Extreme Weather over North America Arising from Variability of the North Pacific Subtropical Jet

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Motivation and goals

- Illustrate role of strong North Pacific subtropical jet (STJ) as a crucial antecedent to intense Midwest cyclone of 26–27 Oct 2010

- Examine tropical and extratropical influences on intensification and elongation of STJ prior to event

- Provide context for STJ–extreme weather:
  - Address variability of STJ and its downstream influence from climatological and composite analysis perspectives
  - Compare October 2010 event to “1978 Cleveland Superbomb”

Outline

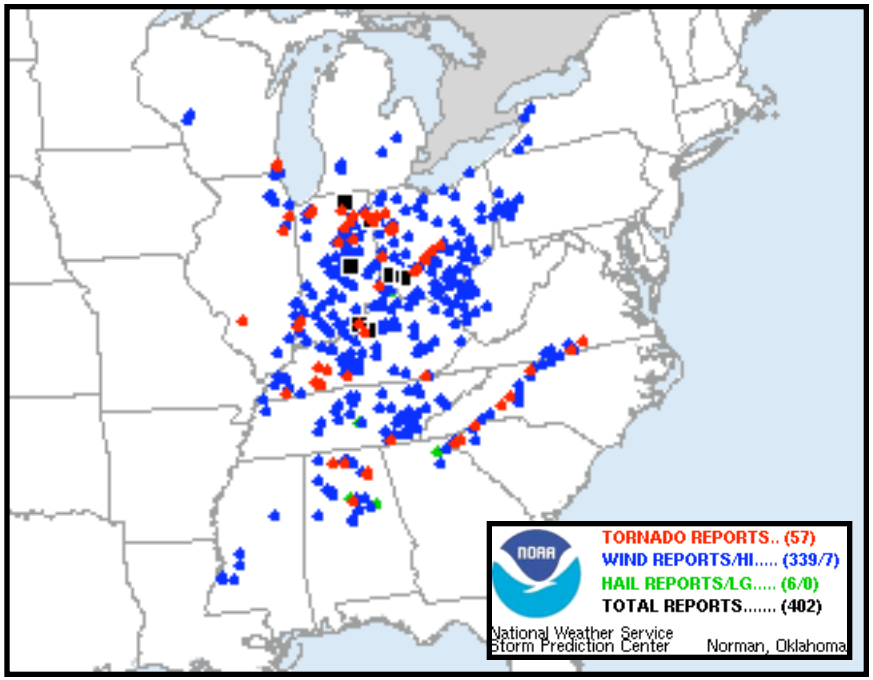
- Cyclone statistics
- Antecedent conditions
- Cyclone evolution
- Composite STJ variability and downstream influence
- Comparison with “1978 Cleveland Superbomb”

Cyclone statistics: High-impact weather

- SLP of 955.2 hPa at Bigfork, MN (ASOS) at 2213 UTC 26 Oct
  - Set MN state record for lowest observed SLP
  - Record lowest observed SLP between Rockies and Appalachians, breaking record set by Jan 1978 Cleveland Superbomb

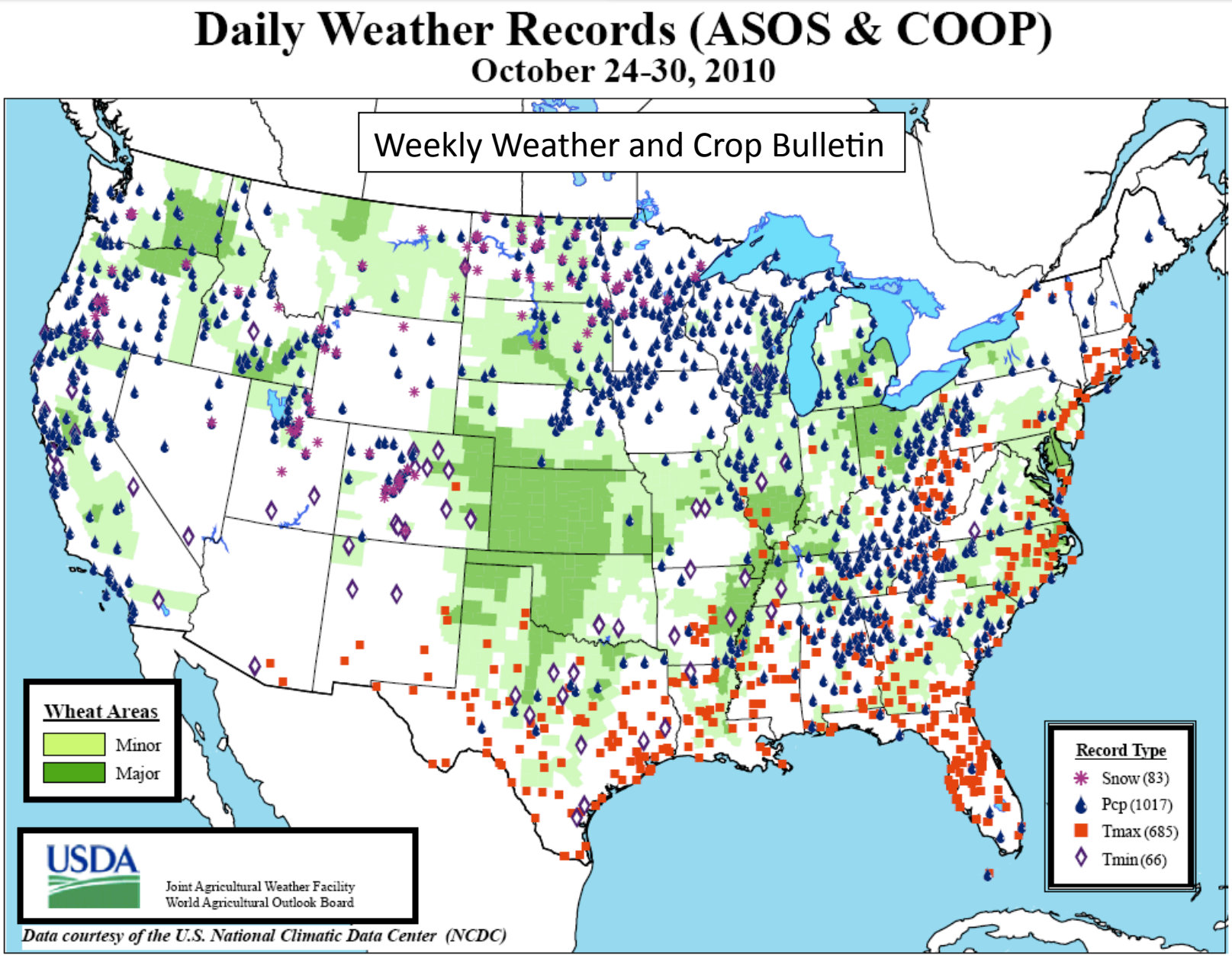
- Strong SLP gradient resulted in 55–65 kt wind gusts

- Long-lived squall line was associated with 400+ severe reports on 26 Oct



SPC Storm Reports: 26 Oct 2010

Cyclone statistics: High-impact weather



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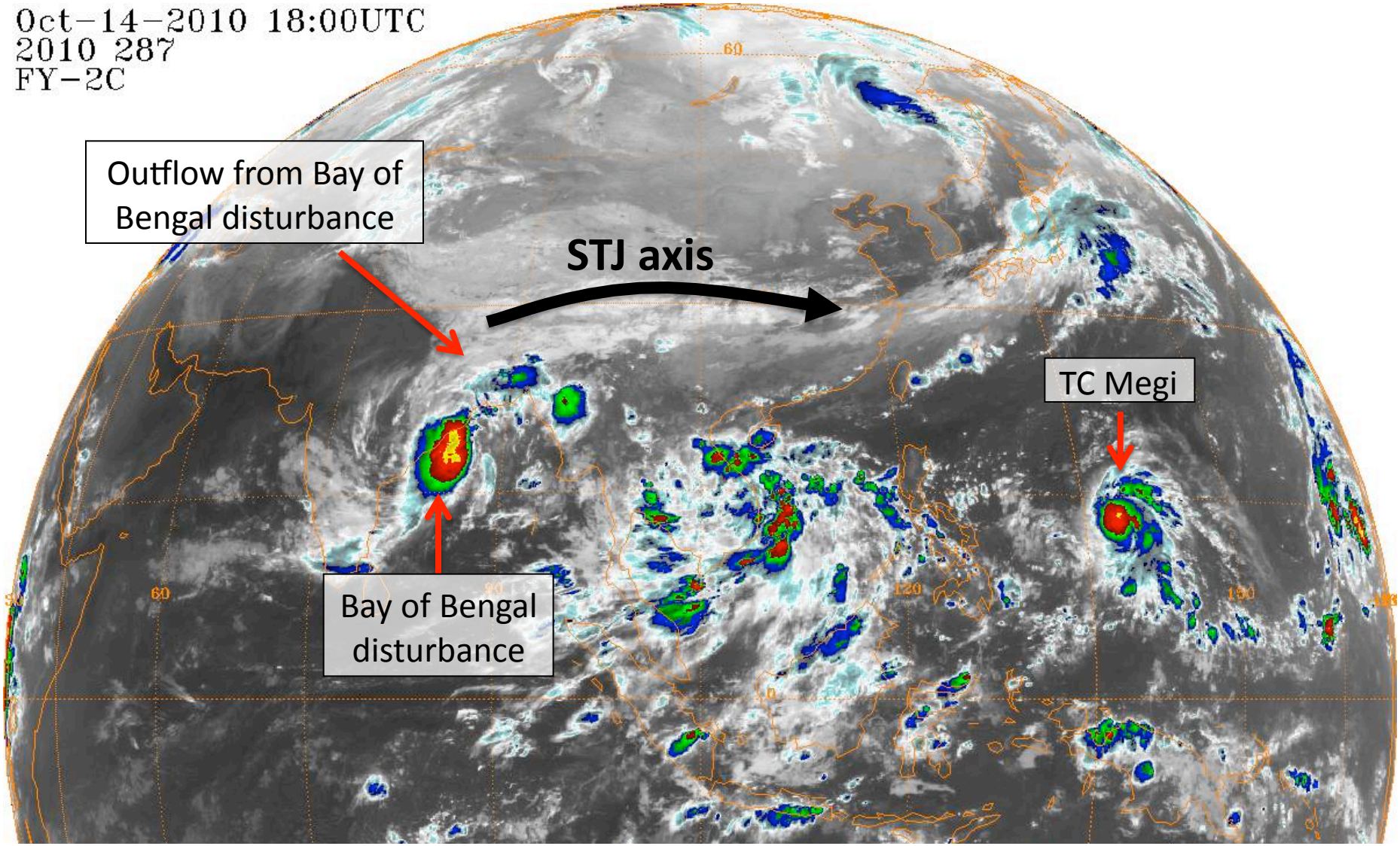
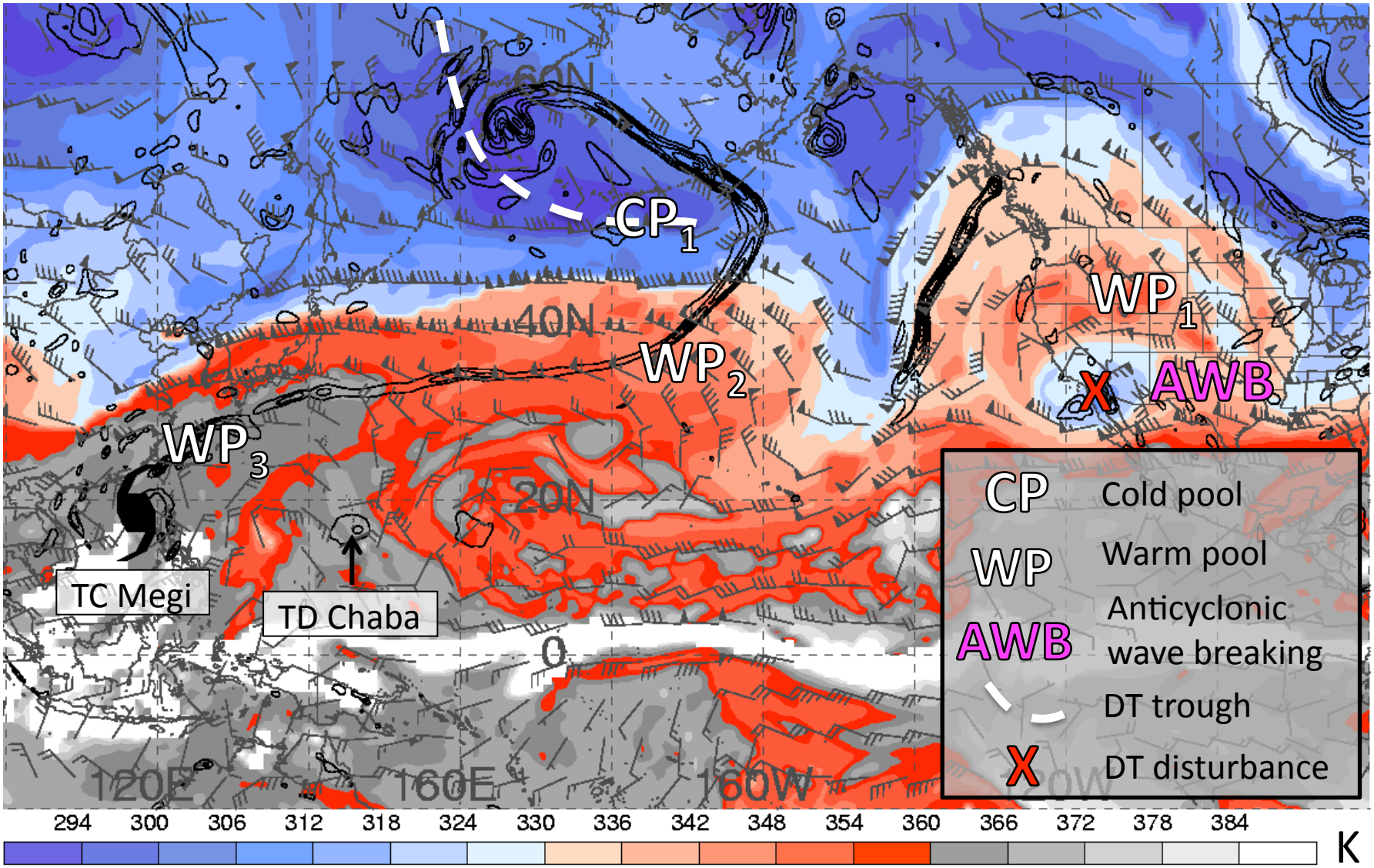
Antecedent conditions: 1800 UTC 14 Oct IR



