Composite Analyses of Low-Skill Arctic Cyclones during Summer

Kevin A. Biernat, Lance F. Bosart, and Daniel Keyser

Department of Atmospheric and Environmental Sciences

University at Albany, State University of New York

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Motivation and purpose

- Arctic cyclones (ACs) are synoptic-scale low pressure systems that frequently form over the Arctic or move into the Arctic from lower latitudes during summer.

- It is anticipated that forecast error growth associated with interactions between ACs and the synoptic-scale flow over the Arctic, baroclinic processes, and latent heating may contribute to relatively low forecast skill of ACs and the synoptic-scale flow over the Arctic.

- Examine features and processes governing the evolution of intense low-skill ACs occurring during periods of low forecast skill of the synoptic-scale flow over the Arctic during summer.

Arctic forecast skill evaluation

- Utilize day-5 forecasts of 500-hPa geopotential height initialized at 0000 UTC during June–August 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.

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

Arctic forecast skill evaluation

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

- Refer to forecasts initialized 5 days prior to low-skill days as **low-skill forecasts**.

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

Identification of low-skill ACs

- Create a climatology of ACs occurring during June–August 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.

- Identify ACs that occur during low-skill periods.

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 5 days prior to the time of lowest SLP of the ACs when located in the Arctic during low-skill periods.

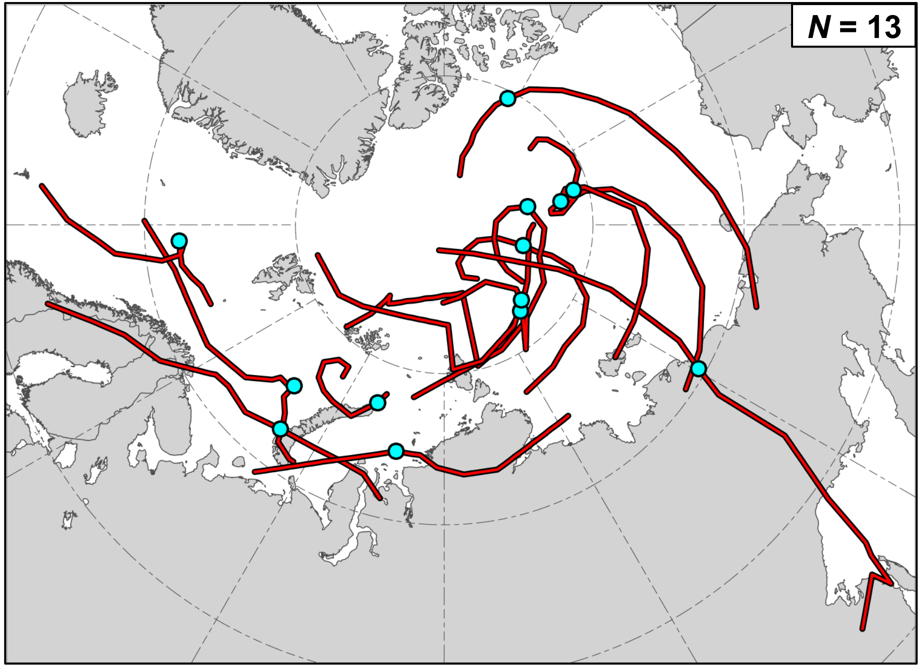
- Calculate day-5 intensity RMSE based on minimum SLP of the ACs at the aforementioned time of lowest SLP using ERA-Interim as verification.

- Refer to ACs associated with the top 25% of day-5 intensity RMSE as low-skill ACs.

