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.

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

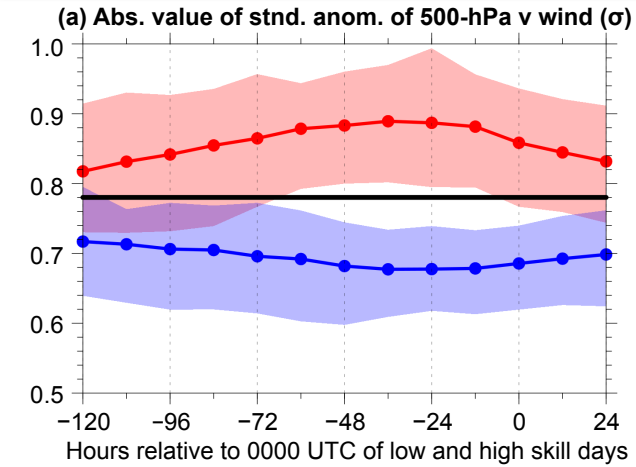
Arctic forecast skill evaluation

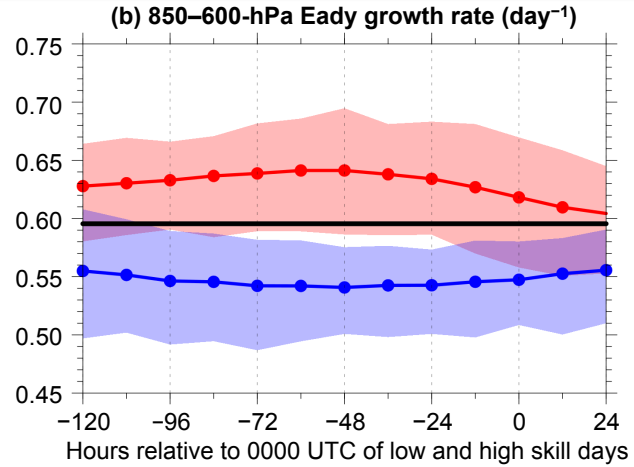
- Refer to forecast days valid at day 5 associated with the top and bottom 10% of σ_{RMSE} as **low-skill days and high-skill days**, respectively.

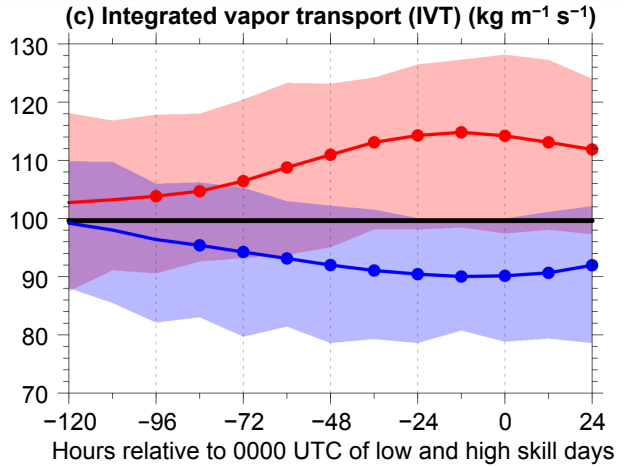
- Refer to forecasts initialized 5 days prior to low-skill days and high-skill days as **low-skill forecasts and high-skill forecasts**, respectively.

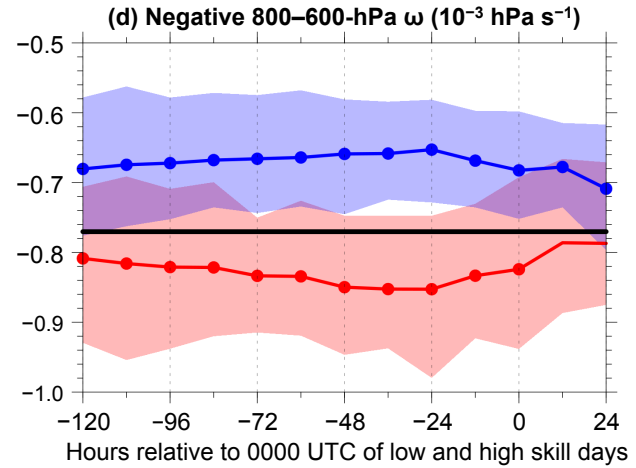
- Refer to time periods through day 5 encompassed by low-skill forecasts and high-skill forecasts as **low-skill periods and high-skill periods**, respectively.

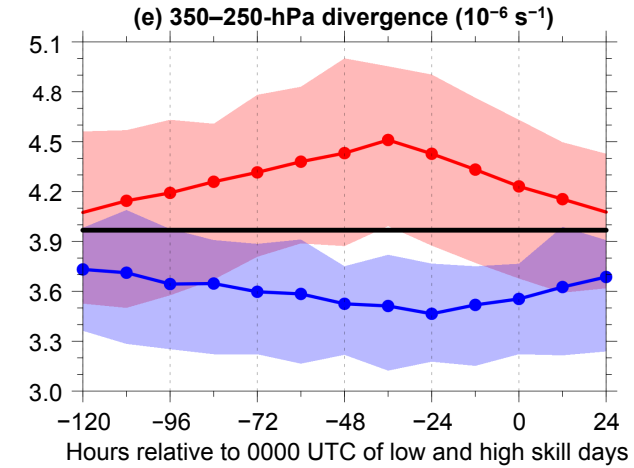
Quantities characterizing the Arctic environment











Legend

Distribution of quantities area-averaged over the Arctic (≥ 70°N)

- Low-skill mean
- High-skill mean
- 2007–2017 climo mean

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

Shading: Interquartile range

Data: 1° ERA-Interim

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

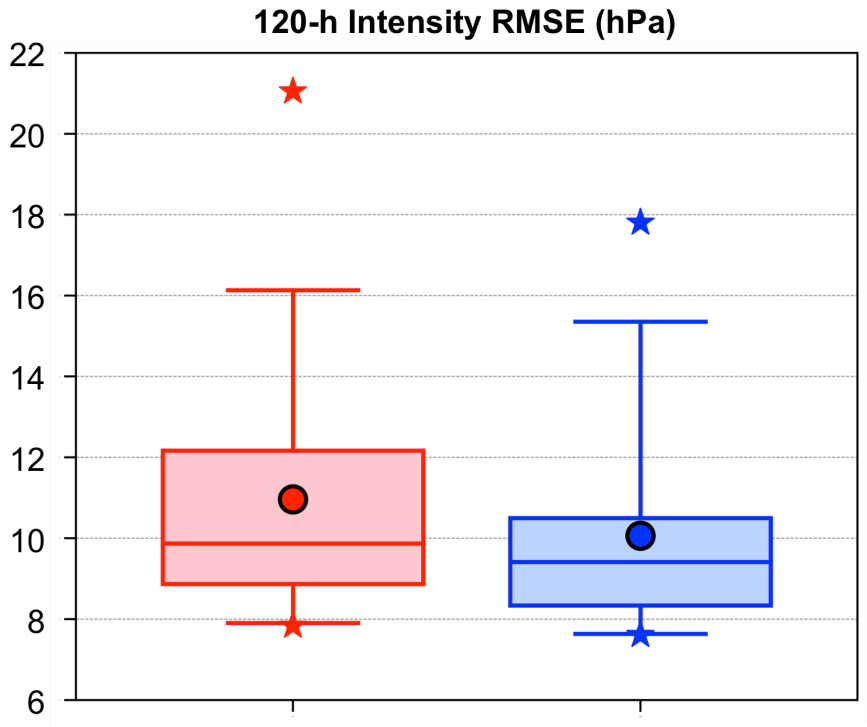
- Track ACs in forecasts from GEFS reforecast dataset v2 by utilizing an objective sea level pressure (SLP)-based tracking algorithm (Crawford et al. 2020).

