Arctic Climate Forum Consensus Statement

Summary of 2022 Arctic Summer Season and the 2022-2023 Arctic Winter Seasonal Climate Outlook
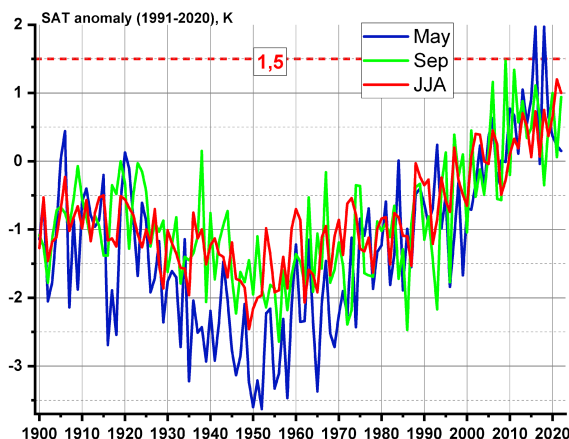
CONTEXT

Figure 1: May, September and summer (JJA) average surface air temperature anomalies (ref. 1991-2020). Dotted lines – UN +1.5 threshold. Graphics produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

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) are close to the highest in the time series of observations for 1900-2022 and approaching the UN +1.5°C threshold (figure 1) though significant interannual and interregional variations do occur, both in warm and cold periods. The minimum Arctic ice extent in summer 2022 occurred 17-18th September and was close to the 12th mildest in row since 1979, with the majority of the regions having similar rank of the ice extent. For the second year in row the old ice remained on the eastern lanes of the Northern Sea Route through the whole summer season.

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 10th session of the ACF held online on 26-27 October 2022 and coordinated by the Nordic Node of ArcRCC-Network hosted by Norway.

HIGHLIGHTS

For the whole period May – September 2022 polar vortex (on the 500 hPa isobaric surface) typically had 3-4 nodes over Central Arctic, Greenland, Alaska and Siberia causing corresponding cyclonic activity underneath and blocking anticyclone features in other regions. Surface atmosphere inherited features of the upper processes with a sequence of changes from the zonal to meridian forms of circulation ad blocking events in corresponding regions.

Temperature:
During May – September 2022 only positive anomalies of the surface air temperature occurred for the whole land Arctic with extremes in June (4th in row) and August (1st in row). Preliminary resulting rank for JJA 2022 for the land Arctic is the 2nd in row (from 1950), though large regional and inner season variations and changes in anomaly sign do occur. For the marine Arctic colder conditions occurred in May 2022, close to normal - in June – August and colder in September. Surface air temperatures during winter 2022-2023 are forecast to be above normal in all regions across the Arctic. The confidence of the forecast is moderate-high with the exception of the Beaufort-Chukchi and Alaska-Western Canada regions where the confidence is low-moderate.

Precipitation:
During summer 2022 lesser precipitation occurred in the Western Siberia and parts of Western Canada regions. Greater precipitation was observed in the Western Nordic, Central Siberia, parts of Eastern Canada and Chukchi and Canada and Alaska regions. Somewhat close to normal conditions were observed in the Central Arctic Wetter than normal conditions are expected in most Arctic regions during winter 2022-2023.The confidence in the precipitation forecast is low. Exceptions are the Greenland Sea, the Aleutian Islands in southwest Alaska and Scandinavia where there is no forecast because of no agreement between the models.

Sea-ice:
The 12th in row summer Arctic ice cover minimum observed in September 2022 as well as general ice conditions were very similar to the 2021 and second time in row significantly differed from 2019 and 2020. The Barents and Kara Seas were completely ice free with the ice edge significantly northward of Svalbard, while the ice conditions in parts of the Laptev, Eastern Siberia, Beaufort Seas were close to 40 years normal with both the NW passage and the NSR formally remaining blocked in the transit straits. A near normal freeze-up is forecasted for the Barents, Bering, Chukchi, and Greenland seas, as well as for Hudson Bay and the Sea of Okhotsk. An early freeze-up is forecasted for Baffin Bay, and the East Siberian and Labrador seas. For the Beaufort, Kara and Laptev seas, a later than normal freeze-up is forecasted. The forecast for most of the Arctic March ice extent is near normal for the Bering and Northern Baltic seas, as well as in the Sea of Ohkotsk. Below normal ice extent is forecasted for the Greenland and Barents seas whereas above normal coverage is the most probable outcome for the Labrador Sea.

UNDERSTANDING THE CONSENSUS STATEMENT

This consensus statement includes: a seasonal summary and forecast verification for temperature, precipitation, and sea-ice for the previous Arctic summer season 2022; an outlook for the upcoming Arctic winter season 2022-2023. 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.
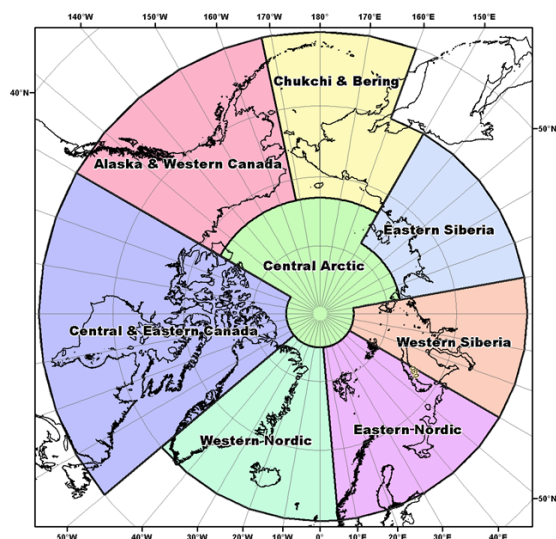

Figure 2: Regions used for the seasonal summary and outlook of temperature and precipitation
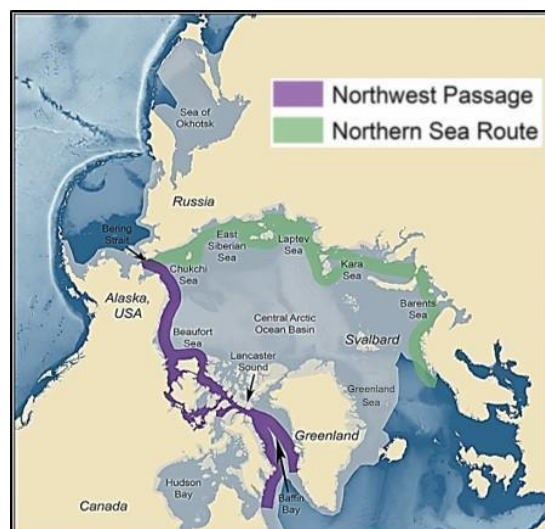

Figure 3: Sea-Ice Regions. Map Source: Courtesy of the U.S. National Academy of Sciences

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. Additional sea ice information is incorporated from the CFSm5 model forecast available from NOAA's Climate Prediction Centre. The Baltic Sea forecasts are developed using outputs from the ECMWF Long-Range Forecasts, UK MetOffice, and NOAA CFSv2. When northern hemisphere sea ice extent is at its maximum in March of each year,

forecasts are available for the following peripheral seas where there is variability in the ice edge: Barents Sea, Greenland Sea, Bering Sea, Eastern Siberian Sea, Northern Baltic Sea, Labrador Sea, and the Sea of Okhotsk. In addition to these regions, forecasts for sea ice freeze-up are also available for Baffin Bay, Beaufort Sea, Bering Sea, East Siberian Sea, Kara Sea, Laptev Sea, Chukchi Sea, Barents Sea, Greenland Sea, Hudson Bay, Labrador Sea and the Sea of Okhotsk. Additional forecast support for key shipping areas is 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
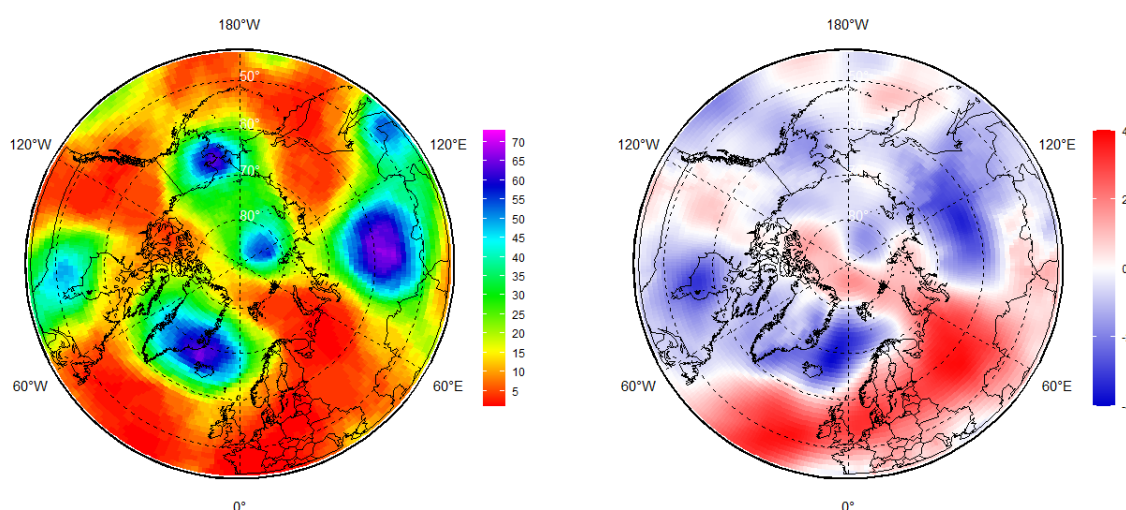
Summary for May – September 2022:

Figure 4: JJA 2022 H500 ranks for 1950-2022 period (left) and MSL anomaly (ref. 1991-2020 period) (right). Maps produced by the AARI. Data source: CCCS ERA5

For the whole period May – September 2022, the polar vortex (dark violet, 500HPa geopotential height pattern (H500), figure 4 left, data for May and September not shown here) typically had 3-4 nodes over Central Arctic, Greenland, Alaska and Siberia causing corresponding cyclonic activity underneath and blocking anticyclone features in other regions.

