Note: There is a video that accompanies this practice question set! You can find it here: https://drive.google.com/drive/folders/1ewKqzVXqrkNlVrCQr4CrAvqZBCuQrmBl

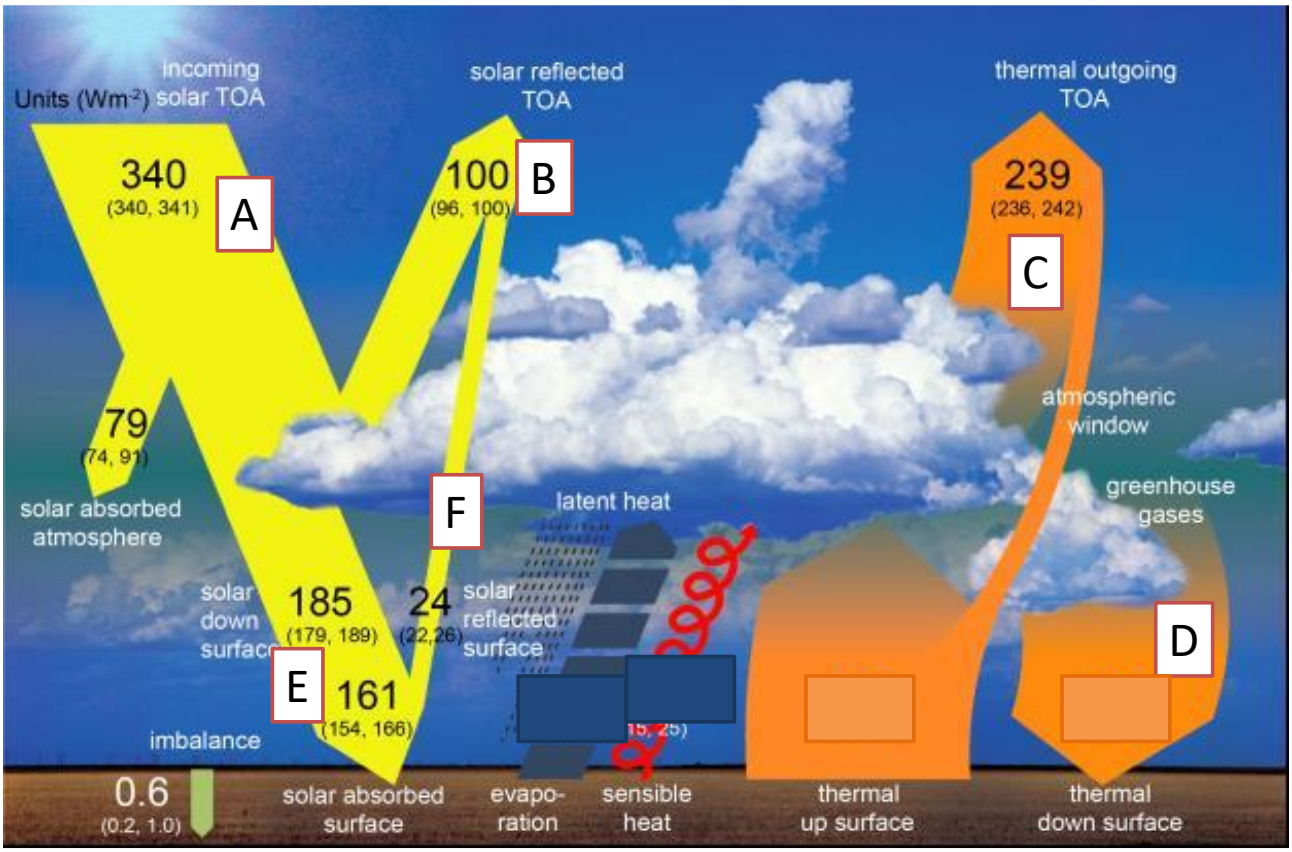

Figure 1 for BIO171. CAPTION from Figure 2.11 from IPCC report: Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in [Watts per meter^2], adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints…

"Thermal" refers to thermal radiation or heat radiation. "Solar" refers to solar radiation. "TOA" means "Top Of Atmosphere." The incoming and outgoing energy are not in balance. Some of the energy is stored in the earth (imbalance flux). Sensible and evaporative heat loss is the loss of heat by the earth to the atmosphere through transfer into the matter in the atmosphere (the gases); for example, warm pavement warms the air above the warm pavement. Radiation is electromagnetic; EM radiation can be absorbed by gases and transformed into another type of energy, but it is not the heat of gases. A Watt is a Joule per second (energy per unit time). Watts per meter^2 is sort of like water flowing past a dam in a river, except it is energy flowing past the area, not water. Climate Change 2013: The Physical Science basis: http://www.climatechange2013.org/

