Lower-Latitude Linkages to Two Intense Arctic Cyclones in Early June 2018

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Motivation

- **Rare occurrence of two sequential intense Arctic cyclones, AC1 and AC2, in early June 2018**
- **AC1 formed over southern Europe in response to a deepening trough in northwesterly flow**
- **AC2 formed east of Greenland and may have had antecedent vorticity "DNA" from TS Alberto**
- **AC1 and AC2 underwent a cyclonic rotation over the Arctic Ocean during which AC2 absorbed AC1**

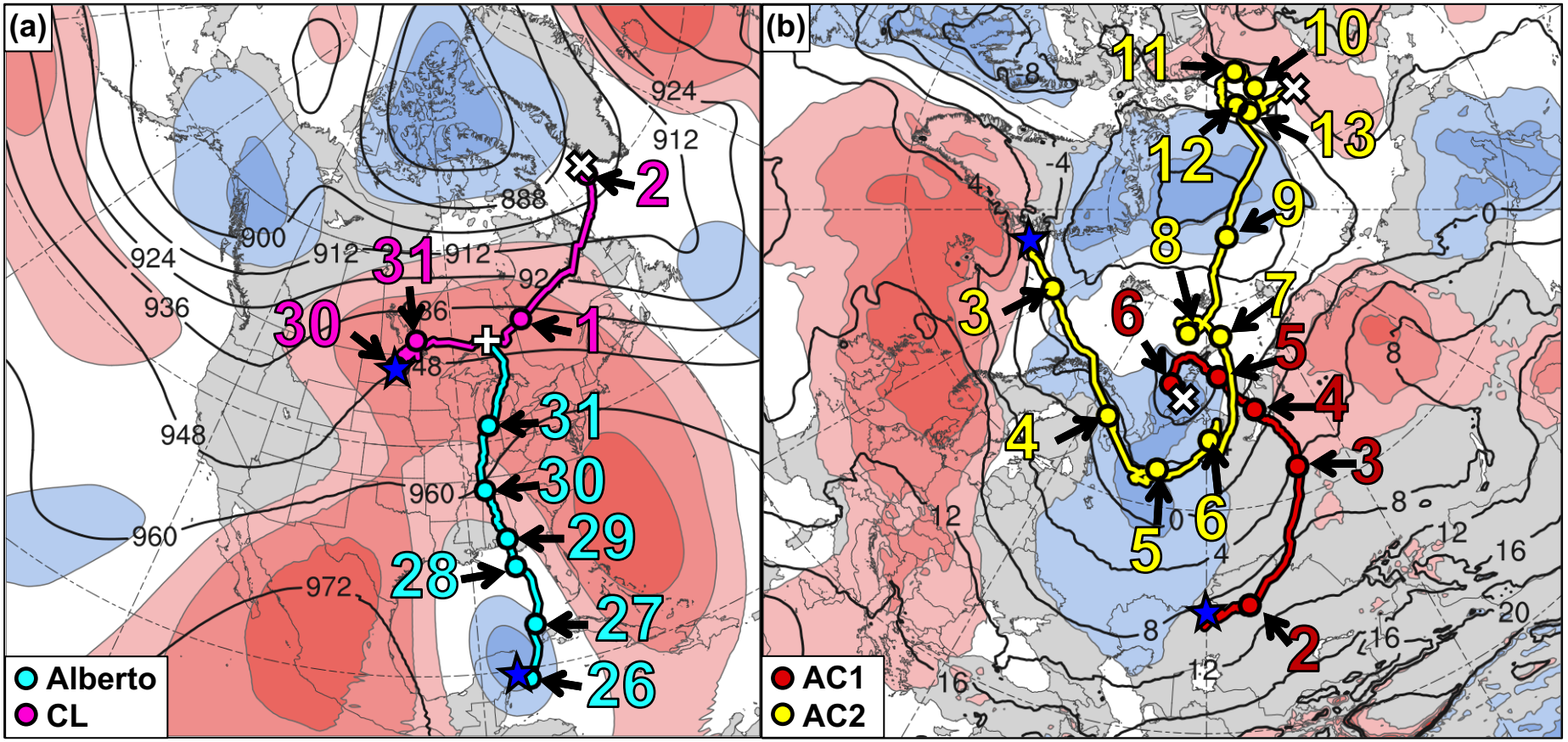
Data and Methods

- **Gridded ERA-5 datasets (0.25°) were downloaded to depict all analysis fields**
- **Gridded ERA-I datasets were used to compute mean and standardized anomalies**
- **TS Alberto and surface cyclones were tracked from NHC positions and ERA-5 datasets, respectively**
- **Szapiro and Cavallo (2018) algorithm was used to identify and track tropopause polar vortices (TPVs)**
- **NOAA HYSPLIT Trajectory Model was used to compute backward trajectories**

Big Picture

- **AC1 and AC2 tracks and intensities**
- **Relevant TPV tracks**
- **Standardized 300-hPa height anomalies and 850-hPa temperature anomalies**

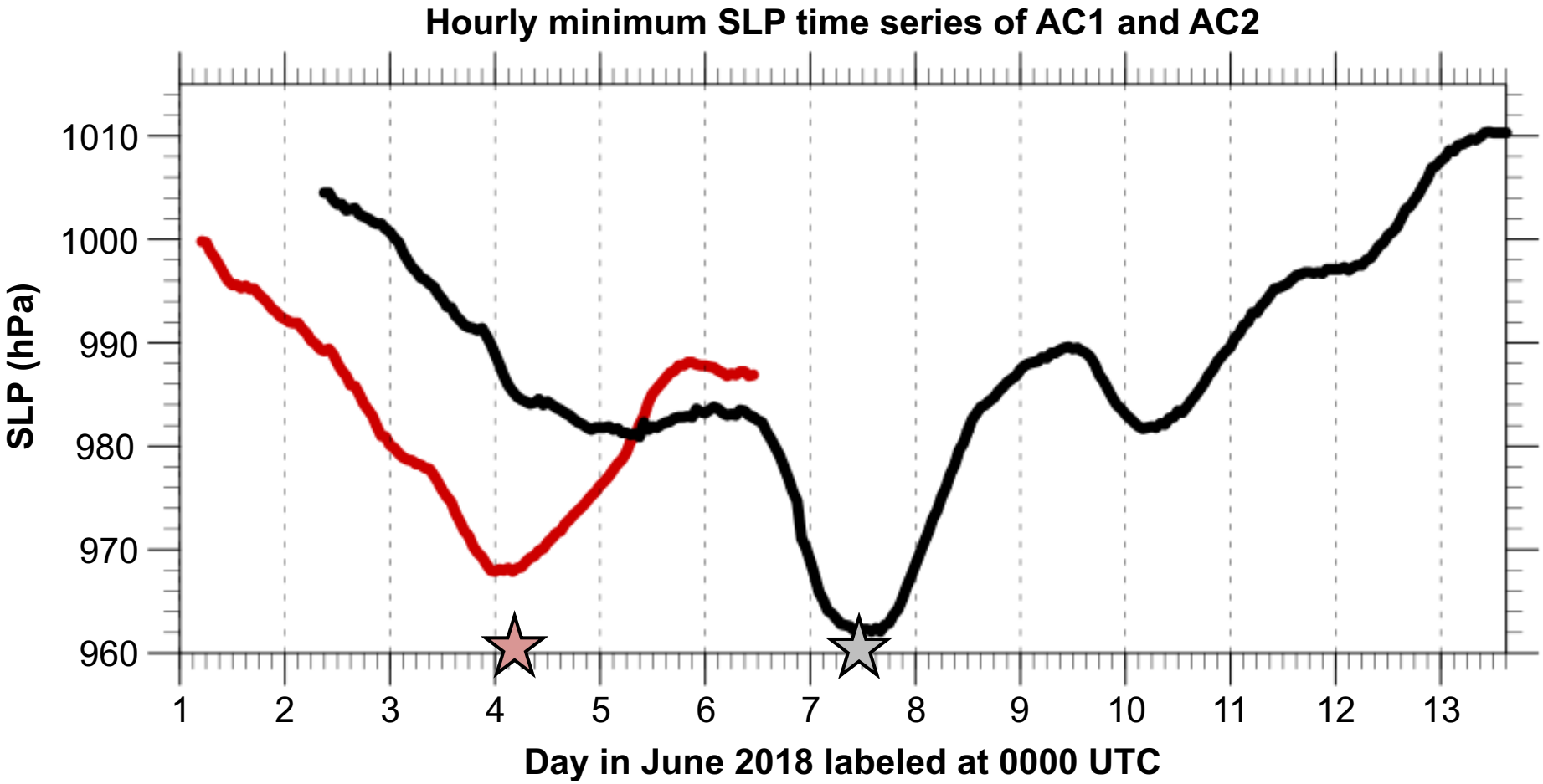
Track and Intensity of Cyclones



Cyclone	Genesis	Lysis	Lifetime
AC1	1 June	6 June	~5 d
AC2	2 June	13 June	~11 d

(a) 26 May–1 June 2018 time-mean 300-hPa geopotential height (dam, black) and standardized geopotential height anomalies (σ, shaded); (b) 1–7 June 2018 time-mean 850-hPa temperature (°C, black) and standardized temperature anomalies (σ, shaded).

Track and Intensity of Cyclones



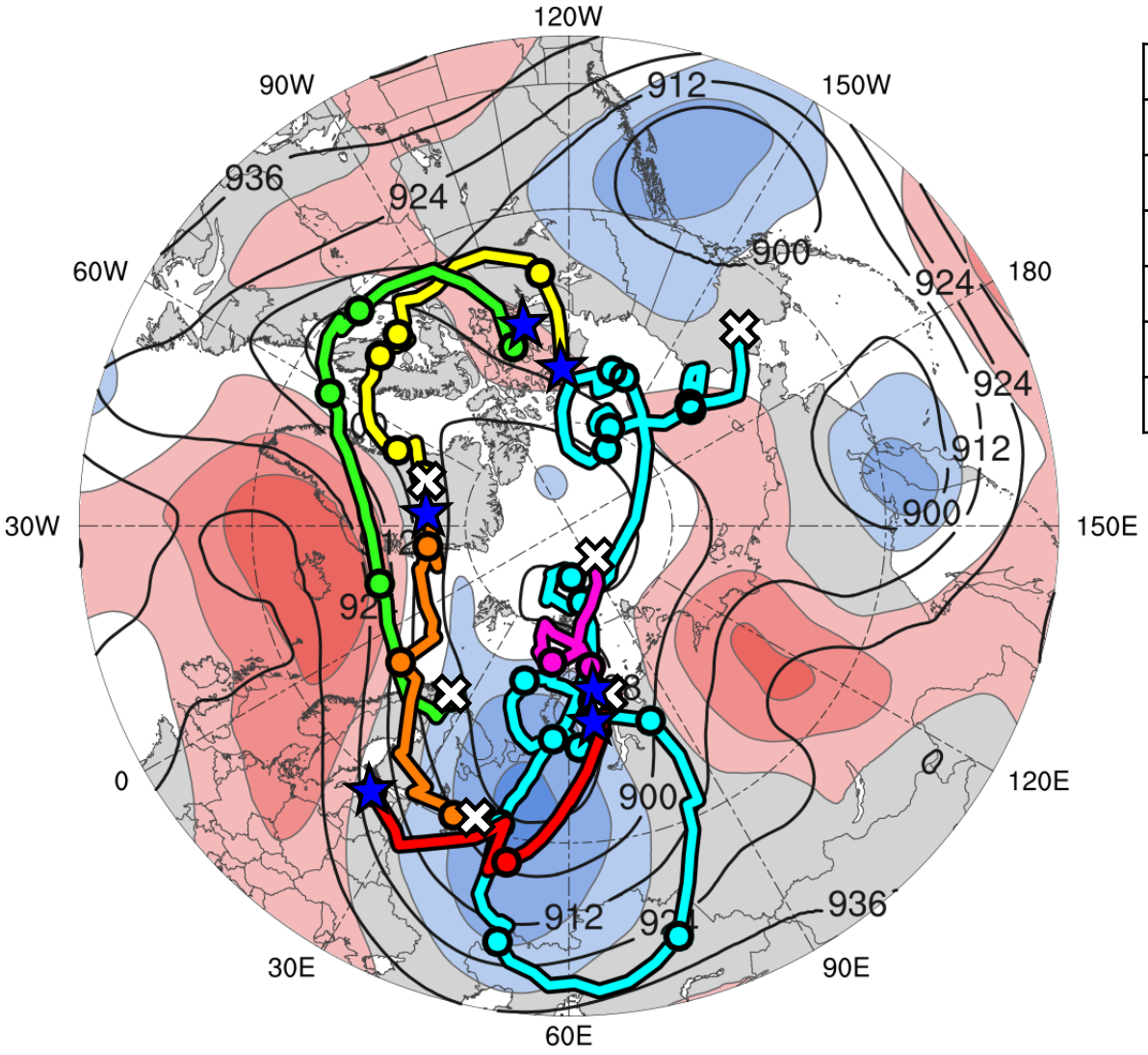
AC1

Peak intensity of AC1 at
0400 UTC 4 June 2018 (967.9 hPa)

AC2

Peak intensity of AC2 at
1100 UTC 7 June 2018 (962.0 hPa)

Tracks of TPVs



TPV	Genesis	Lysis	Lifetime
TPV 1a	29 May	3 June	~5.4 d
TPV 1b	2 June	5 June	2.5 d
TPV 1c	5 June	7 June	~2.4 d
TPV 1d	6 June	8 June	2 d
TPV 2	30 May	15 June	17 d
TPV 3	30 May	4 June	~4.4 d

TPV 1a **TPV 1d**
TPV 1b **TPV 2**
TPV 1c **TPV 3**

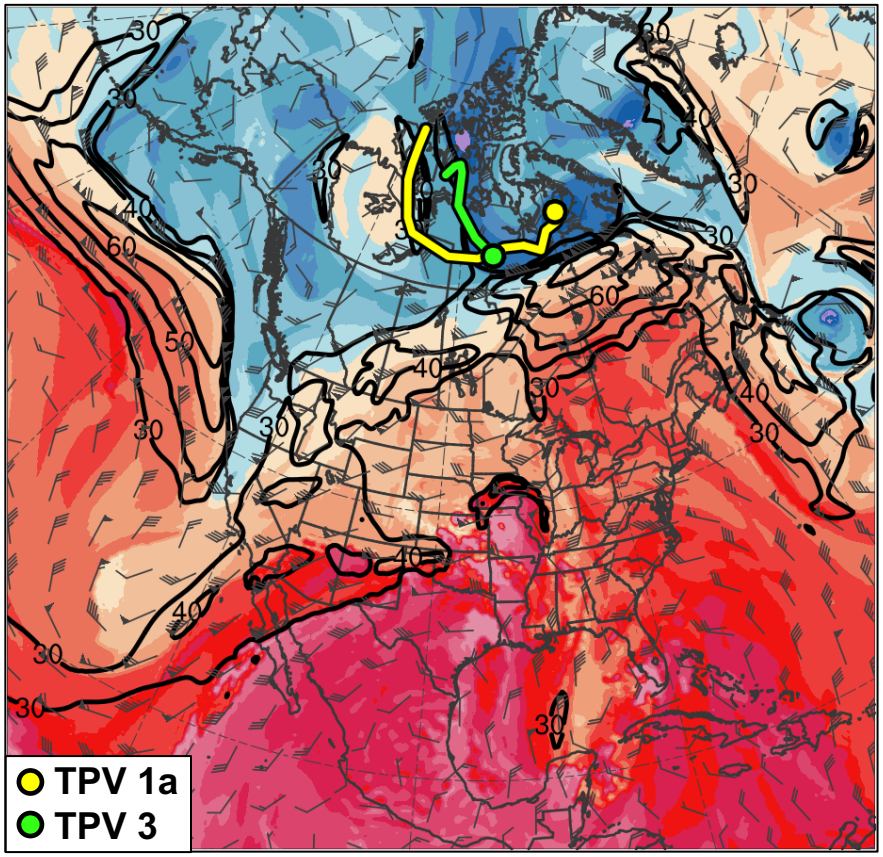
Genesis **Lysis**

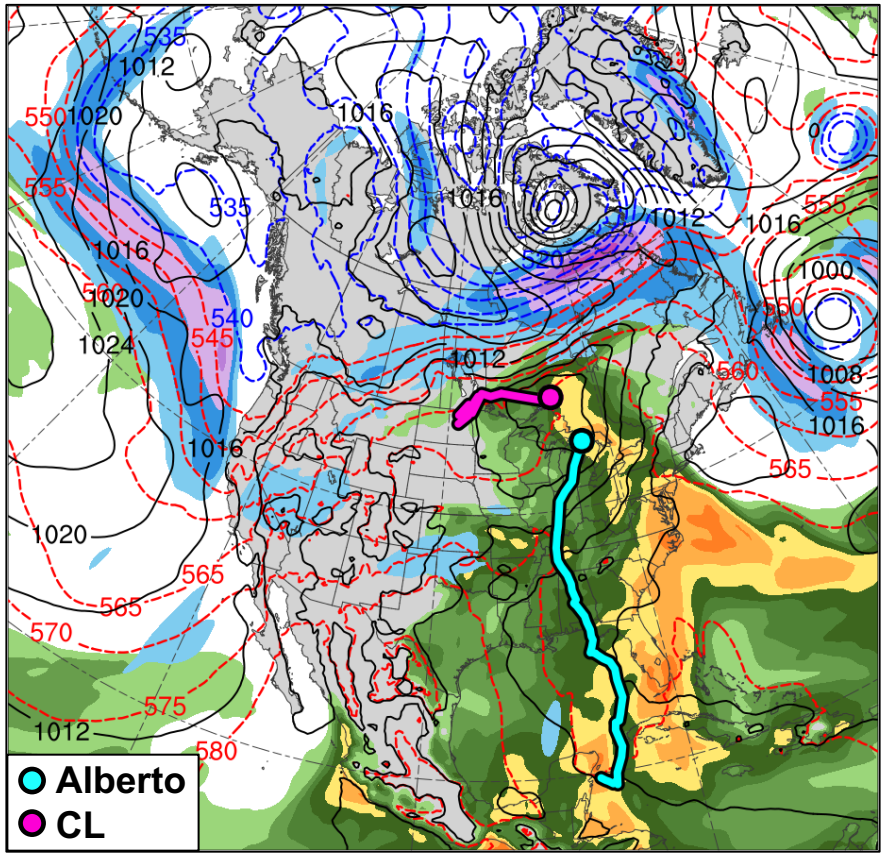
0000 UTC positions

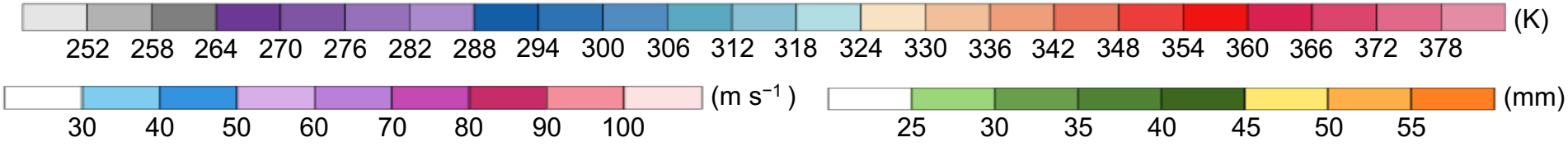
1–7 June 2018 time-mean 300-hPa geopotential height (dam, black) and standardized geopotential height anomalies (σ, shaded)

