The Contributions of Tropopause Polar Vortices and Remnant Tropical Moisture from Tropical Storm Alberto to the Development of Two Intense Arctic Cyclones in June 2018

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1) Motivation and Background

- Arctic cyclone 1 (AC1) formed along an old cold frontal boundary northeast of the Caspian Sea, moved poleward, performed a cyclonic loop with a subsequent Arctic cyclone (AC2) near the north coast of Russia, and eventually merged with AC2 over the Arctic Ocean
- AC2 formed via lee cyclogenesis east of Greenland, and may have had some "DNA" from the remnants of Tropical Storm (TS) Alberto, which moved poleward across the central U.S. and northeastern Canada
- Arctic cyclones may be associated with strong surface winds and poleward advection of warm, moist air, contributing to reductions in Arctic sea-ice extent (e.g., Zhang et al. 2013)
- Heavy precipitation, strong surface winds, and large waves due to Arctic cyclones may pose hazards to ships navigating through open passageways in the Arctic Ocean
- Tropopause polar vortices (TPVs) are tropopause-based vortices of high-latitude origin (e.g., Cavallo and Hakim 2010) that may act as precursors to the development of Arctic cyclones (e.g., Tao et al. 2017)
- The comparative rarity of two sequential intense Arctic cyclones that interacted with one another, one of which (AC2) may have had antecedent DNA from TS Alberto, motivates this presentation

2) Data and Methods

- Data: ERA5 (Hersbach and Dee 2016) gridded to 0.25° horizontal resolution for all fields, with ERA-Interim (Dee et al. 2011) 1979–2010 mean and standard deviation of selected fields for calculation of standardized anomalies
- Manually tracked AC1, AC2, and a Canadian low (CL) by following the locations of minimum sea level pressure (SLP)
- Tracked TS Alberto using National Hurricane Center positions of TS Alberto during 1500 UTC 25 May–0600 UTC 29 May 2018 and remnants of TS Alberto using ERA5 afterward

