ACF

Arctic Climate Forum

WORLD METEOROLOGICAL ORGANIZATION

ARCTIC REGIONAL CLIMATE CENTRE (ArcRCC) Network

12th Arctic Climate Forum (ACF-12)

6 – 7 November 2023, from 16:00 to 19:00 UTC

GoTo Meeting Logistics

Agenda DAY 2

TIME (UTC)	ITEM	DETAILS
16:00 (10')	**Day 1 Sum Up and Day 2 Intro**	Becki Heim - NOAA
16:10 (30')	**Arctic Summer 2023 Seasonal Summary:** • Atmospheric patterns • Temperature, precipitation, sea-ice, polar ocean and land hydrology based on observations and reanalysis data • Briefs for winter 2023-2024	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 the past season • Forecast for the next season	Anastasiia Revina - AARI, Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva - Hydromet Centre
16:55 (15')	**Q&As on Seasonal Summary of Observations**	Moderator: Jelmer Jeuring - MET Norway

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

AARI

May – September 2023 Arctic Seasonal Review

Vasily Smolyanitsky (text, obs, sea ice),

Anastasia Revina (ERA5), Anna Danshina (CMEMS)

Arctic and Antarctic Research Institute (AARI)

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

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Content of seasonal review for MJJAS 2023 (May – September 2023)

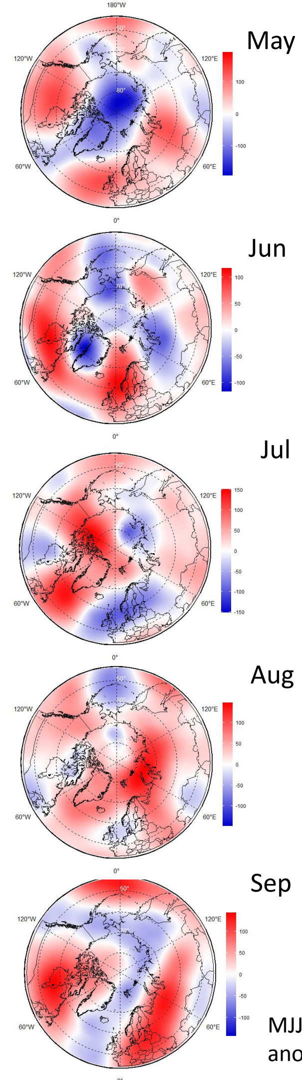
- Atmosphere
  - Precursors in atmospheric circulation
  - Surface air temperature and precipitation
- Sea ice
  - Precursors in atmosphere and polar ocean
  - Ice extent, conditions, thickness and volume
  - September 2023 summer minimum
- Polar Ocean
  - Heat content, waves and swell height (storminess)
  - pH (acidification/alkalization estimates)
- Land hydrology
  - river discharge
  - snow height and extent
- Briefs on bioclimatic weather severity
  - Introduction to particular report by Anastassiya Revina and Svetlana Emelina

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

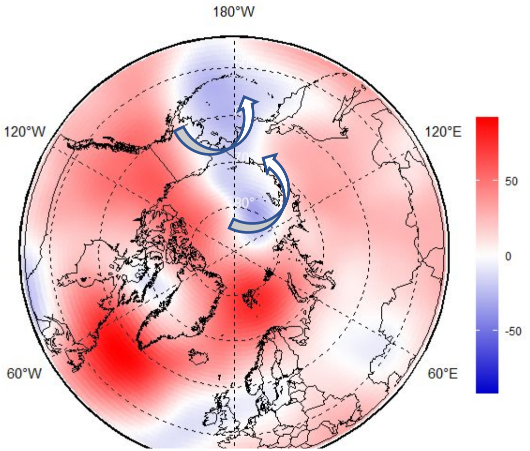
Atmosphere

- Precursors: atmospheric circulation
- Surface air temperature
- Precipitation

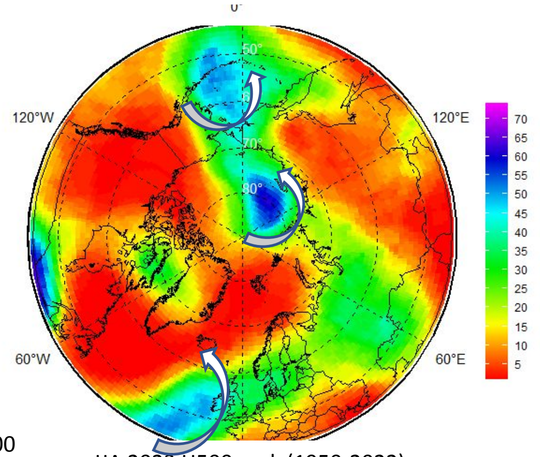
MJJAS 2023 upper atmosphere circulation (H500)



MJJAS 2023 H500 anomaly (1991-2020)



JJA 2023 H500 anomaly (1991-2020)



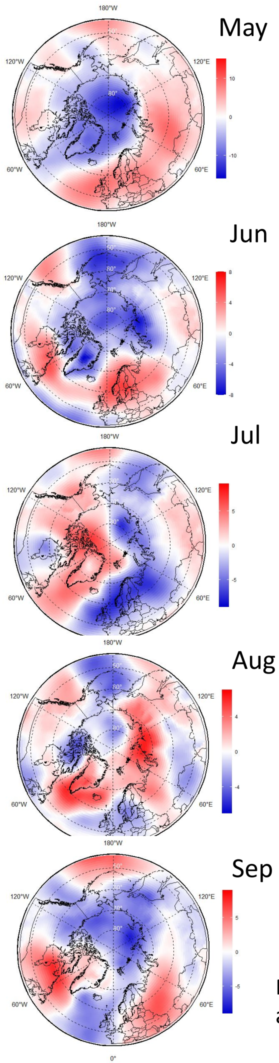
JJA 2023 H500 rank (1950-2022)

For the whole period May – September 2023 polar vortex (on the 500 hPa isobaric surface) typically had 1-3 nodes over Central Arctic, Greenland, Alaska and Siberia causing corresponding cyclonic activity underneath and blocking anticyclone features in other regions

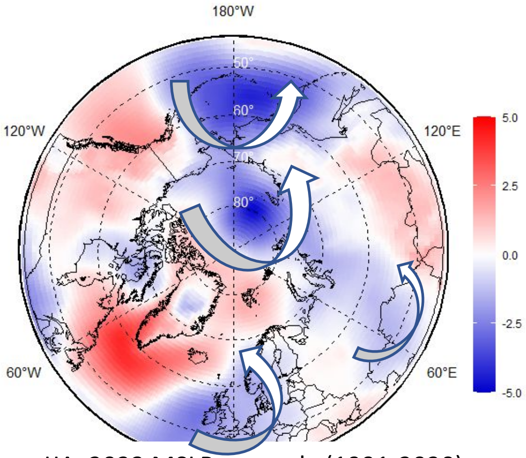
- May – major center of the vortex over N Pole region
- June, July – polar vortex is dissipating with major centers over Greenland and Alaska (June) and Alaska (July) moving to Central Canada, Siberia and Nordic regions.
- August – major center over Bering and Chukchi Seas with blocking anticyclone over Siberia
- September – diffuse region from Western Nordic to Central Siberia and further to Alaska region with an anticyclone over Eastern Nordic and Central Canada

[AARI / ERA5 analysis and reanalysis]

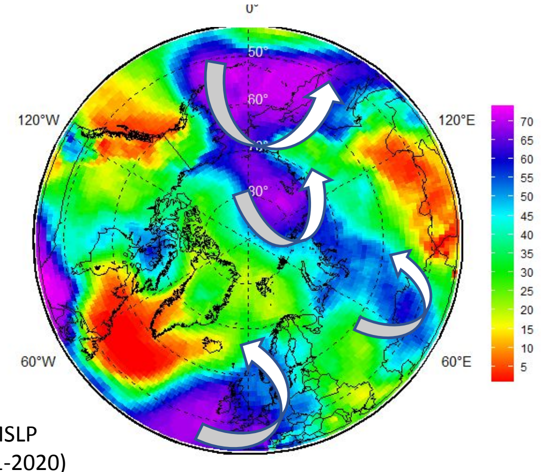
MJJAS 2023 surface atmospheric circulation



MJJAS 2023 MSLP anomaly (1991-2020)



JJA 2023 MSLP anomaly (1991-2020)



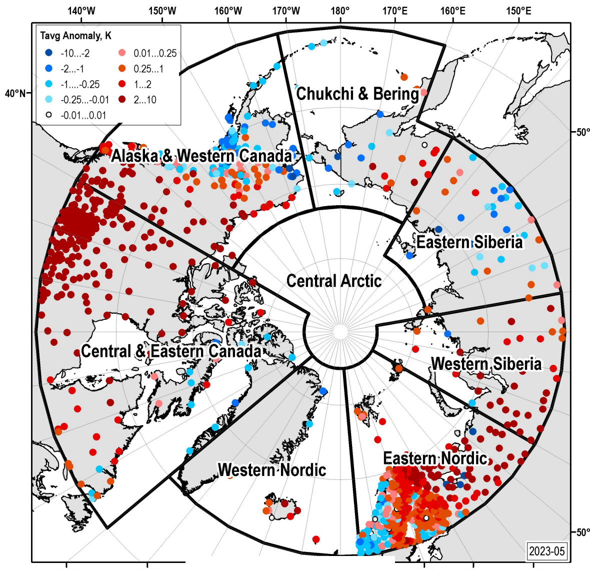
JJA 2023 MSLP rank (1950-2022)

Surface atmosphere inherits features of the upper processes with a sequence of changes from the zonal to meridian forms of circulation in corresponding regions:

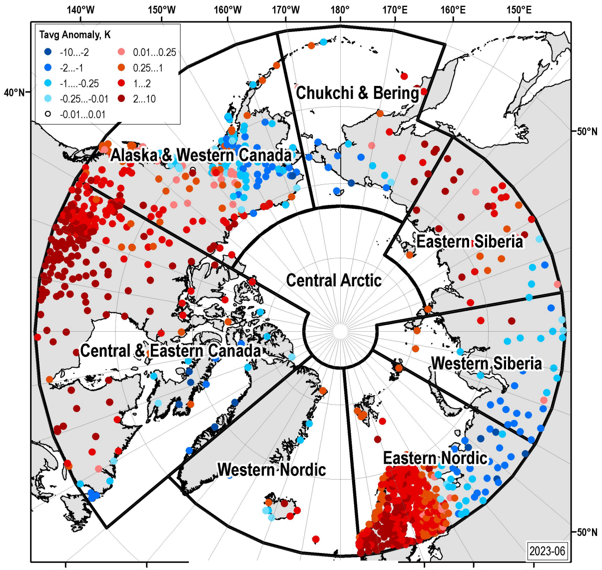
- All sectors are characterized by a complexity of circulation patterns during the season
- In the Atlantic-Eurasian sector, atmospheric processes in Jule and September are characterized by a occurrence of the western zonal circulation. In August a large-scale meridional form of circulation may be noticed
- In the Pacific-American in June and September zonal processes are predominant with zonal circulation predominant in July and August.
- In the polar region in May, June, August trajectories of the North Atlantic cyclones are shifted northward, while in July and September trajectories are close to normal.

[AARI / ERA5 analysis and reanalysis]

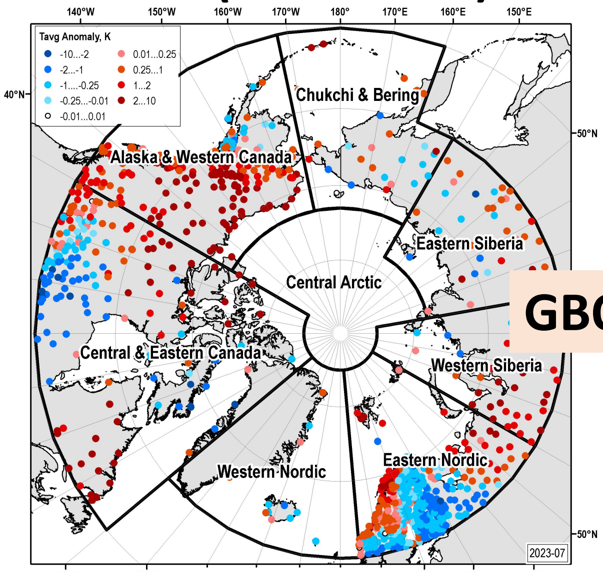
Surface air temperature: May, Jun, Jul 2023 anomalies (1991-2020)



May 2023

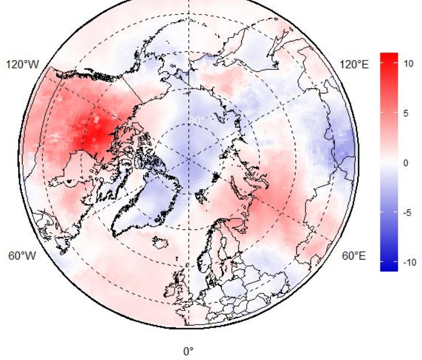


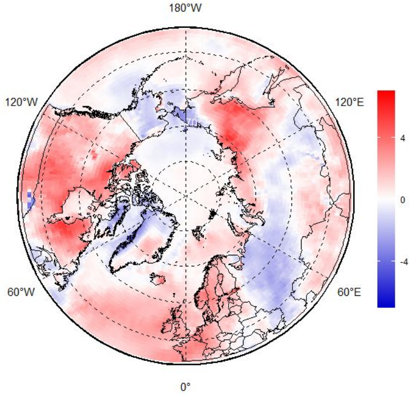
Jun 2023

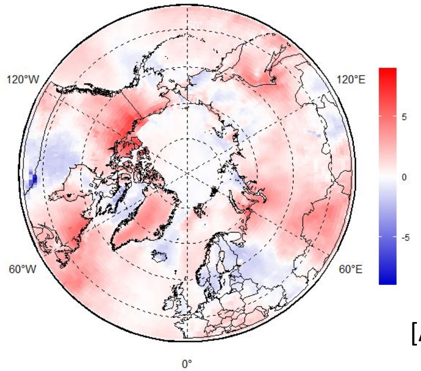


Jul 2023

GBON



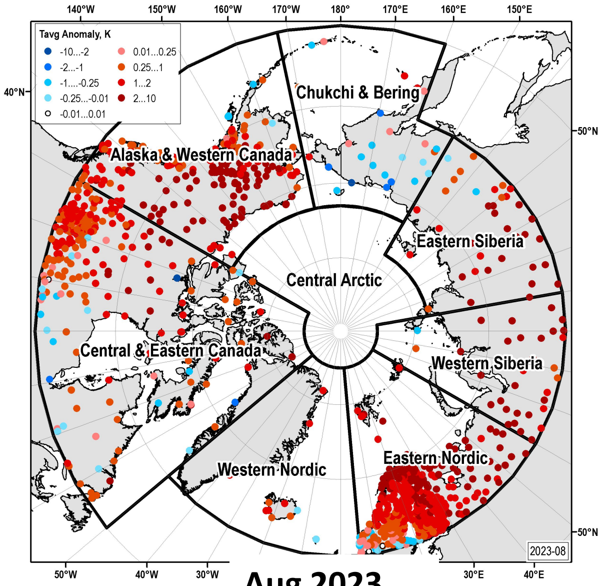




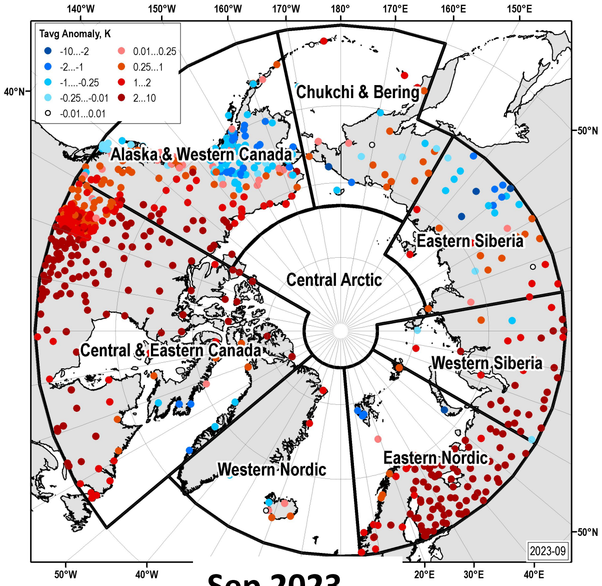
ERA5

[AARI / ERA5]

Surface air temperature: Aug, Sep 2023 anomalies (1991-2020)

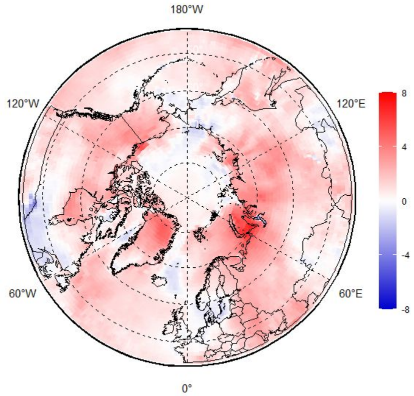


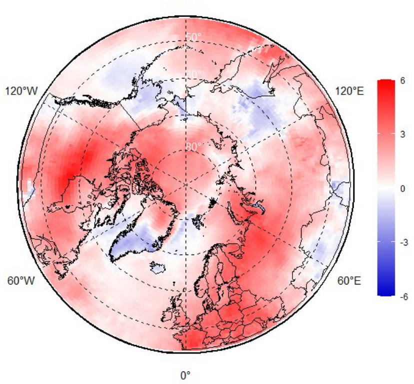
Aug 2023



Sep 2023

GBON





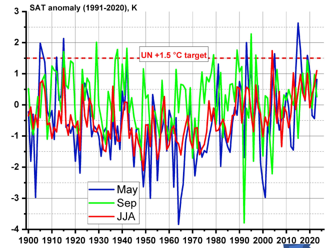
ERA5

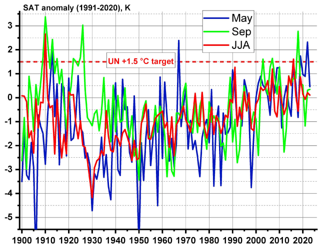
[AARI / ERA5]

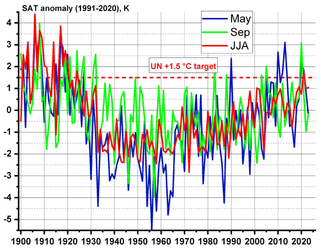
Surface air temperature (stations)

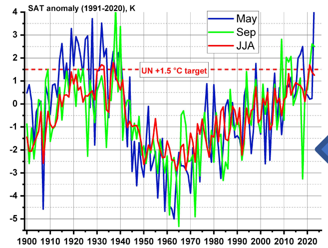
May – Sep 2023 anomalies and ranks (1158 stations used)

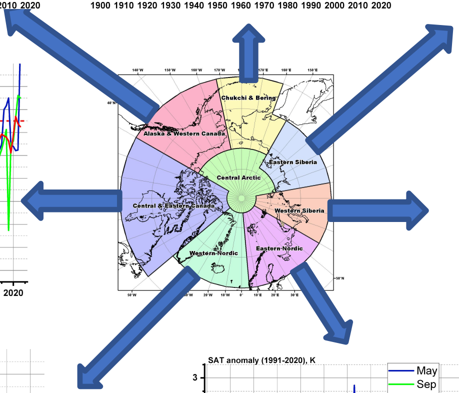
anomalies relative to: 1991-2020, ranks: 1950-2023

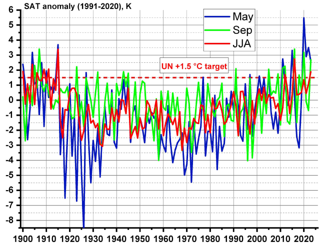


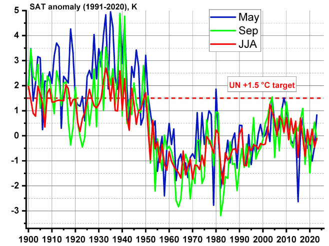


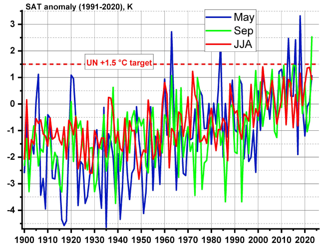












Region	Alaska & W Canada	Central & E Canada
2023-05	0.82| 10|1964|2015	4.75| 1|1963|2023
2023-06	-0.04| 19|1949|2004	2.45| 2|1902|1921
2023-07	1.61| 2|1959|2019	0.18| 19|1972|2021
2023-08	1.80| 2|1969|2004	1.17| 4|1968|2022
2023-09	0.26| 32|1992|1995	2.50| 3|1965|1938
JJA 2023	1.10| 2|1949|2004	1.25| 4|1968|2021

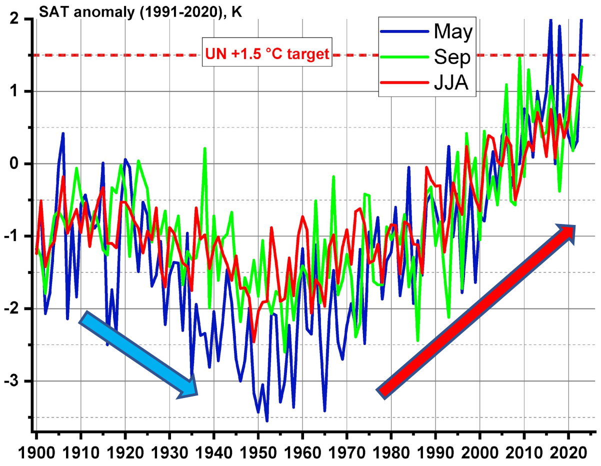
Region	Western Nordic	Eastern Nordic
2023-05	0.83| 13|1979|1935	1.06| 9|1935|2018
2023-06	-0.13| 25|1983|1909	1.31| 14|1941|2020
2023-07	-0.64| 44|1970|1933	-0.15| 26|1949|2018
2023-08	0.47| 10|1983|1939	1.61| 3|1918|2006
2023-09	-0.17| 27|1982|1939	2.53| 1|1939|2023
JJA 2023	-0.11| 25|1983|1933	0.93| 8|1949|2002

Region	Western Siberia	Eastern Siberia	Chukchi & Bering
2023-05	2.59| 6|1926|2020	-0.21| 25|1956|1906	0.46| 19|1906|1967
2023-06	0.71| 14|1933|2012	1.23| 7|1958|1906	0.35| 14|1933|2016
2023-07	1.55| 6|1934|1911	0.06| 22|1939|1908	0.23| 16|1930|2010
2023-08	3.05| 2|1917|1907	1.81| 1|1915|2023	-0.18| 27|1998|1910
2023-09	2.69| 3|1996|1907	-0.17| 30|1957|1908	0.35| 18|1965|1910
JJA 2023	1.89| 2|1968|1915	1.04| 3|1972|1906	0.11| 18|1930|1910

Anom(Rank|Yearmin|Yearmax)

[AARI / WMO GTS]

Surface air temperature (based on stations data)

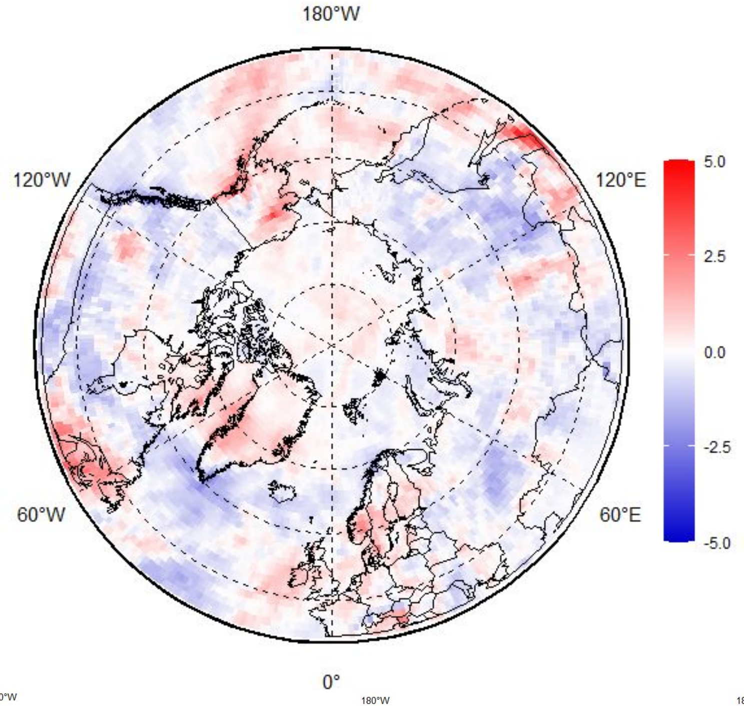


Region	Arctic total
2023-05	2.15 | 1|1952|2023
2023-06	1.24 | 3|1949|2021
2023-07	0.45 | 9|1949|2018
2023-08	1.58 | 1|1956|2023
2023-09	1.34 | 2|1956|2009
JJA 2023	1.08 | 3|1949|2021

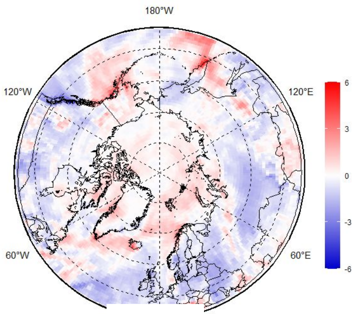
Anom(Rank|Year$_{min}$|Year$_{max}$)

- During **start of summer 2023 (May-Jun)** **strong** or **extremely positive** anomalies of the surface air temperature were observed for **Eastern Nordic** (9th – 14th in row), **Western** (6th – 14th in row) and **Eastern Siberia** (7th in row in June), **Alaska and Western Canada** (10th in row in May), **Central and Eastern Canada** (1st – 2nd in row), with **Western Nordic** and **Chukchi-Bering** regions remaining close to normal
- During **mid-summer (Jul-Aug)** similar **strong** or **extremely positive** anomalies were observed over all regions with exception of Chukchi-Bering: the **Western** (10th in row in August) and **Eastern Nordic** (3rd in row in August), **Western** (6th and 2nd) and **Eastern Siberia** (1st in row in August), **Alaska and Western Canada** (2nd in August) and **Central and Eastern Canada** (4th – 3rd).
- **By the end of summer in September 2023** similar **extremely positive** anomalies were observed over **Eastern Nordic** (1st in row), **Western Siberia** (3rd in row), **Central and Eastern Canada** (3rd in row) with **some negative** anomalies over **Western Nordic** (27th in row) and **Eastern Siberia** (30th in row).
- Conclusions for the **Central Arctic** (due to lack of in-situ observations) are done on reanalysis, and include partly colder conditions in May 2023, close to normal in Jun – August and warmer in September 2023.
- For the whole **land Arctic** during May – August 2023 only **extremely positive** anomalies were observed with ranks varying from the record **1st** (May, August) to 9th (July). Preliminary resulting rank for JJA 2023 for the land Arctic is the **3rd in row** (from 1950), though large regional and inner season variations and changes in anomaly sign continue to occur. In general lesser scale of anomalies is observed for the Artic regions with a greater share of the sea are – the Western Nordic and Chukchi-Bering.

