An Examination of Low-Skill Arctic Cyclones During Summer

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Overview

- Identify periods of low and high forecast skill of the synoptic-scale flow over the Arctic and low-skill Arctic cyclones (ACs) occurring during these periods.
- Examine dynamical and thermodynamic quantities characterizing the Arctic environment and low-skill ACs during low-skill and high-skill periods.
- Conduct AC-centered composite analyses of intense low-skill ACs during low-skill periods to identify features and processes governing the evolution of these ACs.

Arctic forecast skill evaluation

- Utilize day-5 forecasts of 500-hPa geopotential height initialized at 0000 UTC during June, July, and August of 2007–2017 from 11-member 1° GEFS reforecast dataset v2 (Hamill et al. 2013).

- Calculate area-averaged root mean square error (RMSE) of 500-hPa geopotential height over the Arctic, using ERA-Interim as verification.

- Calculated standardized anomaly of area-averaged RMSE (σ_{RMSE}).

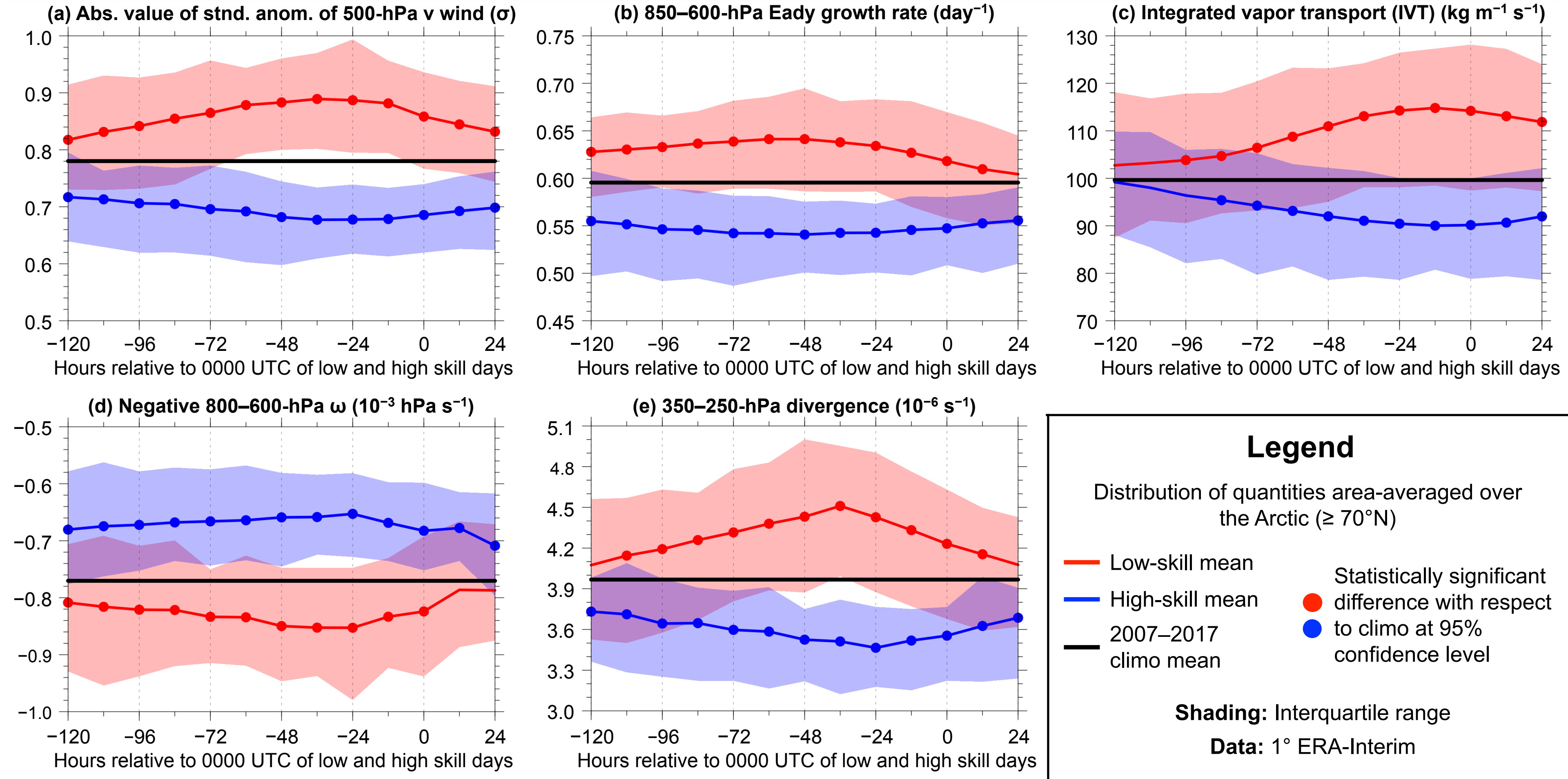
Arctic forecast skill evaluation

- Refer to forecast days valid at day 5 associated with the top and bottom 10% of σ_{RMSE} as **low-skill days and high-skill days**, respectively.

- Refer to forecasts initialized 5 days prior to low-skill days and high-skill days as **low-skill forecasts and high-skill forecasts**, respectively.

- Refer to time periods through day 5 encompassed by low-skill forecasts and high-skill forecasts as **low-skill periods and high-skill periods**, respectively.

