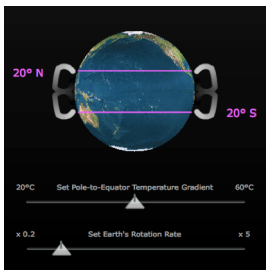
Homework–Module 2 Name:

1) The length of day has steadily increased throughout earth's history. Geological evidence[1][2][3] suggests that the length of day was 21.9±0.4 hours 620 million years ago (Mya) and 18.7±0.25 hours billion years ago (Gya). In other words, the rotation rate of Earth was about 10% faster 620 Mya and 28% faster 1.4 Gya. If we assume the earth's atmosphere had same horizontal pressure distribution then as it does now (which it did not and will overlook for this question), what changes in the geostrophic wind speeds (faster or slower) would you expect relative to today's conditions over the middle latitudes? Explain your answer using concepts of module 2. (Hint: consider how the Coriolis force changes with the earth's rotation rate.)

   There is a 600-character limit for all questions.

[1] https://www.scientificamerican.com/article/earth-rotation-summer-solstice/
[2] http://adsabs.harvard.edu/abs/2000RvGeo..38...37W
[3] http://www.pnas.org/content/early/2018/05/30/1717689115

2) The Hadley circulation of today has rising motion near the equator and sinking motion near 30° latitude (section 9.3 of H&P). If the earth did not rotate, a single-cell model with an equator-to-pole Hadley cell would exist (section 9.2 of H&P). In view of the earth's slowing rotation rate being 10% faster 620 Mya and 28% faster 1.4 Gya, how is the north-south extent of the Hadley cell changing with increasing time?



Held & Hou model applet.

We can explore this sensitivity with a simple model of the Hadley cell (Held and Hou, 1980). The sensitivity of north-south extent of the Hadley cell to changes in the rotation rate can be examined using a simple model[4]. The default settings for the model are for today's rotation rate and an observed equator-to-pole temperature difference of 40 K (Aside: a 70 K difference is more appropriate for this model.)

a) Use the model to determine at what rotation rate the Hadley cell would first extend poleward of the Arctic Circle and Antarctic Circle (~67 degrees latitude).

b) Use the model to determine at what latitude the Hadley would extend if earth's rotation rate was 10% faster than today, which corresponds to a length of day of about 21.9 hours.

c) Use the model to determine at what latitude the Hadley would extend if earth's rotation rate was 28% faster than today, which corresponds to a length of day of about 18.7 hours

[4] http://physicalscience.jbpub.com/ackerman/meteorology4e/appletFiles/chap7/hadley/hadley.html

The most recent assessment from International Panel on Climate Change (IPCC 2103) states that during the 20 year period of 2016 to 2036 (see Fig. 11-10[5] of IPCC report AR5-WG1), the average surface temperatures over high latitudes of the wintertime northern hemisphere will warm by 3˚C, which is more than any other region of the world. On the other hand, the tropics are expected to warm the least, 1˚C or less. If the IPCC surface temperature projections materialize, it follows that features of the global circulation during northern hemisphere winter could change too. Answer the remaining questions based on the IPCC projections.

3) What changes in the intensity (i.e. average speed) of the polar jet stream (increase or decrease) would you expect if the polar troposphere warms 2˚C more than the tropics? Explain your answer using concepts of module 2. Material in sections 8.1 to 8.5 and 9.1 of H&P could prove especially useful.

4) What changes in the intensity of extratropical cyclones during winter would you expect if the average tropics-to-pole temperature difference decreases by 2˚C? Again, explain your answer using concepts of module 2. Section 10.3 of H&P is particularly relevant to the question. (Ignore the impact that changes in temperature would have on atmospheric moisture content.)

[5] http://www.ipcc.ch/report/graphics/images/Assessment Reports/AR5 - WG1/Chapter 11/Fig11-10.jpg

5) If the polar regions warm 2˚C more than the equatorial regions, what would be the impact on the Hadley cell? Use the Hadley cell model of question #2 to answer the question.