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**ARCTIC
SUMMER 2024 CONFIRMS
SEA ICE RETREAT**

NOVEMBER 2024

POLAR WATCH

Polar regions monitoring and forecasting



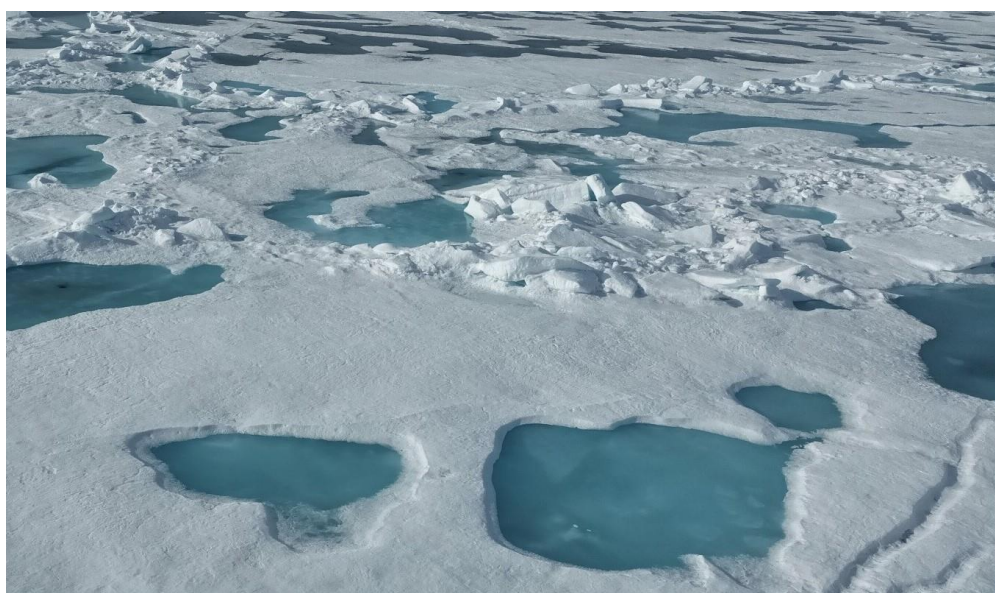
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New record for minimum sea ice extent at the end of summer

The summer 2024 confirmed the multi-decadal trend in sea ice retreat, including the Central Arctic Ocean.

Although not a remarkable record in terms of inter-annual anomalies in Arctic sea ice extent, the summer of 2024 confirms the now well established multi-decadal trend of Arctic sea ice cover decreasing in extent and volume, and becoming less compact in virtually all geographical areas, including the central Arctic Ocean. This new normal for the Arctic is the result of a warmer climate, the effects of which have been unambiguously felt over the last few decades, and in which the pack ice cover is becoming more vulnerable to the inter-annual variations still present in atmospheric and oceanic conditions.



Visual aspect of the ice pack at the geographic North Pole on July 30, 2024. A highly fragmented ice pack littered with pools of melting ice. *Credit : Le Cercle Polaire.*

"At 4.28 million de km², the minimum sea ice extent of summer 2024 is the 7th least ice-covered annual minimum since 1979."

The extent of the Arctic pack ice reached its annual minimum on September 11, a relatively early minimum even if the exact date remains uncertain due to the lack of data for the days that followed. With a pack ice extent of 4.28 million km² (Fig. 1), this was the seventh-lowest annual minimum since satellite observations of Arctic pack ice began in 1979. However, it does not surpass the record annual minima of 2012 and 2020, when the pack ice cover shrank to an average area of less than 4 million km² in September.

