12th Arctic Climate Forum Consensus Statement

ACF
Arctic Climate Forum

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.

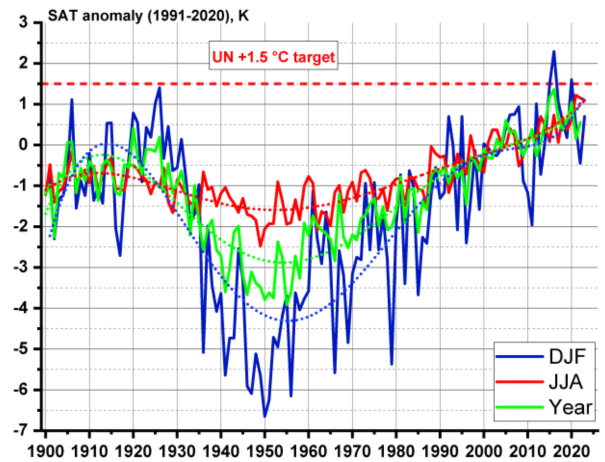


Figure 1: Annual, summer (JJA) and winter (DJF) average surface air temperature anomalies (ref. 1991-2020) for 1900-2022/2023 period. Dotted lines correspond to polynomial approximations. Graphics produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

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 is 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 around the beginning of the summer melt and sea ice break-up (May/June) and around the beginning of the winter sea ice freeze-up (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 strikingly large positive SAT anomalies 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 subseasonal 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 Arctic regions with a greater share of the sea area – the Western Nordic and Chukchi-Bering.
For the November-December-January 2023/24 period, there is a probability of 50% or more that temperatures will be above normal in all regions across the Arctic. The highest probabilities for an above normal summer (70-80% or more) are in the eastern Canadian Arctic, coastal parts of the eastern Nordic regions and over the two Siberian regions, eastern and western

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 November-December-January 2023/24 period over the largest part of the Arctic region, there are expectances for an above normal precipitation. These probabilities are rather moderate (40% or more) for most of the Arctic domains with an exception of the western and eastern Siberian regions where there are probability expectancies of 50-60% or more.

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 northern route of the Northwest Passage shipping lanes until the time of freeze-up.
For the upcoming winter 2023/2024 season, an earlier 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 later than normal freeze-up is forecasted for the southern part of the Beaufort Sea. The winter maximum ice extent is expected to be below normal for the Bering and Labrador Seas; near normal for the Barents, Greenland and Okhotsk Seas and above normal in the north Baltic. For the sea ice outlook, ‘normal’ is the 2014-2022 period.

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 (from May to September 2023) and an outlook for the upcoming 2023/2024 Arctic winter season (from November 2023 to January 2024 period for temperature and precipitation and from November 2023 to March 2024 period for sea ice). Experimental products with outlooks for snow water equivalent, sea-surface temperature and weather severity index are also included in this consensus statement. Figure 2 shows the regions, which are defined by the ArcRCC-N members on the basis of accepted regional practices to capture the different geographic features and environmental factors influencing temperature, precipitation and other Arctic ECVs. Figure 3 shows the established shipping routes and regions used for the sea ice products.

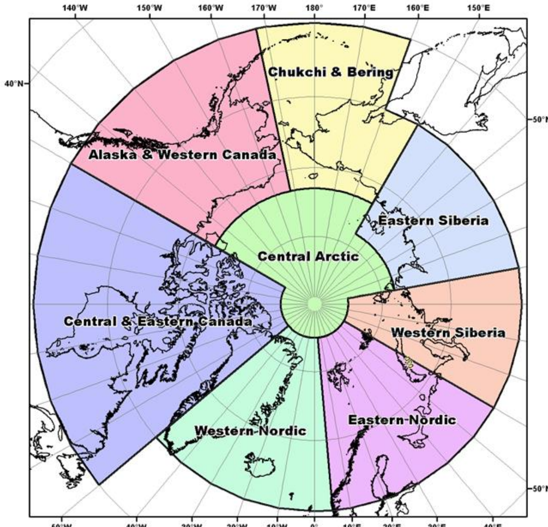


Figure 2: ArcRCC-N regions accepted for seasonal summaries and outlooks

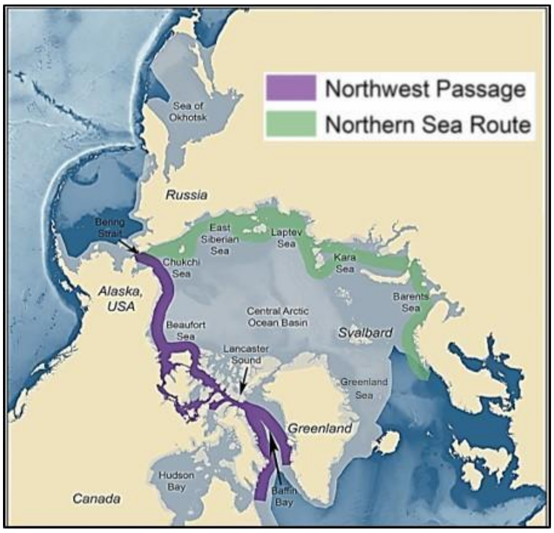


Figure 3: Sea ice Regions. Map Source: Courtesy of the U.S. National Academy of Sciences

Seasonal summaries for temperature, precipitation, sea ice and other Arctic ECVs 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 SeaIceWatch and 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 for efficiently underlining the most recent interannual variability.

The seasonal forecasts for temperature and precipitation are based on thirteen 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 by the WMO to be providing the most reliable objective forecasts.

Sea Ice and snow water equivalent 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; the outlook is a subjective 'ensemble' of probabilistic/deterministic model forecasts. Therefore, for sea ice the forecast confidence is a subjective assessment of hindcast model skill, ensemble spread and forecast agreement between models. When sea ice extent is at its maximum in March of each year, forecasts become available for the following peripheral seas where there is variability in the ice edge: Barents Sea, Bering Sea, Greenland Sea, North Baltic Sea, Labrador Sea and Sea of Okhotsk. In addition, forecasts for sea ice freeze-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.

TEMPERATURE

Summary for May – September 2023

During the start of summer 2023 (May-Juny), extremely positive anomalies of the surface air temperature (SAT) were observed (table 1) for the Central and Eastern Canada (1st – 2nd consecutive in row). Strong positive SAT anomalies were observed for Eastern Nordic, Western and Eastern Siberia, Alaska and Western Canada. SAT in Western Nordic and Chukchi-Bering regions remained close to normal. During mid-summer (July-August), similar extremely positive anomalies were observed (table 1) over Eastern Nordic, Siberia, Alaska and Canada (1st – 4th consecutive in row) with lower positive anomalies and negative for the Western Nordic and Chukchi-Bering regions (10th – 44th consecutives in row). 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 lower positive anomalies over Chukchi-Bering (18 consecutive in row) or even negatives anomalies over Western Nordic and Eastern Siberia (27th - 30th consecutives in row). Conclusions for the Central Arctic (due to lack of in-situ observations) were based on reanalysis, including colder than normal conditions in May 2023, close to normal in June – August and warmer than normal in September 2023 (figure 4).

