Linkages Between Tropopause Polar Vortices and the Great Arctic Cyclone of August 2012

UNIVERSITY AT ALBANY
State University of New York

Daniel Keyser[1]*, Kevin Biernat[1], Lance F. Bosart[1], and Steven M. Cavallo[2]
*E-mail: dkeyser@albany.edu
[1]University at Albany, SUNY
[2]University of Oklahoma

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1) Background

- Tropopause polar vortices (TPVs) are tropopause-based vortices of high-latitude origin and are material features (e.g., Cavallo and Hakim 2010)
- TPVs may interact with and strengthen jet streams and act as precursors to the development of Arctic cyclones, including the Great Arctic Cyclone of August 2012 (hereafter AC12; e.g., Simmonds and Rudeva 2012; Tao et al. 2017)
- 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
- AC12 formed over Siberia on 2 August 2012 and tracked northeastward into the Arctic, reaching a minimum central sea level pressure (SLP) of 962.3 hPa at 1000 UTC 6 August in the ERA5 (Hersbach and Dee 2016)
- Strong surface winds and waves associated with AC12 helped break up thin Arctic sea ice (e.g., Parkinson and Comiso 2013) and contributed to increased upward ocean heat transport and bottom melting of ice, with sea-ice volume decreasing twice as fast as normal during AC12 (e.g., Zhang et al. 2013)
- This study will examine linkages between TPVs and AC12

2) Data and Methods

- Data: ERA5 at 0.3° horizontal resolution
- Utilized TPV tracking algorithm (Szapiro and Cavallo 2018) to identify and track TPVs of interest for AC12
- Manually tracked a predecessor surface cyclone (L1) and AC12 by following the locations of minimum SLP

