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Seasonal Characteristics and Trends in Precipitation Partitioning in the Arctic

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Abstract. Driven by growing impacts of changing precipitation amounts and phase on the Arctic's natural and built environment, we examine seasonal patterns and trends in Arctic precipitation and partitioning between its liquid and solid forms. Use is made of data from the ERA5 reanalysis, Automated Surface Observing System stations over land, and a climatology based on present weather reports over the Arctic Ocean. In the Atlantic sector of the Arctic, most precipitation falls as rain in all seasons in the extreme south, but snowfall is high over its northern parts. Annual precipitation over the dry central Arctic Ocean and terrestrial polar deserts almost always falls as snow. Even during the summer, typically 50% of precipitation over the central Arctic Ocean falls as snow. Over land, nearly all summer precipitation falls as rain, except in the Canadian Arctic Archipelago where summer snowfall is still common. Annual precipitation has increased since 1979, primarily in the Barents Sea sector, accompanied by generally downward trends in snowfall and, hence, upward trends in liquid precipitation. Across much of the Arctic, the rainfall to total precipitation ratio has increased only in summer, while in the Atlantic sector, the rainfall to total precipitation ratio has increased in all seasons.

1 Introduction

Arctic surface air temperatures are increasing more rapidly than for the globe as a whole (Rantanen et al., 2022). This Arctic Amplification of warming, which has numerous causes, is associated with changing precipitation patterns. Historically, most of the annual precipitation in the Arctic (apart from the warm Atlantic sector) has fallen as snow. However, as the Arctic warms, one expects both an increase in total precipitation (due to more atmospheric water vapor and a stronger poleward moisture flux convergence), a shift towards more rainfall, and larger precipitation events (e.g., Duo et al., 2022; McCrystall et al., 2021). Indeed, annual precipitation for the Arctic viewed as a whole now appears to have a detectable upward trend (ARC, 2024).

This paper focuses on the seasonal and spatial variability of Arctic precipitation, its phase (rainfall versus snowfall) and how precipitation totals and its phase are changing. It makes primary use of ERA5 variables of total precipitation, snowfall, and liquid precipitation over the period 1979-2023. Additional data sources, used primarily for validation of ERA5, include Automated Surface Observing System (ASOS) reports of precipitation phase over land, an early climatological analysis of precipitation phase on the Arctic Ocean from present weather reports (Clark et al., 1997) and published studies of ERA5 precipitation. This paper represents a contribution to the Arctic Rain on

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Snow (AROSS) study, part of the National Science Foundation Navigating the New Arctic (NNA) Initiative. AROSS focuses on understanding impacts of rain on snow (ROS) and extreme precipitation events on the Arctic natural and built environment, with a special focus on reindeer herding practices (Serreze et al., 2021). A consequence of ROS events is that rainfall, when followed by a temperature drop, can result in the formation of hard, icy crusts. Impacts can be immediate (such as on travel) or evolve or accumulate. There have been recorded events of starvation-induced die-offs of tens of thousands of reindeer, caribou, and musk oxen. Voveris and Serreze (2023) describe the meteorology behind some of these ROS events and point out that even a small precipitation event can have large consequences. Thus, a greater understanding of how Arctic precipitation is changing will inform how these events may also be changing, by either a reduction in snowpack or increasing rain events.

The present study addresses the following question: What are the present-day seasonal and spatial patterns of precipitation and partitioning (liquid versus snowfall) across the Arctic, and how have these patterns changed over the study period in response to the warming Arctic climate?

2 Data Sources

2.1 ERA5 Reanalysis

Atmospheric reanalyses are widely used in the research community (Zhao et al. 2010). The European Centre for Medium-Range Weather Forecast (ECMWF) Reanalysis version 5 (ERA5) (Hersbach et al., 2020) employs four-dimensional variational data assimilation (4D-Var) (Rabier, 2005). Observations assimilated into the ERA5 system include surface data, radiosonde profiles, ship-based measurements, aircraft reports and satellite data. While ERA5 extends back to 1950, we use data from 1979 to 2023. The availability of satellite observations from 1979 onward significantly improves estimates of precipitation and atmospheric conditions in the Arctic (Xiong et al., 2022). As with any reanalysis, one must be aware that the assimilation database has changed over time (Hersbach et al., 2020) which can introduce biases, especially in earlier records with fewer observational constraints (Simmons et al., 2021).

We use 6-hourly data at 31 km horizontal resolution of total precipitation, liquid precipitation, rainfall, and snowfall. Total precipitation represents the accumulation of all forms of precipitation. Liquid precipitation is obtained by subtracting snowfall from total precipitation. Along with rainfall, this may also include sleet and freezing rain. After a forecast is generated, ERA5 applies a post-processing step to adjust precipitation fields based on available surface observations. However, these observations are not incorporated into the model during the assimilation phase. As a result, ERA-5 precipitation estimates are primarily influenced by the model's internal physics and parameterizations (Herbach et al., 2020). Accuracy of precipitation fields in ERA5 hence depends largely on the model's ability to simulate precipitation processes effectively (Bromwich et al., 2016). The determination of precipitation phase in ERA5 is based on a combination of near-surface air temperature, atmospheric moisture, and model-based calculations within the forecast system. Wet bulb temperature is a key factor in the determination. In some cases,

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mixed-phase precipitation may occur within a small temperature range with temperatures just above freezing (Hersbach et al., 2020; Xiong et al., 2022).

ERA5 is considered one of the most reliable reanalysis datasets for Arctic precipitation (Graham et al., 2019) and performs well in capturing precipitation phase (Xiong et al. 2022). Loeb et al. (2022) concludes that ERA5 effectively captures the spatial distribution and frequency of precipitation events in eastern Canadian Arctic and Greenland. Serreze et al. (2022) show that ERA5 successfully represents broad precipitation trends and seasonal variations over the Canadian Arctic. Barrett et al. (2020) compared precipitation estimates from six atmospheric reanalyses (NASA MERRA, NASA MERRA2, NOAA CFSR/CFSv2, ECMWF ERA-Interim, ECMWF ERA5, and JMAO JRA55) against records from the Russian North Pole series of drifting camps over the central Arctic Ocean. They find that the time series of annual precipitation over the central Arctic Ocean correlates well between all reanalyses, and that all of the reanalyses capture the basic spatial and seasonal patterns of Arctic precipitation. All reanalyses depict that the majority of total annual precipitation over the central Arctic Ocean comes from small events, less than 1 mm/day. As part of the present study, we compare ERA5 depictions of precipitation partitioning against the ASOS database and an Arctic Ocean climatology described in more detail below.

2.2 ASOS Database

As part of the AROSS project, a database of the Arctic precipitation phase was compiled using reports from stations in the Automated Surface Observing System (ASOS) networks of the United States, Canada, Greenland, Iceland, Norway, Sweden, Finland and Russia. The database has records from 244 stations. Records used here span the period 1979 to 2023.

