Climate Science Research for Educators and Students (CSRES): Understanding Sun/Earth/Atmosphere Interactions

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http://www.instesre.org/GCCE/GCCEHome.htm
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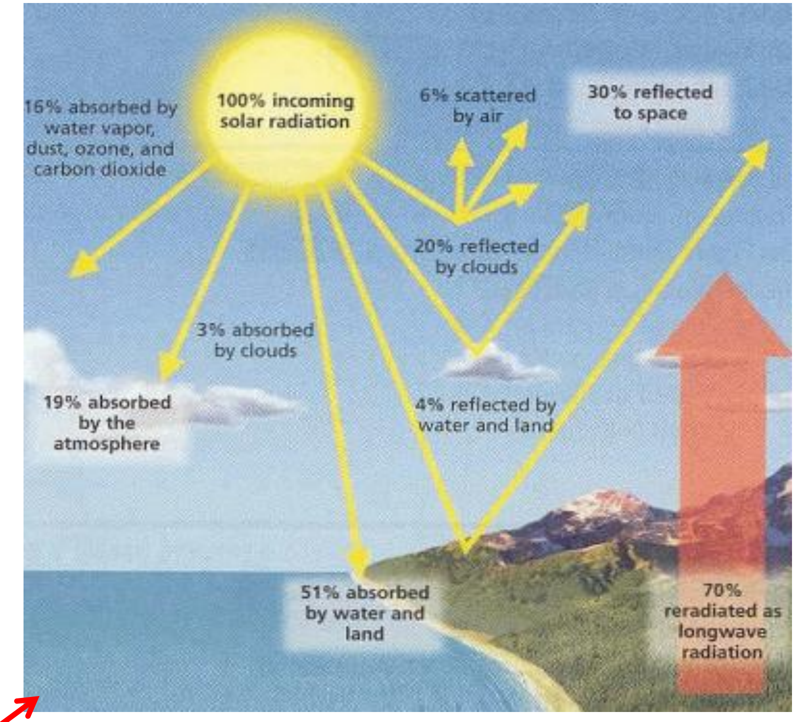
The Challenges:

1. Help teachers and students understand Earth's radiative balance – a fundamental (but poorly understood!) concept for climate science.

2. Help to build an infrastructure that supports student inquiry and research in Earth/climate science, and that will help build a STEM workforce and an informed citizenry to engage in the climate change debate during the 21st century.

Hardly anybody understands these graphics!



Allison, Mead A., Arthur T. DeGaetano, Jay M. Pasachoff. *Earth Science*. Holt, Rinehart and Winston, 2006.

The CSRES Team:

Principal Investigator: David Brooks, IESRE

Co-Investigator: Peter Schmidt, Queens College

Investigator: Mark Miksic, Queens College

Evaluator: Gaylen Moore

NASA/AESP educators

NY-area secondary school science teachers/mentors/students

Other schools around the country

A "Top Down" Approach:

1. Develop mentoring, equipment, and protocols that enables secondary school science teachers/mentors to support student climate-related inquiry and research that will be competitive in high-level national science competitions.

CSRES believes that students will gain "ownership" of fact-based climate science and Earth/sun/atmosphere interactions only through making their own climate measurements.

2. Yearly workshops at Queens College/CUNY, outreach through NASA/AESP, collaboration with GCCE project at Drexel University.

Some NY-area teachers work exclusively with students developing science fair projects. CSRES believes that reaching this kind of audience should be the first step in developing a supporting infrastructure for student climate science.

3. Involve students in workshops during second and third years.

Students, teachers, and scientists all need to be involved in the development of collaborative student-focused climate science.

What do we expect from you?

- **Help your students develop competitive climate-related science projects, initially(?) focusing on Earth's energy balance (<u>a basic metric for project evaluation</u>).**
- Learn how to use data from NASA and other sources, plus solar and atmosphere monitoring instruments provided by the project.
- Develop your own understanding of Earth's energy balance and how to relate the gobal to the local.
- Make use of project personnel and mentors to design and implement research that has educational AND scientific value.
- Collaborate with your peers to start building an infrastructure to support authentic climate science research experiences for your students.
- Work with your administration to develop the institutional support required to support authentic science research in schools. esearch is how scientists learn more about Earth's climate and this experience should be part of student learning, too.
- Play an active role in all project activities.
- Conduct your own research projects.
- Share what you have learned with your peers (for example, NSTA presentations?)