Surface atmosphere inherited features of the upper processes with a sequence of changes from the zonal to meridian forms of circulation in corresponding regions (figure 4 right, data for May and September not shown here). In the Atlantic-Eurasian sector, atmospheric processes in May and August were characterized by occurrence of the western zonal circulation while in September a large-scale meridional circulation prevailed in the region. In the Pacific-American in June meridional circulation was predominant, but in July and September it was replaced by the zonal atmospheric circulation. In the polar region in May, partly July and August trajectories of the North Atlantic cyclones were situated normally or shifted northward, while in June and September, trajectories were shifted southward in comparison with the norm.

TEMPERATURE

Summary for May – September 2022 (see technical summary for greater details):

At the start of summer 2022 (May - June) strong positive anomalies of the surface air temperature occurred in Western (3rd – 5th in row) and Eastern Siberia (12th – 6th in row)

(figure 5). For Alaska and Western Canada (31st – 5th) anomalies switched from strong negative to strong positive. Other strong positive anomaly occurred in May in Chukchi and Bering (2nd in row). During mid-summer (July - August) strong positive anomalies were observed over the Eastern Nordic in August (3rd in row), Western and Eastern Siberia (5th - 7th in row) and extremely positive – in the Central and Eastern Canada (5th – 1st in row). Negative anomalies were observed in July in the Western Nordic region (37th in row). By the end of summer in September 2022 similar extremely positive anomalies occurred over the Central and Eastern Canada (2nd in row) and Western Nordic (6th in row), while the Eastern Nordic (44th in row), Western (45th in row) and Eastern Siberia (48th in row) experienced negative anomalies. Due to lack of surface marine observations, conclusions for the Central Arctic were done using the reanalysis (figure 6, information for single months not shown here) and included partly colder conditions in May 2022, close to normal in June – August and colder in September April 2022.
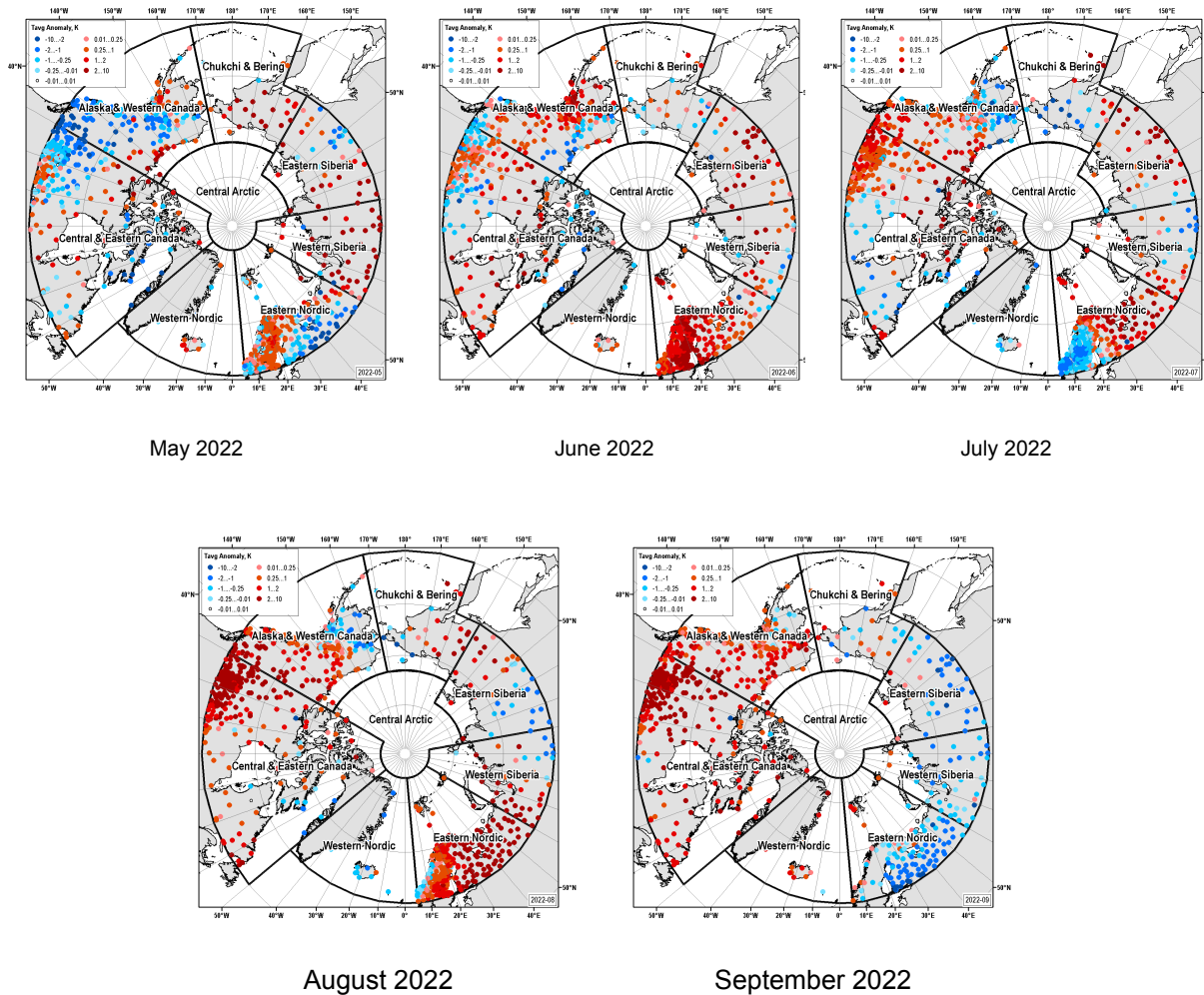

May 2022   June 2022   July 2022

August 2022   September 2022

Figure 5: May – September 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.
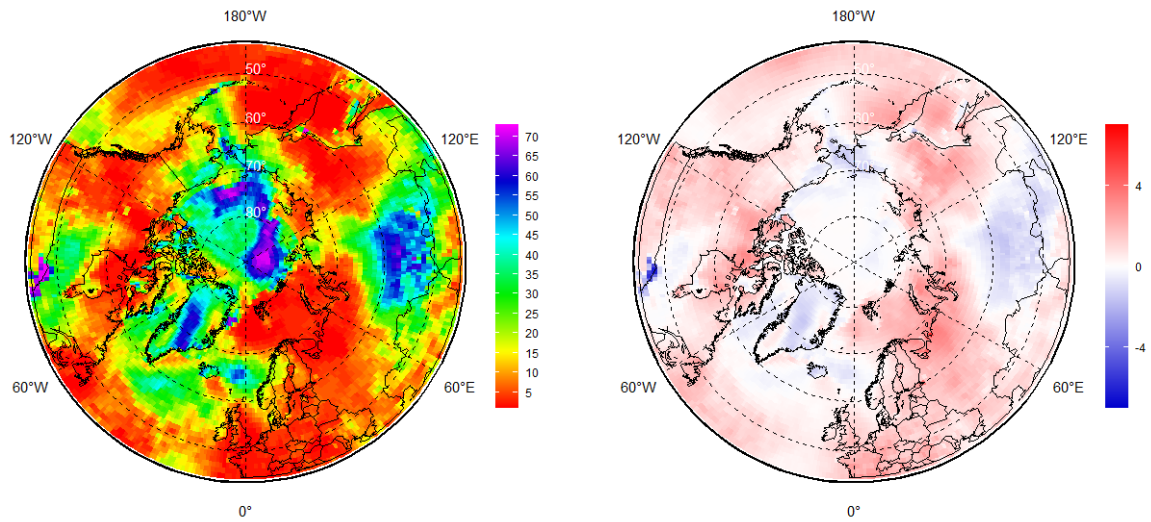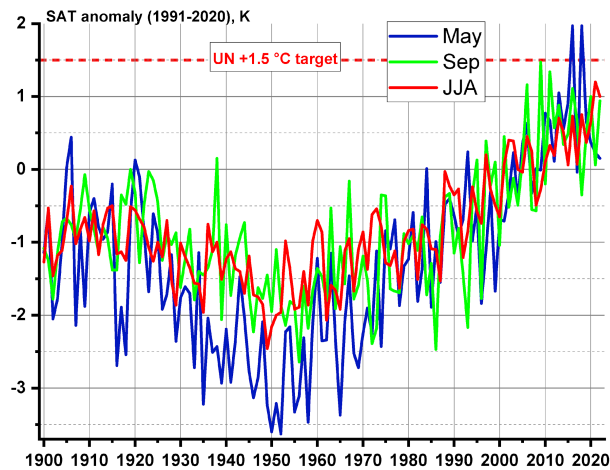
Figure 6: JJA surface air temperature ranks for 1950-2022 period (left) and anomalies (ref. 1991-2020) (right). Data source: AARI. Maps produced by the AARI. Data source: CCCS ERA5.