- 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



Legend

95%
75%
median
25%
5%

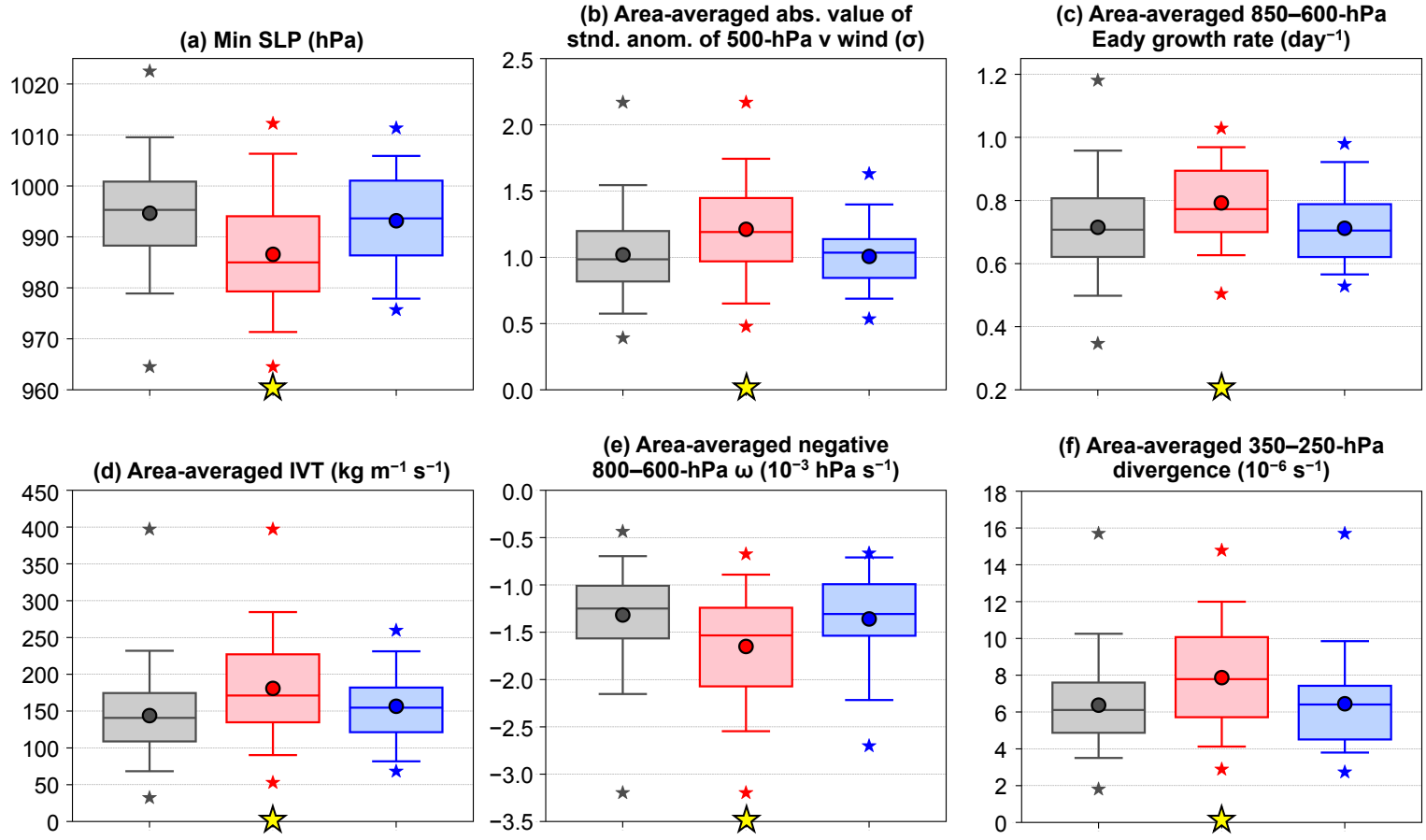
mean

min and max

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

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

Quantities characterizing low-skill ACs



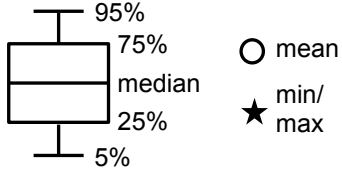
Legend

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)



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°).

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.

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.

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

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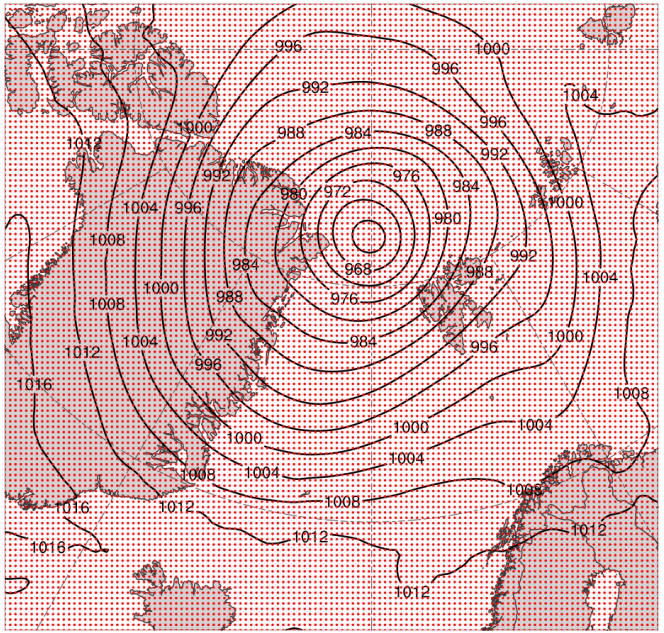

SLP (black) on 25 × 25 km EASE2 grid (grid points in red) valid 1200 UTC 6 Aug 2012

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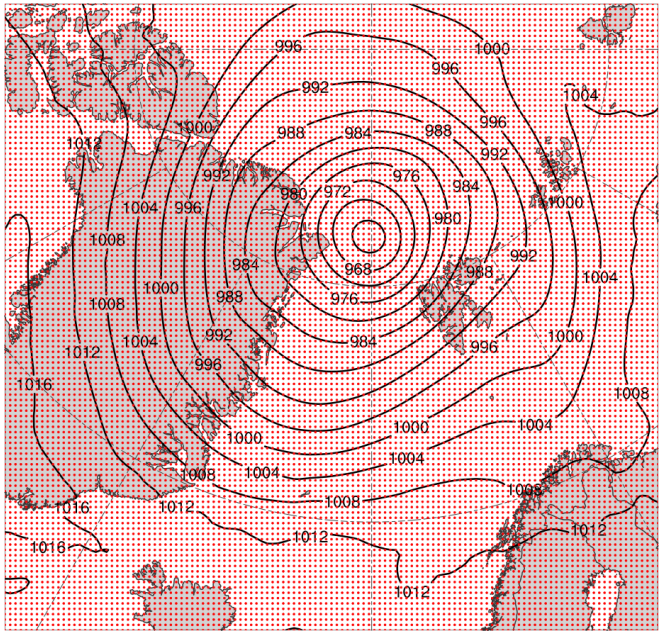
- For each lag time:
  - Determine mean latitude and longitude of ACs.
  - Rotate and project ERA5 grids to a 25 × 25 km Equal-Area Scalable Earth 2.0 (EASE2) grid such that the AC center lies on y-axis (0° longitude) of the EASE2 grid.
  - Shift projected grids to mean latitude of ACs.



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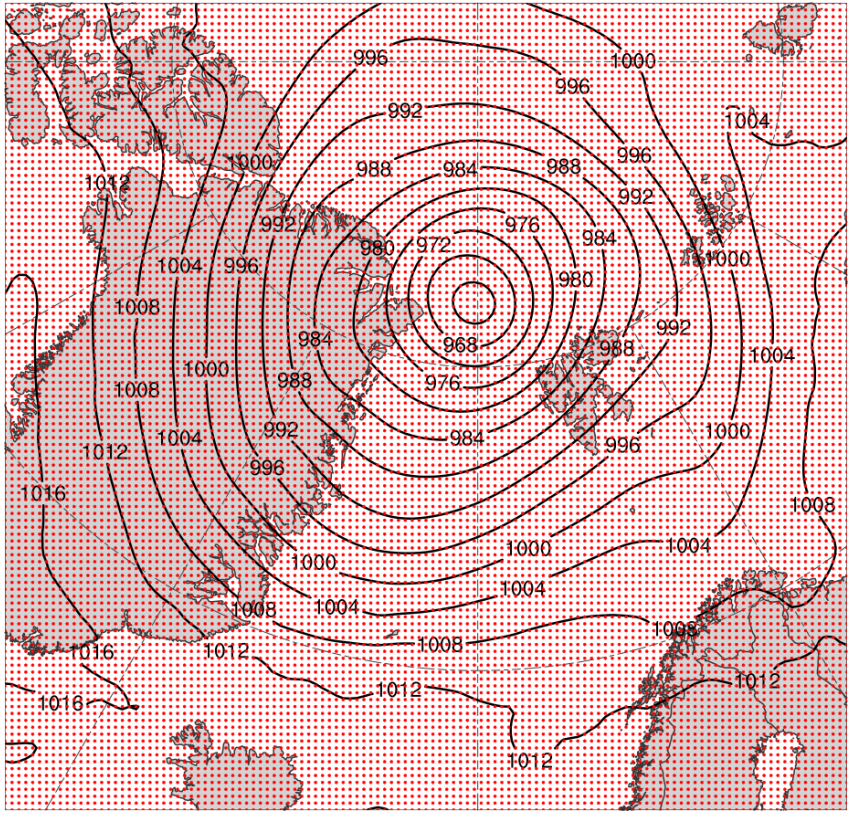
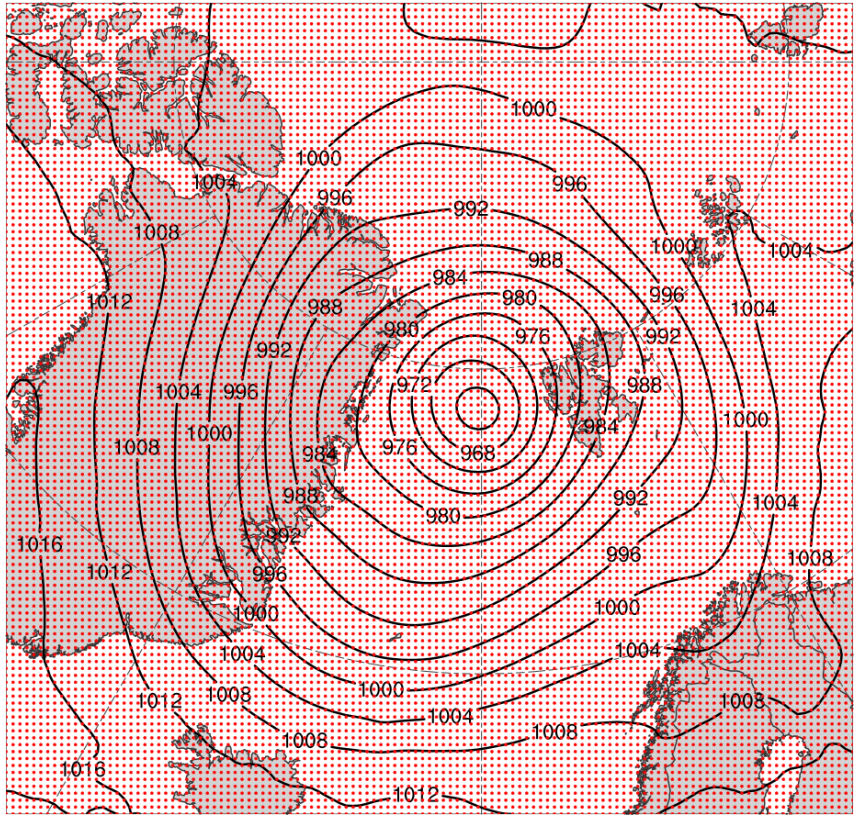
AC-centered composites

