Arctic Climate Forum Consensus Statement

Summary of 2021-2022 Arctic Winter Season and the 2022 Arctic Summer 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 1900-2022 (figure 1) though significant interannual variations occur, in particular in cold periods. The maximum Arctic ice extent in winter 2022 was close to the ten mildest in row since 1979 and occurred earlier by two weeks than average, however significant variations in space continue to occur including the Canadian Arctic ice cover approaching the median of the last 40 years, presence of old ice on the eastern Northern Sea Route lanes and very mild ice conditions in the Sea of Okhotsk.

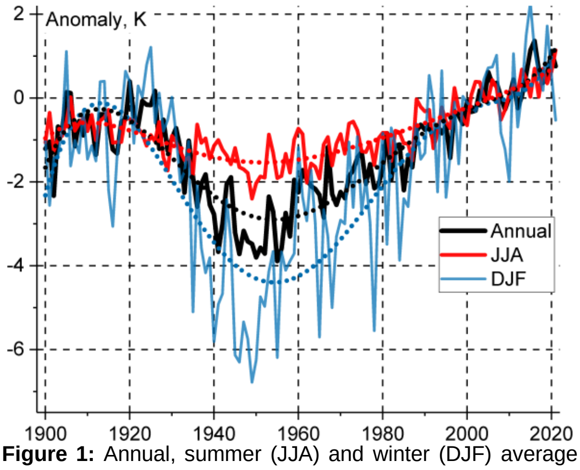


Figure 1: Annual, summer (JJA) and winter (DJF) average surface air temperature anomalies (ref. 1991-2020) Dotted lines – corresponding polynomial approximations. Graphics produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

To support Arctic decision makers in this changing climate, the Arctic Climate Forum (ACF) established in 2018 and convened by the Arctic Regional Climate Centre Network (ArcRCC-Network) under the auspices of the World Meteorological Organization (WMO) provides consensus climate outlook statements in May prior to summer thawing and sea-ice break-up, and in October before the winter freezing and the return of sea-ice. The role of the ArcRCC-Network is to foster collaborative regional climate services amongst Arctic meteorological and ice services to synthesize observations, historical trends, forecast models and fill gaps with regional expertise to produce consensus climate statements. These statements include a review of the major climate features of the previous season, and outlooks for the upcoming season for temperature, precipitation and 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 twice a year in May and October, the latter typically held online. This consensus statement is an outcome of the 9th session of the ACF held online on 24-25 May 2022 and coordinated by the North American Node of ArcRCC-Network hosted by Canada.

HIGHLIGHTS

During NDJ (November - January) 2021/2022 an intense bi-center polar vortex was observed with centers over the Hudson Bay and the Barents Sea which led to prevalence of meridian circulation (transfer south/north) in the troposphere over Western Siberia and Canada regions, zonal one over other parts of the Arctic and subsequent effects in surface circulation. Further in season during FMA (February - April) 2022 bi-center polar vortex shifted counter-clockwise with centers over the Hudson Bay and central Siberia and caused general meridian type of circulation in Eastern Canada and Siberia regions. Blocking positive mean sea level pressure (MSLP) anomalies were observed in February from Central Siberia through Alaska to Central Canada and in April as a vast area of high pressure over Arctic Ocean, Northern Canada and Alaska.

Temperature: During the first part of winter prominent negative surface air temperature (SAT) anomalies (ref. WMO period 1991-2020) were observed mainly in the Alaska & Western Canada and Eastern Nordic regions while Central and Eastern Canada, Western Nordic and Siberia experienced prominent positive anomalies. Second part of winter and early spring experienced slight negative anomalies in Alaska, Canada in general and Nordic regions and similar positive anomalies over Siberia and Chukchi regions. The whole land Arctic during the season experienced slight negative anomalies though strong differences between the months were observed.
Surface air temperatures during summer 2022 are forecasted to be above normal in almost all regions across the Arctic. The confidence of the forecast is low to moderate for most of the land areas of the Arctic region with the exception of Eastern Canada, Northwest Greenland and south parts of Siberia where the confidence is high.

Precipitation: During the whole season the general wetter (snowy) conditions occurred in most parts of Canadian, Alaska, Bering & Chukchi and Western Nordic regions. Drier conditions occurred in parts of Eastern Nordic, Siberia and Central Arctic regions. The least amount of precipitation was for the Eastern Nordic and Siberia regions. More abundant precipitation was observed in the Western Nordic, Bering and Chukchi and Canada and Alaska regions.
Somewhat drier or close to normal conditions are estimated for the Central Arctic. Confidence in the precipitation forecast Arctic-wide is low. There is no model agreement over most land and ocean areas in the Arctic. Above normal precipitation is forecasted for the Canadian Arctic Archipelago, Alaska, eastern Siberia and the Beaufort/ Chukchi /Bering Seas. Below normal precipitation is forecasted over parts of Western Canada and Northern Europe.

Sea-ice: Arctic maximum winter ice extent, 13^{th} in row (15.2 mln km^2) was reached 2 weeks earlier than average (since 1979) on 21-22 Feb 2022, though prevalence of negative surface air temperature anomalies at the end of winter 2022 stimulated ice growth till end of April 2022 and led to greater than median (for 1979-2022) ice extent in Canadian Arctic. Estimates of the total Arctic sea ice volume continue to show its significantly decreased state – close to 3^{rd} lowest for 2004-2022 after 2020 and 2021.
A later than normal break-up is forecasted for the Barents, Beaufort, Greenland and Labrador Seas. A near normal break-up is forecasted for Baffin and Hudson Bays and the Chukchi Sea. An earlier than normal break-up is forecasted for the Canadian Arctic Archipelago and the Kara and Laptev seas. The forecast for most of the Arctic is a near normal September ice extent. Below normal ice extent is forecasted for the Laptev and Kara Seas.

UNDERSTANDING THE CONSENSUS STATEMENT

This consensus statement includes: a seasonal summary and forecast verification for temperature, precipitation, and sea-ice for the previous 2021/2022 Arctic winter season including November, December 2021 and January 2022 (NDJ 2021/2022) and February, March and April 2022 (FMA 2022); an outlook for the upcoming 2022 Arctic summer season (June, July, August and September 2022). 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

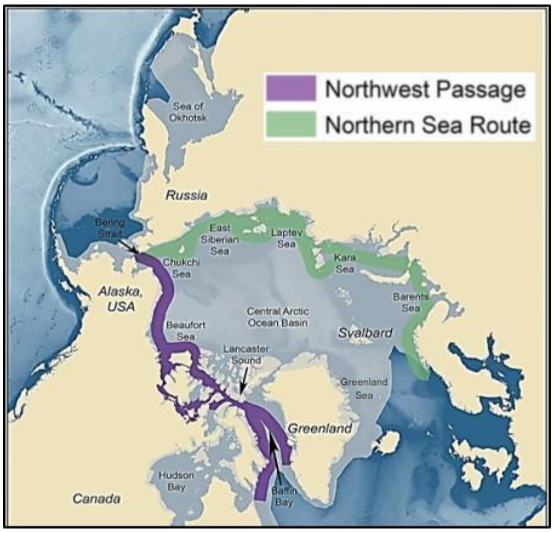


Figure 3: Sea-Ice Regions. Map Source: Courtesy of the U.S. National Academy of Sciences

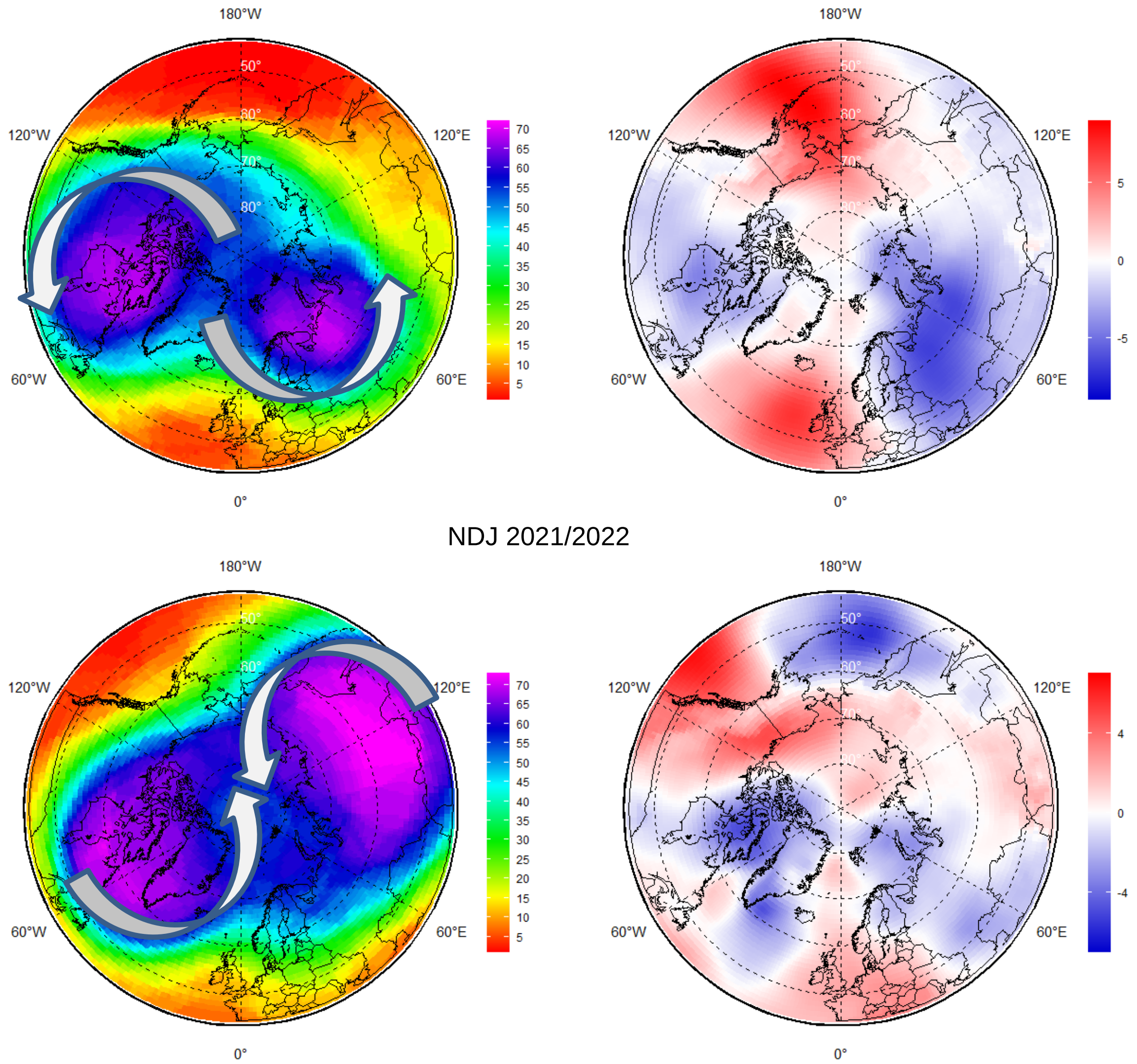
Seasonal summaries of temperature, precipitation, and sea-ice are based on a synthesis of routine observations at polar stations and marine mobile platforms, sea ice analysis from the national Ice Services, satellite estimates of sea ice extent and thickness, WMO GCW SnowWatch data, and a set of modern 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.