Quantities characterizing the Arctic environment



Identification of low-skill ACs

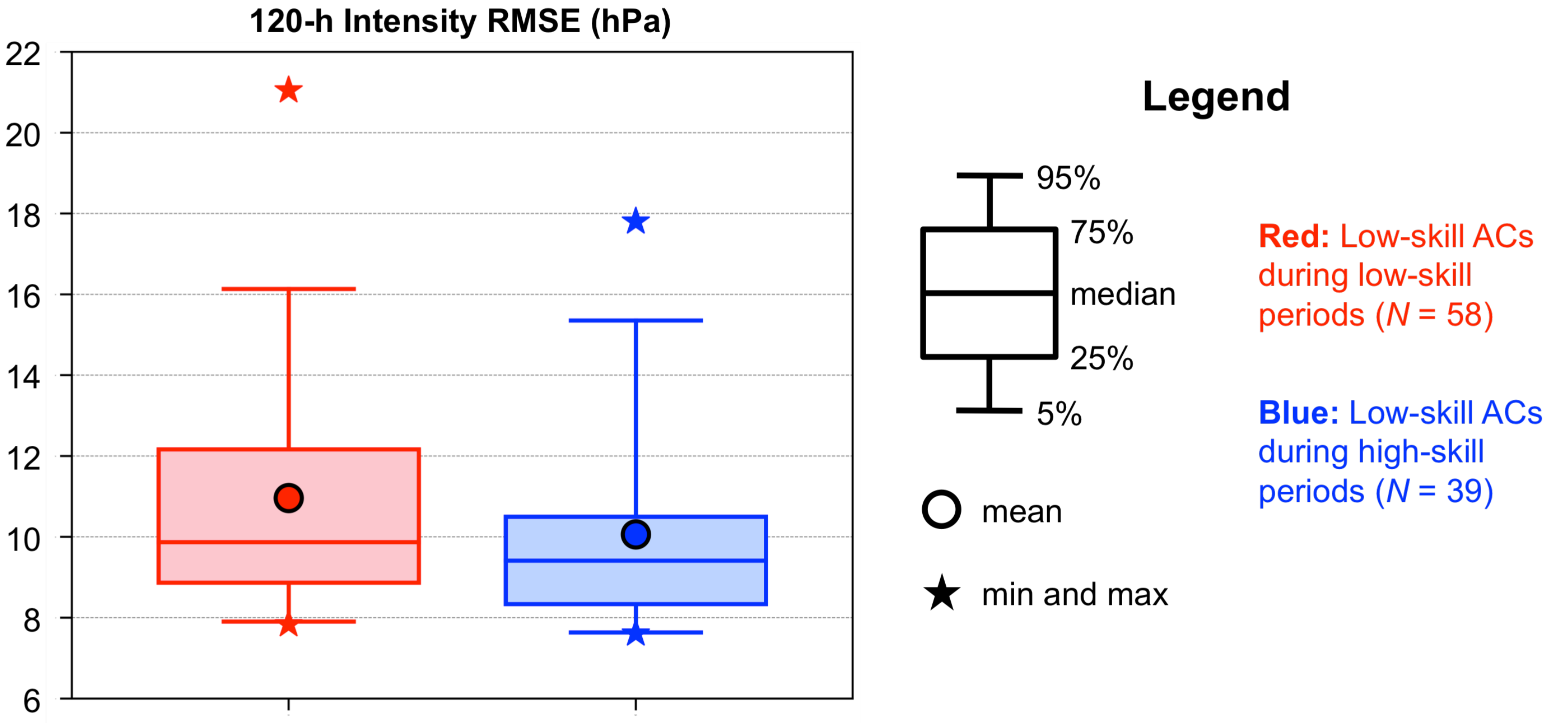
- Create a climatology of ACs occuring during June, July, and August of 2007–2017 by obtaining cyclone tracks from 1° ERA-Interim cyclone climatology prepared by Sprenger et al. (2017).

- Deem cyclones that last ≥ 48 h and spend at least some portion of their lifetimes in the Arctic (> 70°N) as ACs.

