17.3 STATIC STABILITY IN THE EXTRATROPICAL TROPOPAUSE REGION

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1 INTRODUCTION

This paper investigates the static stability in the extratropical tropopause region (a full version can be found in Wirth 2003, or on my home page*). It is the third part is a series of studies trying to understand the impact of conservative balanced motion on the extratropical tropopause region (Wirth 2000, Wirth 2001, Wirth 2003).

2 MOTIVATION FROM OBSERVATIONS

The study was motivated by the observations of Birner et al. (2002), who composed a large number of radiosonde temperature profiles from Southern Germany using the thermal tropopause as a common reference level. As illustrated in figure 1, one obtains a characteristic profile of buoyancy frequency squared N^2 with a sharp peak just above the tropopause and slighly enhanced values below the tropopause in comparison with typical tropospheric values further below.

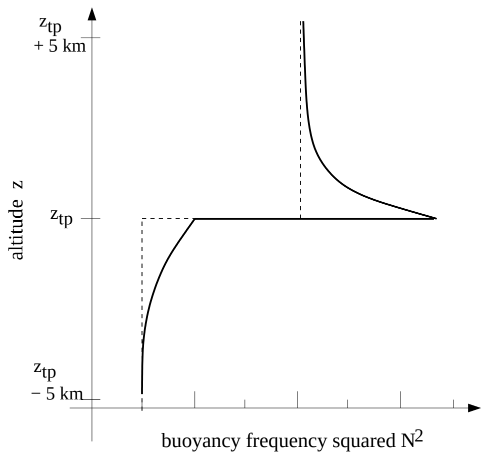

Figure 1: *Schematic representation of $N^2(z)$ in the tropopause region as observed by Birner et al. (2002). The solid line corresponds to the high resolution radiosonde data, and the dashed line depicts a hypothetical reference profile with piecewise constant N^2.*

Here we ask the following question: given a background atmosphere (fig. 2) with piecewise constant N^2, what is the impact of conservative balanced dynamics on the profiles of static stability in the tropopause region, and may the observed behavior be at least partly due to balanced dynamics?

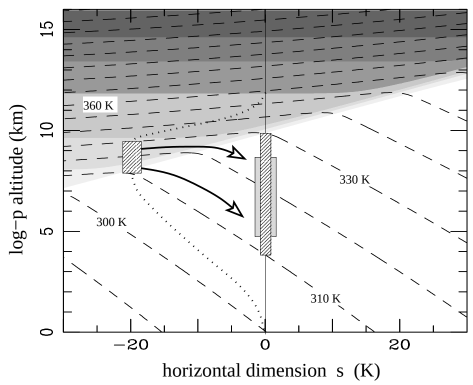

Figure 2: *Background atmosphere with the dashed contours depicting potential temperature and the shading potential vorticity. The hatched vertical columns and the arrows illustrate the construction of a cyclonic anomaly.*

3 CURRENT APPROACH

First we specify axisymmetric distributions of potential vorticity (PV) on an f-plane such that they can be interpreted as being the result of a formation process with conservative advection across the gradients of the background atmosphere (see fig. 2). Assuming hydrostatic and gradient wind balance, we perform PV inversion and subsequently analyze the vortices, paying special attention to the profiles of N^2 in the tropopause region.

Our PV anomalies are characterized by a radial scale ΔR and the tropopause potential temperature anomaly $\Delta\theta$. "Related" cyclones and anticyclones are treated identically except for the sign of $\Delta\theta$. As illustrated in figure 3 (and investigated in more detail in Wirth 2001) this leads to a pronounced asymmetry between cyclones and anticyclones.

