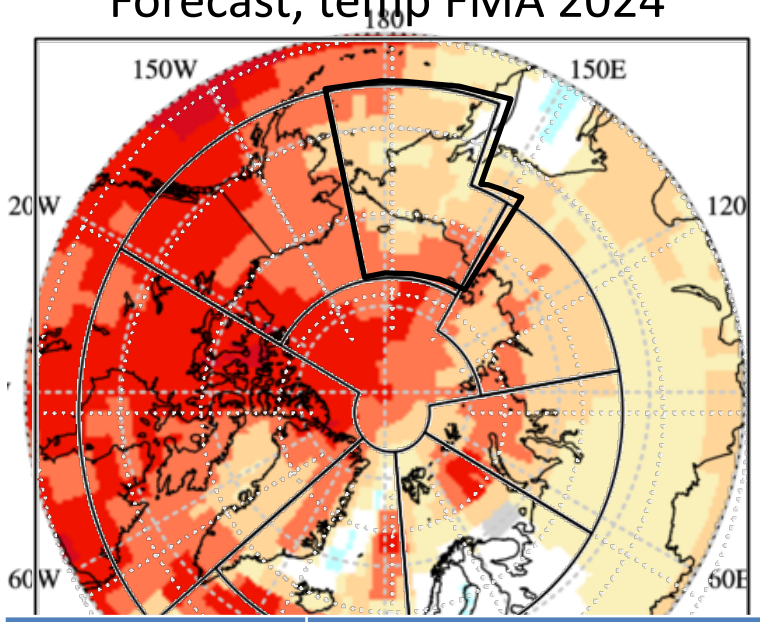
Above normal

Near normal

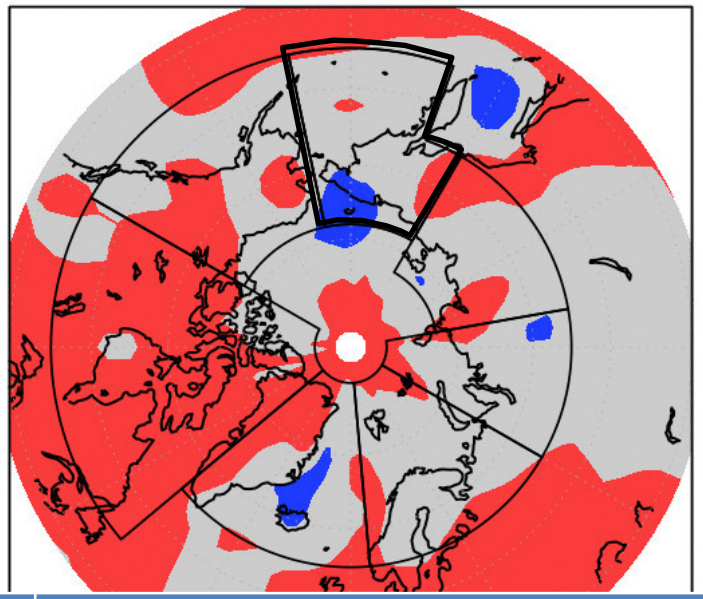
Below normal

Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	Above normal	Mostly above normal	90%
W. Nordic	Below normal and non-decisive in the center, above normal outside	Below normal in the center, mostly near normal	40%
E. Nordic	Non decisive over the continent, above in the north	Mostly near normal	Miss where forecast
W. Siberia	Above normal	Near normal	miss
E. Siberia	**Above normal**	**Mostly near normal**	**20%**
Chukchi-Bering			

Forecast, temp FMA 2024



ERA5 Reanalysis, Temperature FMA2024



Verification Temperature

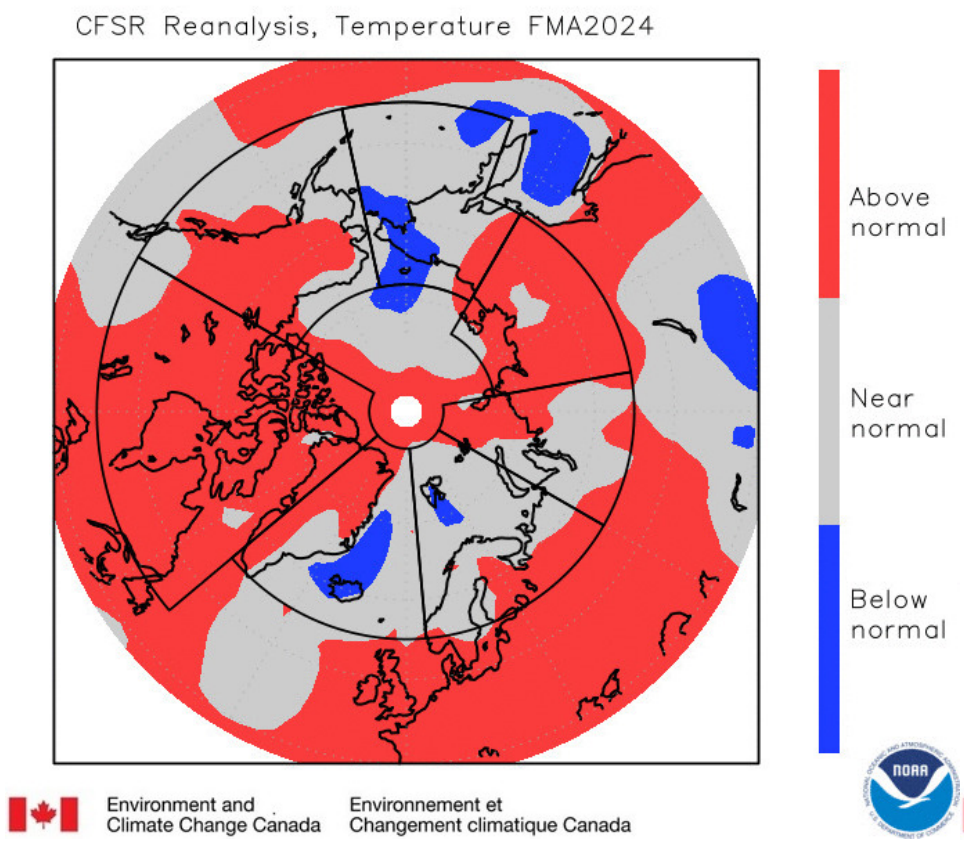
Above normal

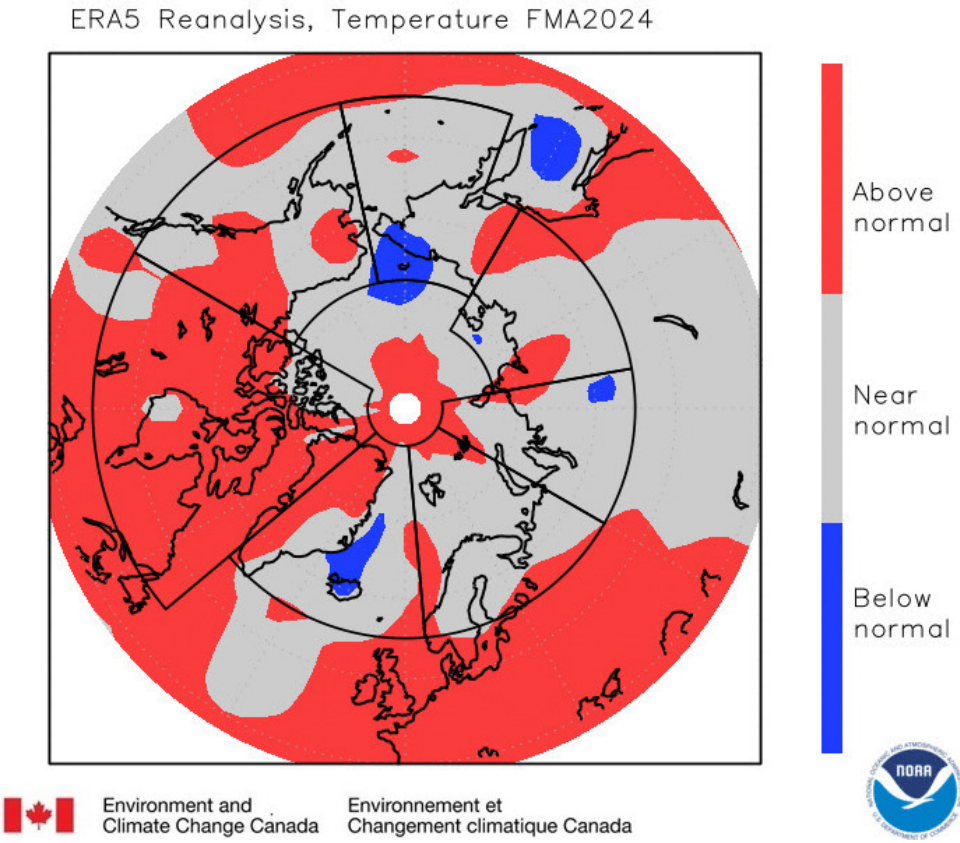
Near normal

Below normal

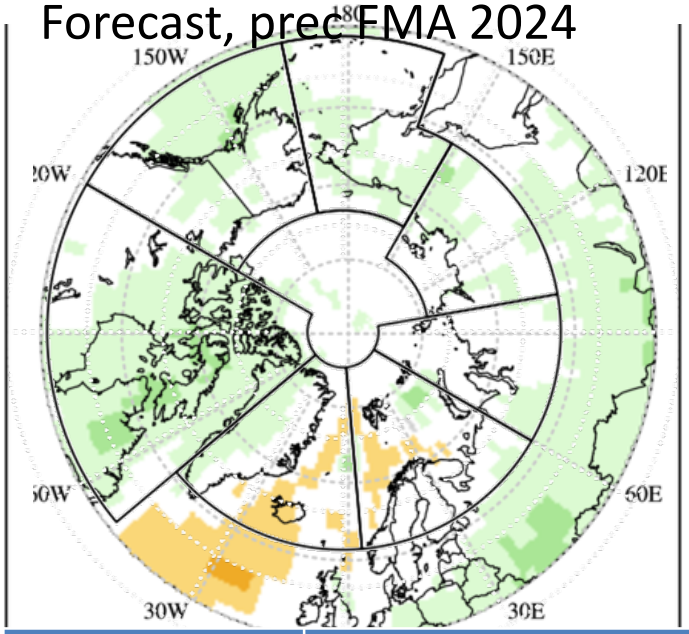
Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east near normal in the western parts	40%
C. - E. Canada	Above normal	Mostly above normal	90%
W. Nordic	Below normal and non-decisive in the center, above normal outside	Below normal in the center, mostly near normal	40%
E. Nordic	Non decisive over the continent, above in the north	Mostly near normal	Miss where forecast
W. Siberia	Above normal	Near normal	miss
E. Siberia	Above normal	Mostly near normal	20%
Chukchi-Bering	**Above normal mostly**	**Below normal in the north west, near normal**	**miss**

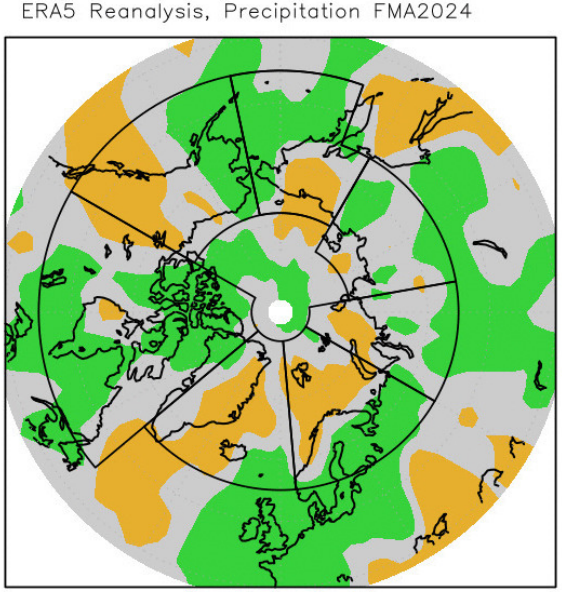
Differences between CFSR and ERA5 reanalysis tercile categories





Verification Precipitation

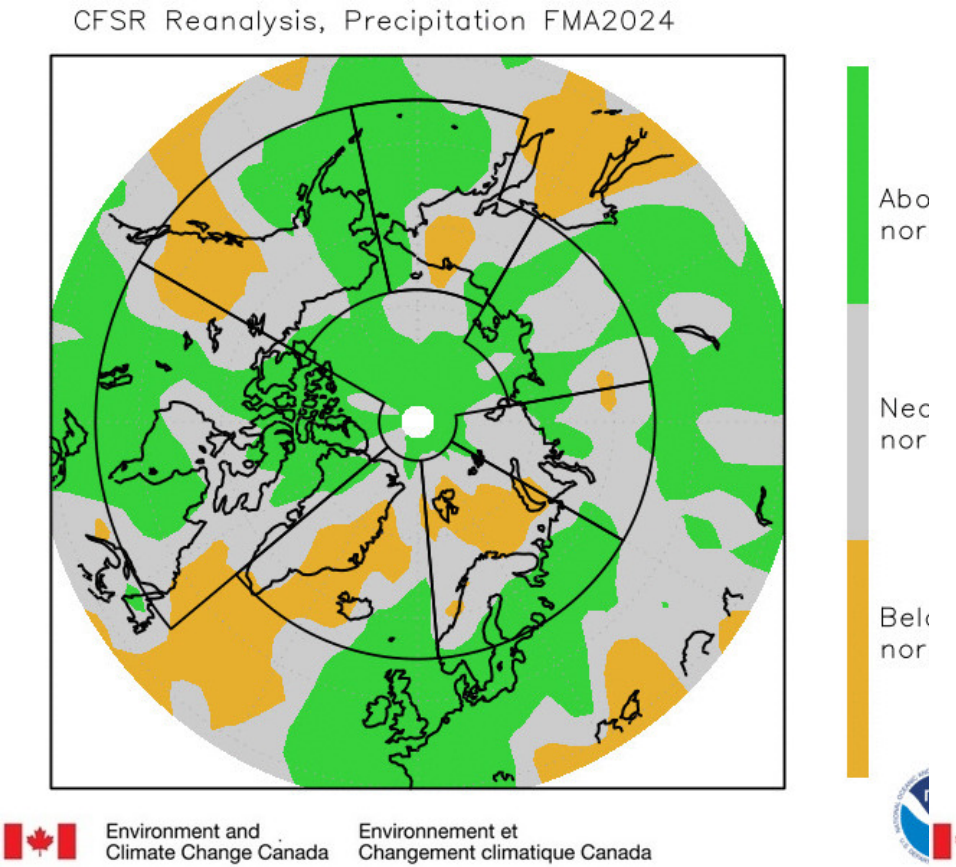


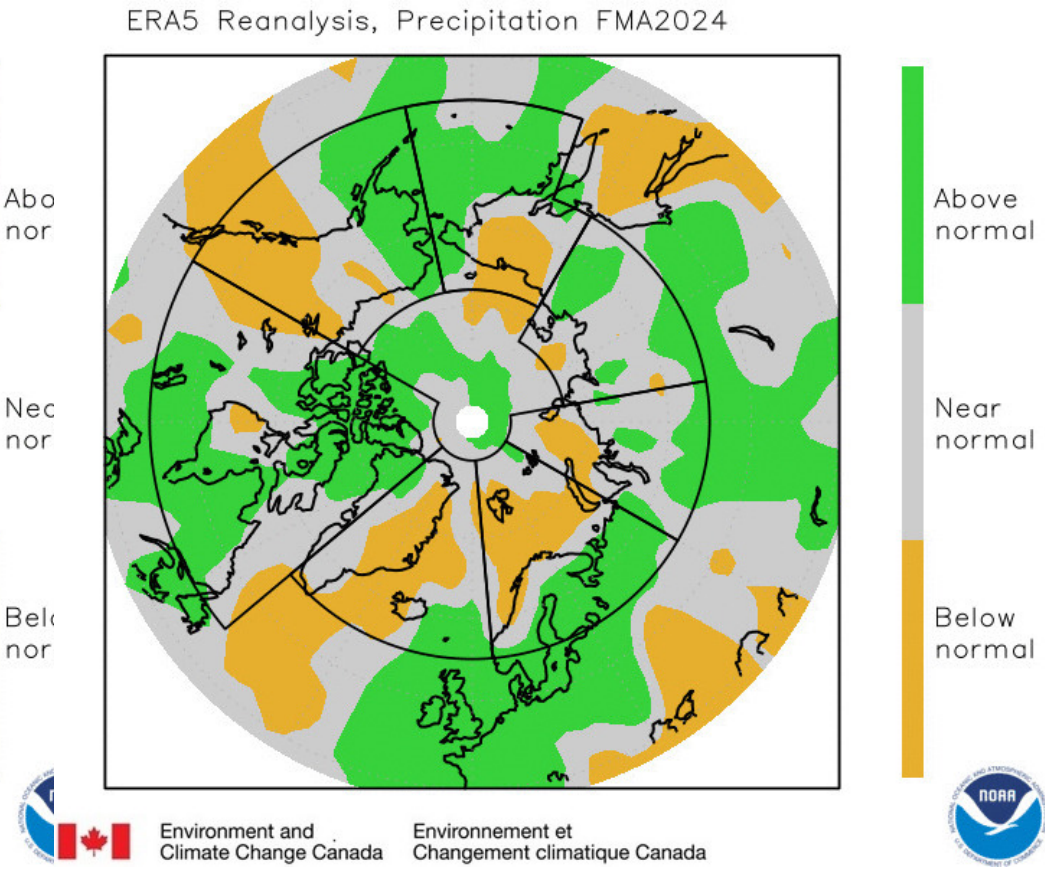


Environment and Climate Change Canada | Environnement et Changement climatique Canada

