Reduced Predictability and Extreme Weather Events over North America Following the Recurvature of Western North Pacific Tropical Cyclones

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Background and motivation

- In Fall 2010, two recurving western North Pacific tropical cyclones (WNP TCs) that underwent extratropical transition (ET) helped to initiate separate episodes of downstream development (DD)

- Each DD episode induced favorable synoptic conditions for extreme warmth over western North America and heavy rain over eastern North America

- Each DD episode was associated with reduced predictability manifested as increased model error and ensemble model spread over North Pacific and North America

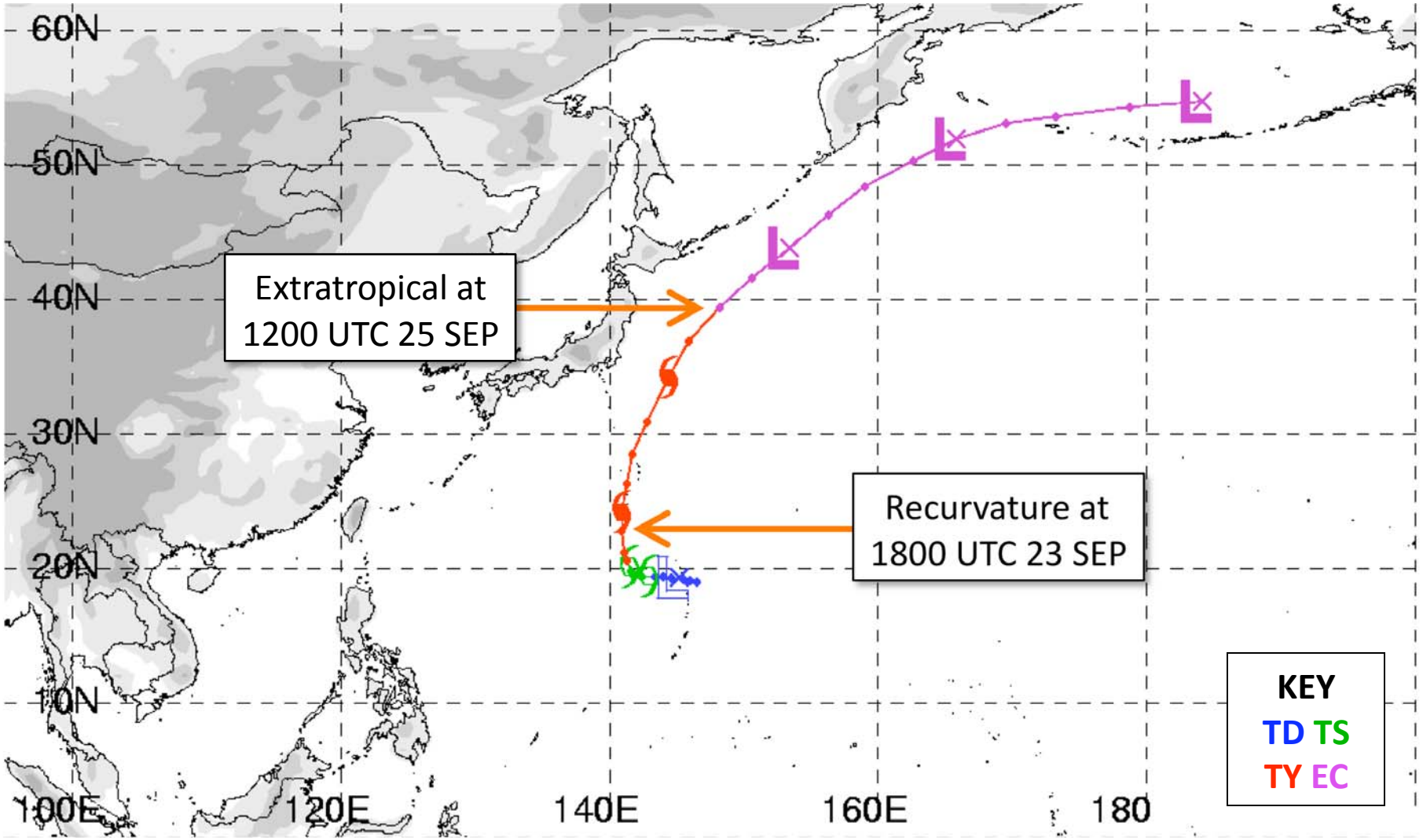
OBJECTIVES

- Present overview of linkages between recurving WNP TCs Malakas (Sep 2010) and Chaba (Oct 2010) and high-impact weather over North America

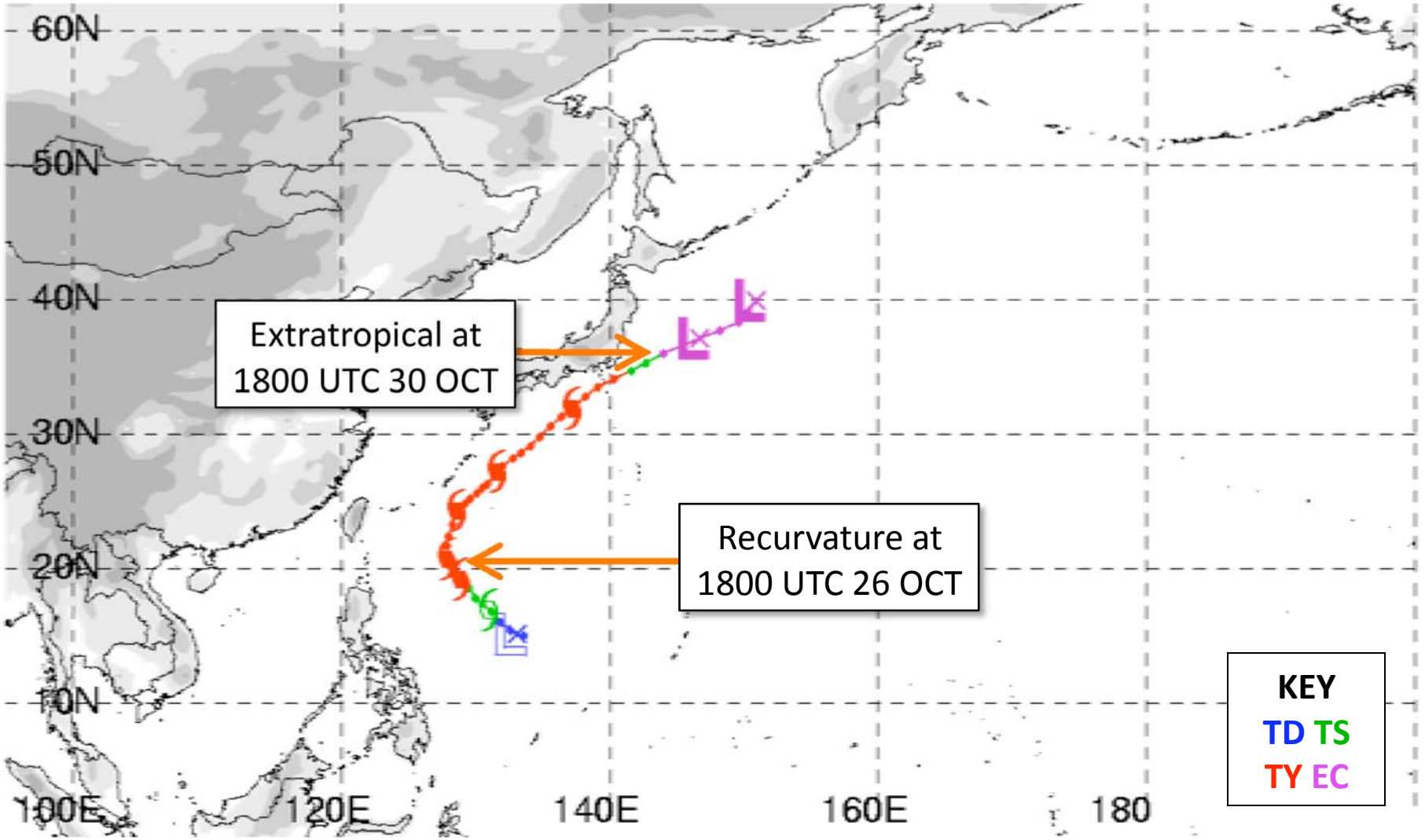
- Compare Rossby wave train (RWT) excitation and dispersion associated with each recurving WNP TC

- Examine forecasts of large-scale flow pattern surrounding recurving TC Malakas

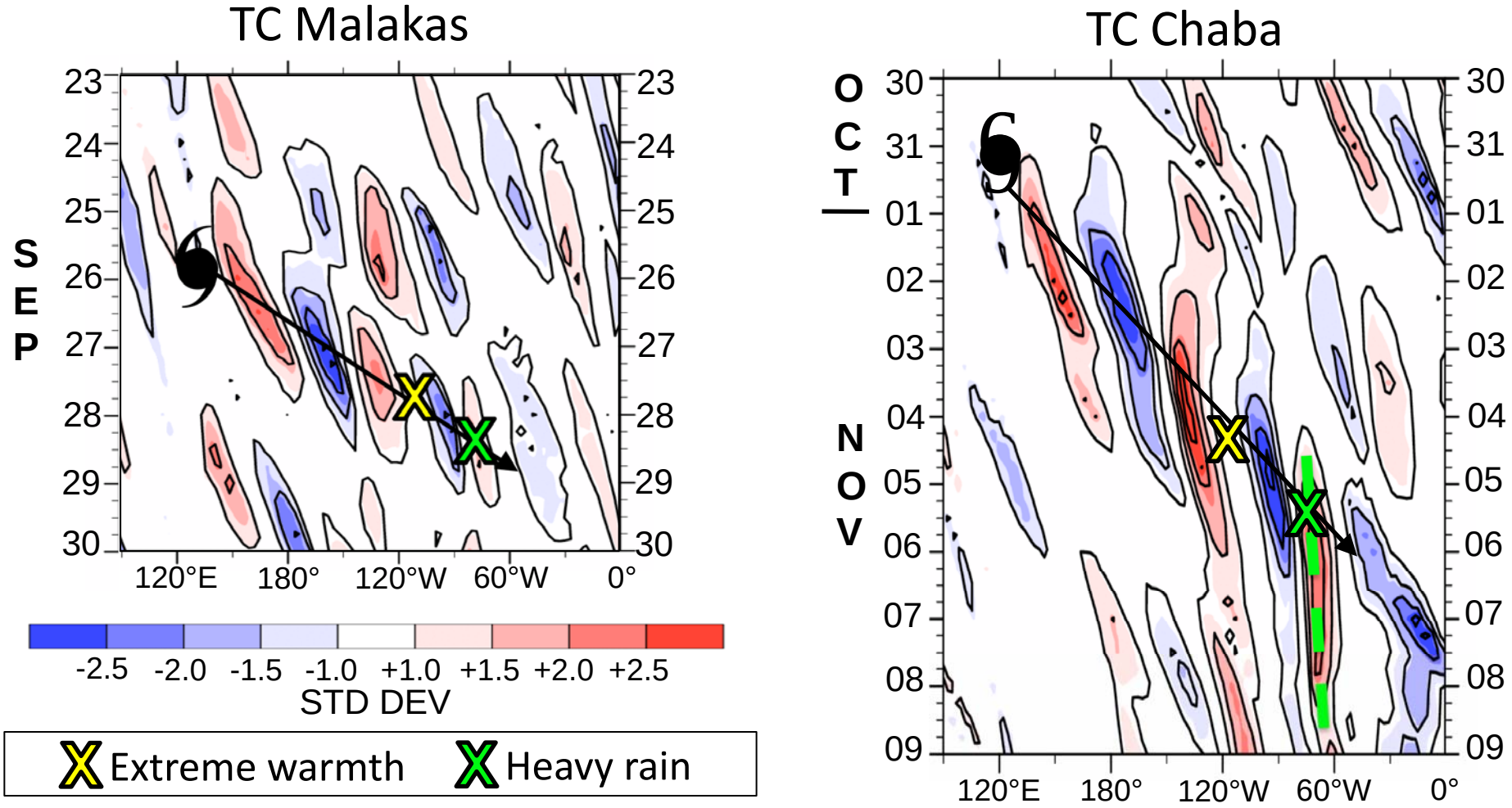
Overview: Malakas JMA Best-Track



Overview: Chaba JMA Best-Track



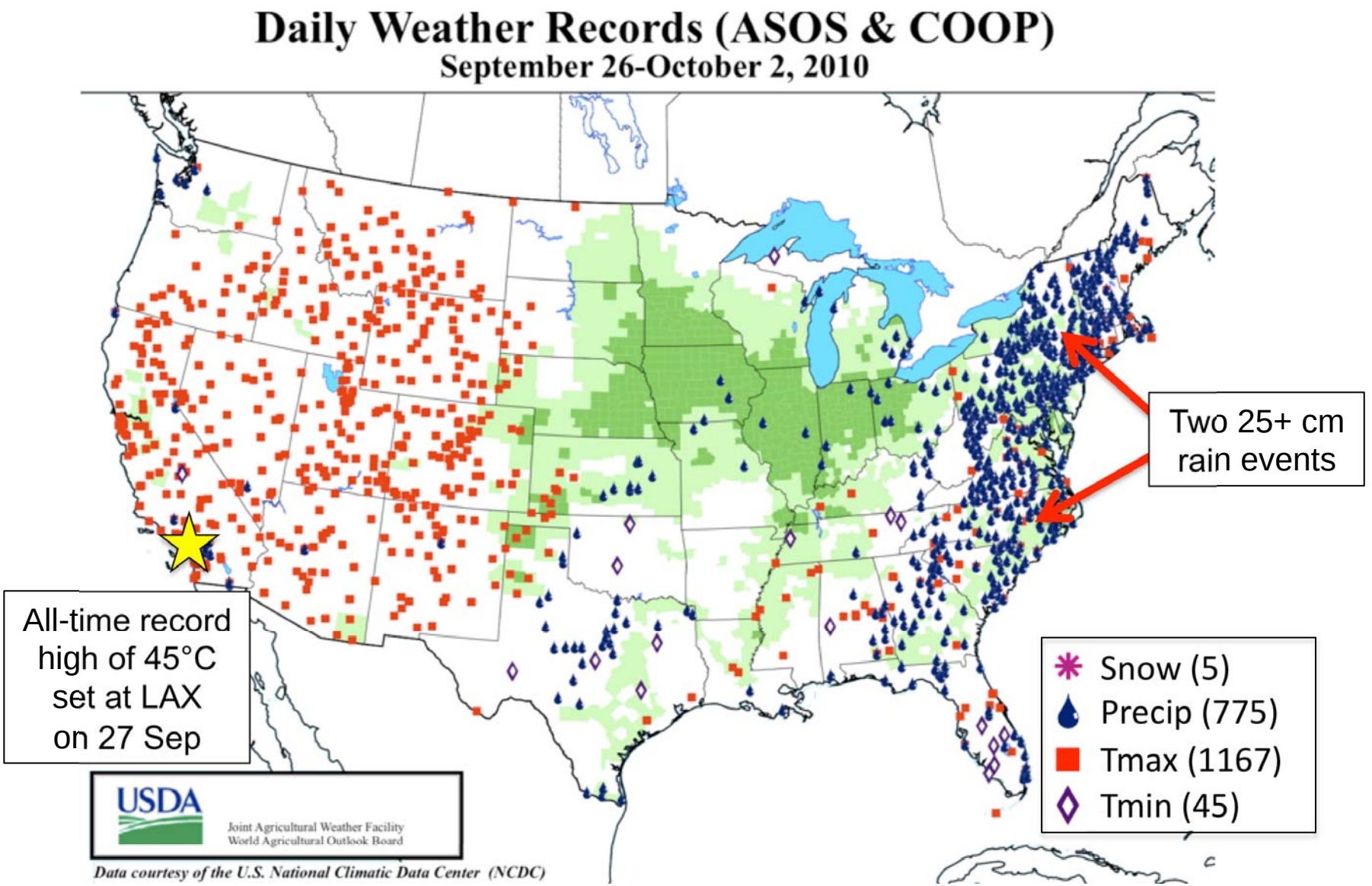
Overview: TCs, DD, and High-Impact Weather



40°–60°N 250-hPa meridional wind anomaly (shaded, std dev) and abs. difference from climatology (solid, every 15 m s^{-1}, zero line omitted)

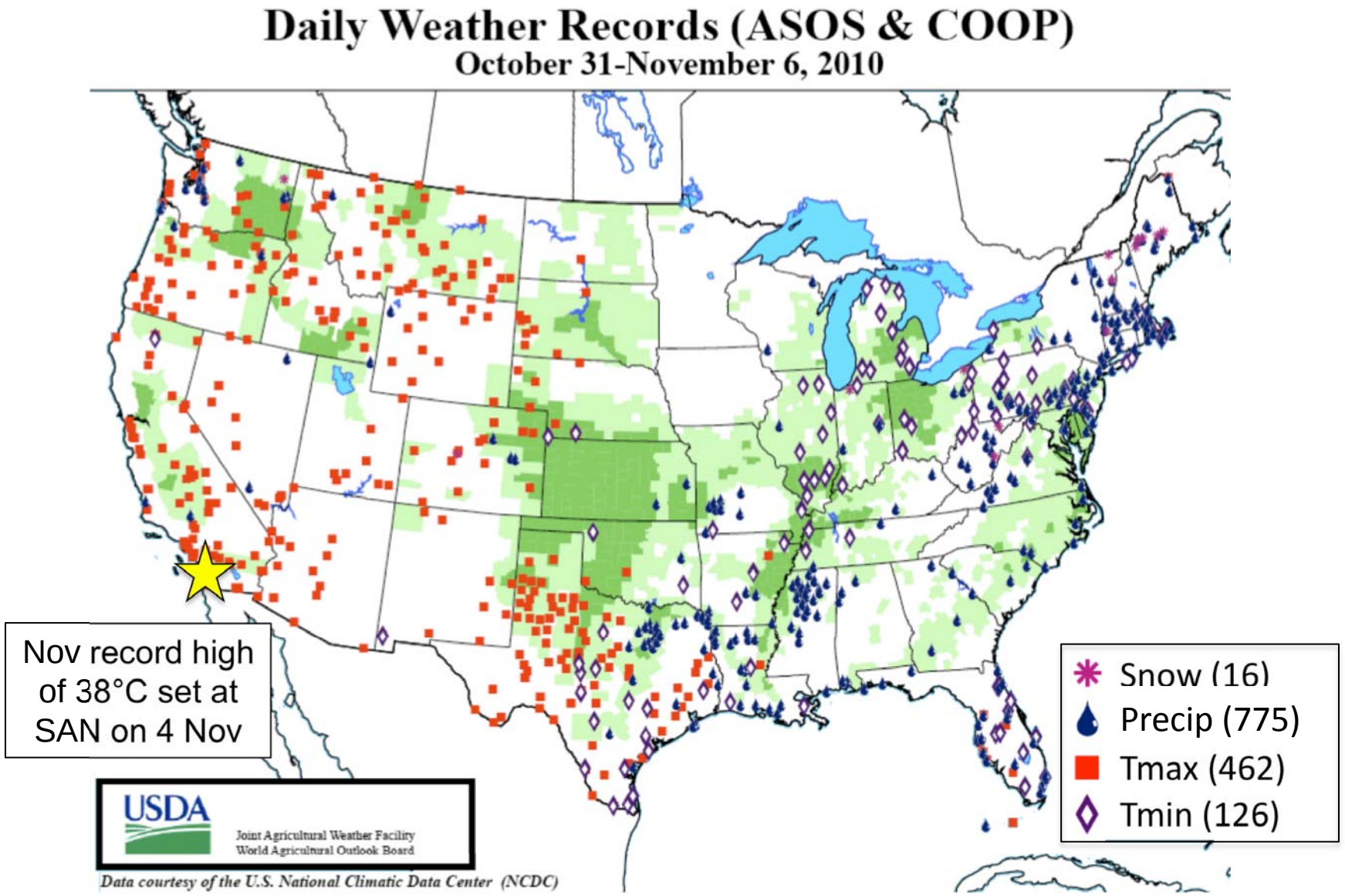
0.5° GFS analysis and 2.5° NCEP–NCAR reanalysis (climatology)