AC-centered composites

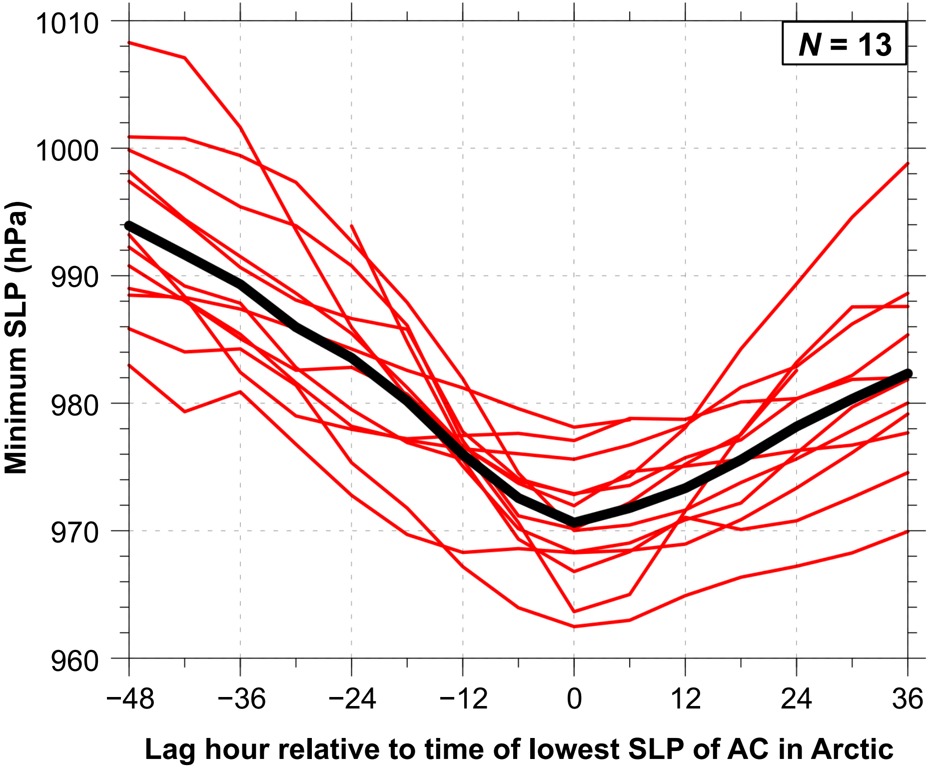
- Construct AC-centered composites of top 25% strongest low-skill ACs (*N* = 13) at various lag times relative to the time of lowest SLP of the ACs when located in the Arctic using ERA5 (0.25° × 0.25°).