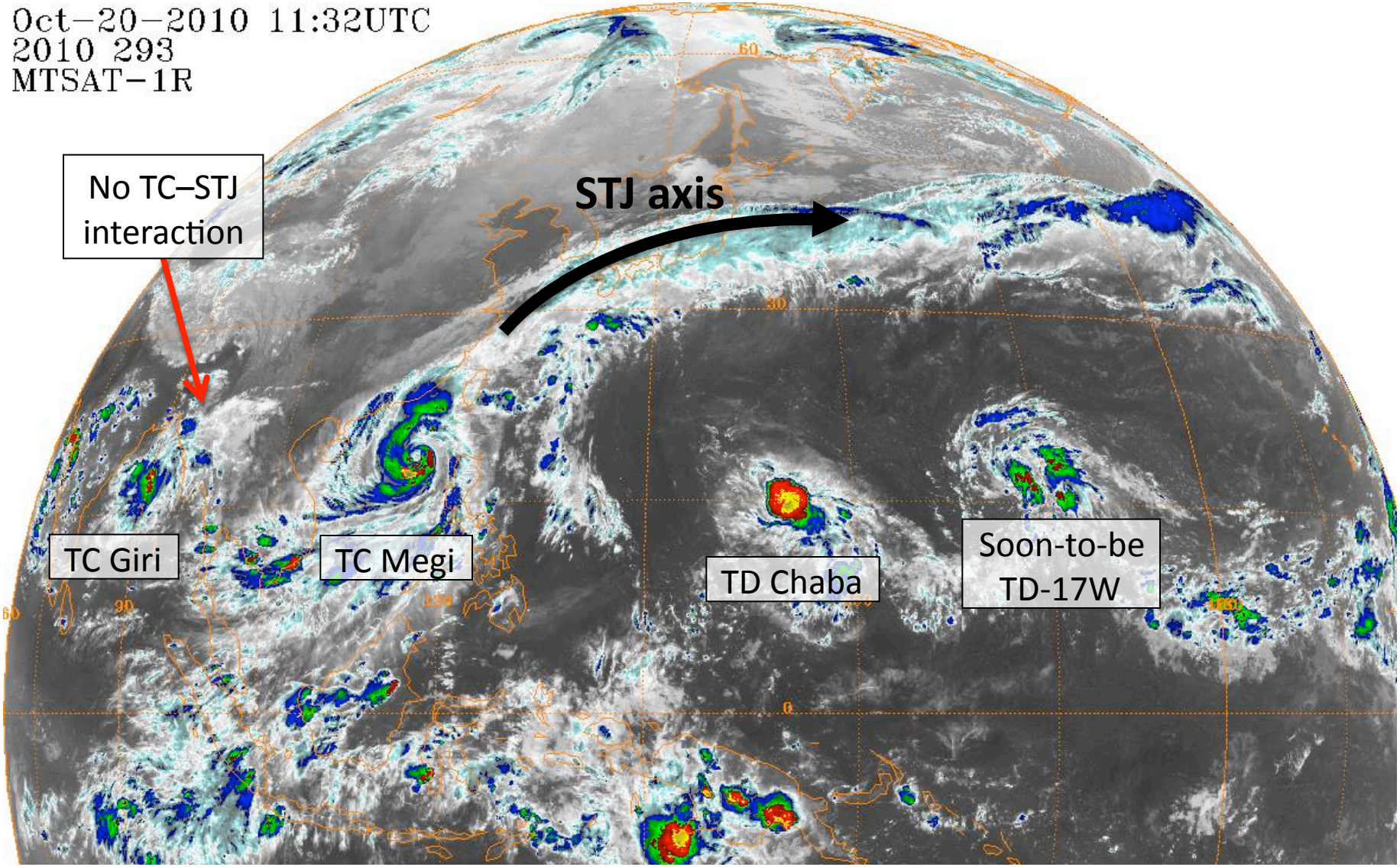
Fen Yung 2E GOES satellite

Antecedent conditions: 1200 UTC 20 Oct DT Plot



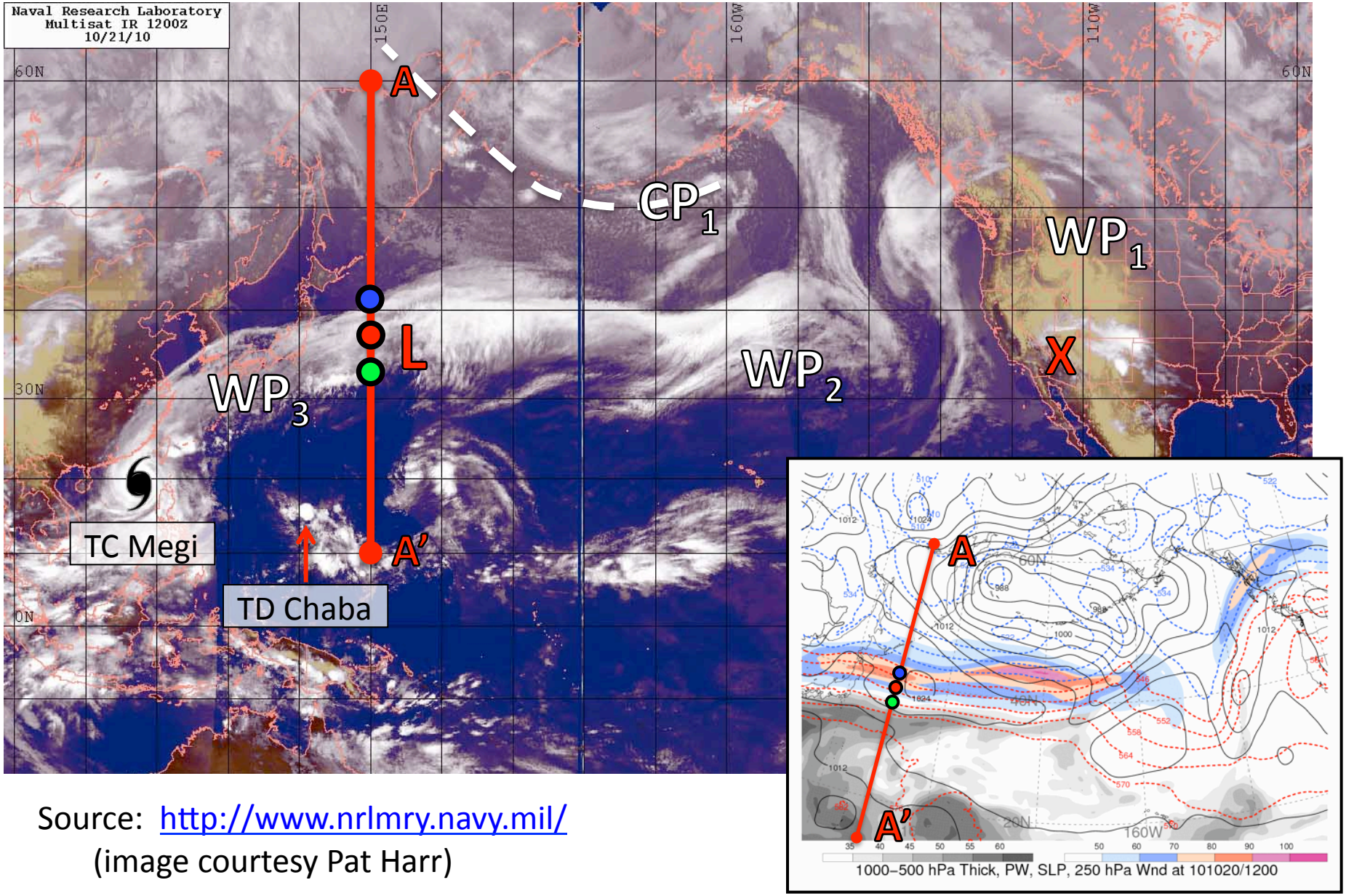
Potential temperature (K, shaded) and wind (kt, barbs) on 1.5-PVU surface; 925–850-hPa layer-averaged cyclonic relative vorticity (black, every 5 x 10^{-5} s^{-1})

Antecedent conditions: 1200 UTC 20 Oct IR



MTSAT-1R GOES satellite

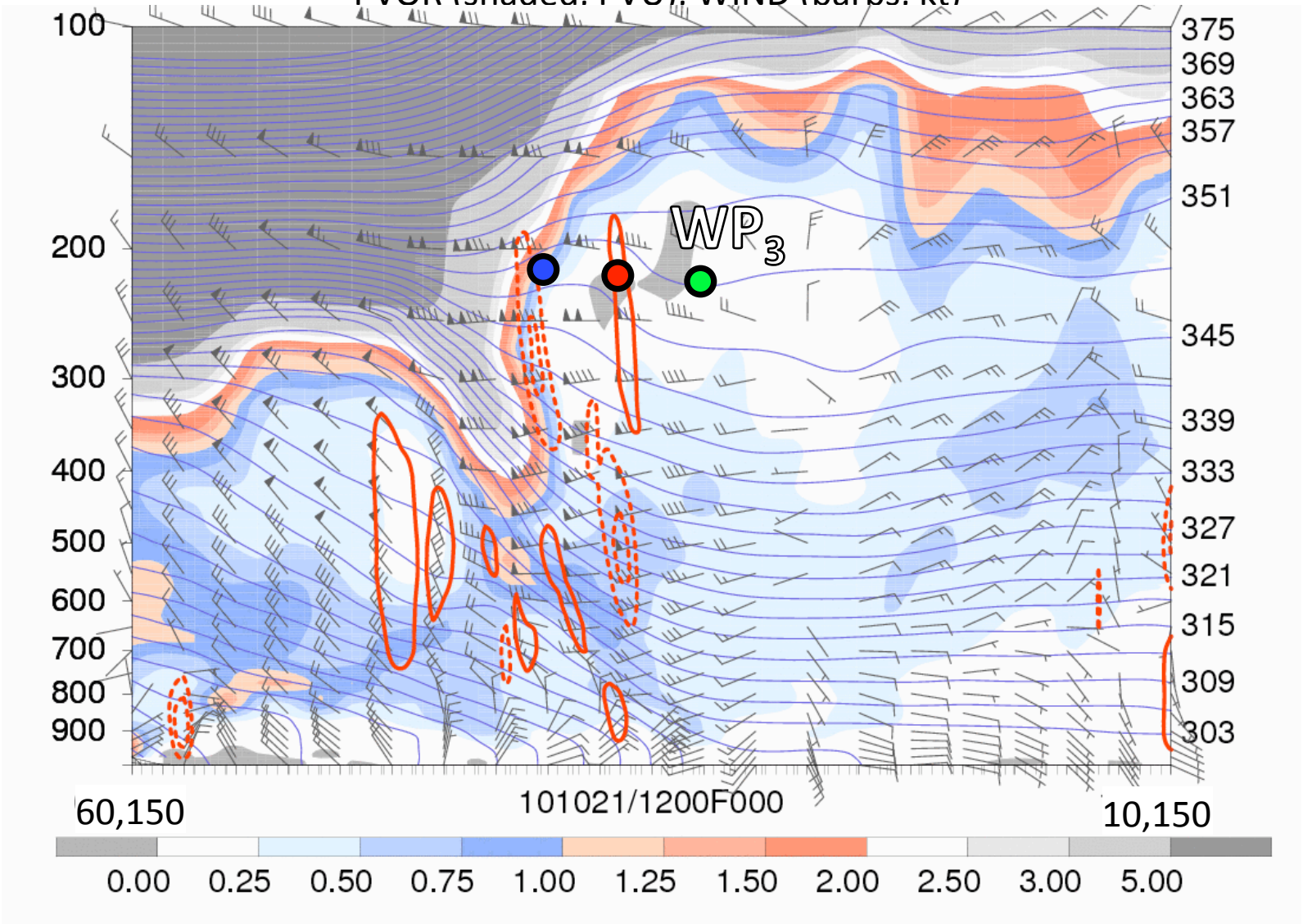
Antecedent conditions: 1200 UTC 21 Oct IR Image



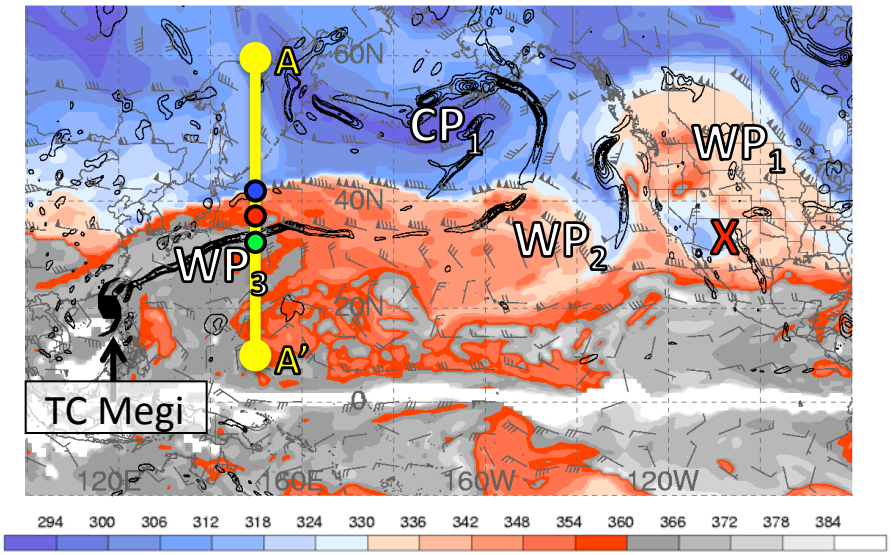
Source: http://www.nrlmry.navy.mil/
(image courtesy Pat Harr)