3) Track and Intensity

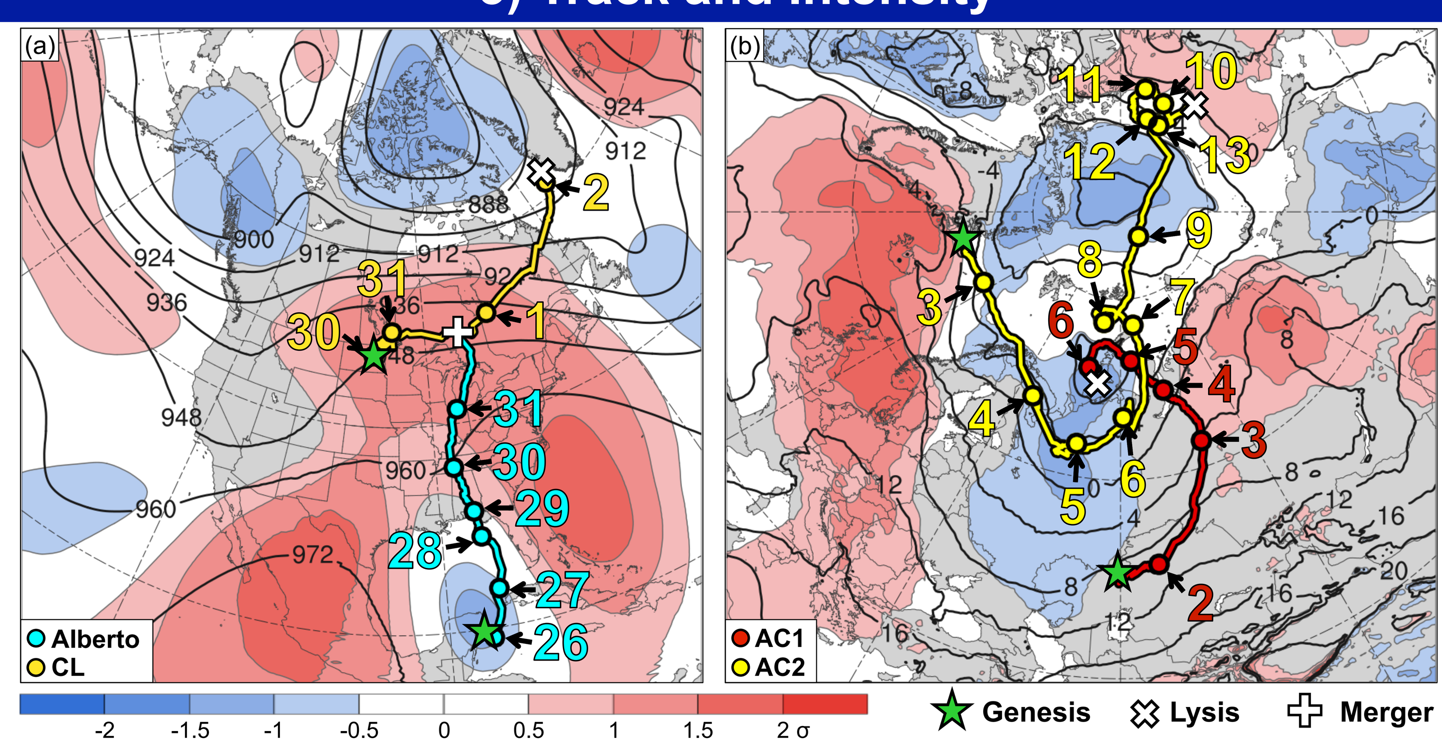

Table 1. Lifetimes of cyclones

Feature	Date of Genesis	Date of Lysis	Lifetime (d)
Alberto	25 May	31 May	~6
CL	29 May	2 June	~3
AC1	1 June	6 June	~5
AC2	2 June	13 June	~11

Figure 1. Tracks of (a) Alberto and a Canadian low (CL), and (b) AC1 and AC2. Also, (a) 26 May–1 June 2018 time-mean 300-hPa geopotential height (dam, gray) and standardized geopotential height anomalies (σ, shaded), and (b) 1–7 June 2018 time-mean 850-hPa temperature (°C, gray) and standardized temperature anomalies (σ, shaded). 0000 UTC positions of cyclones shown by dots, and colored numbers represent dates corresponding to the 0000 UTC positions.

