THE TROPOPAUSE: a most important and little known boundary.

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The tropopause is the boundary in the atmosphere between the troposphere and the stratosphere. Going upward from the surface, it is the point where air ceases to cool with height, and becomes almost completely dry. (Wikipedia)

It was the 1970s and I was in my early years of teaching weather and climate. I enjoyed coffee with older colleagues because they had stories to tell about their research, and the politics of survival within academia. One conversation was with a physicist whose research involved a major concern of the day, the dynamics and distribution of radiation from atmospheric nuclear explosions. I was stunned to learn that he did not know that the tropopause was almost twice as high over the equator as it was at the Poles. He also did not know that the height varied seasonally. In fact he knew almost nothing about the atmosphere including most factors essential to his research such as the pattern, location and effects of the circumpolar vortex.

The tropopause is the very distinct boundary between the troposphere and the stratosphere. It is an interface as important in many ways as the interface between the land/ocean surface and the atmosphere. It is especially critical for its role in the transmission of energy to space.

Computer models of the atmosphere are three-dimensional. The surface is divided into grids that provide very coarse coverage. It is so coarse that it fails to allow inclusion of most factors critical to weather and climate. Most of these factors are defined as sub grid phenomena. For example, individual thunderstorms are a major factor in the transport of heat and moisture from the surface to the upper atmosphere. They dominate the weather of tropical regions and are the most significant mechanism for taking surplus heat energy to the deficit energy regions of the middle and high latitudes. But before we examine that idea we need fundamental information about the structure and major circulation mechanisms within the troposphere. My objective is to demonstrate how so many of the specialist studies on individual components of the atmospheric system are meaningless because of inadequate knowledge of the macroclimate systems.

While the Greeks identified three macroclimate areas, the hot, the temperate, and the cold, the three-dimensional structure of the atmosphere was not really considered until Sir Edmund Halley's ideas about tropical winds at the beginning of the 18^{th} century. Although there was some substance to his ideas they were quickly replaced in 1735 by the tropical cell circulation theorized by George Hadley. He used wind directions from ships logs to create a three-dimensional cell that bears his name. Hadley's system generally explained tropical circulation but there was little advance in knowledge, understanding or theorizing of the pattern for the middle and high latitudes until the middle of the 19^{th} century.

William Ferrel, troubled by limitations of Hadley's work postulated the existence of two other cells, one in the middle latitudes called the Ferrel Cell and one for high latitudes called the Polar Cell.

Over the last many years the Ferrel cell has been in the literature or out. Currently it appears to be in favor again. Here is a diagram (Fig. 1) from the United Kingdom Meteorological Office (UKMO). The second diagram (Fig.2) is from a climatology text published in 1984 and shows the vague perception of the circulation. The same book shows the indecision in a simpler diagram. (Fig.3)

