12th Arctic Climate Forum Consensus Statement

Summary of 2023 Arctic summer Season and the 2023/2024 Arctic Winter Seasonal Climate Outlook

CONTEXT

Arctic temperatures continue to rise at rates greater than the global average. Both the annual, summer and winter surface air temperatures since early 2000s in the Arctic (northward of 50°N within the ArcRCC-N domain) have been close to the highest in the time series of observations for 1900-2023 (figure 1) though significant interannual variations occur for all Arctic Essential Climate Variables (ECV), including the surface atmosphere, sea ice and polar ocean ECVs.

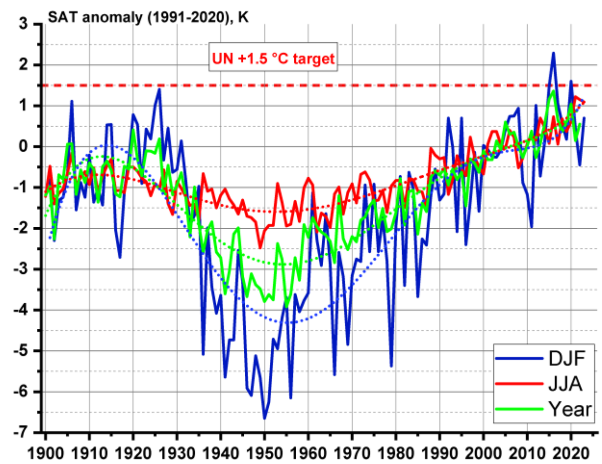


Figure 1: Annual, summer (JJA) and winter (DJF) average surface air temperature anomalies (ref. 1991-2020) for 1900-2022/2023 period. Dotted lines correspond to polynomial approximations. Graphics produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

The role of the ArcRCC-Network is to foster collaborative regional climate services amongst Arctic (hydro)meteorological and ice services, as to meet climate adaptation and decision-making needs among societal actors across the Arctic.
Arctic Climate Forums (ACFs) were established in 2018 and are convened by the Arctic Regional Climate Centre Network (ArcRCC-N) under the auspices of the World Meteorological Organization (WMO).
A main product of the ACFs are the Consensus Statements, which synthesize observations, historical trends, forecasts, and in doing so, include regional expertise. These statements include a review of the major climate features of the previous season and outlooks for the upcoming season for temperature, precipitation, sea-ice and several other experimental forecasts.
The elements of the Consensus Statements are presented and discussed at the Arctic Climate Forum (ACF) sessions, with both providers and users of climate information in the Arctic being held twice a year in May/June and October/November. The Consensus Statements are issued prior to summer thawing and sea-ice break-up (May/June) and before winter freezing and the return of sea-ice (October/November).
This Consensus Statement is an outcome of the 12th session of the ACF held online 6-7 November 2023 coordinated by the North American Node of the ArcRCC-Network and hosted by the US National Oceanic & Atmospheric Administration (NOAA) National Weather Service Alaska Region.

HIGHLIGHTS

Temperature: For the whole Arctic strong and extremely positive SAT anomalies absolutely dominated during May – September 2023. Preliminary resulting rank for JJA 2023 for the land Arctic is the 3rd consecutive in summer from 1950, though large regional and inner season variations and changes in anomaly sign continue to occur. In general, lesser scale of anomalies as well as some negative anomalies are observed for the Artic regions with a greater share of the sea are – the Western Nordic and Chukchi-Bering. For the upcoming winter season (NDJ 2023/2024) high probability of above normal temperatures is forecasted for most of the marine and land Arctic with close to normal temperatures expected only for some areas east of Greenland.

Precipitation: During the summer 2023 drier conditions dominated over parts of Western Nordic, Eastern Siberia, Chukchi and Western Canada regions with wetter conditions over parts of Eastern Nordic, Western Siberia, Alaska and Greenland regions. Close to normal conditions were estimated for the Central Arctic. For the upcoming winter season (NDJ 2023/2024) over a larger part of the Arctic Circle high expectancies are for above normal precipitation. Chances for low than normal precipitation are forecasted for small areas within Western Nordic, Alaska and Bering and Chukchi regions.

Sea-ice: The annual sea ice minimum occurred near 17th September 2023. The value close to 4.4 million square kilometers was the 8th lowest in the satellite era since 1979. Significant negative anomalies were most prominent in the areas of Eurasian and Canadian Arctic though some residual sea ice remained in both the Northern Sea Route and the North Western Passage lanes till the time of freeze-up. The maximum sea ice extent for 2023 was reached in early March 2023. The value close to 14.9 million square kilometers was the 7th lowest in the in the satellite era since 1979, which is opposite to drastic drop of Antarctic winter ice this year. An early than normal freeze-up is forecasted for the Barents, Greenland, northern part of Labrador and parts of the Okhotsk Seas. A near normal freeze-up is forecasted for Baffin Bay, Bering and Chukchi Seas, Hudson Bay, eastern part of Kara Sea and southern part of Labrador Sea. A late than normal freeze-up is forecasted for the southern part of the Beaufort Sea.

UNDERSTANDING THE CONSENSUS STATEMENT

This consensus statement includes: a seasonal summary and forecast verification for temperature, precipitation, and sea-ice for the previous 2023 Arctic summer season (June, July, August and September 2023) and an outlook for the upcoming 2023/2024 Arctic winter season (November. December 2023, January, February, March, April 2024). Experimental products with outlooks for snow water equivalent, sea-surface temperature and effective temperature bioclimatic index are also included in this consensus statement. Figure 2 shows the regions that capture the different geographic features and environmental factors influencing temperature/precipitation. Figure 3 shows the established shipping routes and regions used for the sea-ice products.

Figure 2: Regions used for the seasonal summary and outlook of temperature and precipitation

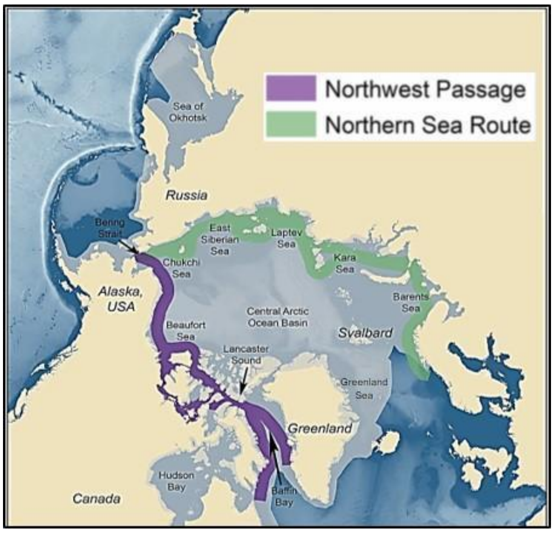


Figure 3: Sea-Ice Regions. Map Source: Courtesy of the U.S. National Academy of Sciences

Seasonal summaries of temperature, precipitation, and sea-ice are based on a synthesis of routine observations at polar stations and marine mobile platforms, sea ice analysis from the national Ice Services, satellite estimates of sea ice extent and thickness, WMO GCW SnowWatch data, and a set of modern reanalysis products including Copernicus climate change service (ERA5, MEMS, GloFAS-ERA5) and NCEP-NCAR reanalysis. Anomalies of the parameters are given in the majority of cases for the new 3rd WMO reference period 1991-2020, which allows to efficiently underline the most recent interannual variability.

The temperature and precipitation forecasts are based on eleven WMO Global Producing Centers of Long-Range Forecasts (GPCs-LRF) models and consolidated by the WMO Lead Centre for Long Range Forecast Multi-Model Ensemble (LC-LRFMME). In terms of models' skill (i.e., the ability of the climate model to simulate the observed seasonal climate), a multi-model ensemble (MME) approach essentially overlays all of the individual model performances. This provides a forecast with higher confidence in the regions where different model outputs/results are consistent, versus a low confidence forecast in the regions where the models don't agree. The MME approach is a methodology well-recognized to be providing the most reliable objective forecasts.

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) with additional use of sea ice forecasts from the Coupled Unified Forecast System (NOAA UFS; 5 ensemble members) and 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. When sea ice extent is at its minimum in September of each year, forecasts are available for the following peripheral seas where there is variability in the ice edge: Barents Sea, Beaufort Sea, Canadian

Arctic Archipelago, Chukchi Sea, Eastern Siberian Sea, Greenland Sea, Kara Sea, and Laptev Sea. In addition to these regions, forecasts for sea ice break-up are also available for Baffin Bay, Bering Sea, East Siberian Sea, Kara Sea, Laptev Sea, Chukchi Sea, Barents Sea, Greenland Sea, Hudson Bay, and Labrador Sea.

