Earth Climate Course

What Determines Global Climate?

Curriculum Module in Review

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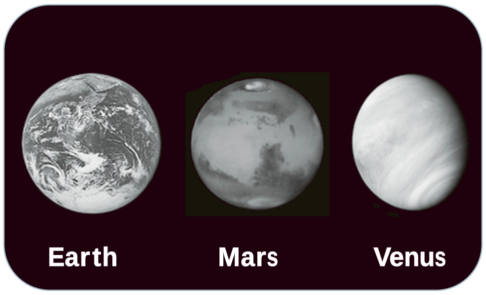
The first module of the GISS/ICP Earth Climate Course (ECC), *What Determines Global Climate?*, is currently in review. Pre-college teachers and graduate education students are the ECC audience, providing them with hands-on learning modules to explore the factors that make Earth the only planet with a habitable climate in our solar system.

Planet Earth is viewed as a closed system composed of an atmosphere with gases and clouds and a surface with ocean, land, and ice regions. The planet's climate, then, is the result of interaction between input energy from the sun and those system components. Coursework and instructional materials for learning about Earth's climate system combine experimentation using physical models with inquiry using interactive computer modeling software and observations from satellites and ground-based instruments. These learning activities ultimately aim to impact pre-college students by developing their aptitude for systems thinking, and the knowledge and skills needed to succeed in the Sciences. All too often, students complete a science course knowing facts. The ECC attempts to give students learning experiences to place these facts into a framework of Earth's climate system and to think about a problem scientifically, a process that fosters development and application in other disciplines.



Students hypothesize temperatures for Earth, Venus, and Mars before experimenting with a computer model to understand planetary habitability.

Three additional ECC modules are also under development, entitled: *What Determines a Region's Climate?, How is Our Planet's Climate Changing?*, and *How are Regional Climates Changing?* Modular structure covers the spatial connections between planetary climate and diverse regional climates, and time progression between present and past climates and potential future climate changes. Taught as an entire course (consecutively or in an alternate sequence), ECC provides the background knowledge that enables students to understand issues related to global warming and it's effect on local matters like water availability and energy conservation. An instructor may also use parts of the modules most appropriate to what he/she is teaching. By integrating the ECC into a science course in any of these formats, students gain insights into current issues, including climate change and global warming, the reliability of models and their predictions and the magnitude of humanity's effect upon our environment.

Instructors incorporating the *What Determines Global Climate?* module can introduce students to basic concepts of radiation theory that explain why factors like the brightness of a planet's surface or the density of its atmosphere are crucial in determining the planet's surface temperature and overall climate. Since this first module presents the ECC learning approach and contains most of the background necessary for a thorough understanding of the other modules, it has taken the longest to produce. This article gives an overview of the activities in *Module 1* and provides ideas on how a typical high school science instructor could utilize it in the classroom.

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NY State Science Standards Addressed by the "What Determines Global Climate?" Module

1. 2a. devise ways of making observations to test proposed explanations
4. 4a. observe and describe transmission of various forms of energy
4. 7a. describe the range of relationships of humans with the living and nonliving environment

Activity 1:
Student Measurements

Students begin with a simple measurement activity that quickly turns into an overview of the range of temperatures found on Earth and within the solar system. Groups of students are asked to measure the temperature of the air inside the classroom and outside the building.

The groups are brought back together to compare their two temperature readings and the nature of the observed difference is discussed. How large a difference is observed will depend on the time of year the class is conducted, and the instructor should be able to elicit a list of modifications made in the classroom environment in order to make the conditions comfortable for humans.

The instructor can then turn the students' thoughts to a more global scale by showing slides from Sahara or in the Antarctic and asking what kind of accommodations would have to be made in these locales to produce a similar level of comfort. This allows the students and the instructor to establish the state of the student's awareness of conditions around the earth.

This first activity ends by asking the students to speculate as to what modifications would be necessary to conduct the class on another planet in the solar system. Students then view a series of slides or photographs of various points in the solar system along with a description of the temperature ranges found there.

Activity 2:
Preparing A Concept Map

After preliminary exposure to the harsh conditions found off the earth, students brainstorm and produce a concept map of what they consider to be the five most important factors affecting the temperature/climate of a planet.

The students work in groups with each team producing its own concept map. The map is structured as a system diagram, with inputs, properties and outputs clearly defined.

Different groups then explain their concept maps to the others and are in turn questioned and evaluated by their peers. These evaluations are based on the clearness and logic of the presentations, and not on the "correctness" of the presenting group's assumptions. These will be self-evaluated experimentally in the third activity.

ICP student researchers. Raysa Rodriguez (at left) and Rosa Andujar (right) working with physical box models.

Activity 3:
Building Physical Models

The third activity revolves around a challenge. Each group is asked to examine their concept map, and using ideas from that map, construct physical models of a hot and a cold planet. Students are provided with a container, light source, thermometer and a selection of various materials (e.g. dark/light gravel, clay, water, plants, plastic sheet) but essentially design their own closed systems, carry out experiments, and evaluate results.

