1 Global Warming

For Instructors

1.1 Hansen Article

Have the students read James Hansen's article from the New York Review of Books before class. Begin class with a 3-minute quiz on the article. Make sure students know before class that they will face a quiz on the article, first thing!

The file `hansenquiz.pdf` (and `hansenquiz.tex`) contains a sample quiz. Any questions that you don't use for the quiz can be used for class discussion. On page 2 of `hansenquiz.pdf` is a list of all the sample questions that we are providing.

Below is a list of the sample questions *and solutions*.

1.
a) What does Dr. Hansen mean by the term "isotherm"? (One sentence.)
`Isotherms are regions in which there is a given average temperature.`

b) Explain **very briefly** what Dr. Hansen means when he says that "isotherms" are moving poleward.
`The Earth is warming, so regions closer to the poles are taking on average temperatures that used to occur only closer to the equator.`

c) Describe briefly an example of an unfortunate consequence of this fact.
`Many plant and animal species will go extinct, as their climate zones move poleward faster than they can migrate.`

2. Give an example of a dire consequence of maintaining what Dr. Hansen calls "business-as-usual." Be specific. (Answers like, "The temperature will rise." or "Bad stuff will happen." will not receive much credit.)
`Any of the following:`
- `50% or more of species on Earth could go extinct.`
- `The polar ice-caps will melt.`
- `Polar animals will go extinct.`
- `Species that require the cold air of high altitudes will go extinct once mountain-tops become too warm.`
- `The water-resources required for civilization will become scarce.`
- `Rising seas and violent storms will lead coastlines to be radically redrawn, eliminating most of the largest population-centers on Earth.`

3. Give an example of a way in which Dr. Hansen thinks that the Kyoto Protocol is superior to "business-as-usual."
Average global temperature is predicted to increase 5° F in the next century under the business-as-usual scenario, but only 2° F if we adopt the Kyoto Protocol.

4. Why does Dr. Hansen mention methane and permafrost? Explain in 3 sentences or less.
Methane is a significant greenhouse gas that contributes to global warming. There are vast quantities of frozen methane hydrates, trapped in permafrost, that -- if released by global warming -- will cause significantly increased warming in a positive feedback loop.

5. Dr. Hansen claims: "Any responsible assessment of environmental impact must conclude that further global warming exceeding ___ degrees Fahrenheit will be dangerous." Fill in the blank.
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6. Why does Dr. Hansen say: "We have reached a critical tipping point."? In your brief answer, please mention the time-frame in which Dr. Hansen claims that drastic changes must be made to avoid "tipping" the wrong way.
If we do not make serious changes in our greenhouse-gas output in the next 10 years, it will be impossible to prevent a 2 degree Fahrenheit increase in average temperature. And if that happens, it is likely that much greater increases in temperature will be unavoidable.

7. Why does Dr. Hansen mention CFCs? (Brief.)
CFCs posed a major threat to our planet, but in the 1970s the media alerted the public to their danger and the public forced politicians to mandate independence from CFCs. We face another atmospheric crises, and similar media attention and public insistence might help save the planet once again.

8.
a) What fraction of species does Dr. Tim Flannery estimate will go extinct under the "business-as-usual" scenario?
60%

b) What about under the alternative scenario?
20%

1.2 Melting Ice

Think-Pair-Share Time

Have the students design and carry out an experiment to test what causes a greater increase in sea-level – when land-based or sea-based ice melts.

Think: Have them first think for 1 minute on their own.
Pair: Then discuss with a partner for 2 minutes.
Share: Then share with the whole class.

(Adjust the suggested times to whatever seems productive.)

Make sure that you have plenty of identical icecubes available, and water, cups, some popsicle sticks, and rulers.

1.3 Coastlines

Put a lot of sand in a fish tank, with a little bit of water (~ 0.5 inch) at the bottom. The sand should make a right-triangle with the edge of the tank, with the hypotenuse being a sloping beach.

Have the students each make a prediction for where the new coastline will be when you add 3 inches of water to the tank. Mark on the side of the tank in wax pencil where the water should rise to.

Don't be shy as you pour the water in – let it splash around. The students should notice that the new coastline is farther inland than just the extension of the wax-pencil line to the old beach.

Discuss the significance of this.

1.4 Expansion

1.4.1 Cooking

Have the students leave their lab handouts at their tables and go as a class to the kitchen.

Make smores with the students. Put marshmallows in the microwave, and add them to graham crackers and chocolate.