Additional seasonal outlooks based on statistical techniques and forecaster expertise are provided for key shipping areas by the Arctic and Antarctic Research Institute (AARI), Alaska Sea Ice Program, and Canadian and Finnish ice services.

TEMPERATURE

Summary for May - September 2023

Following analysis of the observations at the polar stations, during start of summer 2023 (May-June) extremely positive anomalies of the surface air temperature (SAT) were observed for the Central and Eastern Canada (1st – 2nd consecutive in row), strong positive – for parts of Eastern Nordic, Western and Eastern Siberia, Alaska and Western Canada (red color in figure 4) with Western Nordic and Chukchi-Bering regions remaining close to normal (grey and blue in figure 4). During mid-summer (July-August) similar extremely positive anomalies were observed over Eastern Nordic, Siberia and Alaska and Canada (1st – 4th consecutive in row) with similar exceptions lesser positive anomalies for the Western Nordic and Chukchi-Bering regions (red and blue colors in figure 4). By the end of summer 2023 extremely positive anomalies were observed over Eastern Nordic, Western Siberia and Central and Eastern Canada (1st - 3rd in consecutive in row) with much lesser positive or negative anomalies over Western Nordic, Eastern Siberia, Alaska regions (red and blue in figure 4).Conclusions for the Central Arctic (due to lack of in-situ observations) were based on reanalysis(not shown here), including colder conditions in May 2023, close to normal in June – August and warmer in September 2023.

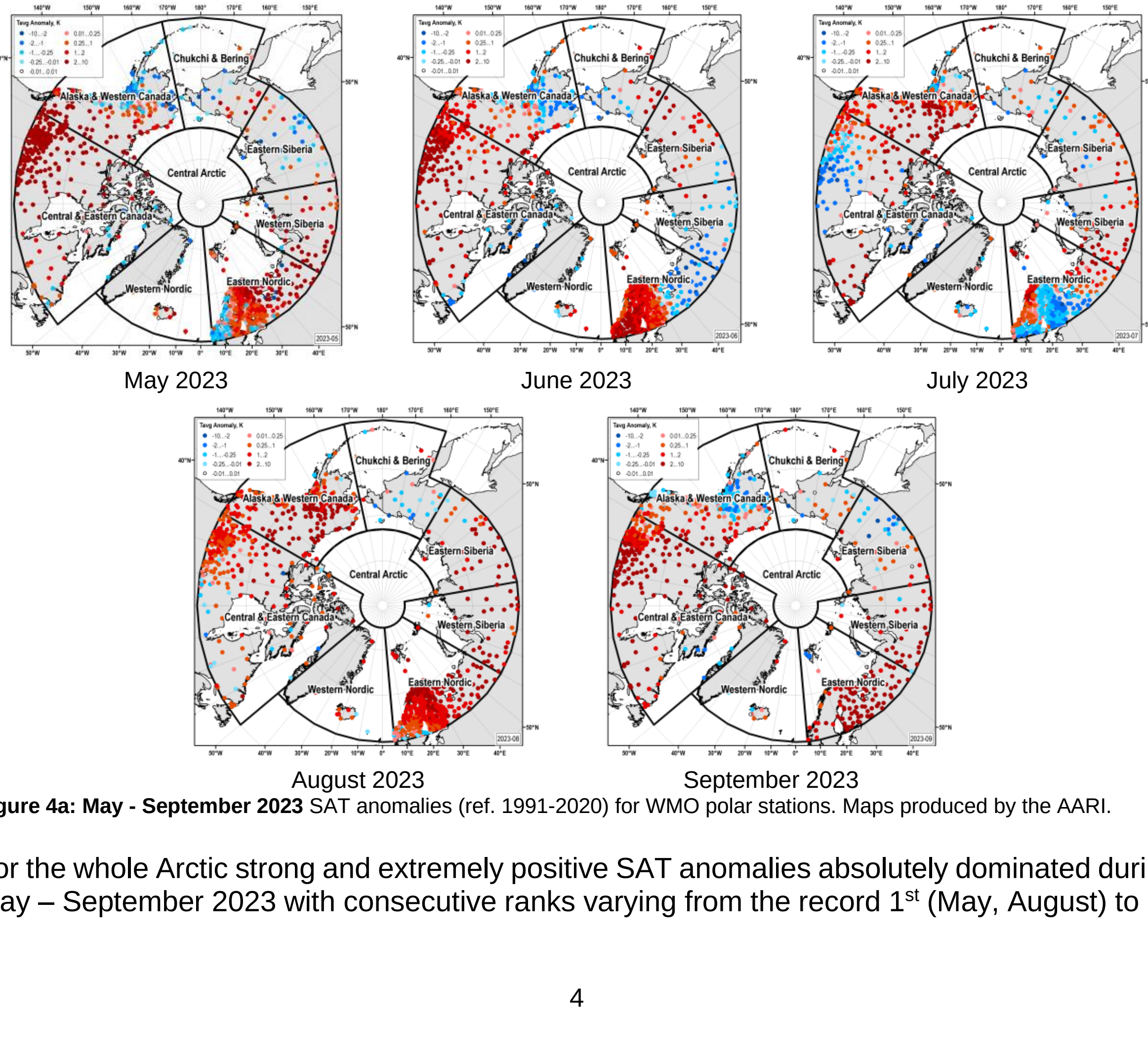


Figure 4a: May - September 2023 SAT anomalies (ref. 1991-2020) for WMO polar stations. Maps produced by the AARI.

For the whole Arctic strong and extremely positive SAT anomalies absolutely dominated during May – September 2023 with consecutive ranks varying from the record 1st (May, August) to 9th

(July). Preliminary resulting rank for JJA 2023 for the land Arctic is the 3rd consecutive in summer from 1950 (red color in figure 5, left), though large regional and inner season variations and changes in anomaly sign continue to occur. In general, lesser scale of anomalies as well as some negative anomalies are observed for the Artic regions with a greater share of the sea are – the Western Nordic and Chukchi-Bering (green color in figure 5, left, blue color in figure 5, right).

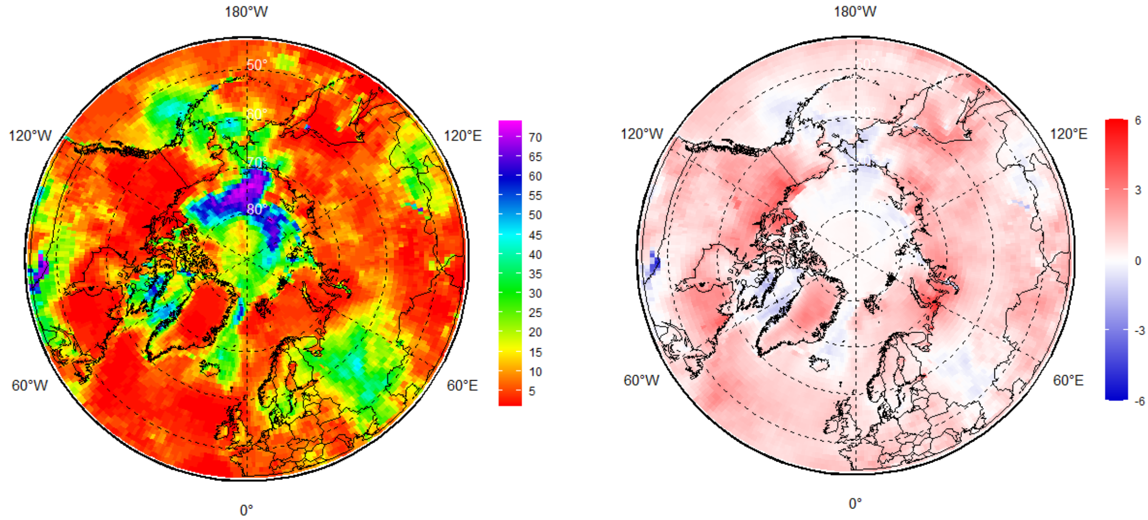
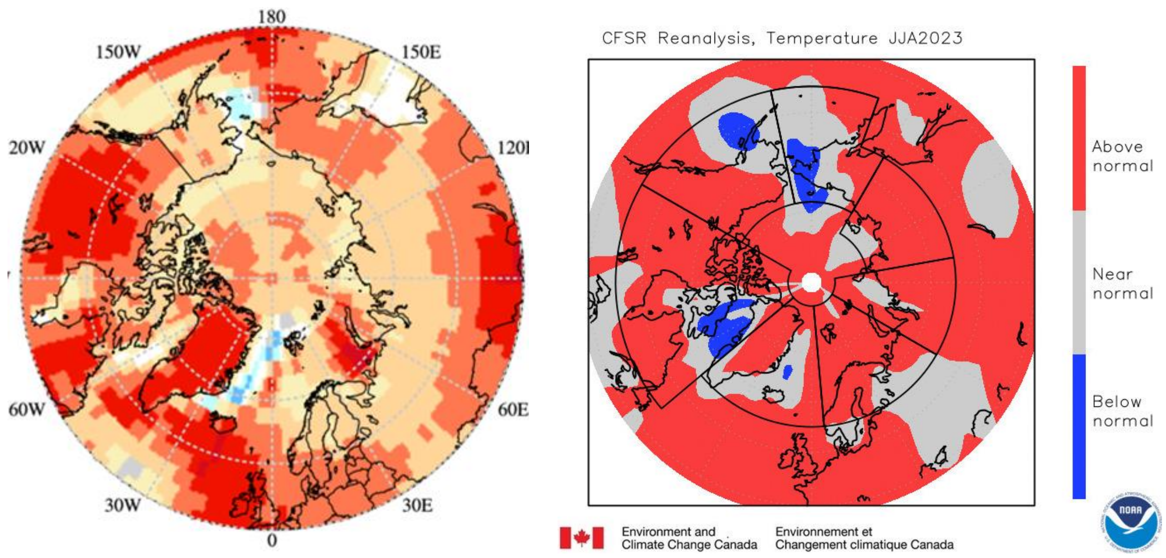