Verif:	Forecast FMA	CFS Reanalysis	Subj. Result
Alaska, W. Can	Abobe normal in the center, equal chances	Above in the west, near normal in center below in the east	miss where forecast
C. - E. Canada	Mostly above normal, equal chances in the west.	Above normal in the south and north, mostly near normal in east and west	30%
W. Nordic	Below normal in south and center, equal chances	Below normal in south and center, near normal elsewhere	20% where forecast
E. Nordic	Mostly equal chances	Below normal in the center, above in the south	%
W. Siberia	Equal chances, above in the southwest	Near normal mostly, above in the south, below normal in the north	10% where forecast
E. Siberia	Equal chances in the souh and center, above in the east and west	Near normal mostly, above in the east	10% where forecast
Chukchi Bering	Equal chances in the south and	Below normal in the north and center, above	miss

Differences between CFSR and ERA5 reanalysis tercile categories





Overall result, subjective verification

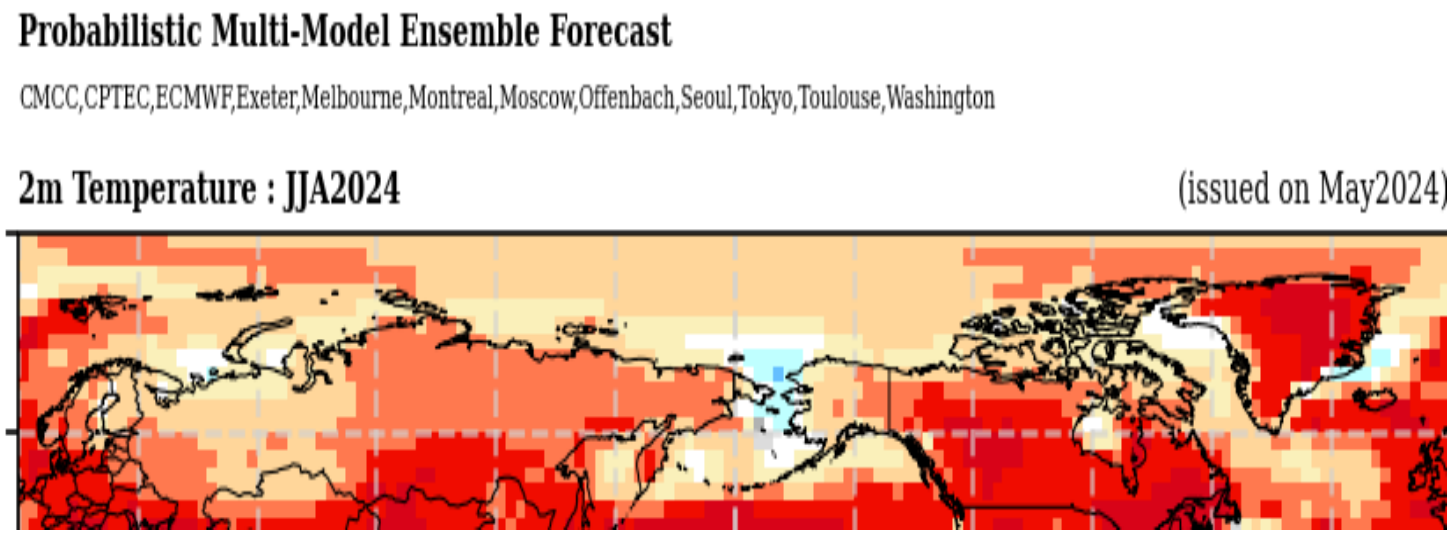
- **Temperature**: Considering all Arctic regions the subjective score is somewhat less than 40%.

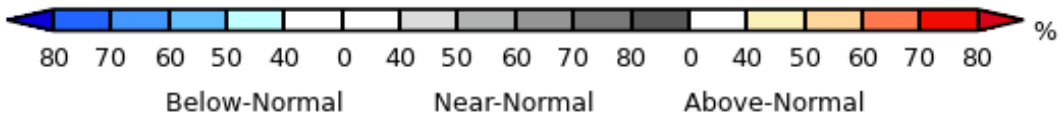
- **Precipitation**: The forecast was not very performant during the second part of the winter, FMA2024

Actual (real time)seasonal forecasts over the Arctic JJA 2024

- Temperature
- Precipitation
- Snow Water Equivalent

Temperature outlook over the Arctic: Jun-Jul-Aug 2024



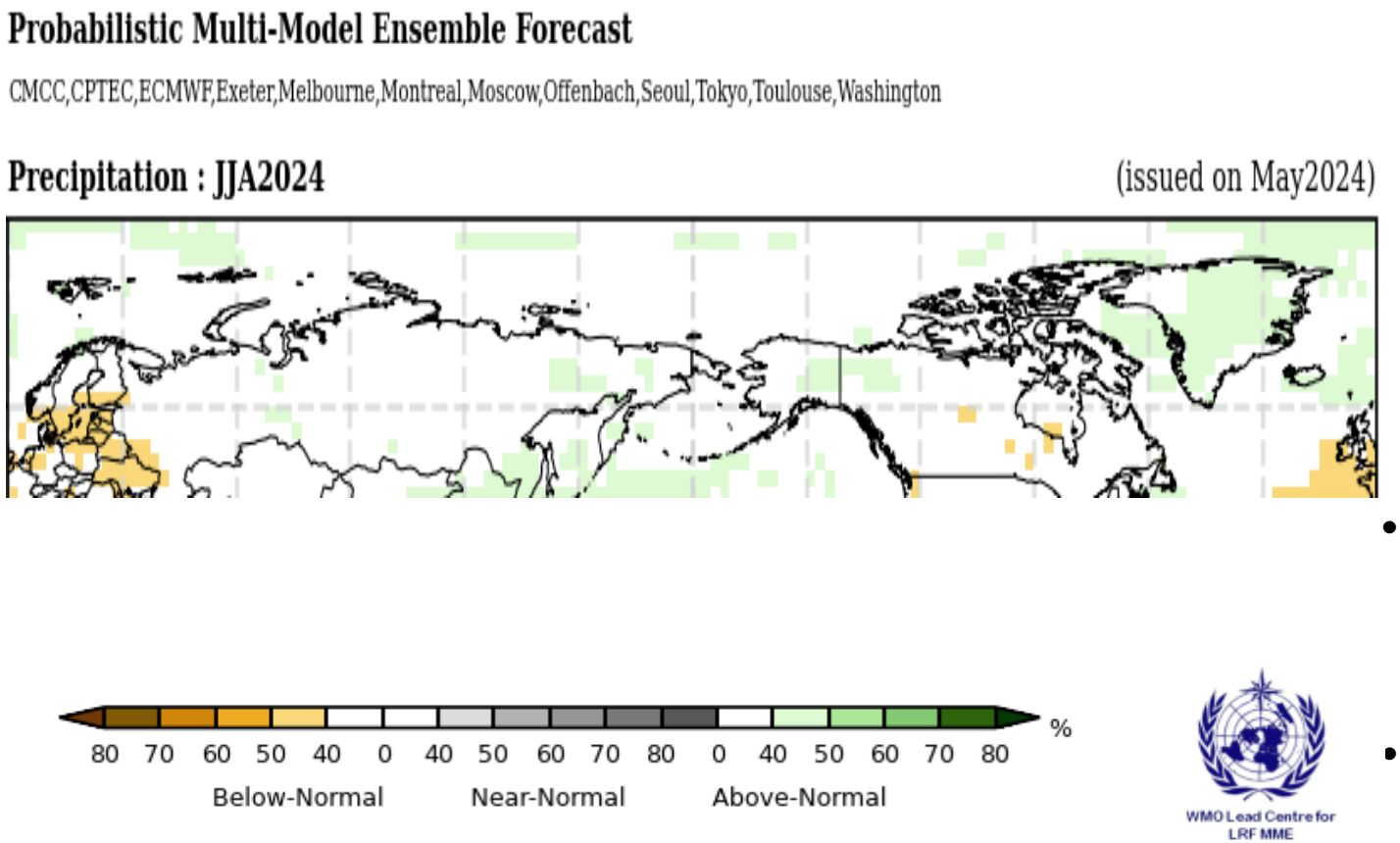


1. Alaska W. Canada
2. Eastern Canadian Arctic
3. Western Nordic
4. Eastern Nordic
5. West Siberia
6. East Siberia
7. Chukchi and Bering

- The redder the color does not mean it is warmer.
- It means we have more confidence in the above normal forecast over that region.

WMO Lead Centre for LRF MME

Precipitation outlook over the Arctic: Jun-Jul-Aug 2024



1. Alaska W. Canada
2. Eastern Canadian Arctic
3. Western Nordic
4. Eastern Nordic
5. West Siberia
6. East Siberia
7. Chukchi and Bering

- The greener the color does not mean it will precipitate more.
- It means we have more confidence in the above normal precipitation forecast over that region.

Global Seasonal Climate Update by WMO

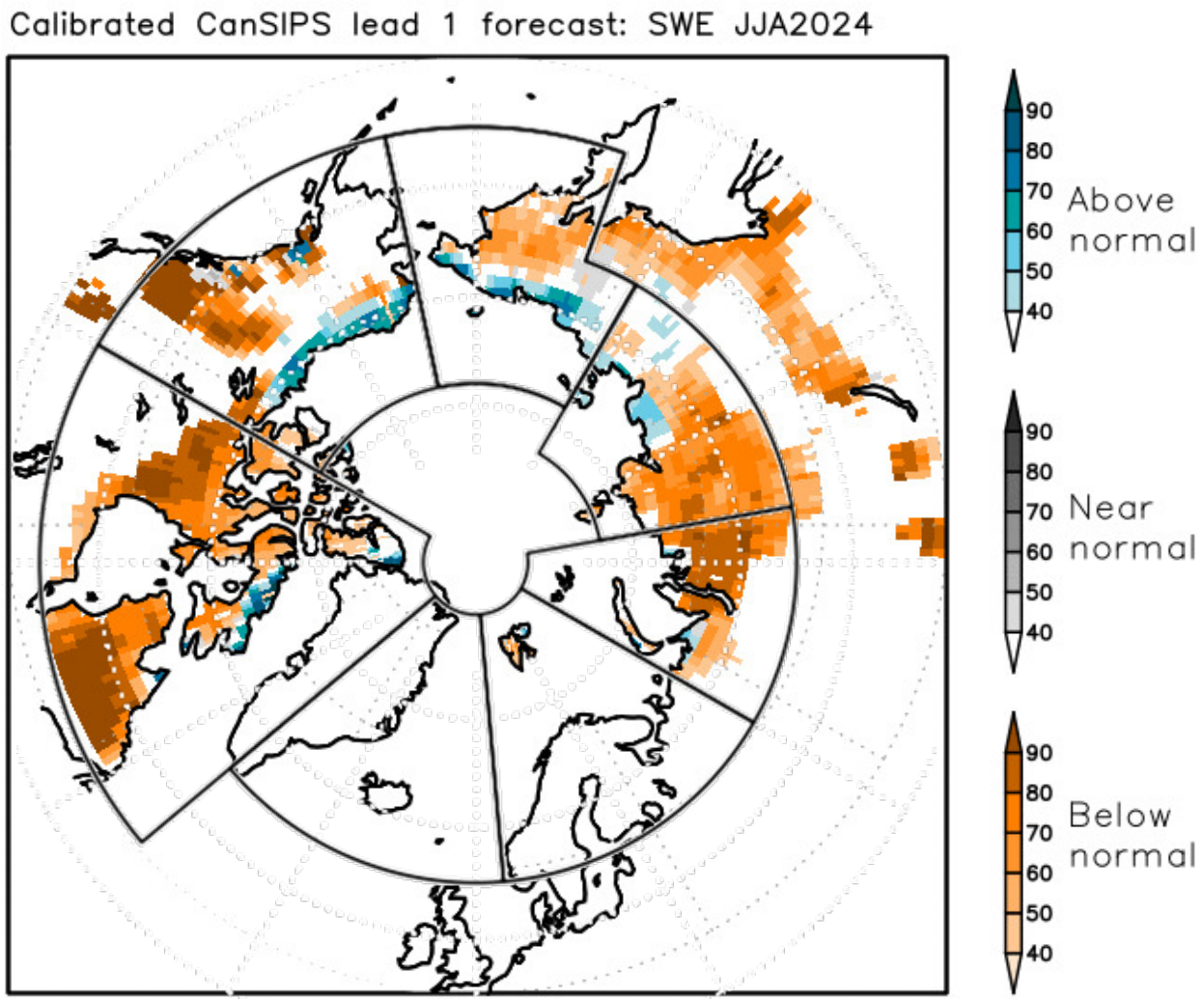
- Global information on state of climate (monitoring and prediction)
- The plots get updated once a month and are available from

https://public.wmo.int/en/our-mandate/climate/global-seasonal-climate-update
https://wmolc.org/gscuBoard/list

- Climate report is available for download

Snow Water Equivalent outlook over the Arctic: Jun-Jul-Aug 2024

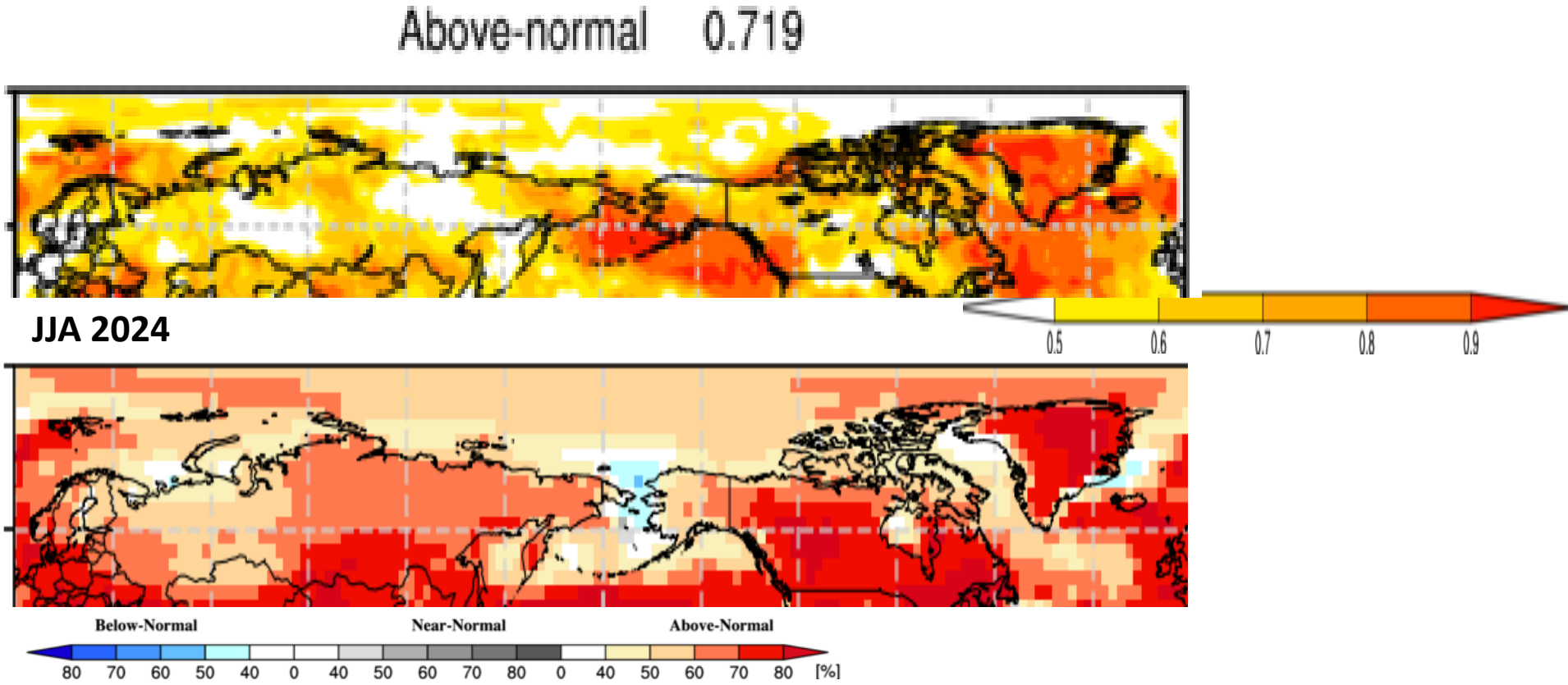
Experimental product



1. Alaska W. Canada
2. Eastern Canadian Arctic
3. Western Nordic
4. Eastern Nordic
5. West Siberia
6. East Siberia
7. Chukchi and Bering