Overview: Malakas High-Impact Weather



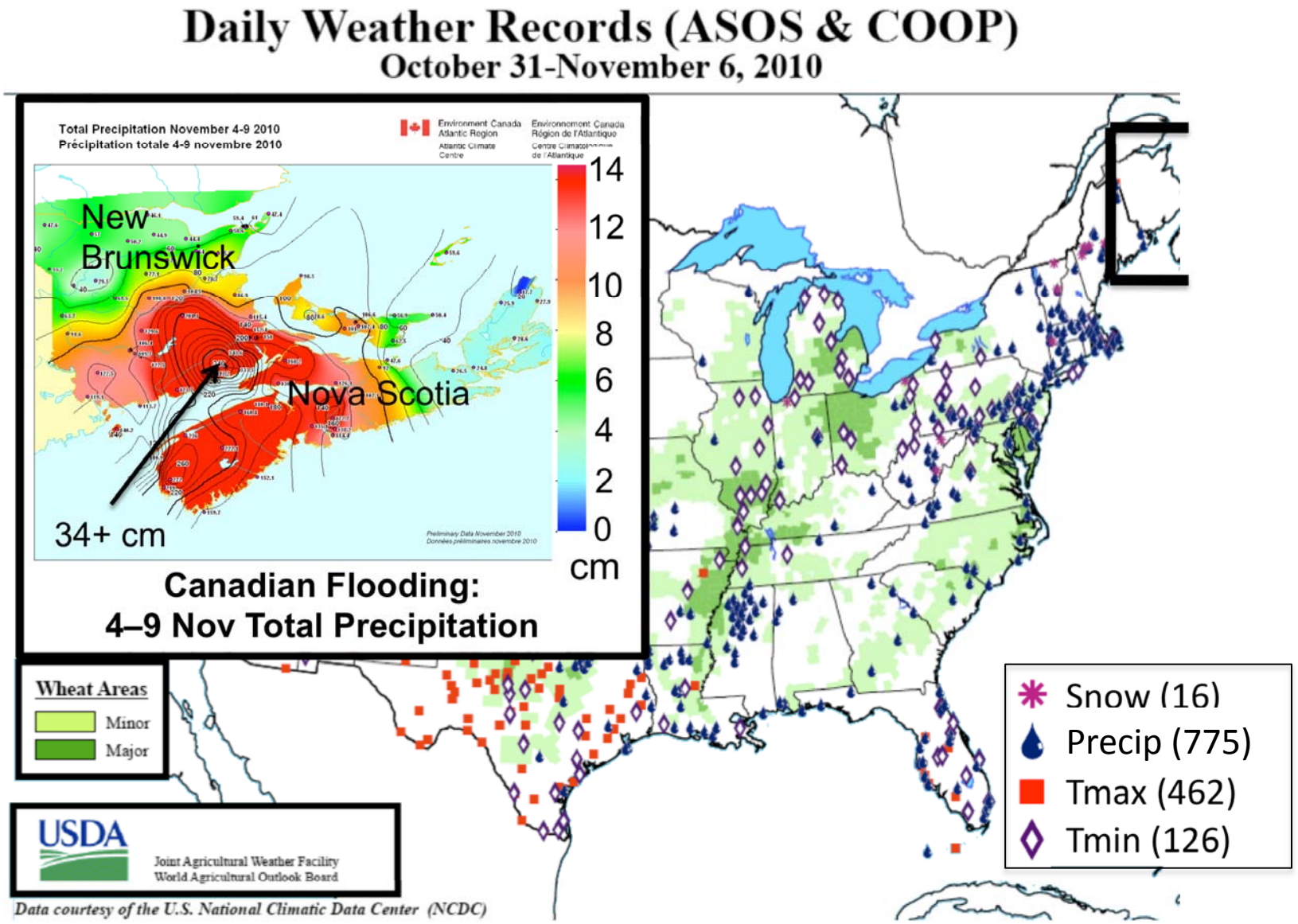
Obtained from Weekly Weather and Crop Bulletin

Overview: Chaba High-Impact Weather



Obtained from Weekly Weather and Crop Bulletin

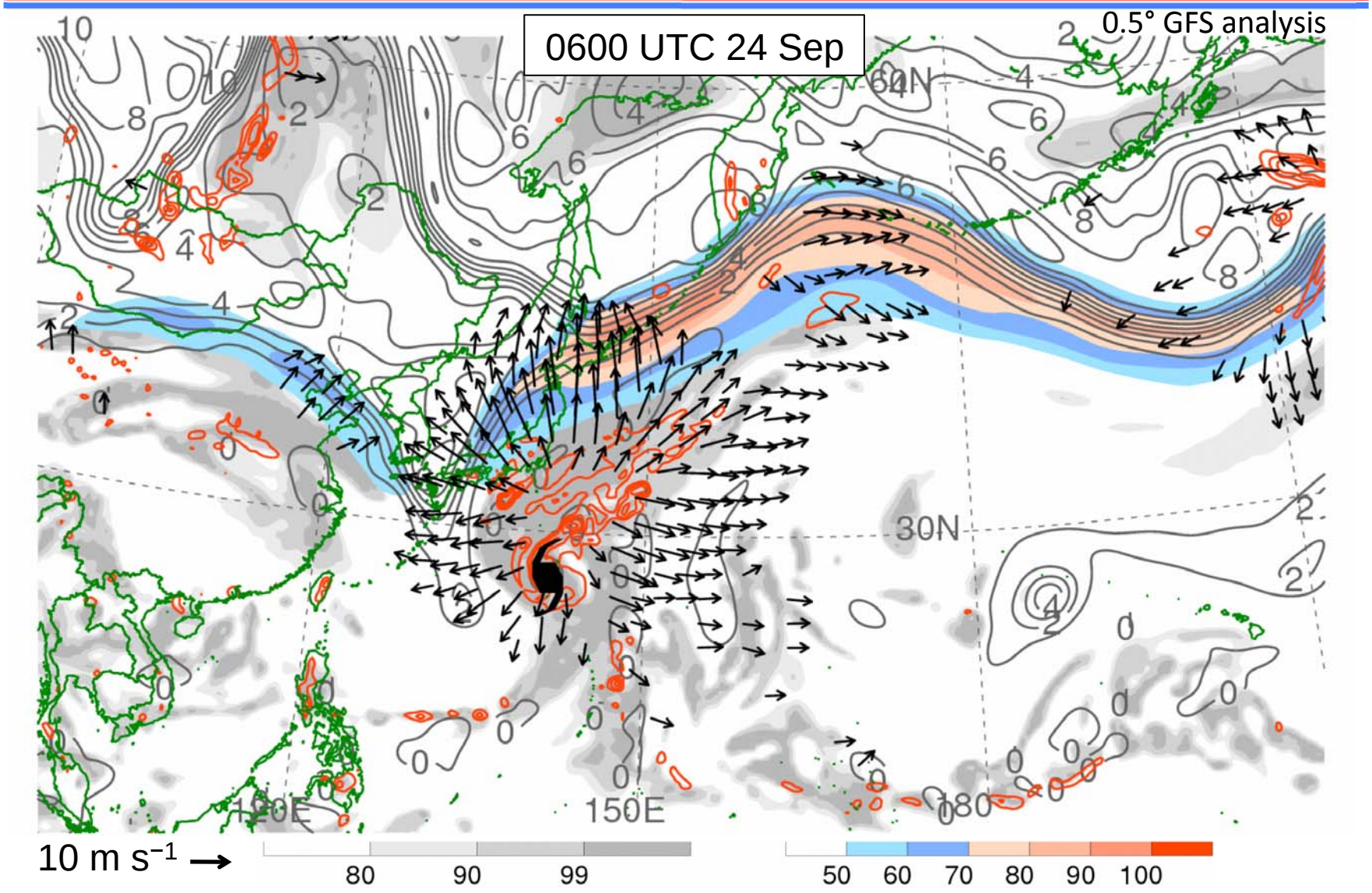
Overview: Chaba High-Impact Weather



Obtained from Weekly Weather and Crop Bulletin

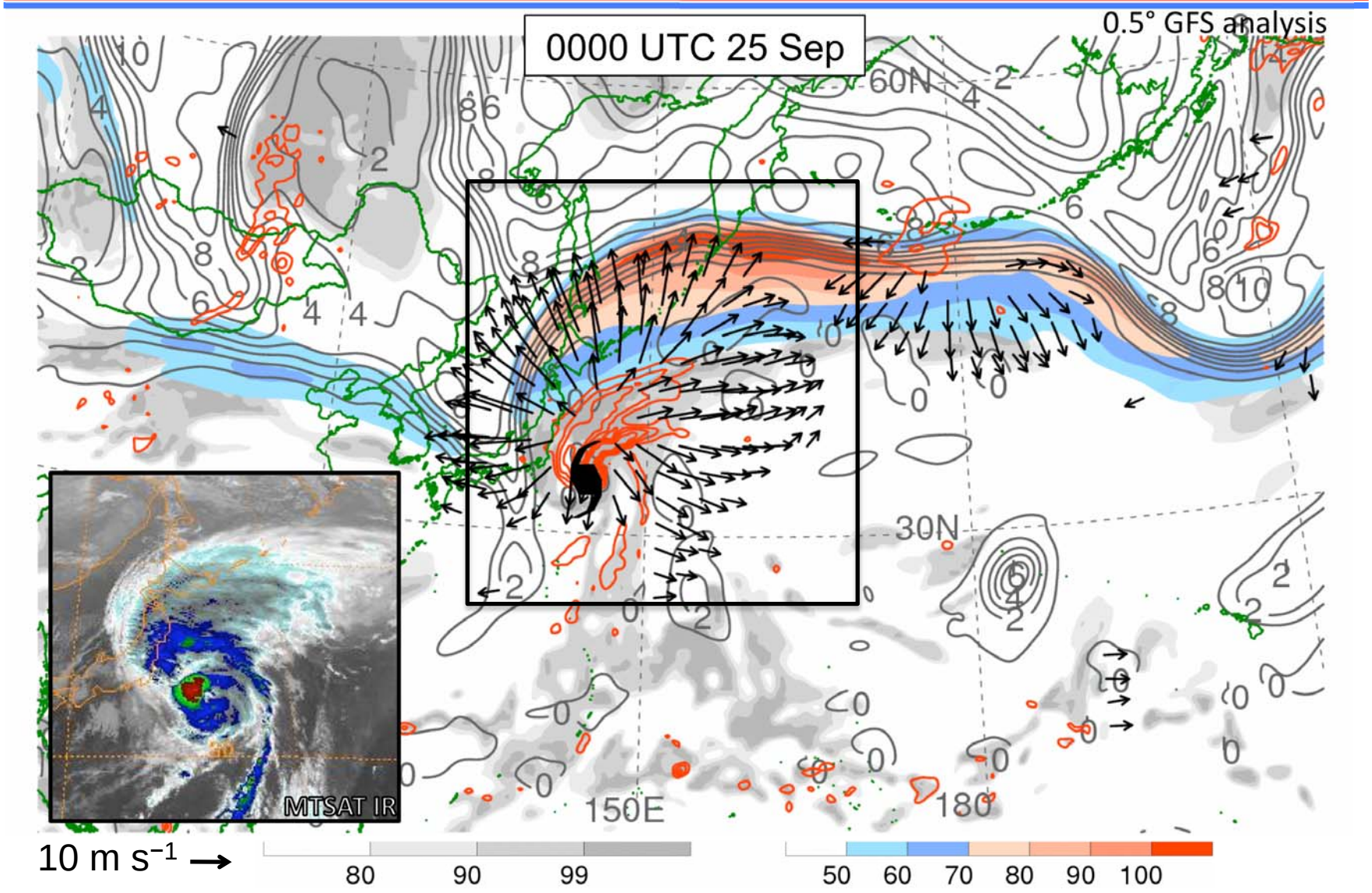
Rossby Wave Train Excitation and Dispersion Associated with TC Malakas

RWT Excitation: Malakas – 12 h After Recurvature



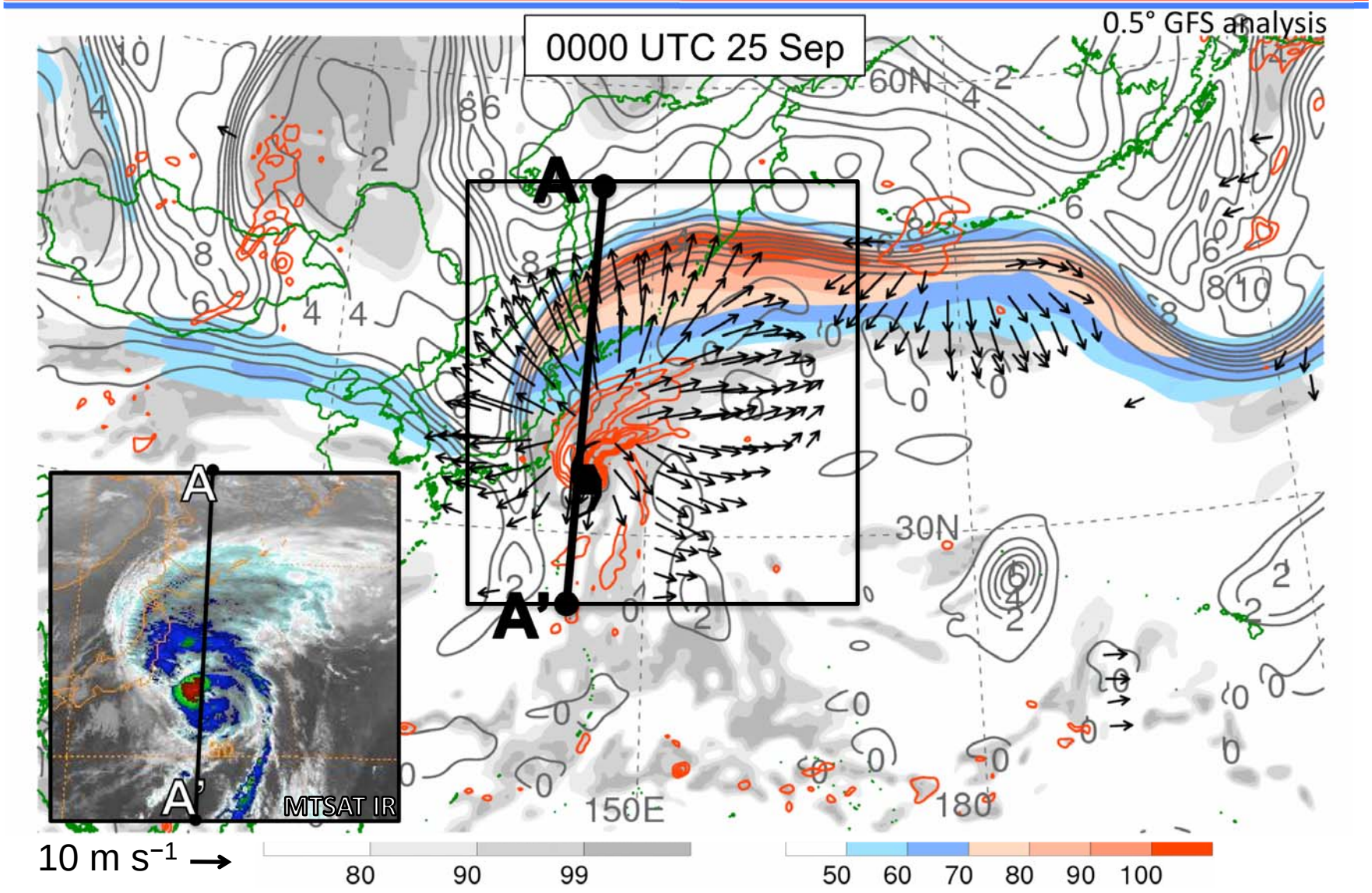
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Malakas – 30 h After Recurvature



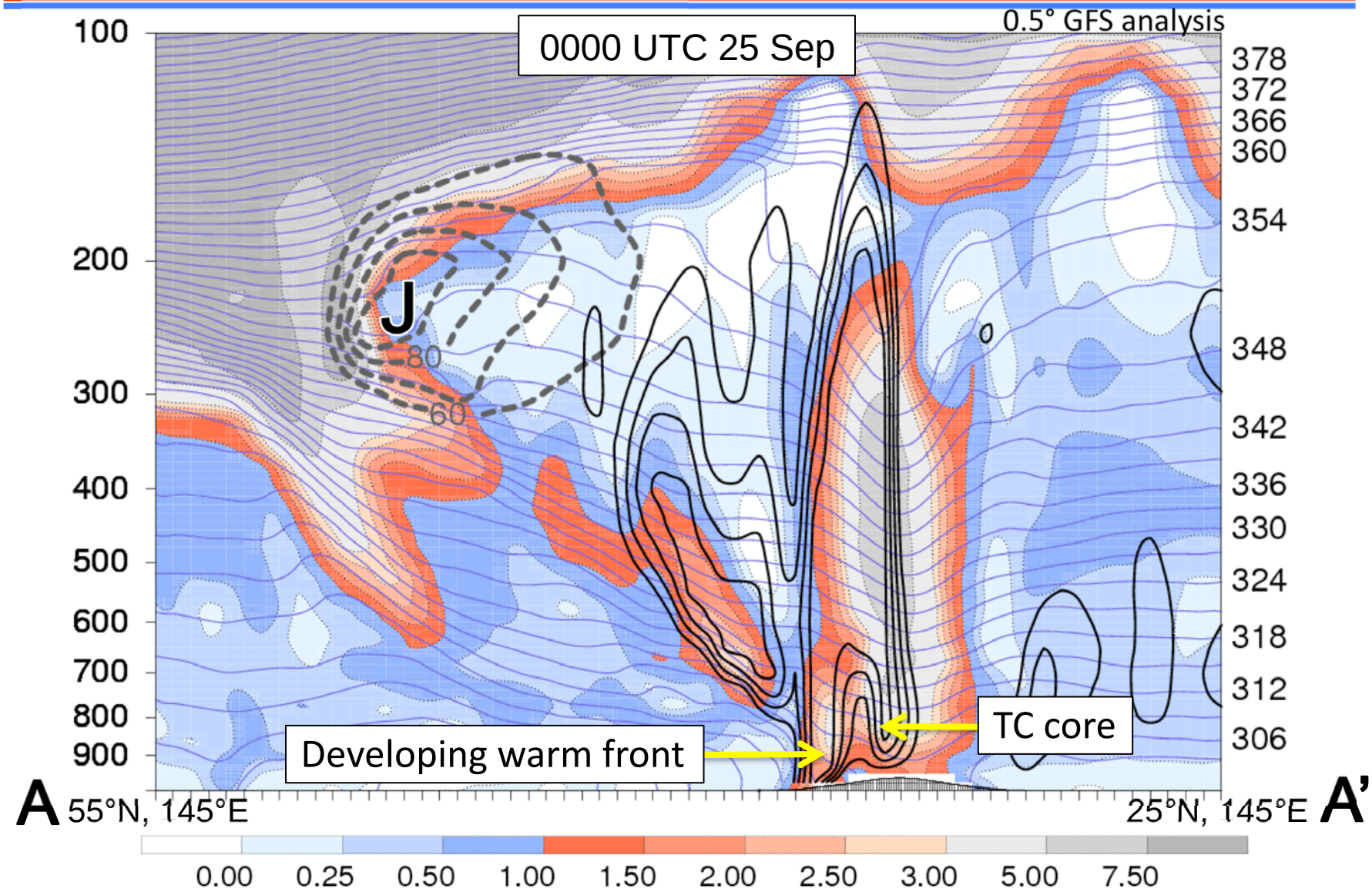
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Malakas – 30 h After Recurvature



