The polar summer Tropopause Inversion Layer

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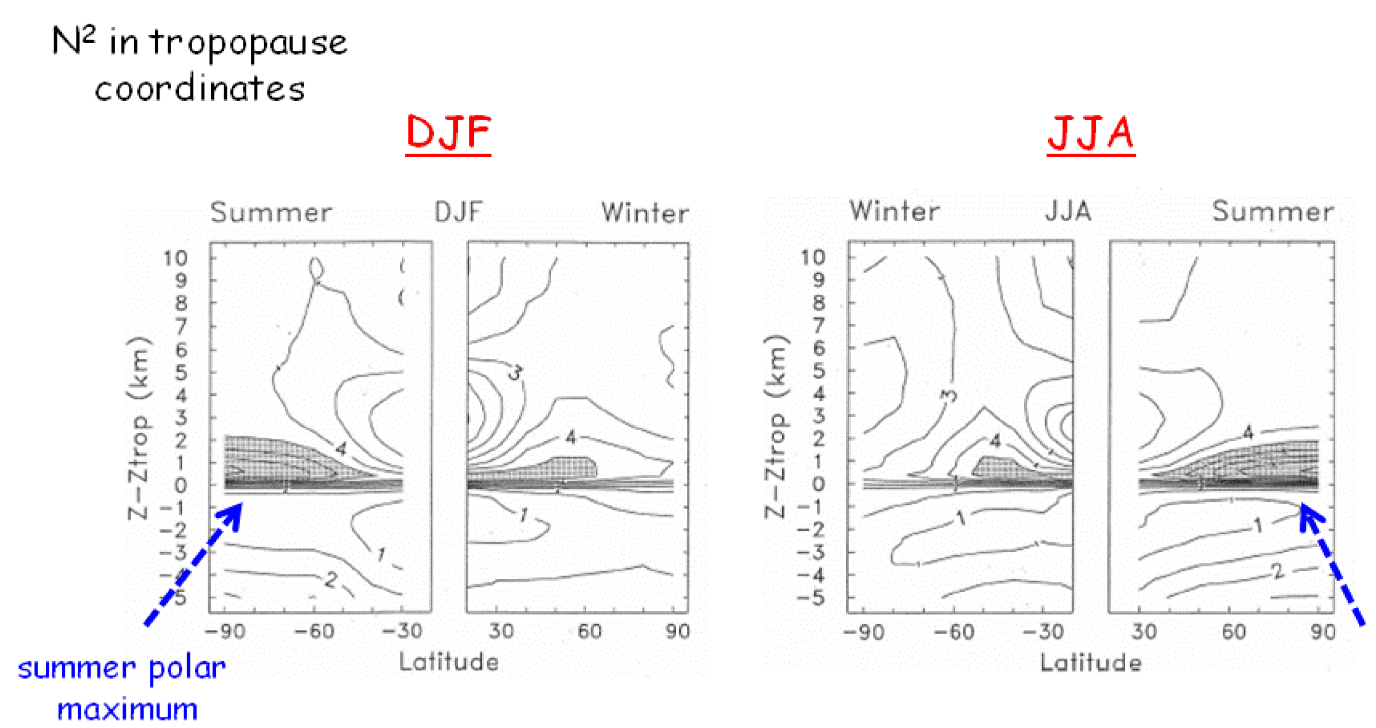
Introduction

