Abstract

Idealized GCM integrations have shown that, in the absence of complex radiative-convective processes, the dry dynamics associated with synoptic-scale baroclinic eddies are able to produce an extratropical tropopause inversion layer (TIL). This inversion layer is qualitatively similar to the observations, but weaker in amplitude and thicker in the vertical. Extending that study, the impact of the stratrophic circulation on the extratropical TIL is examined by introducing a polar vortex and a topographically-induced stratrophic variability in the idealized GCM. It is found that the stratrophic circulation only weakly affects the extratropical TIL. In particular, all integrations show that the summer hemispheric TIL is comparable to the one in the winter hemisphere, in stark contrast to the observations. While further studies are needed, these results suggest that the stratrophic circulation is not a key player in setting the characteristics of the extratropical TIL. Other physical processes, notably radiation and convection, are likely to play an important role, especially for determining the different TIL structures in the summer and winter hemispheres.

Questions & Approaches

- The internal variability of the stratosphere may change the TIL by modifying the vertical structure of \( \omega \). How much? The effect of stratospheric circulation on the TIL is examined by introducing a polar vortex and topography to the idealized GCM (Gerber and Polvani 2008).
- GFGL dynamic core AGCM with a Held-Suarez configuration (T42L40): temperature is relaxed to the zonally symmetric equilibrium temperature profile \( T_e \), and the momentum is dissipated by a simple surface drag.
- Use last 1000 days from 1300-day-long integrations. All fields are generated on the tropopause-based \( \tilde{z} \) coordinate for 10 randomly chosen points.

Results

I. Equilibrium \( T_e \) and \( N^2 \)

Figure 1: Equilibrium \( T_e \) and \( N^2 \) profiles for the winter Hemisphere runs: (left) \( \tilde{z} \)-based composite \( U \) and (right) \( N^2 \) in horizontal equilibrium. The \( \tilde{z} \)-based composite tropopause height from Brune (2006)

II. Winter Hemisphere Results

Figure 2: Zonally averaged climatological tropopause-based \( N^2 \) average for (left) 1DP and (right) 1JA. Shading interval in 10 \( N^2 \). Thick white area represents data gaps. Top part of the diagram show the average latitude at tropopause level. From Birner (2006)

Figure 4: \( T_e \) and \( N^2 \) profiles for the winter Hemisphere runs: Topographic (3-km high mountains at 45\(^\circ\)N with zonal wave number 2 pattern) is shown in blue. The summer Hemisphere run is identical to \( \gamma=0 \) run but latitudinal structure of \( T_e \) is reversed.

Figure 5: Results of winter Hemisphere runs: (top) \( \tilde{z} \)-based composite \( U \) and (bottom) \( N^2 \)

Figure 6: Results of winter Hemisphere runs: (1st, 3rd) \( \tilde{z} \)-based composite \( N^2 \) at 55\(^\circ\)N and 70-80\(^\circ\)N mean, and (2nd, 4th) \( \omega \). Dotted lines denote composite tropopause height

III. Summer Hemisphere Results

Figure 7: Results of summer Hemisphere run: (left) \( \tilde{z} \)-based composite \( U \) and (right) \( N^2 \)

IV. Sensitivity Tests: No Topo & Lower Vortex

Figure 8: Sensitivity runs to (top and bottom left) no topographic and (bottom right) lower polar vortex: \( \tilde{z} \)-based composite \( N^2 \)

RESULTS

1. \( T_e \) & \( N^2 \) profiles (Fig. 4): \( T_e \) does not have a local maximum in \( N^2 \) immediately above the tropopause \( \rightarrow \) No TIL in the forcings.
2. Winter Hemisphere TIL (Fig. 5): TIL amplitude does not change as \( \gamma \) increases, i.e. as polar vortex strengthens.
3. Winter Hemisphere \( N^2 \) and \( w \) (Fig. 6): \( w \) varies systematically by changing \( \gamma \) in the mid stratosphere. But, no change is found near the tropopause, resulting in no change in \( N^2 \) near the tropopause \( \rightarrow \) No sensitivity of TIL.
4. Summer Hemisphere TIL (Fig. 7): The summer hemisphere TIL amplitude is comparable to the one in the winter hemisphere (compare with Fig. 5 right).
5. TIL sensitivity to topography (Fig. 8): Substantial sensitivity is found.

CONCLUSIONS

1. Impact of stratospheric circulations to TIL: Relatively weak.
2. Seasonal variations: Modeled TIL is quantitatively similar in two seasos.
3. Comparisons to observations (Fig. 2 vs. Figs. 5, 7): Modeled TIL is weaker than one in the observations. Our integrations fail to recover the seasonal difference of the TIL in the Northern Hemisphere extratropics.
4. Concluding Remarks: Although dynamical processes are able to produce the qualitative structure of the TIL, they can not capture the quantitative aspects. Other physical processes, such as radiation and convection (e.g. Randel et al. 2007), seems to be crucial for the formation of the extratropical TIL.
5. Future Work: i) Longer integrations to get smoother profiles, ii) Sensitivity tests to the location of polar vortex & different topography.

DEFINITIONS

TIL: Tropopause Inversion Layer. TIL amplitude: Maximum value of \( N^2 \). TIL depth: Distance from maximum to local minimum \( N^2 \). \( \tilde{z} \): tropopause-based height coordinate, \( z \): standard height coordinate.

REFERENCES