3) Track and Intensity

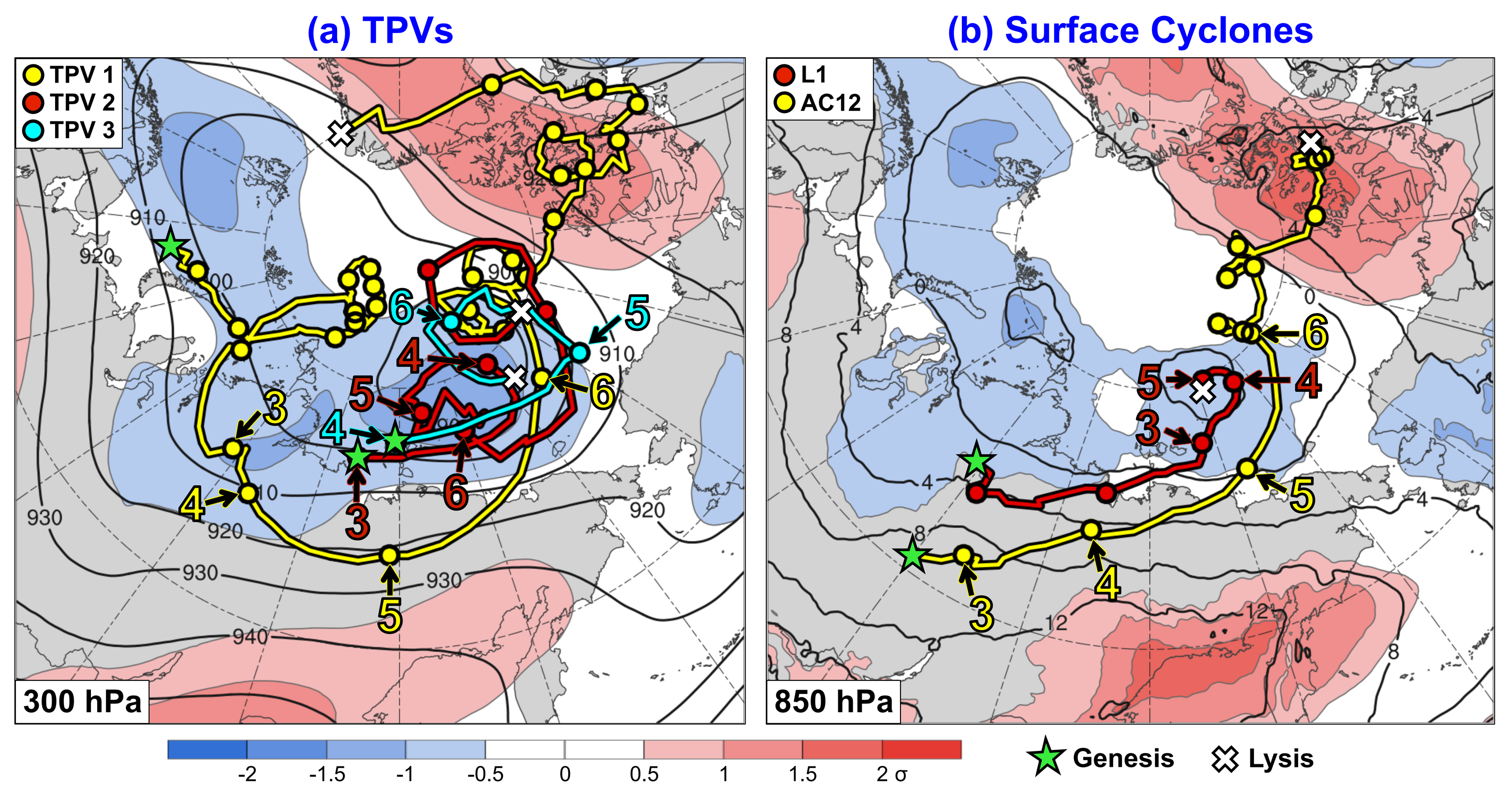

Table 1. Lifetimes of TPVs and surface cyclones

Feature	Date of Genesis	Date of Lysis	Lifetime (d)
TPV 1	23 Jul	19 Aug	~27
TPV 2	3 Aug	9 Aug	~6
TPV 3	4 Aug	6 Aug	~3
L1	31 Jul	5 Aug	~5
AC12	2 Aug	15 Aug	~13

Figure 1. Tracks of (a) TPVs and (b) surface cyclones, and 1–7 Aug 2012 time-mean (a) 300-hPa geopotential height (dam, gray) and standardized anomaly of 300-hPa geopotential height (σ, shaded), and (b) 850-hPa temperature (°C, gray) and standardized anomaly of 850-hPa temperature (σ, shaded). 0000 UTC positions of TPVs and surface cyclones are shown by dots, and colored numbers represent dates corresponding to the 0000 UTC positions.

