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

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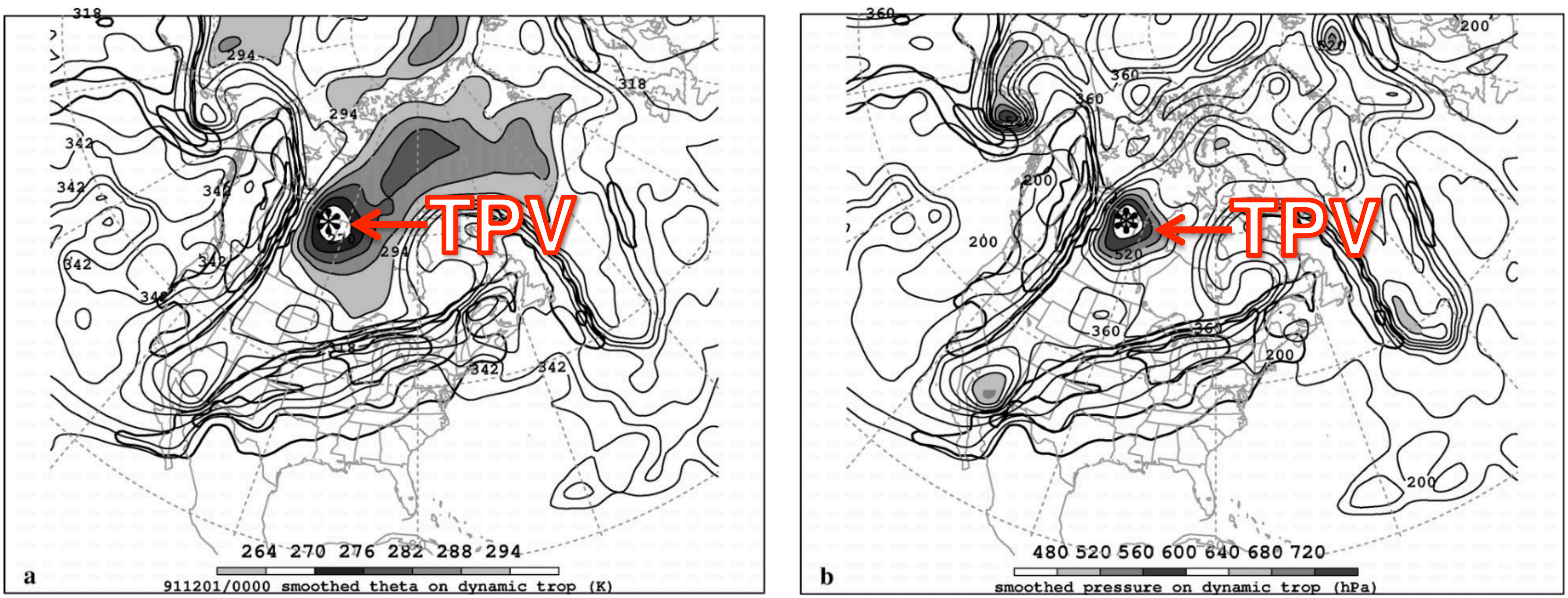
# What are Tropopause Polar Vortices (TPVs)

- TPVs are defined as tropopause-based vortices of high-latitude origin and are material features (Pyle et al. 2004; Cavallo and Hakim 2009, 2010, 2012, 2013)




**(left)** Dynamic tropopause (DT) wind speed (every 15 m s$^{-1}$ starting at 50 m s$^{-1}$, thick contours) and DT potential temperature (K, thin contours and shading) on 1.5-PVU surface valid 0000 UTC 1 Dec 1991; **(right)** same as left except DT pressure (hPa, thin contours and shading).
Adapted from Fig. 11 in Pyle et al. (2004).

# Motivation

- TPVs may interact with and strengthen jet streams, and act as precursors to the development of intense Arctic cyclones (e.g., Simmonds and Rudeva 2012, 2014)
- 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 moving through open passageways in the Arctic Ocean

# The Great Arctic Cyclone of August 2012 (AC12)

- AC12 formed over Siberia on 2 August 2012 and tracked northeastward into the Arctic, reaching a minimum central sea level pressure (SLP) of 966.4 hPa at 1800 UTC 6 August in the CFSR (Simmonds and Rudeva 2012)
- AC12 led to reductions in Arctic sea-ice extent during a time in which sea ice was thin and sea-ice volume was well below normal (Zhang et al. 2013)
- Strong surface winds associated with AC12 helped to break up the thin sea ice (e.g., Parkinson and Comiso 2013)

# The Great Arctic Cyclone of August 2012 (AC12)

- According to Zhang et al. (2013) sea-ice volume decreased twice as fast as normal during AC12 due to melting of the bottom and perimeter of ice floes

- Simmonds and Rudeva (2012) and Yamazaki et al. (2015) found that a TPV played an important role in the lifecycle of AC12

# Outline

- Identification and synoptic examination of three TPVs, a predecessor surface cyclone, and AC12
- Impact of AC12 on Arctic sea-ice extent

# Data and Methods

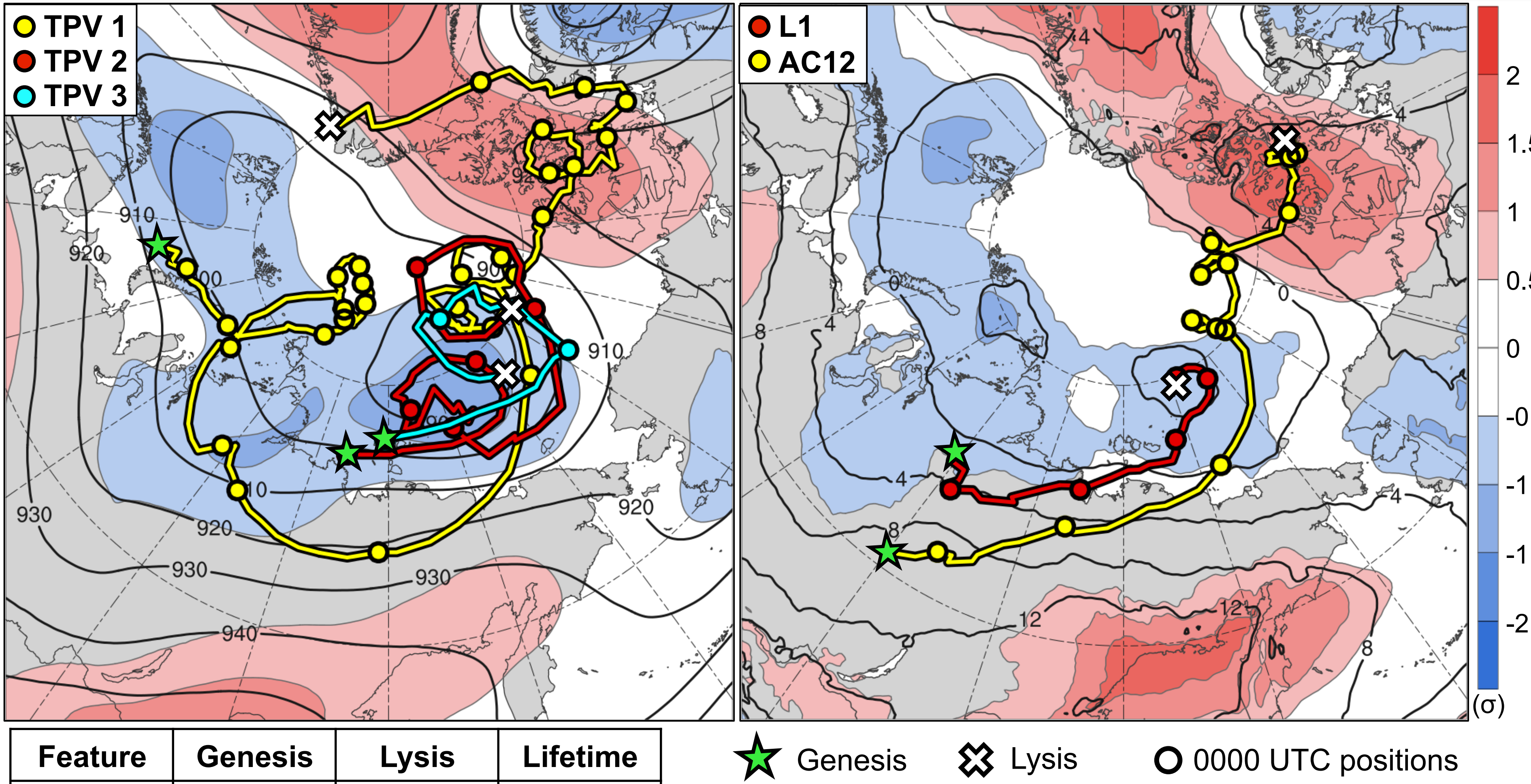
- Data:
  - 0.3° ERA5 (Hersbach and Dee 2016)
- Utilized TPV tracking algorithm developed by Nicholas Szapiro and Steven Cavallo to identify and track TPVs of interest for AC12
  - Input variables: potential temperature, relative vorticity, and wind on 2-PVU surface
  - Potential temperature minima on 2-PVU surface tracked spatially and temporally to create TPV tracks

Link for Tracking Algorithm: https://github.com/nickszap/tpvTrack

# Data and Methods

- Manually tracked the predecessor surface cyclone and AC12 by following the locations of minimum SLP

# TPV and Surface Cyclone Tracks

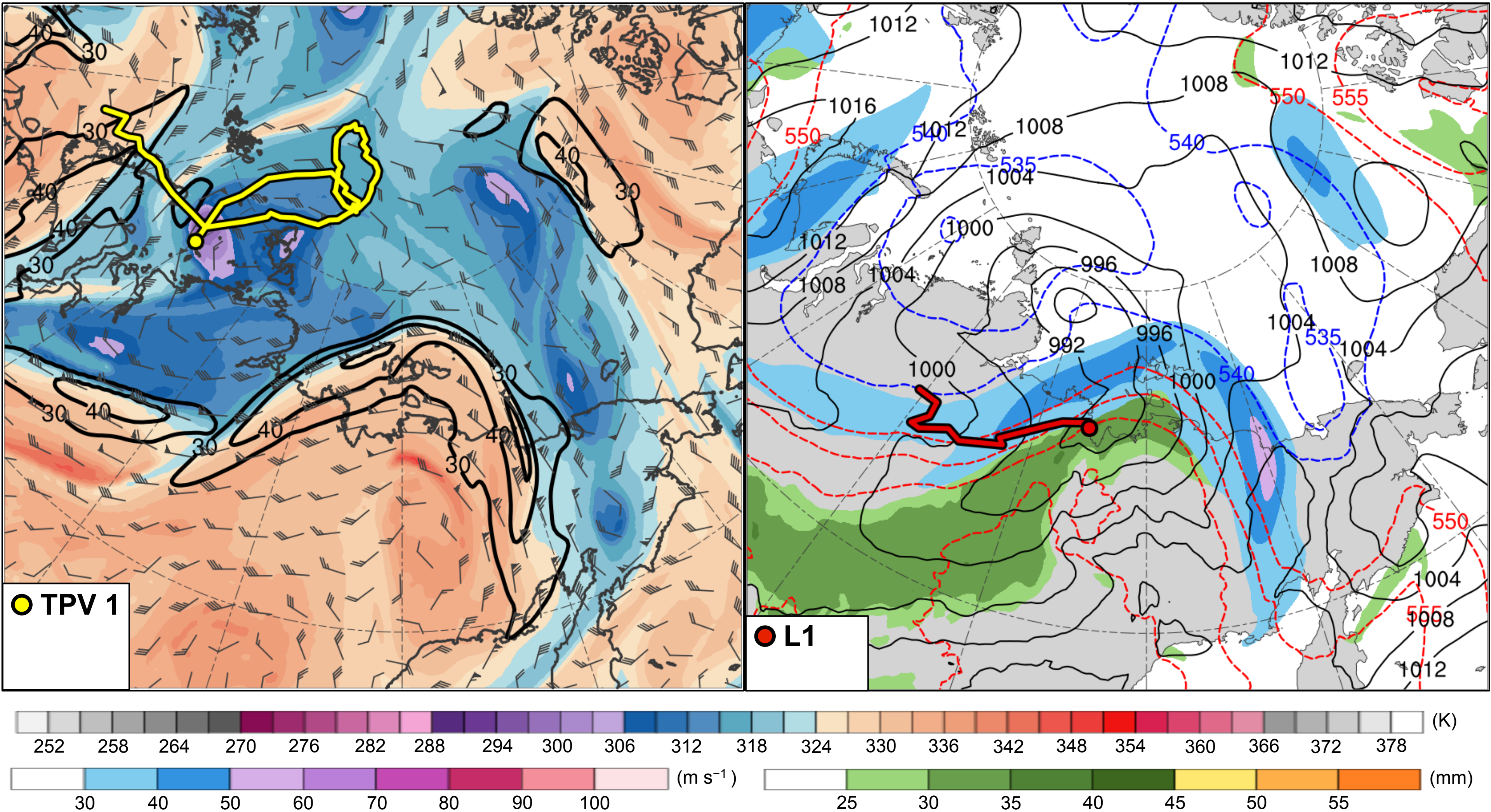



| Feature | Genesis | Lysis | Lifetime |
|---|---|---|---|
| TPV 1 | 23 July | 19 Aug | ~28 d |
| TPV 2 | 3 Aug | 9 Aug | ~6 d |
| TPV 3 | 4 Aug | 6 Aug | ~3 d |
| L1 | 31 July | 5 Aug | ~5 d |
| AC12 | 2 Aug | 15 Aug | ~13 d |

1–7 Aug 2012 time-mean (left) 300-hPa geopotential height (dam, black) and standardized anomaly of 300-hPa geopotential height (σ, shaded); (right) 850-hPa temperature (°C, black) and standardized anomaly of 850-hPa temperature (σ, shaded)

# Synoptic Evolution

0000 UTC 2 Aug 2012

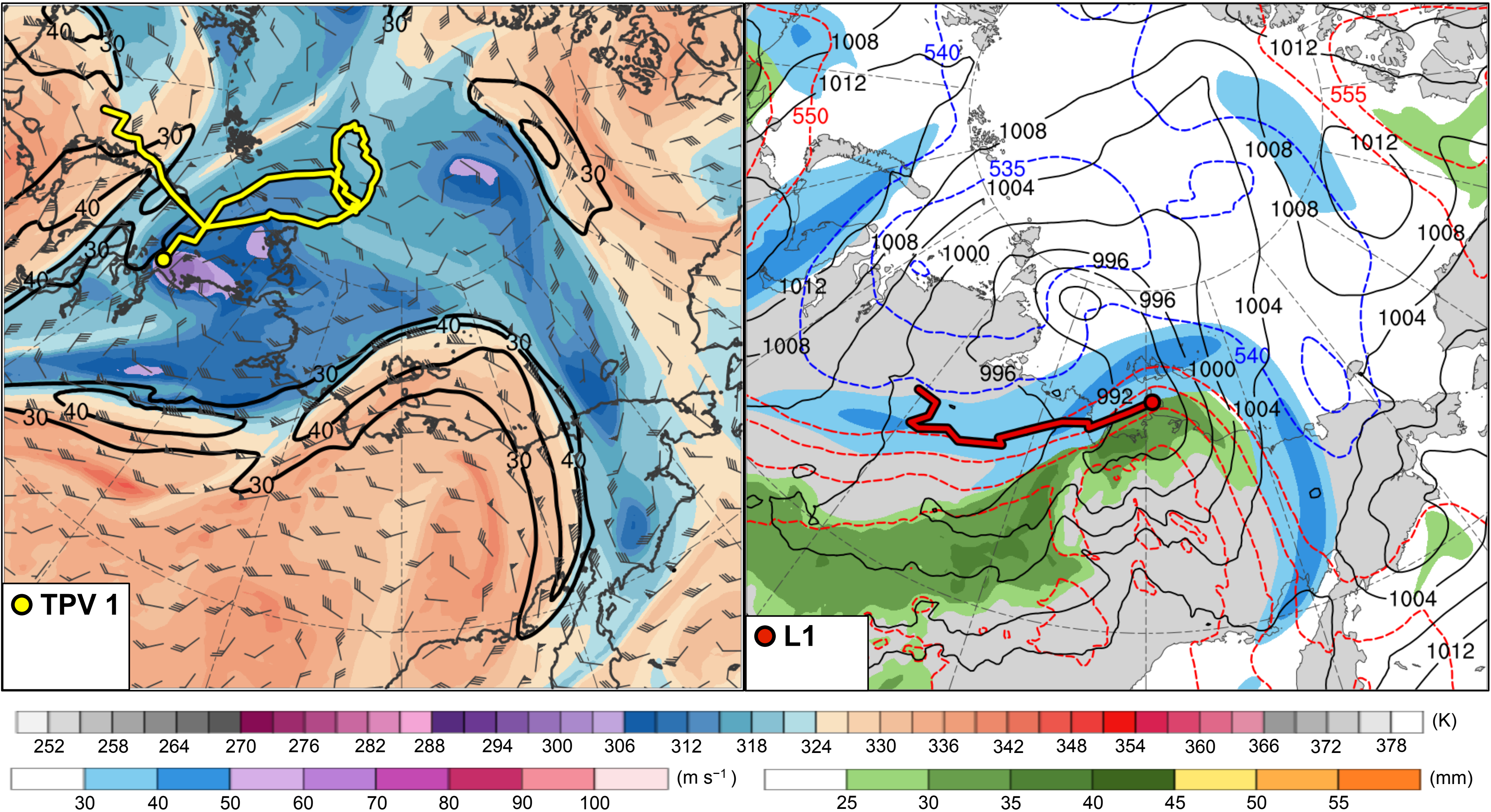



Potential temperature (K, shaded), wind speed (black, every 10 m $s^{-1}$ starting at 30 m $s^{-1}$), and wind (m $s^{-1}$, flags and barbs) on 2-PVU surface

250-hPa wind speed (m $s^{-1}$, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), PW (mm, shaded)