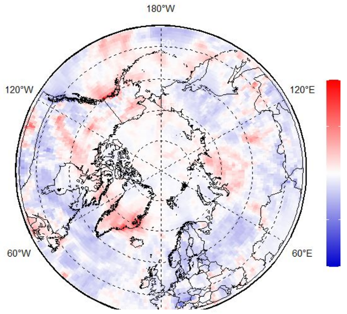
Surface precipitation: monthly JJA 2023 anomalies (1991-2020)



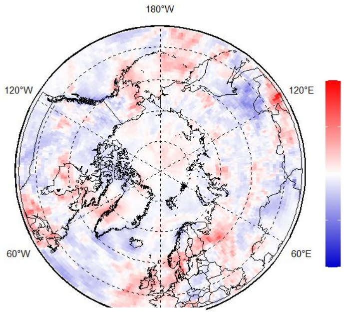
- In general, during the summer season **drier** conditions dominated over parts of Western Nordic, Eastern Siberia, Chukchi and Western Canada regions
- **Wetter** conditions dominated over parts of Eastern Nordic, Western Siberia, Alaska and Greenland regions



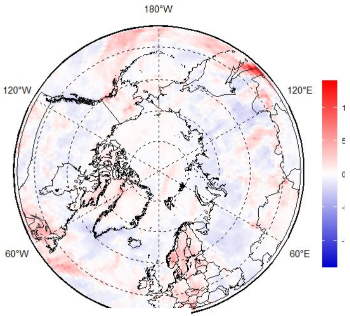
May



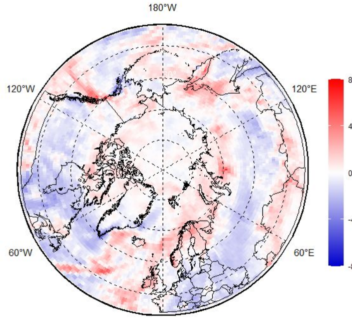
Jun



Jul



Aug



Sep

Surface precipitation: seasonal MJJAS 2023 anomalies (reanalysis)

Region	JJA 2023
Western Nordic	drier
Eastern Nordic	wetter/drier
Western Siberia	wetter/normal
Eastern Siberia	drier
Bering & Chukchi	wetter/drier
W Canada & Alaska	wetter/drier
Central & E Canada	drier/normal
Central Arctic	wetter/normal

Reference period: 1991-2020

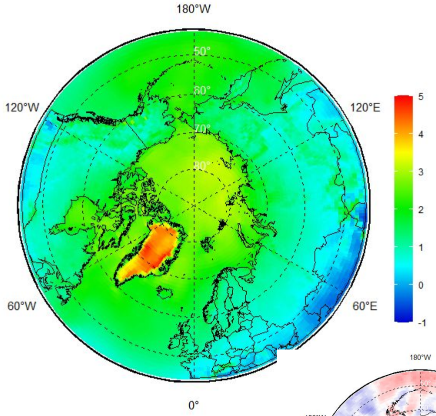
- **Lesser** precipitation occurred in the **Western Nordic** (with exception of Greenland), **parts of Eastern Siberia** and **Eastern Canada** regions
- **Greater** precipitation was observed in the **Western Siberia, parts of Eastern Nordic** and **Alaska** regions.
- Somewhat wetter / close to normal conditions are estimated for the Central Arctic

[AARI / CCCS ERA5]

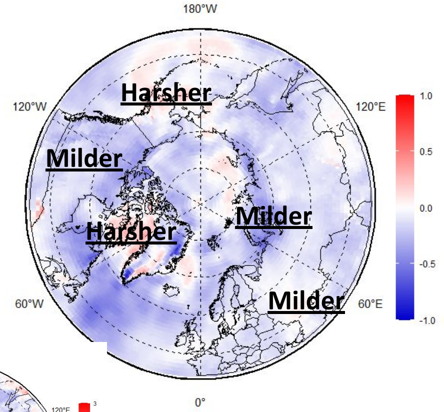
Bioclimatic weather severity

- During summer 2023 milder than for the last 30 years, though still severe, weather severity can be attributed on a basis of Bodman's index to the most of Siberia, Eastern Nordic, Canadian regions.
- Opposite situation – more severe weather can be attributed to parts of Alaska and Greenland regions.
- Particular report on bioclimatic indexes synopsis and forecast will follow.

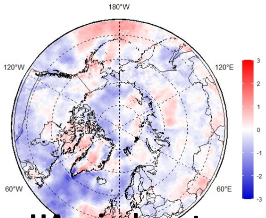
Bodman's weather severity index (S) (dimensionless) is used for bioclimatic evaluation of weather conditions for winter half year and is calculated according to Bodman's formula as
follows: $S = (1 - 0.04\,T)(1 + 0.272\,v)$ where: v is wind speed (in m/s) at 10 m above ground level and T is air temperature (in °C)
The scale in use to assess using S is:
> 6 extraordinary severe 5– 6 extremely severe
3– 5 severe & very severe 1– 3 slightly&less severe
< 1– mild



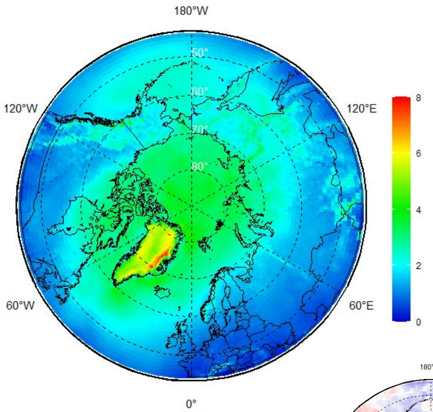
JJA 2023 Bodman's index



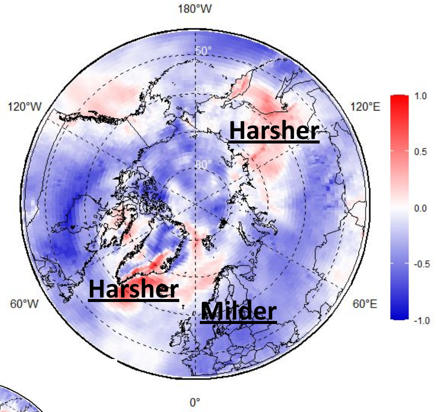
JJA 2023 Bodman's index anomaly (1991-2020)



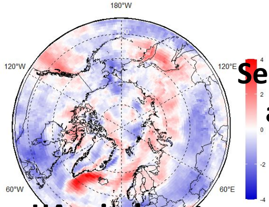
JJA wind gust anomaly



Sep 2023 Bodman's index



Sep 2023 Bodman's index anomaly (1991-2020)



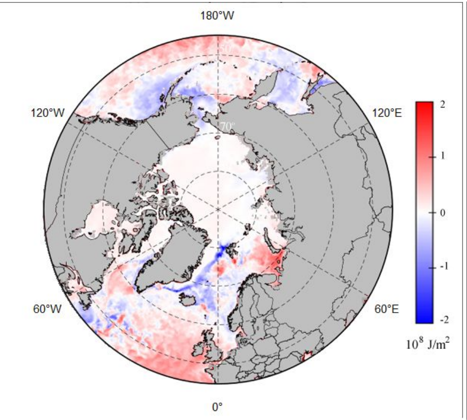
JJA wind gust anomaly

[AARI / CCCS ERA5]

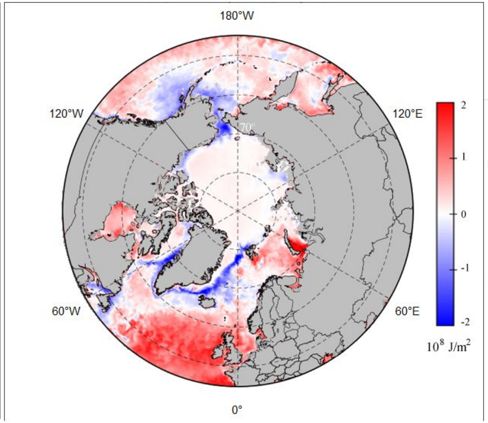
Sea ice

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

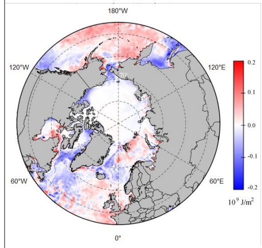
Precursors in atmosphere and polar ocean for JJAS 2023 ice conditions



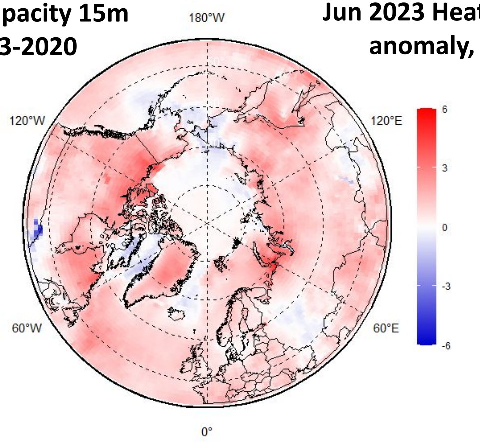
May 2023 Heat Capacity 15m anomaly, 1993-2020



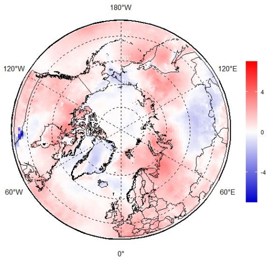
Jun 2023 Heat Capacity 15m anomaly, 1993-2020



Jun 2022



JJA 2023 SAT anomaly, 1991-2020

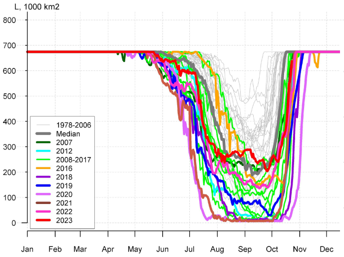


Jun 2022

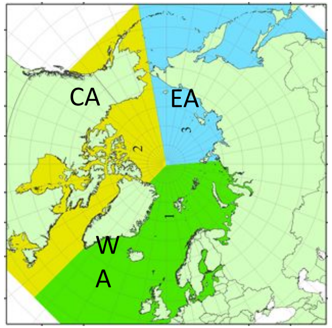
[AARI / CCCS MEMS & ERA5]

- **Negative and close to normal ocean heat capacity (HC) anomaly (to 1993-2020) in upper 15m during May-June 2023 for most of the Arctic slowed ice melt in these regions in similar way as in 2021-2022 (exceptions – Barents, W Kara)**
- Further in season, dominance of **positive** surface air temperature anomalies over Western Eurasian Arctic, W ESS, Beaufort, Hudson Bay and parts of Canadian Archipelago stimulated ice melt, though opposite **negative** or zero anomalies preserved ice cover in parts of Laptev, Eastern Siberia Seas and Canadian Arctic
- Resulting ice conditions in September 2023 resembled the previous year situation including the amount of minimum ice extent and presence of residual ice on the NSR lanes

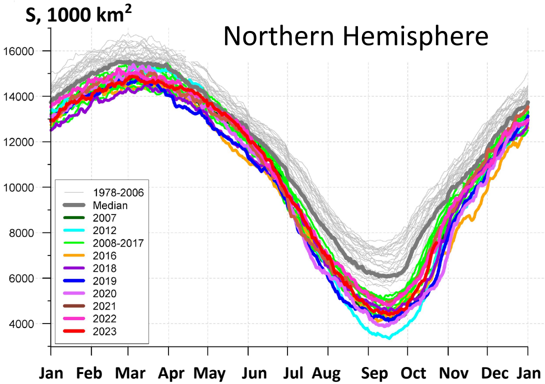
Arctic (NH) seasonal ice extent 1978…. 2023

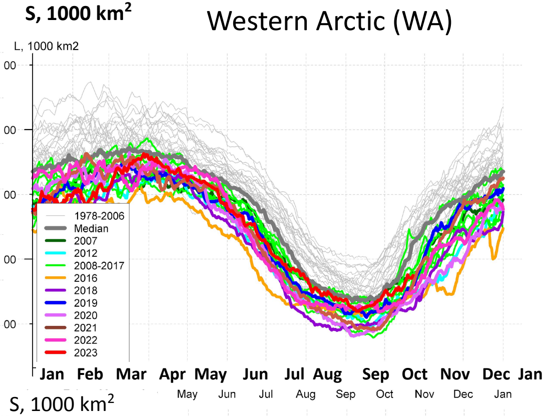


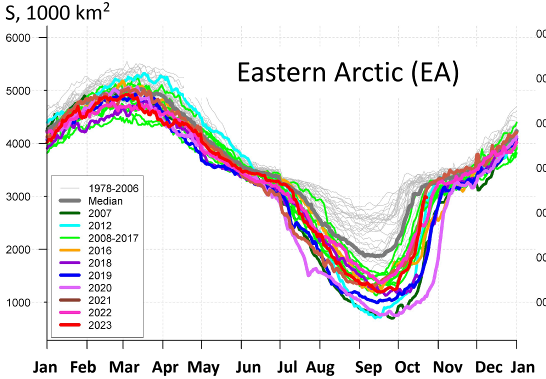
Laptev

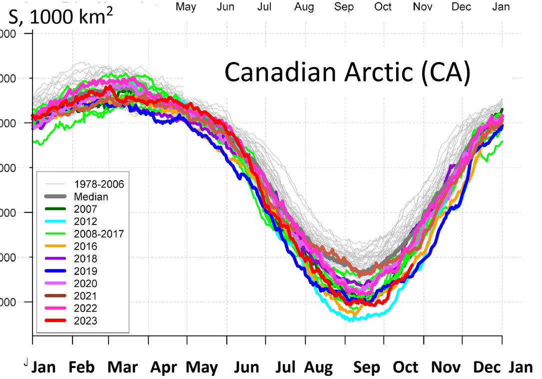


[AARI / NSIDC]









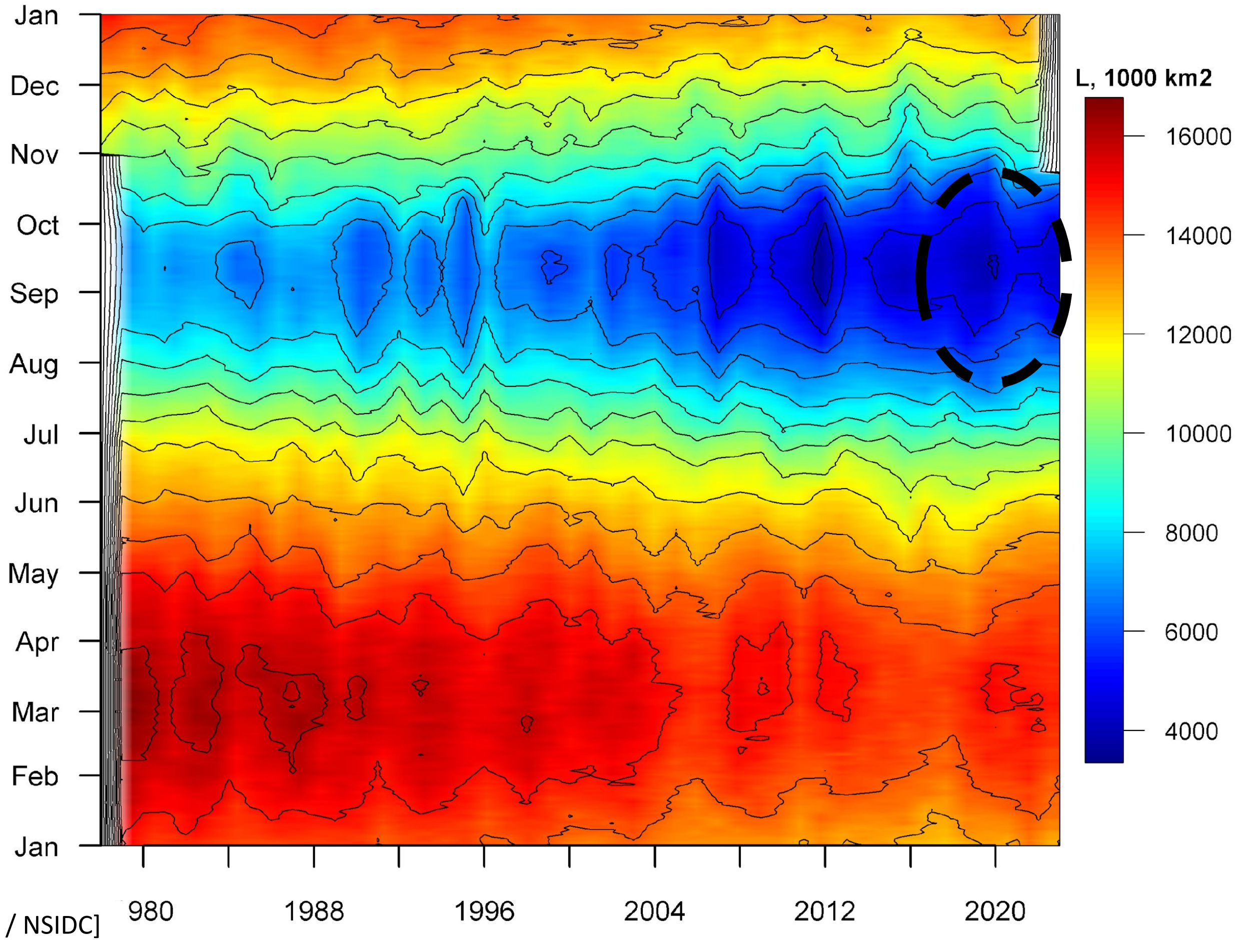
S, 1000 km²

Note: actual values depend on algorithm, technique and source used !

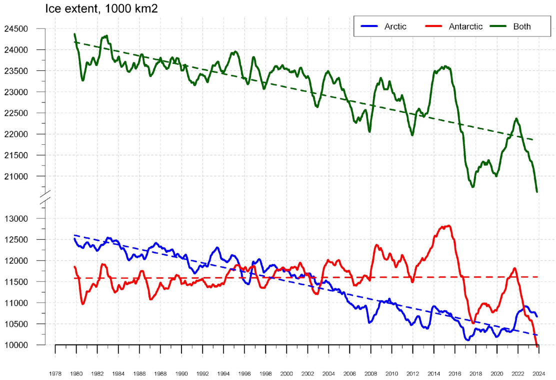
Sep (Min)			Feb/Mar (Max)		
2012	3346	1	2017	14467	1
2020	3882	2	2018	14516	2
2016	4099	3	2015	14526	3
2019	4103	4	2016	14580	4
2007	4189	5	2011	14701	5
2011	4312	6	2006	14867	6
2015	4350	7	2023	14875	7
2023	4401	8	2019	14891	8
2018	4557	9	2007	14931	9
2008	4588	10	2014	14972	10
…	…	…	2021	15100	11
2022	4808	13	…	…	
2021	4848	14	2022	15210	14
…	…		…	…	
1982	7246	43	1988	16461	43
1983	7285	44	1983	16547	44
1980	7611	45	1979	16769	45

- Minimum summer 2023 ice extent, 8th in row, ~4.4 mln km^2 , was reached near 17 Sep 2023 is by 0.4 mln km^2 less than in 2022 (12th in row, ~4.8 mln km^2 reached 18 Sep 2022) but is well within the scale of Arctic ice extent variability since 2007.
- Maximum Arctic (NH) winter 2023 ice extent, 7th in row, ~14.9 mln km^2 (~15,2 in 2022, 14th in row) was reached near 4-5 March 2023, which is close in time to climatic date and scale since 2007, which is opposite to drastic drop of Antarctic winter ice this year.