Antecedent conditions: 1200 UTC 21 Oct cross section

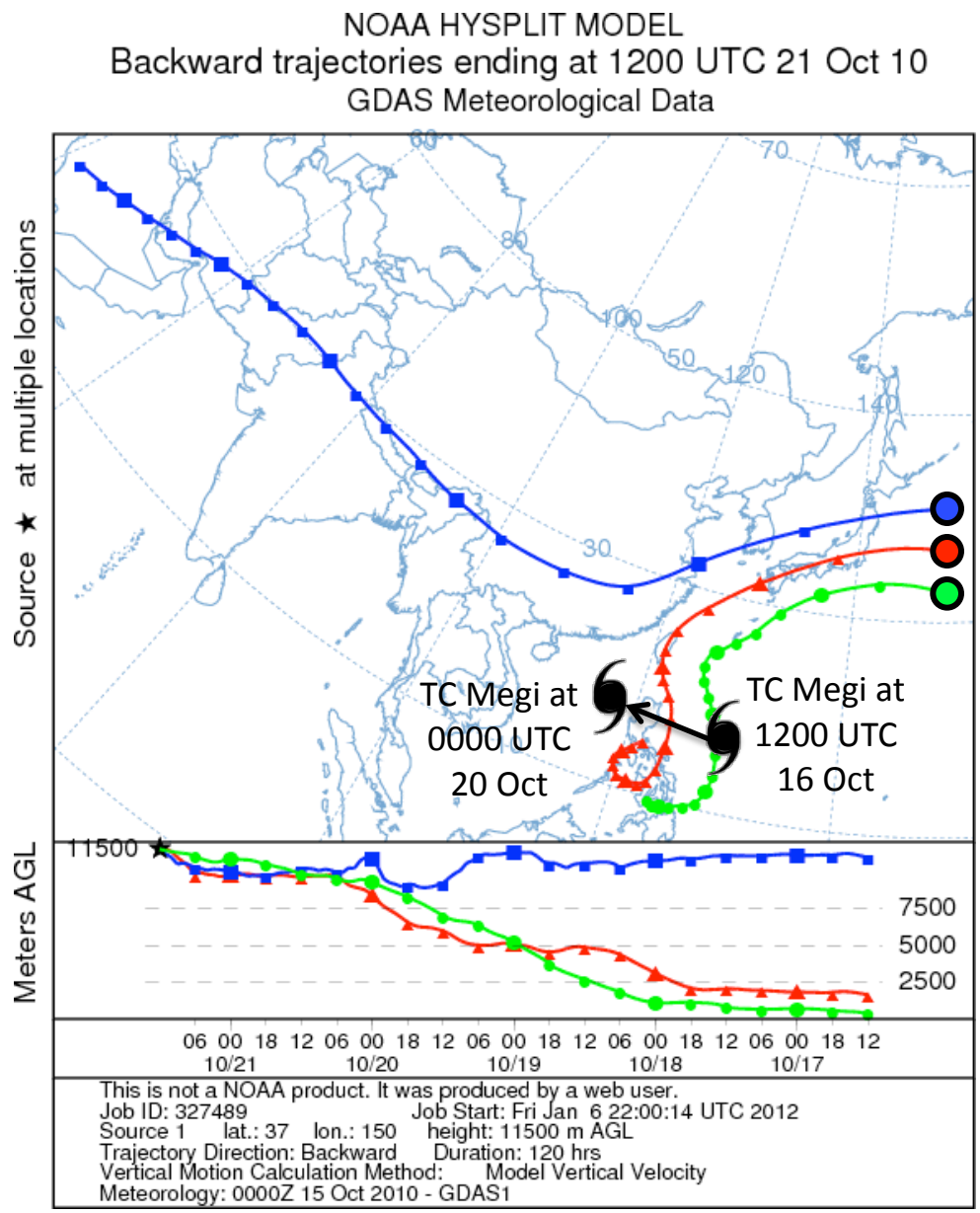
THTA (blue, every 3 dam), VVEL (red, every 3 x 10^{-3} hPa s^{-1})
PVOR (shaded. PVU), WIND (barbs. kt)



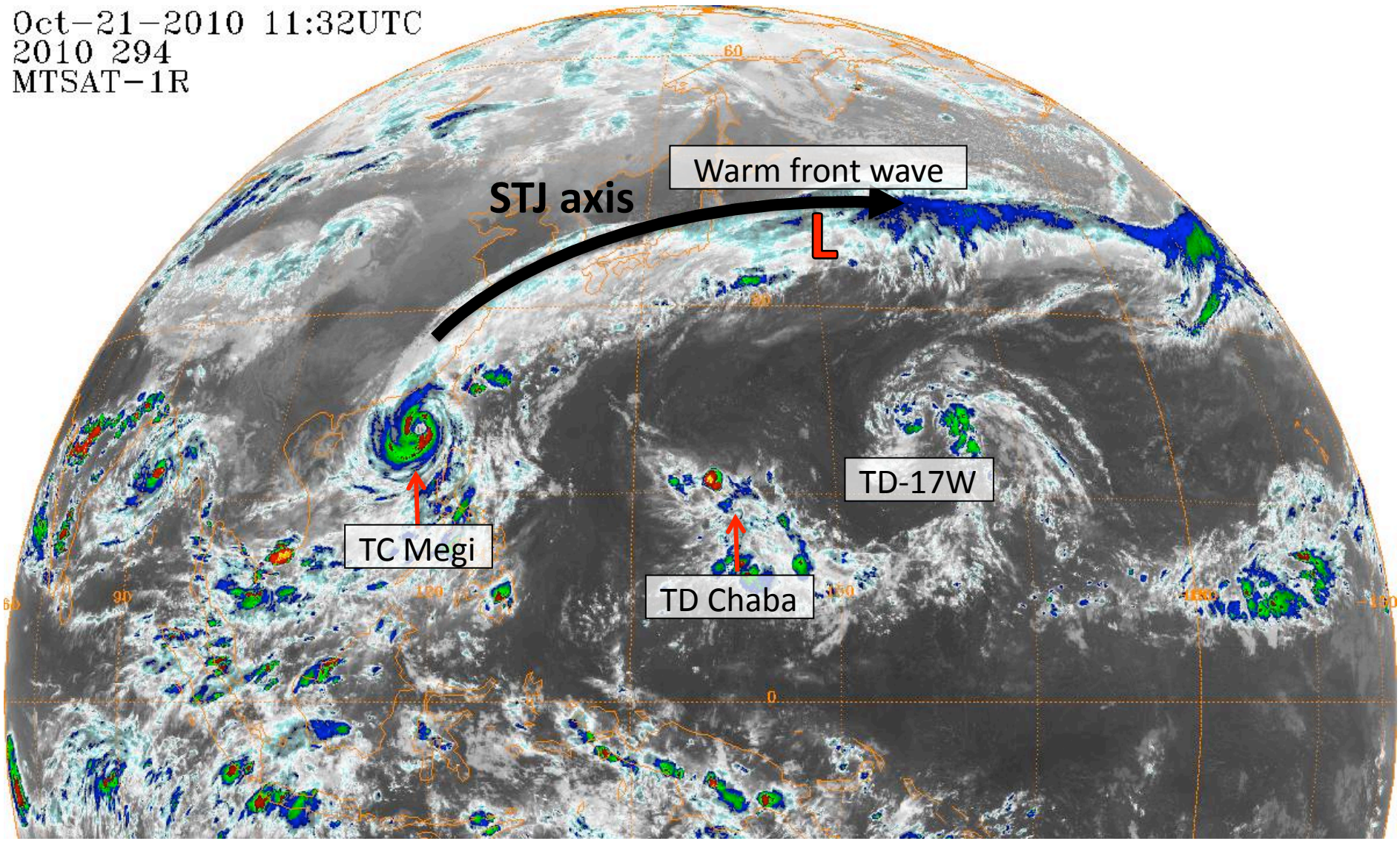
Antecedent conditions: 120-h trajectories ending 1200 UTC 21 Oct



Potential temperature (K, shaded) and wind (kt, barbs) on 1.5-PVU surface; 925–850-hPa layer-averaged cyclonic relative vorticity (black, every 5 x 10^{-5} s^{-1})

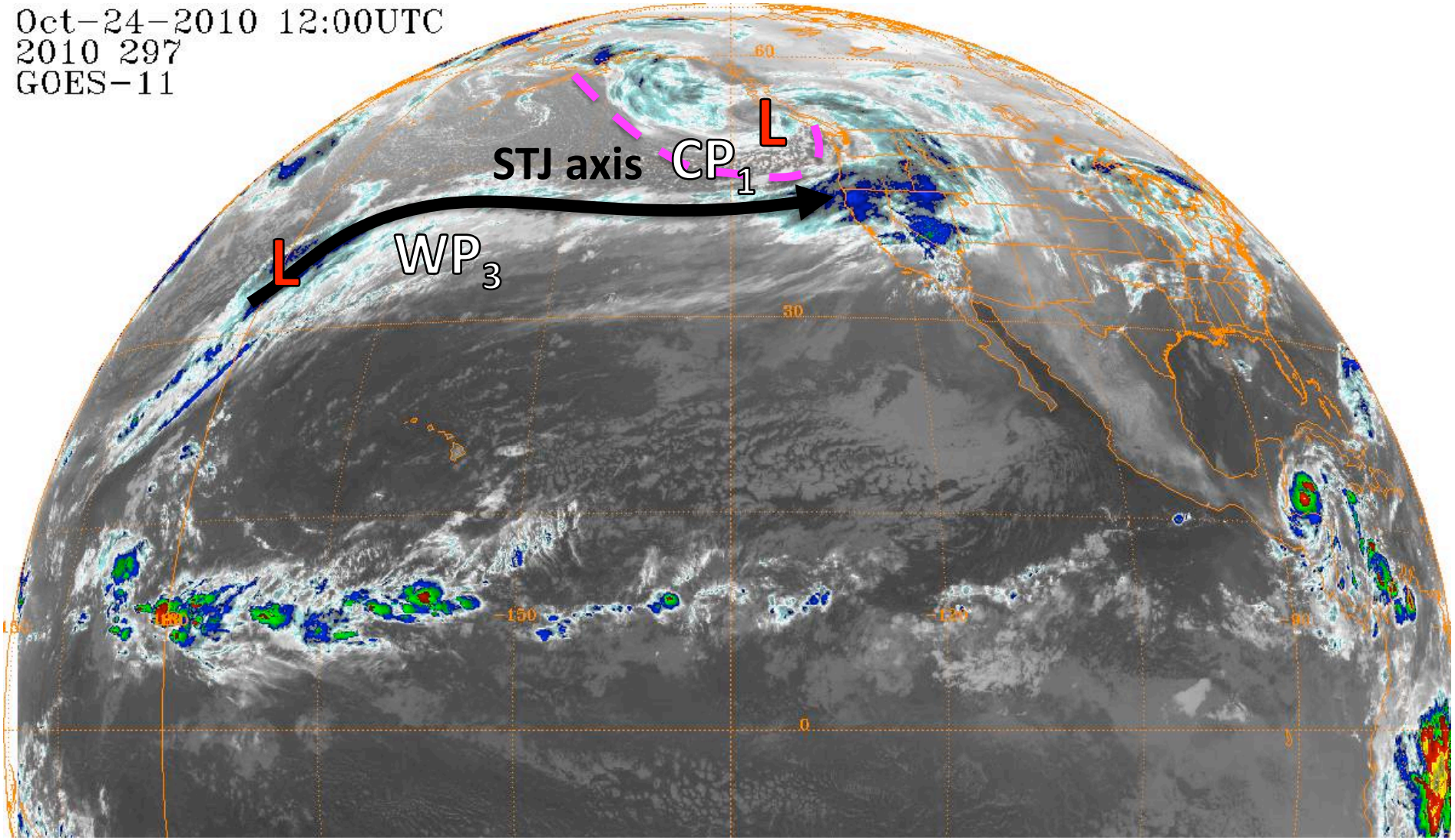


Antecedent conditions: 1200 UTC 21 Oct IR



MTSAT-1R GOES satellite

Antecedent conditions: 1200 UTC 24 Oct IR



GOES-11 satellite

Summary of Tropical Disturbances on Subtropical Jet

Tropical Disturbance	Impact on STJ
Bay of Bengal disturbance (likely TD strength)	Helped to strengthen STJ over Southeast Asia
Giri (Cat 5)	Moved northeast to Myanmar but did not influence STJ
Megi (Cat 3)	Helped to strengthen STJ over western North Pacific
Chaba (TD)	Moved west-northwest but did not influence STJ
TD-17 W (30-kt max sustained wind)	Provided moisture for low-level front, deep ascent along STJ

