# ATM 316 - Some questions for thought
**Fall 2020**

These questions pertain to a figure from the first edition of Wallace and Hobbs' text (attached), which shows vertical cross-sections of zonally-averaged temperature and zonal wind speed as a function of altitude and latitude for Northern Hemisphere January and July. The isotherms are solid contours (interval is 5°C), and isotachs are dashed (interval is 10 m $s^{-1}$, values in ellipses). Westerly winds are depicted with positive values, easterlies with negative values.

1. Define *pressure*. Why does pressure decrease with height? What determines how quickly the pressure decreases with height? Notice that the rate of pressure drop with height *itself* decreases upward. What does this imply?

2. The horizontal axis extends from the pole to equator. Approximately what is the distance in kilometers? How many kilometers per degree of latitude? (Earth's mean radius is 6370 km.)

3. What is the hemispheric three-cell model, and what are the frictionless surface winds that model implies on a rotating Earth? Near the surface, do you see evidence of the three-cell model circulation in the surface winds during the winter?

4. Identify the location of the coldest air in the Northern Hemisphere, in either season.

5. Why is the troposphere shallower at the North Pole than at the equator?

6. Estimate the tropospheric temperature lapse rate in the vertical, in K/km, at the equator, for winter. Is it what you expected?

7. If "warm air rises and cold air sinks", why doesn't the troposphere overturn?

8. Select the -30°C isotherm and follow it from pole to equator. Using this isotherm, how does the meridional temperature gradient vary with latitude? At what latitude is it largest? Why?

9. At the equator, how deep are the tropical easterlies in winter?

10. At what pressure level, altitude, and latitude is the midlatitude westerly zonal wind strongest?

11. At what pressure level and altitude does the principal meridional temperature gradient vanish?

12. Draw a vertical line, representing height, and sketch vectors representing the magnitude and direction of the zonal wind at 30°N during winter. Indicate the height level where the meridional temperature gradient vanishes at this latitude. Indicate the level at which the westerly wind speed is maximum with the letter "J" (for Jet).

13. Why is the midlatitude tropopause westerly jet *weaker* in summer than in winter?

14. Why are the tropical easterlies at the equator *deeper* in summer than in winter? Why are they also *weaker* in summer?

15. Now again consider temperatures above the pole and equator during winter. At 13 km, the temperature difference between equator and pole vanished. Above that, the pole is warmer. Does the temperature difference reverse again?

16. Above the subtropics, the stratospheric zonal wind is weak westerly in winter and strong easterly in summer. Why does the wind direction flip?

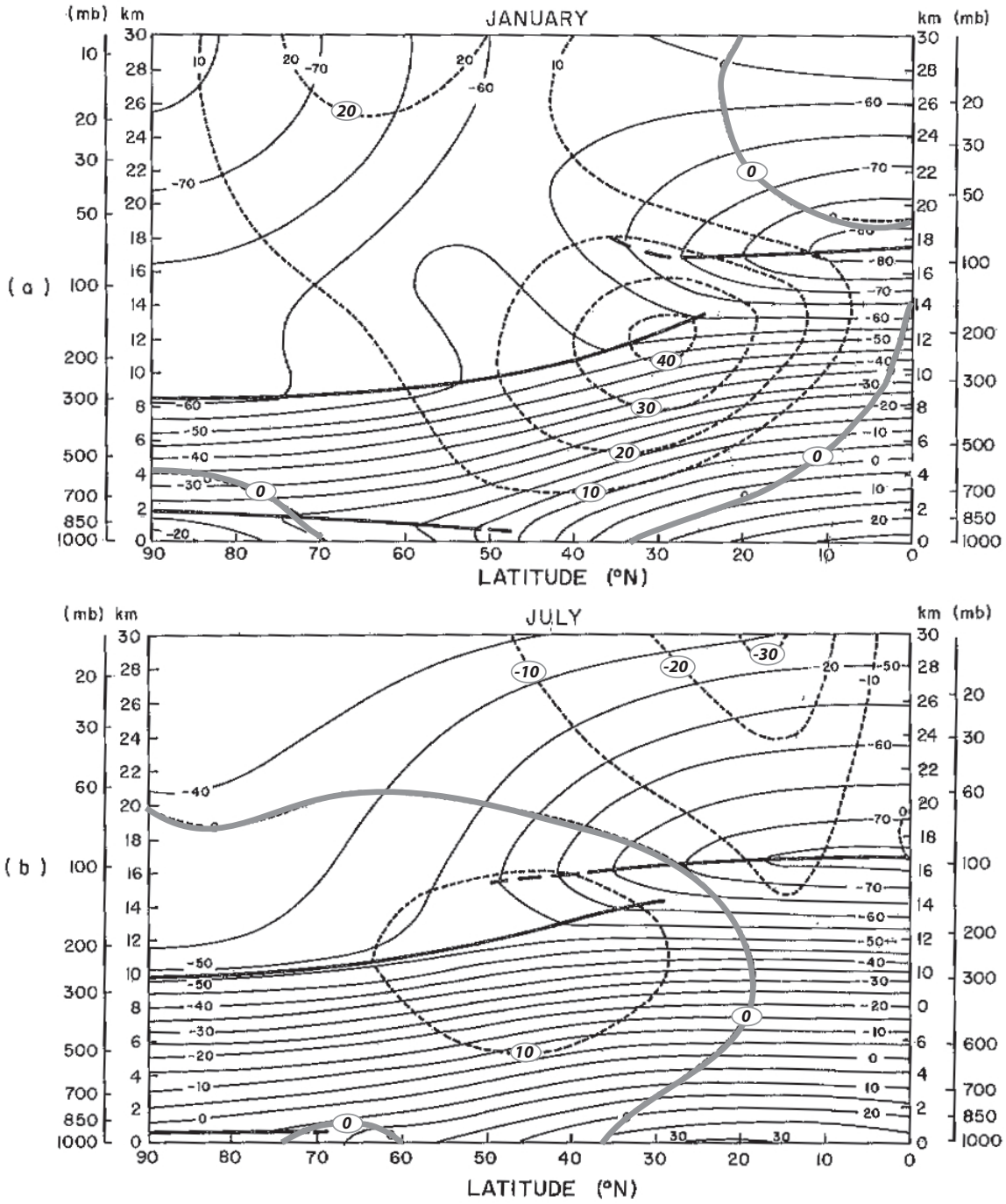


**Fig. 1.11** Meridional cross sections of longitudinally averaged temperature in degrees Celsius (——) and zonal wind in meters per second (– – –) for the northern hemisphere in January (a) and July (b). Positive zonal winds indicate flow from west to east. Heavy lines denote the tropopause and the Arctic inversion. (After *Arctic Forecast Guide*, U.S. Navy Weather Research Facility, 1962.)

Figure 1: Zonally-averaged zonal winds and temperature for the Northern Hemisphere, as a function of altitude, latitude, and season. From Wallace and Hobbs, 1st edition.