Figure 5: Summer 2023 (June – August) SAT anomalies (ref. 1991-2020), left and ranks (ref. 1950-2023). Maps produced by the AARI. Data source: CCCS ERA5

Verification of summer 2023 forecast

The FMA 2023 temperature forecast was verified by subjective comparison between the forecast (Figure 6, left) and re-analysis (Figure 6, right), region by region. A reanalysis is produced using dynamical and statistical techniques to fill gaps, where meteorological observations are not available.

Above normal temperatures were very accurately forecasted for the Western and Eastern Nordic regions with lesser accuracy for the Alaska and Western Canada, Central and Eastern Canada regions where mostly above but also near and below normal temperatures occurred. The areas with moderate and low model agreement were the ocean regions – the Western Nordic and in particular the Chukchi and Bering region where instead of above normal, mostly near normal and in some places below normal temperatures occurred, which is similar to the previous seasonal forecast. Considering all Arctic regions, the subjective score is somewhat more than 60%.



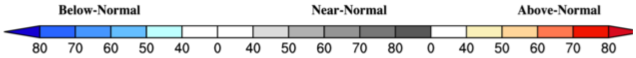


Figure 6: (Left) Multi-model ensemble (MME) probability forecast for surface air temperatures: June, July, and August 2023. Three categories: below normal (blue), near normal (grey), above normal (red); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): NCAR (National Center for Atmospheric Research) Climate forecast System Reanalysis (CFSR) for air temperature for June, July, and August 2023.

Outlook for the first part of winter 2023/2024:

For the November-December 2023 and January 2024 (NDJ23/24) period, there is a probability of 60% or more that temperatures will be above normal in most of the marine Arctic, Eastern Nordic, Western and Eastern Siberia, Eastern and Central Canada (medium and dark red areas in figure 7, table 1). Lesser probability of 40-60% above normal temperatures will be for Bering – Chukchi, Alaska and Western Canada and parts of the Western Nordic regions (light red areas in figure 7, table 1). Close to normal temperatures are forecasted for the areas east of Greenland (white areas in figure 7, table 1).

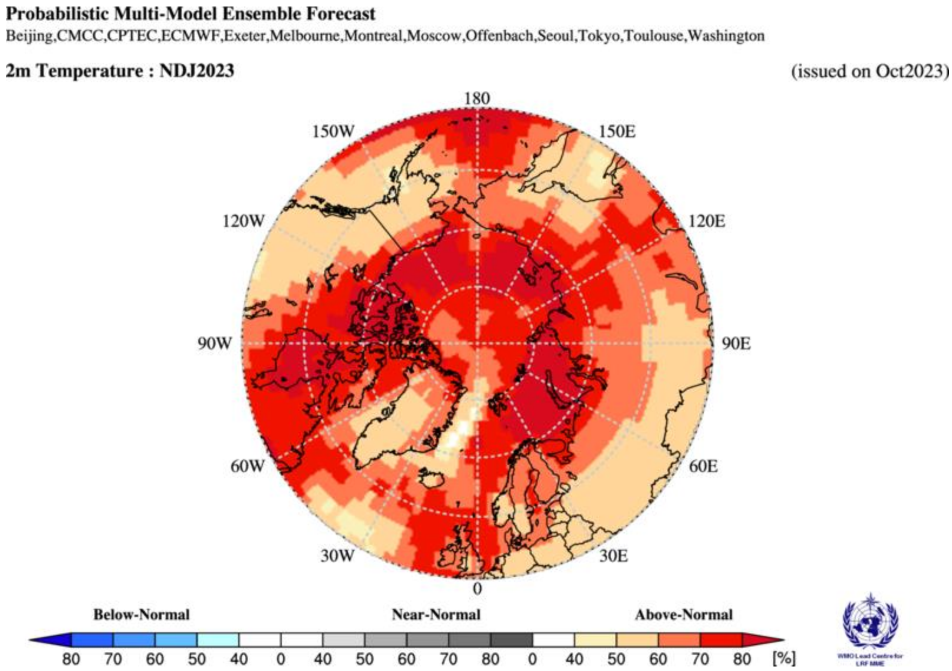


Figure 7: Multi model ensemble probability forecast for temperature for November, December 2023 and January 2024. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org.

Table 1. November, December 2023 and January 2024 outlook: regional forecasts for Arctic temperatures

Region (see Fig.2)	MME Temperature Forecast Agreement	MME Temperature Forecast
Alaska and Western Canada	Low (in southern part), Moderate (northern part)	Above normal
Central and Eastern Canada	High	Above normal
Western Nordic	Low (western part, Greenland water), high (eastern part)	Near normal (western part, Greenland water), above normal (eastern part)
Eastern Nordic	High	Above normal
Western Siberia	High	Above normal
Eastern Siberia	High	Above normal

Bering and Chukchi	Low to moderate (in southern part), Moderate to high (northern part)	Above normal
Central Arctic	High	Above normal

PRECIPITATION

Precipitation Summary for May – September 2023

In general, during the summer season drier conditions dominated over parts of Western Nordic, Eastern Siberia, Chukchi and Western Canada regions (figure 8 left, light and dark blue areas). Wetter conditions dominated over parts of Eastern Nordic, Western Siberia, Alaska and Greenland regions (figure 8 left, light and read areas). Somewhat wetter / close to normal conditions are estimated for the Central Arctic (figure 8 left, light read and white areas).
Impacts of wetter/drier conditions and evaporation were reflected in the summer 2023 Arctic rivers discharge (only overall JJA data is shown as figure 8 right). Greater drainage was seen for Ob', Lena (June, September), Mackenzie (July) and Yukon (May, July). Lesser drainage than normal was seen during summer 2023 period for Yenisei (May, August, September), Lena (July), Mackenzie (May, September), Yukon (June, September). Such mostly greater drainage situation this summer is opposite for Eurasian Arctic during summer 2021-2022 but somewhat similar for American sector for the last two years.

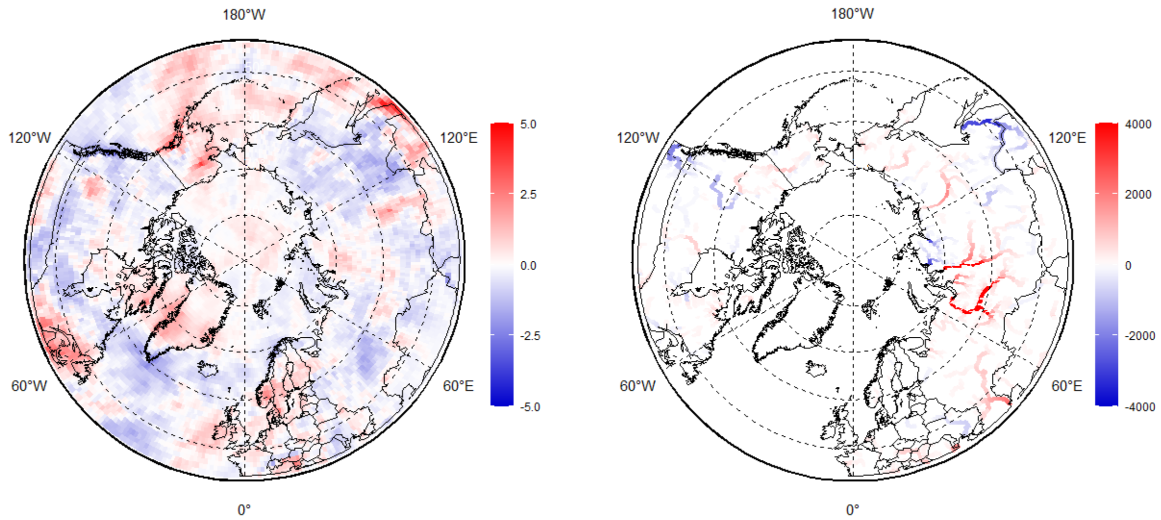


Figure 8: Summer 2023 (June – August) (Left) Surface precipitation anomalies (ref. 1991-2020) and (right) river discharge anomalies (ref. 1991-2020). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5.