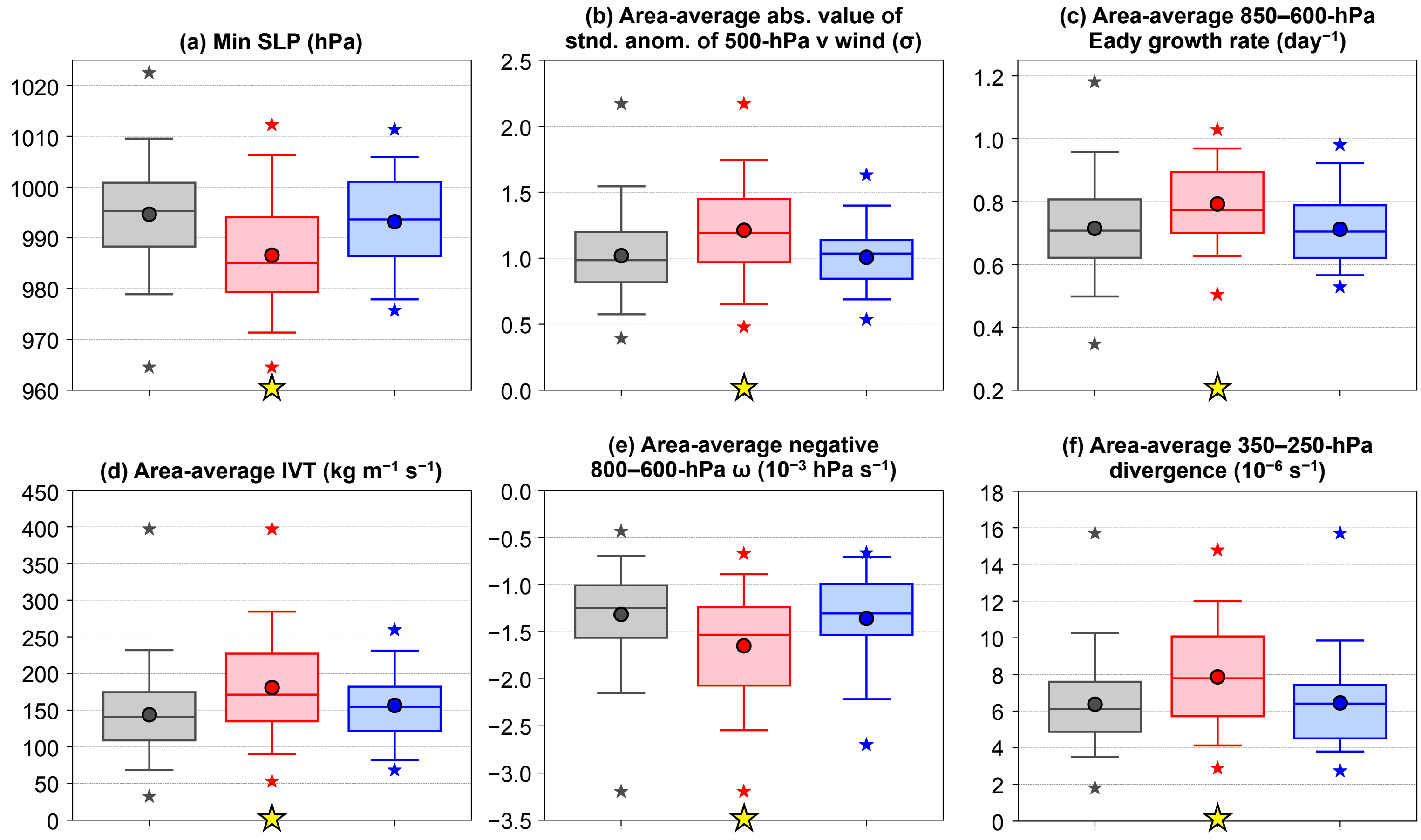
Identification of low-skill ACs

- Track ACs in forecasts from GEFS reforecast dataset v2 by utilizing an objective sea level pressure (SLP)-based tracking algorithm (Crawford et al. 2020).
- Consider forecasts initialized 120 h prior to the time of lowest SLP of the ACs when located in the Arctic during low-skill and high-skill periods.
- Calculate 120-h intensity RMSE based on minimum SLP of the ACs at the aforementioned time of lowest SLP, using ERA-Interim as verification.
- Refer to ACs associated with the top 25% of 120-h intensity RMSE for low-skill and high-skill periods as low-skill ACs for these respective periods.

Identification of low-skill ACs



Quantities characterizing low-skill ACs



Legend

Distribution of most extreme value of quantities characterizing ACs when the ACs are located in the Arctic for the following categories:

Gray: All ACs in 2007–2017 climatology (*N* = 730)

Red: Low-skill ACs during low-skill periods (*N* = 58)

Blue: Low-skill ACs during high-skill periods (*N* = 39)

95%
75%
median
25%
5%

mean

min/max

Statistically significant difference with respect to climatology at 95% confidence level

Area-averaged quantities are calculated within 1000 km of AC center

Data: 1° ERA-Interim

AC-centered composites

- Composite top 25% strongest low-skill ACs during low-skill periods (*N* = 14) at various lag times relative to the time of lowest SLP of the ACs when located in the Arctic using ERA5 (0.25°×0.25°).

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- For each lag time:
  - Determine mean latitude and longitude of ACs.

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  - Rotate and project ERA5 grids to a 25×25 km Equal-Area Scalable Earth 2.0 (EASE2) grid such that the AC center lies on y-axis (0° longitude) of the EASE2 grid.

EASE2 Grid
(source: NSIDC: https://nsidc.org/ease/ease-grid-projection-gt)

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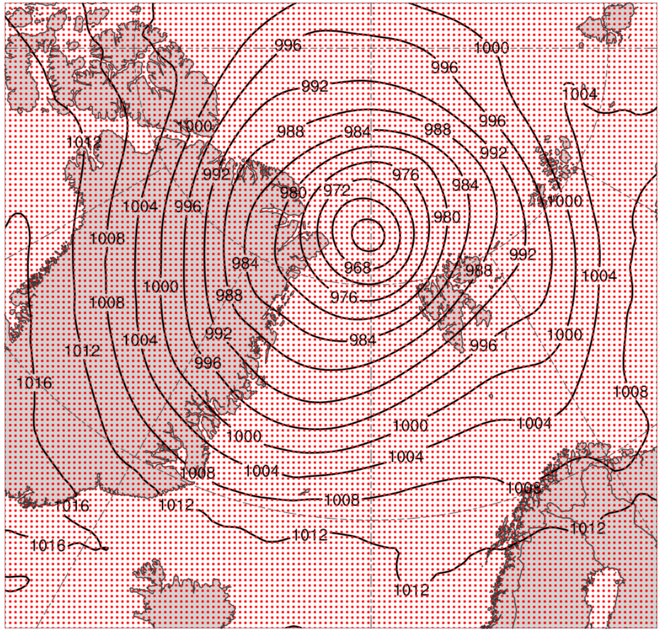

SLP (black) on 25x25 km EASE2 grid (grid points in red) valid 1200 UTC 6 Aug 2012

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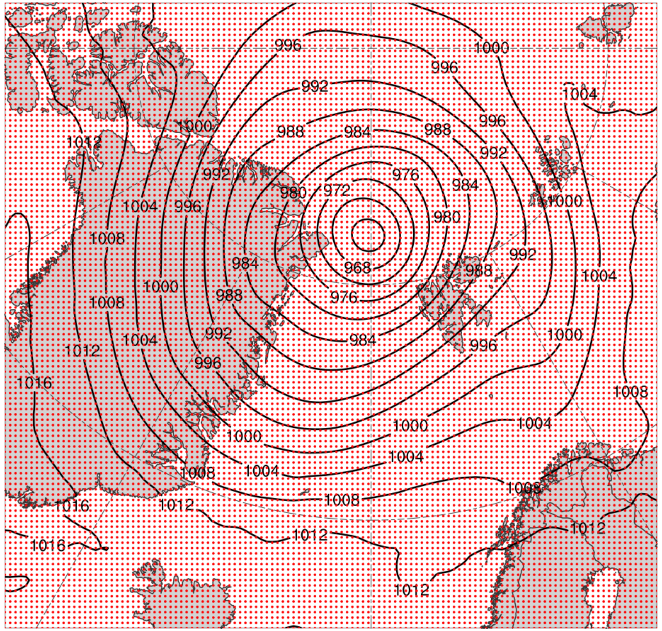
  - Shift projected grids to mean latitude of ACs.