Discussing historical skill over the Arctic, Temperature

(confidence with respect to the historical (1993-2009) skill)

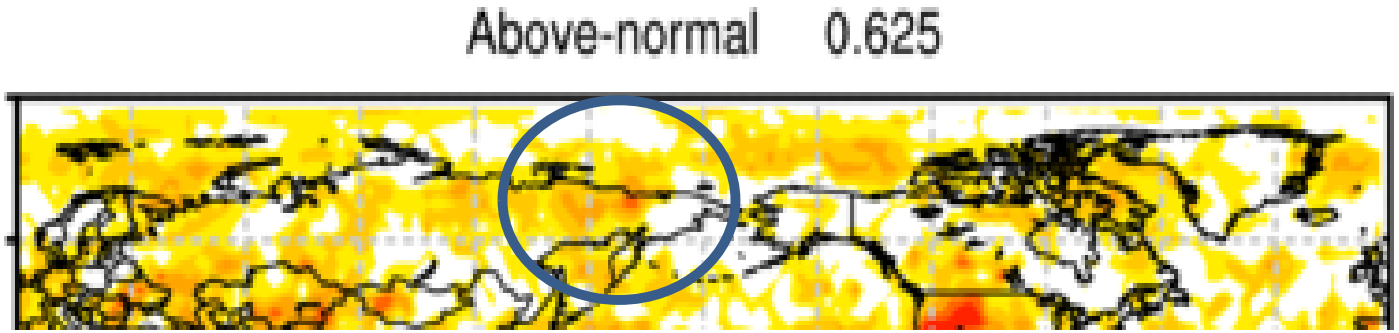


- If a historical skill was good over a certain region (e.g. colored region on the upper figure) we are more confident about the forecast results over the same region

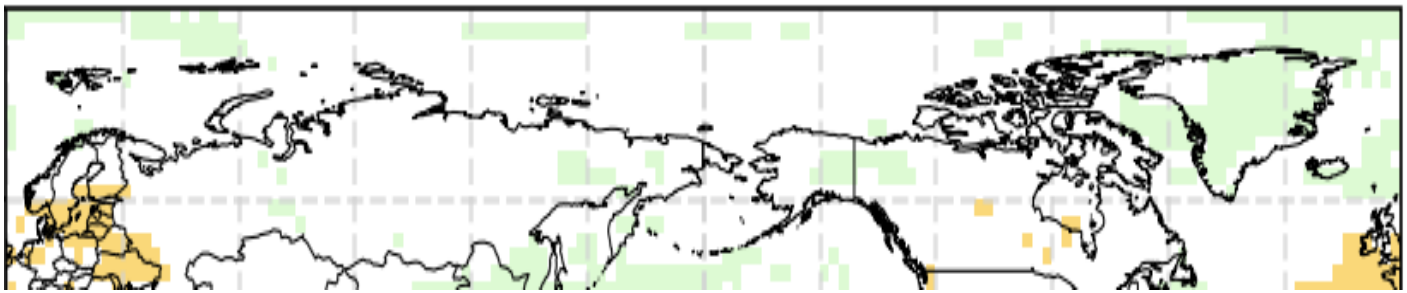
- Overall confidence is moderate in JJA over the Arctic.

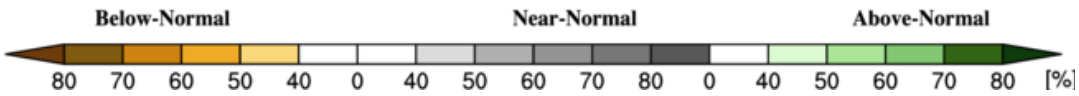
Discussing historical skill over the Arctic, Precipitation

(confidence with respect to the historical (1993-2009) skill)



JJA 2024

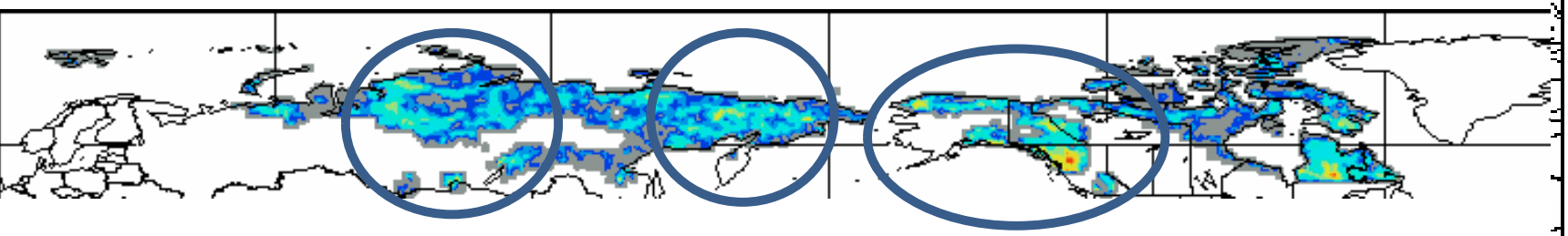


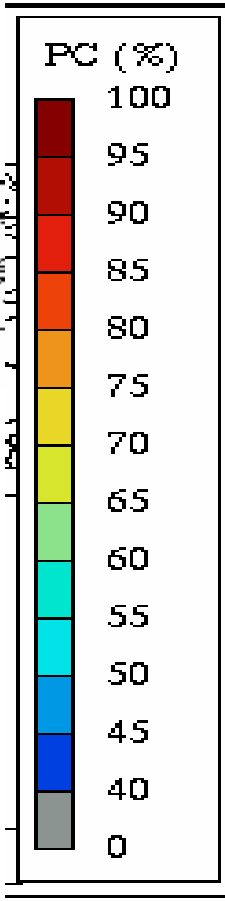


- We don't have a very high confidence in precipitation skill over the Arctic in NDJ.

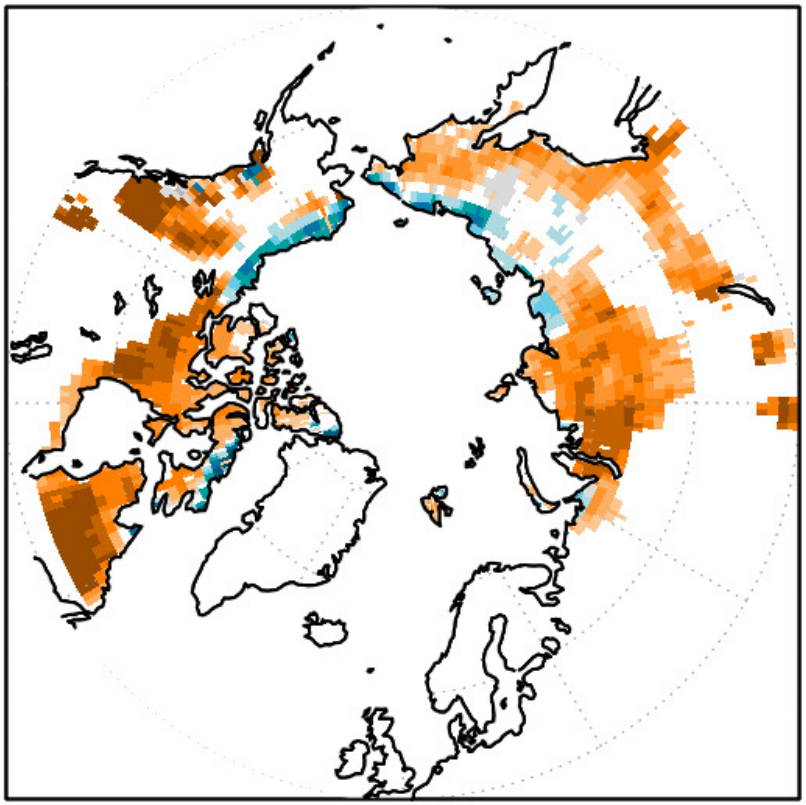
Discussing historical skill over the Arctic, SWE

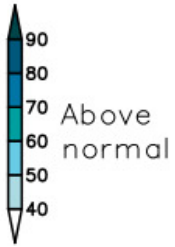
(confidence with respect to the historical skill)

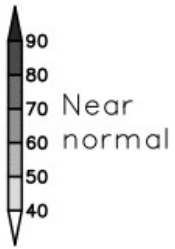


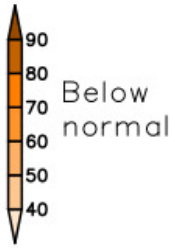


Calibrated CanSIPS lead 1 forecast: SWE JJA2024







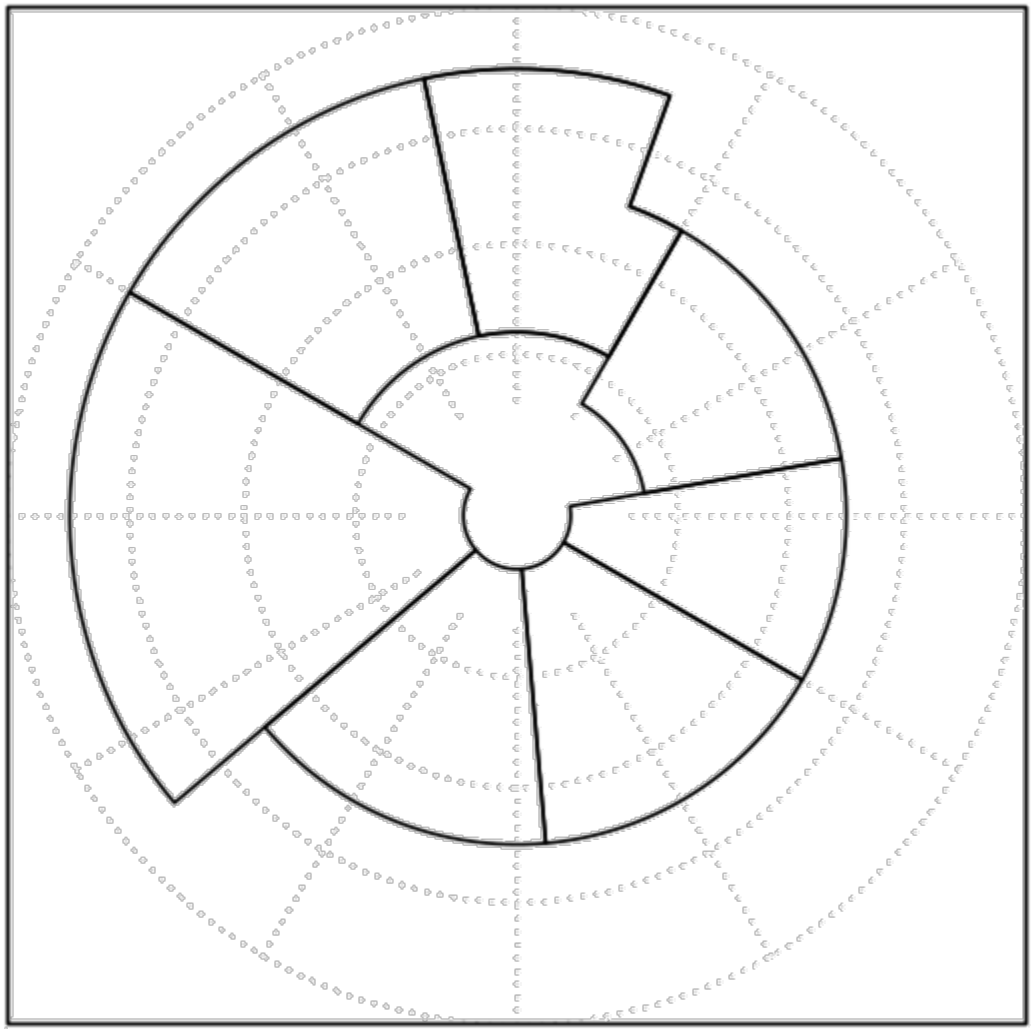


- If a historical skill was good over a certain region (e.g. colored region on the upper figure) we are more confident about the forecast results over the same region

Conclusions

- We use Multi Model Ensemble (MME) approach to calculate seasonal forecast.
- We use probabilistic approach to communicate seasonal forecast results.
- For evaluation over the Arctic we use a combination of observations and model results called re-analysis.
- FMA2024 MME temperature forecast over the Arctic region was less than 40%.. Precipitation forecast was correct mostly over the two Siberian regions.
- We expect above normal temperatures over all Arctic regions this winter with highest probabilities over the North America, western Nordic region and the two Siberian regions (east and west).
- Over the Arctic in JJA24, equal precipitation chances are mostly forecast.
- Below normal snow water equivalent (SWE) is expected over most of the Arctic with an exception of coastal northern regions of Alaska eastern Canada and the two Siberian regions where above normal probabilities are expected.

Thank you!



13th Arctic Climate Forum
May 2024

ACF
Arctic Climate Forum

Winter 2023/24 Sea Ice Outlook Verification and Outlook for Summer 2024

Adrienne Tivy[1]*, Bill Merryfield[1], Arlan Dirkson[1], Gulilat Diro[1], Cathy Reader[1], Michael Sigmond[1], Vasilisa Bragina (Vorobyeva) [23], M.A. Tarasevich[235], E.M. Volodin[2], A. S. Gritsun[2], Amanda Prysizney [1], Brian Brettschneider[4]

1- *Environment and Climate Change Canada; 2- Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences; 3-Hydrometeorological Research Center of Russian Federation; 4-National Oceanic and Atmospheric Administration (NOAA); 5-Moscow Institute of Physics and Technology*

ArcRCC Sea-Ice Outlooks: Content and Methods

Winter Sea Ice Outlook

Freeze-up Forecast

March (maximum) Sea Ice Extent Forecast

Summer Sea Ice Outlook

Break-up Forecast

September (minimum) Sea Ice Extent Forecast

Outlook for sea ice conditions in key shipping regions

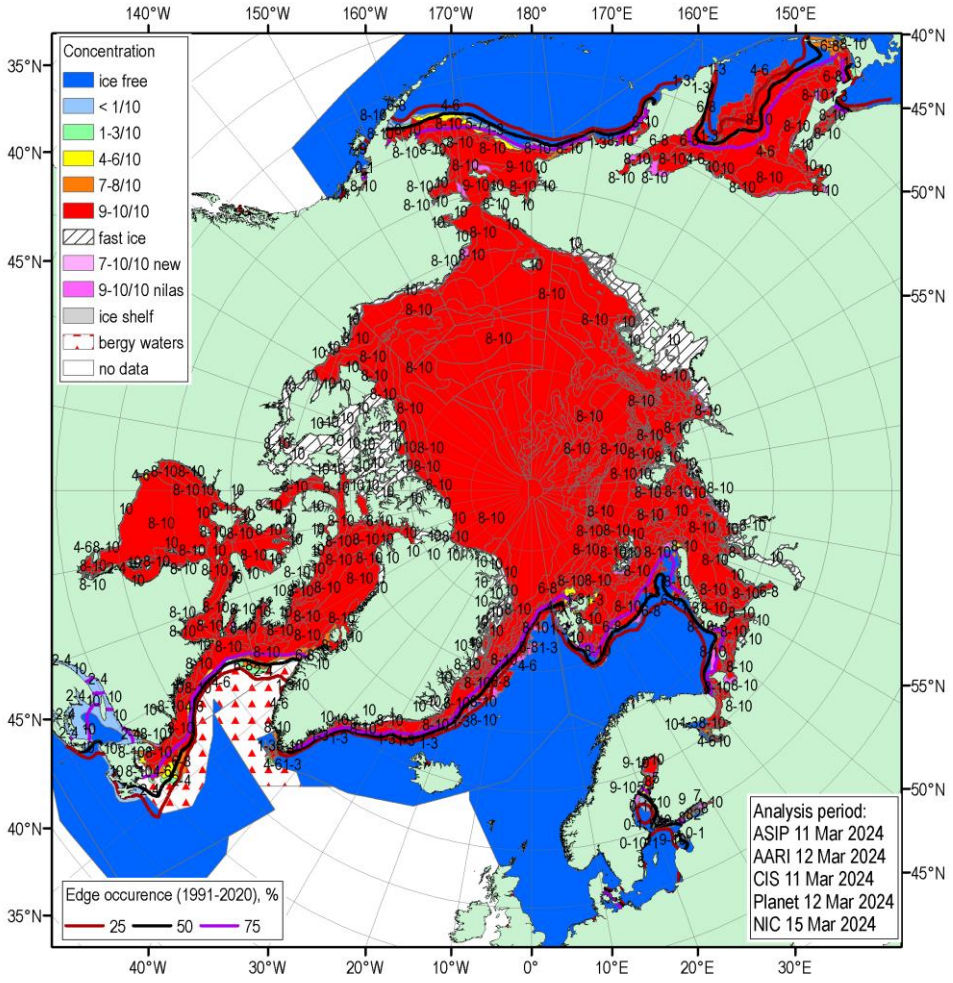
Outlook Production

- Sea Ice Outlooks are based primarily on the Canadian Seasonal to Inter-annual Prediction System (CanSIPSv2.1, 20 ensemble members, 10 each from GEM5-NEMO and CanCM4i)
- Additional use of sea ice forecasts:
  - Coupled Unified Forecast System (NOAA UFS; 5 ensemble members)
  - INM-CM5 climate model (INM RAS/Hydrometcenter of Russia, 10 ensemble members)
- MME for sea ice is not yet available; outlook is a subjective 'ensemble' of probabilistic/deterministic model forecasts; forecast confidence is a subjective assessment of hindcast model skill, ensemble spread and forecast agreement between models