Synoptic-Scale Flow Evolution: North America 30 May–2 June 2018

1200 UTC 31 May 2018



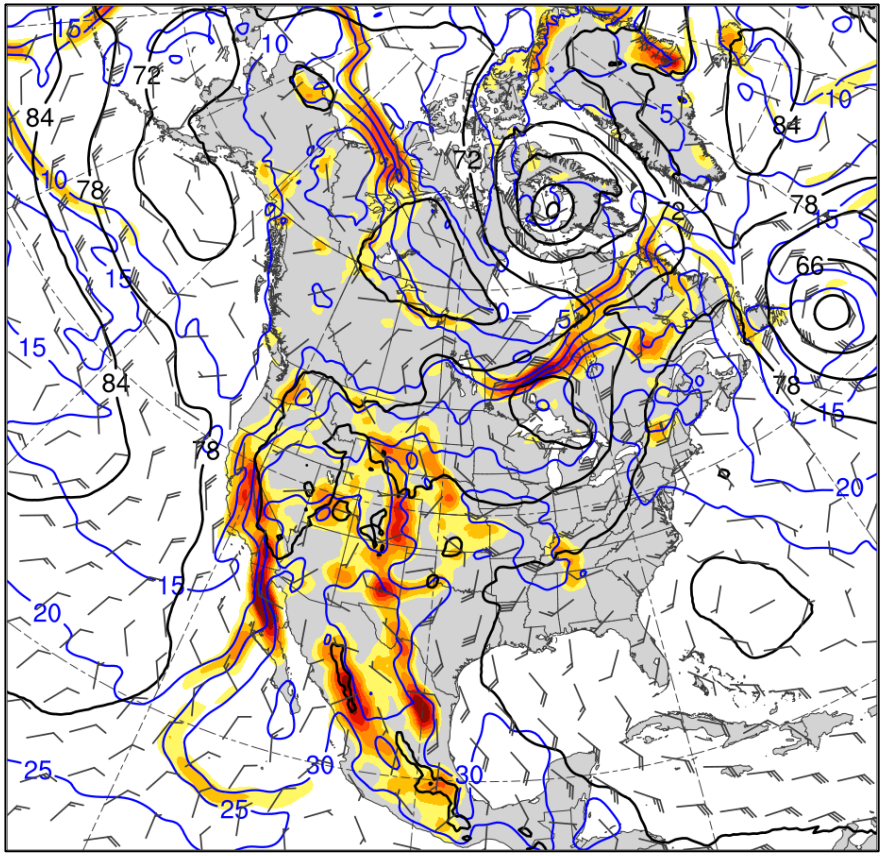


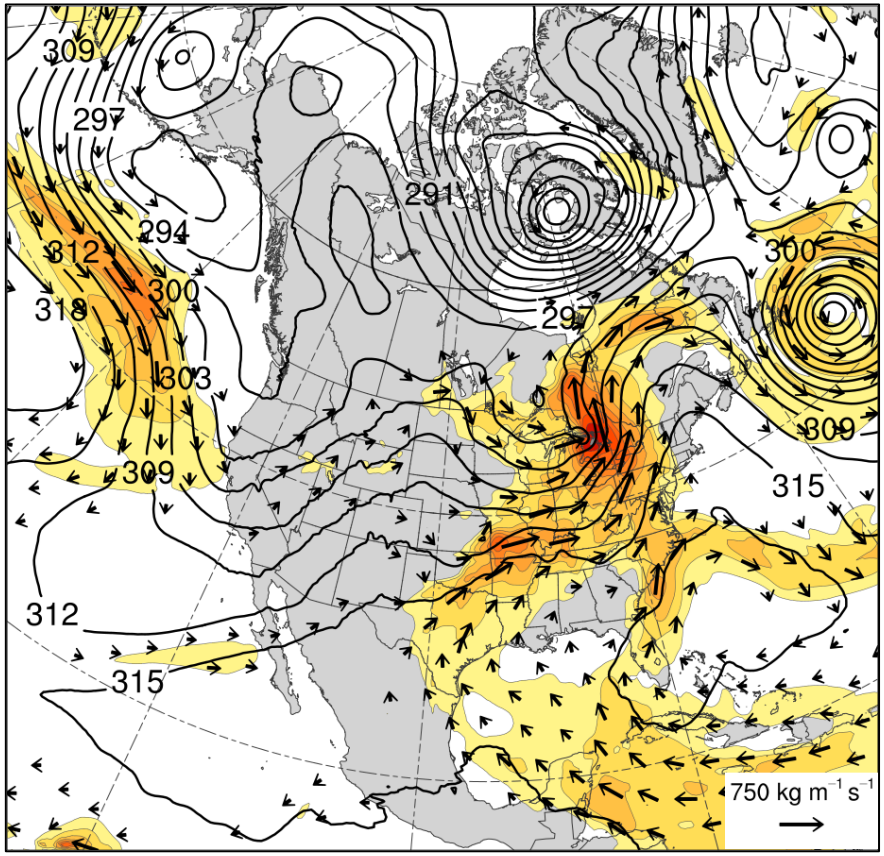


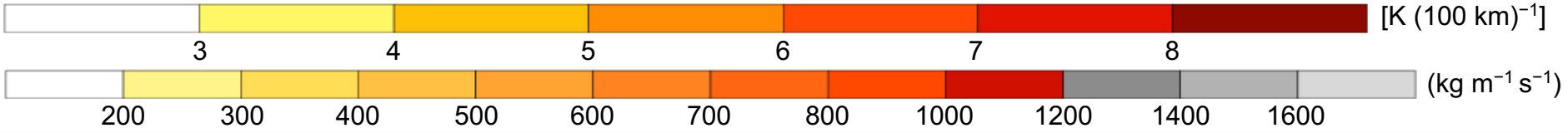
Potential temperature (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs) on 2-PVU surface

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

1200 UTC 31 May 2018



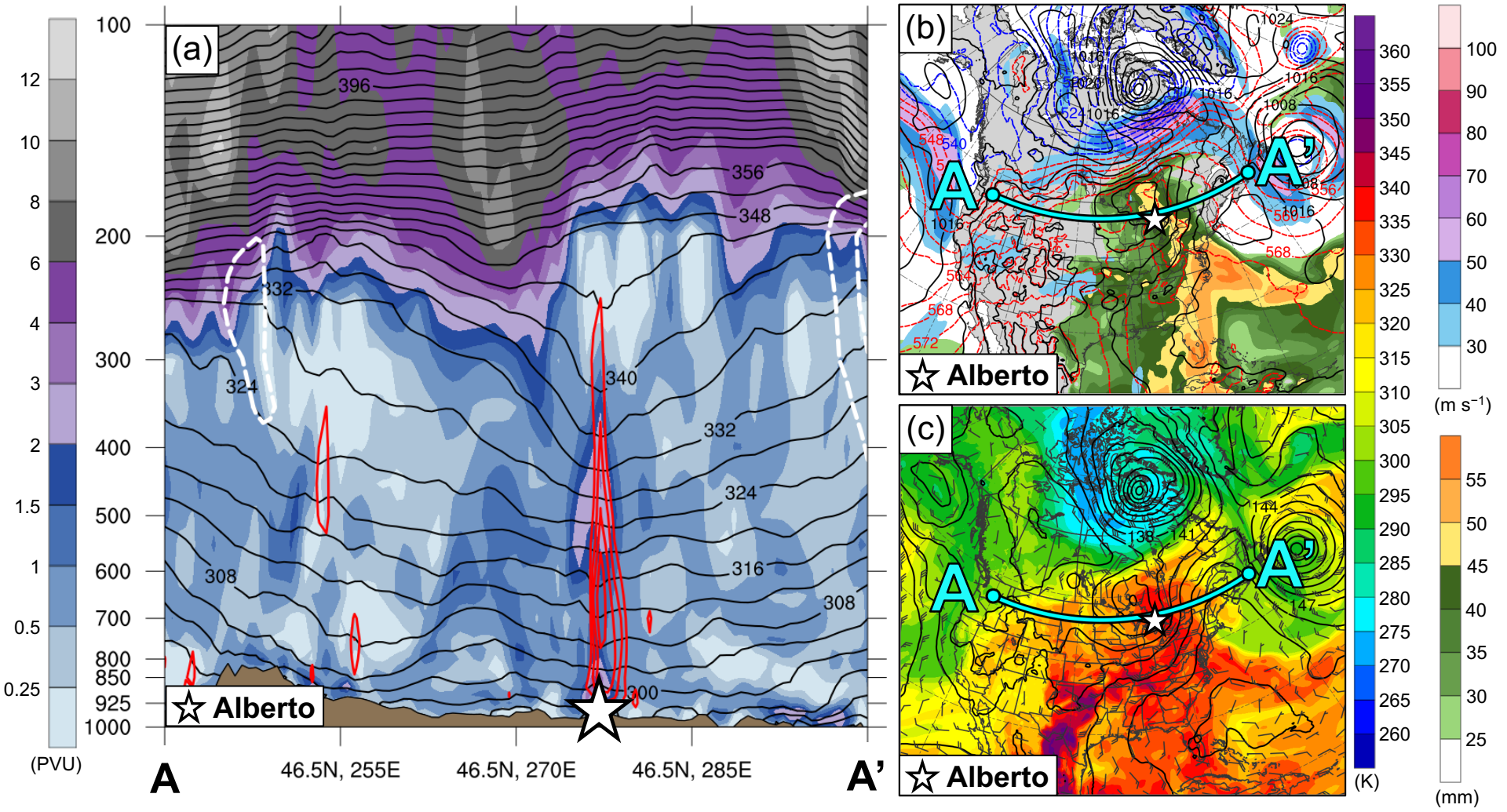




925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

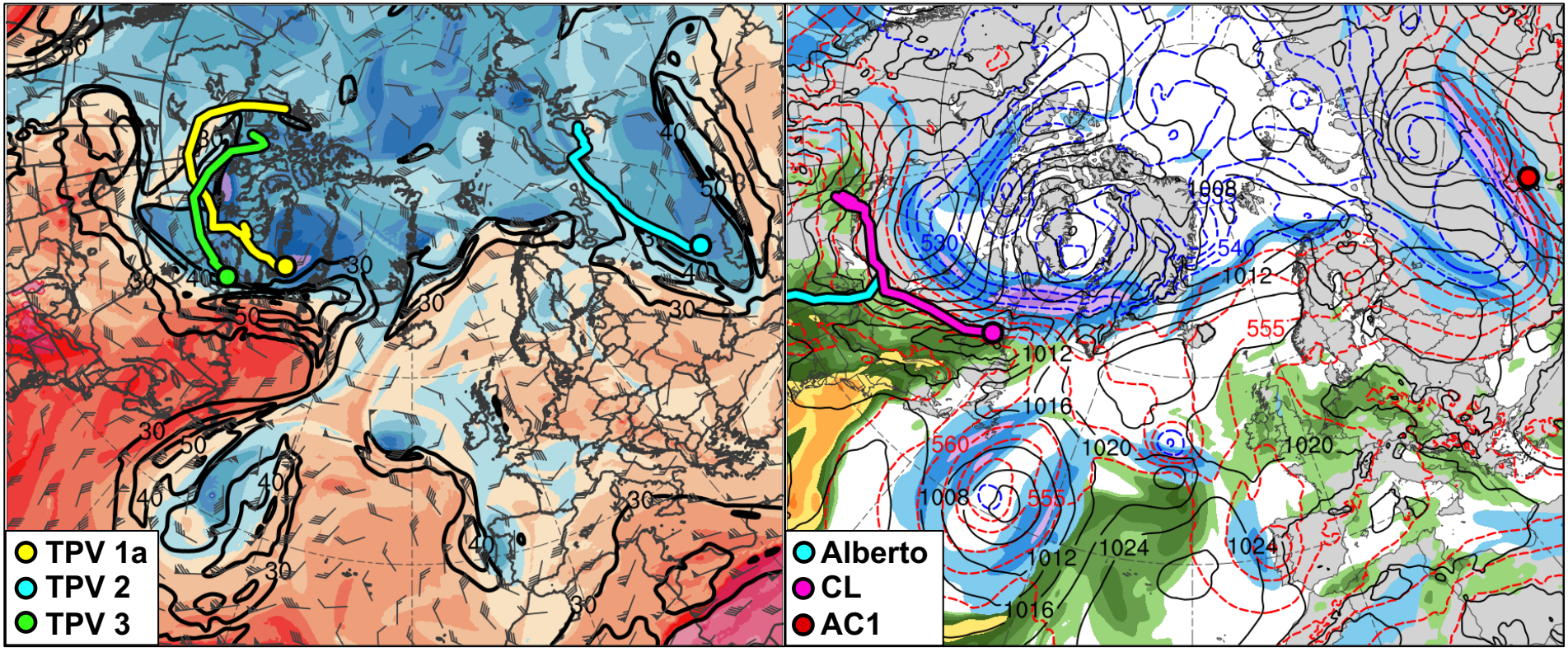
IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

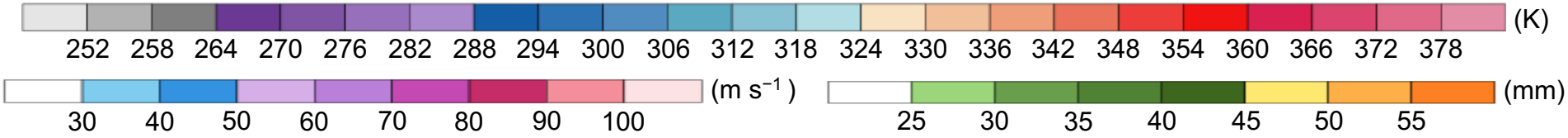
1200 UTC 31 May 2018



(a) PV (PVU, shaded), θ (K, black), ascent (red, every 5 × 10^{-3} hPa s^{-1}), and wind speed (white, every 10 m s^{-1} starting at 30 m s^{-1}); (b) 300-hPa wind speed (m s^{-1}, shaded),1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded); (c) 850-hPa θ_e (K, shaded), geopotential height (dam, black), and wind (m s^{-1}, flags and barb)