Show students a mercury-style thermometer (non-digital). Put the thermometer first in cold water, and then in hot water, and watch as the "mercury" rises.

- Why did the marshmallows expand in the microwave.
  `Hot stuff expanded.`
  (*You can ignore the fact that water turned into vapor unless the students explicitly mention this.*)
- Why does the "mercury" rise when the temperature goes up.
  `Hot stuff expanded.`
- How do you expect the oceans to respond to increasing temperature?
  `Ice will melt and will cause them to rise.`

  Now, ignore the fact that when the temperature increases, ice melts. Again, how do you expect the oceans to respond to increasing temperature?
  `Thermal expansion will cause the water in the oceans to get bigger, which will make the water level rise.`

1.4.2 Calculating

Now, return to the lab classroom.

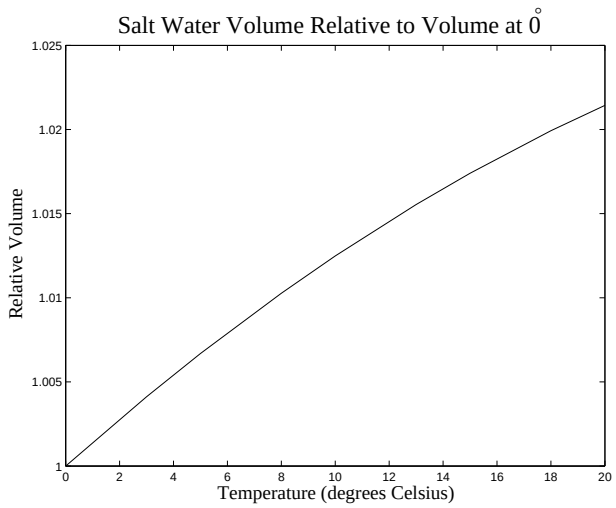
- The volume of a given mass of salt-water scales with temperature approximately as follows:
  $$V_{\text{sea}}(T) \propto 1 + 1.42 \times 10^{-3} \left(T - 0.0124T^2\right) \tag{1}$$
  where T is measured in Celsius.

  Make sure you understand what that $\propto$ symbol means. It's a way of summarizing ratio relationships. For a given temperature, equation (1) is meaningless. It is only useful for comparing the volume of a certain mass of salt-water at two different temperatures.

For example, let's compare the volume of a given mass of salt-water at 3° C to the volume of that same mass at 6° C. Using equation (1) in ratio form, we may write

$$\frac{V_{\text{sea}}(6^\circ)}{V_{\text{sea}}(3^\circ)} = \frac{1 + 1.42 \times 10^{-3}\,(6 - 0.0124 \times 6^2)}{1 + 1.42 \times 10^{-3}\,(3 - 0.0124 \times 3^2)} = 1.0038,$$

which indicates that salt-water takes up 1.0038 times the volume dense (or, is 0.38% less dense) at 6° C than at 3° C. Below is a plot of relative volume as a function of temperature (relative to the volume of a given mass of salt-water at $T = 0$):



There is a mild division in the ocean. Below 1 km below sea-level, the ocean has a fairly different temperature and density than it has above that level. Let's call the level of that division L.

The average ocean temperature below L is about 4 degrees Celsius and above L is about 13 degrees Celsius.

- Use equation (1) to estimate the likely rise in sea-levels if the average ocean temperature above L increases by 5 degrees Celsius.

  a) First, calculate the relative increase in volume:
  `The relative increase in volume is:`

$$\frac{V_{\text{sea}}(18^\circ)}{V_{\text{sea}}(13^\circ)} = \frac{1 + 1.42 \times 10^{-3}\,(18 - 0.0124 \times 18^2)}{1 + 1.42 \times 10^{-3}\,(13 - 0.0124 \times 13^2)} = 1.0043.$$

  b) In what direction(s) can the ocean expand?
  `Only up.`

  c) Use your results from parts a) and b) to answer the question.
  `If the volume increases by 0.43% in the upper 1 km of the ocean, and the ocean has only one direction to expand -- up --, the upper 1 km of the ocean will expand 0.43% up. 1000 m x 0.43% = 4.3 m.`
  `Thermal expansion of the ocean will cause global sea-levels to rise 4.3 m, or 14 feet!!! Even if no land-based ice melts, (which of course it will) a rise in sea-level of 14 feet would basically sink Cape Cod!`

Return to 1.2, Melting Ice...

Make sure that, before you finish the lab, you discuss once again whether the melting of land-based or sea-based ice poses a greater threat to us.