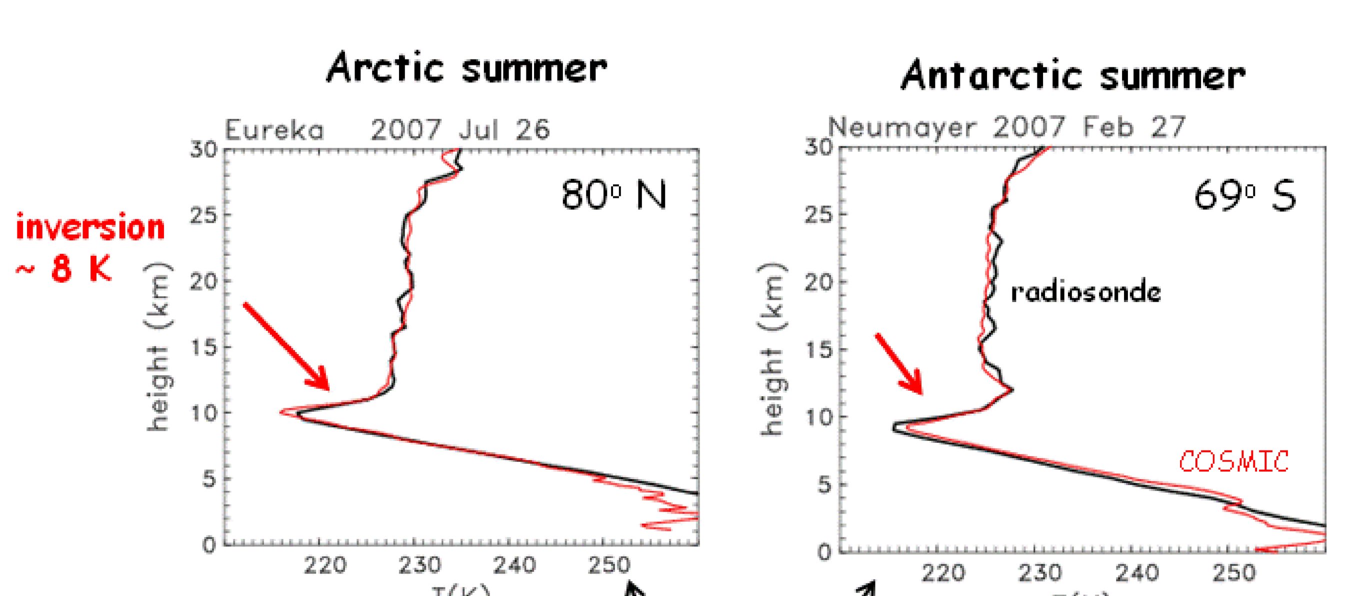
The tropopause inversion layer (TIL) refers to a region of enhanced static stability above the extratropical tropopause, associated with a small temperature inversion. Birner (2002, 2006) discovered the TIL using high resolution radiosonde data organized in tropopause coordinates. GPS radio occultation measurements show that the TIL is a global phenomenon, and also reveal that the strongest inversion layer is observed in the summer polar regions (Randel et al, 2007; Grise et al, 2009)

Climatology of TIL from GPS data



Climatology of static stability in tropopause-relative coordinates derived from GPS data (Randel et al, 2007). High values (shaded) denote the tropopause inversion layer. Note the strongest maxima over the summer poles.

Examples of polar tropopause inversions from radiosondes and nearby COSMIC soundings

