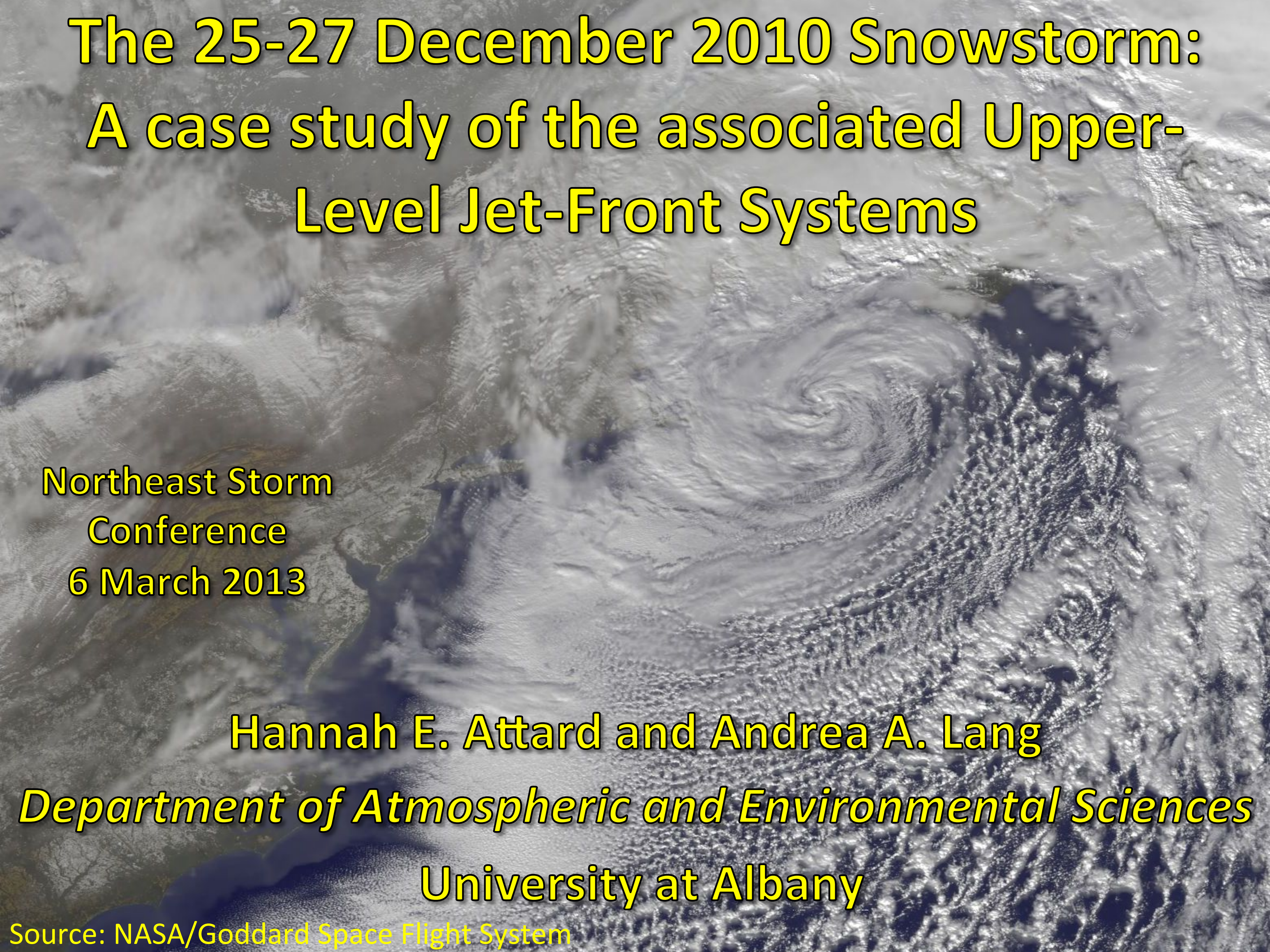


The 25-27 December 2010 Snowstorm: A case study of the associated Upper-Level Jet-Front Systems

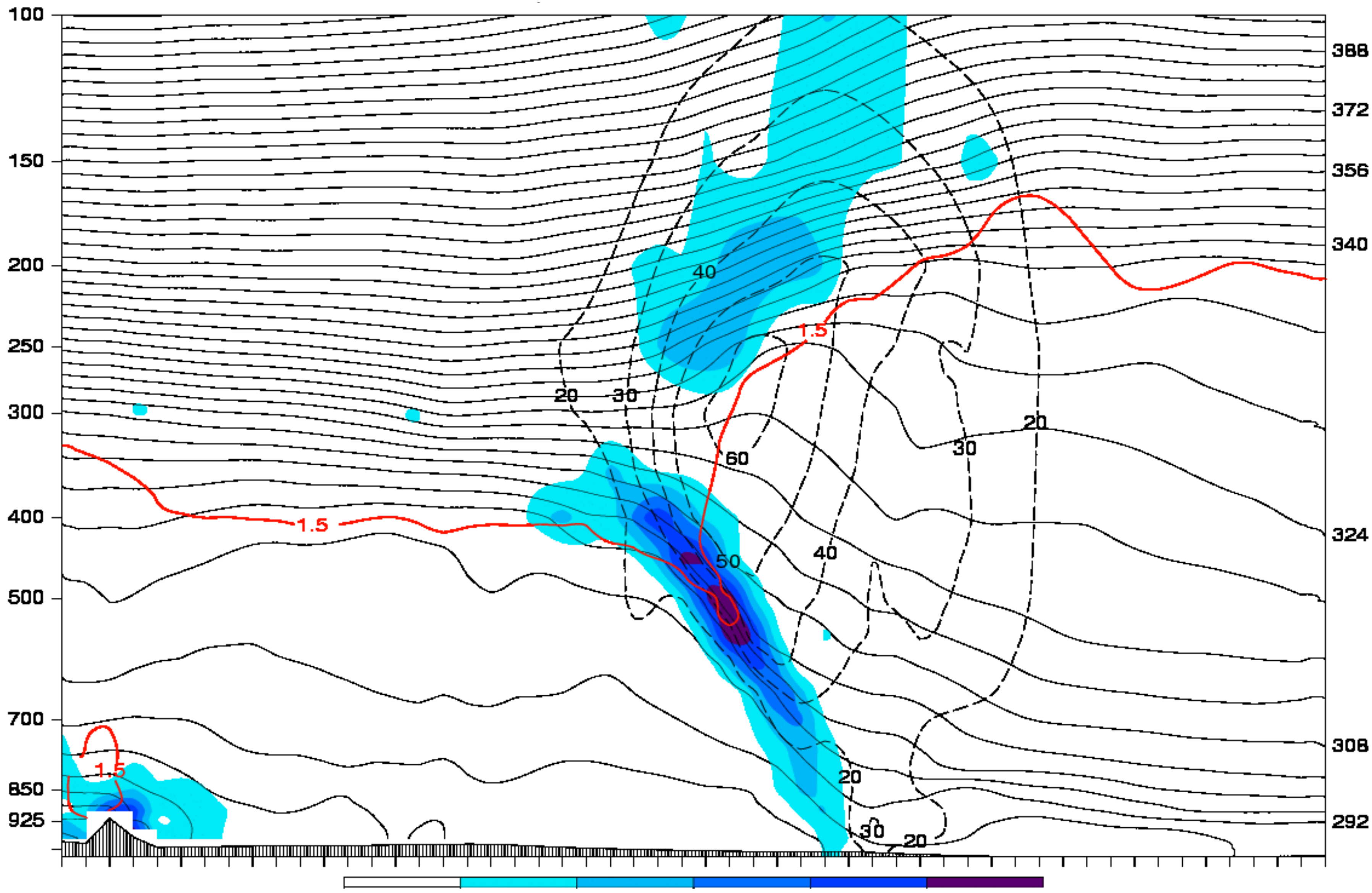
Northeast Storm Conference
6 March 2013

Hannah E. Attard and Andrea A. Lang
Department of Atmospheric and Environmental Sciences
University at Albany

Source: NASA/Goddard Space Flight System

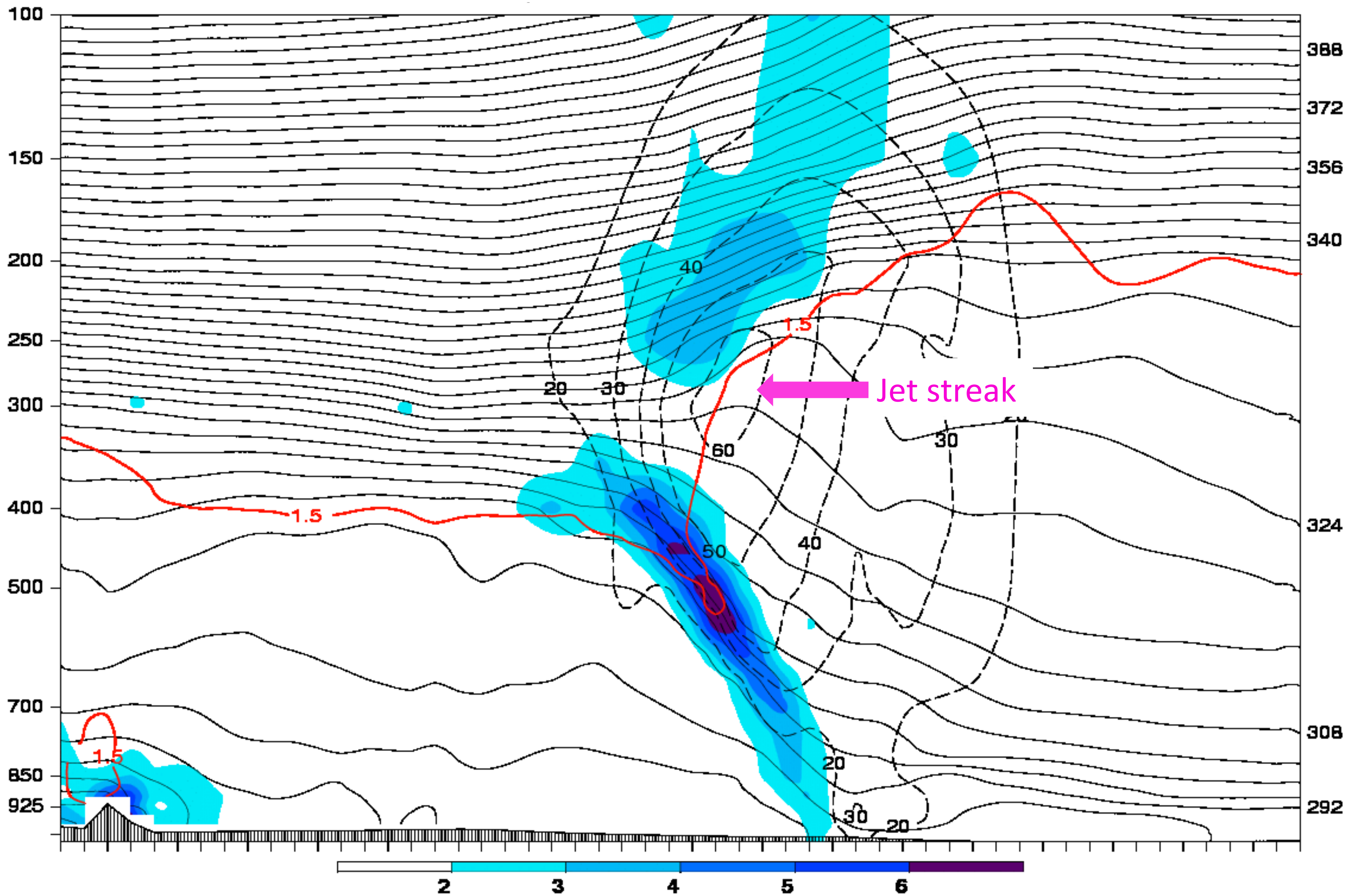
Overview of ULJF Systems

Upper-Level Jet-Front System



Theta contours solid lines; wind speed (m/s) dashed lines; magnitude of theta gradient (K/100km) shaded

Upper-Level Jet-Front System



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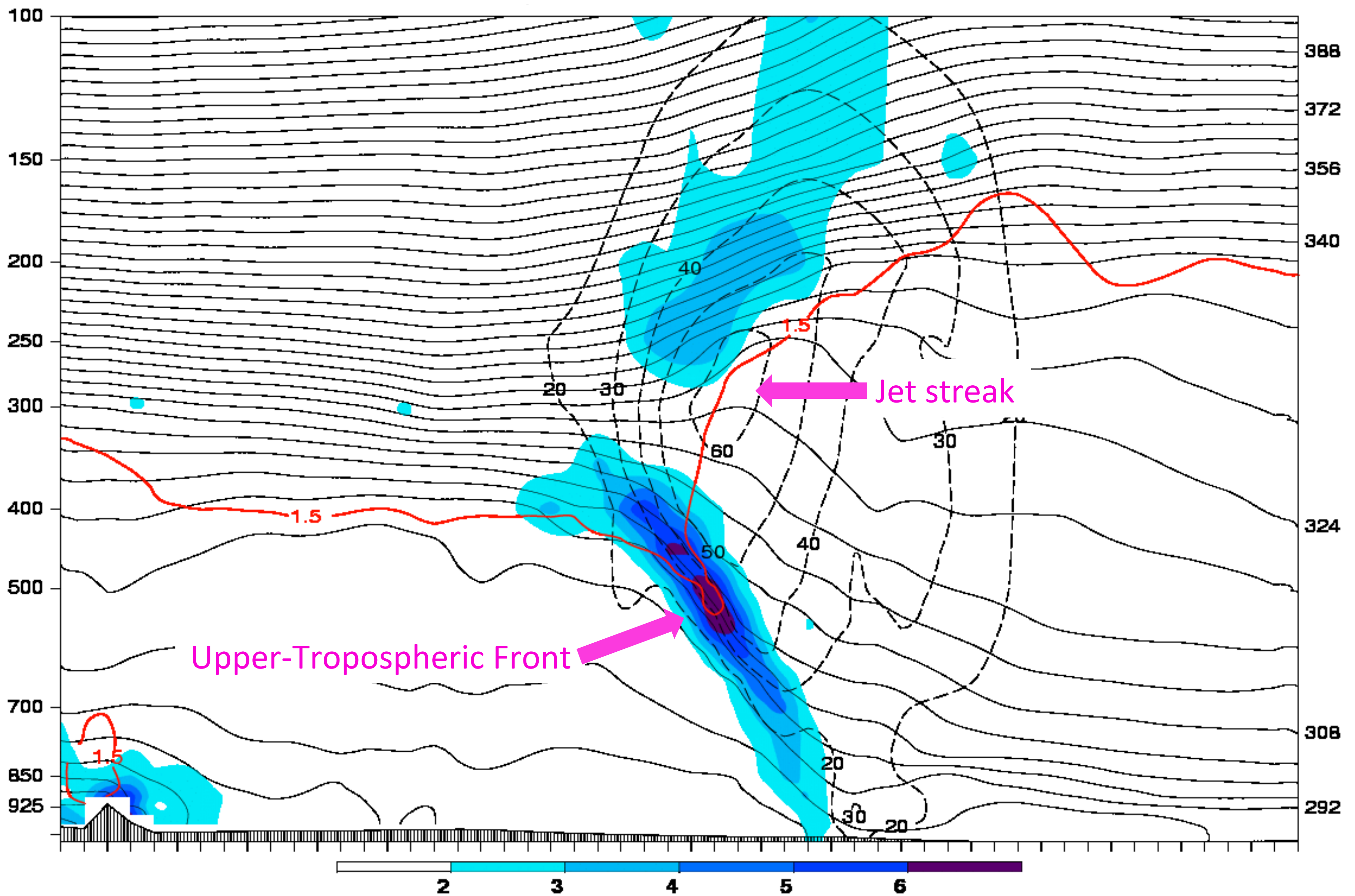

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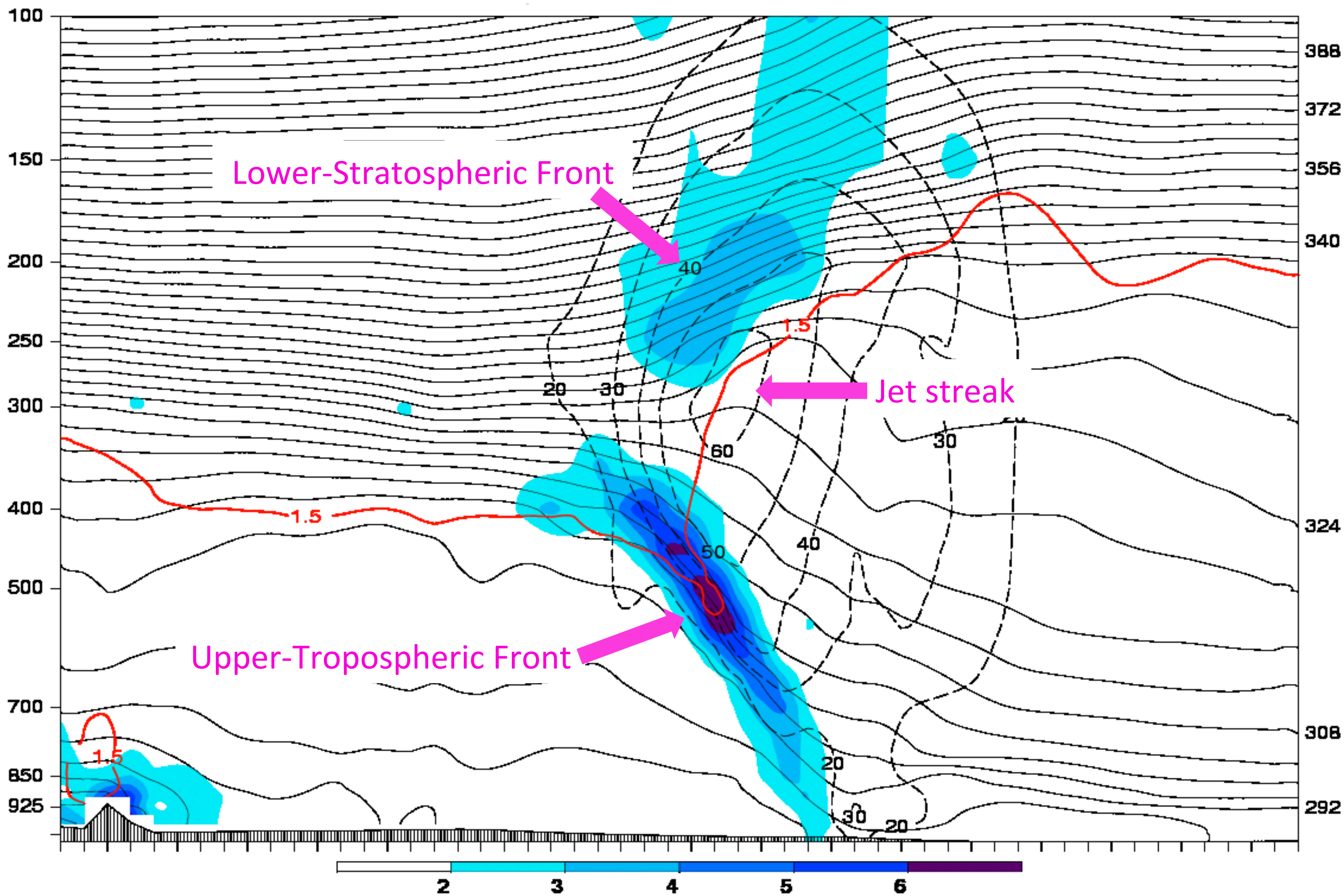

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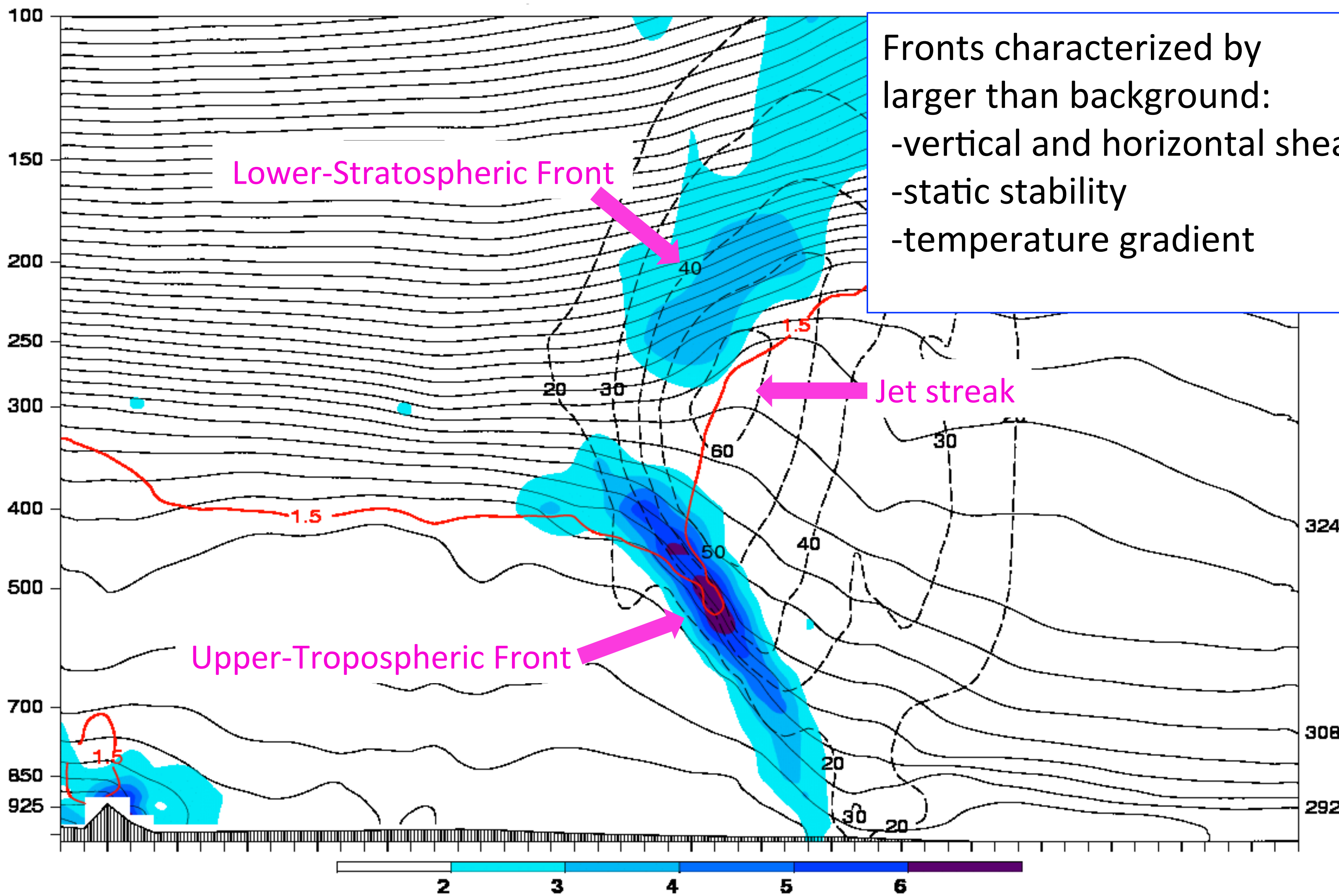
Upper-Level Jet-Front System



Fronts characterized by larger than background:
- -vertical and horizontal shear
- -static stability
- -temperature gradient

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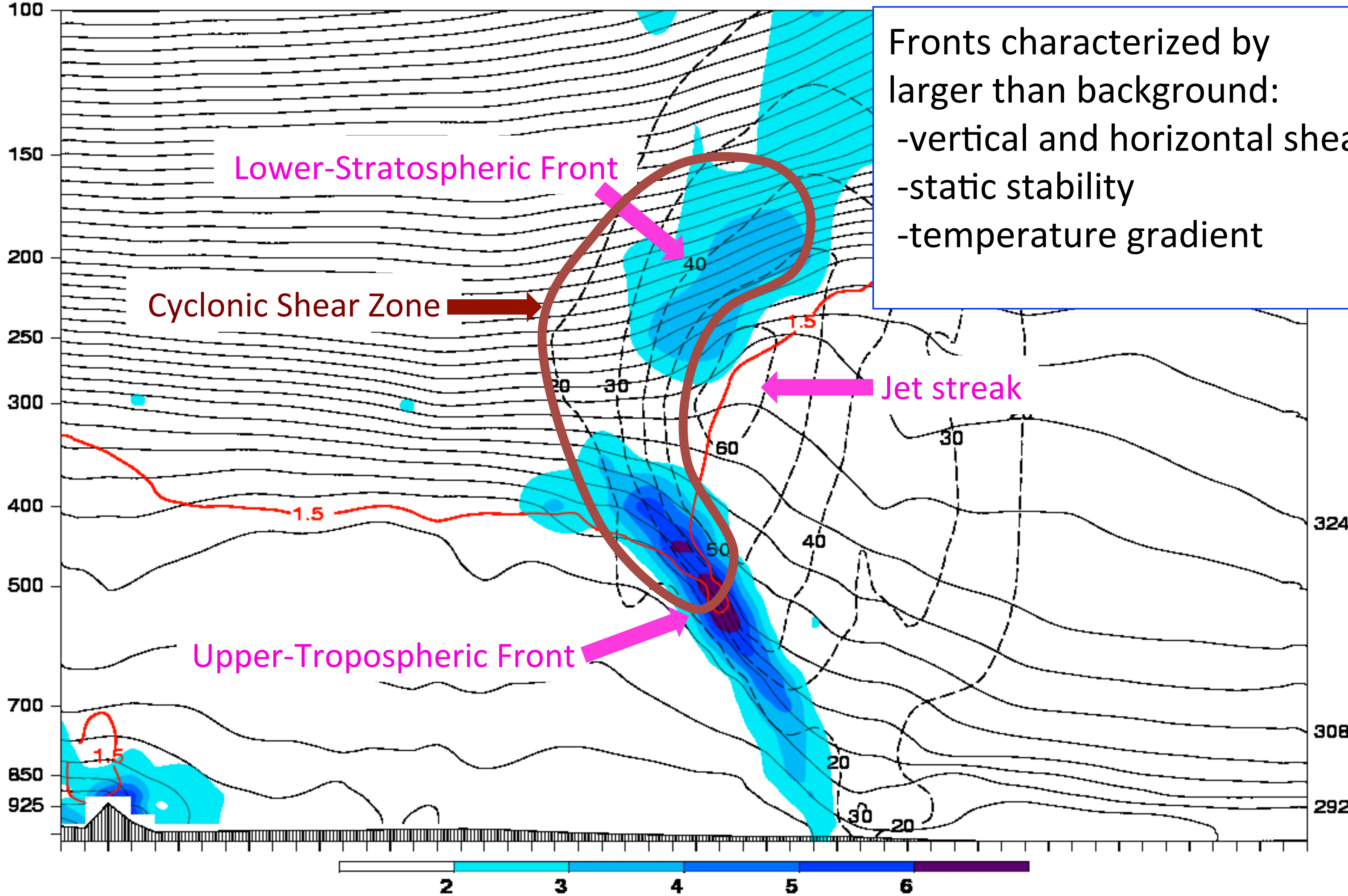
Upper-Level Jet-Front System