# Synoptic Evolution

0600 UTC 2 Aug 2012

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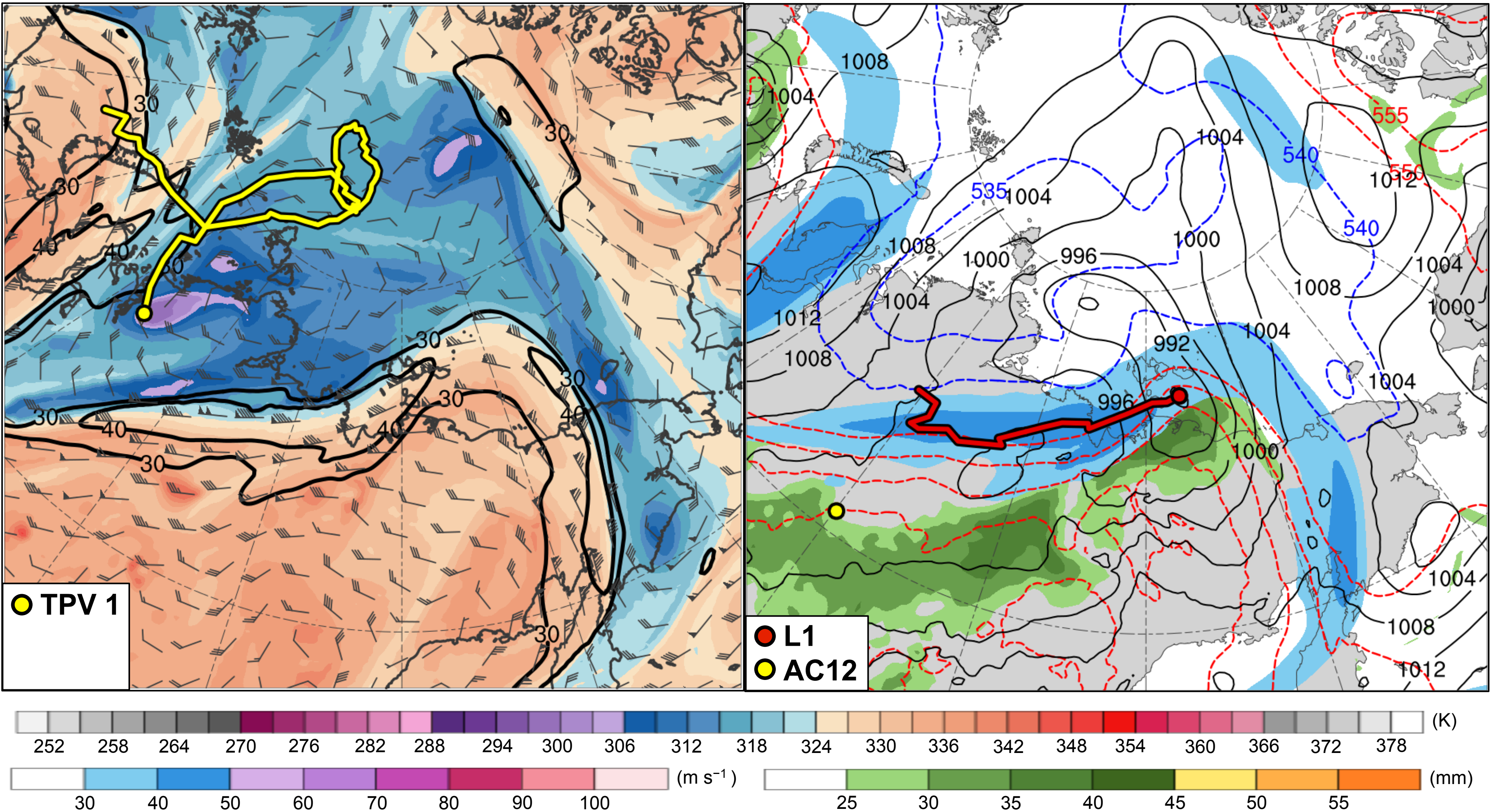
1200 UTC 2 Aug 2012

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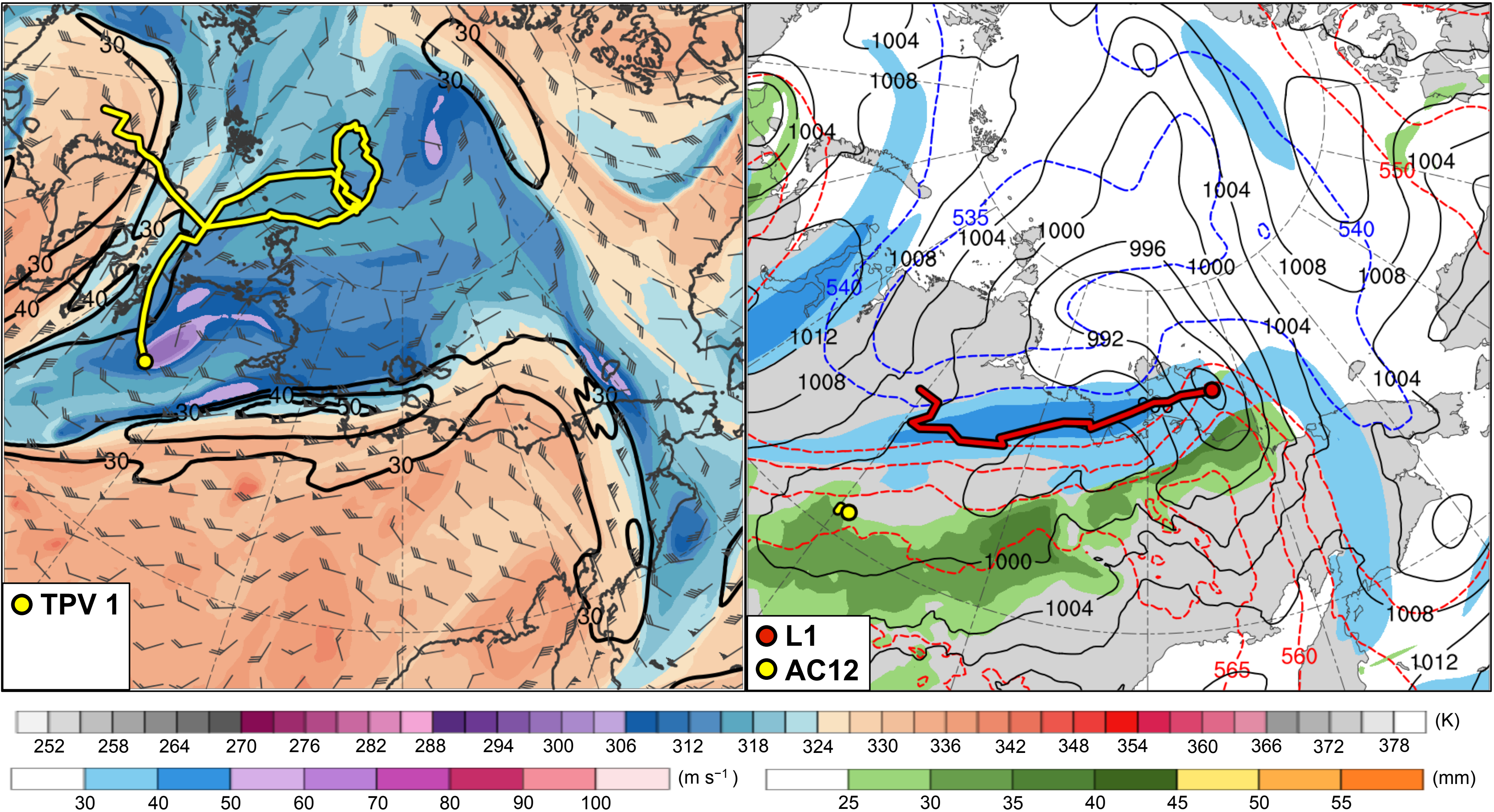


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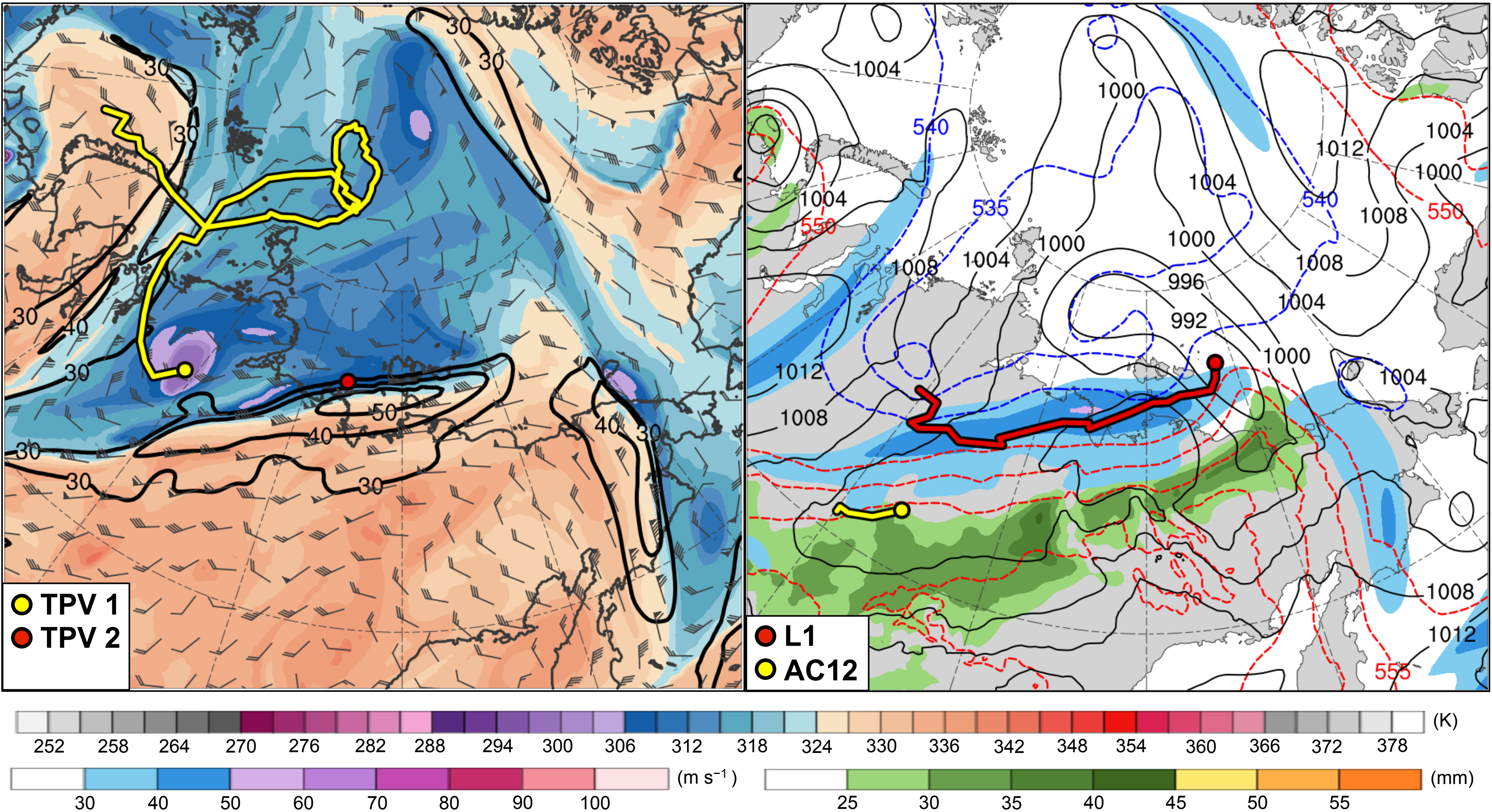


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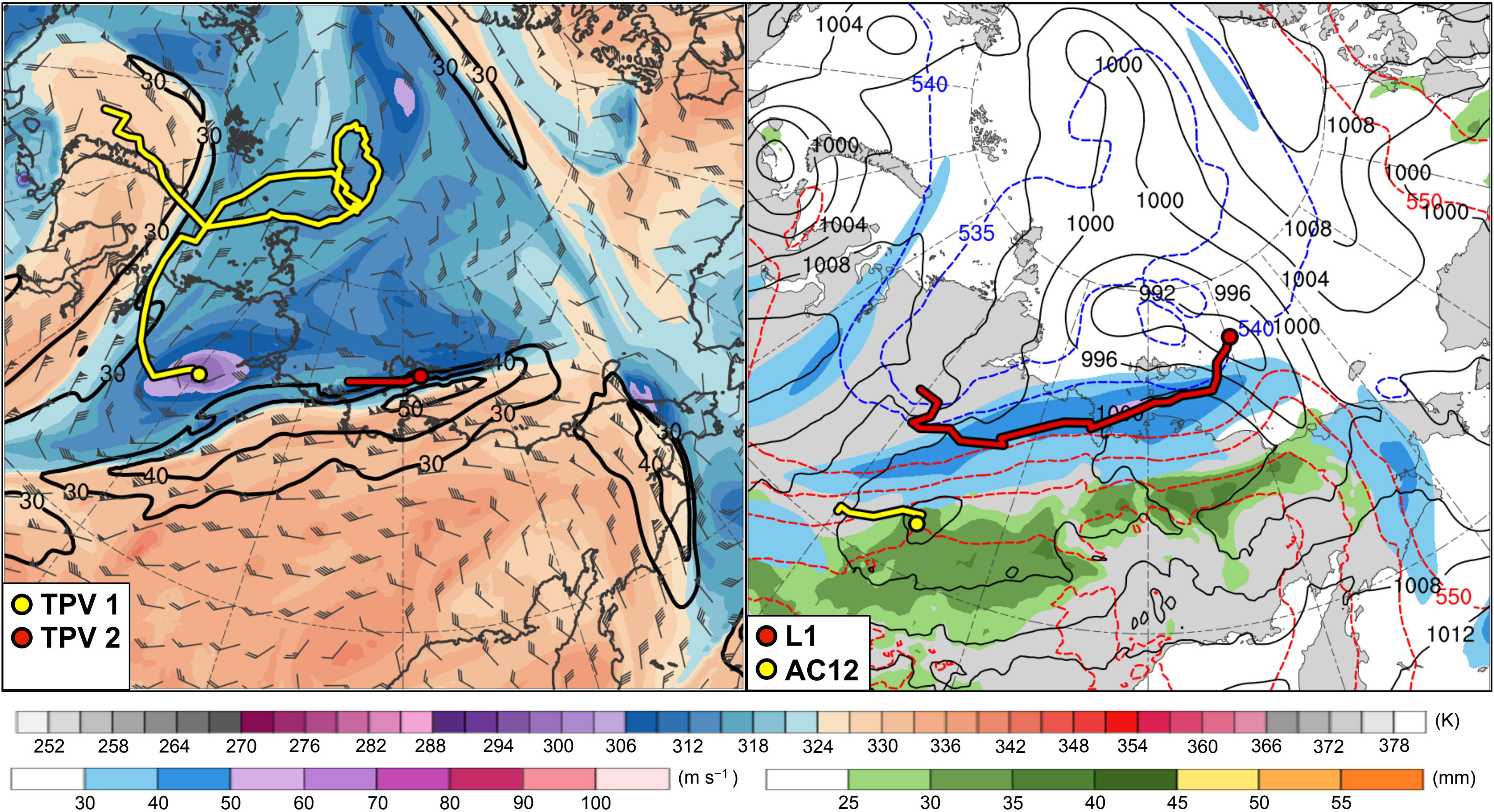


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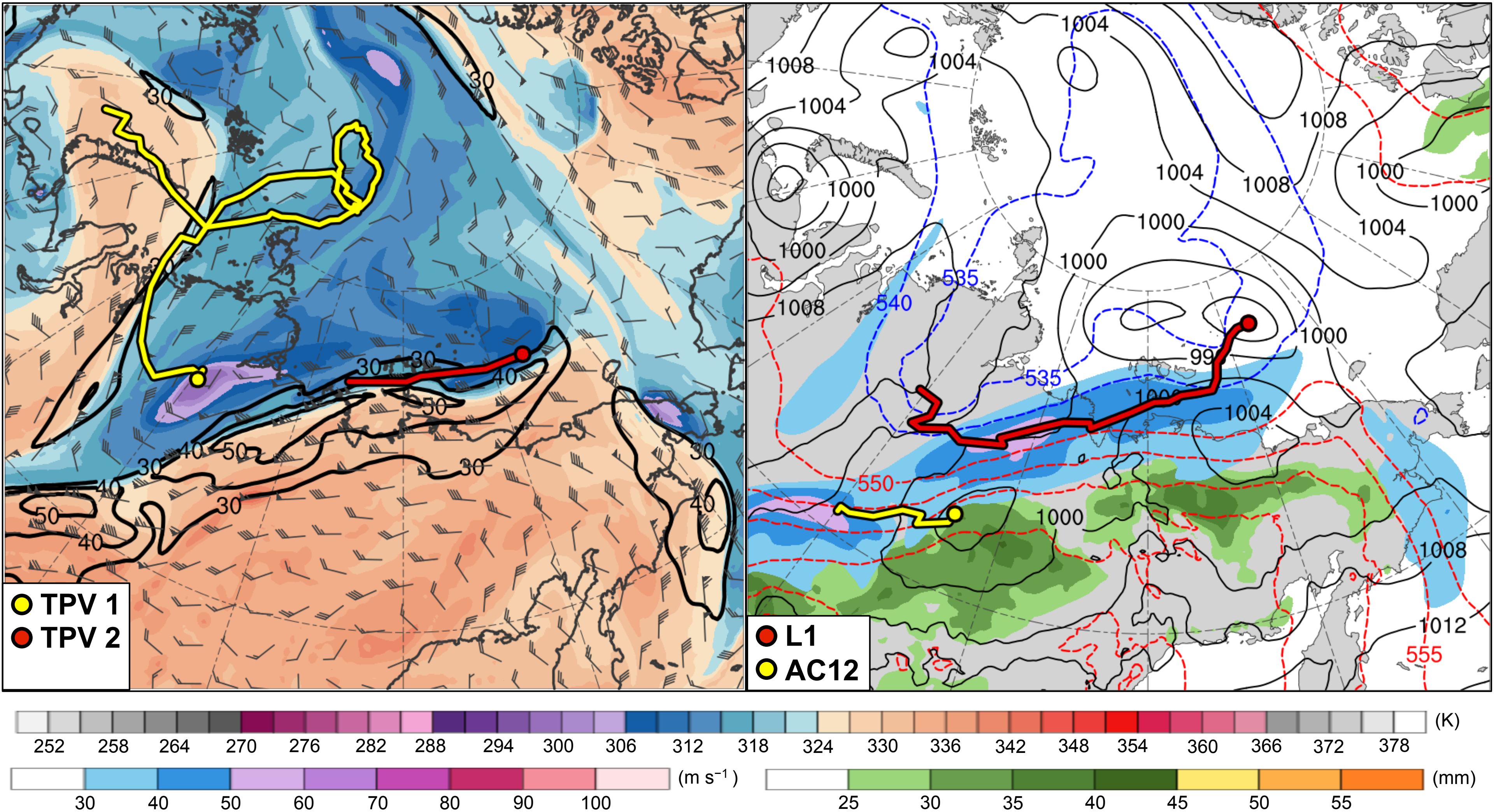