Precipitation type codes in reports are used to identify rain, freezing rain and solid precipitation. These codes are based on automated precipitation type sensors. Manual observations may be used to override automated reports when human observers are on station and when precipitation type reports are deemed erroneous. Reports were quality controlled to ensure logical consistency between near-surface air and dew point temperatures, and reported precipitation type. For example, records with freezing or solid rain reports but with air temperature of 20°C or higher were discarded. At the finest temporal resolution reported (minutes to an hour), rain events were reported 765610 times. Freezing rain was reported 18174 times. For the present study, data was resampled to an hourly frequency. If a given precipitation type was reported during an hour reporting period, that hour was assigned the precipitation type. Hours could be assigned multiple precipitation types if different precipitation types occurred within that hour. For example, if precipitation type transitioned from rain, to freezing rain, to snow in an hour, that hour would be assigned rain, freezing rain and solid precipitation. The spatial distribution of ASOS sites with the numbers of complete years of data as proportional circles is shown in **Figure 1.** A heatmap of events through the database period organized by country is shown in **Figure 2.**

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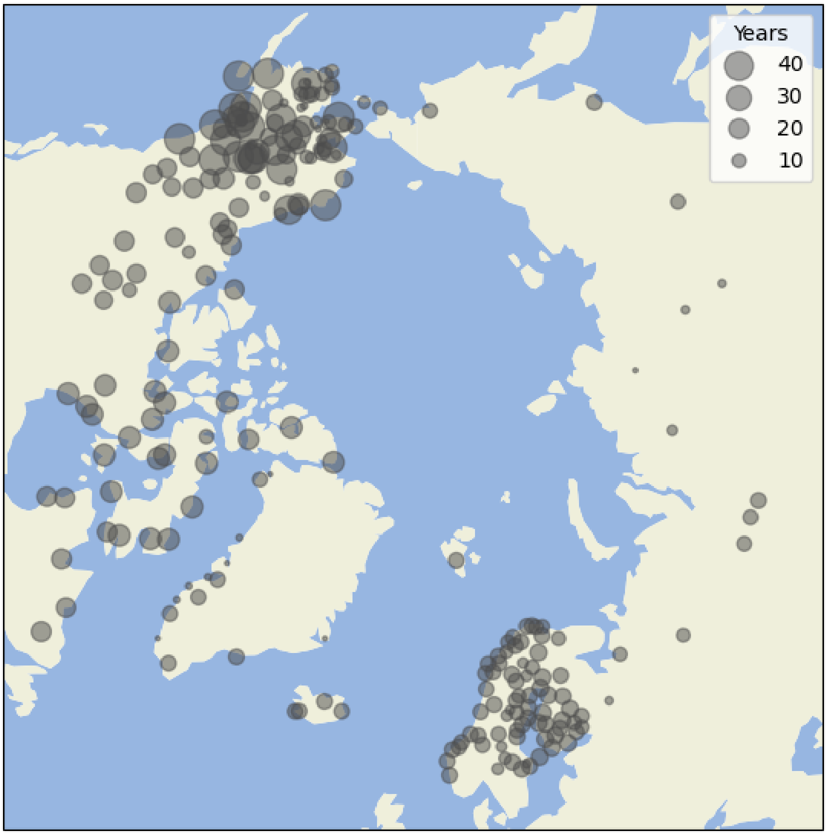

Figure 1: Number of complete years with data shown as proportional circles for ASOS stations.

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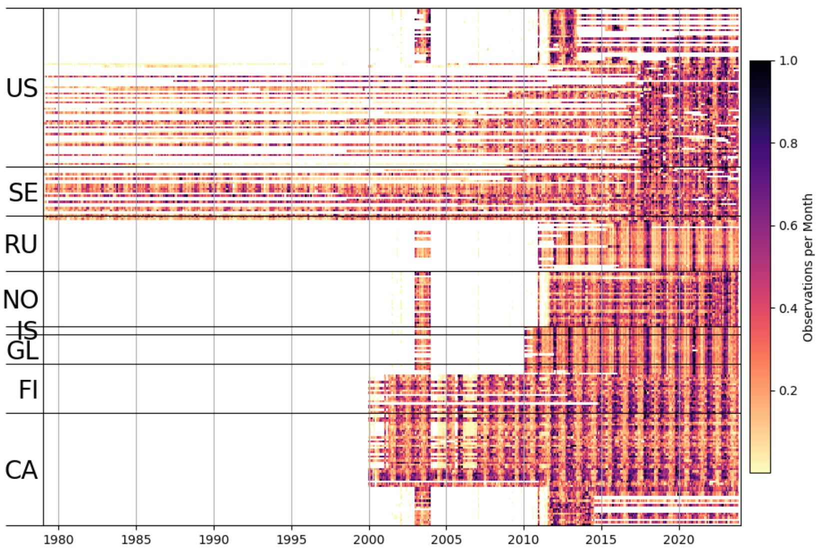

Figure 2: Heatmap of rain events by month for the 2000 to 2020. Reports are organized vertically by country: US United States, SE Sweden, RU Russia, NO Norway, IS Iceland, GL Greenland, FI Finland, CA Canada.

2.3 ICOADS Study

Clark et al. (1996) published a paper highly relevant to the present study of precipitation phase and intensity over the Arctic Ocean based on present weather codes included within the Integrated Comprehensive Ocean-Atmosphere Data Set (ICOADS). Over the central Arctic Ocean, most of the observations are from the Russian North Pole series of camps. These camps were deployed on ice floes or tabular icebergs to gather oceanographic and meteorological data. The record used by Clark et al. (1996) spans the period of 1950-1995. Observations were interpolated into a coarse grid array covering the Arctic Ocean for January and July. Precipitation frequency is the percent of all reports for which any precipitation was observed. Frequency is also given for reports of “medium” and “heavy” precipitation. Phase is based on the percentage of all ICOADS reports for which liquid or solid precipitation was observed. While these data are from an old study and the climate has changed since then, they still provide valuable information on precipitation characteristics that, along with the ASOS database, can be compared to ERA5.

3 Climatological Patterns

3.1 Annual

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We look first at long-term (1979-2023) annual means (totals) of total precipitation, snowfall, liquid precipitation and the liquid/total precipitation ratio from ERA5 **(Figure 3**). As is well known, total precipitation is highest in the North Atlantic sector, particularly in Greenland, the Norwegian and Barents Seas. This reflects the frequent passage of extratropical cyclones and within-region cyclogenesis associated with the North Atlantic cyclone track. As discussed shortly, cold-season evaporation rates are also very high in this region. Locally, orographic uplift, such as that occurs along the southeast coast of Greenland, enhances precipitation (Serreze et al., 1997; Tsukernik et al., 2007). Precipitation is much lower over the central Arctic Ocean and Canadian Arctic Archipelago, the latter region classified as polar desert (Serreze and Barry, 2014). Note the especially low precipitation over the high elevation Greenland Ice Sheet.

Snowfall is low over the central Arctic Ocean and polar desert regions. Snowfall is in turn greatest in the northern North Atlantic sector where total precipitation is high. While the Atlantic sector is the warmest part of the Arctic, reflecting the lack of a sea ice cover and the influence of the warm North Atlantic Drift current, temperatures over its northern portion are still generally cold enough (according to ERA5) for most precipitation to fall as snow. There is much less snowfall in the southern part of this sector, reflecting, of course, a higher incidence of rainfall, up to about 1500 mm off the coast of northern Norway.

It follows that the highest rainfall to total precipitation ratios are in the North Atlantic sector. By contrast, the central Arctic Ocean and the Greenland Ice Sheet have the lowest rainfall-to-total precipitation ratios. Over most of the central Arctic Ocean, 20-25% of annual precipitation falls as rain.

Over the central part of the Greenland ice sheet, liquid precipitation is extremely rare. However, in August 2021, Summit Station located at the highest point of the ice sheet, (3,216 meters above sea level), experienced its first recorded rainfall event (European Space Agency, 2021). According to the National Snow and Ice Data Center (NSIDC), this was the first known instance of rainfall at Summit Station. Warm air intrusions in 2012 and 2019 resulted in brief surface melting, but temperatures were not high enough for rainfall to occur.