Grid before shifting to mean latitude



Grid after shifting to mean latitude

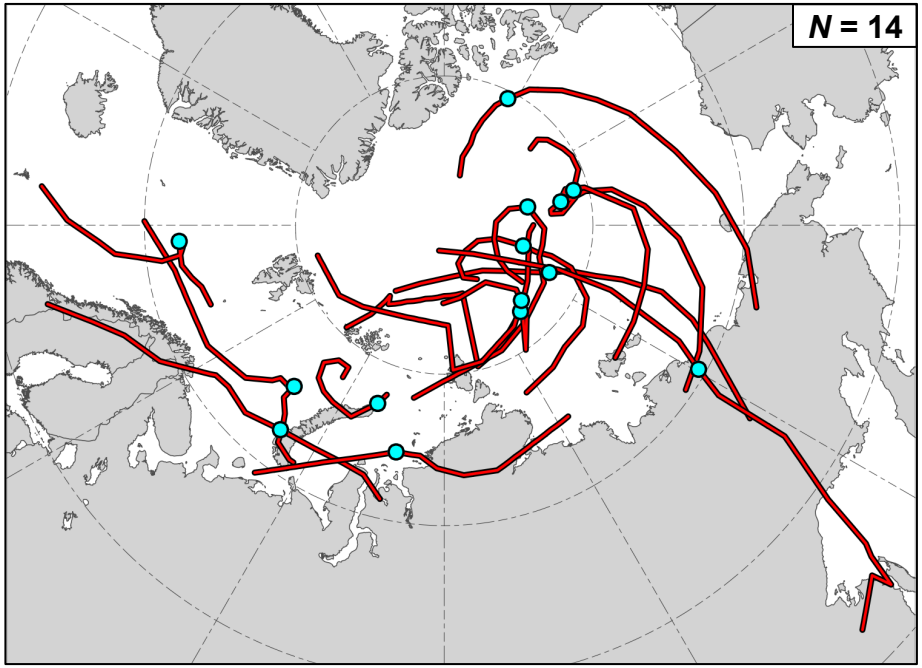


AC-centered composites

- 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°).

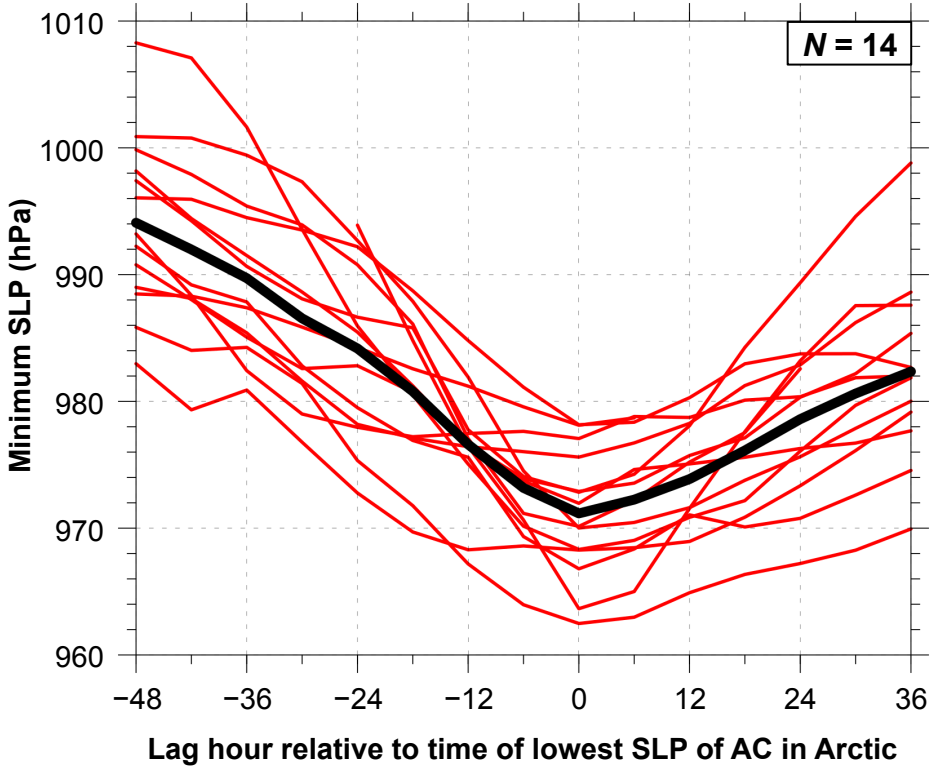
- For each lag time:
  - Determine mean latitude and longitude of ACs.
  - Rotate and project ERA5 grids to a 25 × 25 km Equal-Area Scalable Earth 2.0 (EASE2) grid such that the AC center lies on y-axis (0° longitude) of the EASE2 grid.
  - Shift projected grids to mean latitude of ACs.
  - Rotate shifted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

