Teaching Activity: Flaws in Computerized Climate Models

Introduction: It is becoming more and more common in the environmental science to describe systems of complex and interacting processes involving physics, chemistry and biology through what are termed *numerical models*. Because of the many possible combinations of processes in nature, mathematical models are used when scientists are trying to understand a system's behavior as a whole. Models can be thought of as attempts to create computer likeness of natural systems, so that causes and effects may be better understood. From a scientific position, the most interesting kinds of model development may not exist until our knowledge has increased enough to allow us to design a model where all parts of the system are well understood.

Model results must be checked carefully to catch any possible errors which may occur and could indicate a lack of understanding of the most important processes and interactions. One confidence in models that has been acquired lately is their ability to predict future conditions resulting from changes in single natural processes such as sun spots, volcanic eruptions, or those caused by human activity, such as the emission of industrially produced trace gases. Models put a great deal of responsibility on the shoulders of scientists to critically test them and report the results. Despite the quality control, models do make incorrect predictions, just as weather forecasts do. A lot more research is needed to improve the scientific basis and the performance of the models, and to lessen mistrust of the results.

Objective:

- To understand that there are many questions about the reliability of computerized climate models;

Important Terms; CO_2,CH_4, CFCs, climate models, global warming, greenhouse effect, greenhouse gases, longwave radiation;

Materials: Copies of **Student Activity Sheets**, copies of **Criticisms A, B and C**, paper/pencil;

Procedure:

1. Divide the class into groups of three.
    - Each person in the group will be responsible for reading one of the three **Criticisms, A, B or C.**

2. Within each group, each student reads a criticism and becomes an "expert" on his/her topic.
    - Each student will brief the other members of his group, explain the material, and ask questions.

3. As a group, students should then answer the question # 1- 12 in the **Analysis/Comprehension** section and be ready to use them as part of a class discussion.

4. Have copies of the **Lesson Summary** available to help them formulate ides for the discussion.

5. Reconvene the entire class and allow time for discussion.
   - Have students try to come to some agreement about whether waiting for certainty is best or if the problem is worth acting upon immediately.
   - Ask students to write a short essay explaining the rationale behind their opinions.

Student Activity Sheet: Flaws in Computerized Climate Models

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Objective:

- To understand that there are many questions about the reliability of computerized climate models;

Procedure:

1. Each person in your group will be responsible for reading one of the three **Criticisms, A, B or C**.
   - Each of you will become an "expert" on your topic.
   - You will brief the other members of his group, explain the material, and ask questions.

2. As a group, answer the question # 1- 12 in the **Analysis/Comprehension** section and be ready to use them as part of a class discussion.

3. Use the **Lesson Summary** to help you formulate ides for the discussion.

4. Try to come to some agreement about whether waiting for certainty is best or if the problem is worth acting upon immediately.
   - Write a short essay explaining the rationale behind your opinions.

Criticism A ______________________________

Besides CO_2, a major greenhouse gas in the Earth's atmosphere is water vapor. Evaporation from the oceans and other bodies of water puts water vapor into the atmosphere. The amount of water vapor is closely related to temperature. As temperatures rise, more water evaporates into the atmosphere. So, if temperatures rise from the increase in greenhouse gases, more water vapor would enter the atmosphere. Because water vapor in the atmosphere is what forms clouds, this means there would be more clouds (Henderson - Sellers and Blong, 1989).

But exactly how more clouds will affect global temperatures is cause for uncertainty in the climate models. Clouds help regulate the Earth's temperature. Typically, clouds cover half the Earth and reflect 30 percent of the incoming sunlight back to space. But clouds do more than reflect sunlight. They also absorb long wave energy (heat) radiated by Earth and re-radiate this heat back to the surface. Thus, clouds make their own greenhouse effect. However, at present the reflective behavior of clouds is greater than their greenhouse effect. So, clouds currently have an overall cooling effect on Earth's average global temperature (World Resources Institute 1990).

Will this cooling effect from clouds remain if global warming occurs? It depends on the height of the clouds. High clouds (cirrus clouds) trap Earth's heat well. But low- to mid-level clouds (stratus and cumulus) reflect incoming solar radiation. So, if global warming increase the amount of high clouds, the present cooling effect could be reduced or even changed to a warming effect. This would add to the world's overall global warming. On the other hand, increasing the amount of low - and mid-level clouds might increase the cooling effect and counteract any global warming (World Resources Institute 1990).

Computerized modeling is not year advanced enough to make dependable predictions of the change in cloud heights if global warming occurs. They just don't know which possibility - greater heating or greater cooling from the clouds - will occur with more greenhouse gases.

