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.

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.

Example

- Ozone concentrations illustrate folding of stratospheric air to mid levels.
Another Example

• Single jet core, but similar horizontal and vertical shear
• Strong gradient in trop 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

Jet Core
Tropopause Fold (if stratospheric air folds under tropospheric air)

Development Mechanisms

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

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

Tilting Term

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

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Vorticity Advection Example

Temperature Advection Example

Feedback Mechanism

Feedback Mechanism

Conceptual Model

Source: Mudrick (1974)

Feedback Mechanism


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

Jet core & differential AVA strengthen

Schultz and Doswell (1999)