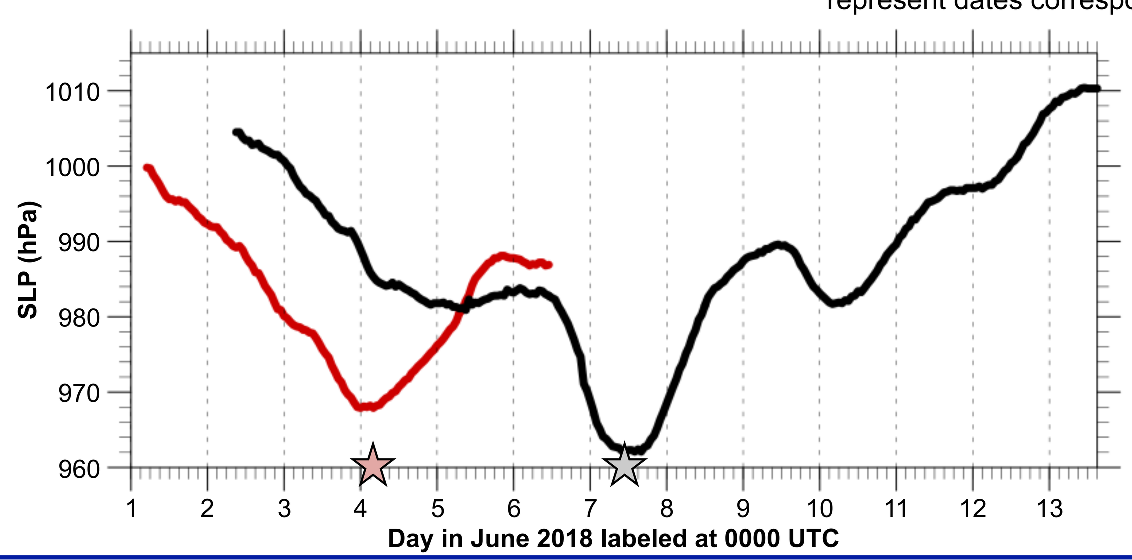

Figure 2. Hourly minimum SLP time series of AC1 and AC2

4) Large-scale Flow Evolution

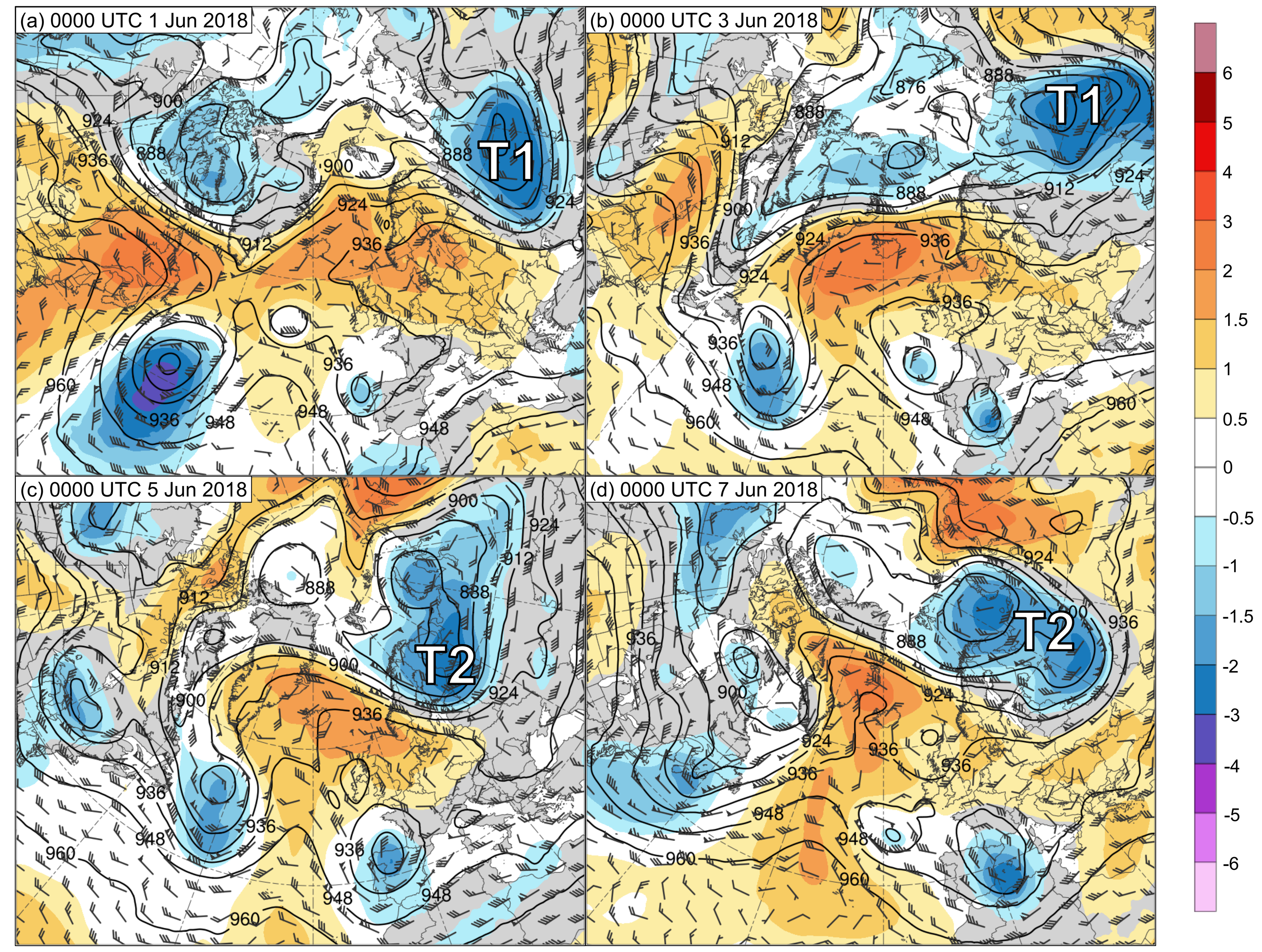

Figure 3. 300-hPa geopotential height (dam, black), winds (m s^{-1}, flags and barbs), and standardized geopotential height anomalies (σ, shaded). T1 an T2 denote deep troughs 1 and 2, respectively.