Seasonal NH ice extent variability: 1978 -2023

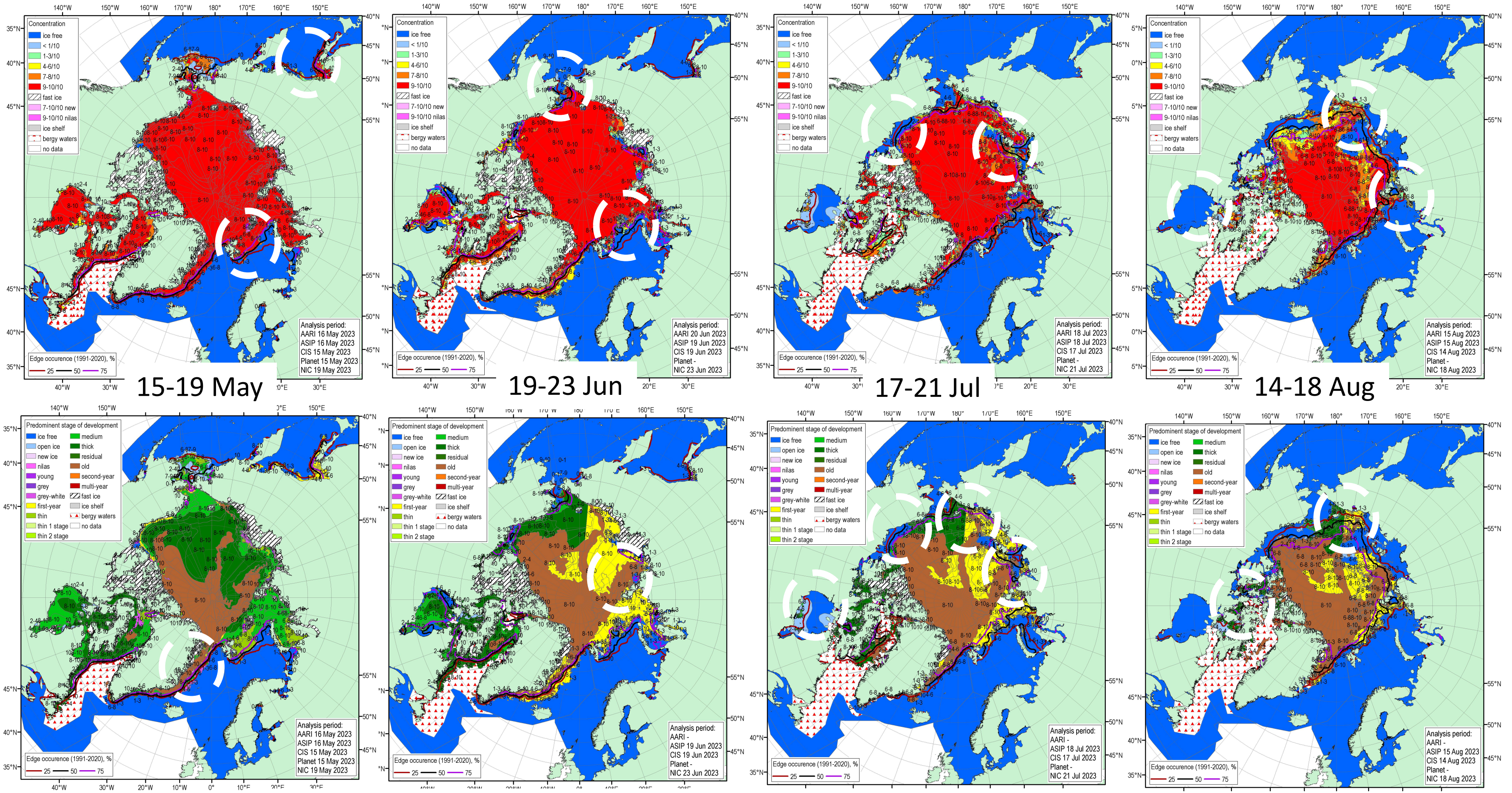


[AARI / NSIDC]



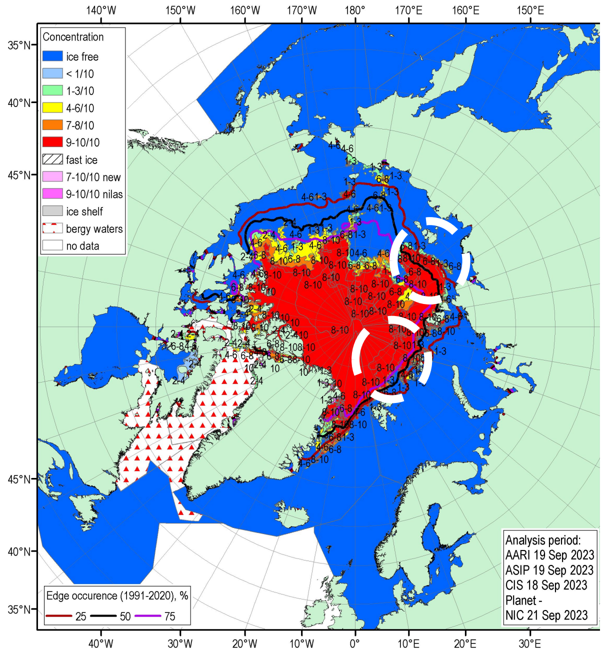
- Seasonal patterns and smoothed annual patters of daily ice extent allow to retrieve additional information on interseasonal and interannual variability of ice extent
- Though both winter maximums and summer minimums are generally diminishing, quasi-cyclicity of 2-6 years continue to occur and may be used for rough estimates of the

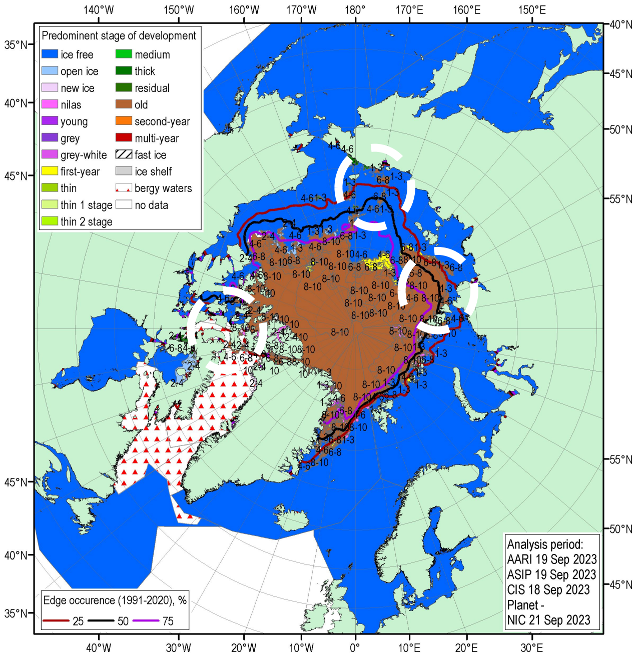
May – Aug 2023 Arctic sea ice – concentration and stage of development



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

Sep 2023 Arctic sea ice – concentration and stage of development at the moment of summer minimum



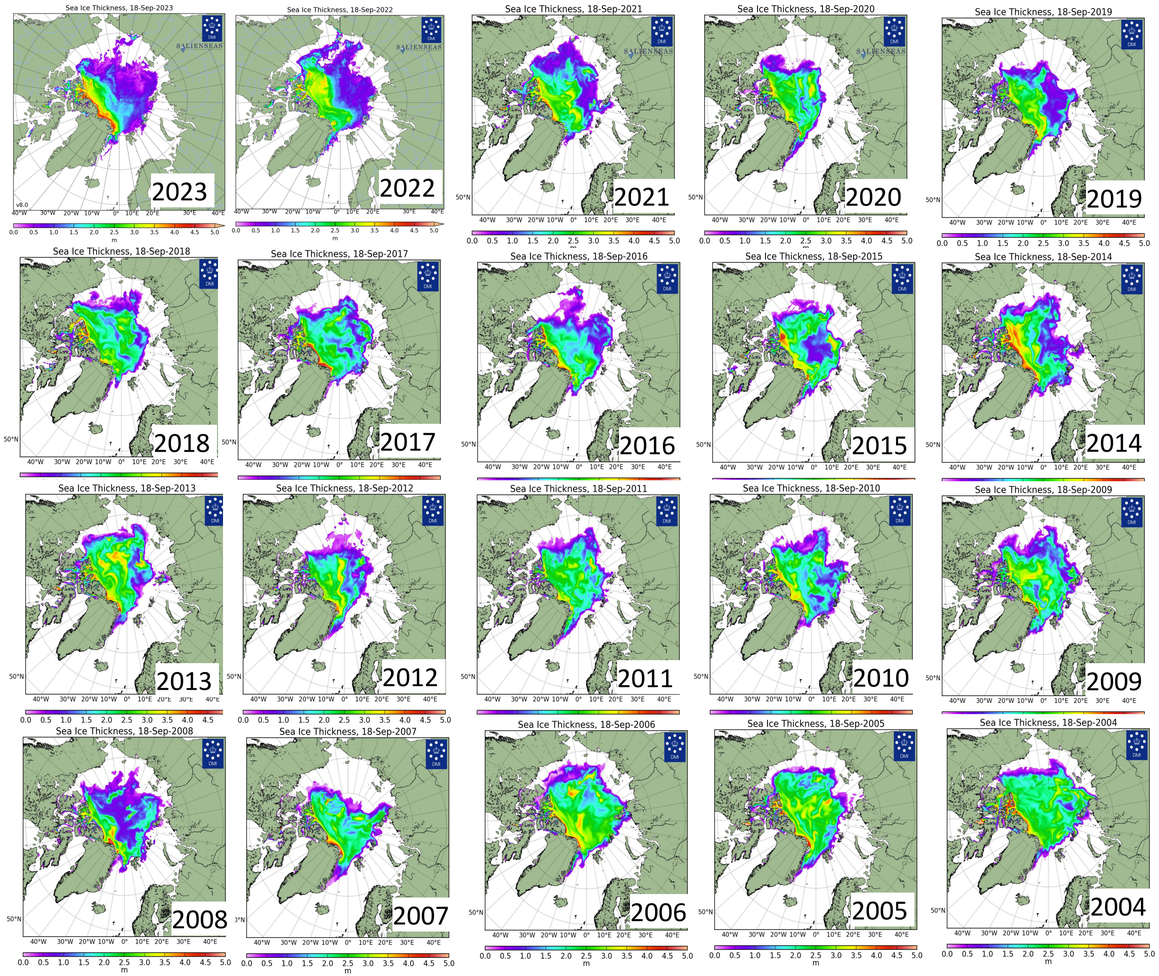


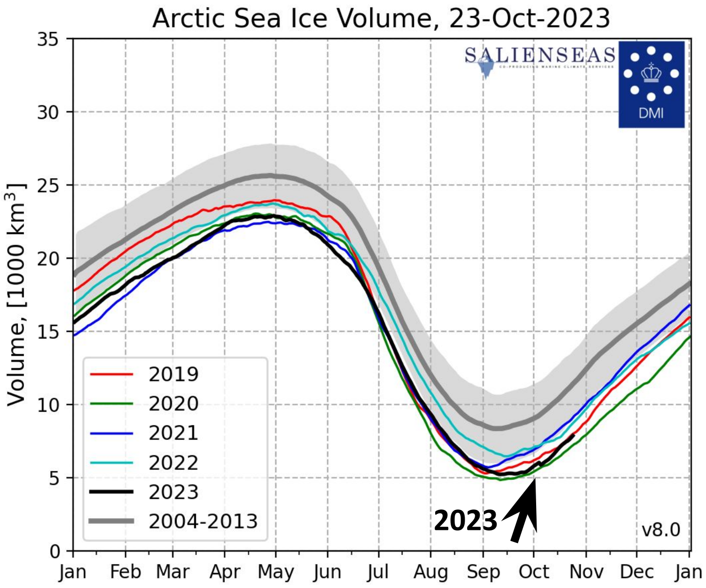
18-21 Sep 2023 (minimum)

- Observed in September 2023 8th in row summer Arctic ice cover minimum as well as general ice conditions though lighter but are in general similar to 2021 and 2022
- While Eurasian Barents, Kara, parts of ESS, Chukchi, Beaufort seas were completely ice free with the ice edge in significant northward position, the ice conditions in the Laptev, eastern ESS, Greenland Seas were close to 40 years median with both the NW passage and the NSR formally remaining blocked in the transit straits
- Area and thickness of both residual and second year ice in September this year for the Arctic Basin was similar as in 2021 and 2022 as recorded during the “North Pole - 41” supply cruise of the “Akademik Treoshnikov”

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

Sea ice thickness for 18 Sep 2004…2023 and ice volume





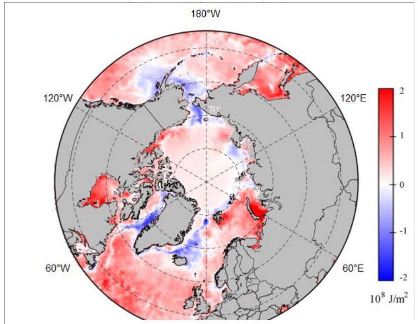
❖ Based on modelling, rank of the total Arctic ice volume for summer 2023 is the 2nd – 3rd lowest for 2004-2023 after 2020 and 2019

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

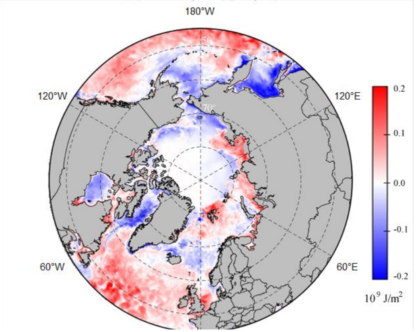
Polar Ocean:

- Upper ocean heat content
- Storms - Wave and swell height
- pH and acidification/alkalization of the Arctic

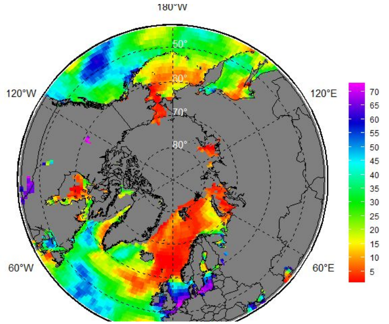
Heat content, waves and pH – JJAS 2023



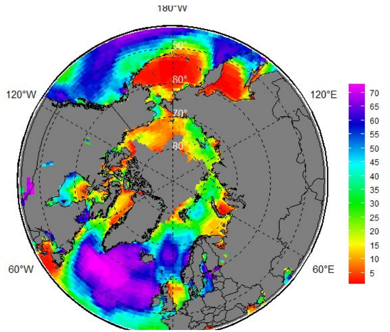
JJA Heat Content 15m anomaly, 1993-2020



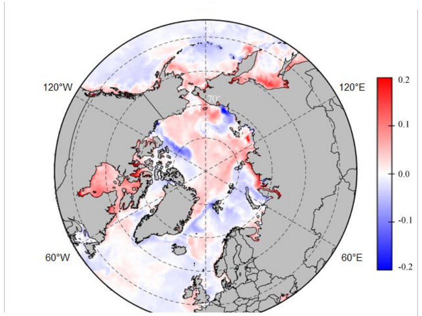
Sep Heat Content anomaly, 1993-2020



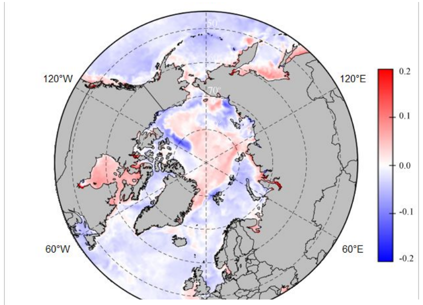
JJA WW&S height rank, 1950-2022



Sep WW&S height rank, 1950-2022



JJA pH anomaly 2m, 1993-2020



Sep pH anomaly 2m, 1993-2020

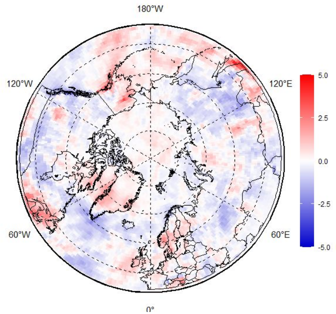
- Prominent **lower** Heat Content (HC) anomaly (to 1993-2020) was noticed in the Greenland, E and N Laptev, Chukchi, E Bering with **higher** HC in the Barents, Kara, S Laptev, Beaufort, Hudson Bay waters. Estimates for Sep 2023 showed switch to negative anomalies for Canadian Arctic, Beaufort, Bering, Chukchi and Okhotsk seas/
- Due to lesser ice extent Chukchi, Beaufort, parts of Kara and Canadian Arctic were exposed to **higher** than in past stormy conditions with **calmer** conditions in parts of the Nordic regions which is similar to 2022
- Numerical models show for the current summer season both **positive** pH anomalies (Arctic Basin, Laptev Sea, coastal parts of Kara Sea, Chukchi, Hudson Bay) and **negative** pH anomalies (Kara, ESS, parts of Greenland Sea) to the 1993-2020 period, which is in general similar to previous summers 2021-2022. The **negative anomalies** may point to **acidification** processes but need verification in situ through the buoys and ship programs.

[AARI / CCCS MEMS & ERA5]

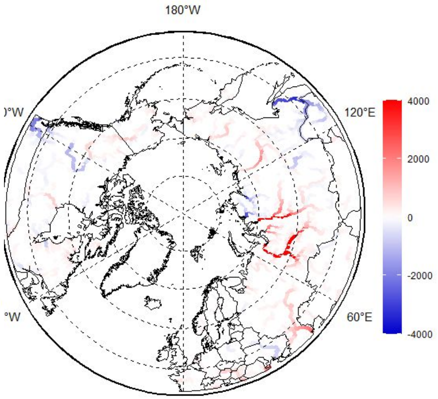
Hydrology and land Snow:

- River discharge
- Snow height and extent

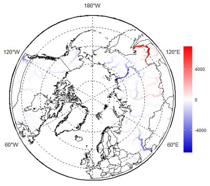
Impacts of summer 2023 precipitation and evaporation on river discharge (reanalysis)



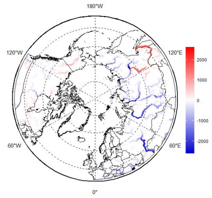
JJA 2023 precipitation anomaly, 1991-2020



JJA 2023 river discharge anomaly, 1991-2020



2021

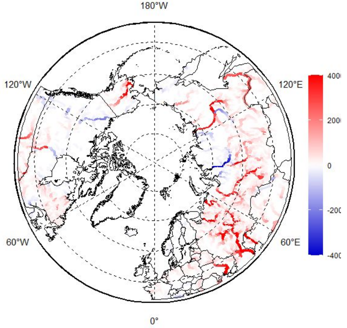


2022

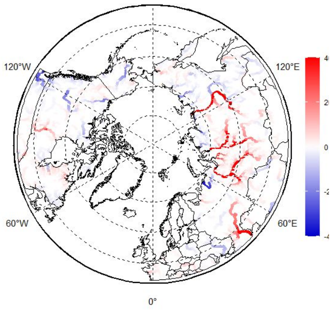
Impacts of wetter/drier conditions and evaporation were reflected in the MJJAS 2023 Arctic rivers discharge:

- **Lesser** drainage than normal was seen during part of the MJJAS period for all Great Arctic rivers with exception of Ob' with significant negative anomalies for Yenisei (May, Aug, Sep), Lena (Jul), Mackenzie (May, Sep), Jukon (Jun, Sep)
- **Greater** drainage was seen for Ob', Lena (Jun, Sep), Mackenzie (Jul) and Yukon (May, Jul)
- Such **greater** drainage situation this summer is opposite to in Eurasian Arctic in summer 2021 and 2022 but somewhat similar for American sector

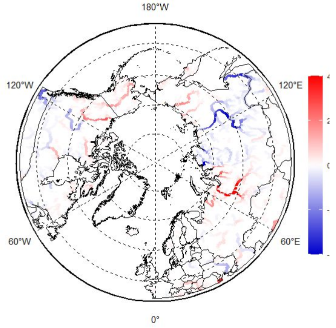
May



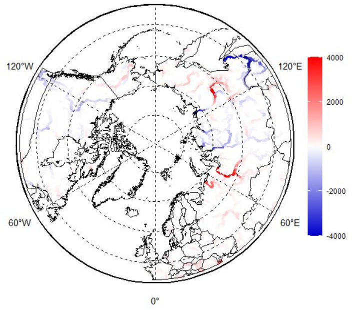
Jun



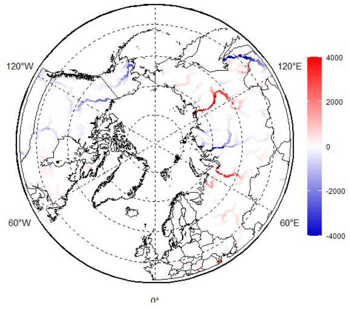
Jul



Aug



Sep

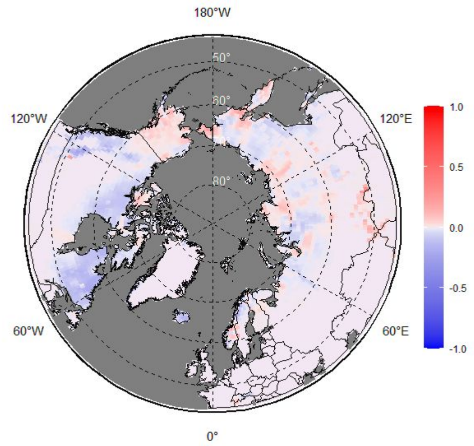


May – September 2023 river discharge anomaly (1991-2020)

AARI / ERA5 reanalysis

MJJAS 2023 land snow

- In May 2023 **lesser** snow height as well as snow extent dominated over Central and Eastern Canada, parts of Central Siberia and Chukchi with **positive** anomalies in Alaska, parts of eastern Siberia
- In September 2023 negative anomalies of snow extent were observed in Canadian and Alaska regions with positive snow extent over Eurasia



May 2023
snow height anomaly (1991-2020)

[AARI / CCCS ERA5 / WMO GCW SnowWatch]

S, 1000 km²

Northern Hemisphere

	2023	1991-2020 Normal		Period of Record from 11-1966		
Month	Area	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
9	5,354	5,508	-154	28/55	7,762 (1972)	3,838 (1990)
8	2,567	2,682	-115	39/55	5,308 (1967)	2,089 (1968)
7	2,806	3,191	-384	44/54	8,210 (1967)	2,325 (2012)
6	5,962	8,134	-2,171	50/56	14,972 (1978)	4,922 (2012)
5	16,742	18,216	-1,474	50/57	23,093 (1974)	15,377 (2010)

Eurasia

	2023	1991-2020 Normal		Period of Record from 11-1966		
Month	Area	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
9	1,708	1,636	72	22/55	3,409 (1977)	540 (1984)
8	176	272	-97	39/55	1,859 (1967)	72 (2020)
7	218	487	-270	42/54	3,551 (1967)	141 (tie)
6	1,749	2,853	-1,103	46/56	7,129 (1978)	1,068 (2012)
5	9,273	9,179	94	35/57	12,511 (1976)	7,262 (2013)

Canada

	2023	1991-2020 Normal		Period of Record from 11-1966		
Month	Area	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
9	1,360	1,544	-184	36/55	2,812 (2018)	647 (1968)
8	319	355	-37	32/55	1,569 (1978)	132 (2009)
7	445	593	-148	43/54	2,718 (1978)	143 (2012)
6	1,847	2,843	-995	55/56	4,899 (1978)	1,604 (2012)
5	4,086	5,797	-1,711	57/57	7,902 (1974)	4,086 (2023)

Alaska

	2023	1991-2020 Normal		Period of Record from 11-1966		
Month	Area	Mean	Departure	Rank	Maximum (Year)	Minimum (Year)
9	146	181	-34	35/55	417 (1996)	35 (1974)
8	58	36	22	28/55	546 (1967)	0 (tie)
7	71	53	18	28/54	445 (1967)	0 (tie)
6	216	258	-42	39/56	856 (1985)	37 (2015)
5	1,073	956	117	22/57	1,486 (1985)	595 (2016)

[GCW / Rutgers Global SnowLab]

Data sources:

