Composite Analyses of Low-Skill Arctic Cyclones During Summer

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Overview

- 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.

- 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.

- **Purpose:** Examine various features and processes governing the evolution of ACs that are characterized by low forecast skill and that occur 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, 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.

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

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

- Select ACs occurring 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 120 h prior to the time of lowest SLP of the ACs when located in the Arctic during low-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 as low-skill ACs during low-skill periods

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°).

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°).

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

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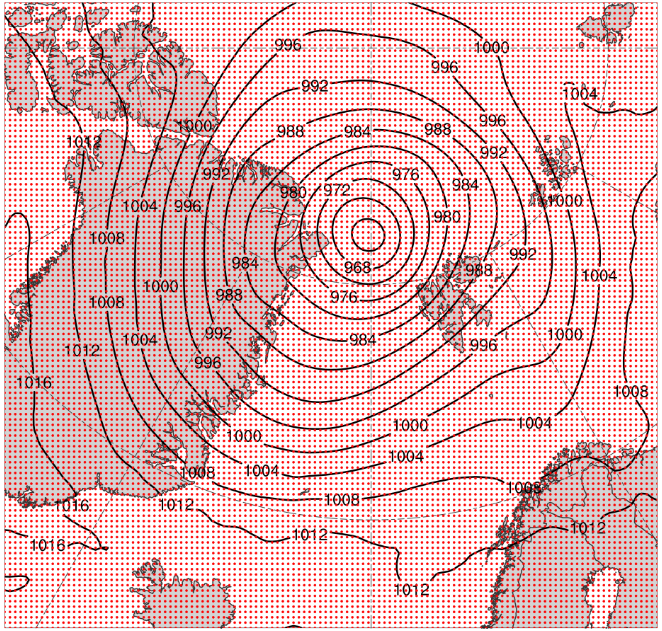

SLP (black) on 25 × 25 km EASE2 grid (grid points in red) valid 1200 UTC 6 Aug 2012

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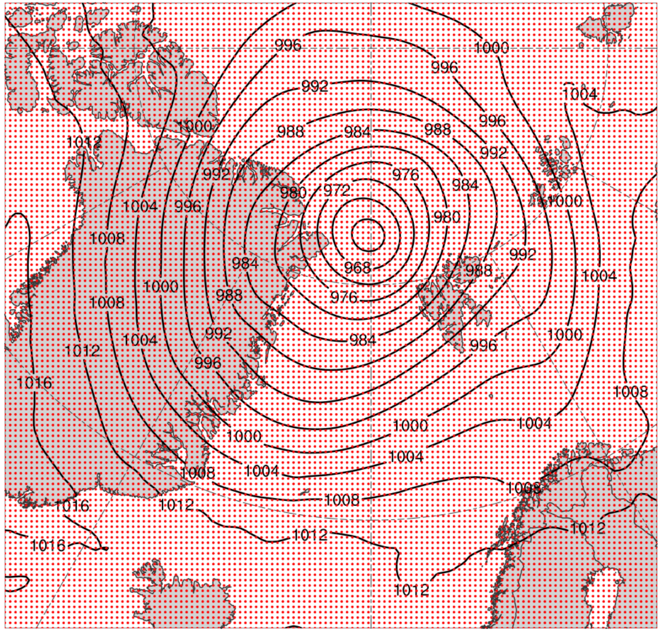
  - Shift projected grids to mean latitude of ACs.



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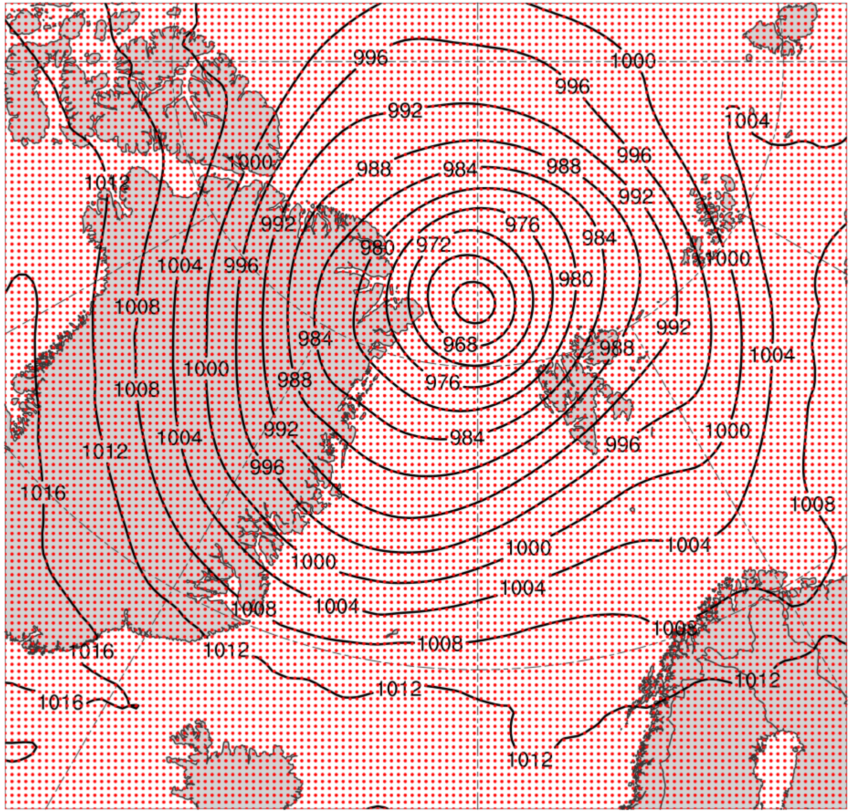
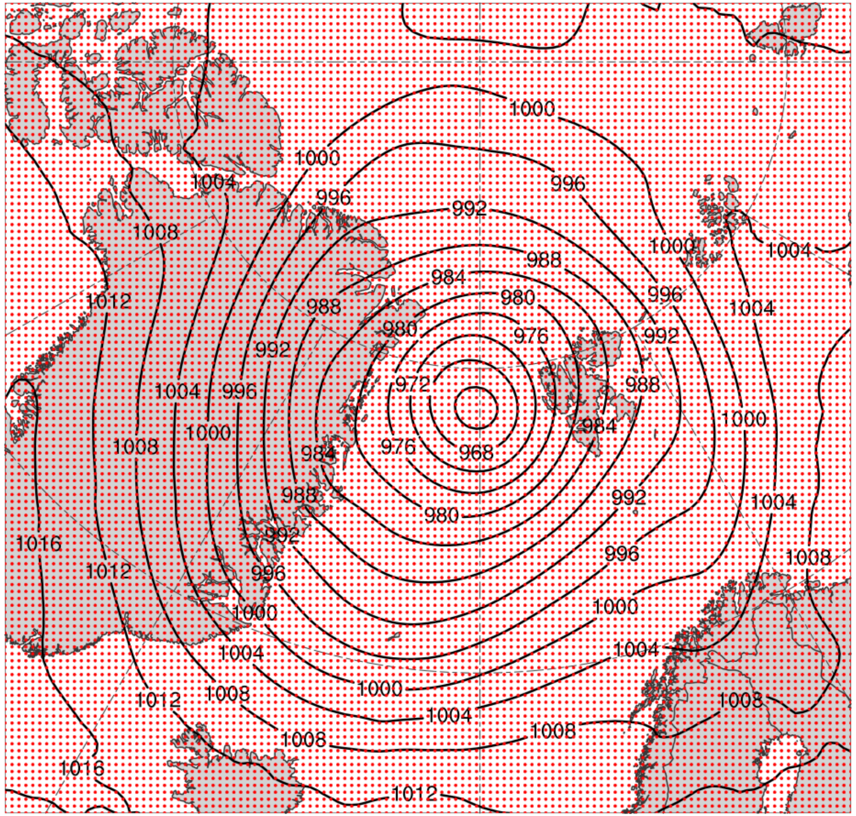
AC-centered composites