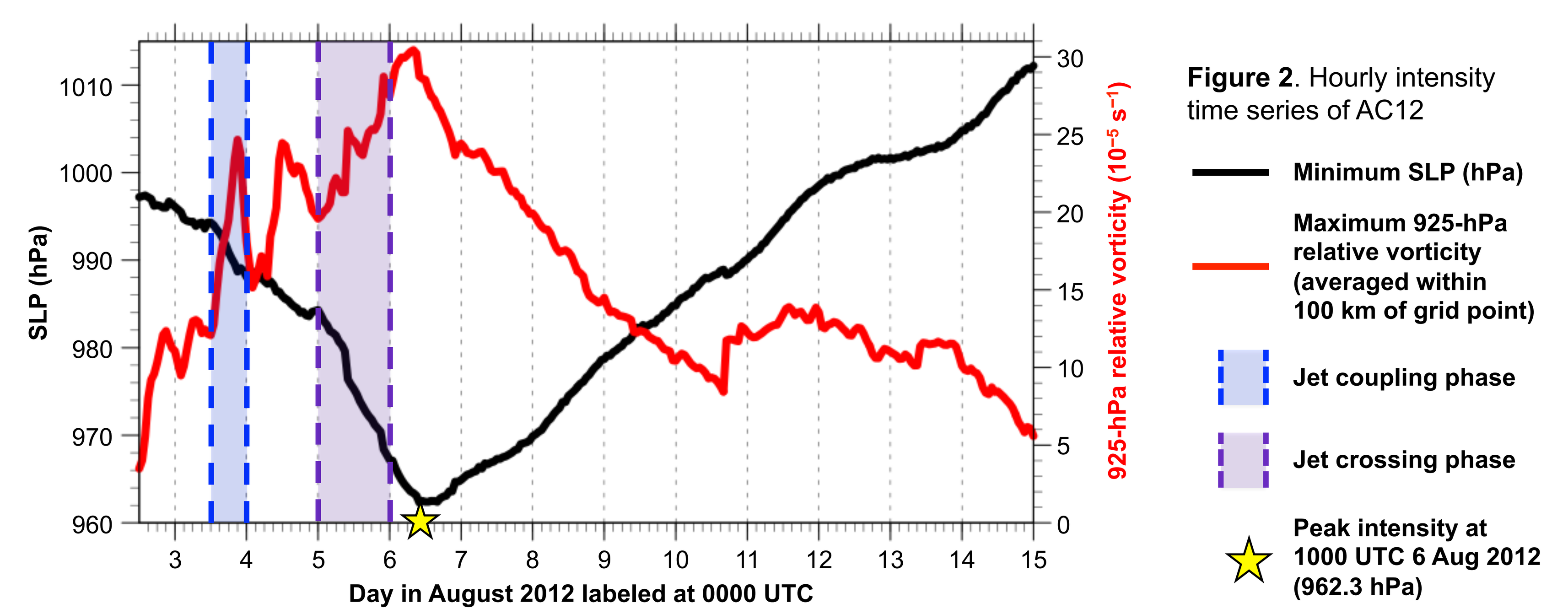

Figure 2. Hourly intensity time series of AC12

4) Synoptic Evolution of TPVs and Cyclones

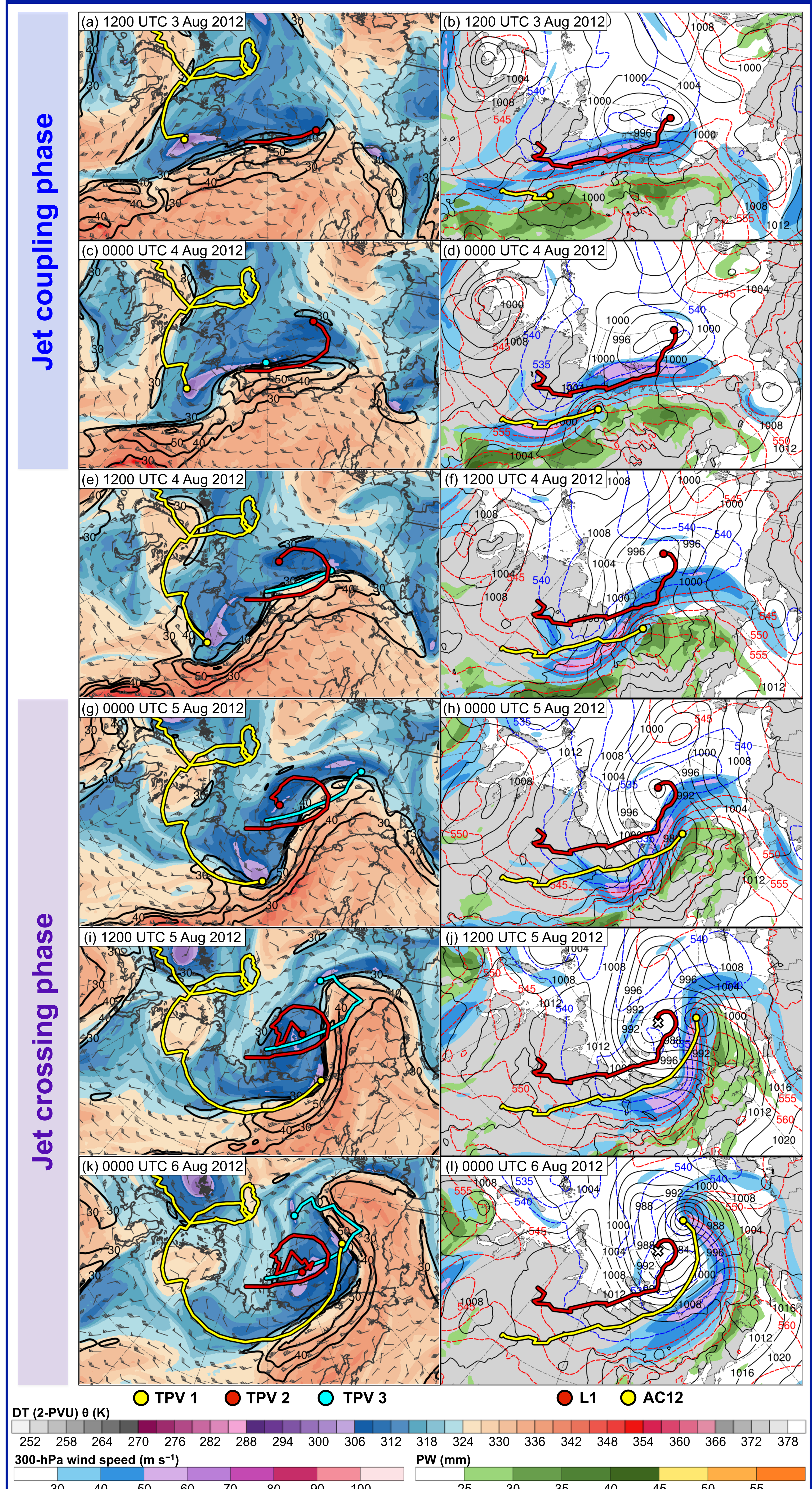

Figure 3. (left) DT (2-PVU surface) θ (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs); (right) 300-hPa wind speed (m s^{-1}, shaded), PW (mm, shaded), 1000–500-hPa thickness (dam, dashed red and blue), and SLP (hPa, black)