Track and intensity of composited ACs

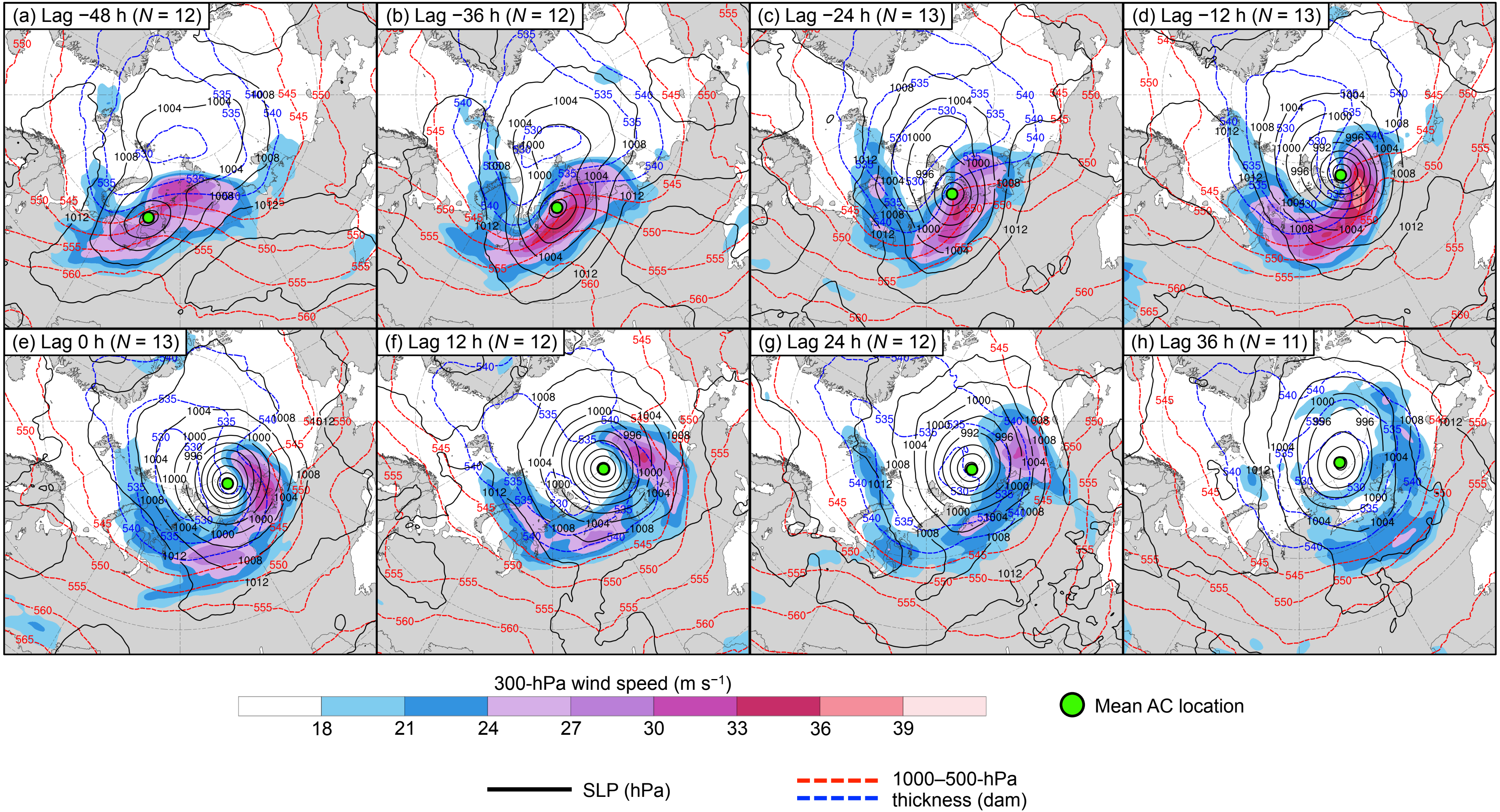


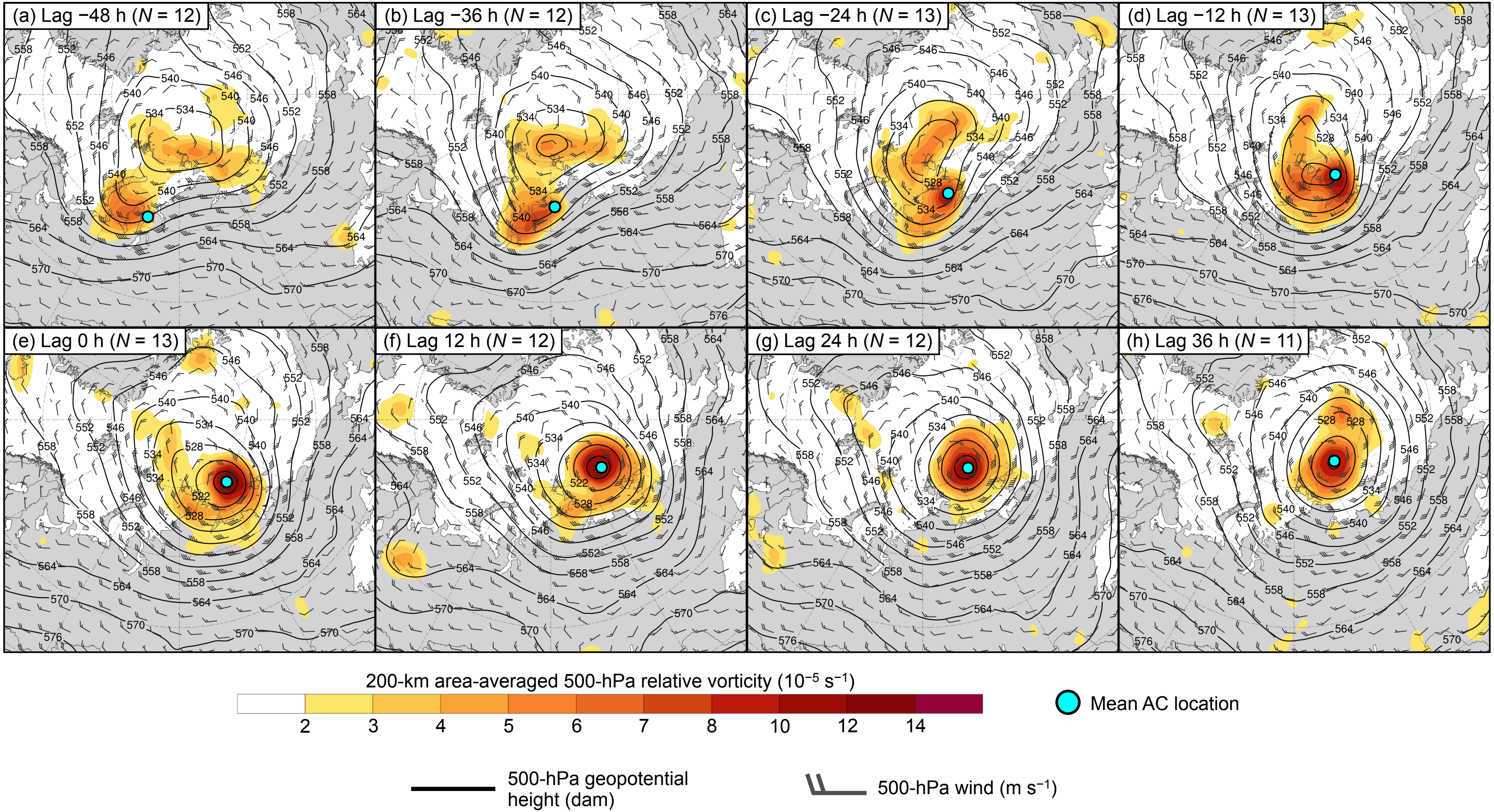
AC location at lag 0 h (time of lowest SLP of AC in Arctic)

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



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


(a) Lag −48 h (N = 12)
(b) Lag −36 h (N = 12)
(c) Lag −24 h (N = 13)
(d) Lag −12 h (N = 13)
(e) Lag 0 h (N = 13)
(f) Lag 12 h (N = 12)
(g) Lag 24 h (N = 12)
(h) Lag 36 h (N = 11)
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)