The majority of the sea-ice extent and experimental freeze-up and break-up forecasts are based on the Canadian Seasonal to Interannual Prediction System (CanSIPSv2), a MME of two climate models. The Baltic Sea forecasts are developed using outputs from the ECMWF Long-Range Forecasts, UK MetOffice, and NOAA CFSv2. A larger multi-model ensemble that will include forecasts from the following WMO GPC-LRFs is under development: ECCC/MSC (CanSIPSv2), NOAA (CFSv2), Meteo-France (System 5), UK MetOffice (GloSea5) and ECMWF (SEAS5). 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. Summer outlooks for key shipping areas are provided by the Arctic and Antarctic Research Institute (AARI), Alaska Sea Ice Program, and Canadian and Finnish ice services, and are based on statistical techniques and forecaster expertise.

ATMOSPHERIC CIRCULATION

Summary for November 2021 - April 2022:



FMA 2022

Figure 4: NDJ 2021/2022 and FMA 2022 H50 ranks for 1950-2021 period (left) and (MSL anomaly (ref. 1991-2020 period) (right). Maps produced by the AARI. Data source: CCCS ERA5

During NDJ 2021/2022 an intense bi-center polar vortex (dark violet, 50hPa geopotential height pattern (H50), figure 4 left) was observed with centers over the Hudson Bay and the Barents Seas. That led to prevalence of meridian circulation (transfer south/north) in the troposphere over Western Siberia and Canada regions and zonal one over other parts of the Arctic. For the surface atmosphere that meant predominance of negative mean sea level atmospheric pressure (MSLP) anomalies (lower pressure, marked in blue, figure 4 right) and cyclonic activity over the Eastern Nordic, Western Siberia and Canada regions. Opposite situation (higher pressure, marked in red, figure 4 right) was observed over Alaska, Bering and Chukchi and the Western Nordic regions.

Further in season during FMA 2022 the bi-center polar vortex shifted counter-clockwise with centers over the Hudson Bay and central Siberia and caused general meridian type of circulation in Siberia and Eastern Canada regions (figure 4 left). However, monthly patterns of the surface atmosphere circulation were fully different in February, March and April with negative MSLP anomalies - cyclonic activity over the Hudson Bay, Canadian Archipelago, Greenland and Nordic regions in February and April (not shown here). Blocking positive MSLP anomalies were observed in February from Central Siberia through Alaska to Central Canada and in April as a vast area of high pressure over Arctic Ocean, Northern Canada and Alaska (figure 4 right).

TEMPERATURE

Summary for November 2021 - April 2022 (see technical summary for greater details):

The start of winter 2021/2022 (November-December) surface air temperature (SAT) experienced prominent positive – in Central and Eastern Canada (3rd in row), Eastern Siberia (7th in row) and negative – Alaska (62nd in row), Eastern Nordic (51st in row) anomalies (to 3rd WMO reference period 1991-2020 and 1950-2021/2022 observation period for ranks) (figure 5). During mid-winter (January-February) strong positive anomalies were observed over the Eastern Nordic (15th in row), Western and Eastern Siberia (4th – 12th in row) with negative anomalies observed over Western Nordic region (56th in row).

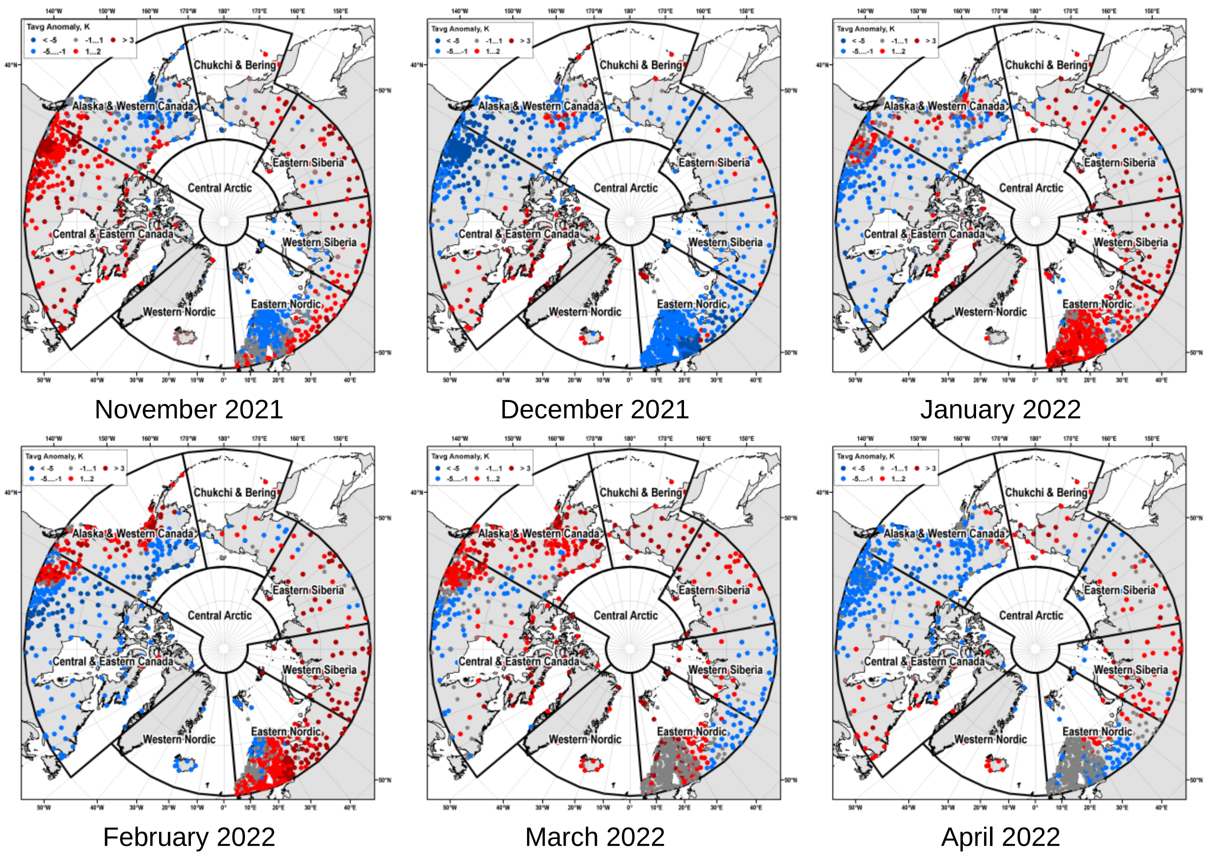
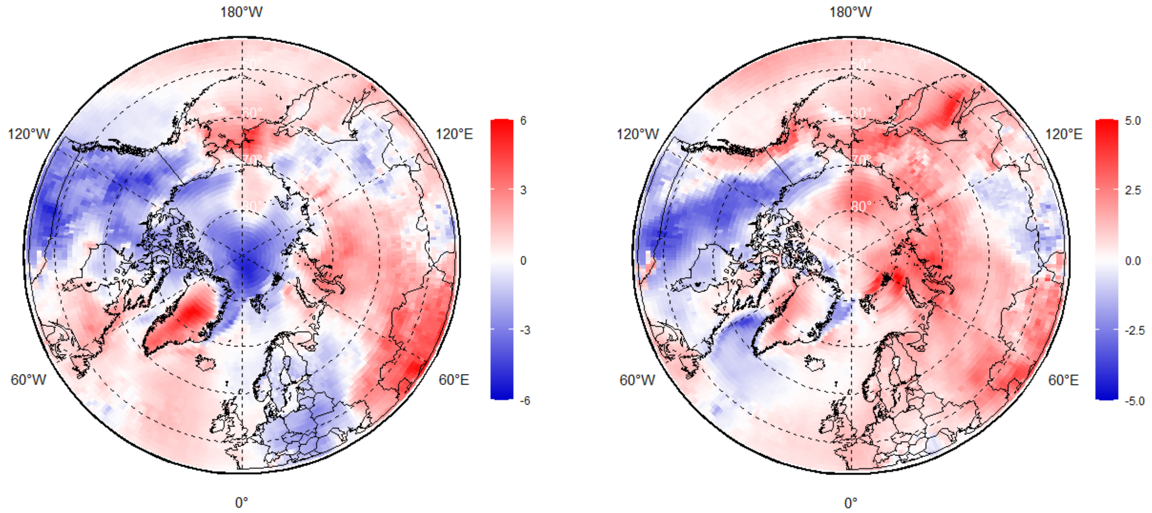


Figure 5: November 2021 – April 2022 monthly averaged SAT anomalies (ref. 1991-2020 period) based on observations at polar stations. Maps produced by the AARI. Note: information for the stations outside of the ArcRCC-N domain is not shown.



NDJ 2021-2022 FMA 2022

Figure 6: NDJ 2021/2022 and FMA SAT anomalies (ref. 1991-2020). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5

Further by the end of winter and early spring in March – April 2022 both positive and negative anomalies were observed over Alaska (29th and 55th in row), Canada (11th and 29th) and Nordic regions and mostly positive over Siberia (16th – 30th in row) and Chukchi (6th – 10th in row) regions (Figure 5).

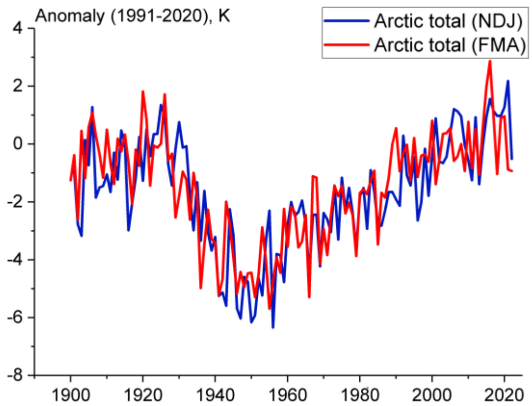


Figure 7: NDJ 2021/2022 and FMA 2022 surface air temperature anomalies (ref. 1991-2020) Graphics produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

Due to lack of surface marine observations conclusions for the Central Arctic done on the basis of reanalysis, include partly colder conditions in November 2021, predominantly warmer in February – March 2021, and colder in December 2021 and April 2022 (figure 6).
For the whole land Arctic, the prominent warmer conditions were observed in November 2021 (12th in row) with prominent colder in December 2021 (47th in row) and April 2022 (38th in row).

It should be mentioned that though extreme monthly negative anomalies occurred with a very few exceptions in the mid-20th century, that could not be the case for extreme positive anomalies which could occur for different months and regions as early as the 1920s (figure 7).

Simultaneously, it should be kept in mind that though positive trends from 1940s-1950s are obvious, the quantitative estimates depend on the chosen WMO reference period and density of the stations, in particular for the marine Arctic within a particular temporal sub-period.

