A Comparison of Arctic Cyclones between Periods of Low and High Forecast Skill of the Synoptic-scale Flow over the Arctic

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Motivation

- Arctic cyclones (ACs) are synoptic-scale cyclones that may originate within the Arctic or move into the Arctic from lower latitudes (e.g., Crawford and Serreze 2016)

- ACs may be associated with strong surface winds and poleward advection of warm, moist air, contributing to Arctic sea-ice loss (e.g., Zhang et al. 2013)

- Heavy precipitation, strong surface winds, and large waves accompanying ACs may pose hazards to ships navigating through open passageways in the Arctic Ocean

Motivation

- Yamagami et al. (2018a,b) show that forecast skill for strong Arctic cyclones can be low
  - Accurate forecasts of the Great Arctic Cyclone of August 2012 extend only out to 2–3 day lead time prior to peak intensity
- Forecast skill of the synoptic-scale flow over the Arctic may be low at times relative to climatology
- It is anticipated that low forecast skill of the synoptic-scale flow over the Arctic may be attributed in part to low forecast skill of ACs

Purpose

- Investigate whether there are differences in the frequency, location, intensity, seasonality, and associated synoptic-scale flow patterns of ACs between periods of low and high forecast skill of the synoptic-scale flow over the Arctic

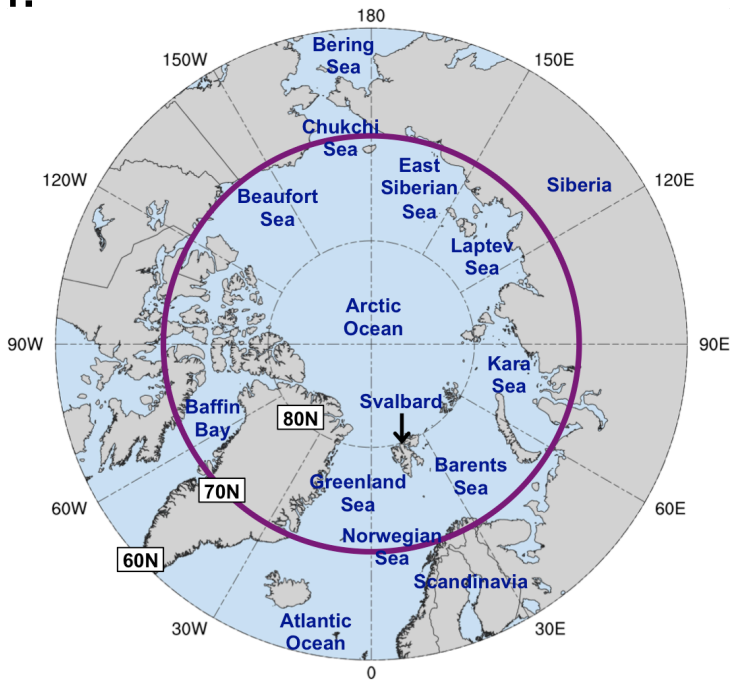
Data and Methods: Arctic Cyclone Identification

- Create a 2007–2017 AC climatology
- Obtain cyclone tracks from 1° ERA-Interim cyclone climatology prepared by Sprenger et al. (2017)
- ACs are deemed cyclones that last ≥ 2 d and spend at least some portion of their lifetimes in the Arctic (>70°N)

Data and Methods: Forecast Skill Evaluation

- Calculate standardized anomaly of ensemble forecast spread of 500-hPa geopotential height (σ_{anom}) and determine area-weighted average of σ_{anom} over the Arctic (≥70°N)

- Utilize forecasts initialized at 0000 UTC during 2007–2017 and valid at day 5 from:
  - 11-member GEFS reforecast dataset v2 (Hamill et al. 2013)
  - 51-member ECMWF Ensemble Prediction System (Buizza et al. 2007)



Data and Methods: Forecast Skill Evaluation

- At each grid point (i), day of the year (d), and forecast lead time (f), $\boldsymbol{\sigma}_{\mathbf{anom}}$ is calculated following Torn (2017) as:

$$\boldsymbol{\sigma}_{anom}(i,d,f) = \frac{\sigma(i,d,f) - \sigma_{mean}(i,d,f)}{\sigma_{stdv}(i,d,f)}$$

$\boldsymbol{\sigma}$ = raw ensemble spread

$\boldsymbol{\sigma}_{\mathbf{mean}}$ = climatological mean ensemble spread

$\boldsymbol{\sigma}_{\mathbf{stdv}}$ = climatological standard deviation of ensemble spread

- σ_{mean} and σ_{stdv} are calculated for 1985–2017 period from the GEFS reforecast dataset v2

Data and Methods: Forecast Skill Evaluation

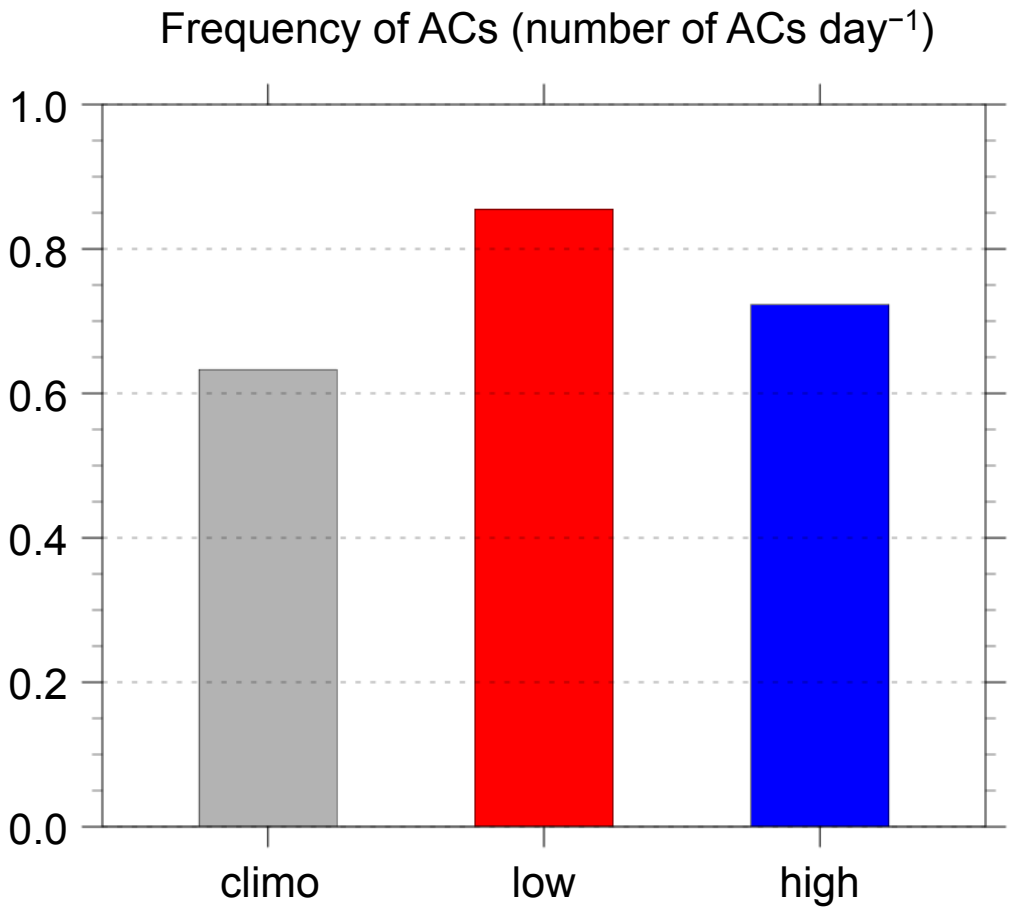
- Forecast days valid at day 5 associated with the top and bottom 10% of the area-weighted average of σ_{anom} in both the GEFS and ECMWF EPS are referred to as **low and high skill days,** respectively

- Time periods beginning five days prior to day 5 (i.e., day 0) through day 5 are referred to as **low and high skill periods**

- ACs that exist in the Arctic (>70°N) at any time within the low and high skill periods are identified

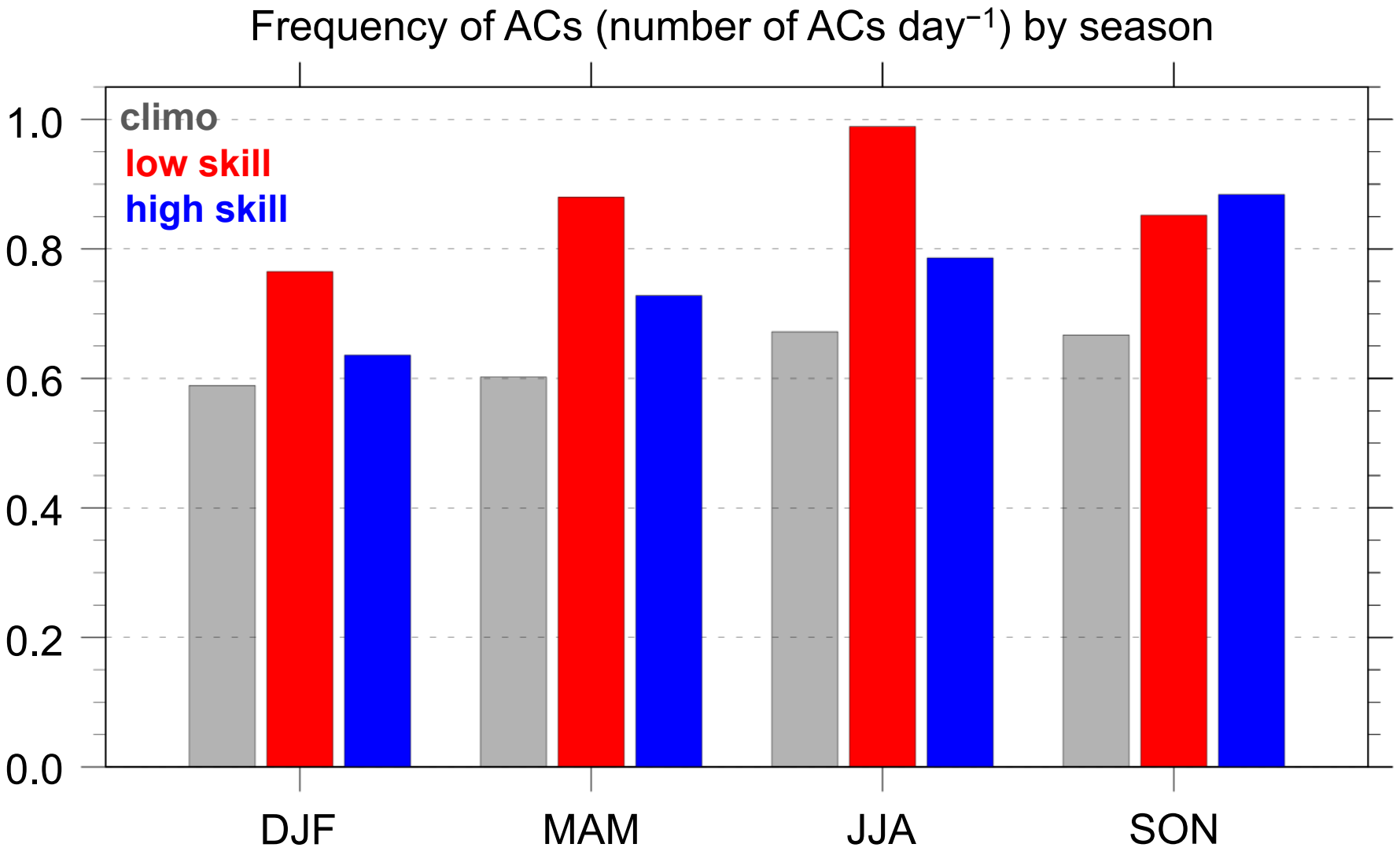
Number and Frequency of ACs

Period	Number of days in period	Number of ACs in period
Climo	4018	2542
Low skill	469	401
High skill	477	345



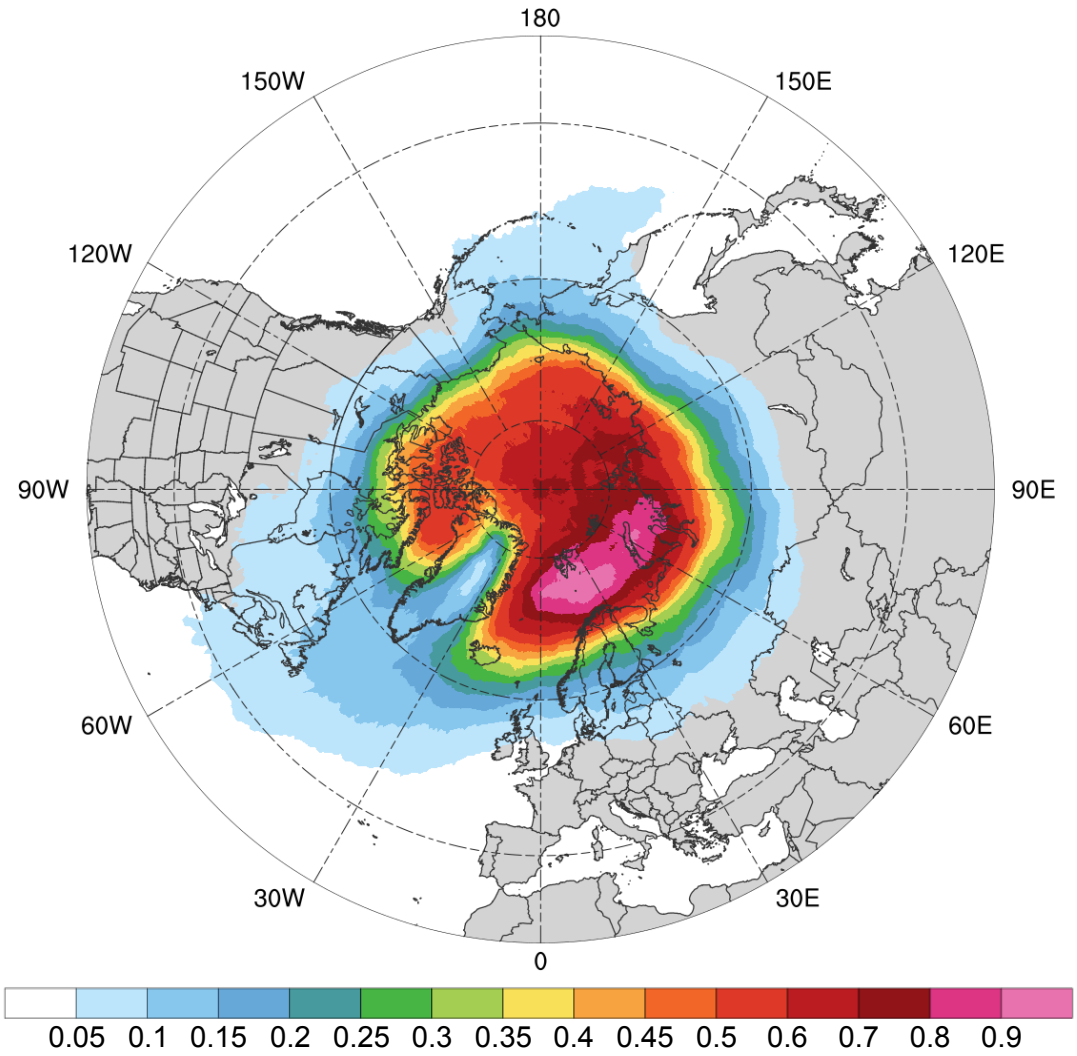
Frequency = number of ACs within period / number of days within period

Frequency of ACs by Season



Frequency = number of ACs within period / number of days within period

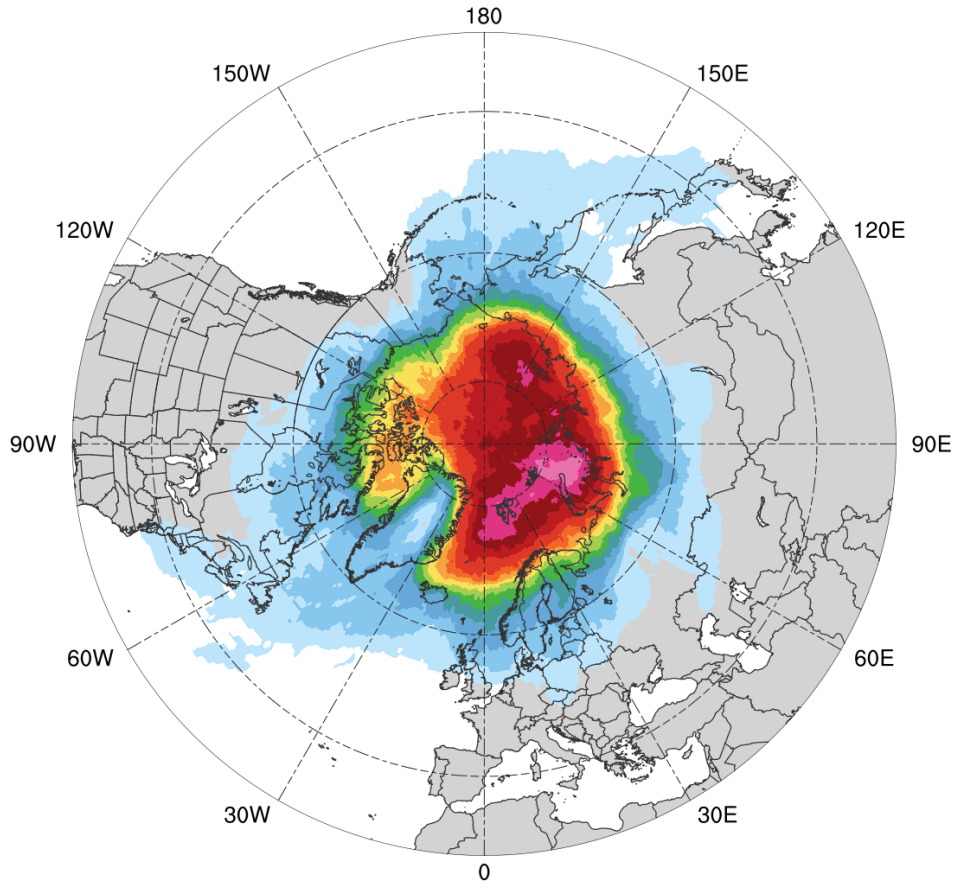
Normalized AC Track Density



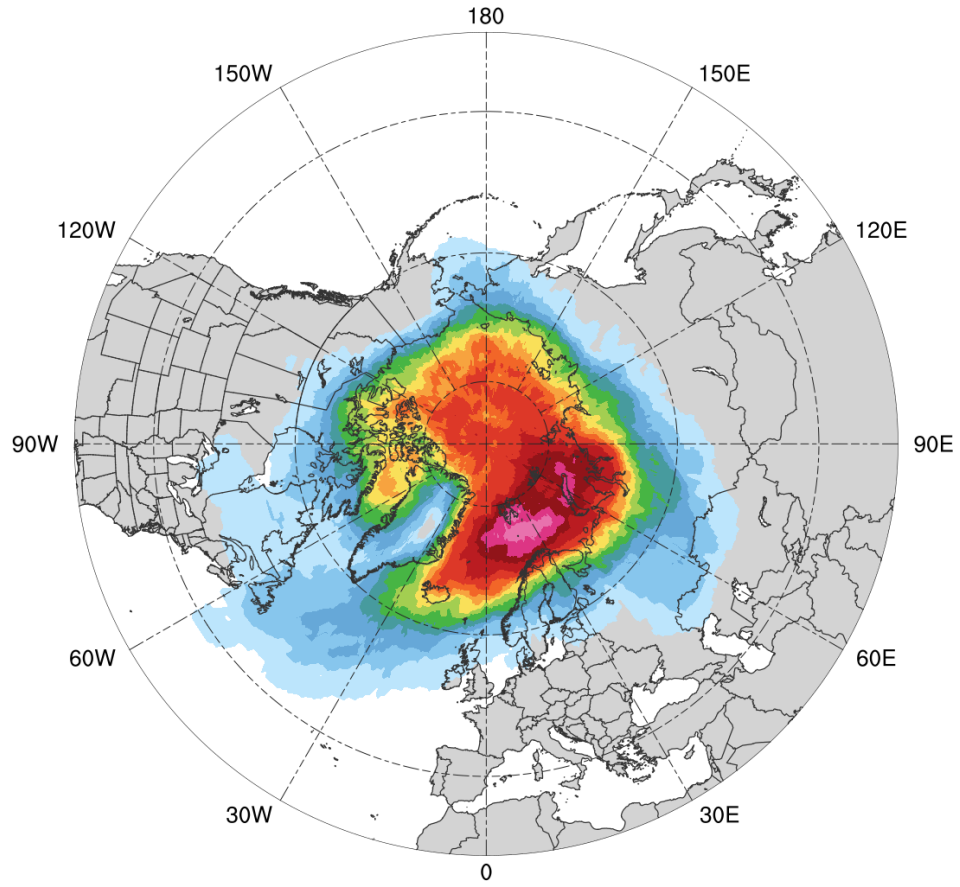
Total number of ACs within 500 km of a grid point, normalized by maximum value

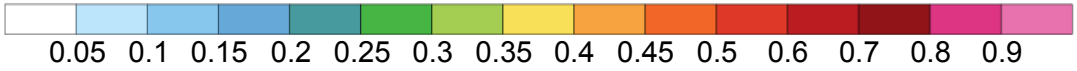
Normalized AC Track Density

Low skill (N = 401)



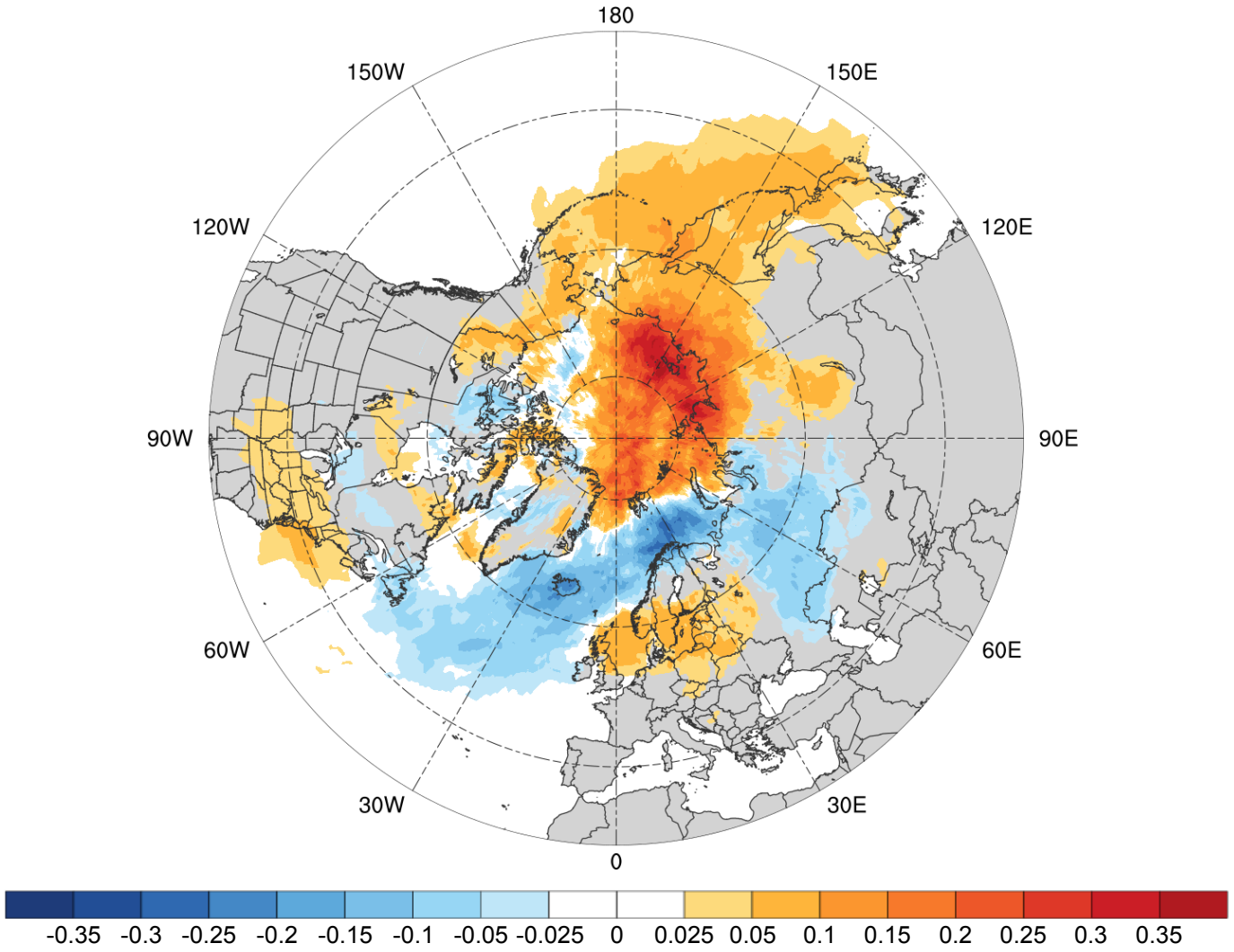
High skill (N = 345)





