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

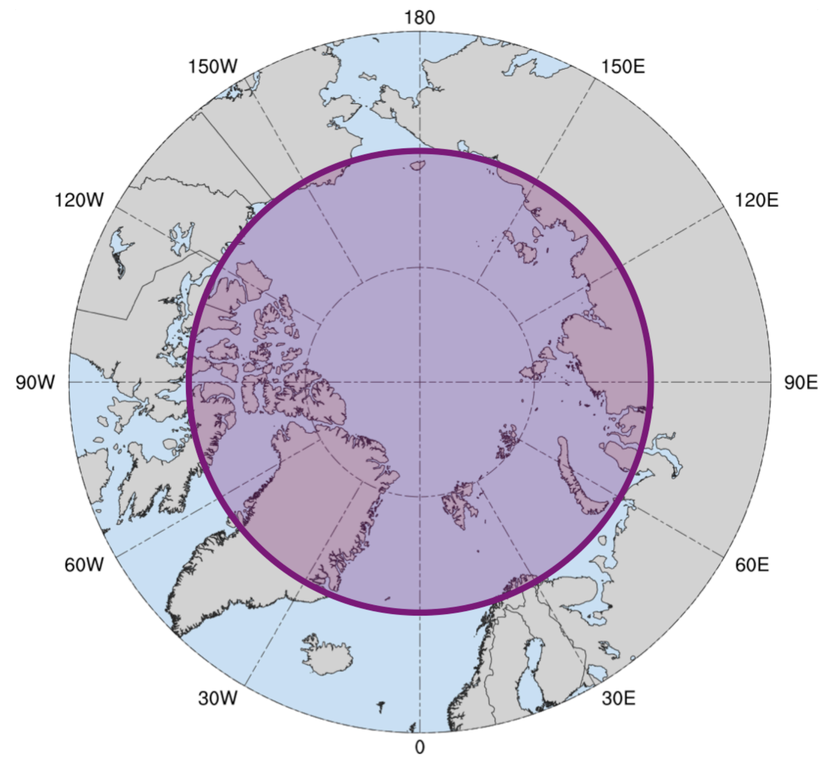
- Arctic cyclones (ACs) are synoptic-scale cyclones that originate within the Arctic or move into the Arctic from lower latitudes (e.g., Crawford and Serreze 2016)
- ACs may be associated with the poleward advection of warm, moist air, which can contribute to alterations of the synoptic-scale flow over the Arctic
- It is anticipated that relatively low forecast skill of the synoptic-scale flow over the Arctic may be attributed in part to forecast error growth accompanying alterations of the synoptic-scale flow induced by ACs

Purpose

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

Data and Methods: AC 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

- Utilize forecasts of 500-hPa geopotential height initialized at 0000 UTC during 2007–2017 and valid at day 5 from 11-member GEFS reforecast dataset v2 (Hamill et al. 2013)

- Calculate area-averaged ensemble forecast spread of 500-hPa geopotential height over the Arctic (≥70°N)

- Calculate area root mean square error (RMSE) of ensemble mean forecasts of 500-hPa geopotential height over the Arctic, using ERA-Interim (Dee et al. 2011) as verification

Data and Methods: Forecast Skill Evaluation

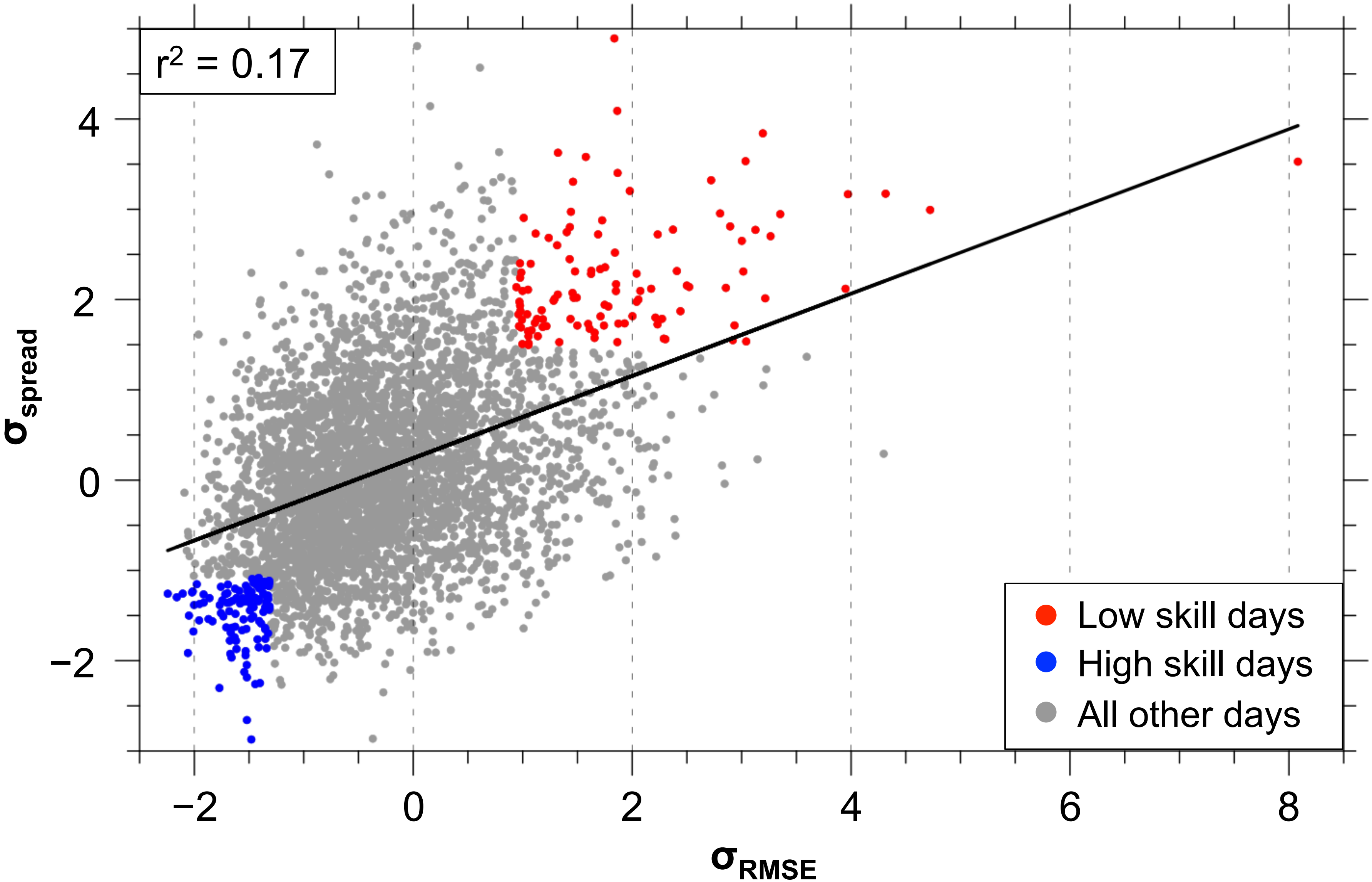
- Calculate standardized anomaly of area-averaged ensemble spread (σ_{spread}) and of area RMSE (σ_{RMSE}) following Moore (2017)

- Forecast days valid at day 5 associated with the top and bottom 10% of σ_{spread} and σ_{RMSE} 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**

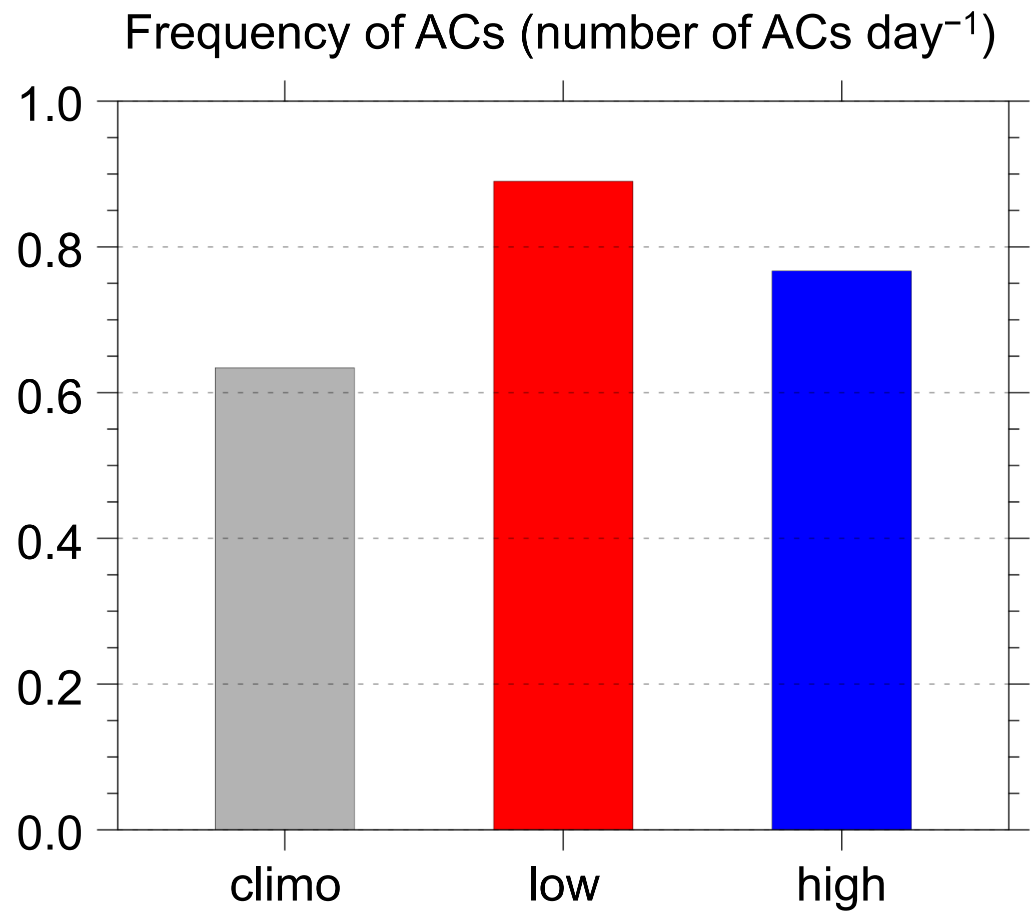
- ACs that exist in the Arctic (>70°N) within the low and high skill periods are selected for further analysis

Data and Methods: Forecast Skill Evaluation



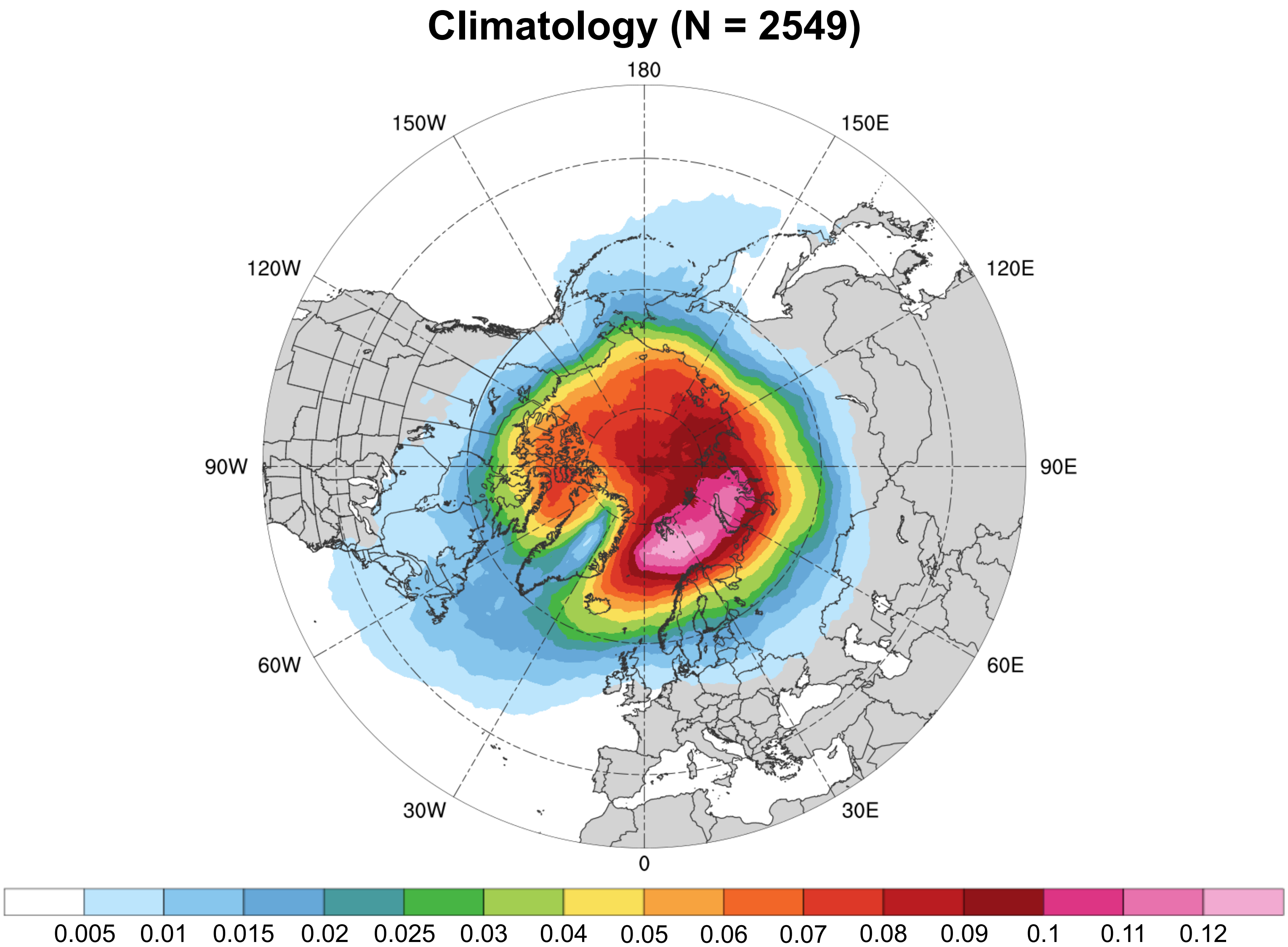
Number and Frequency of ACs

Period	Number of days in period	Number of ACs in period
Climo	4018	2549
Low skill	472	420
High skill	484	371



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

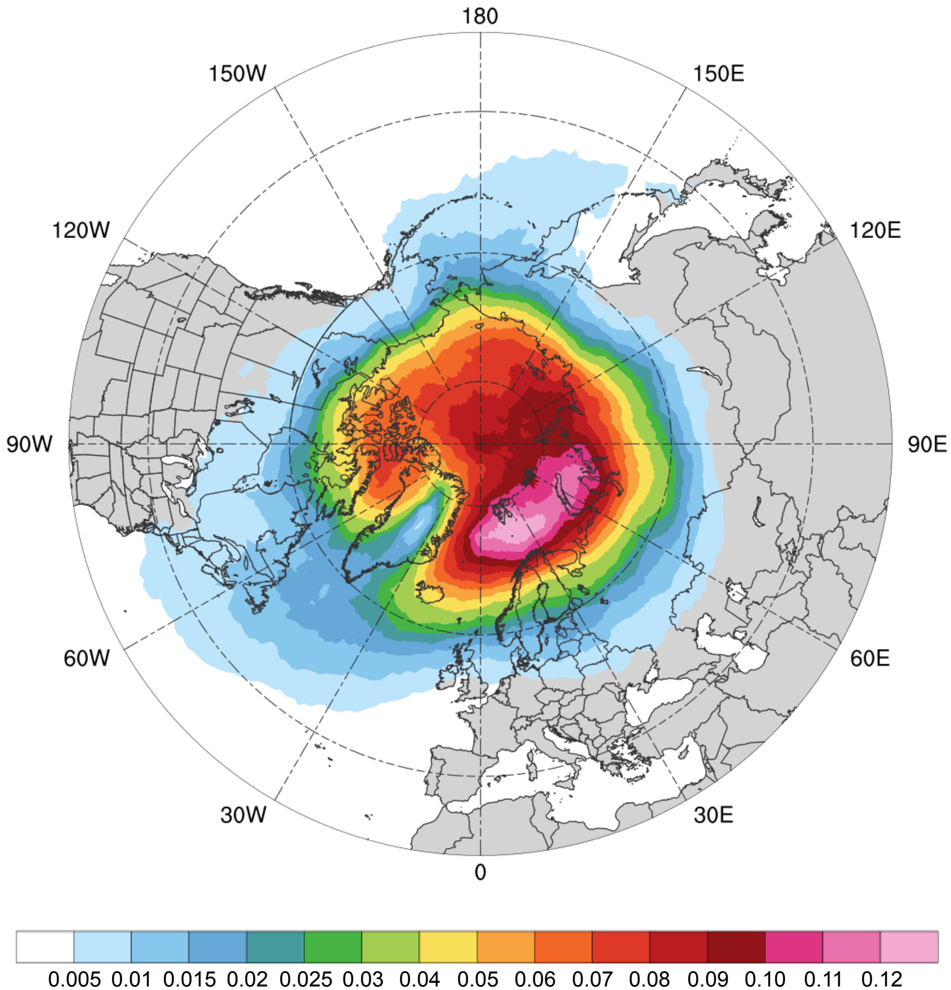
AC Track Frequency



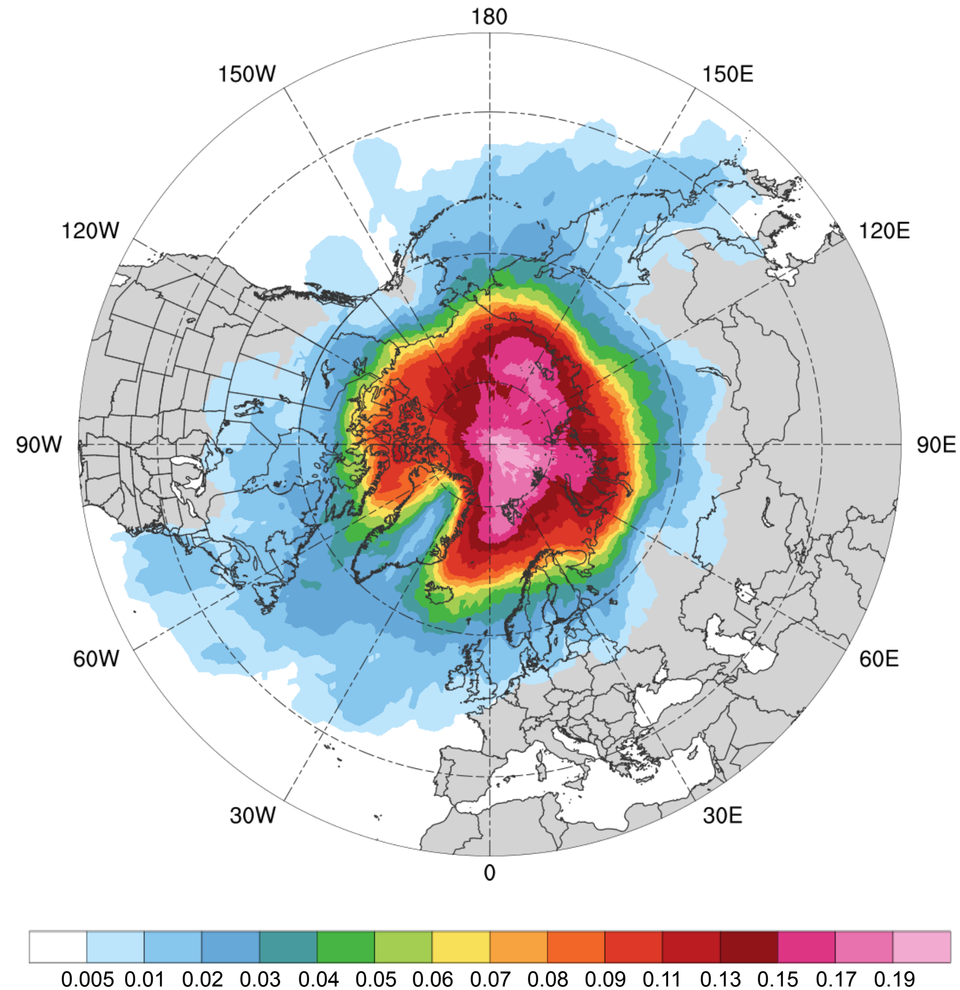
Total number of ACs within 500 km of a grid point,
divided by number of days in period (number of ACs day^{-1})

AC Track Frequency

Climatology (N = 2549)

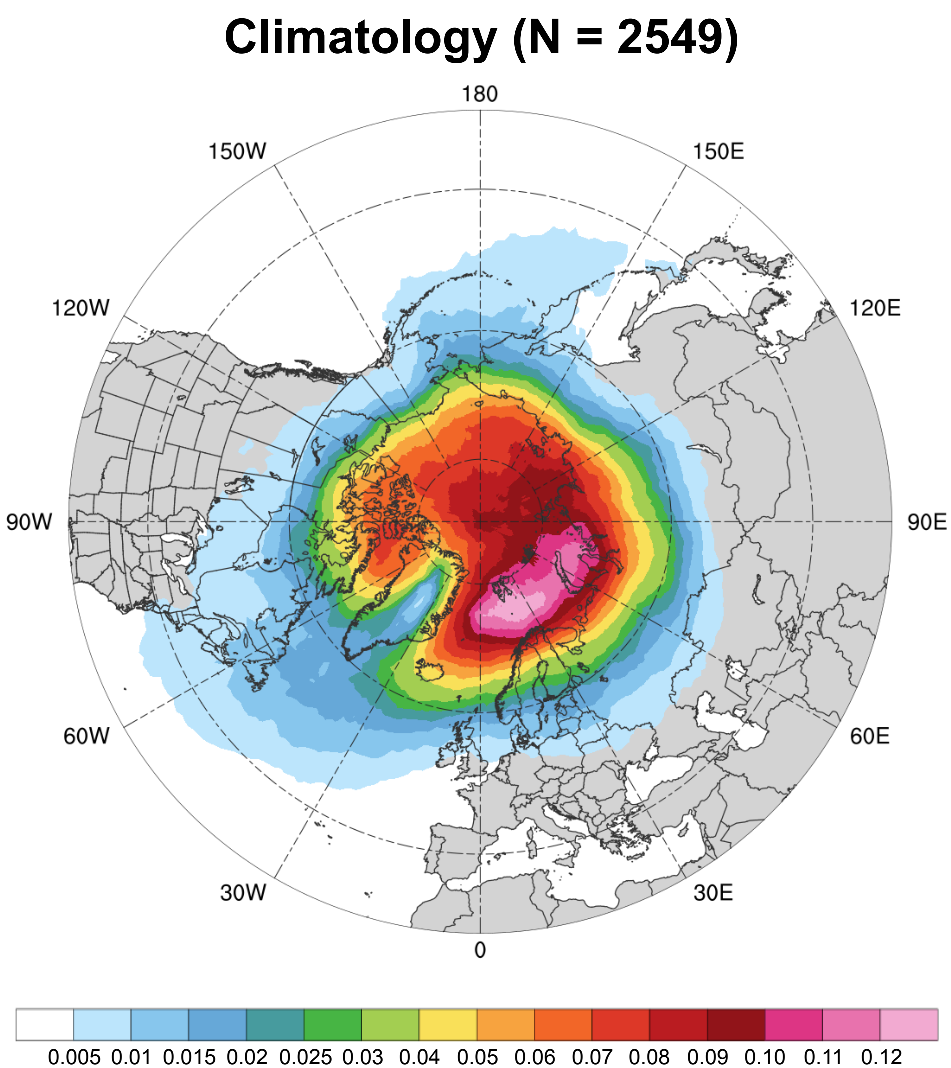


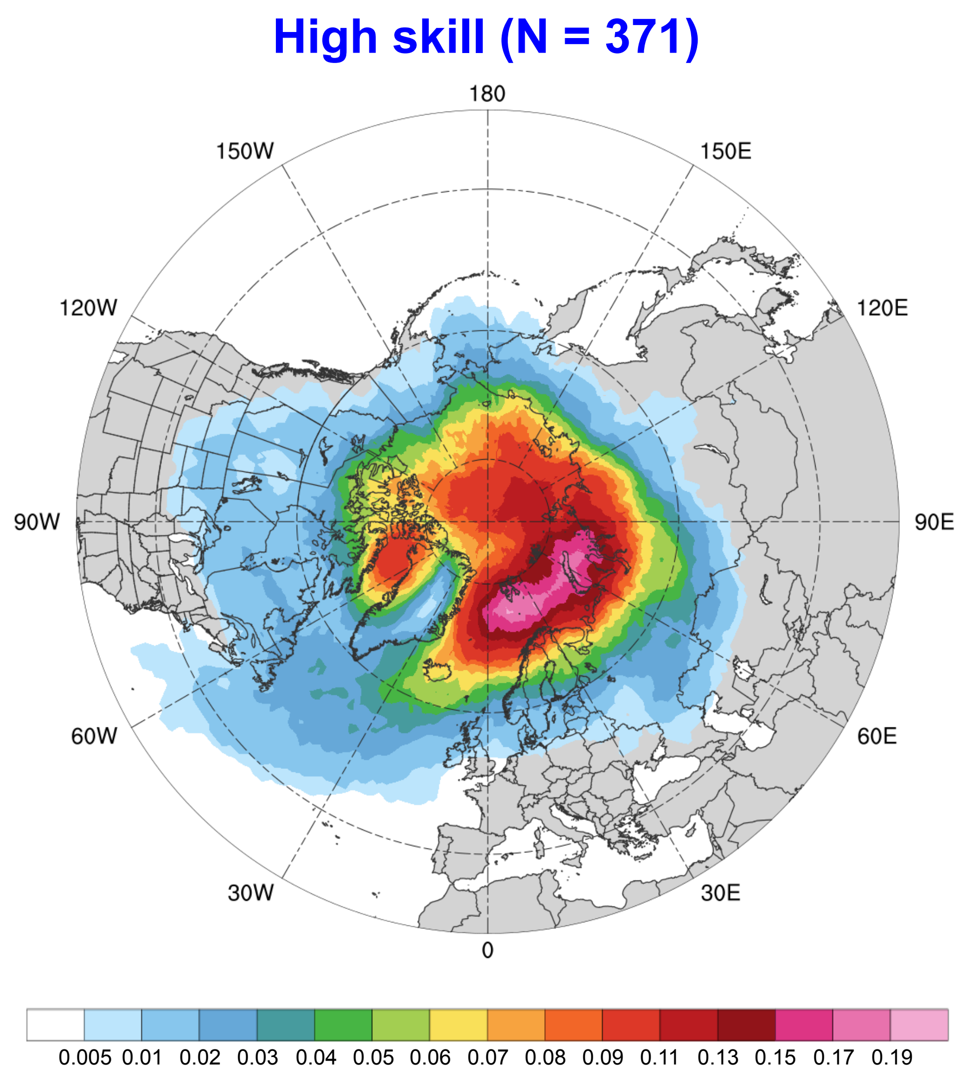
Low skill (N = 420)



Total number of ACs within 500 km of a grid point, divided by number of days in period (number of ACs day^{-1})

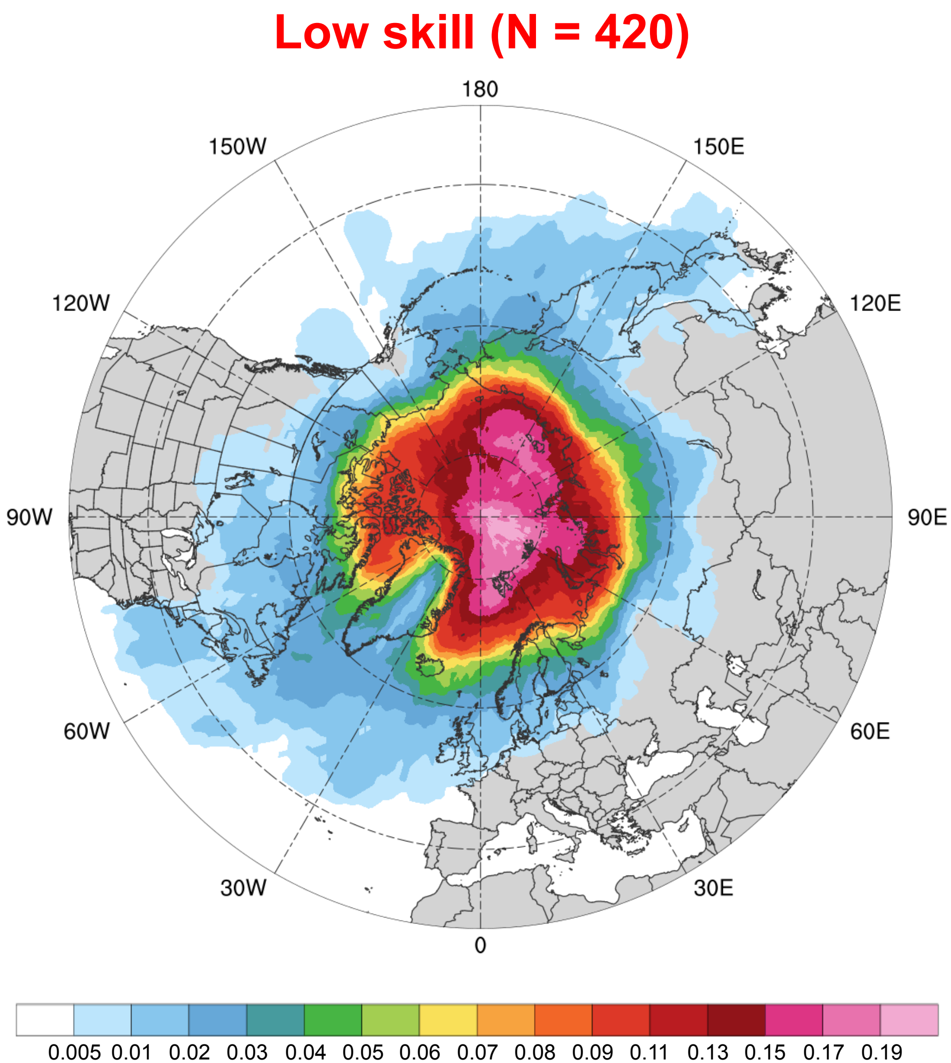
AC Track Frequency

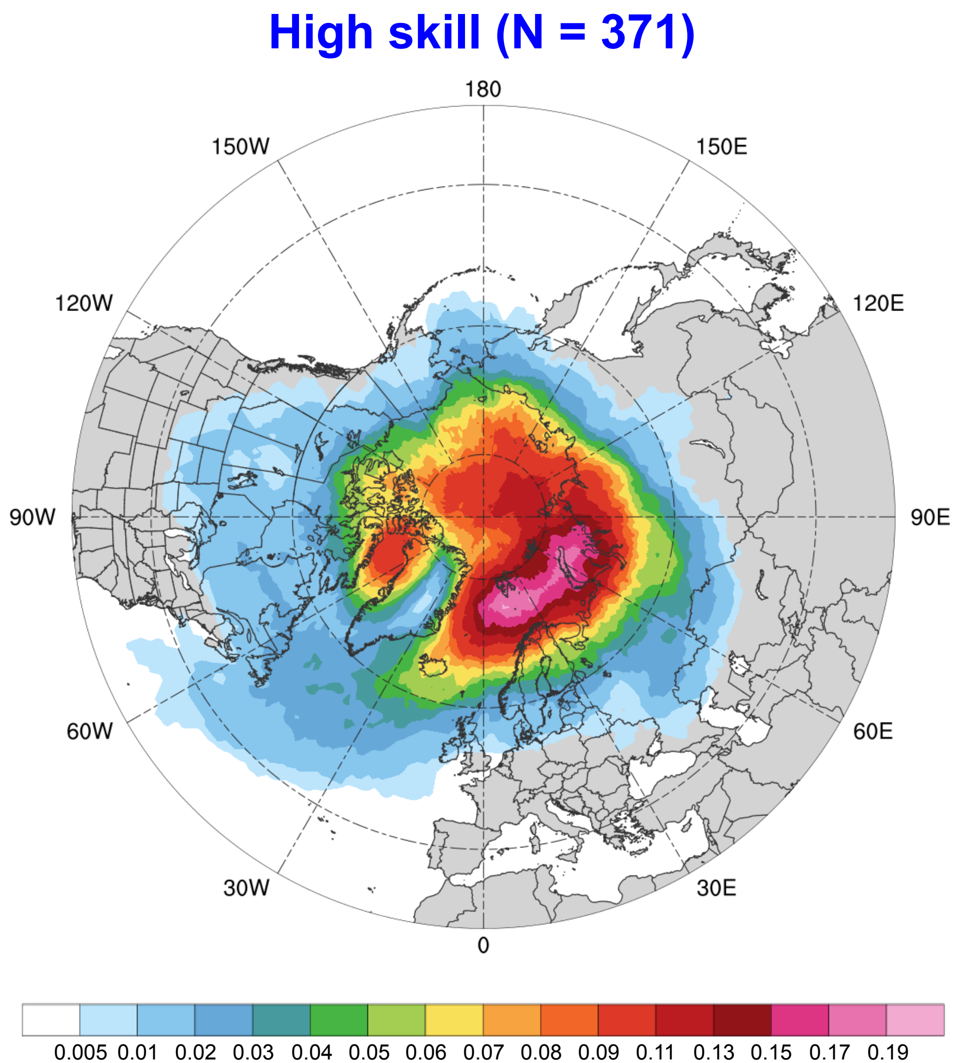




Total number of ACs within 500 km of a grid point,
divided by number of days in period (number of ACs day^{-1})