__Verification of winter 2021/2022 forecast__

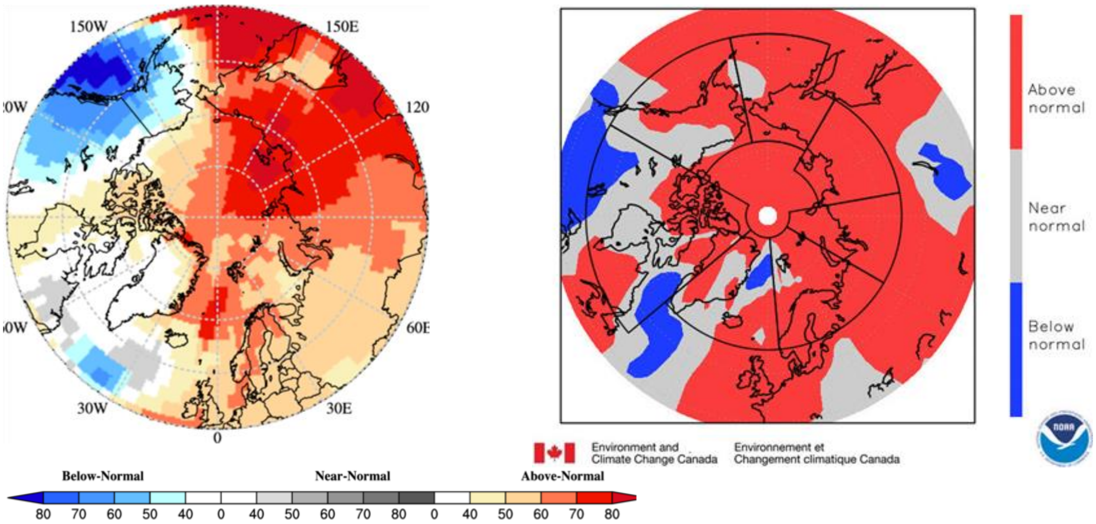


Figure 8: Left) Multi-model ensemble (MME) probability forecast for surface air temperatures: February, March, and April 2022. Three categories: below normal (blue), near normal (grey), above normal (red); no agreement amongst the models is shown in white. Source: www.wmolc.org. Right): NCAR (National Center for Atmospheric Research) Climate forecast System Reanalysis (CFSR) for air temperature for February, March, and April 2022.

The FMA 2022 temperature forecast was verified by subjective comparison between the forecast (Figure 8, left) and re-analysis (Figure 8, right), region by region. A reanalysis is produced using dynamical and statistical techniques to fill gaps when meteorological observations are not available.

Above normal temperatures were accurately forecast for the Eastern Nordic, Eastern Siberia, Western Siberia, Central Arctic and the Chukchi and Bering regions (Figure 6, Table 1). The forecast for Alaska and Western Canada was below normal and the region experienced below normal to near normal temperatures. There were large regions of no model agreement (white areas, Figure 8 left) in the forecast for the Central and Eastern Canada and the Western Nordic regions. In areas where there was some model agreement (red, blue and grey regions, Figure 8 left) the model was accurate in 30% and 50% of the areas (Table 1).

__Outlook for summer 2022:__

For the June-July-August 2022 (JJA22) period, there is a probability of 40% or more that temperatures will be above normal in all regions across the Arctic (orange and red areas in Figure 9). The highest probabilities for an above normal summer (60-70% or more) are in the Eastern and Western Siberian regions and in southern parts of the Chukchi-Bering region (dark red areas in Figure 9, Table 2). The latter region is furthermore expecting above normal probabilities of 50% or more in its central and northern portions. Central and eastern parts of the Eastern Canadian Arctic are also expecting high probabilities of more than 60% for above normal temperatures this summer. The Alaskan and Western Canada region is expecting above normal temperatures with probabilities of at least 40%, coastal and eastern portions of this region are expecting somewhat higher probabilities, 50% or more, for an above normal summer.

Table 1. February, March, and April 2022: Regional Comparison of Observed and Forecasted Arctic Temperature

Regions (see Fig. 2)	MME Temperature Forecast Agreement	MME Temperature Forecast	NCAR CFSR Reanalysis (observed)	MME Temperature Forecast Accuracy
Alaska and Western Canada	Low	Mostly below normal	Mostly near normal in the east and SE, above normal in the west	Miss
Central and Eastern Canada	High	Below normal in the SW, near normal in the east	Below normal in the SW, above normal in the east	30% hit, 70% miss
Western Nordic	High	Above normal in most of the region	Above normal in the SE	50% hit
Eastern Nordic	Moderate	Above normal	Above normal	Hit
Western Siberia	Moderate	Above normal	Above normal	Hit
Eastern Siberia	High	Above normal	Above normal	Hit
Chukchi and Bering	Moderate	Above normal	Above normal	Hit
Central Arctic	Moderate	Above normal	Above normal	Hit

For the Eastern Nordic region, multi-model ensemble (MME) forecast is showing above normal probabilities of 60-70% or higher, in the western parts of the region, while these probabilities are somewhat lower (50% or more) in the southern and eastern parts of the region. Below normal temperatures in Greenland and Labrador seas are a reflection of the MME sea-surface temperature forecast (blue areas in Figure 9, Table 2). Continental parts of the Western Nordic region have expectation of at least 40% or higher for an above average summer (i.e. Scandinavian Peninsula). Somewhat higher probabilities of 50% and higher are expected in the eastern and southern portions of the region.

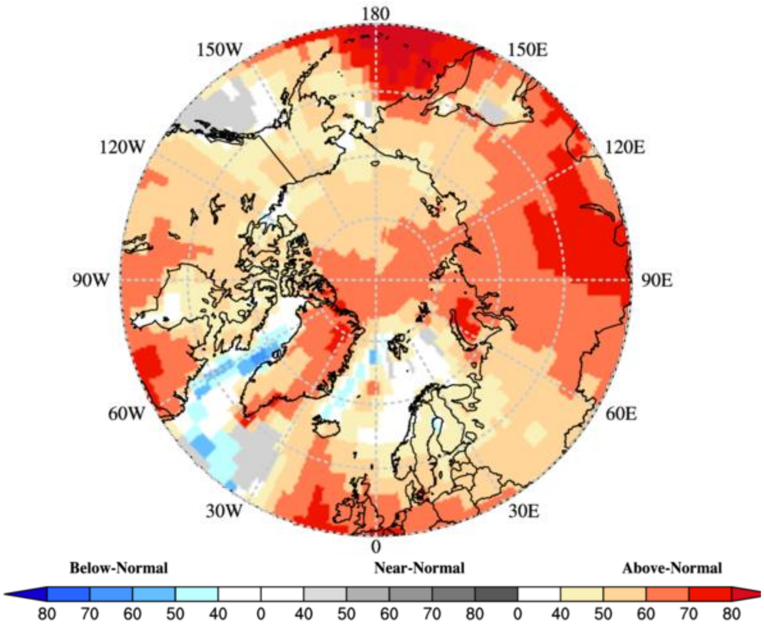


Figure 9: Multi model ensemble probability forecast for temperature for June, July, and August 2022. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org.

Table 2. Summer (JJA) 2022 Outlook: Regional Forecasts for Arctic Temperatures

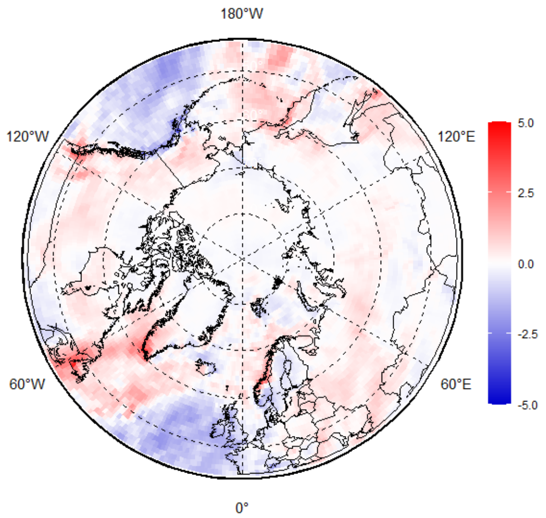
Region (see Fig.2)	MME Temperature Forecast Agreement*	MME Temperature Forecast
Alaska and Western Canada	Low-Moderate	Above Normal; Near Normal Gulf of Alaska
Central and Eastern Canada	Low-Moderate	Above Normal; Below-Normal in Baffin Bay and Labrador Sea
Western Nordic	Low-Moderate	Above Normal; Below-Normal Fram Strait
Eastern Nordic	Low-Moderate	Above Normal; No Forecast for Barents Sea
Western Siberia	Low-Moderate	Above normal
Eastern Siberia	Low-Moderate	Above normal
Chukchi and Bering	Low-Moderate	Above normal
Central Arctic	Low-Moderate	Above normal

*: See non-technical regional summaries for greater detail

PRECIPITATION

Summary for November 2021 - April 2022:

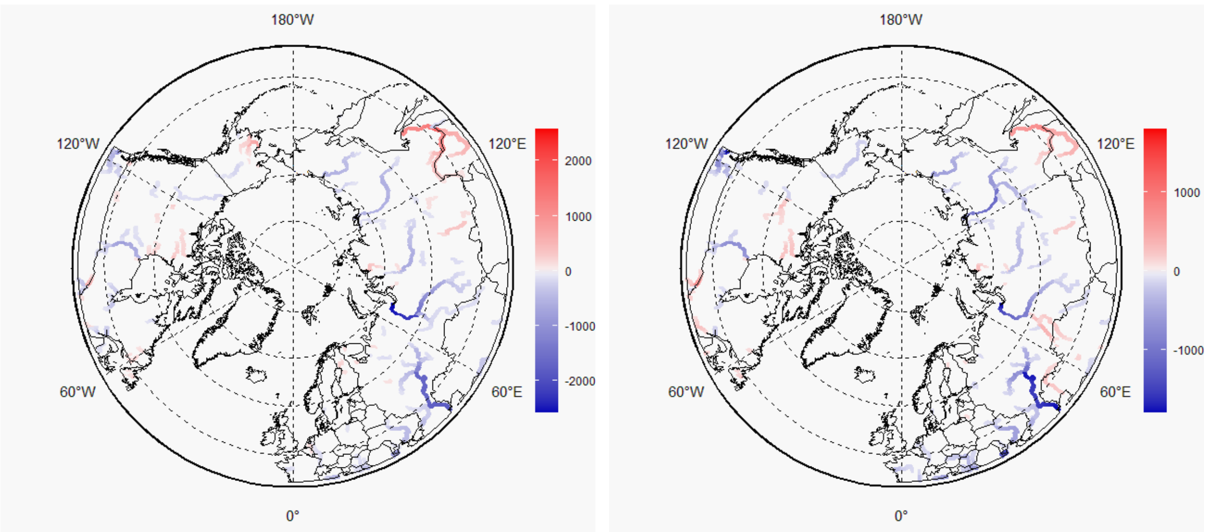
In general, during the whole season wetter (snowy) conditions occurred in most parts of Canada, Alaska, Bering & Chukchi and Western Nordic regions (figure 10). Drier conditions occurred in parts of Eastern Nordic, Siberia and Central Arctic regions. The least amount of precipitation was for the Eastern Nordic and Siberia regions. More abundant precipitation was observed in the Western Nordic, Bering and Chukchi, Canada and Alaska regions. Somewhat drier or close to normal conditions were estimated for the Central Arctic.