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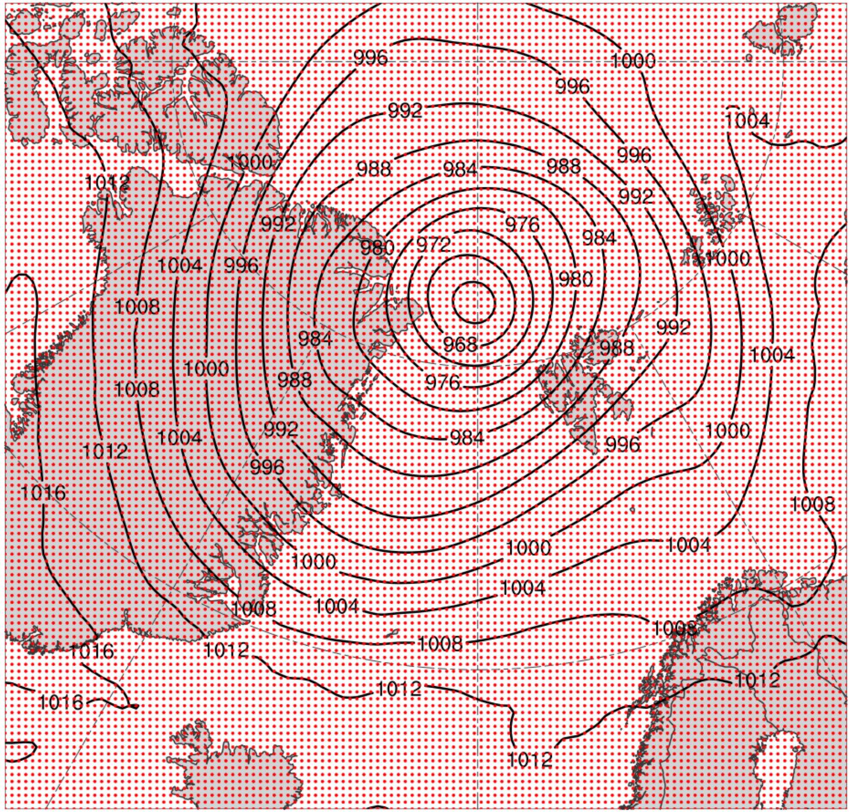
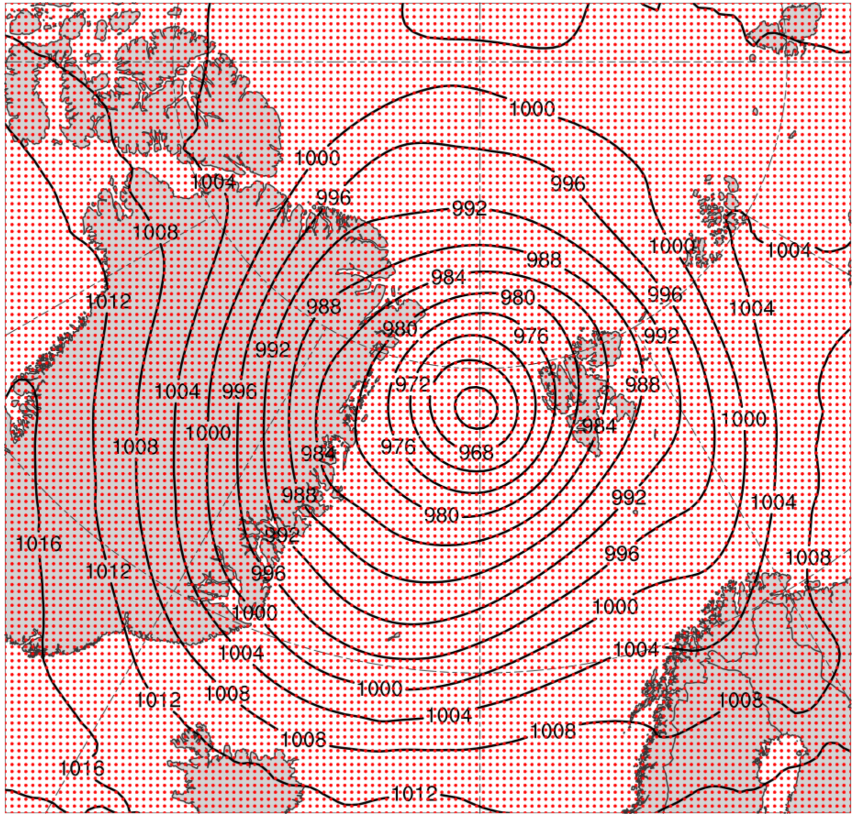
AC-centered composites