1200 UTC 1 Jun 2018

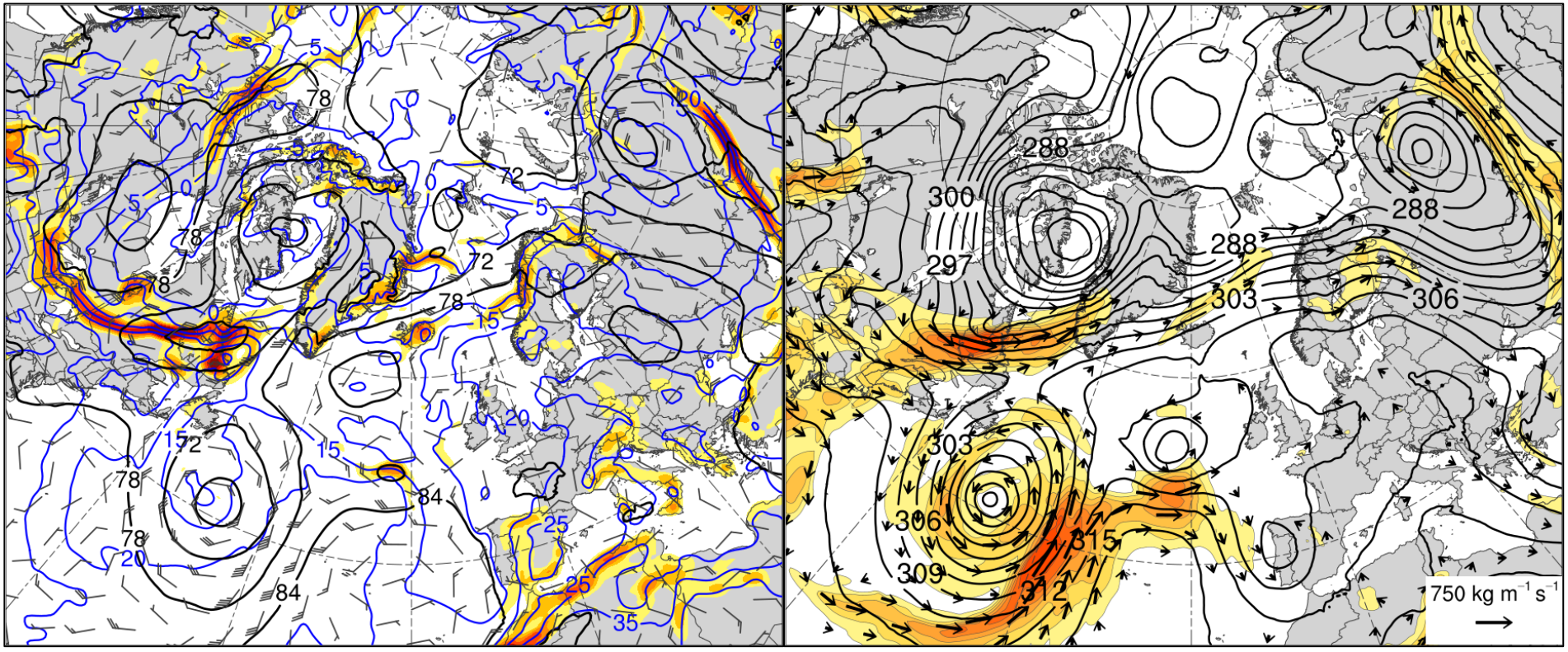


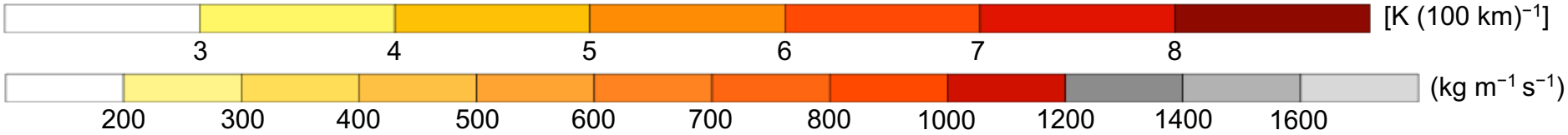


Potential temperature (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs) on 2-PVU surface

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

1200 UTC 1 Jun 2018

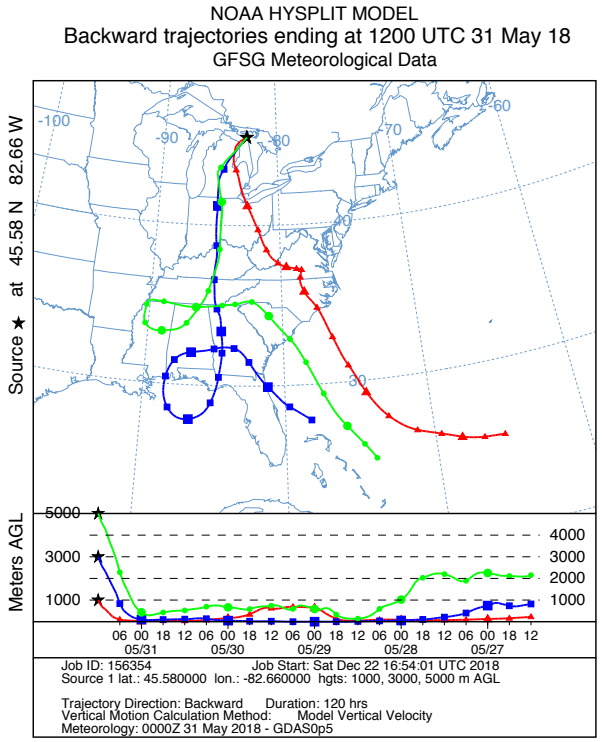


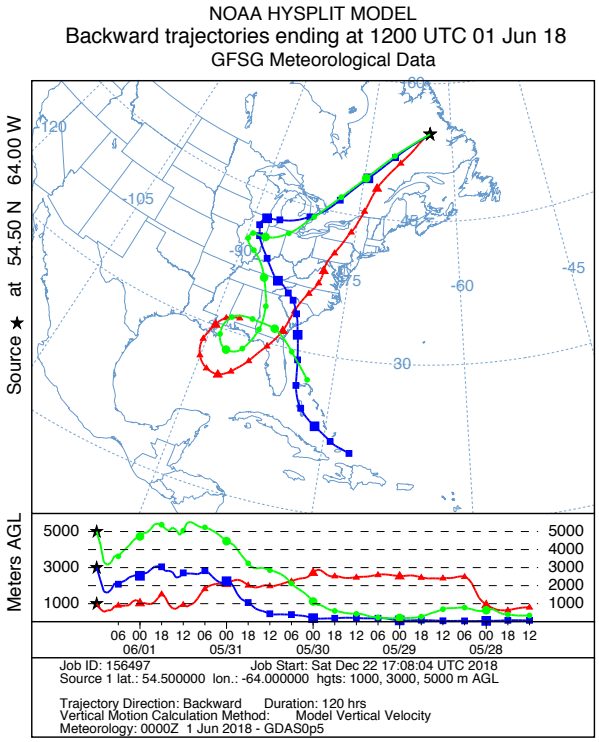


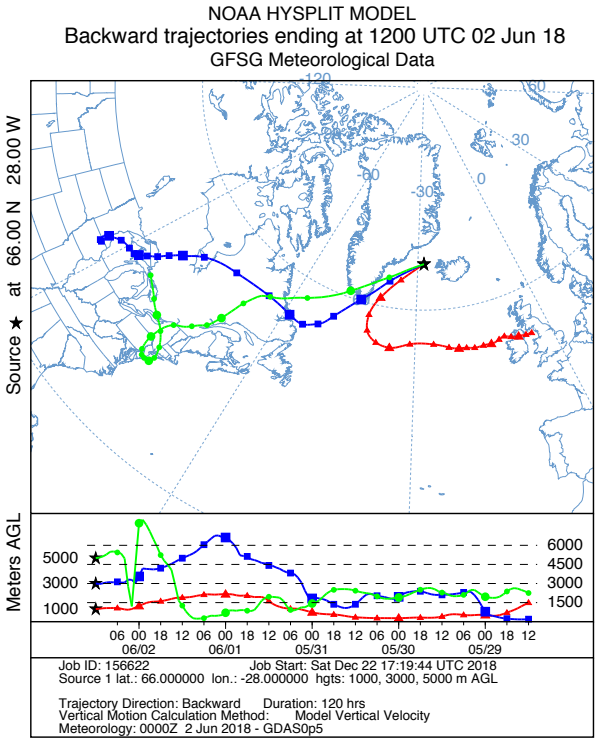
925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

Lagrangian Perspective: Selected Trajectories (Pre-AC2)

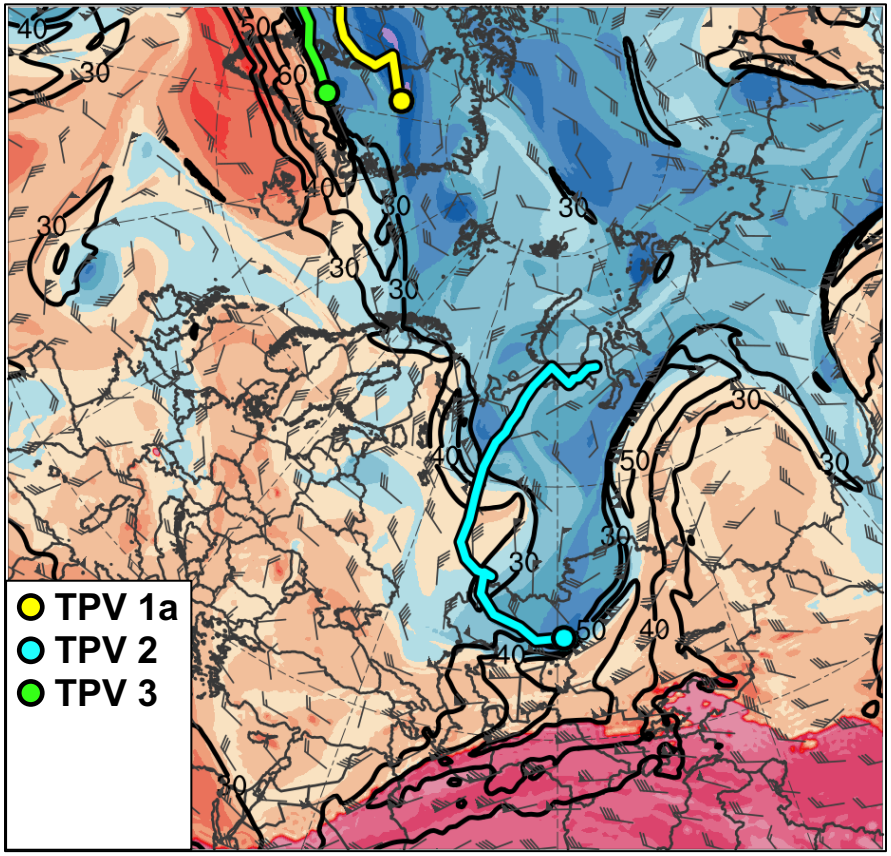


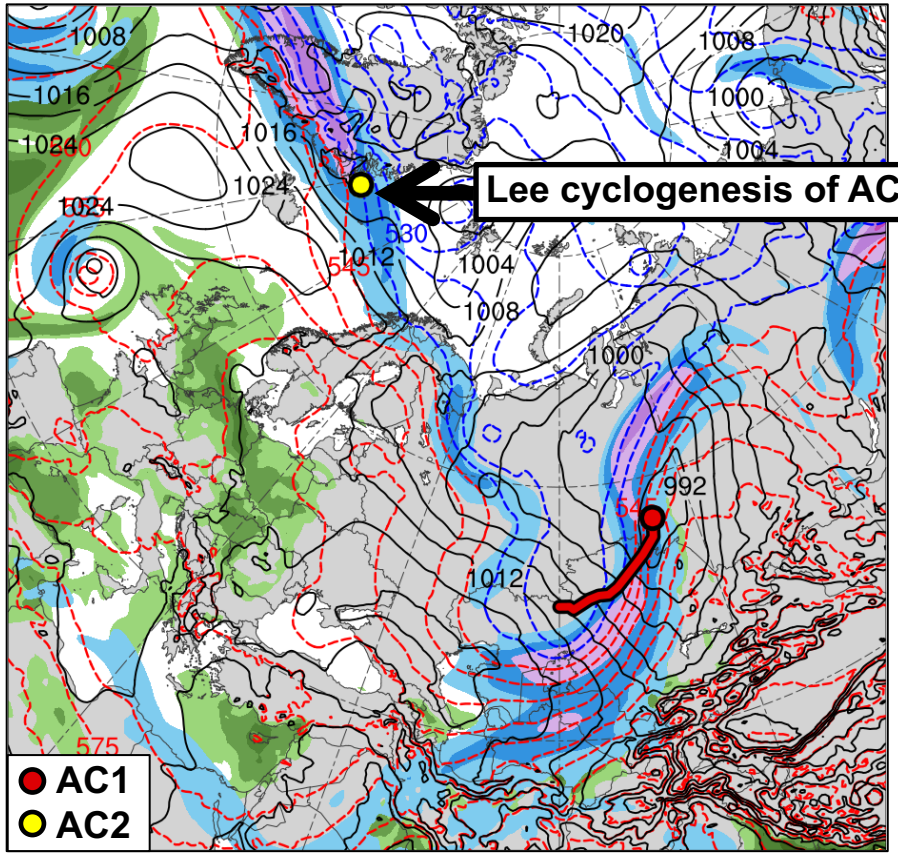


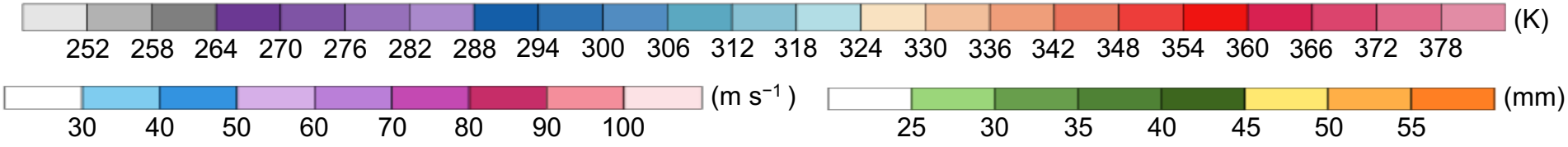


Synoptic-Scale Flow Evolution: Eurasia 2–7 June 2018

1200 UTC 2 Jun 2018



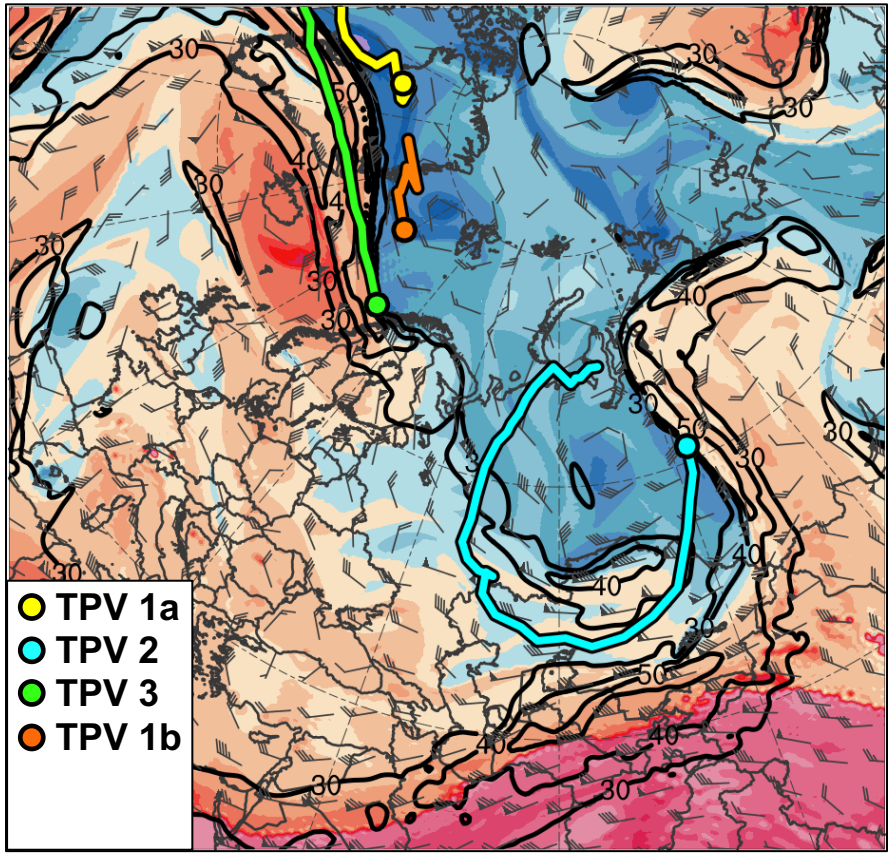


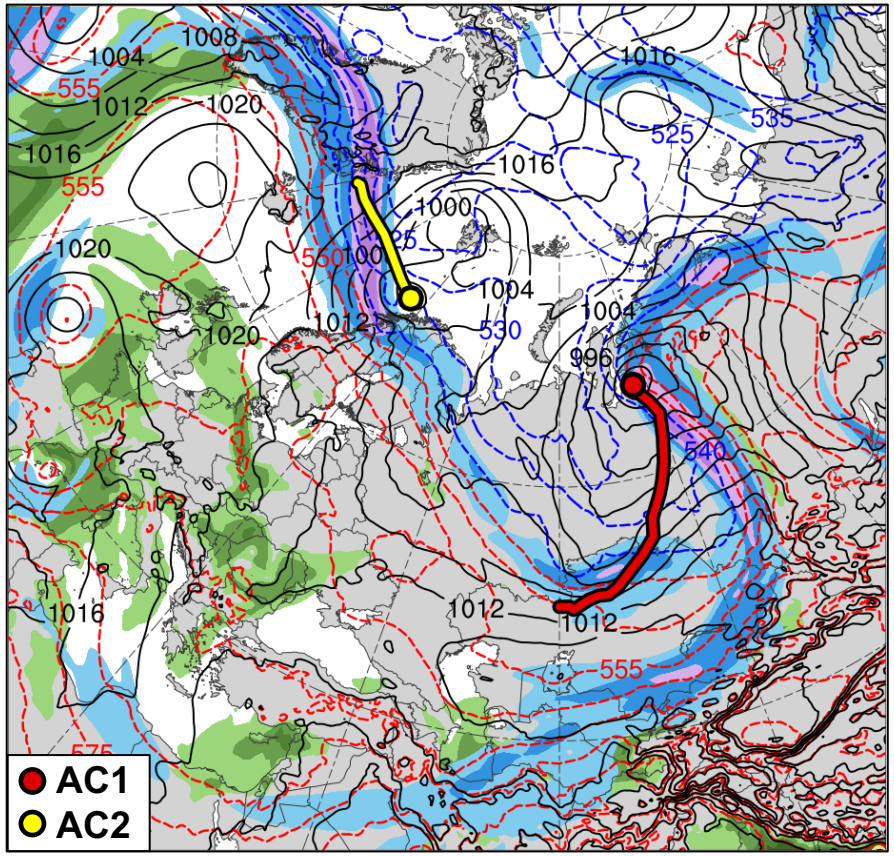


Potential temperature (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs) on 2-PVU surface

