Controls on the Extratropical Tropopause

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Introductions

• Birner et al. (2006) revealed the sharpness of the extratropical tropopause when tropopause-based averaging is used instead of ground-based one which tend to smear out this characteristics.

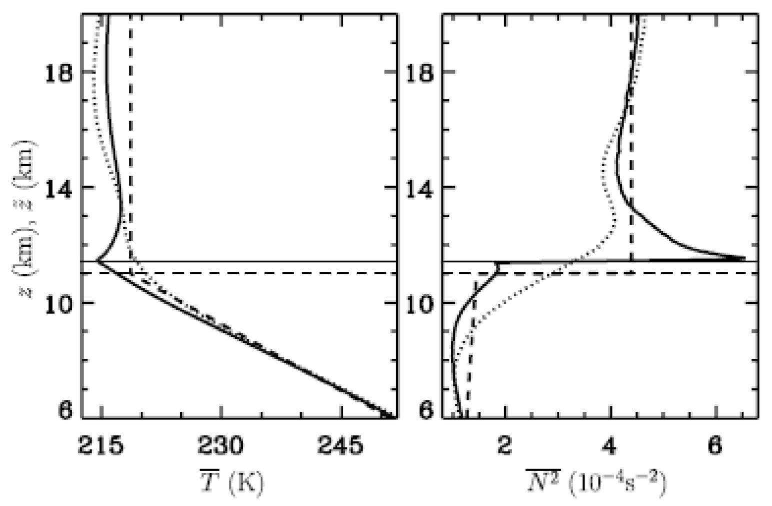


Figure 8. Averaged profiles representative of about 45°N of (left) temperature and (right) buoyancy frequency squared. All stations within the latitude range [41.5°N, 49°N] are included. Dotted lines indicate SLB average, solid lines indicate TB average, and dashed lines indicate profiles of the USSA at 45°N. Horizontal lines denote $\bar{z}_{TP}$.

• Bell and Geller (2008) proposed the idea of ESTL, defined as the vertical distance from the local maximum of N^2 at the tropopause to the local minimum in the stratosphere based on the stability profile, and showed latitudinal variations of ESTL depth for annually and seasonally averaged high-resolution radiosonde data.

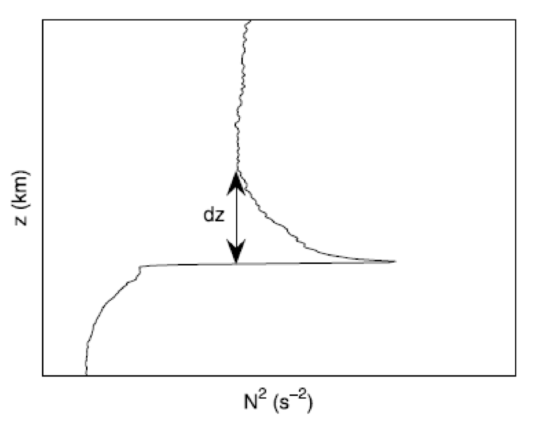


Figure 2. Schematic showing approximate depth of ESTL.

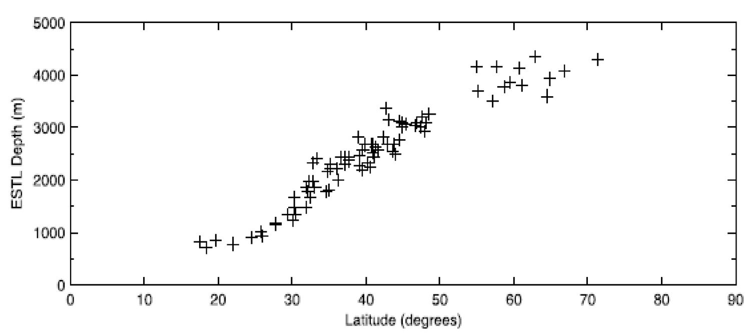


Figure 3. Latitudinal variability of the ESTL depth as defined in the text for annually averaged data from high-resolution radiosonde data.

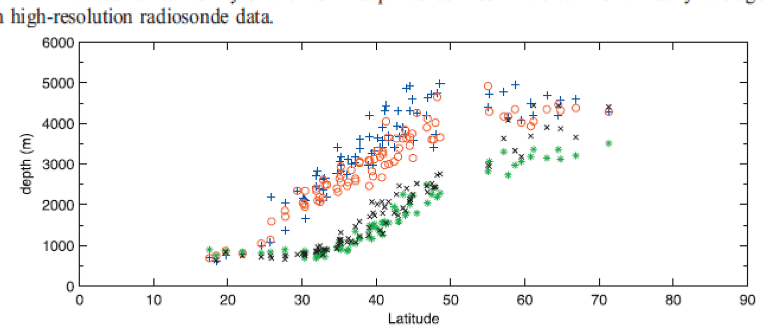


Figure 4. Seasonally averaged latitudinal variability of the ESTL depth for high-resolution data for DJF (blue pluses), MAM (red circles), JJA (green asterisks) and SON (black crosses).