Criticism B ______________________________

About 70 percent of the Earth's surface is covered by oceans. The average depth of the oceans is over 4 kilometers (km). So, there is a huge amount of water that would have to be heated before global warming occurs. But water takes much longer to heat up than air does. The following quote explains why this leads to uncertainty about the accuracy of computerized climate models:

> The heating of the upper part of the ocean (the top 70 meters or so) can be represented by a warming body of water, like a vast swimming pool. We understand a lot about how this top slice of the ocean will warm, but there is almost 4 km below this which is called the "deep ocean". This deep ocean has a circulation of its own, which has to be modeled in the same way that we model atmospheric circulation. All we can say with confidence so far about deep ocean circulation is that it acts in such a way that warm water is pulled down very deeply. The net result of this is that the deep ocean circulation is effectively removing heat from the climate system. Of course, eventually all the deep ocean will warm, but we do not know how long this will take.
>
> (Henderson-Sellers and Blong 1989)

How long will it take for the deep ocean temperatures to rise to the new surface temperature? Most scientists estimate that warming of the deep ocean will take from 80-100 years. But some scientists think it will only take 20 years, and other think that it may take as long as 500 years. However long its takes for the deep ocean to heat, it will slow global climate change down a bit.

Models of ocean circulation are less advanced and therefore less accurate than models of the atmosphere. Predictions about the atmosphere can be tested against observations of other planets. But there is no other ocean in the solar system that can be used to test scientific predictions about our oceans.

Criticism C ______________________

The atmospheric amounts of both CO_2 and CH_4 have risen enormously since 1950. All CFCs came from human actions during the past 50 years. But the record of temperature increases since 1850 shows that most of the warming that occurred during the past century happened before 1950 and the huge increases in greenhouse gases. In fact, the northern hemisphere shows no overall change after about 1940. During this period, CO_2 amounts increased from about 300 ppm to 350 ppm.

In addition, temperatures in the higher latitudes (toward the poles) have not increased during this century as predicted. The evidence shows that there was a rise in temperature *before* there was a significant increase in greenhouse gas emissions. This temperature rise was actually followed by a decline in temperature in higher latitudes. A study in Alaska showed that there was no measurable trend in temperature change since 1960.

Predictions of warming are often based on the similarity of past climate changes to the CO_2 record, as shown by ice cores taken from Antarctica. However, one cannot actually determine from these records whether changes in CO_2 came *before* or *after* changes in temperature.

In addition, human actions also produce substances that counteract the warming. Some of these molecules are common air pollutants in urban areas. For example, molecules of sulfur dioxide can serve as centers around which water vapor condenses, forming clouds. These pollutants can thus brighten clouds. This could increase the reflection of sunlight and reduce the warming from increased greenhouse gases. In fact, this could explain why the northern hemisphere has not yet warmed up as much as predicted, since most sulfur dioxide emissions occurred in the industrialized northern hemisphere.

LESSON SUMMARY

Statement #1. Climatologist Reid Bryson has this to say about climate models:

> A statement of what climate is going to be in the year A.D. 2050 is a 63 years forecast. Do the models have a demonstrated capability of making a 63 year forecast? No. A 6.3 years forecast? No. Have they successfully simulated the climatic variability of the past century? No. They are marvels of mathematics and computer science, but as yet, rather crude imitators of reality.

Statement #2. A statement about climate models by climatologist Stephen Schneider:

> It will take at least 5 years to build the....atmosphere, ocean, biosphere, land-surface, sea-ice and chemistry sub-models that are needed is scientists are to have any hope of predicting the evolving regional climatic changes. Five to ten years may be necessary to get computers large enough to run such models routinely to determine the quality of their forecasts. Also, some five to ten years will pass before major data-gathering projects begin to provide data to validate the various sub-components of such modeling. Thus, 10-20 years is suggested as the time required for everything to come together and for detailed predictive skill to become credible.

Student Activity Sheet #1

ANALYSIS AND CONCLUSIONS

1. Note that clouds can both reflect light and hold surface heat. Explain how these two effects might counteract one another. ____________________

2. In which scenario above would cloud effect a negative feedback? A positive feedback? ____________________

3. What would be a good title for Criticism A? Why? ____________________

4. You read that water takes longer to heat up than air does. Think of an example to show that water temperatures are usually cooler than air temperatures. ____________________

5. Summarize Criticism B in one or two sentences. ____________________

6. What would be a good title for Criticism B? Why? ____________________

7. Sulfur dioxide (SO_2) is known as a major source of acid rain. If Criticism C is correct about the effect of this substance on global warming, should it still be considered a pollutant? Why? ______________________________

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8. Summarize Criticism C in one or two sentences. ______________________________

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9. What would be a good title for Criticism C? Why? ______________________________

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10. Do you think that what you have learned about the greenhouse effect and global warming which support the models outweighs the criticisms in this activity?

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11. Clearly scientists are not in agreement in this subject. What should governments do in the face of this uncertainty? Do you think more research will solve the problem? Why or why not? ______________________________

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12. Should we wait until we are certain that global warming will occur before we take action? Do you think the problems of climate change are severe enough that some action should be taken now? Why do you think as you do? ______________________________

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