Outline

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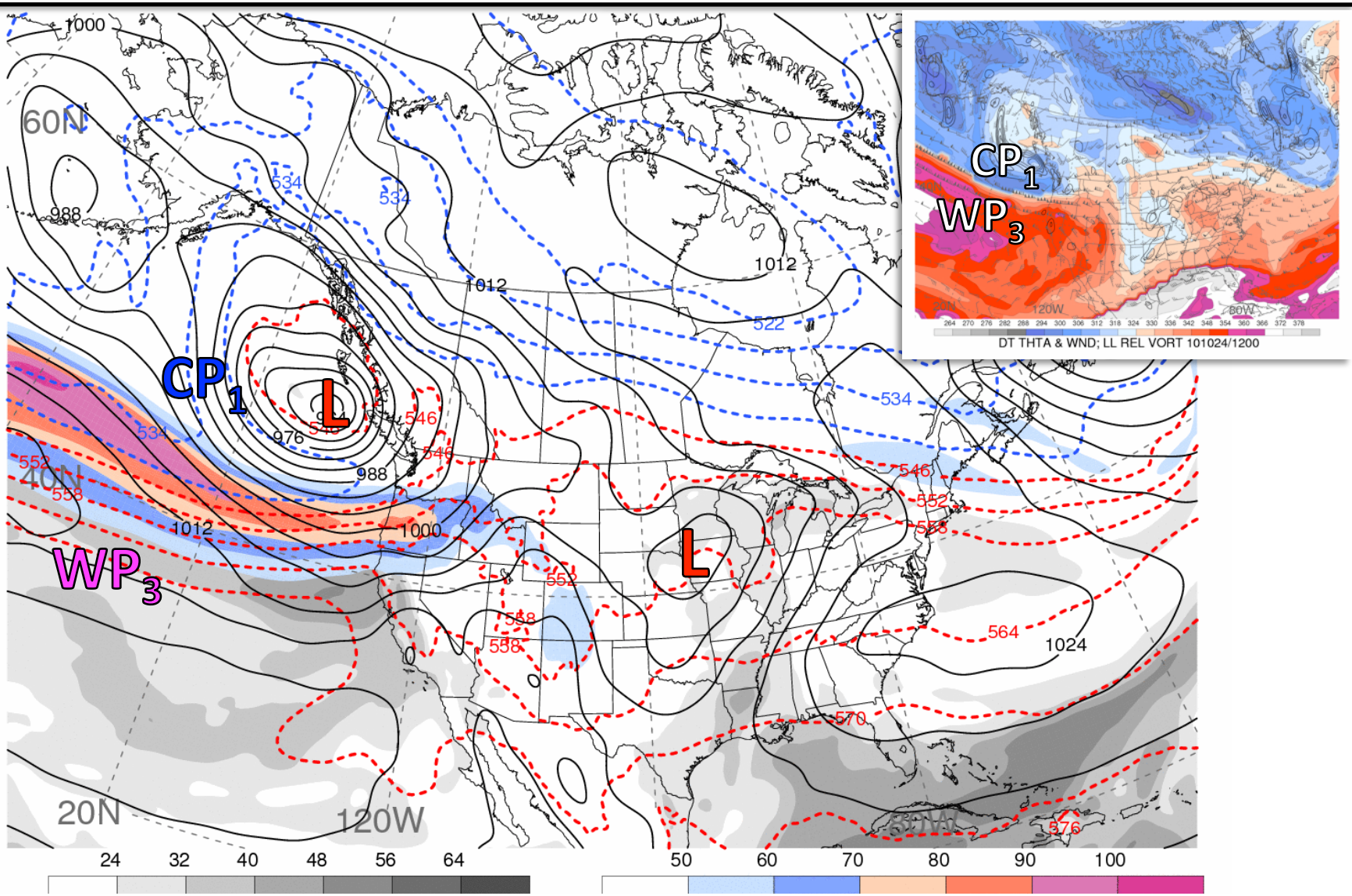
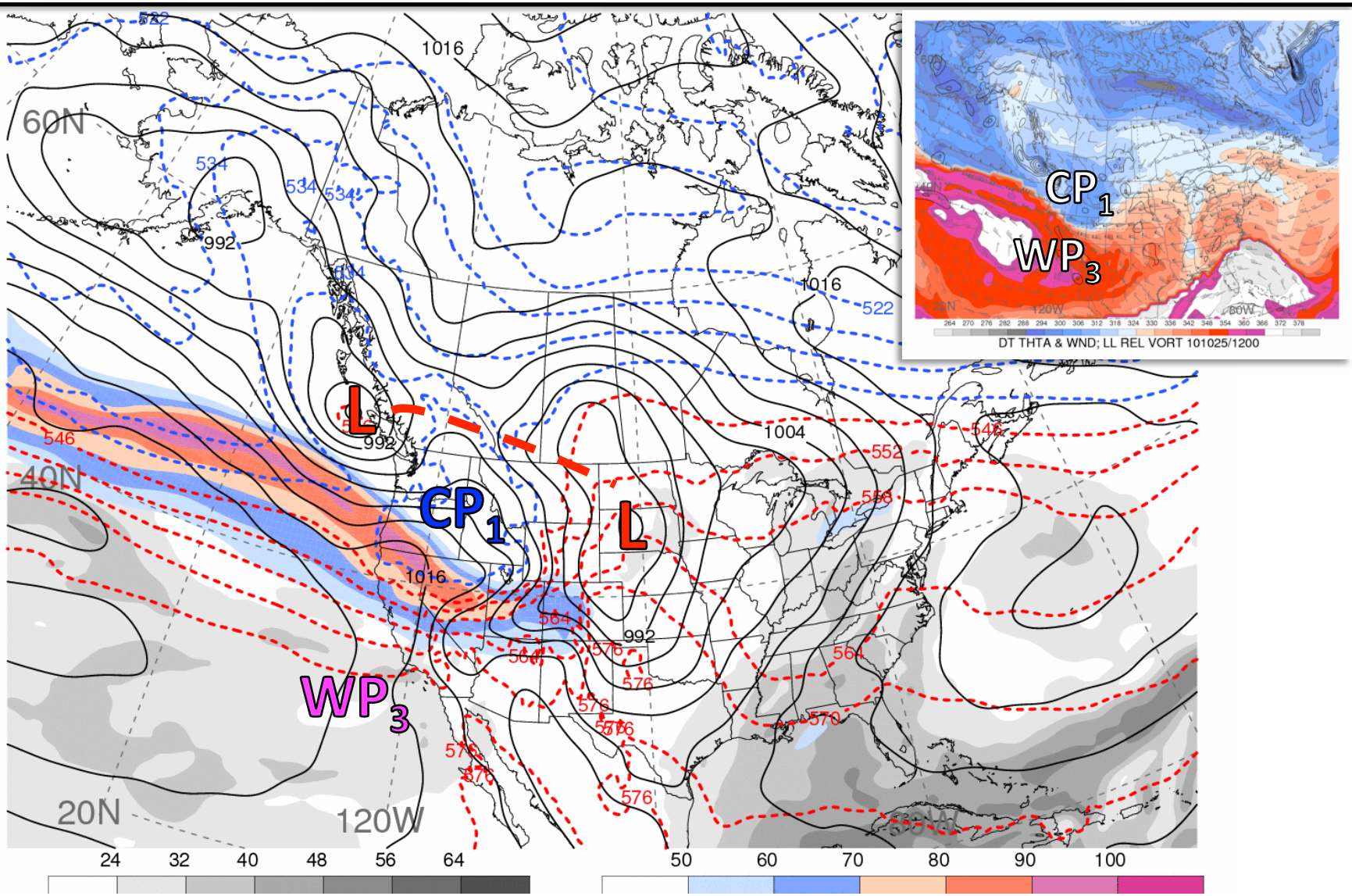
- Composite STJ variability and downstream influence
- Comparison with “1978 Cleveland Superbomb”

Cyclone evolution: 1200 UTC 24 Oct



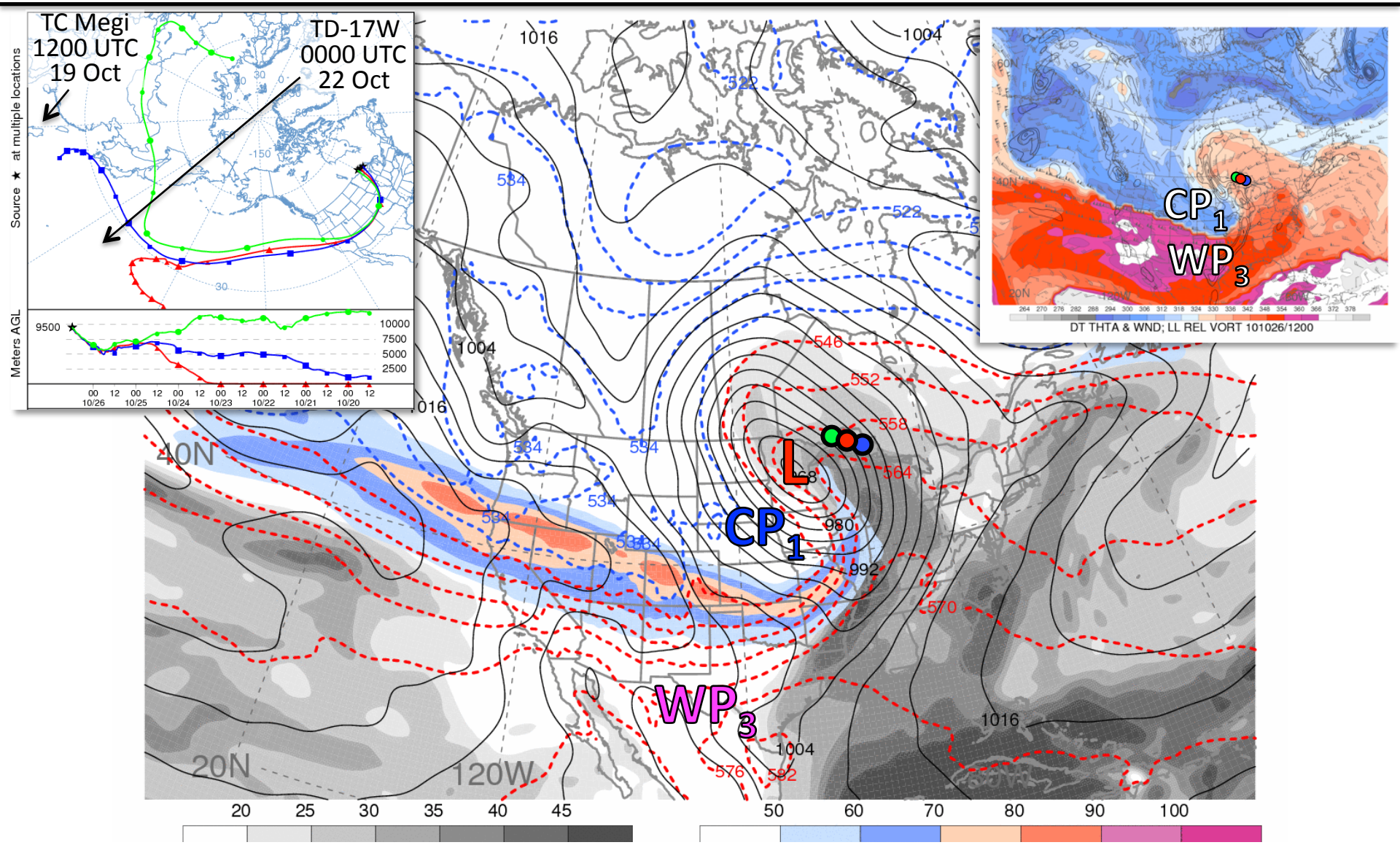
250-hPa wind speed (color shading, m s^{-1}), precipitable water (gray shading, mm), SLP (black, hPa) and 1000–500-hPa thickness (dashed, dam)

Cyclone evolution: 1200 UTC 25 Oct



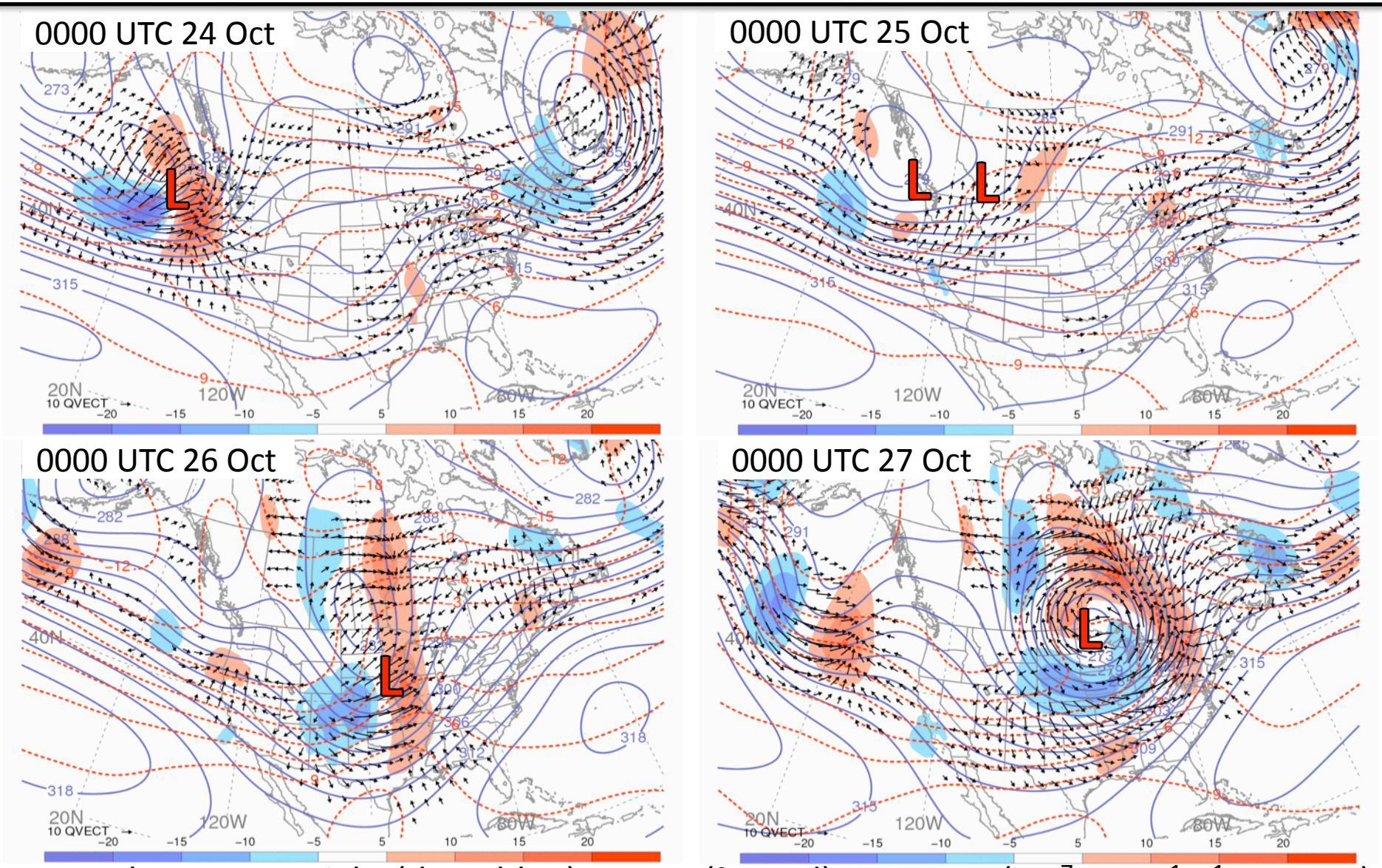
250-hPa wind speed (color shading, m s^{-1}), precipitable water (gray shading, mm), SLP (black, hPa) and 1000–500-hPa thickness (dashed, dam)