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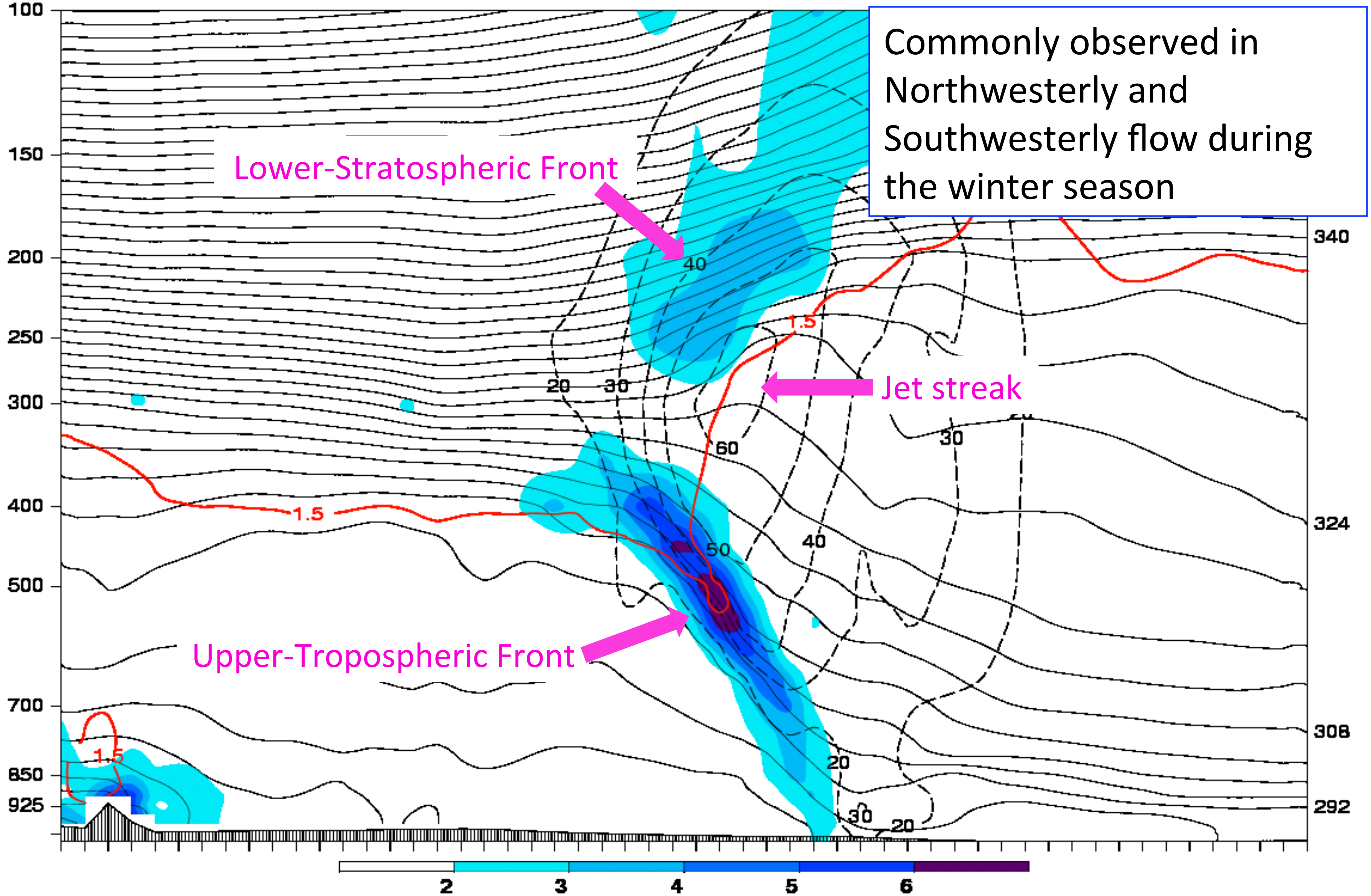

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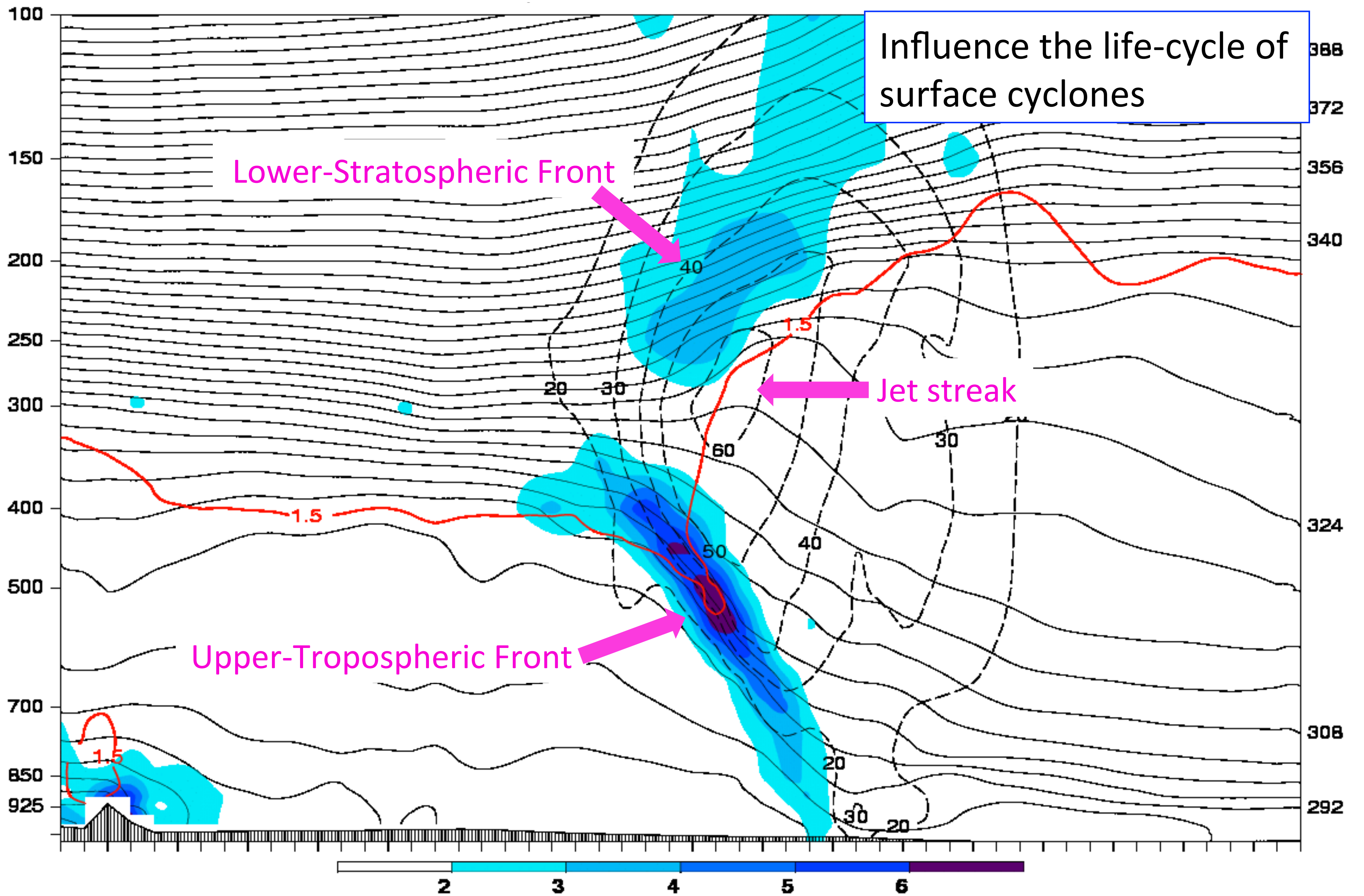
Upper-Level Jet-Front System



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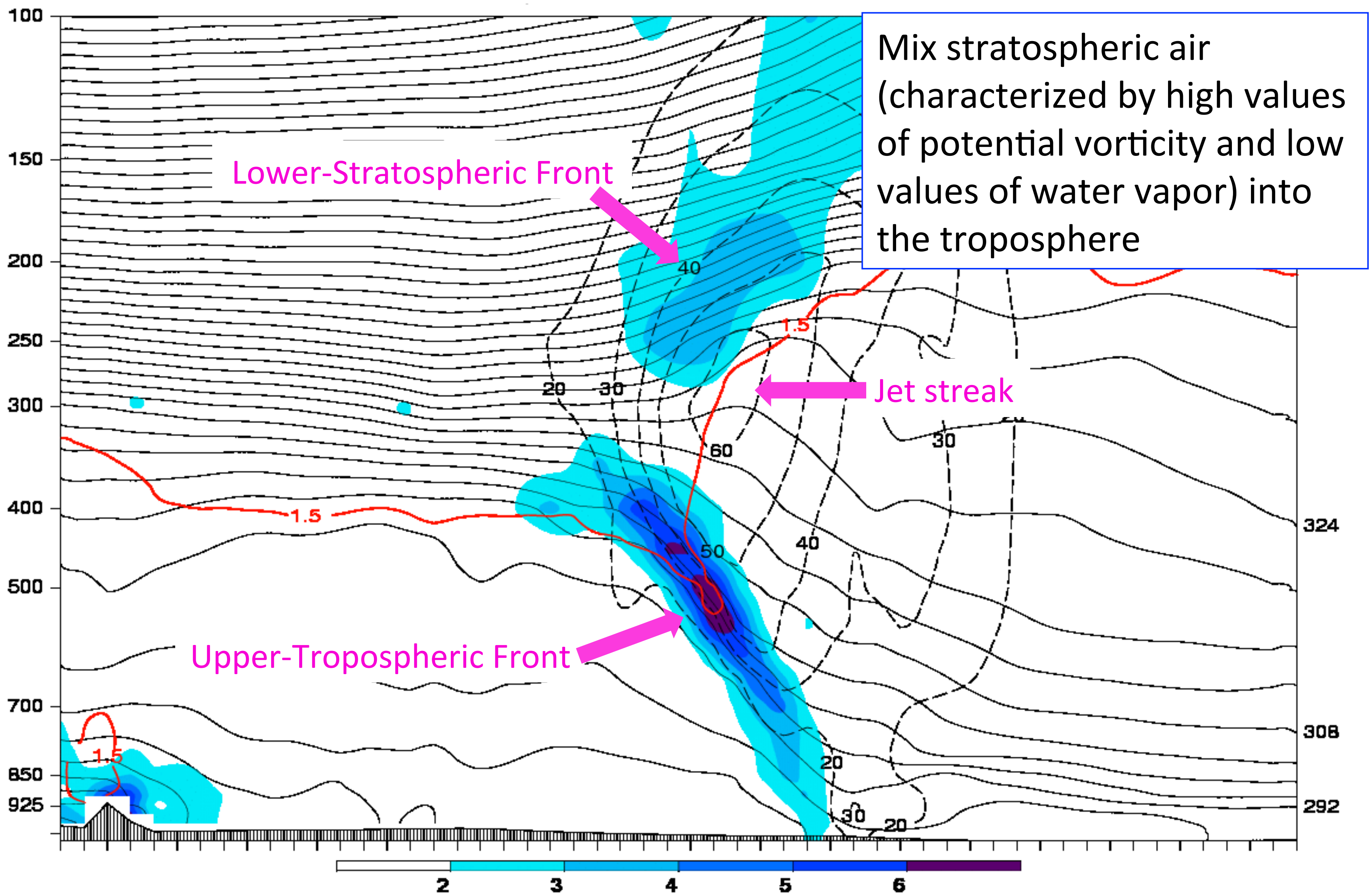
Upper-Level Jet-Front System



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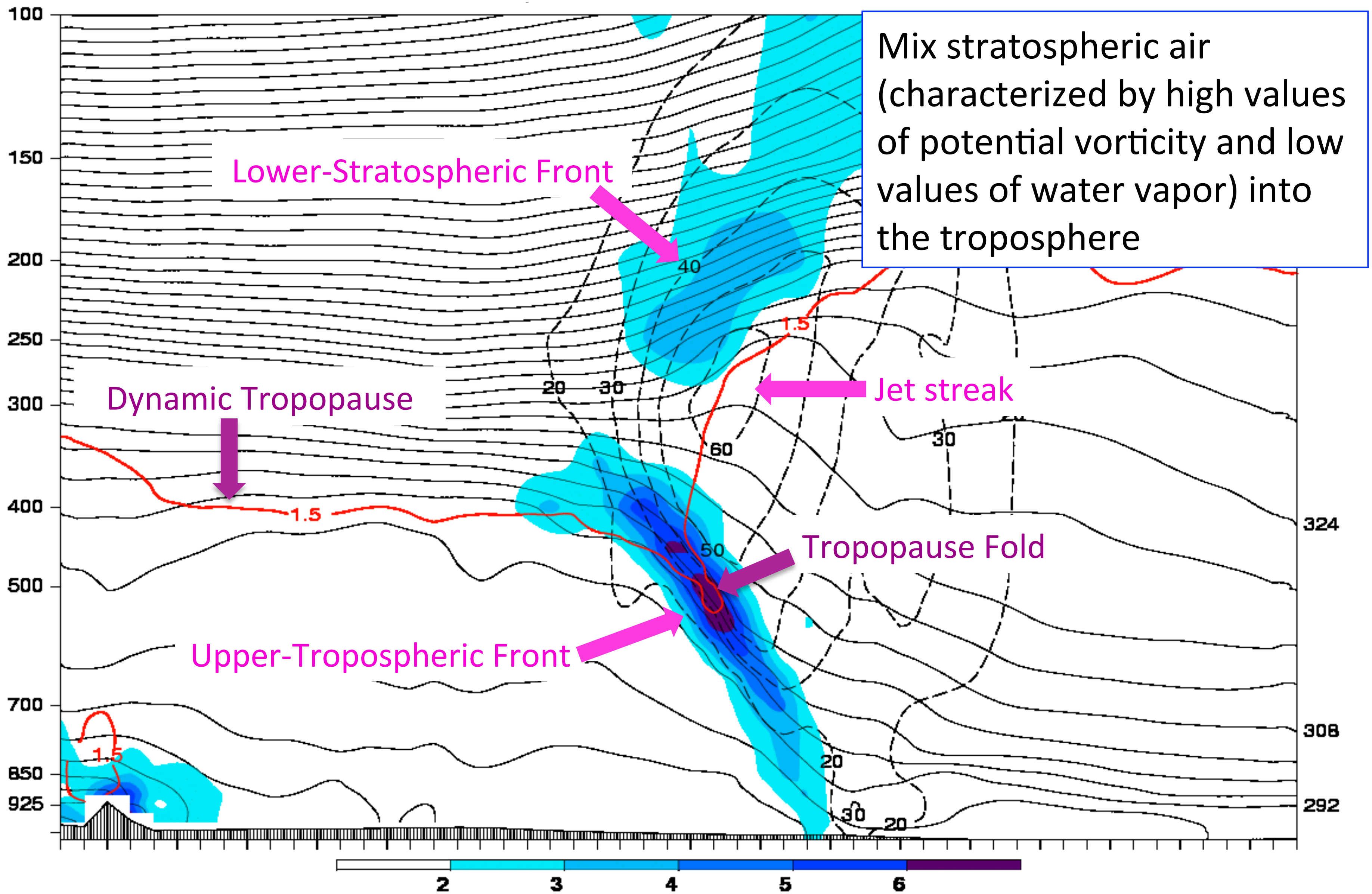
Upper-Level Jet-Front System



Theta contours solid lines; wind speed (m/s) dashed lines; magnitude of theta gradient (K/100km) shaded

25-27 December 2010
East Coast Snowstorm

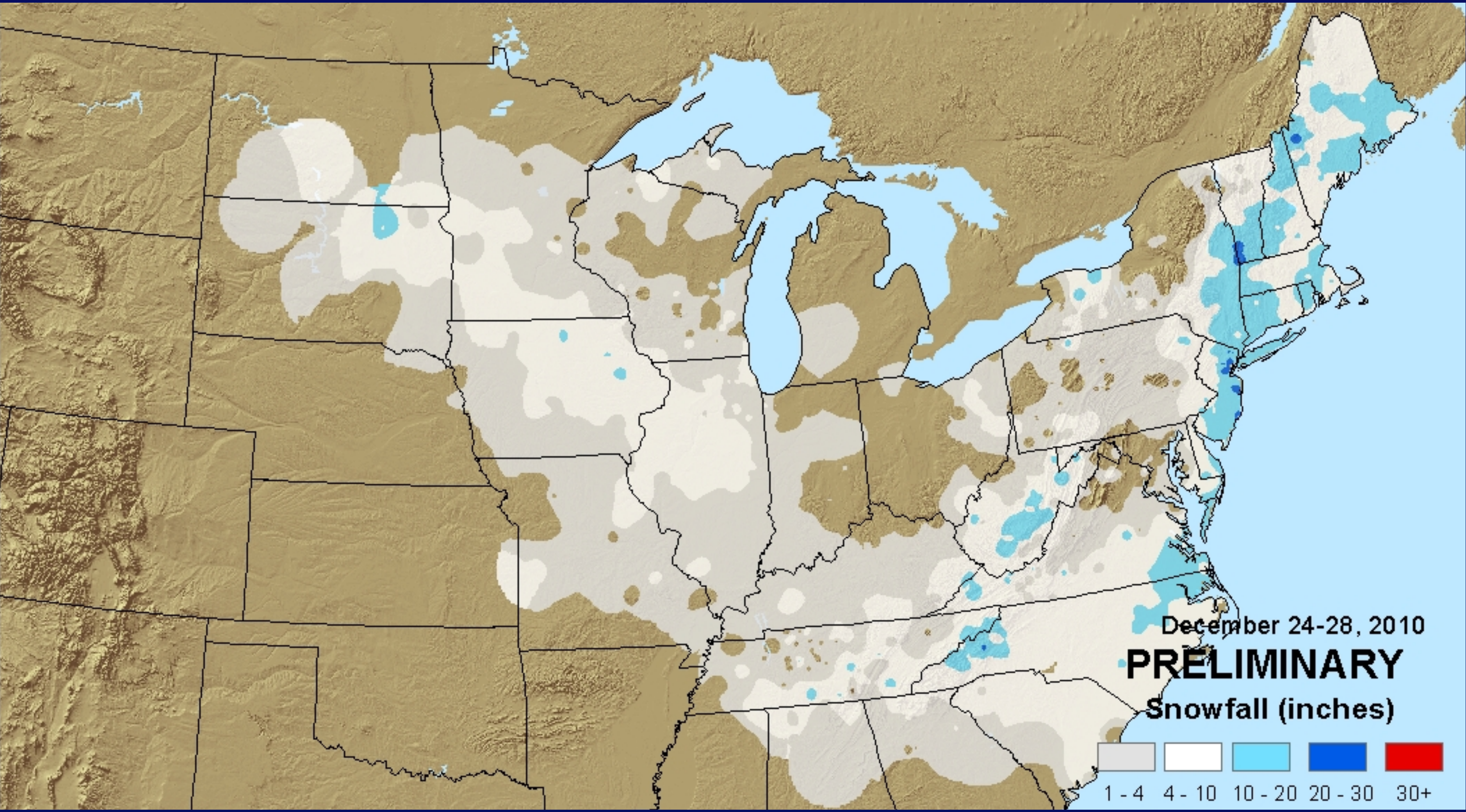
Previous Studies

- Mike Soltow, HPC Meteorologist: *Event Review: December 25-27, 2010 Winter Storm, Eastern United States*
  - Overview of event including: synoptic set up and mesoscale features
- Kocin et al: *The Blizzard of 25-27 December 2010: Forecast Assessment*
  - Assessed predictability issues associated with the storm
- Independent Case Studies

Overview of Storm

- Significant snowfall event for all of the East Coast
  - Blizzard conditions in some locations:
    - Wind speeds of at least 30 kts
    - Visibilities reduced to < ¼ mile due to falling or blowing snow
    - These conditions lasting for at least 3 hours
- The storm occurred during the Christmas Season during peak travel making this a high impact event