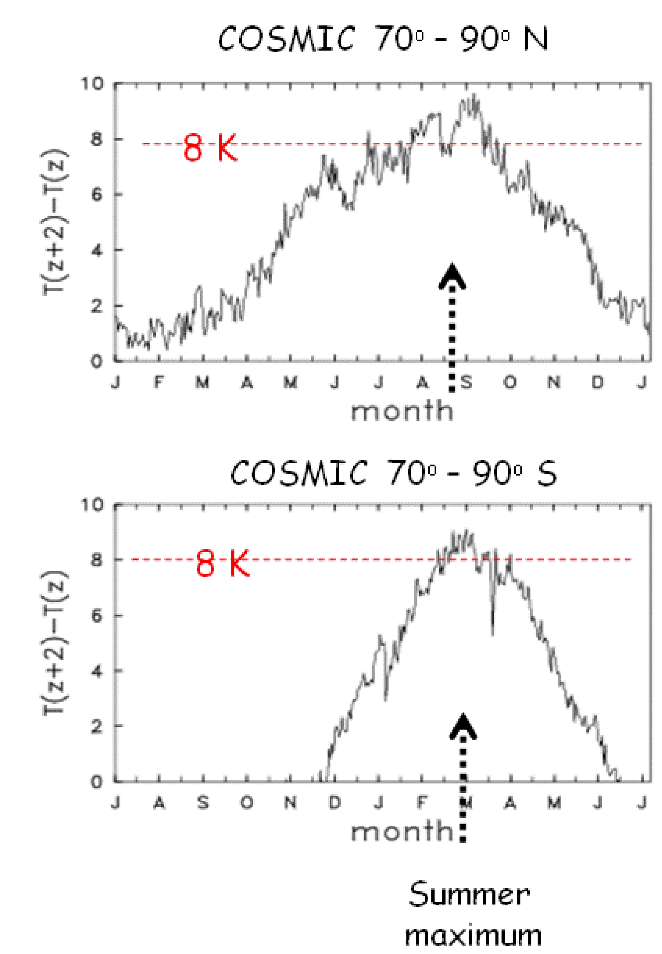


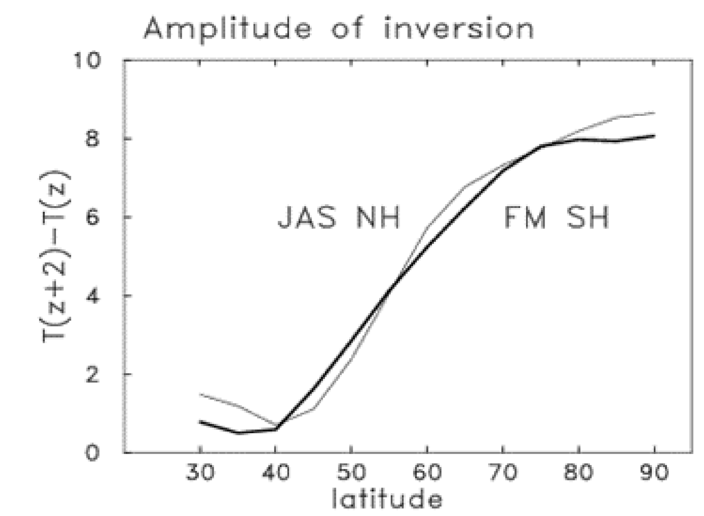
Seasonal behavior of polar tropopause inversion

$T(z_{trop} + 2km) - T(z_{trop})$

Daily data from COSMIC, average over polar cap

Note the maximum in each hemisphere during summer



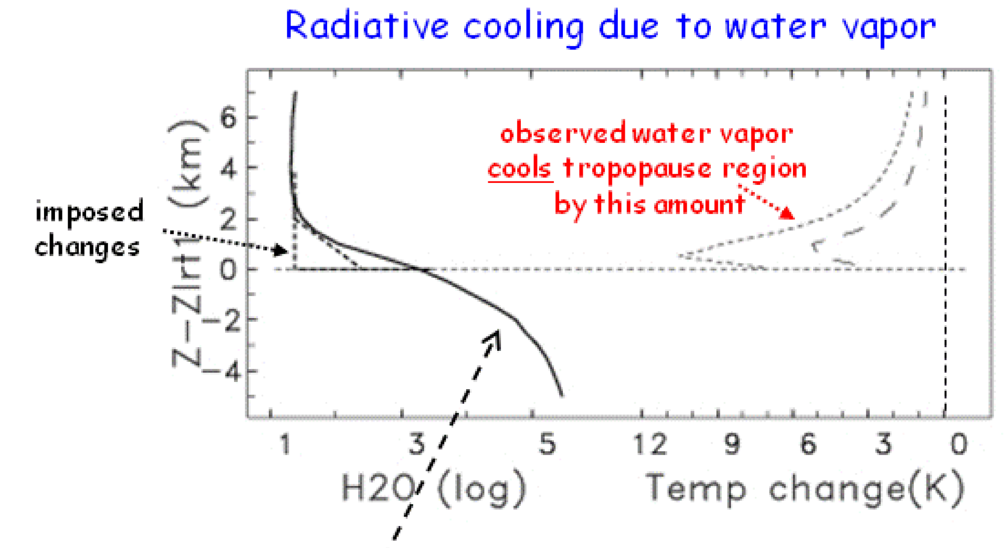


Amplitude of the tropopause temperature inversion as a function of latitude during summer in both hemispheres. The inversion is defined as $T(Z_{trop} + 2\ km) - T(Z_{trop})$.