Grid before shifting to mean latitude



Grid after shifting to mean latitude



AC-centered composites

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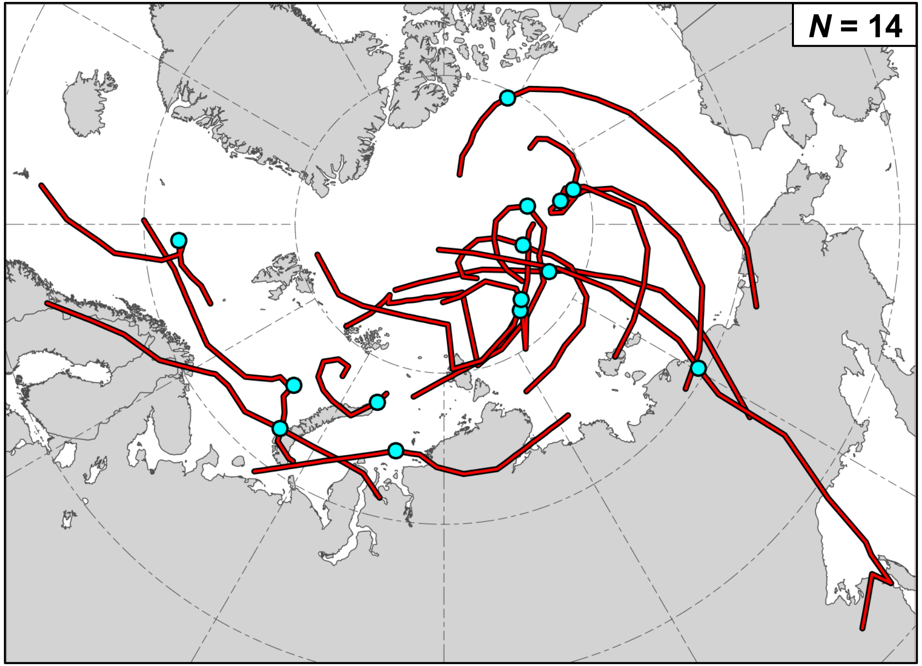
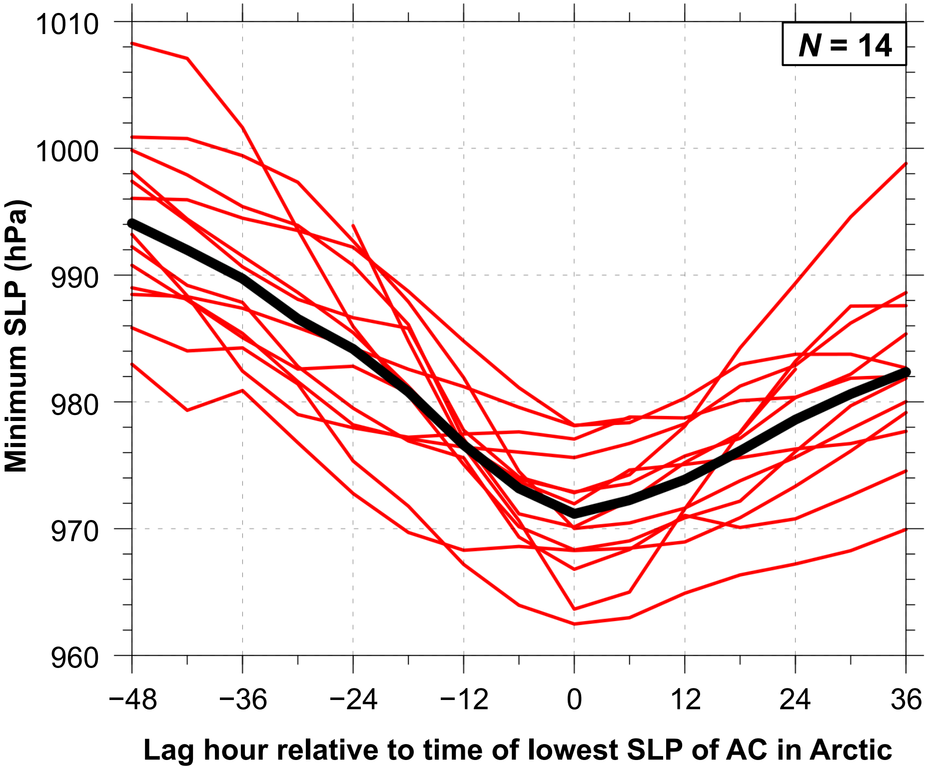
- For each lag time:
  - Determine mean latitude and longitude of ACs.
  - Rotate and project ERA5 grids to a 25 × 25 km Equal-Area Scalable Earth 2.0 (EASE2) grid such that the AC center lies on y-axis (0° longitude) of the EASE2 grid.
  - Shift projected grids to mean latitude of ACs.
  - Rotate shifted grids to mean longitude of ACs.