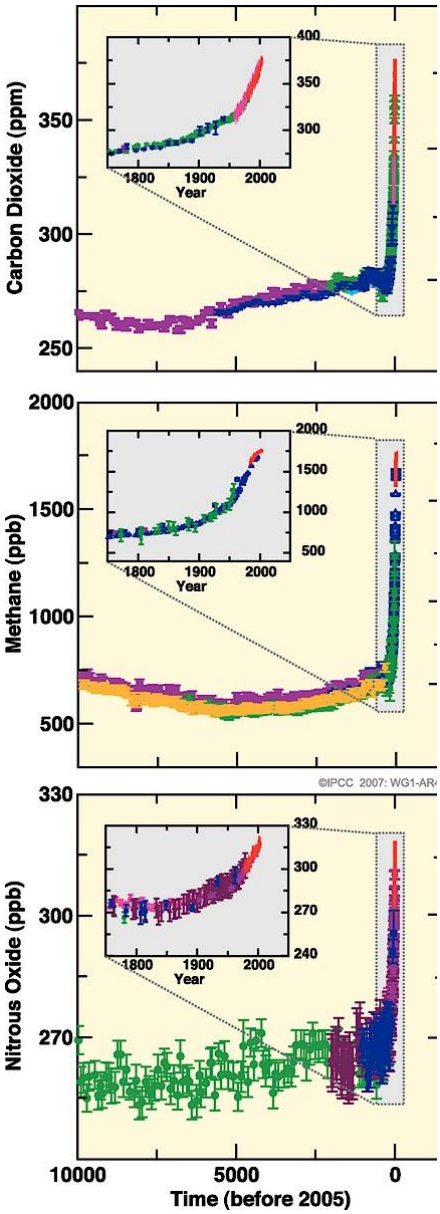

Figure 2 <u>for BIO171 (LEFT)</u>. Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Note that the figure is cropped from the original, for use in class. Measurements are shown from ice cores (symbols with different colors for different studies) and atmospheric samples (red lines)… FROM: IPCC (2007) Fourth Assessment Report: Climate Change 2007.

https://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-spm-1.html

What is causing climate change?

1. **What is "climate change"?** In other words, what is climate? What is changing?
2. **How does "climate" differ from "weather"?**

The accepted hypothesis (explanation) for the recent observed changes in climate on earth is that the greenhouse effect is increasing. This hypothesis has overwhelming support from data.

3. Consider Figure 1 carefully. This is a model explaining the flow (flux) of energy from the sun and through the atmosphere and surface of the earth, back to space.

   a. **In this figure, what is the ultimate source of energy entering the earth system? Which arrow indicates this source of energy?**

   b. **In this figure, why is the amount of energy absorbed by the earth's surface (161 Watts/m^2) lower than the amount of energy that enters the earth system through the outer atmosphere (340 Watts/m^2)? Is this due to the greenhouse effect?**

   c. **In this figure, the energy entering the earth system through the outer atmosphere (yellow arrow - incoming solar TOA: 340 Watts/m^2) is greater than the energy exiting the earth system through the outer atmosphere (yellow arrow – solar reflected TOA: 100 Watts/m^2 plus orange arrow - thermal outgoing TOA: 239 Watts/m^2).**
   Given this, is the heat energy of the earth system increasing? Decreasing? Remaining constant? Why?

   d. **In this figure, where is the "greenhouse effect" illustrated? Which arrow or arrows? Explain your answer.**

   e. **What type(s) of matter (type(s) of chemical) cause(s) the greenhouse effect?** Be very specific; name the chemical(s), as in lecture. Be sure to offer the state of the matter (solid? Liquid? Gas?)

   f. **Do clouds cause the greenhouse effect? Explain.**

Can climate change be changed?

We cannot reduce the incoming solar radiation (arrow A, Fig. 1). Most initiatives regarding slowing or stopping or reversing climate change focus on increasing reflected solar energy (arrow B, Fig. 1) or increasing the heat energy radiated into space (arrow C, Fig. 1). Increasing heat energy radiated into space (arrow C) requires a decrease in the amount of energy re-radiated toward the earth by greenhouse gases (arrow D).

Some people have ideas about how to increase the solar energy reflected into space (arrow B). However, these are not biological, so we will not address them in BIO171.

Understanding how to decrease the heat energy re-radiated toward the earth and how to increase the heat energy radiated into space require applying your knowledge of the biological carbon cycle (*How Life Works* Figure 46.12) and the global, long-term carbon cycle (*How Life Works* Figures 46.8 and 46.9.)

4. Consider Figure 2 (above), which shows the increase in some atmospheric greenhouse gases (GHGs). Using the following questions, determine what needs to happen to cause the change in CO_2 over time to become 0, that is, to make the line become horizontal.
   a. Look at Fig. 46.8 in *How Life Works*. This shows the global carbon cycle. Add up all the fluxes into the atmospheric reservoir (pool). Add up all the fluxes out of the atmospheric reservoir. **What is the difference between these sums? Is the net flux into or out of the atmosphere?**
   b. The difference calculated in (a.) is caused by addition of greenhouse gases to the atmosphere due to human action. Look at Figure 46.5 in *How Life Works*. What have humans done to add greenhouse gases to the atmosphere? Has the pattern changed since 1850? Since 1950?
   c. Has the effect of humans on the flux of greenhouse gas into the atmosphere decelerated? Accelerated? Increased or decreased at a constant rate? (Use Figure 2, above, and your textbook Fig. 46.5 to help you figure this out.)
   d. The difference in GHG flux into the atmosphere, calculated in (a.), causes a change in the flow of solar energy. The solar energy flows from the sun, through the earth system, and eventually into space. **Predict how this difference in greenhouse gas flux is modifying the flow of solar energy through the earth system, using Figure 1.**
   e. **If we want the increase in atmospheric carbon to stop, what changes could be made to the global carbon cycle fluxes**? Make a list using Fig. 46.8 from *How Life Works*. At this point, do not worry about economic or technological feasibility.
5. **If the human-caused increases in all the GHGs in the atmosphere stopped, and the atmospheric pools of these gases remained steady for decades, would the earth likely begin to cool to pre-industrial levels**? Carefully consider Figure 1 (above) prior to answering. Explain your answer using the arrows in Figure 1.