What causes the strong polar inversion layer?

The forcing and maintenance of the TIL is a topic of ongoing research, and dynamical and radiative mechanisms have been proposed. The strong radiative cooling effects of water vapor near the tropopause are one potential mechanism.

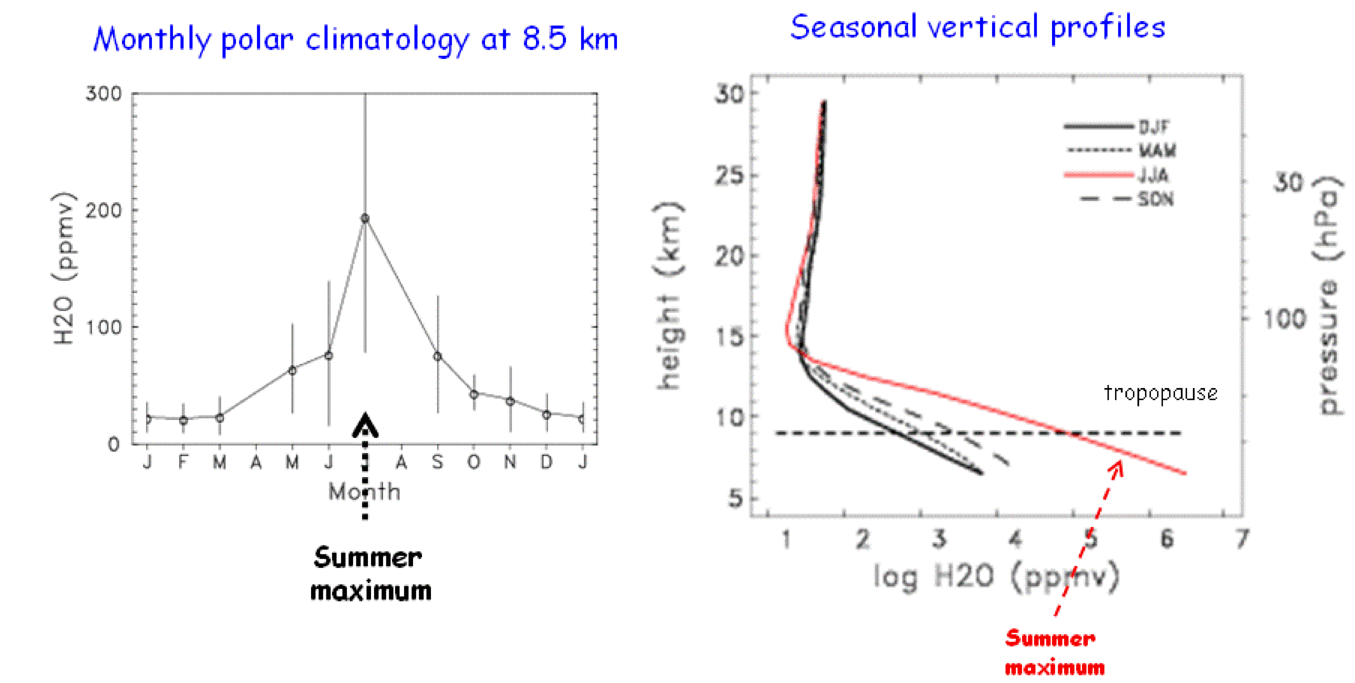
Radiative cooling due to water vapor



Midlatitude calculations from Randel et al 2007

observed water vapor profile (Boulder balloon measurements)