AC-centered composites

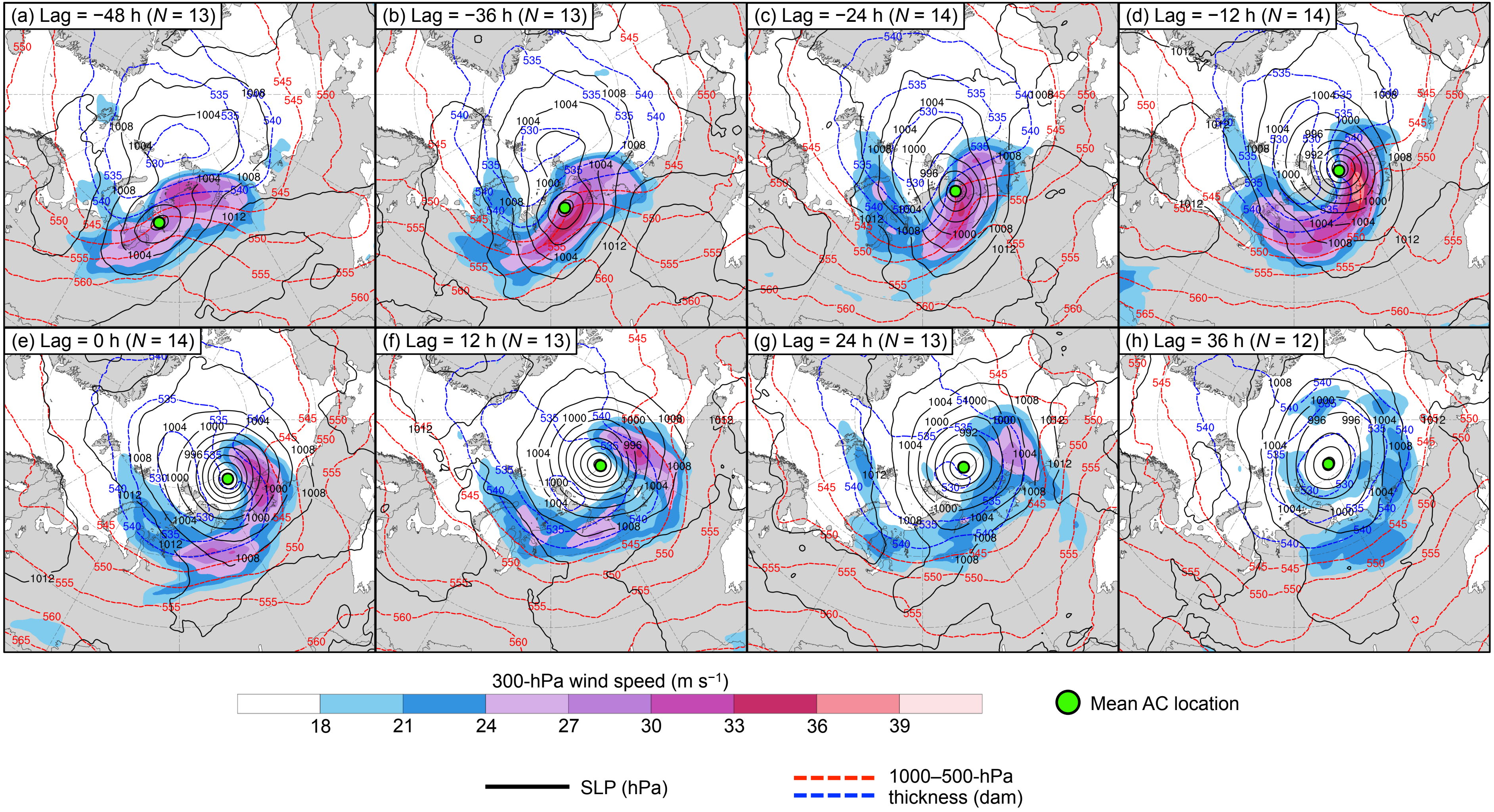


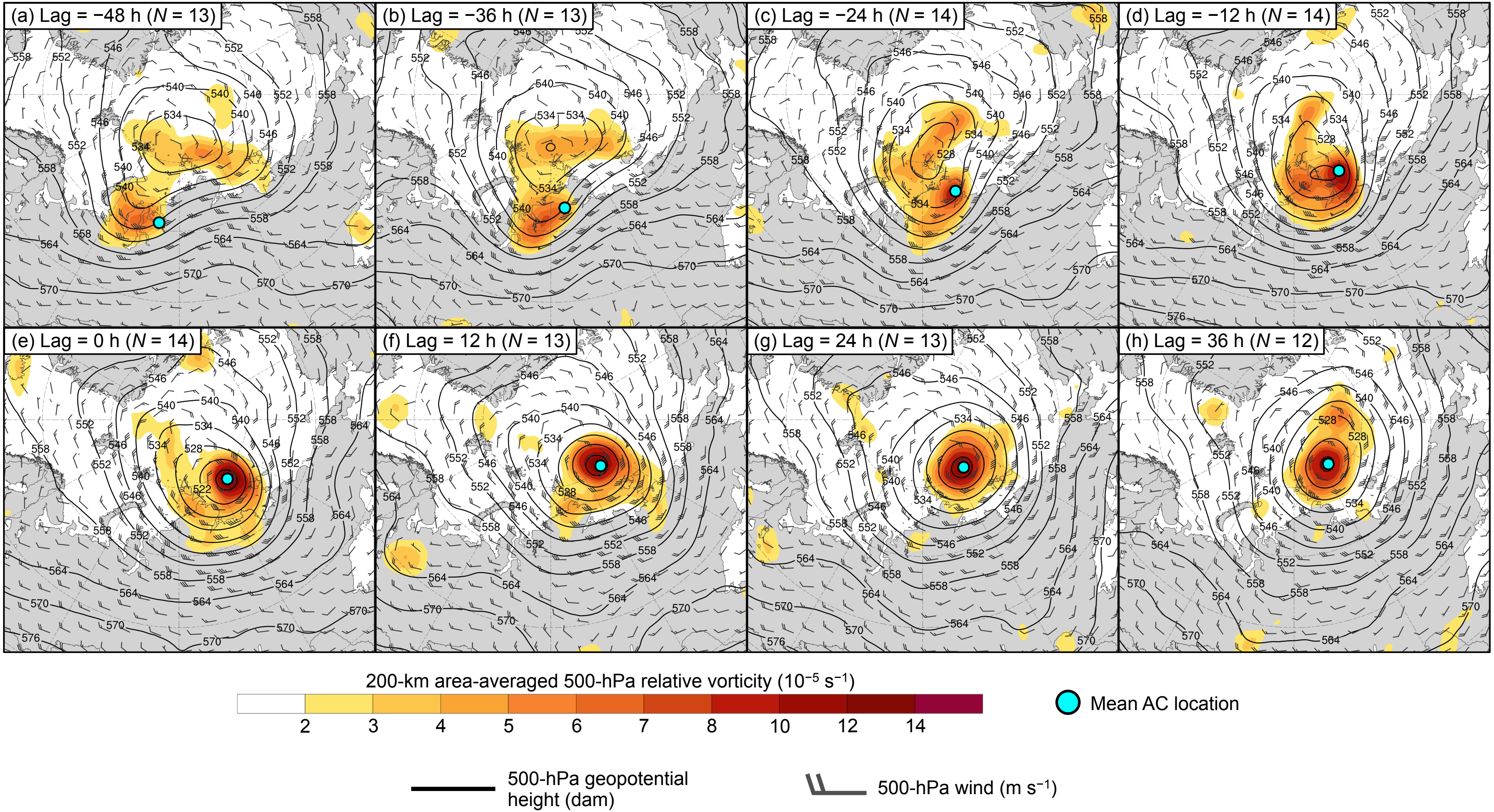
AC location at lag 0 h (time of lowest SLP of AC in Arctic)