6) Interactions between Arctic Cyclones

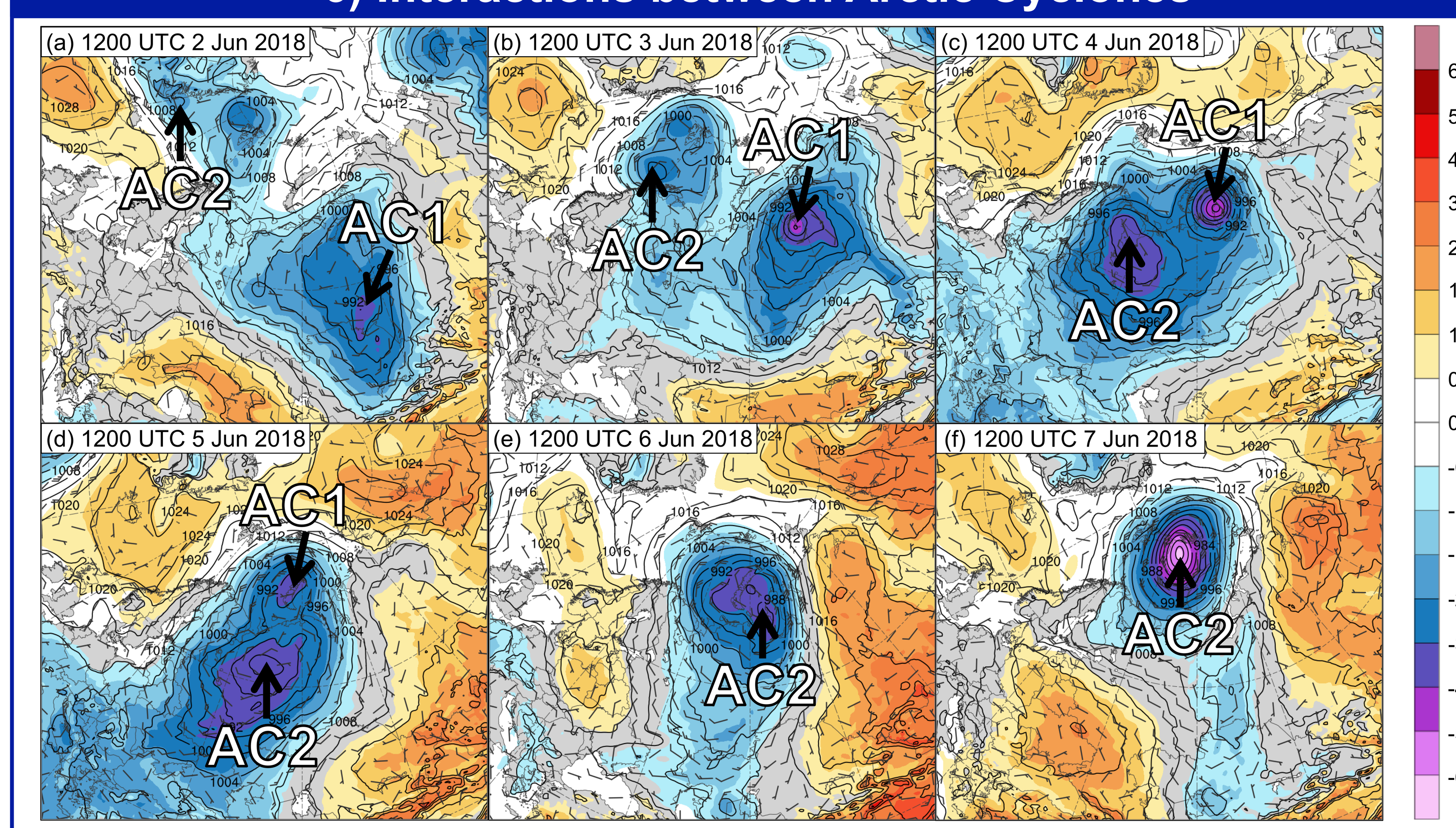

Figure 5. SLP (hPa, black), 10-m winds (m s^{-1}, flags and barbs), and standardized SLP anomalies (σ, shaded)

7) Discussion

- Remnants of TS Alberto are absorbed into the cyclonic/frontal region of CL over southern Canada (Fig. 1a)
- CL moves northeastward, weakens over the Davis Strait, and redevelops as a lee cyclone (AC2) east of Greenland (Figs. 1a,b, 2)
- Successive deep troughs over Eurasia in early June that form in response to cyclonic wave breaking foster development of AC1 and AC2 (Figs. 3b,c,d)
- AC1 forms near the Caspian Sea along a trailing cold front, moves northeastward, deepens, and reaches the Kara Sea (Figs. 4b,c, 5c)
- AC2 intensifies as an ordinary baroclinic cyclone over northwestern Europe in conjunction with a strong jet stream (Figs. 4e,f)
- TPVs embedded within deep troughs likely contribute to rapid deepening of AC1 and AC2 in the left exit region of a jet streak (Figs. 4e,f and Figs. 4i,j)
- AC2 interacts and merges with AC1 and becomes the dominant cyclone, with a peak intensity of 962 hPa and a standardized SLP anomaly of < −6 σ (Fig. 5f)