AC Track Frequency

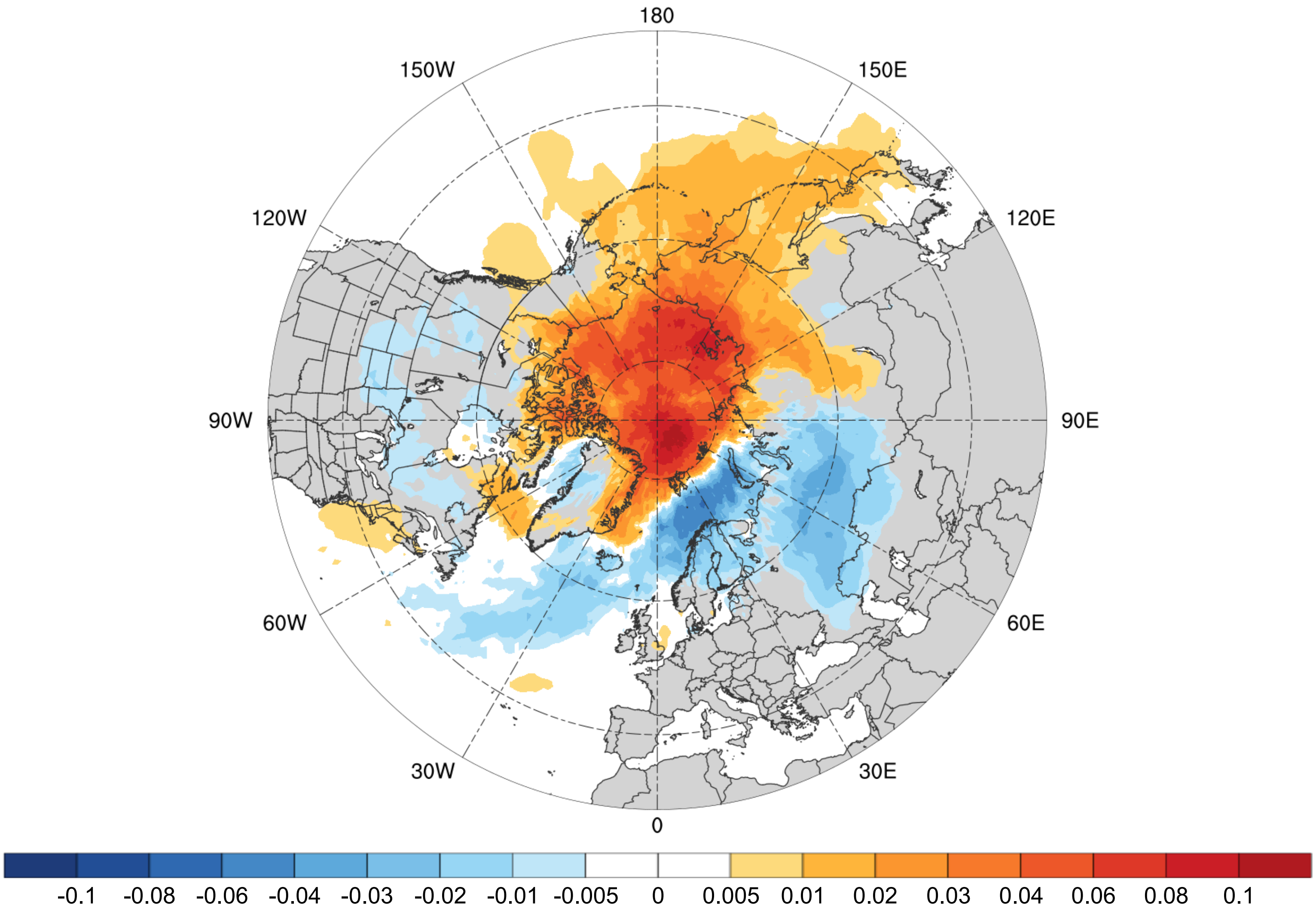




Total number of ACs within 500 km of a grid point,
divided by number of days in period (number of ACs day^{-1})

AC Track Frequency Differences

Low skill minus high skill

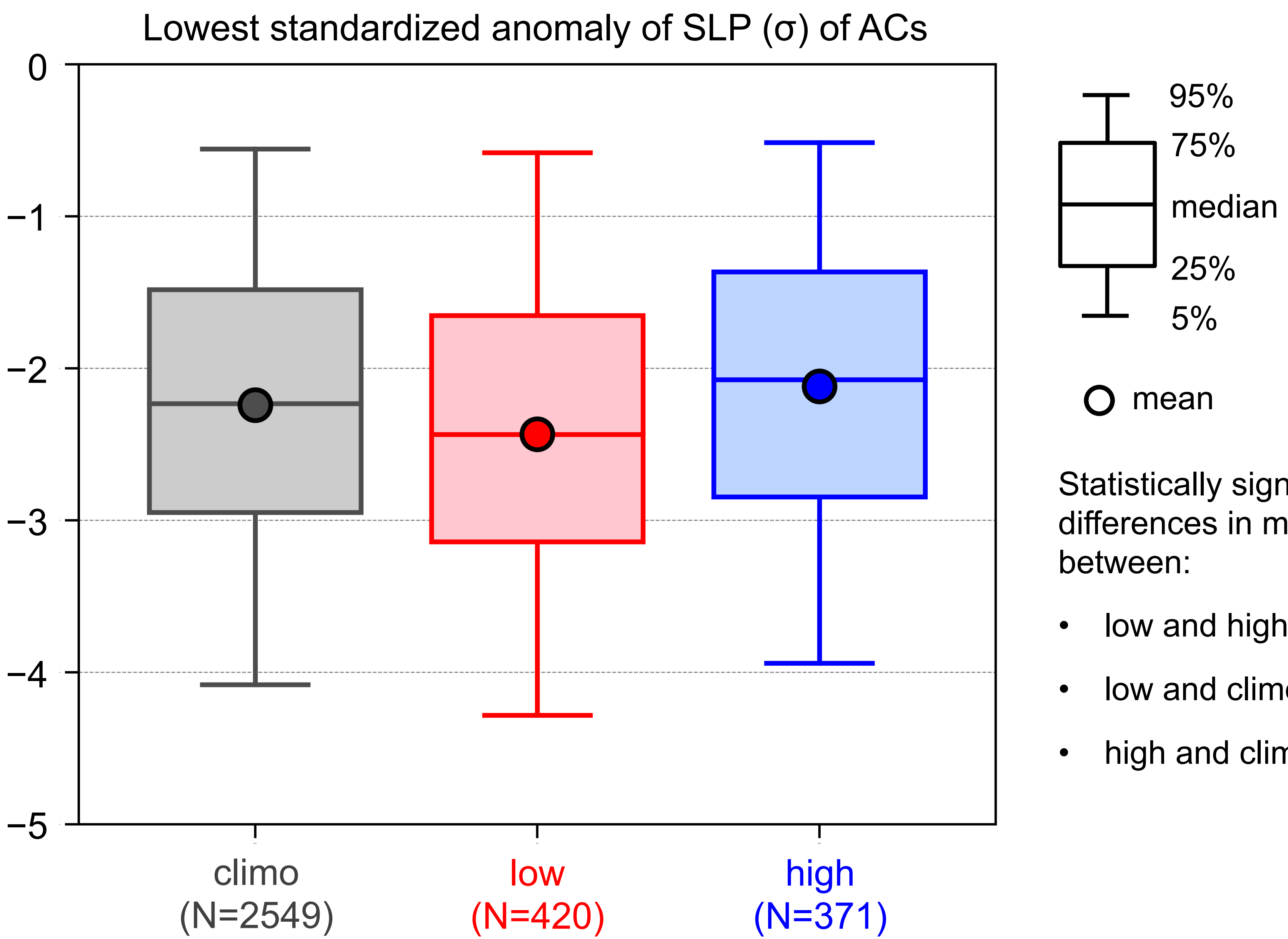


Difference in AC track density (number of ACs day^{-1})

Intensity

- Calculate standardized anomaly of minimum SLP every 6 h during lifetime of an AC and determine lowest standardized anomaly value during lifetime of AC

Intensity



Statistically significant differences in means between:

- low and high
- low and climo
- high and climo

Flow Amplitude

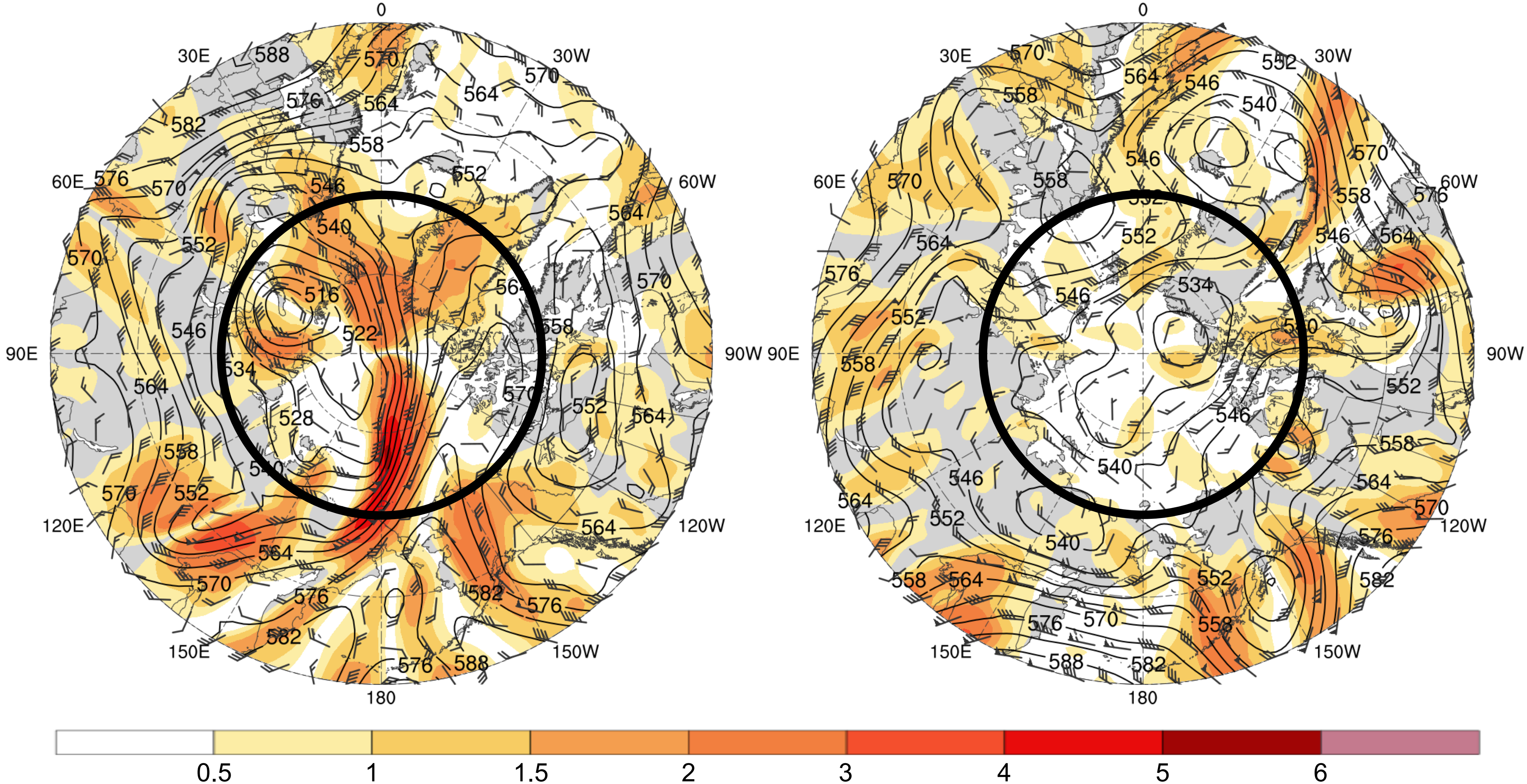
- Calculate absolute value of standardized anomaly of 500-hPa v-wind (hereafter $\boldsymbol{\sigma}_{\mathbf{v}}$) using ERA-Interim

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

Flow Amplitude

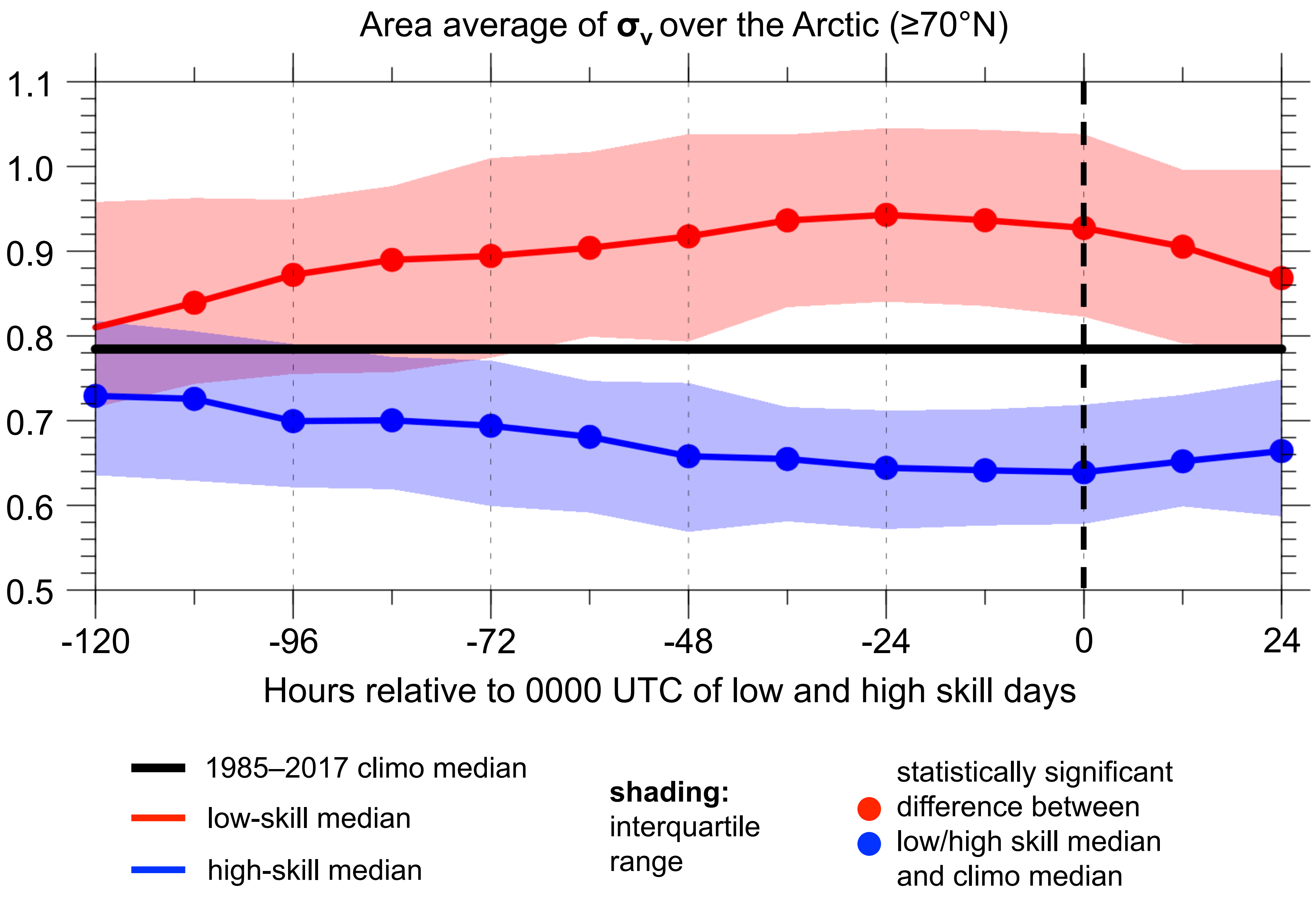
Low skill (avg. σ_v = 1.14)
0000 UTC 28 Aug 2016

High skill (avg. σ_v = 0.45)
0000 UTC 3 Sep 2011



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

Flow Amplitude



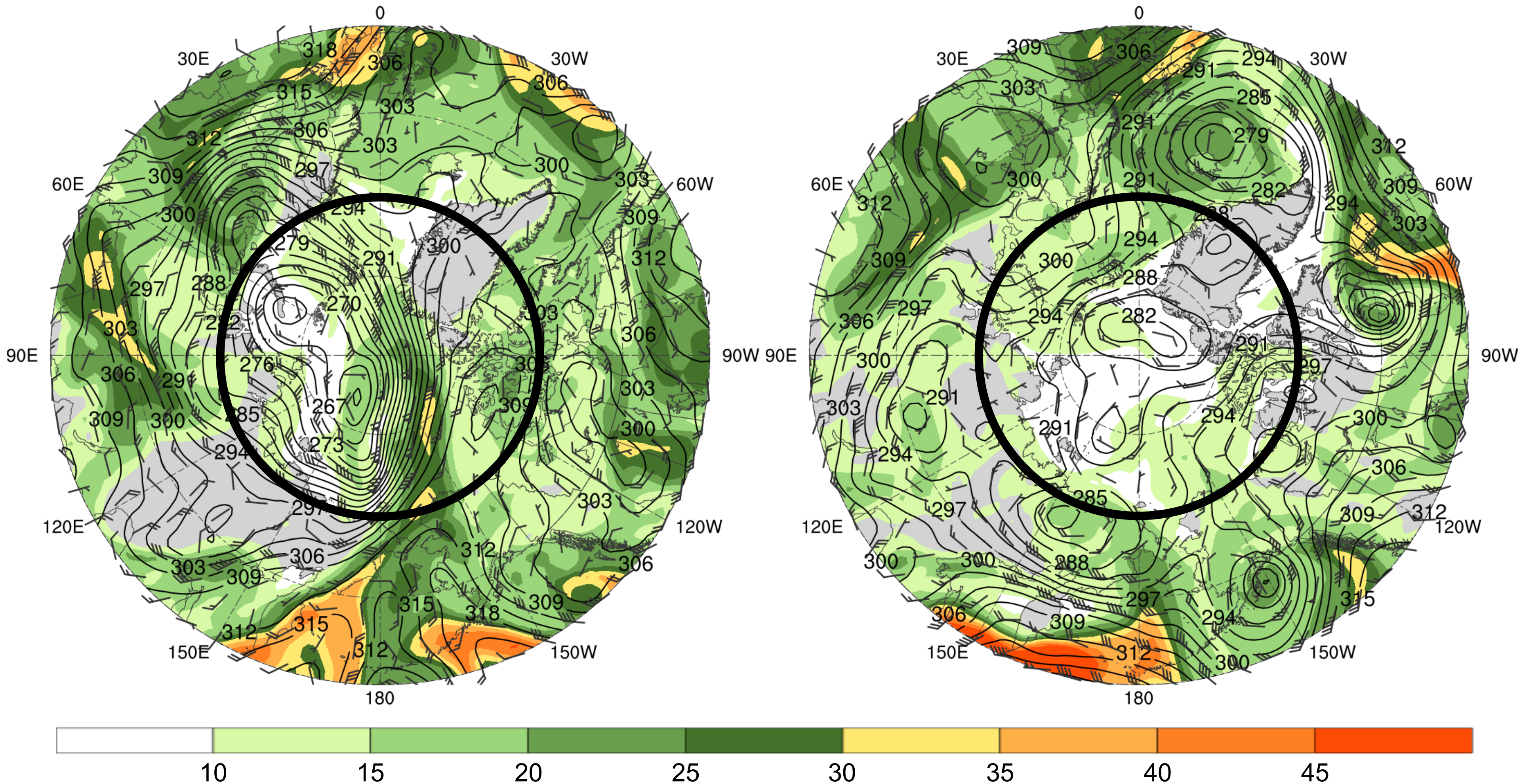
Moisture

- Calculate standardized anomaly PW (hereafter $\boldsymbol{\sigma_{PW}}$) using ERA-Interim
- Calculate area average of positive values of $\boldsymbol{\sigma_{PW}}$ over the Arctic (≥70°N) for low and high skill periods

Moisture

Low skill
0000 UTC 28 Aug 2016

High skill
0000 UTC 3 Sep 2011

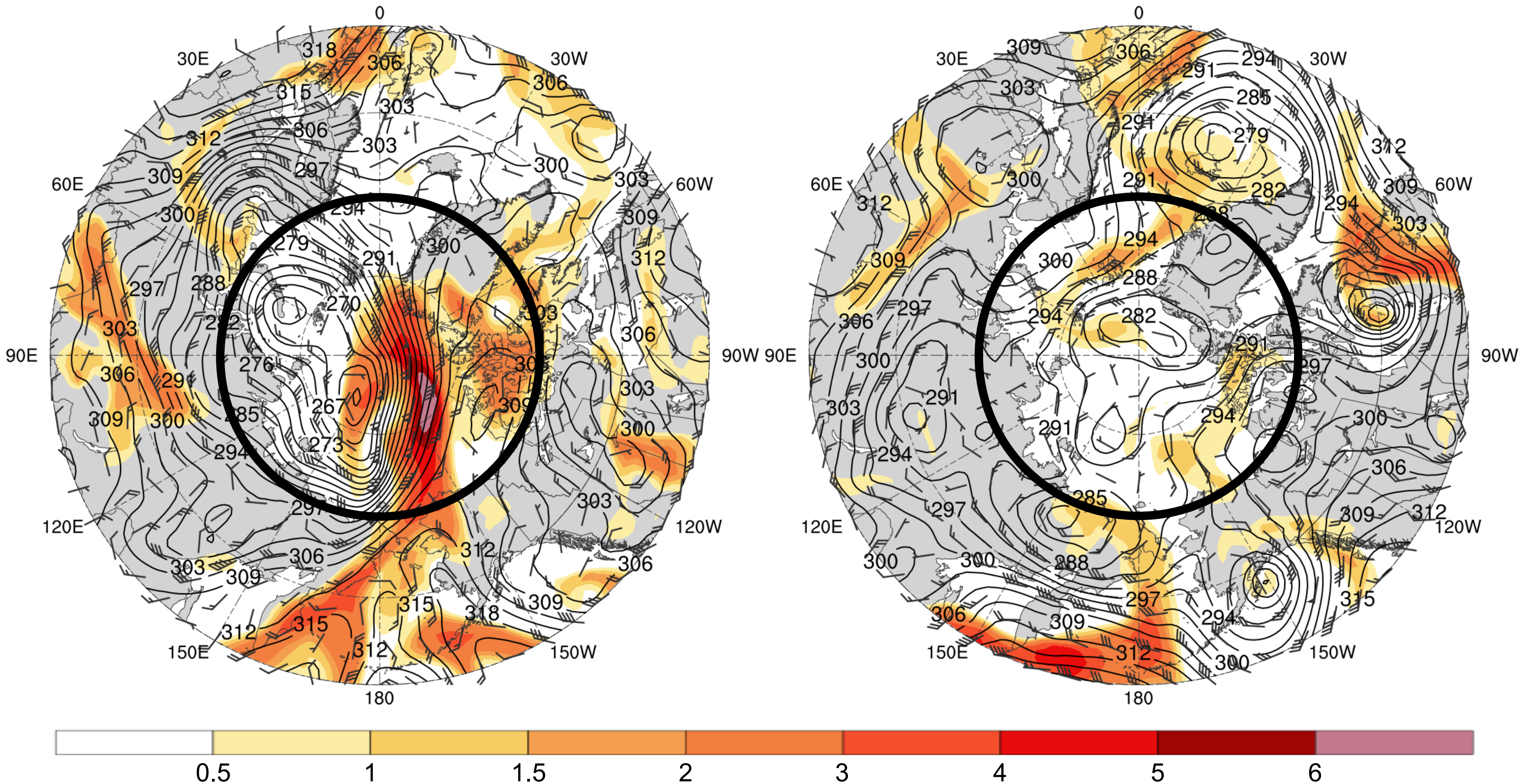


700-hPa geopotential height (dam, black) and wind (flags and barbs, m s^{-1}), and PW (mm, shading) from ERA-Interim

Moisture

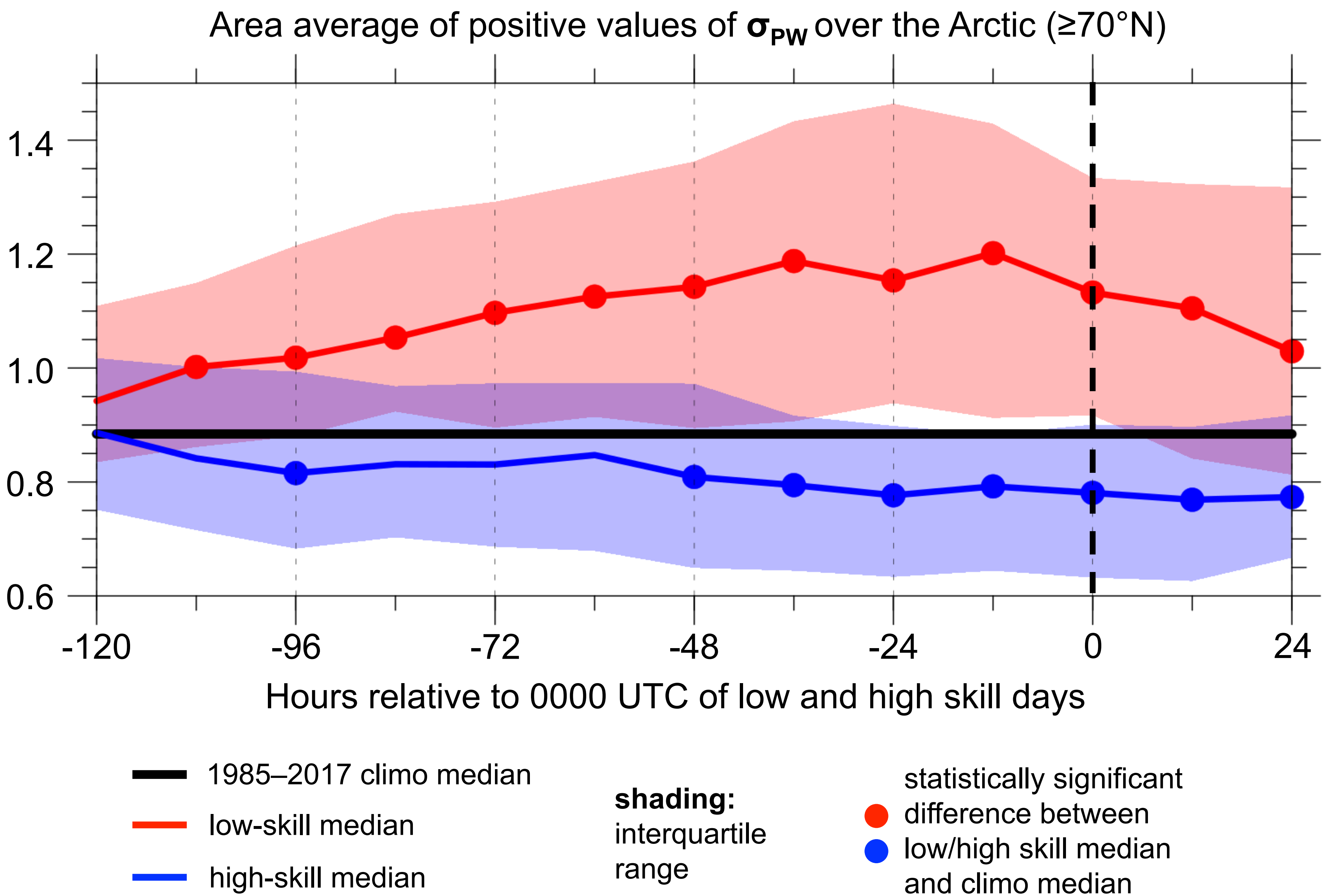
Low skill (avg. positive σ_{PW} = 1.82)
0000 UTC 28 Aug 2016

High skill (avg. positive σ_{PW} = 0.63)
0000 UTC 3 Sep 2011



700-hPa geopotential height (dam, black) and wind (flags and barbs, m s^{-1}), and $\boldsymbol{\sigma}_{PW}$ (shading) from ERA-Interim

Moisture


Area average of positive values of σ_{PW} over the Arctic (≥70°N)
1.4
1.2
1.0
0.8
0.6
-120
-96
-72
-48
-24
0
24
Hours relative to 0000 UTC of low and high skill days
1985–2017 climo median
low-skill median
high-skill median
shading: interquartile range
statistically significant difference between low/high skill median and climo median

Summary

- Arctic cyclone frequency is higher for low skill periods compared to high skill periods
- Arctic cyclones during low skill periods occur more frequently over eastern Eurasia, the northwestern North Pacific, and much of the Arctic Ocean relative to Arctic cyclones during high skill periods
- Arctic cyclones during high skill periods occur more frequently over the northern North Atlantic, Norwegian and Barents Seas, and western Eurasia relative to Arctic cyclones during low skill periods

Summary

- Arctic cyclones tend to be stronger during low skill periods compared to high skill periods
- There tends to be significantly amplified and deamplified synoptic-scale flow over the Arctic relative to climatology during low and high skill periods, respectively
- There tends to be significantly large and small amounts of moisture over the Arctic relative to climatology during low and high skill periods, respectively

Questions? *Email: kbiernat@albany.edu*

- Arctic cyclones tend to be stronger during low skill periods compared to high skill periods
- There tends to be significantly amplified and deamplified synoptic-scale flow over the Arctic relative to climatology during low and high skill periods, respectively
- There tends to be significantly large and small amounts of moisture over the Arctic relative to climatology during low and high skill periods, respectively

Acknowledgments

Ben Moore

References

- Crawford, A., and M. Serreze, 2016: Does the summer Arctic frontal zone influence Arctic Ocean cyclone activity? *J. Climate,* **29,** 4977–4993.