AC-centered composites

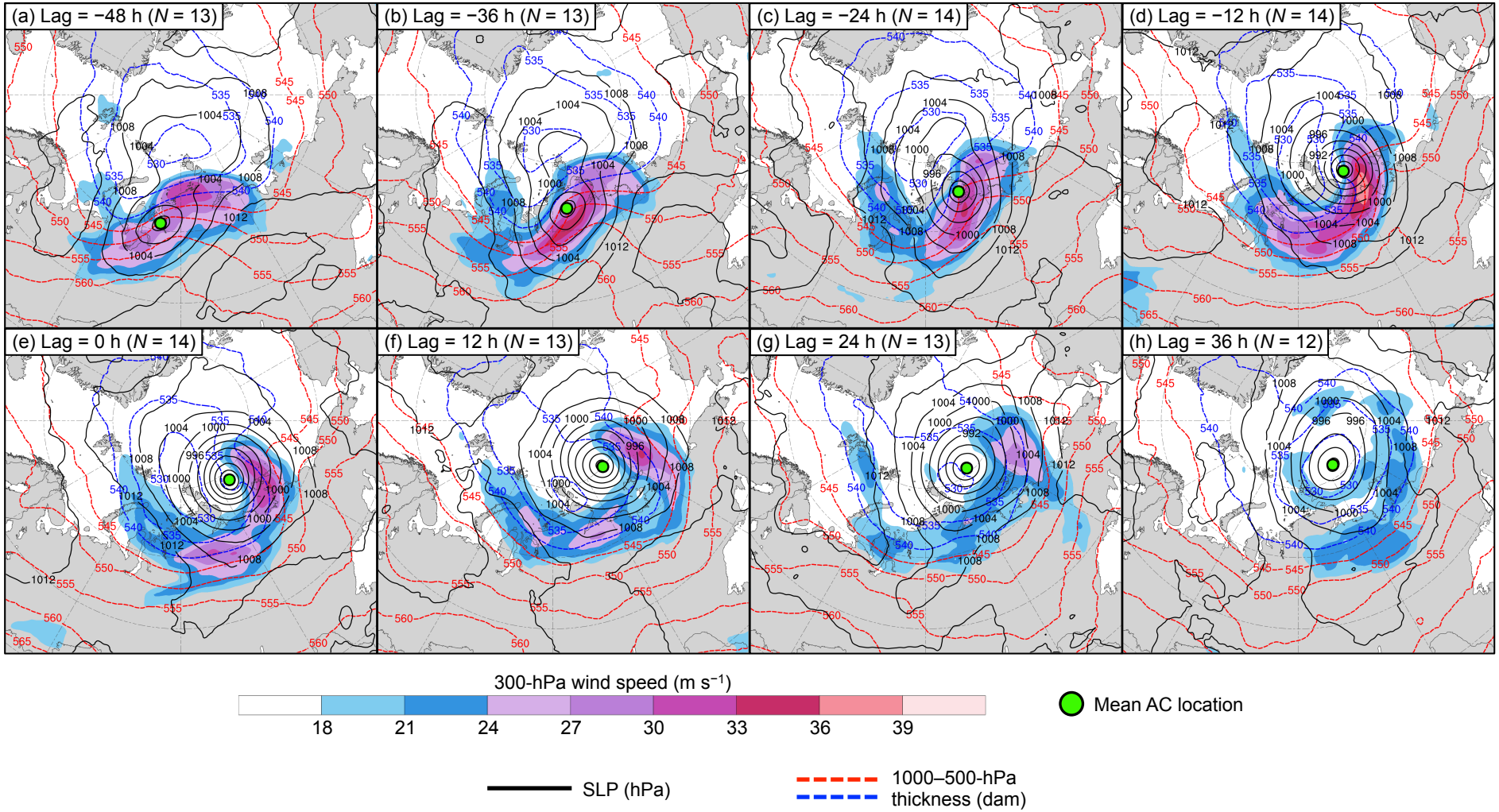


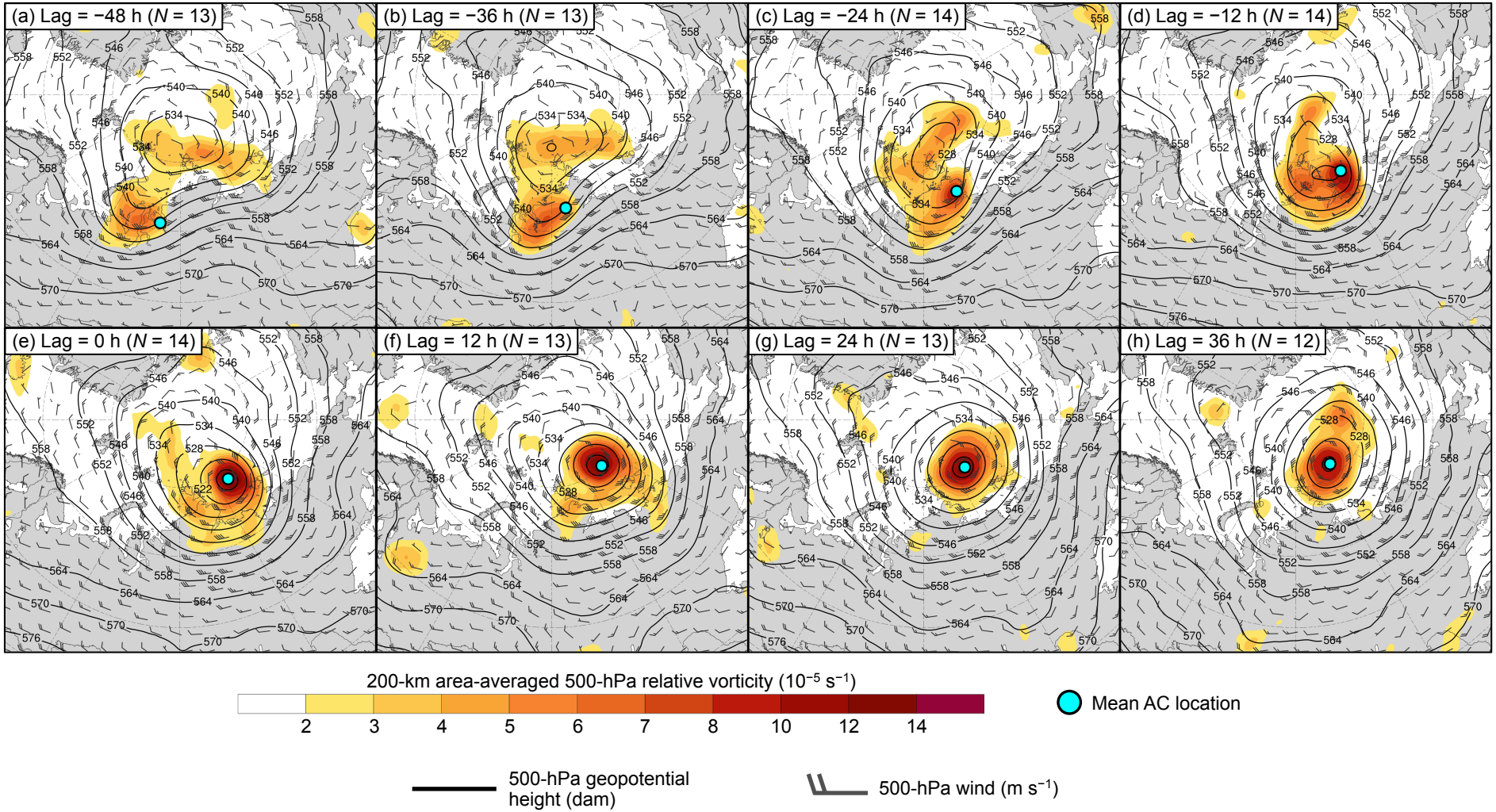
AC location at lag 0 h (time of lowest SLP of AC in Arctic)