• Son and Polvani (2007) found that they could use simplified GCM to generate TIL and reproduce Bell and Geller's (2008) results by adjusting the specified pole-equator temperature difference. But neither Bell and Geller nor Son and Polvani give an explanation for the latitudinal variations of annual and seasonal tropopause height and sharpness.

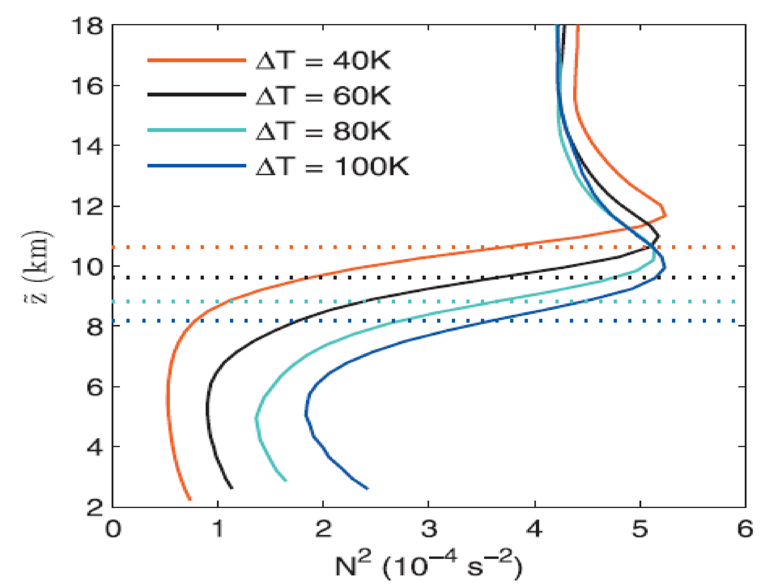


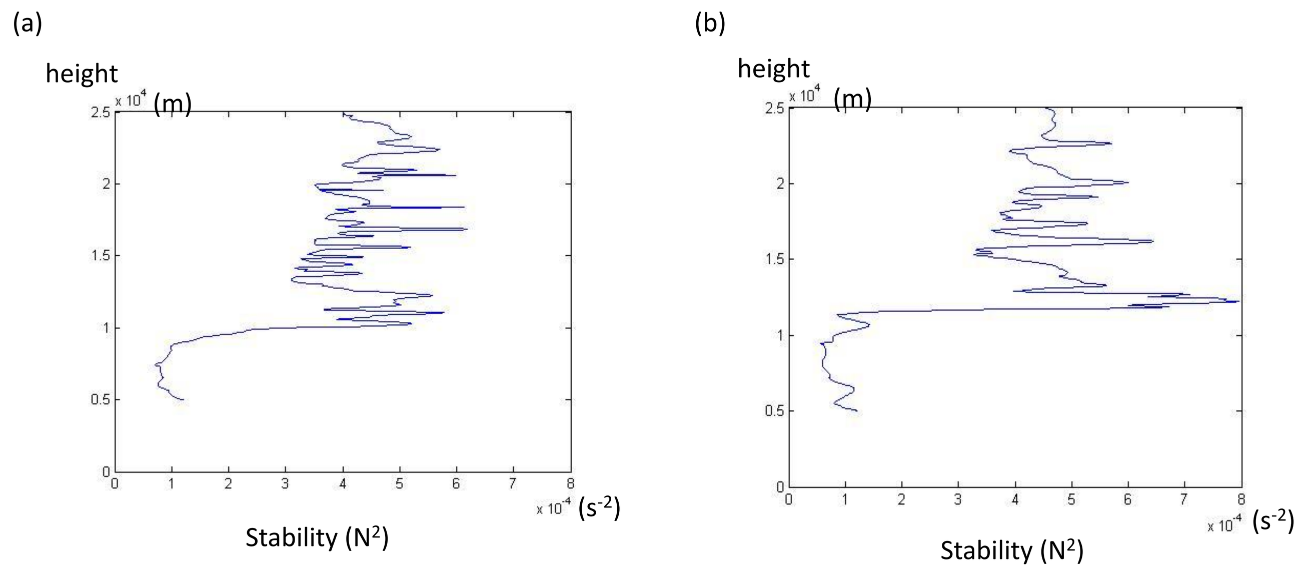
Figure 4. Composite N^2 profiles for different values of ΔT, the equator-to-pole temperature difference in the equilibrium profile T_e from T42L80 integrations with HS forcings. Black solid line: the canonical HS configuration (ΔT = 60 K). Other solid lines: different values of ΔT, as indicated in the legend. Dotted lines show the corresponding time-mean tropopause heights.