- Dee, D. P., and Coauthors, 2011: The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quart. J. Roy. Meteor. Soc*., **137**, 553–597.

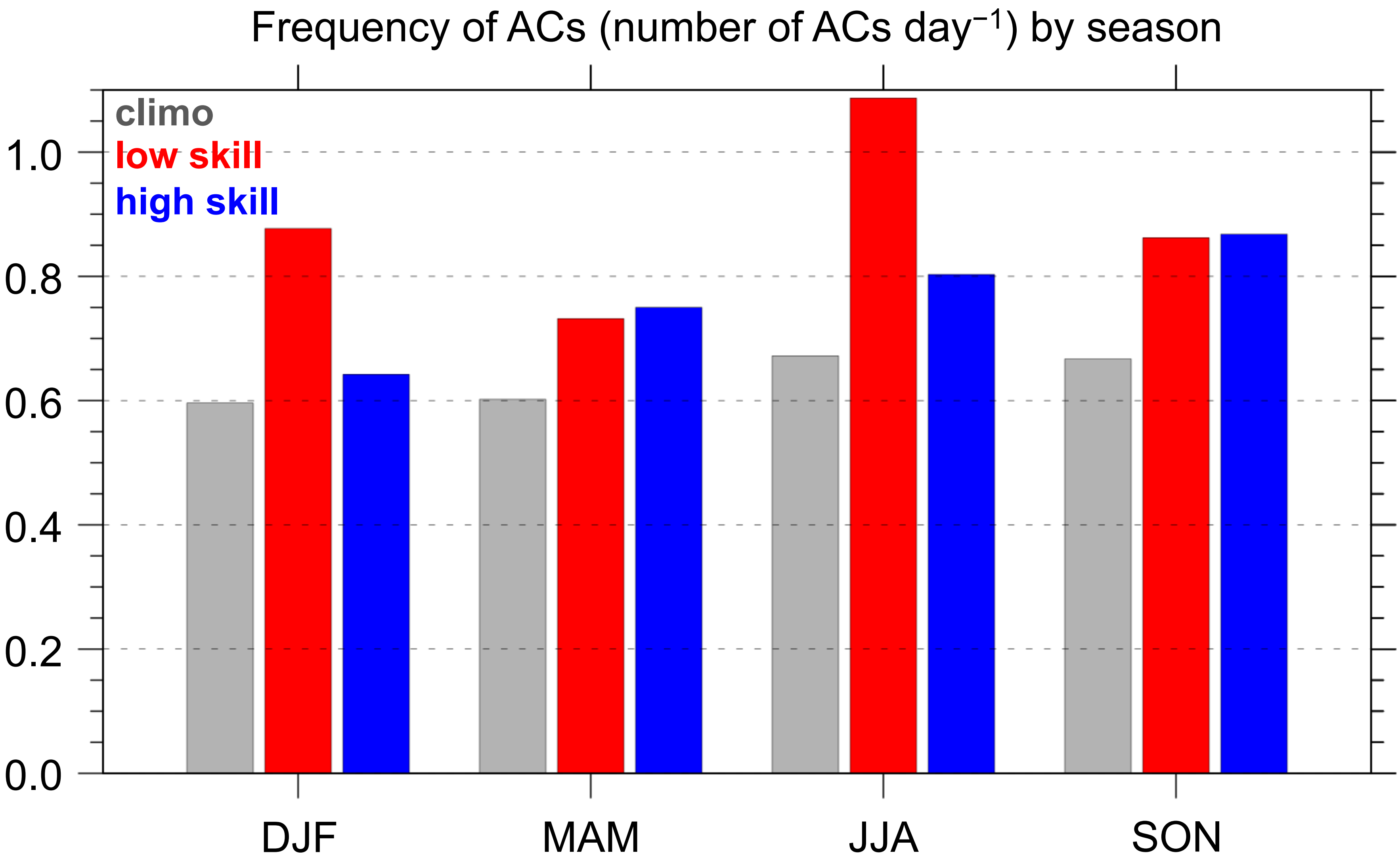
- Hamill, T. M., G. T. Bates, J. S. Whitaker, D. R. Murray, M. Fiorino, T. J. Galarneau Jr., Y. Zhu, and W. Lapenta, 2013: NOAA's second-generation global medium-range ensemble reforecast dataset. *Bull. Amer. Meteor. Soc.*, **94**, 1553–1565.

- Moore, B. J., 2017: Rossby wave breaking and widespread extreme precipitation events in the central and eastern U.S. Ph.D. dissertation, University at Albany, State University of New York, Albany, NY, 182 pp.

- Sprenger, M., and Coauthors, 2017: Global climatologies of Eulerian and Lagrangian flow features based on ERA-Interim. *Bull. Amer. Meteor. Soc.*, **98**, 1739–1748.

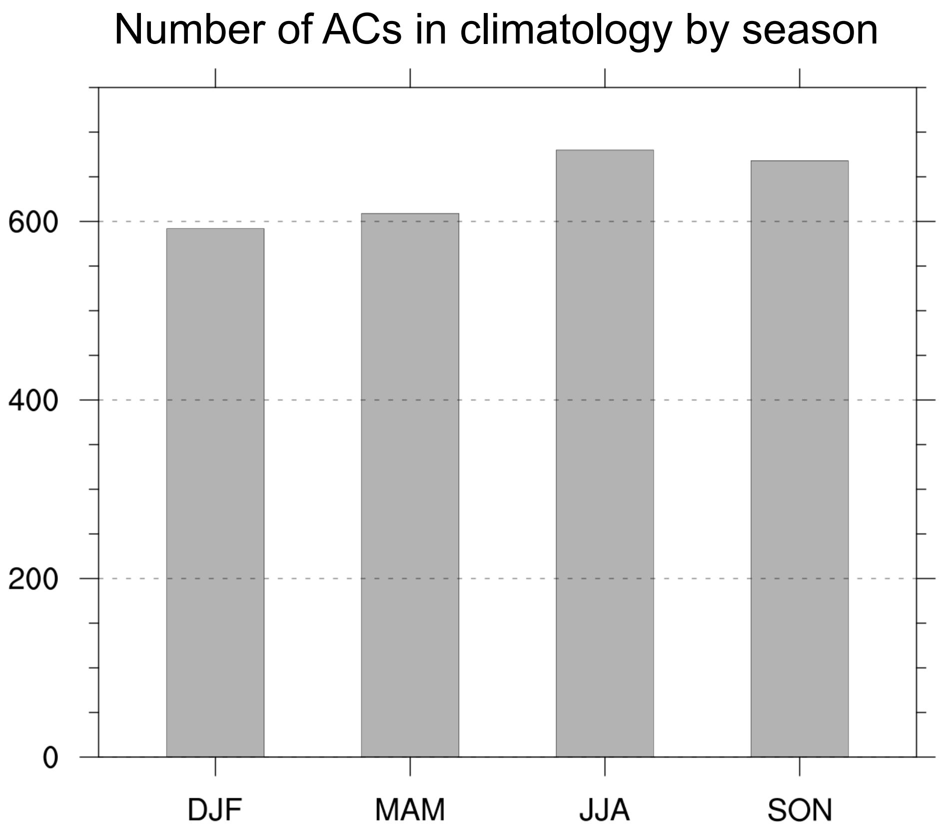
Extra Slides

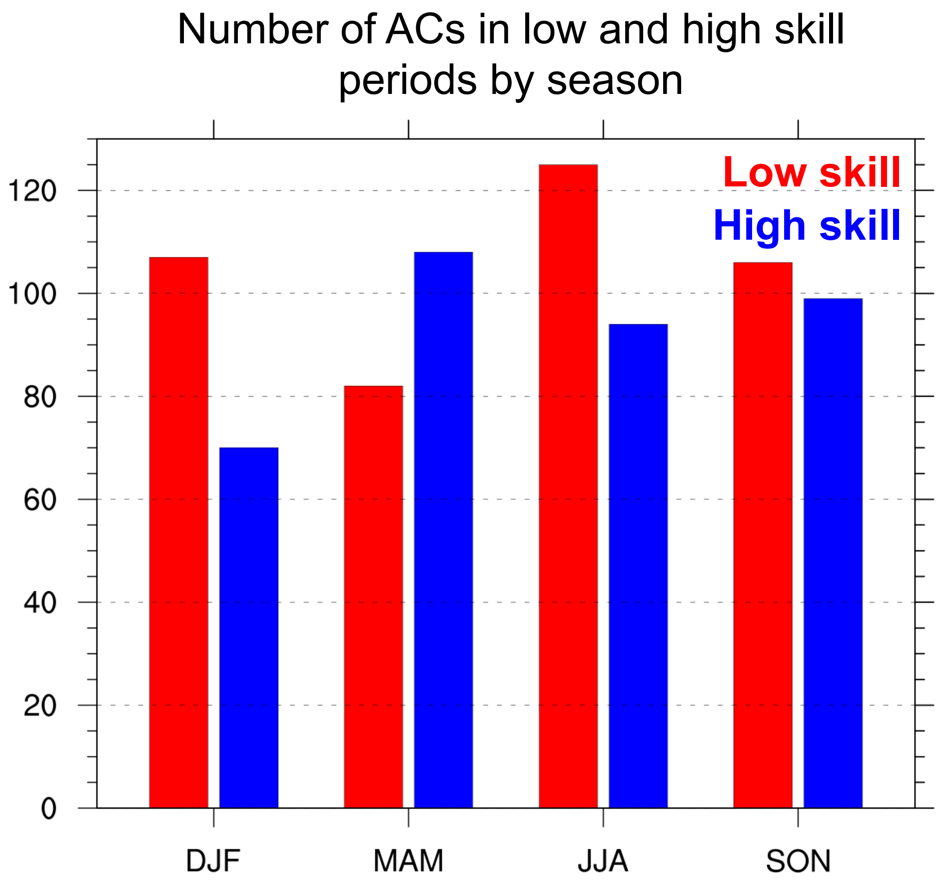
Frequency of ACs by Season



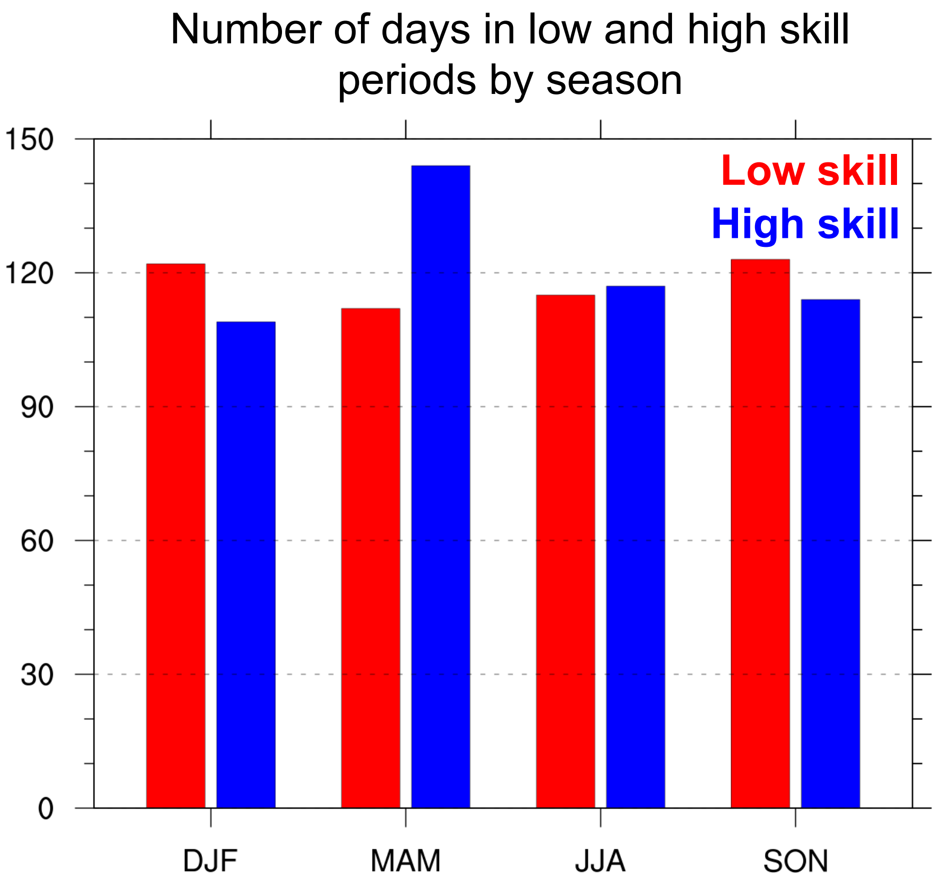
Frequency = number of ACs within period / number of days within period

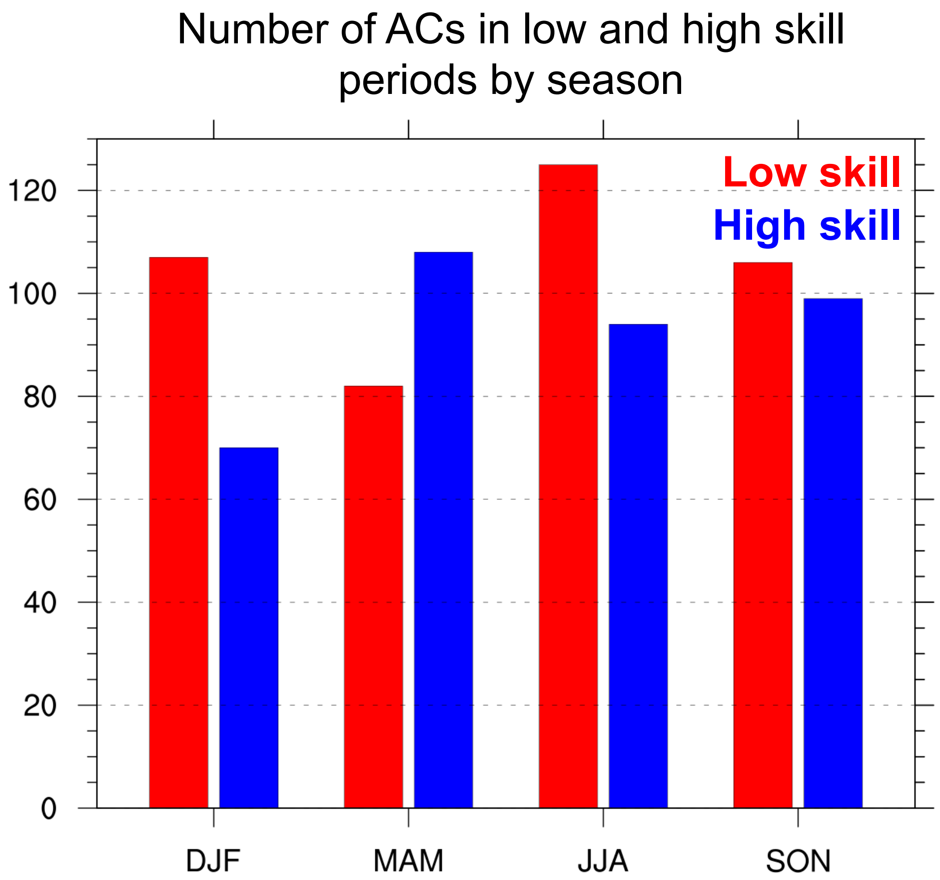
Number of Arctic Cyclones by Season





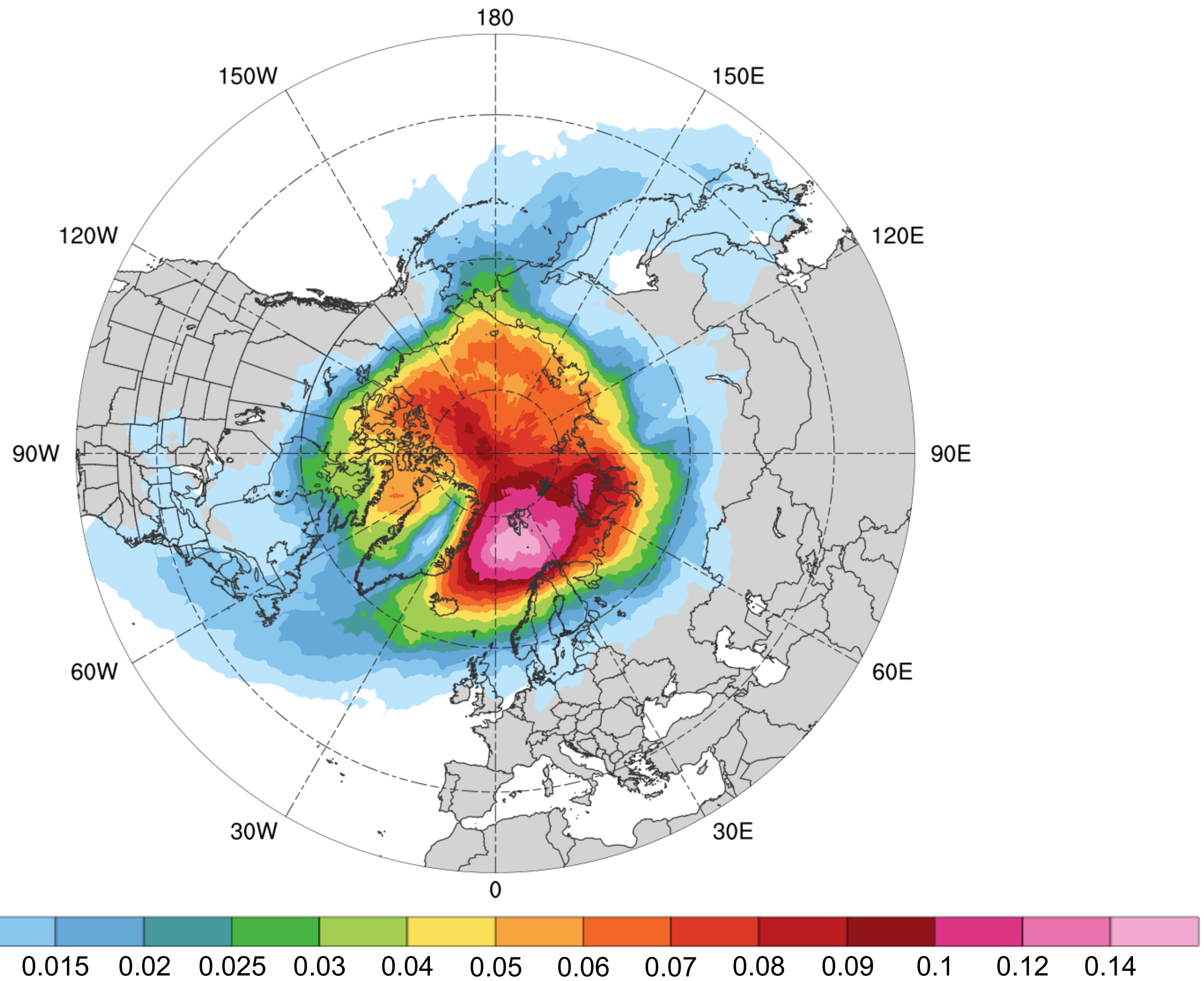
Number of Arctic Cyclones by Season





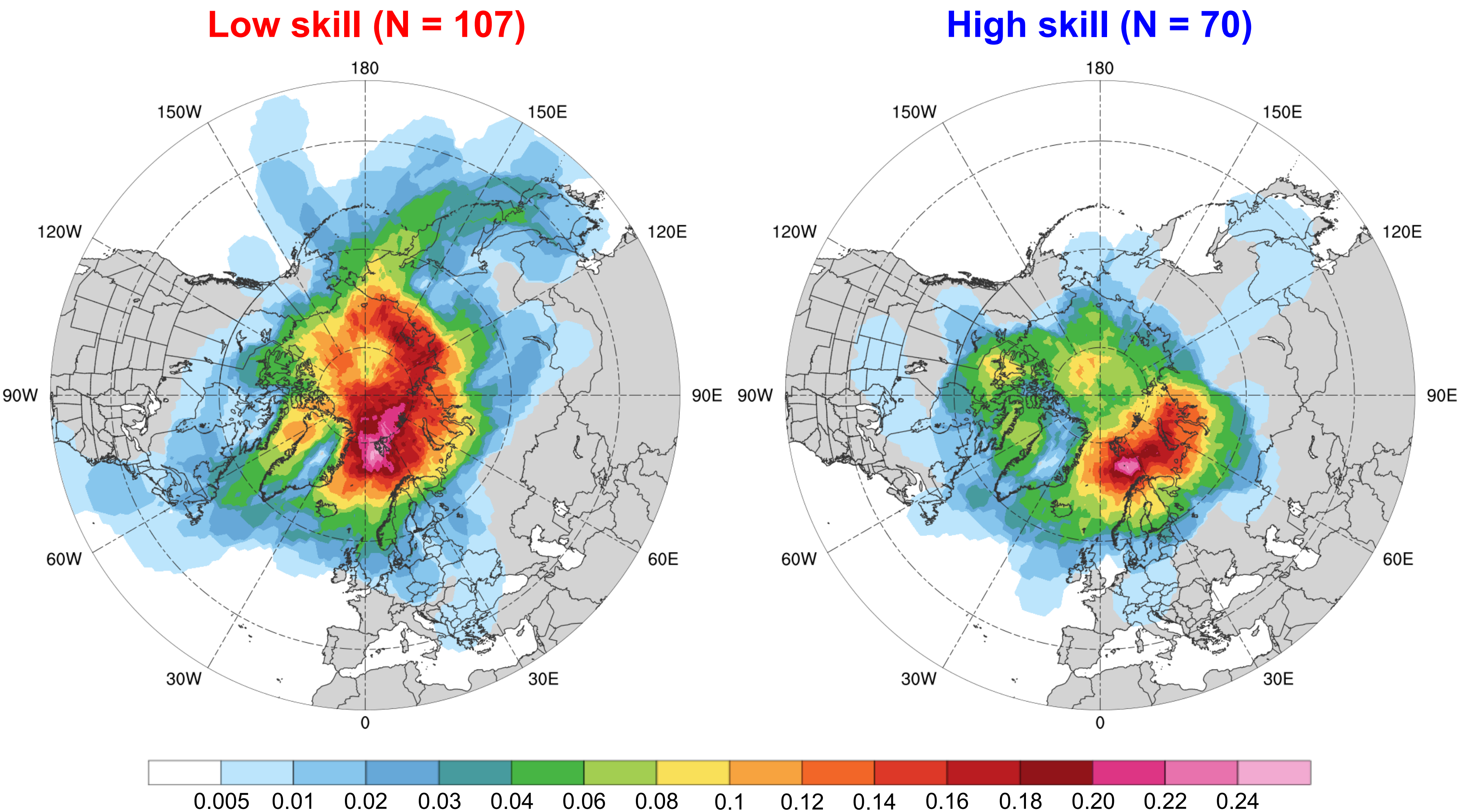
AC Track Frequency (DJF)

Climatology (N = 592)



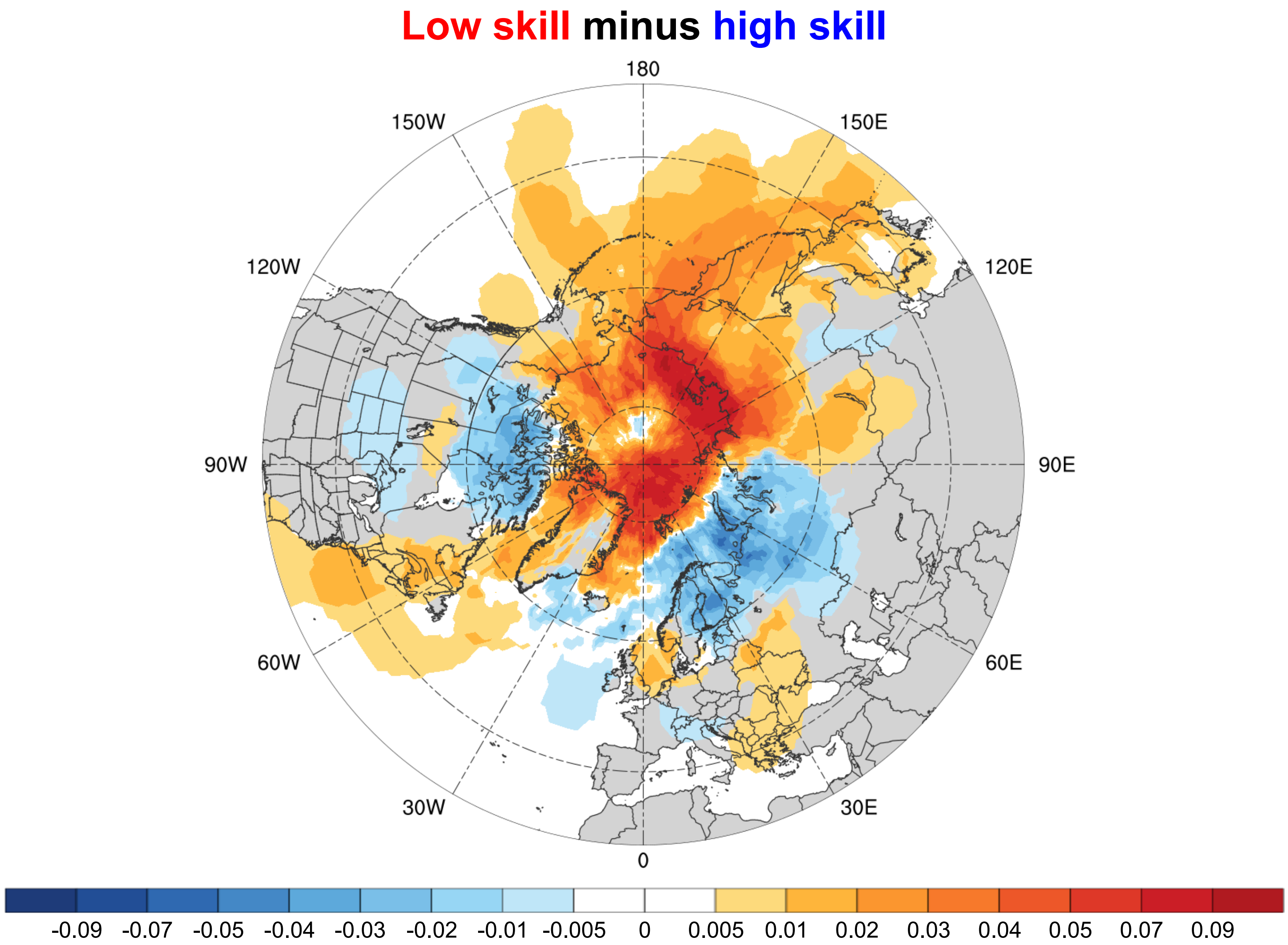
Total number of ACs within 500 km of a grid point, divided by number of days in climatology during DJF (number of ACs day^{-1})

AC Track Frequency (DJF)



Total number of ACs within 500 km of a grid point, divided by number of days in period during DJF (number of ACs day^{-1})