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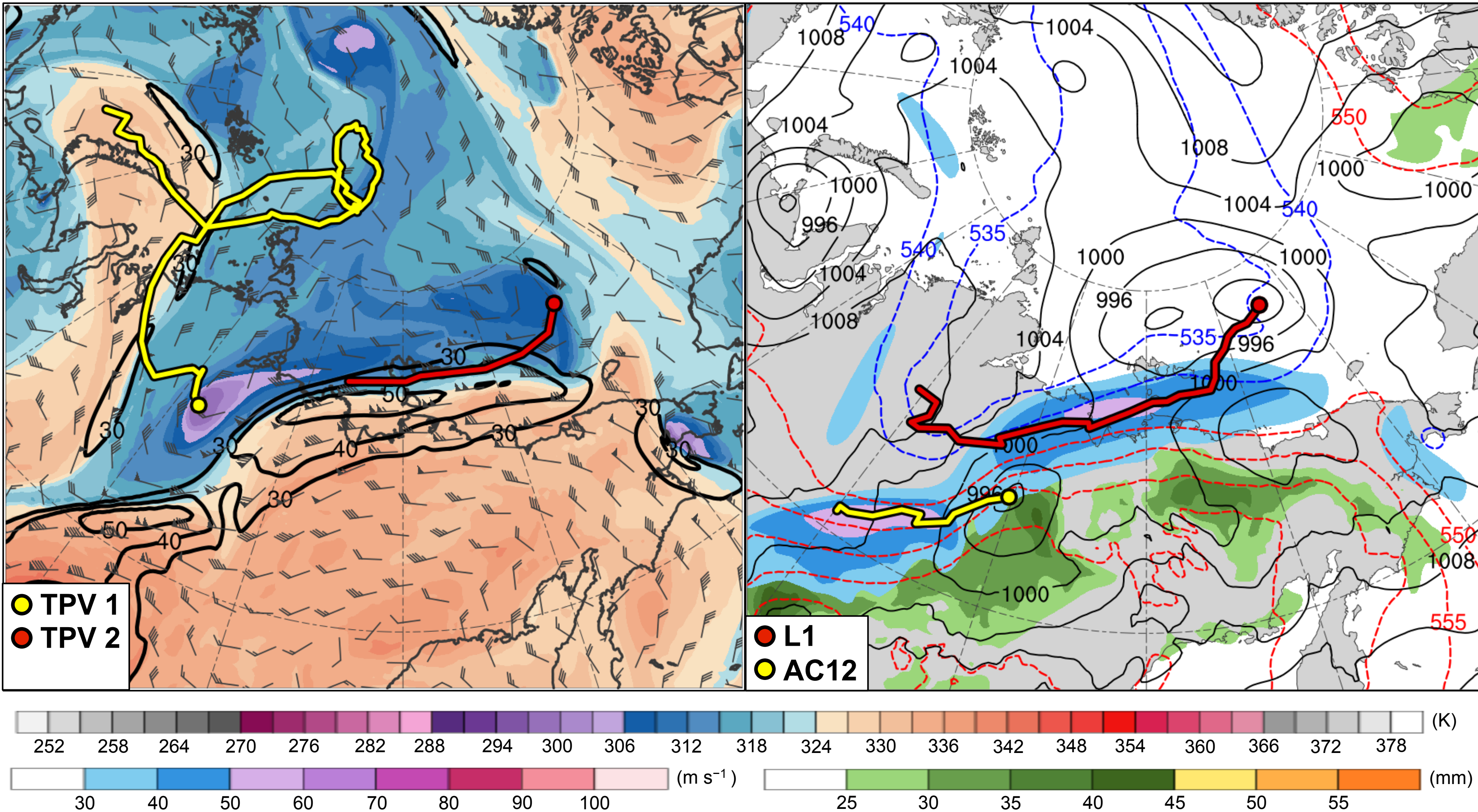


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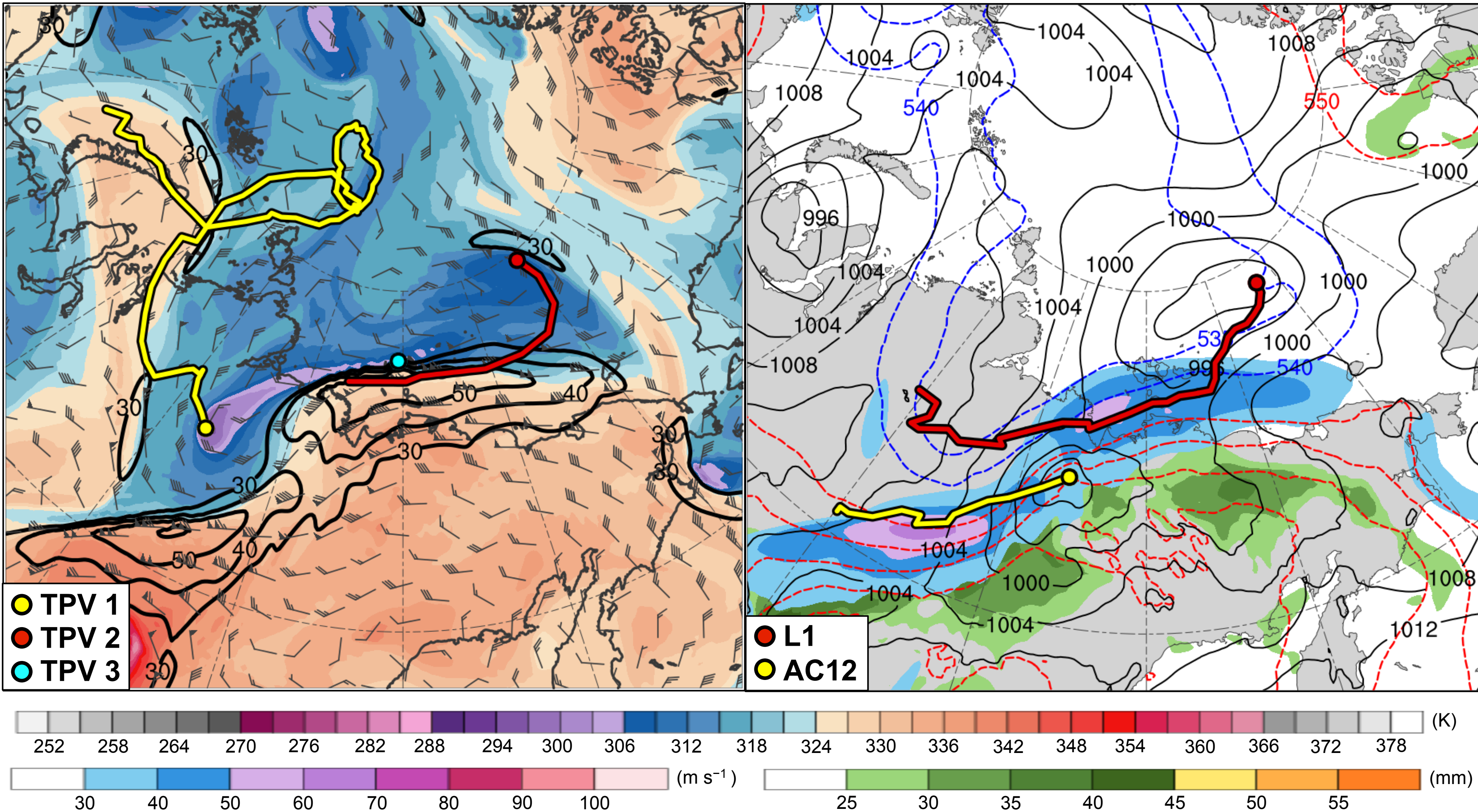


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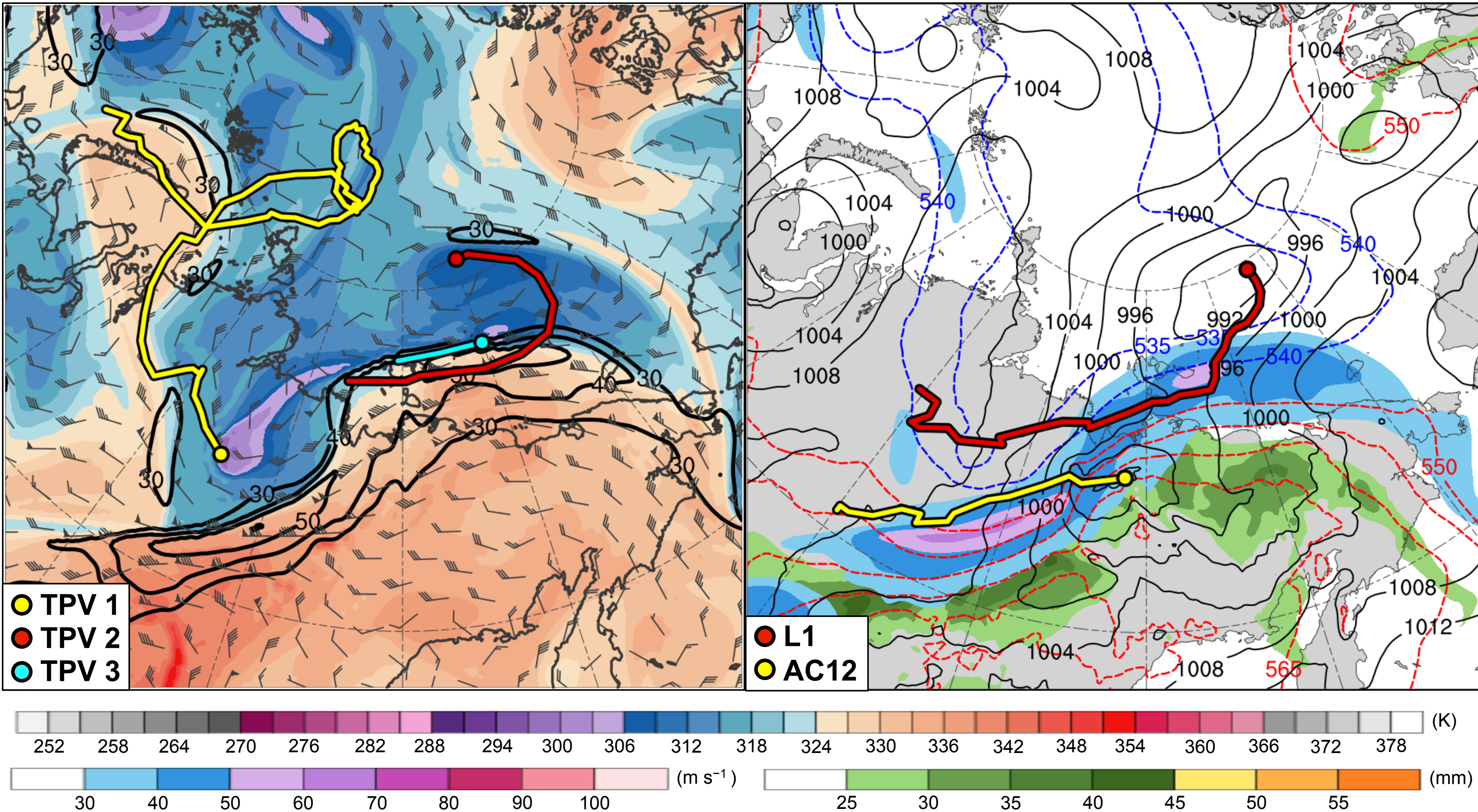


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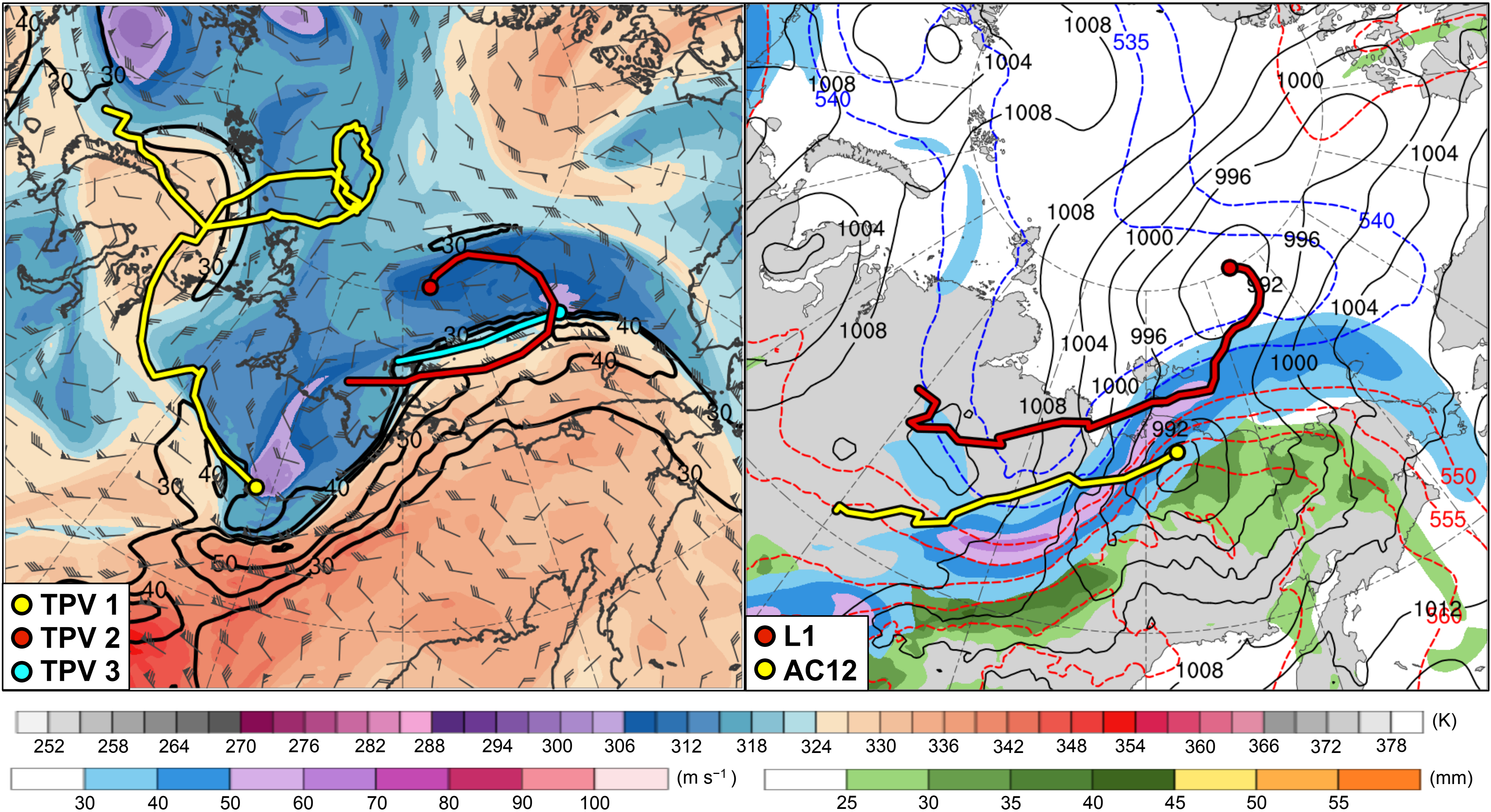


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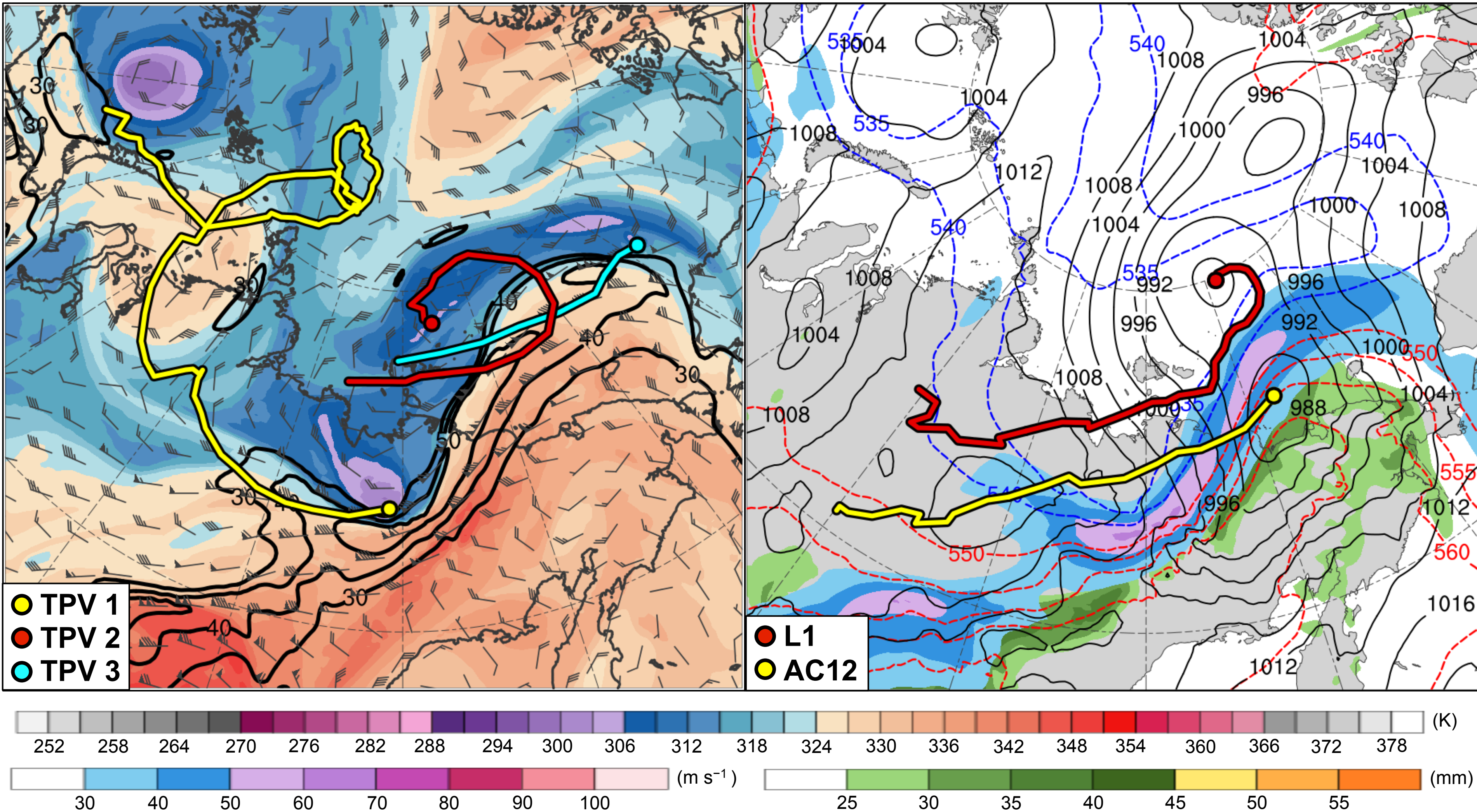