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

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

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

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

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

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

TIME (UTC)	ITEM	DETAILS
16:00 (10')	**Day 1 Sum Up and Day 2 Intro**	Becki Heim - NOAA
16:10 (30')	**Arctic Summer 2023 Seasonal Summary:** • Atmospheric patterns • Temperature, precipitation, sea-ice, polar ocean and land hydrology based on observations and reanalysis data • Briefs for winter 2023-2024	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 the past season • Forecast for the next season	Anastasiia Revina - AARI, Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva - Hydromet Centre
16:55 (15')	**Q&As on Seasonal Summary of Observations**	Moderator: Jelmer Jeuring - MET Norway

Bioclimatic indexes in the Arctic: summary for May 2023– September 2023 and weather Comfort Outlook for winter 2023/2024

Anastasiia Revina

Arctic and Antarctic Research Institute (AARI)

Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva

Hydrometeocentre of Russia

Summary
for May 2023– September 2023

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

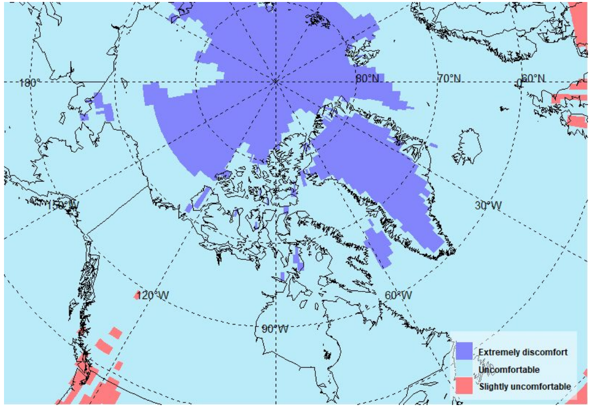
$$ET = T - 0{,}4(T - 10)(1 - f / 100)$$

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

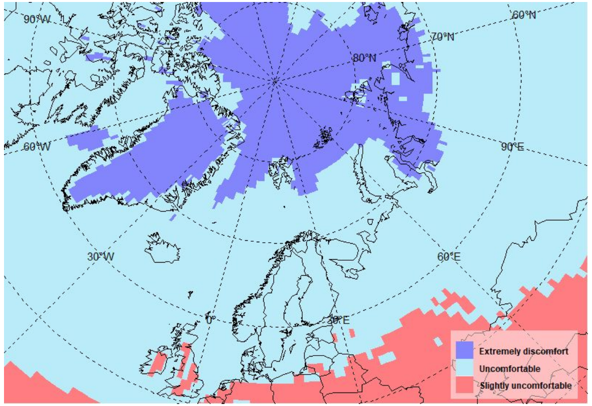
	Thermal sensation	**Physiological effect**	**Comfort sensation**
≥+30	Very hot	Incomprensible heat	Discomfort
+24..+30	Hot	Slightly uncomfortable	Partial discomfort
+18..+24	Warm	Comfortable	Comfort
+12..+18	Slightly warm	Neutral	Partial comfort
+6..+12	Slightly cool	Slightly uncomfortable	Partial discomfort
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 MAM (Mar, Apr, May) 2023

Slightly & less | Severe & very severe | Extremely severe



Alaska and Canada



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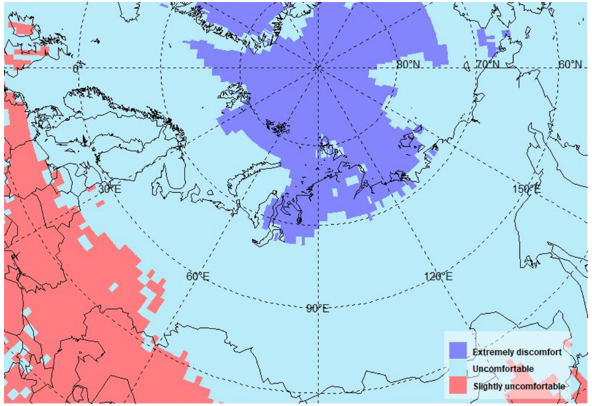
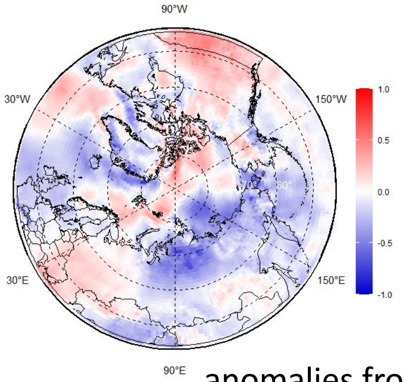
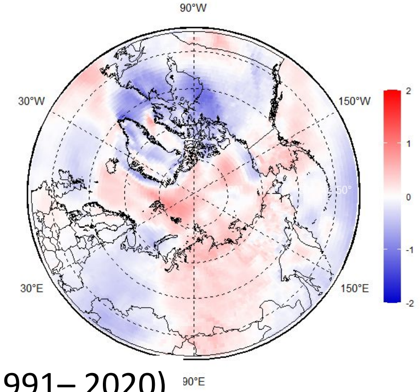


Eurasia





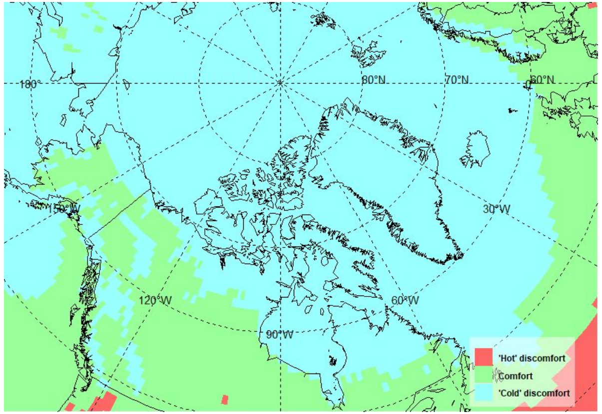
anomalies from (1991– 2020)

202

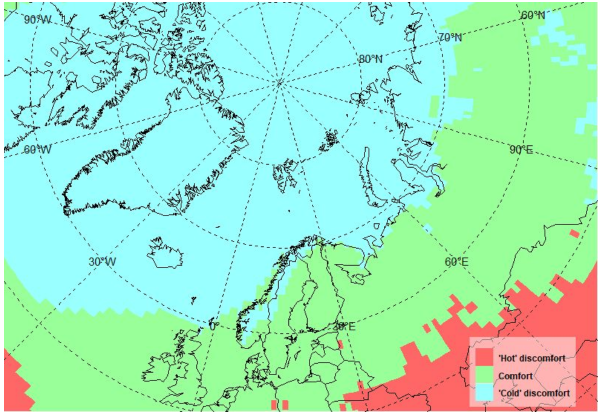
2023

- In spring 2023 there were mostly **severe** conditions everywhere with **extremely severe** conditions in Greenland, Central Arctic, Fram Strait, Nothern Barents, North-East Kara and Laptevih Seas and Taymyr Peninsula.
- There were sufficiently **milder** conditions (**blue color**) than usual based on anomalies from 1991-2020 in East Canada, Arctic Archipelago, Greenland and slightly milder in European part of Russia, Kazakhstan and West Canada. Close to mean for this period were condiions in the Nordic region, Baffin Bay and Bering Sea.
- There were more **severe** conditions (**red color**) in Siberia, Alaska and Gulf of Alaska, Central Arctic, Fram Strait, Norwegian Sea and Nothern Sea Route (NSR) Seas except from south parts of Barents and Kara Seas.
- In comparison with 2022 **milder** and more **severe** conditions are vise versa for most areas except from Greenland, eastern seas of NSR and North

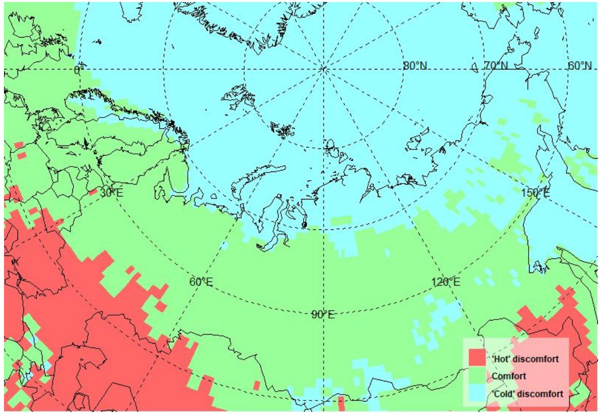
Effective temperature ET   JJA (Jun, Jul, Aug) 2023



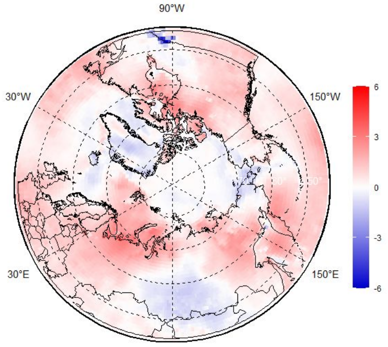
Alaska and Canada

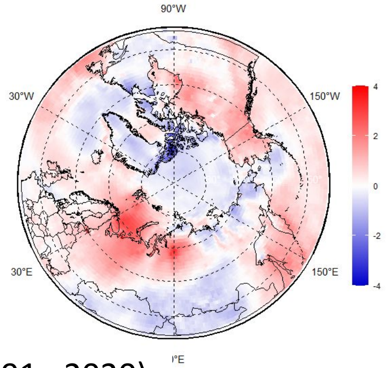


Nordic



Eurasia



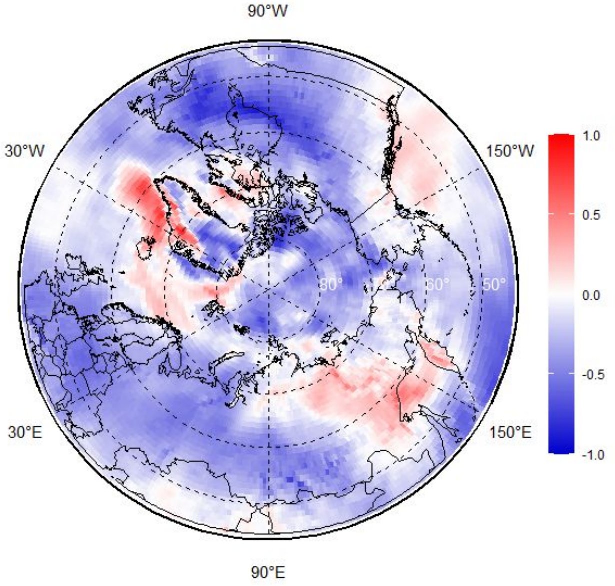


anomalies from (1991– 2020)

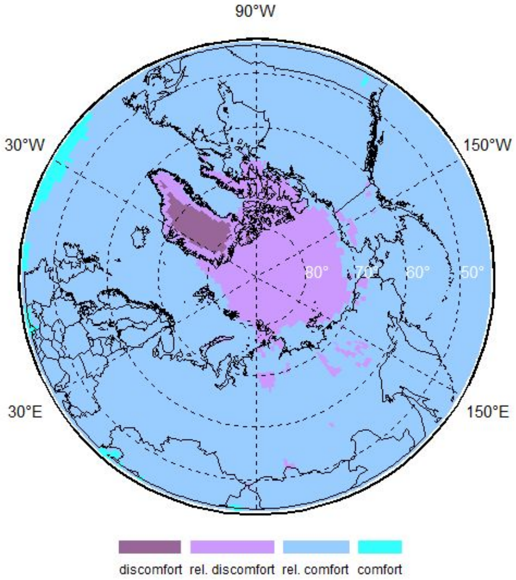
2022   **2023**

- Cold discomfort zone spreads over sea areas, Greenland, Canadian Arctic Archipelago, Hudson Bay with some land area around and Northern-East Siberia (from Taymyr to Chukchi Peninsula). Comfort zone dominates in the land area and borders with ”hot” discomfort zone, that locates in the middle latitudes
- There were more **severe** conditions (blue color) in the Central Arctic, Greenland, Canadian Arctic Archipelago, Davis Strait and Labrador Sea, east seas of NSR with coastal area close to them, Bering Seaand in the southern parts of Siberia and East Canada. **Milder** conditions were in the West Canada and Alaska, Okhotsk Sea, and most prominent **positive** anomalies were in Barents Sea, North of European Russia and northern part of Enisey basin.
- Summer 2023 was quite similar to 2022, except from Canadian Arctic Archipelago and East Canada, where **positive** anomalies changed to **negative** in 2023.

September 2023



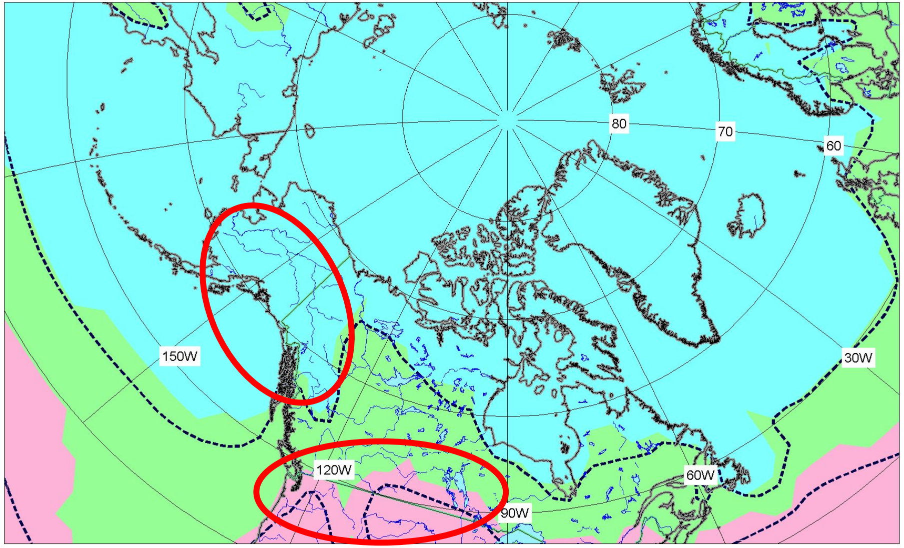
Bodman index (anomalies 1991-2020)



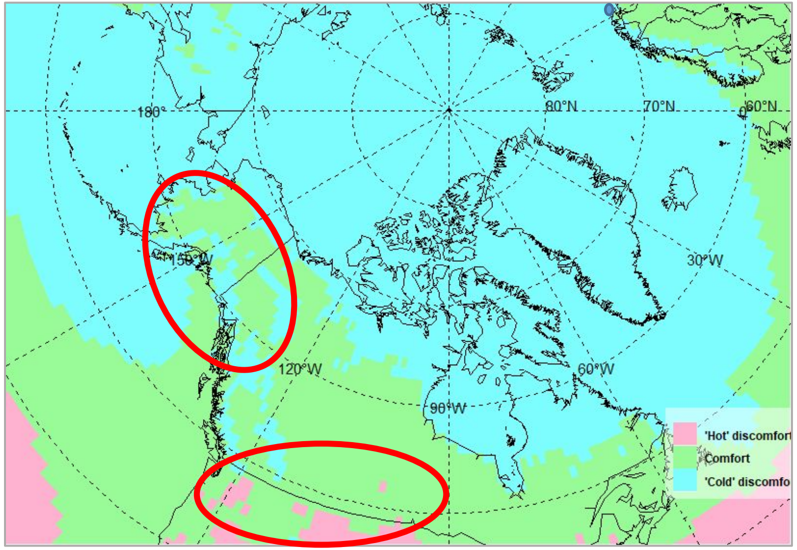
Effective temperature ET

- In September 2023 there were mostly milder (blue color) conditions in the Arctic based on Bodman index anomalies from 1991-2020.
- There were slightly more severe conditions (red color) in the East Siberia, including Lena river basin, Okhotsk Sea and Sahalin island, also Gulf of Alaska and in the Baffin Island, Fram Strait and Norwegian Sea, and distinctly harder conditions in the Denmark Strait and in the South-East Greenland.
- ET shows us the most discomfort conditions also in Greenland, while the majority of the area is in relative comfort conditions except from Central Arctic and Canadian Arctic Archipelago

Summer (JJA) effective temperature ET: Comparison with forecast for Alaska and Canada region



Forecast

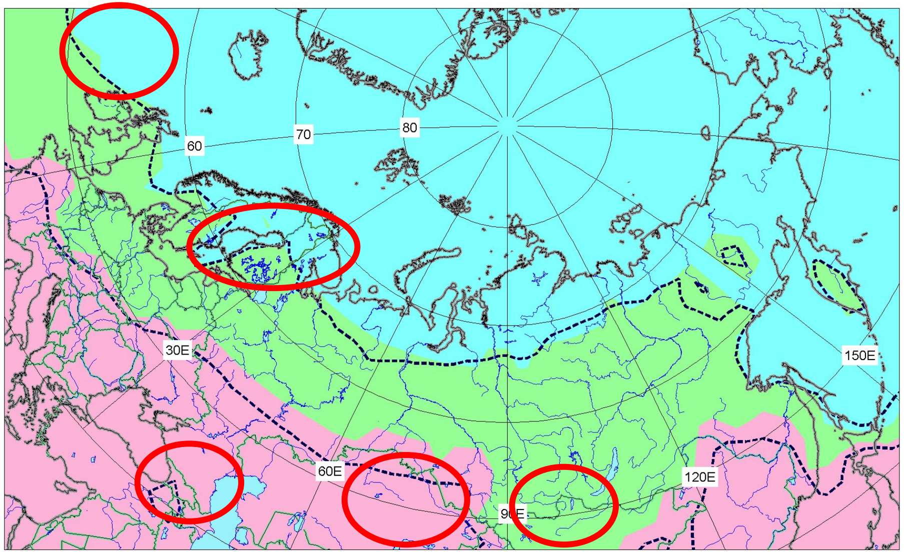


ERA5 data

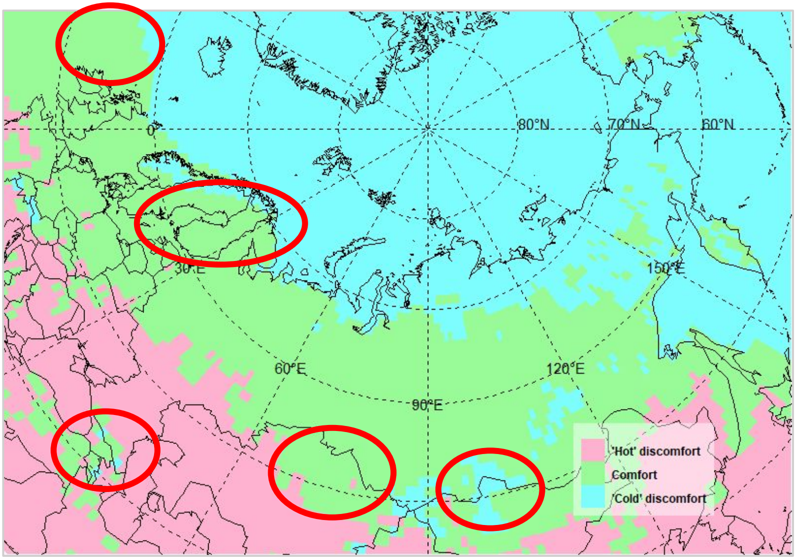
On the whole the forecast for Alaska and Canada region described quite good the ET for summer season.

- The forecast has shown colder conditions for Alaska region, while according to ERA5 reanalysis there was mostly a "comfort" zone.
- In the area to the west from the Great Lakes on the contrary the forecast has shown warmer conditions ("hot" discomfort zone), while there were mostly comfort conditions based on ERA5 data.

Summer (JJA) effective temperature ET: Comparison with forecast for Eurasia region



Forecast



ERA5 data

- The forecast has shown colder conditions in the Norway, north part of Sweden and Finland and Kola Peninsula. ERA5 data reveals ”comfort” zone here, instead of ”cold discomfort” zone. And there is the same situation over the sea area to the west from the British Isles.
- It seems that forecast has overestimated comfort over some mountain landscape, as we see it over Sayan Mountains. And the forecast has shown ”hot” discomfort conditions over Caucasus Mountains, while ERA5 data shows us comfort zone there.
- Also some overestimation of ”hot” comfort was over the North-East Kazahstan, as ERA5 data gives comfort zone there instead of ”hot” discofort in forecast

Weather Comfort Outlook for Winter 2023/2024

Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva

Hydrometeocentre of Russia

tkachukzn@gmail.com

How to predict weather comfort on seasonal timescales?

Complex indicator that takes into account several weather factors ⇔ **Seasonal forecast of these 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

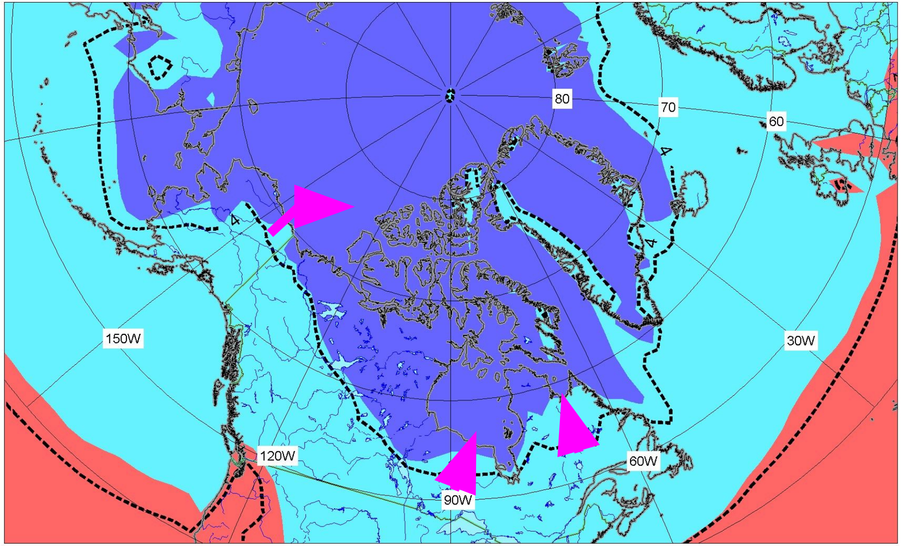
Forecast data

- Test seasonal forecast (NDJFMA 2023/2024) of the model of the Institute of Numerical Mathematics RAS* were used to calculate the indexes values for Winter 2023/2024 and hindcasts 1991-2020 for the norms;
- Resolution 2,5°×2,5° ;
- Initialized October 22, 2023

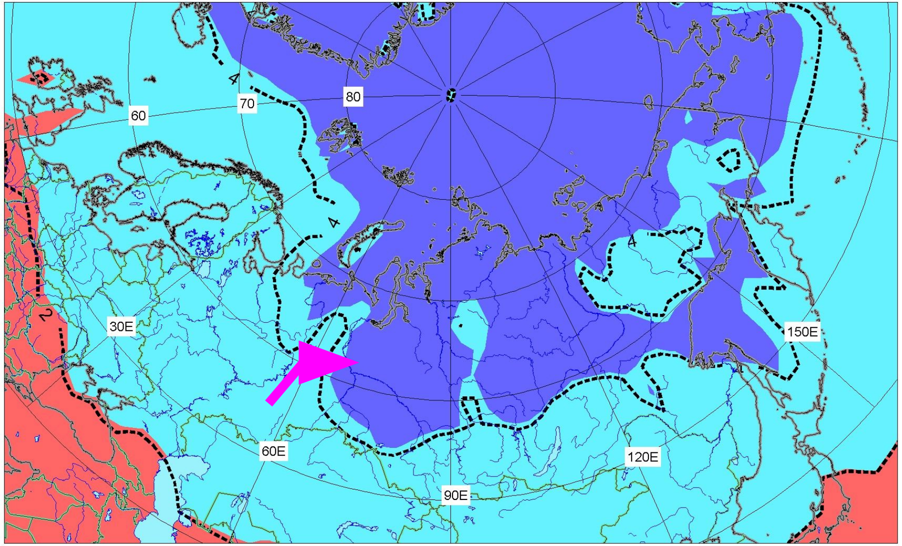
*Vorobyeva, V., Volodin, E.: Evaluation of the INM RAS climate model skill in climate indicesand stratospheric anomalies on seasonal timescale. Tellus A: Dynamic Meteorology andOceanography 73(1), 1–12(2021).https://doi.org/10.1080/16000870.2021.189243535.