Grid before shifting to mean latitude



Grid after shifting to mean latitude



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  - Determine mean latitude and longitude of ACs.
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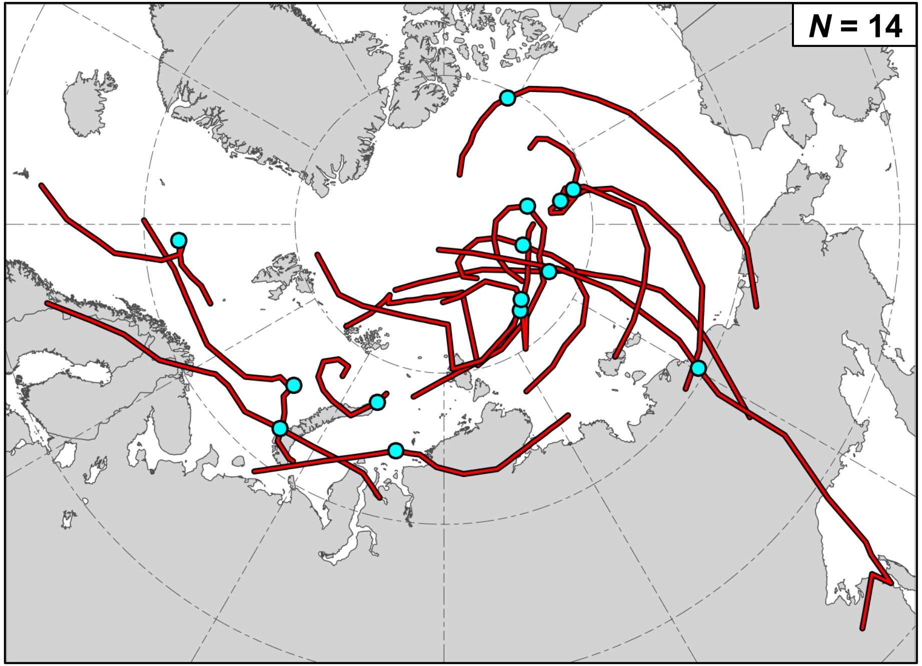
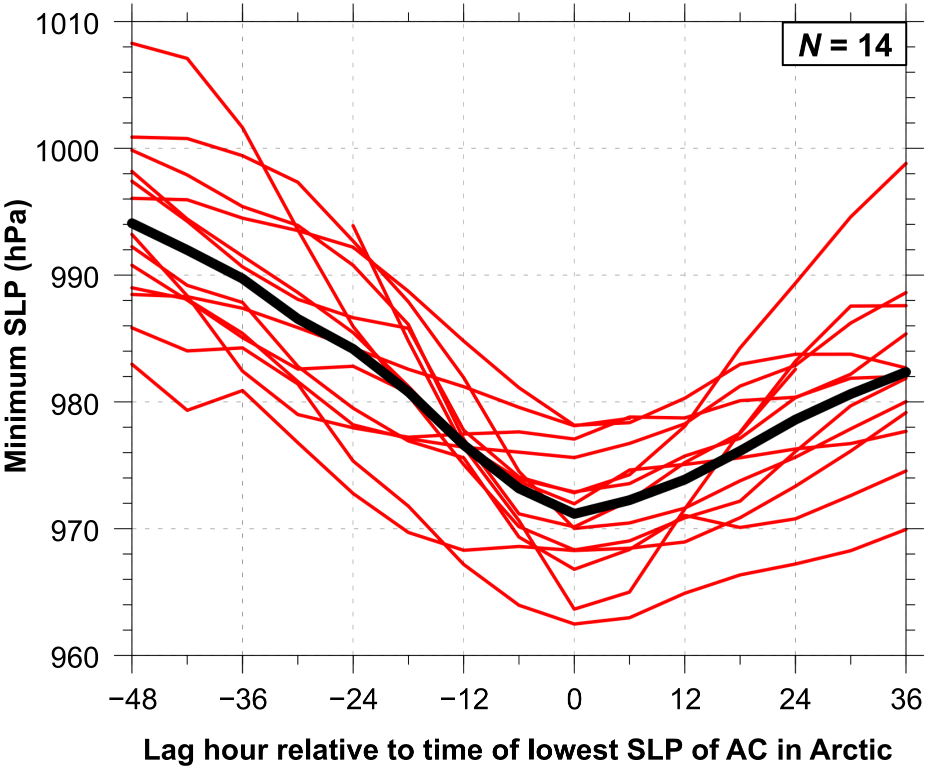
  - Shift projected grids to mean latitude of ACs.
  - Rotate shifted grids to mean longitude of ACs.