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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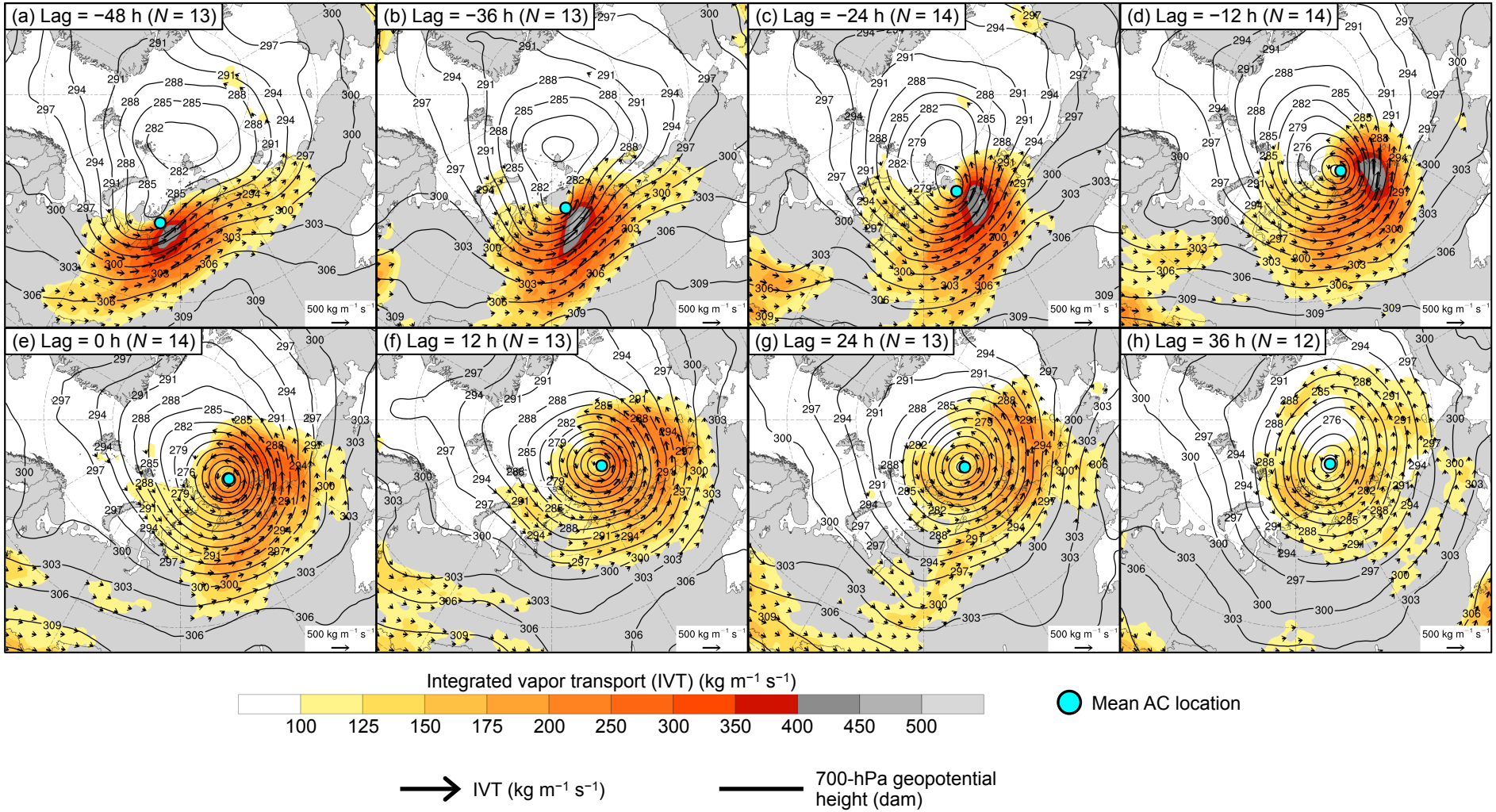
(f) Lag = 12 h (N = 13)
(g) Lag = 24 h (N = 13)
(h) Lag = 36 h (N = 12)
200-km area-averaged 500-hPa relative vorticity (10⁻⁵ s⁻¹)
2
3
4
5
6
7
8
10
12
14
Mean AC location
500-hPa geopotential height (dam)
500-hPa wind (m s⁻¹)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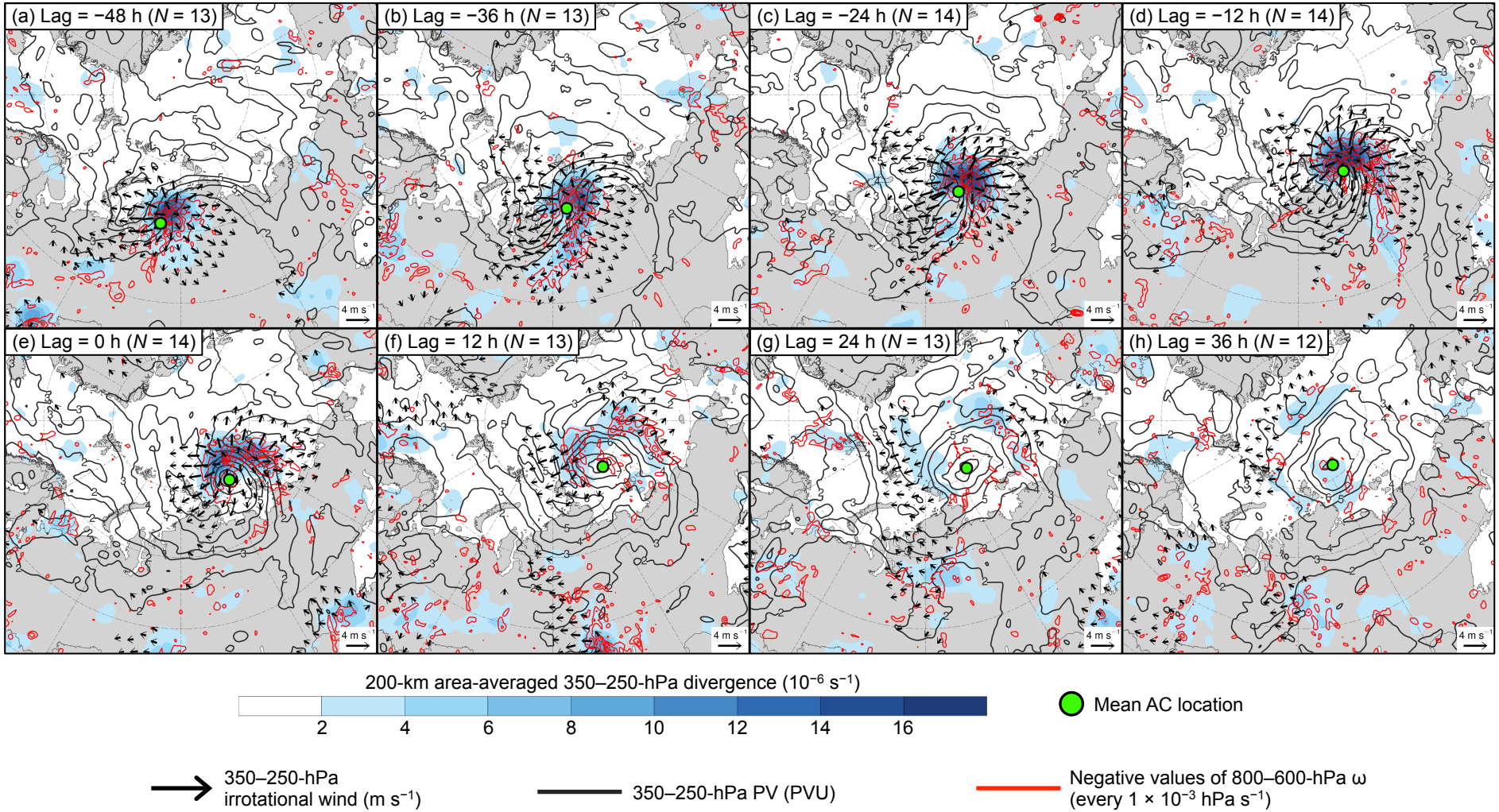
(f) Lag = 12 h (N = 13)
(g) Lag = 24 h (N = 13)
(h) Lag = 36 h (N = 12)
500 kg m⁻¹ s⁻¹
Integrated vapor transport (IVT) (kg m⁻¹ s⁻¹)
100 125 150 175 200 250 300 350 400 450 500
Mean AC location
IVT (kg m⁻¹ s⁻¹)
700-hPa geopotential height (dam)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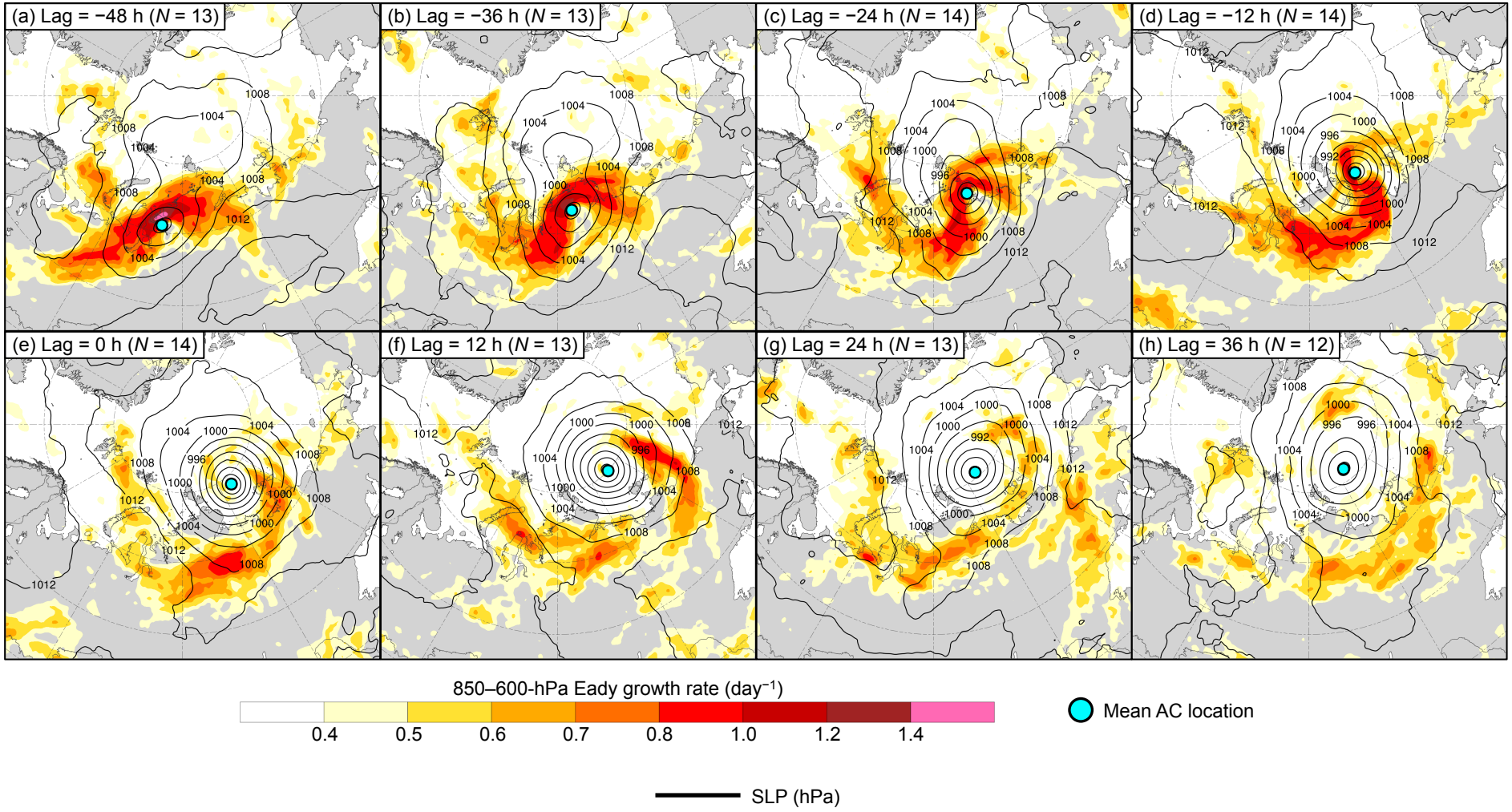
(g) Lag = 24 h (N = 13)
(h) Lag = 36 h (N = 12)
4 m s⁻¹
200-km area-averaged 350–250-hPa divergence (10⁻⁶ s⁻¹)
2
4
6
8
10
12
14
16
Mean AC location
350–250-hPa irrotational wind (m s⁻¹)
350–250-hPa PV (PVU)
Negative values of 800–600-hPa ω (every 1 × 10⁻³ hPa s⁻¹)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(f) Lag = 12 h (N = 13)
(g) Lag = 24 h (N = 13)
(h) Lag = 36 h (N = 12)
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 rates, and potentially greater latent heating during low-skill periods compared to high-skill periods.