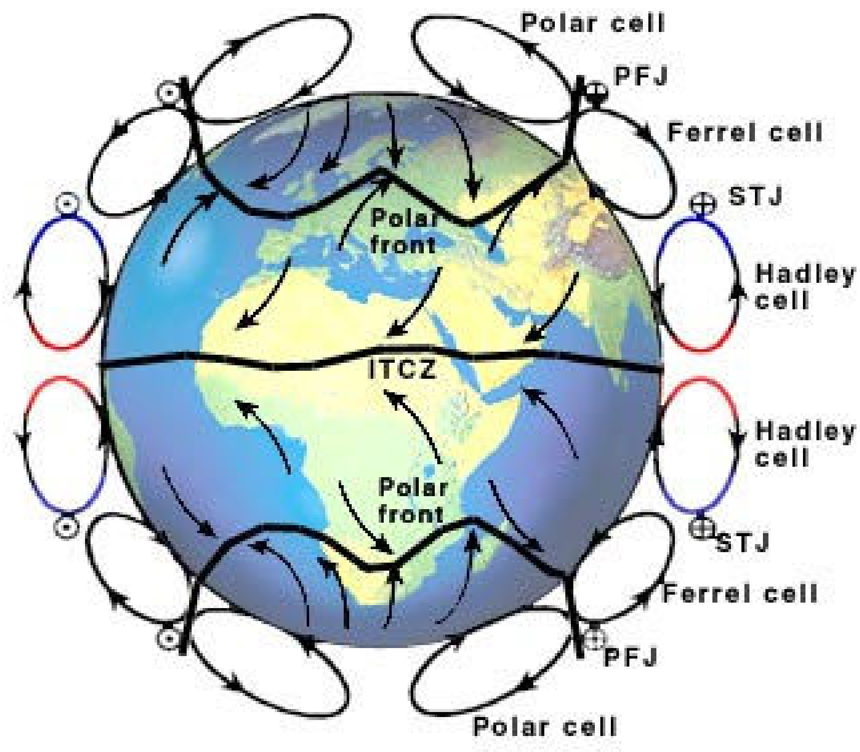

Fig.1

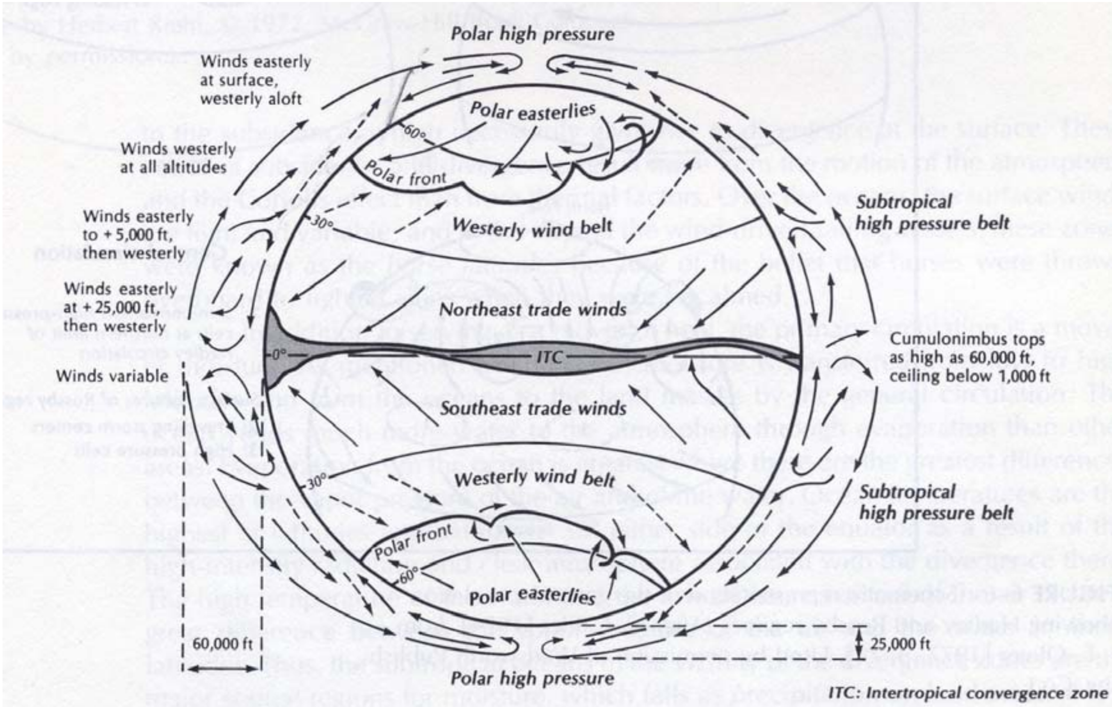
Polar high pressure
Winds easterly at surface, westerly aloft
Winds westerly at all altitudes
Winds easterly to + 5,000 ft, then westerly
Winds easterly at + 25,000 ft, then westerly
Winds variable
Polar easterlies
60°
Polar front
30°
Westerly wind belt
Subtropical high pressure belt
Northeast trade winds
0°
ITC
Cumulonimbus tops as high as 60,000 ft, ceiling below 1,000 ft
Southeast trade winds
30°
Westerly wind belt
Subtropical high pressure belt
Polar front
60°
Polar easterlies
60,000 ft
25,000 ft
Polar high pressure
ITC: Intertropical convergence zone

Fig. 2

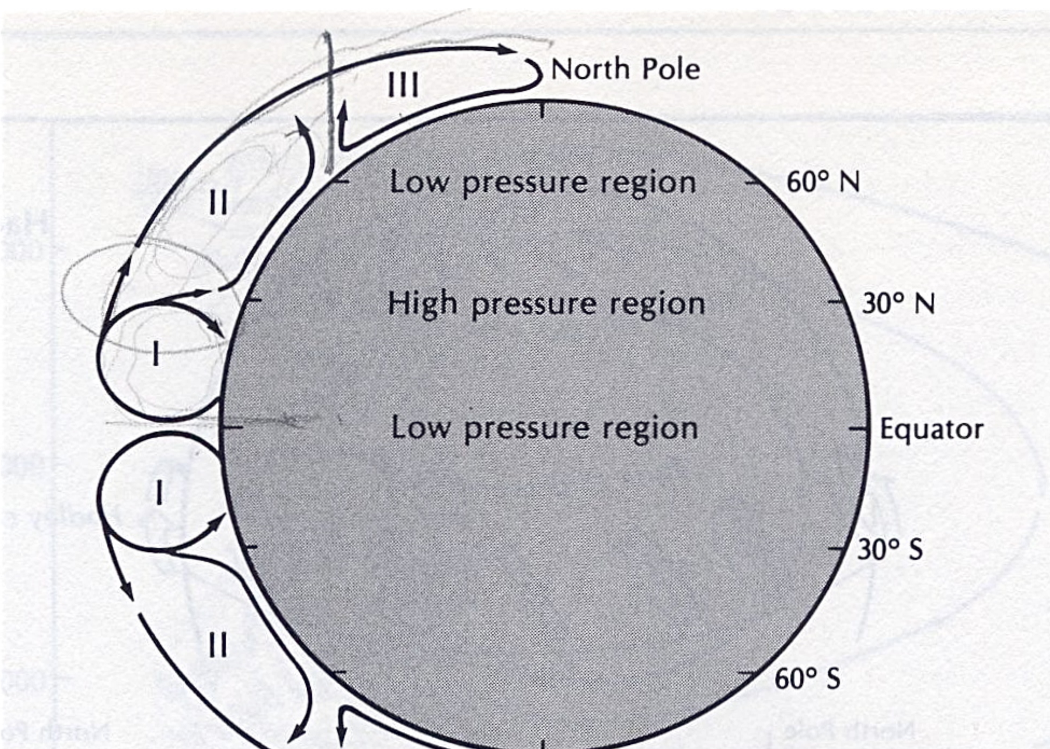
III
North Pole
II
Low pressure region
60° N
I
High pressure region
30° N
Low pressure region
Equator
I
30° S
II
60° S
III
South Pole