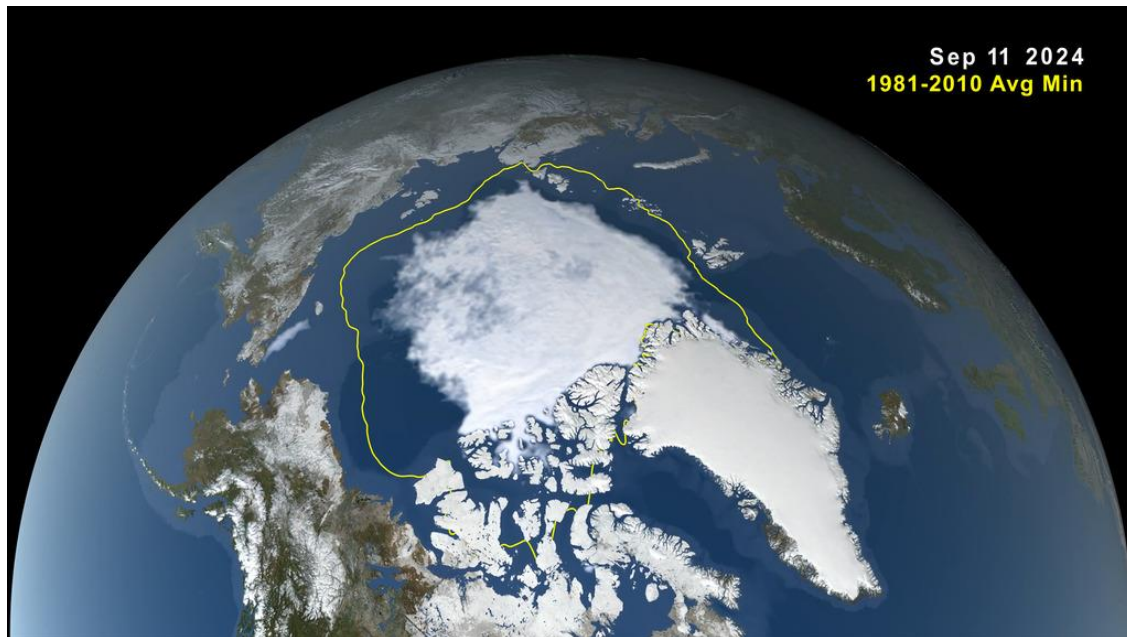


Fig. 1: Extent of Arctic sea ice on September 11, 2024, superimposed on the climatological average over the 1981-2010 period (yellow outline). *Source : NSIDC/NASA Earth Observatory*

However, mid-summer conditions this year suggested a new record: from the last week of July to the end of August, the extent of the Arctic ice pack was well below that of recent years over the same period, even closely following the trend observed in 2012 until the beginning of August. However, this rapid decline slowed at the beginning of September, and was followed by a slow recovery in ice from mid-September onwards.

The year 2024 confirms the observation now made every year: since 2007, the monthly extent of pack ice in September has, without exception, been among the lowest recorded in the 46 years of satellite observation (Fig. 2). September 2024, with an average pack ice extent of 4.38 million km², ranks sixth in the list of least icy Septembers. The persistence of low September values for almost two decades contributes to maintaining a relatively high multiannual rate of decrease in September extent, between -12 and -14%¹ per

¹ Note that these rates are related to a reference value, the climatological average, calculated as the average over the period 1981-2010. This is the average extent of the ice sheet for September.

decade since 1979, depending on the year in which it is estimated, with the exception of the record rate of -14.3% estimated in 2012, reflecting the abrupt decrease in ice extent that year (Fig. 2a). In 2024, this rate is now estimated at -12.13% per decade, corresponding to an average loss of 78,000 km² of pack ice per year, or almost 3 times the surface area of Brittany. However, this vision of a monotonous decline in sea-ice extent over recent decades is largely idealized. The year 2007 brought radical changes, not only in the extent but also in the nature of the Arctic ice pack, changes from which it has not recovered since.