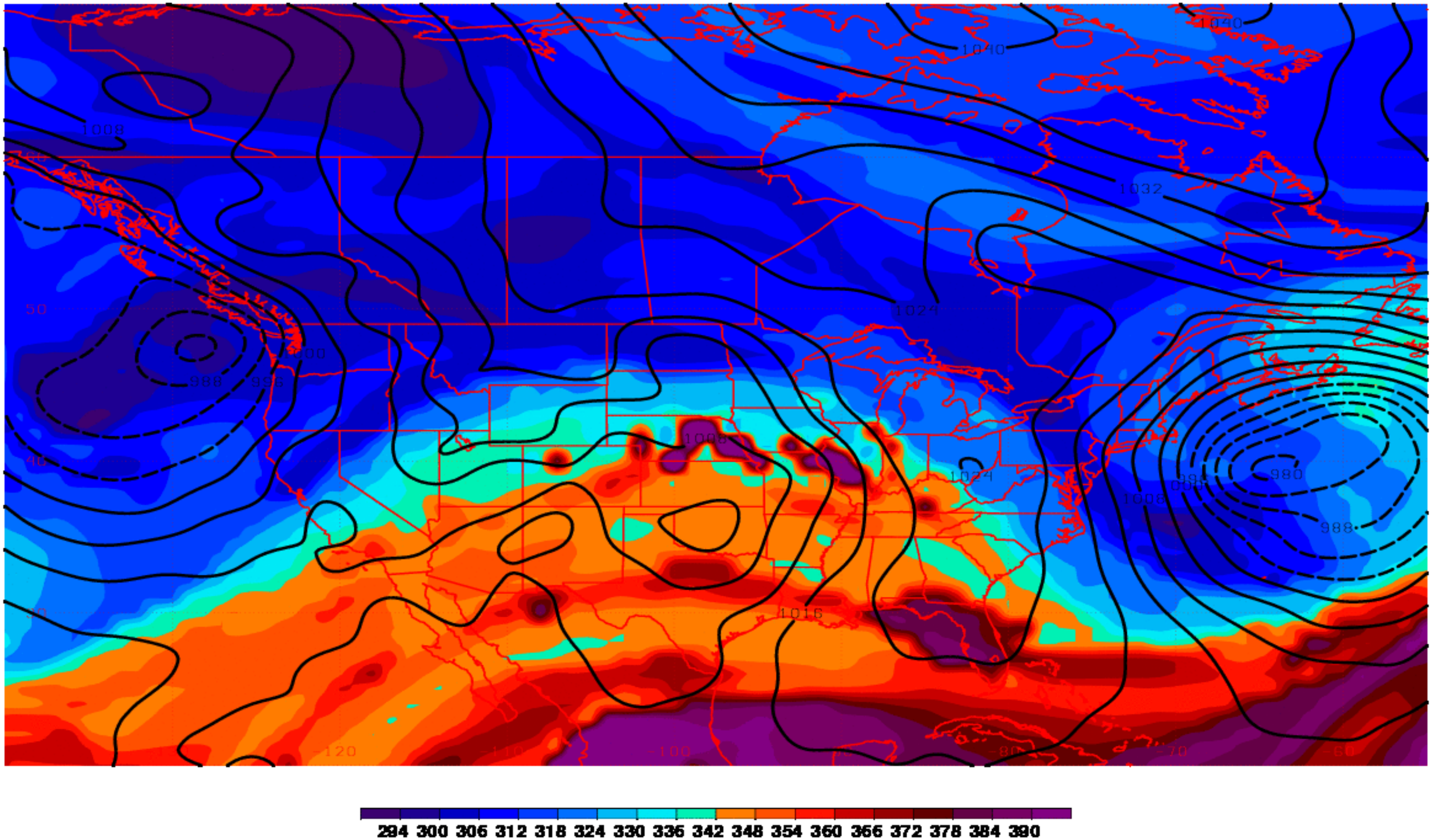
Snowfall Total Map



Source: National Climatic Data Center

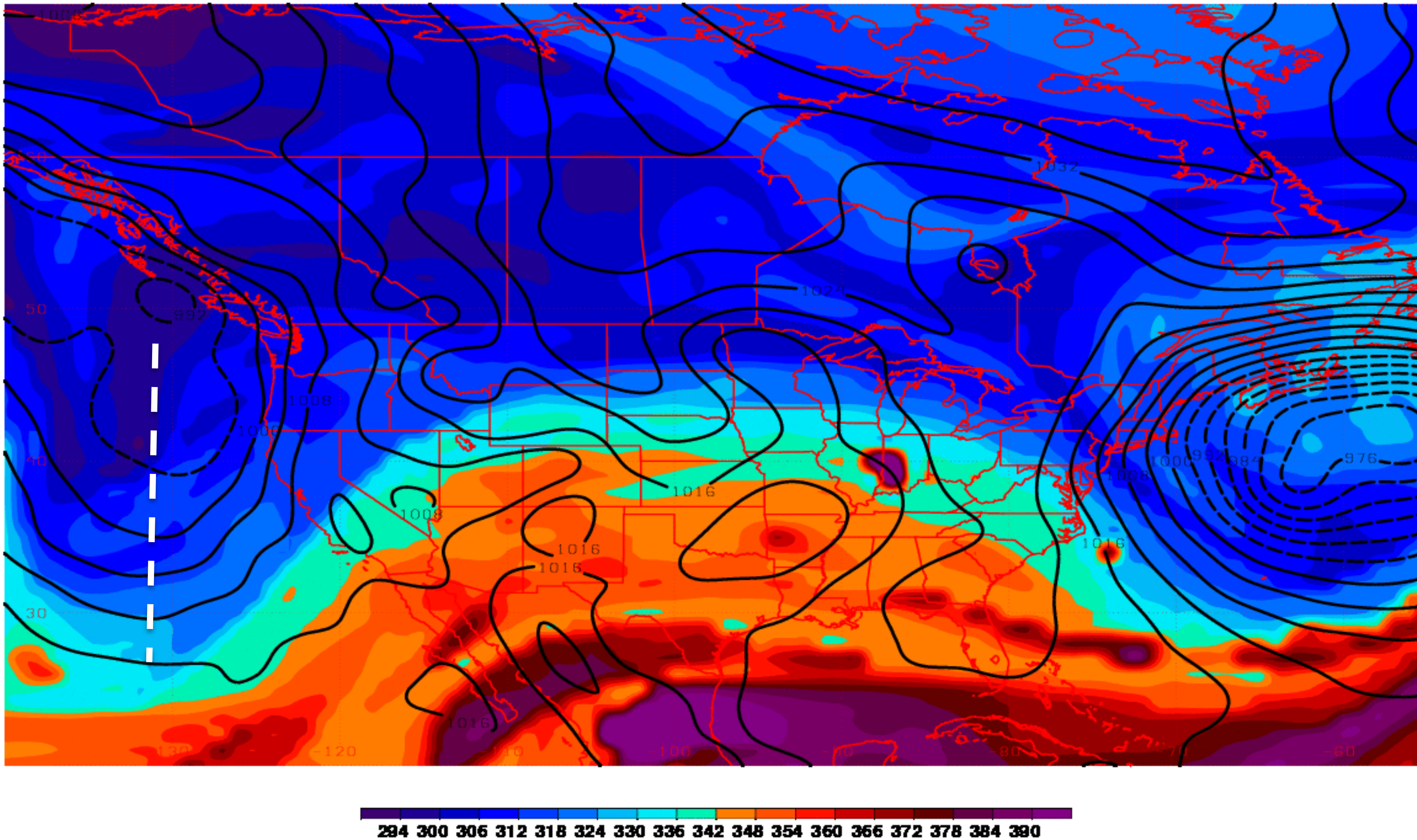
Synoptic Overview

0000 UTC 21 December 2010



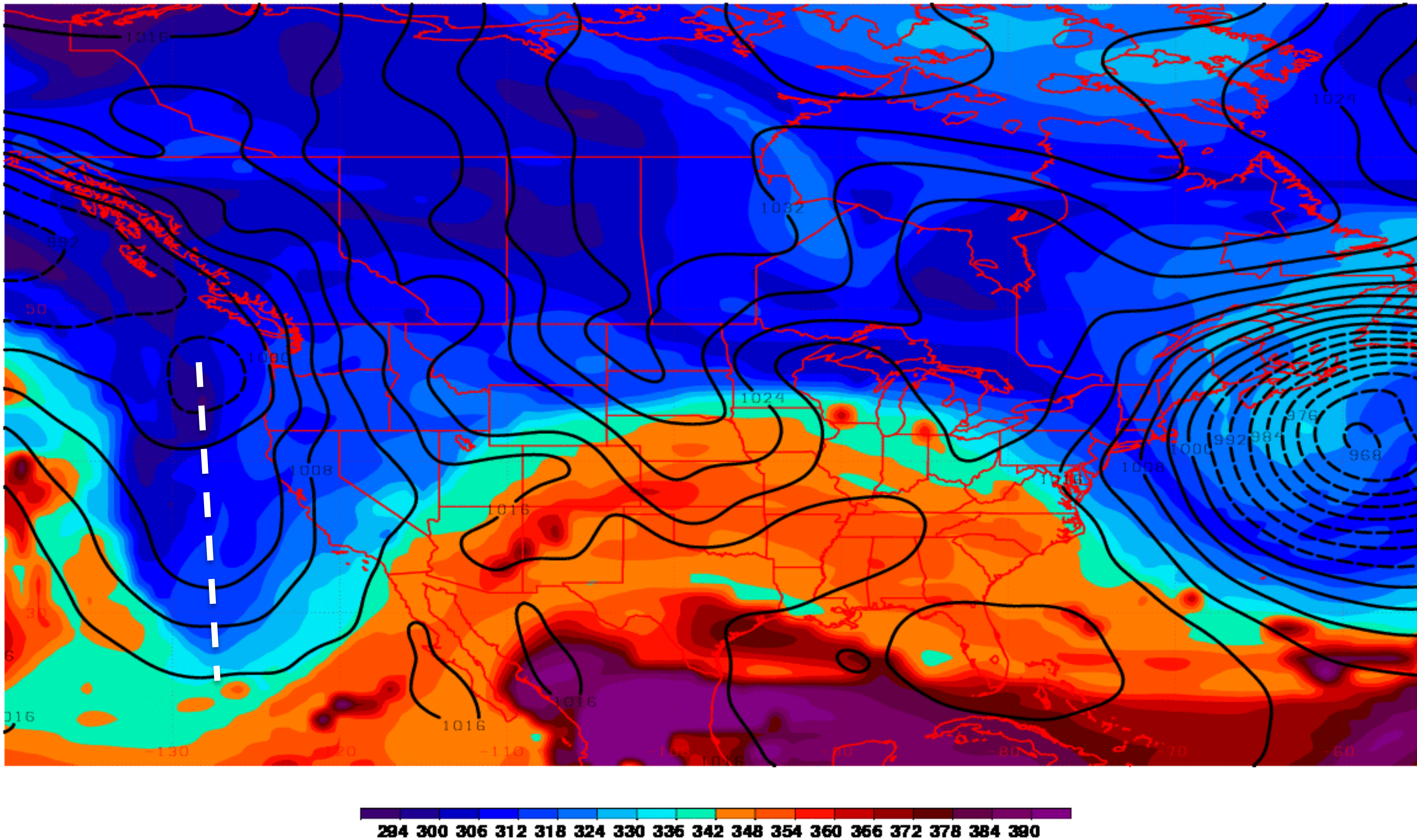
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 21 December 2010



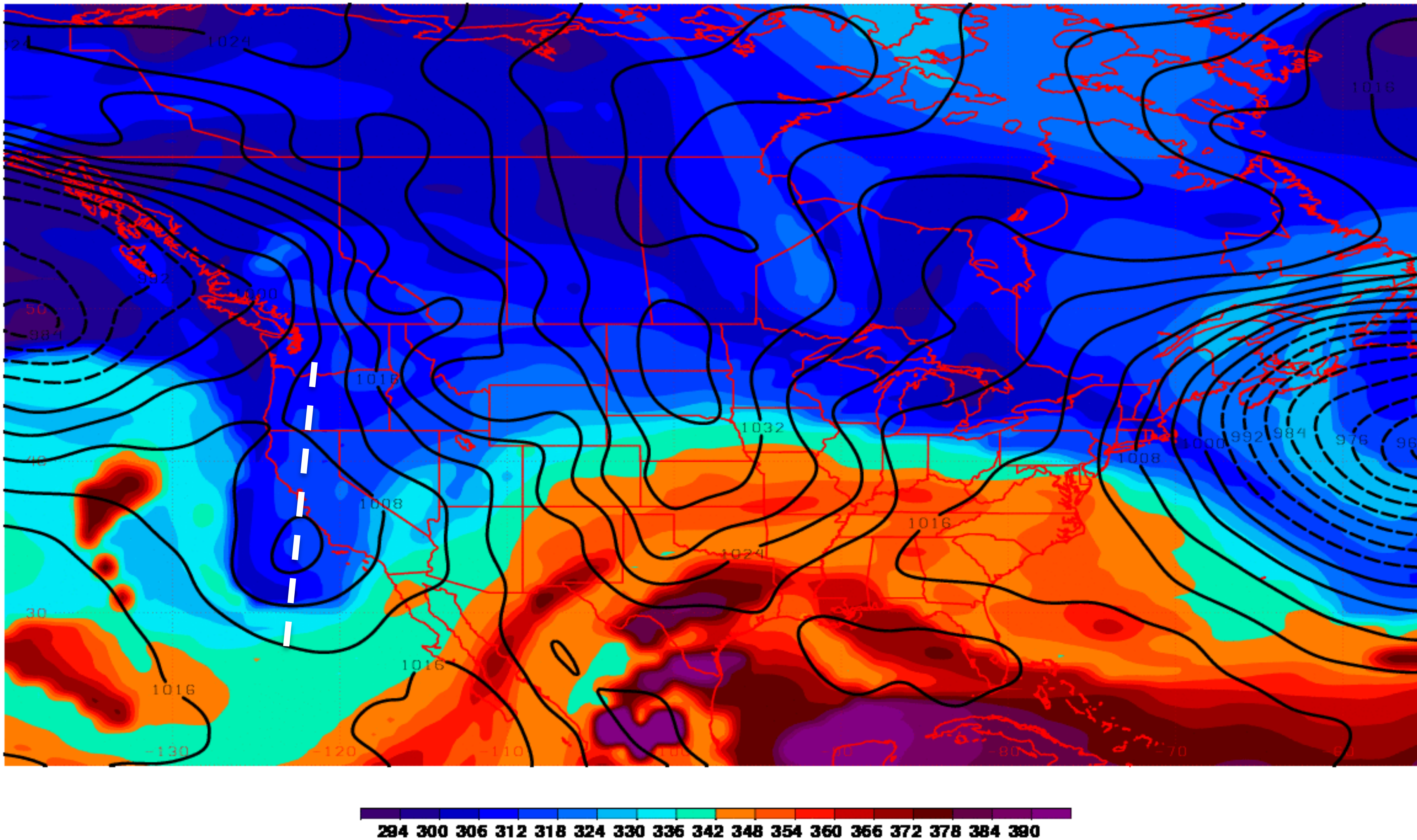
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 22 December 2010



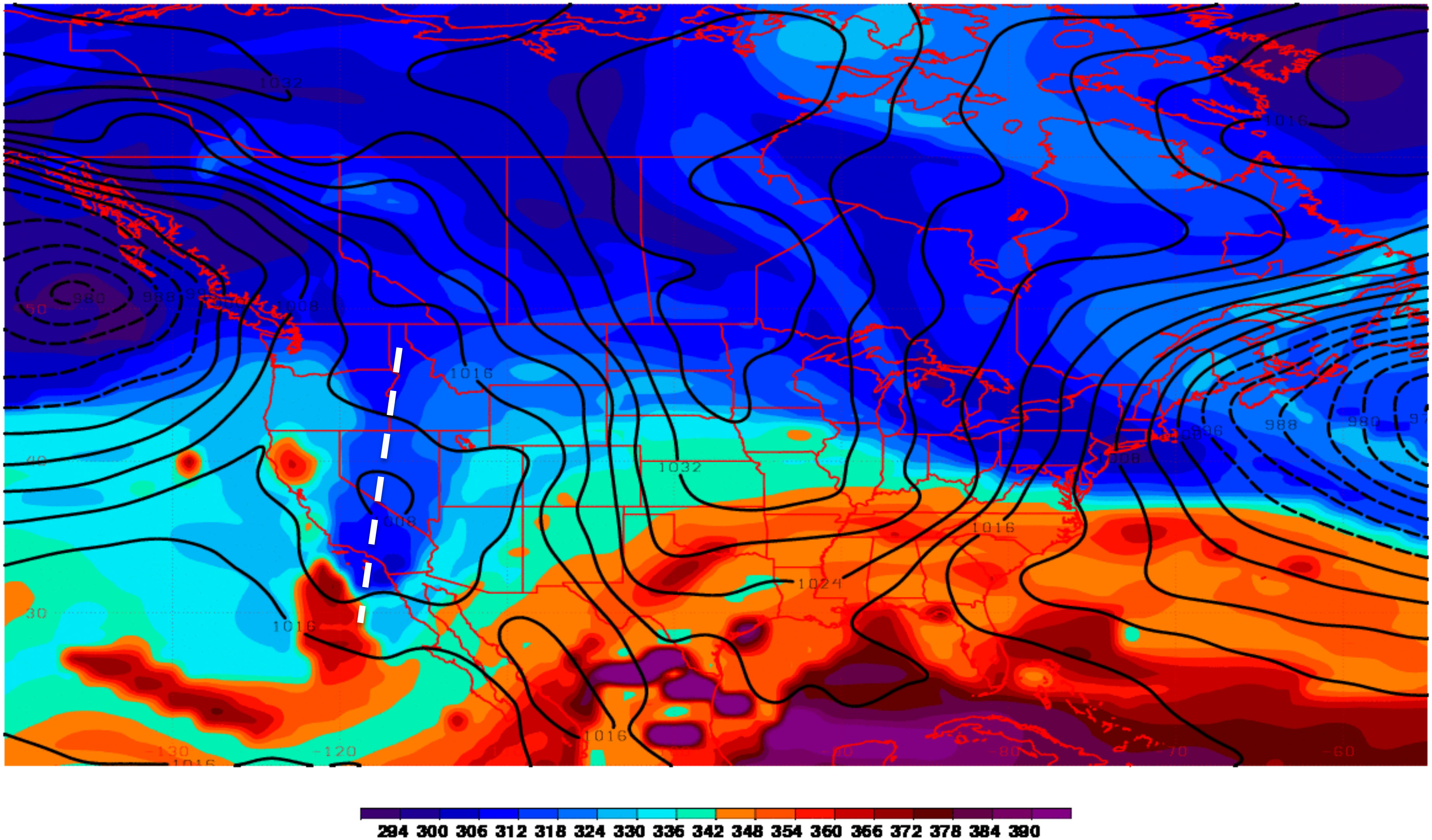
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 22 December 2010



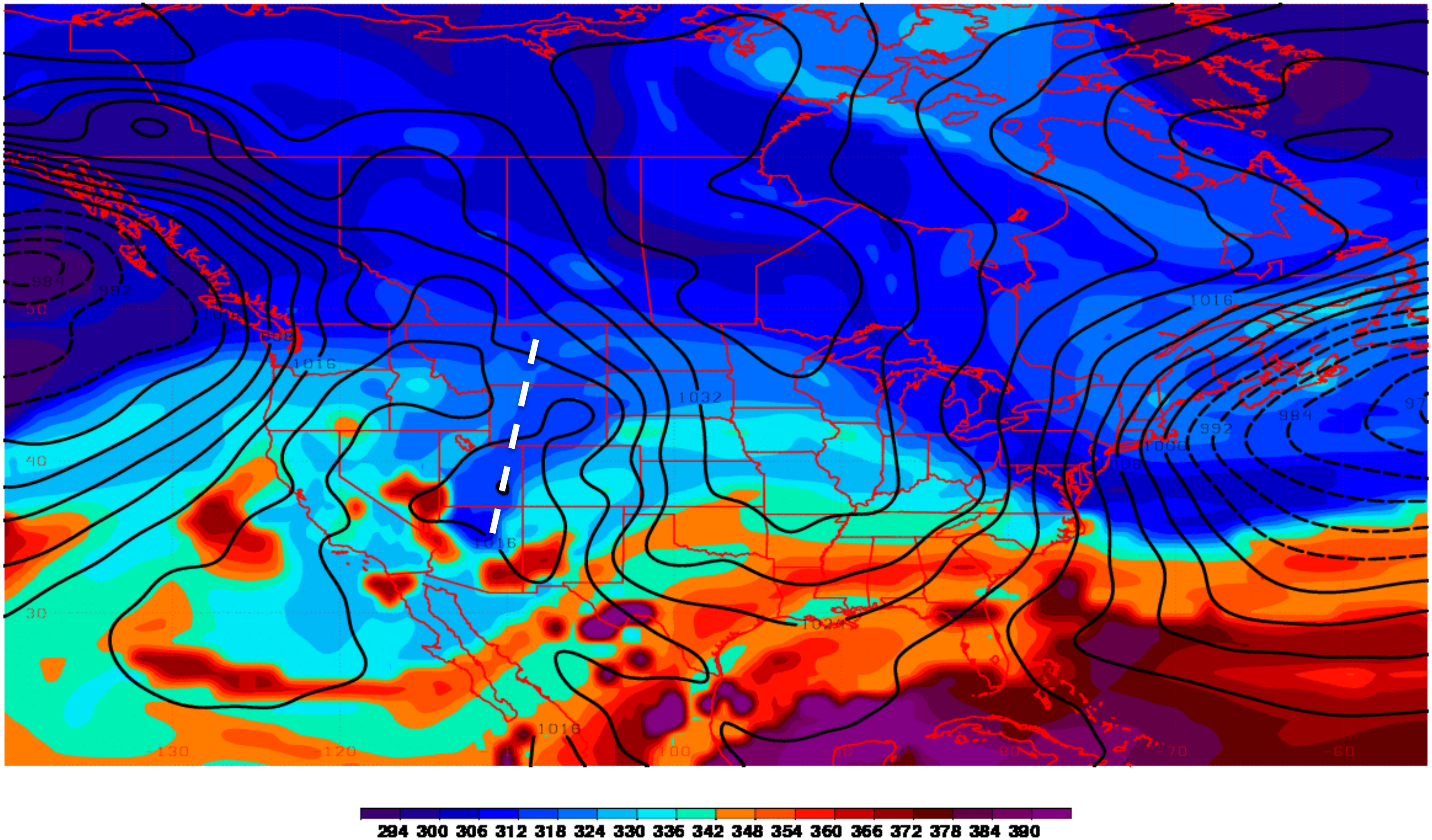
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 23 December 2010



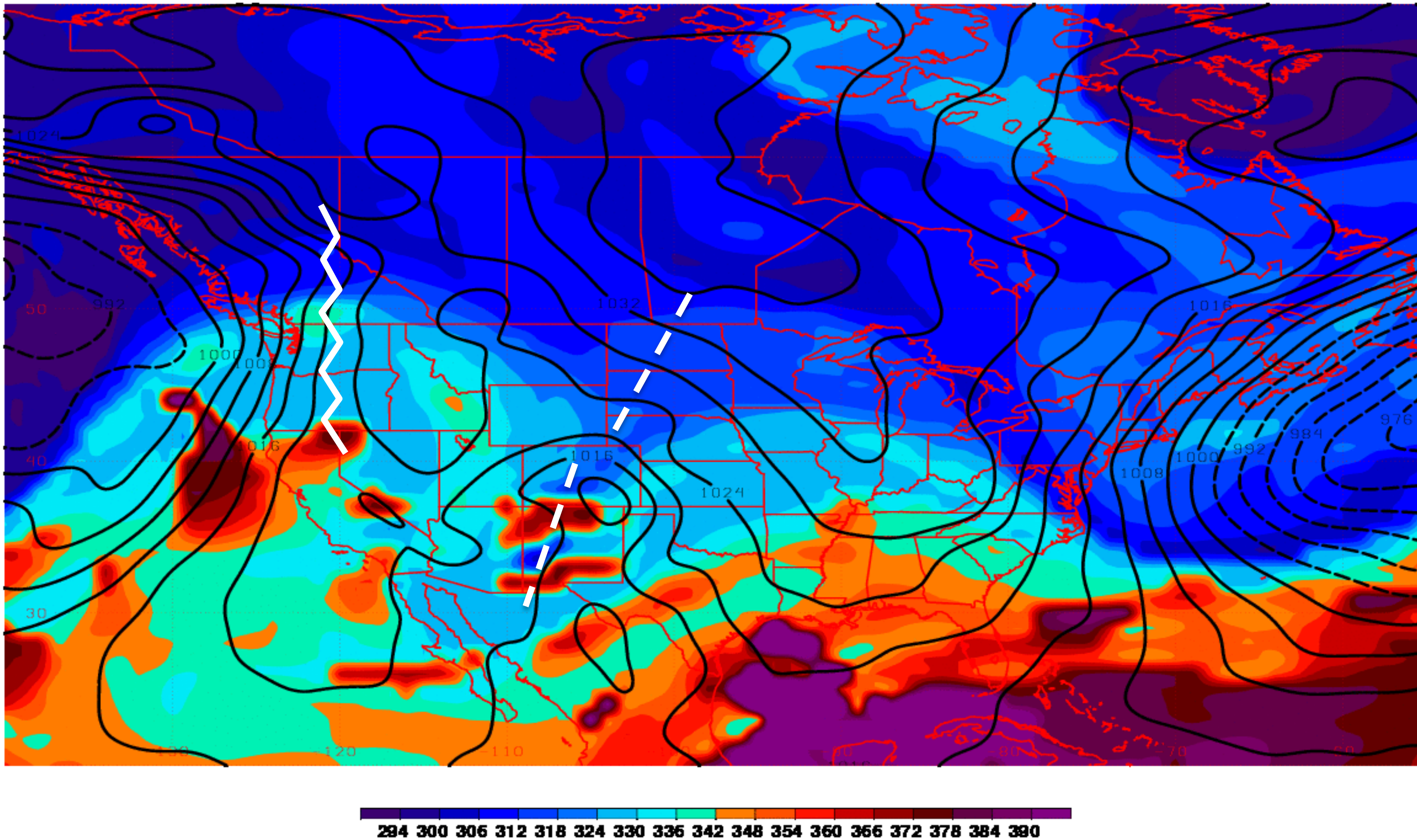
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 23 December 2010



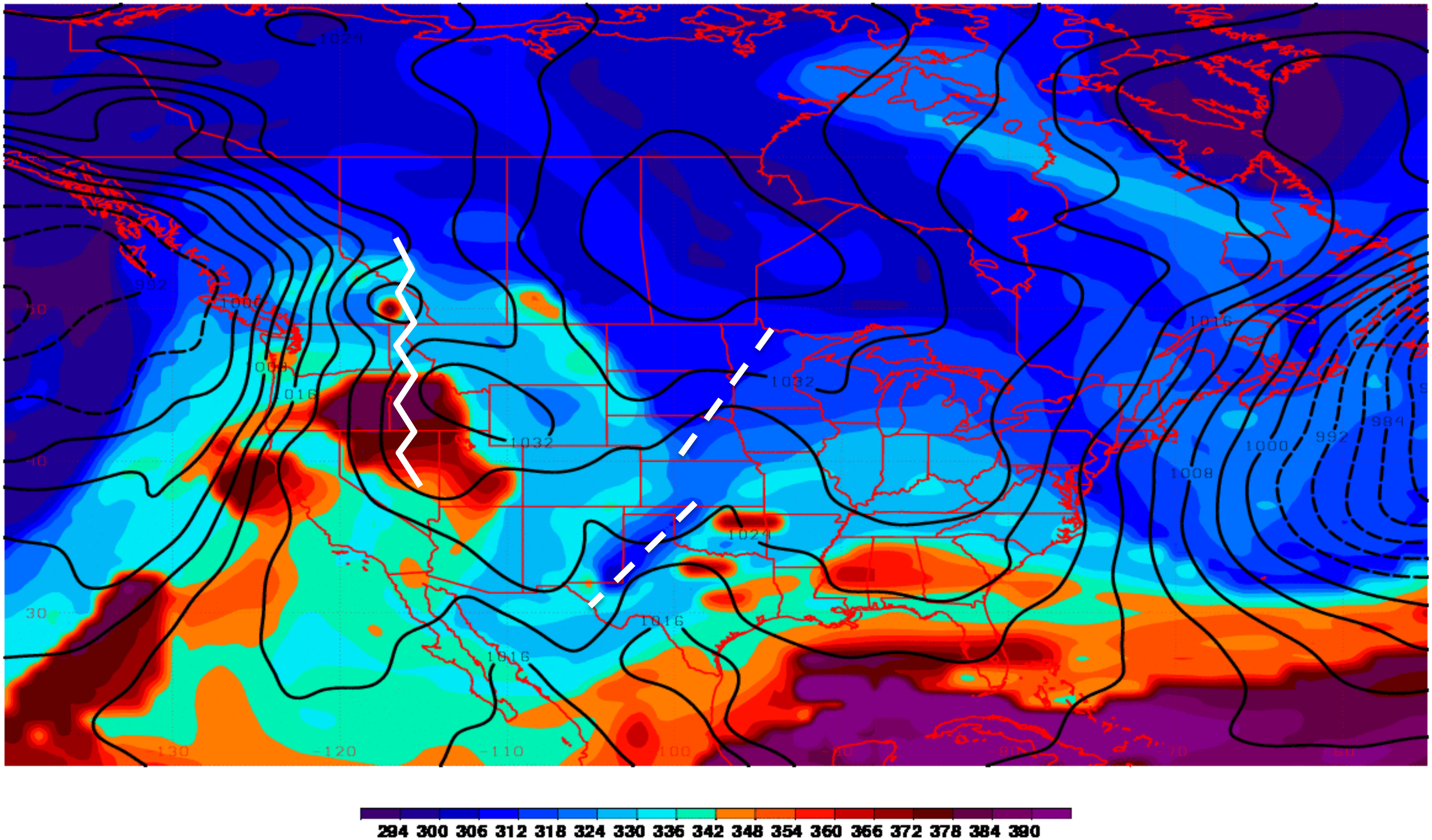
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 24 December 2010