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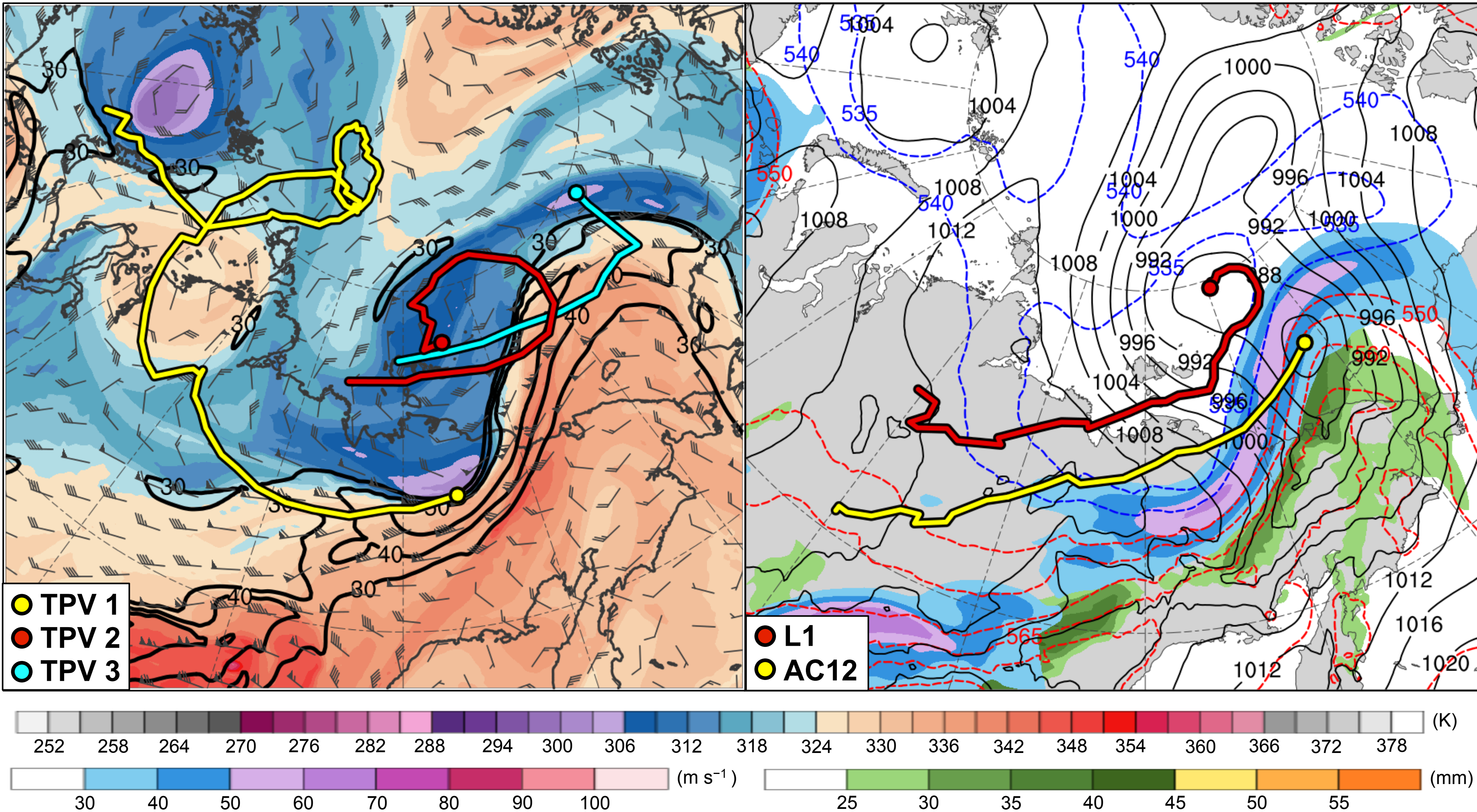
## 0600 UTC 5 Aug 2012

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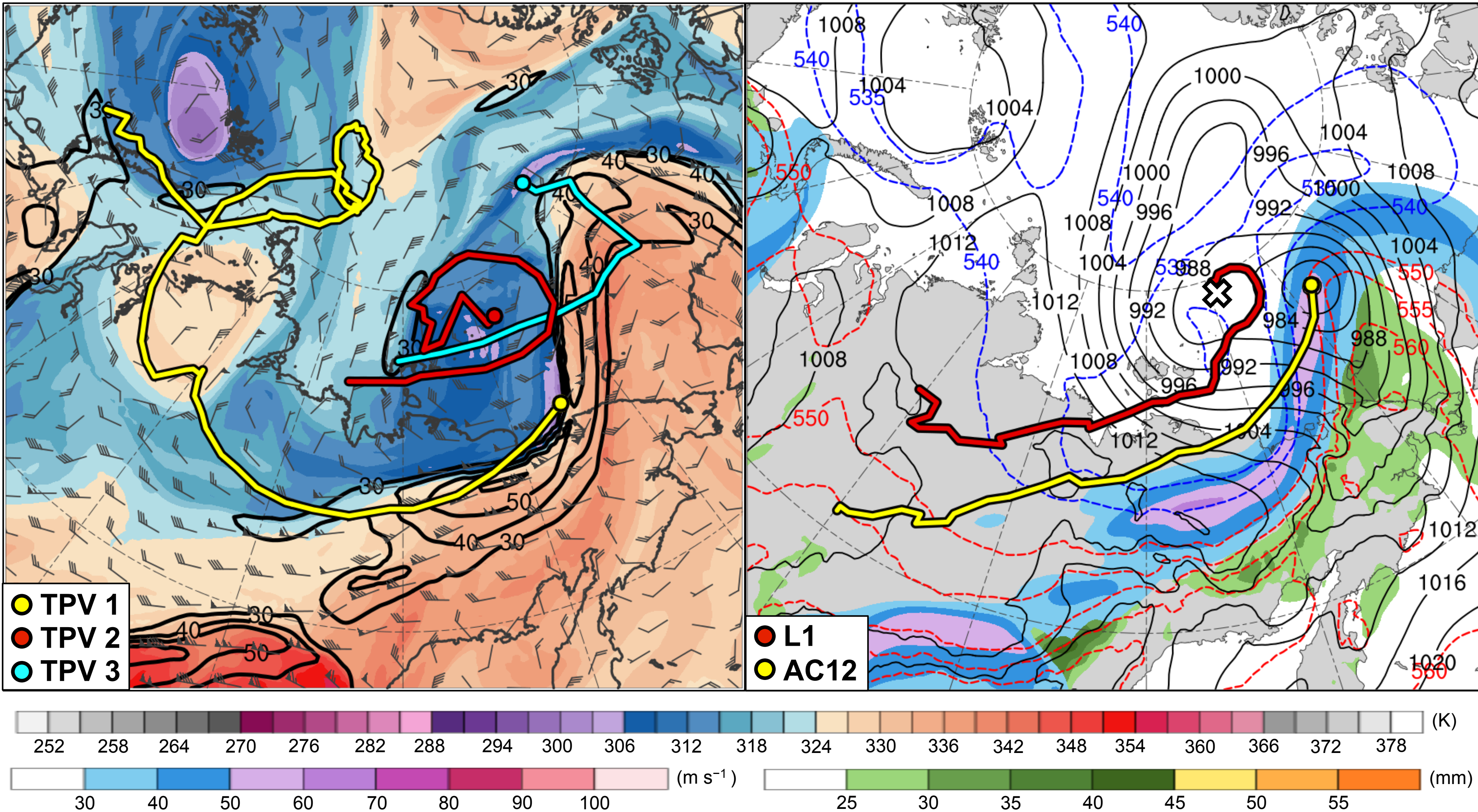


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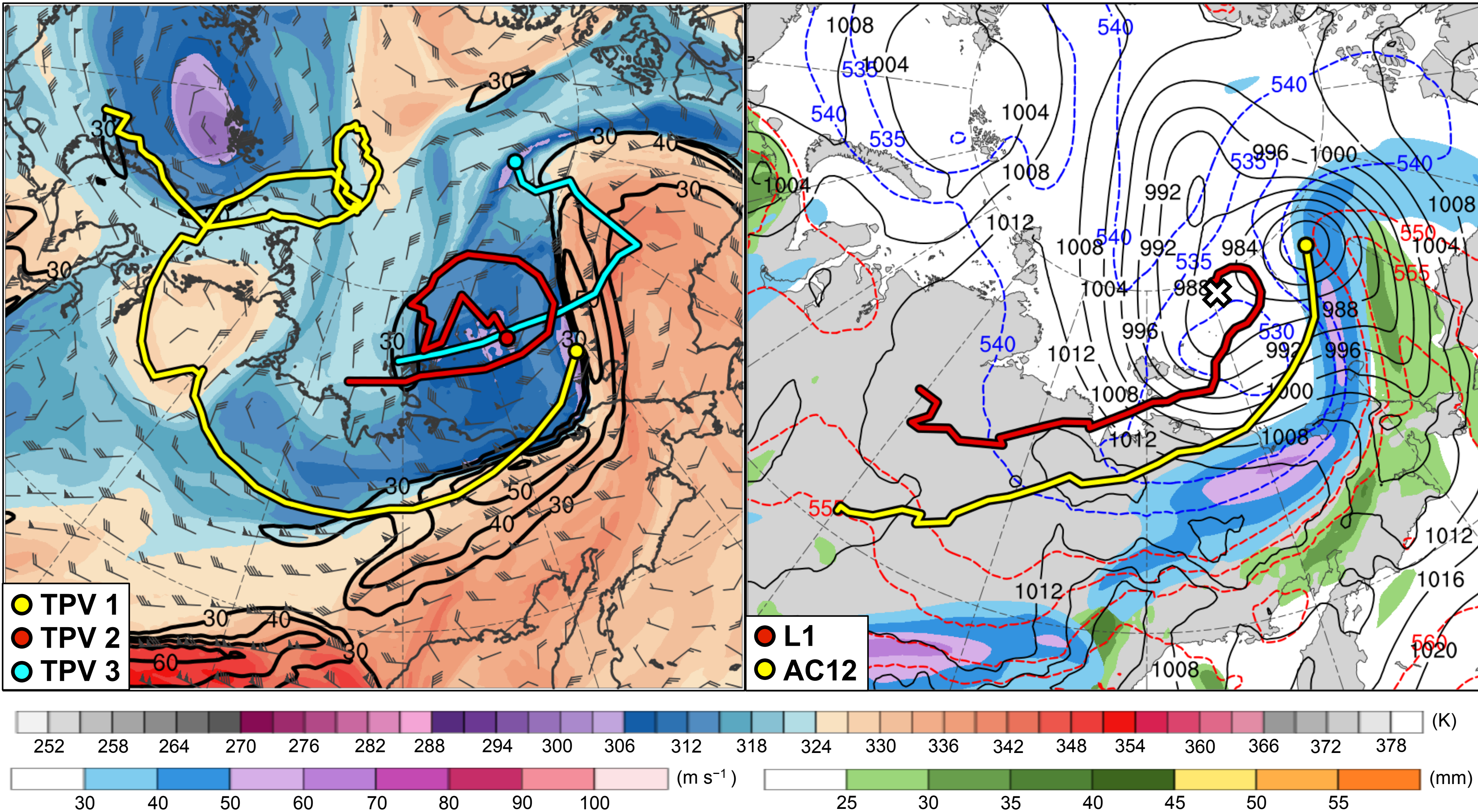
1800 UTC 5 Aug 2012

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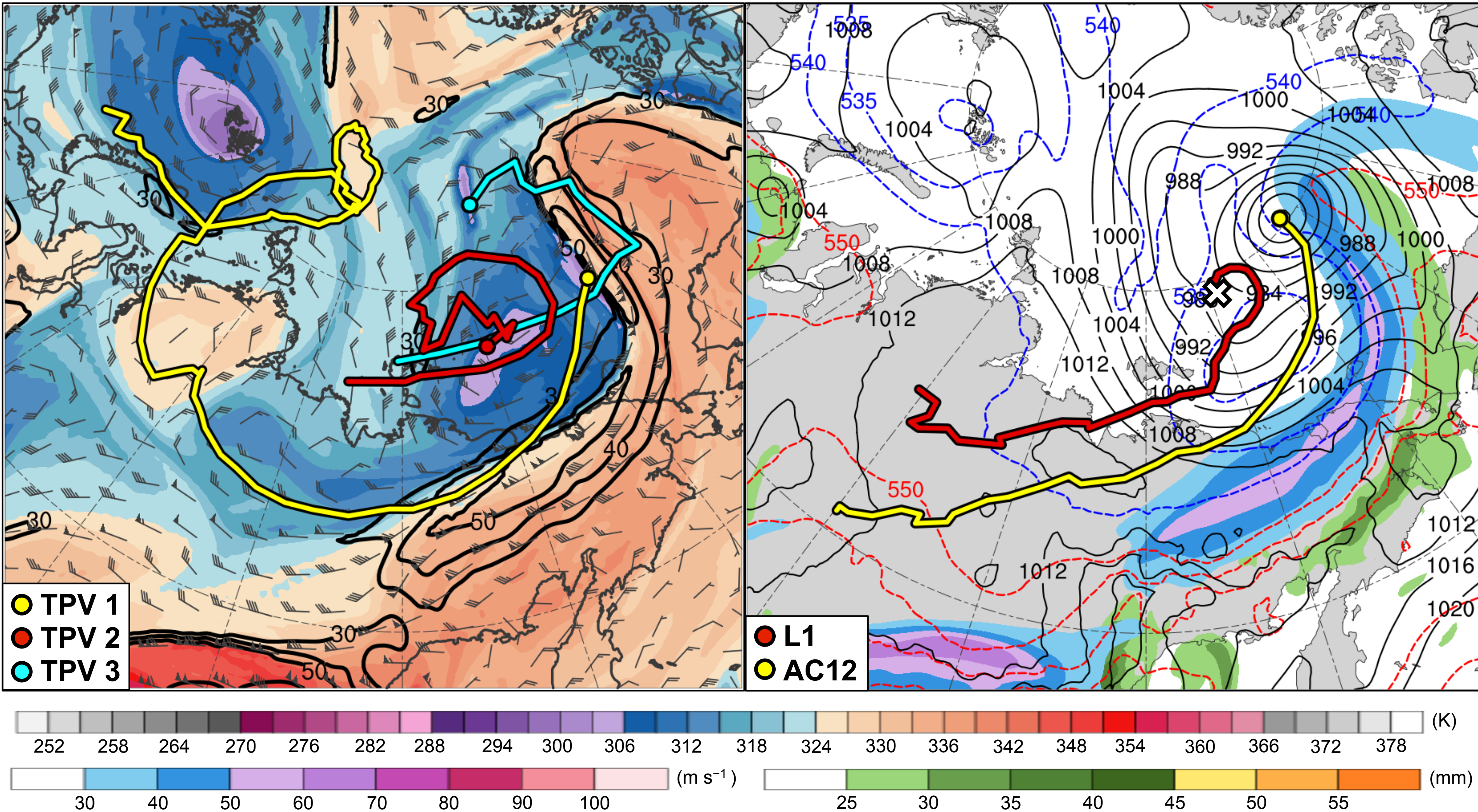


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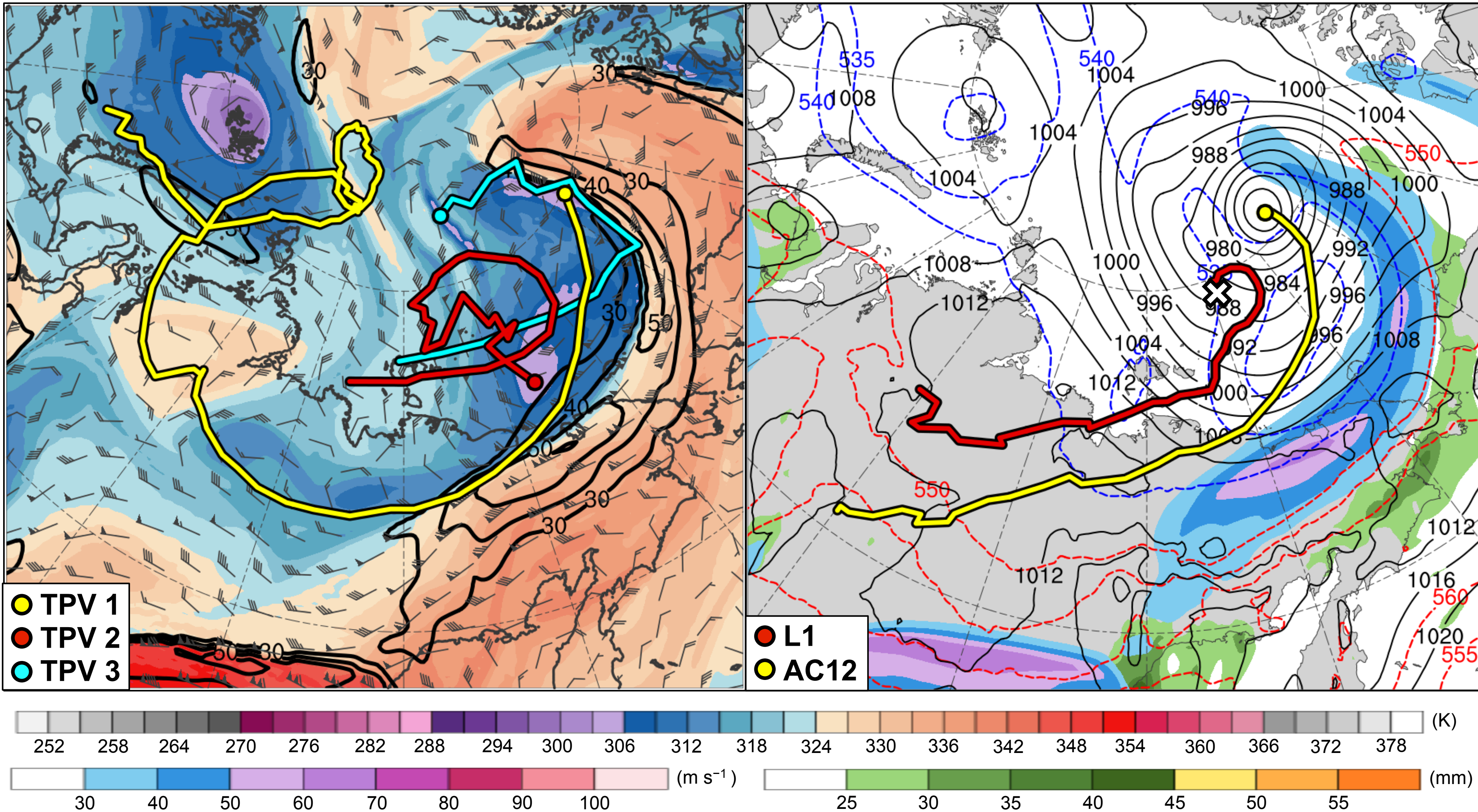
0600 UTC 6 Aug 2012