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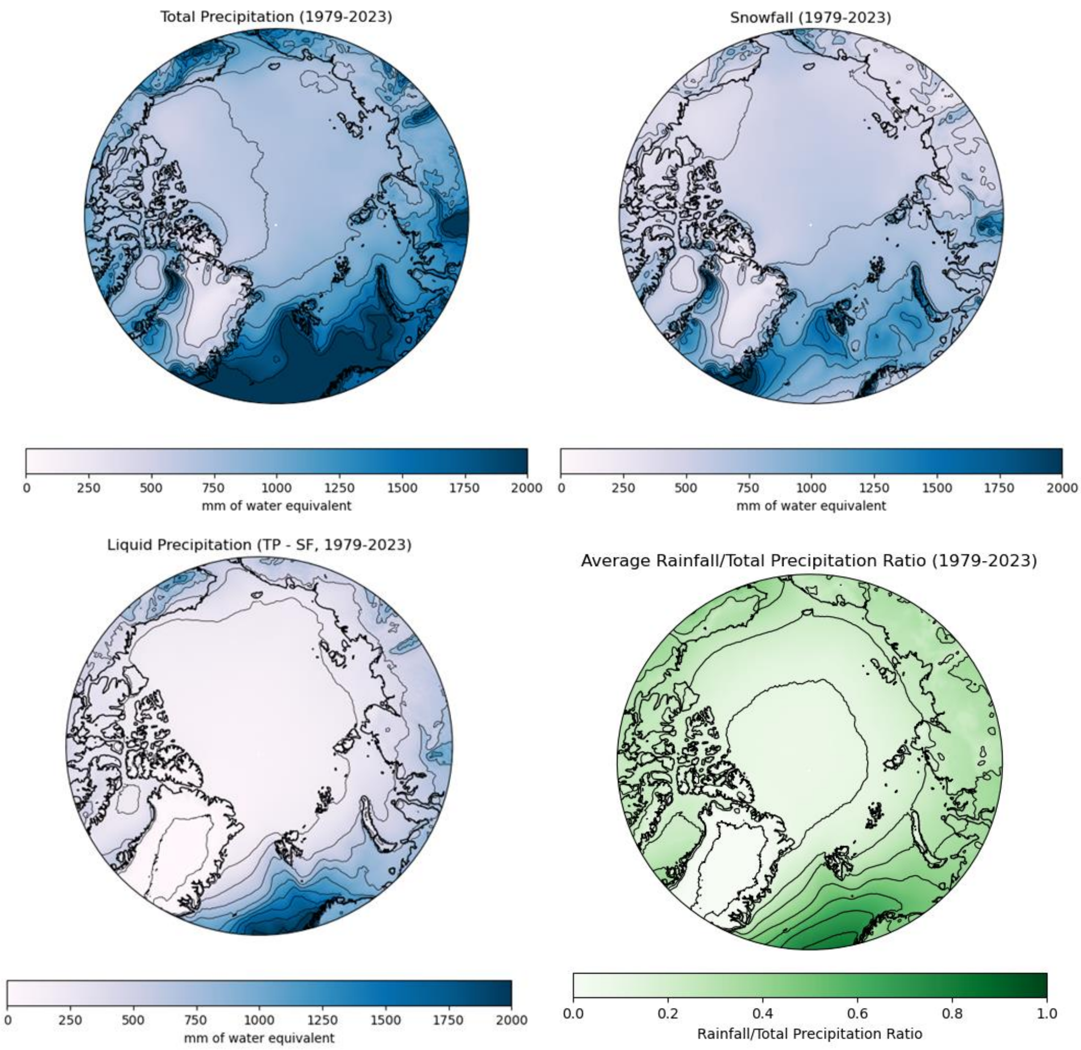

Figure 3: Spatial distribution of annual totals of total precipitation, snowfall, liquid precipitation and the liquid/total precipitation ratio.

3.2 Seasonality

Attention now turns to seasonality, looking first at contrasts between winter (DJF) and summer (JJA) of precipitation, snowfall and liquid precipitation (**Figure 4**). Winter precipitation is particularly low over the central Arctic Ocean and most land areas, reflecting low temperatures (hence little atmospheric moisture) and distance from Atlantic moisture sources. The much higher winter precipitation over the North Atlantic sector clearly stands out.

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The North Atlantic cyclone track is most active at this time, and cyclones are passing over open ocean and can pick up ample moisture. Average winter latent heat fluxes over the ice-free Atlantic sector as depicted in ERA5 are on the order of 80 Wm-2 or even higher, compared to much lower values over the ice-covered central Arctic Ocean and land areas (**Figure 5**). Olafsson and Okland (1994) describe how Arctic air masses moving over these warm Atlantic sector waters develop convective boundary layers that enhance precipitation.

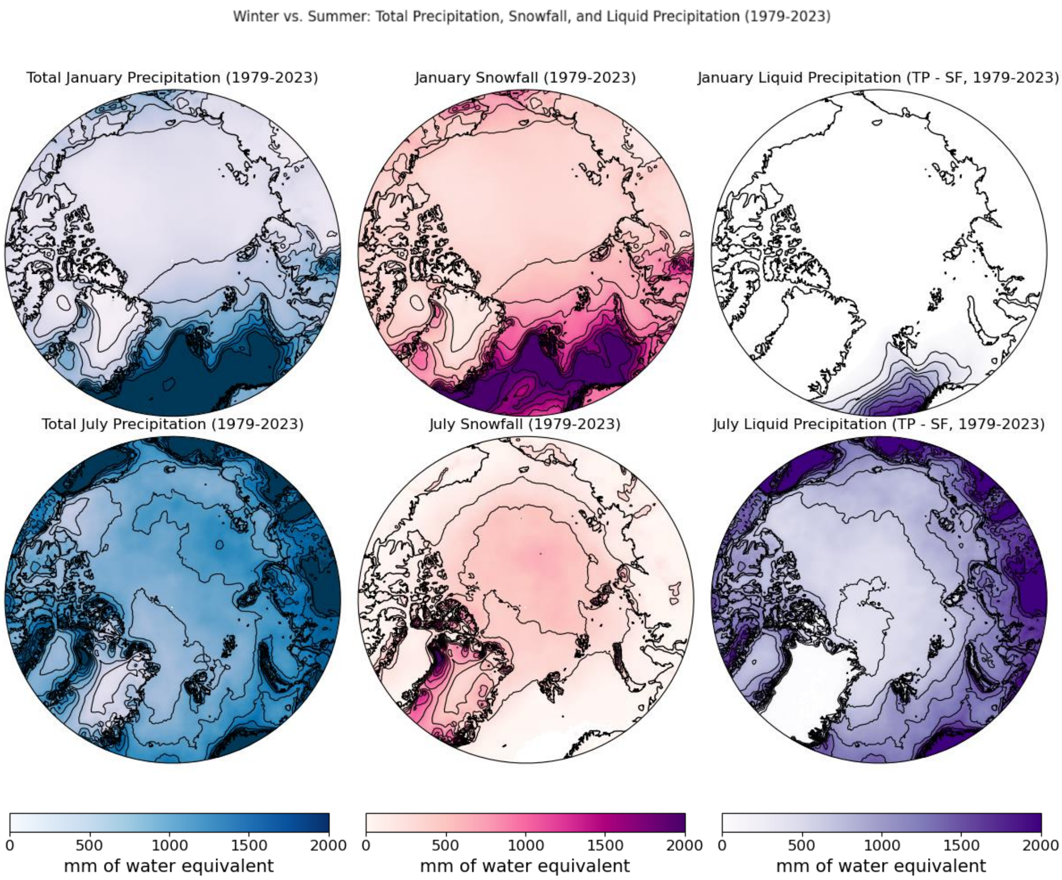

Figure 4: Climatology of total precipitation, snowfall, and liquid precipitation for Winter (top) and Summer (bottom) from ERA5 (1979–2023)