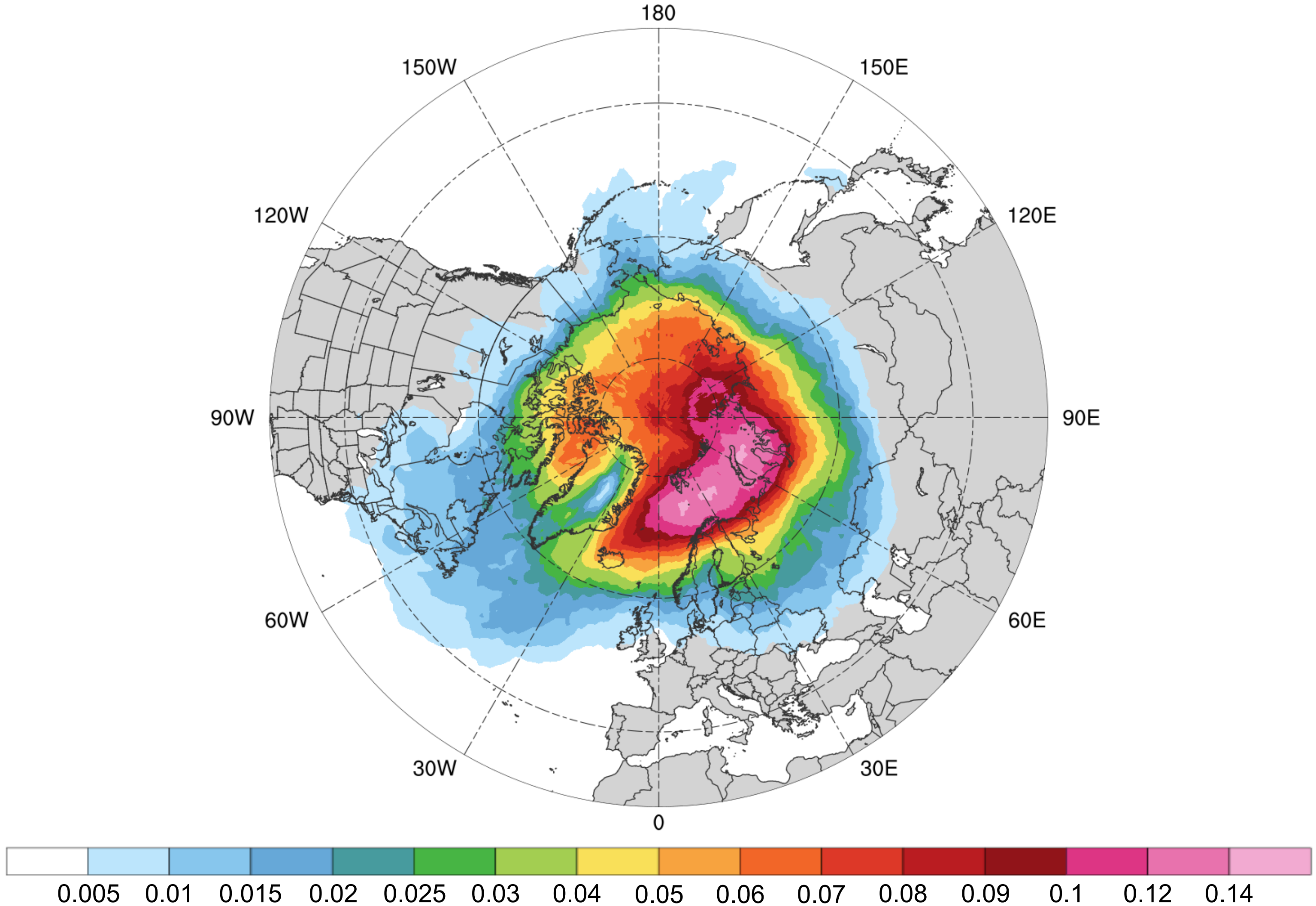
AC Track Frequency Differences (DJF)



Difference in AC track density during DJF (number of ACs day^{-1})

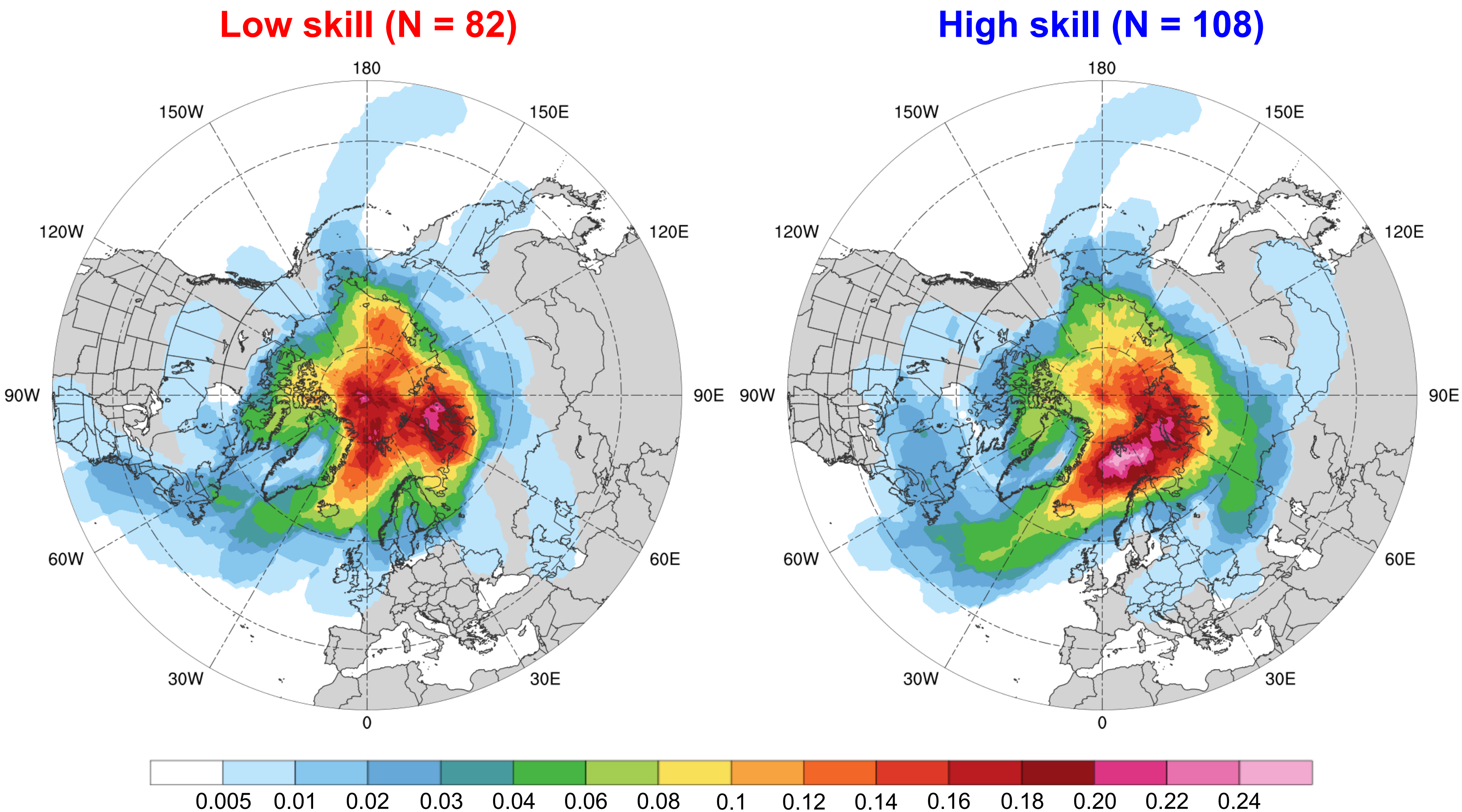
AC Track Frequency (MAM)

Climatology (N = 609)



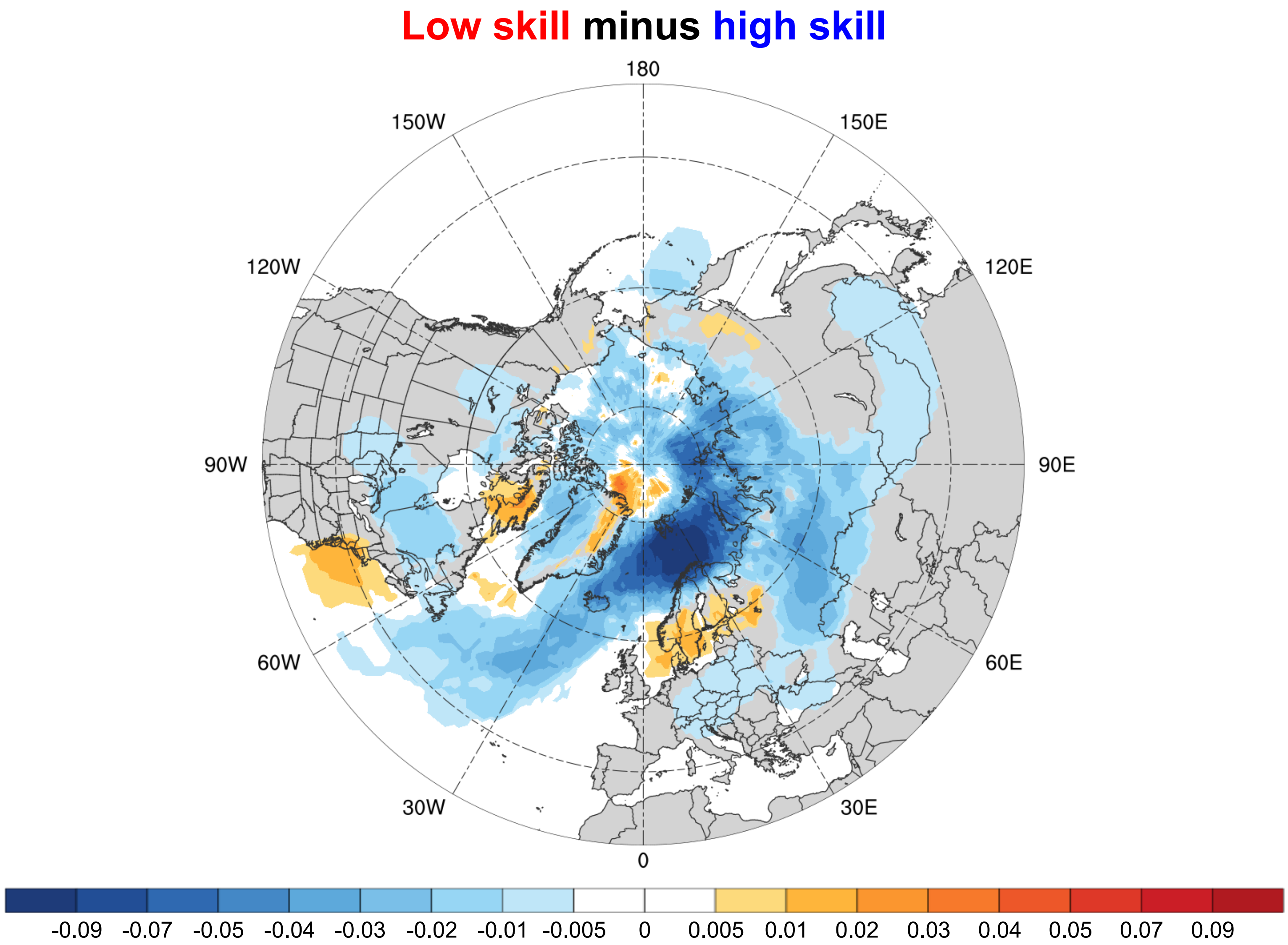
Total number of ACs within 500 km of a grid point,
divided by number of days in climatology during MAM (number of ACs day^{-1})

AC Track Frequency (MAM)



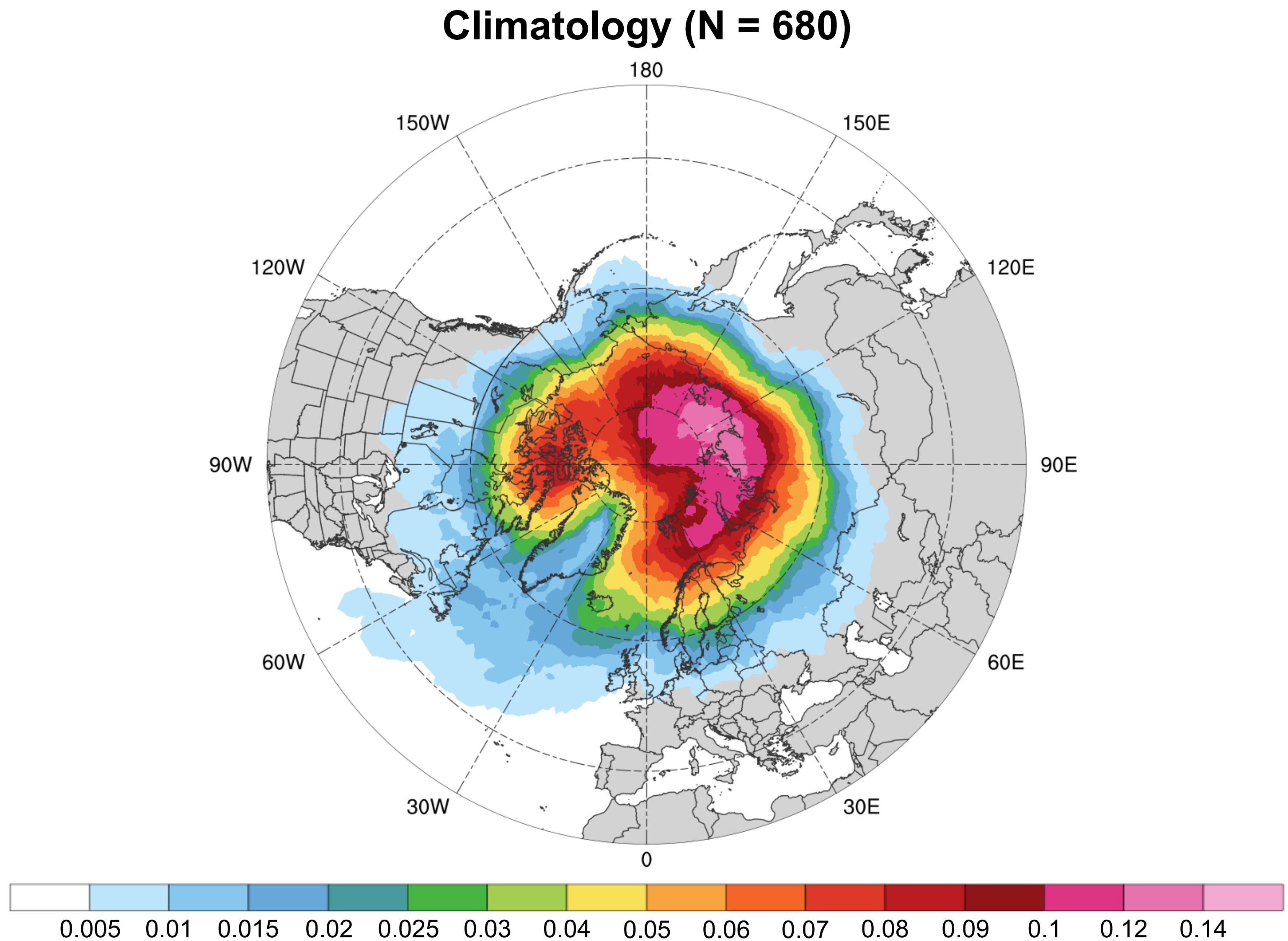
Total number of ACs within 500 km of a grid point, divided by number of days in period during MAM (number of ACs day^{-1})

AC Track Frequency Differences (MAM)



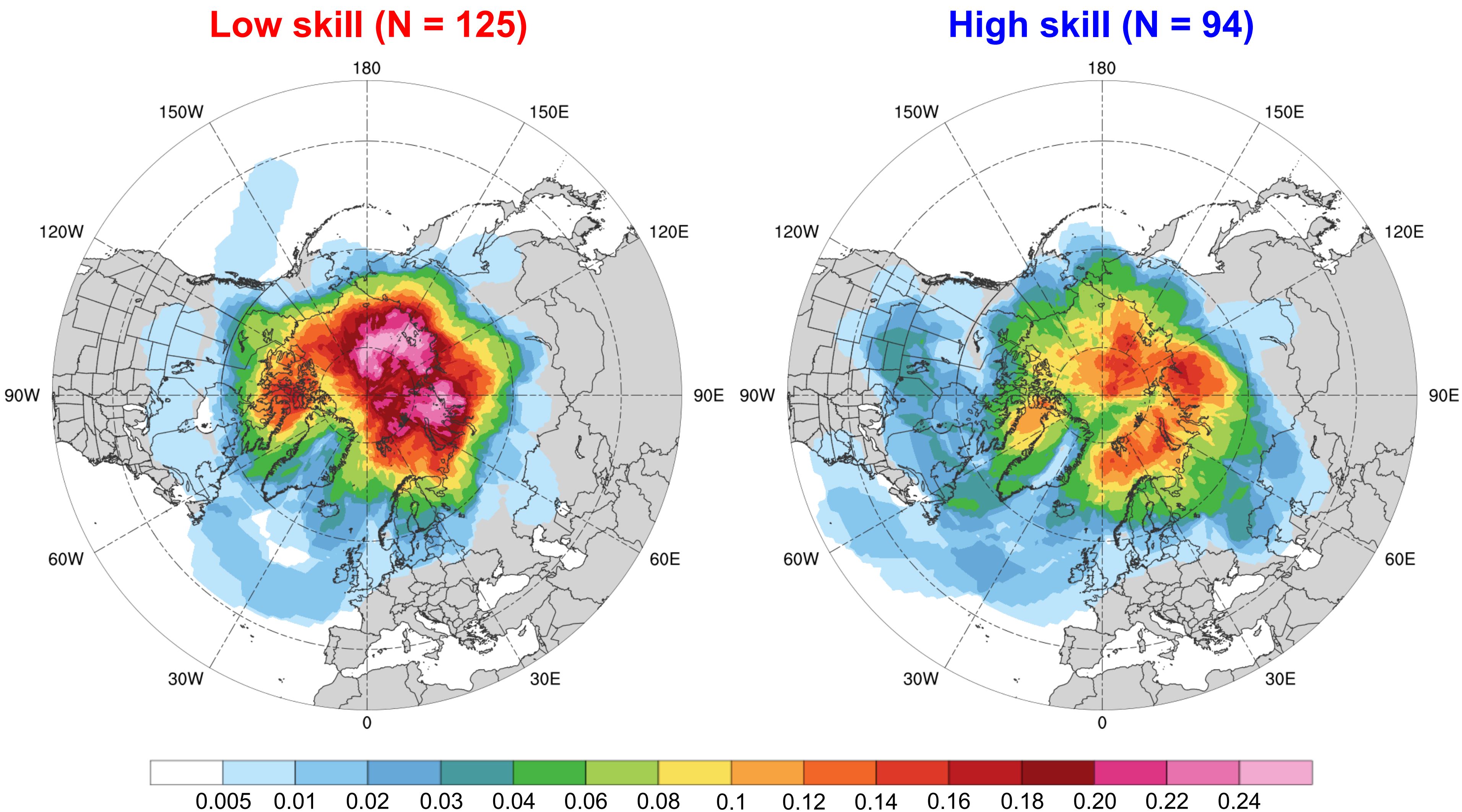
Difference in AC track density during MAM (number of ACs day^{-1})

AC Track Frequency (JJA)



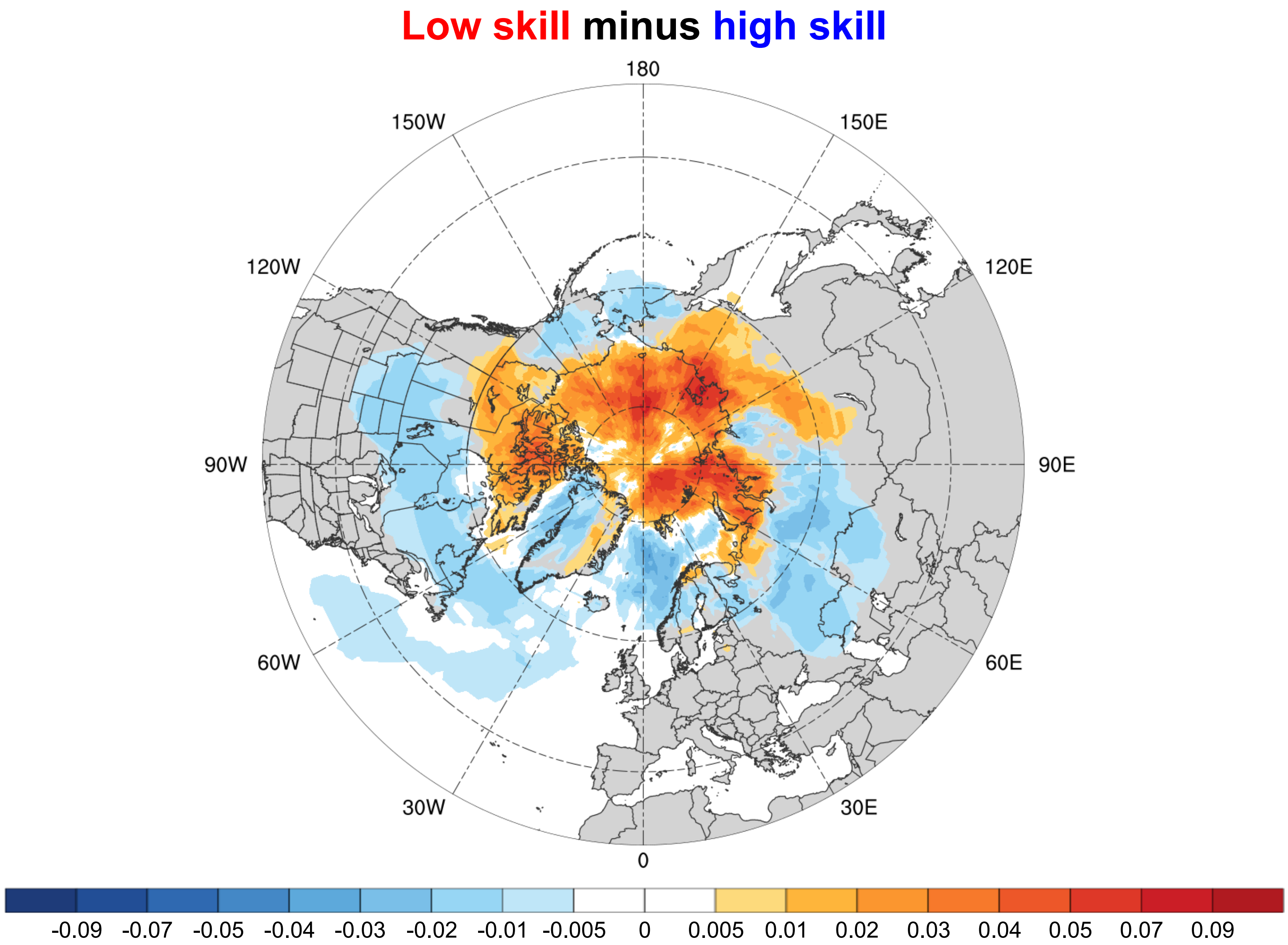
Total number of ACs within 500 km of a grid point,
divided by number of days in climatology during JJA (number of ACs day^{-1})

AC Track Frequency (JJA)



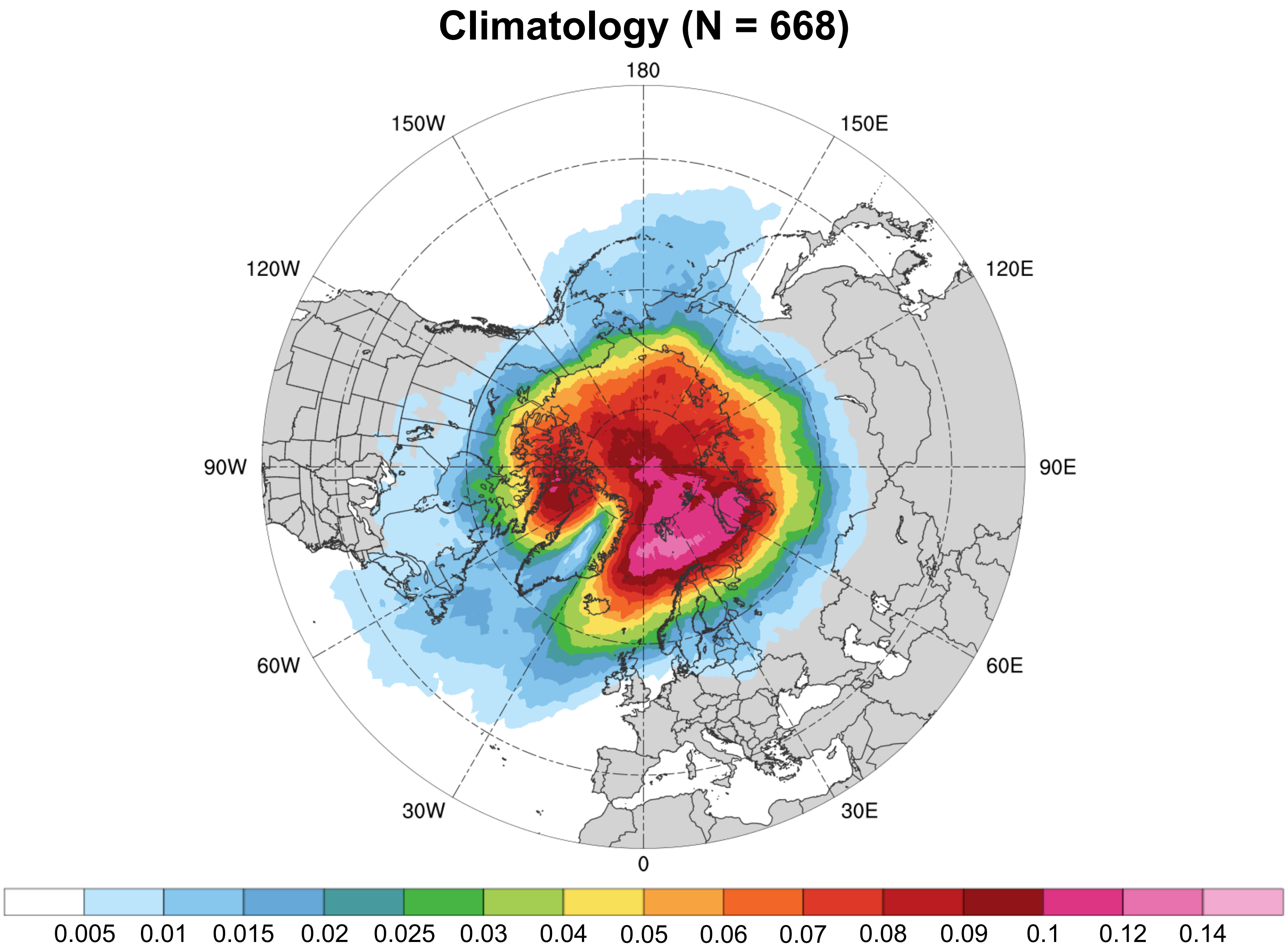
Total number of ACs within 500 km of a grid point, divided by number of days in period during JJA (number of ACs day^{-1})

AC Track Frequency Differences (JJA)



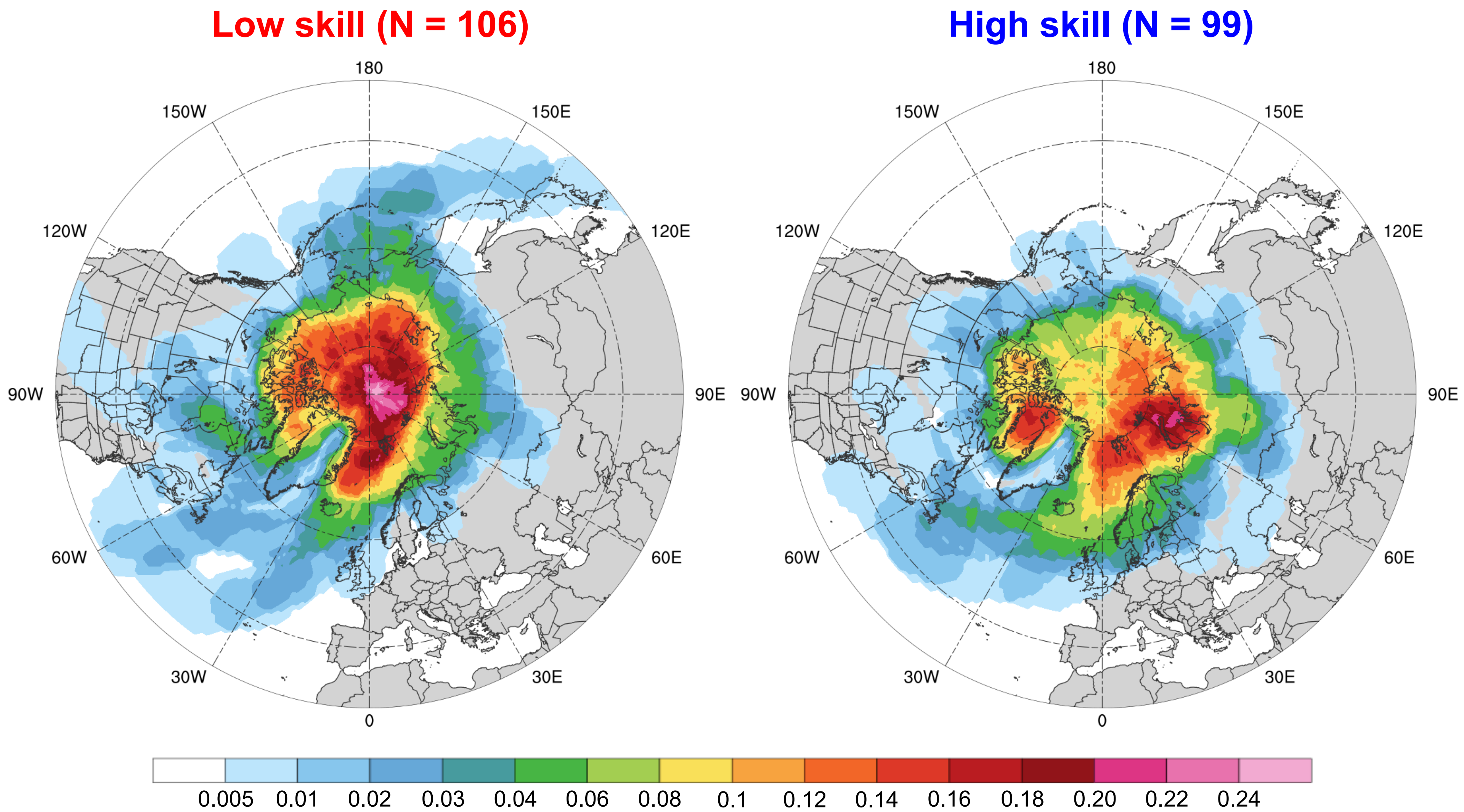
Difference in AC track density during JJA (number of ACs day^{-1})

AC Track Frequency (SON)