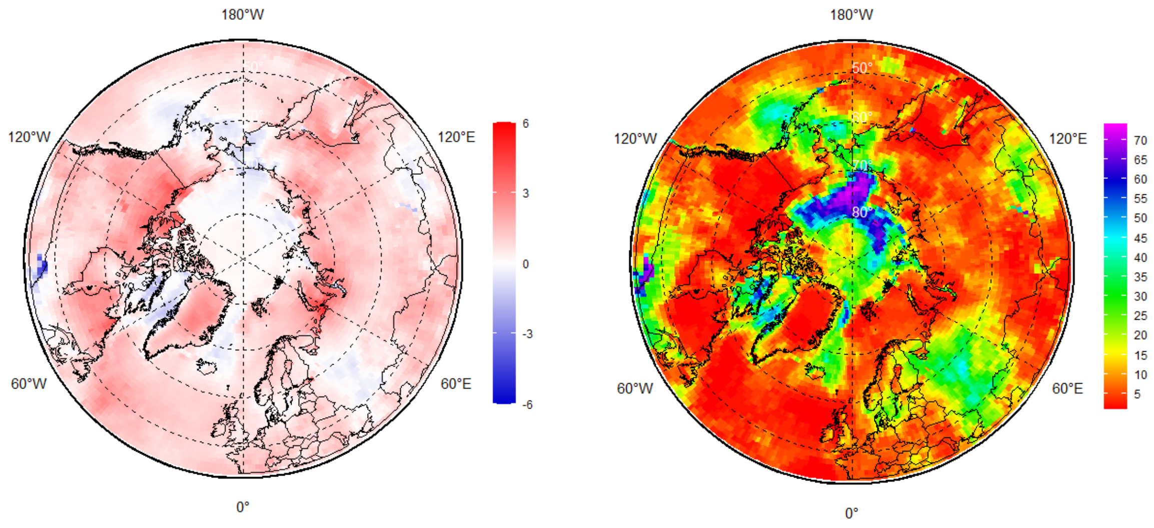


Figure 4: Summer 2023 (June – August) SAT anomalies (ref. 1991-2020), left and ranks (ref. 1950-2023). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5

For the whole Arctic (Figure 4, table 1) strong and extremely positive SAT anomalies dominated during May – September 2023 with consecutive ranks varying from the record 1st (May, August) to 9th (July). Preliminary overall ranking for JJA 2023 for the land Arctic puts this year's summer season on the 3rd place (since 1950), though large regional and inner season variations and changes in anomalies continue to occur. In general, smaller positive anomalies as well as some negative anomalies (figure 4) are observed for the Arctic regions with a greater share of the sea, particularly the Western Nordic and Chukchi-Bering regions.

Table 1. Surface air temperature anomalies (reference period 1991-2020) and consecutive ranks in brackets (reference period 1950-2023) for May – September 2023 by the ArcRCC-N regions based on observations at polar stations

Arctic region / period	Western Nordic	Eastern Nordic	Western Siberia	Eastern Siberia	Chukchi & Bering	Alaska & Western Canada	Central & Eastern Canada	Arctic
2023-05	+0.83 (13)	+1.06 (9)	+2.59 (6)	–0.21 (25)	+0.46 (19)	+0.82 (10)	+4.75 (1)	+2.15 (1)
2023-06	–0.13 (25)	+1.31 (14)	+0.71 (14)	+1.23 (7)	+0.35 (14)	–0.04 (19)	+2.45 (2)	+1.24 (3)
2023-07	–0.64 (44)	–0.15 (26)	+1.55 (6)	+0.06 (22)	+0.23 (16)	+1.61 (2)	+0.18 (19)	+0.45 (9)
2023-08	+0.47 (10)	+1.61 (3)	+3.05 (2)	+1.81 (1)	–0.18 (27)	+1.80 (2)	+1.17 (4)	+1.58 (1)
2023-09	–0.17 (27)	+2.53 (1)	+2.69 (3)	–0.17 (30)	+0.35 (18)	+0.26 (32)	+2.50 (3)	+1.34 (2)
JJA 2023	–0.11 (25)	+0.93 (8)	+1.89 (2)	+1.04 (3)	+0.11 (18)	+1.10 (2)	+1.25 (4)	+1.08 (3)

Verification of summer 2023 forecast

The FMA 2023 temperature forecast was verified by subjective comparison between the forecast (Figure 5, left) and reanalysis (Figure 5, 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 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 for winter 2022/2023. Considering all Arctic regions, the subjective score of the forecast is somewhat higher than 60%.

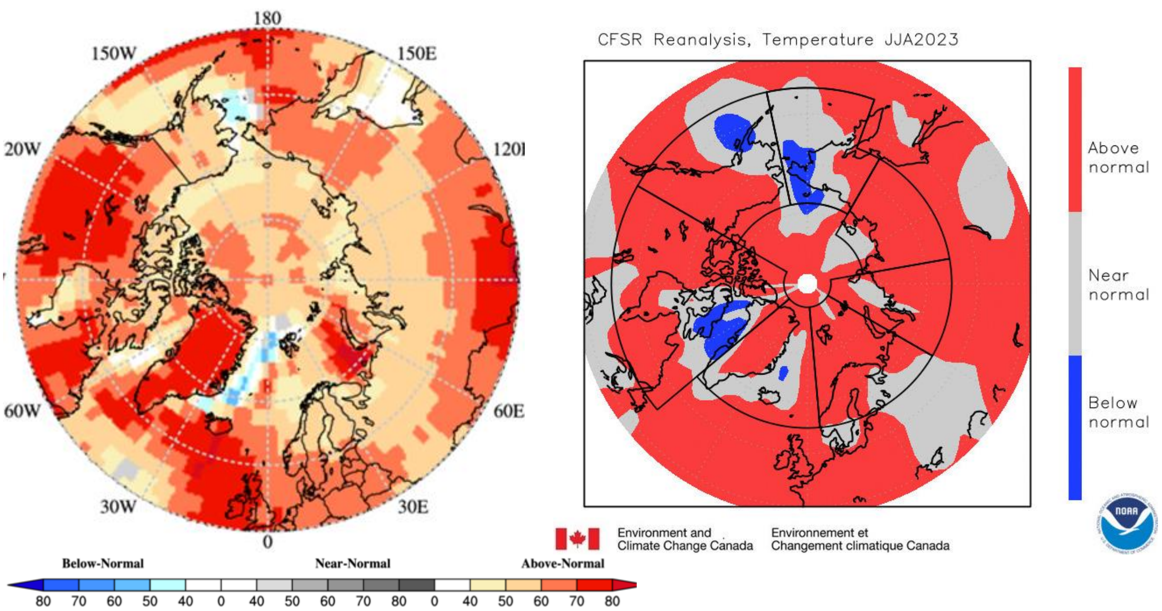


Figure 5: (Left) Multi-model ensemble (MME) probability forecast for surface air temperatures: June, July, and August 2023. Three categories: below normal (blue), near normal (grey), above normal (red); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): NCAR (National 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-January 2023/24 (NDJ23/24) period, there is a probability of 50% or more that temperatures will be above normal in all regions across the Arctic. The highest probabilities for an above normal summer (70-80% or more) are in the eastern Canadian Arctic, coastal parts of the eastern Nordic regions and over the two Siberian regions, eastern and western (medium and dark red areas in figure 6, table 2).

For Alaska and western Canada, Multi Model Ensemble (MME) forecast is showing above normal probabilities of 50% or higher, in the central and southern parts of the region, while these probabilities are somewhat higher (70% or more) in the north (light, medium and dark red areas in figure 6, table 2). Over the western Nordic region, there are probabilities of at least 50% for an above normal start of the winter. This is especially forecasted over the continental parts. Eastern Nordic region has somewhat higher expectancies for an above normal winter, 70-80% over the northeastern Scandinavia (medium and dark red areas in figure 6, table 2). These expectancies are lower in the south (at least 50%). Chukchi and Bering region has also high, above normal, expectancies (more than 60%) in the north and central domain while the probability drops to at least 50% over the southern part (light and medium red areas in figure 6, table 2). This region has very high above normal expectances of at least 70-80% over its northwestern portions.