What can you expect from us?

- Ongoing support for you and your students from project personnel and other scientist/mentors, for climate-related science projects. We will try our best to provide what your students need to succeed and to make CSRES a success!
- Access to instrumentation for your students to use in their projects, including hands-on assistance when required.
- Help with finding, accessing, and interpreting data from NASA and other sources.
- A project website that will updated with project ideas and news from the project.
- Recognition for contributions from you and your students – presentations at professional meetings, web material, (possibly) inclusion in peer-reviewed publications.

Student and Scientist Collaborative Research Partnerships

"Student and Scientist Partnerships (SSPs) are a new kind of collaboration between science and education based on the ability of students to contribute to scientific research. These partnerships offer science new ways of extending its community and hold the promise of revitalizing education by infusing authentic science into the school culture."

(cover page) Proceedings of The National Conference on Student & Scientist Partnerships, 23-25 October 1996. NSF/The Concord Consortium/TERC. http://ssp.terc.edu/ssp.html

“research”: definition

1. careful or diligent search
2. studious inquiry or examination; *especially*: investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws
3. the collecting of information about a particular subject

(http://www.merriam-webster.com/netdict/research)

How does "research" differ from "inquiry"?

"Inquiry" is a process:

"Inquiry is a multifaceted activity that involves

- ***Making observations;***
- ***Posing questions;***
- ***Examining books and other sources of information to see what is already known;***
- ***Planning investigations;***
- ***Reviewing what is already known in light of experimental evidence;***
- ***Using tools to gather, analyze, and interpret data;***
- ***Proposing answers, explanations, and predictions;***
- ***Communicating the results.***

Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations."

(National Committee on Science Education Standards and Assessment, National Science Education Standards, p23, http://www.nap.edu/openbook.php?record_id=4962)

My definition: "Research" is the inquiry process PLUS content. You can have inquiry without authentic science research, but you cannot have authentic science without inquiry.

What is “climate research”?

Climate research is any research activity that:

1. Increases our understanding of the current state of Earth’s climate and its interactions within Earth’s natural systems – atmosphere, biosphere, hydrosphere, lithosphere – **and** the anthrosphere.
2. Increases our understanding of the forces that have shaped, are shaping, and will shape climate, both natural and anthropogenic.
3. Proposes future scenarios for Earth’s climate, based on observation, historical evidence, analysis, modeling, and theory.

What student climate research is *not,* for example:

- "Learning about" Earth's weather and climate.
- Routine meteorological measurements.

"At first blush, meteorology seems ideal for student involvement until you realize that existing meteorological monitoring is so extensive that students can add little, except where their observations are unique. Examples of the latter are: quantifying atmospheric haze, doing microclimate studies, and making observations, such as in the West Pacific, where other reports are not available." (Tinker, Robert: Potential of Student and Scientist Partnerships. Proceedings of The National Conference on Student & Scientist Partnerships, 23-25 October **1996**. NSF/The Concord Consortium/TERC. http://ssp.terc.edu/ssp.html)

- The "big questions" of climate science, e.g., "Is the Earth getting warmer?"; "Are sea levels rising?"; "Will the polar ice caps melt?"

These are questions to which climate scientists not only do not have definitive answers, but are not even sure ***how*** to answer them.

Why the focus on (collaborative) student "research"?

- "Research" is different from inquiry and other kinds of hands-on "learning about" activities.
- Research is how scientists learn more about Earth's climate and this experience should be part of student learning, too.
- Research involves formulating and investigating questions to which answers are not known ahead of time.
- Involvement from scientists is absolutely necessary to ensure that that what students learn about climate is accurate and fair. **Authentic collaborative research in which all stakeholders benefit is the best way to encourage and sustain engagement by the science community.**

Why is science important?

