Tropopause

The tropopause was discovered by Teisserenc de Bort around 1900 by balloon and kite soundings. Thus, he also discovered the stratosphere. The first third of the 35 km thick stratospheric layer is isothermal; then it warms up to nearly 0°C at about 50 km (~ mb). The warming occurs because of absorption of solar ultraviolet radiation by ozone. (Thus the stratosphere is in radiative equilibrium whereas the troposphere is a net radiative heat sink and cools at the rate of 1-2°C per day. The temperature distribution of the troposphere is maintained by heating from below; hence the troposphere is said to be in convective equilibrium.)

The formal definition of the troposphere is that it is a first order discontinuity in the *lapse rate*, $^{dT}/dz$, not temperature. Part of the official NWS definition for the location of the tropopause includes the following criteria:

(i) level where $^{dT}/dz < 2°C/km$ or less

(ii) $d\overline{T}/_{dz}$ does not exceed 2°C/km from the above level (i) to 2 km higher

(iii) $d\overline{T}/_{dz}$ does not exceed 3°C/km over any 1 km layer between (i) and 100 mb.

These criteria do not take dynamical considerations into account. See, e.g., Riley and Bosart (1987, MWR) for an example of how the official criteria can miss the location of the tropopause that is most relevant to the evolution of cyclogenesis.

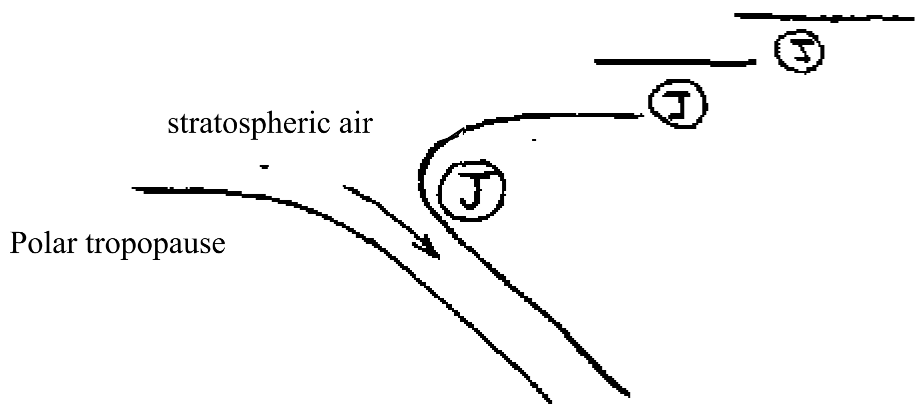
Large variations exist in tropopause height with *latitude*, with *season*, from *day-to-day*, and across a particular weather map (i.e. between troughs and ridges). The *tropical tropopause* is the highest with z ~ 18 km, p ~ 80-100 mb, T ~ -80°C and θ ~ 375-400°K. It is very sharply defined.

In mid-latitudes between the polar and subtropical jet streams, the tropopause has greater variations but averages z ~ 12 km, p ~ 200 mb, T ~ -60°C and θ ~ 325-340°K. It is higher in summer than in winter.

North of the polar jet, the polar tropopause has typical values of z ~ 6-9 km, p ~ 300-400 mb, T ~ -45°C and θ ~ 300-310°K. It is often difficult to identify. For example, consider the case of a sounding in a polar or arctic high in winter where the surface temperature is -50°C, warms up to -40°C by 850 mb and then varies between -40°C to -50°C before gradually warming in the middle stratosphere.

As indicated above, the tropopause height varies significantly from troughs to ridges, with tropopause heights low in cold troughs and high in warm ridges. Since these troughs and ridges propagate, the tropopause height will fluctuate greatly from day to day at a particular location during mid-latitude winters.

Near fronts and jet streams, we often have *multiple* (or overlapping) *tropopauses*. We also see evidence for *tropopause folding*, in which stratospheric air can descend into the troposphere within upper-level frontal zones.