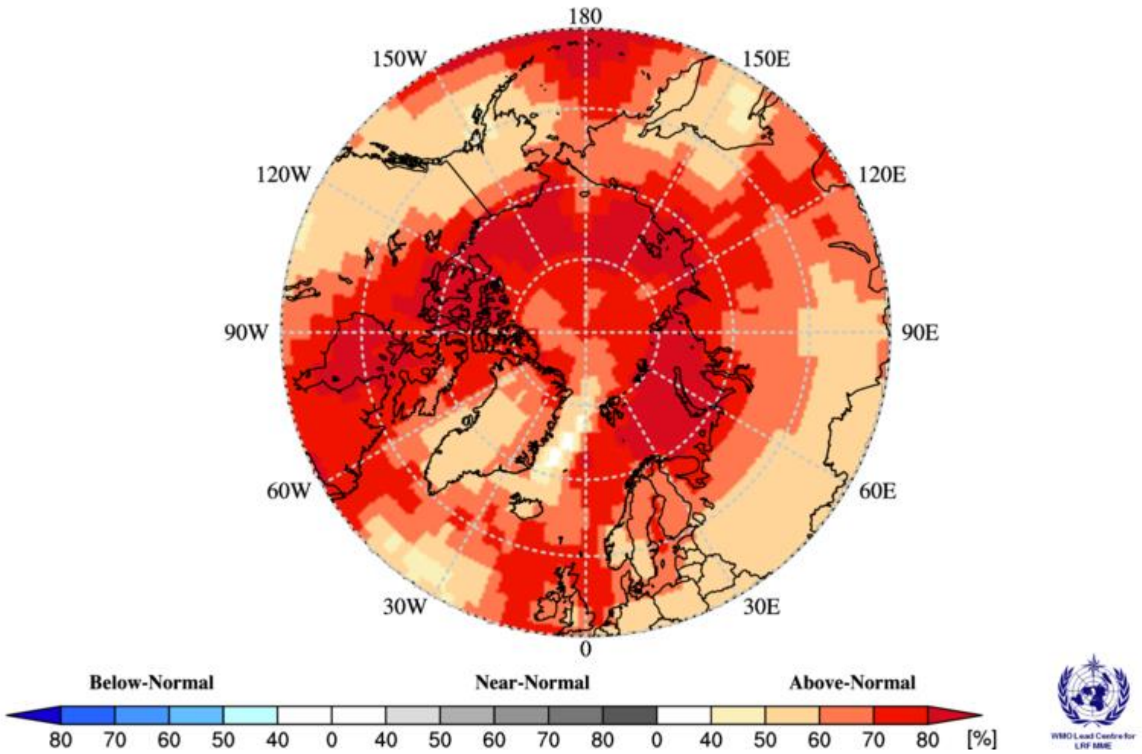


Figure 6: Multi model ensemble probability forecast for temperature for November, December 2023 and January 2024. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org.

Table 2. November, December 2023 and January 2024 outlook: Arctic regional forecasts for surface air temperature

Arctic Region	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

*: See non-technical regional summaries for greater detail

PRECIPITATION

Summary for May – September 2023

During the summer season drier conditions dominated over parts of Western Nordic, Eastern Siberia, Chukchi and Western Canada regions (figure 7 left, light and dark blue areas). Wetter conditions dominated over parts of Eastern Nordic, Western Siberia, Alaska and Greenland regions (figure 7 left, light and red areas). Somewhat wetter than normal conditions occurred over the Central Arctic (figure 7 left, light read and white areas).

Wetter or drier conditions and intencity of evaporation due to SAT anomalies were reflected in the summer 2023 Arctic rivers discharge (figure 7 right). Greater runoffs were seen for Ob', Yenisei, parts of Lena and Yukon drainage areas. Lesser runoffs than normal were seen for parts of Mackenzie drainage areas. Such mostly greater runoff situation this summer is opposite for Eurasian Arctic during summer 2021-2022 but somewhat similar for American sector for the last two years (see ArcRCC-N consensus statements for 2021 and 2022).

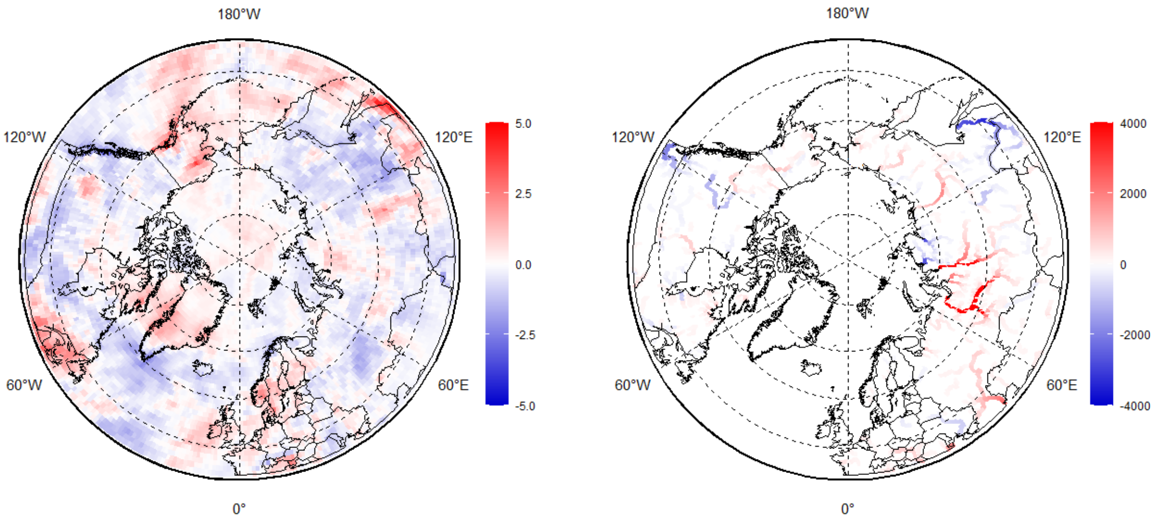


Figure 7: Summer 2023 (June – August) (Left) Surface precipitation anomalies (ref. 1991-2020) and (right) river discharge anomalies (ref. 1991-2020). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5.

Verification of summer 2023 forecast

The JJA 2023 precipitation forecast was verified by subjective comparison between the forecast (Figure 8, left) and reanalysis (Figure 8, right), region by region. As for temperature, precipitation reanalysis is produced using statistical techniques to fill gaps when meteorological observations are not available.

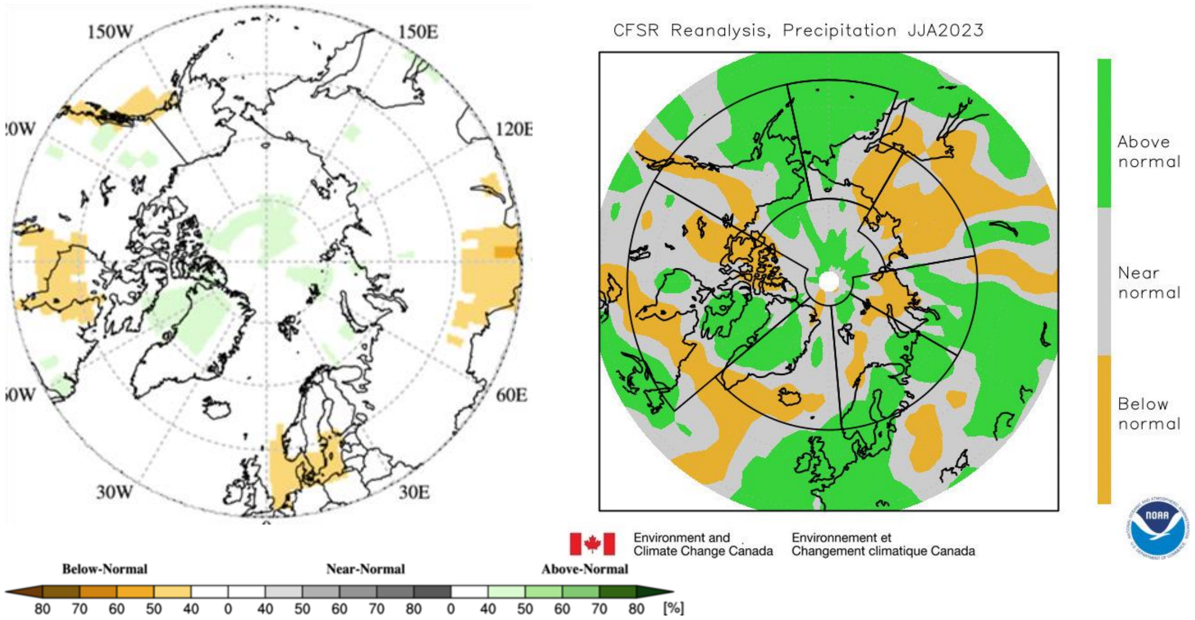


Figure 8: (Left) Multi-model ensemble (MME) probability forecast for precipitation: June, July, and August 2023. Three categories: below normal (brown), near normal (grey), above normal (green); no agreement amongst the models is shown in white. Source: www.wmolc.org. (Right): NCAR CFSR for precipitation for June, July, and August 2023.