Fig. 3

This last diagram does suggest the lower tropopause level over the poles than at the equator; however the difference is much greater.

This diagram (Fig.4) from Wikipedia shows three cells and a greater difference in height of the tropopause.

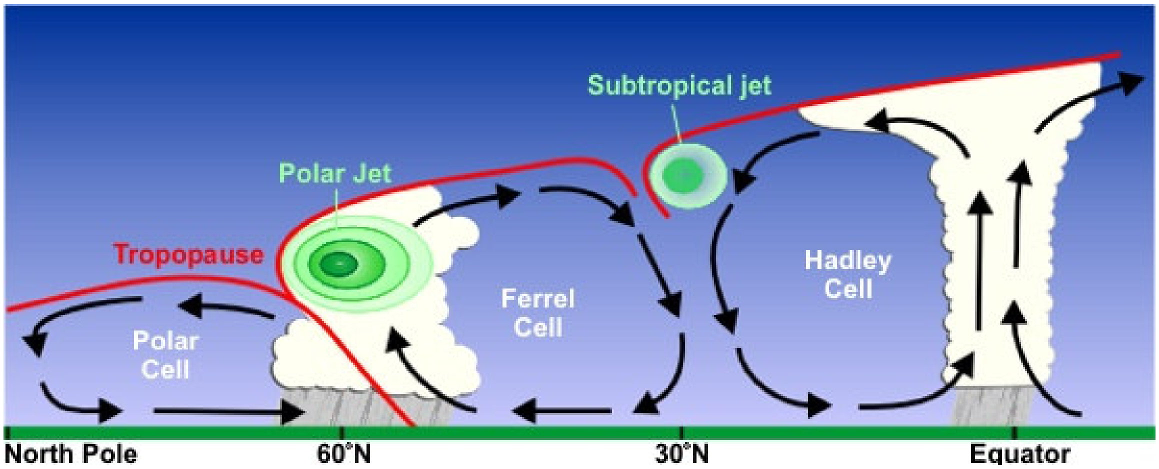

Fig.4

The average height over the equator varies from approximately 17 km in winter to 18 km in summer while it is approximately 7 km over the pole in winter and 10 km in the summer. The difference between the equator and the poles is caused mostly by the temperature difference but also a little by the centrifugal effect from rotation. Greater expansion at the poles between seasons, 3 km compared to 1 km at the equator, is a reflection of the greater range of seasonal temperature.

These diagrams illustrate the problems of understanding the dynamics of the atmosphere let alone the challenges of creating a computer model. Here are a few challenges to illustrate the problems.

1. The more sophisticated models have 24 layers but how do you deal with the seasonal changes in altitude let alone the changes as climate changes?
2. What was the structure of the atmosphere during the Ice Age when the Polar Cell extended much further south to essentially eliminate the Ferrel Cell?
3. How different was the circumpolar vortex, the strong winds within which the Jet Stream is buried?
4. How different was the height of the tropopause during the Ice Age or even the Little Ice Age?
5. How does the expanded surface of the tropopause affect the heat

radiation to space? The change is significant because it is the surface of a sphere so even a 1 km change in the radius increases the surface to space dramatically.

6. Critical points are at the contact zone at the tropopause. These are zones of turbulence and where the strongest winds occur. What happens to heat transfers from the troposphere to the stratosphere at these points, what are effectively ‘gaps’ in the tropopause?
7. These regions at the top of the troposphere are critical to the greenhouse effect where CO2 is supposedly most effective. How is CO2 affected by the changing dynamics and turbulence in these regions?
8. Many commercial aircraft fly close to the tropopause. In winter in the middle and high latitudes they are actually in the lower stratosphere. What effect does this have on the chemical composition of the rarefied air at these altitudes?

Conclusion

Recently Dr John Theon, James Hansen’s former boss at NASA said the *“climate models are useless.” “My own belief concerning anthropogenic climate change is that the models do not realistically simulate the climate system because there are many very important sub-grid scale processes that the models either replicate poorly or completely omit,”* He should add that they do not model the macroclimate conditions such as the tropopause properly either.

Economist Kesten Green and Dr J Scoot Armstrong, a world expert on computer model forecasting said, *“Long-term climate changes are highly complex due to the many factors that affect climate and to their interactions.”*
The tropopause is just one, albeit a very large one.

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