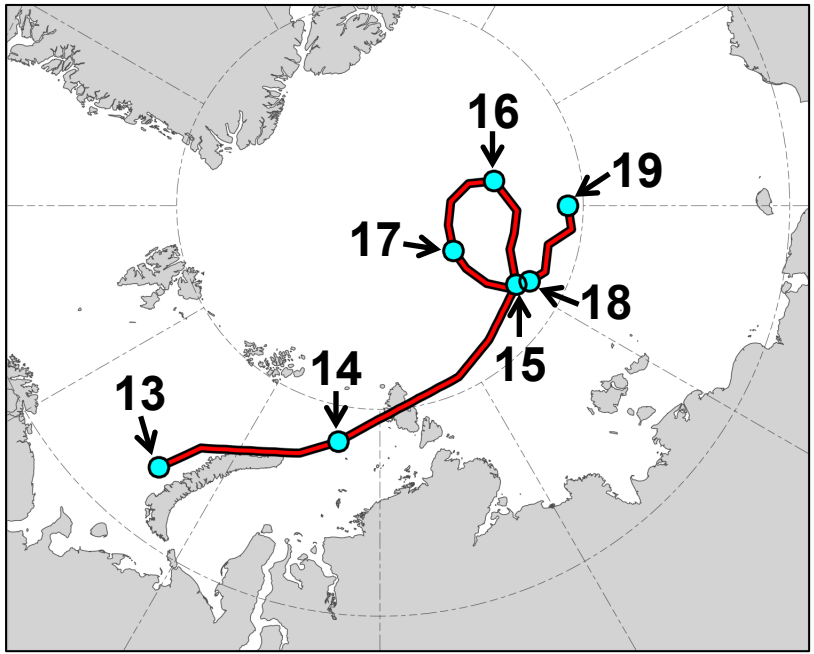
- Low-skill ACs tend to be stronger and embedded in a region of more amplified synoptic-scale flow, greater baroclinic growth rates, and potentially greater latent heating during low-skill periods compared to high-skill periods.

- 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 plays important roles in the intensification of intense low-skill ACs during low-skill periods.

