GEOS2115/2915 2023 Weeks 1-4 Practical Assessment questions.

This document contains the assessment questions that need to be handed in for marking covering the practical exercises in weeks 2, 3 and 4 of GEOS2115. These questions correspond to those highlighted in red text in the edstem.org Jupyter-notebooks.

This assessment task is worth 20% of the grade for the course.

Your report is due at the end of Week 4 **(Midnight on March 19th)** and must be handed in through Canvas.

Assessment questions Week 2 (Planetary energy balance):

Equilibrium Model 2.0

1. Briefly describe 3 problems with Model 2.0 which arise due to its simplicity [**6 marks**].
2. The solar constant isn't really a good name for the incoming solar irradiance as it varies on an 11-year time-scale (and other longer time-scales). Using Model 2.0, calculate the change in equilibrium temperature that can be attributed to the variation of the solar constant on the 11-year time-scale and briefly discuss its magnitude in comparison with the observed temperature increase of ~0.7C over the 20th century. (Hint: Use this website http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant) [**5 marks**]

Time-varying Model 3.0:

3. Try increasing the depth of the surface ocean layer to, say, 250m. Does the equilibrium temperature change? Explain why or why not. What does change? Explain why. **[5 marks]**
4. Volcanic eruption: Describe the response you see in the surface temperature. What effects do you observe if you change the magnitude of the volcanic eruption (e.g. instead of a 10% reduction, try a 20 or 30% reduction) and the time-scale of its effect (e.g. what if the
5. The graph below shows the global surface temperature anomaly (from the 1961-90 mean) for 1980-2005 with the period of the Pinatubo volcanic eruption marked with a black bar. How does the global temperature respond in comparison to the response to an eruption in your model? What are some of the reasons for the differences? **[3 marks]**

Surface Temperature Record
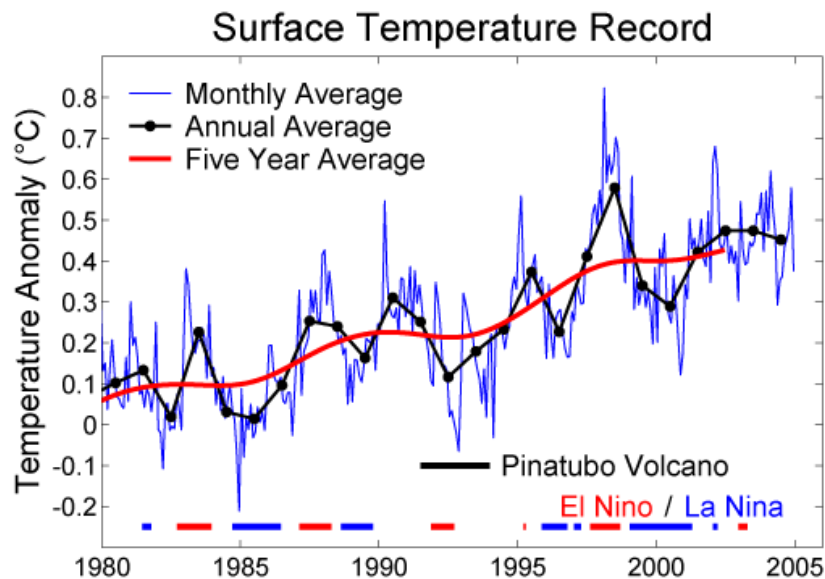
Ice-albedo feedback Model 3.1:

6. Global warming experiment: Imagine that the concentration of greenhouse gases in the atmosphere increases as a result of human activity. Rerun the Model 3.1 simulation with the atmospheric emissivity increased from 0.778 to 0.86. How does the equilibrium (i.e. final year) temperature change? Is this temperature change larger or smaller than the temperature change for the same emissivity increase in Model 2.0? Explain why in your own words. **[5 marks]**

7. Something very different can happen with Model 3.1 if the radiative forcing is decreased (i.e. a cooling). Return the atmospheric emissivity to the original value of 0.778 and investigate what happens as the incoming solar radiation (S0) is decreased. Try decreasing S0 from 1365Wm-2 in intervals of 10Wm-2. What happens as you approach values of 1315Wm-2 and below? Explain why. **[5 marks]**

Assessment questions Week 3 (Historical climate in ACCESS-CM2):

Shortwave radiation and albedo:

8. Why is the top-of-the-atmosphere downward SW radiation uniform in longitude, and what explains its latitudinal structure? **[2 marks]**
9. Where is the albedo maximum and at what values? Why? **[2 marks]**
10. Where is the albedo minimum and at what values? Why? **[2 marks]**
11. Where is the ASR maximum and why? **[2 marks]**

ACCESS-CM2 Longwave radiation:

12. Add code in place of the `???` in the next code block to load the upward longwave radiation at the surface (`LWupSFC`), and the surface net long-wave radiation (`Ln`, being the difference between the upward and downward longwave radiation at the surface). Then modify the plotting code in the next code block to plot these four variables with appropriate colorbar limits (i.e. replace the `vmin` and `vmax` limits given by `???` with appropriate values). Include this plot in your final report. **[2 marks]**

13. Why is the upward LW radiation at the TOA much smaller than that at the surface? **[2 marks]**
14. In which regions is the surface net longwave radiation maximum? Explain why? **[2 marks]**

ACCESS-CM2 total absorbed radiation:

15. By copying code from above, in the next code block add code to both calculate the total absorbed radiation (`TAR`) from `ASR` and `OLR` and make plots of the ASR, the OLR and the TAR. **[3 marks]**
16. Describe the latitudinal structure of the ASR, the OLR and the TAR. Discuss what these results imply about atmospheric and oceanic circulation and heat transport **[3 marks]**