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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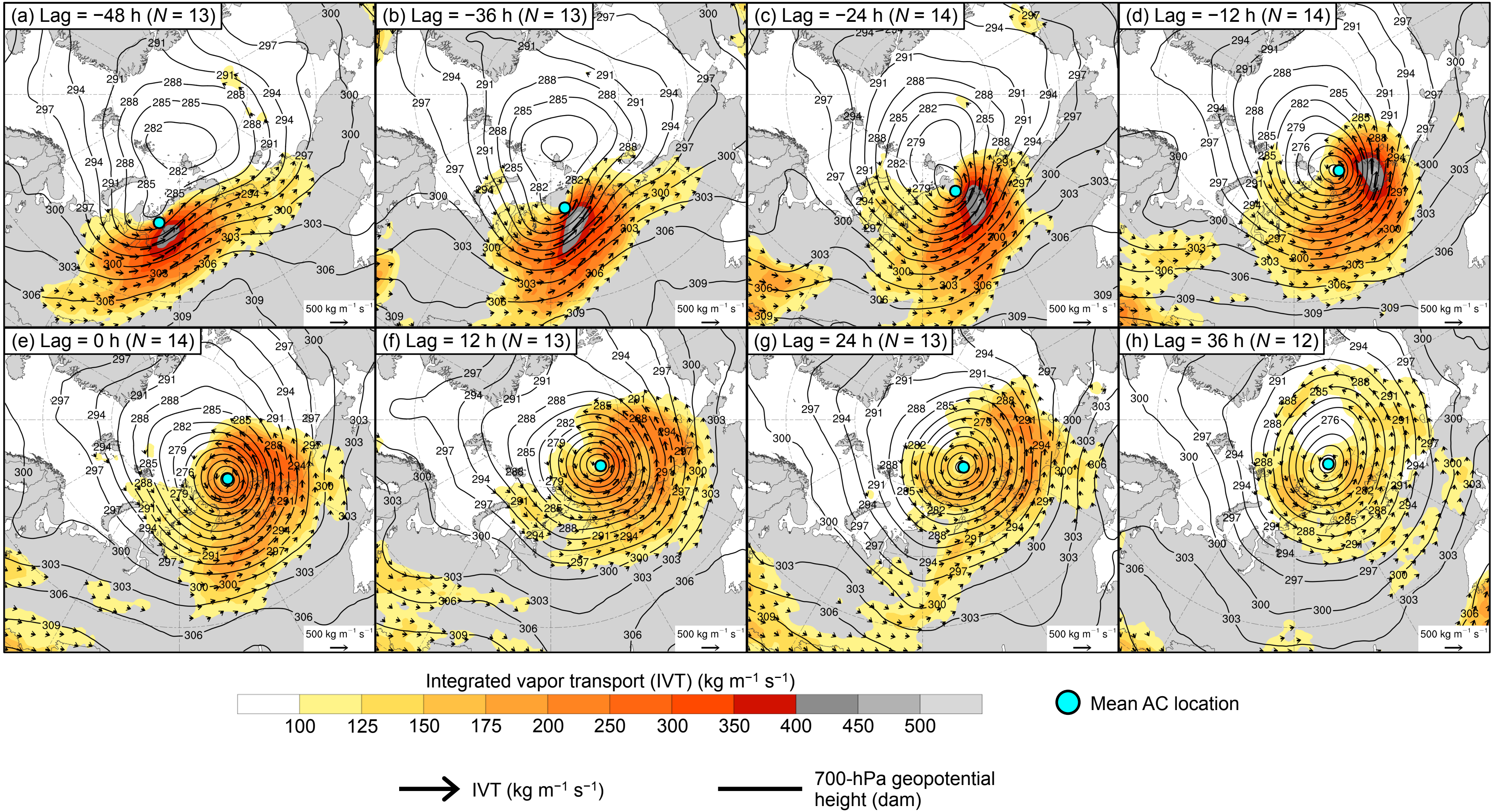
(h) Lag = 36 h (N = 12)
200-km area-averaged 500-hPa relative vorticity (10−5 s−1)
2 3 4 5 6 7 8 10 12 14
Mean AC location
500-hPa geopotential height (dam)
500-hPa wind (m s−1)



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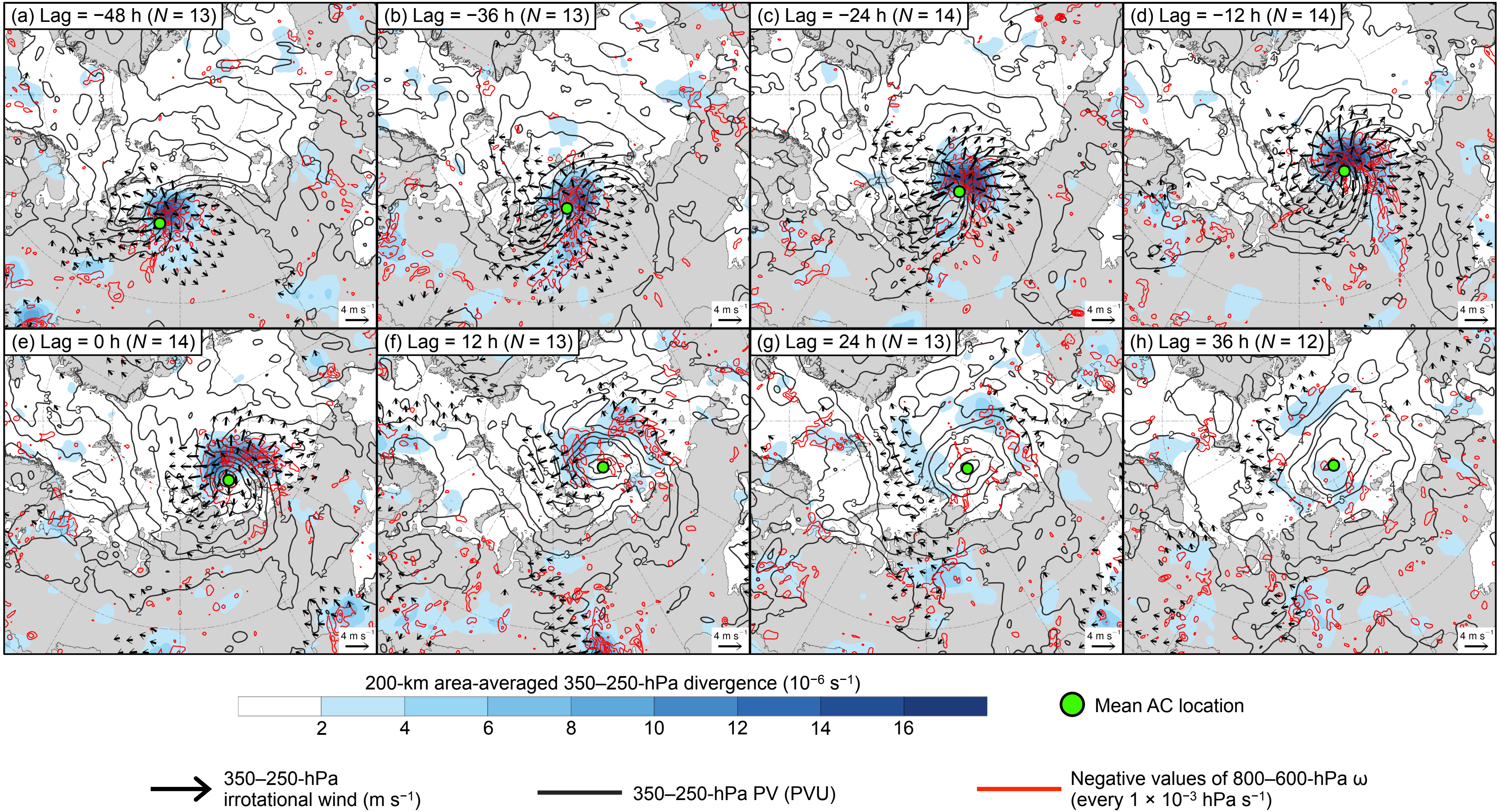
500 kg m−1 s−1
Integrated vapor transport (IVT) (kg m−1 s−1)
100 125 150 175 200 250 300 350 400 450 500
Mean AC location
IVT (kg m−1 s−1)
700-hPa geopotential height (dam)