Comparison:
Actual Winter 2023/24 Conditions
with
Winter 2023/24 Sea Ice Outlook

March 2024 Sea Ice Extent (Actual)

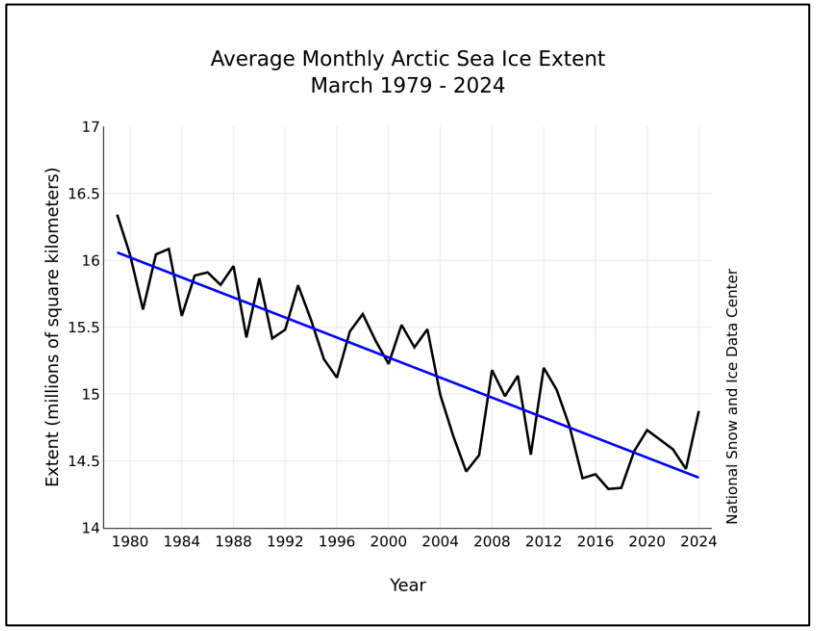
Mid-March 2024 Ice Concentration from Ice Charts (March 11-15)



Source: Arctic and Antarctic Research Institute

- Winter sea ice reached the maximum ice extent March 14th (14th lowest / NSIDC)
- March average (maximum) ice extent (15th lowest, NSIDC)
- largest anomalies in the Labrador Sea / Gulf of St. Lawrence (below normal) and Greenland Sea / Sea of Okhotsk (above normal)

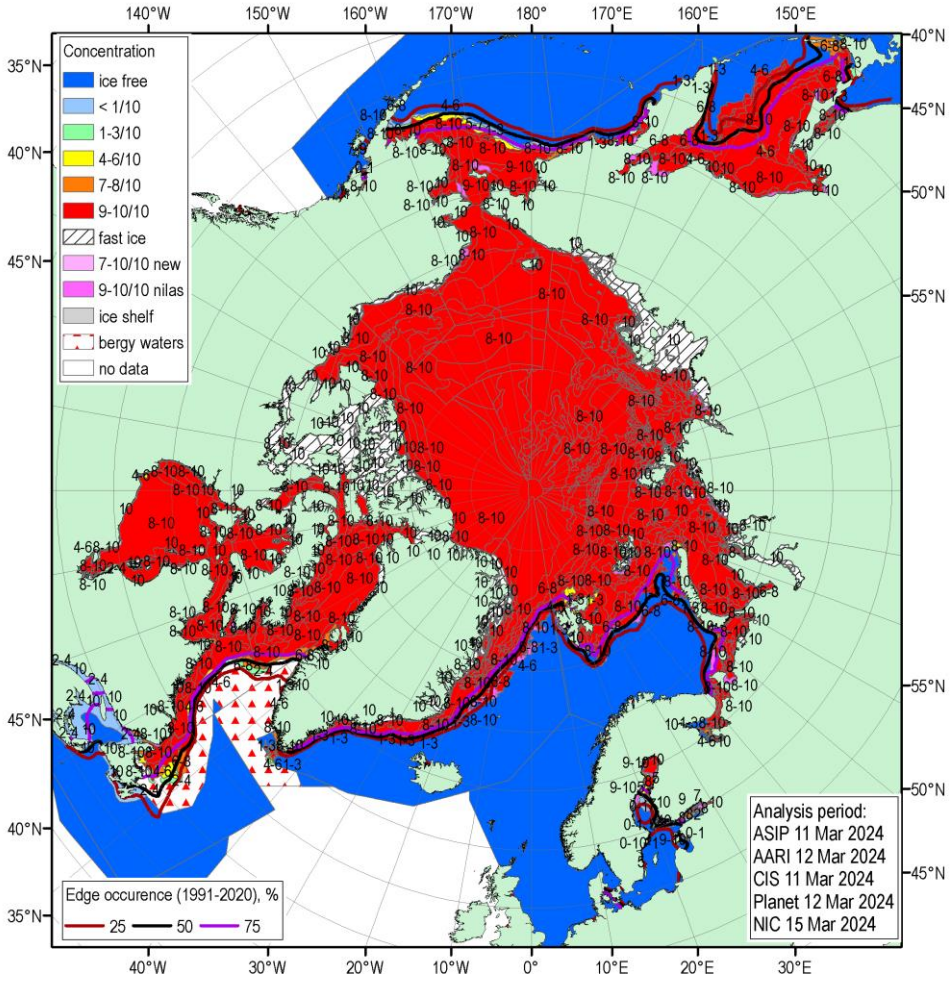
March Northern Hemisphere Sea Ice Extent 1979-2024



Source: National Snow and Ice Data Center

March 2024 Sea Ice Extent (Actual)

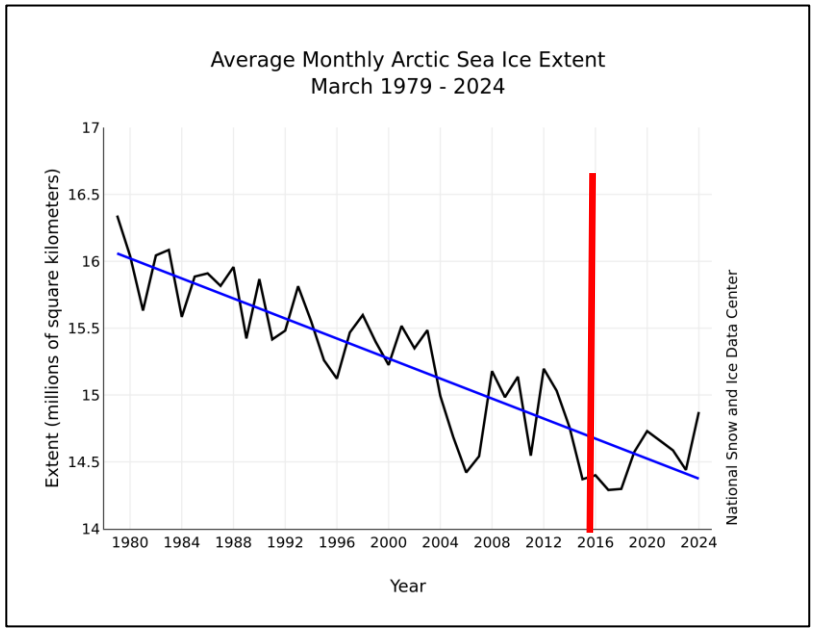
Mid-March 2024 Ice Concentration from Ice Charts (March 11-15)



Source: Arctic and Antarctic Research Institute

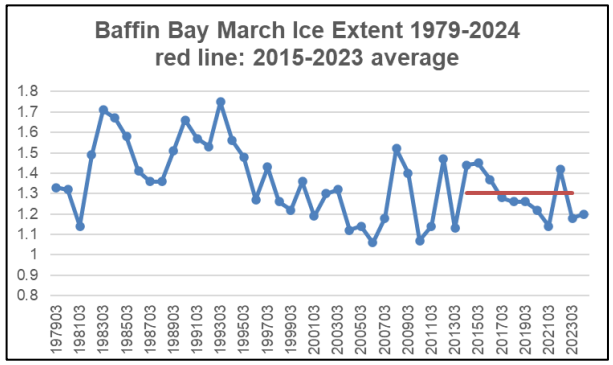
- Because the Arctic sea ice is changing so rapidly, forecasts show predicted conditions compared to the most recent 9 years

March Northern Hemisphere Sea Ice Extent 1979-2024

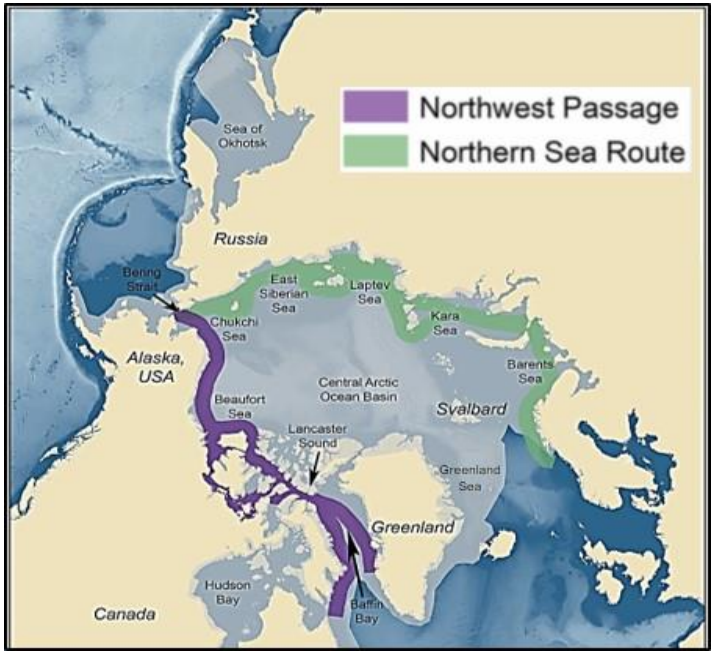


Source: National Snow and Ice Data Center

ArcRCC Winter 2024 Outlook
March Sea Ice Extent
Actual vs Outlook



Verification against observed regional ice extent provided by NOAA calculated from version 4 NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice



[* Regional Sea Ice | National Centers for Environmental Information (NCEI) (noaa.gov)]

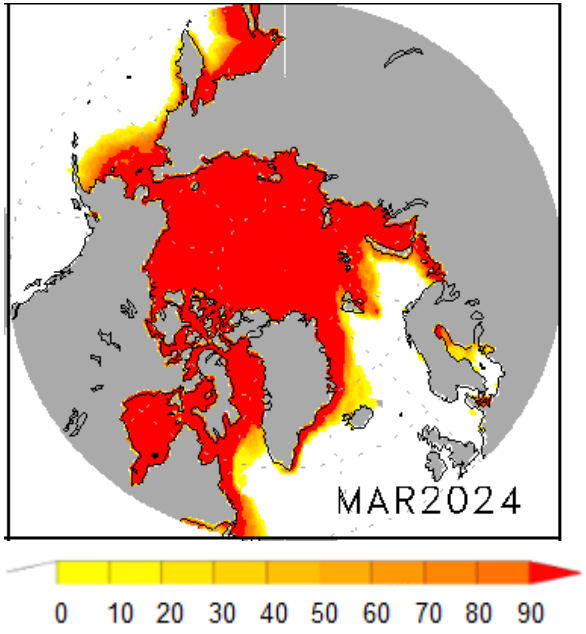
Regions	CanSIPSv2.1 Extent Forecast Confidence	CanSIPSv2.1 Extent Forecast (2015-2023 average)	Observed Ice Extent NOAA/NSIDC CDR1* (2015-2023 average)	Sea-Ice Forecast Accuracy
Barents Sea			Above normal	
Bering Sea			Above normal	
Greenland Sea			Above normal	
North Baltic Sea			Above normal	
Baffin Bay/ Labrador Sea			Below normal	
Gulf of St. Lawrence			Below normal	
Sea of Okhotsk			Above normal	
Barents Sea			Above normal	

Probability of monthly mean March 2024 sea ice concentrations exceeding 15%

CanSIPSv2.1 (ECCC)
Initialized October 1, 2023
Red: 2014-2022 mean ice extent

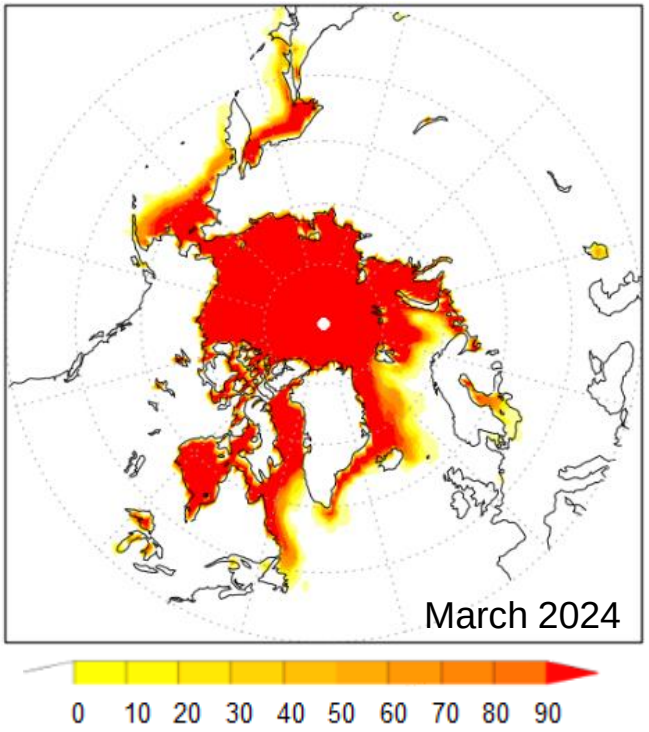
Source: Environment and Climate Change Canada