Historical climate change in ACCESS-CM2

17. What are some possible reasons for the remaining discrepancies between the model and observations? To help you with your answer, load the data for the second ensemble member of the ACCESS-CM2 model (from the file /course/data/ACCESS-CM2-E2_hist_data.nc). Calculate the GMST change in ACCESS-CM2-E2 and add it to the plot above. Include this figure in your final report. Discuss how robust the differences between the modelled and observed GMST are. What are some potential causes for the year-to-year variability? **[6 marks]**

Bonus question (for no marks): Can you identify any year-to-year features that are consistent between ACCESS-CM2 and ACCESS-CM2-E2 (hint: look up the dates of the biggest volcanic eruptions in the recent past)?

18. Explain why the high-latitude northern hemisphere (Arctic) shows a larger warming than the mid-latitudes and tropics. To help with your answer, calculate and plot the change in albedo (`SWupTOA/SWdownTOA`) over the same periods (2004-2014 minus baseline) as shown above. Include this plot in your report. Why might the Antarctic be different? **[4 marks]**

19. Do you notice any differences in the rate of warming of land vs. ocean regions? Why? **[2 marks]**
20. Plot the change in sea level (the variable SL) over the same period. Include this plot in your report. Describe the changes in sea level that you see and explain what might be driving them. **[4 marks]**

Assessment questions Week 4 (Projected future climate change):

GMST response in SSP2-4.5 and SSP5-8.5

21. By adding additional code above, load, calculate and then plot the GMST for the ACCESS-CM2 SSP5-8.5 scenario (along with the historical and SSP2-4.5 scenarios on the same plot as above). Include this plot in your report. Describe the differences that you see between the two scenarios. Also comment on the magnitude and rate of GMST change in the future scenarios compared to during the historical period. **[3 marks]**

Regional changes in surface temperature and precipitation

22. Copy the code above to also plot the spatial structure of the surface temperature change averaged over the last 20 years of the 21st century (2080-2100) of the SSP5-8.5 scenario. Include both SSP2-4.5 and SSP5-8.5 temperature change plots in your final report. Describe the structures you see. Does the spatial structure look similar to the changes over the historical period that we looked at in Week 3? What about over the high-latitude Arctic and Antarctic regions? **[3 marks]**

23. To answer this question, copy the code you made above for the surface temperature changes in 2080-2100 compared to that in 1900-1950 and change it in order to plot the change in precipitation instead (for both SSP2-4.5 and SSP5-8.5 scenarios). Include this plot in your final report **[2 marks]**

24. Describe the changes you see. Which regions show increased precipitation and which regions show decreased precipitation? How does the magnitude of the change compare to the historical precipitation? **[2 marks]**

25. What is the global mean change in precipitation? To answer this plot a time series of the global average precipitation in the historical, SSP2-4.5 and SSP5-8.5 simulations using the `global_average` function. If you need to you can copy some of the code fro the GMST time series plot above (*However; you do not need to subtract any baseline precipitation from the historical simulation in this case).* Include this plot in your report. Explain physically where this change may be coming from (if you're stuck, do some of your own research on changes in the atmospheric water cycle)? **[3 marks]**

26. The changes we are looking at here are in annual mean precipitation. What kind of changes might you expect in rainfall extremes? Would you expect climate models such as ACCESS-CM2 to properly capture these changes? Why/why not? **[2 marks]**

Climate sensitivity: How do different models warm?

27. By filling in the missing sections of code below (marked by a "..."), load and plot the Global Mean Surface Temperature change from the MPI-ESM and CanESM5 models over the historical period and for the SSP2-4.5 and SSP5-8.5 scenarios. Plot these curves along with the ACCESS-CM2 historical, SSP2-4.5 and SSP5-8.5 curves that you already plotted above. Include this plot in your final report. If you wish, you can plot these curves on several different panels/plots to make them easier to see. **[3 marks]**

28. Which model warms the most and which the least? What is the magnitude of the difference? **[2 marks]**

29. Have a (brief - no need to read the whole thing) read of the carbonbrief.org article "CMIP6: the next generation of climate models explained" (https://www.carbonbrief.org/cmip6-the-next-generation-of-climate-models-explained/). In particular, the "Many higher sensitivity models" section. This section has a figure quantifying the climate sensitivity of all the CMIP6 models. Where do the CanESM5, MPI-ESM and ACCESS-CM2 climate models sit in this group? With that knowledge, discuss whether the range of possible GMST responses shown in your figure is a good representation of our uncertainty in that warming rate (according to the CMIP6 models as a whole). **[2 marks]**

30. Why might the models have different climate sensitivities, and thus warming rates? **[3 marks]**

31. The below code cell (copied from the "Bonus Material" section at the end of the Week 3 notebook) plots a time series of the historical SAT in Sydney. Add a few lines to also plot

the SAT from the SSP2-4.5 and SSP5-8.5 scenarios. Then, copy the code from this block to a new code block and modify it to also plot the precipitation in Sydney from the three scenarios. Include these plots in your final report. Describe the changes you see. In particular, describe the magnitude of the change relative to the interannual variability in each variable. Which variable shows the most robust change? Where could this interannual variability be coming from? **[3 marks]**

32. Choose another location around the Planet that you're interested in. Find its coordinates and then plot the changes in surface temperature and precipitation at the location. Include this figure in your final report and describe what it shows and the reasons behind these changes using what you have learnt above. **[2 marks]**