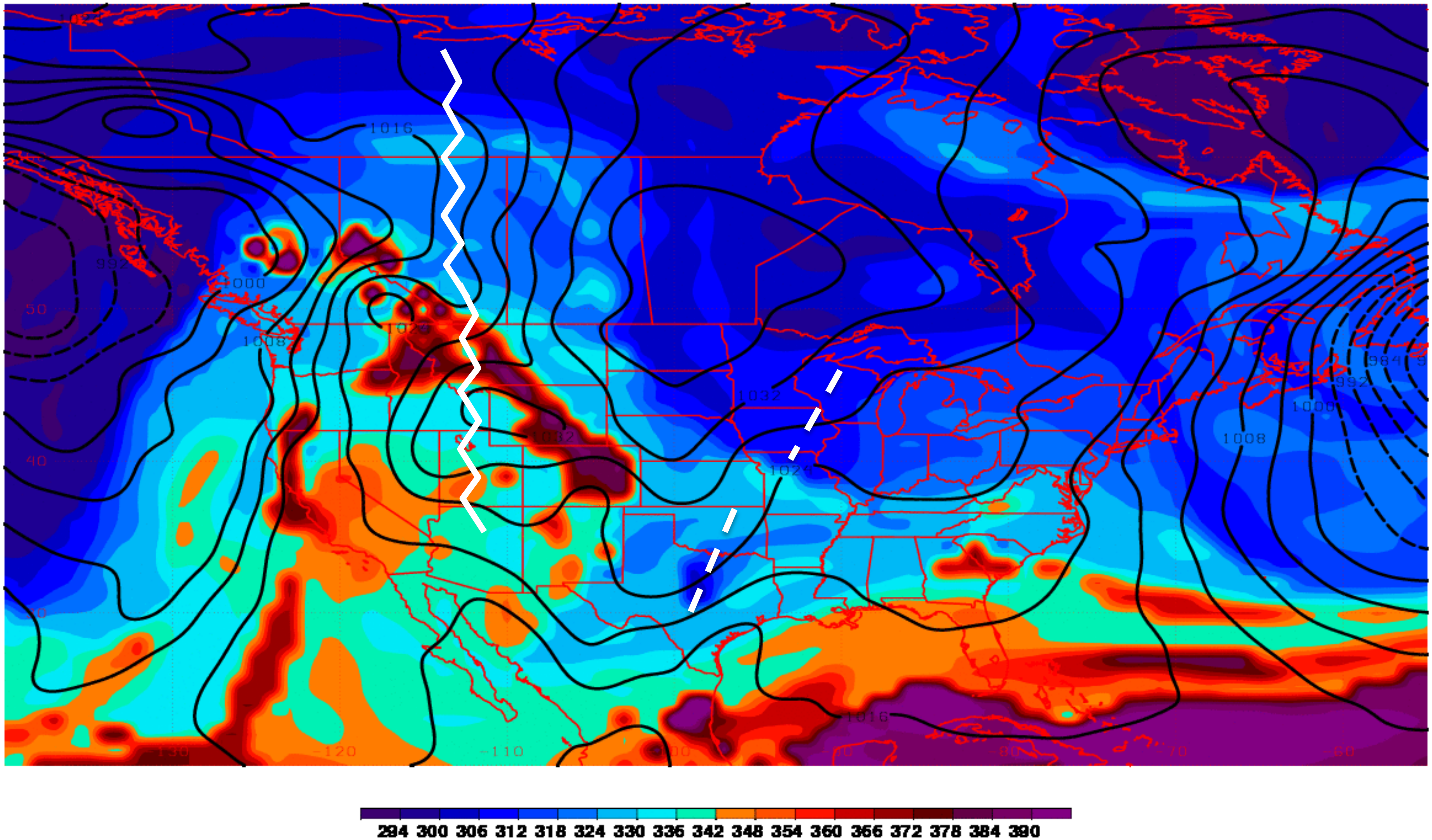
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 24 December 2010



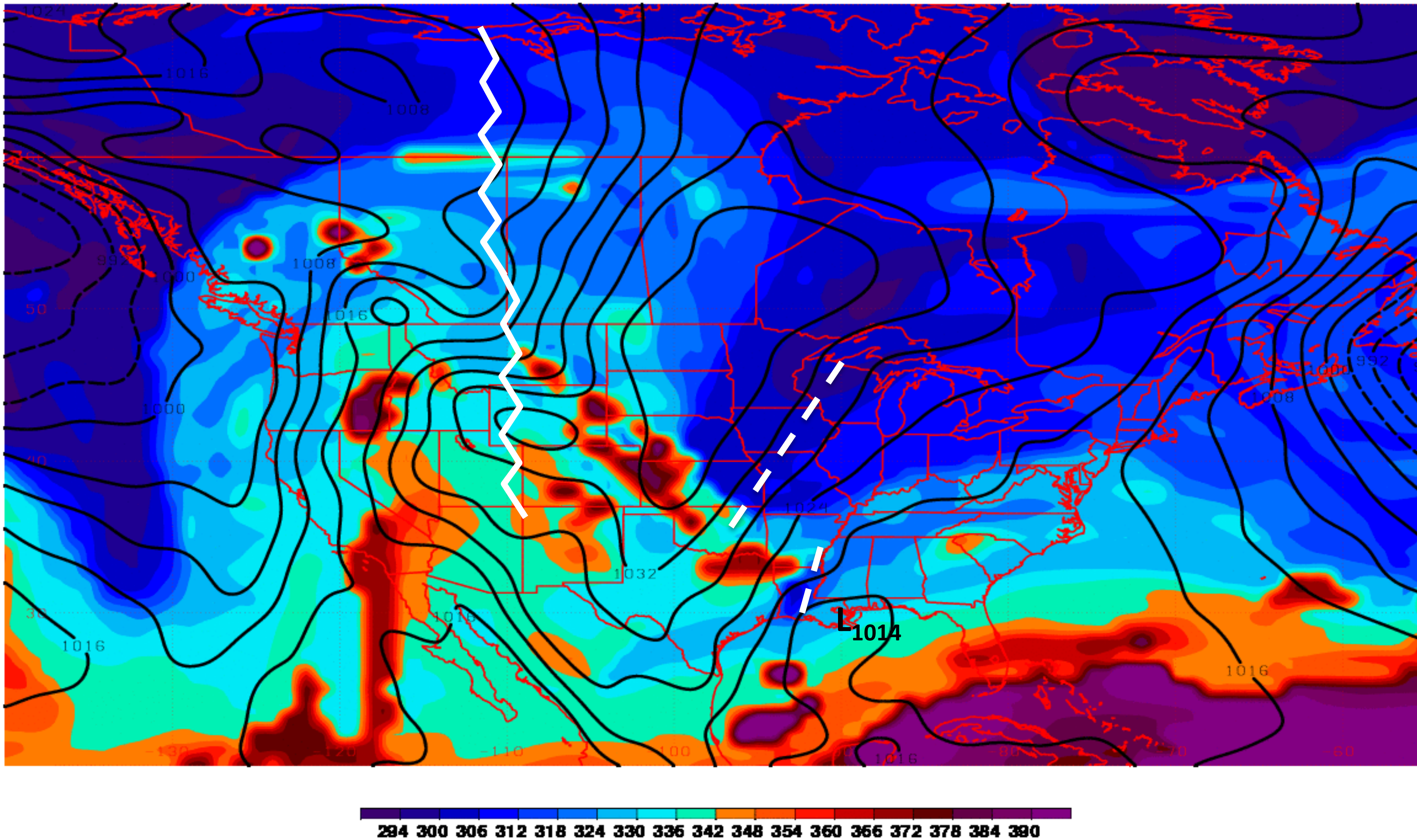
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 25 December 2010



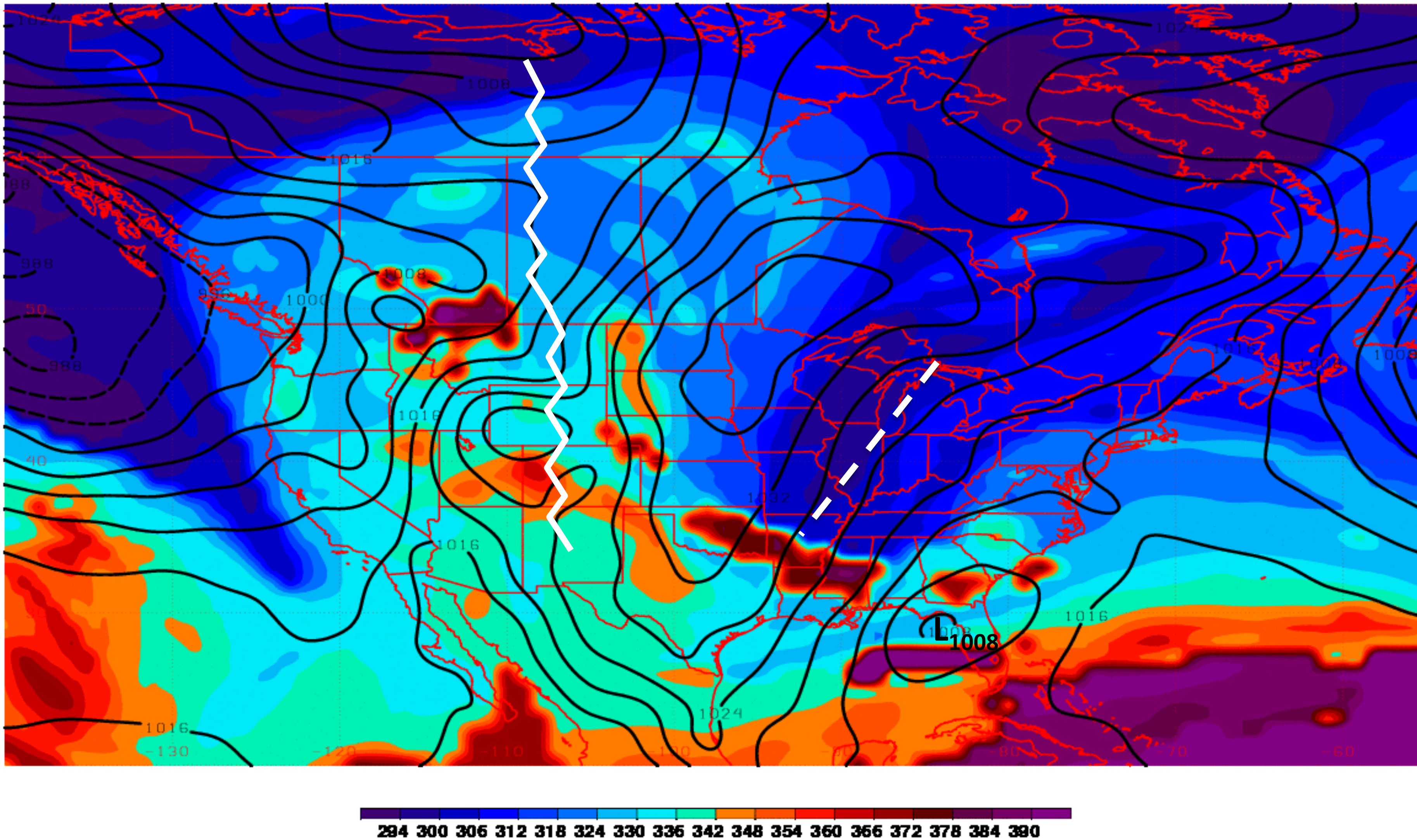
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 25 December 2010



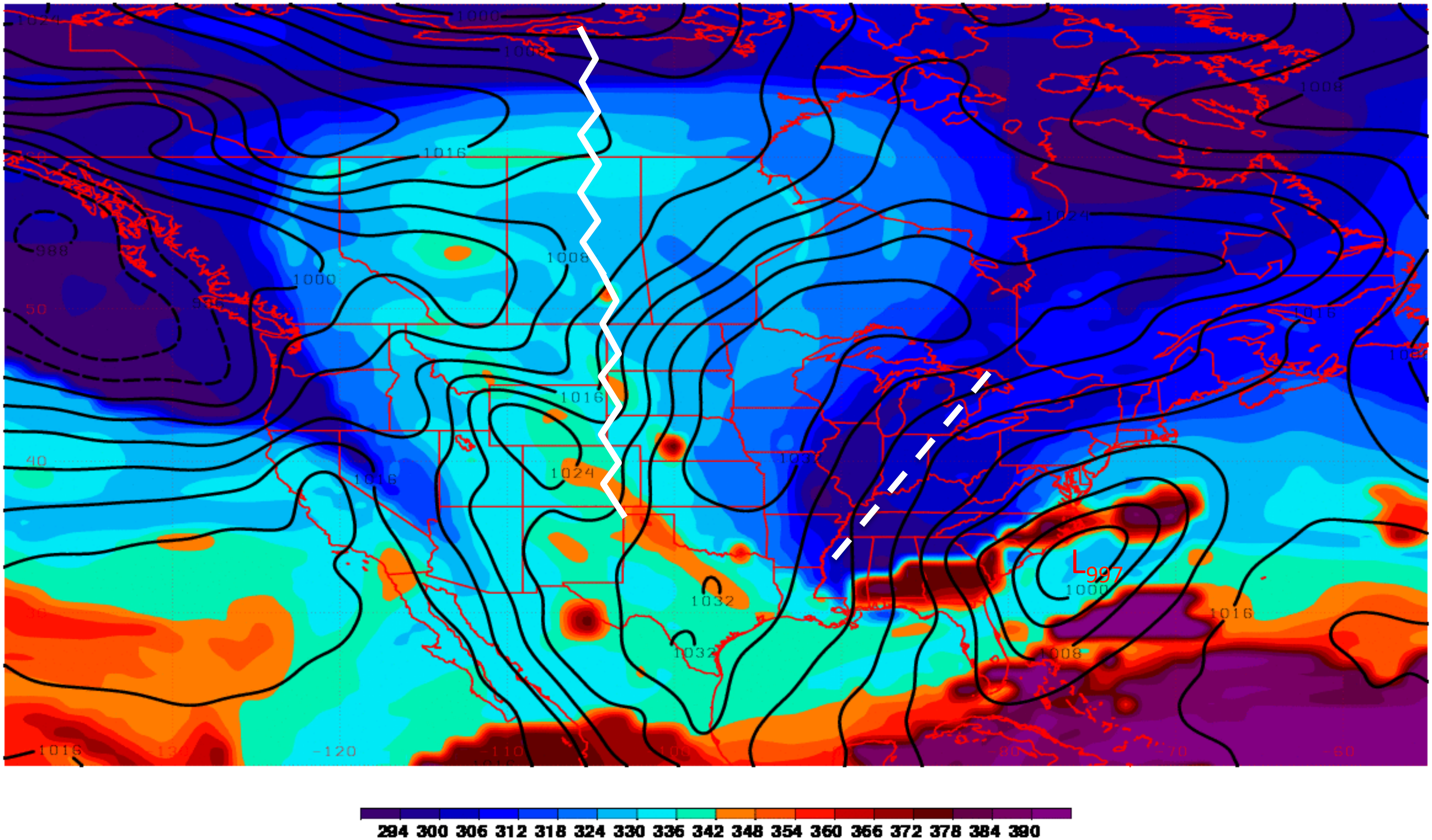
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 26 December 2010



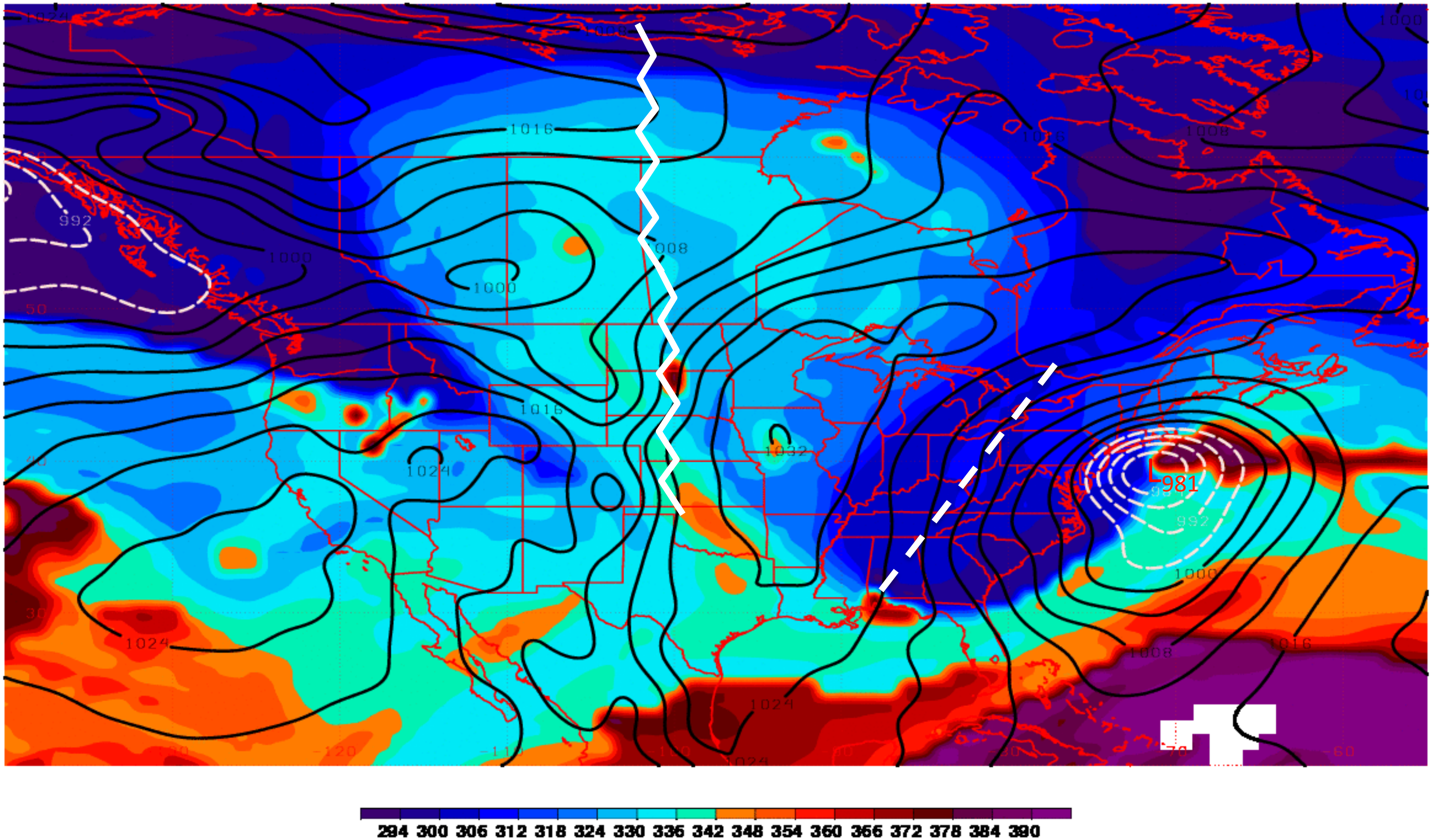
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 26 December 2010



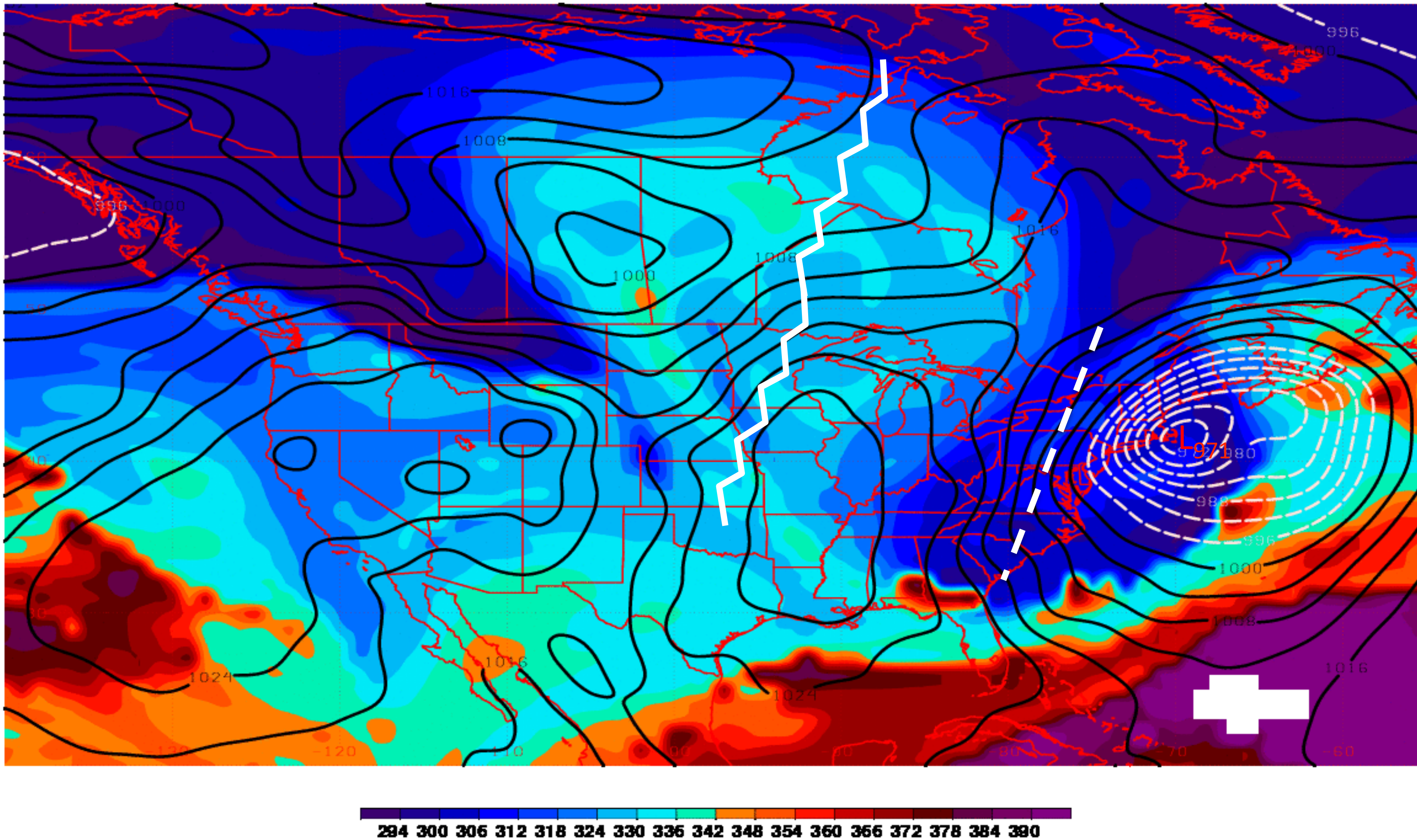
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 27 December 2010



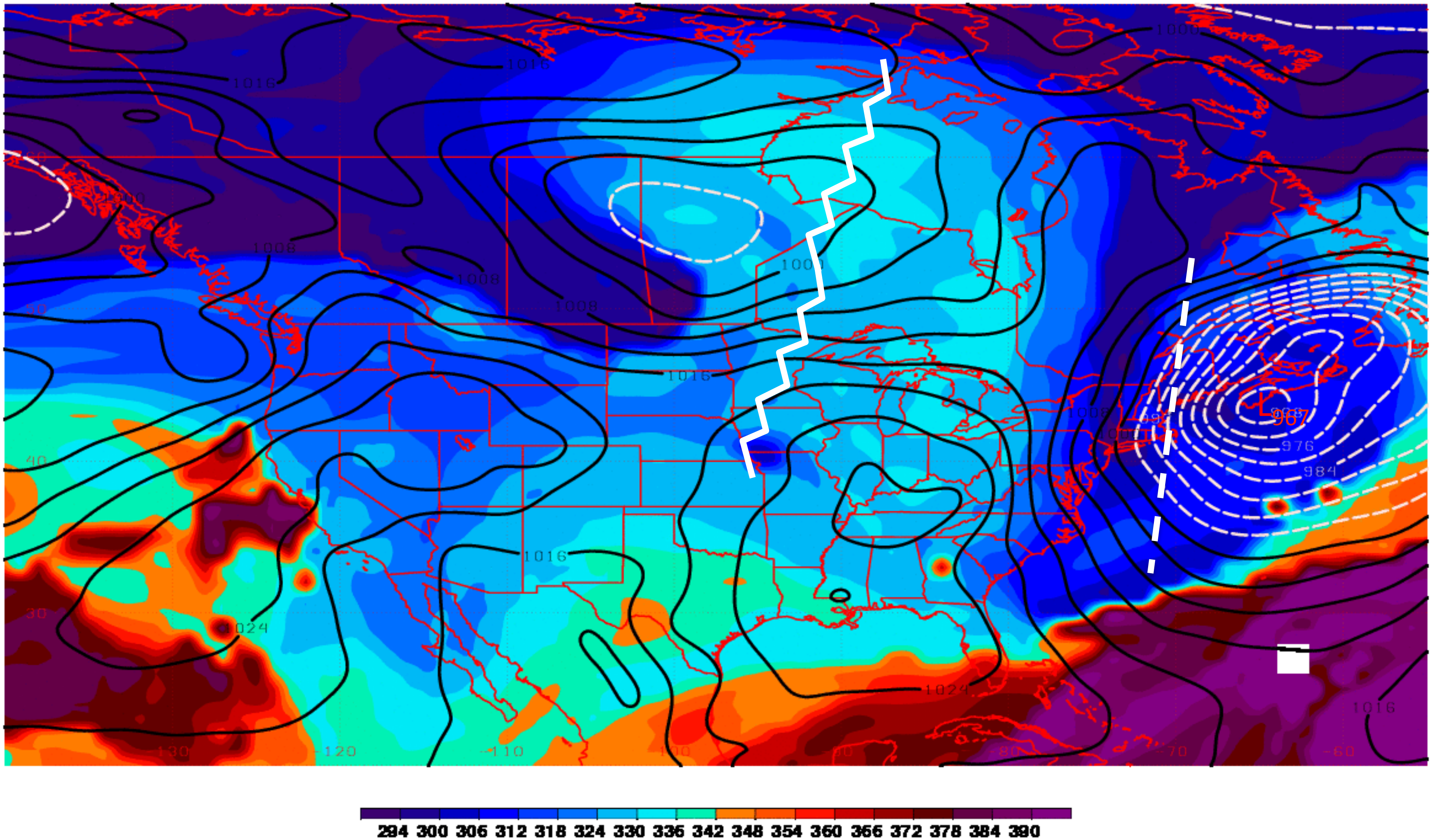
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 27 December 2010



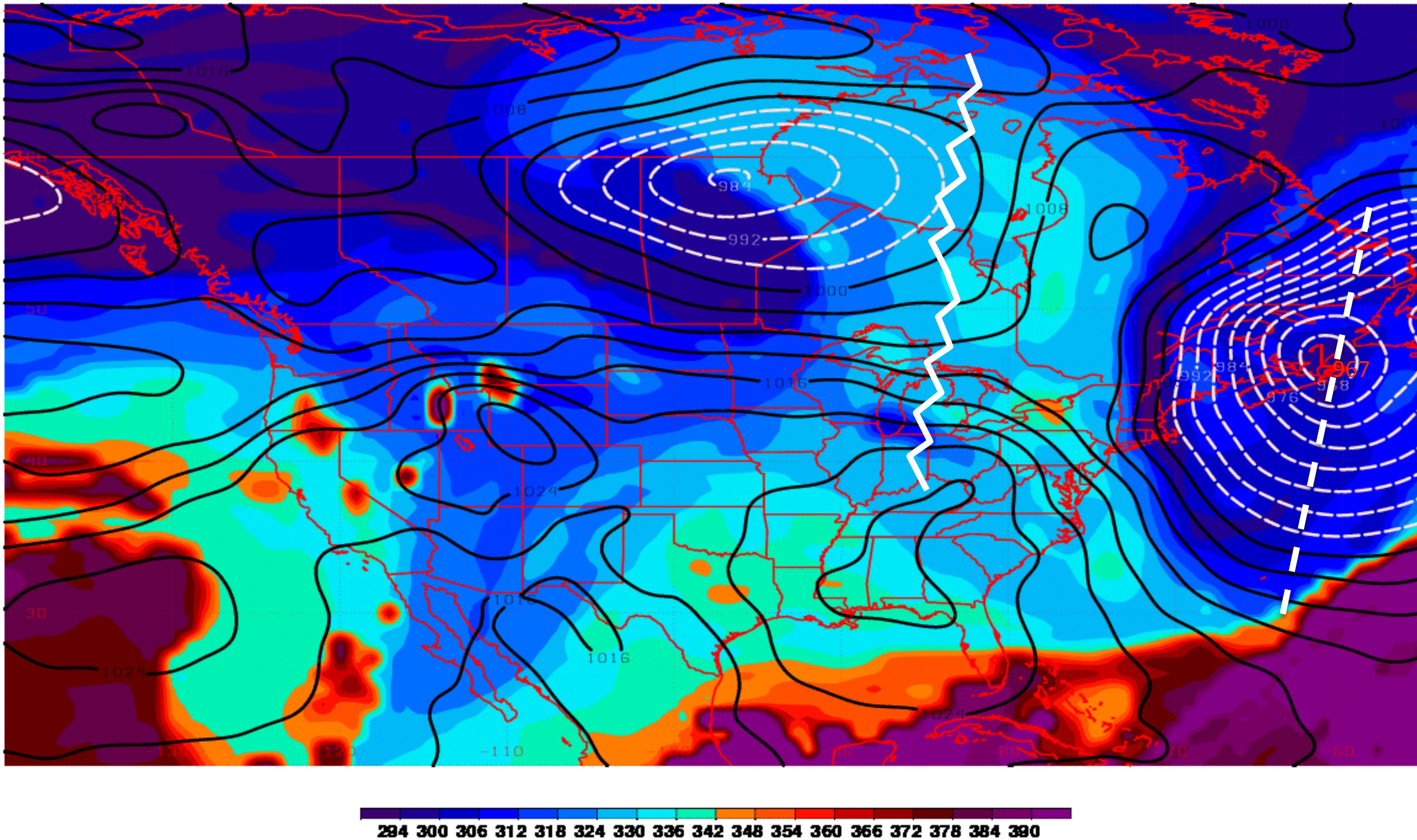
Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

0000 UTC 28 December 2010



Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

1200 UTC 28 December 2010



Theta on 2 PVU Surface [Shaded]; Sea Level Pressure [Contoured, dashed < 1000 hPa]

Motivation for This Research Study

- Kocin et al. concluded that the trough merger that occurred on 25 December was difficult to forecast
- How did ULJF systems impact the upper level flow pattern?