Month	Anomaly	Rank	Year$_{min}$	Year$_{max}$
May	0.15	15	1952	2016
June	**1.02**	4	1949	2021
July	0.52	8	1949	2018
August	**1.41**	1	1956	2022
September	0.94	6	1956	2009
JJA 2022	**1.00**	2	1949	2021

Figure 7: JJA 2022 surface air temperature anomalies (ref. 1991-2020) and monthly statistics. Graphics and tabular data produced by the AARI. Data source: WMO polar stations within the ArcRCC-N domain (see fig.2).

For the whole land Arctic during May – September 2022 period only positive anomalies occurred with extremes in June (4th in row) and August (1st in row) (figure 7). Preliminary resulting rank for JJA 2022 for the land Arctic is the 2nd in row (from 1950), though large interregional (not shown here) and inner seasonal variations and changes in anomaly sign do occur.

Opposite to winter conditions (when the comparable positive anomalies also occurred in 1920s), the summer months of the 2010s-2020s Arctic experience 2-4 times greater positive anomalies than in 1910s-1920s, but that is again NOT the SAME for all ArcRCC-N regions.

Scale of the actual anomalies depends on the WMO reference period chosen and density of the stations network in time, in particular for the marine Arctic.

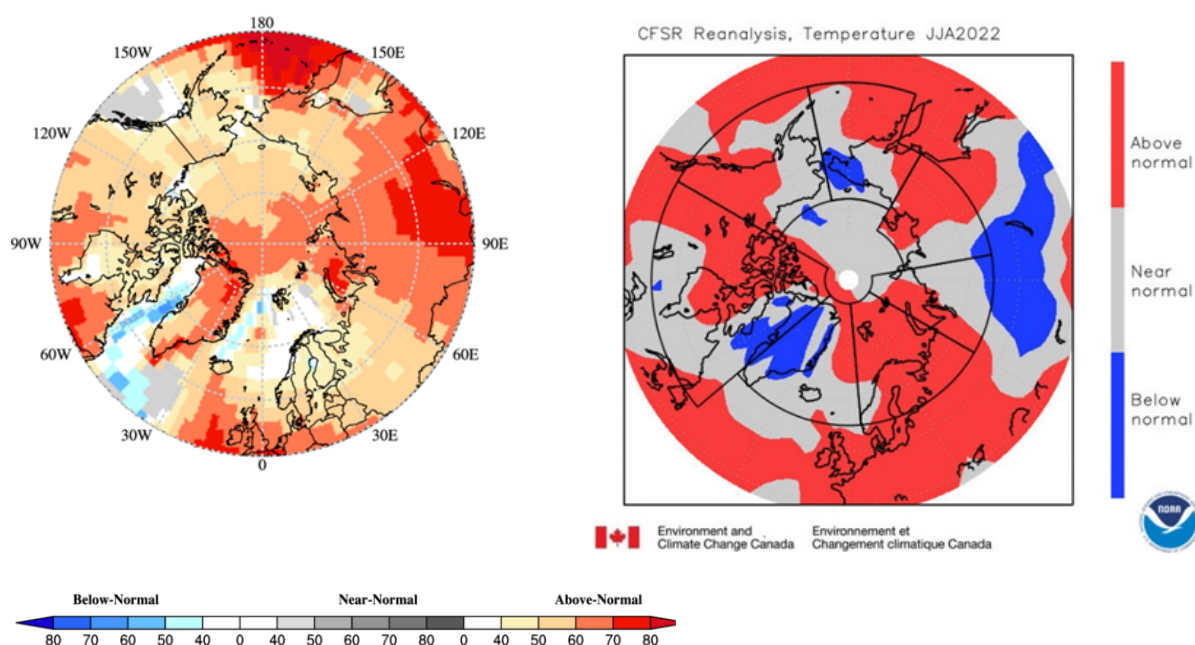***Verification of summer 2022 forecast***

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

The JJA 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 forecasted for the Eastern Nordic, parts of Eastern Siberia, Western Siberia and Alaska Western Canada. Western Nordic region and Central Arctic region were missed by the JJA22 MME forecast. The forecast was partially successful in the Central and Eastern Canada with only northwestern being true to the reanalysis regions. The Chukchi and Bering regions forecast was correctly forecast only in the southern parts of the region (Table1)

Outlook for winter 2022-2023:

For the November-December-January 2022/23 (NDJ22/23) period, there is a probability of 40% or more that temperatures will be above normal in all regions across the Arctic. The highest probabilities for an above normal summer (60-70% or more) are in the eastern and western Siberian regions and in the northern parts of the eastern Canada. Alaskan and western Canada region is expecting above normal temperatures with probabilities of at least 40%. Northern, coastal, portions of this region are expecting somewhat higher probabilities, 50% or more, for an above normal NDJ. Multi-model ensemble (MME) forecast is indecisive (white color on the map) over the southern parts of Alaska-western Canada.

For the eastern Nordic region, MME forecast is showing above normal probabilities of 60-70% or higher, in the north-eastern and southern parts of the region, while these probabilities are somewhat lower (40% or more) in the central and western parts of the region. Continental parts of the western Nordic region have expectation of at least 50% or higher for an above average summer (i.e. Scandinavian Peninsula). Somewhat higher probabilities of 60% and higher are expected in the northeastern, coastal, portions of the region. Chukchi and Bering region has a probability of at least 50% for an above normal winter onset. Western parts of this region have even more chance (60-70%) for an above normal NDJ.

Table 1. June, July and August 2022: Regional Comparison of Observed and Forecasted Arctic Temperature

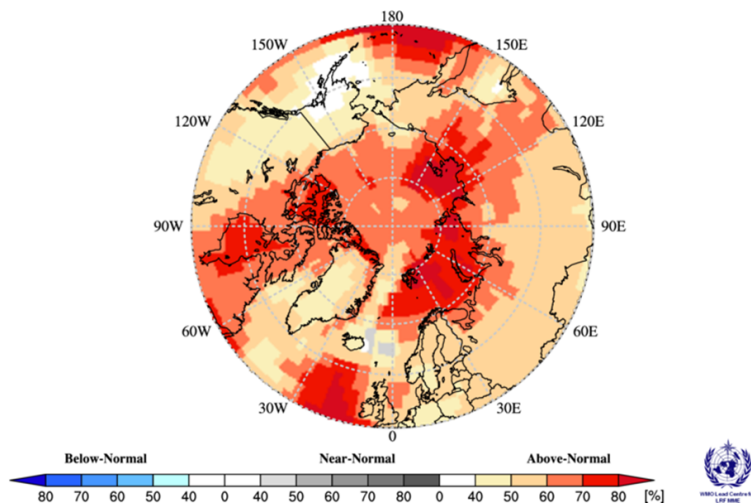| Regions (see Fig. 2)	MME Temperature Forecast Agreement	MME Temperature Forecast	NCAR CFSR Reanalysis (observed)	MME Temperature Forecast Accuracy
Alaska and Western Canada	Low	Mostly above normal	Mostly above normal in the east and SE, near normal in the west	~60% hit
Central and Eastern Canada	Moderate	Above normal on land	Above normal in the west, near normal in the south and east	30% hit, 70% miss
Western Nordic	Low-Moderate	Above normal in most of the region	Above normal in the west, mostly near normal	miss
Eastern Nordic	Low	Above normal	Above normal	Hit
Western Siberia	High	Above normal	Above normal in the west, near normal in the south	40% Hit. 60% miss
Eastern Siberia	High	Above normal	Above normal in the east, near normal in the west	60% Hit, 40% miss
Chukchi and Bering	Low-Moderate	Above normal	Above normal in the south, near and below normal in the north and west	30% Hit., 70% miss
Central Arctic	Moderate	Above normal	Near normal	Miss

Figure 9: Multi model ensemble probability forecast for temperature for November, December and January 2022-23. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 2. Winter (NDF) 2022-23 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/SE Alaska)
Central and Eastern Canada	Moderate-High	Above Normal
Western Nordic	Moderate-High	Above Normal
Eastern Nordic	Moderate-High	Above Normal
Western Siberia	High	Above normal
Eastern Siberia	High	Above normal
Chukchi and Bering	Low-Moderate	Above normal
Central Arctic	Moderate-High	Above normal

*: See non-technical regional summaries for greater detail

PRECIPITATION
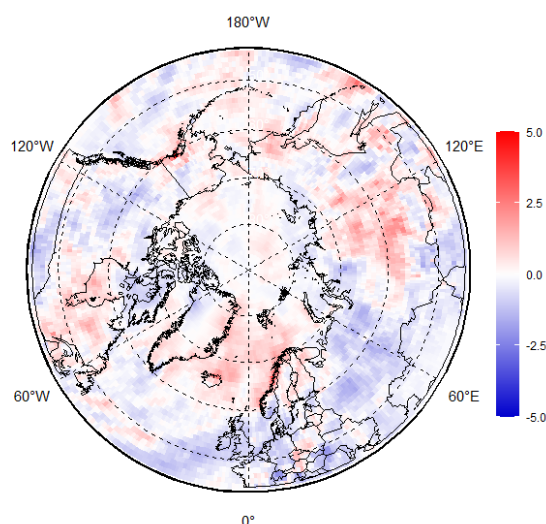
Summary for May – September 2022:

Figure 10. JJA 2022 surface precipitation anomalies (ref. 1991-2020). Map produced by the AARI. Data source: CCCS ERA5