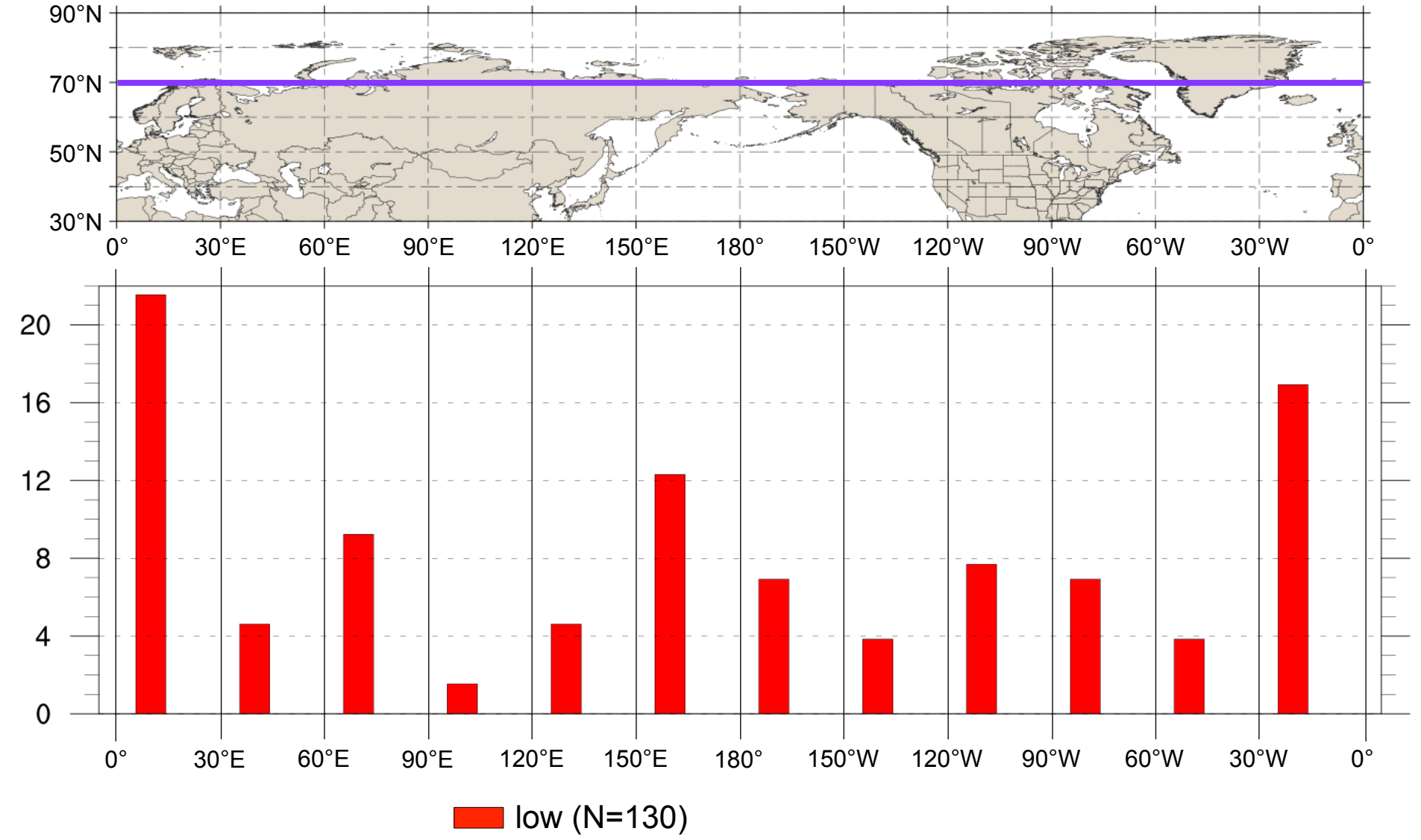
Total number of ACs within 500 km of a grid point, normalized by maximum value

Normalized AC Track Density Differences



Preferred Longitudinal Corridors (DJF)

Distribution of longitude of Arctic cyclones at first time in Arctic (>70°N; % per longitudinal bin) during DJF



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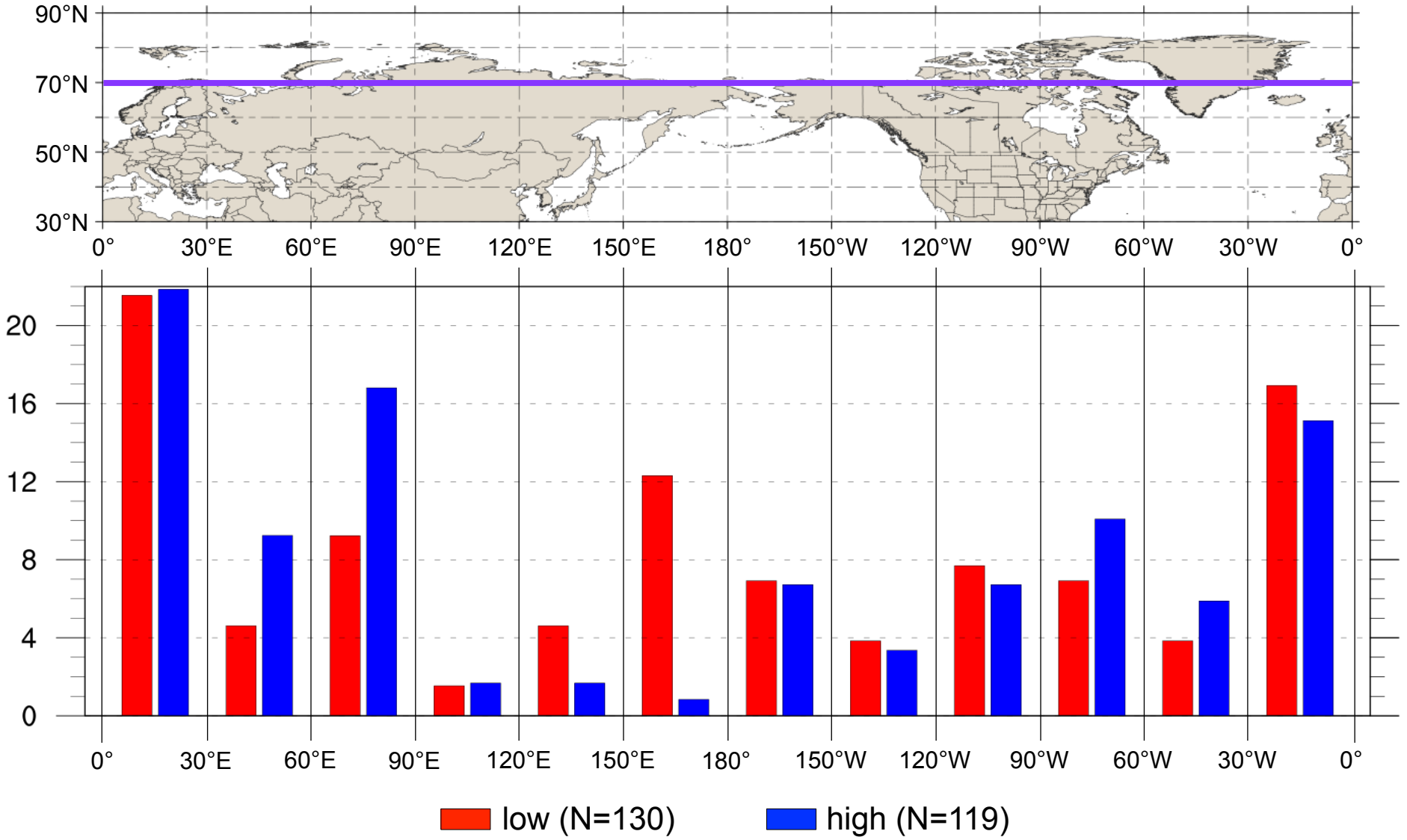
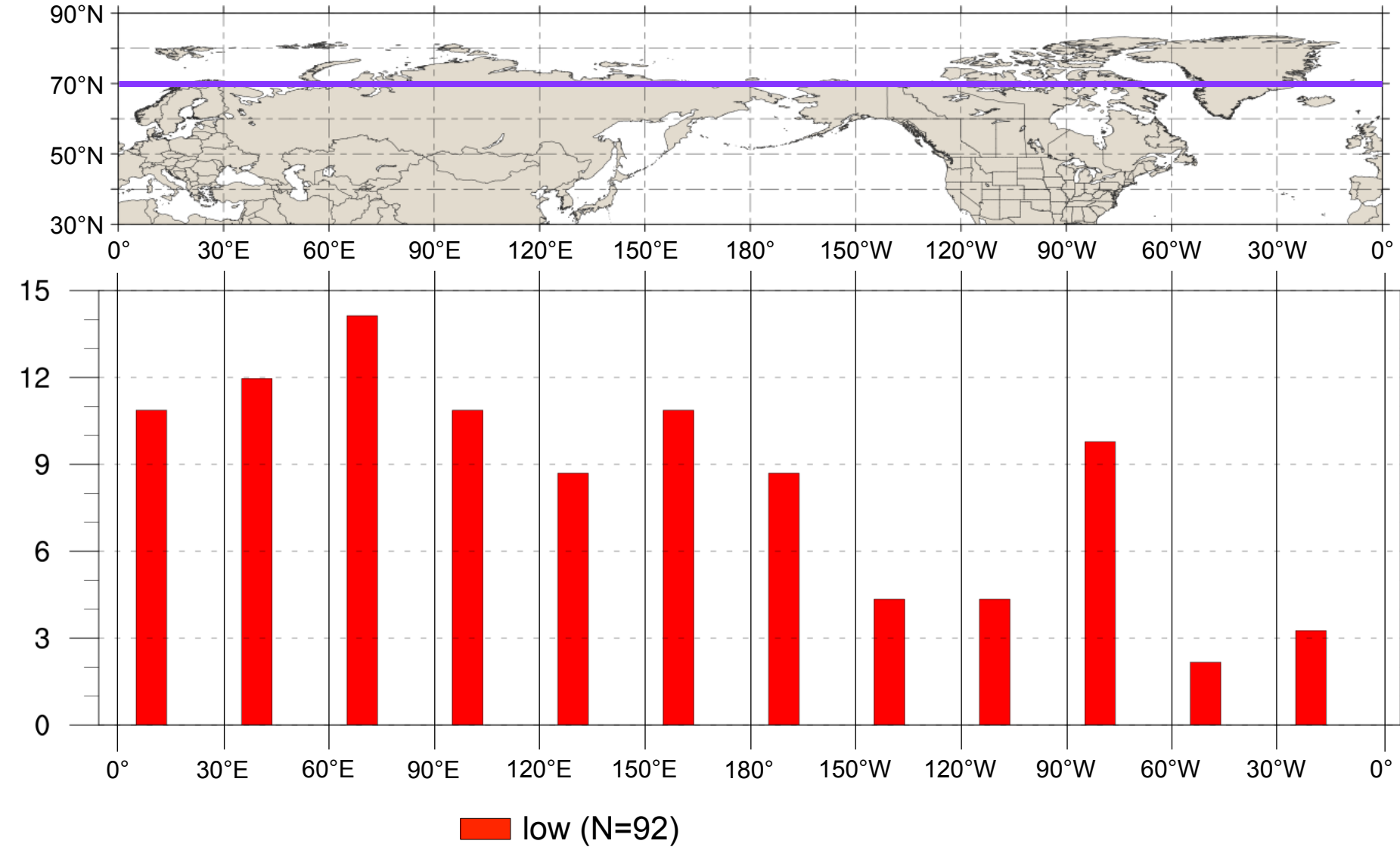


Preferred Longitudinal Corridors (JJA)

Distribution of longitude of Arctic cyclones at first time in Arctic (>70°N; % per longitudinal bin) during JJA



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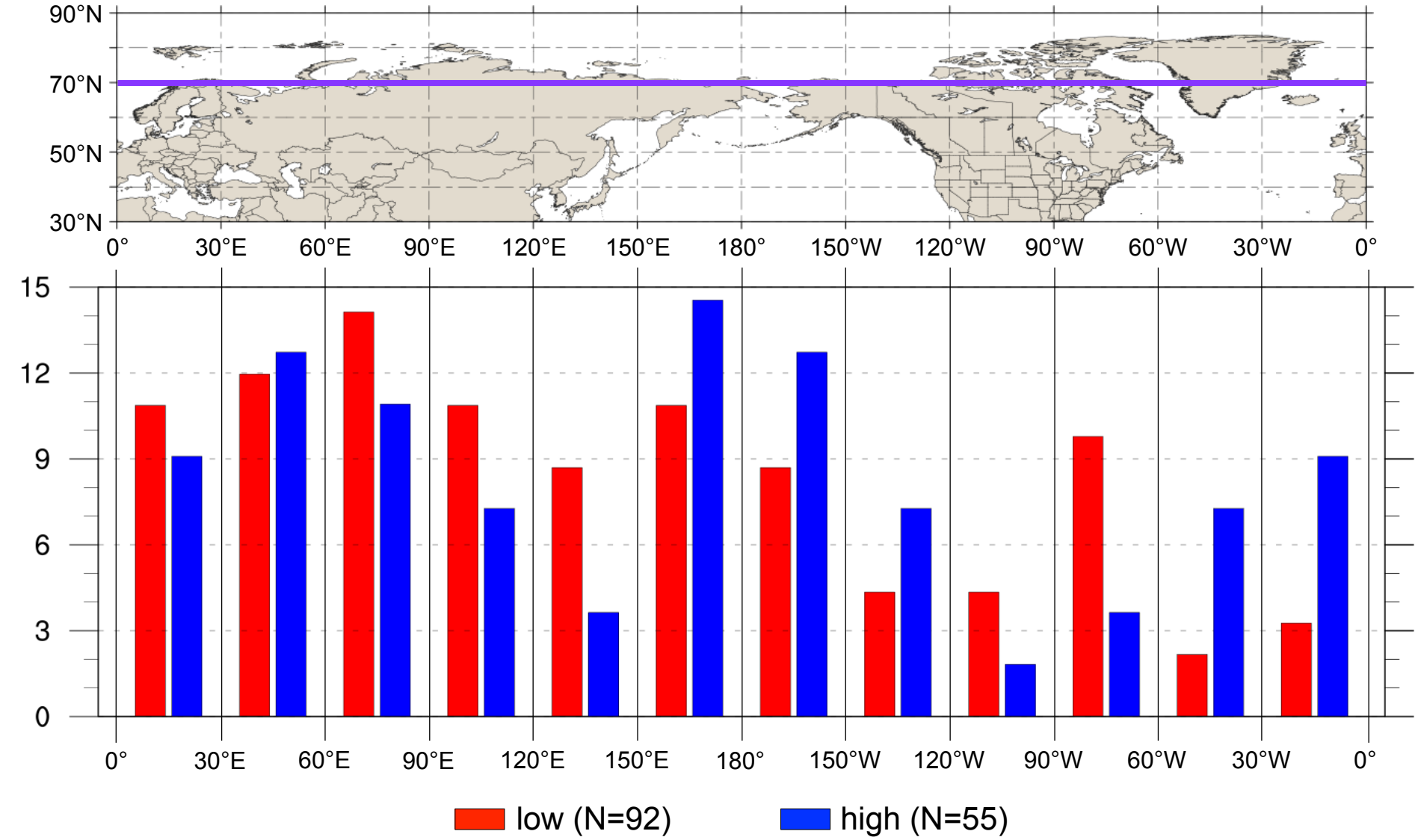
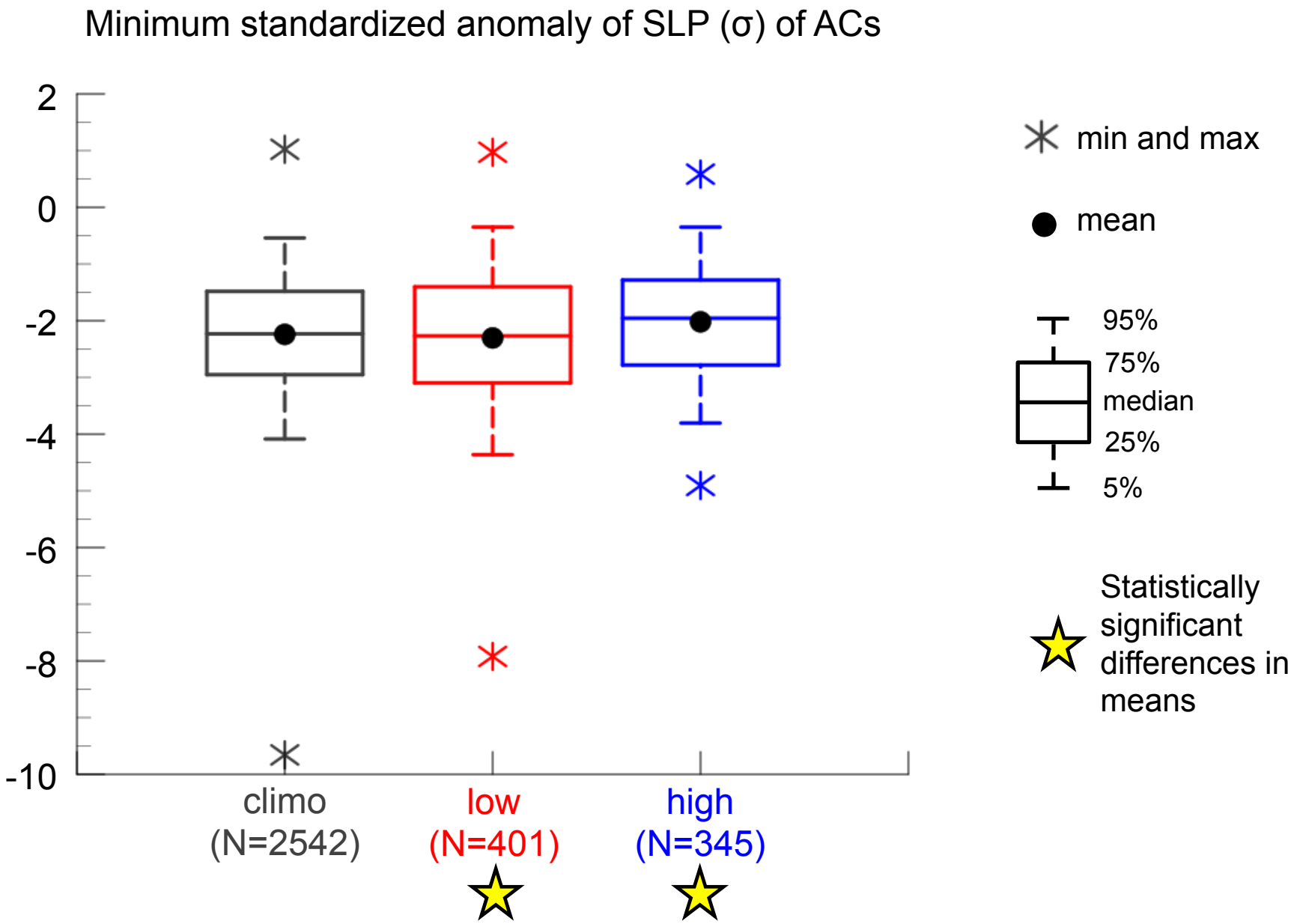
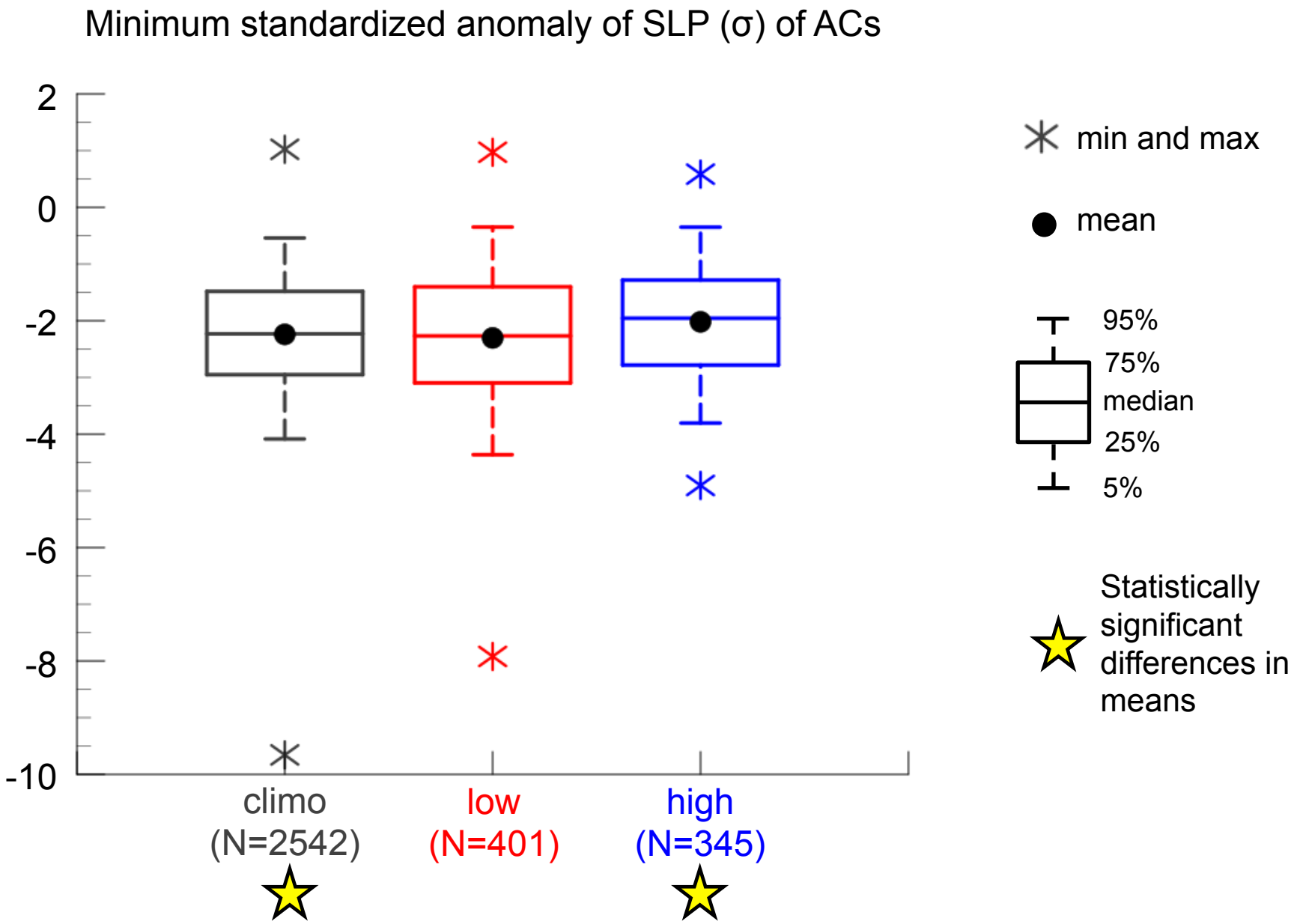