NDJ 2021/2022 FMA 2022

Figure 10. NDJ 2021/2022 and FMA 2022 surface precipitation anomalies (ref. 1991-2020). Map produced by the AARI. Data source: CCCS ERA5.

Impacts of wetter/drier colder/warmer weather conditions were to certain extent reflected in the winter/spring 2021-2022 Arctic rivers discharge though the frozen ground considerably restricted direct effects. Lesser drainage than normal is seen for Ob', most of Yenisei and Lena rivers, and further eastward through the whole season (figure 11). Partly Mackenzie, Yukon and Yenisei rivers experienced greater discharge than normal.



NDJ 2021/2022 FMA 2022

Figure 11. NDJ 2021/2022 and FMA 2022 river discharge anomalies (ref. 1991-2020). Map produced by the AARI. Data source: CCCS ERA5-GloFAS.

Verification of winter 2021/2022 forecast

The FMA 2022 precipitation forecast was verified by subjective comparison between the forecast (Figure 12, left) and reanalysis (Figure 12, right), region by region. As for temperature, precipitation reanalysis is produced using statistical techniques to fill gaps when meteorological observations are not available.

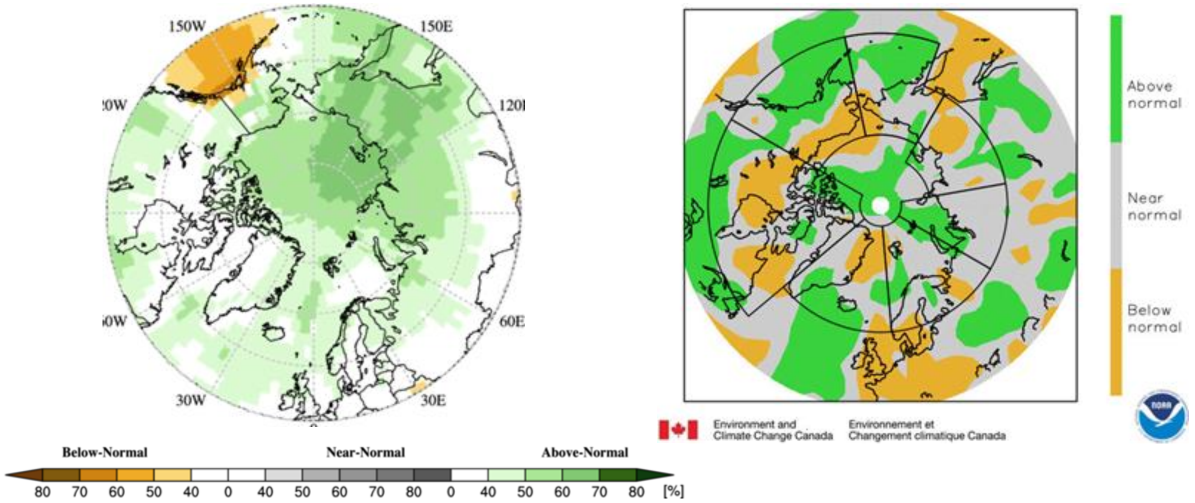


Figure 12: Left) Multi-model ensemble (MME) probability forecast for precipitation: February, March, and April 2022. Three categories: below normal (brown), near normal (grey), above normal (green); no agreement amongst the models is shown in white. Source: www.wmolc.org. Right): NCAR CFSR for precipitation for February, March, and April 2022.

Overall, the accuracy of the FMA 2022 precipitation forecast was low (Figure 12, Table 3). In the regions where there was model agreement, the forecast subjective score ranged between 10% to 50%. The model captured above normal precipitation observed in parts of western and southern Canada. In general, the MME forecast for precipitation was not accurate for FMA 2022.

Outlook for summer 2022:

Over the largest part of the Arctic Circle, there are equal chance expectancies for precipitation this summer (Figure 13: white, light green and light orange areas; Table 4). This means that the MME forecast is not decisive in any of the three probability categories. The indecisive forecast for this summer's precipitation is showing in the eastern and western Siberian regions, most of the Nordic regions with an exception of the southern portion of these two regions where low probabilities (40% or more) for below normal precipitation are expected. Eastern Canada is also expecting equal precipitation chances with an exception of the Canadian archipelago where low probabilities of above normal precipitation are forecasted (light green areas Figure 13, Table 4).

Chukchi and Bering region is expecting above normal precipitation for JJA. Low probabilities of 40% or higher are expected over this region. Alaska and Western Canada are divided to above normal expectancies on the western side (40% or higher), while the southeastern and eastern portions are expecting below normal precipitation (also 40% or higher) this JJA22 (light orange areas in Figure 13, Table 4).

Table 3. February, March, and April 2022: Regional Comparison of Observed and Forecasted Arctic Precipitation

Regions (see Fig. 2)	MME Precipitation Forecast Agreement	MME Precipitation Forecast	NCAR CFSR Reanalysis (observed)	MME Precipitation Forecast Accuracy
Alaska and Western Canada	Low	Above normal, below in the south	Below normal in the north, above in the south	80% miss
Central and Eastern Canada	Low	No model agreement in the north, above normal in the south	Below normal in the north, above in the south	50% where forecast
Western Nordic	Low	Mostly above normal	Above normal in the south, below in the north	30% hit
Eastern Nordic	Low	Mostly above normal	Mostly near normal, below normal over scattered southern regions	90% miss
Western Siberia	Low	Above normal	Above normal in the north, near normal in the south	40% hit
Eastern Siberia	Low	Above normal	Mostly near normal, below normal in the south-east	90% miss
Chukchi and Bering	Low	Above normal	Above normal in the south, mostly near normal over land	40% hit

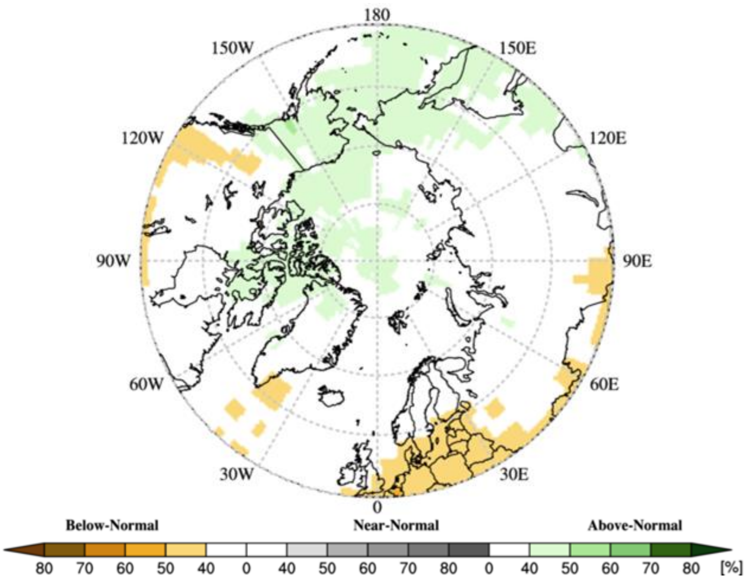


Figure 13: Multi model ensemble probability forecast for precipitation for June, July, and August 2022. Green indicates wetter conditions, orange drier conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 4. Summer (JJA) 2021 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, below normal west coast
Central and Eastern Canada	Low	Above normal in the north; No model agreement south
Western Nordic	Low	No model agreement
Eastern Nordic	Low	Above normal in the south; no model agreement north
Western Siberia	Low	No model agreement
Eastern Siberia	Low	No model agreement
Chukchi and Bering	Low	Above normal
Central Arctic	Low	No model agreement

*: See non-technical regional summaries for greater detail

SNOW WATER EQUIVALENT (experimental product)

Outlook for summer 2022:

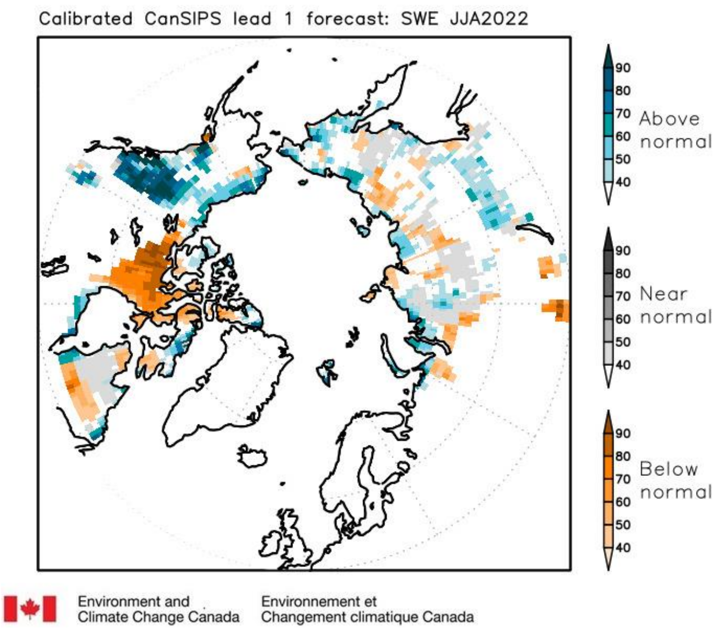


Figure 14: Canadian Seasonal to Interannual Prediction system probability forecast for snow water equivalent for June, July, and August 2022.

Snow water equivalent (SWE) calibrated probabilistic seasonal forecast is performed with the Canadian Seasonal to Interannual Prediction System (CanSIPS). Over the Alaskan and Western Canada region there is probability for an above average SWE ranging from at least 60% in the southeastern parts and of 50% or more in the northern coastal region (Figure 14, Table 5). Over the eastern continental Canadian Arctic, we have expectancies for below normal SWE this summer (at least 50% probability) for the region's central northern side (red areas Figure 14). Near normal probabilities are expected in the region's eastern part (grey areas Figure 14, table 5). The Canadian Archipelago is expecting below normal SWE in the central parts while the eastern and western sectors are expecting above normal SWE (blue areas Figure 14, table 5).
Western Siberian region is expecting near normal snow this summer in the eastern and central parts (grey areas Figure 14), below normal (40% or more) SWE is expected in the coastal parts of western Siberia (red areas Figure 14, table 5), while in the south below normal chances of

40% or more are forecasted. Eastern Siberian region also has above normal (>40%) SWE expectancies in the northern coastal parts while below normal probabilities are expected at the region's eastern and western edges. Coastal Chukchi and Bering region has above normal SWE expectations for this summer (40-50% or more) while the MME is not decisive in the region's central portion (white areas Figure 14, table 5). Southwestern Chukchi and Bering region has equal probability SWE expectancies for this JJA22.