“Knowledge of science can enable us to think critically and frame productive questions. Without scientific knowledge, we are wholly dependent on others as ‘experts.’ With scientific knowledge, we are empowered to become participants rather than merely observers. Science, in this sense, is more than a means for getting ahead in the world of work. It is a resource for becoming a critical and engaged citizen in a democracy.”

(Sarah Michaels, Andrew W. Shouse,and Heidi A. Schweingruber: Ready, Set, Science!: Putting Research to Work in K-8 Science Classrooms, National Academy of Sciences, 2008.)

“Without scientific knowledge, …”

- “The whole [global warming] thing is created to destroy America's free enterprise system and our economic stability.”
  Jerry Falwell (fundamentalist preacher)
- “Global warming -- at least the modern nightmare vision -- is a myth. I am sure of it and so are a growing number of scientists. But what is really worrying is that the world's politicians and policy makers are not.”
  David Bellamy (environmentalist, author)
- “The best thing we can do with environmentalists is shoot them. These headbangers want to make air travel the preserve of the rich. They are Luddites marching us back to the 18th century.”
  Michael O'Leary (Ryanair CEO)
- “Environmental organizations are fomenting false fears in order to promote agendas and raise money.”
  Michael Crichton (author)
- “Some of the scientists, I believe, haven't they been changing their opinion a little bit on global warming? There's a lot of differing opinions and before we react I think it's best to have the full accounting, full understanding of what's taking place.”
  George W Bush (former U.S. President)
- “Much of the debate over global warming is predicated on fear, rather than science… [the threat of catastrophic global warming is the] greatest hoax ever perpetrated on the American people.”

  James Inhofe (U.S. Senator)
- “Climate is gone… [A new Republican House of Representatives] sure as heck [will not pass climate-change legislation that the outgoing Democratic Congress had been unable to pass.]”

  Karl Rove (Republican strategist and former Bush White House official)

Sources: http://www.allgreatquotes.com/global_warming_quotes.shtml, http://www.realclimate.org/index.php/archives/2005/01/senator-inhofe/, www.philly.com

Why is student research important?

- *"Involving the public in the process of scientific investigation… can provide an incredible opportunity to complement… a more rigorous but limited research program."*
- *"People will not rely on scientific information if they don't understand it, or they question the motivation or integrity of the research methods that were used to generate it."*

("Transitions and Tipping Points in Complex Environmental Systems," NSF, 2009)

See the global climate change debate and quotes on previous slide!

Support for student climate research: How are we doing?

- NSF, NOAA, NASA, and other agencies specifically recognize the need to stimulate and support student interest in Earth science to build a future scientific and technical (STEM) workforce. **But…**
- In the competition for students’ attention, at least as reflected in what kinds of science are being done in high-level national student competitions, **Earth/climate science is losing!**
- Why? Because there is virtually no supporting infrastructure to encourage authentic student Earth/climate science research.

How is the competition doing (locally)?

- **Biosciences:** a huge institutional and corporate infrastructure to support student research. (Some question whether this represents a “level playing field” for student science research, or amounts to “corporate research” done by students.)
- **Mathematics/computer science:** a continuous, intensive math curriculum from pre-school through university. (Today’s students are lucky to get *one* Earth science course in 8^{th}-9^{th} grade and maybe an “environmental science” course. There is still debate about whether to accept such courses as “real” science at the college/university level.)

How is the competition doing (globally)?

- The World Economic Forum ranks the United States 52nd (out of 139) in quality of mathematics and science education (45th the previous year).

  (*The Global Competitiveness Report 2009-2010*. http://www.weforum.org/pdf/GCR10/Report/Countries/United%20States.pdf)

- The "Gathering Storm" committee (National Academies of Science) concluded that "the United States appears to be on a course that will lead to a declining, not growing, standard of living for our children and grandchildren." The most pervasive concern [of the original "Gathering Storm" report committee] was considered to be the state of United States K-12 education, which on average is a laggard among industrial economies—while costing more per student than any other OECD country… **Today, for the first time in history, America's younger generation is less well-educated than its parents."**

  Number one recommendation to reverse this course: "Move the United States K-12 education system in science and mathematics to a leading position by global standards."