Cyclone evolution: 1200 UTC 26 Oct



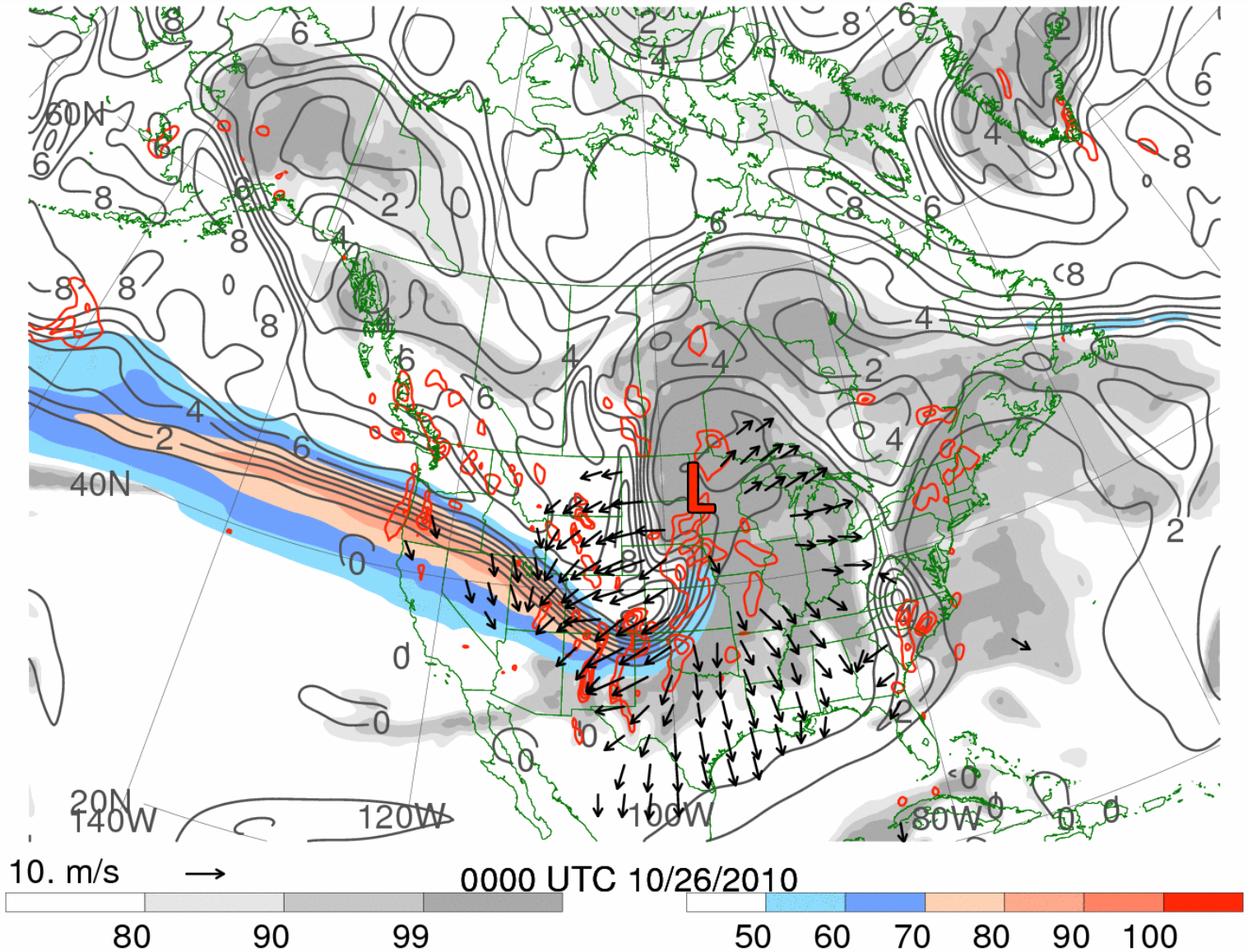
250-hPa wind speed (color shading, m s^{-1}), precipitable water (gray shading, mm), SLP (black, hPa) and 1000–500-hPa thickness (dashed, dam)

Cyclone evolution: Q vectors



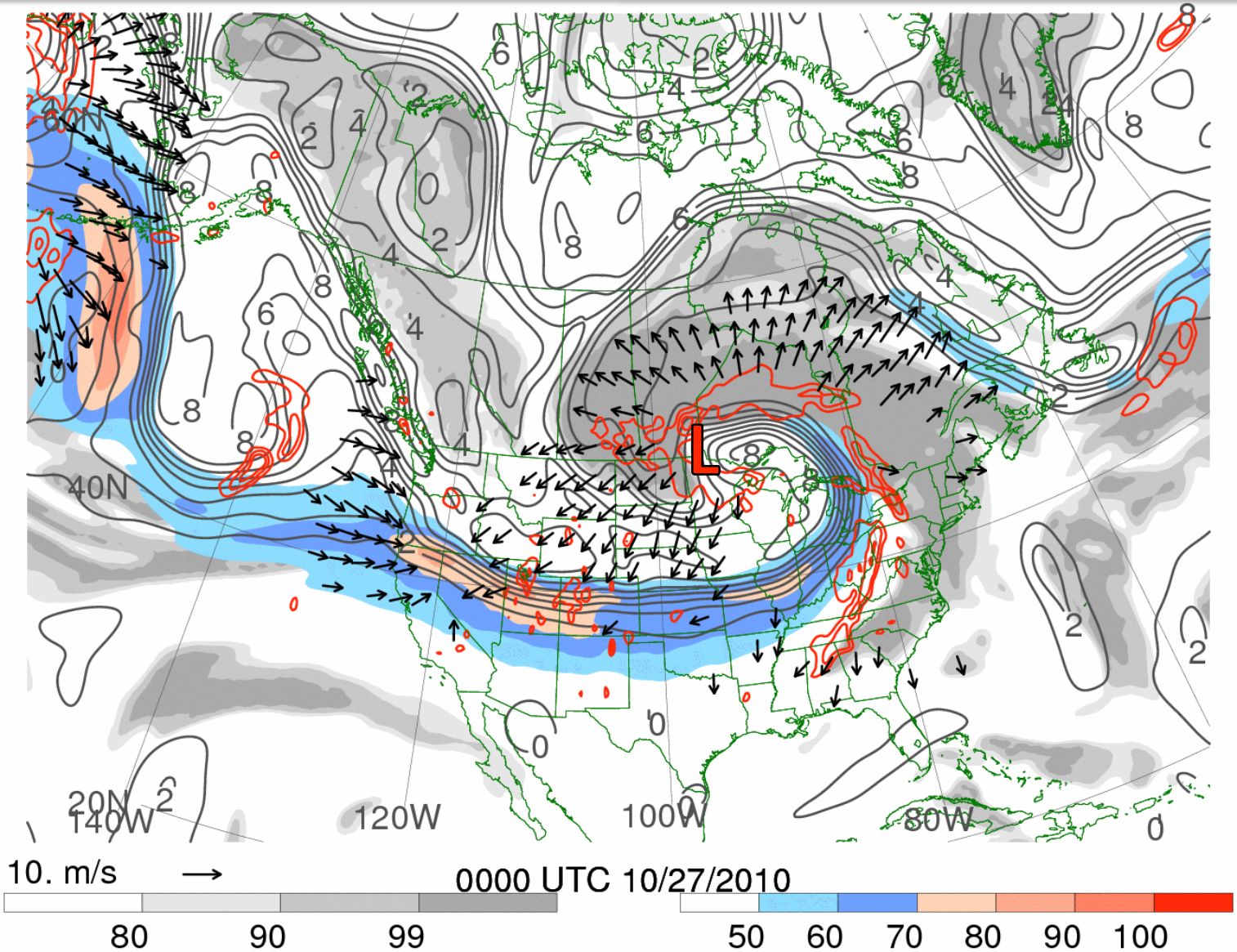
700-hPa Geo. Height (dam, blue), Temp. (°C, red), Q Vector (10^{-7} Pa m^{-1} s^{-1}, vectors), RHS of Q-vector Eqn (10^{-11} Pa m^{-2} s^{-1}, shaded)

Cyclone evolution: Irrotational wind, jet – 0000 UTC 26 Oct



250-hPa WND (m s^{-1}, color shading), PV (PVU, gray), REL HUM (%, gray shading); 300–200-hPa IRROT WND (vectors, m s^{-1}), 600–400-hPa OMEG (red, every 5 x 10^{-3} hPa s^{-1}, neg. values only)

Cyclone evolution: Irrotational wind, jet – 0000 UTC 27 Oct



250-hPa WND (m s^{-1}, color shading), PV (PVU, gray), REL HUM (%, gray shading); 300–200-hPa IRROT WND (vectors, m s^{-1}), 600–400-hPa OMEG (red, every 5 x 10^{-3} hPa s^{-1}, neg. values only)

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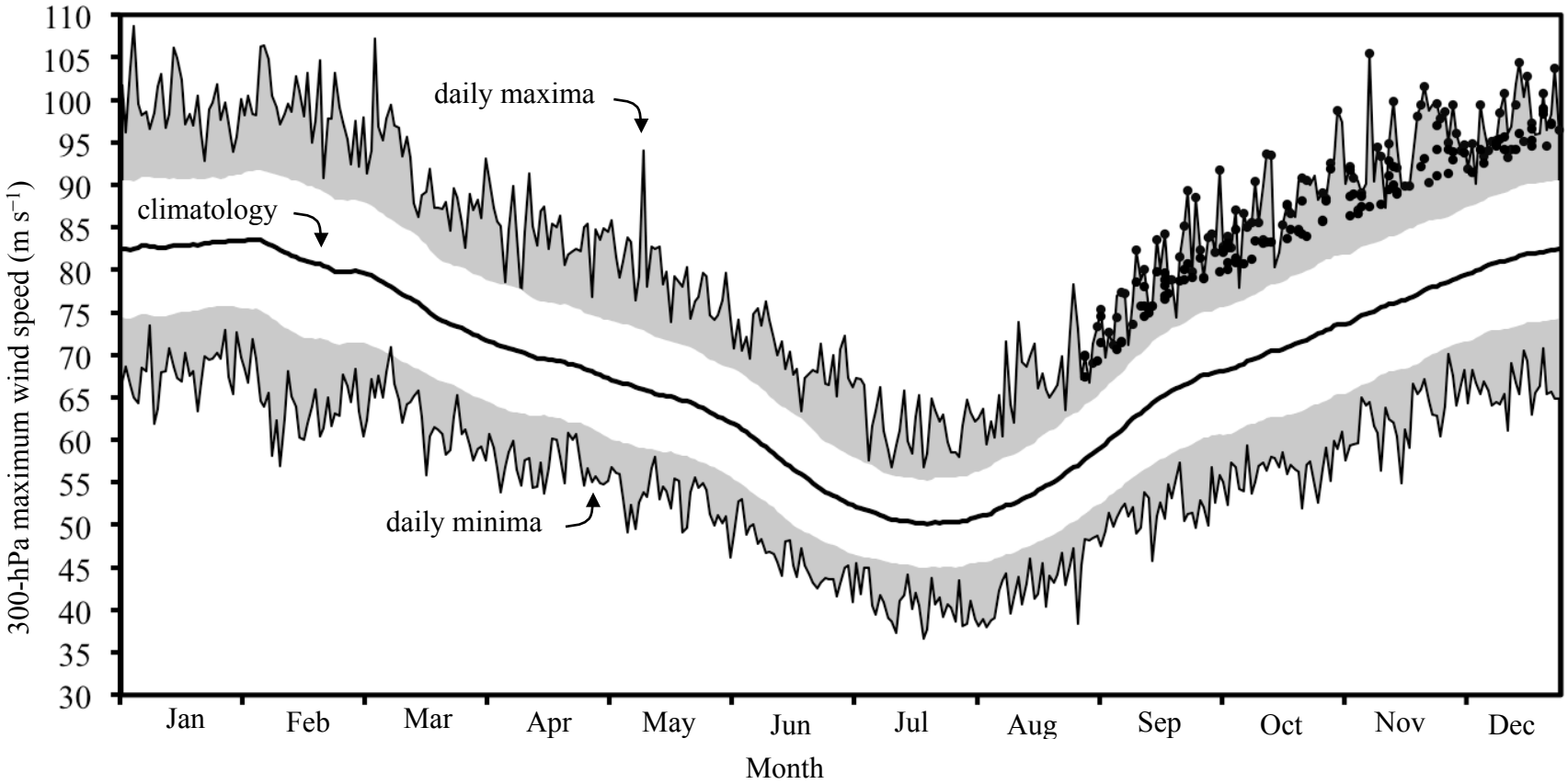
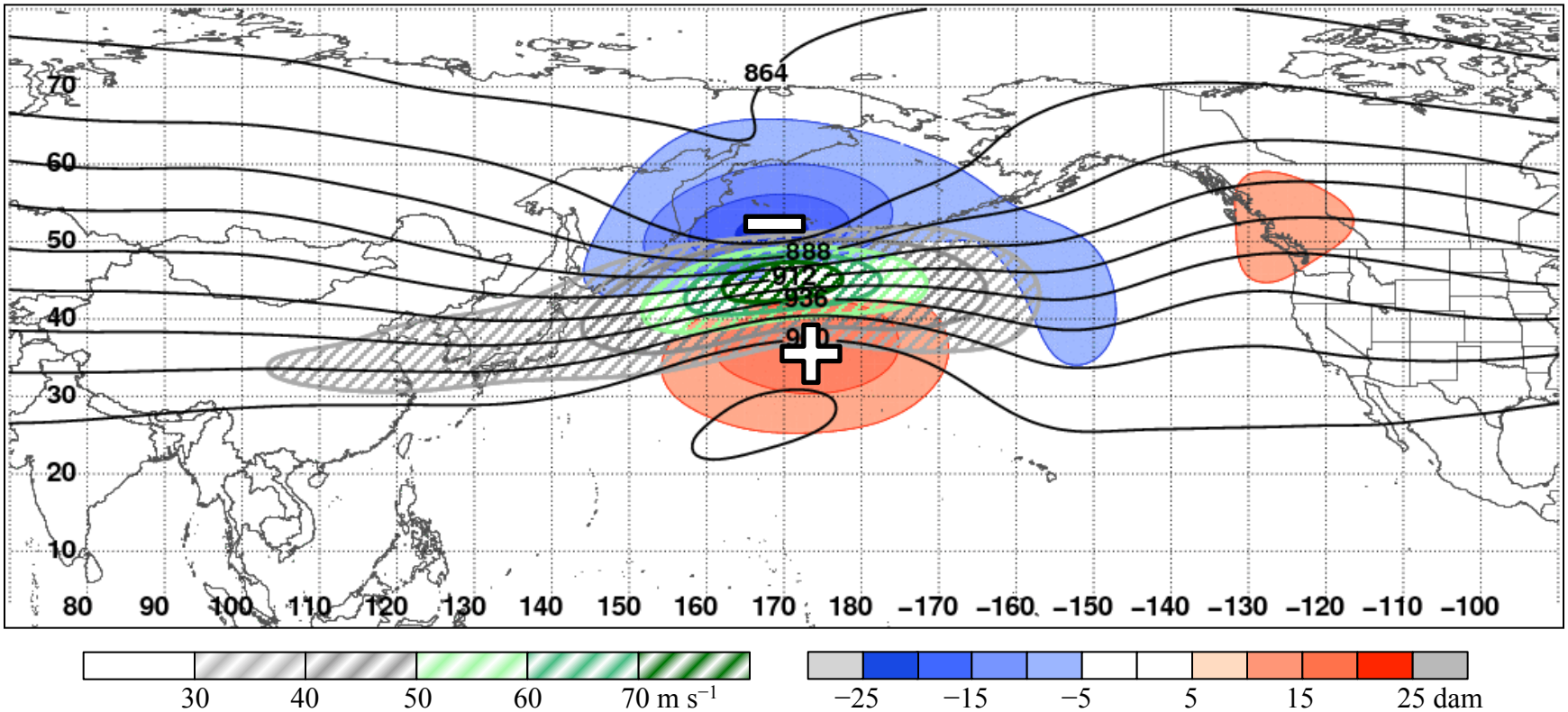
Variability of STJ



Climatology of 300-hPa maximum wind speed (m s^{-1}; thick black line) over the North Pacific for 1979–2008, one standard deviation departure from mean (white shading), and daily maximum and minimum values of climatology (thin black lines). 200 strongest 300-hPa wind speed maxima for September–December indicated by small black dots.