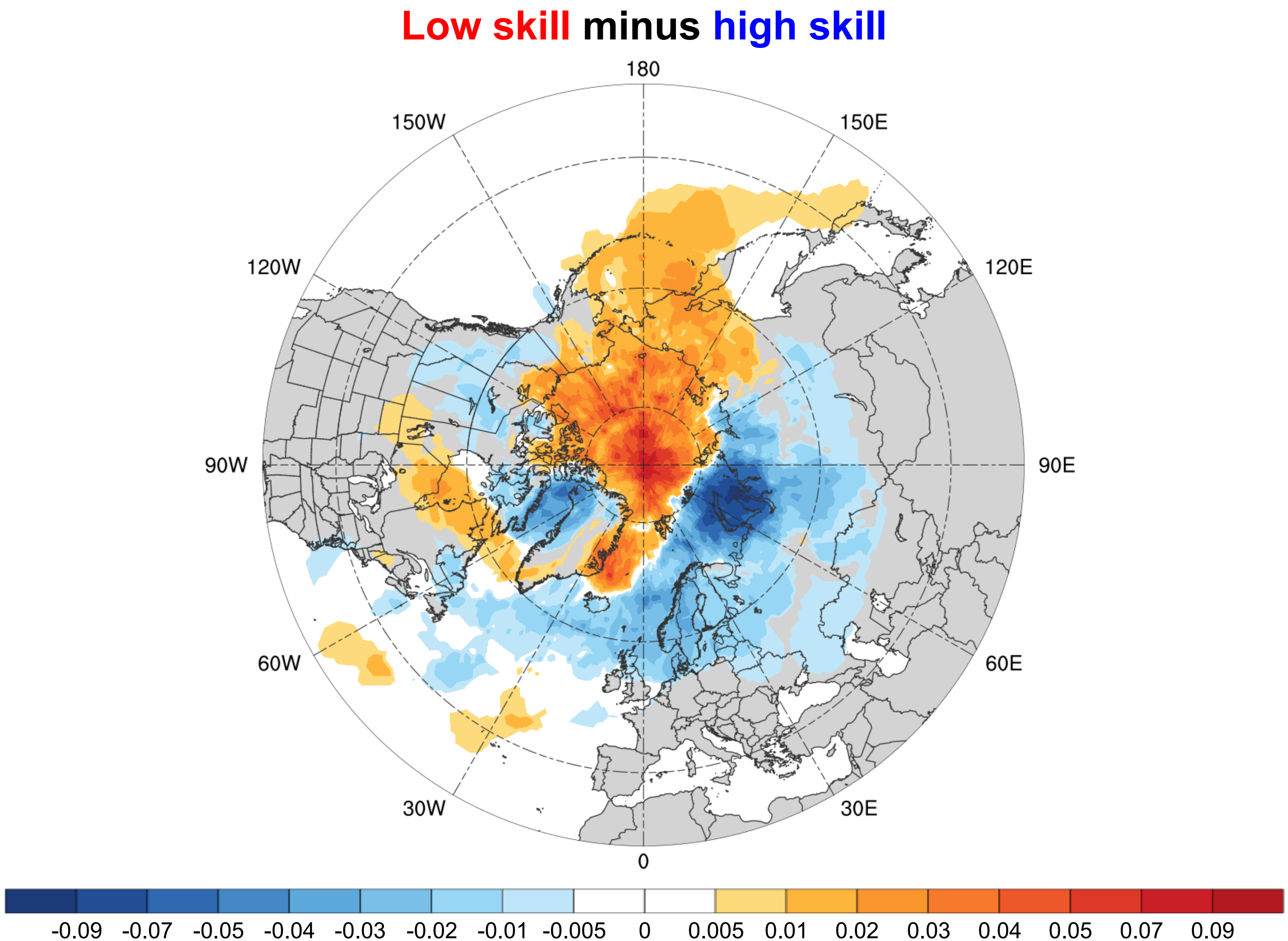
Total number of ACs within 500 km of a grid point,
divided by number of days in climatology during SON (number of ACs day^{-1})

AC Track Frequency (SON)



Total number of ACs within 500 km of a grid point,
divided by number of days in period during SON (number of ACs day^{-1})

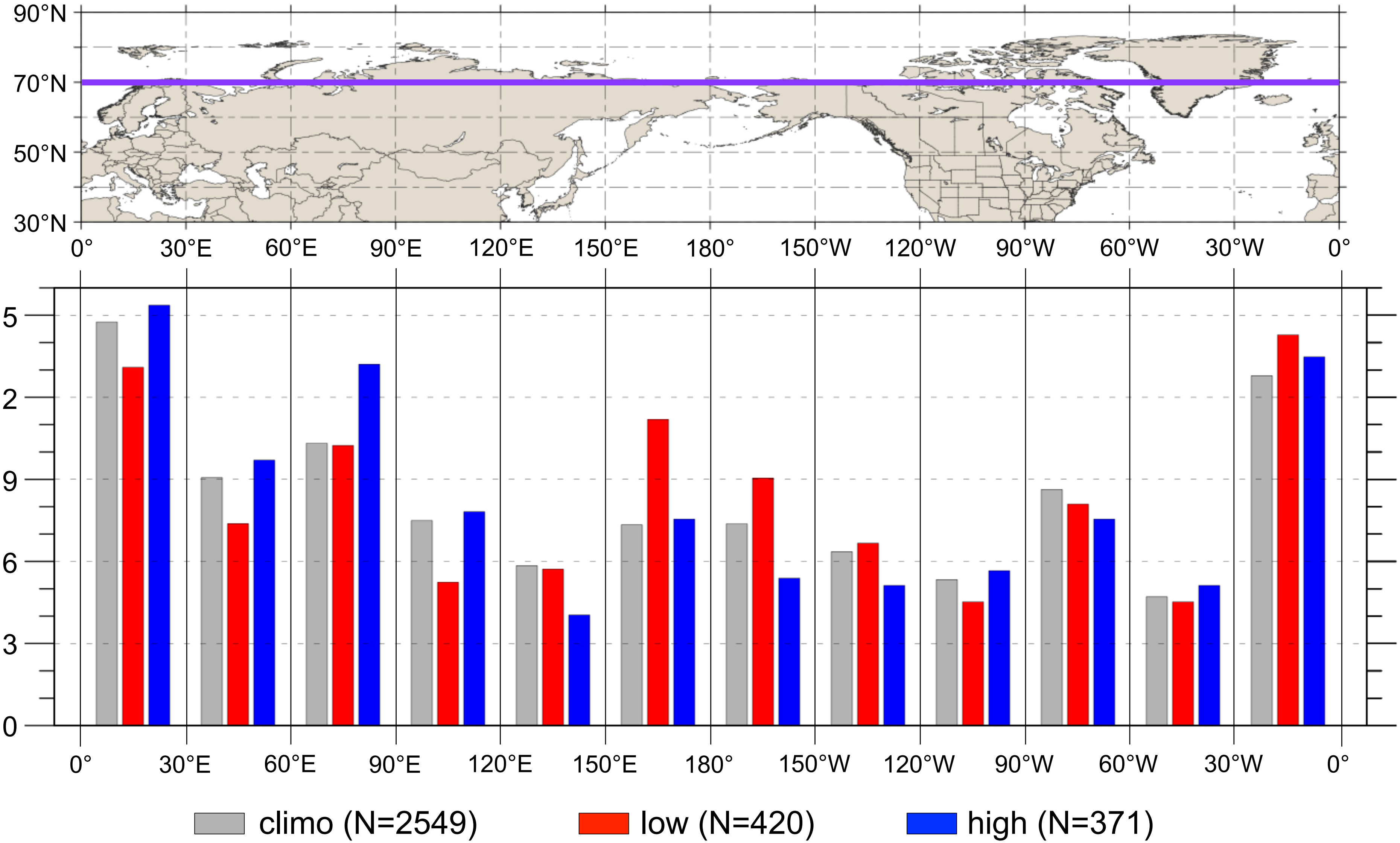
AC Track Frequency Differences (SON)



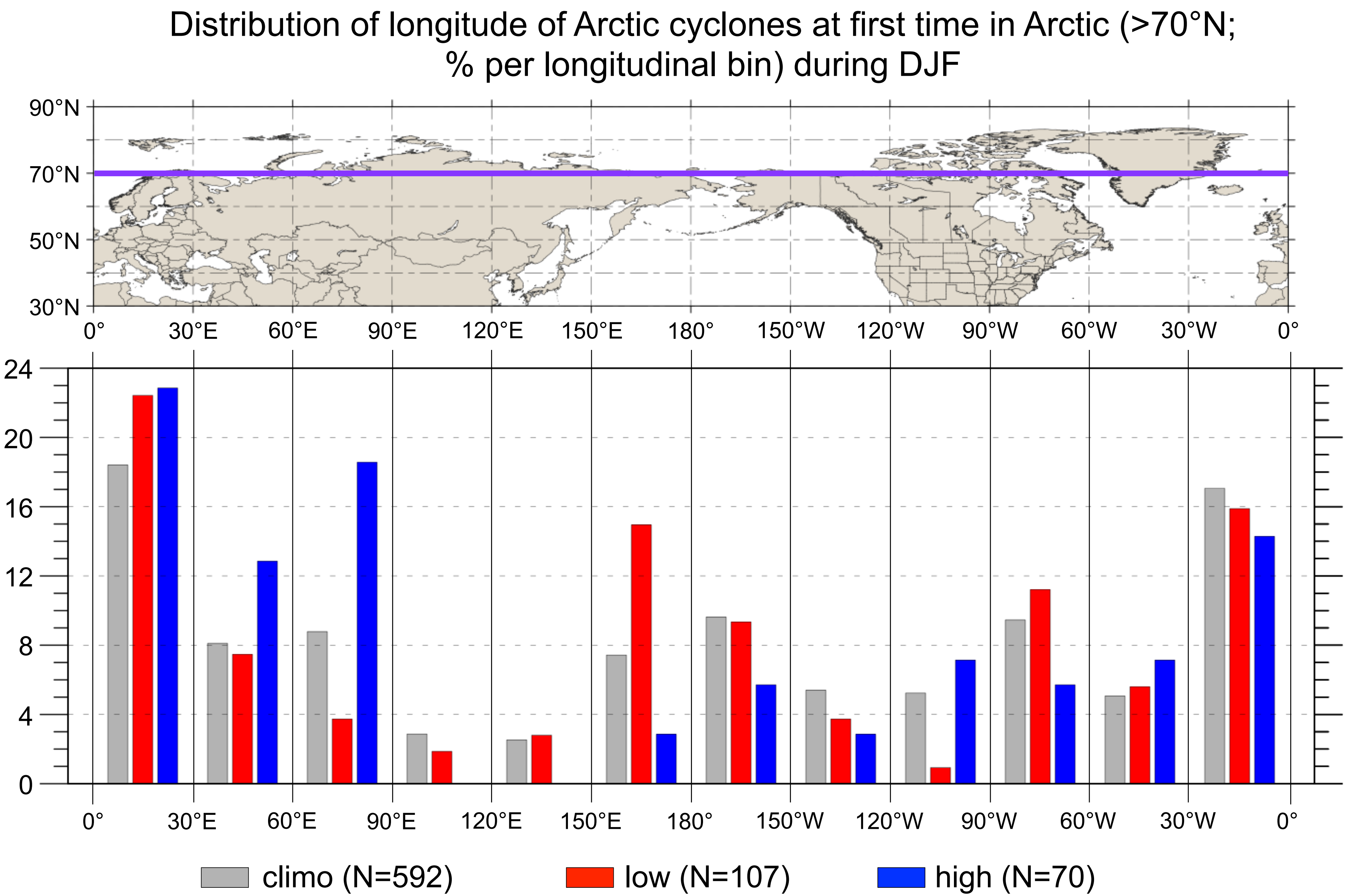
Difference in AC track density during SON (number of ACs day^{-1})

Preferred Longitudinal Corridors

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

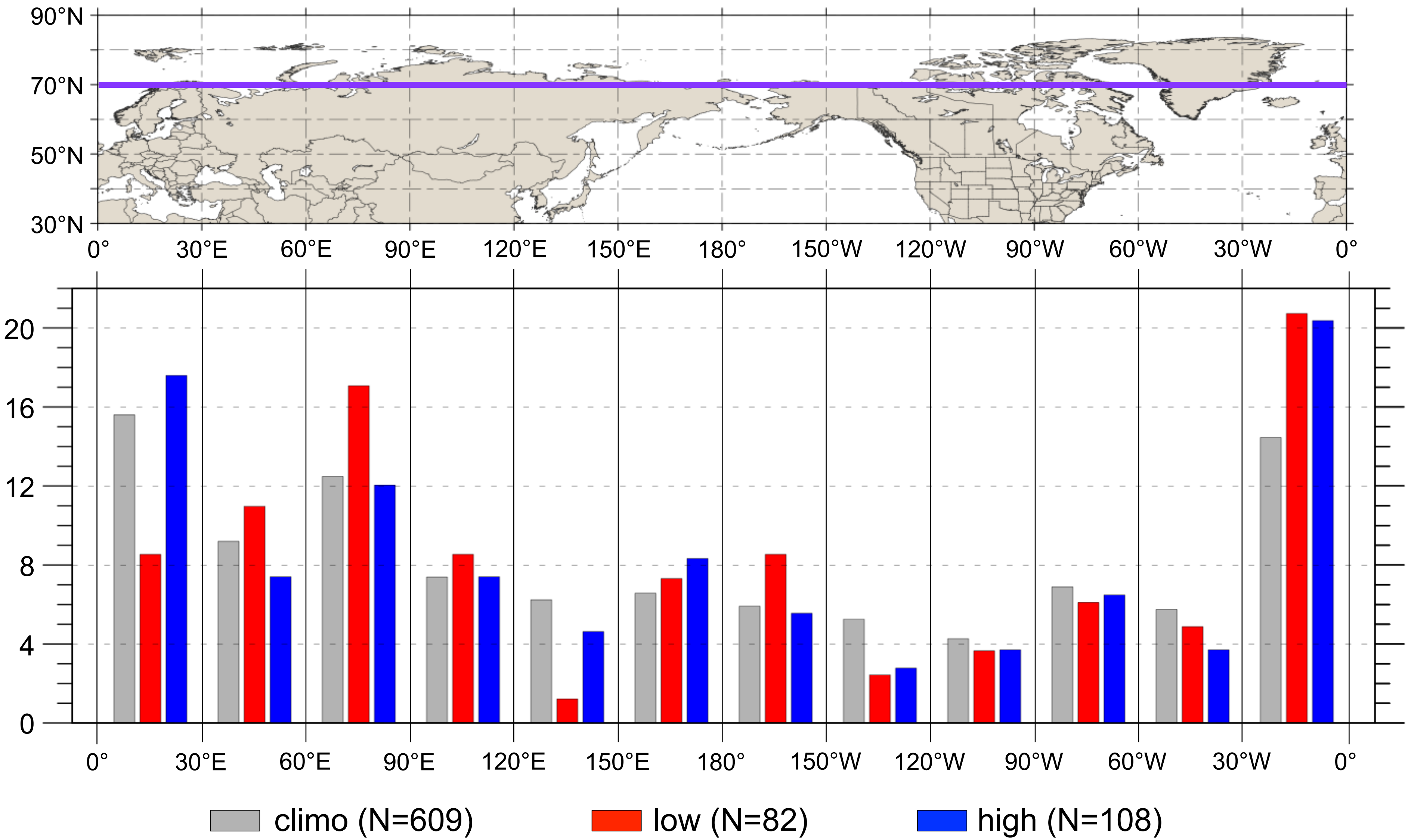


Preferred Longitudinal Corridors (DJF)



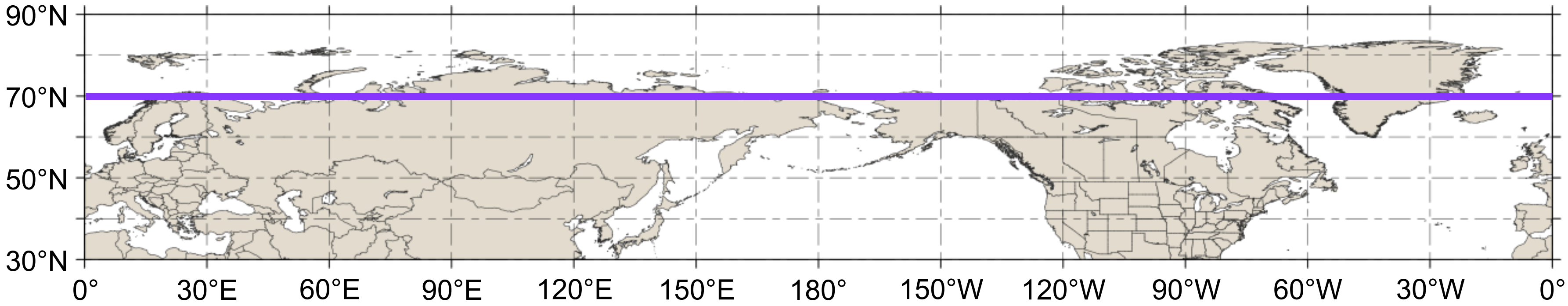
Preferred Longitudinal Corridors (MAM)

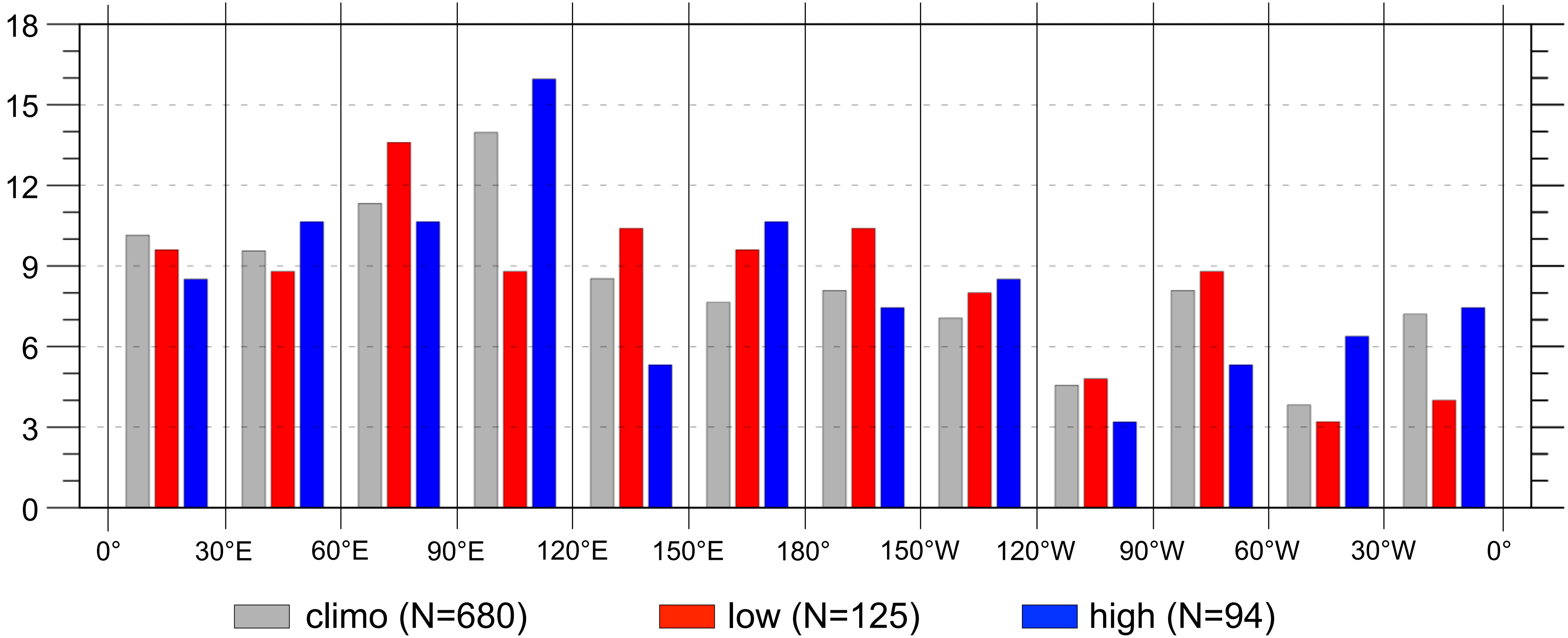
Distribution of longitude of Arctic cyclones at first time in Arctic (>70°N; % per longitudinal bin) during MAM



Preferred Longitudinal Corridors (JJA)

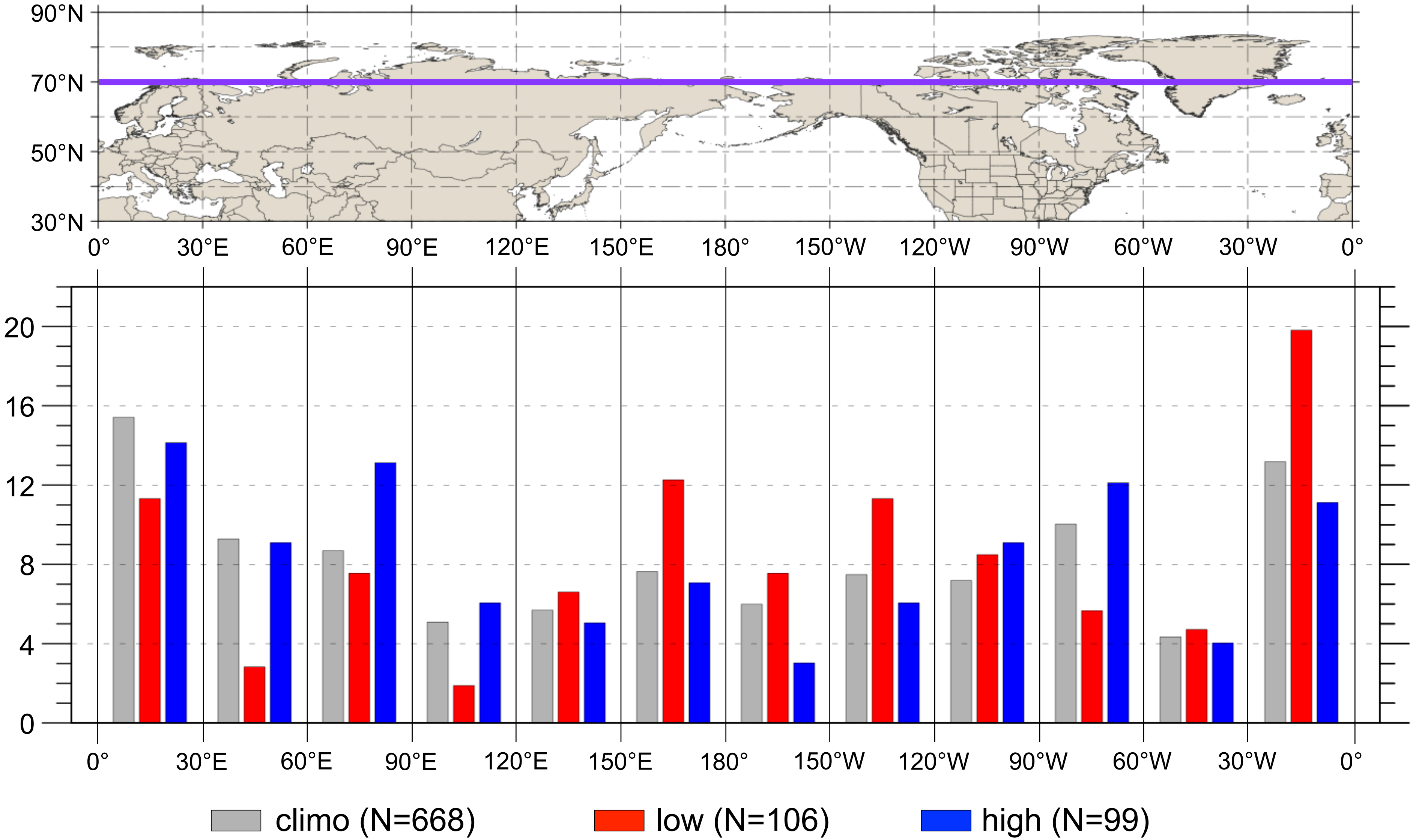
Distribution of longitude of Arctic cyclones at first time in Arctic (>70°N; % per longitudinal bin) during JJA



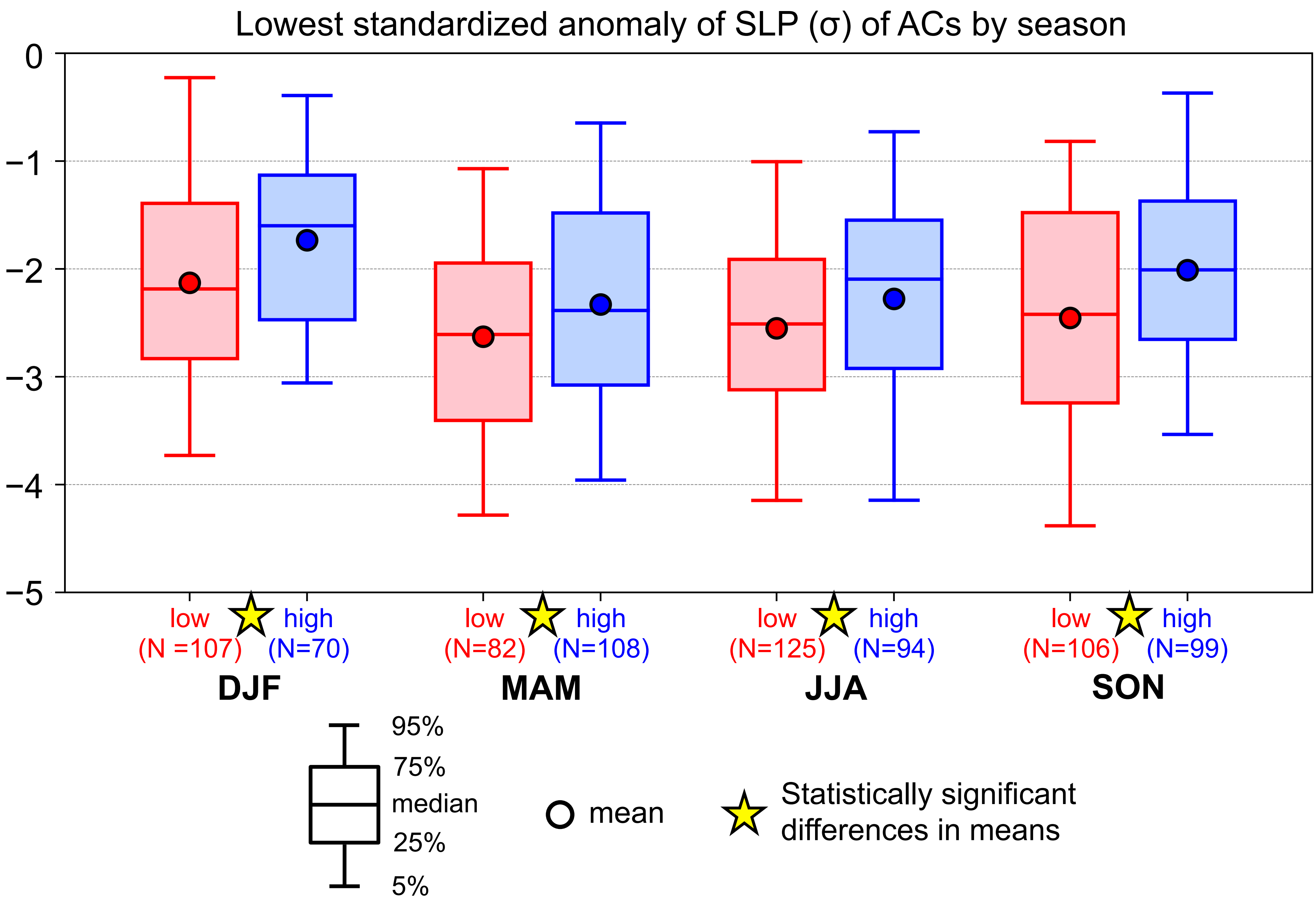


Preferred Longitudinal Corridors (SON)

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



Intensity



Lowest standardized anomaly of SLP (σ) of ACs by season
0
−1
−2
−3
−4
−5
low
(N =107)
high
(N=70)
DJF
low
(N=82)
high
(N=108)
MAM
low
(N=125)
high
(N=94)
JJA
low
(N=106)
high
(N=99)
SON
95%
75%
median
25%
5%
mean
Statistically significant differences in means

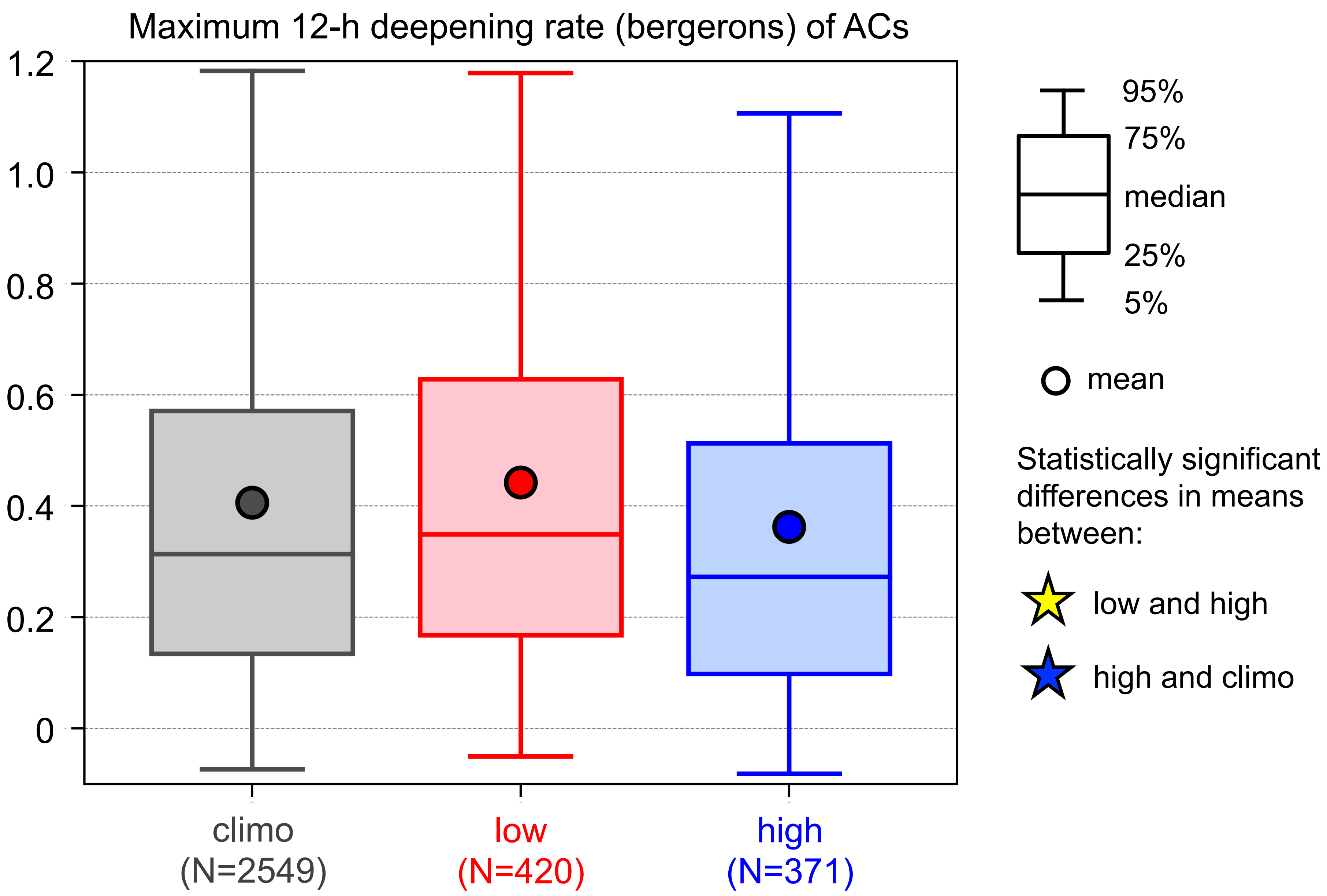
Intensification

- Calculate maximum 12-h deepening rate of cyclone following Sanders and Gyakum (1980) and Zhang et al. (2017)