  (*Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5,* National Academy of Sciences. *http://www.nap.edu/catalog.php?record_id=12999)*

  National Assessment of Adult Literacy (NAAL):A First Look at the Literacy ofAmerica's Adults in the 21st Century. http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006470)

How do we know we're doing real climate research?
The "scientific interest" test

"If students do a climate-related project, when they finish the project will any scientist care whether they did it or not?"

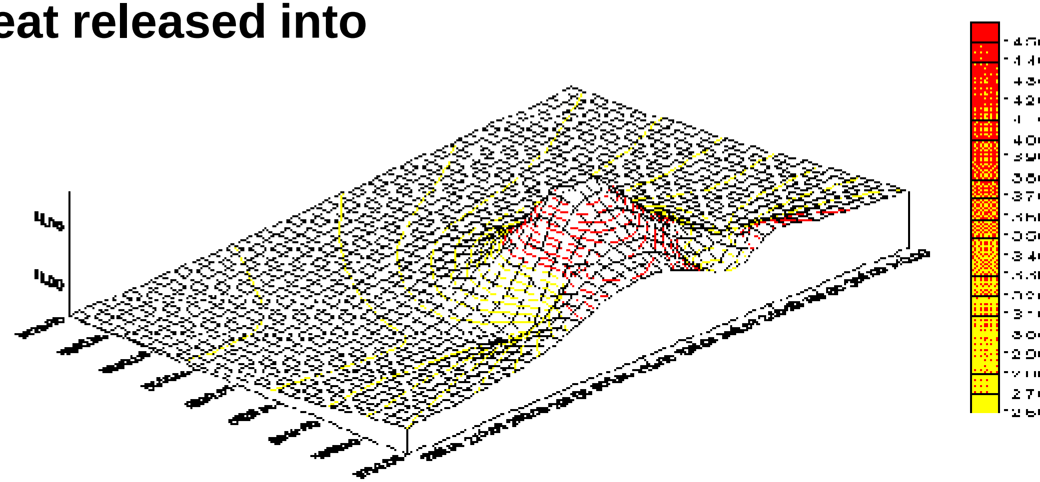
If the answer to this question is "yes," then the project *could* be real research. If the answer is "no," then the project cannot be real research.

Why a “scientific interest” requirement?

- Climate science is changing very rapidly, and even “learning about” activities need to be monitored to make sure their content is accurate and reflects our current understanding of climate and changes in climate.
- “Scientific interest” can take many forms, but without that interest, it will not be possible to sustain high-quality climate-related education or to promote Earth/climate science as an attractive career choice.
- Sustainable scientific interest is motivated and sustained by looking at interesting science questions and engaging in authentic collaborative research.
- Even “learning about” science activities are best developed and implemented in the context of actual research practices, through sustainable scientist/educator partnerships.

Even basic measurements can be useful if they are done within the framework of a well-defined science objective.

"The warming of the nighttime temperature [even in small towns when they are growing] is due to the Urban Heat Island (UHI) effect, which is the result of two main features of urban areas. First, buildings, roads and paved surfaces store heat during the day, which is then released slowly over the evening due to the thermal properties of the surface materials and the building geometry which traps the heat stored during the day. The second contributing factor to the UHI is due to the artificial heat released into the urban atmosphere by combustive processes from vehicles, industrial activity and the heat that escapes from commercial and domestic air conditioning."



Mean summer urban heat island effect, 1985-1994, Melbourne, Australia, 1.81ºC

(http://www.earthsci.unimelb.edu.au/~jon/WWW/uhi-melb.html, http://www.earthsci.unimelb.edu.au/~jon/WWW/deniliquin.html)

Projects involving climate observations are very difficult to start and maintain in any fashion that adds useful data to the understanding of long term climate change. The main barrier here is time, followed closely by instrument accuracy.

