Introduction to Weather & Climate

PHYS 189 Fall 2017

Problem Assignment # 4

Discuss in class 09-25-17 due 09-27-17

This homework set is based on:

Trenberth, K. E., J. T. Fasullo, and J. Kiehl, 2009: Earth's Global Energy Budget. *Bull. Ameri. Meteor. Soc.*, **90**, 311-323, doi: http://dx.doi.org/10.1175/2008BAMS2634.1.

This paper provides the best estimates of energy budgets from where the solar energy enters the top of the atmosphere (TOA), to where it leaves at the TOA, and everything that happens in between. They outline how these estimates are made, and discuss some of the shortcomings of the data. I don't expect that you will understand everything in the paper, but that you will appreciate where the numbers that we have taken for granted come from. This will also introduce you to the structure of a scientific journal and provide some guidance for reading one.

The following are a set of questions related to content in Trenberth et al (2009). Please read over these and choose one that you will answer carefully. Each question is worth 30 points total. Come up with a strategy for answering the question and find the material in the paper that you will need to answer it. We will work together in groups on Monday, September 25 to answer them. You will then write up your answers individually to turn in on Wednesday, September 27. You may have to look up some information online.

No matter which question you choose to answer, answer as many of the sub-questions as possible. Please write up your answer in paragraph form with complete sentences and correct grammar.

1. This paper includes data from several sources to provide estimates of various processes involved in the energy budget for the earth. Describe one of the instruments or models used to collect data for this paper. In particular, include the following:
   (a) What is the instrument or model?
   (b) What data does it provide?
   (c) How was that data used in this paper?
   (d) Which table has data from this data source? What column(s) in that table?
   (e) What are sources of error associated with that instrument or model?
   (f) Are error bars (quantitative uncertainties) given for the data? If so, what are they? If not, why are there no error bars?
2. Surface energy budgets: land versus ocean.
   (a) What are the differences in surface energy balance over ocean compared to land?
   (b) Should balances over ocean be considered separately from land, or is it sufficient to coansider a global average? Explain.
   (c) What are some of the sources of error associated with the surface radiation budget?
   (d) Consider table 1b or 2b. JRA data is used for both data periods. Look at any of the columns associated with surface processes (any of them except for "solar absorbed" or "NET down").
      i. Which process (column) did you choose? Which table did you choose?

ii. Compare the JRA values of that process for ocean, land, and global contributions. How are these related? Why don't we have (ocean value)+(land value)=(global value)?

iii. Based on the numbers given, describe whether land or ocean makes a greater contribution and speculate why.

3. Top of the atmosphere (TOA) energy budgets. Tables 1a and/or 2a.

   (a) Draw a picture of the TOA and indicate arrows to represent "solar in", "solar reflected", and "OLR". "Solar in" and "solar refected" are shortwave radiation values for what happens to the incoming solar radiation. What is OLR? What is its source?

   (b) If there is energy balance an the TOA, then we would expect (Solar in)=(solar reflected)+(OLR). Does this hold for all data sources on a global scale? Which data sources have a global energy balance at the TOA?

   (c) The TOA energy budgets over land are negative for all data sources. What does this imply about net radiation from land? In other words, do we gain more energy or lose more energy over land?

   (d) Now compare TOA budgets over ocean for all data sources. Some values are positive and some are negative, which means that different data sources will conclude that there is net energy gain at the TOA over oceans and other would conclude there is a net energy loss. Are there defiencies with the data sources that would make some numbers more uncertain than others? You don't have to consider all data sources for this part. Choose one data source (one row in either table 1a or 2a) and discuss uncertainties in the data that might lead to errors in the estimations.

4. Data periods: ERBE verus CERES periods.

   (a) What are ERBE and CERES and what dates do these periods each cover? Identify at least 2 advances in data (either instruments or models) that occured between these two periods.

   (b) Two of the authors of "this paper" (data source in tables 2a and 2b, CERES period) contributed to KT97 (ERBE period). KT97 represents one of the data sources in tables 1a and 1b; what does KT97 stand for?

   (c) The global "NET down" for KT97 is zero; the global "NET down" for "this paper" is 0.9. What are the implications of having Net down greater than zero?

   (d) What are the reasons for having a present day best value of 0.9 compared to 0.0 reported in KT97? In other words:

      i. Has the net energy actually increased from the ERBE periods to the CERES period?

      ii. Have there been improvements in data sources (either improvements in instruments or models)? If so, what are some of these improvements?

      iii. What are the error bars on this value?

      iv. What does this imply about the global temperature?