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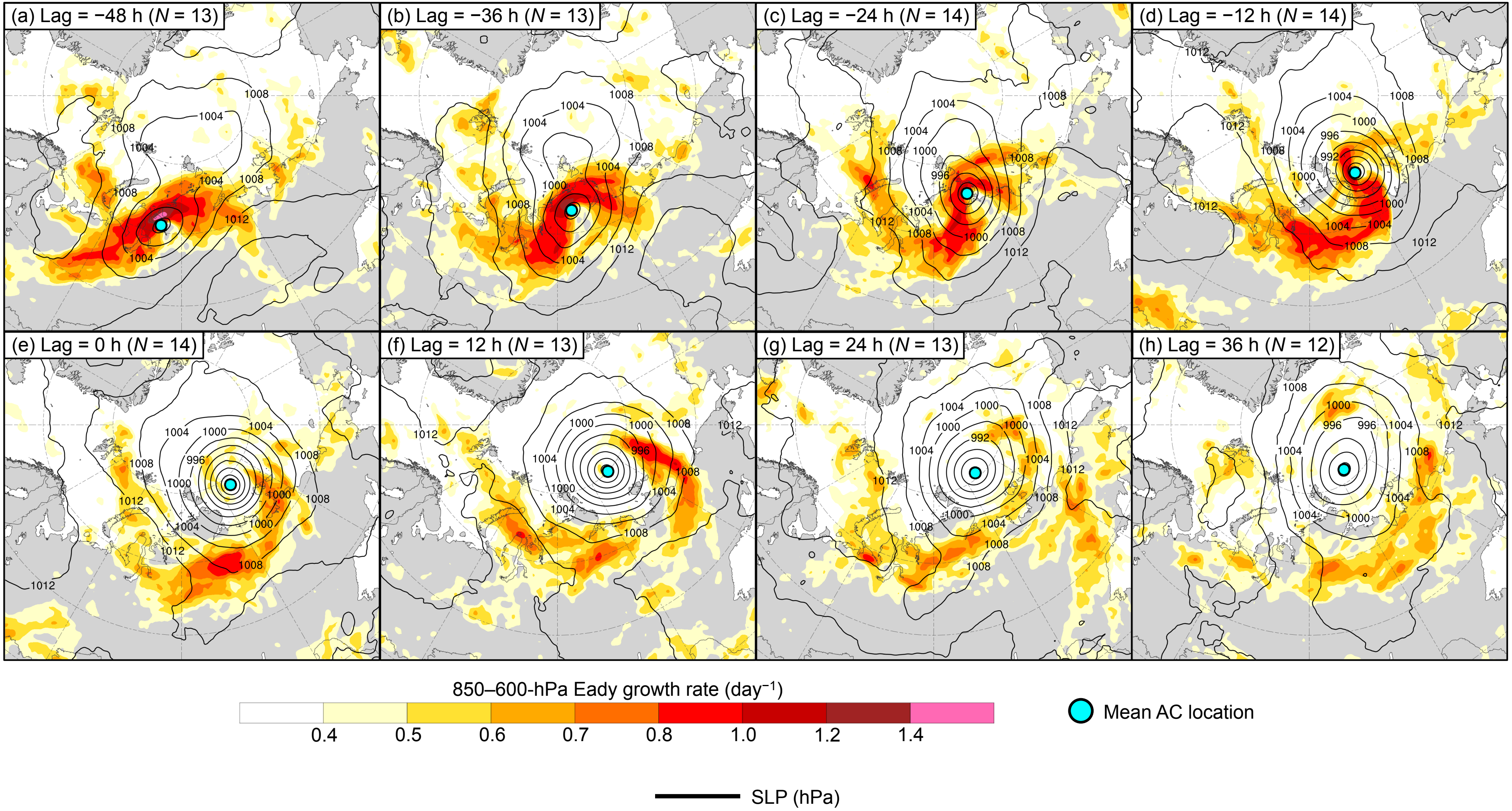
4 m s−1
200-km area-averaged 350–250-hPa divergence (10−6 s−1)
2
4
6
8
10
12
14
16
Mean AC location
350–250-hPa irrotational wind (m s−1)
350–250-hPa PV (PVU)
Negative values of 800–600-hPa ω (every 1 × 10−3 hPa s−1)



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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)

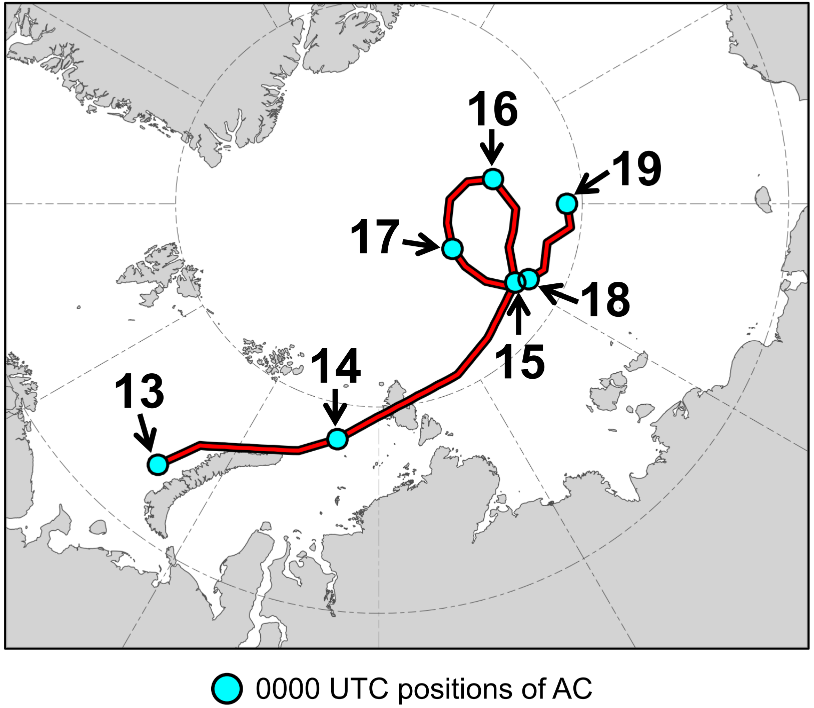
Summary

- 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.

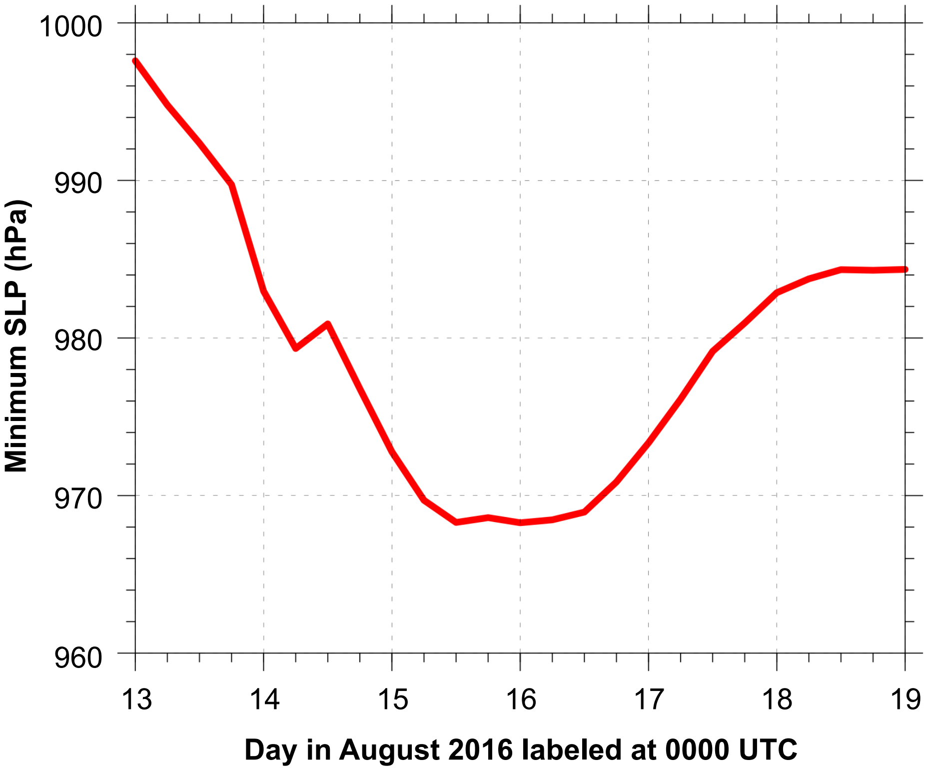
- A combination of baroclinic processes and latent heating likely plays important roles in the intensification of intense low-skill ACs during low-skill periods.