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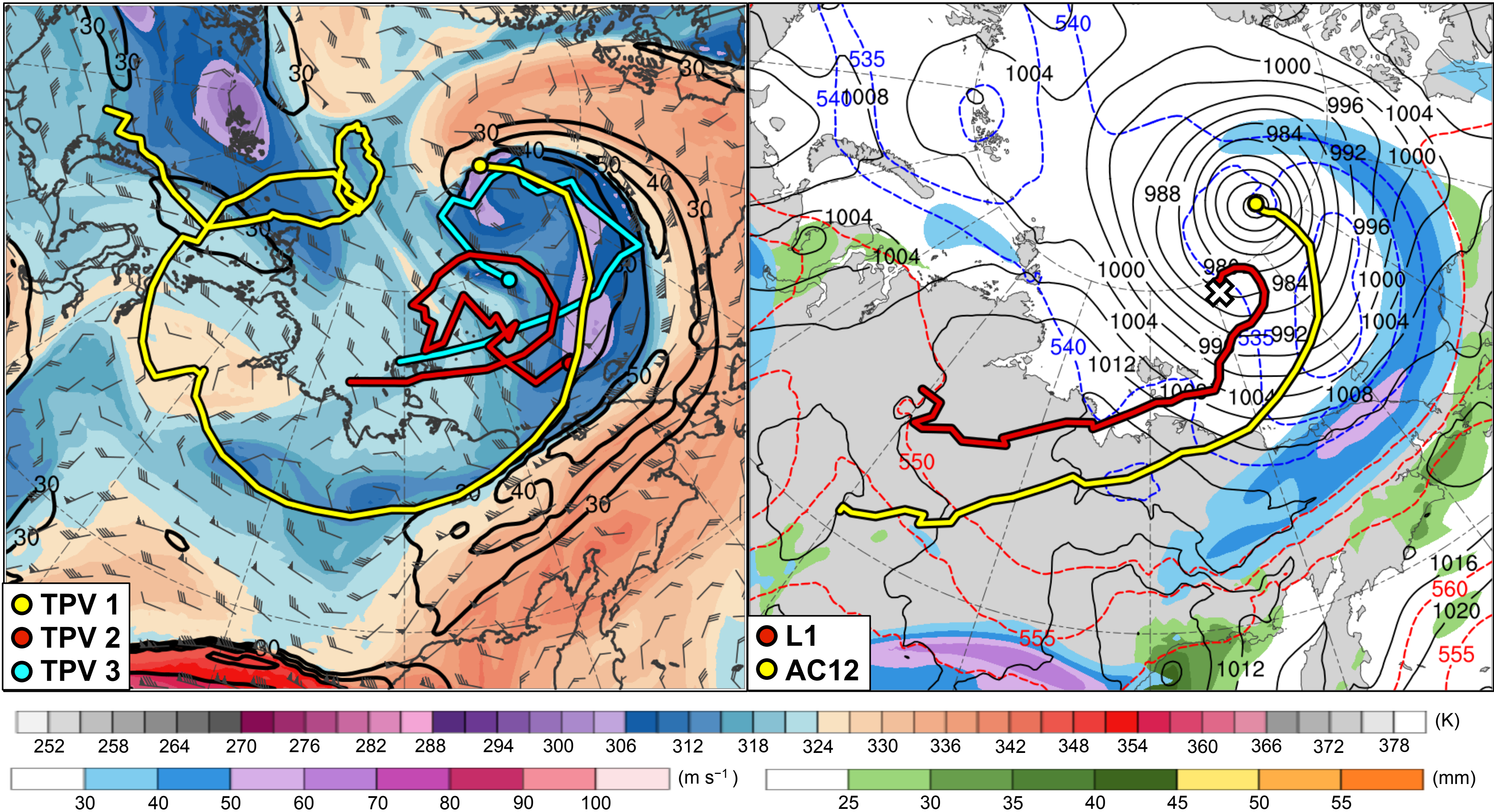


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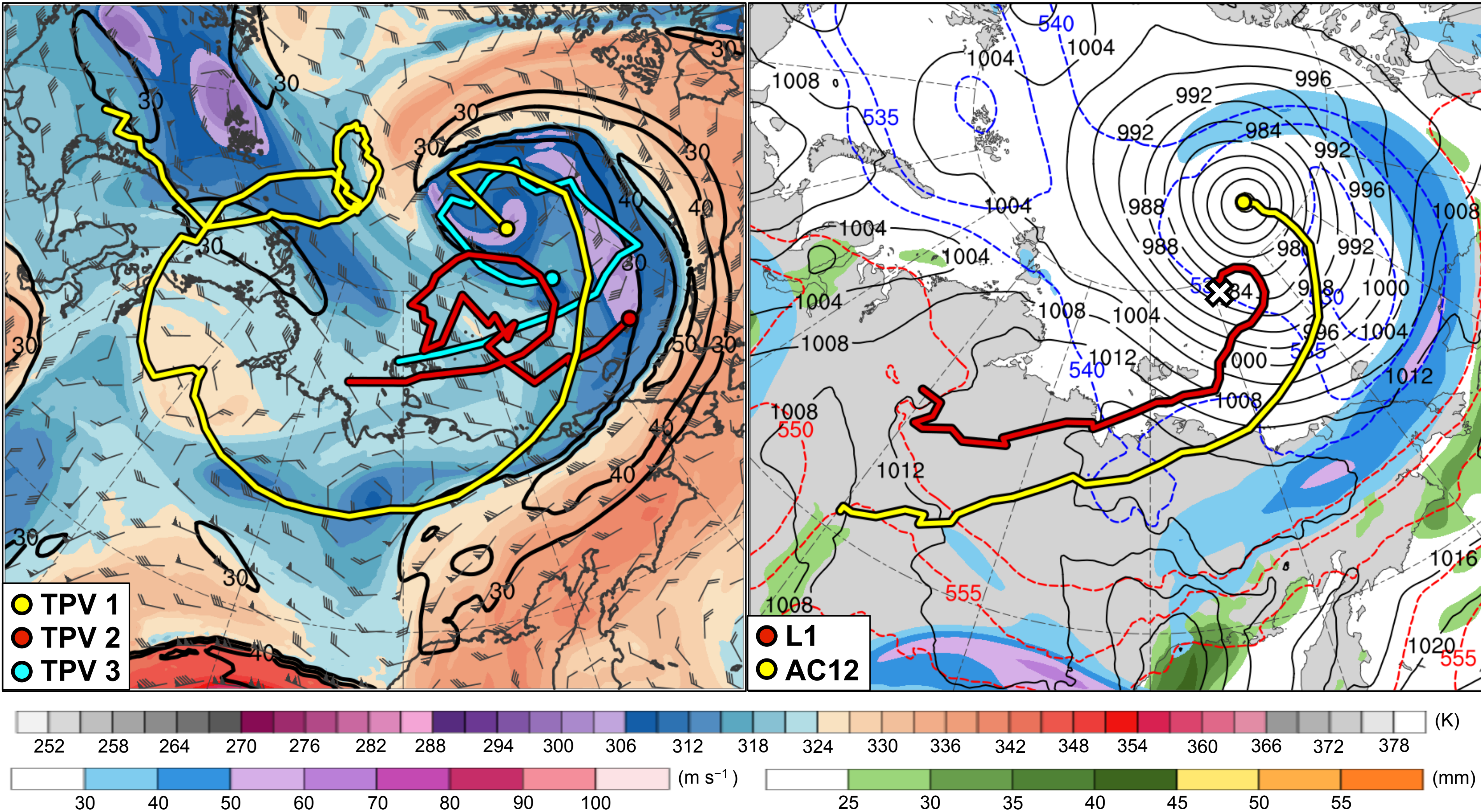


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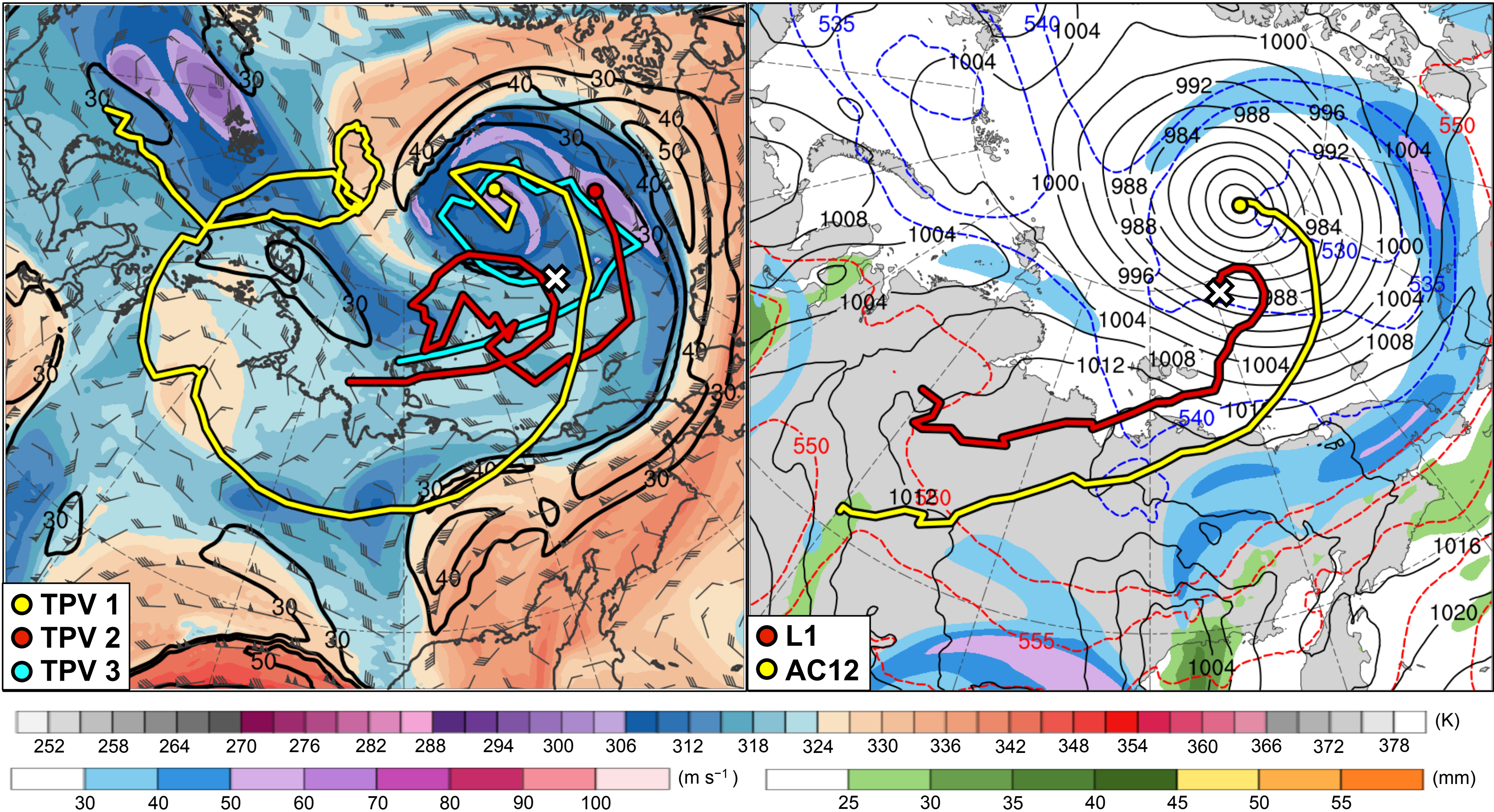


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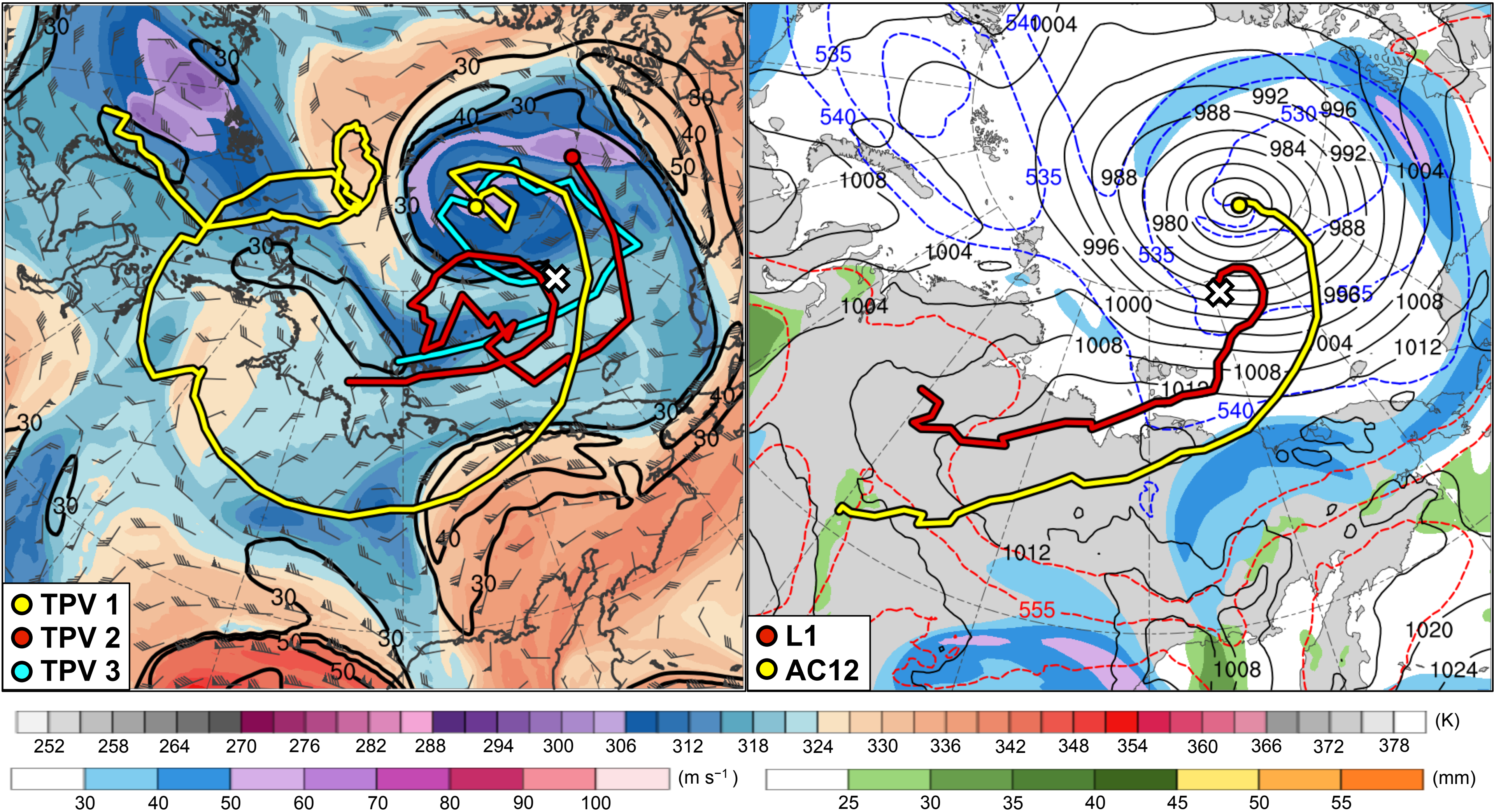


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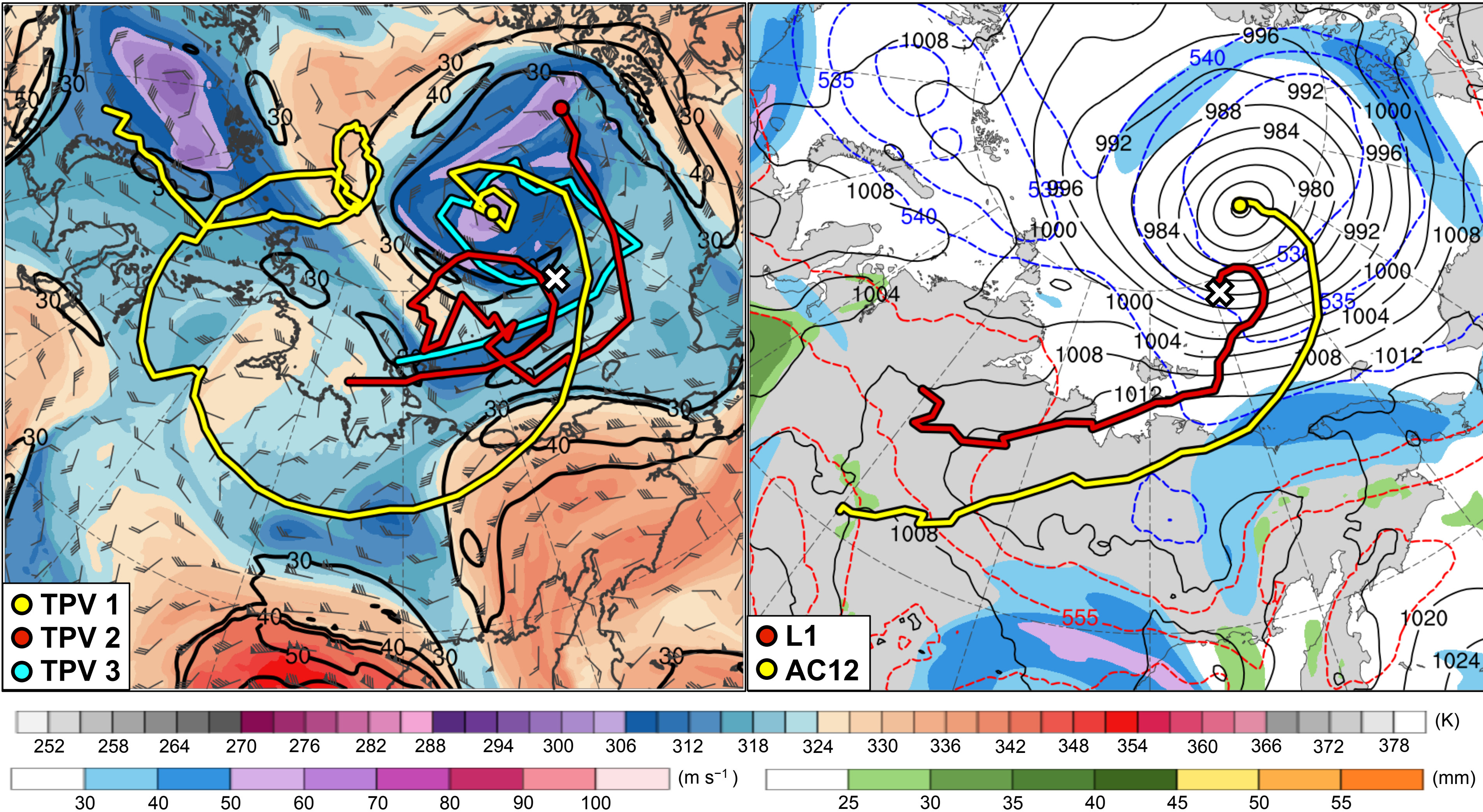


