Upper-Level Fronts

Atmos 5210/6210

Synoptic–Dynamic Meteorology II

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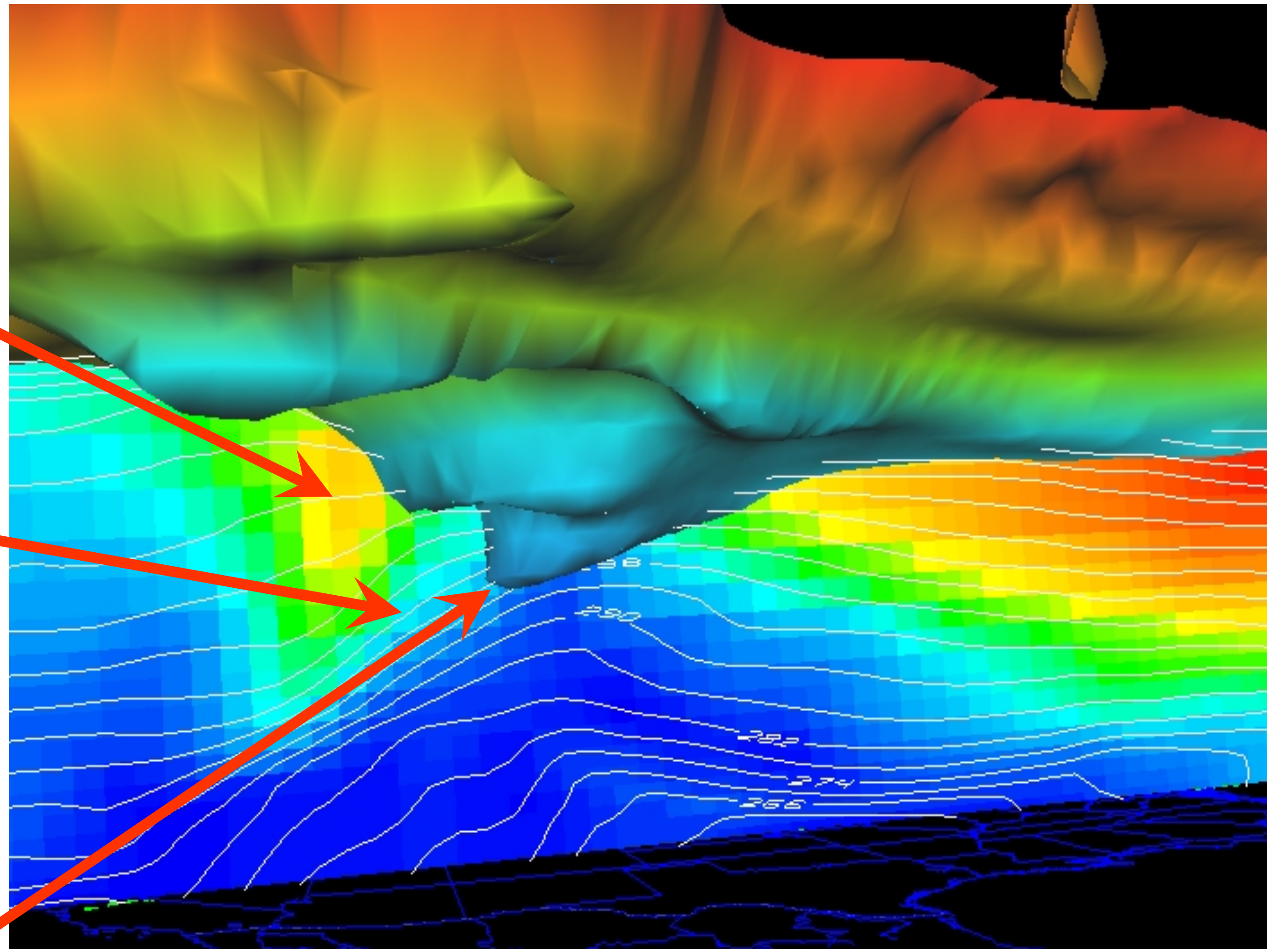
What Is an Upper-Level Front?

- A zone of strong quasihorizontal temperature gradient and high static stability in the middle and upper troposphere which does not necessarily extend to the surface

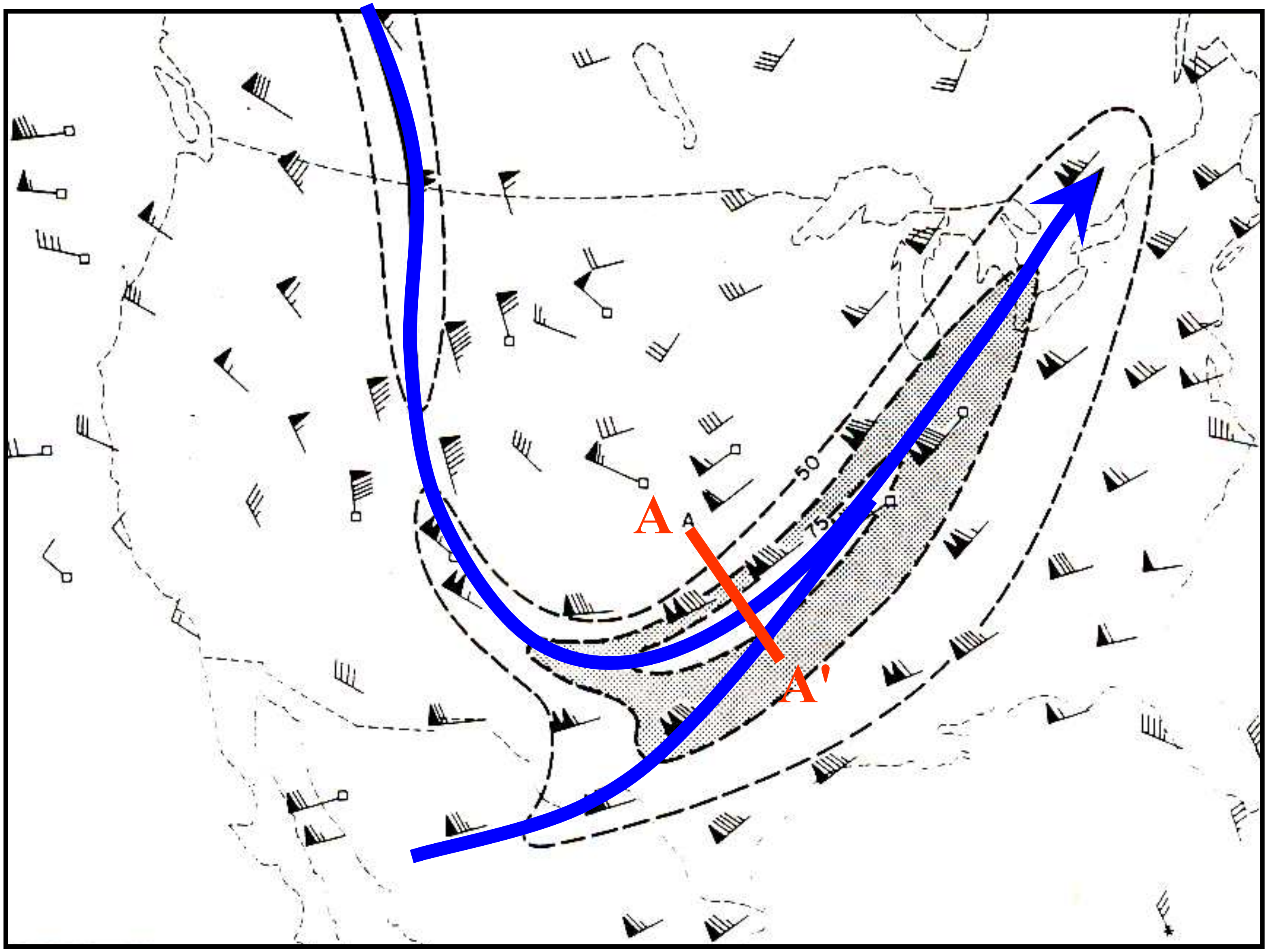
- Not called "cold" or "warm" since the isentropes are typically aligned along the flow