Overall, the accuracy of the JJA 2023 precipitation forecast was mostly non-decisive above all Arctic regions (Figure 8). In the regions where there was model agreement, the forecast subjective score ranged between 10% to 50%. The MME forecast captured mostly above normal precipitation over the Greenland region, but missed the mostly near normal precipitation conditions for the Central and Eastern Canada region.

Outlook for the first part of winter 2023/2024:

For the November-December-January 2023/24 (NDJ23/24) period over the largest part of the Arctic region, there are expectances for an above normal precipitation. These probabilities are rather moderate (40% or more) for most of the Arctic domains with an exception of the western and eastern Siberian regions where we have probability expectancies of 50-60% or more (Figure 9: light green and green areas; Table 3). Southern parts of Alaska and western Canada and southern parts of the western Nordic regions, both, have equal chance expectancies for precipitation for the first part of this winter. Chukchi and Bering region has also higher probability expectancy of 50% or more over its western parts while lower probability of at least 40% is expected over other parts of the domain (Figure 9: light green and green areas; Table 3).

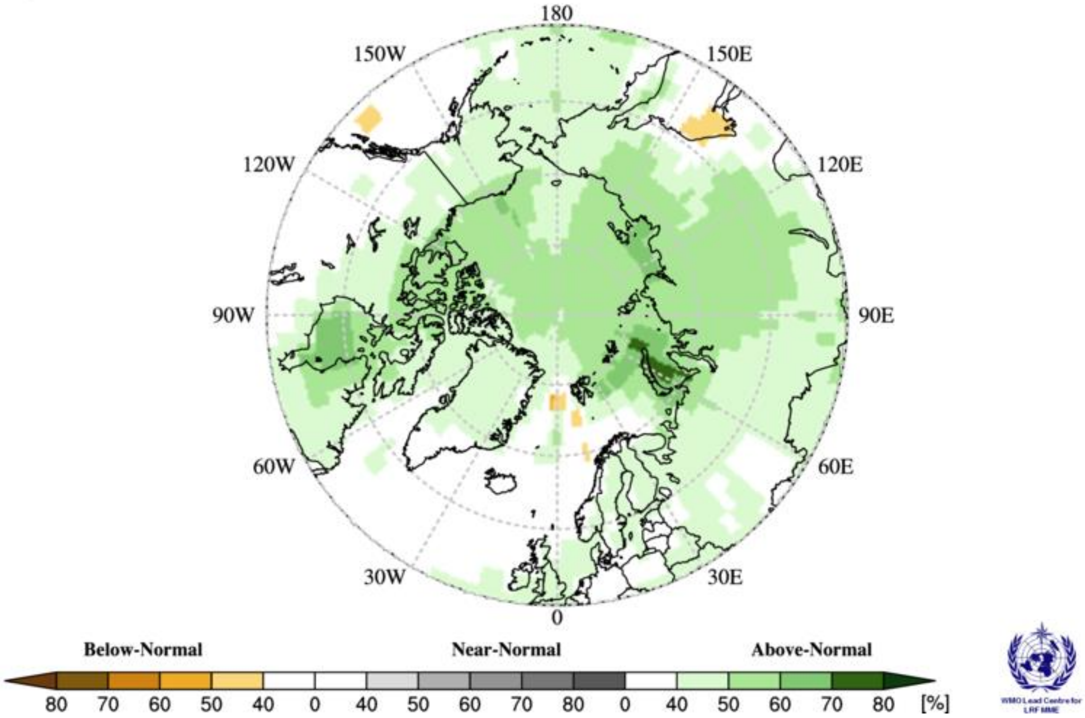


Figure 9: Multi model ensemble probability forecast for precipitation for November, December 2023 and January 2024 period. Green indicates wetter conditions, orange drier conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 3. 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 for November, December 2023 and January 2024 period is performed with Canadian Seasonal to Interannual Prediction System (CanSIPS).

Over the Alaskan and western Canada region there is probability of 40% or more for a below average SWE in the western parts of the domain (orange and white colors on figure 10) while in the domain's central part the MME is not decisive (white color on figure 10). Over the northern, coastal parts of this domain above normal SWE expectances are forecasted with at least 40% probability (blue color on figure 10).

Above normal SWE is expected over Iceland with higher probabilities of at least 50% for the central and western parts of the island (blue color on figure 10). Eastern Nordic region and western parts of the eastern Siberian region are expecting below normal SWE with at least 40% probability (orange color on figure 10). Above normal SWE values are expected over the eastern Siberian region and also over the eastern parts of western Siberia (blue color on figure 10). These probabilities reach values of 60% or higher over some scattered parts of the two regions. Equal chance SWE expectancies are forecasted over the southern parts of the eastern Siberia. Chukchi and Bering region has mostly below normal SWE expectancies (40% or higher) with an exception of the norther coastal zone, where above normal SWE is forecasted with at least 40% probability (blue, white and orange colors on figure 10).

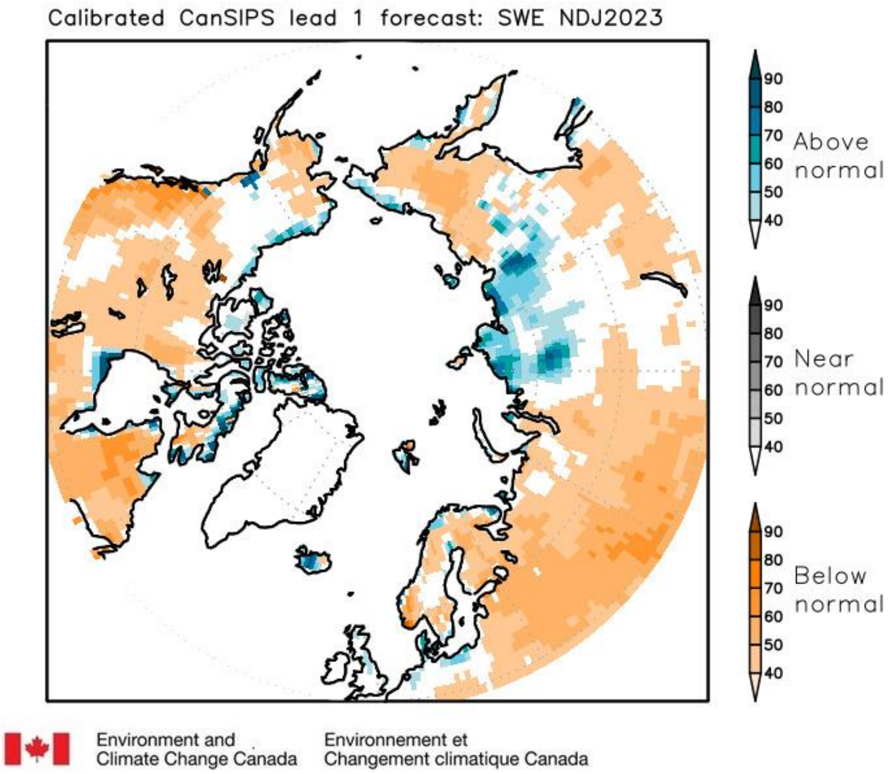


Figure 10: Canadian Seasonal to Interannual Prediction system probability forecast for snow water equivalent for November, December 2023 and January 2024 period.

POLAR OCEAN

Summary for May – September 2023

Prominent negative 15m upper ocean layer Heat Content (HC) anomaly (compared to 1993-2020) was estimated in the Greenland, Northern Laptev, Chukchi and Eastern Bering Sea regions with positive anomaly in the Barents, Kara, southern Laptev, Beaufort, Hudson Bay Seas (figure 11 left). Due to lower sea ice extent in Chukchi, Beaufort, parts of Kara and the Canadian Arctic, these regions were relatively often exposed to stronger wave conditions (not shown here). Calmer than normal wave conditions were observed in parts of the Nordic regions which is similar to summer 2022. 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 11 right) The negative anomalies point to acidification processes though need further with ground-truth data[1].

