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

- Yamagami et al. (2018a,b) show that forecast skill of strong Arctic cyclones (ACs) can be low.

- 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, 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: 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 $\geq 2$ 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 ($\sigma_{\text{anom}}$) following Torn (2017) and determine area-weighted average of $\sigma_{\text{anom}}$ over the Arctic ($\geq 70^\circ\text{N}$)

- 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 (EPS; Buizza et al. 2007)
Forecast days valid at day 5 associated with the top and bottom 10% of the area-weighted average of $\sigma_{\text{anom}}$ 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

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of days in period</th>
<th>Number of ACs in period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climo</td>
<td>4018</td>
<td>2542</td>
</tr>
<tr>
<td><strong>Low skill</strong></td>
<td>469</td>
<td>401</td>
</tr>
<tr>
<td><strong>High skill</strong></td>
<td>477</td>
<td>345</td>
</tr>
</tbody>
</table>

Frequency of ACs (number of ACs day\(^{-1}\))

\[
\text{Frequency} = \frac{\text{number of ACs within period}}{\text{number of days within period}}
\]

The graph shows the frequency of ACs for different periods.
AC Track Frequency

Climatology (N = 2542)

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

Low skill (N = 401)

High skill (N = 345)

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

Minimum standardized anomaly of SLP ($\sigma$) of ACs

- climo (N=2542)
- low (N=401)
- high (N=345)

Statistically significant differences in means

- min and max
- mean
- 95%
- 75%
- median
- 25%
- 5%
- 5%
Intensity

Minimum standardized anomaly of SLP (σ) of ACs

-10 -8 -6 -4 -2 0 2

-10 -8 -6 -4 -2 0 2

climo (N=2542)  low (N=401)  high (N=345)

Statistically significant differences in means
Minimum standardized anomaly of SLP ($\sigma$) of ACs by season

- **Statistically significant differences in means**

<table>
<thead>
<tr>
<th>Season</th>
<th>Low (N)</th>
<th>High (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJF</td>
<td>130</td>
<td>119</td>
</tr>
<tr>
<td>MAM</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>JJA</td>
<td>92</td>
<td>55</td>
</tr>
<tr>
<td>SON</td>
<td>69</td>
<td>61</td>
</tr>
</tbody>
</table>

- Intensity:
  - Low: (N =130) DJF, (N=110) MAM, (N=92) JJA, (N=69) SON
  - High: (N=119) DJF, (N=110) MAM, (N=55) JJA, (N=61) SON

- **Box plot details**:
  - Min and max
  - Mean
  - 95% confidence interval
  - 75% quantile
  - 25% quantile
  - 5% quantile

- **Statistic**
  - Statistically significant differences in means

- The graph shows the distribution of minimum standardized anomalies for different seasons and intensity levels, with statistical significance indicated by stars.
• Calculate absolute value of standardized anomaly of 500-hPa v-wind (hereafter $\sigma_v$) using ERA-Interim

• Calculate area-weighted average of $\sigma_v$ over the Arctic ($\geq 70^\circ$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, black), wind (flags and barbs, m s\(^{-1}\)), and \(\sigma_v\) (shading) from ERA-Interim
Flow Amplitude

Area-weighted average of $\sigma_v$ over the Arctic ($\geq 70^\circ$N)

Hours relative to 0000 UTC of low and high skill days

-120 -96 -72 -48 -24 0

-1.1 -1.0 -0.9 -0.8 -0.7 -0.6 -0.5

1979–2017 climo mean
low-skill mean
high-skill mean

shading:
interquartile range

statistically significant difference between low/high skill mean and climo mean
statistically significant difference between low and high skill means
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 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 occur more frequently over the northern North Atlantic and the adjacent Norwegian and Barents Seas relative to Arctic cyclones during low skill periods
Summary

- Arctic cyclones tend to be stronger during low skill periods compared to high skill periods.