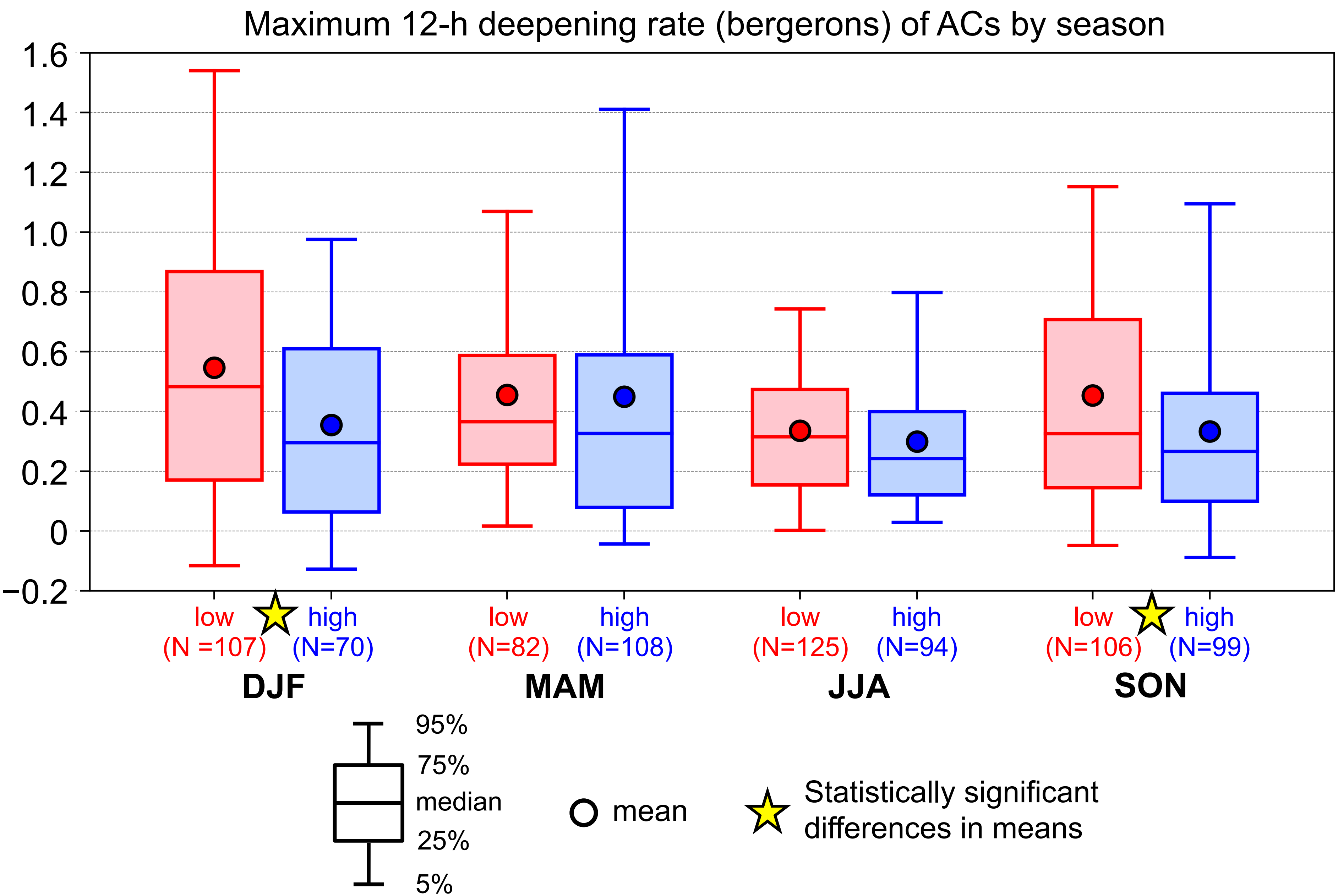
$$\text{12-h deepening rate at } t_0 \text{ (bergerons)} = -\left(\frac{SLP_{t+6\,h} - SLP_{t-6\,h}}{12}\right) \times \left[\frac{\sin(60°)}{\sin\left(\frac{\phi_{t+6\,h} + \phi_{t-6\,h}}{2}\right)}\right]$$

where ϕ = latitude

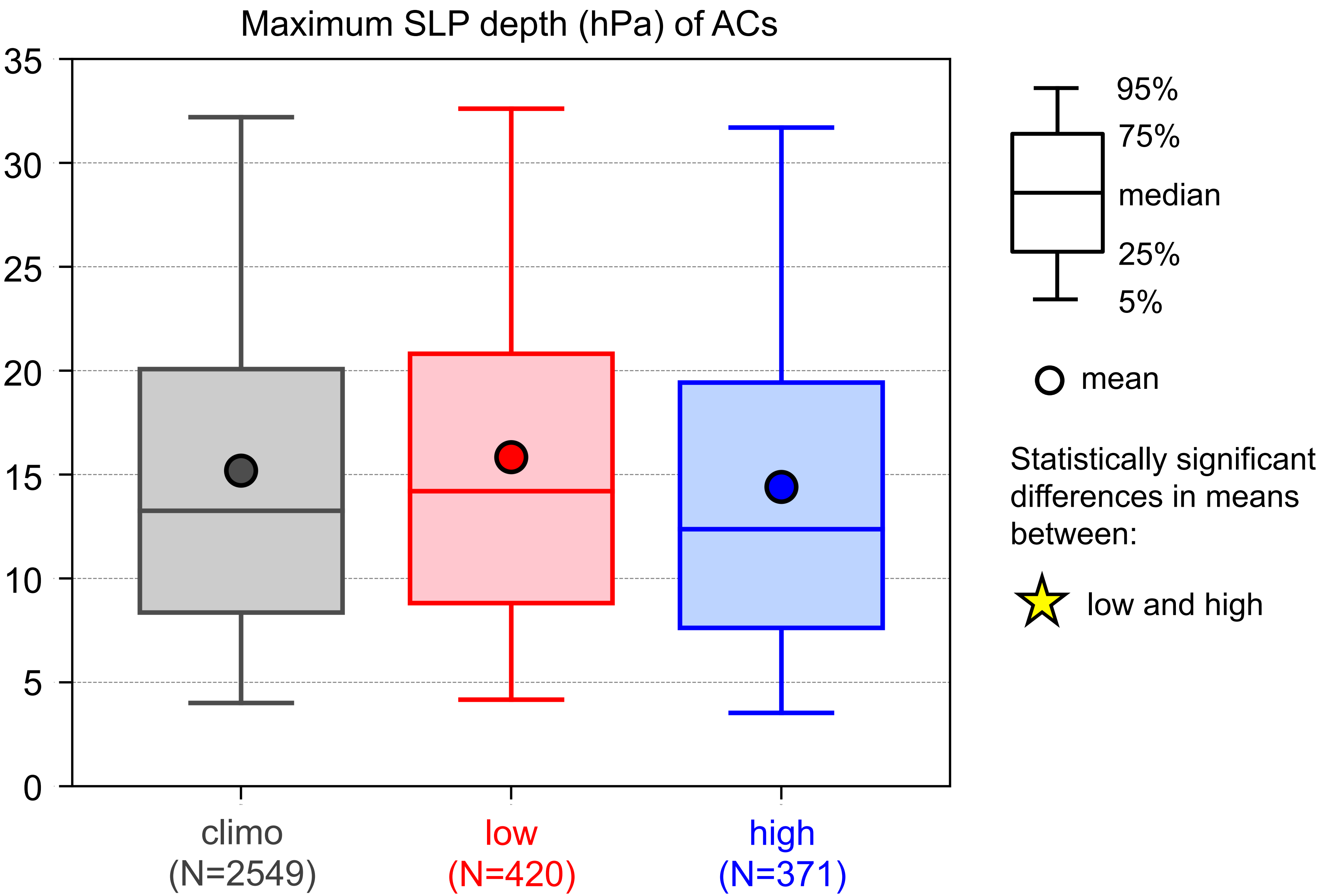
Intensification



Intensification

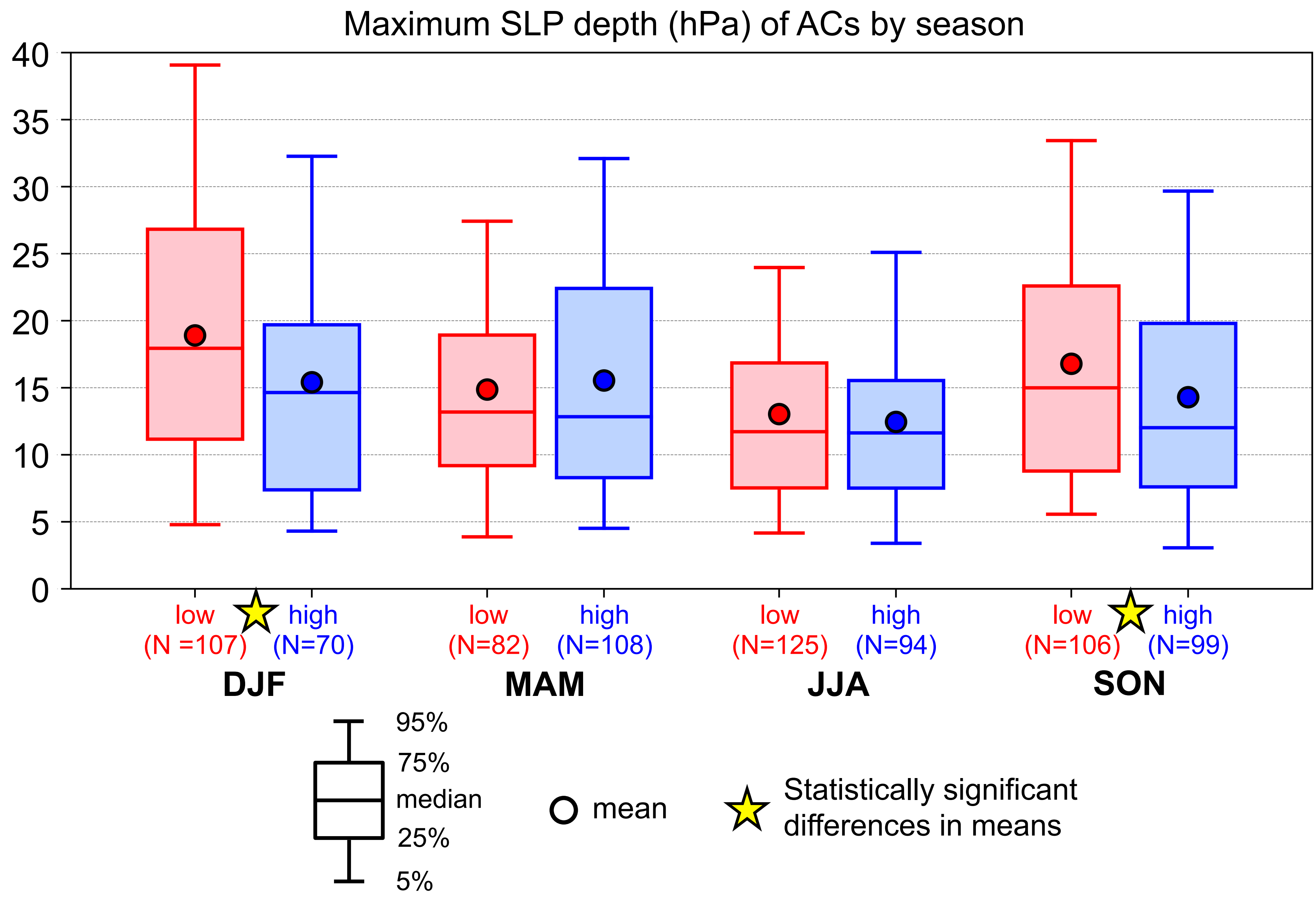


Intensity



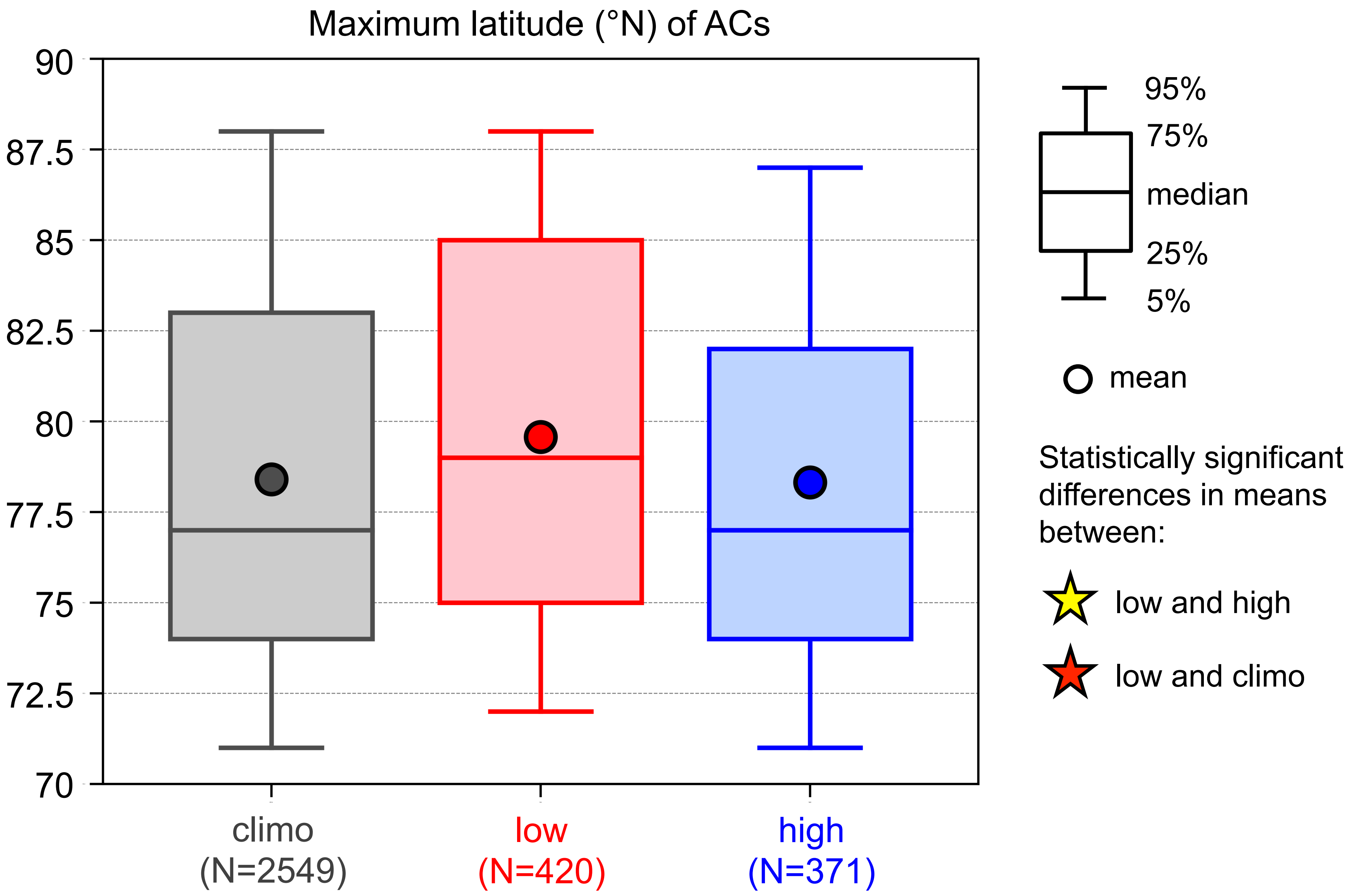
Maximum SLP depth (hPa) of ACs
35
30
25
20
15
10
5
0
climo
(N=2549)
low
(N=420)
high
(N=371)
95%
75%
median
25%
5%
mean
Statistically significant differences in means between:
low and high

Intensity

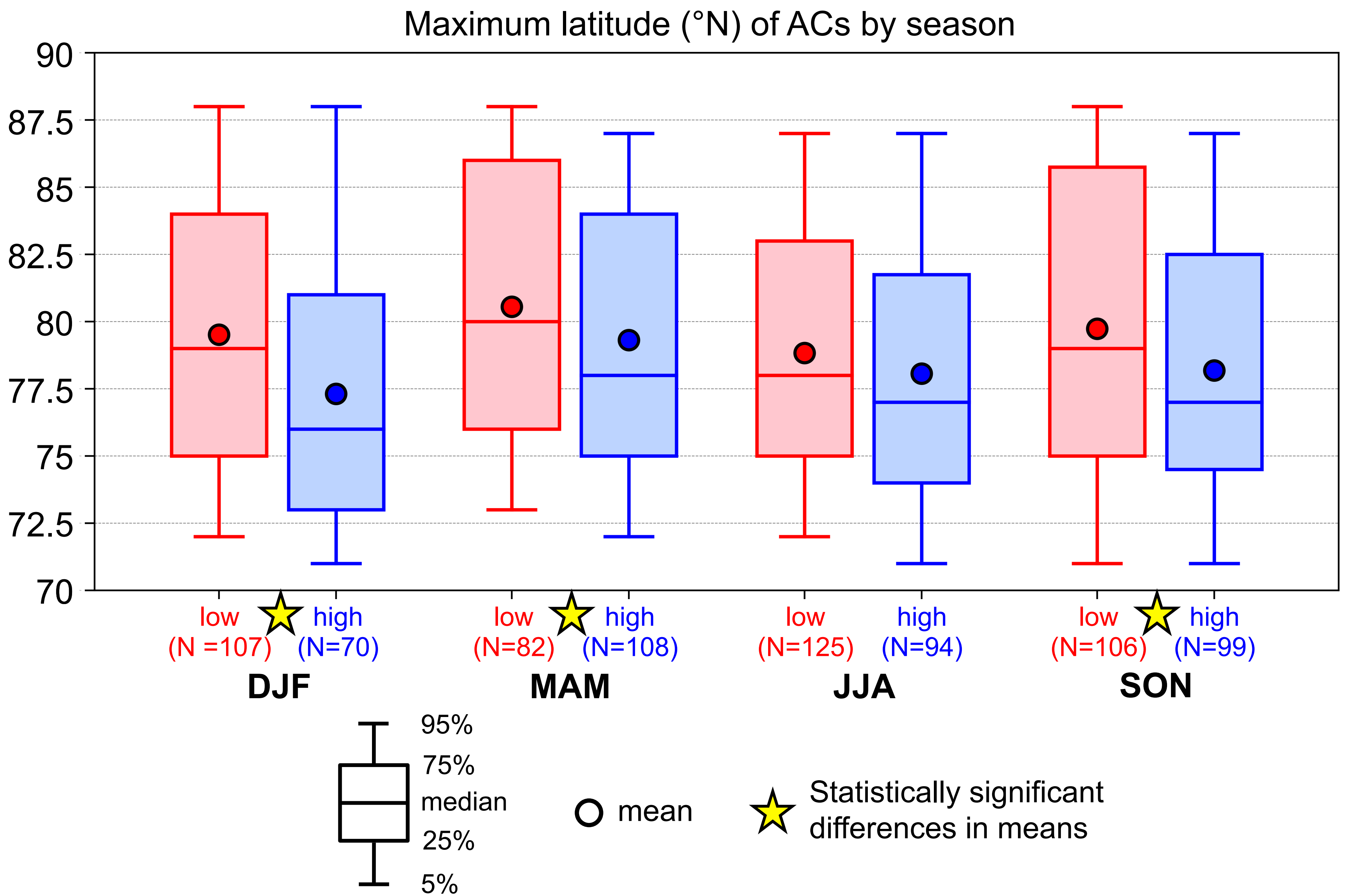


Maximum SLP depth (hPa) of ACs by season
40
35
30
25
20
15
10
5
0
low
(N =107)
high
(N=70)
DJF
low
(N=82)
high
(N=108)
MAM
low
(N=125)
high
(N=94)
JJA
low
(N=106)
high
(N=99)
SON
95%
75%
median
25%
5%
mean
Statistically significant
differences in means