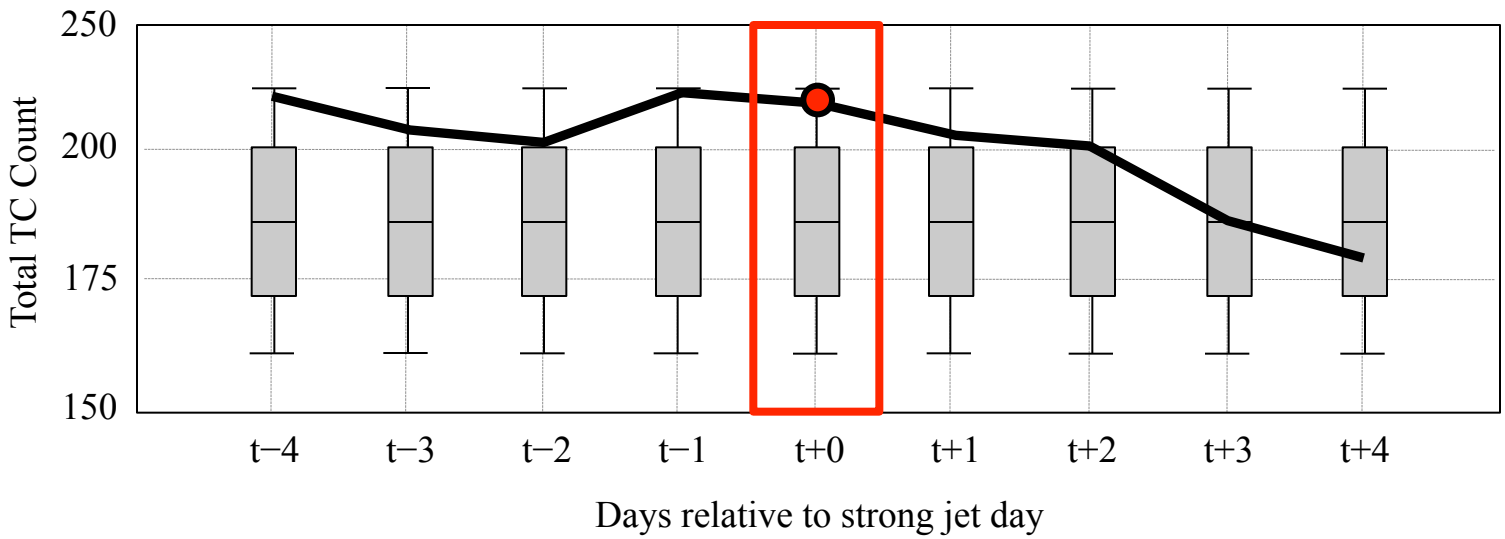
Variability of STJ

STJ-relative composite analysis at 300-hPa (N=200)



STJ-relative composite 300-hPa geo. height (dam; solid contours), geo. height anomaly (dam; shaded in blue–red and for regions of statistically significance >95% confidence level according to a two-sided Student's *t* test), and wind speed (m s^{-1}; shaded gray–green)

Variability of STJ



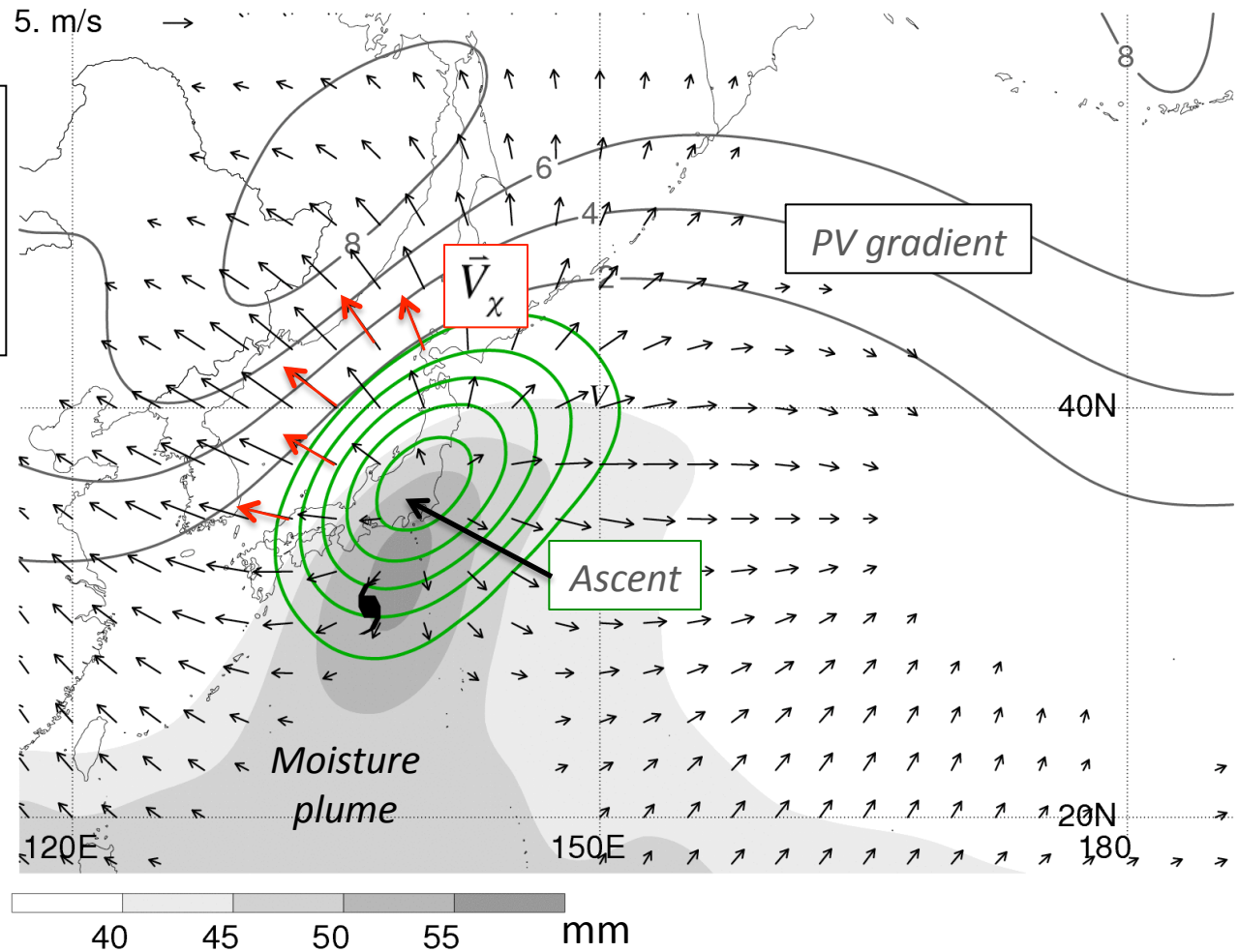
Frequency of WNP TCs relative to strong jet days (bold solid line). Boxes illustrate climatological mean frequency (horizontal black line) and extend to one standard deviation above and below mean. Statistical significance relative to climatology is illustrated by whiskers, which extend to the 95% confidence level.

- **Statistics at t+0 d:**
  - *135 of 200 (~68%) strong jet days associated with at least one TC*
  - *207 TCs present on 135 strong jet days (~1.5 TCs per "event")*
  - *~70% of these TCs undergo recurvature and ET (not shown)*

Recurving TC–Jet interactions

- As a WNP TC recurves, its diabatically driven outflow tends to amplify a ridge and intensify a jet streak

TC–jet interaction strength based on avg. $-\vec{V}_\chi \bullet \nabla_p PV$ over 15° x 15° box and 48-h period



Composite of strong TC–Jet interactions at time of maximum interaction (N = 54)

Emphasized irrotational wind vectors

500-hPa ascent (green, every 1 × 10^{-3} hPa s^{-1}), total-column precipitable water (gray shading, mm), and 200-hPa PV (gray, every 2 PVU) and irrotational wind ($\vec{V}_\chi$ ectors, >2 m s^{-1})

Recurving TC–Jet interactions

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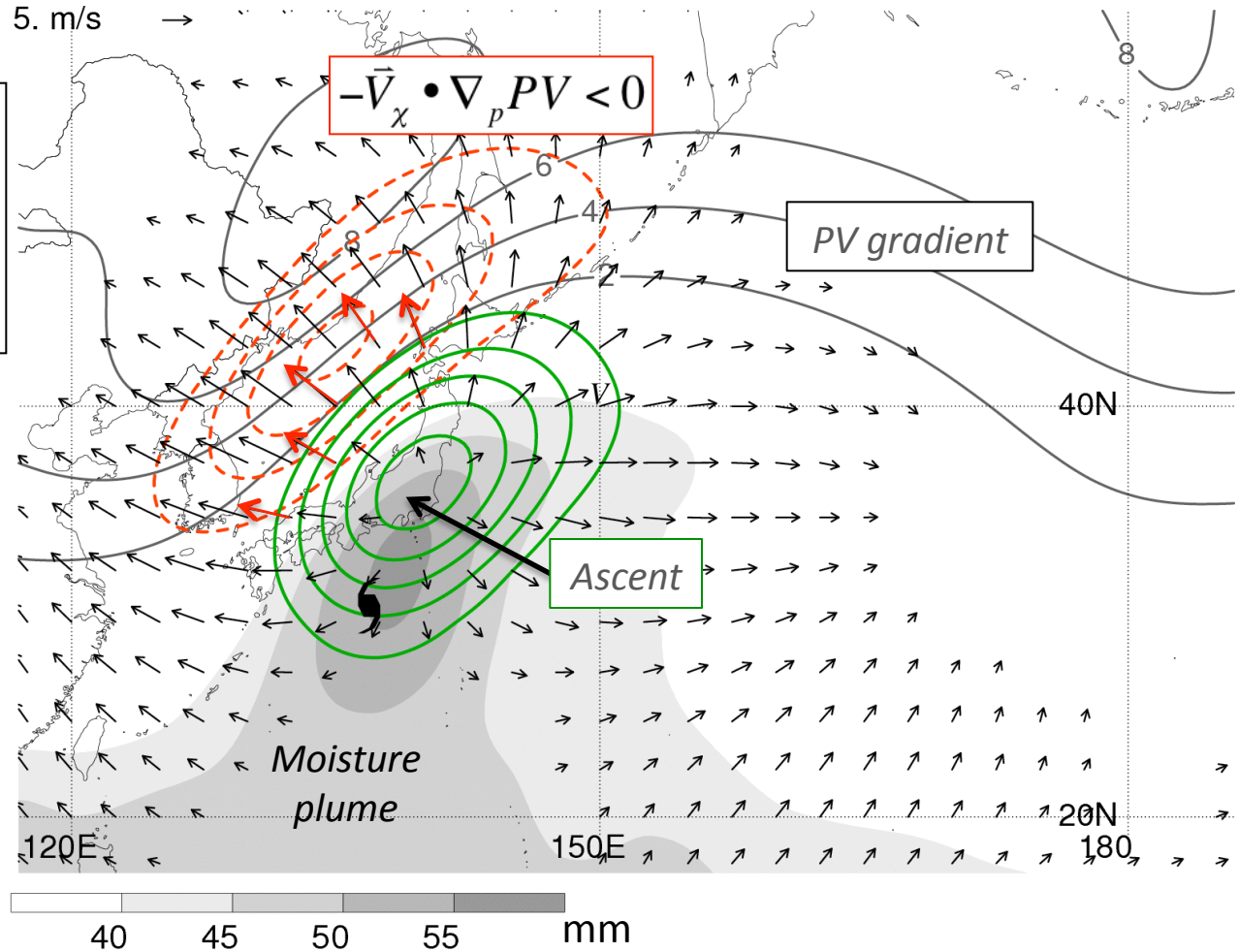
TC–jet interaction strength based on avg. $-\vec{V}_\chi \bullet \nabla_p PV$ over 15° x 15° box and 48-h period



Composite of strong TC–Jet interactions at time of maximum interaction (N = 54)