- Why care?
  - Clear-air turbulence (CAT)
  - Stratospheric–tropospheric exchange
  - Develop concurrently with upper-level jets, troughs, and tropopause folds

Upper Level Fronts, Jets, and the Tropopause

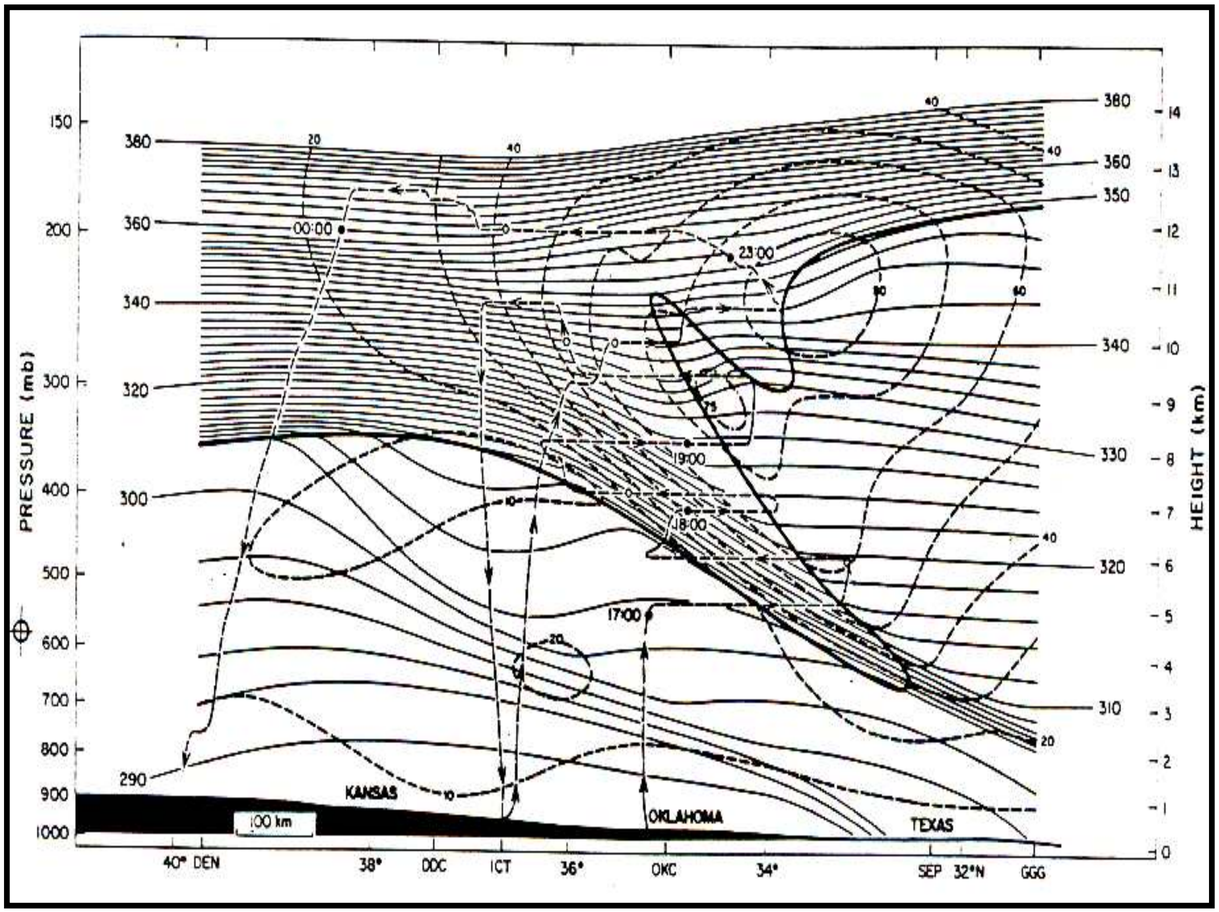


Example



Source: Shapiro (1983)