In general, during the summer 2022 season wetter conditions dominated over most parts of Western Nordic, Eastern Siberia, Chukchi and Bering and Eastern Canada regions (figure 10). Drier conditions dominated over Western Siberia and Central Canada. Eastern Nordic, Alaska and Western Canada, Central Arctic regions experienced both wetter and drier conditions
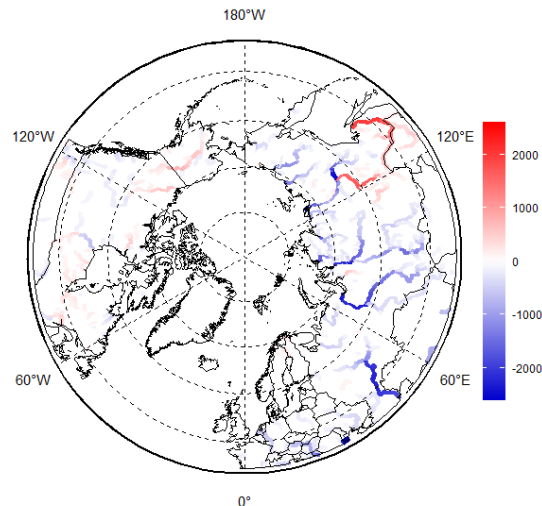
Figure 11. JJA 2022 river discharge anomalies (ref. 1991-2020). Map produced by the AARI.
Data source: CCCS ERA5-GloFAS

Impacts of wetter/drier conditions and evaporation were reflected in the JJA 2022 Arctic rivers discharge. ERA5-GloFAS reanalysis showed lesser drainage than normal for practically all Great Arctic rivers (figure 11) with more significant negative anomalies for Ob, Yenisei, Indigirka for all months. Greater drainage was seen for Mackenzie and Yukon and parts of Lena River system. With exception of Yenisei such drier situation this summer was similar for Eurasian Arctic to summer 2021 but is opposite for American sector as in summer 2021 Mackenzie and Yukon rivers experienced normal or lesser discharge

Verification of summer 2022 forecast

The JJA 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.
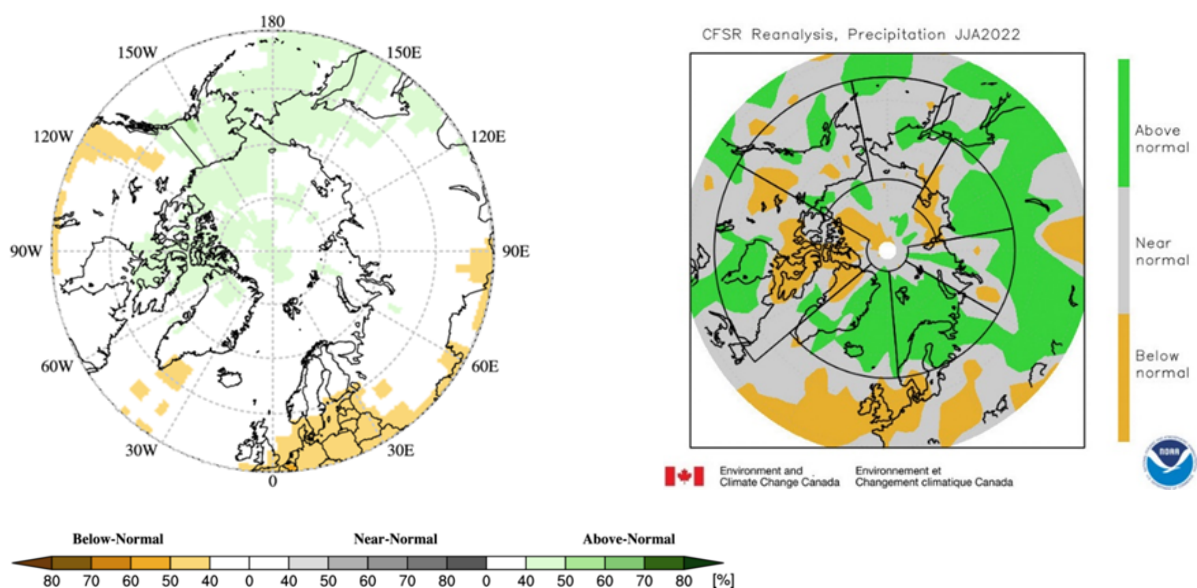

Figure 12: Left) Multi-model ensemble (MME) probability forecast for precipitation: June, July and August 2022. Three categories: below normal (brown), near normal (grey), above normal (green); no agreement amongst the models is shown in white. Source: www.wmolc.org. Right): NCAR CFSR for precipitation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

Overall, the MME forecast for JJA2022 was not decisive (white color on the Fi12 left) over most of the Arctic regions. In the regions where there was model agreement, the MME forecast did not perform very well (Table 3).

Outlook for winter 2022-23:

Over the largest part of the Arctic region, there are expectancies for an above normal precipitation for the first part of the winter NDJ 22/23. These probabilities are rather moderate (40% or more) for most of the Arctic domains with an exception of the northern, coastal, parts of the western and eastern Siberian region where we have probability expectancies of 50-60% or more.

Southern and southwestern parts of eastern and western Nordic regions, respectively, have equal chance expectancies for precipitation for the first part of this winter. Other areas, over these two domains, are expecting above normal precipitation with probabilities of 40% or more for this NDJ 22/23.

Table 3. June, July and August 2022: Regional Comparison of Observed and Forecasted Arctic Precipitation

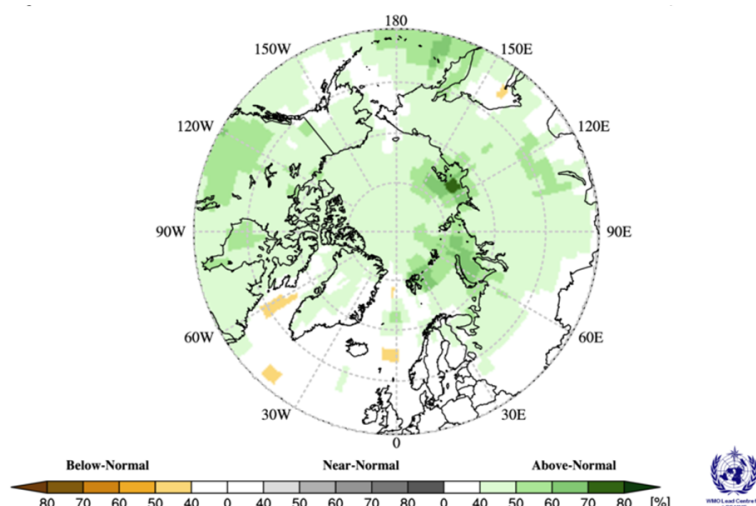| Regions (see Fig. 2)	MME Precipitation Forecast Agreement	MME Precipitation Forecast	NCAR CFSR Reanalysis (observed)	MME Precipitation Forecast Accuracy
Alaska and Western Canada	Low	Above normal mostly, below in the south	Mostly near normal	Miss
Central and Eastern Canada	Low	No model agreement mostly, above in the Canadian archipelago	Below normal in the north and west, above in the southeast	miss where forecast
Western Nordic	Low	No model agreement	Mostly above normal	No forecast
Eastern Nordic	Low	No model agreement	Mostly above normal	No forecast
Western Siberia	Low	No model agreement	Mostly near normal	No forecast
Eastern Siberia	Low	No model agreement	Above normal in the southeast, below and near normal in the north and west	No forecast
Chukchi and Bering	Low	Above normal	Mostly near normal	10% hit

Figure 13: Multi model ensemble probability forecast for precipitation for November, December and January 2022-23. Green indicates wetter conditions, orange drier conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 4. Winter (NDJ) 2022-23 Outlook: Forecasted Arctic Precipitation by Region

Region (see Fig.2)	MME Precipitation Forecast Agreement*	MME Precipitation Forecast
Alaska and Western Canada	Low-Moderate	Near to above normal
Central and Eastern Canada	Low-Moderate	Above normal
Western Nordic	**Low-Moderate**	Above normal (NE Greenland/Svalbard)
Eastern Nordic	**Low-Moderate**	Above normal
Western Siberia	**Low-Moderate**	Above normal
Eastern Siberia	Low-Moderate	Above normal
Chukchi and Bering	Low	Above normal (land areas)
Central Arctic	Moderate-high	Above normal

*: See non-technical regional summaries for greater detail

SNOW WATER EQUIVALENT (experimental product)

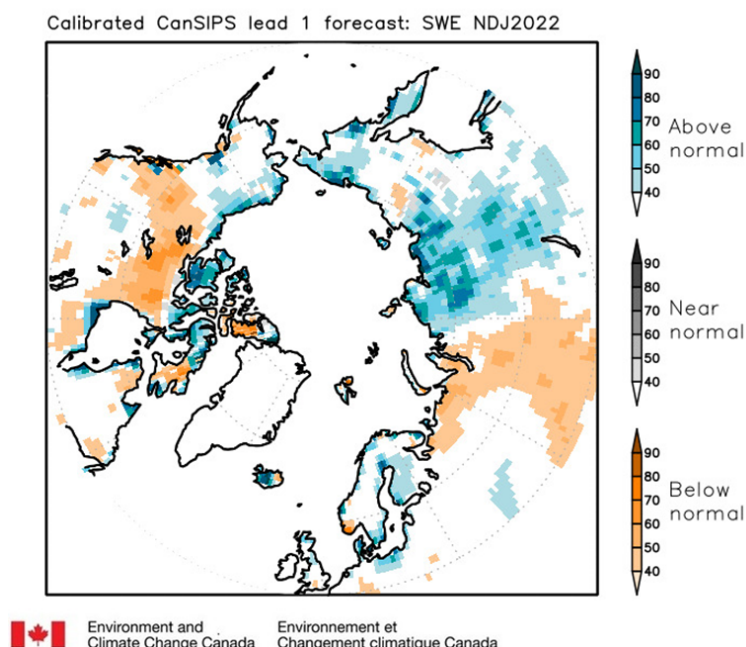***Outlook for winter 2022-2023:***

Figure 14: Canadian Seasonal to Interannual Prediction system probability forecast for snow water equivalent for November, December and January 2022-23.