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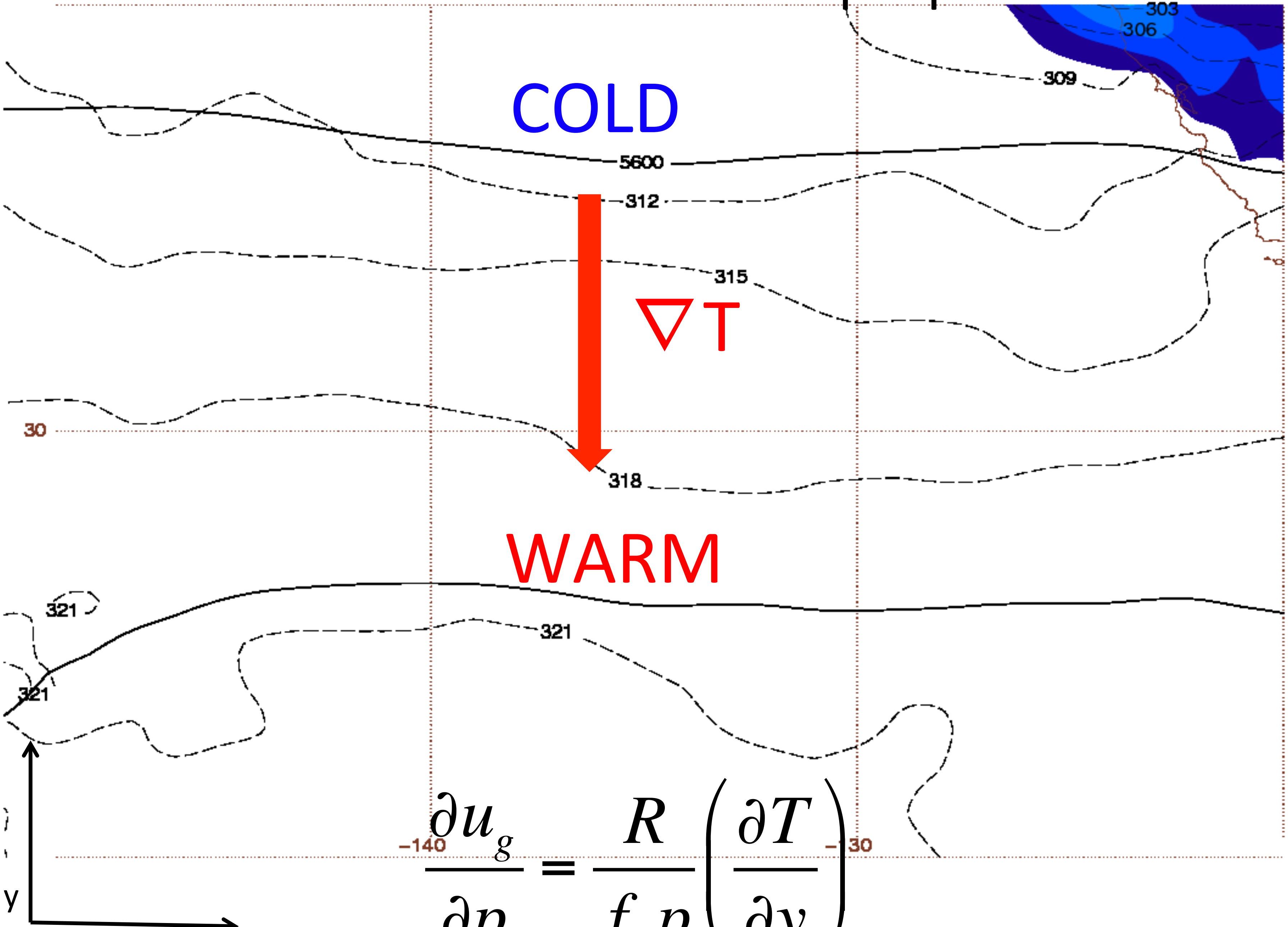
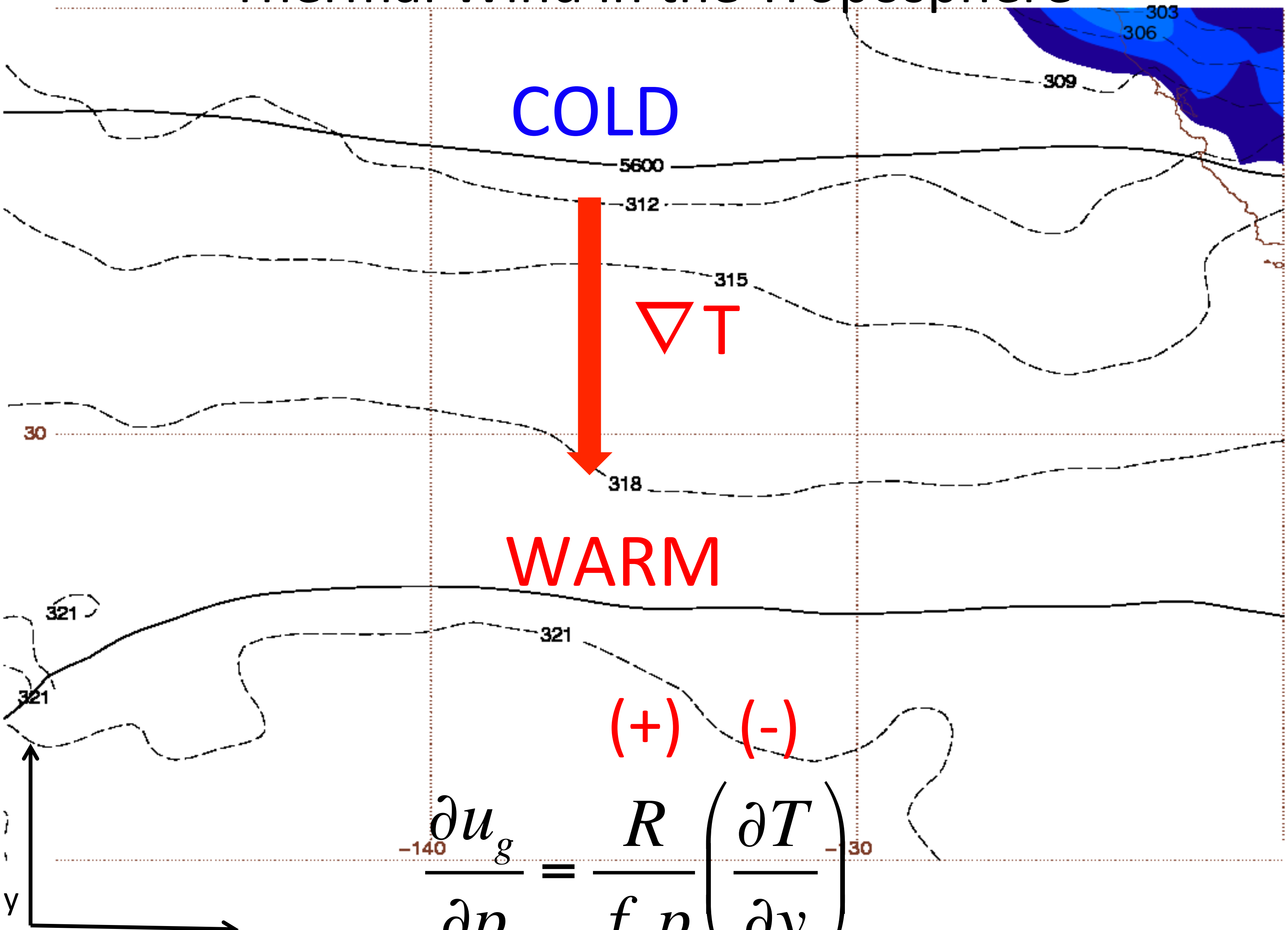
- Kocin et al. concluded that the trough merger that occurred on 25 December was difficult to forecast
- How did ULJF systems impact the upper level flow pattern?
- **Focus on the evolution of one of the ULJF systems**

Thermal Wind in the Troposphere



$$\frac{\partial u_g}{\partial p} = \frac{R}{f_0 p}\left(\frac{\partial T}{\partial y}\right)_p$$

Thermal Wind in the Troposphere



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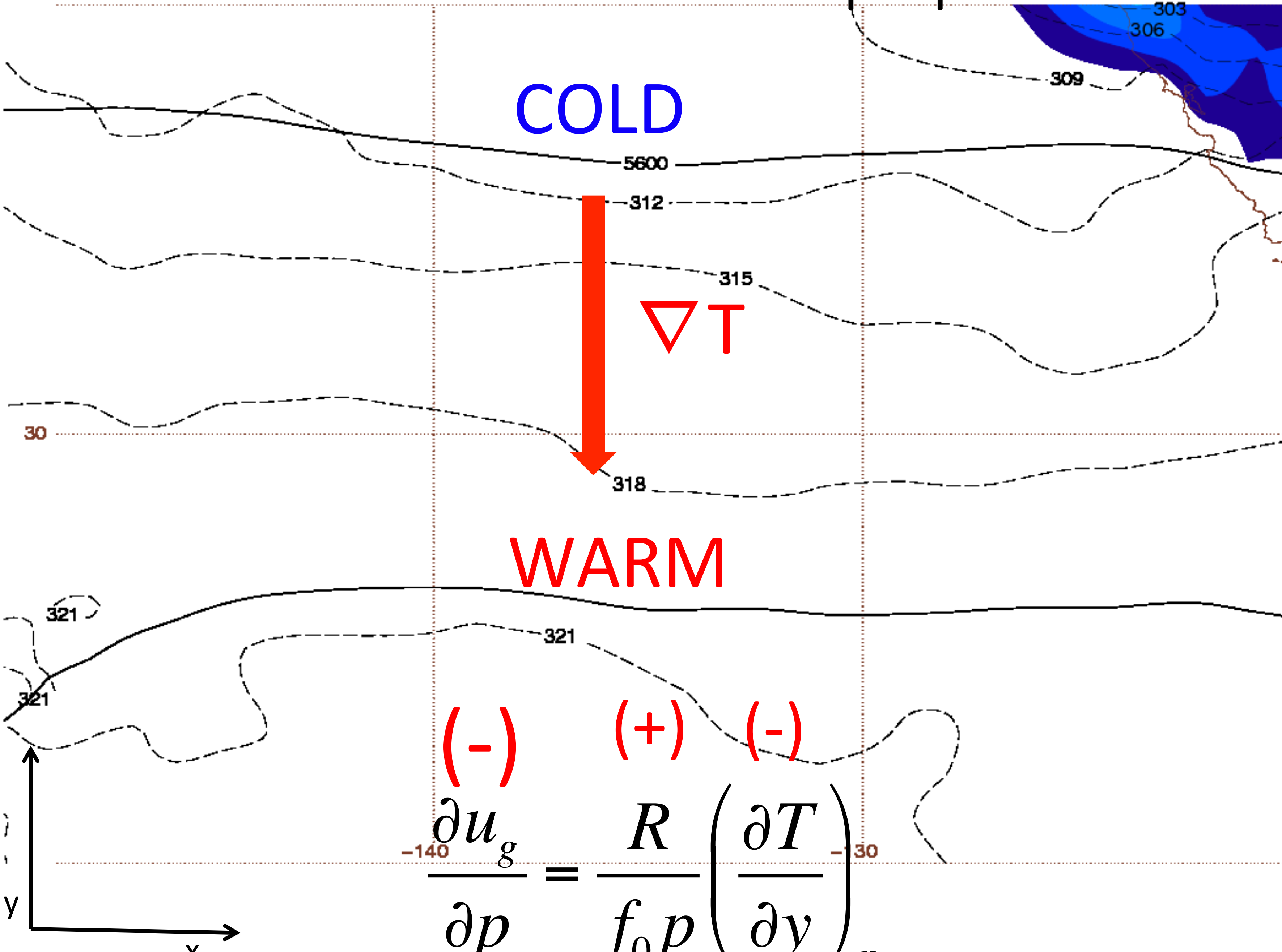

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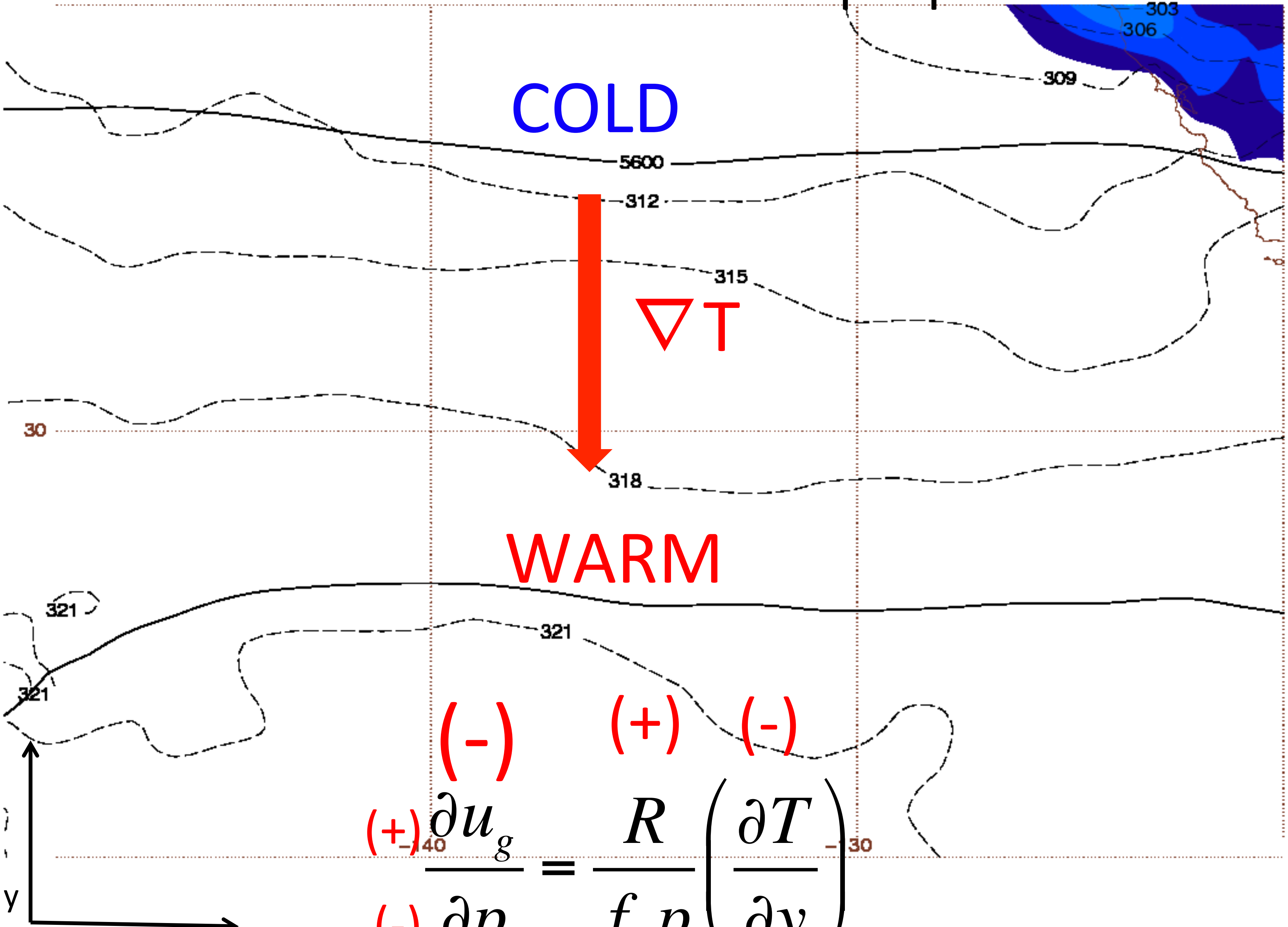
Thermal Wind in the Troposphere

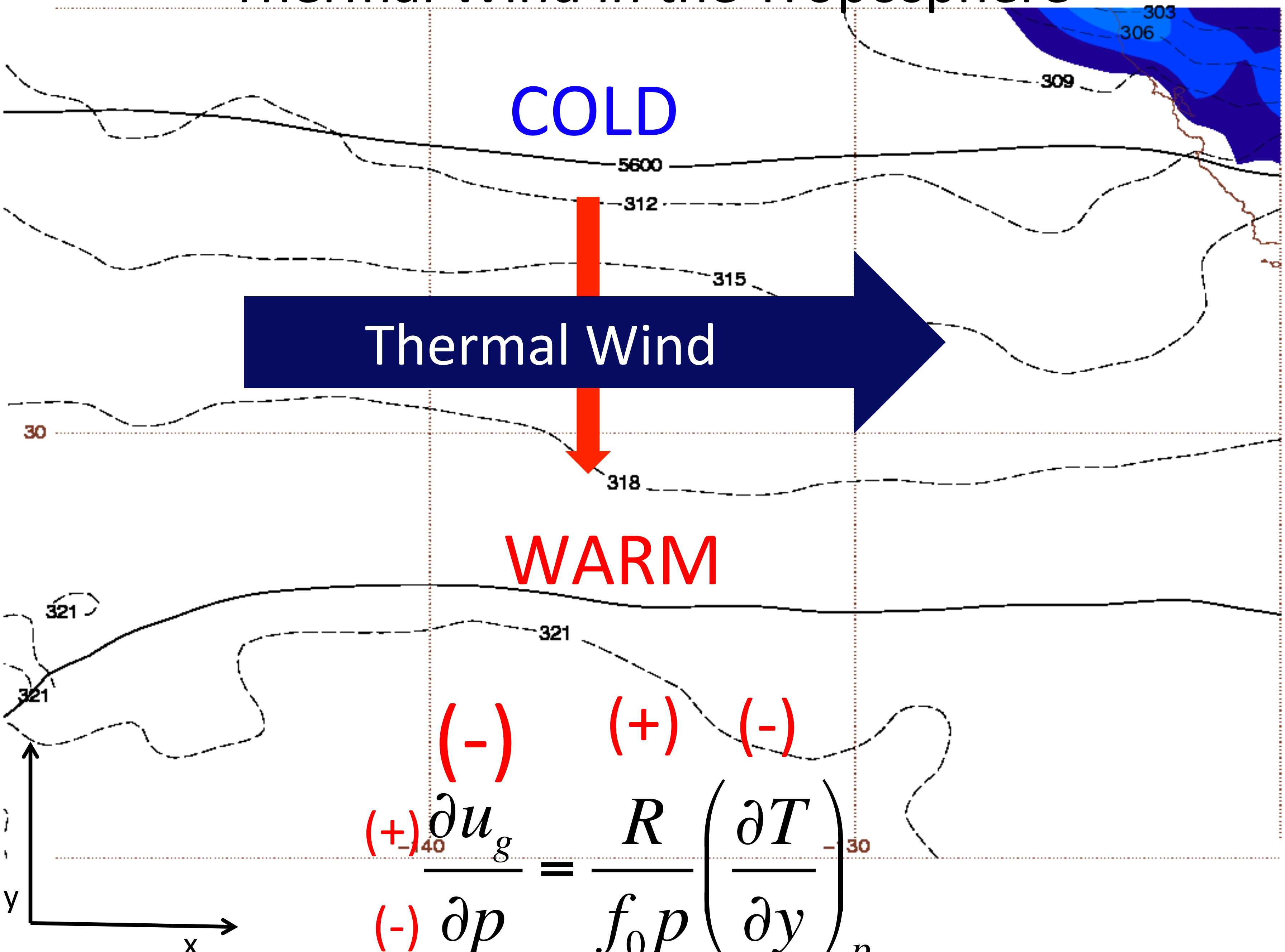


(-) (+) (-)

$$\frac{\partial u_g}{\partial p} = \frac{R}{f_0 p}\left(\frac{\partial T}{\partial y}\right)_p$$

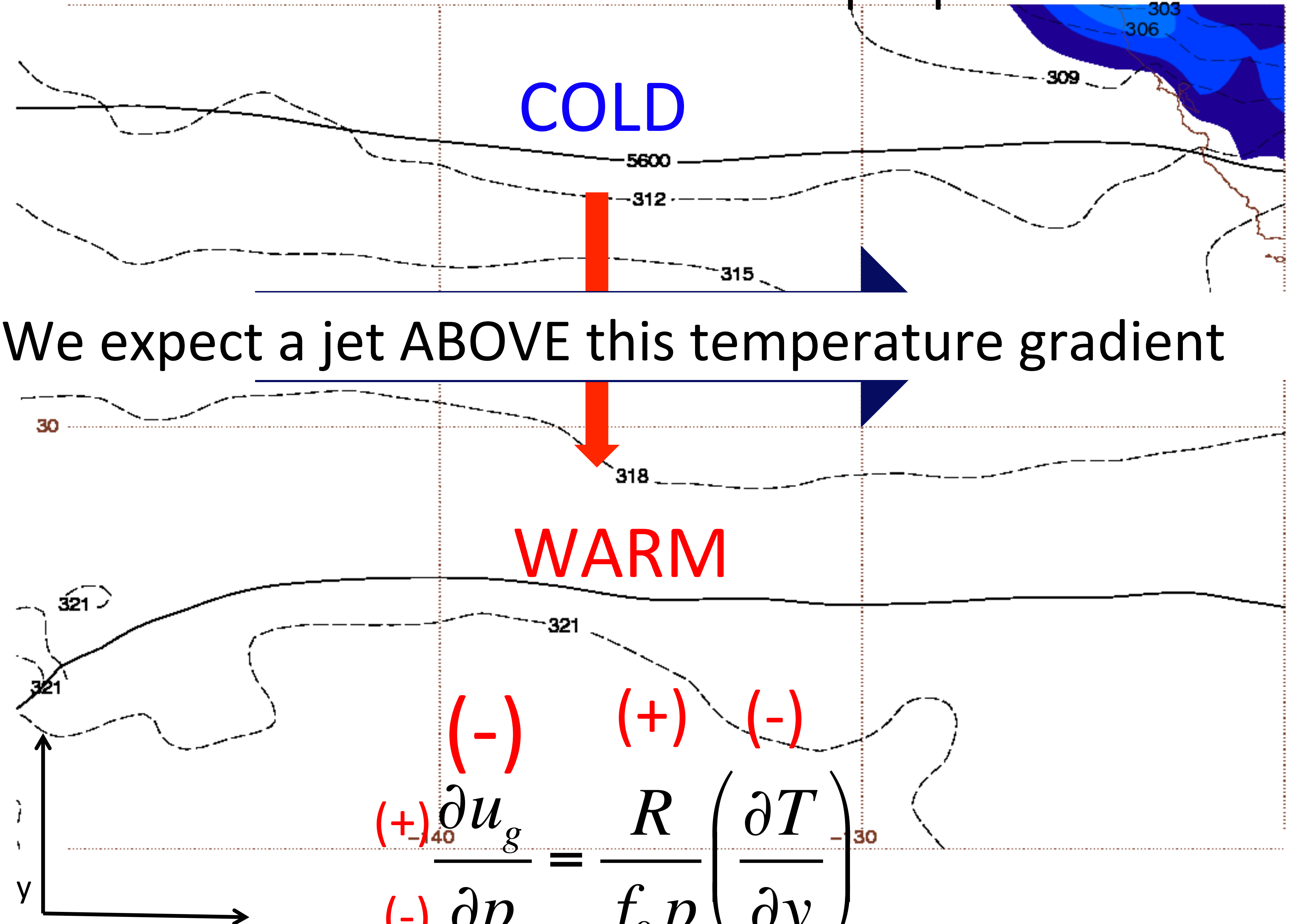
(+) (-)

Thermal Wind in the Troposphere



$$\overset{(+)}{\underset{(-)}{}}\frac{\partial u_g}{\partial p}\overset{(-)}{} = \frac{R}{f_0 p}\overset{(+)}{}\left(\frac{\partial T}{\partial y}\right)_p\overset{(-)}{}$$