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

1200 UTC 3 Jun 2018





252 258 264 270 276 282 288 294 300 306 312 318 324 330 336 342 348 354 360 366 372 378 (K)

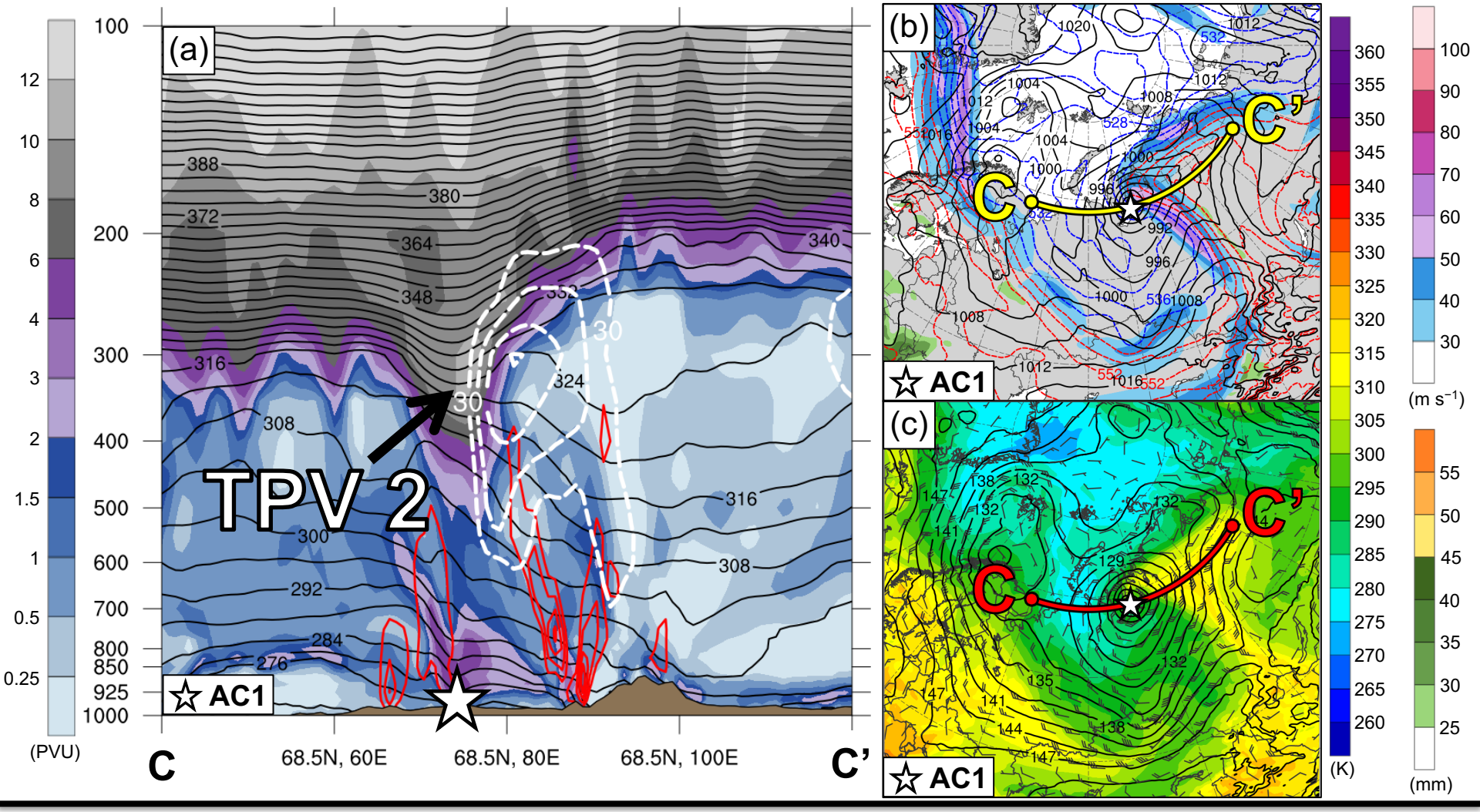
30 40 50 60 70 80 90 100 (m s^{-1})

25 30 35 40 45 50 55 (mm)

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

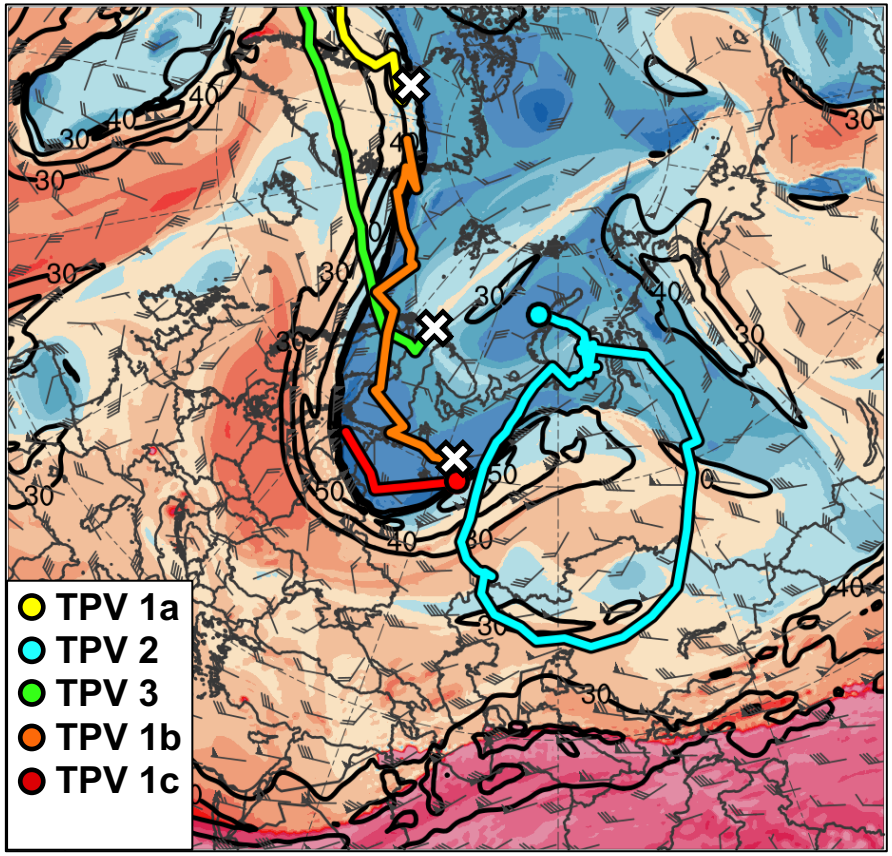
300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded)

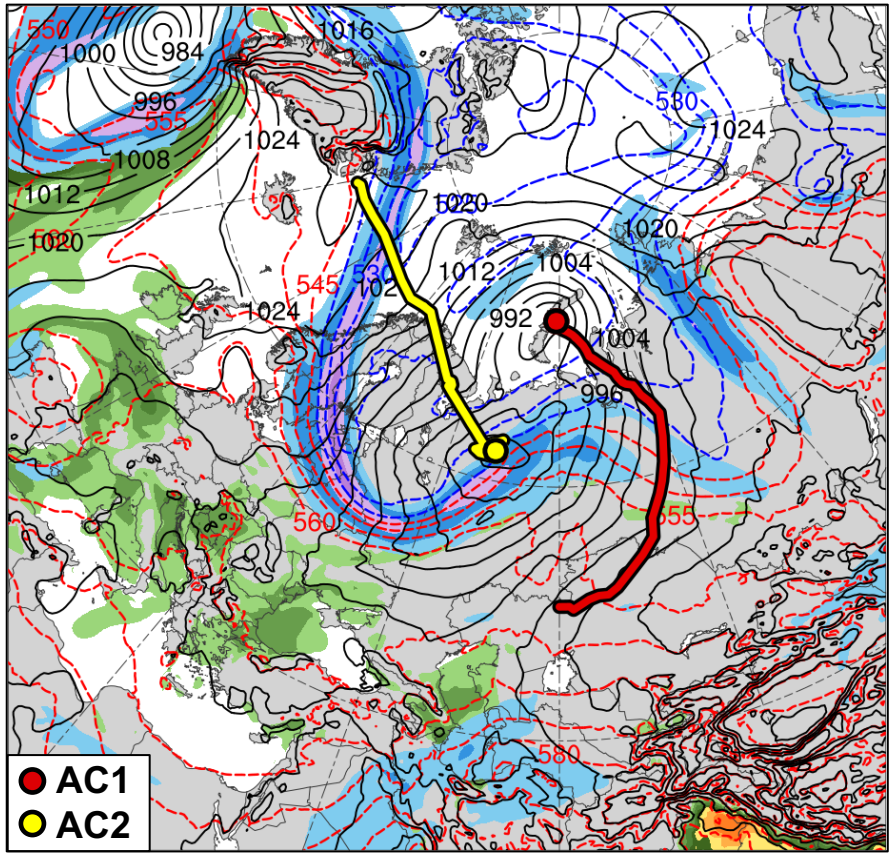
1800 UTC 3 Jun 2018

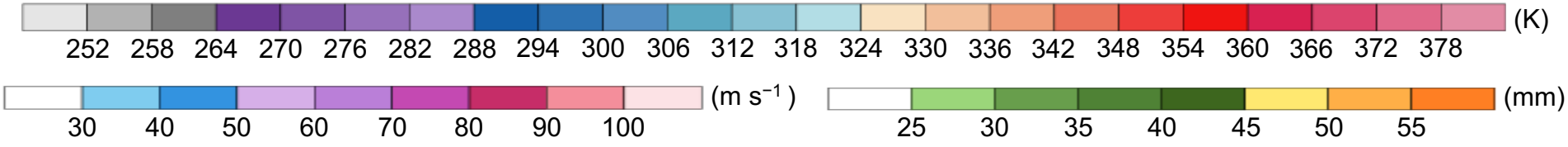


(a) PV (PVU, shaded), θ (K, black), ascent (red, every 5 × 10^{-3} hPa s^{-1}), and wind speed (white, every 10 m s^{-1} starting at 30 m s^{-1}); (b) 300-hPa wind speed (m s^{-1}, shaded),1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded); (c) 850-hPa θ_e (K, shaded), geopotential height (dam, black), and wind (m s^{-1}, flags and barb)

1200 UTC 5 Jun 2018



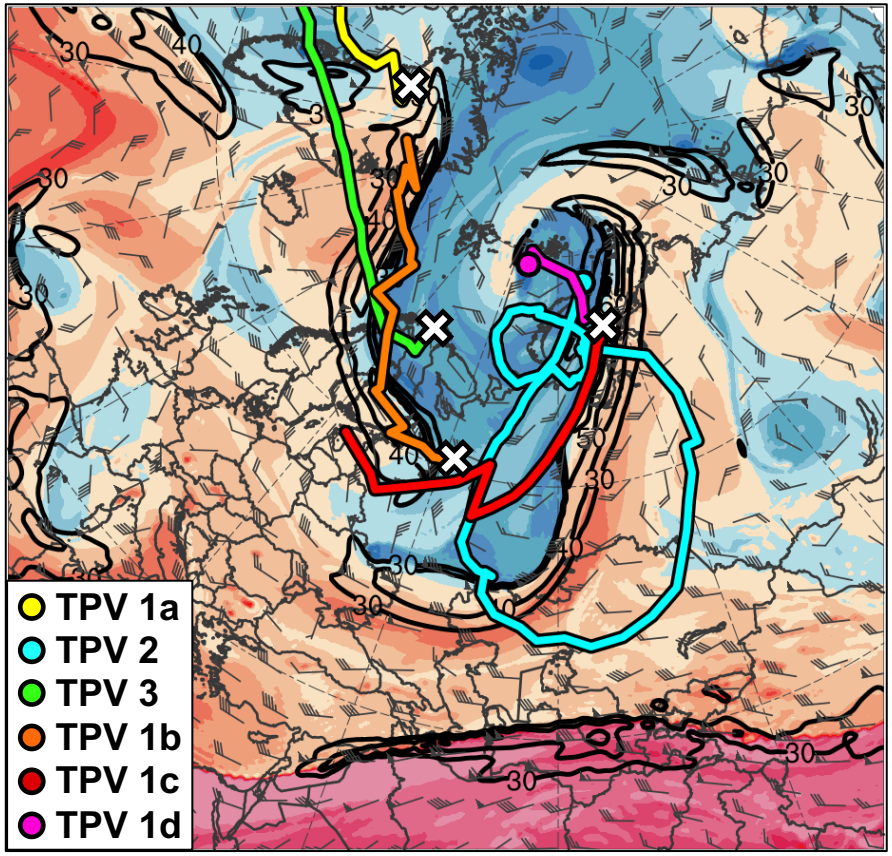


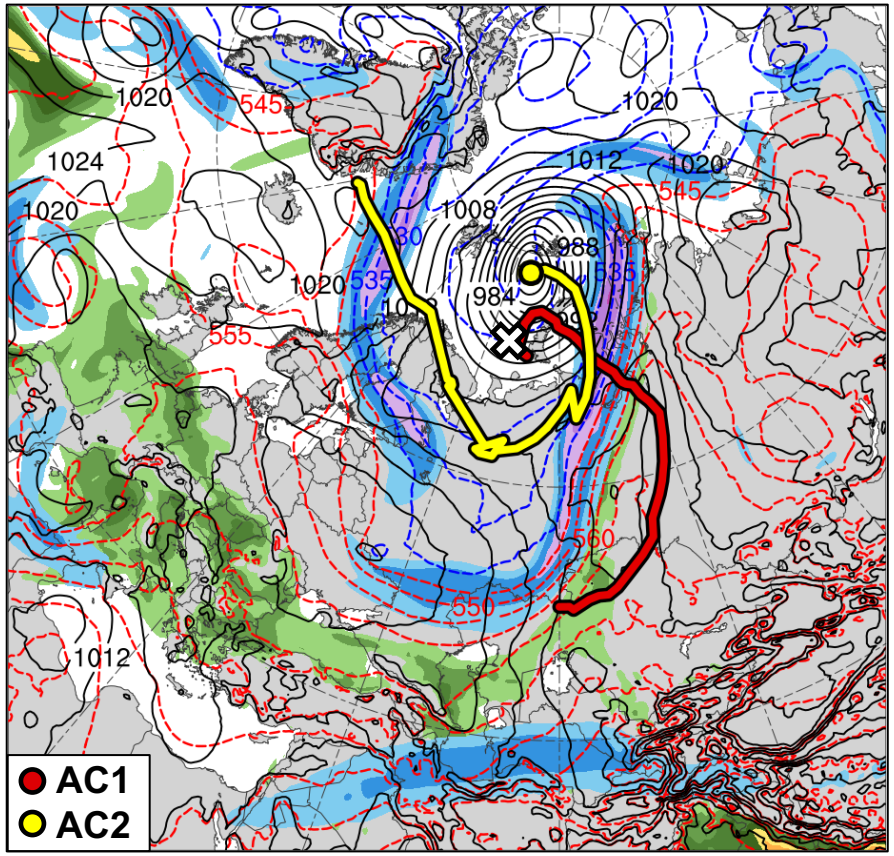


Potential temperature (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs) on 2-PVU surface

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

1200 UTC 7 Jun 2018





252 258 264 270 276 282 288 294 300 306 312 318 324 330 336 342 348 354 360 366 372 378 (K)