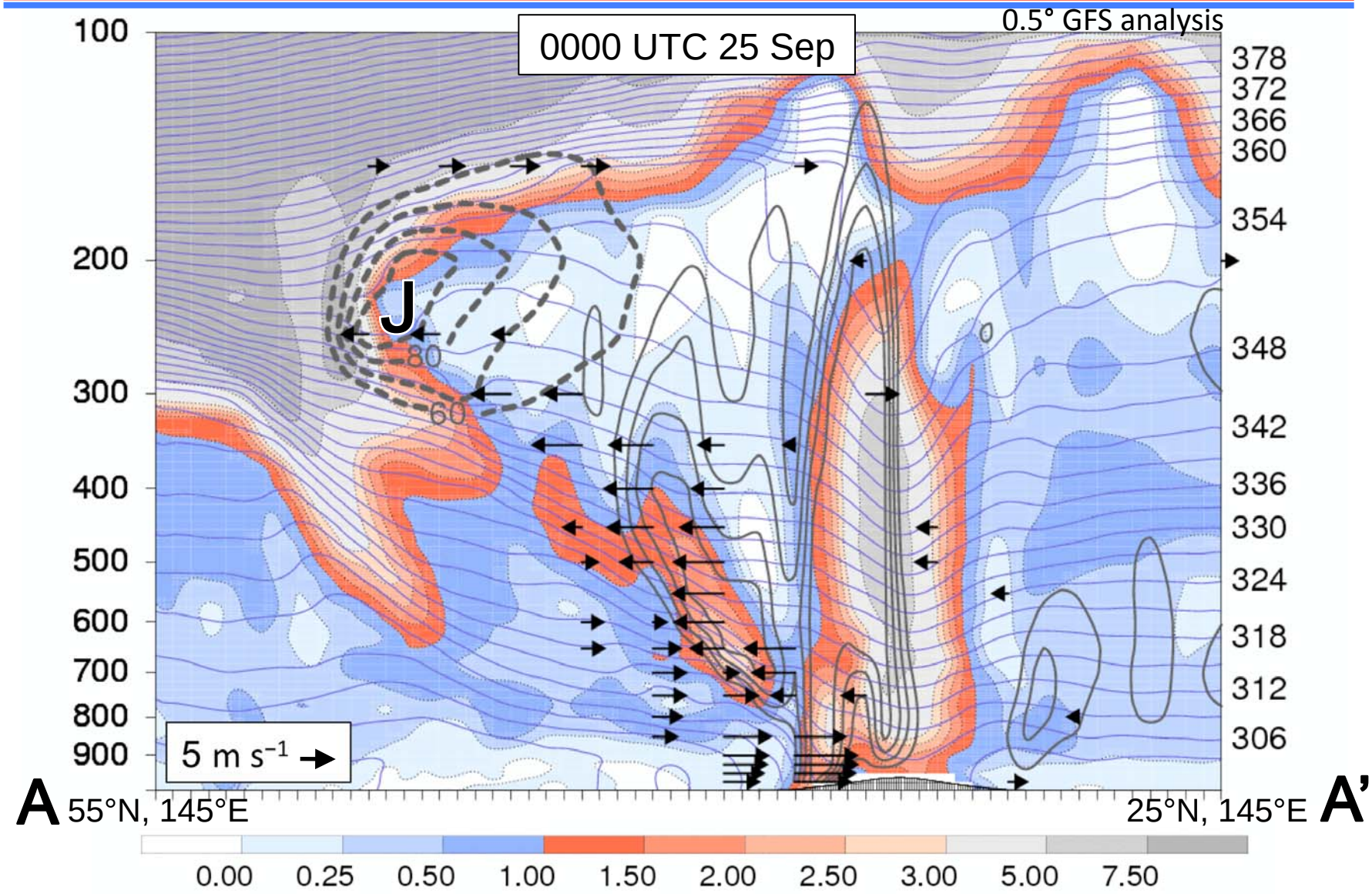
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

Cross Section: Malakas – 30 h After Recurvature



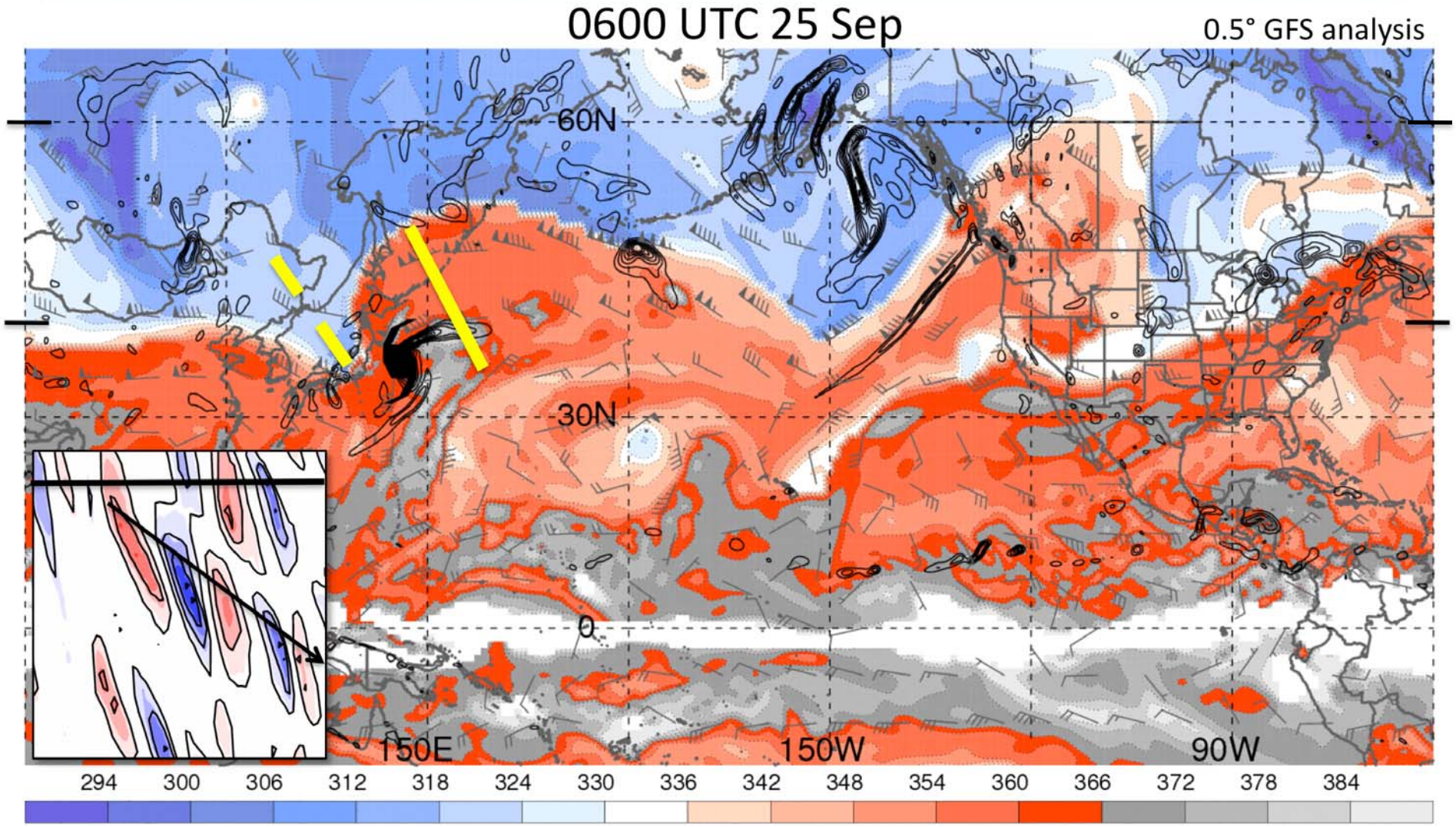
PV (PVU, shaded), potential temperature (blue, K), ascent (black, every 5×10^{-3} hPa s^{-1}), wind speed (dashed gray, m s^{-1})

Cross Section: Malakas – 30 h After Recurvature



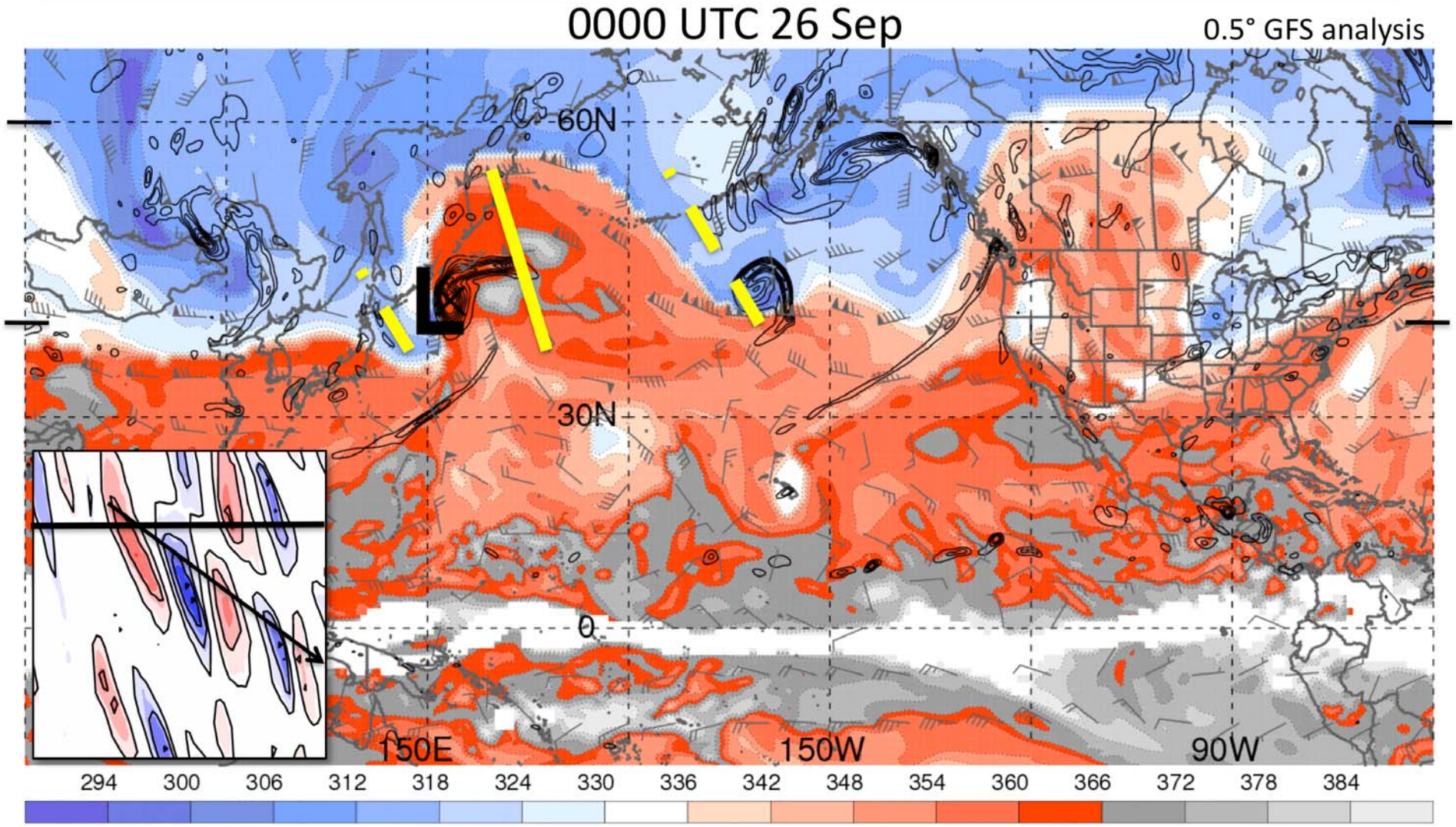
Irrot. wind in x-sect of plane (vectors, >1.5 m s^{-1}), PV (PVU, shaded), pot. temperature (blue, K), ascent (solid gray, every 5 × 10^{-3} hPa s^{-1}), wind speed (dashed gray, m s^{-1})

RWT Dispersion: Malakas – 36 h After Recurvature



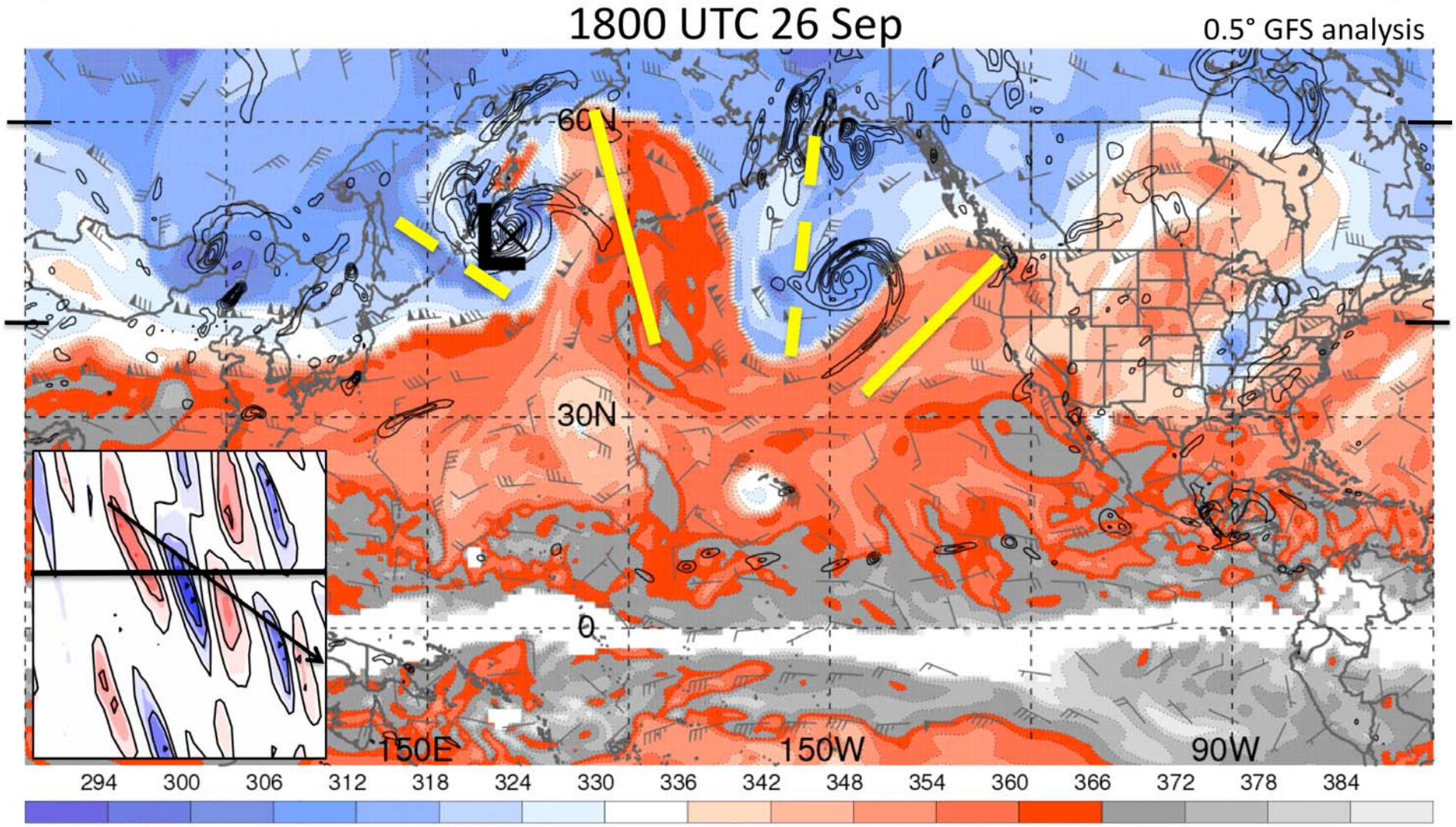
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Malakas – 54 h After Recurvature



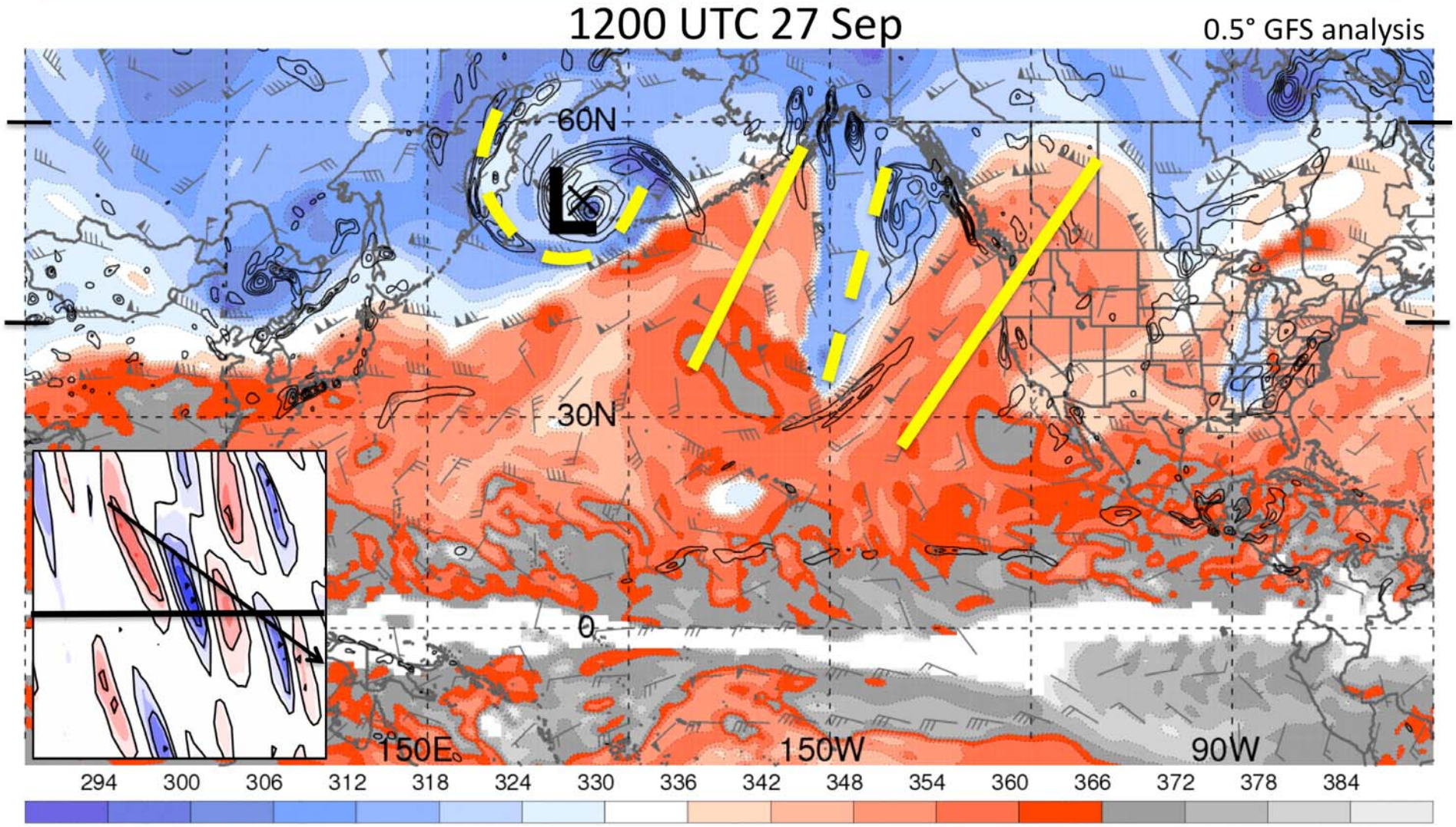
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Malakas – 72 h After Recurvature