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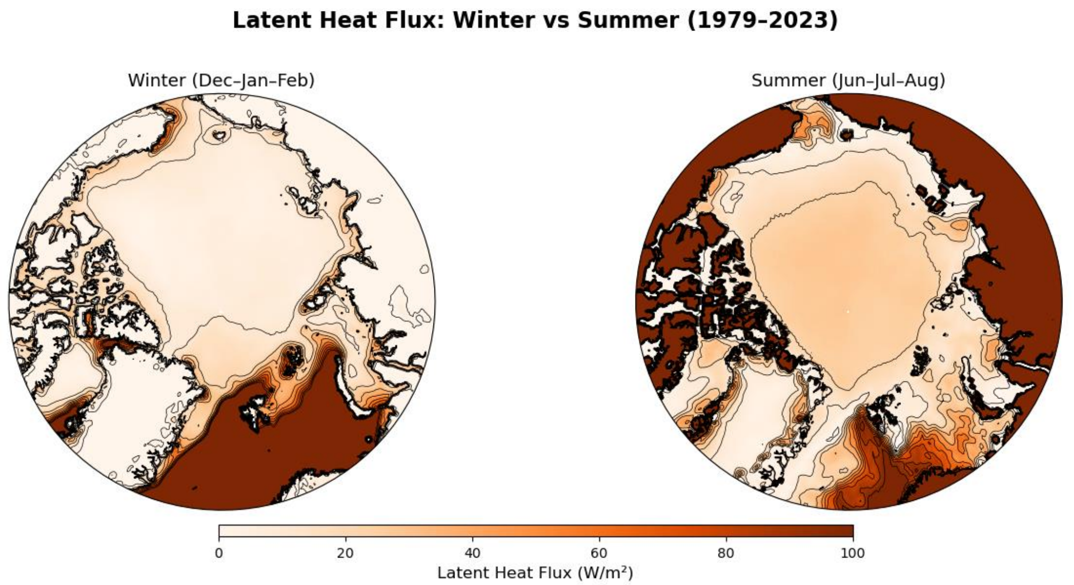

Figure 5: Average latent heat fluxes for winter and summer.

Precipitation over the North Atlantic sector is much lower in the summer. Figure 5 shows Atlantic sector latent heat fluxes are in general lower, and the North Atlantic cyclone track and associated Icelandic Low are also much weaker at this time (Serreze et al., 1997). Summer precipitation is at its seasonal maximum over land areas, reflecting both an increase in cyclone frequency and more frequent convective activity. The high latent heat fluxes over land areas support the higher precipitation amounts compared to winter. The summer precipitation peak over the central Arctic Ocean reflects the seasonal peak in atmospheric water vapor, and a summer/early autumn maximum in cyclone activity. These systems move into the area from the Atlantic and Eurasia, and some form over the Arctic Ocean itself (Serreze and Barrett, 2008). Note that summertime latent heat fluxes are small over the Arctic Ocean due to the melting sea ice cover, limiting saturation vapor pressure and the vertical vapor gradient (Serreze et al., 2014).

As is clear from Figure 4, there are prominent contrasts between winter and summer in snowfall and liquid precipitation. The amount of snowfall is a function of both precipitation amount and temperature, which bears on whether precipitation is in liquid or solid form. For example, over the central Arctic Ocean, the low winter snowfall is primarily a function of low precipitation, while over the land areas in summer, the low snowfall (close to zero in some areas) is due to temperature. Over much of the North Atlantic sector, high winter precipitation leads to ample snowfall.

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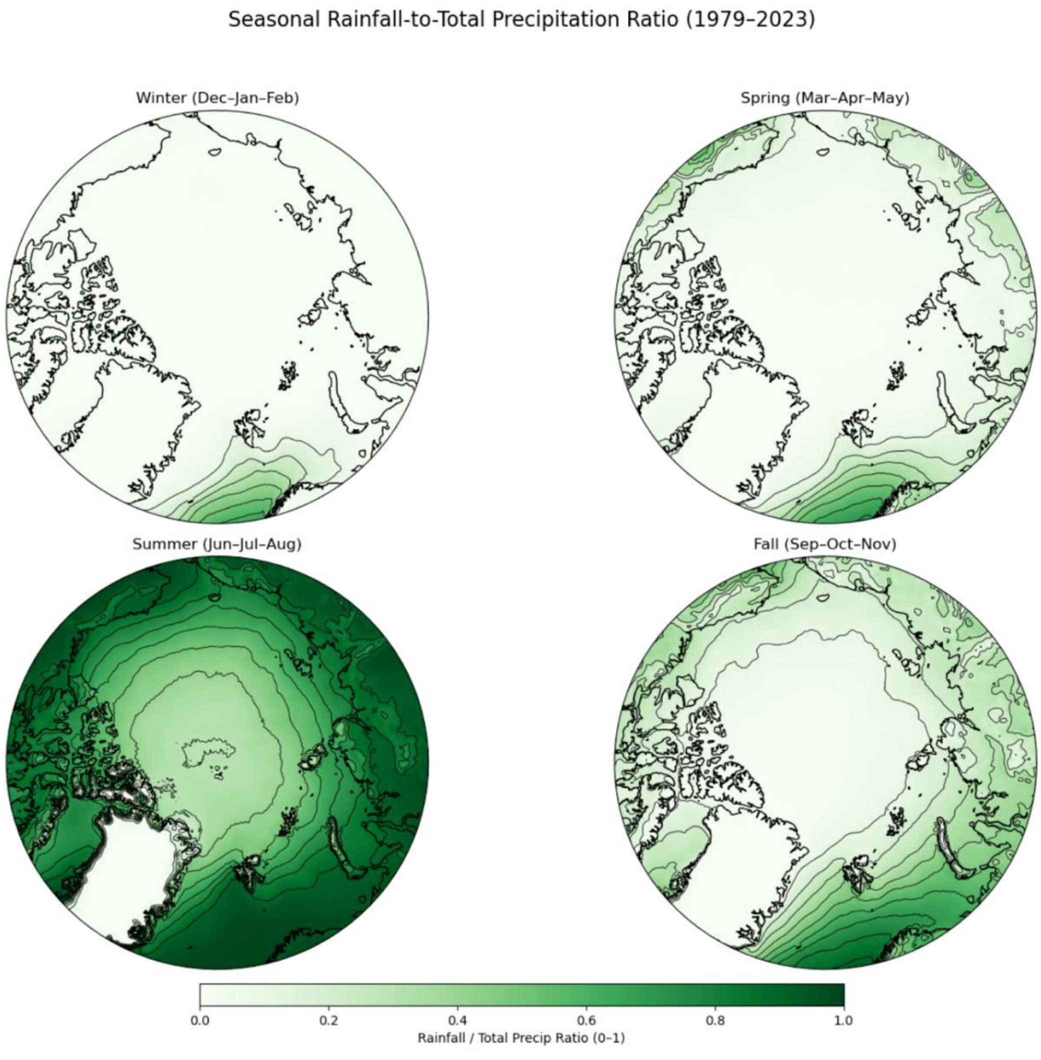

Figure 6: The seasonal distribution of the rainfall-to-total precipitation ratio from 1979 to 2023.