Extra Slides

Example AC in Composite (AC during 13–19 Aug 2016)

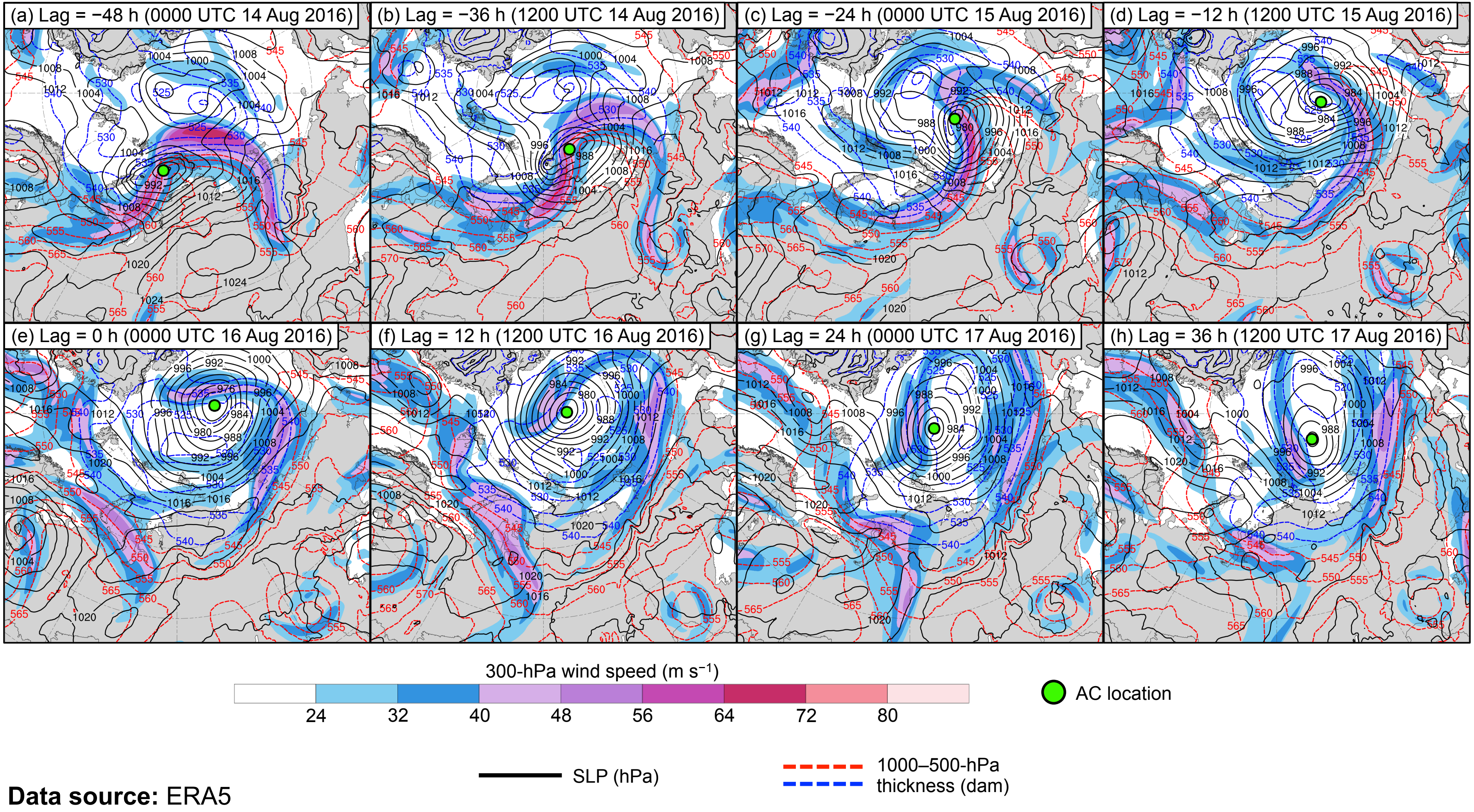


Red line shows track of AC during 13–19 Aug 2016.
Numbers represent dates of 0000 UTC positions of AC.



Time series of minimum SLP (hPa) of AC during 13–19 Aug 2016.