Table 5. Summer (JJA) 2022 Outlook: Forecasted Arctic Snow Water Equivalent (SWE) by region

Region (see Fig. 2)	MME SWE Forecast Agreement*	MME SWE Forecast
Alaska and Western Canada	Moderate	Above normal over northern Alaska and western Canada
Central and Eastern Canada	Moderate	Below normal over northeastern Canada and near normal over eastern Canada
Western Nordic	No model agreement	
Eastern Nordic	No model agreement	
Western Siberia	Low	Highly variable
Eastern Siberia	Low	Highly variable
Chukchi and Bering	Low	Above normal in some areas

*: See non-technical regional summaries for greater detail

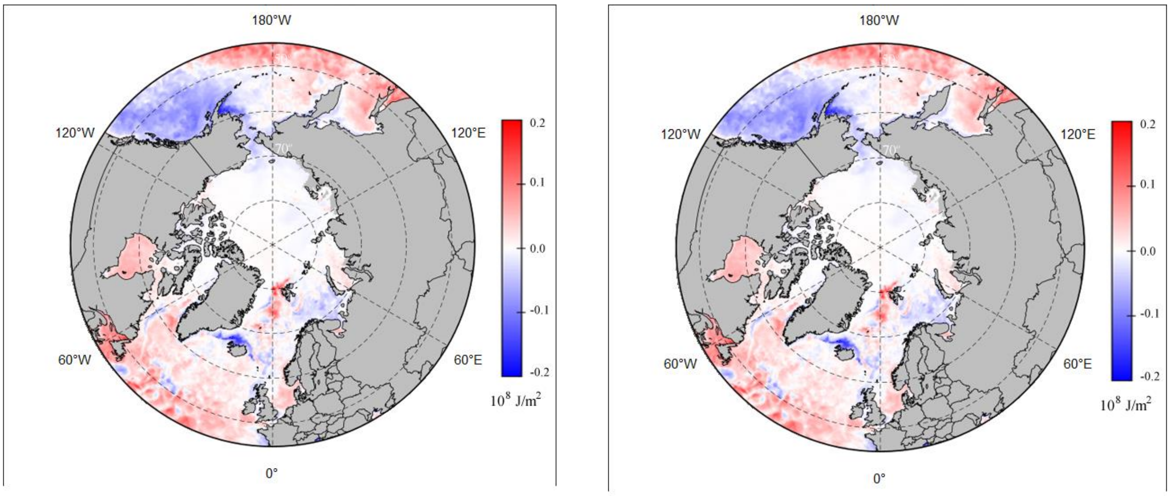
POLAR OCEAN

Summary for November 2021 - April 2022 (see technical summary for greater details):

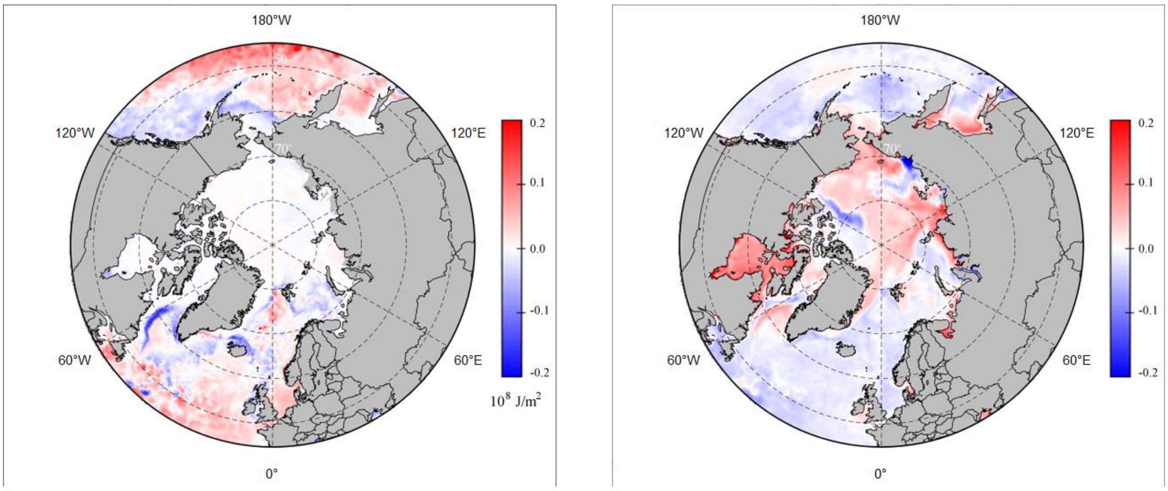
During the first part of the winter 2021/2022 positive anomaly (to 1993-2020) of the Heat Content (HC) of the upper 15 meters ocean layer was observed for the Eastern Canadian Arctic, Western Bering and Okhotsk seas and in Svalbard waters (figure 15 upper left). Somewhat neutral or calmer sea surface conditions (based on reanalysis of the wind waves and swell height) were observed in the Barents and Okhotsk Seas with higher stormier conditions near Iceland and in the Bering Sea (not shown here).

Later in winter the HC anomaly was mostly negative or neutral for most of the Arctic with the same exception for the Sea of Okhotsk and parts of Svalbard waters (figure 15 bottom left). Prominent higher stormier sea surface conditions were observed for the open-water Atlantic sector of the Arctic, W Bering and Okhotsk seas (not shown here).

Numerical models show for the past winter season both neutral and positive pH anomalies (to 1993-2020) or alkalization for the Arctic Basin, Laptev Sea and Okhotsk Seas (figure 15 right).and negative pH anomalies for the Barents, parts of the Kara, East Siberian, Greenland Seas (figure 15 right), the latter may point to acidification though correct conclusions need further verification with ground-truth data



NDJ 2021/2022



FMA 2022

Figure 15: NDJ 2021/2022 and FMA 2022 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 summer 2022 *(experimental product):*

Below normal sea-surface temperature (SST) is expected this summer in Baffin Bay and northern Greenland Sea with probabilities of 50% or higher (blue areas Figure 16, Table 6). The MME is not decisive about SST in the southern parts of the Greenland Sea (off the northern coast of Scandinavian peninsula), hence equal SST chances are expected in this region. Below normal temperatures are also expected within the Canadian Archipelago and southern Beaufort Sea with 40-50% chance (blue areas Figure 16, Table 6). A mix of forecasted probability is shown in the region of the Chukchi Sea, Bering Strait and Bering Sea. Near normal probabilities are expected in the southern Chukchi and northern parts of the Bering Sea while the southern Bering Sea is dominated with high probability (>60%) above normal SST result (red areas Figure 16, Table 6). Coastal regions of East Siberian Sea are expecting above normal SST with a low probability (40% or more) result while equal SST chances are expected in the northern parts. Laptev and Kara Seas both have expectancies of 50% or higher that the SST's will be above normal, highest probabilities are seen in the southern Kara Sea (red areas Figure 16, Table 6). For the Barents Sea, MME is generally forecasting near normal SST this summer with an exception of the southern region where low, above normal, probabilities are expected.

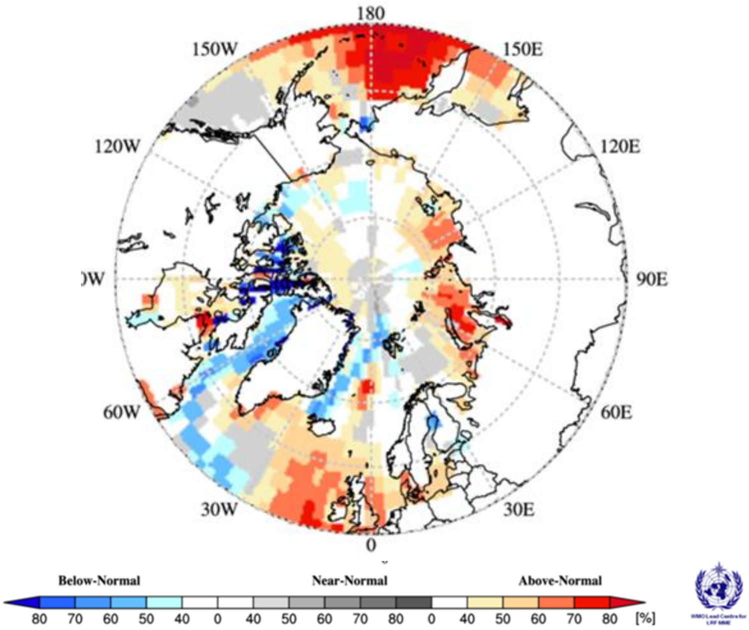


Figure 16: Multi model ensemble probability forecast for sea-surface temperature for June, July, and August 2022. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 6. Summer (JJA) 2021 Outlook: Regional Forecasts for Arctic Sea-surface Temperatures

Region (see Figure 2)	**MME Temperature Forecast Agreement***	**MME Temperature Forecast**
Baffin Bay	Low	Below normal
Barents Sea	Low	Near normal
Beaufort Sea	Low	Variable
Bering Sea	High	Above normal SW Bering; Near normal Gulf of AK
Canadian Archipelago	Moderate	Below normal
Chukchi Sea	Low	Variable
East Siberian Sea	No model agreement	
Greenland Sea	Moderate	Above normal
Hudson Bay	Low	Variable
Kara Sea	Moderate	Above normal
Laptev Sea	Moderate	Above normal
Sea of Okhotsk	Low	Above normal

*: See non-technical regional summaries for greater detail

SEA ICE

Summary for November 2021 - April 2022 (see technical summary for greater details):

Prevailing positive HC anomaly during Oct – Nov 2021 for the Svalbard, Kara, Laptev, Okhotsk Seas and Hudson Bay slowed freezing processes in these regions (figure 15 top left). Oppositely, zero or negative HC anomalies in Oct-Nov 2021 in the East Siberian, Chukchi, Bering and Baffin Seas provided background for close to normal freeze-up. Further in winter occurrence of significant positive SAT anomalies over Arctic Basin in January-February 2022 (figure 6) slowed the ice growth however negative SAT anomalies in April 2022 (not shown here) stimulated ice growth again.