(a) Lag −48 h (N = 12)
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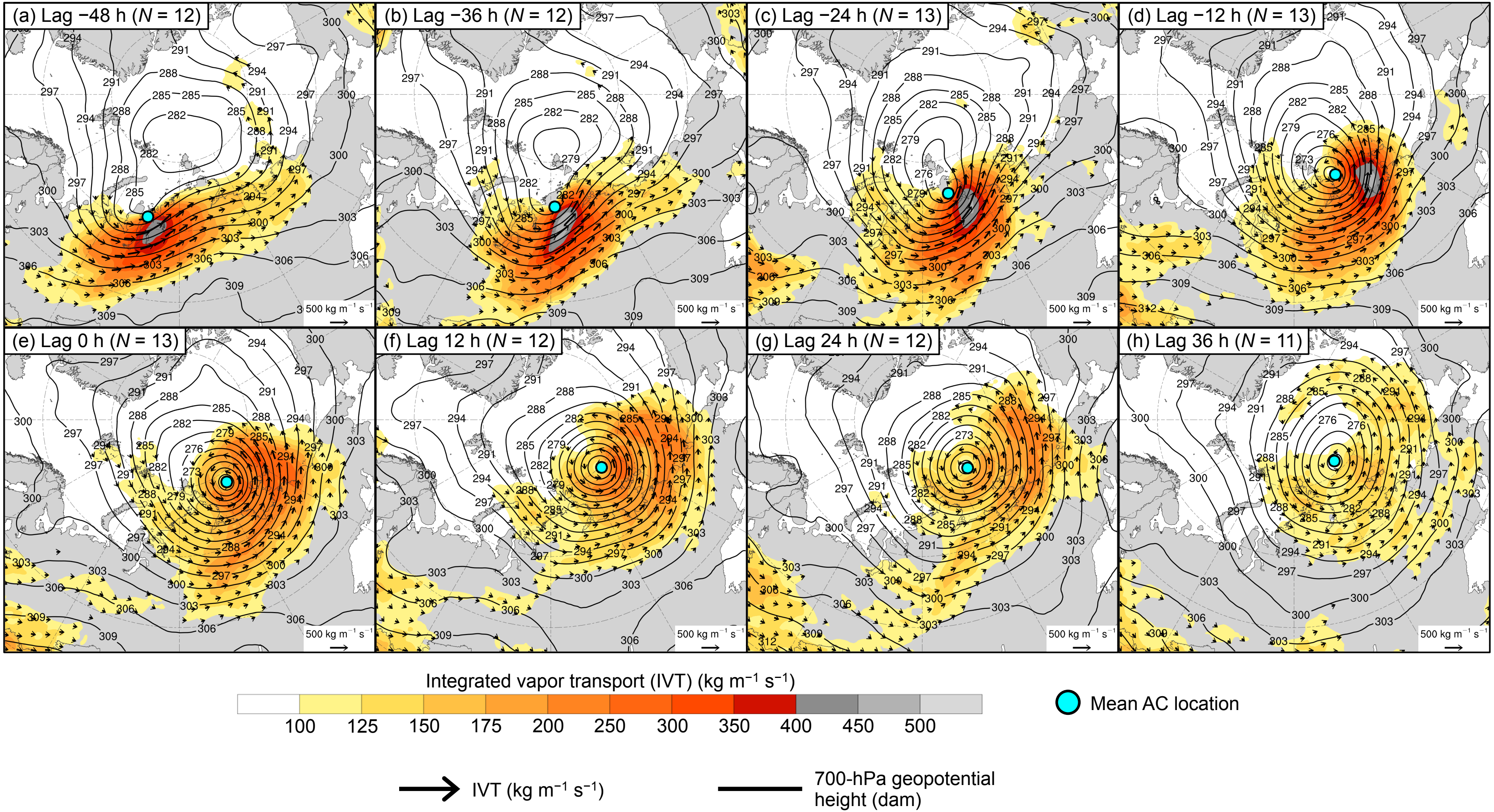
(d) Lag −12 h (N = 13)
(e) Lag 0 h (N = 13)
(f) Lag 12 h (N = 12)
(g) Lag 24 h (N = 12)
(h) Lag 36 h (N = 11)
200-km area-averaged 500-hPa relative vorticity (10⁻⁵ s⁻¹)
2 3 4 5 6 7 8 10 12 14
Mean AC location
500-hPa geopotential height (dam)
500-hPa wind (m s⁻¹)