Thermal Wind in the Troposphere

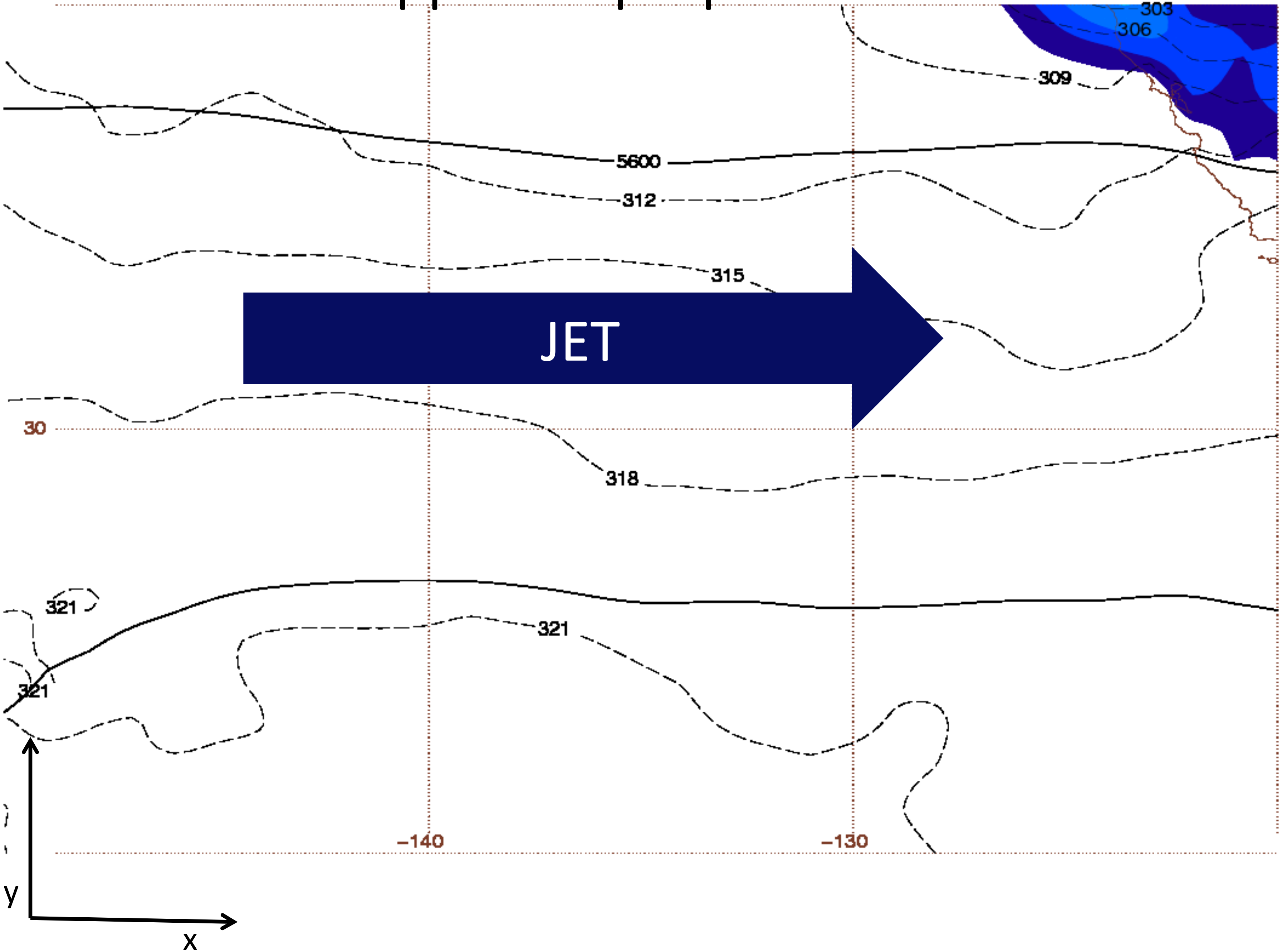


We expect a jet ABOVE this temperature gradient

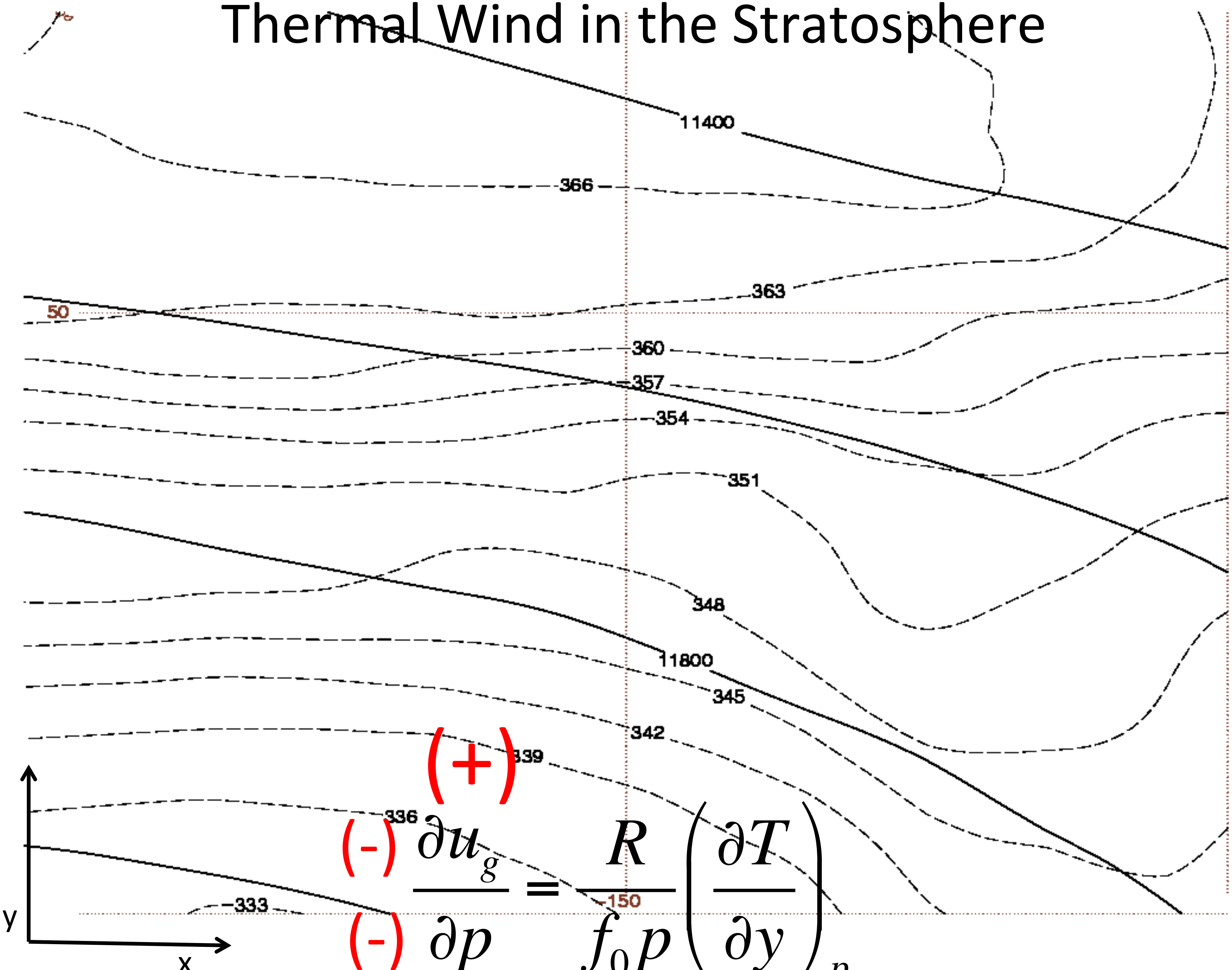
$$\underset{(-)}{\overset{(+)}{\frac{\partial u_g}{\partial p}}} = \frac{R}{f_0 p}\left(\frac{\partial T}{\partial y}\right)_p$$

(-) (+) (-)

Upper-Tropospheric Jet

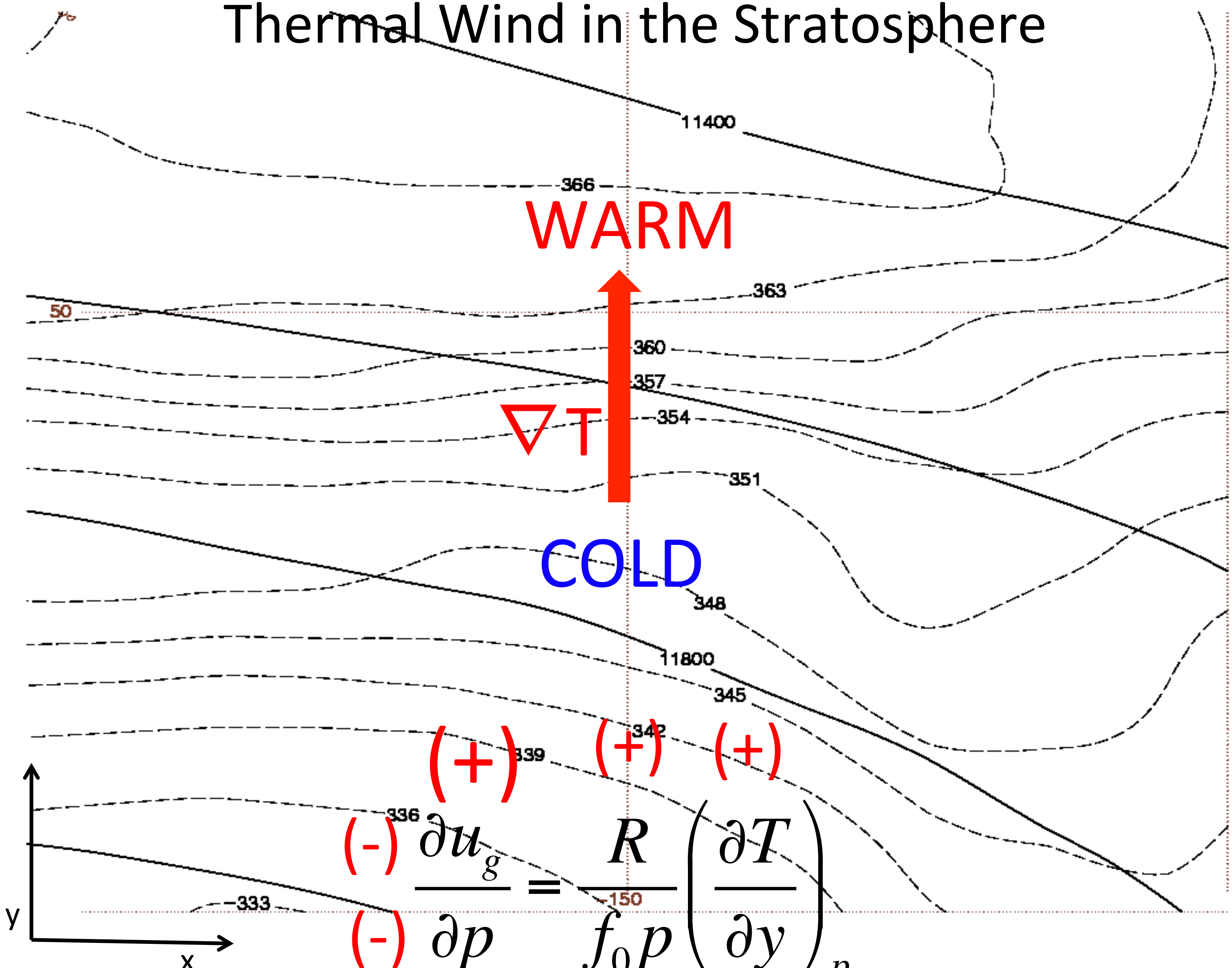


Thermal Wind in the Stratosphere



$$\frac{\partial u_g}{\partial p} = \frac{R}{f_0 p}\left(\frac{\partial T}{\partial y}\right)_p$$

Thermal Wind in the Stratosphere



$$\underset{(-)}{\overset{(-)}{}}\ \frac{\partial u_g}{\partial p} = \overset{(+)}{\frac{R}{f_0 p}} \ \overset{(+)}{} \overset{(+)}{\left(\frac{\partial T}{\partial y}\right)_p}$$

Equations

Potential Vorticity

$$PV = (\zeta + f)\left(-g\frac{\partial\theta}{\partial p}\right)$$

Equations

Potential Vorticity

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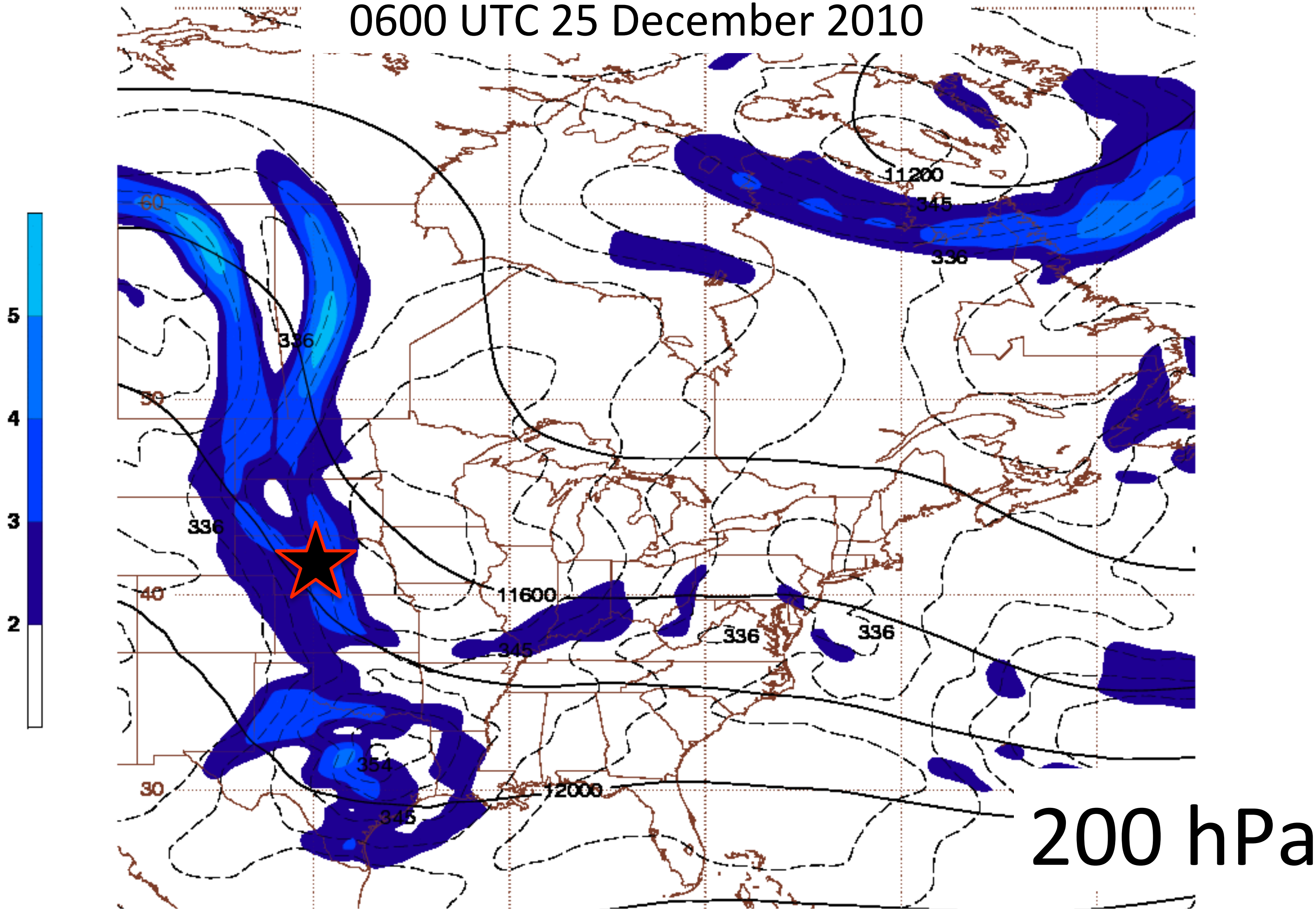
Absolute Vorticity

Static Stability

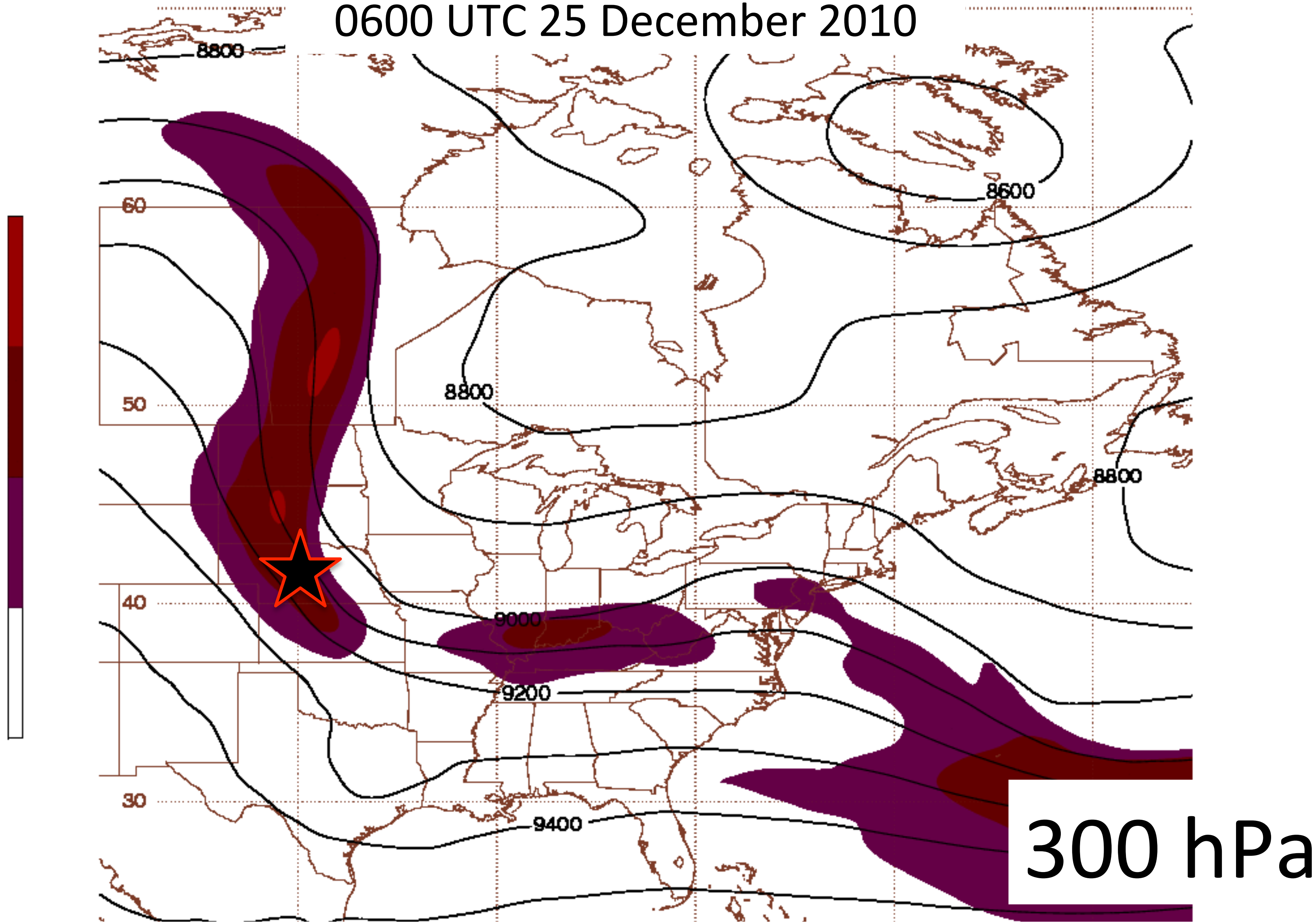
ULJF Systems in this Storm

0600 UTC 25 December 2010



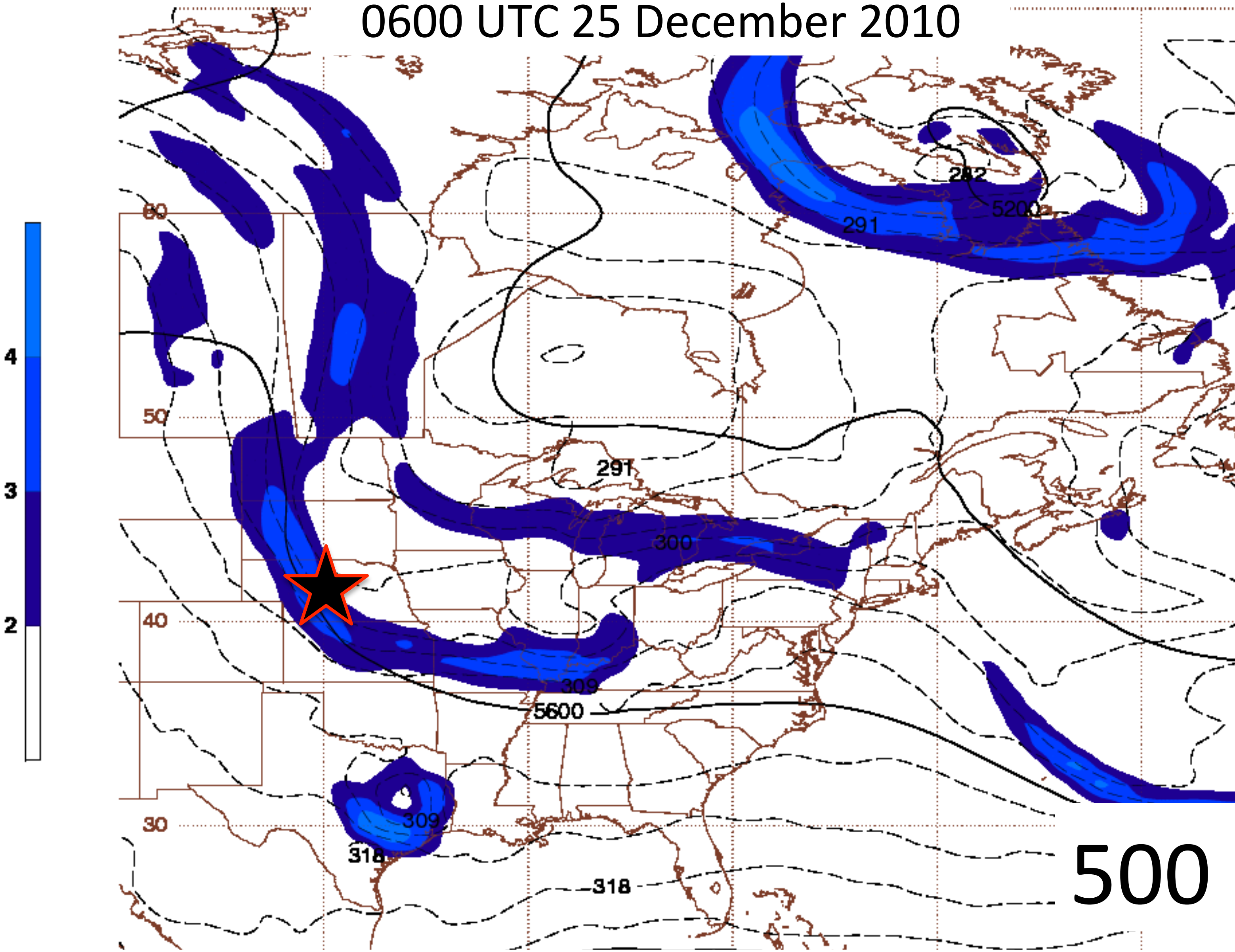
200 hPa Geopotential Height contoured every 200 meters [solid contours]
Theta contoured every 3K [dashed contours]
Magnitude of the Theta Gradient every 1K $(100km)^{-1}$ starting at 2K $(100km)^{-1}$ [shaded]

0600 UTC 25 December 2010



300 hPa Geopotential Height contoured every 100 meters [solid contours]
Magnitude of the wind every 10 m/s starting at 40 m/s[shaded]

0600 UTC 25 December 2010



500 hPa

500 hPa Geopotential Height contoured every 100 meters [solid contours]
Theta contoured every 3K [dashed contours]
Magnitude of the Theta Gradient every 1K $(100km)^{-1}$ starting at 2K $(100km)^{-1}$ [shaded]