Verification of summer 2023 forecast

The JJA 2023 precipitation forecast was verified by subjective comparison between the forecast (Figure 9, left) and reanalysis (Figure 9, right), region by region. As for temperature, precipitation reanalysis is produced using statistical techniques to fill gaps when meteorological observations are not available.

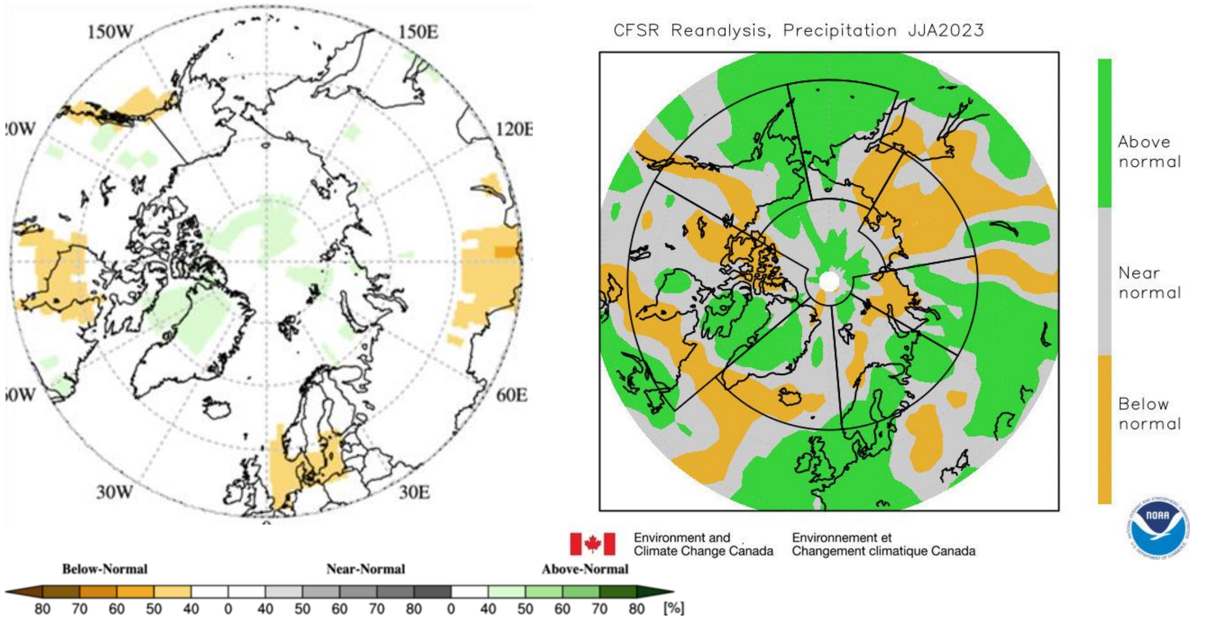


Figure 9: (Left) Multi-model ensemble (MME) probability forecast for precipitation: June, July, and August 2023. Three categories: below normal (brown), near normal (grey), above normal (green); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): NCAR CFSR for precipitation for June, July, and August 2023.

Overall, the accuracy of the JJA 2023 precipitation forecast was mostly non-decisive above all Arctic regions (Figure 9). In the regions where there was model agreement, the forecast subjective score ranged between 10% to 50%. The model captured mostly above normal over the Greenland precipitation but missed mostly near normal precipitation for the Central and Eastern Canada.

Outlook for the first part of winter 2023/2024:

For the November-December 2023 and January 2024 (NDJ23/24) period over a larger part of the Arctic Circle, there are 50-60% chance expectancies for above normal precipitation (Figure 10: light and green areas; Table 2). This means that the MME forecast is decisive in any of the three probability categories. The indecisive forecast for this period above normal precipitation is showing in most of the Nordic, Chukchi and Bering and Western and Alaska regions. High chances for low than normal precipitation are forecasted for small areas within Western Nordic, Alaska and Bering and Chukchi regions (orange areas Figure 10, Table 2).

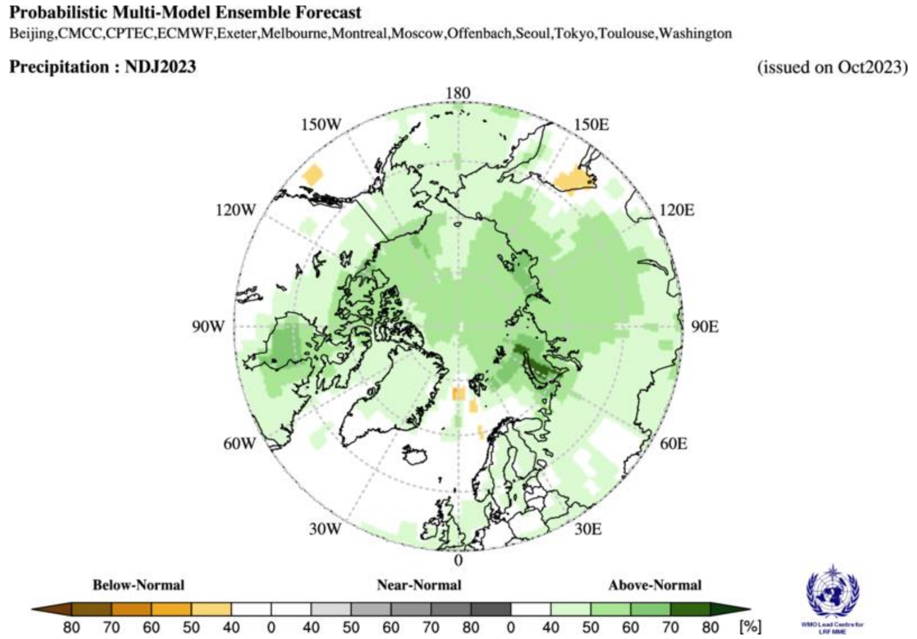


Figure 10: Multi model ensemble probability forecast for precipitation for June, July, and August 2022. Green indicates wetter conditions, orange drier conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 2. November, December 2023 and January 2024 outlook: forecasted Arctic precipitation by region

Region (see Fig.2)	MME Precipitation Forecast Agreement*	MME Precipitation Forecast
Alaska and Western Canada	Low	Above normal over Alaska, No model agreement south, below normal near Gulf of Alaska
Central and Eastern Canada	Low	Above normal
Western Nordic	Low	Mostly no model agreement, below normal in some parts of the Greenland Sea
Eastern Nordic	Low	Above normal in the south, mostly no model agreement in then north
Western Siberia	Low	Above normal
Eastern Siberia	Low	Above normal,
Chukchi and Bering	Low	Above normal, below normal in some parts of the Sea of Okhotsk
Central Arctic	Low	Above normal

*: See non-technical regional summaries for greater detail

SNOW WATER EQUIVALENT (experimental product)

Outlook for the first part of winter 2023/2024:

Snow Water Equivalent (SWE) calibrated probabilistic seasonal forecast is from the Canadian Seasonal to Interannual Prediction System (CanSIPS). Over the coastal areas of Chukchi, Alaskan, western and eastern Canada, Svalbard regions and most of the Central Siberia region there is a probability of 50% or more for an above average SWE (blue areas, figure 11). Over most of the other areas of the Arctic below normal snowfall first part of the winter 2023/2024 (at least 50-60% probability) is forecasted (orange areas, figure 11). No model agreement is for the Greenland, parts of the Central Siberia and western Canada (white areas, figure 11).