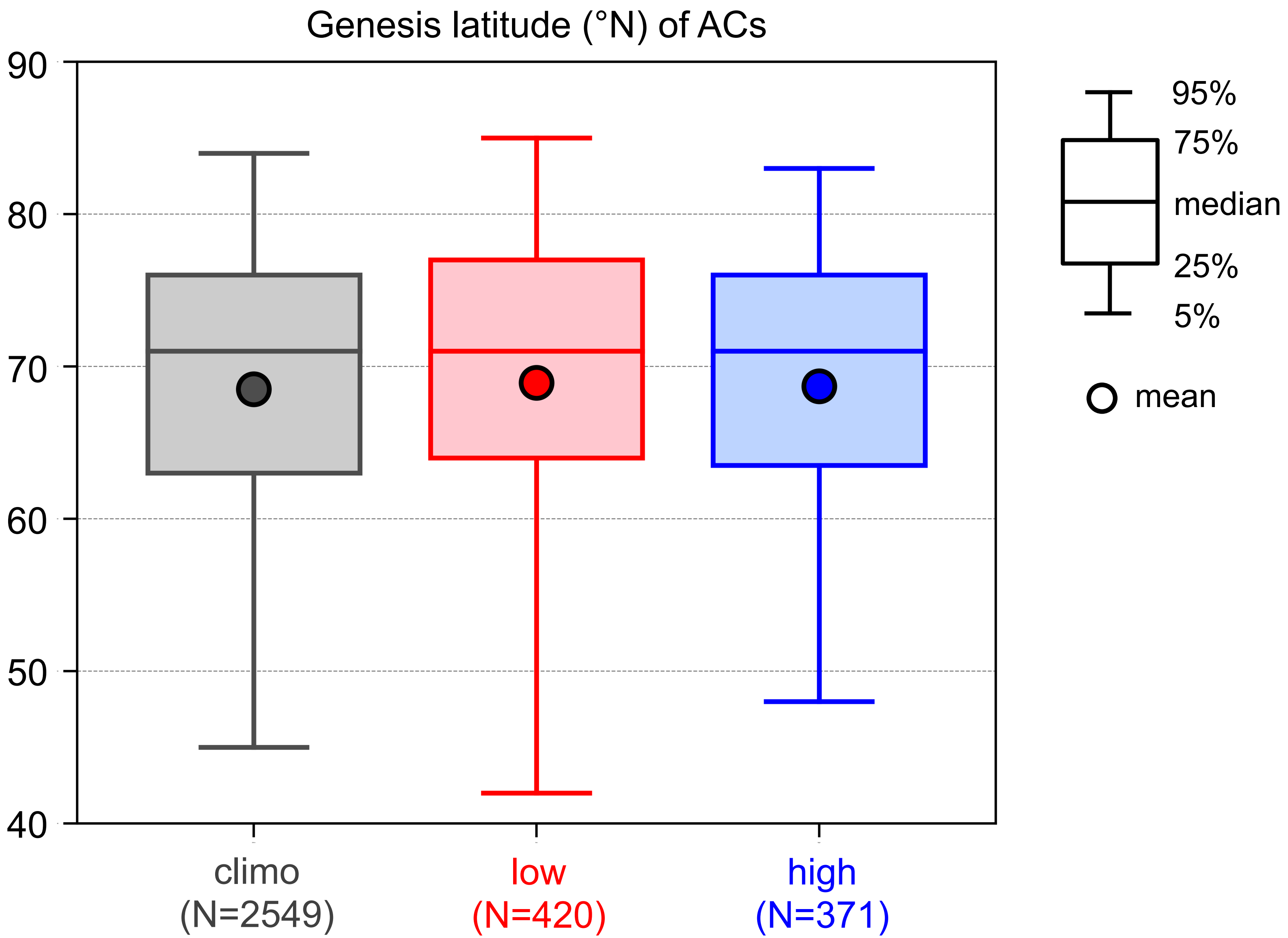
Maximum Latitude



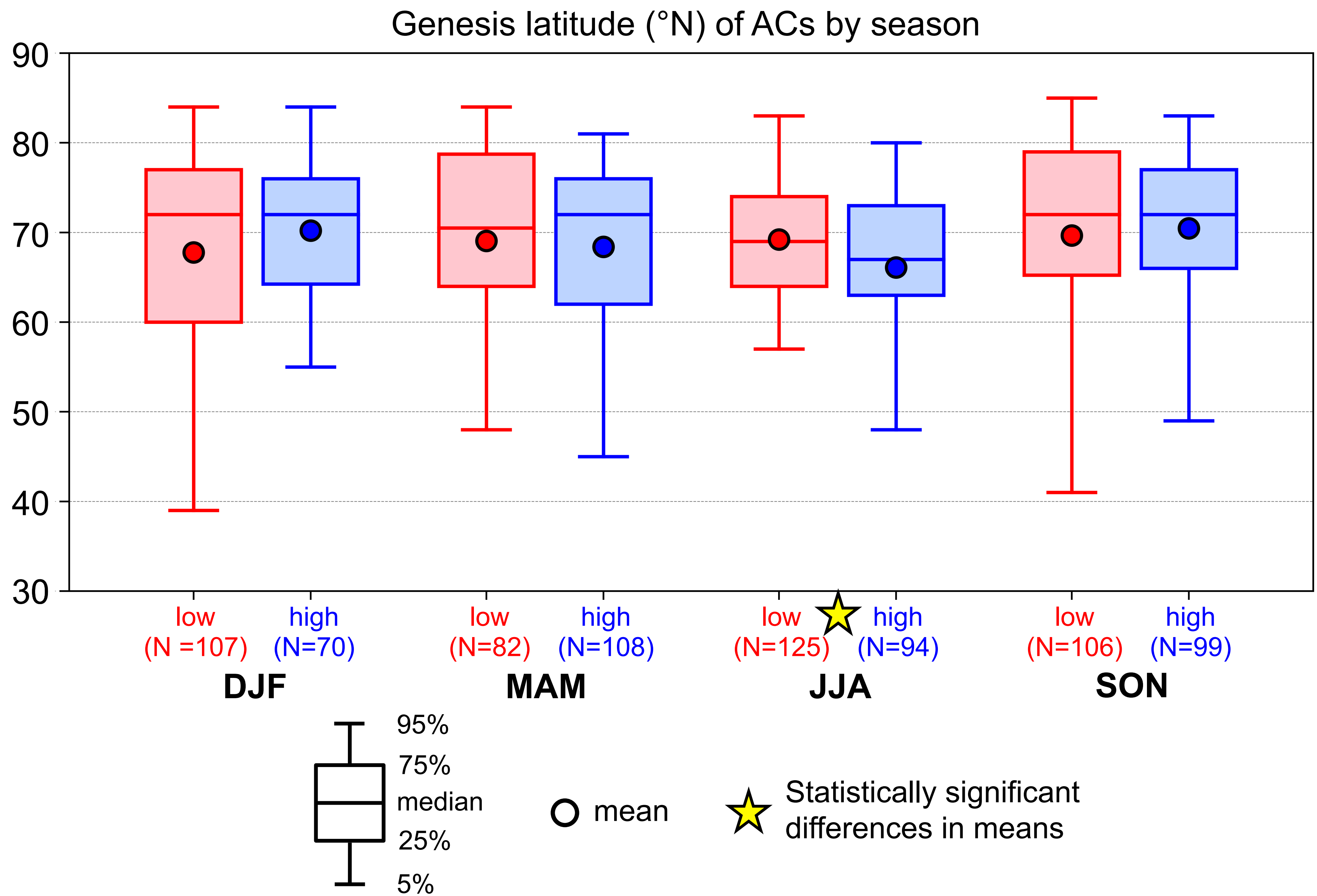
Maximum Latitude



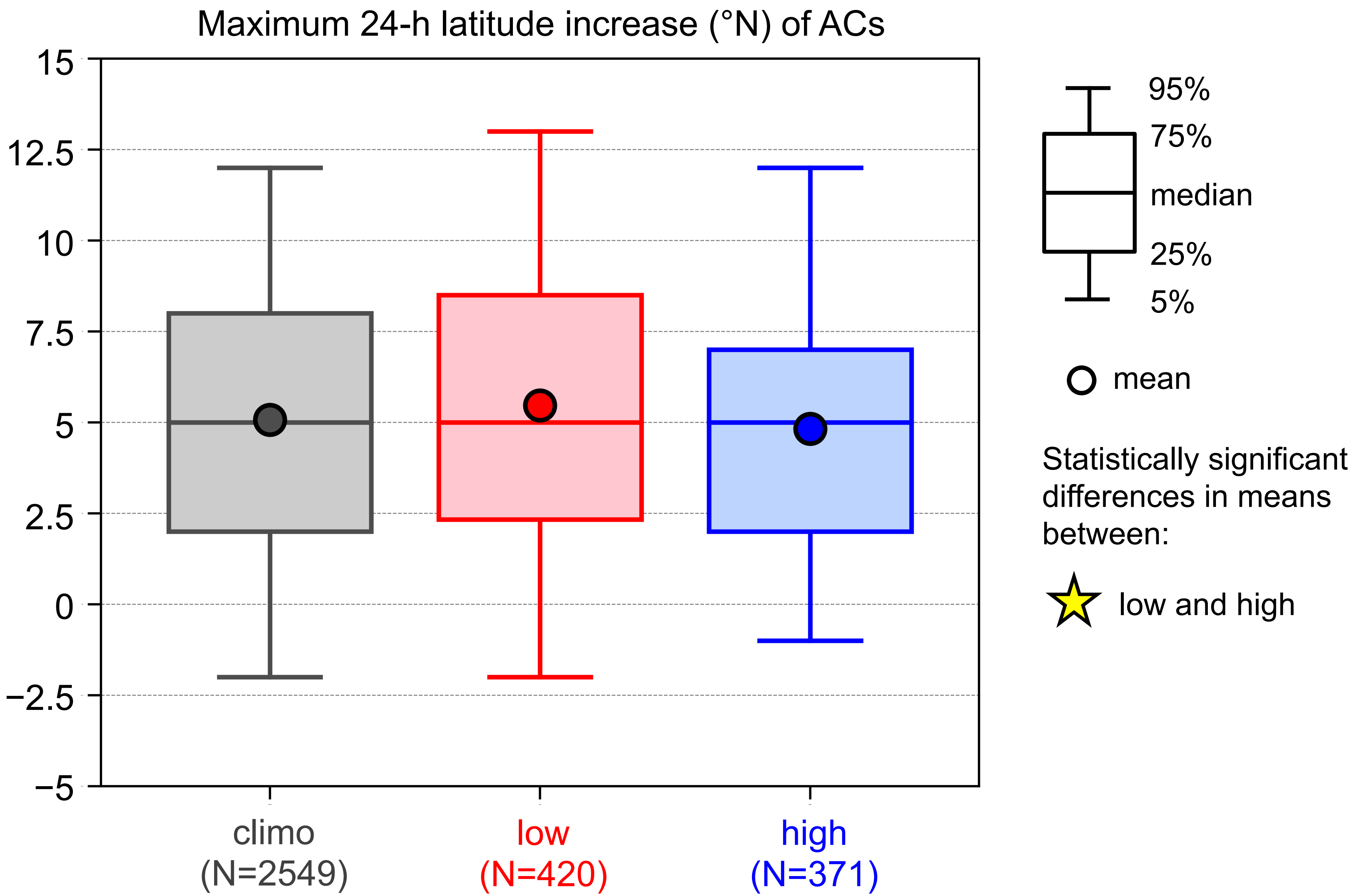
Genesis Latitude



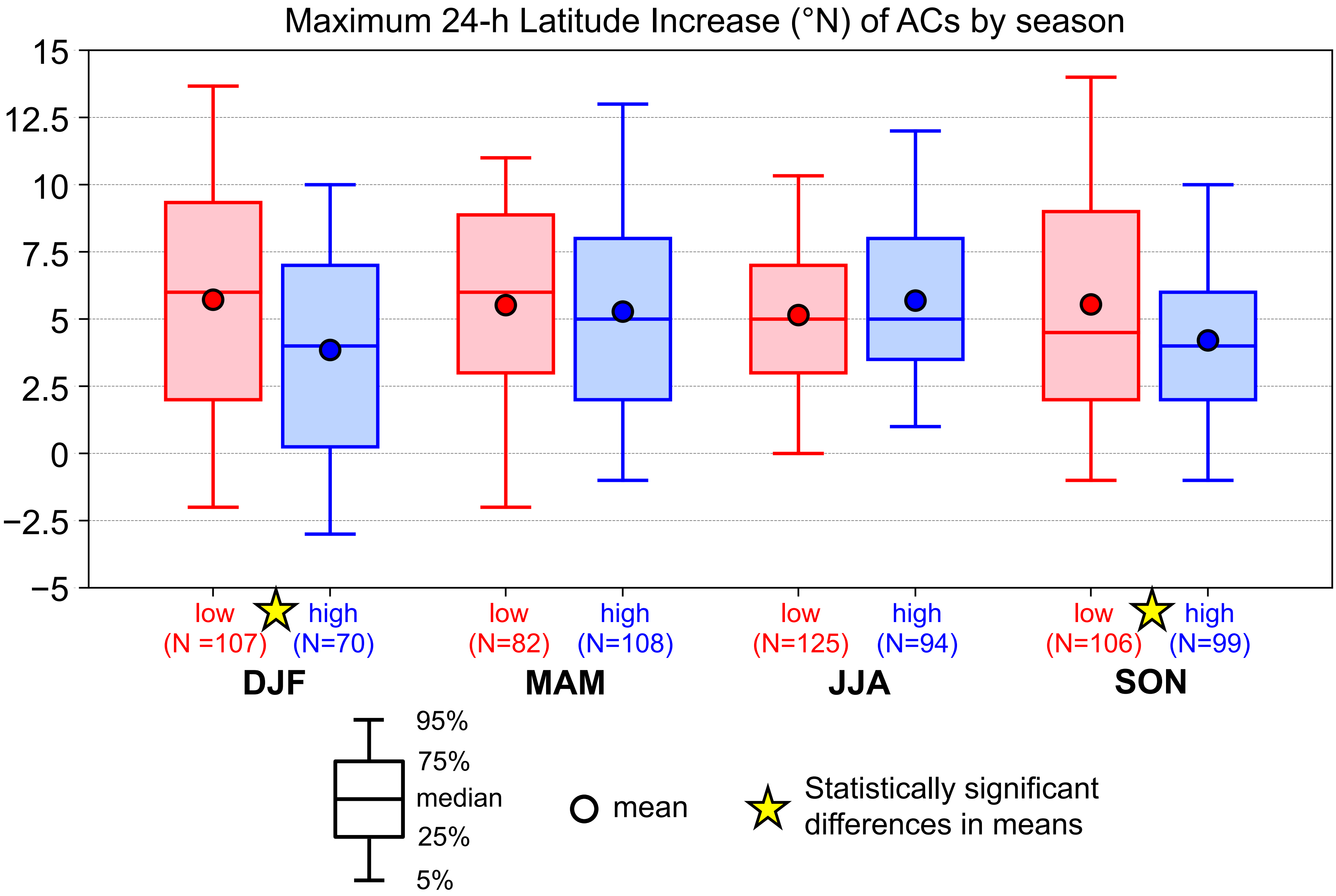
Genesis Latitude



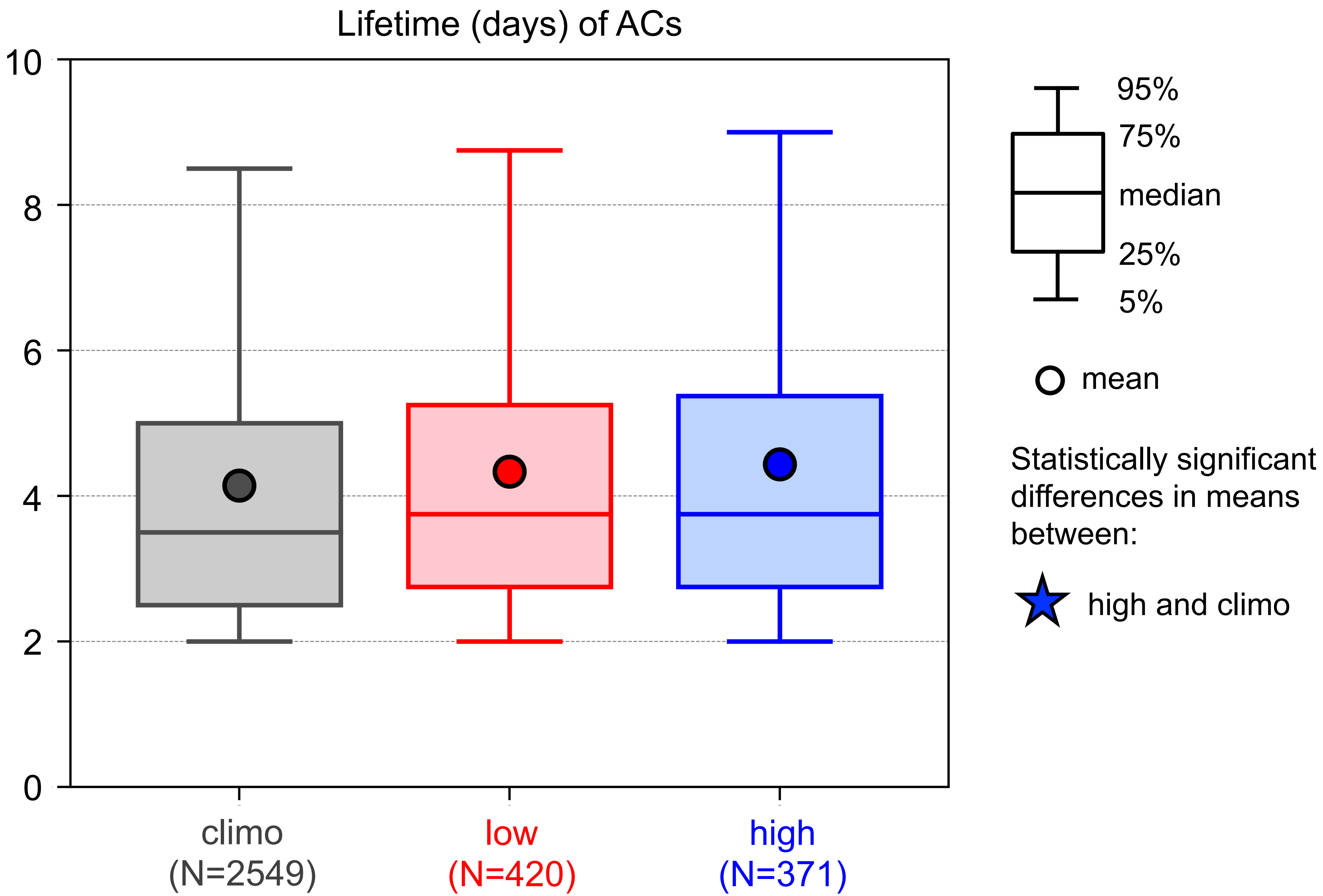
Maximum 24-h Latitude Increase



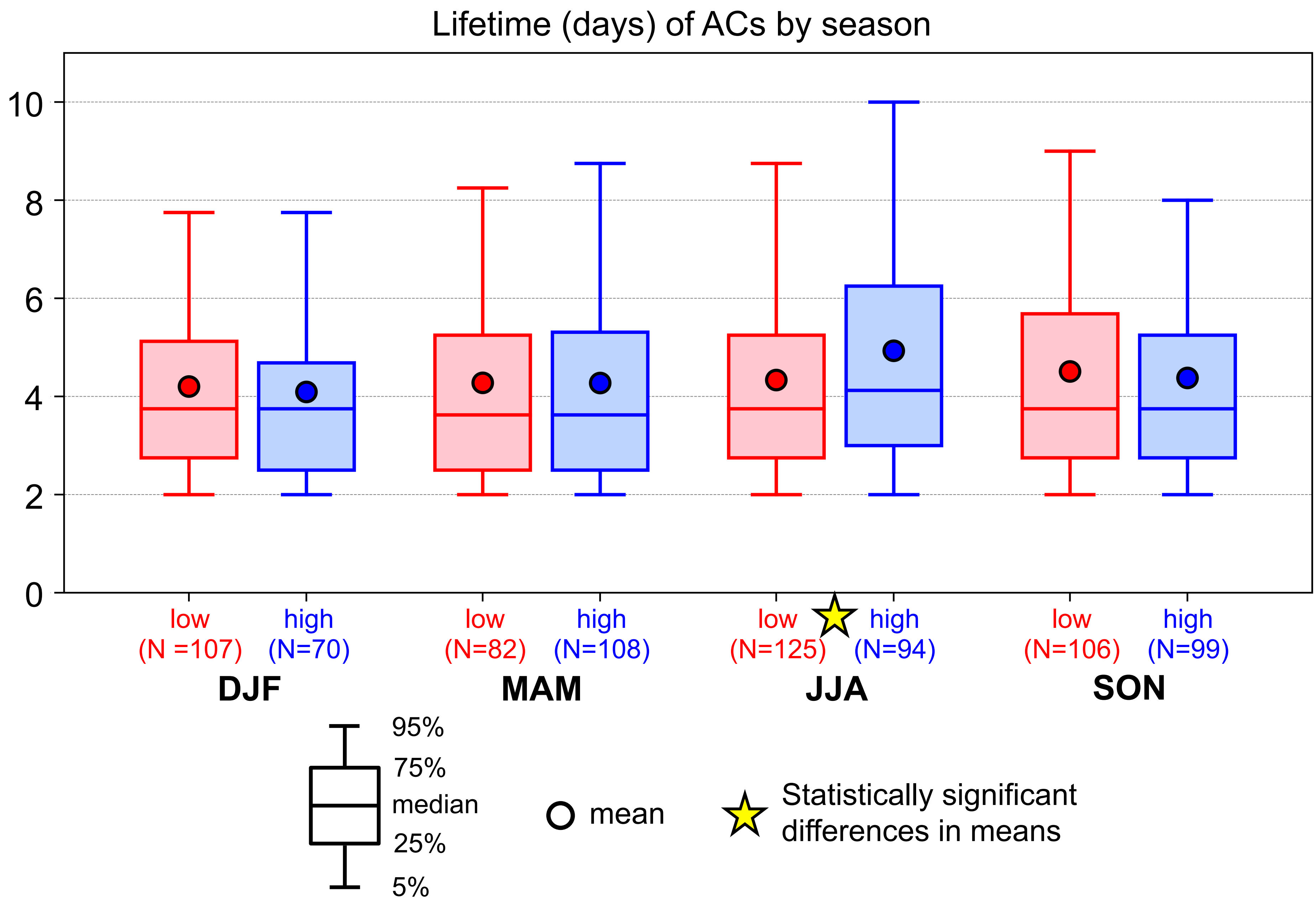
Maximum 24-h Latitude Increase



Lifetime

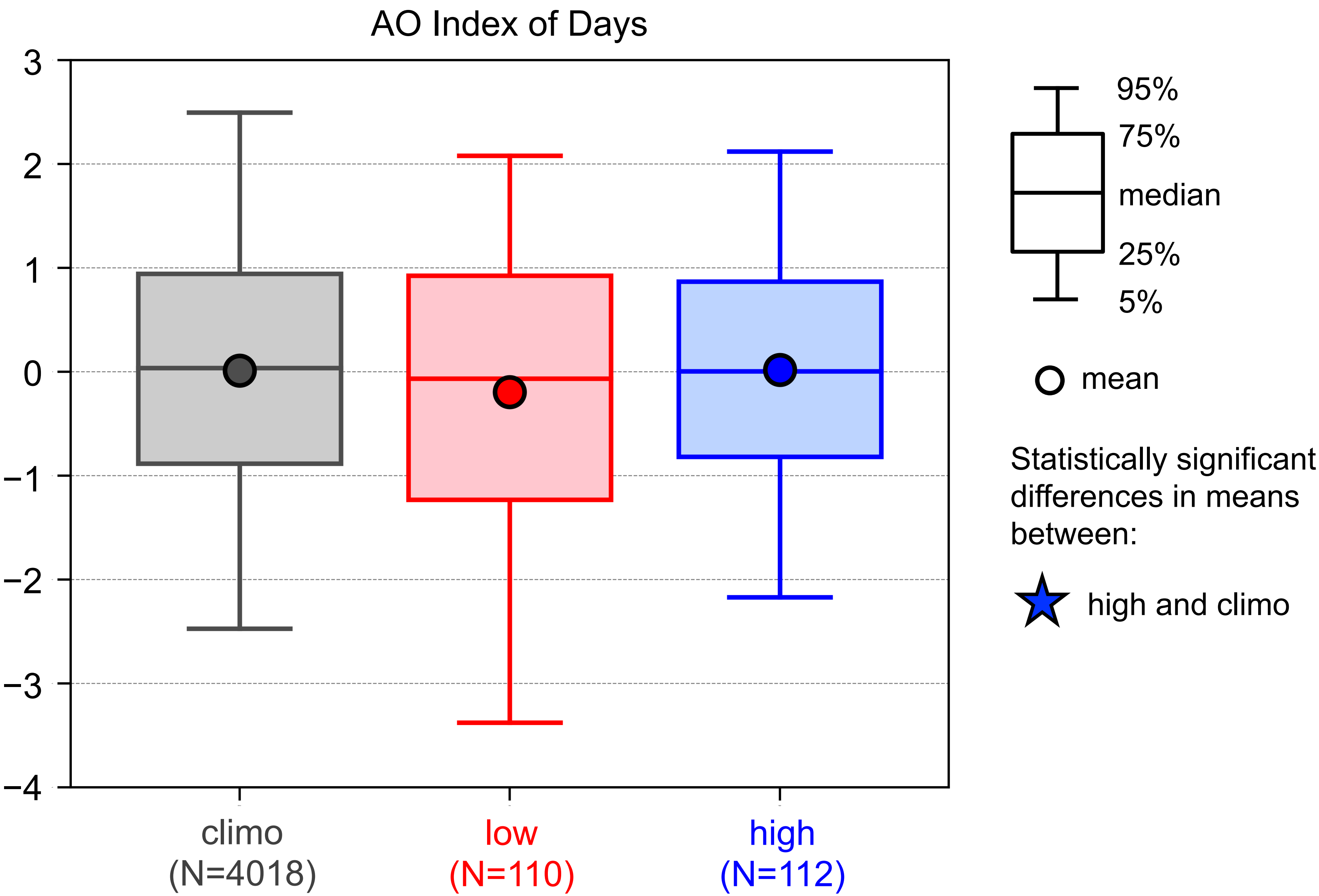

Lifetime (days) of ACs
10
8
6
4
2
0
climo
(N=2549)
low
(N=420)
high
(N=371)
95%
75%
median
25%
5%
mean
Statistically significant differences in means between:
high and climo

Lifetime

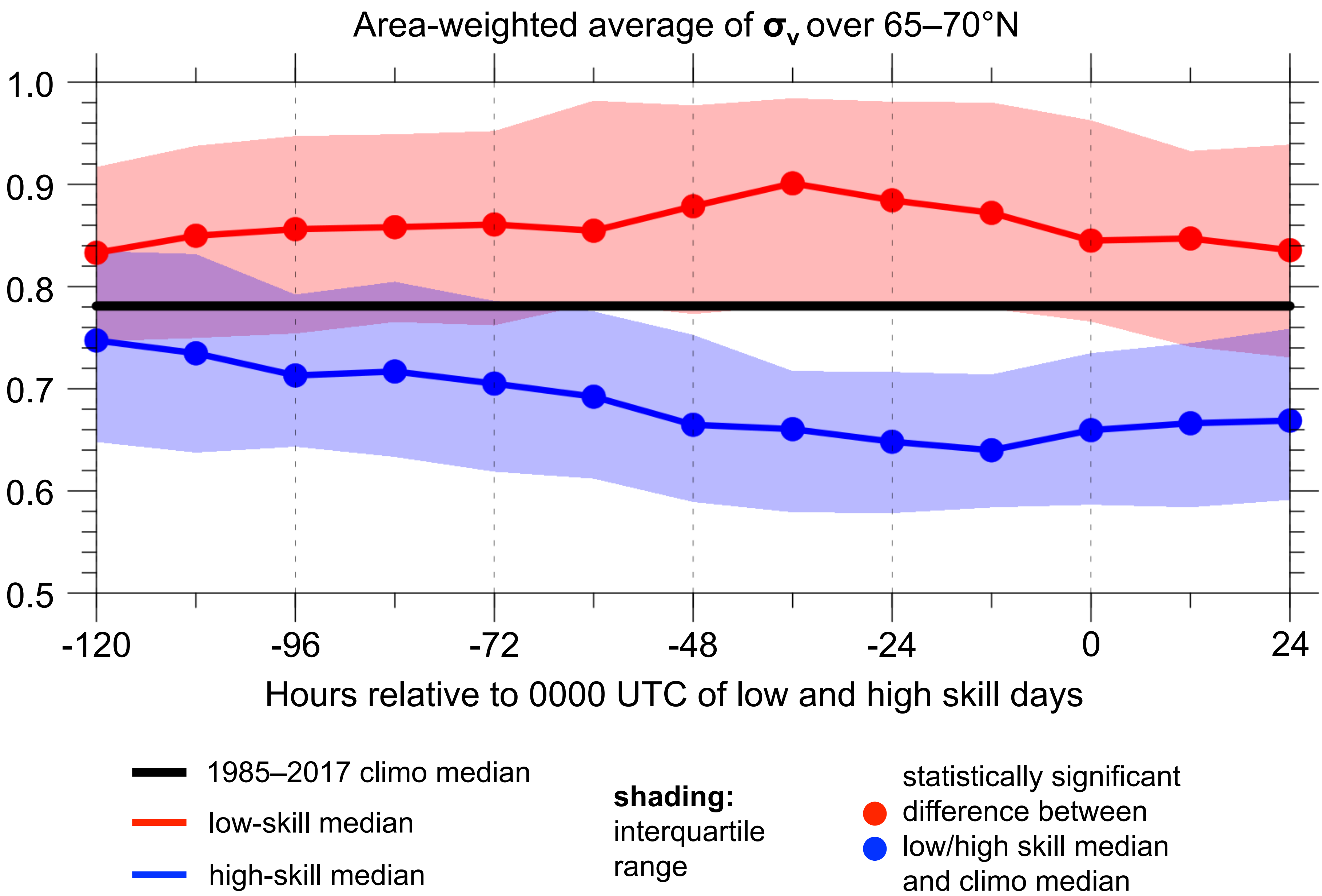


Lifetime (days) of ACs by season
10
8
6
4
2
0
low
(N =107)
high
(N=70)
DJF
low
(N=82)
high
(N=108)
MAM
low
(N=125)
high
(N=94)
JJA
low
(N=106)
high
(N=99)
SON
95%
75%
median
25%
5%
mean
Statistically significant differences in means

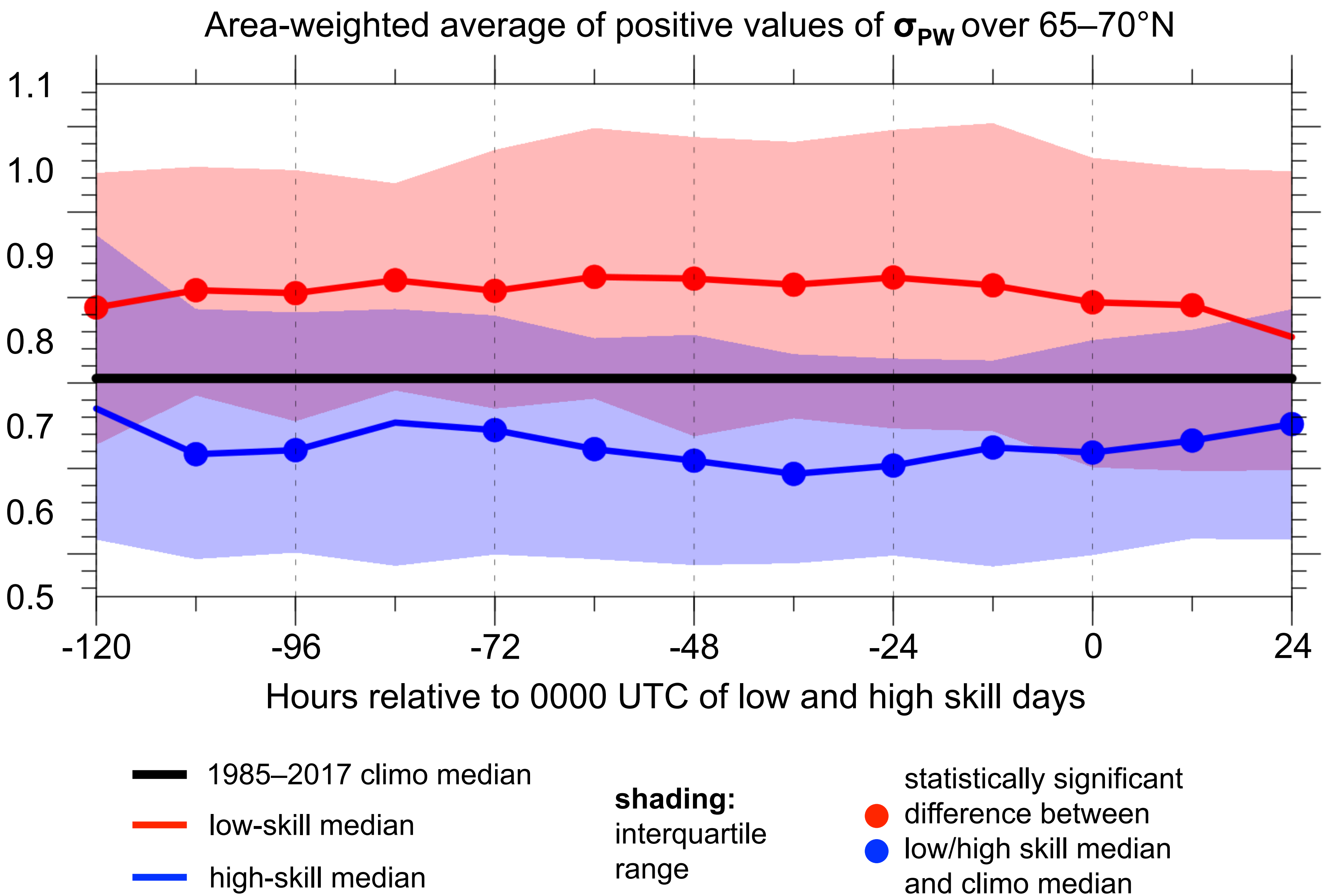
AO


AO Index of Days
3
2
1
0
−1
−2
−3
−4
climo
(N=4018)
low
(N=110)
high
(N=112)
95%
75%
median
25%
5%
mean
Statistically significant differences in means between:
high and climo

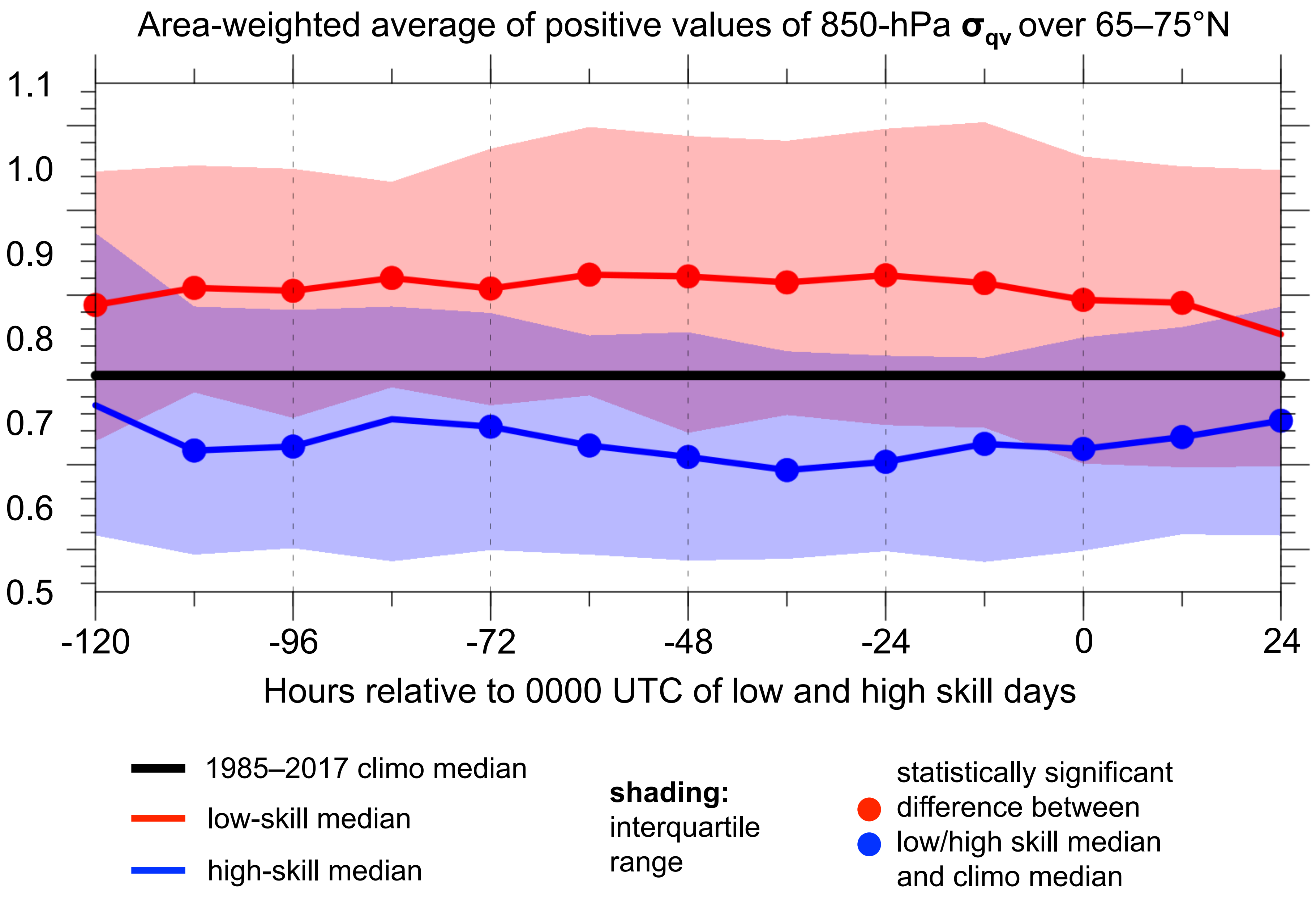
Flow Amplitude (65–75°N)



Moisture (65–75°N)