Severity of the Weather DoF 23/24

Western Hemisphere



Eastern Hemisphere



Slightly & less	Severe & very severe	Extremely severe

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

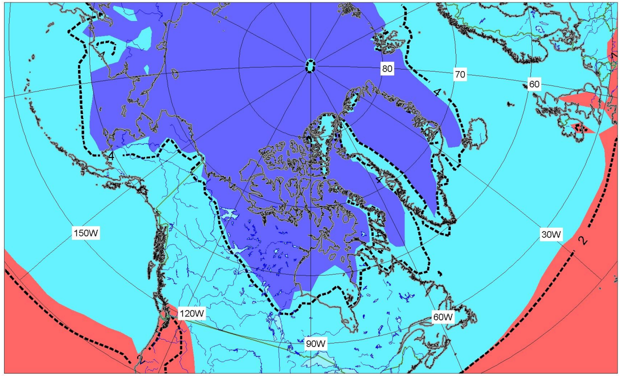
- In the Western Hemisphere in the winter 23/24 **extremely severe conditions** are expected in most of the region;
- **Severe conditions** in southern Alaska, Yukon, Northwest Territories and southern Quebec;
- **No slightly&less** conditions expected in Arctic Zone

- In the Eartern Hemisphere in the winter 23/24 **extremely severe conditions** in Eurasian Node and on Spitsbergen;
- **Severe conditions** in Norway, Sweden, Finland and Iceland, on the Novaya Zemlya archipelago and in the north of Yamal;
- **No slightly&less** conditions expected in Arctic Zone

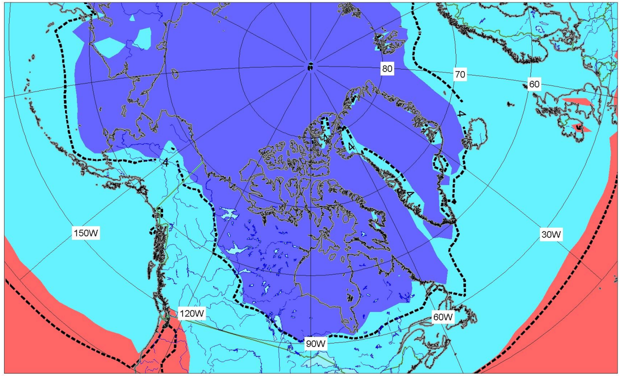
Severity of the weather DJF 23/24

Western Hemisphere

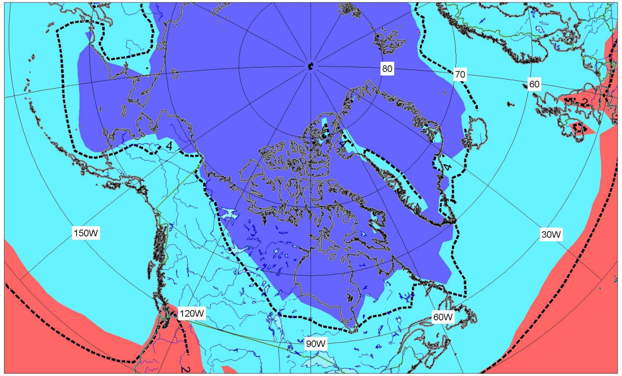
Dec 2023



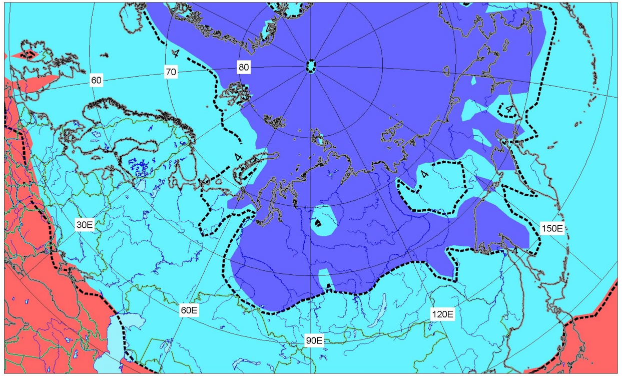
Jan 2024

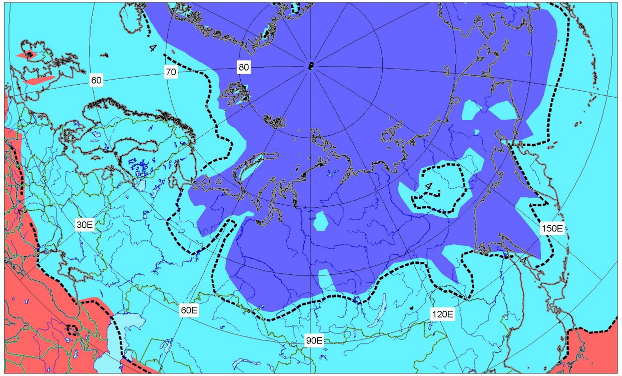


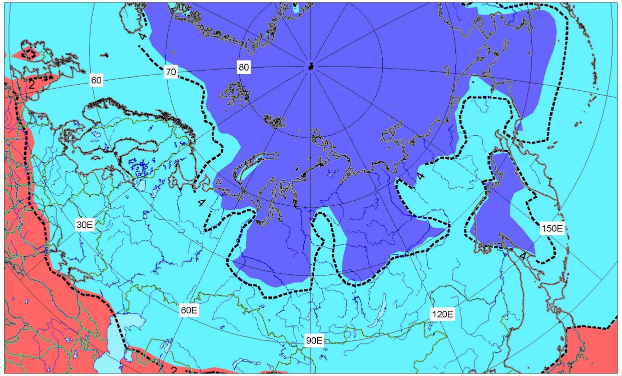
Feb 2024



Eastern Hemisphere







Slightly & less	Severe & very severe	Extremely severe

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

Winter, Dec, Jan and Feb 2023/2024: Regional Comparison of Weather Severity

Regions	Winter	Dec	Jan	Feb
Alaska and Western Canada	***less severe***	***less severe***	***less severe***	less severe
Central and Eastern Canada	less severe	***less severe***	less severe	less severe
Western Nordic	***less severe***	***less severe***	*less severe*	less severe
Eastern Nordic	***less severe***	***less severe***	less severe	less severe
Western Siberia	less severe	less severe	less severe	less severe
Eastern Siberia	less severe	less severe	less severe	less severe
Chukchi and Bering	less severe	less severe	less severe	less severe
Central Arctic	less severe	less severe	less severe	less severe

Slightly & less
Severe & very severe
Extremely severe

***less severe** - relative to average climatic values of B-index (to 1991-2020), but in the same gradation

** ***less severe*** (with gradient) - reduction of cold load on the body by one gradation relative to 1991-2020

This work was financially supported by the Ministry of Education and Science of the Russian Federation (agreement No. 075-15-2021-577 with IAP RAS).

Thank you!

TIME (UTC)	ITEM	DETAILS
16:00 (10’)	**Day 1 Sum Up and Day 2 Intro**	Becki Heim - NOAA
16:10 (30’)	**Arctic Summer 2023 Seasonal Summary:** • Atmospheric patterns • Temperature, precipitation, sea-ice, polar ocean and land hydrology based on observations and reanalysis data • Briefs for winter 2023-2024	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 the past season • Forecast for the next season	Anastasiia Revina - AARI, Svetlana Emelina, Maria Tarasevich, Vasilisa Vorobyeva - Hydromet Centre
16:55 (15’)	**Q&As on Seasonal Summary of Observations**	Moderator: Jelmer Jeuring - MET Norway

Break 15min

ACF
Arctic Climate Forum

WORLD METEOROLOGICAL ORGANIZATION

17:25 (25')	**Temperature, Precipitation, Sea Surface Temperature and Snow/Water Equivalent** • Validation of the outlook for summer 2023 • Outlook for winter 2023-2024 and model confidence	Session Chair: Andrew Palmer - ECCC Marko Markovic - ECCC
17:50 (25')	**Sea Ice Outlook for Winter 2023-2024** • Validation of the summer 2023 outlook • Outlook for winter 2023-2024 and model confidence	Adrienne Tivy - ECCC
18:15 (15')	**Q&As on Validation and Confidence and Sea-Ice Outlooks**	Moderator: Andrew Palmer - ECCC
18:30 (20')	**ACF-12 User & Participant Discussion**	John Nangle & Stephen Baxter - NOAA
18:50 (5')	**Final Thoughts and Wrap-Up**	Becki Heim - NOAA

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Canada

ACF - 12: Verification of the JJA 2023 season
ACF – 12: Seasonal forecast for the NDJ 2023/24 season

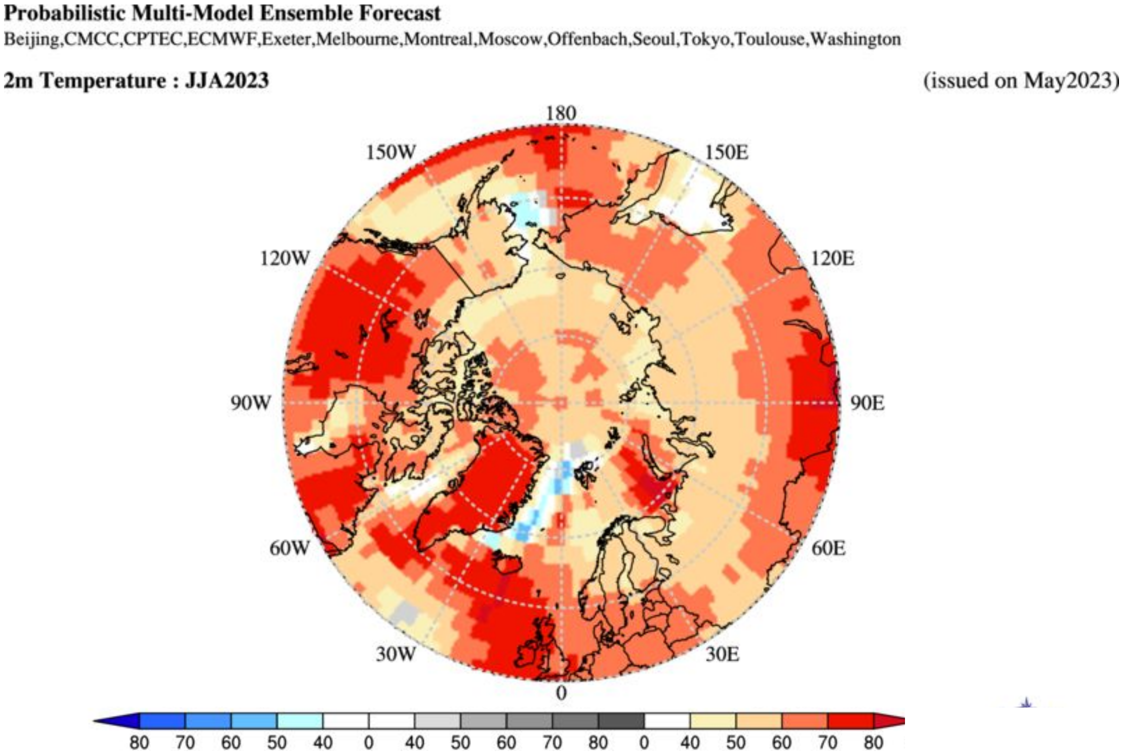
Marko Markovic
Meteorological Service of Canada
Environment and Climate Change Canada

WMO

ACF
Arctic Climate Forum

Seasonal forecast over the Arctic, JJA 2023

reminder

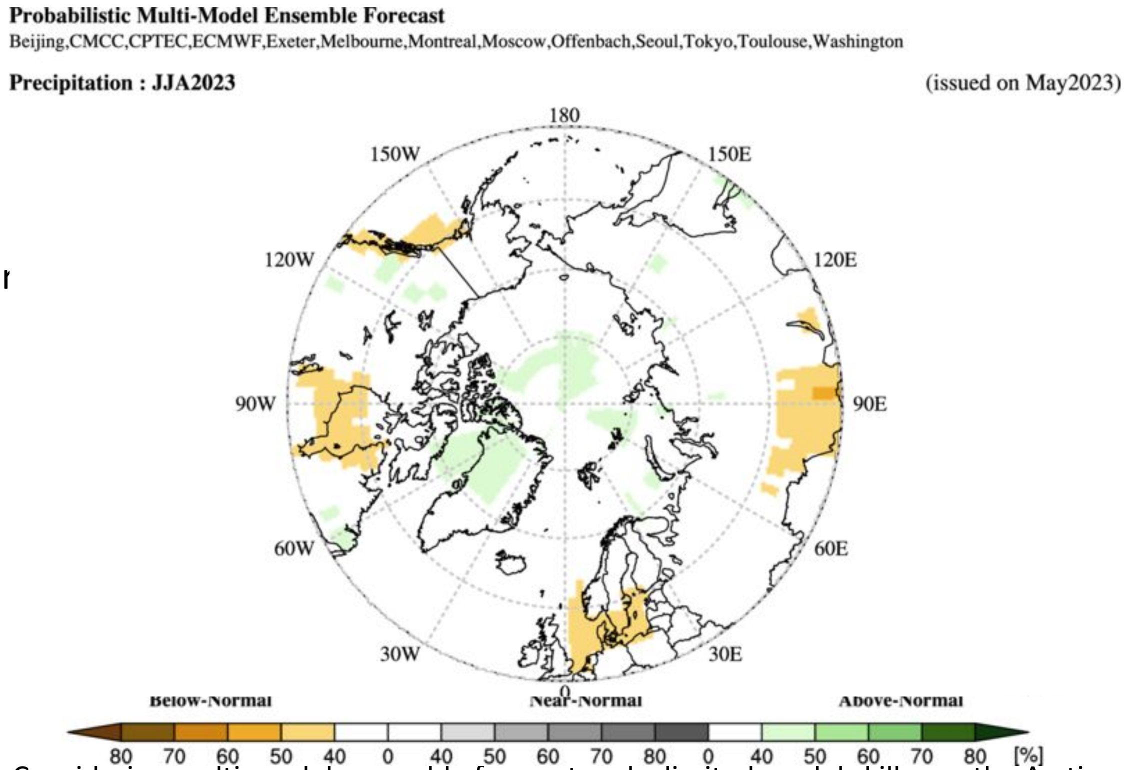


Considering multi-model ensemble forecast and a limited model skill over the Arctic:

Temperature: For June-July-August 2023 (JJA23), there was a probability of 40% or more that temperatures will be above normal in almost all regions across the Arctic. The highest probabilities were over the North America and eastern Nordic region.

Seasonal forecast over the Arctic, JJA 2023

reminder



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

Precipitation: Over most of the Arctic region, MMEs were not decisive (white on the map), so precipitation terciles had equal chances. A few low probability values (>40%) of below-normal precipitation are expected over eastern Canada, southern Alaska and the easter Nordic region.

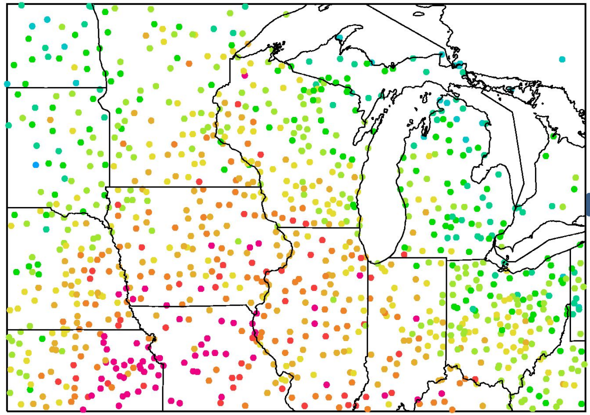
How do we verify seasonal forecasts?

- 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**.

2) station observations Precipitation

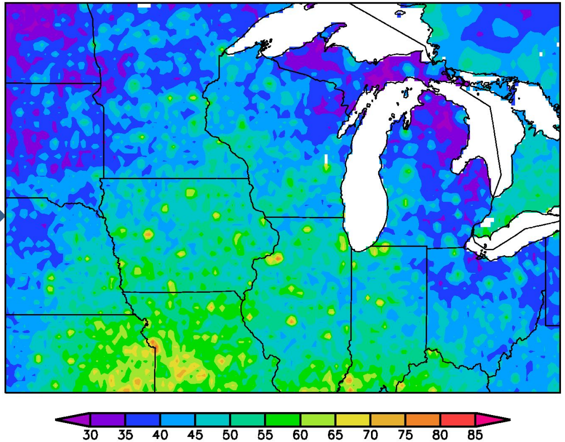


https://dilorenz.github.io/downscaling2/ProbApp/interp.html

Data Assimilation

+ numerical modeling

Precipitation Re-Analysis

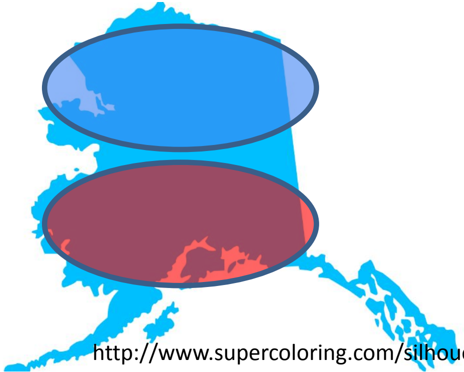


How do we verify seasonal forecasts?

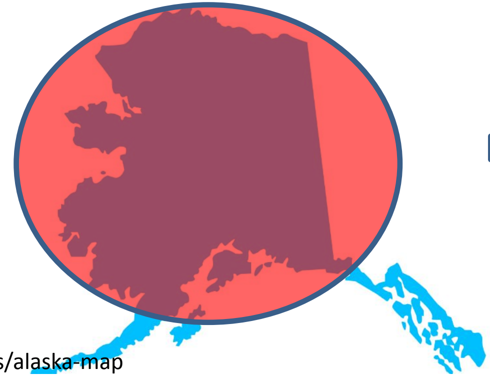
- We need some metric, some number to quantify the verification result
- We call this metric a score

- 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



Observations

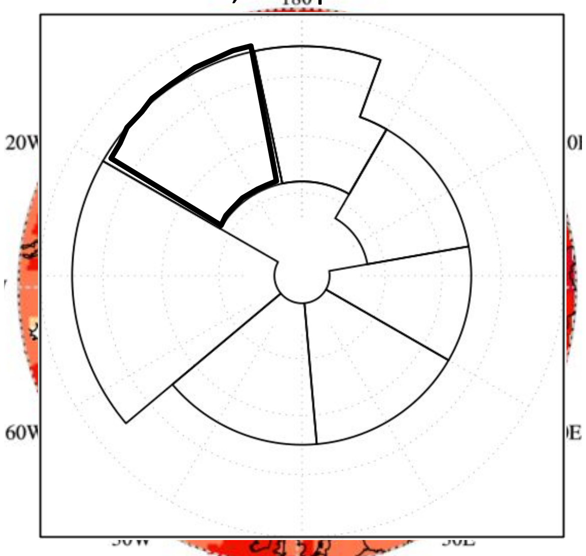


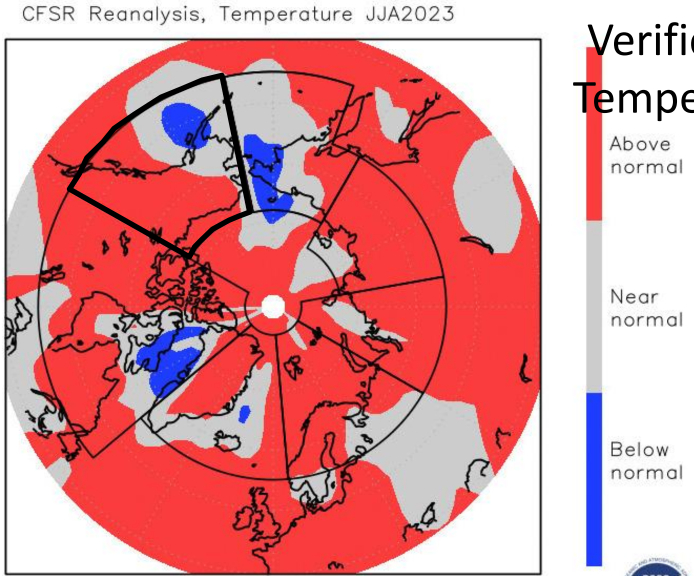
→ a 50% correct forecast

http://www.supercoloring.com/silhouettes/alaska-map

Verification Temperature

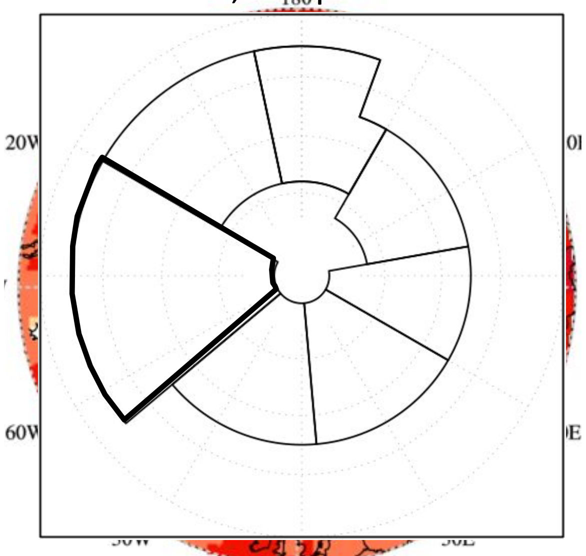
Forecast, temp JJA 2023



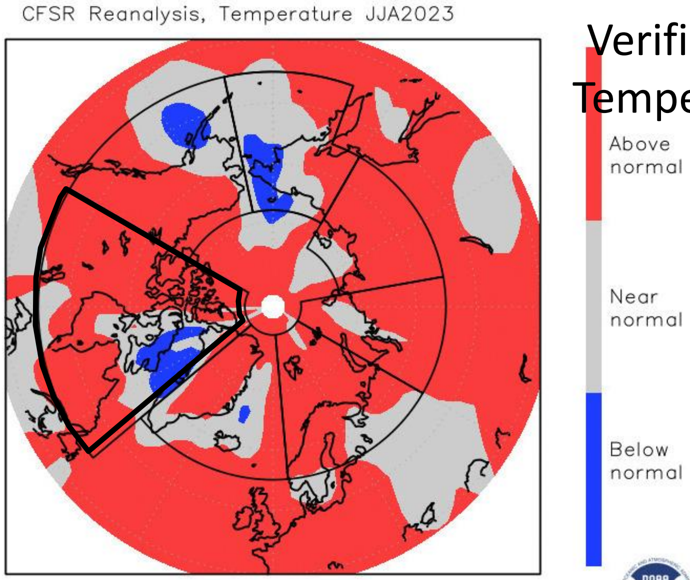


Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	**Above normal**	**Above normal in the east and SE, near and below normal in the west**	**50%**
C. - E. Canada			
W. Nordic			
E. Nordic			
W. Siberia			
E. Siberia			
Chukchi-Berin			