Intensity: Minimum Standardized Anomaly of SLP



Intensity: Minimum Standardized Anomaly of SLP



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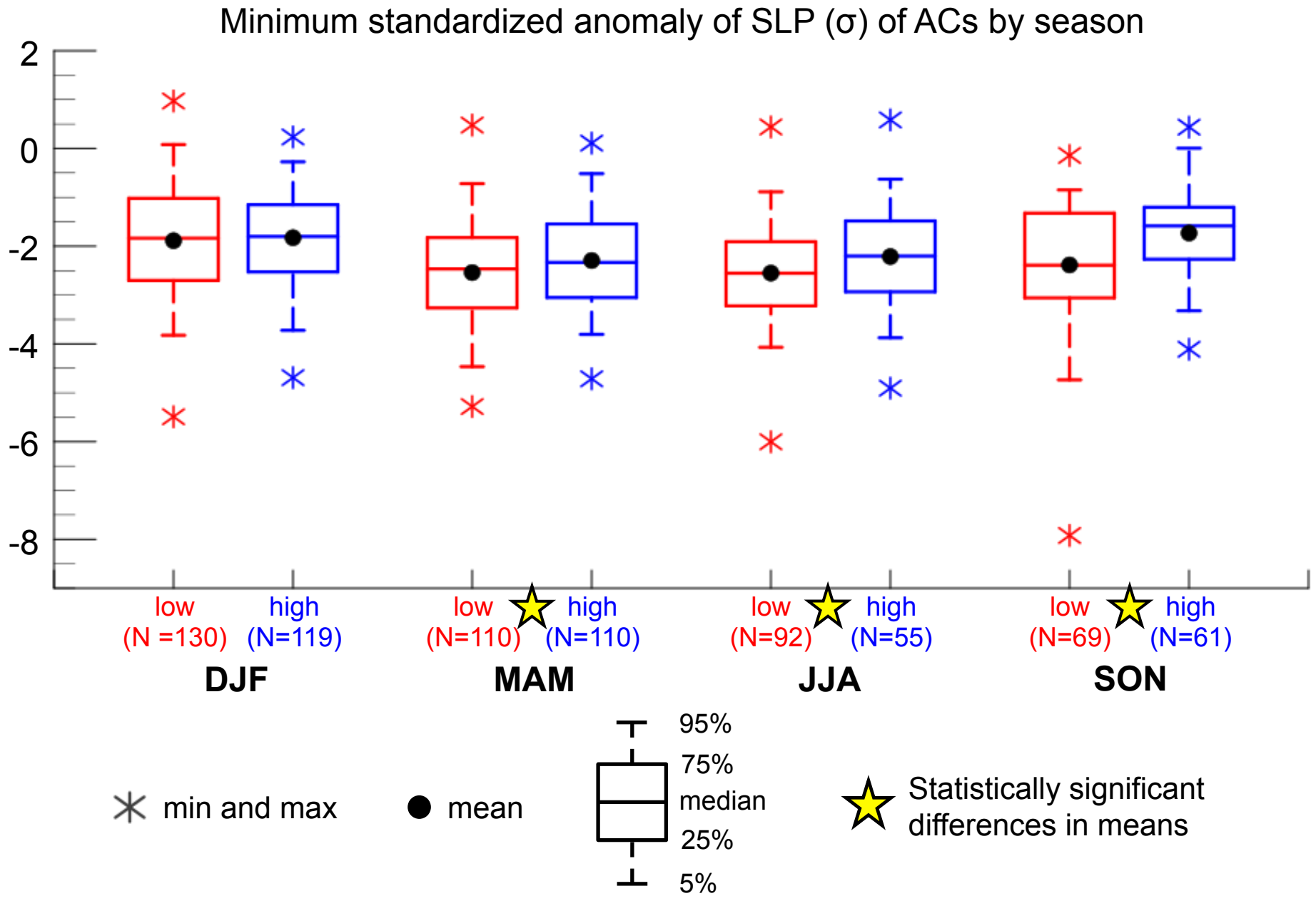
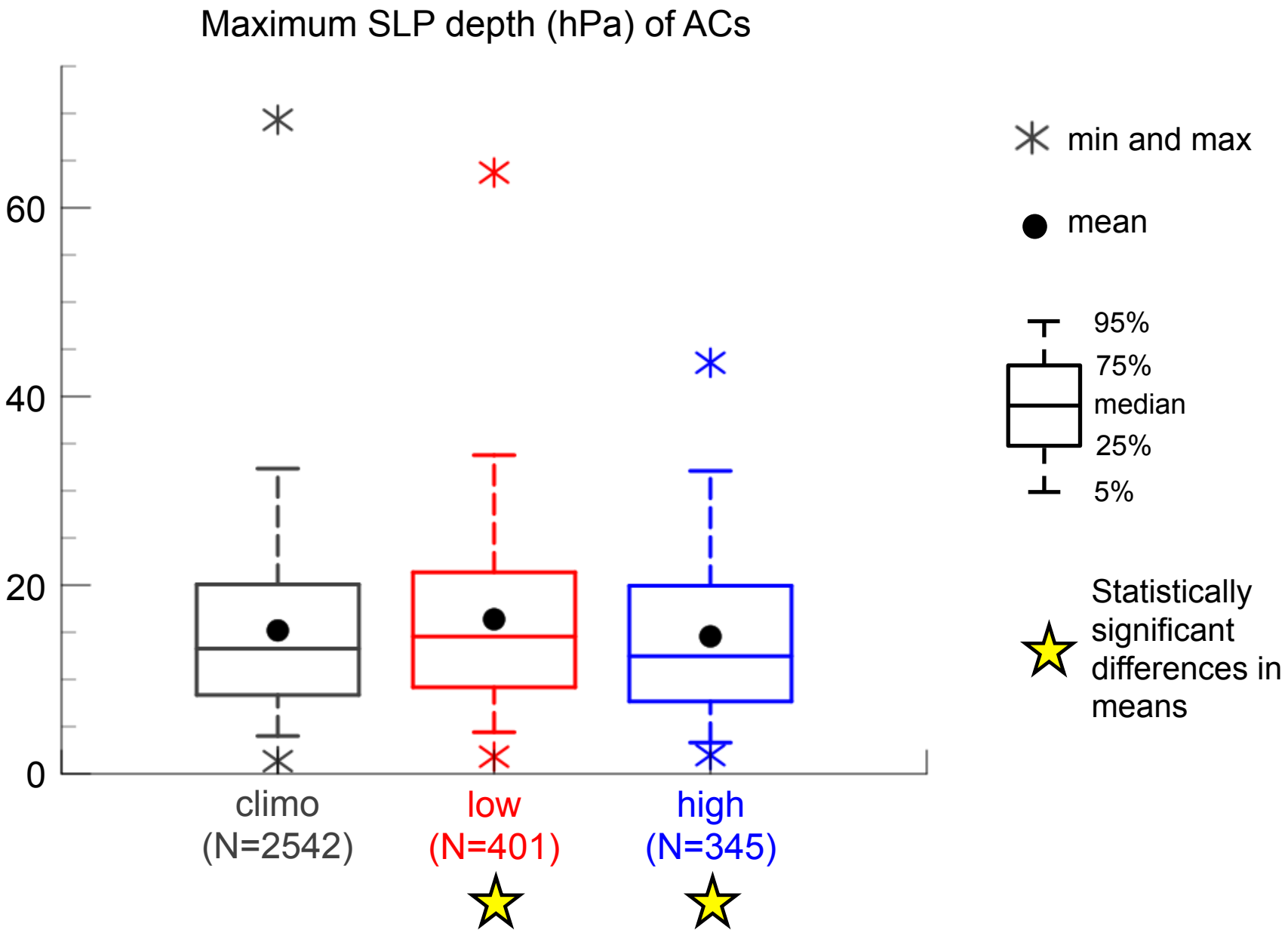
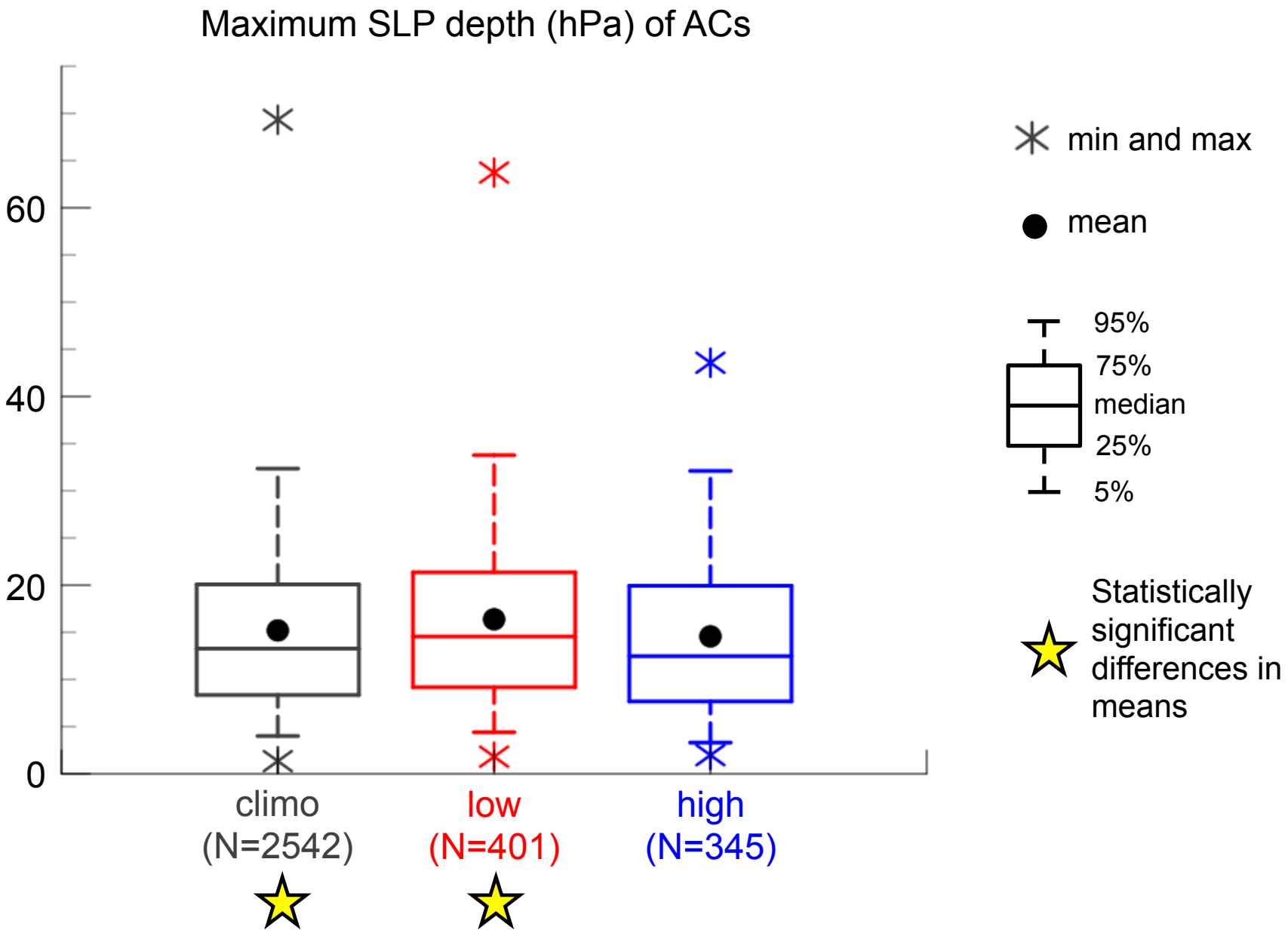


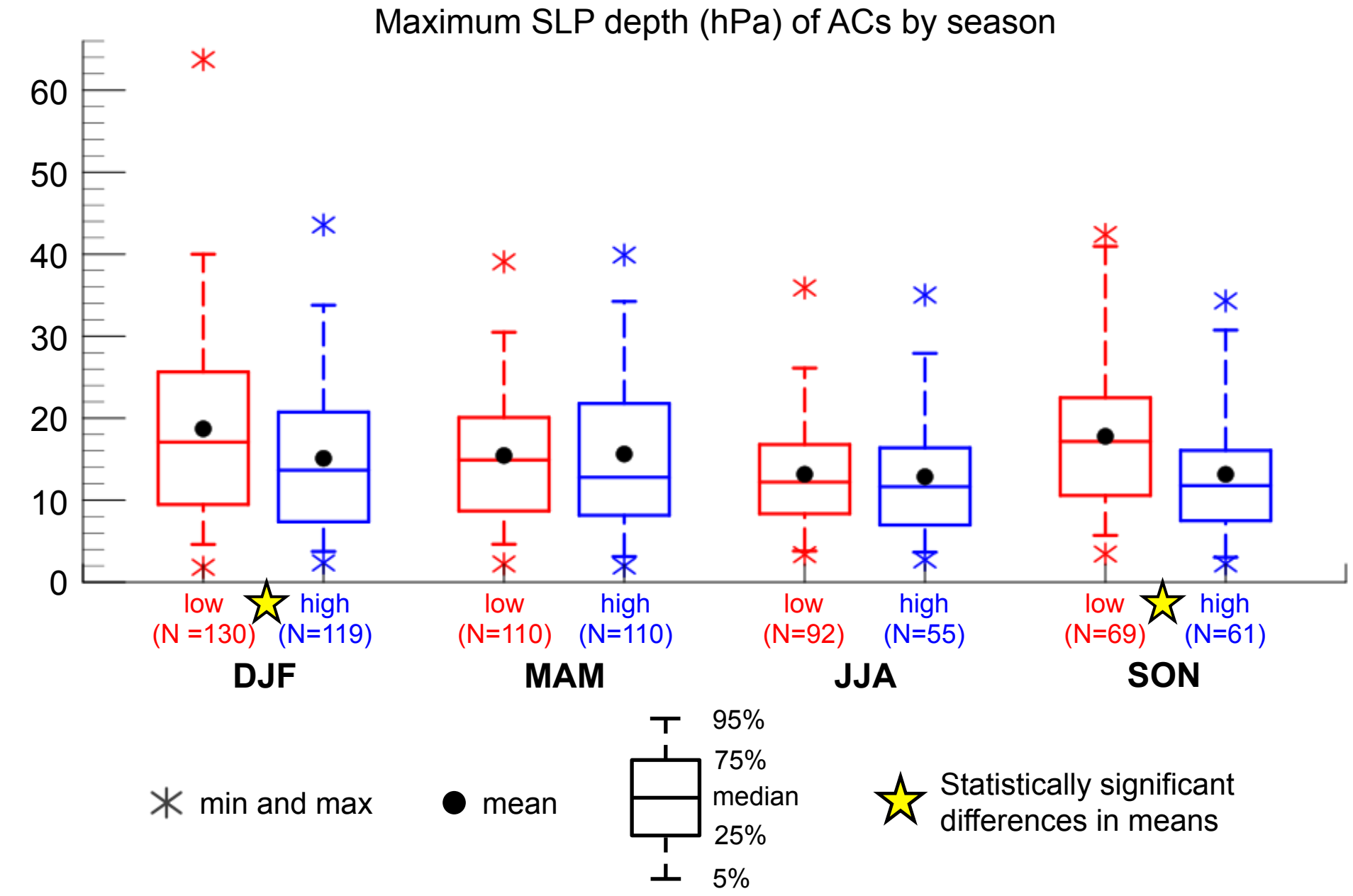
Intensity: Maximum SLP Depth



Intensity: Maximum SLP Depth

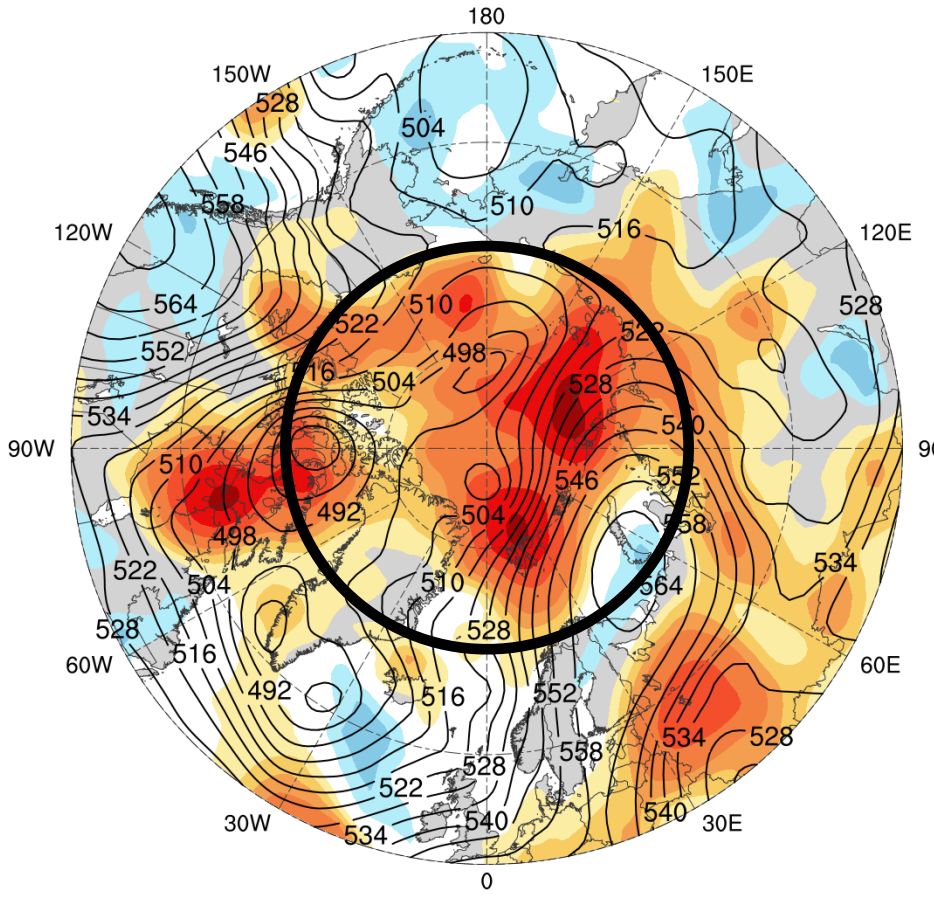


Intensity: Maximum SLP Depth

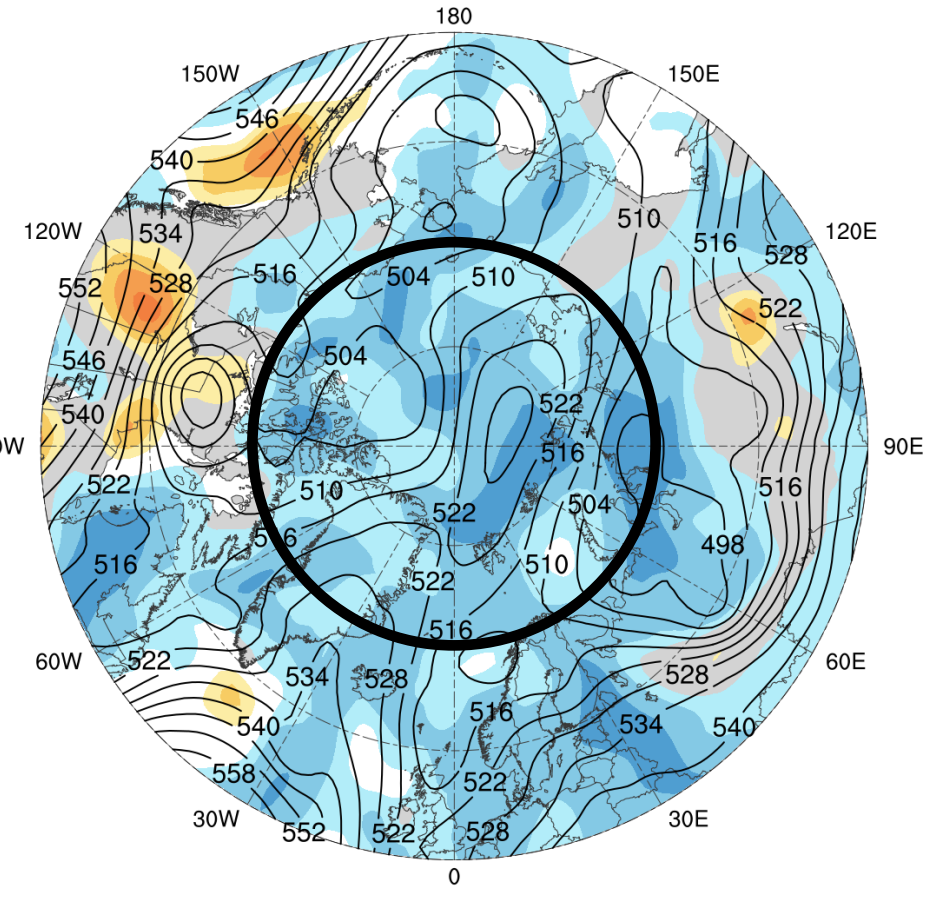


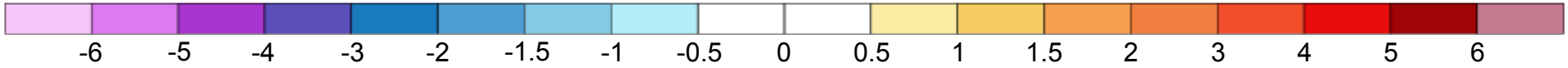
Low and High Skill Example

Low skill (valid 0000 UTC 1 Jan 2016)



High skill (valid 0000 UTC 6 Feb 2009)





Standardized anomaly of ensemble spread of day-5 forecasts of
500-hPa geopotential height (shading) from GEFS reforecast dataset v2;
500-hPa geopotential height (dam, black) from ERA-Interim

Flow Amplitude

- Calculate absolute value of standardized anomaly of 500-hPa v-wind (hereafter $\boldsymbol{\sigma_v}$) using ERA-Interim

- Calculate area-weighted average of $\boldsymbol{\sigma_v}$ over the Arctic (≥70°N) for low and high skill periods

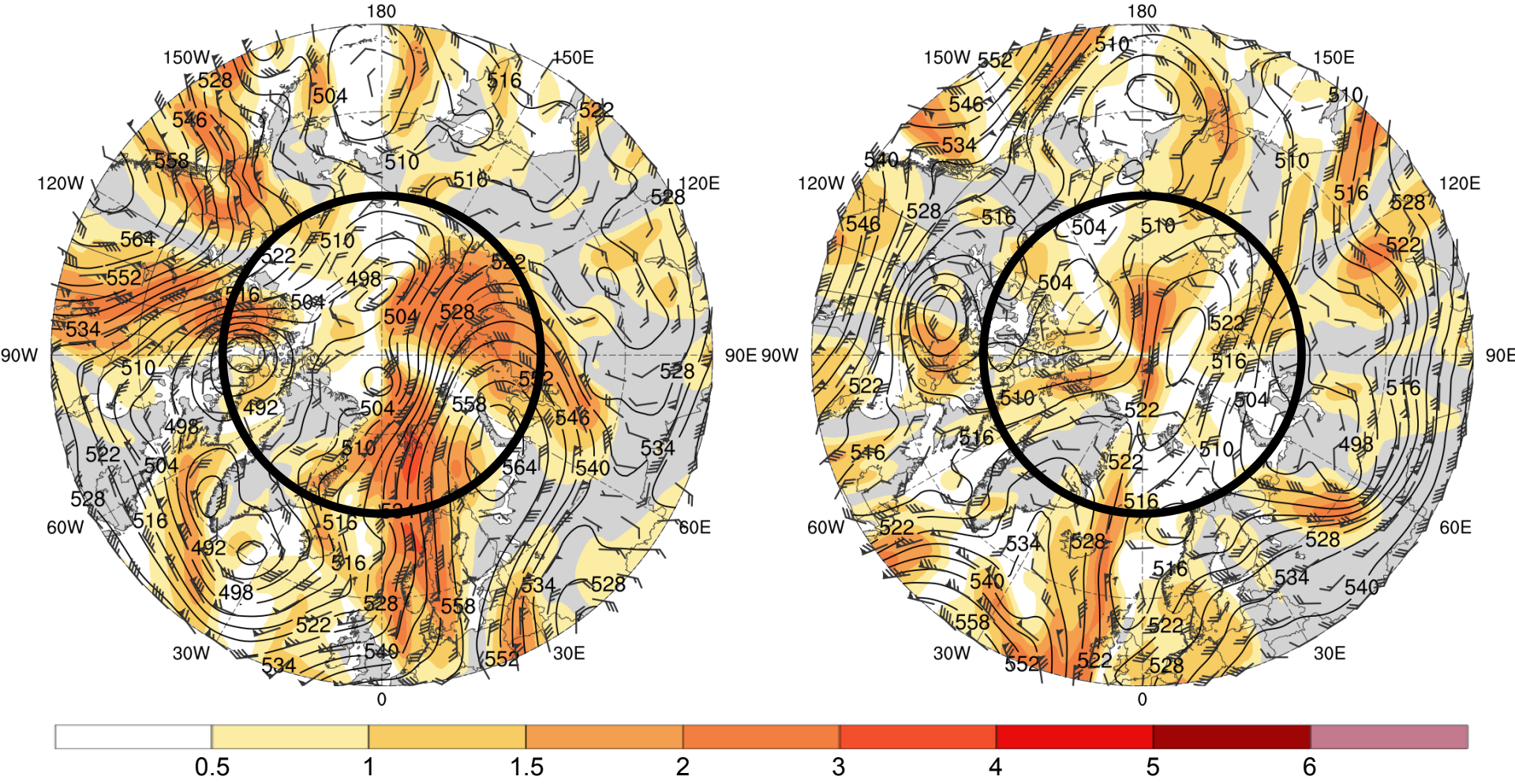
Flow Amplitude

Low skill

0000 UTC 1 Jan 2016

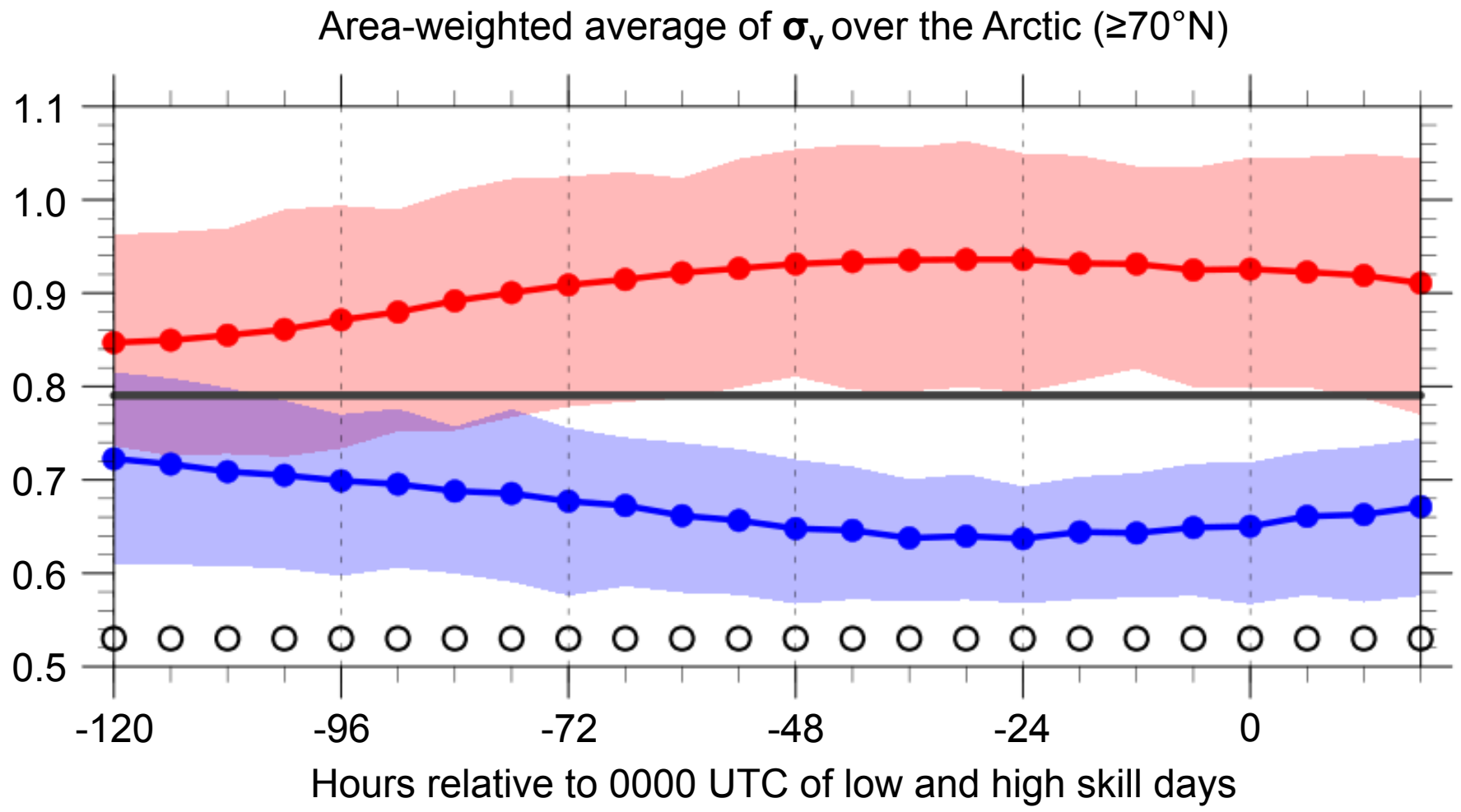
High skill

0000 UTC 6 Feb 2009



500-hPa geopotential height (dam), wind (flags and barbs, m s^{-1}), and σ_v (shading) from ERA-Interim

Flow Amplitude



Conclusions

- Arctic cyclone frequency is higher for low skill periods compared to high skill periods
- Arctic cyclone frequency is highest during JJA for low skill periods and highest during SON for high skill periods
- Arctic cyclone frequency is lowest during DJF for both low and high skill periods

Conclusions

- Arctic cyclones during low skill periods more often occur over northern portions of central and eastern Eurasia and much of the adjacent Arctic Ocean relative to Arctic cyclones during high skill periods

- Arctic cyclones during high skill periods more often occur over the northern North Atlantic and the adjacent Norwegian and Barents Seas relative to Arctic cyclones during low skill periods

Conclusions

- Arctic cyclones tend to be stronger during low skill periods compared to high skill periods, especially during SON

- The synoptic-scale flow over the Arctic tends to be significantly more amplified during low skill periods compared to high skill periods

Questions? ***Email: kbiernat@albany.edu***

- Arctic cyclones tend to be stronger during low skill periods compared to high skill periods, especially during SON

- The synoptic-scale flow over the Arctic tends to be significantly more amplified during low skill periods compared to high skill periods