With such controls in mind, attention turns to **Figure 6**, the rainfall to total precipitation ratio for each season. During winter, liquid precipitation is a large fraction of total precipitation only in the very southernmost regions of the North Atlantic. This is consistent with observations that even Bergen, Norway, lying at about 60°N along the west coast, seldom sees snowfall in winter, due to the North Atlantic Drift Current. While winter rainfall fractions are shown as near zero over most land areas and the Arctic Ocean, harking back to previous discussion, it is known

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that occasional warm air intrusions can allow for brief wintertime rain or freezing rain events over the central Arctic Ocean. In recent years, there have been extreme cases of wintertime warming. On February 2, 2025, temperatures near the North Pole reached the melting point, more than 20°C above average (The Guardian, 2025).

During spring, the rainfall fraction increases over land areas. However, snowfall is still by far the dominant precipitation type over much of the Arctic Ocean away from land areas and the Atlantic sector. The highest ratios of course occur during the summer. Over the Atlantic sector, essentially all summer precipitation falls as rain. Rainfall is also dominant over land areas, the obvious exception being the high, cold Greenland ice sheet. Note, however, that over the central Arctic Ocean, about half of all precipitation still falls as snow according to ERA5

As summer fades to autumn, the rainfall fraction decreases as temperatures fall. However, early autumn still shows high rainfall fractions over the northern North Atlantic (not shown). This area remains ice-free year-round, and temperatures remain high for the latitude. By contrast, precipitation phase shifts over the central Arctic Ocean are more prominent due to the lower temperatures associated with both increasing latitude and greater distance from marine warmth.

3.3 Comparisons with ICOADS Records

The Clark et al. (1996) study, based on the ICOADS data base over the period 1950-1995, while certainly dated, provides valuable independent estimates of precipitation phase as well as intensity over the Arctic Ocean and North Atlantic sector. **Figure 7** and **Figure 8** show the key results for January and July reproduced from that study. The ICOADS data (as with the ASOS data described below) are expressed as the percent of all precipitation observations in liquid or solid form, the percent of all observations in which precipitation occurred and (for ICOADS) when the precipitation was coded as moderate to heavy. While this differs from the ERA5 analysis which shows the ratio between liquid and total precipitation, results from the two studies are still comparable.

The ICOADS records from 1950-1995 show 95% - 99% of all January precipitation events over the central Arctic Ocean falling as snow. This broadly corresponds to a rainfall to total precipitation ratio of 0.01 to 0.05 in ERA5 data which shows an overwhelming dominance of solid precipitation during winter, even in today's warmer climate. As mentioned earlier, there have been some recent rainfall events over the central Arctic Ocean in winter, associated with intrusions of warm moist air originating in the Atlantic. It is of interest, however, that even in the older ICOADS records, there were still occasional liquid precipitation events in winter. Consistent with the much higher precipitation totals over the northern North Atlantic shown in ERA5 and other studies, the ICOADS records show this region as having a much higher frequency of moderate to heavy precipitation as compared to the central Arctic Ocean, where most precipitation events are small.

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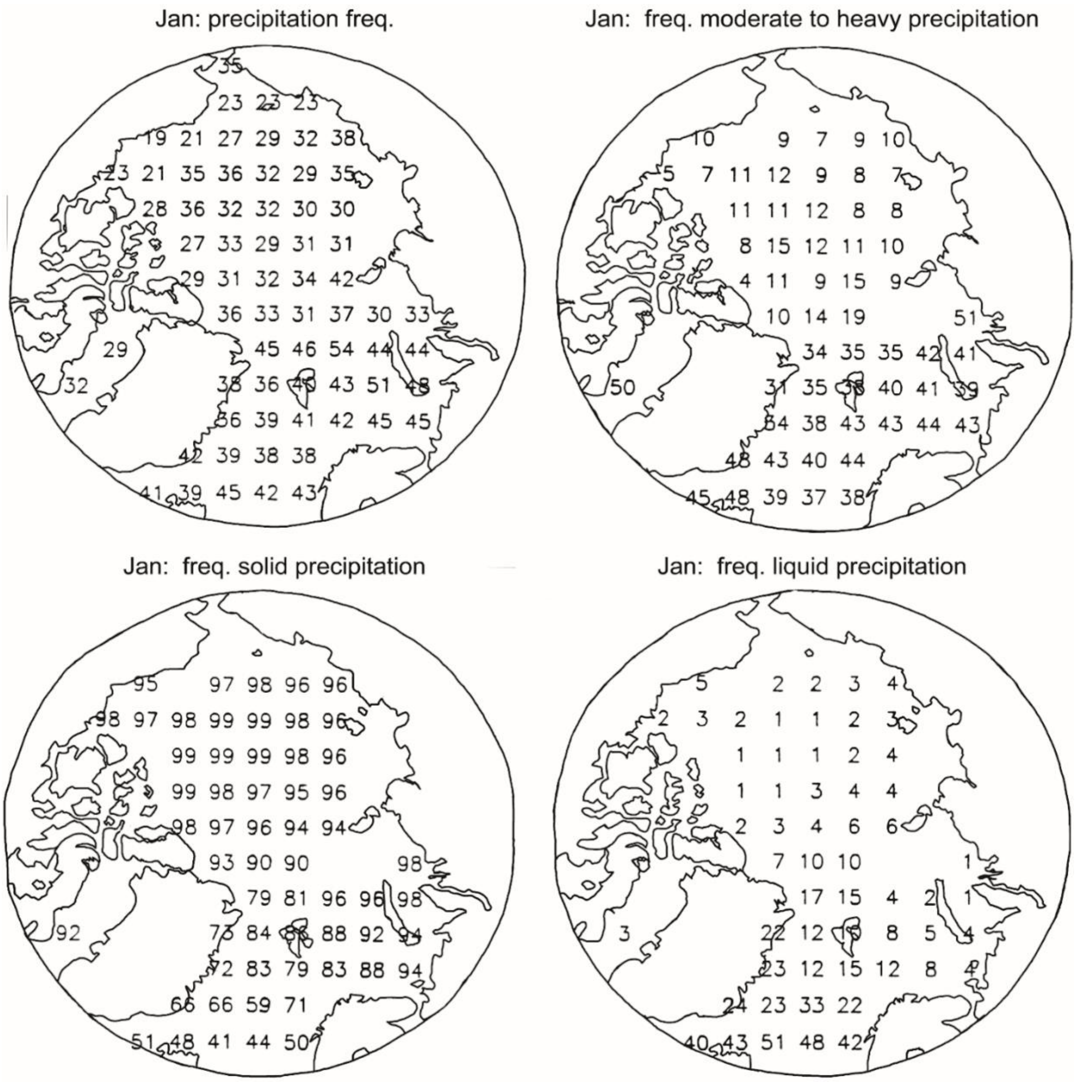

Figure 7: Seasonal distribution of precipitation phase over the Arctic for January, based on COADS data, reproduced from Clark et al. (1996).