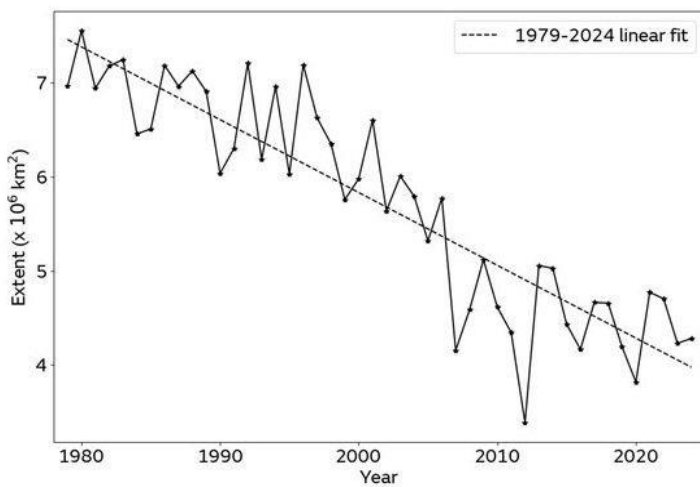


Fig. 2a: Average extent of Arctic sea ice in September over the period 1979-2024. The dotted line represents the linear fit of the extent evolution over this period, equivalent to a trend of -12.13% per decade. Source: Met Office/NSIDC Sea Ice Index

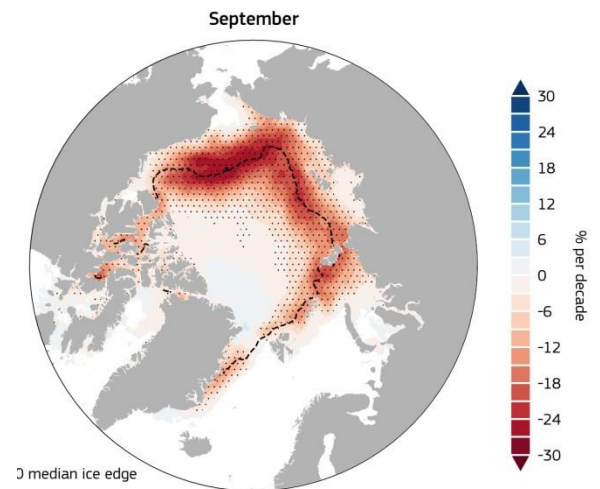


Fig. 2b: Trend in Arctic Sea Ice concentration in September over the period 1979-2023. The dotted line delimits the area where this trend is significant. Source : C3S/ECMWF/EUMETSAT

The spectacular reduction in sea ice extent in summer 2007 corresponded to the massive evacuation of multi-year ice² from the western Arctic basin towards the Greenland Sea. An anomalous atmospheric circulation created by higher atmospheric pressures over Greenland and the Beaufort Sea and lower pressures over the Eurasian coasts had pushed the ice accumulated on the North Canadian and North Greenland coasts towards its main outlet, the Fram Strait located between Greenland and the Svalbard archipelago. This loss of multi-year ice was never compensated for by the ageing of an equivalent quantity of younger ice, which would have remained in the Arctic basin. On the contrary, the progressive thinning of first-year ice, linked to Arctic warming, made it more vulnerable

² Multi-year ice is ice that is more than one year old. The Arctic multi-year ice reservoir is replenished each year at the end of summer by first-year ice that has survived the summer melt.

to atmospheric action: shorter growth period, faster melting, accelerated drift and deformation, less compact pack ice - all these factors worked to prevent the reconstitution of older ice in the years that followed.

