The polar summer Tropopause Inversion Layer

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The tropopause inversion layer (TIL) Birner, 2002, 2006 JGR

average vertical structure from *high-resolution* radiosondes near 45° N, calculated using ground-based and tropopause-based coordinates.
examples using GPS data in tropopause-based coordinate

- **temp**
- **stability**

- height relative to tropopause

layer of high stability
Climatology of TIL from GPS data

N² in tropopause coordinates

DJF

summer polar maximum

JJA

Randel et al, JAS, 2007
The polar summer tropopause inversion layer

Radiosonde at Eureka (80° N)

- Persistent feature, observed in almost all profiles during summer in both hemispheres (why?)
- Important for understanding dynamical (and chemical) coupling between troposphere and stratosphere
Radiosondes and nearby COSMIC soundings

COSMIC allows ~100 times more observations than radiosondes, to study space-time variability of inversion layer
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Strength of polar tropopause inversion

\[ T(z_{trop} + 2\text{km}) - T(z_{trop}) \]

Daily data from COSMIC, average over polar cap

*COSMIC 70° - 90° N*

*COSMIC 70° - 90° S*

Arctic

Antarctic

Summer maximum
Latitudinal structure of summer inversion

$T(z_{trop} + 2\text{km}) - T(z_{trop})$
Synoptic scale modulation of polar tropopause height and inversion strength

GPS soundings and 200 hPa vorticity

Distribution of polar vorticity
Synoptic scale modulation of polar tropopause height and inversion strength

**Result:** dynamics modulates inversion strength: stronger for anti-cyclones; weaker for cyclones
Balanced dynamical structure (Hoskins et al. 1985)

**Cyclonic**

- Strong stability (inversion layer)
- High tropopause
- Warm

**Anti-cyclonic**

- Low tropopause
- Cold
- Warm
What causes the strong polar inversion layer?

Radiative cooling due to water vapor

Observed water vapor profile in tropopause coordinates

Imposed changes

Midlatitude calculations from Randel et al 2007
Polar water vapor measurements from ACE-FTS satellite

Seasonal cycle near tropopause

ACE 55N–90N  8.5km

Seasonal vertical profiles

ACE 55N–90N

- DJF
- MAM
- JJA
- SON

Summer maximum
Radiative response to UTLS water vapor

Fixed Dynamical Heating calculations

ACE water vapor (input to calculation)

Enhanced water vapor leads to strong cooling near tropopause

Not shown: seasonal ozone changes have small radiative impact
**Key points:**

- Tropopause Inversion Layer is a ubiquitous global feature.

- Strongest TIL observed in polar summer stratosphere, with similar behavior in both hemispheres. Average inversion > 8 K.

- (relatively small) modulation by synoptic variability

- Large polar summer maximum in $H_2O$ near tropopause is a likely explanation.