Tropopause sharpness

• Wirth (2004) proposed that the sharpeness of extratropical tropopause is greater when upper troposphere relative vorticity is anticyclonic. Randel et al. (2007) found that observed cyclonic/anticyclonic asymmetry does not account for the observed sharpness. Thus, they suggested that other forcing might be needed (i.e. radiative cooling).

Hypothesis 1

•Baroclinic mixing is an irreversible process that is likely to be responsible for the sharpness of the extratropical tropopause.



Vertical stability profile for Dodge City. (a) before the baroclinic wave passing over Dodge City and (b) iafter it passing over Dodge Cirty. This shows that baroclinic wave did sharpen and lift the extratropical tropopause.

• I have shown in my master thesis that the partial correlation between the distance from the jet and the tropopause height is higher than that between the upper tropospheric relative vorticity for 3 stations in a winter.

	Dodge City	Omaha	Riverton
Distance from jet	0.61	0.71	0.68
Upper tropospheric relative vorticity	0.57	0.49	0.53

The partial correlation between the tropopause height with each variance when the other one is fixed for 2003 winter.

• red: Dodge City, Kansas (38°N, 100°W)
• blue: Omaha, Nebraska (41°N, 96°W)
• green: Riverton, Wyoming (43°N, 108°W)

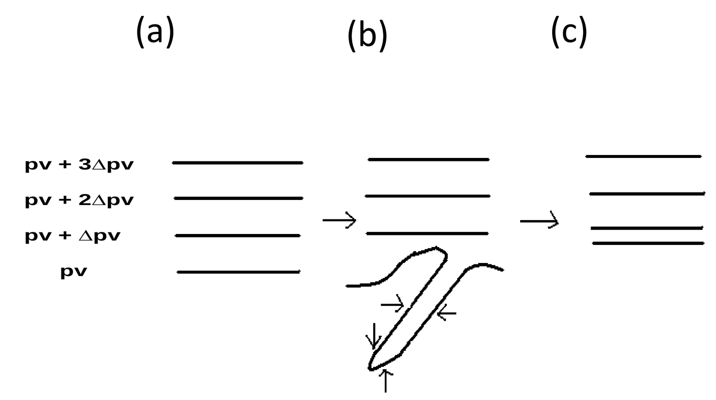
Hypothesis 2

• Son and Polvani (2007) found that the tropopause is more sensitive when they changed the horizontal resolution, whereas little change occurred when the vertical resolution was changed.

• It has been noted that more small-scale filamentary structure is seen in the tropopause potential temperature in winter than in summer, and also more is seen poleward than equatorward of the jet (e.g., Nielson-Gammon, 2001).

• Our hypothesis is that proper resolution of the filamentary mixing is necessary to reproduce the observed tropopause sharpness. The plan is to use high-resolution, mechanistic GCM modeling to test our hypothesis.

Schematic demonstration of the tropopause sharpening by baroclinic mixing. (a) Potential Vorticity (PV) contours (b) baroclinic wave scratches down the higher PV to lower PV below and mixing (c) enlarging the PV gradients and thus sharpening the tropopause.



Ongoing Work

• I used CAM5 to conduted 3-year run with four resolutions (T42L30, T42L60, T85L30, and T85L60) with Held-Suarez forcing in Eulerian core, and got similar results of Son and Polvani's, which the tropopause sharpness is more sensitive to the choices of horizontal resolutions than vertical ones.