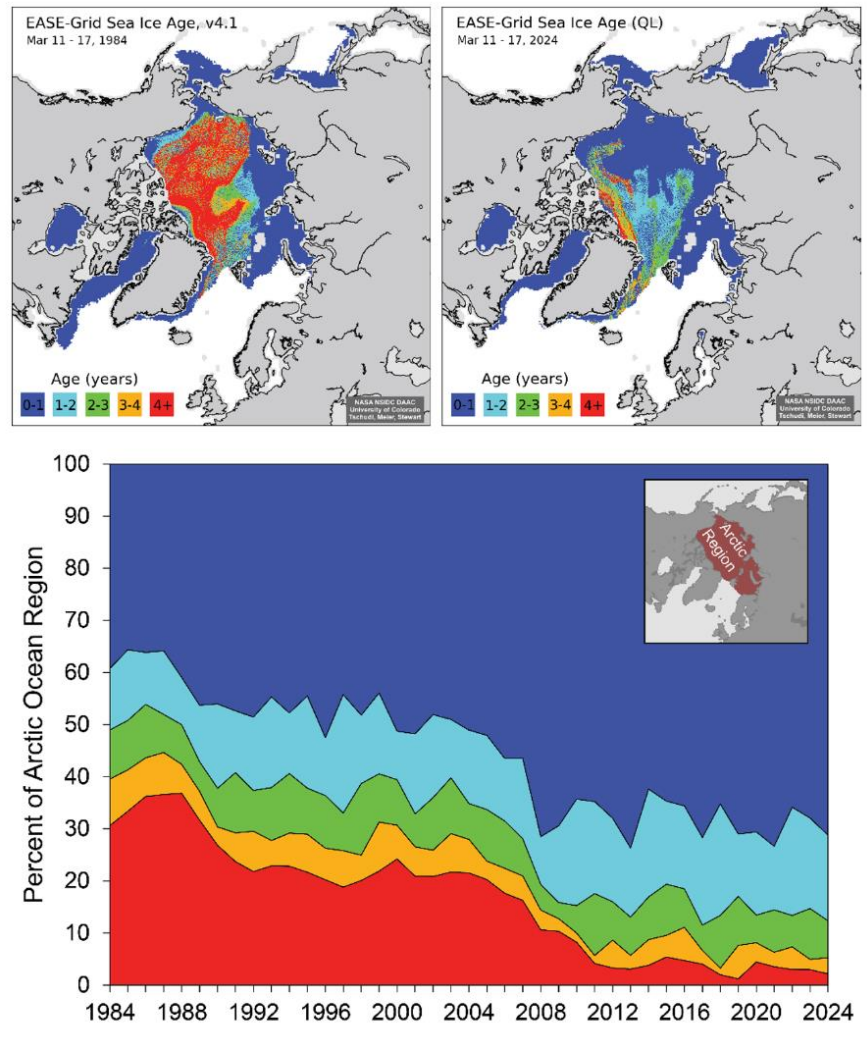


Fig. 3: Evolution of Arctic sea ice age classes over the period 1984-2024 : spatial distribution in the months of March 1984 and March 2024 (top) ; proportion of area occupied as a function of year, for different age classes (bottom). *Source: NSIDC EASE-Grid Sea Ice Age (Tschudi et al. 2019b).*

In the mid-1980s, multi-year ice occupied over 60% of the Arctic Ocean's surface, whereas over the past decade its contribution has fallen to less than 30%, with the winter of 2024 confirming a decrease in second-year ice compared with 2023 (Fig. 3). While the summer of 2007 marked the start of a sharp decline in the proportion of multi-year ice in the Arctic, 2012 saw a spectacular melting of multi-year ice, particularly in the Beaufort Sea. The year 2012 saw the almost total disappearance of the oldest of these ice sheets, those aged 5 years or more.

The changing nature of sea ice cover, marked in particular by the massive reduction in multi-year ice in the Amerasian Basin, has had repercussions throughout the Arctic Ocean, including in the central region where pack ice was previously relatively preserved. Ice concentration, once thought to be close to 100% in this year-round region, has largely decreased in places, the ice has become thinner and the melt season has lengthened by several days due to earlier melt initiation and later ice recovery. In August and September 2024, as in most recent years, ice concentrations in the central Arctic Ocean were everywhere below the monthly climatological mean, and the negative trends in these concentrations, assessed over the satellite period, are now significant over a large part of this region (Fig. 2b). These upheavals point to a possible increase in human activity in the central region³ of the Arctic Ocean.

"The ice concentration in the central Arctic Ocean region, once thought to be close to 100%, has fallen significantly in many areas."