SWE calibrated probabilistic seasonal forecast is performed with Canadian Seasonal to Interannual Prediction System (CanSIPS). Over the Alaskan and western Canada region there is probability of 50% or more for an above average SWE in the northern coastal region. Over the southern and eastern parts of this domain below normal SWE expectances are forecasted with at least 40% probability.

Over the northern continental Canadian Arctic, we have expectancies for below normal snowfall this winter (at least 40-50% probability). Canadian Archipelago is expecting above normal snow with an exception of southern parts of Baffin and Victoria islands expecting below normal SWE.

Central part of the western Nordic region (Island) is expecting above normal SWE in the west (50% or more) while below normal expectances are forecasted over the eastern parts of the island. Western Siberian region is expecting below normal snow amounts this winter in the western and central parts (40% or more), while above normal SWE is forecasted over the eastern parts of the region. Eastern Siberian region also has above normal (>50%) SWE expectancies in all parts of the region with the central and northern parts having the highest probabilities of at least 60% and higher. Coastal zones of the Chukchi and Bering region have above normal SWE expectations for this summer (40-50% or more) while the MME is not decisive in the region's central and eastern portions.

Table 5. Winter (NDJ) 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	Low	Near to above normal: Alaska/Western Canada Below normal: Eastern Canada
Central and Eastern Canada	Moderate	Above normal: northern Nunavut Below normal: southern Nunavut
Western Nordic	No model agreement	
Eastern Nordic	No model agreement	
Western Siberia	Low-Moderate	Below normal: west/central regions Above normal: east of western Siberia
Eastern Siberia	High	Above normal
Chukchi and Bering	Moderate	Above normal

*: See non-technical regional summaries for greater detail

POLAR OCEAN

Summary for May – September 2022 (see technical summary for greater details):

During May – September 2022 prominent lower Heat Content (HC) (ref. 1993-2020) was observed for the Greenland waters, Northern Laptev, Chukchi, Eastern Bering and Okhotsk Seas with higher HC for the Barents, Kara, Southern Laptev Seas, Svalbard and Franz-Josef Land waters (figure 15, information for May and September 2022 not shown here).

Due to lesser ice extent, areas of the Chukchi, Bering Seas, other parts of Eurasian shelf seas and Canadian Arctic were exposed to higher than in past stormy conditions with calmer conditions in parts of the Nordic regions (not shown here).

Numerical models showed for the past summer season both positive pH anomalies (Arctic Basin, Laptev Sea, coastal parts of Kara Sea, Chukchi, Hudson Bay) and negative pH (Kara, Eastern Siberia, Greenland Seas) anomalies (ref. 1993-2020) which was in general similar to previous summer 2021 (figure 15, information for May and September 2022 not shown here). The negative anomalies may point to acidification processes though to verify such fact we need direct measurements, e.g., through additional sensors on IABP buoys or with AMAP data.
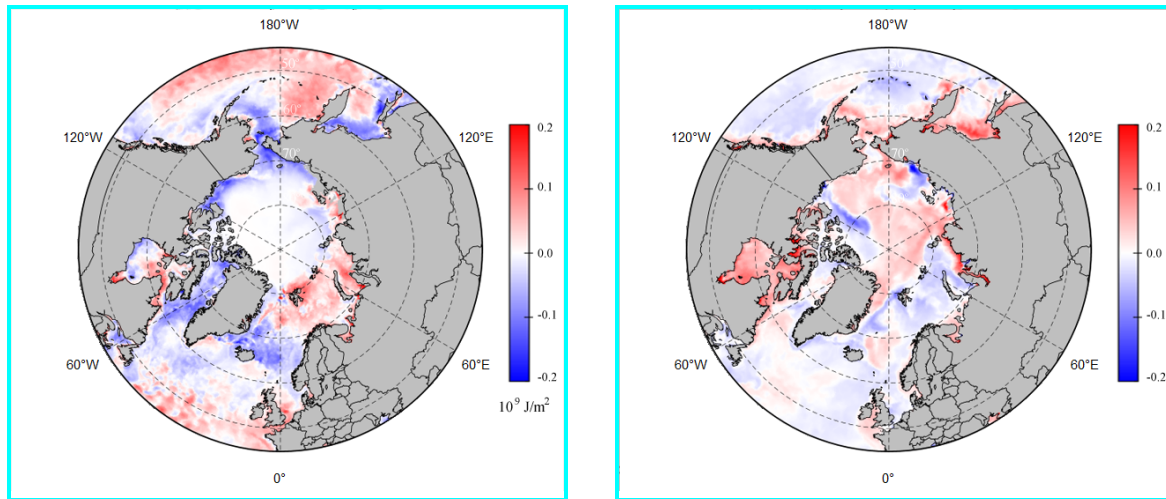
Figure 15: JJA 2022 upper 15 m ocean layer Heat Content (left) and upper 2m ocean pH (right) anomalies (ref. 1993-2020 period). Maps produced by the AARI. Data source: CCCS MEMS.

Sea-Surface Temperature Outlook for winter 2022-23 *(experimental product):*

Over the largest portion of the Arctic seas, the multi-model ensemble approach is forecasting above normal SST's. The highest probabilities for an above normal SST's are forecasted for Barents and Kara Seas with probabilities of more than 70%. East Siberian and southern parts of the Beaufort Sea are expecting near normal SST conditions for the first part of the winter. Similar result is expected for the central and northern Chukchi Sea while the southern portions of this basin is expecting to have above normal SST with a probability of at least 40%. Above normal SST forecasts are ranging from 50-60% probability in the Laptev Sea region.

Hudson Bay is expecting higher probabilities for an above normal SST's with values higher than 70%. Similar, above normal, probabilities are expected in Canadian Archipelago while, in Baffin Bay, MME is forecasting near normal SST in the north and below normal SST in the southern parts with approximately 40% expectancies.
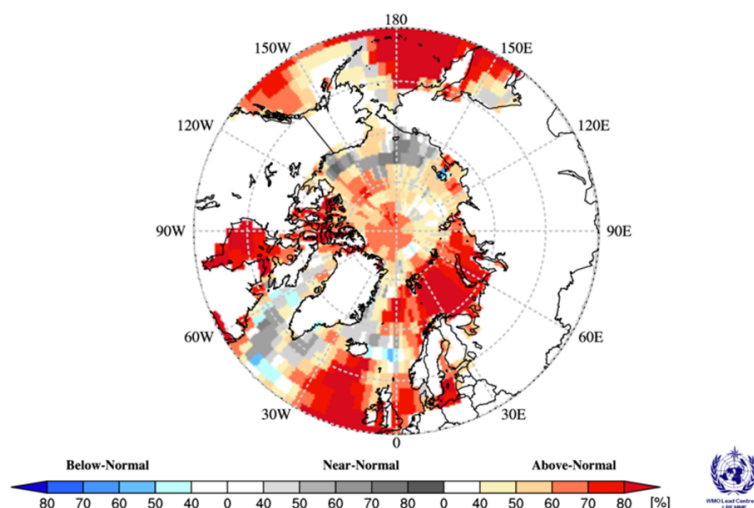

Figure 16: Multi model ensemble probability forecast for sea-surface temperature for November, December and January 2022-23. Red indicates warmer conditions, blue colder conditions and white, no agreement amongst the models. Source: www.wmolc.org

Table 6. Winter (NDJ) 2022-23 Outlook: Regional Forecasts for Arctic Sea-surface Temperatures

Region (see Figure 2)	MME Temperature Forecast Agreement*	MME Temperature Forecast
Baffin Bay	Low	Variable
Barents Sea	High	Above normal
Beaufort Sea	Low	Near to above normal
Bering Sea	Low-Moderate	Above normal; no model agreement near Aleutian Islands
Canadian Archipelago	High	Above normal
Chukchi Sea	Low	Near-above normal
East Siberian Sea	Low	Near normal
Greenland Sea	Low	Near-above normal
Hudson Bay	High	Above normal
Kara Sea	Moderate-High	Above normal
Laptev Sea	Low-Moderate	Above normal
Sea of Okhotsk	High	Near (north) to above normal

*: See non-technical regional summaries for greater detail

SEA ICE

Summary for May – September 2022 (see technical summary for greater details):