AC-centered composites

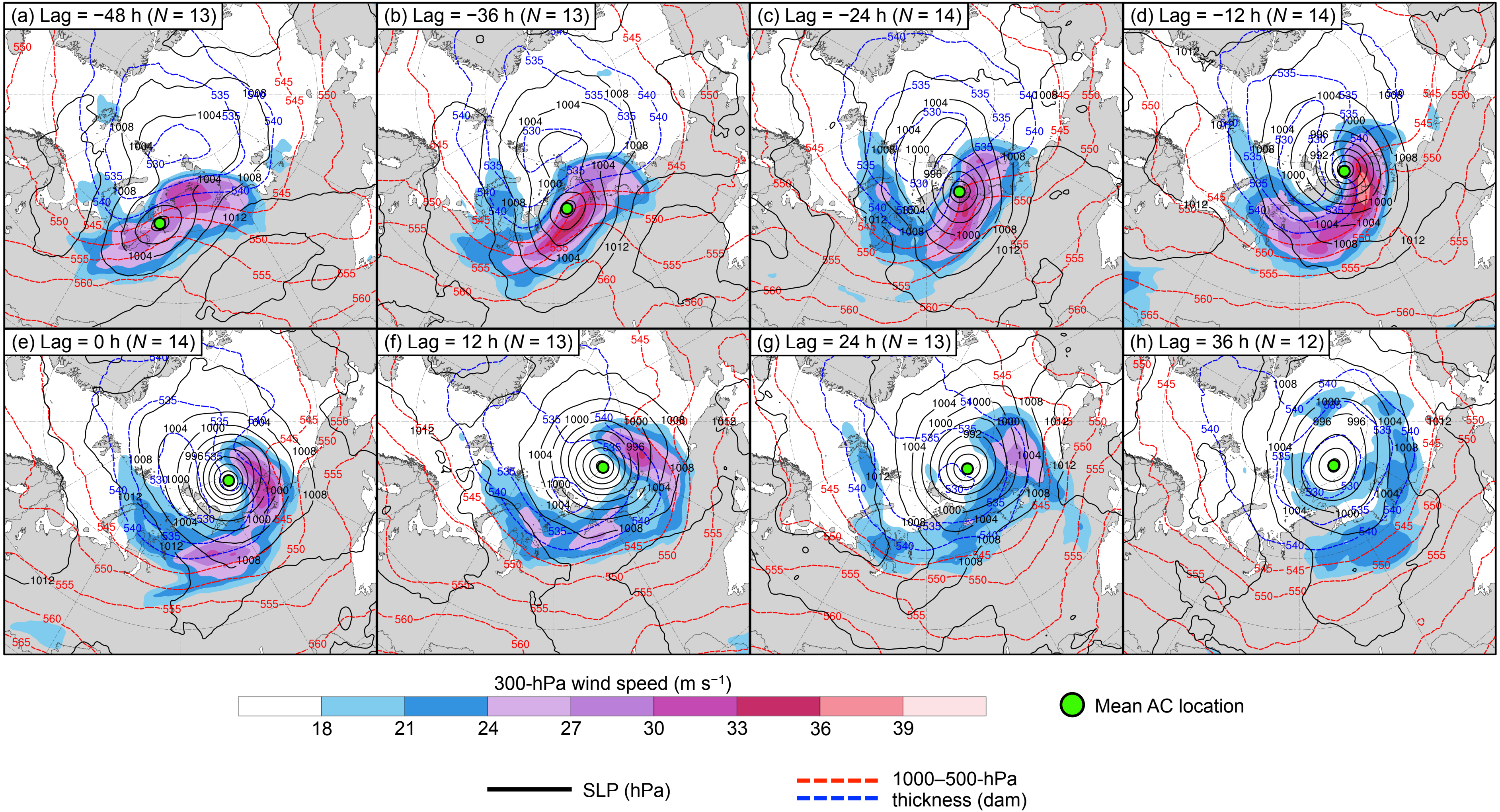


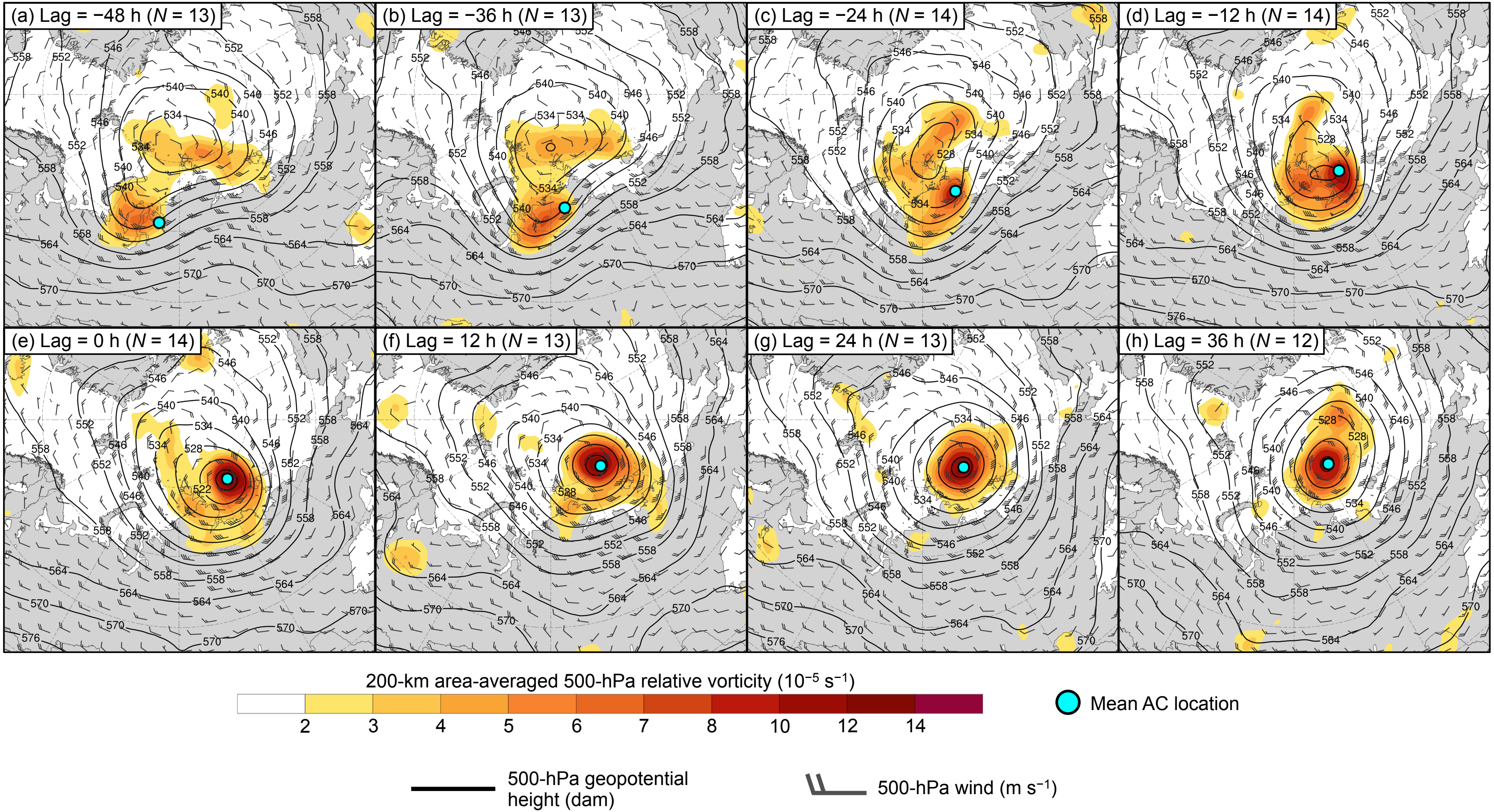
AC location at lag 0 h (time of lowest SLP of AC in Arctic)

Red lines show tracks of ACs during lag –48 h to lag 36 h, when valid.



Time series of minimum SLP (hPa) of ACs (red) and of mean minimum SLP (hPa) of ACs (black) during lag –48 h to lag 36 h, when valid.


(a) Lag = −48 h (N = 13)
(b) Lag = −36 h (N = 13)
(c) Lag = −24 h (N = 14)
(d) Lag = −12 h (N = 14)
(e) Lag = 0 h (N = 14)
(f) Lag = 12 h (N = 13)
(g) Lag = 24 h (N = 13)
(h) Lag = 36 h (N = 12)
300-hPa wind speed (m s−1)
18 21 24 27 30 33 36 39
Mean AC location
SLP (hPa)
1000–500-hPa thickness (dam)