References

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5) Cross Sections

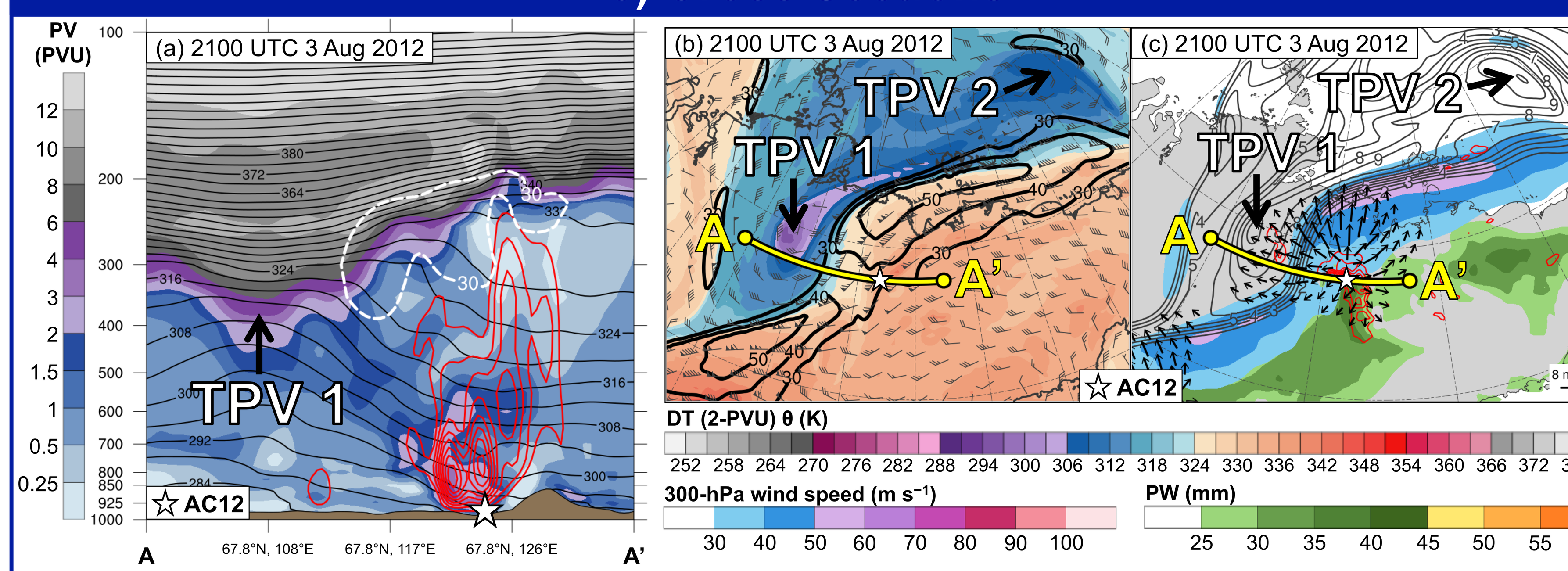

Figure 4. Cross section along AA' at 2100 UTC 3 Aug 2012 of (a) PV (PVU, shaded), θ (K, black), wind speed (white, every 10 m s^{-1} starting at 30 m s^{-1}), and ascent (red, every 5 × 10^{-3} hPa s^{-1}); (b) DT (2-PVU surface) θ (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs); (c) 350–250-hPa PV (PVU, gray) and irrotational wind (m s^{-1}, vectors), 300-hPa wind speed (m s^{-1}, shaded), PW (mm, shaded), and 800–600-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1}).

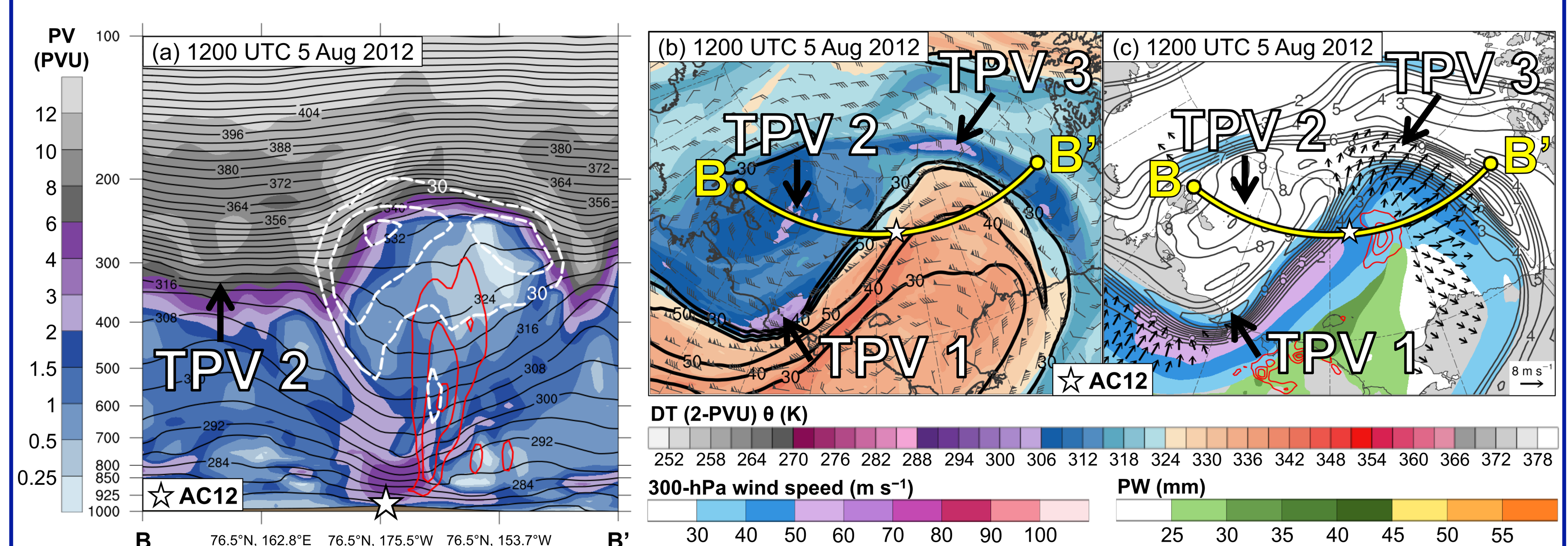

Figure 5. As in Fig. 4, but for cross section along line BB' at 1200 UTC 5 Aug 2012.