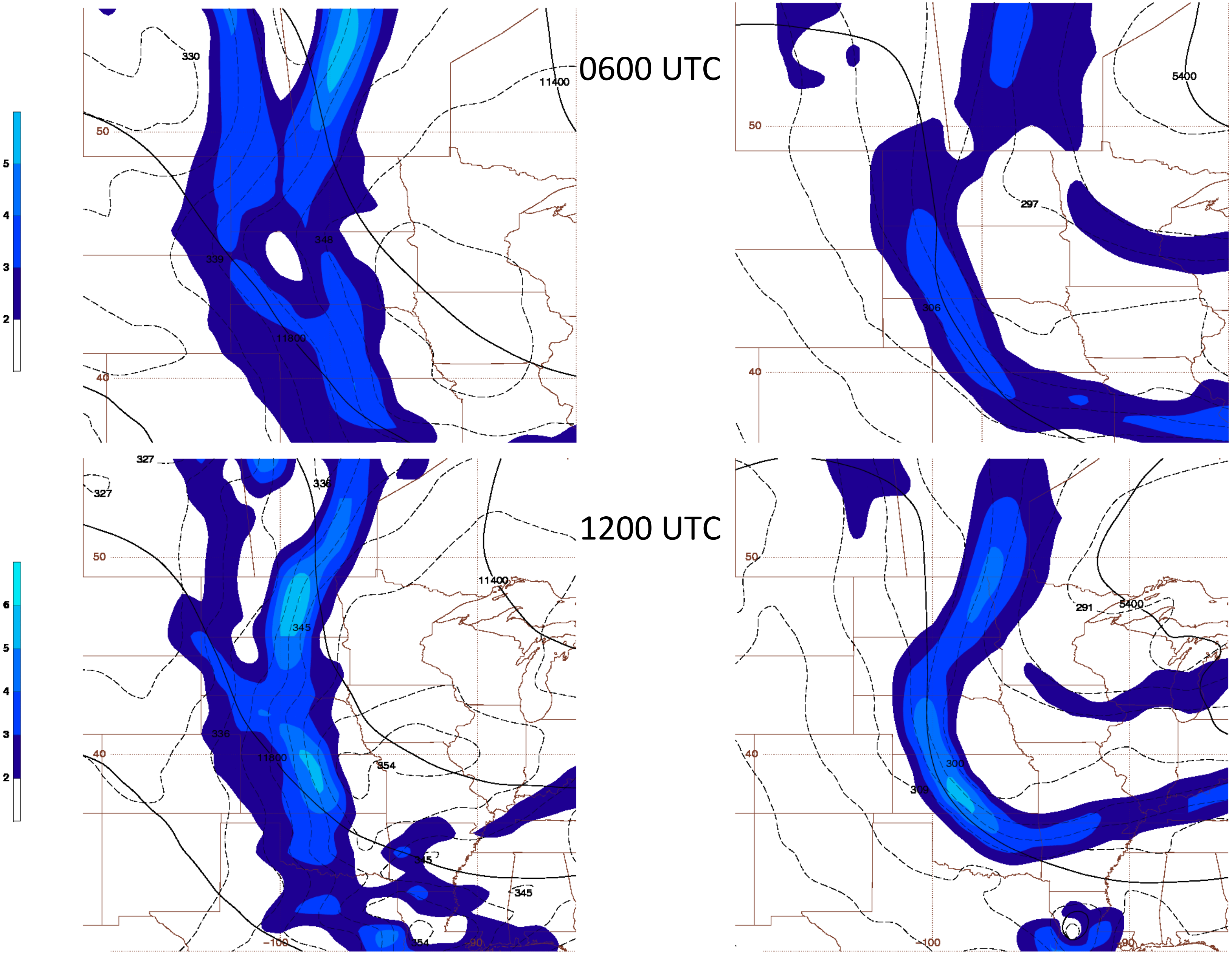
Evolution of ULJF

25 December 2010

Front 2

200 hPa

500 hPa



Geopotential Height every 200 m (100m) at 200 hPa (500hPa) [solid]

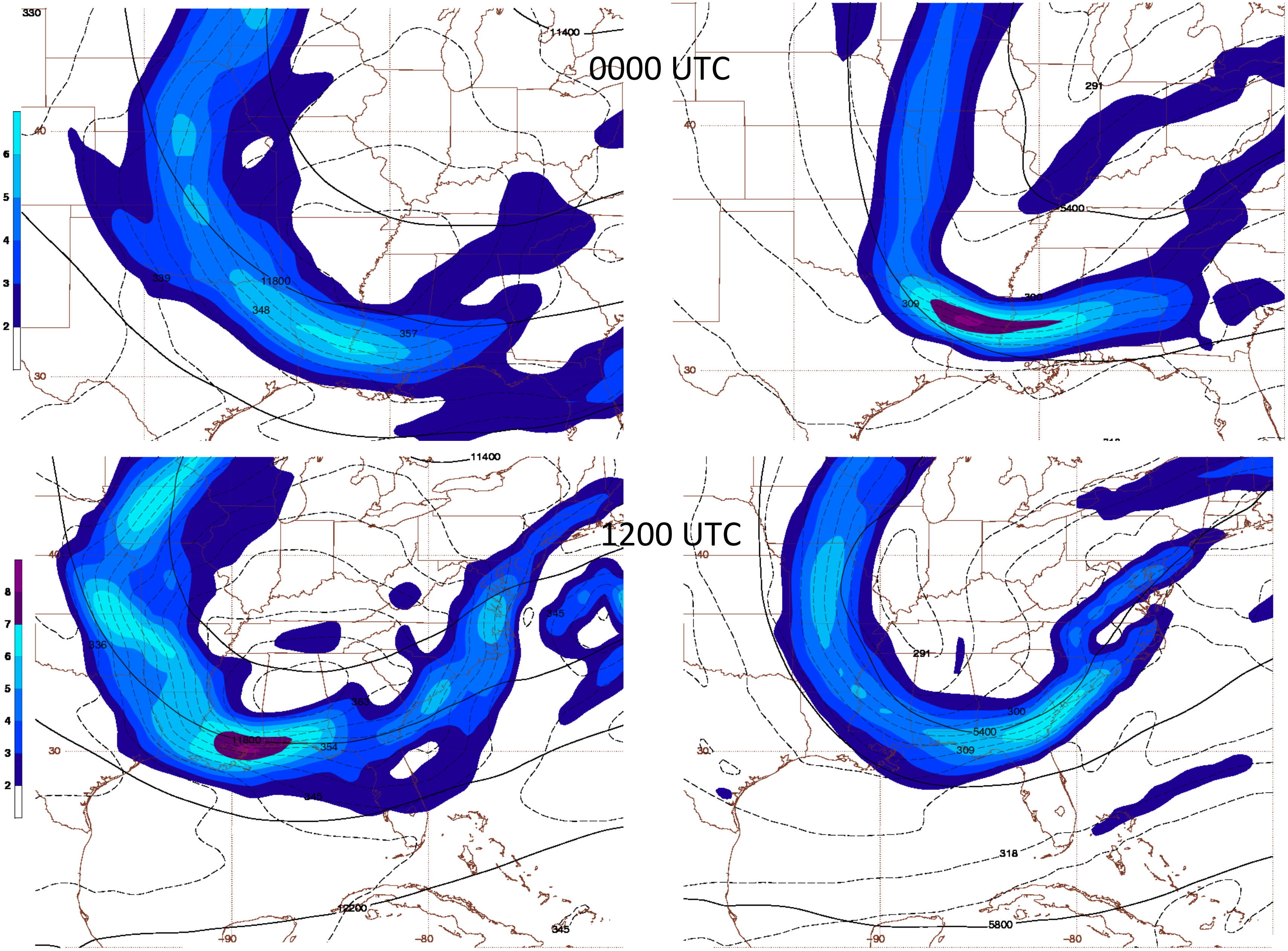
Theta every 3K [dashed]

Magnitude of theta gradient every 1K $(100km)^{-1}$ starting at 2K $(100km)^{-1}$ [shaded]

Front 2

26 December 2010

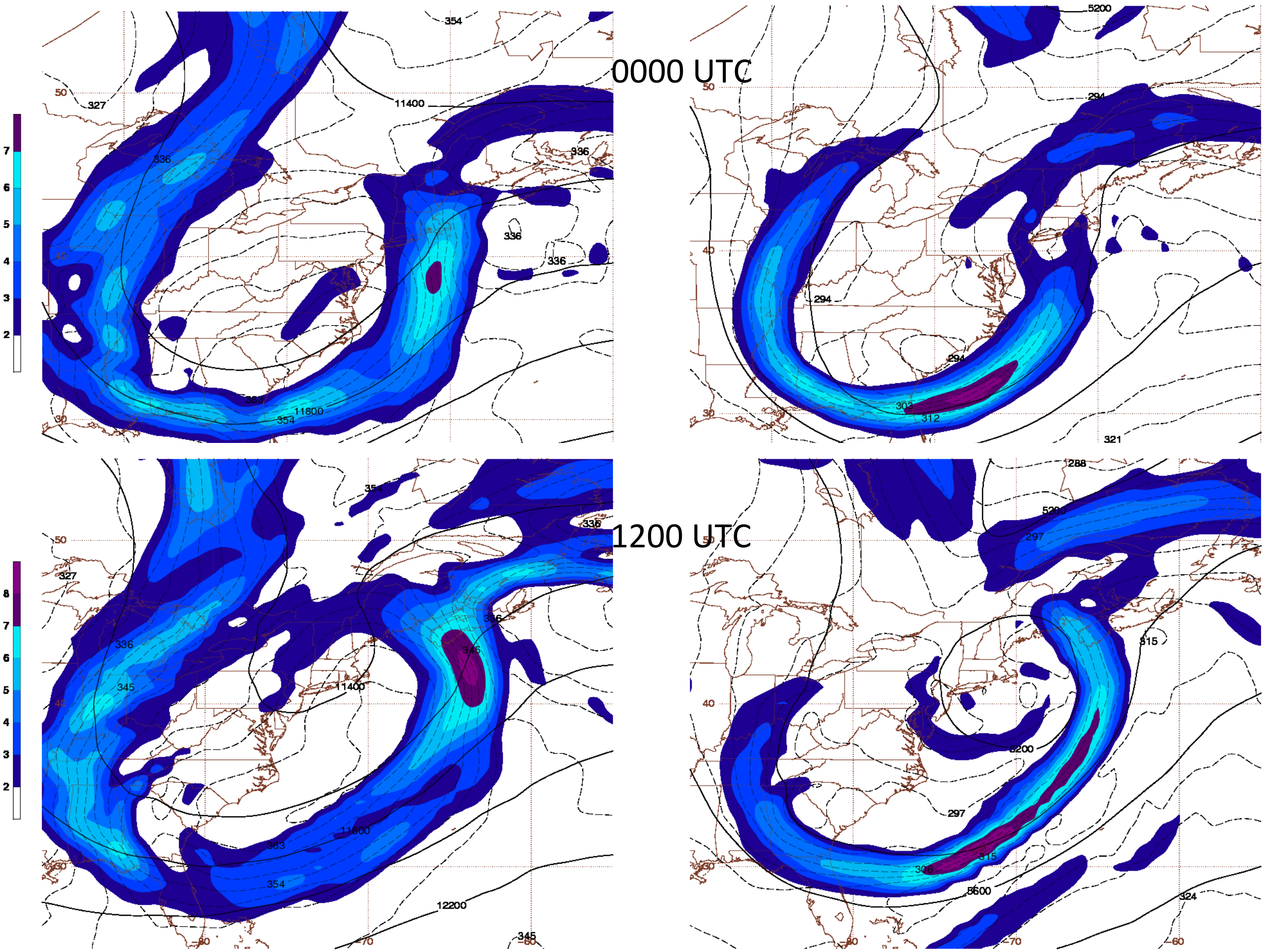
200 hPa   500 hPa



Front 2

27 December 2010

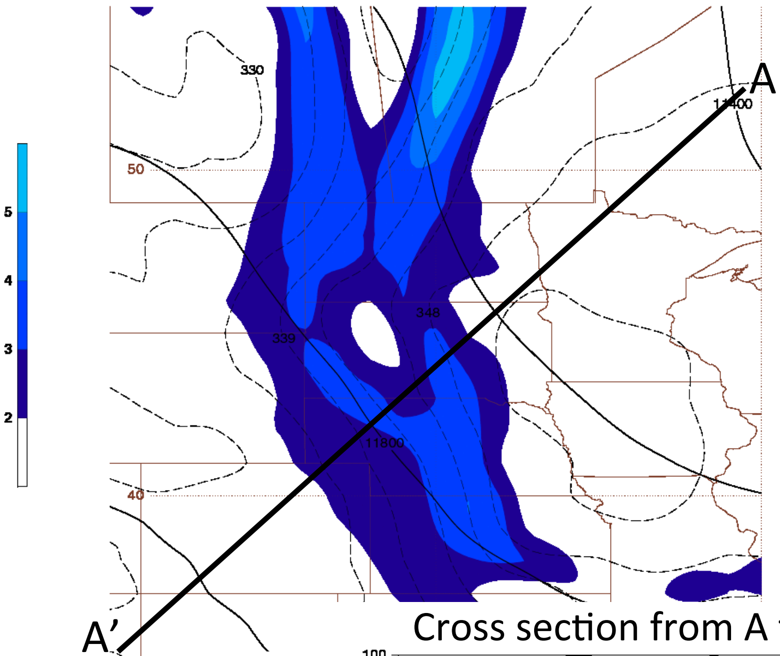
200 hPa   500 hPa



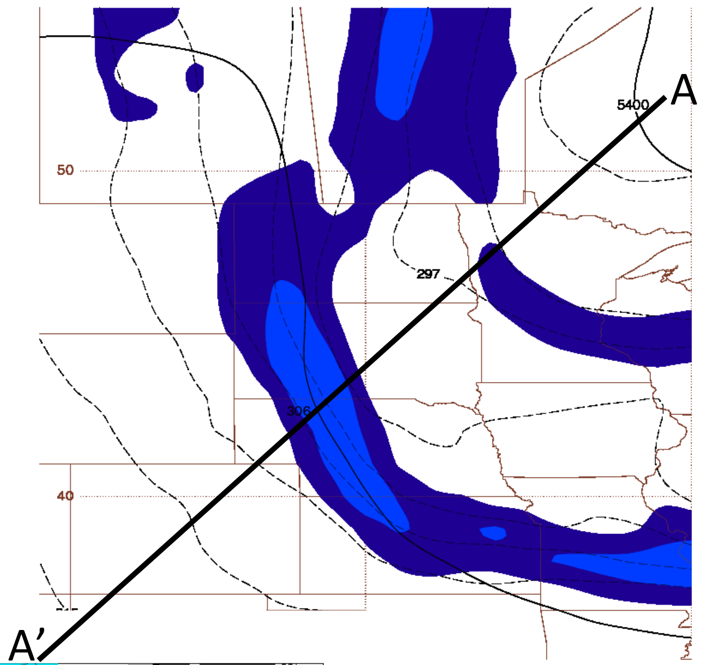
0600 UTC 25 December 2010

0600 UTC 25 December 2010

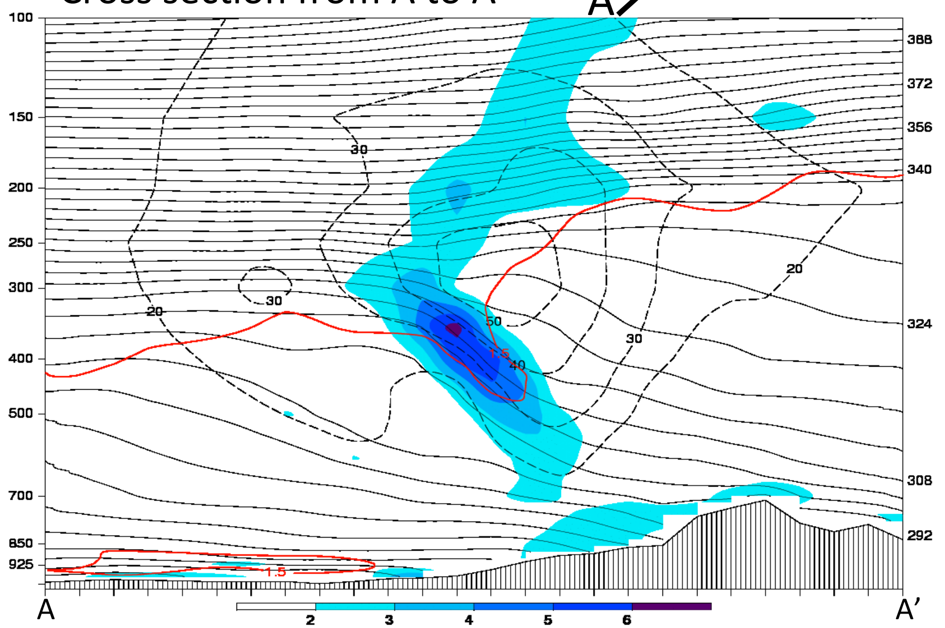
200 hPa



500 hPa



Cross section from A to A’



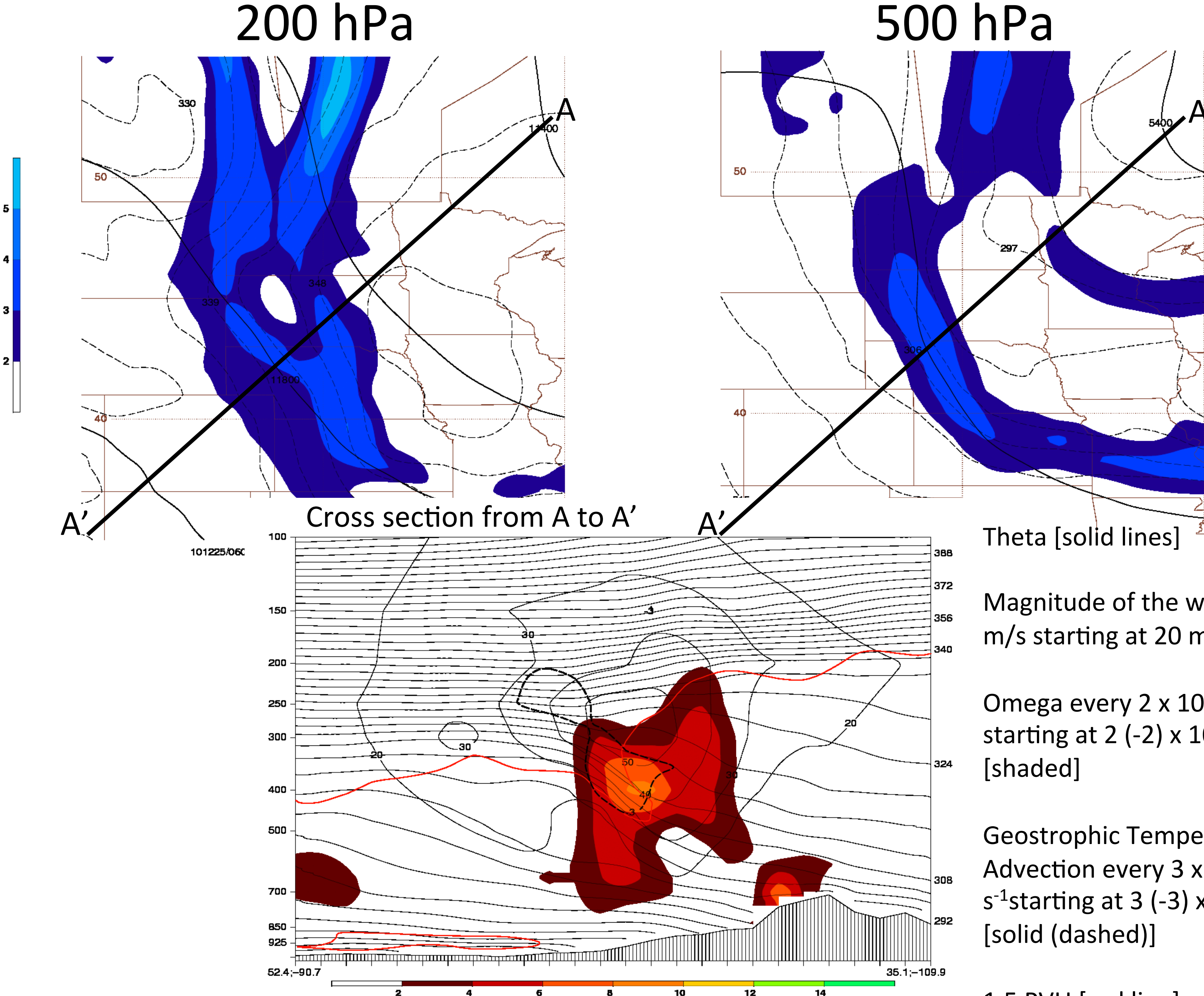
Theta [solid lines]

Magnitude of the wind every 10 m/s starting at 20 m/s [dashed]

Magnitude of the theta gradient every 1K (100 km)$^{-1}$ starting at 2 K (100 km)$^{-1}$ [shaded]

1.5 PVU [red line]

0600 UTC 25 December 2010



Theta [solid lines]

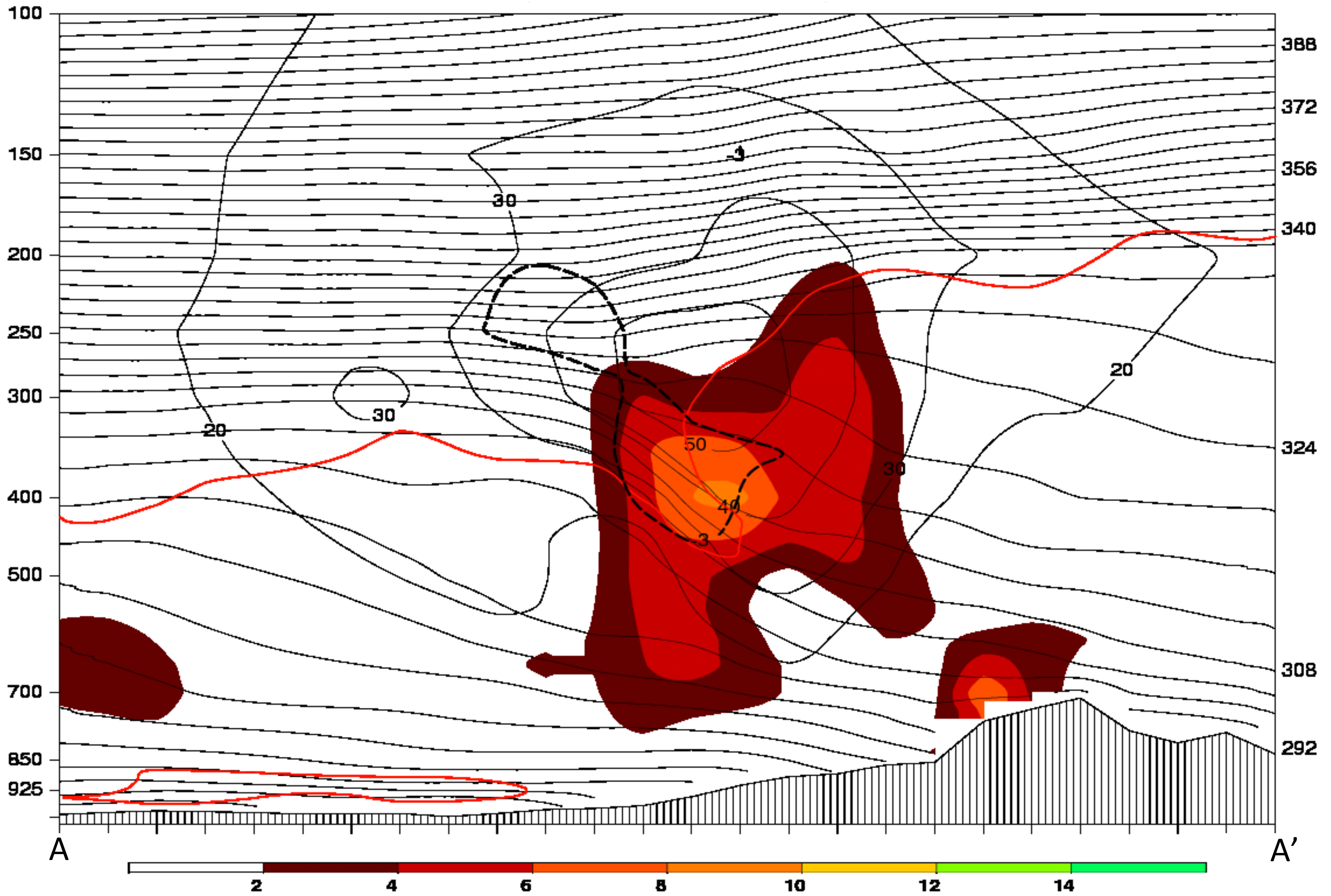
Magnitude of the wind every 10 m/s starting at 20 m/s [dashed]

Omega every 2×10^{-3} hPa s^{-1} starting at 2 (-2) $\times 10^{-3}$ hPa s^{-1} [shaded]

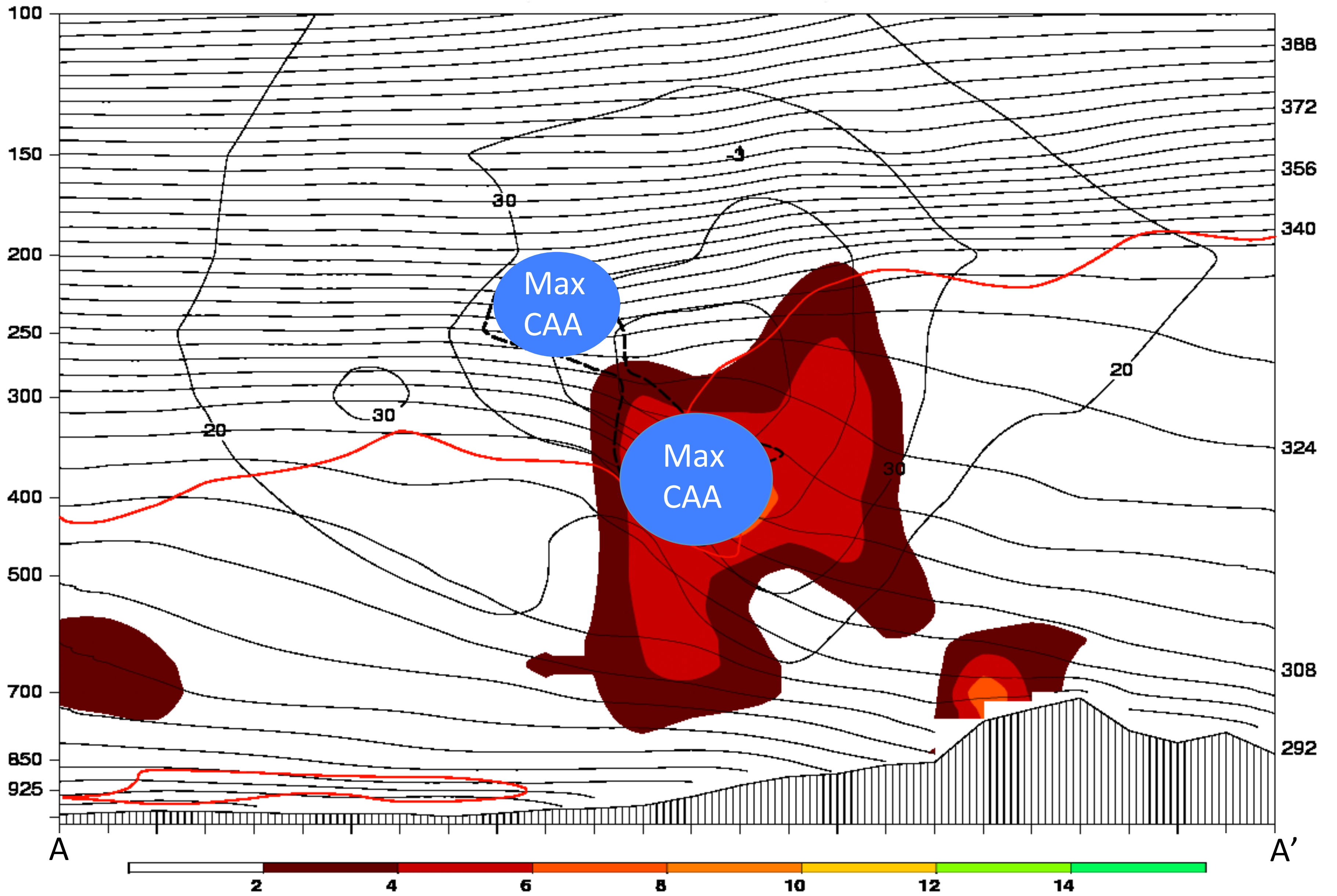
Geostrophic Temperature Advection every 3×10^{-4} K s^{-1}starting at 3 (-3) $\times 10^{-4}$ K s^{-1} [solid (dashed)]