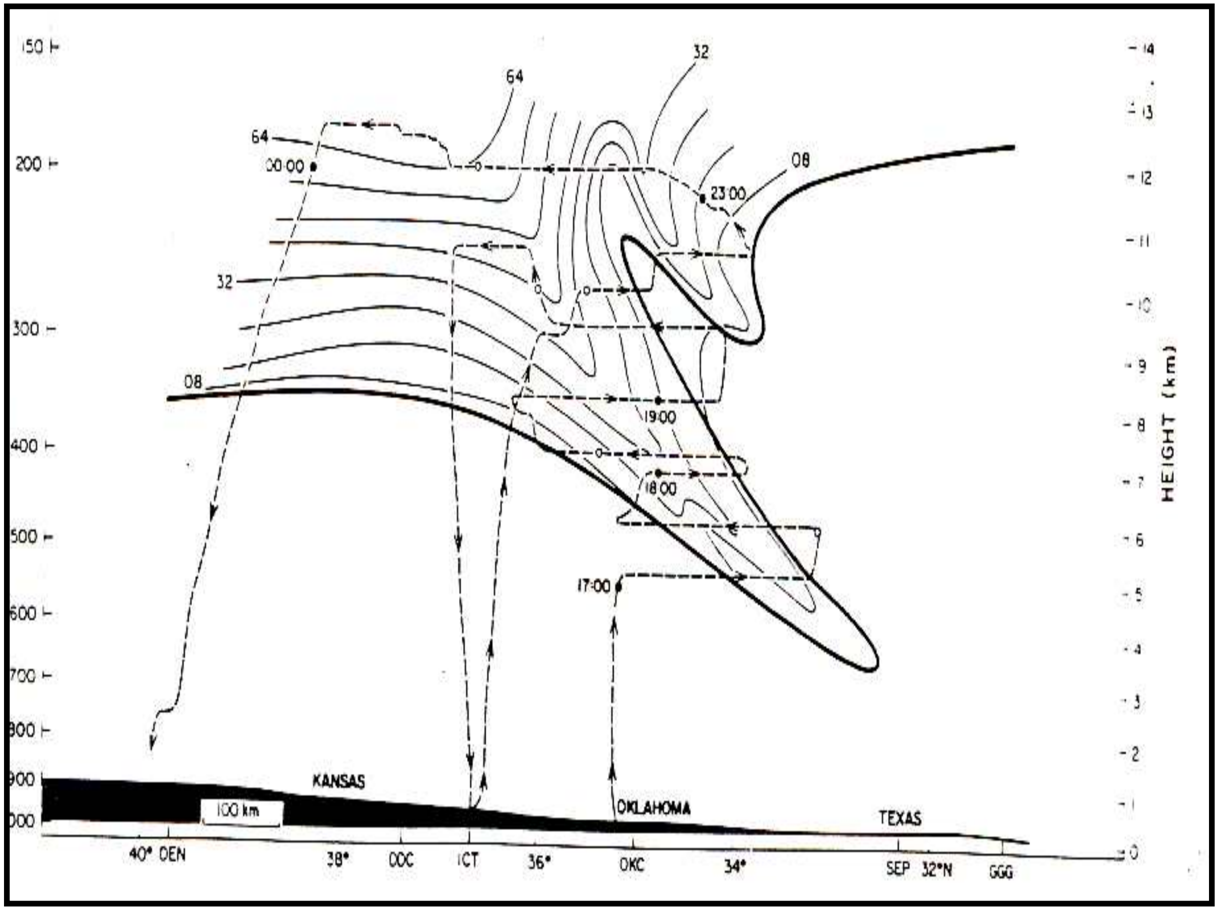
Example



- Vertical wind shear = 30 m s^{-1} (100 mb)$^{-1}$
- Horizontal shear = 35 s^{-1} (100 km)$^{-1}$
- Two jet cores
  - Polar jet ~300 hPa
  - Subtropical ~250 hPa
- Folded trop beneath both jet cores – produced by secondary circulation

Source: Shapiro (1983)

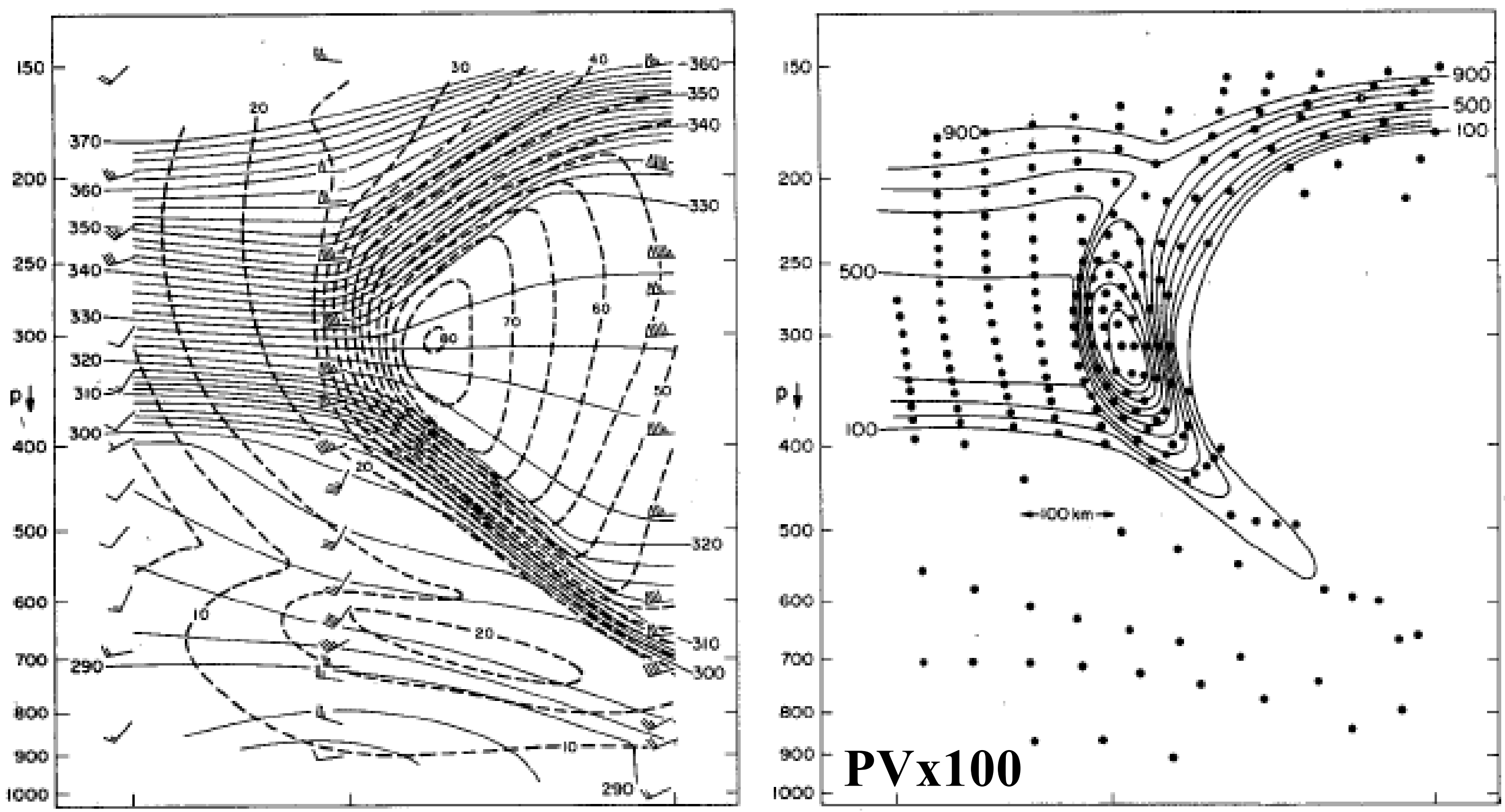
Example



- Ozone concentrations illustrate folding of stratospheric air to mid levels

Source: Shapiro (1983)