References

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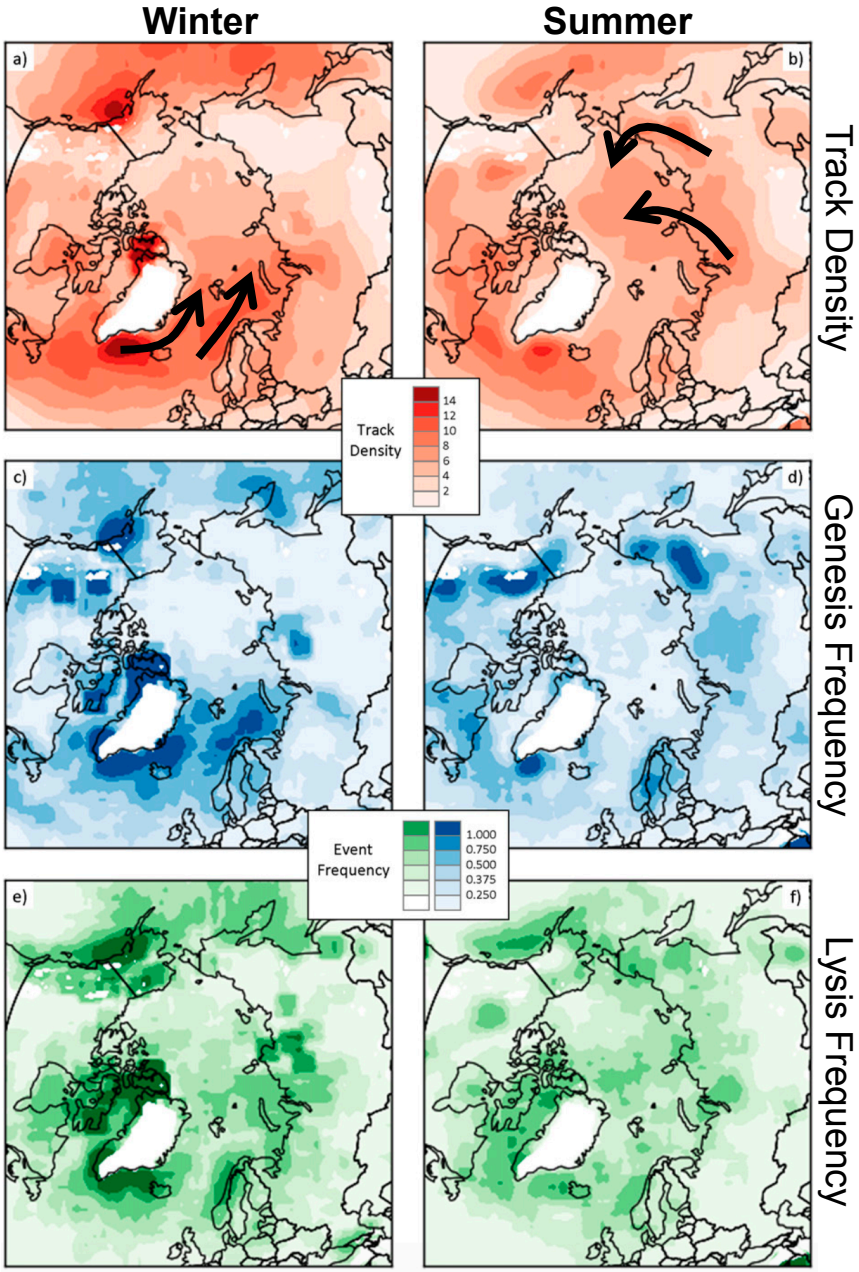
Extra Slides

Background



- Arctic cyclones may originate within and outside of Arctic
- During winter, Arctic cyclones often originate from North Atlantic
- During summer, Arctic cyclones often originate from Eurasia

Figure 3 adapted from Crawford and Serreze (2016)

Background

- Highly-amplified flow may enable cyclones and associated intrusions of warm, moist air to enter the Arctic

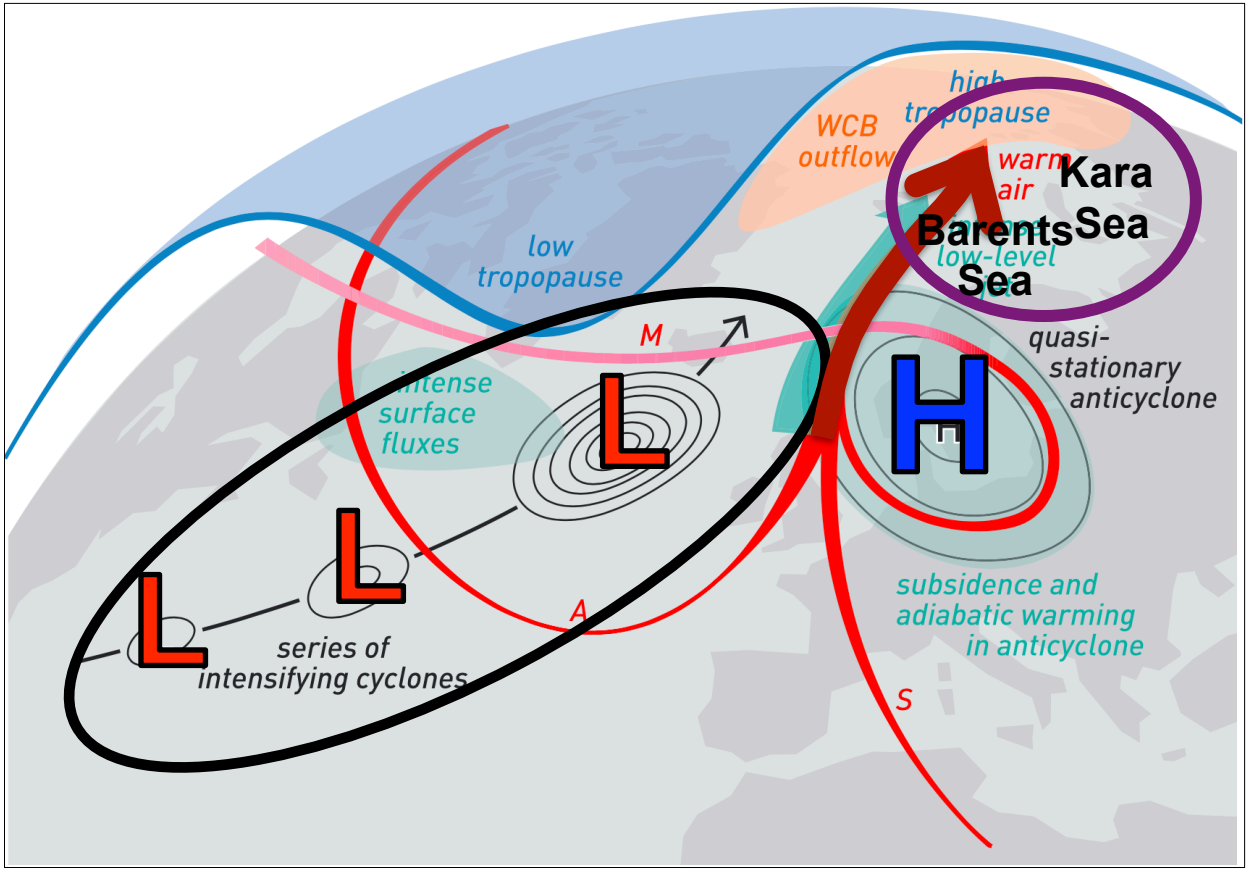
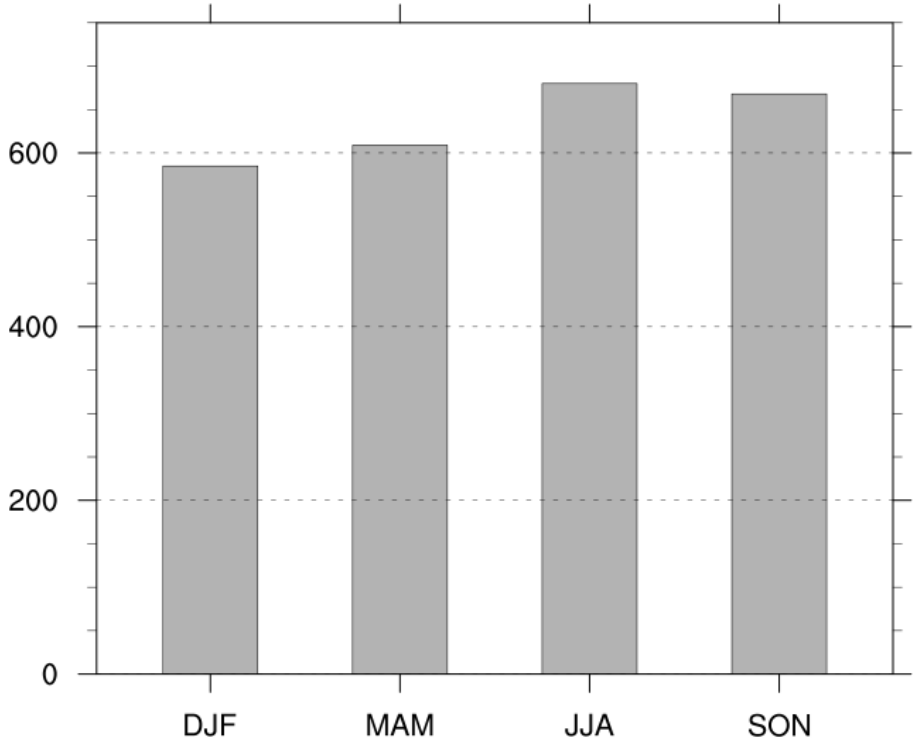


Figure 4 adapted from Binder et al. (2017)

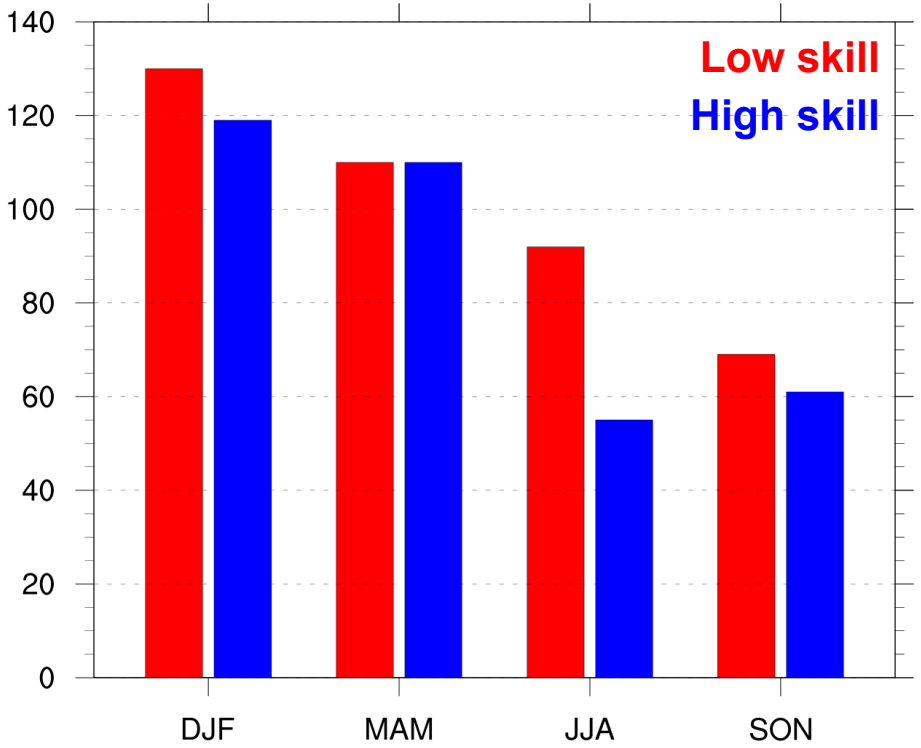
- During late Dec 2015 and early Jan 2016, warm, moist air transported between series of cyclones and blocking anticyclone (Binder et al. 2017)
- More than 30 cm of sea ice thinning in the Barents and Kara Seas occurred during this event

Number of Arctic Cyclones by Season

Number of Arctic cyclones in climatology by season

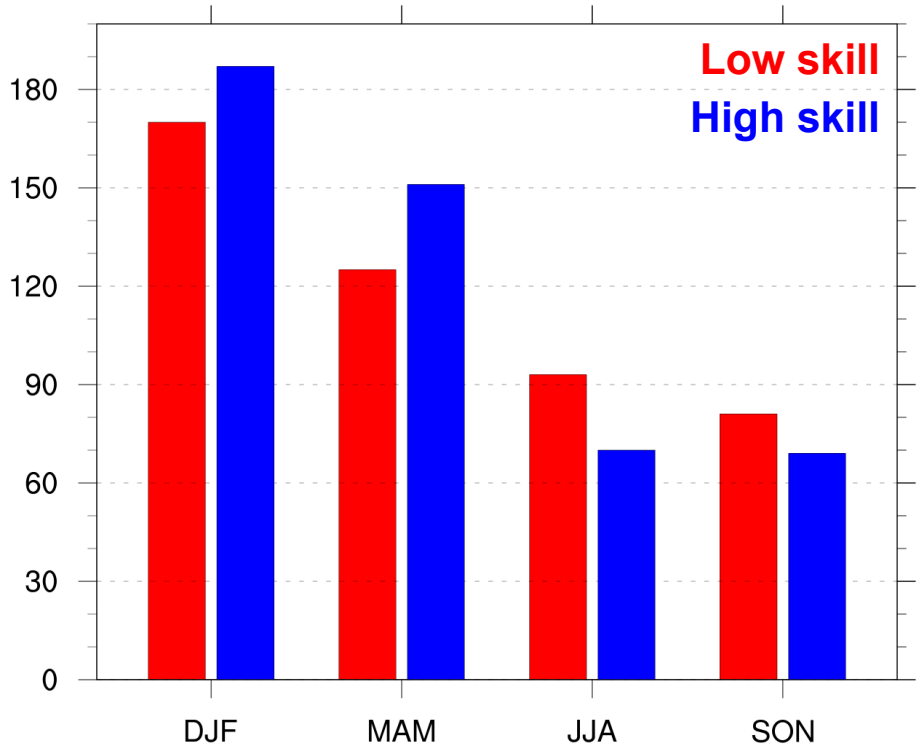


Number of Arctic cyclones in low and high skill periods by season

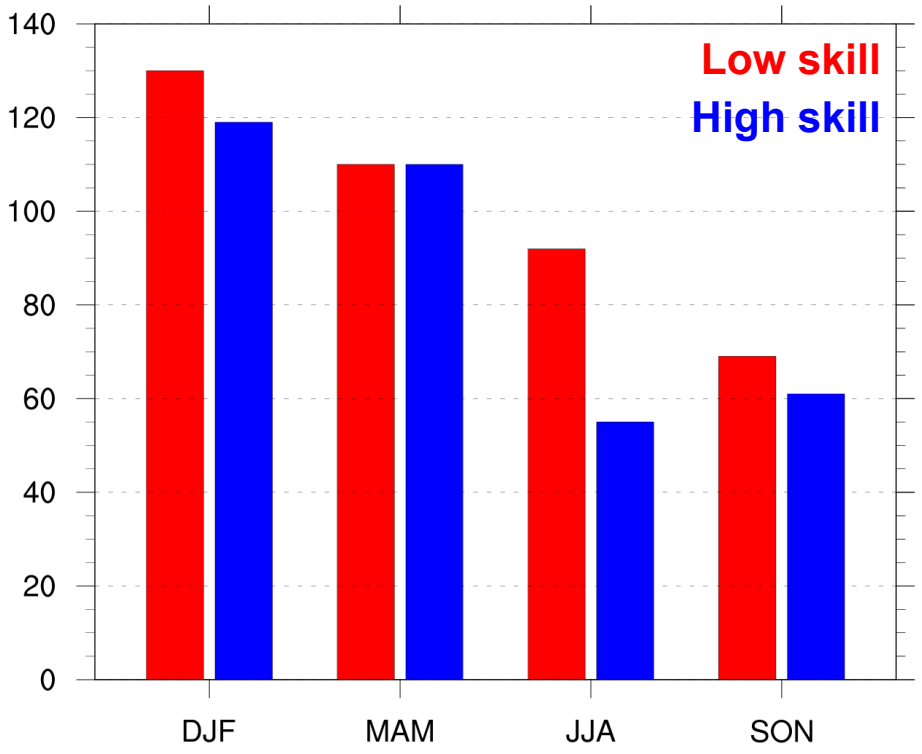


Number of Arctic Cyclones by Season

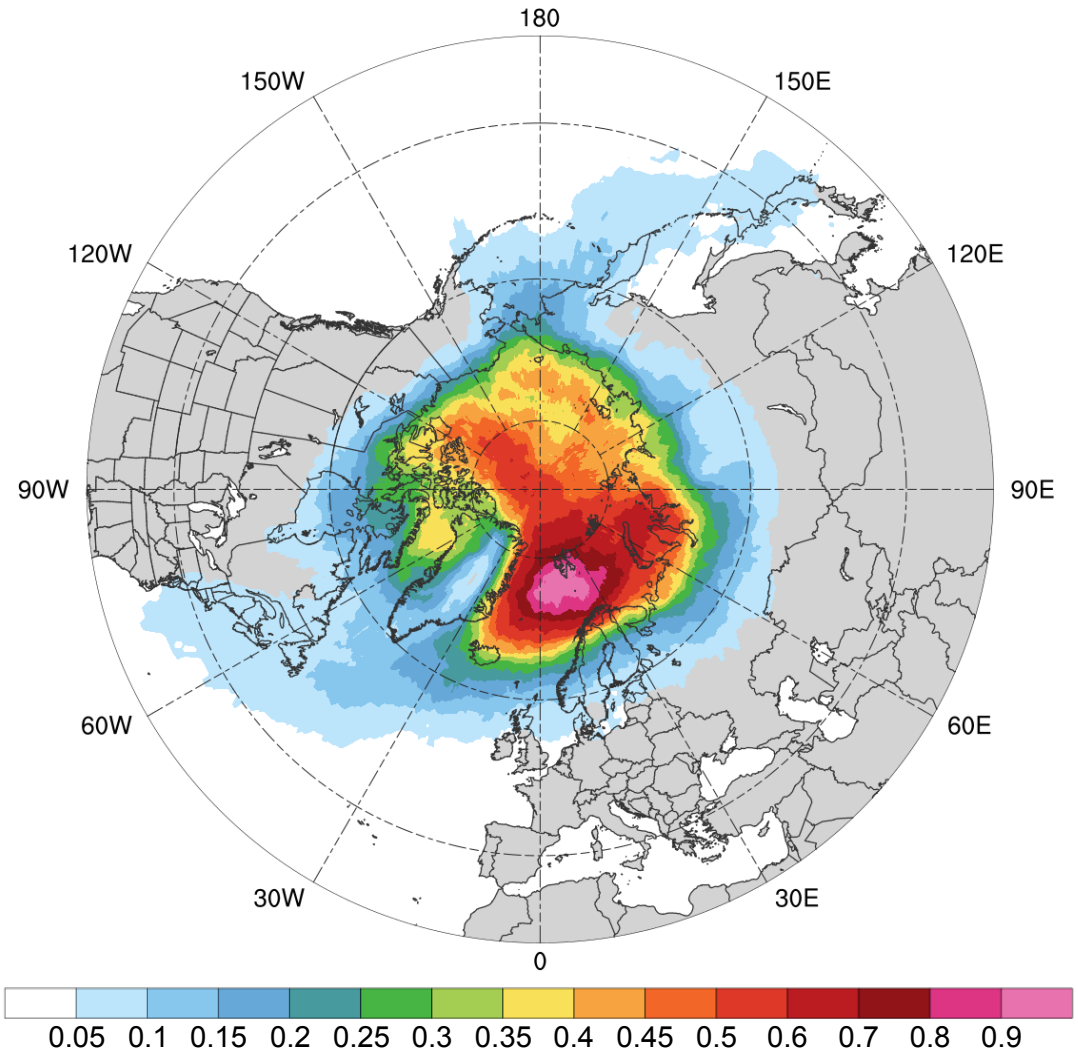
Number of days in low and high skill periods by season



Number of Arctic cyclones in low and high skill periods by season



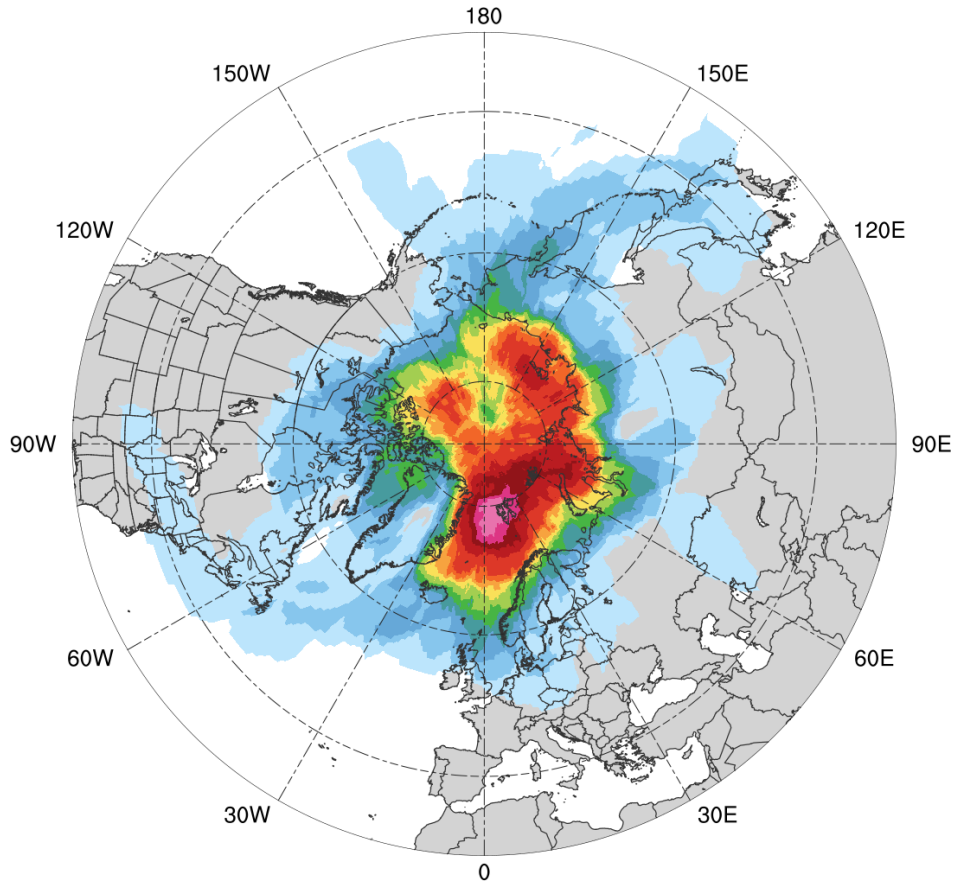
Normalized Track Density (DJF)



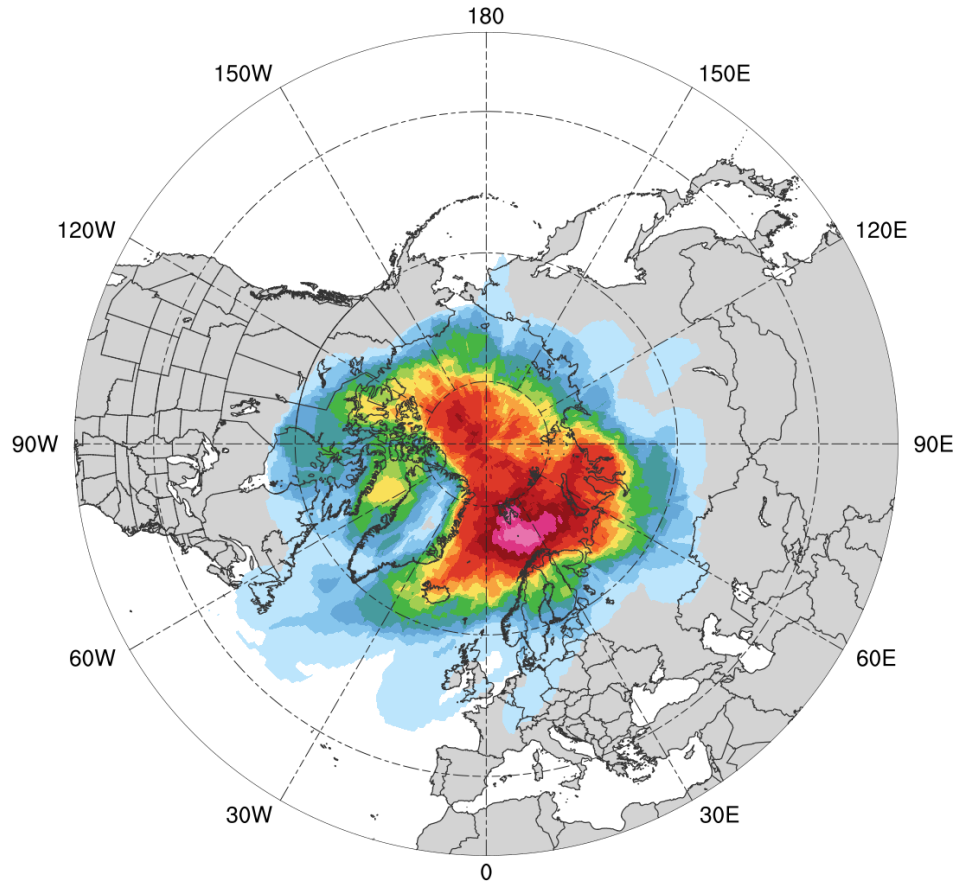
Total number of Arctic cyclones during DJF within 500 km of a grid point, normalized by maximum value

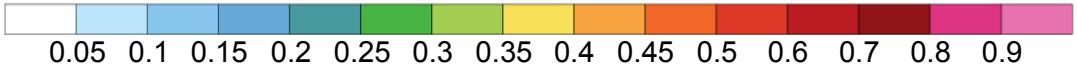
Normalized Track Density (DJF)

Low skill (N = 130)