6) Impacts of AC12 on Arctic Sea Ice

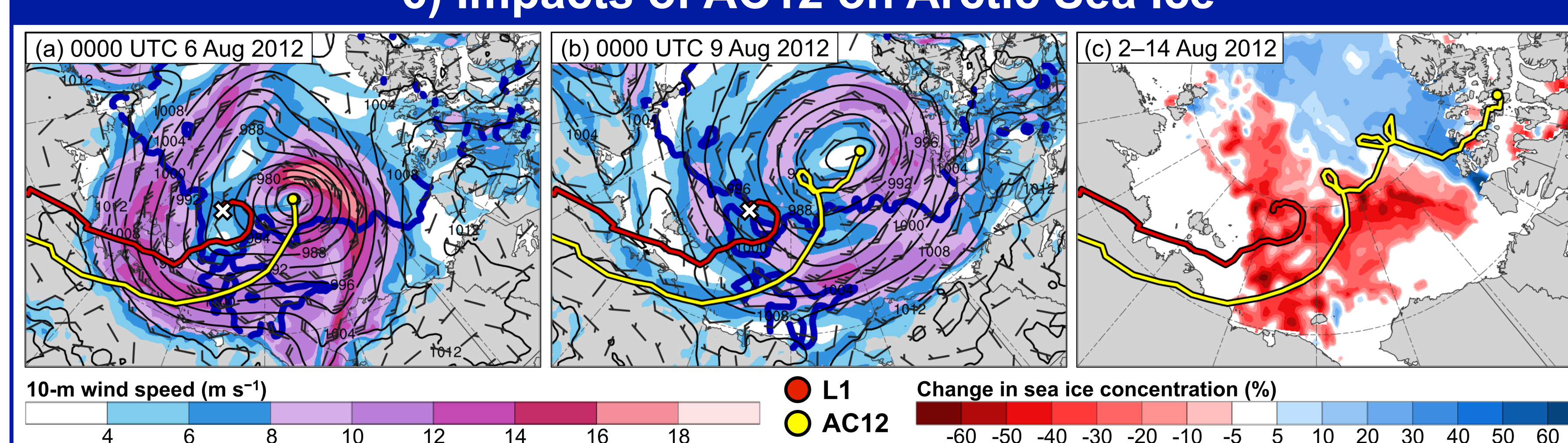

Figure 6. (a) SLP (hPa, black), 10-m wind (m s^{-1}, flags and barbs), and 20% contour of sea-ice concentration (thick blue) at (a) 0000 UTC 6 August 2012 and (b) 0000 UTC 9 August 2012; (c) change in sea-ice concentration during 2–14 August 2012 (%, shaded).

7) Discussion

- TPV 1 approaches and interacts with AC12 in a region of strong baroclinicity (Figs. 1a,b and Figs. 3a–l), likely supporting the development of AC12 through baroclinic processes
- TPV–jet interactions involving TPV 1, TPV 2, and TPV 3 likely contribute to the formation of a dual-jet configuration and jet coupling over AC12 (jet coupling phase; Figs. 3a–d)
- Latent heating related to low-level ascent in the presence of warm, moist air in region of jet coupling likely contributes to the formation of a PV tower associated with AC12 (Figs. 4a–c) and concomitant intensification of AC12 (Fig. 2)
  - Interaction between TPV 1 and PV tower (Figs. 4a–c) likely supports the intensification of AC12
- Cold air advection in the wake of L1 helps maintain the strong baroclinicity in the vicinity of AC12 (e.g., Figs. 3d,f), which, along with interaction between L1 and AC12 (Figs. 3h,j), may further support the intensification of AC12
- Most rapid intensification of AC12 occurs on 5 Aug 2012 (Fig. 2), when AC12 crosses from the warm side to the cold side of a strong upper-level jet streak (jet crossing phase; Figs. 3g–l)
  - Latent heating may contribute to PV tower associated with AC12 and intensification of AC12 during jet crossing phase (Figs. 5a–c), though this contribution may be smaller than that during jet coupling phase (compare Figs. 5a,c to Figs. 4a,c)
- Widespread, relatively strong surface winds associated with AC12 contribute to reductions in Arctic sea-ice extent as AC12 meanders slowly over the Arctic (Figs. 6a–c)