Another Example



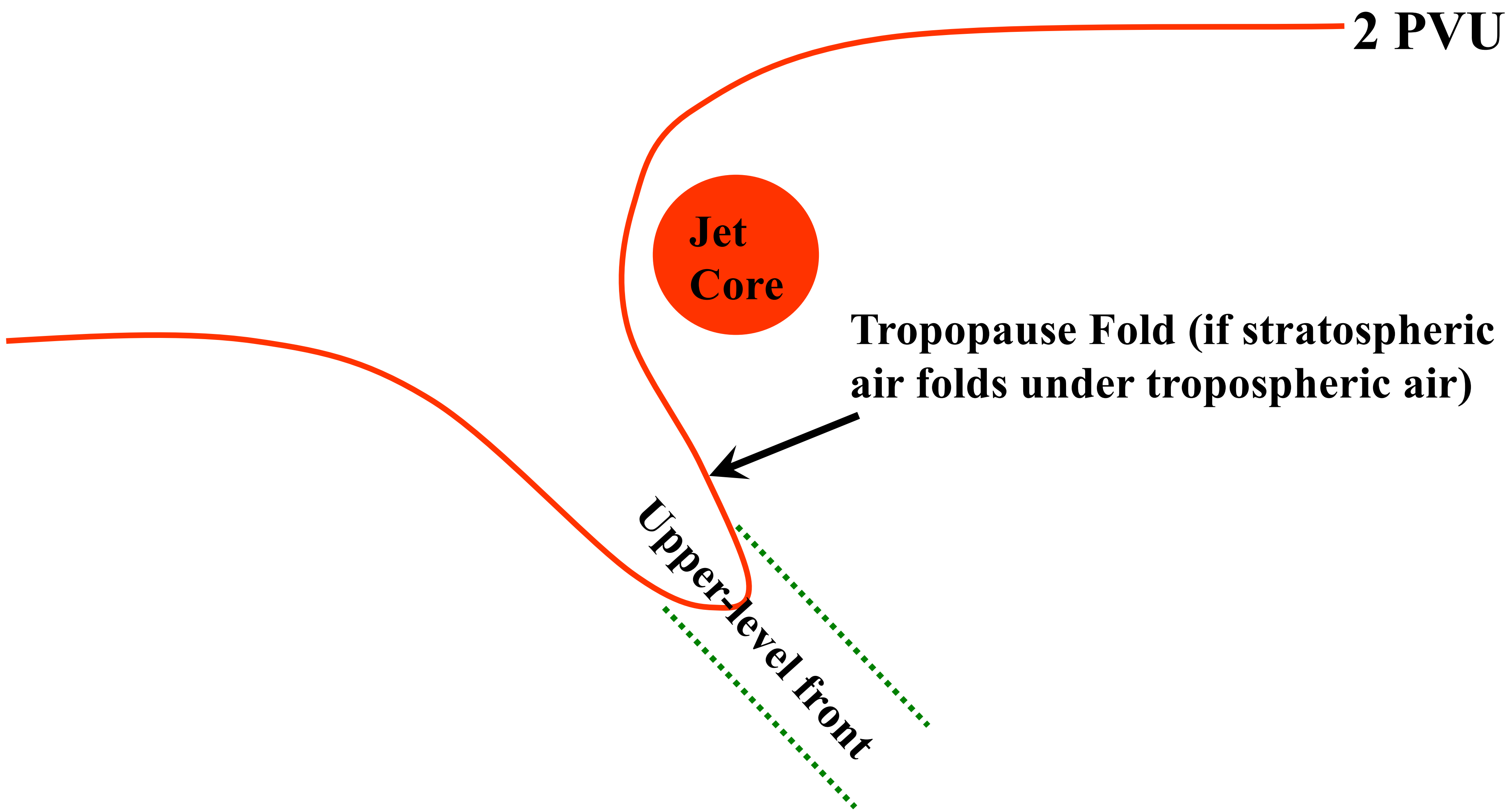
- Single jet core, but similar horizontal and vertical shear
- Strong gradient in rop height (2 PVU) across jet core

Source: Shapiro (1981)

Key Characteristics

- Strong horizontal and vertical wind shear, particularly below and on the cyclonic side of the jet core
- Clear-air turbulence (CAT) arising from shear
- Tropopause steeply sloped on cyclonic side of jet and folded beneath jet core
  - Large gradient in dynamic tropopause height across jet core