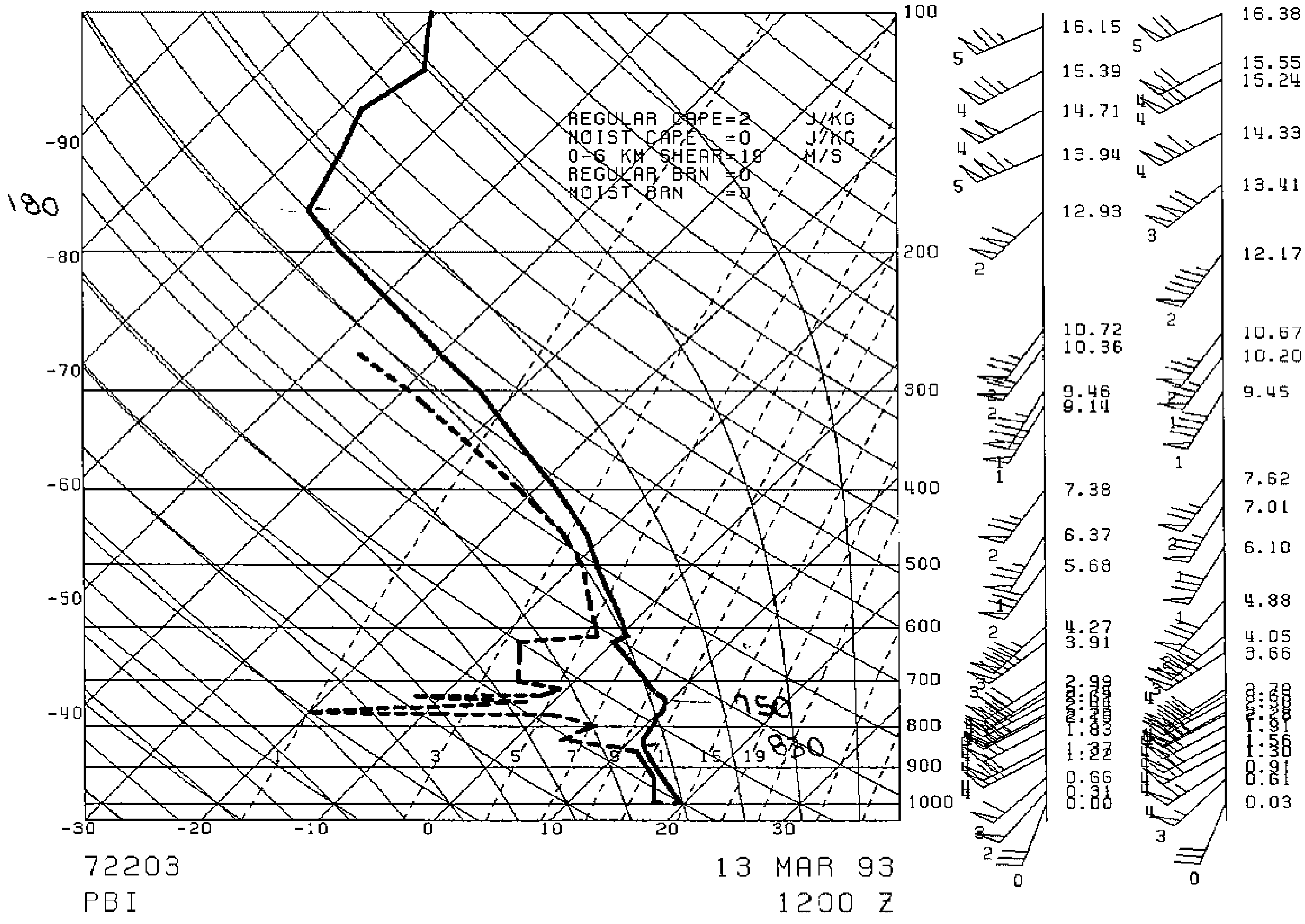


We will list three reasons why the tropopause is of *dynamical importance* to tropospheric weather events.

1. It locates the base of the stratosphere which is a layer of high static stability. Thus it acts to damp vertical motion on both large and small scales. It is most noticeable when it acts as an upper lid to deep convection causing the spreading out of cirrus anvil clouds.

2. It marks the reversal of the tropospheric north-south temperature gradient. This causes the jet stream to be near the tropopause (via the thermal wind equation).

3. Tropopause folds may play an important role in cyclogenesis due to the conservation of potential vorticity principle. $\zeta_p = (\zeta + f)_\theta \, \partial\theta/\partial p$ is large in the stratosphere. If a body of air with large ζ_p enters the troposphere via a tropopause fold and encounters a region of lower static stability, then relative vorticity must increase to conserve ζ_p.