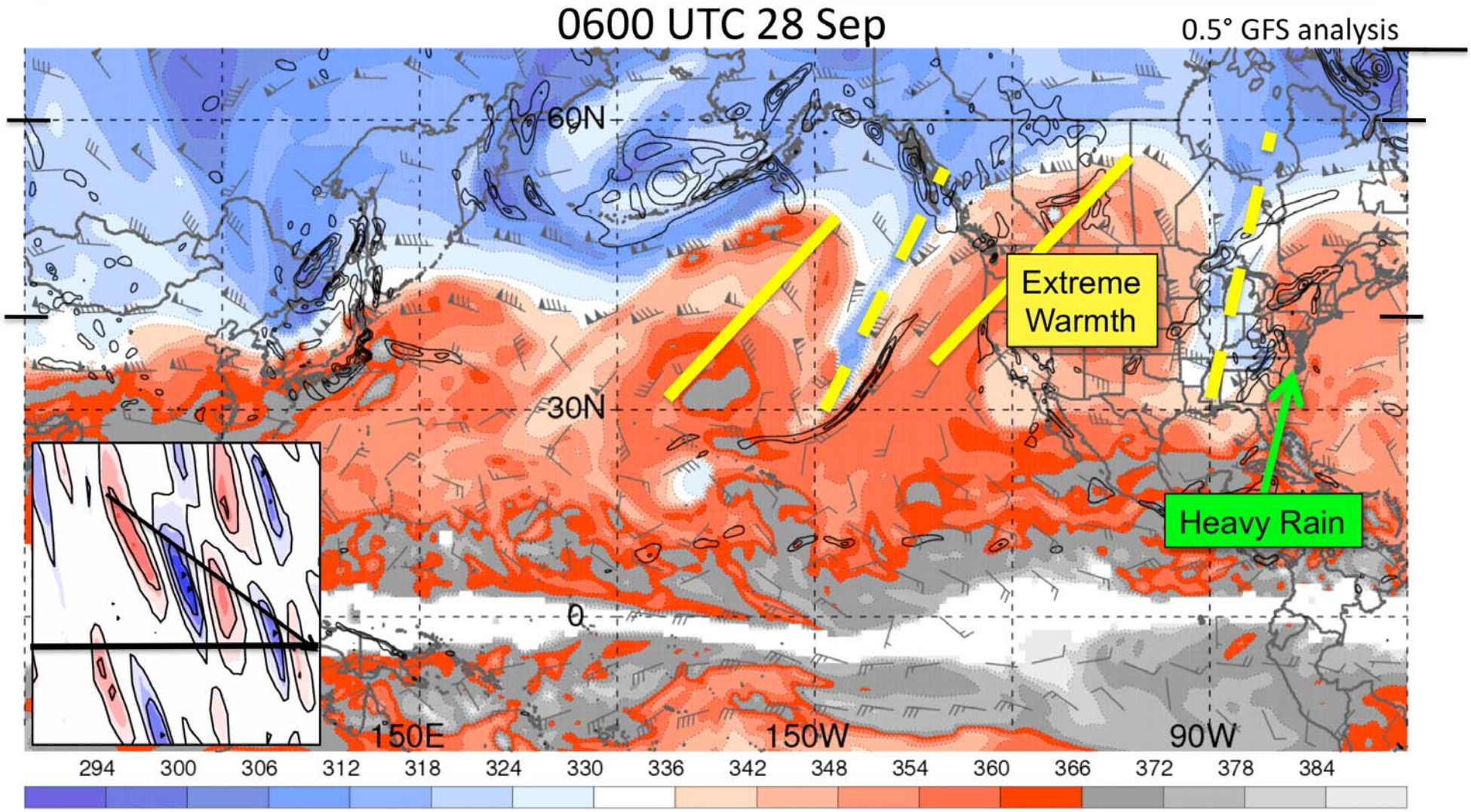
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Malakas – 90 h After Recurvature



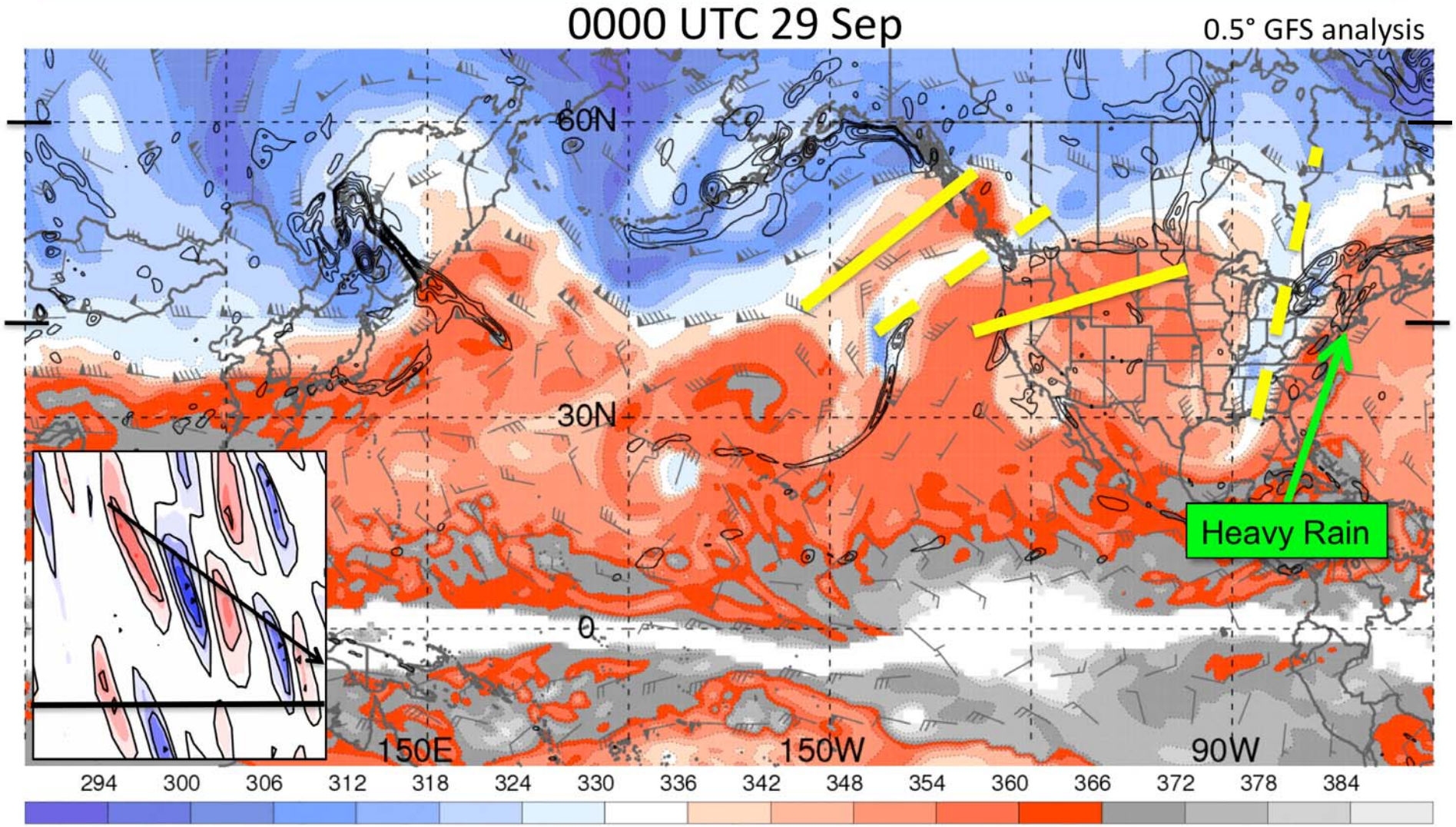
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Malakas – 108 h After Recurvature



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

RWT Dispersion: Malakas – 126 h After Recurvature



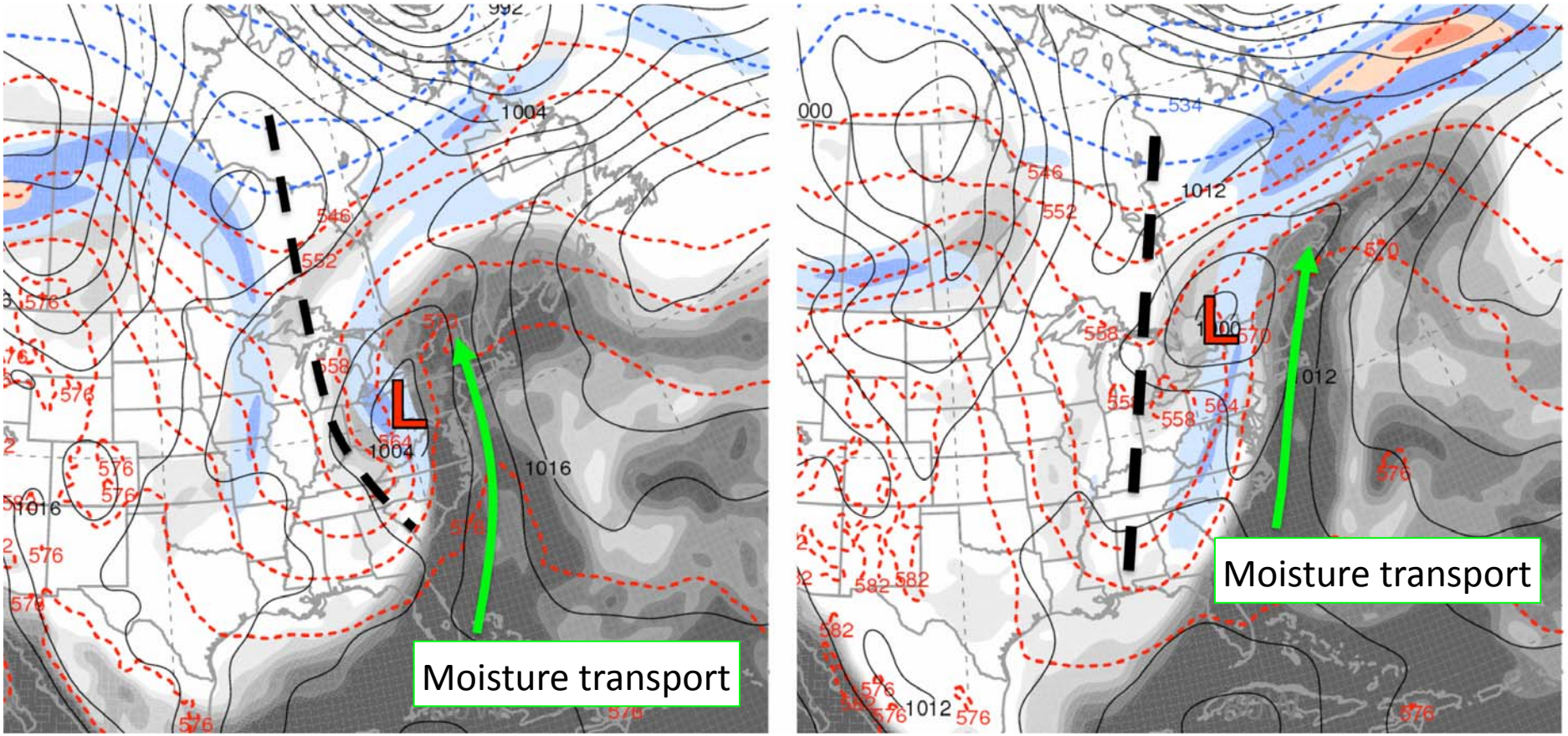
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

Heavy Rain Downstream of Malakas

0.5° GFS analysis

108 h after recurvature

126 h after recurvature



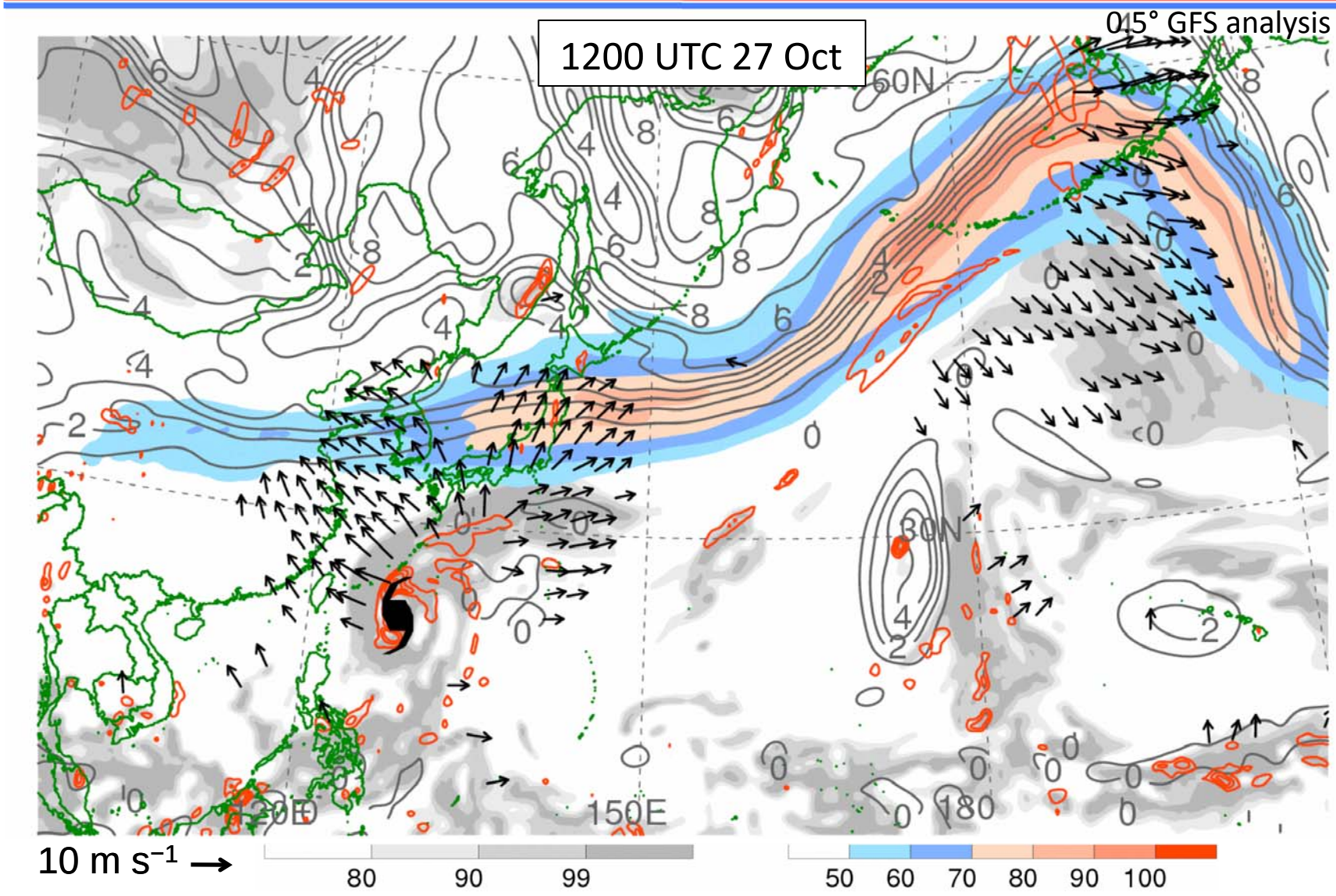
0600 UTC 28 Sep

0000 UTC 29 Sep

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

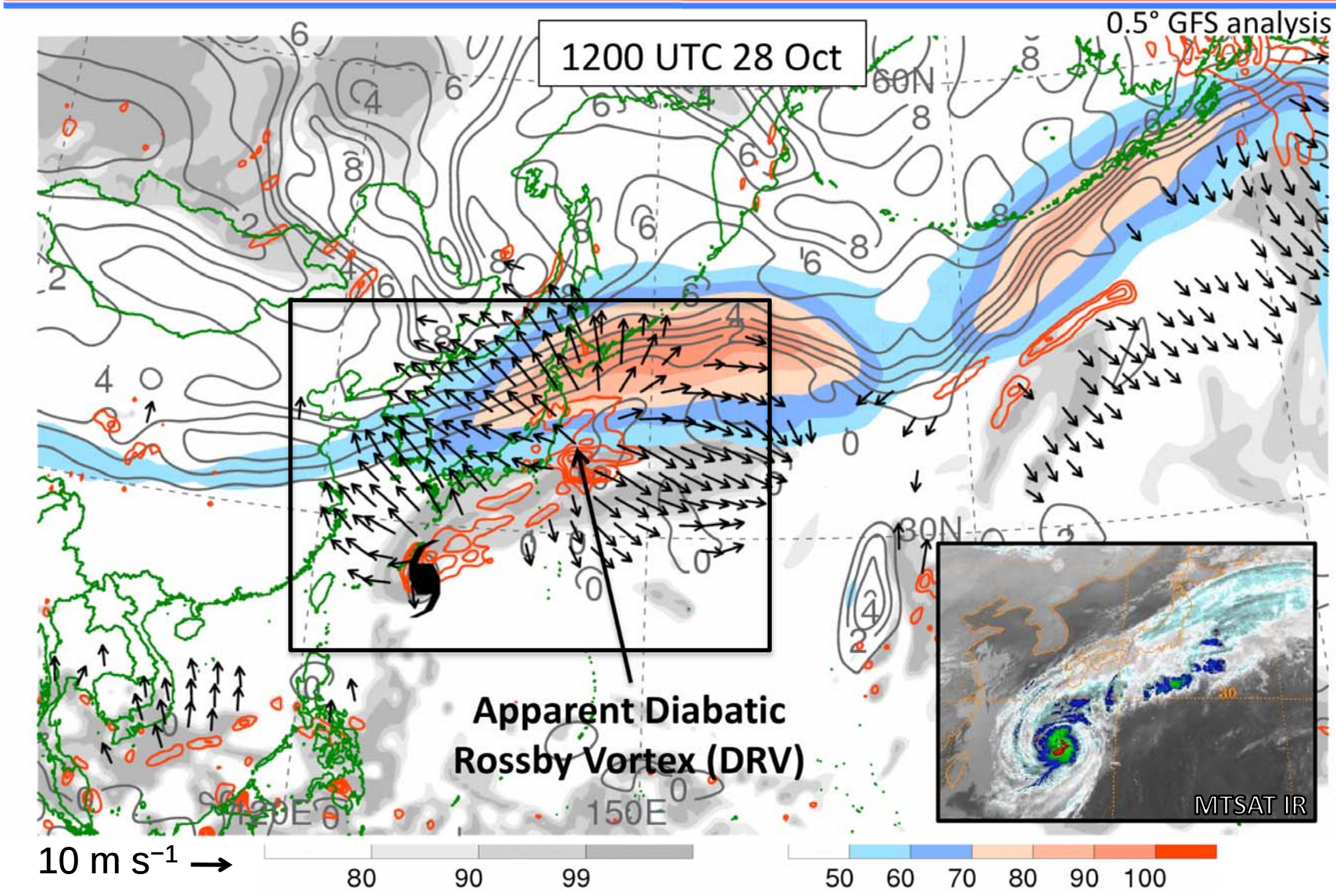
Rossby Wave Train Excitation and Dispersion Associated with TC Chaba

RWT Excitation: Chaba – 18 h After Recurvature



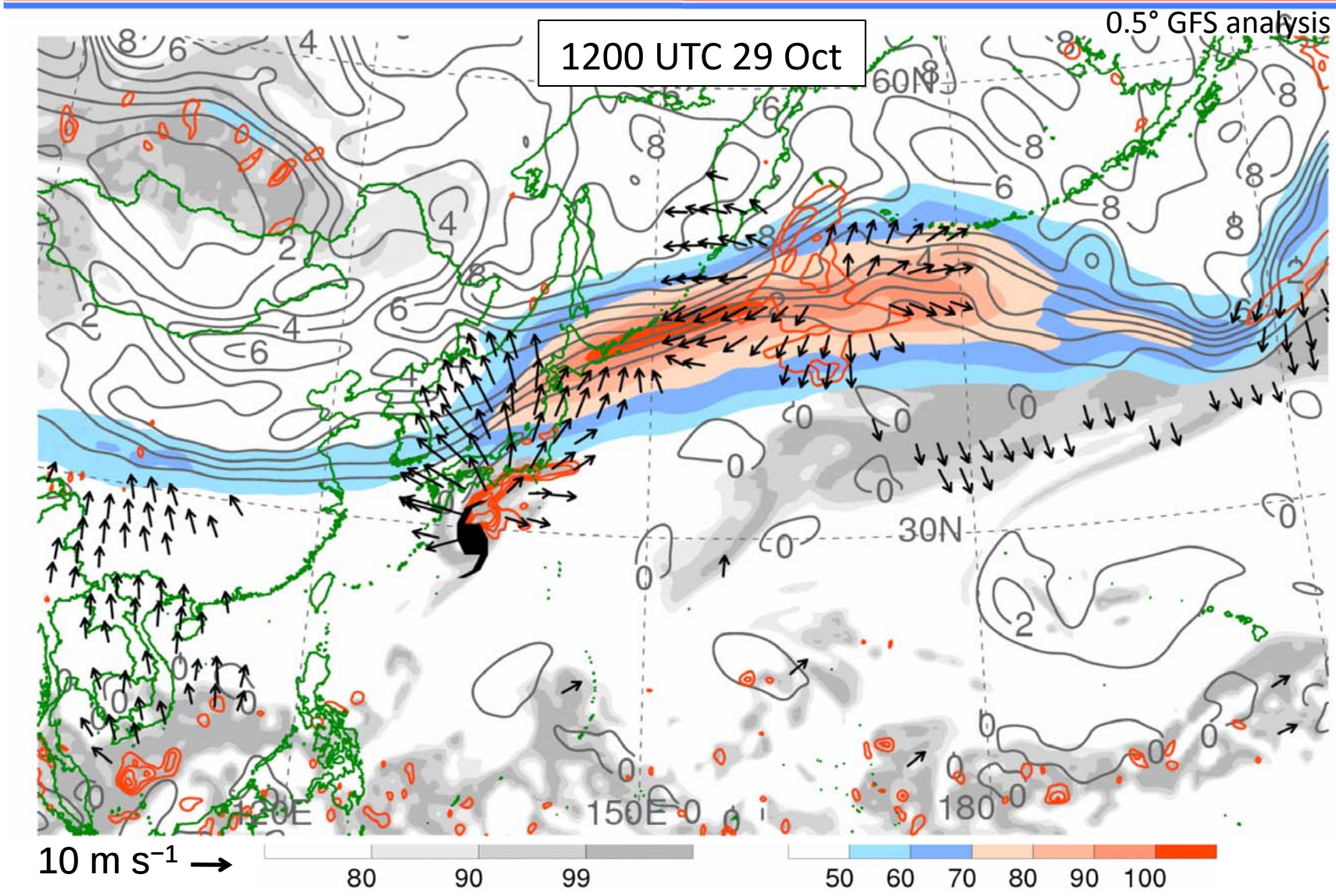
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 42 h After Recurvature