Conceptual Model



Development Mechanisms

- If y is positive toward the cold air, frontogenesis is given mathematically as

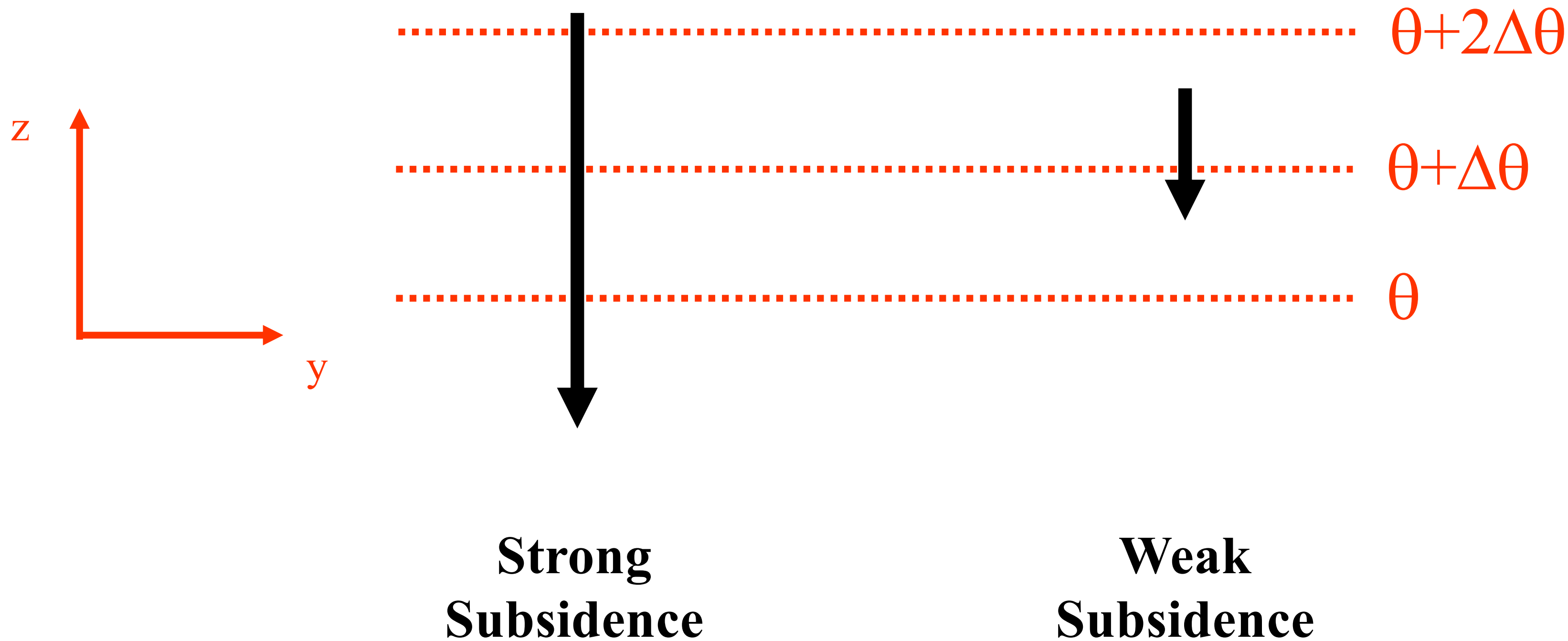
$$Fr = \frac{D}{DT}|\nabla_2\theta| = \frac{\partial\theta/\partial y}{|\partial\theta/\partial y|}\left[\underbrace{\frac{\partial}{\partial y}\left(\frac{D\theta}{Dt}\right)}_{\text{Differential diabatic heating/cooling}} - \underbrace{\frac{\partial\theta}{\partial y}\frac{\partial v}{\partial y}}_{\text{Confluence}} - \underbrace{\frac{\partial\theta}{\partial z}\frac{\partial w}{\partial y}}_{\text{Tilting}}\right]$$

- In northwesterly large-scale flow, upper-level frontogenesis is initiated by horizontal variations in subsidence (i.e., the tilting term)

Tilting Term

- Differential vertical motion tilts a vertically oriented potential temperature gradient into the horizontal

$$Fr = \frac{D}{DT}|\nabla_2\theta| = -\left[-\frac{\partial\theta}{\partial z}\frac{\partial w}{\partial y}\right]$$