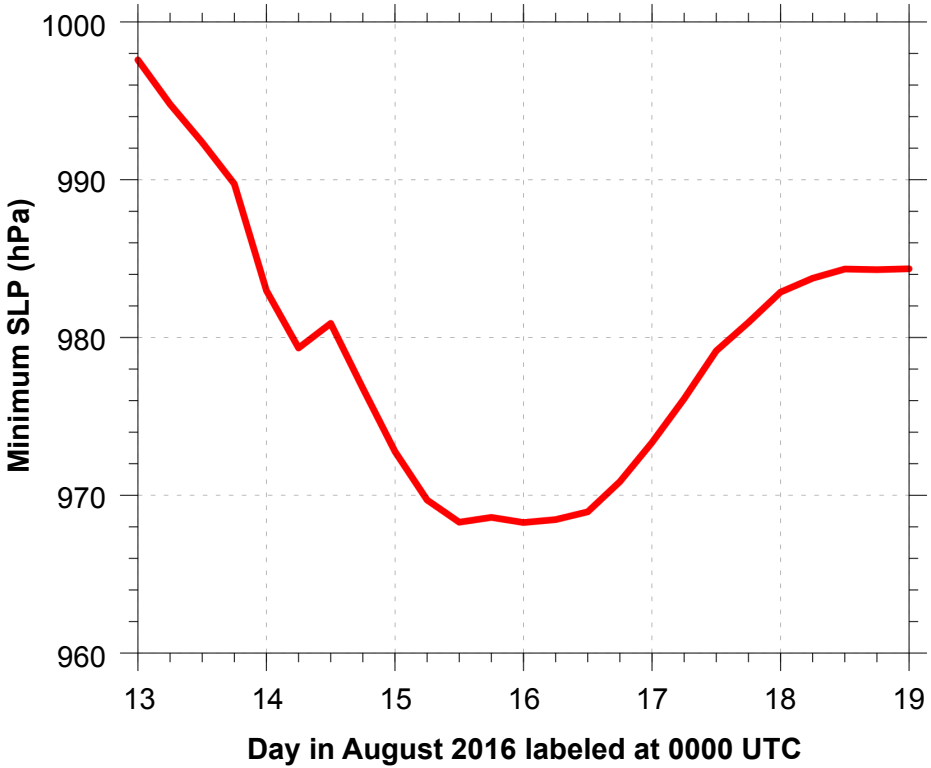
Extra Slides

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



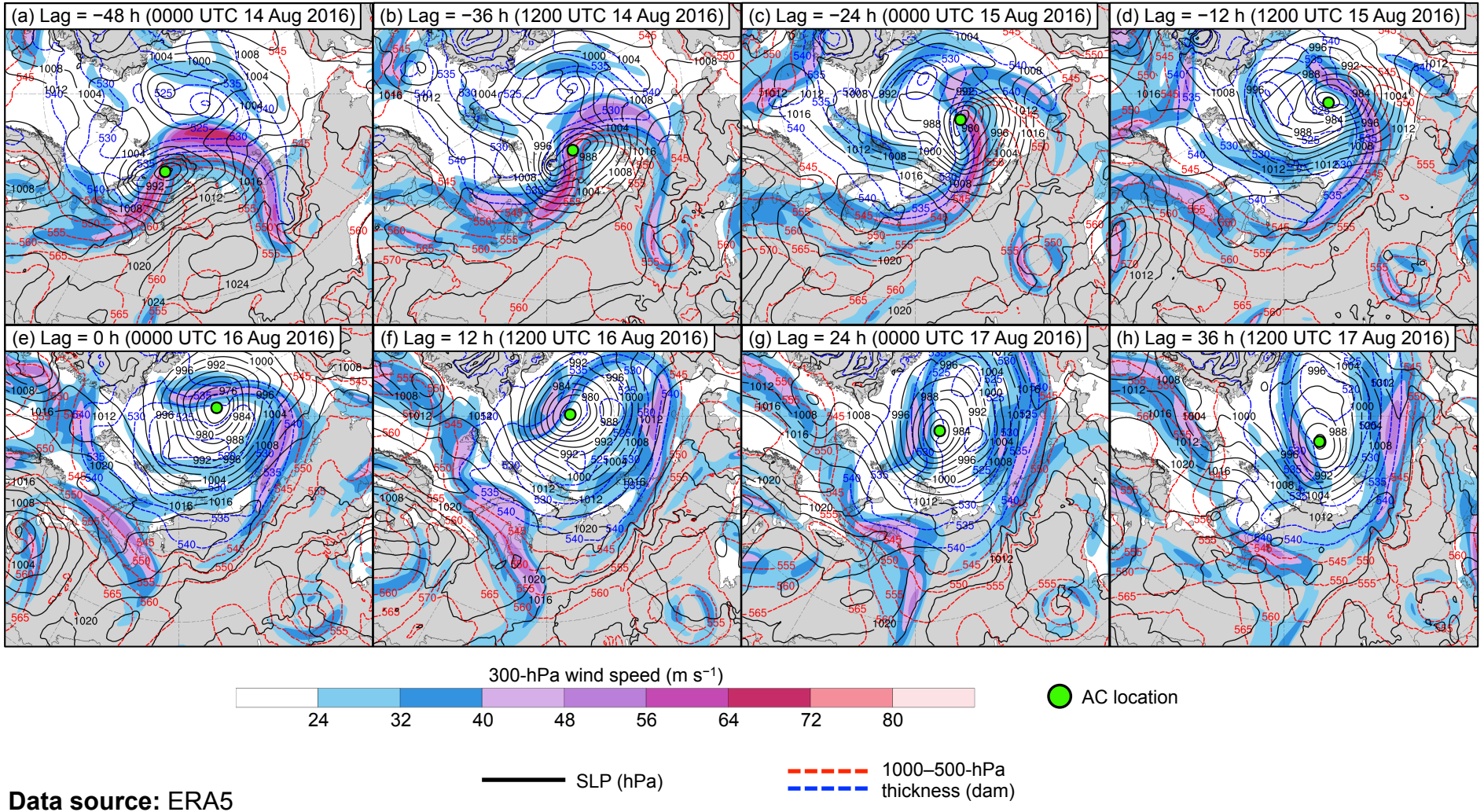
0000 UTC positions of AC

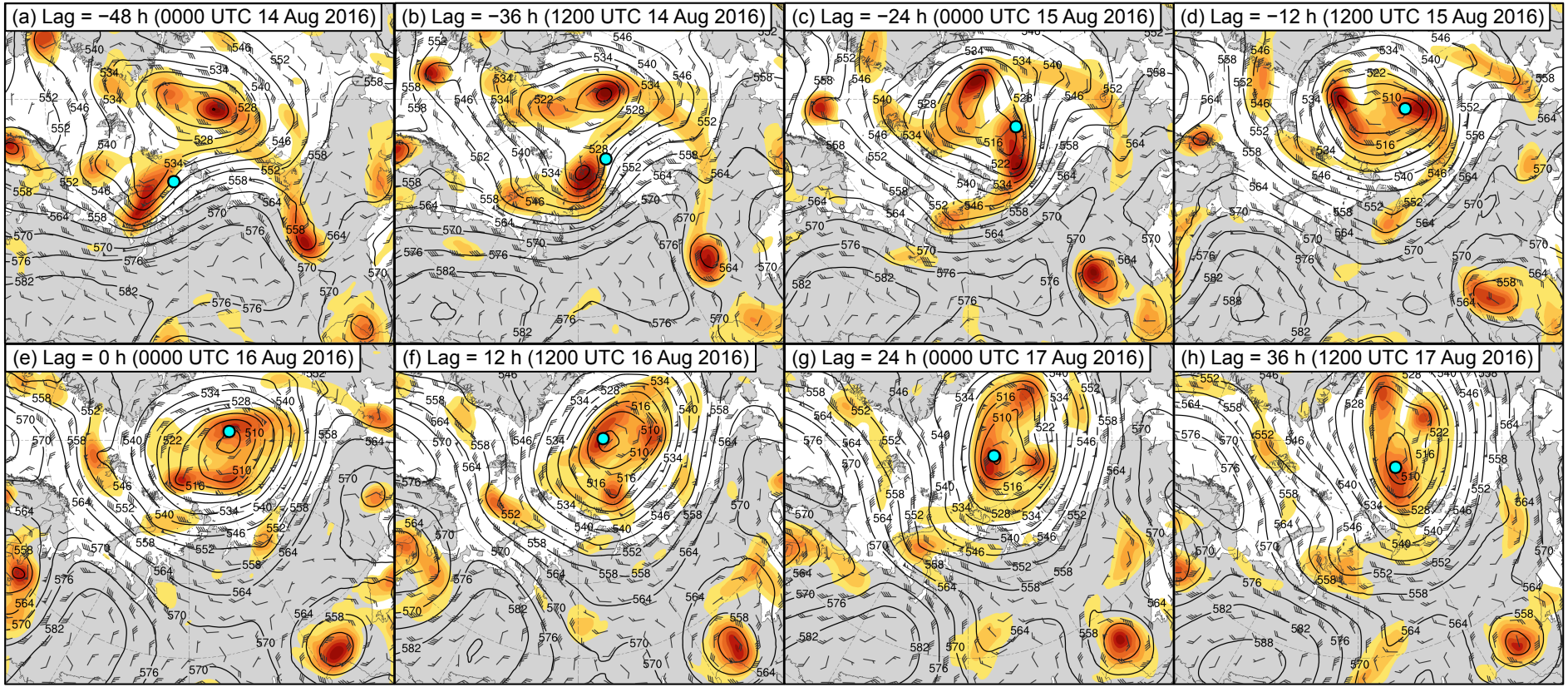
Red line shows track of AC during 13–19 Aug 2016.
Numbers represent dates of 0000 UTC positions of AC.



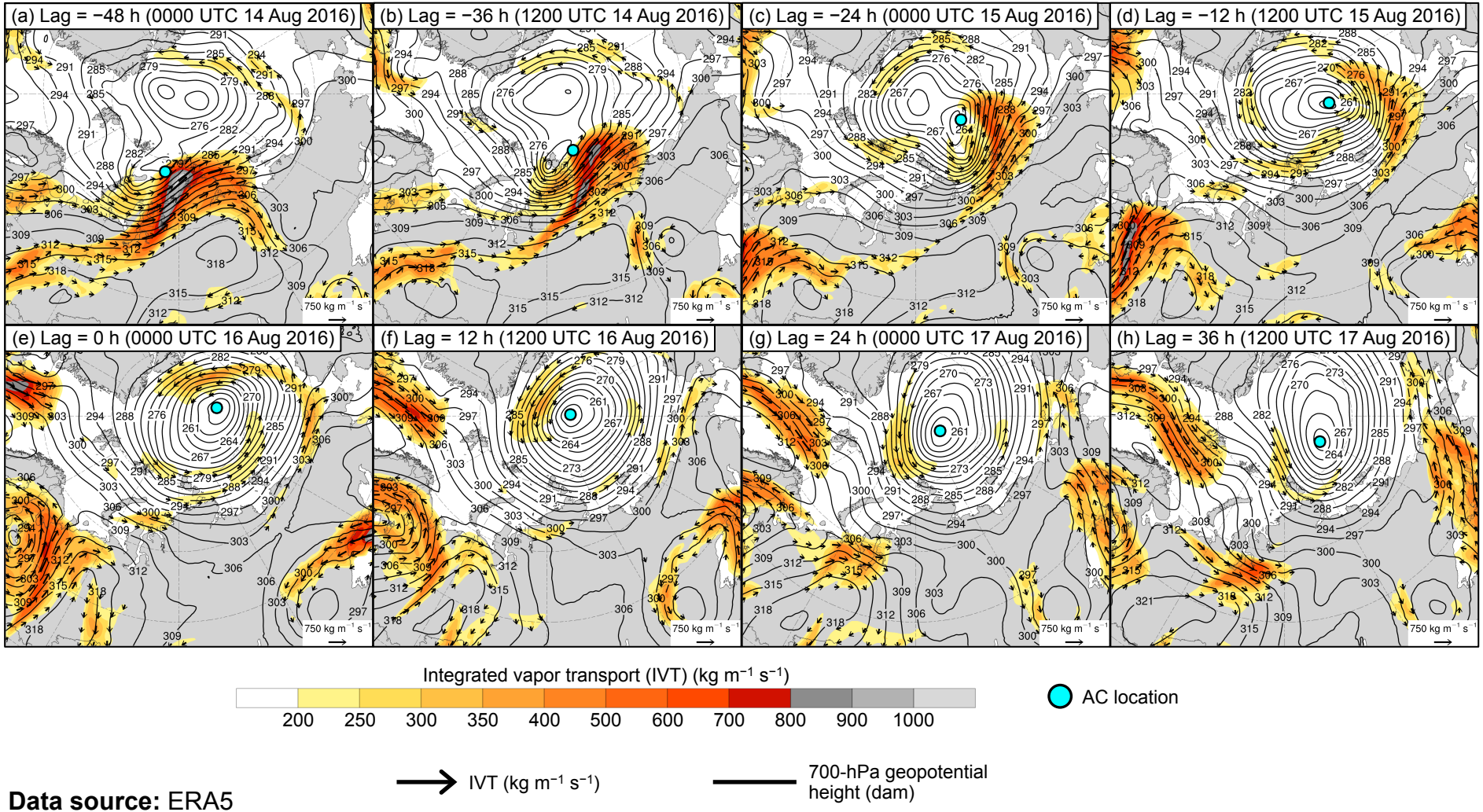
Time series of minimum SLP (hPa) of AC
during 13–19 Aug 2016.