At the same time as the central Arctic Ocean seems to be becoming more accessible, navigability conditions in the passages of the North Canadian Archipelago remain uncertain (Fig. 4). Freeze-up in these passages is influenced by the flow of ice from the Arctic Ocean, which originates along the northern coasts of the Queen Elizabeth Islands and Greenland, where the thickest and most compact multi-year ice is now confined. This flow is vulnerable to the atmospheric conditions that govern the eventual drift of this ice towards the passages. The summer of 2024 was remarkable in this respect: while, as is the case almost every year, the “northern route”⁴ immediately south of the Queen Elizabeth Archipelago remained partially blocked by ice until mid-September, a reversal of the prevailing winds at that date halted the southward drift of the ice while bringing in warm air, thus maintaining exceptionally low freeze-up in this passage. On October 1, 2024, the “northern route” was ice-free, setting a record for the last 50 years and dethroning the record set in 2011.

³ As seen last summer when the conventional tourist icebreaker “Commandant Charcot” used the North Pole route (or transpolar route) to reach the Atlantic from the Pacific.

⁴ The route through Parry Channel into the Arctic Ocean at M'Clure Strait.



Fig. 4: Ice concentration of the various Northwest Passage routes on July 13, 2024. *Source : NASA Earth Observatory/Lindsay Doermann.*

Low freeze-up does not mean improved seaworthiness; the latter depends on the level of risk involved, and in particular on the probability of drifting ice on the ship's route. Since 2007, the Canadian Northern Passages, like the rest of the Arctic, have seen their multi-year ice cover diminish, largely due to the prevented ageing of first-year ice. This weaker freeze-up has made it possible to establish a multi-year ice flow in the previously blocked passages of the Queen Elizabeth Archipelago, at the cost of a weaker, but also more intermittent and less predictable, ice flow than in the passages further west. As long as a flow of drifting multi-year ice from the Arctic Ocean continues to feed the passages of the North Canadian Archipelago, the navigational risk on these shipping routes will remain high, despite the fact that freeze-up is slowing down as a result of global warming (-33% compared with the climatological average for multi-year ice area over the period 2007-2020).

Producing reliable projections of Arctic freeze-up remains an essential challenge for anticipating future accessibility. The first-order metric for measuring this is pack ice extent. However, the evidence of a persistent downward trend over the last 40 years does not allow us to predict what will happen to the ice pack in the years or decades to come. The linear - i.e. constant over time - rate of decline in sea-ice extent (Fig. 2a) is an

idealization, and in reality varies according to the periods considered⁵, making any extrapolation into the future problematic.