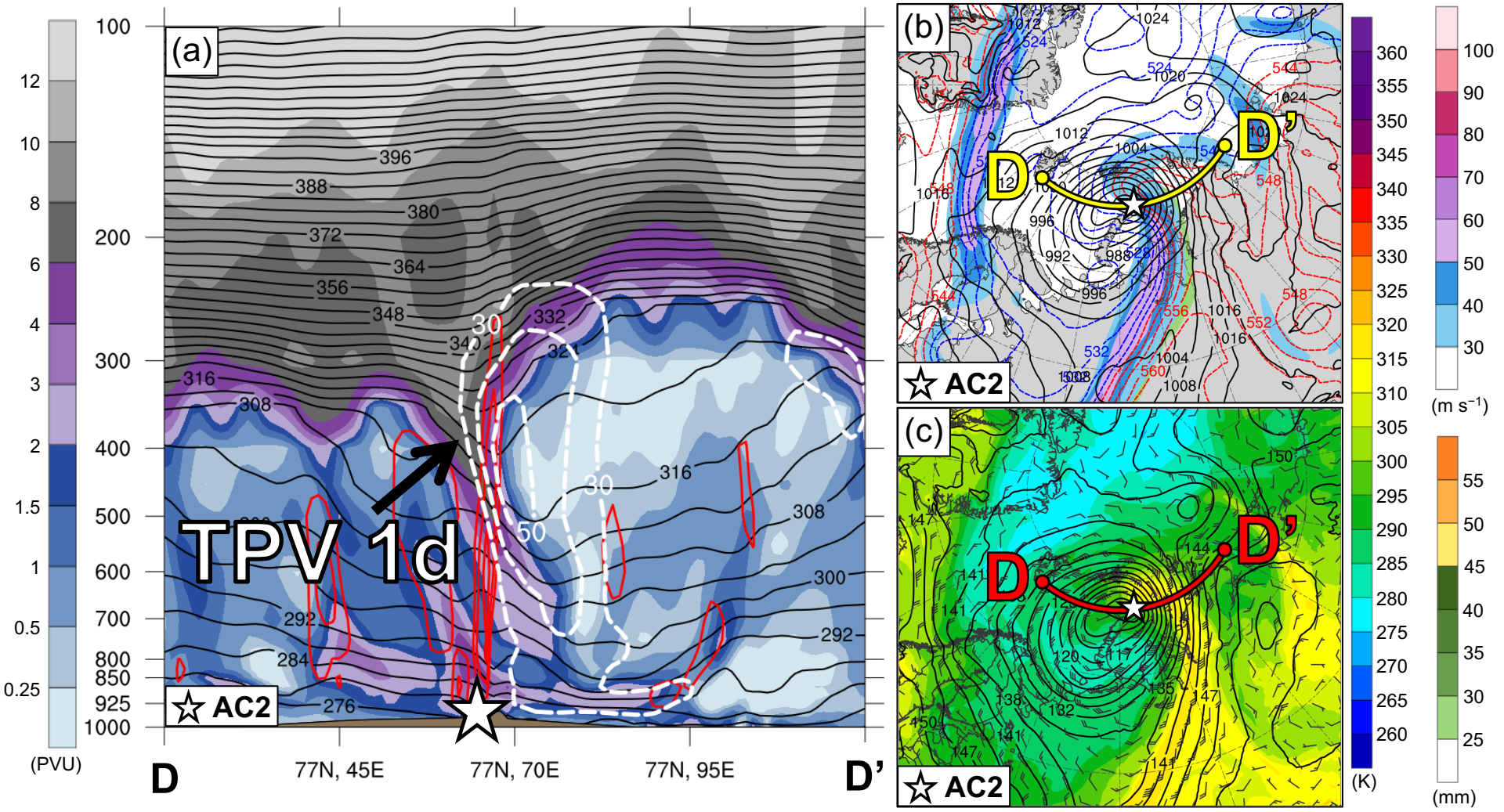
30 40 50 60 70 80 90 100 (m s^{-1})

25 30 35 40 45 50 55 (mm)

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

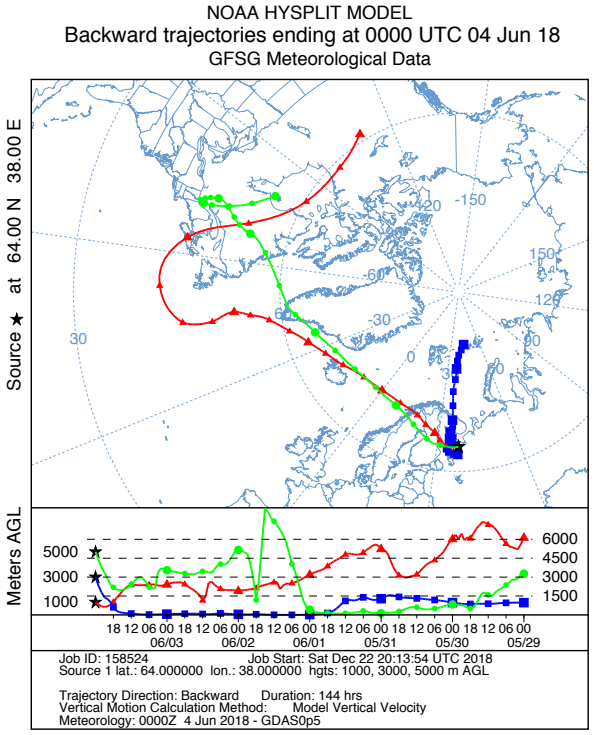
300-hPa wind speed (m s^{-1}, shaded), 1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded)

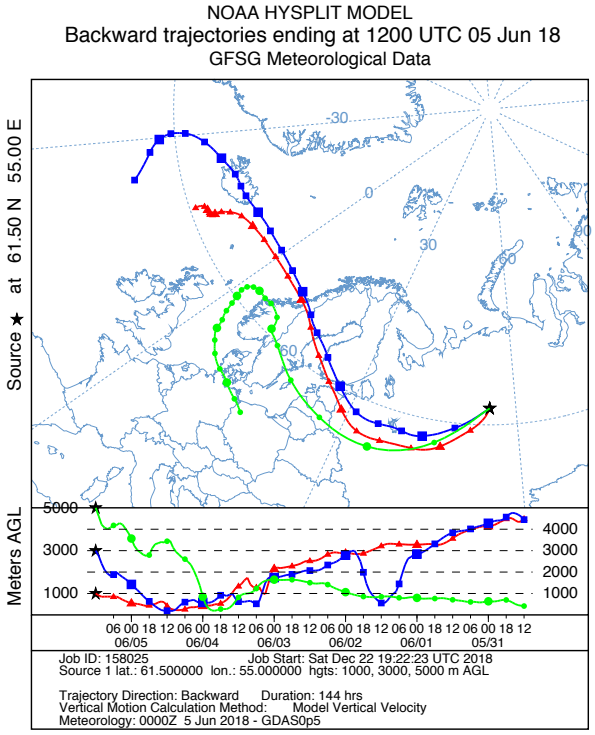
0000 UTC 7 Jun 2018

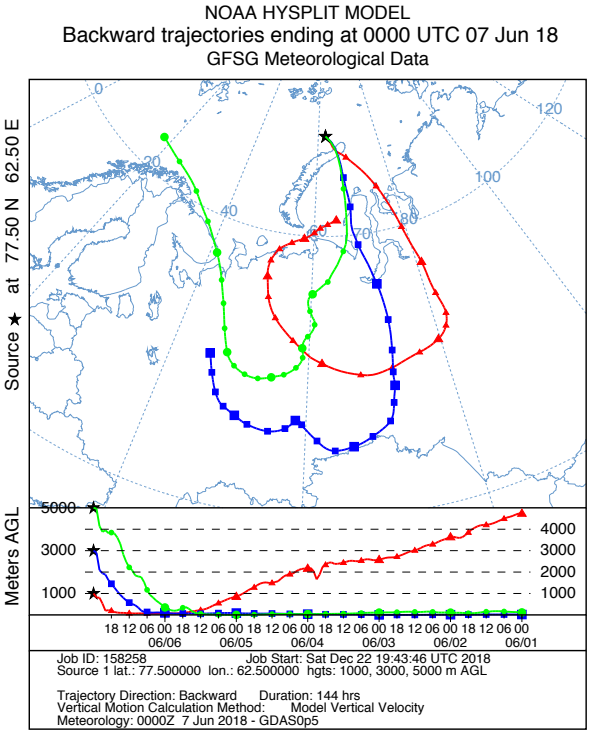


(a) PV (PVU, shaded), θ (K, black), ascent (red, every 5 × 10^{-3} hPa s^{-1}), and wind speed (white, every 10 m s^{-1} starting at 30 m s^{-1}); (b) 300-hPa wind speed (m s^{-1}, shaded),1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded); (c) 850-hPa θ_e (K, shaded), geopotential height (dam, black), and wind (m s^{-1}, flags and barb)

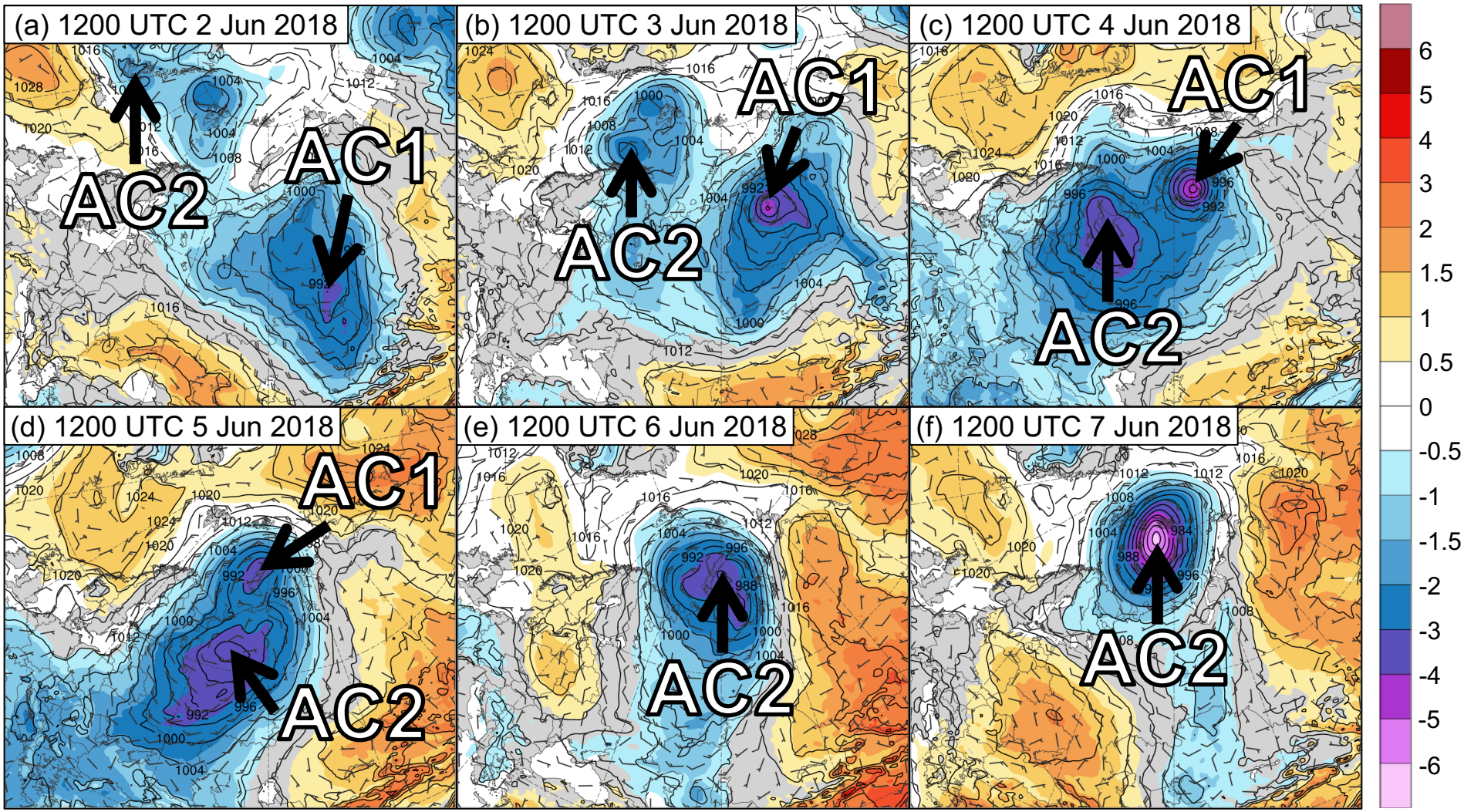
Lagrangian Perspective: Selected Trajectories (AC2)







Interactions between Arctic Cyclones



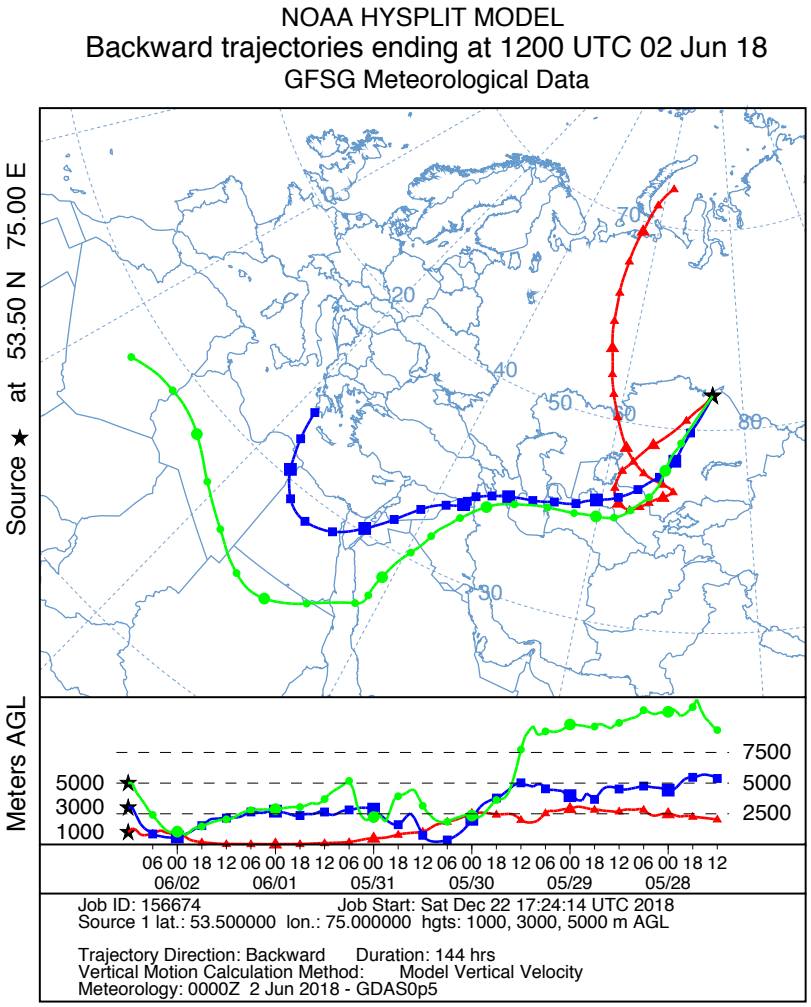
SLP (hPa, black), 10-m winds (m s^{-1}, flags and barbs), and standardized SLP anomalies (σ, shaded)

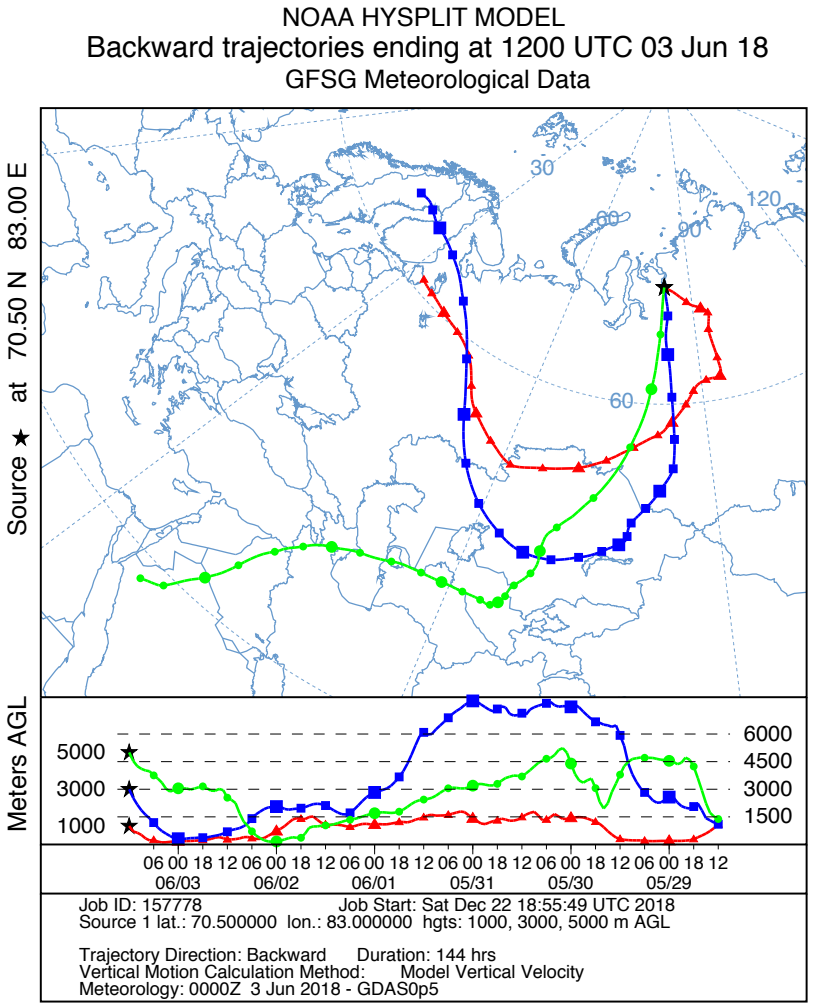
Conclusions:

- **Anomalously amplified flow from eastern North America to Europe permits midlatitude disturbances to reach the Arctic**
- **TS Alberto remnants merge with a Canadian cyclone, move northeastward and weaken over the Davis Strait windward of Greenland**
- **AC2 forms in the lee (east) of Greenland near the nose of a strong upper-level jet and along a moisture axis linked back to TS Alberto**
- **AC1 forms along a cold front near the Caspian Sea ahead of an amplified upper-level trough, deepens northeastward, and reaches the Kara Sea**
- **Cyclonic wave breaking and amplifying flow over western and central Europe enables AC1 and AC2 to strengthen and move poleward**
- **TPVs embedded within deep upper-level troughs foster rapid deepening of AC1 and AC2 in the left-exit regions of jet streaks**
- **AC2 absorbs AC1 after a Fujiwara cyclonic rotation, becomes the dominant Arctic cyclone (962 hPa), and has a standardized SLP anomaly of $< -6\ \sigma$**

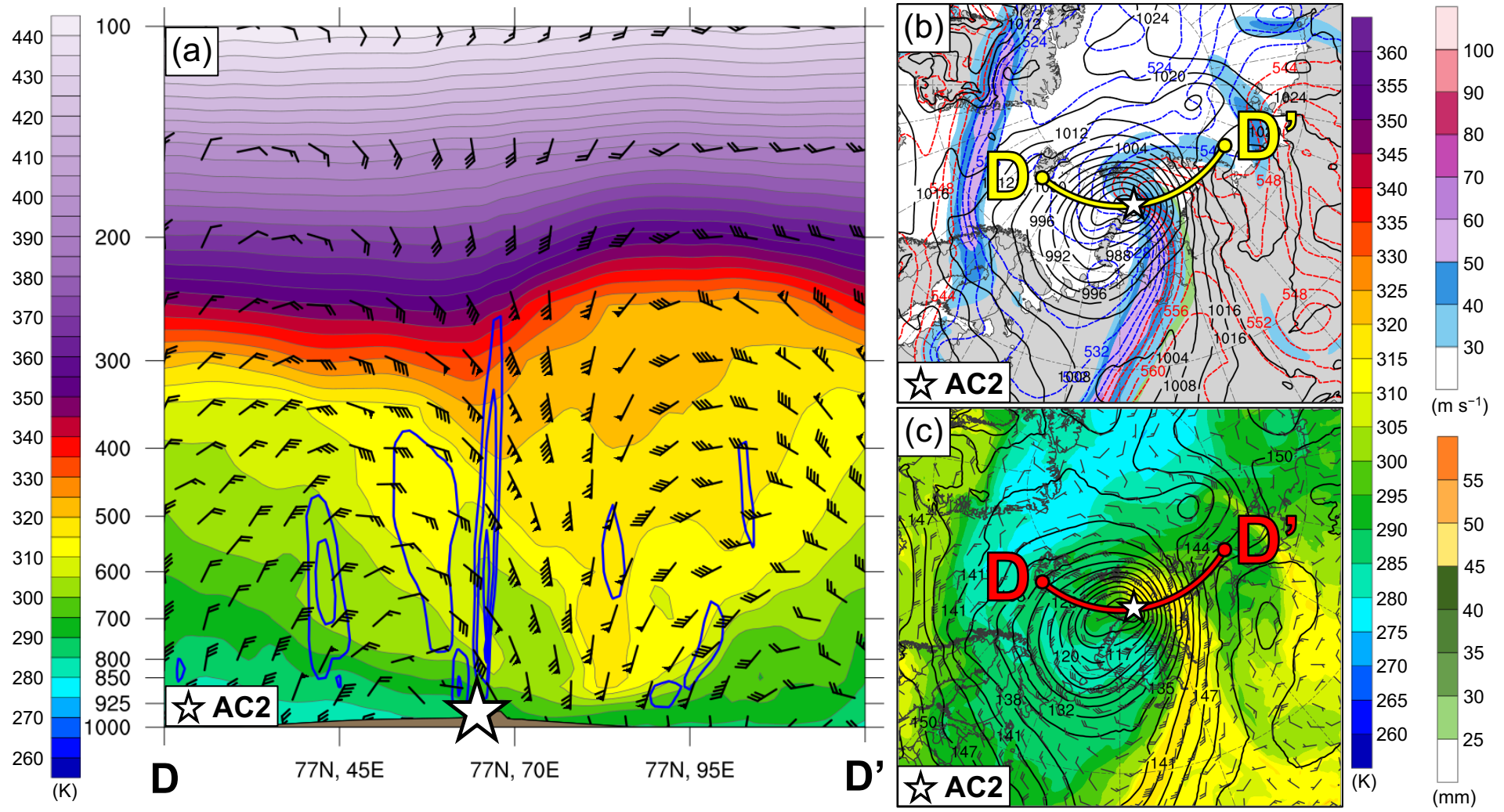
Extra Slides

Lagrangian Perspective: Selected Trajectories (AC1)



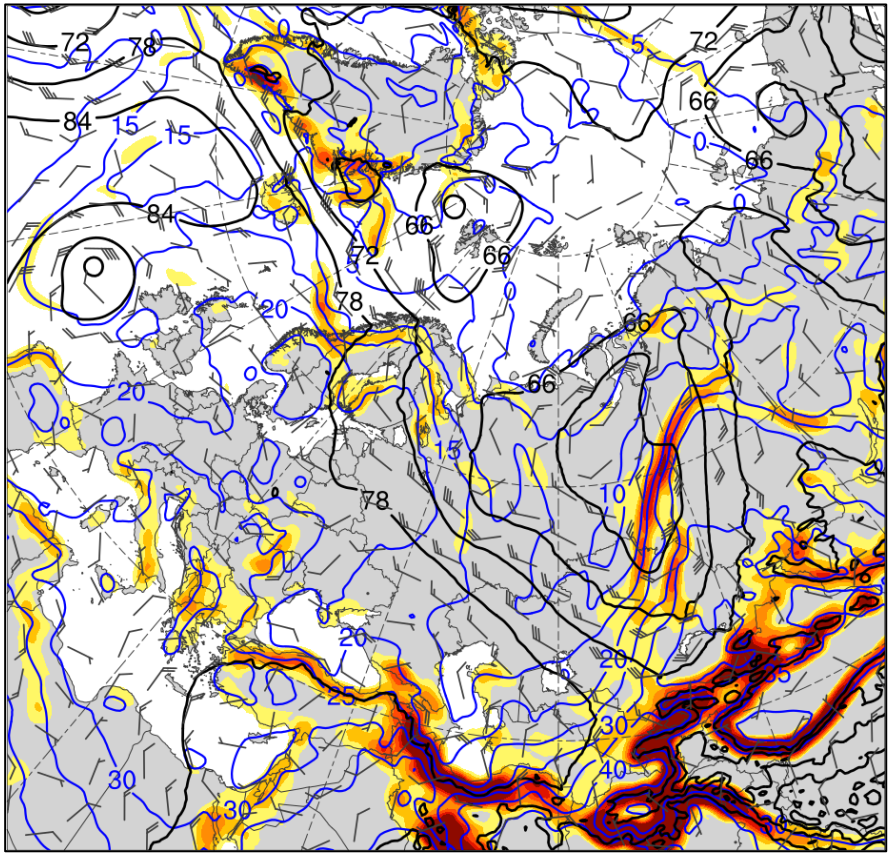


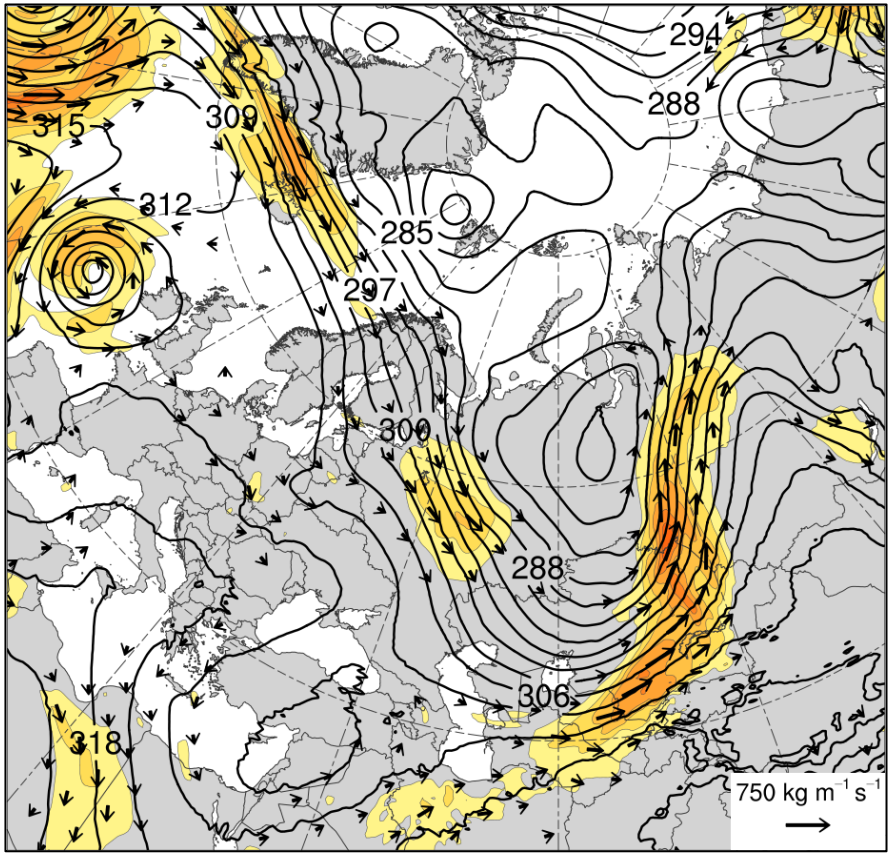
0000 UTC 7 Jun 2018



(a) θ_e (K, shaded), ascent (blue, every 5×10^{-3} hPa s^{-1}), and wind (m s^{-1}, flags and barb); (b) 300-hPa wind speed (m s^{-1}, shaded),1000–500-hPa thickness (dam, blue/red), SLP (hPa, black), and PW (mm, shaded); (c) 850-hPa θ_e (K, shaded), geopotential height (dam, black), and wind (m s^{-1}, flags and barb)

1200 UTC 2 Jun 2018





[K (100 km)$^{-1}$]

3 4 5 6 7 8

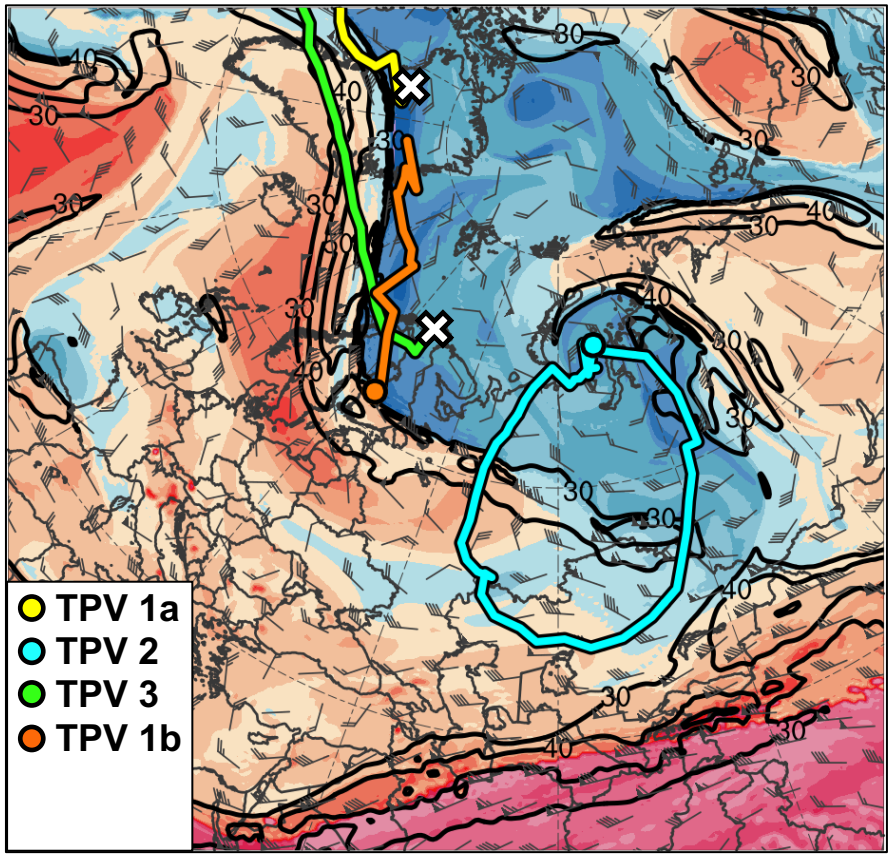
(kg m^{-1} s^{-1})

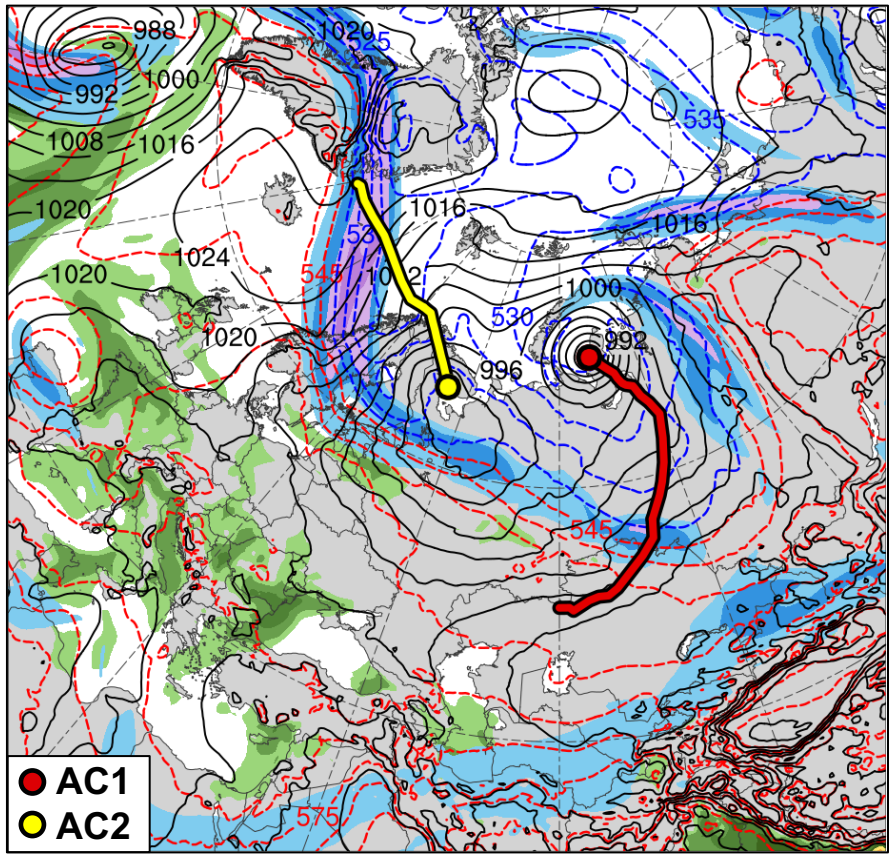
200 300 400 500 600 700 800 1000 1200 1400 1600

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)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

1200 UTC 4 Jun 2018





252 258 264 270 276 282 288 294 300 306 312 318 324 330 336 342 348 354 360 366 372 378 (K)