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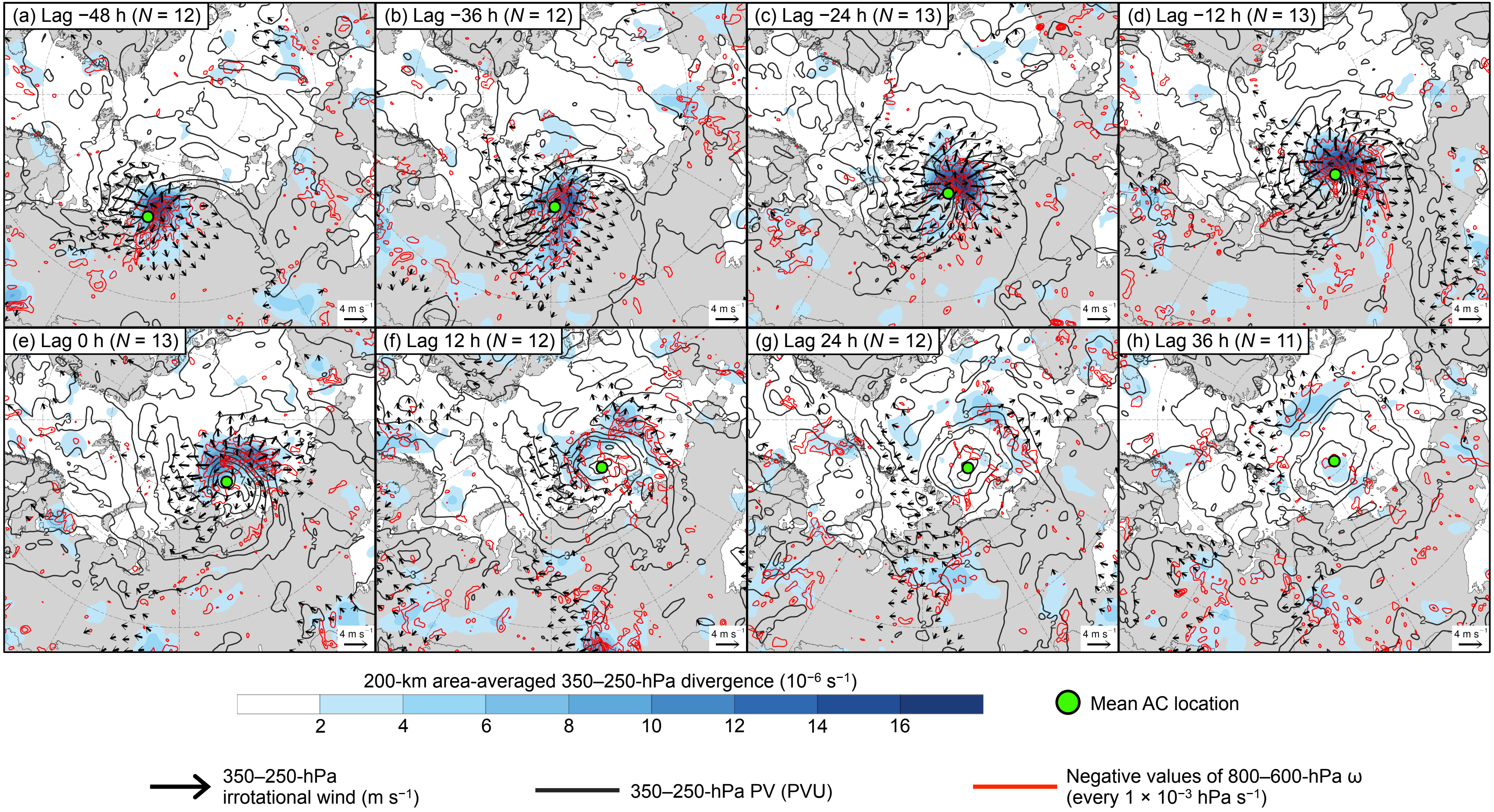
(f) Lag 12 h (N = 12)
(g) Lag 24 h (N = 12)
(h) Lag 36 h (N = 11)
500 kg m⁻¹ s⁻¹
Integrated vapor transport (IVT) (kg m⁻¹ s⁻¹)
100
125
150
175
200
250
300
350
400
450
500
Mean AC location
IVT (kg m⁻¹ s⁻¹)
700-hPa geopotential height (dam)



