METR 113: Assignment 1 (Spring 2011)
Solution Sheet

Part 1: Based on data the last 100+ years, a fairly indisputable statement is as follows:

> "*Increasing carbon dioxide concentrations in the atmosphere have been an inevitable result of providing for increasing human population and maintaining an ever-increasingly industrialized society*".

Discuss why this is the case by showing and briefly discussing key data that support this statement.

*The concentration of carbon dioxide in the atmosphere has increased over the industrial era, the period from around year 1750 to today. This is shown in **Figure 1**, which shows carbon dioxide concentrations in the atmosphere as deduced from ice core measurements the last 1000 years. As seen, carbon dioxide concentrations have increased from a pre-industrial value of around 280 ppm to around 350 ppm by year 2000. Current-day levels (year 2010) are around 390 ppm.*

*The increase in carbon dioxide concentrations is mainly a result of fossil-fuel combustion and biomass burning. This can be seen in **Figure 2**, which shows a breakdown of the sources of greenhouse gas emissions among different source categories. Since carbon dioxide is the most abundantly emitted greenhouse gas, the breakdown in Figure 2 is essentially that for carbon dioxide. Fossil fuel combustion is the main source of the 'energy' emissions (60%) in the chart. The increased carbon dioxide in the air as a result of these emissions has been the key driver to the industrialization characterizing the industrial era. Fossil fuel combustion also contributes to the 'agricultural' emissions (14%) in Figure 2 through (among other things) its use for powering modern farming machinery. Biomass burning comprises the major portion of the 'Land Use Change/Forestry' (19%) emissions in Figure 2. A major reason for biomass burning is to clear space for agricultural land. Through these processes, increased carbon emissions, and therefore carbon dioxide in the atmosphere, have been a consequence of increasing agricultural yields the last 50+ years necessary to support food needs for increasing global population.*

*The above points are further emphasized in **Figure 3**, which shows the growth of the global "ecological footprint" the last 50+ years. The "ecological footprint" is a composite measure of global resource use that accounts for several resource categories, which are denoted on the figure. Additional details can be found at http://www.footprintnetwork.org/en/index.php/GFN/. As seen from the figure, the energy portion of the footprint (denoted as "carbon uptake – land") is the major reason for the growth of the overall footprint the last 50+ years. Other categories of resource use, by comparison, have only modestly grown over time. This emphasizes how energy use has been essential for providing resources for growing populations, particularly by increasing yields from cropland. Increased carbon emissions and resulting increase in carbon dioxide concentrations in the atmosphere, since this is a consequence of this increased energy use, are therefore inherently a result of increasing yields from earth's biocapable areas (cropland, fisheries, etc …).*

Part 2: One may then expand the above statement as follows (see underlined):

> *"Increasing carbon dioxide concentrations in the atmosphere and resulting global warming have been an inevitable result of providing for increasing human population and maintaining an ever-increasingly industrialized society."*

What would need to be additionally established for this expanded statement to be true? Why might you suspect, or "hypothesize", it to be true based on specific things covered so far in class? Why would this only be a hypothesis, however, and not clear support that this statement is true?

To support the added underlined section in the above statement, global warming needs to be proven to be mainly caused by increasing carbon dioxide concentrations (or more generally increasing greenhouse gas concentrations) in the atmosphere. Based on material covered so far in class, one may suspect global warming to be caused by increased carbon dioxide concentrations based on the following two pieces of evidence:

1. *Globally averaged near-surface and tropospheric temperature has increased the last 100+ years nearly coincidentally with carbon dioxide concentrations. In addition, like carbon dioxide, globally averaged temperature showed only modest variations prior to the start of the industrial era (circa 1750). These points are illustrated in **Figure 4**, which shows the increase in globally-averaged temperature over the last 1000 years for the northern-hemisphere (similar trends can be seen in a plot of southern hemisphere data). Comparing this plot with Figure 1, it is seen that temperature and carbon dioxide levels trace each other closely.*

2. *It is known that carbon dioxide is a greenhouse gas, and therefore acts to absorb infrared radiation emitted by the earth surface and re-emit some of this back to the surface. This process is popularly referred to as the "greenhouse effect". An increase in carbon dioxide concentrations would therefore, theoretically, increase the greenhouse effect and therefore lead to increased warming of the earth's surface and lower atmosphere (troposphere).*

Taken together, these two clearly support a hypothesis that global warming is caused by increasing greenhouse gases in the atmosphere. However, this would still only be a hypothesis, and not proof of the link. Concerning the first point, the fact that two variables trace each other closely does not mean that one (A) causes the other (B). 'B' could instead be causing 'A', or there could instead be no relationship at all, with instead the close tracing of the two variables being merely coincidental. Concerning the second point, the identification of a physical mechanism linking global warming to increased carbon dioxide concentration does not mean that this mechanism is the main reason for the increased warming. There could be other equally plausible mechanisms explaining the warming that have nothing to do with increasing carbon dioxide concentrations.