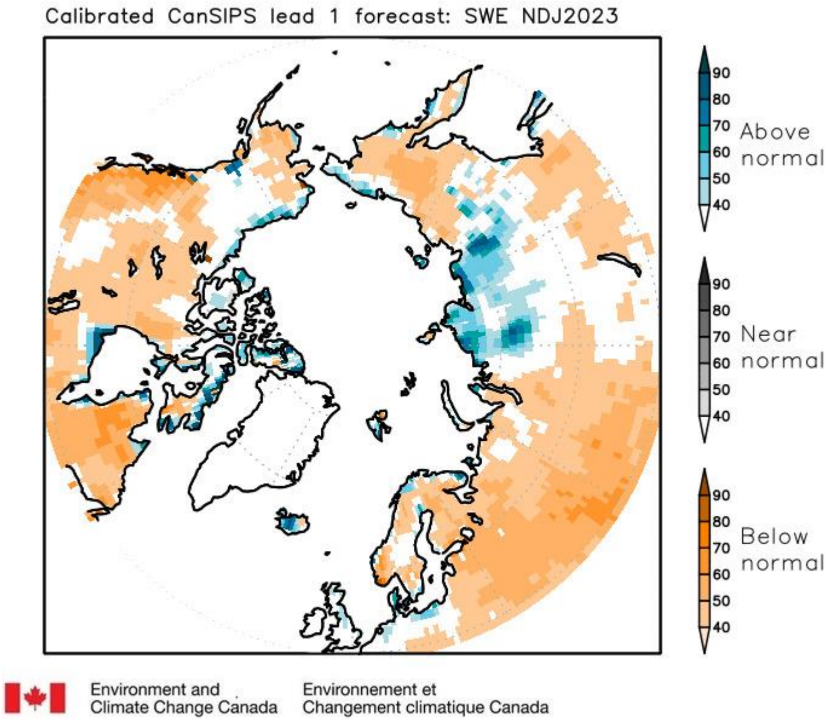


Figure 11: Canadian Seasonal to Interannual Prediction system probability forecast for snow water equivalent for November, December 2023 and January 2024.

POLAR OCEAN

Polar Ocean Summary for May – September 2023

Prominent negative 15m upper ocean layer Heat Content anomaly (to 1993-2020) was estimated in the Greenland, Northern Laptev, Chukchi, Eastern Bering Seas with positive anomaly in the Barents, Kara, southern Laptev, Beaufort, Hudson Bay Seas (figure 12 left). 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 (not shown here). For the current summer season, the numerical models show 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 (figure 12 right). The negative anomalies may point to acidification processes though need further with ground-truth data.

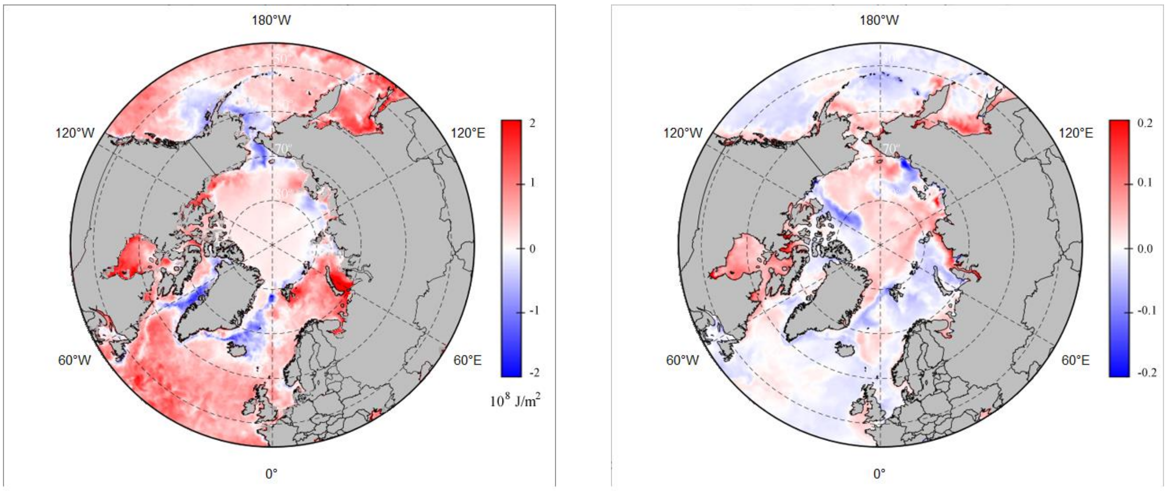


Figure 12: JJA 2023 HC upper 15 m ocean layer (left) and pH (right) anomaly (ref. 1993-2020 period). Maps produced by the AARI. Data source: CCCS MEMS.

Sea-Surface Temperature Outlook for the first part of winter 2023/2024 (experimental product):

Below normal sea-surface temperature (SST) is expected first part of winter only in some areas of Greenland Sea (blue areas in figure 13, table 3). High probability of above normal SST (>70%) is forecasted for the Norwegian, Barents, Kara, Bering Seas, Canadian archipelago, Hudson Bay (red and dark red areas in figure 11, table 3). Low probability of above normal SST (40-60%) is forecasted for the Laptev, Greenland, Okhotsk Seas, parts of Chukchi Sea and Baffin Bay (light red areas in figure 13, table 3). Near normal SST is forecasted for most of the Eastern Siberian Sea (grey areas in figure 13, table 3).

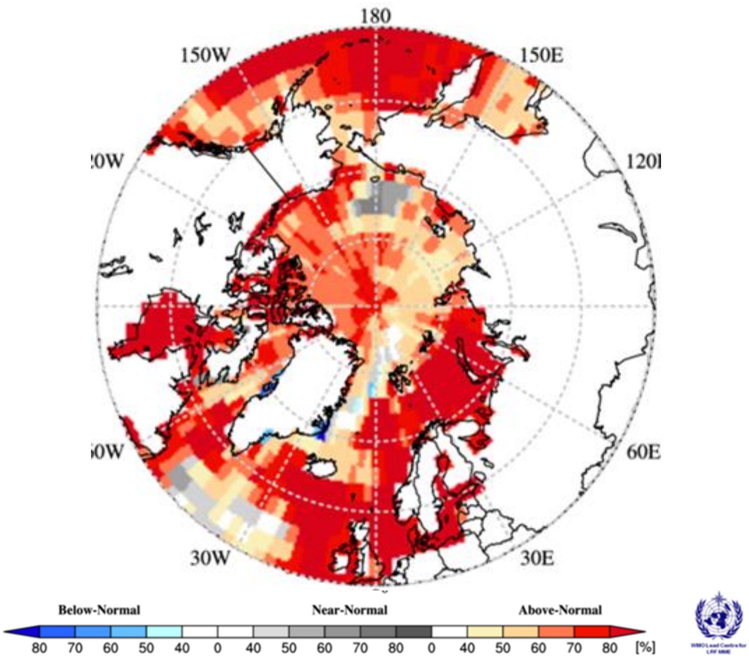


Figure 13: Multi model ensemble probability forecast for sea-surface temperature for November, December 2023 and January 2024.. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 3. November, December 2023 and January 2024 outlook: regional forecasts for Arctic sea-surface temperatures

Region (see Figure 2)	MME Temperature Forecast Agreement*	MME Temperature Forecast
Baffin Bay	Moderate to high	Above normal
Barents Sea	High	Above normal
Beaufort Sea	Moderate to high	Above normal
Bering Sea	High to moderate	Above normal
Canadian Archipelago	High	Above normal
Chukchi Sea	Moderate to high	Above normal; near normal in the northmost areas
East Siberian Sea	High to moderate	Near normal
Greenland Sea	Low to moderate	Variable
Hudson Bay	High	Above normal
Kara Sea	High	Above normal
Laptev Sea	Moderate to low	Above normal
Sea of Okhotsk	Low to moderate	Above normal

SEA ICE

Summary for May – September 2023

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 with exceptions in Barents and western part of the Kara Seas. Further in season, dominance of positive surface air temperature anomalies over Western Eurasian Arctic, Western part of the Eastern Siberian Sea, Beaufort Sea, 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

Minimum summer 2023 ice extent equal to ~4.4 million square km occurred near 17 September 2023 (actual values depend on algorithm, technique and source used) and was 8th consecutive in row for satellite era since 1979 (figure 14 left). That is well within the scale of Arctic ice extent variability since 2007. Maximum Arctic (Northern Hemisphere) winter 2023 ice extent, 7th consecutive in row, was equal to ~14.9 million square km and occurred near 4-5 March 2023, which is also close in time to climatic date and scale since 2007 but is opposite to the drastic drop of Antarctic winter ice this year. 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 ice extent changes for the next years (figure 14 right).