Forecast, temp JJA 2023

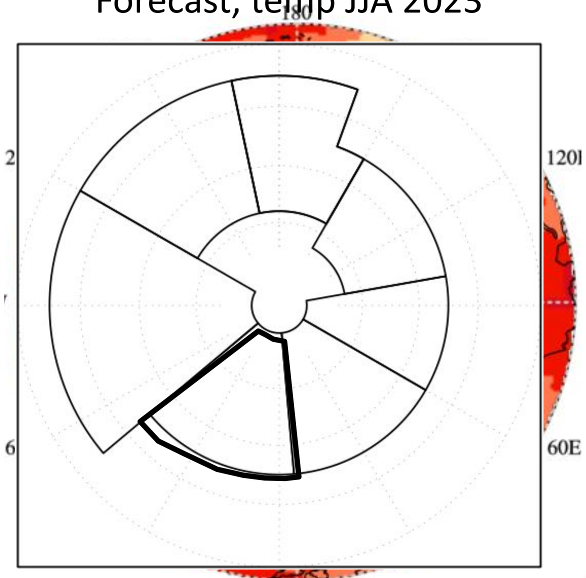


Verification Temperature



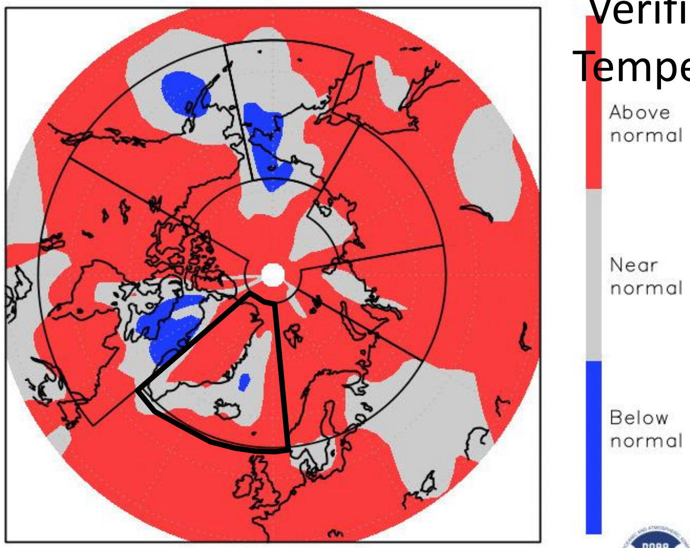
Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
C. - E. Canada	**Above normal**	**Mostly above, near and below normal in the west**	**70%**
W. Nordic			
E. Nordic			
W. Siberia			
E. Siberia			

Forecast, temp JJA 2023



CFSR Reanalysis, Temperature JJA2023

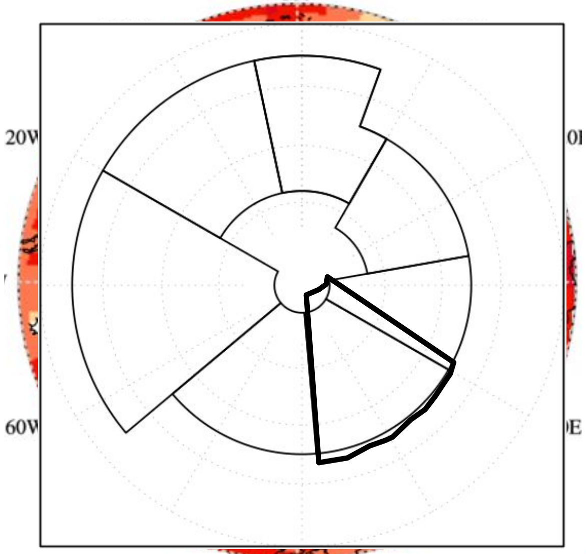
Verification Temperature

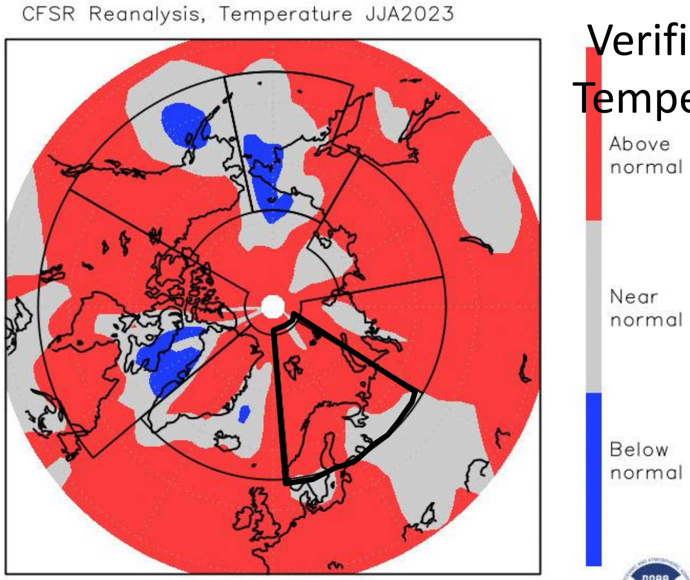


Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
C. - E. Canada	Above normal	Mostly above, near and below normal in the west	70%
W. Nordic	**Mostly above, below over the G. sea**	**Near normal over G. Sea above over Greenland**	**40%**
E. Nordic			
W. Siberia			
E. Siberia			

Verification Temperature

Forecast, temp JJA 2023

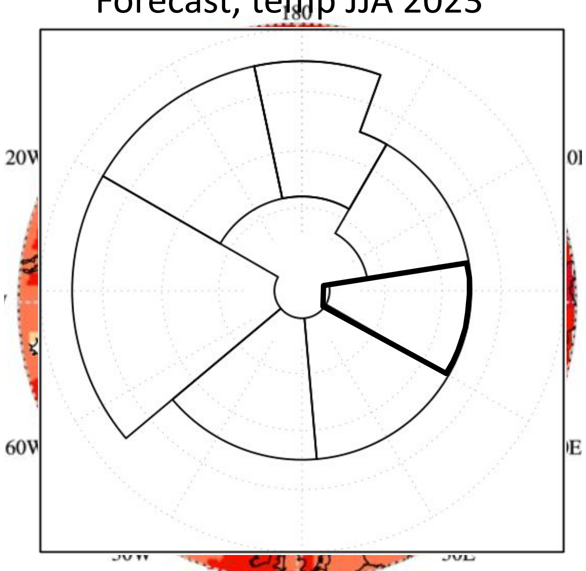




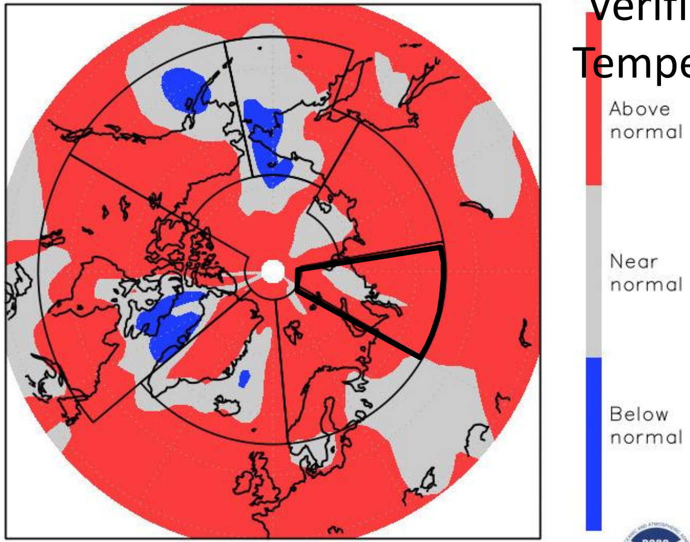
Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
C. - E. Canada	Above normal	Mostly above, near and below normal in the west	70%
W. Nordic	Mostly above, below over the G. sea	Near normal over G. Sea above over Greenland	40%
E. Nordic	**Above normal**	**Mostly above normal**	**90%**
W. Siberia			
E. Siberia			

Verification Temperature

Forecast, temp JJA 2023



CFSR Reanalysis, Temperature JJA2023



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Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
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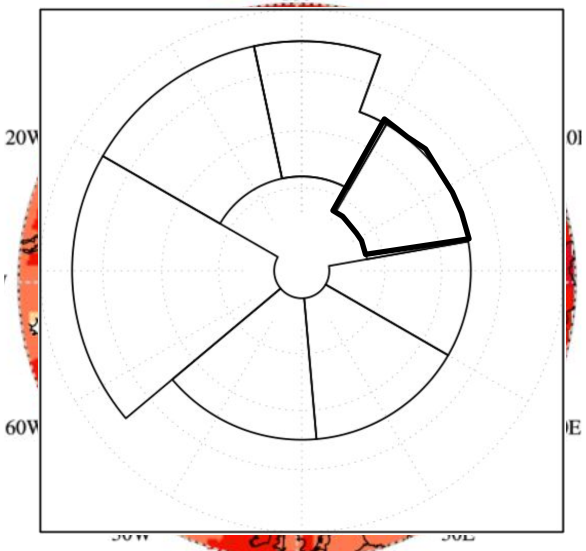
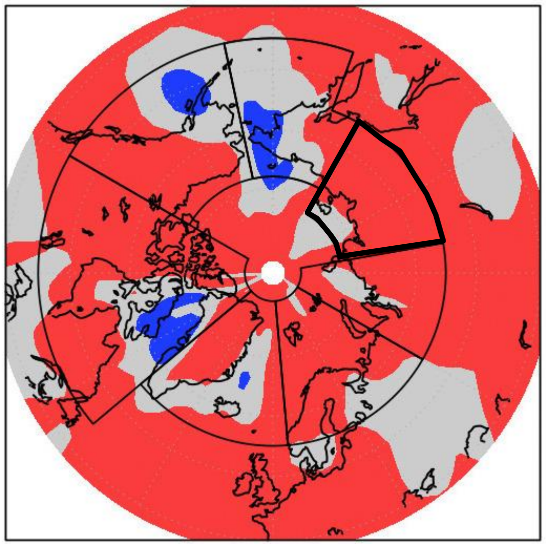
W. Nordic	Mostly above, below over the G. sea	Near normal over G. Sea above over Greenland	40%
E. Nordic	Above normal	Mostly above normal	90%
W. Siberia	**Above normal**	**Mostly above normal**	**90%**
E. Siberia			

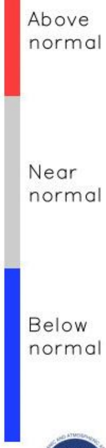
Forecast, temp JJA 2023



CFSR Reanalysis, Temperature JJA2023

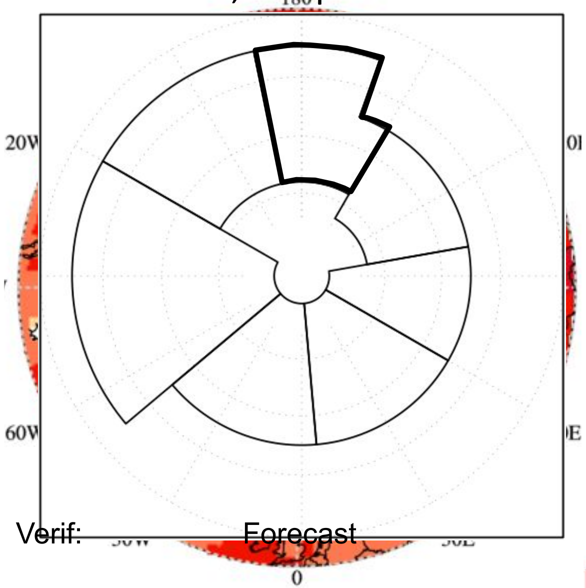


Verification Temperature



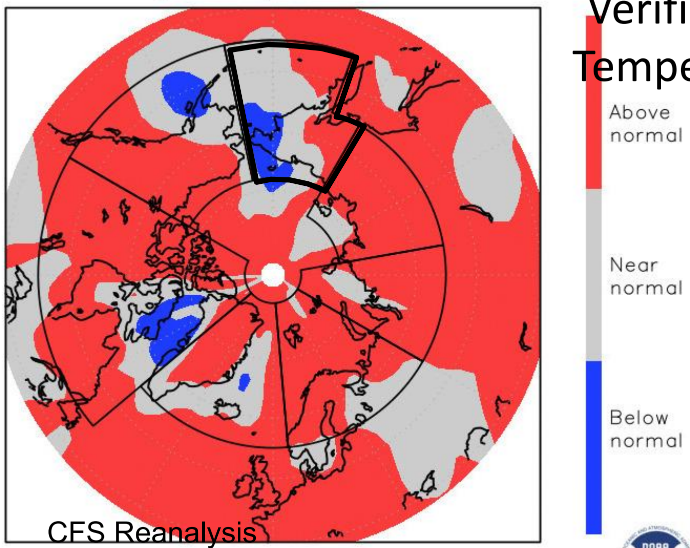
Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
C. - E. Canada	Above normal	Mostly above, near and below normal in the west	70%
W. Nordic	Mostly above, below over the G. sea	Near normal over G. Sea above over Greenland	40%
E. Nordic	Above normal	Mostly above normal	90%
W. Siberia	Above normal	Mostly above normal	90%
E. Siberia	Above normal	Mostly above normal	90%

Forecast, temp JJA 2023



CFSR Reanalysis, Temperature JJA2023

Verification Temperature



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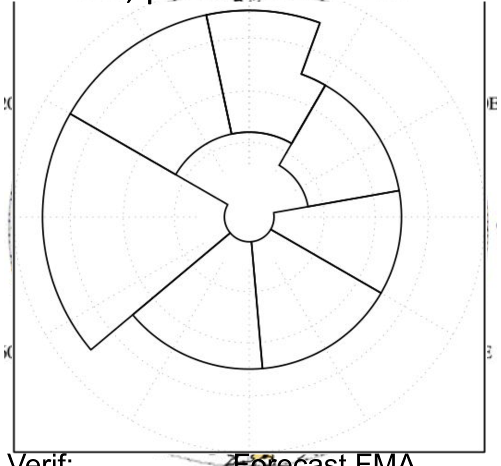
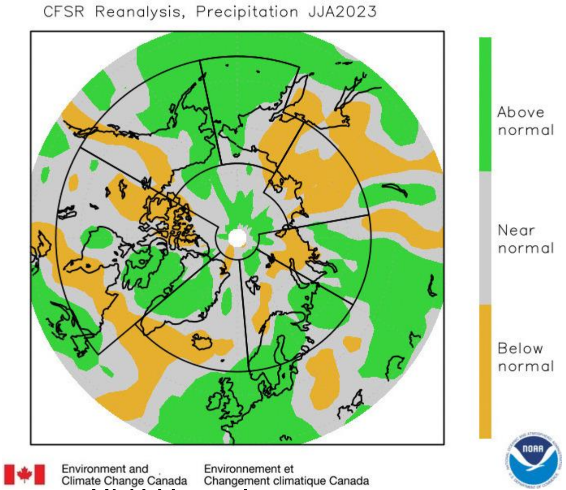
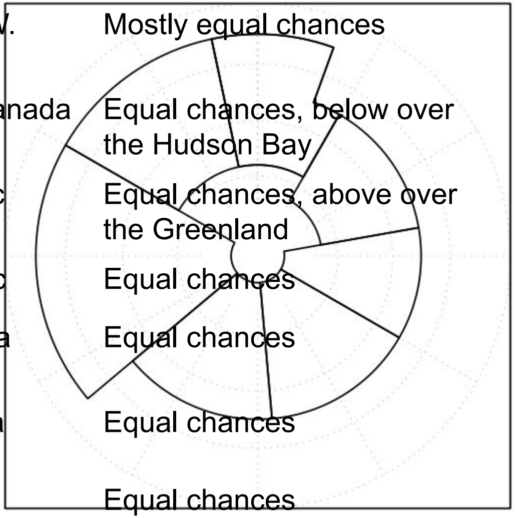
Verif:	Forecast	CFS Reanalysis	Subj. Result
Alaska, W. Can	Above normal	Above normal in the east and SE, near and below normal in the west	50%
C. - E. Canada	Above normal	Mostly above, near and below normal in the west	70%
W. Nordic	Mostly above, below over the G. sea	Near normal over G. Sea above over Greenland	40%
E. Nordic	Above normal	Mostly above normal	90%
W. Siberia	Above normal	Mostly above normal	90%
E. Siberia	Above normal	Mostly above normal	90%
Chukchi-Beri	Above normal	Mostly near normal, below in the east	30%

Verification Precipitation

Forecast, prec JJA 2023







Verif:	Forecast FMA	CFS Reanalysis	Subj. Result
Alaska, W. Can	Mostly equal chances	Above in the west, near normal in center and east	%
C. - E. Canada	Equal chances, below over the Hudson Bay	Mostly near normal in the south, below normal in the east and west	Miss, where forecasted
W. Nordic	Equal chances, above over the Greenland	Mostly above over the Greenland, below normal in the south	Hit, where forecasted
E. Nordic	Equal chances	Above over the continental parts	%
W. Siberia	Equal chances	Above over the continental parts, below in the north	%
E. Siberia	Equal chances	Mostly below normal	%
Chukchi Bering	Equal chances	Mostly near normal in the central parts, above in the south and above in the	%

Overall result, subjective verification

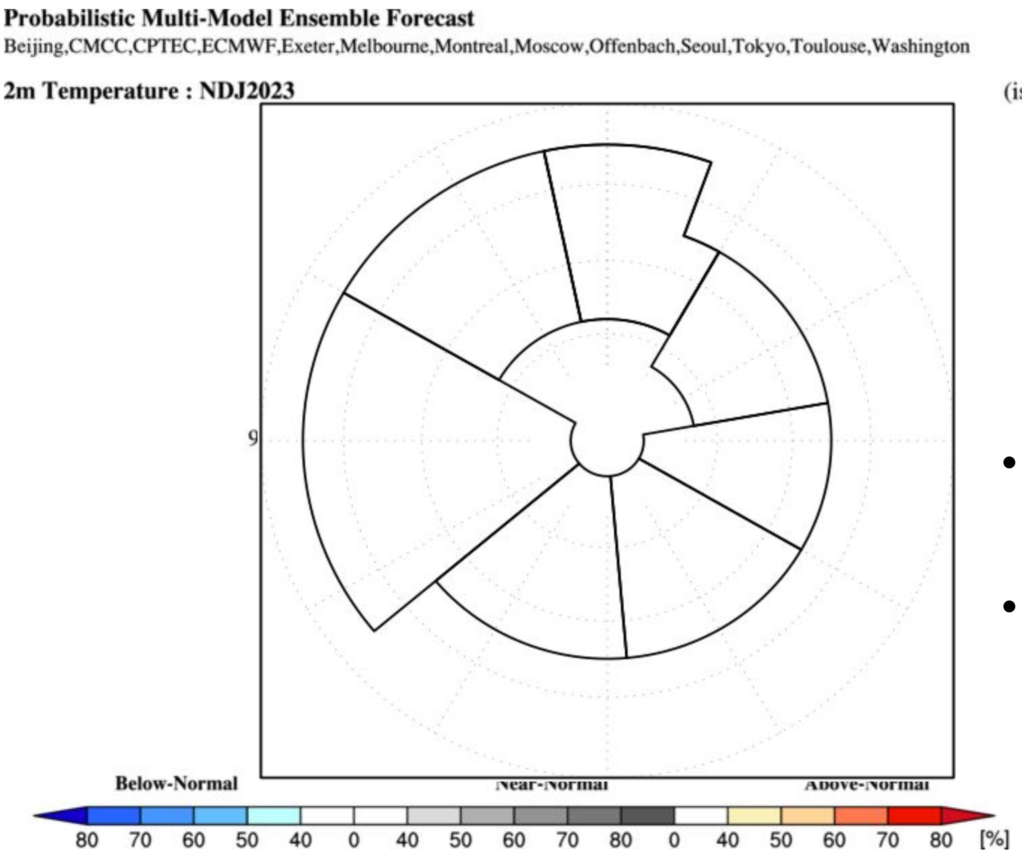
- **Temperature**: Considering all Arctic regions the subjective score is somewhat more than 60%.

- **Precipitation**: The forecast was mostly non-decisive above all Artcic regions.

Actual (real time)seasonal forecasts over the Arctic NDJ 2023/24

- Temperature
- Precipitation
- Sea Surface Temperature
- Snow Water Equivalent

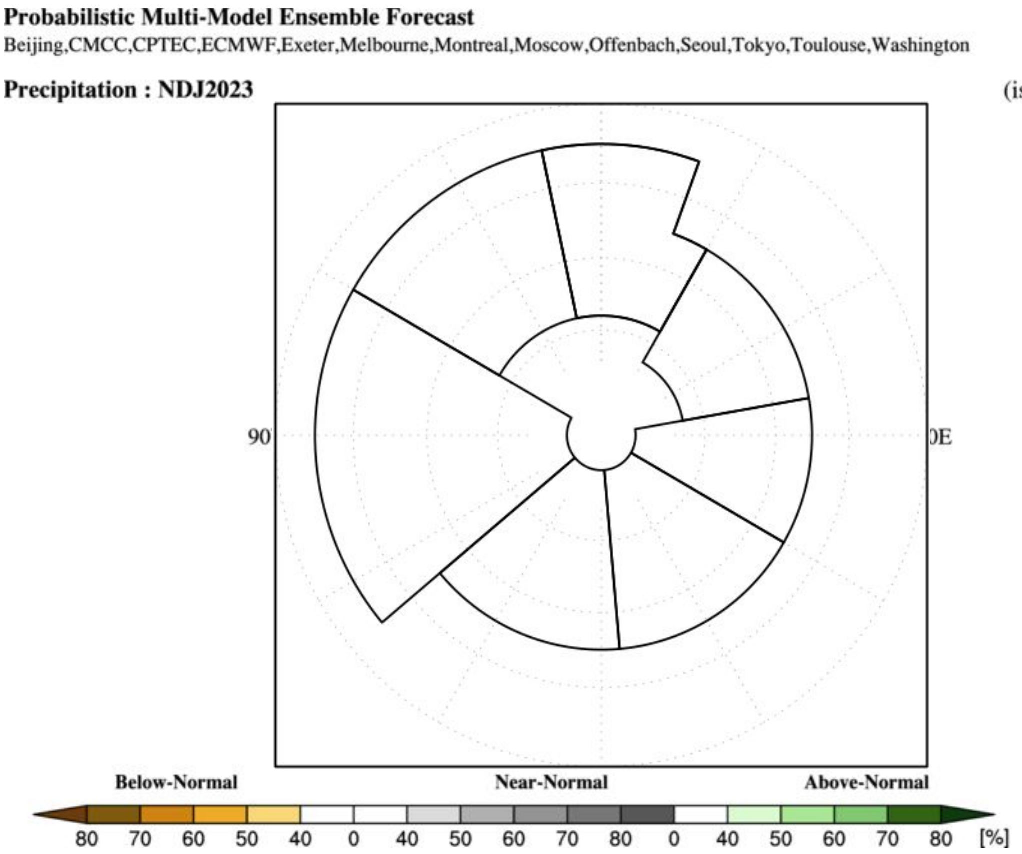
Temperature outlook over the Arctic: Nov-Dec-Jan 2023/24



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.

Precipitation outlook over the Arctic: Nov-Dec-Jan 2023/24



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.