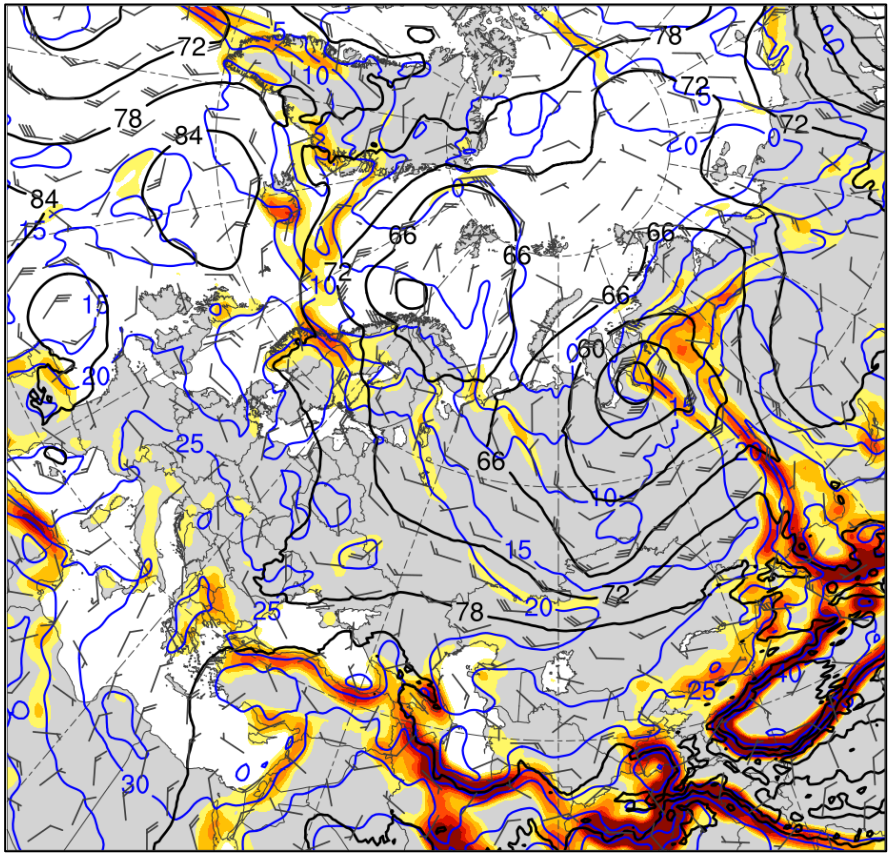
30 40 50 60 70 80 90 100 (m s^{-1})

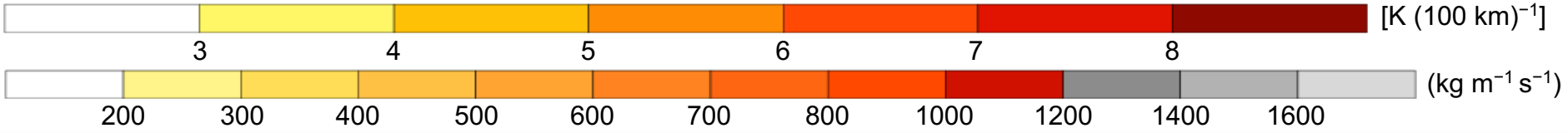
25 30 35 40 45 50 55 (mm)

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

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

1200 UTC 3 Jun 2018

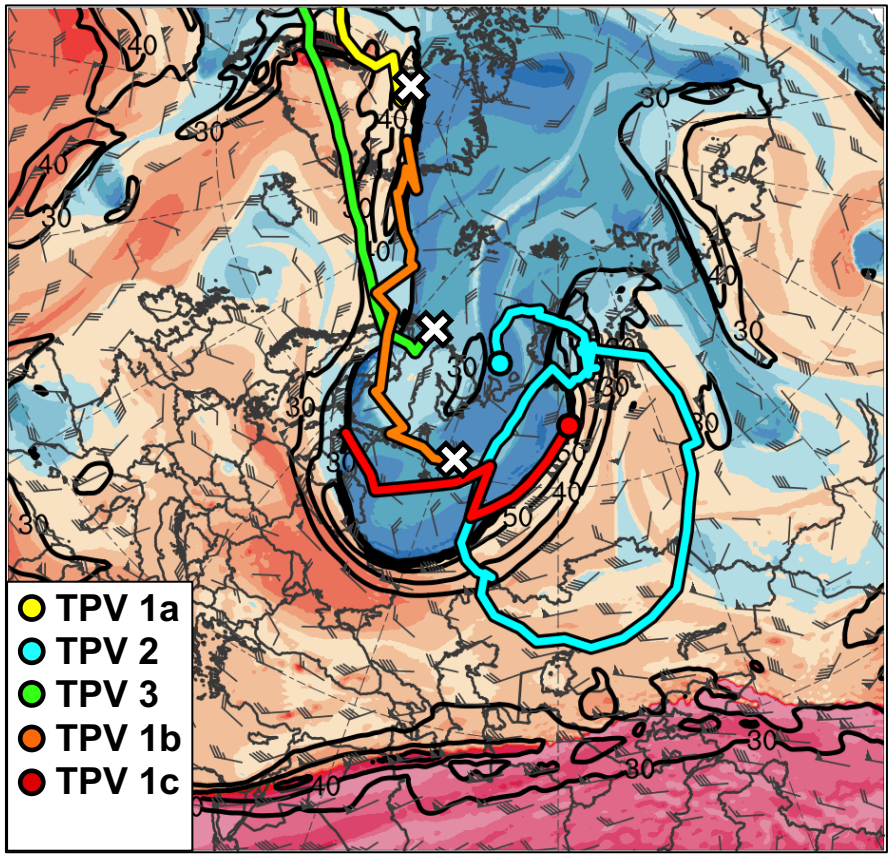


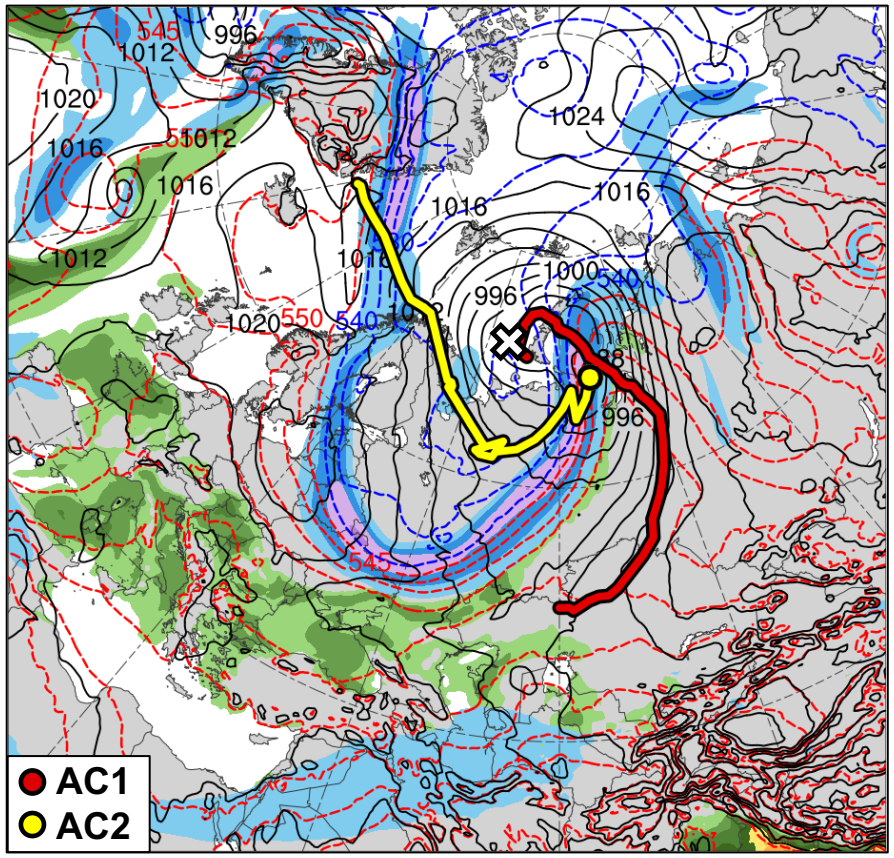


925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

1200 UTC 6 Jun 2018





252 258 264 270 276 282 288 294 300 306 312 318 324 330 336 342 348 354 360 366 372 378 (K)

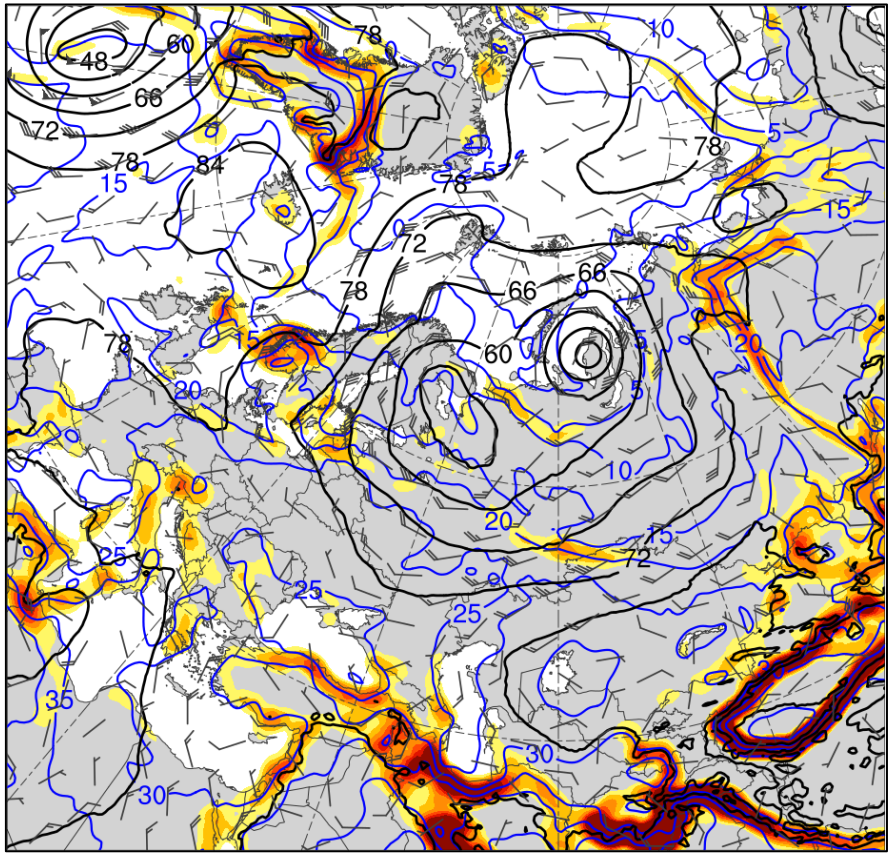
30 40 50 60 70 80 90 100 (m s^{-1})

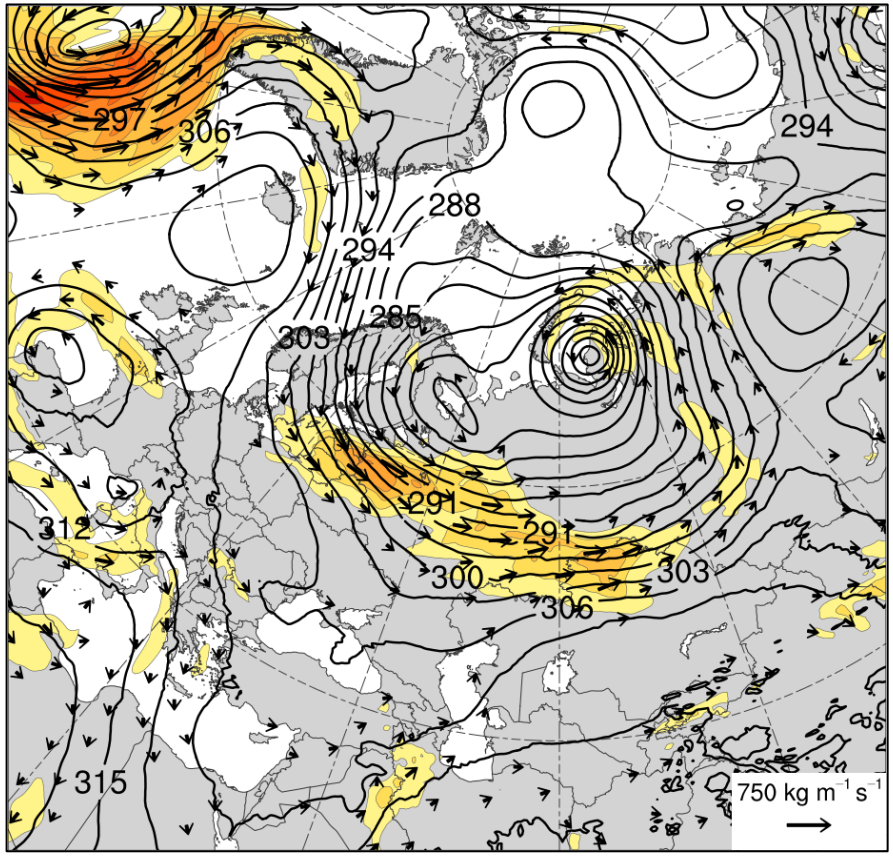
25 30 35 40 45 50 55 (mm)

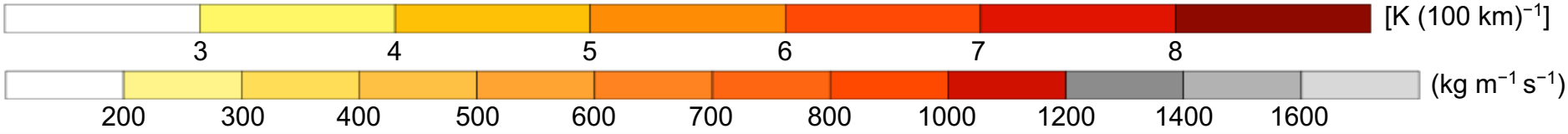
Potential temperature (K, shaded), wind speed (black, every 10 m s^{-1} starting at 30 m s^{-1}), and wind (m s^{-1}, flags and barbs) on 2-PVU surface

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

1200 UTC 4 Jun 2018



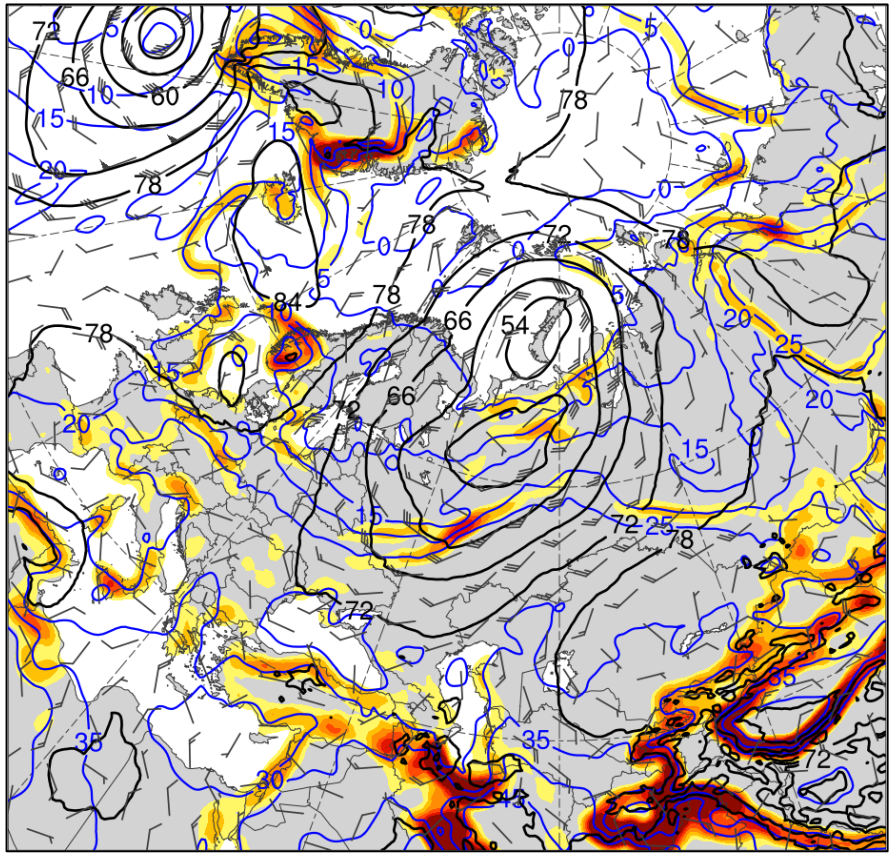


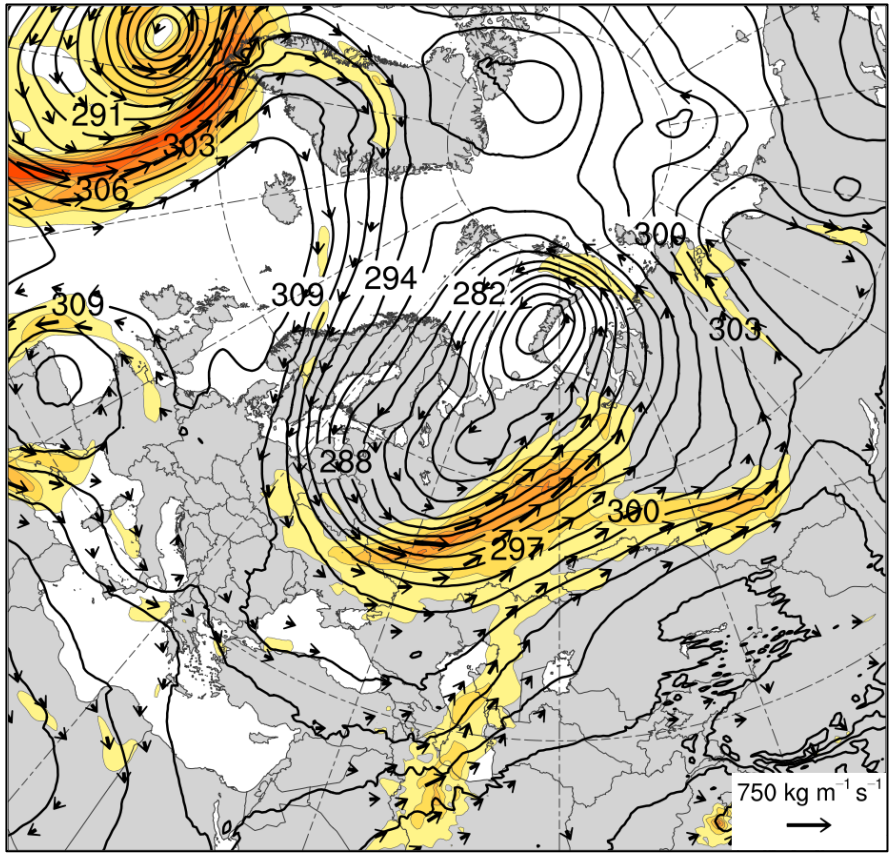


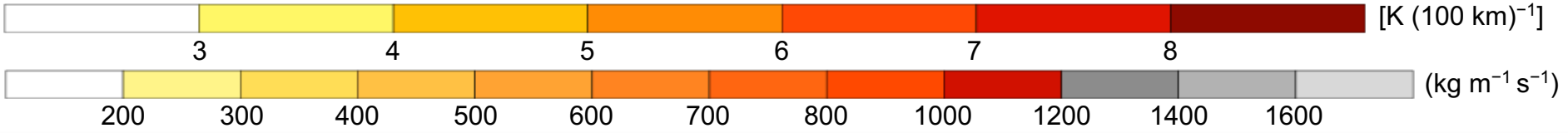
925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