Negative and close to normal ocean heat capacity (HC) anomaly (to 1993-2020 and more important - to 2020, not shown here) in upper 15m layer during June 2022 for most of the Arctic slowed ice melt in these regions which is similar to 2021, with exceptions in the Barents and North-Eastern parts of the Kara Seas. Further in season, dominance of positive surface air temperature anomalies over Western Eurasian Arctic, Laptev Sea, Hudson Bay and Canadian Archipelago (figure 6) stimulated ice melt, however, opposite negative or zero anomalies preserved ice cover in parts of Eastern Siberia and Beaufort Seas. Resulting ice conditions in September 2022 resembled the previous year situation including the minimum ice extent which is again strongly opposite to 2019 and 2020.
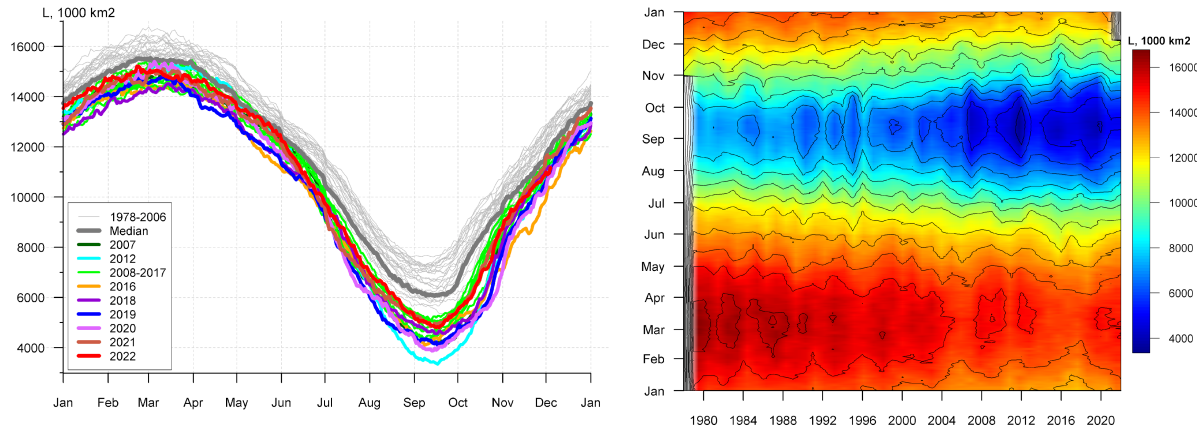
Figure 17: Arctic (Northern Hemisphere) daily (left) and daily seasonal (right) ice extent for 1978- 2022. Graphics produced by the AARI. Data source: NSIDC.

During melt period most of the Arctic Seas experienced ice extent decline at top of the last 10-15 years but below the 40 years median (figure 17 left). The Sea of Okhotsk in addition to very mild winter ice conditions, experienced very quick decline of ice cover by May 2022. Seasonal pattern of daily ice extent (figure 17 right) allows to retrieve additional information on interseasonal variability of ice extent. Though both winter maximums and summer minimums continue to diminish, special features retrieved from the pattern proved the assumption made at ACF9 that summer ice cover in 2022 will be greater or similar to 2021.

Minimum summer ice extent, 12th in row or close to 4.8 mln km^2, reached on 17-18 September 2022 (precise values of the minimum ice extent and its date slightly vary across the ice services and centers following total concentration threshold and data source used) which is just slightly less than that for 2021 (13th in row, reached 12 September 2021) and by 0.9 mln km^2 greater than the 2020 summer minimum. This summer 12th in row minimum somewhat correlates with the similar winter 12th in row maximum.
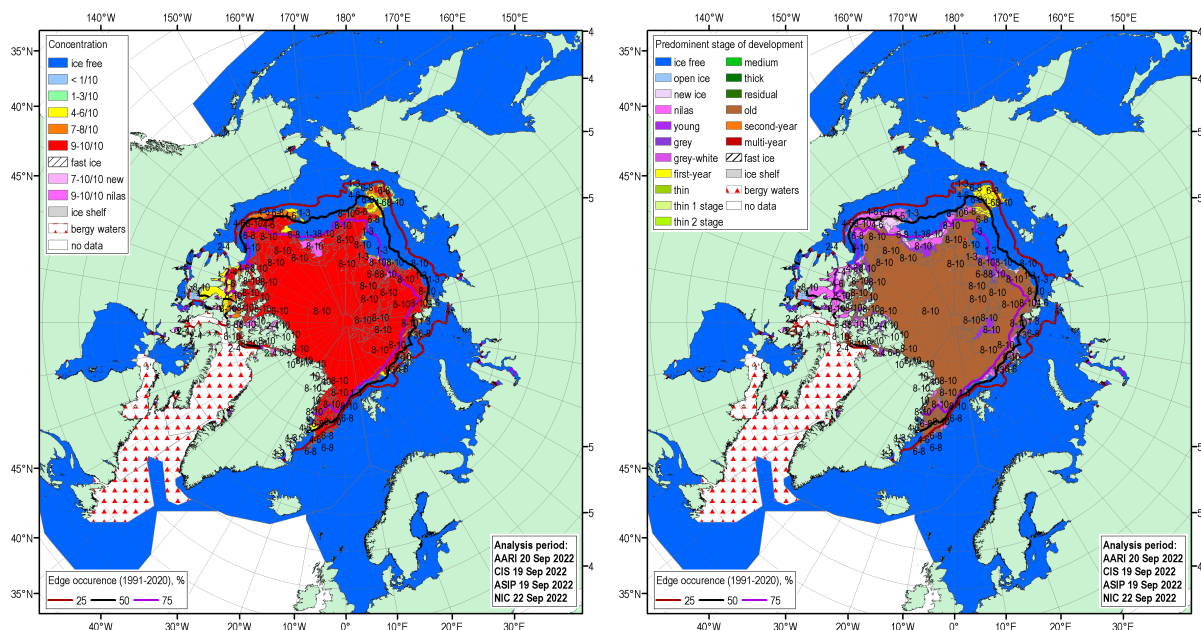

Figure 18: Blended Arctic sea-ice chart (AARI, CIS, NIC, NOAA ASIP) for 19-22 September 2022 and sea-ice edge occurrences for 15-20 September (ref. 1991-2020). Left: total concentration, right: predominant stage of development. Graphics produced by the AARI.

19

The general ice conditions observed in September 2022 (figure 18), are very similar to that for 2021 and for second time in row significantly differ from 2019 or 2020. While Eurasian Barents, Kara (that is opposite to 2021) shelf seas were completely ice free with the ice edge significantly northward of Svalbard, the ice conditions in parts of the Laptev, Eastern Siberia, Beaufort Seas were close to 40 years normal with both the North-West Passage and the Northern Sea Route formally remaining blocked in the transit straits which is again opposite to last pentade. Area and thickness of both residual and second year ice in September this year for the Arctic Basin was similar as in 2021 as recorded during summer cruise by the AARI research vessel "Akademik Treoshnikov".

Estimate of the total Arctic ice volume in September 2022, based on numerical modelling (DMI, see polarportal.dk) is close to the 3rd - 4th lowest (ref. 2004-2022) after 2019-2021 (not shown here).

Sea-Ice Outlook verification for September 2022 ice extent:

The forecast for the September 2022 Sea ice extent was based on output from CanSIPSv2, an MME of two climate models, and verified poorly (right column, Table 7). Near normal ice extent was correctly forecasted for the Beaufort Sea and below normal was appropriately forecasted for the Canadian Arctic Archipelago. The model did not forecast the below normal ice extent in the Chukchi and East Siberian seas, the near normal ice cover in the Barents Sea, nor the above normal extent for the Greenland, Kara or Laptev seas.

Outlook for Winter Freeze-up 2022-23

Sea ice freeze-up is defined as the first day in a 10-day interval where ice concentration rises above 50% in a region. The outlook for winter freeze-up shown in Figure 19 displays the sea ice freeze-up anomaly from CanSIPSv2 based on the nine-year climatological period from 2013-2021. 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 2022-23 winter freeze-up for the different Arctic regions are shown in Table 8.

Table 7. Summary 2022: Regional Comparison of Observed and Forecasted Minimum 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	Below normal	Near normal	Miss
Beaufort Sea	High	Near normal	Near normal	Hit
Greenland Sea	High	Near normal	Above normal	Miss
Canadian Arctic Archipelago	Moderate	Below normal	Below normal	Hit
Chukchi Sea	High	Near normal	Below normal	Miss
East Siberian Sea	Moderate	Near normal	Below normal	Miss
Kara Sea	High	Below normal	Above normal	Miss

Laptev Sea	High	Below normal	Above normal	Miss

A later than normal freeze-up (red areas, Figure 19; Table 8) is forecasted for the Beaufort, Kara and Laptev Seas. A near normal freeze-up is forecast for the Chukchi, Barents, Bering, and Greenland seas, in addition to the Sea of Okhotsk and Hudson Bay. An earlier than normal freeze-up is forecast for the Labrador and East Siberian seas, and in Baffin Bay.
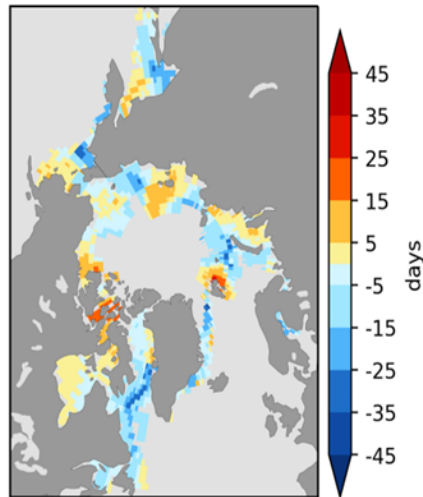

Figure 19: Forecast for the 2022-23 winter freeze-up expressed as an anomaly (difference from normal) where freeze-up is defined as the first day in a 10-day interval where ice concentration rises above 50%. Source: CanSIPSv2 (ECCC).
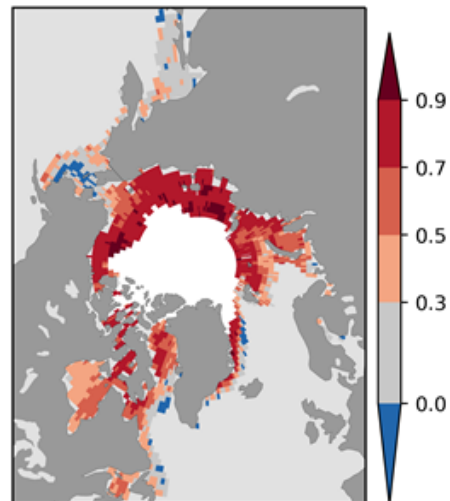
Figure 20: Historical forecast skill defined as the detrended anomaly correlation coefficient based on the 1990-2020 period. Source: CanSIPSv2 (ECCC).