Experimental UFS forecast (NOAA)
Initialized September 21-25, 2023



Source: U.S. NOAA

Experimental INMCM5 forecast
Initialized October 1, 2023



Source: INM RAS / Hydrometcenter Russia

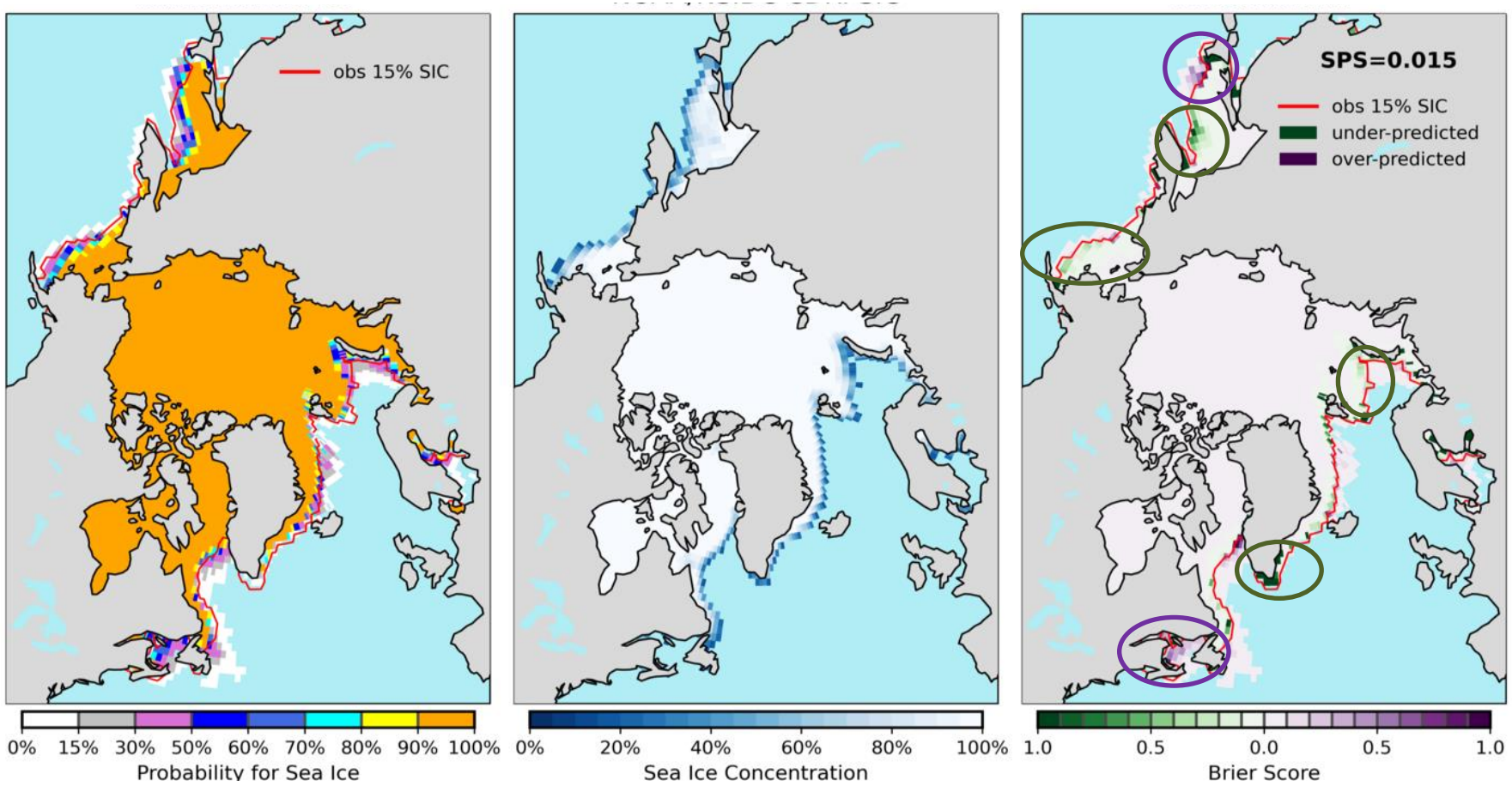
Verification of CanSIPSv2.1 probabilistic forecast for March 2024: Probability of ice concentration exceeding 15%

Forecast from Oct 1, 2023

CanSIPS v2.1 Forecast
Probability of ice concentration > 15%
Red: observed Sep2023 extent

Observed Ice Concentration
NOAA/NSIDC CDR

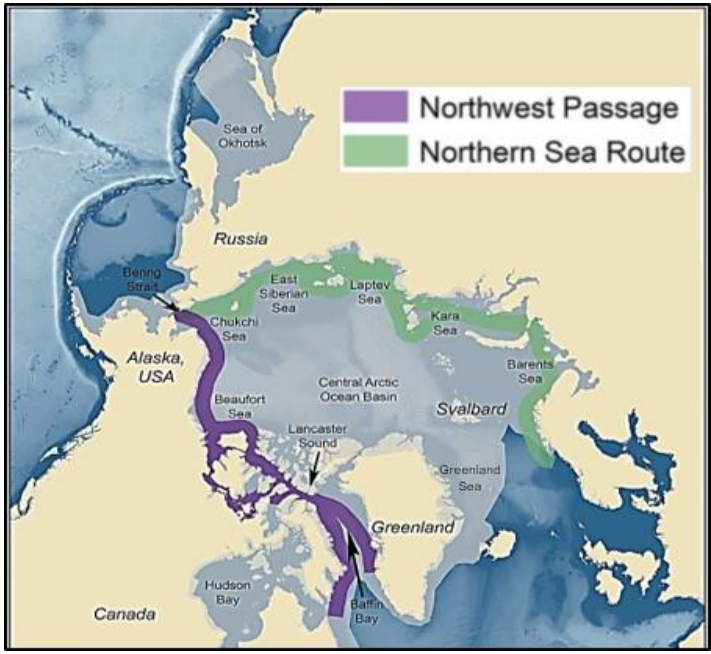
Forecast Error
Spatial Probability Score
Red: observed Sep2023 extent



*SPS = Spatial Probability Score
(lower is better)

Source: Environment and Climate Change Canada

ArcRCC Winter 2024 Outlook
March Sea Ice Extent
Actual vs Outlook



Forecast Categories (2015-2023 normal) :

- Above normal ice extent
- Near normal ice extent
- Below normal ice extent

Outlook Confidence Categories:

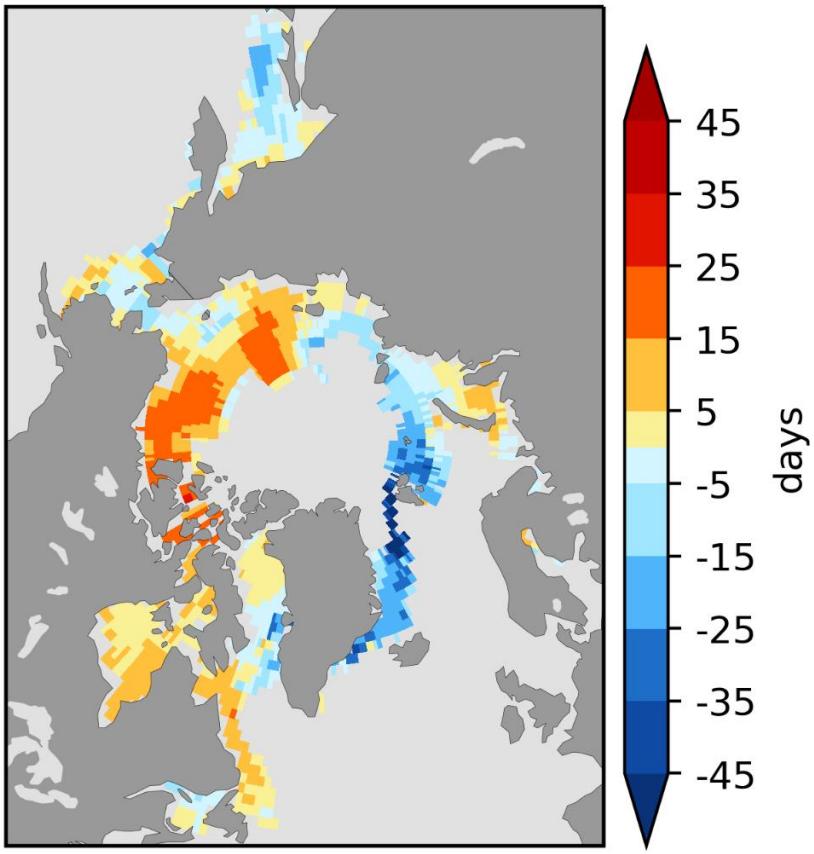
- low
- moderate
- high

Regions	CanSIPSv2.1 Extent Forecast Confidence	CanSIPSv2.1 Extent Forecast (2014-2022 average)	Observed Ice Extent NOAA/NSIDC CDR1* (2014-2022 average)	Sea-Ice Forecast Accuracy
Barents Sea	High	Near normal	Above normal	**Miss**
Bering Sea	Moderate	Below normal	Above normal	**Miss**
Greenland Sea	High	Near normal	Above normal	**Miss**
North Baltic Sea	Moderate	Above normal	Above normal	**Hit**
Baffin Bay/ Labrador Sea	High	Below normal	Below normal	**Hit**
Gulf of St. Lawrence	High	Below normal	Below normal	**Hit**
Sea of Okhotsk	Moderate	Near normal	Above normal	**Miss**
Barents Sea	High	Near normal	Above normal	**Miss**

* Regional Sea Ice | National Centers for Environmental Information (NCEI) (noaa.gov)

ArcRCC Winter 2024 Outlook
Sea Ice Freeze-up

CanSIPS v2.1 Freeze-up Date Anomaly
2014-2022 reference period
forecast from Oct 1



Source: Environment and Climate Change Canada

What is *Normal* freeze-up?

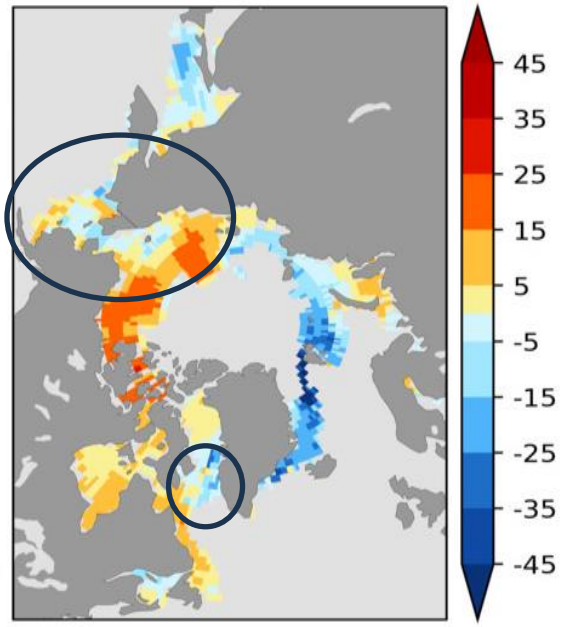
- The average date when the ice concentration drops below 50%
- Based on 2014-2022 reference period

Freeze-up Categories:

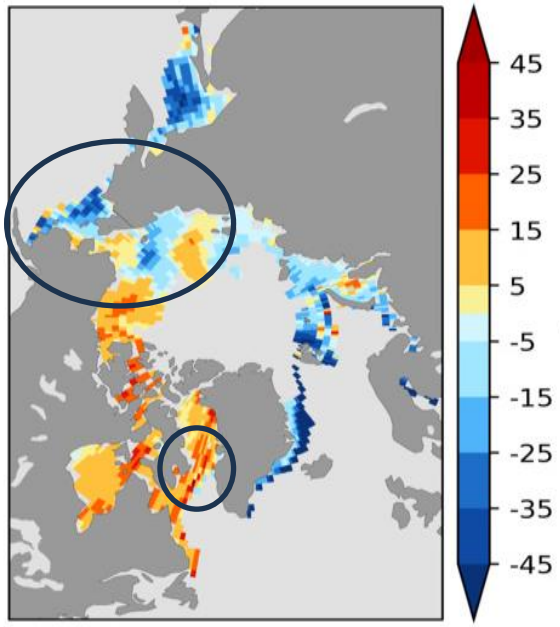
- Red-Orange: Early freeze-up
- Yellow-Light Blue: Near normal freeze-up
- Blue: Late freeze-up
- The freeze-up outlook has three confidence categories: low, moderate and high. The confidence categories are based on the skill of past forecasts.

Verification of CanSIPSv2.1 deterministic forecast for Winter 23/24 Freeze-up

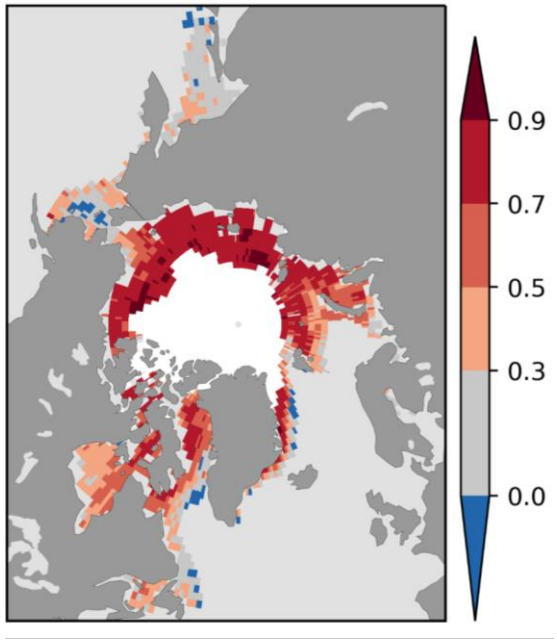
Forecast
Freeze-up date anomaly



Observed
Freeze-up date anomaly



Historical Skill
1993-2002
anomaly correlation detrended



CanSIPS v2.1 Freeze-up Date Anomaly
2014-2022 reference period
forecast from Oct 1

Verification of CanSIPSv2.1 probabilitstic forecast for Winter 23/24 Freeze-up

Forecast

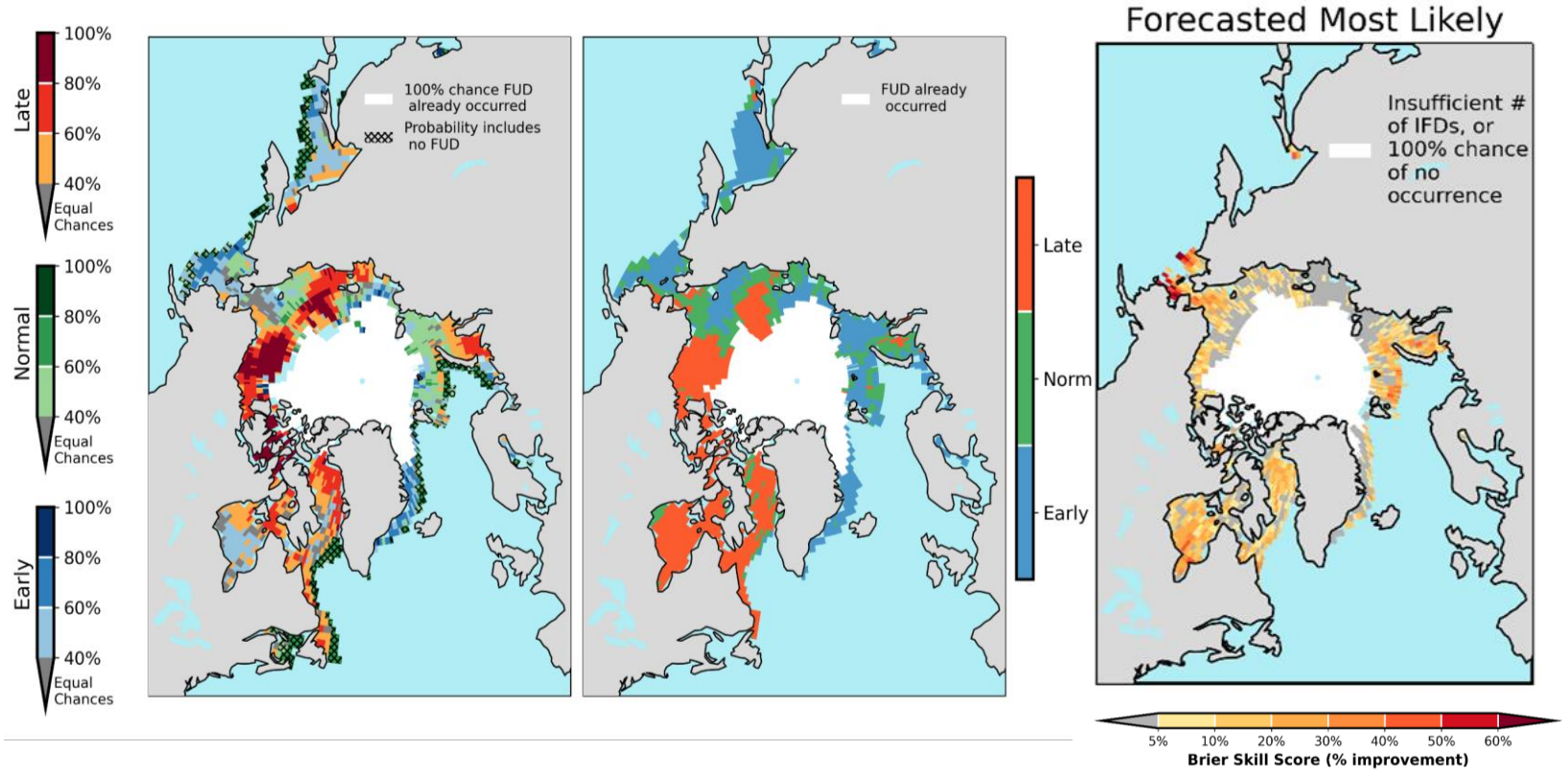
Probability of early, near-normal or late freeze-up