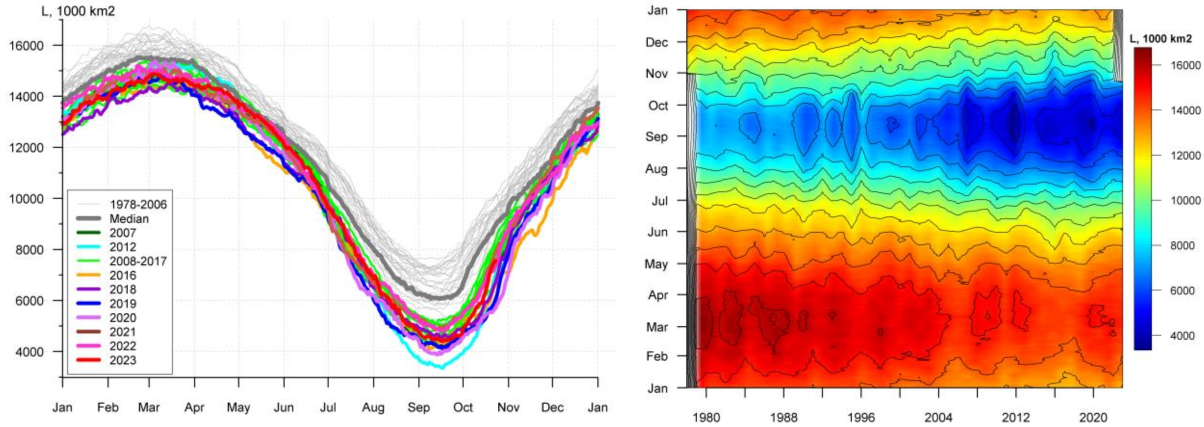


Figure 14: Arctic (Northern Hemisphere) daily (left) and daily seasonal (right) ice extent for 1978- 2023. Graphics produced by the AARI. Data source: NSIDC.

Observed in September 2023 summer Arctic ice cover minimum as well as general ice conditions though lighter but are in general similar to 2021 and 2022 (figure 15). While Eurasian Barents, Kara, parts of Eastern Siberian Sea, Chukchi, Beaufort Seas were completely ice free with the ice edge in significant northward position, the ice conditions in the Laptev, eastern part of the Eastern Siberian Sea, Greenland Seas were close to 40 years median with both the North West passage and the Northern Sea Route formally remaining blocked in the transit straits.

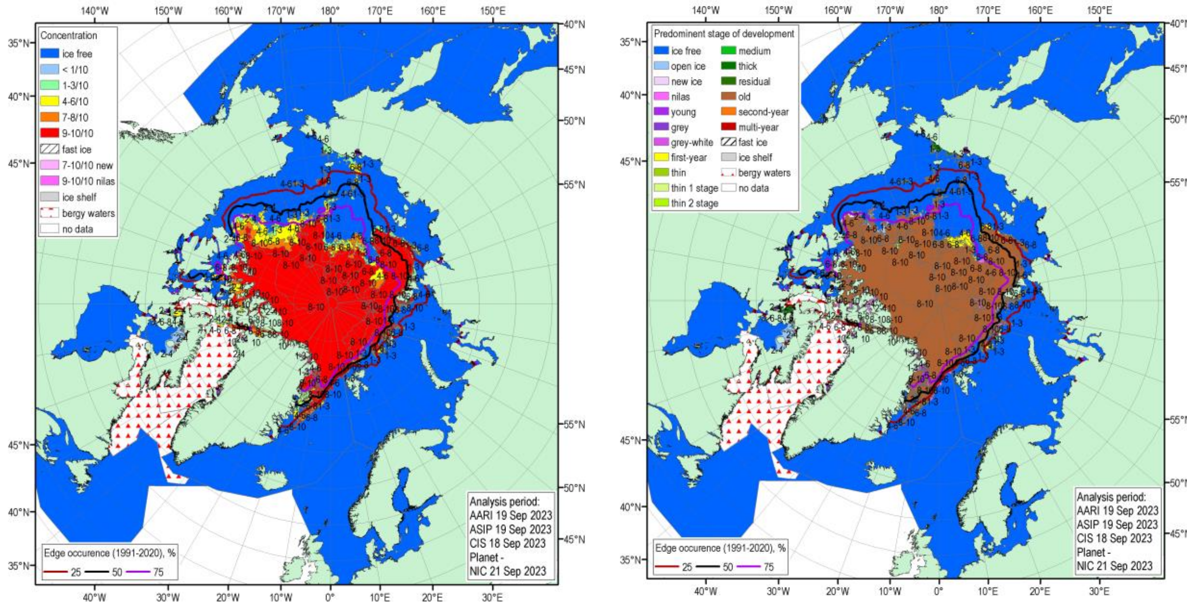


Figure 15: Blended Arctic sea-ice chart (AARI, ASIP, CIS, NIC) for 18-21 September 2023 and sea-ice edge occurrences for 16-20 September for 1991-2020 reference period. Left: total concentration, right: predominant stage of development. Graphics produced by the AARI.

Sea-Ice Outlook verification for September 2023 ice extent and summer 2023 break-up dates:

The forecast for September 2023 Sea ice extent was primarily based on output from CanSIPS v2.1. Below normal ice extent was correctly forecasted for the Beaufort, East Siberian, Chukchi Seas and Canadian Arctic Archipelago, same correct forecast of near normal extent was done for the Barents Sea (figure 16). The model did not forecast the above normal ice extent in the Greenland, Kara and Laptev Seas (green areas in figure 16). Success of the summer 2023 sea ice break-up dates (also based on output from CanSIPS v2.1) is much more variative. The model correctly forecasted near normal sea ice break-up dates in the Barents, Beaufort Seas, late break-up dates for southern Bering and Greenland Seas, early break-up dates for the Labrador Sea but missed the break-up dates anomalies for the Baffin Bay, mostly Eurasian Arctic (with exception of Barents) and the Hudson Bay.

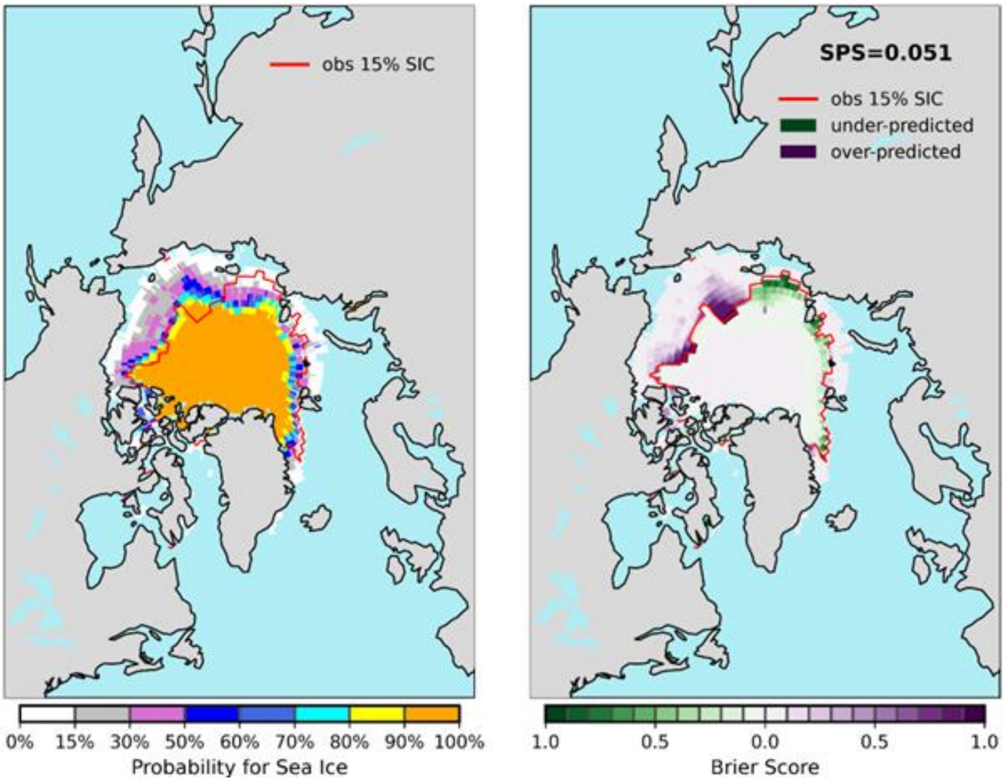


Figure 16: (Left). CanSIPS v2.1 forecast of probability of ice concentration > 15%. (Right) Forecast Error as spatial probability Score. Observed September 2023 ice extent is shown by red line.