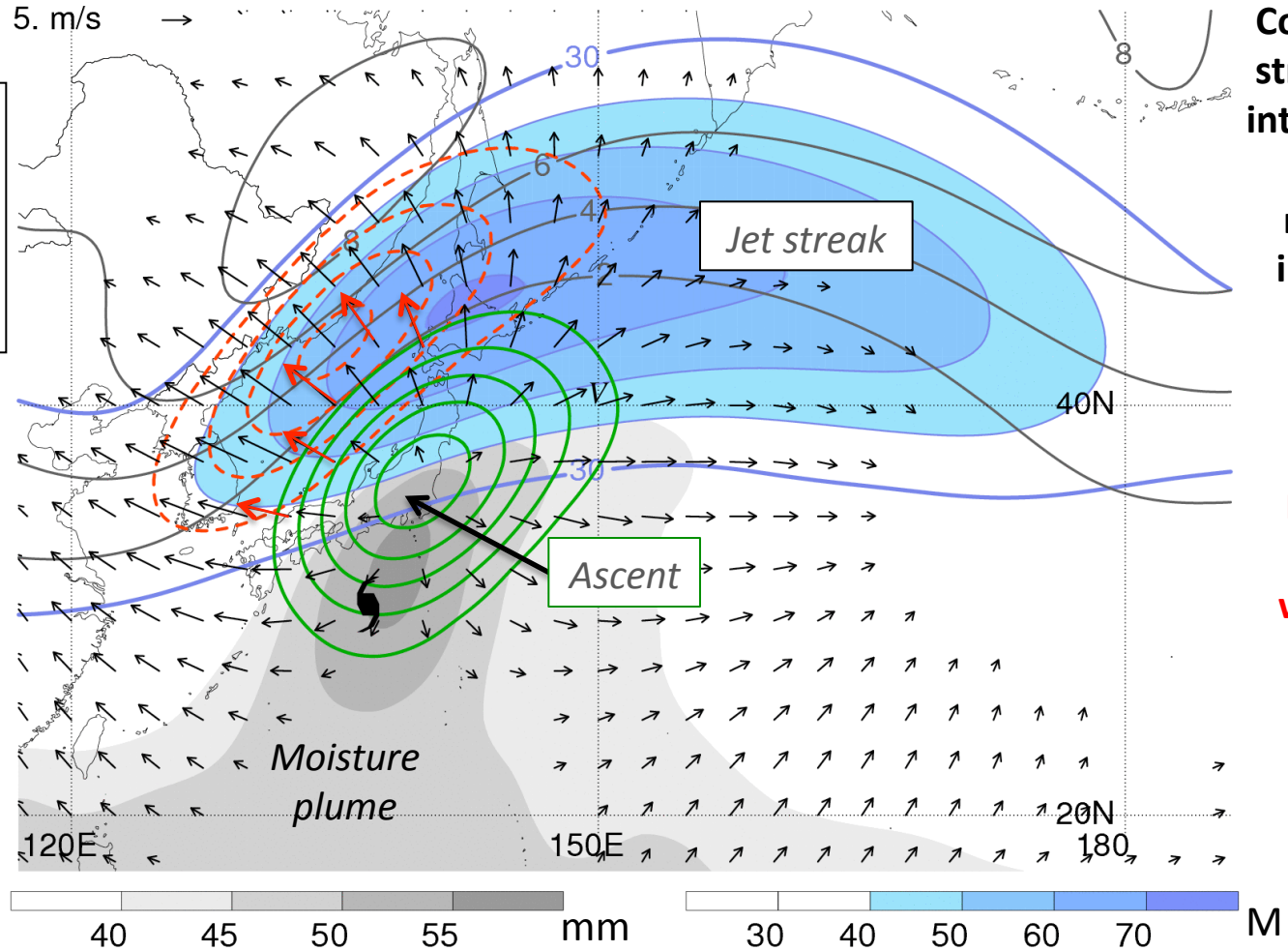
Emphasized irrotational wind vectors

500-hPa ascent (green), precipitable water (gray shading), and 200-hPa PV (gray), irrot. wind (vectors) and PV advection by irrotational wind ($-\vec{V}_\chi \bullet \nabla_p PV$; dashed red, every 2 PVU day^{-1}, negative values only)

Recurving TC–Jet interactions

- As a WNP TC recurves, its diabatically driven outflow tends to amplify a ridge and intensify a jet streak

TC–jet interaction strength based on avg. $-\vec{V}_\chi \bullet \nabla_p PV$ over 15° x 15° box and 48-h period

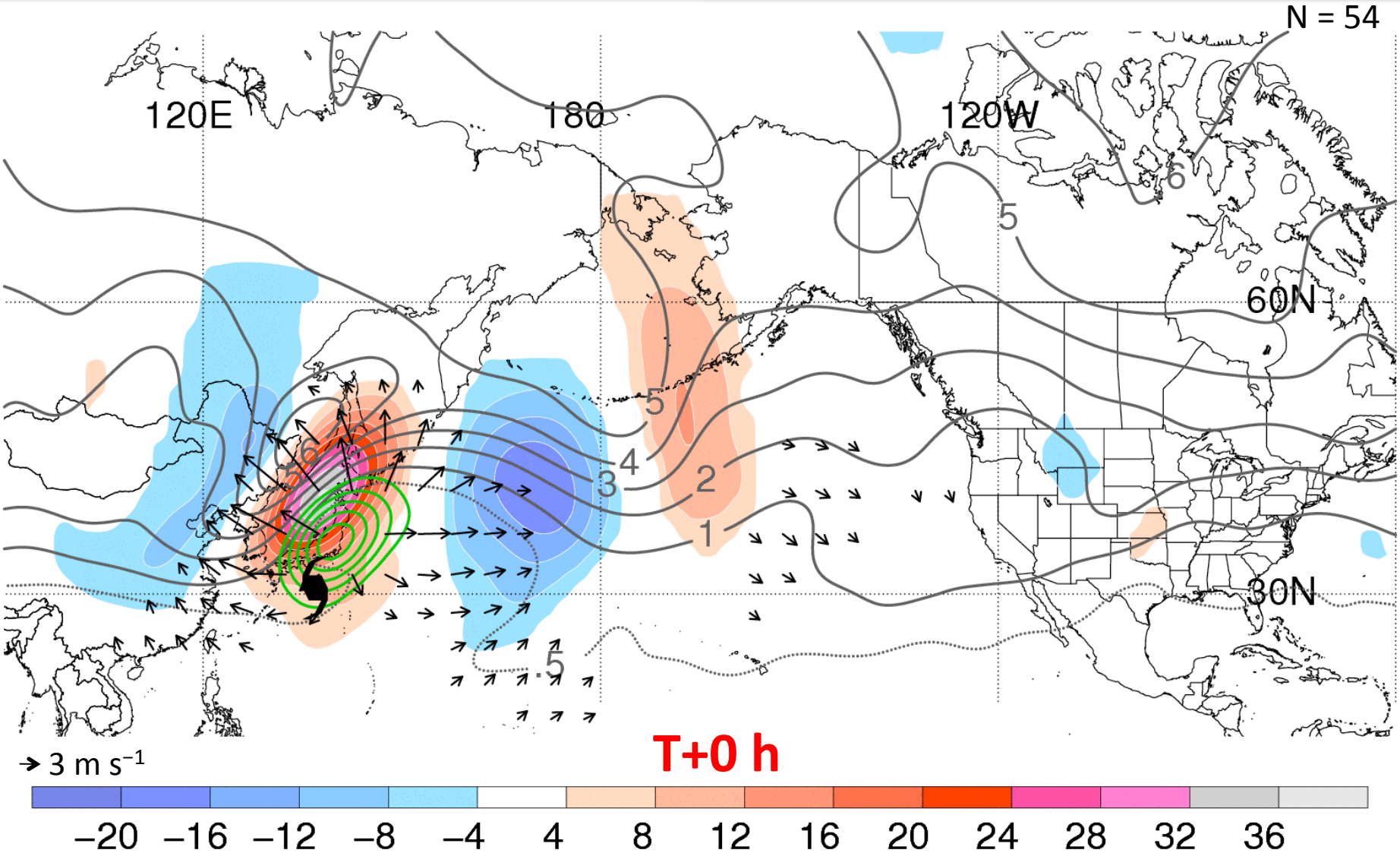


Composite of strong TC–Jet interactions at time of maximum interaction (N = 54)

Emphasized irrotational wind vectors

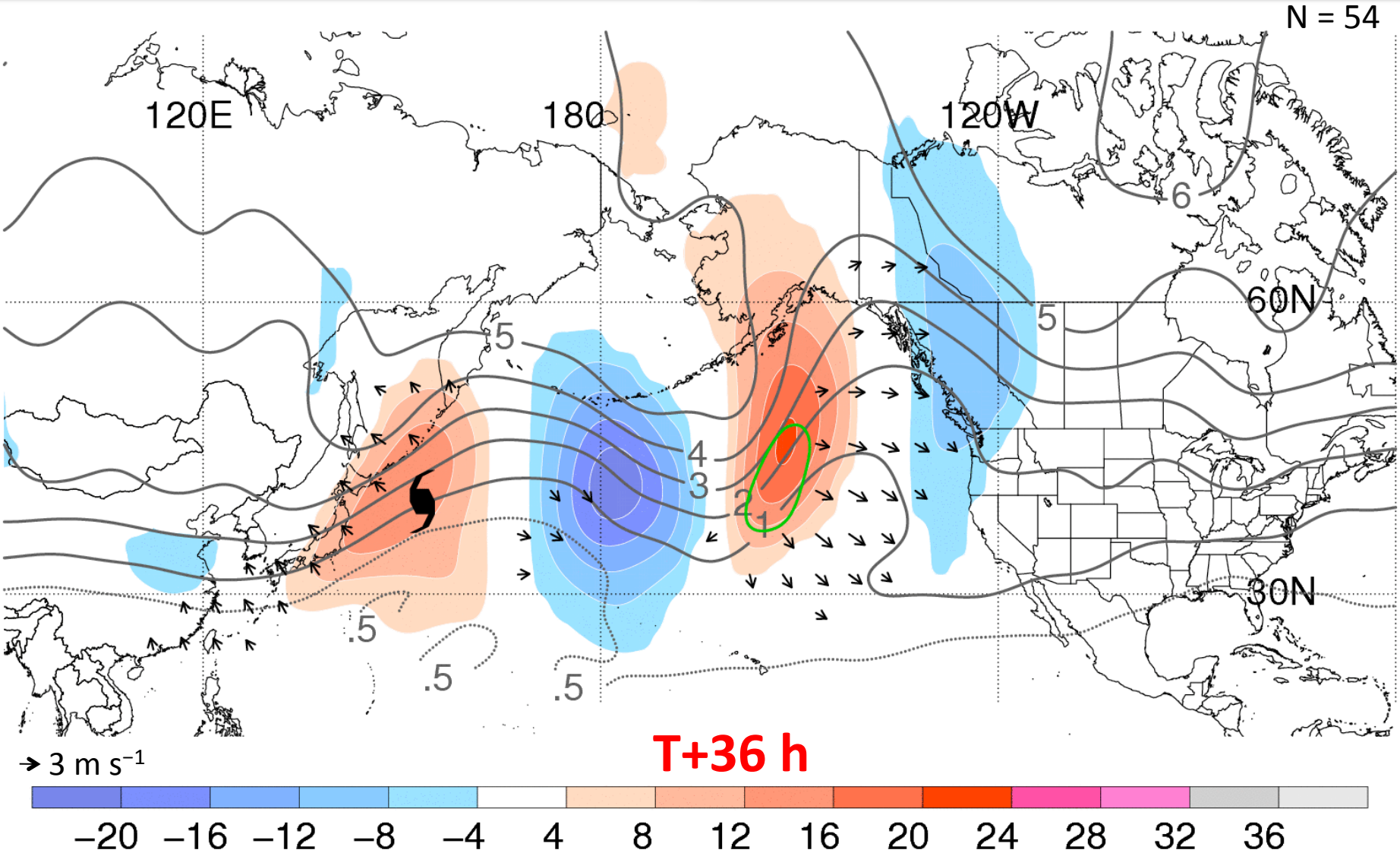
500-hPa ascent (green), precipitable water (gray shading), and 200-hPa PV (gray), irrot. wind (vectors) and PV advection by irrotational wind (dashed red), and wind speed (shaded, m s^{-1})

Recurving TC–Jet interactions: Downstream influence



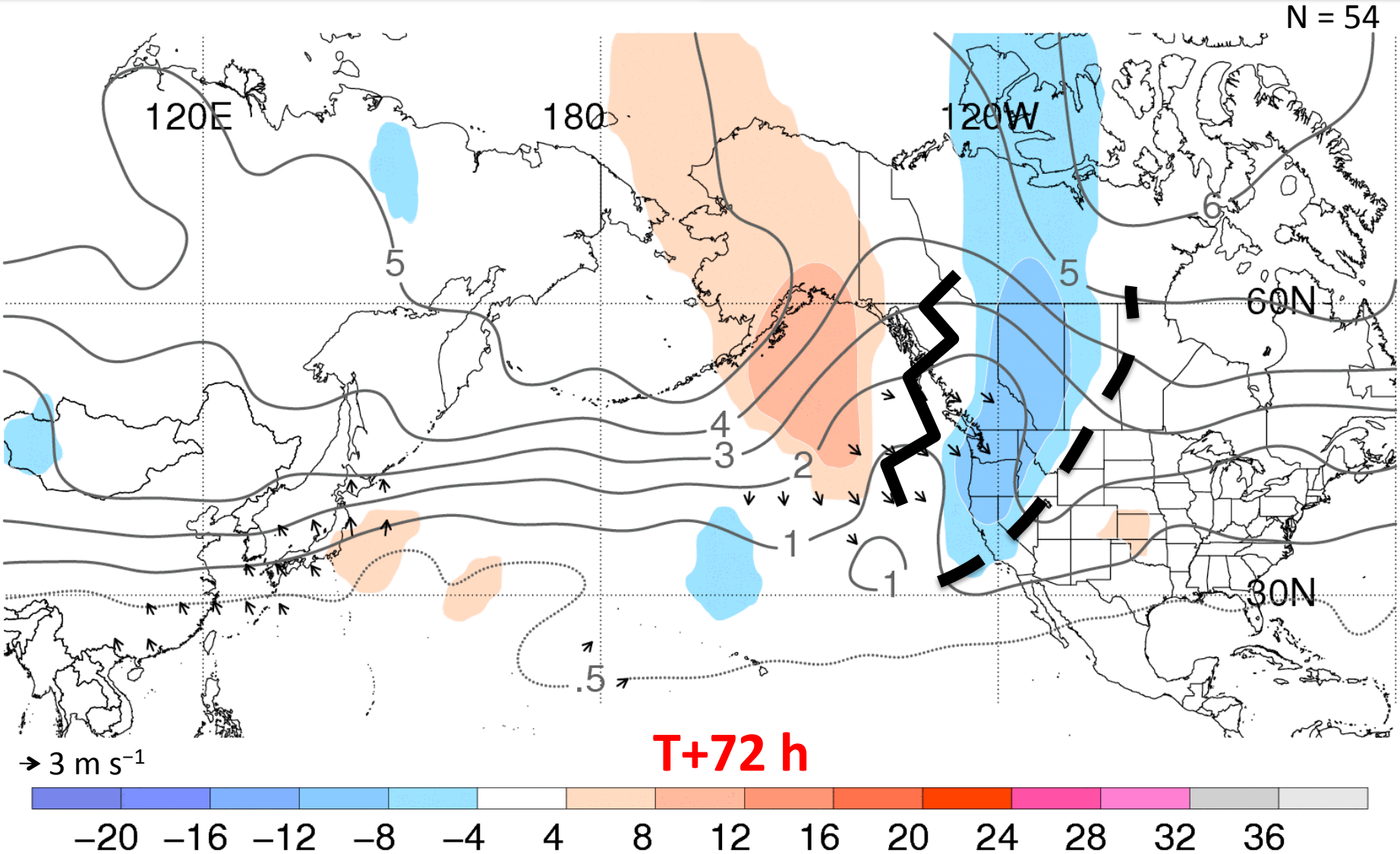
250-hPa meridional wind anomaly (shaded, m s^{-1}), PV (black, PVU), and irrotational wind (vectors, >1.75 m s^{-1} only); 500-hPa ascent (green, every 1×10^{-3} hPa s^{-1})