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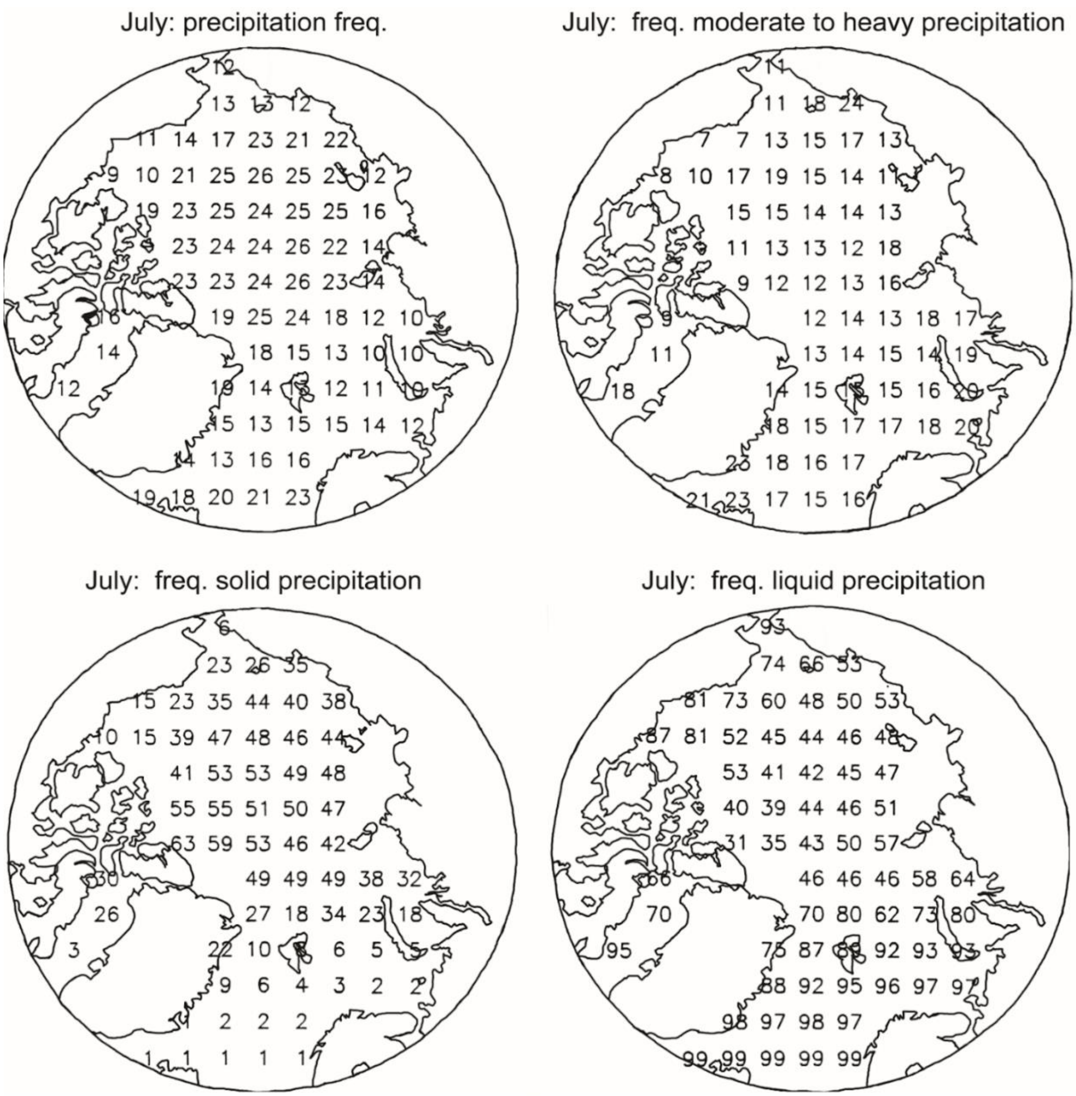

Figure 8: Seasonal distribution of precipitation phase over the Arctic for July, based on COADS data, from Clark et al. (1996). Used to validate ERA-5 precipitation phase.

For July (Figure 8), the ICOADS records depicts approximately 40% - 60% of precipitation events over the central Arctic Ocean representing snow, and only infrequent snowfall over the northern North Atlantic, in overall agreement with the ERA5 summer results. Note also the reduction over the North Atlantic sector in the frequency of moderate to heavy precipitation, consistent with the lower amounts of summer precipitation here shown in ERA5 due to the weaker north Atlantic cyclone track.

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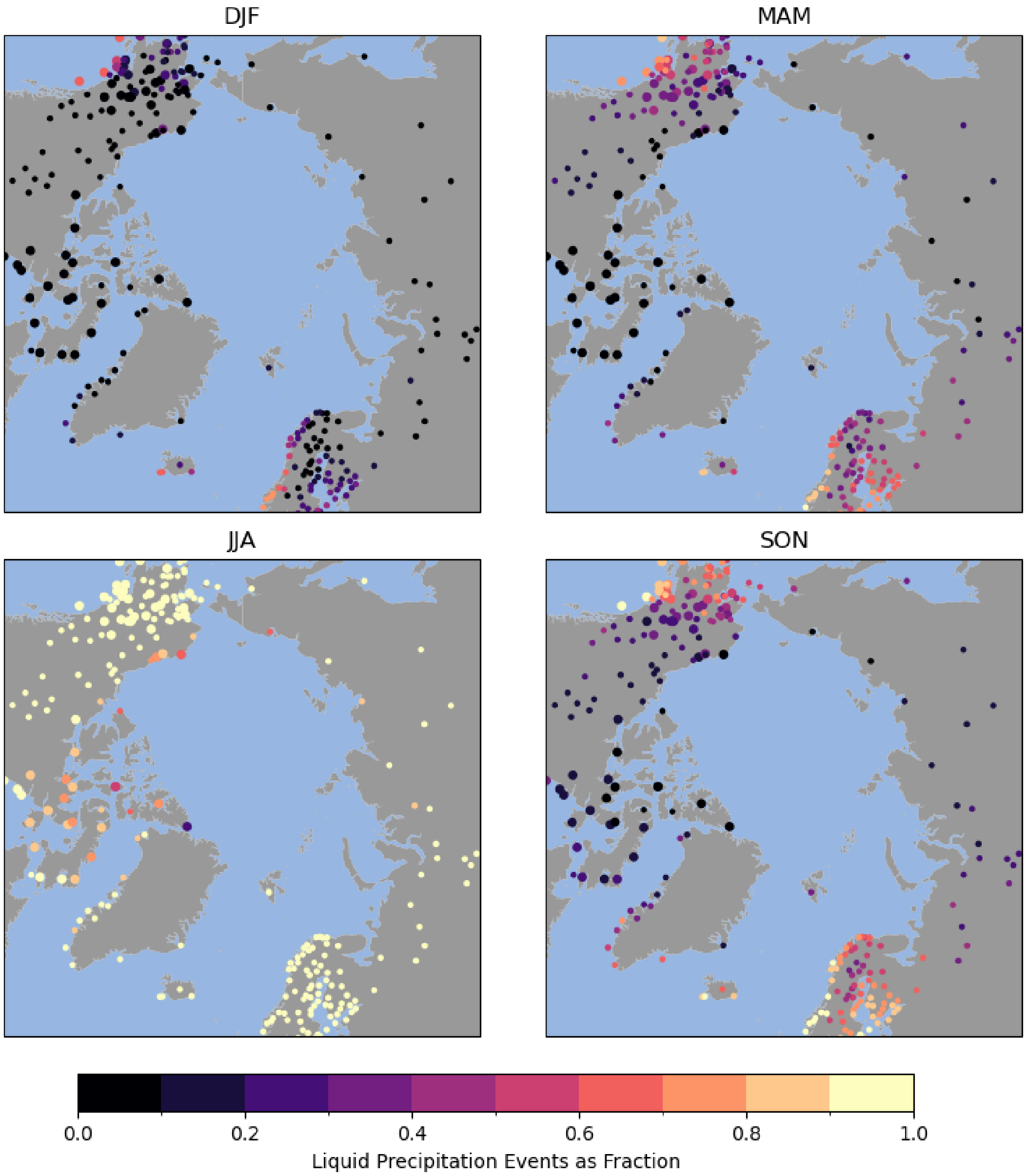