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

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


Extra Slides
At each grid point \((i)\), day of the year \((d)\), and forecast lead time \((f)\), \(\sigma_{anom}\) is calculated following Torn (2017) as:

\[
\sigma_{anom}(i, d, f) = \frac{\sigma(i, d, f) - \sigma_{mean}(i, d, f)}{\sigma_{stdv}(i, d, f)}
\]

- \(\sigma\) = raw ensemble spread
- \(\sigma_{mean}\) = climatological mean ensemble spread
- \(\sigma_{stdv}\) = climatological standard deviation of ensemble spread

\(\sigma_{mean}\) and \(\sigma_{stdv}\) are calculated for 1985–2017 period from the GEFS reforecast dataset v2.
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
Frequency of ACs by Season

Frequency of ACs (number of ACs day$^{-1}$) by season

Frequency $= \frac{\text{number of ACs within period}}{\text{number of days within period}}$

- DJF
- MAM
- JJA
- SON

Frequency $= \text{number of ACs within period} / \text{number of days within period}$
Track Frequency Differences

Low skill minus climatology

High skill minus climatology

Difference in AC track frequency (number of ACs day$^{-1}$)
Total number of ACs within 500 km of a grid point, divided by number of days in climatology during DJF (number of ACs day$^{-1}$)
Track Frequency (DJF)

Low skill (N = 130)

High Skill (N = 119)

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

Low skill minus high skill

Difference in AC track density during DJF (number of ACs day$^{-1}$)
Total number of ACs within 500 km of a grid point, divided by number of days in climatology during MAM (number of ACs day$^{-1}$)
Track Frequency (MAM)

Low skill (N = 110)

High Skill (N = 110)

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

Low skill minus high skill

Difference in AC track density during MAM (number of ACs day⁻¹)
Track Frequency (JJA)

JJA climatology (N = 680)

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

Low skill (N = 92)

High Skill (N = 52)

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

Low skill minus high skill

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

SON climatology (N = 668)

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

Low skill (N = 69)

High Skill (N = 61)

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

Low skill minus high skill

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)

- **climo (N=2542)**
- **low (N=401)**
- **high (N=345)**
Preferred Longitudinal Corridors (DJF)

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

climo (N=585)  low (N=130)  high (N=119)
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

- climo (N=680)
- low (N=92)
- high (N=55)
Preferred Longitudinal Corridors (SON)

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

Distribution of AC genesis latitude (% per latitude bin)

- 10°N
- 20°N
- 30°N
- 40°N
- 50°N
- 60°N
- 70°N
- 80°N
- 90°N

- climo (N=2542)
- low (N=401)
- high (N=345)
Distribution of Arctic cyclone genesis latitude (% per latitude bin) during DJF

- climo (N=585)
- low (N=130)
- high (N=119)
Distribution of Arctic cyclone genesis latitude (% per latitude bin) during MAM

- **climo (N=609)**
- **low (N=110)**
- **high (N=110)**
Distribution of Arctic cyclone genesis latitude (% per latitude bin) during JJA

- Grey bars: climo (N=680)
- Red bars: low (N=92)
- Blue bars: high (N=55)
Genesis Latitude (SON)

Distribution of Arctic cyclone genesis latitude (% per latitude bin) during SON

- climo (N=668)
- low (N=69)
- high (N=61)
Intensity: Maximum SLP Depth

Maximum SLP depth (hPa) of ACs

- Climo (N=2542)
- Low (N=401)
- High (N=345)

Statistically significant differences in means.
Intensity: Maximum SLP Depth

Maximum SLP depth (hPa) of ACs

- Min and max
- Mean
- 95%
- 75%
- Median
- 25%
- 5%

Statistically significant differences in means

climo (N=2542)
low (N=401)
high (N=345)
Intensity: Maximum SLP Depth

Maximum SLP depth (hPa) of ACs by season

DJF MAM JJA SON

0 10 20 30 40 50 60

* min and max  ● mean

95% 75% 50% 25% 5%  
Statistically significant differences in means
Intensity: Minimum SLP

Minimum SLP (hPa) of Arctic cyclones

- Climatic (climo) (N=2542)
- Low (N=401)
- High (N=345)

* min and max

- Mean
- 95%
- 75%
- Median
- 25%
- 5%
Intensity: Minimum SLP

Minimum SLP (hPa) of Arctic cyclones by season

- DJF: Low (N=130) vs. High (N=119)
- MAM: Low (N=110) vs. High (N=110)
- JJA: Low (N=92) vs. High (N=55)
- SON: Low (N=69) vs. High (N=61)

- Min and max
- Mean
- Median
- 95% confidence intervals
- Statistically significant differences in means