Outlook for winter 2023/2024 sea ice freeze-up

Sea ice freeze-up is defined as the date when the ice concentration rises above 50%). The outlook for winter freeze-up shown in Figure 17 left displays the sea ice freeze-up anomaly from CanSIPSv2 based on the nine-year climatological period from 2014-2024. The qualitative 3-category (high, moderate, low) confidence in the forecast is based on the historical model skill (Figure 17, right). A summary of the forecast for the winter 2023/2024 sea-ice freeze-up for the different Arctic regions is shown in Table 4.

An early than normal freeze-up dates (blue areas, figure 17 left; Table 4) is forecasted for the Barents, Greenland, northern part of Labrador and parts of the Okhotsk Seas. A near normal freeze-up (light blue and light-yellow areas, figure 17 left, Table 4) is forecasted for Baffin Bay, Bering and Chukchi Seas. Near normal to late freeze-up (light yellow areas, figure 17 left, Table 4) is forecasted for Hudson Bay, eastern part of Kara Sea and southern part of Labrador Sea. A late than normal freeze-up is forecasted for the southern part of the Beaufort Sea.

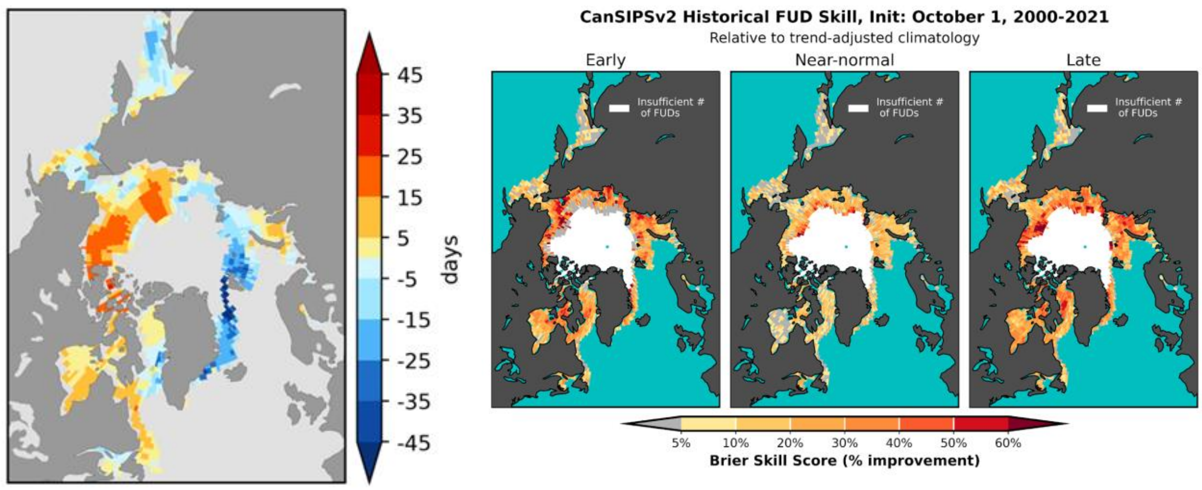


Figure 17: (Left) Deterministic freeze-up forecast from CanSIPSv2.1: freeze-up date anomaly from 2014-2022 average. (Right) CanSIPs v2 historical FUD skill relative to trend-adjusted climatology.

Table 4. Winter 2023/2024 outlook: regional forecasts for Sea ice freeze-up date anomalies

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

Outlook for March 2024 Maximum Sea Ice Extent

Maximum sea ice extent is achieved each year for the Northern Hemisphere sub-polar and polar seas during the month of March (more precisely between the late February – mid Mach). Table 5 categorizes the sea ice extent forecast confidence and relative extent (i.e., near normal, below normal, above normal) with respect to a 2014-2022 climatology for the Arctic region. The forecast for March 2024 maximum sea ice extent is presented on figure 18. The below normal March ice extent is forecasted for Bering and Labrador Seas (Table 5), near normal – for the Barents, Greenland and Okhotsk Seas, above normal – for the northern part of the Baltic Sea.

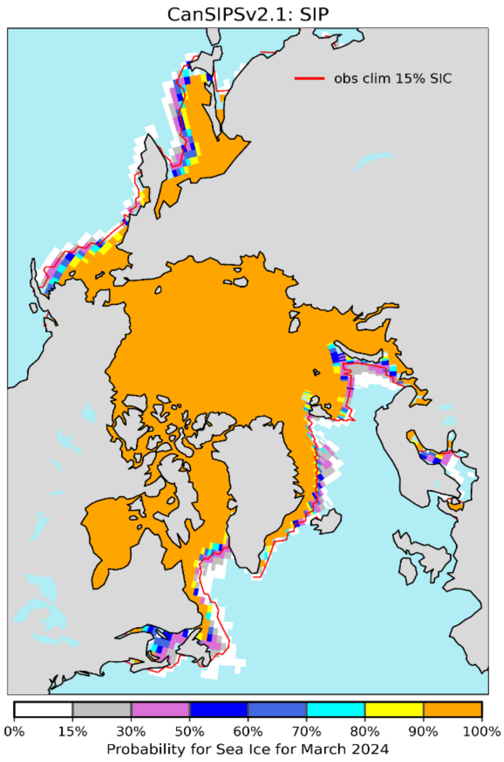


Figure 18: CanSIPSv2.1 March 2024 Sea ice extent (probability of sea ice total concentration exceeding 15%)

Table 5. March 2024 outlook: sea ice extent anomalies by regions

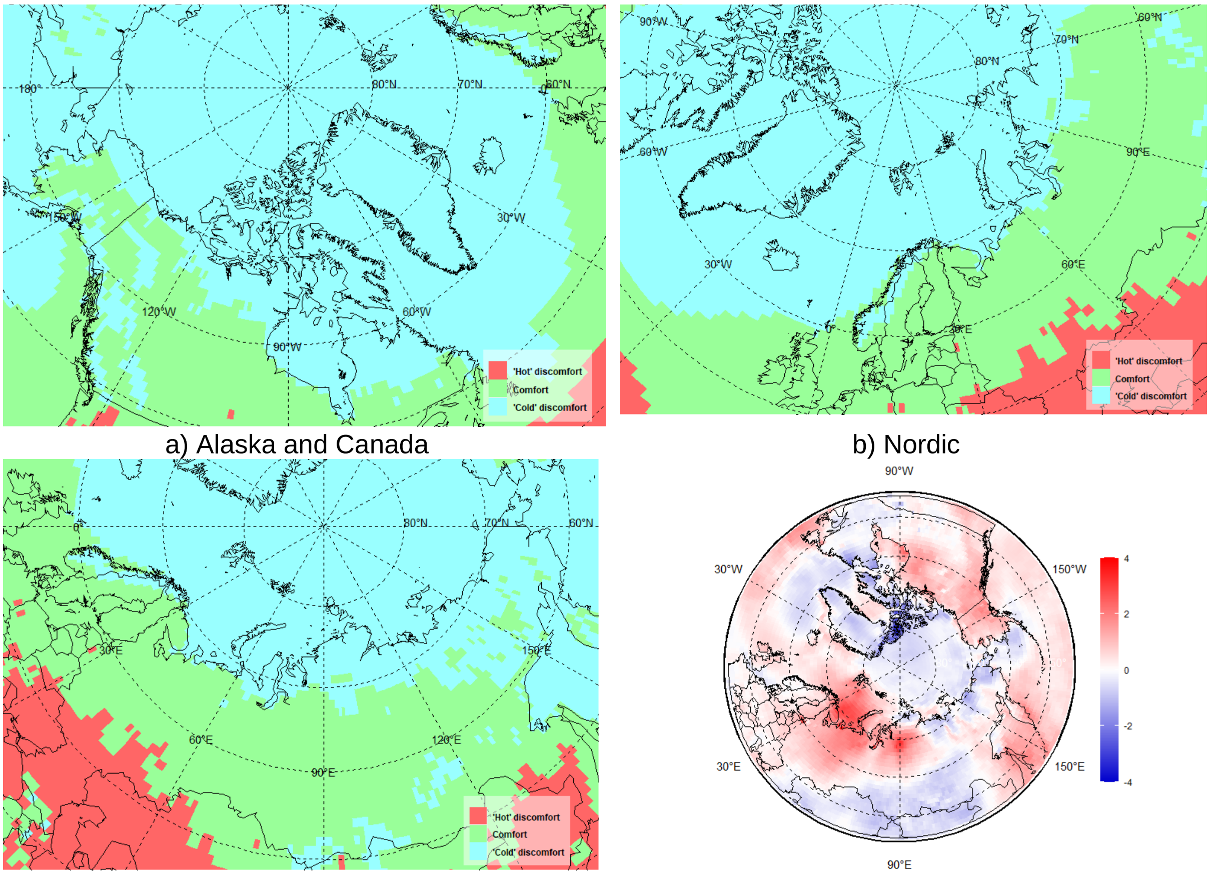
Regions	**Sea-Ice Forecast Confidence**	**Sea-Ice Forecast Extent**
Barents Sea	High	Near normal
Bering Sea	Moderate	Below normal
Greenland Sea	High	Near normal
Northern Baltic Sea	Moderate	Above normal
Labrador Sea	High	Below normal
Sea of Okhotsk	Moderate	Near normal