Recurving TC–Jet interactions: Downstream influence



250-hPa meridional wind anomaly (shaded, m s^{-1}), PV (black, PVU), and irrotational wind (vectors, >1.75 m s^{-1} only); 500-hPa ascent (green, every 1×10^{-3} hPa s^{-1})

Recurving TC–Jet interactions: Downstream influence



250-hPa meridional wind anomaly (shaded, m s^{-1}), PV (black, PVU), and irrotational wind (vectors, >1.75 m s^{-1} only); 500-hPa ascent (green, every 1×10^{-3} hPa s^{-1})

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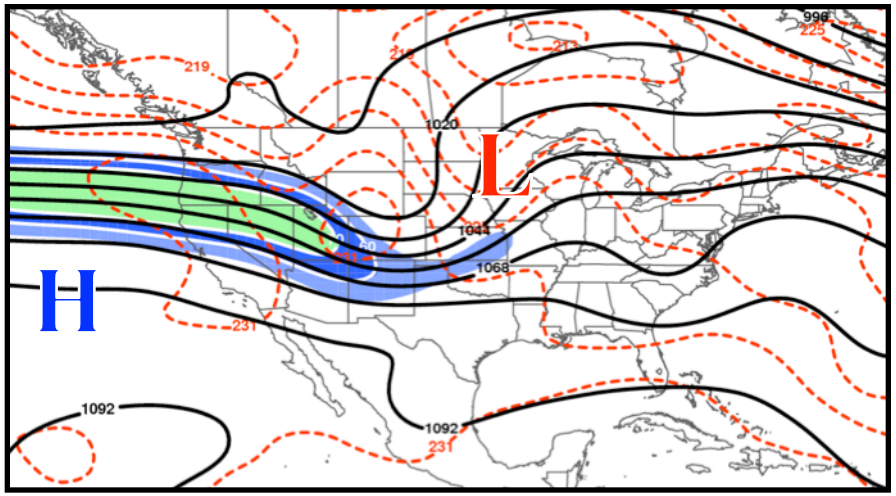
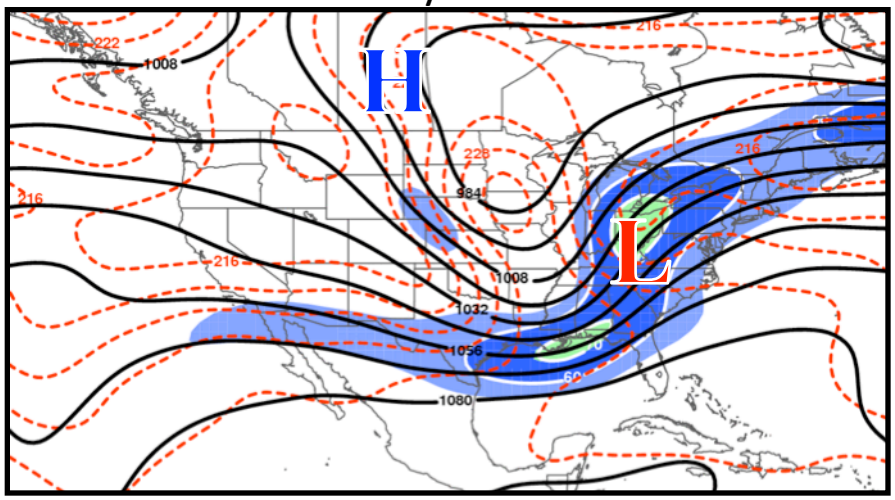
Comparison with 1978 Superbomb: 250-hPa

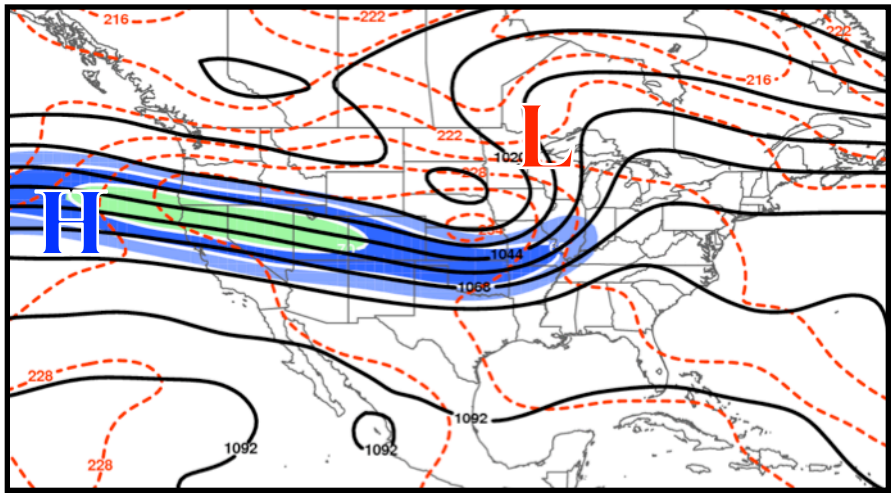
0000 UTC 26 October 2010



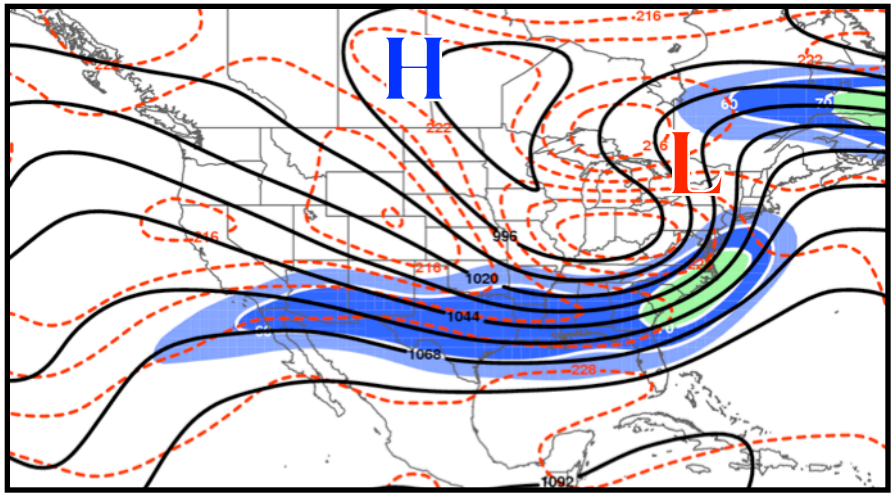
0000 UTC 26 January 1978



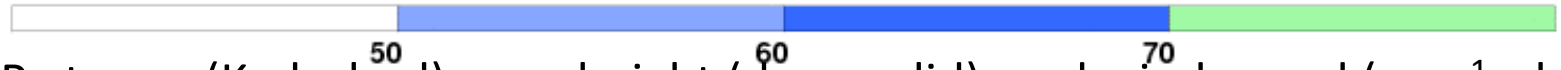
1200 UTC 26 October 2010



1200 UTC 26 January 1978



2.5° NCEP–NCAR reanalysis

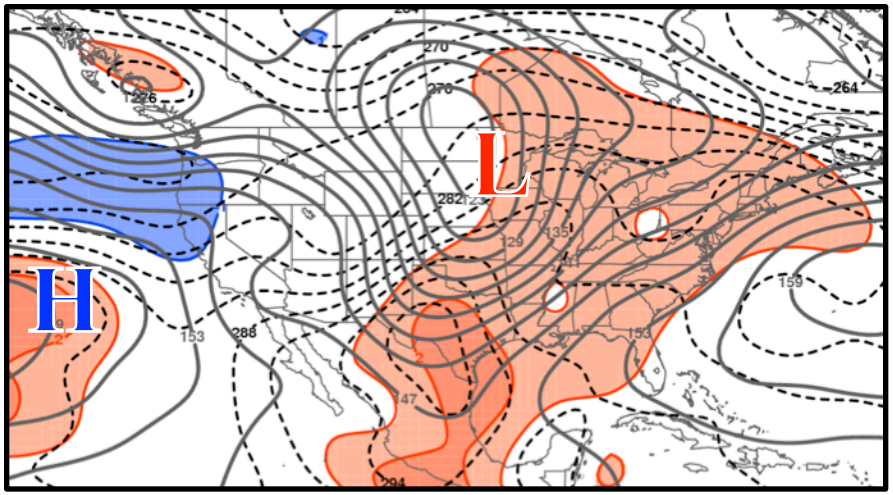


m s^{-1}

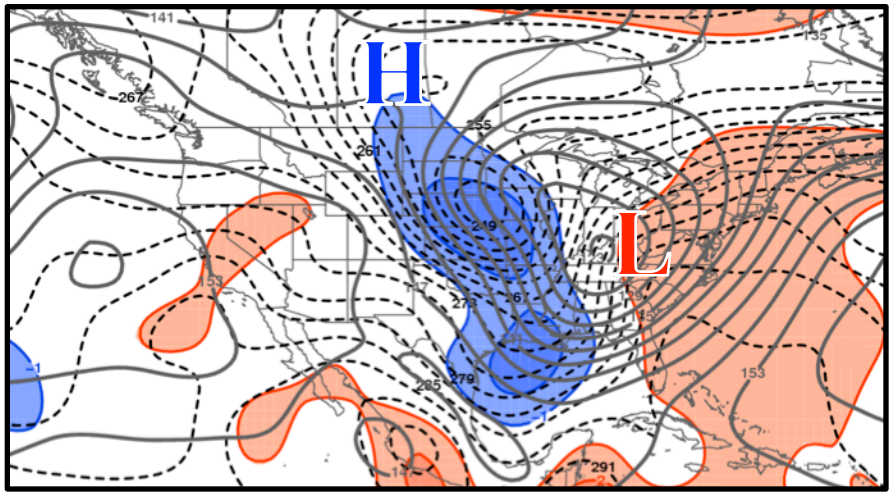
250-hPa temp. (K, dashed), geo. height (dam, solid), and wind speed (m s^{-1}, shaded)

Comparison with 1978 Superbomb: 850 hPa

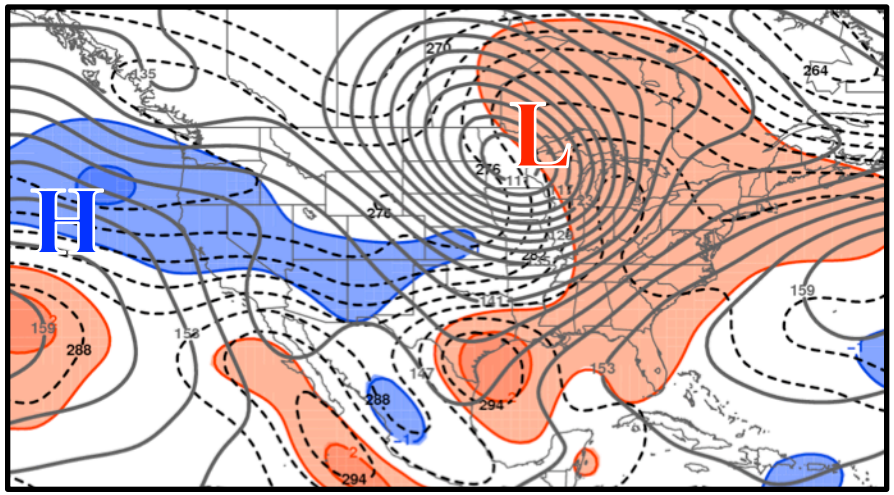
0000 UTC 26 October 2010



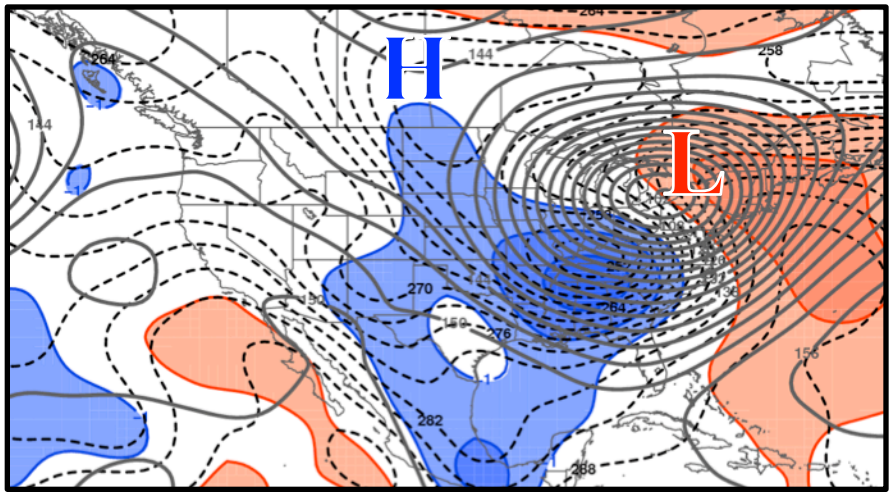
0000 UTC 26 January 1978



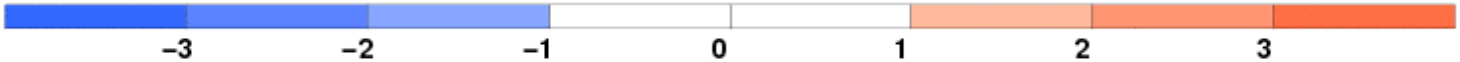
1200 UTC 26 October 2010



1200 UTC 26 January 1978



2.5° NCEP–NCAR reanalysis



SD

850-hPa temp. (K, dashed), std. temp. anomaly (SD, shaded), and geo. height (dam, solid)

Conclusions

October 2010:

- Strong Pacific STJ developed from juxtaposition of TC/TD-related warm pools and trough-related cold pools
- TC/TD related diabatic outflow strengthened PV gradient and STJ from Asia eastward across North Pacific
- STJ entrance & exit region dynamics governed structure & evolution of surface cyclone from East Pacific to Midwest

Synthesis:

- Strong jet streams over North Pacific occur in association with tropical and polar disturbances
- Recurving TC–Jet interactions can induce significant downstream flow anomalies and high-impact weather