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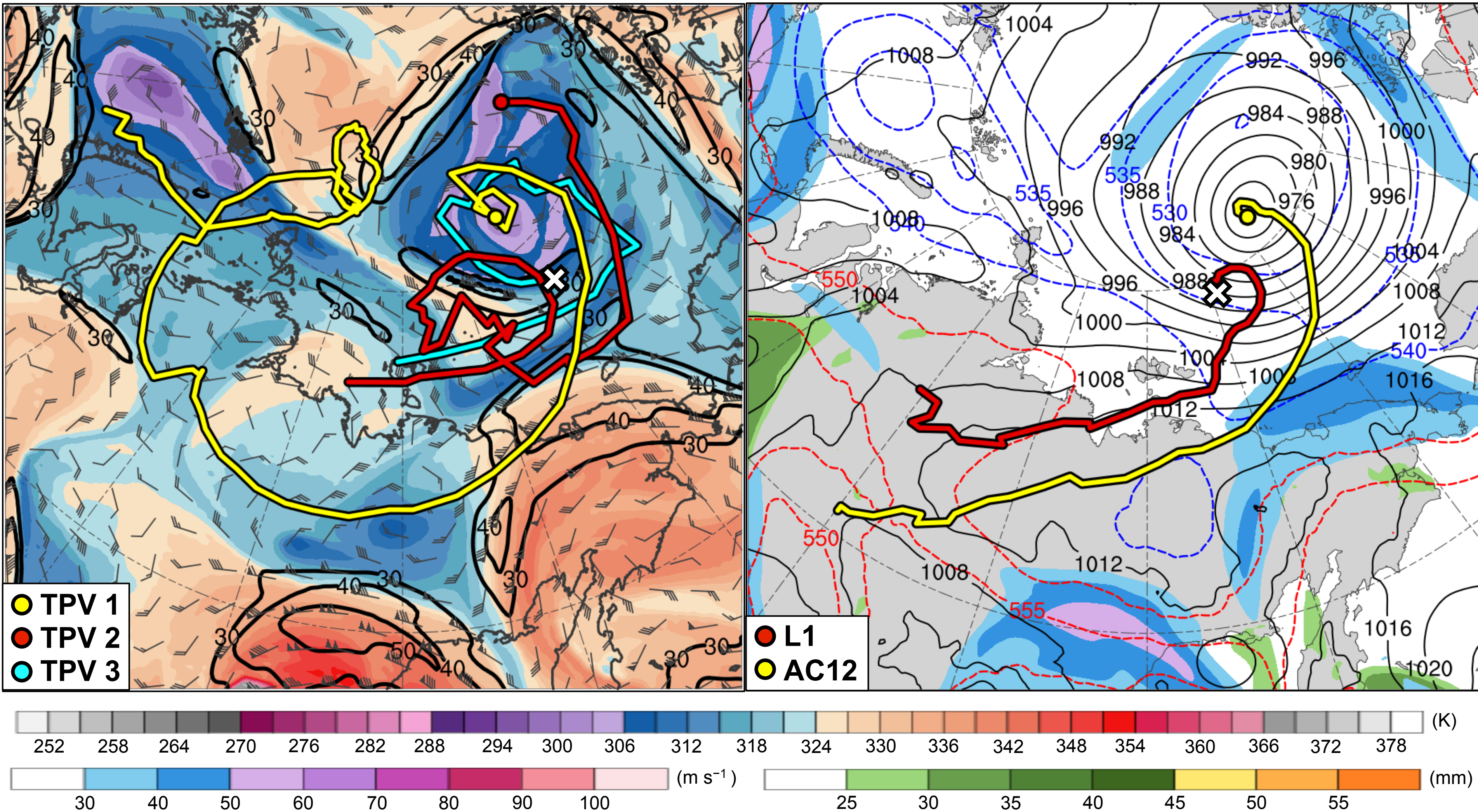


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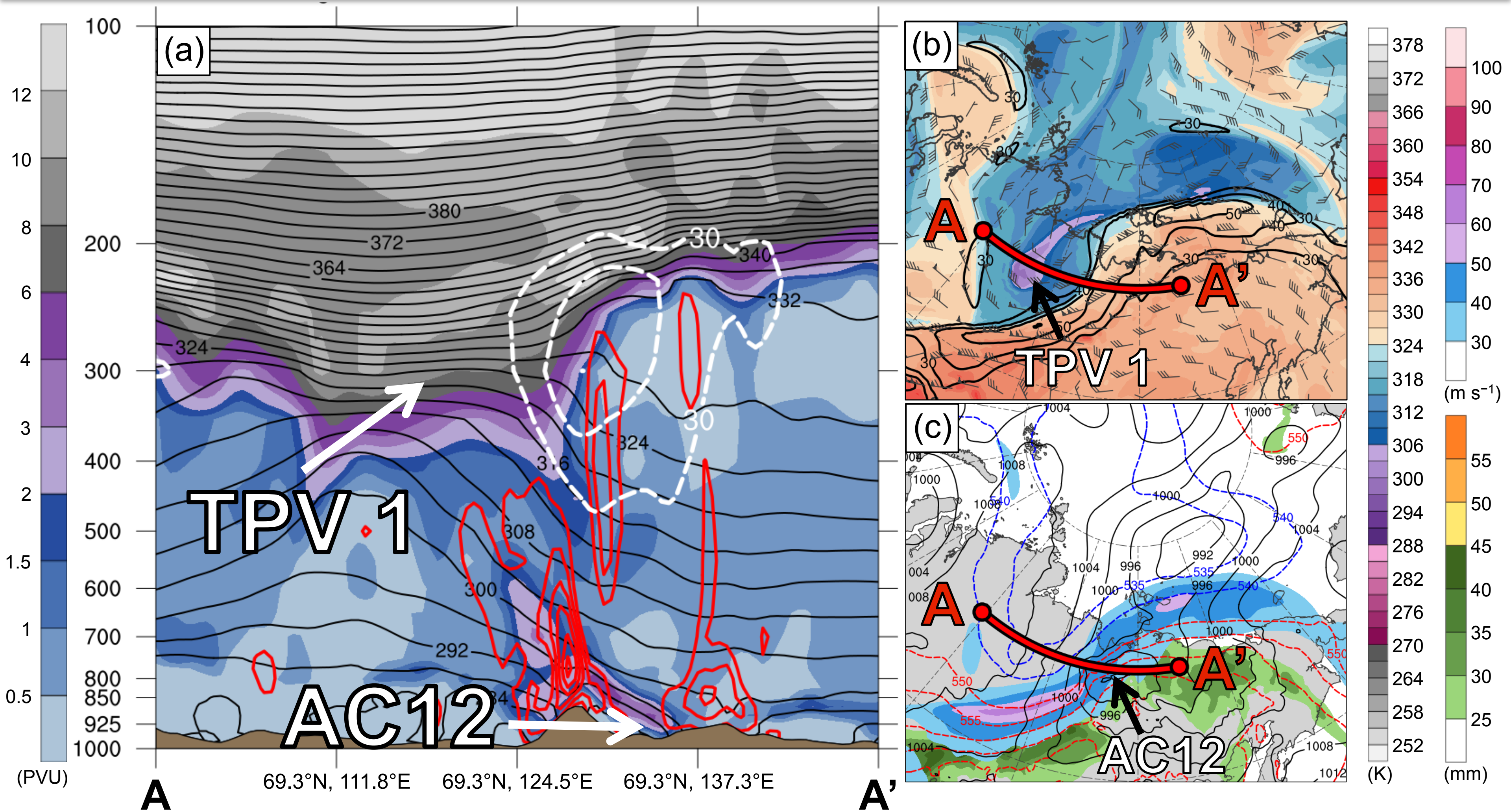
# Cross Sections

0600 UTC 4 Aug 2012




(a) PV (PVU, shaded), θ (K, black), ascent (red, every $3.0 \times 10^{-3}$ hPa $s^{-1}$), and wind speed (dashed white, m $s^{-1}$); (b) DT (2-PVU surface) θ (K, shaded), wind speed (black, m $s^{-1}$), and wind (m $s^{-1}$, flags and barbs); (c) 250-hPa wind speed (m $s^{-1}$, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), PW (mm, shaded)

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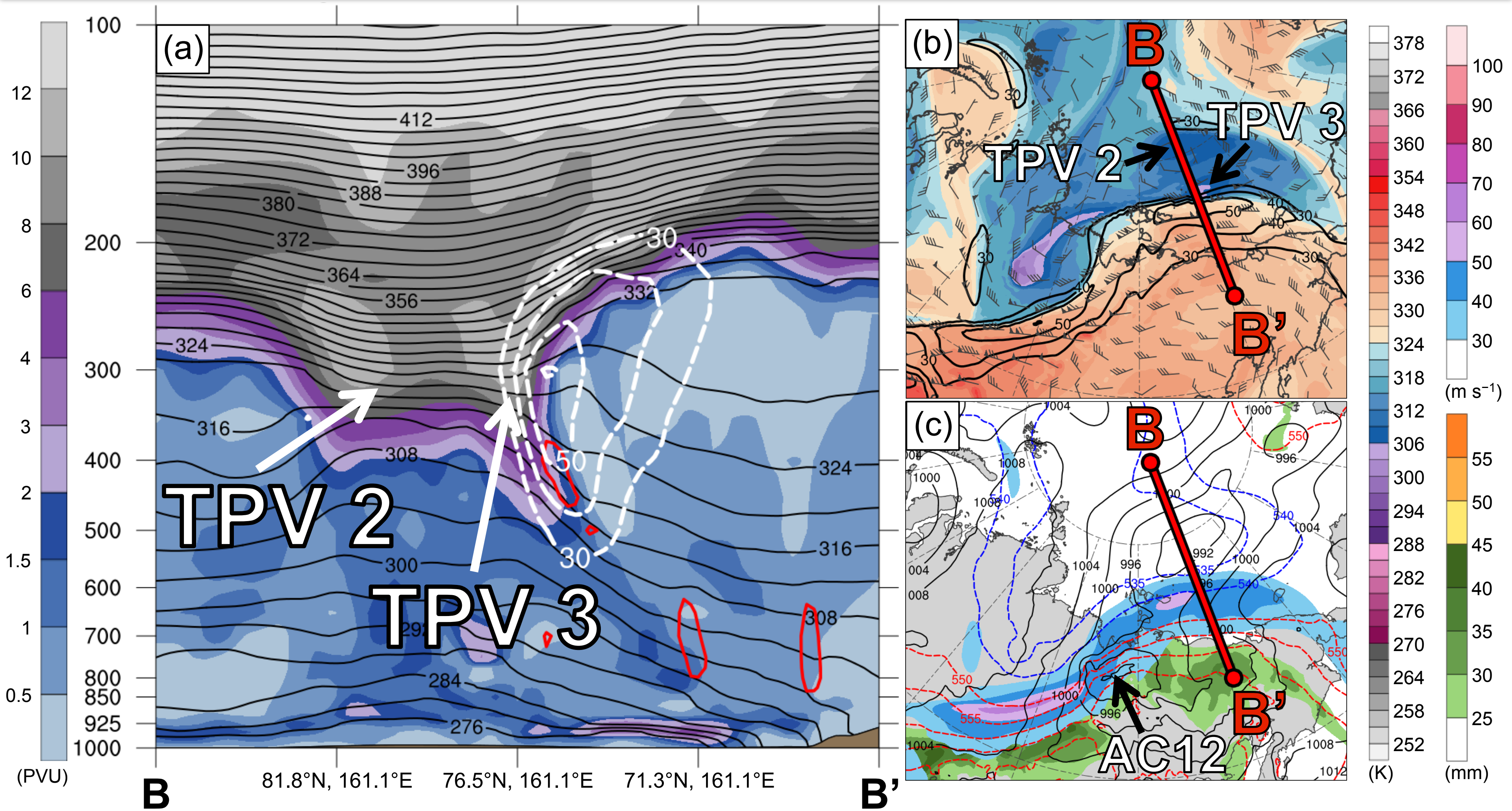


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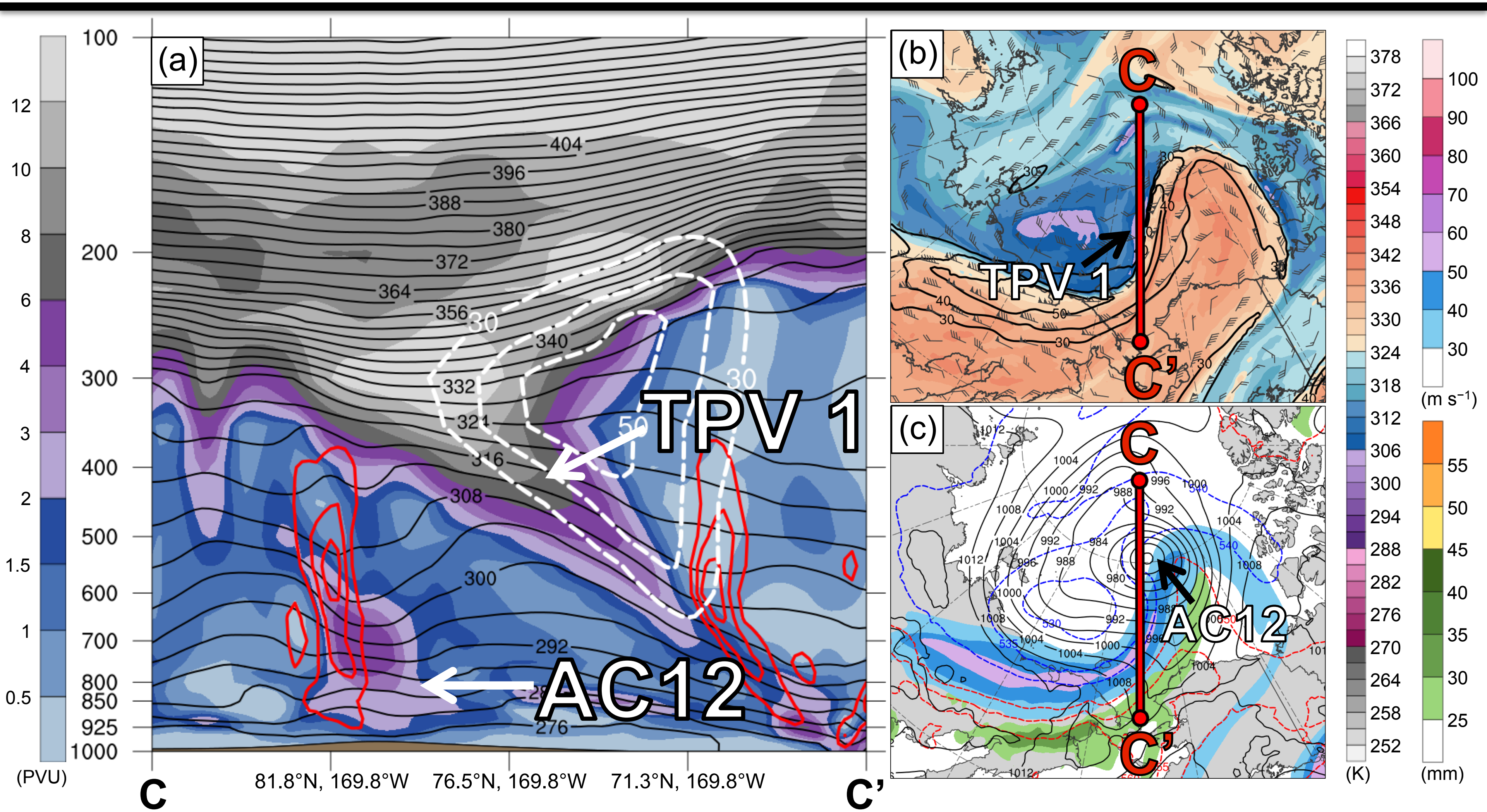


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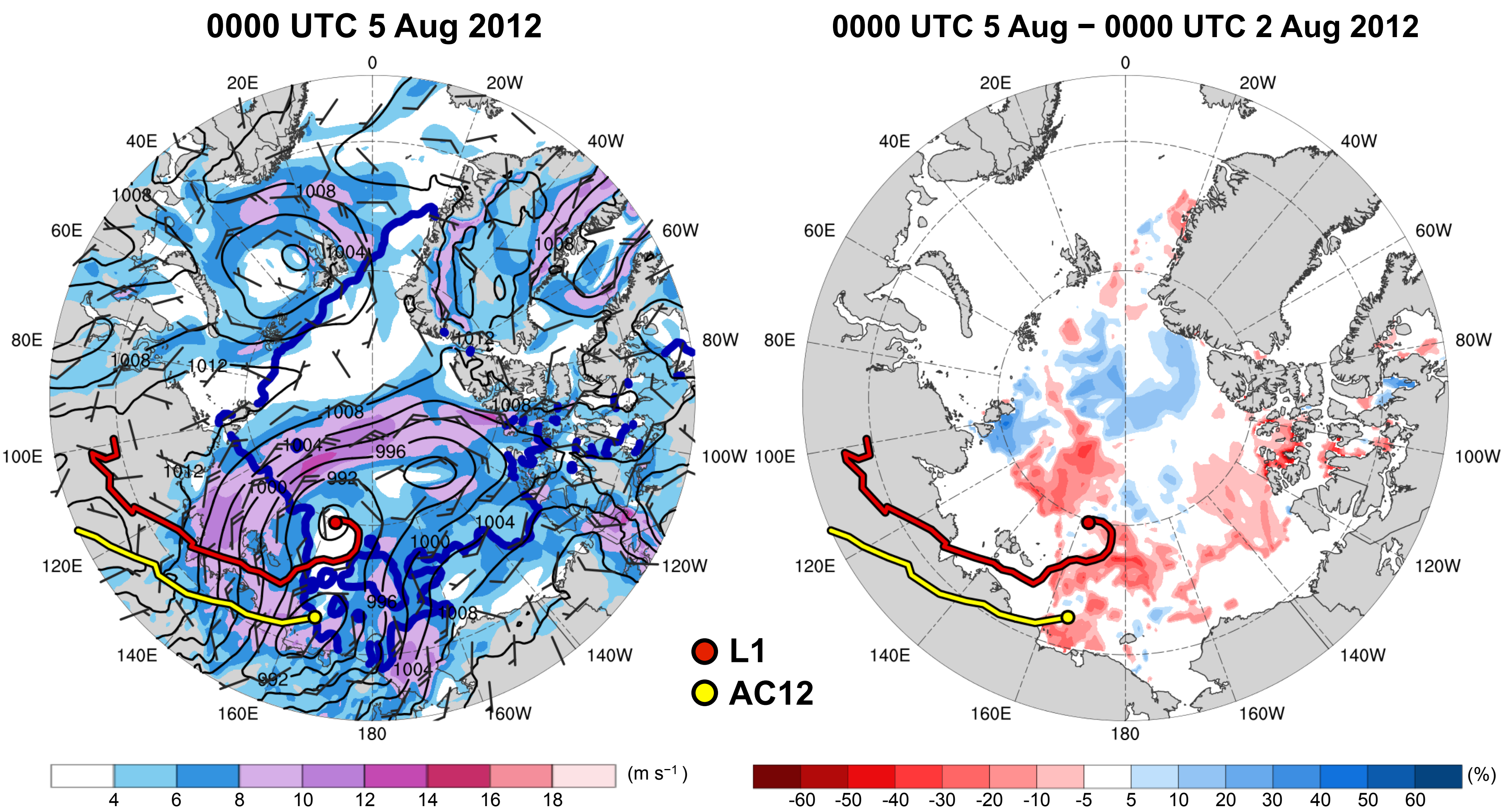
# Reduction in Arctic Sea Ice

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| SLP (hPa, black); 10-m wind speed (m $s^{-1}$, shaded) and wind (m $s^{-1}$, black barbs); and 20% contour of sea-ice concentration (thick blue) | Change in sea-ice concentration (shaded, %) since 0000 UTC 2 Aug 2012 |