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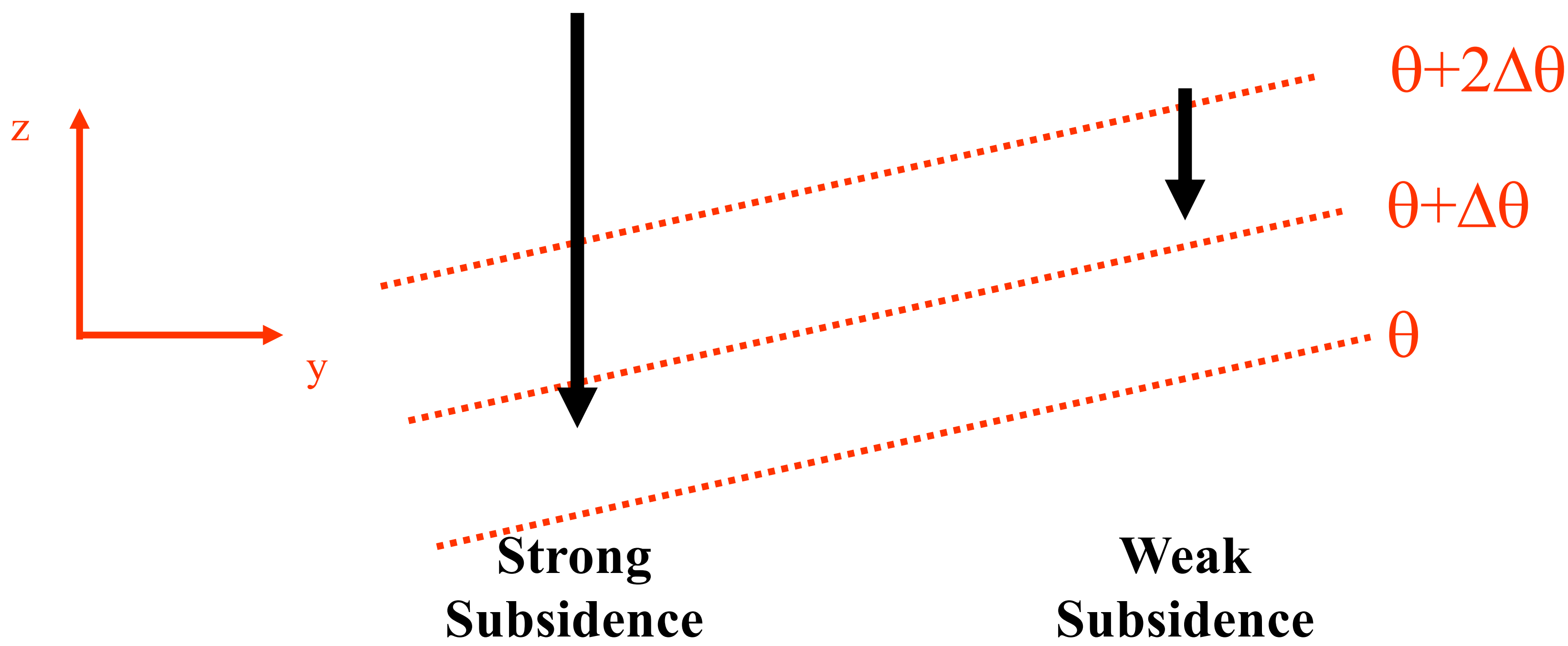
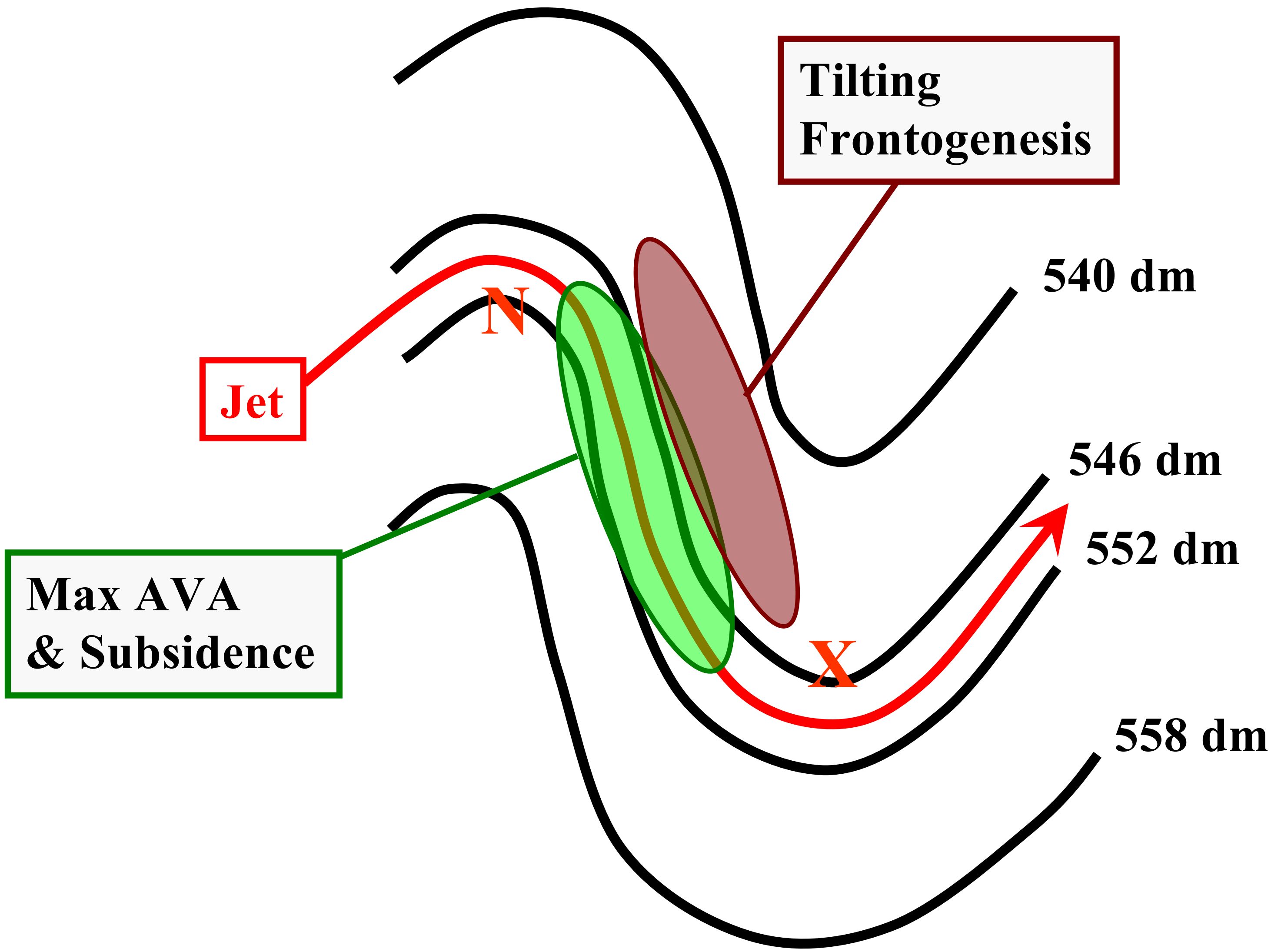
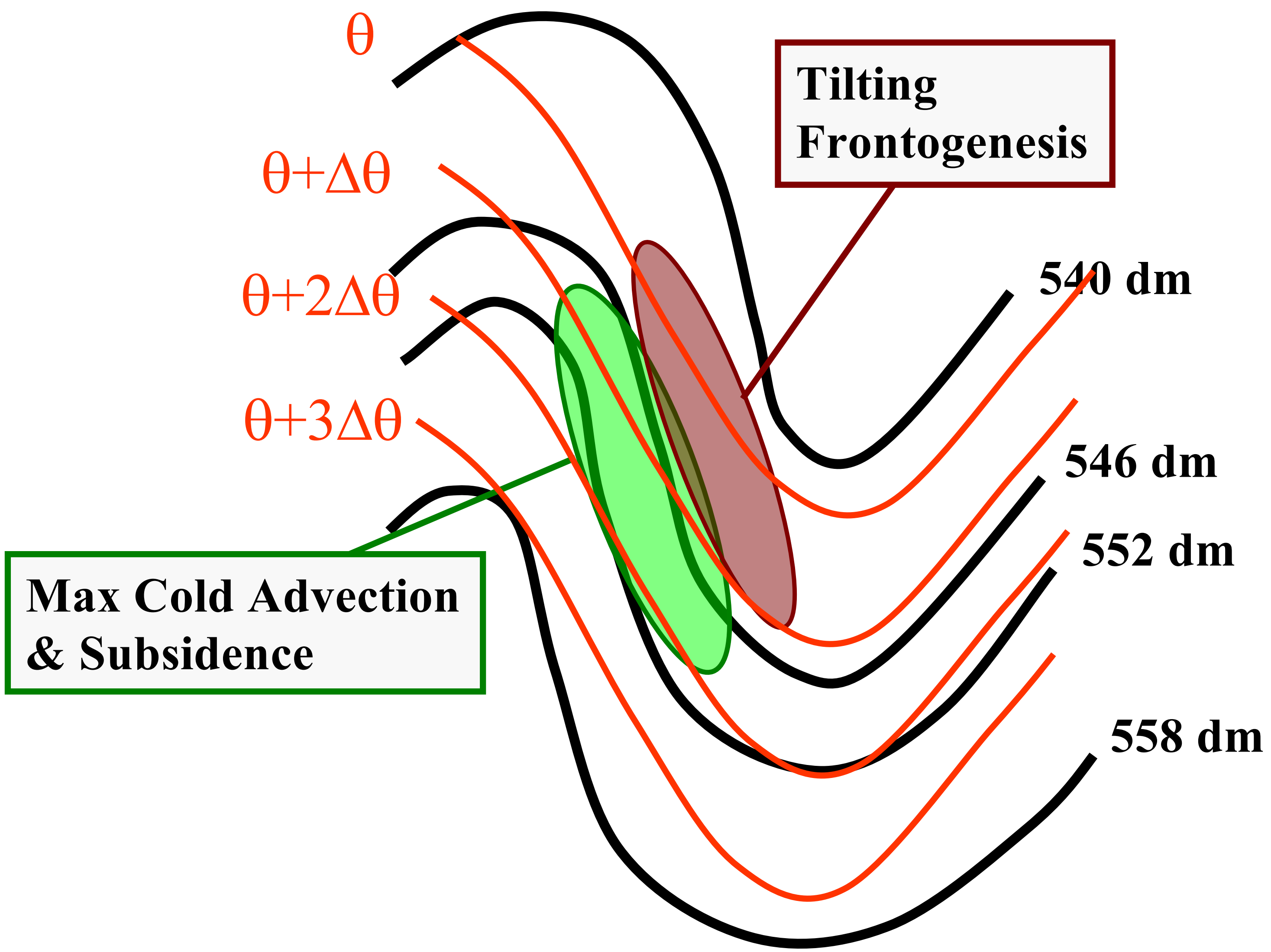