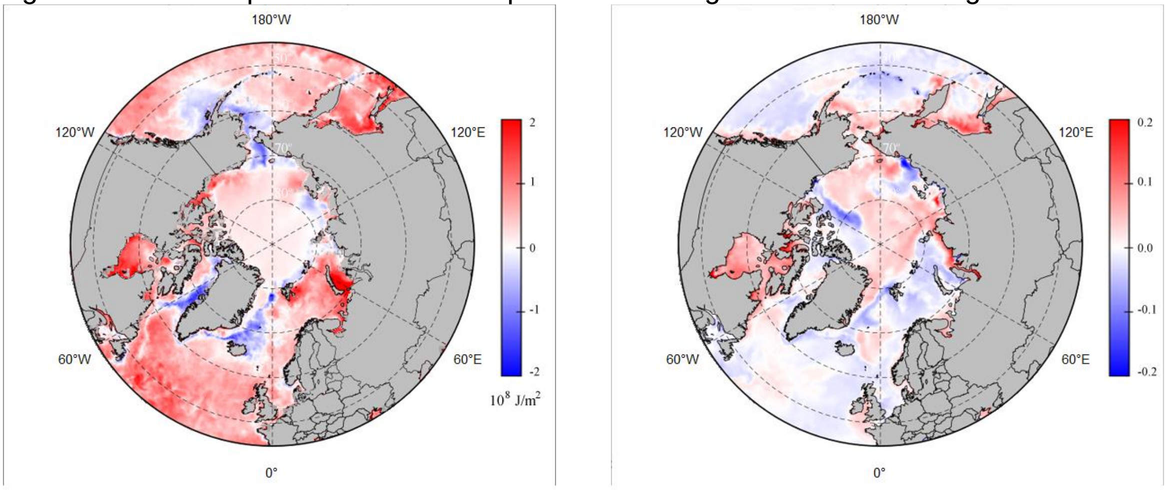


Figure 10: JJA 2023 HC upper 15 m ocean layer (left) and pH (right) anomaly (ref. 1993-2020 period). Maps produced by the AARI. Data source: CCCS MEMS.

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

For November, December 2023 and January 2024 period over the largest portion of the Arctic seas, the multi-model ensemble approach is forecasting above normal sea surface temperature (SST) (red and dark red areas in figure 11, table 4). The highest probabilities for an above normal SST's are forecasted for Barents and Kara Seas and Hudson Bay with probabilities of more than 70%. Laptev sea has somewhat lower above normal (50% or higher) SST probabilities of 50% and higher while near normal probability (40% or higher) chances are expected in East Siberian Sea. In the Beaufort and Chukchi Sea and in Canadian Archipelago at least 60% probability of above normal SST is expected for the start of the winter. Below normal SST is expected for the start of winter only in some areas of the Greenland Sea (blue areas in figure 11, table 4).

[1] Surface seawaters in the Arctic have a pH of about 8.1, with a range of about 7.5 to 8.4. The term ocean acidification refers to an increase in acidity (i.e., a decrease in pH). AMAP, 2019. Arctic Ocean Acidification Assessment 2018: Summary for Policy-Makers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. 16 p.

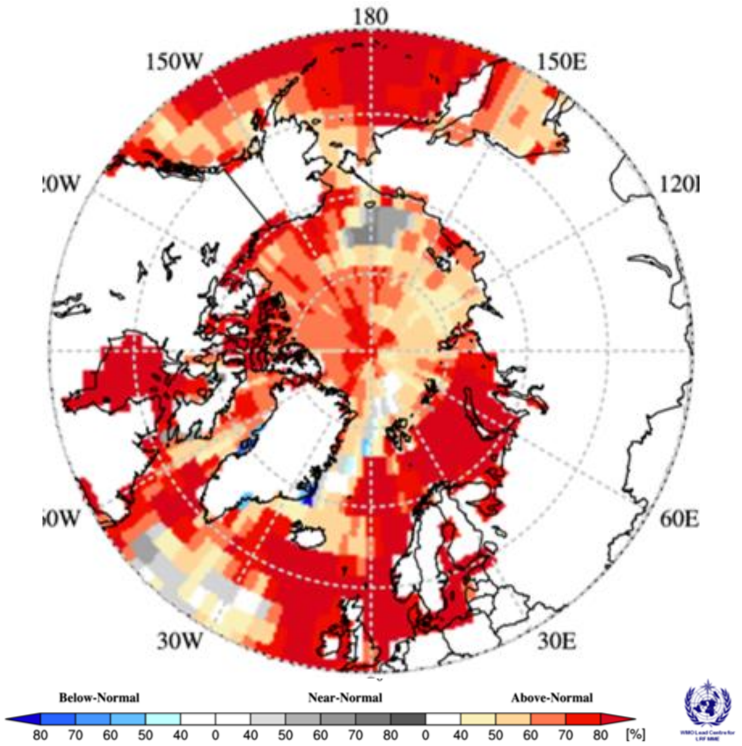


Figure 11: Multi model ensemble probability forecast for sea-surface temperature for November, December 2023 and January 2024 period. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 4. November, December 2023 and January 2024 outlook: regional forecasts for Arctic sea-surface temperatures

Region	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	Above normal, near normal and below normal
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

During May-June 2023 negative or close to normal the upper 15m ocean layer HC conditions slowed ice melt across the Arctic regions with exceptions in Barents and western part of the Kara Seas which is similar to 2021-2022. Further into the 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. However, negative anomalies or (close to) normal air temperature conditions preserved sea ice cover in parts of Laptev, Eastern Siberia Seas and Canadian Arctic. Resulting ice conditions in September 2023 resembled the previous year's situation including the amount of minimum ice extent and presence of residual ice on the NSR lanes (see ArcRCC-N consensus statements for fall 2021 and 2022).

Minimum summer 2023 sea ice extent equal to ~4.4 million square km occurred near 17 September 2023[2] and was ranked as 8^{th} consecutive in a row (within the satellite era since 1979, figure 12 left). Observed sea ice extent was well within the scale of Arctic ice extent variability since 2007. 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 12 right).

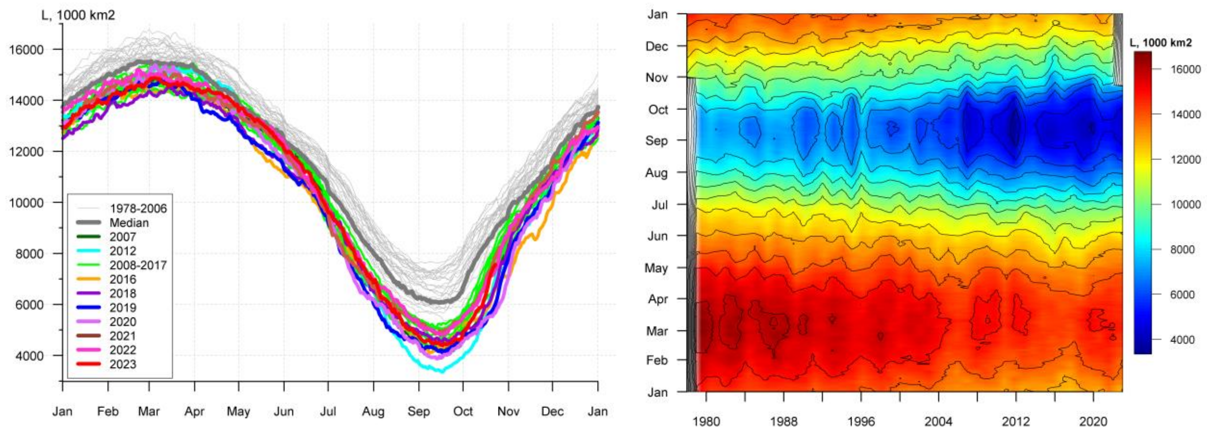


Figure 12: Arctic (Northern Hemisphere) daily annual (left) and daily seasonal (right) ice extent for 1978- 2023. Graphics produced by the AARI. Data source: NSIDC.