Data source: ERA5


(a) Lag = −48 h (0000 UTC 14 Aug 2016)
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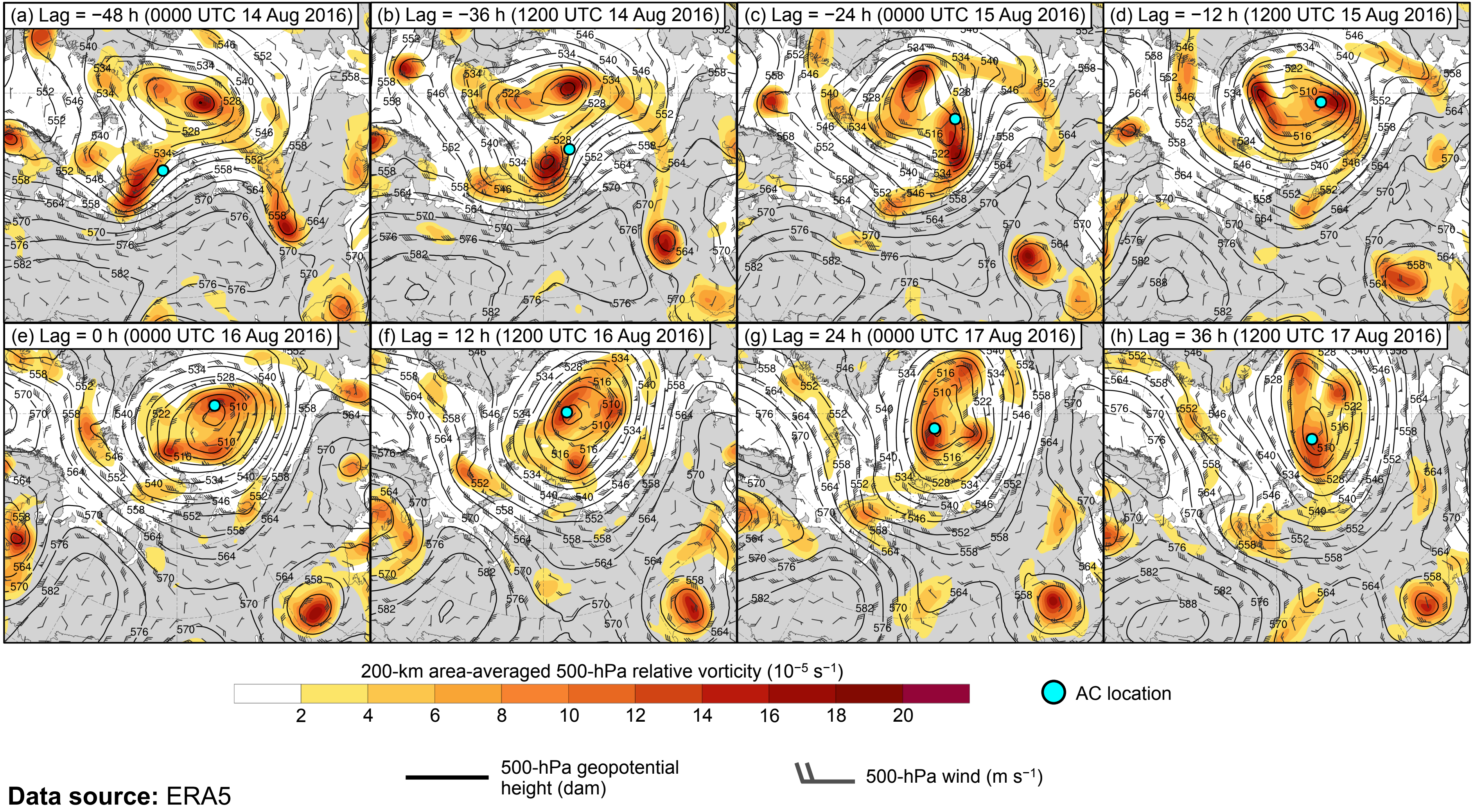
(f) Lag = 12 h (1200 UTC 16 Aug 2016)
(g) Lag = 24 h (0000 UTC 17 Aug 2016)
(h) Lag = 36 h (1200 UTC 17 Aug 2016)
300-hPa wind speed (m s⁻¹)
24 32 40 48 56 64 72 80
AC location
SLP (hPa)
1000–500-hPa thickness (dam)
Data source: ERA5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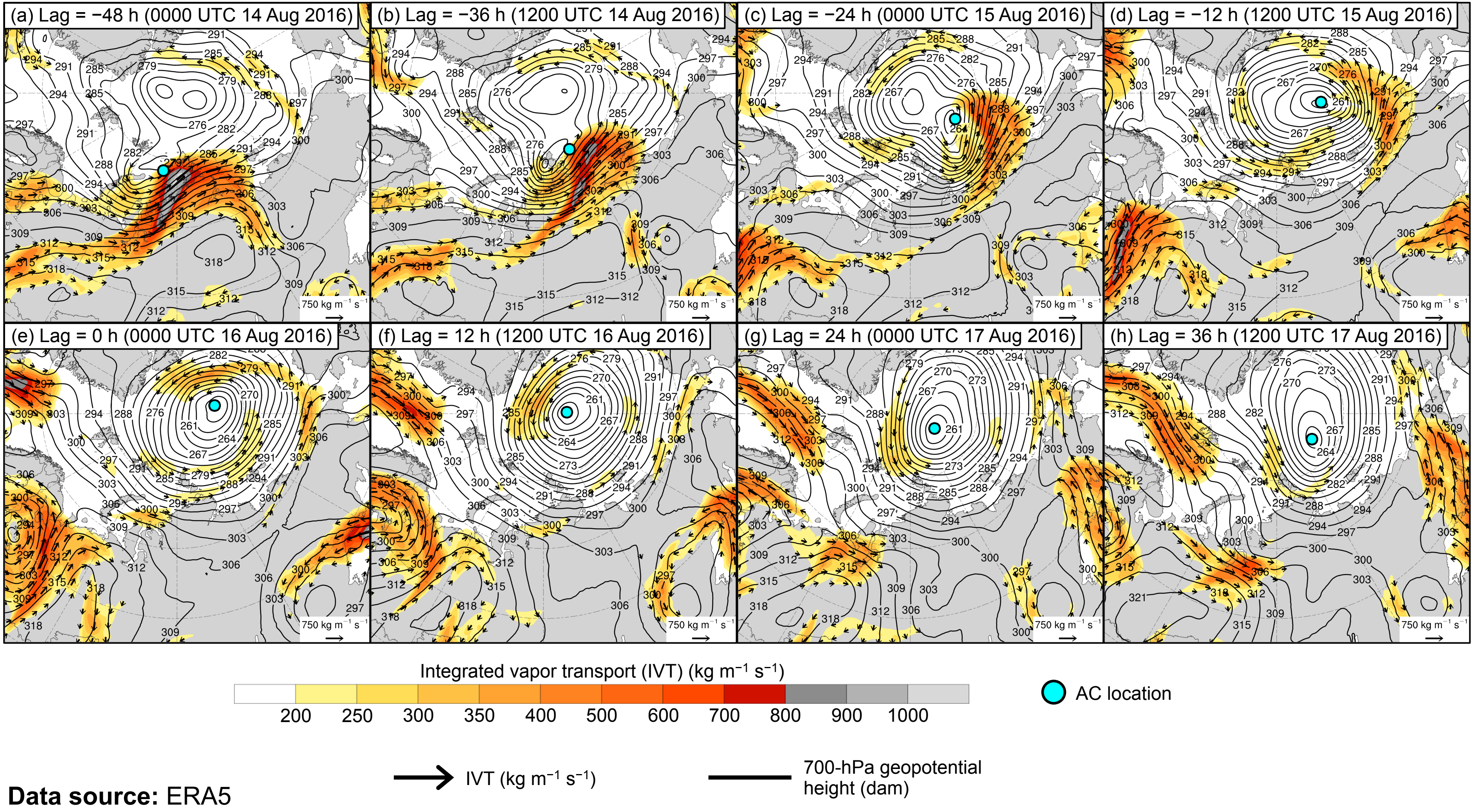
200-km area-averaged 500-hPa relative vorticity (10^{-5} s^{-1})