Observed

Historical Skill

1994-2023

Brier Skill Score



Verification: ArcRCC Sea-Ice Freeze-up Outlook for 2023/24

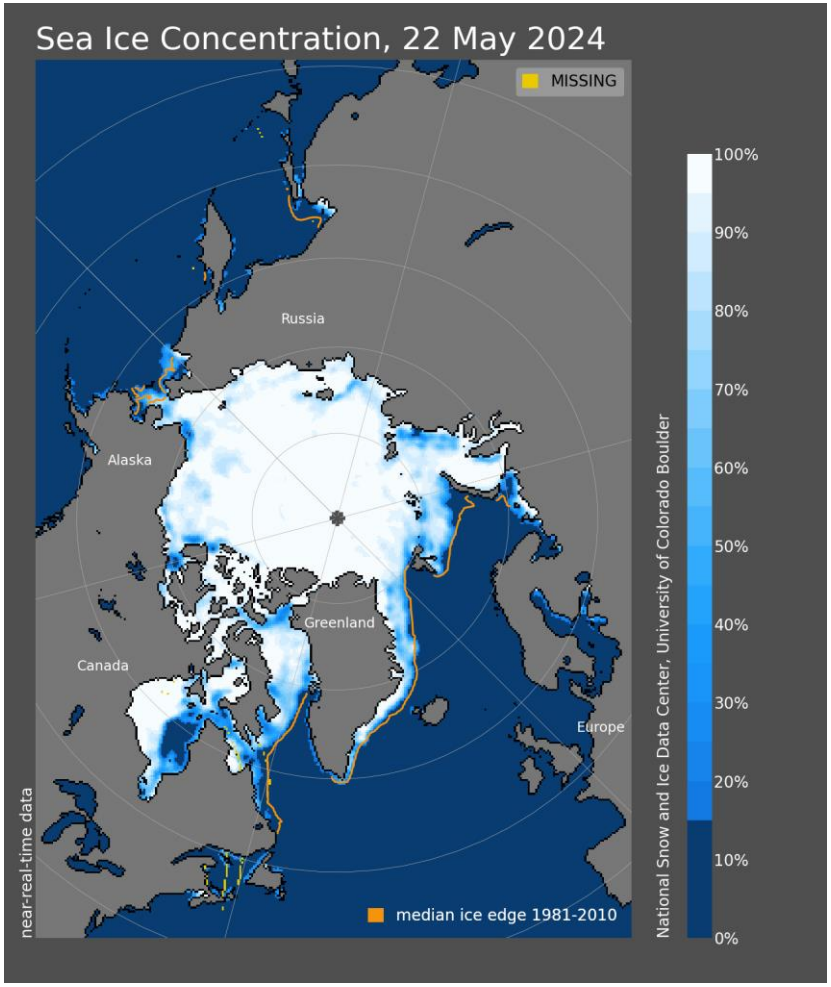
Regions	CanSIPS Sea-Ice Forecast Confidence	CanSIPS Sea-Ice Forecast	Observed Freeze-up	CanSIPS Sea-Ice Forecast Accuracy
Hudson Bay	Moderate	Near normal to late	Late	**Hit (where there's skill)**
Baffin Bay	Moderate	Near normal to late (south)	Late	**Hit (where there's skill)**
Labrador Sea	High	Late	Late	**Hit**
Greenland Sea (S)	High	Early	Early	**Hit**
Barents Sea	High	Early	Early	**Hit**
East Siberian	Already occurred			
Laptev Sea	Already occurred			
Kara Sea (E)	High	Near normal to late		**~Hit**
Chukchi Sea	High	Near normal	Early (S)/Late(N)	**Miss**
Beaufort Sea (S)	High	Late	Late	**Hit**
Sea of Okhotsk	Low	Near normal to early	Early	**~Hit**
Bering Sea	Low	Near normal	Early	**Miss**

ArcRCC Sea Ice Outlook
Summer 2024

ArcRCC Summer 2024 Outlook
Sea Ice Break-Up

What is Normal break-up?

- the date when the ice concentration falls below 50%
- based on past 9-year reference period (2015-2023)

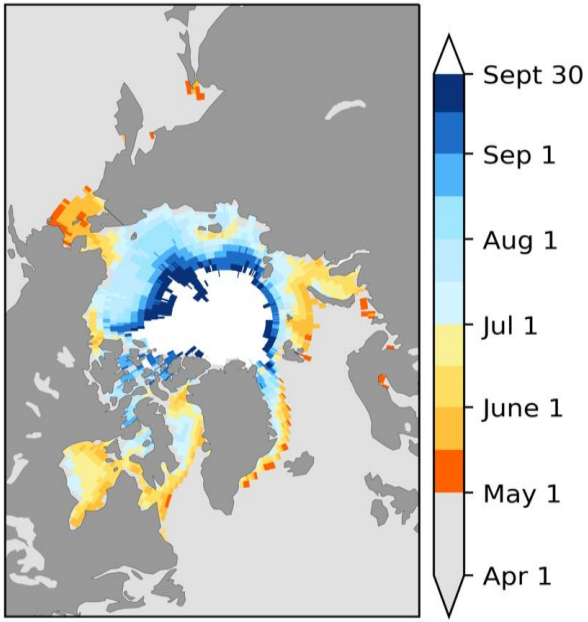


Regions	CanSIPSv2.1 Sea-Ice Forecast Confidence	CanSIPSv2.1 Sea-Ice Freeze-up Forecast
Barents Sea		
Greenland Sea		
Baffin Bay		
Hudson Bay		
CAA		
Beaufort Sea		
Chukchi Sea		
East Siberian Sea		
Bering		
Laptev Sea		
Kara Sea		
Barents Sea		

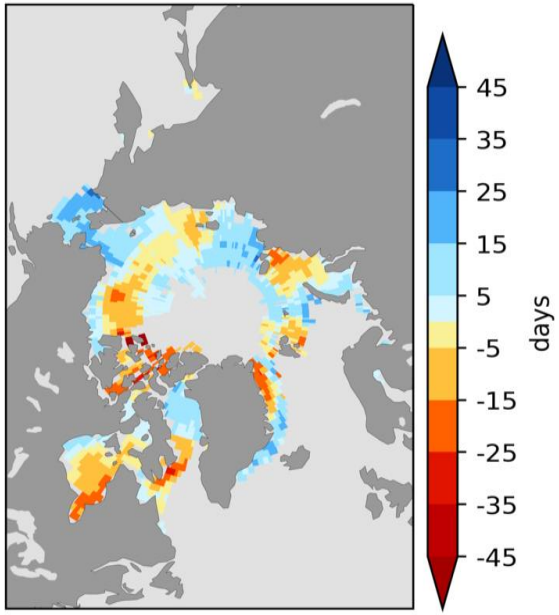
Source: National Snow and Ice Data Center

CanSIPS v2.1 deterministic forecast for break-up

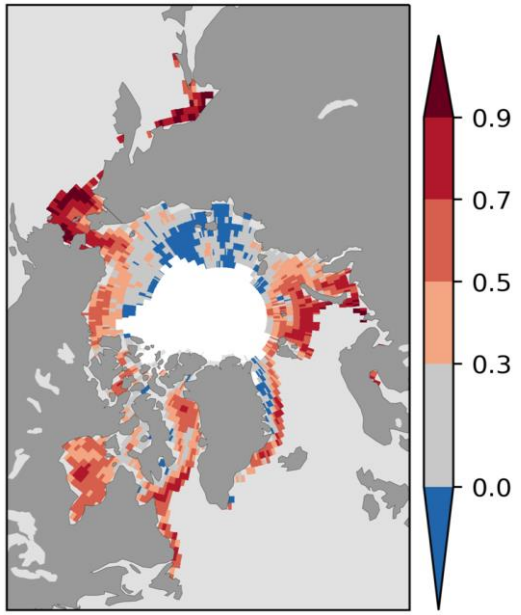
CanSIPS v2.1 Break-up Date
bias corrected
forecast from May 1



CanSIPS v2.1 Break-up Date Anomaly
2015-2023 reference period
forecast from May 1



Historical Skill 1994-2023
anomaly correlation detrended

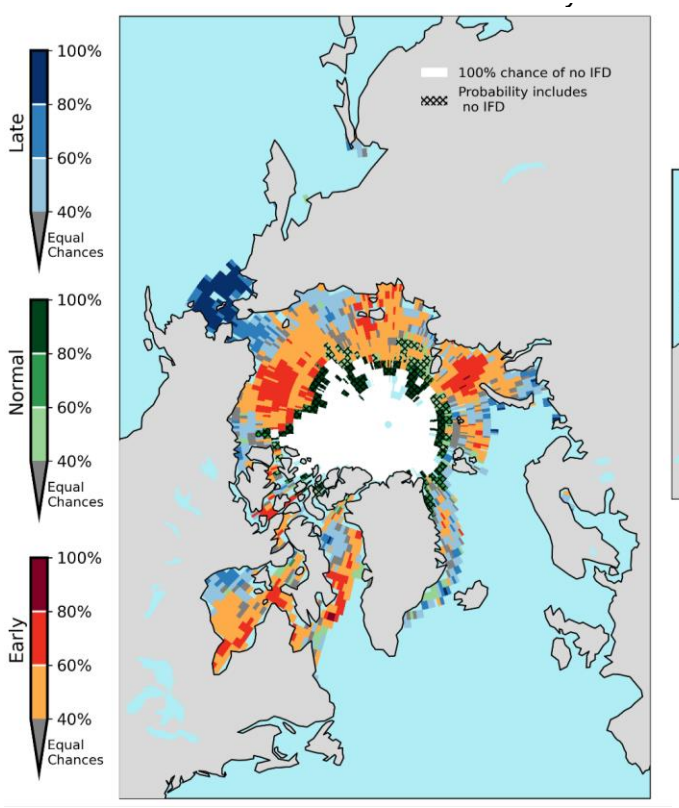


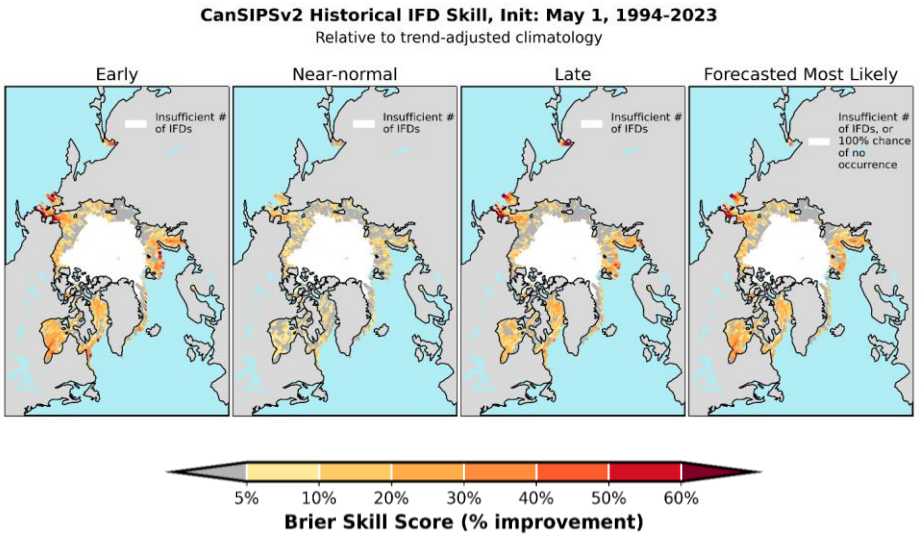
CanSIPS v2.1 probabilistic forecast for break-up: Chance of early, near-normal or late break-up dates relative to 2015-2023

White area represents 100% chance that retreat does not occur (concentration never <50%)

Hatching indicates where near-normal category is most likely, and includes the case that retreat does not occur (concentration never <50%)

CanSIPS v2.1 Probability for Early, Near-Normal or Late Break-up
forecast from May 1

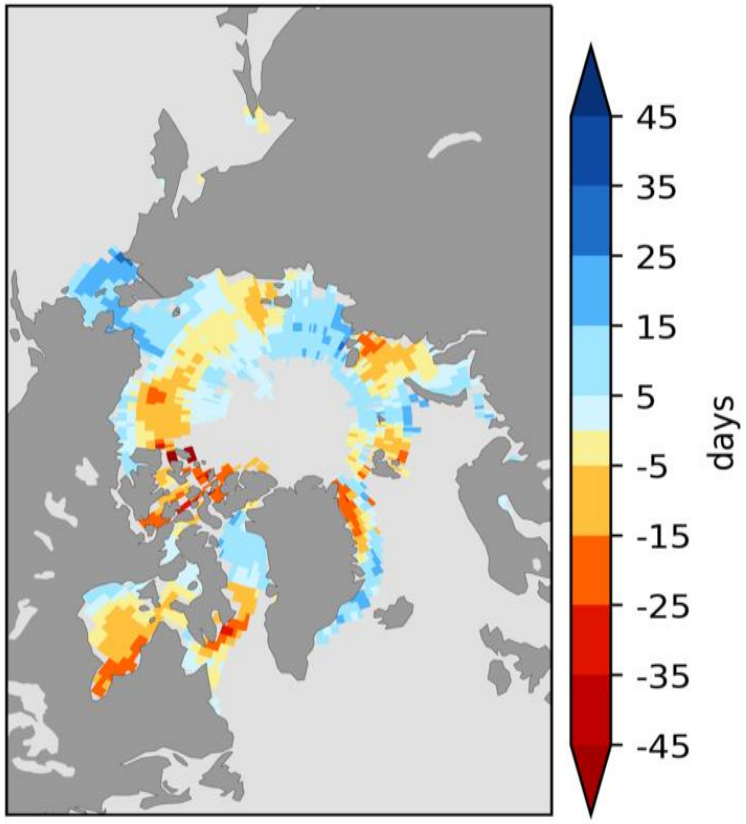




In historical skill maps, white areas represent locations that were too seldom ice free in 1994-2023 for skill to be calculated

ArcRCC Summer 2024 Outlook
Sea Ice Break-up

Deterministic break-up forecast from CanSIPSv2.1: break-up date anomaly from 2015-2023 average.



What is Normal break-up?

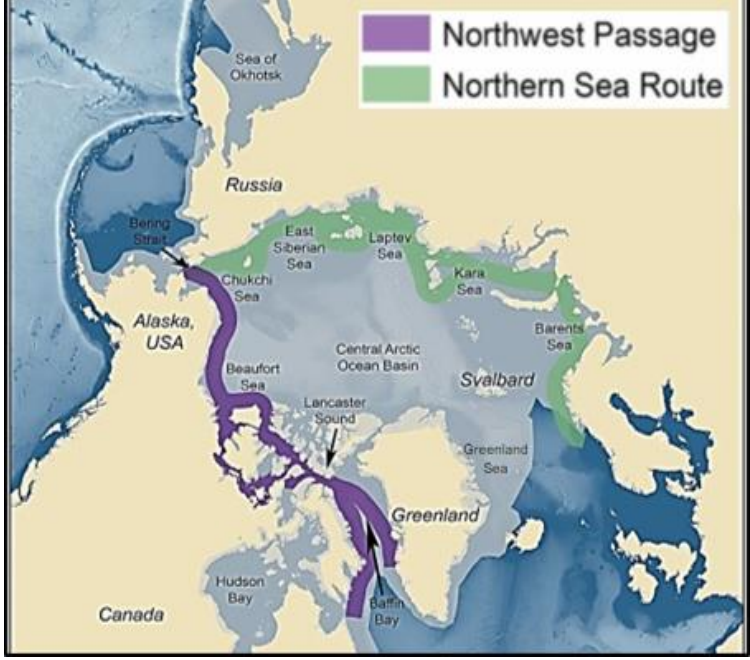
- the date when the ice concentration drops below 50%
- based on past 9-year reference period (2015-2023)

Break-up Categories:

- Red = Late break-up
- Yellow-light Blue = Near normal break-up
- Blue = Early break-up

Regions	CanSIPSv2.1 Sea-Ice Forecast Confidence	CanSIPSv2.1 Sea-Ice Break-up Forecast
Bering	High	**Late**
Chukchi Sea	Moderate	**Late, Early (North)**
Beaufort Sea	Moderate	**Early; Late (Southeast)**
CAA	Low	**Early**
Hudson Bay	High	**Early (East); Late (West)**
Baffin Bay	High	**Early (South); Late (North)**
Greenland Sea	Low	**Late-normal (South); Early (North)**
Barents Sea	High	**Early (West), Late (East)**
Kara Sea	Moderate	**Late (east); Early (west)**
Laptev Sea	Low	**Late**
East Siberian Sea	Low	**Late (South); Early (North)**

ArcRCC September 2024 Sea Ice Extent Outlook



What is Normal Ice Extent?