BIOCLIMATIC INDEXES ***(experimental product):***

Estimates of the weather comfort or bioclimatic indexes are commonly done for the mid-latitude, sub-polar and polar regions using either the Bodman's weather severity index developed specifically for the Arctic cold season which is a derivative of the surface wind speed and air temperature and varies from slightly severe to extremely severe, or the effective temperature ET (year-round) which is a derivative of surface air temperature and relative humidity and varies from comfort to extremely discomfort.

Summary for summer 2023:

During June, July, August 2023 the "cold" discomfort zone (blue areas in figure 19a-c) spread 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 dominated in the land areas (green color in figure 19a-c) and the "hot" discomfort zone (red color in figure 19a-c) was located southward in mid-latitudes. From climatic aspect during summer 2023 there were more severe conditions (blue color in figure 19d) in the Central Arctic, Greenland, Canadian Arctic Archipelago, Davis Strait and Labrador Sea, eastern part of the NSR, Bering Sea and in the southern parts of Siberia and East Canada. Milder conditions were in the Western Canada and Alaska, Okhotsk Sea (light red color in figure 19d), and most prominent mild anomalies (red color in figure 19d) were in Barents Sea, North of European Russia and northern part of Yenisei basin. Summer 2023 was quite similar to 2022 with exceptions in Canadian Arctic Archipelago and Eastern Canada where positive anomalies changed to negative in 2023.



a) Alaska and Canada b) Nordic

c) Eurasia d) JJA 2023 ET anomalies from 1991-2020

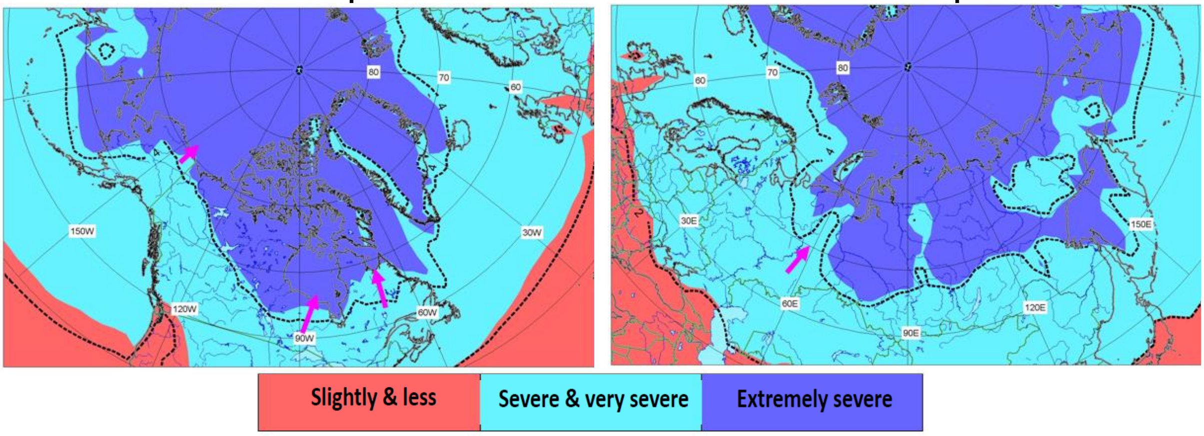
Figure 19: Effective temperature indexes for June – August 2023. Maps produced by the AARI. Data source: CCCS ERA5.

Outlook for winter 2023/2024 (experimental)

Forecast of the bioclimatic indexes is provided in a form of forecasted Bodman's weather severity index for December 2023, January and February 2024 (figure 20 and table 6) and is based on the test seasonal forecast of air temperature and wind speed produced by the Institute of Numerical Mathematics, Russian Academy of Science. The same model was used to calculate hindcasts for 1991-2020 norms (dotted lines).

In the Western Hemisphere in the winter 2023/2024 extremely severe conditions are expected in most of the region (dark blue color in figure 20). Severe conditions (light blue color in figure 19) are expected in southern Alaska, Yukon, Northwest Territories and southern Quebec. In the Eastern Hemisphere in the winter 2023/2024 extremely severe conditions (dark blue color in figure 20) are expected for Central and Eastern Siberia and Svalbard. Severe conditions (light blue color in figure 20) are expected for Nordic region, Novaya Zemlya archipelago and in the southern part of Yamal Peninsula. No slightly & less severe conditions are expected in Arctic Zone.

Western Hemisphere **Eastern Hemisphere**



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

Figure 20: Bodman's weather severity index forecast for December 2023, January and February 2024. Maps produced by the Hydrometcenter Russia. Data source: Institute of Numerical Mathematics Russian Academy of Science.

Table 6: Regional comparison of Bodman's weather severity index for winter 2023/2024

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

Notes: less severe – relative to average climatic values of Bodman's 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.

Background and Contributing institutions

The Arctic seasonal climate summary and outlooks were prepared for ACF-12 in partnership by the Canadian, Danish, Finnish, Icelandic, Norwegian, Russian, Swedish and United States meteorological agencies, sea ice services and contributions of the WMO GCW.
The ArcRCC-Network, a collaborative arrangement with formal participation by all the eight Arctic Council member countries, is in demonstration phase to seek designation as a WMO RCC-Network, and its products and services are in development and are experimental. For more information, please visit https://arctic-rcc.org/acf-fall-2023.

Acronyms:

AARI: Arctic and Antarctic Research Institute
ArcRCC-Network: Arctic Regional Climate Centre Network https://www.arctic-rcc.org/
ACF: Arctic Climate Forum
AMAP: Arctic Monitoring and Assessment Programme
CAA: Canadian Arctic Archipelago
CanSIPSv2: Canadian Seasonal to Inter-annual Prediction System
CAP: Common Alerting Protocol
CCl: WMO Commission for Climatology
CCCS: Copernicus climate change service
CBS: WMO Commission for Basic Systems
CIS: Canadian Ice Service
DMI: Danish Meteorological Institute
ECCC: Environment and Climate Change Canada
ECMWF: European Centre for Medium-Range Weather Forecasts
ESA: European Space Agency
FMI: Finnish Meteorological Institute
GCW: Global Cryosphere Watch
GPCs-LRF: WMO Global Producing Centres Long-Range Forecasts
GloFAS-ERA5: CCCS operational global river discharge reanalysis
GloSea5: Met Office Global Seasonal forecasting system version 5
H50, H500: Geopotential heights 50hPa, 500hPa
HYCOM-CICE: HYbrid Coordinate Ocean Model, Coupled with sea-ICE
IICWG: International Ice Charting Working Group
IMO: Icelandic Meteorological Office
IOC: Intergovernmental Oceanographic Commission
LC-LRFMME: WMO Lead Centre for Long Range Forecast Multi-Model Ensemble
MEMS: CCCS Marine environment monitoring service
MSLP: Mean sea level pressure
NAO: North Atlantic Oscillation
NIC: National Ice Center (United States)
NCAR: National Center for Atmospheric Research
NCAR CFSR: National Center for Atmospheric Research Climate Forecast System Reanalysis
NMI: Norwegian Meteorological Institute
NOAA/NWS/NCEP/CPC: National Oceanic and Atmospheric Administration/National Weather Service/National Centers for Environmental Prediction/Climate Prediction Center (United States)
NSIDC: National Snow and Ice Data Center (United States)
MME: Multi-model ensemble
NSR: Northern Sea Route
NWP: Northwest Passage
PIOMAS: Pan-Arctic Ice Ocean Modeling and Assimilation System
RCC: WMO Regional Climate Centre
RCOF: Regional Climate Outlook Forum
SAT: Surface air temperature
SST: Sea surface temperature
SMHI: Swedish Meteorological and Hydrological Institute
WMO: World Meteorological Organization