2 4 6 8 10 12 14 16 18 20
AC location
500-hPa geopotential height (dam)
500-hPa wind (m s^{-1})
Data source: ERA5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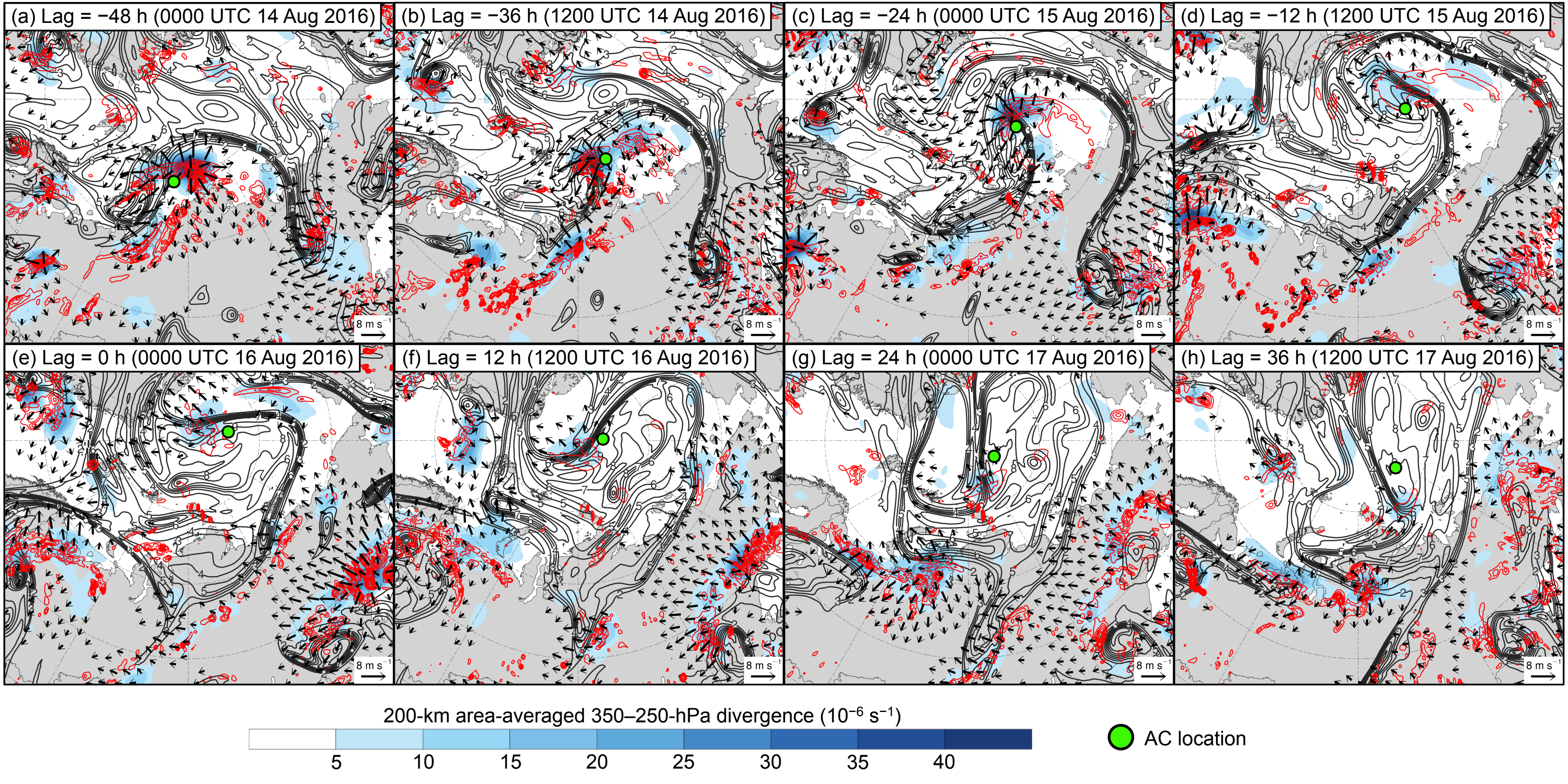
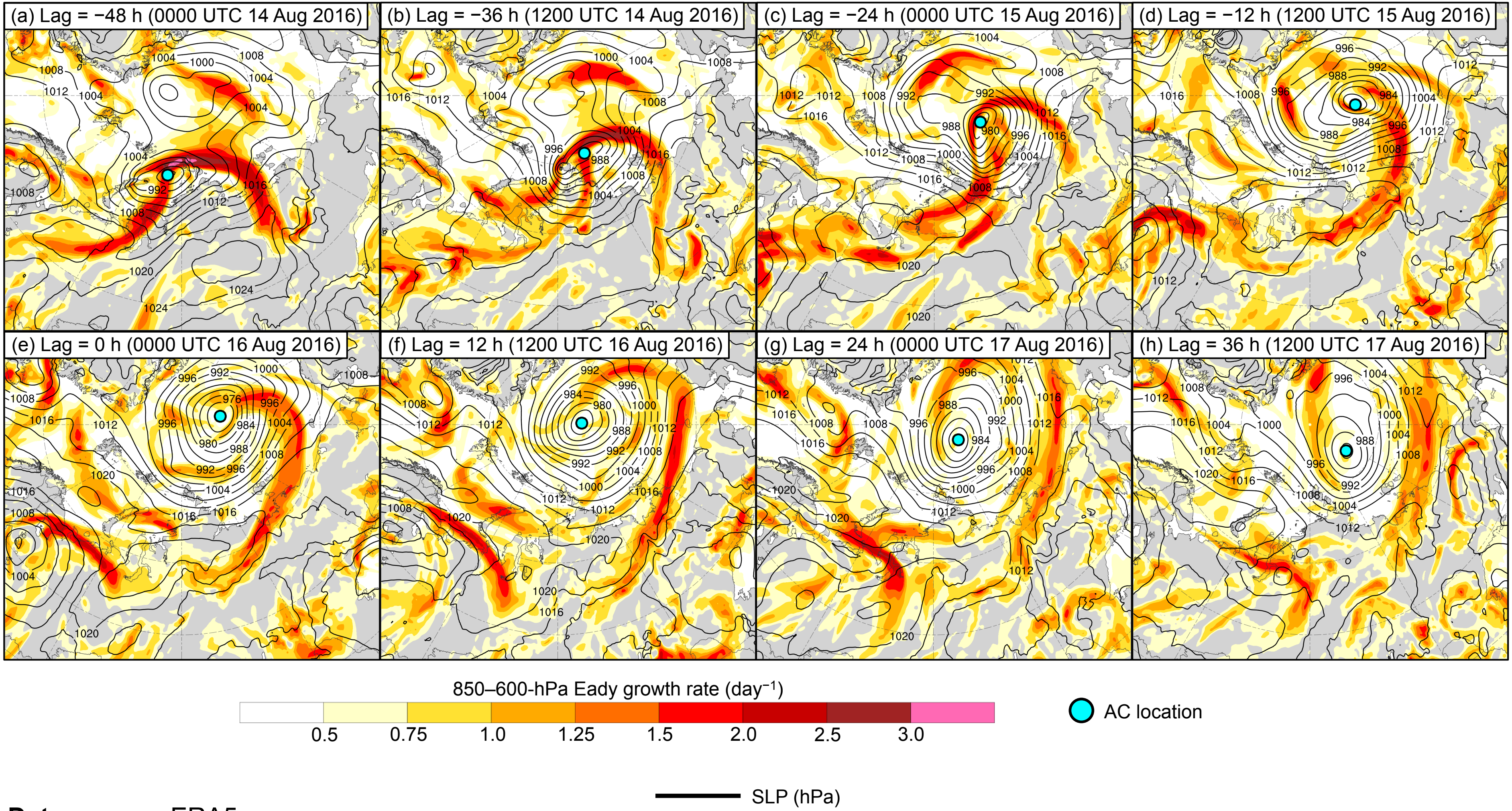
(h) Lag = 36 h (1200 UTC 17 Aug 2016)
750 kg m⁻¹ s⁻¹
Integrated vapor transport (IVT) (kg m⁻¹ s⁻¹)
200 250 300 350 400 500 600 700 800 900 1000
AC location
IVT (kg m⁻¹ s⁻¹)
700-hPa geopotential height (dam)
Data source: ERA5



Data source: ERA5



Data source: ERA5