Table 8: Winter 2022-23 Regional Outlook for Arctic Sea Ice Freeze-up

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

Sea of Okhotsk	Low	Near normal

Outlook for March 2023 Maximum Sea Ice Extent

Maximum sea ice extent is achieved each year during the month of March 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 March 2023 maximum sea ice extent is presented on figure 20a, the March 2023 ice concentration anomaly from 2013-2021 is shown on figure 20b and the forecast skill is shown as figure 20c.
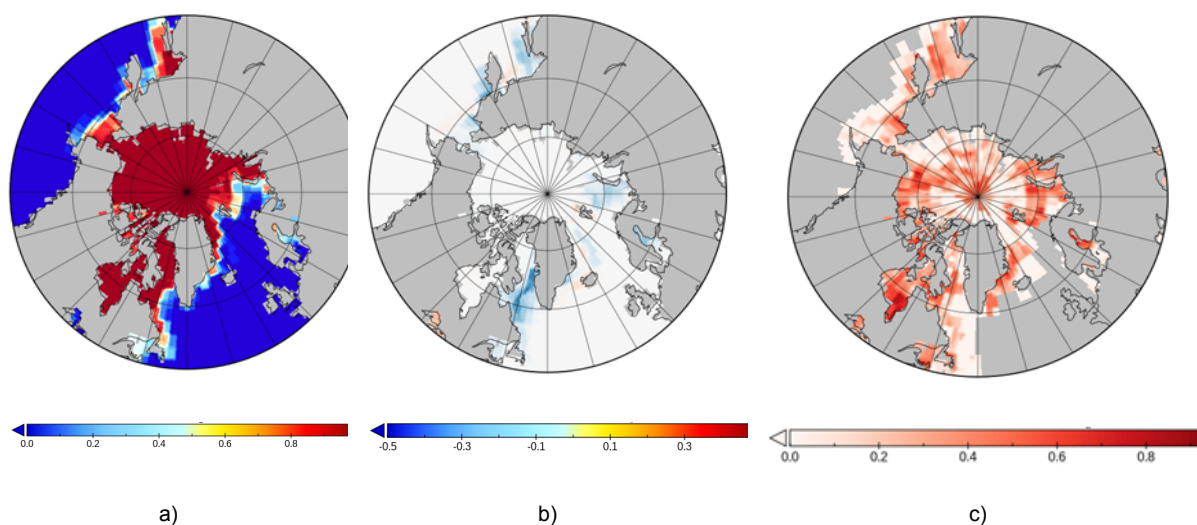

a)   b)   c)

Figure 20 (a) March 2023 ice concentration; (b) March 2023 ice concentration anomaly based on the 2013-2021 period and (c) Historical skill 2000-2020 measured by the anomaly correlation coefficient. Source: CanSIPSv2 (ECCC).

Below normal ice extent in March 2023 is forecast for the Greenland and Barents seas, above normal for the Labrador Sea, and near normal ice cover for the Sea of Okhotsk, Bering Sea, and Northern Baltic Sea (Table 9).

Table 9: **Winter 2023 Regional Outlook for Maximum Sea-Ice Extent**

Regions (see Figure 2)	CanSIPSv2 Sea-Ice Extent Forecast Confidence	CanSIPSv2 Sea-Ice extentForecast
Barents Sea	High	Below normal
Bering Sea	Low	Near normal
Northern Baltic Sea	High	Near normal
Greenland Sea	High	Below normal
Labrador Sea	Low	Above normal
Sea of Okhotsk	Moderate	Near normal

BIOCLIMATIC INDEXES *(see technical summary for greater details and definitions of the indexes):*
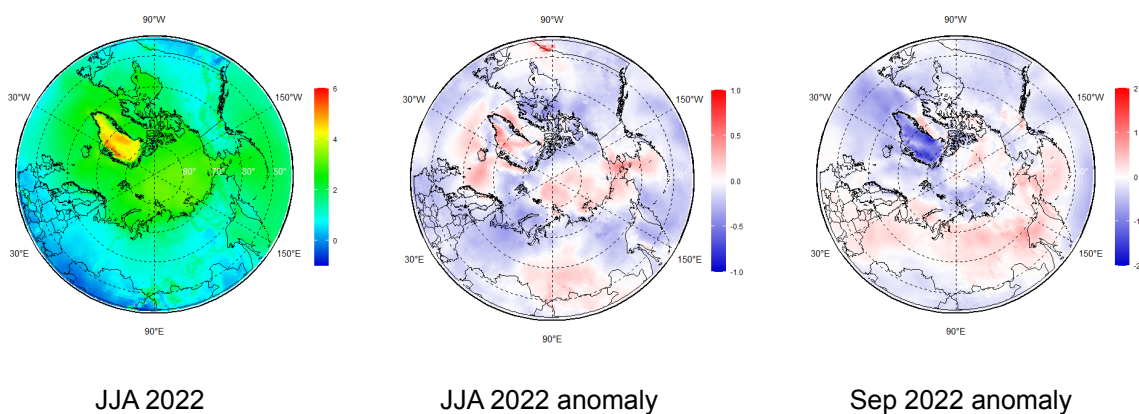
Summary for May – September 2022:

Bioclimatic indexes are used to assess the general weather severity or general impact of the weather either to humans or specific human activity by combining particular environmental parameters. The most widely indexes include the Bodman's index of weather severity combining surface air temperature and wind speed extremes and the Effective Temperature (ET) combining surface air temperature and relative humidity. The scale in use to assess the weather severity using S is > 6 as extraordinary severe, 5– 6 as extremely severe, 3– 5 as severe & very severe, 1– 3 as slightly or less severe and finally < 1 as mild. The ET scale in use includes extremely discomfort, discomfort, relatively discomfort, relatively comfort and comfort.

In summer 2022 the Bodman's index of weather severity (figure 21) had rather small positive anomalies in Western Siberia, in the eastern seas of the Northern Sea route, in the Norwegian Sea and in South Eastern Greenland, but mainly the S had the negative anomalies, which means that the conditions were mainly milder than average (ref. 1991-2020). In September 2022 the Eurasia had positive anomalies, which means more severe conditions than average, especially in the Eastern Siberia. In Greenland there was a strong negative anomaly (milder conditions).

Monthly ET values (figure 21) show that during May – September 2022 (June, August are not shown) the relative comfort zone prevailed in the Arctic region with the comfort zone appearing only in JJA 2022 with the biggest area in July.

Bodman's index (*S*) of weather severity

| JJA 2022 | JJA 2022 anomaly | Sep 2022 anomaly |

Effective temperature *ET*

| May 2022 | July 2022 | September 2022 |

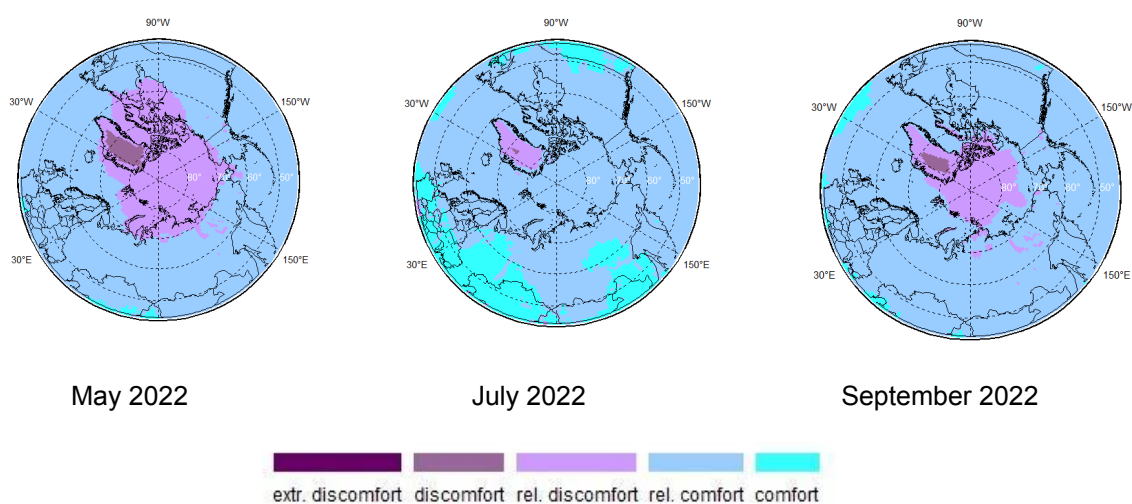extr. discomfort discomfort rel. discomfort rel. comfort comfort