WMO Lead Centre for LRF MME

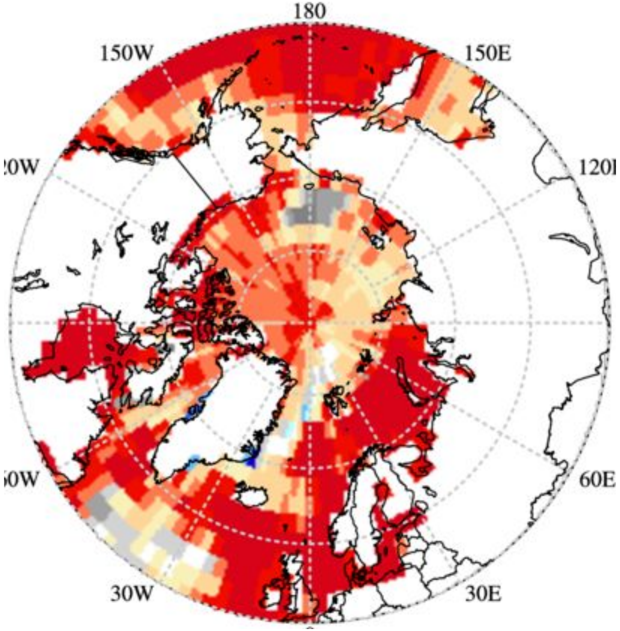
Global Seasonal Climate Update by WMO

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

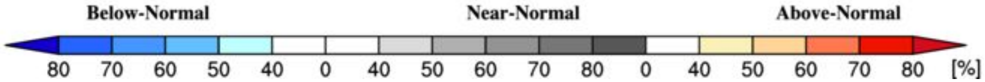
https://public.wmo.int/en/our-mandate/climate/global-seasonal-climate-update
https://wmolc.org/gscuBoard/list

- Climate report is available for download

Sea Surface Temperature outlook over the Arctic: Nov-Dec-Jan 2023/24

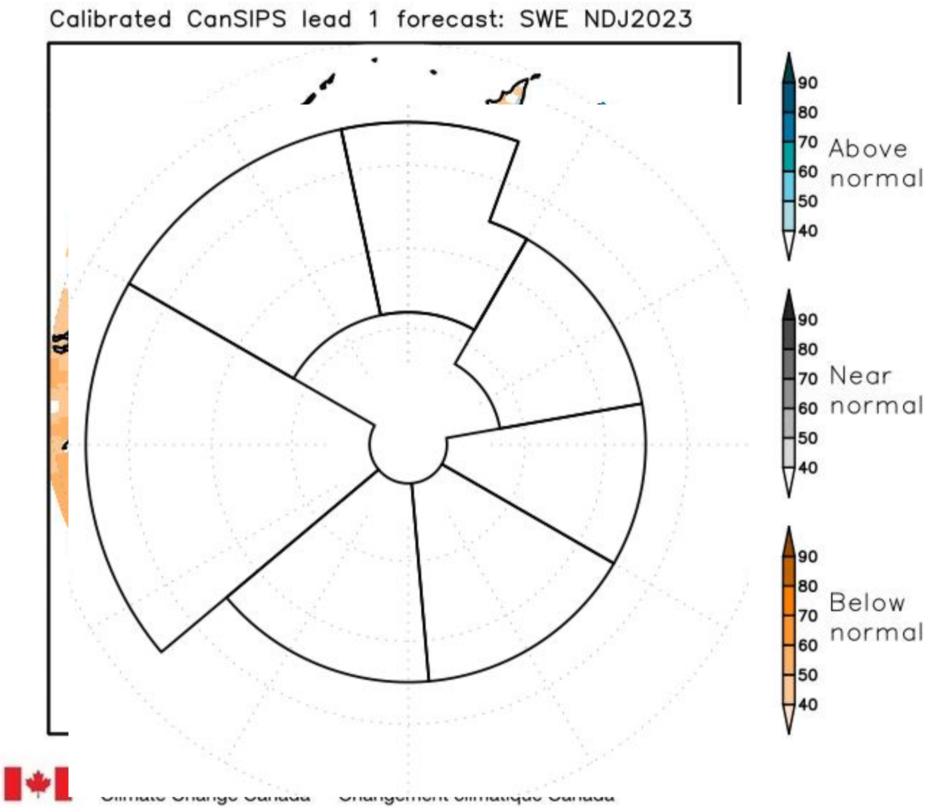


https://nsidc.org/arcticseaicenews/map-of-the-arctic-ocean/



Snow Water Equivalent outlook over the Arctic: Nov-Dec-Jan 2023/24

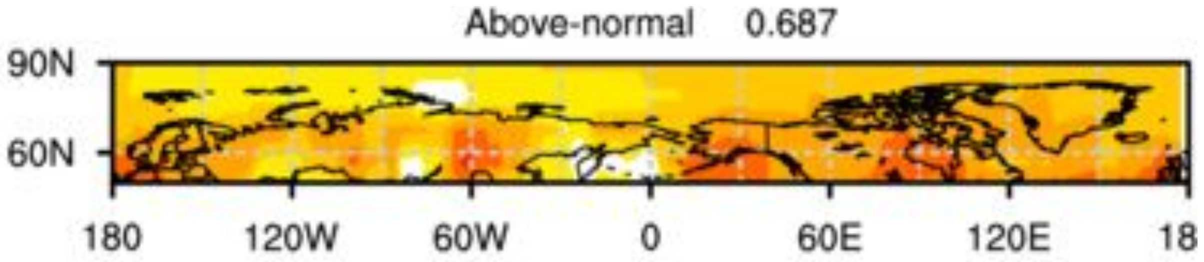
Experimental product

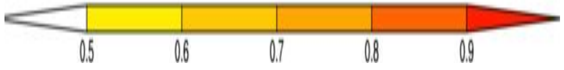


1. Alaska W. Canada
2. Eastern Canadian Arctic
3. Western Nordic
4. Eastern Nordic
5. West Siberia
6. East Siberia
7. Chukchi and Bering

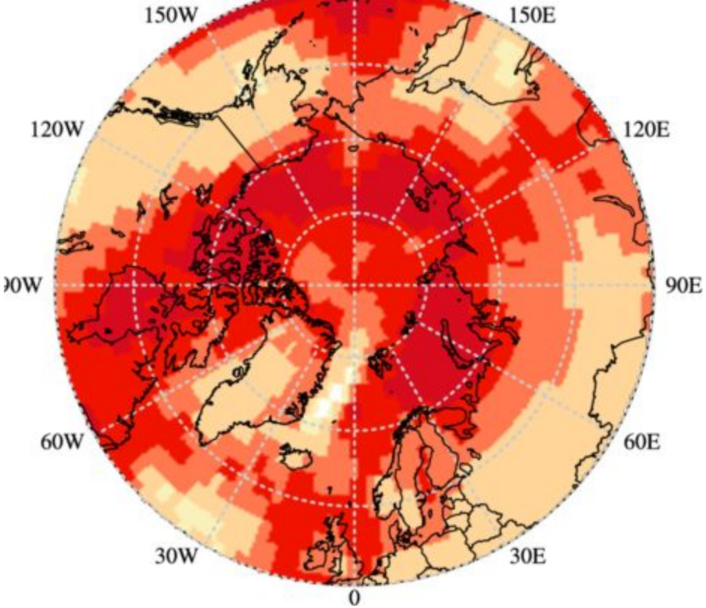
Discussing historical skill over the Arctic, Temperature

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

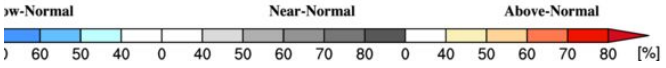




NDJ 2023/24

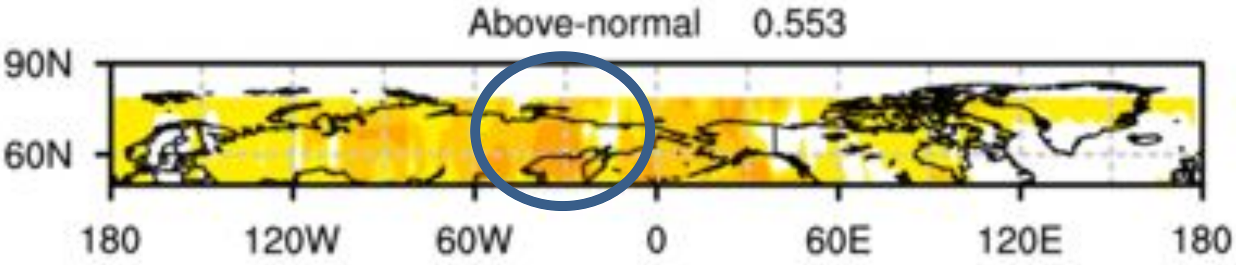


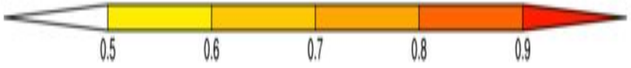
- If a historical skill was good over a certain region (e.g. colored region on the upper figure) we are more confident about the forecast results over the same region
- Overall confidence is moderate in JJA over the Arctic.



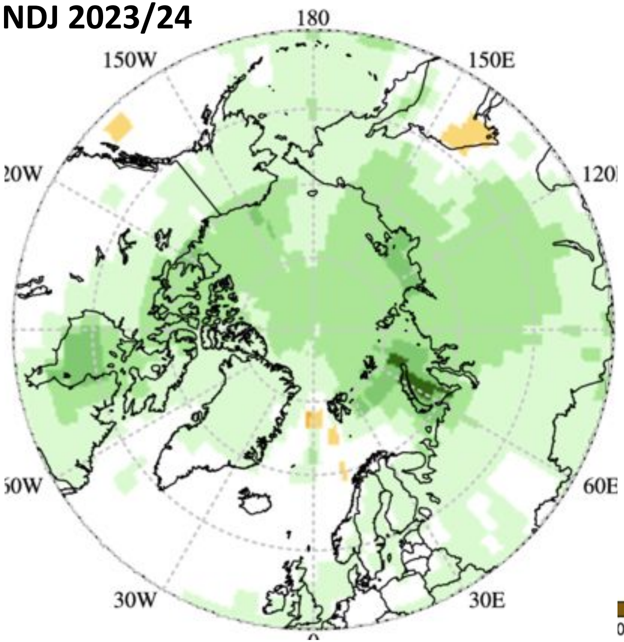
Discussing historical skill over the Arctic, Precipitation

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

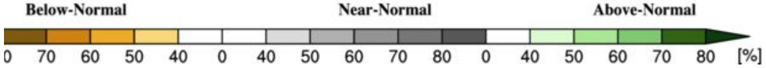




NDJ 2023/24

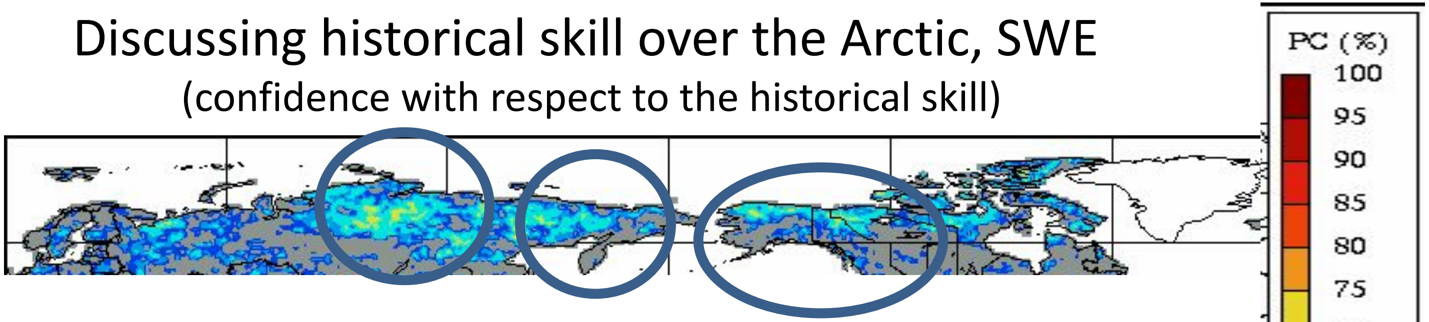


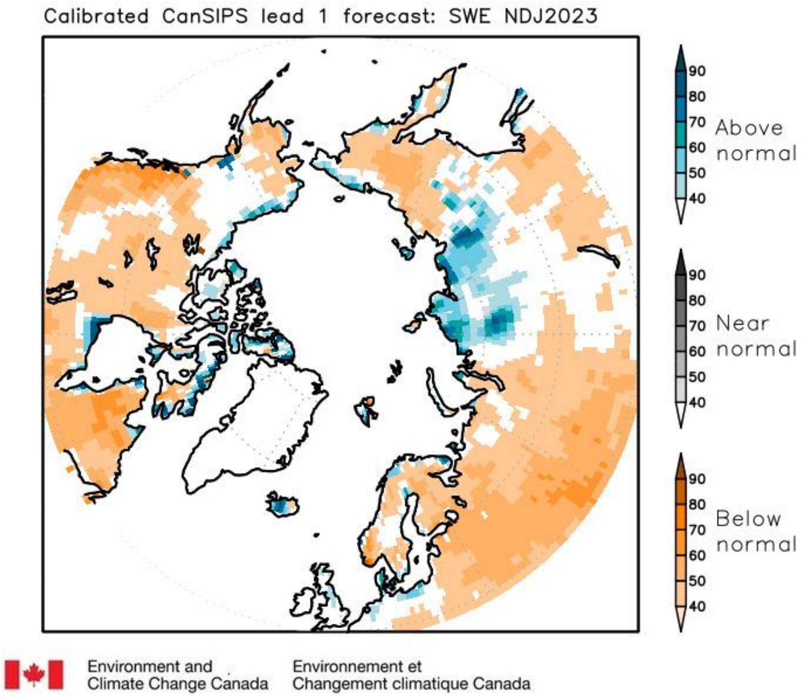
- We don’t have a very high confidence in precipitation skill over the Arctic in NDJ.



Discussing historical skill over the Arctic, SWE

(confidence with respect to the historical skill)





- 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.
- JJA2023 MME temperature forecast over the Arctic region was ~60$ correct. Precipitation forecast was correct mostly over the two Siberian regions.
- We expect above normal temperatures over all Arctic regions this winter with highest probabilities the eastern Canada and the two Siberian regions (east and west).
- Over the Arctic in NDJ23/24, above normal precipitation probabilities are mostly forecasted.
- Above normal SST is forecasted for most of the Arctic seas.
- Below normal snow water equivalent (SWE) is expected over most of the Arctic with an exception of the western Siberian region where above normal, low probability, expectances are forecast.

Thank you!

ACF

Arctic Climate Forum

17:25 (25')	**Temperature, Precipitation, Sea Surface Temperature and Snow/Water Equivalent** • Validation of the outlook for summer 2023 • Outlook for winter 2023-2024 and model confidence	Session Chair: Andrew Palmer - ECCC Marko Markovic - ECCC
17:50 (25')	**Sea Ice Outlook for Winter 2023-2024** • Validation of the summer 2023 outlook • Outlook for winter 2023-2024 and model confidence	Adrienne Tivy - ECCC
18:15 (15')	**Q&As on Validation and Confidence and Sea-Ice Outlooks**	Moderator: Andrew Palmer - ECCC
18:30 (20')	**ACF-12 User & Participant Discussion**	John Nangle & Stephen Baxter - NOAA
18:50 (5')	**Final Thoughts and Wrap-Up**	Becki Heim - NOAA

12th Arctic Climate Forum November 2023

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

A. Tivy[1]*, Bill Merryfield[1], Arlan Dirkson[1], Gulilat Diro[1], Cathy Reader[1], Michael Sigmond[1], V. V. Vorobyeva[2,3], M. A. Tarasevich[2,3,4], E. M. Volodin[2], A. S. Gritsun[2]

1- *Environment and Climate Change Canada; 2- Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences; 3-Hydrometeorological Research Center of Russian Federation; 4-Moscow Institute of Physics and Technology*

ACF
Arctic Climate Forum

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

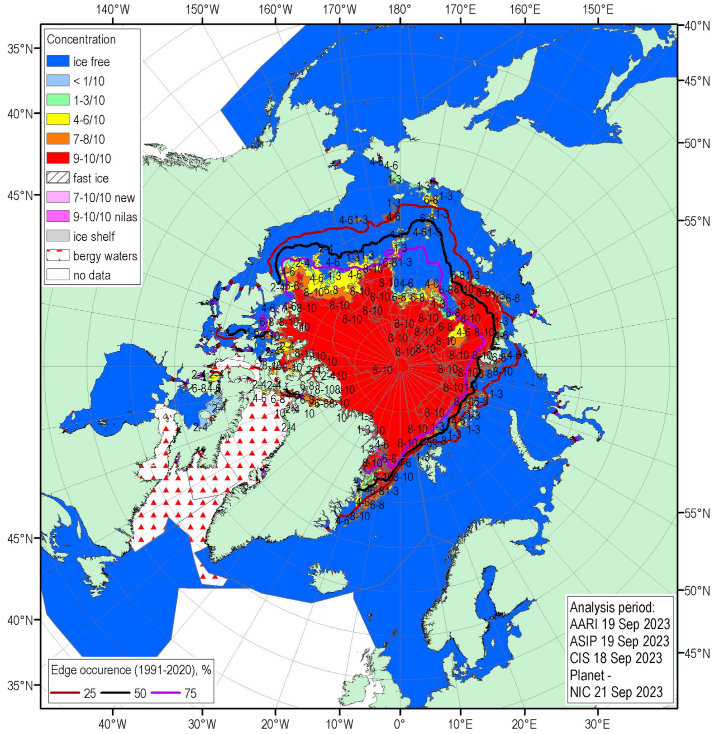
Outlook Production

- 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 Summer 2023 Conditions
with
Summer 2023 Sea Ice Outlook

September 2023 Minimum Sea Ice Extent (Actual)

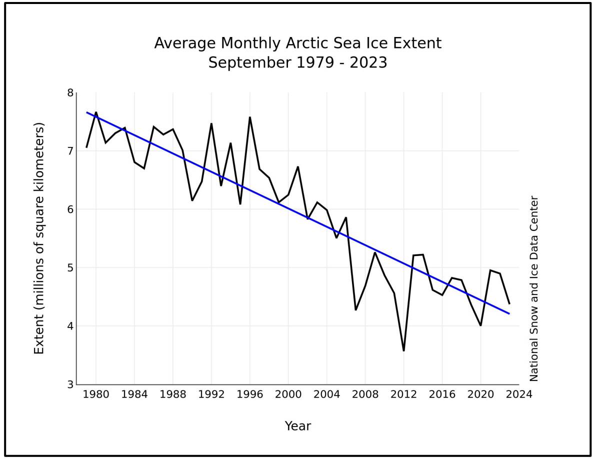
Mid-September 2023 Ice Concentration from Ice Charts (Sep18-21)



Source: Arctic and Antarctic Research Institute

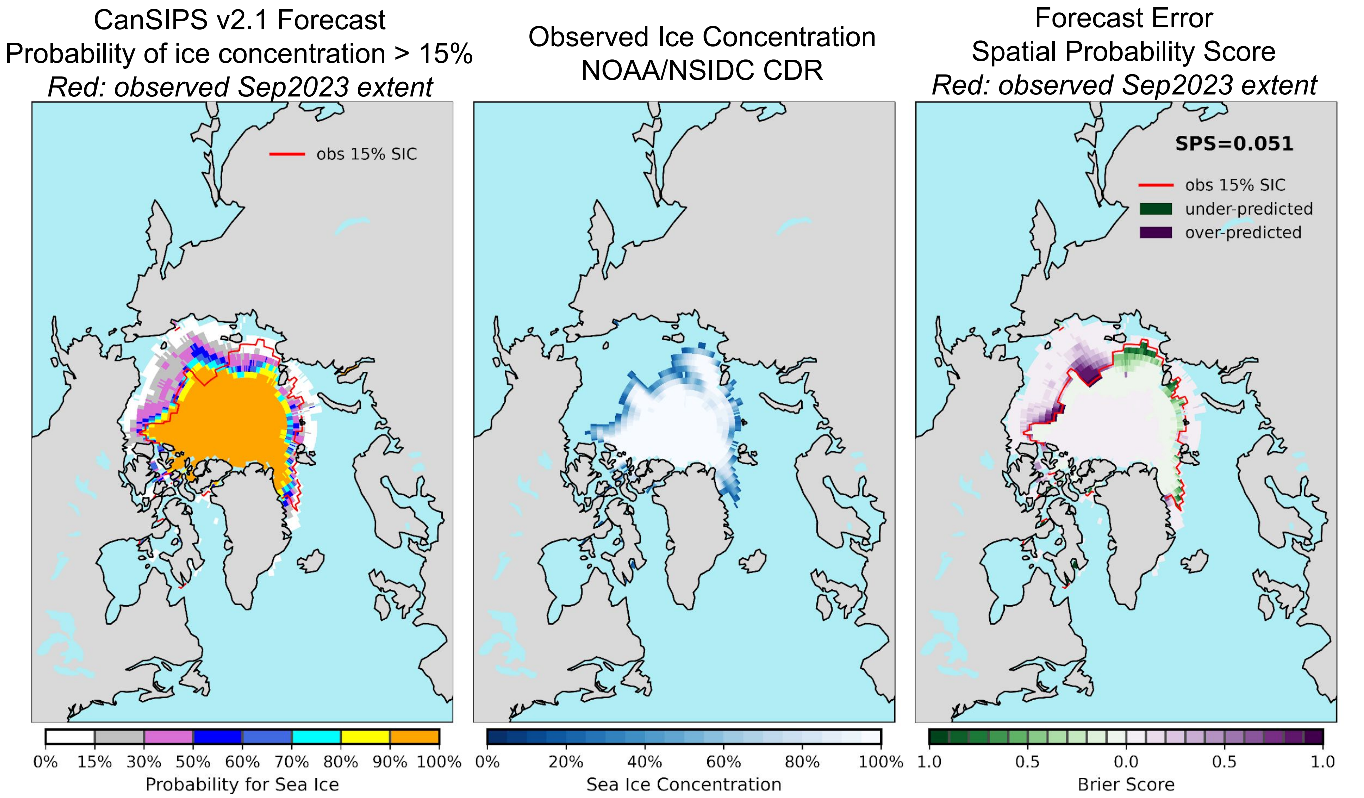
- Summer sea ice reached the minimum ice extent in mid-September (8th lowest/NSIDC)
- September average ice extent 5th lowest
- Below normal extent: Beaufort, Chukchi, East Siberian and Kara Seas
- Near normal extent: Laptev and Greenland Seas

September Northern Hemisphere Sea Ice Extent 1979-2023



Source: National Snow and Ice Data Center

CanSIPS v2.1: Probability of September 2023 sea ice concentration exceeding 15% Forecast from May 1, 2023

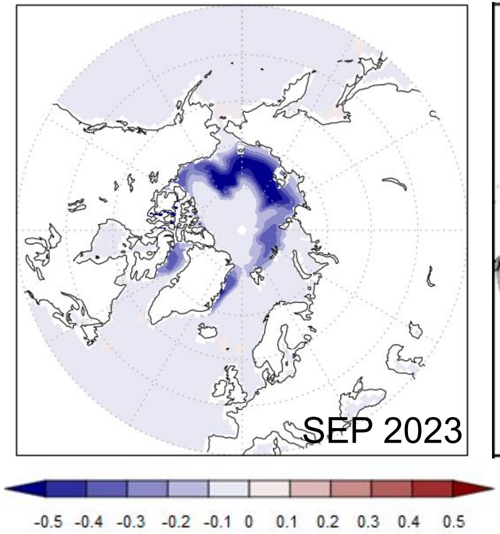


*SPS = Spatial Probability Score
(lower is better)

Source: Environment and Climate Change Canada

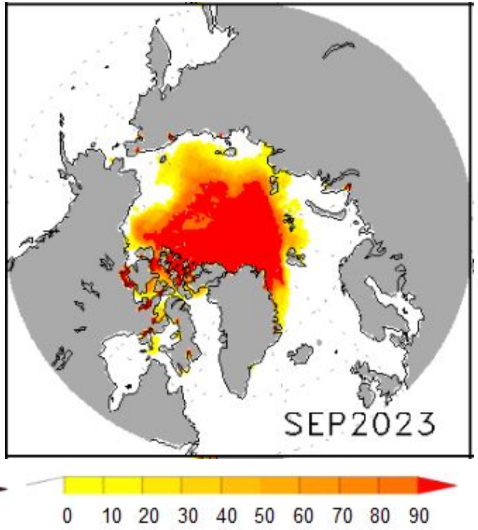
Experimental Deterministic Forecasts of September 2023 Sea Ice Concentration
Forecasts from April/May 2023

Experimental INMCM5 forecast
Initialized May 1, 2023
(anomaly from 2014-2022)