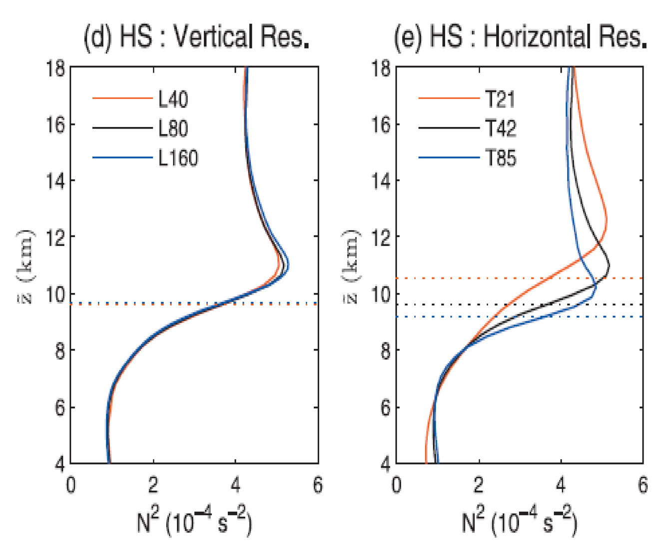
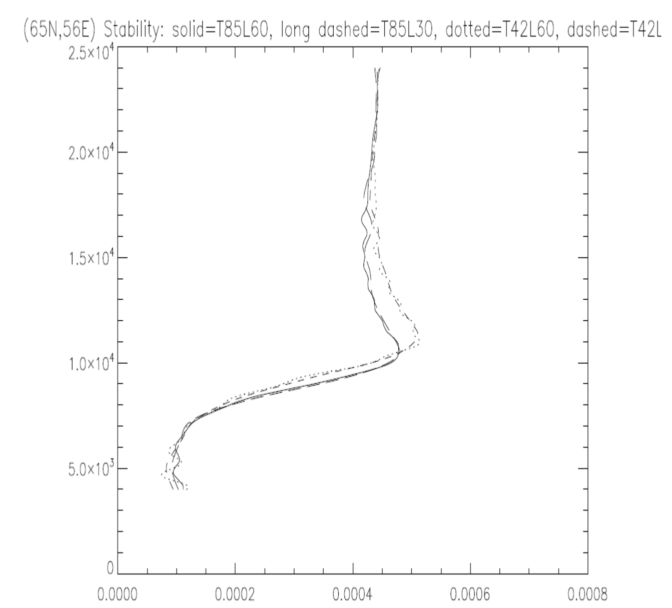


Figure 2 from Son and Polvani (2007) (d) at T42 with 40, 80 and 160 vertical levels and (e) with 40 levels at T21, T42 and T85 horizontal resolutions. In all panels, the dotted horizontal line shows the time-mean tropopause height.



Stability profile of 3-year run for (65°N, 56°E) for four resolutions.
Solid: T85L60
Long dashed: T85L30
Dotted: T42L60
Dashed: T42L30

How Sharp a tropopause can be seen in a model?

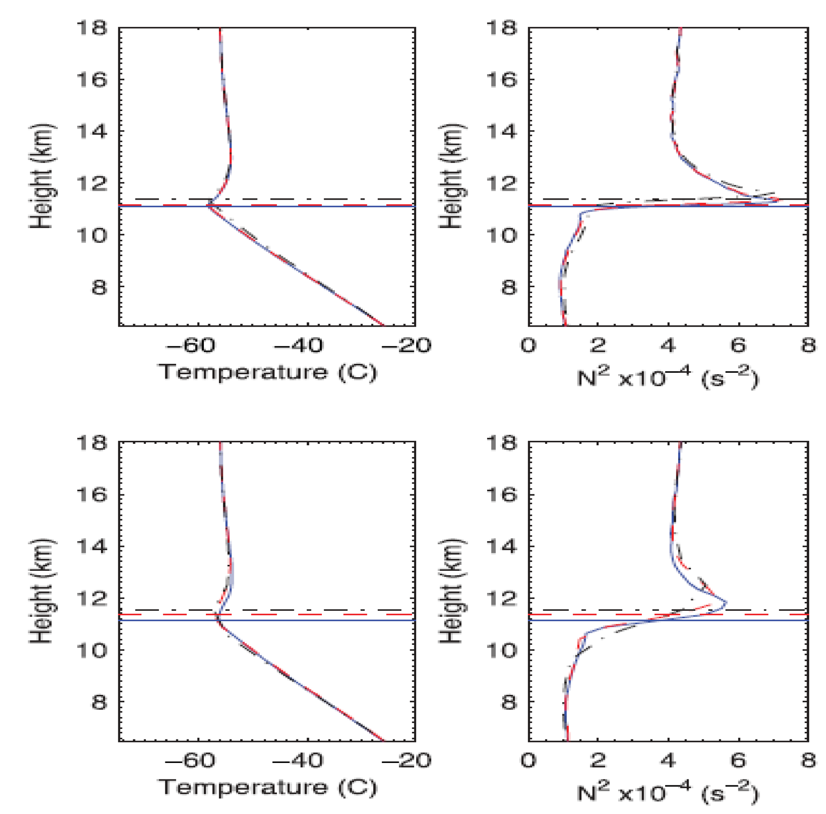


Figure 9. (left) Temperature and (right) stability for varying interpolation resolutions. (top) The 30 m (blue), 60 m (red), and 120 m (black) interpolation resolutions. (bottom) The 240 m (blue), 480 m (red) and 960 m (black) interpolation resolutions. Horizontal dashed line indicates time mean tropopause for each resolution experiment.

• Want to visualize the filaments at different resolutions for comparison to observations.
- Calculate PV from the instantaneous (U, V, T, P) output of CAM5.
- Try to use potential temperature filaments on tropopause PV surface to visualize the mixing and compare to observations (e. g., Nielsen-Gammon).
- Might have to use more sophisticated visualization.

• See if the correlation between the jet and the tropopause height can also be seen from the model output as was seen in my master thesis.