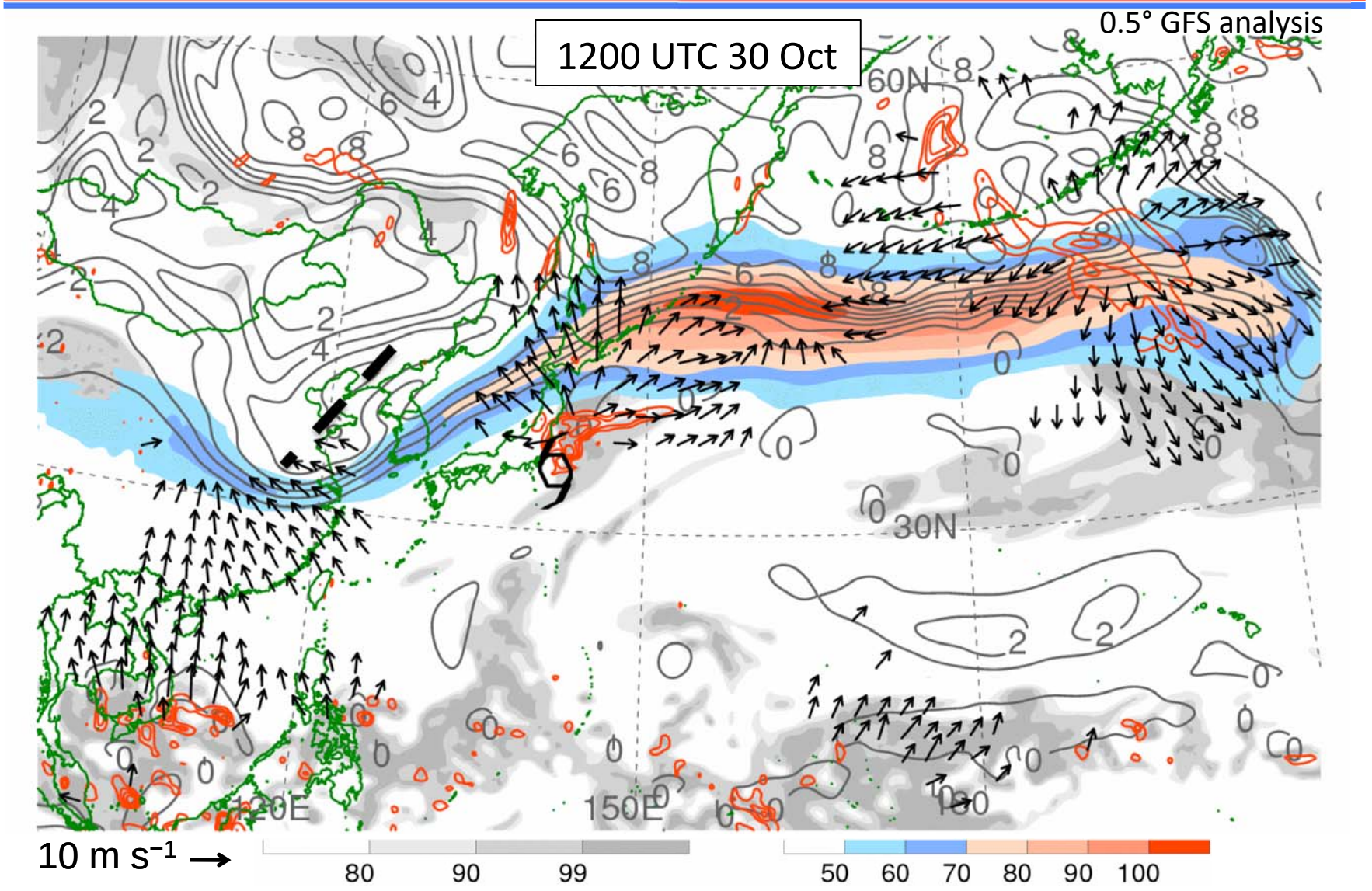
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 66 h After Recurvature



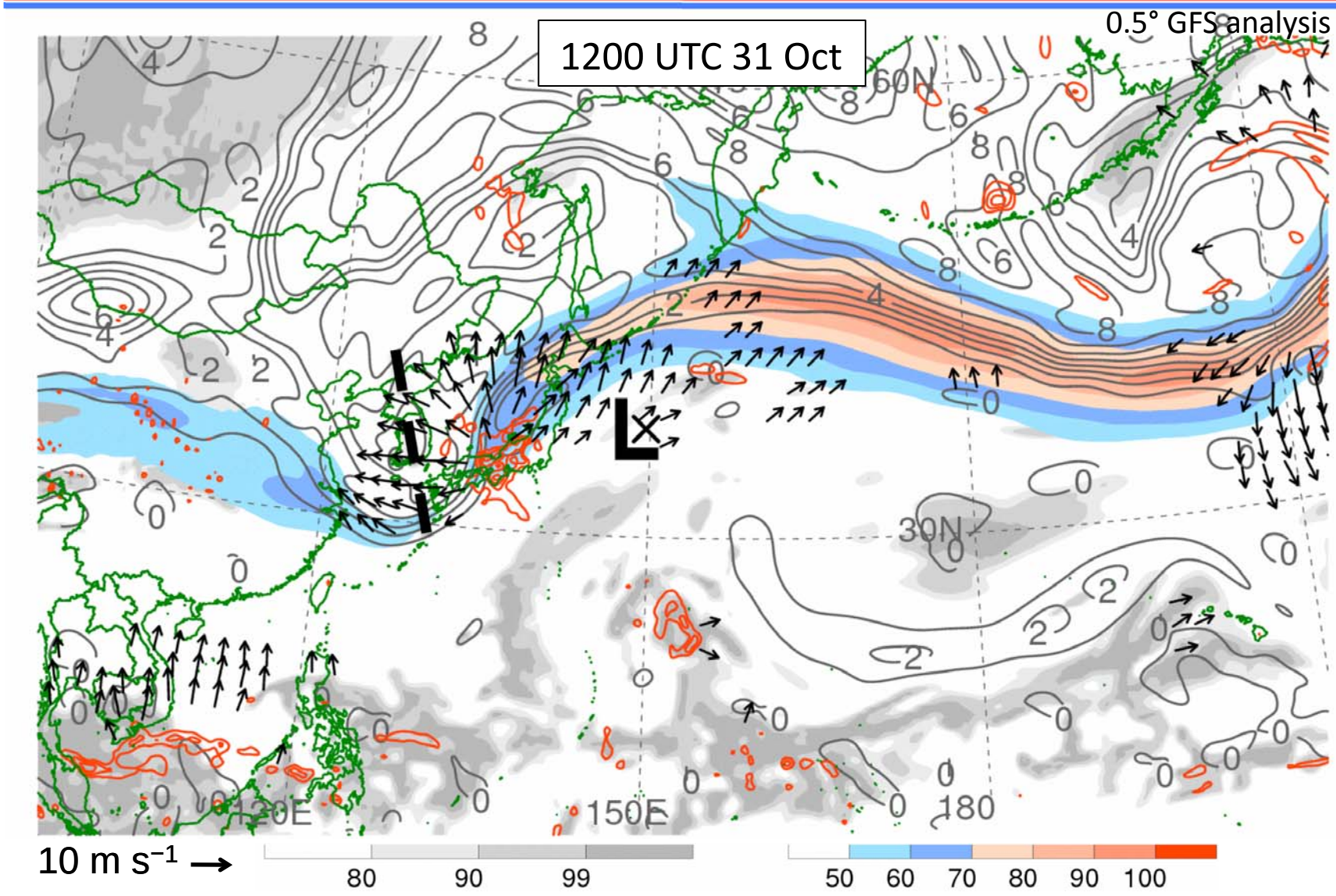
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 90 h After Recurvature



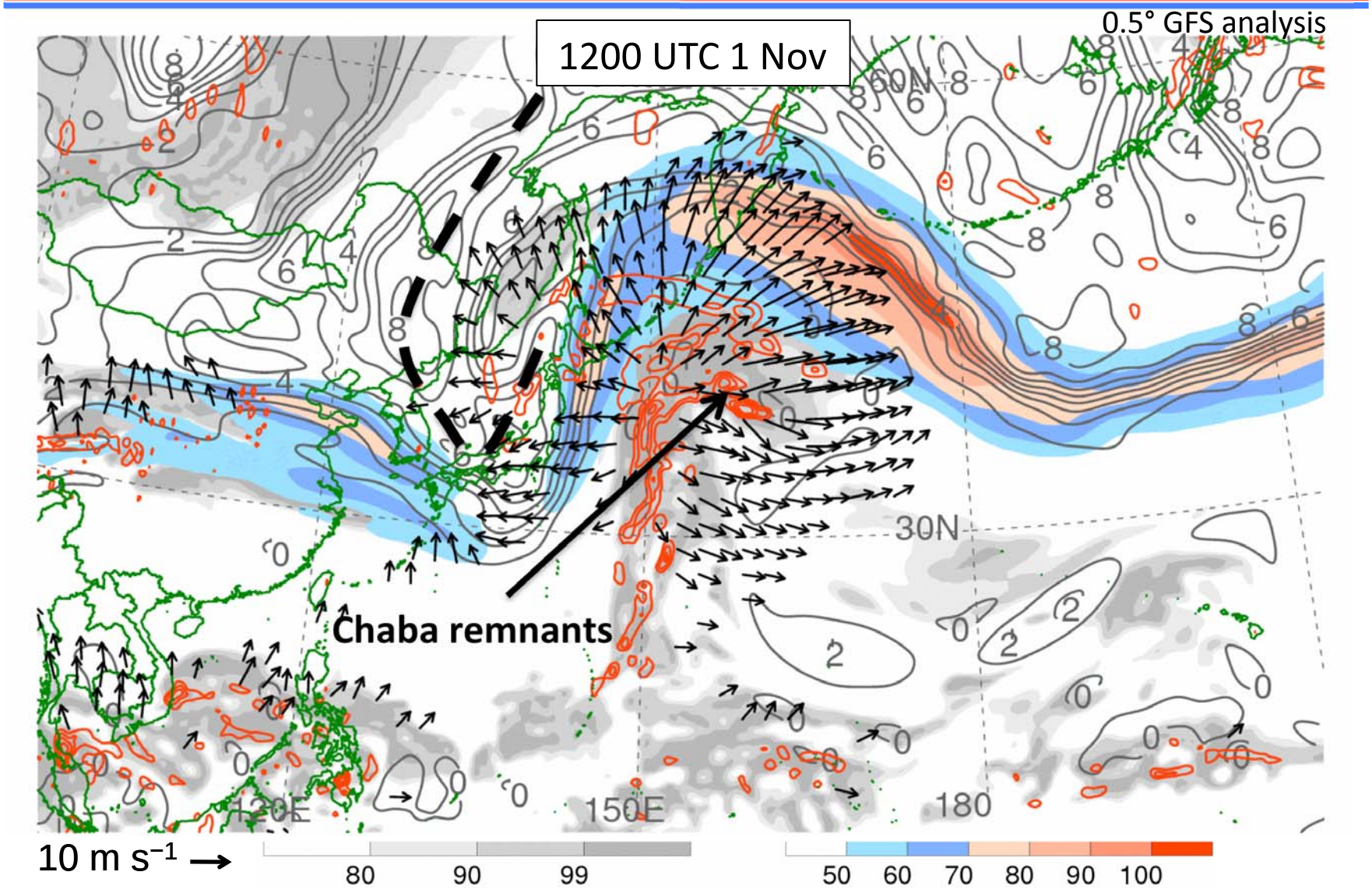
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 114 h After Recurvature



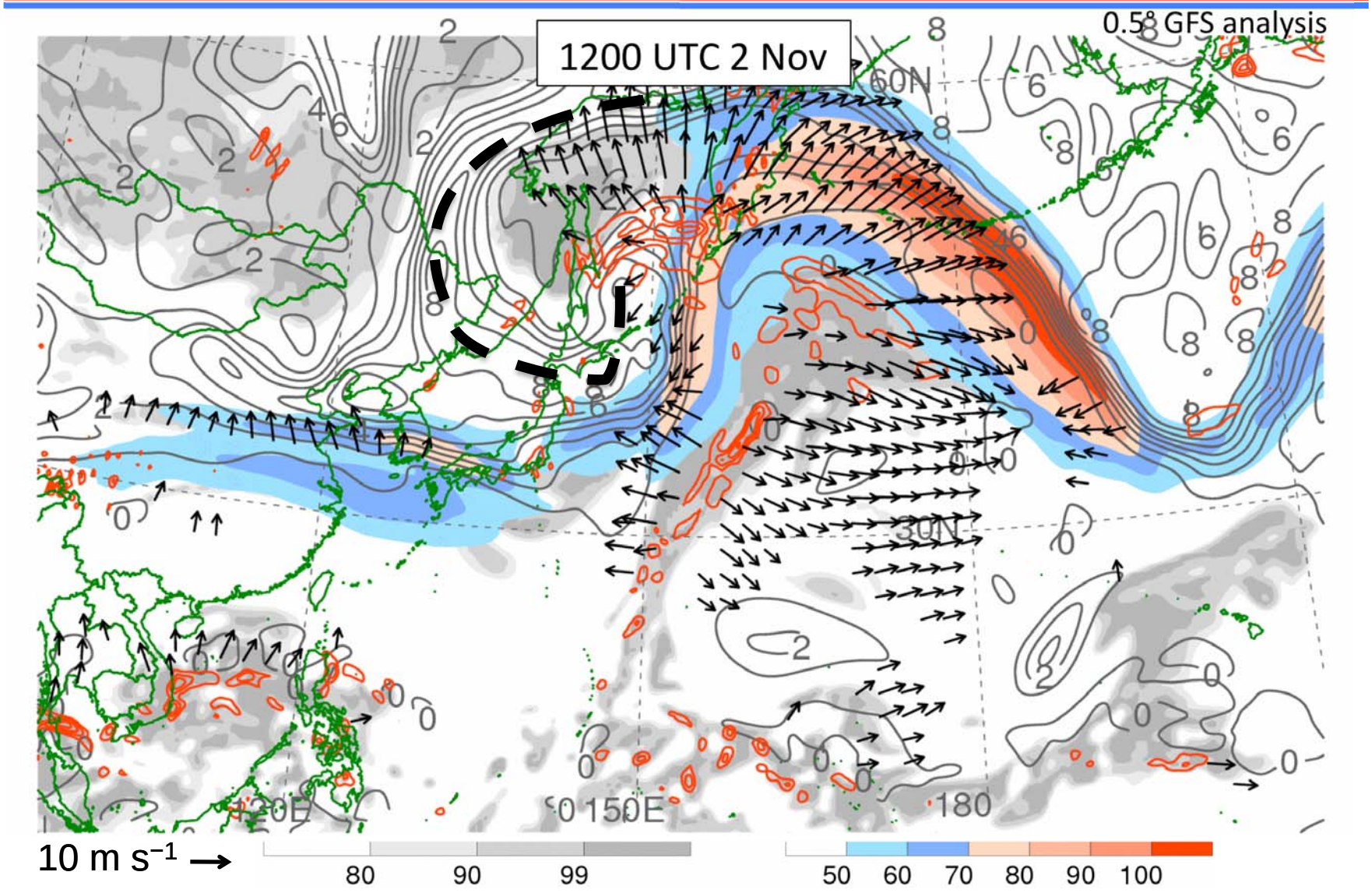
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 138 h After Recurvature



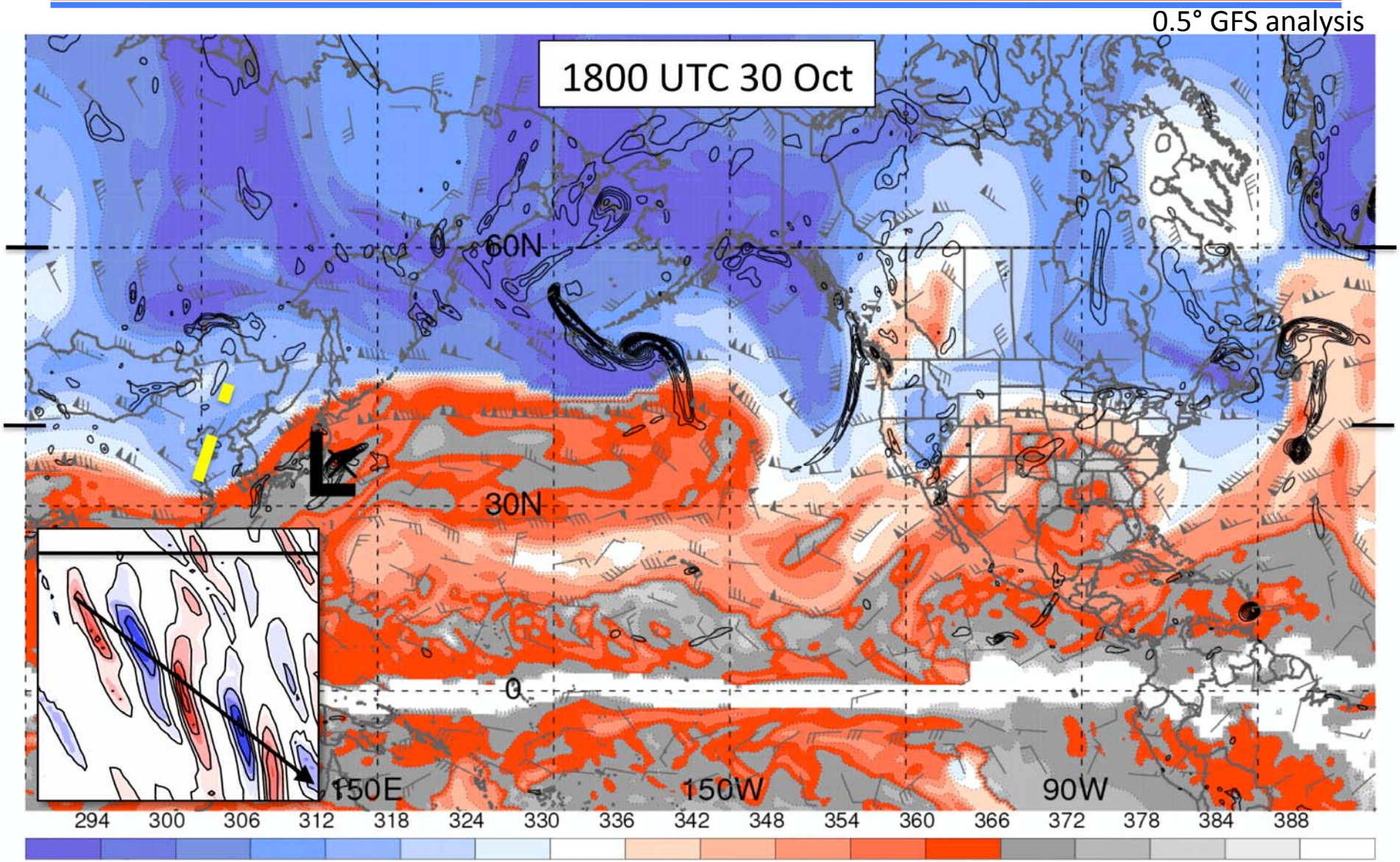
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Excitation: Chaba – 162 h After Recurvature