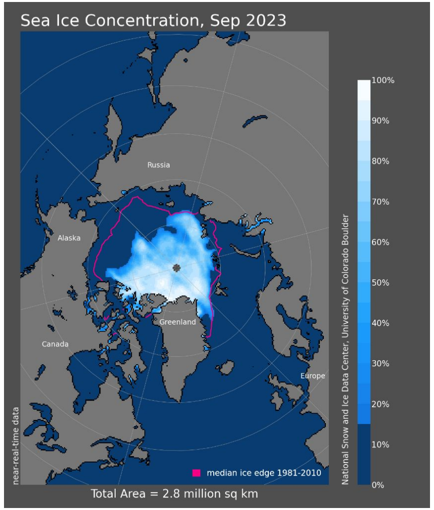
Source: Arctic and Antarctic Research Institute

Experimental CFSm5 forecast
(NOAA)
Initialized April 21-25, 2023



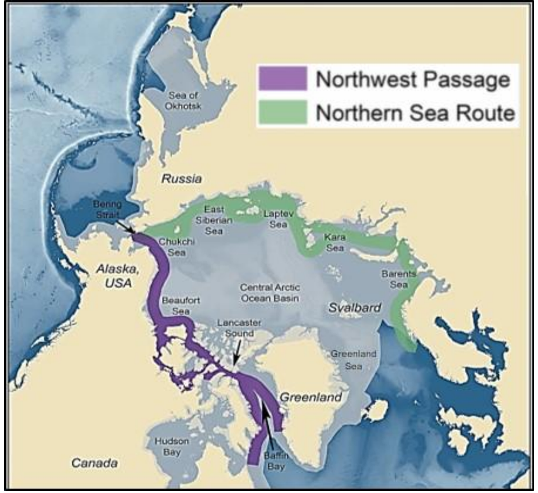
Source: U.S. NOAA

Observed Ice Concentration
NOAA/NSIDC CDR
(pink: 1981-2010 median ice edge)



Source: National Snow and Ice Data Center

ArcRCC Summer 2023 Outlook
September Sea Ice Extent
Actual vs Outlook



Forecast Categories (2014-2022 normal) :

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

Outlook Confidence Categories:

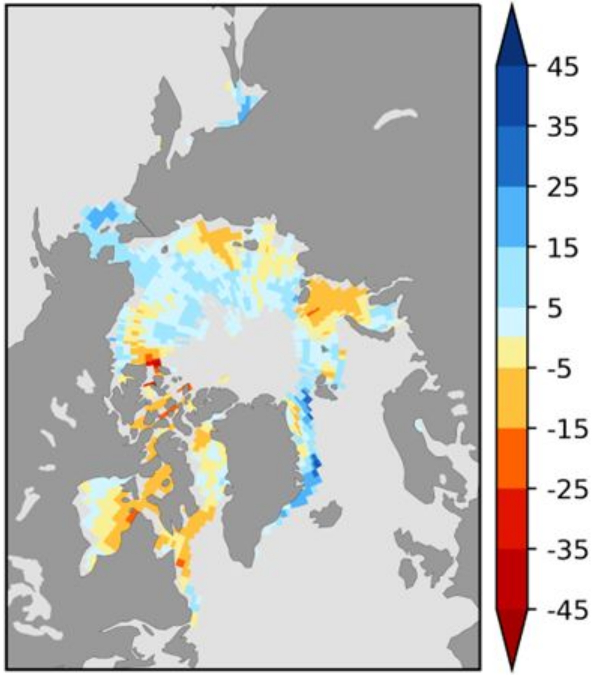
- low
- moderate

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
Beaufort Sea	High	Below normal	Below normal	Hit
East Siberian Sea	Moderate	Below normal	Below normal	Hit
Canadian Arctic Archipelago	High	Below normal	Below normal	Hit
Chukchi Sea	High	Below normal	Below normal	Hit
Barents Sea	Moderate	Near normal	Near normal	Hit
Greenland Sea	Moderate	Near normal	Above normal	Miss
Kara Sea	Moderate	Below normal	Above normal	Miss
Laptev Sea	Moderate	Below normal	Above normal	Miss

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

ArcRCC Summer 2023 Outlook
Sea Ice Break-up

CanSIPS v2.1 Break-up Date Anomaly (based on 2014-2022 reference period; forecast from May 1))



Source: Environment and Climate Change Canada

What is *Normal* break-up?

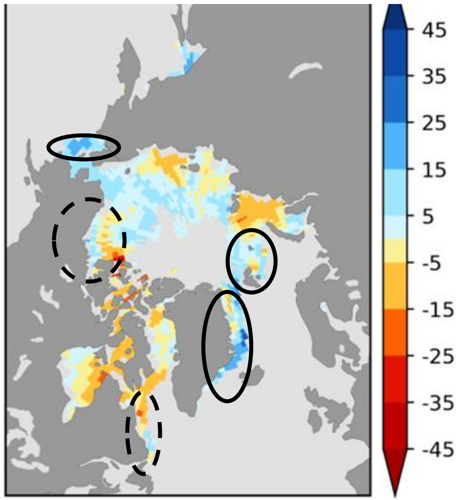
- The average date when the ice concentration drops below 50%
- Based on 2014-2022 reference period

<u>Break-up Categories</u>:

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

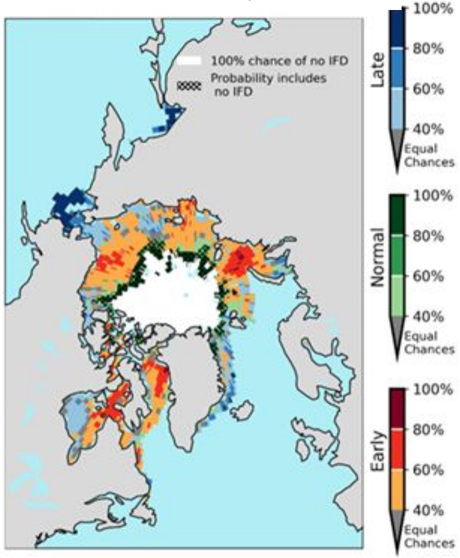
ArcRCC 2023 Sea-Ice Break-Up Outlook
Actual vs. Outlook

Deterministic break-up forecast from CanSIPSv2.1, May 1 2023: break-up date anomaly from 2014-2022 average

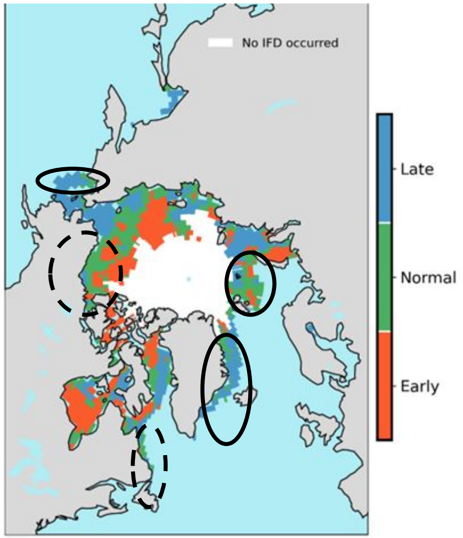


Source: Environment and Climate Change Canada

Probabilistic break-up forecast from CanSIPSv2.1, May 1 2023



Observed Break-up NOAA/NSIDC CDR



Approx. Correct Category

Correct Category

ArcRCC Sea-Ice Break-up Outlook 2023

Actual vs. Outlook

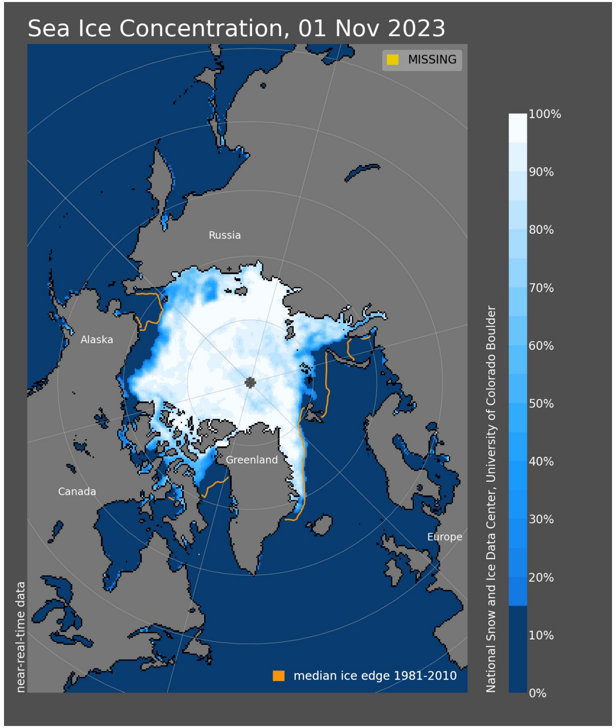
Regions	CanSIPSv2.1 Forecast Confidence	CanSIPSv2.1 Breeak-Up Forecast	Observed Break-up	CanSIPSv2.1 Forecast Accuracy
Baffin Bay	High	Near normal	Early (N); Late (SW)	Miss
Barents Sea	High	Near normal	Normal	Hit
Beaufort Sea	High	Near normal	Normal (S); Early (N)	~Hit
Bering Sea (N)	Already occurred			
Bering Sea (S)	Moderate	Late	Late	Hit
Chukchi Sea	Moderate	Near normal	Late	Miss
East Siberian Sea	Low	Early	Late to near normal	Miss
Greenland Sea	High	Late	Late	Hit
Hudson Bay	High	Near normal (W); Early (E)	Early	~Miss
Kara Sea	High	Early	Early (W); Late (N)	~Miss
Labrador Sea	High	Early	Early (N); Normal (S)	~Hit
Laptev Sea	Low	Early	Normal	Miss

ArcRCC Sea-Ice Outlook
Winter 2023-24

ArcRCC 2023-24 Winter Outlook
Sea Ice Freeze-up

What is Normal freeze-up?

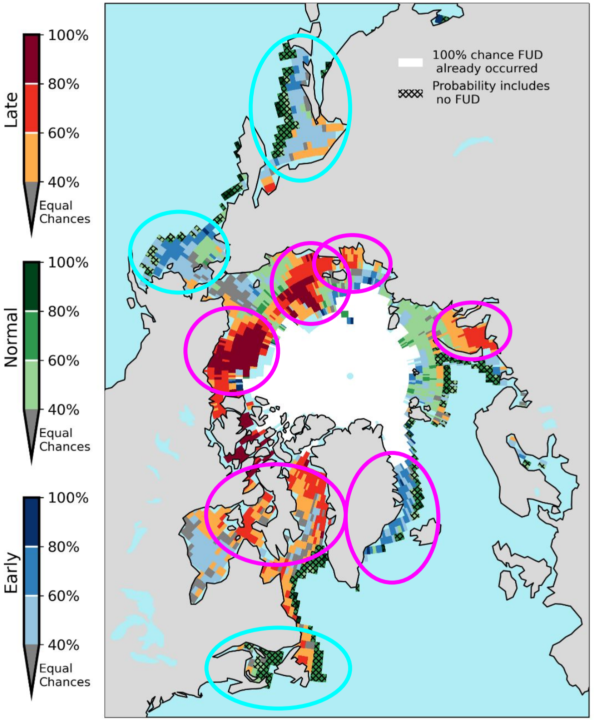
- the date when the ice concentration rises above 50%
- based on past 9-year reference period (2014-2022)



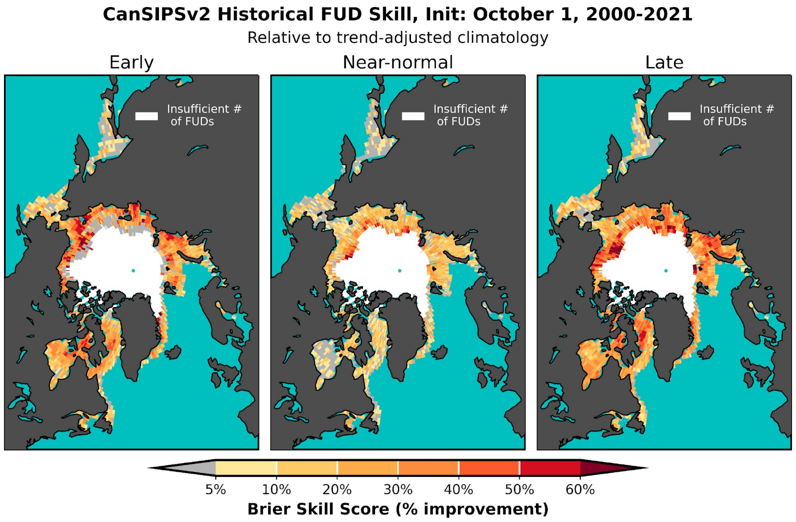
Source: National Snow and Ice Data Center

Regions	CanSIPSv2.1 Sea-Ice Forecast Confidence	CanSIPSv2.1 Sea-Ice Freeze-up Forecast
Baffin Bay		
Barents Sea		
Beaufort Sea (S)		
Bering Sea		
Chukchi Sea		
East Siberian	Already occurred	
Greenland Sea (S)		
Hudson Bay		
Laptev Sea	Already occurred	
Labrador Sea		
Kara Sea (E)		
Sea of Okhotsk		

CanSIPSv2.1 Probabilistic Freeze-up Date Forecast
Winter 2023-24



Source: Environment and Climate Change Canada

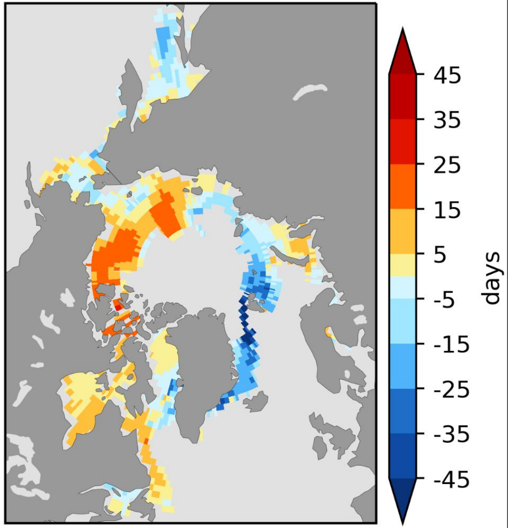


Poor/Neutral historical skill for forecasted category

Positive historical skill for forecasted category

- White area represents locations that were never ice-free or freeze-up has already occurred (concentration never <50%)
- Hatching indicates where near-normal category is most likely, and includes the case that freeze-up does not occur (concentration never >50%)

ArcRCC 2023-24 Winter Outlook Sea Ice Freeze-up



Source: Environment and Climate Change Canada

Deterministic freeze-up forecast from CanSIPSv2.1: freeze-up date anomaly from 2014-2022 average.

What is Normal freeze-up?

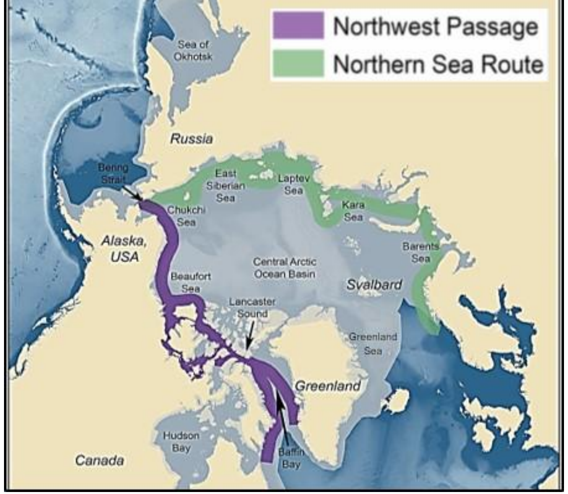
- the date when the ice concentration rises above 50%
- based on past 9-year reference period (2014-2022)

Freeze-up Categories:

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

Regions	CanSIPSv2.1 Sea- Ice Forecast Confidence	CanSIPSv2.1 Sea-Ice Freeze-up Forecast
Baffin Bay	High	Near normal
Barents Sea	High	Early
Beaufort Sea (S)	High	Late
Bering Sea	Low	Near normal
Chukchi Sea	High	Near normal
East Siberian	Already occurred	
Greenland Sea (S)	High	Early
Hudson Bay	Moderate	Near normal to late
Kara Sea (E)	High	Near normal to late
Labrador Sea	Moderate	Near normal to late (south) and early (north)
Laptev Sea	Already occurred	
Sea of Okhotsk	Low	Near normal to early

ArcRCC March 2024 Sea Ice Extent Outlook



What is Normal Ice Extent?

- average ice extent over the past 9-year reference period (2014-2022)
- ice extent defined using 15% ice concetration

Forecast Categories (2014-2022 normal) :

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

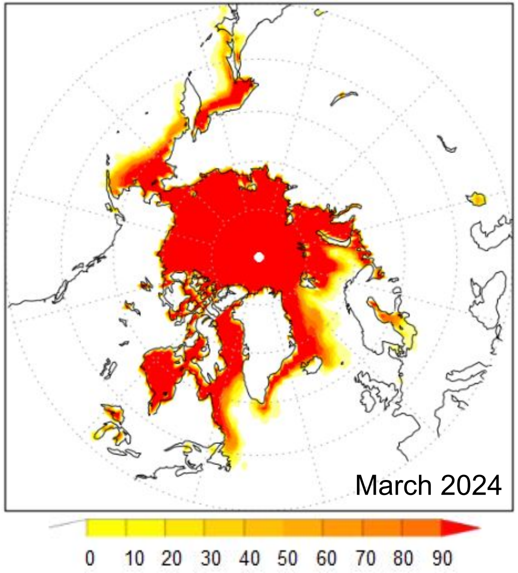
Outlook Confidence Categories:

- low
- moderate
- high

Regions	Sea-Ice Forecast Confidence	Sea-Ice Forecast Extent
Barents Sea		
Bering Sea		
Greenland Sea		
Northern Baltic Sea		
Labrador Sea		
Sea of Okhotsk		

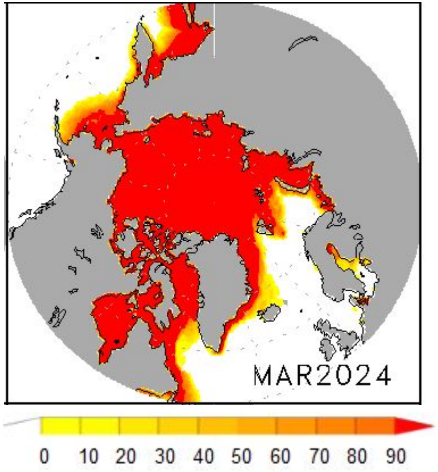
Probablity of monthly mean March 2024 sea ice concentrations exceeding 15%

Experimental INMCM5 forecast
Initialized October 1, 2023



Source: Arctic and Antarctic Research Institute

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



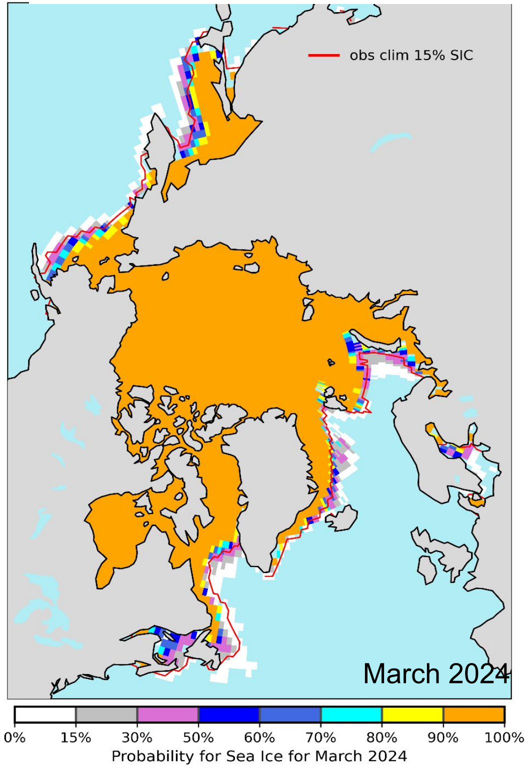
Source: U.S. NOAA

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

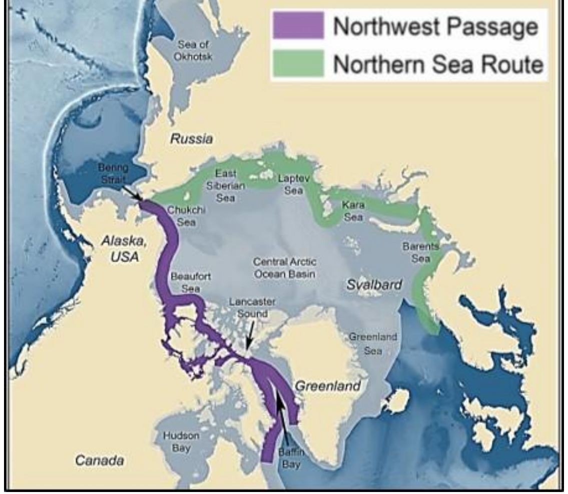
Source: Environment and Climate Change Canada

ArcRCC March 2024 Sea Ice Extent Outlook

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



Source: Environment and Climate Change Canada



Regions	Sea-Ice Forecast Confidence	Sea-Ice Forecast Extent
Barents Sea	High	Near normal
Bering Sea	Moderate	Below normal
Greenland Sea	High	Near normal
Northern Baltic Sea	Moderate	Above normal
Labrador Sea	High	Below normal
Sea of Okhotsk	Moderate	Near 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, 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, 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, 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 forecasting system

Zhu, J., W. Wang, Y. Liu, A. Kumar, D. DeWitt, 2023: Advances in Seasonal Predictions of Arctic Sea Ice With NOAA UFS. *Geophysical Research Letters*, **50**, e2022GL102392, https://doi.org/10.1029/2022GL102392

Spatial Probability Score

Goessling, H. F., T. Jung, 2018: A probabilistic verification score for contours: Methodology and application to Arctic ice-edge forecasts. *Quarterly Journal of the Royal Meteorological Society*, **144**, 735-743, https://doi.org/10.1002/qj.3242

INM-CM5 Climate Model

Vorobyeva V. and Volodin E. 2021. Evaluation of the INM RAS Climate Model Skill in Climate Indices and Stratospheric Anomalies on Seasonal Timescale, Tellus A: Dynamic Meteorology and Oceanography, 73 (1), doi: 10.1080/16000870.2021.1892435

E. M. Volodin, E. V. Mortikov, S. V. Kostrykin, V. Y. Galin, V. N. Lykossov, A. Gritsun, N. Diansky, A. Gusev, and N. Iakovlev. 2017. Simulation of the Present Day Climate with the Climate Model INMCM5, Climate Dynamics, 49 (11-12), pp. 3715–3734, doi: 10.1007/s00382-017-3539-7

Arctic Climate Forum

Thank you for your attention!

Arctic Regional Climate Center Network

ACF
Arctic Climate Forum

17:25 (25')	**Temperature, Precipitation, Sea Surface Temperature and Snow/Water Equivalent** • Validation of the outlook for summer 2023 • Outlook for winter 2023-2024 and model confidence	Session Chair: Andrew Palmer - ECCC Marko Markovic - ECCC
17:50 (25')	**Sea Ice Outlook for Winter 2023-2024** • Validation of the summer 2023 outlook • Outlook for winter 2023-2024 and model confidence	Adrienne Tivy - ECCC
18:15 (15')	**Q&As on Validation and Confidence and Sea-Ice Outlooks**	Moderator: Andrew Palmer - ECCC
18:30 (20')	**ACF-12 User & Participant Discussion**	John Nangle & Stephen Baxter - NOAA
18:50 (5')	**Final Thoughts and Wrap-Up**	Becki Heim - NOAA

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Thank You for Participating!