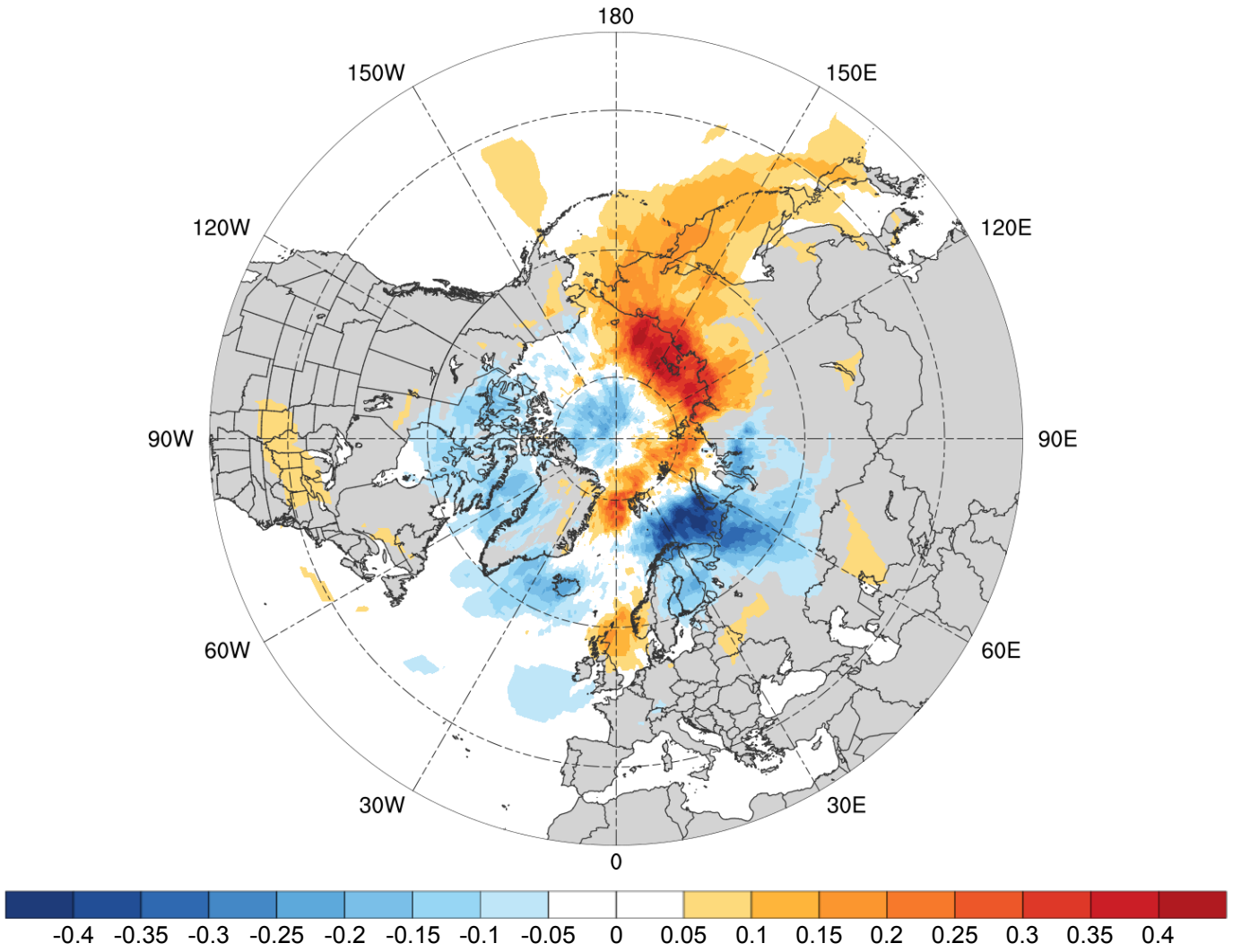
High Skill (N = 119)





Total number of Arctic cyclones within 500 km of a grid point during DJF, normalized by maximum value, for each period

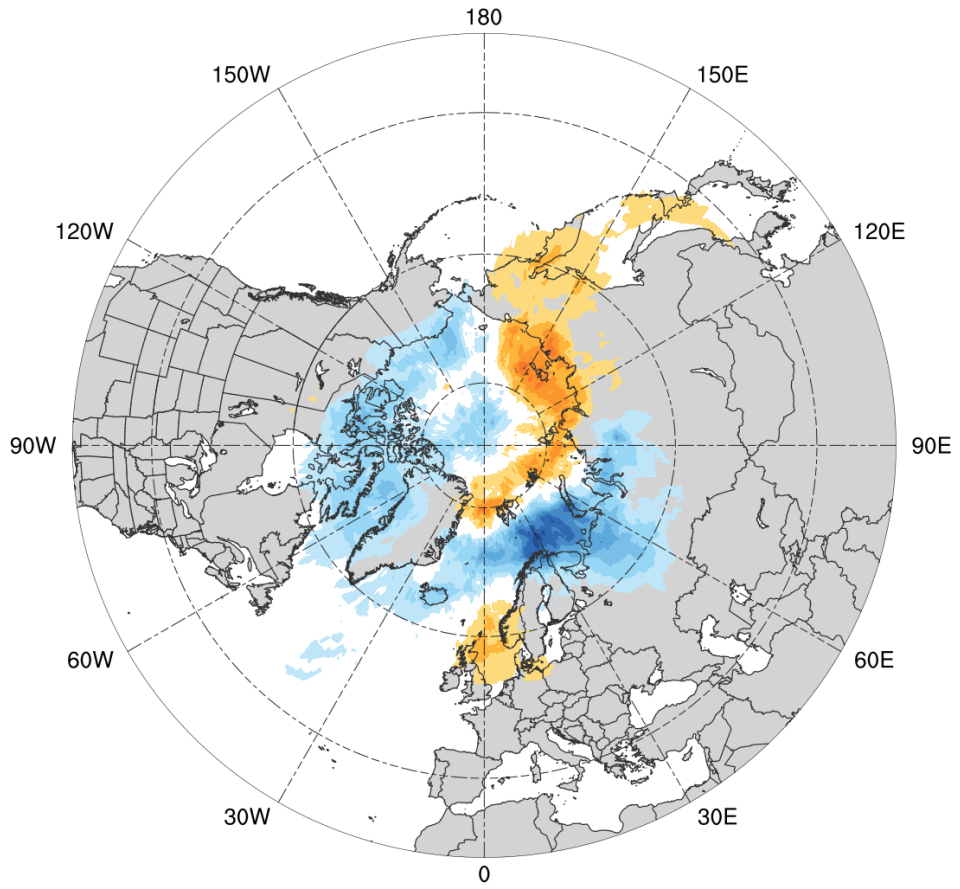
Normalized Track Density Differences (DJF)



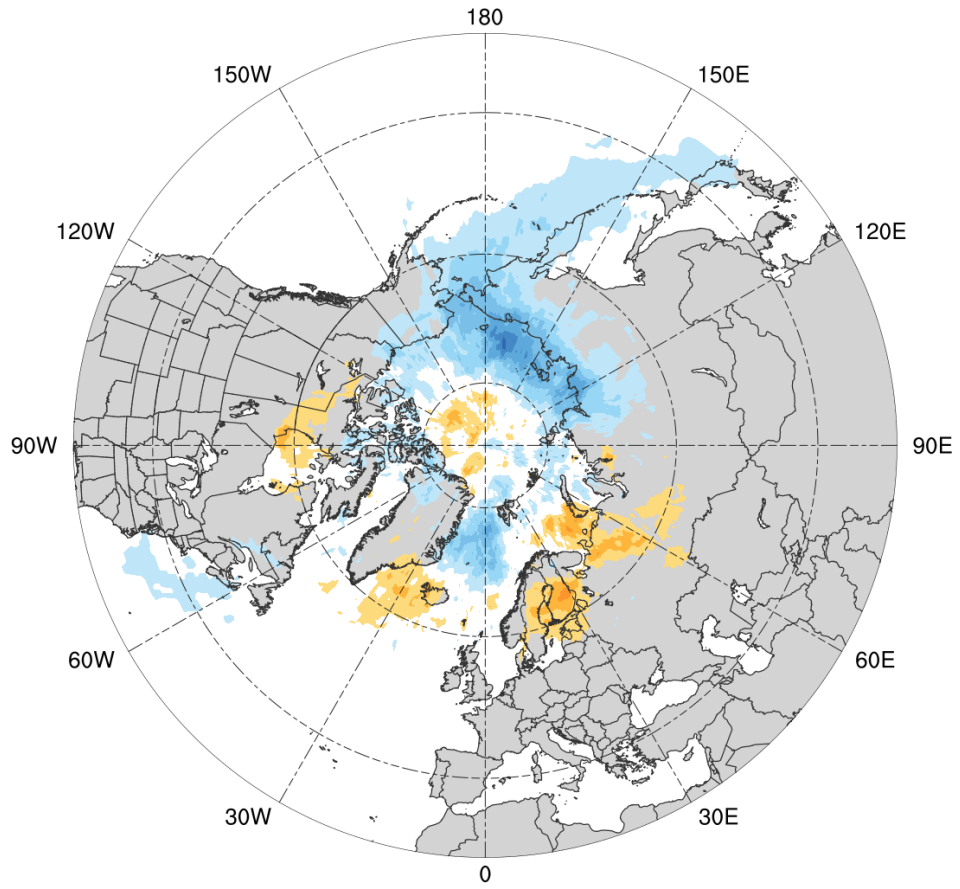
Difference in normalized Arctic cyclone track density during DJF

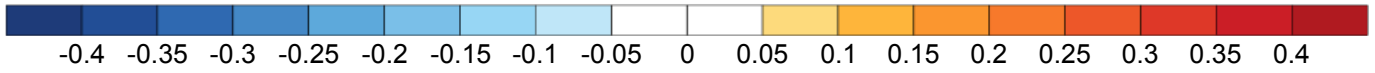
Normalized Track Density Differences (DJF)

Low skill minus climatology



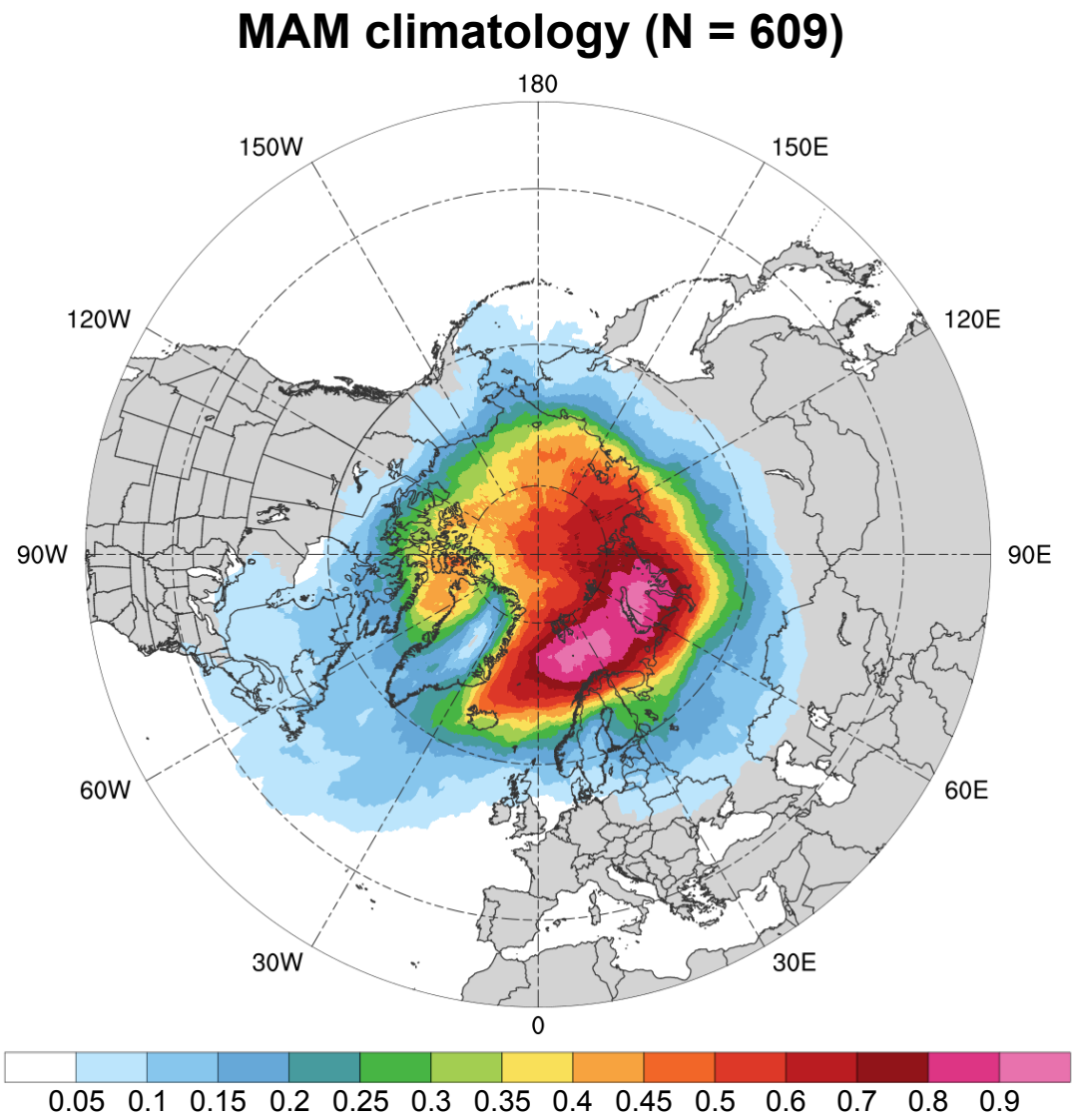
High skill minus climatology





Difference in normalized Arctic cyclone track density during DJF

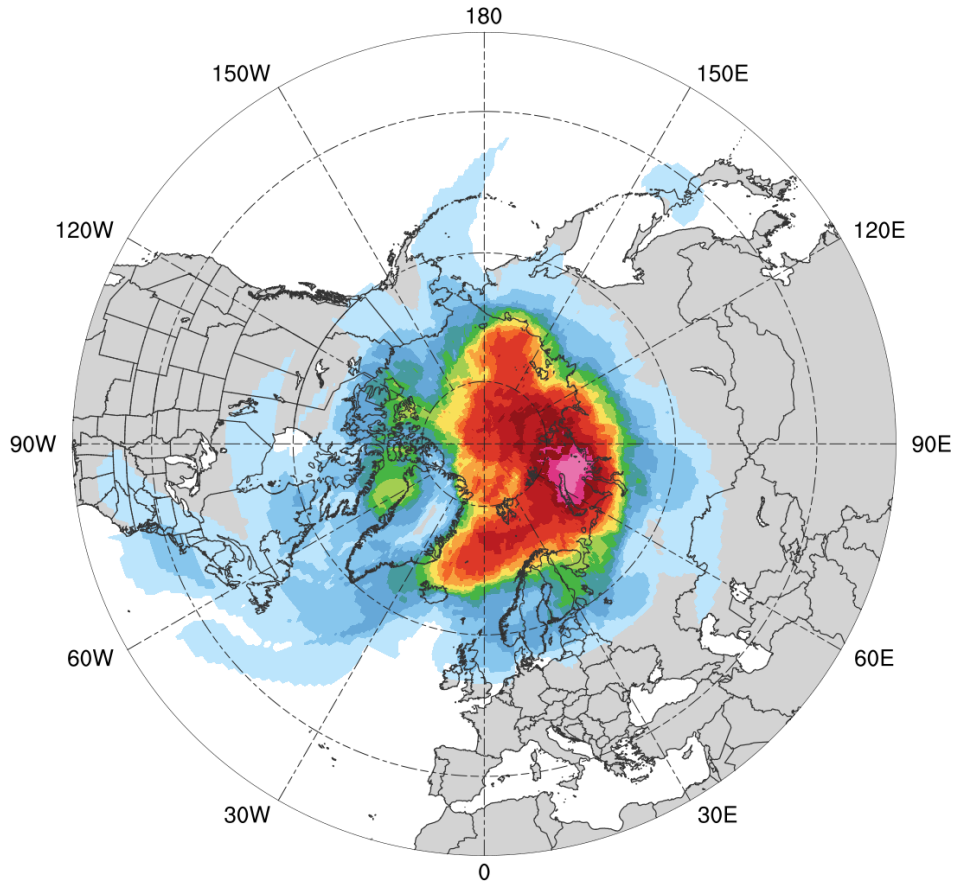
Normalized Track Density (MAM)



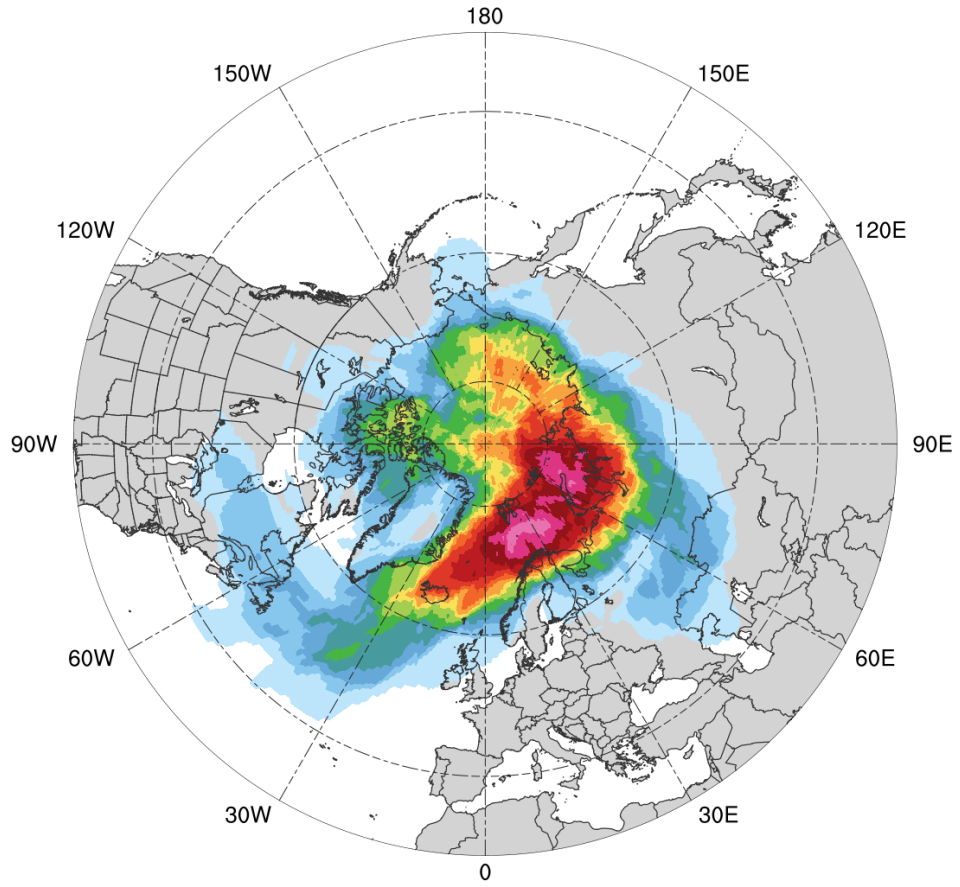
Total number of Arctic cyclones during MAM within 500 km of a grid point, normalized by maximum value

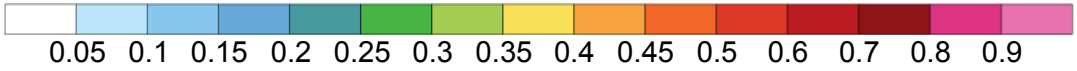
Normalized Track Density (MAM)

Low skill (N = 110)



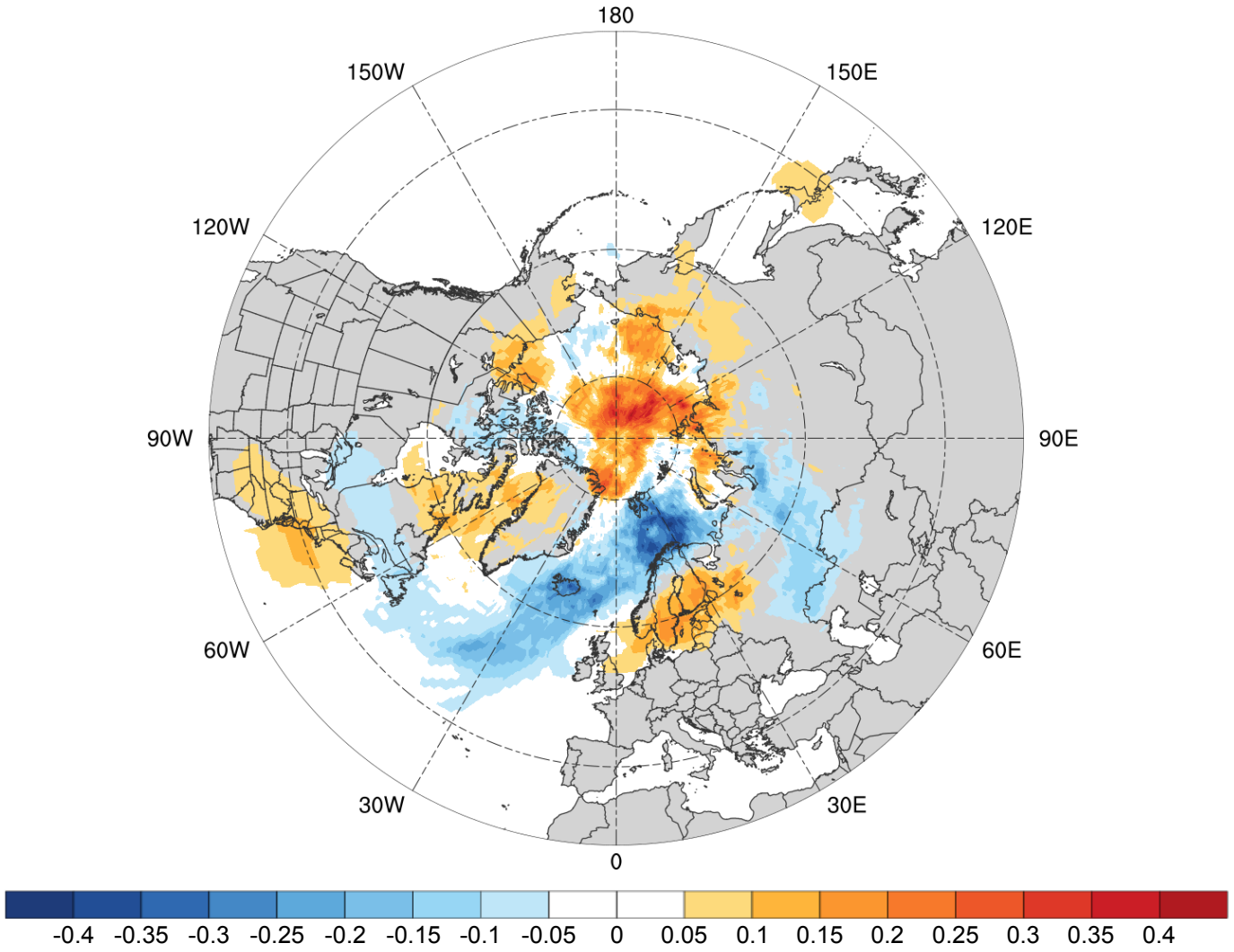
High Skill (N = 110)





Total number of Arctic cyclones within 500 km of a grid point during MAM, normalized by maximum value, for each period

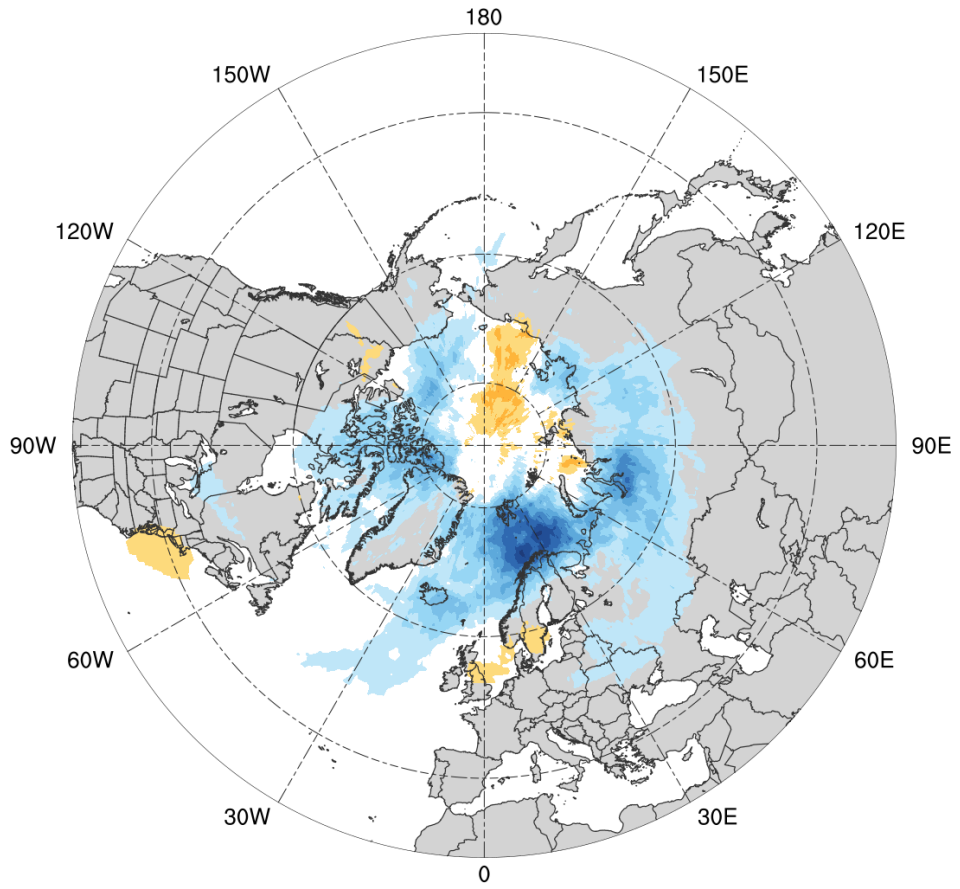
Normalized Track Density Differences (MAM)