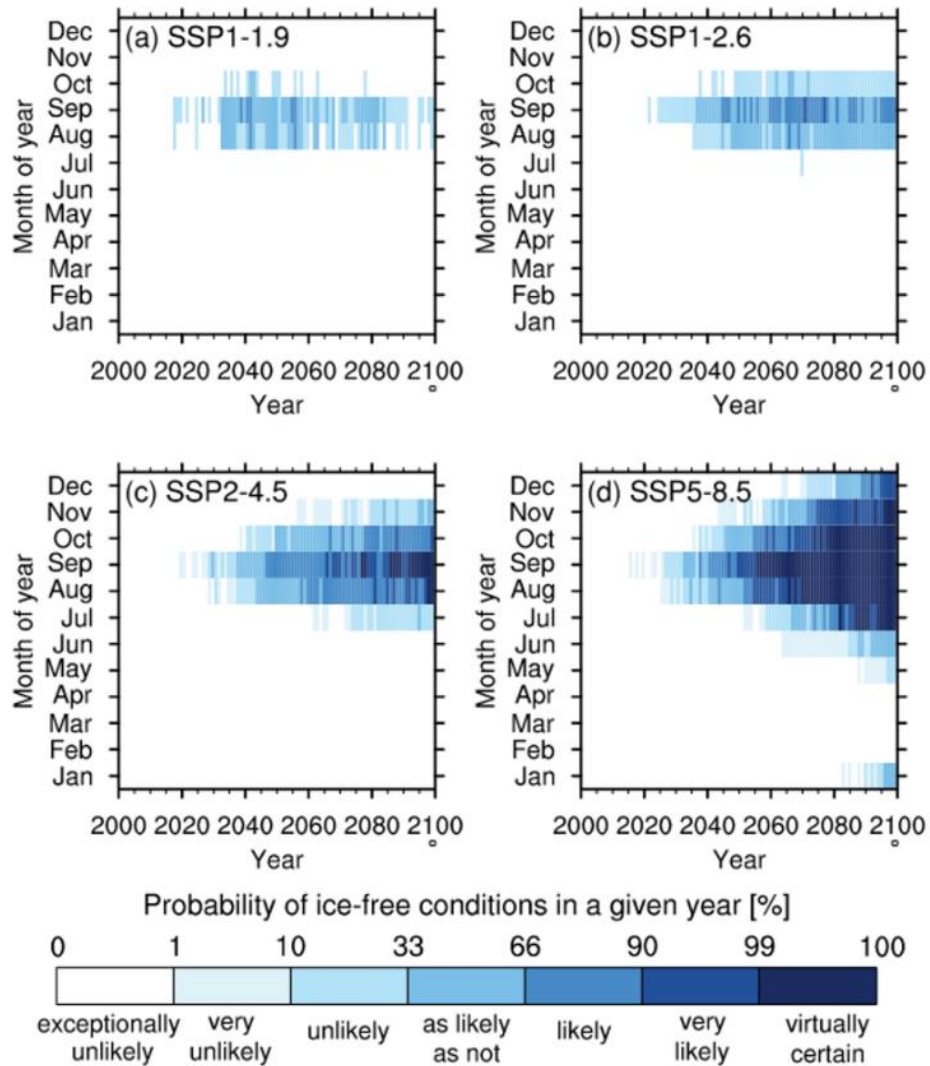


Fig. 5: Probability of occurrence of an ice-free Arctic Ocean (or « blue ocean ») as a function of month and year during the 21st century, for various climate scenarios of greenhouse gas emissions. Analysis of a selection of simulations from the CMIP6 (*Coupled Model Intercomparison Project*) exercise. The SSP5-8.5 scenario assumes high-carbon economic development while the SSP1-1.9 scenario follows the Paris Agreement objective of average warming below 1.5°C. Source : Jahn et al. 2024.

Coupled Earth system models provide an estimate within the framework of scenarios built on socio-economic assumptions implying different trajectories for future greenhouse gas emissions (from which are derived warming scenarios that vary according to the response of the models). The projections derived from these models are fraught with numerous uncertainties, which can be quantified within the framework of

⁵ For example, Fig. 2a shows that the linear decrease in sea-ice extent is faster over the period 1996-2007 and slower over the post-2007 period.

intercomparison projects⁶, the bulk of these uncertainties being linked to the internal variability of the Earth system (more than 50% of the uncertainty over the extent of the September ice pack), on top of which are superimposed the uncertainties linked to the realism of emission scenarios and those linked to model imperfections. As a result, we can only speak of the probability of freeze-up, or the probability of occurrence of an ice-free Arctic Ocean (or “blue” ocean⁷). For the past fifteen years, scientists have been seeking to reduce this uncertainty, in particular by selecting the most relevant models and results⁸.

It is now considered «probable» (more than 66%) that an isolated event during which the Arctic would be free of ice on average over the month of September will occur as early as the middle of the 21st century (these maturities being shortened by several years, 4 years on average, if daily adjustment data are taken into account), and this regardless of the emission scenario (Fig. 5). However, the emission path followed in the future will be crucial because it will determine the frequency, duration and spatial distribution of these very low-freeze episodes. The maps are in our hands to delay as much as possible the emergence of conditions that will continue to undermine unique environments and socio-ecosystems whose existence is largely attributable to the ice pack.

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For Polar Watch

⁶ Like the *Coupled Model Intercomparison Project*, whose 6th exercise (CMIP6) provided data for the latest IPCC assessment report.

⁷ The notion of “blue” ocean is to be contrasted with that of “white” or frozen ocean (Newton et al., 2016). It is now agreed, somewhat arbitrarily, that the Arctic Ocean is free of ice if the extent of the ice pack is less than 1 million km².

⁸ See for example the summary article by Jahn et al., *Nature Reviews Earth and Environment*, 2024.

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