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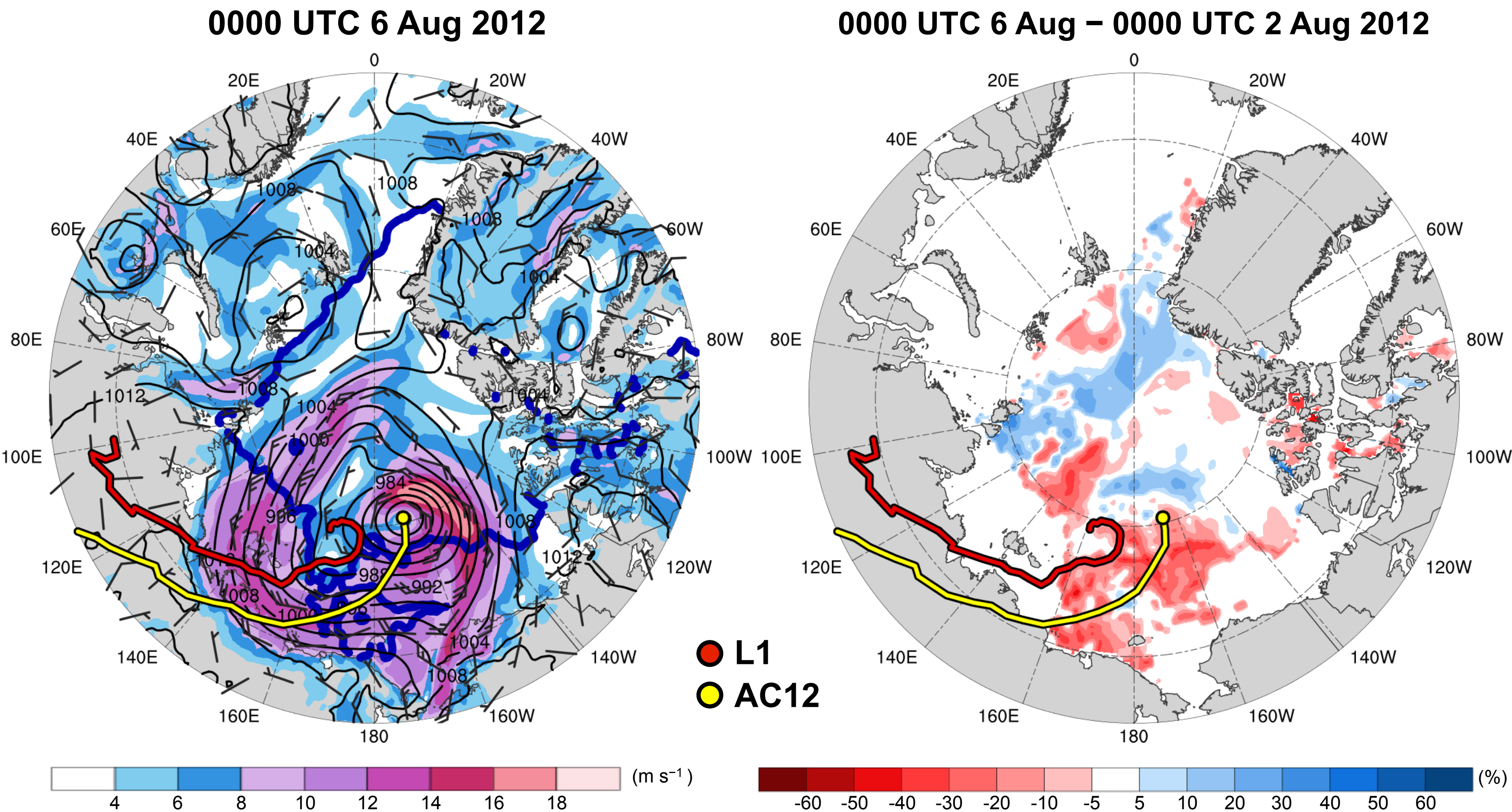


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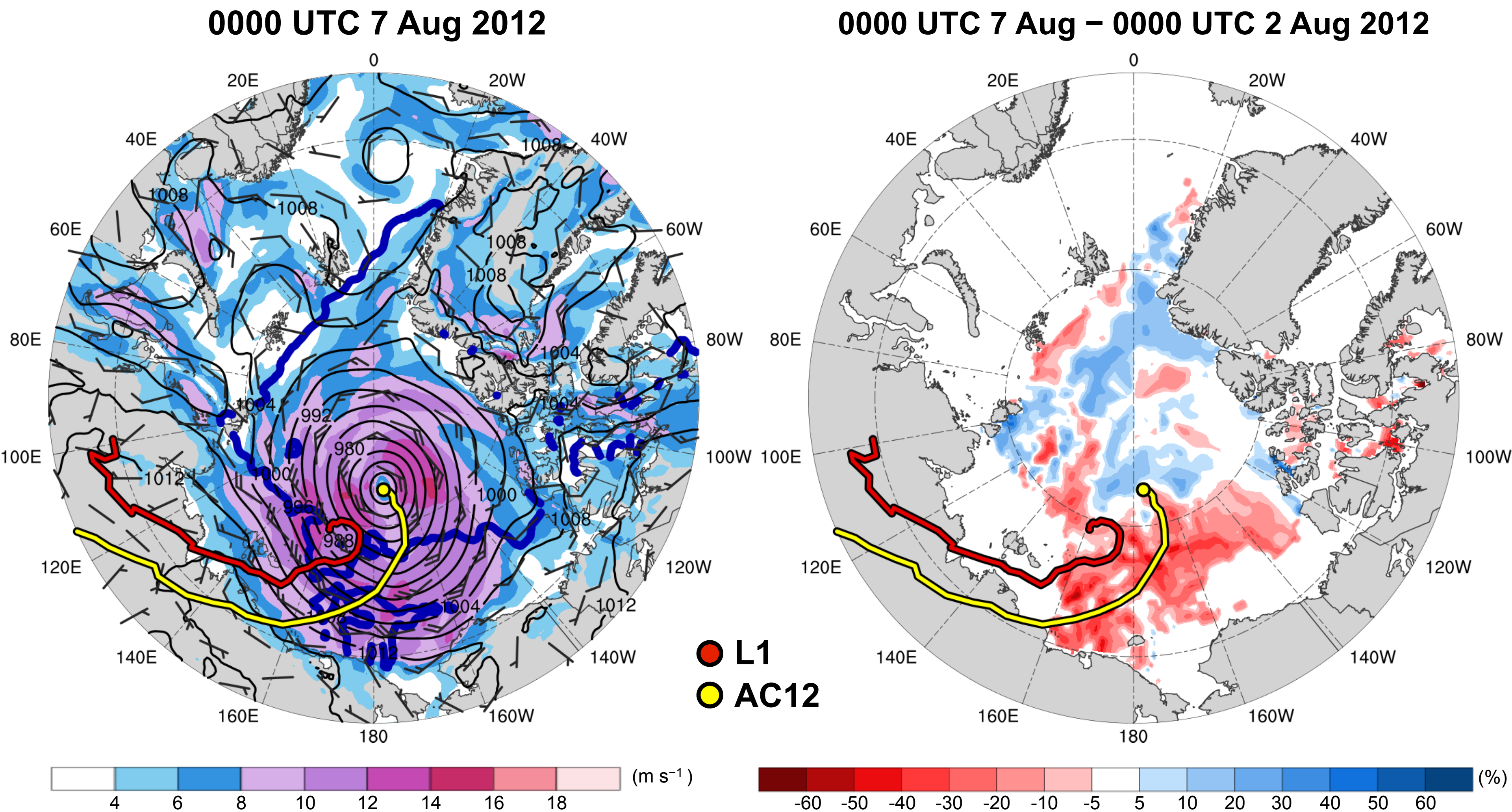


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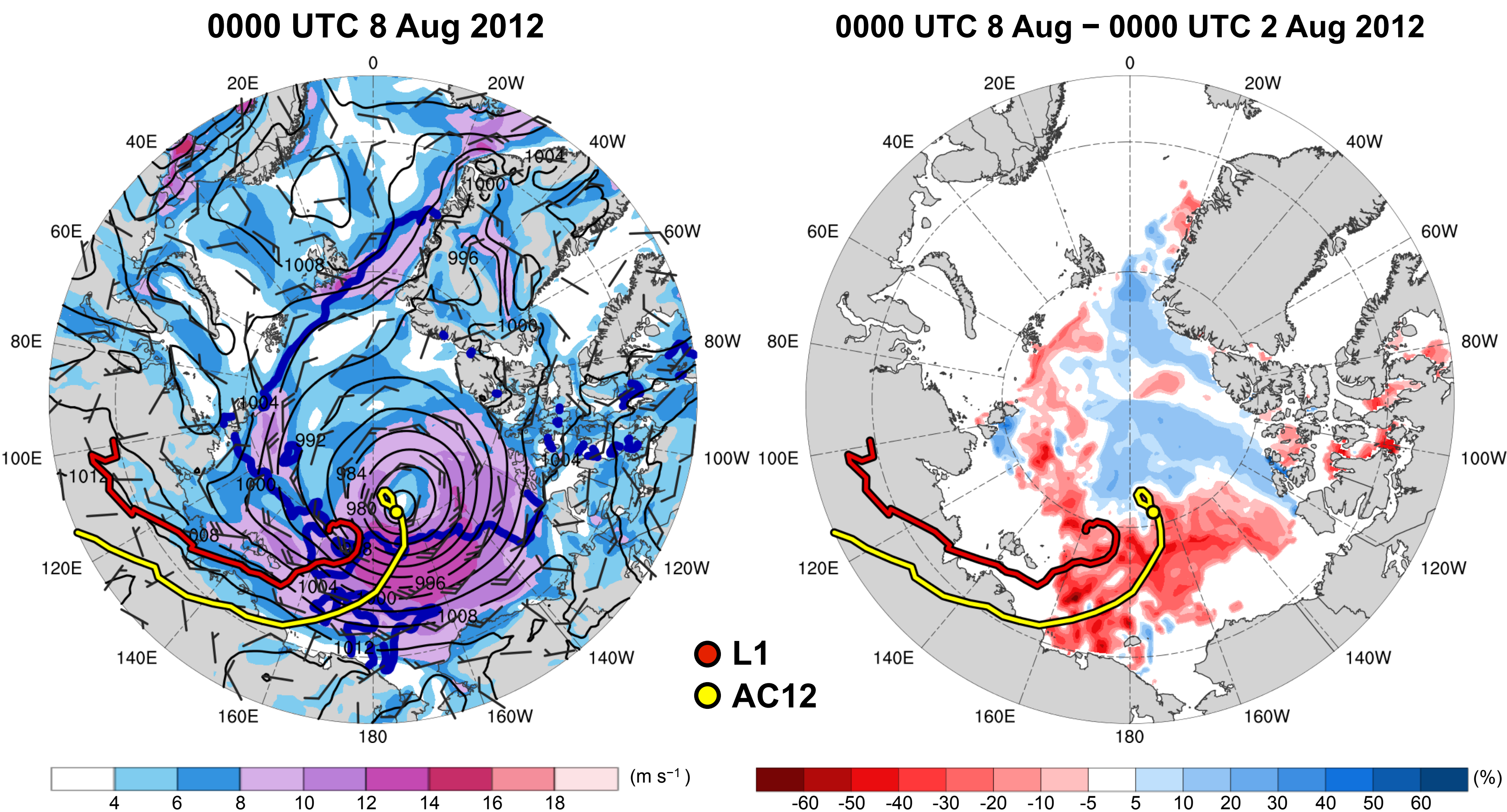


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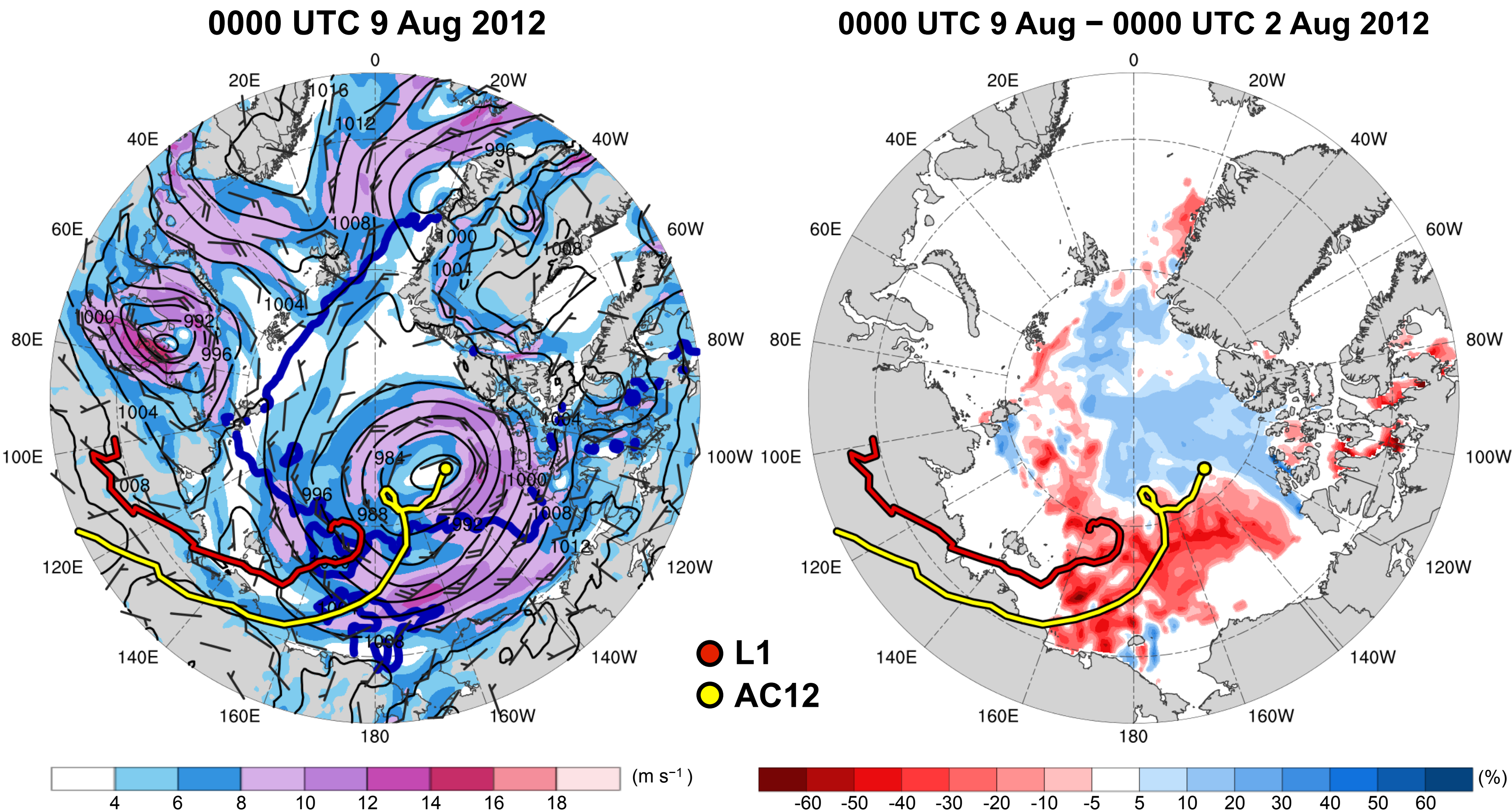


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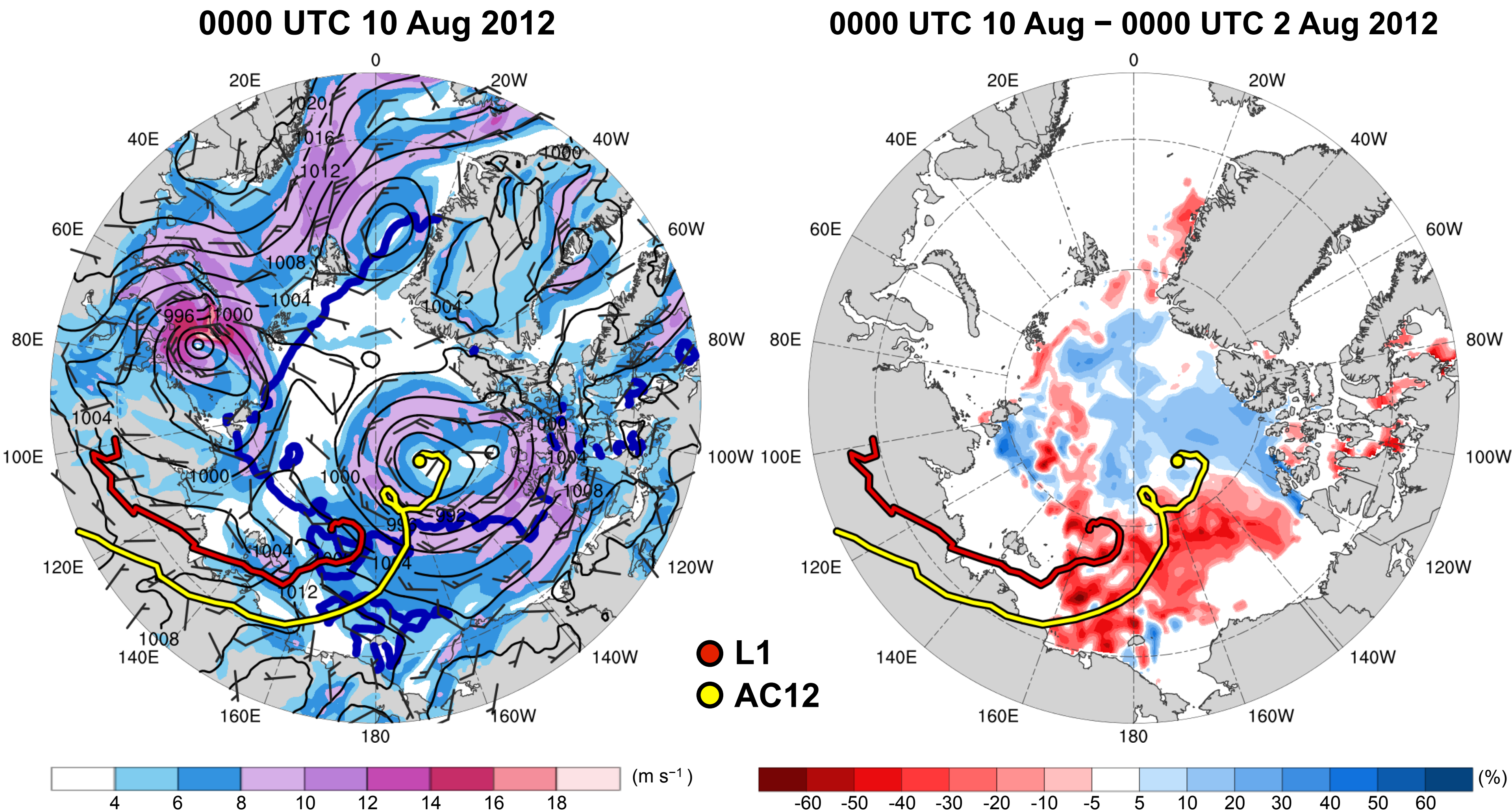