Vorticity Advection Example



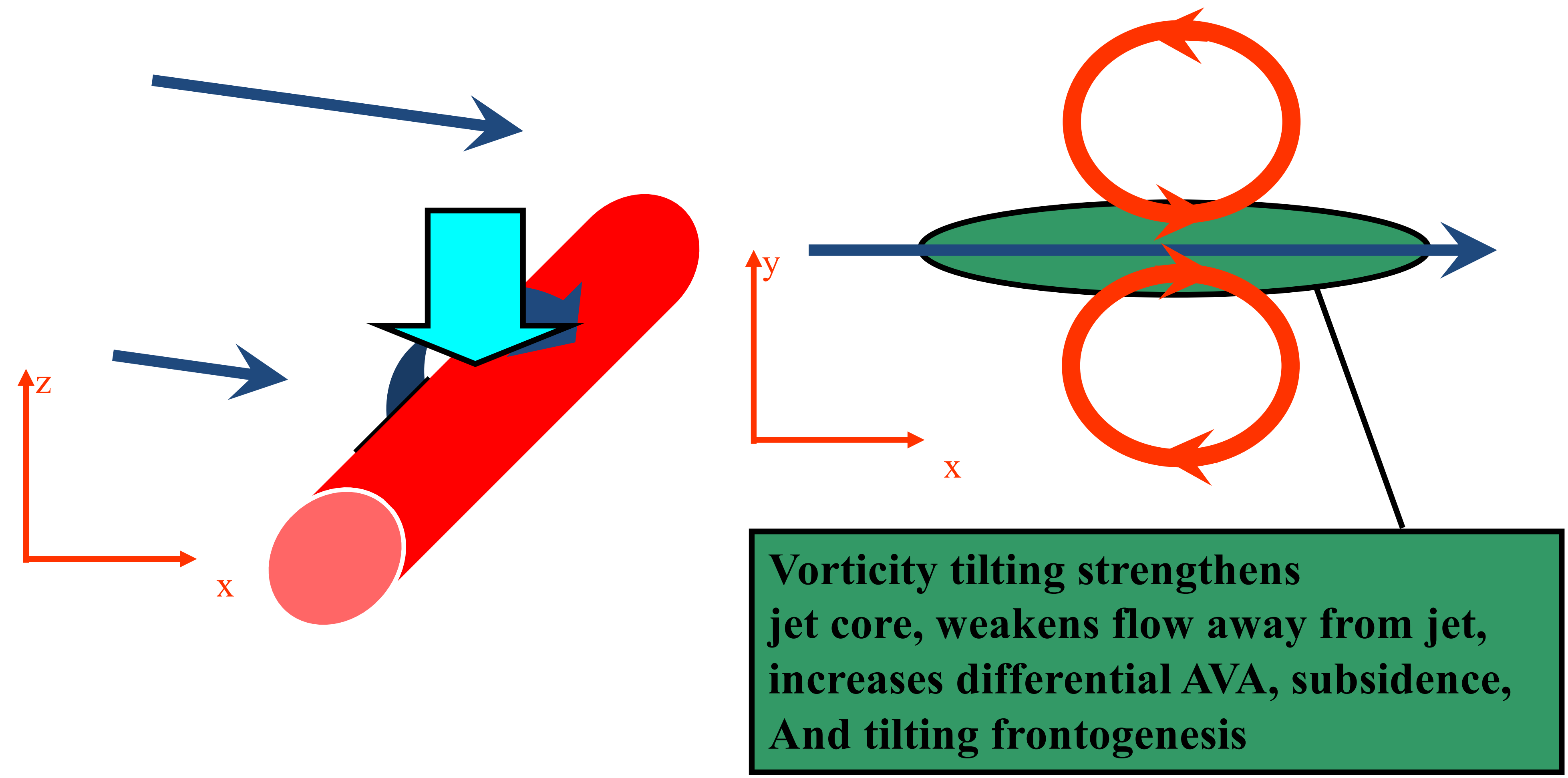
Downstream of a ridge on the cyclonic side of a jet