The sea ice conditions in September 2023 were lighter but in general similar to same period in 2021 and 2022 (figure 13). While Eurasian Barents, Kara, parts of Eastern Siberian Sea, Chukchi, Beaufort Seas were completely ice free and with the ice edge in significant northward position, the ice conditions in the Laptev, the eastern part of the Eastern Siberian Sea and the Greenland Seas were close to the 40-year median. Notably, as a result both the northern route of the Northwest Passage and the Northern Sea Route formally remained blocked in the transit straits.

[2] Actual values and precise consecutive ranks depend on algorithm, technique and source used, as well as period used for averaging. For comparison see NSIDC October 2023 Arctic ice news and analysis - http://nsidc.org/arcticseaicenews/2022/10/.

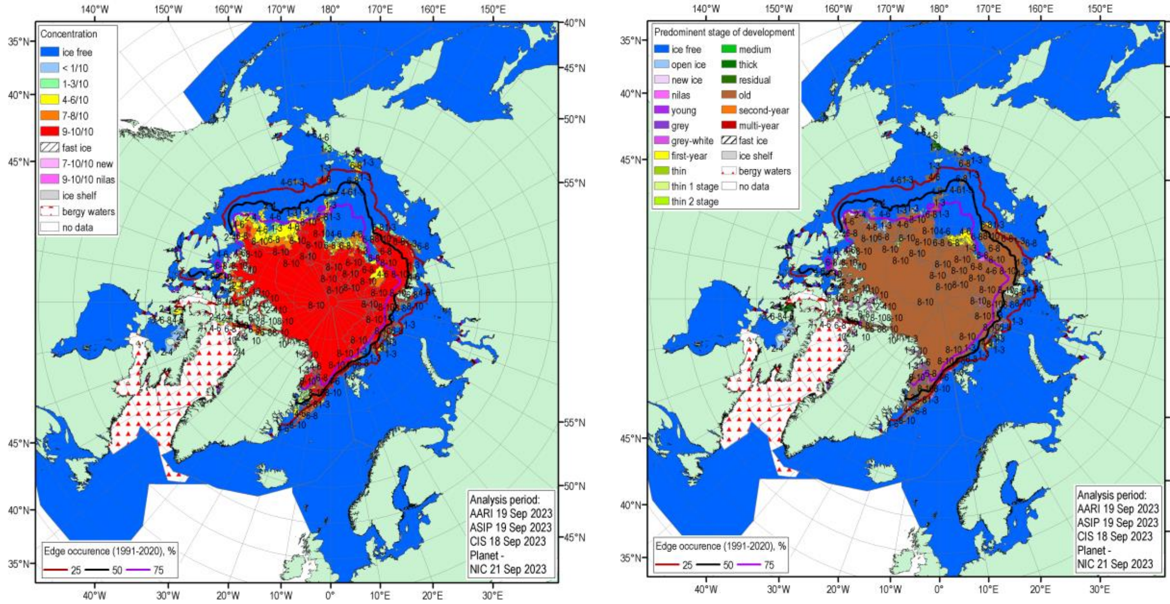


Figure 13: Blended Arctic sea ice chart (AARI, ASIP, CIS, NIC) for 18-21 September 2023 and sea ice edge occurrences for 16-20 September for 1991-2020 reference period. Left: total concentration, right: predominant stage of development. Graphics produced by the AARI.

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 (see ArcRCC-N consensus statement for spring 2023). Below normal ice extent was correctly forecasted for the Beaufort, East Siberian, Chukchi Seas and Canadian Arctic Archipelago. Similarly, a correct forecast of near normal extent was predicted for the Barents Sea (figure 14). The model did not forecast the above normal ice extent in the Greenland, Kara and Laptev Seas (green areas in figure 14). Forecast accuracy for the summer 2023 sea ice break-up dates (also based on output from CanSIPS v2.1) is highly variable across the Arctic regions. 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. However, the forecast missed the break-up dates anomalies for the Baffin Bay, the major part of Eurasian Arctic (with exception of Barents) and the Hudson Bay.

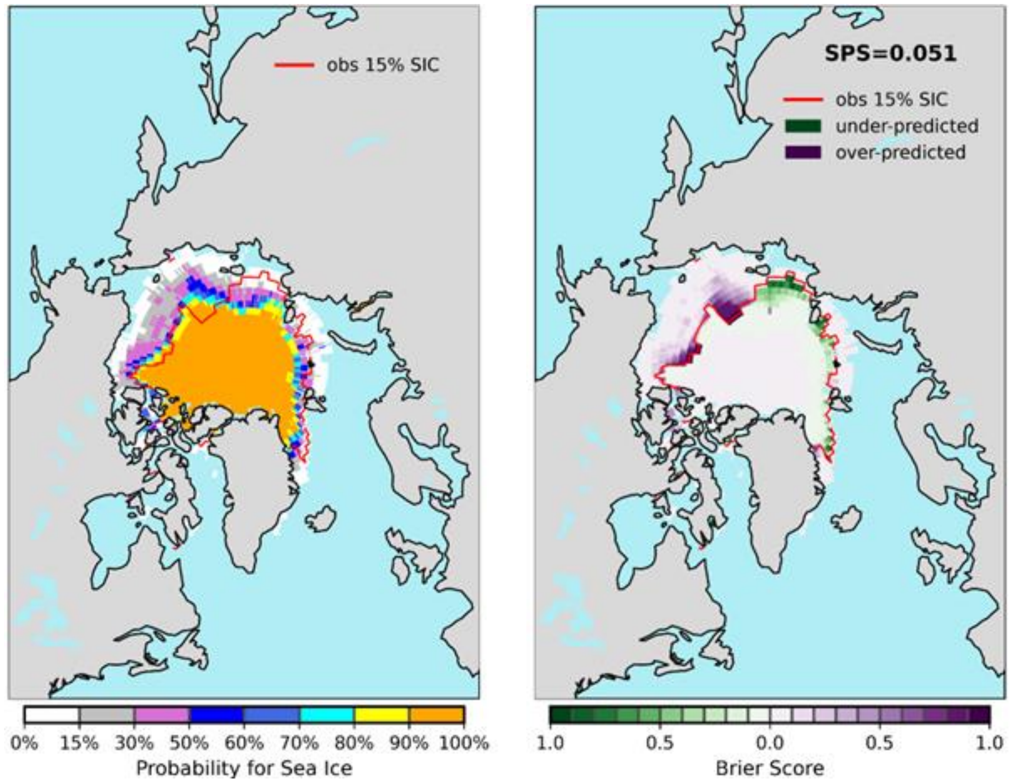


Figure 14: (Left). CanSIPS v2.1 forecast of probability of ice concentration > 15%. (Right) Forecast Error as spatial probability Score. Observed September 2023 ice extent is shown by red line.

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 15 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 16). A summary of the forecast for the winter 2023/2024 sea ice freeze-up for the different Arctic regions is shown in Table 5.

Earlier than normal freeze-up dates (blue areas, Figure 15; Table 5) are forecasted for the Barents, Greenland, northern part of Labrador regions, and parts of the Okhotsk Seas. A near normal freeze-up (light blue and light-yellow areas, Figure 15, Table 5) is forecasted for Baffin Bay, Bering and Chukchi Seas. Near normal to late freeze-up (light yellow areas, Figure 15, Table 5) is forecasted for Hudson Bay, eastern part of Kara Sea and southern parts of the Labrador Sea. A later than normal freeze-up is forecasted for the southern part of the Beaufort Sea.