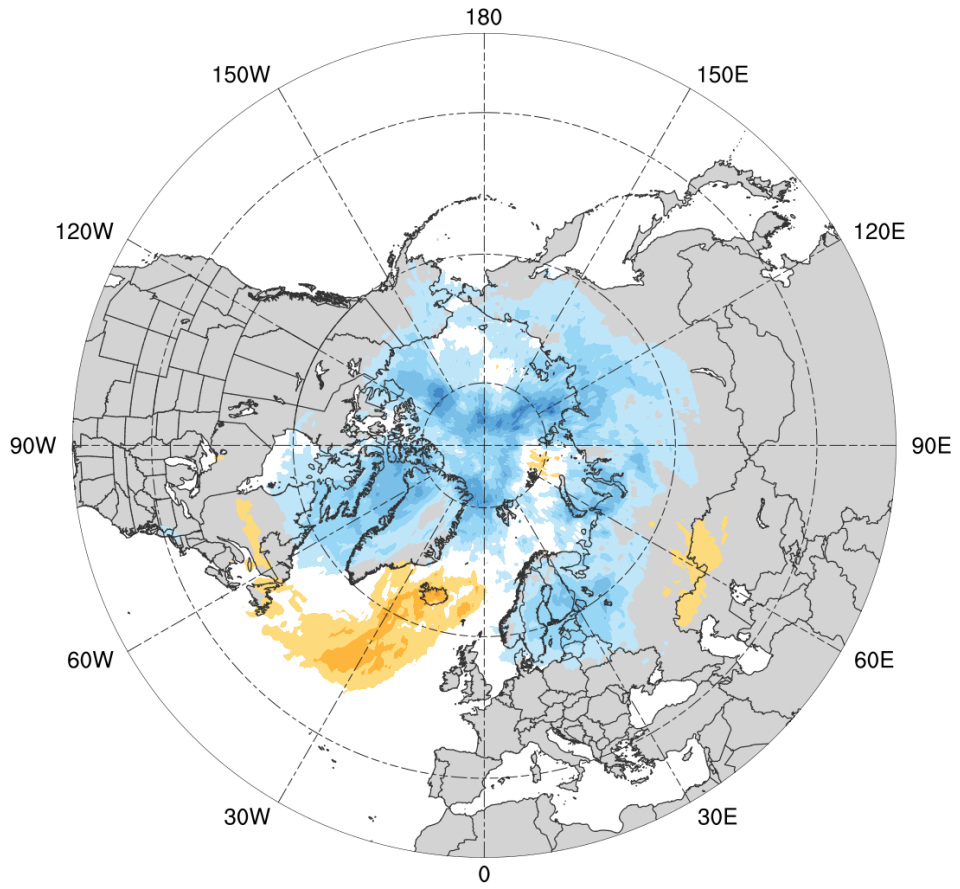
Difference in normalized Arctic cyclone track density during MAM

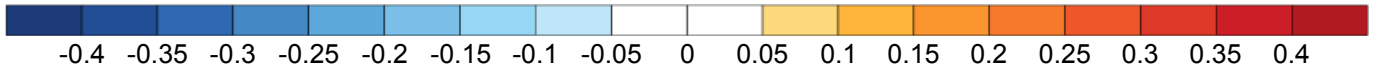
Normalized Track Density Differences (MAM)

Low skill minus climatology



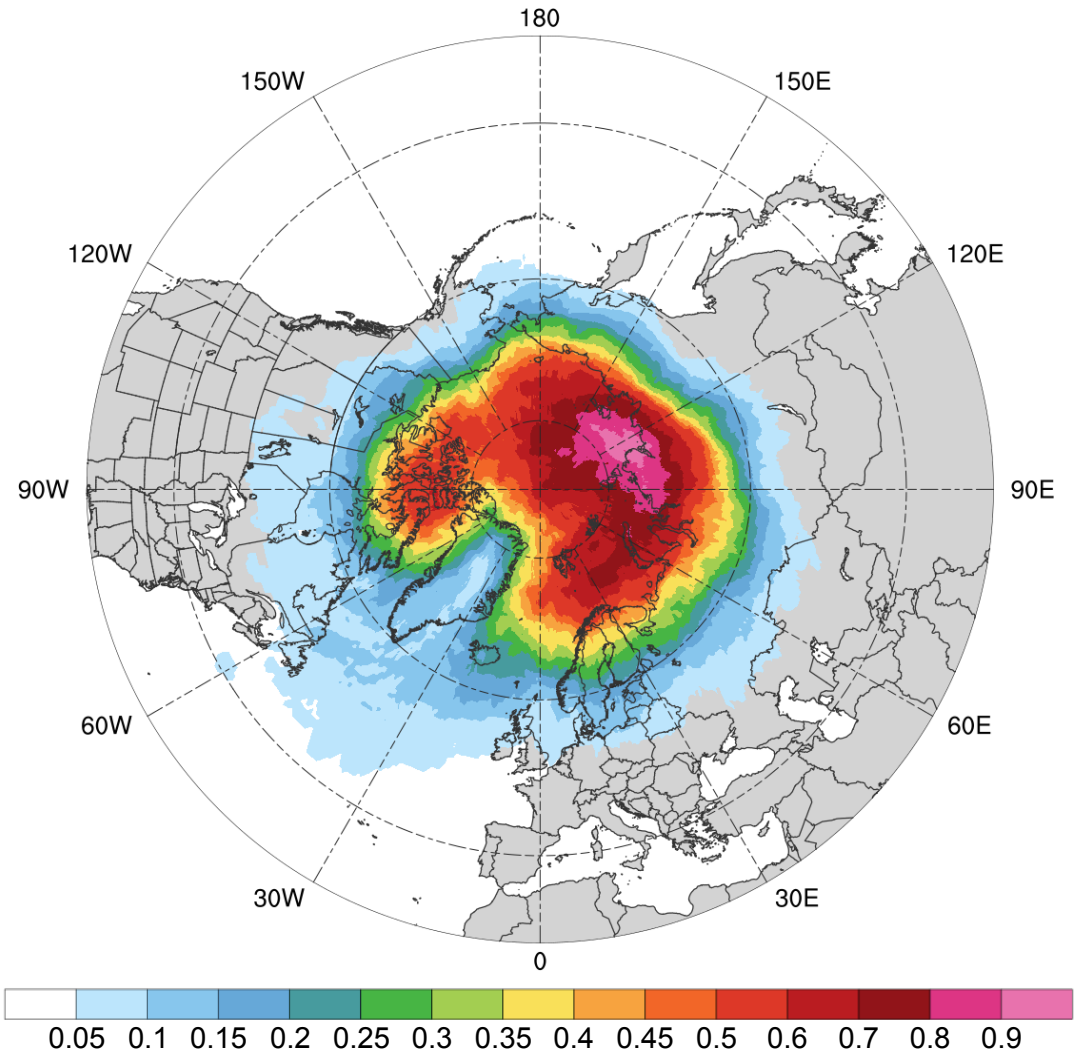
High skill minus climatology





Difference in normalized Arctic cyclone track density during MAM

Normalized Track Density (JJA)

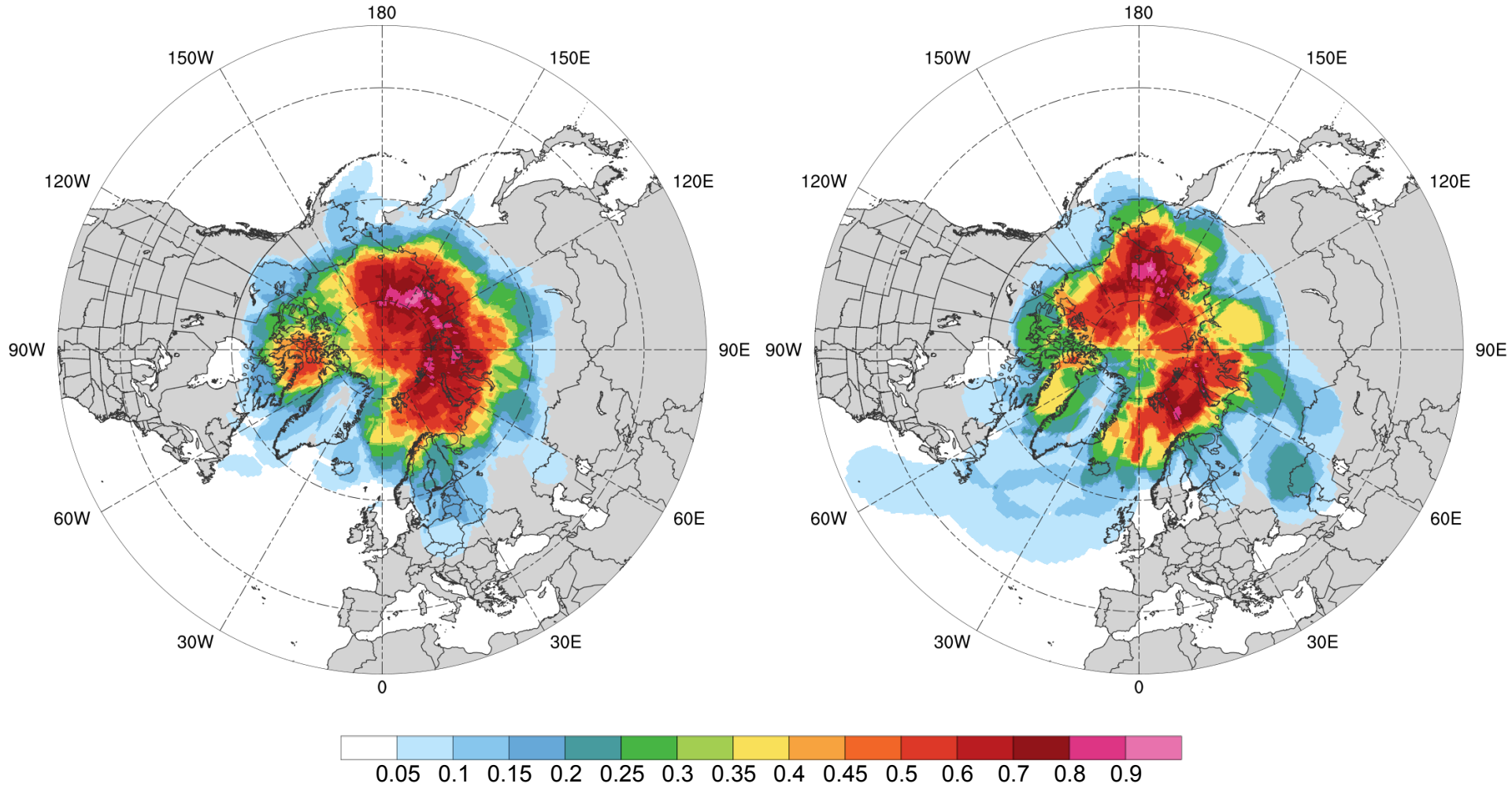


Total number of Arctic cyclones during JJA within 500 km of a grid point, normalized by maximum value

Normalized Track Density (JJA)

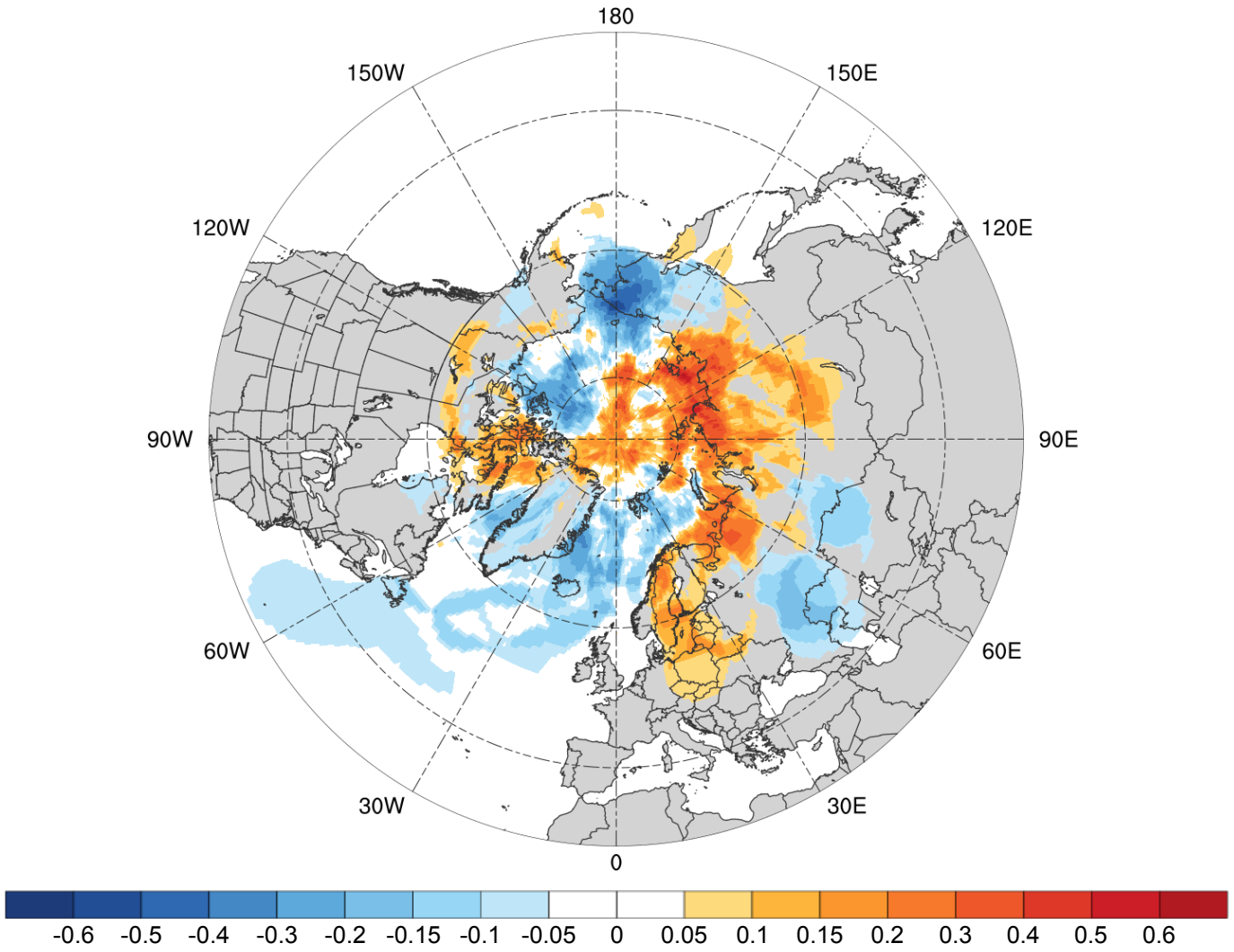
Low skill (N = 92)

High Skill (N = 52)



Total number of Arctic cyclones within 500 km of a grid point during JJA, normalized by maximum value, for each period

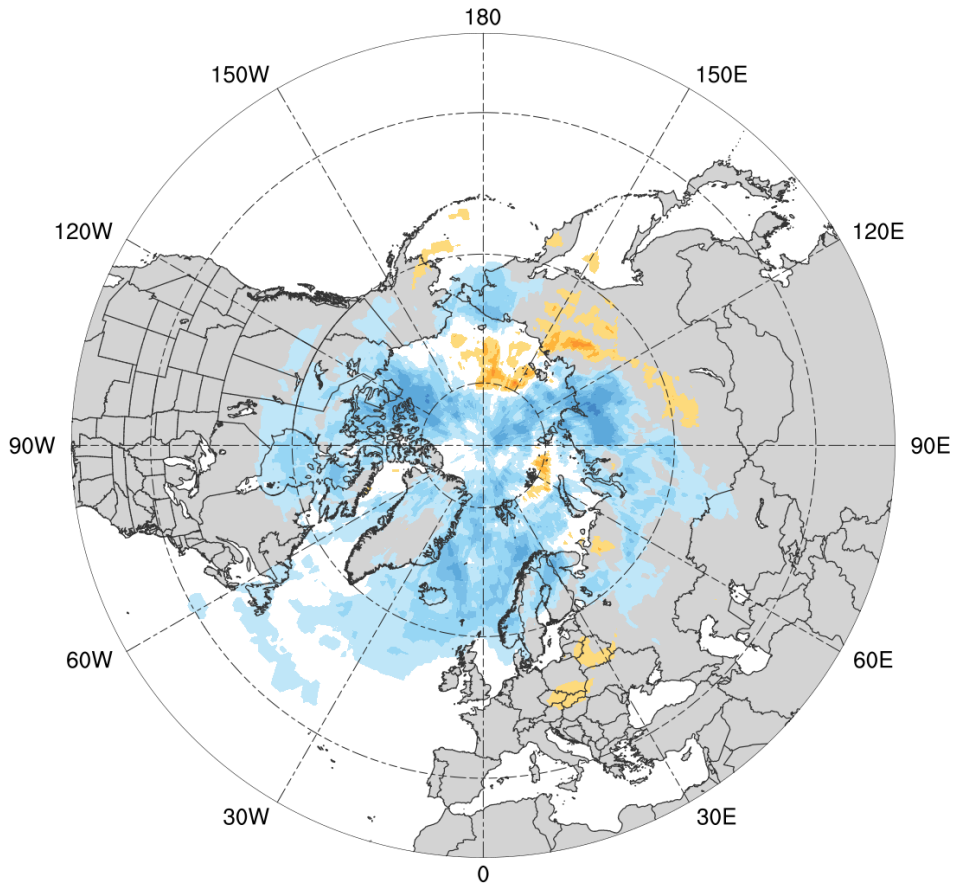
Normalized Track Density Differences (JJA)



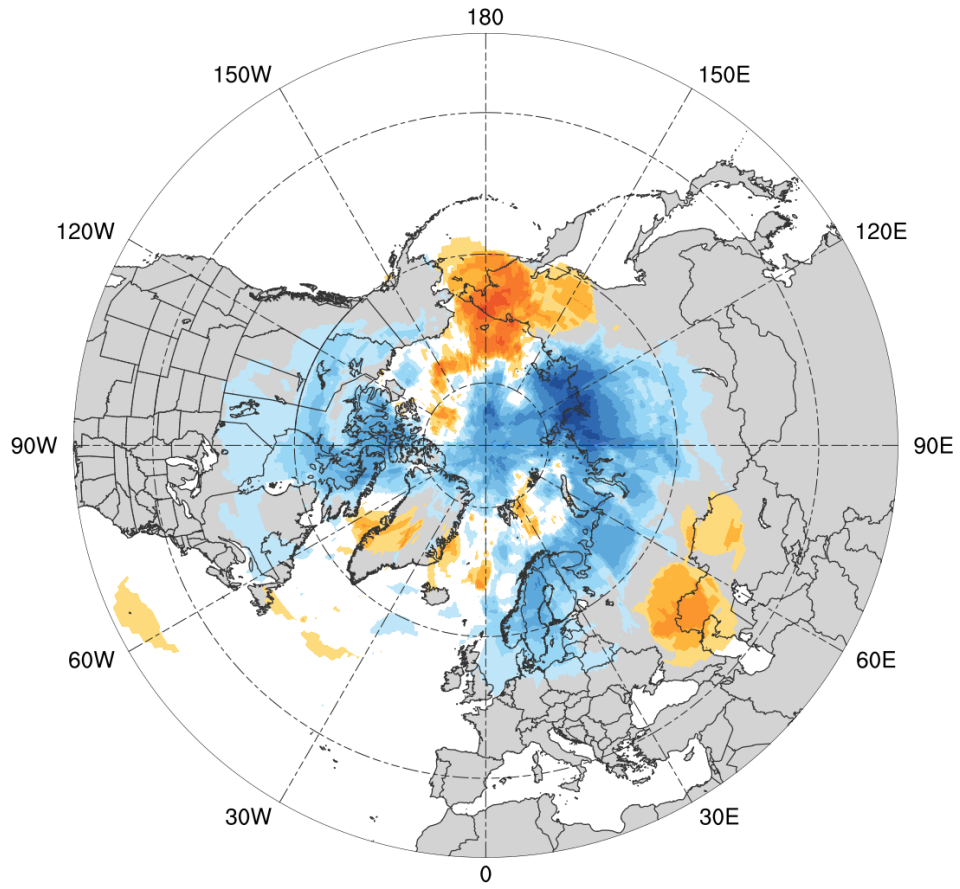
Difference in normalized Arctic cyclone track density during JJA

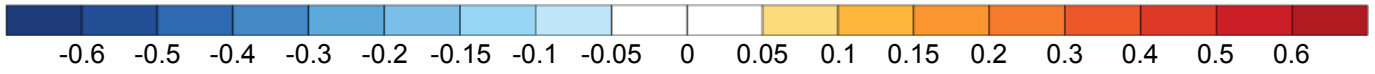
Normalized Track Density Differences (JJA)

Low skill minus climatology



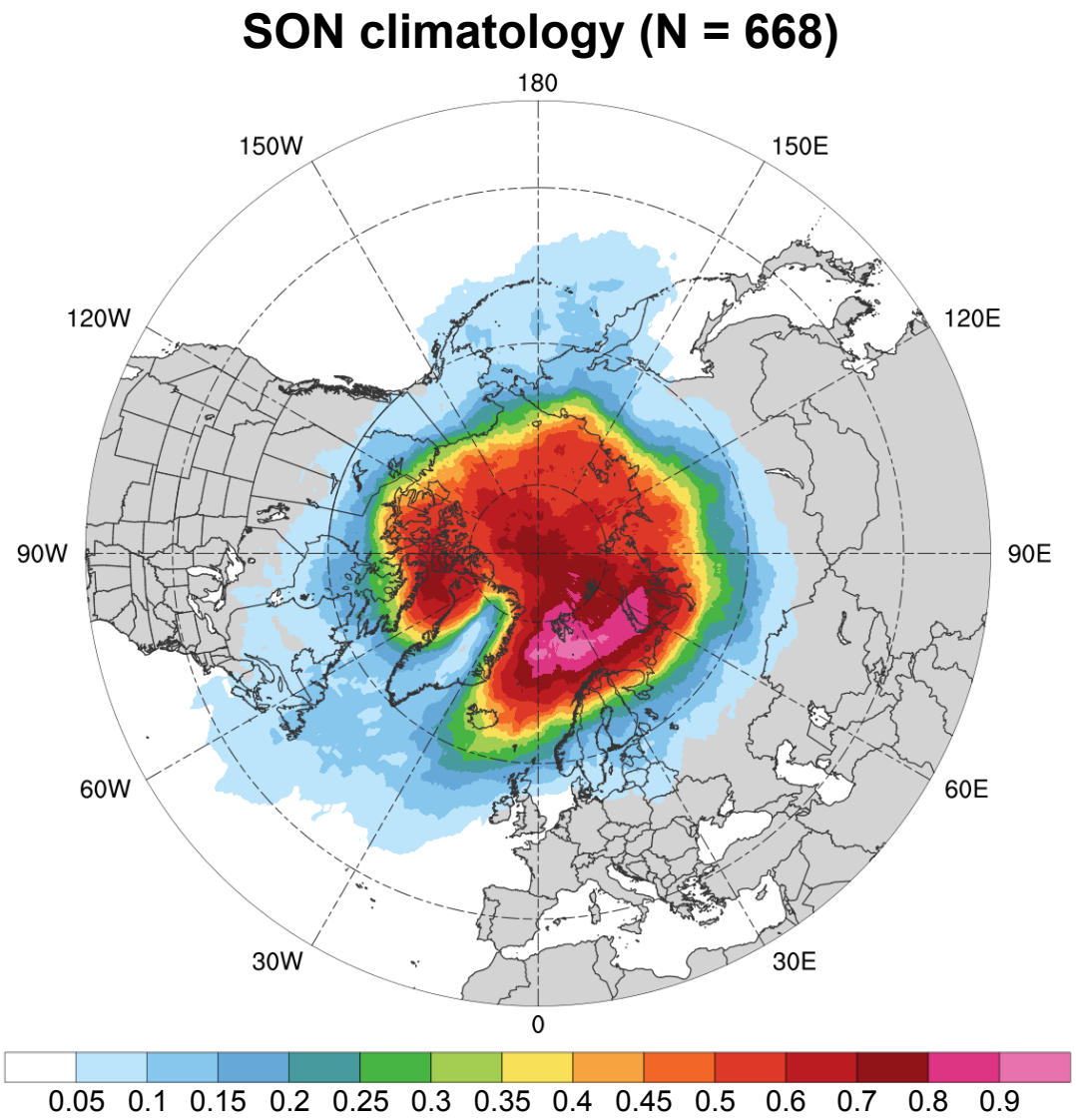
High skill minus climatology





Difference in normalized Arctic cyclone track density during JJA

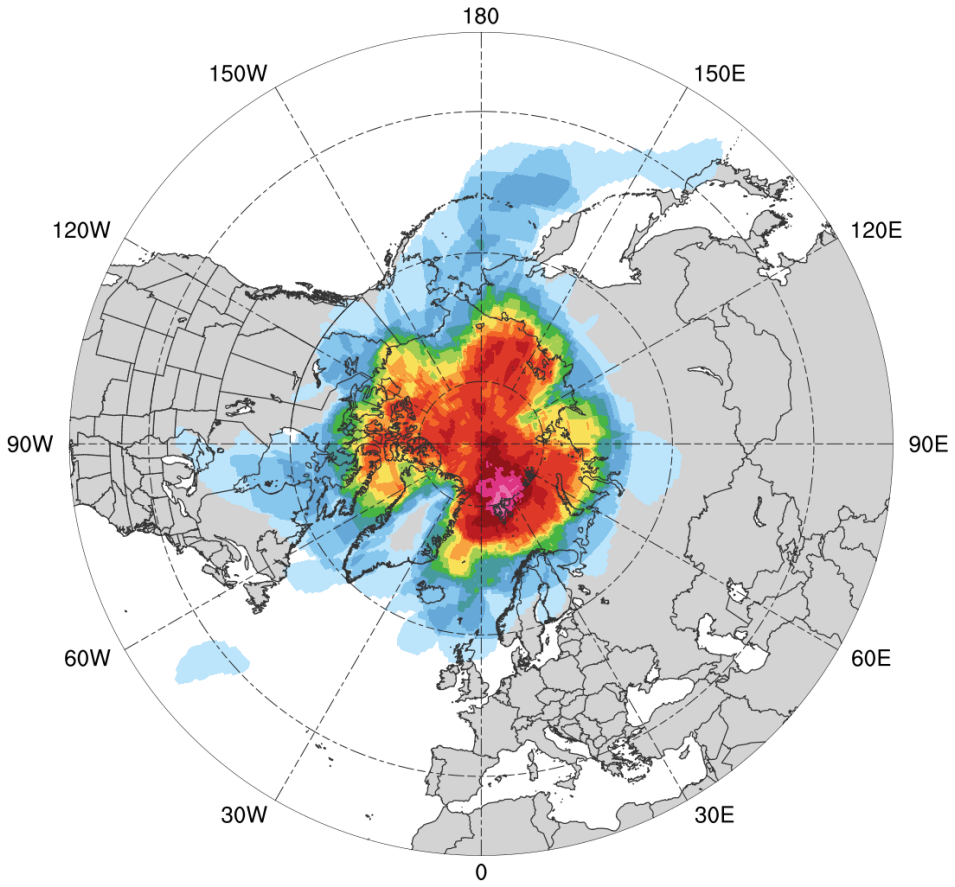
Normalized Track Density (SON)