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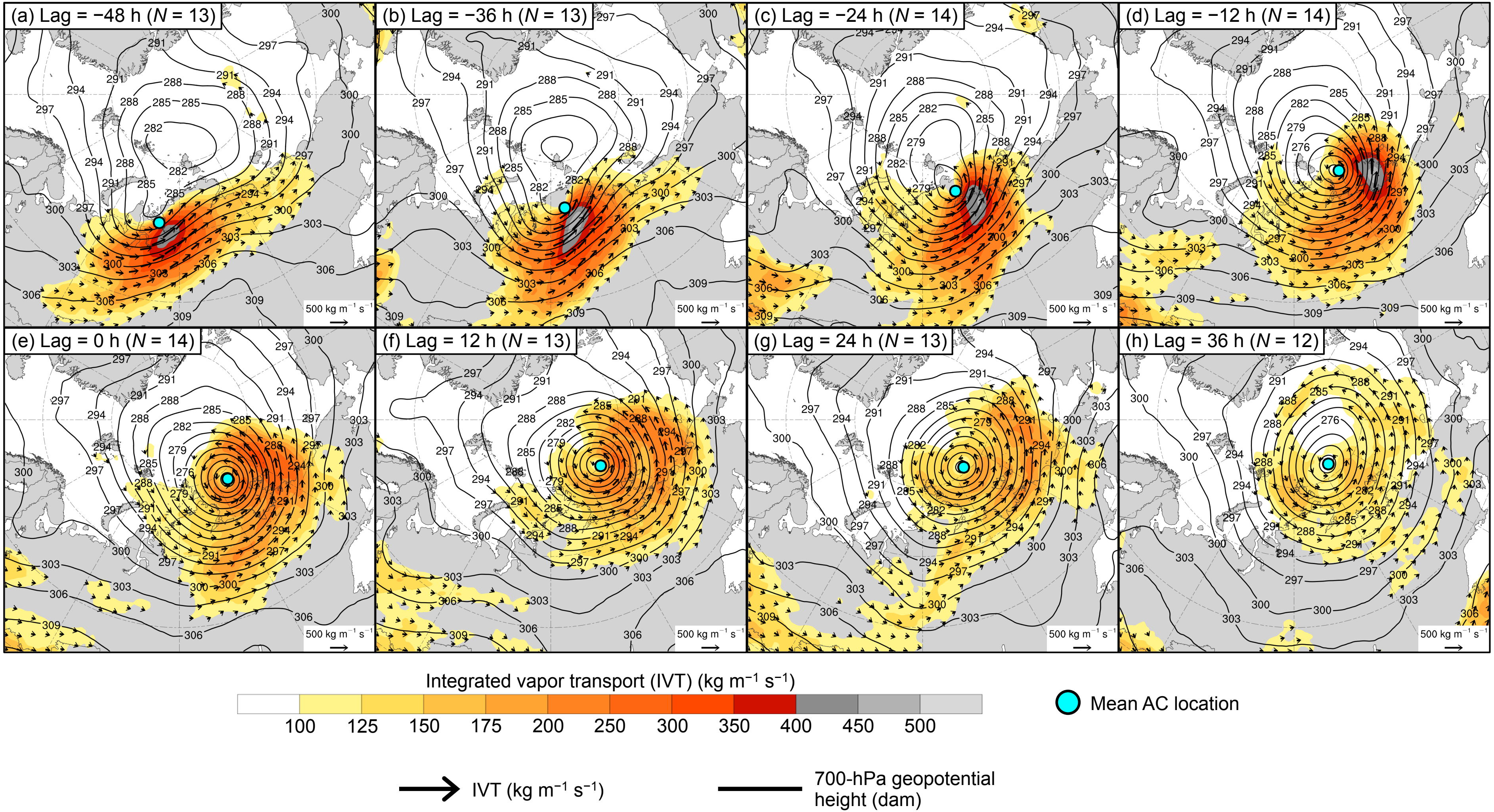
200-km area-averaged 500-hPa relative vorticity (10⁻⁵ s⁻¹)
2 3 4 5 6 7 8 10 12 14
Mean AC location
500-hPa geopotential height (dam)
500-hPa wind (m s⁻¹)



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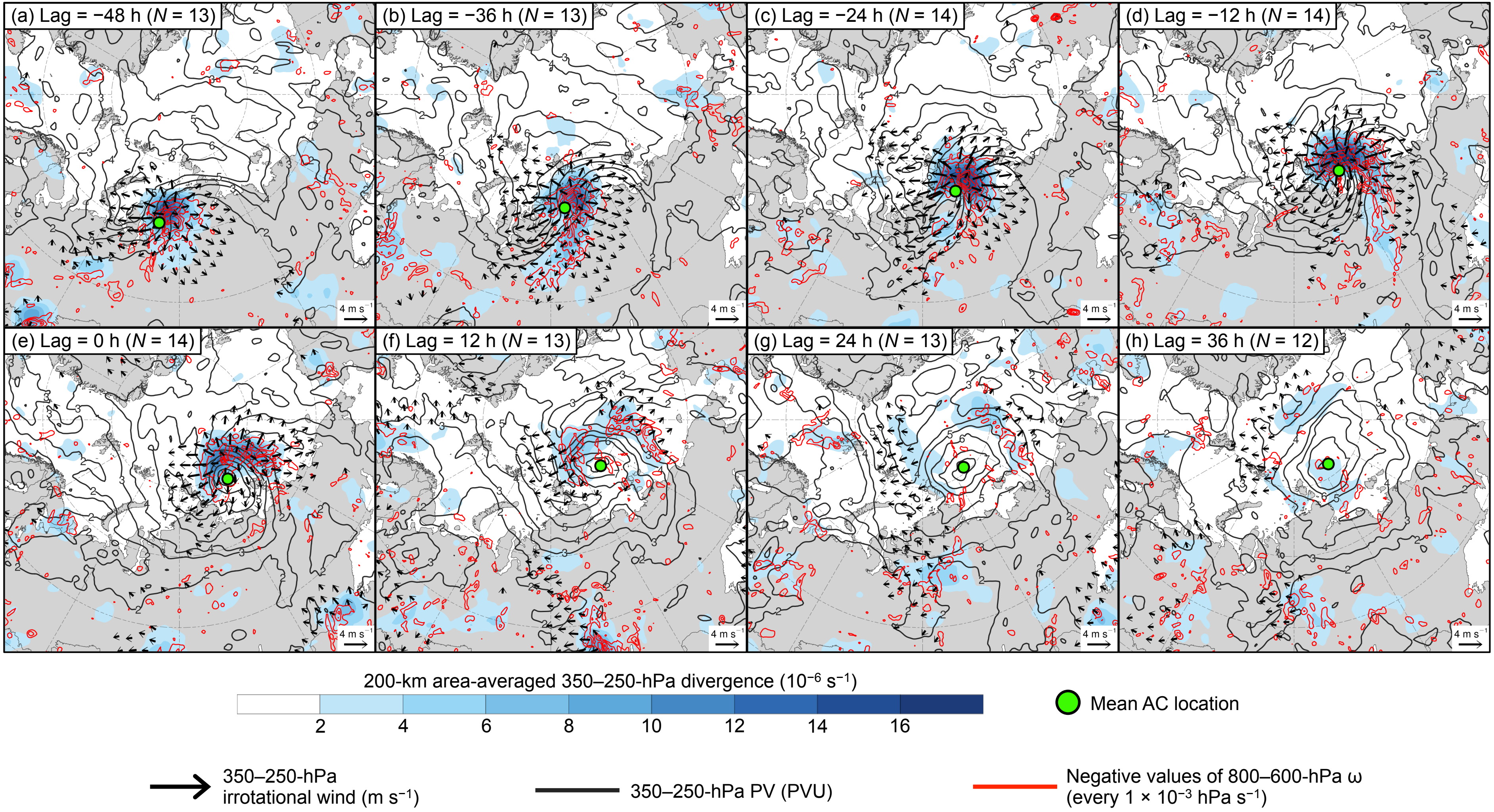
500 kg m⁻¹ s⁻¹
Integrated vapor transport (IVT) (kg m⁻¹ s⁻¹)
100
125
150
175
200
250
300
350
400
450
500
Mean AC location
IVT (kg m⁻¹ s⁻¹)
700-hPa geopotential height (dam)