However, there are a variety of smaller scale studies that can tell an interesting story about climate processes with relatively low cost instruments:

1. Urban heat island - your example below is quite feasible as long as temperature observations take place in a comparable manner at individual locations. For example some schools are part of school-based obs networks, but the instruments are clamped on to the roof or some similarly inappropriate locations. If they are all like that, fine, but the problem comes with inconsistency of siting across a network ... the results would not be spatially comparable. You might be better off driving along the main axes of a town with a car with a good temperature output, rather than use an inconsistent observation network.

2. Land use/land cover and climate - transects of climate measurements can be designed on a very local scale to go across ecotones where there is a transition from one ecosystem to another, or smaller field scale changes where you go from one land cover to another. Fairly low cost instruments can be deployed with the cooperation of the land owner(s); for instance, HOBO temperature instruments, and still allow sufficient accuracy to see the potential impacts of land cover change on temperature, or can be tied in to vegetation gradients. Land cover change can lead to climate change on a local basis. A simple 2-point study would compare the diurnal temperature cycle over an irrigated lawn versus over a non-irrigated lawn ... might be able to get cooperation from a local golf course. Finally, transect near water bodies might also be interesting to characterize.

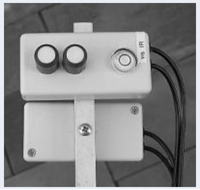
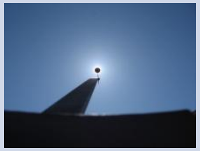
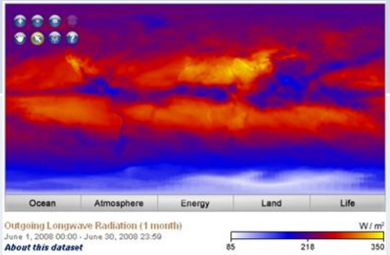
3. Topographic gradients - like (2), except temperature and precipitation differences across stations located at different elevations and on slope facets facing in a variety of directions.

4. Climate station representativeness - with the cooperation of a climate station observer and the owner of the land where it is situated, set up low cost instruments both at the site and at random locations around the station to see how representative its measurements are of the local environment. In situ measurements are made at a point and some points may be better than others in representing the overall climate conditions of an area.

Studies based on measurements usually come down to spatial gradients in climate, if one does not have many years for a study. The main point is to be consistent in the way one measures, quality of site, exposure of instruments, etc. Other student studies based on using historical climate observations taken by others, or on using simple to complex climate models are also available, if the student has an aptitude for and access to good computers. I do not know if anyone plays around with physical models of climate (like terrariums subject to changing radiation levels, moisture availability, etc.), but I guess that is more of a demonstration of processes rather than an actual science experiment. That would be fun for looking at aspects of geoengineering.

Michael A. Palecki, Science Project Manager, U.S. Climate Reference Network, NCDC, Asheville, NC (email, 11/11/2010

Facilitating Student Climate Research

Measurement/Data	Source
Silicon-based pyranometer for measuring insolation (teachers and students can build it for $10). The performance of these instruments has been characterized as part of NREL's yearly radiometer calibration project.	
Two two-channel radiometers for measuring surface reflectivity (broadband and near-IR). These detectors need only a relative calibration, rather than an absolute radiometric calibration.	
Inexpensive hand-held sun photometers for measuring aerosol optical thickness and water vapor. The visible-light sun photometers use LEDs as spectrally selective Light detectors. The WV instruments use filtered photodiodes	
Thermopile sensor for measuring surface thermal radiation. This device uses a sensor (~$25) found in "non-contact" IR thermometers.	
Solar aureole photography for measuring atmospheric turbidity. This requires a simple fixture and a digital camera with manual settings.	
	Space- and ground-based views: AERONET, AIRNow, CRN, GPS-MET, My NASA Data, NEO

CSRES Milestones

- Summer workshops at Queens College, all three years. Students join the workshop in 2nd and 3rd years.
- Starting Year 1: Develop instruments and experiment protocols, suitable for authentic student research.
- Starting Year 1: Develop website for data collection and dissemination.
- Starting Year 1: Teachers and students collaborative with scientist mentors to develop authentic research projects, suitable for high-level national science competitions.
- NY-area participants collaborate with schools in other parts of the country, assisted by NASA/AESP coordinators.