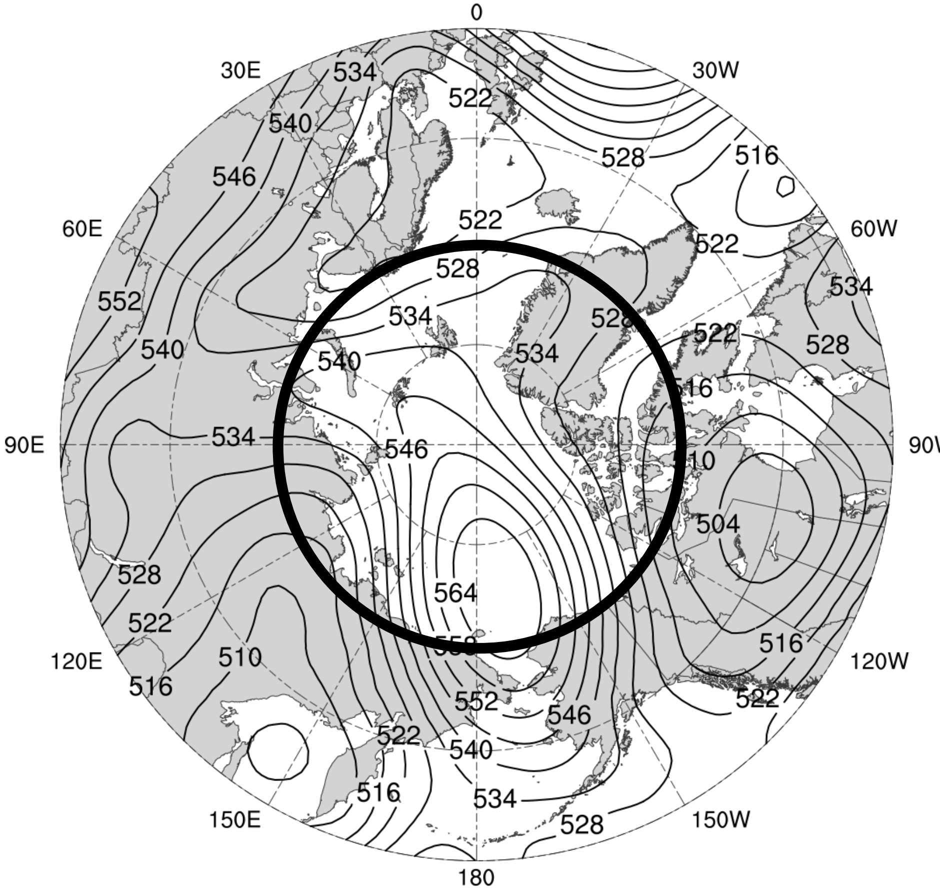


Meridional Moisture Flux (65–75°N)

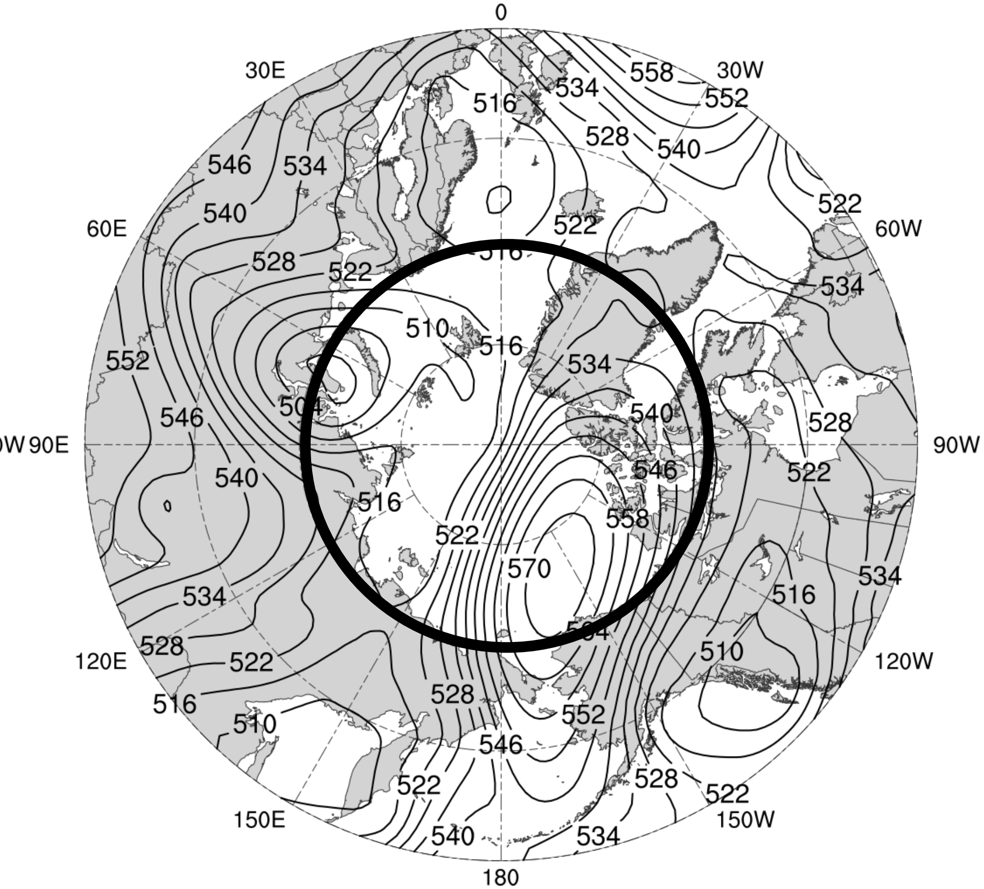


Worst Low Skill Day

GEFS Mean 5-d Forecast
valid 0000 UTC 3 Dec 2007

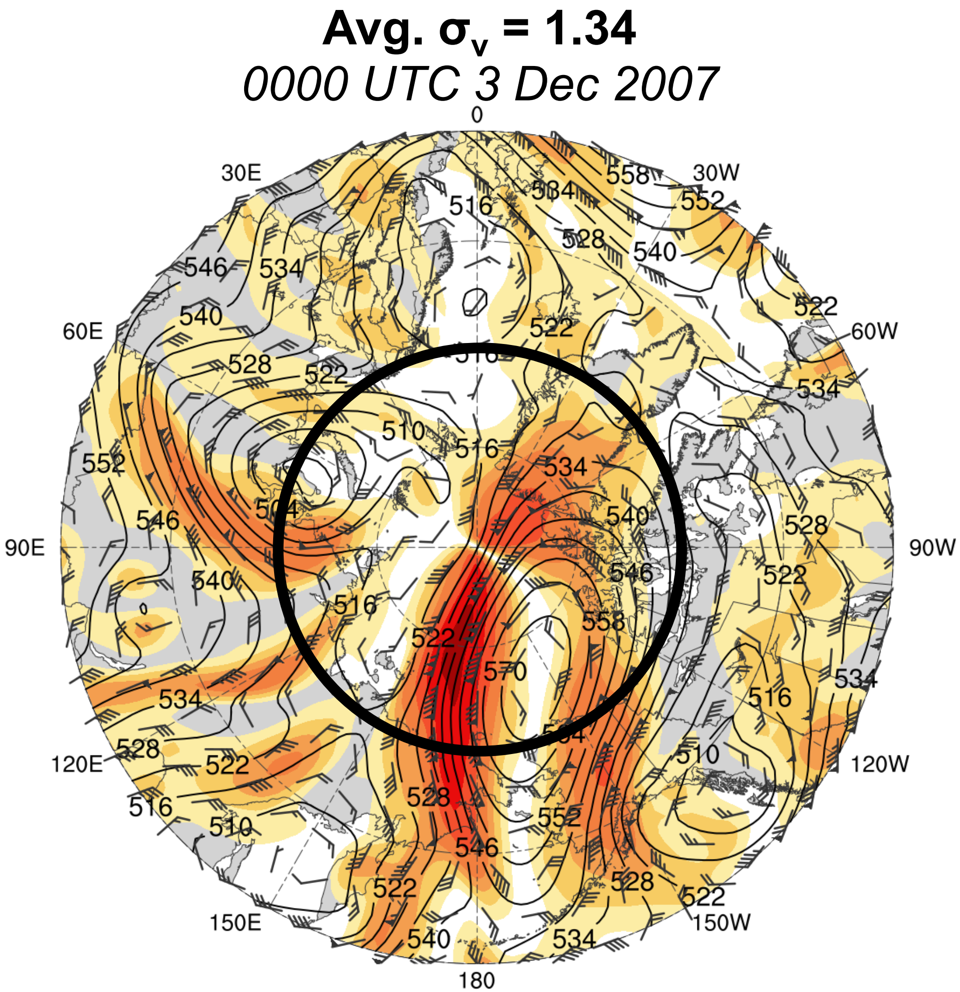


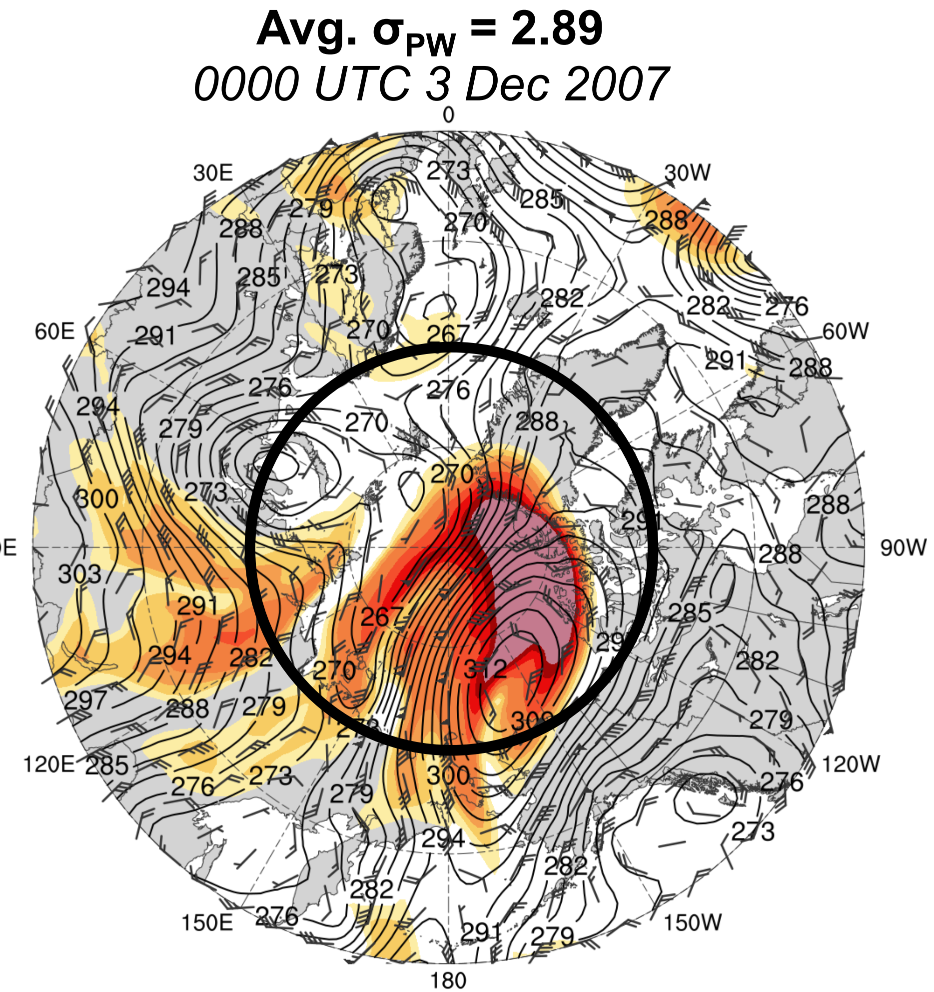
ERA Interim Analysis
valid 0000 UTC 3 Dec 2007



500-hPa geopotential height (dam, black)

Worst Low Skill Day

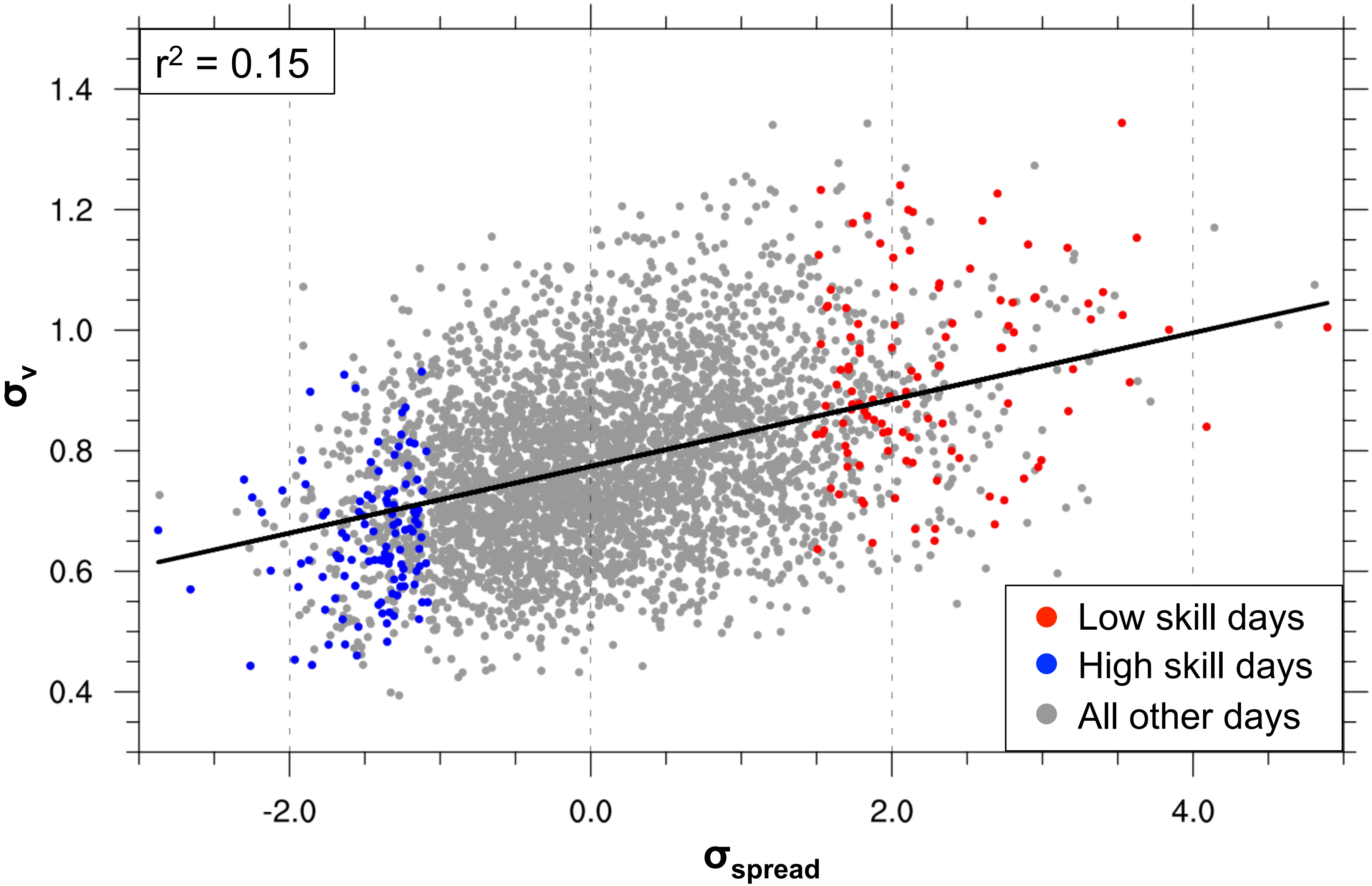




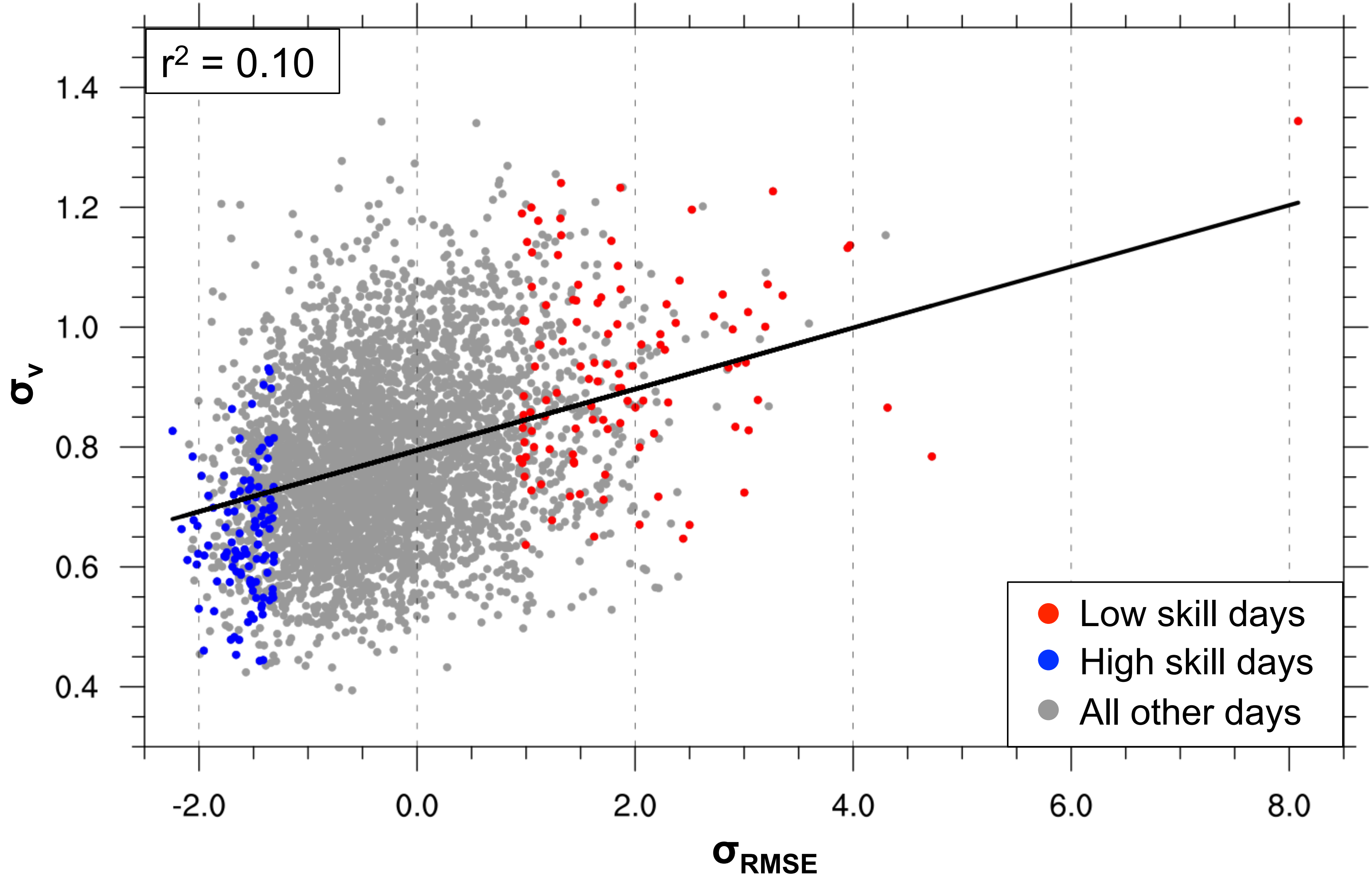
500-hPa geopotential height (dam, black), wind (flags and barbs, m s^{-1}), and $\boldsymbol{\sigma_v}$ (shading)

700-hPa geopotential height (dam, black), wind (flags and barbs, m s^{-1}), and positive values of $\boldsymbol{\sigma_{PW}}$ (shading)

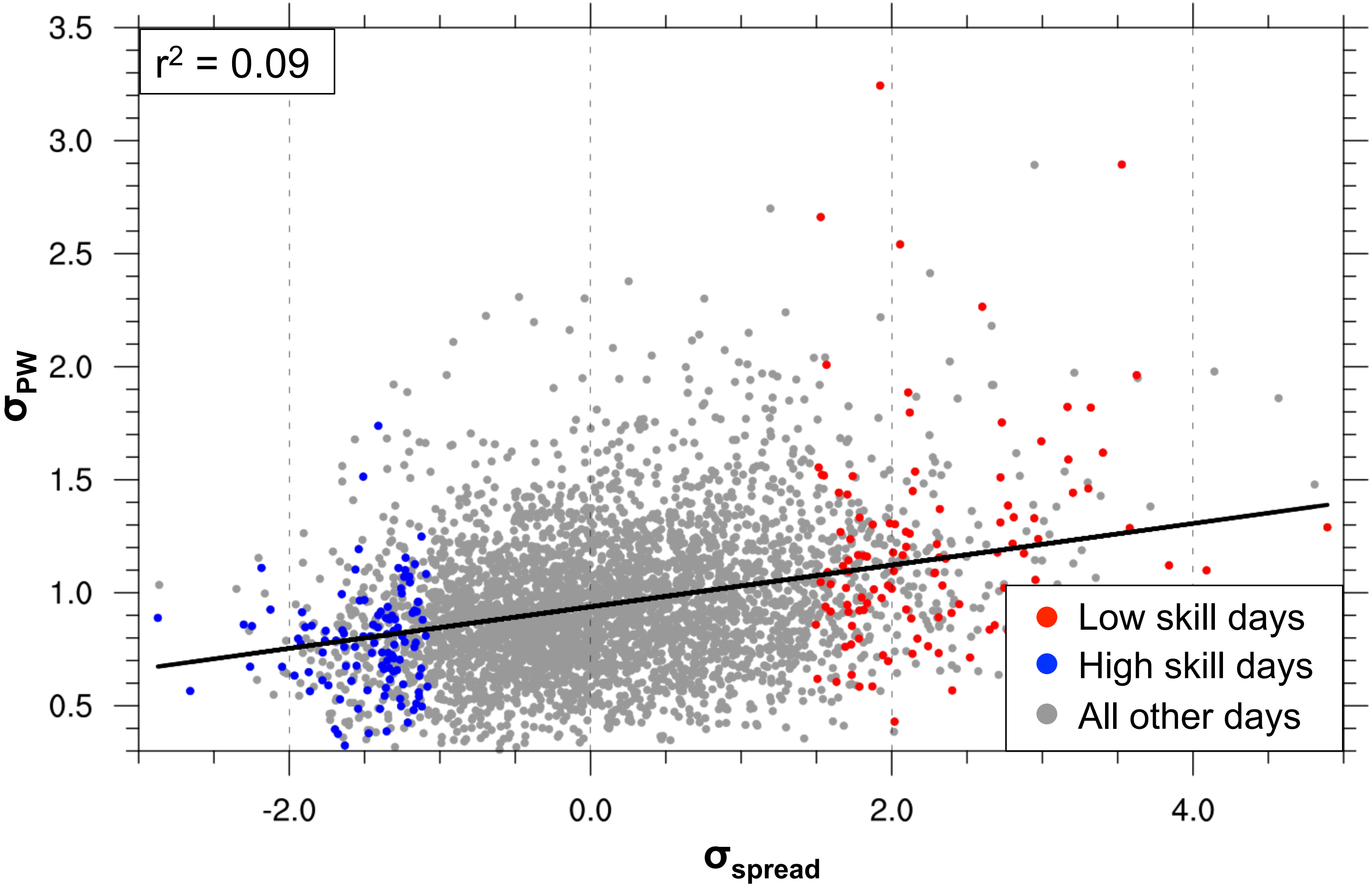
σ_{spread} VS σ_v



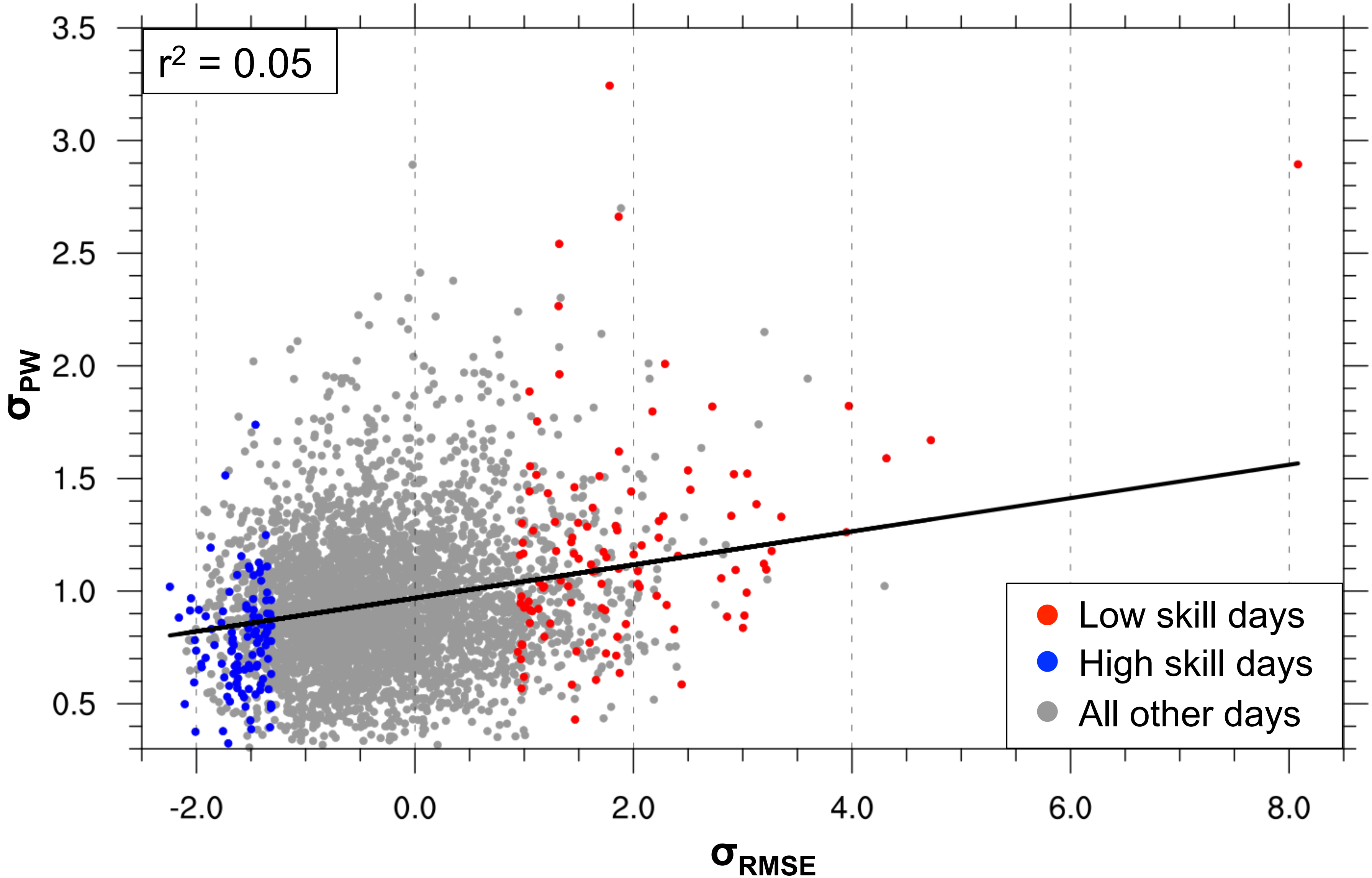
σ_{RMSE} vs σ_v



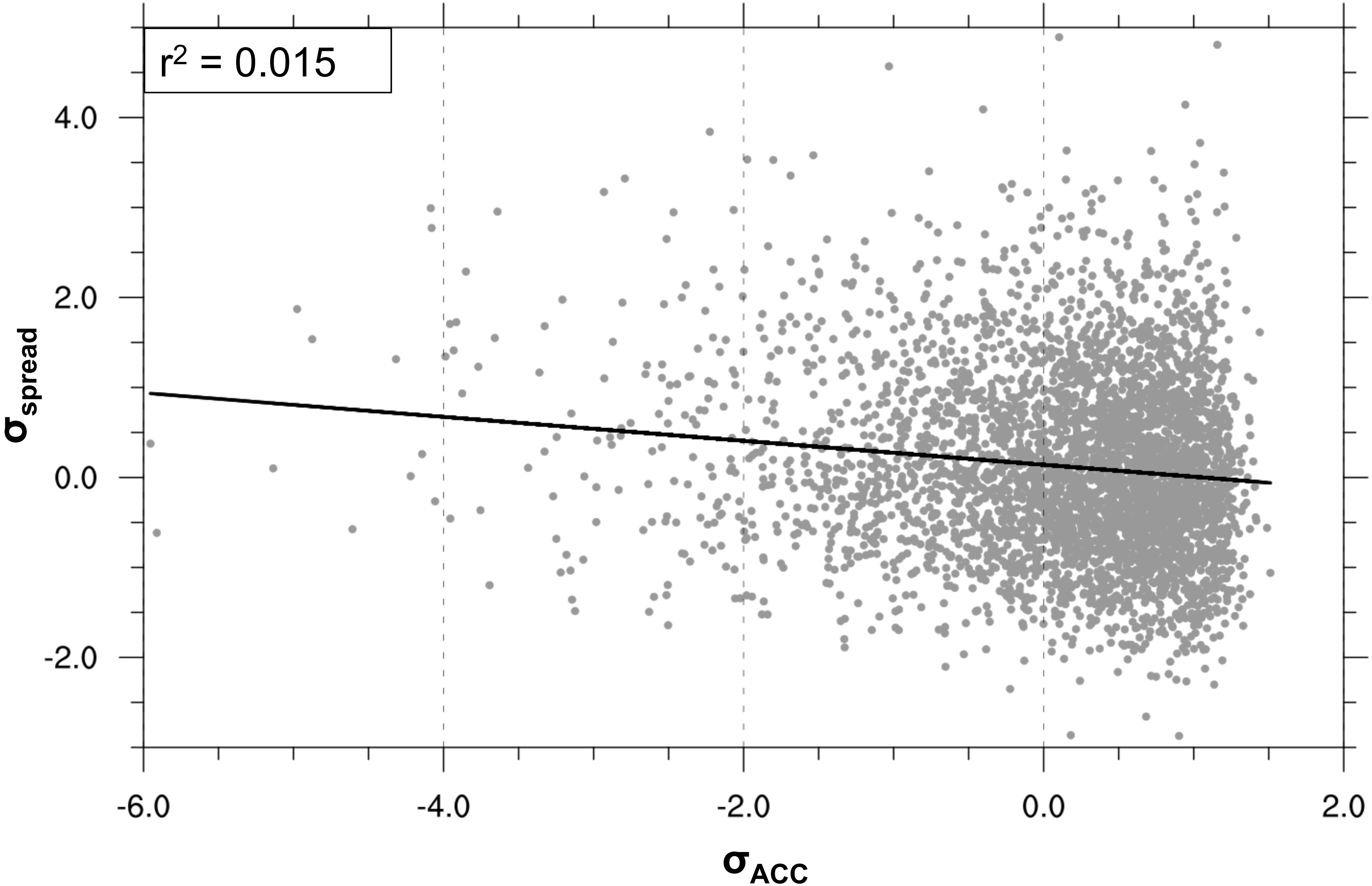
σ_{spread} vs σ_{PW}



σ_{spread} vs σ_{PW}



σ_{ACC} vs σ_{spread}



σ_{ACC} vs σ_{RMSE}