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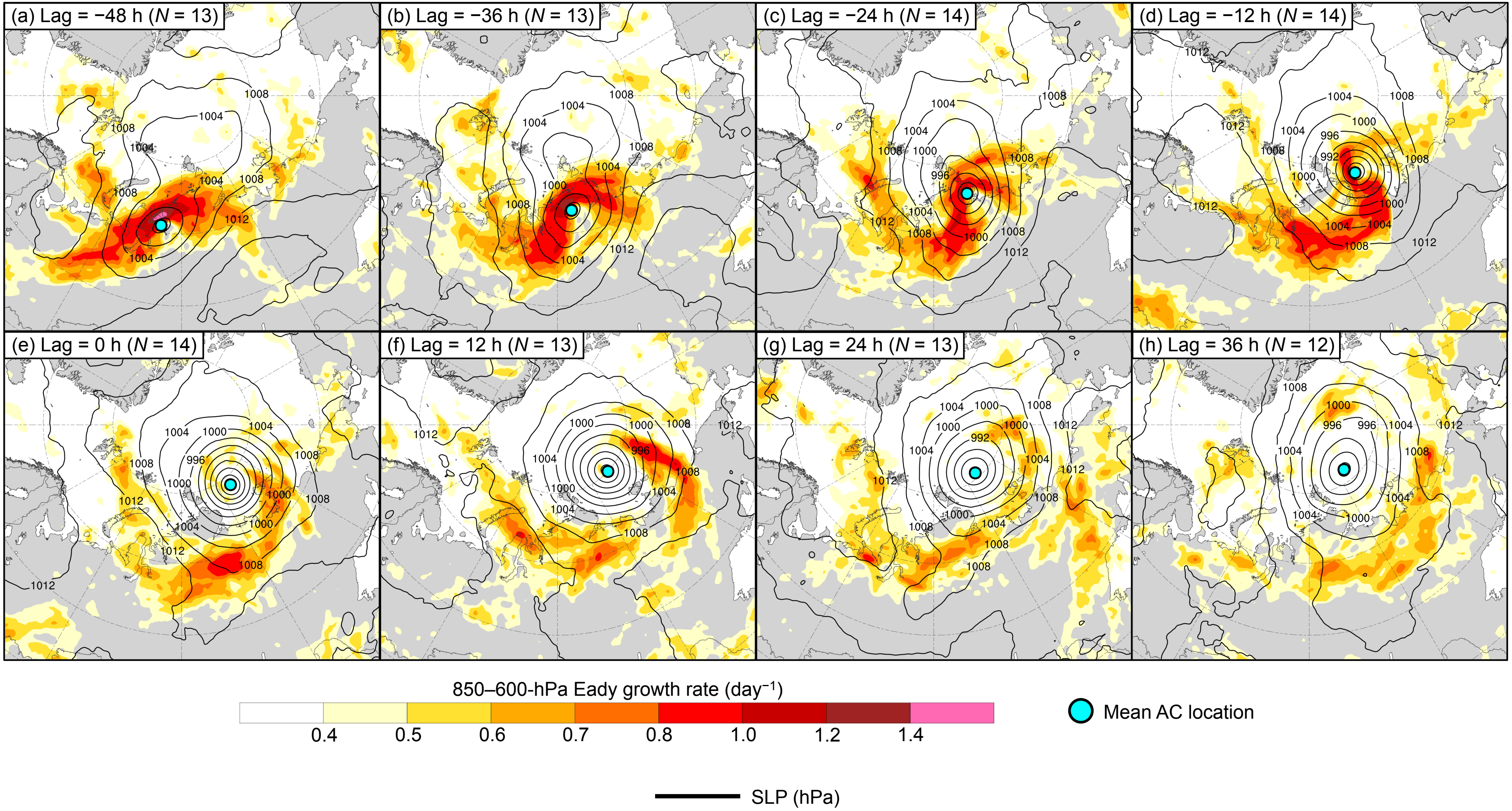
4 m s⁻¹
200-km area-averaged 350–250-hPa divergence (10⁻⁶ s⁻¹)
2
4
6
8
10
12
14
16
Mean AC location
350–250-hPa irrotational wind (m s⁻¹)
350–250-hPa PV (PVU)
Negative values of 800–600-hPa ω (every 1 × 10⁻³ hPa s⁻¹)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850–600-hPa Eady growth rate (day−1)
0.4 0.5 0.6 0.7 0.8 1.0 1.2 1.4
Mean AC location
SLP (hPa)

Summary

- The Arctic environment tends to be characterized by more amplified synoptic-scale flow, greater baroclinic growth, and potentially greater latent heating during low-skill periods compared to high-skill periods.

- Low-skill ACs tend to be stronger and embedded in a region of more amplified synoptic-scale flow, greater baroclinic growth, and potentially greater latent heating during low-skill periods compared to high-skill periods.

- Intense low-skill ACs during low-skill periods intensify downstream of a mid-to-upper-tropospheric vortex in a region of relatively strong lower-to-midtropospheric baroclinicity, lower-to-midtropospheric ascent, tropospheric-integrated vapor transport, and upper-tropospheric divergence.

- A combination of baroclinic processes and latent heating likely play important roles in the intensification of intense-low-skill ACs during low-skill periods.