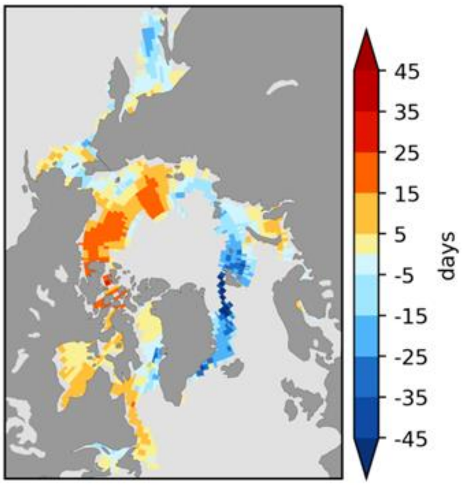


Figure 15: Deterministic freeze-up forecast from CanSIPSv2.1: freeze-up date anomaly from 2014-2022 average

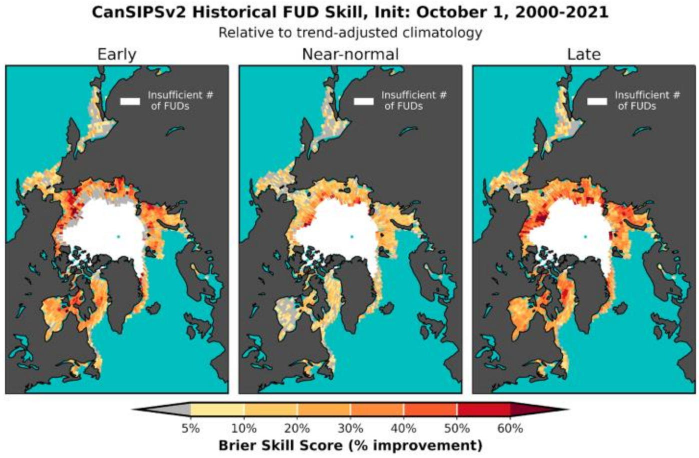


Figure 16: CanSIPs v2 historical FUD skill relative to trend-adjusted climatology.

Table 5. 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 March). Table 6 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 in figure 17. A below normal March ice extent is forecasted for Bering and Labrador Seas (Table 6). Near normal sea ice extent is forecasted for the Barents, Greenland and Okhotsk Seas, while an above normal extent is forecasted for the northern part of the Baltic Sea.

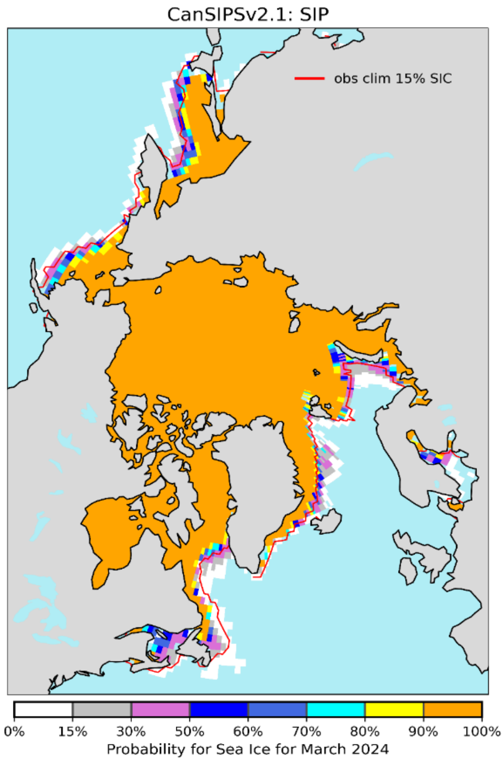


Figure 17: CanSIPSv2.1 March 2024 Sea ice extent (probability of sea ice total concentration exceeding 15%)

Table 6. March 2024 outlook: sea ice extent anomalies by regions

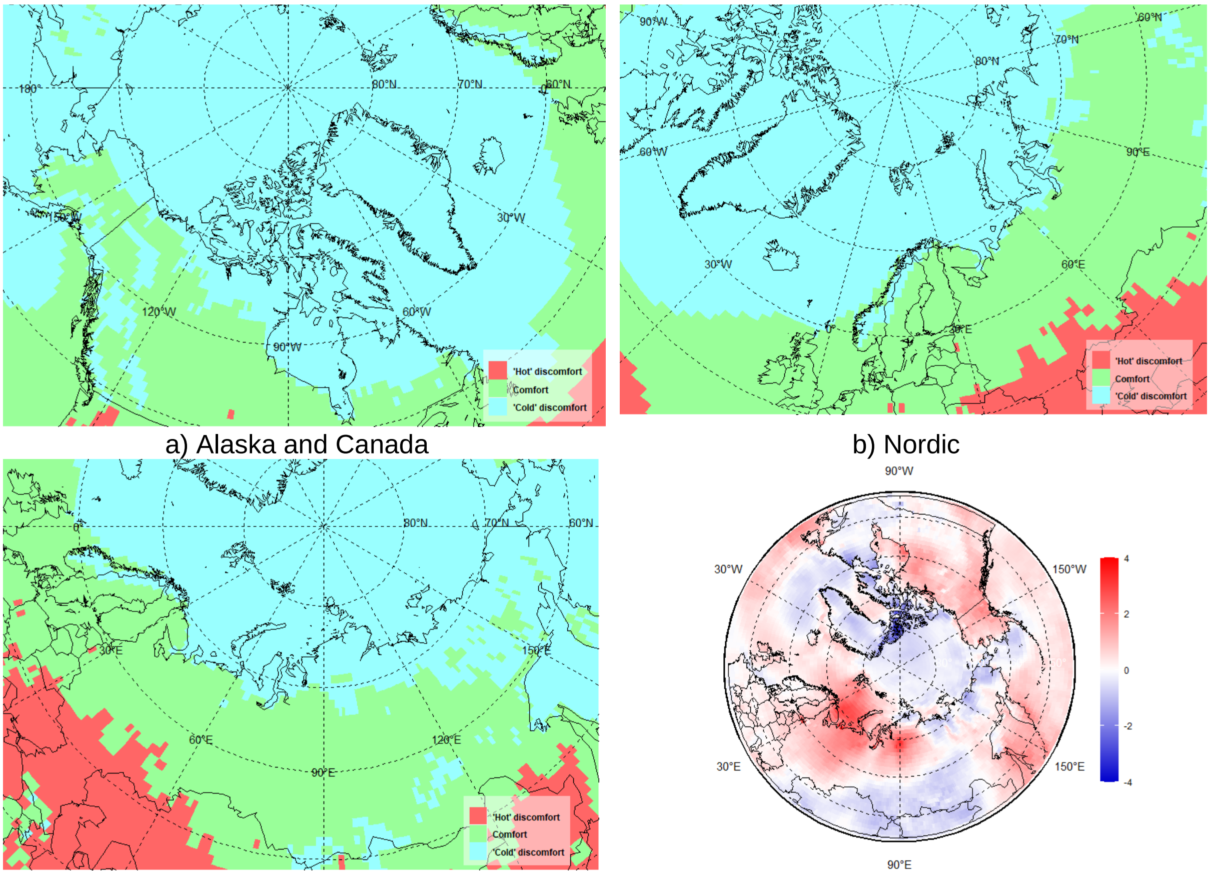
Regions	Sea ice Forecast Confidence	Sea ice Forecast Extent
Barents Sea	High	Near normal
Bering Sea	Moderate	Below normal
Greenland Sea	High	Near normal
Northern Baltic Sea	Moderate	Above normal
Labrador Sea	High	Below normal
Sea of Okhotsk	Moderate	Near normal

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 the Bodman's weather severity index (developed specifically for the Arctic cold season, based on a derivative of surface wind speed and air temperature and scaled from slightly severe to extremely severe), or the effective temperature ET (year-round, based on a derivative of surface air temperature and relative humidity and scaled from comfort to extremely discomfort).