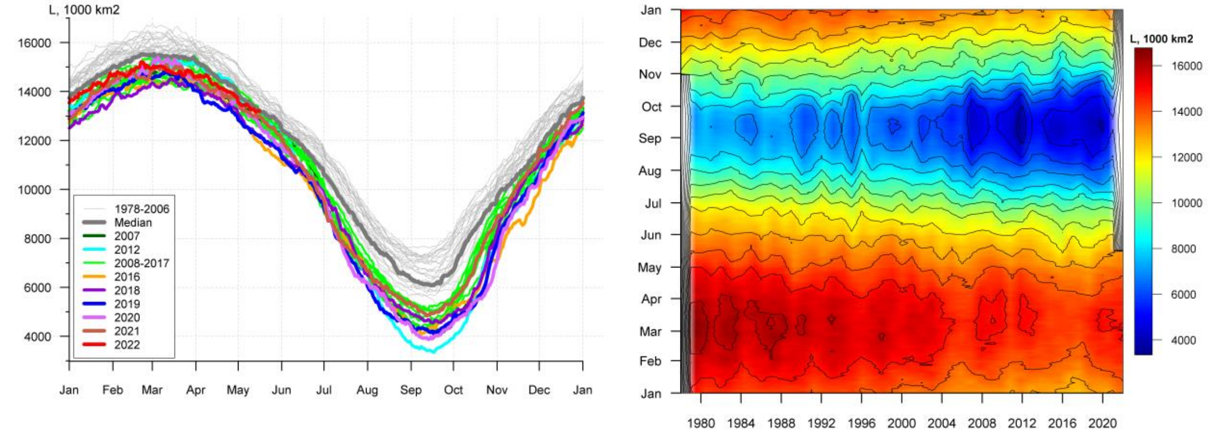


Figure 17: Arctic (Northern Hemisphere) daily (left) and daily seasonal (right) ice extent for 1978- 2022. Graphics produced by the AARI. Data source: NSIDC.

Maximum winter ice extent, 13th in row since 1979 (~15.2 mln km^2) was close to that for 2021 (~15,1 mln km^2, 10th in row), occurred on 21-22 Feb 2022 (11 March in 2021) and somewhat correlated with the previous summer 2021 minimum (12th in row) (figure 17 left). Earlier by 1-2 weeks than 1979-2022 average occurrence of the date of maximum ice extent was mostly due to degraded state of the Sea of Okhotsk ice cover though prevalence of negative surface air temperature anomalies over the Arctic Ocean by the end of winter 2022 stimulated general ice growth till the end of April 2022 as well as led to greater than 45years median ice extent in Canadian Arctic (not shown here). Seasonal patterns of daily ice extent (figure 17 right) allow to retrieve additional information on interseasonal variability of ice extent. Though both winter maximums and summer minimums continue to diminish there is a certain hint to possibility for summer ice cover in 2022 to be greater than in 2019-2021.

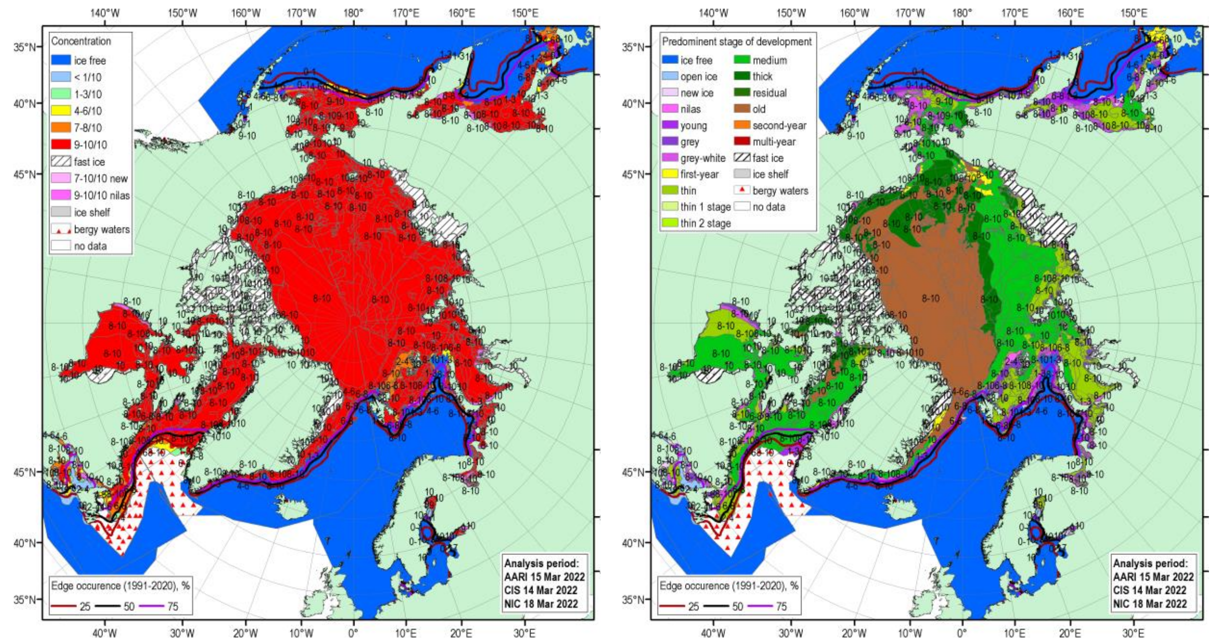


Figure 18: Blended Arctic sea-ice chart (AARI, CIS, NIC) for 14-18 March 2022 and sea-ice edge occurrences for 11-15 March for 1991-2020 reference period. Left: total concentration, right: predominant stage of development. Graphics produced by the AARI.

Other special features of ice conditions in the Arctic during autumn – winter 2021/2022 included (figure 18) occurrence of residual and further in season of second-year ice in the NE Kara and northern parts of the East Siberian Sea or within eastern lanes of the Northern Sea Route (NSR), lighter than median ice conditions in the Eastern Canadian Arctic during first part of the winter but heavier than median during late winter (not shown here) and light ice conditions in the Sea of Okhotsk during the whole winter period which is opposite to 2021.

ESA CryoSAT-2 altimetric measurements show the Arctic Basin sea ice thickness general distribution in March 2022 similar to the mean 2011-2022 pattern (not shown here) with estimate of the total Arctic ice volume (e.g. by DMI, see polarportal.dk), based on modelling as somewhat the ~3rd lowest for 2004-2022 after 2020 and 2021 (not shown here).

Sea-Ice Outlook for summer 2022 and verification for March 2022 ice extent:

The forecast for March 2022 sea ice extent was based on output from CanSIPSv2, an MME of two climate models, and verified well (right column, Table 7). Near normal ice extent was correctly forecasted for the Barents Sea, Greenland Sea, North Baltic Sea and the Labrador Sea. Below normal ice extent in the Gulf of St. Lawrence was correctly forecast. The model did not forecast the below normal ice extent in the Bering Sea.

Outlook for Spring Break-up 2022

Sea ice break-up is defined as the first day in a 10-day interval where ice concentration falls below 50% in a region. The outlook for spring break-up shown in Figure 19 displays the sea ice break-up anomaly from CanSIPSv2 based on the nine-year climatological period from 2012-2020. The qualitative 3-category (high, moderate, low) confidence in the forecast is based on the historical model skill (Figure 20). A summary of the forecast for the 2022 spring break-up for the different Arctic regions are shown in Table 8.

Table 7. Winter 2021-2022: Regional Comparison of Observed and Forecasted Maximum Sea-Ice Extent

Regions (see Figure 2)	CanSIPS Sea-Ice Forecast Confidence	CanSIPS Sea-Ice Forecast	Observed Ice Extent	CanSIPS Sea-Ice Forecast Accuracy
Barents Sea	High	Near normal	Near normal	Hit
Bering Sea	High	Near normal	Below normal	Miss
Greenland Sea	Moderate	Near normal	Near normal	Hit
Northern Baltic Sea	Low	Near normal	Near normal	Hit
Gulf of St. Lawrence	Low	Below normal	Below normal	Hit
Labrador Sea	Low	Below normal	Near normal	Hit

A later than normal break-up (blue areas, Figure 19; Table 8) is forecasted for the Barents, Beaufort, Greenland and Labrador Seas. A near normal break-up is forecast for Baffin Bay, Hudson Bay and the Chukchi Sea. An earlier than normal break-up is forecast for the Canadian Archipelago and the Kara and Laptev seas.

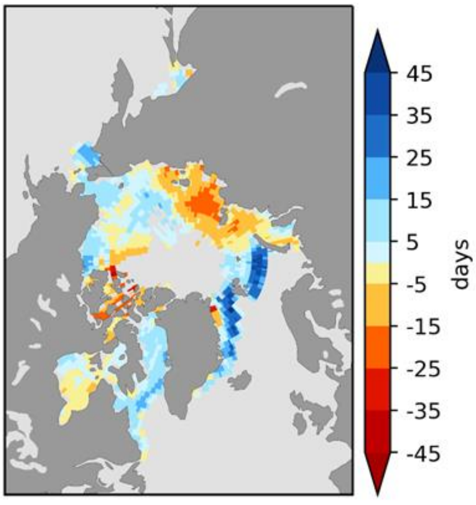


Figure 19: Forecast for the 2022 spring/summer break-up expressed as an anomaly (difference from normal) where break-up is defined as the first day in a 10-day interval where ice concentration falls below 50%. Source: CanSIPSv2 (ECCC).

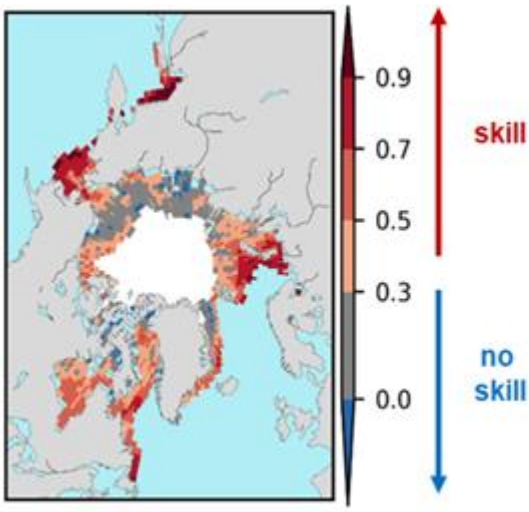


Figure 20: Historical forecast skill defined as the detrended anomaly correlation coefficient based on the 1981-2019 period. Source: CanSIPSv2 (ECCC).

Table 8: **Spring 2022 Regional Outlook for Arctic Sea Ice Break-up**

Regions (see Figure 2)	CanSIPSv2 Sea-Ice Forecast Confidence	CanSIPSv2 Sea-Ice Break-up Forecast
Baffin Bay	High	Near normal
Barents Sea	High	Late
Beaufort Sea	High	Late
CAA	Low	Early
Chukchi Sea	Moderate	Near normal
East Siberian	Low	Near normal
Greenland Sea	High	Late
Hudson Bay	High	Near normal
Kara Sea	High	Early
Labrador Sea	High	Late
Laptev Sea	Low	Early

Outlook for September 2022 Minimum Sea Ice Extent

Minimum sea ice extent is achieved each year during the month of September in the northern hemisphere. Table 9 categorizes the sea ice extent forecast confidence and relative extent (i.e., near normal, below normal, above normal) with respect to a 2013-2021 climatology for the Arctic region. The forecast for September 2022 minimum sea ice extent is presented on figure 20a, the September 2022 ice concentration anomaly from 2013-2021 is shown on figure 20b and the forecast confidence is shown as figure 20c.

The forecast for most of the Arctic is a near normal September ice extent (Table 9). Below normal ice extent is forecast for the Laptev and Kara Seas (Table 9).