1200 UTC 5 Jun 2018



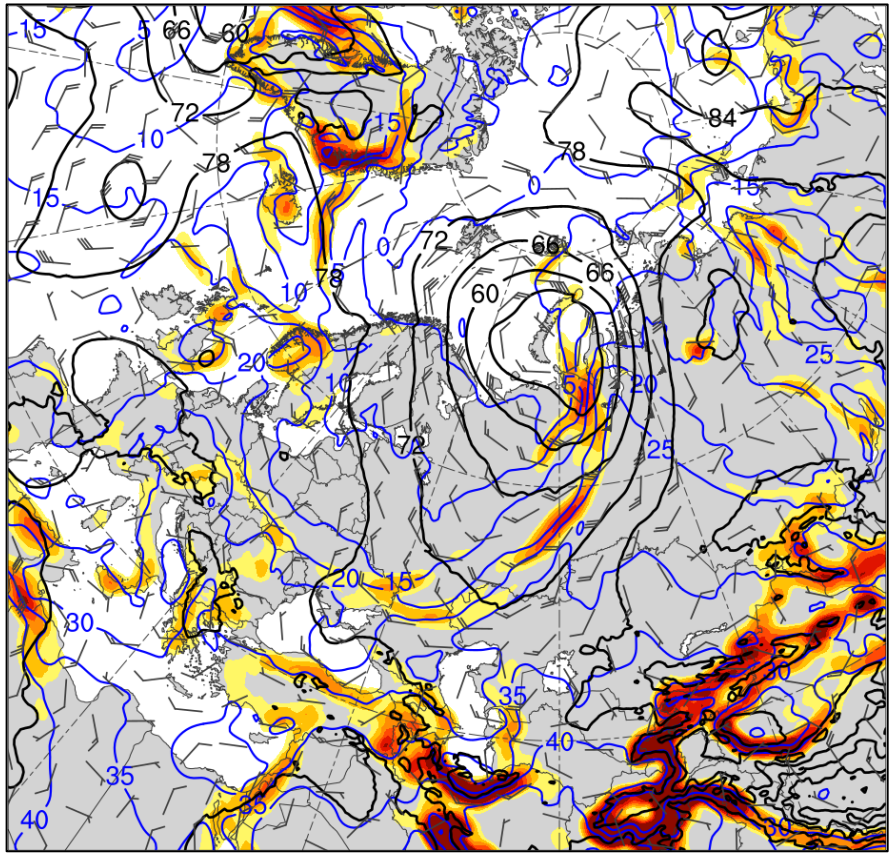


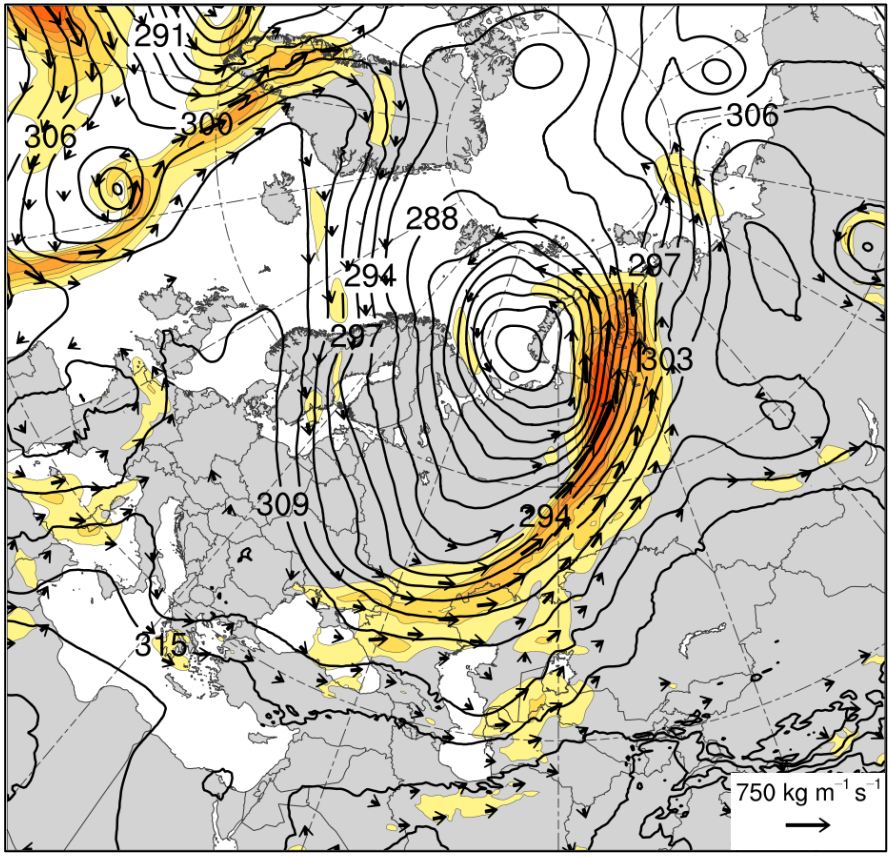


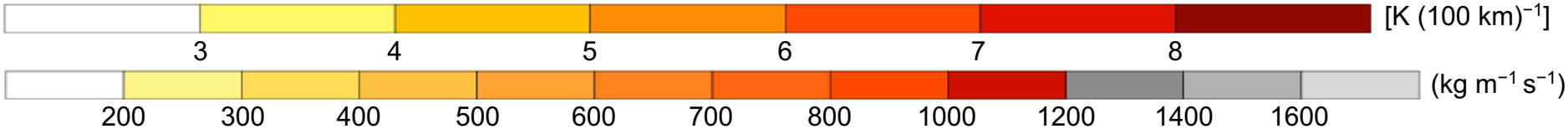
925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

1200 UTC 6 Jun 2018



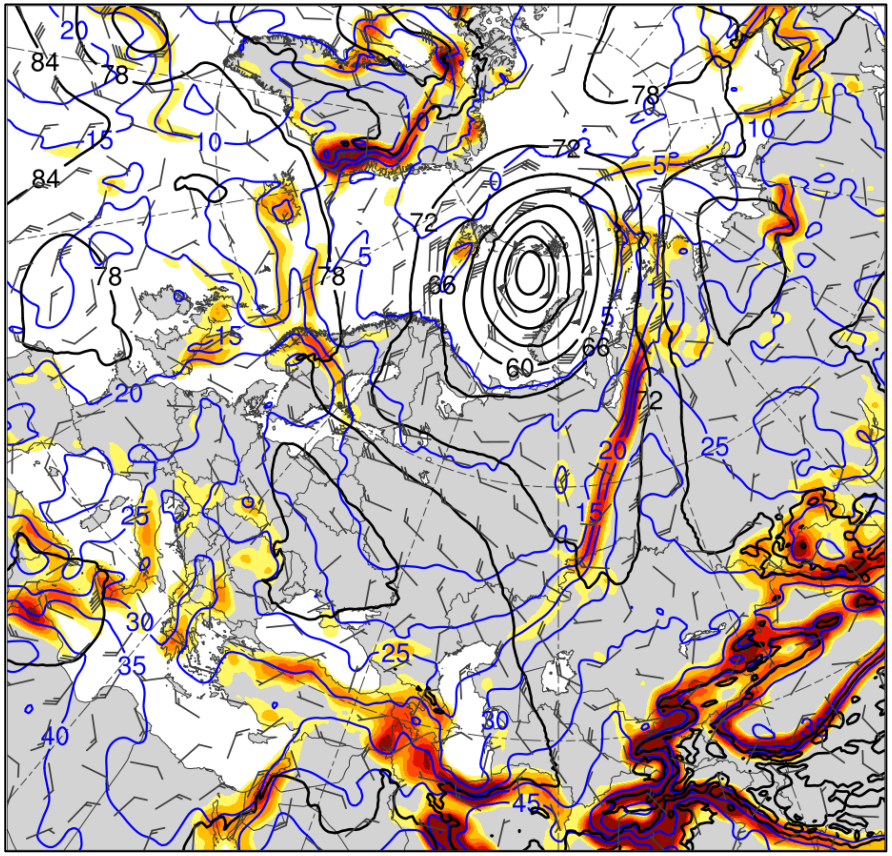


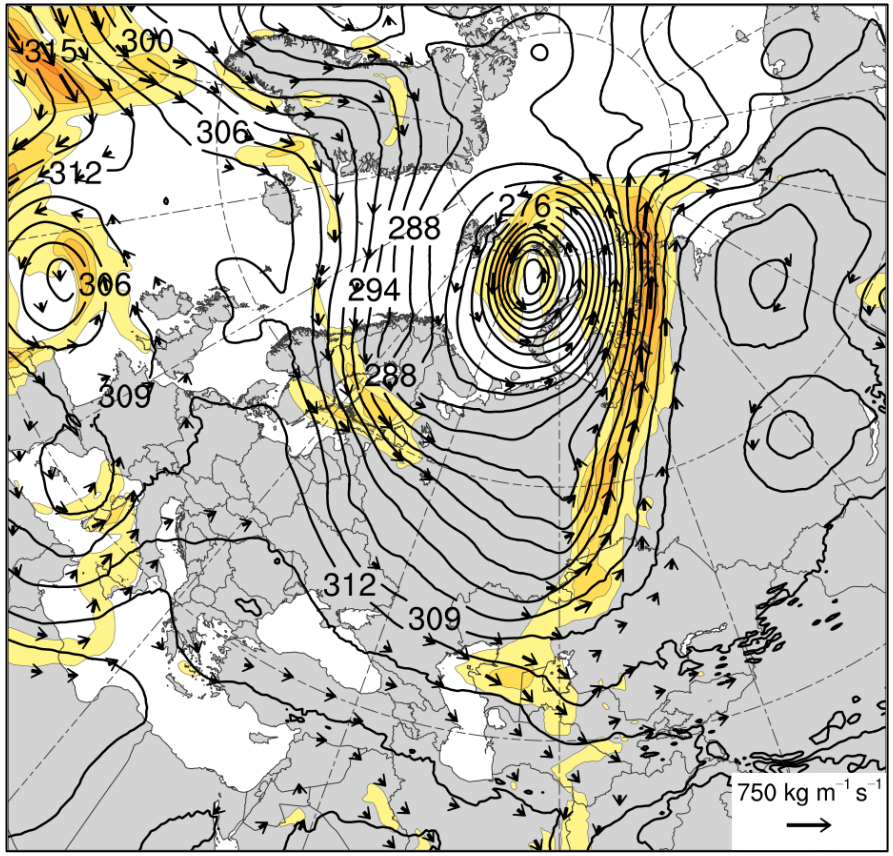


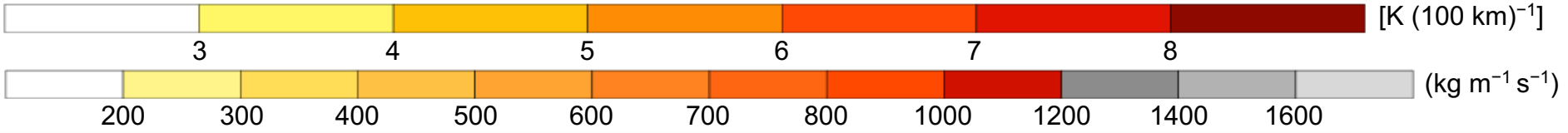
925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

1200 UTC 7 Jun 2018



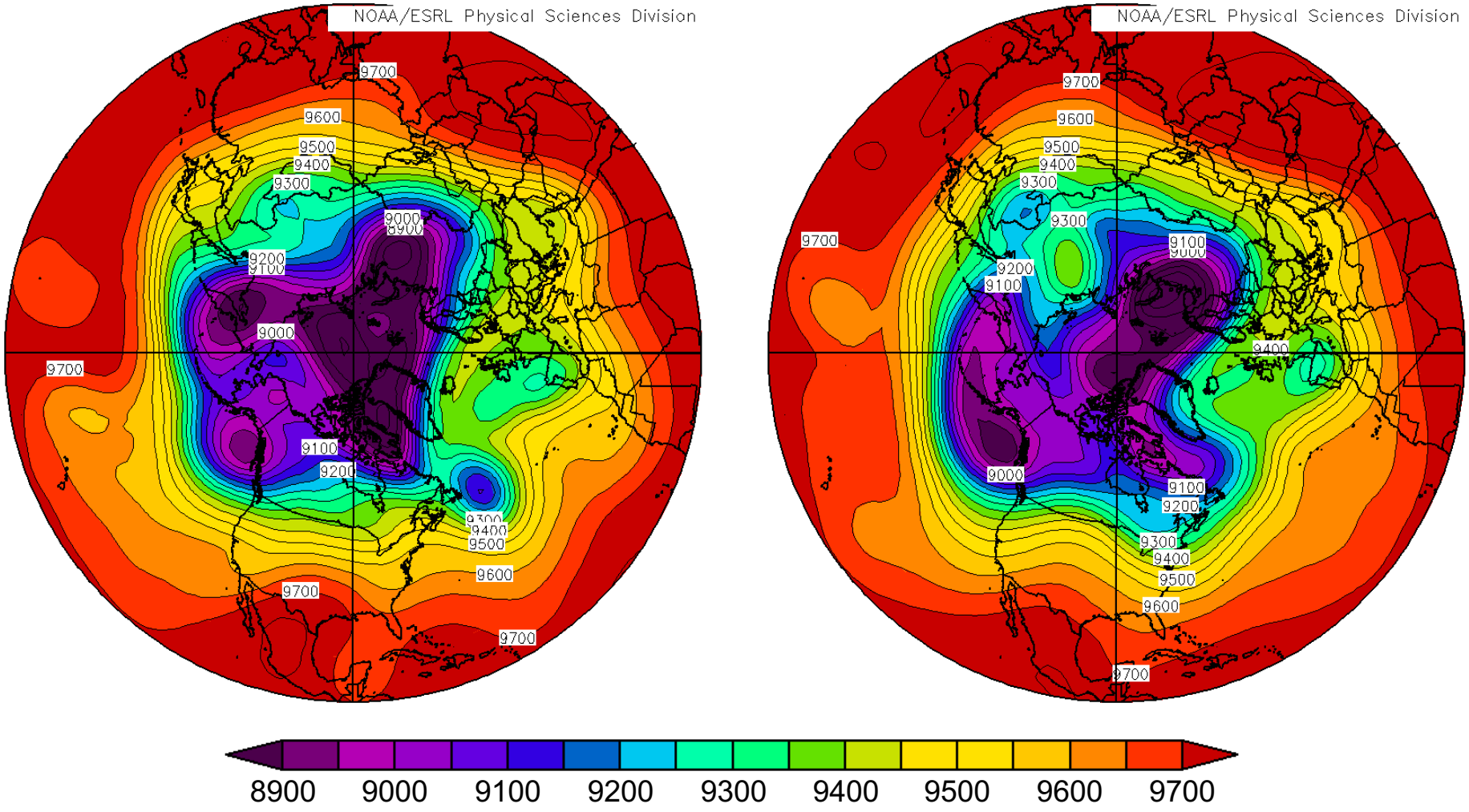




925-hPa area-averaged (100 km) θ gradient [K (100 km) $^{-1}$, shaded], θ (°C, blue), geopotential height (dam, black), and winds (m s^{-1}, flags and barbs)

IVT (kg m^{-1} s^{-1}, shaded and vectors) and 700-hPa geopotential height (dam, black)

Mean 300-hPa Geopotential Heights (m) for 1–4 June 2018 (left) and 4–7 June 2018 (right)



Anomaly 300-hPa Geopotential Heights (m) for 1–4 June 2018 (left) and 4–7 June 2018 (right)