

1. **Mountain Torque** calculation.

Recall this equation from Grotjahn (2007, DAO, 43: 3-15)

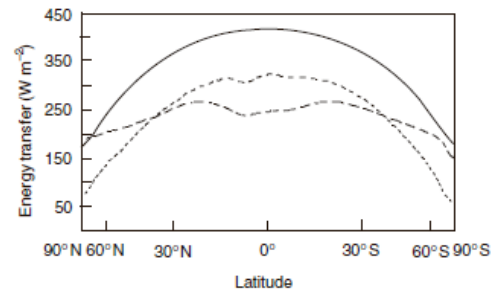
$$\int_0^{2\pi} \int_{-\pi/3}^0 \tau a^3 \cos^2(\varphi) d\varphi d\lambda = \int_0^{z_{top}} \int_{-\pi/3}^0 \{P_E - P_W\} a^2 \cos(\varphi) d\varphi dz$$

The equation was applied for motion in the Southern Hemisphere. For this problem make a similar calculation but for the Canadian Rockies. Note: the two sides won't be equal here. Use latitude range: 45N to 60N and the mountain ridge line height of 2km. Near surface average zonal is 3 m/s while the near surface vector wind speed is 10 m/s. Sea level pressure along the Pacific coast is about 1010 mb and over the Canadian plains is 1020 mb. Let $\tau = -\rho C_D |\mathbf{V}|u$ (negative sign because taken from perspective of atmosphere). Assume density has an average at 800m and estimate it using a scale height 8km. Let $C_D = 2 \times 10^{-3}$ $\rho_s = 1.25 \text{ kg/m}^3$.

- (4 pts) Calculate the mountain torque from the Canadian Rockies from these conditions. Assume that the pressure difference goes to zero linearly with height.
- (4 pts) Calculate the frictional torque for the region from 140W to 110W.
- (2 pts) Compare your answers in parts a and b. Discuss which is larger, whether they are opposing or reinforcing each other. Frame your discussion (using complete sentences) in terms of the direction of each torque applied to the solid earth. Note: earth rotates eastward.

2. **Radiative temperatures** at various atmospheric locations, see table.

Location	TOA solar (W/m ²)	Absorbed solar (W/m ²)	Terrestrial (W/m ²)
North Pole	175	75	195
38 N	340	235	235
Equator	415	320	250



- (6 pts) Calculate the average annual albedo at each of the 3 stations from this data. Obtain albedo at these 3 locations from fig. 3.7. (Assume 80N has same albedo as 90N.) Discuss similarities and/or differences between the 2 sets of estimates.
- (10 pts) Assume that emissivity is constant and equals 0.9 for the spectrum of terrestrial emission. Calculate the implied annual mean temperatures for each location based on local radiative balance, i.e. upon using the absorbed solar radiation. Calculate the implied annual mean temperature based upon the terrestrial emissions. (There are 5 distinct values, since absorbed solar radiation and terrestrial emission are the same at 38N.)
- (4 pts) Calculate the difference in temperature between using local radiative balance versus the actual emission for the Equator and the North Pole. What percent of the emission is due to heat transport at the two locations? 'Percent' means $\{T \text{ difference} / \text{local } T\} * 100\%$ so the fraction is <0 at the equator.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written. Full credit requires proper units be included. Any plot must be completely and unambiguously labeled, including title and axes. Show ALL math steps.