- average ice extent over the past 9-year reference period (2015-2023)
- ice extent defined using 15% ice concentration

Forecast Categories (2015-2023 normal) :

- Above normal ice extent
- Near normal ice extent
- Below normal ice extent

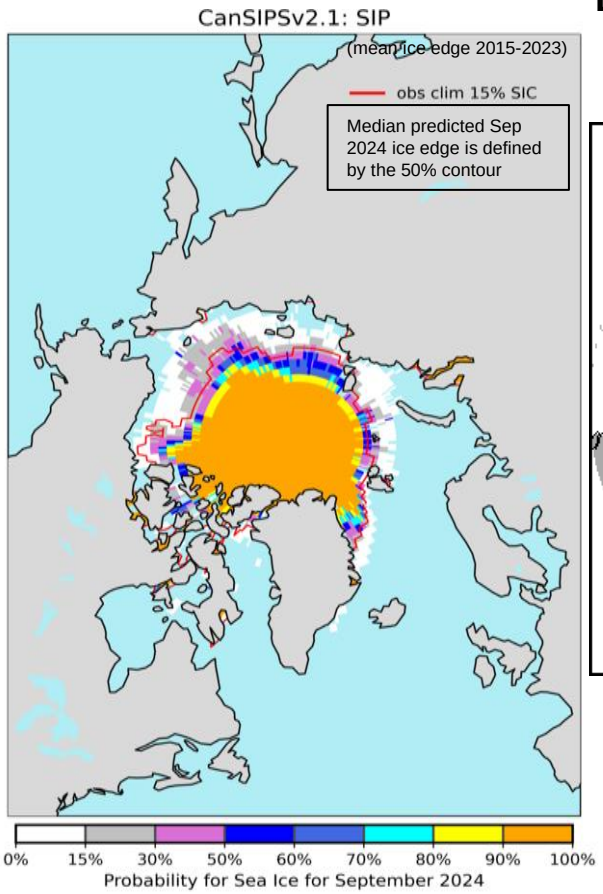
Outlook Confidence Categories:

- low
- moderate
- high

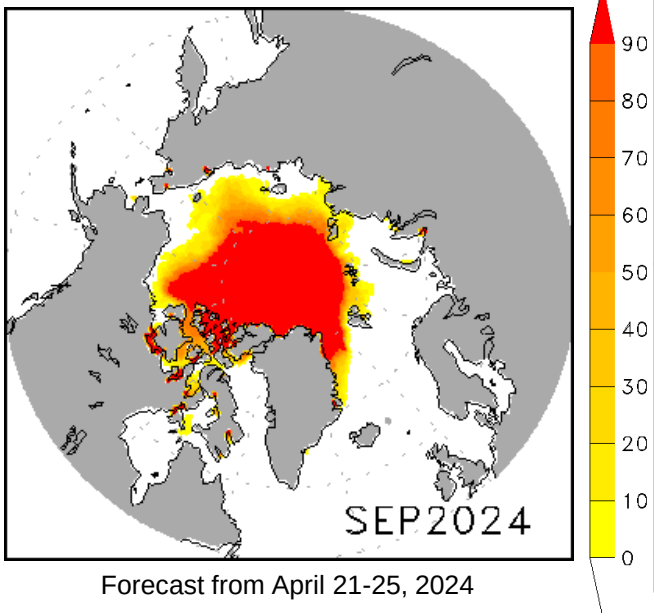
Regions	Sea-Ice Forecast Confidence	Sea-Ice Forecast Extent
Greenland Sea		
Barents Sea		
Kara Sea		
Laptev Sea		
East Siberian Sea		
Chukchi Sea		
Beaufort Sea		
Canadian Arctic Archipelago		

Model Guidance for September Ice Extent: Probability of monthly mean September 2024 sea ice concentrations exceeding 15%

CanSIPS v2.1 Forecast
Forecast from May 1, 2024



Experimental UFS forecast (NOAA)
Forecast from April 21-25, 2024

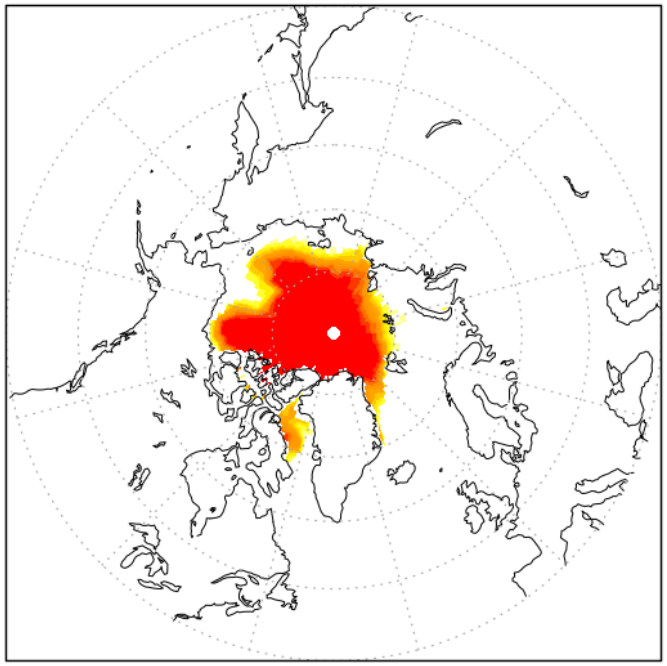


Forecast from April 21-25, 2024

NOAA experimental UFS forecast from

https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

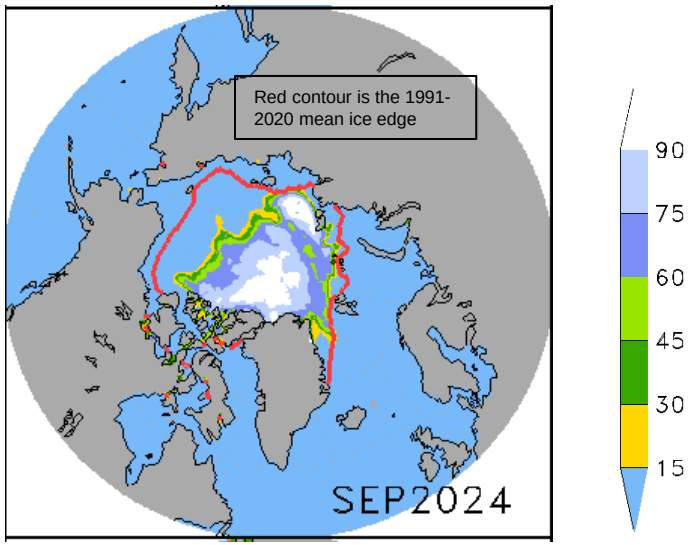
Experimental INMCM5 Forecast
Forecast from April 22, 2024



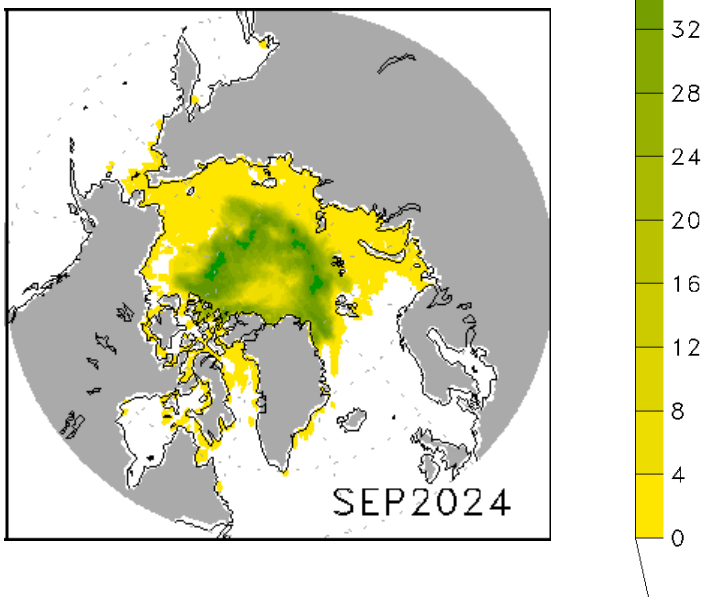
Forecast from April 22, 2024

Model Guidance for September Ice Extent: Deterministic forecast of ice concentration

Experimental UFS forecast (NOAA)
Ice Concentration (%)
Forecast from April 21-25, 2024

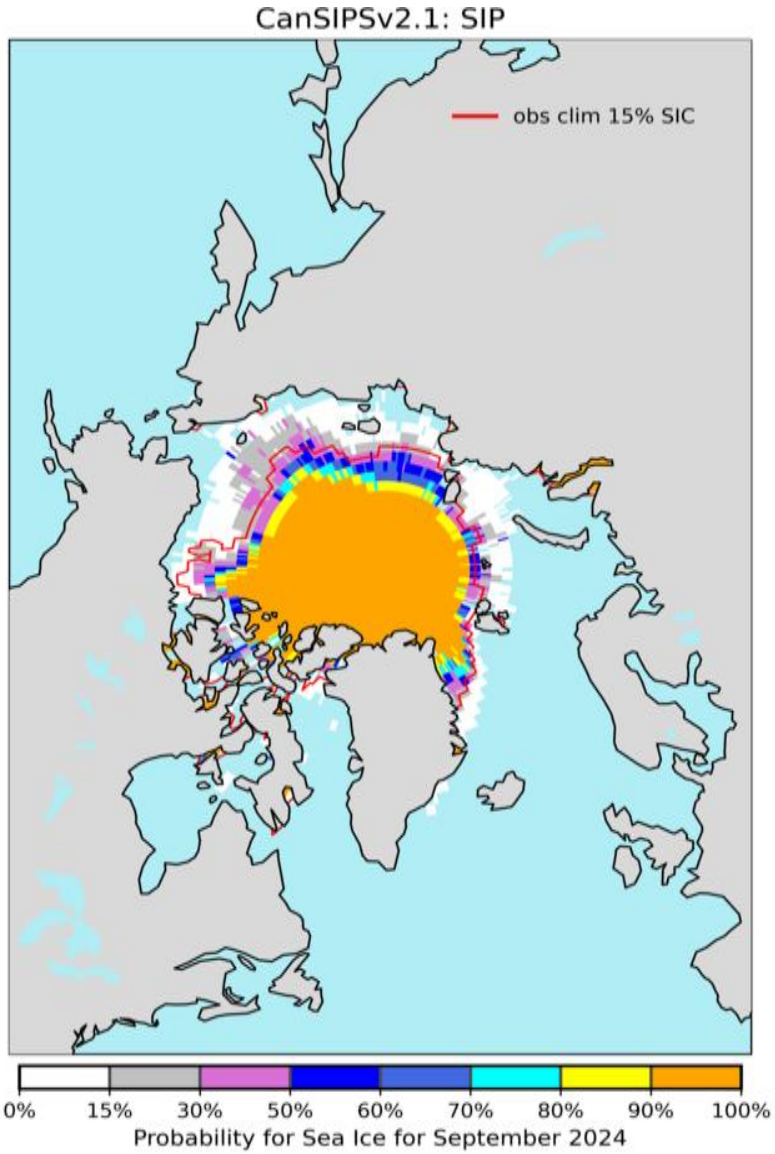


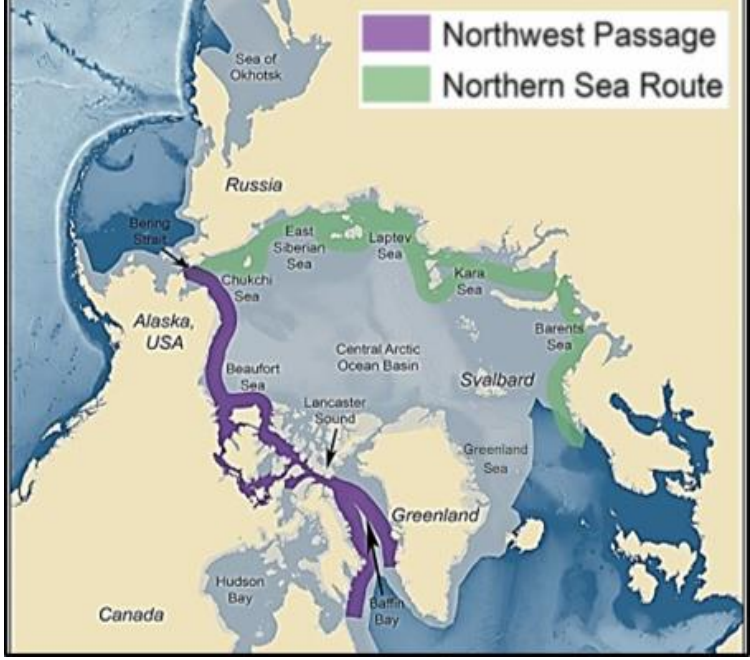
Experimental UFS forecast (NOAA)
Standard Deviation
Forecast from April 21-25, 2024



NOAA experimental UFS forecast from
https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

ArcRCC September 2024 Sea Ice Extent Outlook





Regions	Sea-Ice Forecast Confidence	Sea-Ice Forecast Extent
Greenland Sea	moderate	**Below normal**
Barents Sea	moderate	**Below to near normal**
Kara Sea	moderate	**Below normal**
Laptev Sea	moderate	**Below normal**
East Siberian Sea	moderate	**Below normal**
Chukchi Sea	moderate	**Below normal**
Beaufort Sea	moderate	**Below normal**
Canadian Arctic Archipelago	low	**Below normal**

2024 Summer Ice Conditions in Key Shipping Areas

Produced by the National Ice Services

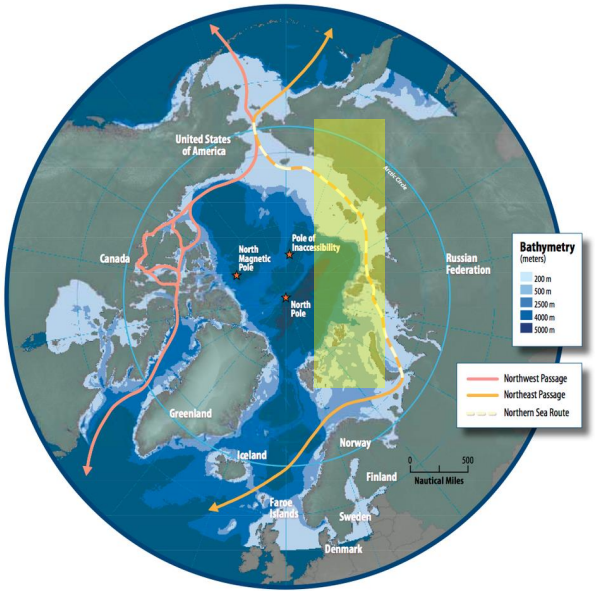


Figure from Arctic Council - Arctic marine shipping assessment

Northern Sea Route

During the summer of 2024, **above-normal** temperatures are expected with moderate confidence throughout the Northern Sea Route, except for the Chukchi Sea, where **below-normal** temperature anomalies are expected.
This leads to **below-normal** sea ice concentrations over most of the Northern Sea Route.

However, due to the **late** break-up of the southern part of the Chukchi Sea and the East Siberian Sea, shipping across the Northern Sea Route is expected to start **later than normal**.