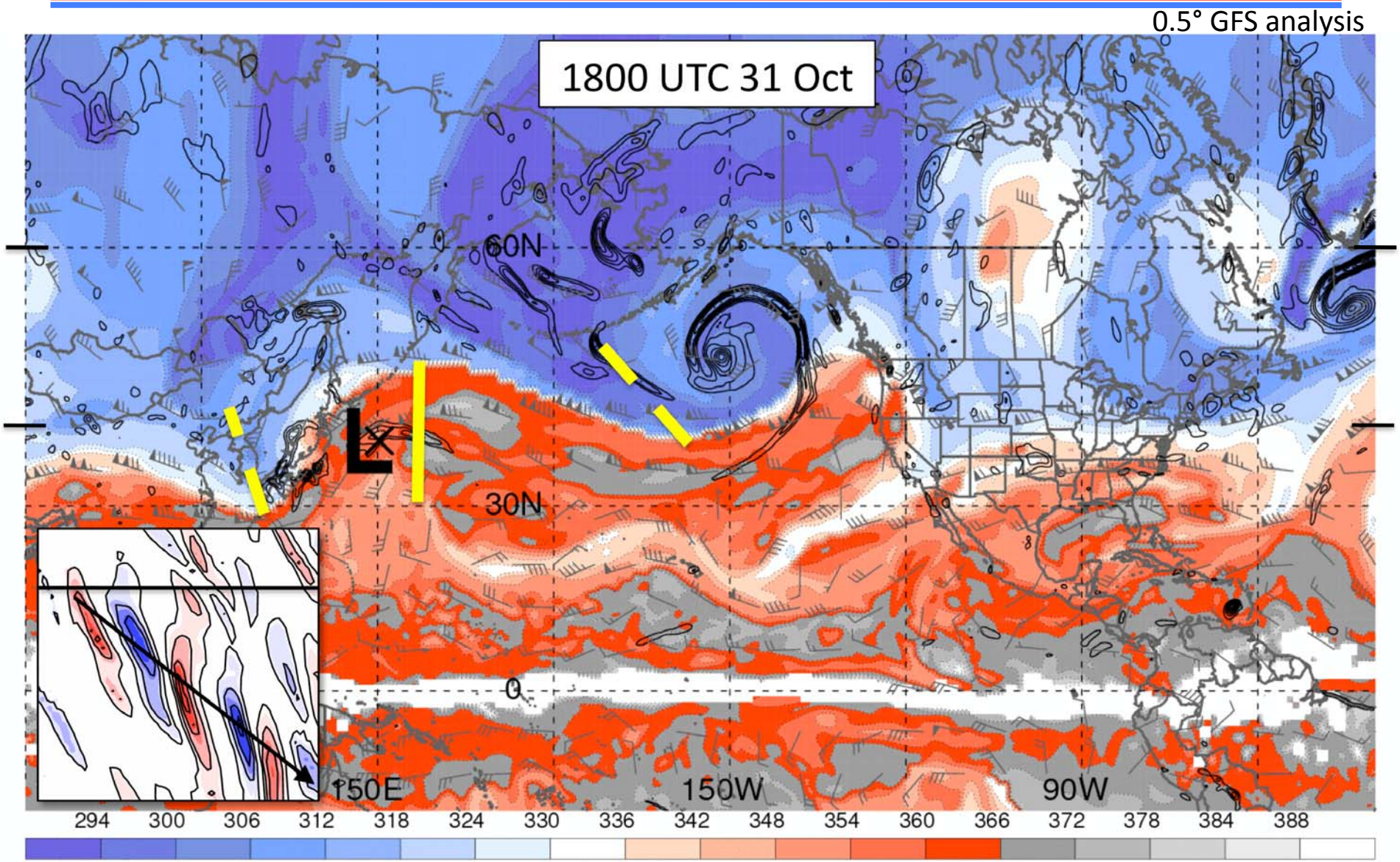
250-hPa wind speed (m s^{-1}, color shading), PV (PVU, gray), relative humidity (%, gray shading); 300–200-hPa irrot. wind (vectors, >5 m s^{-1}), 600–400-hPa ascent (red, every 5 × 10^{-3} hPa s^{-1})

RWT Dispersion: Chaba – 96 h After Recurvature



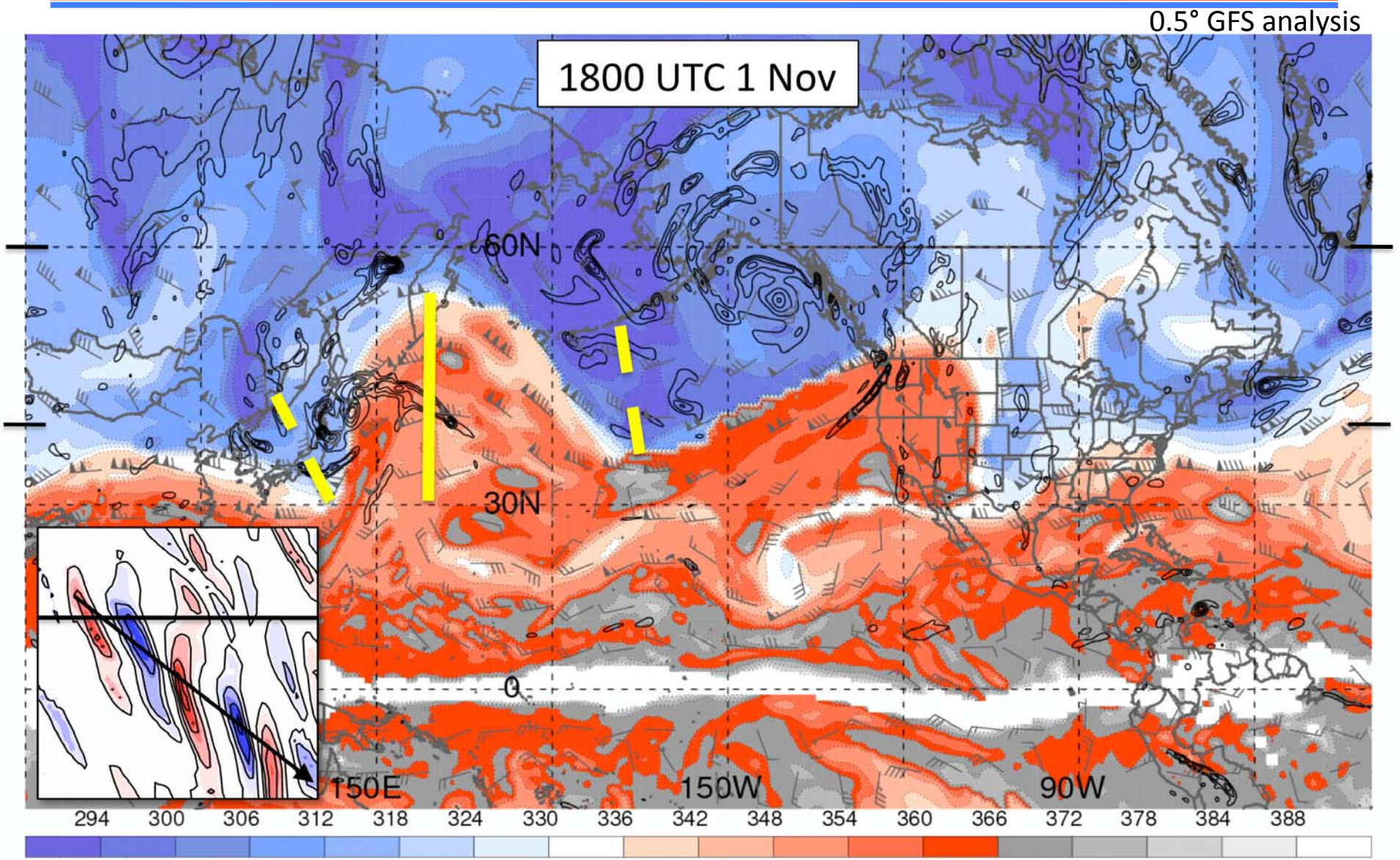
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 120 h After Recurvature



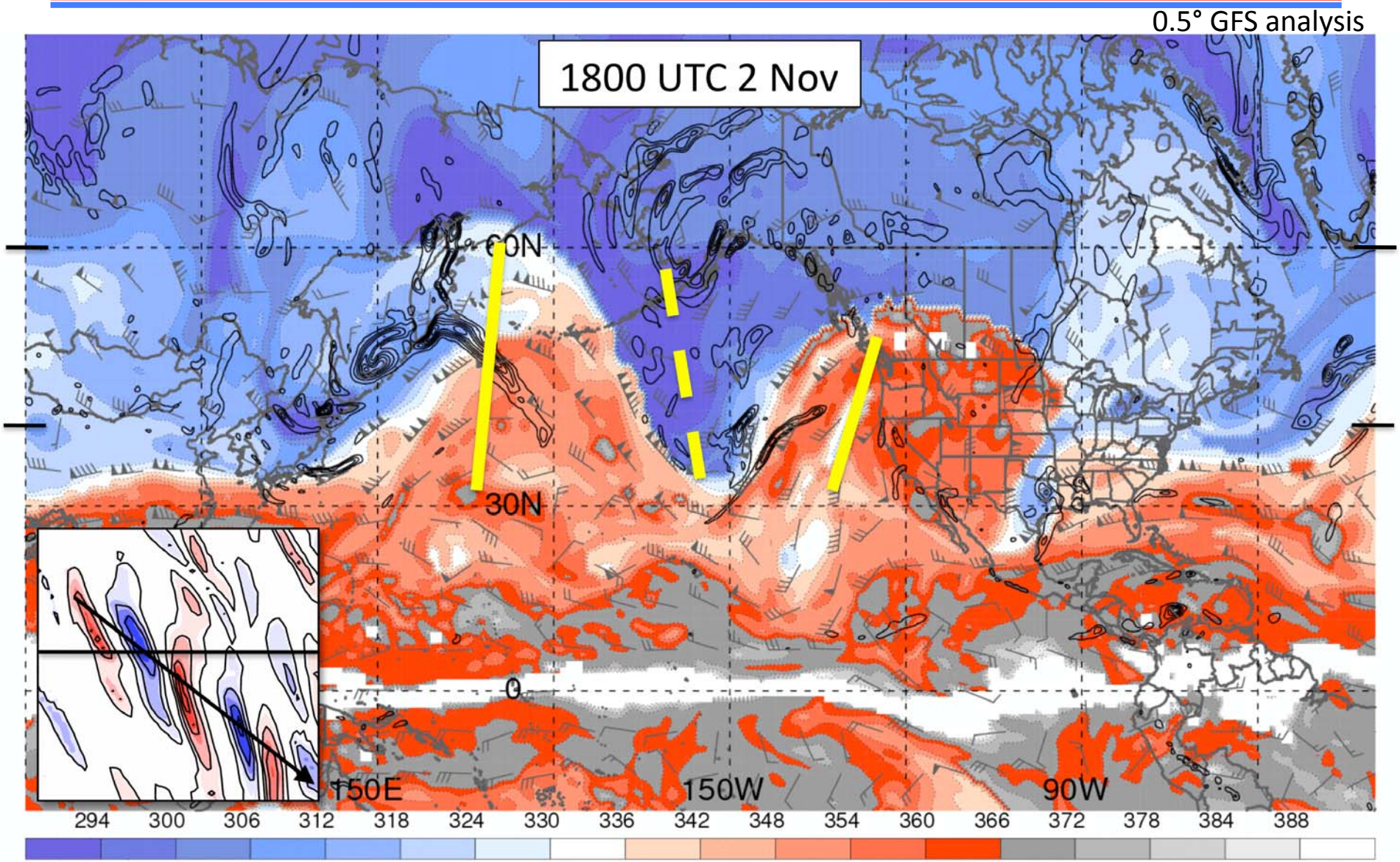
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 144 h After Recurvature



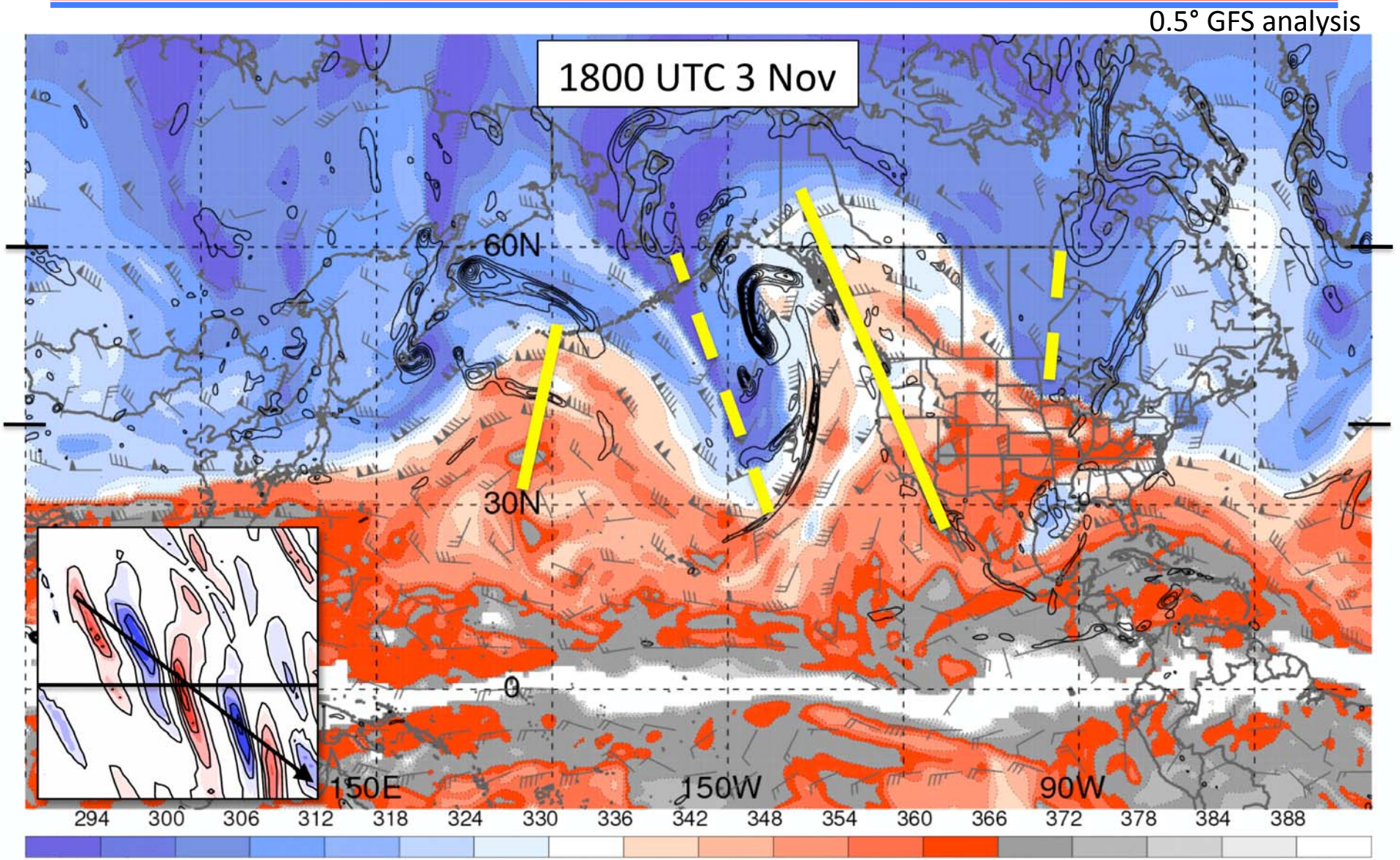
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 168 h After Recurvature



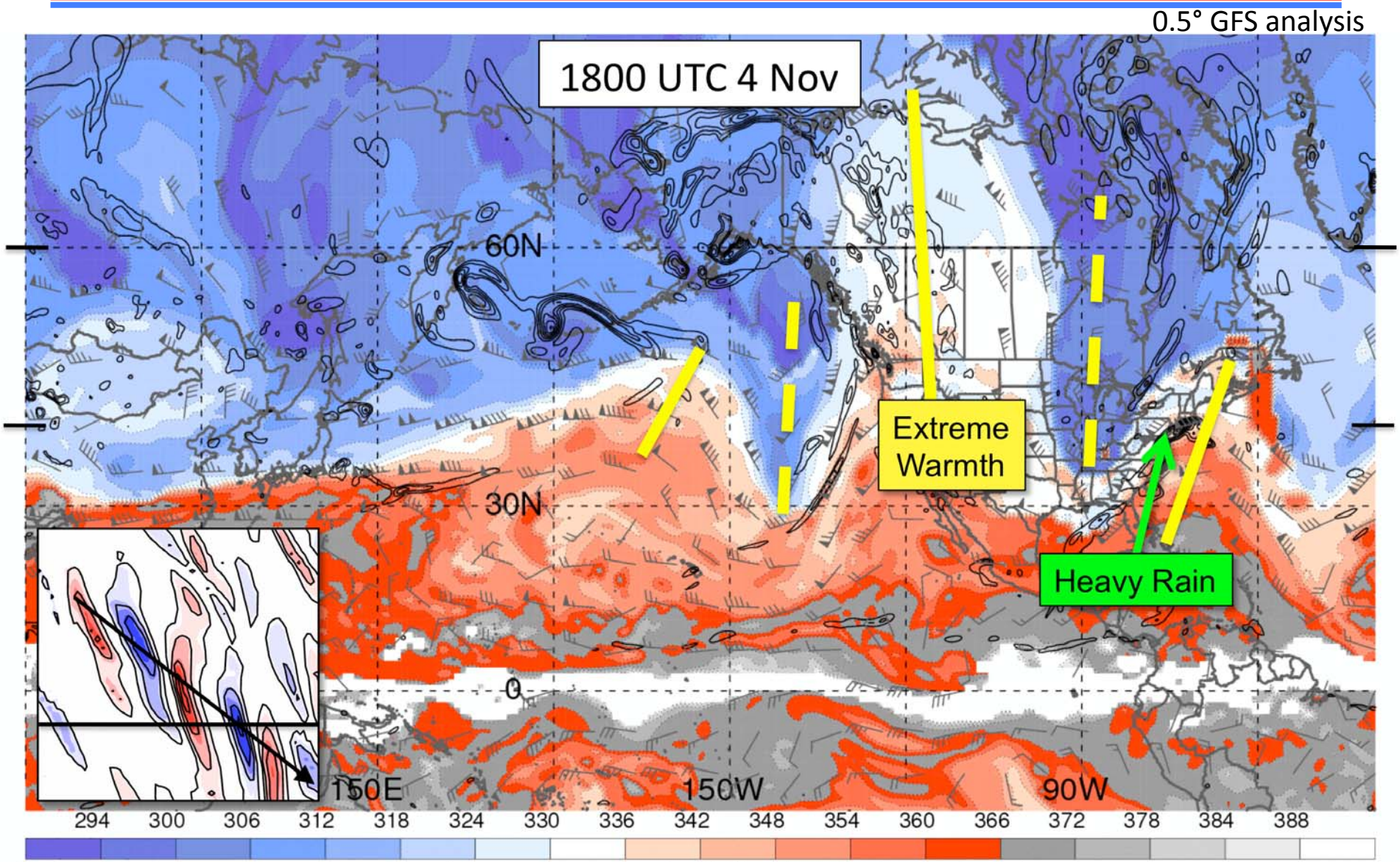
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 192 h After Recurvature