Summary for summer 2023:

During June, July, August 2023 the "cold discomfort" zone (blue areas in figure 18) spread over sea areas, Greenland, Canadian Arctic Archipelago, Hudson Bay as well as some land areas around and Northern-East Siberia from Taymyr to Chukchi Peninsula. "Comfort" zone was located in subpolar land areas (green color in figure 18) and the "hot discomfort" zone (red color in figure 18) was located southward in mid-latitudes. During the summer 2023 season, there were more than normal severe conditions (blue color in figure 18d) 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 18d), and most prominent mild anomalies (red color in figure 18d) 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 (see ArcRCC-N consensus statement for fall 2022).



a) Alaska and Canada b) Nordic

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

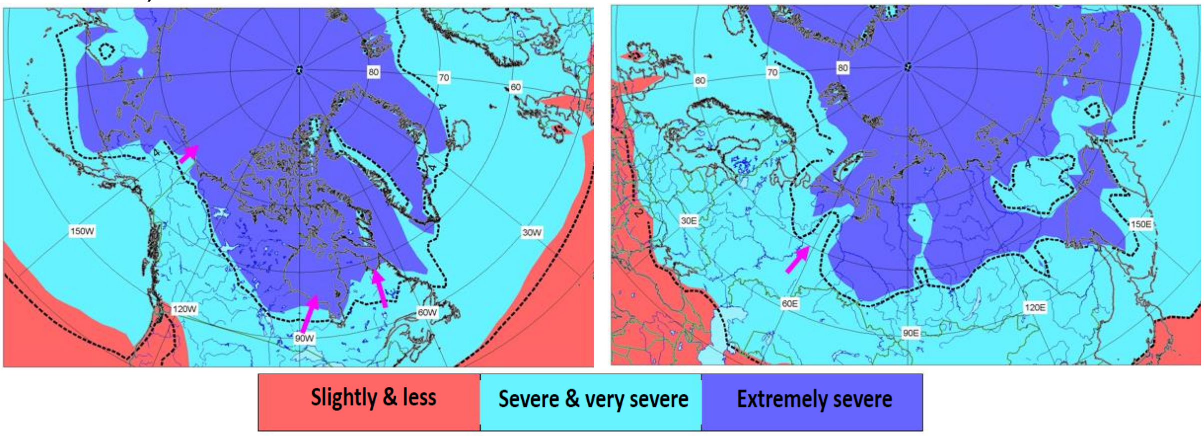
Figure 18: Effective temperature indexes for June – August 2023. Maps produced by the AARI. Data source: CCCS ERA5.

Outlook for winter 2023/2024 (experimental)

Forecast of the bioclimatic indexes is provided based on the Bodman's weather severity index for period December 2023 - February 2024 (figure 19 and table 7) 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 part of the ArcRCC-N area in the winter 2023/2024 "extremely severe" conditions are expected in most of the regions (dark blue color in figure 19). "Severe" conditions (light blue color in figure 19) are expected in southern Alaska, Yukon, Northwest Territories and southern Quebec. In the eastern part of the ArcRCC-N area in the winter 2023/2024 "extremely severe" conditions (dark blue color in figure 19) are expected for Central and Eastern Siberia and Svalbard areas. "Severe" conditions (light blue color in figure 19) are expected for both Western and Eastern Nordic regions, Novaya Zemlya archipelago and in the southern part of Yamal Peninsula. No "slightly & less severe" gradation of weather severity is expected in Arctic Zone.

Alaska, Canada and Western Nordic **Eurasia**



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

Figure 19: 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 7: 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.

OBSERVED EXTREME EVENTS

Category	Location	Rarity	Impacts associated with event
Alaska and Western Canada			
Wildfires	Western Canada	The area burned was a record high for the region and the length of the fire season was record long (early start in May).	Public health impacts from smoke affected all of western Canada and parts of Alaska. The entire city of Yellowknife was evacuated for three weeks - an unprecedented event.
Flood	Juneau, Alaska	Unprecedented in modern times.	A glacial outburst flood on the Mendenhall River created record high streamflow on the Mendenhall River. Very damaging river erosion damaged or destroyed a number of residences.
Central and Eastern Canada			
Temperature	Northwest Territories, Nunatsiavut, Nunavut	Inuvik - all-time record high temperature of 33C, ranks 1st warmest for July and for the summer season. Happy Valley-Goose Bay ranked 3rd warmest summer on record. End of July, very warm – Resolute had July temperature of 18.9C, close to breaking its all-time record	Polar bear attacks - "Climate change has made it difficult to predict wildlife in that region". "It's well known among Traditional hunters that sea Mammal meat at this time of year can be bad" - warmer weather. Earlier means botulism risk is higher during non-traditional times
Hot and dry weather, wildfires	West-Central NU – Bathurst Inlet, Nunavik	Extremely rare tundra fire Wildfires	First territorial state of emergency for wildfire in Nunavut's history. Evacuation of a small seasonal community. Wildfire smoke traveled across Nunavut including Baffin Island – first time in memory. Air quality alerts issued for Igloolik
Sea ice	ISR, NU	Early break-up	Adjustments to traditional hunting and fishing activities. Large increase in SAR calls
Western Nordic			
Wind	Iceland, May	Unusually cold and windy weather at the end of May	Vegetation damage, trees and shrubs lost much of their leaves
Temperature	Iceland, Northeast and East, June	Warmest June on record in Northeast and East Iceland	None
Precipitation, drought	Iceland, South and west, July	It was unusually dry in July and part of August in South and West Iceland. In many places the driest July on record.	Rivers dried up and challenges for agriculture
Extreme precipitation	Iceland, East fjords and part of the North, 18-19 September	Extreme precipitation. Highest daily precipitation amount on record at several weather stations in the North	Several houses in the town of Seyðisfjörður were evacuated due to landslide risk. Landslides caused some road damages in these areas
Eastern Nordic			
Temperature	Tromso (Norway)	8-9 August 2023 Warmest night ever recorded in Tromso (24.7°C in Lyngen,	None

		Norway), and second warmest night ever recorded in August in Norway.	
Sea ice	Fram Strait	Very high sea ice extent throughout June in the northern Fram Strait.	This has resulted in the re-routing of planned research cruises due to the sea ice thickness encountered to the north of the area.
Icebergs	Svalbard	Multiple large calving events with associated iceberg outbreaks from Nordaustlandet from mid-August, the largest event since 2015 occurred 17-24 August likely in response to a week of warm weather that preceded it.	No reported incidents
Western Siberia			
Temperature	Yamalo-Nenets and Khanty-Mansyisk districts	Three heat waves in Salekhard: 1-7 July (t> 33°C), 2-8 August (t ~ 30°C) and 8-15 September (six records of maximum daily air temperature)	Increase in the number of ambulance calls.
Temperature and precipitation	Urban areas in Yamalo-Nenets district	Due to warm and wet weather, mosquitoes and midges were more active in July. In June, due to the cold weather, the situation was calm.	Many complaints from local residents on social networks, many cases of child bites in Salekhard.
Temperature and precipitation	Pastures in Yamalo-Nenets district	Heavy precipitation and warm weather in July	Problems with reindeer grazing: heavy rains flooded pastures, due to the abundance of midges, deer required constant additional treatment from insects.
Eastern Siberia			
Precipitation (snow)	Norilsk	Snowfall on 12 July 2023 (before that, «summer snow» in Norilsk in July fell on 21 July 2018 and 20 July 20 1992)	The snow cover did not form and the snow melted quickly. No consequences reported
Precipitation (heavy rain)	Taymir peninsula area	Heavy rains in Norilsk on 20-25 August 2023	Heavy rains caused flooding and interruptions in public transport. The rains were accompanied by thunderstorms that were unusual for Norilsk.
Temperature and precipitation	Yakutia (Sakha)	Dry and hot weather throughout the season	Fire danger from moderate to extreme in the northwest and northeast of Yakutia in July and August.
Chukchi and Bering			
Late sea ice break-up	Chukchi	Due to late ice break-up, summer navigation in ports began later. In the port of Anadyr on 29 June 2023 (in 2022 – 13 June)	Potential difficulties for routine transportation as from the port of Anadyr food and fuel are delivered to hard-to-reach areas

Background and Contributing institutions

The Arctic seasonal climate summary and outlooks were prepared for ACF-12 in partnership between the Canadian, Danish, Finnish, Icelandic, Norwegian, Russian, Swedish and United States meteorological agencies, sea ice services and with contributions from 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
SWE: Snow Water Equivalent
WMO: World Meteorological Organization