Part 3: One may then further change, or alternatively phrase, the statement as follows:

> "*Increasing ~~carbon dioxide concentrations in the atmosphere and resulting global warming~~ air pollution concentrations in the atmosphere have been an inevitable result of providing for increasing human population and maintaining an ever-increasingly industrialized society.*

What would need to be established for this changed statement to be true? That is, what would need to be established so that we can change the phase crossed out to "air pollution concentrations in the atmosphere"?

For something to be an air pollutant, it must be clearly established that it can potentially build-up in concentrations in the atmosphere that are harmful in some respect. In this case, therefore, resulting global warming from increased carbon dioxide concentrations in the atmosphere must be shown, at least potentially in a way that's practically significant, to be harmful to human health and/or welfare.

The implication from the above sequence of statements is that the "air pollution" referred to in the statement in Part 3 is carbon dioxide. Why can't 'air pollution' instead refer to air pollution species in general? To answer this, give and briefly discuss one example of an air pollution species for which the above statement is false.

*The above statement cannot apply to air pollution species in general since there are many examples of air pollution species whose concentrations have actually decreased alongside increasing industrialization and population growth. One example is carbon monoxide in the United States, a graph of which shown in **Figure 5**. The plot shows concentration measurements in the U.S. since around 1980. As seen, carbon monoxide concentrations in the U.S. have decreased with time over recent decades, which is a result of better regulation of this pollutant gas. Increasing air pollution concentrations are therefore not an inherent consequence of increased industrialization and population growth. Instead, the validity of this link would depend on the specific air pollutant species considered.*