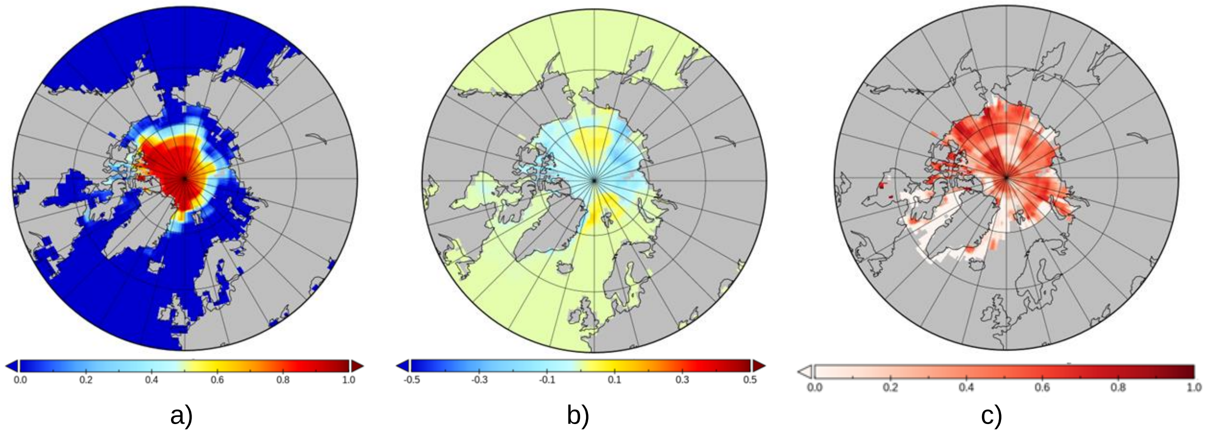


Figure 20 (a) September 2022 ice concentration; (b) September 2022 ice concentration anomaly based on the 2013-2021 period and (c) Historical skill 2000-2020 measured by the anomaly correlation coefficient. Source: CanSIPSv2 (ECCC).

Table 9: **Summer 2022 Regional Outlook for Minimum Sea-Ice Extent**

Regions (see Figure 2)	CanSIPSv2 Sea-Ice Extent Forecast Confidence	CanSIPSv2 Sea-Ice extentForecast
Barents Sea	Moderate	Near normal
Beaufort Sea	High	Near normal
Canadian Arctic Archipelago	Moderate	Near normal
Chukchi Sea	High	Near normal
Eastern Siberian Sea	High	Near normal
Greenland Sea	Low	Near to above normal
Kara Sea	Moderate	Below normal
Laptev Sea	High	Below normal

Outlook for key shipping regions:

Bering Sea

Bering Sea ice extent was higher early in the 2021-22 season than any year since 2012 and above the 1991-2020 median for most of February. The ice extent dropped dramatically in April, second largest since 1979, driven by a thin ice cover in the eastern Bering Sea. Limited ice remains in the Bering Sea, with most being located in the western portion of the sea. South of 60°N, waters are ice free. Ice free conditions are expected as far north as St. Lawrence Island by mid-June, and for the remainder of the sea during the second half of June.

Coastal Beaufort Sea

Break-up of sea ice is expected to be later than normal for the coastal Beaufort Sea this summer with an overall near normal extent through the season. Near coastal areas show lower than normal old ice amounts, but higher than normal concentrations are notable further offshore. This area of old ice could become a navigation issue if it is transported southwest of Banks Island. Amundsen Gulf remains predominantly fasted, when climatologically it is usually mobile at this time of the year.

Northwest Passage

Sea ice breakup in the Northwest Passage (NWP) will be earlier than normal and the extent will be lower than normal this summer. Old ice concentrations are higher than normal through the northern NWP route in general. The transport and mobility of old ice in the Canadian Arctic Archipelago remains a concern as these areas of anomalously high concentrations of old ice could come to impact important navigation corridors and “chokepoints” in the passage.

Hudson Bay and Hudson Strait

Near normal to slightly faster than normal sea ice break-up is underway in Hudson Bay and Hudson Strait. Moderately warmer than normal air temperatures this spring are contributing to this trend. Near normal ice breakup and decay is predicted for Hudson Bay and Hudson Strait. Ice free conditions are expected by late July for Hudson Strait. The last remaining ice is forecasted to melt from southwestern Hudson Bay by mid-August.

Baffin Bay
Near normal sea ice break-up is forecasted for Baffin Bay this summer based on a currently near normal ice extent in the region, along with forecasted near normal temperatures in the area of interest. This winter, the Nares Strait ice bridge did not form as is usually the case. This ice bridge prevents the incursion of old ice from the Arctic Ocean into northern Baffin Bay. At present, old ice concentrations are lower than normal in the region but warrant monitoring.

Svalbard
Winter 2021-22 ice extents were near the 1991-2020 average. Current sea ice coverage is significantly higher than normal however. Near the north-east Greenland side of Fram Strait, landfast ice extent is larger than previously observed this spring. This ice is anchored in place by a greater number of grounded icebergs than have been seen in the past decade, on the Belgica Bank (shallow continental shelf). Signs of breakup have not been observed yet through May as cold, calm conditions are persisting in the region.

Northern Sea Route
Challenging ice conditions are not expected in the Northern Sea Route (NSR) for the entirety of spring and summer 2022. Light ice conditions are forecasted along the NSR in the Barents Sea, southwestern Kara Sea, Laptev Sea and western section of the East Siberian Sea. Near normal conditions are predicted for the northeastern Kara Sea, eastern portion of the East Siberian Sea and for the southwestern section of the Chukchi Sea. Significant early retreat of ice cover and fast ice breakup are forecasted for the NSR this summer.

BIOCLIMATIC INDEXES ***(see technical summary for greater details and definitions of the indexes):***

Summary for winter 2021/2022:

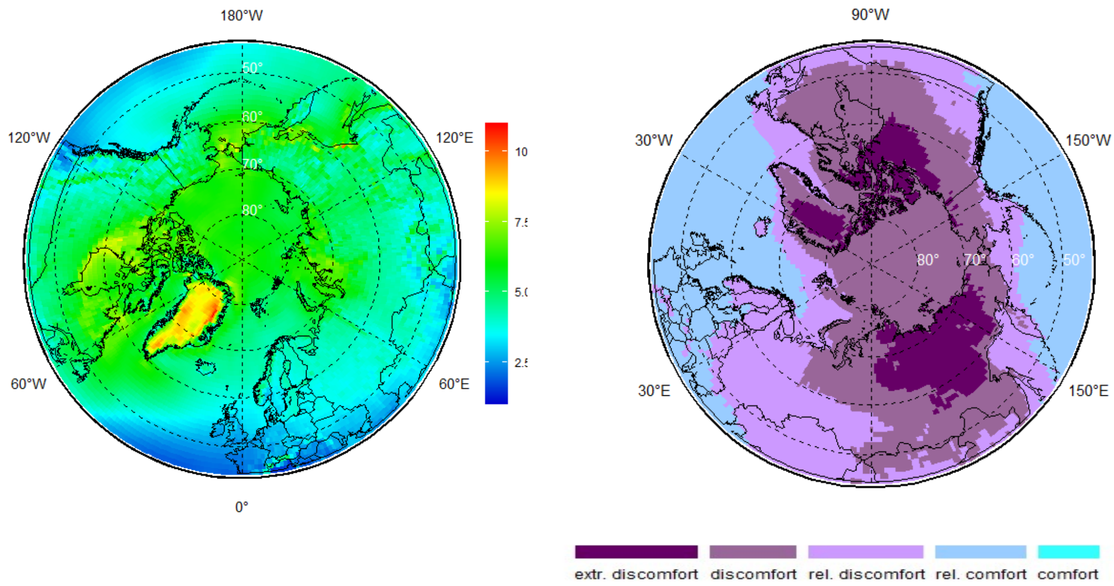


Figure 21: Bioclimatic indexes in DJF2021/2022 - Bodman's weather severity index (left) and Effective temperature – ET (right). Maps produced by the AARI. Data source: CCCS ERA5.

Arctic winter 2021/2022 continues to be within very severe (5 - 6) and extremely severe (>6) zones according to Bodman's index (figure 21 left). Effective temperature ET index (figure 21 right) shows the discomfort zones, with a stronger difference between extreme discomfort and discomfort zones in Western Siberia. For this season, analysis of the Bodman's index anomaly (to 1991-2020 period) shows milder conditions in the Eurasian part and more severe conditions in the Canadian-American part (not shown here). It is in agreement with ET positive anomalies in Eurasian part excluding certain areas of Yakutia and Northern America. Southern Greenland, Bering Sea and Kamchatka areas have positive anomalies for all indexes.

Outlook for Summer 2022 (experimental)

Forecast of the bioclimatic indexes is provided in a form of forecasted effective temperature ET values for June – August 2022 (figure 21) and is based on the test seasonal forecast of air temperature and humidity 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). The common “cold discomfort” is forecasted for most of the Arctic regions through the whole summer season, though appearance of the “comfort” zones may be seen in July in parts of Alaska, Canada and Eastern Nordic regions. It is also possible to distinguish the shift of the "comfort" zone to the north relative to the average climatic values (1991-2020).