245 **Figure 9: Number of hours with liquid precipitation expressed as a fraction of the total number of hours with any type of precipitation for climatological seasons from the AROSS database. Large symbols represent stations with more than 20 years of data for the 1979 to 2023 period. Small symbols are for stations with shorter records.**

3.4 Comparisons with ASOS Records

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Figure 9 shows the number of hours with a report of liquid precipitation expressed as a fraction of the total number of hours with either liquid or solid precipitation reported by season for stations in the AROSS database. This is essentially equivalent to the liquid to solid precipitation ratios just examined. Stations with more than 20 years of record are represented using large circles. The majority of these stations are in North America. The winter results are consistent with results from ERA5 rainfall/total precipitation ratios. The AROSS database shows that few events are liquid in winter, exceptions being sites in extreme southern Alaska and along the Norwegian coast. The pattern for spring is similar, except sites in southern Alaska and the Norwegian coast are more numerous and the liquid fractions are higher. In the summer months, liquid precipitation is the majority almost everywhere, the exception being over the Canadian Arctic Archipelago, where snow events can still be common. Autumn marks the transition back to the winter pattern, as decreasing temperatures reduce the fraction of rainfall.

From an analysis of Ku-Band Quikscat radar data over November through February from 2000-2009 (Bartsch 2010a, 2010b, Bartsch et al., 2010), Scandinavia and northwestern Russia emerge as “hotspots” for rain on snow events (in some places up to 12 events per year). This is consistent with the fairly high frequency of liquid precipitation events in this area from the ASOS data for winter, spring and autumn, and is also clear when we look at the correspondence between rain events in the ASOS database and the occurrence of snow on the ground (not shown). It is unfortunate that few ASOS records are available over much of central and eastern Russia, but the few stations that do exist point to a low frequency of rain events in the cold season, consistent with the QuikScat analysis indicating one or zero ROS events per year in this area characterized by a highly continental climate.

An event of particular note occurred over the Yamal Peninsula of Russia as well as neighboring coastal regions 8-10 November, 2013 east of the area of highest ROS frequency seen in the Quikscat analysis. This event is described by Forbes et al. (2016), who note that several other Yamal events have been recorded in recent years. After the 2016 event, ice covered an area of approximately 27,000 km^2 and completely blocked reindeer from foraging, leading to the death of 61,000 animals between November 2013 and June 2014.

4 Trends

4.1 Precipitation

As the Arctic warms, one expects more rain events, and while this implies more ROS events, a caveat is that the snow-covered season will shorten, therefore rain will increasingly fall on bare ground. Climate models are in near universal agreement that Arctic precipitation will increase (McCrystal et al., 2021), driven by rising atmospheric moisture availability, which enhances precipitation as warming temperatures allow for greater evaporation, a greater moisture holding capacity of the atmosphere, and hence a poleward moisture transport. There is emerging evidence that, at least assessed for the Arctic region as a whole, Arctic precipitation is indeed increasing (Walsh et al., 2023).

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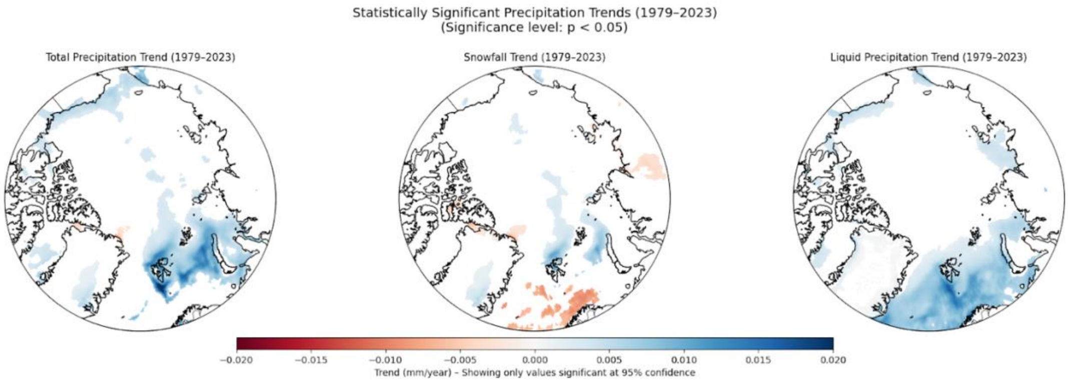

Figure 10: Linear trends in annual total precipitation, snowfall, and liquid precipitation from 1979 to 2023. Only trends that are statistically significant at the 95% confidence level are shown by colors.

Figure 10 shows linear trends in annual precipitation, snowfall and liquid precipitation over the period 1979-2023. Of particular note are the statistically significant increases over the Barents and Kara Seas Sea and around the Svalbard archipelago. It hence seems that the conclusion that Arctic precipitation, considered for the region as a whole (Walsh et al.,2023), is largely due to increases in this area.

In explanation, this is the one area of the Arctic that has experienced substantial reductions in winter sea ice extent, linked to a stronger inflow of warm and salty Atlantic water (Lien et al. 2017). Harking back to previous discussion, this warm Atlantic water, underlying very cold air, can result in large latent heat fluxes to the atmosphere and unstable low level boundary layers, favoring increased precipitation. Digging into this further, the increase in winter precipitation as depicted by ERA5 is in part convective precipitation (not shown). Convective-type precipitation is known to occur in winter in the Norwegian Sea where warm water underlies cold air, fostering high evapotranspiration and unstable boundary layers (Olaffson and Okland, 1994), and it appears that such wintertime convective precipitation is now moving into higher latitudes as winter sea ice retreats.

Annual snowfall has fairly pronounced downward trends only over the Atlantic side of the Arctic, but these are spotty in spatial extent as are the local increases poleward of Svalbard. Liquid precipitation by contrast has widespread positive annual trends over the North Atlantic sector and Barents Sea pointing to the warming conditions.

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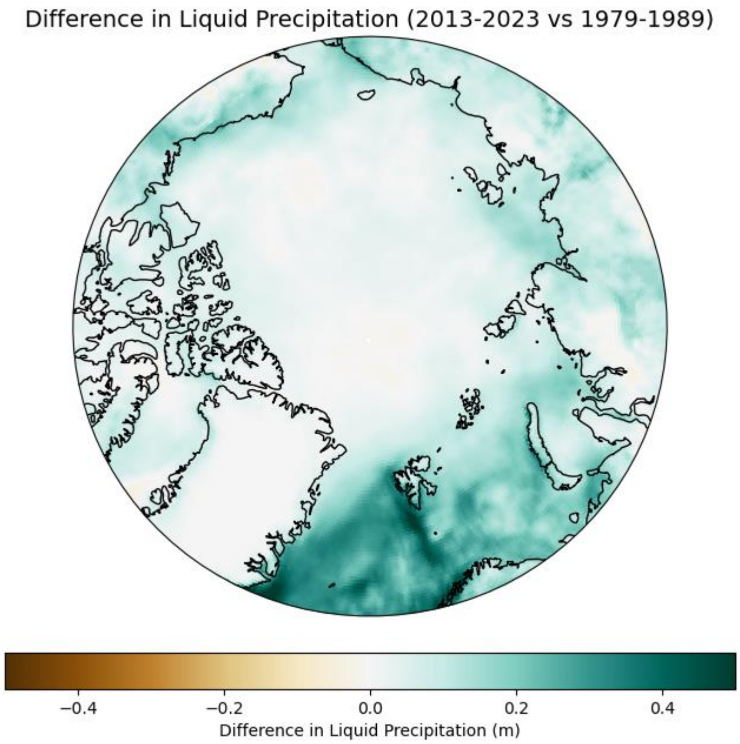

Figure 11: The difference in annual liquid precipitation between the recent period (2013–2023) and an earlier baseline period (1979–1989).