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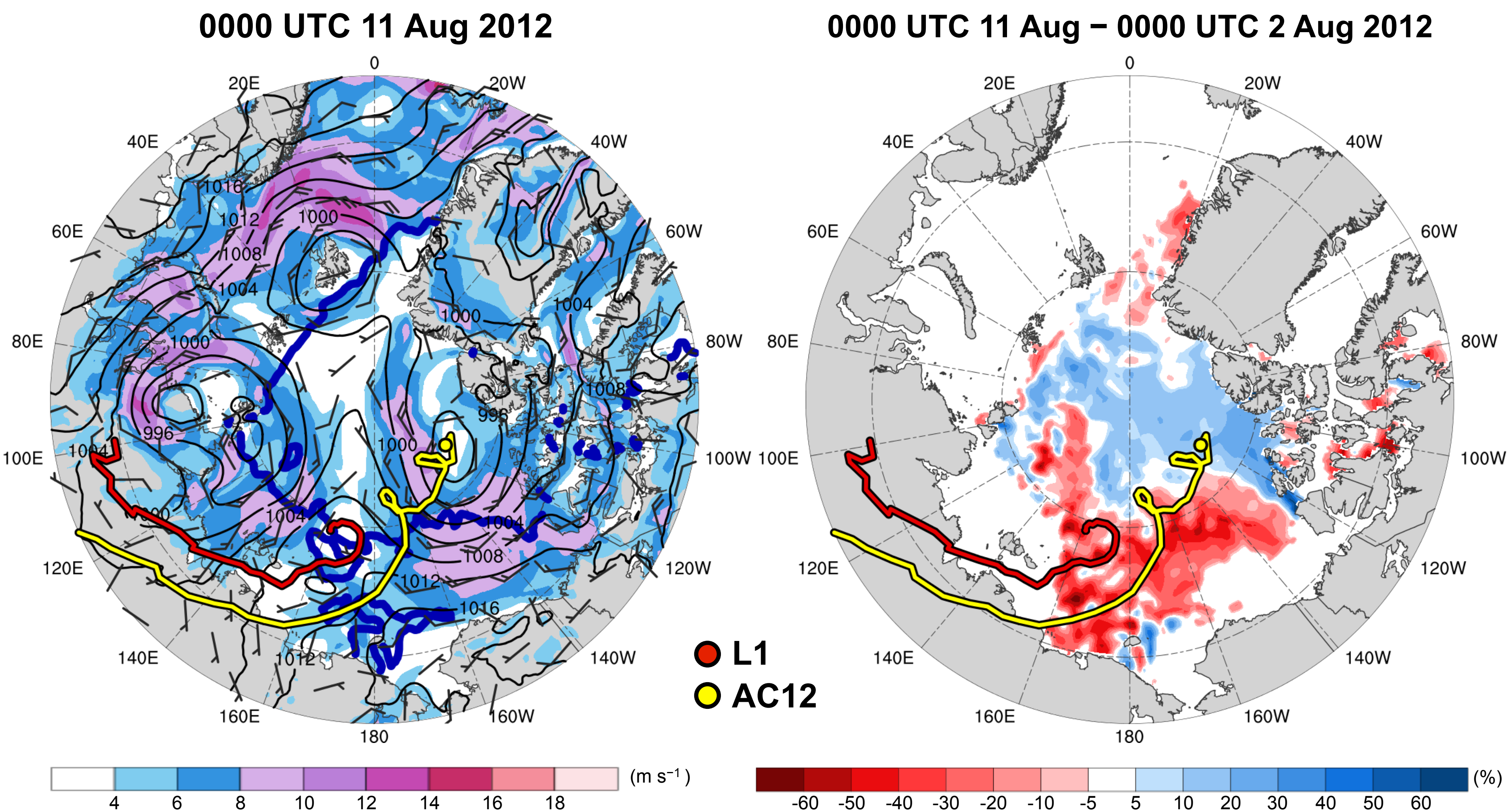
# Reduction in Arctic Sea Ice




SLP (hPa, black); 10-m wind speed (m $s^{-1}$, shaded) and wind (m $s^{-1}$, black barbs); and 20% contour of sea-ice concentration (thick blue)

Change in sea-ice concentration (shaded, %) since 0000 UTC 2 Aug 2012

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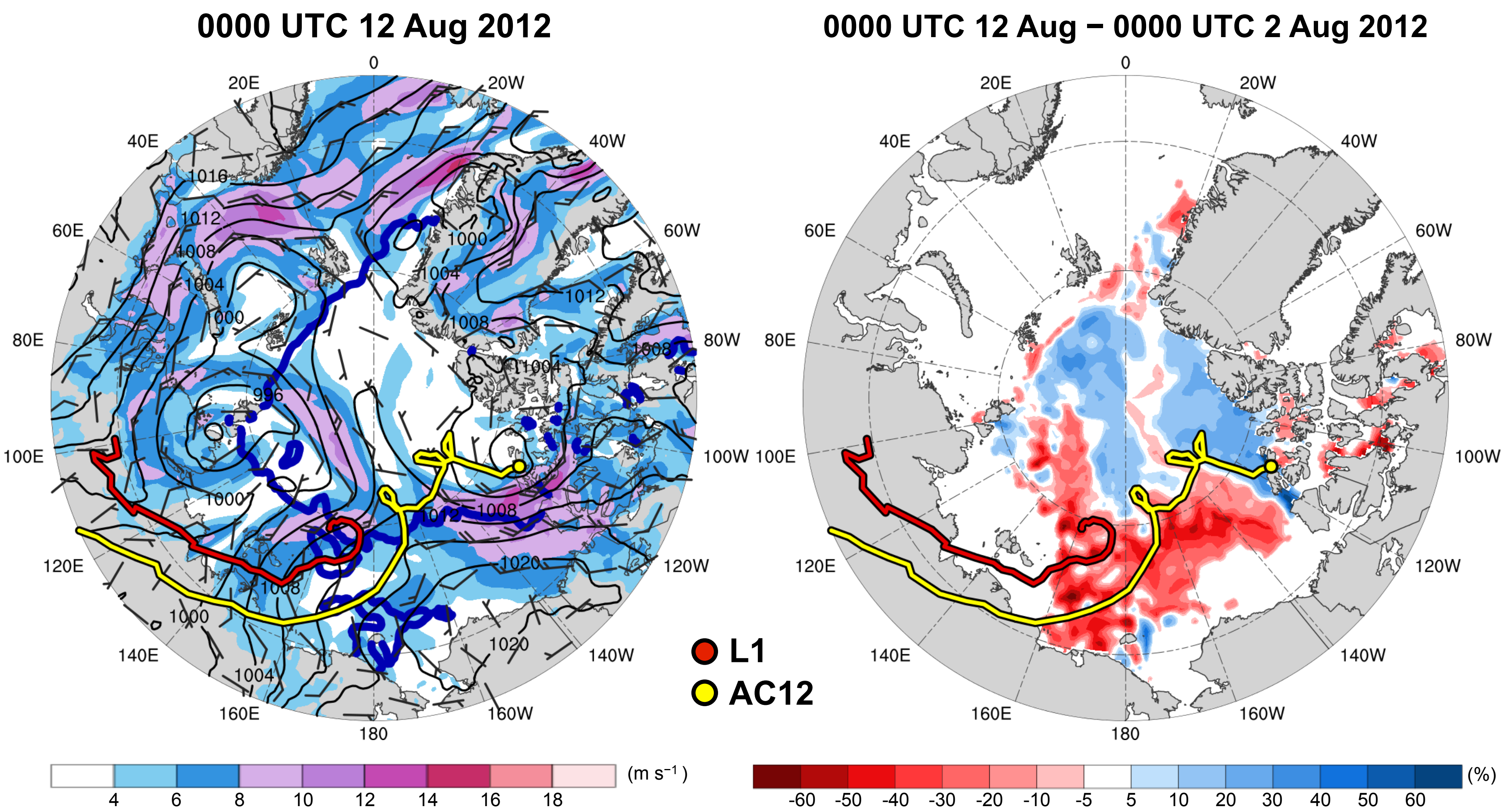
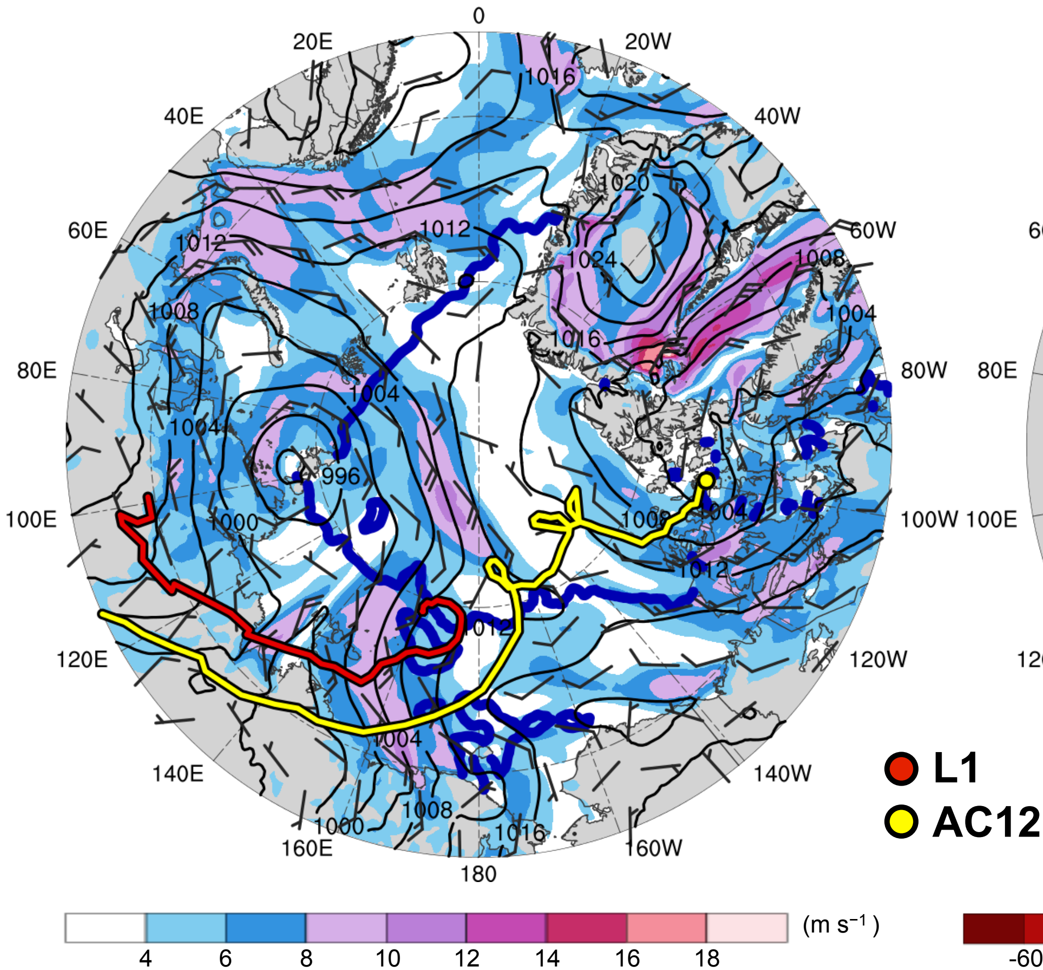



| SLP (hPa, black); 10-m wind speed (m s$^{-1}$, shaded) and wind (m s$^{-1}$, black barbs); and 20% contour of sea-ice concentration (thick blue) | Change in sea-ice concentration (shaded, %) since 0000 UTC 2 Aug 2012 |
|---|---|

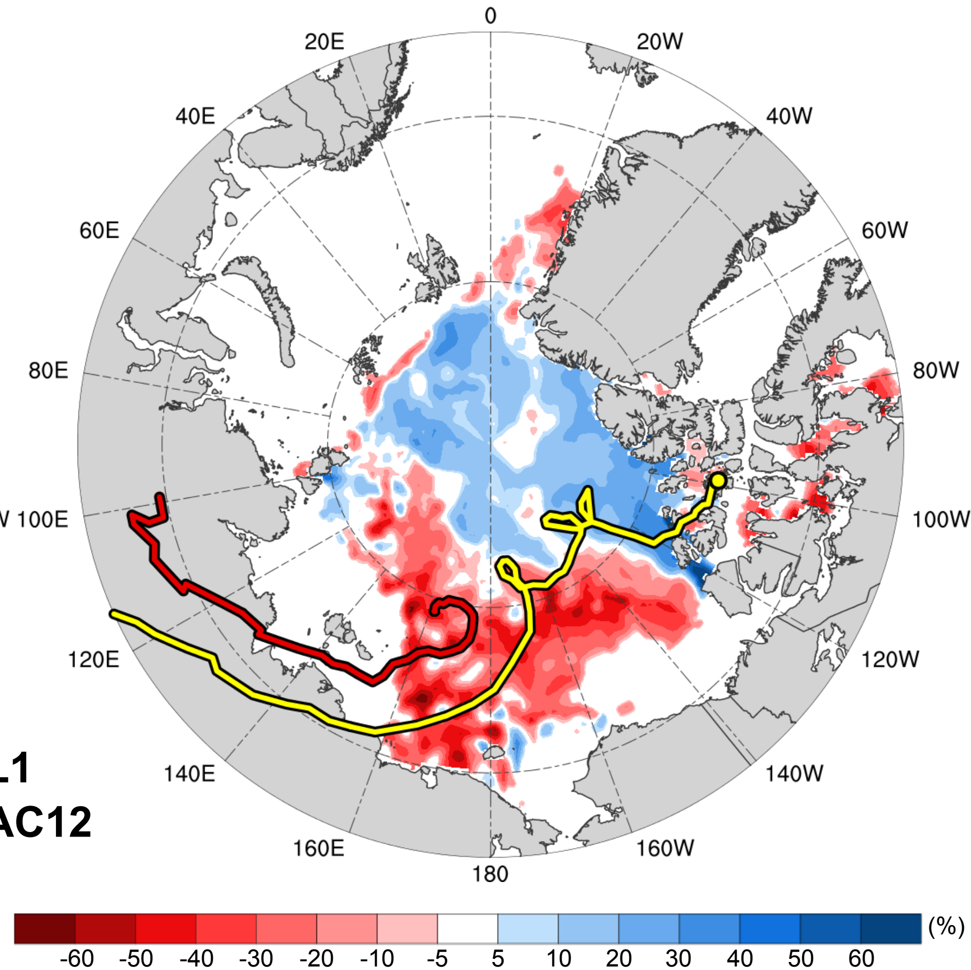
# Reduction in Arctic Sea Ice

**0000 UTC 13 Aug 2012**



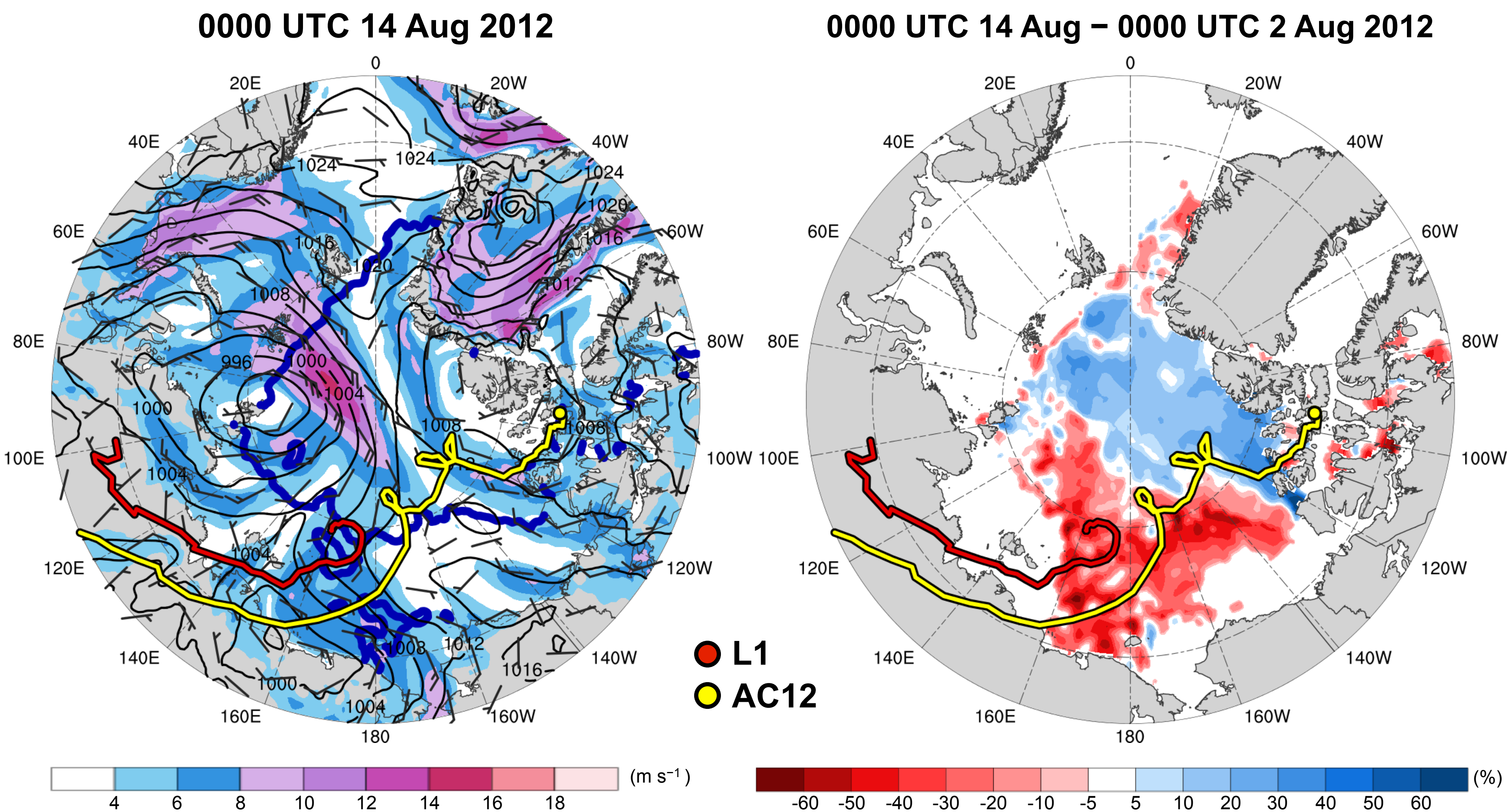

SLP (hPa, black); 10-m wind speed (m s$^{-1}$, shaded) and wind (m s$^{-1}$, black barbs); and 20% contour of sea-ice concentration (thick blue)

**0000 UTC 13 Aug – 0000 UTC 2 Aug 2012**




Change in sea-ice concentration (shaded, %) since 0000 UTC 2 Aug 2012

# Reduction in Arctic Sea Ice




SLP (hPa, black); 10-m wind speed (m $s^{-1}$, shaded) and wind (m $s^{-1}$, black barbs); and 20% contour of sea-ice concentration (thick blue)

Change in sea-ice concentration (shaded, %) since 0000 UTC 2 Aug 2012

# Conclusions

- TPV 1 approaches and interacts with AC12 in a region of strong baroclinicity, likely supporting the development of AC12 via 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
- Presence of warm, moist air and relatively strong lower-tropospheric ascent in region of jet coupling likely contribute to formation of a potential vorticity (PV) tower associated with AC12

# Conclusions

- Interaction between TPV 1 and the PV tower associated with AC12 likely supports the intensification of AC12
- L1 interacts and merges with AC12, which may further support the intensification of AC12
- After attaining a minimum SLP of 962 hPa, AC12 moves slowly over Arctic, where its expansive surface wind field contributes to reductions in Arctic sea-ice extent

# **Questions?** 

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**Acknowledgments**

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