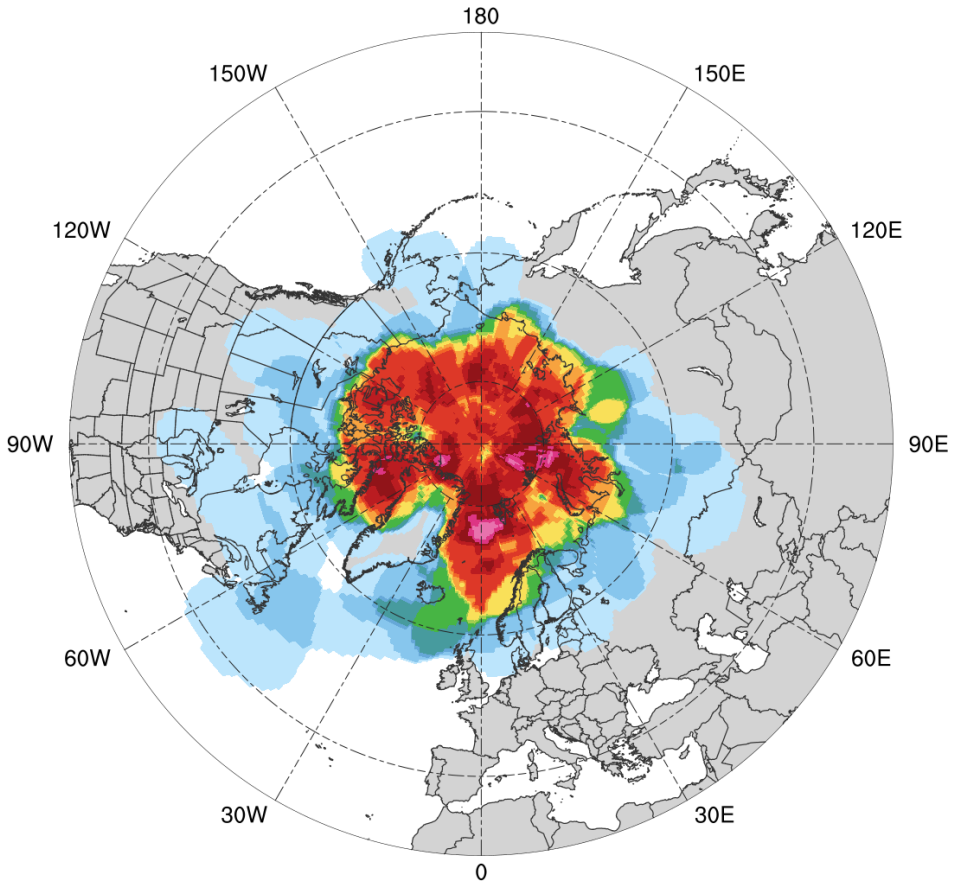
Total number of Arctic cyclones during SON within 500 km of a grid point, normalized by maximum value

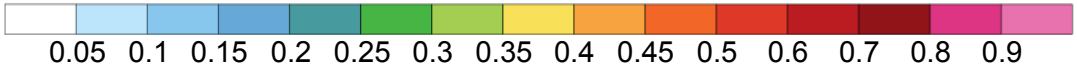
Normalized Track Density (SON)

Low skill (N = 69)



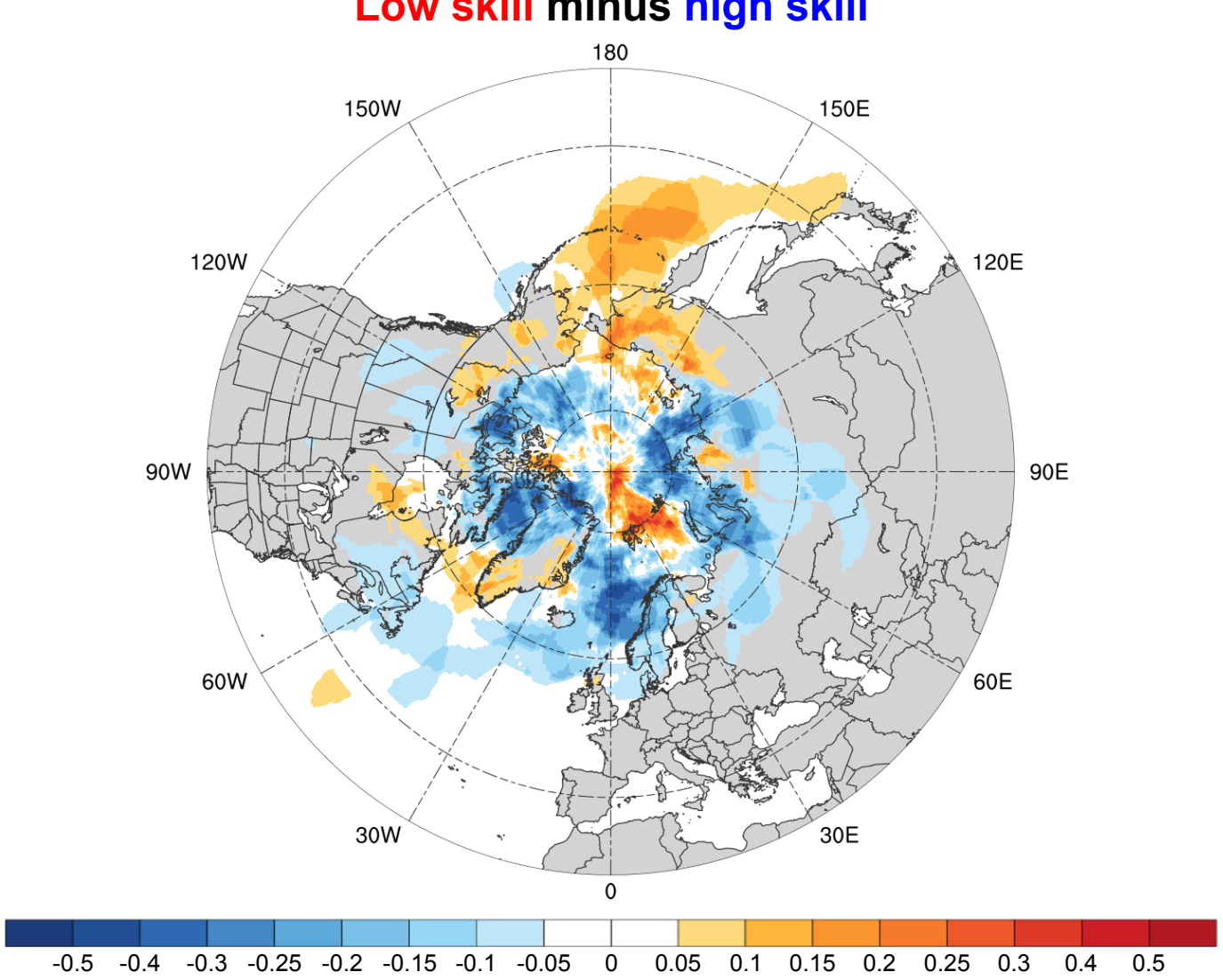
High Skill (N = 61)





Total number of Arctic cyclones within 500 km of a grid point during SON, normalized by maximum value, for each period

Normalized Track Density Differences (SON)

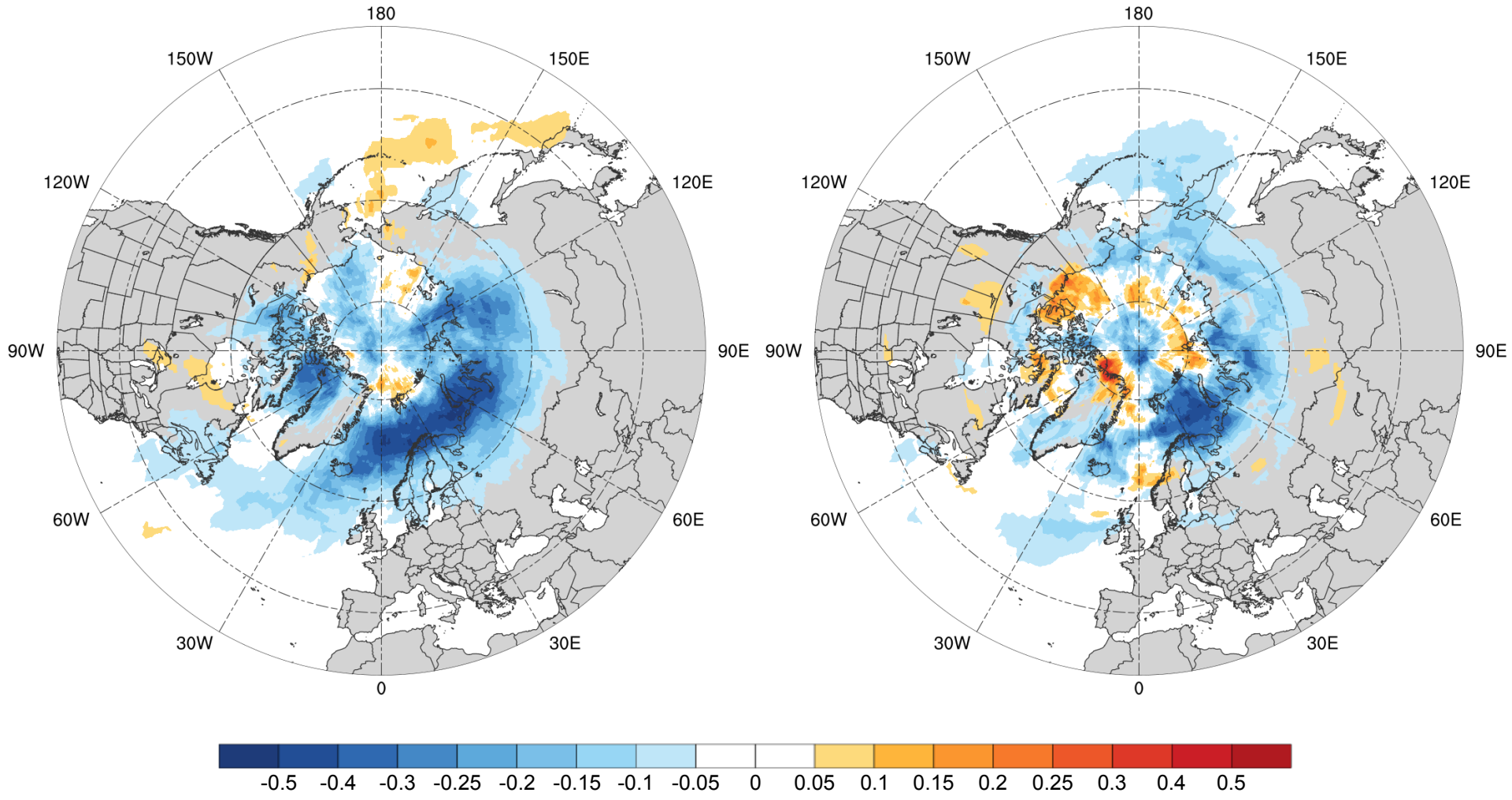


Difference in normalized Arctic cyclone track density during SON

Normalized Track Density Differences (SON)

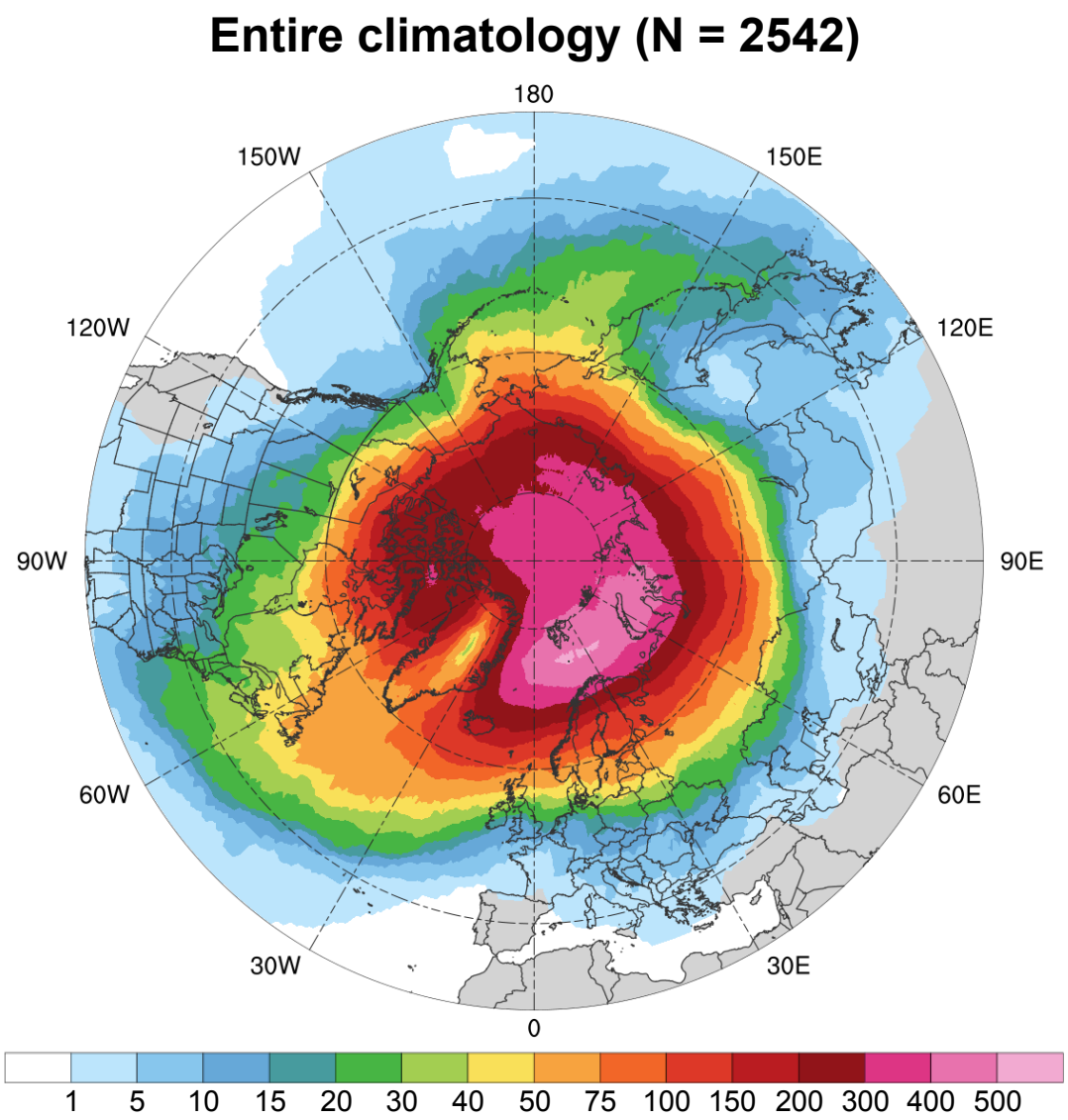
Low skill minus climatology

High skill minus climatology



Difference in normalized Arctic cyclone track density during SON

Track Density

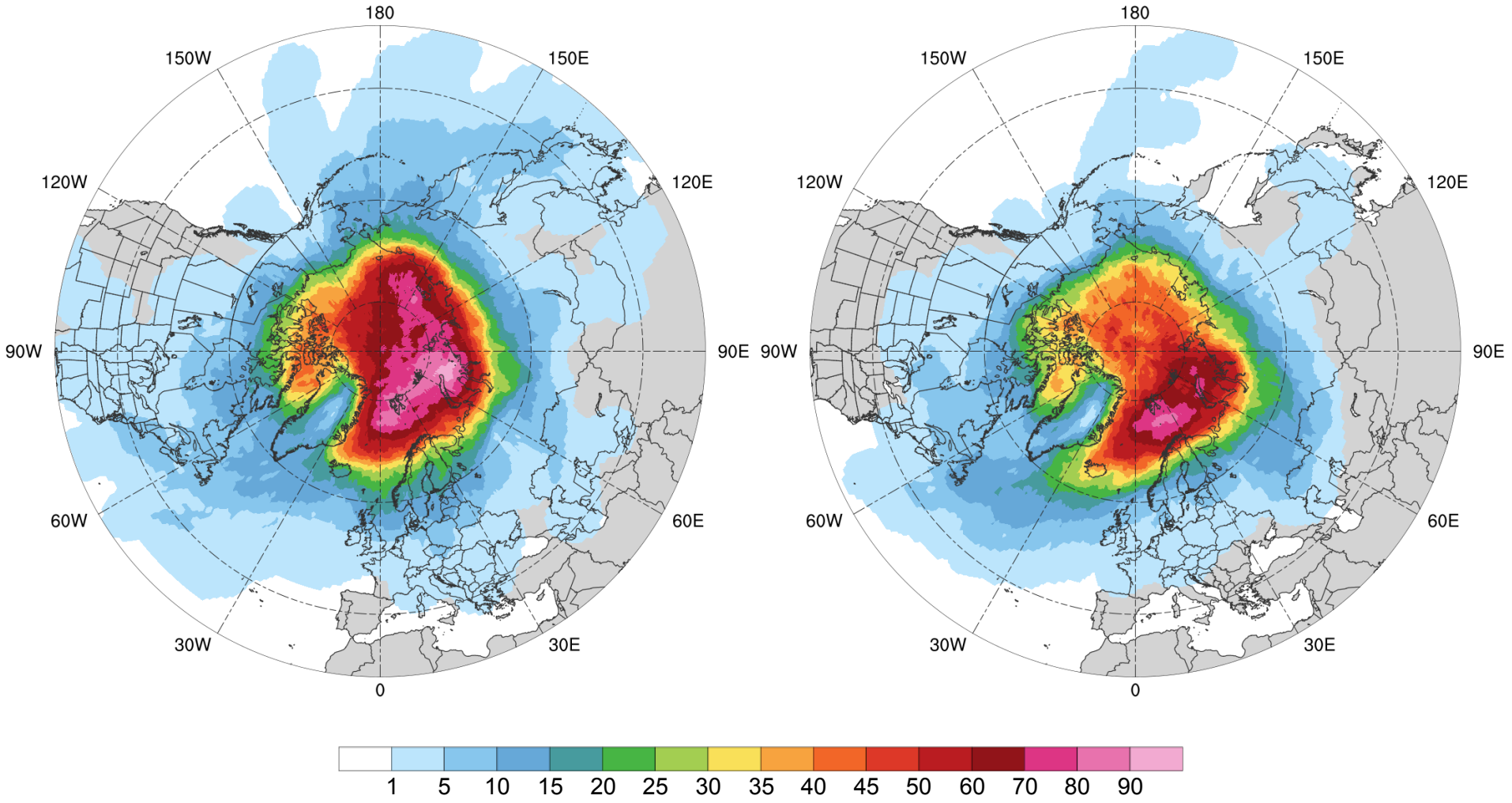


Total number of Arctic cyclones within 500 km of a grid point

Track Density

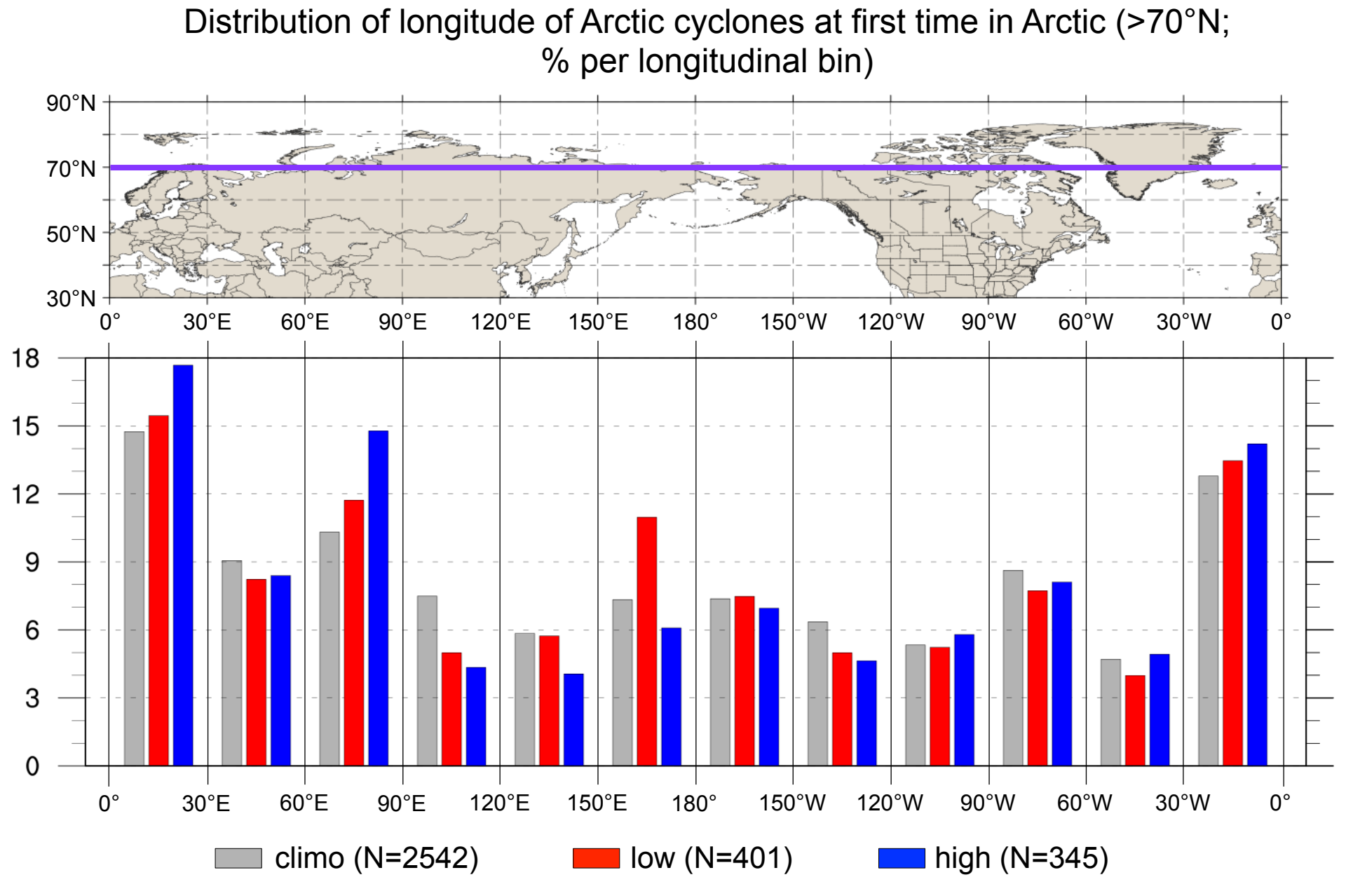
Low skill (N = 401)

High Skill (N = 345)



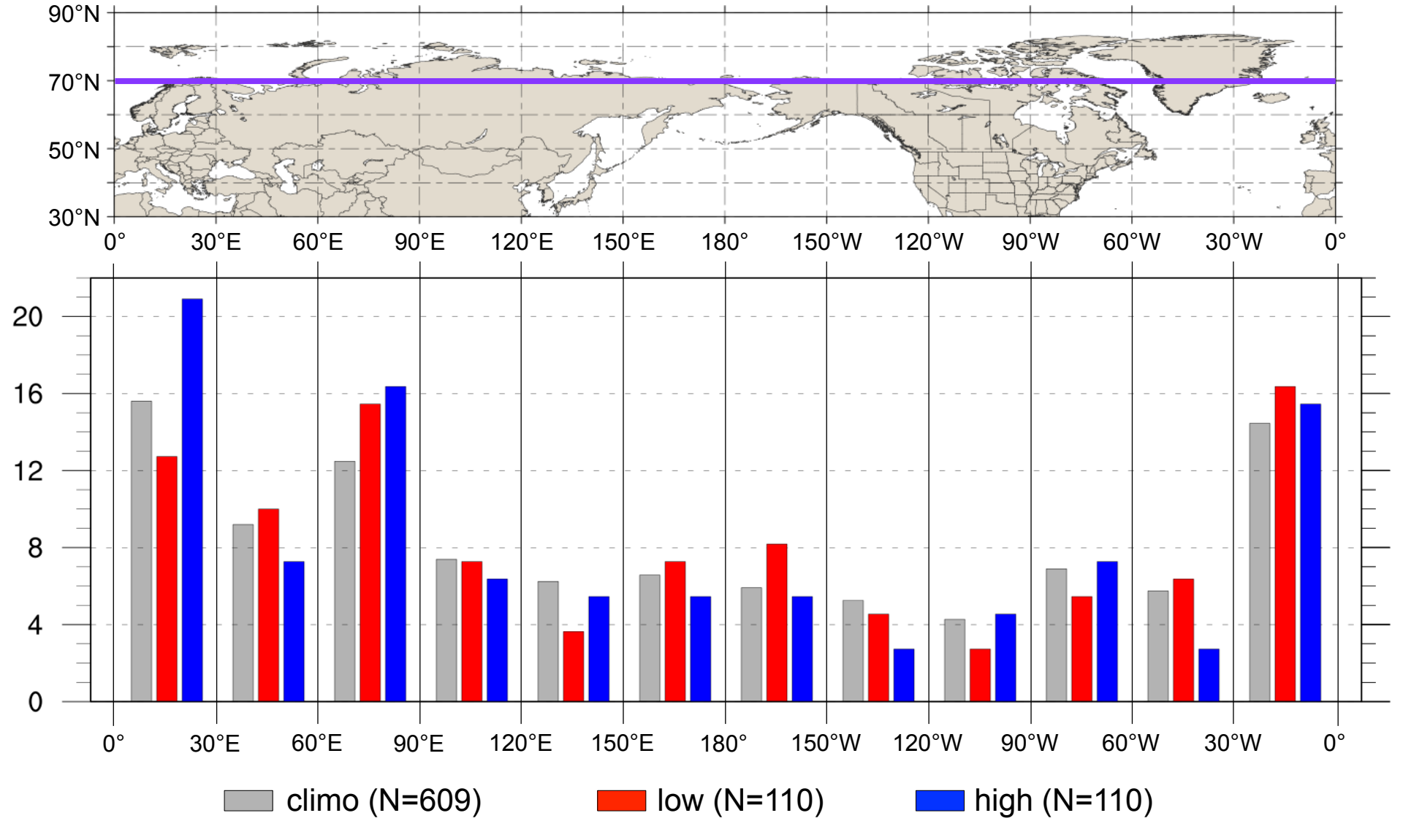
Total number of Arctic cyclones within 500 km of a grid point