As linear trends can sometimes be misleading, **Figure 11** shows the difference in annual liquid precipitation between the first (1979-1989) and last (2013-2023) decades of the study period. The larger amount of liquid precipitation over the north Atlantic sector is particularly striking.

4.2 Liquid to Total Precipitation Ratio

Seasonal trends in the liquid to total precipitation ratio follow in **Figure 12**. Statistically significant positive trends are fairly widespread in summer, but there are nevertheless large areas over the Arctic Ocean where no significant trends are present. Even in summer, trends over the Greenland Ice Sheet are essentially zero. Positive trends are less widespread in autumn. Statistically significant positive trends in winter and spring are apparent only in the North Atlantic sector. Phrased differently, away from the Atlantic sector, it has yet to warm sufficiently to see a change in the ratio over much of the Arctic except during summer, and even in summer, ratios over large areas of the ocean are essentially unchanged. Winter precipitation has increased over the Atlantic sector, and while locally, there are increases in snowfall, the increase in the liquid precipitation fraction dominates, yielding an upward trend in the winter rainfall to total precipitation ratio.

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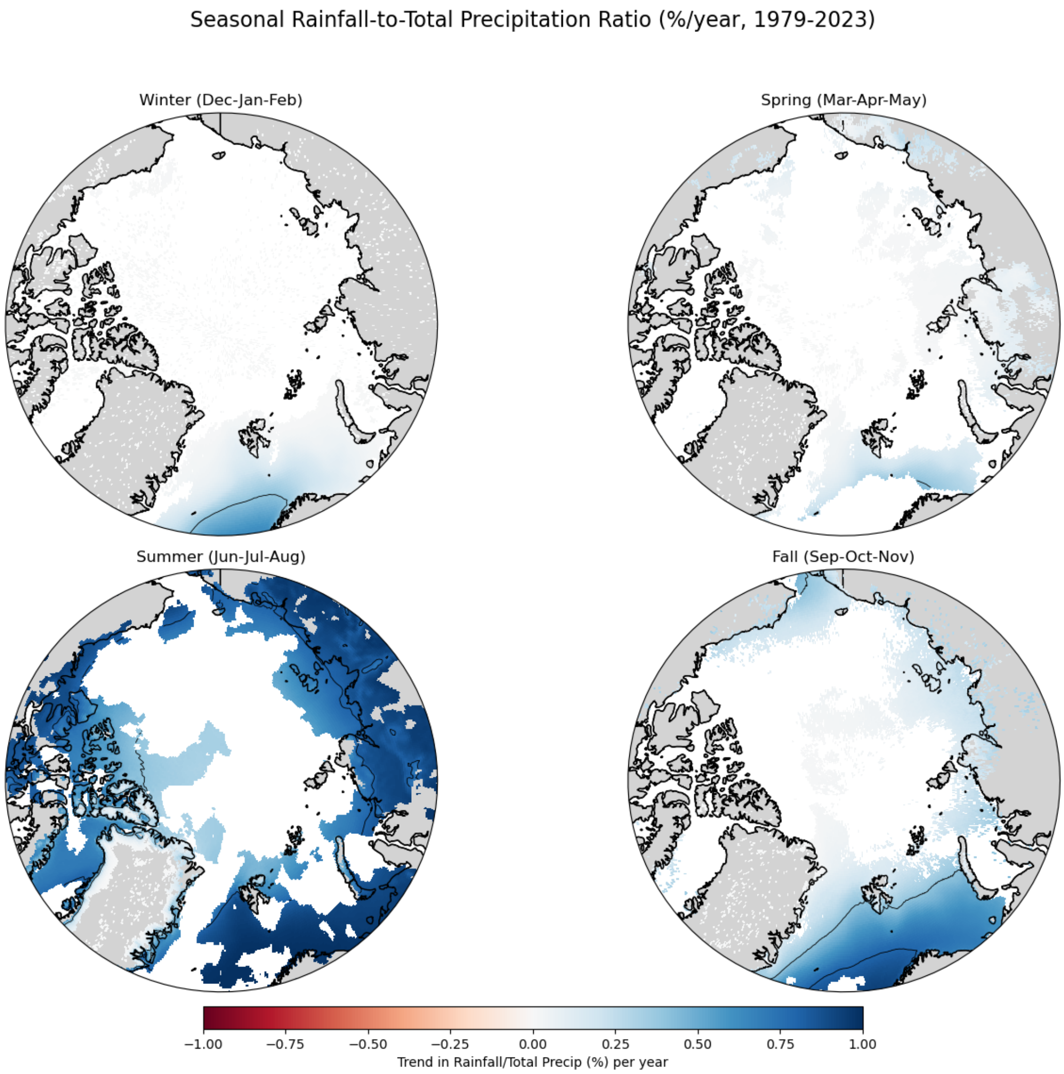

Figure 12: Seasonal trends in rainfall to total precipitation (1979–2023). Only trends that are statistically significant at the 95% confidence level are shown by colors.

5 Synthesis and Discussion

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What are the present-day seasonal and spatial patterns of precipitation partitioning (liquid versus snowfall) across the Arctic, and how have these patterns changed through the warming Arctic climate?

To address this question, it was first necessary to ask: Is ERA5 up to the task of providing sufficiently reliable estimates of precipitation and its phase? Prior validation studies, as well as the work presented here based on the ASOS and ICOADS climatologies, argue that the answer is yes. While uncertainty remains, ERA5 has demonstrated consistency with independent datasets in capturing precipitation phase changes and trends. This is important given that the Arctic's surface station network is sparse and insufficient for capturing spatial precipitation patterns (ARC, 2023). Therefore, reanalysis data remains the best tool for evaluating large-scale precipitation patterns and trends across the region.

Analysis of the ERA5 data records over the period 1979-2023 reveals a complex picture of a seasonally varying and evolving hydrological regime. Over most of the study region, annual precipitation falls mainly as snow, the clear exception being the Atlantic sector where temperatures are fairly high, reflecting the ice-free conditions. During summer, roughly half of precipitation still falls as snow, surprisingly similar to snowfall fractions based ICOADS records for 1950-1999 when the Arctic was cooler. Analysis of the ERA5 data shows an increase in annual precipitation, primarily in the Norwegian, Barents and Kara Seas. Reports that precipitation increases for the Arctic viewed as a whole, in line with climate model predictions, must be tempered by recognition of these strong regional expressions of change. At least some of these regional increases likely have a convective component linked to winter sea ice loss. Apart from the north Atlantic sector, the rainfall-to-total precipitation ratio has appreciably increased across much of the Arctic only during summer. Increases outside of the northern North Atlantic sector in other seasons are much more limited.

With continuing warming, we can expect a more pronounced change in the ratios, which even in the absence of changing precipitation amounts raises the concerns about cascading effects of rain on snow events on Arctic ecology and the built environment. A key issue in this regard is that as the climate warms, the length of the snow-covered season will decrease, implying an increase in rain on bare ground. A next step is to make further use of the database compiled from the ASOS sites to provide comprehensive assessment of changes in rain on snow events.

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