Figure 21: Bodman's index of weather severity in JJA 2022, its anomaly in JJA and September 2022 and Effective Temperature in May, July and September 2022. Maps produced by the AARI. Data source: CCCS ERA5.
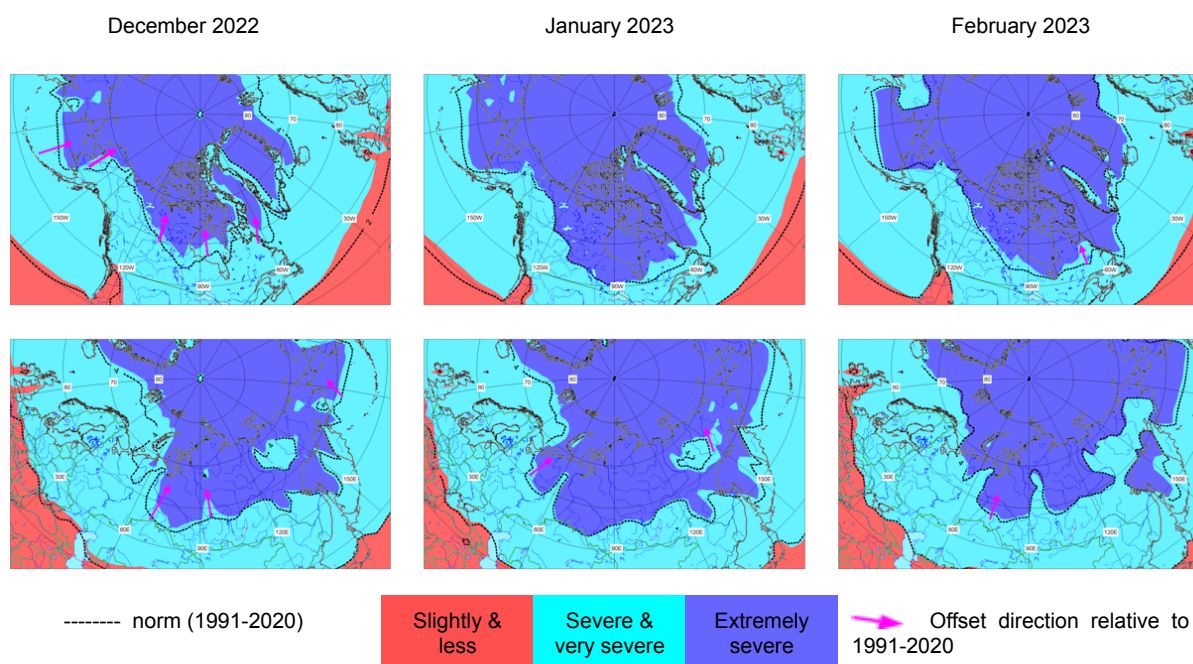
utlook for DJF 2022/2023 (experimental)

December 2022	January 2023	February 2023

-------- norm (1991-2020)	Slightly & less	Severe & very severe	Extremely severe	→ Offset direction relative to 1991-2020

Figure 22: Bodman's index of weather severity forecast for December – February 2022/2023. Maps produced by the Hydrometcenter Russia. Data source: Institute of Numerical Mathematics Russian Academy of Science.

Test seasonal forecast (ONDJFM 2022/2023) of the model of the Institute of Numerical Mathematics Russian Academy of Science were used to calculate the Bodman's weather severity indexes values for winter 2022/2023 and hindcasts 1991-2020 for the norms. The forecast (figure 22) shows expansion of the severe & very severe and extremely severe zones from December 2022 to February 2023 with the harshest both for the Eurasian and American sectors in January 2023.

MAJOR CLIMATE RELATED RISKS AND IMPACTS

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

Alaska and Western Canada

Past season
- Widespread dry spring conditions from June through early July for Alaska and the Yukon Territory, causing widespread drought conditions in the early summer. There was a dramatic change to above normal precipitation from July through September for southern Alaska and parts of the Yukon Territory. Heavy rains adversely impacted agriculture in South and Central Alaska.
- In June, river flooding in the Yukon Territory due to high snowpack melt caused road washouts and landslides.
- Record deep cyclones in the Bering Sea during mid-September and in the Chukchi Sea in early October produced widespread coastal flooding. Some Alaska coastal communities were very severely impacted, including loss of community and subsistence infrastructure, utilities and fuel.
- Alaska experienced the 7th highest area burned since 1950, with unprecedented wildfires in southwest Alaska. In the Northwest Territory, the wildfire season continued into October.

Coming season and ongoing impacts of climate change
- 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
- Exceptional high temperatures recorded in Greenland (more than 8°C above the monthly mean in some regions) in September 2022 leading to surface melting.
- Record high June-July-August average temperatures were registered in Ny-Ålesund (+6.1 °C) and Longyearbyen (+ 7.4 °C) in Svalbard. The values were 1.7 °C and 1.9 °C above the 1991-2020 climatology, respectively.
- The northernmost county in Norway, Troms and Finnmark was 1-3 °C above 1991-2020 climatology during June-July-August.
- Exceptionally strong heatwave in mid-August in Finland (for example 31.7° C in Pori on 16 August which is the highest temperature recorded in Finland so far in summer).
- Record-dry June-July and the 2nd driest June-August period in Åland, Finland.
- The wettest summer on record locally in the South Ostrobothnia region (for example in Seinäjoki city).
- The area covered by sea ice in the Barents Sea was extremely low in summer 2022.
- Overall, Spring 2022 was relatively dry in Sweden.
- Sweden was warmer for June and August, and colder in September compared to the reference period. In parts of southern Sweden, it was a very dry summer.
- Record high temperature (37.2°) measured in Målilla (southern Sweden) on 21 July which is the highest temperature in Sweden since June 1947.
- October 2022 was overall warmer than normal in Sweden,and in some regions the monthly mean temperature was up to 2.5 degrees warmer than the 1991-2020 reference period.

Coming season and ongoing impacts on climate change
- For December-January-February 2022 - 2023, bioclimatic indexes (Bodman's weather severity index) indicate severe to very severe weather conditions (uncomfortable working conditions) in Scandinavia, and extremely severe weather conditions (extremely uncomfortable working conditions) over most of Greenland.

Western Siberia

Past season

- In June 2022 two heat waves with a duration of 6 and 7 days with an average daily air temperature above the norm by 10-17°C were observed in the Yamalo-Nenets District;
- A state of emergency was declared in the Nenets District in August – due to abnormally hot weather, the Pechora River became shallow, the ferry service with the Komi Republic or the main land way to get to the "mainland" was stopped. Since it was a holiday period, hundreds of people who traveled by car could not get home.
- In the end of August and September a cold wave (11 days) occurred in the northern part of the Western Siberia. In Salekhard a new absolute minimum temperature record for September was set: -10.0°C (previous -8.0°C in 1940). As a result, the heating season began on September 1 (earlier than normal).

Coming season and ongoing impacts of climate change

- Temperatures and precipitation forecast above normal indicates high cyclonic activity, which is also associated with the frequency of blizzards and fogs. Such conditions may affect the operation of airports in remote areas.
- Precipitation above normal impacts transition of reindeer to winter pastures in December - a large amount of precipitation at this time can form high snowdrifts which will complicate access to feed and movement for both animals and people.
- Temperature above normal means warm weather at the end of winter and beginning of spring which can cause an earlier opening of rivers from ice - thus, reindeer herders may have to move the reindeer to summer pastures earlier.

Eastern Siberia

Past season
- Two heat waves were observed in June in the north-eastern of Sakha-Yakutia (7 and 5 days with an average daily air temperature above the norm by 7-8 °, in the town of Oymyakon (the cold pole of the northern hemisphere), the surface air temperature reached +32.9°C. Hot and dry weather in May and June 2022 led to forest fires, but their area for the entire fire hazard for this the period was by 43 times less than in 2021.
- Due to prolonged rains from 7 to 14 July 2022, the Yana River overflowed and broke through the dam, as a result, the town of Verkhoyansk was flooded. 54 personal plots were flooded. Local residents were evacuated to temporary accommodation centers. 10 adults and 7 children were taken to hospitals.
- Due to the warm weather, the ice drift on the northern rivers was very active in May-June 2022. On the Yenisei River near the port of Dudinka, blocks of ice came ashore and cut off power lines. The river started to break-up only 3 days later than the absolute record set on May 21, 1997.

Coming season and ongoing impacts of climate change
- Near normal ice extent means close to average navigation conditions in the Laptev and Eastern Siberian Seas during the coming winter
- Temperatures and precipitation above normal means warm and humid weather which often causes influenza, SARS, and pneumonia and further means a pressure on medical services that need to travel to remote areas in severe cases.

<u>Chukchi and Bering</u>

Past season
- Higher precipitation was associated with a high frequency of cyclones accompanied by gusty winds and rising waves. In the port of Anadyr for JJA precipitation was by 30% above normal, the number of days with precipitation was 48 (climate - 19). During the summer season, the port was repeatedly closed due to weather conditions, as was the local airport.
- Passenger navigation in the port of Anadyr began at the usual time (June 13) but ended earlier than usual and earlier than in 2021. Due to intense ice formation in the Anadyr Estuary, **ice** navigation began earlier than normal (October 19);
- Due to early break-up earlier start of navigation in the port of Okhotsk was observed: May 4th (in 2021 - June 1st).
-

Coming season and ongoing impacts of climate change
- Earlier than normal freeze-up and normal March 2022 sea-ice extent would increase risks of winter navigation in comparison to 2021.
- Earlier start of winter will favor under-ice fishing for local residents

<u>Central Arctic</u>

Past and coming seasons
- No significant extremes and risks associated atmosphere parameters and sea ice

Background and Contributing institutions

These Arctic seasonal climate summary and outlook were prepared for ACF-10. 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-fall-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