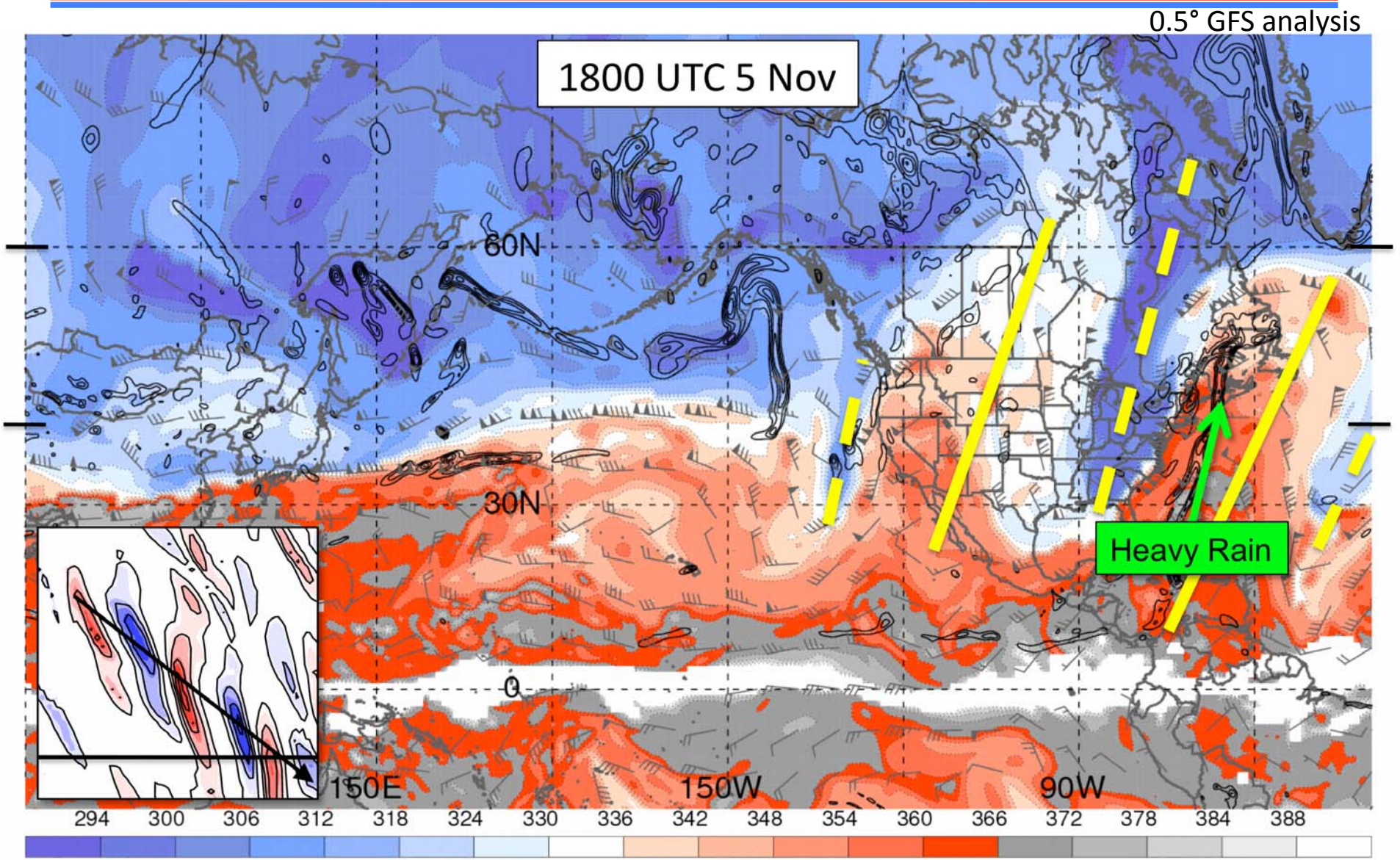
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 216 h After Recurvature



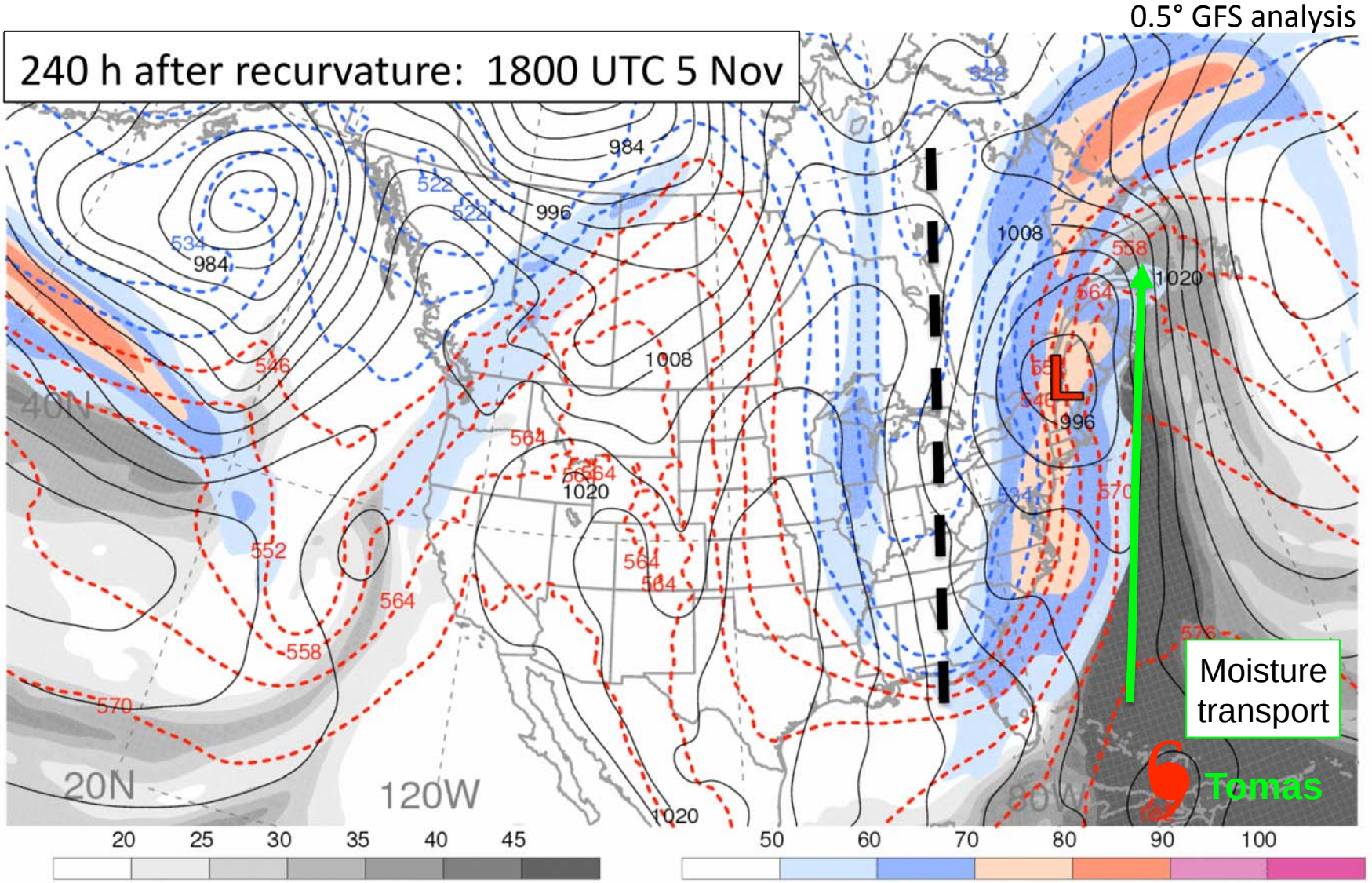
Potential temperature (K, shaded) and wind (kt, barbs) on the dynamic tropopause (1.5-PVU surface); 925–850-hPa cyclonic relative vorticity (black, every 5×10^{-5} s^{-1})

RWT Dispersion: Chaba – 240 h After Recurvature



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

Heavy Rain Downstream of Chaba

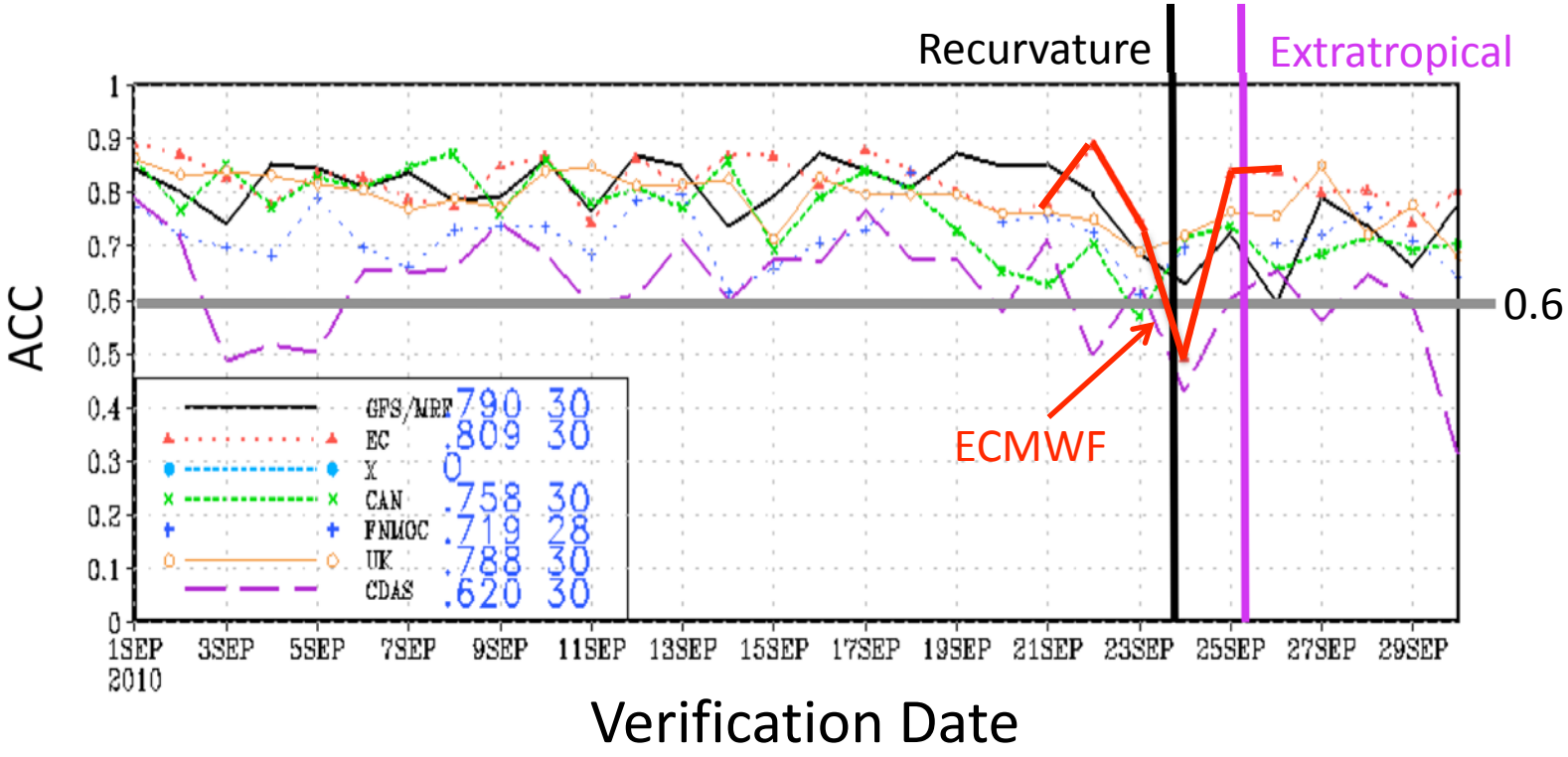


Precipitable water (mm, gray shading), 250-hPa wind speed (m s^{-1}, color shading), 1000–500-hPa thickness (dam, dashed), and SLP (hPa, solid)

Predictability Associated with TC Malakas

Predictability During Malakas Recurvature

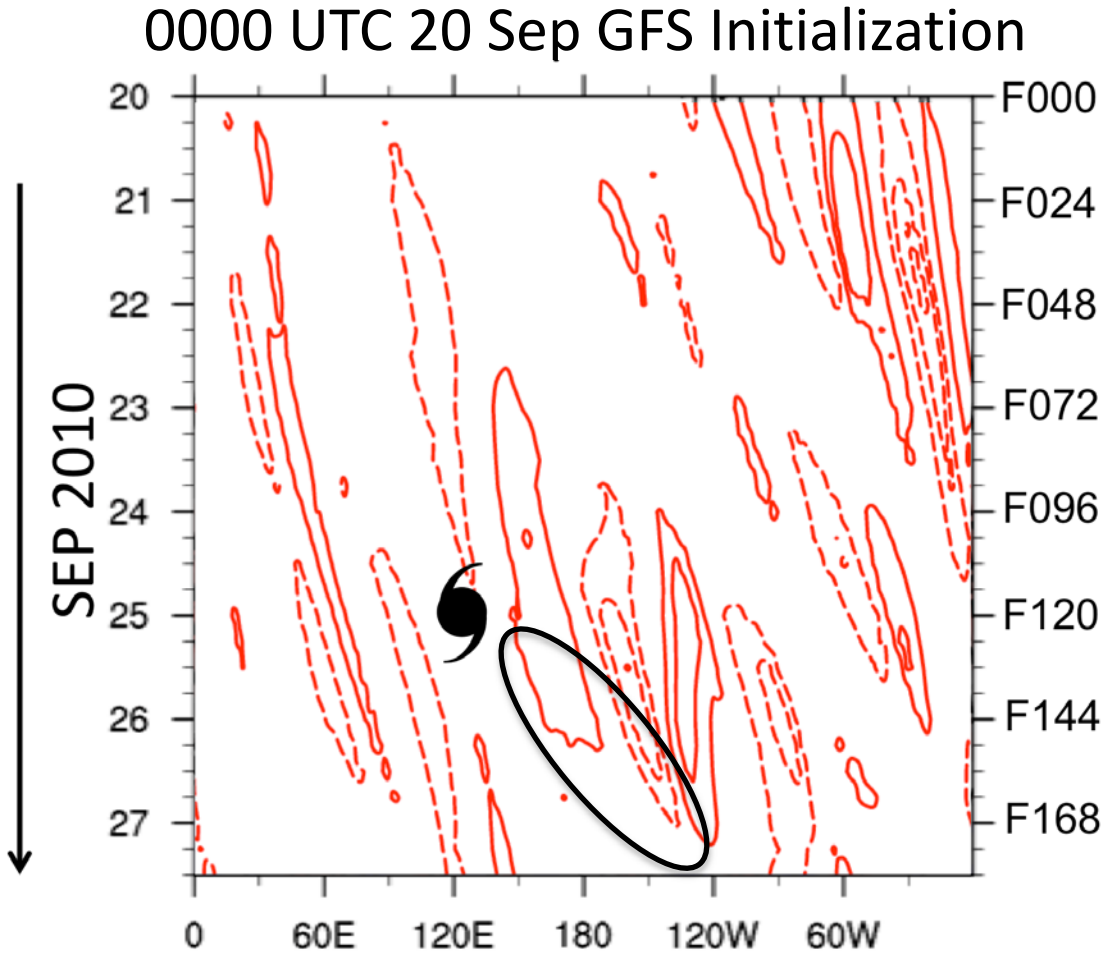
NH (20°–80°N) Anomaly Correlation Coefficients for 6-d 500-hPa Geopotential Height Forecasts Verifying 1–30 Sep 2010



- All global models exhibit reduced skill for forecasts verifying during recurvature and ET of Malakas

http://www.emc.ncep.noaa.gov/gmb/STATS/STATS.html

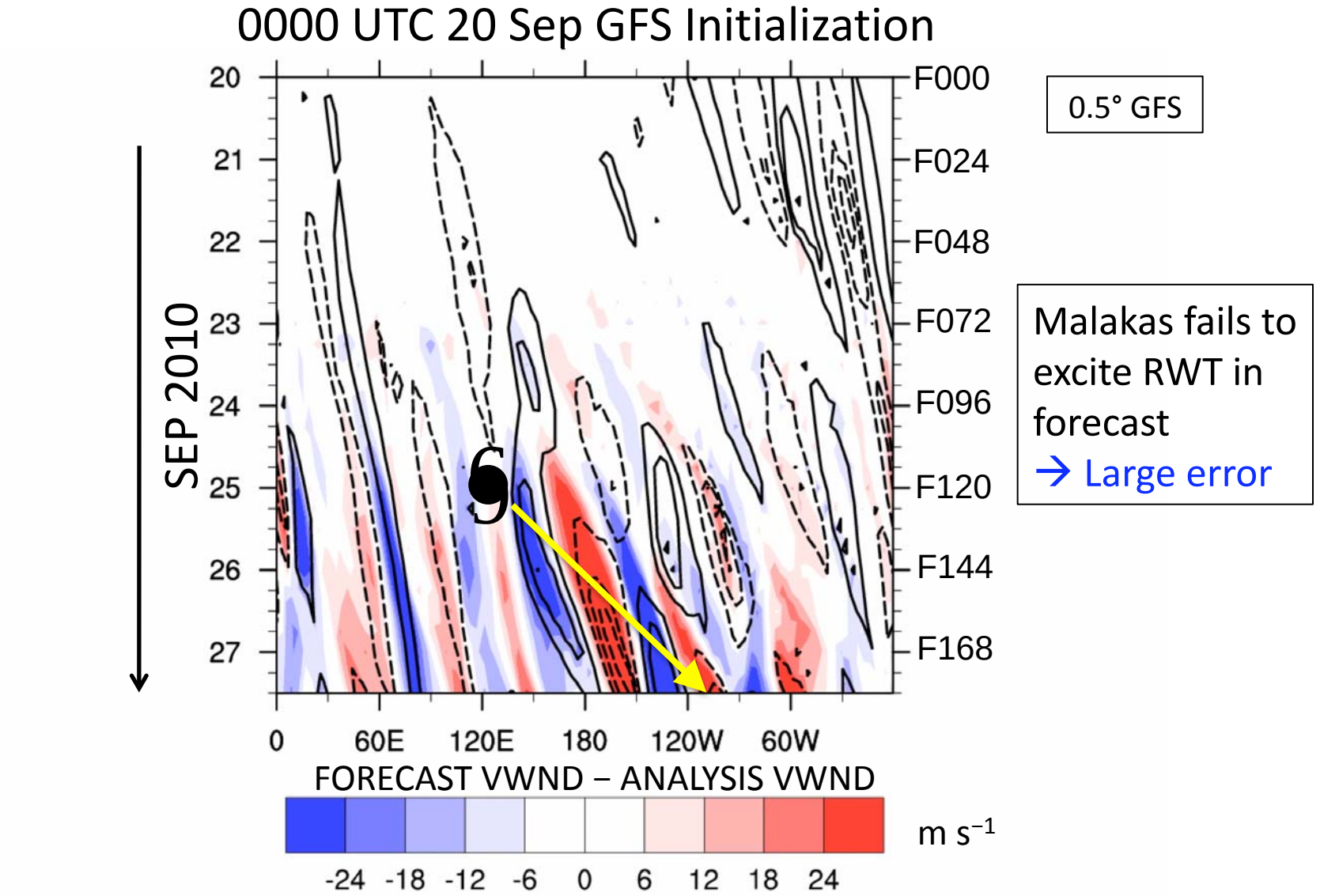
Predictability During Malakas Recurvature



40°–60°N averaged 250-hPa meridional wind forecast

[contoured every 15 m s^{-1}, positive (negative) values solid (dashed); zero line omitted]