5) Synoptic Evolution of Arctic Cyclones

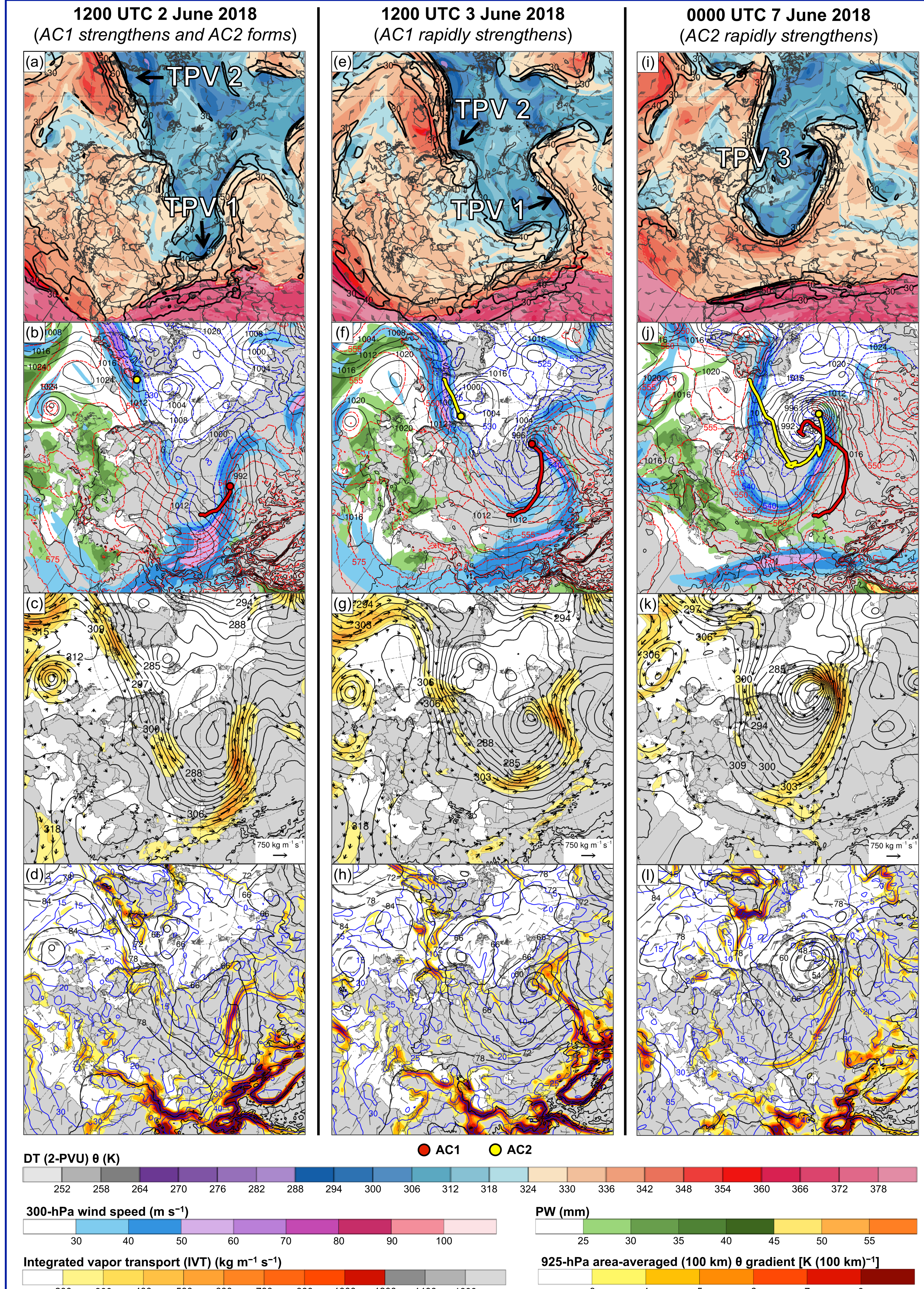

Figure 4. (*first row*) DT (2-PVU surface) θ (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and winds (m s^{-1}, flags and barbs);
(*second row*) 300-hPa wind speed (m s^{-1}, shaded), PW (mm, shaded), 1000–500-hPa thickness (dam, dashed red and blue), and SLP (hPa, black);
(*third row*) IVT (kg m^{-1} s^{-1}, shaded and vectors), and 700-hPa geopotential height (dam, black) and winds (m s^{-1}, flags and barbs);
(*fourth row*) 925-hPa area-averaged (100 km) θ gradient [K (100 km)$^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

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