4 RESULTS

Composing the two profiles of N^2 from the center of the vortices of figure 3 with the thermal tropopause as common reference level yields the profile shown

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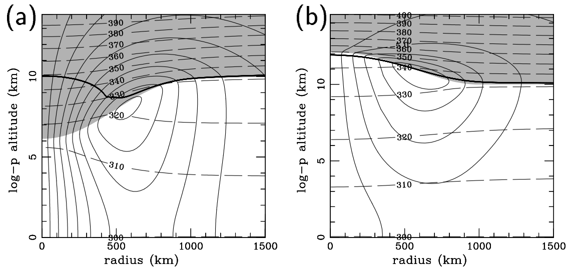

Figure 3: *"Related" cyclonic (a) and anticyclonic (b) vortices for $\Delta R = 1000$ km and $\Delta\theta = \pm 20$ K (solid contours for tangential wind, dashed contours for potential temperature, gray shading for stratospheric PV, thick solid line for thermal tropopause).*

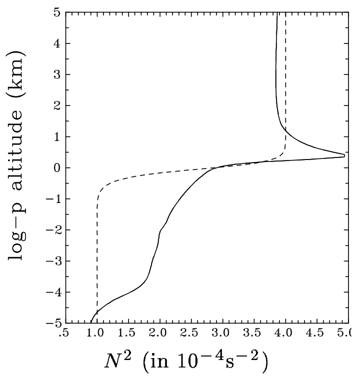

Figure 4: *Composite profile of N^2 (solid) derived from the vortices of figure 3, using the thermal tropopause as common reference level. The dashed line shows N^2_{ref} from the background atmosphere. The vertical coordinate is distance from the reference level.*

in figure 4 (solid line). Interestingly, this composite features a pronounced peak of N^2 above the reference level and enhanced values below the reference level in comparison with the reference profile N^2_{ref} (dashed line), suggesting a connection with the observations (cf. fig. 1).

The analysis reveals that the peak in figure 4 is a "real feature" and originates from the anticyclonic vortex. The enhanced values of N^2 below the reference level should be viewed as an artefact owing to the fact that for the cyclonic vortex the thermal tropopause (bold line in figure 3a) is well above the dynamical tropopause, which would be the more appropriate choice as reference level.

5 INTERPRETATION

As detalied in Wirth (2003), the difference regarding the profiles of N^2 between cyclones and anticyclones can be related to the asymmetry between cyclones and anticyclones. It can be shown that the factor

$$\mathcal{F} = f_0/\tilde{\zeta}_a \tag{1}$$

plays an important role, where f_0 denotes the Coriolis parameter and $\tilde{\zeta}_a$ is the isentropic absolute vorticity. In a static atmosphere $\mathcal{F} = 1$; for strong cyclones $\mathcal{F} \to 0$, while for strong anticyclones $\mathcal{F} \to \infty$. This demonstrates the cyclone-anticyclone asymmetry in the present context.

6 FURTHER REMARKS

Although the peaked structure of N^2 in the anticyclonic case appears to be a robust feature, there is a certain dependence on the choice of the background atmosphere. This dependence may be relevant in the real atmosphere, since poleward advection typically imports high values of PV from the subtropical lower stratosphere. This is likely to further enhance the peak of N^2 above the reference level for anticyclonic vortices.

To test the robustness of our results we computed composite profiles of N^2 using a large number of profiles from different vortices varying ΔR and $\Delta\theta$ and using each vortex to extract several profiles of N^2 at different radii. The resulting composite N^2 (not shown) features similar, albeit weaker characteristic deviations from N^2_{ref} as before.

7 CONCLUSION

The current approach is highly idealized. In particular it does not address the question of what determines the piecewise constant nature of N^2 in the background atmosphere. Nevertheless, regarding the fact that our basic mechanism is related to fundamental properties of balanced flow and encouraged by the good qualitative agreement of our results with the observations of Birner et al. we conclude that nonlinear balanced dynamics is likely to play a role in producing the characteristic shape of the profile of static stability in the extratropical tropopause region, and especially in producing the sharp peak in N^2 right above the tropopause.

REFERENCES

Birner, T., A. Dörnbrack, and U. Schumann, 2002: How sharp is the tropopause at midlatitudes? *Geophys. Res. Lett.*, **29**, 10.1029/2002GL015,142.

Wirth, V., 2000: Thermal versus dynamical tropopause in upper tropospheric balanced flow anomalies. *Quart. J. Roy. Met. Soc.*, **126**, 299–317.

Wirth, V., 2001: Cyclone-Anticyclone Asymmetry Concerning the Height of the Thermal and the Dynamical Tropopause. *J. Atmos. Sci.*, **58**, 26–37.

Wirth, V., 2003: Static stability in the extratropical tropopause region. *J. Atmos. Sci.*, in print.