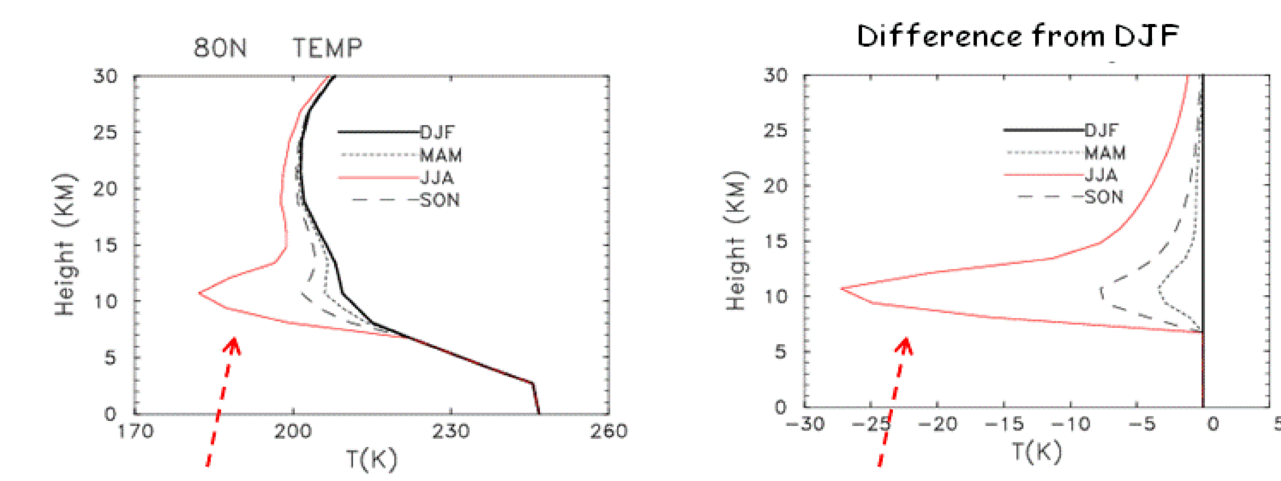
Climatology of polar water vapor from ACE-FTS measurements



Polar water vapor measurements from the ACE-FTS satellite show a large seasonal cycle, with maximum during summer (an order of magnitude increase compared to winter). This is primarily due to tropospheric temperature variations (the relative humidity is more constant over the year). Note that the water vapor variations extend into the lower stratosphere (the tropopause mixing layer, discussed using ACE-FTS data in Hegglin et al. 2009).

Radiative response to UTLS water vapor

Fixed Dynamical Heating (FDH) calculations



Enhanced water vapor leads to strong cooling near tropopause

Not shown: seasonal ozone changes have small radiative impact

These plots show the temperature response to seasonal water vapor variations derived from FDH calculations, using the ACE-FTS water vapor profiles as input. The summertime UTLS water vapor maximum gives strong cooling near the tropopause, resulting in a strong tropopause inversion.

Key points:

- The strongest tropopause inversion layer occurs during polar summer. It is a ubiquitous feature with similar characteristics in both hemispheres.
- There is a strong seasonal variation of water vapor in the polar UTLS, with a summer maximum. Radiative heating (FDH) calculations suggest water vapor contributes to strong cooling near the tropopause, and is a primary mechanism for the polar summer TIL.

References

Birner, T., 2006: Fine-scale structure of the extratropical tropopause region, *J. Geophys. Res.*, 111, D04104, doi:10.1029/2005JD006301.

Grise, K., D. Thompson and T. Birner, 2009: A global survey of static stability. J. Climate, submitted.

Hegglin, M. I., C. D. Boone, G. L. Manney, and K. A. Walker (2009), A global view of the extratropical tropopause transition layer from Atmospheric Chemistry Experiment Fourier Transform Spectrometer O3, H2O, and CO, J. Geophys. Res., 114, D00B11, doi:10.1029/2008JD009984.

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