Temperature Advection Example



Downstream of a ridge on the cyclonic side of a jet

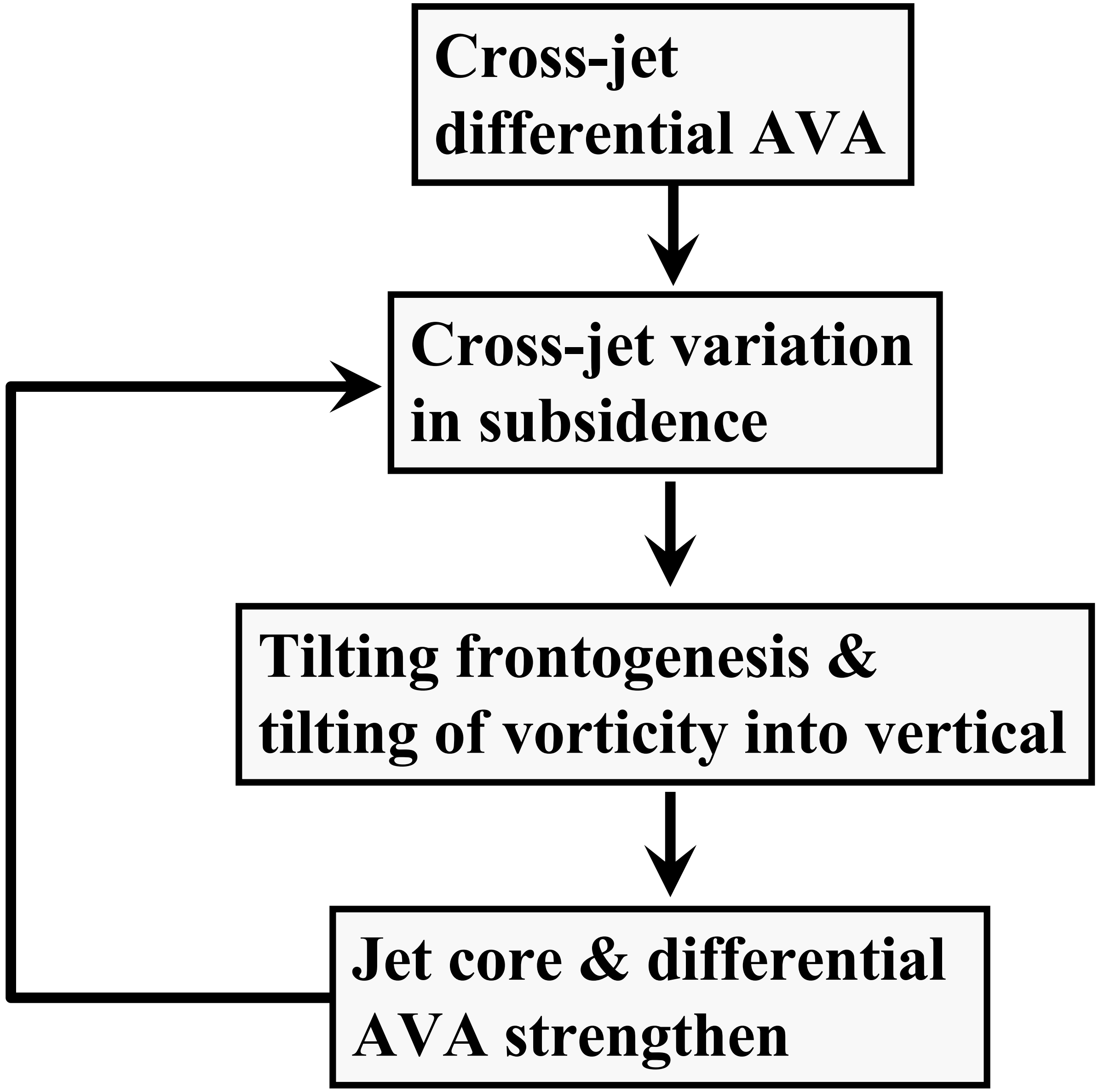
Feedback Mechanism



Vorticity associated with vertical wind shear is tilted into the vertical by differential subsidence, intensifying jet, AVA, and tilting frontogenesis

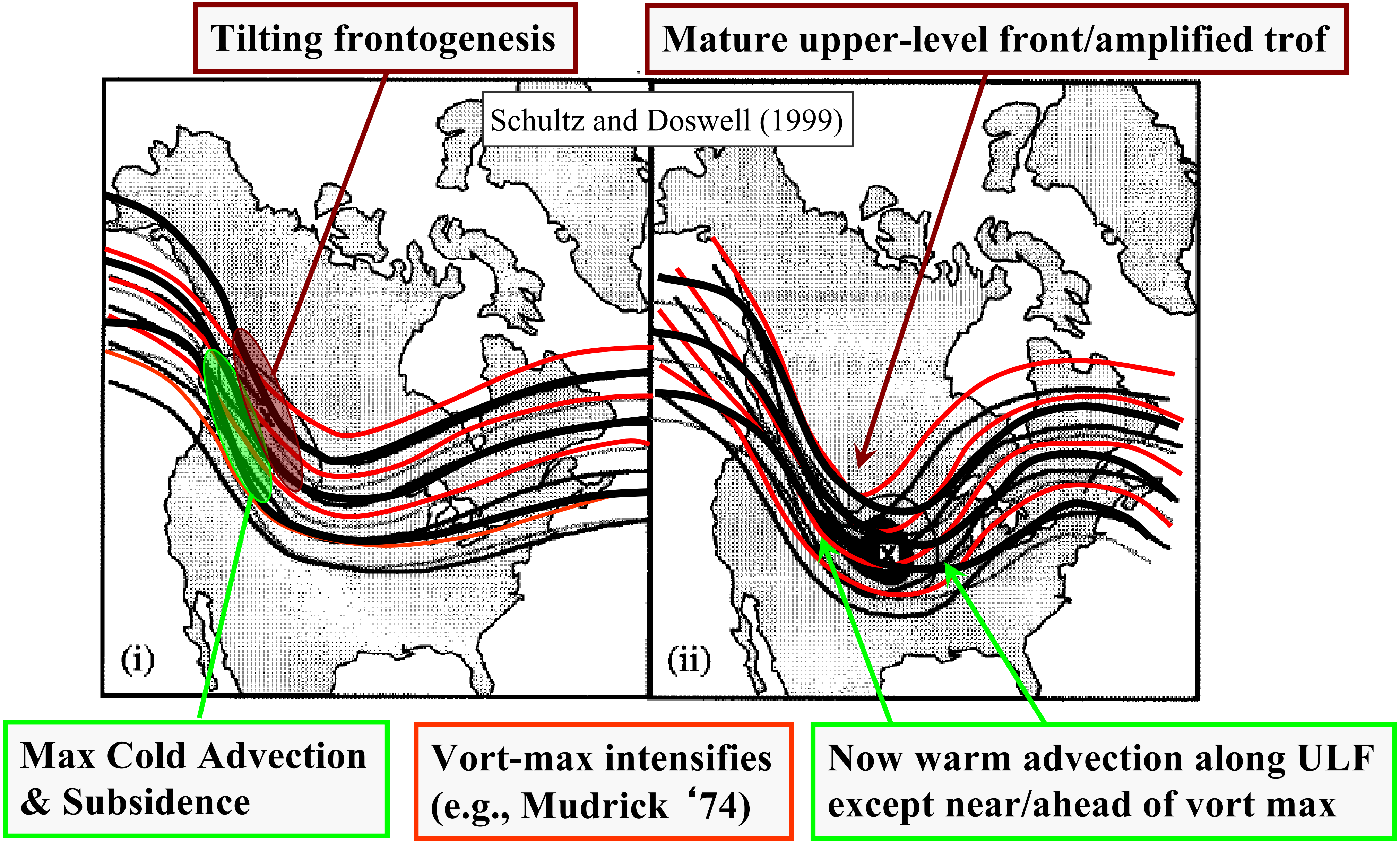
Source: Mudrick (1974)

Feedback Mechanism



Source: Mudrick (1974), Bluestein (1993)

Conceptual Model



Class Activity

- Open the IDV Bundle Bundles -> Real-Time-WX -> Diagnostics -> PV-Thinking

- Locate an upper-level front

- Orient vertical cross sections so they are normal to the front

- Identify the following features in the cross section
  - Upper-level front
    - Identify both the strong potential temperature gradient and strong wind shear
    - Jet core
    - Tropopause fold

- How do these characteristics compare to the conceptual models and examples provided in this talk?