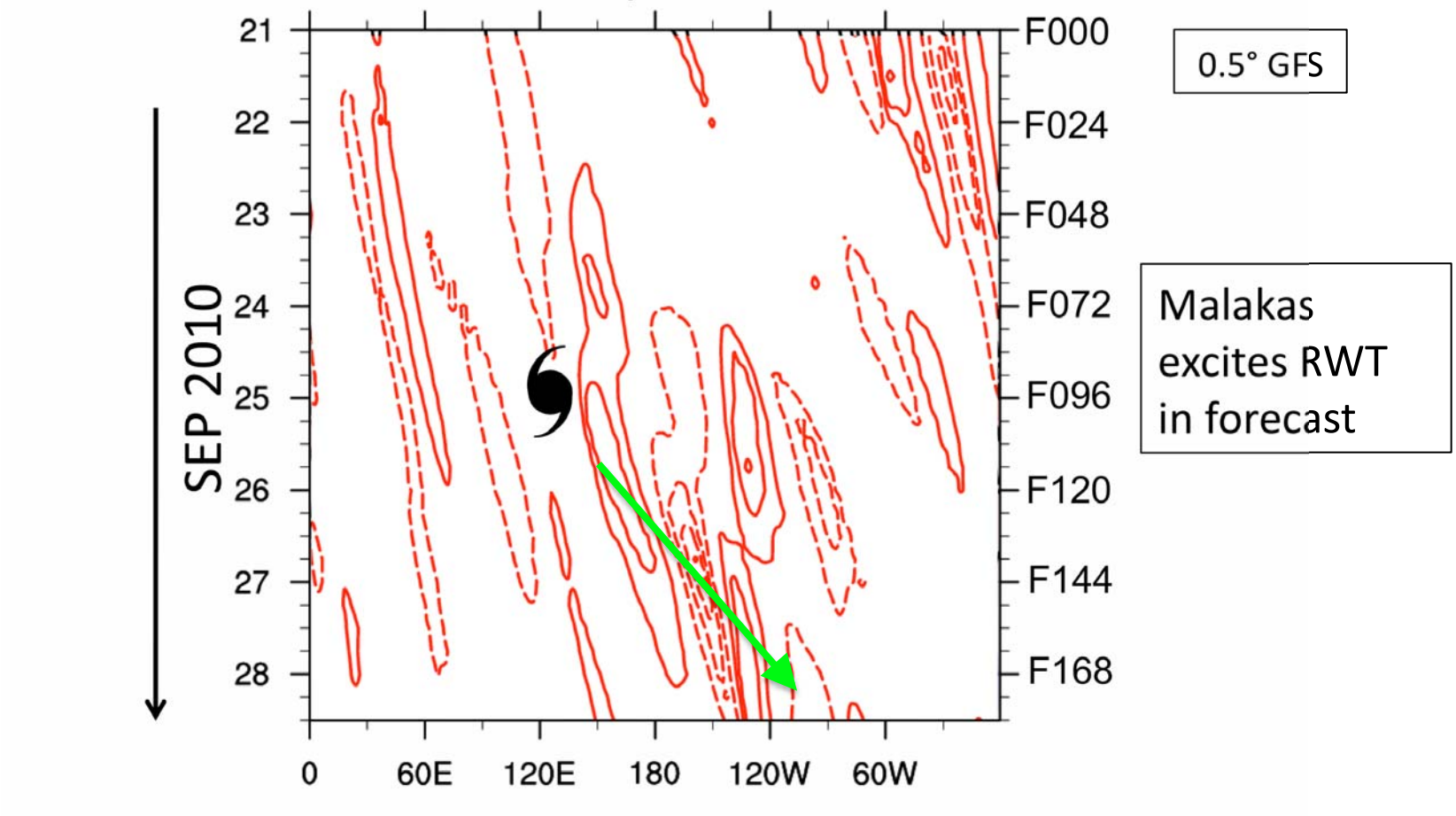
Predictability During Malakas Recurvature



40°–60°N averaged 250-hPa vwnd analysis [contoured every 15 m s^{-1}, pos. (neg.) values solid (dashed), zero line omitted] and error (shaded in m s^{-1})

Predictability During Malakas Recurvature

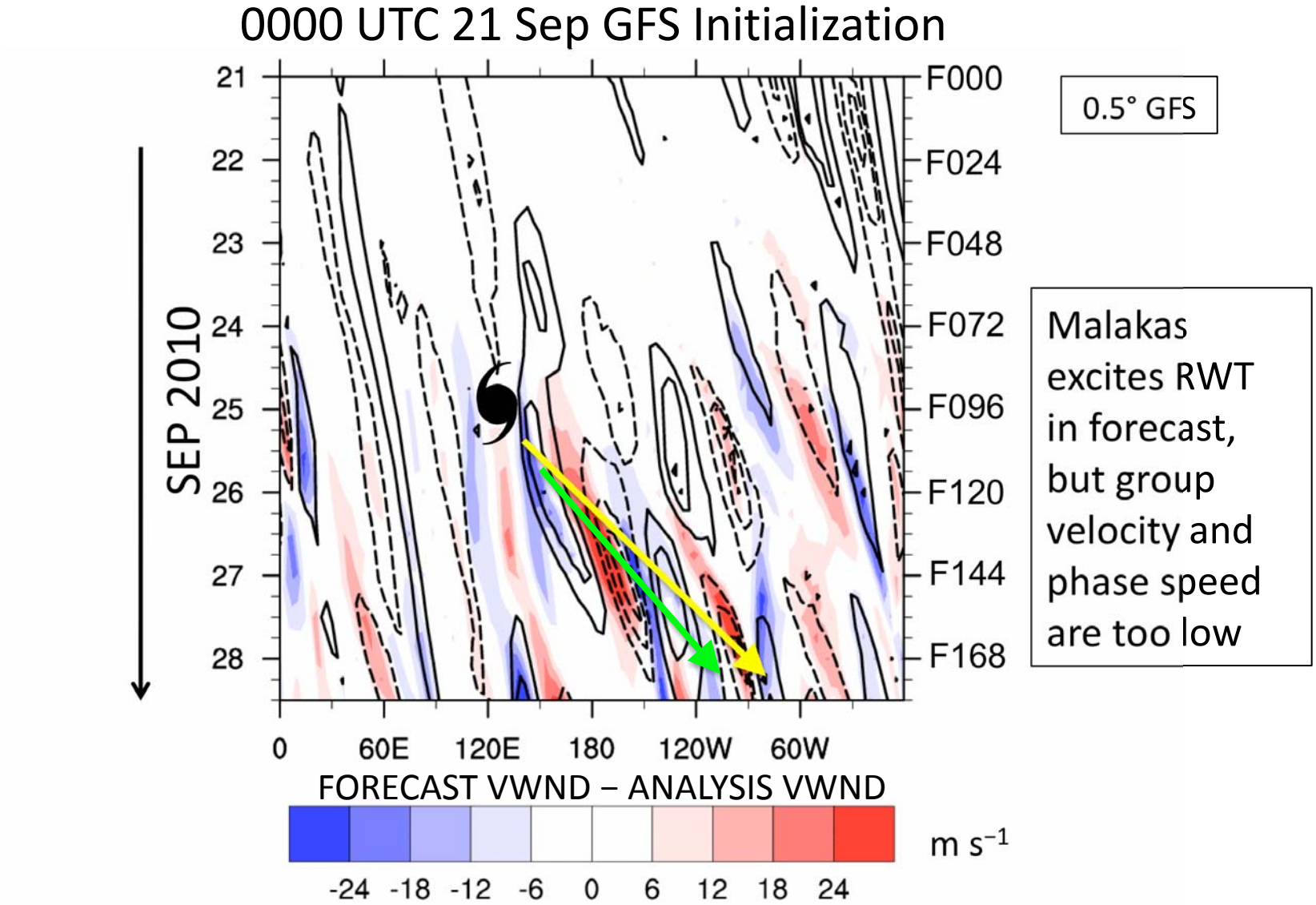
0000 UTC 21 Sep GFS Initialization



40°–60°N averaged 250-hPa meridional wind forecast

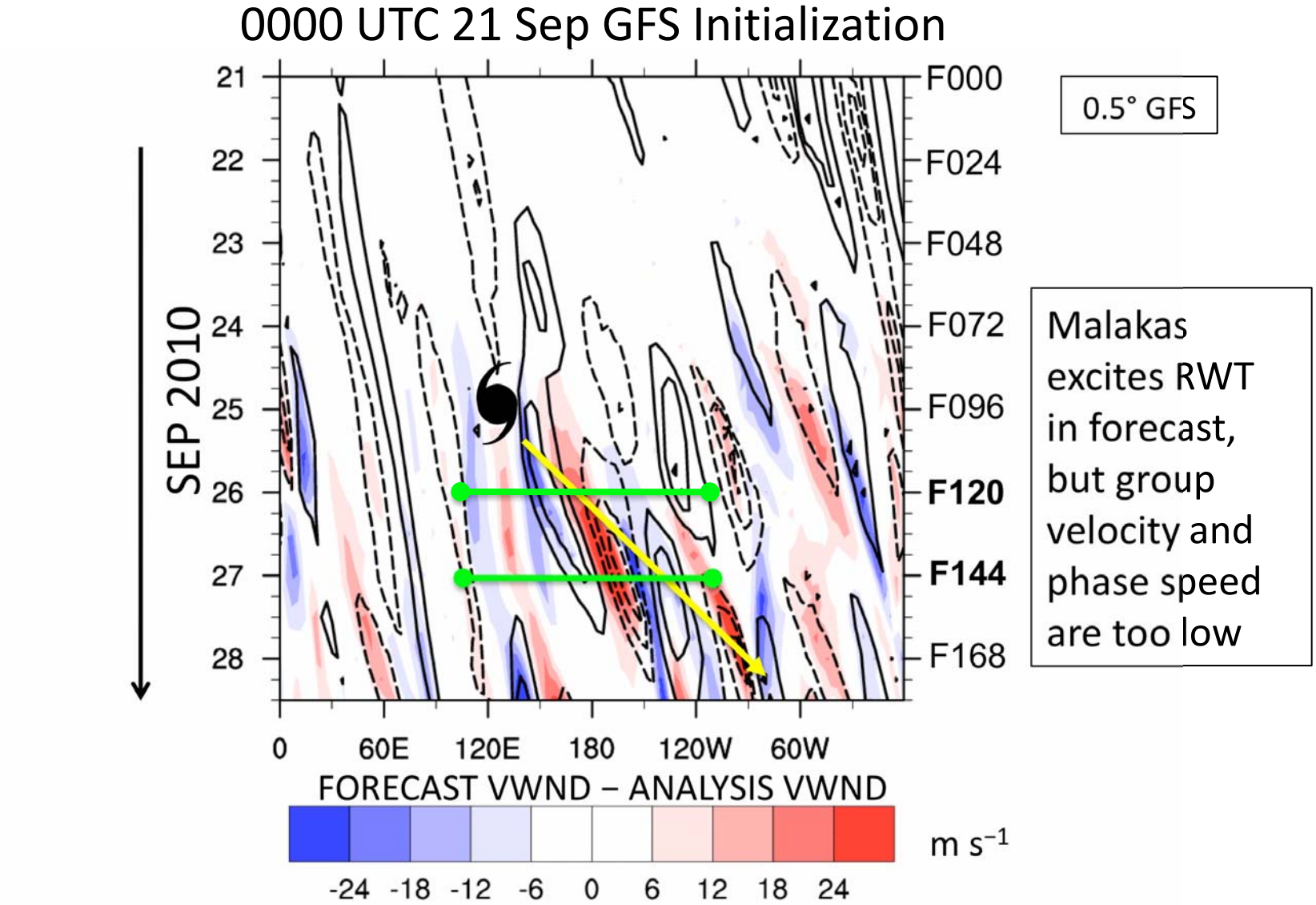
[contoured every 15 m s^{-1}, positive (negative) values solid (dashed); zero line omitted]

Predictability During Malakas Recurvature



40°–60°N averaged 250-hPa vwnd analysis [contoured every 15 m s^{-1}, pos. (neg.) values solid (dashed), zero line omitted] and error (shaded in m s^{-1})

Predictability During Malakas Recurvature

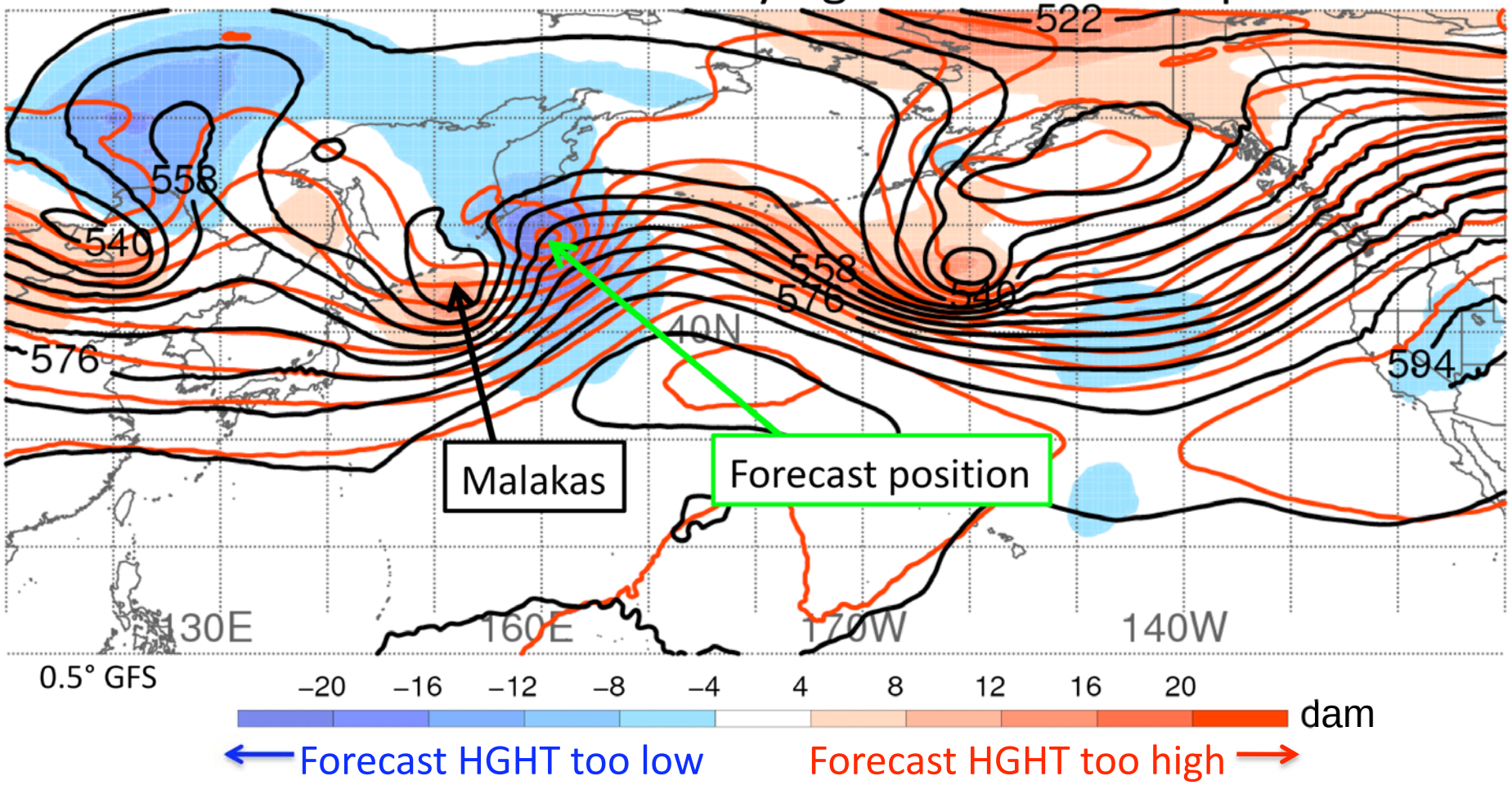


40°–60°N averaged 250-hPa vwnd analysis [contoured every 15 m s^{-1}, pos. (neg.) values solid (dashed), zero line omitted] and error (shaded in m s^{-1})

Predictability During Malakas Recurvature

0000 UTC 21 Sep GFS Initialization

120-h Forecast Verifying 0000 UTC 26 Sep

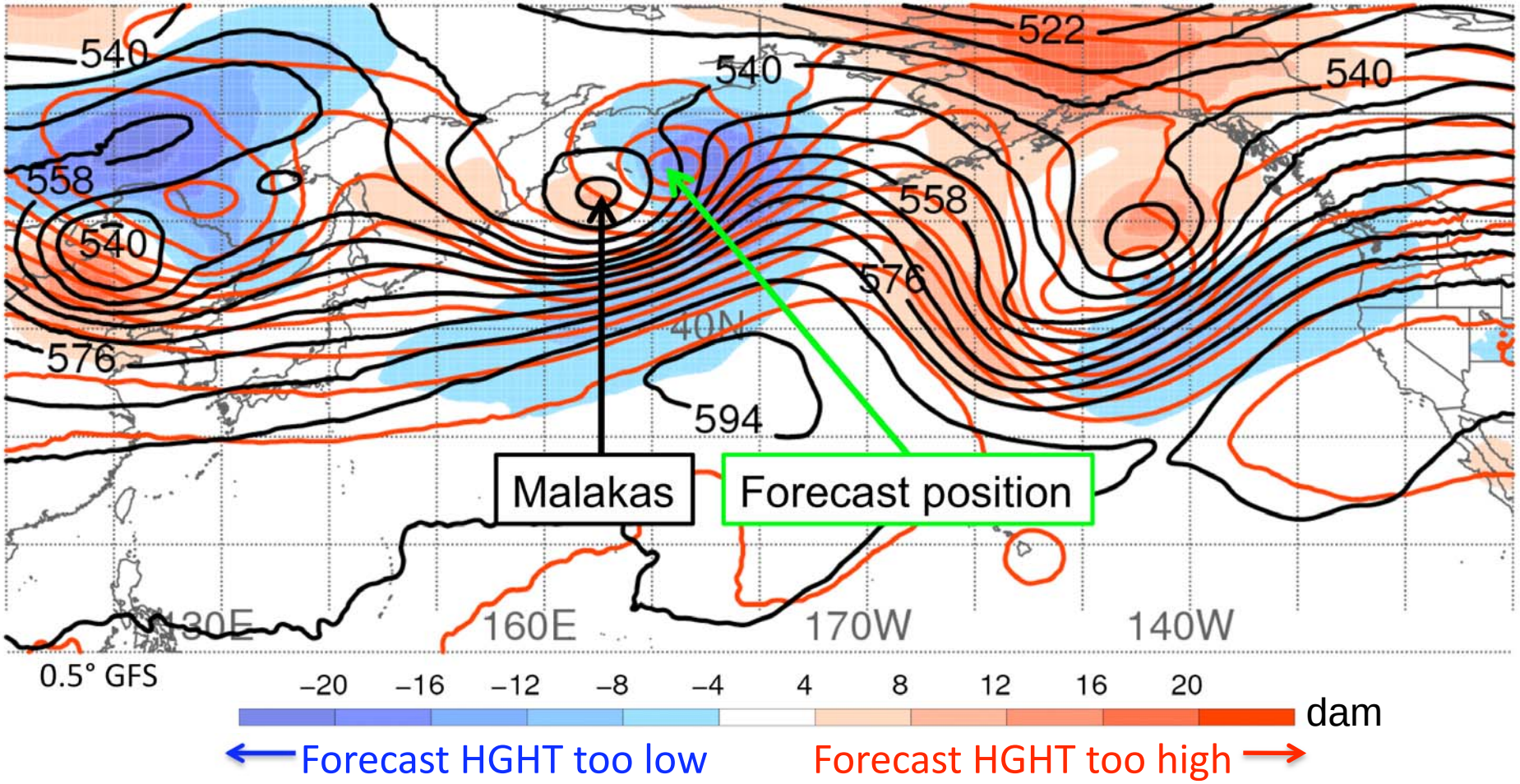


500-hPa geopotential height analysis (black, dam), forecast (red, dam), and forecast error (shaded, dam)

Predictability During Malakas Recurvature

0000 UTC 21 Sep GFS Initialization

144-h Forecast Verifying 0000 UTC 27 Sep



500-hPa geopotential height analysis (black, dam), forecast (red, dam), and forecast error (shaded, dam)

CONCLUSIONS

- Recurving TCs can serve as precursors to DD and associated high-impact weather via different types of TC–jet stream interactions:

  Malakas: Diabatic outflow poleward of TC core directly excites a RWT by inducing ridge amplification and jet streak intensification along jet stream

  Chaba: Diabatic outflow poleward and downstream of TC core strengthens and elongates jet stream, preconditioning environment for RWT excitation

- Forecast errors associated with Malakas-induced RWT lead to poor forecasts of large-scale flow pattern over North Pacific and North America