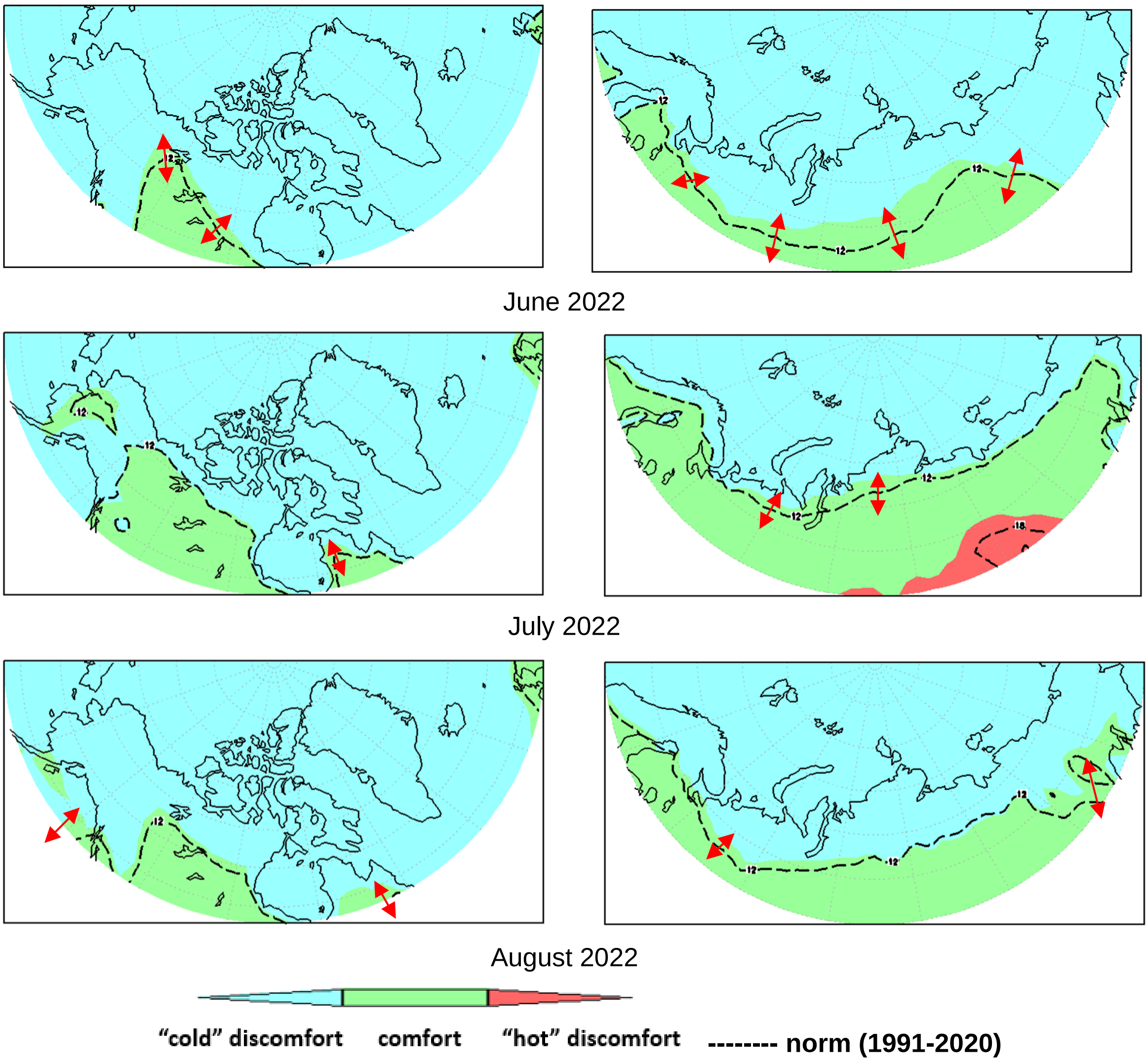


Figure 22: Effective temperature (ET) forecast for June - August 2022. Maps produced by the Hydrometcenter Russia. Data source: Institute of Numerical Mathematics Russian Academy of Science.

MAJOR CLIMATE RELATED RISKS AND IMPACTS

Weather alerts by the Icelandic Meteorological Office during the last winter season

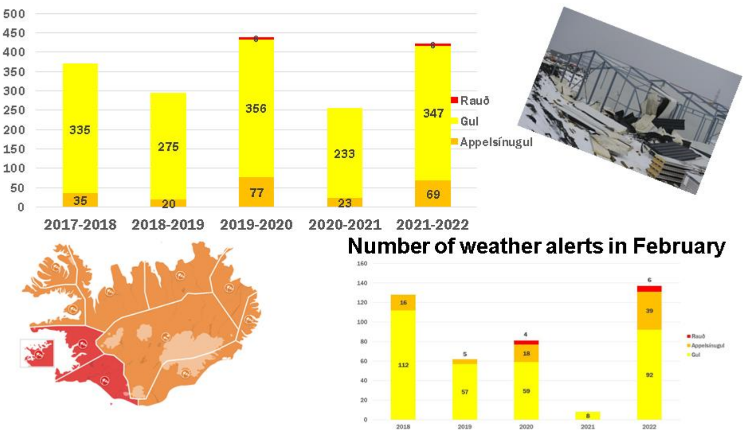


Figure 23: Number winter weather alerts in Iceland

Changes in climate continue to trigger various extreme events. As an example, this consensus statement provides statistics for weather alerts issued by the Icelandic Meteorological Office during the last winter season. The Icelandic region (part of Western Nordic) had a severity of storms and storm tracks connected to the positive phase of the North Atlantic Oscillation (NAO+) for some part of the period as well as related to Atlantic blocking. There was some heavy snow in Reykjavík in February and March. Figure 23 provides information on the number of weather alerts in Iceland for the past winter compared to previous years (the Icelandic CAP warning system is up since 1 November 2017).

The number of warnings for the winter 2021-2022 is similar to the warnings during 2019-2020 as well as 2014-2015, however both of those winter had the number of storms spread from early December to middle of March. This winter (2021-2022) storms started later - the first week of January and kept going until the middle of March, those months were thus worse than the same months during previously stormy winters. Storm surge is an increasing problem along the south and north coasts of Iceland. Damage due to storm surge increases with sea level rise.

Major risks and impacts for the ArcRCC-N regions (see non-technical summary for greater details)

Alaska and Western Canada

Past season

- Very wet (snowy) winter in the west part of Western Canada. In Yukon, new monthly records of snow were set in many communities. In Eastern Alaska, federal resources were required for snow removal, after very heavy snow episodes December to early January.
- Very cold winter in Prince George, Yellowknife and Kotzebue, while Kodiak saw the highest Alaska temperature ever in December.
- A historic snow, rain and ice period from December 20 to 30 in central interior of Alaska lead to widespread power outages and to hazardous road conditions that persisted until spring
- The record setting snowpack in many watersheds across the territory will result in higher-than-average freshet flows and lake levels this spring and summer and increases the potential for flooding in many areas.

Coming season and ongoing impacts of climate change

- High early summer river levels in Alaska and Yukon
- Increased risk of coastal flooding, thawing permafrost coastal erosion and risks to community infrastructure
- All marine mammals with habitat on sea ice may be more difficult to harvest, while early loss of sea ice increases the risk of high summer ocean temperatures with a risk to salmon return.

- Crabbing for coastal communities may be impacted owing to lack of stable ice nearshore

Central and Eastern Canada

Past season

- Prolonged cold in Labrador through January and February
- On March 12-14, a major storm set a new all-time lowest barometric pressure reading of 945.1 millibars at Cartwright

Coming season and ongoing impacts of climate change

- Warmer conditions lead to less ice, thus more potential for ships. In some regions (e.g., Pond Inlet-Baffin Island) more ships have an impact on wildlife, notably narwhals, thus on important source food supply for Inuit people
- No areas of Central and Eastern Nordic Canada are of concern of wildland fires for May.
- In June the wildfire severity anomaly starts to grow in the Eastern part of the Northwest Territories (NWT) and the Southeast part of Nunavut with a peak in severity in August. Cool weather in September will reduce fire severity but it will remain above normal.

Western and Eastern Nordic

Past season

- In Iceland, storms started later than usual and were more compact in a shorter timeframe resulting in stormy packed few months.
- Storm surge is an increasing problem along the south and north coasts of Iceland.
- Many areas suffered from weather conditions that resulted in pastures 'locked' by ice
- Variable temperatures alternating freeze and thaw
- In February 2022, a new national record for monthly precipitation was made in Finland, when Siuntio Sjundby received 142.7 mm of precipitation during the month.
- In central Finland, the winter was exceptionally snow-rich, with record-high snowpack values measured in many stations in the beginning of April.
- Significant variations in grazing conditions between different areas. Many reindeer have not been able to graze naturally. Herders have been giving artificial food during much of the winter season

Coming season and ongoing impacts of climate change

- Above normal conditions for temperature are expected to result in favorable conditions for agriculture, how favorable, however, also depends on precipitation but the outlook for precipitation is very uncertain.
- In Iceland, warmer conditions are likely to enhance glacial melting throughout the melting season, which should result in favorable conditions for the hydropower industry. Above average melting will continue the glacial mass loss of previous decades.

Western Siberia

Past season

- Small amount of precipitation in Franz Josef Land resulted in a low snow depth. As a result, polar bears left the islands - they could not use the snowdrifts as dens. Franz Josef Land and the Novaya Zemlya archipelago are the main "maternity homes" for polar bears in the Russian Arctic.
- During the week (March 2-9) abnormally cold weather was observed in the Nenets Autonomous Okrug with the average daily air temperature below the norm by 11-18C.
- In April 2022, due to rains, snowfalls and a sharp drop in air temperature, 70% of the territory of the Seyakha tundra was covered with a thick crust of ice. 260 families with herds of deer found themselves in the icing zone, which could not get through to the reindeer moss. During the winter and spring in the Seyakha tundra, according to

preliminary estimates of reindeer herders, about two thousand animals died due to lack of food. The reindeer left for free grazing in search of reindeer moss, some of them rushed off after their wild relatives in an unknown direction.

Coming season and ongoing impacts of climate change

- A risk of forest fires is possible in region at the beginning of the summer due to above normal temperatures forecasted in the north of West Siberia.
- The threat of river flooding in Ob' and Yenisei is uncertain.
- High temperatures may lead to continued permafrost degradation and coastal erosion.
- Shipping in the Northwest Passage from west to east is expected to start earlier than normal with safe and easy ice conditions for independent navigation of large-capacity tankers, gas carriers and bulk vessels

<u>Eastern Siberia</u>

Past season

- High frequency of snowstorms with visibility below 500 m. This dangerous phenomenon lasting 3-4 days was recorded from December to March in the north of Yakutia 6 times, in the north of the Krasnoyarsk Territory 4 times. Such conditions disrupted the operation of airports and road transport.
- A cold wave in the north of the Krasnoyarsk Territory (December 14-22). Minimum temperatures reached -50...-53°C. During this period, an increase in the number of domestic fires was noted.

Coming season and ongoing impacts of climate change

- Due to the high fire danger that is already observed in the south and centre of Siberia at the moment and the predicted high temperature, a difficult fire situation can be assumed throughout the season
- Shipping across the Northern Sea Route is expected to be start earlier than normal with safe and easy ice conditions

<u>Chukchi and Bering</u>

Past season

- Due to the early freeze-up, the northern sea route was closed earlier than usual. Several ships got stuck in the ice. This led to delays in the delivery of food to remote areas of the Chukotka Peninsula and, as a result, a rise in food prices. Three icebreakers were used to help ships.
- For 3 weeks, with short breaks, heavy snowfalls were observed, on some days a strong snowstorm with a visibility of less than 500 m with a wind of 20-25 m/s, on the coast of the Bering Sea with gusts of 33-38 m/s. Flights were canceled, schools were closed.
- Maximum temperature records in Magadan: January 5 -0.5°C (previous -0.6 °C 1969)

Coming season and ongoing impacts of climate change

- Above normal precipitation may increase the threat of river flooding in Indigirka and the Kolyma
- Shipping across the Northern Sea Route is expected to be start in time on time due to normal breakup from the ice of the Chukchi and East Siberian seas
- Wet and warm weather will form the condition for coastal erosion. As a result, nesting conditions may be disturbed for seabirds and rookeries of seals and sea cows

Central Arctic

Past season

- Ice formation began more intensively, the presence of residual ice contributed to that (this was observed for the first time in the last five years)
- Ice captivity since the second half of November with about 20 vessels of various ice classes captured in the Northern Sea Route due to their low ice classes
- Vessels were released with help from icebreakers

Coming season and ongoing impacts of climate change

- Shipping across the Northern Sea Route is expected to start on time

Background and Contributing institutions

These Arctic seasonal climate summary and outlook were prepared for ACF-9. Contents and graphics were prepared in partnership with 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-spring-2022.

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