Figure 1

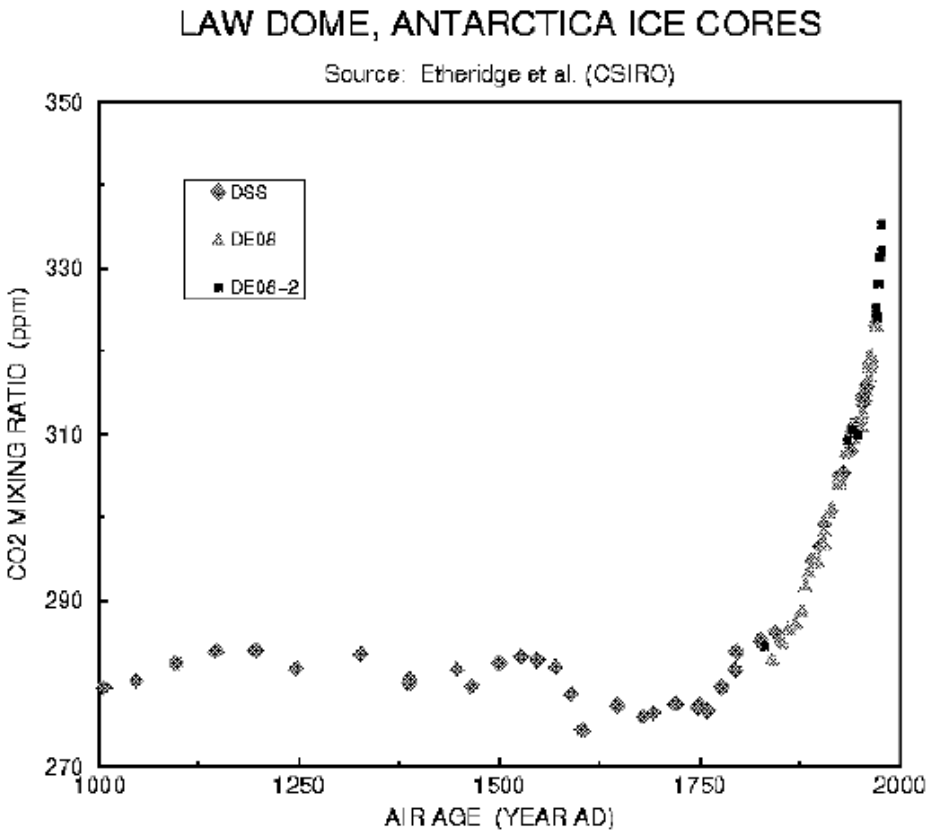


Figure 2

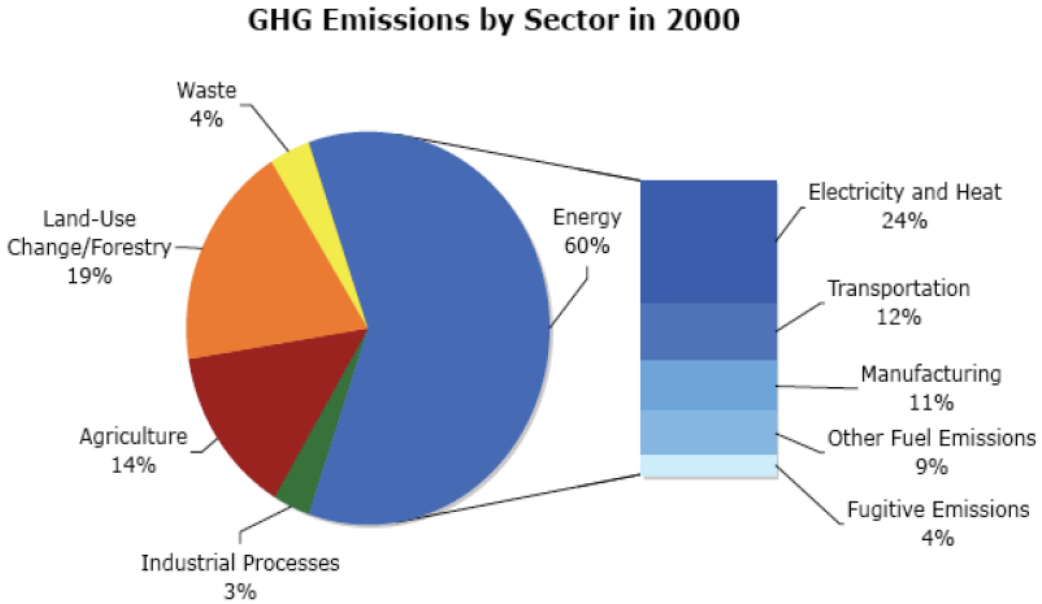


Figure 3

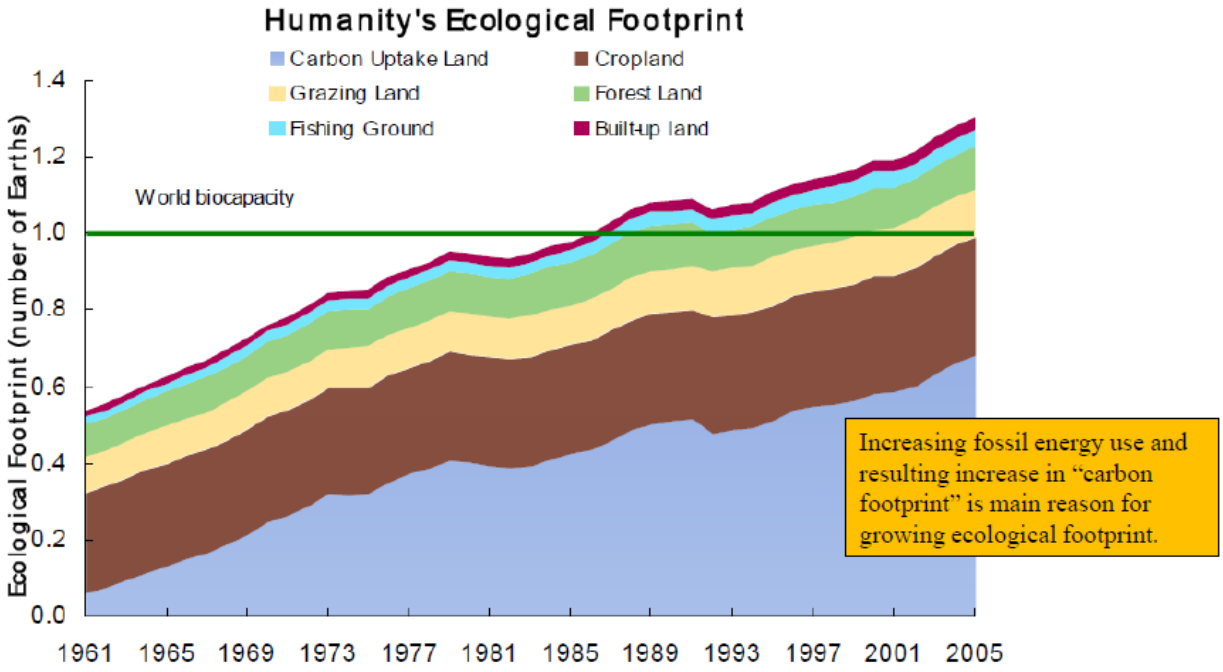


Figure 4

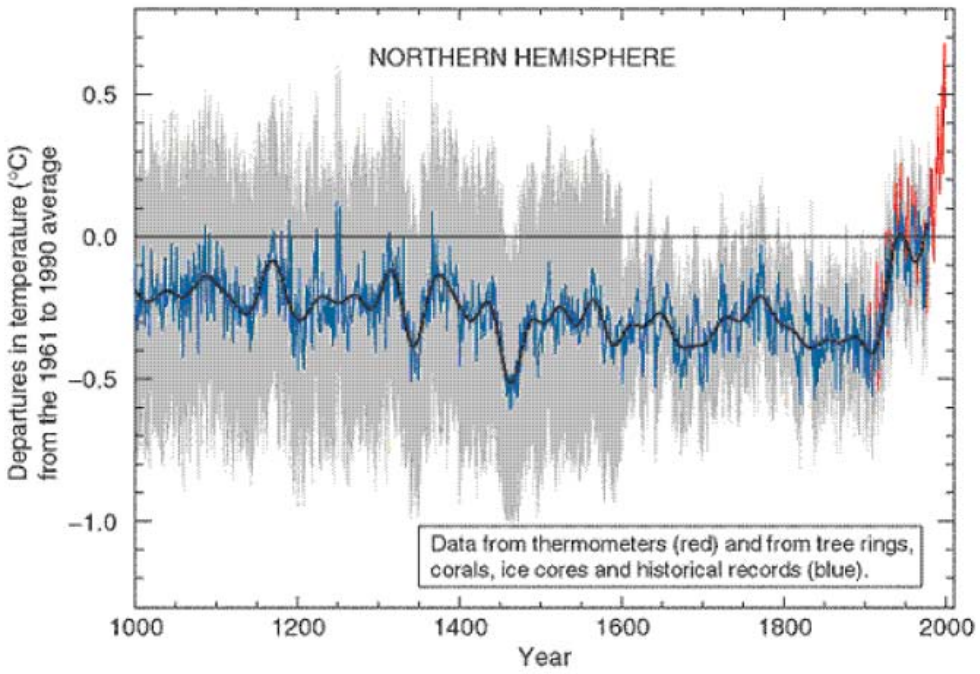
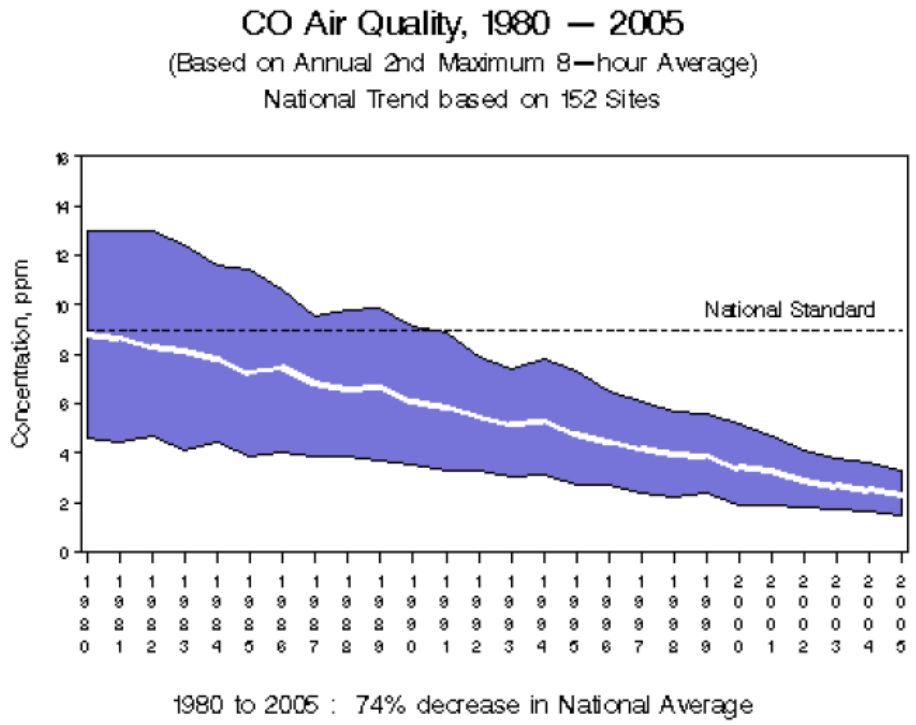


Figure 5



Grading: General guidance to interpreting the score assigned on your paper. Actual score may be different by a couple points or so from scores below, generally due to mark-offs for relatively noticeable typos, grammar, formatting errors.

Score	**General Interpretatation**
90	Got main points for all questions. Generally well-written (substantial yet concise, few problems with grammar/typos).
85	Generally got main points for all questions, but perhaps not exactly or some minor problems explaining. Generally well-written (substantial yet concise, few problems with grammar/typos).
80 (Reason 1)	Generally got main points for questions, but perhaps not as much for one of the question. A few more problems with grammar/typos start to appear.
80 (Reason 2)	Generally got main points, but discussion was not substantial enough. Need to explore and write more.
75	Generally got main point for one question, but not as much for the other two. More problems with grammar/typos start to appear.
70	Generally got main point for one questions, but not for the other two. More problems with grammar/typos.
60/65	Did not get main points, or if so just for one question. In general, not enough thought and writing. Fairly widespread grammar/typos.