Outlook: later than normal start to the shipping season

Region	Break-up	Multi Model Agreement
Kara Sea	**Late (east)** **Early (west)**	Moderate
Laptev Sea	**Early**	Moderate
East Siberian Sea	**Late** **Early (north)**	Moderate Low (north)
Chukchi Sea	**Late** **Early (north)**	Moderate (low in the north)

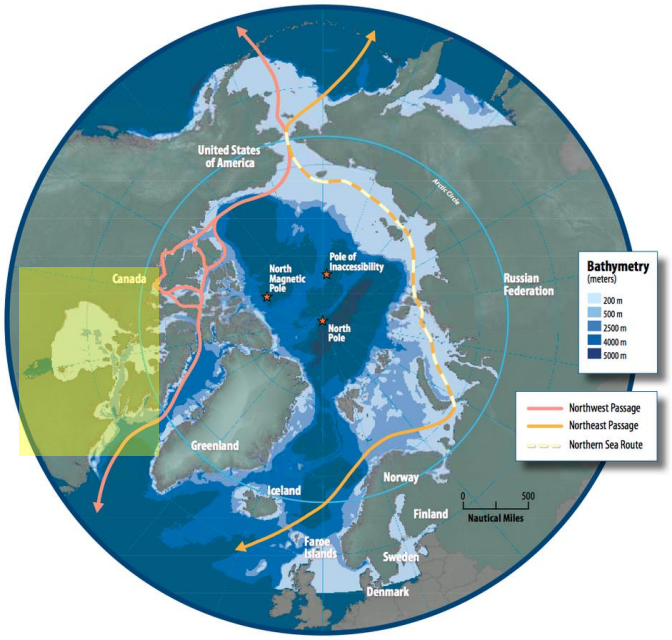
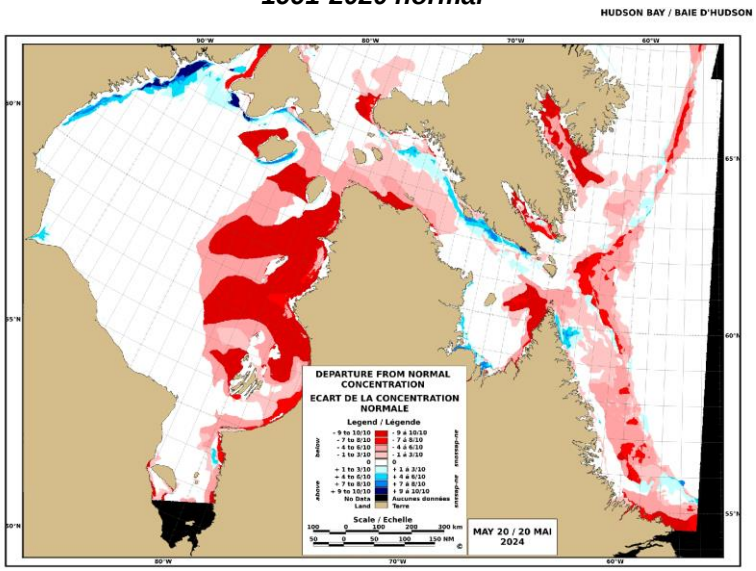


Figure from Arctic Council - Arctic marine shipping assessment

May 20 Ice Concentration Anomaly
1991-2020 normal



Hudson Bay and Hudson Strait

current conditions as of May 20th

- below normal ice concentrations compared to 30-year normal
- below normal ice cover compared to the last 10 years
- melt more advanced than at this time last year

Model forecast for earlier than normal break-up, warmer than normal spring temperatures. If the break-up forecast for eastern Hudson Bay is correct, ice could linger by the port of Churchill a little later than normal

Outlook: normal shipping season, an early start is likely

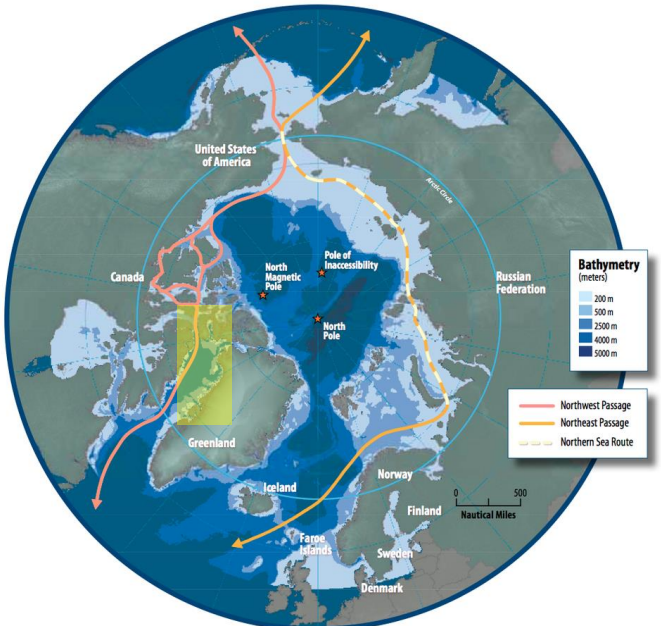
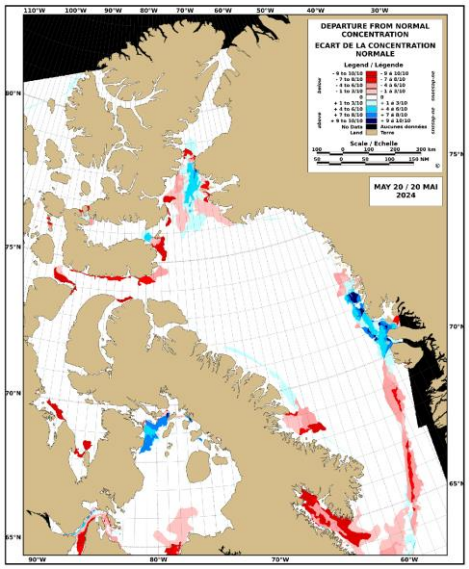
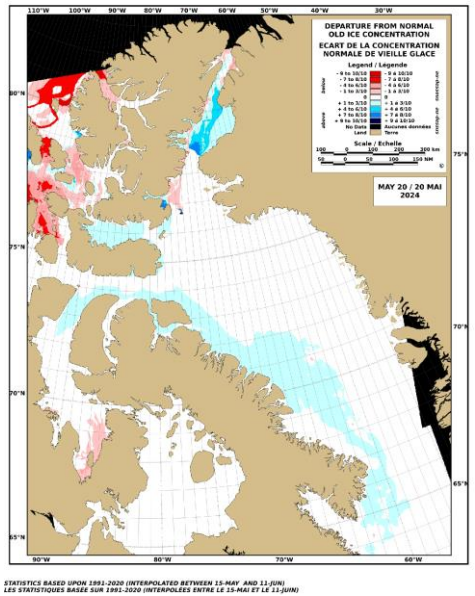


Figure from Arctic Council - Arctic marine shipping assessment

May 20 Ice Concentration Anomaly
1991-2020 normal



May 20 Old Ice Anomaly
1991-2020 normal



Baffin Bay

current conditions as of May 20th

- below normal ice concentration compared to 30-year normal
- below normal ice cover compared to the last 10 years
- less ice cover compared to last year
- slightly more old ice in the area compared to 30-year normal
- old ice area comparable to last year

Model forecast for an early clearing (south), warner than normal air temperatures in southern Baffin Bay but no model agreement in northern Baffin Bay.

Outlook: normal shipping season, an early start is likely

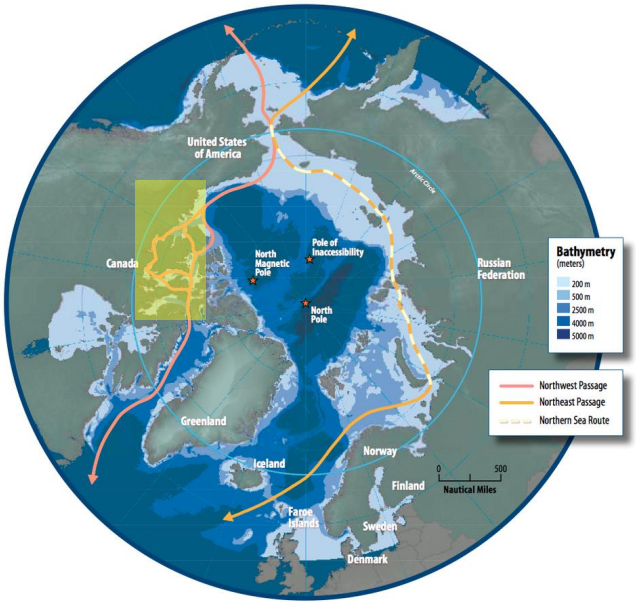
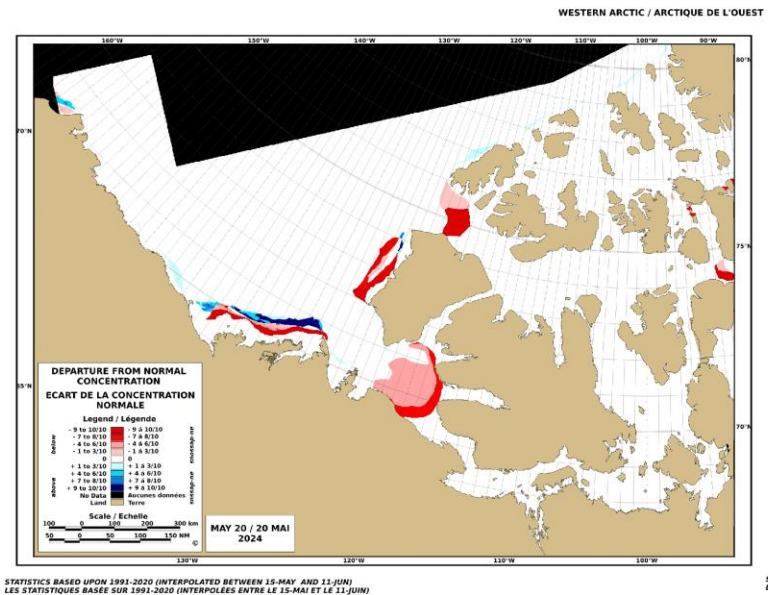
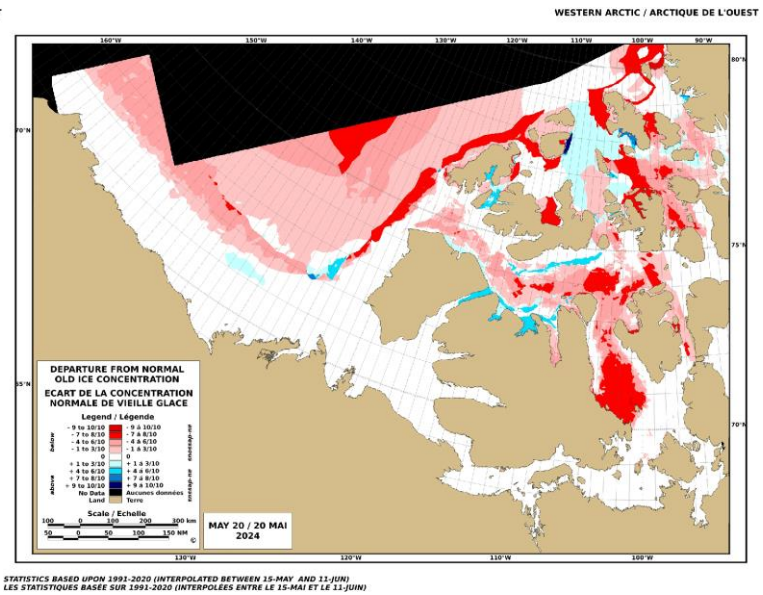


Figure from Arctic Council - Arctic marine shipping assessment

May 20 Ice Concentration Anomaly
1991-2020 normal



May 20 Old Ice Anomaly
1991-2020 normal



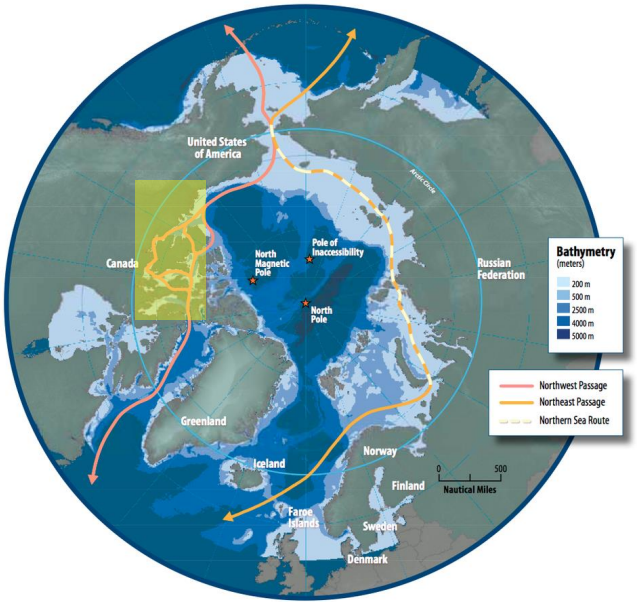


Figure from Arctic Council - Arctic marine shipping assessment

Northwest Passage

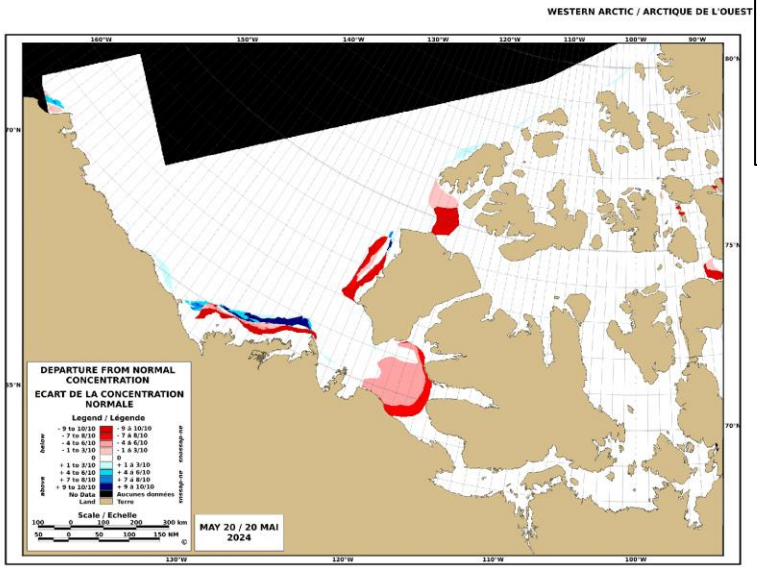
current conditions as of May 20th

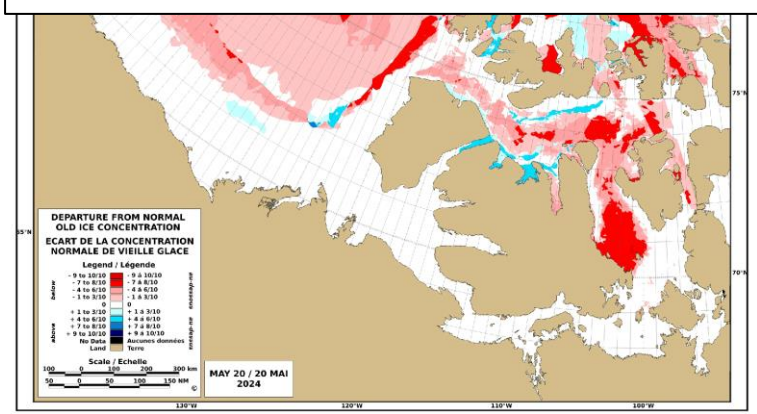
- earlier than normal clearing for this time of year in M'Clure Strait (northern route) and Amundsen Gulf (southern route) compared to 30-year and 10-year normals
- considerably less MYI in the regional compared to 30-year and 10-year normals

Model forecast for an early clearing (low skill) and warmer than normal air temperatures

Outlook: normal shipping season, an early start is likely

May 20 Ice Concentration Anomaly
1991-2020 normal





Models and methods

ECCC CanSIPSv2 seasonal forecasting system

Lin, H., W. J. Merryfield, R. Muncaster, G. C. Smith, M. Markovic, F. Dupont, F. Roy, J.-F. Lemieux, A. Dirkson, S. Kharin, W.-S. Lee, M. Charron, A. Erfani, 2020: The Canadian Seasonal to Interannual Prediction System Version 2 (CanSIPSv2). *Weather and Forecasting*, **35**, 1317-1343, https://doi.org/10.1175/WAF-D-19-0259.1

ECCC CanSIPSv2.1 seasonal forecasting system

https://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/tech_notes/technote_cansips-210_e.pdf

SIP forecasting method

Dirkson, A., W. J. Merryfield and A. H. Monahan, 2019: Calibrated Probabilistic Forecasts of Arctic Sea Ice Concentration. *Journal of Climate*, **32**, 1251-1271, https://doi.org/10.1175/JCLI-D-18-0224.1

IFD/FUD deterministic forecasting method

Sigmond, M., M. C. Reader, G. M. Flato, W. J. Merryfield and A. Tivy, 2016: Skillful seasonal forecasts of Arctic sea ice retreat and advance dates in a dynamical forecasting system. *Geophysical Research Letters*, **43**, 12,457-12,465, https://doi.org/10.1002/2016GL071396

IFD/FUD probabilistic forecasting method

Dirkson, A., B. Denis, M. Sigmond and W. J. Merryfield, 2021: Development and calibration of seasonal probabilistic forecasts of ice-free dates and freeze-up dates. *Weather and Forecasting*, **30**, 301-324, https://doi.org/10.1175/WAF-D-20-0066.1

NOAA UFS sea ice forecasts

Zhu, J., W. Wang, Y. Liu, A. Kumar, and D. DeWitt, 2023. Advances in seasonal predictions of Arctic sea ice with NOAA UFS. *Geophysical Research Letters*, *50*(7), p.e2022GL102392, https://doi.org/10.1029/2022GL102392

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Thank you for your attention!

Arctic Regional Climate Center Network

Icelandic Met Office

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Final thoughts

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Thank you!

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