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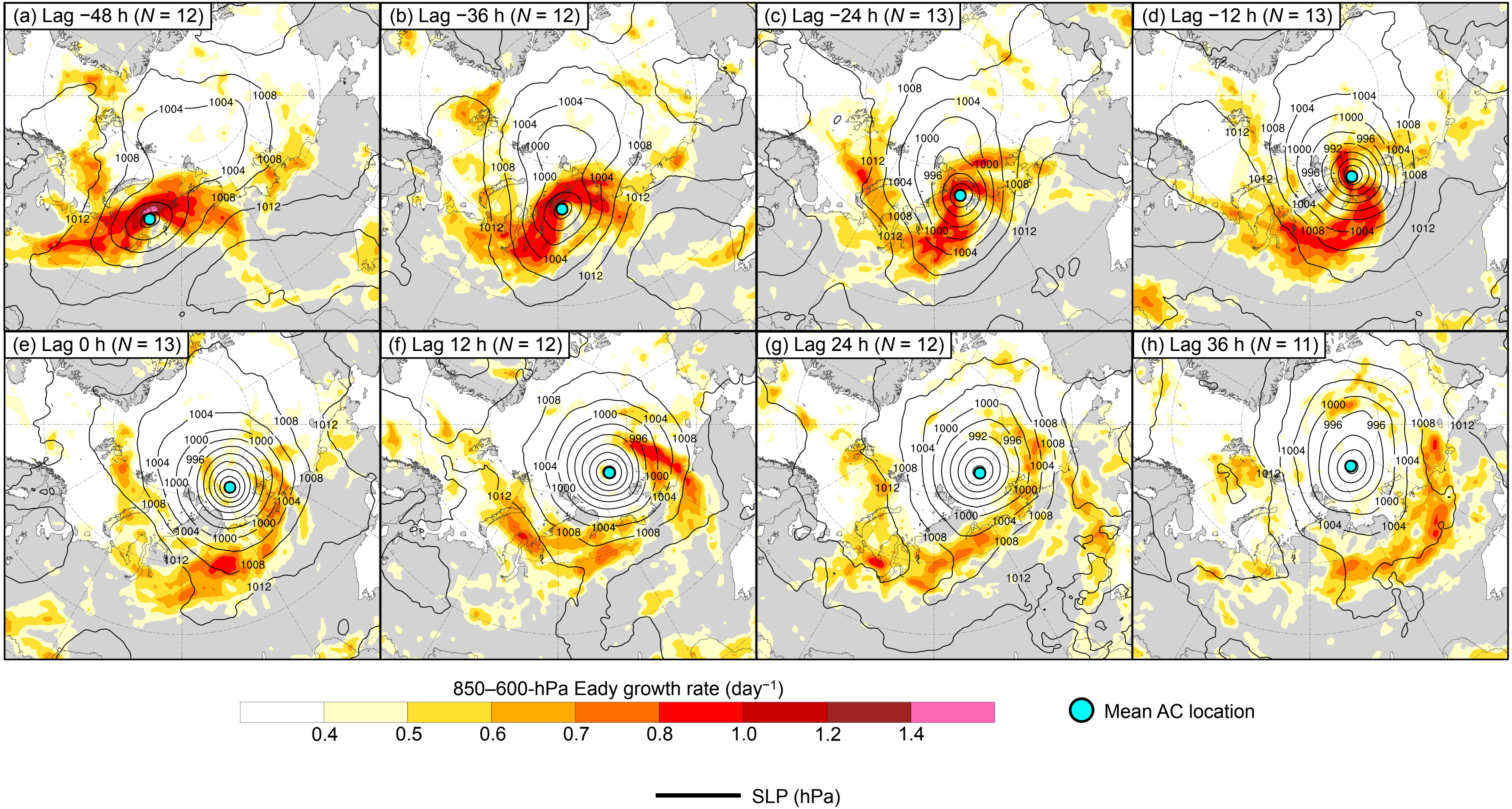
(g) Lag 24 h (N = 12)
(h) Lag 36 h (N = 11)
4 m s−1
200-km area-averaged 350–250-hPa divergence (10−6 s−1)
2 4 6 8 10 12 14 16
Mean AC location
350–250-hPa irrotational wind (m s−1)
350–250-hPa PV (PVU)
Negative values of 800–600-hPa ω (every 1 × 10−3 hPa s−1)



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(g) Lag 24 h (N = 12)
(h) Lag 36 h (N = 11)
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 composite AC intensifies downstream of an upper-tropospheric potential vorticity maximum 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 play important roles in the intensification of intense low-skill ACs.