Preferred Longitudinal Corridors



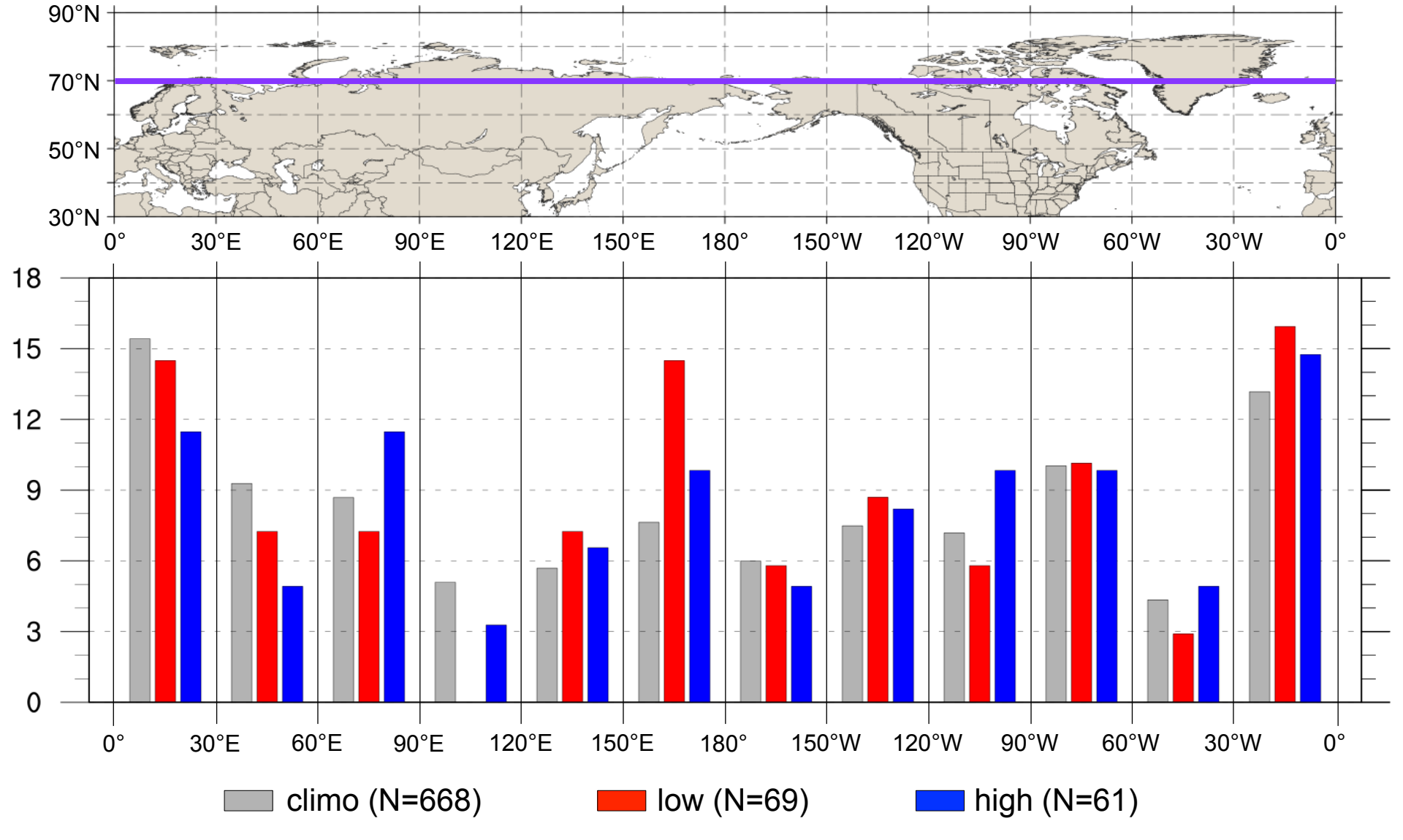
Results: Preferred Longitudinal Corridors (MAM)

Percentage of Arctic cyclones per longitude bin according to longitude of Arctic cyclones at first time in Arctic (>70°N) during MAM

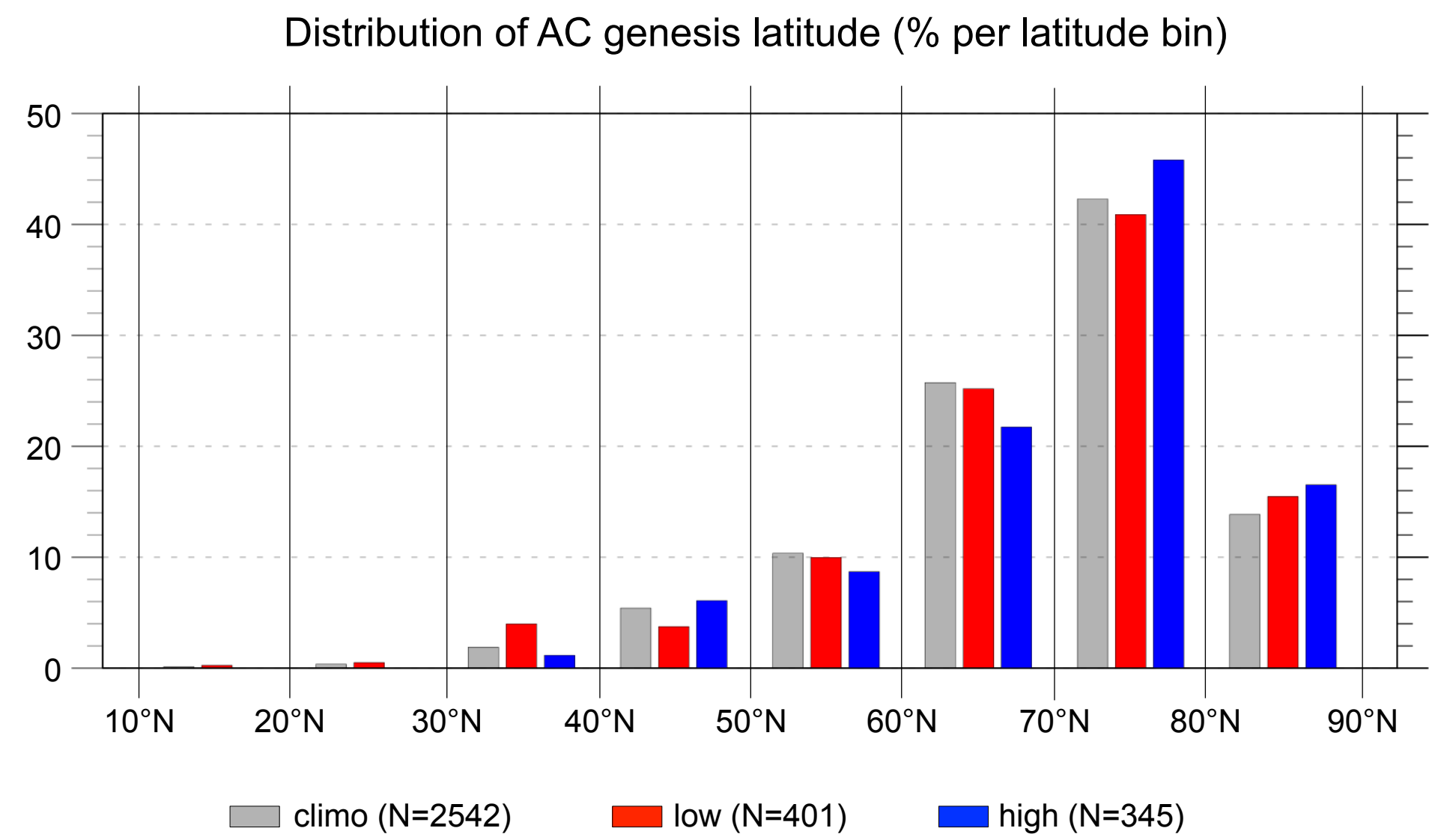


Results: Preferred Longitudinal Corridors (SON)

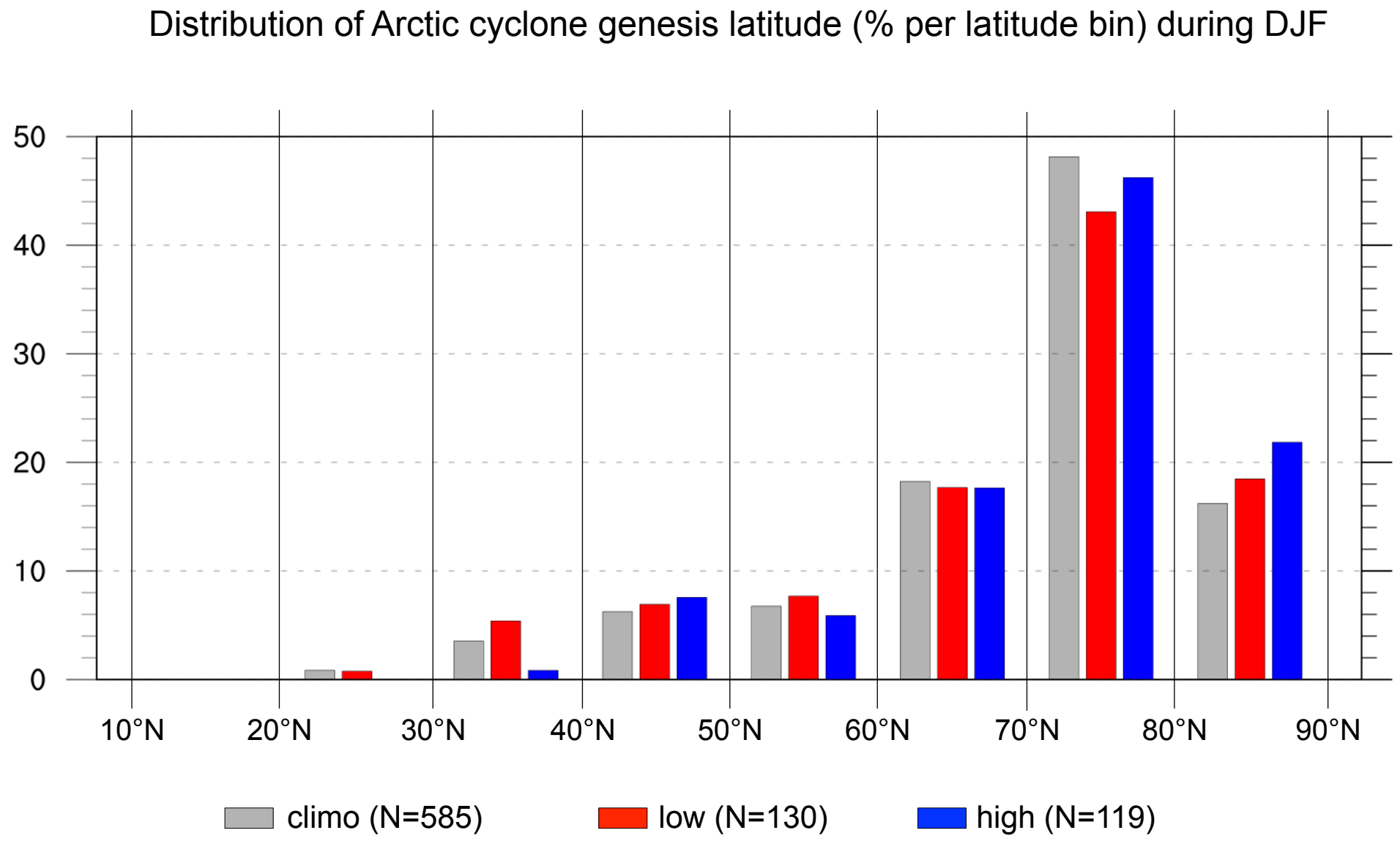
Percentage of Arctic cyclones per longitude bin according to longitude of Arctic cyclones at first time in Arctic (>70°N) during SON



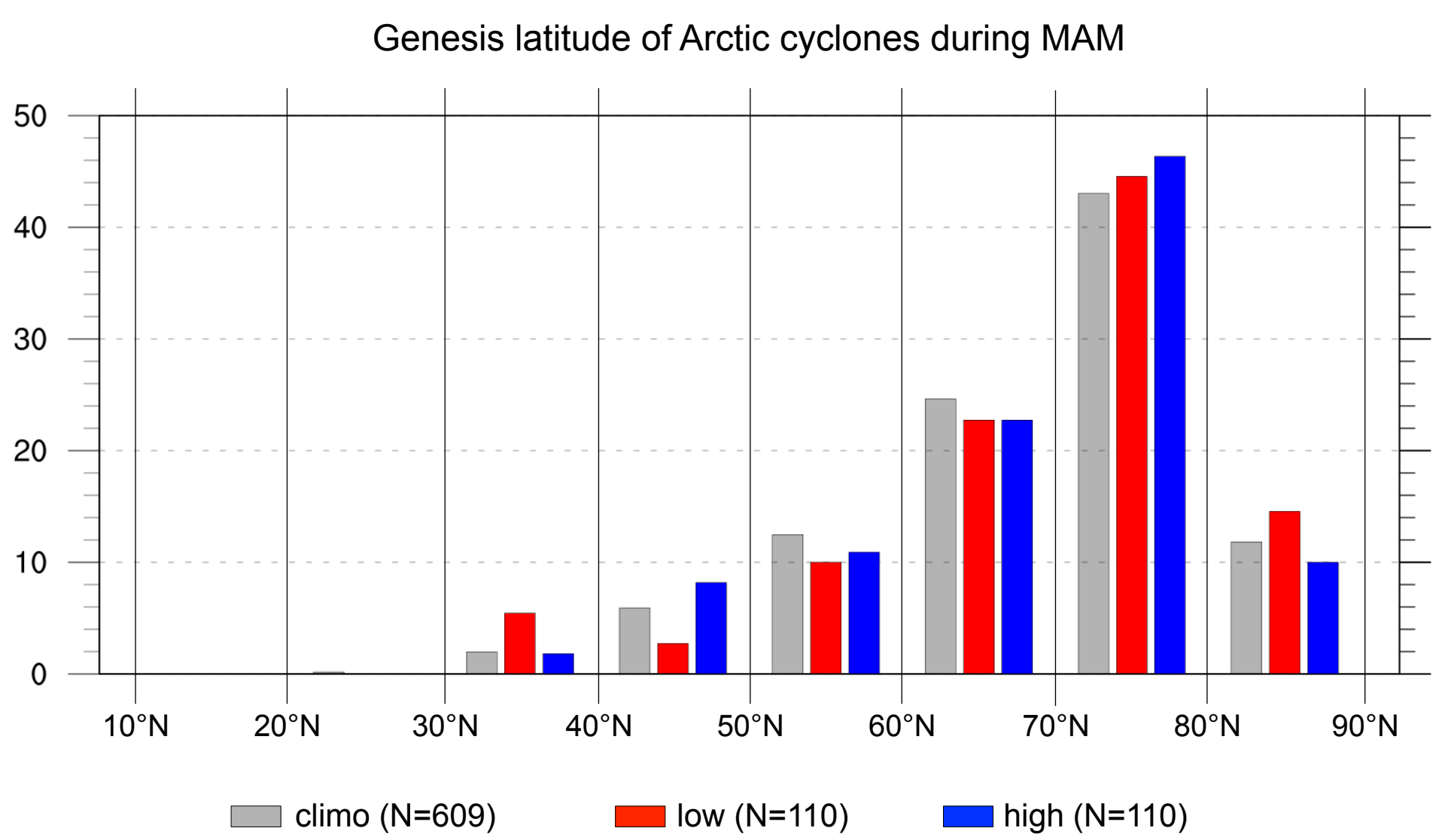
Genesis Latitude



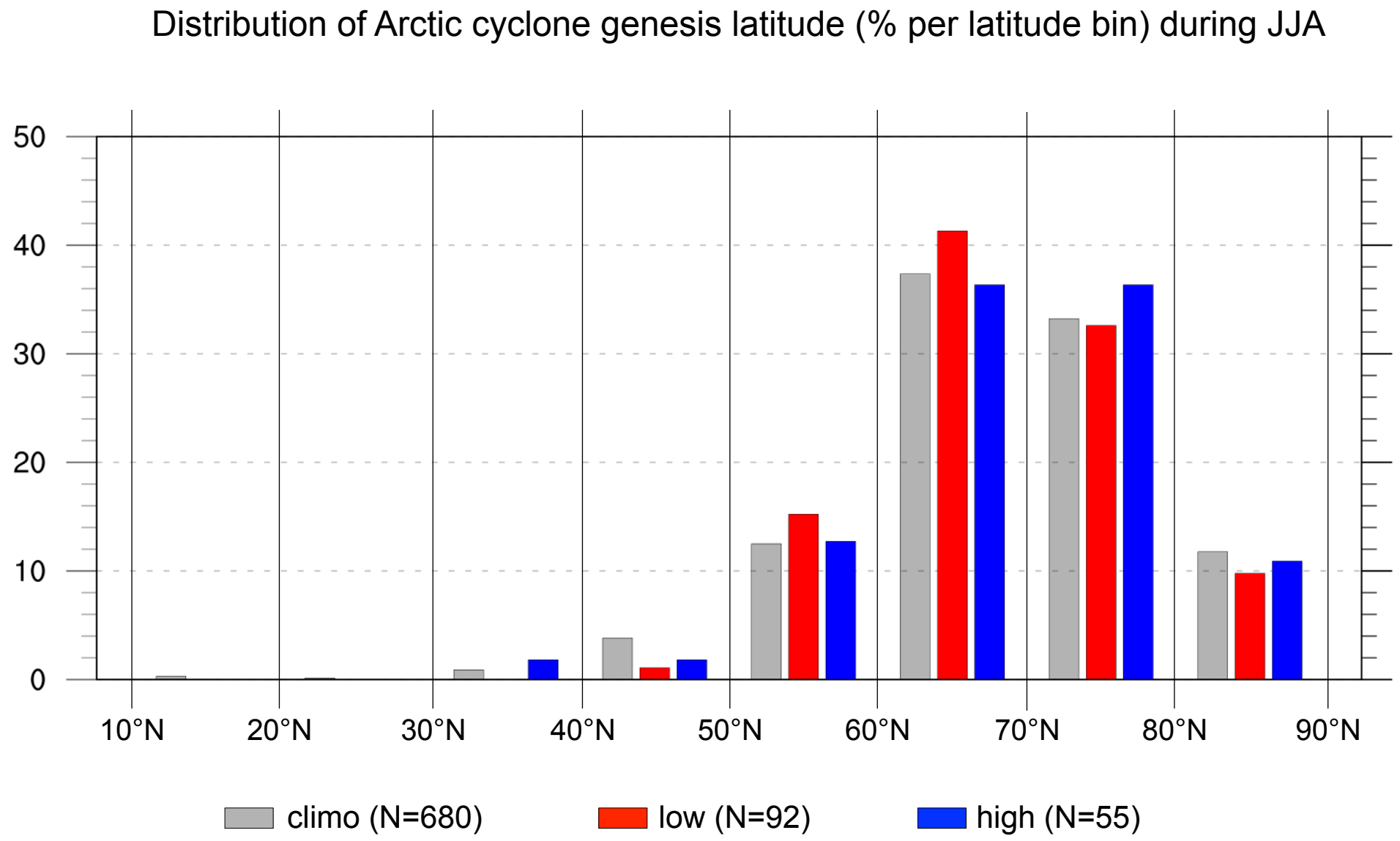
Genesis Latitude (DJF)



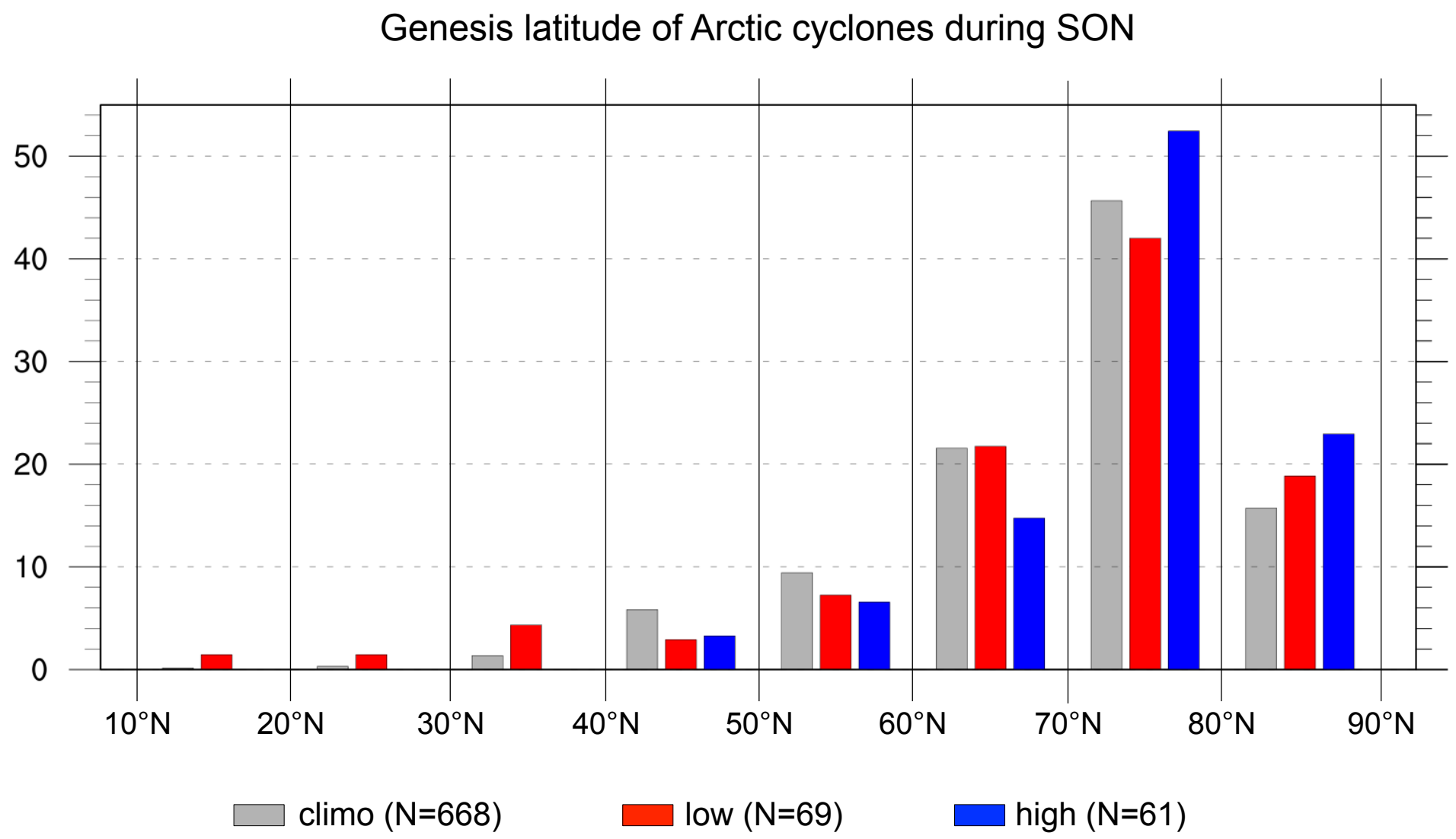
Genesis Latitude (MAM)



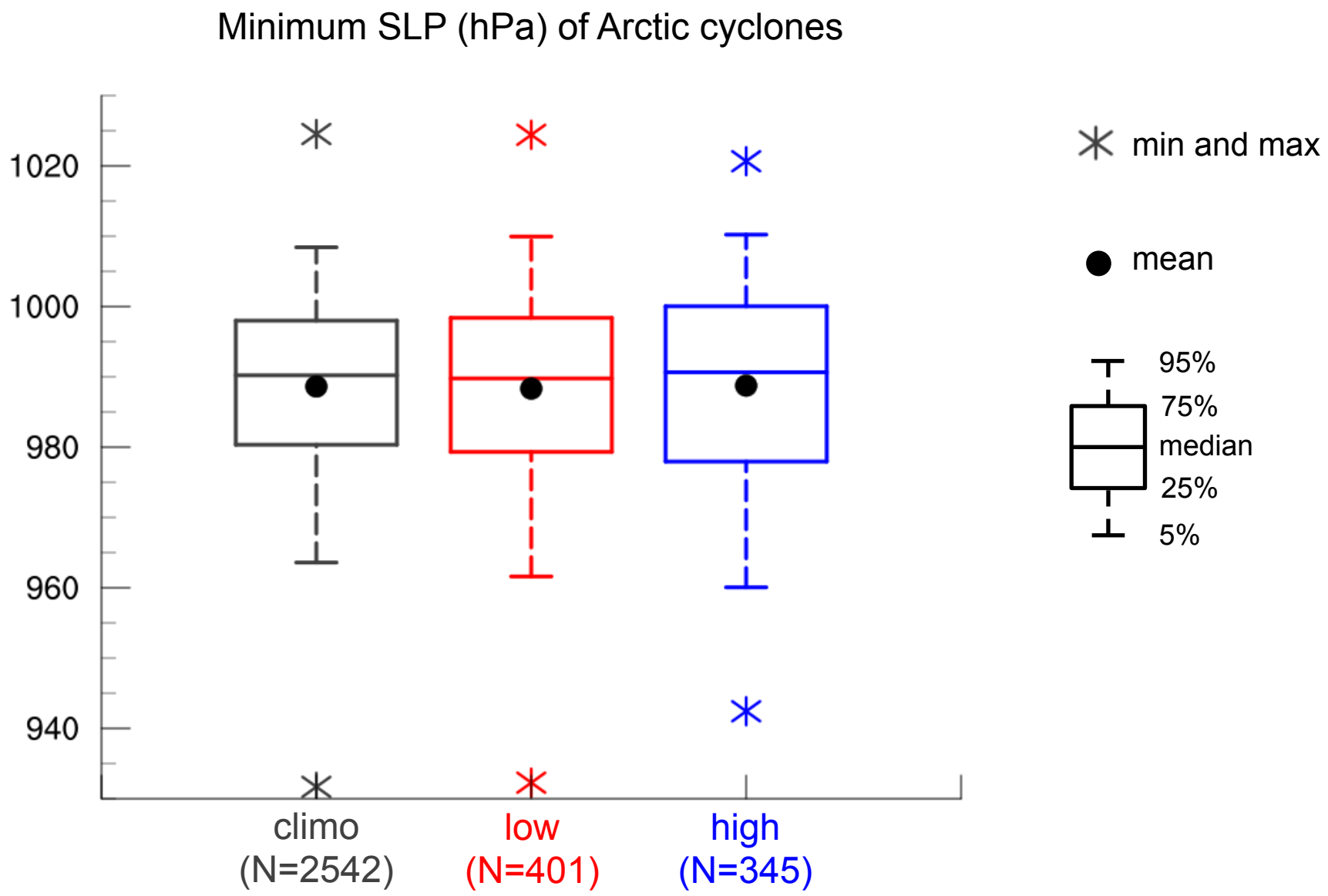
Genesis Latitude (JJA)



Genesis Latitude (SON)



Intensity: Minimum SLP



Intensity: Minimum SLP