REGULAR CAPE=2 J/KG
MOIST CAPE =0 J/KG
0-6 KM SHEAR=19 M/S
REGULAR BRN =0
MOIST BRN =0
100
200
300
400
500
600
700
800
900
1000
-30
-20
-10
0
10
20
30
-90
-80
-70
-60
-50
-40
16.15
15.39
14.71
13.94
12.93
10.72
10.36
9.46
9.14
7.38
6.37
5.68
4.27
3.91
16.38
15.55
15.24
14.33
13.41
12.17
10.67
10.20
9.45
7.62
7.01
6.10
4.88
4.05
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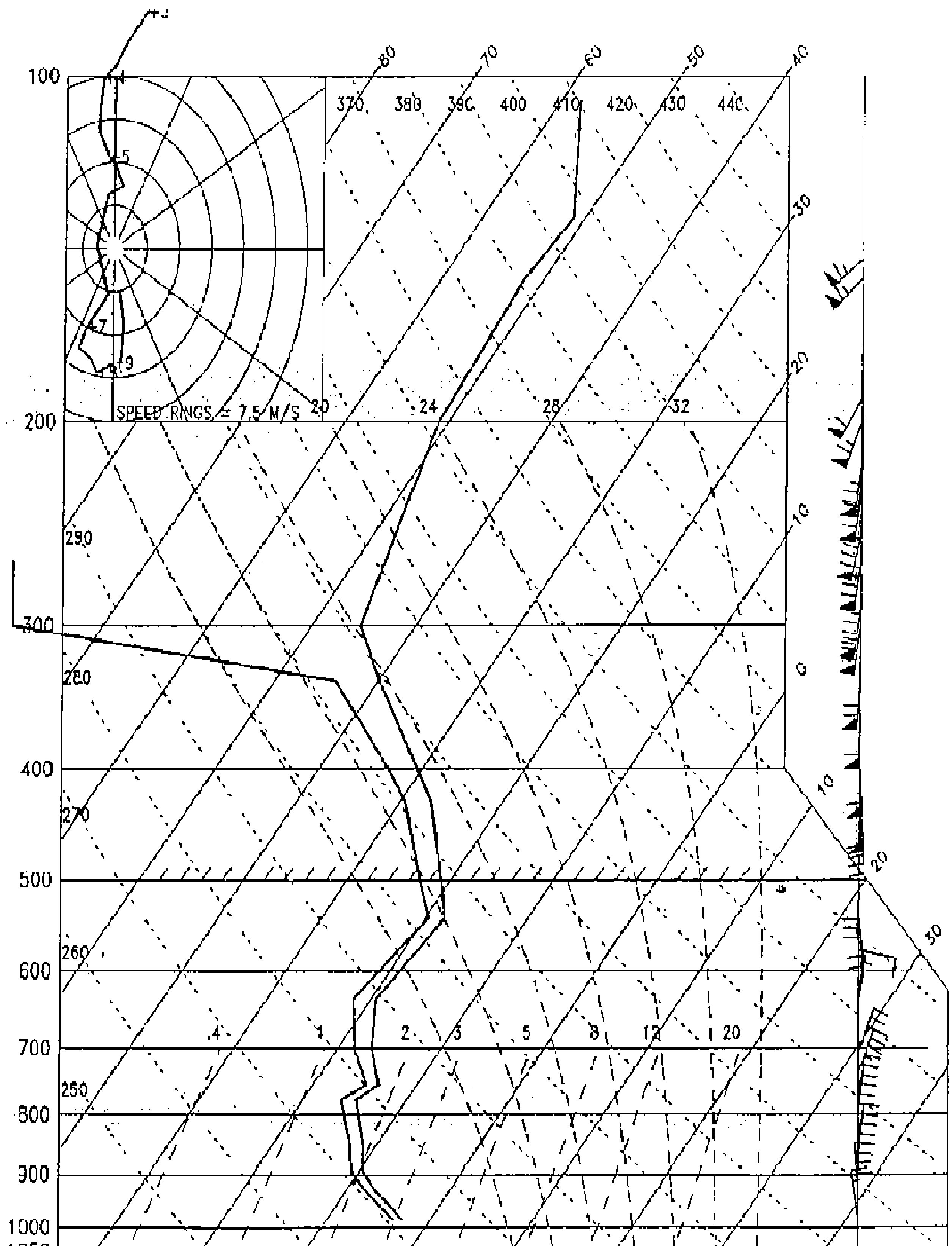
72203
PBI
13 MAR 93
1200 Z



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