They are asked to maximize the temperature difference of the two models, but are only allowed to alter one condition between the models. Other conditions must be identical. The group that produces the greatest temperature difference based on their choice of one condition "wins" the competition.

Groups compare their results and evaluate the relative importance of climate variables including albedo, distance from the source of energy, brightness of the source and presence of an atmosphere. If time permits, they can modify their experiments in order to maximize their difference. During a class lecture/discussion, results are examined in the context of the actual temperature difference between a hot and cold planet, specifically Venus and Mars.

This activity ends with a discussion of the usefulness of these student-built physical models in science and their limiting factors.

- 6. 1c. defining the boundary conditions when doing systems analysis to determine what influences a system and how it behaves
- 6. 2b. collect information about the behavior of a system and use modeling tools to represent the operation of the system
- 6. 4. equilibrium is a state of stability due either to a lack of changes (static equilibrium) or a balance between opposing forces (dynamic equilibrium)

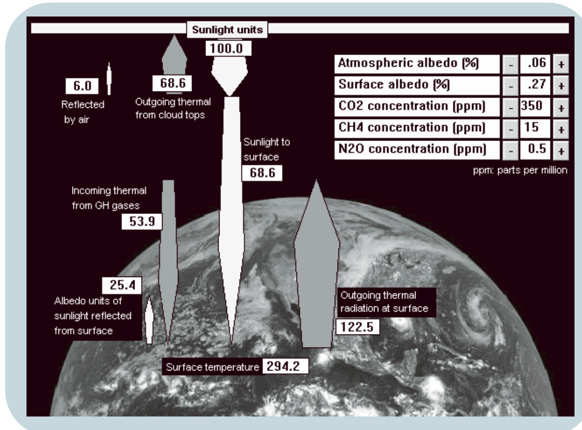
Activity 4:
Using Computer Models

Students are introduced to a different type of a system model, the mathematical or computer model. The purpose of using a mathematical model is to produce temperature differences that more accurately represent the observed temperature difference of Venus and Mars, and to run repeated experiments under varying conditions in a timely manner. To facilitate students' understanding of a computer model, they are asked to design an Excel spreadsheet that will enable them to calculate the black body temperature of a planet given the brightness of the energy source and distance from the source.

After a brief introduction to Excel, they are given the inverse square relationship for distance and the Stefan-Boltzmann relationship for black body temperature and asked to design a spreadsheet to determine the temperature of a black body planet. They use their completed spreadsheets to determine the black body temperatures of Venus, Earth and Mars and compare these with known surface temperatures of these planets. Based on their experience with the physical models, the students are asked to suggest modifications that could be made to their mathematical models in order to reduce discrepancies between their calculated temperatures and observed values.

Activity 5:
Introduction to Satellite Data

One of the suggestions will be to include the albedo of the planet. Students are given a map of the surface albedo of the earth derived from satellite observations. They work in groups to determine the average albedo of one-sixth of the earth's surface, using an Albedo Calculator spreadsheet.



Visualization of a Model Planet computer courseware.

All groups then combine their results to determine the average albedo of the earth. This value is then used with the ICP's GEEBITT (Global Equilibrium Energy Balance Interactive Tinker Toy) Excel spreadsheet model (found at http://icp.giss.nasa.gov/education) to determine the black body surface temperature of the earth with an albedo. Similar approximations are made for the albedos and surface temperatures or Venus and Mars.

Once again, students will notice discrepancies with actual temperatures of the surfaces of these planets. They are then provided with a more detailed version of the GEEBITT model, which includes an atmospheric factor. They are asked to manipulate this atmospheric factor to produce realistic surface temperatures for Venus, Earth and Mars.

In the discussion that follows, students should state that the magnitude of the atmospheric factor for Venus is much larger than for Earth or Mars and that the factor for Mars is quite small. They should relate these results to what they know about the atmospheres of the three planets and this "atmospheric factor" should be related to the Greenhouse Effect.

The activity ends with students using the *Visualization of a Model Planet* computer model (authored by Professor Sam Borenstein of York College). Using this, students can see each step of the process through which input energy from the sun interacts with the planetary system's properties to determine equilibrium surface temperature of the planet.

A similar teaching process, relying on the concept of a system and using physical and computer models as the main tools, is followed in all four modules of the ECC. *Module 1*, in exploring the main factors that establish surface temperature of a planet, sets the stage for the other three. Variations in these factors at a local level across the surface of a planet clarifies the variety of conditions found in local climates, as well as changes in global climate that have occurred through time. The role humans may play in future climate change will also become clear as students realize which of these factors can be most affected by the activities of humanity.

Attention Teachers:

If you are interested in assisting in the review of *What Determines Global Climate?* and receiving a copy of the module to try in your class, please email Carolyn Harris, Director, Institute on Climate and Planets, at *charris@giss.nasa.gov*

ACKNOWLEDGEMENTS:
ROBERT KRUCKEBERG, A. Philip Randolph High School
PATRICK CUSHING, New Rochelle High School
for their contributions to this ECC module.