Data source: ERA5


(a) Lag = −48 h (0000 UTC 14 Aug 2016)
(b) Lag = −36 h (1200 UTC 14 Aug 2016)
(c) Lag = −24 h (0000 UTC 15 Aug 2016)
(d) Lag = −12 h (1200 UTC 15 Aug 2016)
(e) Lag = 0 h (0000 UTC 16 Aug 2016)
(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



Data source: ERA5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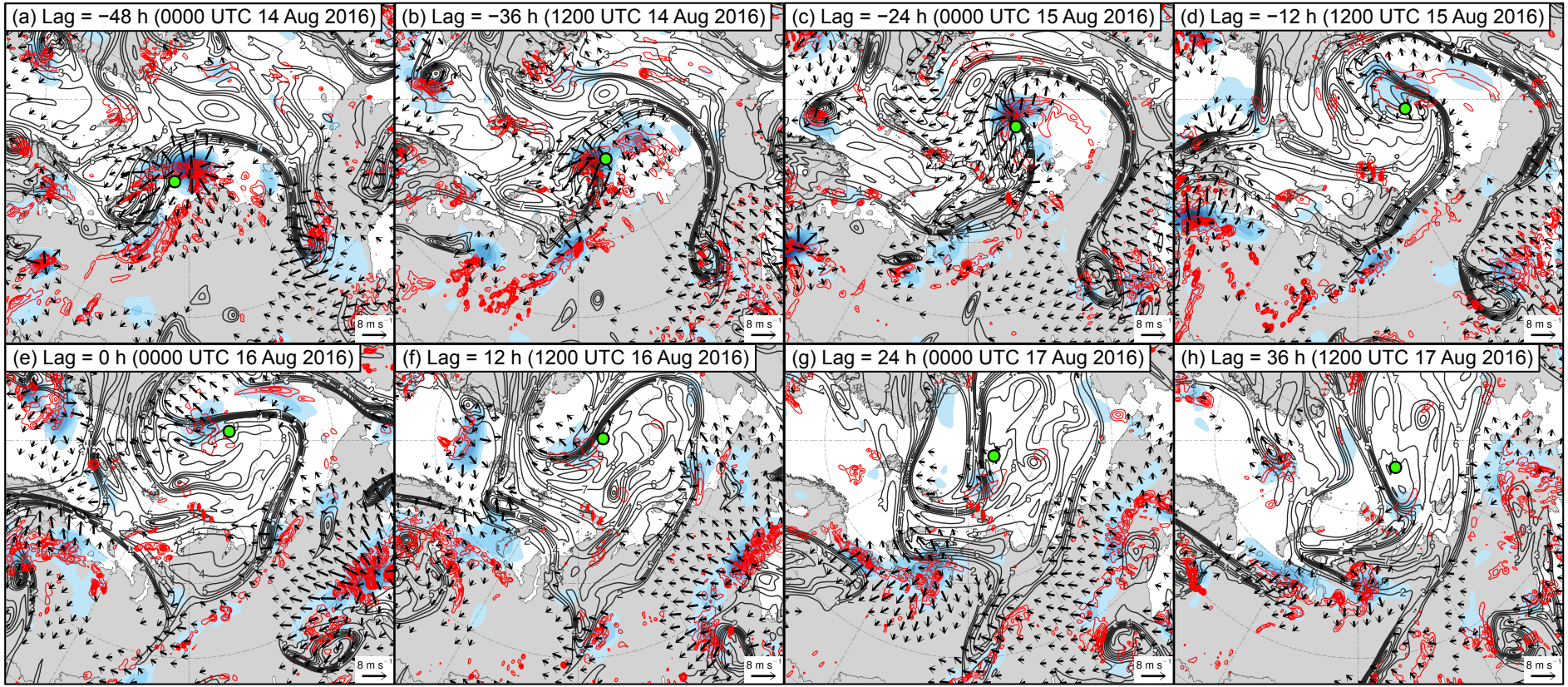
(f) Lag = 12 h (1200 UTC 16 Aug 2016)
(g) Lag = 24 h (0000 UTC 17 Aug 2016)
(h) Lag = 36 h (1200 UTC 17 Aug 2016)
750 kg m⁻¹ s⁻¹
Integrated vapor transport (IVT) (kg m⁻¹ s⁻¹)
200 250 300 350 400 500 600 700 800 900 1000
AC location
IVT (kg m⁻¹ s⁻¹)
700-hPa geopotential height (dam)
Data source: ERA5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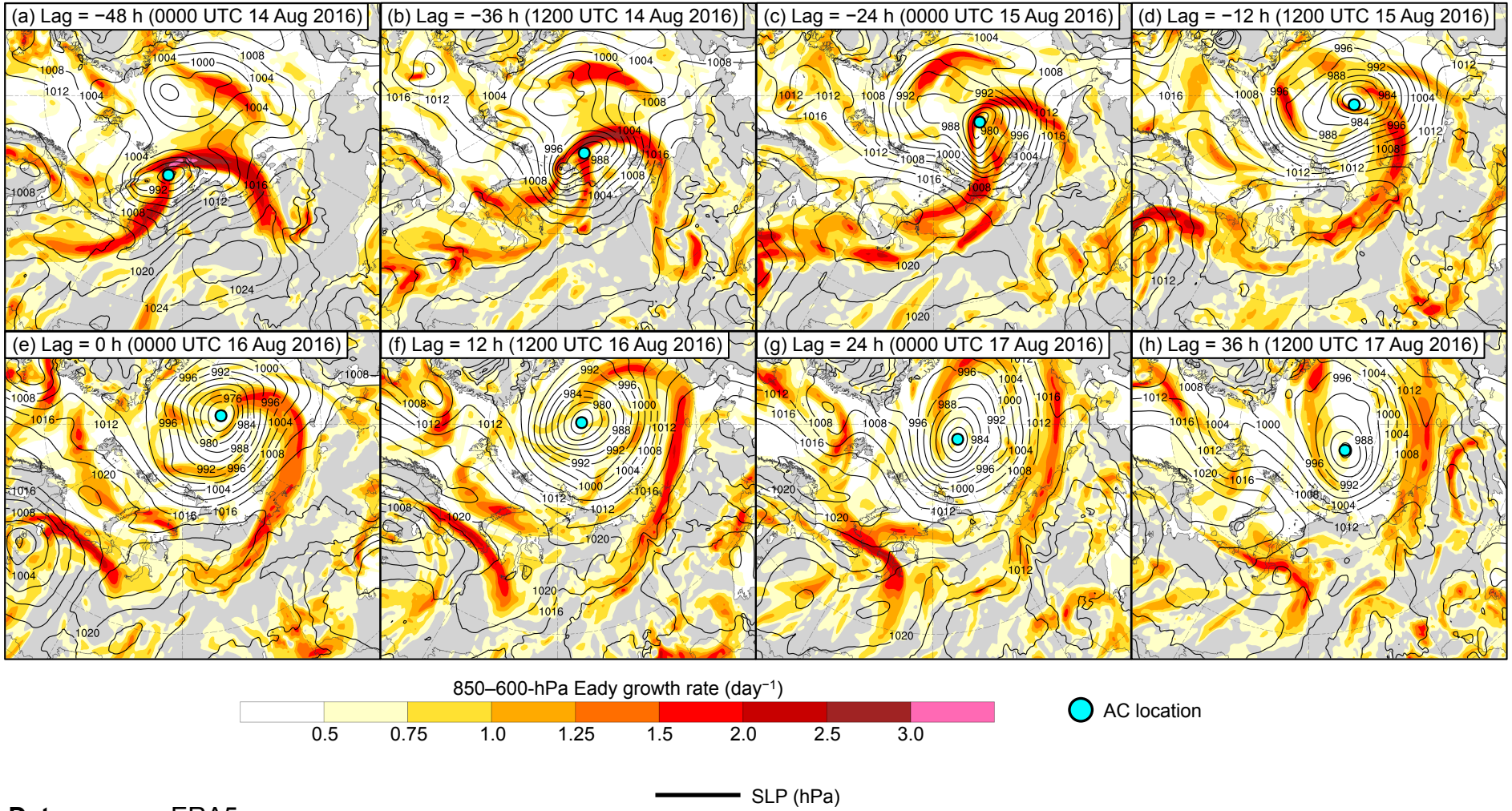
(e) Lag = 0 h (0000 UTC 16 Aug 2016)
(f) Lag = 12 h (1200 UTC 16 Aug 2016)
(g) Lag = 24 h (0000 UTC 17 Aug 2016)
(h) Lag = 36 h (1200 UTC 17 Aug 2016)
8 m s⁻¹
200-km area-averaged 350–250-hPa divergence (10⁻⁶ s⁻¹)
5
10
15
20
25
30
35
40
AC location
350–250-hPa irrotational wind (m s⁻¹)
350–250-hPa PV (PVU)
Negative values of 800–600-hPa ω (every 1 × 10⁻³ hPa s⁻¹)
Data source: ERA5



Data source: ERA5