1.5 PVU [red line]

0600 UTC 25 December 2010

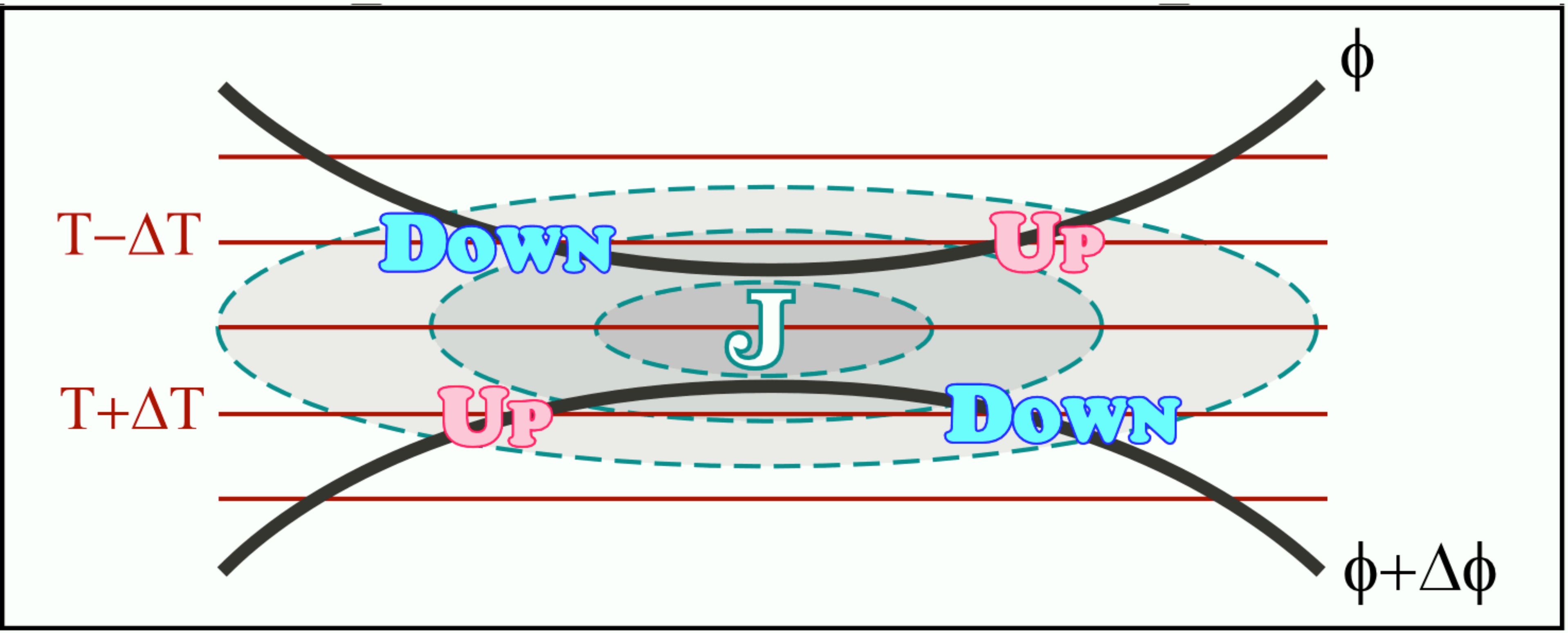


0600 UTC 25 December 2010



Upper Tropospheric Jet Circulations (below the jet core)

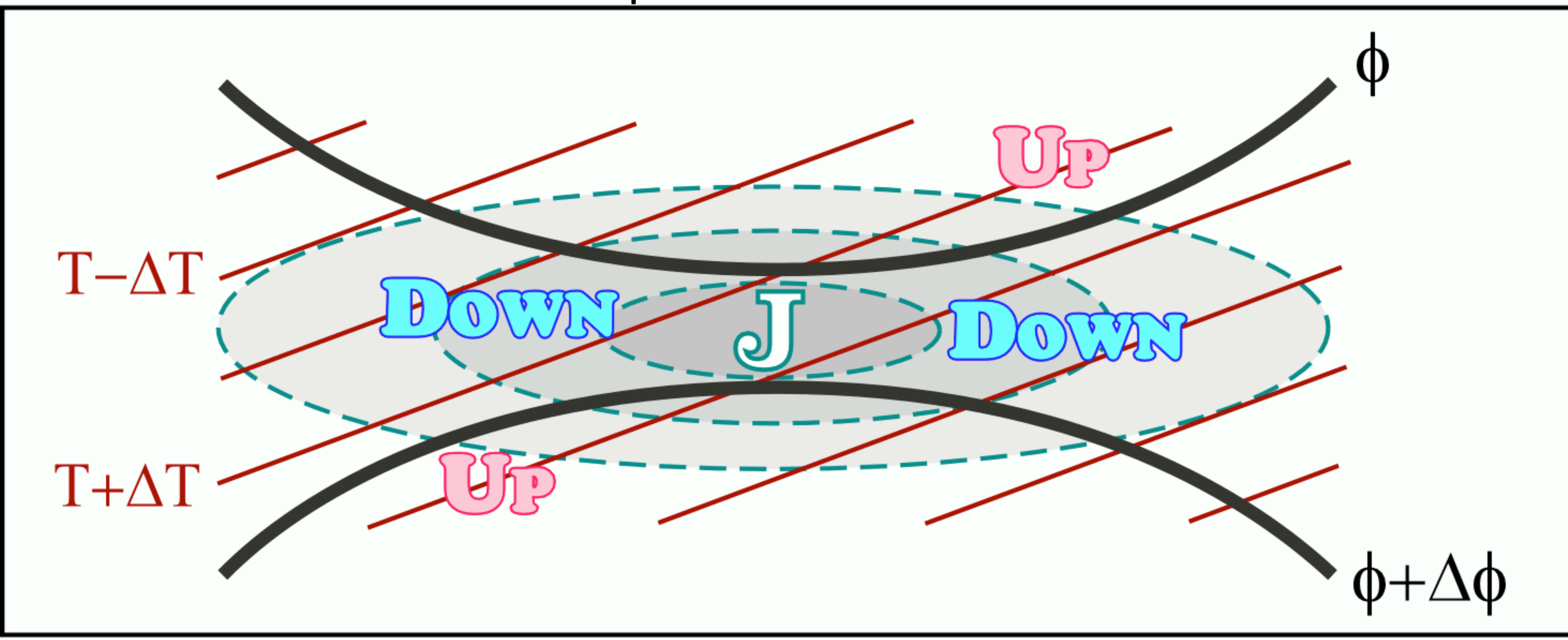
Traditional Jet Circulation



From Lang and Martin (2010)

Upper Tropospheric Jet Circulations (below the jet core)

Geostrophic CAA Jet Circulation



From Lang and Martin (2010)

0600 25 December Conclusions

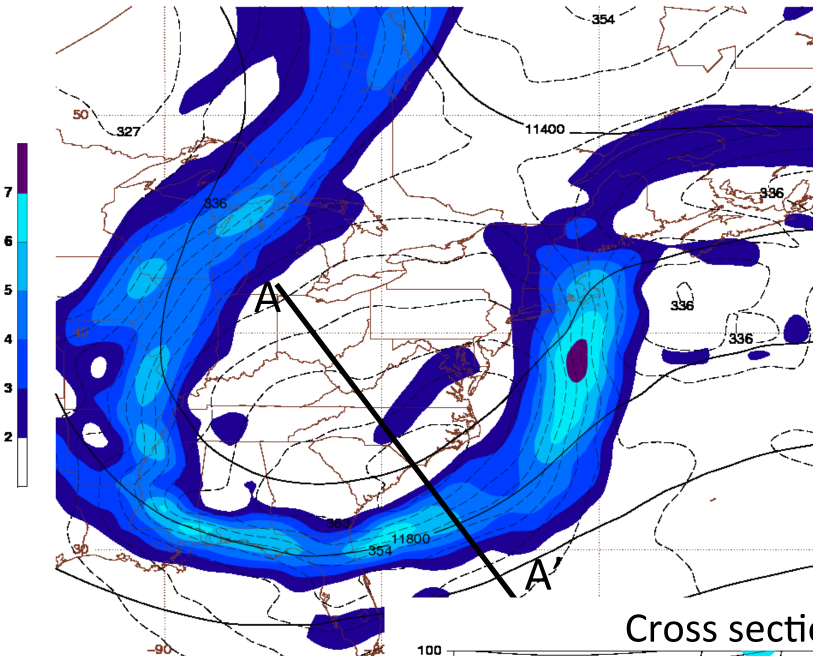
- The ULJF system and associated subsidence are amplifying the vorticity in the trough
- Increased slope of the tropopause leads to a more intense jet streak
- The ULJF circulations and amplification of the northern trough are associated with the merger of the shortwave trough to the south

0000 UTC 27 December 2010

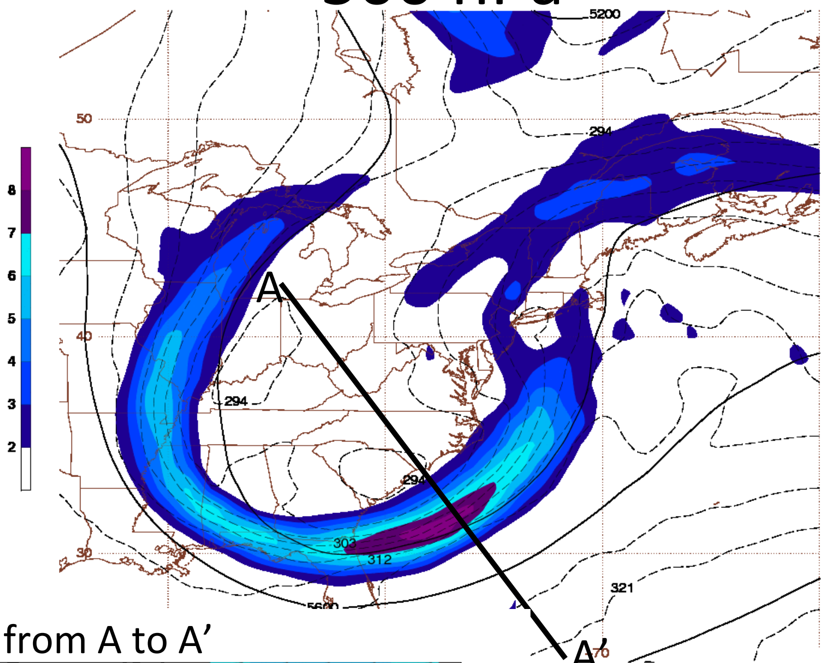
0000 UTC 27 December 2010

Front 2

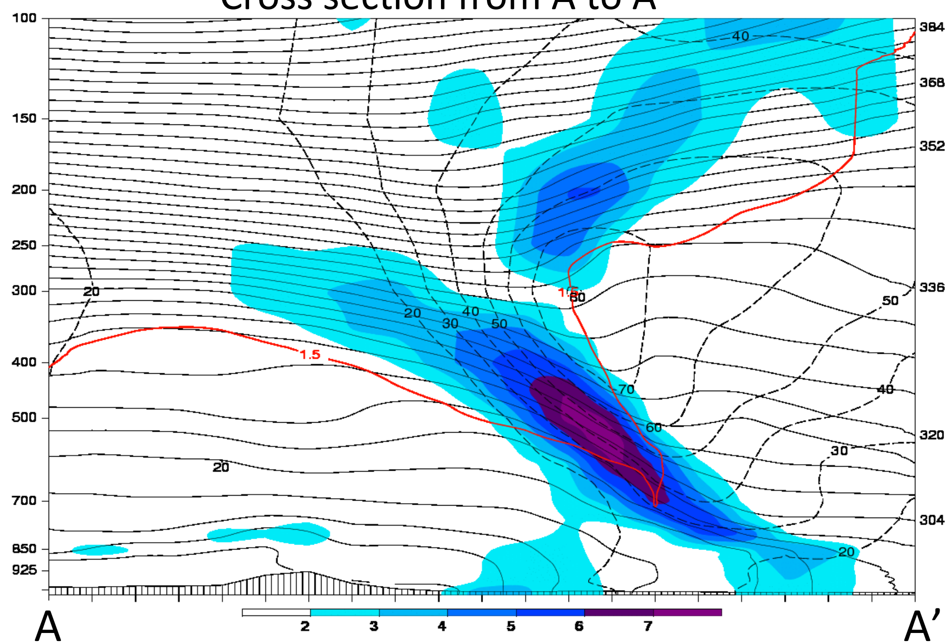
200 hPa



500 hPa



Cross section from A to A’



Theta [solid lines]

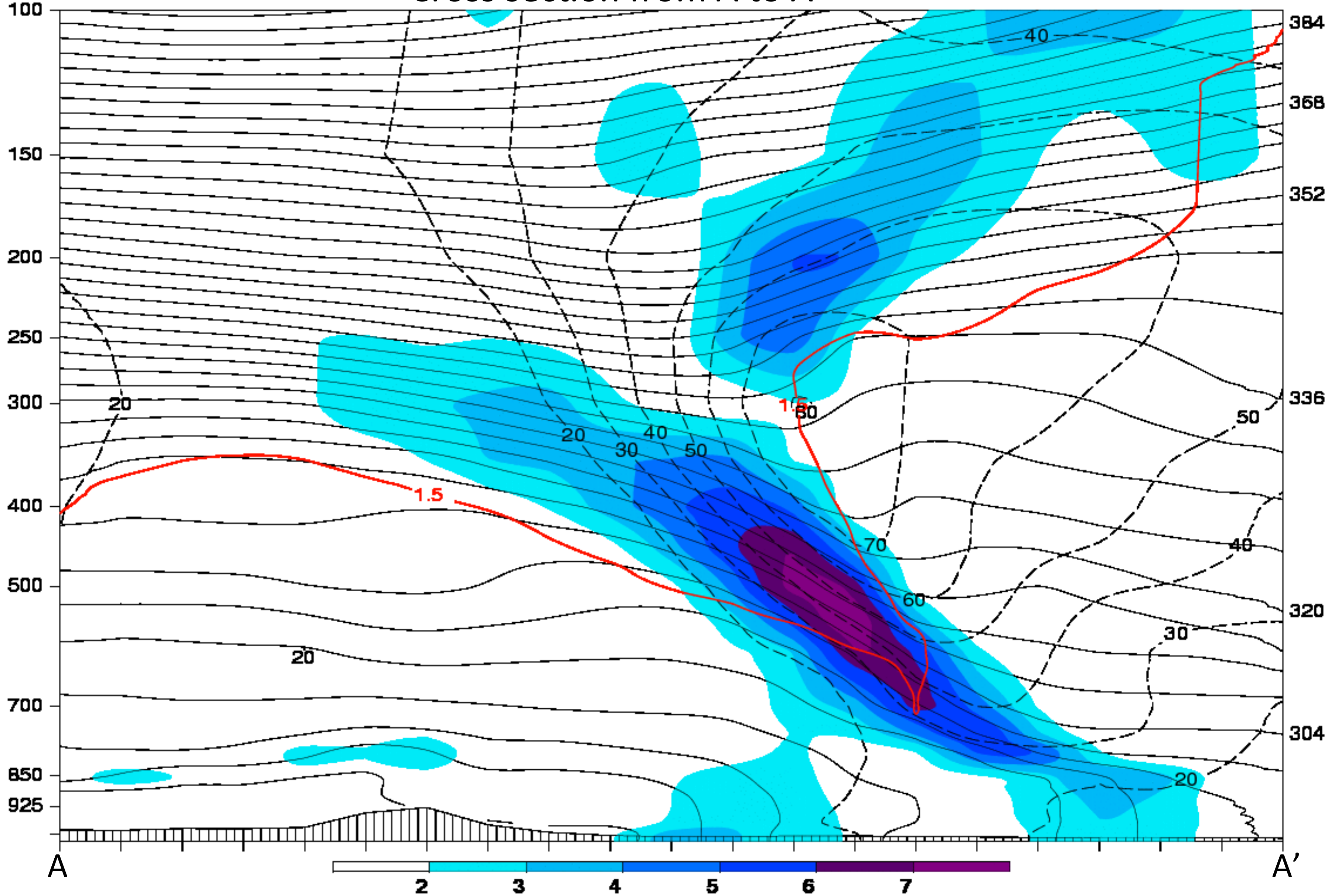
Magnitude of the wind every 10 m/s starting at 20 m/s [dashed]

Magnitude of the theta gradient every 1K (100 km)$^{-1}$ starting at 2 K (100 km)$^{-1}$ [shaded]

1.5 PVU [red line]

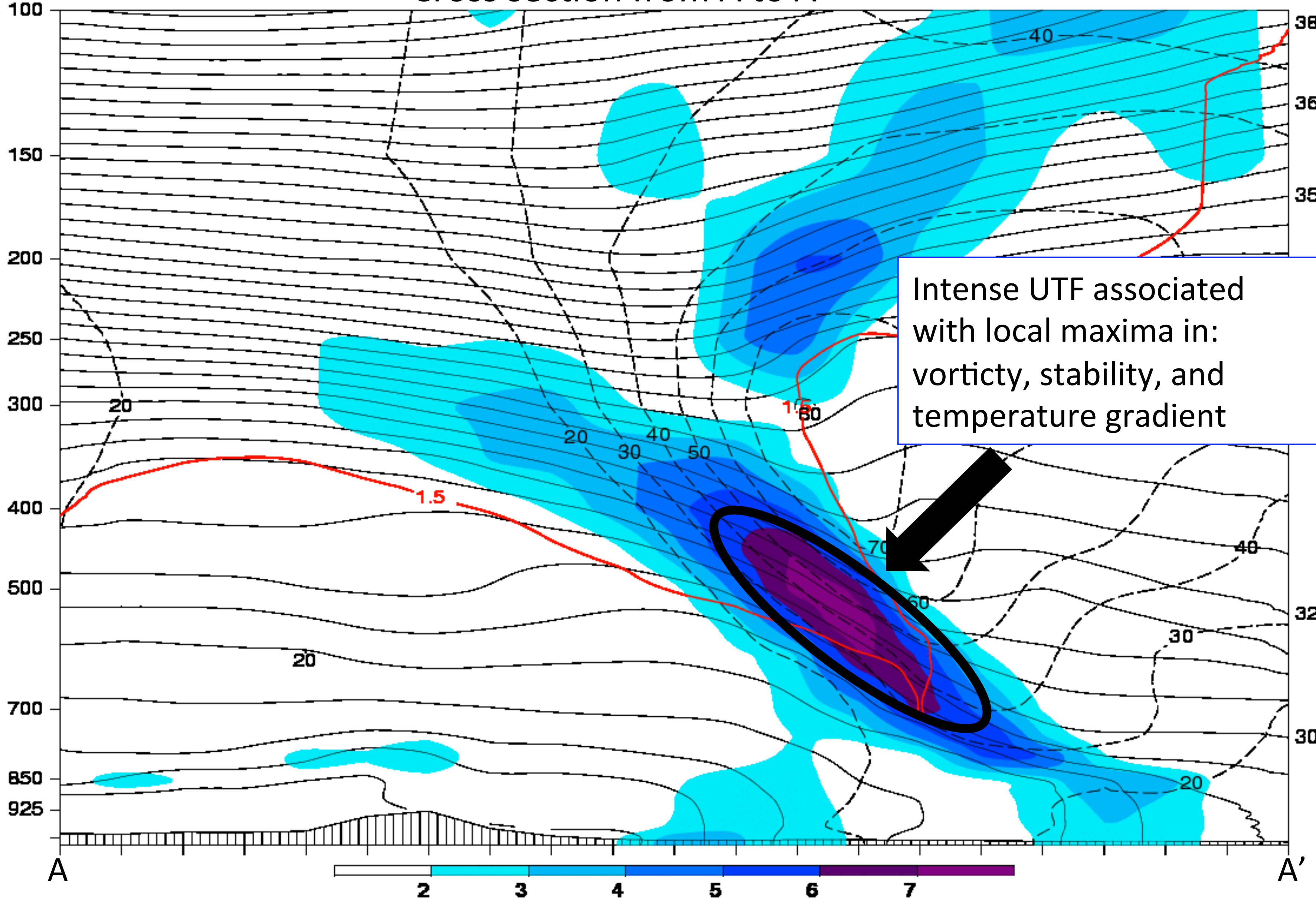
0000 UTC 27 December 2010

Cross section from A to A’



0000 UTC 27 December 2010

Cross section from A to A'



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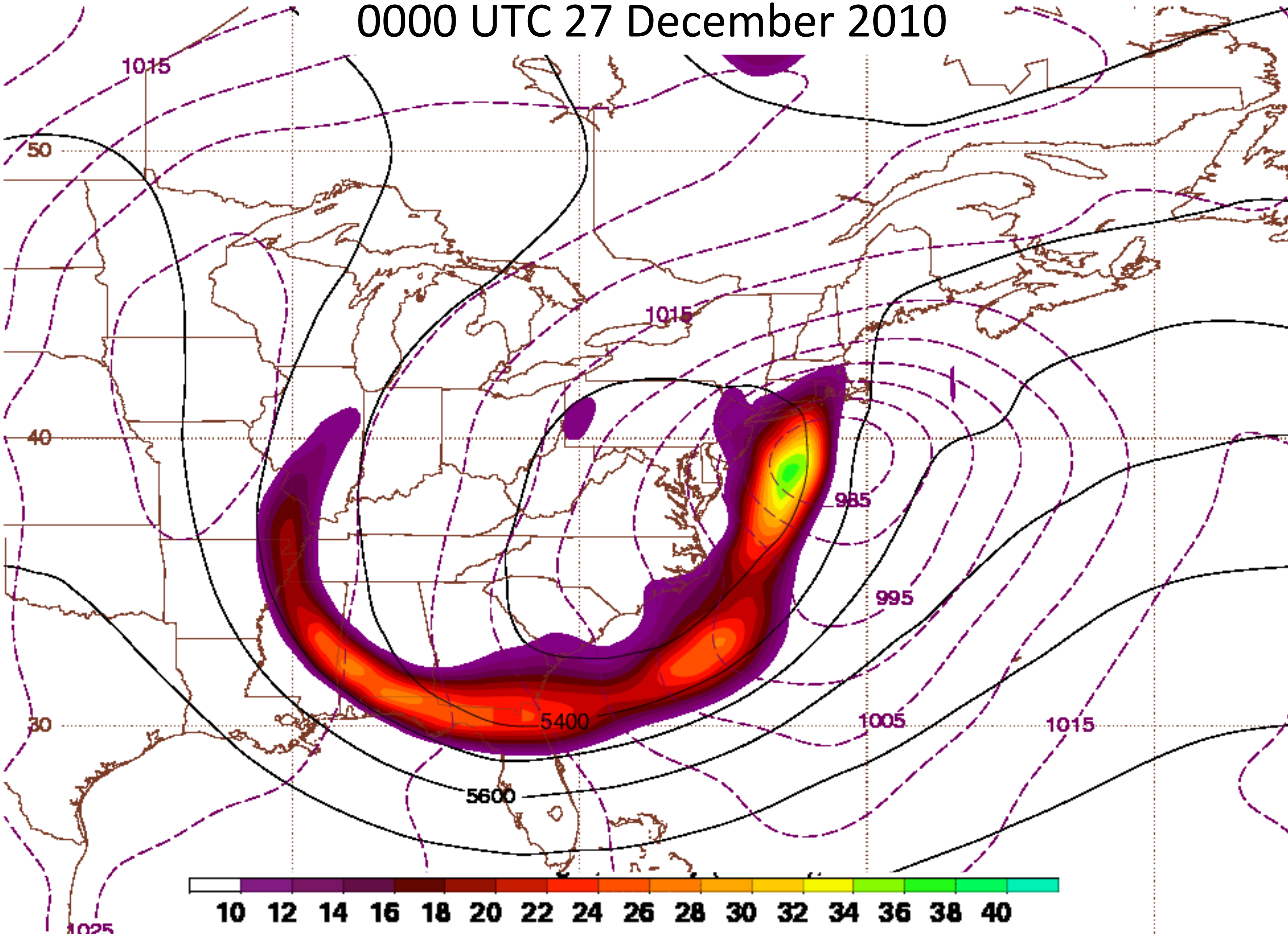

500 hPa Geopotential Height contoured every 100 meters [solid contours]
Sea Level Pressure every 5 hPa [dashed]
Vorticity every 2 x 10^{-5} s^{-1} starting at 10 x 10^{-5} s^{-1} [shaded]

Forcings for Ascent above Surface Cyclone

1. Divergence of ageostrophic wind (downstream of trough axis)

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    2. Shear Vorticity
    3. Upper tropospheric frontogenesis

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} Positive Vorticity Advection downstream of trough → Strong Ascent

Forcings for Ascent above Surface Cyclone

1. Divergence of ageostrophic wind (downstream of trough axis)

Deep Surface Cyclone!

1. Curvature Vorticity
2. Shear Vorticity
3. Upper tropospheric frontogenesis

} Positive Vorticity Advection downstream of trough → Strong Ascent

0000 27 December Conclusions

- High PV air is being brought into the troposphere from the stratosphere
- High vorticity in the location of the UTF →
  large vorticity advection → increase strength of the surface cyclone

Conclusions

- Upper level fronts significantly influence the strength and location of the jet streaks (thermal wind)
- The tropopause fold associated with the UTF gives high PV stratospheric air a pathway into the troposphere
- High PV $\longrightarrow$ high vorticity $\longrightarrow$ large vorticity advection $\longrightarrow$ significant ascent $\longrightarrow$ deepening of cyclone

Future Work

- Better understand ULJF systems, specifically LSFs
- How frontogensis of LSFs influences ULJF systems
- Create a climatology of LSFs during North American winters